# Invasive Ant Risk Assessment

## Anololepis gracilipes

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# (A)  PEST INFORMATION

### A1. Classification

| | |
|---|---|
| Family: | Formicidae |
| Subfamily: | Formicinae |
| Tribe: | Plagiolepidini |
| Genus: | *Anoplolepis* |
| Species: | *gracilipes* |



Richard Toft, Landcare Research

1 mm

### A2. Common names

Yellow crazy ant (O'Dowd 2004a).

Also know as ashinaga-ki-ari (Japanese), crazy ant (English), gramang ant (Indonesian), long-legged ant (English), Maldive ant (English-Seychelles) (O'Dowd 2004a).

### A3. Original name

*Formica gracilipes* Smith

### A4. Synonyms or changes in combination or taxonomy

*Formica longipes* Jerdon, *Formica trifasciata* Smith, *Anoplolepis longipes* (Jerdon), *Plagiolepis longipes* (Jerdon), *Prenolepis gracilipes* (Smith), *Plagiolepis gracilipes* (Smith).

Note: there is a large body of literature on this species under the name *Anoplolepis longipes*.

### A5. General description (worker)

*Identification*

*Size*: total length around 4 mm.

*Colour*: body colour yellow, gaster brownish to greenish.

*Surface sculpture*: head and body mostly with inconspicuous sculpture; appearing more or less smooth and shining.

*General description*: head oval, antennae and legs remarkably long (Fig. 1). Antennae 11-segmented, each segment

longer than wide; scapes at least twice as long as the length of the head, or longer. Eyes relatively large and protruding. Mandibles each with 8 teeth. Clypeus produced medially, with convex anterior margin; without longitudinal carinae. Alitrunk slender; pronotum narrow, with almost straight dorsum in profile. Anterior portion of mesonotal dorsum, back to the propodeum, gently concave in profile; metanotal groove absent. Propodeum without spines, propodeal dorsum convex in profile. One node (petiole) present; thick, with an inverted-U-shaped crest. Erect hairs present on head and gaster, lacking on dorsum of mesosoma. Stinger absent; acidopore present.

Sources: Japanese ant image database (www39), Australian ants online (www36).

*Ant Image Database, Japan*



*Gary Alpert, Harvard University*

**Fig. 1:** *Image of* Anoplolepis gracilipes*: a) dorsal view (Source: Ant Image Database, Japan); b) lateral view, scale bar 2 mm (Source: Gary Alpert, Harvard University).*

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## A6. Behavioural and biological characteristics

### A6.1 Feeding and foraging

*Anoplolepis gracilipes* forages continuously across the ground and in the canopy over a wide range of temperatures (O'Dowd 2004a). Food is discovered rapidly, even more rapidly than by *Paratrechina longicornis* (Lester & Tavite 2004). Initially described as a scavenger, it has been called subsequently a "scavenging predator". It preys on a variety of litter and canopy fauna, from small isopods, myriapods, molluscs, arachnids, and insects to large land crabs, birds, mammals, and reptiles. Foragers lack a sting but they subdue and kill prey by spraying formic acid. In addition to these protein-rich foods, *A. gracilipes* obtains carbohydrates and amino acids from plant nectaries and especially from honeydew excreted by Homoptera, which it tends on stems and leaves of a wide variety of tree and shrub species (O'Dowd 2004a).

### A6.2 Colony characteristics

*Anoplolepis gracilipes* colonies are polygyne (multi-queened), generally without intraspecific aggression among workers (Passera 1994), although intraspecific aggression has recently been found between two geneotypes on Tokelau (one from an old invasion; one from a new (P. Lester, pers. comm.)). Lack of intraspecific aggression within populations allows the formation of "supercolonies", sometimes extending continuously over large areas (10–150 ha) (O'Dowd 2004a). In favourable conditions *A. gracilipes* can attain very high densities: 10 million/ha in the Seychelles (Haines & Haines 1978) and > 20 million/ha on Christmas Island (K. Abbott, unpubl. data). Nest size averages about 4000 individuals (wwwnew77). Worker production is continuous, though fluctuating, throughout the year (O'Dowd 2004a). Sexual stages can be present year round, but in most instances, initiation of brood follows the onset of the wet season. Researchers have reported an increase in nest size and foraging activity in the dry season (O'Dowd 2004a). Colonies readily migrate if disturbed (Passera 1994).

It takes 76–84 days for worker eggs to reach maturity at 20–22°C (Fluker & Beardsley 1970). Eggs hatch in 18–20 days, and worker larvae develop in 16–20 days from hatching. Worker pupae need around 20 days for development, while those of queens require 30–34 days for development. Workers live for approximately 6 months, and the queens for several years (wwwnew77). Queens lay about 700 eggs annually throughout their life span (wwwnew77).

Nesting requirements are generalized; they nest under leaf litter, in cracks and crevices in the soil, usurp land crab burrows, readily colonize bamboo sections when placed on the forest floor, and in canopy tree hollows (O'Dowd 2004a). They also nest under the ground substrate (generally consisting of broken coral or coarse sand, with some organic material), in urban structures, and in anthropogenic debris (Lester & Tavite 2004).

## A7. Pest significance and description of range of impacts

### A7.1 Natural environment

*Anopolepis gracilipes* is capable of invading native forest habitats and attaining high densities (Haines & Haines 1978; K. Abbott, unpubl. data). The best-known invasions by *A. gracilipes* have occurred in Hawaii (Fluker & Beardsley 1970), the Seychelles (Haines et al. 1994), and Christmas Island (O'Dowd et al. 2003). Increase in the abundance of *A. gracilipes* is usually associated with an increase in honeydew-producing Hemiptera, and it is hypothesised that the acquisition and utilisation of honeydew are keys to their population build up and subsequent impacts (D. O'Dowd, pers. comm.).

It preys on a variety of litter and canopy fauna, from small isopods, myriapods, molluscs, arachnids, and insects to large land crabs, birds, mammals, and reptiles (Haines & Haines 1978; Gillespie & Reimer 1993; Feare 1999; Green et al. 1999; Lester & Tavite 2004). In addition to these protein-rich foods, *A. gracilipes* obtains carbohydrates and amino acids from plant nectaries and especially from honeydew excreted by Homoptera, which it tends on stems and leaves of a wide variety of tree and shrub species (Haines & Haines 1978; Rao et al. 1989; K. Abbott, unpubl. data). They may drive away reptiles from infested areas by crawling over them and spraying formic acid (Haines et al. 1994).

Some of the most dramatic effects of this ant have been on Christmas Island in the Indian Ocean. O'Dowd et al. (2003)

reported large declines in populations of the land crab *Gecarcoidea natalis* from impacts of large populations of *A. gracilipes*, which spray acid into the crabs' gills, eyes and mouthparts, resulting in death within 48 hours. The extreme abundance of these ants, their omnivorous diet and their effective elimination of red land crabs have resulted in substantial ecosystem change within invaded areas.  In the absence of herbivorous crabs, the forest on Christmas Island is becoming dense, while some tree species are dying-off locally as a result of extreme scale insect infestations. Secondary invasions of giant African land snails (*Achatina fulica*) and shade-intolerant woody weeds may follow invasion by *A. gracilipes*, further degrading native forests (Lake & O'Dowd 1991).  There is evidence for a decline in the density of *A. gracilipes* on Christmas Island (P. Green & K. Abbott, unpubl. data), but no reason is suggested for this decline.

In the Seychelles, a large variety of organisms have been affected by the invasion of *A. gracilipes* (Haines & Haines 1978; Feare 1999; Gerlach 2004). These ants kill land crabs of the genus *Cardisoma*. The Seychelles' endemic skink *Mabuya seychellensis* disappeared from areas where the ant was abundant (Feare 1999).  Sooty terns failed to occupy nesting sites and some chicks of the white tern, *Gygis alba,* were killed by *A. gracilipes*.  Large numbers of insects were killed and some trees were also killed as a result of having their roots undermined (Feare 1999). In the Seychelles, as on Christmas island, *A. gracilipes* densities were observed to decrease several decades after invasion, though the reason for this decline is unknown (Haines & Haines 1978; Haines et al. 1994). Haines and Haines (1978) reported that impacts were predominantly quantitative rather than qualitative, i.e. the densities of impacted species were reduced rather than them being eliminated altogether.

*Anoplolepis* will generally only demonstrate aggression towards other ants when defending resources (P. Lester, pers. obs.). If involved in a battle with another ant species, *A. gracilipes* will curve its abdomen up toward the head of its attacker and spray a defensive substance from poison glands located in the abdomen (wwwnew77). This secretion is highly toxic to other ants as well as to other individuals within the colony and is a very effective defence. Lester and Tavite (2004) recorded a significant reduction in ant species diversity with increasing *A. gracilipes* densities in newly invaded areas in Tokelau, and ant colonies (*Tetramorium* sp.) were observed being attacked. On Guadalcanal, in the Solomon Islands, *A. gracilipes* was not dominant, but a component of a diverse ant fauna comprising many tramp species (Greenslade & Greenslade 1977).

## A7.2 Horticulture

The greatest harm to horticulture is likely to result from an increase in honeydew-producing insects on trees and crops. Yellow crazy ants help the dispersal of these insects and also indirectly contribute to increased damage by protecting them against natural enemies (wwwnew77). Their increase in abundance can facilitate the build up of sooty moulds (Capnodiaceae), which can inhibit photosynthesis (Wood et al. 1988) and eventually affect yields.

This ant does not damage plants directly (wwwnew77). However, it has been recorded as removing soil from around roots (Haines et al. 1994), which may subject the roots to invasion by diseases (wwwnew77).

*Anoplolepis gracilipes* is known to prey upon newborn pigs, dogs, cats, rabbits, rats, and chickens (Haines et al. 1994). They irritate animals by crawling over them and periodically spraying acid.  Of most concern to people in the Seychelles, were the mortality, displacement and irritation of domestic animals (Haines & Haines 1978; Haines et al. 1994), but this only occurred where ants were very abundant.

It has been regarded as a beneficial insect, used previously in biological control trials in cocoa plantations, where it reduced numbers of insect pests due to its predatory tendencies and aggressive behaviour (Entwistle 1972; Room 1975; Room & Smith 1975).

## A7.3 Human impacts

*Anoplolepis gracilipes* has been recorded as a domestic nuisance in the Seychelles (Haines & Haines 1978; Haines et al. 1994), where the majority of the 246 people surveyed in 1978 regarded them as a general nuisance because they

crawled all over people (Fig. 2) and food in the home. They were also considered a medical problem, causing acute distress by entering ears, nose, eyes and open wounds, especially in the young and old.

On Christmas Island, in areas where population densities were extremely high, *A. gracilipes* workers would accumulate between socks and shoes if these were not covered properly and the wearer stayed in the area for a prolonged period (over an hour (K. Abbott, pers. obs.)). In a few instances, people sustained formic acid burns around the ankles, which resulted in scarring; and on one occasion a foraging worker ant fell from an overhead branch into the eye of a field worker, causing formic acid burns to their cornea (K. Abbott, pers. obs.).

On Mahe, in the Seychelles, *A. gracilipes* was a severe household pest and a nuisance in public buildings, hotels, food and drink processing establishments, and the local hospital (Lewis et al. 1976).



*Fig. 2:* A. gracilipes *workers crawling over the foot of a field worker.*

## A8. Global distribution

### A8.1 Native range

The origin of *A. gracilipes* is the subject of much debate, though is thought likely to be either Asia (Wheeler 1910) or Africa (Wilson & Taylor 1967). Early records show it to be present on both continents before 1900. Africa is the origin of all other members of the genus, but the distribution of *A. gracilipes* appears restricted in Africa (Fig. 3). Wetterer (2005) describes *A. gracilipes* as likely to be from Asia, and perhaps as even native to Christmas Island but this appears unlikely.

### A8.2 Introduced range

*Anoplolepis gracilipes* has been found widely throughout the moist tropical lowlands of Asia, the Indian Ocean, and the Pacific Ocean and occurs between the Tropics of Cancer and Capricorn (Fig. 3). It has also been reported from some higher altitude areas in Tibet and China (wwwnew54), which represent extreme temperature outliers. The validity of the Tibetan record in particular (in terms of specimen identity and ongoing presence outdoors) is questionable (Wetterer 2005). For these outlying records, further sampling at the same site would be useful to determine whether there is any evidence for the ongoing presence of this species.

In tropical Asia, *A. gracilipes* has been recorded from most countries: Brunei, Cambodia, China, India, Indonesia, Malaysia, Myanmar, Papua New Guinea, the Philippines, Singapore, Sri Lanka, Taiwan, Thailand, and Vietnam (Wetterer 2005). In the Indian Ocean, *A. gracilipes* has been reported from most tropical island groups: Agalega, Christmas Island, Cocos-Keeling Island, Réunion, Mauritius, Rodrigues, and the Seychelles. In the Pacific, *A. gracilipes* has been reported from virtually every tropical island group. In tropical Melanesia it is known from all groups: Fiji, New Caledonia, Solomon Islands (excluding Santa Cruz Islands), and Vanuatu. It has also been widely reported in Micronesia: Caroline Islands, Gilbert Islands, Mariana Islands, Marshall Islands, Palau, Rotuma, and Santa Cruz Islands, as well as in Polynesia: Austral Islands, Cook Islands, Gambier Islands, Hawaii, Line Islands, Marquesas Islands, Niue, Samoa, Society Islands, Tokelau Islands, Tonga, Tuamotu Islands, Tuvalu, and Wallis and Futuna. For tropical Africa, records only exist from Dar es Salaam, Tanzania, and the nearby island of Zanzibar. It has also established populations on mainland Australia, on the Nhulunbuy Peninsula in the Northern Territory.

The ant has also been reported in Brisbane, Cairns, and Townsville in Australia; Valparaiso in Chile; Durban in South Africa; and Zayul in Tibet, but these records are all likely temporary incursions and/or were eradicated, as there is no evidence of permanently established populations (Wetterer 2005; C. Vanderwoude, pers. comm.). In 2004, new populations were found in Rocklea, Brisbane, and Edmonton, Cairns (C. Vanderwoude, pers. comm.).

### A8.3 History of spread

*Anoplolepis gracilipes* has become widespread over a long period. It was already recorded from virtually the full range of its current known distribution before 1900: from India (1851), Southeast Asia (1854), Chile (1859), Polynesia (1867), Melanesia (1876), Mexico (1893), East Africa (1893), Australia (1894), and Indian Ocean islands (1895) (Wetterer 2005). Wilson and Taylor (1967) recorded 14 archipelagoes in the Pacific as having *A. gracilipes*, but it is still spreading within the Pacific (e.g., Tokelau (Lester & Tavite 2004)) and new incursions are being detected in Australia (C. Vanderwoude, pers. comm.) and New Zealand (S. O'Connor, pers. comm.).

## A9. Habitat range

*Anoplolepis gracilipes* is primarily a species of the lowland, tropical rainforest. Most collection records are below 1200 m in elevation, and in moist habitats. There is a record from 1550 m in Lincang, China (Wetterer 2005), but the validity of several records from this area are unclear. Bingham (1903) wrote that *A. gracilipes* was found throughout India "except in the hot dry portions of the North-Western Provinces, the Punjab and parts of Central India". Veeresh (1987) also noted

that *A. gracilipes* preferred moist habitats in India. In newly invaded areas such as northern Australia, *A. gracilipes* is found in moist forests along rivers and in the city of Darwin (Clark 1941; Majer 1984). It does not occur in the arid zone of Australia, but is restricted to the wet/dry tropics of Northern Territory and the wet tropics of Queensland (B. Hoffmann, pers. comm.).

Nesting requirements are generalized; they nest under leaf litter, in cracks and crevices in the soil, usurp land-crab burrows, and readily colonize bamboo sections when placed on the forest floor.  They also nest in canopy tree hollows.  In coconut plantations, *A. gracilipes* nests at the base of trees and in the crowns of coconut palms and feeds on nectar secreted from male flowers and from honeydew-producing scale insects (O'Dowd 2004a).

It is capable of invading both disturbed and undisturbed habitats, including tropical urban areas, plantations, grassland, savannah, woodland, and rainforest (O'Dowd 2004a). This species does not appear to have as close an association with urban buildings as other tramp species and has not been reported established in heating buildings in cities in temperate regions.
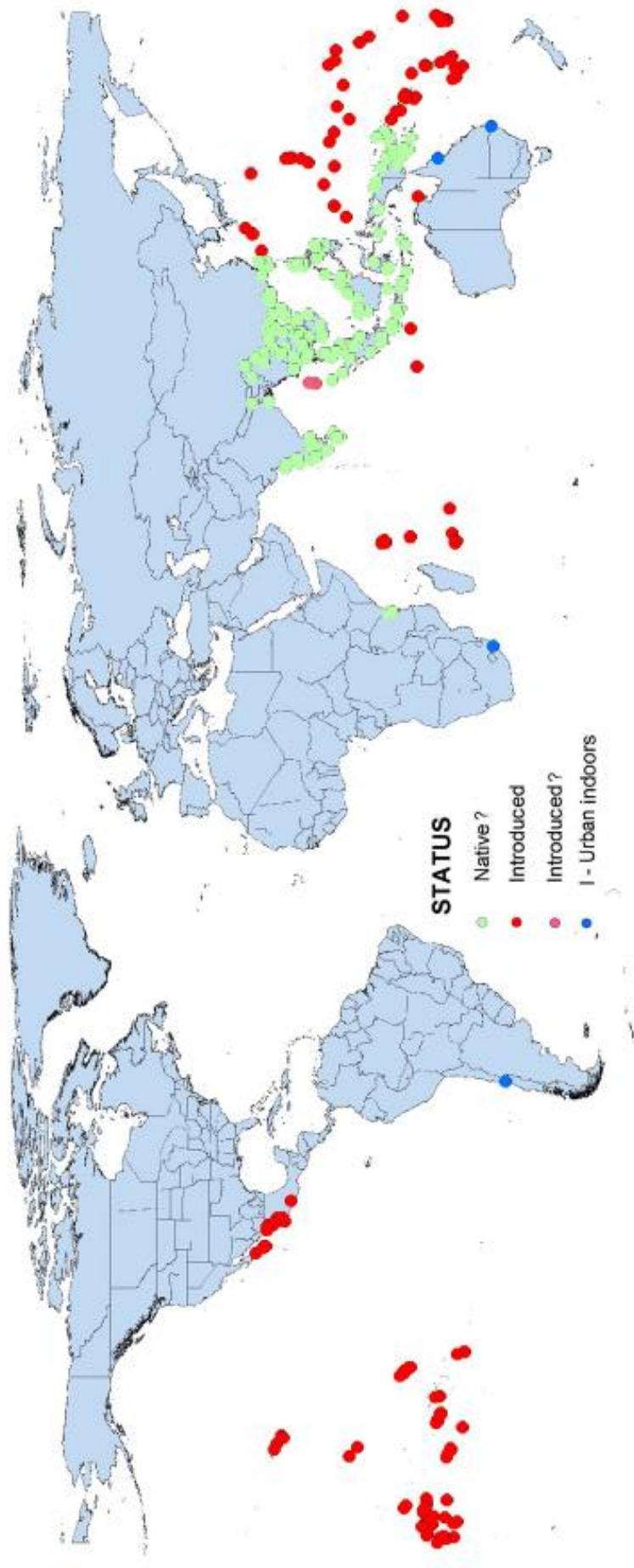
**Fig. 3:** *Distribution records in Landcare Research Invasive Ant Database of Anoplolepis gracilipes as at 31 March 2005. Africa or Asia is thought to be the native range (green). Sites that the ant is reported to be established and adventive are red, and those where it is probably adventive are pink. The blue dots represent sites where nest or nests have been detected or have established temporarily but have been eradicated. There are no records for this species from temperate locations associated with permanently heated buildings.*

# (B) LIKELIHOOD OF ENTRY

## B1. Identification of potential pathways

*Anoplolepis gracilipes* can be considered a classic "tramp" ant species, due to its reliance on human-mediated dispersal and close association with humans generally (Holldobler & Wilson 1990; Passera 1994). O'Dowd (2004a) listed several methods of ranslocation of this species: in soil, produce and timber, packaging material, potted plants, and sea containers. This species has also been observed being moved between islands within the Pacific on fresh produce such as taro (P. Lester, pers. comm.; K. Abbott, pers. comm.). They may be consuming parts of these crops or be nesting in them. Haines and Haines (1978) observed this ant to be moved in pre-fabricated building materials, coconut husks, cinnamon, other building materials and topsoil. They have been found nesting in the magazines of artillery on the return from Timor of Australian troops (K. Abbott, pers. comm.).

*Anoplolepis gracilipes* has been intercepted on a wide range of commodities entering New Zealand (Table 1), most frequently on fresh produce (of many different types) and in empty containers. The high frequency of interceptions in empty containers is evident in both the historical and the recent interception data, whereas the relative interception rate in fresh produce is reduced in recent data. Historical ant interception data for New Zealand are likely to be heavily skewed in favour of plant/produce type commodities, as these are the only commodities for which ID of live ants has been a requirement (S. O'Conner, pers. comm.). Only the most recent interception data (from 2003) are truly representative of ant contamination across all pathways/commodities (Table 1). Timber, personal effects, and various miscellaneous freight types are commodities with which the ant is commonly associated. This species has not been intercepted on imported nursery stock

From 1955 to March 2004, interceptions were predominantly on goods from the Pacific (Table 2). Interceptions from Europe and mainland US may be an error, or *A. gracilipes* has contaminated freight during transit, as it has not been reported from these locations.

Apparently viable colonies and queens of *A. gracilipes* have survived transportation by sea to New Zealand from a variety of Pacific and Asian countries. Live queens have been intercepted on eight occasions on produce and timber arriving in the New Zealand spring, summer, autumn and winter (October, November, December, January, March, and June).

Two nests have also been intercepted in empty containers from the Solomon Islands and Samoa in July and October.

Australian border interception data also highlight the wide range of freight types with *A. gracilipes* stowaways, and the risk posed by empty containers (Table 3). The origin of freight is predominantly the Pacific Islands and Melanesia (Table 4). The one record from New Zealand is likely to have been a transit passenger (on taro in air baggage).

## B2. Association with the pathway

As indicated previously, *A. gracilipes* is well established across the Pacific region and throughout much of the world's tropical rainforest areas. It is also found in disturbed habitats, including tropical urban areas, plantations, and grassland (O'Dowd 2004a; Lester & Tavite 2004). Large amounts of trade come into New Zealand from areas of the Pacific Region and Asia where this ant is established. Interceptions showing its association with a wide range of commodities, including empty containers, suggest it is usually a stowaway, rather than having host-specific associations. This lack of host association makes it difficult to target surveillance at particular commodities. In addition, the wide range of countries from which it is intercepted from at the New Zealand border (and in Hawaii and Australia) make targeting specific pathways for *A. gracilipes* particularly difficult.

## B3. Summary of pathways

A summary of freight coming to New Zealand from localities within 100 km of known sites with *A. gracilipes* infestation is presented in Figure 4 (see also Appendix 1). Total volumes of freight from localities with this ant nearby during 2001–2003 were relatively high, representing about 12.9% of total air freight and 14% of total sea freight (18% of sea freight where the country of origin was reported).

The large amount of freight originating from infested counties and the casual association of this ant with a wide variety of freight types indicates many potential pathways for *A. gracilipes*.  However, for some of the locations (e.g., Christmas Island, and Gove Peninsula (Northern Territory, Australia)), most of the freight is transported in bulk, e.g., fertilizer, and hence a lower risk pathway.  For ants that are typically stowaways on a wide range of commodities, our assumption is that the opportunity of transportation is low for commodities that are transported here in bulk as there are unlikely to be nests within the commodity. There may still be some risk as ants have been intercepted on ships, although it is unknown if the ants live in the ship permanently or come out of cargo in transit. In contrast, commodities like second-hand machinery and vehicles or containerised freight awaiting shipment offer numerous opportunities as nest sites for budding colonies and colonies can be subsequently transported to new locations.

Sea freight from those countries with *A. gracilipes* is transported to 12 New Zealand ports (Table 5).  For Whangarei, Bluff, Gisborne, and possibly New Plymouth, the types of freight are restricted, and the tonnages of goods that are not likely to be transported in bulk tankers are low, suggesting these ports are lower risk compared with others (Appendix 2). The remaining ports have high volumes and a range of commodities, suggesting all are at risk of *A. gracilipes* arriving in sea freight.

Air freight arrives at three New Zealand airports (Table 6). A wide range of commodity types are air freighted from these countries, with produce from the Pacific (a high-risk pathway) representing one of the biggest tonnages (Appendix 1b).

Additional data are available on container movements into New Zealand for the first quarter of 2004 (Source: MAF Quarantine service).  These data have full and empty container movements, but do not have associated freight types or the weight of goods in the containers.  About 17 140 containers originating from countries with established *A. gracilipes* populations arrived in New Zealand during this period (Appendix 3).

Interceptions of *A. gracilipes* do not appear to reflect the numbers of containers entering New Zealand from infested countries, as interceptions on freight from the Pacific are over-represented.  This may be due to a combination of factors: the abundance *A. gracilipes* in the vicinity of export facilities in these countries; the volume of fresh produce that comes from the Pacific (a commodity that is often contaminated, and records of which are over-represented in the historical interception data); the environment where containers are stored being highly suitable for nests (reflected by the detection of ants and ant colonies in empty containers); inspections already targeting Pacific freight as a high risk pathway and hence biasing interceptions from this area; and the proximity of the Pacific to New Zealand, meaning sea freight arrives here in a short timeframe, which increases the chances of ants surviving transportation.

A large number of empty containers enter New Zealand from Pacific countries. Empty containers predominantly end up at Tauranga, Whangarei, and Auckland (Appendix 4). This appears to be a high-risk pathway, with interceptions commonly reported from empty containers (See Tables 1&3), including 2 colonies. This indicates Whangarei is at considerably higher risk for *A. gracilipes* arrival than is indicated by the amount of non-bulk freight entering the port (Appendix 2).

**Table 1:** Commodities from which *A. gracilipes* has been intercepted (both border and post border) before and after a directive to identify all ants intercepted entering New Zealand. Cases where a queen (q) or nest (n) were intercepted are highlighted (this will be a minimum estimate, as in many cases the stage is recorded as unknown).

| Freight type | 1964–end 2002 | q or n | 2003–March 2004 | q or n |
|---|---|---|---|---|
| Fresh produce | 17 | 1 | 2 | 1 |
| Cut flowers | 6 | | | |
| Miscellaneous | 10 | | 1 | |
| Nursery stock | 0 | | | |
| Personal effects | 2 | 1 | 5 | |
| Plant products | 4 | | | |
| Stored products | 0 | | | |
| Timber | 10 | 1 | 3 | |
| Ship (separate from freight) | | | 3 | |
| Container[a] | 12 | 6 | 9 | |

[a] Mostly listed specifically as empty.

**Table 2:** Country of origin for New Zealand border interceptions of *A. gracilipes*.

| | # Interceptions | |
|---|---|---|
| Country | 1964–2002 | 2003–March 2004 |
| Cook Islands | 5 | 0 |
| Europe | 1 | 0 |
| Fiji | 15 | 3 |
| Hawaii | 2 | 0 |
| Hong Kong | 2 | 0 |
| Indonesia | 1 | 0 |
| Philippines | 1 | 0 |
| PNG | 12 | 4 |
| Samoa | 10 | 5 |
| Singapore | 1 | 0 |
| Solomon Is | 2 | 3 |
| Tonga | 5 | 1 |
| Unknown | 5 | 4 |
| USA | 1 | 0 |
| Wallis & Futuna Is | 3 | 2 |
| Vanuatu | 0 | 1 |

**Table 3:** Commodities from which *A. gracilipes* has been intercepted at the Australian border. Data from January 1986 to 30 June 2003 (Source: Department of Agriculture, Fisheries and Forestry, Canberra).

| Commodity | No. |
|---|---|
| Air baggage | 7 |
| Container (empty) | 15 |
| Container (various non-plant products) – external | 8 |
| Container (various non-plant products) – internal | 16 |
| Foodstuffs | 1 |
| Fresh produce | 7 |
| Household effects | 1 |
| Ship hold | 1 |
| Tanktainer, bulk | 1 |
| Timber or timber products | 14 |
| Vehicles/machinery | 6 |
| Wharf/devanning site | 2 |

**Table 4:** Country of origin for Australian border interceptions of *A. gracilipes*.  Data from January 1986 to 30 June 2003 (Source: Department of Agriculture, Fisheries and Forestry, Canberra).

| Country | No. |
| --- | --- |
| East Timor | 1 |
| Fiji | 6 |
| Hong Kong | 1 |
| Indonesia | 14 |
| Malaysia | 2 |
| New Caledonia | 1 |
| New Zealand | 1 |
| Papua New Guinea | 15 |
| Polynesia (French) | 2 |
| Samoa (American) | 12 |
| Singapore | 3 |
| Solomon Islands | 1 |
| Sri Lanka | 1 |
| Thailand | 2 |
| Unknown | 6 |
| Vanuatu | 3 |
| Wallis & Futuna Islands | 3 |
| Western Samoa | 3 |

**Seafreight (tonnes)**

- .001 - 100
- 100 - 500
- 500 - 1000
- 1000 - 5000
- 5000 - 10000
- 10000 - 50000
- 50000 - 100000
- 100000 - 500000
- 500000 - 1000000
- 1000000 - 5000000

***Fig. 4a:*** *Summary of sea freight coming to New Zealand from localities within 100 km of sites from where A. gracilipes has been reported. Values represent the total freight (tonnes) during 2001, 2002 and 2003 (source: Statistics New Zealand). Details of locations and freight types are given in Appendix 1.*
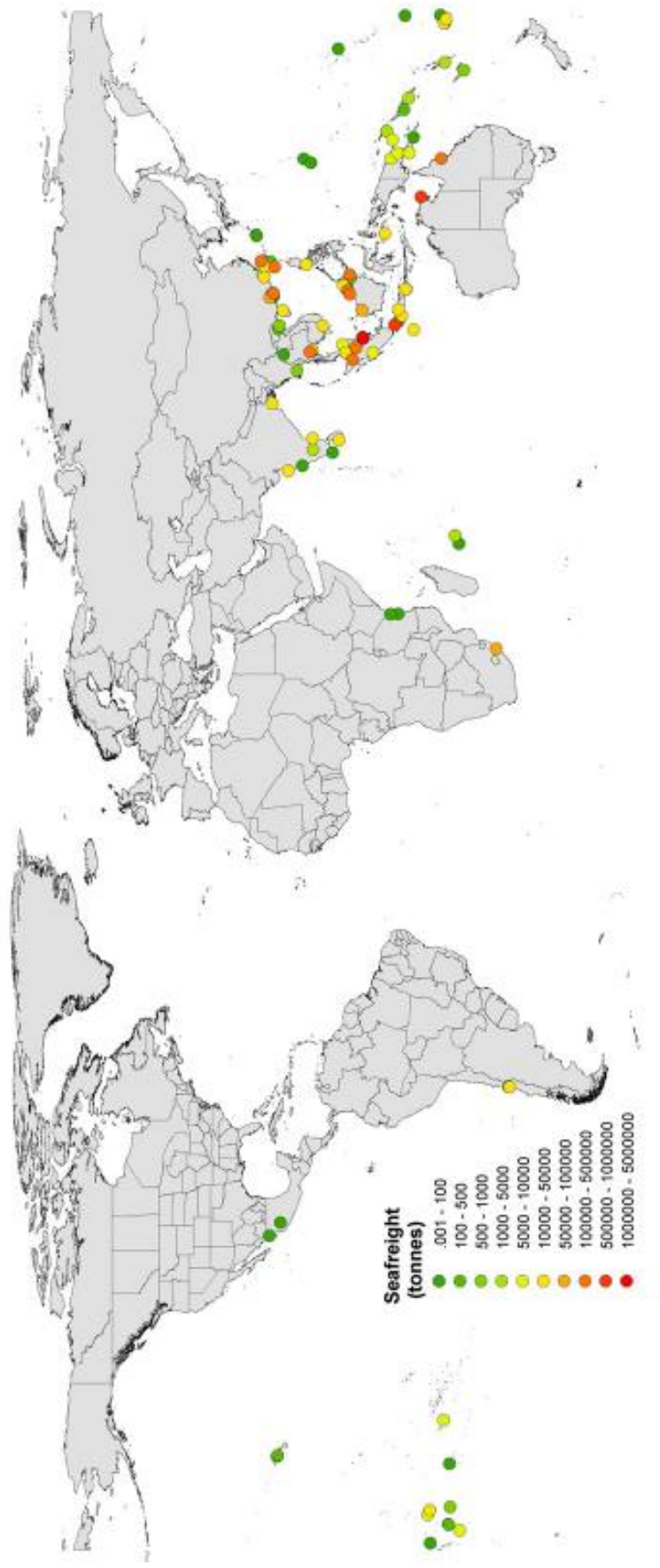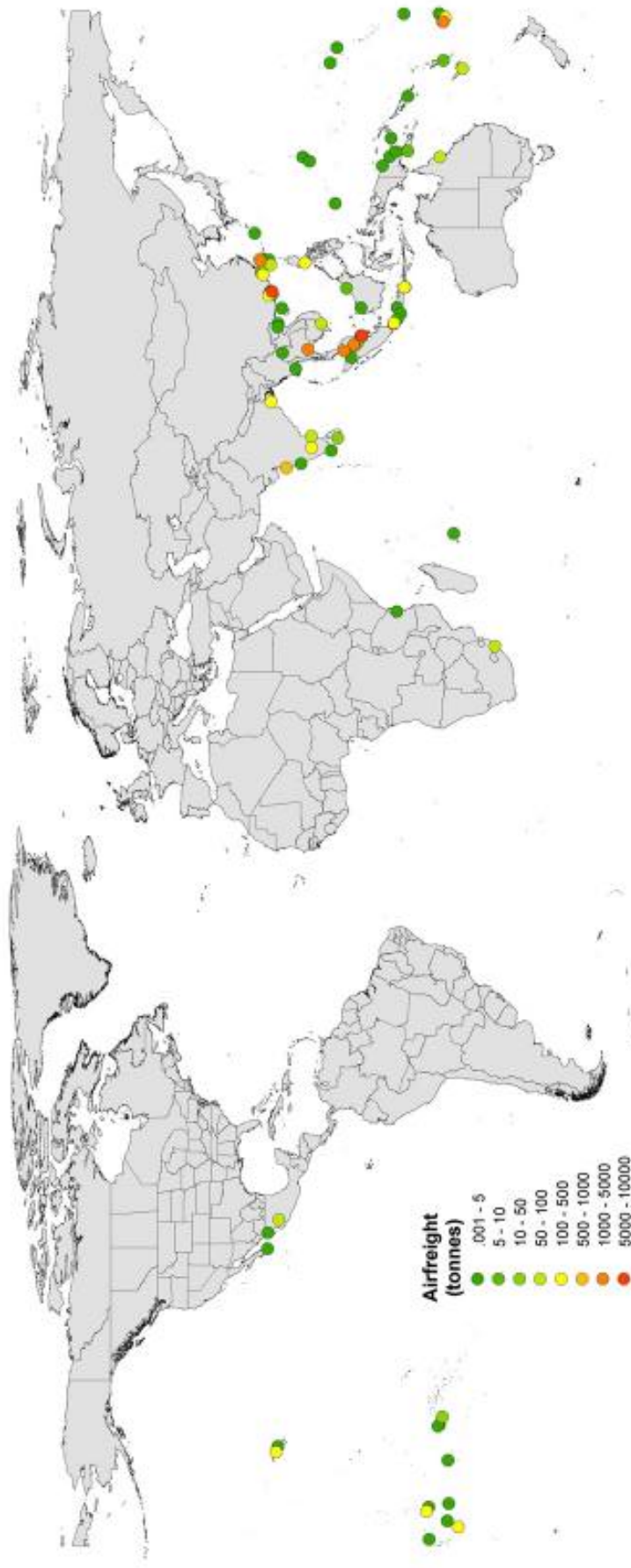
**Fig. 4b:** *Summary of air freight coming to New Zealand from localities within 100 km of sites from where A. gracilipes has been reported. Values represent the total freight (tonnes) during 2001, 2002 and 2003 (source: Statistics New Zealand). Details of locations and freight types are given in Appendix 1.*

**Table 5:** Volume of sea freight coming to New Zealand ports during 2000–2003 from countries with *A. gracilipes* (countries included are listed in Appendix 1). Freight data from Statistics NZ.

| NZ port | Sea freight (tonnes) |
| --- | --- |
| Auckland Seaport | 1 921 879 |
| Tauranga Seaport | 937 827 |
| Invercargill Seaport (Bluff) | 692 578 |
| Whangarei | 678 602 |
| Christchurch Seaport (Lyttelton) | 537 542 |
| Wellington Seaport | 281 464 |
| Napier | 189 347 |
| Dunedin Seaport | 75 352 |
| Timaru | 71 891 |
| New Plymouth | 61 110 |
| Nelson | 35 651 |
| Gisborne | 1561 |

**Table 6:** Airports receiving freight from locations within 100 km of *A. gracilipes* infestation from 2000 to 2003 (locations used are listed in Appendix 1). Freight data from Statistics NZ.

| Airport | Air freight (tonnes) |
| --- | --- |
| Auckland Airport | 29 807 |
| Christchurch Airport | 3074 |
| Wellington Airport | 96 |
| Hamilton Airport | 15 |

# (C) LIKELIHOOD OF ESTABLISHMENT

## C1. Climatic suitability of regions within New Zealand for the establishment of the ant species

The aim of this section is to compare the similarity of the New Zealand climate to the locations where the ant is native or introduced using the risk assessment tool BIOSECURE (see Appendix 5 for more detail). The predictions are compared with two species already established in New Zealand (*Ph. megacephala* and *L. humile*) (Appendix 6). In addition a summary climate risk map for New Zealand is presented; this combines climate layers that most closely approximate those generated by the risk assessment tool Climex.

### C1.1 Climate limitations to ants

Given the depauperate ant fauna of New Zealand (only 11 native species), and the success of many invasive ants through-out the world in locations with diverse ant faunas (e.g., Human & Gordon 1996), competition with New Zealand's native ant species is unlikely to be a major factor restricting the establishment of invasive ants in New Zealand, although competition may be important in native forest where native ant abundance and diversity is higher (R. Harris, pers. obs.). For some species, the presence of other non-native ants in human-modified environments may limit their distribution (e.g., *Solenopsis invicta* has severely restricted the distribution of *S. richteri* and *L. humile* within the USA (Hung & Vinson 1978; Porter et al. 1988)) or reduce their chances of establishment. However, in most cases the main factors influencing establishment in New Zealand, should queens or colonies arrive here, are likely to be climatic.

A significant relationship between maximum (and mean) daily temperature and foraging activity for both dominant and subordinate ants species indicated temperature rather than interspecific competition primarily determined the temporal activity of ant communities in open Mediterranean habitats (Cerda et al. 1998). Subordinates are active over a wider range of temperatures (Cerda et al. 1998). In California, *L. humile* foraging activity was restricted by temperature attaining maximum abundance at bait at 34°C, and bait was abandoned at 41.6°C (Holway et al. 2002b).

Temperature generally controls ant colony metabolism and activity, and extremes of temperature can kill adults or whole colonies (Korzukhin et al. 2001). Oviposition rates may be slow and may not occur at cooler temperatures (e.g., *L. humile* does not lay eggs below a daily mean air temperature of 18.3°C (Newell & Barber (1913) quoted in Vega & Rust 2001)). At the local scale, queens may select warmer sites to nest (Chen et al. 2002).

Environments with high rainfall reduce foraging time and may reduce probability of establishment (Cole et al. 1992; Vega & Rust 2001). High rainfall also contributes to low soil temperatures. In high rainfall areas, it may not necessarily be rainfall per se that limits distribution but the permeability of the soil and the availability of relatively dry areas for nests (Chen et al. 2002). Conversely, in arid climates, a lack of water probably restricts ant distribution, for example *L. humile* (Ward 1987; Van Schagen et al. 1993; Kennedy 1998), although the species survives in some arid locations due to anthropogenic influences or the presence of standing water (e.g., United Arab Emirates (Collingwood et al. 1997) and Arizona (Suarez et al. 2001)).

New Zealand has a cool temperate climate and most non-native ant species established here have restricted northern distributions, with most of the lower South Island containing only native species (see distribution maps in New Zealand information sheets (wwwnew83)). Few adventive species currently established in New Zealand have been collected outside urban areas in the cooler lower North Island and upper South Island (R. Harris, unpubl. data); for some this could reflect a lack of sampling, but the pattern generally reflects climatic limitations. In urban areas, temperatures are elevated compared with non-urban sites due to the warming effects of buildings and large areas of concrete – the "Urban Heat Island" effect (Changnon 1999). In addition, thermo-regulated habitats within urban areas (e.g., buildings) allow ants to avoid outdoor temperature extremes by foraging indoors when temperatures are too hot or cold (Gordon et al. 2001).

*C1.2 Specific information on* Anoplolepis gracilipes

*Anoplolepis gracilipes* remains poorly studied in comparison with *Solenopsis invicta* and *Linepithema humile* (Holway et al. 2002a).  Little specific data on climatic tolerances were found for this species*.*

In hot climates, high midday temperatures prevent *A. gracilipes* workers from foraging on ground surfaces hotter than 44ºC, and foragers' activity declines below 25ºC (O'Dowd 2004a).  Optimal foraging is reported to occur between surface temperatures of 25 and 30ºC and is limited by strong winds and heavy rain (wwwnew77). Others have reported *A. gracilipes* workers to forage continuously between temperatures of 21ºC and 35ºC (Haines & Haines 1978; K. Abbott, unpubl. data), and temperature has been implicated as a limiting factor for establishment (Haines & Haines 1978).  High rainfall may also be important, as brood production events depend on the onset of the rainy season in Papua New Guinea, the Seychelles, and Christmas Island (Baker 1976; Haines & Haines 1978; K. Abbott, unpubl. data).

A Climex prediction of the distribution of *A. gracilipes* in Australia indicates that northern areas, particularly coastal areas of Northern Territory and Queensland, may be suitable (O'Dowd 2004b).  All areas considered even marginally suitable (receiving an ecoclimatic index score above 0) have higher mean annual temperatures than northern New Zealand.

The risk to New Zealand might usefully be assessed from the distribution of *A. gracilipes* in Hawaii, where it is generally found in the lowlands (< 900 m) (Reimer 1994).  It has been found at 1200 m on Haleakala (Medeiros et al. 1986, cited in Reimer 1994), but this was at a tourist car park and the ant is likely not established.  Ant species that occur in Hawaii's colder mountainous areas (900–1800 m, Reimer 1994) include *Pheidole megacephala* (which has a very restricted northern distribution in New Zealand (Appendix 6)), and *Linepithema humile*.  *Linepithema humile* also extends into the dry subalpine communities in Hawaii (1800–2700 m (Reimer 1994)), and its New Zealand distribution extends into the South Island (Appendix 6).

*C1.3 BIOSECURE analysis*

For the assessment of *A. gracilipes*, 175 locality records were used in the BIOSECURE analysis (Fig. 5).  Range data indicate *A. gracilipes* occurs predominantly in hot, wet climates (Table 7).  Temperatures in New Zealand are cold compared with locations where this species is established (compare Table 7 & 8). There is no overlap in mean annual temperature (MAT) and minimal overlap for the average minimum temperature of the coldest month (MINT) (Fig. 6). Overlap for MINT is due to a cold outlier – a record from Cocos (Keeling) Island reported by O'Dowd (2004a). Vapour pressure (VP) and mean annual solar radiation (MAS) also show similarity only to northern NZ (Fig. 7). Seasonality of temperature has low similarity with southern New Zealand and alpine areas. Other climate parameters are less discriminating for NZ.

*Climate summary*

The general climate summary for the international range of *A. gracilipes* indicates low similarity to New Zealand, particularly compared with that for *L. humile* (Fig. 8). Climate summary graphs are less useful than individual climate layers, as contrasts between species and regions of New Zealand are lost.

*Climate match conclusions*

We are unsure if *A. gracilipes* originated in Asia or Africa, but it has spread throughout the Pacific and Asian regions. By 1900 it had spread throughout much of its current range. It  primarily occurs between the Tropics of Cancer and Capricorn, and is a wet tropical and subtropical species.  Despite a long history of invading new areas this species has not established in temperate locations with a climate similar to New Zealand.

There are few experimental data on development rates and activity of this ant in relation to temperature. Comparison of current distribution indicates that New Zealand is too cold.  It is unlikely that winters restrict distribution but rather that summers would not be sufficiently hot. The lack of summer heat is likely to restrict the development of brood, allowing few generations to be raised during summer, and restricting foraging activity. It is predicted that the climate is less suitable for

*A. gracilipes* than it is for *Ph. megacephala*, a species that has a very restricted New Zealand distribution, and which, to date, has not been collected outside suburban Auckland (see Appendix 6). For *S. invicta*, which is established in colder climates than *A. gracilipes* or *Ph. megacephala,* New Zealand is considered marginal (Sutherst & Maywald 2005), with (in an average year) only one site out of fifty northern sites (North Shore, Auckland) having air temperatures that are likely sufficiently warm to allow workers to complete development in less than 12 months (S. Hartly, unpubl. data). Three sites out of 22 have soil temperatures that are suitable for completion of one generation in a year, compared with 11 sites out of 22 deemed suitable for *L. humile* (based on soil temperatures; Hartley & Lester 2003).

Establishment, at least temporarily, cannot be ruled out in exceptionally warm summers and hot micro-sites, e.g., beside tarmac, where temperatures are elevated compared with the surroundings. It is not known if colonies would be able to develop sufficiently to reproduce and compete with temperate ants species.

Records were recently found of *A. gracilipes* in high altitude areas of China (see Fig. 3), but nothing is reported of the environment where they occur, or of their abundance. It remains uncertain if these records are *A. gracilipes* or in fact another species. Wetterer (2005) considers the records "too far outside the apparent climatic tolerance of *A. gracilipes*, both in terms of latitude and elevation, for them to be from a permanent outdoors population". Such sites likely have very cold winters and hot summers. Populations from that region may have different temperature tolerances and developmental temperatures compared with *A. gracilipes* populations from tropical locations. However, there is currently a very low risk of transportation of ants from these areas to New Zealand due to the lack of trade pathways (see Fig. 4).
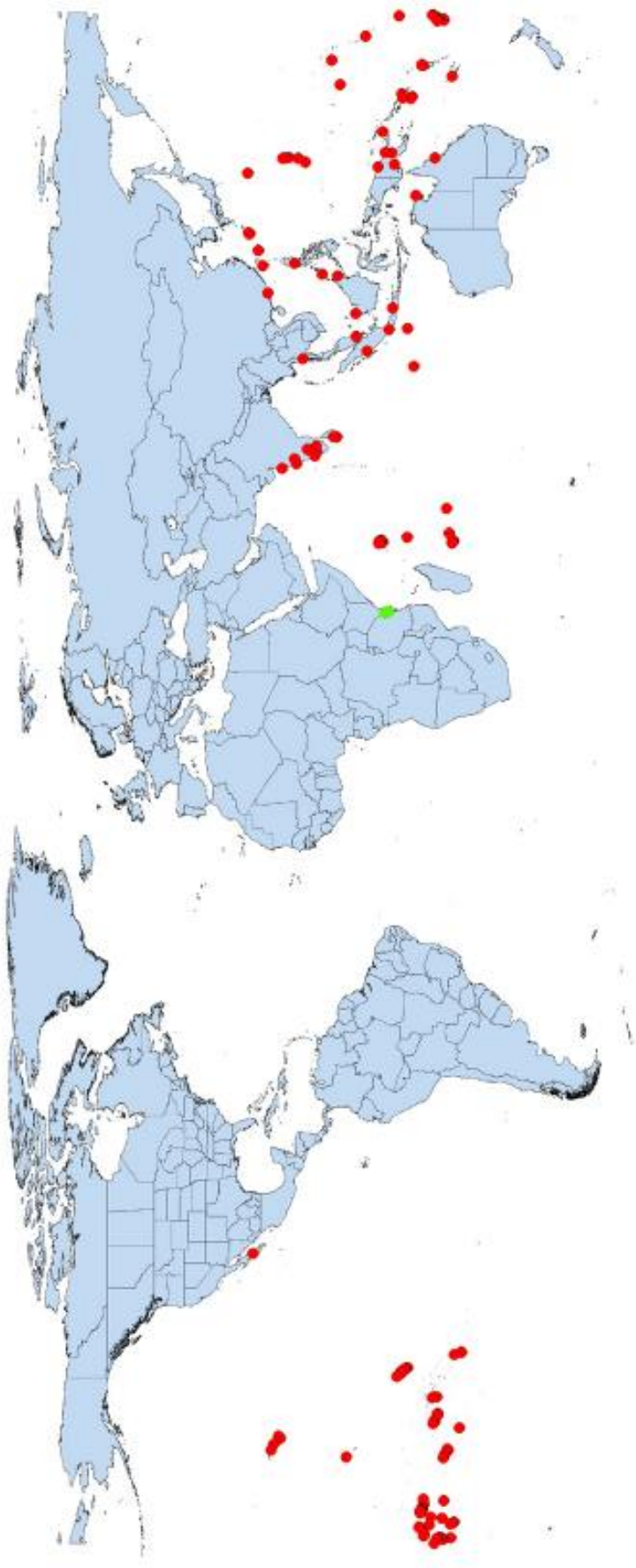
***Fig. 5:*** *Distribution records available at the time the BIOSECURE analysis of Anoplolepis gracilipes was run. Africa (green) is assumed as the native range for analysis; the remainder of the data areas are in red.*

**Table 7:** Comparison of climate parameters for native and introduced range of *Anoplolepis gracilipes*. These represent the ranges from the grid squares in which the ant occurs. The native dataset is uninformative in this species as it is not clear if Africa or Asia is the native range, and few collection records have been found from Africa.

| Parameter | n | Mean | Minimum | Maximum |
|---|---|---|---|---|
| *Mean Annual Temperature (°C) (MAT)* | | | | |
| Native Range | 2.0 | 26.0 | 25.9 | 26.0 |
| Introduced Range | 173.0 | 25.5 | 20.5[a] | 28.1 |
| *Minimum Temperature (°C) (MINT)* | | | | |
| Native Range | 2.0 | 17.6 | 15.6 | 19.6 |
| Introduced Range | 173.0 | 20.4 | 0.7 | 26.1 |
| *Mean Annual Precipitation (mm) (PREC)* | | | | |
| Native Range | 2.0 | 1117.0 | 1115.0 | 1119.0 |
| Introduced Range | 173.0 | 2268.0 | 122.0 | 4602.0 |
| *Mean Annual Solar Radiation (MAS)* | | | | |
| Native Range | 2.0 | 16.4 | 16.2 | 16.6 |
| Introduced Range | 173.0 | 15.7 | 13.3 | 20.5 |
| *Vapour Pressure (millibars) (VP)* | | | | |
| Native Range | 2.0 | 25.5 | 25.0 | 26.0 |
| Introduced Range | 173.0 | 25.9 | 17.0 | 31.0 |
| *Seasonality of Temperature (°C) (MATS)* | | | | |
| Native Range | 2.0 | 4.2 | 3.6 | 4.8 |
| Introduced Range | 173.0 | 5.3 | 0.6 | 23.8 |
| *Seasonality of Precipitation (mm) (PRECS)* | | | | |
| Native Range | 2.0 | 193.0 | 191.0 | 195.0 |
| Introduced Range | 173.0 | 227.7 | 25.0 | 921.0 |
| *Seasonality of Vapour Pressure (millibars) (VPS)* | | | | |
| Native Range | 2.0 | 6.0 | 6.0 | 6.0 |
| Introduced Range | 173.0 | 6.0 | 1.0 | 17.0 |

[a] Mean annual temperature for Brisbane where *Anoplolepis gracilipes* recently found established is approximately 20.4°C

**Table 8:** Range of climate parameters from New Zealand (N = 196 GRIDS at 0.5 degree resolution). Data excluding distant island groups (Chatham, Bounty, Antipodes, Campbell, Auckland, and Kermadec Islands).

| Parameter | Min | Max | Mean |
|---|---|---|---|
| MAT | -0.5 | 16.6 | 10.9 |
| MINT | -8.3 | 7.8 | 3.0 |
| PREC | 356.0 | 5182.0 | 1765.0 |
| MAS | 11.2 | 14.3 | 13.0 |
| VP | 4.0 | 15.0 | 9.7 |
| MATS | 6.4 | 10.6 | 8.8 |
| PRECS | 23.0 | 175.0 | 60.5 |
| VPS | 4.0 | 8.0 | 5.9 |
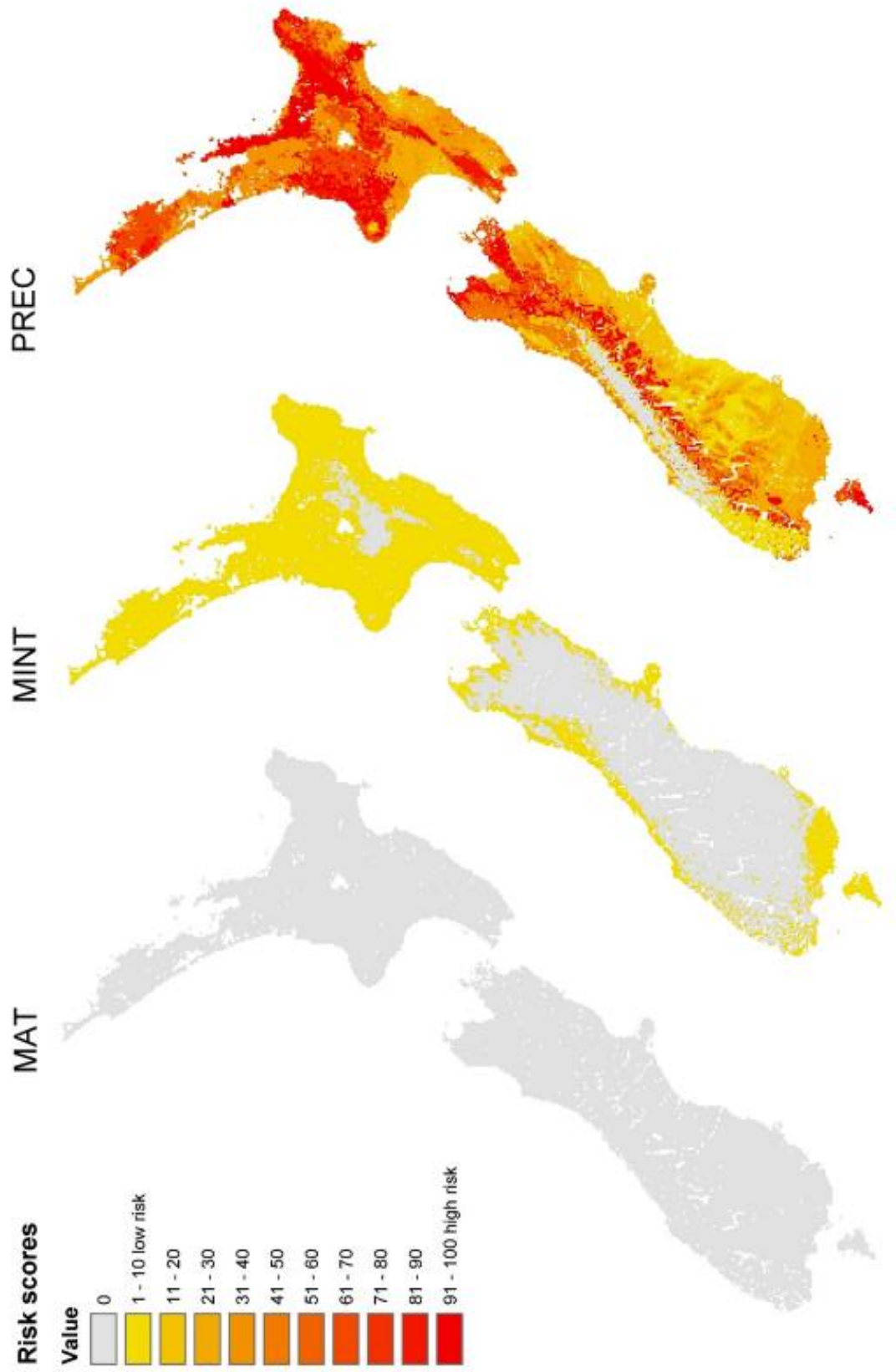
**Fig. 6**: *Similarity of native + introduced ranges of Anoplolepis gracilipes to New Zealand for MAT, MINT, and PREC.*

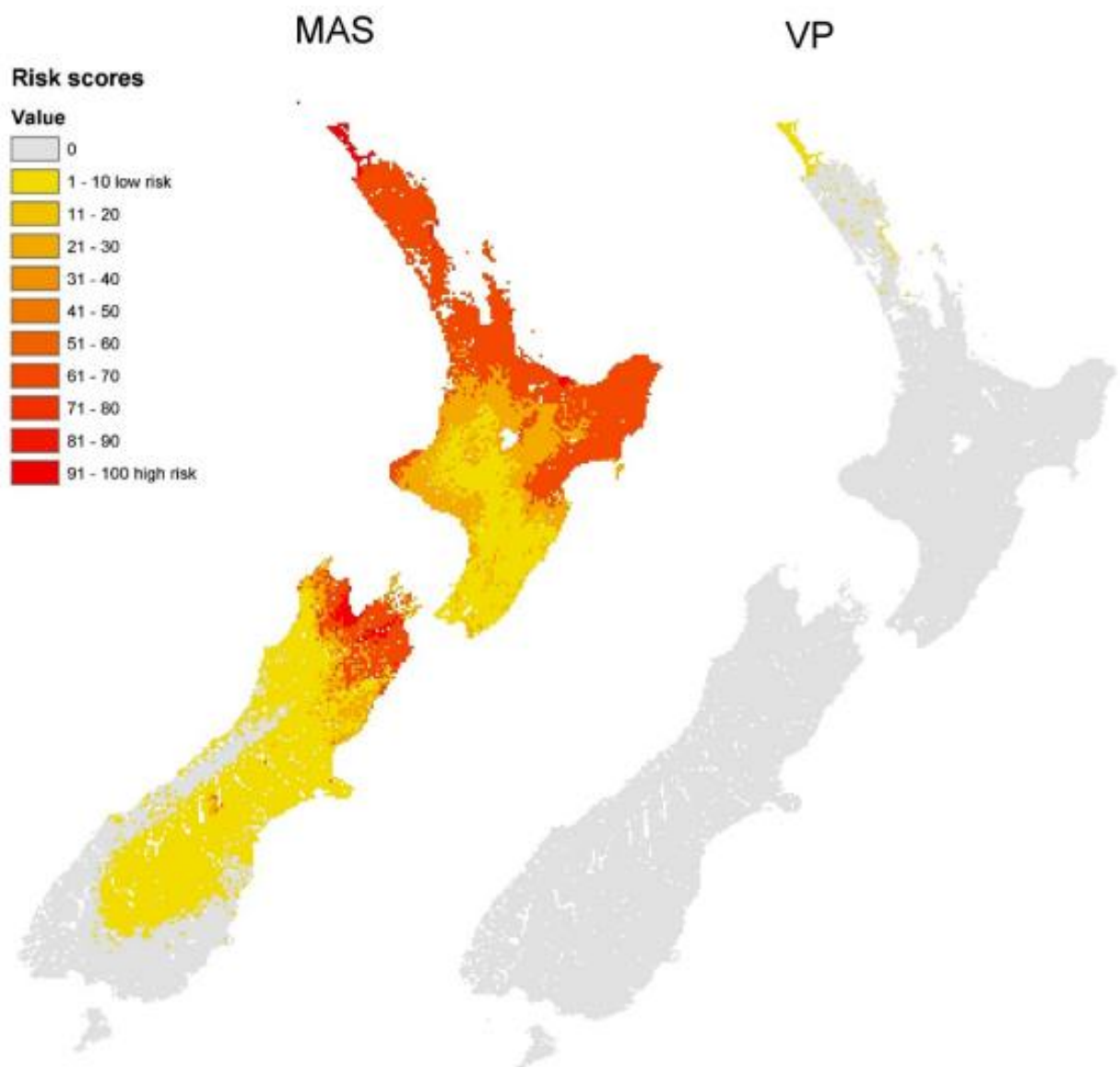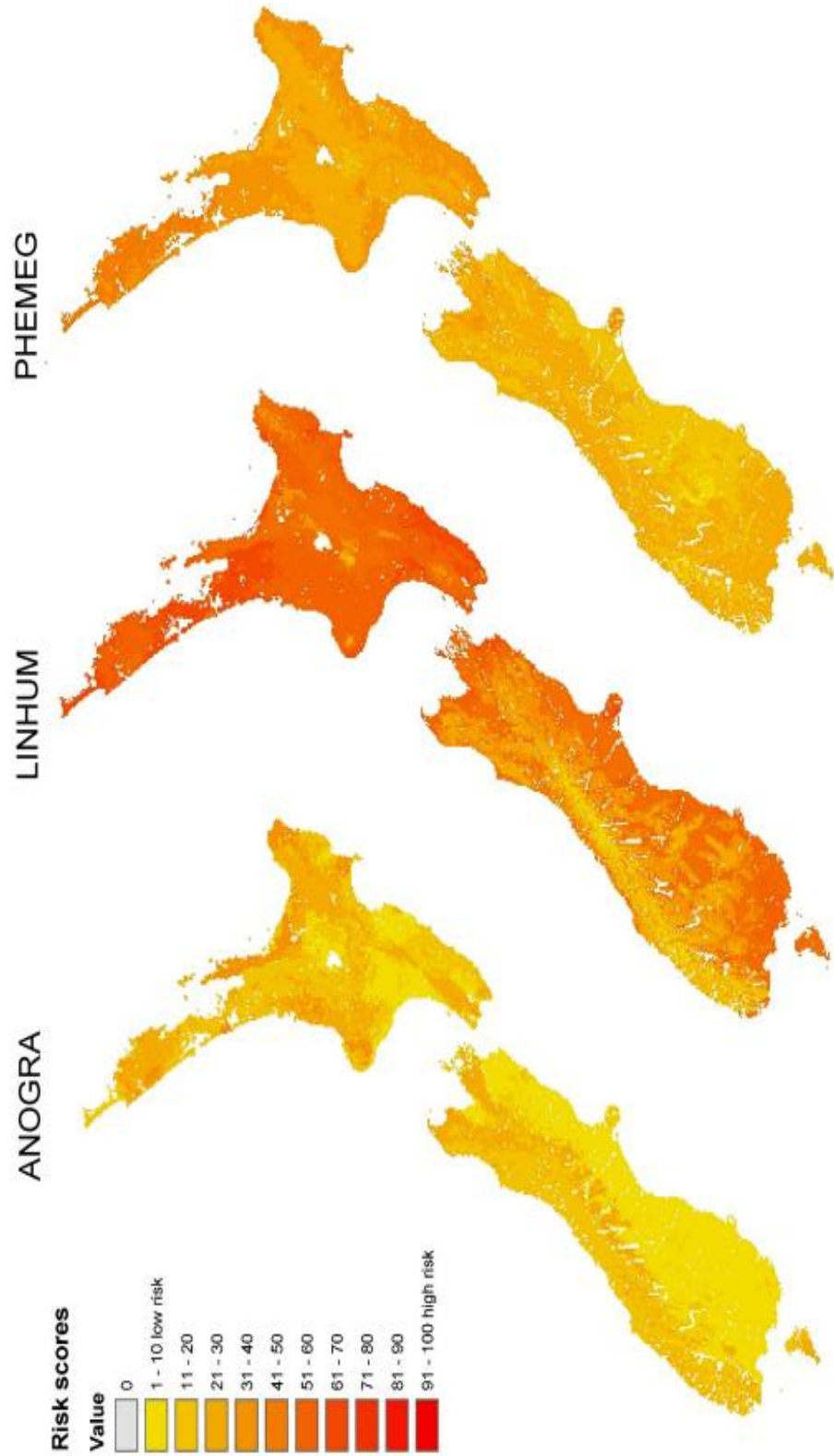**Fig. 7:** *Similarity of native + introduced ranges of* Anoplolepis gracilipes *to New Zealand for MAS and VP.*

*Fig. 8:* Comparison of climate similarity of New Zealand and the international ranges of A. gracilipes, L. humile and Ph. megacephala based on the mean of the similarity scores of five climate layers (MAT, MINT, PREC, VP, and PRECS). This presentation approximates that produced by the risk assessment tool Climex.

## C2. Potential to establish in protected environments

Although *A. gracilipes* is associated with humans and is common in disturbed areas, nearly all published records indicate that it nests outdoors, though it does forage inside houses (Haines & Haines 1978). To our knowledge, there have been no reports of it nesting inside buildings; however, on Christmas Island it frequently colonises the edges of buildings, gardens and nearby drainpipes (K. Abbott, pers. obs.). Records exist of other invasive ant species establishing indoors in urban areas in temperate climates (e.g., *Wasmannia auropunctata* (Naumann 1994) and *Paratrechina longicornis* (wwwnew47), but no such records were found for *A. gracilipes*.

Nests of this species have been found in Auckland (Summer 2002) and Mt Maunganui (June 2003) during incursion responses resulting from detections of *P. longicornis* on ant surveillance baits. The Auckland find was a small nest at the end of a wharf. This was in an area where timber from the Pacific was unloaded and stored for fumigation. The Mt Maunganui find was along a sheltered drain next to a container storage and repair yard. The yard receives empty containers from the Pacific, a pathway known to transport ants. It is not known if a solitary queen initiated each nest or if workers and queen(s) were transported to the sites. No brood was evident in the nests so they cannot be considered as evidence that establishment would have resulted had they not been detected and treated.

## C3. Documented evidence of potential for adaptation of the pest

No information was found relating to the adaptation potential of *A. gracilipes*. They have a broad diet and ability to nest in a wide range of locations, both which should favour survival in new conditions if climatic conditions allow development. Brood production events are flexible and can occur once or twice a year (Baker 1976; Haines & Haines 1978; K. Abbott, unpubl. data) depending on the onset of the rainy season. The wet season in the humid equatorial tropics usually occurs from about November through to May.

If the high altitude records from Asia (see Fig. 3) are correctly identified as *A. gracilipes,* and populations are permanently established, then it may indicate potential for cold adaptation. Our assumption is that these are not valid records, possibly representing another species, or they occur in lower altitude warm microclimates within the mountainous region, as they do not fit available information on the climate envelope of this species. There are no records from temperate climates outside Asia suggesting adaptability to cold.

## C4. Reproductive strategy of the pest

*Anoplolepis gracilipes* colonies are reported to be polygynous where they have invaded (Baker 1976; Haines & Haines 1978; Rao & Veeresh 1991; K. Abbott, unpubl. data), and data are not available on the reproductive schedule in its native range. The reproductive phenology of *A. gracilipes* is similar on Christmas Island (K. Abbott, unpubl. data), Indonesia (Van der Goot 1916), the Solomon Islands (Greenslade 1971a, 1971b), Papua New Guinea (Baker 1976), the Seychelles (Haines & Haines 1978), and in India (Rao & Veeresh 1991), in that the production of sexual brood is dependent on the onset of rains (Fig. 9).

Workers and worker brood are present in nests year round, males are usually produced up to 2 months before the wet season, and queen brood is typically produced 1–2 months before the wet season and continues throughout the wet season. The wet season in the humid equatorial tropics usually occurs from about November through to May. Baker (1976) and Haines and Haines (1978) described two brood production events in *A. gracilipes* in Papua New Guinea and the Seychelles, respectively. On Christmas Island there was evidence of only one brood production event (K. Abbott, unpubl. data). Nonetheless, this event is dependent on the onset of the rainy season.

The main method of dispersal and colony foundation is colony budding, where a queen or queens leave a nest with a group of workers to form a new colony nearby. There is no aggression between nests, and exchange of workers occurs between colonies. Both adult males and newly emerged queens possess wings and have the ability to fly. Mating flights

have not previously been documented for *A. gracilipes*, but Dammerman (1929) suspected that they occurred. The simultaneous capture of relatively high numbers of winged queens and males on Christmas Island suggests that mating flights do occur at the onset of rains (K. Abbott, pers. obs.), the main advantage being an increased rate of spread. Winged queens were observed at light sources (and generally lit areas) for up to 3 days following the first rains of the wet season in January 2001 (K. Abbott, pers. obs.). No information on distances of flights is available and it is unknown if alates are able to start new colonies themselves, or if they must join existing colonies to survive (O'Dowd 2004a). Baker (1976) reported that the number of dealate queens (those that have shed their wings) increases in the nest after new queens emerge, indicating that either some new queens mate in the nest and remain, or that at least some that leave the nest return. No reports were found confirming that queens can initiate a nest independently.
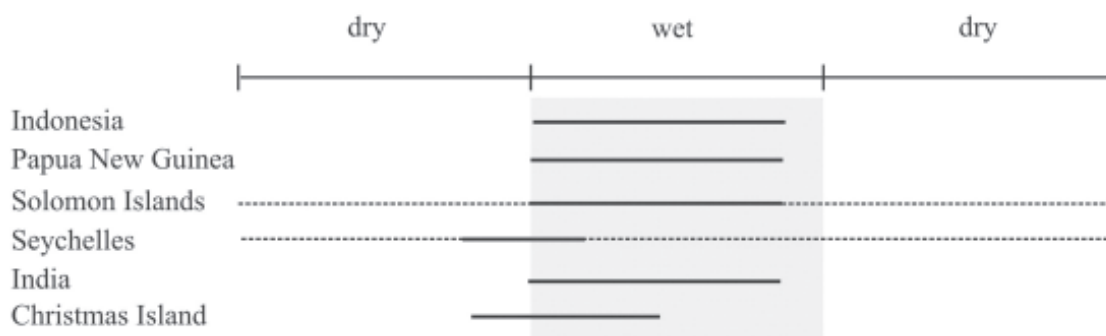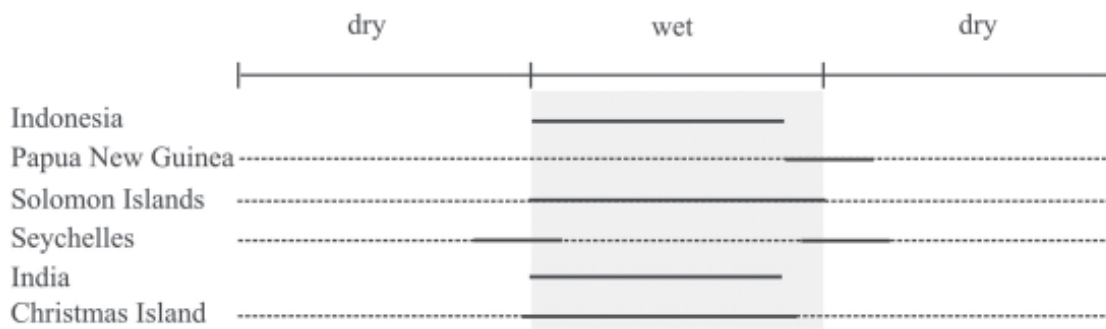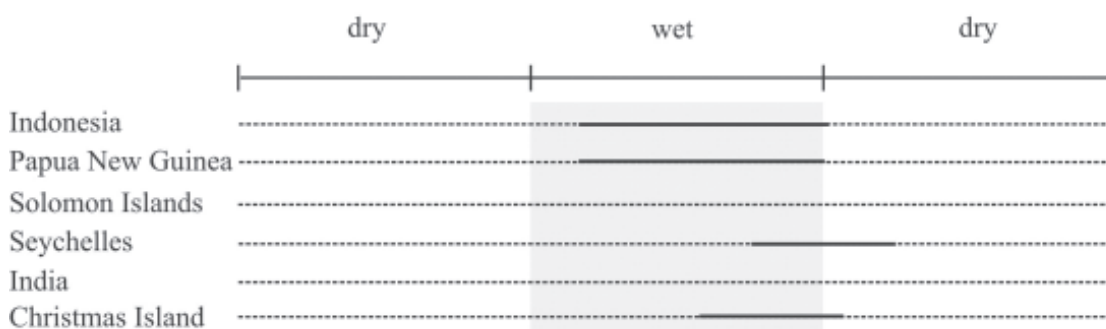


*Fig. 9: A comparison of* A. gracilipes *male, alate and dealate queen phenology between five studies in various locations. Heavy lines indicate the time when most individuals were recorded, and dotted lines indicate the presence of low number of individuals. The wet season is shown in grey and dry season either side. (Sources: Indonesia (Van der Goot 1916); Papua New Guinea (Baker 1976); Solomon Islands (Greenslade 1971b); Seychelles (Haines & Haines 1978); India (Rao & Veeresh 1991); Christmas Island (K. Abbott, unpubl. data)).*

## C5. Number of individuals needed to found a population in a new location

To our knowledge, no research has been conducted on this aspect of *A. gracilipes* life history. As budding is thought to be the primary mode of dispersal (Haines & Haines 1978; Veeresh 1990, cited in Passera 1994), a queen plus workers are likely to be needed to found a population at a new location. However, queens are relatively large, and an inseminated queen may have the capacity to start a new colony in isolation. Workers alone are incapable of founding a new nest.

Incursions of *A. gracilipes* found in New Zealand were small colonies without brood, suggesting the workers and at least one queen were transported rather than a queen alone.

## C6. Likely competition from existing species for ecological niche

*Anoplolepis gracilipes* displaces other ant species where it is dominant (Fluker & Beardsley 1970; Greenslade 1971a; Haines et al. 1994; K. Abbott, unpubl. data); however, the mechanism whereby these ants were displaced was not investigated. In Hawaii, *L. humile, Ph. megacephala* and *A. gracilipes* exclude one another where one species is dominant (Fluker & Beardsley 1970), but the mechanism for this is not known.

As boundaries of *A. gracilipes* supercolonies expanded and their density increased on Christmas Island, other ant species richness declined (K. Abbott, unpubl. data). *Anoplolepis gracilipes* co-exists with native and other ant species throughout its introduced range at relatively low densities; however, it is when the ants increase in density that competition becomes an important factor in their, and other ant species' continued existence in a given area. Workers exhibit virtually no intraspecific aggression within and between supercolonies on Christmas Island (K. Abbott, unpubl. data), and in other areas where *A. gracilipes* has been introduced (Passera 1994). However, intraspecific aggression has been found between two genotypes on Tokelau (one from an old invasion; one from a new (P. Lester, pers. comm.)).

The presence of other ant species more suited to temperate climates at the site of an incursion in New Zealand (e.g., *Linepithema humile, Doleromyrma darwiniana* (Darwin's ant) may increase competition pressures and reduce the chances of establishment of *A. gracilipes*.

## C7. Presence of natural enemies

Natural enemies of *A. gracilipes* have never been recorded. Greenslade (1972) reported that *A. gracilipes* appeared to have no important enemies except other ants. *Anoplolepis gracilipes* is a member of the subfamily Formicinae (sprays formic acid which it stores in its abdomen), and is unpalatable to most vertebrate predators.

## C8. Cultural practices and control measures applied in New Zealand that may affect the ant's ability to establish

Practices at the point of incursion (e.g., seaports and airports) are most likely to affect the ability of *A. gracilipes* to establish at those sites. Presently, there are no routine treatments of port areas that would decrease the chances of survival for *A. gracilipes*. However, there are intermittent treatments of incursions of other invasive ant species in and around ports that would reduce the chances of new propagules surviving if they were present at the time of treatment.

Existing invasive ant surveillance in and around ports should be sufficiently thorough to detect any significant *A. gracilipes* incursion (consisting of a large expanding colony or colonies). As the climate is suboptimal, such colonies may be rare. Routine surveillance failed to pick up the single nests at Auckland and Mt Maunganui; these were only found when more detailed searching was conducted following detection of other species. These nests had no brood present and therefore workers would not have been collecting protein and may not have been actively foraging. Also foragers would only be active if ground surface temperatures were 21–35°C (Haines & Haines 1978). If missed by surveillance one year, they would likely be picked up in subsequent surveillance if the site was sufficiently warm to allow development.

If *A. gracilipes* was missed by surveillance and established at a site it might be noticed as something unusual by the general public due to its distinctive appearance.  For this species Auckland (sea and airports) and Tauranga, would be the focus sites for surveillance, based on their mild climate (although generally considered too cold for permanent establishment), high volumes of non-bulk freight, and empty containers entering the ports from countries with this ant. In addition, Whangarei should be added to the surveillance list based on its mild climate and the number of empty containers it receives from the Pacific. Ongoing invasive ant surveillance should include all sites that receive and store empty containers from overseas.

# (D) LIKELIHOOD OF SPREAD AFTER ESTABLISHMENT

## D1. Dispersal mechanisms

There are three methods of dispersal that, combined, have contributed to the spread of *A. gracilipes* at local, regional, national and international scales: human-mediated dispersal, budding, and independent colony founding.

Most significant is human-mediated dispersal, where colonies are inadvertently transported to new location by humans, for example, in potted plants, containers, or rubbish. The association is as a stowaway using any available nesting space, as opposed to a host-specific association. This makes identification of particular risk goods and their targeting particularly difficult. The ant has been intercepted entering New Zealand in a wide range of freight types (see Section B1).

*Anoplolepis gracilipes* also spreads naturally from established colonies in two ways. First, colony budding (Haines & Haines 1978; Rao et al. 1991; K. Abbott, unpubl. data), where queens walk on foot accompanied by workers to a new nesting site, up to 3.2 m from their nest (Rao et al. 1991). In ideal conditions colony expansion and budding may occur regularly through summer. Second, winged dispersal by inseminated queens to uninfested areas where they start a colony of their own. This mode of dispersal has not been confirmed for *A. gracilipes*, but may explain apparent establishment of isolated nests on Christmas Island (K. Abbott, pers. obs.). Colony budding is thought to be the primary dispersal method.

## D2. Factors that facilitate dispersal

To our knowledge, there have been no studies suggesting natural factors in the dispersal of *A. gracilipes*. The occurrence of budding is likely to relate to the size of the colony and the number of queens present. Altered environmental conditions may occasionally promote crowding of newly dealated queens, and as a result, the founding of colonies by multiple queens is usually flexible in a particular species (Holldobler & Wilson 1990). In extreme high densities, *A. gracilipes* on Christmas Island formed 'mega-nests', where there were often upward of 1000 queens in a single nest (K. Abbott, unpubl. data).

Budding will aid human-mediated dispersal as colonies move into new sites. The suboptimal climate in New Zealand will restrict development rates of workers and queens, thus restricting the number of generations that occur per year and the rate of colony expansion and occurrence of budding. A single generation may not be able to be completed successfully over most of New Zealand, as even development predictions for the temperate adapted *Linepithema humile* indicated large areas of New Zealand are probably too cold for a single generation to be completed successfully (Hartley & Lester 2003).

Colonies readily migrate if disturbed (Passera 1994), so disturbance of an area would promote movement to new nesting sites.

## D3. Potential rate of spread in its habitat range(s)

Dispersal within a habitat is primarily by budding (but aerial dispersal might occur). Colony boundaries are dynamic, and in favourable conditions can expand. However, boundaries can also remain stationary or contract, and reasons for this are unknown. Movement of boundaries may be due to available resources outside their range. Haines and Haines (1978) reported rates of spread in the Seychelles of between 0.1 and 1.1 m/day (36.5–401.5 m/year), and K. Abbott (unpubl. data) found rates of movement (contraction and expansion of boundaries) of between 48 and 163.2 m/year on Christmas Island. Queens can walk 3.2 m from their focal nest (Rao et al. 1991). All these studies were conducted in tropical locations, and are likely to overestimate the potential for *A. gracilipes* to spread by budding in New Zealand conditions.

The rate of spread is potentially much larger through human-mediated dispersal, but is reliant on a suitable microclimate

for survival and growth at the point of arrival.  For *L. humile* in New Zealand, which spreads by similar means, the median distance of human-mediated dispersal was estimated to be between 10 and 72 km (Ward et al. 2005).

## D4. Presence of natural enemies

The presence of other ant species more suited to temperate climates in New Zealand (e.g., *Linepithema humile* and *Doleromyrma darwiniana* (Darwin's ant)) may increase competition pressures and reduce the chances of spread. It is unlikely that *A. gracilipes* would coexist with either species.

# (E) THE ENVIRONMENTAL, HUMAN HEALTH AND ECONOMIC CONSEQUENCES OF INTRODUCTION

## E1. Direct effects

### E1.1 Potential for predation on, or competition with New Zealand's indigenous fauna

International data point to the potential for significant impacts on a whole range of indigenous fauna. However, the species is considered highly unlikely to establish permanently in New Zealand, or at worst in limited sites with elevated temperatures compared with the general surroundings. Establishment inside heated buildings is unlikely based on the ants' international distribution, but could occur next to buildings if elevated temperatures were maintained. In such locations native biodiversity values would be low.

If climate predictions are wrong and *A. gracilipes* was to establish in northern New Zealand, it would invade natural habitats as it has overseas. The consequences of establishment would depend on the resulting ant density. The worst case scenario is that "supercolony" densities result. Other ant species would be then displaced (e.g., Fluker & Beardsley 1970) and invertebrate communities disrupted through predation, competition, and scale insect tending (e.g., Feare 1999). Native vertebrates would be attacked and may be unable to breed in areas where the ant was present (e.g., Feare 1999). The ant could threaten species with restricted northern distributions (e.g., land snails). Plants susceptible to Homoptera would be reduced in abundance through dieback caused by the increased abundance of these insects (e.g., O'Dowd et al. 2003), and undermining of roots (e.g., Feare 1999). Such densities and impacts are considered highly unlikely as they have only been reported from tropical climates.

Establishment, if it occurs, is more likely to be at lower densities. Co-existence with other ants is likely (K. Abbott, pers. obs.), and in some cases *A. gracilipes* may be displaced by other ants (e.g., Fluker & Beardsley 1970). Although some community compositional changes are likely to result (as they will with the establishment of any new species in native habitats) the survival of any species is unlikely to be threatened.

### E1.2 Human health-related impacts

Given the low probability of establishment and build up of significant numbers at any site, health-related impacts are likely to be minimal and restricted to northern New Zealand. When present the ant can be a household pest. Formic acid burns are possible if a large nest was disturbed.

### E1.3 Social impacts

Activity of the fast-moving foragers (on very hot days) could cause a nuisance. However, in many northern urban areas it would likely encounter competition with *L. humile* (see distribution map Appendix 6), and the social impacts are unlikely to be worse than those associated with *L. humile* (Harris 2002).

### E1.4 Agricultural/horticultural losses

We found no data on direct agricultural/horticultural losses caused by *A. gracilipes*. If moderate densities were achieved on farms it could become a nuisance to domestic stock. In abundance *A. gracilipes* can prey upon newborn pigs, dogs, cats, rabbits, rats, and chickens (Haines et al. 1994). The ant is capable of removing roots around plants, increasing honeydew producing scales, and causing the build up of sooty mould on fruit and foliage, which would result in reduced plant photosynthesis and growth, and reduced crop yields and quality (e.g., Haines et al. 1994; Wood et al. 1988). Such impacts are unlikely to be significant in conventional orchards that use insecticides. For crops to be significantly impacted ant densities would also need to be greater than the existing low density ant populations that already occur in such situations (Lester et al. 2003).

Any detrimental impacts will in part be offset by the beneficial impacts of the ant as a predator of other pest species; the ant has been used in biological control trials (Entwistle 1972; Room 1975; Room & Smith 1975).

## E1.5 Effect(s) on existing production practices

No major consequences for existing production practices are foreseen.

## E1.6 Control measures

Poisoning with toxic bait is the most effective method for control of *A. gracilipes*. Successful control programs have been carried out for high densities of *A. gracilipes* in the Seychelles (Haines & Haines 1979a ,1979b, 1979c, 1979d) and on Christmas Island (Green et al. 2004), both using toxic bait distributed throughout infested areas.

Bait and toxicant development for the control of *A. gracilipes* in the Seychelles resulted in the use of the organochlorine insecticide Aldrin incorporated into a bait based on a carrier of sieved coir waste (fibre from around the seed of coconut palm) (Haines & Haines 1979b; 1979d). Large-scale baiting programmes were organised in October 1975 and April 1976. Large areas were baited at the recommended rate of 10 kg/ha, and abatement of the ant was estimated to cost £4.00–8.00/ha per year (based on 1976 estimates including materials, freight and labour) (Haines & Haines 1978).

On Christmas Island, after unsuccessful laboratory and field trials with several commercially available ant poisons, fish-meal bait was chosen, with an active constituent of fipronil at 0.1 g/kg. The bait was developed in conjunction with Aventis CropScience Pty Ltd and Bayer Environmental Science under the name Presto® 01 Ant Bait. It is now (2005) manufactured by BASF Australia under the name Adonis®. Fipronil is one of a new phenylpyrazole class of neurotoxic insecticides, and disrupts normal nerve function by targeting the ã-aminobutyric acid type A (GABA) receptor system of animals, particularly invertebrates. The bait is currently unregistered in Australia, but is permitted for use on Christmas Island by Parks Australia North under emergency permit PER 4091 issued by the National Registration Authority.

Initially, bait was distributed on foot through the rainforest. However, some areas of Christmas Island were inaccessible, and an aerial baiting programme was developed to control supercolonies over the entire island (distributing poison bait by helicopter). The aerial baiting campaign was highly successful, and had a significant effect on crazy ant activity. There was 166-fold decline in ant activity following bait application by helicopter, and non-target effects were minimal (Green et al. 2004).

For small, localised incursions, direct nest treatment methods currently used for other invasive ants (direct application of insecticide to nests) are likely to be sufficient (V. Van Dyke, pers. comm.).

Adonis is not registered in New Zealand, so could not be used off the shelf if there was an incursion. Fipronil based Xstinguish™ Argentine ant bait is registered in New Zealand, so it would be relatively easy to register Adonis®. The process may take 3–6 months. The bait is currently not in commercial production, but relatively large amounts (100 kg) are being produced and trialled on Tokelau (K. Abbott, pers. comm.).

## E2. Indirect effects

### E2.1 Effects on domestic and export markets

No effects on domestic or export markets have been documented. However, if *A. gracilipes* was to become established in New Zealand and transported to another country where crazy ants were absent, it could affect import health standards applied to New Zealand exports.

## E2.2 Environmental and other undesired effects of control measures

No documented cases were found of unacceptable adverse non-target effects arising directly from the use of toxic baits for control of *A. gracilipes*. However, fipronil, widely used in ant control programmes, is currently under review in Australia due to reports of negative effects on non-target species and human health (APVMA 2003).

Fipronil is a broad-spectrum insecticide, and will kill any invertebrate via contact and ingestion, and therefore may represent a threat to invertebrates in the direct baiting area, or in foraging distance of the bait. It is also highly toxic to some fish and aquatic invertebrates (wwwnew81), so extreme care its needed when using fipronil near waterways.

There are no documented cases of resistance of any ant to pesticides.

# (F)  LIKELIHOOD AND CONSEQUENCES ANALYSIS

## F1. Estimate of the likelihood

### F1.1 Entry

*Anoplolepis gracilipes* currently has a *high* risk of entry.

This assessment is based on:

- *A. gracilipes* having been frequently intercepted at the New Zealand border (61 times between 1997 and end 2002, and 21 times between start of 2003 and March 2004 during a period of full reporting of interceptions).

- the species having the potential to stowaway in a wide range of freight, reflected in the diverse array of interceptions. It is also relatively frequently intercepted associated with empty containers.

- *A. gracilipes* exhibiting typical tramp ant characteristics that promote the chances of queens with workers being transported; polygyny, budding, mobile colonies, and unicolonial habits.

- it having a widespread distribution in Asia (high freight volumes to New Zealand) and the Pacific (a high-risk pathway for ants entering New Zealand).

*Data deficiencies:*

- not all ants intercepted at the New Zealand border are reported, and not all are identified to species, so interception records could underestimate entry of any species. It is also not always clear in interception data if castes other than workers were intercepted.

### F1.2 Establishment

*Anoplolepis gracilipes* currently has a *low* risk of establishment.

This assessment is based on:

- suitable habitat for nesting being close to sites of arrival or devanning, but available climate information suggesting this wet tropics species is unlikely to establish permanently in New Zealand. Winter temperatures are unlikely to kill colonies as the ant is established at sites with winters as harsh as lowland New Zealand.  However, mean annual temperatures are lower in New Zealand than sites of establishment, indicating summer temperatures will restrict colony development and foraging.

- the required reproductive stages occasionally arriving in New Zealand. Queens accompanied by workers are required for the successful establishment of a colony, and both queens and queens with workers have been intercepted at the New Zealand border. Also incursions of this species have occurred in New Zealand but there is no evidence of brood being successfully produced, or of more than a single colony being present.

- this species not showing a history of establishing in temperate climates in close association with heated buildings.

- the ant having been widely distributed in the Asia and the Pacific for many years without any confirmed establishments in temperate Asia, southern Australia or New Zealand.

- there being competition from other adventive ants, which would restrict establishment chances at some locations.

- the large size and highly visible foraging of this ant helping early detection of established populations.

- there being proven methods for management of large incursions.

Surveillance targeting other invasive ants (particularly *S. invicta*) is likely to cover this species adequately, provided monitoring is on hot days (surface temperatures of 25 and 30ºC) when *A. gracilipes* is most active.

*Data deficiencies:*

- there are only limited experimental data on the climate tolerances of *A. gracilipes*. The climate assessment is based principally on climate estimates from known sites of establishment, a Climex prediction for Australia, and consideration of the restricted alpine distribution in Hawaii.

- the ability of *A. gracilipes* to establish in temperate sites dominated by *Linepithema humile* is unknown; however, this is assumed to be unlikely.

- successful eradication of large populations of this ant has not yet been demonstrated.

- there is uncertainty about the distribution of *A. gracilipes* in inland high altitude regions of Asia that represent cold temperature outliers in the international distribution. Further knowledge of exactly where *A. gracilipes* is within this region, and the environmental conditions it is exposed to, is needed to determine if these populations indicate ability to establish in colder climates than predicted in this pest risk assessment.

## F1.3 Spread

*Anoplolepis gracilipes* has a *low* risk of spread from a site of establishment.

This assessment is based on:

- areas of New Zealand considered climatically suitable for spread are highly restricted to at worst, some hot microclimates in northern New Zealand

- lack of suitable habitat occurring in New Zealand. A range of disturbed and undisturbed wet habitats are favoured. Forests are colonised by this ant, but New Zealand forests are likely to be too cold.

- the assumption that colonies in most situations would not attain sufficient size to produce reproductives and disperse via budding. Sub-optimal summer temperatures are likely to restrict foraging and colony development and extend the period from colony arrival to the production of reproductives and further budding. In most locations summer would be too cold for successful development of reproductives.

- budding will limit the initial spread to areas adjacent to points of introduction and human-mediated dispersal would be the primary method of spread. Rates of spread will be low due to low productivity of colonies.

- an effective management strategy exists for populations of this ant that would reduce chances of further spread.

*Data deficiencies:*

- while Northern New Zealand's climate is considered generally unsuitable for *A. gracilipes*, it is unclear exactly what this means should a queen with workers arrive at a location. It could mean no successful development of brood, or alternatively, development at a very slow rate permitting establishment but restricting population densities. Experiments investigating development rates of brood and survival of colonies at low temperature are needed to better understand the likelihood of persistence at sub-optimal temperatures.

*F1.4. Consequences*

The consequences of the presence of *A. gracilipes* in New Zealand are considered *medium/high*.

This assessment is based on:

- a worst case scenario, i.e. the assumption that climate predictions underestimate the distribution of *A. gracilipes*, which could establish permanent populations in hot microclimates in northern New Zealand.

- hot microclimates within native and disturbed habitats being invaded.

- the potential for significant impacts on a whole range of indigenous fauna. Invertebrates, vertebrates, and plants could potentially be impacted through worker defence via formic acid spraying, predation and competition for food, and through Homoptera tending. The consequences of establishment would depend on the resulting ant density. Densities resulting in "supercolony" formation would be highly unlikely to occur.

- minor medical consequences of establishment, as a result of the spraying of formic acid by foragers.

- the presence of colonies in urban areas being conspicuous due to large active foragers and foragers' propensity to enter buildings and feed. It is likely that there would be expenditure on pest control. The social impacts of *A. gracilipes* are unlikely to be worse than those of *L. humile*.

- detrimental impacts occurring in horticulture through tending of Homoptera, wherever the ant established.

*Data deficiencies:*

- all information on detrimental impacts of this ant is from tropical climates, which limits its applicability to New Zealand. Studies of the success of spread, population densities, and impacts in more temperate climates are needed to better predict consequences for New Zealand. A potential location for such studies would be the edge of its altitudinal limit in Hawaii. Also of future interest will be the expansion of the northern limit of the population established in Mexico: will it spread north into California?

## F2. Summary table

Ant species:          *Anoplolepis gracilipes*

| Category | | | Overall risk |
|---|---|---|---|
| Likelihood of entry | High | Frequent interceptions. | Medium |
| | | Many pathways. | |
| | | Wide range of commodity associations. | |
| Likelihood of establishment | Low | Tropical species. | |
| | | Likely that NZ too cold. | |
| | | Unlikely to nest in heated buildings. | |
| Likelihood of spread | Low | Sub-optimal conditions. | |
| | | Slow rate of increase and spread. | |
| | | Good options for management. | |
| Consequence | Medium–high | Potentially high if high densities, but predicted to be low anywhere it established. | |

A detailed assessment of the Kermadec Islands is beyond the scope of this assessment.

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(NB: a copy of all web page references is held by Landcare Research (M. Stanley) should links change)

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## (I) Acknowledgements

# (J) Appendices

## Appendix 1: Freight summary

**Table a.** Summary of sea freight coming to New Zealand from localities within 100 km of known sites with *A. gracilipes*. Values represent the total freight (tonnes) during 2001, 2002 and 2003. Total freight is broken into different commodity types (source: Statistics New Zealand). NB: New Zealand received some freight from all locations listed, but if total freight is below 500 kg it is listed as 0 tonnes. Details of freight types that comprise each category are given (c) as are the categories (HS2 Chapters) used to classify incoming freight in the Statistics New Zealand database (d).

| Country | Port of export | Total freight | Appliances | Fibres | Bulk | Foodstuffs | Furniture | Furs | Glass | Metals | Produce | Wood | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American Samoa | Pago Pago | 18872 | 929 | 3 | 21 | 5 | 0 | 0 | 0 | 17796 | 0 | 0 | 17 |
| Australia | Cairns, QL | 117546 | 0 | 0 | 0 | 68684 | 0 | 0 | 0 | 0 | 0 | 0 | 48862 |
| Australia | Gove, NT | 677832 | 0 | 0 | 677832 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brunei Darussalam | Bandar Seri Begawan | 133354 | 0 | 0 | 133334 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 |
| Brunei Darussalam | Muara | 21 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chile | Las Ventanos | 220 | 0 | 0 | 0 | 144 | 0 | 0 | 0 | 76 | 0 | 0 | 0 |
| Chile | Valparaiso | 30564 | 108 | 16 | 5443 | 13016 | 9 | 0 | 91 | 2135 | 7125 | 1022 | 1599 |
| China | Chiwan | 2957 | 202 | 65 | 1851 | 188 | 155 | 5 | 31 | 281 | 71 | 40 | 68 |
| China | Guangzhou (Canton) | 68269 | 1634 | 549 | 56342 | 1526 | 1013 | 121 | 2916 | 2129 | 94 | 399 | 1545 |
| China | Haikou | 15418 | 6 | 70 | 15000 | 105 | 41 | 7 | 0 | 42 | 0 | 136 | 11 |
| China | Huangpu | 38933 | 2482 | 1098 | 15217 | 4050 | 2892 | 146 | 4452 | 3498 | 201 | 1850 | 3047 |
| China | Quanzhou | 2102 | 228 | 64 | 468 | 244 | 13 | 11 | 336 | 279 | 112 | 205 | 142 |
| China | Shekou | 2012 | 87 | 30 | 106 | 170 | 149 | 5 | 889 | 314 | 35 | 104 | 124 |
| China | Shenzhen | 3347 | 288 | 53 | 105 | 108 | 392 | 51 | 1913 | 254 | 0 | 55 | 127 |
| China | Xiamen | 43808 | 1826 | 3612 | 6814 | 1378 | 3500 | 1531 | 5986 | 11934 | 363 | 342 | 6521 |
| China | Yantian | 13267 | 3561 | 167 | 95 | 103 | 3887 | 183 | 1961 | 1922 | 6 | 321 | 1062 |
| China (Hong Kong) | Hong Kong SAR | 455059 | 64385 | 33371 | 154811 | 27265 | 32065 | 5596 | 27075 | 60995 | 3831 | 9946 | 35718 |
| China (Hong Kong) | Kowloon | 188 | 10 | 20 | 0 | 0 | 42 | 30 | 1 | 36 | 0 | 37 | 14 |
| China (Macau) | Macau | 26 | 6 | 12 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 4 |
| Christmas Island | Christmas Island | 31500 | 0 | 0 | 31500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cook Islands | Aitutaki | 93 | 67 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 22 | 0 | 1 |
| Fiji | Lautoka | 13455 | 574 | 219 | 0 | 7892 | 160 | 4 | 1 | 817 | 1570 | 1296 | 921 |
| Fiji | Nadi | 839 | 4 | 2 | 0 | 16 | 0 | 0 | 0 | 14 | 774 | 28 | 28 |
| Fiji | Savusavu | 66 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 65 | 0 |
| Fiji | Suva | 40544 | 940 | 464 | 83 | 8512 | 290 | 3 | 82 | 2211 | 18069 | 9328 | 562 |
| French Polynesia | Papeete | 5364 | 321 | 1 | 6 | 4530 | 9 | 0 | 0 | 463 | 11 | 1 | 21 |
| Guam | Guam | 50 | 2 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| India | Banddar | 98 | 0 | 12 | 0 | 37 | 2 | 0 | 11 | 25 | 0 | 0 | 11 |
| India | Bangalore | 1599 | 7 | 16 | 104 | 802 | 38 | 0 | 256 | 181 | 58 | 62 | 75 |

| Country | Port of export | Total freight | Appliances | Fibres | Bulk | Foodstuffs | Furniture | Furs | Glass | Metals | Produce | Wood | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| India | Bombay (Mumbai) | 31975 | 890 | 3753 | 6603 | 5258 | 744 | 191 | 4196 | 5475 | 1469 | 401 | 2994 |
| India | Calcutta | 13477 | 28 | 2441 | 423 | 118 | 2 | 75 | 522 | 9724 | 35 | 1 | 107 |
| India | Madras | 11132 | 181 | 798 | 3118 | 1186 | 82 | 38 | 3389 | 1204 | 104 | 141 | 892 |
| India | Panaji, Goa | 25 | 0 | 1 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 1 |
| India | Trivandrum | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Indonesia | Ambon, Molucas | 12412 | 0 | 0 | 12412 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Indonesia | Bandung, Java | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Indonesia | Belawan, Sumatra | 111834 | 0 | 19 | 107464 | 627 | 10 | 0 | 0 | 2515 | 0 | 1198 | 1 |
| Indonesia | Benoa, Bali | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Indonesia | Cilacap, Java | 28013 | 0 | 0 | 28012 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Indonesia | Denpasar, Bali | 34971 | 0 | 0 | 34660 | 55 | 13 | 0 | 4 | 12 | 0 | 225 | 1 |
| Indonesia | Jakarta, Java | 627407 | 7678 | 6649 | 482350 | 25252 | 2467 | 74 | 21925 | 45631 | 26 | 28056 | 7300 |
| Indonesia | Padang (Teluk Bajur), Sumatra | 7689 | 0 | 9 | 0 | 6224 | 0 | 4 | 0 | 40 | 5 | 1416 | 0 |
| Indonesia | Semarang, Java | 36975 | 80 | 921 | 30220 | 1 | 3453 | 0 | 796 | 72 | 5 | 1411 | 12 |
| Japan | Naha, Okinawa | 53 | 44 | 1 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| Japan | Okinawa, Okinawa | 31 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 20 |
| Malaysia | Bagan Luar (Butterworth) | 299 | 0 | 0 | 0 | 279 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Malaysia | Kota Bharu | 6244 | 0 | 0 | 0 | 6186 | 0 | 0 | 0 | 47 | 0 | 11 | 0 |
| Malaysia | Kota Kinabalu, Sabah | 31106 | 9 | 0 | 0 | 30674 | 42 | 0 | 0 | 28 | 0 | 353 | 0 |
| Malaysia | Kuala Lumpur | 23218 | 1102 | 569 | 772 | 664 | 9374 | 2 | 3245 | 5404 | 8 | 1411 | 669 |
| Malaysia | Kuching, Sarawak | 95477 | 100 | 4 | 81027 | 13269 | 71 | 0 | 74 | 530 | 0 | 36 | 364 |
| Malaysia | Labuan, Sabah | 416604 | 0 | 0 | 416604 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Malaysia | Miri, Sarawak | 186361 | 0 | 0 | 186361 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Malaysia | Pasir Gudang, Johor | 120238 | 2267 | 180 | 177 | 92311 | 3555 | 5 | 10597 | 7282 | 5 | 2952 | 908 |
| Malaysia | Penang (Georgetown) | 30233 | 1752 | 748 | 258 | 7349 | 2379 | 1 | 623 | 10781 | 3 | 4846 | 1493 |
| Malaysia | Port Kelang (Port Swettenham) | 310463 | 13748 | 2833 | 114442 | 64152 | 15717 | 110 | 14352 | 57884 | 661 | 13392 | 13173 |
| Malaysia | Prai | 15 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 13 | 0 |
| Malaysia | Sipitang, Sabah | 7 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Malaysia | Tanjong Pelepas | 270508 | 16335 | 5042 | 105266 | 26303 | 5137 | 420 | 37261 | 38394 | 3643 | 24398 | 8308 |
| Malaysia | Tawau, Sabah | 219 | 0 | 0 | 0 | 43 | 0 | 0 | 21 | 0 | 0 | 155 | 0 |
| Malaysia | Tumpat | 76 | 1 | 0 | 0 | 0 | 64 | 0 | 0 | 11 | 0 | 0 | 0 |
| Marshall Islands | Majuro | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 | 0 |
| Mauritius | Port Louis | 1257 | 67 | 12 | 0 | 788 | 7 | 0 | 23 | 361 | 0 | 2 | 19 |
| Mexico | Guadalajara, GRO | 39 | 0 | 0 | 0 | 6 | 8 | 0 | 0 | 0 | 0 | 0 | 3 |
| Mexico | Mazatlan, SIN | 15 | 0 | 0 | 0 | 0 | 9 | 0 | 6 | 0 | 0 | 0 | 0 |
| Myanmar | Yangon (Rangoon) | 775 | 0 | 2 | 0 | 15 | 1 | 0 | 7 | 0 | 0 | 750 | 0 |
| New Caledonia | Noumea | 812 | 262 | 1 | 12 | 31 | 0 | 1 | 0 | 58 | 411 | 3 | 35 |
| Niue | Niue Island | 606 | 9 | 0 | 0 | 42 | 5 | 0 | 0 | 5 | 544 | 0 | 0 |
| Northern Mariana Islands | Saipan | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Papua New Guinea | Alotau | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 |
| Papua New Guinea | Kimbe | 7382 | 0 | 0 | 0 | 6897 | 0 | 0 | 0 | 0 | 0 | 485 | 0 |
| Papua New Guinea | Lae | 6421 | 233 | 0 | 122 | 2587 | 31 | 0 | 1 | 402 | 0 | 2990 | 55 |
| Papua New Guinea | Madang | 5396 | 72 | 0 | 0 | 1486 | 0 | 0 | 0 | 0 | 0 | 3829 | 9 |
| Papua New Guinea | Port Moresby | 7025 | 248 | 0 | 10 | 1208 | 1 | 0 | 0 | 79 | 0 | 5467 | 11 |

| Country | Port of export | Total freight | Appliances | Fibres | Bulk | Foodstuffs | Furniture | Furs | Glass | Metals | Produce | Wood | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Papua New Guinea | Rabaul | 1093 | 0 | 0 | 0 | 933 | 0 | 0 | 0 | 0 | 0 | 158 | 2 |
| Philippines | Manila | 25224 | 924 | 1401 | 719 | 9993 | 666 | 37 | 295 | 6839 | 2947 | 451 | 951 |
| Reunion | St Denis de La Reunion | 90 | 37 | 0 | 0 | 21 | 0 | 0 | 0 | 32 | 0 | 0 | 0 |
| Samoa | Apia | 6594 | 411 | 14 | 1 | 3275 | 1 | 0 | 0 | 666 | 2166 | 38 | 23 |
| Singapore | Jurong | 46 | 44 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Singapore | Singapore | 1204093 | 60294 | 16705 | 641019 | 76567 | 9858 | 583 | 47443 | 257167 | 7200 | 44352 | 42903 |
| Singapore | Singapore Container Terminal | 95555 | 8284 | 4242 | 10745 | 11364 | 1671 | 70 | 7422 | 37763 | 1991 | 6455 | 5547 |
| Solomon Islands | Honiara, Guadalcanal Island | 3205 | 83 | 1 | 63 | 471 | 0 | 0 | 0 | 0 | 312 | 2225 | 49 |
| Solomon Islands | Noro, New Georgia | 226 | 0 | 0 | 0 | 127 | 0 | 0 | 0 | 0 | 0 | 1 | 98 |
| South Africa | Durban | 59503 | 3535 | 1071 | 7339 | 8560 | 241 | 4 | 1567 | 12990 | 234 | 13539 | 10423 |
| Sri Lanka | Colombo | 11891 | 38 | 1241 | 218 | 5417 | 18 | 0 | 1266 | 2149 | 717 | 479 | 348 |
| Taiwan | Kaohsiung | 143597 | 3742 | 1284 | 71543 | 1982 | 3691 | 33 | 2467 | 52419 | 105 | 1946 | 4385 |
| Taiwan | Keelung (Chilung) | 117117 | 12861 | 17064 | 11309 | 3466 | 4087 | 130 | 2815 | 57590 | 32 | 801 | 6959 |
| Taiwan | Suao | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Taiwan | Taichung | 34258 | 1360 | 155 | 1109 | 972 | 1483 | 6 | 1089 | 27198 | 9 | 69 | 806 |
| Taiwan | Taipei | 23820 | 1867 | 499 | 10496 | 211 | 435 | 34 | 595 | 8960 | 1 | 92 | 630 |
| Taiwan | Taitung | 108 | 10 | 0 | 0 | 12 | 15 | 0 | 0 | 67 | 3 | 0 | 0 |
| Tanzania | Dar es Salaam | 4 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 1 |
| Tanzania | Tanga | 32 | 2 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thailand | Bangkok | 463060 | 36771 | 5583 | 88891 | 101865 | 4602 | 304 | 88983 | 105922 | 3191 | 16557 | 10391 |
| Thailand | Chiang Rai | 83 | 5 | 0 | 0 | 21 | 1 | 0 | 19 | 4 | 12 | 0 | 22 |
| Thailand | Koh Sichang | 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 97 | 0 | 0 | 0 |
| Thailand | Sriracha | 34663 | 714 | 10 | 12532 | 3619 | 1 | 0 | 747 | 14404 | 21 | 82 | 2534 |
| Tonga | Neiafu | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tonga | Tongatapu-Nuku'alofa | 5782 | 558 | 0 | 12 | 174 | 13 | 0 | 3 | 516 | 4335 | 159 | 12 |
| Tonga | Vava'u | 369 | 18 | 0 | 0 | 5 | 0 | 0 | 0 | 11 | 333 | 1 | 1 |
| Tuvalu | Funafuti | 44 | 35 | 0 | 0 | 1 | 0 | 0 | 0 | 7 | 0 | 1 | 0 |
| USA | Honolulu, HI | 335 | 43 | 3 | 0 | 16 | 19 | 0 | 0 | 219 | 0 | 0 | 35 |
| USA | Pearl Harbour, HI | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vanuatu | Port Vila | 2158 | 188 | 0 | 0 | 1474 | 0 | 396 | 12 | 22 | 57 | 4 | 4 |
| Viet Nam | Haiphong | 979 | 53 | 52 | 90 | 0 | 165 | 2 | 183 | 147 | 0 | 8 | 279 |
| Viet Nam | Hanoi | 426 | 10 | 44 | 0 | 94 | 8 | 0 | 40 | 35 | 177 | 12 | 5 |
| Viet Nam | Ho Chi Minh City | 43845 | 520 | 1236 | 1 | 6645 | 10398 | 408 | 14925 | 4031 | 1290 | 1184 | 3207 |
| Wallis & Futuna Islands | Futuna Island | 19 | 12 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |

**Table b.** Summary of air freight coming to New Zealand from localities within 100 km of known sites with *A. gracilipes*. Values represent the total freight (tonnes) during 2001, 2002 and 2003. Total freight is broken into different commodity types (source: Statistics New Zealand). NB: New Zealand received some freight from all locations listed, but if total freight is below 500 kg it is listed as 0 tonnes. Details of freight types that comprise each category are given (c) as are the categories (HS2 Chapters) used to classify incoming freight in the Statistics New Zealand database (d).

| Country | Port of export | Total freight | Appliances | Produce | Pharmaceuticals | Metals | Glass | Furniture | Fur | Footwear | Foodstuffs | Fibres | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American Samoa | Pago Pago | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Antigua and Barbuda | Antigua | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Argentina | Buenos Aires-Ezeisa Apt | 155 | 24 | 0 | 66 | 23 | 2 | 2 | 11 | 5 | 9 | 1 | 9 |
| Australia | Cairns, QL | 77 | 5 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 63 | 0 | 4 |
| Australia | Darwin, NT | 5 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Bangladesh | Dhaka | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| Belize | Belize City | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bolivia | La Paz | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brazil | Campinas, SP | 8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 3 | 0 |
| Brazil | Guarulhos Apt/Sao Paolo, SP | 20 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 2 | 6 |
| Brazil | Rio Grande, RS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brazil | Salvador, BA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brazil | Santos, SP | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| Brazil | Viracopos Apt/Sao Paulo, SP | 29 | 3 | 0 | 0 | 7 | 1 | 0 | 0 | 3 | 0 | 13 | 1 |
| Brunei Darussalam | Bandar Seri Begawan | 5 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Canada | Winnipeg Apt, MB | 3 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Canada | Winnipeg, MB | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| China | Beijing | 120 | 23 | 2 | 11 | 25 | 1 | 3 | 2 | 0 | 4 | 33 | 16 |
| China | Huangpu | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| China | Shekou | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| China | Shenzhen | 8 | 8 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 2 |
| China | Yantian | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| China (Hong Kong) | Hong Kong SAR | 7514 | 2458 | 2 | 53 | 615 | 51 | 434 | 203 | 237 | 87 | 2301 | 1073 |
| China (Hong Kong) | Kowloon | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| China (Macau) | Macau | 6 | 2 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cook Islands | Aitutaki | 4 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Costa Rica | San Jose | 33 | 0 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyprus | Larnaca | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Cyprus | Limassol | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyprus | Nicosia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ecuador | Guayaquil | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| El Salvador | Acajutla | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| El Salvador | San Salvador | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fiji | Lautoka | 37 | 0 | 24 | 0 | 1 | 0 | 0 | 0 | 2 | 7 | 2 | 0 |

| Country | Port of export | Total freight | Appliances | Produce | Pharmaceuticals | Metals | Glass | Furniture | Fur | Footwear | Foodstuffs | Fibres | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fiji | Nadi | 4316 | 31 | 2733 | 6 | 5 | 0 | 3 | 3 | 301 | 661 | 550 | 23 |
| Fiji | Suva | 127 | 5 | 4 | 0 | 0 | 0 | 0 | 0 | 64 | 17 | 29 | 7 |
| French Polynesia | Bora Bora | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| French Polynesia | Papeete | 17 | 6 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 3 | 1 | 4 |
| French Polynesia | Raiatea | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Germany | Kwajalein | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Germany | Saint George's | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Guam | Guam | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Guatemala | Guatemala City | 6 | 0 | 1 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 1 | 0 |
| Haiti | Port-au-Prince | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| India | Banddar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| India | Bangalore | 150 | 43 | 61 | 0 | 2 | 6 | 12 | 0 | 0 | 5 | 22 | 10 |
| India | Bombay (Mumbai) | 509 | 55 | 21 | 86 | 40 | 9 | 12 | 6 | 16 | 13 | 225 | 25 |
| India | Calcutta | 170 | 11 | 0 | 0 | 7 | 0 | 0 | 104 | 0 | 1 | 43 | 3 |
| India | Cochin | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 2 |
| India | Jaipur | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Indonesia | Bandung, Java | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 |
| Indonesia | Belawan, Sumatra | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Indonesia | Benoa, Bali | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Indonesia | Denpasar, Bali | 286 | 50 | 1 | 5 | 30 | 13 | 7 | 16 | 13 | 3 | 87 | 60 |
| Indonesia | Semarang, Java | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Indonesia | Surabaya-Tanjung Perak, Java | 155 | 5 | 0 | 1 | 9 | 0 | 0 | 0 | 3 | 123 | 6 | 7 |
| Jamaica | Kingston | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Japan | Okinawa, Okinawa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Laos | Vientiane | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Malaysia | Kuala Lumpur | 1660 | 861 | 1 | 24 | 282 | 16 | 40 | 12 | 5 | 50 | 154 | 216 |
| Malaysia | Kuching, Sarawak | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Malaysia | Pasir Gudang Johor | 16 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Malaysia | Penang (Georgetown) | 1675 | 1569 | 0 | 1 | 24 | 0 | 5 | 20 | 0 | 20 | 7 | 27 |
| Malaysia | Port Kelang (Port Swettenham) | 16 | 1 | 0 | 0 | 12 | 1 | 2 | 0 | 0 | 0 | 0 | 1 |
| Malaysia | Tanjong Pelepas | 22 | 4 | 0 | 0 | 4 | 1 | 2 | 1 | 0 | 3 | 4 | 4 |
| Mauritius | Port Louis | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Mexico | Guadalajara, GRO | 83 | 71 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 1 | 5 |
| Mexico | Merida, YUC | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Mexico | Mexico City | 178 | 163 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 3 | 7 | 1 |
| Myanmar | Yangon (Rangoon) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nicaragua | Managua | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Panama | Colon | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Panama | Panama City | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Papua New Guinea | Madang | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Paraguay | Asuncion | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Peru | Callao | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Peru | Lima | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 45 | 0 | 0 | 15 | 0 |
| Philippines | Manila | 232 | 156 | 4 | 2 | 33 | 1 | 8 | 3 | 0 | 2 | 7 | 15 |

| Country | Port of export | Total freight | Appliances | Produce | Pharmaceuticals | Metals | Glass | Furniture | Fur | Footwear | Foodstuffs | Fibres | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Puerto Rico | San Juan | 50 | 2 | 0 | 18 | 1 | 0 | 0 | 0 | 2 | 5 | 0 | 21 |
| Singapore | Singapore | 9844 | 5382 | 168 | 114 | 1000 | 105 | 125 | 71 | 66 | 278 | 544 | 1994 |
| Singapore | Singapore Container Terminal | 11 | 5 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Solomon Islands | Honiara, Guadalcanal Island | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| South Africa | Durban | 85 | 20 | 0 | 2 | 22 | 1 | 6 | 1 | 0 | 3 | 12 | 18 |
| Sri Lanka | Colombo | 34 | 3 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 11 | 14 | 3 |
| Taiwan | Keelung (Chilung) | 119 | 52 | 0 | 2 | 20 | 2 | 6 | 0 | 0 | 0 | 27 | 10 |
| Taiwan | Suao | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Taiwan | Taichung | 11 | 6 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| Taiwan | Taipei | 2811 | 1856 | 3 | 23 | 347 | 20 | 60 | 11 | 2 | 7 | 278 | 205 |
| Thailand | Bangkok | 1602 | 415 | 36 | 32 | 285 | 23 | 34 | 38 | 25 | 55 | 404 | 254 |
| Tonga | Neiafu | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tonga | Tongatapu-Nuku'alofa | 149 | 3 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 119 | 0 | 4 |
| Tonga | Vava'u | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tuvalu | Funafuti | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| UK | London | 1927 | 508 | 0 | 256 | 224 | 40 | 54 | 8 | 5 | 45 | 153 | 634 |
| UK | London-Gatwick Apt | 57 | 18 | 0 | 4 | 8 | 1 | 1 | 0 | 0 | 1 | 2 | 21 |
| UK | London-Heathrow Apt | 4629 | 1240 | 3 | 266 | 628 | 63 | 75 | 17 | 17 | 182 | 343 | 1794 |
| UK | Stansted Apt/London | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| UK | Tilbury | 11 | 6 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| United Arab Emirates | Dubai | 57 | 12 | 0 | 0 | 7 | 1 | 2 | 0 | 1 | 13 | 3 | 17 |
| United Arab Emirates | Jebel Ali | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| United Arab Emirates | Sharjah | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Uruguay | Montevideo | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 |
| US Virgin Islands | Frederiksted, St Croix | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| US Virgin Islands | St Croix Island Apt | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Beaumont, TX | 8 | 8 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Brownsville, TX | 9 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Brunswick, GA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Buffalo, NY | 10 | 4 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 4 |
| USA | Charleston, SC | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| USA | Columbus, MS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Corpus Christi, TX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Dallas-Fort Worth Reg, TX | 415 | 221 | 0 | 17 | 80 | 2 | 9 | 1 | 1 | 3 | 15 | 67 |
| USA | Fort Lauderdale, FL | 18 | 11 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 3 |
| USA | Fort Myers, FL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Freeport, TX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Galveston, TX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Honolulu, HI | 386 | 185 | 4 | 3 | 26 | 4 | 12 | 4 | 0 | 14 | 16 | 118 |
| USA | Houston, TX | 152 | 68 | 0 | 1 | 55 | 0 | 3 | 0 | 0 | 0 | 4 | 21 |
| USA | Jacksonville, FL | 11 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| USA | Kahului, HI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Kings Bay, GA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Lake Charles, LA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Country | Port of export | Total freight | Appliances | Produce | Pharmaceuticals | Metals | Glass | Furniture | Fur | Footwear | Foodstuffs | Fibres | Other |
|---------|----------------|---------------|------------|---------|-----------------|--------|-------|-----------|-----|----------|------------|--------|-------|
| USA | Miami, FL | 63 | 27 | 2 | 0 | 4 | 0 | 3 | 0 | 1 | 1 | 2 | 23 |
| USA | Mobile, AL | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Orlando, FL | 44 | 7 | 25 | 1 | 7 | 0 | 1 | 0 | 0 | 0 | 0 | 3 |
| USA | Palm Beach, FL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | Pensacola, FL | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | San Antonio, TX | 9 | 8 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| USA | Tampa, FL | 33 | 22 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| USA | Texas City, TX | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | West Palm Beach, FL | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vanuatu | Port Vila | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 1 |

Table c. Details of the freight types that comprise each category and the categories (HS2 Chapters) used to classify incoming freight in the Statistics New Zealand database (source: Statistics New Zealand). Description of categories provided in Table d.

| Mode of transport | Type of freight | HS2 Chapters |
| --- | --- | --- |
| Sea freight | Appliances and machinery | 84–89 |
| | Fibres etc | 50–63 |
| | Bulk freight | 25, 27, 28, 31 |
| | Foodstuffs | 2–4, 9–23 |
| | Furniture/toys etc | 94, 95 |
| | Furs and skins | 41–43 |
| | Glass, ceramics etc | 68–70 |
| | Metals, plastics, organic chemicals etc | 72–81, 26, 29, 32, 39, 40 |
| | Produce | 6–8 |
| | Wood based products | 44–48 |
| | Other | All remaining chapters |
| Air freight | Appliances and machinery | 84–89 |
| | Produce | 6–8 |
| | Pharmaceutical products | 30 |
| | Metals, plastics, organic chemicals etc | 72–81, 26, 29, 32, 39, 40, 83 |
| | Glass, ceramics etc | 68–70 |
| | Furniture/toys etc | 94, 95 |
| | Fur and skins | 41–43 |
| | Footwear | 64 |
| | Foodstuffs | 2–4, 9–23 |
| | Fibres etc | 50–63 |
| | Other | All remaining chapters |

Table d. Description of categories (HS2 Chapters) used to classify incoming freight in the Statistics New Zealand database.

| Categories | Description |
|---|---|
| 01 | Animals; live |
| 02 | Meat and edible meat offal |
| 03 | Fish and crustaceans, molluscs and other aquatic invertebrates |
| 04 | Dairy produce; birds' eggs; natural honey; edible products of animal origin, not elsewhere specified or included |
| 05 | Animal originated products; not elsewhere specified or included |
| 06 | Trees and other plants, live; bulbs, roots and the like; cut flowers and ornamental foliage |
| 07 | Vegetables and certain roots and tubers; edible |
| 08 | Fruit and nuts, edible; peel of citrus fruit or melons |
| 09 | Coffee, tea, mate and spices |
| 10 | Cereals |
| 11 | Products of the milling industry; malt, starches, inulin, wheat gluten |
| 12 | Oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit, industrial or medicinal plants; straw and fodder |
| 13 | Lac; gums, resins and other vegetable saps and extracts |
| 14 | Vegetable plaiting materials; vegetable products not elsewhere specified or included |
| 15 | Animal or vegetable fats and oils and their cleavage products; prepared animal fats; animal or vegetable waxes |
| 16 | Meat, fish or crustaceans, molluscs or other aquatic invertebrates; preparations thereof |
| 17 | Sugars and sugar confectionery |
| 18 | Cocoa and cocoa preparations |
| 19 | Preparations of cereals, flour, starch or milk; pastrycooks' products |
| 20 | Preparations of vegetables, fruit, nuts or other parts of plants |
| 21 | Miscellaneous edible preparations |
| 22 | Beverages, spirits and vinegar |
| 23 | Food industries, residues and wastes thereof; prepared animal fodder |
| 24 | Tobacco and manufactured tobacco substitutes |
| 25 | Salt; sulphur; earths, stone; plastering materials, lime and cement |
| 26 | Ores, slag and ash |
| 27 | Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes |
| 28 | Inorganic chemicals; organic and inorganic compounds of precious metals; of rare earth |

| Categories | Description |
|---|---|
| | metals, of radio-active elements and of isotopes |
| 29 | Organic chemicals |
| 30 | Pharmaceutical products |
| 31 | Fertilizers |
| 32 | Tanning or dyeing extracts; tannins and their derivatives; dyes, pigments and other colouring matter; paints, varnishes; putty, other mastics; inks |
| 33 | Essential oils and resinoids; perfumery, cosmetic or toilet preparations |
| 34 | Soap, organic surface-active agents; washing, lubricating, polishing or scouring preparations; artificial or prepared waxes, candles and similar articles, modelling pastes, dental waxes and dental preparations with a basis of plaster |
| 35 | Albuminoidal substances; modified starches; glues; enzymes |
| 36 | Explosives; pyrotechnic products; matches; pyrophoric alloys; certain combustible preparations |
| 37 | Photographic or cinematographic goods |
| 38 | Chemical products n.e.s. |
| 39 | Plastics and articles thereof |
| 40 | Rubber and articles thereof |
| 41 | Raw hides and skins (other than furskins) and leather |
| 42 | Articles of leather; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silk-worm gut) |
| 43 | Furskins and artificial fur; manufactures thereof |
| 44 | Wood and articles of wood; wood charcoal |
| 45 | Cork and articles of cork |
| 46 | Manufactures of straw, esparto or other plaiting materials; basketware and wickerwork |
| 47 | Pulp of wood or other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard |
| 48 | Paper and paperboard; articles of paper pulp, of paper or paperboard |
| 49 | Printed books, newspapers, pictures and other products of the printing industry; manuscripts, typescripts and plans |
| 50 | Silk |
| 51 | Wool, fine or coarse animal hair; horsehair yarn and woven fabric |
| 52 | Cotton |
| 53 | Vegetable textile fibres; paper yarn and woven fabrics of paper yarn |
| 54 | Man-made filaments |
| 55 | Man-made staple fibres |
| 56 | Wadding, felt and non-wovens, special yarns; twine, cordage, ropes and cables and articles thereof |

| Categories | Description |
| --- | --- |
| 57 | Carpets and other textile floor coverings |
| 58 | Fabrics; special woven fabrics, tufted textile fabrics, lace, tapestries, trimmings, embroidery |
| 59 | Textile fabrics; impregnated, coated, covered or laminated; textile articles of a kind suitable for industrial use |
| 60 | Fabrics; knitted or crocheted |
| 61 | Apparel and clothing accessories; knitted or crocheted |
| 62 | Apparel and clothing accessories; not knitted or crocheted |
| 63 | Textiles, made up articles; sets; worn clothing and worn textile articles; rags |
| 64 | Footwear; gaiters and the like; parts of such articles |
| 65 | Headgear and parts thereof |
| 66 | Umbrellas, sun umbrellas, walking-sticks, seat sticks, whips, riding crops; and parts thereof |
| 67 | Feathers and down, prepared; and articles made of feather or of down; artificial flowers; articles of human hair |
| 68 | Stone, plaster, cement, asbestos, mica or similar materials; articles thereof |
| 69 | Ceramic products |
| 70 | Glass and glassware |
| 71 | Natural, cultured pearls; precious, semi-precious stones; precious metals, metals clad with precious metal, and articles thereof; imitation jewellery; coin |
| 72 | Iron and steel |
| 73 | Iron or steel articles |
| 74 | Copper and articles thereof |
| 75 | Nickel and articles thereof |
| 76 | Aluminium and articles thereof |
| 78 | Lead and articles thereof |
| 79 | Zinc and articles thereof |
| 80 | Tin; articles thereof |
| 81 | Metals; n.e.s., cermets and articles thereof |
| 82 | Tools, implements, cutlery, spoons and forks, of base metal; parts thereof, of base metal |
| 83 | Metal; miscellaneous products of base metal |
| 84 | Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof |
| 85 | Electrical machinery and equipment and parts thereof; sound recorders and reproducers; television image and sound recorders and reproducers, parts and accessories of such articles |
| 86 | Railway, tramway locomotives, rolling-stock and parts thereof; railway or tramway track fixtures and fittings and parts thereof; mechanical (including electro-mechanical) traffic signalling equipment of all kinds |
| 87 | Vehicles; other than railway or tramway rolling stock, and parts and accessories thereof |

| Categories | Description |
|---|---|
| 88 | Aircraft, spacecraft and parts thereof |
| 89 | Ships, boats and floating structures |
| 90 | Optical, photographic, cinematographic, measuring, checking, medical or surgical instruments and apparatus; parts and accessories |
| 91 | Clocks and watches and parts thereof |
| 92 | Musical instruments; parts and accessories of such articles |
| 93 | Arms and ammunition; parts and accessories thereof |
| 94 | Furniture; bedding, mattresses, mattress supports, cushions and similar stuffed furnishings; lamps and lighting fittings, n.e.s.; illuminated signs, illuminated name-plates and the like; prefabricated buildings |
| 95 | Toys, games and sports requisites; parts and accessories thereof |
| 96 | Miscellaneous manufactured articles |
| 97 | Works of art; collectors' pieces and antiques |
| 98 | New Zealand miscellaneous provisions |

# Appendix 2: Summary of freight types entering New Zealand ports

Summary of freight types entering New Zealand ports from 2000 to 2003 from countries with *A. gracilipes* (countries used are listed in Appendix 1). Freight data source – Statistics NZ. For details of freight chapters see Appendix 1c&d.

| NZ seaport | Freight type | Freight chapters | Sea freight (tonnes) |
|---|---|---|---|
| Auckland Seaport | Appliances and machinery | 84–89 | 234279 |
| | Bulk freight | 25, 27, 28, 31 | 190677 |
| | Fibres etc | 50–63 | 129477 |
| | Furniture/toys, etc. | 94, 95 | 122226 |
| | Furs and skins | 41–43 | 11848 |
| | Glass, ceramics, etc. | 68–70 | 249517 |
| | Metals, plastics, organic chemicals, etc. | 72–81, 26, 29, 32, 39, 40 | 553429 |
| | Other | | 126698 |
| | Other foodstuffs | 2–4, 9–23 | 152197 |
| | Produce | 6–8 | 93192 |
| | Wood-based products | 44–48 | 182370 |
| Christchurch Seaport (Lyttelton) | Appliances and machinery | 84–89 | 21612 |
| | Bulk freight | 25, 27, 28, 31 | 523298 |
| | Fibres, etc. | 50–63 | 20144 |
| | Furniture/toys, etc. | 94, 95 | 18156 |
| | Furs and skins | 41–43 | 2228 |
| | Glass, ceramics, etc. | 68–70 | 60002 |

| NZ seaport | Freight type | Freight chapters | Sea freight (tonnes) |
|---|---|---|---|
| | Metals, plastics, organic chemicals, etc. | 72–81, 26, 29, 32, 39, 40 | 103060 |
| | Other | | 18602 |
| | Other foodstuffs | 2–4, 9–23 | 50331 |
| | Produce | 6–8 | 13669 |
| | Wood-based products | 44–48 | 37562 |
| Dunedin Seaport | Appliances and machinery | 84–89 | 4501 |
| | Bulk freight | 25, 27, 28, 31 | 233652 |
| | Fibres, etc. | 50–63 | 3005 |
| | Furniture/toys, etc. | 94, 95 | 698 |
| | Furs and skins | 41–43 | 7 |
| | Glass, ceramics, etc. | 68–70 | 832 |
| | Metals, plastics, organic chemicals, etc. | 72–81, 26, 29, 32, 39, 40 | 4773 |
| | Other | | 3189 |
| | Other foodstuffs | 2–4, 9–23 | 6799 |
| | Produce | 6–8 | 293 |
| | Wood-based products | 44–48 | 17044 |
| Gisborne | Bulk freight | 25, 27, 28, 31 | 1500 |
| | Glass, ceramics, etc. | 68–70 | 62 |
| Invercargill Seaport (Bluff) | Appliances and machinery | 84–89 | 53 |
| | Bulk freight | 25, 27, 28, 31 | 1418888 |
| | Fibres, etc. | 50–63 | 185 |
| | Furniture/toys, etc. | 94, 95 | 72 |

| NZ seaport | Freight type | Freight chapters | Sea freight (tonnes) |
|---|---|---|---|
| | Furs and skins | 41–43 | 0 |
| | Glass, ceramics, etc. | 68–70 | 492. |
| | Metals, plastics, organic chemicals, etc. | 72–81, 26, 29, 32, 39, 40 | 1529 |
| | Other | | 6993 |
| | Wood-based products | 44–48 | 55 |
| Napier | Appliances and machinery | 84–89 | 3599 |
| | Bulk freight | 25, 27, 28, 31 | 4470345 |
| | Fibres, etc. | 50–63 | 2763 |
| | Furniture/toys, etc. | 94, 95 | 2130 |
| | Furs and skins | 41–43 | 367 |
| | Glass, ceramics, etc. | 68–70 | 6842 |
| | Metals, plastics, organic chemicals, etc. | 72–81, 26, 29, 32, 39, 40 | 19134 |
| | Other | | 7092 |
| | Other foodstuffs | 2–4, 9–23 | 13137 |
| | Produce | 6–8 | 1356 |
| | Wood-based products | 44–48 | 3829 |
| Nelson | Appliances and machinery | 84–89 | 3171 |
| | Bulk freight | 25, 27, 28, 31 | 27225 |
| | Fibres, etc. | 50–63 | 886 |
| | Furniture/toys, etc. | 94, 95 | 953 |
| | Furs and skins | 41–43 | 5 |
| | Glass, ceramics, etc. | 68–70 | 8506 |

| NZ seaport | Freight type | Freight chapters | Sea freight (tonnes) |
|---|---|---|---|
| | Metals, plastics, organic chemicals, etc. | 72–81, 26, 29, 32, 39, 40 | 2828 |
| | Other | | 129 |
| | Other foodstuffs | 2–4, 9–23 | 474 |
| | Produce | 6–8 | 881 |
| | Wood-based products | 44–48 | 737 |
| New Plymouth | Appliances and machinery | 84–89 | 1553 |
| | Bulk freight | 25, 27, 28, 31 | 99003 |
| | Fibres, etc. | 50–63 | 23 |
| | Furniture/toys, etc. | 94, 95 | 1044 |
| | Furs and skins | 41–43 | 10 |
| | Glass, ceramics, etc. | 68–70 | 675 |
| | Metals, plastics, organic chemicals,etc. | 72–81, 26, 29, 32, 39, 40 | 2756 |
| | Other | | 241 |
| | Other foodstuffs | 2–4, 9–23 | 3598 |
| | Produce | 6–8 | 0 |
| | Wood-based products | 44–48 | 25 |
| Tauranga Seaport | Appliances and machinery | 84–89 | 287341 |
| | Bulk freight | 25, 27, 28, 31 | 808381 |
| | Fibres, etc. | 50–63 | 2091 |
| | Furniture/toys, etc. | 94, 95 | 10081 |
| | Furs and skins | 41–43 | 10706 |
| | Glass, ceramics, etc. | 68–70 | 14380 |

| NZ seaport | Freight type | Freight chapters | Sea freight (tonnes) |
|---|---|---|---|
| | Metals, plastics, organic chemicals, etc. | 72–81, 26, 29, 32, 39, 40 | 24544 |
| | Other | | 11348 |
| | Other foodstuffs | 2–4, 9–23 | 72973 |
| | Produce | 6–8 | 5691 |
| | Wood-based products | 44–48 | 24801 |
| Timaru | Appliances and machinery | 84–89 | 1170 |
| | Bulk freight | 25, 27, 28, 31 | 124976 |
| | Fibres, etc. | 50–63 | 672 |
| | Furniture/toys, etc. | 94, 95 | 758 |
| | Furs and skins | 41–43 | 94 |
| | Glass, ceramics, etc. | 68–70 | 762 |
| | Metals, plastics, organic chemicals, etc. | 72–81, 26, 29, 32, 39, 40 | 5653 |
| | Other | | 1297 |
| | Other foodstuffs | 2–4, 9–23 | 10785 |
| | Produce | 6–8 | 313 |
| | Wood-based products | 44–48 | 1114 |
| Wellington Seaport | Appliances and machinery | 84–89 | 21475 |
| | Bulk freight | 25, 27, 28, 31 | 279337 |
| | Fibres, etc. | 50–63 | 3751 |
| | Furniture/toys, etc. | 94, 95 | 12994 |
| | Furs and skins | 41–43 | 998 |
| | Glass, ceramics, etc. | 68–70 | 22148 |
| | Metals, plastics, organic chemicals, etc. | 72–81, 26, 29, 32, 39, 40 | 90471 |

| NZ seaport | Freight type | Freight chapters | Sea freight (tonnes) |
|---|---|---|---|
| | Other | | 15773 |
| | Other foodstuffs | 2–4, 9–23 | 13270.1 |
| | Produce | 6–8 | 9802.5 |
| | Wood-based products | 44–48 | 39376.2 |
| Whangarei | Appliances and machinery | 84–89 | 72.8 |
| | Bulk freight | 25, 27, 28, 31 | 2965702.3 |
| | Glass, ceramics, etc. | 68–70 | 185.2 |
| | Other foodstuffs | 2–4, 9–23 | 213.0 |
| | Wood-based products | 44–48 | 136.0 |

# Appendix 3: Summary of containers

Summary of containers entering New Zealand from countries with *A. gracilipes* in the first 3 months of 2004.  Freight data source – MAF Port Authority.

| Country of origin | Full | Empty | Total |
|---|---|---|---|
| China | 5536 | 19[a] | 5555[b] |
| Singapore | 2170 | 44 | 2214 |
| Thailand | 2021 | 0 | 2021 |
| Indonesia | 1862 | 1 | 1863 |
| Malaysia | 1757 | 8 | 1765 |
| Taiwan | 1145 | 1 | 1146 |
| India | 558 | 0 | 558 |
| Vietnam | 385 | 0 | 385 |
| Philippines | 331 | 0 | 331 |
| Fiji | 299 | 2 | 301 |
| Papua New Guinea | 134 | 141 | 275 |
| French Polynesia | 35 | 192 | 227 |
| New Caledonia | 1 | 127 | 128 |
| Cook Islands | 13 | 104 | 117 |
| Sri Lanka | 72 | 0 | 72 |
| American Samoa | 66 | 2 | 68 |
| Solomon Islands | 32 | 29 | 61 |
| Tonga | 51 | 0 | 51 |
| Samoa | 25 | 0 | 25 |
| Myanmar | 7 | 0 | 7 |
| Vanuatu | 6 | 0 | 6 |
| Hawaii | 5 | 0 | 5 |
| Mauritius | 2 | 0 | 2 |
| Guam | 1 | 0 | 1 |

[a] All from Hong Kong

[b] Includes only containers from southern ports (including Hong Kong)

# Appendix 4: Container destinations

Destination of containers entering New Zealand from countries with *A. gracilipies* in the first 3 months of 2004. Freight data source – MAF Port Authority. Containers from the temperate northern Chinese ports are excluded.

| Port | Full | Empty | Total |
|---|---|---|---|
| Auckland | 9530 | 62 | 9592 |
| Christchurch | 2213 | 0 | 2213 |
| Tauranga | 1741 | 437 | 2178 |
| Wellington | 1427 | 5 | 1432 |
| Napier | 631 | 0 | 631 |
| Dunedin | 344 | 0 | 344 |
| Timaru | 233 | 0 | 233 |
| Whangarei | 10 | 157 | 167 |
| Nelson | 136 | 9 | 145 |
| New Plymouth | 101 | 0 | 101 |
| Bluff | 98 | 0 | 98 |
| Palmerston North | 5 | 0 | 5 |

# Appendix 5: Details of BIOSECURE methodology

BIOSECURE is a computer-based decision tool for management of biosecurity risks to New Zealand's indigenous ecosystems. The model runs over Landcare Research's intranet using specifically designed software with links to databases and GIS software.

## Methods

### Input data

Records of species occurrence are obtained from the scientific literature, ant collections records available on the web, and from communication with various researchers. Records for an exact collection locality or relatively defined area are predominantly used. For the mainland USA some data on county records are included (e.g., Callcott & Collins 1996) with the county seat used as the data point, and for many islands presence/absence information is all that was available. Data points are separated into those of introduced and native range. Within the introduced range, records closely associated with urban areas are identified and a separate analysis conducted excluding these data in order to separate risks associated with urban areas and heated buildings from other habitats. These data sets are submitted to BIOSECURE.

### Climate summary

For each location, climate data was obtained for eight parameters (Table A5.1) from global climate surfaces based on half-degree grid square resolution. Summary data for each parameter (N, mean, minimum, maximum) are presented for native and introduced range separately.

**Table A5.1:** Global climate surfaces used in BIOSECURE.

| Abbreviation | Climate Parameters |
| --- | --- |
| MAT | Annual mean of the monthly mean temperature (ºC) |
| MINT | Mean temperature of the coldest month (ºC) |
| MATS | Seasonality of temperature - absolute difference in mean temperature between the warmest and coldest months (ºC) |
| PREC | Mean annual precipitation (mm) |
| PRECS | Seasonality of precipitation - absolute difference in mean precipitation between the wettest and driest months (mm) |
| VP | Annual mean of the monthly mean vapour pressure (kPa) |
| VPS | Seasonality of vapour pressure - absolute differences in mean vapour pressure between the most humid and the least humid months (kPa) |
| MAS | Annual mean of monthly mean solar radiation (MJ/m$^2$/day) |

*Climate similarity scores*

For each climate parameter a frequency distribution of the data points is produced. The frequency distribution is then divided into 10 equal bins between the minimum and maximum values. Two additional bins of the same size are added, one above and one below the outermost values. Each bin gets a score between 1 (the additional two bins) and 100 based on the rescaled frequency of occurrence of the data within each bin (Fig. A5.1). Then all global grids are allocated a similarity (or risk) score between 0 (the climate parameters value for that grid square is outside the values in the bins) and 100.

The climate similarity scores for New Zealand are projected onto a 25 m resolution climate surface that forms part of the LENZ environmental domains (Leathwick et al. 2003).

Outlier data in each climate layer are checked. Data points are removed and the analysis re-run only if they are identified as entry errors, or the collection site was not well defined. In addition, if the outlying data point falls on the margin between two grids it is automatically allocated to a grid in the processing. If this automatic allocation results in an outlier (e.g., the grid is predominantly mountainous and has extreme temperature values) then the data are altered to move the point into the neighbouring grid.
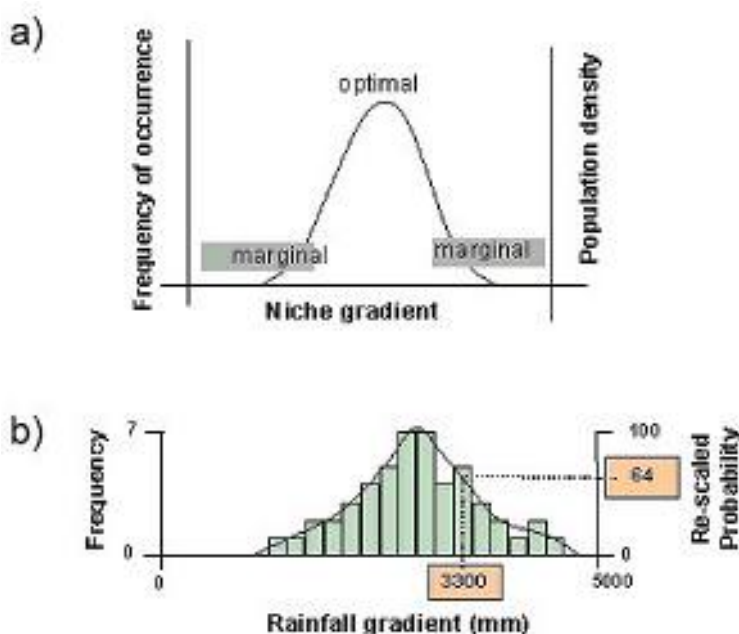


*Fig. A5.1: Stylised representation of the conversion of input data points to similarity scores. (a) The input data are assumed to represent the niche of the species for a particular parameter. (b) The frequency distribution is divided into a series of bins across the range of the data, allowing any point on the globe to be compared with this distribution and given a similarity score from 0 (outside the range of the data) to 100 (bin with highest frequency of data = optimal climate) (figure modified from a presentation of G. Barker).*

Individual climate layers are assessed for distinctiveness between the international data and New Zealand, and presented in the results if they show a high degree of discrimination (large areas of New Zealand with no similarity or in the marginal zone relative to the international data. MAT, MINT and PREC are routinely presented to allow comparison between species).

An overall summary risk map is also presented; this represents the mean of the similarity scores of five climate layers (MAT, MINT, PREC, VP, PRECS). This presentation approximates the summary map produced by the risk assessment tool Climex.

# Appendix 6: Summary of current known distribution and BIOSECURE analysis for two ant species already established in New Zealand.

*Linepithema humile* is widely distributed in northern New Zealand while *Pheidole megacephala* is restricted to Auckland despite being established since the 1940s (Fig. A6.1).

### *Prediction of New Zealand range for* Linepithema humile *(Argentine ant)*

Native range data for this species overlap with northern New Zealand for MAT. MINT shows similarity for a greater area, but still within northern New Zealand. MAS shows low similarity with New Zealand. The other parameters show some discrimination within New Zealand. The introduced range greatly extends the areas of similarity of New Zealand, as the ant has become widely distributed globally, particularly in areas of anthropogenic disturbance. Large areas of the North Island and the northern South Island show overlap for MAT (Fig. A6.2), and all other parameters show greater overlap. For many areas where temperature parameters show high similarity, there is marginal similarity for rainfall (at the high end), which may restrict its distribution (Fig. A6.2).

For MAT the climate in the native + introduced non-urban sites still shows considerable overlap with New Zealand (Fig. A6.3). However, this may be overstated as 3 cold outliers, from native habitat in Chile (Snelling 1975) contribute to the overlap of MAT across southern New Zealand, but these records could be another species, as the taxonomy of *Linepithema* in South America is in need of revision (A. Wild, pers. comm.).

### *Predictions of New Zealand range for* Pheidole megacephala *(big-headed ant)*

Native range data suggests most of New Zealand is too cold for *Ph. megacephala*, with overlap for MAT only for the far north of the North Island. This overlap results from a single record from grassland by a highway in Pietermaritzburg, South Africa (Samways et al. 1997). The native + introduced range suggests potential range overlap with Northern NZ for MAT (Fig. A6.4), which results principally from urban records, from Sana'a in Yemen (Collingwood & Agosti 1996), and from an imprecise record from "central Spain" (Collingwood 1978). Most of the North Island and coastal South Island is within the range of data for MINT. Precipitation is too high in south-western and alpine areas, and these areas are too cold (Fig. A6.4). Other climate parameters are highly suitable across much of New Zealand.

For the native + introduced (non-urban range), MAT overlap is minimal (Fig. A6.5), and caused only by the single point from Pietermaritzburg, South Africa. Overlap of MINT is reduced but there is still overlap for large areas of northern New Zealand. Results for the other climate parameters are the same as for the analysis of native + introduced range.
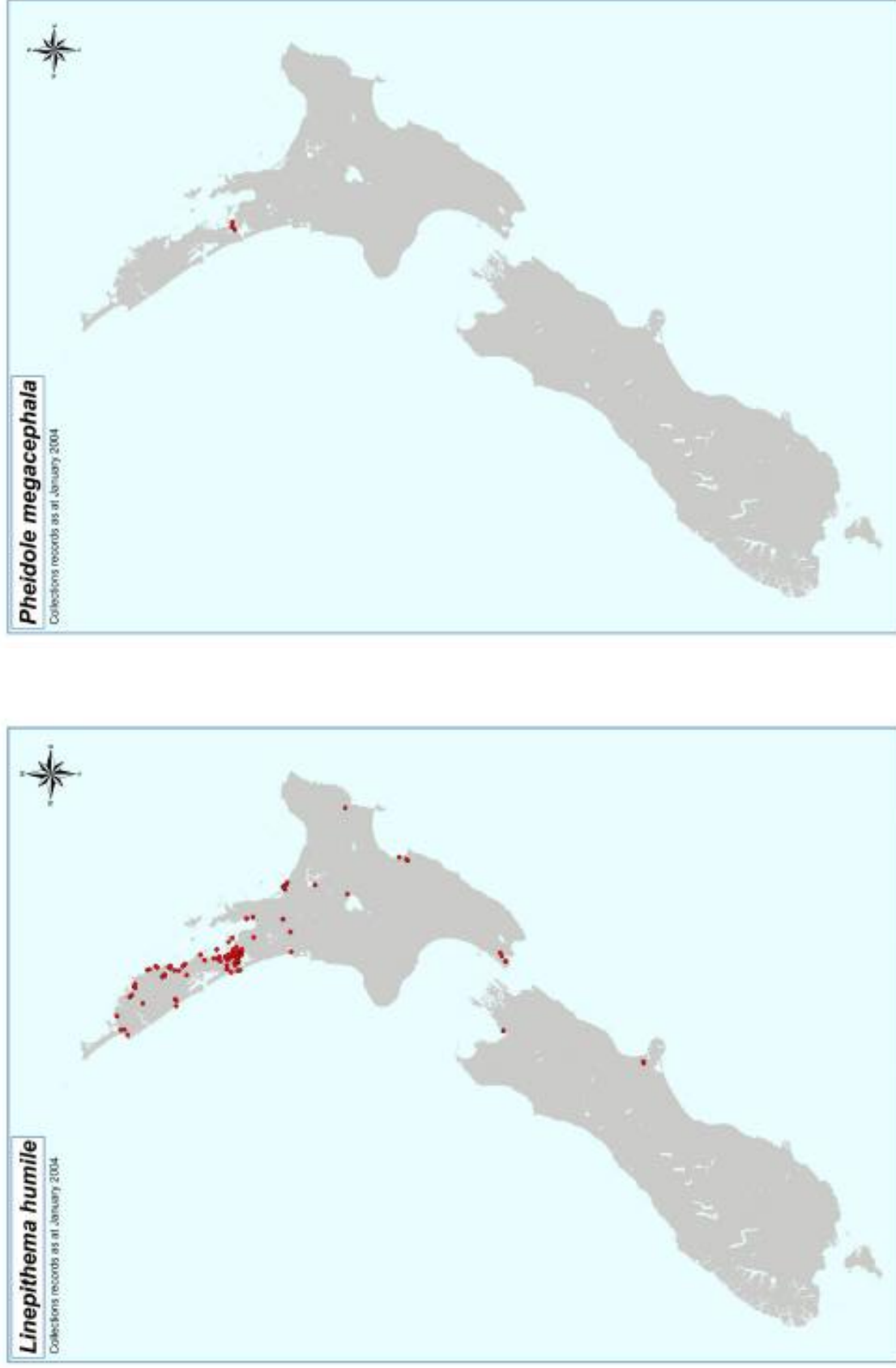
**Linepithema humile**

Collections records as at January 2004

**Pheidole megacephala**

Collections records as at January 2004

**Fig. A6.1:** *New Zealand sites where* L. humile *and* Ph. megacephala *are known to be established.*

**Risk scores**

Value

0
1 – 10 low risk
11 – 20
21 – 30
31 – 40
41 – 50
51 – 60
61 – 70
71 – 80
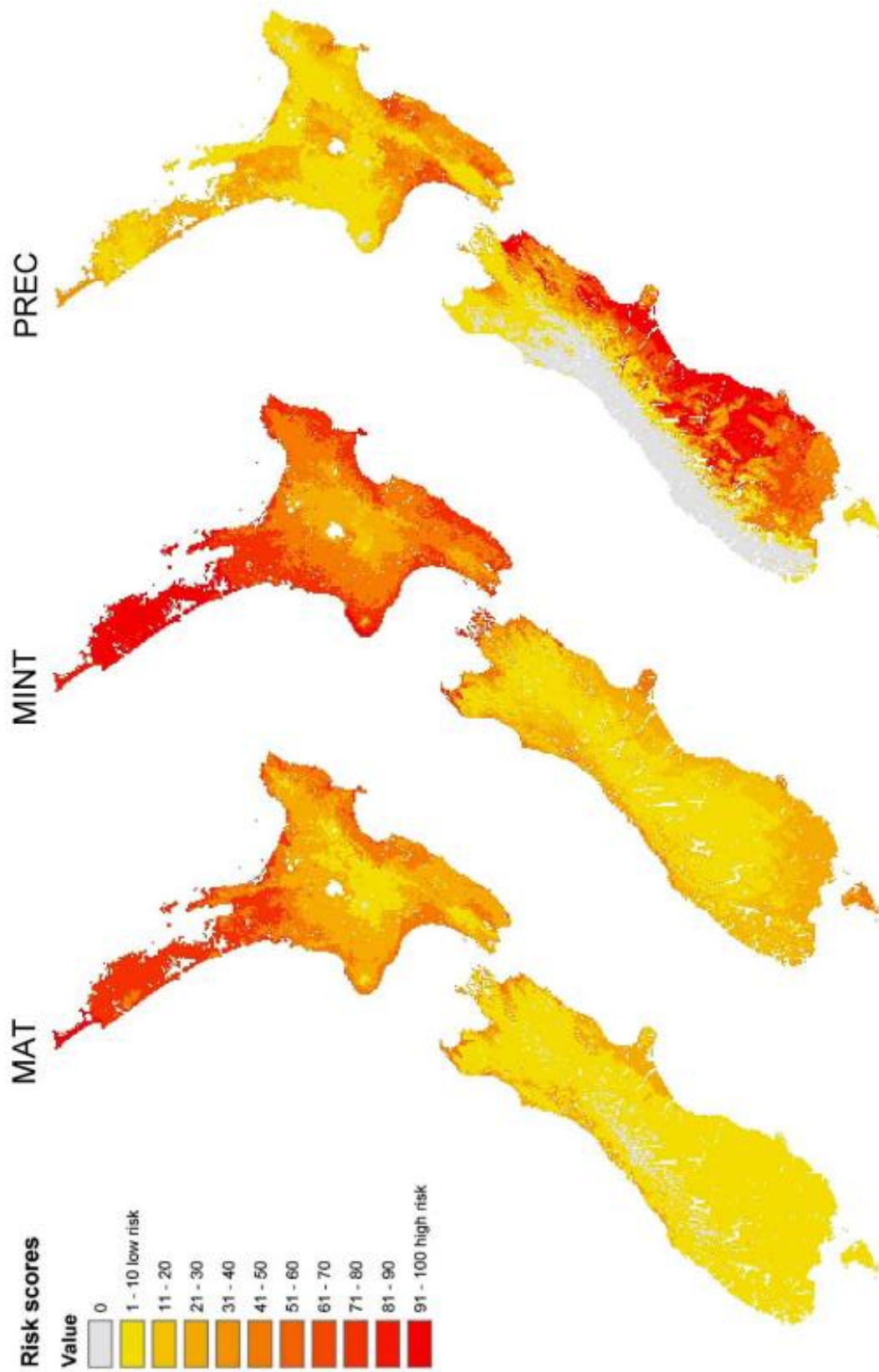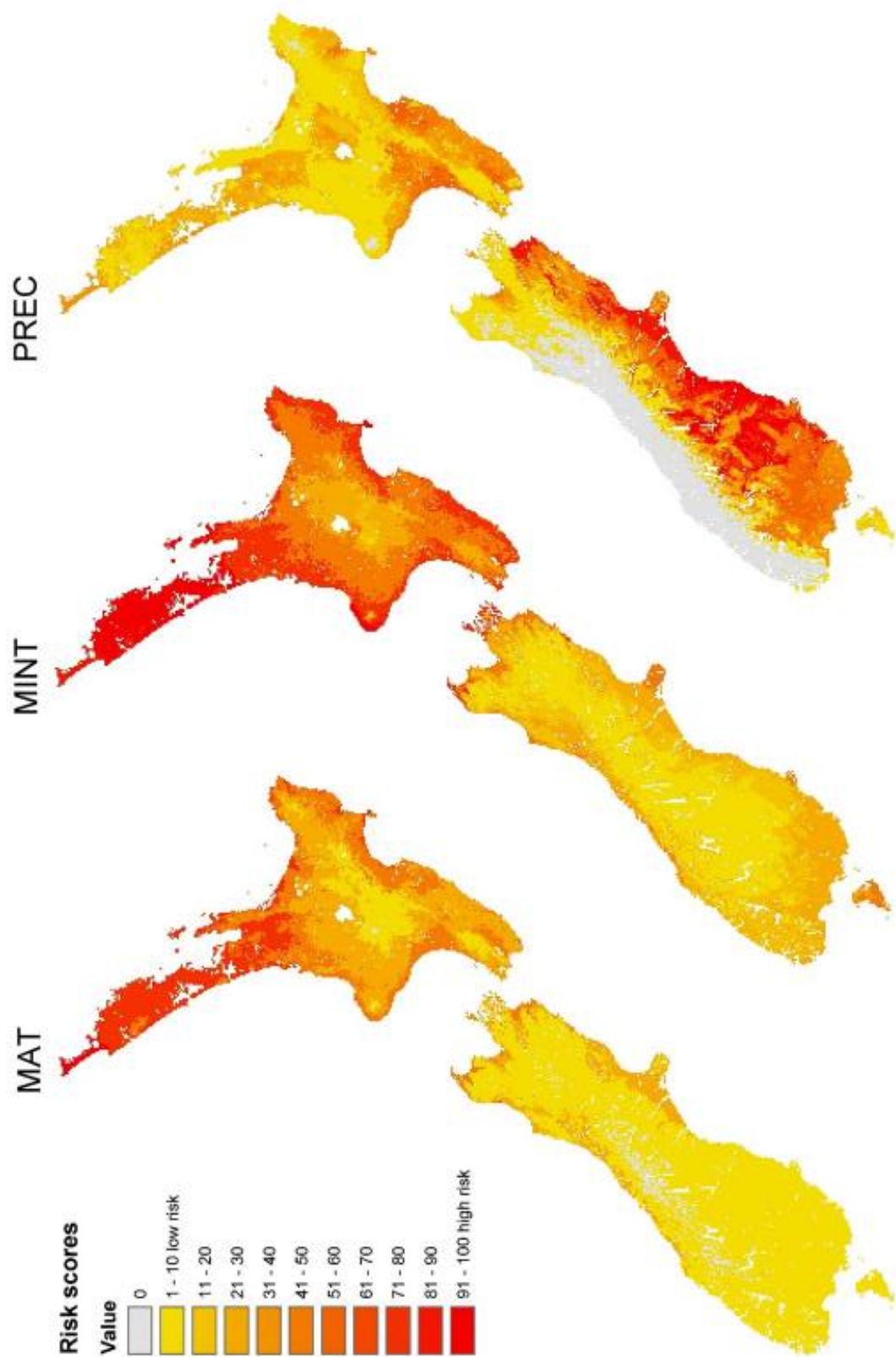81 – 90
91 – 100 high risk

MAT

MINT

PREC

***Fig. A6.2:*** *Similarity of native + introduced ranges of L. humile to New Zealand for MAT, MINT and PREC.*

**Fig. A6.3:** *Similarity of native + non-urban introduced ranges of L. humile to New Zealand for MAT, MINT and PREC.*
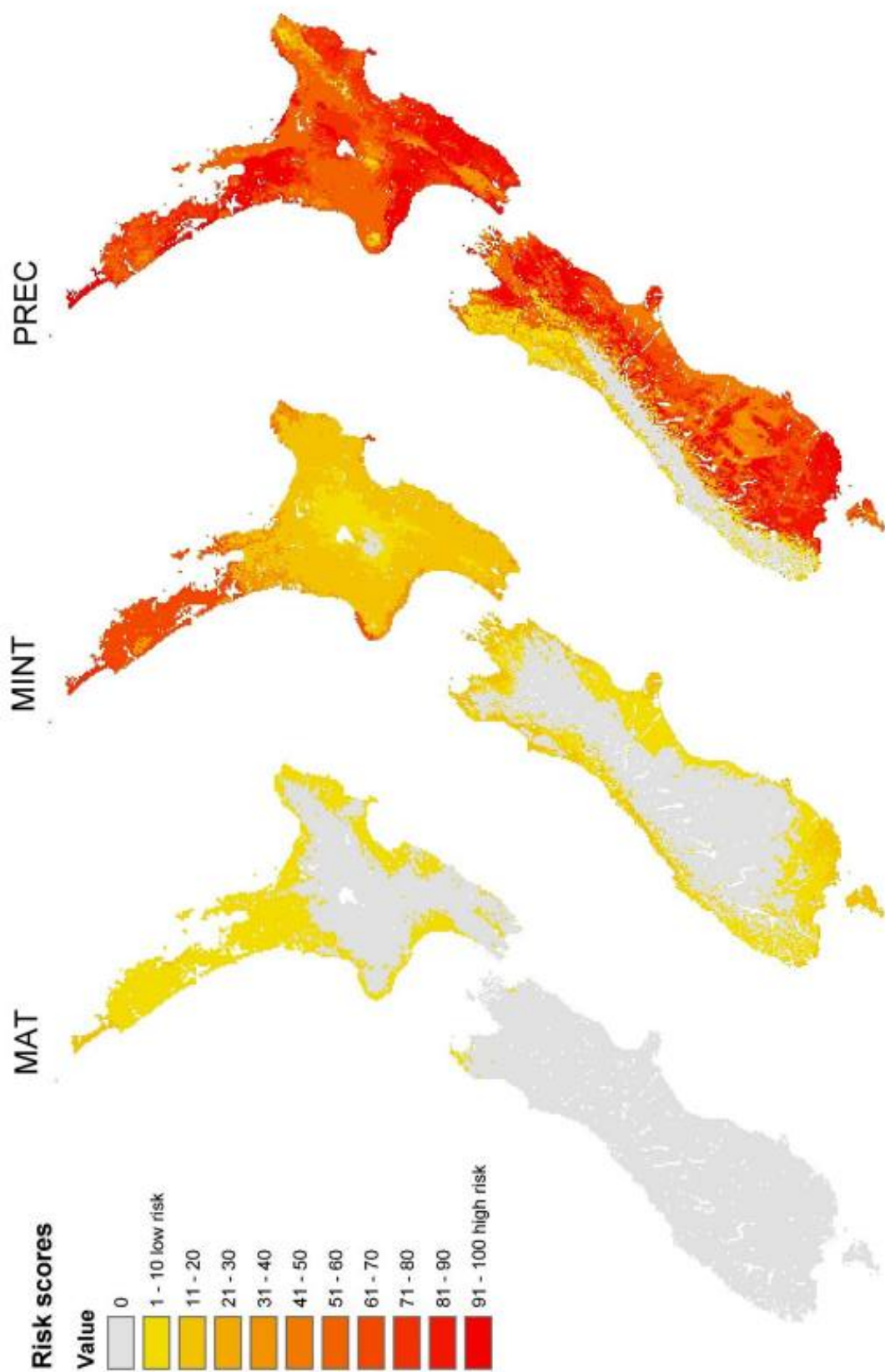
**Risk scores**

**Value**

- 0
- 1 - 10 low risk
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100 high risk

*Fig. A6.4: Similarity of native + introduced ranges of Ph. megacephala to New Zealand for MAT, MINT and PREC.*

**Risk scores**

Value

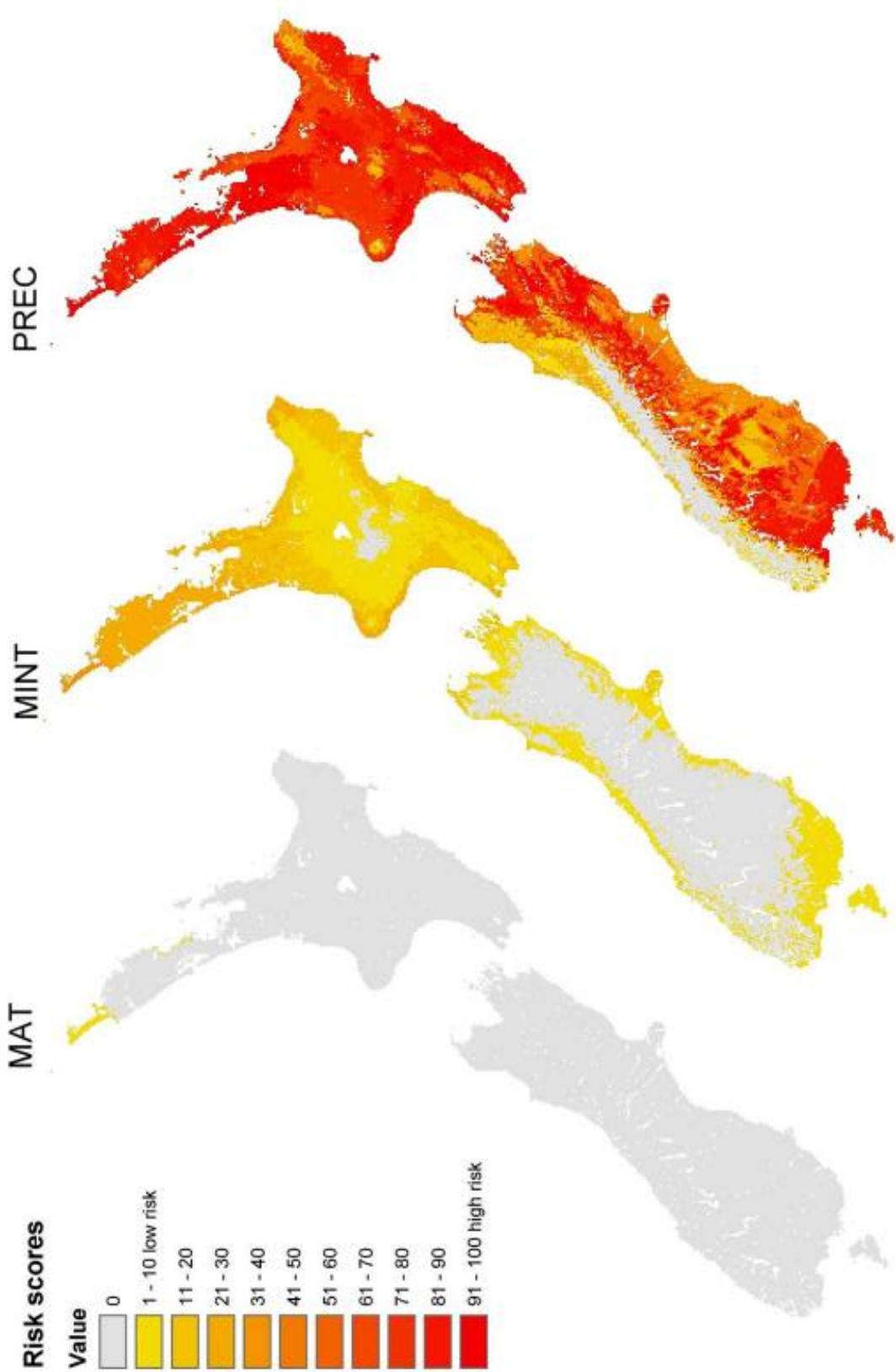| | |
|---|---|
| | 0 |
| | 1 – 10 low risk |
| | 11 – 20 |
| | 21 – 30 |
| | 31 – 40 |
| | 41 – 50 |
| | 51 – 60 |
| | 61 – 70 |
| | 71 – 80 |
| | 81 – 90 |
| | 91 – 100 high risk |

MAT

MINT

PREC

*Fig. A6.5: Similarity of native + non-urban introduced ranges of Ph. megacephala to New Zealand for MAT, MINT and PREC.*