Invasive Ant Risk Assessment

Wasmannia auropunctata

Harris, R.; Abbott, K.; Lester, P.

(A) PEST INFORMATION

A1. Classification

Family:	Formicidae
Subfamily:	Myrmicinae
Tribe:	Blepharidattini
Genus:	*Wasmannia*
Species:	*auropunctata*

Hawaii Department of Agriculture

A2. Common name(s)

Little fire ant (Wetterer & Porter 2003)

Also known as little red fire ant, little introduced fire ant, small fire ant, West Indian stinging ant, cocoa-tree ant (English); fourmi rouge, petit fourmi de feu, formi électrique (French, French-New Caledonia); formiga pixixica, hormiga colorada, hormiga roja, hormiguilla, pequena hormiga de fuego, albayalde (Spanish, Spanish-Puerto-Rico); formi Sangundagenta, tsanagonawenda (Gabon) (Wetterer & Porter 2003; www41).

A3. Original name

Tetramorium auropunctatum Roger

A4. Synonyms or changes in combination or taxonomy

Xiphomyrmex atomum Santschi, *Wasmannia glabra* Santschi, *Hercynia panamana* Enzmann, *Ochetomyrmex auropunctatus* (Roger), *Wasmannia auropunctata* var. *atoma* (Santschi)

Current subspecies: nominal plus *Wasmannia auropunctata* var. *australis* Emery, *Wasmannia auropunctata* var. *laevifrons* Emery, *Wasmannia auropunctata* var. *nigricans* Emery, *Wasmannia auropunctata* var. *obscura* Forel, *Wasmannia auropunctata st. pulla* Santschi, *Wasmannia auropunctatus r. rugosa* Forel

BIOSECURITY NEW ZEALAND

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A5. General description

Identification

Size: monomorphic. A very small ant – total length approximately 1.5 mm (Fig. 1).

Colour: light brown to golden brown, the gaster often somewhat darker.

Surface sculpture: head, alitrunk and nodes are heavily sculptured, appearing dull; gaster unsculptured, appearing shiny.

General description: antennae 11-segmented; last 2 segments greatly enlarged. Antennal scape (first segment) inserted into a distinct groove (scrobe) that extends almost to the posterior border of the head. Eyes relatively small, with about 6 ommatidia in the longest row. Mandibles each with 5 teeth, the topmost (nearest clypeus) small. Clypeus without longitudinal carinae. Anterodorsal angles of the pronotum acute. Metanotal groove weak. Propodeum with a pair of long, sharp spines, set closely together at the base, strongly diverging and slightly incurved when seen from above. Two nodes present, the first (petiole) is "hatchet-like," almost rectangular in profile and higher than the second (postpetiole). Body sparsely covered with long, erect hairs.

Sources: Wetterer & Porter 2003; www28; www53

On-line key: wwwnew57

a)

b)

Fig. 1: *Images of Wasmannia auropunctata; a) group of workers on the end of a chop-stick (note very small size) (Source: Ellen Van Gelder), b) dorsal view of worker with larvae (Source: S.D. Porter, USDA-ARS).*

A6. Behavioural and biological characteristics

A6.1 Feeding and foraging

Foragers are slow moving (about a tenth the speed of *Paratrechina longicornis*) and can form trails extending many metres to and from food sources (Meier 1994; Deyrup et al. 2000). *Wasmannia auropunctata* is a generalist feeder on invertebrates, seeds and other plant material; a large portion of its diet is honeydew collected from Homoptera (Clark et al. 1982; Torres 1984). Some food is scavenged but active predation also occurs (Clark et al. 1982), and they pirate food from other ants (Brandao & Paiva 1994). They recruit in large numbers to food sources and cooperate to carry large items (Clark et al. 1982; Tennant 1994). Foragers utilise plants with extra-floral nectaries (de la Fuente & Marquis 1999; Deyrup et al. 2000). Workers forage continuously in the arid zone on the Galapàgos (Clark et al. 1982) but are more active at night in Puerto Rico (Torres 1984). Foraging is less affected by wind, rain, direct sunlight and time of day or night, than that of *Solenopsis geminata* or *P. longicornis* (Meier 1994).

Workers are highly aggressive to other ant species and in some locations where they have invaded, they are able to exclude other ant species completely and dominate an area (Jourdan 1997; Clark et al. 1982). In their native range they do not defend territories, but recruit to and defend food resources close to their nest (Torres 1984), and the degree of monopolization can vary with the size of the food (McGlynn & Eben Kirksey 2000).

A6.2 Colony characteristics

Both multiple queened (polygyne) and single queened (monogyne) colonies occur (Wetterer & Porter 2003). Colonies show low intraspecific aggression (unicolonial) and high interspecific aggression. Queens typically live about a year (Passera 1994). Sexuals are produced throughout most of the year (Passera 1994). On Santa Cruz Island,Galapàgos, Clark et al. (1982) estimated densities of 1000–5000 workers/m^2 in an area where *W. auropunctata* was abundant.

Single nests of little fire ants may contain several dealate (wingless) reproducing queens, numerous workers, pupae, larvae and eggs. They do not have a structured nest but use any available space: under leaf debris, rotten tree limbs, stones, in the crotches of trees or clumps of grass, behind the sheaths of palms or palmettos or in spaces between plants and soil (Spencer 1941, cited in Ayre 1977). Nests are found on the ground or in trees (Clark et al. 1982). Colonies are highly mobile and will relocate if disturbed (Ulloa-Chacon 1990, cited in Passera 1994).

Nest densities are higher in areas where this species has become a pest in its introduced range (0.75–2.7 aggregations/m^2 on the Galapàgos (Lubin 1984; Ulloa-Chacon & Cherix 1990)) than in the native range (0.05–0.13 nests/m^2 in Panama (Levings & Franks 1982)).

A7. Pest significance and description of the range of impacts

A7.1 Natural environment

There have been many recent reports of negative impacts caused by *W. auropunctata* in introduced locations, mostly from the Galapàgos Islands (e.g., Clark et al. 1982; Lubin 1984; Abedrabbo 1994; Brandao & Paiva 1994; de la Vega 1994; Ulloa-Chacon & Cherix 1994). It is responsible for reducing ant and other invertebrate abundance and species diversity (Clark et al. 1982; Lubin 1984; Wetterer & Porter 2003), and it may also affect the nesting activities and young of reptiles and birds (Causton et al. in press). *Wasmannia auropunctata* eats the hatchlings of tortoises and attacks the eyes and cloacae of adult tortoises (www41); it also aids the build up and spread of the cottony cushion scale (*Icerya purchasi* Maskell), which it protects from predators (Causton 2001, cited in Causton et al. in press).

When it invaded New Caledonia in the 1970s, *W. auropunctata* was predicted to become a pest; by 2001 it had caused a decrease in native lizard abundance (Jourdan et al. 2001) and affected the rich native ant fauna (Le Breton et al. 2003). It was by far the most abundant ant species, representing over 90% of the total catch in invaded areas. It was sampled 90 m into pristine rainforest, but was most abundant in the first 20 m (Le Breton et al. 2003). Native ant species richness was significantly reduced up to at least 60 m into the forest.

On the small Puerto Rican Island of Palminitos, a large number of ant extinctions (including *Paratrechina longicornis* and *Tapinoma melanocephalum*) may be the result of colonisation by *W. auropunctata* (Torres & Snelling 1997). Elsewhere in Puerto Rico it coexists with many other ant species (Torres 1984). In Florida it "practically blankets the ground" in a few sites (Deyrup et al. 2000), but is generally a minor species (Deyrup et al. 2000; Cherry 2003). The sites of abundance have high densities of plants with extra-floral nectaries. High density populations also occur on the island of New Providence, Bahamas (Deyrup et al. 2000). Plants that reward ants benefit from the presence of *W. auropunctata* through increased growth, increased seed production and reduced herbivory (Ness & Bronstein 2004).

Within its native range *W. auropunctata* may be common in urban settlements (Delabie et al. 1995; Fowler et al.1990), fields (Jeanne 1979), mangroves (Dejean et al. 2003), plantation forestry including coffee (Perfecto & Vandermeer 1996; Ramos et al. 2003), secondary growth forest (Vasconcelos 1999; Barberena-Arias & Aide 2003) and undisturbed forest (Jeanne 1979; Tennant 1994; Kaspari 1996; Vasconcelos 1999). Its distribution is patchy and it can be a common (Culver 1974) or a minor component (Armbrecht & Perfecto 2003) of the ant community. It often coexists with other ants (Tennant 1994; Vasconcelos 1999; Bestelmeyer 2000), although Armbrecht & Ulloa-Chacon (2003) found a highly significant negative relationship between the richness of the ant community and the abundance of *W. auropunctata* in samples from tropical dry forest fragments of Colombia. This could reflect the response of *W. auropunctata* to increasing perturbation levels in the interior of the forests (Armbrecht & Ulloa-Chacon 2003), rather than exclusion of other species.

This ant has the potential to affect a range of vertebrates. In Gabon, house cats (*Felis catus*) often have *W. auropunctata* in their fur, and may develop corneal cloudiness and blindness (www41). Furthermore, elephants (*Loxodonta africana*) with corneal cloudiness are common in Lope and Petit Loanga, as well as Wonga Wongue Reserve on the central coast of Gabon (100 km south of Libreville). In the Solomon Islands, locals report that their dogs (*Canis domesticus*) were all gradually blinded by the ants' venom and rarely lived more than five years.

Wasmannia auropunctata interferes with seed dispersal of myrmecochorous plants by reducing dispersal distances and leaving seed exposed on the soil surface (Ness & Bronstein 2004), although seeds are much smaller component of the diet than for *Solenopsis geminata* (Torres 1984).

A7.2 Horticulture

In many areas, *W. auropunctata* is a significant horticultural pest. It stings field labourers and they may be unwilling to pick fruit in infested areas (Smith 1965). It enhances populations of honeydew-producing homopterans, which are a pest in their own right and damage their host plant by sucking sap and encouraging the build up of sooty mould (e.g., cocoa and citrus in Brazil (Fowler et al. 1990), citrus in Puerto Rico (Michaud & Browning 1999), and cocoa in Cameroon (de Souza et al. 1998)). Naumann (1994) observed "several hundred" of these ants tending scale insects on individual lily leaves in a tropical glasshouse in Canada. The association between *W. auropunctata* and Homoptera may increase the occurrence of diseases, including viral and fungal infections (www41).

Wasmannia auropunctata has some beneficial role as a predator of other pests (e.g., in citrus (Jaffe et al. 1990)), and in Cameroon its presence is encouraged to limit cocoa pests (Majer 1986), although this may not be a wise strategy (de Souza et al. 1998). In the Solomon Islands, *W. auropunctata* controls a serious pest of coconuts, *Amblypelta cocophaga,* and is also displacing two other dominant pest ants, *Iridomyrmex cordatus* and *Pheidole megacephala,* which do not protect coconut palms from *A. cocophaga* (Macfarlane 1985, cited in Way & Khoo 1992). Plants with extra-floral nectaries are protected from herbivory by the ant and are hence less attacked by leaf pathogens (de la Fuente & Marquis 1999).

A7.3 Human impacts

Wasmannia do not sting en masse when disturbed, unlike *Solenopsis* fire ants (Ayre 1977). However, people are frequently stung by workers falling out of trees, foraging across outdoor chairs, or floating in swimming pools when they become pressed against skin (Deyrup et al. 2000). Workers were abundant on ornamental plants and shade trees in home gardens in New Caledonia, where their presence made pruning shrubs and tress "a tedious operation" (Fabres & Brown 1978). The sting can be very painful at first, then itch intensely for up to 3 days (Spencer 1941, cited in Ayre 1977). Numerous stings over a short period can cause the victim to become pale and shaky (Smith 1965).

Foraging trails may invade houses (Deyrup et al. 2000), where they are attracted to fatty and oily household foods and dirty and sweaty clothing, but not sweets (Fernald 1947, cited in Thompson 1990; Naumann 1994). In Florida they occur in houses relatively infrequently; only two samples were collected in a survey of ants treated by pest control employees (Klotz et al. 1995). In Brazil, *W. auropunctata* may be a common house infesting ant (Delabie et al. 1995). Foragers were only rarely sampled in hospitals (Fowler et al. 1993), so even though capable of mechanical vectoring of bacteria (Bueno & Fowler 1994), they probably have a very limited role in disease transmission.

A8. Global distribution

A8.1 Native range

Wasmannia auropunctata is native to central and South American regions (New World Tropics; Fig. 2). It may not be native west of the Andes in South America (www41).

A8.2 Introduced range

Wasmannia auropunctata has been introduced to at least six Pacific island groups (Wetterer & Porter 2003), including Hawaii, New Caledonia, Tuvalu, Solomon Islands, Vanuatu, Wallis and Futuna, and the Galapàgos Islands (Wetterer & Porter 2003; www41). It is also considered introduced to mainland USA (Florida and California), the Caribbean, and the African nations of Gabon and Cameroon (Wetterer et al. 1999). The only location on the South American continent where it is believed to be introduced is mainland Ecuador (www41).

A8.3 History of spread

Wasmannia auropunctata became established in the Galapàgos Islands in the early 20th century (Clark et al. 1982). It was first found outdoors in Florida in 1924 (Wheeler 1929, cited in Ayre 1977) and by 1935 had become a pest in citrus groves (Spencer 1941, cited in Ayre 1977). It is a much more recent arrival in the Pacific; arriving in New Caledonia in the 1970s (Jourdan et al. 2001), in the Solomons before 1978 (Fabres & Brown 1978) and in Vanuatu in 1998 (wwwnew13). It was first collected in Hawaii in 1999 (Conant & Hirayama 2000). It has also been reported relatively recently from Fiji (Wetterer, pers. comm., cited in Nishida & Evenhuis 2000); however, this appears to be an error. Wetterer collected ants in Fiji in 1996 but did not collect *W. auropunctata* (J. Wetterer, pers. comm.), and it was not collected during a 2004 collecting trip around Viti Levu that included the port areas (D. Ward, pers. comm.). Further spread in the Pacific through trade is highly likely.

A9. Habitat range

Wasmannia auropunctata has been described as a true generalist in its choice of nest sites and habitats (Le Breton et al. 2003 and references therein). It occurs in a range of habitats from urban settlements (Delabie et al. 1995; Fowler et al. 1990) and fields (Jeanne 1979) through to undisturbed forest (Jeanne 1979; Tennant 1994; Kaspari 1996; Vasconcelos 1999). Generally, *W. auropunctata* nests in unstable microhabitats favouring species that can cope with frequent migrations (Holldobler & Wilson 1990; Passera 1994; Armbrecht & Perfecto 2003); it can occur in habitats that are wet or dry (Deyrup et al. 2000) and it will nest on the ground or in trees. Unlike *Solenopsis geminata*, it does not colonise disturbed habitats rapidly.

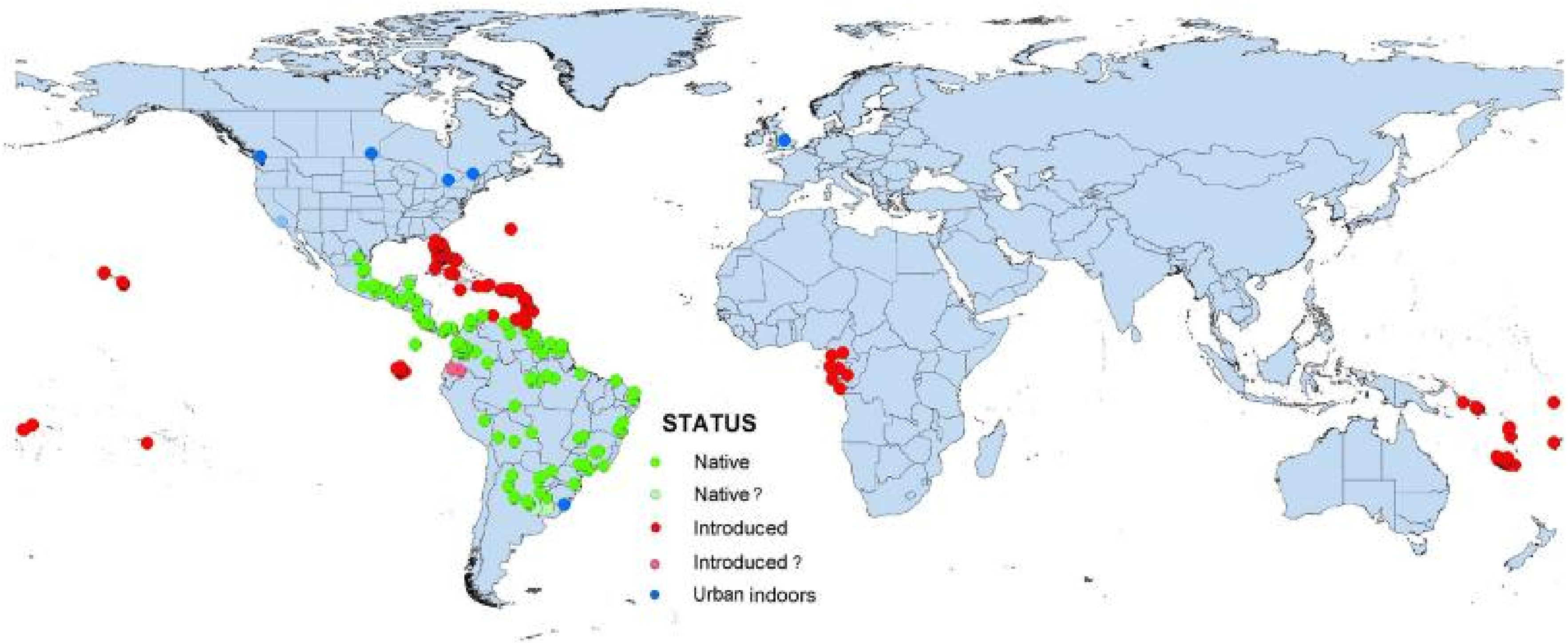


Fig. 2: *Global distribution of* W. auropunctata*. Data from Landcare Research Invasive Ant Database as at February 2005. The blue urban records are those where the ant was reported only within buildings.*

(B) LIKELIHOOD OF ENTRY

B1. Identification of potential pathways

Wasmannia auropunctata is considered one of the classic "tramp" ant species, due to its reliance on human-mediated dispersal and close association with humans (Holldobler & Wilson 1990; Passera 1994). Pathways for the introduction of *W. auropunctata* to new locations include both natural (e.g., floating on vegetation and debris), and human-mediated routes (e.g., the nursery trade, transportation in soil, packaging materials moved by road sea or air (www41)). Transportation in coconut nursery stock is particularly common in the Solomon Islands (www41). One hypothesis for the introduction and spread of *W. auropunctata* in Hawaii is transportation in association with fish-tail palms (*Caryota* spp.) (P. Conant, pers. comm., cited in Gruner 2000). Causton et al. (in press) suggest that it is easily transported on fruits and vegetables and that the growing trade between countries has facilitated the spread of *W. auropunctata*.

According to MAF records, there have been only two recorded interceptions of *W. auropunctata* at the New Zealand border. One (November 1997) was at Auckland airport on cut flowers from the Solomon Islands, and the other (March 2004) was at Auckland seaport in a commercial timber shipment from Papua New Guinea. Considering the very small size of this ant (< 2 mm) the two interceptions may represent only a relatively small component of the total number of entries of this species into New Zealand.

In Australia there have been 11 interceptions of *W. auropunctata* from 1988 through 2003 (data from January 1986 to 30 June 2003; Department of Agriculture, Fisheries and Forestry, Canberra). These interceptions were from air passengers and air freight originating from the Solomon Islands (8), USA (2) or New Caledonia (1). All but one of the interceptions were associated with air passengers (mostly carrying plants, cut-flowers, or woven baskets or matting). Multiple life stages and large numbers of ants were present in some of the interceptions. The one air freight interception was on live bromeliad nursery stock, from mainland USA. In Hawaii, only one interception from Florida and one find "at large" have been reported (data from January 1995 to May 2004; Hawaii Department of Agriculture).

The Landcare Research Invasive Ant Database does not currently have any records of *W. auropunctata* from PNG. The interception from PNG may represent an error or a case of infestation in transit, but if not, i.e. the ant is indeed established in PNG, this would represent a significant increase in the risk pathways to New Zealand (see section B3).

B2. Association with the pathway

Wasmannia auropunctata has a casual association as a hitchhiker/stowaway with freight and in particular air passengers. It is well established and widespread in the Americas and the low interception rates from this source suggest the risk of its spread to New Zealand (or Australia) from the Americas is low. It is a relatively recent arrival in the Pacific and is likely to spread further. The large amounts of trade arriving in New Zealand from areas of the Pacific probably represent New Zealand's greatest risk of arrival in the future. It may already be established in other Pacific countries, but the small size of the ant, and lack of resources for survey and ant identification, may mean accurate detection and reporting will take many years without specific surveys. This ant is commonly associated with urban areas, as reflected by the interceptions in personal effects. It has been intercepted only infrequently compared to other tramp ants common in the southern hemisphere, but interception rates may increase as its distribution in the Pacific increases. Air passengers from Pacific countries with known infestations represent one of the most likely pathways to New Zealand and may warrant specific targeting. Importation via this pathway is not likely to be detected by current invasive ant surveillance because this focuses on ports of entry and devanning sites for cargo.

B3. Summary of pathways

A summary of freight coming to New Zealand from localities within 100 km of known sites of *W. auropunctata* infestation is presented in Fig. 3 (also see Appendix 1). During the 2001–2003 period, total volumes of freight from localities near this ant were moderately high, representing about 6.0% of total air freight and 5.2% of sea freight (6.6% of sea freight where the country of origin was reported). However, risks associated with Canada, the UK, and California are probably negligible as it is unlikely the ant is established in those countries (and if present, its distribution is likely to be highly restricted). Also, the record from Fiji appears to be an error. With these locations removed, at-risk freight represents only 0.3% of total air freight and 0.8% of sea freight (1.0% of sea freight where country of origin reported).

About 9626 tonnes of sea freight originated from infested sites in the Pacific over the 2001–2003 period (current Hawaiian infestations are not near seaports and Fiji is excluded). Of the 9626 tonnes, 8% was fresh produce, 98% of which originated from Noumea and Honiara. 54% of the total was other foodstuffs, 88% of which originated from Papeete and 9% from Honiara. About 107 tonnes of air freight originated from infested sites in the Pacific; 54% of this was produce, all of it exported from Noumea.

Air freight and passengers from New Caledonian (Noumea) may currently represent one of the highest risk routes for introduction into New Zealand. However, if *W. auropunctata* is established in PNG (one of the New Zealand interceptions was in timber from PNG), this would represent a significant increase in risk of transport to New Zealand, as 197 000 tonnes of sea freight and 8 tonnes of air freight originated from PNG over the 2001–2003 period. Of the sea freight from PNG, 170 000 tonnes is bulk freight and probably a low risk pathway, but the remainder (27 000 tonnes) is about 3 times the amount from currently known risk sites in the Pacific.

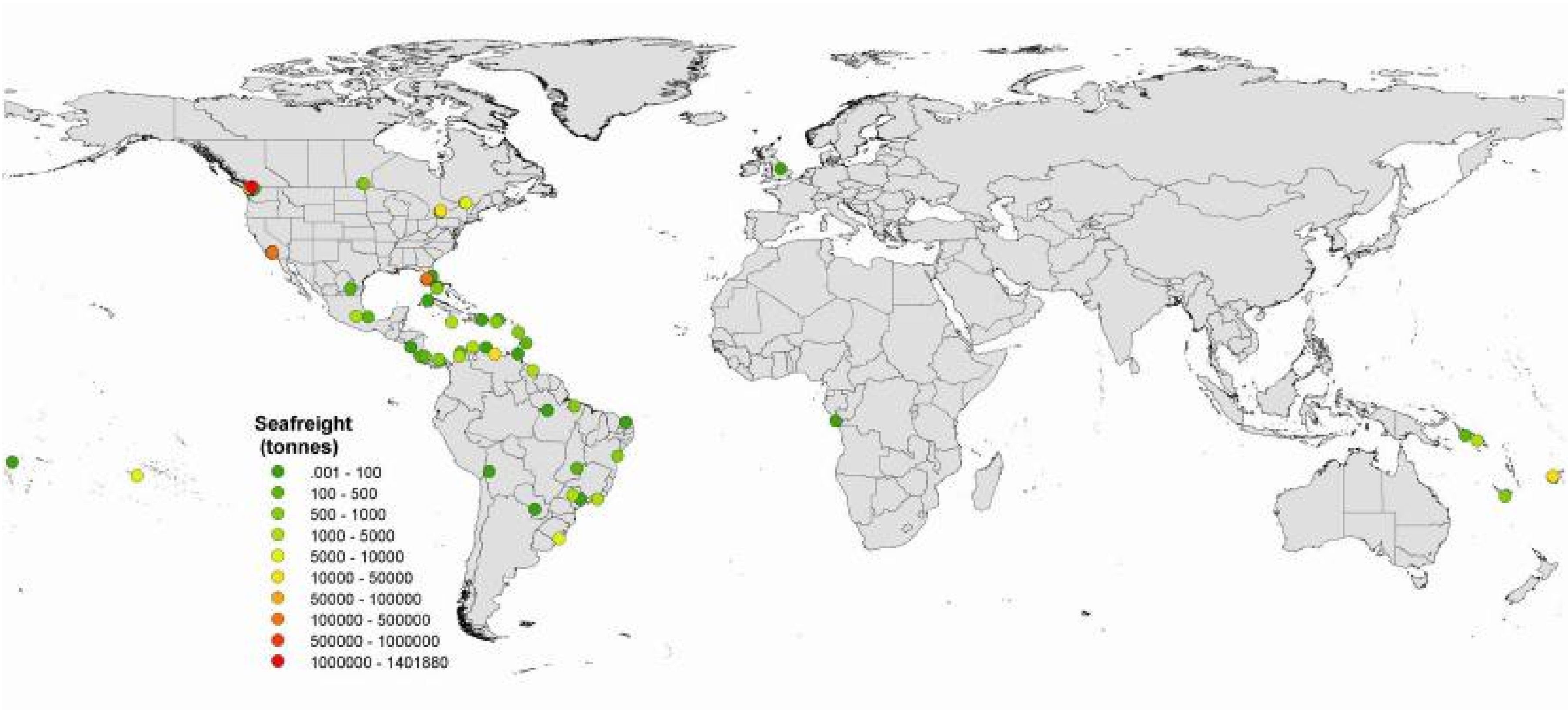


Fig. 3a: Summary of sea freight coming to New Zealand from localities within 100 km of known sites with W. auropunctata *present. Values represent the total freight (tonnes) during 2001, 2002 and 2003 (source: Statistics New Zealand). Details of locations and freight types are given in Appendix 1.*

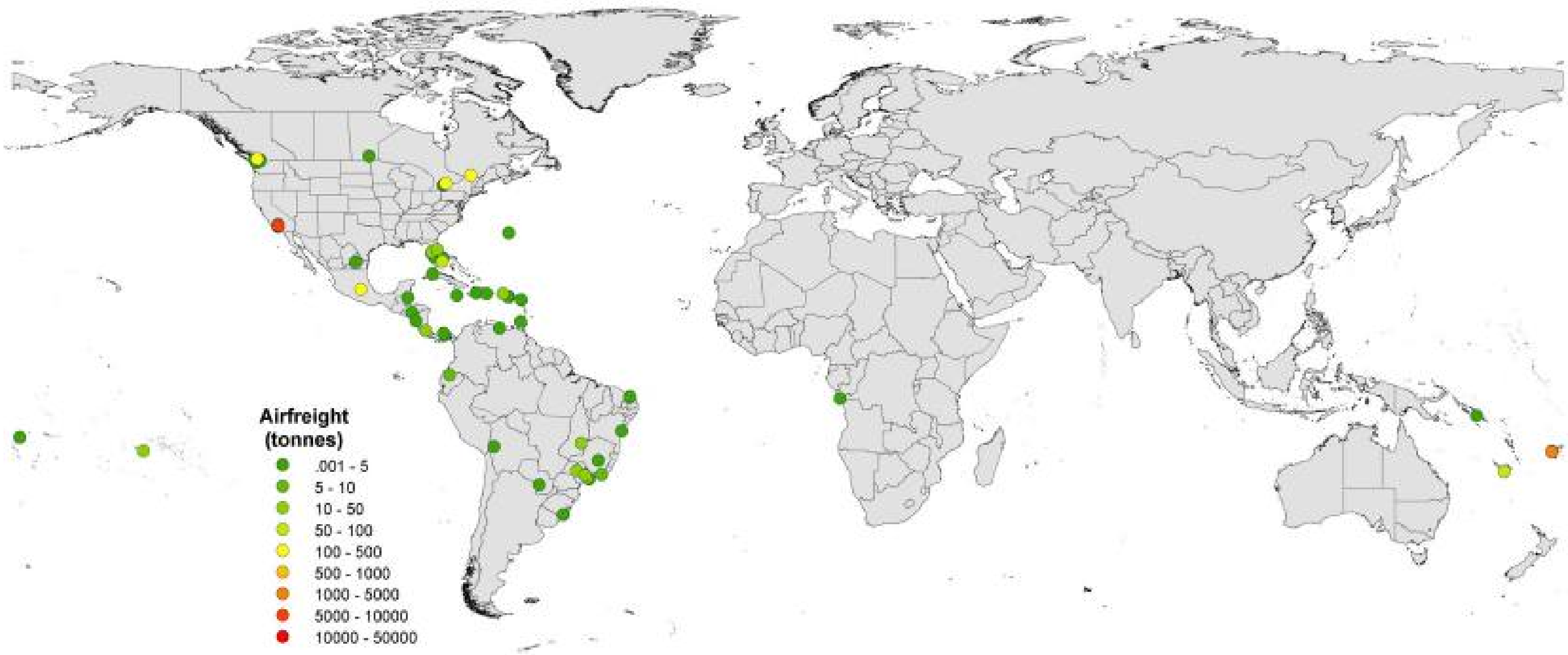


Fig. 3b: *Summary of air freight coming to New Zealand from localities within 100 km of known sites with* W. auropunctata *present. Values represent the total freight (tonnes) during 2001, 2002 and 2003 (source: Statistics New Zealand). Details of locations and freight types are given in Appendix 1.*

(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 2 for more detail). The predictions are compared with those for two species already established in New Zealand (*Ph. megacephala* and *L. humile*) (Appendix 3). 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 throughout the world in locations with diverse ant faunas (e.g., Human & Gordon 1996), competition with New Zealand 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 ant species indicated that temperature rather than interspecific competition primarily determined the temporal activity of ant communities in open Mediterranean habitats (Cerda et al. 1998). Subordinates were active over a wider range of temperatures (Cerda et al. 1998). In California, *L. humile* foraging was restricted by temperature; ants were most abundant at bait at 34°C, and bait was abandoned at 41.6°C (Holway et al. 2002b).

Temperature generally controls the metabolism and activity of ant colonies, 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 nest sites (Chen et al. 2002).

Environments with high rainfall reduce foraging time and may reduce the 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; most of the lower South Island contains 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 because of 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 enabling foraging indoors when temperatures are too hot or cold (Gordon et al. 2001).

C1.2 Specific information on W. auropunctata

No experimental data on climatic preferences were found for this species. However, various reports indicate that *W. auropunctata* is likely to be limited to areas with high temperatures. In Argentina, small myrmicines, including *W. auropunctata*, were most active on baits when the soil surface temperature was above 30°C (some activity over the range 10–37°C) (Bestelmeyer 2000). Outdoor populations of *W. auropunctata* appears to occur only in tropical localities (Ayre 1977). In the USA it is common in southern Florida, occurring sporadically as far north as Marion County (Latitude 29° 30' N) (Deyrup et al. 2000). The Bermuda population (Latitude 32° 20' N) is the northernmost well-established population of *W. auropunctata* (www41). It has been reported in Los Angeles (34° N) and San Francisco (37° 45' N); although this is well north of its apparent latitudinal limits, the warming effects of these cities may allow the ant to persist there (www41). Nevertheless, it seems likely that *W. auropunctata* cannot survive Californian winters outside buildings (www41). The lack of any recent Californian records suggests that *W. auropunctata* has not spread widely and may in fact no longer persist in that State (www41).

On Santa Cruz Island in the Galapàgos, *W. auropunctata* is absent from the "wettest and driest" locations, and in the Island's cooler higher altitude centre, although the boundaries of the population expand in summer and contract in winter (Clark et al. 1982). El Nino increases rainfall in the Galapàgos and favours expansion of the range in arid zones (rainfall increases from a mean of 374 mm to > 3500 mm during El Nino) (Meier 1994). Lubin (1984) also reports the distribution of *W. auropunctata* to be limited by extreme conditions on the Galapàgos, i.e. high temperature and low humidity, or low temperature and high humidity, but did not quantify these limits.

A Climex prediction of the distribution of *W. auropunctata* in Australia indicates that northern areas, particularly coastal areas of Northern Territory and Queensland, may be most suitable for establishment (O'Dowd 2004). All areas considered even marginally suitable (receiving an ecoclimatic index score (ECI) above 0) have a higher mean annual temperature than northern New Zealand. The area of Australia where the ECI > 0 is greater for *W. auropunctata* than for *Anoplolepis gracilipes,* and similar to the prediction for *Solenopsis geminata*, but considerable smaller than the area predicted for *Pheidole megacephala.* Victoria, Tasmania and southern Western Australia are all unsuitable (ECI = 0).

The risk to New Zealand might usefully be assessed from the distribution of *W. auropunctata* in Hawaii, where it has only been reported from lowland areas (< 900 m) (Wetterer & Porter 2003). This may indicate that New Zealand is too cold, although it is a relatively recent Hawaiian arrival and may not yet have reached its full distribution. Ant species that occur in Hawaii's mountainous areas (900–1800 m, Reimer 1994) include *Pheidole megacephala* (which has a very restricted northern distribution in New Zealand (Appendix 3)) 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 3).

C1.3 BIOSECURE analysis

175 locality records were used for the assessment of *W. auropunctata*, about two thirds originating from the native range (Fig. 4). Climate parameters used are defined in Appendix 2.

Native range data indicate that mean annual temperature (MAT) overlaps with northern New Zealand (compare Table 1 and 2), but only for the coldest outliers. The MAT outliers are in mountainous regions of Colombia (Armbrecht & Ulloa-Chacon 2003) and Ecuador (Wetterer & Porter 2003). Overlap of the native range data and New Zealand for minimum temperature of the coldest month (MINT) is considerably wider, and all other climate parameters overlap with New Zealand much more than MAT. The introduced range extends the temperature overlap due to records from heated glasshouses in cold climates, particularly Canada (Fig. 5a).

The climate from sites in the native + introduced non-urban range shows no more overlap for MAT with New Zealand than the native range, as the climate from sites in the introduced non-urban range is tropical and is therefore less similar to New Zealand than the climate from high altitude areas within the native range (Fig. 5b). Vapour pressure (VP) at sites with *W. auropunctata* shows relatively low overlap with New Zealand (Fig. 6).

Climate summary

The general climate summary for the international range of *W. auropunctata* indicates low similarity to New Zealand, particularly compared to *L. humile* (Fig. 7). Climate summary graphs are less useful than individual climate layers as contrasts in the risk between species and regions of New Zealand are less evident.

Climate match conclusions

Available data indicate that New Zealand has low climatic similarity with sites where *W. auropunctata* is established. There is some overlap for MAT and MINT, more so than for *Pheidole megacephala*, due to inclusion of data points from mountainous regions within South America. However, these points may reflect outliers because of the estimation method. BIOSECURE approximates climate for an entire half-degree grid square. If a grid square is generally mountainous with an ant present only at the bottom of a valley, the temperature estimate from that grid square used in the analysis will be lower than that actually experienced at the site where the ant is located. None of the records of *W. auropunctata* from its current introduced range indicate that temperate areas are at risk of establishment outside urban development (there are outliers from heated glass houses).

The lack of sufficiently high temperatures over summer for foraging and colony development is likely to severely limit the likelihood of this species establishing permanently outdoors in New Zealand. Cold temperatures over winter may also restrict establishment. In warm microhabitats colonies may persist for some time if above average temperatures were maintained. In such situations it is likely the suboptimal temperatures would restrict rates of development and spread.

Wasmannia auropunctata is capable of surviving at least temporarily in very cold climates in heated glasshouses containing tropical plants, but because most of the surrounding habitat would be unsuitable for establishment, these populations would probably be easy to eradicate. This habit of survival in urban areas does not appear to be as common as with some other species (e.g., *Paratrechina longicornis* and *Monomorium pharaonis*), and the species has not been reported from inside factories and hospitals in temperate locations.

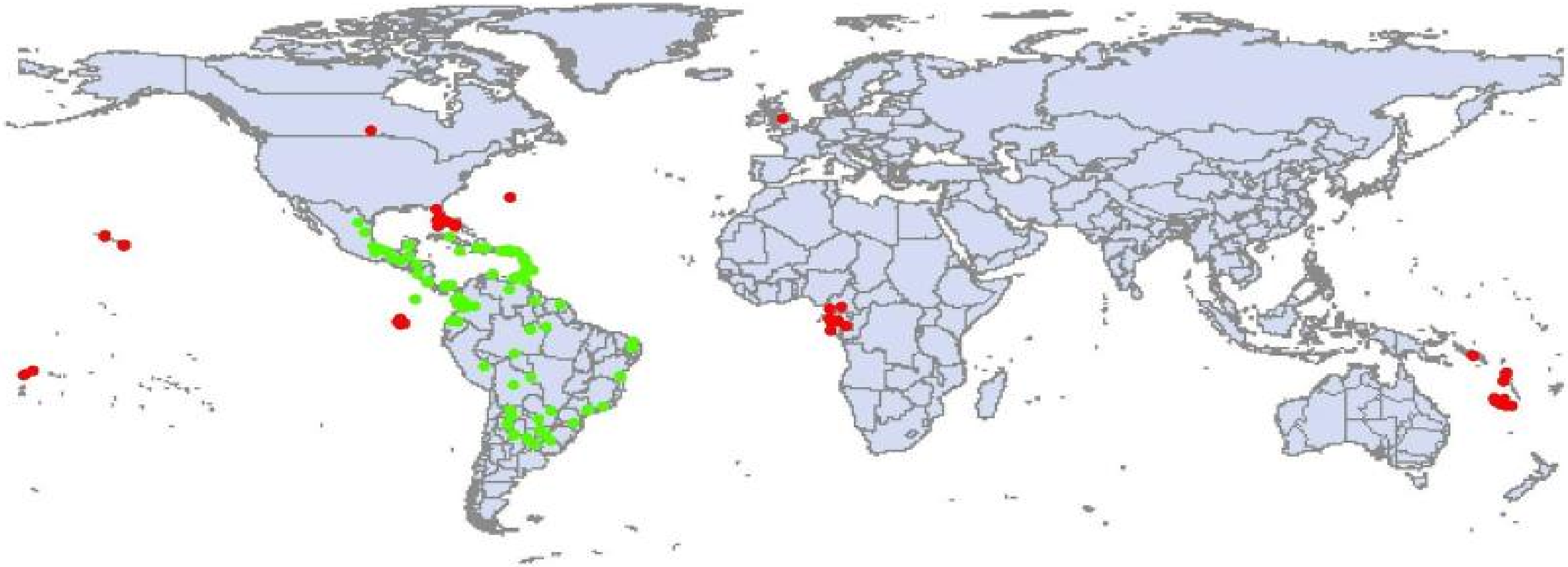


Fig. 4: *Native (green) and introduced (red) distribution records used in BIOSECURE analysis of* W. auropunctata.

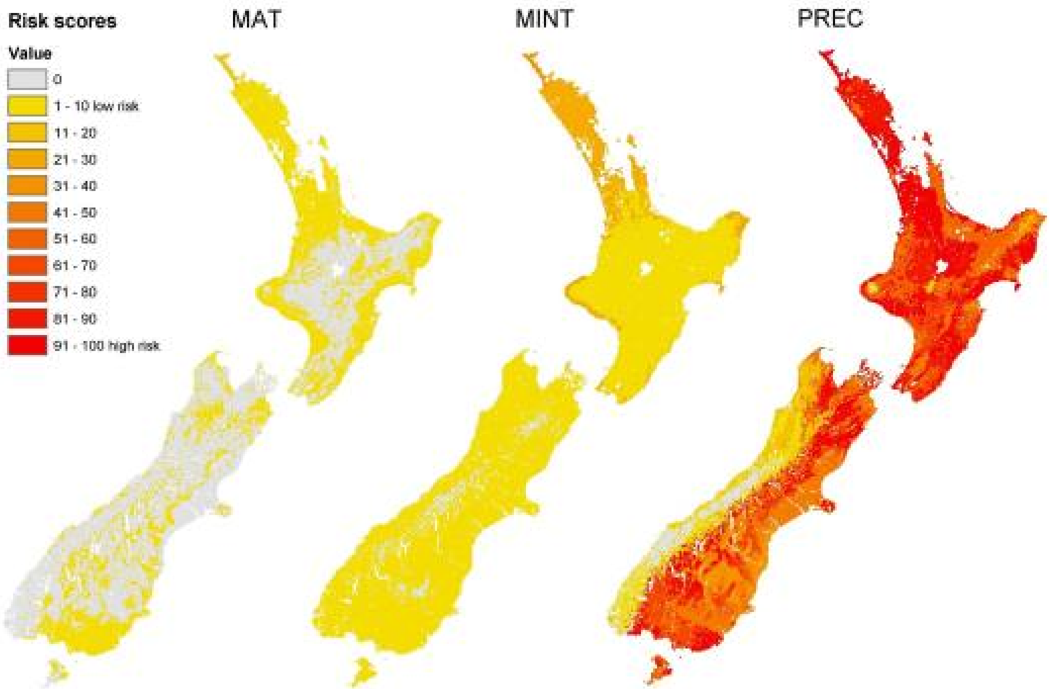
Table 1: Comparison of climate parameters for native, introduced, and introduced non-urban range of W. a uropunctata.

Paramete r	n	Mean	Minimum	Maximum
Mean Annual Temperature (°C)				
Native Range	102.0	23.3	13.7	27.4
Introduced Range	73.0	23.0	2.7	27.0
Introduced Non-urban Range	68.0	23.6	18.2	27.0
Minimum Temperature (°C)				
Native Range	102.0	16.3	-0.1	24.4
Introduced Range	73.0	15.1	-21.5	23.5
Introduced Non-urban Range	68.0	16.0	5.8	23.5
Mean Annual Precipitation (mm)				
Native Range	102.0	1704.0	384.0	4835.0
Introduced Range	73.0	1559.0	384.0	3217.0
Introduced Non-urban Range	68.0	1594.0	384.0	3217.0
Mean Annual Solar Radiation				
Native Range	102.0	16.4	11.9	21.4
Introduced Range	73.0	15.0	9.1	17.0
Introduced Non-urban Range	68.0	15.1	9.1	17.0
Vapour Pressure (millibars)				
Native Range	102.0	22.4	11.0	29.0
Introduced Range	73.0	22.4	7.0	30.0
Introduced Non-urban Range	68.0	23.0	18.0	30.0
Seasonality of Temperature (°C)				
Native Range	102.0	7.5	0.9	23.5
Introduced Range	73.0	7.9	1.1	37.7
Introduced Non-urban Range	68.0	7.5	1.1	18.1
Seasonality of Precipitation (mm)				
Native Range	102.0	187.6	41.0	422.0
Introduced Range	73.0	158.1	25.0	366.0
Introduced Non-urban Range	68.0	161.6	41.0	366.0
Seasonality of Vapour Pressure (millibars)				
Native Range	102.0	6.0	1.0	13.0
Introduced Range	73.0	7.5	2.0	15.0
Introduced Non-urban Range	68.0	7.4	2.0	15.0

Table 2: 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

a)



b)

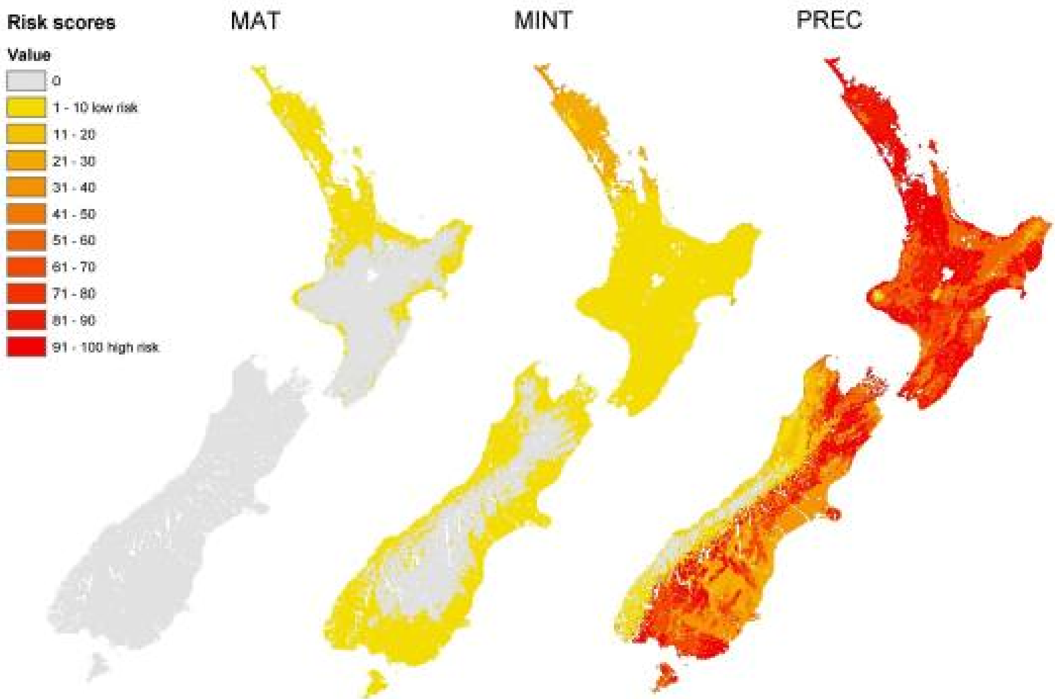


Fig. 5: *Similarity of a) native + introduced ranges and b) native + introduced non-urban ranges of* W. auropunctata *to New Zealand for MAT, MINT, and PREC.*

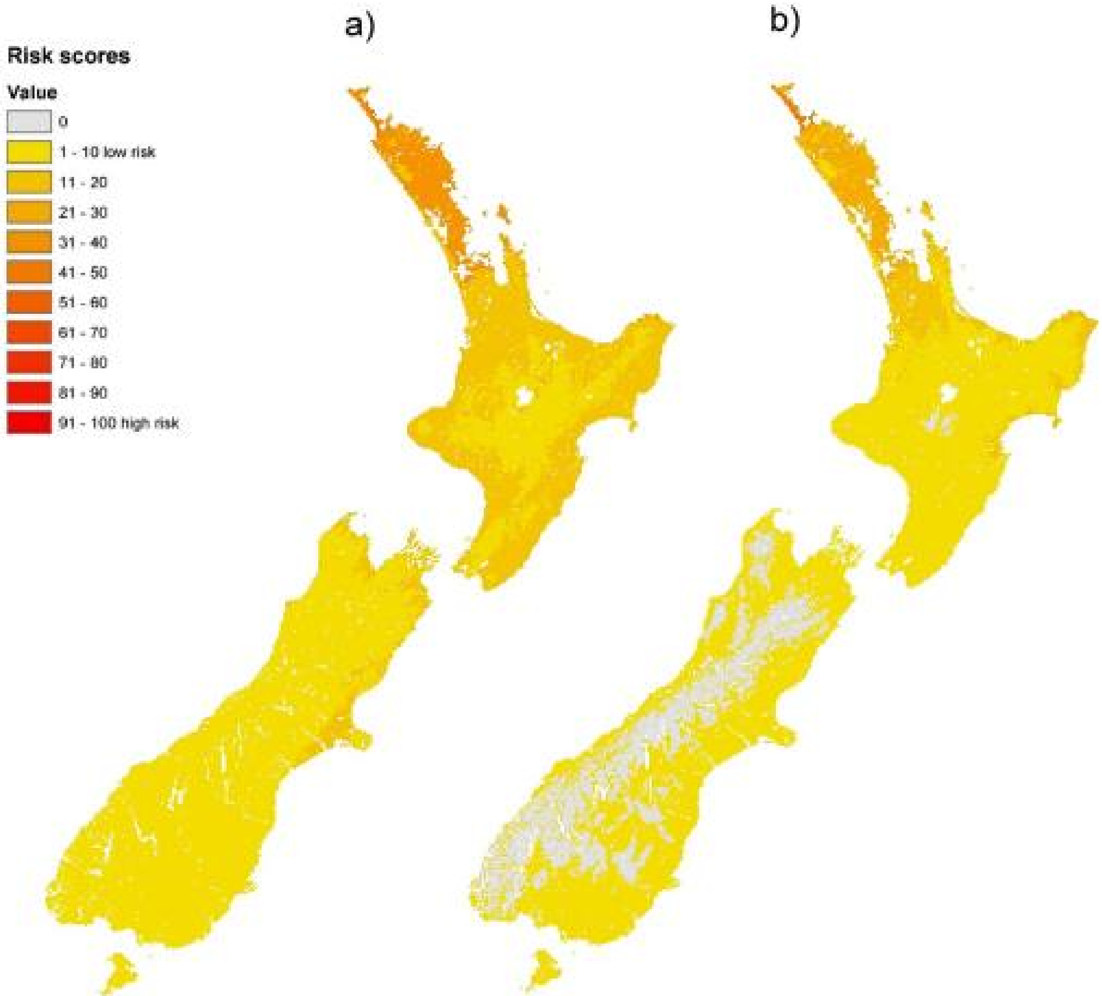


Fig. 6: *Similarity of a) native + introduced ranges and b) native + introduced non-urban ranges of* W. auropunctata *to New Zealand for VP.*

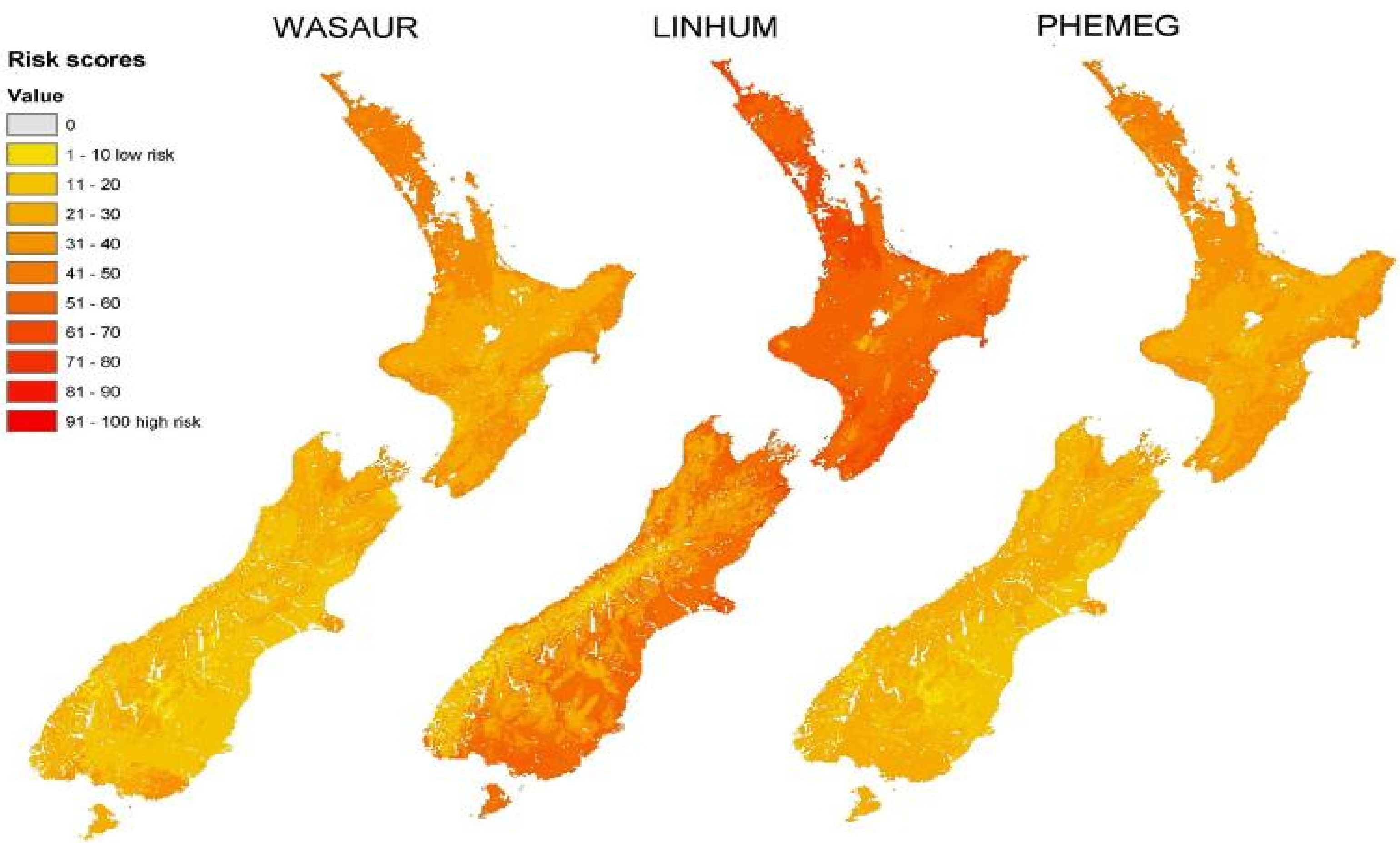


Fig. 7: Comparison of climate similarity to New Zealand of the international ranges of W. auropunctata, L. humile *and* P. megacephala *based on the mean of the similarity scores of five climate layers (MAT, MINT, PREC, VP, PRECS). This presentation approximates that produced by the risk assessment tool Climex. The presentations represent native + introduced (non-urban) ranges.*

C2. Potential to establish in protected environments

Wasmannia auropunctata has been recorded as a house pest (Fernald 1947), and found in hospitals in its native Brazil (Bueno & Fowler 1994). In New Caledonia and Vanuatu, *W. auropunctata* was found in the immediate vicinity of human habitations and was thought to invade houses in search of food (Jourdan 1997; Jourdan et al. 2002). There are several records of *W. auropunctata* existing outside its normal temperature tolerance range (at least temporarily), all from heated tropical glasshouses: one in the UK and three in Canada (Wheeler 1929, cited in www40; Ayre1977; Anon. 1979; Naumann1994; wwwnew54). The environment in which the ant was found in California is not known, but there is doubt as to the ant's continued presence (www41).

Wasmannia auropunctata could probably establish in protected environments in New Zealand. This is more likely to be in greenhouses, where plants may harbour honeydew-producing hemipterans, than in heated buildings where plants are scarce.

C3. Documented evidence of potential for adaptation of the pest

There is no direct documented evidence of adaptation of *W. auropunctata* to new adverse conditions. It has successfully invaded glasshouses; however the tropical conditions within these glasshouses mirror those of its native range.

C4. Reproductive strategy of the pest

W. auropunctata is polydomous (a colony consisting of many nests) and polygynous (many queens in one nest) (Wetterer & Porter 2003). The primary method of dispersal from a nest is by budding, where queens accompanied by workers walk to a new nest location nearby. Newly emerged queens and males have wings and Torres et al. (2001) collected large numbers of *W. auropunctata* (up to 1128 males and 741 females) in light traps on Puerto Rico, mostly during the rainy season. They suggested that *W. auropunctata* can only fly short distances, but this might mean they can disperse more rapidly into uninfected areas. Kaspari et al. (2001) sampled alates in flight traps in Panama mostly during the 4 and 5th lunar months (25 March–20 May). Such flights of males and females may occur only where *W. auropunctata* is native. There is no evidence to suggest that *W. auropunctata* undergo nuptial flights on the Galapàgos (Causton et al. in press). Queens from nuptial flights probably return to existing nests, as independent nest founding is considered highly unlikely (Ulloa-Chacon 1990, cited in Passera 1994).

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

Workers alone are incapable of founding a new nest as they are sterile (Ulloa-Chacon & Cherix 1988, cited in Ulloa-Chacon & Cherix 1990). As independent colony founding is also highly unlikely (Ulloa-Chacon 1990, cited in Passera 1994) a queen with workers would need to be transported to found a new population.

C6. Likely competition from existing species for ecological niche

On New Caledonia, Vanuatu and the Galapàgos archipelago, where *W. auropunctata* has invaded and occurs in high densities, other ant species are either totally absent or their populations are severely reduced (Clark et al. 1982; Jourdan et al. 2002; Le Breton et al. 2003). Native New Caledonian ants were even excluded from some invaded areas with low *W. auropunctata* densities (Le Breton et al. 2003). However, *W. auropunctata* is attacked by, and competes with several ant species in the Galapàgos (de la Vega 1994), indicating that where it is not dominant numerically, competition with existing ant species may help determine its niche. It is unclear exactly what factors are required for high densities, but tropical climate and release from dominant competitors appear prerequisites. This does not necessarily imply depauperate existing ant communities as New Caledonia has a relatively rich native ant community (Taylor 1987), especially compared to other oceanic islands (Morrison 1997).

Wasmannia auropunctata appears to interact competitively with other invasive species. *Pheidole megacephala* and *W. auropunctata* did not co-occur within houses in Bahia, Brazil (Delabie et al. 1995). In the Havana greenbelt in Puerto Rico, *W. auropunctata* dominates baits in sunny sites while *Ph. megacephala* dominates in the shade (Levins et al. 1973). On the Galapàgos the distribution of *Solenopsis geminata* and *W. auropunctata* did not overlap; their populations were separated by an unoccupied area of several metres along a common boundary (Lubin 1984).

In New Zealand, the presence of other dominant ant species more suited to temperate climates at the site of an incursion (e.g., *Linepithema humile* and *Doleromyrma darwiniana*) may increase competition and reduce the chances of establishment at those sites. *Pheidole megacephala* would probably not limit the likelihood of establishment of *W. auropunctata* as this species has a highly restricted New Zealand distribution, and where present does not appear to be abundant nor pestiferous (Berry et al. 1997; Don & Harris 2005). Were *W. auropunctata* to nest arboreally in New Zealand, it would compete for nest sites with *Technomyrmex albipes* and *Ochetellus glaber*, neither of which is considered a dominant species and hence unlikely to restrict the distribution of *W. auropunctata*.

C7. Presence of natural enemies

There are no natural enemies present in New Zealand that would reduce chances of establishment. Within the native range of *W. auropunctata* the army ant *Neivamyrmex pilosus* has been observed carrying off brood (Tennant 1994) and a species of *Orasema* (Hymenoptera, Eucharitidae) parasitizes *W. auropunctata* in Cuba and Puerto Rico, but its impact on the population is unknown (Heraty 1994). Tennant (1994) suggests phorid flies probably attack *Wasmannia,* and that a study of natural enemies is needed. A spider mimic, *Opopaea* (=*Diblemma*) *donisthorpi* (O. Pickard-Cambridge), of *W. auropunctata* has been reported (Donisthorpe 1927, cited in Cushing 1997), but is unlikely to have any substantial effect on the ant population.

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

There is no routine treatment of port areas that would influence the survival of colonies; however, treatment of other invasive ant incursions around port areas would likely reduce chances of survival of any *W. auropunctata* colonies present.

National ant surveillance currently (2002–2005) being undertaken annually in and around ports should be thorough enough to detect an incursion of *W. auropunctata* at those locations provided the surveillance occurs on hot days in summer when foragers are likely to be active. The ant is highly attracted to peanut butter baits (Causton et al. in press), which are used in the surveillance. Interception records (see section B1) indicate surveillance around airports may be warranted for this species. Also, focussing on luggage of passengers returning from Pacific countries known to have this ant should be a priority for detection, as this is a common pathway into Australia, and it is not just workers that have been intercepted. However, *W. auropunctata* workers are very small which makes visual inspections for this ant particularly difficult: even if seen, it may not be recognised as an ant (see Figure 1a).

The fact that this ant has a painful sting, and is highly likely to be found in close association with urban areas should aid its detection should establishment initially go unnoticed.

(D) LIKELIHOOD OF SPREAD AFTER ESTABLISHMENT

D1. Dispersal mechanisms

Two methods of dispersal have together aided the spread of *W. auropunctata* at local, regional, national and international scales: human-mediated dispersal, and budding.

Most significant is human-mediated dispersal, without which it may never have reached its current locations. *W. auropunctata* is a 'tramp' ant (Holldobler & Wilson 1990; Passera 1994) well known for being transported via human commerce and trade. Interception records suggest it has so far been relatively rare in sea freight and air freight entering New Zealand and Australia (see Section B above), more often being transported in luggage of air passengers.

In the absence of human-mediated dispersal, introduced populations of *W. auropunctata* will spread predominantly by budding (Clark et al. 1982). In favorable years the population may spread up to 500 m (Meier 1994). Some spread on floating vegetation/debris (particularly logs) during floods is also likely.

D2. Factors that facilitate dispersal

Natural: W. auropunctata populations are not stable over time (Medeiros et al. 1995), sharing a propensity to disperse regularly when habitat or microhabitat disturbance occurs. In the Galapàgos, *W. auropunctata* becomes more abundant and widespread in wet conditions, probably as a result of high precipitation during El Nino years (Causton et al. in press). Budding will limit the initial spread of an invasive ant to areas adjacent to points of introduction or to source habitats (Suarez et al. 2001).

Artificial: If *W. auropunctata* should establish, the most important contributor to its ongoing spread from an area of incursion is probably the movement of soil, potted plants, and other goods.

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

Lubin (1984, 1985) recorded rates of spread for *W. auropunctata* on Santa Cruz Island (Galapàgos Archipelago) of 170 m/year and up to 500 m in El Nino years. During 1982–83, an extraordinary El Nino Southern Oscillation induced 8 months of the heaviest rains on the Galapàgos within a century, and promoted the rapid expansion of *W. auropunctata* into the arid zone (Meier 1994). Males and queens of *W. auropunctata* have been observed in high numbers in light traps, confirming they can fly. Nevertheless, there is no evidence of independent colony formation, but this has not been unequivocally discounted.

Wasmannia auropunctata has an affinity for tropical climates. If it became established in New Zealand, it is likely that the rate of reproduction, population build up and therefore dispersal (particularly via budding) would be low compared with rates in the tropics.

D4. Presence of natural enemies

Other than interactions with other ant species there are no natural enemies in New Zealand that would reduce chances of establishment.

(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

Wasmannia auropunctata is an ant of tropical climates. It appears unlikely that it will establish permanent populations in New Zealand (outside tropical glasshouses) let alone be a significant threat to native fauna. However, if *W. auropunctata* were to become established outside urban areas, this would most likely be in warm coastal sites and offshore islands in northern New Zealand.

International data point to potential for significant impacts on a wide range of indigenous fauna and suggest this species could occupy a range of habitats from open fields (Jeanne 1979) to intact forest (Jeanne 1979; Tennant 1994; Kaspari 1996; Vasconcelos 1999; Le Breton et al. 2003). The severity of impact is most likely to relate to the population densities achieved. A link between plants with extra-floral nectaries and high *W. auropunctata* abundance has been reported internationally (Deyrup et al. 2000), but such plants are absent from the New Zealand native flora. Soil surface temperature would probably be an important factor determining whether habitats were suitable for colonisation. In New Zealand during summer, soil and air temperatures inside forested habitats are several degrees colder than for pasture (Young & Mitchell 1994; Davies-Colley et al. 2000). This would be likely to severely restrict foraging activity and colony development on the ground for this tropical ant. Optimal foraging temperatures (up near 30°C (Bestelmeyer 2000)) would not occur. Any establishment at ground level would probably be in open areas where direct solar heating of the soil surface could occur. *W. auropunctata* could possibly survive solely arboreally in some forested areas in northern New Zealand, but the necessary canopy temperatures are unknown.

Fifty-five invertebrates are listed as threatened in Northland. Predation is by far the biggest threat thought to be facing New Zealand's endemic invertebrates, although for larger species the threat is considered to be mostly from vertebrates (McGuinness 2001). Within northern areas, habitats such as coastal dunes, grassy areas, and perhaps open forest margins would be most at risk of colonisation by *W. auropunctata*. Invertebrates favouring these warm open habitats would face predation and competition from *W. auropunctata*, which is capable of altering invertebrate and vertebrate communities, at least in tropical locations (Lubin 1984; Jourdan et al. 2001). The venomous sting of *W. auropunctata* may give it a greater ability to subdue vertebrate and large invertebrate prey (Holway et al. 2002a).

Particular species at risk from predation would be those with highly restricted distributions in open habitats. This may include the threatened *Placostylus* land snails (e.g., Brook 2003; Stringer & Grant 2003), four species of endemic northern tiger beetles (*Cicindela* spp.) (Larochelle & Larivière 2001), the nationally endangered coastal moth *Notoreas* "Northern" (Geometridae) (Patrick & Dugdale 2000), a suite of endemic micro-snails (e.g., *Succinea archeyi* (Brook 1999)), and possibly the endangered kauri snail, *Paryphanta busbyi watti* (Stringer & Montefiore 2000), although the scrub habitat of this species may protect it. The effects of competition and predation would likely alter the invertebrate community if the establishment of *W. auropunctata* at a site increased the total biomass of ant predators These impacts would be similar to those predicted if *L. humile*, which are already established in New Zealand and still spreading, were to establish in open habitat in Northland (Harris 2002). Other ants likely to cause similar impacts include *Solenopsis geminata, S. invicta* and *S. richteri*.

New Zealand herpetofauna, many of which are rare and restricted in distribution (Daugherty et al. 1994; Towns et al. 2001), may be at risk anywhere in the potential distribution range of *W. auropunctata*. Both oviparous and viviparous species would be at risk, with eggs and hatchlings vulnerable to predation. Nocturnal species may have limited interactions with *W. auropunctata* if their refuges in the day are safe from foragers, as it will likely be too cold for foraging at night under New Zealand conditions. Species that favour dense vegetation are unlikely to be at risk because those sites would be too cold for *W. auropunctata* to forage.

Some of New Zealand's bird species that nest on the ground or arboreally in Northern coastal areas and northern offshore islands would probably be affected if *W. auropunctata* established in their nesting areas. Although the adults are probably not at risk, eggs and newly emerged young may be preyed upon. Seabirds may be affected because of their habitat overlap with *W. auropunctata* (Taylor 2000). For example, Buller's Shearwater (*Puffinus bulleri*) breeds only on the Poor Knights Islands and nests in burrows (Taylor 2000), so could be at risk. Also at risk could be stitchbirds (*Notiomystis cincta*). Stitchbirds build their nests in tree cavities and are restricted to a few offshore islands in northern New Zealand (Anon. 2005).

Establishment of *W. auropunctata* in the canopy of forest areas would probably increase ant predation on invertebrates and might increase the densities of Homoptera in that microhabitat. Invertebrate communities in the canopy are poorly studied, so impacts are difficult to predict.

E1.2 Human health-related impacts

Wasmannia auropunctata has a painful sting and occurs in disturbed habitat such as urban and horticultural areas. Wherever it establishes it will occasionally cause injury to humans and domestic animals when workers on vegetation or the ground are trapped against skin. As the ant is very small it will probably not be seen before it stings. Multiple stings are likely to require some people to seek medical assistance. No reports of severe, systemic allergic reactions were found. The incidence of people being stung will depend on the abundance of the ant at sites of establishment. Establishment in tropical glasshouses would likely result in gardeners being regularly stung as is reported in Canada (Naumann 1994). Despite being recorded as a house pest and in hospitals in Brazil, there has been no documented evidence of *W. auropunctata* causing health problems related to disease transmission or stinging patients.

E1.3 Social impacts

In urban areas where the ant becomes established, it could disrupt lifestyles, particularly outdoor activities that have a greater risk of contact with ants (e.g., picnics, gardening). Ant control would necessary within a heavily infested area to allow such activities to continue.

E1.4 Agricultural/horticultural losses

Impacts on agriculture/horticulture will largely depend on whether *W. auropunctata* achieves high population densities. At worst, this is likely to occur only at a few northern locations. The presence of the ant in crops that are hand picked would result in stings occurring to pickers; where the ant was consistently present, this could make it difficult to get pickers. This ant's sting also has the potential to injure domestic stock, causing corneal cloudiness and blindness, as has been reported in Africa and the Solomon Islands (www41).

Impacts would also occur through tending of Homoptera (reducing production, spoiling the fruit and/or spreading disease), but the ant would need to be present in sufficient numbers to significantly elevate pest densities. Ants already occur in such situations in New Zealand, but at low population densities (Lester et al. 2003). They are not likely to be a significant pest in orchards that use insecticides. Conversely, in orchards the ant has some beneficial effects because it preys on other pest species.

E1.5 Effect(s) on existing production practices

Establishment in crops that are handpicked (outdoors or in a glass house) may affect harvesting due to the threat to workers of stinging.

E1.6 Control measures

(This section is largely based on the review of baiting by Stanley (2004))

The food preferences of *W. auropunctata* have been well studied by Williams and Whelan (1992) in laboratory and field tests in the Galapàgos Islands. In laboratory tests, peanut butter, followed by honey, were more attractive to foragers than all other food types offered (foods in order of attractiveness: peanut butter; honey; honey water; pineapple juice; tuna oil; dark karo syrup; mint jelly; light karo syrup; soy bean oil; orange juice; molasses; apple juice; coca cola syrup) (Williams & Whelan 1992). Laboratory tests conducted on preferences for oil types confirmed soybean oil was most attractive to *W. auropunctata* (oils in order of attractiveness: soybean; tuna; sunflower; peanut; safflower; codliver) (Williams & Whelan 1992).

The attractiveness of commercial ant baits relative to food attractants, such as peanut butter, was also tested in both the laboratory and field by Williams and Whelan (1992). In laboratory tests, Amdro® was slightly less attractive than peanut butter, while Logic® was significantly less attractive than peanut butter. However, Logic® has the same bait matrix (soybean oil on corn grit) as Amdro®, therefore the toxin (1% fenoxycarb) must have repelled *W. auropunctata* (Williams & Whelan 1992). In the field, Amdro®, peanut butter, lard and Raid Max® (N-ethyl Perfluorooctane-sulfonamide with peanut butter) were the most attractive to *W. auropunctata*, while Logic® was only slightly more attractive than water (foods in order of attractiveness: Amdro®, peanut butter, lard, Raid Max®; Maxforce®; honeywater; peanut butter oil; honey; Logic®; water) (Williams & Whelan 1992).

During control and eradication programmes on the Galapàgos Islands, several food attractants have been used to monitor changes in *W. auropunctata* populations. Tuna oil and peanut butter were used on Santa Fe Island in 1987 and proved highly attractive to foragers, but unfortunately also to birds, lizards and rats (Abedrabbo 1994). Hot dogs (5-mm thick pieces of beef sausage) on wire flags were used during the eradication programme on Marchena Island in 2001 and were attractive to *W. auropunctata*; but a large proportion were eaten by lizards and crabs (Causton et al. in press.). Peanut butter, suggested by Williams and Whelan (1992), was successfully used for monitoring during the Marchena Island eradication programme (Causton et al. in press). Not only was the peanut butter highly attractive to *W. auropunctata* foragers, but the placement and methodology used prevented removal by lizards and doves (Causton et al. in press).

Methoprene baits (0.4%) used in a field experiment on Santa Cruz Island (Galapàgos Islands) in 1989–90 were highly attractive, but reduced populations by only 50–75% after 3 months (Ulloa-Chacon & Cherix 1994).

Williams and Whelan's (1992) laboratory and field tests confirming the attractiveness of Amdro® to foragers paved the way for control programmes against *W. auropunctata* in the Galapàgos Islands. Laboratory tests on small colonies showed Amdro® caused 100% mortality in all colonies within 20 days (Williams & Whelan 1992). Amdro® was applied to the 3 ha of Santa Fe Island infested by *W. auropunctata* in 1987 and eradication was successful (Abedrabbo 1994). Similar methodology was used on an eradication programme on Marchena Island in the Galapàgos Islands, but control proved ineffective, and by 1998, 17 ha was infested (Wetterer & Porter 2003). Failure to control *W. auropunctata* was probably because funding ceased before control was completed, and because of El Nino conditions that suited *W. auropunctata* populations (Causton et al. in press). Funding was obtained for another eradication attempt in 2001 and Amdro® was applied to 21 ha of Marchena Island infested by *W. auropunctata*. After 2 broadcast applications of Amdro® and follow-up applications on two small infestations that initially survived, no *W. auropunctata* individuals have been detected since October 2002 (Causton et al. in press; C. Causton, pers. comm.).

Results from trials and control programmes on the Galapàgos Islands indicate *W. auropunctata* can be effectively controlled and even eradicated using Amdro®, provided adequate eradication and monitoring techniques are used and funding is available to complete the task (Abedrabbo 1994; Causton et al. in press). Also hydramethylnon degrades rapidly in sunlight and therefore the timing of bait applications may influence its efficacy (Vander Meer et al. 1982). On Marchena the eradication programme to date (2001 – end 2003) has cost approximately US$183 423, and assuming that no more ants are found a further US$136 000 will be required for monitoring over the next four years. The total projected cost of removing *W. auropunctata* from one hectare of infested area was estimated in 2004 to be US$15 584 (Causton et al. in press).

E2. Indirect effects

E2.1 Effects on domestic and export markets

No effects on domestic or export markets have been recorded. However, if *W. auropunctata* became established in New Zealand and was transported from to another country where they were absent, it could affect import health standards in New Zealand.

A large incursion detected in New Zealand could lead to movement controls on a range of freight, including produce, cut-flowers and potted plants, until eradication was achieved or abandoned.

E2.2 Environmental and other undesired effects of control measures

There have been no documented cases of unacceptable, adverse, non-target effects arising directly from the use of baits for control of *W. auropunctata*. However, this may be a consequence of a lack of monitoring for these effects. DDT, infamous for its effects on the environment, was originally used on Santa Fe Island in the Galapàgos for ant control; DDT is no longer used, and Amdro containing hydramethylnon is the recommended bait for *W. auropunctata*. Hydramethylnon (AC217, 300) is a slow-acting metabolic inhibitor that blocks the formation of ATP (wwwnew61) and degrades rapidly in sunlight (photolysis) (Vander Meer et al. 1982). While there is minimal risk to non-target insects from hydramethylnon as it is not absorbed through insect cuticle, there is some risk to scavenging arthropods and arthropod predators feeding on the bait. It is of low toxicity to most vertebrates but is highly toxic to fish, so extreme care would be needed treating *W. auropunctata* near waterways. It does not appear to accumulate in the environment (Vander Meer et al. 1982; wwwnew59; wwwnew60). Amdro is a group 20A insecticide, and resistance to these insecticides is possible through normal genetic variability in any insect population; however, there are no documented cases of ant resistance to pesticides.

(F) LIKELIHOOD AND CONSEQUENCES ANALYSIS

F1. Estimate of the likelihood

F1.1 Entry

Wasmannia auropunctata currently has a *medium* risk of entry.

This assessment is based on:

- there being only two records of *W. auropunctata* entering New Zealand.
- the likelihood, considering the very small size of this ant (< 2 mm), that the two interceptions under represent the total number of entries of this species into New Zealand.
- the potential of this species to stowaway in freight, as it occurs in a wide variety of habitats. In Australia it has most often been intercepted associated with personal effects of aeroplane passengers.
- *W. auropunctata* exhibiting typical tramp ant characteristics that increase the likelihood that queens with workers will be transported, i.e., polygyne colonies, budding, mobile colonies, and unicolonial habits.
- *W. auropunctata* being well established and widespread in the Americas yet the interception rates from this source are low, suggesting the risk of entry to New Zealand via this route is low.
- the ant having a limited, but expanding, distribution in the Pacific but not being established in Australia. These regions are high risk pathways for ants entering New Zealand.

This assessment of medium risk of entry should be reconsidered if the interception rate increases (> 1 interception/ year). An increase in interceptions is likely if the ant's distribution in the Pacific increases significantly to affect pathway risks to New Zealand, e.g., confirmation of establishment in PNG or discovery at any seaports or airports in any location with a high volume of freight or empty containers coming to New Zealand. Establishment in Australia near ports exporting freight to New Zealand would also increase the likelihood of interceptions in 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 underestimate entry risks. It is also not always clear from interception data if castes other than workers were intercepted.
- there is likely to be a considerable lag in reporting new establishments of *W. auropunctata* (and other invasive ants) in the Pacific due to the lack of resources and people able to survey and identify ants. Proactive surveying by New Zealand for ants at high volume trade exit points in the Pacific would improve the knowledge of the distribution of *W. auropunctata,* identification of further risk pathways and improve overall risk assessment. The presence or absence of the ant in PNG should be determined, if not already done so, due to the interception record from that country.

F1.2 Establishment

Wasmannia auropunctata currently has a *low* risk of establishment.

This assessment is based on:

- queens accompanied by workers being required for successful establishment of a colony, whereas most interceptions have been of workers alone.
- available climate information suggesting this tropical species is unlikely to establish outdoors in New Zealand. Winter temperatures are unlikely to kill colonies as it is established at sites in the Americas with harsher winters than lowland New Zealand. However, summer temperatures are low compared to sites where it is established, restricting colony development and foraging.

- *W. auropunctata* being able to establish in temperate regions in tropical glass houses, but these are unlikely to be close to ports of entry or transitional facilities. This assumes contaminated tropical plants are not imported into such glasshouses.
- there currently being limited pathways from New Zealand's Pacific trading partners for budded colonies to arrive in New Zealand in a fit reproductive state.
- no history of ant species establishing in New Zealand directly from northern hemisphere populations.
- lack of natural enemies in New Zealand; competition from adventive ants would restrict establishment at some locations.
- the small size of the ant hindering early detection of an incursion, but its painful sting enhancing probability of detection.
- there being proven methods for eradication of large incursions of this ant.

Targeting other invasive ants for surveillance (particularly *Solenopsis invicta*) is likely to sample this species as it is strongly attracted to peanut butter, provided monitoring is on hot days (ground surface temperature above 30°C) when *W. auropunctata* is most active.

Data deficiencies

- there is only limited experimental data on climate tolerances of *W. auropunctata*. The present climate assessment is based principally on climate estimates from known sites of establishment, on the restricted northern distribution in Florida (outside of heated buildings), and the lack of temperate records from the introduced range (including a restricted alpine distribution on the Galapàgos).
- some climate outliers resulted from distribution records from within alpine regions of South America. These suggest some overlap in mean annual temperatures with northern New Zealand. It was assumed that the climate the sites of occurrence is in valleys and is warmer than the estimated temperatures for those grid squares which average altitude within the grid squares to estimate temperature. This assumption needs confirmation.
- the probability of ants being transported from the Americas to New Zealand in sea freight or air freight and arriving in a reproductively fit state is unknown, but is assumed to be low.
- the ability of *W. auropunctata* to establish in temperate sites dominated by *Linepithema humile* is unknown but is assumed to be low.

F1.3 Spread

Wasmannia auropunctata has a *low* risk of spread from a site of establishment.

This assessment is based on:

- areas of New Zealand considered climatically suitable being highly restricted; hot microclimates occur in some urban areas and possibly in other habitats in northern New Zealand.
- suitable habitat for this ant occurs in New Zealand. Diverse habitats are favoured, including urban areas and grasslands. Forests are colonised 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 New Zealand locations, summer is considered too cold for successful development of reproductives.

- budding will limit the initial spread to areas near points of introduction and human mediated dispersal would be the primary method of spread.
- an effective eradication strategy exists for populations of this ant. This would enable populations to be managed and further spread to be reduced.

Data deficiencies

- northern New Zealand's climate is considered generally unsuitable for *W. auropunctata*. However, it is unclear just what this means should a queen with workers arrive at a location. It could mean no successful development of brood, or 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.
- the eradication strategy for this ant has not been attempted in a temperate climate.

F1.4. Consequences

The consequences of the presence of *W. auropunctata* in New Zealand are considered *medium/high*.

This assessment is based on:

- *W. auropunctata* having the potential to establish outside tropical glass houses in New Zealand. This could include some urban areas and also hot microclimates in coastal northern North Island and northern offshore islands.
- open, unshaded, native habitats in northern New Zealand being invaded. Both invertebrates and vertebrates could potentially be affected because of predation, competition for food and the workers' defensive behaviour (stinging). However the extent of detrimental impacts depends on population densities. Numerically dominant populations of *W. auropunctata* will likely be rare because temperature would limit developmental rates and foraging.
- there being significant medical consequences of establishment even at low ant densities, due to human reactions to the venom.
- the presence of colonies in urban areas occasionally impacting negatively on outdoor activities and resulting in initiation of pest control.
- limited detrimental impacts on agriculture (e.g., stinging domestic stock) and horticulture (e.g., stinging pickers) wherever the ant established.

Data deficiencies

- we assume that the level of impact of an adventive ant on any New Zealand native system is proportional to the density of its population, but this is untested. The impact of *S. invicta* on other ant species has been shown to be less at the extremes of its range in North America, where *S. invicta* densities are lower.
- we have assumed some ability to establish outdoors. If temperature outliers from mountainous regions in South America are incorrect due to the estimation method then the risk of outdoor establishment and consequences of the presence of *W. auropunctata* in New Zealand are overstated.
- all information on detrimental impacts of this ant is from tropical climates, limiting its applicability to New Zealand. Studies of spread, population densities, and impacts in temperate climates are needed to better predict consequences for New Zealand. Potential locations for comparison would be alpine areas of Hawaii (if it eventually spreads into such areas), Los Angeles and San Francisco (if still established), and possibly alpine areas of New Caledonia and Vanuatu (if it eventually spreads into such areas and they are sufficiently cool to approximate temperatures in northern New Zealand).

F2. Summary table

Ant species: ***Wasmannia auropunctata***

Category			Overall risk
Likelihood of entry	Medium	Limited interceptions.	Low - medium
		Limited but expanding distribution in the Pacific.	
Likelihood of establishment	Low	Unlikely to establish outdoors.	
		May establish in glasshouses.	
		Proven methods for eradication.	
Likelihood of spread	Low	Slow development.	
		Limited suitable sites.	
		Proven methods for eradication	
Consequence	Medium - high	Medical consequences of establishment.	
		Potential for impacts on invertebrates and vertebrates.	

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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Causton, C., Charles Darwin Research Station, Galapàgos. causton@fcdarwin.org.ec

Harris, R., Perth, Australia. r3plust@westnet.com.au

Ward, D., Auckland University, New Zealand. d.ward@auckland.ac.nz

Wild, A., University of California, Davis, USA. alexwild@myrmecos.net

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(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 *W. auropunctata.* Values represent the total freight (tonnes) during 2001, 2002 and 2003. NB: All locations receive some freight but if it is below 500 Kg is listed as 0 tonnes. Details of the freight types that comprise each category are given in Table c, as are the categories (HS2 Chapters) used to classify incoming freight in the Statistics New Zealand database (description provided in Table d).

Country	Port of export	Total freight	Appliances	Fibres	Bulk	Foodstuffs	Furniture	Furs	Glass	Metals	Produce	Wood	Other
Barbados	Bridgetown	306	2	0	0	298	0	0	2	0	0	0	3
Bolivia	La Paz	41	24	0	0	0	0	0	0	0	17	0	0
Brazil	Belem, PA	756	0	0	0	0	14	0	0	0	172	570	0
Brazil	Brasilia, DF	167	59	0	0	0	0	0	20	88	0	0	0
Brazil	Campinas, SP	20	3	0	0	17	0	0	0	0	0	0	0
Brazil	Macau, RN	33	17	0	0	0	0	0	0	0	0	16	0
Brazil	Rio de Janeiro, RJ	4494	327	3	13	1910	5	0	433	1200	17	108	478
Brazil	Rio Grande, RS	9341	38	0	0	4329	50	15	69	1947	0	98	2795
Brazil	Salvador, BA	633	1	1	0	388	0	0	3	113	0	0	128
Brazil	Santarem, PA	57	1	0	0	31	0	0	0	0	0	26	0
Brazil	Sao Paulo, SP	1367	258	7	2	112	33	0	222	46	0	222	466
Brazil	Viracopos Apt/Sao Paulo, SP	16	0	0	0	0	0	0	0	0	0	0	16
Canada*	Chemainus, BC	2548	0	0	0	0	0	0	0	0	0	2548	0
Canada*	Crofton, BC	934	0	0	0	0	0	0	0	0	0	934	0
Canada*	Montreal, QC	7452	278	115	1458	2857	81	26	21	1259	30	704	623
Canada*	Montreal-Dorval Apt, QC	513	43	5	5	333	8	0	16	67	0	0	35
Canada*	New Westminster, BC	26959	1948	42	122	2957	39	20	137	2082	74	19402	133
Canada*	Oakville, ON	42	0	0	0	35	0	0	6	1	0	0	0
Canada*	Toronto Apt, ON	2088	355	6	62	985	28	0	5	603	0	4	40
Canada*	Toronto, ON	18010	1710	21	485	2332	186	0	304	1390	10950	73	559
Canada*	Vancouver Apt, BC	38307	541	93	8001	28164	64	0	176	402	24	732	110
Canada*	Vancouver, BC	1401880	4736	558	1302629	73541	420	2	1599	8462	3738	5659	537
Canada*	Victoria Apt, BC	9	9	0	0	0	0	0	0	0	0	0	0
Canada*	Victoria, BC	0	0	0	0	0	0	0	0	0	0	0	0
Canada*	Winnipeg Apt, MB	678	18	0	0	325	330	0	0	5	0	0	0
Canada*	Winnipeg, MB	725	41	0	0	283	375	0	0	12	0	0	14
Colombia	Barranquilla	294	0	0	0	102	0	0	0	0	0	0	192
Colombia	Buenaventura	1922	0	0	0	1800	3	0	55	64	0	0	0

Country	Port of export	Total freight	Appliances	Fibres	Bulk	Foodstuffs	Furniture	Furs	Glass	Metals	Produce	Wood	Other
Congo	Pointe Noire	14	0	0	0	0	0	0	0	0	0	14	0
Costa Rica	Puerto Limon	292	0	0	0	254	0	0	0	5	33	0	0
Costa Rica	San Jose	120	0	0	0	52	0	0	0	0	69	0	0
Cuba	Habana	23	0	0	0	23	0	0	0	0	0	0	0
Dominica	Portsmouth	976	913	0	0	25	4	0	0	31	0	1	0
Dominican Republic	Santo Domingo	74	0	0	0	0	0	0	22	52	0	0	0
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	0	28
French Polynesia	Papeete	5364	321	1	6	4530	9	0	0	463	11	1	21
Guyana	Georgetown	2598	0	0	21	0	0	0	0	2004	0	573	0
Jamaica	Kingston	2084	0	6	0	2016	0	0	0	0	23	38	0
Mexico	Mexico City	1495	84	15	21	1198	5	0	10	57	0	37	68
Mexico	Monterrey, NLE	151	19	0	0	92	5	0	36	0	0	0	0
Mexico	Veracruz, VER	498	296	14	82	0	0	0	2	86	0	0	19
Netherland Antilles	Willemstad, Curacao	77	0	0	0	0	0	0	0	0	0	0	77
New Caledonia	Noumea	812	262	1	12	31	0	1	0	58	411	3	35
Nicaragua	Managua	39	0	0	0	39	0	0	0	0	0	0	0
Panama	Balboa	167	4	3	0	19	0	0	0	45	45	8	42
Panama	Colon	544	37	0	0	0	0	0	0	12	494	0	0
Panama	Cristobal	162	117	0	0	0	0	0	0	22	23	0	1
Panama	Panama City	147	8	9	0	93	0	19	0	6	0	2	9
Paraguay	Asuncion	89	0	0	0	89	0	0	0	0	0	0	0
Puerto Rico	Ponce	703	0	0	0	699	0	0	0	0	0	0	5
Puerto Rico	San Juan	167	0	0	0	159	0	0	0	0	0	0	8
Solomon Islands	Honiara, Guadalcanal Island	3205	83	1	63	471	0	0	0	0	312	2225	471
Solomon Islands	Noro, New Georgia	226	0	0	0	127	0	0	0	0	0	1	127
Trinidad and Tobago	Port of Spain	71	23	0	40	8	0	0	0	0	0	0	0
UK*	Beckingham	17	0	0	0	17	0	0	0	0	0	0	0
USA	Burbank Apt, CA	44	28	0	0	3	0	0	0	1	0	10	2
USA	Fort Lauderdale, FL	43	28	0	0	15	0	0	0	0	0	0	0
USA	Gramercy, LA	4667	0	0	0	4667	0	0	0	0	0	0	0
USA	Long Beach, CA	125753	8771	945	65911	25023	795	131	1654	10317	3028	1997	7180
USA	Los Angeles, CA	386498	47014	3118	88274	79498	3102	246	4544	67318	39961	12227	41195
USA	Miami, FL	596	197	13	1	4	24	0	6	109	10	23	209
USA	Orlando, FL	80	4	0	9	0	2	0	0	29	0	0	36
USA	Port Everglades, FL	2	2	0	0	0	0	0	0	0	0	0	0
USA	San Pedro, CA	617	11	102	0	0	1	0	0	272	0	21	208
USA	St Petersburg, FL	51	0	0	0	0	0	0	0	51	0	0	0
USA	Tampa, FL	272758	23	0	272714	0	0	0	0	20	0	0	1
Venezuela	Caracas	23832	8	11	23813	0	0	0	0	0	0	0	0
Venezuela	Puerto Bolivar	2944	0	0	0	0	0	0	0	0	2944	0	0
Wallis & Futuna Islands	Futuna Island	19	12	0	0	5	0	0	0	0	1	0	0

Table b. Summary of airfreight coming to New Zealand from localities within 100 km with known sites of *W. auropunctata.* Values represent the total freight (tonnes) during 2001, 2002 and 2003. NB: All locations receive some freight but if it is below 500 Kg is listed as 0 tonnes. Details of the freight types that comprise each category are given in Table c, as are the categories (HS2 Chapters) used to classify incoming freight in the Statistics New Zealand database (descriptons provided in Table d).

Country	Port of expot	Total freight	Appliances	Produce	Pharmaceuticals	Metals	Glass	Furniture	Fur	Footwear	Foodstuffs	Fibres	Other
Angola	Cabinda	0	0	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
Belize	Belize City	0	0	0	0	0	0	0	0	0	0	0	0
Bermuda	Hamilton	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	Belo Horizonte	1	0	0	0	0	0	0	0	0	0	0	0
Brazil	Brasilia, DF	27	0	0	0	0	0	0	0	0	26	0	0
Brazil	Campinas, SP	8	0	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	Macau, RN	0	0	0	0	0	0	0	0	0	0	0	0
Brazil	Rio de Janeiro, RJ	6	0	0	0	1	1	0	0	1	0	1	1
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	0	0	0	0	0	0	0	2	0	0	0
Brazil	Sao Paulo, SP	15	3	0	0	1	0	0	1	1	0	6	3
Brazil	Viracopos Apt/Sao Paulo, SP	29	3	0	0	7	1	0	0	3	0	13	1
Canada*	Hamilton Apt, ON	1	1	0	0	0	0	0	0	0	0	0	0
Canada*	Montreal, QC	99	46	0	1	17	0	2	0	0	13	5	15
Canada*	Montreal-Dorval Apt, QC	106	52	0	7	16	0	1	0	1	0	7	20
Canada*	Nanaimo Apt, BC	0	0	0	0	0	0	0	0	0	0	0	0
Canada*	Oakville, ON	1	1	0	0	0	0	0	0	0	0	0	0
Canada*	Toronto Apt, ON	352	114	0	89	65	5	3	0	0	7	4	64
Canada*	Toronto, ON	300	100	0	50	55	9	4	1	0	1	6	72
Canada*	Vancouver Apt, BC	241	140	3	10	25	3	6	1	0	8	6	38
Canada*	Vancouver, BC	108	52	10	0	9	5	2	0	0	14	5	12
Canada*	Victoria Apt, BC	0	0	0	0	0	0	0	0	0	0	0	0
Canada*	Victoria, BC	0	0	0	0	0	0	0	0	0	0	0	0
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
Costa Rica	San Jose	33	0	33	0	0	0	0	0	0	0	0	0
Cuba	Habana	0	0	0	0	0	0	0	0	0	0	0	0
Dominican Republic	Santo Domingo	0	0	0	0	0	0	0	0	0	0	0	0
Ecuador	Quito	5	0	0	0	0	0	0	0	0	0	5	0
Fiji*	Lautoka	37	0	24	0	1	0	0	0	2	7	2	0
Fiji*	Nadi	4316	31	2733	6	5	0	3	3	301	661	550	23

Country	Port of expot	Total freight	Appliances	Produce	Pharmaceuticals	Metals	Glass	Furniture	Fur	Footwear	Foodstuffs	Fibres	Other
French Polynesia	Papeete	17	6	0	0	3	0	0	0	0	3	1	4
Germany*	Saint George's	0	0	0	0	0	0	0	0	0	0	0	0
Haiti	Port-au-Prince	0	0	0	0	0	0	0	0	0	0	0	0
Honduras	Tegucigalpa	0	0	0	0	0	0	0	0	0	0	0	0
Jamaica	Kingston	0	0	0	0	0	0	0	0	0	0	0	0
Mexico	Mexico City	178	163	0	0	3	0	0	0	0	3	7	1
Mexico	Monterrey, NLE	5	5	0	0	0	0	0	0	0	0	0	0
New Caledonia	Noumea	88	23	58	0	1	0	1	0	0	2	0	4
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
Paraguay	Asuncion	2	0	0	0	0	0	0	0	0	0	2	0
Puerto Rico	San Juan	50	2	0	18	1	0	0	0	2	5	0	21
Solomon Islands	Honiara, Guadalcanal Island	2	0	0	0	0	0	0	0	0	1	0	0
US Virgin Islands	Frederiksted, St Croix	1	0	0	0	0	0	0	0	0	0	0	0
US Virgin Islands	St Croix Island Apt	0	0	0	0	0	0	0	0	0	0	0	0
USA*	Bellingham, WA	0	0	0	0	0	0	0	0	0	0	0	0
USA	Burbank Apt, CA	1	0	0	0	0	0	0	0	0	0	0	0
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	Long Beach, CA	12	4	0	0	6	0	0	0	0	0	0	2
USA	Los Angeles, CA	9298	3840	629	79	1470	108	317	54	27	340	378	2055
USA*	Lynden, WA	0	0	0	0	0	0	0	0	0	0	0	0
USA	Miami, FL	63	27	2	0	4	0	3	0	1	1	2	23
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	San Pedro, CA	0	0	0	0	0	0	0	0	0	0	0	0
USA	St Petersburg, FL	0	0	0	0	0	0	0	0	0	0	0	0
USA	Tampa, FL	33	22	0	0	2	0	1	0	0	0	0	8
USA	West Palm Beach, FL	1	0	0	0	0	0	0	0	0	0	0	0
Venezuela	Caracas	0	0	0	0	0	0	0	0	0	0	0	0
Wallis & Futuna Islands	Futuna Island	0	0	0	0	0	0	0	0	0	0	0	0

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 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

Categories	Description
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
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

Categories	Description
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
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: Details of BIOSECURE methodology

BIOSECURE is a computer-based decision tool for the 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 were obtained for eight parameters (Table A2.1) 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 A2.1: Global climate surfaces used in BIOSECURE.

Abbreviation	Climate Parameters
MAT	Annual mean of the monthly mean temperature (°C)
MINT	Mean temperature of the coldest month (°C)
MATS	Seasonality of temperature - absolute difference in mean temperature between the warmest and coldest months (°C)
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

A frequency distribution of the data points is produced for each climate parameter. 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. A2.1). 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.

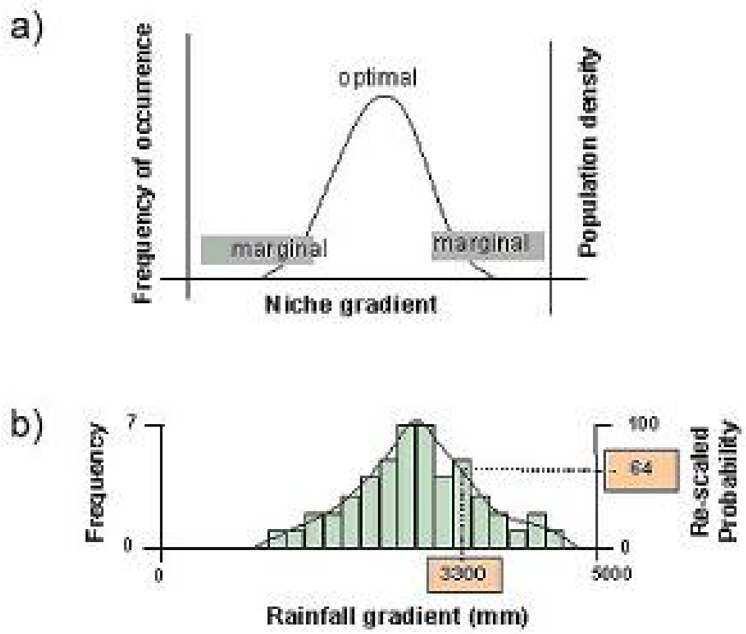

***Fig. A2.1:** Stylised representation of the conversion of input data points to similarity scores. (a) The input data are assumed to represent the niche of the species for a particular parameter. (b) The frequency distribution is divided into a series of bins across the range of the data, allowing 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 3: 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. A3.1).

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. A3.2), 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. A3.2).

For MAT the climate in the native + introduced non-urban sites still shows considerable overlap with New Zealand (Fig. A3.3). 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, and these records may be a different 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 suggest 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. A3.4), 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 also too cold (Fig. A3.4). Other climate parameters are highly suitable across much of New Zealand.

For the native + introduced (non-urban range), MAT overlap is minimal (Fig. A3.5), 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.

Fig. A3.1: *New Zealand sites where* L. humile *and* Ph. megacephala *are known to be established.*

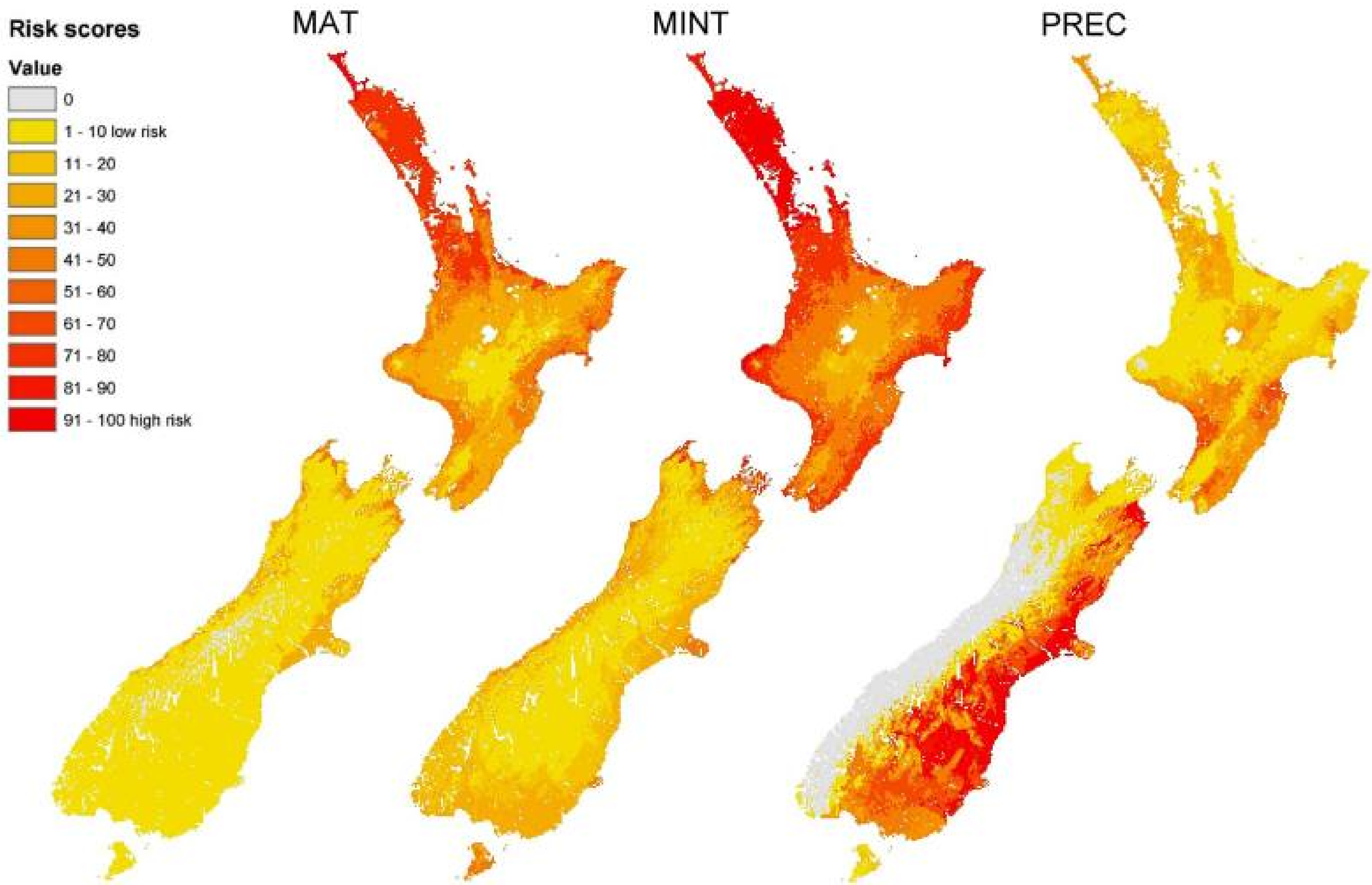

Fig. A3.2: Similarity of native + introduced ranges of L. humile *to New Zealand for MAT, MINT and PREC.*

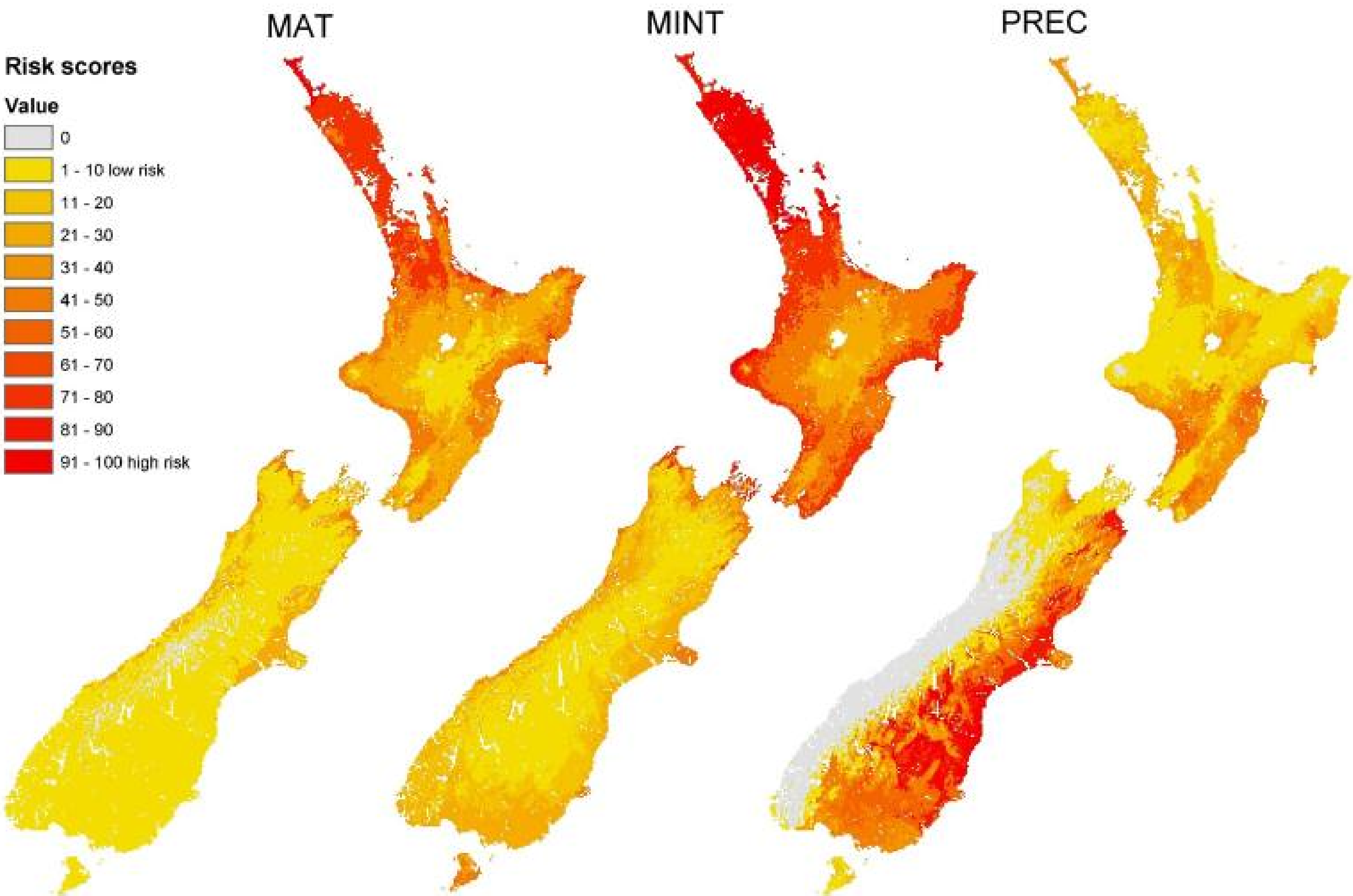

Fig. A3.3: *Similarity of native + non-urban introduced ranges of* L. humile *to New Zealand for MAT, MINT and PREC.*

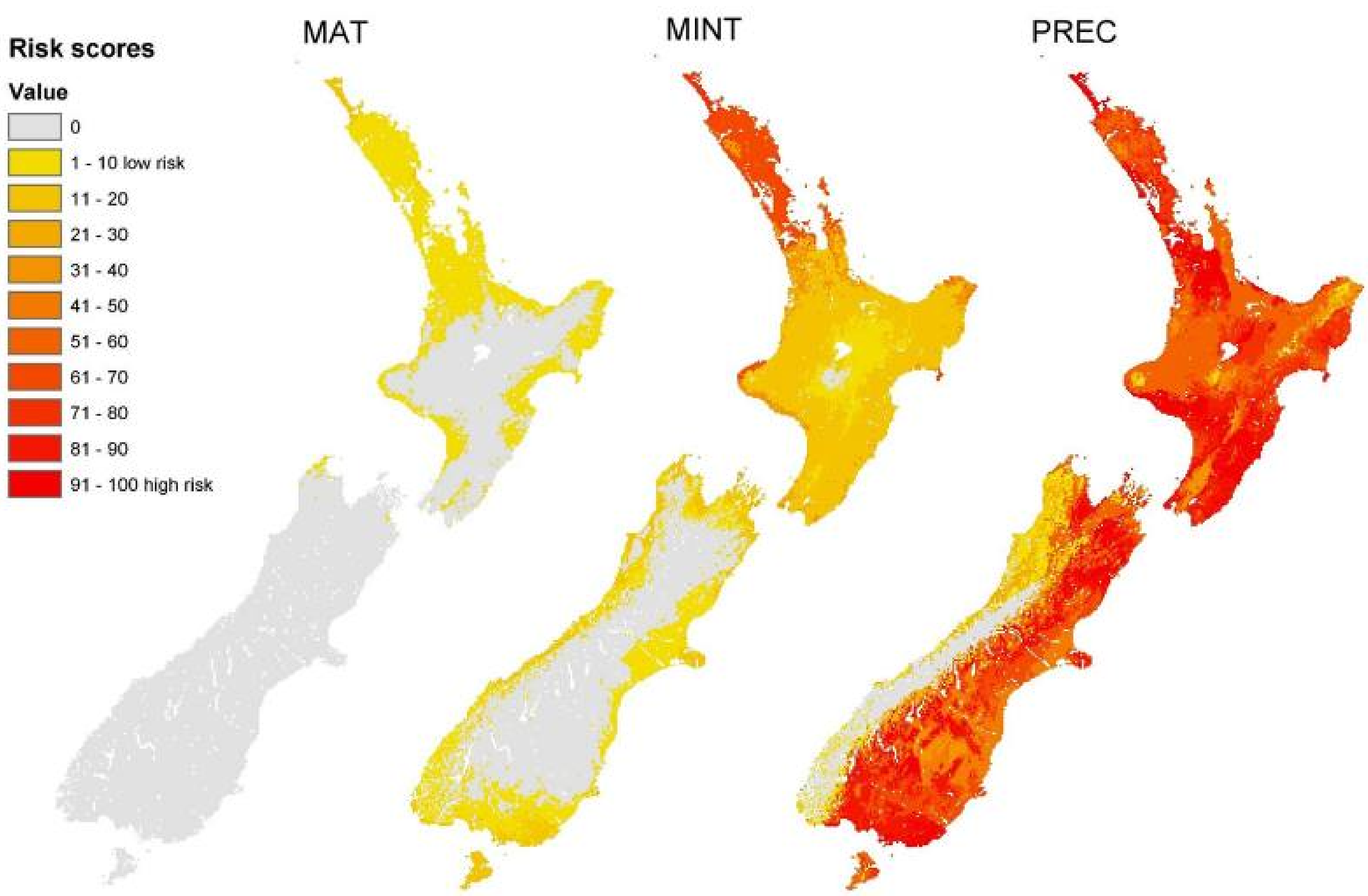

Fig. A3.4: *Similarity of native + introduced ranges of* Ph. megacephala *to New Zealand for MAT, MINT and PREC.*

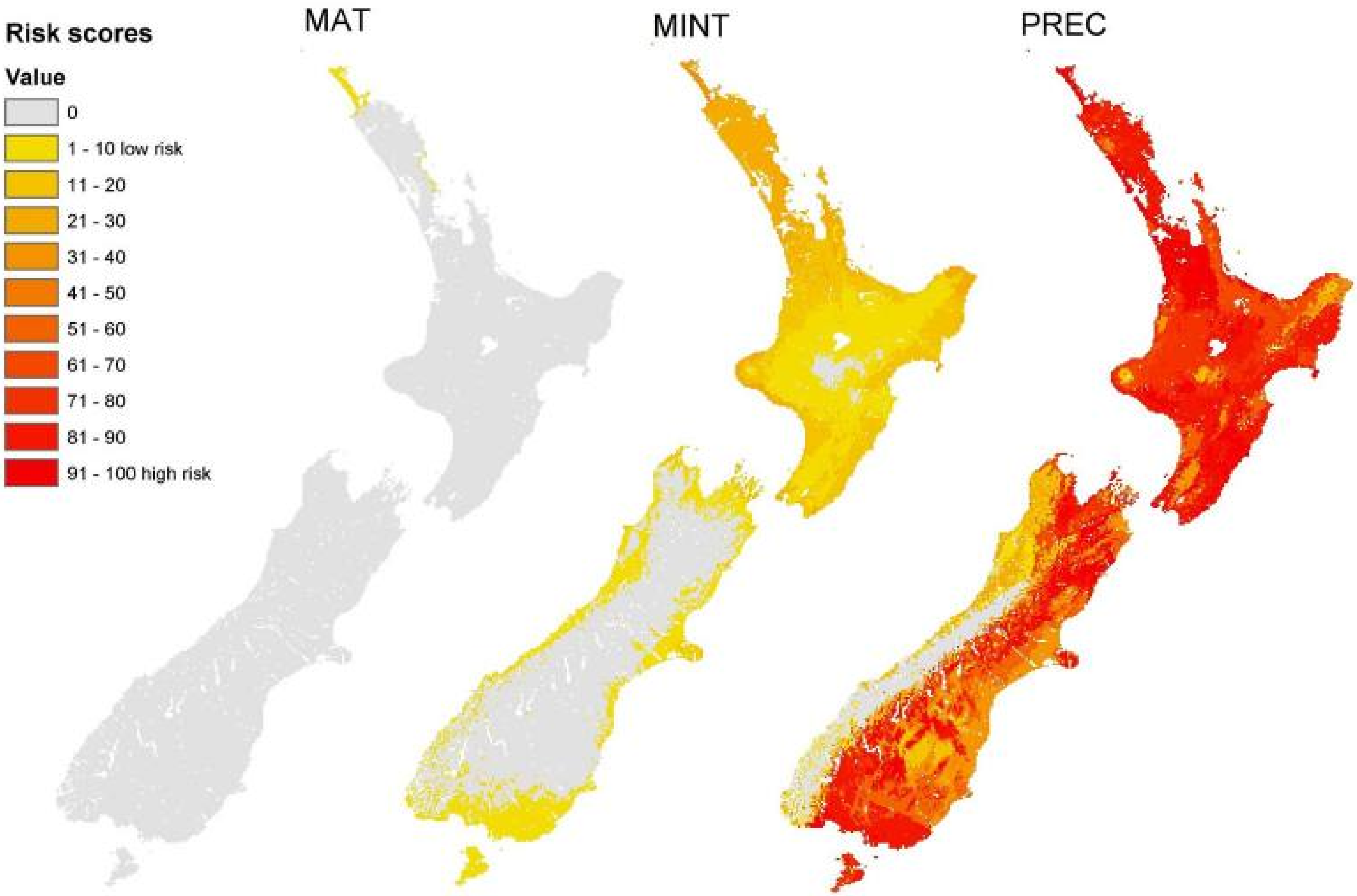

Fig. A3.5: *Similarity of native + non-urban introduced ranges of* Ph. megacephala *to New Zealand for MAT, MINT and PREC.*