Argentine and other ants (Hymenoptera: Formicidae) in New Zealand horticultural ecosystems: distribution, hemipteran hosts, and review

Philip J. Lester [1,2], Chris W. Baring [3], Christopher G. Longson [1], & Stephen Hartley [1]

[1] School of Biological Sciences, Victoria University of Wellington, PO Box 600, Wellington

[2] Corresponding author, *phil.lester@vuw.ac.nz*

[3] MAF Quarantine Service, Centreport, Waterloo Quay, PO Box 3042, Wellington

Abstract

Approximately 30 exotic ant species have been introduced into New Zealand, including the Argentine ant *Linepithema humile* (Mayr). Many of these ant species are known to affect horticulture worldwide by tending hemipteran insects. These ants may protect these hemiptera from their natural enemies, resulting in higher pest densities and potential economic loss. Our aim in this work was to survey the ant species associated with the various horticultural crops in the North Island. Our focus was on *L. humile*, but we also collected other ants and associated hemipteran species. *Linepithema humile* appeared to be an opportunistic species and was found on fifteen of eighteen common horticultural crops that we surveyed, as well as on a variety of other plants. It was observed tending 15 different species of hemipteran insects. *Linepithema humile* has been previously observed tending some of these hemipteran insects overseas, such as the black scale *Saissetia oleae* (Olivier). Other observed *L. humile*-hemipteran-plant associations reported here have not previously been recorded, such as with the spirea aphid *Aphis spiraecola* Patch on plum trees. Eleven other species of ants were found on horticultural crops. *Paratrechina vaga* (Forel) was common and also tended hemipteran insects on apple, citrus, and tamarillo. Other common ants were *Tetramorium grassii* Emery, *Monomorium antarcticum* (Smith), *Pheidole rugosula* Forel and *Ph. vigilans* (Smith). Another adventive ant, *Ph. megacephala* (Fab.), was only sampled in Auckland despite having been in New Zealand for over 50 years. Many of these invasive ants thus do not appear threatening to horticultural crops, though *L. humile* appears likely to be a significant economic pest for a variety of crops.

Keywords: Formicidae, mutualism, aphids, scale, mealybug, fruit trees, citrus, grape, kiwifruit

Introduction

The ant fauna of New Zealand is comprised of approximately 40 species, of which only nine to eleven are considered to be endemic (Valentine & Walker 1991, Harris & Berry 2001). The adventive fauna includes the Argentine ant (*Linepithema humile* (Mayr)) and *Pheidole megacephala* (the 'big-headed ant' (Fab.)), both of which are amongst the most damaging invasive ant species around the world (Holway *et al*. 2002). *Linepithema humile* is native to South America (Suarez *et al*. 2001, Tsutsui *et al*. 2001), though it has since spread to all continents except Antarctica (Holway *et al*. 2002). In New Zealand it was first detected in Auckland during 1990 (Green 1990). However, since then *L. humile* has spread to at least twelve locations throughout the North Island, as well as Christchurch and Nelson (Charles *et al*. 2002). It is predicted to survive the climate in many areas of New Zealand, especially in the upper half of the North Island (Hartley & Lester 2003). *Pheidole megacephala* (Fab.) is believed to be native to Africa (Wilson & Taylor 1967). This ant was first collected in New Zealand in 1942 and has since been found at several sites around Auckland and on the Kermadec Islands, but appears not to have spread much further (Berry *et al*. 1997). Other invasive ants have been introduced into New Zealand, including *Paratrechina vaga* (Forel) which is known as a horticultural pest elsewhere (Carter 1967).

Invasive ants are being increasingly recognized for their ability to alter the flora and fauna of their new habitat. For example, *L. humile* can directly affect plants by inhibiting pollination or seed dispersal (Visser *et al*. 1996, Christian 2001). Invasive ants can also reduce local biodiversity of both vertebrates (e.g. Sockman 1997, Suarez *et al*. 2000) and invertebrates (e.g. Cole *et al*. 1992, Bolger *et al*. 2000), though increasing the abundance of some species. Hemipteran insects (e.g., aphids, mealybugs, scale insects) that produce "honeydew", or sweet liquid exudates, are often protected from

their natural enemies by ants. This protection can be so effective that hemipteran densities may become sufficiently high to cause economic damage to crops (e.g. Gonzalez-Hernandez *et al*. 1999, Addison & Samways 2000). Outside of New Zealand, *L. humile* have been associated with hemipteran pests on a wide variety of horticultural crops that are also produced in New Zealand including grape (Addison & Samways 2000) and citrus crops (Pinto 1997).

Invasive ant species, such as *L. humile*, may thus represent a significant threat to New Zealand horticulture through a variety of potential mechanisms. Our primary aim in this paper was to determine horticultural crops that would be infested by the Argentine ant *L. humile*. Consequently, we focused on crops near areas that these ants had recently invaded. The secondary aim in this work was to survey the other ant species associated with horticultural crops in the North Island. In addition, we collected and identified hemipteran insects being tended by all ants on these crops.

Methods

We sampled horticultural crops from the North Island, New Zealand, in January and February, 2002. Fieldwork locations were primarily based near urban areas where *L. humile* infestations had been previously recorded (Charles *et al*. 2002). In addition, sites were identified from a media campaign asking growers to report instances of ants infesting their crops (Lester & Longson 2002). The sampling sites known to have *L. humile* were (from north to south) Kaitaia, Kerikeri, Whangarei, Dargaville, Warkworth, Whangaparaoa, Auckland, Morrinsville, Tauranga, Te Puke, Hamilton, Gisborne, Napier and Hastings. Trapping was carried out in the horticultural crops closest to these infestations, after approaching individual growers for permission to set traps. Though we were primarily interested in commercial horticultural crops, private orchards and trees in urban areas were also examined. Traps consisted of 40 mL vials baited with a protein-based bait (after Harris *et al*. 2002) and were lined with the sticky substance Tanglefoot®, (The Tanglefoot Company, Grand Rapids, Michigan, USA) to capture ants. Peanut butter was also added to the traps, after trials indicated that this, in addition to the protein-based bait, caught a higher ant diversity than either bait alone. Four researchers working as two teams set out a total of 1224 traps. A wide range of crops were sought for sampling at each site. Traps were set out in a rectangular grid, usually along the margin of a stand of horticultural plants. Grids consisted of 16 traps, with 8 traps placed at ground level and 8 placed off the ground, within the crop plants. The traps were left out overnight, to ensure that ants active at night or in the twilight period would have time to access the bait. Where ant trails were directly observed on the crops, samples were taken of ants using an aspirator. All ants were preserved for identification.

Where ants were found in horticultural crops, the plants were subsequently examined for ants tending hemipteran insects. An association was concluded relevant if an ant was observed to collect honeydew from a hemipteran species directly. When a hemipteran-ant association was observed, the ants and hemiptera were placed in 70% ethanol for identification in the laboratory. Certain hemipteran species, although not elicited to produce honeydew, provided honeydew as expelled droplets which ants were able to monopolise (see Markin 1970). Scale insects were identified using methods described by Hodgson and Henderson (2000), aphids using methods described by Teulon *et al*. (1999), and mealybugs using methods set out by Cox (1987).

Results and discussion

Ants were collected from a total of 305 different locations around the northern half of the North Island (Fig. 1). A total of 12 ant species were found, associated with a variety of horticultural crops (Table 1). Four ant subfamilies were represented: Dolichoderinae, Formicinae, Myrmicinae and Ponerinae.

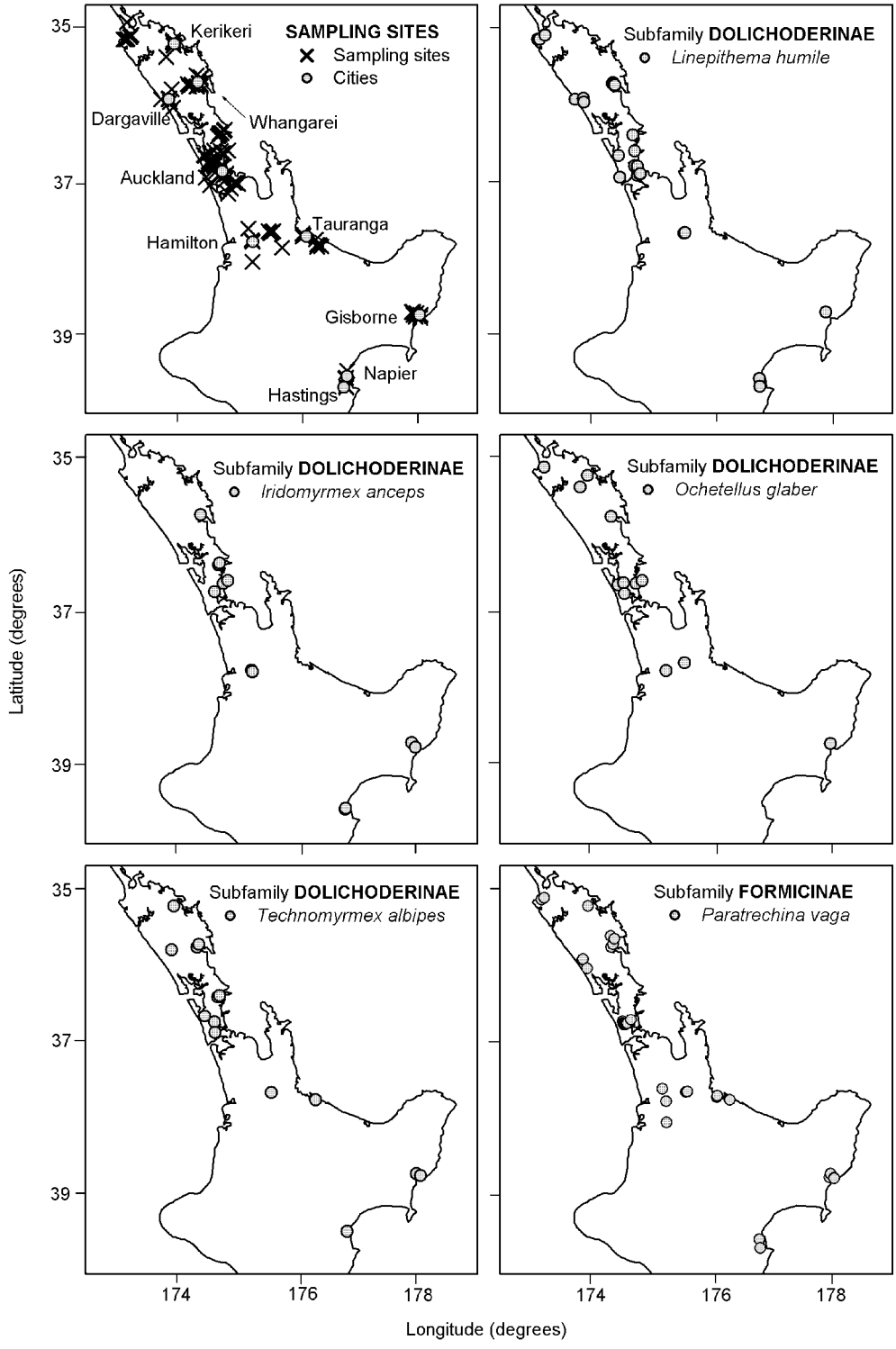

Figure 1. The location of sampling sites and the distribution of dolichoderine and the one formicine ant species caught at these sites during the sampling in January and February 2002.

Table 1. Ant utilization of horticultural crops. For each crop x ant combination there are two values separated by a comma: the first states the number of occasions the species was recorded arboreally, while the second records the number of times the species was observed on the crop floor (but not in the trees). Ant species: *I.a., Iridomyrmex anceps; L.h., Linepithema humile; O.g., Ochetellus glaber; Te.a., Technomyrmex albipes; Pa.va., Paratrechina vaga; M.ac., Monomorium antarcticum; M.ap., M. antipodum; Ph.r., Pheidole rugosula; Ph.m., P. megacephala; Ph.vi., P. vigilans; Tt.g., Tetramorium grassii; H.e., Hypoponera eduardi; P.c., Pachycondyla castanea.*

	Ant species											
Crop	*I.a.*	*L.h.*	*O.g.*	*Te.a.*	*Pa.va.*	*M.ac.*	*M. ap.*	*Ph.r.*	*Ph.m.*	*Ph.vi.*	*Tt.g.*	*H.e.*	*P.c.*
PIPFRUIT													
Apple		3, 1			4, 1	1, 2		1, 4			1, 1	0, 1	
Pear		1, 0			1, 0	0, 1		1, 0					
CITRUS													
Orange	1, 1	6, 0		2, 1	5, 1	2, 3	1, 3	0, 2		0, 1	0, 3	0, 1	
Mandarin		6, 0		1, 0	3, 0	3, 3		0, 4		1, 0	2, 3		
Grapefruit		1, 0		1, 0	1, 0	0, 3	0, 1						0, 1
Lemon		6, 0											
GRAPE	1, 1	7, 1	1, 3		6, 3	3, 7		1, 3		0, 2	2, 3		
KIWIFRUIT			1, 0		1, 0	2, 6	0, 1	0, 2	0, 1		2, 4		
STONEFRUIT													
Peach		3, 0			1, 0			1, 2			1, 1		
Plum		2, 0				1, 2		1, 2			0, 2		
Nectarine		0, 1											
Cherry		1, 0											
SUBTROPICAL FRUIT													
Avocado			1, 0			1, 0	1, 0			0, 1			
Olive													
Feijoa	1, 0	2, 0		1, 0		1, 0		1, 0			0, 1		
Persimmon		1, 0	1, 0	1, 0	1, 1	1, 1	0, 1	1, 2			1, 1		
Tamarillo		1,0	1, 0	1, 0							0, 1	0, 1	
Passionfruit		2, 0											

Subfamily Dolichoderinae: *Linepithema humile*

The Argentine ant *Linepithema humile* was observed on 15 of the 18 common horticultural crops that were examined, as well as a variety of other plants. It was commonly noted foraging on the trees and not just on the crop floor (Table 1). This ant was frequently observed on all types of citrus and in vineyards, occasionally at very high densities. When on citrus crops, *L. humile* was observed to feed on the honeydew exudates from 11 different species of aphids, scale or mealybug insects (Table 2). It was frequently associated with the Chinese wax scale *Ceroplastes sinensis* Del Guercio. Sooty mould was commonly observed on citrus trees, apparently resulting from an excess of honeydew production by these scale insects. Such associations between *L. humile* and hemipteran insects were observed on citrus trees over the entire area of sampling, from Kaitaia to Hastings (Fig. 1). Infestations on citrus crops were observed in both commercial and private orchards, and on individual trees grown in residential areas. *Linepithema humile* was also associated with a range of hemipteran insects in a number of other crops. It was observed with the woolly apple aphid *Eriosoma lanigerum* (Hausmann) in a private apple orchard in Dargaville and in a backyard crab-apple tree in Morrinsville. Stonefruit and subtropical crops were also periodically observed with heavy *L. humile* infestations, and with hemipteran mutualists (Table 2). Sooty mould was observed frequently and some

leaf bronzing on species such as tamarillo crops, apparently resulting from feeding by high numbers of aphids. Tamarillo also had high numbers of ants foraging in its flowers. Additionally, *L. humile* was observed in a number of other crops and plants not shown in Table 1. Infestations of *L. humile*, which were almost always associated with hemipteran insects, were observed on walnut (*Juglans* sp.), gum trees (*Eucalyptus* spp.), pine trees (*Pinus* sp.), and vegetables such as carrots (*Daucus* carota L.) and tomatoes (*Lycopersicon esculentum* Miller). In the walnut trees, *L. humile* nests were observed within rooting branches and at the base of these trees within the soil.

In other parts of the world, *L. humile* is considered a problem on many of these crops. Citrus crops were known to be deleteriously affected by these ants in America and South Africa at the beginning of last century (Newell & Barber 1913, Potgieter 1937). The ant interrupts biological control of scale insects and mealybugs on a variety of citrus crops including lemon, oranges and grapefruit (Samways *et al*. 1982, Reeve & Murdoch 1986, Phillips 1986). *Linepithema humile* has continued to be a problem on citrus crops in these and other areas, primarily by such associations with hemipteran insects (Markin 1970, Samways et al. 1982, Majer 1993). As the associations between *L. humile* and the hemipteran insects *Coccus hesperidum* L., *Ce. sinensis* and *S. oleae* have been observed elsewhere (Timberlake 1913, Flanders 1943, Buckley & Gullan 1991), our observations of these mutualisms in New Zealand citrus crops should come as no surprise. Grapes are another crop known to be affected by *L. humile* (Addison & Samways 2000). In Brazil, *L. humile* forms mutualistic relationships with the scale insect *Eurhizococcus brasiliensis* (Hempel) on the root system of the vines (Soria *et al*. 1996). Such below-ground interactions between *L. humile* and hemipteran insects were not investigated in our study.

In Hastings, one apiarist reported that his honeybee hives had been attacked by *L. humile* until an insecticide was applied to the area around the hives. When we sampled this area, only a few *L. humile* were observed entering the hives. Honeybees and *L. humile* were also observed to forage on flowers for nectar from pohutukawa (*Metrosideros excelsa* A. Richard), New Zealand bottlebrush (*Knightia excelsa* R. Brown) and agapanthus (*Agapanthus* spp.). With 24 h foraging, *L. humile* also appear to compete with bees for nectar in a number of plants elsewhere (Buys 1987, Markin 1970). In Australia, South Africa and the United States, *L. humile* have been observed raiding honeybee hives, killing bees and stealing honey and destroying hives (Pasfield 1968, Anderson *et al*. 1980, Pinto 1997, Vega & Rust 2001). One author suggested that it was impossible to keep bees in some areas due to the presence of *L. humile* (Taber 1994).

No previous references were obtained that indicated *L. humile* had been problematic on crops such as kiwifruit, stonefruit or pipfruit crops, although these ants are known to forage in pipfruit (Daugaard & Grauslund 1998). Elsewhere, *L. humile* have been observed farming hemipteran insects in almonds (Heimpel *et al*. 1997), bananas (MacDougall 1926), guava (Potgieter 1937), olives (Way *et al*. 1997), and pineapple (Rohrbach *et al*. 1988). These ants appear very opportunistic, forming mutualisms with hemipteran insects in a wide variety of plants, and are cited as one of the six worst invasive ants (Holway *et al*. 2002). Because they are more aggressive than many other species, *L. humile* appears more effective at protecting hemipterans from their natural enemies, resulting in higher numbers of these pests (Buckley & Gullan 1991). The high densities and lack of intraspecific competition of *L. humile* throughout their introduced range (Tsutsui *et al*. 2000) must also contribute to the high abundance of hemipteran pests. It seems likely that *L. humile* will be a significant pest in a range of New Zealand crops, especially in crops under organic management, as managers have fewer options for hemipteran or ant control in these properties.

Subfamily Dolichoderinae: other species

Three other adventive dolichoderine species were sampled in horticultural crops: *Iridomyrmex anceps* (Roger), *Ochetellus glaber* (Mayr), and *Technomyrmex albipes* (Smith). *Iridomyrmex anceps* was found associated with horticulture as far north as Whangarei (Fig. 1). Earlier records of this ant in New Zealand showed it to have a much wider distribution, from Napier to Matahina Forest in the Bay of Plenty (Faulds 1970). We found *I. anceps* in association with passionvine hopper *Scolypopa australis* (Walker) on both oranges and grape

Table 2. Hemipteran species observed to be tended by ants in the horticultural crops. The numbers represent the number of different locations where the tending was observed. *I.a., Iridomyrmex anceps; L.h., Linepithema humile; O.g., Ochetellus glaber; T.a., Technomyrmex albipes; P.va., Paratrechina vaga; T.g., Tetramorium grassii.*

Crop and insect species	Common name	Ant species					
		I.a.	*L.h.*	*O.g.*	*T.a.*	*P.va.*	*T.g.*
APPLE							
Aphis craccivora Koch	Black bean aphid		1				
Eriosoma lanigerum (Hausmann)	Woolly apple aphid		2				
Pulvinaria vitis (L.)	Cottony grape scale		1				
Scolypopa australis (Walker)	Passionvine hopper					1	
CITRUS							
Aphis gossypii Glover	Melon aphid		1				
Aphis spiraecola Patch	Spirea aphid		1		1	1	
Toxoptera citricidus (Kirk)	Black citrus aphid		3				
Pseudococcus viburni (Signoret)	Obscure mealybug		2				
Aonidiella aurantii (Maskell)	Californian red scale		1				
Ceroplastes sinensis Del Guercio	Chinese wax scale		7			1	1
Coccus hesperidum L.	Brown soft scale		2				
Parasaissetia nigra (Nietner)	Nigra scale		1				
Saissetia coffeae (Walker)	Hemispherical scale		3			1	1
Saissetia oleae (Olivier)	Black scale		1				
Scolypopa australis (Walker)	Passionvine hopper	1	2				1
GRAPE							
Scolypopa australis (Walker)	Passionvine hopper	1	2				
PEACH							
Toxoptera aurantii (Boyer de Fonscolombe)	Black citrus aphid		1				
PLUM							
Aphis spiraecola Patch	Spirea aphid		2				
FEIJOA							
Ceroplastes sinensis Del Guercio	Chinese wax scale		1		1		
Coccus hesperidum L.	Brown soft scale		1				
Saissetia coffeae (Walker)	Hemispherical scale		2				
TAMARILLO							
Aphis gossypii Glover	Melon aphid		1	1	1	1	
PASSIONFRUIT							
Pseudococcus viburni (Maskell)	Obscure mealybug		2				

(Tables 1, 2). Charles (1993) also recorded *I. anceps* on citrus and grape crops, and additionally persimmons, where it was observed tending two mealybug species *Pseudococcus longispinus* (Targioni Tozzetti) and *P. calceolariae* (Maskell).

Technomyrmex albipes was also widely distributed and was found on three of the four citrus crops in our survey, and on subtropical crops. It has been recorded from citrus and persimmon crops tending mealybugs in New Zealand previously (Charles 1993). We did not find *Ochetellus glaber* on citrus, pipfruit or stonefruit crops, only on subtropical fruit, kiwifruit, and grape crops (Table 1). While most of these records showed it to be foraging arboreally, on only one occasion did we find it associated with a hemipteran insect (Table 2). However, Charles (1993) observed *O. glaber* tending the mealybug *Pseudococcus viburni* (Signoret) (=*affinis* Maskell) in Hawkes Bay apple orchards. Brown (1958) cited this species as uncommon and

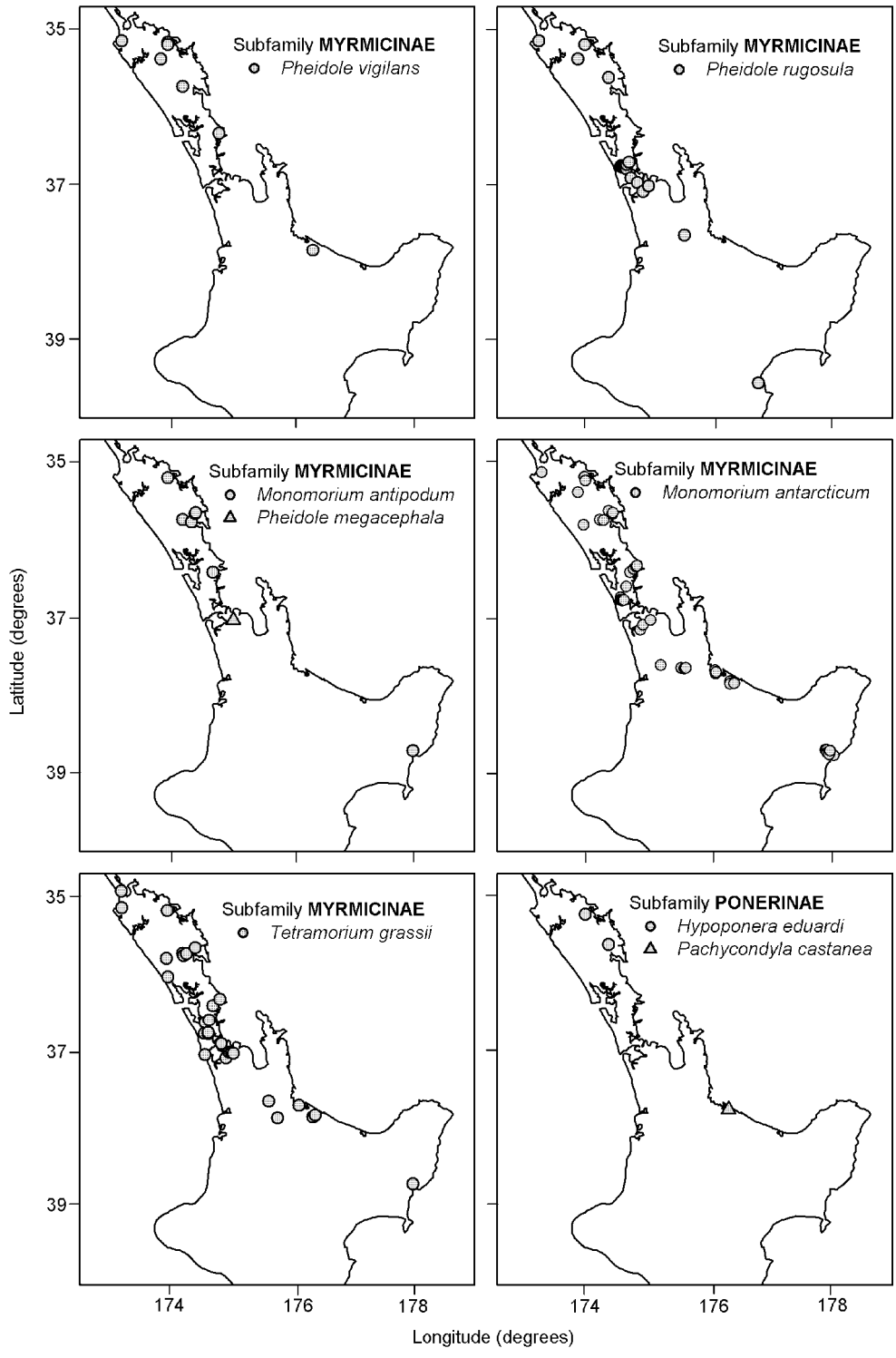

Figure 2. The distribution of myrmicine and ponerine ant species caught at the sampling sites during the sampling in January and February 2002.

occurring only in small populations around Auckland. It appears that this species has substantially increased its range since this time (Fig. 1).

These dolichoderine species were found in association with hemipteran pests less frequently than with *L. humile*. However, in the infestations that we observed, densities of *L. humile* were generally much larger than for these other species. As a consequence, hemipteran populations with these other species were much smaller and probably less apparent, perhaps less likely to be observed.

Subfamily Formicinae

The adventive formicine ant *Paratrechina vaga* (Forel) was found throughout the sampling areas (Fig. 1). As with *L. humile*, it was most commonly observed on citrus and grape crops. It was commonly observed foraging within the crop, rather than just on the crop floor. *Paratrechina vaga* was observed tending five different hemipteran species (Table 2). Previously *P. vaga* has been observed tending the mealybug *Pseudococcus longispinus* on azalea (Charles 1993) and aphids on shrubbery in Auckland (Brown 1958).

As well as tending hemipteran insects, we also observed *P. vaga* feeding from plants directly. At one commercial orange orchard in Gisborne, it appeared to be biting young leaves and drinking the oozing sap. In another mandarin orchard, this species was observed nesting in roots and appeared to be damaging the trees. Finally in a grapefruit orchard it was observed drinking nectar from flowers.

Subfamily Myrmicinae

Six species of myrmicine ants were observed: the native species *Monomorium antarcticum* (Smith), along with the four adventive ants *Pheidole megacephala* (Fabricius), *Ph. rugosula* Forel, *Ph. vigilans* (Smith), and *Tetramorium grassii* Emery, as well as *Monomorium antipodum* Forel for which there is some debate as to its native or adventive status (Brown 1958, Don *et al*. 2001).

Pheidole megacephala was only caught once, foraging on the floor of a kiwifruit orchard in south Auckland (Fig. 2). It was not observed in the canopy of this orchard nor was it associated with any hemipteran insects or apparent crop damage. Overseas, *Ph. megacephala* can be a significant pest on a variety of horticultural crops, due to mutualisms with hemipteran insects (e.g. Samways *et al*. 1982, Gonzalez-Hernandez *et al*. 1999). Its abundance, distribution and effects worldwide have resulted in it being classified as one of the worst invasive ants (Holway *et al*. 2002). Taylor (1961) describes *Ph. megacephala* as well established in Auckland, but this species has not spread further. Climatic factors appear to limit this species within New Zealand (Berry *et al*. 1997).

The other two *Pheidole* species had a much wider distribution. *Pheidole rugosula* was caught on 10 of the 18 crops types examined. *Pheidole vigilans* was less frequently observed and only at the more northern sampling sites (Fig. 2). Both species were mostly frequently caught on the ground and were not observed tending hemipteran insects. Berry *et al*. (1997) cite *P. rugosula* and *P. vigilans* as having been collected on wind-fallen fruit including apple, citrus, crab-apple, and peaches, but never tending hemipteran insects directly on these crops. In addition, *P. rugosula* was collected directly while attacking a range of insects (Berry *et al*. 1997).

Tetramorium grassii was observed in 10 of the 18 horticultural crops (Table 1), and in all sampling regions except Napier and Hastings (Fig. 2). It was observed in the tree canopies and with the scale insects *C. sinensis, Saissetia coffeae* (Walker), and *Scolypopa australis* in citrus crops. In South Africa, *T. grassii* has been observed in citrus and subtropical fruit orchards tending hemipteran insects (Samways 1990). The frequency of our collections indicates it is a common ant in horticultural crops, though it was never observed in high numbers at any collection site. Taylor (1961) suggests that it prefers the warmer northern climates such as in Auckland, but *T. grassii* appears to be adapted to the cooler parts of the North Island as well.

Monomorium antarcticum was also absent in samples from the Napier and Hastings regions (Fig. 2), though known from throughout New Zealand (Smith 1896, Brown 1958). It may have been extirpated by invasive species such as *L. humile* in these crops; a result recently observed in urban areas of New Zealand (Brightwell 2002). Elsewhere, *M. antarcticum* was more commonly observed and was occasionally found foraging in tree canopies (Table 1). It was observed in association with leaf-hoppers and once with a mealybug species, but unfortunately these insects

were not collected for identification. The most common crops in which *M. antarcticum* were found were in vineyards and kiwifruit orchards, though most of the samples were collected from the floor of these crops. This ant has previously been collected in vineyards, tending the mealybug *Pseudococcus longispinus* (Charles 1993). It has long been known to form mutualistic relationships with other hemipteran species on native plants (Smith 1896).

Monomorium antipodum was less frequently observed and only twice was it seen in crop canopies (Tables 1, 2). Its utilization of horticultural crops was primarily on the east coast of the North Island (Fig. 2). Don *et al*. (2001) reported this species to be distributed from the far north of the North Island, extending through the east coast, as far south as Wellington and in the far north of the South Island. Little is known about the ecology of this species.

Subfamily Ponerinae

The two ponerine ants *Hypoponera eduardi* (Forel) and *Pachycondyla castanea* (Mayr) were found infrequently on the floor of the horticultural crops and never in the arboreal samples (Fig. 2, Table 1). These species were not observed tending any hemipteran insects. Both genera are known in Australia as hunting ants, with species occasionally specializing in Collembola or termites (Shattuck 1999). It seems likely that they are playing a similar role in New Zealand and are probably not deleterious to horticulture.

Conclusions

This paper documents horticultural crops in the North Island that were found to harbour *L. humile* and other native and exotic ants. It is almost certain that ants are associated with a wider variety of crops and hemipteran insects, but this study highlights specific crops that are likely to be colonized by *L. humile* as it continues to spread. It is predicted to survive the climate in large areas of New Zealand where much of the country's horticultural crops are produced (Hartley & Lester 2003). This invasive ant appears very opportunistic in its associations with a variety of hemipteran insects: some species it has been associated with before, but many in this report were not previously recorded in the literature. After invading an area, it reaches high densities and secondary outbreaks of hemipteran pests are likely to develop. Species such as *Paratrechina vaga* also appear to tolerate the climate in large areas of New Zealand especially with crops where few pesticides are applied. Other ant species, including *Pheidole megacephala*, appear to be less able to tolerate New Zealand's climate and are likely to be less of a threat to horticulturalists and other biodiversity.

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