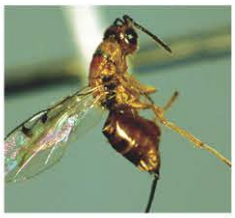
Invertebrates and fungi associated with privet, *Ligustrum* spp. (Oleaceae), in New Zealand



Landcare Research
Manaaki Whenua

Invertebrates and fungi associated with privet, *Ligustrum* spp. (Oleaceae), in New Zealand

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Summary

Project and Client

- A survey of the invertebrate fauna and plant pathogens associated with privet, *Ligustrum* spp., in New Zealand was carried out between July 2009 and May 2012 by Landcare Research for the National Biocontrol Collective.

Objectives

- To survey the invertebrate fauna and plant disease symptoms associated with privet, *Ligustrum* spp., in New Zealand, and identify the herbivores (and their associated predators and parasitoids) and plant pathogens present.

Methods

- The invertebrate fauna associated with privet, *Ligustrum* spp., was sampled at 39 New Zealand sites, ranging from Kaeo in the north of the North Island to Maruia in the South Island, and plant pathogens associated with privet were sampled at 34 sites, ranging from Kaeo in the north to Granity in the South Island.

Results

- No specialised privet invertebrates were found during the survey (except perhaps for *Trichophysetis cretacea* whose host range is not yet fully understood).
- The overall damage that could be attributed to invertebrate herbivory was minimal.
- The most obvious foliage damage appeared to be caused by lepidopteran larvae, particularly from the family Tortricidae and to a lesser extent Geometridae.
- One particularly interesting moth, currently thought to be *Trichophysetis cretacea*, was reared from privet berries.
- Sap feeders, and in particular *Scolypopa australis*, *Siphanta acuta* and *Nezara viridula*, were recorded in relatively high numbers.
- Thirty species, or taxonomic groupings, of herbivorous adult beetles were recorded but foliage damage attributed to beetles was minimal.
- Generalist predators found on privet included spiders, ladybirds, lacewings, earwigs, ants and praying mantids.
- Various symptoms were observed during the surveys. These ranged from marginal and terminal necrosis to individual leaf spots.
- Based upon morphological traits and phylogenetic analysis of ITS rDNA sequences, a total of 67 fungi, representing 27 genera, were found associated with diseased privet. The dominant genera were *Arthinium, Colletotrichum, Epicoccum, Fusarium, Pestalotiopsis* and *Phoma.*

Conclusions

- Privet is attacked by a wide range of native and introduced invertebrates in New Zealand but overall damage appears to be minimal with none of the herbivore niches well utilised.
- Lepidopteran larvae, particularly from the family Tortricidae and to a lesser extent Geometridae, appear to be the most damaging invertebrates currently feeding on privet in New Zealand.
- Sap feeders were recorded in relatively high numbers but the damage caused by sap feeders is very difficult to quantify.
- Generalist predators and parasitoids identified during this survey could affect some potential biocontrol agents.
- Privet species were infected by a range of plant pathogenic fungi – most of which have a broad host range – and no specialised plant pathogens were recovered from privet during this survey.
- There were very few instances of severe damage due to plant pathogens, with the majority of damage associated with tip and marginal damage, which may have been associated with premature senescence or nutrient deficiency.

Recommendations

- In light of our conclusions that invertebrate herbivore damage to privet in New Zealand is minimal, and that no specialised plant pathogens are known to be present on privet in New Zealand, we recommend that a classical biological control programme for privet should proceed.
- A glasshouse/field-based assessment of the efficacy of mycoherbicide cut-stump applications of wood rot fungi, being trialled for willow and poplar, should be undertaken.
- Further research should be carried out on the moth (currently thought to be *Trichophysetis cretacea*) that was reared from privet berries, to confirm its identity and to determine its potential impact in New Zealand.

1 Introduction

A survey of the invertebrate fauna and plant pathogens associated with privet, *Ligustrum* spp., in New Zealand was carried out between July 2009 and May 2012 by Landcare Research for the National Biocontrol Collective. This was a recommendation of the feasibility study investigating prospects for biocontrol of privet in New Zealand (McGregor 2000).

2 Background

According to information accessed by the feasibility study conducted by Dr Peter McGregor in 2000, four species of privet are adventive in New Zealand: *Ligustrum lucidum*, *L. sinense*, *L. ovalifolium* and *L. vulgare*. *L. lucidum* and *L. sinense* are considered to be serious weeds that are a major threat to the environment and *L. lucidum* is listed as an unwanted organism on the MPI Unwanted Organisms Register (http://www.biosecurity.govt.nz/pests/registers/uor). Privet causes two main problems. First, it invades native plant communities and degrades them by replacing native species, such as shrubs and mid-canopy trees, and suppresses regeneration of native species by reducing seedling survival and growth (Auckland Regional Council 1999; Greene & Blossey 2011); and second, it is perceived by the public as a cause of allergies including hay fever and asthma (Webb et al. 1988).

Privet is highly invasive because its abundant dark bluish or purplish black berries are eaten and dispersed by birds (Figure 1). Although the leaves of mature privet are poisonous to stock (Connor 1977) it is not a serious problem in pasture because stock eat the seedlings and fresh growth. It severely infests land under lax management, including fence lines, drains and road verges. In these areas it can interfere with power and telephone lines, and clearing operations can be hampered by the weed's hard, resilient stems and trunks (James & Mortimer 1984).

Figure 1 Tree privet (*Ligustrum lucidum*) in bloom with fruit.

The leaves of the privet tree *L. obtusifolium* have been reported to retain a strong lysine-decreasing activity caused by enzymatically-active oleurpein, an iridoid glycoside (Konno et al. 2009). Protein treated with this activity become innutritive to insects because of the loss of lysine. Therefore it has been hypothesised that lysine-decreasing activity acts to defend privet trees against generalist herbivores.

Privet pollen is often blamed for allergies such as hay fever and asthma, but it has been argued that privet pollen does not cause these allergies on any significant scale because the flower is pollinated by insects (e.g. Webb et al. 1988). Privet is generally insect-pollinated but if the pollen is not taken away by insects, the position of the anthers allows the pollen to be dispersed by the wind and privet pollen is indeed abundant in air. An Australian study showed that pollen of *Ligustrum sinense* and *L. lucidum* was among the most abundant of all airborne pollens in south-west Sydney (Bass & Morgan 1997). Furthermore, the pollen of olive (*Olea europaea*), which is closely related to privet, is an important cause of hay fever and asthma in the Mediterranean area (e.g. Subiza et al. 1995; Damato et al. 1998; Florido et al. 1999).

The ability of natural enemies to attack new hosts is strongly influenced by the evolutionary history of those potential hosts (Briese 1996), so in any biological control programme it is essential to understand the relationships between the target plant and its relatives, particularly those that are economically or culturally significant. The approximately 40 species of *Ligustrum* L. that are native across Europe to eastern Asia and south to Queensland (Webb et al. 1988) belong to Oleaceae, a family that includes many economically and culturally significant trees. Naturalised species of Oleaceae in New Zealand, other than *Ligustrum* spp., include ash (*Fraxinus excelsior* L.), five species of jasmine (*Jasminum beesianum* Forrest et Diels; *J. humile* L.; *J. mesnyi* Hance; *J. officinale* L.; and *J. polyanthum* Franchet), African olive (*Olea europaea* L. subsp. *africana*), lilac (*Syringa vulgaris* L.) and forsythia (*Forsythia suspensa* (Thunb.) (Webb et al. 1988). Many cultivars of these species are grown as ornamentals, and the European olive (*Olea europaea* L. subsp. *europaea*) is an increasingly important crop; conversely, the jasmines can be weedy and *Jasminum polyanthum* is listed as a Surveillance Pest Plant and a Community Initiatives Pest Plant in the Auckland region (Auckland Regional Council 2007). The only indigenous Oleaceae are the four species of *Nestegis*: *N. cunninghamii* (Hook. f.) (maire, black maire), *N. lanceolata* (Hook. f.) (white maire), *N. montana* (Hook. f.), and *N. apetala* (Vahl).

Of these exotic and indigenous species, lilac is most closely related to the privets (Green & Fliegner 1991; Qin 1996). It typically grows less vigorously in New Zealand than in many other countries; nevertheless, because it is a valued ornamental plant, any prospective biocontrol agents would have to be tested rigorously to ensure that they did not attack it.

Privet control is difficult because many of the habitats it invades preclude blanket spraying and make individual plants hard to find. Seedlings can be pulled or dug out, while older plants can be cut down but the stumps must be treated with herbicide to prevent resprouting (Auckland Regional Council 1999). Standing trees can also be poisoned by making a series of downward-sloping holes or cuts around the trunk and filling these with herbicide ('stem injection') (Madden & Swarbrick 1990). This is a useful method for trees that would otherwise be difficult to fell. Madden and Swarbrick (1990) calculated the costs of effective herbicide treatment of *Ligustrum lucidum* in Australia and concluded that stem injection of metsulfuron methyl (Escort®) was the most cost effective treatment.

Biological control could offer some advantages over current control methods. Use of host-specific biocontrol agents would reduce chemical herbicide impacts on desirable flora. Biological control also offers continuous action and self-dispersal that current control methods do not offer. Certain privet species are considered to be weeds in the USA, Australia, Argentina, Mauritius and La Réunion (Shaw 1999; Zhang et al. 2008b) and there are excellent prospects for collaboration with colleagues overseas on a biological control programme for privet.

CABI Europe-UK has been involved with a biological control programme for *Ligustrum robustum* subsp. *walkeri*, which has had a serious impact in Mauritius and is threatening the pristine endemic forests of La Réunion. An initial literature review (Shaw 1999) revealed a considerable number of natural enemies on the genus *Ligustrum* including more than 70 arthropods and 120 fungi. Surveys for potential biocontrol agents were carried out in Sri Lanka (the area of origin of the target weed), India, Vietnam and China and three arthropod agents were selected for host range testing. One of the three species passed the host range testing, a moth called *Epiplema albida*, but unfortunately permission and funding for the moth to be imported into La Réunion did not materialise (Shaw 2008). However, a leaf spot fungus, *Thedgonia* sp., has arrived accidentally on La Réunion and is reported to be causing serious damage to the privet there.

Ligustrum sinense (Chinese privet) has become one of the worst invasive plants in the south-eastern United States where it is naturalised and considered a severe threat to ecosystems from Texas to Florida, and north as far as the New England states (Faulkner et al. 1989; Stone 1997). Surveys for natural enemies that might be suitable for use in a biological control programme in the United States were conducted in China during 2005 and 2006 and more than 100 phytophagous insect species were found feeding on *L. sinense* (Zhang et al. 2008a). Two of the most promising species, a leaf-mining flea beetle, *Argopistes tsekooni*, (Coleoptera: Chrysomelidae) (Zhang et al. 2008b) and a lace bug, *Leptoypha hospita*, (Hemiptera: Tingidae) (Zhang et al. 2011), have since be studied in more detail. The beetle is probably not sufficiently specific to release in the United States as it attacks some of their native species (James Hanula, USDA-Forest Service, Georgia, pers. comm.), but this agent may be sufficiently specific for release in New Zealand. The lace bug is going through the final stages of host range testing and it is hoped to be able to request permission to release it soon.

Figure 2 Privet hedge, Dunedin.

This report describes the results of a survey of the invertebrate fauna and plant pathogens associated with *Ligustrum lucidum* (tree privet), *L. sinense* (Chinese privet) and *L. vulgare* in New Zealand. The main aims of the survey were to determine whether any specialist privet invertebrates or pathogens are already present in New Zealand, whether any generalist invertebrate herbivores or pathogens are exerting a significant adverse impact on privet in New Zealand, and to record the invertebrate parasitoids and predators associated with the herbivorous invertebrates on privet. Such information is useful at the early stages of a biological control programme because:

1. If exotic specialist species are discovered to have been accidentally introduced into New Zealand they can be removed from the list of novel candidate agents, ensuring resources are not wasted re-importing something that is already here, and ways of improving their efficacy can be investigated (e.g. development of mycoherbicides).

2. Knowledge of native arthropod species that attack exotic weeds can help predict which candidate weed biocontrol agents are likely to be predated or parasitised and therefore ineffective, assisting with agent prioritisation (Paynter et al. 2010).

3 Objectives

- To survey the invertebrate fauna and plant disease symptoms associated with privet, *Ligustrum* spp., in New Zealand, and identify the herbivores (and their associated predators and parasitoids) and plant pathogens present.

4 Methods

4.1 Invertebrates

The invertebrate fauna of privet, *Ligustrum* spp., was surveyed at 39 New Zealand sites, ranging from Kaeo in the north of the North Island to Maruia in the South Island, between July 2009 and May 2012 (Figure 1 and Appendix 1). Twenty-one *Ligustrum lucidum* sites, 15 *L. sinense* sites and 3 *L. vulgare* sites were surveyed for invertebrate fauna. At each site 10 collection locations were selected. A collecting tray, 80 × 80 cm, was placed under suitable parts of selected plants, and the foliage above the tray was hit five times with a solid stick. Most invertebrates that fell onto the tray were collected with an aspirator and preserved in 95% alcohol. Caterpillars (Lepidoptera) were collected live and placed, along with privet foliage, in ventilated containers to rear through to adult for identification. Parasitoids emerging from the larvae were identified.

A rapid visual inspection (generally less than a minute for each of the 10 collection locations at each site) was made of foliage, branches and tree trunks for signs of invertebrates such as gall-formers, leaf miners, scale insects and wood borers. Invertebrates found during the visual inspections were collected live, along with the plant material they were on, for identification.

If fruit was present, approximately 100 berries were collected randomly from each site and stored in ventilated rearing containers to identify fruit-feeders and seed-feeders. At each site, a visual estimate was made of the amount of herbivore-related damage, and the likely cause of the damage was noted (e.g., adult beetles, leafroller caterpillars).

The invertebrates collected were identified to species or genus level where feasible. However, some invertebrates were placed into groups of related species (e.g. ‘spiders’). They were then ranked on a scale of abundance according to the total number of individuals collected, and the number of sites at which they were present. They were classed as rare, occasional, common or abundant according to the definitions below:

rare: fewer than 5 individuals collected

occasional: 5–15 individuals collected, **or** present at fewer than 5 sites

common: 16–99 individuals collected **and** present at 5 or more sites

abundant: 100+ individuals collected **and** present at 7 or more sites

4.2 Plant pathogens

Plant pathogens associated with privet were surveyed at 34 New Zealand sites, ranging from Kaeo in the north of the North Island to Granity in the South Island, between July 2009 and April 2012 (Figure 3 and Appendix 1). Nineteen *Ligustrum lucidum* sites, 12 *L. sinense* sites and 3 *L. vulgare* sites were surveyed for plant pathogens (N.B. two sites were not sampled for plant pathogens as no disease symptoms were observed). At each site plants were inspected for signs of damage by pathogens, and diseased leaves or flowers were placed in paper bags,

kept cool in transit and then in a cool store between 4–10°C until processing. Collected material was usually processed within 5 days of collection.

In the laboratory, disease symptoms were recorded and photographed. A dissecting microscope was used to search necrotic areas for fungal reproductive structures. Small pieces of tissue (c. 3 × 3 mm) were cut from the edge of diseased areas and surface-sterilised. Sterilisation was by immersion in 70% ethanol for 30 seconds followed by rinsing in two washes of sterile Reverse Osmosis water. The tissue fragments were blotted dry with clean paper towels and placed on potato dextrose agar (PDA; Difco Labs, Detroit, MI, USA) with 0.02% streptomycin (Sigma, St Louis, MI, USA), contained in 9-cm Petri dishes. Plates were incubated under near-ultraviolet and white light (12-hour photoperiod) at temperatures of 22 ± 2°C (day) and 18 ± 2°C (night).

Fungal colonies that grew out of the tissue fragments were transferred to fresh plates of PDA. Each identified isolate was given a unique number. Isolates that produced spores were identified to species level where possible. All pure mycelial isolates had their ITS ribosomal gene sequenced, using a standard PCR protocol with the fungal-specific primers ITS1F and ITS4 (Gardes & Bruns 1993). Sequences obtained were subjected to a GenBank BLASTn search to determine the closest sequence-based match. Species identifications were confirmed using spore or cultural morphology plus the sequence data where possible.

Taxonomic literature and fungal systematists were consulted to determine which of the identified fungi were likely to be causing the damage and which of the agents were associative saprotrophs, and/or endophytic organisms.

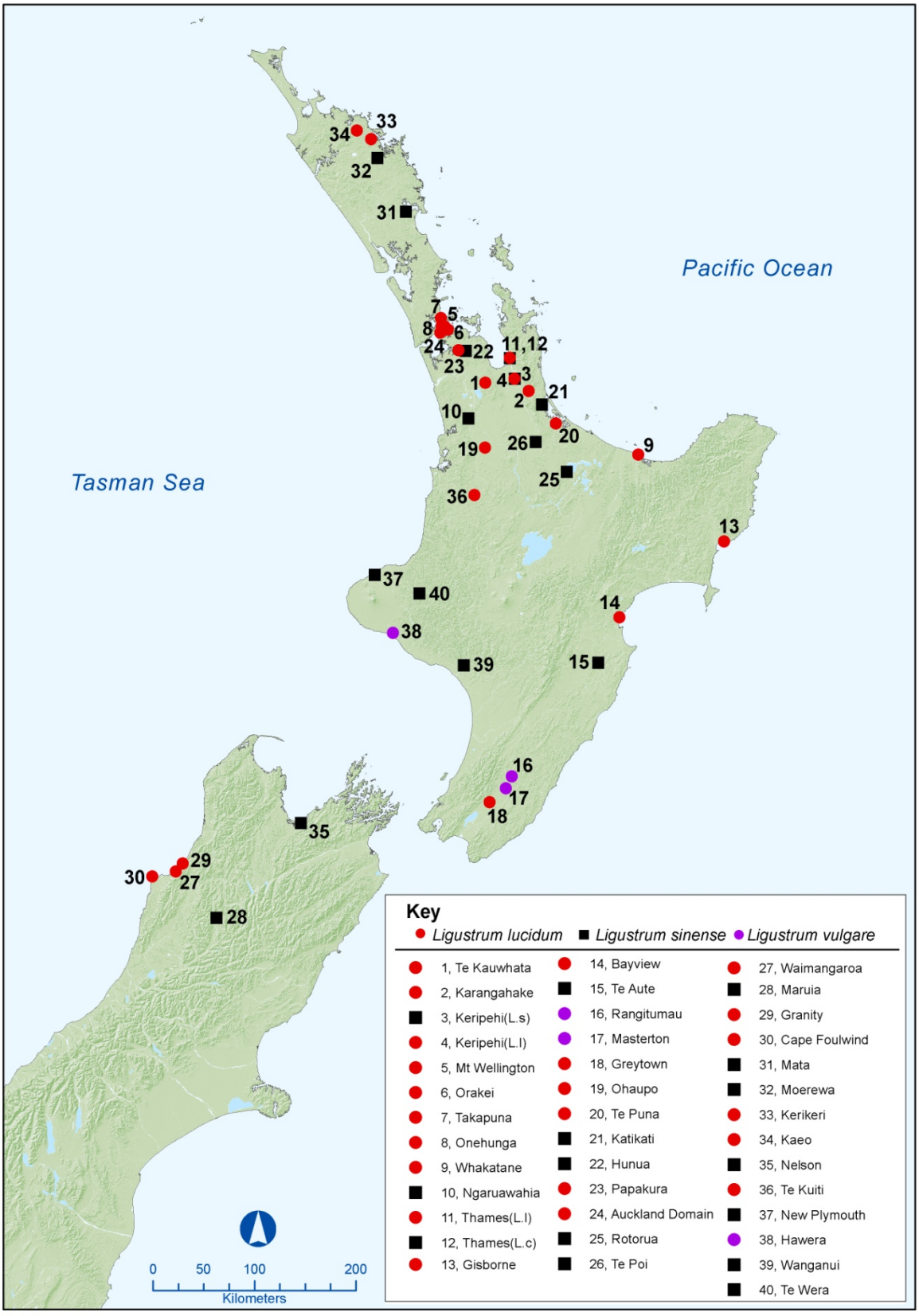

Figure 3 *Ligustrum lucidum*, *L. sinense* and *L. vulgare* sites sampled for invertebrates and plant pathogens.

5 Results

5.1 Invertebrates

Invertebrates were collected from 21 *Ligustrum lucidum* sites, 15 *L. sinense* sites and 3 *L. vulgare* sites. A full list of invertebrates found in association with privet during this survey is presented in Appendix 2.

Herbivores

A total of 67 herbivorous invertebrate species were recorded from the three privet species during this survey and a further 17 groups of taxonomically related herbivorous species were recorded (where identification to species level was not feasible). Table 1 lists the abundant, common and occasional herbivorous invertebrates collected from *Ligustrum lucidum* and *L. sinense*.

For *Ligustrum lucidum* two herbivorous species, *Siphanta acuta* and *Scolypopa australis*, were classed as 'abundant'. A further 4 herbivorous species or taxonomic groupings were classed as 'common', 14 were 'occasional' and 41 were 'rare' (Table 1; Appendix 2).

For *Ligustrum sinense* only one herbivorous species, *Scolypopa australis*, was classed as 'abundant'. A further 5 herbivorous species or taxonomic groupings were classed as 'common', 14 were 'occasional' and 34 were 'rare' (Table 1; Appendix 2).

Ligustrum vulgare was only sampled at three sites so the frequency categories do not apply to it; see Appendix 2 for a full list of invertebrates found on *L. vulgare*.

Foliage damage attributable to invertebrate herbivory was minimal. Leaves that were more than 10% consumed were rare and the overall amount of foliage consumed by herbivores was estimated to be less than 2%.

The most obvious foliage damage appeared to be caused by the larvae of a range of moth species, especially larvae from the family Tortricidae (leafrollers) and to a lesser extent from the family Geometridae (looper moths). If the family Tortricidae was treated as a taxonomic group it would be classed as 'common' and this ranking has been included in Table 1 next to the family Tortricidae to emphasise its relative importance. Leafroller larvae were sometimes found still inside 'rolled' leaves on the plant, but more commonly they were collected from the beating tray after being dislodged. A number of moth larvae, collected to rear through to adult for identification, died during rearing, and parasitoids emerged from some of them (Appendix 2).

One particularly interesting moth, currently thought to be *Trichophysetis cretacea*, was reared from privet berries. Adults of this moth were first found in New Zealand in 1999 (Hoare 2001) but its host plants were unknown and its host range is yet to be determined The larvae of this moth feed inside the berries and leave a neat round exit hole when they leave to pupate. They appear to be feeding on the fruit rather than the seeds. The moth was not present at all sites but where it was present it was sometimes causing a moderate amount of damage

to the berries. Native puriri moth caterpillars, *Aenetus virescens*, were common on *Ligustrum lucidum* in particular, producing characteristic tunnels and feeding scars in the trunks.

Twenty-nine species, or taxonomic groupings, of sap feeders were recorded from the three *Ligustrum* species during this survey. Passionvine hoppers (*Scolypopa australis*) were classed as abundant on both *L. lucidum* and *L. sinense*; green planthoppers (*Siphanta acuta*) were abundant on *L. lucidum* and common on *L. sinense*; and the green vegetable bug (*Nezara viridula*) was common on both *L. lucidum* and *L. sinense* (Table 1). All other sap feeders recorded from *L. lucidum* and *L. sinense* were classed as either occasional or rare. One sap feeder, the scale insect *Lindingaspis rossi* (Diaspidae), was found in very large numbers at one site (Te Kauwhata) and was present in lower numbers at one other site (Whakatane). The reason for the outbreak occurring at the Te Kauwhata site is unknown and as it was recorded from only two sites it was classed as occasional (recorded on *L. lucidum* only).

Thirty species, or taxonomic groupings, of herbivorous adult beetles were recorded from the three privet species during this survey but foliage damage attributed to beetles was minimal. Many of these species might not have fed on privet but used the plant as shelter. For example, a gorse seed weevil (*Exapion ulicis*) was found during the survey and this species only feeds on gorse.

A variety of slugs and snails were found on privet and privet foliage occasionally showed typical slug or snail damage, and slime trails were occasionally visible, particularly low down on the plants. However, many of the snail species were very small and only the brown garden snail, *Cantareus aspersus*, and the larger slugs are likely to have caused obvious damage.

Slaters (order Isopoda) were classed as common on both *Ligustrum lucidum* and *L. sinense*, and may have caused some damage to living tissue, but are likely to have been feeding mostly on dead and decaying material. European earwigs, *Forficula auricularia*, were 'common' on *L. sinense*. They are omnivorous and can cause damage to living plant tissue.

Predators and parasitoids

Many moth larvae died during rearing and parasitoids emerged from some of these. Predatory and parasitic species that may inhibit introduced biocontrol agents for privet are recorded in Appendix 2. Larvae of a particularly interesting parasitoid were found protruding from the abdomens of several juvenile green planthoppers (*Siphanta acuta*). This parasitoid is most probably *Dryinus koebelei*, a species native to Australia and Papua New Guinea and first found in New Zealand in 2004 (Olmi 2007).

Table 1 Abundant, common and occasional herbivores collected from *Ligustrum lucidum* and *L. sinense*, at 21 and 15 New Zealand sites respectively during 2009–2012
Note: See Appendix 2 for a full list of invertebrates collected from privet (including herbivores classed as rare that are not listed here in Table 1).

Taxon	Common name	Origin	*L. lucidum* Abundance (number of individuals)	*L. sinense* Abundance (number of individuals)
Phylum Mollusca	**Molluscs**			
Gastropoda	**Slugs and snails**			
Cantareus aspersus Müller	Brown garden snail	Introduced		Occasional (11)
Unidentified snails			Common (168)	Occasional (16)
Unidentified slugs			Occasional (6)	
Phylum Arthropoda				
Coleoptera	**Beetles**			
Chrysomelidae	Leaf beetles			
Eucolaspis sp.	Bronze beetle	Native		Occasional (8)
Curculionidae	Weevils			
Asynonychus cervinus Boheman	Fuller's rose weevil	Introduced	Occasional (7)	
Catoptes sp.		Native	Occasional (5)	
Irenemus sp.		Native	Occasional (5)	
Microcryptorhynchus sp.		Native	Occasional (7)	
Elateridae	Click beetles			
Conoderus exsul (Sharp)	Pasture wireworm	Native		Occasional (6)
Melandryidae	Leaping beetles			
Hylobia plagiata Broun		Native		Occasional (19)
Dermaptera	**Earwigs**			
Forficula auricularia Linnaeus	European earwig	Introduced		Common (21)

Taxon	Common name	Origin	*L. lucidum* Abundance (number of individuals)	*L. sinense* Abundance (number of individuals)
Hemiptera	**Bugs**			
Aphididae	Aphids			
Unidentified Aphidae				Occasional (5)
Aphrophoridae	Spittle bugs			
Philaenus spumarius (Linnaeus)	Meadow spittle bug	Introduced		Occasional (13)
Diaspidae	Armoured scale insects			
Lindingaspis rossi (Maskell)	Ross's black scale	Introduced	Occasional (1000+)	
Flatidae	Planthoppers			
Siphanta acuta (Walker)	Green planthopper	Introduced	Abundant (106)	Common (68)
Pentatomidae	Shield bugs			
Nezara viridula (Linnaeus)	Green vegetable bug	Introduced	Common (51)	Common (57)
Ricaniidae	Planthoppers			
Scolypopa australis (Walker)	Passionvine hopper	Introduced	Abundant (1000+)	Abundant (915)
Lepidoptera	**Moths and butterflies**			
Crambidae				
Trichophysetis cretacea Butler		Introduced	Occasional (12)	Occasional (38)
Geometridae	Looper moths			
Unidentified Geometridae			Occasional (7)	Occasional (8)
Hepialidae				
Aenetus virescens larvae (Doubleday)	Puriri moth	Native	Common (19)	
Psychidae	Bag moths			
Liothula omnivora (Fereday)	Common bag moth	Native	Occasional (5)	
Lepidoscia sp.		Introduced	Occasional (9)	

Taxon	**Common name**	**Origin**	***L. lucidum*** **Abundance (number of individuals)**	***L. sinense*** **Abundance (number of individuals)**
Tortricidae	Leafroller moths		Common (25)	Common (51)
Ctenopseustis sp.	Brownheaded leafroller	Native	Occasional (6)	Occasional (12)
Unidentified Tortricidae			Occasional (9)	Common (29)
Unidentified Lepidoptera			Occasional (5)	
Orthoptera	**Crickets, grasshoppers, weta**			
Gryllidae				
Ornebius aperta Otte and Alexander		Introduced	Occasional (34)	Occasional (9)
Tettigoniidae				
Caedicia simplex (Walker)	Katydid	Native		Occasional (8)
Thysanoptera	**Thrips**			
Thripidae				
Thrips obscuratus (Crawford)	New Zealand flower thrips	Native		Occasional (20)

5.2 Plant pathogens

Various disease symptoms were observed during the surveys. These ranged from marginal and terminal necrosis to individual leaf spots (Figures 4, 5 and 6). There was also a range of symptoms relating to physiological stress and senescence.

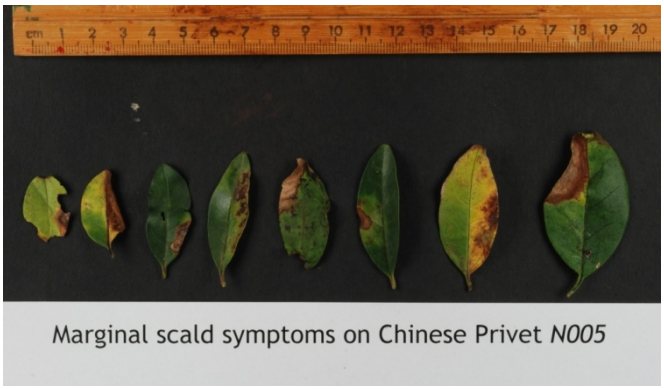

Figure 4 Examples of marginal necroses.

Figure 5 Examples of tip necroses.

Figure 6 Leaf necrosis symptoms exhibited in privet.

Based upon morphological traits and phylogenetic analysis of ITS rDNA sequences, a total of 67 fungi, representing 27 genera, were found associated with diseased privet. The dominant genera were *Arthinium*, *Colletotrichum*, *Epicoccum*, *Fusarium*, *Pestalotiopsis* and *Phoma* (Table 2).

Table 2 Dominent fungi associated with plant disease in privet

Pathogen	**Disease symptom**
Alternaria alternata, *A. arborescens*, *Alternaria* sp.	Leaf spot
Aurebasidium pullulans	Saprophyte, endophyte
Botryosphaeria dothidea	Leaf blight
Botrytis sp.	Leaf blight
Cladosporium cladosporoides, *C. tenuissimum*	Leaf spot
Colletotrichum fuscum C1297.6-10, *C. gloeosporioides* NZ clade. C1294	Leaf blight, leaf spot
Epicoccum purpurascens	Saprophyte, endophyte
Fusarium graminearum, *F. verticillioides*, *F. tricinctum*	Leaf blight
Leptosphaerulina chartarum, *Leptosphaerulina* sp.	Leaf blight
Neofusicoccum australe, *N. parvum*, *Neofusicoccum* sp.	Leaf blight, scald
Paraconiothyium sporulosum	Secondary saprophyte
Pestalotiopsis maculiformans, *P. vismiae*, *Pestalotiopsis* sp.	Secondary saprophyte, endophyte,
Phoma exigua, *P. macrostoma*, *P. theicola*	Leaf blight
Stemphylium sp.	Saprophyte, necrotroph

A full list of fungal recoveries from all sites is provided in Appendix 3.

6 Conclusions

A wide range of native and introduced invertebrates is associated with *Ligustrum lucidum*, *L. sinense* and *L. vulgare* in New Zealand but there appear to be no specialised privet-feeding invertebrates in New Zealand at present, except perhaps for *Trichophysetis cretacea* whose host range is not yet fully understood (see below). The damage caused by invertebrate herbivory was minimal and the overall amount of privet foliage that appeared to be consumed or damaged by herbivorous invertebrates at our survey sites was estimated to be less than 2%. These rates are an order of magnitude lower than defoliation rates of *L. sinense* recorded at sites in its native range in China (Zhang et al. 2008a).

Lepidopteran larvae, particularly from the family Tortricidae and to a lesser extent Geometridae, appear to be the most damaging invertebrates currently feeding on privet in New Zealand. The discovery of moth larvae feeding inside privet berries was very interesting. The moth is currently thought to be *Trichophysetis cretacea*, which is native to China and Japan where it is known to be a pest of jasmine (*Jasminum polyanthum*), which is in the same family (Oleaceae) as privet. Further research is needed to determine its potential impact in New Zealand, especially given that jasmine is both a popular ornamental species and an increasingly important weed in warmer parts of the country.

Sap feeders, and in particular *Scolypopa australis*, *Siphanta acuta* and *Nezara viridula*, were recorded in relatively high numbers on privet during this survey. However, the damage caused by sap feeders like these, either directly by removal of nutrients or indirectly by puncturing the plant and possibly allowing the entry of pathogens, is difficult to quantify.

The combined effect of generalist predators such as spiders, earwigs, ants, and praying mantids could inhibit the effectiveness of some potential invertebrate biocontrol agents for privet. The parasitoids identified during this survey could particularly affect some potential lepidopteran biocontrol agents. For example, *Meteorus pulchricornis* is known to have a very wide host-range and has been recorded from eight lepidopteran families in New Zealand (Berry & Walker 2004). Leafrollers would no doubt be more damaging to privet if it weren't for the control exerted on them by parasitoids. Any leafrollers introduced as biocontrol agents for privet would also be likely to be targeted by parasitoids.

Specialised privet biocontrol agents are unlikely to meet with any significant competition from resident herbivores as none of the 'herbivore niches' on privet appear to be well utilised in New Zealand. Therefore there is considerable scope for the introduction of host-specific invertebrate biocontrol agents that could markedly reduce the vigour of privet in New Zealand.

Privet species were parasitised by a range of plant pathogenic fungi – most of which have a broad host range – and no specialised plant pathogens were recovered from privet during this survey. There were very few instances of severe damage due to plant pathogens, with the majority of damage associated with tip- and marginal damage, which may have been associated with premature senescence or nutrient deficiency.

Damage was rarely extensive throughout a tree canopy, with the typical damage being localised or associated with some physical injury. In the main, the leaf symptomology was minor or 'cosmetic' without any systemic infections or rusts.

7 Recommendations

In light of our conclusions that invertebrate herbivore damage to privet in New Zealand is minimal, and that no specialised plant pathogens are known to be present on privet in New Zealand, we recommend that:

1. A classical biological control programme for privet should proceed as follows:

    a) Collaborate with the USDA, who have already conducted surveys for potential invertebrate biocontrol agents for *Ligustrum sinense* in China, to prioritise potential biocontrol agents according to their potential to damage privet and the likelihood of adequate host-specificity.

    b) Undertake host-range tests on *Argopistes tsekooni* (a leaf-mining flea beetle) and *Leptoypha hospita* (a lace bug). Host-range testing of these two species has already been conducted in the United States and only the New Zealand native genus *Nestegis* and a few additional exotic ornamentals need to be tested for New Zealand.

    c) Introduce host-specific invertebrates to New Zealand as classical biocontrol agents.

    d) Collaborate with the USDA to conduct surveys of plant pathogens associated with *L. sinense* in China and prioritise potential biocontrol agents according to their potential to damage privet and the likelihood of adequate host-specificity.

    e) Undertake host-range tests of selected plant pathogens on plant species of importance to New Zealand.

    f) Introduce host-specific plant pathogens to New Zealand as classical biocontrol agents.

2. Additionally, a glasshouse/field-based assessment of the efficacy of mycoherbicide cut-stump applications and drill-and-inject of wood rot fungi, being trialled for willow and poplar, should be undertaken.

3. Carry out research on the moth that was reared from privet berries to:

    a) Verify that it is *Trichophysetis cretacea*.

    b) Determine its host range in New Zealand.

    c) Determine its potential impact in New Zealand.

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Appendix 1 – Privet survey (New Zealand 2009–2012) site details

Note: *Refer to Figure 3 in the main body of the report for site locations.*

Site no.	Site name	Privet species	Collection date	Invertebrates collected	Pathogens collected	Pathogen ref. no.
1	Te Kauwhata	*L. lucidum*	1 Jul 09	Yes	Yes	M125
2	Karangahake	*L. lucidum*	2 Jul 09	Yes	Yes	M123
3	Keripehi (*L.s*)	*L. sinense*	2 Jul 09	Yes	Yes	M124
4	Keripehi (*L.l*)	*L. lucidum*	2 Jul 09	Yes	Yes	M126
5	Mt Wellington	*L. lucidum*	28 Jul 09	Yes	Yes	M134/135
6	Orakei	*L. lucidum*	28 Jul 09	Yes	Yes	M136/137
7	Takapuna	*L. lucidum*	2 Aug 09	No	Yes	M138
8	Onehunga	*L. lucidum*	12 Aug 09	Yes	Yes	M139/140
9	Whakatane	*L. lucidum*	2 Nov 09	Yes	Yes	M160
10	Ngaruawahia	*L. sinense*	7 Dec 09	Yes	Yes	M169
11	Thames (*L.l*)	*L. lucidum*	15 Jan 10	Yes	Yes	M177
12	Thames (*L.c*)	*L. sinense*	15 Jan 10	Yes	Yes	M178
13	Gisborne	*L. lucidum*	8 Feb 10	Yes	Yes	M195
14	Bayview	*L. lucidum*	9 Feb 10	Yes	Yes	M196
15	Te Aute	*L. sinense*	10 Feb 10	Yes	Yes	M198
16	Rangitumau	*L. vulgare*	10 Feb 10	Yes	Yes	M197
17	Masterton City	*L. vulgare*	11 Feb 10	Yes	Yes	M199/194
18	Greytown	*L. lucidum*	11 Feb 10	Yes	No	M193
19	Ohaupo	*L. lucidum*	25 Feb 10	Yes	Yes	M201
20	Te Puna	*L. lucidum*	26 Feb 10	Yes	Yes	M200
21	Katikati	*L. sinense*	26 Feb 10	Yes	Yes	M202
22	Hunua	*L. sinense*	10 Mar 10	Yes	Yes	M203
23	Papakura	*L. lucidum*	10 Mar 10	Yes	Yes	M204
24	Auckland Domain	*L. lucidum*	7 Apr 10	Yes	Yes	M190
25	Rotorua	*L. sinense*	8 Feb 12	Yes	No	-
26	Te Poi	*L. sinense*	8 Feb 12	Yes	No	-
27	Waimangaroa	*L. lucidum*	6 Apr 12	Yes	No	-
28	Maruia	*L. sinense*	13 Apr 12	Yes	No	-
29	Granity	*L. lucidum*	14 Apr 12	Yes	Yes	N011
30	Cape Foulwind	*L. lucidum*	14 Apr 12	Yes	No	-
31	Mata	*L. sinense*	16 Apr 12	Yes	Yes	N006
32	Moerewa	*L. sinense*	16 Apr 12	Yes	Yes	N005
33	Kerikeri	*L. lucidum*	17 Apr 12	Yes	Yes	N007
34	Kaeo	*L. lucidum*	17 Apr 12	Yes	Yes	N008
35	Nelson	*L. sinense*	26 Apr 12	Yes	Yes	N010
36	Te Kuiti	*L. lucidum*	8 May 12	Yes	Yes	N012
37	New Plymouth	*L. sinense*	9 May 12	Yes	Yes	N013
38	Hawera	*L. vulgaris*	9 May 12	Yes	Yes	N014
39	Wanganui	*L. sinense*	10 May 12	Yes	Yes	N017
40	Te Wera	*L. sinense*	10 May12	Yes	Yes	N016

Appendix 2 – Invertebrates associated with privet, *Ligustrum lucidum*, *L. sinense* and *L. vulgare*, at 39 New Zealand sites (2009–2012)

Key: Definition of frequency categories for *L. lucidum* and *L. sinense* (*L. vulgare* was only sampled at three sites so the frequency categories do not apply to it)

rare: fewer than 5 individuals collected in total

occasional: 5–15 individuals collected, **or** present at fewer than 5 sites

common: 16–99 individuals collected **and** present at 5 or more sites

abundant: 100+ individuals collected **and** present at 7 or more sites

Note: *BCA = introduced biocontrol agent*

Taxon	Common name	Feeding mode	*L. lucidum* Abundance class and (number of individuals)	*L. sinense* Abundance class and (number of individuals)	*L. vulgare* Number of individuals	Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)
Phylum Mollusca	**Molluscs**					
Class Gastropoda	**Slugs and snails**					
Cantareus aspersus Müller	Brown garden snail	Herbivorous	Rare (2)	Occasional (11)		**33**,15,32,37
Unidentified snails		Herbivorous	Common (168)	Occasional (16)		**5,6,8,9,33,34**,3,35,37
Unidentified slugs		Herbivorous	Occasional (6)	Rare (4)	2	**11,34,36**,40,***17,38***
Phylum Arthropoda						
Class Crustacea						
Isopoda	**Slaters**					
Unidentified Isopoda		Saprophytic	Common (52)	Common (64)	34	**1,5,8,9,30,33,36**,31,32,37,39,40,***16,38***

Taxon	Common name	Feeding mode	*L. lucidum* Abundance class and (number of individuals)	*L. sinense* Abundance class and (number of individuals)	*L. vulgare* Number of individuals	Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)
Class Arachnida						
Acarina	**Mites and ticks**					
Anystidae						
Anystis sp.	Whirlygig mite	Predatory	Common (17)	Occasional (20)	(3)	**4,6,13,19,24**,10,26,28,35,***16,17***
Oribatida	**Oribatid mites**					
Unidentified Oribatida		Fungivorous	Rare (1)	Rare (1)		**1**,35
Araneida	**Spiders**					
Unidentified Araneida		Predatory	Abundant (383)	Abundant (293)	(48)	**1,2,4,5,6,8,9,11,13,14,18,19,20,23, 24,27,29,30,33,34,36**,3,10,12,15,21,22,25,26, 28,31,32,35,37,39,40,***16,17,38***
Pseudoscorpiones	**Pseudoscorpions**					
Unidentified Pseudoscorpiones		Predatory	Occasional (6)	Rare (3)		**20,34**,26,40
Class Diplopoda	**Millipedes**					
Unidentified Diplopoda		Saprophytic		Rare (4)		40
Class Collembola	**Springtails**					
Unidentified Collembola		Saprophytic	Occasional (5)			**2,24**

Taxon	Common name	Feeding mode	*L. lucidum* Abundance class and (number of individuals)	*L. sinense* Abundance class and (number of individuals)	*L. vulgare* Number of individuals	Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)
Class Insecta	**Insects**					
Blattodea	**Cockroaches**					
Celatoblatta sp.		Saprophytic	Common (58)	Common (32)		**2,5,6,8,13,18,20,23,24,34**,10,12,15,32,37,40
Celeriblattina major		saprophytic	Rare (1)			**20**
Parellipsidion sp.		Saprophytic	Occasional (29)	Occasional (23)		**11,24,33,34**,25,26,39
Coleoptera	**Beetles**					
Aderidae	**Puppet beetles**					
Xylophilus sp.					1	***16***
Anobiidae	**Borer beetles**					
Xyletobius sp.		Saprophytic	Rare (1)			**19**
Anthicidae	**Ant beetles**					
Macratria sp.		Saprophytic		Rare (4)		10
Sapintus deitzi Werner and Chandler		Saprophytic	Rare (3)			**1**
Sapintus pellucidipes (Broun)		Saprophytic	Rare (2)	Rare (3)		**34**,10
Anthribidae	**Fungus weevils**					
Cacephatus incertus (White)		Fungivorous			1	***16***
Garyus altus (Sharp)		Fungivorous	Rare (2)	Rare (1)		**18,19**,3

Taxon	Common name	Feeding mode	*L. lucidum* Abundance class and (number of individuals)	*L. sinense* Abundance class and (number of individuals)	*L. vulgare* Number of individuals	Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)
Phymatus phymatodes (Redtenbacher)		Fungivorous		Rare (1)		25
Pleosporius bullatus (Sharp)		Fungivorous		Rare (1)		37
Sharpius brouni (Sharp)		Fungivorous	Occasional (5)	Occasional (10)		**2,5,33,34**,15,25,37,40
Brentidae						
Exapion ulicis (Forster)	Gorse seed weevil	Herbivorous (gorse BCA)	Rare (1)			**36**
Cantharidae	**Soldier beetles**					
Asilis sp.		Predatory		Rare (1)		10
Carabidae	**Ground beetles**					
Philophlaeus luculentus (Newman)		Predatory		Rare (1)		12
Cerambycidae	**Longhorn beetles**					
Bethelium signiferum (Newman)	Wattle longhorn		Rare (1)			**11**
Oemona hirta (Fabricius)	Lemon tree borer			Rare (2)		10
Psilocnaeia sp.			Occasional (11)	Rare (1)		**5,13,14,18**,12
Xuthodes punctipennis Pascoe	Speckled longhorn		Rare (1)			**20**
Xylotoles griseus (Fabricius)			Occasional (8)	Rare (1)		**2,6,11,20,23**,40

Taxon	Common name	Feeding mode	*L. lucidum* Abundance class and (number of individuals)	*L. sinense* Abundance class and (number of individuals)	*L. vulgare* Number of individuals	Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)
Xylotoles laetus White			Occasional (5)	Rare (4)	1	**13,20,34**,25,29,37,***38***
Xylotoles sp.				Rare (3)		25,26
Zorion batesi Sharp	Flower longhorn	Adults: pollen		Rare (1)		10
Zorion guttigerum (Westwood)	Flower longhorn	Adults: pollen		Rare (2)		10
Zorion sp.	Flower longhorn	Adults: pollen	Rare (1)			**11**
Chrysomelidae	**Leaf beetles**					
Adoxia sp.		Herbivorous		Rare (2)		10
Bruchidius villosus (Fabricius)	Broom seed beetle	Herbivorous (broom BCA)			1	***17***
Eucolaspis sp.	Bronze beetle	Herbivorous	Rare (1)	Occasional (8)		**11**,10,25
Coccinellidae	**Ladybirds**					
Coccinella undecimpunctata Linnaeus	Eleven-spotted ladybird	Predatory (BCA)		Rare (1)	6	15,***17***
Cryptolaemus montrouzieri Mulsant	Mealybug ladybird	Predatory (BCA)	Occasional (8)			**6**
Epilachna vigintioctopunctata Fabricius	Hadda beetle	Herbivorous	Rare (1)			**24**
Halmus chalybeus (Boisduval)	Steely-blue ladybird	Predatory (BCA)	Abundant (199)	Abundant (124)		**1,2,4,5,6,8,9,11,13,14,19,20,24,34,36**,3,10,12,15,21,22,25,32,35,37,39
Illeis galbula (Mulsant)	Fungus-eating ladybird	Fungivorous	Rare (2)	Rare (1)		**8,20**,37

Taxon	Common name	Feeding mode	*L. lucidum* Abundance class and (number of individuals)	*L. sinense* Abundance class and (number of individuals)	*L. vulgare* Number of individuals	Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)
Rhyzobius fagus (Broun)		Predatory		Rare (4)		37
Serangium maculigerum Blackburn		Predatory	Rare (3)			**24**
Stethorus sp.	Mite-eating ladybird	Predatory	Rare (1)			**1**
Corylophidae	**Hooded beetles**					
Sericoderus sp.		Fungivorous	Occasional (8)	Rare (1)		**33**,25
Unidentified Corylophidae		Fungivorous	Rare (1)			**1**
Cryptophagidae	**Cryptic beetles**					
Micrambina sp.		Pollen/Fungus feeder	Occasional (15)	Common (22)		**5,8,11,19,29,30,33,34**,10,12,25,37,40
Paratomaria sp.		Pollen/Fungus feeder	Rare (1)	Occasional (16)		**9**,10,26
Curculionidae	**Weevils**					
Aneuma rubricale (Broun)		Herbivorous	Rare (2)			**19**
Asynonychus cervinus Boheman	Fuller's rose weevil	Herbivorous	Occasional (7)	Rare (3)	1	**5,14,36**,35,37,40,***17***
Catoptes sp.		Herbivorous	Occasional (5)	Rare (2)		**29,30**,37
Dendrotrupes sp.		Herbivorous	Rare (1)			**19**
Didymus sp.		Herbivorous	Rare (4)	Rare (2)		**9,29**,37
Hoplocneme sp.		Herbivorous		Rare (3)		10

Taxon	**Common name**	**Feeding mode**	***L. lucidum* Abundance class and (number of individuals)**	***L. sinense* Abundance class and (number of individuals)**	***L. vulgare* Number of individuals**	**Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)**
Hylastes ater (Paykul)	Black pinebark beetle	Herbivorous		Rare (2)		31
Irenimus sp.		Herbivorous	Occasional (5)	Rare (4)	1	**18,20,24**,25,***17***
Microcryptorhynchus sp.		Herbivorous	Occasional (7)	Rare (1)		**6,9**,25
Pactola variabilis Pascoe		Herbivorous		Rare (1)		40
Pactola sp.		Herbivorous	Rare (1)			**9**
Peristoreus rufirostris (Broun)		Herbivorous			14	***16***
Phlyctinus callosus Boheman	Garden weevil	Herbivorous		Rare (4)	2	37,***17***
Scolopterus aequus Broun		Herbivorous		Rare (4)		10
Sericotrogus subaenescens Wollaston		Larvae and adults In dead wood	Rare (3)	Rare (2)		**8,9**,12
Stenoscelis hylastoides Wollaston		Herbivorous	Rare (1)			**5**
Stephanorhynchus lawsoni Sharp		Herbivorous		Rare (2)		10
Tysius bicornis (Fabricius)		Herbivorous	Rare (2)	Rare (2)		**11**,10
Elateridae	**Click beetles**					
Conoderus exsul (Sharp)	Pasture wireworm	Herbivorous	Occasional (5)	Occasional (6)		**19,23,34**,15,25,31,32
Conoderus posticus (Eschscholtz)		Herbivorous		Rare (3)		32

Taxon	Common name	Feeding mode	*L. lucidum* Abundance class and (number of individuals)	*L. sinense* Abundance class and (number of individuals)	*L. vulgare* Number of individuals	Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)
Ctenicera sp.		Herbivorous		Rare (3)		10
Hapatesus electus Nebois		Herbivorous	Rare (1)			**24**
Erotylidae	**Handsome fungus beetles**					
Loberus depressus (Sharp)		Fungivorous/ Saprophytic	Rare (1)			**6**
Loberus nitens (Sharp)		Fungivorous/ Saprophytic	Common (48)	Rare (1)		**5,6,11,13,19**,10
Laemophloeidae						
Cryptolestes ferrugineus (Stephens)	Rusty grain beetle	Herbivorous	Rare (1)			**13**
Latridiidae	**Mildew beetles**					
Aridius bifasciatus (Reitter)		Fungivorous	Rare (1)	Rare (1)		**19**,15
Bicava sp.		Fungivorous	Occasional (8)	Occasional (8)	1	**1,5,6,9,14,20,30,33**,25,26,37,***16***
Cortinicara sp.		Fungivorous		Occasional (16)		10,25,28,40
Melandryidae	**Leaping beetles**					
Hylobia plagiata Broun		Herbivorous		Occasional (19)		37,39,40
Hylobia sp.		Herbivorous		Rare (1)		10
Mordellidae	**Pintail beetles**					
Zeamordella monacha Broun		Pollen feeder		Rare (1)		12

Taxon	Common name	Feeding mode	*L. lucidum* Abundance class and (number of individuals)	*L. sinense* Abundance class and (number of individuals)	*L. vulgare* Number of individuals	Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)
Mycetophagidae	**Fungus beetles**					
Litargus vestitus (Sharp)		Fungivorous	Common (27)			**1,4,5,6,13,24,33**
Nitidulidae	**Sap beetles**					
Hisparonia hystrix (Sharp)		Fungivorous	Rare (1)			**34**
Phalacridae	**Bald beetles**					
Phalacrus uniformis frigoricola Thompson and Marshall		Fungivorous	Rare (2)			**8,33**
Salpingidae	**Bark mould beetles**					
Salpingus bilunatus Pascoe		Fungivorous	Occasional (7)	Occasional (7)		**6,11,19**,25
Salpingus perpunctatus Broun		Fungivorous		Rare (3)		37
Salpingus sp.		Fungivorous		Rare (1)		25
Scirtidae	**Marsh beetles**					
Unidentified Scirtidae		Predatory	Common (52)	Occasional (21)		**1,4,19,29,30,34**,3,10,15,40
Silvanidae	**Flat beetles**					
Cryptamorpha desjardinsi (Guérin)	Desjardin's flat beetle	Fungivorous	Occasional (10)			**2,5,13,24**

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Staphylinidae	**Rove beetles**					
Astenus guttula Fauvel		Predatory	Rare (1)	Rare (1)		**1**,32
Notolinus socius (Fauvel)		Predatory		Rare (1)		25
Sepedophilus sp.		Predatory	Rare (1)	Rare (1)		**13**,31
Stenomalium sp.		Predatory		Rare (1)		10
Unidentified Aleocharinae		Predatory	Rare (1)			**30**
Tenebrionidae	**Darkling beetles**					
Artystona rugiceps Bates		Lichen-feeder	Rare (1)	Rare (1)		**11**,22
Artystona erichsoni (White)		Lichen-feeder	Rare (1)			**34**
Trogossitidae	**Cadelle beetles**					
Lepidopteryx sp.		Predatory	Rare (1)			**6**
Zopheridae	**False darkling beetles**					
Tarphiomimus indentatus Wollaston		Herbivorous	Rare (1)			**2**
Dermaptera	**Earwigs**					
Forficula auricularia Linnaeus	European earwig	Omnivorous	Rare (3)	Common (21)	9	**23,24**,25,32,37,39,40,***16,17,38***

Taxon	Common name	Feeding mode	*L. lucidum* Abundance class and (number of individuals)	*L. sinense* Abundance class and (number of individuals)	*L. vulgare* Number of individuals	Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)
Diptera						
Tachinidae	**Bristle flies**					
Trigonospila brevifacies (Hardy)	Australia leafroller Tachinid	Parasitoid (BCA)		Rare (3)		12,22,39
Hemiptera	**Bugs**					
Acanthosomatidae						
Oncacontias vittatus (Fabricius)		Sap feeder	Rare (2)	Rare (1)		**27,36**,40
Anthocoridae	**Minute pirate bugs**					
Unidentified Anthocoridae		Predatory	Rare (4)	Occasional (13)	4	**13,30,33**,12,25,26,37,40,*16*
Aphididae	**Aphids**					
Unidentified Aphididae		Sap feeder	Rare (1)	Occasional (5)		**27**,28
Aphrophoridae	**Spittle bugs**					
Carystoterpa fingens (Walker)		Sap feeder	Rare (1)			**11**
Carystoterpa vagans Hamilton and Morales		Sap feeder	Rare (1)			**11**
Carystoterpa sp.		Sap feeder	Rare (3)			**9**
Philaenus spumarius (Linnaeus)	Meadow spittle bug	Sap feeder	Rare (3)	Occasional (13)	2	**11,23,36**,10,15,26,***16***

Taxon	Common name	Feeding mode	*L. lucidum* Abundance class and (number of individuals)	*L. sinense* Abundance class and (number of individuals)	*L. vulgare* Number of individuals	Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)
Cixiidae						
Zeoliarus oppositus (Walker)		Sap feeder		Rare (2)		10
Koroana rufifrons (Walker)		Sap feeder		Rare (2)		10
Coccidae	**Soft scales**					
Unidentified Coccidae		Sap feeder	Rare (1)			**29**
Delphacidae						
Ugyops pelorus Fennah		Sap feeder	Rare (2)			**6,9**
Diaspididae	**Armoured scale insects**					
Lindingaspis rossi (Maskell)	Ross' black scale	Sap feeder	Occasional (1000+)			**1,9**
Flatidae	**Planthoppers**					
Anzora unicolor (Walker)	Grey planthopper	Sap feeder	Rare (1)		2	**13,*16***
Siphanta acuta (Walker)	Green planthopper	Sap feeder	Abundant (106)	Common (68)	4	**1,2,4,5,6,9,11,14,19,20,23,24,27,29,30,34,36**, 3,12,15,21,22,25,26,31,32,35,37,39,40,***38***
Lygaeidae	**Seed bugs**					
Rhypodes sp.		Sap/seed feeder	Rare (1)	Rare (1)		**6**,10

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Membracidae						
Acanthucus trispinifer (Fairmaire)	Horned tree hopper	Sap feeder	Rare (4)			**6,8**
Miridae	**Mirid bugs**					
Chaetedus sp.		Sap feeder		Rare (1)		12
Chinamiris sp.		Sap feeder	Rare (2)			**6,34**
Deraeocoris maoricus Woodward		Predatory		Rare (1)		37
Diomocoris sp.		Sap feeder	Rare (4)			**14,18**
Romna sp.		Predatory		Rare (1)		26
Sejanus albisignatus (Knight)		Predatory/pollen feeder		Rare (1)		35
Sidnia kinbergi (Stål)	Australian crop mirid	Sap feeder		Rare (1)		10
Stenotus binotatus (Fabricius)	Slender crop mirid	Sap feeder		Rare (2)		10,12
Unidentified Miridae			Rare (3)	Rare (3)		**14**,10
Nabidae	**Damsel bugs**					
Nabis biformis (Bergroth)		Predatory	Rare (2)	Occasional (7)	5	**13,20**,12,22,***16,17***
Nabis sp.		Predatory		Occasional (8)		10,15

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Pentatomidae	**Shield bugs**					
Cermatulus nasalis (Westwood)	Brown soldier bug	Predatory	Rare (1)	Rare (2)		**9**,15,22
Cuspicona simplex Walker	Green potato bug	Sap feeder	Rare (3)			**11,24**
Dictyotus caenosus (Westwood)	Brown shield bug	Sap feeder	Rare (1)	Rare (2)		**14**,12
Glaucias amyoti (Dallas)	New Zealand vegetable bug	Sap feeder	Occasional (13)			**6,9,24,36**
Monteithiella humeralis (Walker)		Sap feeder	Rare (2)			**9,19**
Nezara viridula (Linnaeus)	Green vegetable bug	Sap feeder	Common (51)	Common (57)		**2,6,9,11,13,20,23,24,29,33**,12,21,22,26,32,39
Oechalia schellenbergii (Guerin)	Schellenberg's soldier bug	Predatory	Rare (4)	Rare (3)		**1,4,20**,3,21
Reduviidae	**Assassin bugs**					
Unidentified Reduviidae		Predatory	Rare (4)			**11,13,24**
Ricaniidae	**Planthoppers**					
Scolypopa australis (Walker)	Passionvine hopper	Sap feeder	Abundant (1000+)	Abundant (915)	31	**11,13,14,18,19,20,23,24,27,29,30,33,34,36**,12,15,21,22,25,26,31,32,35,37,39,40,***16,17,38***
Rhyparochromidae						
Brentiscerus putoni (White)		Sap/seed feeder	Rare (1)			**36**
Targarema electa White		Sap/seed feeder	Rare (2)			**34**

Taxon	Common name	Feeding mode	*L. lucidum* Abundance class and (number of individuals)	*L. sinense* Abundance class and (number of individuals)	*L. vulgare* Number of individuals	Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)
Targarema stali White		Sap/seed feeder		Rare (4)		10
Unidentified Hemiptera juveniles				Rare (2)		35
Hymenoptera	**Bees, wasps, ants**					
Braconidae	**Parasitic wasps**					
Meteorus pulchricornis Wesmael		Parasitoid	Rare (4)	Rare (4)	1	**6,19,20**,21,22,40,***17***
Venanides sp.		Parasitoid		Occasional (6)		22
Dryinidae						
Unidentified Dryinidae – probably *Dryinus koebelei* (Perkins)		Parasitoid of *siphanta acuta*	Rare (4)			**24**
Formicidae	**Ants**					
Iridomyrmex sp.		Omnivorous	Occasional (26)	Occasional (8)		**9,33**,25,31
Linepithema humile (Mayr)	Argentine ant	Omnivorous	Occasional (32)	Occasional (10)		**6,11**,12
Monomorium antarcticum (F. Smith)	Southern ant	Omnivorous	Occasional (25)		21	**24,34,*16***
Ochetellus glaber (Mayr)		Omnivorous	Common (65)	Occasional (10)		**2,9,13,14,23,24,**22,25
Paratrechina sp.	Garden ant	Omnivorous	Abundant (101)	Common (59)		**9,11,13,19,23,24,33,34**,12,21,22,25,31,32,35, 37
Prolasius advena (Smith)	Small brown bush ant	Omnivorous	Rare (2)	Occasional (9)		**27**,10

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Technomyrmex jocosus Forel	White-footed house ant	Omnivorous	Common (38)	Occasional (25)	7	**1,8,11,14,19,20,33**,15,21,31,***38***
Tetramorium grassii Emery		Omnivorous	Occasional (5)	Rare (1)		**19,20**,39
Ichneumonidae						
Ctenopelmatinae		Parasitoid	Rare (1)			**1**
Lepidoptera	**Moths and butterflies**					
Crambidae						
Trichophysetis cretacea Butler		Herbivorous	Occasional (12)	Occasional (38)		**33,34**,15,21,32,29
Geometridae	**Looper moths**					
Gellonia dejectaria Walker		Herbivorous		Rare (1)		22
Unidentified Geometridae		Herbivorous	Occasional (7)	Occasional (8)		**11,14,36**,10,12,22,25,37,40
Hepialidae						
Aenetus virescens larvae (Doubleday)	Puriri moth	Herbivorous	Common (19)			**2,5,6,8,11,24**
Psychidae	**Bagmoths**					
Liothula omnivora (Fereday)	Common bag moth	Herbivorous	Occasional (5)			**1,4,20**
Lepidoscia sp.		Herbivorous	Occasional (9)	Rare (3)		**5,11,33,34**,22,32,40

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Tortricidae	**Leafroller moths**					
Cnephasia jactatana (Walker)	Black lyre moth	Herbivorous	Rare (2)			**33,34**
Ctenopseustis herana (Felder and Rogenhofer)		Herbivorous	Rare (2)	Rare (1)		**30**,35
Ctenopseustis sp.	Brownheaded leafroller	Herbivorous	Occasional (6)	Occasional (12)		**2,5,6,11,19,34**,12,21,25,26,31,32
Epalxiphora axenana Meyrick	Sharp-tipped bell moth	Herbivorous		Rare (2)		12,37
Epiphyas postvittana (Walker)	Lightbrown apple moth	Herbivorous		Rare (3)		26,32
Planotortrix notophaea Turner		Herbivorous	Rare (2)			**30**
Planotortrix sp.	Greenheaded leafroller	Herbivorous	Rare (4)	Rare (4)		**2,4,11,34**,10,21,25
Unidentified Tortricidae		Herbivorous	Occasional (9)	Common(29)	2	**5,11,14,18,24,36**,3,12,15,21,22,25,26,31,37,39,40,***16,17***
Unidentified Lepidoptera			Occasional (5)	Rare (3)		**19,20,29,30**,10,12,35
Mantodea	**Praying mantids**					
Miomantis caffra Saussure	African praying mantis	Predatory	Rare (2)	Rare (2)		**11,13**,35
Orthodera novaezealandiae (Colenso)	New Zealand praying mantis	Predatory	Rare (3)	Occasional (8)		**33**,15,26,37

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Neuroptera	**Lacewings**					
Micromus tasmaniae (Walker)	Tasmanian lacewing	Predatory	Rare (4)	Occasional (5)	8	**8,11,14,18**,12,15,26,39,*17*
Orthoptera	**Crickets, grasshoppers, weta**					
Anostostomatidae						
Hemideina thoracica White	Auckland tree weta	Herbivorous/ Omnivorous	Rare (4)	Rare (1)		**24,34**,37
Gryllidae	**Crickets**					
Ornebius aperta Otte and Alexander		Herbivorous	Occasional (34)	Occasional (9)		**6,5,33**,31
Tettigoniidae	**Long-horned grasshoppers**					
Caedicia simplex (Walker)	Katydid	Herbivorous	Rare (3)	Occasional (8)	1	**11,14,36**,12,26,32,37,40,*38*
Conocephalus sp.	Field grasshopper	Herbivorous		Rare (4)		10,15,37
Phasmatodea	**Stick insects**					
Clitarchus hookeri (White)	Smooth stick insect	Herbivorous	Rare (1)			**11**
Psocoptera	**Book lice**					
Trogiidae						

Taxon	**Common name**	**Feeding mode**	***L. lucidum* Abundance class and (number of individuals)**	***L. sinense* Abundance class and (number of individuals)**	***L. vulgare* Number of individuals**	**Collection sites (*L. lucidum* sites in bold) (*L. sinense* sites not bold) (*L. vulgare* sites in bold italics)**
Unidentified Trogiidae		Saprophytic/ Fungivorous		Occasional (32)		28
Unidentified Psocoptera		Saprophytic/ Fungivorous	Common (47)	Common (54)	2	**4,6,8,11,13,18,19,20,26,30**,10,12,25,26,28, 35,40,***16***
Thysanoptera	**Thrips**					
Sub-Order Terebrantia						
Aeolothripidae						
Aeolothrips fasciatus (Linnaeus)		Herbivorous	Rare (4)			**13**
Thripidae						
Thrips obscuratus (Crawford)	New Zealand flower thrips	Herbivorous	Rare (4)	Occasional (20)		**13**,10
Sub-Order Tubulifera						
Unidentified Tubulifera		Fungivorous	Rare (1)	Rare (1)		**30**,25

Appendix 3 – List of all microbes recovered from all sites

Sample number	Pathogen
M123	*Cladosporium tenuissimum*, *C. cladosporoides*, *Colletotrichum fuscum* C1297.6-10, *Colletotrichum gloeosporioides* NZ clade. C1294, *Epicoccum purpurascens*, *Fusarium verticillioides*, *Leptosphaerulina chartarum*, *Neofusicoccum parvum*, *Paraconiothyium sporulosum*, *Phoma exigua*
M124	*Alternaria* sp., *Cladosporium tenuissimum*, *C. cladosporoides*, *Mycosphaerella coacervata*, *Phoma glomerata*, *Preussia australis*
M125	*Cladosporium cladosporioides*, *Epicoccum purpurascens*, *Neofusicoccum australe*, *Phoma exigua*
M126	*Alternaria triticina*, *Epicoccum purpurascens*, *Neofusicoccum australe*, *Phaeosphaeriopsis musae*
M128	*Colletotrichum graminicola*, *Cryptococcus victoriae*, *Pestalotiopsis vismiae*, *P. maculiformans*
M129	*Camarosporium brabeji*, *Cladosporium cladosporoides*, *Pestalotiopsis vismiae*
M134	*Cladosporium tenuissimum*, *C. cladosporoides*, *Cryptococcus* sp., *Neofusicoccum* sp.
M136	*Colletotrichum gloeosporioides*, *Myrothecium* sp., *Neofusicoccum australe*
M138	*Alternaria alternata*, *A. arborescens*, *Neofusicoccum* sp., *Pestalotiopsis vismiae*, *P. maculiformans* or *P. cocculi*
M160	*Aureobasidium pullulans*, *Lewia infectoria*, *Pestalotiopsis*, *Stagonophora*, *Botryosphaeria dothidea*, *Davidiella tassiana*, *Alternaria* sp.
M169	*Phoma macrostoma*, *Aureobasidium pullulans*
M177	*Phoma macrostoma*, *Aureobasidium pullulans*, *Stagonophora*, *Botryosphaeria dothidea*, *Davidiella tassiana*, *Alternaria* sp.
M178	*Phoma theicola*, *Pestalotiopsis*, *Aureobasidium pullulans*
M190	*Epicoccum purpurascens*, *Neofusicoccum australe*, *Phoma* sp.
M193	*Alternaria*, *Lewia infectoria*, *Stagonospora*
M196	*Botryosphaeria dothidea*, *Epicoccum purpurascens*, *Lewia infectoria*
M197	*Cladosporium tenuissimum*, *Davidiella tassiana*, *Diaporthe viticola*, *Fusarium tricinctum*, *Phoma theicola*
M198	*Alternaria* sp., *Aureobasidium pullulans*, *Colletotrichum* sp. *Epicoccum purpurascens*, *Lewia infectoria*, *Phoma theicola*
M199	*Aureobasidium pullulans*, *Epicocccum purpurascens*, *Lewia infectoria*, *Kabatiella microsticta*, *Stemphylium* sp.
M200	*Colletotrichum acutatum*

Sample number	Pathogen
M201	*Aureobasidium pullulans*, *Botryosphaeria dothidea*, *Colletotrichum* sp., *Kabatiella microsticta*, *Lewia infectoria*, *Phoma theicola*
M202	*Colletotrichum* sp.
M203	*Colletotrichum* sp.
M204	*Alternaria* sp., *Lewia infectoria*
N005	*Fusarium graminearum*; *Fusarium* sp., *Epicoccum purpurascens*
N06	*Epicoccum purpurascens*, *Cladosporium* sp., *Colletotrichum* sp., *Nigospora* sp., *Aureobasidium* sp., *Leptosphaerulina* sp., *Xylaria* sp.
N07	*Pestalotiopsis* sp./ *Fusarium* sp., *Arthrinium* sp., *Epicoccum purpurascens*, *Xylaria* sp.,
N08	*Fusarium* sp., *Pestalotiopsis* sp., *Epicoccum purpurascens*, *Hypochrea pachbasioides*, *Phoma* sp., *Phyllosticta* sp., *Fusarium* sp.
N010	Sooty mould
N012	*Cladosporium* sp., *Epicoccum purpurascens*, *Pestalotiopsis* sp.
N013	*Aureobasidium pullulans*, *Cladosporium* sp., *Colletotrichum* sp., *Epicoccum purpurascens*, *Fusarium* sp., *Neofusicoccum australe*
N014	*Arthrinium sachari*, *Cladosporium* sp., *Microdochium* sp., *Neofusicoccum australe*, *N. parvum*, *Nigospora oryzae*, *Phomopsis* sp.
N016	*Epicoccum purpurascens*, *Fusarium asiaticum*, *Phyllosticta jasmini*, *Phoma exigua*, *Sclerotium sclerotiorum*, *Botryotinia fuckeliana*
N017	*Diaporthe phaseolorum*, *Epicoccum purpurascens*, *Phomopsis* sp., *Phyllosticta jasmini*, *Phoma exigua*