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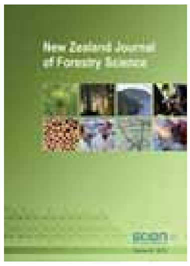

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Interceptions and incursions of exotic *Sirex* species and other siricids (Hymenoptera: Siricidae)†

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Abstract

The family Siricidae has more than 100 species in about 11 genera. Nearly all species are native to the Northern Hemisphere although there is an endemic genus (*Afrotremex*) in southern Africa. Collectively they are known as woodwasps or horntails. All siricids are wood borers and several species are forestry pests to varying degrees. New Zealand has a single species of siricid woodwasp, *Sirex noctilio* F., thought to have been accidentally introduced around 1900. Two recent and noteworthy siricid incursions are presented as case studies, with an emphasis on the science used in decision support. The first case study describes the advantages of using morphological and molecular diagnostic approaches in combination. This case resulted in the first published host record association between *S. noctilio and Amylostereum areolatum* (Chaillet ex Fr.) Boidin in *Cedrus atlantica* (Endl.) Manetti. The second case study reports the application of published life cycle developmental data to assess establishment risk, and profiles the entry of *Sirex juvencus* (L.) into New Zealand within timber stamped with the International Standards for Phytosanitary Measures (ISPM) 15 mark, and the Ministry of Agriculture and Forestry Biosecurity New Zealand's actions to mitigate this high-risk pathway. Historical records of siricid interceptions at New Zealand's border are examined and discussed, in relation to patterns of interception records over time and the key species intercepted.

Keywords: Sirex woodwasp; Siricidae; *Amylostereum*; border; detection; incursion; interception.

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Introduction

New Zealand has a single species of siricid woodwasp, *Sirex noctilio* F., which is native to Eurasia but has been present here since about 1900 (Bain, 2005). Globally, there are more than 100 species in ca. 11 genera, known collectively as woodwasps or horntails. All belong to the family Siricidae (Hymenoptera), hence they are also commonly known as siricids, and many are forestry pests to varying degrees. Tree damage caused by these insects is partly related to wood tunnelling by the larvae. More importantly, however, siricid attack results in deposition of a phytotoxic mucus and infection by various symbiotic basidiomycete wood-decay fungi, which are carried by siricid adults (e.g. Coutts, 1969a; 1969b). Worldwide, two common siricid symbionts are *Amylostereum areolatum* (Chaillet ex Fr.) Boidin, and *A. chailletii* (Pers.) Boidin (Slippers et al., 2003). Both species of fungi are present in New Zealand and are

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considered non-regulated organisms by the Ministry of Agriculture and Forestry Biosecurity New Zealand (MAFBNZ).

Stressed trees affected by overstocking or drought are generally considered more susceptible to attack by *Sirex* spp., therefore encouraging the occurrence of outbreaks (Morgan, 1968). *Sirex noctilio* outbreaks between 1946 and 1951 caused considerable mortality of *Pinus radiata* (D.Don) trees in central North Island plantations. Unhealthy trees over an area of 120,000 ha were primarily affected (Gilmour, 1965). There have been no further significant outbreaks in New Zealand due to the combined effects of a successful biological control programme (using a nematode that sterilises adult female *Sirex* (Nuttall, 1989)) and changed silvicultural practices (which resulted in fewer overstocked stands) (Bain, 2005; Hurley et al., 2007). However, unsuccessful *Sirex* attacks of dominant trees can cause resinous blemishes which, in turn, can reduce clearwood quality and lead to log downgrade (McConchie & Dick, 2000). New Zealand was the first country where *S. noctilio* was recorded as a biological invader but since then it has also established in Australia (detected in 1952), more recently in Uruguay, Argentina, Brazil, South Africa, Chile (Bain, 2005; Hurley et al., 2007) and, most recently, in the United States of America (USA) (Hoebecke et al., 2005) and Canada (de Groot et al., 2006). Other introduced siricids are the Asian horntail, *Eriotremex formosanus* (Matsumura), which has become established in the USA (Smith, 1996) and the Eurasian *Tremex fuscicornis* Fabr. which is now established in Australia (CSIRO, 2004) and Chile (Parra Sanhueza, 2005). In the USA, border interceptions of siricids are common, mostly in crating and other kinds of wood packaging (e.g. Hoebeke et al., 2005). The use of solid wood packaging materials is recognised as an important pathway for the introduction of wood borers and bark beetles (Brockerhoff et al., 2006; Haack, 2006, Humble, 2010).

In this paper, historical records of siricid border interceptions in New Zealand are examined and discussed in relation to both the patterns of interception over time and the key species intercepted. Also, two recent and noteworthy siricid incursions are presented as case studies, with an emphasis on the science used to support practical decisions. The first case study describes the advantages of using a combination of morphological and molecular diagnostic approaches to identify species of siricid involved in the death of trees at a New Zealand golf club. The second case study reports the application of published life cycle developmental data to assess establishment risk, profiles the entry of *Sirex juvencus* (L.) into New Zealand within treated timber, and MAFBNZ's actions to mitigate this high-risk pathway.

Methods

The Ministry of Agriculture and Forestry Biosecurity New Zealand has maintained records of exotic organisms intercepted at the border and post-border since 2001. Prior to this date, New Zealand forestry-related exotic organism interceptions were recorded by the New Zealand Forest Research Institute (currently trading under the name 'Scion'), with records dating back to 1948 (Bulman, 1990; Brockerhoff et al., 2006). Both these databases were interrogated for historical data relating to interceptions of Siricidae. Data were summarised to identify key species and possible trends over time.

Results and Discussion

A total of 34 discrete siricid interception events occurred between 2001 and July 2008 (Table 1). Most frequent interceptions were of the three species: *Sirex noctilio* (32%), *S. juvencus* (44%), and *Urocerus gigas* (L.) (12%). These data suggest a similar chance of *S. noctilio* (already present in New Zealand) and *S. juvencus* being intercepted, with 11 and 15 discrete interceptions for each species, respectively. Interceptions were made at the border (16 interceptions) during MAFBNZ clearance procedures, and post-border (18 interceptions) (Table 1) after goods had been officially cleared. The term "border" refers not only to sea- and air-ports but also to MAFBNZ approved Transitional Facilities (TF) where imported goods are inspected by MAFBNZ Accredited Persons (MAF, 2008) and where unpacking of the imported goods frequently occurs. These are mostly located near sea- and air-ports, industrial estates, and national road- and rail-transport corridors. Border interceptions are typically confirmed by the presence of exit holes in timber and/or adult siricids found inside a shipping container while still at the port of entry (note, frass is not normally observed with siricid-infested lumber until after the appearance of flight holes). The term "post-border" refers to instances of exotic siricids found at locations not at the border. These may be contained interceptions (e.g. inside buildings or containers), or a detection uncontained in time and space, in which case an incursion response is initiated. That such a large proportion of interceptions were made post-border is considered likely related to: (i) the short time (1 – 2 days) goods spend "at the border" relative to "post-border"; and (ii) the low efficacy of visual border inspections to detect siricid larvae/pupae inside timber. Consequently, border interceptions are generally more localised and easily contained, so are usually more rapidly responded to, than post-border detections. Once imported goods leave the border, incerception becomes more difficult which leads to a greater risk of a pest becoming established post-border.

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TABLE 1: Interceptions at the border and post-border of exotic siricids associated with goods imported into New Zealand during the period 2001 and 2008 (MAFBNZ interception data), The abbreviation 'TF' refers to MAFBNZ-approved Transitional Facilities where inspections are carried out by MAFBNZ Accredited Persons).

Species	**Number of discrete interceptions**			
	Border	**TF Border**	**Post-border**	**Total**
Sirex juvencus (L.)	3	3	9	15
Sirex noctilio F.	2	2	7	11
Urocerus gigas (L.)	2	1	1	4
Xeris sp.	1	0	0	1
Other Siricidae spp.	2	0	1	3
Total	**10**	**6**	**18**	**34**

Of the 373 siricid interception events recorded between 1952 and 2000 (Table 2), the greatest proportion (38%) were of *Sirex juvencus*, suggesting this species presented the greatest risk of entry to New Zealand. Graphical assessment of all siricid interception data revealed a high degree of annual variability (Figure 1), although interceptions occurred in all but six of the 56 years studied. Most interception events were of a single siricid species (93%), but 19 interceptions involved two species, and a single interception involved three species. Fluctuations in the historical incidence of siricid interceptions are considered likely to reflect many factors. Such factors include: variation in volumes of risk goods arriving into New Zealand; the country of import; seasonal and long-term siricid abundance in the country of origin; impacts of individual high-risk import pathways; border inspection and entry protocols; and record keeping. This list is not considered exhaustive, and given the diversity, complexity, and likely interactions of these various factors, no attempts were made to identify significant causative factors through numerical correlation. The inherent limitations of such border interception data have been explored in more detail by Work et al. (2005). However, a visual assessment to compare the pattern of each species' historical interceptions to the pattern of the total species interceptions over time (Figure 1), revealed no large scale difference. This suggests, within the limitations of the data, that whatever interplay of factors influence historical siricid

TABLE 2: Interceptions of exotic siricids associated with goods imported into New Zealand during the period 1950 and 2000 (interception data from the Forest Research Institute / Scion).

Species	**Number of interceptions (%)**
Sirex juvencus (L.)	142 (38.1)
Urocerus gigas (L.)	63 (16.9)
Xeris spectrum (L.)	40 (10.7)
Sirex sp.	18 (4.8)
Sirex cyaneus F.	12 (3.2)
Sirex noctilio F.	8 (2.1)
Tremex columba (L.)	5 (1.3)
Urocerus sp.	5 (1.3)
Sirex areolatus (Cresson)	4 (1.1)
Tremex sp.	3 (0.8)
Xeris sp.	3 (0.8)
Sirex nigricornis F.	1 (0.3)
Urocerus augur (Klug)	1 (0.3)
Urocerus albicornis (F.)	1 (0.3)
Xeris tarsalis (Cresson)	1 (0.3)
Unidentified sp.	66 (17.7)
Total	**373 (100%)**

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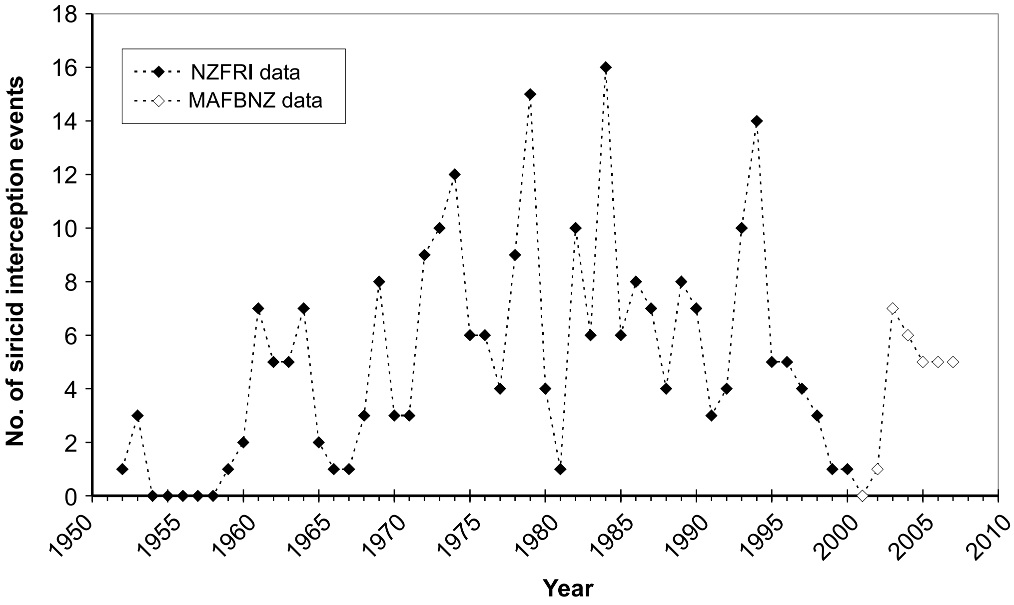

FIGURE 1: Number of annual exotic siricid interception events, and percent of total siricid interceptions, associated with imported goods into New Zealand during the period 1950 to 2008. ('NZFRI', New Zealand Forest Research Institute / Scion interception data; 'MAFBNZ', Biosecurity New Zealand interception data; for more information on data sources see 'methods').

interceptions, these factors appear to influence all species equally. Despite the various limitations of these data, this report represents the best available information on the relative arrival frequency of deffierent siricid species. Analysis of long-term interception data indicates that the relative frequency of interceptions of individual species can give some indication of the probability of establishment (Brockerhoff et al., 2006; Haack, 2006). In the case of siricid interceptions and establishments, it is curious that although *S. juvencus* has been intercepted more often than *S. noctilio*, the latter has become established not only in New Zealand but also seven other countries in at least five geographically separate regions (Bain, 2005; Hoebecke et al., 2005) whereas, to our knowledge, *S. juvencus* has not become established outside its native range, despite its frequent translocation and the availability of suitable host trees. This suggests that *S. juvencus* is perhaps less capable of colonising new territories.

Virtually all siricid interceptions were associated with imported timber used as packaging of non-wooden goods, such as wooden pallets, wooden crates, and dunnage (i.e. wooden spacers used within shipping containers or in the hold of ships to prevent movement of goods). Changes to New Zealand's border inspection standards for wood packaging materials were initiated during 2003, with the aim of addressing risks from wood borers (including siricids), bark beetles and other regulated pests. Since then, International Standard for Phytosanitary Measures (ISPM) No. 15 (FAO, 2002, 2009) has been fully implemented (in 2005 or 2006) by most countries. Standard No. 15 requires solid wood packaging to be treated, usually by heat or fumigation. These treatments are designed to reduce the risk of introduction of siricids and other organisms associated with solid wood packaging.

In addition to policies and procedures designed to keep siricids and other wood and bark borers out of New Zealand, specialist staff exist within MAFBNZ who are tasked to investigate post-border interceptions and initiate incursion responses when necessary. Compared to incursions of many other organisms dealt with by MAFBNZ, siricid incursion responses have the advantage of available published information on matters such as developmental life cycle and biology, dispersal ability, and adult behaviour. Such information provides the basis for rational decision making, leading to favourable biosecurity outcomes with the least expenditure (Burnip & Froud, 2008). We report on two post-border investigations involving siricids to illustrate the circumstances of such cases and MAFBNZ's responses in each situation.

Case study 1: Russley Golf Club

In March 2008, siricid larvae were found associated with *Amylostereum* spp. fungi in ca. 20 dead and dying trees of mixed *Cedrus* (cedar) and *Larix* (larch) species, at the Russley Golf Club in Christchurch, New Zealand. Staff at MAFBNZ were contacted as the species of siricid involved was thought to be new to New Zealand. This hypothesis was based on the single *Sirex* species present in New Zealand, *S. noctilio*, as never previously having been recorded (to our knowledge) attacking cedar in New Zealand

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or elsewhere; whereas *Sirex juvencus* and *Urocerus gigas* were thought to attack a wider range of conifers. Both of these siricid species are considered regulated species by MAFBNZ due to their potential to be significant forestry pests. Furthermore, if the siricid was a recent incursion of an exotic species, the associated *Amylostereum* species might also have been an exotic species that was not yet present in New Zealand. The initial identification of *Amylostereum* species and report of a siricid infestation were made by an independent plant pathologist who had been contracted by the golf club to address the issue of the dying cedar trees.

Most adult siricids are readily characterised using morphological differences (Benson, 1943; Viitasaari & Midtgaard, 1989; Schiff et al., 2006). Unfortunately, no adults were found during the initial examination of felled cedar trees. Differentiation between species of siricids is extremely difficult when based solely on larval morphology as the same features are shared by most of the siricid species which might be expected to be intercepted at New Zealand's borders. Larvae are a creamy white and typically reach a length of at least 25 mm when fully grown (final instar). All larvae have rudimentary legs, and have a distinctive dark spine at the rear of the abdomen. Currently no keys to identify siricid larvae to species have been developed, nor is this likely because of physical similarities. Consequently, a project using molecular diagnostic methods was initiated to compare the siricid larvae found with larvae known to be *Sirex noctilio*, collected from elsewhere in New Zealand.

Staff from MAFBNZ visited the site and felled other affected trees. The trunk and main branches were then cut into short rounds. Their examination revealed extensive borer galleries and the presence of numerous siricid larvae including early-, mid-, and late-instars. Several exit holes on the bark were found, indicating some larvae had completed their life cycle and dispersed as adults. Staining of the wood by *Amylostereum areolatum* was also visually evident in virtually all cut sections. Trunk sections were split with an axe with the objective of finding a pre-emergence adult. This resulted in a single adult being found, and definitive morphological identification revealed the siricid to be *Sirex noctilio*, the species already present in New Zealand. This identification was later verified by the molecular diagnostic project on siricid larvae initiated earlier.

Molecular diagnostics (direct sequencing) was also used to validate the identification of the associated *Amylostereum* fungus. This was determined as *Amylostereum areolatum*; the *Amylostereum* fungi commonly found in association with *Sirex noctilio* in New Zealand *Pinus* spp.

Further questioning of the golf club grounds staff revealed a recent change to the herbicide product applied to the base of the cedar trees had caused needle-fall on some trees. We think the reduced moisture content and other changes that resulted from this herbicide damage resulted in the cedars becoming stressed and, therefore, attractive and susceptible to *Sirex noctilio* attack. This appears to represent the first published record of an association between *Sirex noctilio* and *Amylostereum areolatum* on *Cedrus atlantica* as a host tree (Burnip et al., 2008).

Case study 2: Printing machinery

Timber stamped with the ISPM 15 mark indicates compliance with that standard, which regulates wood packaging material in international trade (FAO, 2009). Shipments involving machinery with wood packaging material that had been marked as treated according to ISPM 15 (FAO, 2009) were considered low risk and these goods were exempt from MAFBNZ border inspection. In July 2006, adult *Sirex juvencus* were detected at an industrial site in Christchurch. These adults emerged from wooden pallets marked as treated according to ISPM 15. These wooden pallets had arrived from Germany as packaging for printing machinery and had been present in New Zealand for two months prior to the detection of *Sirex juvencus*. This information, together with an estimated presence of more *Sirex juvencus* emergence holes than adults that could be accounted for, meant there was a risk adults had successfully escaped into the environment. Adding to the risk was the presence of mature host trees in a park, ca. 1 km away.

The life cycle and general biology of several *Sirex* spp. are relatively well understood, and relevant published information is readily available that could be applied to the incursion response and to assess the establishment risk of this species. In the absence of readily accessible information on *Sirex juvencus* biology, information on *Sirex noctilio* was used to estimate *Sirex juvencus* egg and larval development. These estimates indicated that immature stages developed progressively more slowly at temperatures below 15 ºC and reached a lower threshold at about 6 – 7 ºC (Madden, 1981). Complete development apparently depends on temperatures occurring within the range of 12.5 – 33.5 ºC although eggs can remain dormant for several months at lower temperatures (Madden, 1981). However, under natural conditions, oviposition occurs in summer or autumn, within a few days of the emergence of adults, and not during winter when this event occurred.

The mean daily temperatures in Christchurch during July are ca. 11 ºC and frosts are common at night, suggesting that conditions for the development of immatures were not optimal. Furthermore, based on the number of exit holes and recovered adults, only a few *Sirex juvencus* could have escaped. After emergence, males typically swarm around tree tops prior to mating with females. In this case, for successful

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mating to have occurred, this would have required an unlikely encounter of a male and a female following their dispersal from an industrial site with only few and mostly deciduous trees in the immediate vicinity. Even if successful mating had occurred, this would then have required locating a host tree, oviposition, and successful development under suboptimal conditions. Finally, because small colonising populations are strongly affected by Allee effects and stochastic dynamics, there is a high probability of extinction (Liebhold & Tobin, 2008, 2010).

In assessing the risk associated with this incursion, the available information was insufficient to determine this risk with certainty. However, it was concluded that this was unlikely to have led to a successful establishment because it would have required the occurrence of a string of unlikely events. Nonetheless, it is easy to imagine this event having a different outcome had the consignment arrived during summer, when environmental conditions would be more favourable. Consequently, all consignments arriving into New Zealand involving this printing machinery company were flagged for full MAFBNZ border inspection. The goods were previously exempt from a full MAFBNZ border inspection because shipments involving machinery with wood packaging material that has been marked as treated according to ISPM 15 (FAO, 2009) are considered low risk. Border inspections for this company continued for 12 months. At the end of this period no further biosecurity risks had been detected and the additional border inspection requirement was lifted.

Follow-up surveillance within a risk zone surrounding the point of detection was considered not justified, based on the overall perception of a low establishment risk, together with a low likelihood of detection using surveillance methods for *Sirex juvencus* available at that time. As of mid-2010, no further *Sirex juvencus* were found in the vicinity of the site where the incursion occurred.

Conclusions

The siricid interceptions reported here and establishments elsewhere (for example, *Eriotremex formosanus* in the USA) demonstrate an on-going risk of future woodwasp introductions. Phytosanitary treatments of wood packaging materials according to ISPM 15 have probably reduced, but not eliminated, this risk (Zahid, 2008; Haack & Petrice, 2009), although we have not attempted to detect such an effect on the basis of our interception records. However, siricid larvae are frequently concealed deep inside wooden items. Consequently, detecting infestations in incoming cargo through visual inspection is difficult, and mitigation measures such as those undertaken as part of ISPM 15 may not be as consistently effective as for organisms that are typically found near the surface of wood packaging materials.

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References

Bain, J. (2005). *Sirex noctilio* (Hymenoptera: Siricidae) - the New Zealand experience. In K. W. Gottschalk (Ed.), *Proceedings of the 16th USDA Interagency Research Forum on Gypsy Moth and Other Invasive Species, Annapolis, MD, 18-21January 2005*. (p. 2.). Gen. Tech. Rep. NE-337. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station.

Benson, R. B. (1943). Studies in Siricidae, especially of Europe and Southern Asia (Hymenoptera, Symphyta) *Bulletin of Entomological Research*, *34,* 27-51.

Brockerhoff, E. G., Bain, J., Kimberley, M. O., & Knížek, M. (2006). Interception frequency of exotic bark and ambrosia beetles (Coleoptera: Scolytinae) and relationship with establishment in New Zealand and world-wide. *Canadian Journal of Forest Research*, *36,* 289-298.

Bulman, L. S. (1990). Bugs and health — integral part of forest protection strategy. *What's new in Forest Research No. 197*. Rotorua, New Zealand: Forest Research Institute.

Burnip, G., & Froud, K. (2008). Characterisation of science inputs when investigating exotic organism incursions. In K. J. Froud, A. I. Popay & S. M. Zydenbos (Eds.), *Surveillance for biosecurity: Pre-border to pest management.* (pp. 97-110). Christchurch, New Zealand: New Zealand Plant Protection Society.

Burnip, G., Harvey, I. C., Voice, D., & Braithwaite, M.

ISSN 0048 - 0134 (print)
ISSN 1179-5395 (on-line)

(2008). New host association for *Sirex noctilio* and *Amylostereum areolatum* on *Cedrus atlantica*. *New Zealand Plant Protection*, *61,* 191.

Coutts, M. P. (1969a). The mechanism of pathogenicity of *Sirex noctilio* on *Pinus radiata*. I. Effects of the symbiotic fungus *Amylostereum sp.* (Telophoraceae). *Australian Journal of Biological Science*, *22,* 915-924.

Coutts, M. P. (1969b). The mechanism of pathogenicity of *Sirex noctilio* on *Pinus radiata*. II. Effects of *S. noctilio* mucus. *Australian Journal of Biological Science, 22,* 1153-1161.

Commonwealth Science and Industry Research Organisation (CSIRO). (2004). Tremex wasp, *Tremex fuscicornis* Fabricius. *Australian insect common names.* Retrieved 11 May 2010 from http://www.ento.csiro.au/aicn/name_c/a_3749.htm

de Groot, P., Nystrom, K., & Scarr, T. (2006). Discovery of *Sirex noctilio* (Hymenoptera: Siricidae) in Ontario, Canada. *Great Lakes Entomologist*, *39,* 49-53.

Food and Agriculture Organization of the United Nations (FAO). (2002). *International standards for phytosanitary measures: guidelines for regulating wood packaging material in international trade, Publ. No. 15*. Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO). (2009). *International standards for phytosanitary measures: Revision of ISPM No. 15, regulation of wood packaging material in international trade*. Rome, Italy.

Gilmour, J. W. (1965). The life cycle of the fungal symbiont of *Sirex noctilio*. *New Zealand Journal of Forestry*, *10,* 80-89.

Haack, R. A. (2006). Exotic bark and wood-boring Coleoptera in the United States: recent establishments and interceptions. *Canadian Journal of Forest Research* 36: 269-288.

Haack, R. A., & Petrice, T. R. (2009). Bark- and wood-borer colonization of logs and lumber after heat treatment to ISPM 15 specifications: the role of residual bark. *Journal of Economic Entomology*, *102,* 1075-1084.

Hoebeke, E. R., Haugen, D. A., & Haack, R. A. (2005). *Sirex noctilio*: Discovery of a palearctic siricid woodwasp in New York. *Newsletter of the Michigan Entomological Society*, 50 (1 & 2), 24-25.

Humble, L. (2010). Pest risk analysis and invasion pathways - insects and wood packing revisited: What have we learned? *New Zealand Journal of Forestry Science, 40 Suppl.,* S57-S72.

Hurley, B. P., Slippers, B., & Wingfield, M. J. (2007). A comparison of control results for the alien invasive woodwasp, *Sirex noctilio*, in the southern hemisphere. *Agricultural and Forest Entomology*, *9,* 159-245.

Liebhold, A. M., & Tobin, P. C. (2008). Population ecology of insect invasions and their management. *Annual Review of Entomology*, *53,* 387-408.

Liebhold, A. M., & Tobin, P. C. (2010). Exploiting the Achilles heels of pest invasions: Allee effects, stratified dispersal and management of forest insect establishment and spread. *New Zealand Journal of Forestry Science, 40 Suppl.,* 25-33.

Madden, J. L. (1981). Egg and larval development in the woodwasp, *Sirex noctilio* F. *Australian Journal of Zoology*, *29,* 493-506.

Ministry of Agriculture and Forestry, Biosecurity New Zealand (MAFBNZ) (2008). *Standard for general transitional facilities for uncleared goods. Requirements for facilities and operators*. Wellington, New Zealand:

McConchie, D., & Dick, M. (2000). *Sirex* degrade in logs. *Forest Health News*, *98*. Rotorua, New Zealand: Forest Research Institute.

Morgan, F. D. (1968). Bionomics of Siricidae. *Annual Review of Entomology*, *13,* 239-256.

Nuttall, M. J. (1989). *Sirex noctilio* F., sirex wood wasp (Hymenoptera: Siricidae). In: P. J. Cameron, R. L. Hill, J. Bain, J., & W. P. Thomas (Eds.), *Review of Biological Control of Invertebrate Pests and Weeds in New Zealand from 1874 to 1986*. London, UK: CAB International Institute of Biological Control.

Parra Sanhueza, P. (2005). Integrated management of *Tremex fuscicornis* Fabr. *Chile Forestal*, *308,* 40-43.

Schiff, N. M., Valley, S. A., LaBonte, J. R., & Smith, D. R. (2006) Guide to the siricid woodwasps of North America. (FHTET-2006-15). Morgantown, WV: U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team. http://www.treesearch.fs.fed.us/pubs/29220

Slippers, B., Coutinho, T. A., Wingfield, B. D., & Wingfield, M. J. (2003). A review of the genus *Armylostereum* and its association

ISSN 0048 - 0134 (print)
ISSN 1179-5395 (on-line)

with woodwasps. *South African Journal of Science, 99,* 70-74.

Smith, D. R. (1996). Discovery and spread of the Asian horntail, *Eriotremex formosanus* (Matsumura) (Hymenoptera: Siricidae), in the United States. *Journal of Entomological Science*, *31,* 2116-117.

Viitasaari, M., & Midtgaard, F. (1989). A contribution to the taxonomy of horntails with notes on the genus *Sirex* Linnaeus (Hymenoptera, Siricidae). *Annales Entomologici Fennici, 55,* 103-110.

Work, T., McCullough, D., Cavey, J., & Komsa, R. (2005). Arrival rate of nonindigenous insect species into the United States through foreign trade. *Biological Invasions*, *7,* 323-332.

Zahid, M. (2008). Quarantine risks associated with solid wood packaging materials receiving ISPM 15 treatments. *Australian Forestry*, *71*(4), 287-293.

ISSN 0048 - 0134 (print)
ISSN 1179-5395 (on-line)