Reprinted from Australian Forestry, Vol. 53, No. 4 — Pages 266-270

10612.

D. A. Haugen[1] and M. G. Underdown[2]

[1] Department of Entomology, Waite Agricultural Research Institute, Glen Osmond, South Australia 5064.
[2] Woods and Forests Department, Jubilee Highway East, Mount Gambier, South Australia 5290.

Release of parasitoids for Sirex noctilio *control by transporting infested logs*

Revised manuscript received 8 October 1990

Aust. For., 1990, 53 (4), 266–270

Release of parasitoids for Sirex noctilio *control by transporting infested logs*

D. A. Haugen[1] *and M. G. Underdown*[2]

[1] Department of Entomology, Waite Agricultural Research Institute, Glen Osmond, South Australia 5064.
[2] Woods and Forests Department, Jubilee Highway East, Mount Gambier, South Australia 5290.

Summary

The Woods & Forests Department of South Australia released *Megarhyssa nortoni* by distributing infested logs throughout its southeastern region during October 1988. Logs were transported from a compartment known to have a high density of *M. nortoni* to 143 release sites. An estimated 18 000 female *M. nortoni* emerged from these logs from October to December.

Rhyssa hoferi, *Rhyssa persuasoria*, and *Schlettererius cinctipes* were found to be established in another plantation, but releases by transporting logs were not practical because densities of these species were too low. Techniques that may increase the parasitoid density within trees are suggested.

A strategy for releasing parasitoids should include log transport, in addition to the release of adult parasitoids obtained from insectary cultures or from field-collected logs.

Key words: *Sirex noctilio*, *Megarhyssa nortoni*, biological control, forest pest management.

Introduction

Sirex noctilio F. is a major pest of *Pinus radiata* plantations in Australia. Biological control of sirex was intensively investigated during the 1960s and 1970s under the auspices of the National Sirex Trust Fund. A world-wide search for natural enemies of siricids was conducted, and approved species were released in Australia (Taylor 1967, 1976, Bedding 1974).

The nematode *Deladenus siricidicola* Bedding, which sterilizes female sirex, is the key biological control agent in Australia (Bedding and Akhurst 1974, Neumann and Morey 1984). Nematodes can reach >90% infection in a sirex population within four years after introduction and lead to a collapse of a sirex outbreak (Taylor 1981, Neumann and Morey 1984).

Parasitoids also can have a substantial influence on sirex populations. Before nematodes were widely established in Tasmania, parasitoids reached levels that destroyed 60-80% of the sirex population (Taylor 1981). Taylor (1976) recommended a complex of parasitoid species with a diversity of species and geographic strains. The effectiveness of each species in regulating a sirex population is expected to vary with climatic conditions; therefore, each species should be released in sufficient numbers to give it a reasonable chance for establishment in each region. Five species, *Ibalia leucospoides* (Hochenwarth), *Megarhyssa nortoni* (Cresson), *Rhyssa hoferi* Rohwer, *Rhyssa persuasoria* (L.) and *Schlettererius cinctipes* (Cresson), were selected for field release in Victoria (Neumann *et al.* 1987). These species were originally selected to complement one another rather than compete for the same component of a sirex population (Taylor 1981).

Parasitoids for field release have been primarily obtained from insectary cultures. *Ibalia leucospoides* was more productive in culture than the other species (Neumann *et al.* 1987), so emphasis was placed on culturing it for release. From 1970-1985, 84% of parasitoids released in Victoria were *I. leucospoides*, while the other species had relatively minor to nominal releases (*M. nortoni* = 12%, *R. persuasoria* = 3%, *R. hoferi* < 1%, and *S. cinctipes* < 1% of parasitoids released) (Neumann and Minko 1981, Neumann *et al.* 1987). Insectary cultures of the parasitoids were discontinued during 1986 (Australian Forestry Council 1987), and *I. leucospoides* was supplied exclusively from field-collected logs held in cages. Also, *M. nortoni* was collected from a field population in northeastern

Revised manuscript received 8 October 1990

Victoria during 1987 for release in southwestern Victoria and southeastern South Australia (the Green Triangle region), in response to the sirex outbreak (Haugen and Underdown 1990).

Releases of each parasitoid species are needed as sirex invades new areas. Various tactics to produce these parasitoids should be assessed for their efficiency and reliability. This paper details a project in which *M. nortoni* was released by transporting field-collected logs containing larvae and pupae. Also, a survey was done to assess the feasibility of this method for releasing *R. hoferi, R. persuasoria*, and *S. cinctipes* within the Green Triangle region.

Release of *Megarhyssa nortoni* by log transport

Megarhyssa nortoni was found to be well established in a *P. radiata* plantation near Mount Gambier, South Australia during November 1987. This plantation was planted in 1967 and was thinned in 1979. Thirty-one male and 32 female *M. nortoni* were released there during November 1983. Sirex- associated tree mortality in 1987 was 10-20% of current stocking (i.e., 65-130 dead trees/ha). During October 1988, the Woods and Forests Department of South Australia (W&F) transported logs containing *M. nortoni* from this 'source' plantation to others throughout its southeastern region.

Planning phase

To plan this project, decisions and information were required on 1) the number and location of release sites, 2) the intended number of female *M. nortoni* to emerge at each site (i.e., release intensity), and 3) the density of *M. nortoni* in the logs.

1) Release sites — The distribution of *M. nortoni* in the southeastern region was estimated using the known establishments (emergences from monitoring cages and other confirmed sightings) in relation to previous release sites. Release sites for 1988 were selected in sirex-infested plantations outside the distribution of *M. nortoni* with approximately 2-3 km between sites. A total of 143 sites were selected.

2) Release intensity — A release intensity of 100 female *M. nortoni* per site was designated for this project. This intensity was greater than previous adult releases in the Green Triangle, which were 15-45 females per site (Haugen 1990), and greater than the recommendation of 40-60 females for release of adults (Haugen *et al.* 1990). A greater release intensity was prescribed for the log transport method because these parasitoids would emerge as adults during a 2-3 month period.

3) Parasitoid density — An estimate of the *M. nortoni* density (i.e., number of emerging females per linear metre of log) was required to calculate the number of logs to be deposited at each release site. Twenty-five logs, 0.8 m long, were collected from candidate trees (i.e., trees with sirex exit holes from the previous emergence period) in the 'source' plantation during the first week in August 1988. These samples were caged and placed in a heated room held at 25°C. Insect emergence was recorded weekly over the emergence period (22 August to 30 September). An average of 3.6 female and 22.3 male *M. nortoni* emerged per linear metre of log. The average yield from logs to be transported was expected to be lower because of less rigorous log selection. Further calculations were based on 2.5 females/m, and a minimum of 40 m of log was prescribed for each release site.

Implementation phase

Approximately 800 candidate trees were felled in the 'source' plantation with a feller-buncher. Tree felling with a chainsaw was considered too hazardous because these trees were prone to break while felling. Logs, 1.8 m long, were cut from these trees where exit holes were present. Logs were forwarded to an access road and loaded on a semitrailer for transport to release sites. At each release site, 25-30 logs were manually off-loaded and placed upright under the forest canopy. A total of 3660 logs (9 loads) were transported to the 143 sites during 12-21 October 1988.

Seven logs were randomly selected from each semitrailer load and placed in an insectary cage to estimate the *M. nortoni* emergence from the production logs. These 63 samples produced an average

Table 1: Cost of the project to redistribute *Megarhyssa nortoni* during 1899.

Item	Quantity	Cost ($)
Production of Logs		
Labour	62 worker days	6200
Feller-Buncher	15 machine hours	1500
Forwarder	36 machine hours	2200
Supplies		200
Transport and Distribution of Logs		
Labour	24 worker days	2400
Semitrailer	1500 km	1700
Miscellaneous		300
Total		14 500

of 2.8 female and 8.5 male *M. nortoni* per m of log. Thus, an average of 127 females and 390 males emerged from the logs at each release site (a total of 18 000 females). The main emergence period was from mid October to mid November. This project was completed at a cost of $14 500 (Table 1) or $0.80 per female *M. nortoni*.

Availability of other parasitoid species for log transport

Releases of *R. hoferi, R. persuasoria,* and *S. cinctipes* were minimal in the plantations of the Green Triangle prior to 1987 (Haugen 1990). Establishment of these species had not been detected in the Green Triangle before 1988. Allotments of these species were requested for release by W&F during 1987 and 1988; however, they were no longer available from the AFC Sirex Parasitoid Breeding Program (Australian Forestry Council 1987).

The only area in the Green Triangle where all three species had been released was at a CSR-Softwoods plantation near Dartmoor, Victoria (Table 2). A survey to determine establishment and density of these parasitoids in this plantation began during August 1988 by caging 42 logs, 1.2 m long. All three species emerged, but they were at low densities (Table 3). These sample logs had 1082 exit holes prior to caging that were estimated to be 676 sirex, 363 *I. leucospoides*, and 43 short-life-cycle *M. nortoni* based on emergences during January-April 1988 from this plantation (CSR-Softwoods, unpublished data). Therefore, total adult emergences were

Table 2. Summary of the five species[1] of parasitoids released, by number of release sites (RS) and number of females (♀♀), at the Dartmoor plantation prior to 1987.

	IL		MN		RH		RP		SC	
Year[2]	RS	♀♀	RS	♀♀	RS	♀♀	RS	♀♀	RS	♀♀
77/78	5	718	3	90	0	0	1	9	0	0
78/79	1	206	1	33	0	0	1	29	0	0
79/80	5	547	1	13	0	0	2	25	0	0
80/81	3	694	1	18	1	14	1	24	0	0
81/82	2	270	0	0	0	0	0	0	0	0
82/83	0	0	0	0	1	18	0	0	1	18
83/84	0	0	0	0	0	0	0	0	0	0
84/85	0	0	0	0	0	0	0	0	0	0
85/86	1	294	0	0	0	0	0	0	0	0

[1] IL = *Ibalia leucospoides*, MN = *Megarhyssa nortoni*, RH = *Rhyssa hoferi*, RP = *Rhyssa persuasoria*, SC = *Schlettererius cinctipes*.
[2] October to April.

Table 3. Parasitoid emergence, by species[1] and sex, from 42 logs collected at the Dartmoor plantation on 10 August 1988.

Week	MN		RH		RP		SC		RL	
Ending[2]	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
23 SEP	0	0	0	0	1	0	0	0	0	0
30 SEP	5	0	0	0	2	0	0	0	0	0
07 OCT	13	1	0	0	0	0	0	0	0	0
14 OCT	35	8	0	0	1	0	0	0	0	0
21 OCT	28	16	0	0	0	1	0	0	0	0
28 OCT	28	65	0	0	0	1	0	0	0	0
04 NOV	12	50	0	0	0	0	0	0	0	0
11 NOV	1	15	0	0	0	0	1	0	0	0
18 NOV	0	4	0	0	0	0	9	1	0	0
25 NOV	1	1	0	3	0	1	19	3	0	1
02 DEC	0	0	3	3	0	0	2	4	0	1
09 DEC	0	0	0	0	0	0	2	6	0	0
16 DEC	0	0	0	0	0	0	0	3	0	0
23 DEC	0	0	0	0	0	0	1	2	0	0
30 DEC	0	0	0	0	0	0	1	0	0	0
Total	123	160	3	6	4	3	35	19	0	2

[1] MN = *Megarhyssa nortoni*, RH = *Rhyssa hoferi*, RP = *Rhyssa persuasoria*, SC = *Schlettererius cinctipes*, RL = *Rhyssa lineolata*.
[2] no emergence from 10 August to 16 September.

estimated to be 47.0% sirex, 25.3% *I. leucospoides*, 22.7% *M. nortoni*, 3.8% *S. cinctipes*, 0.6% *R. hoferi*, 0.5% *R. persuasoria* and 0.1% *Rhyssa lineolata* (Kirby). Emergence periods of *M. nortoni*, *R. persuasoria*, and *S. cinctipes* (Table 3) were consistent with results from Tasmania (Taylor 1981) and Victoria (Neumann *et al.* 1987). The emergence of *R. hoferi* was the first indication of an established field population in Australia.

The emergence of *R. lineolata* from these logs is noteworthy. No releases of this species had been recorded in Victoria (Neumann *et al.* 1987) or South Australia (Haugen 1990). It was released in Tasmania, and a culture was consigned to the Foresry Commission of Victoria (Taylor 1976). However, it was not one of the five species retained in culture by the AFC Parasitoid Breeding Program after 1978 (Australian Forestry Council 1978).

Discussion

The number of *M. nortoni* released by transporting logs during 1988 was considerably greater than past production from insectary cultures. The AFC Parasitoid Breeding Program had produced a total of 5600 female *M. nortoni* for release during 1977-1986 compared to the 18 000 females for this project in one year. This redistribution project was relatively inexpensive at $0.80/female, whereas the estimated production cost was $5.00/female for the AFC Parasitoid Breeding Program in 1988 (P. Andrew, pers. comm.).

A one-year project to introduce *M. nortoni* throughout W&F's southeastern region was completed because large quantities of logs containing this parasitoid were available and many sirex-infested plantations did not have an established population of *M. nortoni*. Ideally, parasitoid releases should occur within two years after the detection of sirex in a locality (Haugen *et al.* 1990), so the parasitoids can become well established before sirex can reach outbreak levels.

Transportation of logs from the Dartmoor plantation to release *R. hoferi*, *R. persuasoria*, and *S. cinctipes* was not practical because these parasitoids were at low densities and few candidate trees were available. The density of a species would probably need to be > 0.5 females/m for this to be a viable option. Options for increasing the sirex density, and thus the parasitoid density, include installing a trap tree system (Neumann *et al.* 1982, Neumann and Morey 1984) and placing unmated female sirex with glued wings on these trees (Coutts 1965, Dolezal 1967). Furthermore, a 'field insectary' could be developed to produce a specific group of parasitoids (e.g., *R. hoferi*, *R. persuasoria*, and *S. cinctipes*). A small isolated plantation should be selected to release these species without competition from the other biological control agents. The parasitoid populations can be fostered by installing trap trees and adding female sirex to these trees. After a few years, the parasitoid species can be redistributed in logs or collected from caged logs.

A release strategy should include the following options for obtaining parasitoids:

- insectary cultures to supply adults for release,
- field-collected logs held in cages to supply adults for release, and
- logs containing larvae and pupae for transporting to release sites.

Insectary cultures are the only option until a parasitoid species is readily retrievable from a field population. Field-collected logs can supply the quantities for release once a parasitoid is well established in a plantation. The decision between transporting logs or releasing adults obtained from caged logs should be based on the efficiency of each method for the current situation in a region.

Acknowledgments

We wish to express appreciation to P. Andrew for providing release data from the AFC Sirex Parasitoid Breeding Program. Particular appreciation is due to CSR-Softwoods for access to their Dartmoor plantation. We are grateful to P. Andrew, A. Keeves, and K. L. Taylor for commenting on an earlier draft of this manuscript. Sirex research by the senior author is supported by a grant from the Woods & Forests Department.

References

Australian Forestry Council (1978) — Situation report for National Sirex Committee. In 'Annual Report of Forest Pests and Diseases Committee', 4 April 1978, Launceston.

Australian Forestry Council (1987) — Review of the sirex program and the future of the program. State Forests and Lands Service, Victoria. In 'Annual Report of Forest and Forest Products Pests and Diseases Committee', 24 June 1987, Canberra.

Bedding, R. A. (1974) — Five new species of *Deladenus* (Neotylenchidae), entomophagous-mycetophagous nematodes parasitic in siricid woodwasps. *Nematologica* **20**: 204–225.

Bedding, R. A. and Akhurst R. J. (1974) — Use of the nematode *Deladenus siricidicola* in the biological control of *Sirex noctilio* in Australia. *J. Aust. ent. Soc.* **13**: 129–135.

Coutts, M. P. (1965) — *Sirex noctilio* and the physiology of *Pinus radiata*. Some studies of interactions between the insect, the fungus, and the tree in Tasmania. Forestry and Timber Bureau, Australia, Bull. No. 41. 79 pp.

Dolezal, J. E. (1967) — Some observations on behaviour of *Sirex noctilio* when used for artificial attack on *Pinus radiata*. *Aust For. Res.* **2**(4): 26–30.

Haugen, D. A. (1990) — Control procedures for *Sirex noctilio* in the Green Triangle: Review from detection to severe outbreak (1977-1987). *Aust. For.* **53**: 24–32.

Haugen, D. A. and Underdown, M. G. (1990) — *Sirex noctilio* control program in response to the 1987 Green Triangle outbreak. *Aust. For.* **53**: 33–40.

Haugen, D. A., Bedding, R. A., Underdown, M. G. and Neumann, F. G. (1990) — National strategy for control of *Sirex noctilio* in Australia. *Aust. Forest Grower* **13**(2): Special Liftout Section No. 13. 8 pp.

Neumann, F. G. and Minko G. (1981) — The sirex wood wasp in Australian radiata pine plantations. *Aust. For.* **44**: 46–63.

Neumann, F. G. and Morey J. L. (1984) — Influence of natural enemies on the Sirex wood wasp in herbicide-treated trap trees of radiata pine in north-eastern Victoria. *Aust. For.* **47**: 218–224.

Neumann, F. G., Harris, J. A., Kassaby, F. Y. and Minko G. (1982) — An improved technique for early detection and control of the sirex wood wasp in radiata pine plantations. *Aust. For.* **45**: 117–124.

Neumann, F. G., Morey J. L. and McKimm, R. J. (1987) — The sirex wasp in Victoria. Department of Conservation, Forests and Lands, Victoria, Bulletin No. 29. 41 pp.

Taylor, K. L. (1967) — The introduction, culture, liberation, and recovery of parasites of *Sirex noctilio* in Tasmania, 1962-67. Australia CSIRO Div. Entomol. Tech. Paper No. 8. 19 pp.

Taylor, K. L. (1976) — The introduction and establishment of insect parasitoids to control *Sirex noctilio* in Australia. *Entomophaga* **21**: 429–440.

Taylor, K. L. (1981) — The sirex woodwasp: Ecology and control of an introduced forest insect. In 'The Ecology of Pests — Some Australian Case Histories'. (R. L. Kitching and R. E. Jones, eds), pp. 231–248. CSIRO, Melbourne, Australia.