RHYSSA LINEOLATA (HYMENOPTERA : ICHNEUMONIDAE), AS A PARASITE OF *SIREX NOCTILIO* IN NEW ZEALAND

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ABSTRACT

Rhyssa lineolata (Kirby), a native of North America, was found in New Zealand in 1955. It parasitises **Sirex noctilio** F. and was initially the most plentiful rhyssine emerging from logs taken from forests in which it had been found. Although the total level of parasitism appears unchanged, **R. lineolata** has since been almost completely superseded by the closely related **Rhyssa persuasoria** (L.). Adult **R. persuasoria** begin emerging a few weeks earlier than **R. lineolata**, and this seems to give them a competitive advantage.

Between 1959 and 1964 **R. lineolata** was liberated in nine forests but has not yet been recovered from any of them. It has, however, spread naturally to five forests in the southern half of the North Island. The furthest of these are 240 km apart.

R. lineolata was exported to Tasmania in 1962 for insectary breeding and field release.

INTRODUCTION

The North American ichneumonid *Rhyssa lineolata* (Kirby) was first reported in New Zealand by Zondag and Nuttall (1961). Established in Hawke's Bay, it had probably entered the country accidentally in imported timber. It was found in both Esk and Gwavas forests in 1958, and the following year was shown to parasitise *Sirex noctilio* F. The first discovery reported was at Esk (25 November 1958, M. A. Stoodley), but following publication of this record a female *R. lineolata* captured near Esk on 24 December 1955 was given to the Forest Research Institute (FRI) by its collector, Dr J. S. Armstrong of Taupo. This is the earliest known specimen, although it was not identified as *R. lineolata* at the time.

The behaviour of *R. lineolata* is similar to that of the well-established *Rhyssa persuasoria* (L.) which was introduced 1928-29 and 1931 (Miller and Clarke, 1935). In spring and early summer females drill their ovipositors into wood to paralyse and then lay eggs on *Sirex* larvae. After hatching, the *Rhyssa* larvae consume their hosts and then remain quiescent until the following spring when, after pupation, adults emerge from the wood. At 24°C rhyssine eggs hatch in 2 days, the fifth and final instar is reached 9 days later, and feeding can be completed in a further 5 to 10 days (Spradbery, 1968a). Adult *R. persuasoria* feeding on naturally occurring honeydew were found to have a mean life span of 62 days for males and 52 days for females (Hocking, 1967).

To obtain specimens of *R. lineolata* and assess parasitism, logs of radiata pine (*Pinus radiata* D. Don) found to contain rhyssine larvae were collected in the FRI outdoor insectary before the spring flight season. The logs also contained larvae of *Guiglia schauinslandi* (Ashmead), a native orussid occasionally parasitic on *Sirex*. Larvae of *Sirex* which had remained more than one year in the wood were also present, and in later collections there were a few *Ibalia leucospoides* Hochenwarth. This ibaliid, which flies in summer and parasitises eggs or very young larvae of *Sirex*, was released in Esk and Gwavas forests in 1959 and was recovered from Esk in 1961 and Gwavas in 1962 (Nuttall, 1972). As most of the *Sirex* and *Ibalia* originally in the trees had emerged in the summer prior to collection, the logs showed many exit holes. After the emerging *Sirex* and parasites had been counted, the *R. lineolata* were used for breeding, release in forests, or export to Tasmania. This paper gives details of these activities, discusses the effect of *R. lineolata* and *R. persuasoria* upon each other, and records the present known distribution of *R. lineolata* in New Zealand.

INSECTARY EMERGENCE AND CULTURING

The emergence from logs collected in Esk and Gwavas in the years following the discovery of *R. lineolata* is given in Table 1. It will be seen that in both forests there were marked declines in the numbers of *R. lineolata* and in its share of the total parasitism of *Sirex*.

TABLE 1—Rhyssine emergence from logs collected from Esk and Gwavas forests

		R. lineolata		R. persuasoria		Amount of parasitism by rhyssines due to:	
Forest	Year	Total	(% Males)	Total	(% Males)	R. lineolata	R. persuasoria
Esk	1959/60	319	(65)	138	(56)	70%	30%
	1960/61	274	(79)	224	(79)	55%	45%
	1961/62	115	(88)	394	(76)	23%	77%
	1962/63	210	(80)	3391	(75)	5.8%	94.2%
	1963/64	24	(71)	310	(60)	7.2%	92.8%
	1964/65	21	(81)	1418	(82)	1.5%	98.5%
Gwavas	1959/60	673	(56)	32	(88)	95.5%	4.5%
	1960/61	970	(74)	149	(75)	87%	13%
	1961/62	337	(78)	343	(82)	50%	50%
	1963/64	75	(76)	214	(69)	26%	74%

The degree of parasitism of *Sirex* was not determined for the 1959 logs (Zondag and Nuttall, 1961). However, exit holes made by adult *Sirex* and by parasites in logs collected in the four subsequent years were counted after insectary emergence had ceased. This gave an estimate of the number of *Sirex* larvae which had originally been present. The number of exit holes equals the number of *Sirex* larvae, less those which die in the wood without being parasitised. The rhyssines and *G. schauinslandi* which

had emerged were each expressed as percentages of the total exit hole count, and Table 2 shows the amount of *Sirex* parasitism which could be credited to each species. The amount of multiple parasitism (when an individual host is attacked more than once by one or more species of parasite) or hyperparasitism (when one parasite attacks another parasite) occurring amongst the two *Rhyssa* species and *Guiglia* could not be determined. However, only one adult parasite has been known to emerge after multiple parasitism or hyperparasitism, and therefore the percentages show the final amount of parasitism for which each of the species was responsible. The number of *I. leucospoides* either present within the *Sirex* larvae when these were attacked by rhyssines, or parasitised when they were free in the wood, is not known. Hyperparasitism of *Ibalia* by *R. persuasoria* has been described by Chrystal (1930) and Hanson (1939).

TABLE 2—The percentage of **Sirex** larvae parasitised by rhyssines and **Guiglia schauinslandi** in logs collected from Esk and Gwavas forests

Forest	Year	**R. lineolata**	**R. Persuasoria**	**G. schauinslandi**	Total
Esk	1960/61	13.0%	10.6%	4.6%	28.2%
	1961/62	3.5%	11.8%	1.2%	16.5%
	1962/63	3.2%	52.2%	0.8%	56.2%
	1963/64	3.3%	42.1%	1.2%	46.6%
Gwavas	1960/61	38.5%	5.9%	0.3%	44.7%
	1961/62	17.6%	17.9%	0.9%	36.4%
	1963/64	12.4%	35.4%	0.3%	48.1%

In 1959, 310 of the emerging female *R. lineolata* were released on *Sirex*-infested radiata pine logs in another compartment of the insectary and the following year 238 males and 29 females emerged. In 1960, 100 female *R. lineolata* were used for culturing and these gave rise to 241 progeny (211 males and 30 females). Because of such poor returns insectary culturing was discontinued. Rhyssines have a haplo-diploid method of sex determination with males occurring parthenogenetically and females developing from fertilised, diploid eggs. Although males had been present in the insectary compartment used for oviposition, there was evidently insufficient mating to produce enough female offspring.

The peak insectary emergence of *R. lineolata* females from logs collected in Esk and Gwavas forests was usually 3-5 weeks after that of *R. persuasoria.* Typical emergence patterns are shown in Fig. 1.

At one time it was thought that interbreeding had occurred between *R. persuasoria* and *R. lineolata* since some of the *R. persuasoria* emerging from the Esk and Gwavas logs had yellow coxal markings similar to those of *R. lineolata.* To obtain examples of *R. persuasoria* which had not been in contact with *R. lineolata,* logs were collected from three South Island forests. The emerging *R. persuasoria* had a range of yellow and brown coxal variations similar to those of *R. persuasoria* from Esk and Gwavas, thus

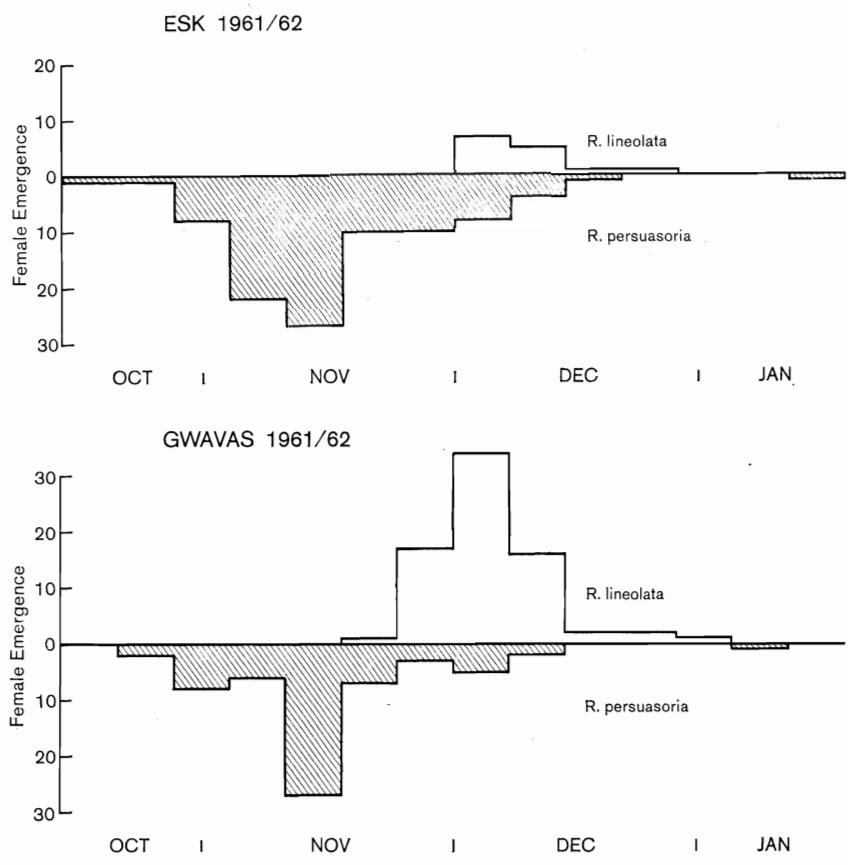

FIG. 1—Insectary emergence of female **R. lineolata** and **R. persuasoria** from logs, Esk and Gwavas forests in 1961/1962. The graphs are typical of the usual emergence pattern for these two rhyssines. Note the earlier start of **R. persuasoria** emergence and the difference in time between peaks.

showing that such variation occurs naturally within populations of *R. persuasoria,* and is not an indication of introgression with *R. lineolata.*

LIBERATION OF *R. LINEOLATA*

A total of 326 male and 331 female *R. lineolata* emerging in the insectary were released in nine forests during the period December 1959 to January 1964 (Table 3 and Fig. 2). The consignment to Golden Downs was delayed 6 days in the post and, of the 40 males and 40 females dispatched, only eight males and three females survived. All other consignments travelled well and although no oviposition was observed many of the insects were reported to be very active on release. No liberations were made in 1964/65 owing to insufficient numbers emerging in the insectary (Table 1). After this time no logs were collected from Esk and Gwavas, owing to the scarcity of *Sirex*-attacked trees in these forests, and the concentration of insectary resources on other parasites recently imported from overseas (Nuttall, 1967; 1970).

Presumably *R. lineolata* originally established itself in New Zealand from a small emergence from imported timber. The numbers released, therefore, with the exception of those at Golden Downs, should have been sufficient to achieve establishment. However, in the years since liberation no *R. lineolata* have been seen flying in any of the nine forests concerned nor were there any emergences from check logs brought to FRI from six of the forests. By comparison *R. persuasoria* became established after less than 200 females were placed in the field (Miller and Clark, 1937).

TABLE 3—Liberation of **R. lineolata** in New Zealand

Conservancy	Forest	Compartment	Date	Males	Females
Auckland	Maramarua	1 & 2	24.12.63	15	11
	"	2	10. 1.64	5	12
	Waipoua	5	30.11.61	53	34
	Waitangi	3	23.12.59	26	31
	Woodhill	64	23. 1.61	50	52
Rotorua	Kaingaroa	19	7. 2.61	8	15
	Rotoehu	33	6. 1.61	76	75
	Tahorakuri*	Kaimanawa Rd.	28.12.60	66	75
Nelson	Golden Downs	39	18.12.61	8	3
Canterbury	Hanmer	16	20.12.61	19	23
			TOTAL	326	331

* N.Z. Forest Products Ltd, Tahorakuri Blk. All others are State Forests.

EXPORT TO TASMANIA

To assist with the biological control of *S. noctilio* in Tasmania, 53 male and 30 female *R. lineolata* were shipped to the Hobart insectaries of the CSIRO in December 1962. These insects were used for insectary culture and field release (Taylor, 1967). A few *R. lineolata* were recovered from the field in the years 1963-65 (Taylor, 1967) but none has been found since (Taylor, pers. comm.).

KNOWN DISTRIBUTION OF *R. LINEOLATA* IN NEW ZEALAND

The earliest records, Esk 1955 and Gwavas 1958, were followed in 1965 by sightings and capture of the insect in the plantations of Hawke's Bay Forests Ltd, Waikoau. The first record outside the Hawke's Bay area came in December 1964, when a female was seen ovipositing in Compartment 15, Ngaumu Forest. Logs from the tree on which oviposition was observed yielded two male *R. lineolata* the following year. The latest record came in 1972 when six males emerged from logs which had been collected in Santoft Forest. (The numbers of *R. persuasoria* emerging from the same logs were: Ngaumu 15 males and four females, Santoft 13 males and one female.)

Thus *R. lineolata* has been recorded from widespread points in the southern half of the North Island (Fig. 2); it is not known to occur elsewhere in New Zealand.

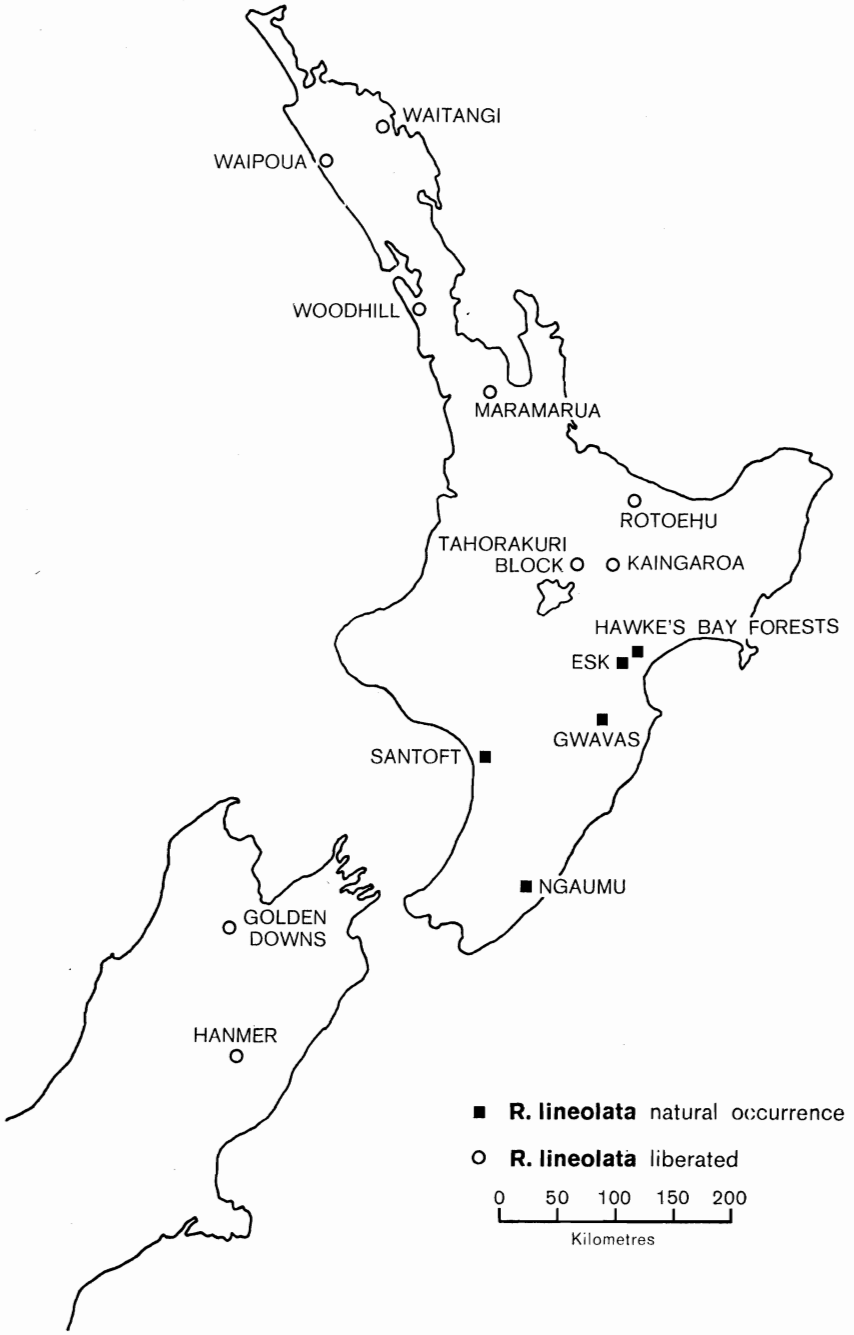

FIG. 2—New Zealand forests in which **R. lineolata** is known to occur, or in which it has been released.

DISCUSSION

The discovery of this parasite led to concern that a host insect of North American origin might also have became established. Although *S. noctilio,* a European species, is present in Ontario (Krombein, 1958) it seemed most likely that *R. lineolata* arrived on a host not previously recorded in New Zealand. However, no such host was found in the 1959 collection of logs from Esk and Gwavas (Zondag and Nuttall, 1961), and none has emerged from any subsequent collection from these two forests. In the past 14 years, pine logs have been brought into the insectary from many other forests throughout the country for parasite breeding, but no host other than the well-established *S. noctilio* has emerged.

An interesting feature of the emergence data (Table 1) is the decline of *R. lineolata* and the corresponding rise in importance of *R. persuasoria.* At first it was thought from the high number emerging that *R. lineolata* was a more effective parasite than *R. persuasoria.* The predominance of *R. lineolata* could have been due to better detection of potential hosts than *R. persuasoria* or better adaptation to local climatic conditions. However, the later reversal of numbers in favour of *R. persuasoria* indicated that neither climate nor searching ability favoured one *Rhyssa* species more than the other.

Consideration of the direct effect of one species of parasite on another is relevant to an examination of the fluctuations in emergence. Owing to the later peak emergence of *R. lineolata* females (Fig. 1), it is possible that some *R. persuasoria* larvae already present in the wood could be parasitised by the *R. lineolata.* However, since *R. lineolata* was superseded it seems that hyperparasitism is not important. The difference in emergence times almost certainly favours *R. persuasoria.* The potential number of hosts for *R. lineolata* must be reduced by the earlier flying *R. persuasoria* parasitising many of the accessible *Sirex* larvae. In addition, since females of *R. persuasoria* are present earlier in the season than *R. lineolata,* eggs laid by *R persuasoria* hatch first, and if both rhyssines parasitise the same *Sirex* larva then the larva of *R. persuasoria* could destroy the *R. lineolata* egg during feeding on the host. Occasional damage to rhyssine eggs by *R. persuasoria* larvae when present on the same host has been observed by Spradbery (1968b). Hence competition for hosts and destruction of *R. lineolata* eggs may account for the predominance of *R. persuasoria* in the later collections of logs.

The initial high population of *R. lineolata* at Esk and Gwavas was presumably due to its being well established in or near to these forests before many *R. persuasoria* were present. If so, *R. lineolata* would have been able to take advantage of the increase in *Sirex* numbers, but *R. persuasoria* by its earlier emergence would gain supremacy in later years. There are no records of the parasite state in these forests prior to the discovery of *R. lineolata* in 1958. Attack by *Sirex* had only become evident in the preceding few years and both forests were young, Gwavas having been started in 1944 and Esk in 1950.

It might be thought that the difference in peak emergence times and consequent extension of the period when large numbers of female rhyssines are flying would result in more *Sirex* larvae being destroyed. However, although the predominance of *R. persuasoria* and *R. lineolata* varies the total amount of parasitism can remain fairly constant (Gwavas figures, Table 2). These parasites contribute towards control of *Sirex*;

what is important is the total number of *Rhyssa* in the forest, not which of the two species is more numerous.

CONCLUSION

Competition with *R. persuasoria* probably explains the insignificance of *R. lineolata* as a parasite of *Sirex* in New Zealand, and contrary to early indications it now seems unimportant in biological control. However, the presence of *R. lineolata* does not appear to affect the total rate of parasitism, and it might be useful should any collapse occur in the *R. persuasoria* population. Its present spread suggests that *R. lineolata* can persist even when *Sirex* numbers are low.

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