The Introduction, Culture, Liberation, and Recovery of Parasites of *Sirex noctilio* in Tasmania, 1962–67

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THE INTRODUCTION, CULTURE, LIBERATION, AND RECOVERY OF PARASITES OF *SIREX NOCTILIO* IN TASMANIA, 1962–67

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Summary

Intensive work on the biological control of *Sirex noctilio* began in Tasmania in spring 1962. *Rhyssa persuasoria* and *Ibalia leucospoides*, both introduced some years earlier from New Zealand by the Tasmanian Department of Agriculture, were found to be well established at the site of liberation. *Rhyssa persuasoria* has not been found outside the forest in which it was liberated, but *I. leucospoides* has already dispersed to areas at least 50 miles away.

Further introductions of these two species have been made from Europe since 1962 and in addition nine other parasite species have been imported. These came from north-west India, Europe, and western North America. Four species (*Rhyssa lineolata*, *R. himalayensis*, *Megarhyssa nortoni nortoni*, and *Ibalia ensiger*) have been liberated but it will not be possible to determine if they have become established before the spring and summer of 1967–68. Insectary rearing of *M. nortoni nortoni* and *I. ensiger* has been particularly successful and these two are regarded as the most promising of the new species introduced.

Ibalia leucospoides has been distributed to several sites in the north and on the west coast of Tasmania, and to Victoria; *I. ensiger* has been distributed throughout the *Sirex*-infested area of Victoria, and has been sent to New Zealand. *Megarhyssa nortoni nortoni* has been liberated at several sites in Victoria.

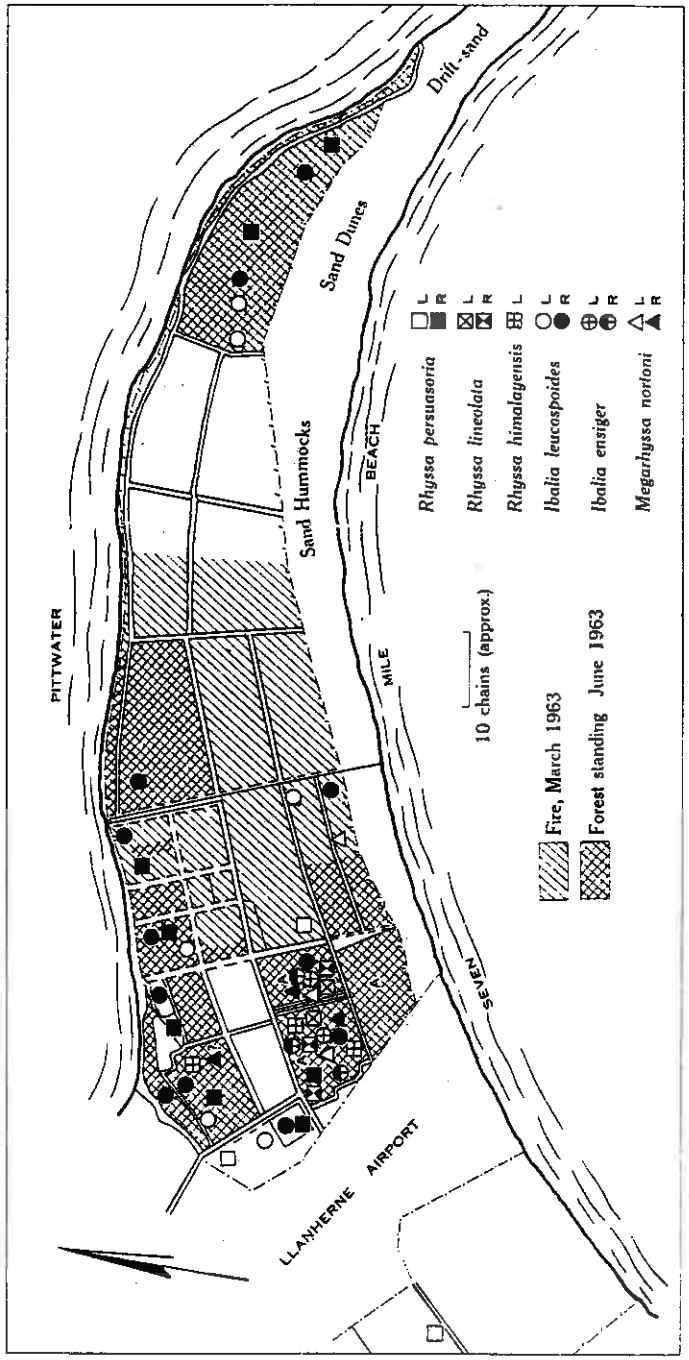
I. Introduction

Sirex noctilio F. was first discovered in a private plantation of *Pinus radiata* D. Don. at Pittwater, near Hobart, Tasmania in March, 1952 (Gilbert and Miller 1952). In view of the considerable mortality of *P. radiata* that the wasp had caused in New Zealand (Rawlings 1948; Rawlings and Wilson 1949) it was recognized as a potential threat to valuable plantations of this species in Australia.

Research workers in New Zealand were interested in the possibility of biological control of *S. noctilio* before it caused major damage, and following their request for parasites, research was carried out in England by Chrystal and Myers (1928*a*, 1928*b*), Chrystal (1930), and Hanson (1939). In the years 1928–31 *Rhyssa persuasoria* (L.) a larval parasite of several species of the Siricidae, was introduced into New Zealand (Miller and Clark 1935). Two years later Miller and Clark (1937) reported that it was successfully established.

Early attempts to establish *Ibalia leucospoides* (Hochenw.) in New Zealand were unsuccessful (Miller and Clark 1935) but in 1950 it was again introduced and reared successfully (Rawlings 1951, 1953). It was liberated first in 1954, and by 1957 was well established in New Zealand forests (Zondag 1959).

* Division of Entomology, CSIRO, Canberra.



1.—*Pinus radiata* plantation of Forestry Pulp and Paper Company at Pittwater, Tas., showing liberation and recovery points for parasites of *x noctilio*. "Recovered" symbols in regrowth blocks usually apply to the block as a whole. *A*, Regrowth areas; *L*, liberated; *R*, recovered.

After an initial period in which attempts were made to eradicate *Sirex noctilio* in Tasmania, the Tasmanian Department of Agriculture approached the New Zealand authorities (D.S.I.R. and the Forest Research Institute) for shipments of *R. persuasoria* and *I. leucospoides*. In November and December 1957 shipments of *R. persuasoria* were received (Anon. 1958), and after being checked for ectoparasites and disease, the insects were liberated in the plantation at Pittwater. In February 1959 and February 1960 shipments of *I. leucospoides* were received and liberated in the same plantation (Anon. 1959, 1960).

Rhyssa persuasoria was recovered from logs at Pittwater in 1959 and 1960–61, and *I. leucospoides* was recovered in 1960 from a log cut from one of the trees on which it had been liberated the year before (L. W. Miller, personal communication), but the establishment of both species remained uncertain up to the end of 1962.

In December 1961 *S. noctilio* was discovered in Victoria (Irvine 1962). This finding led to the establishment of the National Sirex Fund, and a programme of research covering many aspects of the problem was started. This paper describes the work which has been done in Australia on biological control up to the end of the summer of 1966–67, with particular reference to the establishment of the two species previously introduced, and to other species obtained since 1962 from various parts of the world. More detailed papers on aspects of their ecology will follow.

II. The Establishment and Dispersal of Rhyssa persuasoria and Ibalia leucospoides

Studies began at Hobart in the spring of 1962, and by the end of that year both parasite species previously introduced from New Zealand were found in logs collected in various parts of the Pittwater plantation. Numbers of *I. leucospoides* emerged during the summer, originating from nearly all collection points. The original liberations of *R. persuasoria* were in the main western block of the plantation (see Fig. 1). In 1962 this species was fairly numerous at the western end of the forest, but a limited sample indicated that its density was much lower in a block at the eastern end. This block was separated from the western block by a large area which had been clear-felled at about the time of liberation (Fig. 1). In 1963 and 1964 the density of *R. persuasoria* increased in the eastern block. Together with the fact that *R. persuasoria* has not been collected anywhere outside the Pittwater forest, this suggests that the females tend to remain within the forest, and will only spread a short distance without the assistance of man.

The density of *R. persuasoria* in the Pittwater forest has never been high, and it seems unlikely that it will be a very efficient parasite in the monoculture conditions which are usual in Australian *P. radiata* forests. Morgan and Stewart (1966) and Hocking (1967*a*) have demonstrated the importance of food on the longevity and egg-laying activity of the females, and suitable food (honeydew) appears to be present only in very small quantities on the few scattered eucalypts growing in and around the forest at Pittwater.

Sirex-infested logs have been collected at widely separated points in Tasmania

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Sirex-infested logs have been collected at widely separated points in Tasmania since 1962, and *I. leucospoides* has emerged from those collected at many localities in the south-east (see Fig. 2). The more distant of these localities from Pittwater, and

the years in which *I. leucospoides* was first recorded at each, are shown in Table 1. It is possible that *I. leucospoides* occurs between the Brighton–Campania and the

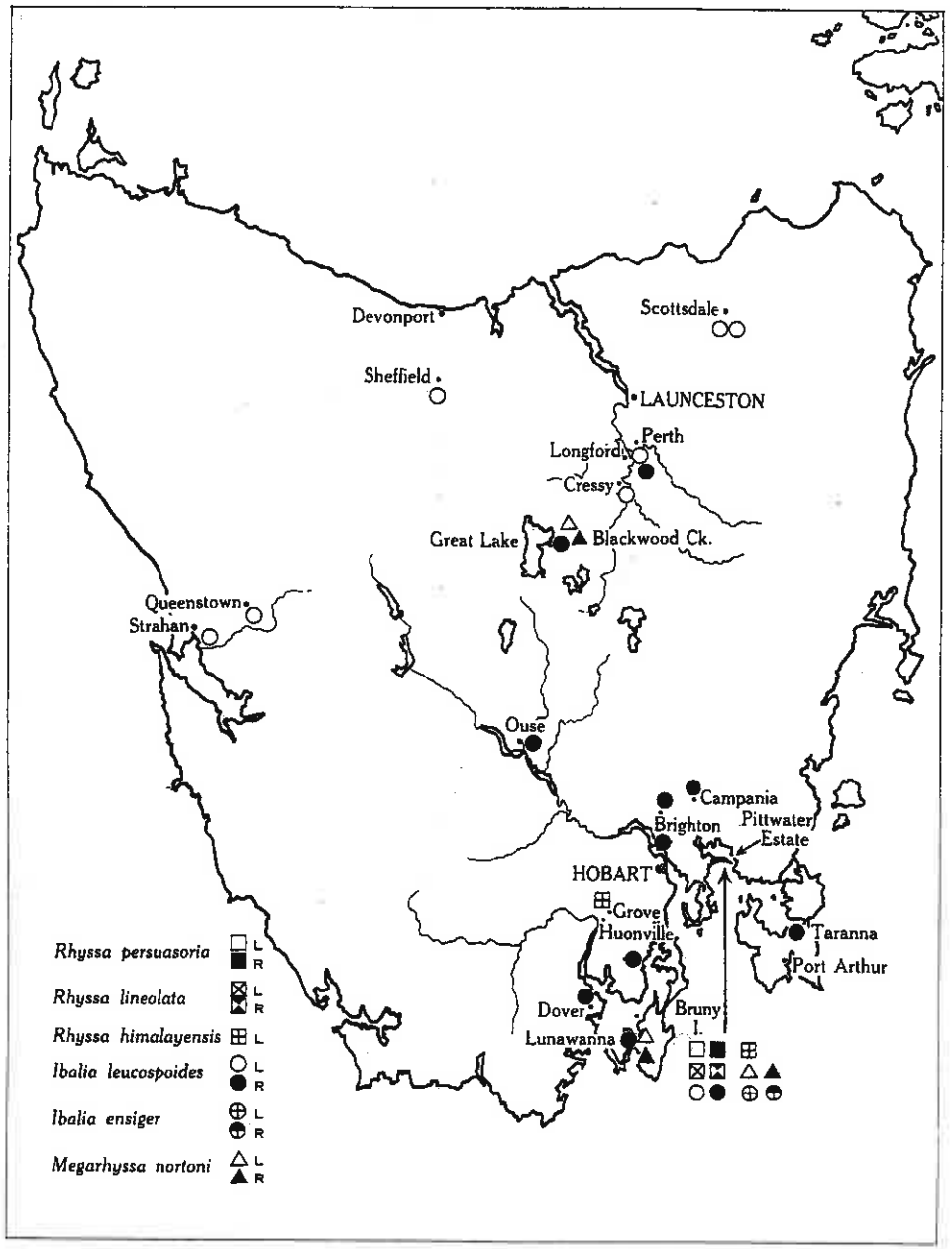

Fig. 2.—Tasmania, showing liberation (*L*) and recovery (*R*) points for parasites of *Sirex noctilio*.

Cressy–Perth areas, where it was liberated in 1963 and 1964, but no sampling has been done between the two areas.

These records show that *I. leucospoides* has spread from Pittwater and occupied most of the south-east quarter of Tasmania apparently without human assistance, in a relatively short time. Furthermore, in many of these localities, its density relative to that of *Sirex* was reasonably high when it was first discovered. Since 1962 *I. leucospoides* has been liberated at a number of sites in northern Tasmania, and at Queenstown and Strahan on the West Coast (see Table 4). It was recovered in 1966–67 at Blackwood Creek, 12 miles from Cressy, the nearest liberation site.

Stocks of *R. persuasoria* and *I. leucospoides* have been imported from New Zealand by the Forests Commission, Victoria since the discovery of *Sirex* in Victoria in 1962. Consignments of *I. leucospoides* were also imported from Hobart (see Table 5). Liberations of both species were made in an area directly east of Melbourne and in East Gippsland. *I. leucospoides* is known to be established in the former but not the latter area. *R. persuasoria* has not been recovered in either (Irvine, personal communication).

TABLE 1

RECOVERIES OF IBALIA LEUCOSPOIDES IN SOUTH-EASTERN TASMANIA

Locality	First Recorded	Approximate Distance from Pittwater (miles)	Direction from Pittwater
Lunawanna, South Bruny I.	1963	40	S.
Dover	1964	40	SSW.
Grove	1964	23	WSW.
Ouse	Jan. 1967	50	WNW.
Brighton	1964	18	WNW.
Campania	Jan. 1967	18	N.
Taranna, Tasman Peninsula	1964	23	SE.

III. Methods of Collection, Shipping, and Rearing

(*a*) *Collection*

There is an advantage in rearing parasites in an insectary, in that, if mating is ensured, the full reproductive life of the females can be availed of, whereas field-collected material has an unknown expectancy of reproductive life. Rearing is virtually obligatory if field populations are sparse, but if the insects are abundant and easily collected the disadvantage of lower mean reproductive life is unimportant. This is shown by the success achieved in the introduction of *Rhyssa himalayensis* Wilk. and *Megarhyssa nortoni nortoni* (Cresson).

The initial stocks of *R. himalayensis* came from siricid-infested logs caged at Srinagar, Kashmir. The collectors soon found, however, that they could obtain these insects readily in the field when they learned to recognize the trees attractive to them. The parasites were placed in mailing boxes as they were collected, and shipped in the same boxes (P. R. Dharmadhikari, personal communication).

Megarhyssa nortoni, *Rhyssa alaskensis* Ashmead, and *R. persuasoria* from North America were field-collected because when they were discovered in California and Nevada in 1964, facilities were not available for caging logs. Furthermore, large numbers of *M. nortoni* were available, and they were easily collected with the help of students in a nearby summer camp (E. A. Cameron, personal communication).

The entire imported stock of *Ibalia ensiger* Norton, *Rhyssa lineolata* (Kirby), and all species from Europe came from caged logs. There are formidable problems in collecting and transporting logs in Europe, but the populations of these insects there are too low for field collection of adult insects to have been rewarding.

(*b*) *Shipping*

All shipments from India were air-freighted in specially constructed boxes. The insects were provided with split raisins and wads of cotton wool moistened with sugar solution, and the boxes were lined with wet polyurethane plastic foam. The boxes were then wrapped in calico and in some instances a further covering of impervious paper was provided for part or all of the journey. Mortality was high in many of these shipments. In some of the early shipments it was due to lack of water, and in later shipments it may have been due to excessive humidity in hot weather. The 1963 shipments from California were also placed in mailing boxes, packed in vermiculite. Although some mortality occurred this method was fairly successful.

The simplest and most successful method was that used by the Sirex Biological Control Unit, CSIRO, at Silwood Park, in shipping parasites from England (Plate 1, Fig. 1). Expanded polystyrene flowerpots were used for all species. Water was provided in a small specimen tube, plugged by a cottonwool wick, which was inserted through a cork fitting into the hole in the bottom of the flowerpot. The cork also held in position a strip of rice paper partly smeared with honey. The top of the flowerpot was covered with fine mosquito net held firmly by rubber bands. This container was packed in a strong cardboard box and wrapped in brown paper. Mortality of parasites shipped in this way was very low, the only insects which died being very small individuals.

A modification of this method has been described by Cameron (1965). His shipments in 1964 by this method arrived with only slight mortality.

(*c*) *Insectary Rearing*

When work commenced in Tasmania, ample supplies of *Sirex*-infested logs for larval parasites (*Rhyssa* and *Megarhyssa* spp.) could be collected in the forest at Pittwater. Since 1963, however, the *Sirex* population there has fallen to a relatively low level, and it has been necessary to collect infested material throughout Tasmania. In the past 4 years the field-collected supplies have been supplemented by culturing *Sirex* in the insectary, and by importing infested logs from Victoria.

Sirex noctilio was cultured in the insectary by placing females on logs cut in the forest from the heads of trees felled for milling. The heads were left lying in the forest for varying periods, depending on the weather, to allow removal of water by transpiration to a point where the wood was dry enough for the development of *Sirex*. A rough estimate of moisture content was made by measuring and weighing each log, and this was usually checked by means of the oven-drying test. The optimum range of moisture content was 70–110% (of oven-dry weight) and logs falling outside this range were normally discarded. Some logs were obtained by using the New Zealand technique of lodging trees for a few weeks before cutting into sections (Zondag 1959, p. 2).

Culture logs prepared as above were frequently infected by blue stain fungi (e.g. *Ceratocystis* sp.) which are antagonistic to the symbiotic fungus (*Amylostereum chailletii* (Fr.) Boidin) associated with *S. noctilio*, and thus interfere with the development of *Sirex*. In order to reduce the incidence of this infection, the freshly cut ends, branch stubs, and any scars were painted with a suspension of a fungicide (Captan-Flit 406) especially if the logs were to be stored before exposure to *Sirex*.

It was found that although high numbers of *Sirex* reached maturity in the culture logs they were usually small insects. The larvae were large enough for culturing *Rhyssa* spp. in about half of the logs, but only a few contained very large larvae suitable for culturing *Megarhyssa* spp. Consequently, most field-collected material (naturally infested) was reserved for *Megarhyssa*.

Rhyssines received during the winter were examined first for mite infestation, and if free were placed on *Sirex*-infested logs in the warm rooms (*c.* 21°C). Most species were provided with a dilute solution of honey in water, so that water and food were continuously available on the surface of filter paper below an inverted glass container on a petri dish. *Megarhyssa* spp. will feed readily on blocks of candied honey supplied in open dishes, water being provided separately. Females normally live for at least 3 weeks under these conditions.

Ibalia spp. received during the winter require logs containing *Sirex* eggs about 14 days old. In the first year an attempt was made to rear female *Sirex* larvae in tubes, using the method described by Rawlings (1953). This method was abandoned, firstly because it was difficult and time-consuming to obtain sufficient large larvae, and secondly because the adults reared in this way were lethargic and did not oviposit actively. In later years female *Sirex* were obtained by incubating infested logs at about 26°C from about mid-April throughout the winter. The first adults emerged after about 8 weeks so that females were available from about the end of June. *Ibalia* spp. are usually not available in the Northern Hemisphere before the end of July. Initially, food (honey and split raisins) and water were provided for *Ibalia* spp., but feeding was rarely seen and both *I. leucospoides* and *I. ensiger* have oviposited effectively without food or water.

A small percentage of each generation of *R. persuasoria* and *M. nortoni* always emerges 3–4 months after oviposition, but between 80 and 90% of the progeny normally emerge the following spring. The larva of *R. persuasoria* consumes the host larva in 3–5 weeks and then normally enters diapause (Hocking 1967*b*). Attempts were made (Hocking, unpublished data) to break the diapause of *Rhyssa* and *Megarhyssa* spp. so that the progeny of adults received in autumn or winter would emerge in the following late spring or early summer, before the peak of *Sirex* emergence. As a result of her experiments, in 1964 logs were kept in the warm room for 5 weeks or more after oviposition and then placed in a cold room at 6–7°C for

12 weeks, after which they were kept under normal atmospheric conditions. Under this regime between 20 and 30% of the parasites emerged during the summer, and a few during the winter, but most of the remainder still did not emerge until the following spring. In subsequent years it was decided that there was little to be gained by trying to break the diapause, and all logs, after a period of 5–6 weeks in the warm room at 21°C following oviposition, were transferred to open insectaries under atmospheric conditions.

TABLE 2

SIRICID PARASITES INTRODUCED INTO TASMANIA SINCE 1962

Species	Origin	Year	No. of Shipments	Live Insects Received			Progeny to end of April 1967		
				♂	♀	Total	♂	♀	Total
Ibalia drewseni	Europe	1964	2	7	8	15	—	—	—
	Europe	1965	5	19	10	38	—	—	—
I. ensiger (Plate 3, Fig. 1)	U.S.A.	1963	5	67	49	116	145	59	204
I. leucospoides (Plate 3, Fig. 2)	England	1963	4	29	27	56	5	1	6
	Europe	1964	8	170	135	305	4	—	4
	Europe	1965	5	91	93	184	71	39	110
Megarhyssa emarginatoria (Plate 3, Fig. 5)	Europe	1964	4	30	42	72	11	8	19
M. nortoni nortoni (Plate 3, Fig. 3)	U.S.A.	1964	7	79	220	299	276	191	467
Rhyssa alaskensis (Plate 2, Fig. 6)	U.S.A.	1963	1	1	2	3	—	—	—
	U.S.A.	1964	5	?	7	?	4	9	13
R. amoena (Plate 2, Fig. 5)	Europe	1965	3	3	6	9	23	4	27
R. himalayensis (Plate 2, Fig. 3)	India	1963	10	14	90	104	80	13	93
	India	1963	11	(larvae)		193	—	—	—
	India	1964	9	65	206	271*	54	29	83
	India	1965	9	11	56	67	82	36	118
R. lineolata (Plate 2, Fig. 4)	N.Z.	1962	3	51	30	81*	533	29	562
R. persuasoria (Plate 2, Fig. 2)	England	1963	2	8	16	24	117	14	131
	Europe	1964	11	177	147	324	415	114	529
	U.S.A.	1964	5	?	6	?	1	4	5
	Europe	1965	4	163	184	337	515	76	591
	Spain	1964	1	—	2	2	—	—	—
Schlettererius cinctipes (Plate 3, Fig. 6.)	U.S.A.	1963	1	—	1	1	3	4	7

* Part of shipments liberated direct in field.

IV. PARASITES INTRODUCED SINCE 1962

Details of parasite introductions in the years 1962–65 are shown in Table 2. It will be seen that culturing has been satisfactory with only three species (*M. nortoni nortoni*, *I. ensiger*, and *R. persuasoria*) of which reasonably large numbers were received. Greater success was expected with *R. lineolata* which, coming from New Zealand, did not require acclimatisation but there were few females in the first generation and it is probable that not all of those originally received were mated.

Rhyssa himalayensis was received from India in large numbers for 3 successive years, and the females oviposited well in the warm room. The sex ratio in the first generation was satisfactory but the numbers have always been small in relation to the numbers of parent females. Furthermore, most of them have emerged in late summer and autumn, and some even in winter. Therefore it has been difficult to get sufficient females emerging in spring to establish a viable culture. Although this has been achieved numbers were still small at the end of the 1966–67 season.

The failure of *I. leucospoides* in 1963 can be partly explained by the fact that when the first shipments were received from England it was not realized that the females preferred to oviposit in *Sirex* eggs or larvae at least 14 days after *Sirex* oviposition. In 1964 most of the logs used for shipments from Europe were too wet for satisfactory development of *Sirex*. The emergence of 39 females in the progeny of the 1965 shipments should ensure a culture from European stock.

Although reasonable numbers of *Megarhyssa emarginatoria* Thunberg were received from Europe in 1964, the females displayed little interest in the logs provided; the logs contained plenty of large *Sirex* larvae, but numbers of *M. emarginatoria* emerging from them were very small.

The females of *Rhyssa amoena* Grav. received from Europe in 1965 tended to remain in the darker corners of the cubicle, and oviposition, which was rarely observed, seemed to occur more at dusk than in bright daylight.

Emergence of *R. alaskensis* Ashmead resulting from the 1964 shipments from California was quite high for the small number involved. Unfortunately, three of the four males emerged in autumn, and the fourth emerged in the following spring, at a later date than most of the females.

Ibalia drewseni Borries received from Europe in 1964 and 1965 was provided with logs containing *Sirex* eggs and newly hatched larvae, as well as some containing more advanced *Sirex* larvae. Some probing of oviposition drills was seen but no *I. drewseni* emerged. This species is possibly a hyperparasite on *Rhyssa* or *Megarhyssa* as its emergence in Europe coincides with that of the larval parasites, not with that of any siricid species (Wilson and Spradbery, personal communication). No further importations of *I. drewseni* will be made until further research on its biology has been done in Europe.

Only one female of *Schlettererius cinctipes* (Cresson) was received in 1963 from California, and no others have been received since. Little is known of this species but, being a stephanid, it is thought to be normally a parasite of wood-boring Coleoptera. The single female was provided with one log containing *Sirex* larvae and the resulting progeny consisted of three males and four females. This species has been reported in more detail elsewhere (Taylor 1967).

V. PARASITES CULTURED IN THE INSECTARY

Details of parasite culturing in the insectary from the progeny of original importations are shown in Table 3. They are compiled, in the main, from the principal stock cultures: they are not complete because in some instances females were used for experiments on diapause (*R. himalayensis*, *M. nortoni*); to determine

their effect on other species (*S. cinctipes*); or to compare their biology with that of other species (*I. ensiger*, *M. nortoni*).

Females of *R. lineolata*, *M. nortoni*, and *I. ensiger* were not all kept in the insectary for their full reproductive lives. Many of them, after a short period during which they oviposited in the insectary, were liberated in the field or shipped to other centres. Most species do not begin to oviposit until about a week after emergence. Thus keeping them in the insectary until a few days after they begin ovipositing has

TABLE 3

SIRICID PARASITES CULTURED IN THE HOBART INSECTARY SINCE ORIGINAL IMPORTATIONS

Species	Year	Parent Females		Emergences to end of April, 1967			
		No.	Origin	Year	♂	♀	Total
Ibalia ensiger	1965	59*	I†	1966	1117	728	1845
	1966	*c.*300	I	1967	4350	3021	7371
I. leucospoides	1966	>100	I	1967	1338	1141	2479
Megarhyssa emarginatoria	1965–66	7	I	1966	2	3	5
M. nortoni nortoni	1964–65	191*	I	1965	319	251	570 } 607
				1966	12	25	37 }
	1965–66	*c.*300*	I	1966	697	419	1116
	1966–67	*c.*400*	I	1967‡	53	31	84§
Rhyssa alaskensis	1965–66	8	I	1966	10	14	24
R. amoena	1966	3	I	—	—	—	—§
R. himalayensis	1963–64	*c.* 6	I	1964–65	not recorded		
	1964–65	*c.* 16	I	1965–66	79	27	106
	1965–66	32	I	1966	204	28	232
R. lineolata	1963	29*	I	1964	129	18	147
	1965–66	2	F‖	1966	9	2	11
R. persuasoria	1965–66	94	I and F	1966	607	153	760
Schlettererius cinctipes	1964	4	I	1965	31	23	54
	1965	23	I	1966	17	10	27

* Kept in insectary for short period of oviposition before field-liberation or shipping.
† Insectary.
‡ To 30.iv.67.
§ Emergence is continuing or further emergence is expected.
‖ Forest.

two advantages: (1) their progeny in the insectary provide a culture for the following year; and (2) they begin ovipositing as soon as they are liberated and therefore are not subjected to bird predation during an unproductive period.

The solitary male of *R. alaskensis* which emerged later than the females in the spring of 1965 was not seen to mate with any of them, and after prolonged attempts to induce mating, seven of the nine females were placed in a cage with the one male and with several logs containing *Sirex* larvae. Emergence from these logs in spring 1966 (10 males, 14 females) indicated that all or most females were in fact mated. The other two females were mated (with some difficulty) with males of *R. persuasoria* and later they oviposited on separate logs. No progeny emerged from these. The mating behaviour of *R. alaskensis* in 1966 was similar to that of *R. persuasoria*. It is known that males of *R. persuasoria* are not ready to mate until a few days after emergence, whereas females usually mate as soon as they emerge.

The second Australian generation of *Megarhyssa emarginatoria*, emerging in spring 1966, consisted of two males and three females (two of the latter when the last male was moribund). The first female, which was mated, did not oviposit actively, so it is unlikely that a culture will be established without further introductions.

TABLE 4

LIBERATION AND RECOVERY OF SIRICID PARASITES IN TASMANIA 1962–67

Species	Year	Locality	Liberations			Recoveries			Remarks
			♂	♀	Season	♂	♀	Total	
Ibalia ensiger	1965	Pittwater	32	27	Sum.	—	—	—	
	1966	Pittwater	265	209	Sum.	?	4	?	No males identified
	1967	Pittwater	—	—	—	28	22	50	
I. leucospoides	1963	Perth	67	58		—	—	—	
	1963	Cressy	308	227		—	—	—	
	1964	Longford	426	320		—	—	—	
	1964	Perth	419	289		emerged from tree on which liberated in 1963			
	1964	Cressy	67	71	Sum.	—	—	—	
	1965	Queenstown							
	1965	Strahan	188	234		—	—	—	
	1966	Scottsdale district	273	493		—	—	—	
	1966	Beulah	267	313		—	—	—	
	1967	Blackwood Ck.	—	—	—	9	6	15	
M. nortoni nortoni	1965	S. Bruny I.	0	73	Sum.	—	—	—	
	1965	Pittwater	4	38	Aut.	—	—	—	
	1965–66	Pittwater	134	150	Spr.–Sum.	—	3	3	Recovered autumn 1966
	1965	Blackwood Ck.	—	40	Spr.	—	—	—	Larva cut out of tree in spring 1966
	1966	Pittwater	—	—	—	34	18	52	From tree cages
						67	43	110	From field-collected logs
	1967	S. Bruny I.	—	—	—	3 larvae			Larvae cut out of tree in May 1967
Rhyssa himalayensis	1964	Grove	55	36	Aut.	—	—	—	
	1964	Pittwater	51	91	Aut.	—	—	—	
	1964	Pittwater	5	1	Spr.	—	—	—	
R. lineoloata	1962	Pittwater	0	8	Spr.	—	—	—	
	1963	Pittwater	398	30	Spr.	6	1	7	Recovered in field-collected logs
	1964	Pittwater	53	15	Spr.	3	1	4	
	1965	Pittwater	—	—	—	10	2	12	From tree cages and logs
	1966	Pittwater	—	—	—	—	—	—	
R. persuasoria (English strain)	1964–65	Pittwater	0	56*	Spr. & Sum.	cannot be identified			

* Includes 12 "local" females mated with males from culture of English strain.

A total of 14 males and three females of *Rhyssa amoena* emerged in the autumn and winter of 1966, and good emergence was expected in spring. However, this did not occur and the prospects of establishing a culture from the original shipments are not good.

Following the discovery of nematodes in *R. persuasoria*, *R. himalayensis*, and *R. amoena* in July 1965 (Hocking 1967*c*) the culturing technique was altered. As far

as possible all females of larval parasites, except *M. nortoni*, were placed on single billets (short logs), and the females were dissected when they died to check for nematode infection. If the female was infected, the billet on which it had worked was destroyed. The policy was adopted of liberating only the progeny of nematode-free females. The large numbers of *M. nortoni* made mass culturing of this species necessary. In the process, however, over 250 individuals were examined for the presence of nematodes, with negative results, and this species is considered free of infection.

TABLE 5

SIRICID PARASITES DISTRIBUTED FROM TASMANIA 1962–67

Species	Year	Shipped to:	Number Shipped			Use
			♂	♀	Total	
Ibalia ensiger	1966	Rotorua, N.Z.	112	100	212	Culturing
	1967	Victoria	351	275	626	Culturing
	1967	Rotorua, N.Z.	200	200	400	Culturing (50) and liberation
	1967	Victoria	2659	2389	4848	
I. leucospoides	1963	Victoria	1243	815	2058	Liberation at various sites; metropolitan and east Gippsland areas
	1964	Victoria	3471	2314	5785	
	1965	Victoria	465	320	785	
	1967	Victoria	282	276	558	
M. nortoni nortoni	1965	Victoria	25	102	127	Culturing
	1966	Victoria	0	370	370	Liberation metropolitan (230) east Gippsland (140) areas
R. himalayensis	1966	Victoria	11	11	22	Culturing
R. persuasoria	1966	Victoria	61	61	122	Culturing

Prior to 1965 no screening for nematodes was done, and it is possible that infected females of *R. persuasoria* and *R. himalayensis* were liberated.

VI. Liberation and Distribution of Parasites

Tables 4 and 5 show details of parasites liberated in the field or distributed to other centres from Hobart.

Although *R. persuasoria* was already well established in the forest at Pittwater, further liberations were made in 1964–65 of the progeny of individuals imported from England. These were either English females mated with English males, or females emerging from logs collected in the forest (referred to as "local" females) mated with English males. *Rhyssa persuasoria* has not yet been liberated at any other locality in Tasmania, so that its ability to disperse without human assistance can be studied.

It has been possible to collect only small quantities of infested material from Grove and Bruny I. since parasites were liberated there. So far, *R. himalayensis* has not been recovered in Tasmania. On Bruny I. at the time [illegible]

in 1965, only a few infested trees were evident, so others were lodged in an attempt to attract *Sirex* and thus provide infested material for the parasites if they emerged the following year. This was done again in the next season. *Sirex* density in the area is low, but it is expected to increase as a result of fires in February 1966, because scorched trees are known to be attractive to *Sirex*. *Megarhyssa* larvae were recovered in May 1967 from infested trees on Bruny I. which indicates that it is established there.

No further liberations of any of these species were made in Tasmania during the 1966–67 season and this will provide an opportunity to study their ability to establish themselves. Sampling is being carried out in many areas, either by collecting billets for storage in the insectary, or, in three study areas, by fixing cages on the trees (Plate 1, Figs. 2, 3, and 4).

VII. Discussion

It is clear that *I. leucospoides* can disperse rapidly and over quite long distances. Once it reaches a new area, its numbers build up rapidly. There is little doubt that *I. ensiger* will also disperse well, so that it should only be necessary to establish these two species at a few key points. On the other hand, present indications are that *Rhyssa* spp., and probably *Megarhyssa* spp., will have to be distributed to all *Sirex*-infested forests, even when they are separated by only a few miles.

There is some evidence in Europe that *I. leucospoides* is a more important parasite than *R. persuasoria* in the drier sites (E. Schimitschek, personal communication) and its relatively greater success at Pittwater, where the rainfall is low, indicates that this is so.

The efficiency of *R. persuasoria* might be expected to increase considerably in higher rainfall areas, particularly in the presence of other plant species, preferably broad-leaved, which support a reasonably high population of honeydew-producing insects. The same is likely to apply to all species of *Rhyssa* and *Megarhyssa*, but no doubt there is considerable variation in their ability to search for food.

Collections in Europe have shown that *Sirex noctilio* is the dominant siricid species in the Mediterranean region, where also *Pinus* spp. are more common than other conifers (Wilson and Spradbery, personal communication). Although the two parasite species established in New Zealand (*R. persuasoria* and *I. leucospoides*) were obtained from England, they have a wide range in Europe, extending to the Mediterranean, and are obviously adapted to a wide range of host siricids in a variety of conifers.

The two Californian species (*M. nortoni nortoni* and *I. ensiger*) which have been so successful in the insectary at Hobart came from a region with a climate similar to that of eastern Australia, and one in which *Pinus* spp. were the predominant conifers. *Rhyssa alaskensis* and *Schlettererius cinctipes*, although obtained in only small numbers from the same forests, have performed well in culture, and are likely to be useful parasites.

The reasons for the failure of *M. emarginatoria* and *R. amoena* are still obscure. Their biology in Europe is being studied. Shipments from Europe in 1967 will go to Rotorua, N.Z., where conditions might be more favourable for them.

Efforts are still being made to obtain parasites from Japan and Canada which represent different climatic zones. Like *R. himalayensis*, the parasites from these countries may not adapt themselves readily to conditions in Tasmania. However, although *Sirex* at present occurs mainly at low altitudes in Tasmania and Victoria it may later spread to higher altitude forests, where parasites from cooler climates could prove to be more successful.

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Appendix

Identification of Introduced Parasites of Sirex noctilio

Plates 2 and 3 have been included to facilitate the recognition of these parasites. It is emphasized, however, that some native parasitic Hymenoptera superficially resemble the imported species, and it is always advisable to collect specimens for expert examination. It is also important to remember that in most species there is considerable variation in the colour patterns, and in some instances even a specialist cannot identify an individual specimen with certainty. This is particularly so when specimens are very small. The range of size in *S. noctilio* and all its introduced parasite species is very great. For example, males of both *Sirex* and *Rhyssa* spp. can vary in length from about 0·5 to 1·5 in.

The following notes, used in conjunction with the photographs, will help to indicate the important characters of each species.

(i) *Ibalia* spp. (Plate 3, Figs. 1 and 2)

This genus is easily recognized. The ovipositor is not normally visible in a resting insect, being retracted inside the abdomen. The abdomen in both sexes is laterally compressed and the adult insects seldom exceed 0·75 in. in length. For tentative identification of the species in the field, a useful guide is that both sexes of *I. ensiger* usually have a light brown abdomen, whereas the abdomen of *I. leucospoides* is usually dark brown. The female of *I. ensiger* has a dark brown patch on the upper margin of the abdomen towards the apex, and this is a fairly reliable character.

(ii) *Megarhyssa* spp.

The ovipositor is distinctly longer than the body, and the average size of these insects is greater than in any other genus. During oviposition the tips of the ovipositor sheath remain on the bark surface and the sheath is folded back as the ovipositor is inserted (Plate 3, Fig. 4). The expansion of the last abdominal segment (Plate 3, Fig. 3) at the beginning and end of oviposition is also characteristic of *Megarhyssa*. The males have a long, thin, shiny abdomen of uniform thickness.

Megarhyssa nortoni nortoni (Plate 3, Fig. 3).—This subspecies is reddish brown, black, and yellow; the lateral spots on the abdomen of the female are oval and yellow; and the legs are light brown, black, and yellow.

Megarhyssa emarginatoria (Plate 3, Fig. 5).—This species is mostly black and white; the lateral spots on the abdomen of the female are white, elongate, and irregular in shape; and the legs are reddish brown.

(iii) *Rhyssa* spp.

The ovipositor in this genus is about as long as the body, or slightly longer. During oviposition the ovipositor sheath usually springs back from the bark surface to its normal position (see Plate 2, Figs. 2 and 4). The males have an elongated pear-shaped abdomen. It is emphasized that very small males of *Rhyssa* spp. lack many of the distinguishing characters.

Rhyssa lineolata (Plate 2, Fig. 4) and *R. amoena* (Plate 2, Fig. 5).—The females of these two species always have white bands on the antennae, which distinguishes them from other species of *Rhyssa*. The dark portions of the antennae are black or dark brown in *R. lineolata*, whereas in *R. amoena* they are usually a lighter brown. The white bands are present in all except very small males of *R. lineolata*. They are normally not distinct in *R. amoena* males, although the lighter brown antennae, as in the females, makes them fairly easy to recognize.

Rhyssa persuasoria (Plate 2, Fig. 2).—The female of this species normally has two white spots on the last abdominal segment. All other species have a narrow white band on this segment, although occasionally it is broken into two spots in individ ual specimens. Sometimes in *R. persuasoria* the spots are fused into one band, and sometimes the spots are almost entirely lacking. In such cases it is necessary to examine the coxae (the basal segments of the legs) which in this species are coloured in various combinations of light brown and white, sometimes without any white.

Rhyssa himalayensis (Plate 2, Fig. 3).—Both sexes normally can be easily recognized by a white spot on the back of the thorax. This is often absent in small specimens, and the black-and-white colour of the coxae is a useful additional character in this species (see also *R. alaskensis*).

Rhyssa alaskensis (Plate 2, Fig. 6).—Unlike the two previously described species, *R. alaskensis* has no distinctive character for field use. Females have a continuous white band on the last abdominal segment, but the coloration of the coxae varies from black and white to brown and white.

In short, *R. persuasoria*, *R. himalayensis*, and *R. alaskensis* can easily be separated if the main distinguishing characters are clear, as they usually are in medium-sized or large specimens. If the specimens are small (say less than 0·75 in. body length) any identification should be regarded as merely tentative.

(vi) *Schlettererius cinctipes* (Plate 3, Fig. 6)

This parasite species is easy to recognize. The ovipositor is very long, and about one-third of the sheath towards the tip is white; the legs are short; and the head is large and roughened. The abdomen is black and brown in both sexes, and roughly pear-shaped.

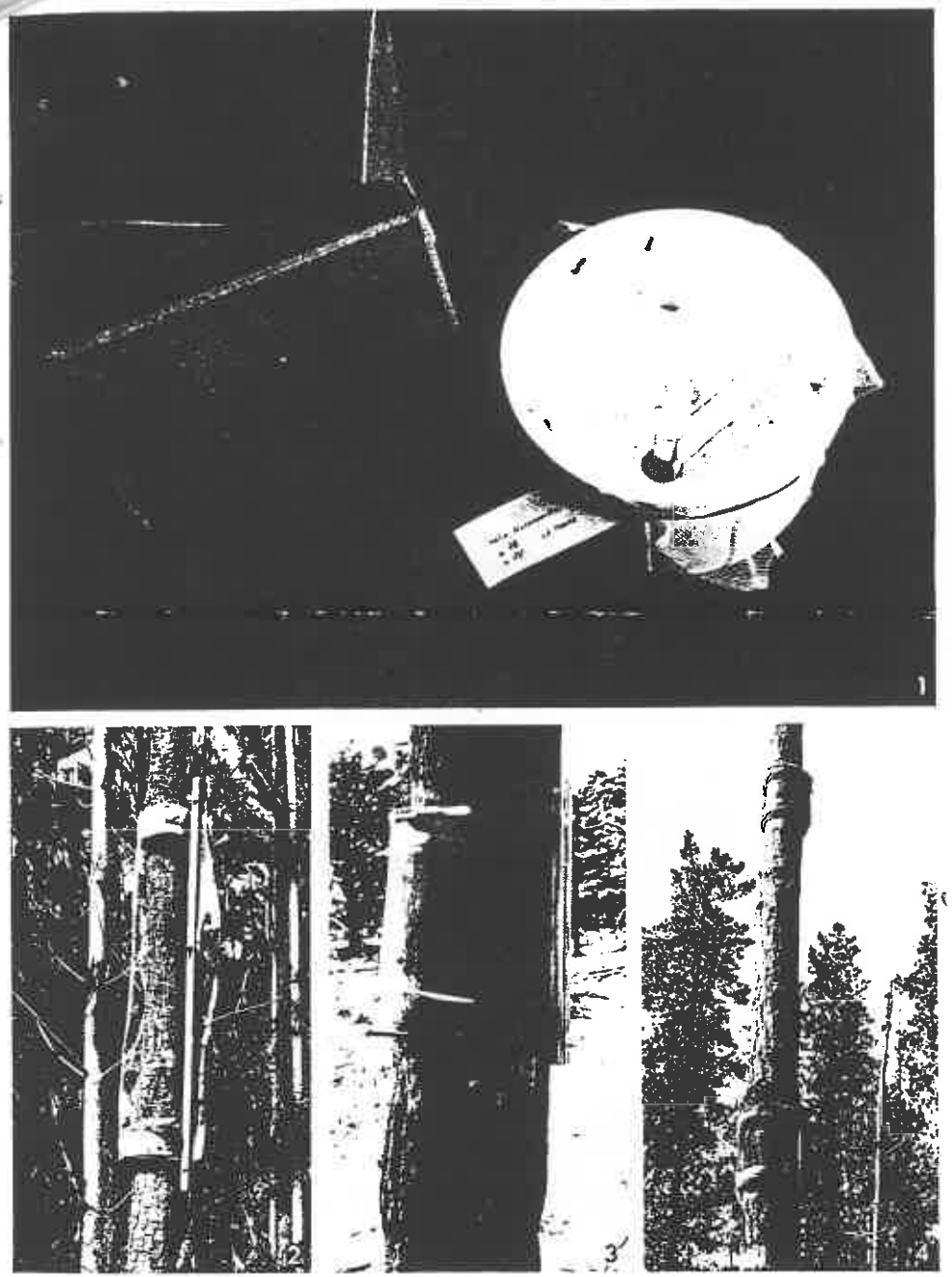
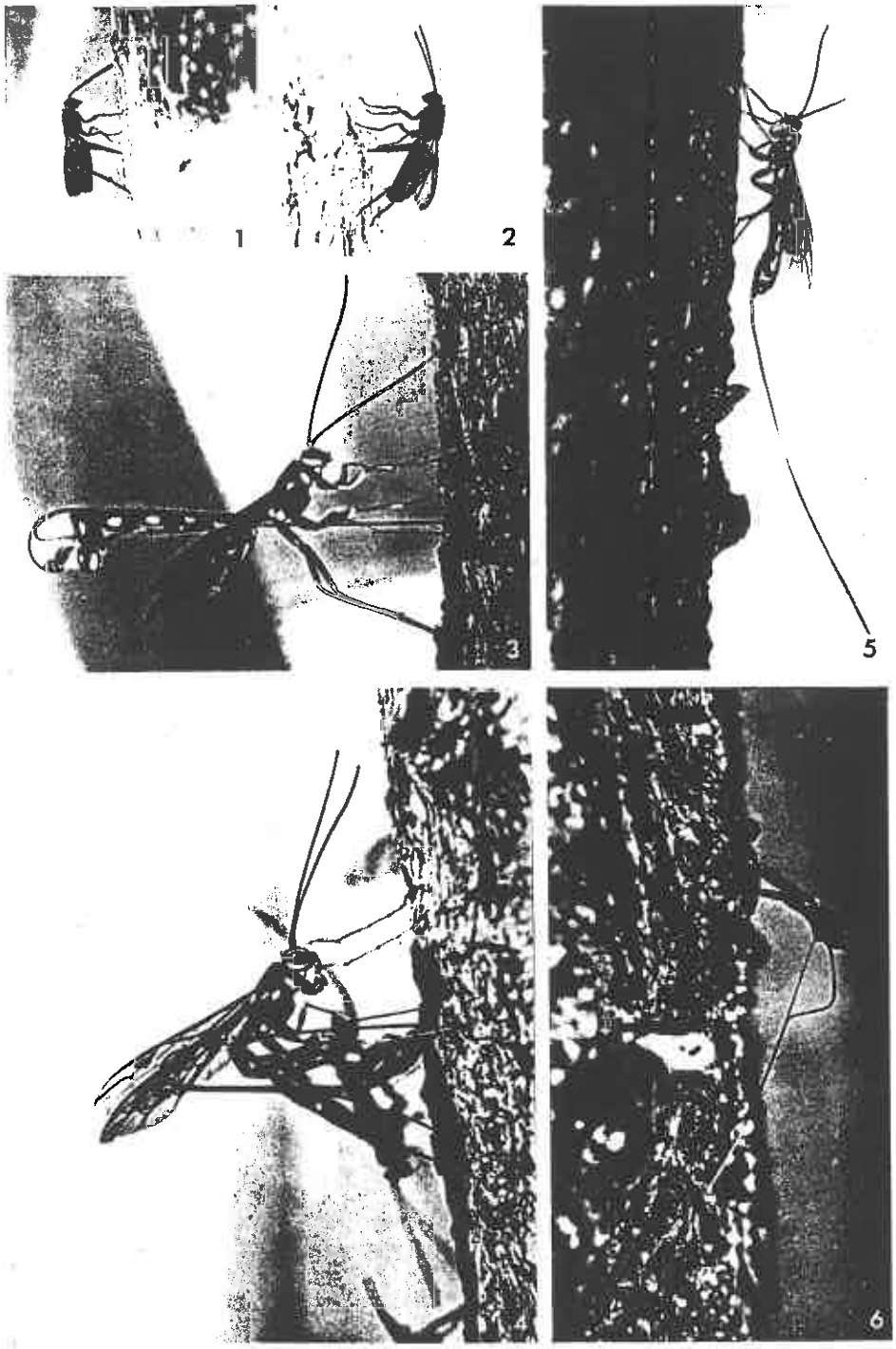


Fig. 1.—Container used for shipping of parasites by Sirex Biological Control Unit, Silwood Park, England.

Figs. 2, 3, 4.—Cages used for recovery of insects from standing trees. *2*, Cage (3 ft long) for small trees; *3*, *4*, cages (1 ft long) for large trees.

Figs. 1–6.—*Sirex noctilio* and *Rhyssa* spp. (females ovipositing). All approximat natural size. *1*, *Sirex noctilio*; *2*, *Rhyssa persuasoria*; *3*, *R. himalayensis*; *4*, *R. lineola* *5*, *R. amoena*; *6*, *R. alaskensis*.



Figs. 1–6.—*Ibalia* spp., *Schlettererius cinctipes*, and *Megarhyssa* spp. (females; all except *M. emarginatoria* ovipositing). All approximately natural size, except when otherwise stated. *1*, *Ibalia ensiger*; *2*, *I. leucospoides*; *3*, *Megarhyssa nortoni nortoni* inserting ovipositor; *4*, *M. nortoni nortoni* with ovipositor fully inserted; *5*, *M. emarginatoria* (×⅓); *6*, *Schlettererius cinctipes*.