HYMENOPTEROUS PARASITES OF WILLOW INSECTS.

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Introduction.

The cricket-bat willow, *Salix alba* var. *caerulea*, Smith, is subject to the disease known as " watermark," caused by *Bacterium salicis* (Day), emend. Dowson, which renders the wood useless for bat manufacture. *B. salicis* is apparently restricted to the wood of the tree, and insects, which feed upon or inhabit the wood during a part of their life-cycle, are suspected of being involved in disease transmission. With a view to finding which insects were most likely to be responsible for the transmission of the disease, the writer undertook a survey of the insect fauna of the bat willow in the Eastern Counties of England during 1936 and 1937 on behalf of H.M. Forestry Commission and the Agricultural Research Council. In the course of this work a number of Hymenopterous parasites of willow insects were obtained. The nature of the work was such that the wood-inhabiting insects were studied rather than those feeding upon the leaves or sucking the sap. Incidental observations were occasionally made on insects other than those inhabiting the wood and on willows other than the bat willow. These, however, were few, and the majority of the records are of parasites bred from insects inhabiting the wood of the bat willow.

One or more specimens of all the Chalcidoidea and Proctotrupoidea and of all the Ichneumonoidea, except *Angitia vestigialis*, Ratz., and *Rhogas irregularis*, Nees, have been retained in the collection at the British Museum (Natural History).

Parasites of Wood-Inhabiting Insects.

Insects commonly found inhabiting the wood of the bat willow were the larvae of the gall-midges, *Rhabdophaga saliciperda*, Duf., and *Rhabdophaga* sp., and the sawfly, *Euura atra*, Jur., and these were most strongly suspected of being involved in the transmission of the " watermark " disease. *Rhabdophaga* sp. differs from *R. saliciperda* in a number of structural details, and is apparently an undescribed species. One of the most conspicuous of these structural differences is in the shape of the process at the base of the antennal sheaths in the pupa, to which Barnes (1935) assigns taxonomic value. In *Rhabdophaga* sp., the antennal sheaths in the pupa have a large triangular process at the base similar to that in *R. triandraperda*, Barnes, and not elongated and pointed as in *R. saliciperda*. The larva of *Rhabdophaga* sp. invariably inhabits the wood of young shoots and is almost always located near a bud, which becomes bright red and slightly swollen and fails to open.

Further support for the separation of *Rhabdophaga* sp. and *R. saliciperda* as distinct species is given by a study of their parasites. *Torymus pulchellus*, Thoms., *Tetrastichus roesellae*, DeG., and *Platygaster* sp., were the three parasites found most commonly attacking *Rhabdophaga* sp. None of these species was ever bred from *R. saliciperda*. On the other hand the most common species parasitizing *R. saliciperda* was *Eurytoma saliciperdae*, Mayr, which was never obtained from *Rhabdophaga* sp. The only parasite bred from both gall-midges was *Microterys clavellatus*, Dalm., and this appears to be the first record of this species attacking CECIDOMYIIDAE.

Parasites and hyperparasites bred from these wood-inhabiting species are listed below.

Host Species.	Parasites.	Notes.
Rhabdophaga sp. (Diptera, Cecidomyiidae).	*Torymus pulchellus*, Thoms. ...	abundant
	Eupelmus urozonus, Dalm. ...	rare, hyperparasite ?
	Microterys clavellatus, Dalm. ...	rare
	Tetrastichus rosellae, DeG. ...	abundant
	Tetrastichus inunctus, Nees ...	rare, hyperparasite
	Tetrastichus flavovarius, Nees ...	?
	Platygaster sp.	abundant
Rhabdophaga saliciperda Duf. (Diptera, Cecidomyiidae).	*Eurytoma saliciperdae*, Mayr ...	abundant
	Tridymus salicis, Nees	rare
	Microterys clavellatus, Dalm. ...	rare
	Pleurotropis sp.	?
	Calliceras sp.	?
	Conostigmus sp.	?
Euura atra Jur. (Hymenoptera, Tenthredinidae).	*Eurytoma salicis*, Thoms. ...	abundant
	Tridymus salicis, Nees	rare, hyperparasite ?
	Tetrastichus flavovarius, Nees ...	rare, hyperparasite
	Tetrastichus ? *acuminatus*, Ratz.	rare, hyperparasite

Superfamily ICHNEUMONOIDEA.

Family ICHNEUMONIDAE.

Angitia vestigialis, Ratz.

This species appears to be a well known endoparasite of *Pontania proxima*, Lep., and is recorded by Carleton (1937) as emerging in large numbers from this host. A single female emerged on 28th August 1936, from a gall of *P. proxima* on a leaf of bat willow collected at Writtle, Essex, on 15th August 1936 (Callan, 1939).

Exochus sp.

Exochus is recorded as a parasite of various Lepidoptera. A single male emerged on 8th August 1936, from a gall of *Euura atra*, Jur., on a shoot of bat willow collected at Earl's Colne, Essex, on 20th July 1936. It is improbable that *Exochus* sp. was a parasite of *E. atra*. A more likely explanation is that the gall was one of the previous year within which an undetermined Lepidopterous larva had taken refuge, and that this was parasitized by *Exochus* sp.

Meniscus frontalis, Desv.

Meniscus is recorded as a parasite of AEGERIIDAE and other Lepidoptera. Three males and six females emerged from 10th June to 14th July 1936, from a number of

old stumps of *S. viminalis* collected at Batford, near Harpenden, Herts. Specimens of *Aegeria formicaeformis*, Esp., were also obtained from this material, and it is extremely probable that *M. frontalis* was a parasite of this species (Callan, 1940).

Sagaritis sp.

A single male emerged on 13th June 1936, from an undetermined Lepidopterous larva found feeding on the leaves of bat willow on 14th May 1936, at Ulting, Essex.

Thersilochus ? rufiventris, Brisch.

Thersilochus appears to be a parasite of various Coleoptera. On 15th June 1936, a number of males were observed assembling in large numbers around a few females, which were ovipositing in the galls of *Pontania proxima*, Lep., on the leaves of bat willows at Writtle, Essex. A number of these galls were collected at a later date, from which specimens of *P. proxima* emerged on 15th, 21st and 22nd August 1936, but no specimens of *T. rufiventris* were obtained. It is probable, but by no means certain, that *T. rufiventris* was a parasite of *P. proxima* (Callan, 1939).

The weevil, *Balaninus salicivorus*, Payk., lays its eggs in the galls of *P. proxima*, in which the larvae feed. This weevil was obtained in some numbers from this locality and it now seems more likely that *T. rufiventris* was a parasite of this species and not of *P. proxima*.

Family BRACONIDAE.

Dacnusa albipes, Hal.

Dacnusa appears to be a very specialized genus limited for host almost entirely to leaf-mining Diptera, especially AGROMYZIDAE. Two females were bred from Dipterous mines in leaves of bat willows collected at Harold Wood, Essex, on 21st July 1936. They emerged on 1st August 1936. The host was almost certainly *Phytomyza tridentata*, Lw. Nixon (1937) records that Mr. A. H. Hamm has bred this species from *P. tridentata* on *S. caprea* and on black poplar in Oxfordshire.

Rhogas irregularis, Nees.

A single female emerged on 20th June 1936, from some old stumps of *S. viminalis* collected at Batford, near Harpenden, Herts. Specimens of *Aegeria formicaeformis*, Esp., were also obtained from this material, and it is extremely probable that *R. irregularis* was a parasite of this species (Callan, 1940).

Trioxys aceris, Hal.

Trioxys is a well known Aphid parasite. A single specimen was obtained from a shoot of bat willow from Cambridge, Cambs., emerging in May 1937. Although the shoot was infested by *Rhabdophaga* sp. it is probable that this was not the host, but that the parasite emerged from an Aphid on the shoot.

Superfamily CHALCIDOIDEA.

Family TORYMIDAE.

Torymus tipulariarum, Zett.

Hoffmeyer (1930) records this species from galls of *Rhabdophaga salicis*, Schrk., *R. rosaria*, L., and *R. clavifex*, Kieff., on *Salix*. Two males of this species emerged on 6th June 1936, and one female on 10th June 1936, from *R. rosaria* galls on bat willow from Writtle, Essex. Two females were obtained in 1937 from *R. rosaria*

galls on bat willow, one emerging on 30th June from galls from the above locality and the other on 6th June from galls collected at Lt. Wratting, Suffolk. A single female was bred in June 1937 from *R. salicis* galls on *S. caprea* from Pickmere, Cheshire. These galls produced two other parasites, *Tridymus salicis*, Nees, and a *Platygaster* sp., as well as *R. salicis*.

Torymus pulchellus, Thoms.

Hoffmeyer (1930) records this species from Cecidomyiid galls on *Salix*. Sixteen females in all were bred from red bud galls of *Rhabdophaga* sp. on bat willows. In 1936 three from Ulting, Essex, emerged on 19th, 20th and 23rd June, two from Chelmsford, Essex, on 19th June and one from the same locality on 30th June, and three from Roxwell, Essex, on 21st June, 1st and 2nd July. In 1937 seven from Cambridge, Cambs., emerged on 10th, 11th, 15th, 18th (2), 19th and 21st June, the emergence not starting until 16 days after that of *Rhabdophaga* sp. was complete (see fig. 1).

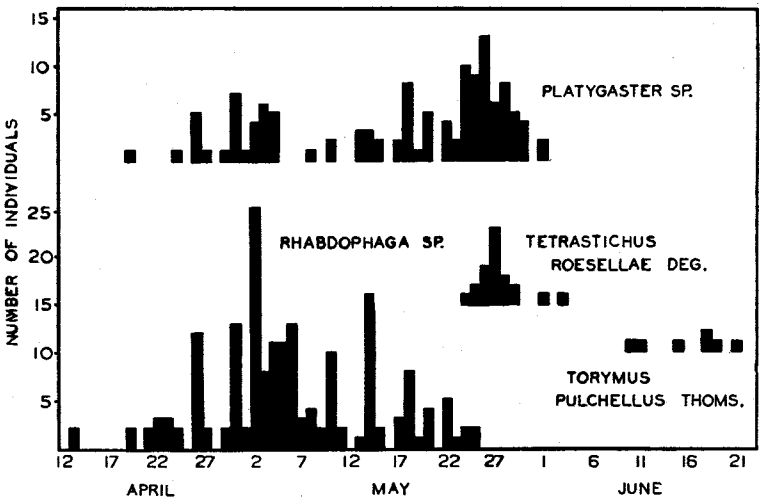

Fig. 1. Histograms showing emergence of the Gall-Midge, *Rhabdophaga* sp., and its parasites, *Torymus pulchellus*, Thoms., *Tetrastichus roesellae*, DeG., and *Platygaster* sp., at Cambridge in 1937.

Family EURYTOMIDAE.

Eurytoma saliciperdae, Mayr.

Mayr (1878) records this species from galls of *Rhabdophaga saliciperda*, Duf., on *Salix*. Barnes (1935) records it from *R. saliciperda* on bat willow and on *S. fragilis*. *E. saliciperdae* was bred from large woody galls of *R. saliciperda* on the branches of bat willow and *S. fragilis*. In all 13 males and 11 females were obtained. The species emerged from a number of galls on bat willow from Writtle, Essex, from 20th to 26th June 1936, and from a single gall on *S. fragilis* from Batford, near Harpenden, Herts., in June 1937. The galls from Writtle also produced *Pleurotropis* sp. and *Conostigmus* sp., the latter a doubtful parasite of *R. saliciperda*, and that from Batford produced three other parasites, *Tridymus salicis*, Nees, *Microterys clavellatus*, Dalm., and *Calliceras* sp.

Eurytoma salicis, Thoms.

Mayr (1878) records this species from galls of *Cryptocampus medullarius*, Hart. *Euura pentandrae*, Cam.) on *Salix*. Nielsen (1906), in giving an account of *C. angustus*,

Htg. (*E. atra*, Jur.) from galls on willows, records *Eurytoma* sp. as a parasite in Denmark. This is almost certainly *E. salicis*. He makes the interesting observation that the *Eurytoma* larva is usually not fully grown after it has completely destroyed its host, and then begins to feed on the pith of the willow shoot in the same way as the host larva. It is well known that some parasitic larvae supplement their animal food with a vegetable diet, and this appears to be a good example of this habit. Such observations as have been made in the present study strongly support this conclusion. In this connexion it is interesting to note that the genus *Eurytoma* exhibits a very wide diversity of habits, ranging from a completely zoophagous diet to one entirely phytophagous. Many of the parasitic species attack a wide range of hosts, while others are specific. The phytophagous species include a number of pests which destroy the seeds of various plants.

E. salicis was bred from galls of *Euura atra*, Jur., on bat willow from Essex, Cambridgeshire and Suffolk. In all, 35 males and 26 females were obtained. A single gall usually yielded no more than one parasite, but occasionally a number of individuals were bred. Thus one individual was obtained thirty-seven times, two four times, three twice, and four and six once each, from a single gall. From localities in Cambridgeshire the rate of parasitism was 19·8 per cent. In Essex the rate of parasitism was not calculated, but appeared to be rather higher. In 1936 parasites emerged from 8th May to 8th July with a maximum emergence about the middle of June. In 1937, parasites emerged only from 1st to 22nd June, with a maximum emergence about 7th June. The emergence of *Eurytoma* did not start until that of *Euura* was for all practical purposes complete, the maximum emergence of the parasite taking place more than a month (37 days) after that of its host (see fig. 2).

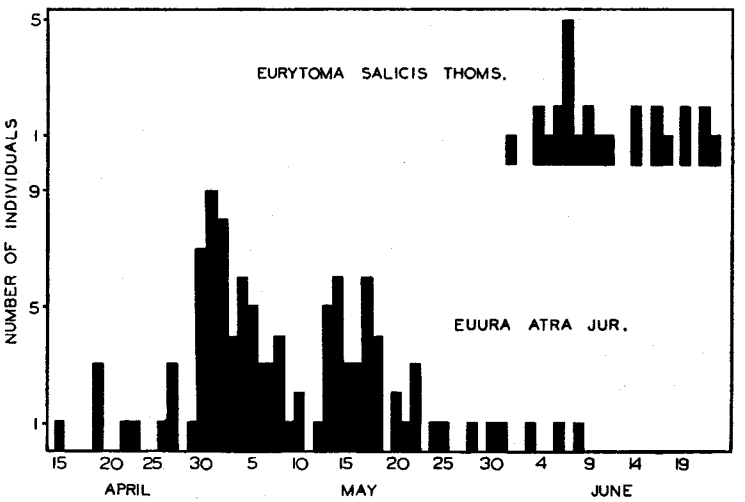

Fig. 2. Histograms showing emergence of the Sawfly, *Euura atra*, Jur., and its parasite, *Eurytoma salicis*, Thoms., at Cambridge in 1937.

Family PTEROMALIDAE.

Tridymus salicis, Nees.

Tridymus has been recorded as attacking various CECIDOMYIIDAE. Barnes (1935) records *Tridymus salicis*, Nees, as a parasite of *Rhabdophaga triandraperda*, Barnes, and *R. saliciperda*, Duf., on *Salix triandra* and *S. fragilis* respectively.

A single female was bred in June 1937 from a *R. saliciperda* gall on a branch of *S. fragilis* from Batford, near Harpenden, Herts. Three males and three females were bred in June 1937 from galls of *R. salicis*, Schrk., on *S. caprea* from Pickmere, Cheshire. Two males and one female emerged from 2nd to 12th June 1937, from galls of *Euura atra*, Jur., on bat willow from Cambridge. Although no observations were made of the parasites actually feeding on larvae of *E. atra*, this may have been the host species, which would be the first record of *T. salicis* as a parasite of TENTHREDINIDAE. On the other hand it may have been acting as a hyperparasite of *E. atra* through *Eurytoma salicis*, Thoms.

Eutelus ? semiclavatus, Ratz.

A larva of this species was found feeding externally on a *Euura* larva at Grantchester, Cambs. The host larva was almost certainly that of *E. venusta*, Zad., being found within a gall formed from the enlarged petiole of a leaf of *S. fragilis*. The parasite larva when first observed was only partly grown, and the *Euura* larva was not yet dead. Later the host larva was killed and the parasite continued to feed upon it until the body contents were consumed. When fully fed the parasite pupated and emerged as a female on 26th May 1937.

Family EUPELMIDAE.

Eupelmus urozonus, Dalm.

This ubiquitous species is recorded from a very wide range of hosts as both a parasite and a hyperparasite. The writer has previously bred it from galls of *Rhodites rosae*, L., on rose, 183 galls out of 815 collected yielding the parasite, and 93 males and 372 females being obtained. In these galls *E. urozonus* not only attacks *R. rosae*, but also the inquiline Cynipid, *Periclistus brandti*, Ratz. It also acts as a hyperparasite of both these species.

A fully fed larva of *E. urozonus* was found within a shoot of bat willow at Rayne, Essex, on 4th May 1936. It was in the same position as that typically occupied by *Rhabdophaga* sp. The larva pupated and gave rise to a female on 25th May 1936. It is probable either that the host was *Rhabdophaga* sp., or that *E. urozonus* was acting as a hyperparasite of this species through one of its more abundant parasites, such as *Torymus pulchellus*, Thoms., or *Platygaster* sp.

Family ENCYRTIDAE.

Microterys clavellatus, Dalm.

The majority of records refer to this species as a Coccid parasite. One female emerged on 15th May 1936, from a shoot of bat willow from Rayne, Essex, and three females on 16th July 1936, from a shoot of bat willow from Writtle, Essex. These were probably parasites of *Rhabdophaga* sp. Three females emerged on 22nd May 1937, from a single larva of *Rhabdophaga* sp. removed from a shoot of bat willow from Cambridge. Three females emerged on 25th May 1937, from a single larva of *R. saliciperda* removed from a branch of *S. fragilis* from Batford, near Harpenden, Herts.

These appear to be the first records of *M. clavellatus* as a parasite of CECIDOMYIIDAE.

Family EULOPHIDAE.

Pleurotropis sp.

Pleurotropis is a parasite with a wide host range and has frequently been recorded as attacking CECIDOMYIIDAE. Barnes (1935) records *Pleurotropis ? caenus*, Walk.,

from either *Rhabdophaga purpureaperda*, Barnes, or *R. justini*, Barnes, on *Salix purpurea*.

A single specimen emerged on 20th June 1936, from a gall of *R. saliciperda*, Duf., on a branch of bat willow from Writtle, Essex. Although it is not certain it is probable that the host was *R. saliciperda*.

Tetrastichus roeselliae, DeG.

This species is a well known parasite of CECIDOMYIIDAE and a few other insects. Barnes (1935) records it from *Rhabdophaga triandraperda*, Barnes, on *S. triandra* and from either *R. purpureaperda*, Barnes, or *R. justini*, Barnes, on *S. purpurea*.

A single male emerged on 20th May 1936, from a gall of *R. rosaria*, L., on bat willow from Ulting, Essex. A female was obtained on 30th June 1937, from a *R. rosaria* gall on bat willow from Writtle, Essex, from which *Torymus tipulariarum*, Zett., also emerged. From 24th May to 3rd June 1937, 5 males and 17 females emerged from galls of *Rhabdophaga* sp. on bat willow from Cambridge. *Platygaster* sp. was also obtained from these galls (see fig. 1).

Tetrastichus inunctus, Nees.

This species is recorded from a fairly wide range of hosts. The writer has previously bred what is believed to be this species as a parasite of *Periclistus caninae*, Htg., an inquiline Cynipid in the galls of *Rhodites eglanteriae*, Htg., on rose. Barnes (1934) records it from galls of *Rhabdophaga heterobia*, H. Lw., on *S. triandra*.

A larva of this species was found feeding externally on what appeared to be another Chalcidoid larva within a bat willow shoot at Roxwell, Essex. It was in the same position as that typically occupied by *Rhabdophaga* sp. The larva when first observed was only partly grown ; it pupated when fully fed and emerged as an adult on 23rd June 1936. It is most probable that *Rhabdophaga* sp. was the host, *T. inunctus* acting as a hyperparasite of this species through one of its parasites. A single individual of *T. inunctus* emerged on 14th August 1936, from a gall of *Rhabdophaga* sp. on bat willow at Cambridge.

Tetrastichus flavovarius, Nees.

This species is a well known parasite of CECIDOMYIIDAE and a few other insects. Barnes (1935) records it as a parasite of *Rhabdophaga triandraperda*, Barnes, and *R. saliciperda*, Duf., on *S. triandra* and bat willow respectively.

A single individual emerged on 1st July 1936, from a gall of *Rhabdophaga* sp. on bat willow from Roxwell, Essex. In 1937 one individual emerged from 2nd to 12th June from a gall of *Euura atra*, Jur., on bat willow from Cambridge, and another on 3rd June from a similar gall on bat willow from Ickleton, Cambs. It seems probable that in this case *T. flavovarius* was acting as a hyperparasite of *E. atra* through *Eurytoma salicis*, Thoms.

Tetrastichus ? acuminatus, Ratz.

Two females emerged on 4th and 6th July 1937, from galls of *Euura atra*, Jur., on bat willow from Cambridge. *Eurytoma salicis*, Thoms., was also obtained from similar galls collected at the same time. It seems probable that *T. acuminatus* was acting as a hyperparasite of *E. atra* through *E. salicis*.

Family MYMARIDAE.

Polynema sp.

Polynema appears to be a well known egg parasite, attacking especially the eggs of Hemiptera. A single specimen was bred from a woody shoot of bat willow collected

at Rayne, Essex, on 21st May 1936, and emerging on 15th June 1936. It was thought that this had emerged from one of a number of COCCIDAE infesting the shoot, but it is more probable that it was parasitizing an egg inserted in the bark of the shoot, probably that of a Capsid.

Superfamily PROCTOTRUPOIDEA.

Family CALLICERATIDAE.

Calliceras sp.

Calliceras is a parasite and hyperparasite of wide host range, including various Diptera. It has been recorded as attacking CECIDOMYIIDAE. A single specimen was obtained from a gall of *Rhabdophaga saliciperda*, Duf., on a branch of *S. fragilis* collected at Batford, near Harpenden, Herts., on 31st May 1937, and emerging on 7th June 1937. Although it is not certain, it is probable that the host was *R. saliciperda*.

Conostigmus sp.

Conostigmus is a parasite of various Diptera. It has apparently not been recorded as attacking CECIDOMYIIDAE. A single specimen was obtained from a gall of *Rhabdophaga saliciperda*, Duf., on a branch of bat willow collected at Writtle, Essex, on 17th June 1936, and emerging on 26th June 1936. Although it is not certain, it is possible that the host was *R. saliciperda*.

Family SCELIONIDAE.

Telenomus punctatissimus, Mayr.

Telenomus is a well-known egg parasite, attacking a wide range of hosts, especially the eggs of Lepidoptera and Hemiptera. A number of specimens were bred from the eggs of *Phalera bucephala*, L. (buff-tip moth) on leaves of bat willow from Chelmsford, Essex. They emerged on 7th August 1936.

Platygaster sp. (*a*).

Barnes (1935) records *Platygaster cecidomyiae*, Ratz., as a parasite of *Rhabdophaga saliciperda*, Duf., on *S. fragilis*. He also records *Platygaster* sp. (? *philinna*, Walk.) as a parasite of *R. triandraperda*, Barnes, on *S. triandra* and of either *R. purpureaperda*, Barnes, or *R. justini*, Barnes, on *S. purpurea*.

Four females of *Platygaster* sp. were obtained in 1936 from galls of *Rhabdophaga* sp. on bat willow from Rayne, Ulting and Lt. Waltham, Essex, emerging on 15th and 20th May and 4th June.

Platygaster sp. was bred in 1937 from galls of *Rhabdophaga* sp. on bat willow from Cambridge. A single gall usually yielded only one parasite but occasionally a number of individuals were obtained. In all, 63 males and 59 females were obtained. The rate of parasitism was 40·5 per cent. Emergence of parasites occurred from 19th April to 1st June, coinciding approximately with that of *Rhabdophaga* sp., although the maximum emergence of *Platygaster* took place 24 days later than that of its host (see fig. 1).

Platygaster sp. (*b*).

One male and six females were bred in June 1937 from galls of *Rhabdophaga salicis*, Schrk., on *S. caprea* from Pickmere, Cheshire. *Platygaster* sp. was probably a parasite of *R. salicis*, but may have been acting as a hyperparasite of this species through *Tridymus salicis*, Nees, which was also bred from these galls.

Platygaster sp. (*c*).

A single female emerged on 17th May 1936, from a gall formed from an enlarged bud of *S. caprea* from Bicknacre, Essex. The host was almost certainly a Cecidomyiid, probably a *Rhabdophaga* sp.

Summary.

1. Eight Ichneumonoidea, fourteen Chalcidoidea and six Proctotrupoidea are recorded as parasites of willow insects.

2. The majority of records are of parasites bred from insects inhabiting the wood of the cricket bat willow, *Salix alba* var. *caerulea*, Smith, the more important being *Torymus pulchellus*, Thoms., *Tridymus salicis*, Nees, *Eupelmus urozonus*, Dalm., *Microterys clavellatus*, Dalm., *Tetrastichus roesellae*, DeG., *Tetrastichus inunctus*, Nees, *Tetrastichus flavovarius*, Nees, *Tetrastichus* ? *acuminatus*, Ratz., and *Platygaster* sp.

3. *Microterys clavellatus* is recorded for the first time as a parasite of Cecidomyiidae.

4. Evidence is given for the separation of the gall-midges, *Rhabdophaga* sp. and *R. saliciperda*, Duf., as distinct species based both on structural differences and on a study of their parasites, for the three parasites found most commonly attacking *Rhabdophaga* sp. were never bred from *R. saliciperda*, and the most common species parasitizing *R. saliciperda* was never obtained from *Rhabdophaga* sp.

5. It is confirmed that *Eurytoma salicis*, Thoms., supplements its animal diet with vegetable food.

6. The rate of parasitism of *Euura atra*, Jur., by *Eurytoma salicis* is given as 19·8 per cent., and that of *Rhabdophaga* sp. by *Platygaster* sp. as 40·5 per cent.

7. Histograms are given of *Rhabdophaga* sp. and its parasites, *Torymus pulchellus*, Thoms., *Tetrastichus roesellae*, DeG., and *Platygaster* sp., the emergence of *Platygaster* sp. coinciding approximately with that of its host.

8. Histograms are given of *Euura atra*, Jur., and its parasite, *Eurytoma salicis*, Thoms., the emergence of which did not start until that of its host was practically complete.

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