THE SIREX WOOD-WASPS AND THEIR IMPORTANCE IN FORESTRY.

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(PLATES IX–XI.)

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Introduction.

This paper on the biology and forest relations of certain British wood-wasps or "horntails" (Hymenoptera, SIRICIDAE), which is based upon some studies recently carried out at Oxford (1926–27), was originally inspired by the recent accounts that have appeared concerning the destructive activities of one of the steel-blue species in New Zealand. There the wood-wasps are causing considerable anxiety on account of their attacks on *Pinus radiata*, and quite recently the New Zealand Government approached the Imperial Bureau of Entomology with a request that their newly established parasite laboratory at Farnham Royal, Bucks., might take up the study of the wood-wasp parasites, with a view to their collection and exportation to New Zealand. I have had the pleasure of co-operating with the Bureau in this work and this paper is intended to serve as an introduction to a later publication on the parasites of the woodwasps, which will be published subsequent to the completion of certain investigations now proceeding. A preliminary paper on the parasites of the wood-wasps has already been published (Bull. Ent. Res., xix, pp. 67–77).

The objectives in the present work have been threefold: to review the literature of the SIRICIDAE up to date; to present the results of some recent studies made by myself on the biology and forest relations of two British species; and, lastly, to touch briefly on the *Sirex* problem in New Zealand, with particular reference to the question of control measures. I should like at this point to acknowledge my indebtedness to Dr. J. G. Myers, of the Imperial Bureau of Entomology, for helpful criticism; to Dr. James Waterston, of the British Museum (Natural History), who has kindly contributed some systematic notes on the British wood-wasps, which are published here by kind permission of the Trustees of the British Museum; to the President and Fellows of Magdalen College, Oxford, for their kindness in granting access to the wood at Tubney, near Oxford, where most of the work has been carried out; and to Mr. H. S. Hanson, of South Molton, North Devon, who has helped materially with specimens and personal records from that district.

Systematic Notes on British Wood-wasps.*

While the determination of any of the *Sirex* species occurring in Britain seldom presents special difficulties, their tabulation is by no means easy owing to the

* By Dr. James Waterston.

notorious instability of the available characters. Particularly is this the case with the neuration. Thus, *S. gigas* occasionally shows a first transverse brachial vein completely or imperfectly developed. British *S. noctilio* apparently have this vein incomplete, but in continental examples it may be fully developed. The neuration

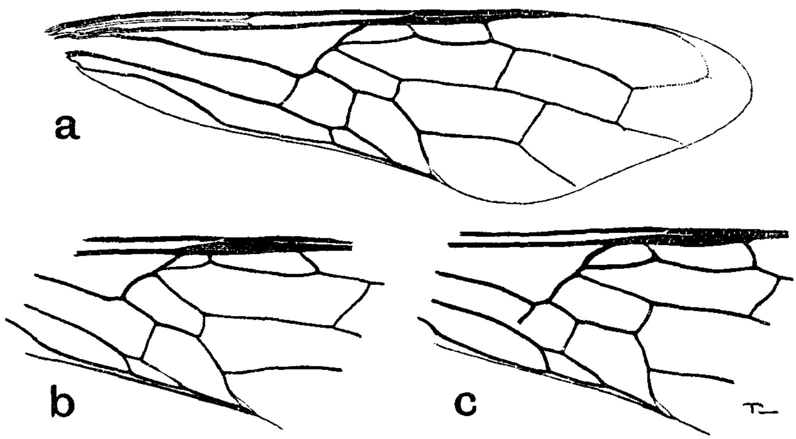

Fig. 1. Neuration of forewing: *a*, *Sirex cyaneus;* *b*, *S. gigas;* *c*, *S. noctilio.*

of *S. cyaneus* appears to be more constant, but (though rarely) it is not invariably to be relied upon.

The ♂ genitalia, at least in larger examples, can be drawn out in fresh specimens and studied in this way. The outer lobe (squamula) of the stipes appears to be

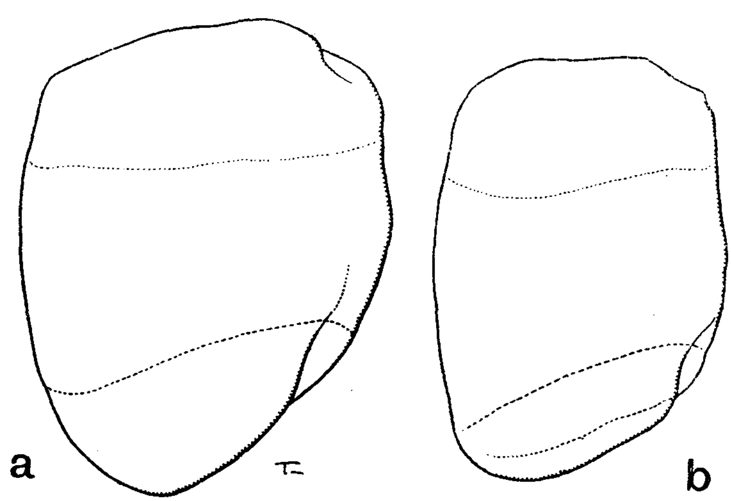

Fig. 2. Genitalia—apical appendage (squamula) of stipes: *a*, *Sirex noctilio;* *b*, *S. cy neus.*

narrower and straighter ventrally in *cyaneus* than in *noctilio*, and there are other differences in the apparatus seen from below.

As regards the synonymy of *Sirex* I have followed Bradley (1913) (*vide infra*).

Curtis (1829) designates *S. juvencus*, L., as the genotype. His figure and description apply to *S. noctilio*, Fab. Fortunately, however, this in no way alters the application of the name.

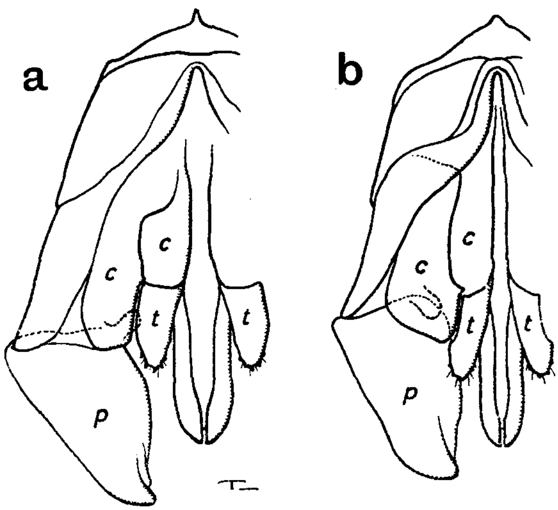

Fig. 3 Genitalia—from below: *a*, *S. noctilio*; *b*, *S. cyaneus*. (Lettering corresponds to that in Boulangé's monograph.)§

Normal examples of the four wood-wasps now occurring in Britain may be separated by the following key.

1. Head with a conspicuous yellow spot on the temples behind each eye; vertex *broadly black* separating the spots widely. Forewings with *one* transverse brachial nervure (fig. 1, *b*) ... ... *gigas*, L.
   Head immaculate; *two* transverse brachial nervures (fig. 1, *a*, *c*) 2
2. Females 3
   Males 5
3. Projecting portion of the ovipositor sheath, seen from above, nearly as long as tergites ix+x; first transverse brachial nervure complete *cyaneus*, F.
   Projection of sheath never much longer than tergite x; first transverse brachial nervure usually incomplete 4
4. Antennae wholly infuscated or black; cornus sub-equilateral; impression on tergite ix distinctly transverse; sheath distinctly shorter than tergite x *noctilio*, F.
   Antennae with scape (whole or part), pedicel and 3–5 normal funicular joints clear testaceous or ferruginous; cornus elongate triangular; impression variable, never distinctly transverse; sheath and tergite x subequal *juvencus*, L.
5. Apex of abdomen from the 8th segment black with (more or less) submetallic reflections; all femora darkened, and in the hind legs black except narrowly at apex; first transverse brachial nervure generally incomplete *noctilio*, F.
   Apex of abdomen and all femora ferruginous (the contrast between femur and tibia striking in the hind leg) 6
6. Antennae basally rufescent or pale; 1st transverse brachial nervure incomplete *juvencus*, L.
   Antennae entirely infuscated or black; 1st transverse brachial nervure complete *cyaneus*, F.

§ Boulangé, Mém. Trav. Facultés catholiques Lille, xxviii, 1924.

Sirex (*Urocerus*) *gigas*, L.

This, our only representative of the subgenus *Urocerus*, is a conspicuous yellow and black species, which is easily recognised. The large black spot (about as wide as two-thirds of the vertex) separating the paler ones on the temples distinguishes this species in both sexes from others found in the Palaearctic Region, e.g., *augur*, Kl., *fantoma*, F., *cedrorum*, Sm., *japonicus*, Sm., *xanthus*, Cam., in which there is at most a narrow darker line extending backwards behind the anterior ocellus, and hardly

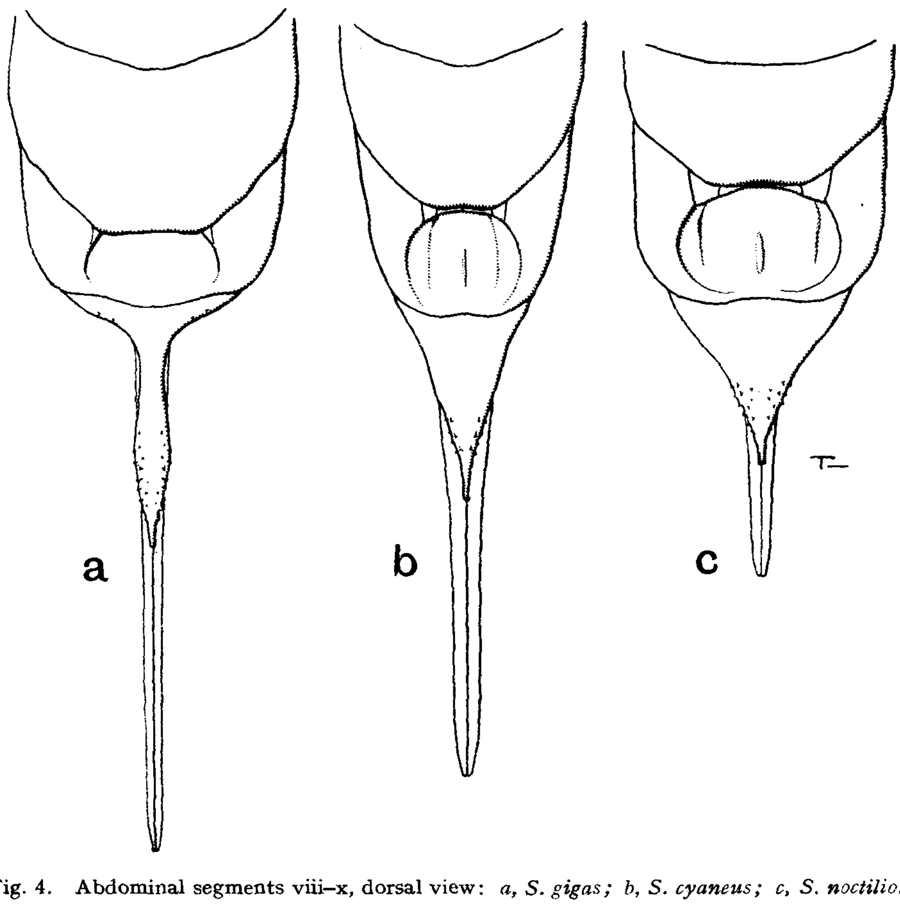

Fig. 4. Abdominal segments viii–x, dorsal view: *a*, *S. gigas*; *b*, *S. cyaneus*; *c*, *S. noctilio*.

wider than this organ. Confusion, however, may arise between *U. gigas*, L., *U. flavicornis*, F. (♂, ♀) and *U. albicornis*, F. (♀) (both North American). The first two may be separated as follows :—

U. gigas.

♂. Scape variable (black, black and yellow, or yellow) ; flagellum yellow, as is also tergite vii. Tergite ii infuscated, as a rule, only along anterior edge, and not to beyond one-half posteriorly.

U. flavicornis.

♂. Scape black ; flagellum basally ferruginous, and distally infuscated (*i.e.*; from 6th–8th joint to apex, which may be black). Tergite vii black ; tergite ii more extensively infuscated, pale mainly at sides.

♀. Tergite viii entirely yellow; tergite ix infuscated basally (sometimes only at sides), pale (yellow) broadly towards apex; tergite x wholly yellow.

♀. Tergite viii yellow only on basal third, black beyond; tergite ix wholly black; tergite x black, only the spike yellow.

According to Professor J. C. Bradley (J. Ent. & Zool. v, p. 19, 1913) the males of *U. albicornis* and *U. flavicornis* are indistinguishable.

In the British Museum are two males (Hudson's Bay) placed under *albicornis*, F., by the late F. D. Morice. These can be separated from *flavicornis*, F., by the more elongate hind tarsus, in which the first joint is slender, nearly seven times as long as wide, whereas in *albicornis* (Nova Scotia) this joint is barely five times as long as broad. In ♀ *albicornis* the abdomen is wholly black save for a pale spot at the side on tergite viii. Both of these North American species have occurred in England in the London District, and their captures have resulted in regrettable additions to synonymy; *U. albicornis*, F., was thus re-described as *Sirex stephensi*, Kirby 1882, and *U. flavicornis*, F., as *Sirex bizonatus*, Steph. 1835. The type of *U. stephensi* and cotypes (?) of *U. bizonatus* are still extant in the British Museum. *U. augur*, Kl., is also reported to have occurred in Britain, but I have seen no example so taken.

Sirex noctilio, F.

In the male this species is recognisable at once by the colour of the legs, antennae and abdomen (apex), as well as by the usually imperfect first transverse brachial nervure. The first two, and part of the third tergites are dark, and more or less metallic. The darkening of tergite iii may reach back to two-thirds, but it is generally incomplete laterally. In the female the abdomen is stout and broad, parallel-sided to the end of the 9th segment, and rather abruptly pointed on the 10th tergite.

The general surface of tergites ii–viii is dull blackish, and remains so however the insect is turned. Tergite i, beyond the usual large punctures, is smooth and shining, especially along the posterior margin.

Sirex cyaneus, F.

♂. Abundantly distinct from *S. noctilio*, F., but separable from ♂ *S. juvencus* sometimes only by the colour of the antennae; tergites i and ii wholly, iii on disc, and iv (a basal spot or spots) blue-black.

♀. The abdomen is more slender and tapers gradually from the middle of the 8th segment. The impression on tergite ix is subcircular, and at its bottom clearly longer than broad. The general surface of tergites ii–viii is dark blue from above, and distinctly coerulescent from other angles. Tergite i, beyond the usual large punctures, is faintly scaly reticulate and hence not brilliantly shining on the posterior half.

Sirex juvencus, L.

♂. See note under *cyaneus*, F.

♀. Distinguished by the incomplete transverse nervure, and the basally rufescent antennae. In the abdomen rather more like *cyaneus* than *noctilio*, but the ovipositor is slightly shorter than in the former, and the cornus a trifle narrower than in the latter.

The colour of the forewings, in the specimens of *juvencus* in the British Museum, is noticeably darker on rather more than the apical half, *i.e.*, from the level of the first cubital cell. In *noctilio* and *cyaneus* the wings are sub-hyaline and more or less broadly infuscated along the outer margins.

Status of the Species discussed.

Only in the case of *S. juvencus*, L., can any doubt arise as to the application of the name or the status of the insects determined by the above key. The name must be used to designate a blue-black *Sirex* with the antennae basally rufescent, and Evans (Scottish Naturalist, p. 176, 1922) has pointed out that the male of *S. noctilio* may show this character—probably owing to immaturity. Evans' specimens had the apex of the abdomen dark and were found in galleries in timber, with ♀♀ clearly *noctilio.*

The ♂ of *S. cyaneus* (*i.e.*, reared with normal females of that species) may show on both wings an incomplete first transverse brachial nervure, and if the pale colour of the antennae basally can be due to immaturity, such a specimen would be indistinguishable from *S. juvencus* ♂.

The ♀ of *S. juvencus* is much more definable than the ♂. The ovipositor is relatively longer than in *noctilio*, and shorter than in *cyaneus*. The cornus, too, seems to be intermediate in shape, but I have not seen enough material to offer a decided opinion. In discussing these blue-black wood-wasps I have quite deliberately avoided using the longitudinal impression on the vertex, and the rugulosity of the saw-sheath as characters. They seem to me too variable to be relied upon. The tarsal characters noted by Thomson require further elucidation, and have not been dealt with here.

Status as British Insects.

U. gigas, *S. noctilio* and *S. cyaneus* are at the present day thoroughly established in Britain, but the position of *S. juvencus* is more doubtful. Examples of all four taken by J. F. Stephens are still extant in the British Museum.

No one, however, has yet collected and critically analysed the records of *Sirex* taken in England, though such a work might throw interesting light on the progress of the invader *S. cyaneus*. Since the War *U. gigas* and *S. cyaneus* have frequently been sent to the writer for determination, while true *S. noctilio* appears to be less common. *S. juvencus* has been received only twice, on each occasion probably as an importation.

Mr. Evans' notes on the wood-wasps (*Sirex*) in Scotland, already referred to, give an admirable summary of the subject. *U. gigas* was first recorded as a Scottish insect in 1813, and has now been reported from thirty of the Watsonian counties and vice-counties. It is absent, indeed, only in the extreme north and certain of the islands.

"Blue-black" wood-wasps have been known for fifty years in Scotland, and have now been noted in fourteen of the Watsonian areas. In nine (probably ten) of these *S. cyaneus* has been identified, and in two *S. noctilio*. In one county (Linlithgow) the latter species has been definitely proved to be established.

General Review of Sirex Literature.

Continental.—The important continental literature on the biology and forest relations of the SIRICIDAE dates from the beginning of the 19th century, and the earliest papers are of German origin. J. M. Bechstein was one of the pioneer workers and devoted a section of his "Forstinsektologie," published at Gotha in 1818, to the family, in which he gave a general account of the morphology and biology of *S. gigas* and *S. juvencus*, his work being chiefly remarkable for the statements made as to the predatory habits of the adults, which will be discussed later on. Bechstein's work together with that of other contemporary observers was summarised by Ratzeburg in 1844 in his great work "Die Forstinsekten," which contains a detailed description of the morphology and biology of the two species mentioned above, and also discusses at some length the forest relations of the species with special reference to their appearance in forests that have been severely damaged by defoliating insects. This work must be regarded as the principal source from which many subsequent writers derived much of their material. After Ratzeburg's time the next important contribution to the literature was Hartig's "Die Familien der Blatt-und Holzwespen," which appeared in 1860. In the section of this book that deals with the SIRICIDAE, Hartig gives a very complete account of the larval life of *S. juvencus*, which includes some valuable observations on the characteristics of its larval tunnels and the nature of the frass. He also deals with the question of *Sirex* as an enemy of green trees and compares its status as a primary pest with that of the bark-beetles, which he regards as being immeasurably more important. Describing the life of the adults in detail he criticises at some length Bechstein's statement that they prey on other insects and cites the observations of other writers on the same subject. He concludes his account of the family with a complete systematic review. Taschenberg's textbook, "Forstwirtschaftliche Insektenkunde," followed Hartig's work in 1874, and in this a useful review of the family is given, chiefly based on the work of previous writers, some of whose errors are repeated. He deals almost entirely with *S. juvencus*, giving only a very brief account of *S. gigas*. André's book, "Species des Hyménoptères d'Europe et d'Algerie," followed Taschenberg in 1879, and in this a small section is devoted to the family. The biological notes on the species, which largely follow Bechstein's work, contain numerous errors and do not give any data regarding host trees. A long list of insect parasites is given without any data referable to their occurrence, and this was apparently drawn upon by Rudow in 1919, who quotes a similar list, without however furnishing any further details. In 1881 there appeared a paper by Wachtl entitled "Die Stahlblau Fichten- und violette Kiefernholzwespe *S. juvencus* Linne und *S. noctilio* Fabr.", in which he gave a complete morphological comparison of these species in the form of parallel keys, and also dealt briefly with their biology and distribution.

Eight years later, in 1889, Herman Borries, a Danish entomologist, published a paper on the "Occurrence and Distribution of Insect Pests in the Danish Conifer Forests." A section of this paper is devoted to the SIRICIDAE and gives a brief account of the distribution of *Sirex* in Denmark, together with some biological observations, some of the most valuable of which are those concerning the pairing habits.

In the year 1895 there appeared Judeich & Nitsche's "Forstinsektenkunde," which was published as the 8th edition of Ratzeburg's "Die Waldverderber und ihre Feinde." In this book a very complete review of the SIRICIDAE is given, covering not only the systematic side of the subject but also dealing in full detail with the biological aspect. The references to previous workers are very complete, and this work forms an indispensable guide to all literature published up to that time.

From 1895 up to the present day the most important continental works on the subject are Enslin's monograph "Die Blatt-und Holzwespen," in Vol. iii of Schröder's "Insekten Mitteleuropas," Stuttgart, 1914, and Scheidter's recent paper on the biology of *S. augur* and *S. gigas* in Bavaria published in 1923. Enslin's work contains a useful introduction to the biology of the Tenthredinoidea as a whole, and gives well illustrated systematic keys to the families and a comprehensive bibliography of the literature on the group. Scheidter's paper is valuable for its biological detail and includes several hitherto unrecorded observations on the oviposition of *S. gigas*, which will be dealt with subsequently in a comparison of the habits of this species with those of *S. cyaneus*.

British Literature.—The earliest reference to *Sirex* in Britain that I have been able to find occurs in Martyn's edition of Moses Harris' "Exposition of British Insects," London, 1792. The wood-wasp referred to, which is described and figured together with its larva under the name of *S. torvus*, is one of the steel-blue species and bears a strong resemblance in the length of its ovipositor to *S. cyaneus*. It is interesting to note that, discussing the identity of the species, Harris has grave doubts as to its being synonymous with *S. juvencus*, L. The larva is noted as living in dead wood.

Donovan (Natural History of British Insects, xi, London, 1806) records *S. juvencus* as having been taken in a London dwelling-house. He describes the species as a wood borer, but gives no further details. The figure of the insect, which is excellently reproduced on a full-page plate, is almost certainly that of *S. cyaneus*. Curtis (British

Entomology, vi, London, 1829) refers to two species of *Sirex*, *S. gigas* and *S. juvencus*. He records *gigas* from Norwich, Wilts, Kent, Berks, and near London ; and *juvencus* from fir (?) groves in Norfolk, Suffolk, Hants and Yorkshire. Some interesting biological details are given by him in respect of material received from the Hon. Chas. Harris, of Heron Court, Gloucestershire. This was obtained from some fir (? pine) trees that had suffered severely from heat and drought during the summers of 1825 and 1826. The adult wood-wasps were taken only in dead trees and eight males are recorded as emerging simultaneously. These, he relates, proved to be strong on the wing, and when released immediately rose to a considerable height. This, as we shall see, probably bears out a statement by Borries on the habit of the males at pairing time. Large numbers of males, he continues, were found during the same year (1826) flying round the towers of York Minster. These, he says, were probably seeking females, which were issuing from timbers used in supporting the roof. Shuckard (Magazine of Natural History, 1837) records *S. cyaneus* (*duplex*) from black spruce (*Picea nigra*) in Cambridgeshire, emerging at the end of May and early June. He gives no biological details, however. Three years later, in 1840, Westwood published his Introduction to the Modern Classification of Insects, in Vol. ii of which he devotes a small section to the morphology of *S. juvencus*, dealing especially with the structure of its ovipositor. He quotes an interesting record of the occurrence of this species from Bewdley Forest, Worcestershire, communicated by Mr. Raddon. During the first part of the season (1836) the proportion of females to males was only 1 in 12, while during the latter part, *i.e.*, the last 2 to 3 weeks, only females appeared. The wood-wasps continued to emerge until the end of November.

In 1882 W. F. Kirby's list of the Hymenoptera in the British Museum appeared, and in this *S. cyaneus* is recorded as having been taken by Stephens, Shuckard and Lubbock. Lubbock's specimens were bred from larch, but otherwise no record of host trees is given. From 1887 up to the present day the most important contributions to the literature include the following works :—Cameron's "Monograph of the British Phytophagous Hymenoptera," which is entirely systematic ; Morice's "Help Notes towards the Determination of British Tenthredinoidea," also systematic ; and the works of Miss Ormerod (Manual of Injurious Insects and Methods of Prevention, pp. 256–260, 1890), MacDougall (1907) and William Evans (1922).

Evans' paper is the most comprehensive account of the SIRICIDAE that has so far appeared in this country. He gives a complete historical account of the records of *Sirex* in Scotland, which is supplemented by statistical details. His biological notes, which will be discussed more fully later on, are also most valuable.

American Literature.—The American literature on the SIRICIDAE attacking conifers is, practically speaking, apart from systematic papers by Bradley and others, confined to brief records of their occurrence. Felt in his "Insects of Park and Woodland Trees," 1905, refers briefly to two species, *Sirex* (*Urocerus*) *albicornis*, F., and *Sirex* (*Paururus*) *cyaneus*, F., but the majority of other writers are content with simple records of their capture and locality. No really comprehensive account of the biology of any American species attacking conifers has appeared as yet.

Biology of S. cyaneus and S. gigas in Britain.

The major portion of the biological work has been carried out on *S. cyaneus*, this species being the only one present in the larch wood at Tubney where most of the field work was done.

Flight Period and Habits of the Adults.

The flight period of the two species overlaps to a considerable extent. *S. gigas* appears earlier and is found on the wing from June onwards until the autumn. My own records of the flight of this species during 1927 do not extend beyond 9th September, but Evans records their appearance in the South of Scotland in early October.

S. cyaneus appears as a rule towards the end of July or even later, according to the season. In 1927, for example, the flight did not become general until mid-August and the last adult was seen on 23rd September. I have no record of its appearance in flight as late as October, although Evans records finding the insect flying as late as 6th October. The flight period for both species is at its height from July to September, and this is in general agreement with the observations of Continental workers such as Hartig, Taschenberg and others. All the adults that emerged at Tubney developed, to the best of my knowledge, from larvae that had pupated some 5 weeks previously. Cases are known, however, of the insects wintering in the adult stage, and I have recently seen examples of this in both species from silver fir logs at South Molton, North Devon. I have never found *S. cyaneus* overwintering in the larch at Tubney, nor do I consider that it is by any means a common occurrence, as it seems probable that adults remaining thus in the wood over winter might be exposed to the grave danger of fungus attack, due to over-moist conditions. Further reference to the finding of emerging adults covered with fungus mycelium is made on page 000. The adults fly in bright sunlight and when in flight make a noisy buzzing sound, which has been well described by the German writers by the word "schwirren," the onomatopoeic significance of which must instantly strike anyone who has heard the insect when in flight. Bechstein, describing the flight habits, says of *S. gigas*: "The wood-wasp flies in the warm months of July and August, when pairing takes place, and the adults live by preying on other weaker insects, for example, flies"; and in another place, referring to *S. juvencus*, he writes: "This insect preys on other insects upon which it feeds." This view of the *Sirex* adult as a predator is not peculiar to Bechstein; Hartig also quotes the observations of an old writer, Jordens by name, who recorded the wood-wasps as predacious on the adults of the nun moth (*Lymantria monacha*), which he said were captured on the wing. Another writer, Thiersch, is also quoted by him to the same effect, viz. :—"The wasps not only feed on the sap of trees, *e.g.*, silver fir, etc., but also on small insects which they catch on the bark of trees and also in flight." The predatory habit is also referred to by Taschenberg, who states that the adult wood-wasps capture now and again small insects in flight, in a similar fashion to the large sawflies of the genus *Tenthredo.*

Hartig views the above statements with grave doubt and regards the evidence upon which they are based as being insufficient. With the latter view I am inclined to agree, and certainly no record of predatory habits on the part of the wood-wasps has been made by myself, nor can I find any mention of it in the British literature. The females are much the most commonly observed either on the wing, or at rest upon the bark of trees. This indicates a marked preponderance of females over males, and Scheidter observes in this connection that in a catch of several hundred adults of *S. augur* only 10 were males, and of *S. noctilio* only in one case was the majority of a catch composed of males, this having been probably made at a time when the males were just emerging and were easily caught. My own records of *S. cyaneus* also show a marked excess of females over males, the proportion being almost 2 : 1 over a period of two years, and recent figures from North Devon indicate a similar state of affairs.

During the flight period in Tubney Wood males were seen on only three occasions, once resting on the bark of a tree about 6 feet from the ground, and twice flying at a considerable height. Apropos of this, Borries quotes an observation made by Drewsen at Strandmöllen in Denmark, that wood-wasps pair in the tree-tops, after which the females descend to the lower levels for egg-laying. In the work at Tubney this summer pairing was never observed in the open, although it occurred in the cages on two occasions. The observation quoted above offers a reasonable explanation of the failure both to find adults pairing in the open, and also to observe many males in flight.

Oviposition.

Oviposition proceeds with great vigour in warm and sunny weather, but the wasps also show some activity on cloudy days and even when rain is falling. In very wet weather it is more usual, however, to find them sheltering in bark crevices. Hartig observed that the adult females of *S. juvencus* swarmed at sundown, and Scheidter also states that the females of *S. augur* and *S. noctilio* oviposited only in the late afternoon. I have found no evidence of time selection in either *gigas* or *cyaneus*, *e.g.*, *gigas* was found ovipositing in the middle of the day, while *cyaneus*, commencing about 10 a.m., would continue throughout the day until the early evening, in some cases without any marked interval of rest. Oviposition was observed in both species, in *S. gigas* on 8th July, and in *S. cyaneus* on many occasions from August until late September. *S. gigas* was found ovipositing in a sawmill where there was a considerable quantity of larch and pine logs and sawn timber. The insect selected a small freshly

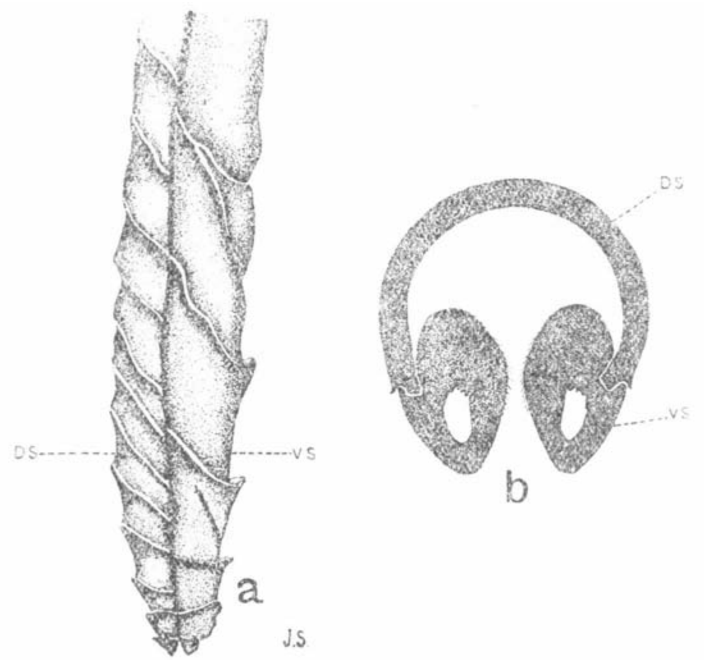

Fig. 5. Ovipositor of *S. cyaneus*: *a*, apex, showing the serrated setae, ×35; *b*, transverse section, showing the ventral valves (v.s.) slightly separated from one another, ×70. d.s. = dorsal seta, v.s. = ventral seta.

cut larch log and began its task at 11.25 a.m., boring three oviposition tunnels in the course of half an hour, each operation lasting 8–9 minutes. Two of these tunnels, on subsequent examination, failed to reveal any sign of eggs, and it was thought at first that these had been overlooked. It was discovered later, however, that the insect frequently makes trial borings, sometimes of considerable depth, in which, for some reason or another, she fails to oviposit.

Before boring commences, a close examination of the bark is made with the antennae, this operation being followed by further preliminary testing with the ovipositor and sheath, which may be withdrawn several times before a favourable spot is found. Having chosen the place of oviposition the insect raises herself upon the two outer valves that form the sheath of the ovipositor. Once she is firmly established in the desired place, the latter are released and spring back to their original horizontal position, exposing the thin flexible tube-like ovipositor which the insect proceeds to insert into the wood with a rapid sawing movement of the toothed setae, the whole operation being accompanied by rhythmical movements of the abdomen.

It is at this point that the first egg is laid at the bottom of the tunnel. Subsequently the ovipositor is gradually withdrawn, coming to rest several times during the process. From the position of the eggs in the tunnel, lying as they do one above the other, it seems very probable that each halting place of the ovipositor represents the deposition of another egg. The halting of the ovipositor while being withdrawn is not, however, to be confused with the sawing action of the organ while the oviposition tunnel is still in course of construction.

The ovipositor (fig. 5) in transverse section can be divided into 3 parts, a dorsal valve, representing the fused inner gonapophyses of segment 9, and two ventral valves developed from the gonapophyses of segment 8.

The outer dorsal portion of each ventral valve is deeply grooved to enable the flanged portion of the dorsal valve to fit closely into it. The egg tube is formed by the

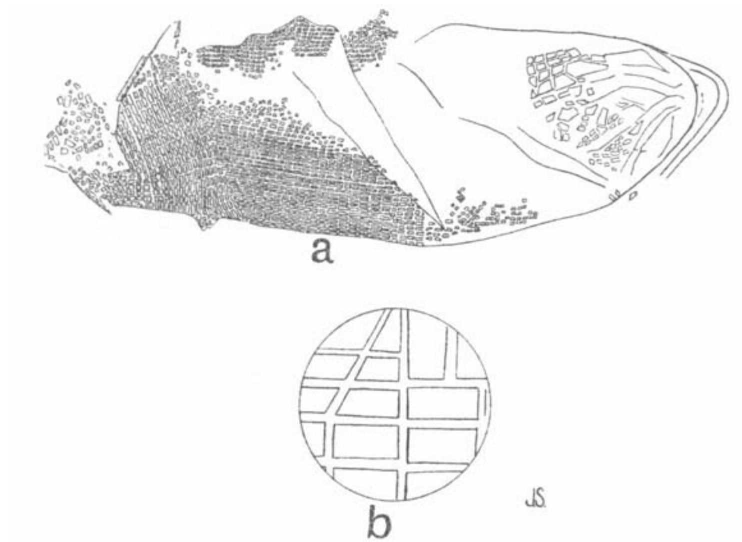

Fig. 6. Egg ot *S. cyaneus; a*, sheath, × 60; small portion of sheath, × 225.

union of these valves, and if the ovipositor of an adult be examined at the time of egg laying the tube will be found full of eggs which are passing down into the oviposition tunnel. The diameter of the egg tube when empty is 0·27 mm., and on comparing this with the average diameter of the eggs which pass down it, it was found that these measured 0·36 mm. at their widest part, consequently exceeding the diameter of the egg tube by 0·09 mm. This difference in diameter is fairly constant, and the question arises as to how the egg passes down the tube into the oviposition tunnel. This is probably effected by a slight flattening out of the egg as it passes down the tube, proof of which has been found in eggs dissected out of the tube, and further the fact that the egg tube is oval in shape rather than circular confirms this ; moreover a lubricant fluid also assists the eggs in their passage down the tube. This fluid has been observed exuding from the tip of the ovipositor of *S. cyaneus* during the discharge of the eggs. Further, it has been found in all cases that the eggs are surrounded in the oviposition tunnel by a white glistening sheath of a glutinous nature.

This sheath coats the tunnel walls and also the eggs, from which it is extremely difficult to remove it. Under the microscope it always breaks up into a constant pattern (fig. 6) which somewhat resembles crystalline structure.

I found no trace of any such covering on the eggs that were still lying in the egg tubes, and therefore conclude that this substance is a glandular secretion, which, passing down the oviduct into the ovipositor, acts as a lubricant for the passage of the eggs. Burmeister (Manual of Entomology, p. 190, pl. xxvii, fig. 10) describes and figures a glandular appendage in the female reproductive organs of *S. gigas*, which he calls the gum gland. This, he says, contains a white glutinous liquid that covers the eggs and fastens them to " objects." He does not, however, figure the nature of this covering, so I am unable to compare my findings with his. Lastly, the eggs are assisted in their passage down the tube by the opening out of the two ventral valves, which increases the diameter of the tube. The actual occurrence of this can be seen when oviposition is in progress, as the eggs are sometimes visible passing down the tube through the slit formed by the opening out of the two ventral valves. The inner margins of these are covered with closely placed hairs, and it is possible that when they separate from one another the hairs act as a protection against the entry of foreign bodies, e.g., wood frass, etc., which might block up the egg tube. Close observation of oviposition is a simple matter, as the insect, completely absorbed in her task, allows one to follow her movements even with a hand lens. The oviposition habits of *S. cyaneus* do not differ in their essentials from those of *gigas*, but several instances were recorded in which the operation lasted from half an hour to one hour. These long periods are, however, unusual.

The oviposition tunnel is circular and in diameter measures slightly more than the greatest diameter of the egg, leaving ample room for the swelling of the egg when the young larva develops. The oviposition tunnel penetrates the wood either at right angles to the longitudinal axis of the stem, or at a slant, and it varies in depth from 6–7 mm. up to 18–20 mm. The oviposition holes are easy to locate with a little practice, even on the bark, for some time after the insect has departed. Plate ix shows the location of a number of such holes ringed round with white paint on a larch at Tubney, which was frequented by the adults. The oviposition holes on this tree were legion, and further reference to their density is made elsewhere. In the case of fresh trees it is still easier to locate the oviposition holes on the wood surface by removing the bark, when each hole can be seen surrounded by an area of discoloured tissue, which is due to the necrosis of the cells in its immediate vicinity. It was formerly believed that only one egg was deposited in each tunnel, but Scheidter recently showed in the case of *S. gigas* that this was not always the case. He figures one tunnel of this species which has had 6 eggs deposited in it. I have also found with *S. cyaneus* that one egg to a tunnel is the exception rather than the rule. Three to four eggs to a tunnel is quite a common number, and in some cases I have found as many as six or seven.

The total capacity of egg-laying varies considerably in different species. Scheidter, for example, found by dissection of the ovaries in *S. augur* an average of over 1,000 eggs, whereas in *S. noctilio* the average was only 400. Dissection of the egg tubes in large females of *S. cyaneus* taken at Tubney in September 1926 gave 300–400 on the average.

It is a common occurrence to find adults that have died while egg laying still fixed to the tree with the ovipositor buried in the wood. Two reasons can be assigned for this : First, the insect often chooses a place for oviposition where the sap flow is too strong, with the result that once the ovipositor is inserted she is unable to withdraw it, the moist condition of the wood causing the fibres to close in and hold it fast. Three or four dissections of adults that were found in this position were made during the summer, and in all cases the state of the egg tube showed that oviposition was at its height. Secondly, however, it is possible that some of the insects that were caught in this manner are those which, having come to an end of their egg-laying, are exhausted by their labours and thus perish in the completion of their task.

The egg (fig. 7) in both species is fusiform and translucent. It measures 1·25 to 1·5 mm. in length, is markedly constricted at one end and rather broadly rounded at the other. No definite pattern can be traced on the surface of the chorion. The eggs are deposited right up to the tunnel opening.

The incubation period is, so far as I have been able to calculate from my observations this summer (1927), 3 to 4 weeks. The young larva is completely developed before it leaves the egg (fig. 7), out of which it bites its way with the mandibles.

The first young larva found this summer on 29th August had already begun boring its own tunnel This larva measured 2 mm. in length and was one of the earliest hatched of the season, as three days later, on 1st September more young larvae were found which were still lying in the oviposition tunnel, not having begun to bore on their own account. Eggs were found up to 22nd October, and young larvae just leaving their egg-shells up to 8th November. The height of the oviposition period I take to be from the middle of August to the middle of September, and calculating 4 weeks as a maximum for the incubation period, I conclude that young larvae should still be found in the oviposition tunnels until early in November. The records which have been taken agree very closely with this estimate. On dissecting some oviposition tunnels of *S. cyaneus* recently (February 1928), two larvae were found lying in them not yet free from their egg-shells. This indicates that in the case of eggs laid late in the season, the incubation period may be much longer than usual. I have found only two cases of this so far.

The young Larva.

The morphology of the mature larva of *S. gigas* and *S. juvencus* has been described by Ratzeburg, Hartig, Cameron and others, and Yuasa, in his " Classification of the

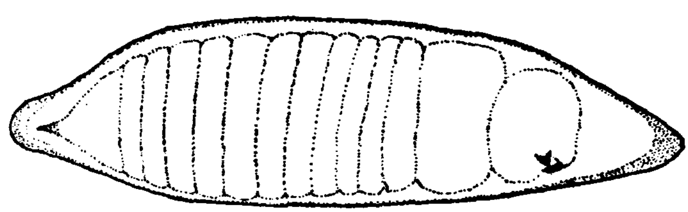

Fig. 7. *S. cyaneus:* egg with young larva *in situ*, × 60.

Larvae of the Tenthredinoidea," has described the larva of *Tremex columba*, Jurine, as a type of the family. The following notes refer to the first larval stage of *S. cyaneus* found in the oviposition tunnels at Tubney.

The first stage larva still under the cover of the eggshell is pale white and translucent, only the strongly chitinous mandibles and terminal spine showing dark brown in colour. The larva on hatching measures 1–25 mm. in length and has a uniformly cylindrical body which tapers somewhat towards the anal end. The body surface, examined superficially, appears smooth and shining, but on closer examination it is found to be covered with minute spines which are placed in regular rows on every segment. These spines, which hardly rise above the surface of the integument, do not seem sufficiently well developed to afford the larva much aid in locomotion. The head, which (as in the later stages) is markedly overhung by the prothoracic segment, is dome-shaped, smooth and shining, and directed ventrally.

The antennae (fig. 8, *b*), which are apparently two-jointed, have a truncate terminal joint armed with a number of blunt spines. In the mature larva the antennae are three-jointed and have their terminal joint markedly pointed. The mouth-parts (fig. 8) are well developed and exhibit the following characters : The labrum (*a*) is markedly asymmetrical, a characteristic which is developed to an even greater degree in the later stages. On its front margin there are several rows of spinous processes, giving it a markedly roughened appearance. This is in contrast to the labrum of the mature larva in which the front margin is entire and heavily chitinized. The two mandibles also differ markedly from one another; the right mandible (*d*), which lies above the left when at rest, is somewhat quadrate in shape and bears a large lobe on its inner side and four blunt teeth on its outer margin; in the left mandible (*c*) the inner lobe is much less strongly developed and the outer margin is provided with only three teeth.

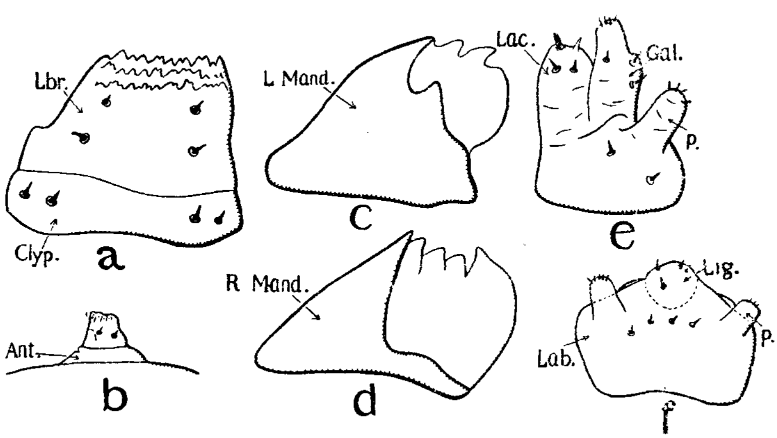

Fig. 8. *S. cyaneus:* mouth-parts and antenna of young larva, × 225.

The maxillae (*e*) are fleshy, the palpi one-jointed and conical, bearing a number of blunt setae at the tip. The galea is broad at the base and markedly constricted at the tip, on which there are a number of spines. The lacinia is more dome-shaped and bears at least three well-marked spines at the tip. The labium (*f*) is soft and fleshy with well marked single-jointed palpi. The ligula is circular and fits closely into the deep emargination of the mentum. Mamma-like thoracic legs are already well developed, and each bears a prominent terminal spine. The spiracles number nine pairs, of which the prothoracic pair are much larger than the rest. They are markedly circular in form and in this respect differ from the later stages, in which they are oval. The terminal abdominal segment is hollowed out in a deep depression on the tergum, at the apex of which are borne two short blunt tubercles. Beyond these lies the chitinous terminal spine, which in the first stage larva is markedly shorter than in the later stages.

The function of the terminal spine has always been considered to be concerned with the packing of the boring dust by the larva in its tunnel. After watching several larvae working in their burrows I have come to the conclusion that it also serves the larva as a terminal support, being driven into the sides of the tunnel for this purpose.

The young larva constructs its tunnel at right angles to the oviposition tunnel and continues to bore in this direction for a short distance before it turns inwards towards the heartwood. Many studies were made of these tunnels and text-fig. 9 shows some typical examples that were drawn as they appeared on 27th–29th September 1927.

Figure 9, *a* shows a sloping egg tunnel at the commencement of which, just below the wood surface, a larva has hatched, and is commencing to bore along the sap wood. In figure *b* the tunnel is vertical, and contains three larvae, all of which have begun their tunnels ; and in figures *c* and *d* some newly hatched larvae are seen still lying in the oviposition tunnel, only one having begun to bore. All these figures are drawn from freshly dissected specimens and represent the varying conditions which one may expect to find in the oviposition tunnels during September and October. The study of the oviposition and young larval tunnels has been found to be of great importance in the study of the Cynipid *Ibalia*, and will be referred to again in the paper on that parasite.

The larva tunnels in the outer sapwood for the first part of its life. When it has grown to a length of 8–9 mm. it turns inwards towards the heartwood, usually following a more or less vertical direction, either upwards or downwards. As it proceeds on its way the tunnel behind is closely packed with frass, and at intervals in this the cast larval skins are to be found tightly wedged between the frass layers. Moulting begins very early in larval life, the first moult in two cases being found in

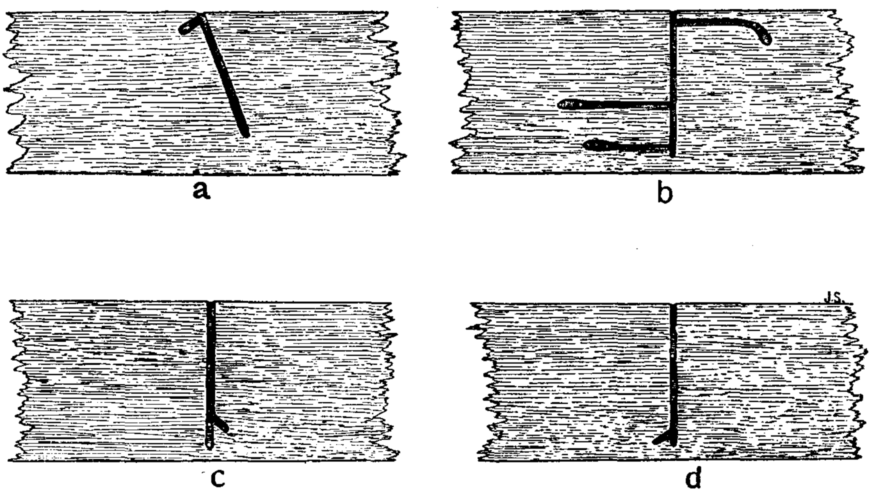

Fig. 9. *S. cyaneus:* oviposition tunnels and young larval galleries.

the frass of the oviposition tunnel itself ; and in another instance the indications were that, in the early stages at least, moulting occurs at short intervals. Recent examinations of the tunnels of very young larvae have shown that 3–4 moults take place at intervals of 1·8 mm. between each.

Direction and Length of the Larval Tunnels.

Generally speaking, the larva tunnels right to the heartwood and then curves round, returning towards the wood surface in preparation for pupation and the emergence of the adult. The variation in direction of the tunnel is, however, considerable, according to the nature of the wood. Thus larvae of *S. gigas* working in silver fir wood that was rough and knotty were often found coming up quite close to the surface in the course of their borings, in order, apparently, to avoid passing through a knotty area, the tunnel subsequently returning to the heartwood. It is, on the other hand, surprising how often one finds the larvae boring through the hardest wood. The larvae of *S. cyaneus*, when present in badly cankered larch stems, often pass straight through the worst cankered places, where the wood is very hard and resinous and consequently difficult to penetrate. Usually, however, such places are avoided, the direction of the tunnel often being abruptly altered so as to skirt around the outside of the cankered area. There are many records in the literature of *Sirex* adults boring through coverings of lead sheeting, sometimes of considerable thickness. While this is certainly remarkable when one considers the unfamiliar nature of the medium through which the insect finds its way, the actual difficulty of boring through lead cannot, one imagines, be very much greater than that experienced by the larvae in hard and resinous wood.

Hartig records that he has found tunnels of *S. juvencus* 2–2½ feet long. The longest tunnels I have any records of are those of *S. gigas* in silver fir from South Molton, North Devon, which were measured by Mr. H. S. Hanson and reached a length of only 15 inches. In a larch log of 7 inches diameter, from which some quite large specimens of *S. cyaneus* had emerged, seven tunnels were dissected out and measured, giving the following results : 6·2, 6·8, 8·4, 8·7, 10, 10·2, 10·1 inches ; while in another log only 4 inches in diameter one tunnel totalled 8 inches ; 10 inches to 1 foot is a fair estimate of the maximum length of the tunnels of *S. cyaneus* in larch at Tubney. The tunnels of *S. gigas* are probably longer on the average ; certainly on the basis of a few specimens it would appear so, but the data on this point are at present insufficient.

Pupation.

J. H. Fabre, in an essay entitled " The Problem of the Sirex," has described how in *S. augur* the larva, when full-grown, lies lengthwise in the tree not far from the centre of the trunk. In this position metamorphosis takes place and the adult insect, on emerging, is faced with the problem of cutting its way out through the wood in which it lies a prisoner. In the vertical plane in which it lies this is a difficult task for the heavily armoured adult, which is incapable of bending the body freely. The task is accomplished, according to Fabre, by the construction of an exit gallery which is the wide arc of a circle, whose lower extremity is connected with the larval tunnel, and whose upper extremity is prolonged in a straight line, which ends at the surface with a perpendicular or slightly oblique incidence. The wide connecting arc, which enables the insect to adjust its position gradually, is a curve which Fabre has shown approximates as nearly as possible to the circumference of a circle, and the construction of which is a constant feature of the species even over lengths that sometimes exceed four inches. These remarkable observations by the great French naturalist have not been duplicated in the case of *S. cyaneus*. Many pupal chambers of that species have been examined, and in nearly every case the pupal cell was so constructed that the adult was afforded a perfectly straight forward passage to the outside, whether it chose to proceed in an oblique or horizontal direction. Further, with reference to Fabre's statement as to the difficulty that would be experienced by an adult turning round a sharp-angled tunnel, several pupal cells of *S. cyaneus* have been found that show the cells lying parallel to the wood surface, the exit hole being at right angles, an indication that the adults emerging from them must have been able to bend their bodies considerably in order to emerge successfully (fig. 10).

S. cyaneus pupae were found from the end of June onwards, and the depth of wood in which they lie varies considerably. The average depth is from three-quarters to half-an-inch, but in many cases, especially in male pupae, the pupal cell lies less than a quarter of an inch from the exterior. This apparent difference in the depth at which male and female pupae are found may be compared with some observations made by a Russian worker, N. K. Stark, in a recent paper on " The Distribution of the Sexes of some Longicorn Larvae in Trees." This author working on the longhorn beetles, *Callidium sanguineum*, L. and *Saperda scalaris*, L., in old oak wood, found that the larvae and pupae which occurred at different depths were not of the same sex. The females invariably occurred in the deeper galleries and fed longer than the males, which were usually superficial feeders. The author suggests that the same distribution of the sexes may apply to *Acanthocinus aedilis*, L., another longicorn borer in pine, and to *Pissodes pini*, L., a common weevil enemy of young pine plantations. I have good reason to believe that the distribution of the pupae in *S. cyaneus* shows the same peculiarity, which, as the author suggests, is due to variation in the length of the larval tunnel.

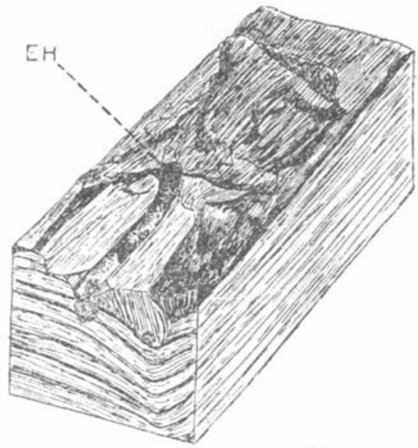

Fig. 10. *S. cyaneus:* abnormal pupal cell. EH=exit hole.

Larvae have been found ready for pupation in tunnels that were only separated from the exterior by a thin layer of bark; but such cases are unusual. Scheidter found pupae of *S. augur* 4¾ inches from the wood surface. The pupae of *S. cyaneus* when lying too deep in the wood often perish *in situ,* either in the pupal stage or as adults. For example, while examining silver fir logs for *S. gigas* material recently, I was struck by the numbers of adults that were found dead in their tunnels, sometimes in the pupal chamber, sometimes on their way to the outside. These adults were nearly always covered with fungus, but whether this fungus was the cause of death or an after-growth, I do not know; but I imagine that the death of the pupae and likewise that of the adult is due to some organism whose attack is induced by change of moisture conditions in the wood. The duration of the pupal stage in *S. cyaneus* varies from 5–6 weeks.

Length of the Life-cycle in Siricidae.

The minimum period estimated by most writers for the Siricid life-cycle is two years, and with this my observations on *S. cyaneus* agree. Estimating the average duration of the egg stage at 4 weeks and the pupal period at 6 weeks, this leaves 21 months for the larval stages. From observations recently made on larvae which have hatched from eggs laid in September 1927, it would appear that up to the end of the first six months of their life the larvae reach a length of only 2–4 mm. These larvae, starting to grow in the spring, probably finish up their first year one-third to half grown. At this rate of development the approximate distribution of the stages in a two-year life-cycle would be as follows :—

Year.	Month.	Stage.
1926	August–mid-September ...	Adults ovipositing
	Mid-September–October ...	Eggs; young larvae
	October–December ...	Larvae (small, 1·2 mm.)
1927	January June	Larvae (small to 1/3 grown)
	July–December	Larvae (1/3–1/2)
1928	January–July	Larvae (1/2–full grown)
	July	Pupae
	August	Adults

Study of the relative sizes of larvae found living in the same tree at different periods of the year has shown that it is always possible to find both large and small forms at one and the same time, and this certainly suggests a possible two-year cycle. To obtain an exact figure is a matter of some difficulty, as it is fairly obvious that the period must vary considerably, depending largely upon the various factors, physical and chemical, which operate both inside and outside the wood of the tree. I do not think that we may expect to find cases of extreme length of life-cycle in the SIRICIDAE, such as have been quite often recorded of the Cerambycid wood borers, whose adults have been known to emerge from wood 17, and even 40, years after it had been converted into furniture. In these cases the dry nature of the medium has prolonged a life-cycle that normally would have been completed in 3–4 years. Dry wood conditions, no doubt, do prolong the life-cycle of SIRICIDAE to some extent, and cases have been recorded of wood-wasps emerging from the wood of a building 2½ years after its completion. Shuckard also quotes an instance of *S. cyaneus* (*duplex*) emerging from the joists of the floor of a dwelling-house that had been built over three years. Wood-wasps have also been recorded as emerging from furniture long after its completion. It is as well to remember, however, in attempting to estimate the length of life-cycle in such cases, that wood-wasps will oviposit readily in sawn timber beams or planks, and that it is possible therefore that the wood from which the insects are emerging may have been attacked somewhat later than calculation allowed for. There is, moreover, always the possibility that in the case of timber in buildings, moisture conditions may be more favourable to a slight prolongation of the life-cycle, and, further, that the insects living in a protected environment may not perish *in situ* so readily as they do when living in logs lying exposed in the open. Under natural conditions in the forest, prolonged periods are not to be expected, and in the case of *S. cyaneus* an average period of 2½ years may be estimated, with a possible maximum of 3 years. In cases where the adults are found overwintering in the wood, this, of course, at once lengthens the cycle by at least 6–9 months, as adults found in the wood in November are not likely to emerge before June or July of the following year.

Host Trees.

Nearly all authors have attempted in the past to assign preferential host trees to each species of *Sirex*. Thus *S. noctilio* was considered to be mainly a pine insect, which sometimes attacked silver fir and very occasionally spruce. *S. gigas* was generally regarded as chiefly an enemy of spruce, but was also recorded on silver fir, pine and larch ; Borries records it as a serious enemy of 120-year-old larch in Denmark.

Leisewitz in 1898 published a list of the European SIRICIDAE, arranged according to their host trees, and shows quite clearly that no such preferential host selection really occurs in nature. Scheidter sums up the evidence on this point in the following passages : " From this discussion the main fact emerges that neither *gigas* nor *juvencus* can be said to prefer one host tree to another. They will choose that one which is peculiar to, or most abundant in, the particular district where they occur . . . and therefore I do not think that we can designate these species as monophagous, since they are bound to no one particular species of host tree." " On the other hand," he continues, " *S. gigas* and *S. augur* are attracted to the largest trees, while *noctilio* and *juvencus* prefer trees in the pole stage." This he attributes to the fact that the two first-named species, having longer ovipositors, can penetrate the thicker bark of the larger trees more easily, while the last two, with their shorter ovipositors, are more or less confined to younger trees. From an examination of records in the literature the same conclusions appear to apply to *S. gigas* and *S. cyaneus* in this country. Evans records the two species from both pine and silver fir in Scotland, and I have records of the two species in Scots pine, silver fir, larch and spruce in Devon. In Tubney Wood *S. cyaneus* is the only species breeding in larch, to which it confines itself, leaving the Scots pine untouched. Adults of *S. gigas* were sometimes found during the flight season in and around the wood, but it was ascertained that they were breeding in some old spruce and silver fir trees about half a mile distant. I have not found *S. gigas* averse from attacking young stems in the pole stage, having seen it ovipositing in larch poles at Tubney and also in Devon. I think, however, that there is something to be said in favour of its preference for older trees, though one might remark at the same time that *S. cyaneus* also appears to be quite capable of attacking these. The size of tree attacked may, in some cases, be no guide at all. *S. cyaneus*, for instance, is often found in the tops of larch trees not more than 3 inches in diameter.

Variation in Size of Adults.

Great variation was found in the size of the adults of *S. cyaneus* both bred from larch in cages and also taken in the open at Tubney. This phenomenon is well known in the SIRICIDAE, and Bischoff (Biologie der Hymenopteren, p. 22) alludes to it in the following passage: "In the phytophagous forms, the wood-boring SIRICIDAE are especially notable for the extreme variability in size that they exhibit, a characteristic which they share with many other wood-boring insects, and which in the case of the dwarf forms must be due to poor nourishment. In close relationship with the development of the host larvae, stands also that of the parasites, a phenomenon that is especially noticeable in those members of such groups as the PIMPLINAE which parasitise wood-borers." Evans refers to this great variation in size of the adults and gives the following figures for *S. gigas* and *S. cyaneus* respectively :—

S. gigas—large adults (measured from the front of the head to the end of Segment 8), 38, 36, 35 mm. ; small adults, 24, 18 mm.

S. cyaneus—large adults (measured as above), 30 mm. ; small adults, 16 mm.

I have also collected some figures of the variation in size of both sexes of *S. cyaneus* taken in Tubney during the past two years. Using the same method of measurement as Mr. Evans, I got the following results :—

Sex.	*Small.*	*Large.*
Male	10 mm.	18, 20 mm.
Female	10, 13, 15 mm. ...	17, 17, 22, 22, 23, 24, 24, 24, 24, 24 mm.

I have also found that this variation in size occurs in both *Rhyssa* and *Ibalia*. It is especially noticeable in the former parasite and will be further discussed in the paper dealing with that species.

Of the general truth of the statement that variation in size is related to conditions of nourishment, there can be no serious doubt. The exact nature of these conditions is, however, most difficult to ascertain. For instance, one may breed dwarf forms of both sexes of *S. cyaneus* in logs of 8 inches diameter, as well as in those which are only 3–4 inches, and conversely large adults can be bred from quite small stems. Two factors probably come into the question: the chemical constituents of the wood at different stages of decay, and its moisture content. Of the first, little or nothing is known, and one can only suggest the possibility that when wood reaches a certain stage of decay there is not enough nourishment left of the right kind to enable the insects to attain their normal size. As regards the second factor, moisture content, this must also play some part, although it is at the moment very ill-defined. I have noticed, however, that from logs kept in cages over a long period and allowed to become too dry, very small adults of both sexes were reared. Similarly in the case of trees cut in the open, I believe that smaller trees will produce undersized adults in a shorter period than larger trees, for the reason that the drying out process is much more rapid in the one than in the other.

Dr. J. Waterston has given me the following note in respect of variation in the size of adult wood-wasps in the British Museum collection.

Sirex gigas ranges in length from 12 to 40 mm. according to Enslin. The British Museum, however, possesses a magnificent ♀ of 51 mm. with an expanse of 68 mm. An average-sized female (expanse 50 mm.) is 38 mm. long. A male with the same expanse is somewhat shorter (32 mm.).

S. noctilio is only a little inferior to *S. gigas* in size. The body of the female is relatively slightly shorter. The largest examples in the British Museum measure: ♂, length 34 mm., expanse 58 mm.; ♀, length 38 mm., expanse 56 mm.

In *S. cyaneus* the body of the female is longer than in *S. noctilio*: ♂, length 31 mm., expanse 51 mm.; ♀, length 43 mm., expanse 56 mm.

No large examples of *S. juvencus* have been examined. The measurements of the largest ♀ are, length 26 mm., expanse 40 mm.

The Forest Relations of the Siricidae.

One of the most fundamental principles that research in forest entomology, especially during recent years, has laid down, is that for the proper understanding of the biology of an insect something more than a mere catalogue of entomological data is required. It is now realised that the insect *per se* is only one factor in the vast biological complex of the forest, and that if we would really understand its biology and seek to control its activities, we must take account of many factors and base our conclusions on a conception of the whole. This principle holds good in the case of *Sirex*, and I now propose to consider the problem in relation to the following questions: (*a*) do the SIRICIDAE attack healthy trees?; and (*b*) if they do not, what are the factors concerned that render the host tree more susceptible to attack?

All Continental workers, including the earliest writers, are agreed upon one point, namely, that where wood-wasps are present trees which are in a sickly condition, from whatever cause, or which are suppressed by other trees, are liable to attack. Thus Bechstein says that subsequent to the devastation of large areas by the nun moth (*Lymantria monacha*) or bark-beetles (SCOLYTIDAE), wood-wasps may become abundant, and he quotes in support of this statement the records of such outbreaks in the Thuringerwald in 1778, 1787, 1797 and 1804. Ratzeburg also shares this view and quotes instances from Brandenburg in 1835, 1836 and 1843, and a later outbreak in East Prussia in 1850.

In all these cases the wood-wasps played a secondary rôle, causing technical damage to timber, and this we may consider as well established. The evidence on the primary status of wood-wasps as pests is, however, far from unanimous. Balzereit is one of the early workers quoted by Ratzeburg who considers that wood-wasps are sometimes primary and capable of attacking healthy trees. Of spruce, for example, he writes, "penetrated as they are by thousands of bore holes, they have the resin running down their trunks in streams on hot days and soon die as a result." Ratzeburg criticising this sentence says: "I can hardly believe that the latter (the wood-wasps) are to be considered as primary enemies, and that the flow of resin on the tree-trunks, as well as the discolouration which appears in the sapwood in the neighbourhood of the oviposition holes, is to be laid entirely to their charge . . . the cause appearing to me to be more likely due to the activity of bark-beetles in the cambial region." Ratzeburg admits, however, that when present in great numbers, it is possible that wood-wasps do attack and kill healthy trees under certain conditions.

Hartig, writing some years later, discusses the ability of *Sirex* to attack green trees in the following passage: "So much is certain, that the damage by the wood-wasp larvae does not produce such serious after-effects as do the tunnels of those beetle larvae that mine between the bark and the wood. The innermost bark layer and the sapwood region is the location of the sap flow and the place where all further stem growth occurs, so that damage to the organic tissues functioning here must exert an influence on the whole plant. In comparison with this, the damage done by the wood-wasp larvae in the wood itself is only limited in effect and almost without any influence on the general health of the tree . . . We may conclude, therefore, that when a tree is attacked by wood-wasp larvae and dies in a short time, this tree was already sickly from another cause, which, apart from insect injury, would have ultimately caused its death."

In another place he also says that he has observed spruce trees which, although very unhealthy and attacked by wood-wasps, nevertheless continued to maintain a precarious existence for a long time. This last observation is supported by von Hagen, who found in Silesia that trees attacked over a 7-year period, while suffering considerably in loss of increment, were in no case killed outright.

These views are shared by the later writers, and Scheidter, the most recent of these, says that in the Bavarian Frankenwald the importance of wood-wasps is entirely technical, in which rôle, however, they are often serious. The American literature on SIRICIDAE contains practically no references to their forest relations. Felt mentions one species *S.* (*Urocerus*) *albicornis*, F., as attacking spruce (*Picea*), hemlock (*Tsuga*) and silver fir (*Abies*) in the eastern States and Canada, and says that while reports of considerable injuries to coniferous trees in the north-west territories have been received, comparatively little damage is usually done by the insect in the United States. I had occasion to observe this species in Eastern Canada (Ontario) during the autumn of 1919 on a visit to a stand of Balsam fir (*A. balsamea*) and made a few notes upon it during a brief stay. The area in question was quite a small one and the trees averaged 45–50 years of age. They had suffered considerably from wind damage and other troubles, fungus root rot among the number. At the time of my visit a heavy thinning was in progress, the stand having been marked as a sample plot, and there was a good deal of felled timber about in piles and also strewn singly on the ground. Large numbers of adults were flying at the time, and I endeavoured to ascertain what type of tree was most favoured by them for oviposition purposes. The choice available was considerable: green, healthy trees, vigorous as regards height growth and diameter increment ; obviously sickly trees, still green but dying rapidly ; and felled logs and branches, both green and dry. In the short time at my disposal, detailed observations were out of the question, but I was led to the conclusion that of the three types mentioned, the insects avoided the green and vigorous stems, but frequently attacked dying trees, not always successfully, on account of the strong resin flow in which the ovipositing adults were sometimes caught. Felled logs were most favoured of all, and it appeared likely that if fallen trees were present the insects would prefer these to standing trees in the majority of cases. It was with this idea in my mind that the experiments at Tubney Wood about to be described, were arranged.

Field Studies in Tubney Wood, Oxford.

The wood in which the field work has been carried out forms a small part of a mixed plantation of Scots pine and larch planted in about equal proportions. The area was planted in 1891–92 and the portion of wood in which observations were made is low-lying, quite a considerable part of it being very swampy. On my first visit to the wood, a superficial survey indicated this part as being the most likely to yield *Sirex* trees in numbers, so marked was the difference between the condition of the trees on it as compared with those on the drier portions.

The larch are in the pole stage and vary from 3 inches up to about 9 inches D.B.H., the average height being about 35–40 feet. The proportion of dead trees varies slightly, being greatest in the wetter parts. Apart from dead trees there are all gradations of green trees from healthy full-crowned trees to sickly poles that have less than one-fifth of their crown remaining. Through the kindness of Mr. W. R. Day, Mycologist to the Imperial Forestry Institute, I was able to make a survey of the wood in company with him to collect data on the following points : (1) the general condition of the larch and its relation to soil conditions, silvicultural treatment, etc.; (2) the presence of root fungi as antecedent to, or contemporary with, the *Sirex* attack.

These two points were considered apart from the insect question. During this survey the root systems of a dozen trees were examined, both standing and windblown stems being chosen. The first general conclusion which was arrived at was that the swampy nature of the ground over a large part of the area resulted in the tree roots being under water for many months of the year. The soil in these parts is light sand on top with stiff sandy clay below, which holds the water. The result is that the root system of the majority of the larch is extremely poor with consequent poor crown production, a state of matters that neglect of thinnings has increased. Two root fungi were looked for, *Armillaria mellea*, the honey fungus, and *Fomes annosus*. On a previous preliminary survey it was thought that one or both these fungi might be prevalent, causing primary injury. After searching both in the field and in the laboratory, however, no sign of the rhizomorphs of *A. mellea* or of the mycelium of *Fomes* could be traced. Slight indications of attempted penetration of *Armillaria* in times past were found, but nothing extensive. On the other hand extensive root rot was present, the tap-roots of many trees being completely destroyed. This was entirely due to the waterlogged condition of the soil. Further proof of bad soil conditions was shown by the lack of fresh root development in the deeper roots, most of the new rootlets coming from the superficial parts. Further, although thinnings had as a rule been entirely neglected, even where the trees had opened out naturally and had been given a chance to grow, they had remained at a standstill, a fact that can only be explained by the soil conditions, which are inhibiting proper root action and development. This cessation of growth is well shown by a study of the wood rings, and dates back for at least 10 years. A further indication of bad soil conditions was found in the number of trees suffering from larch canker (*Dasycypha calycina*), which is a common symptom on areas of poor soil. An earlier survey gave a total of 50 per cent. of the trees as suffering from canker in some degree or other, most of the worst cases being in the wettest parts. The Scots pine, in contradistinction to the larch, is healthy, apart from a few windfalls here and there on the exposed south-western side.

Primarily then, the area is manifestly unsuitable for the larch, which is going back in health as a result. It now remains to show what part the insects play.

In the first place, it was found, more than once, that many trees which were obviously in a dying condition, that is, they had lost from a third to half their crown, showed no sign of insect damage at all. Apart from *Sirex*, the most obvious insect borer present was the larch longhorn borer (*Tetropium gabrieli*, Weise), a very common species in larch woods. *Tetropium* was found in some cases preceding *Sirex*, but quite as often the attack of the two insects coincided. Thus on 18th October 1927, a young larva of *Tetropium* was found just commencing its burrow in the bark of a tree in which *Sirex* had oviposited during the summer. *Tetropium* very often attacks trees which are half dead and have lost half their normal crown. *Sirex*, on the other hand, as a rule allows the tree to go much further before eggs are laid. I could find no sign of the presence of bark-beetles in numbers in the trees, previous to attack by *Tetropium* and *Sirex*, nor were there any signs on the needles of defoliating insects that could have played any part in bringing the trees to their present state.

During the summer, when the flight period of the *Sirex* approached, plans were made for ascertaining by experiment what type of tree would be most favoured by them for oviposition, and how far gone in decay the wood of a tree might be before it became unsuitable as a dwelling place for the larvae. The preliminary survey had shown that wood-wasp larvae were to be found in trees which were quite bare of foliage, but of which the wood, although sound, was fairly dry. It was also known, and has been observed by previous writers, that very much decayed wood is quite unsuitable for wood-wasps. The methods now used were two in number, and included trap stems and direct observations over long periods of the selection of standing trees by the adults.

Six trap trees were selected in the first instance, three of which were wind-blown trees with full-grown crowns and had their roots half-buried in the ground, while of the other three, two had less than half their foliage remaining and the third was quite dead. These trees were closely watched throughout the season, and the results obtained from them brought out one point quite clearly, namely, that of the three wind-blown trees, two were evidently still much too green to attract the wood-wasps for oviposition, while when placed on the third they would oviposit, but did not seem to be particularly attracted to it when left to their own devices. Of the other three, the dead tree was quite unattractive and the last two only moderately so. The adults seemed to be much more attracted to standing trees, and it was from these that the best positive records were obtained. Here again the insects were never found either upon trees with full green crowns or upon trees quite bare of foliage, the favourite type of tree being one that still retained a small part, a quarter or less, of its foliage. On such trees the insects settled and oviposited freely, and marked preference was even shown for particular trees, one of which is shown in Plate ix. This tree was from the 19th August onwards constantly visited by wood-wasps, the egg-laying operations of more than 20 adults being studied on it over a period lasting until late in September. Large numbers of oviposition holes were found on this tree, and the position of a number of these was marked by placing white rings round them, which are clearly visible in the accompanying photograph. The density of the oviposition holes was considerable in places, no fewer than six being found in one square foot of bark. This density was surpassed by a later record, a photograph of which appears in Plate xi, fig. 3, showing six oviposition tunnels lying within one half-inch square. All these holes contained larvae and eggs, but in many other cases trial borings that did not contain eggs were quite often found. Even so, however, the density of egg-laying must have been considerable. In this connection Evans, writing of *S. cyaneus* on silver fir, records that on a stem 15-feet long by 3½ feet diameter the total *Sirex* population, judging from the number of flight holes, must have numbered close on 500. In logs which contain large numbers of larvae it is remarkable how comparatively seldom one finds the tunnels running into one another. This does, of course, occur, and in rare cases tunnels can be found crossing each other at right angles. Trees of all sizes, ranging from 4 to 10 inches in diameter at breast height, were selected by the adults and oviposition extended from within 6 inches of the soil level up to the top.

The experiments at Tubney Wood have been supplemented by other observations, notably in North Devon, where, through the kindness of Mr. H. S. Hanson I was enabled to visit, in January 1928, a number of woods where *Sirex* occurs. Both *S. gigas* and *S. cyaneus* are plentiful in this part of the country and attack Scots pine, larch, spruce and silver fir. The best example of *Sirex* attack as a secondary pest was found in a silver fir wood near South Molton, North Devon, where trees over 40 feet high were dying in patches as a result of root rot caused by *Fomes annosus*, the *Sirex* appearing only on those trees in which the root rot was fairly well advanced. Some larch woods visited also showed that *Sirex* was a sure indicator of unfavourable conditions, although the cause of the trouble sometimes necessitated careful search. In one or two cases wind-blown trees were found attacked, but usually only after they had been down a little time. The above experiments and observations on standing trees susceptible to *Sirex* attack bring out the following points clearly :—

(1) That standing trees with full or half-green crowns are quite unsuitable for oviposition.

(2) That the tree has to be quite badly diseased before conditions favourable to *Sirex* appear.

(3) That the choice of trees suitable for oviposition is restricted and possibly lies between certain limits of moisture content which are at present unknown.

It is impossible at the moment to explain why cut logs are suitable for oviposition almost at once, while wind-blown trees, which still have their crowns and roots intact but are exposed to the drying influence of sun and wind, should be apparently unsuitable for a season at any rate. Recognition of standing trees suitable for oviposition is therefore difficult, but during this last season considerable help was obtained from a study of the Cynipid parasite (*Ibalia*) during its flight period. The females of this parasite on more than one occasion picked out fresh *Sirex* trees for us, the last time being late in October long after the *Sirex* had disappeared. The trees favoured by *Ibalia* all closely resembled one another in the state of the crown, of which only a quarter to a fifth remained.

Once the eggs are laid and the larvae have started work, they can continue to bore in the wood even when it has apparently dried out considerably, or when the tissues have become permeated with fungus mycelium. Thus I have found silver fir logs, the wood of which was full of fungus, with large numbers of *Sirex* boring in them. Once these larvae have matured, however, and the adults have emerged, such logs are no longer suitable for the raising of another generation. The logs by this time have reached a stage of decay at which the wood becomes soft and crumbly, and such conditions are quite unsuited to the young stages.

I should like at this point to refer to an important paper just published by Buchner entitled " Holznahrung und Symbiose," which may be described as an extended survey of the symbiotic relationships existing between wood-boring insects and fungous or bacterial symbionts. Most of the new work deals with the bark and wood-boring Coleoptera, but some remarkable new observations on *Sirex* are also described, and it is these that I should like to discuss here.

Buchner has found that the SIRICIDAE have living in association with them symbiotic fungi. These are carried by the adults in two pear-shaped glands lying at the base of the ovipositor, which contain countless numbers of strap-shaped *Oidia* of a Basidiomycete, which he states are conveyed at oviposition into the egg-tunnel. There, it appears, they develop, the mycelium ramifying through the surrounding tissues, and when the larva hatches the fungus-filled wood is taken into the alimentary tract. This Buchner suggests may represent a totally new variation of *Ambrosia* culture, in that the insect does not use the fungus itself as food, but depends on its containing an enzyme, which, acting upon the wood particles in the alimentary tract, brings them into a digestible form. These fungi, he says, are only found in the wood-boring SIRICIDAE, being absent in the parasitic ORYSSINI. He states that the *Oidia* are still present in the glands of dried museum specimens.

With a view to testing these conclusions an examination was made of an adult *S. cyaneus* that had been preserved in spirit for some months. After some difficulty, the glands described by Buchner were isolated and mounted, after treatment with cotton blue. They were found, as Buchner states, full of fungus bodies, which strongly resembled the *Oidia* as described and figured by him. Examination of the oviposition tunnel and the young larval tunnels was then made, and a number of sections stained in different ways were prepared. These showed quite clearly that the tissue in the immediate neighbourhood of the oviposition tunnel and young larval gallery was thoroughly permeated by the hyphae of a Basidiomycete fungus, and it was interesting to note that the hyphae were particularly dense in the region where the young larva was feeding. Buchner has not himself investigated the further developments of the fungus in the oviposition tunnel, larval gallery and surrounding wood, but concerning these he writes : " It must be that the oviposition tunnels are filled with eggs and fungus alternately and that by the time the larvae have hatched the wood in their immediate neighbourhood has been thoroughly penetrated by fungus mycelium." The proof of this statement was found in many sections cut from the oviposition tunnels of *S. cyaneus,* and, further, in one section of an oviposition tunnel, the eggs in which had perished, the gelatinous egg-covering which lines the tunnel wall was permeated by numerous hyphae, affording clear proof that the fungus precedes the hatching of the larvae in beginning operations upon the wood.

Buchner's work has opened up a totally new line of enquiry, which should throw a flood of light upon the problem of the food requirements of wood-wasp larvae. The results of his future work will be awaited with interest, and meanwhile we also intend to investigate the question in the case of *S. cyaneus,* especially as regards the identity of the fungus itself, and its behaviour in the alimentary tract. That we have in this case, as Buchner says, an important example of symbiosis before us, there cannot, in my opinion, be much doubt.

Status of Sirex as a Forest Pest in Britain.

This can be considered from two aspects : (1) the relation of *Sirex* to the living tree; and (2) its importance as a timber pest. As regards the first of these, we must consider the *Sirex* as indicators of pathological conditions rather than as prime factors in their production. This rôle, as we have seen, they share with such longhorn wood-borers as *Tetropium* in larch woods, and they may in one sense be looked upon as beneficial, in that they call the forester's attention to the need for further enquiry into the underlying causes of ill-health. The recognition by foresters of the close connection getween the prevalence of such pests as *Sirex* and the health of a stand is one which will become increasingly important in this country as our coniferous areas, now in the young stage, approach maturity.

From the timber point of view the importance of *Sirex* has never loomed large in this country. Definite records of losses due to their work are almost non-existent. Miss Ormerod records *S. juvencus* (? *cyaneus*) as causing damage to 70-year-old silver fir in Cumberland in 1889, but in this case only some 40 trees were involved, the total loss being about £40.

It is unfortunate that no statistics are forthcoming concerning the losses in home-grown timber due to *Sirex,* as it is possible that such figures, if available, would show the wood-wasps to be more important than is generally realised. This would apply more especially to timber stored in yards and warehouses. In a recent conversation with a small timber dealer in the west country, I was informed that the proportion of logs rendered worthless as the result of *Sirex* borings was in many cases by no means negligible. This is probably quite often the case, but one has always to remember the possibility that the wood has been previously weakened by fungi, and thus rendered worthless quite apart from the work of *Sirex.*

Natural Enemies of Sirex.

Woodpeckers are said to destroy the larvae of *Sirex.* Scheidter regards them as being their principal natural enemies and cites woodpecker marks as useful indications of infestation. Evans also records that in Scotland, the Great Spotted Woodpecker, *Dendrocopus major,* L., attacks both *gigas* and *cyaneus* indiscriminately. Woodpecker work is much in evidence on the larch at Tubney and after examining many trees both here and in other localities, I have come to the conclusion that it is the larvae of the larch longhorn, feeding between the bark and wood, which they seek out, rather than those of *Sirex.* A good deal of the woodpecker work does not appear to me to penetrate sufficiently deep into the wood to capture the *Sirex* grubs.

Wishing to obtain further information on this point, I have examined some of the literature dealing with the food of woodpeckers, especially such results as are based on stomach analyses. I have selected the work of Collinge in this country, Rörig and von Vietinghoff von Riesch in Germany, and Beal in the United States. In all cases the records of *Sirex* grubs in the stomachs of woodpeckers are conspicuous by their rarity. Collinge, for example, reports on 91 specimens, of which *D. major*, L., numbered five, *D. minor*, L., eight, and *Gecinus viridis*, L., 78. He estimates the percentage of insect food at 75, and gives a list of bark-beetles, weevils, longhorn beetles, LUCANIDAE and wood-boring Lepidoptera, but does not mention *Sirex*. The records of Von Riesch and Rörig tell practically the same story; and in the important monograph by Beal on the food of woodpeckers in the United States, which contains a mass of detail based on stomach analyses, *Sirex* grubs are never considered. That *Sirex* grubs are sometimes sought out by woodpeckers is undoubtedly true, but I do not believe that they are a primary object of search, and certainly the records quoted above would seem to support this view.

Mention has already been made of the frequency with which in certain localities one finds *Sirex* adults apparently killed by fungi while on their way out of the wood. Nothing is known, so far as I am aware, of the cause of this or whether it is sufficiently widespread to be of much importance. The insect parasites, *Rhyssa persuasoria*, L., and *Ibalia leucospoides*, Hochenw., have already been mentioned in the introduction to this paper and have been dealt with in a separate paper (Bull. Ent. Res., xix, p. 67, 1928).

Sirex in Australia and New Zealand.

The presence of *Sirex* in Australia and New Zealand has been known for a number of years. In Australia Levick reported in 1926 the occurrence of *S. gigas* imported in "white deal" from Danzig, which had been used in buildings, but states that there is no evidence that the insect has become established in Australia. The danger of its occurrence was, however, sufficiently realised by the authorities to cause them to list *Sirex* as an injurious pest under the Vegetation and Vine Diseases Act of 1915, which empowered quarantine officers to seize and burn all timber found to be infested. In New Zealand the situation is more serious. One of the steel-blue species, the exact identity of which is uncertain, although it has been provisionally determined as *S. juvencus*, has been present in that country for some years. Mr. David Miller, the Government Entomologist, who has watched its progress during the last few years, refers to its work in his recent bulletin on Forest and Timber Insects in New Zealand. He states that the original home of the insect was on the east coast of the North Island, but adds that by the year 1925 it became evident that its range had considerably extended.

The chief host tree is *Pinus radiata* (*insignis*), of which it attacks not only felled stems, but also living trees. It is also known to attack native species, having been found boring in weather boards of the New Zealand conifer rimu (*Dacrydium cupressinum*). Dr. R. J. Tillyard, of the Cawthorn Institute, Nelson, New Zealand, has also described the activities of the insect in a recent newspaper article entitled: "The Giant Horntail," which appeared in the "Nelson Evening Mail" of 9th February 1927. In this article Dr. Tillyard records his opinion that the insect was introduced into New Zealand from North America in Oregon lumber and gives two other localities, viz., Feilding and Marlborough provinces, as being infested. He regards the climatic conditions of New Zealand as being very suitable to the insect and dwells especially upon the large size which they may attain under the favourable climatic conditions of their new home. In a recent paper on the "Ancestry of the Order Hymenoptera" he discusses the feeding habits of the wood-wasps in New Zealand and states that they have taken to burrowing in the sapwood of the pine (p. 308). This cannot be regarded as a sign of any radical change in the habits of the insect, consequent upon their establishment in New Zealand. It has already been shown that in Europe and elsewhere wood-wasp larvae spend quite a considerable portion of their life burrowing in the sapwood layers. In America, he says, wood-wasps are kept in check by the severe winter conditions, and he also instances the power exercised by the parasites *Rhyssa* and *Ibalia* in both Europe and America as a check upon their increase. Further he states that in New Zealand standing green trees are attacked quite as often as fallen stems, and advocates the establishment of mixed plantations as one means of mitigating the severity of attack.

Sufficient evidence has already been adduced to show that under European, and so far as we know American, conditions wood-wasps are not, as a rule, considered to be primary enemies, in that they do not usually attack healthy trees, and it is this aspect of the problem in New Zealand which requires the most careful study. Two possibilities suggest themselves; either that under the climatic conditions of New Zealand the insect has so changed its habits as to become a primary pest, in which case the seriousness of the problem can hardly be over-estimated; or that there is some underlying cause which predisposes the pine to their attack, the nature of which is so far unknown. Dr. Tillyard's theory that intense cold plays a considerable part in the control of *Sirex* in America is hardly tenable in view of the fact that these insects are quite as abundant in the coniferous forests of the colder regions of the continent as they are in the warmer climate of the western seaboard.

So far as the control exercised by parasites is concerned, their presence, no doubt, does act to some extent as a check on the increase of the insect to abnormal proportions. At the same time it must be realised that, parasites notwithstanding, *Sirex* play an important part in Europe and America, not as primary pests, but as members of the vast army of insects which attack fallen timber and render it unfit for structural purposes. This would certainly not be the case were the parasites as effective as Dr. Tillyard would have us believe.

While I do not wish to under-estimate the important part played by the parasites in control, for I think their introduction into New Zealand could not fail to be a very important step, yet I consider that for the complete solution of the problem attention should be directed to another aspect of the question which concerns the forester.

It is said, for instance, that the insect is attacking healthy trees. What do we understand by the term "healthy tree"? It is well known to foresters that the determination of a tree as being in perfect health is often extremely difficult, especially where exotic species are concerned. Plantations of such species often maintain an outwardly healthy appearance for a number of years, while in reality their condition may be far from satisfactory. This may be due to unsuitable soil, exposure, and similar factors, or as we have already shown, to fungus disease, the presence of which is often unsuspected until other more obvious agents of destruction follow in its wake. *Sirex*, as we have seen, is one of the commonest of these "after-effects," and therefore I would submit that one of the most urgent needs at the present time in dealing with this problem in New Zealand is a thorough study of the conditions, silvicultural and otherwise, under which *Pinus radiata* is being grown, as I feel confident that it is there that the real cause of the trouble will be found.*

Summary.

(1) A complete review of the classification and status of the Siricid wood-wasps occurring in Britain is given in this paper.

(2) The biology of *S. cyaneus*, F., which has been studied at Tubney Wood, Oxford, during the past two years, is described, together with supplementary notes on *S. gigas*, L.

* Since the above was written a paper has appeared by Mr. A. C. Clark, Christchurch College, Canterbury, New Zealand, "The Infestation of *Sirex juvencus* in Canterbury" (Te Kura Naghere, no. 2, pp. 10-16, December 1927). I received this paper too late for inclusion in my own work but it has been reviewed in the Rev. App. Ent. XVI, p. 221, 1928. Mr. Clark's work on *Sirex juvencus* is the first attempt at a thorough study of the insect in relation to forest conditions in New Zealand, and some of his conclusions bear out the truth of what has been said above to a remarkable degree.

(3) A study of the forest relations of *S. cyaneus* at Tubney has shown that this species cannot be considered a primary enemy of healthy green trees. Trees which are favoured by *Sirex* are usually markedly unhealthy from one cause or another. At Tubney unsuitable soil conditions were the principal factors.

(4) *Sirex* and *Tetropium gabrieli*, Weise, the larch longicorn beetle, may occur almost simultaneously as indicators of pathological conditions in larch woods.

(5) In North Devon *Fomes annosus*, a root fungus, was the predisposing factor in the case of silver fir attacked by *Sirex*.

(6) Both *S. cyaneus* and *S. gigas* may occur in the same tree. This was found to be the case at South Molton, North Devon, in silver fir. *S. gigas* appears to prefer larger trees, and it is not present in the larch at Tubney Wood, which is in the pole stage.

(7) The primary object of the work was to acquire a knowledge of the parasites of *Sirex*, *Rhyssa persuasoria*, L., and *Ibalia leucospoides*, Hochenw. Both parasites were studied at Tubney, and have already been dealt with (Bull. Ent. Res. xix p. 67, 1928).

(8) It is considered probable that the results obtained in the above study will throw some light on the *Sirex* problem in New Zealand. Emphasis is therefore laid upon the importance of studying the silvicultural conditions in relation to *Sirex* attack.

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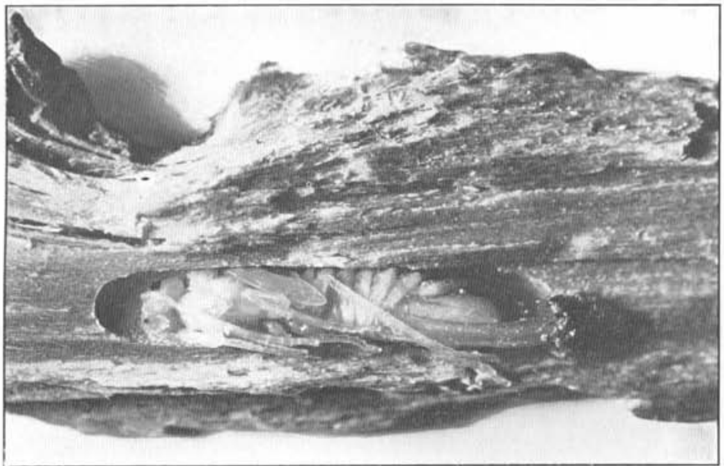
Sirex tree in Tubney Wood; a favourite haunt of the adults during August and September; the white rings indicate where females oviposited.

Explanation of Plate X.

Fig. 1. Pupa of *Sirex cyaneus,* Tubney Wood, July 1927. The eyes have already darkened and the last larval skin is still attached to the ovipositor sheath.

Fig. 2. *Sirex* larva in a small log of silver fir burrowing in the superficial layers of the wood, although nearly full-grown ; this may occur quite often in small logs that are full of larvae.

Fig. 3. Egg of *Sirex gigas* lying in the oviposition tunnel.



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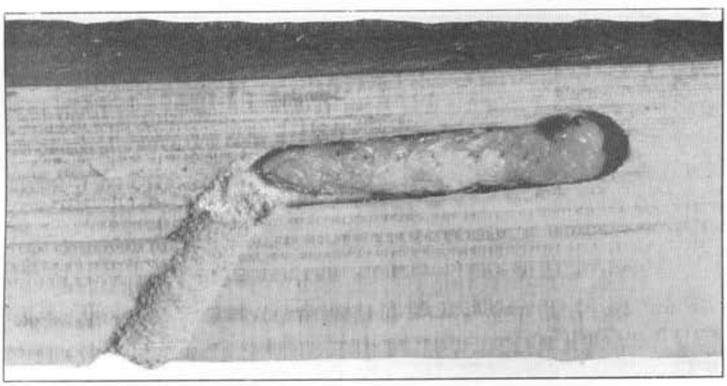

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Explanation of Plate XI.

Fig. 1. Pupal chamber of *Sirex cyaneus* in larch, showing the average depth at which it is found in the wood.

Fig. 2. Tunnels of young *Sirex* larvae in the sapwood of silver fir. The oviposition tunnel from which the two larval tunnels arise can be distinctly seen. Note also the vertical direction of the tunnels made by the larvae in the earliest stages.

Fig. 3. Inner surface of larch bark showing six oviposition holes of *S. cyaneus* within half a square inch ; each tunnel contained young larvae.

Fig. 4. Exit holes of *Sirex gigas* in silver fir. (Specimen from Mr. H. S. Hanson, North Devon.)

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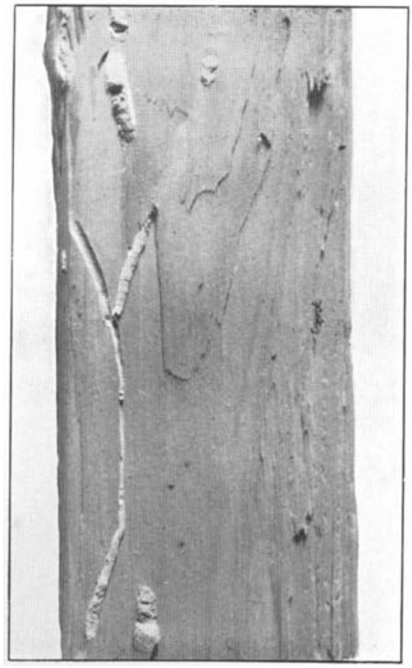

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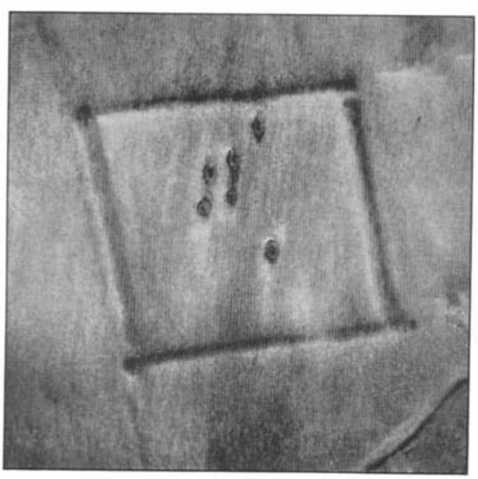

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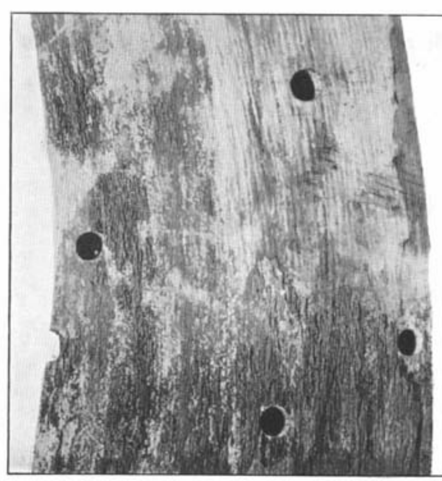

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