QUEENSLAND.

BUREAU OF SUGAR EXPERIMENT STATIONS.

DIVISION OF ENTOMOLOGY.
BULLETIN No. 13.

Natural Enemies of Sugar-Cane Beetles in Queensland.

BY

J. F. ILLINGWORTH.

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Bureau of Sugar Experiment Stations,
Brisbane, 1st August, 1921.

The Under Secretary,
Department of Agriculture, Brisbane.

SIR,—I have the honour to submit for publication as Bulletin No. 13 of the Division of Entomology, Bureau of Sugar Experiment Stations, a manuscript entitled "Natural Enemies of Sugar-cane Beetles in Queensland," by Dr. J. F. Illingworth.

I have, &c.,
H. T. EASTERBY, General Superintendent.

Approved: E. G. E. SCRIVEN, Under Secretary.

FOREWORD.

WHILE preparing a bulletin on the Australian sugar-cane beetles and their allies, I found that we had so many data dealing with the natural enemies of these pests, especially after our investigation of the epidemic of fungus at Greenhills during 1920, that I decided it would be best to present these studies in two separate papers. The first of these, "A Study of Natural Methods of Control for White Grubs," is in press and will appear as Bulletin No. 12 of our series.

The importance of these organisms in the economy of nature can hardly be over-estimated, for, even in the case of our worst pests, natural enemies undoubtedly destroy by far the greater majority; yet, even with the remainder, those that escape these foes—probably less than 10 per cent.—man frequently has a keen struggle for supremacy. We can only conjecture what would be his fate without the assistance of these organisms; hence, any effort to become familiar with the complex interrelation of our natural allies is time and money well spent.

Separated as we are in North Queensland from practically all library facilities, investigation has been carried on under a considerable handicap. Fortunately I brought along my own meagre library, and, with this and the many separates and pamphlets supplied by the Colonial Sugar Refining Company and various other investigators, I have been able to review the literature cited in the bibliography. This information has given me many suggestions, and I am sincerely grateful to all these friends, in various parts of the world, for the invaluable aid that they have given me.

I am also indebted to Mr. E. Jarvis for the assistance that he gave me in the early part of my investigation, while breeding out the *Campsomeris* wasps, and for the care with which he has executed the drawings in this paper.

And, finally, I am under the deepest of obligations to Mr. A. P. Dodd, since we owe much of our present knowledge of the natural enemies of cane-grubs to the years that he spent here in conscientious work, breeding out the many species of beetles occurring in cane areas. And, furthermore, I would be lacking in gratitude if I did not commend his splendid loyalty and his enthusiastic devotion to his chosen science.

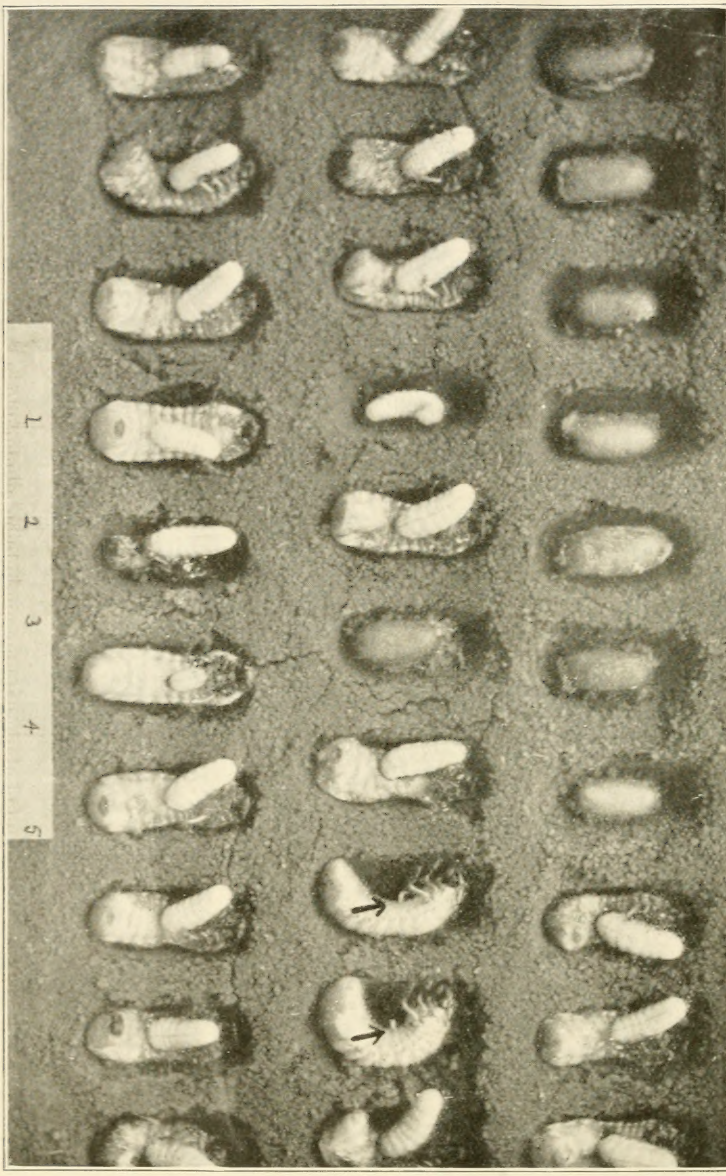

PLATE I.—Showing various stages in the development of the *Campsomeris* wasps, as they appeared in the trays. Arrows indicate eggs in position. Cocoons of the wasps are to be seen in cells on right. (Reduced; see scale.)

Natural Enemies of Sugar-Cane Beetles in Queensland.

INTRODUCTION.

Since Australia appears to be the natural home of Scarabæid beetles, this fauna being perhaps the richest in the world, it is not surprising that natural enemies are equally numerous here. While in a few instances we have certain species of these beetles developing in such hordes that they completely devastate crops, the great majority of our species are seldom conspicuous, since they are undoubtedly held in check by natural enemies. Indeed these natural controlling factors are so numerous that it is a difficult matter to understand how any destructive cane-beetles can continue to reproduce in such numbers.

Undoubtedly man, in his clearing of the forests, has upset the balance of nature. At any rate there is no question that he has been a most important agent in the depletion of the native bird life; and these feathered friends are probably the principal factor in limiting the increase of Scarabæid beetles. Moreover, cultivation has had a retarding influence upon many of the parasitic insects, especially the wasps, which normally feed upon nectar; hence the destruction of all the native flowering plants has had a tendency to drive them far into the wilds, leaving the pests to multiply in our fields without these restrictions. However, experiment has shown that we can do much to attract these friendly insects and retain them in our fields by planting nectar-bearing flowers.

Of the many natural agents which combine to hold cane-grubs in check it is a difficult matter to say which is the most important, but, from observations in certain favoured fields during the exceptional seasons of 1920 and 1921, it would appear that none has greater possibilities than the green Muscardine fungus (*Metarrhizium anisopliæ* Metsch.). In these same fields, too, a bacterial disease (*Micrococcus nigrofaciens* Northrup) occurred, but it was not nearly so virulent. Though predatory mammals, lizards, frogs, &c., frequently aid materially, birds are undoubtedly our strongest allies. Districts which are regularly visited by the ibises and crows are particularly favoured, for these birds seldom overlook either grubs or beetles. Parasitic and predaceous insects, too, are particularly abundant in Queensland; of these the digger wasps are probably the most efficient. According to Froggatt (14) about 50 species of Scoliids have been described from Australia, and about 300 species of Thynnids.

Hence with all these natural enemies, and probably many others that we have not yet learnt to recognise, it is surprising that even a very few of our numerous species of Scarabæid beetles should be able to multiply into such devastating hordes. Yet, as Davis has well said (40), when we further reflect that these enemies are likewise attacked by parasites, that some birds and mammals which destroy the beetles may also destroy the beneficial parasites, that the adult of one predaceous larva may prey on the adult of a similar predaceous larva, and that the predaceous larvæ likewise may attack one another, we begin to realise the immense complexity of the interrelations of these animals.

DISEASES.*

FUNGI undoubtedly play a most important part in grub control, especially when climatic conditions are suitable for their propagation. Fully a decade ago Mr. Tryon (22), in an able address before the Australian Sugar Producers' Association, stressed the importance of the Muscardine fungus (*Metarrhizium anisopliæ* Metsch.), and urged adequate inquiry as to the methods of multiplying and distributing this useful parasite to combat cane-grubs. And again, in 1914, this same author (25) gave a most comprehensive report upon this fungus, where we read:—

"In the field experiment, healthy and Muscardine-infested grubs were intermixed at the bottom of a rectangular excavation, so that they might come in contact one with another, and then covered with scrub soil rich in humus to a depth of 18 inches. By this crude method, based on the observation that the disease-affected grubs occurred in well-defined areas in the canefields where they were discovered, it was expected that spore-laden soil would be obtainable.

"In the laboratory experiment, it having been observed that the spores formed by the *Metarrhizium* fungus, although very numerous, were also very small, falling into the interstices of the surface of paper when placed upon it; and were with difficulty only moistened, resting in masses on the surface of water, a soil both extremely fine and also unusually rich in organic matter was employed. This had been discovered under peculiar circumstances by the writer, at Bahana Creek, and conveyed some miles to the laboratory for the purpose. In this soil, when dry, it was found practicable to mix the spores, so as to have a relative large quantity of infective material available, and it was noted that it served to originate the disease in cane-grubs confined in vessels containing it—as was found at the expiration of nearly six months, when on revisiting the district the results of a few of the laboratory experiments could still be appraised. It is conceived that it would be quite possible to produce this material in large quantities and distribute it in the drills whilst planting.

"As pointed out by me, in my report on the 'Grub Pest in the Mackay District' in 1896, and in lectures on the subject since, and

* Since these diseases have been discussed at length in Bulletin No. 12, they will only be referred to briefly here.

notably in the one delivered at Nelson, Cairns, in June, 1908, there are grounds for concluding, with but little doubt, that the fungus enemy of Cane Beetle Grubs has, in the past, had considerable influence in locally controlling the numbers and destrictiveness of these marauders of our principal tropical agricultural industry, and that it will continue to do so. It appears within the possibilities of scientifically devised methods to assist nature by distributing to a larger extent than is spontaneously realised, this destructive agent through which it works.''

Following upon the peculiar climatic conditions of June and July, 1920, such contagion developed among grubs in certain fields where spores existed in the soil, that the pest was practically wiped out. Moreover, at Greenhills it was not uncommon to find a bacterial disease working in conjunction with the fungus. Indeed so destructive were these diseases that by the end of July it was a difficult matter to locate any living grubs, under such conditions, where shortly before the epidemic had set in there had been a hundred or more per stool. As a natural result, when digging in these fields we could see the grey-green masses of spores that had developed on the dead grubs, and the soil was evidently thoroughly permeated with spores. At any rate, healthy grubs placed in pots of this soil quickly succumbed to the disease, so I decided to recommend the distribution of such soil (48) as widely as possible in other grub-affected areas. It has since occurred to me that this infection could probably be better facilitated by dusting a little of the spore-laden soil over the plants in the planter, for in this way it would be thoroughly distributed throughout the fields.

PREDATORY MAMMALS

Often have an important bearing in relation to the control of white grubs. Here in Queensland, the bandicoots (*Perameles* sp.) undoubtedly should head the list. Mr. Tryon (6) (22) (23) also mentions various species of pouched mice (*Antechinomys, Sminthopsis, Phascologale*) which have grub-eating proclivities, but I have never had an opportunity to observe them. The flying-foxes (*Pteropus* sp.), too, though inveterate fruit-destroyers, come in for consideration as destroyers of the adult beetles. Furthermore, on the farm we have valuable allies in the hogs, wherever the crop is to be ploughed out, for these animals are ravenous after the grubs. Some dogs, also, even follow the ploughs to pick them up.

Bandicoots.—Though bandicoots are known to be omnivorous feeders, my experience with them in the canefields has been rather favourable than otherwise. While it is a fact that they uncover and cut off many of the cane-roots in their search after grubs, I am convinced that most of their efforts are in the right direction, for they appear to be able to locate the grub by sense of smell, since they usually dig only in the affected parts of the field. My first definite knowledge as to their insectivorous habits was from the dissection of a specimen, 21st July, 1918, killed during the night in the cane by a dog. Its stomach contained a larva of a cutworm, five caterpillars of unknown species, four locusts, one centipede, two large spiders, eight small spiders, two slugs, one small beetle, many small ants, three large ants, eight large crickets, six small crickets, sixteen footless larvæ similar to cane-borer, many legs and other parts of ground beetles, and numerous other remains of insects; together with the following bits of plants, which were probably accidentally swallowed: a bit of tree-bark, three small roots, two bits of grass, two small leaves of a weed, and a piece of a dry stick. This certainly suggests an insect diet, and especially at a time of the year when insects were most difficult to find.

Specimens examined during March, when the cane-grubs were active near the surface of the soil, indicated a strong preference for this pest, for the stomach was usually well supplied with the chitinous remains of the grubs, with no signs of plant tissue.

The teeth of bandicoots are adapted to an insect diet, so they probably turn their attention to potatoes and other garden products when driven to it through a scarcity of grubs and other insects.

I was interested in this connection to read the remarks of Mr. G. Pott (9), of Proserpine, who stated—

"In Proserpine, bandicoots are very numerous and grubs very scarce. You find that where the grubs attack the cane the bandicoots attack the grubs."

Flying Foxes.—Though I have not been able to make any personal observations upon the insectivorous habits of the flying-foxes, we have the evidence of several careful observers among the growers. Mr. Jodrell (22) noticed the grass under palm-trees at his place at Innisfail covered to a considerable depth with the masticated remains of cane-beetles. He felt certain that these had been killed by the thousands of flying-foxes which frequented the trees during the night. In discussing this matter with Mr. Jodrell since, he told me that the wing-cases of the greyback beetles were easily recognised in the excrement of the bats.

Another grower, Mr. R. D. Rex at South Mossman, also made careful observations on the fruit-bats, which congregated in the beetle-feeding trees, even where no fruit was present. He, also, stated that the ground under the trees was strewn with broken parts of the beetles each morning, clearly indicating that the bats had been feeding upon the insects.

Moles and Shrews.—I might also mention here that two of the most useful grub-destroyers in other countries are the moles and shrews. From my experience with these animals in the United States, I would say that they ought to be thoroughly beneficial to infested cane areas. Reviewing the literature, I note that the introduction of these friendly agents has been discussed here from time to time, but none of the recommendations have ever been acted upon.

Mr. Tryon (6) carefully reviewed the pros and cons with regard to the European mole for the sugar-growers; and Mr. Boyd, editor of the "Queensland Agricultural Journal" (10), later went into the matter very thoroughly, urging its introduction for the destruction of grubs; but nothing came of these efforts.

Mr. J. J. Davis (40), in his recent comprehensive paper on the natural enemies of white grubs in the United States, writes in regard to moles and shrews—

"The common mole (*Scalopus aquaticus*) is probably next in importance. Mr. Theo. H. Scheffer, after examining the stomach contents of 200 moles taken in all months of the year, concludes that white grubs and earthworms constitute the bulk of their food; and Mr. J. A. West finds from a study of the stomach contents of moles collected under varying conditions in various parts of Illinois, that a good per cent. of the food of moles consists of white grubs and May beetles.

"Mr. George G. Ainslie, of the Bureau of Entomology, made some interesting observations on the feeding habits of the common mole in confinement. The mole, which was taken in a field at Nashville, Tenn., June 28, 1911, was fed ten large Phyllophaga grubs, two wireworms, and one webworm in succession, all of which it ate with relish. The mole would eagerly take a grub, quickly crush its head between its teeth, and leisurely eat the remainder of the grub.

"At Farmington, Mich., October 23, 1914, A. F. Satterthwait saw an abundance of mole tunnels in an old timothy sod badly infested with grubs, the unusual amount of mole work in this field indicating that they, as well as skunks, were attracted there to feed on the grubs. A similar observation was made by Joe S. Wade, of the Bureau of Entomology, at Shawnee, Okla., the mole tunnels being conspicuous, especially in the worst-infested parts of the field. At Ashboro, Indiana, we found a quantity of May beetle remains at the end of a mole tunnel, and on several occasions have traced the mole-runs in cornfields infested with grubs and found them leading directly to hills where grub injury had occurred. All our field observations indicate that the moles play a significant role in the natural control of white grubs.

"The shrew is also well known for its fondness for May beetles and white grubs, and A. F. Shull estimates that a single short-tailed shrew (*Blarina brevicauda*) during one month might kill and use for food 450 May beetles; and Mr. F. E. Wood writes: 'Probably no other mammal, unless it be the skunk when on its good behaviour, is so uniformly beneficial to the farmer.'"

LIZARDS.

The Lizards in cane areas of North Queensland are of such monster size that they are undoubtedly of considerable economic value, especially in their habit of feeding upon both beetles and grubs. The short, thick-bodied, blue-tongued lizard (*Tiliqua scincoides*) is well known among growers as a grub-destroyer. They have been observed at work (21) while digging for the grubs, their excavations being very similar to those made by bandicoots, though several growers have told me that they are able to distinguish the difference. The iguanas (*Varanus* sp.) are more omnivorous feeders, but being arboreal in habit and large in size—ranging up to 7 feet—they are destructive to birds during the nesting season. Hence their economic value is questionable, though I have found beetles in their stomachs, together with frogs, small lizards, and grasshoppers.

FROGS.

Frogs, moreover, are undoubtedly among our most valuable allies, and, from their large size and abundance in most of our Northern cane districts, they certainly must have an important bearing in checking beetles and other pests. A large green variety was usually present around my light traps, snapping up the beetles that fell outside the pans.

BIRDS.

Birds, under natural conditions, are probably the most efficient of all enemies of the grub-pest. Unfortunately, however, they do not receive the encouragement to remain near settlements that their value demands. There is far too much careless shooting; so that, even if the birds are not hit, they become so frightened that they congregate and nest more in the wild uncultivated areas.

Thoughtless man is too ready to grab the gun when he sees a hawk or an owl, and I have even seen the small birds shot in great numbers for food, right alongside cane areas, and by individuals whose main support was from this crop. Under such conditions, is it any wonder that our most valuable insectivorous birds shun us? Even the hawks and owls as a class are of great economic importance. Investigation has demonstrated that these predaceous birds feed largely on noxious rodents and the larger insects, such as grasshoppers, Scarabæid beetles (i.e. cane beetles), &c., and from their tremendous capacity and appetites their usefulness is hard to over-estimate. In the United States, careful study of the stomach contents of the hawks and owls showed conclusively their tremendous value to man's interests. Of the seventy-two species and subspecies, only two were considered enemies of the farmer.

Queensland is naturally rich in bird life, and fortunately there is still time to encourage these friendly allies. Not only should shooting be limited, for it frightens away the valuable species, but, further, these birds should receive every encouragement during the nesting season. Then, too, the greatest care should be exercised with the use of poisons on the farm, to prevent the destruction of the bird life.

Some of the birds which are of particular economic importance to the North Queensland farmer, because of their relation to the grub-pest, may well be noted. Fortunately, moreover, during the flight of the beetles, many others, even the fruit-eating birds, turn their attention to these pests and live upon this abundant, easily procured food; hence it is difficult to say what birds are not our friends, until accounts are footed up.

THE IBISES are certainly of tremendous importance to the districts wherever they occur. Two species commonly visit the region around Cairns soon after their nesting season, both the straw-necked (*Carphibis spinicollis*) and the white (*Ibis molucca*), though the latter is only in small numbers. These birds breed in great colonies, I am told, in the open marsh-land, near the sea-coast, south of Townsville. At any rate, during my recent trip (March, 1921) to the cane areas near Ayr, I saw the adults of both the above species together in great flocks, and was told on good authority that they followed the ploughs the year round in the Lower Burdekin valley. This fact may account for the scarcity of the grub-pest in that region, for these insects have never appeared in such numbers as to seriously harm the crops.

In the Cairns district, as I have already intimated, we are not so favoured, for we seldom see these birds from February to May, during which time they are probably away nesting. When they do return, however, they are particularly voracious, and it is not uncommon to see hundreds of them following the ploughs day after day. They wait quietly in the fields during the noon period for the ploughmen to return to work, when they follow the furrows assiduously, apparently never getting enough. On one occasion, 28th June, 1918, when we saw several hundred ibises thus following the ploughs near Gordonvale, I suggested definite observations, and Mr. Girault noted the following:—

"As the ploughman started a furrow, I followed close behind so as to keep in advance of the birds and to keep them out of the way for a short while. I marked the first seven grubs seen with a long twig inserted into the ground near each, then following on for some distance in order to allow the birds to settle in the furrow behind in their usual manner. When they had done this, I halted and allowed them five minutes. Then I walked rapidly back to the marked specimens; they had been eaten. This was repeated with similar results. It ought to be noted here that these grubs, stage III *albohirtum,* were not very active, hence did not enter the ground soon; this was made sure of, too, by observation.

"I then made a new start on a furrow 300 yards long, following close to the plough, counting 59 stage III *albohirtum* the whole length. The birds came in behind as we progressed and followed nearly the whole length of the furrow; there were nearly enough of them to fill the furrow, since they were in single file. At the other end of the furrow I halted and waited eight minutes or till the birds had covered all the length, except that part—about ten yards—nearest me. I then returned along the furrow, and counted only nine grubs, and these were on the ten yards not visited by the birds. There can be no doubt that the birds cleaned the furrow of the grubs, even in this short while. From where I stood, too, I could actually see them engulf the large grubs.

"These birds are very patient and persistent in their attendance upon ploughmen. I have seen them equally so when no grubs were being turned up in the furrows, nothing but earthworms. But they seemed to have expectations."

During the flight of the beetles in January, 1919, I had an excellent opportunity to observe the ibises feeding upon the adult cane-beetles. It was just about daybreak when I came upon great numbers of smaller birds in the beetle-feeding trees, with a flock of ibises underneath. The small birds, while attempting to eat the large beetles, knocked many to the ground and these were quickly devoured by the waiting ibises. Shortly after, when the morning flight of *Lepidiota frenchi* started, the ibises gave their undivided attention to this species, deftly plucking the beetles from the various stems just before they entered the soil. Even after all the beetles had disappeared from sight among the grass-roots, the ibises continued to locate them with their long slender beaks, which apparently are very sensitive at the tip. In some instances, while I watched the birds with the binoculars, I saw them stick their beaks full-length into grass and rubbish and extract beetles with remarkable deftness.

On another occasion, 1st July, 1920, fully 500 ibises congregated in a badly devastated field at Greenhills, where they were found to be doing excellent work by probing for the grubs, which were near the surface at that time. The ground about the base of the stools was full of punctures, especially where the stools had fallen over. So intent were they upon their work that I was able to approach near enough to see the birds actually making the punctures; and few grubs were found under such stools when we dug.

Crows (*Corvus australis*) are certainly worthy of more consideration from the farmer. While I have had little experience with the Australian species, since it does not occur in the Cairns district, I am very familiar with the habits of the closely allied forms in the United States. Therefore, I cannot do better than give Mr. Tryon's (6) remarks on these birds as they occurred at Mackay:—

"Perhaps the premier place amongst birds as a grub-destroyer should be assigned to the common crow, for though it usually haunts the precincts of slaughter-yards, and fattens on the food supply they yield, it will on occasion resort to the arable ground in quest of this insect, and is especially addicted to following the plough and consuming whatever grubs are upturned by it. It is on the outskirts of the land devoted to cane cultivation that these birds occur in larger numbers than elsewhere, for here they congregate from the unsubdued bush beyond wherever food is forthcoming. Mr. Colenso, who shares the opinion with the writer—that 'crows perform a greater service than any other member of the feathered tribe, as grub-destroyers'—stated that he had 'on one occasion seen from two to three thousand crows following the plough. The air was literally black with them as they arose, and though the grubs were so numerous as to present the appearance of a white skein along the furrow, these birds were able to consume all that the plough exposed.' So serviceable indeed are these crows considered that on the Homebush Plantation they are trapped continuously, and afterwards sent off to one of the Northern rivers to assist in coping with the grub-pest most prevalent there. The purpose in so doing is, however, partly defeated; since the crows are especially liable to congregate about the local slaughter-yards there, or even to migrate to a distance where similar sources of food supply, as these offer, exist. The crow, however, has its detractors. Amongst these may be numbered farmers who have experienced loss through its attacking maize cobs at the time the grain is passing into its milk condition."

Hawks.—In addition to what I have said in regard to hawks above, I would like to call especial attention to the insectivorous habits of the large brown hawk (*Hieracidea berigora*) which is so abundant in most cane districts. While, like the crows, these hawks devour flesh if procurable, they seldom kill animals; their principal food is undoubtedly largely composed of insects. I have seen them in great numbers following swarms of grasshoppers, and I have no doubt that they eat quantities of the cane-beetles while these insects are in the trees or on the wing during the day. With regard to their grub-eating proclivities we have no direct data, but this apparently has been abundantly proved in the Mackay district, where they are stated (6) to have occurred in thousands, following the ploughs and consuming the upturned grubs.

The Laughing Jackass (*Dacelo leachii*) is also a bird of prime importance to the cane-farmer. We have found that he is particularly fond of our large cane-beetles in every stage of their development. Yet, unfortunately, it is a bird that is often shot, because of its playful proclivities of chasing other birds and young chickens. A specimen killed at our station, about 4 p.m. on 26th December, 1918, when chasing a lot of chicks, just after it had torn up the nest of a small bird, had a stomach packed full of greyback beetles, and nothing else. Furthermore, it is not uncommon to see them following the ploughs probing for the large grubs. Therefore they are evidently very useful when diverted from their habit of annoying other bird life.

The Pewee Lark (*Grallina picata*) and the Indian Myna (*Acridotheres tristis*) are probably the most useful of the smaller birds which combat the grub-pest in our Northern districts. These birds are frequently observed following the ploughs in their search for grubs, most of which are too large for them to swallow. In a few instances I have been near enough to watch the pewees attack the larger specimens, beating the heads off and swallowing them, while the softer parts, which are filled with soil, were left on the ground. Both the pewees and the mynas are also mortal enemies of the adult cane-beetles. In fact, I have always found these, usually associated with the yellow-bellied fig-bird (*Sphecotheres flaviventris*), the leatherhead (*Tropidorhynchus buceroides*), the blue jay (*Graucalus melanops*), and the drongo (*Chibia bracteata*), early in the morning in the beetle-feeding trees. Most of these birds are so shy that it is difficult to observe them closely. By approaching cautiously, however, I was able to watch them with my binoculars. The pewees and fig-birds were usually greatly in the majority. The beetles clinging to the leaves were seized by the birds, which took them systematically and beat them to pieces on the larger limbs. During this feeding, of course many beetles, or parts of beetles, fell to the ground, and it was not unusual to see the pewees dash down after the lost specimens. In some instances fowls and ibises, as has been noted, congregated beneath such trees to gather up the crumbs.

The Shining Starling (*Calornis metallica*), though usually a fruit-eater, should also be added to this list of smaller birds that feed largely upon the cane-beetles during their flight. This species, though gregarious among their own kind, do not mix so commonly with the other birds while feeding.

The Dollar-bird (*Eurystomus pacificus*), too, though a very shy fellow, is said to be an important destroyer of the beetles while on the feeding trees back in the "bush."

There are also probably many other birds that should come in for consideration here because of their relation to the grub-pest; the following occur to me as worthy of special notice:—

The Cuckoo Pheasant or Swamp Pheasant (*Centropus phasianus*) is insectivorous, and, being a fairly large bird occurring constantly in the vicinity of fields of sugar-cane, it is reputed to feed upon both the grubs and the beetles. Unfortunately we have no data as to the stomach contents, and this bird is so shy that probably no one has even been able to observe it eating. It is safe to say, however, that it is a bird that should be protected and encouraged.

The Nightjars (*Eurostopus* sp.) and the Mopoke (*Podargus* sp.) are all strictly insectivorous, and are known to feed upon large night-flying beetles. These birds only fly at night; sleeping by day in secluded spots they are seldom seen, though often fairly abundant in the vicinity of cultivated areas. Their food is principally taken on the wing, which adapts them perfectly for feeding upon our cane-beetles just as they emerge after dusk. In California, while collecting for the Biological Survey, I had considerable experience with birds of this family. Often when I shot them after dusk, I marvelled at the size and number of the living beetles which they had crowded into their capacious gullets. Since the insects are always swallowed alive by these birds, one wonders how they can withstand the terrible scratching of so many Scarabæid beetles on the delicate membrane of their alimentary canal. One gets some realisation of the powerful digging qualities of these beetles when he tries to hold several in his closed hand for a few minutes. There is no question that these valuable birds should be everywhere protected.

Poultry.—While on the subject of birds it may be as well to remark further in regard to the value of poultry in destroying the grub-pest. From the number of insects they eat it would appear to be simply a matter of supplying enough hens to rid the place of both grubs and beetles. This has been tried at various times (3) (16) on rather extensive scales, but the problem is too broad for fowls alone to handle. It is an excellent idea, however, to have a few trap-trees around the homestead, where the beetles can be shaken off each morning for the fowls to devour. In this way we not only can save feed, but at the same time help to deplete this terrible pest.

PREDACEOUS INSECTS, MITES, AND CENTIPEDES.

Predaceous Insects.—Among the predaceous insects whose habits we have particularly studied, are several species of Asilids, a species of Tabanid, a giant Elaterid beetle, a Pentatomid bug, and the omnivorous ant (*Pheidole megacephala*).

The robber-flies, so called because they are thought to be injurious, particularly in that they sometimes eat honey-bees, are fairly common in most sugar-cane districts. Though the flies themselves are of considerable economic value, being predaceous on many pestiferous insects, sometimes even killing adult beetles (14), yet we are chiefly concerned with the larvæ, several kinds of which are mortal enemies of our cane-grubs. The largest and also the most abundant form occurring in grub-infested areas here is *Promachus doddi* Bezzi (Plate III, fig. 1). The larvæ of this species, which are commonly turned up by the ploughs, are creamy-white, long and tapering at each end, with no feet. The life-cycle has not been definitely determined, since we have not been able to give sufficient time to carry them right through from the egg. In colder countries, however, where studies have been made on related species, development apparently requires three years. Yet field observations, here in the tropics with almost continual growth, would lead us to conclude that this period is very much shorter—in fact, probably not more than one year, thus agreeing with the life-cycle of their beetle host.

On 7th June, 1912, Girault made the first discovery of an Asilid larva attacking a grub in the field here, and wrote the following note, which I take from our files:—

"While following the plough to-day in recently cleared forest land, two large white maggots were found together with a large cane-grub. The latter was partly collapsed and seemed to be dead but its body showed no injury and was not decomposed; it looks as if the maggots have partly sucked it dry. Their prehensile head makes this seem probable. Upon temporarily confining them with some grubs the next day, the smallest one attached itself to the thorax near the base of the hind legs on one side of one of the moderate-sized grubs and remained thus, its body coiled up like a snake; after several minutes it was forced to relieve itself and I could see no mark at the place of attachment."

Subsequently, Mr. Dodd reared three species of Asilids (34), the larvæ of which were found feeding upon cane-grubs. The fourth species, mentioned by him that failed to emerge, has since been found to have been the larva of a Tabanid.

On 30th December, 1920, I discovered two clusters of Asilid eggs glued to the tips of cane-leaves (Plate III, fig. 2); the larvæ in one case were just hatching. I immediately put both these masses of eggs into a pot of loose soil with six small cane-grubs.

9th January, 1921, I found three of these tiny fly larvæ attached to grubs (Plate III, fig. 3); the other grubs were already killed, evidently by being bitten by the Asilid larvæ. I then supplied nine more small grubs, removing the three dead ones; hence they had twelve grubs altogether. Later in the day I added five more small grubs; and at 5 p.m. found another grub dead.

12th January, I found that six of the grubs had been killed by the young Asilids; hence a total of ten killed, with ten live grubs in the soil.

13th January, two more grubs killed, leaving eight.

14th January, six more dead; so I supplied eight fresh grubs, = ten alive; sixteen dead had been removed.

16th January, only one grub was alive in the jar, so I supplied nine more, = ten alive; total dead twenty-five.

17th January, five more grubs were dead.

18th January, four more dead; as only one remained alive I supplied nine more grubs; dead = 34 to date.

19th January, two grubs were dead.

22nd January, six grubs dead; only two remained alive, so I supplied eight; total dead 42.

23rd January, two more grubs were dead; there had also been a remarkable decrease in the number of the Asilids.

25th January, five grubs dead.

28th January, two more grubs were dead, and I could only find one Asilid. Had this little predator eaten up his mates? I could see no other reason for their disappearance. Furthermore, I have definitely known the older larvæ to destroy one another when placed in a small box of soil together. Unfortunately, I was not able to carry this experiment further.

Observations in the field would also indicate that there must be a tremendous mortality among the Asilid larvæ, for the eggs are so numerous that if they all developed there would hardly be grubs enough to supply them. As a matter of fact, however, these dipterous larvæ are rather few and far between compared with the number of grubs that are turned up while ploughing a field.

The larva of the large Elaterid (*Agrypnus mastersi* Pascoe) is also a most wonderful predator, but unfortunately we do not know of any way to make this species more prolific. The following detailed study of the habits of one of these larvæ, as carried out by Mr. Dodd, is of such vital interest that I have decided to give his notes in full:—

"A very large Elaterid larva, taken from a canefield at Gordonvale on 27th October, 1914, was confined in a tin in damp earth. Between then and 16th November, it was given five stage III grubs of *Lepidiota frenchi, L. rothei,* and *Anoplognathus boisduvali,* all of which disappeared.

Nov. 16th.—It was given three stage III grubs of *L. rothei.*

17th.—Two of the grubs were partly eaten.

Nov. 19th.—The three grubs were dead and partly eaten; supplied with two stage III grubs of *L. rothei.*

26th.—The grubs were all dead or eaten; supplied with three stage III grubs of *L. rothei* and one stage III grub of *L. frenchi.*

To the end of November it had killed 10 grubs.

Dec. 1st.—Grubs all dead or eaten; supplied with four stage III grubs of *L. rothei.*

7th.—Grubs all dead or eaten; supplied with two stage III grubs of *L. frenchi.*

10th.—Grubs dead; supplied with two stage III grubs of *L. frenchi.*

19th.—Grubs dead and eaten; given three stage III grubs of *L. frenchi.*

23rd.—Grubs dead and partly eaten; given three stage III grubs of *L. frenchi.*

30th.—Grubs dead and partly eaten; given two stage III, one stage II, grubs of *Dasygnathus australis.*

To the end of December it had killed 28 grubs.

1915.

Jan. 6th.—Grubs completely eaten; given one stage II grub of *D. australis* and two stage III grubs of *L. frenchi.*

8th.—One grub completely eaten, two partly so; given three stage II *D. australis* grubs.

12th.—All grubs eaten; supplied with three stage III *Lepidiota consobrina* grubs.

18th.—All grubs dead and practically eaten; supplied with two stage III grubs of *L. frenchi* and one stage III grub of *D. australis.*

21st.—All grubs partially eaten; given three stage III grubs of *L. frenchi.*

25th.—All grubs partially eaten; given three stage III grubs of *L. frenchi.*

28th.—All grubs partially eaten; given three stage III grubs of *L. frenchi.*

To the end of January it had killed 49 grubs.

Feb. 2nd.—All grubs dead and partially eaten; given two stage III grubs of *D. australis.*

4th.—Both grubs alive and untouched.

8th.—Both grubs still alive. The Elaterid has just moulted.

11th.—Both grubs dead and partially eaten; given three stage III grubs of *L. frenchi.*

15th.—Grubs dead and mostly eaten; given three stage III grubs of *D. australis.*

Feb. 17th.—Grubs dead and mostly eaten; given six stage III grubs of *D. australis*.

26th.—All grubs wholly eaten; given four stage III grubs of *D. australis*.

To the end of February it had killed 66 grubs.

Mar. 2nd.—Grubs dead and almost wholly eaten; given three stage III grubs of *D. australis*.

4th.—Grubs dead and mostly eaten; given one stage II, two stage III, grubs of *Lepidoderma albohirtum*.

8th.—Grubs dead and mostly eaten; given one stage II, two stage III, grubs of *L. albohirtum*.

10th.—Grubs dead and partially eaten; given three stage III grubs of *D. australis*.

12th.—Grubs dead and mostly eaten; given three stage III grubs of *D. australis*.

15th.—Grubs dead and mostly eaten; given two stage III grubs of *D. australis* and one stage III grub of *L. albohirtum*.

18th.—One *D. australis* grub alive, the other grubs dead and partly eaten.

20th.—Grub dead and partially eaten; given three stage III grubs of *A. boisduvali*.

22nd.—Grubs dead and mostly eaten; given three stage III grubs of *D. australis*.

24th.—Grubs dead and mostly eaten; given two stage III grubs of *L. albohirtum*.

26th.—Grubs dead and partially eaten; given two stage II, one stage III, grub of *L. albohirtum*.

29th.—Grubs dead and mostly eaten; given three stage III grubs of *D. australis*.

To the end of March it had killed 99 grubs.

April 1st.—Grubs dead and mostly eaten; given one stage II, one stage III, grubs of *L. albohirtum*, and one stage III grub of *A. boisduvali*.

6th.—Grubs dead and mostly eaten; given four stage III grubs of *D. australis*.

9th.—Grubs dead and mostly eaten; given two stage III grubs of *L. albohirtum* and one stage III grub of *D. australis*.

12th.—Grubs dead and partially eaten; given two stage III grubs of *D. australis* and one stage III grub of *A. boisduvali*.

14th.—Grubs dead and partially eaten; given two stage III grubs of *L. albohirtum*.

April 16th.—Grubs dead and partially eaten; given three stage III grubs of *D. australis.*

19th.—Grubs dead and mostly eaten; given two stage III grubs of *D. australis.*

22nd.—Grubs dead and mostly eaten; given three stage III grubs of *D. australis.*

24th.—Two grubs dead but not eaten.

28th.—Remaining grub still alive; given two stage III grubs of *L. albohirtum.*

30th.—*D. australis* and one *L. albohirtum* grubs dead but not eaten.

To the end of April it had killed 126 grubs in just over six months.

May 3rd.—Remaining *L. albohirtum* grub dead but not eaten; given two stage III grubs of *A. boisduvali.*

5th.—One of the grubs dead and a little eaten, the other one alive.

31st.—Remaining larva still alive.

To the end of May it had killed 128 grubs.

June 9th.—Remaining grub still alive. The Elaterid has just moulted.

19th.—Grub still alive.

28th.—Grub dead; given two stage III grubs of *L. albohirtum.*

To the end of June it had killed 129 grubs.

July 7th.—Grubs dead; given three stage III grubs of *L. albohirtum.*

17th.—Grubs dead; supplied with three stage III grubs of *L. albohirtum.*

30th.—Grubs dead; given three stage III grubs of *D. australis.*

To the end of July it had killed 137 grubs.

Aug. 16th.—Two grubs dead; the other had pupated and was removed; given three stage III grubs of *Horonatus optatus.*

23rd.—Grubs all dead; given two stage III grubs of *Lepidiota caudata* and one stage III grub of *L. albohirtum.*

31st.—Grubs all dead; given one stage III grub of *L. albohirtum,* two stage III grubs of *L. rothei,* and one stage III grub of *A. boisduvali.*

To the end of August it had killed 145 grubs.

Sept. 6th.—Grubs all dead; given two stage III *L. albohirtum* and two stage III *A. boisduvali* grubs.

14th.—Grubs all dead; given four stage III grubs of *A. boisduvali.*

Sept. 22nd.—Grubs all dead; given four stage III grubs of *A boisduvali.*

28th.—Grubs all dead; given four stage III grubs of *A. boisduvali.*

To the end of September it had killed 161 grubs.

Oct. 7th.—Grubs all dead; given four stage III grubs of *A. boisduvali.*

18th.—Grubs all alive. The Elaterid has just moulted.

26th.—Three of the grubs dead and partially eaten; given two stage III grubs of *L. caudata.*

To the end of October it had killed 167 grubs, i.e. in just twelve months.

Nov. 1st.—*L. caudata* grubs both eaten, but the *A. boisduvali* grub is still alive; given three stage III grubs of *L. frenchi.*

8th.—One *L. frenchi* grub dead and eaten, the other grubs alive.

16th.—Both *L. frenchi* grubs dead and eaten, but the *A. boisduvali* grub is still alive; given four stage III grubs of *L. frenchi.*

22nd.—All grubs dead and eaten; given four stage III grubs of *L. frenchi.*

28th.—All grubs dead and eaten; given four stage III grubs of *L. frenchi.*

To the end of November it had killed 181 grubs.

Dec. 7th.—Grubs dead and eaten; given four stage III grubs of *L. frenchi.*

14th.—Grubs dead and eaten; given four stage III grubs of *L. frenchi.*

20th.—All grubs dead and eaten; supplied with five stage III grubs of *L. frenchi.*

29th.—All grubs dead and eaten; given five stage III grubs of *L. frenchi.*

To the end of December it had killed 198 grubs.

1916.

Jan. 3rd.—All grubs dead and eaten; given six stage III grubs of *L. frenchi.*

10th.—All grubs dead and eaten; given six stage III grubs of *L. frenchi.*

17th.—All grubs dead, but one not eaten; given five stage III grubs of *L. frenchi.*

24th.—All grubs dead and partially eaten; given five stage III grubs of *L. frenchi.*

To the end of January it had killed 220 grubs.

Feb. 1st.—All grubs dead and eaten; given five stage III grubs of *L. frenchi.*

"At this stage I left the laboratory, and handed the experiment over. The Elaterid, which was quite large when captured, had killed 230 grubs in 17½ months; and during that time it had moulted three times. It will be noticed that at the time of moulting the larva does not feed for some days; in one instance it starved for six weeks.

"Subsequently Mr. Jarvis made the following notes:—'On February 21st, all grubs dead and eaten; given two stage III grubs of *L. frenchi*. On April 5th, given seven large grubs (the Elaterid had lived since February 21st on the two stage III grubs of *L. frenchi* given on that date, viz. 44 days, and was active and normal when looked at on April 5th, although slightly shrunken in appearance; the soil was dry and fresh moist earth was substituted on April 5th). On May 12th, gave six stage III grubs of *L. albohirtum*. The Elaterid had moulted between April 5th and May 12th. On May 19th, given three stage III grubs of *L. albohirtum*. On June 1st, given three stage II grubs of *Xylotrupes australicus*. On September 6th, given four stage III larvæ of *D. australis*, and two pupæ of *L. albohirtum*.'

"There is no further record, and I do not know what became of this interesting insect."

Since the above specimen did not complete its development, it is interesting to add the following notes, also by Mr. Dodd, of a larva which was almost full-grown when secured, and from which the beetle finally developed:—

"On 29th May, 1915, at Gordonvale, a single large Elaterid larva was found in a red volcanic canefield, badly infested with *Lepidoderma albohirtum* grubs, in following the plough. It was kept in confinement and given two stage III larvæ of *L. albohirtum*. 16th June, grubs alive till to-day, when one has apparently been eaten. 19th, the other grub has apparently been eaten, and the Elaterid is in a cell. 28th, the earth on the side of the tin cage is now consolidated in the form of a cocoon; the Elaterid is probably pupating. 7th October, no change up to this date, when the cocoon was opened slightly, finding a healthy pupa. 26th, a freshly emerged beetle is now in the cocoon. 2nd January, the beetle died to-day, living thus long since its emergence without food."

Since the first of these larvæ was very large when found in the field and lived for about two years in confinement without pupating, eating and apparently contented all the while, its life-cycle must be very long —at least three or four years.

The Pentatomid bug (*Amyotea hamata* Walk.) is frequently seen in the beetle-feeding trees, and on several occasions it has been caught in the act of sucking the juice from a beetle. Mr. Dodd has also made the following observations upon this species:—

"At Greenhills, on December 10th, 1920, I saw a bug of this species with an adult of *Anoplostethus lætus* as prey among the foliage of a young bloodwood. This bug has previously been recorded as preying on *Repsimus æneus*, and a specimen in the collection has such a beetle on its beak.

"On 5th January, 1921, at Meringa, an adult of *Lepidoderma albohirtum* was found dead among the foliage with one of these bugs beside it. The bug was not actually seen with the beetle, but I am confident that he had it, and we had disturbed him before seeing him. It was captured and placed in a glass jar; next day an adult *Lepidiota rothei* was placed in the jar. The beetle was still alive on 7th January. At 8 a.m. on 8th January it was found that the bug had killed the beetle and still had it transfixed, its beak being inserted through the elytron near its apex. Although the jar was freely moved about, and the foliage on which the bug hung disturbed, it still held its prey. I placed the leaf in such a position that the bug was head down, the beetle suspended on its beak without other support. At 10 a.m. it still held its prey, only now the beak was inserted on the left elytron toward the prothorax and two feet were resting on it. At 1.30 p.m. the beetle was again being held without support, the beak inserted against the anterior coxæ. Disturbing the bug it let the beetle fall; however, it immediately reinserted the beak in the suture between the prothorax and mesothorax, and was still in this position at 4.30 p.m., when interference caused it to let go. The bug was found dead on the morning of the 10th."

THE COMMON OMNIVOROUS ANT (*Pheidole megacephala*) probably does little damage to cane-beetles (20) while they are in a healthy condition, though they are quick enough to attack injured specimens of both beetles and grubs, eating them out. In Bulletin No. 16 I have described a mortal combat between a gravid female beetle and these ants, in which by a lucky chance the beetle finally escaped. Nevertheless, we have great trouble, when experimenting with cane-beetles, to keep the ants from destroying both the grubs and the adult insects, especially when they are in close confinement.

MITES, too, are usually troublesome in the breeding cages, but we seldom see them in any numbers in the field. On one occasion, 29th September, 1914, Mr. Dodd found a larva of *Lepidiota caudata* from Harvey's Creek, which had the legs densely crowded with small acarids, some being present on the apical abdominal segments also. Yet this larva was alive and in good condition otherwise, as far as could be seen.

During 1909 it was reported that mites were destroying the cane-grubs in the Isis district (19), but Mr. Tryon (18), after briefly investigating the matter, decided that the mites were not parasitic, and that the grubs were probably succumbing to other causes, the mites being simply an after-effect.

THE MONSTER CENTIPEDES of the tropics are well-known predators, especially congregating in the vicinity of buildings, where they prey upon cockroaches, &c. It is interesting, however, to know that they also relish our cane-grubs, and that they will even dig for them. Mr. Girault made the following interesting observations:—

"At Gordonvale on 26th October, 1913, a workman brought me a common large Chilopid, common in this vicinity and which was coiled round its mass of eggs. The animal was in the bottom of a bottle. The man said that he had seen this animal capture Scarabæid grubs by taking them with the mandibles behind the head, and he wanted me to test them in respect to this. Accordingly, two days later in the morning, I prepared a battery jar about half full of moist loam, made an oval depression in the latter, and partly covered this with a piece of wood. The bottle was then inverted and the animal so directed that it fell gently into the cavity prepared for it. During this exchange it did not lose control of its eggs.

"In a short while it commenced to excavate the cavity to enlarge it, using its head and jaws and placing the excavated pellets in a pile near the edge of the cavity. After about fifteen minutes I placed a Scarabæid grub near the pile of removed earth, and before long the centipede moved over to it and attempted to capture it. It succeeded in this, grasping its victim by the back of the head, soon afterward piercing the throat. Then it leisurely took a meal.

"Subsequently it was given several other grubs which it ate at once, but after several days it escaped."

Again, during November, 1916, Mr. Jarvis (31) had an experience with a large bluish brown centipede, which took up its quarters in one of the cages where cane-grubs were being reared. This specimen had already eaten several of the grubs when discovered, and had a tunnel into the soil with two openings at the surface, each of which was partly surrounded by a ridge composed of the particles brought up from below.

PARASITIC INSECTS.

Though a number of parasitic enemies, of both the grubs and the beetles, have come under observation, there are undoubtedly many more to be discovered. Those already observed belong to the Hymenopterous families Scoliidæ and Thynnidæ, and the Dipterous families Dexiidæ and Tachinidæ. The members of the first three families are parasitic upon the grubs, while, so far, we have only reared tachinids from the adult beetles.

Scoliidæ.

Australia is fortunately rich in these most efficient Scarabæid parasites. Nevertheless, we have learned that their value here, as in other continental areas where they naturally occur, is considerably reduced by hyper-parasites. Two of these have been constantly found, a Bombylid fly and a Rhipiphorid beetle.

Dr. F. X. Williams, an expert on wasps, who has studied these insects in various countries of the Pacific, gives the following most excellent summary of the Scoliidæ (45) :—

"This family comprises a large number of digging wasps of rather depressed and compact form that prey almost wholly on the larvæ of lamellicorn beetles.* They have a very general distribution, and in the

* According to Burkill (1917), *Scolia erratica* Sm. in the Straits Settlement, &c., attacks the grubs of the Red Cocoanut Weevil (*Rhyncophorus ferrugineus*) as well as those of a Rhinoceros Beetle (*Oryctes*).

tropics particularly are represented by many species of formidable size. They are not highly specialised wasps and form no nests; yet their olfactory, or more probably their auditory, powers must be highly developed since female Scoliidæ are able to locate their prey well buried in the soil, decayed wood, &c. Each species is more or less restricted to a certain species of lamellicorn grub, so that we may regard the diversity and abundance of the latter in a given region as an index to the scoliid fauna of that place.

"The adults are often found at flowers; the female wasp, however, usually spends the afternoon hours seeking her prey, and both sexes of many species pass the night underground. In certain cases the males, as in the American *Elis*, sleep congregated on weeds, Sweet Clover (*Melilotus alba*) being a special favourite.

"The beetle grub may be stung to permanent paralysis, as in *Scolia* sp., or it may be only temporarily immobilized in the case of *Tiphia*. *Scolia* fastens her egg delicately so that the head end is cemented against the venter of the helpless grub, whereas *Tiphia*, as if mindful of the eventual activity of her now quieted victim, affixes her egg much more securely—but not always so firmly that it may not sometimes be rubbed off by the wandering host—gluing it for its length transversely on a certain portion (varying with the species) of the venter, more rarely on the dorsum.* The *Scolia* grub then, secure on its motionless victim, transforms in its birthplace, but the young *Tiphia* may be treated to a more or less perilous ride underground, surviving which, it spins up where its victim perishes.

"In order to escape from the cocoon, the wasps of the genus *Scolia*, at least in part, neatly cut off the top of the cocoon; *Tiphia*, on the other hand, gnaws a somewhat irregular hole near or at the head end of its prison.

"The Scoliidæ of the Philippines are represented by numerous species, some of them giants in size. Many are forest insects, some appear partial to bamboo groves, while others prefer the open lowlands.

"The family is of decided economic importance, as the nature of the literature on these wasps clearly shows."

During our studies in the Cairns district we have become somewhat familiar with the following species:—*Campsomeris radula* Fabr., *C. tasmaniensis* Sauss., *C. ferruginea* Fabr., *C. carinifrons* Turn., *Scolia formosa* Guer., *Discolor soror* Sm., *Liacos insularis* Sm., *Anthrobosca morosa* Sm., and *Tiphia intrudens* Sm. var. *brevior* Turn. The first two and the sixth are by far the most common in our canefields, the others being more rarely taken at flowers in the uncultivated areas.

It is not uncommon, on sunny mornings at almost any season of the year, to see myriads of the male wasps of *Campsomeris radula* and *tasmaniensis* flying close over the surface of the ground in canefields

* In many cases, at least, the beetle grubs stung by *Tiphia*, while quite active, yet exhibit, when handled, a comparative muscular weakness in the thoracic region.

where grubs have been particularly injurious. This flight is evidently in search of mates, for the females usually come out of the ground on bright mornings to feed. The males of these species apparently do not re-enter the soil, even at night, for I have frequently observed them roosting in clusters on dry weeds, especially along the headlands of grubby canefields. On one such occasion, in 1917, following a heavy rain, I found myriads of these lonely males clustered together on dead lantana stems adjoining the cane. Of the 47 that I collected in my hands from a few of the clusters, 28 were *C. tasmaniensis* and 19 *C. radula.* About three hours after sunrise the next morning, the female wasps were also out in force, feeding on the nectar of various flowering weeds, *Crotalaria,* &c., along the headlands.

Digging among the grubby stools of cane in this field we came upon a grub in a cell about 9 inches deep, guarded by a female *C. radula.* The wasp had apparently already stung the grub and made a cell for it, though there was no egg upon it; she objected decidedly to our interference, for she repeatedly pushed soil into the opening as fast as we removed it. We then carefully filled in the hole, so that we could make later observations upon her activities. The next morning I carefully dug away the soil again, and found it supersaturated with the rain which had fallen during the night. The wasp was found dead in a small cell about 6 inches from the surface. The grub was in the same cell where we had seen it before, but it had no egg upon it. Evidently we disturbed the wasp just when she was ready to lay, and she must have succumbed in the saturated soil.

When so many males are seen flying over a grubby field, it is probably correct to conclude that almost as many females are working beneath the soil. At any rate, when the females are out of the ground on sunny mornings they are evidently more numerous at the flowers than their mates. Furthermore, our field notes would indicate that these wasps are on the wing in almost equal abundance at every season of the year.

The cocoons, too, are turned up by the ploughs throughout the year; and during the season that grubs are plentiful near the surface it is not uncommon, especially on heavy soils, to plough out grubs with the maggot-like larvæ of the wasps attached to them. Hence, in the earlier part of the investigations of the grub-pest at Gordonvale, when much of the information was sought behind the ploughs, many of these, and other natural enemies of the grubs, were collected and bred out (34). Several attempts were also made to get the wasps to oviposit, by placing them in cages with live grubs in the soil, and though these wasps usually paralysed the grubs they laid no eggs upon them. Since it was most important to know more on the breeding habits of these friendly insects, as well as the interrelation of their natural enemies, especially their hyperparasites, I decided soon after my arrival to try breeding the wasps.

Breeding Work.

Methods devised by Muir (36), so successful in the work with *Scolia manilæ*, were tried, and our *Campsomeris* wasps responded splendidly. Apparently the main thing that had been lacking in previous experiments here was the nectar-like food for the wasps; for when this was supplied, in the form of diluted honey placed in tiny droplets on a bit of leaf on the surface of the soil in each pot, the wasps were seemingly quite normal in their activities.

Early in September, 1917, since the *Campsomeris* wasps were rather plentiful in the vicinity of our experimental plots at Meringa, we began this breeding work in earnest. Since my own time was largely taken up with fieldwork, I was compelled to turn over much of this detail to Mr. Jarvis, whose notes, wherever they appear, are given in parentheses.

In this work we used the small milk-tins, about a half-pint size, placing the soil to within about an inch of the top. A single grub was placed in each tin with a female wasp, captured at flowers in the field. Each tin was given a designation number and covered. We found that the wasps entered the soil at once, and usually the grub was paralysed soon after, though it was several hours before an egg was deposited. The contents of each tin were examined morning and evening, and as soon as we found an egg deposited the grub was removed and a fresh one supplied. Once a day, usually in the evening, we put in a bit of fresh leaf with several drops of the diluted honey placed upon it. The wasps were often found out of the soil feeding on this nectar when the tins were opened up in the morning.

The parasitized grubs were at first placed singly on a bed of sand in small, flat, open-mouthed bottles, in which they developed very well, and were usually able to spin up their cocoon successfully. Yet this method I soon found required too much attention. I tried making earthen cells, in which to place the grubs, but our soil proved unsatisfactory, for the cells frequently collapsed. I then devised a new plan, which was more adapted to our particular needs, where the wasps were to be reared on a rather large scale. In this I used wooden trays similar to the greenhouse "flats," 12 by 14 inches inside measurement and 3 inches deep. Soil 2 inches deep was firmly pressed into each of these, and this was then indented with oval cavities, just the shape of the normal cell, which the wasp makes in the soil for the grub. I finally made a mould to form these depressions in the soil very rapidly; and I was able to get exactly sixty of them in each tray.

As fast as the grubs were parasitized they were placed in these depressions on their backs, and it was not necessary to handle them again. By this method they were as well separated as if in their original cells in the soil, and they could not disturb one another; hence, the larvæ of the parasites developed very satisfactorily. However, when they finished feeding and tried to spin up their cocoons, I found the same trouble that we had experienced when the grub had been kept in the shallow bottles—the larval wasps were sometimes unable to form the upper side of their cocoons, since the earthen cells had no roof to act as points of attachments. When we were working with the small jars I found that the cocoons were readily completed whenever I dropped a bit of paper over them. I tried this in the trays when the larvæ were through feeding, and found that it worked equally well.

The cocoons were then left in the cells to emerge, attention being given to keep the soil from drying out. There was not much difficulty experienced in this matter, since I kept the trays stacked, one upon another. To collect the wasps as they emerged, a small glass test-tube was inserted through a hole made in the end of each tray, just above the level of the soil; this being the only entrance of light, the wasps naturally came into these tubes as fast as they emerged, and were easily removed.

Some Typical Individual Records.

A *Campsomeris radula* female captured on 28th September, 1917, was kept in confinement for twenty-seven days, after which interval she deposited twenty-five eggs on stage III grubs of *Lepidiota frenchi* between the dates 26th October and 26th November, which produced six males and eight females. This wasp (No. 20) died on 10th February, 1918, after living seventy-six days in confinement, and her record of the eggs laid is given in Table No. 1 :—

Table No. 1, showing the Egg Record of Campsomeris radula, Wasp No. 20. A Spring Brood.

Egg No.	Laid.	Hatched.	Life of Maggot.	Cocoon Stage.	Emergence and Sex of Wasp.	Life Cycle.
			Days.	Days.		Days.
XXX ..	Oct. 27	Oct. 30	9	39	Dec. 16 ; male	50
OO ..	28	30	10	38	17 ; female	50
BB ..	29	Nov. 1	8	37	16 ; male	48
CC ..	30	2	7	40	19 ; male	50
FF ..	31	3	8	34	15 ; male	45
HH ..	Nov. 1	4	8	42	25 ; female	54
KK ..	2	5	8	42	25 ; female	53
MM ..	6	9	7	37	24 ; male	48
NN ..	7	10	7	41	28 ; female	51
SS ..	8	11	8			
TT ..	9	12	9	38	29 ; female	50
UU ..	10	13	7	35	25 ; male	45
X ..	11	14	8	37	29 ; female	48
AX ..	12	15	8	34	27 ; female	45
CX ..	14	17	9	32	28 ; female	44
DX ..	15	18	9	31	28 ; male	43
FX ..	16					
HX ..	17	20	7	38	Jan. 4 ; female	48
JX ..	18	20	7	39	5 ; female	48
KX ..	20	22	8	35	4 ; male	45
MX ..	21	24	8			
NX ..	23					
PX ..	24	27	8			
QX ..	25	28	..	..	14 ; female	50
RX ..	27	30				
Average	..	..	8	36·88	..	48·16

Though this wasp was inspected only once a day, the regularity with which she worked was interesting. Since this is a spring brood the resulting averages of three days for the egg stage, eight days for the larval stage, almost thirty-seven days for the cocoon or pupal stage, with forty-eight days for the entire life-cycle, are probably fairly normal.

On 19th December, 1917, I captured two large healthy female wasps of *C. tasmaniensis* in the field, feeding at flowers. These were given the numbers X and 21. The first lived forty-eight days in confinement and died on 4th February, 1918, after laying thirty-four eggs. Her record is given in Table No. 2:—

Table No. 2, showing the Egg Record of Campsomeris tasmaniensis, Wasp X. A Summer Brood.

Egg No.	Laid.	Hatched.	Life of Maggot.	Cocoon Stage.	Emergence and Sex of Wasp.	Life Cycle.
			Days.	Days.		Days.
X1 ..	Dec. 20					
X2 ..	22	Dec. 24				
X3 ..	23	26	7	39	Feb. 6 ; male	45
X4 ..	29					
X5 ..	30					
X6 ..	31					
X7 ..	Jan. 1	Jan. 4	7	35	15 ; male	45
X8 ..	2					
X9 ..	3					
X10 ..	4					
X11 ..	5	8	7			
X12 ..	5					
X13 ..	7					
X14 ..	7					
X15 ..	8					
X16 ..	9	12	7			
X17 ..	9					
X18 ..	11	14	8			
X19 ..	12					
X20 ..	12					
X21 ..	13					
X22 ..	14	17	7	39	Mar. 4 ; female	49
X23 ..	15					
X24 ..	16					
X25 ..	16					
X26 ..	18	21	8			
X27 ..	19	22	7	41	11 ; female	51
X28 ..	19	22	7			
X29 ..	21	24				
X30 ..	21					
X31 ..	24	27	6	41	14 ; female	49
H32 ..	24					
X33 ..	27					
X34 ..	28					
Average	..	..	7·1	39	..	47·8

The second wasp, No. 21, was our most interesting one as to the number of eggs that she produced, after being captured. She lived fifty-one days in confinement, and died on 7th February, after laying sixty-five eggs. Her record is given in full in Table No. 3:—

TABLE No. 3, SHOWING THE EGG RECORD OF CAMPSOMERIS TASMANIENSIS, WASP No. 21. A SUMMER BROOD.

Egg No.	Laid.	Hatched.	Life of Maggot.	Cocoon Stage.	Emergence and Sex of Wasp.	Life Cycle.
			Days.	Days.		Days.
21/1 ..	Dec. 20	Dec. 23	8	36	Feb. 4 ; male	46
21/2 ..	22	25	7	35	4 ; male	44
21/3 ..	24	27				
21/4 ..	28	..	..	35	8 ; male	42
21/5 ..	30	Jan. 1				
21/6 ..	Jan. 1	3	8	..	14 ; male	44
21/7 ..	2	4				
21/8 ..	3	5	8	..	20 ; female	48
21/9 ..	3	6	8			
21/10 ..	4	7				
21/11 ..	5	8	7			
21/12 ..	5	7	8	40	23 ; female	49
21/13 ..	6	9				
21/14 ..	7	10	6	31	16 ; male	40
21/15 ..	7	10	8			
21/16 ..	8					
21/17 ..	9	11	7	36	22 ; male	44
21/18 ..	9	12				
21/19 ..	9	12	8	39	27 ; female	49
21/20 ..	11	13				
21/21 ..	12	14				
21/22 ..	12	14	8			
21/23 ..	13	15	8			
21/24 ..	13	15	8			
21/25 ..	14	17	9	35	Mar. 1 ; female	46
21/26 ..	14	17	6			
21/27 ..	15					
21/28 ..	15	17	8	39	4 ; female	48
21/29 ..	16					
21/30 ..	16	18	8	59	25 ; female	68
21/31 ..	17	20	7	38	5 ; female	47
21/32 ..	17	20	7			
21/33 ..	18	20				
21/34 ..	18	20	8			
21/35 ..	19					
21/36 ..	20					
21/37 ..	20					
21/38 ..	21	23	8	40	11 ; female	49
21/39 ..	21	24	8	34	6 ; male	44
21/40 ..	22	25	8	33	6 ; male	43
21/41 ..	22	25	8	38	11 ; female	48
21/42 ..	23	25	8	34	8 ; male	44
21/43 ..	24	26	8			
21/44 ..	24					
21/45 ..	25	27	8	33	8 ; male	42
21/46 ..	25					
21/47 ..	26	..	..	..	17 ; female	40
21/48 ..	26	28	8	38	14 ; male	47
21/49 ..	27	29	8	35	12 ; male	44
21/50 ..	27	30	7	41	18 ; female	50
21/51 ..	28	30	9	38	18 ; female	49
21/52 ..	28	30	8			
21/53 ..	29					
21/54 ..	29	Feb. 1	8	36	16 ; male	46
21/55 ..	30					
21/56 ..	30					
21/57 ..	31	2				
21/58 ..	31					
21/59 ..	Feb. 2					
21/60 ..	2					
21/61 ..	3	6	7			
21/62 ..	5	7				
21/63 ..	5	7	8	43	30 ; female	53
21/64 ..	5	8				
21/65 ..	6					
Average	..	..	7·75	37·65	..	46·79

It will be noted that both wasps, Nos. X and 21, had an increase of efficiency in the early part of January. During that month Mr. Jarvis was away on his annual leave, so I had to have full charge of this breeding work. I at once began to experiment with these two wasps in particular, to see if I could get them to lay more eggs. From the records I found that each wasp had not averaged an egg a day, so I tried giving them more attention, and removed the grubs as soon as they were parasitized. To do this I tipped them out of the tins very early in the morning, at noon, and late in the evening. On 3rd January I was rewarded by getting two eggs from No. 21, and on the 5th both wasps laid twice. Later in the month, it will be noted, this two-egg record was rather constant. Furthermore, on 9th January No. 21 gave me three eggs on paralysed grubs, and she did this again on 5th February. Thus I finally came to the conclusion that two eggs per day was approximately the best average work of one of these wasps; so made it a practice to examine them early in the morning and late in the afternoon. This practice disturbed the wasps less and they were found to do better under it.

Again, it was interesting to note that, when I put more than one grub in the soil with a wasp at the same time, she invariably paralysed them all, though she never laid on more than one. On one occasion, just to note the result, we placed fifteen third-stage grubs of *Lepidiota frenchi* with one of the wasps in a large flower-pot of soil, and left them together overnight. The result next morning was most encouraging, for only three grubs remained alive. The wasp had paralysed twelve of the grubs, but only one had an egg upon it.

Evidently these wasps consider the grubs their enemies, else why should this individual have paralysed so many more than she could possibly require for her progeny? Undoubtedly, however, this habit would be most beneficial to our crops, if the wasps were more plentiful.

Autumn and Winter Broods.

Though we have but little data from actual breeding, field observations clearly show that these wasps continue their beneficial activities throughout the year. The temperature of even our coldest winter nights seldom dropping to 40 deg. Fahr. does not seriously inconvenience such hardy parasites, for the adults are always to be found at flowers as soon as the sun warms up a bit in the morning. And, furthermore, we find the larvæ and cocoons in the soil just as abundantly in winter as at any other season. Yet there is no doubt that both temperature and moisture play important parts in the activities of insects; therefore it was not surprising to find in our breeding work that the life-cycle was considerably lengthened as the nights got cooler, or when the cocoons were exposed to drying atmosphere. Hence we may naturally conclude that during the winter, even under natural conditions, their period of development would be materially increased. Summing them up it appears that there are probably at least four distinct broods each year; for convenience we have designated these by the name of the four seasons—spring, summer, autumn, and winter. The first two have been described in detail above, so it is interesting to add here a brief tabulation of the available data on the autumn brood.

On 4th March, 1919, Mr. Jarvis collected three *Campsomeris* wasps at flowers, and placed them in separate tins of soil, each supplied with a grub; these were given the numbers 47, 51, and 79. On 14th March he collected wasp No. 38, and on 19th March No. 22, both at flowers along the Mulgrave River. On this latter date No. 25 was secured from a window in the laboratory. The data on the progeny of these six wasps, though far from complete, are given in Table No. 4:—

TABLE No. 4, SHOWING PARTIAL DATA ON AUTUMN BROOD OF SIX CAMPSOMERIS WASPS.

Egg No.	Laid.	Emerged.	Life Cycle.	Sex.	Species.
			Days.		
22/1	Mar. 20	May 12	53	Male	*C. tasmaniensis*
25/1	23	18	56	Female	*C. tasmaniensis*
38/1	16	16	61	Female	*C. tasmaniensis*
38/2	17	1	45	Male	
47/1	12	2	51	Male	*C. tasmaniensis*
51/1	6	5	60	Male	*C. tasmaniensis*
51/2	10	6	57	Female	
51/5	12	14	63	Female	
51/7	13	9	57	Male	
51/9	15	16	62	Female	
79/1	7	6	60	Female	*C. radula*
79/3	10	9	60	Female	
79/4	11	1	51	Male	
Average ..	..	..	56·2		

Though, unfortunately, this breeding work was not continued throughout the year, we have made numerous observations upon both the winter brood and the parent wasps in the field. During June, 1918, the wasps were particularly abundant in the Cairns district, being especially seen flying to flowers and close over the surface of the ground in grubby fields. Digging in one of these fields at Hambledon on 20th June, I found the wasp cocoons exceedingly abundant and at the rather shallow depth of about 12 inches. This was accounted for because the soil was very hard and stony just below cultivation, so that it was impossible to dig without a bar. I estimated that about 37·5 per cent. of the grubs in this instance had been eaten by the larvæ of the wasps.

Again, during the winter of 1920, the wasps were observed in great numbers in the fields, both at Meringa and at Greenhills. On 14th July, while investigating the depth of the grubs of *Lepidoderma albohirtum* in our Meringa plots, cocoons in considerable numbers were turned up at depths of from 12 to 18 inches. I estimated that in this spot 25 per cent. or more of the grubs had succumbed to the wasps.

Digging a pit a cubic yard in size, in another grubby field at Meringa, on the same day, we found the progeny of the wasps even more numerous, and at depths of 12 to 24 inches, the deepest being a young larva attached to a paralysed living grub in a well-defined cell; this cell was about 1 inch by 2 inches in size, and the grub was lying on its back. The soil in this field was very loamy, so that it was easy for the wasps to go deep. At 9 a.m. many of the wasps, both males and females, were observed here feeding on the flowers of the pink burr. The abundance of nectar-bearing plants in this vicinity had undoubtedly attracted the wasps in considerable numbers, and probably accounted for the high rate (60 per cent.) of parasitism.

At Greenhills, 3rd August, 1920, we also found many cocoons of these wasps while excavating; apparently 20 per cent. of the grubs had succumbed to them.

The remarkable delay in the emergence of wasps where the cocoons were exposed to the drying effect of the atmosphere has been recorded by Mr. Dodd (34), and this retarding factor has been noted on numerous occasions subsequently. Hence for the larvæ to develop in their normal period they must be kept fairly moist. It is probably for this reason that the mother wasp usually goes so deep into the soil with the paralysed grub before constructing a chamber for the development of her offspring. In one instance, while digging to a depth of 4 feet in the Greenhills soil, I found one of these cocoons in a cell 42 inches from the surface, and many at depths of from 2 to 3 feet.

I wish to call attention here to the fact that the number of wasp cocoons turned up by ploughing red volcanic soils is no criterion of the value of these friendly insects in the fields. The abundance of data that we have accumulated during the past four years by digging deep all go to show that most of the paralysed grubs are put lower than the ploughs go. Hence the only way to arrive at the percentage of parasitism would be to excavate under grubby cane-stools here and there in the fields, to a depth of approximately 4 feet.

Parthenogenesis of Campsomeris.

A specimen of *C. radula* (wasp O) bred from egg KK of Table No. 1, and presumably unfertilised, lived only twelve days, laying seven eggs. It was further interesting, however, that the only two of these that developed produced a male and a female, thus suggesting that, though the vitality was remarkably shortened, these wasps were able to reproduce both sexes without mating. With a desire for further evidence of this remarkable power of the *Campsomeris* wasps to reproduce parthenogenetically, a number of separate experiments were started at once. The results of these will be given hereunder.

Wasp OO, *C. radula,* derived from egg HX of Table No. 1, was kept unfertilised, and after an interval of four days she was given a third-stage grub of *L. frenchi,* on which she deposited an egg at once. Though this wasp lived only twenty-seven days, she deposited nineteen eggs on third-stage grubs of *L. frenchi.* Eight of these came to maturity in the usual time, but only one produced a female wasp. This interesting record is given in full as Table No. 5:—

TABLE No. 5, SHOWING THE EGG RECORD OF CAMPSOMERIS RADULA, WASP OO.

Egg No.	Laid.	Hatched.	Life of Maggot.	Cocoon Stage.	Emergence and Sex of Wasp.	Life Cycle.
			Days.	Days.		Days.
OO/1 ..	Jan. 9	Jan. 12	..	..	Feb. 21 ; male	43
OO/2 ..	10	13	7	33	22 ; male	43
OO/3 ..	11	14	7	33	23 ; male	43
OO/4 ..	13	16	7			
OO/5 ..	13	16	7			
OO/6 ..	15	18	7	32	26 ; male	42
OO/7 ..	16	19	6	31	25 ; male	40
OO/8 ..	17					
OO/9 ..	17	20	7			
OO/10 ..	18					
OO/11 ..	20	23	7	32	Mar. 3 ; male	42
OO/12 ..	22					
OO/13 ..	22	25				
OO/14 ..	23					
OO/15 ..	24	27	7	32	7 ; male	42
OO/16 ..	25					
OO/17 ..	28	30	7	40	19 ; female	50
OO/18 ..	28					
OO/19 ..	Feb. 1	Feb. 4				
Average	..	..	6·9	33·28	..	43·125

"Wasp OOO, *C. radula*, derived from egg QX of Table No. 1, was carefully excluded from all possibility of mating. She lived thirty-two days and also produced nineteen eggs; of these only ten developed, and all were males.

"Wasp K, *C. tasmaniensis*, derived from egg X27 of Table No. 2, though not allowed to copulate, was much more prolific. She lived sixty-two days, laying eighty-four eggs, and finally came to an untimely end, being cut to pieces by a grub. Forty-five cocoons were obtained, from which emerged thirty-seven males and one female; the seven remaining cocoons failed to emerge, and the pupæ in them were found to be rotted."

Most remarkable for the number of eggs produced by an unfertilised female was wasp Q, hatched from the thirty-eighth egg laid by wasp No. 21. This wasp emerged on 11th March, 1918, and began laying at once, which she kept up until 20th May, depositing ninety-five eggs. The next day she was found dead, and had lost ten segments of one antenna, a segment of one intermediate tarsus, and two segments of the other, while both of the posterior tarsi were considerably mutilated. These ninety-five eggs produced sixty-eight cocoons, from which issued forty-two wasps, all males; the remaining cocoons contained rotting pupæ.

In most of our other experiments along this line the eggs all developed into males. Finally, however, we took the lone female that developed from egg OO/17 of the unfertilised wasp OO on 19th February; this wasp also was not permitted to meet a male, but she laid upon a grub the day after emerging, and, though she met an untimely death at the hands of a grub that she was attempting to sting on 29th February, she had already laid seventeen eggs. Several of these eggs, however, failed to hatch, but turned brown and dried, as though lacking fertility. Four of the larvæ spun cocoons, but the only wasp that was obtained from these was a male. Hence it would appear that the vitality is largely spent in the second generation, without mating. Yet it is remarkable that they are able to reproduce both males and females at all without mating, even in the first instance.

Further Biological Observations.

"*The Egg* of *Campsomeris radula* measures 3·20 mm. by ·90mm.; colour greyish white, elongate-cylindrical, with longitudinal axis slightly curved, and rounded ends, that attached to the grub being less obtuse than the other. Occasionally eggs are not regularly cylindrical throughout their length, but may bulge slightly near the centre."

"It was found that the eggs were not always placed in the normal position, on the third abdominal segment of the venter of the grub, but sometimes nearer to the thorax, or not on the central line."

"A wasp, tipped suddenly out of its cage, was seen to be clinging to its host, and in the act of laying an egg, which projected about three-quarters of its length from the ovipositor. The insect remained clinging to the grub, and finished ovipositing in the broad daylight, gluing the egg as usual to the ventral surface."

"The eggs were easily detached and transferred to other grubs. Four eggs laid on 12th March, 1918, were detached and placed on a single grub, where they hatched and developed into maggots, that ultimately spun abnormally small cocoons. A male wasp emerged from one of these on 7th May, and a male and female four days later."

In our experimental work the eggs were frequently subjected to destroying agencies. "Fully 20 per cent. of the eggs obtained from a cage of females of *C. tasmaniensis* during December were destroyed by a species of *Acarus,* that very often occurs as a predaceous enemy on the bodies of soil-frequenting white grubs. In another instance 40 per cent. of the eggs laid during January were destroyed by Acari."

"Eggs, too, were often found to be diseased and to turn brown and dry up. They also became marked with short brown streaks near the attached end, in which case they ultimately rotted away and became discoloured with brown shades as though destroyed by bacteria."

The Larvæ were also subject to attacks of a fungus, especially when very young, and sometimes they became entirely covered by a white fluffy growth.

"In the event of a host dying before the maggot has attained advanced growth, the latter, if a couple of days old, may be successfully transferred to another paralysed grub, and will again pierce its skin and resume feeding. If, however, the parasite be half grown it will be necessary when transferring to make an incision in the skin of the host, and place the head of the maggot against the hole; when it will sometimes resume feeding, but not infrequently fail to become attached and consequently perish."

The larvæ, just prior to spinning their cocoons, eject water at intervals from the end of the body, whenever disturbed, squirting it to a distance of 6 inches or more. I can offer no explanation for this peculiar habit.

"On 15th January, 1918, a maggot of *C. tasmaniensis* that had been unable to complete the upper surface of its cocoon, because the cell lacked a roof, as noted above, was placed on its mat of silk in a special cell to watch the transformation to the pupal condition. Six days later, exudation of moisture had taken place, and it had shrunken noticeably, the segmentation being very angular and conspicuous. Next day the maggot had shrunken to 19 mm. in length, the skin having lost its glossy appearance, and viewed with a lens the entire surface was seen to be closely wrinkled. The head-end had contracted and lost the power of vigorous motion, the segmentation showing as angular ridges. Pupation took place on 26th January (eleven days after spinning)."

"*The Adult Males,* just after emerging, have a habit of remaining in the vicinity of their empty cocoons, as being, presumably, the most likely spot for the appearance of the females. Males that emerged from cocoons at the insectary were at once thrown out of the door, but after flying for a time close at hand they invariably tried to get back to the breeding cages, and if the door happened to be closed they flew round to the window and were observed trying to get into the room."

"*Method of Paralysing Grub.*—On 4th February a pot of soil (clay-loam) 1 foot in depth was prepared, and a specimen of *C. radula* was placed on top of the soil with a stage III grub of *L. frenchi* lying close to it. During the next ten minutes the wasp paralysed four grubs of *L. frenchi,* its mode of attack being to seize them by one mandible and at once sting them on the ventral surface, just anteriorly of the front coxæ. After a few seconds the sting is withdrawn and immediately thrust into the throat just in front of the maxillæ, the whole operation lasting less than a minute, the sting being kept moving slightly as though probing the wounds and administering successive injections of the poison. The fourth grub was paralysed at 2.55 p.m. and by 3 o'clock had been undermined and half-buried by the industrious wasp, which came two or three times to the surface bringing with it pieces of soil, when it crawled over the uncovered portion of the grub's body as if to gauge its dimensions, and then again disappeared below the soil, which was heaped loosely around the half-buried grub. No further motion was noticed for three minutes, and then the body was suddenly pulled vigorously downwards, leaving only the three last segments exposed to view; the wasp having apparently been busy in the soil, excavating a tunnel for the reception of its victim. No further movement was apparent for six minutes, when the body was again pulled downwards, leaving the anal segment just visible among the loose earth and level with the surface. By 3.12 p.m. another pull down, and the grub had disappeared from view (seventeen minutes after being paralysed). When examined next day at 9 a.m. the wasp was on the surface, and the grub was found 10 inches below ground level, and 2½ inches out of the perpendicular; thus it had been transported from the surface in a vertical direction at an angle of about 80 degrees. The grub was lying with its venter in a horizontal position, and an egg had been laid in the normal situation.

"On 5th February a wasp was placed on the surface of the same pot of soil used in the above experiment, at 9.30 a.m., a grub of *L. frenchi* being placed with it. The insect stung the grub in the same manner, and whilst so engaged allowed me to pick up the grub and examine the mode of attack through a pocket lens in a strong light. The wasp had hold of one mandible of the grub near its base, in such manner that the latter could not properly close its jaws or bite in a forcible manner. After the sting, however, the free mandible of the victim seemed powerless to move, and no attempt was made to bite. The grub was stung at 9.30 a.m. and thirteen minutes later the anal segment alone was visible at ground level, the wasp then coming to the surface and at once burrowing below again. By seventeen minutes from the time of stinging the grub had been buried out of sight. When examined next day, at 9.30 a.m., the grub was found 4½ inches below the soil, and 2 inches out of the perpendicular; it was lying at an angle, venter uppermost, among the soil, and no egg was present.

"On 6th February another specimen of *C. radula* was placed on the surface of the soil with a cane-grub (*L. frenchi*) and whilst engaged in stinging was examined under a strong light. It was plainly seen that when stinging the second time the sting was thrust into the throat just in front of the maxillæ and moved about in a probing manner but not withdrawn, the reason inferred for such an action being the greater facility afforded for injecting a quantity of the paralysing fluid. The first sting is administered between the head and the anterior coxæ. When examined next day at 11 a.m. the grub was found at a depth of 5½ inches, while the angle of the line of transportation was about 18 degrees. It was lying on its back, venter uppermost, but not in a cell, and an egg was attached in a normal position. Two holes were noticed on the surface from which the wasp had emerged, one where the grub had been lying when stung, and the other 3 inches from it."

On one occasion I placed a wasp, *C. tasmaniensis,* in a large glass jar with moist soil to a depth of 6 inches, and supplied her with a large third-stage grub of *Lepidoderma albohirtum,* which I dropped in on the surface of the soil beside her. She at once became alert and moved around to the back of the grub as it lay on its side. The wasp then waited until the grub raised its head, when she sprang on the side of its body and seized it by the nearest mandible. This hold being secured, the grub appeared powerless to close its jaws, and she proceeded to sting it as noted above. Doubtless the wasps under natural conditions sometimes fail to get such a death-grip, and they themselves are then bitten and torn to pieces, as has been observed during our breeding work, and noted above. A few hours later I found the wasp with the grub at the bottom of the jar, working away industriously. Since she was at one edge and unable to go deeper, she proceeded to travel around and around in plain view, so that I was able to observe her activities. She first dug ahead of the grub, pushing the soil back around it until she had no more room to dump the soil; then she seized the grub and pulled it forward into the new cavity, when she continued in the same methodical order to excavate in front of the grub again. She travelled twice around the jar while I watched her, during several hours, so I gave up the idea of waiting for her to lay an egg upon the host. Next morning, however, the grub was in an oval cell at the edge, and lying on its back, so that I could clearly see an egg placed in the normal position on its venter.

It would appear that it is the instinct of these wasps to go as deep as possible, as we have observed in the field; but it certainly looks as though they waste a lot of valuable time; yet they probably know best. Since the hyperparasites are rather abundant in cocoons placed near the surface, by going deep they probably better avoid these enemies, as well as secure more even conditions as to moisture, temperature, &c.

It appeared to be rather a delicate problem for the wasp to sting the grub just the right amount. If she gave it too much venom the host died too soon, sometimes even before her egg hatched; and on the other hand, if she gave it too little the grub revived, and the loosely attached egg was soon knocked off. In our work we experienced considerable difficulty with both of these extremes. Since, as we found, it took about three days for the larva to hatch and approximately eight days to feed, the following tabulation indicates on an average the difficulties that we had to contend with on account of the grubs dying too soon.

DURATION OF LIFE OF GRUBS PARALYSED BY CAMPSOMERIS.

Date Stung.	Date Died.	Average Days Lived.
		Days.
Jan. 6	Jan. 21	15
6	25	19
8	12	4
13	15	2
14	25	11
16	20	4
17	Feb. 3	17
21	Jan. 29	8
21	28	7
22	31	9
23	26	3
25	Feb. 1	7
30	1	2
31	8	8
Average ..	..	8·3

Hosts.—Since these wasps reproduce continually throughout the year, they must necessarily adapt themselves to a variety of hosts. Their main prey, *Lepidoderma albohirtum,* being only available during the first half of the year, they continue by using any of the closely related grubs, especially those having a two-year life-cycle. Mr. Dodd (34) records the above host, and three others—*Lepidiota rothei, L. caudata,* and

Anoplognathus boisduvali—and during our extensive breeding, 1917-18, we added *Lepidiota frenchi* to this list. It was interesting to observe, at that time, that the *Campsomeris* wasps took no notice of the large third-stage grubs of *Dasygnathus australis*, not even paralysing them.

The Importance of Nectar-bearing Plants for Scoliids.

It is well known that the adults of these parasites subsist upon sweet secretions, which they secure largely from flowers, when they are to be had; they also feed upon honeydew, and in breeding them in captivity we found that they take any form of liquid-sweet that is offered them.

As far back as 1901, Mr. J. C. Clarke (11), of the Hambledon Sugar-mill, Cairns, called attention to the importance of planting Congo or pigeon pea (*Cajanus indicus*) around each field, and the growing of the Bona Vista bean (*Dolichos lablab*) as a crop for green manure, so as to encourage the multiplication of parasitic insects which feed on the nectar. He observed that the parasitic wasps were abundant at the flowers; and at the time of harvesting the cane, close by in the same field, he discovered many of the larvæ of these parasites in the soil where they were destroying the cane-grubs.

In Mauritius, too, the interesting observation was made that *Tiphia parallela,* which was introduced from Barbados, only reproduced successfully in localities where nectar-bearing flowers were present (33). In its native home this species never was known to visit flowers, for it fed upon the honeydew from aphids. In Mauritius, however, plant lice are so well controlled by natural enemies that the wasps were compelled to turn their attention to flowers for existence.

These observations would suggest that our own native parasites of the white grub might be considerably assisted and encouraged if we provided them with suitable nectar-bearing flowers in the vicinity of the infested cane areas. Naturally these wasps in their quest for food are led far into the wild country, and, since they can find their natural prey (white grubs) there under the grass-roots, they seldom return to the cane areas to oviposit. At any rate this suggestion is borne out by observations in every district where we know the wasps to occur.

Along the banks of the Mulgrave River these wasps, of various species, are commonly found on almost any sunny morning feeding on the blossoms of *Crotalaria* and other weeds. Also, in the grubby districts near the South Johnstone Central Mill, I have frequently seen the female *Campsomeris* wasps in abundance feeding on the flowers of the pink burr, and whatever suitable cultivated flowers were available. The Klondyke cosmos, or daisy, an orange-coloured flower, appeared to be particularly attractive to the wasps. Then, too, at Babinda, where the native scrub borders the new cane areas, it is not uncommon to see these wasps feeding on the flowers of wild raspberry and other native plants. Undoubtedly this feature of the problem is worthy of considerable further study.

Notes on Other Species.

We have not been able to investigate the life-history of the several other scoliids, but no doubt it is very similar to that given above.

Discolia soror Smith, our next plentiful species in cane areas, appears to prefer sandy-loam fields along the river flats. Here they feed on the flowers of *Eugenia* and other plants; they are also particularly fond of the honeydew on the leaves of corn infested with leafhoppers. In fact in this latter situation one can collect most of our Scoliid and Thynnid wasps.

Mr. Dodd has reared specimens from cocoons collected while ploughing, and the wasps emerged on the following dates:—29th June, 27th August, 11th and 25th November, and 3rd December.

Scolia (Diclis) formosa Guerin apparently favours the areas bordered by native scrub; at least all of our specimens have been taken in such localities by Mr. Dodd. He found them at Kuranda feeding on flowers of *Duranta*, at Babinda on the flowers of pumpkin and an unknown creeper in company with *Campsomeris tasmaniensis*, and at Greenhills on the flowers of *Evodia*.

Campsomeris (Triclis) ferruginea Fabr. also apparently favours the borders of scrub. Our specimens were taken by Mr. Dodd at Greenhills in January on the flowers of *Tristania* and *Evodia*, and at Kuranda in April on flowers of an unknown scrub tree.

Campsomeris carinifrons Turner appears to be rather rare in the Cairns district. I have seen the males feeding at the flowers of the pink burr at Greenhills. A female captured by Mr. Dodd at our station on the flowers of the pigeon pea, in June 1920, refused to take any notice of stage III grubs of *Anoplognathus* and *Anomala* kept in the soil with it for several days.

Liacos insularis Smith is also found near scrub. The few specimens observed by Mr. Dodd were captured on dead wood in the scrub. He tried to get a female to parasitize third-stage grubs of *L. albohirtum*, *Anoplognathus*, and *Anomala*; these were kept a week in soil with the wasp without result. In June, 1920, Mr. Dodd also took a female in the early morning asleep on foliage at Babinda.

Tiphia intrudens var. *brevior* Turner is rather common in the Cairns district. Specimens were frequently seen around cornfields at Meringa feeding on honeydew.

Hyperparasites of the Scoliid Wasps.

That such abundant parasites should themselves be parasitized is a foregone conclusion. For many years it has been known that they were preyed upon by various species of Bombylid flies and Rhipiphorid beetles, in countries where the life-histories of scarabæid grubs have been carefully studied. Hence it was not surprising that Mr. Dodd (34) discovered these same parasitic enemies of the wasps here—the natural home of lamellicorn beetles—during the stage in the investigation when many thousands of the cane-grubs were being collected. In this breeding work he established definitely the relation of *Hyperalonia funesta* Walker, and *Emenadia cucullata* Macleay, to our common scoliid parasites.

H. funesta is very common in the cane areas about Gordonvale, and is seen everywhere in grass paddocks, even far removed from canefields. These flies have a characteristic habit of hovering low over the ground, the wings vibrating so rapidly that only the body can be seen, and it appears to be motionless in the air. Again, they are frequently seen on the ground, where they appear to be intently examining the surface of the soil. Mr. Davis (40) remarked that since the flies are incapable of entering the soil, and in view of the further fact that they frequent flowers and feed on honeydew produced by aphids at the same time that the scoliids are active, it is conceivable that the flies oviposit on the flowers or possibly directly on the wasps and that their eggs are carried away by the host and deposited with its own on the white grubs.

Mr. Dodd observed that the larva pupates within the host cocoon; and he took pupæ from these cocoons in October. The pupæ, as shown in the drawing, is a curious-looking creature with projecting spines from the head and tail. The abdomen is rather cylindrical with peculiar comb-like rows of curved spines topping the ridges on the dorsal surface, undoubtedly used to support the body and to aid the insect in its movements when emerging.

Emenadia cucullata, our most common Rhipiphorid beetle, is frequently met with in considerable numbers resting on the leaves of fig along roadsides and bordering cane areas. Mr. Dodd (34) bred this species from scoliid cocoons. Apparently nothing is definitely known of the habits of the adult beetles and the way in which they parasitize the wasps. Mr. Davis (40) hazards the suggestion that the egg is probably laid on or near flowers frequented by the wasps, or possibly upon the host itself, and that the egg or the recently hatched Rhipiphorid larva becomes attached to the wasp and is in due course deposited on a white grub at the same time that the wasp deposits her own egg.

It would be interesting to know what percentage of the scoliids are destroyed by these parasitic enemies, but unfortunately this is a phase of the problem on which we have no data. Yet, when we consider the comparative abundance of wasps that are known to prey upon grubs in our cane areas, we are forced to conclude that a very large majority of them must succumb to natural causes. Otherwise, with their prolific reproduction they would be able to hold our cane-beetles in check with no other assistance.

Thynnidæ.

These wasps are included here because they probably have an important bearing upon the grub-pest, though as yet there is little definite data. However, the suggestion by Froggatt (14) that they probably lay their eggs upon lamellicorn larvæ has recently been demonstrated by Dr. Williams (46). The former author gives the following interesting summary of this family:—

"These handsome flower-wasps are closely allied to the members of the previous family, as they have similar wingless females of such peculiar shapes that, if examined alone, they would never be taken for the consorts of the large wasp-like *Thynnus*, with its long stout antennæ, well developed legs, and large powerful wings. The males fly about the flowers of *Leptospermum* and eucalypts, and when captured bite and pretend to sting by turning up the tip of the abdomen, which ends in a horny, harmless process. Fortunately, when hunted for in summer, most of our commoner species can be taken *in copula* with the smaller female, with which he flies about quite easily; when caught the female immediately detaches herself and falls to the ground, where she crawls out of sight, so that care must be taken by the collector to keep each pair captured in a box by themselves, or else when once mixed up it is impossible to determine unknown species. Australia is the headquarters of this group, for, of about 400 described species, 300 are peculiar to this country; the others are chiefly confined to Brazil and Chili in South America, with a few from Asia and the Islands. Smith has described a great number in the British Museum catalogues; Westwood, others; and Guerin, those collected during the Voyage de Coquille in 1830; but as many of these were determined from single specimens of one sex, it is certain that, when a collection of sexed specimens can be compared with the types, the number of species will suffer considerable reduction.

"Nothing definite is known about the earlier stages of their development; I have, however, obtained cocoons composed of a stout silken case enveloped in a thin outer second papery covering, oval in form, with a nipple-like projection at the extremity, from which I have bred one of our large species. These cocoons are buried several inches in the ground like those of the *Scolias*, so that the females, which are furnished with short, stout, spiny legs well adapted for digging, probably lay their eggs in lamellicorn larvæ living in the loose soil."

Several species of this family are abundant in the Cairns district, the most common ones collected in the vicinity of cornfields, where honeydew is available, being *Zaspilothynnus vernalis* Turner, *Thynnus pulchralis* Smith, *Epactiothynnus bipartitus* Turner, and *E. opaciventris* Turner. The males of the first two species are beautiful, large wasps; their wingless mates, living in the soil, probably paralyse grubs in a manner similar to that already described.

Dr. Williams (46), while in Australia in 1919, experimented with our commonest small species, *Epactiothynnus opaciventris,* and found that the little wingless female was very effective in paralysing lamellicorn grubs. Conditions, however, did not appear to suit the wasp, so only one egg was deposited. It was placed on the mid-ventral line; thus in appearance their work is very similar to that of the Scoliids. Concluding this short paper Williams remarked upon our immense Thynnid population of several hundred species, far outnumbering the *Scoliidæ*, and thought that it might be affirmed with some degree of certitude that, like the latter, they preyed essentially on lamellicorn beetle grubs.

Dexiidæ.

Mr. Dodd reared eight species of these beautiful flies from cane-grubs, during his investigations of many thousands of this pest, and came to the conclusion that the percentage of grubs destroyed by them was decimal (34). In recent years, however, we have done scarcely any of this work behind the ploughs, so have little new material to present, except as to the occurrence of the adults.

Though these flies are usually more common in scrub areas, the following species are frequently rather abundant in the fields about Gordonvale:—*Rutilia inornata* G. & M., *R. splendida* Don., *R. pellucens* Macq., and *Amenia imperialis* Rob. Desv.

The first is the dull species with bluish reflections, designated by Mr. Dodd as D. No. 4. He bred it from grubs of *Dasygnathus* and *Anoplognathus*.

The second, a bright blue-green species, is frequently seen on the trunks of trees and on posts adjoining canefields. Mr. Dodd reared it from *Dasygnathus* grubs, and designated it as D. No. 23.

The third, a dull species with greenish reflections, was reared by Mr. Dodd from the grubs of *Lepidiota rothei*.

The fourth is a brilliant green species with a bright-yellow face. Though we have no data as to its relation to the grubs of sugar-cane, its abundance in certain grubby fields would suggest that it was there for that purpose. I caught dozens of these showy flies at the edge of our experimental plots at Meringa, during the 1918 season, when grubs were there in such numbers that they did considerable damage to the crop. We placed the flies in cages over soil containing grubs, but failed to get any noticeable result. Dissection of the females, however, showed that they still retained a few maggots of rather large size; and in one instance a maggot about $\frac{3}{8}$ inch in length was dropped by a fly that I was holding rather tightly. It is generally supposed that these flies drop their maggots into cracks, &c., in soil which is infested with grubs, hence retaining the larvæ for a considerable period would enable them to develop strength, so that they would be better able to successfully locate their hosts.

Another beautiful light-green species has been commonly observed at Greenhills, especially by Mr. Dodd during the last two seasons, 1920 and 1921. In his earlier notes (34) he designated this unnamed species D. No. 33, when he bred it from *Anomala* and *Horonotus* grubs. The adults are frequently observed during the day sitting on cane-leaves and on posts in locations where grubs of the above hosts were plentiful in the soil.

Tachinidæ.

Two species of this family have been repeatedly reared from beetles taken in the field. The small brown dipteron with a dark head, which Mr. Dodd (34) designated as D. 6, is by far the most common. This insect was first bred out in 1914; and though numbers of the flies have developed every season from beetles collected in the field, we have been unable to get the species determined. Whilst these flies are only about $\frac{5}{16}$ inch in length, their progeny appear to be rather numerous, for we find from six to a dozen in a single beetle. They apparently favour the greyback beetles, *Lepidoderma albohirtum,* since these insects are exposed on the feeding-trees both during day and night; yet during the past season (1921) I bred them from several *Lepidiota frenchi,* a species which hides in the soil during the day.

The large Tachinid, a specimen of which was first bred by Mr. Jarvis (35) during January, 1917, is also fairly common in the region about Gordonvale. During the past season I have secured puparia of this fly from both of the above species of beetles. I have invariably found a single larva in each beetle, just as Mr. Jarvis did, so he was probably incorrect in assuming that this parasite normally lays two or more eggs on a single beetle. The fly is a very conspicuous species, and yet we have been unable to get it determined. Large specimens are fully $\frac{1}{2}$ inch in length; the head and upper part of thorax are bright golden, the latter marked with two black longitudinal stripes on either side of the median line, the inner stripes shorter; the forward portion of the scutellum is also blackish; the abdomen is black, marked by three broad grey cross-bands. This species is found in the foliage of trees in which the beetles feed, and is usually more common near scrub.

ANNOTATED BIBLIOGRAPHY.

(1) 1892. TURNER, R. E.—Insect Pests (*Lepidoderma albo-hirta*). Sugar Journ. & Trop. Cult. i, Oct. Supplement, p. 5.

Life-history and control measures. *See also* editorial, p. 182.

(2) 1893. TRYON, H.—Insects as Fungus Hosts. Trans. Nat. Hist. Soc. Qld. i, 51-59.

A general review of the relation of fungi to insects.

(3) 1894. COLONIAL SUGAR REFINING CO.—Grubs and Insect Pests (orig. rept. pub. 1893). Sugar Journ. & Trop. Cult. iii, 103, 124.

Notes on parasitic fungus imported from France to Homebush and Goondi; results not promising Also notes on other fungi, fowls as predators, &c.

(4) 1895. OLLIFF, A. S.—Australian Entomophytes or Entomogenous Fungi, and some account of their Insect Hosts. Agr. Gaz. N.S.W. vi, 402-414, four plates.

An historical account of these fungi, together with descriptions of the various species studied.

(5) 1895. WALLER, E. S.—The Grub Pest. Sugar Journ. & Trop. Cult. iv, 115.

Advocates protection of native birds.

(6) 1896. TRYON, H.—Grub Pests of Sugar-cane. Dept. Agr. Brisbane, July, 1895; pub. 1896.

Among many other phases of the subject, discusses natural enemies.

(7) 1896. TRYON, H.—Grubs. Sugar Journ. & Trop. Cult. v, 145.

A reprint of some of the factors of control as outlined in his bulletin on the grub-pest of sugar-cane.

(8) 1898. "SCRUTATOR."—The Grub Pest (*Lepidiota squamulata*). Sugar Journ. & Trop. Cult. vii, 146.

In an orchard on Pioneer River a persimmon tree had many dead beetles under it for past two years. The leaves were much eaten, and the ground was white with the corpses of the beetles. Beetles confined after feeding on this tree soon died, while some from a fig lived for a considerable period.

See also editorial, p. 244.

(9) 1899. POTT, G.—Cane Grubs. (Agr. Conf. Mackay.) Qld. Agr. Journ. v, 136.

In the Proserpine district, bandicoots were plentiful and grubs scarce. They go after the grubs. The birds also destroy an enormous quantity of grubs and should be protected. Much of the trouble probably was due to the destruction of birds by kanakas.

(10) 1902. BOYD, A. J.—Extermination of the Cane Grub. Qld. Agr. Journ. x, 468.

An excellent description of the mole, *Talpa europæa* (?); urging its introduction for the destruction of the grubs.

See also xix, 328.

(11) 1902. FROGGATT, W. W.—A Natural Enemy of the Sugar-cane Beetle in Queensland. Agr. Gaz. N.S.W. xiii, 63.

Gives an account of Mr. J. C. Clarke's observations at Hambledon Mill, dealing with wasp parasites of cane-beetles. Also advocating certain flowering plants to attract the wasps.

(12) 1902. TRYON, H.—A Parasite of Sugar-cane Beetle Grubs. Sugar Journ. & Trop. Cult. xi, 151.

Life-history and habits of a wasp, *Dielis formosa* Guerin.

Also published in Qld. Agr. Journ. x, 133.

(13) 1904. COLONIAL SUGAR REFINING CO.—Notes on the Means of Checking the Grub Pest. Printed Circular, 1st Nov. 1904.
No apparent results were gotten from the sowing of fungus.

(14) 1907. FROGGATT, W. W.—Australian Insects. William Brooks & Co., Ltd., publishers, 17 Castlereagh St., Sydney.
Thynnidæ (p. 100): about 300 species described; "young probably reared on lamellicorn larvæ."
Scoliidæ (p. 102): "about 50 species have been described from Australia."
Elateridæ (p. 166): "*Agrypnus mastersi* ranges from W. Aust. to Qld."
Asilidæ (p. 298): "*Craspedia coriaria* destroys cane beetles."
Tachinidæ (p. 312): "Australian species not worked up."
Dexiidæ (p. 313): "Parasitic on lamellicorn grubs."

(15) 1909. COLONIAL SUGAR REFINING CO.—Grubs. Ann. Rept. 1909, p. 43-52.
Experiments with young sorghum or imphi at Goondi to kill grubs gave no apparent results.

(16) 1909. GIBSON, ALFRED.—Fowls and the Grub Pest. Aust. Sugar Journ. i, 184.
An extensive experiment, using travelling fowl-houses, &c.

(17) 1909. LUCAS, A. H. S., & LE SOUEF, W. H. D.—The Animals of Australia.
The fruit-bats (Pteropodidæ), p. 36. Pouched mice (*Antechinomys, Sminthopsis, Phascologale*), p. 119-125. Bandicoots (Peramelidæ), p. 133. Lizards (Varanididæ), p. 236; (*Tiliqua*), p. 246. Frogs (*Amphibia*), p. 259.

(18) 1909. TRYON, H.—A Cane-grub Parasite. Aust. Sugar Journ. i, 79.
The mites infesting the grubs were not held responsible for their death, Lynwood Estate, Isis district.

(19) 1909. YOUNG BROS., Messrs.—A Cane-grub Parasite. Aust. Sugar Journ. i, 29.
A mite attacking grubs.

(20) 1910. TRYON, H.—The Cane-grub Pest. Aust. Sugar Journ. ii, 409.
Discusses preservation of natural enemies, and introduction of others, stating that he knows of no insect enemies of the cane-beetles outside of Queensland that he could commend for introduction. The introduced ant (*Pheidole megacephala*) is not considered an important enemy of the cane-grub.

(21) 1911. MAUGHAN, J. C.—Natural Enemies of the Cane Grub. Aust. Sugar Journ. iii, 161.
Brown lizard eating grubs; the holes that they excavate are very similar to the work of bandicoots.

(22) 1911. TRYON, H.—Grub Pest of Sugar-cane, *Lepidiota albohirta;* a neglected aspect. Aust. Sugar Journ. ii, 532.
A discussion of natural enemies. 1, predatory mammals; 2, predatory birds; 3, predatory insects; 4, parasitic insects; and 5, plant parasites (fungi and bacteria).
Fungus prolific at Goondi in 1895. Fungus cultures from France had previously been sown in that locality. No subsequent trouble from grubs there. Suggests application of fungus to other fields.
Mr. Jodrell referred to flying-foxes killing beetles; and also his experience with the fungus.

(23) 1911. TRYON, H.—Natural Enemies of the Cane Grub. Aust. Sugar Journ. iii, 62.
Discussion of bandicoot and pouched mice as grub-destroyers.

(24) 1914. JARVIS, E.—Cane Grub Destruction. Aust. Sugar Journ. vi, 582.
Discusses parasitic control, with remarks on hyperparasites, parasitic fungi, &c. The Samoan fungus liberated in fields around Gordonvale.

(25) 1914. TRYON, H.—Cane Grub and Muscardine Fungus. Aust. Sugar Journ. vi, 631.

Green Muscardine fungus from Samoa said to already occur in the Cairns district; named *Metarrhizium anisopliæ* (Metschinoff) Sorokin. This fungus found in 1901 on Mr. Blackwell's farm, also at Highleigh. This article summarises information on this important subject.

(26) 1915. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. vi, 803.

Notes on experimental work with Samoan fungus.

(27) 1915. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 140.

Discusses natural control: fungus, mammals, birds, and insect enemies, &c.

(28) 1915. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 301.

Preliminary notes on the habits of the interesting Elaterid beetle larva, which Mr. Dodd kept under observation for a period of almost two years. Mr. Dodd's complete notes on this specimen are given above.

(29) 1915. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 525.

Notes on predaceous and parasitic enemies of cane-grubs, and hyperparasites.

(30) 1916. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. viii, 218.

Notes on occurrence of Muscardine fungus at Meringa.

(31) 1916. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. viii, 679.

Notes on centipede destroying cane-grubs.

(32) 1916. JARVIS, E.—Notes on Insects Damaging Sugar-cane in Queensland. Qld. Bur. Sugar Exp. Sta. Div. Ent. Bull. No. 3.

A list given of the natural insect enemies of cane-grubs, p. 35.

(33) 1917. CHARMOY, D. D'E. DE.—Report on the Importation of Scoliid Wasps from Madagascar. Dept. Agr. Mauritius, Dec. 1917.

Calls attention to the importance of nectár-bearing plants for success with these wasps.

(34) 1917. DODD, A. P.—The Cane Grubs of Australia, part ii. Qld. Bur. Sugar Exp. Sta. Div. Ent. Bull. No. 6.

A continuation of the studies begun in Bull. No. 2, with notes on natural enemies, hyperparasites, &c.

(35) 1917. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. ix, 121.

Notes on dipterous parasites of cane-beetles; also refers to common parasites of the grubs.

(36) 1917. MUIR, F.—The Introduction of *Scolia manilæ* Ashm. into the Hawaiian Islands. Ann. Ent. Soc. Am. x, 207.

This parasite was introduced to combat *Anomala orientalis* Waterhouse, which was first recognised in the Hawaiian Islands during July, 1912, supposedly from Japan.

This paper not only describes the successful methods used in establishing this wasp, but other valuable notes on death-factors of the beetle are given—*i.e.*, other parasitic and predaceous insects, fungi, &c.

(37) 1918. BALLOU, H. A.—Feeding Habits of the Parasites of the Hardback Grubs. The Agr. News, Barbados, xvii, 250.

Advocates nectar-bearing plants for attraction of wasps, which parasitize cane-grubs. The writer cites the successful work done with these wasps in Mauritius.

(38) 1918. CHARMOY, D. D'E. DE.—The Importation of *Tiphia parallela* from Barbados to Mauritius. Dept. Agr. Mauritius, Scientific Ser. Bull. No. 6.

(39) 1918. ILLINGWORTH, J. F.—Monthly Notes on Grubs and other Cane Pests. Qld. Bur. Sugar Exp. Sta., Div. Ent. Bull. No. 7.

Notes on Muscardine fungus (p. 10), parasites (pp. 12, 14-16, 19-21, 29), bandicoot and pouched mice (p. 22).

(40) 1919. DAVIS, J. J.—Contribution to a Knowledge of the Natural Enemies of *Phyllophaga*. State of Illinois Nat. Hist. Survey Bull. Urbana, xiii, article v.

Life-histories are given of the various parasitic and predaceous insects attacking the Melolonthid beetles of the genus *Phyllophaga*. Particulars are also given of other diseases caused in white grubs by Nematodes, Protozoa, bacteria, and fungi, with a list of the birds, mammals, and amphibia that prey upon them.

(41) 1919. ILLINGWORTH, J. F.—A Successful Method of Breeding Parasites of White Grubs. Journ. Econ. Ent. xii, 455.

(42) 1919. ILLINGWORTH, J. F.—Monthly Notes on Grubs and other Cane Pests, series 2. Qld. Bur. Sugar Exp. Sta. Div. Ent. Bull. No. 8.

Discusses parasites, and the value of nectar-bearing flowers.

(43) 1919. JARVIS, E.—Insect Friends of the Cane-grower. Qld. Agr. Journ. xii, 301.

A brief compiled summary of the enemies of the cane-grubs.

(44) 1919. MUIR, F.—The Progress of *Scolia manilæ* Ashm. in Hawaii. Ann. Ent. Soc. Am. xii, 171.

Records the successful reduction of *Anomala orientalis* by means of the above parasite.

(45) 1919. WILLIAMS, F. X.—Philippine Wasp Studies. Hawaiian Sugar Planters' Assn. Ent. Ser. Bull. No. 14.

Among many others, gives excellent life-history studies of various species of Scoliidæ and Thynnidæ.

(46) 1919. WILLIAMS, F. X.—A Note on the Habit of *Epactiothynnus opaciventris* Turner, an Australian Thynnid wasp. Psyche, xxvi, 160.

Lamellicorn grubs paralysed, just as the Scolias sting their prey, and in one case an egg was attached to the venter of the grub.

(47) 1920. ILLINGWORTH, J. F.—Monthly Notes on Grubs and other Cane Pests, series 3. Qld. Bur. Sugar Exp. Sta. Div. Ent. Bull. No. 10.

Discusses various natural factors in the control of cane-grubs, &c.

(48) 1921. ILLINGWORTH, J. F.—A Study of Natural Methods of Control for White Grubs. Qld. Bur. Sugar Exp. Sta. Div. Ent. Bull. No. 12.

Results of experiments with the green Muscardine fungus and bacterial diseases for grub control.

ANTHONY JAMES CUMMING, Government Printer, Brisbane.

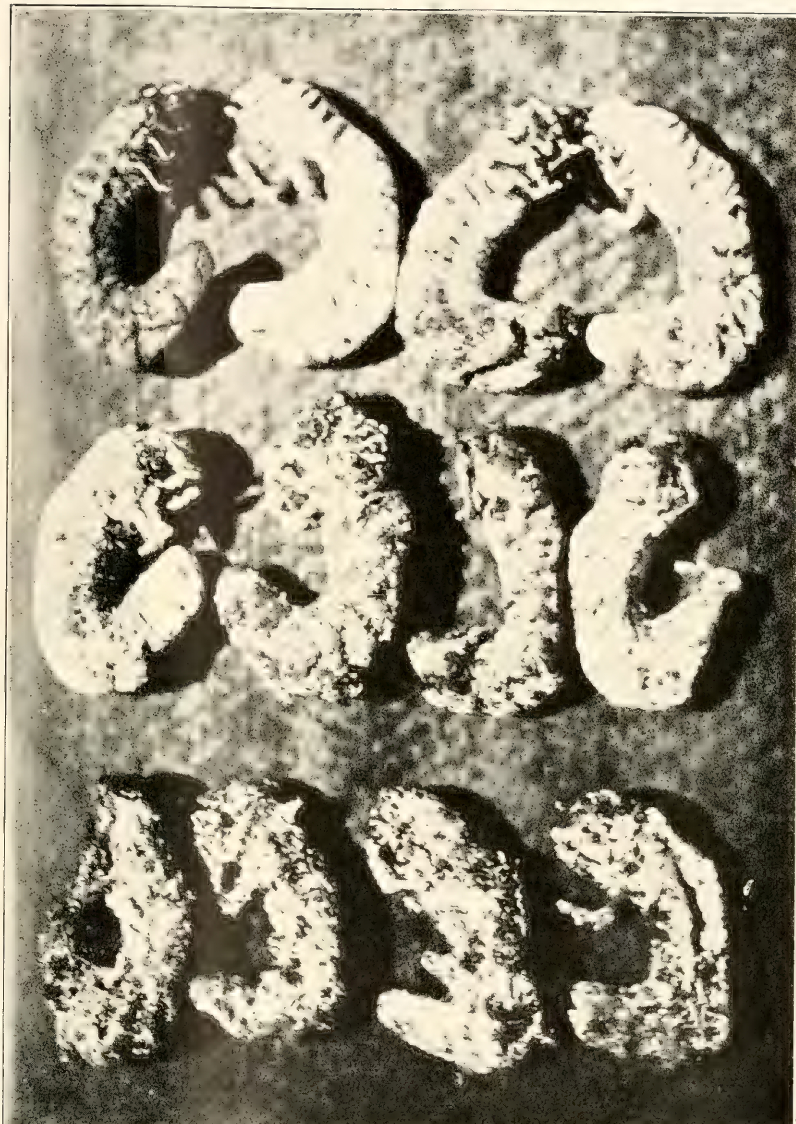

PLATE II.—Grubs killed by the fungus *Metarrhizium anisopliæ* Metsch., showing successive stages in the development of this disease organism, as it gradually changes the tissues of the grub into myriads of grey-green spores.

PLATE III.—PREDACEOUS ENEMIES OF CANE GRUBS.

Fig. 1. *Promachus doddi* Bezzi, female. Natural size.

Fig. 2. Egg-mass of same, taken from leaf of sugar-cane. Natural size.

Fig. 2a. Same, enlarged.

Fig. 2b. Separate egg of same, more enlarged, showing segmented larva doubled up inside.

Fig. 3. Grub paralysed by newly hatched Asilid maggot, attached to skin on thorax.

Fig. 4. Maggot; full-grown.

Fig. 5. Asilid pupa.

Fig. 6. Larva of *Agrypnus mastersi* Pascoe.

Fig. 7. The parent beetle, a skip-jack.

Plate III

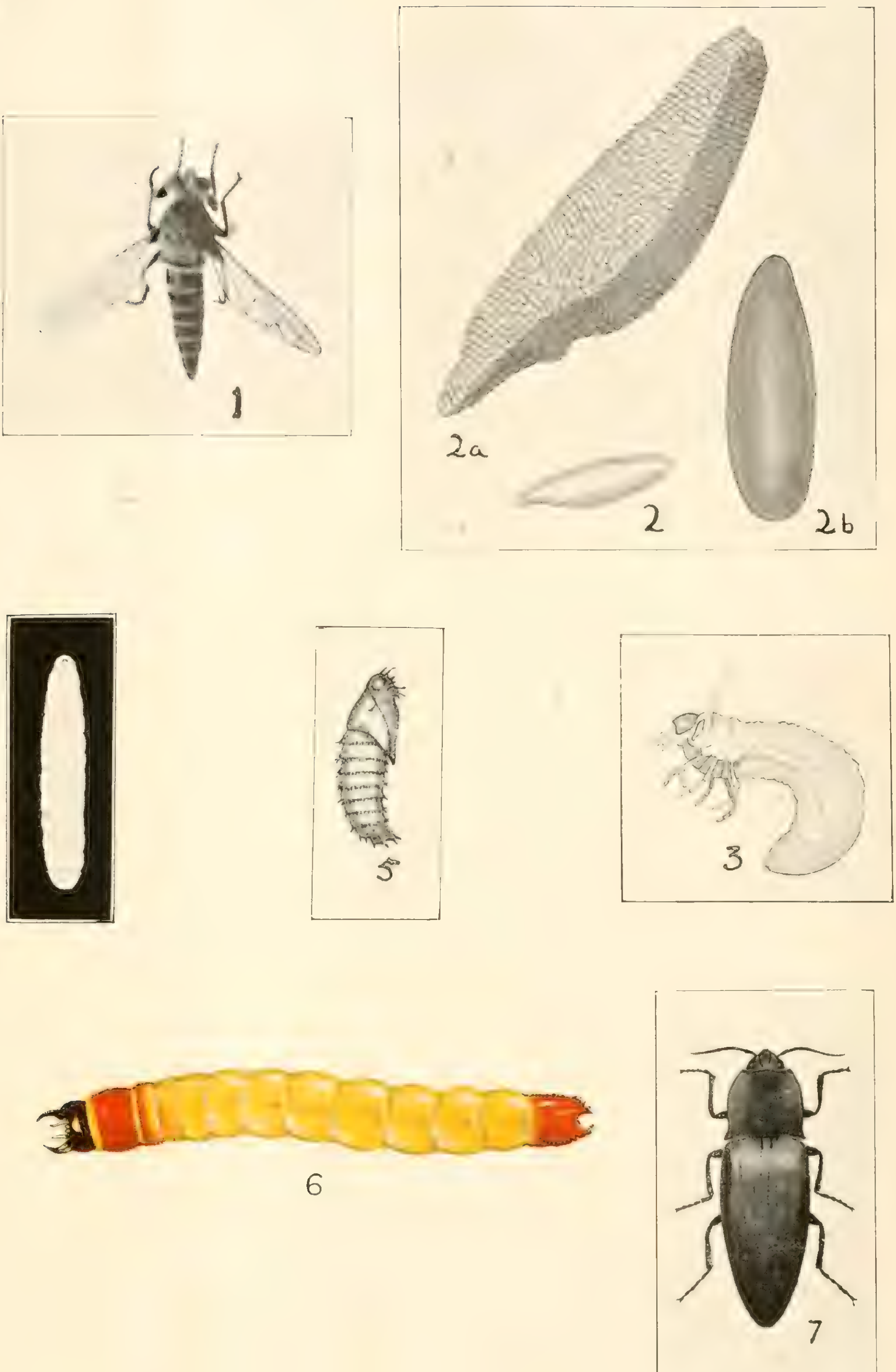

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Plate IV.—Stages in the Life History of Campsomeris radula Fabr.

Fig. 1. Adult female. Natural size.

Fig. 2. Adult male. Natural size.

Fig. 2a. Vertex, showing the three characteristic yellow spots. $\times$ 5.

Fig. 2b. Labrum, plain, which is characteristic of this species. $\times$ 5.

Fig. 2c. Pygidium, with characteristic yellow on proximal portion. $\times$ 7.

Fig. 3. Paralysed grub, showing characteristic position of the wasp egg. Natural size.

Fig. 4. The egg, two views. Magnified.

Fig. 5. A male larva feeding; age seven days. Natural size.

Fig. 6. A female larva, ten days old, still feeding. Natural size.

Fig. 7. The cocoon of the wasp, in cell. Natural size.

Fig. 8. The pupa of same, in cocoon. $\times$ 2.

Plate IV

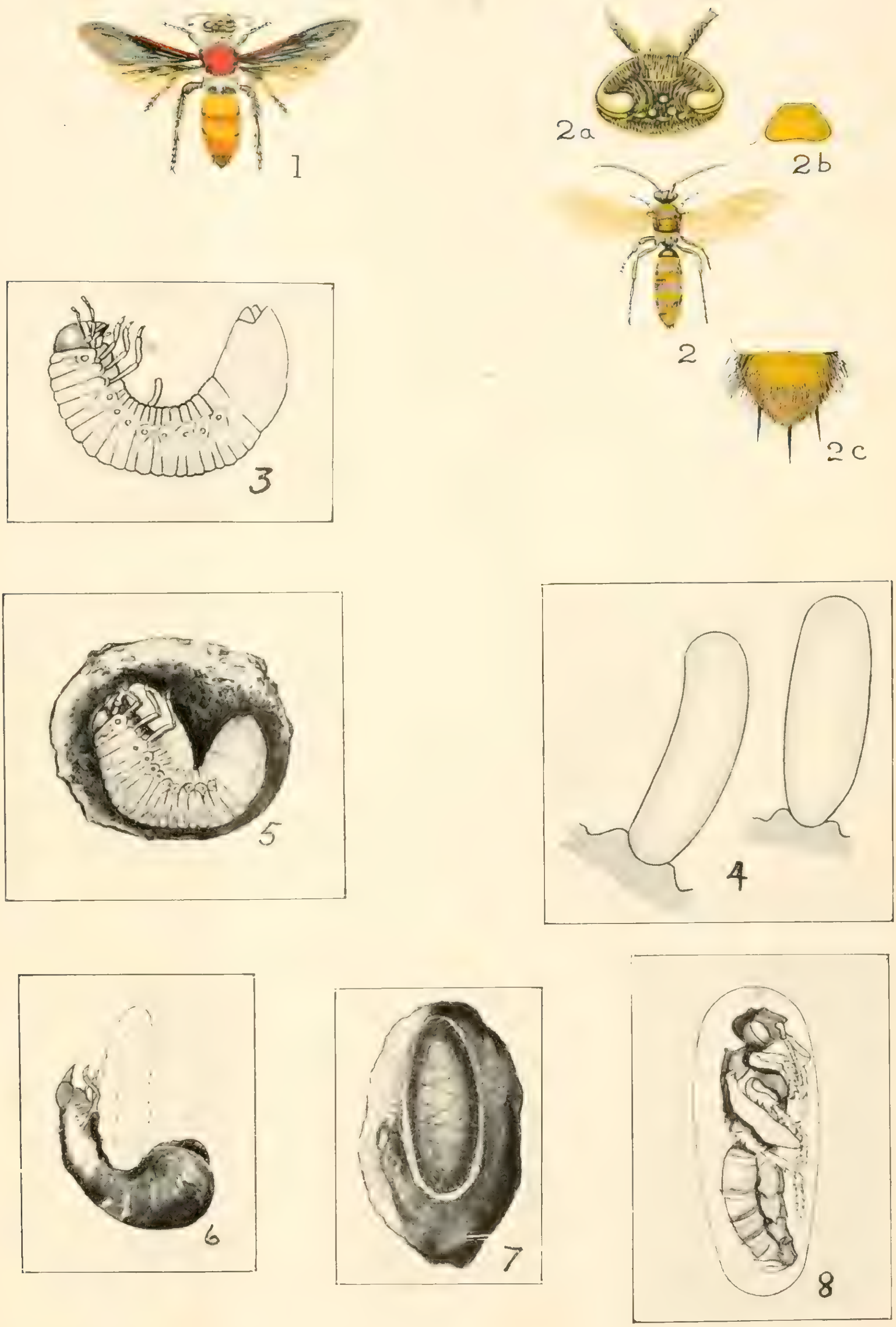

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Plate V.—Common Scoliids of the Cairns District.

Fig. 1. *Campsomeris tasmaniensis* Sauss., female, the usual marking. Natural size.

Fig. 2. Male of same. Natural size.

Fig. 2a. Showing the two characteristic small yellow spots. × 5.

Fig. 2b. Pygidium with no yellow, which is characteristic of this species. × 9.

Fig. 2c. Labrum, showing characteristic dark spot in centre. × 5.

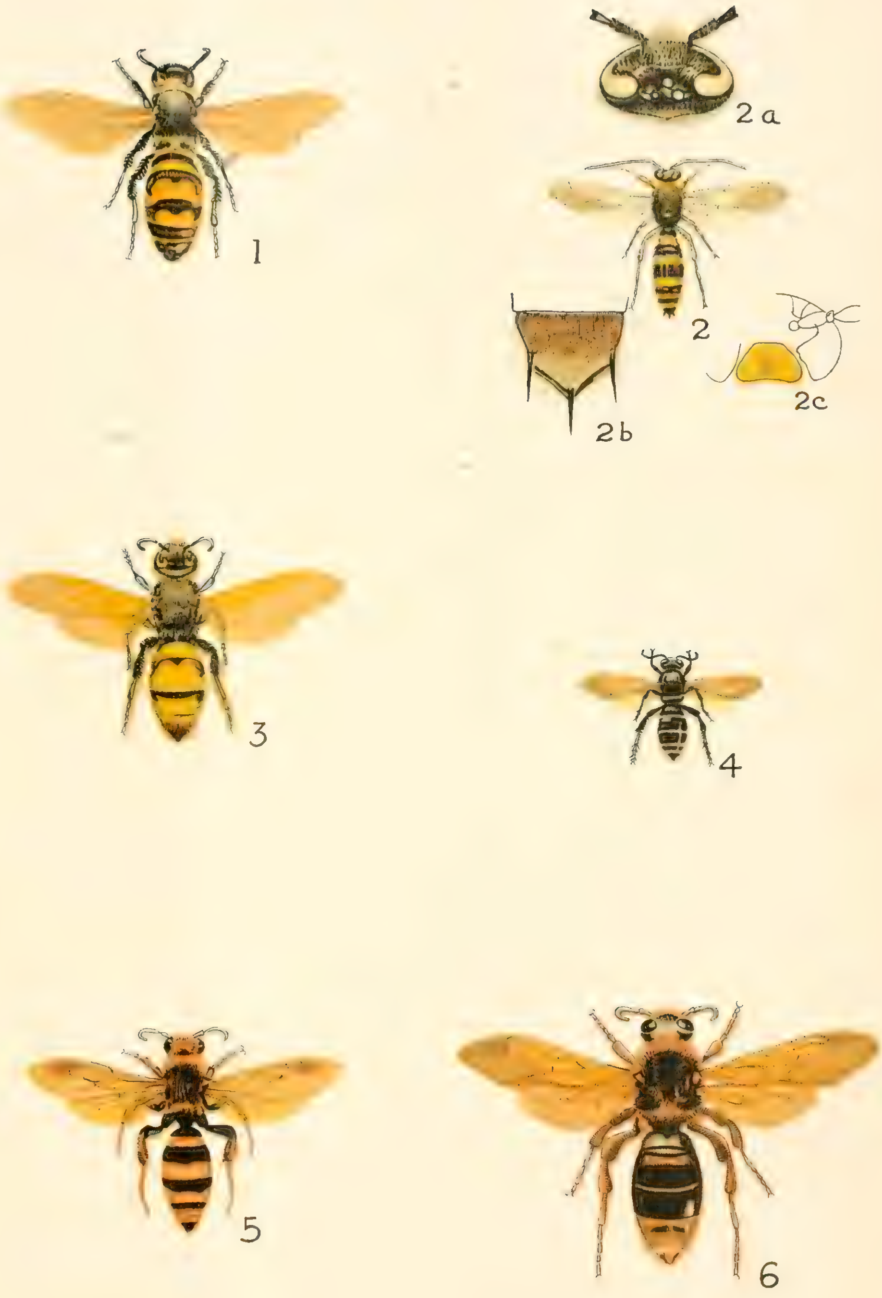
Fig. 3. *C. tasmaniensis*, a variation in the marking of the female. Natural size.

Fig. 4. *Campsomeris carinifrons* Turner, female. Natural size.

Fig. 5. *Scolia formosa* Guer., female. Natural size.

Fig. 6. *Campsomeris ferruginea* Fabr., female. Natural size.

Plate V



Del. E. Jarvis.

PLATE VI.—COMMON SCOLIIDS AND THYNNIDS OF THE CAIRNS DISTRICT.

Fig. 1. *Scolia soror* Smith, female. Natural size.

Fig. 2. Male of same. Natural size.

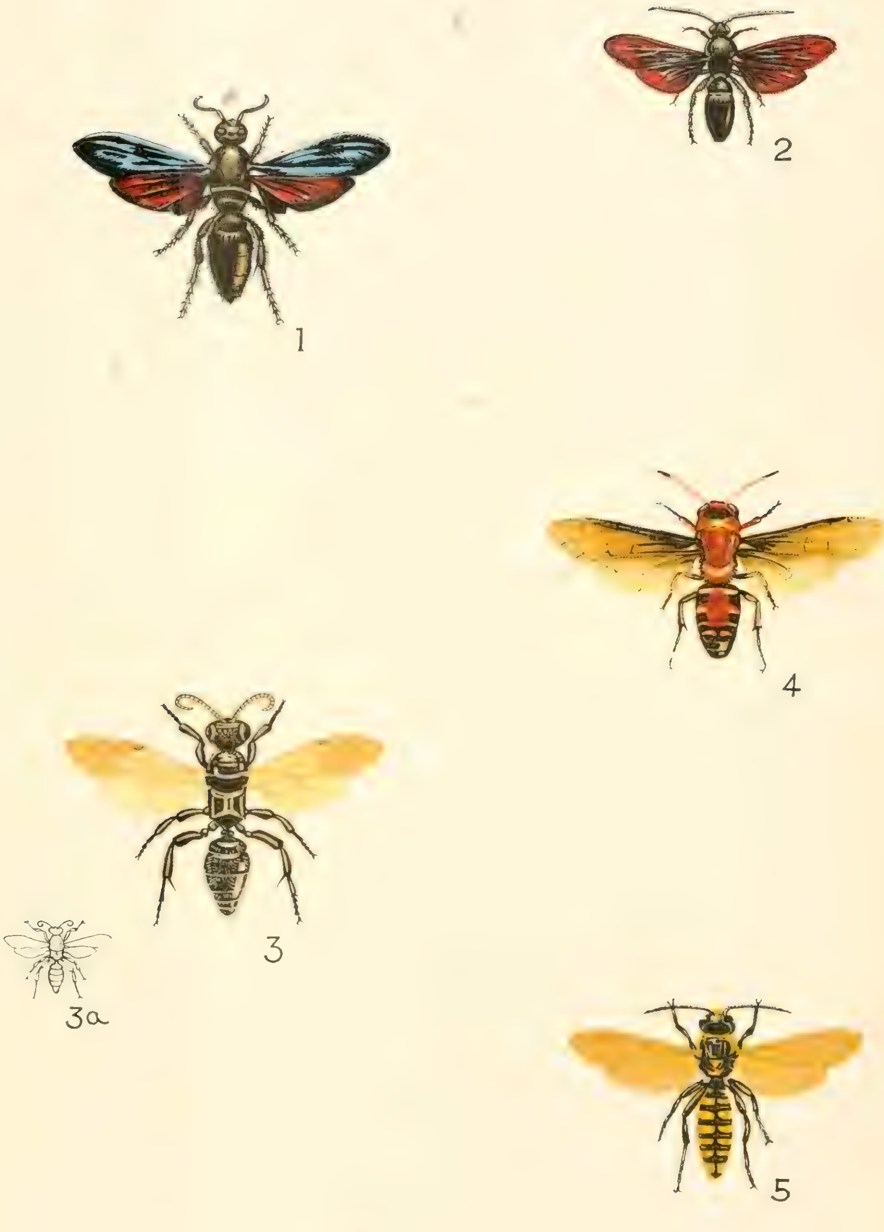
Fig 3. *Tiphia intrudens* var. *brevior* Turner, female. × 3.

Fig. 3a. Outline, showing natural size of above.

Fig. 4. *Thynnus pulchralis* Smith, male. Natural size.

Fig. 5. *Zaspilothynnus vernalis* Turner, male. Natural size.

Plate VI



Del. E. Jarvis.

Plate VII.—Hyperparasites of Scoliid Wasps.

Fig. 1. *Hyperalonia funesta* Walker. × 2.

Fig. 2. A pupa of one of these flies. × 2. (After Davis.)

Fig. 3. A Rhipiphorid beetle. × 3. (After Davis.)

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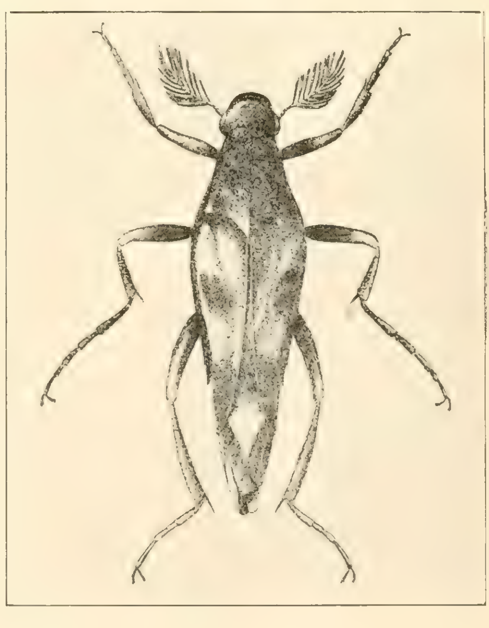

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Plate VIII.—Apparatus Used in Breeding Campsomeris Wasps.

At the left, the small tins with covers, in which the female wasps were kept in soil while parasitizing grubs.

The parasitized grubs are shown in the top tray; resting on this is the wooden mould which was used to form the rows of depressions for the grubs.

At the right, the glass tubes from which the wasps were secured as fast as they emerged.