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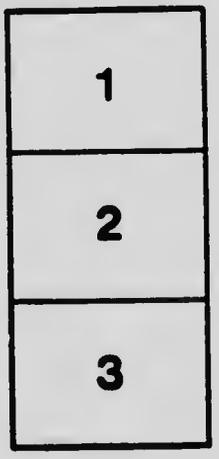

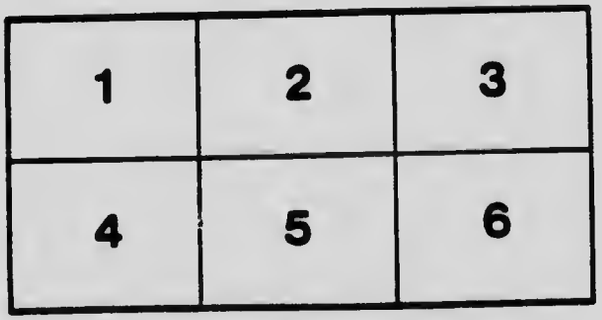

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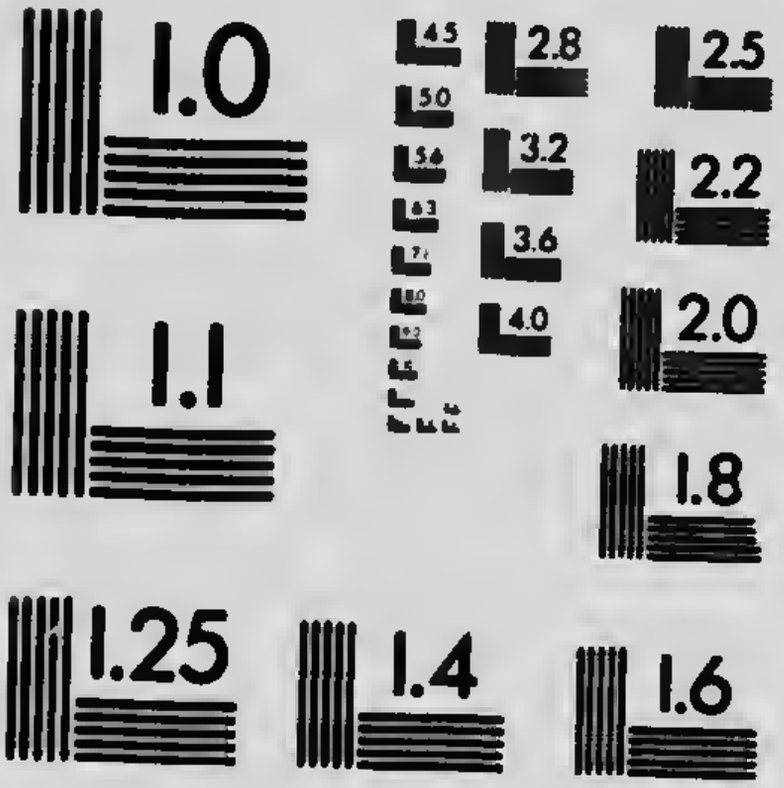

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EXPERIMENTAL FARMS.

DIVISION OF ENTOMOLOGY

THE LARGE LARCH SAWFLY

[*Nematus erichsonii*]

WITH AN ACCOUNT OF ITS PARASITES, OTHER NATURAL ENEMIES AND MEANS OF CONTROL

BY
C. GORDON HEWITT, D.Sc.
Dominion Entomologist

BULLETIN No. 10.—Second Series

Entomological Bulletin No. 5

Bulletins of the Second Series of the Bulletins of the Experimental Farms treat of such subjects as are of interest to a limited class of readers and are mailed only to those to whom the information is likely to be useful

Published by direction of the Hon. MARTIN BURRELL, Minister of Agriculture, Ottawa.

OTTAWA
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1912

Fig. 1

Fig. 2

Fig. 3

Fig. 4

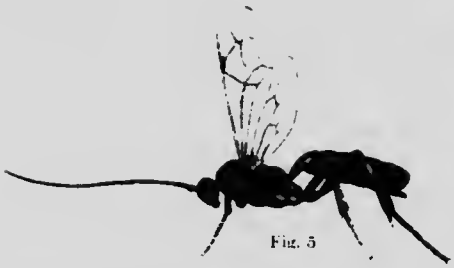

Fig. 5

PLATE 1.—EXPLANATION OF FIGURES.

Fig. 1.—Adult Sawfly, *N. erichsonii*, female. Enlarged 2½ times.
Fig. 2.—Terminal growing shoot of branch of larch. The brown portion has been killed by injuries caused by the "saw" of the female sawfly in depositing the eggs.
Fig. 3.—Full grown larva of *N. erichsonii*. Enlarged 2½ times.
Fig. 4.—Fungal parasite, *Isaria farinosa*; cordyceps stage enlarged about two times.
Fig. 5.—Ichneumon parasite, *Mesoleius tentheclinis* Morley. Enlarged.

C.G.H. del. ad. nat.

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Chief Assistant Entomologist—Arthur Gibson.

Assistant Entomologist for Forest Insects—J. M. Swaine, M.Sc., B.S.A.

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CENTRAL EXPERIMENTAL FARM
OTTAWA, ONT. MAY, 15, 1912.

To the Honourable
THE MINISTER OF AGRICULTURE,
Ottawa, Ont.

SIR,—I have the honour to submit for your approval Bulletin No. 10 of the Second Series (and No. 5 of the Division of Entomology) entitled "The Large Larch Sawfly," prepared by Dr. C. Gordon Hewitt, Dominion Entomologist.

The Large Larch Sawfly has, in the past thirty or forty years worked inestimable injury to our tamarack or larch forests in Canada. The immense areas involved, the rapidity of the spread of the insect and the usual inaccessibility of larch forests in summer, all combine to render the control of this insect pest, by artificial methods, quite impracticable.

For these reasons, investigations, of which this bulletin is a brief report, have been carried on in the control of the insect by natural means, such as mammals, birds and parasitic insects.

This work has been in progress for several years, in a broad field, covering practically all the larch growing areas of Europe and America. The conclusions should therefore be of exceptional value to those interested either from a scientific standpoint or in a practical way in the control of the spread of this insect and in preserving the larch, constituting as it does no inconsiderable part of our forest wealth, from injury.

I have the honour to be, sir,

Your obedient servant,

J. H. GRISDALE,
Director, Dominion Experimental Farms.

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CONTENTS.

	PAGE.
Introduction	7
History and Distribution	9
Description	12
Parthenogenesis	13
Life-history	14
The Depredations of the Insect, their appearance and effects	18
Food plants	20
Natural Enemies	21
Mammals	21
Birds and Bird Encouragement	22
Parasitic Insects	25
Predaceous Insect	35
Parasitic Fungus	36
Preventive Measures	38
Remedial Measures	39
Economic value of the Larch	41

INTRODUCTION.

The Large Larch Sawfly[1] (*Nematus erichsonii* Hartig) is the most serious insect which attacks the larch (*Larix* spp.) which in North America is also called the tamarack or hackmatak,[2] these being the native Indian names for the genus *Larix*. Its original home would appear to be Europe where its attacks were first recorded, and I believe it was introduced into North America. My chief reasons in support of this belief are as follows: wherever it is found, it displays a most decided preference for the European larch (*Larix europaea*). It was not discovered in North America until about 1881, when it was found first in the Harvard Arboretum, into which a large number of trees of various kinds are annually imported from all parts of the world. Its wide distribution, however, would indicate an earlier introduction. Introduced in this manner, without its native parasites, one would expect its history subsequent to introduction and establishment to be what it actually proved to be, rapid and devastating as will be seen in the following account. It has spread through the eastern portion of Canada and the United States and has destroyed from fifty to one hundred per cent. of the native larch or tamarack (*Larix americana*). Had it been a native insect it is probable that its history would have been different and its depredations less destructive. In England, its depredations, though smaller in extent, are economically more serious at the present time than in North America, where the larch, except when cultivated as an ornamental tree, does not yet constitute an important factor as a timber product. Its value as a timber tree in Canada will undoubtedly increase with the exhaustion of the supply of other species of trees, apart from the fact that for certain purposes it is unsurpassable, as will be mentioned later. Further, the American larch, *L. americana*, will grow in swamps and muskeg regions, large areas of which occur in Canada, and which are unsuitable without drainage for any other type of conifer-producing saleable timber.

Before the beginning of this study in 1906, the insect had not received much attention in Europe, brief data only having been given by Saxesen, Tischbein (1840) and Ratzeburg. The only available account of value was that of Packard[3] resulting from his study of the insect in the eastern states of the Union in the years 1882-1884. This account, however, was not very complete and it was very desirable that a more complete study should be made of its life-history habits and means of control both natural and artificial, especially in view of its relation to the English plantations of larch whose preservation is of great importance. The results of my preliminary investigations and recommendations resulting therefrom were incorporated in three reports made to the Waterworks Committee of the Corporation of the city of Manchester in August, 1907, November, 1907, and March, 1908, respectively. These results, together with further studies of the life-history and natural means of control, were published at the request of the Board of Agriculture in 1908,[4] a previous account of Packard's work and the English outbreak having been written by MacDougall.[5] This work was continued in the Department of Economic Zoology of the Manchester University (Eng.) and in the English Lake District and a

[1] This species is called popularly the Large Larch Sawfly to distinguish it from the smaller black species *Lyda* (*Nematus*) *laricis* Hrtg. which attacks the larch in Europe and which I have reared in England.

[2] In Nova Scotia the larch is frequently called the 'Juniper.'

[3] *Packard, A. S.* "Fifth Report of the United States Entomological Commission—Insects injurious to forest and shade trees," 1886-1890. (*N. erichsonii*, pp. 879-890, pls. 9 and 26.)

[4] *Hewitt, C. G.* "The Large Larch Sawfly, *Nematus erichsonii*." *Journ. Board Agriculture. Vol. 15, pp. 649-660, 1 pl. 1908.*

[5] *MacDougall, R. S.* "The Large Larch Sawfly, (*Nematus erichsonii*)." *Journ. Board of Agriculture. Vol. 13, pp. 385-394, 1 pl. 1906.*

further report on the progress of the work was given to the Association of Economic Biologists at Oxford in July 1909.[1] Two months later, I left England for Canada to take up the duties of Dominion Entomologist. Opportunity was now afforded to study the insect under North American conditions, as some workers still doubted the identity of the species. During the past three years, therefore, the insect has been studied in Canada and in the United States. Further, at my request, Mr. A. W. B. Edwards, the Forester of the Manchester Water Works, has sent me supplies of the cocoons from Cumberland (England) which enabled me to continue my studies of the English parasites of the sawfly, and also to study the European form side by side with the American form. The following is an account of the work I have carried on since 1906. It is not complete—no investigation can be so considered—but it appeared advisable at this stage to write as complete an account as possible in order to assist further work, and the further study of the means of control. I wish to acknowledge my indebtedness to Mr. Joseph Mangan of the Manchester University (Eng.) who has continued the work in England, under the direction of Prof. S. J. Hickson, since my departure in 1909, and who has kindly communicated to me his results, which coincide with my own, and which have been published[2] since the greater part of this was written.

[1] Proceedings of the Association of Economic Biologists, *pp. 6-7. Vol. 4 of Journ. Economic Biology.*
[2] *Mangan, J.* "Some remarks on the parasites of the Large Larch Sawfly *Nematus erichsonii*." *Journ. Econ. Biol. Vol. 5, pp. 92-94, 1910.*

HISTORY AND DISTRIBUTION.

In Europe.

Previous to 1840, this insect appears to have been recorded twice in Europe as being injurious to *Larix europaea*. In the Hartz mountains it was recorded by Saxesen and on the plains of Holstein it was found by Tischbein who observed the adults on the wing in the middle of May. Ratzeburg[2] describes it chiefly from Tischbein's account and gives a brief account of its habits, together with an excellent figure. It has been recorded at different times in Sweden, Holland and Denmark and, in 1907, it was reported to me from Switzerland. Prof. Paul Noel, of Rouen, and Prof. Henri, of Nancy, inform me that *N. erichsonii* is not known in France. It has been recorded from Finland in 1902, where it was feeding upon *Larix europaea* and *L. sibirica*. In England, although I was informed of what is a doubtful record of its occurrence about fifty years ago, it was first officially reported to the Board of Agriculture and Fisheries in 1906 from the county of Cumberland. I was told, however, by several observers in the English Lake District that the attack of the insect was noticed five or six years previous to this.

It has been found in several isolated localities in England and Wales and specimens were sent to me in 1908 from Dumfrieshire in Scotland, but the depredations of the insect are most serious in the Lake District, where over 15,000 trees had died by 1909 by repeated defoliation. A detailed account of this infestation has already been given by MacDougall (*l.c.*) and myself (1908). More recently the Board of Agriculture and Fisheries have given an account of the distribution, from which it appears that the area of infestation is spreading, which I also found to be the case during a recent visit to England (Jan., 1912).

In America.

It was first discovered in America by Hagen, who recorded it from Massachusetts in 1881 in the following note published in "*The Canadian Entomologist*," vol. 13, p. 37 (Jan., 1881):—

> "*Nematus Erichsonii* on *Larix europaea*.—A large number of larvæ, very young to nearly full grown, some probably full grown, were sent living with the twigs. The larvæ agree perfectly with the description and figure in Ratzeburg's Forst-Insekten, Tom. III, pl. 3, fig. 4. The species is not represented in the collection here, neither in the larval nor in the imago state. It is not mentioned in Mr. Norton's catalogue of N. Am. *Tenthredinidæ*. I have to remark that the larvæ of the three other species living in Europe on *Larix*, viz., *Lyda laricis*, *Nematus solea* and *compressa*, from their description, do not agree with those sent to me. I am indebted to the Harvard Arboretum and its director, Mr. Chas. S. Sargent, for these specimens."

---

[1] *Ratzeburg, J. T. C.* "Die Forst-Insekten." Vol. 3, pp. 121–122, pl. III, fig. 4.

[2] "The Distribution of the Large Larch Sawfly in Great Britain." *Journ. Board of Agriculture. Vol. 16, pp. 981–991.*

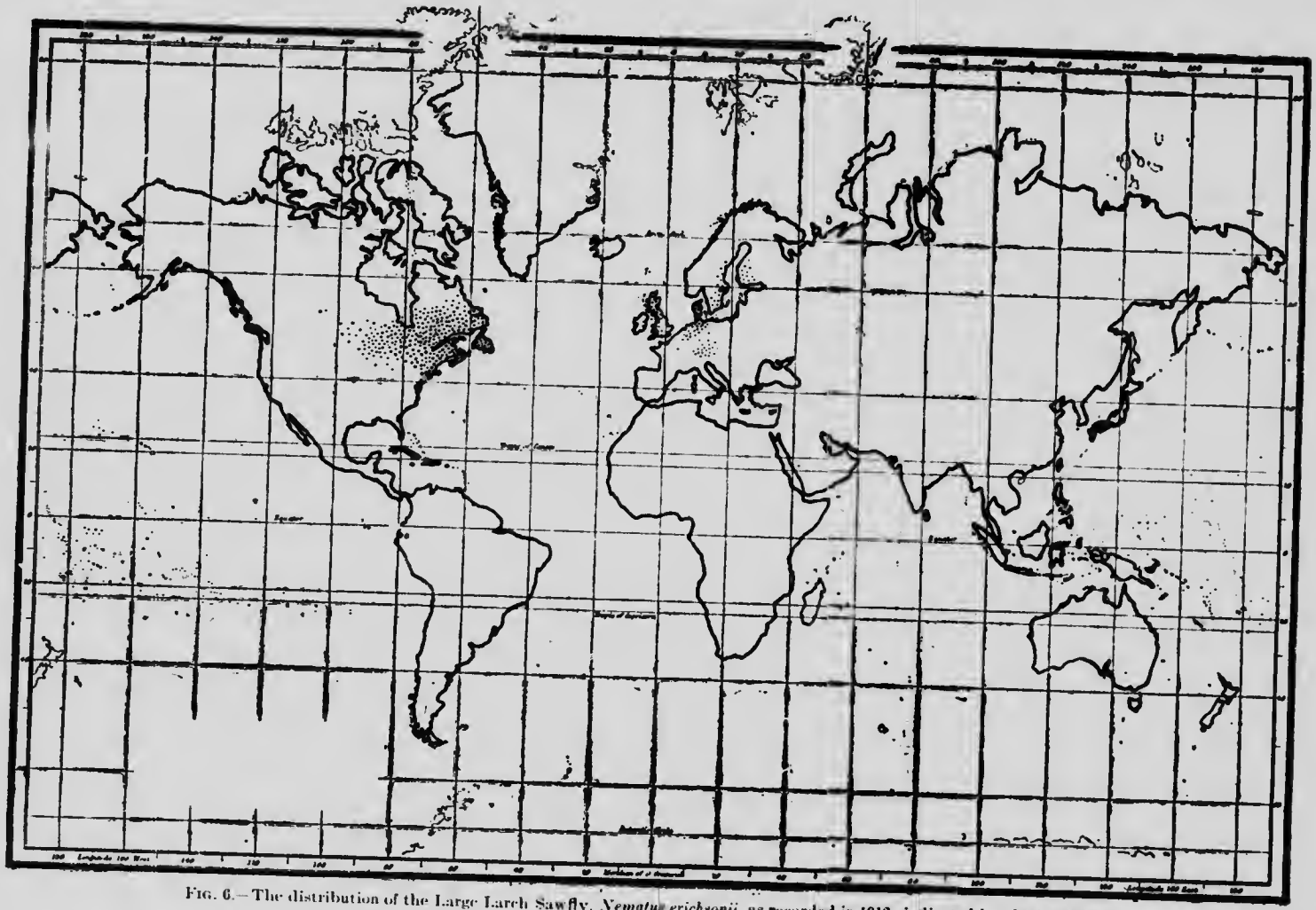

FIG. 6.—The distribution of the Large Larch Sawfly, *Nematus erichsonii*, as recorded in 1912; indicated by shaded areas.

The following note of Hagen's, which I found attached to the original specimens of *Nematus erichsonii* in Hagen's collection now in the Museum of Comparative Zoology, Harvard University, would appear to indicate that it had been observed several years previous to 1881:—

"The larvæ appear of late years on European larch in different parts of Eastern Massachusetts, and threaten to become a serious drawback to the cultivation of this valuable tree. July 6, 188[illegible] Mr. C. S. Sargent. The determination is *mine*.—H.A.H."

Packard (*t.c.*) gives an account of its distribution in the United States up to the time of writing (1890). In 1881 it had been reported in Maine, and it was observed at Brunswick in Maine in 1882. In these years, very great destruction of larch was caused by the insect. It was found in New Hampshire in 1882. Lintner[1] first observed it in the State of New York in 1883, the infestation covering many square miles of swamps. It has been found in Pennsylvania, where, in 1892 (*"Insect Life," vol. IV, p. 219*), it was recorded as injuring hemlock. Extending westward, it has invaded Minnesota, and Ruggles[2] (1910) states that it has become a very serious pest on the tamarack in northern Minnesota. Its western limit in the United States would appear to correspond fairly closely with that in Canada. Hopkins[3] recently stated that "during several extensive outbreaks since 1880 (it) has killed from fifty to one hundred per cent. of the mature larch over vast areas in the north-eastern United States and south-eastern Canada. It is evident that the amount of merchantable-sized timber that has died as a result of defoliation by this insect will aggregate many billions of feet."

In 1883, Fyles reported its appearance in eastern Canada on *Larix americana* (*Can. Entom. vol. 15, page 205, 1883*) and two years later Fletcher[4] gave an account of its occurrence with some observations on the habits of the larvæ. It was found throughout the province of Ontario, Quebec, New Brunswick, and Nova Scotia. J. J. Jack[5] in reporting the depredations of the sawfly in Quebec in 1885, states: "I had noticed these larvæ on the larch trees in former years, but they were not so generally abundant and I had not the opportunity to study them. My father has told me that about thirty years ago the tamarack woods were entirely defoliated and looked as though scorched by fire, and he thinks that the sawfly larvæ were probably the cause. It was more noticeable at that time as there were large tracts of land covered with tamarack forest that have now entirely disappeared."

In 1906, when the extent of the infestation in Canada and the results of the insect's depredations again assumed a serious magnitude, Fletcher[6] gave an historical account of its occurrence in Canada subsequent to the year 1882, which appeared to have been the year of its arrival in Canada from the United States. During the next three years it effected enormous injuries to the American larch or tamarack. He states: "After three or four years of being stripped, the larches over millions of acres and practically over the whole of eastern Canada, were almost wiped out. With this large destruction of its food plants, the insect practically disappeared and little has been heard of it until last year (1905) when it again became noticeable upon ornamental European larches and, in a few places, was observed on the young growth of larches in swamps."

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[1]*Lintner, J. A.* "Fifth Report on the Injurious and other Insects of the State of New York," 1889, pp. 164–173.

[2]*Ruggles, A. G.* "The Larch Sawfly (*Lygaronematus erichsonii* Hartig) in Minnesota." *Canadian Entomologist. Vol. 42, pp. 93–94, 1910.*

[3]*Hopkins, A. D.* "Some Insects injurious to Forests.—Insect depredations in North American Forests and practical methods of prevention and control." *Bull. No. 58. Part V, pp. 57–101. Bur. Entom. U.S. Dept. Agr. 1909.*

[4]*Fletcher, J.* "The Larch Sawfly, *N. erichsonii*." *Fifteenth Annual Report of the Ent. Soc. of Ontario, pp. 72–77, 1885.*

[5]*Fletcher, J* (1906). "Report of the Entomologist and Botanist" in the *Report of the Exp. Farms o Canada for 1905, pp. 190–191.*

[6]*Seventeenth Ann. Rep. Entomological Soc. of Ontario, 1887, p. 17.*

Fig. 6.—The distribution of the Large Larch Sawfly, *Nematus erichsonii*, as recorded in 1912; indicated by shaded areas.

Further, he states: "A feature of the last outbreak of 1882–1885 was the rapidity with which the attack spread and the suddenness[1] with which it disappeared. Occasional specimens of the sawfly or of the colonies of the larvæ have been seen from time to time since 1885, but there has been no noticeable destruction until the present year. The territory over which this insect is known to have spread in the old outbreak is all through Ontario, Quebec and the Maritime provinces right up to Labrador." That is, the infested area appeared to coincide with the distribution of the *Larix*. It was not thought that the last outbreak had reached west of Lake Superior but, in 1909 and 1910, I found that most of the larches along the Canadian Pacific Railway almost as far as Winnipeg had been stripped by the larvæ, although I did not observe it in the prairie provinces nor in British Columbia. It has also been reported to me by surveyors and engineers from James Bay across to Labrador. In July, 1911, Mr. N. Criddle reported the defoliation of tamaracks about 120 miles west of Winnipeg, and in 1910 it was reported by the Forestry Branch from Battleford, Saskatchewan. The occurrence and depredations of this insect in the Riding Mountain Forest Reserve in Manitoba, were reported to me in 1911 by Mr. T. R. Dickson of the Forestry Branch of the Department of the Interior. These observations indicate that it is gradually spreading westward; in eastern Canada it is perhaps safe to say that its distribution corresponds with that of *Larix americana*.

DESCRIPTION OF *NEMATUS ERICHSONII*, HARTIG.

(Plate I, Fig. 1.)

This species was originally described by Hartig[2] in 1837 under the name of *Nematus erichsonii*. Marlatt, however, in his account[3] of the Nematinæ of North America has included it in the genus *Lygæonematus* of Konow[4], although the characters differentiating this genus from *Pachynematus* do not appear to be very great. It has also been included in the genus *Holocneme*.

Marlatt has also included Cresson's *Nematus notabilis*, described from Massachusetts in 1890, in this species. His description of the male was made from a single Canadian specimen. As I am able to confirm his description from an examination of about twenty males which I have reared in England and Canada in 1908, 1909 and 1910, I shall give his description of the species, with a few modifications, more especially in the description of the male. (Specimens in coll. Div. Entom., Ottawa).

Female.

The females vary a little in size but the average length is 11 mm. and the expanse of the wings is 20–22 mm; they are moderately robust in size. The head and thorax are finely punctured, entire body shining; clypeus scarcely emarginate, almost truncate; frontal and lateral ridges of ocellar basin rounded, indistinct; vertex nearly smooth; antennal fovea long, shallow, deepest at apex; antennæ about as long as head and thorax, rather robust, tapering, joints 3 and 4 subequal; sheath broad, rounded, truncate tip; cerci flattened and tapering; intercostal vein hyaline, indistinct, but anterior to basal and nearly at right angles to costa; first transverse cubital indistinct or wanting, stigma moder-

[1]This sudden disappearance does not appear to have been due, as is sometimes the case, to the effect of natural means of control but to the exhaustion of the food supply owing to the death of the trees resulting from repeated defoliation.

[2]Original description in "Die Familien der Blattwespen und Holzwespen nebst einer allgemeinen Einleitung zur Naturgeschichte der Hymenopteren" Berlin, 1860, pp. 187–188.

[3]Marlatt, C. L. "Revision of the Nematinae of North Ameriea." *U.S. Dept. Agr. Div. Entomology, Bull. No. 8, Tech .Ser., 1896.*

[4]Deutsche Entom. Zeit. vol. 35, p. 247, 1890.

ately broad, not acuminate; claw with minute inner tooth near apex. Colour black, tip of clypeus, basal two-thirds of tibiæ, apices of trochanters and extreme angles of pronotum yellowish-white; femora, tips of anterior tibiæ and their tarsi, dorsal and ventral sides four basal abdominal segments, except in the proximal portion of the first segment, orange-rufous; extreme tips of middle femora above, hind femora more broadly, distal half of hind tibæ and the hind tarsi black; wing veins black except the costa which is fulvous and the anal vein which is whitish; wings slightly infuscated; dusky spot in the second cubital cell is large and prominent. The posterior end of the abdomen as seen from the sides is shown in Fig. 7, B. The saw-like ovipositor is seen projecting slightly and one of the saws is shown in Fig. 8.

Male.

The male is smaller and slightly more slender than the female, its average length being 9 mm. with a wing expanse of 15 mm. The abdomen is not wider than the thorax and is of a uniform width; procidentia keeled, somewhat constricted basally, short and not projecting beyond the seventh dorsal segment; terminal ventral segment very slightly emarginate at the truncate apex. The terminal ventral segment of the male is shown in Fig. 7, A. Colour, black; antennæ, four basal segments of the abdomen dorsally, except a portion of the median region of the first segment, the lateral regions of the fifth and sixth segments, the whole of the ventral side of the abdomen and the coxæ except the bases of the coxæ, reddish-yellow; the tips of the tibiæ and tarsi of the third pair of legs dark brown; portion of the face below the antennæ, portion of lower orbits, pronotum and tegulæ, creamy white; wings as in the female.

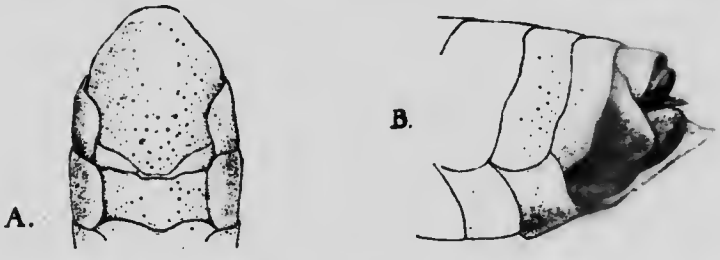

FIG. 7—A. Ventral view of posterior end of abdomen of male, *N. erichsonii*.
B. Lateral view of posterior end of abdomen of female *N. erichsonii*, showing the ovipositor slightly protuding.

PARTHENOGENESIS.

Nematus erichsonii is almost a wholly parthenogenetic species, that is, the females lay eggs almost entirely without fertilisation by the male. The proportion of males to females is generally less than four per cent., and in the three years 1908–1910 when the numerical proportions of males and females emerging were observed, it was found that a total of 6,181 cocoons yielded 6,158 females and 23 males. Mangan (*t.c.* 1910) states "the parthenogenetic origin of the vast majority of the sawfly larvæ was again evident as hardly more than two per cent. of the samples which emerged were males." In no case during my investigations was a female seen in coitu with a male and all the larvæ which have been reared have hatched from eggs deposited by unfertilised females; fertilisation was easily prevented by so great a scarcity of males, in fact it would be difficult to obtain fertilised eggs. This fact, the occurrence of a normal parthenogenetic habit, has no little influence on the abundance of the insect as the female begins

to deposit her eggs very shortly after emerging and there is no dependence upon the presence of the male. Parthenogenesis was proved in the first instance by isolating the females immediately they had emerged from the cocoons. MacDougall* has recently confirmed experimentally the parthenogenetic reproduction of *N. erichsonii*.

B. A.

FIG. 8—A. One of the blades of saw-like ovipositor of female *N. erichsonii*.
B. End of blade more highly magnified.

LIFE-HISTORY.

The life-history of *Nematus erichsonii* in England was first studied completely in England in 1908 and again in 1909. During 1910 and 1911, I continued the observations on European cocoons imported from England and also studied the life-history of the Canadian form collected on the grounds of the Central Experimental Farm, Ottawa. The following account is based, therefore, on four years' observations of the European form and two years' observations of the American form made for purposes of comparison and confirmation of the previous records of Packard, which were the only records existing of a complete nature. In certain details, Packard's observations were incorrect; this was due no doubt to the fact that he did not work with much material nor does he appear to have repeated his experiments. My own observations have been confirmed by Mr. J. Mangan, of the Manchester University (Eng.) who assisted me in 1909 and subsequently continued the work in England.

In England, the first saw-flies emerged on April 27, 1908, April 26 in 1909, and in Canada, from imported cocoons, on April 22, 1910. The maximum number of sawflies emerged during the first week in June, and it is during that time that the sawflies have been seen on the wing. In Canada, eggs were found upon the terminal shoots of European larch on May 28, and the larvæ emerged the same day. In Europe, Tischbein records the females as occurring about the middle of May. Packard states that the eggs are laid about the middle of June in Massachusetts to the early part of July in northern Maine. These eggs would appear to have been deposited by late-hatched females in view of my own observations at Ottawa, in a more northerly latitude. The female sawflies are seen on the wing in England until the end of July, the emergence being spread over a period of two months. On this account, one frequently finds full-grown larvæ on trees upon which recently-hatched larvæ are also seen and some observers have mistakenly inferred a second brood; in no case, however, either in the laboratory or outside, has an adult emerged from a cocoon formed in the same year and the species is without doubt single-brooded.

On emerging from the cocoons, the female sawflies soon take to the wing and begin to lay their eggs. Larch shoots offered to recently-emerged females are immediately attacked and this may account for the fact that, in the majority of cases, the lower branches of the trees are the first to be attacked.

* 'Nature'. *Vol. 89, pp. 52-53. (Mar. 14, 1912.)*

Ovip -ition.

The female invariably chooses the young terminal s..oots upon which to deposit her eggs; in no case have eggs been found upon the lateral verticils of leaves. The insect usually stands with the head directed towards the twig and grasping the young leaves she bends the terminal portion of the abdomen downwards until it is almost at right angles to the shoot. The saws are now extended and an incision made into the tender stem of the green shoot. Mr. Mangan, who, in 1909, made careful observations at the time of ovipositior, found that it usually took from three to six minutes to make the incision a:.. deposit the egg in the slit thus made. Three and a half hours would be spent in ovipositing on a single shoot.

Each female deposits from forty to fifty eggs; this has been confirmed by dissecting out the mature eggs from the ovaries. This number may be deposited on a single shoot; in some shoots as many as seventy eggs have been found, but the usual number of eggs deposited on a single shoot appears to be about thirty. In the majority of cases, the slits are made only along one side of the young shoot and the eggs are placed alternately. In some cases, the eggs may be three or four abreast and owing to the subsequent growth of the shoot their positions may be changed and the shoot curls over as will be described in the next section.

.GG.

The eggs are vitreous .n appearance and cylindrically oval in shape; the shape, however, .. vary slightly owing to the thin chorion being subjected to unequal pressure. The average length of the egg is 1.5 mm In a few days the larvæ may be seen within the eggs and in all cases

Fig. 9—Portion of terminal shoot of larch in which eggs of *N. crichsonii* have been inserted by the female.

their heads appear to be directed towards the tip of the shoot. As the whole of the egg is inserted within the slit made by the saw-like ovipositor of the female it is important that the cephalic end of the egg should be the end exposed as this is essential for the successful emergence of the larva. The larvæ observed hatched in eight to ten days after the eggs were deposited. In

England the larvæ hatched on June 10; in Canada (Ottawa) they hatched on May 27. It is interesting to note that larvæ collected in the grounds of the Central Experimental Farm in 1910 and 1911 from the same European larch tree underwent the first ecdysis on the same date—May 31. A few minutes only are occupied in the process of hatching and the empty chorion is left in the slit, the larva levering its body out.

Larva.

Previous to this study of the life-history of *N. erichsonii*, Packard was the only observer who had recorded the details concerning the larval history. In one respect, the observations which were made in England did not agree with Packard's, as I found that the larvæ moulted five times, that is, there were six larval stages. Packard states "there appear to be but three moults or changes of the skin, *i.e.*, four stages of the larvæ." I stated in my preliminary account that "this difference in our results may be due to the fact that the observations were made in different countries." I am now inclined to believe that this suggestion is correct as a result of the study of the life-history of the species in Canada. On the 30th May (1910) larvæ in the first stadium were collected at Ottawa, the eggs having hatched probably on the 27th as the first ecdysis took place on May 31st, and in breeding experiments in 1911, larvæ which emerged from the eggs on May 27th underwent the first ecdysis on May 31st. The life-history of this series was as follows:—

Larvæ hatched	May 27 (probably).
1st ecdysis	May 31.
2nd "	June 4.
3rd "	June 8.
4th "	June 13.
Larvæ began to spin cocoons	June 17.

In the experiments of 1911, larvæ hatched on May 25, began to spin cocoons on June 12th, thus occupying sixteen days in their development from the time of hatching to the time of spinning their cocoons as compared with twenty-one days in 1910. The experiments in 1911 also gave four ecdyses before spinning the cocoons. The development in England (Manchester) was found to be longer, as the following results given in my preliminary paper indicate:—

Eggs deposited	May 31 to June 2.
Larvæ hatched	June 10.
1st ecdysis	June 13 to 14.
2nd "	June 18.
3rd "	June 21.
4th "	June 24.
5th "	June 28.
Larvæ began to spin cocoons	July 2.

There is an additional ecdysis in April or May of the following year when the insect which has passed the winter in the larval stage transforms into the pupal stage.

It would appear therefore, that there are four or five ecdyses during the adult feeding life of *L. erichsonii*, and a further ecdysis in the cocoon. It is possible that Packard missed one of the stages, as the above experiments were confirmed by a study of a series of the cast heads. Packard also states that "the larvæ appear to attain their full size in about four to seven days after hatching," and this statement has always been copied in the subsequent accounts. It is not supported by any of my experiments in England or North America, as a glance at the foregoing examples will indicate.

PLATE III.

FIG. 24—Hessian food-house, one of a number erected on the Manchester Corporation Waterworks' Estate, Thirlmere, Cumberland, England, for the winter feeding of birds.

FIG. 25—Nesting box for birds as used at Thirlmere, England.

FIG. 22—Fungal parasite, *Isaria farinosa; Isaria* stage, on cocoons of *N. erichson*

FIG. 23—Cocoons of *N. erichsonii* showing the teeth marks of the vole *Microtus agrestis* which has extracted and eaten the larvæ.

The newly-hatched larvæ are greenish-white and measure 2 mm. in length. The head is abnormally large and at first similar in colour to the body with brownish-black eyes and brown jaws. By the end of twenty-four hours, the head has become sepia-brown in colour and the body assumes a greenish appearance owing to the presence of food in the intestine. A few hours after hatching the larvæ begin to adopt the peculiar and characteristic, presumably defensive, attitude, turning the posterior half of the body over the back so that the anal extremity is directed forwards and upwards. They creep down the shoot to the adjacent verticils of leaves where, about six hours after hatching, they begin to feed, in consequence of which their intestines become green in colour. The newly-hatched larvæ were never found feeding upon the leaves of the terminal shoots but always on the leaves inferior to these. When first they begin to feed, they do not completely eat the leaves, but nibble out portions along each side of a leaf which has, in consequence, a serrate appearance and subsequently withers. In later life they completely eat the leaves, beginning at the distal end and gradually eating the leaf away to the base. All the leaves of a verticil are removed in the same way, leaving only the brown base. Although the characteristic use of the terminal end of the body for clinging to the leaves is not so pronounced in this stage as in the later ones, the habit may sometimes be noticed in this stage when the larvæ are on slender leaves.

After the first ecdysis the head is jet black and the legs are also black, the dorsal surface of the larva is still green and the ventral surface a pale green. When the larva has undergone the second ecdysis the dorsal surface assumes the normal bluish-grey or glaucous appearance, the underside of the body being a pale or pea-green.

The full-grown larva (Plate I, Fig. 3,) measures about 16–18 mm. in length. The head is jet black and the three pairs of thoracic appendages are also black. There are seven pairs of abdominal appendages. The dorsal surface is glaucous or greyish-green in colour except immediately behind the head, which, like the ventral surface, is pale or sea-green. The demarcation between the two

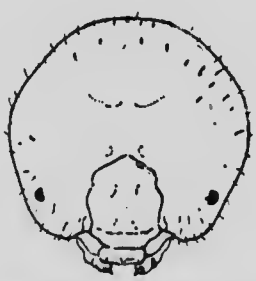

FIG. 10—Head of mature larva of *N. erichsonii*.

colours is very distinct laterally. The dorsal surface is also covered with very minute and separated tubercles. Scattered over the body are a number of short brownish spines. The skin of the larva is thrown into slight folds, on many of which a row of wart-like tubercles can be distinguished. The mandibles are four-toothed and the maxillæ four-jointed.

In the New England States, the larvæ usually become full-grown about the end of July or beginning of August. Packard states that a few still occur on trees in Massachusetts as late as the last week in August or early in September. The first cocoons not under experimental conditions were found in England at the end of July. I found larvæ, in England, at the end of August, and in

Canada during the latter part of August. As the breeding experiments have shown, in England they may become full grown as early as the first week in July and in Canada by the middle of June. This disparity between the first and last dates for the larvæ corresponds to the length of time over which the time of emergence for the adults is spread.

When they are full grown, they descend from the branches of the tree to the ground where they spin brown, fibrous cocoons beneath the turf or moss round the base of the trunk or under stones.

The habits of the larvæ are of interest. Mention has already been made of the habit which they have of turning up the hind portion of the body over the back, making the larva somewhat S-shaped. This action no doubt corresponds to the "terrifying attitude" adopted by larvæ of the other orders, particularly the lepidopterous family *Notodontidae*. When the larvæ are in the third and fourth larval stages, they congregate in masses, as many as sixty larvæ having been counted in a single mass. These are usually the larvæ which have emerged from the eggs deposited in the same terminal shoot. This habit is of importance in the eradication of the larvæ as will be shown later. In discussing the remedial measures Packard states: "Jarring the trees will prove a good remedy, the worms once shaken off the tree cannot ascend the trunk as they do not, like cankerworms, climb trees." This is incorrect. When the larvæ are dislodged from the branches either by the wind or rain, they re-ascend the trunk and ultimately regain the branches and twigs. The prevention of this is discussed later.

Cocoon.

The cocoon measures 10 mm. in length and 5 mm. broad. It is dark brown in colour and fibrous in character, having a fairly firm texture. In the cocoon the larva contracts and passes the winter in the larval state, unchanged in colour, changing to the pupa in the following April or May, usually two or three weeks before the emergence of the adult.

THE DEPREDATIONS OF THE INSECT, THEIR APPEARANCE AND EFFECTS.

The sawfly larva belongs to that large class of leaf-destroying insects which are economically important by reason of their defoliating forest trees in an extensive manner. While, however, the main damage is inflicted by the larvæ, this species is unique, as this study has shown, owing to the fact that the adult insects themselves inflict injuries of a serious nature. The effects of the attacks, therefore, must be considered separately as caused by the adults and larvæ respectively.

The Injurious Effect of the Adult Sawfly.

In depositing the eggs, the sawfly invariably chooses the young, green, terminal twig in which to insert the eggs, as I have already indicated in describing the oviposition. The result of the injuries inflicted during this process is that the terminal twig either dies or is permanently injured and distorted. (See Plate 1, Fig. 2.) Where a large number of eggs have been deposited all round the length of the young terminal shoot, it usually turns brown and dies and the presence of these curled-up, brown, dead terminal shoots often serves to indicate the presence of the larvæ on the tree. When the terminal shoot is killed in this manner the growth is arrested and the form of the tree may be affected. In many cases the eggs are deposited along one side only

of the young terminal shoot, with the result that the growth on that side is seriously interfered with and retarded, causing the shoot to curl in the direction of the injured side. The extent of the curvature varies, but not infrequently it will curve through a complete circle and continue growing in the original direction.

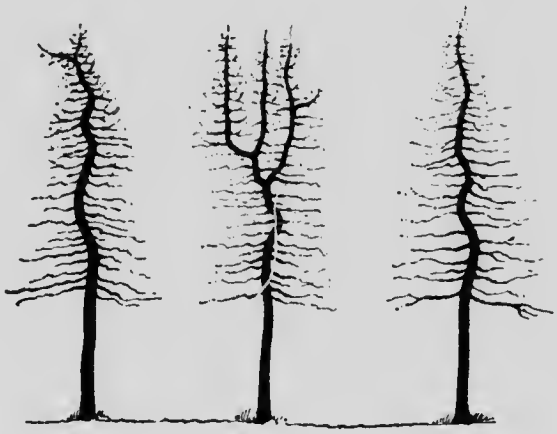

FIG. 11—Winter aspect of larches deformed by early injuries inflicted by adult females of *N. erichsonii*.

When the apical terminal shoot is affected in either of the above ways, the result is serious to the growth of the tree. If the shoot is killed, its place is usually taken by a lateral shoot which will affect the straight character of the subsequent timber. Where the shoot is not killed, but is bent or curled, a permanent kink, as shown in the illustration (Fig. 11), may be caused. In those parts of Canada in which the sawfly was abundant and destructive in the years 1882-6, the effect of the injury of the sawflies to the apical terminal shoots of the young trees constituting the second growth at that time on the growth of the trees is very plainly shown by the crooked character of the trunks of young trees which have now grown up and are upwards of thirty years old. The effect of this type of injury upon the young trees whether the growth is natural or planted is a serious one as affecting the ultimate value of the trees as timber. Further, it is an injury which cannot be prevented if the adult sawflies are present.

THE DEPREDATIONS OF THE LARVÆ.

Immediately the larvæ emerge from the eggs they begin to feed. At first they feed along the sides of the needle-like leaves giving them a serrate character and causing them to curl and wither. As they grow they begin to eat the whole of the leaf, beginning at the apex and gnawing it completely to the base. In this manner they destroy all the leaves on a single verticil and all the verticils of leaves on a branch, with the result that the tree, entirely stripped of its green leaves, has the normal winter appearance in the middle of summer. The defoliation of the tree usually begins on the lower branches. This is no doubt due to the fact that the females, on emerging, deposit their eggs chiefly on the terminal shoots of the lower branches of the trees and when the larvæ emerge they defoliate these branches, subsequently working their way upwards and stripping the whole of the tree

When the trees have been completely defoliated for three successive years or more, they usually die. The death of the tree is sometimes caused by its efforts to overcome the effects of defoliation. Trees which are defoliated in the summer will sometimes produce a second crop of leaves late in the year from what would have been the next year's buds. Not only is this a severe tax on the resources of the tree but these leaves are usually killed by frost. Forest trees and those closely planted are more liable to succumb to the effects of repeated defoliation than more sparsely planted or isolated trees. This is due to the fact that the former are usually provided with a crown of green leaves only, and this is the sole means of obtaining organic food. The loss of this source of supply is more serious to the tree than the loss of the foliage is to an isolated tree whose branches during the summer are green to the base and able to store more reserve food during the short time the leaves are present.

The depredations of the larvæ are usually first noticeable in July, the stripping of the leaves producing a brown appearance. In the case of a serious attack the trees will be completely stripped by August, and the bare twigs and branches give the forest the appearance which it has when the trees are devoid of their leaves in the depth of winter, the larch being a deciduous tree. As the larch produces its leaves early in the season it naturally might be concluded that, by the time the leaves were removed by the sawfly larvæ, the trees would have stored sufficient reserve food material to minimize the prejudicial effects of unnatural defoliation before the proper time. Experience teaches us, however, that this is not the case and that closely growing larches succumb to the effects of repeated defoliation after two or three years.

SUBSEQUENT INSECT ATTACKS.

When the tree has its vitality reduced by repeated defoliation by the sawfly larvæ, even though it may not succumb to the depredations of the sawfly, it is more liable to be attacked by a number of species of bark beetles belonging to the group of Scolytidæ or Ipidæ, the most destructive and deadly of all forest insects. Certain of the more common bark beetles attacking the larch in eastern Canada have been described by Mr. J. M. Swaine[1] of this Division. The eastern larch beetle, *Dendroctonus simplex* Lec., is common in eastern Canada and occurs in the north-eastern states of the Union. It will attack living trees when they have been weakened or injured, destroying even the largest timber. *Ips balsameus* Lec. may also attack larch. Other species found attacking the dying bark were *Dryocœtes autographus* Ratz, *Dryocœtes n. sp.* and *Ips callatus* Eich. All these species may attack larch trees weakened by the defoliation of the sawfly and complete the destruction should it not have been already accomplished.

FOOD PLANTS OF *N. ERICHSONII.*

So far as I have been able to observe, both under natural conditions and by experiment, *Nematus erichsonii* feeds only upon species of Larch (*Larix*). In forests and plantations where other conifers occurred with larch, although the larches would be completely defoliated the larvæ did not appear to touch the other conifers such as species of *Picea, Abies* or *Pinus* and I was not able to induce them to feed on these species in the experiments. Reference has already been made, however, to its occurrence on hemlock in Pennsylvania, in 1892.

[1] "Some Insects of the Larch." *Forty-first Ann. Report Ent. Soc. Ontario, pp. 81–88, 1911.*

Among the species of *Larix*, as I have already stated, the larvæ, showed a most decided preference for the European larch, *L. europaea*, (*L. decidua* Mill.) under natural conditions. Nevertheless, as the history of the insect in North America shows, they defoliate and kill the American larch, *L. americana* Michx. (*L. laricina* (du Roi) Koch). I have also found them feeding upon and defoliating the Japanese larch, *L. leptolepis* End!., which some foresters have believed to be immune, and also upon the Siberian larch *L. sibirica* Ledeb. The last species has been found attacked by the sawfly in Finland.

NATURAL ENEMIES.

When an insect, such as the larch sawfly occurs over a large area the natural enemies are the only factors which are able to control it. This being the case, the study of these natural enemies and of the means by which they may be effectively increased and assisted in their work constitutes the most important section of the investigation. The natural factors in the control of *L. erichsonii* have been studied since the beginning of this work and although this section cannot be considered to be complete, it describes so far as it has been possible to discover, the chief natural enemies. These consist of mammals, birds, parasitic and predaceous insects and fungal parasites and they will be considered in this order together with the means that may be or have been adopted to make use of them.

Mammals.

The two small mammalian enemies of the sawfly are of interest as they attack the sawfly in a stage, namely the cocoon stage, in which the insect is safe from most of its enemies.

The Field Vole or Meadow Mouse, *Microtus* (*Arvicola*) *agrestis*.

In November 1907, it was found that large numbers of the larvæ were being extracted from the cocoons of the sawfly in the Thirlmere region of the English Lake

Fig. 12—Field vole or meadow mouse, *Microtus agrestis*, extracting larvae of *N. erichsonii* from cocoons

District. At the base of a single tree hundreds of empty cocoons could be found at the entrance of and along the burrows of the rodents. The marks of the teeth at the edges of the open ends of the cocoons first drew my attention to the fact,

(Plate 2 Fig. 23). Later, this species was caught in traps baited with hibernating larvæ which had been extracted from the cocoons and on microscopic examination of the stomach contents of the rodents it was found that the larvæ constituted practically the entire diet of the voles or meadow mice at that time of the year. In all the larch woods which were visited, large numbers of the empty cocoons were found and the voles were most active in burrowing underneath the turf around the bases of the trees in search of the cocoons. It was estimated that the larvæ had been extracted from about 25 per cent of the cocoons collected in different localities in 1907–8. In the following year their work appeared to be still more effectual and about 50 per cent. of the cocoons examined had been attacked by voles.

The insect-eating habit of the vole is not a little remarkable as they are normally phytophagous and constitute one of the forester's chief pests. This change of habit which the presence of an abundance of food induced, which also happened in the case of the birds, altered for the time the economic standing of the vole and, as they were obviously acting as important agents in the control of the sawfly, their destruction was not advised unless they should increase to dangerous proportions.

The White-footed or Deer Mouse, *Peromyscus maniculatus artemesiæ.*

Dr. A. K. Fisher of the United States Biological Survey informs me that this mouse was found in the State of Michigan feeding upon the larvæ in the cocoons of *N. erichsonii*, which it stored up. It is of very great interest to find in North America another example, such as *M. agrestis* furnished, of a phytophagous mammal becoming, for a time insectivorous. The white-footed mouse feeds mainly on seeds and grain. Among cocoons received from southern Manitoba, I have found cocoons from which the larvæ had been extracted by a small species of rodent, possibly *P. m. artemesiæ.*

Birds.

It was found by careful and continued observations in the English Lake District that the following species of birds were feeding upon the larvæ:

Blue Tit, (*Parus cæruleus*).
Coal Tit, (*Parus ater*).
Great Tit, (*Parus major*).

These three species of insectivorous birds were feeding largely on the larvæ when the latter were in their earlier stages. Chaffinches, (*Fringilla cælebs*) which are chiefly graminivorous, were observed feeding on the full grown larvæ.

Starlings (*Sturnus vulgaris*), Jackdaws (*Corvus monedula*) and Rooks or Crows (*Corvus frugilegus*) gathered in considerable numbers on the infested trees and fed upon larvæ. The Rooks (Crows) not only took the larvæ off the trees but were found to feed especially upon the full grown larvæ when they were on the ground and crawling under the turf to pupate. In many instances, the turf round the bases of the trees was riddled with holes made by the beaks of the birds searching for the larvæ.

Annand[1] observed rooks, starlings, tits and jackdaws feeding upon the larvæ. He records the fact that the jay was most useful in searching for the cocoons and extracting the larvæ.

It was not a little surprising that these birds consumed the larvæ in large quantities as the larvæ of *N. erichsonii* appear to have a resinous flavour which ordinarily might be considered distasteful to a bird.

[1] *Annand, J. F.* "Observations on the Large Larch Sawfly (*Nematus erichsonii*, Hart) with suggestions for remedial and preventive treatment in infested larch woods." *Quart. Journ. Forestry Vol. IV, pp. 203–221, 3 figs. and pl.*

On account of the valuable work which the birds were doing in destroying the larvæ, measures were taken on the Thirlmere estate of the Manchester Corporation Waterworks Committee to protect and encourage them. In the larch woods in that region there were few facilities afforded for the building of nests and there was a great scarcity of birds in the infested region. Accordingly, nesting boxes were provided. These were made in two sizes, a smaller size for small insectivorous birds such as tits, etc., and the large size for starlings, etc. Some of the nesting boxes were bored out of solid portions of the trunks of larch and birch after the pattern of the well-known Berlepsch boxes. An equally suitable and much more easily made box was devised (see Fig. 13). This was made of larch slabs or the rejected outer portions of the timber bearing the bark.

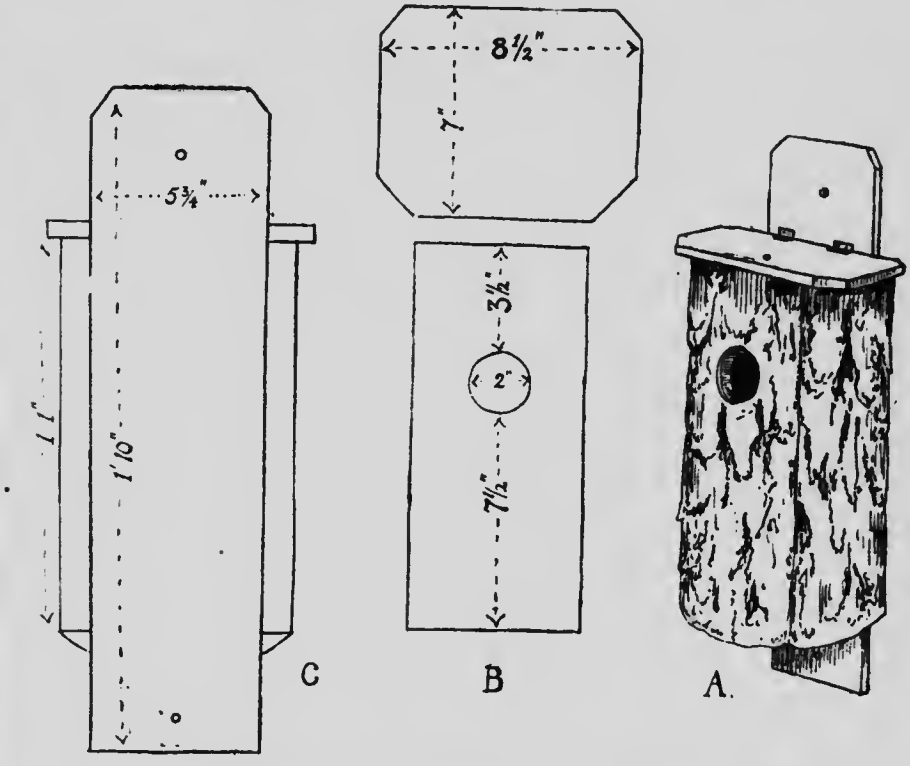

FIG. 13—Structural details of nesting box for bird encouragement.
A. Nesting-box ready for hanging. B. Lid and front of box. C. View of box from back.

Three equal lengths were nailed together to form three sides of a large box the outside of which bearing the bark was round and the inside square. The fourth side was made up of a flat piece of wood forming the back of the box; this piece was longer and projected above and below the box thus providing means of attaching the box to the tree. The top and bottom of the box were made of slab wood. The bottom was nailed on and several holes were bored through it to keep the nest dry. The top was hinged to the flat board at the back and when in use was fastened down by means of a screw which allowed the lid to be opened for the purpose of cleaning out the old nests. These nesting boxes were made cheaply out of waste lumber at the saw mill. They were attached

to the trees by means of two pieces of wire passing through holes in the top and bottom of the back board respectively. (See Plate 3, Fig. 23). The method of hanging nesting boxes, etc., is fully treated in Hiesemann's excellent book (1908) to which those interested in the subject are referred. The need of these boxes and the result of their provision is indicated by the results; although the number of nest boxes hung was not great, nevertheless, they were sufficient to demonstrate their value. In the first year (1908) sixty nest boxes were hung and 19 or 31.3 per cent were occupied. In view of this encouraging result it was decided to distribute additional nest boxes. Accordingly in 1909, 114 additional boxes were distributed and in that year 46.5 per cent. of the boxes were occupied. I am indebted to Prof. S. J. Hickson, under whose direction the work is being carried on, and to Mr. Mangan, for information with regard to the results of this experiment subsequent to my leaving England. In 1910, the number of boxes was increased to 280 and of these 161 or 57.5 per cent. were occupied. Sixty-seven more boxes were added in 1911 and of these 347, the birds occupied 229 or 65.9 per cent. of the boxes available. These results may be summarised as follows:

Year.	1908	1909.	1910.	1911.
Percentage of boxes utilised.....	31.6	46.5	57.5	65.9

This gradual increase from year to year of the percentage of the boxes occupied by the birds is very significant, especially as there was a concomitant yearly increase in the number of boxes provided. The number of boxes which were provided was small, but the results of the experiments were sufficient to indicate, among other things, that in localities where nesting sites are few, birds will readily use nesting boxes if these are provided, although this fact hardly required confirmation in view of the experience in certain of the German forests and elsewhere. It also indicated that in proportion as more facilities were provided for nesting, more birds availed themselves of the opportunities. On several occasions I found that two broods had been raised during the season in a single box. All these facts demonstrate most clearly the value of the provision of nesting boxes as a means of increasing bird life and the proportion of useful insectivorous birds in a given region. The boxes distributed in the plantations of hardwoods were utilised more generally than those distributed in plantations of pure larch. It was further observed that the birds, including the tits, favoured the type of box whose construction has been described above in preference to the Berlepsch type, of which a number were distributed. The preference of the former made the percentage of nests occupied probably less than it would have been if all the nest boxes had been of the type the birds appeared to prefer.

Parasites and Predaceous Insects.

Although birds and mammals are important factors in preventing the increase or maintaining a natural control when once this has been gained, they cannot be regarded as playing a very important part in obtaining control of a pest once it has become abnormally abundant. The parasitic insect or fungus increases rapidly in numerical abundance with the increase in numbers of its host, in this case the sawfly. In both cases the numerical abundance of host and parasite will increase in proportion to the available food supply, which is the larch in the former case and the sawfly larva in the latter. If the parasite, or parasites when several are working together, is effective, it will increase numerically to such an extent that its food supply, the host insect, will be destroyed before the exhaustion of the available food supply of the host, that is before the destruction of the larch. This does not take place in the case of the birds, as their numbers do not increase in a manner comparable to that of the insect parasites. The increase in abundance of the insect pest causes the numeri-

eal increase of birds by attraction and not by reproduction, and this increase may be artificially assisted by the adoption of means of encouragement and protection. The birds are attracted in numbers by the presence of food in abundance, but the latter does not determine their increase in the same manner that the percentage of parasites is increased.

The study of the parasitic insects in England was of great interest and practical importance as it demonstrated control by natural means and indicated the possibility of utilising these natural means of control in combating the pest on a large scale where artificial methods were impracticable and valueless. In giving the results of my observations on the parasites in 1908, the statement was made that "It is of importance to study the numerical proportions of the parasites in the different localities, as it may eventually be found that in certain localities the percentage of cocoons containing parasites is so great that some practical benefit may accrue from the distribution of these highly-parasitised cocoons in localities where the percentage of the parasites is much lower." This rough method of distributing the parasites would naturally have resulted in the distribution of the hyper-parasites also, but the subsequent history of the outbreak appeared to indicate that their influence was negligible under the circumstances. My departure from England in 1909 necessitated my relinquishing the study of the English parasites and the biology of the same in their native country. Accordingly, infected cocoons were obtained from England in 1910 and 1911 for a continuation of a study of these parasites in Canada, and in England the observations were continued after my departure by my successor, Mr. Joseph Mangan, under Prof. S. J. Hickson's direction, to both of whom I am extremely grateful for keeping me advised as to the progress of the work in England and an acknowledgment is made wherever their observations are recorded in this account.

PARASITIC INSECTS.

The parasitic insects which were found belonged to the three families: *Hymenoptera*, *Diptera* and *Coleoptera*. The majority are included in the first family and these are the most important economically. In the following account neither a systematic arrangement nor a geographical division is given, instead an endeavour has been made to arrange them according to their economic importance as indicated by the present investigation. Such an arrangement is very artificial and may not represent the real state of affairs; it affords, however, a convenient method of presenting the results of my observation.

Mesoleius tenthredinis Morley, (*MSS.*)

(Plate I, Fig. 5.)

In May and June, 1908, I reared a number of specimens of this parasite, one of the Ichneumonidae Tryphoninæ, from cocoons collected during the previous winter around Thirlmere in the English Lake District. Specimens were submitted to Mr. Claude Morley, who in reply (5th June, 1908) stated that, although he had not yet thoroughly worked out the group Tryphoninæ, he had very little doubt that the two females and male which I had sent were *Mesoleius aulicus* Grav. On this account I have referred to this species in all my work and writings up to the present time as *Mesoleius aulicus* Grav., having subsequently satisfied myself that my specimens answered Gravenhorst's description[1], this author having described it under the name of *Tryphon aulicus*. Mr. Mangan, who continued my work in England, also called this species *M. aulicus*. I was not a little surprised, therefore, to find the following statement

[1] *Gravenhorst, I. L. C.* "Ichneumonologia Europeæ." Vol. II, pp. 173-175, 1829.

in a foot-note to the description of *M. aulicus* in Mr. Morley's recent account of the British Ichneumons (Vol. IV, p. 157, 1911) in which reference to Mr. Mangan's use of this specific name is made:

"Both Dr. C. Gordon Hewitt, and Mr. Halbert of the Dublin Museum, have given me examples of the *Mesoleius* bred from the Cumberland *Holocneme*[1], and they are certainly distinct from, though closely allied to, *M. aulicus* Grav. I do not recognize the species and have not met with it elsewhere; it may be new and I hope to refer to it at some future time."

As lapse of time and further study appeared to have changed Mr. Morley's views in regard to this Ichneumon since I had first reared it in 1908, I wrote to him (Feb., 1912) and called his attention to his previous remarks, already mentioned. At the same time, further specimens of this Ichneumon were submitted to Mr. Morley with the request that he would report the results of his examination. In reply I have received the following description of this parasite from Mr. Morley, and he informs me that he has sent a copy to the '*Transactions of the Entomological Society of London*' for publication under the title "A New Species of Ichneumonidæ." In reference to his previous determination he states: "It was impossible to tell you what your species was with any certainty . . . . till I had worked on the genus for my volume IV."

As Mr. Morley has named it *Mesoleius tenthredinis* I am accepting this name for this new species to which I have hitherto referred as *M. aulicus*.

Mesoleius tenthredinis Morley, (MSS.)

"Head stout and hardly constricted behind the internally submarginate eyes; vertex somewhat broad and impressed on either side of ocelli; clypeus apically and laterally depressed, with its apex slightly emarginate centrally and hardly convex; the stout and equally bidentate mandibles, palpi and clypeus dull testaceous, or in ♂ stramineous with face centrally concolorous. Antennæ apically attenuate, with the first flagellar joint fully half as long again as the second; black with only the ♂ scape stramineous beneath. Thorax not gibbous, stout, dull, anteriorly subelevated and discally deplanate, with distinct notauli; mesopleuræ very finely and subalutaceously punctate, with the speculum glabrous and glittering; metathorax dull and very closely punctate; areola narrow, subparallel-sided and somewhat distinct with its lateral carinæ and that of the smoother and excavate petiolar area entire; spiracles small and circular. Scutellum black or in ♀, together with whole postscutellum, sometimes apically or mainly rosy. Abdomen of ♀ fusiform and immaculate black, of subcylindrical and apical incisures of second and third segments obsoletely refuscent; the three basal ♂ segments gradually explanate; the first strongly carinate basally, slightly longer than hind coxæ with its discal sulcus narrow and distinct to centre and in ♂ stronger, spiracles before its centre, basal scrobes large and subcircular, and postpetiole of ♀ finely margined; ventral plica of ♂ stramineous and valvulæ of ♀ not compressed; terebra obliquely deflexed, apically truncate and not extending beyond anus. Legs fulvous and not slender; hind ones with their tibiæ distinctly spinulose and black with a broad testaceous band before the base and the black calcaria longer than half metatarsi; their tarsi black and distinctly subincrassate with onychii large and onyches stout; ♂ with trochanters and anterior coxæ stramineous white, the hind coxæ castaneous or black and their calcaria with basal two-thirds of tibiæ white. Wings hyaline and somewhat broad; radix and tegulæ stramineous; stigma broad and infuscate piceous; areolet wanting or very rarely subentire, transverse and petiolate, emitting the bifenestrate recurrent nervure further from the intercubital

[1] *Nematus erichsonii*

than the latter is long; lower basal postfurcal and but little oblique; anal emitted from centre of brachial cell; first recurrent of hind wing a little longer than basal radial abscissa; nervellus opposite and geniculate hardly below its centre. Length, 9–10 mm.

In structure it is very closely allied to *Mesoleius* (*Scopesus*) *pallidifrons* Holmgr., as set forth by Thomson (Opuse. Ent. 2032) and by its author, both in his *Monographia* of 1855 and *Dispositio* of 1876, which is said to differ from the females of *Mesoleius imitator* and *M. geniculatus* Holmgr., in the apically more broadly depressed clypeus, etc., but materially differing in its nigrescent stigma, pale coxæ, trochanters and ♀ tegulae, posteriorly broader head and very determinate metanotal carinæ. Among our British species it must be inserted after *Mesoleius bicolor* Grav."

The average length of *M. tenthredinis* is 9.5 mm (about three-eighths of an inch) and the breadth across the expanded wings is 17 mm.

In 1908, from 331 cocoons of *N. erichsonii*, 19 specimens of this parasite emerged, indicating that 5.8 per cent. of the larvæ had been parasitised. In the winter following, a large number of cocoons were collected and in the summer of 1909, out of 5,821 cocoons, there emerged 624 specimens of *Mesoleius tenthredinis*, indicating that the number of larvæ parasitised had increased to 10.9 per cent. On account of my leaving England in September, 1909, arrangements were made to continue the study by having cocoons collected in the spring and shipped to Canada. This was done and in the summer of 1910, 1,260 specimens of *M. tenthredinis* were obtained from 1,946 cocoons, a percentage of 64.7. Practically the same degree of parasitism, namely 62 per cent. was observed by Mr. Mangan in England. The result of this high degree of parasitism on the part of *M. tenthredinis*, associated to some extent, no doubt, with other controlling natural factors such as voles, birds and the fungus *Isaria farinosa*, was that the sawfly was practically eradicated. The larches in the infested region which had been completely defoliated in the previous two years were perfectly green. Mr. Mangan informed me that the sawfly larvæ were very scarce. The history of the pest was of great interest as indicating the operations of natural means of control.

On account of the economic importance of *Mesoleius tenthredinis* as a natural factor in the control of the sawfly, arrangements were made to import the parasitised cocoons into Canada with a view to establishing the parasite in different regions within the infested area. Owing to the comparative scarcity of the pest it was unusually difficult to collect the living cocoons in large quantities and a comparatively small number only of the cocoons were obtained. In the summer of 1910, over 1,000 specimens of *M. tenthredinis* reared from the English material were liberated in the arboretum and forest belt of the Central Experimental Farm at Ottawa and about 150 were liberated in the Algonquin National Park, Ont. The cocoons which were imported during 1911 were distributed in the following places: near Quebec city, by Mr. G. C. Piche; St. Agathe des Monts, P.Q.; at Point Platon, P.Q., by the late Mr. E. G. Joly de Lotbiniere; and in the Algonquin National Park, Ont., by the Superintendent Mr. G. Bartlett. A small lot of infested cocoons were sent to Mr. R. H. Pettit, State Entomologist of Michigan. A sixth lot was retained in the Division of Entomology for a further study of the English parasites. It was interesting to find that the practical disappearance of the sawflies from the infested region had resulted in a considerable falling-off in the number of cocoons infested with *M. tenthredinis* in 1910, these emerging, of course, in 1911. Of the cocoons received from Thirlmere, England, in 1911, statistical studies were made of two small collections only, the rest of the cocoons being distributed in the hope of establishing *M. tenthredinis* in Canada in the manner I have just mentioned. In the collections of cocoons which were retained at Ottawa, out of 202 cocoons, 25 specimens of *M. tenthredinis* emerged, indicating a parasitism by *M. tenthredinis* of 12.5 per cent. In the collection of cocoons which was sent to

Mr. R. H. Pettit, State Entomologist of Michigan at the Michigan Agricultural College, East Lansing, Mich., he found *M. tenthredinis* parasitising 7.05 per cent. of a collection of 956 cocoons.

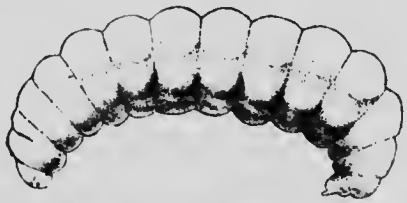

FIG. 14—Full-grown larva of *Mesoleius tenthredinis* Morley.

It was found that while the percentage of the larvæ parasitised by *M. tenthredinis* had fallen, the percentage parasitised by such species as *Microcryptus labralis* and *Aptesis nigrocincta* had increased slightly: this is discussed later.

It is evident that *M. tenthredinis* is a most important factor in the control of *N. erichsonii*. On this account further efforts are being made to introduce and establish this species in Canada (see p. 41).

The earliest date upon which *M. tenthredinis* was found to emerge from the cocoons of the sawfly was April 28th and they continued to emerge until the second week in July. The maximum number of parasites emerged June 7th to 9th and during the same period the maximum number of the adults of *N. erichsonii* emerged. The parasites were found flying in the infested districts in July. The full-grown larva of *M. tenthredinis* is shown in Fig. 14. It measures 11-12 mm. in length. In January, 1912, when endeavouring to find a locality in the Lake District (England) where the parasites were abundant, I dissected a large number of the parasitised larvæ of *N. erichsonii*, after extracting them from the cocoons, and found that the larvæ of *M. tenthredinis* were about half grown, measuring 5-6 mm. in length on the average. This would indicate that the growth of the parasite is relatively slow and that the parasitic larva does not become mature until [illegible] May, when fully grown larvæ of *M. tenthredinis* may be found in the [illegible]s of *N. erichsonii*. Mangan found that the ovaries of females of *M. tenthredinis* contained thirty to forty fully matured ova. MacDougall states that there are 20 egg tubes and he counted 160 eggs at the time of dissection; these are, presumably, mature and immature eggs. Sawfly larvæ in which the female ichneumon has oviposited may be frequently recognised by the presence of a dark brown spot on the body where the ovipositor was inserted.

Cœlopisthia nematicida Packard.

(Fig. 15.)

This small chalcid parasite is native to North America. It was originally referred to by Packard[1] in the first account of his investigations on *N. erichsonii*. In this account he states:

> "A number of cocoons sent to us by Mr. Atkins were found in every case to be tenanted by a minute chalcid parasite, belonging to the genus *Pteromalus*. If new it may be called *Pteromalus nematicida* (Plate XII, Fig. 8). About one hundred of these issued from the cocoons in the breeding box during May, 1883. This parasite must therefore be a most destructive enemy of the larch worm."

[1] In "The Report of the Entomologist," Ann. Rep. of the Commissioner of Agriculture, 1883. Washington, D.C., pp. 138-142.

Beyond the figure of the parasite, which is given and again reproduced with the above account in the Fifth Report of the United States Entomological Commission (1890), no further description is given. The correspondence in this account would indicate that Mr. Charles F. Atkins collected the cocoons in Maine. Until this insect was rediscovered in Canada and described by me (1911)[1] with observations on its life-history, made with the assistance of Mr. G. E. Sanders of this Division, I am not aware of any description of it having been given subsequently to Packard's brief reference to it.

It was first reared from cocoons of the sawfly collected in the larch section of the forest belt on the Central Experimental Farm, Ottawa, in May, 1910. Mr. C. T. Brues, of the Bussey Institution of the Harvard University, confirmed my identification of the species as Packard's *P. nematicida* and placed it in Förster's genus *Cœlopisthia*. The occurrence of the parasite was discussed with Mr. W. F. Fiske in charge of the Gipsy Moth Parasite Laboratory (of the U.S. Bureau of Entomology) at Melrose Highlands, Mass., who also examined cocoons of *N. erichsonii* collected at Wellesley, Mass., and found the pupæ of this parasite in these cocoons on July 28, 1910. Mr. Fiske most kindly arranged for cocoons to be collected for me from the same locality and these were received on September 13th.

The following account of the life-history of this parasite is taken from my paper already mentioned and subsequent observations have been added. It is to be regretted that it has not been possible so far to follow the development of the several broods of a single line of parasites through the complete year.

FIG. 15—*Cœlopisthia nematicida* Pack. Female enlarged 12 times.

FIG. 16—Female *C. nematicida* ovipositing in cocoon of *N. erichsonii*. (enlarged).

The development of the last and overwintering brood was studied. Females were observed ovipositing on September 13th. The time occupied in the process varied. A single female which was isolated for observation, remained in the same position for 1½ hours (see Fig. 16) with her ovipositor inserted in the cocoon. She then removed her ovipositor and walked away, moving about for twenty minutes, after which she returned and inserted her ovipositor in almost the same spot as before and remained in this position ovipositing for fifty-five minutes.

[1] *Hewitt, C. G.* "On *Cœlopisthia nematicida* Pack. A Chalcid Parasite of the Large Larch Sawfly, *Lygœonematus erichsonii* Hartig." *Can. Entom. Vol. 43, pp. 297–303.*

In several instances, two females were seen ovipositing in the same cocoon. The numerical abundance of the eggs that may be deposited in a single cocoon may be judged from the fact that in one case eighty-one eggs were counted on a single larva; in another case forty-seven pupæ and adults were contained in a single cocoon. Five cocoons examined on May 1, 1912, contained 70, 68, 69, 73 and 50 larvæ respectively. The sawfly larvæ in cocoons in which the chalcids had deposited eggs appeared less active than those in uninfected cocoons; this may be due possibly to some paralysing action on the part of the female when ovipositing.

The eggs are .3 mm. in length and transparently white. In shape they are ovally elongate having one end broader than the other, and are slightly curved (Fig. 17). They are deposited externally upon the sawfly larva chiefly in the anterior and thoracic region and appear to be laid in masses with no attempt at placing them, were this possible. In three days all the larvæ had hatched from eggs deposited by females on September 13th.

The larva when newly emerged, is transparent and vitreous in appearance. In feeding they attach themselves to the host larva in a leech-like manner and for a day or two they did not appear to leave the place of original attachment but they moved their positions later. The larva continues to feed externally with its head buried in the side of its host. They became mature in twelve days. In the case of the overwintering brood they hibernated as full grown larvæ in the cocoons of the host. Mature larvæ of the overwintering brood were found

FIG. 17—Anterior end of cocoon of *N. erichsonii* cut open showing eggs of *C. nematicida* on the body of the sawfly larva; enlarged 15 times. A single egg is shown at the side enlarged 30 times.

FIG. 18—Full grown larva of *C. nematicida*, enlarged 20 times.

in cocoons in May, still attached to and apparently feeding upon the host larva. In the case of the summer brood the adults emerged about twenty-three days after the eggs were deposited. The adults of the hibernating brood, the eggs of which were deposited in September, did not emerge until the following April, making the length of time of development of the overwintering brood about seven months. The full grown larva (Fig. 18) measures 2.35 mm. in length. It is white and the body, which consists of thirteen segments, has the dorsal side more strongly convex.

As the development of a single line of the parasites was not followed throughout a complete year, it is not possible to make statements with regard to the number of broods in the year with certainty. I believe, however, that it is safe to make inferences from the observations which were made on material collected in Massachusetts and in Canada. In one batch of cocoons, adults emerged on October 9th from cocoons in which eggs had been deposited on September 13th to 16th, from which it would appear that the time of development of a summer brood was about 23 days. It has been found that the females oviposit shortly after emergence, so that no lengthy period necessarily intervenes between the development of the broods if the parasite can find healthy cocoons of the sawfly.

The prevalence of healthy cocoons of the host would determine the efficiency of the parasite. It has been found in studying the life-history of the host *N. erichsonii* that the sawfly larvæ may become full grown and form the cocoons as early as June 12th to June 17th, which would mean that in any year cocoons of that year's sawfly larvæ could be found from the middle of June. Further it has also been found that sawflies will continue to emerge from the cocoons of the larvæ of the previous year until the end of June, which indicates that there is a supply of the previous year's larvæ in their cocoons until the first or second week in June. In short, it has been found that cocoons containing larvæ of *N. erichsonii* may be found throughout the year, the time of least abundance being in June. It may be assumed, therefore, that if the chalcid *C. nematicida* can find healthy cocoons, and this has been shown to be possible during practically the whole of the year, the production of broods may continue throughout that portion of the year during which the climatic conditions permit the activity of the chalcids. From my observations on the emergence of the chalcids, this takes place from the latter part of May to the beginning of October, namely, about five months. On the basis of these facts, there is sufficient time for the development of about six broods during the open season; assuming that healthy cocoons are available on the emergence of the adult chalcids. The cocoons are usually so located under the turf as to be readily accessible to these small chalcids, which on emerging from one cocoon would soon seek a healthy host. The evidence afforded by the study of the parasite and by the history of the prevalence of its host in certain localities would indicate that *C. nematicida* is a factor of great value in the natural control of *N. erichsonii* wherever the chalcid occurs. In a collection of cocoons made in a small larch plantation on the Central Experimental Farm, Ottawa, in April, 1912, five out of fifty cocoons selected at random contained this parasite, the rest being empty, and I am strongly of opinion that in this plantation the sawfly has been controlled by this chalcid.

The adult insect is illustrated. The average length of the female is 1.7 mm. to 2.1 mm., and of the male 1.6 mm. The colour of the body is black; the thorax has metallic dark-green reflections and the abdomen is smooth and shining; the legs are light brown. (For a full specific description the original account should be consulted).

Diglochis spp.

In the Report of the State Entomologist of Minnesota for 1909-1910, Mr. A. G. Ruggles states that of several hundred cocoons of *N. erichsonii* collected in Minnesota, 10 to 15 per cent. were parasitised by a species of *Diglochis*. As this appeared to be a parasite of some importance I wished to enquire more closely as to its identity and Mr. Ruggles kindly sent me specimens for examination which were afterwards submitted to Mr. Brues. Writing in July, 1911, Mr. Brues informed me that the *Diglochis* agrees well with Ratzeburg's *Pteromalus klugii* (see Ratzeburg, 1844) which is probably a *Diglochis* like the Minnesota specimens. There are at present 873 species listed as *Pteromalus* and only *P. omnivora* Walker, the type of the genus *Diglochis*, is as yet included in the latter genus which no doubt includes the other species now listed as *Pteromalus*.

Ratzeburg bred *Pteromalus* (*Diglochis*) *klugii* in 1841 from the cocoons of *N. erichsonii* collected in the Grand Duchy of Posen; I do not know of any subsequent records of the species having been reared from this host.

Microcryptus labralis Grav.

This species which was described by Gravenhorst under the name *Phygadeuon labralis*, was first bred in 1909 from *N. erichsonii* collected in the English Lake District. Since that year it has been found each year in gradually increasing numbers. Mr. Claude Morley who kindly identified the first specimens thought it might be a hyperparasite. I am of the opinion, however, from its behaviour that it is a primary parasite, though, as the breeding experiments

FIG. 19—*Microcryptus labralis* Grav.

appeared to indicate, not a very potent one. Mr. Mangan (1910) is of the same opinion. In 1910 the percentage of cocoons parasitised by *M. labralis* was about 1.5. In 1911 in material sent over, as in 1910, to Canada from Thirlmere, out of 1,138 cocoons, 19 specimens of *M. labralis* were reared being a percentage of 16.

Aptesis nigrocincta Förster.

A few specimens of this peculiar wingless ichneumon were reared from cocoons of *N. erichsonii* imported from Thirlmere, England, in 1910 and 1911. It is reddish-brown in colour with the head, metathorax, posterior half of dorsal region of segment three and the dorsal region of fourth segment of the abdomen, distal portion of antennae and the tips of the femora or tibiae of the third pair of legs black.

The specimens emerged during the latter half of May 1910 and 1911.

Spilocryptus incubitor Ström.

Three specimens, all females, of this species with deformed wings emerged on the 13th and 15th May, 1911, from cocoons from Thirlmere, England, and were identified for me by Mr. Claude Morley.

Cœlichneumon fuscipes Grav.

A single specimen of this rather large dark coloured species emerged on 25th April, 1910, from material received from Thirlmere, England.

Gratichneumon annulator Fab.

A single female of this species which has been determined by Mr. Claude Morley emerged on 18th May, 1911, from cocoons from Thirlmere, England.

Cryptus minator Grav.

A single specimen was reared from Thirlmere, England, cocoons in May, 1910.

Perilampus sp.

My friend, Mr. W. F. Fiske in charge of the Gipsy Moth Parasite Laboratory, Melrose Highlands, Mass. collected some cocoons of *N. erichsonii* in September, 1909, in the forest near Lake Nebagamon, Wisconsin. One of these cocoons was opened in March, 1910, by Mr. H. E. Smith who discovered the minute first stage larva of the "planidium" type attached externally to the sawfly larva. Mr. Fiske, who kindly sent me the specimen, informs me that it is quite similar to the planidium of *Perilampus hyalinus* Say, in size and structure but very different in structural detail. This difference I have since confirmed from Mr. Smith's description[1] of *P. hyalinus*. This minute larva is almost invisible to the unaided eye, being about three-tenths of a millimetre (less than one eightieth of an inch) in length. *P. hyalinus* is a hyperparasite or secondary parasite of the hymenopterous and dipterous (tachinid) parasites of the fall webworm *Hyphantria textor* Harris. Another species of *Perilampus*, namely *P. caprinus* Förster, has been reared in Massachusetts from puparia of the tachinid parasites of the gipsy and brown-tail moths.

Perilissus filicornis.

This species of hymenopteron is given by Cameron (1885) as a parasite of *N. erichsonii*. Brischke recorded *P. lutescens* as a parasite of *N. erichsonii*.

Microgaster sp.

Lintner (1885) states: "The larvæ collected were remarkably free from parasitic attacks. A single small white cocoon apparently of a *Microgaster*, was obtained from a half-grown example."

DIPTEROUS PARASITES—TACHINIDÆ.

Frontina (*Masicera*) *tenthredinidarum* Townsend.

FIG. 20—Larva of tachinid fly, probably *Exorista* sp.

Two specimens of the tachinid were received from Mr. Gordon Leavitt, St. John, N.B. They had been reared by him from *N. erichsonii* in 1910, and were determined by Mr. J. D. Tothill of this Division. This species was described by Townsend[2] from a single specimen reared by Mr. W. H. Harrington, Ottawa, from a sawfly larva, the species of sawfly not being stated, but it may have been *N. erichsonii*, which is common about Ottawa. The parasite issued in July.

[1] *Smith, H. S.* "The Chalcidoid genus Perilampus and its relations to the problem of Parasite Introduction." Part IV of Technical Results from the Gipsy Moth Parasite Laboratory. *Bull. No. 19, Tech. Ser., Bur. Ent. U.S. Dept. Agr., 1913.*

[2] *Townsend, C. H. T.* "The North American Genera of Calyptrate Muscidæ. Paper IV Sarcophagidæ and Muscidæ." *Trans. Amer. Ent. Soc. Vol. 19, p. 285-286, 1892.*

Exorista crinita Rond.

Each year from 1909 to 1911 specimens of this species have been reared by Mr. Mangan and myself from *N. erichsonii* cocoons collected in Cumberland, England.

Tachinid larvæ, one of which is illustrated herewith (Fig. 20), were obtained by me from the larvae of *N. erichsonii* in the summer of 1908 and from hibernating larvæ in January, 1912, in Cumberland, Eng., and it is not improbable that these are the larvæ of this species.

Exorista sp.

Mr. Mangan has sent me for determination four Tachinids, three male and one female, reared from 1911 cocoons collected at Crummock Lake, Cumberland, Eng. Mr. J. D. Tothill has examined them and finds them to be either identical with or close to *Exorista alacris* Meig.

COLEOPTERA.

In a letter to me of July 28th, 1910, Mr. W. F. Fiske says:—"I also found two larvæ of a small parasitic beetle, apparently either a *Clerid* or *Trogositid*. One of these larvæ was dead and mouldy and the other had left the *Nematus* cocoon and spun a rough silken cocoon of its own. This is the first parasitic beetle which I have ever seen attacking sawfly larvæ."

ACARI.

In June, 1909, a large number of female sawflies emerging from cocoons collected in Cumberland, Eng., the cocoons being kept in moss and turf collected at the same time, were found to be infested with small reddish brown mites in the hypopal stage. These were submitted to Mr. A. D. Michael who kindly identified them as hypopi of *Histiostoma rostro-serratum*. Although they are parasitic in a sense their attachment to the sawfly is for the purpose of securing their dispersal.

PROBABLE HYPERPARASITES AND DOUBTFUL PARASITES REARED FROM *N. erichsonii* MATERIAL.

In the study of parasites it is very frequently most difficult to decide whether a species of parasite is primary, that is parasitic on the original host, or secondary, that is parasitic on a primary parasite in which case it is usually called a hyperparasite. This can be decided only by further special studies of the species in question and their habits. In the present investigation a number of such doubtful cases occurred.

Hemiteles necator Grav.

This species emerged on 28th April, 1910, from material collected in Cumberland, Eng., and was identified by Mr. C. T. Brues. It may possibly be a primary parasite. Gravenhorst refers to a record of Fabricius of the larvæ living in the larvæ of Phalaenae.

Anacharis typica Walker.

A single male of this species was reared by Mr. J. Mangan on the 8th May, 1910, from material collected at Thirlmere, Cumberland, Eng. and it was deter-

mined for me by Mr. Claude Morley. Handlirsch records the rearing of this species from the neuropteron *Hemerobius nervosus* Fabr. The living larvæ measured about 3 mm. in length.

Figites sp.

Two specimens were reared in 1910 from material from Cumberland, Eng. These insects are usually parasitic upon diptera. They may have been parasitic on tachinid parasites or upon some unnoticed dipterous pupæ.

Microplitis sp.

A single female braconid referred to this genus by Mr. Claude Morley was reared from English cocoons (Cumberland) on May 10, 1911.

PREDACEOUS INSECT.

Hemiptera: *Pentatomidæ*.

Podisus modestus Dallas.

This predaceous or blood-sucking bug has been frequently found feeding upon the larvæ of *N. erichsonii*. Fletcher found it in 1884 destroying the sawfly larvæ at Brome, Que. Lintner (1889) records it as a predaceous enemy of *N. erichsonii*. He found it in July feeding on the sawfly larvæ and remarks that: "In fastening upon its prey, in almost every instance observed its probosis was inserted near the anal end of the larva." Packard says: "We also noted several bugs, a species of *Podisus*, near the common *spinosus*, preying upon the fully grown worms; it ascends the tree and pierces the worm with its beak, carrying it down the tree and sucking its blood, rendering it lifeless." The species was no doubt *P. modestus* which closely resembles the common *P. maculiventris* Say (formerly *P. spinosus* Dall.)

FIG. 21—Predaceous Bug: *Podisus modestus* Dall.

P. modestus (Fig. 21) is common throughout Canada and the north-eastern United States. The collections of the Division of Entomology contain specimens from Quebec, Ontario, Manitoba and British Columbia; Van Duzee states that it occurs as far west as Dakota, Nebraska, Colorado and Montana in the United States. It measures about four-tenths of an inch in length. Its colour is yellowish-brown to dusky brown with very fine darker brown markings. The sides of the shield-like prothorax are produced into blunt spines. This species may be distinguished from *P. maculiventris* by its slightly smaller size, paler colour and by the possession of a short ventral spine.

Parasitic Fungus.

Isaria farinosa (Dicks) Fr.

(Plate I, Fig. 4; Plate II, Fig. 22.)

Shortly after beginning my investigations on *N. erichsonii* it was found that the hibernating caterpillars were attacked by a parasitic fungus belonging to the *Cordyceps* group. This fungus appeared in the form of white patches on the cocoons and also as elongated stalks of sporophores of the conidial form. As it was believed that the larvæ on entering the soil for hibernation and to spin their cocoons would become infected if the spores of this fungus were in the soil, experiments were carried out in 1909 with a view to testing the validity of this belief. A piece of ground which continued use had shown to be uninfected with spores of this fungus was chosen in a region where the sawfly does not occur and young larch trees were planted. A large number of larvæ were placed on these larches and the ground round the bases of the young trees was infected by distributing specially infected soil and litter containing the spores. Unfortunately an accident to the small group of larches and my removal to Canada prevented a satisfactory conclusion to this experiment.

When cocoons of *N. erichsonii* were received from England in 1910, a certain proportion was infested with the fungus and accordingly I handed some of them to Mr. Güssow, Dominion Botanist, in order that he might study the problem of infection. The results of these studies have since been published.[1] Mr. Güssow identified the fungus, after having cultivated it, as *Isaria farinosa* and the same fungus was found on cocoons which were collected by me near Ottawa. The question which it was necessary to decide was whether this fungus was growing saprophytically on the sawfly cocoons, that is, growing on the sawfly larvæ which had died from other causes, or whether it was a parasite and capable of attacking and infecting healthy larvæ. Mr. Güssow's experiments and conclusions were as follows:

"These cocoons" (referring to the *Isaria* covered cocoons which had been provided for the purposes of these experiments) "were placed together with the moss in which they were imported from England into a flat glass dish. The moss was moistened and a well-fitting lid preserved the moisture satisfactorily. The cage was kept in the dark under ordinary laboratory temperature. In about 22 days a considerable quantity of sporophores of the *Isaria* were produced. Originally 23 cocoons showing the white patches of the fungus were placed in the cage. No adult insect emerged from these cocoons. Some of the cocoons were dissected at intervals and were found to contain a blackened or dirty yellowish adult. The dissected cocoons were replaced and the *Isaria* developed further. I then obtained a handful of cocoons which were carefully examined and which showed no signs of an infection whatever. They were divided in equal numbers, 30 cocoons serving in each of the following experiments:

"*Experiment A.*—These sound living cocoons were introduced into a breeding chamber and were carefully kept free from external infection from *Isaria* spores. It was sought to ascertain how many of the cocoons would produce living adults and those emerging were carefully recorded. Ten adult larch sawflies emerged in the course of ten days. Eleven parasitic insects were also found to emerge from the cocoons; the remainder of the cocoons did not 'hatch' at all. Some of these were found, on dissection, empty. Some showed remains of a dead adult. Only one cocoon showed signs of *Isaria*.

"*Experiment B.*—The same number of cocoons were used. These were placed together with infected moss and cocoons bearing *Isaria* spores into a

[1] *Güssow, H. T.* "Observations on the Parasitism of *Isaria farinosa* (Dicks) Fr. with special reference to the Larch Sawfly (*Nematus erichsonii* Hartig). *Trans. Roy. Soc. Canada, 3rd series, Vol. 4, pp.95-99*, 1911.

small breeder. After ten days, six adults and six parasites were observed and were left confined in the cage. One of the first peculiar symptoms observed in these cocoons was a darkening in colour of 16 of them; the colour of the normal cocoons being light chocolate, while in these cases the colour was of a pronounced dull chocolate tinge. Four more adults emerged on subsequent occasions. Although no signs of *Isaria* were then noticeable on the darkening cocoons some of them were dissected and microscopically examined. Two of the examined cocoons showed the interior walls lined with white fungus hyphæ; others showed fungal hyphæ in the dead adult's body. Later on white fluffy patches occurred externally rather suddenly on most of the remaining cocoons. From the appearance of these fungous growths it was evident that they were formed by the *Isaria*. About two months after beginning the experiments, the fungi formed the well-known forked sporophores and the microscopical characters proved the fungus to be *Isaria*. Spores had been produced abundantly at very early stages and no doubt had become disseminated throughout the cage. When about three months after starting this experiment I examined the interior of the cage again, I found the whole moss superficially and throughout the layer studded with fine whitish colonies of fungi. These were examined and found to be small colonies of *Isaria*. These colonies remain up to date very minute, but never disappeared. New ones constantly appeared and at present the moss is peculiarly studded all over with minute *Isaria* colonies. These colonies having no supply of congenial food remained small and were of course of starved appearance. I next separated a few and transferred them to a petri dish containing nutrient gelatine. Here they made three days' rapid growth and no doubt would have covered in the usual way the whole surface but for the appearance of gelatine liquifying bacteria which put a premature end to my observation. Nevertheless, it was proved repeatedly that the fungus spots consisted of *Isaria farinosa* and no other. It was surprising to me that never throughout these experiments, was I able to observe other fungi; like *Penicillium* and other common moulds. Several important conclusions may be drawn from these experiments :

"1. Granted that the cocoons used in experiments A and B were in equal condition as far as their being alive is concerned, it is shown from the greater number of adults or parasites emerging from cage (experiment A) and from the infection of a large proportion of cocoons in experiment B that the fungus *Isaria farinosa* is truly parasitic on larch sawfly cocoons.

"2. It is evident that spore infection of the cocoons had taken place. On one occasion I observed the infection of the adults; they died rapidly but remained uninfected.

"3. The fungus *Isaria farinosa* is capable of vegetating saprophytically for a considerable length of time, provided sufficient moisture is available. The conditions under which this mode of life was observed were close to natural conditions.

"4. Owing to this saprophytic mode of life there remains little doubt that the pupating larvae of the larch sawfly infect themselves when taking to the ground for pupation. The colonies observed in the moss appeared about the end of July and continued to show up to the end of September, during which time, of course, the pupation[1] of the larch sawfly takes place in nature."

"I have to record some observations on another experiment undertaken to discover whether it is possible to infect larch sawfly adults and cocoons with spores of *Isaria* from pure cultures. For this purpose a flat glass dish containing sphagnum was sterilized on three successive days in an hot air sterilizer. Although the moss became brown in colour it still retained satisfactorily moisture subsequently introduced. I then placed a number of living adults and cocoons in this apparatus and dusted the whole with spores that had been produced in a pure culture of *Isaria*. The living adults had all died after three days and

[1] *Note.*—By "pupation" Mr. Gussow refers to the entering of the soil by the larvæ to spin the cocoons in which, of course, they hibernate and, strictly speaking, do not pupate until the following spring.

none of those (11) emerging from the cocoons contracted the fungous disease. After 21 days no more adults emerged, although 13 cocoons remained, which I had evidence to believe contained living adults. Of these, nine eventually developed the typical *Isaria* and the moss also began to be covered with numerous *Isaria* colonies. This experiment confirms my other observations and also indicates that the disease may be artificially introduced even at so late a stage in the development of the larch sawfly. Infection takes place in nature, no doubt, much earlier."

"Although none of my experiments were made under strictly natural conditions, that is to say in the open air, yet the observation that the fungus *Isaria* is regularly found year after year on the larch trees when once it has been found, may indicate that the results obtained really closely show what takes place in nature."

The above results and observations are confirmatory of my belief and observations as to the method of infection. They also indicate that the fungus is an important factor in the control of the disease, which is supported by my own and Mr. Mangan's observations under forest conditions. In certain cases the number of cocoons attacked has been as high as twenty-five per cent. Such a percentage of infection was observed by me in one locality in Cumberland in January, 1912. While this fungus is important practically, its widespread character would render the value of artificial distribution questionable.

PREVENTIVE AND REMEDIAL MEASURES.

The adoption of any practicable measures against a pest of the nature of the larch sawfly when it is widely spread and native to the country, is a matter of very great difficulty. There are, however, certain measures of prevention and control which this investigation and other work resulting from it have indicated to be of value.

Preventive Measures.

The most important measure is to keep a very careful watch on larch plantations or forests for the first signs of defoliation by the caterpillars. When twigs are seen stripped of their foliage a close inspection should be made for the presence of the characteristic larvæ or their green excrement "pellets" which can often be found when the larvæ are beyond reach or sight. It may be possible to control or eradicate the pest in its earlier stages when a few trees only are attacked.

Planting. In replanting or afforesting areas pure stands of larch should be avoided if possible. It has been observed that pure stands of larch are injured most by the depredations of the larvæ. In my first Report to the Manchester Corporation Waterworks Committee (August 1907) the following suggestion was made:—"In order to minimise the attack of the larch *Chermes* which is often a source of trouble to larch and spruce, I would suggest that in future the trees be planted in belts as far as possible rather than in a mixed manner, alternating larch and spruce with a belt of hard wood. This would lessen the risk of all the larches in a plantation being attacked by any pest similar to the one under consideration. If larch and spruce were divided by a belt of hardwood they would be less likely to suffer from the attacks of the injurious *Chermes*. This method of planting trees in belts has also the advantage of preventing, to a great extent, the spread of fire should it break out." As a result of subsequent recommendations of Dr. Fisher the Manchester Corporation are not planting pure larch but mixtures. Annand (1910) makes similar suggestions with regard to avoiding the formation of pure larch plantations and the planting of isolation belts. He also recommends the underplanting of young plantations of pure larch with shade-enduring species to check the growth of mosses and grasses indispensable to the safety of the cocoons.

THE ENCOURAGEMENT AND PROTECTION OF BIRDS.

The importance of a plentiful supply of insectivorous birds is becoming recognised in certain European countries and their encouragement is a necessary adjunct of any system of forest protection, where the abundance of insectivorous bird life is below normal. The method of making the nesting boxes has been described already (p. 23). The distribution of these should be supplemented by the erection of "food houses" in different places. The Hessian "food house," devised by Baron von Berlepsch, is the most convenient form and can be easily erected by any one at very little cost. A number of these "food-houses" (Plate III, Fig. 24) have been erected on the Estate of the Manchester Corporation Waterworks in Cumberland (England) and are proving to be of great value. Their method of construction and other information relating to the encouragement of birds is given by Hiesemann whose valuable book has been translated.[1]

Remedial Measures.

The measures which may be adopted for the control and eradication of the larch sawfly will vary according to the extent and character of the infestation. Measures practicable for single or small collections of trees whose value is due to their ornamental character are not, in many cases, practicable on a large scale in the plantation or forest, as experiments early in this investigation showed. In fact, remedial measures of an artificial nature are practicable only in the case of small collections of trees or in plantations of a limited area. In the forest the only remedial measures which will offer any hope of success are those of aiding natural means of prevention and control.

Spraying. Where individual or small groups of ornamental trees or plantations of young trees are attacked, the spraying of the trees with an arsenical poison to kill the larvæ is practicable and may be adopted. In one of my previous reports (1907) spraying with a solution of arsenite of copper was recommended for the protection of the plantations of young trees in Cumberland. This was used in the proportion of 1 lb. of copper arsenite to about 130 gallons of water; one pound of flour was added to make the solution more adhesive to the foliage. Paris green in the proportion of one-quarter pound to forty gallons of water or lead arsenate in the proportion of two pounds to forty gallons of water may be used, the lead arsenate being preferable to other arsenical insecticides. In 1909 on the Estate of the Manchester Corporation at Thirlmere, Cumberland, England, about forty acres of young trees reaching a height of about eight feet were sprayed with the copper arsenite and flour at a cost of about $1.48, or six shillings and one penny, per acre, and by this means the defoliation of the young trees was prevented.

The trees should be sprayed when the larvæ are discovered feeding, which will be approximately from the latter half of May to July.

Destruction of cocoons. The destruction of the cocoons by raking up and collecting the litter and turf around the bases of the trees and burning in heaps with lime has been recommended, but it was found that the cost of the treatment on anything approaching a large scale was prohibitive. In the case of a few ornamental trees the expense might be justified.

Hand picking and crushing. Where plantations of young trees are severely attacked advantage may be taken of the clustering habit of the young larvæ which may be destroying by crushing with the gloved hand as they cluster together on the twigs, or they may be collected in buckets. This method was found effectual in the case of young plantations.

Jarring the trees.—Packard stated that as the larvæ, once shaken off the tree,

[1] *Hiesemann, M.* "How to attract and protect Wild Birds." Translated by E. S. Buckheim: Witherby and Co., London, 1908.

cannot ascend the trunk as they do not climb trees, jarring the trees would prove a good remedy. This is not to be recommended, however, as the larvæ are able to ascend the trunks of trees on which account the following method of tar-banding the trees was tried in Cumberland on the Thirlmere estate of the Manchester Corporation.

Tar-banding.—Heavy rains and high winds cause large numbers of the almost fully grown larvæ to fall off the trees and after such storms, also after they have completely defoliated neighbouring trees, the larvæ may be found ascending the trunks of the trees in large numbers. To prevent this the trees were tar-banded in the following manner: A band of rough bark was removed from the trunk of the tree by means of a draw-knife and a layer of tar was painted round the trunk. The tar remained for about a fortnight sufficiently adhesive to catch the larvæ and the cost of treating the trees was from $1.00. to $1.25 (four to five shillings) per acre. (Plate IV, Fig. 26.)

AIDING THE NATURAL MEANS OF CONTROL.

Where the sawfly is spread over a considerable area of mature timber it is not possible to adopt any of the above measures. If nothing is done, two things may happen: either the trees will be killed by repeated defoliation from year to year, or the natural enemies of the sawfly will obtain control before the trees have been killed. In eastern Canada the former happened owing to the natural enemies being too few and powerless, or absent. In view of such a result several English landowners cut down their larches after they had been defoliated by the sawfly fearing the trees would be eventually killed. As the trees had not reached maturity and their full value, the premature felling was a loss. In order to determine whether the parasites would gain control before the death of the trees had been caused by the sawfly, the statistical study of the parasites, already mentioned in the description of the parasitic means of control, was begun. Another purpose of this statistical study was to determine whether the natural rate of increase in the parasites and their abundance would render the transfer of the parasites from a severely infested locality to another locality into which the sawfly had recently spread valuable as a remedial measure. This idea was adopted in England by the Board of Agriculture and steps were taken, I believe, to distribute in Wales parasites obtained from cocoons collected in Cumberland, where our statistical investigations had shown that they were increasingly abundant, where a newly discovered outbreak was spreading. Before such transference of parasites from one region to another is made, however, a study should be made of the parasites in the new locality to see whether the transference will be advantageous, and subsequently to what extent the transference has been successful and has proved beneficial. This method of assisting nature in gaining control of an insect pest is not a new one, but appears to have been first suggested by Riley in 1871 in Missouri, U.S.A., and in the following year a French authority, F. Decaux, made a similar suggestion with regard to the distribution of the parasites of an apple weevil (*Anthonomus* sp.) In the same year Le Baron, State Entomologist of Illinois, U.S.A., attempted the distribution of a small hymenopterous parasite (*Aphelinus mali*) of the oyster shell scale (*Lepidosaphes ulmi*) from one part of the State to another. Howard and Fiske[1] (1911) have given a very complete account of instances since that time of the transportation of parasites from one part of a certain country to another part. Although the instances in which these means of control have been attempted are not many, there is undoubtedly a very great field for its trial and investigation in the future, and when we have a more complete knowledge of the parasites of our native pests and the conditions

[1] *Howard, L. O. and Fiske, W. F.* "The Importation into the United States of the Parasites of the Gipsy and Brown-tail Moths: A Report of Progress with some consideration of previous and concurrent efforts of this kind." *Bull. 91, Bureau of Ent., U.S. Dept. Agric., 1911.*

FIG. 26.—Larches at Thirlmere, England, defoliated by *N. ericksoni*. The trees have been tar-banded. Note the spruce and pine on the left of the photograph not attacked by the sawfly.

governing their increase and their relations to their ho[illegible] shall be in a better position to determine whether, and to what extent, the parasitic means of control can be utilized in obtaining control of extensive outbreaks.

An attempt is being made at the present time to introduce the ichneumon parasite *Mesoleius tenthredinis* from the counties of Cumberland and Westmoreland, England, into Canada. Small quantities of the parasites were bred out from English cocoons in 1910 and 1911 and liberated in Canada. In 1910, several hundred specimens of *M. tenthredinis* were liberated in the grounds of the Central Experimental Farm, Ottawa, and a number were liberated in the Algonquin Park, Ont. In 1911, English cocoons of the sawfly infested with *M. tenthredinis* were distributed in the following localities: near Quebec city, near St. Agathe, Que.; in Algonquin Park, Ont.; near Point Platon, Lotbiniere Co., Que. (see page 27). In addition, further specimens were liberated at Ottawa and a box of cocoons was sent to Mr. R. H. Pettit, State Entomologist of Michigan, who is endeavouring to colonise the parasites in that state. Unfortunately the percentage of the cocoons containing the parasite *M. tenthredinis* in 1911, was not so great as in previous years. With a view to making further importations of cocoons from England infested with *M. tenthredinis*, I visited the Lake District in England in January, 1912. A locality was found near Grasmere, Westmoreland, where a considerable percentage of the hibernating larvæ were found on dissection to be parasitised. Through the kindness of Sir William Ascroft, the owner of the infested locality, and the co-operation of the Manchester Waterworks Committee, whose chairman, the late Sir Bosdin Leech, had been interested in this matter since the insect first appeared in the district, Mr. A. W. B. Edwards, the forester of the Manchester Corporation, has superintended the collection of infested cocoons for shipment to Canada. The cocoons were shipped packed in moss and litter in ten seven-pound biscuit tins, the whole being shipped in a single crate. This method of shipping has proved successful, if arrangements are made to prevent over-heating *en route*. An attempt is now being made to establish the parasite *M. tenthredinis* in the Riding Mountain Forest Reserve in Manitoba, where the sawfly is abundant at the present time. Time only will show whether the colonisation of the parasites has been successful, as it is hoped and anticipated that it will be. Not until the parasitic enemies of the larch sawfly have become sufficiently widespread and abundant to successfully cope with the unusual increase in the numbers of the sawfly in any particular locality, as appears to be the case in Europe, will outbreaks cease to have the serious consequences which have been experienced in the past in Canada and the United States.

THE ECONOMIC VALUE OF THE LARCH.

The value of the larch or tamarack for the purposes of afforestation and timber production is often lost sight of or minimised in Canada, owing to the fact that we have at present an abundance of those species of forest trees producing timber of a higher general commercial value.

In reply to my request for some information as to the uses of the larch in Canada, Mr. R. H. Campbell, Director of the Forestry Branch of the Department of the Interior, has kindly given me the following information. One of the most important uses of the larch in Canada is for railway ties. The wood lasts well in contact with the ground. Owing to the fact that it holds a spike well it is used extensively on curves in railway lines. It is also used in shipbuilding for ship's timber and knees, particularly for the latter purpose. When wooden ship-building was in a flourishing condition in Canada, large quantities of larch were used for that purpose, but with the decline of the industry the use of the larch has greatly diminished. The timber is also used for fences, telegraph poles and for mining timbers. It is sometimes sawn into lumber, especially

in the north-west and is used for lath and shingles when better woods are not readily available. To a small extent it is employed in the manufacture of cars, agricultural implements and cheap furniture.

In speaking of the larch in the Riding Mountain Forest Reserve, Manitoba, Mr. J. R. Dickson[1] states: "Owing to the strength of this timber, its durability in contact with the ground combined with its great length and small taper, it is a very valuable species for posts, rafters, fencing and construction work generally. Moreover, it is the favourite and highest priced fuel wood on the local markets. But although for these reasons it is a tree of vast utility to the settler, yet to the mill man it is a "light bodied" tree, normally of too small a diameter to cut into profitable saw material. For this reason larch should not be favoured over white spruce on good soils, but for all the more poorly drained areas it is the species to be favoured." The American larch is said to be an intolerant species and is nearly always found in either pure stands of trees of similar age or as the dominant tree in a mixture.

As we have seen, the sawfly prefers the European Larch (*Larix europaea*) to the native North American species (*Larix americana.*) The European larch, however, is probably preferable for reforestation purposes. In a valuable paper "Reforestation of the Natural Forests"[2] Mr. W. T. Cox states: "European larch is a desirable tree for commercial planting in the United States. It is a rapid grower and produces heavy, hard, strong, flexible and very durable wood. It has been successfully grown in the United States from New England to South Dakota and South to Kansas and Virginia, to which general region it is adapted for commercial planting. It does well in eastern Washington also. European larch is rather fastidious in regard to soil, requiring one that is deep, light, fresh and well-drained and does not flourish in swamps as does the American larch. It may be established by direct seeding, or by planting two-year-old seedlings or transplants from the nursery. It should be sown or planted in mixture with other species rather than pure, in a proportion of one larch to two or more trees of other species, the trees being spaced four to six feet apart each way."

In the arboretum of the Central Experimental Farm, Ottawa, both the European larch planted in 1889 and the Siberian larch planted in 1896 have been found hardy and able to stand the severe winters.

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[1] "The Riding Mountain Forest Reserve." *Bull. No. 6, Forestry Branch, Dept. Interior, Canada, 42 pp. 18 pl. 1909.*

[2] *Bull. No. 98. Forest Service, U.S. Dept. Agriculture, p. 53.*