THE BIOLOGY AND EXTERNAL MORPHOLOGY OF THE HEMLOCK LOOPER, LAMBDINA FISCELLARIA FISCELLARIA (GUENÉE), IN NEWFOUNDLAND (LEPIDOPTERA, GEOMETRIDAE)

by

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INTRODUCTION

The hemlock looper, Lambdina fiscellaria fiscellaria (Guenée), has been an important forest pest in Newfoundland for many years. Outbreaks have been reported from widely separated parts of the Province, and in most cases, there has been a high mortality of balsam fir, Abies balsamea (L.) Mill. (Fig. 1). A study of the insect was initiated in the spring of 1950, in Newfoundland, by the Division of Forest Biology, Dominion Department of Agriculture. The object of the study was to determine what factors influence the rise and fall of looper populations. Unfortunately, the outbreak had reached its peak when the study was started. In 1951 populations had fallen to an endemic level, resulting in rather meagre information on many aspects of the investigation.

Biological and population studies of the hemlock looper and associated insects were carried out by the writer and an assistant at a summer field station established near Lake St. George, St. George's District, Newfoundland. The station was used from May to September in 1950 and 1951. Studies on the external morphology of all developmental stages of the species were made at the Dominion Entomological Laboratory, Fredericton, N. B. Morphological studies were conducted to discover if specimens found in Newfoundland and New Brunswick are conspecific. Although climatic conditions and forest composition are fairly similar in both provinces the looper has never been a serious pest in the latter. The results of these biological and morphological investigations are contained in the following sections.

TAXONOMY

Ellopia fiscellaria Guenée (8).--Barnes and McDunnough (1).--McDunnough (12)
Ellopia flagitiaria Guenée (8)
Therina fiscellaria (Guenée) Hulst (11a)
Therina fiscellaria var. *peccataria* Swett. (18)
Therina fiscellaria var. *johnsoni* Swett. (18a)
Ellopia turbataria Barnes and McDunnough (1).--McDunnough (12)
Lambdina fiscellaria fiscellaria (Guenée) Capps (2)

Lambdina fiscellaria fiscellaria (Guenée) is a member of the family Geometridae, subfamily Ennominae, tribe Cingiliini. The genus is primarily North American but contains a few Central American species. It is closely allied to *Besma* and to the Old World *Ellopia*. The genus *Ellopia*, to which *L. fiscellaria fiscellaria* (Guenée) had been previously assigned, was revised by Capps (2), who concluded that no true *Ellopia* species occurred on the American continents. He proposed the new generic name *Lambdina* for all American species hitherto assigned to *Ellopia*. Capps also designated the previously distinct species *Ellopia somniaria* Hulst as a variety of *fiscellaria*.

L. fiscellaria fiscellaria (Guenée) is similar to other varieties of the species. Two of these, *L. fiscellaria pultaria* (Guenée) and *L. fiscellaria laeta* (Hulst) occur in Florida, Arizona and New Mexico. For the present only those occurring in the Northern States and Canada, namely, *L. fiscellaria lugubrosa* (Hulst) and *L. fiscellaria somniaria* (Hulst), will be considered. Capps (2) does not make a very definite distinction between the varieties *fiscellaria* and *lugubrosa*, and states, "The name *lugubrosa* should be applied to the northern and rather dark, heavily dusted with fuscous, variety of *fiscellaria* on *Abies* and *Tsuga*". Three specimens which agreed very well with this description were reared in Newfoundland. Concerning *L. fiscellaria somniaria* (Hulst), Capps writes, "Specimens of *somniaria* are larger, a slightly ocherous with the dusting of fuscous more intense than in specimens of typical *fiscellaria* .... the name *somniaria* should be applied to the northwestern variety of *fiscellaria* on *Quercus*". De Gryse and Schedl (5) studied the larval structure of the two varieties and found the mandibular teeth of *fiscellaria* to be sharp while those of *somniaria* were blunt and sometimes almost obliterated. Capps also compared larval mandibles and noted that differences were not constant enough to permit an accurate separation. The present study of larvae from localities in New Brunswick indicates that the variation described by de Gryse and Schedl is not confined to *somniaria*. Only four New Brunswick specimens were available but in all cases the teeth were blunt and in one instance practically obliterated. A similar study on Newfoundland material showed that, although there were individual differences the teeth were sharp and clear cut. The only morphological difference between New Brunswick and Newfoundland material was in the structure of the larval mandible.

Lambdina fervidaria was described as new by Hübner in 1831. Hulst (11) separated *somniaria* from *fervidaria* mainly on the basis of colour, and on the width of the borders of the transverse bands of the wings. Capps feels that _fervidaria_ represents an oak feeding form, and is a colour variety or race of _fiscellaria_. If Capps is correct Hübner's name should take precedence and be the specific name for the complex now recognized under _fiscellaria_.

The similarity of the _fiscellaria_ varieties and the confusion which exists in their identity indicate that the members of the group are very closely related. As the differences in most cases are confined mainly to colour, there might be some justification for amalgamating certain varieties and considering them as geographical races.

DISTRIBUTION

Lambdina fiscellaria fiscellaria (Guenée) is a common North American species. According to Watson (20) its range extends from the Atlantic to the midwestern states and Manitoba. Craighead (4) states that it is distributed from Georgia to Wisconsin and southwestern Ontario, and northeasterly to Newfoundland. Monroe (13) claims that it occurs in British Columbia with *L. fiscellaria somniaria* (Hulst). It is a common species in Maine, the Maritime Provinces, and Newfoundland. Accounts in the literature indicate that its distribution in North America coincides with the distribution of the various species of hemlock (*Tsuga*) and balsam fir, its principal host trees.

EPIDEMIOLOGY

The history of the hemlock looper in Newfoundland shows that four periods of severe attack have occurred since 1912. Swaine, cited by de Gryse and Schedl (5), reported a severe outbreak that defoliated many acres of balsam fir in St. George's District in 1912 and 1913. He also reported severe attacks near St. John's in 1925 and assumed that they started in 1920. About 1930 two separate infestations killed extensive areas of balsam fir in the St. Barbe District (3). From 1947 to 1950 outbreaks developed more or less independently in the southern, western, and northern regions of the Island. This historical background suggests that looper attacks in Newfoundland follow a cycle of 10 to 15 years. Heavy outbreaks exist for about three years. In addition to the outbreaks reported from Newfoundland, de Gryse and Schedl (5) cite records of severe attacks in Michigan, Wisconsin, New York, Maine, Ontario and Quebec.

The looper is generally described as a defoliator of hemlock, <u>Tsuga</u> <u>canadensis</u> (L.). In Ontario de Gryse and Schedl (5) found that hemlock stands most susceptible to attack are those over 80 years old, occurring as pure stands, or mixed to a small extent with white pine, <u>Pinus</u> <u>strobis</u> L. According to Watson (20) outbreaks in Quebec have been more severe in pure stands of balsam fir than in a mixed forest. He also states that severe defoliation of balsam fir has occurred in stands containing up to 45 per cent of spruce. Observations in Newfoundland indicate that most infestations are associated with stands containing 80 to 90 per cent mature balsam fir. Intensity of attack appears to vary directly with the age class and vigour of the stand.

METHODS OF STUDY

Extensive sampling of all stages shows that the larval and pupal stages were best for population studies. In the early part of the season sampled trees were felled over a large canvas mat. After the removal and additional jarring of the branches, first instar larvae were collected from the mat. The same trees were used for determining the percentage of hatch. The sampling unit in this case was the lower part of the stem.

When larvae were larger two methods of collecting were employed. The procedure in the first method was as follows: the mat was placed on the ground at the base of the sample tree, which was then beaten with a 10-foot pole. The larvae were collected from the mat and the population was expressed as number of larvae per tree. The second method was the branch selection technique described by Morris (14) for spruce budworm sampling on standing trees. The crown was divided into four vertical zones by ocular estimation. Two branches were removed from each zone by means of pruning shears attached to an aluminium pole 25 feet long. Each branch was lowered to the mat. Its length and mean width were recorded and the population was expressed as number of larvae per 100 square feet of foliage.

In conjunction with sampling, a study was made of pupal distribution on the tree. Ten balsam fir trees were divided into 4-foot sections. Each section was examined for old and new pupae. Sampled trees were representative of the stand, and had a D.B.H. of 7 inches, a height of 40 to 50 feet and a crown depth of 20 to 25 feet.

Larvae and pupae collected for population studies were reared for parasites. Data on moulting, duration of stages, feeding and oviposition were obtained from experiments conducted in a laboratory tent. Individual rearings were carried out in 6- by 1-inch shell vials, the tops of which were covered with cheese cloth. Group rearings were made in cages 16 inches high, 12 inches wide and 8 inches deep. These cages were constructed of wood, with cloth backs and removable glass fronts. Foliage placed in the cages was held in metal containers filled with water.

Measurements of larval head widths were made with a binocular microscope, one ocular being equipped with a calibrated micrometer.

Equipment used in the study of larval responses to light consisted of a tightly sealed cardboard carton, 8- by 9- by 11-inches. A circular hole one inch in diameter was cut in one end, into which a shell vial was fitted. Larvae were dropped in the box through an opening cut in the top, which was sealed after each experiment had been started.

Data on fecundity were obtained from adults which deposited their eggs in sleeve cages made of wire screening. A male and a female were placed in each cage, which was then pulled over a branch of a living tree. After the female died the cage and the branch were examined for eggs, and the female was dissected for oocytes.

Anatomical studies were made during the winter on preserved material. A preservative, K.A.A.D., developed by Peterson (15) for preserving larvae was used. They were placed in the K.A.A.D. solution for an hour after which they were transferred to 70 per cent alcohol. Pupae and adults were placed directly in 70 per cent alcohol. Before the adults were dissected they were treated with a 10 per cent potassium hydroxide solution to remove soft tissues and bring out sutures more clearly. Dissections were done under glycerine whenever possible. In the immature stages only characteristics thought to be significant taxonomically were examined.

BIOLOGY

Larvae

Number and Duration of Instars

De Gryse and Schedl (5) state that five larval instars occur in Ontario. In Newfoundland there are four instars. Data on the duration of instars are summarized in Table 1. The developmental period of each instar is shown as an average for 1950 and 1951. The total larval period ranges from 43 to 55 days. The average is 48.9 days.

The measurements of head widths of over 400 field-collected larvae fall within four rather distinct groups (Table 2). These coincide with the theoretical head widths, which is additional evidence of four instars under field conditions. In calculating the theoretical head widths, the average ratio of increase was used. The growth ratio was found by dividing each arithmetic mean by the preceding one, and finding the average of the three ratios. The ratio between the first and second instars was 1.652; between the second and third 1.691; and between the third and fourth 1.657. The average ratio was 1.667. The theoretical head widths of the later instars were calculated by multiplying the average width of the first instar by successive powers of the ratio 1.667.

The occurrence of four instars in Newfoundland may be considered as normal for the region. Taylor (19) quotes Dyar (1890) as follows: "If two sets of observations show a different number of stages for the same insect, but each follows its own

TABLE 1

Duration of Larval Instars of *Lambdina fiscellaria fiscellaria* (Guenée) Expressed in Days

Rearing no.	I Instar	II Instar	III Instar	IV Instar
1	12	9	9	15
2	13	10	9	16
3	13	9	9	15
4	14	10	11	13
5	14	9	11	17
6	15	9	10	17
7	14	9	9	16
8	15	10	10	16
9	16	9	9	15
10	15	11	10	16
Total days	141	95	97	156
Mean	14.1	9.5	9.7	15.6

TABLE 2

Summary of Head Width Measurements of Four Larval Instars of <u>Lambdina fiscellaria fiscellaria</u> (Guenée) Collected in the Field

	I Instar	II Instar	III Instar	IV Instar
Number measured	120	101	101	105
Range	.37-.43 mm.	.60-.72 mm.	1.00-1.38 mm.	1.65-2.05 mm.
Arith. mean	.403 mm.	.666 mm.	1.126 mm.	1.866 mm.
Calc. mean (R = 1.667)	.403 mm.	.672 mm.	1.220 mm.	2.034 mm.
Probable error of mean	±.00125	±.00182	±.00560	±.00593
Standard deviation	±.0185	±.0266	±.0832	±.0081
Coeff. variation	4.59	3.99	7.39	.434

progression, we may conclude that this variation is actual; but if either set shows a lack of regular progression that one we must regard with suspicion". Considering the actual means of the four instars in relation to the calculated means, it is evident that there is a close approximation to a uniform growth ratio, throughout the four larval instars.

The standard deviation for each of the four instars is relatively small compared to the corresponding mean, as shown by the low coefficients of variation. The low probable error of the mean indicates that the value of the mean is fairly precise.

Field Development

Hatching.--Hatching commenced between June 6 and June 12, and continued until late June or early July. Field observations made in the latter part of June, 1951, suggest an explanation for the long hatching period. A considerable number of recently emerged first instar larvae were found clinging to strands of sphagnum moss, and leaves of *Cornus canadensis* L. growing in cool, shaded locations, on old stumps and logs. Eggs had been deposited on these sites the previous fall, and hatching had been retarded by the lower temperatures. Eggs laid in exposed places such as on tree trunks and branches, etc. were exposed to the sun and therefore hatched earlier. When eggs laid in oviposition cages were kept in the laboratory, all at the same temperature, hatching was completed three days after the first larva emerged.

Occurrence of Instars.--Data on the occurrence of instars in the field were obtained from periodic collections (Figure 2). Larvae in the first, second, third, and fourth instars were collected on June 12, June 22, July 1, and July 14 respectively. The corresponding peaks of development occurred on June 1, July 5, July 14, and August 2. The last larva was collected on August 18. There was a considerable overlapping of instars (Figure 2).

Larval Food

De Gryse and Schedl (5) report that third and fourth instar larvae can complete their development on a great number of food plants. They concluded that the first and second instars are restricted to hemlock as their food plant. Watson (20) writes, "In the early (instars), the caterpillars are found feeding on all kinds of small vegetation such as Amelanchier, Acer rubrum, A. spicatum, Vaccinium, and Cornus. Older caterpillars are sometimes found on birch but their presence is probably only casual .... Under cage conditions third (instar) caterpillars were successfully brought to maturity on a diet of birch foliage". He also states that first instar larvae cannot subsist on old foliage of either spruce or balsam fir.

A few experiments were carried out on Newfoundland material to discover what kinds of foliage were suitable as larval food. Only plant species usually found in infested areas were tested. The data obtained from these experiments are summarized in Table 3, which shows that newly hatched larvae cannot survive when restricted to the following diets: 'old' balsam fir needles, 'old' white spruce needles, sphagnum moss, alder, mountain ash, raspberry, and Cornus. Some feeding occurred on the last four species. One specimen fed on raspberry and two on Cornus moulted to the second instar. These were abnormally small. First instar

TABLE 3

Summary of Experiments to Determine Kinds of Foliage Suitable as Food for Larvae of *Lambdina fiscellaria fiscellaria* (Guenée)

Diet	Date	No. living	Instar	Percentage dead
Balsam fir, *Abies balsamea* (L.) (Mill.), old foliage	6/17	50	1st	0
	6/19	26	1st	48
	6/21	12	1st	76
	6/23	0	1st	100
White spruce, *Picea glauca* (Moench) Voss., old foliage	6/17	50	1st	0
	6/19	25	1st	50
	6/21	0	1st	100
Alder, *Alnus rugosa* (Du Roi) Spreng. var. *americana* (Regel) Fern.	6/3	50	1st	0
	6/7	44	1st	12
	6/11	39	1st	22
	6/15	16	1st	68
	6/17	11	1st	78
	6/19	1	1st	98
	6/21	0	1st	100
Mountain ash, *Sorbus americana* Marsh.	6/5	50	1st	0
	6/9	30	1st	40
	6/13	25	1st	50
	6/17	15	1st	70
	6/19	10	1st	80
	6/20	0	1st	100

(cont'd)

TABLE 3 (cont'd)

Diet	Date	No. living	Instar	Percentage dead
Cornus canadensis L.	6/29	10	1st	0
	7/7	5	1st	50
	7/9	4	1st	60
	7/11	2	2nd	80
	7/17	0	2nd	100
Sphagnum moss	6/29	10	1st	0
	7/1	4	1st	60
	7/3	2	1st	80
	7/5	0	1st	100
Raspberry, *Rubus idaeus* var. *aculeatissimus* Regel & Tiling	6/17	10	1st	0
	6/22	3	1st	70
	7/10	1	2nd	90
	7/22	0	2nd	100
Balsam fir, old foliage	7/5	40	1st	0
	7/8	16	(after 7 days feeding on new foliage)	60
	7/12	9		77
	7/14	5	1st	87
	7/16	2	1st	95
	7/21	0	1st	100
White spruce, old foliage	7/6	40	1st	0
	7/8	30	(after 7 days feeding on new foliage)	25
	7/10	12		70

(cont'd)

TABLE 3 (cont'd)

Diet	Date	No. living	Instar	Percentage dead
White spruce, old foliage	7/14	2	1st	95
	7/16	0	1st	100
Balsam fir, old foliage	6/27	20	2nd	0
	7/6	15	2nd	25
	7/8	5	4 ... 3rd; 1 ... 2nd	75
	7/10	3	3rd	85
	7/31	0	4th	85
White spruce, old foliage	6/27	20	2nd	0
	7/3	20	2nd	0
	7/6	4	2nd	80
	7/8	2	2nd	90
	7/9	0	2nd	100
Raspberry	6/27	20	2nd	0
	7/3	20	2nd	0
	7/8	4	2 ... 2nd; 2 ... 3rd	80
	7/12	3	1 ... 2nd; 2 ... 3rd	85
	7/18	1	3rd	95
	7/27	0	3rd	100

larvae which had been fed new balsam fir, or new spruce foliage for seven days were transferred to old foliage of the same species. None of these survived, although a few moulted. Newly hatched larvae under similar conditions were reared successfully to pupation on new shoots of balsam fir or white spruce, or foliage of birch (Betula papyrifera Marsh.) or maple (Acer spicatum Lam. and A. rubrum L.).

All second instar specimens fed old spruce foliage died. Only three of 20 supplied with old balsam fir foliage pupated. Some second instar larvae provided with raspberry leaves moulted to the third instar, but did not complete development.

Third and fourth instar larvae were reared to the pupal stage on old foliage of balsam fir and white spruce. The last two instars have occasionally caused serious defoliation of birch and maple, but only when these species occur in stands of severely defoliated balsam fir. Very light feeding by these instars has been observed on alder and mountain ash.

Cannibalism was evident in all experiments where larvae were provided with unacceptable diets.

Longevity without Food

A starvation experiment conducted by Watson (20) showed that first instar larvae cannot survive more than four days without food. The majority of his specimens died on the second or third day. Hopping (10) carried out a similar experiment on L. fiscellaria somniaria (Hulst) and found that newly hatched larvae of this species could live from 7 to 14 days. Observations made in Newfoundland corroborated those of Watson.

Description of Feeding

Larval feeding is done without any shelter or concealment, and is rather inconspicuous during the first month. Third and fourth instar larvae feed voraciously and very wastefully. Needles are rarely entirely consumed. They are partially eaten or have only the epidermis on one side removed. On a heavily infested tree practically every needle will show evidence of feeding. This injured foliage dries out and imparts the reddish colour typical of a heavy outbreak.

Migratory Habits

All authors who have investigated the hemlock looper have made special mention of the wandering habits of larvae. In the first two instars larval movement is not very apparent. First instar larvae have been seen crawling up the tree trunk. Apparently they were moving away from hatching sites in search of food. In the third and fourth instars, larval movement is very conspicuous in a heavily infested area. There seems to be a constant inter- and intra-tree movement. For example, on a tree 7 inches D.B.H. 53 third instar larvae were counted on the basal four feet of the stem, and many more were suspended from the branches on their silken threads. By means of these threads they drop to lower branches of the same tree, to other trees or to the ground. Those reaching the ground ascend the nearest tree or stump. Movement appears to be intensified on bright days. On rainy days larvae can sometimes be seen hanging motionless from the branches on very short threads.

Phototactic Behaviour

Several experiments were carried out to determine the reactions of larvae to diffuse light. The equipment used has been described in a previous section. Ten first instar larvae were dropped in the empty carton. After four hours they had all migrated to the vial. When the experiment was repeated with balsam fir branches in the carton, six larvae migrated to the light after four hours. After nine hours the container was opened and the remaining four larvae were found feeding on new foliage. Ten larvae were established on new balsam fir shoots. There was no migration to the vial. When larvae were starved for 24 hours and placed in the empty carton they came to the light in less than an hour.

Five first instar larvae were placed in the shell vial and the carton was placed in the direct rays of the sun. The temperature outside the vial was 88° F. There was no migration away from the light. When this series of experiments was repeated using second and third instar larvae similar results were obtained.

After larvae had been in the fourth instar for a short period, they would not come to the vial. When five larvae were placed in the vial four crawled into the carton. The one remaining had reached the prepupal phase of development.

These experiments suggest an explanation for larval movement. The first three instars react positively to light. This reaction is strong in starved larvae, and enables them to reach suitable feeding sites at the branch tips. When a food supply is found the response is either weakened or the photic stimulus is replaced by some other stimulus. Crowding at the branch tips forces some larvae to drop on silken threads. As larvae grow larger this crowding becomes more pronounced, and more larvae drop from the branches. The positive response to light causes those on the ground to ascend the nearest tree or stump. Those on the branches crawl towards the periphery of the tree. Thus there is a continuous movement. Prior to the prepupal phase, a photonegative stimulus causes larvae to seek secluded, darkened sites for pupation.

It appears that high temperatures do not affect the photic response. This conclusion should be verified under better experimental conditions.

Pupae

Time and Duration of the Pupal Stage

The first pupae were collected in the field on August 2. The earliest pupation of field collected larvae occurred on July 30. Material reared from the egg in cages began pupating as early as July 14. The maximum number of pupae occurred in the field on August 16. The time spent in the pupal stage was determined from 20 individual rearings. It ranged from 20 to 23 days, averaging 22 days. The duration of the pupal period was the same for both males and females. Dethier (6) states that this species overwinters in the pupal stage.

Pupation Sites

De Gryse and Schedl (5) found that the preferred pupation site was on the ground, under fallen leaves, branches, and small stones in the moss and debris. Dethier (6) writes, "Pupae are fastened parallel to the balsam needles by a few strands of silk". In Newfoundland the only pupae found on the forest floor were not more than six inches from a tree or stump. Only rarely were any collected from damp sites. They were never found attached to balsam fir needles as described by Dethier. Favoured pupation sites were dry, decayed stumps, bark crevices, among the lichens on the tree trunk, and behind pieces of bark.

Data obtained from studies of pupal distribution on the tree are summarized in Table 4. It will be observed that the number per four foot section decreases from the base of the tree to the top. A few pupae were found on the branches, in accumulations of frass and dead needles, or among lichens. Over 90 per cent of those on the tree pupated on the stem. Of those found on the stem 62.2 per cent occurred below the crown.

Adults

Emergence

Adult emergence from field-collected pupae started on August 21, and continued until September 17. Moths were first observed in the field two days after the laboratory emergence dates. Females have been seen in the field as lata as October 20.

The daily emergence of adults for both males and females is shown in Table 5. The mean emergence dates for males was August 30 preceding that of females by four days. Male moths

TABLE 4

Distribution of *Lambdina fiscellaria fiscellaria* (Guenée) Pupae on Ten Balsam Fir Trees, Seven Inches D.B.H., Divided into Four-foot Sections

Section no. from base	No. observations	Pupae per four-foot section			Per cent pupae per four-foot section		
		Mean	S.D.	S.E.	Mean	S.D.	S.E.
1	10	31.8	±16.9	±5.3	23.2	±7.7	±2.4
2	10	19.7	± 7.8	±2.4	14.3	±5.1	±1.6
3	10	17.8	± 9.9	±3.1	12.0	±3.6	±1.1
4	10	17.1	± 8.5	±2.7	12.2	±4.0	±1.2
5	10	11.9	±10.7	±3.3	7.7	±4.9	±1.5
6	10	11.9	±10.9	±3.4	7.5	±4.4	±1.4
7	10	7.2	± 7.6	±2.4	4.8	±4.1	±1.3
8	10	8.2	± 6.9	±2.2	5.7	±3.1	±1.0
9	10	8.2	± 9.9	±3.1	5.3	±4.8	±1.5
10	10	6.9	± 8.6	±2.7	4.8	±4.4	±1.4
11	9	2.8	± 3.3	±1.1	2.1	±2.4	± .7
12	2	.4	± 1.4	± .7	.4	±2.0	± .6

TABLE 5

Daily Emergence of *Lambdina fiscellaria fiscellaria* (Guenée) Adults in 1950

Emergence date		No. males	No. females	Emergence date		No. males	No. females
Aug.	21	2	--	Sept.	3	18	22
"	22	6	1	"	4	20	21
"	24	16	4	"	5	20	21
"	25	18	8	"	6	6	29
"	26	20	10	"	7	3	10
"	27	18	14	"	8	4	25
"	28	23	15	"	9	10	25
"	29	29	30	"	10	--	3
"	30	19	29	"	12	--	13
"	31	31	37	"	14	--	11
Sept.	1	13	32	"	17	1	--
"	2	16	36				

were seen in the field five days before females.

Sex Ratio

Sex ratio studies were made on over 1,000 adults reared from field collected larvae and pupae. Of the adults reared 55.1 per cent were females and 44.9 per cent were males. In material reared from eggs that had been deposited in oviposition cages, the number of males exceeded the number of females; 32.6 per cent being females against 67.4 per cent males. De Gryse and Schedl (5) found that in field collected specimens 89.2 per cent were males and 10.8 per cent were females. In rearing experiments they found the percentages of males and females to be 67.6 and 32.4 respectively.

Longevity

The life-span of the unfed adult looper was determined from 50 adults of each sex reared in oviposition cages; a male and a female to each cage. Females lived from 10 to 17 days; males from 8 to 10 days. The average length of life of females and males was 14.3 and 9.4 days respectively. Two females fed diluted corn syrup lived 23 and 24 days respectively. When the adult feeds, the extended antennae commonly are in a state of rapid vibration. The proboscis is completely extended and its tip is immersed in the liquid. Feeding does not last longer than a few seconds at a time.

Flight

During the day moths are usually found in sheltered positions on the tree trunk. A few males have been observed flying on warm days, but all flights appeared to be aimless.

Males are capable of more active flight than females. The latter when fully gravid are very sluggish. When disturbed they fly only a few feet. After some eggs have been deposited they are able to fly longer distances. Generally both sexes are quiescent in the morning and early afternoon, but become active in the late afternoon and evening.

Mating and Oviposition

Mating was observed in only one instance. It occurred at 10:00 p.m. Both the male and the female had recently emerged. They remained _in coitu_ for about five minutes. Normal females had a pre-ovipositional period of from three to five days. Some malformed individuals have been seen ovipositing immediately after emergence.

Eggs are usually deposited singly but sometimes in small groups of two or three. They are attached in such a way that the two poles are free. The eggs are laid on the moss and lichens on the tree trunk, under old bark scales, in the mossy covering of old stumps and logs, and in old webbing, etc., where the previous year's larvae had pupated. They have been seen on balsam fir needles only in one instance under cage conditions. Dethier (6) mistakenly states that eggs are affixed flattened side down in rows on the upper surface of balsam needles.

Fecundity of Females

Fecundity studies were made on females collected in the field in the late larval, and pupal stages. The number of eggs laid by each female and the number of oocytes remaining after death were counted (Table 6). The number of eggs and oocytes per

TABLE 6

A Summary of Fecundity Studies on *Lambdina fiscellaria fiscellaria* (Guenée) Adults

Year	No. of adults	Stage rearing started	Food supplied	Eggs laid		Oocytes in females at death		Total eggs and oocytes	
				No.	Mean	No.	Mean	No.	Mean
1950	50	4th instar and pupae	B. Fir	2,731	54.6	426	8.6	3,157	63.2
1951	37	" "	" "	2,390	64.6	111	3.0	2,501	67.6
"	11	Egg	" "	749	68.1	52	4.7	801	72.8
"	6	"	W. Birch	392	65.3	28	4.7	420	70.0
"	24	"	Maple	1,618	67.4	110	4.6	1,728	72.0
"	15	"	W. Spruce	1,106	73.7	106	7.1	1,212	80.8

female ranged from 39 to 106 in 1950, and from 47 to 122 in 1951. The averages for the two years were 63.1 and 67.6 respectively. De Gryse and Schedl (5) found that the lowest number of eggs per female was 41; the highest 148. The average number was 100.3.

Information on fecundity in relation to diet was obtained from females reared from eggs on different kinds of foliage (Table 6). It will be observed that there was very little variation in egg and oocyte counts, whether females were reared on new balsam fir, birch, or maple foliage. Specimens reared on new shoots of white spruce had a slightly higher count per female.

Natural Control

Parasites

Thirteen species of parasites have been reared in Newfoundland by the writer and the Forest Insect Survey. Five of these were taken at Lake St. George. Table 7 lists the species reared and contains information on their distribution, life histories, and other hosts. Records from New Brunswick and Nova Scotia are also included for comparison.

The most common species on the Island were Aoplus velox (Cress.) and Apanteles sp. nr. flavovariatus (Mues.). A. velox (Cress.) was with one exception obtained from pupal collections and of 557 pupae reared for parasites in 1950; 32.2 per cent were parasitized by this species. The parasite was not reared in 1951 when the looper population had dropped to an en-

TABLE 7, PART 1

Parasites of *Lambdina fiscellaria fiscellaria* (Guenée) in the Maritime Provinces and Newfoundland. A Summary of Their Life History, Abundance, Distribution and Other Hosts

Species and abundance	Stage of host		Adult emergence dates	Distribution		Other hosts (see part 2)
	Larva issued from	Adult issued from		Year col-lected	Regional	
			Diptera, Tachinidae			
Anetia eufitchiae Tns. (R)	P		9/10-10/8	1949	Nfld.	--
Chaetophlepsis orbitalis Webb. (R)	L (U)		3/10	1940,48	N.S.	15,25,35,37
Chaetophlepsis semiothisae Brks. (R)	L (U)		3/8	1944	N.S.	7,13,16,25,32 34,35,36,37
[3]*Compsilura concinnata* Mg. (R)	L (U)		9/2-9/18	1940,48 49	N.S.	3,4,5,11,19,20 22,24,27,38,39
Ictericophyto spinosa (Coq.) (R)	L		S	1949	N.S.	--
[1]*Madremyia saundersii* Will. (C)	L (U)		8/12-9/7	1944-45 48-51	Nfld. N.S., N.B.	1,7,8,10,13,18 21,25,35
[2]*Phryxe pecosensis* Tns. (R)	P		8/27-9/27	1947,50	Nfld.,N.B.	1,8,14,26,28

(cont'd)

TABLE 7, PART 1 (cont'd)

Species and abundance	Stage of host		Adult emergence dates	Distribution		Other hosts (see part 2)
	Larva issued from	Adult issued from		Year collected	Regional	
[4]*Winthemia occidentis* Reinhard (R)	P		S	1950-51	Nfld.	--
Xanthoernestia antennata Tns. (R)	L		10/4	1941	N.B.	12,16,35
Xanthophyto labis Co. (R)	L		10/4	1941	N.B.	30
			Hymenoptera, Ichneumonidae			
Aoplus velox (Cress.) (C)		P	8/26-9/24	1947 49-50	Nfld.	--
[1]*Apechthis ontario* Cress.		P	9/6-9/23	1947,49	Nfld.	1,8,25
Casinaria semiothisae Walley (R)	L (U)		S	1949	N.B.	16,35,36,37
Mastrus aciculatus (Prov.) (R)	P		S	1947	Nfld.	--
Phaeogenes gaspesianus (Prov.) (R)		P	8/15	1946	Nfld.	--
Pimpla aquilonius (Cress.) (R)		P	9/16-9/30	1947	Nfld.	--
[2]*Pimpla pedalis* (Cress.) (R)		P	9/15-9/19	1947	Nfld.	8,9,20,23,33,38

(cont'd)

TABLE 7, PART 1 (cont'd)

Species and abundance	Stage of host		Adult emergence dates	Distribution		Other hosts (see part 2)
	Larva issued from	Adult issued from		Year col-lected	Regional	
	Hymenoptera, Braconidae					
Apanteles sp. nr. flavovariatus (Mues.) (C)	L		S	1945,50-51	Nfld. N.B.	--
Rogas sp. (R)	L (U)		8/28-9/3	1947	Nfld.	2,6,7,17,29,35,40
Zele sp. (R)	L (U)		8/21-8/29	1950	N.B.	25,26
	Hymenoptera, Sclerionidae					
Telenomus dalmani (Ratz.) (C)		Egg	S	1950-51	Nfld.	--

Key to symbols used in table: (C) = common; L = larva; P = pupa; (R) = rare; S = spring or summer, (when the adult parasite emerges in the spring or summer, the date of emergence is unknown. Such material is incubated in the laboratory); U = ultimate instar (where no symbol occurs after L the instar from which the parasite emerged is not known).

(cont'd)

TABLE 7, PART 1 (cont'd)

Introductions: [1]to N.B., N.S. and Nfld., against C. fumiferana (Clem.); [2]to N.B. and N.S. against C. fumiferana (Clem.); [3]to N.B. and N.S. against S. salicis L.; [4]to Nfld. against L. fiscellaria fiscellaria (Guenée).

TABLE 7, PART 2

List of Other Hosts of Parasites of *Lambdina fiscellaria fiscellaria* (Guenée)

1. *Acleris variana* Fern.
2. *Acronicta dactylina* Grt.
3. *Acronicta fragilis* Gn.
4. *Acronicta oblinita* A. & S.
5. *Anisota rubicunda* Fab.
6. *Autographa* sp.
7. *Caripeta divisata* Wlk.
8. *Choristoneura fumiferana* (Clem.)
9. *Cimbex americana* (Leach.)
10. *Cingilia catenaria* Dru.
11. *Datana ministra* Dru.
12. *Ectropis crepuscularia* Schiff.
13. *Elaphria versicolor* Grt.
14. *Erranis tiliaria* Harr.
15. *Eufidonia discospilata* Wlk.
16. *Eupithecia filmata* Pears.
17. *Eupithecia palpata* Pack.
18. *Feralia jocosa* Gn.
19. *Graptolitha* sp.
20. *Hemerocampa leucostigma* A. & S.
21. *Hydromena divisaria* Wlk.
22. *Hyphantria textor* Harr.
23. *Malacosma disstria* Hbn.

(cont'd)

TABLE 7, PART 2 (cont'd)

24. *Nematocampa limbata* Haw.
25. *Neptyia canosaria* Wlk.
26. *Nyctobia limitaria* Wlk.
27. *Nymphalis antiopa* L.
28. *Oporina autumnata* Swett.
29. *Paraphia pinata* Pack.
30. *Parharmonia* sp.
31. *Pero morrisonarius* Hy. Edw.
32. *Protoboarmia porcelaria* Gn.
33. *Schizura ipomeae* Dbldy.
34. *Semiothisa bisignata* Wlk.
35. *Semiothisa granitata* Gn.
36. *Semiothisa oweni* Swett.
37. *Semiothisa sexmaculata* Pack.
38. *Stilpnotia salicis* L.
39. *Telea polyphemus* Cram.
40. *Xylena antennata* Wlk.

demic level, and only eight pupae were collected. *Apanteles* sp. nr. *flavovariatus* (Mues.) parasitizes second instar larvae. Upon the completion of feeding the parasite maggot issues from the empty skin of the dead host larva. The cocoon is small and white, and is attached to the twigs or needles of balsam fir trees. In 1950 only a few specimens were taken; in 1951, 30.0 per cent of 173 larvae collected died from parasitism by this species. The difference is not necessarily significant, and can be explained by a change in rearing methods. In 1950 large numbers of looper larvae were reared on living trees in large outdoor cages. The habits of the parasite were not understood at that time and undoubtedly many of the cocoons were overlooked. In 1951 parasitism was determined from field collected larvae reared individually, which gave more reliable results in estimating parasitism.

Disease

A disease of the hemlock looper was first reported from Newfoundland in 1949 (16). In 1950, it was prevalent in all outbreak areas. R. D. Sheppard (17) reported that most of the larvae collected at Bonne Bay, St. Paul's Inlet, and Parson's Pond were diseased and many were dead. A co-operator at Hawkes Bay also noted the presence of many dead specimens at the time of collecting.

Mortality from disease has been observed only in third and fourth instar larvae, and pupae. The first diseased specimens were seen in the field on August 2 in 1950 and July 26 in 1951. Dead larvae were flaccid, and generally were suspended from the needles by their ventral and anal prolegs. Sometimes they were stretched full length on a twig or leaf. Some specimens became covered with a white mould a few hours after death. Preliminary observations by D. Elgee at the Fredericton Laboratory suggested that the disease was a polyhedral virus. However, additional investigation by Dr. F. T. Bird indicated that uric acid crystals were mistaken for polyhedral bodies in the earlier examination. Bird expressed the opinion that the disease was a capsule virus. More detailed studies are required before a definite determination can be made.

Table 8 is a summary of data on the relationship between larval population and mortality. Although these data are based on observations in only two areas they indicate that the effectiveness of this disease is dependent on a high larval population. Field mortality by dates of third and fourth instar larvae, and pupae is shown in Table 9. It will be observed that except for two instances the percentage of dead larvae declined steadily after the first collection. An explanation for this apparent reduction in field mortality is that many dried out cadavers were lost through the action of wind and rain. Actual field mortality is much closer to the first percentage than it is to the average.

In 1950 many of the emerging adults were malformed. This was thought to be the result of unsatisfactory rearing conditions. In 1951 malformed adults were rare. It is possible that this malformation was caused by disease that had not killed the pupae.

TABLE 8

Summary of Collections of Third and Fourth Instar Larvae and Pupae of *Lambdina fiscellaria fiscellaria* (Guenée), Showing Relationship between Population and Mortality

Locality	Year	No. collected		Percentage mortality		Percentage survived
		Total	per 100 sq. ft. foliage	Field	Laboratory	
Spruce Brook	1950	549	28.5	25.6	9.4	65.0
Spruce Brook	1951	123	2.4	10.2	9.5	80.3
Little George's	1950	698	48.9	42.6	37.3	27.3
Little George's	1951	3	--	0.0	0.0	100.0

TABLE 9

Field Mortality by Dates of Third and Fourth Instar Larvae and Pupae of <u>Lambdina fiscellaria fiscellaria</u> (Guenée) in 1950

Locality	Date	No. collected		Percentage dead
		Total	per 100 sq.ft. foliage	
Little George's	8/2	202	56.7	71.2
Little George's	8/3	92	50.7	50.0
Spruce Brook	8/4	98	22.2	35.3
Little George's	8/4	196	52.3	34.0
Little George's	8/7	145	49.4	30.3
Spruce Brook	8/8	132	31.4	34.8
Spruce Brook	8/12	130	30.5	25.0
Little George's	8/14	63	35.4	28.0
Spruce Brook	8/15	96	32.0	20.2
Spruce Brook	8/18	93	26.4	13.8

Starvation

Starvation of first instar larvae also plays an important part in terminating outbreaks in areas where complete defoliation of the host trees occurred in the previous year. This was very apparent in one of the study areas. Soon after hatching, large numbers of larvae were observed crawling up the trunks of completely defoliated balsam fir trees. As no food was available, these larvae were not able to survive. The summer population was very light, and was confined to birch trees only.

Mortality from starvation also occurs when eggs are deposited on unfavourable sites. When eggs are laid on moss-covered stumps and fallen trees, hatching occurs, but many of the young larvae are unable to reach suitable food. They are found clinging to moss strands, on which they are unable to feed. Up to 20 newly-emerged larvae have been counted on a stump six inches in diameter. In some cases a small food supply was available in the form of balsam fir or birch seedlings.

MORPHOLOGY

Eggs

Hemlock looper eggs are pale green when first laid. Fertilized eggs turn coppery brown after about two weeks. Unfertilized eggs retain the green colouring, and the chorion collapses. Parasitized eggs change to a dark blue or black. Eggs are broadly oval in shape and have one pole flattened (Fig. 3). Dethier (6) has described the egg as being compressed laterally. The chorion appears to be smooth to the naked eye, but under the microscope it is covered with fine reticulations.

Larvae

First Instar

Head 0.37 to 0.43 mm. wide; colour dark brown to black, except for light membranous ventral areas. The body ground colour is dull white. Each thoracic segment bears a blackish transverse band on the dorsum. The first five abdominal segments are marked by black annulations. The remaining segments are not distinctly banded, but are black, streaked with the white ground colour. As larvae grow older the black colour fades and ten days after hatching the former black markings are distinctly gray. The abdominal segments also have a greenish tinge and the previously indistinct black pinaculae of setae alpha and beta become conspicuous on the first eight segments. Sub-dorsal and sub-spiracular lines extend the full length of the larval body. Two lines extend along the venter between the third paid of thoracic legs and the ventral prolegs. These are not widely separated and may merge at some points.

Second Instar

Head 0.60 to 0.73 mm. wide; colour dark brown, but unlike first instar larvae there are distinct lighter areas, sometimes nearly white, in the frontal and dorsal regions. Larvae usually have a greenish tinge. A broad, whitish, dorsal band with dark markings, and a blackish lateral band streaked with white extends the whole length of the larval body. The lateral borders of the dorsal band are usually whiter than the mesal portion. The pinaculae of setae alpha and beta are very distinct on the first eight abdominal segments. A narrow, black or brownish line extends longitudinally through these pinaculae. The colour of the venter is grayish white. As in first instar larvae, a pair of dark longitudinal lines extend between the third pair of thoracic legs and the ventral prolegs. The venters of the first five abdominal segments are each marked by a medial, blackish, irregular area.

Third Instar

Head 1.00 to 1.38 mm. wide; colour dark brown to black with conspicuous irregular whitish areas. Body colour resembles that of second instar larvae. There is greater individual variation in this instar with larval colour ranging from light green to dark brown.

Fourth Instar

Head 1.65 to 2.05 mm. wide. The amount of light colouring on the head has increased considerably, and in some cases the only darkened areas are those surrounding the bases of setae. Body colour is difficult to describe, as variation is very extensive. The typical pattern is similar to that of third instar larvae.

Head, Frontoparietal Region.--The structure of the head does not differ greatly from that of other lepidopterous larvae. The midcranial sulcus (MCS) lies along the median line of the head and branches into two arms, each of which represents the combined transfrontal and frontogenal sulci. The triangular sclerite enclosed by these sulci is the antefrons (AF) which bears two setae and two setal punctures ventrally (Plate 1, Fig. 3). The coronal suture (CS) is a light coloured line extending along either side of the midcranial sulcus; it branches and continues as the frontal suture (FS) parallel to the transfrontal frontogenal sulci. The sclerite thus marked off is the adfrontal (ADF) which is wide dorsally and greatly narrowed ventrally. The adfrontal sclerite is inconspicuous in the first and second larval instars, barely discernible in the third instar, and clearly defined in the fourth. The coronal and frontal sutures comprise the ecdysial line, along which the head capsules of fourth instar larvae split in moulting. When the first, second and third instars moult the head capsule does not split. The clypeus (CP) is mostly membranous except for a narrow dorsal portion which bears two pairs of setae laterally.

The arrangement of head setae and setal punctures is illustrated in Plate 1. In naming these structures Heinrich's (9) method of separating them into groups and naming each group after its position on the head is followed. The setal pattern of the head differs from that illustrated by Dethier (6) in the relationship between the lateral and posterodorsal setae, and the number of setal punctures. Dethier also shows three setae rather than two setae and one puncture for each adfrontal sclerite.

Labrum.--The labrum varies in colour from greenish-yellow to light brown. The portion surrounding the labral notch is brown. Labral setae are arranged as shown in Plate 2, Fig. 4. They are named according to the method adopted by Heinrich (9), in which all setae on the labrum are divided into median and lateral groups, and named accordingly.

Mandibles.--These are light brown distally and dark brown proximally. Each has two distinct ridges and a trace of a third (Plate 2, Fig. 1). There are eight or nine teeth, five of which are sharp and clear cut. The others are truncate and not so distinct. The mandibles of larvae from localities in New Brunswick differ slightly. All the teeth are truncate, and in one specimen examined they were almost completely obliterated. The eighth and ninth teeth are more clearly defined. Usually, in Newfoundland material, these teeth are either not separated or if so by only a small notch.

Maxillolabial-hypopharyngeal Complex.--This complex comprises the lower lip, and is formed by the union of the maxillae, labium, and hypopharynx (Plate 2, Fig. 4). The maxillae are fused distally. The main part of each maxilla is the stipes (STI), a T-shaped sclerite bearing two setae. One arm of the T extends anteriorly and is hidden between the maxilla and labium. A small triangular sclerite is found at the end of this anterior arm. The cardo (CD), a small sclerite at the base of the maxilla, is marked by a deep notch. Two incomplete, sclerotized rings, each bearing a distal seta, support the two-segmented maxillary palpus (MP) and a mesal lobe-like structure bearing two cones and three setae. The labium consists of a large submentum (SM), membranous except for two small proximal sclerites and bearing two medial setae. A large incomplete ring-shaped sclerite the mentum (M), surrounds the distal end of the labium. This sclerite has a long anterior extension, which acts as a support for the lightly sclerotized hypopharynx. Two small setae are borne on its distal margin. The labial palpus (LP) is composed of a slender, proximal segment and a minute, distal one, each bearing a terminal seta. The palpus arises from a membranous area mesal to the semicircular palpiger (PP). A narrow posterior extension of the palpiger unites with the mentum. The spinneret (SP) is borne distally and is surrounded proximally by a narrow circular sclerite. It is rounded at the tip, and its walls are supported by two traingular lateral sclerites, and an elongate mesal sclerite (Plate 2, Fig. 3). The hypopharynx is continuous with the anterior surface of the labium.

Setal Pattern of the Body.--The setal patterns of the prothoracic, mesothoracic, the first three and last four abdominal segments are illustrated in Plate 3. Fracker's (7) system of using Greek letters to name body setae has been adopted. Several secondary setae, and three setal punctures on the prothorax, observed to be constant in occurrence and position are included but are unnamed.

Crochets.--Crochets occur on the mesal aspect of the prolegs, and have a biordinal arrangement. The hooks near the centre are very minute on the ventral proleg, and are represented by a row of small sclerites on the anal proleg thus forming what Peterson (15) calls an interrupted mesoseries.

Pupae

Pupal length ranges from 11 to 15 mm.; the average of 50 measurements being 13.5 mm. Newly formed pupae are light green in colour, but after 36 hours they take on the characteristic darker colour. This is yellowish-brown with irregular darker brown markings. Variations in the intensity of the latter account for colour extremes which are quite common. The cremaster and the tenth abdominal segment are always much darker than the other body parts.

Abdominal segments two to seven are coarsely pitted anteriorly; segments two to six are reticulate posteriorly, the reticulations being very conspicuous on segments four, five and six. The first abdominal segment is sparsely pitted throughout. A posterior band of segment seven and the whole of segment eight is smooth. The cremaster (CRE) is dorse-ventrally flattened and rugose, and extends posteriorly as two terminal cremastral hooks (CH) (Plate 4). Six smaller hooks are variously located on the cremaster. Spiracles (SPI) are conspicuous on abdominal segments two to seven. The first spiracle is concealed by the wing cover and the eighth has no distinct opening. The anal opening (ANU) occurs on an elevated portion of the venter of segment ten. Dorsally the anterior border of the latter segment bears seven or eight tooth-like structures, the clefts of which are lined by numerous minute hairs.

Male and female pupae can be readily distinguished. The genital opening (GO) of the male is on a small elevation on the posterior part of segment nine. The female opening lies between segments eight and nine. The antennal covering of males is also wider than that of females.

Adults

Colour

The colour of adult loopers varies from a yellowish-brown to a grayish brown. The forewing has two transverse grayish-black lines and a spot of the same colour midway between the lines, near the costal margin (Figs. 4, 5). An ochraeous lateral and mesal band sometimes borders the outer and inner lines respectively. A single transverse band, sometimes bordered laterally with ochraeous, marks the hind wing. A grayish black spot sometimes occurs mesad of this transverse band.

Head and Antennae

The head capsule is a comparatively simple structure (Plate 5, Figs. 1, 2). The most conspicuous sclerite of the frontal region is the antefrons (AF) which is broad and slightly compressed laterally, where it is bounded by the frontogenal sulci (FGS), which extend from the subgenal region to the edge of the antennal sockets. These sulci become somewhat indistinct dorsally. In the base of each sulcus near its junction with the frontoclypeal sulcus is the anterior tentorial invagination (AT). The frontoclypeal sulcus (FCS) delimits the ventral margin of the antefrons, and cuts off a reduced clypeus. The clypeus bears two lateral hairy lobes, the pilifers (P), between which is the small membranous, triangular-shaped labrum (LM). A groove between the mesal edges of the antennal sockets, contains an indistinct whitish line (TFS), which probably represents a reduced transfrontal sulcus.

The vertex and occiput are not separated. A sulcus (OP) arises dorso-laterally in the postoccipital sulcus and extends anteriorly over the vertex almost to the antennal socket. This separates the postgenal and occipital regions. The postoccipital sclerite (POS) borders the occipital foramen dorsally and laterally. Dorsally it projects over the foramen. Two triangular sclerites extend mesally from the postgenae. These are the hypostomae (H) with which the anterior ends of the lateral cervical sclerites articulate. The posterior tentorial bridge (PTB) completely closes off the occipital foramen ventrally.

The female antennae are filamentous; those of the male are bipectinate. Each antenna consists of from 45 to 49 segments. The scape (SCE) is bluntly clavate, slightly curved and larger than the other segments. A blunt antennifer (ANF) forms the articulatory point for the scape. A short carina extends ventrally from the dorso-lateral margin of the antennal socket. The lateral ocellus (O) is located behind the antennal socket and dorsad of the compound eye. The compound eyes are subglobular, and prominent laterally.

Mouthparts

A small membranous labrum is borne distally by the clypeus. Mesad of the ventral edges of the compound eyes are two small triangular sclerites (MD), which represent the functionless mandibles. The maxilla consists of the galea or proboscis (GA), an elongate stipes (STI), a rounded cardo (CD), and a membranous, one-segmented, maxillary palpus (MP) (Plate 5, Fig. 3). The cardo articulates with the postgena and the stipes. The galea articulates with the stipes proximally. The labium is composed of a membranous postlabium (PL), supported by the tentorial bridge, and a sclerotized prementum (PM) which is immovably attached to the head and which bears the three-segmented labial palpus (LP). The prementum narrows ventrally and articulates with the stipes. The basal segment of the labial palpus is long and curved forward. The second segment is about two-thirds the length of the basal; the third segment is small.

Thorax

The Cervix.--The cervix is largely membranous except for a pair of Y-shaped sclerites, the lateral cervical sclerites (LC) (Plate 6, Figs. 2, 3). The stem of the Y articulates with the anterior margin of the prothoracic episternum. The posterior arms lie dorsad of the anterior edge of the prothoracic sternum (SN). The anterior arms articulate with the hypostomal sclerites.

The Prothorax.--The pronotum (PN) is composed of four sclerites (Plate 6, Fig. 1). The proximal sclerite articulates with the anterior margin of the prescutum of the mesothorax, which is depressed at the point of articulation. Separated from the proximal sclerite by a membranous area, is an anterior curved sclerite, to which a narrow sclerite is fused distally. From the latter, two arms, the pronotal arms (PO), extend to fuse with the episternum. The patagia (PT) consist of two lightly sclerotized, hairy lobes, attached to and lying dorsad of the pronotal arms.

The episternum (ES1) of the prothorax is oblong and convex (Plate 6, Fig. 3). Dorsally it merges with the ventral margin of the pronotal arms. Posteriorly it is fused with a lunate sclerite which probably represents an epimeron (EP1). This sclerite is attached to the sternum posteriorly. Anteriorly the episternum is merged with the sternum by a narrow precoxale (PR), which limits the front of the coxal cavity. The basisternum (BS1) extends dorsally and caudally. Anteriorly it articulates with the posterior margin of the pleuron and posteriorly with the spinasternum (SS). The latter is a narrow sclerite, which extends ventrally and posteriorly. It bears a small spine caudally and internally. Its posterior end is widely bifurcate and is attached to the basisternum (BS2) of the mesothorax.

<u>The Mesothorax</u>.--The prescutum (PSC) of the mesothorax is a narrow sclerite along the anterior edge of the scutum (Plate 6, Fig. 1). It is directed ventrally and is almost invisible from the dorsal aspect. Laterally it is produced into two narrow prealars (PRA). The scutum (S2) is very prominent. Behind the tegular incision it is produced laterally into a well developed

suralare (SU) which serves as an anterior fulcrum for wing movement. Directly anterior to the suralare is the subtegula (ST) which is directed into a lateral depression of the scutum. It is triangular in shape and ventrally is attached to an extension of the pleural wing process. Attached to the subtegula is the conspicuous lunate tegula (TG), which is strongly convex anteriorly and which extends posteriorly over the antero-lateral portion of the scutum. Ventrally the tegula is produced to extend beneath the base of the forewing. Posterior to the suralare the margin of the scutum is produced into a forward projecting lobe, the adnotale (AL), which articulates with the first axillary wing sclerite. Behind the adnotale is the adanale (AN) which articulates with the third axillary wing sclerite. The postadanale (PA) is an extension of the postscutellum. It articulates with the epimeron dorsally, and extends anteriorly to support the adanale.

The scutellum (SCL2) lies posterior to the scutum. It is somewhat ovoid in shape and laterally it extends into the membranous axillary cord (AXC) which is continuous with the posterior margin of the wing.

The postscutellum (PC2) is a narrow sclerite concealed between the scutellum and the metathoracic scutum. A large spatulate-like sclerite, the postphragma, extends from it internally.

The pleuron of the mesothorax is divided into an anterior episternum and a posterior epimeron (Plate 6, Fig. 3). The episternum is divided by a horizontal sulcus into a dorsal anepisternum (AE2) and a ventral katepisternum (KE2). The latter merges with the basisternum ventrally. The epimeron (EP2) is V-shaped. The anterior arm extends to the pleural wing process, and the posterior arm articulates with the postadanale. A sclerotized arm extends internally to fuse with a bridge formed by the furcasternal arms. The subalare (SA) is an irregular lightly sclerotized plate above the epimeron. The basalare (BA) is a partially detached curved sclerite lying dorsad of a fold in the dorsal margin of the anepisternum which also may represent part of the **basalare**. The pleural wing process (PWP) forks dorsally. A short arm articulates with the second axillary wing sclerite; a long arm extends anteriorly to join the subtegula.

The mesothoracic basisternum (BS2) is a triangular sclerite invaginated longitudinally to form a mid-ventral suture and an internal keel-like ridge. The furcasternum (FS2) is represented by two narrow sclerites arising from the basisternum posteriorly. Two strongly sclerotized arms extend from them internally and unite to form a strong bridge, to which sclerotized arms from the postero-dorsal regions of the epimera are fused. The pleural apophyses have no connection with the pleural ridges.

The Metathorax.--The metathoracic scutum (S3) is composed of two lobe-like sclerites separated by the scutellum (SCL3) (Plate 6, Fig. 1). Laterally the scutum is produced into a suralare and an adanale, which articulate with the first and third axillary wing sclerites respectively. The anterior edge of the scutellum is greatly enrolled. Posteriorly and laterally it is produced into the axillary cord of the hind wing. The postscutellum lies immediately caudad of the scutellum and is represented mainly by an invagination. A lateral extension of the postscutellum fuses with the epimeron posteriorly to form a postalar bridge.

The metapleuron is divided vertically by the pleural suture, into an anterior episternum (ES3) and a posterior epimeron (EP3) (Plate 6, Fig. 3). The episternum contains a medial ovate membranous area and merges with the basisternum ventrally. Dorsad of the episternum is the small basalare (BA) which is elongate and hooked anteriorly. A lightly sclerotized circular structure, ventrad of the basalare is the basalar pad. The epimeron is V-shaped. The subalare (SA) is situated between the arms of the V. Except for a fork-shaped portion, this structure is lightly sclerotized.

The basisternum (BS3) of the metathorax is narrow, broadly V-shaped, inwardly keeled and has a mid-ventral suture (Plate 6, Fig. 2). Caudally it is produced into a furcasternum (FS3). The apophyses from the furcasternum branch into an anterior and a posterior pair of arms. The anterior arms are short and stout. The posterior arms are longer and fuse with the ventral margins of the epimera.

The Thoracic Appendages

The Legs.--(Plate 7, Figs. 3, 4, 5). The coxa of the prothoracic leg is cylindrical, broadest near the base, gradually curving to a narrower distal apex. In addition to an articulation with the coxal process of the pleuron, it also has an anterior articulation with the elongate trochantin (TN) (Plate 6, Fig. 3). The coxae of the mesothoracic and metathoracic legs are divided by a basicostal suture into an anterior eucoxa (EC) and a posterior meron (M). In addition to the articulation of the meron with the pleuron the eucoxae also articulate with the apices of the furcasterna. Distally the coxae articulate with the trochanter (TR). The trochanters of all three legs are irregular rings articulating with the apices of the coxae, and firmly attached to the proximal apices of the femora (FM). The femora are of approximately equal lengths. The tibia (T) of the prothoracic leg is short and bears a single stout spine proximally on the inner margin. This spine extends the full length of the tibia. The mesothoracic tibia bears distally on its inner margin a pair of spurs of unequal lengths. The hind tibia is long and bears two pairs of spurs of unequal lengths, an apical pair, and a pair just beyond the middle of the inner margin. The tarsi (TA) consist of five segments of which the basitarsi are longest. The apical segments, or distitarsi (DT) bear a pair of sickle-shaped claws, at whose base the unguitractor is conspicuous.

<u>The Wings</u>.--The wings are attached to the body by articular membranes which contain several axillary sclerites (Plate 6, Fig. 1). The humeral plate (HP) at the anterior margin of the base of the forewing articulates with the costal vein (C). The first axillary sclerite (1AX) lies caudad of the humeral plate. It has articulations with the humeral plate, the suralare, the adnotale and the second axillary sclerite (2AX). The latter articulates with the pleural wing process and with a triangular sclerite posteriorly, which in turn articulates with the third

axillary sclerite (3AX). The frenulum (F) of the male consists of a single spine directed obliquely forward from the humeral angle of the hind wing. In the female the frenulum is divided into a group of bristles.

The wing venation is interpreted according to the Comstock Needham system (Plate 7, Figs. 1, 2). As in most Lepidoptera the base of the medius in both wings has been lost for the length of the discal cell. The base of the subcosta of the hind wing makes a prominent bend into the humeral angle. The first radius of the hing wing coalesces with the subcosta for a short distance.

The Abdomen and Genitalia

The Abdomen.--The abdomen is elongate, somewhat conical in shape and composed of ten segments. The last two segments in the male and the last three in the female are modified to form the genitalia, which is retracted within the last visible segment. Each segment is joined by the conjunctival membrane, and the posterior margin of each segment slightly overlaps the anterior margin of the one following. The first tergite is lightly sclerotized but has strong sclerotized lateral margins, which fuse with the metathoracic postscutellum. The first abdominal sternite fuses with the second to form a wide plate beneath the first and second tergites. Segments one to seven bear the abdominal spiracles in the pleural region.

Male Genitalia.--Structures of the male genitalia (Plate 8, Figs. 2, 3) are derived from the modified ninth and tenth abdominal segments.

The claspers (CL) form the most conspicuous part of the male genitalia. These are large, lightly sclerotized double-walled lobes, slightly tapering and blunt at their apices. The basal portion of each clasper is membranous but has narrow sclerotized posterior and anterior borders. The inner membranous wall is attached dorsally to the vinculum (V) while the outer wall has a ventral attachment to the anellus (ANL). The sclerotized posterior border of each clasper bears an articulatory condyle for articulation with the vinculum, and then continues mesally. The opposing ends do not meet, but are joined by a narrow membranous band. This sclerotized extension of the clasper is the transtilla (TA). The vinculum is dorsal in position and consists of two elongate sclerites arranged like a V, having the apex membranous, and the tip of each arm articulating with the tegumen (TE), and the posterior border of the clasper. The tegumen is well developed and forms a roof over the genitalia. The sclerotized anterior border of each clasper has an articulation with the juxta (JX). The latter is a rectangular sclerite attached to the anterior ventral surface of the anellus; it is deeply invaginated, and assisted by the anellus, is produced into an elongate furca (JL) which bears numerous spines on its mesal surface. Immediately posterior to the juxta is the anellus, which is a lightly sclerotized funnel-like cone surrounding the aedeagus (AE). The base of the anellus forms two strongly sclerotized arms which extend to the posterior border of the claspers. It is to these arms that the inner wall of each clasper is attached. The arms of the anellus are also fused with the juxta and the furca. The point of attachment to the furca is marked by a V-shaped notch. The aedeagus is an elongate, sclerotized tube which extends posteriorly and ventrally between the arms of the vinculum, and into the funnel-like anellus. It emerges on the ventral side of the anellus. The posterior end is asymmetrical and spoonlike terminating in a narrow tip or titillator. The rounded side bears several small spines.

Other genitalic structures are the posterior uncus (U), which widens anteriorly to articulate with the gnathos (GN). The latter is U-shaped; its arms curve mesally at their tips and its base curves ventrally and bears numerous spines on the ventral surface. The socii are paired membranous lobes arising near the ventral base of the uncus; each lobe bearing numerous setae. The anus (ANU) is located in the membrane between the arms of the gnathos.

Female Genitalia.--The eversible female genitalia is normally retracted within the seventh segment. The three terminal segments of the abdomen have not been modified as much as those of the male. A pair of setal covered lobes, the ovipositor lobes (1X, X), are found on each side of the anal and oviporus openings (ANU and OPS) (Plate 8, Fig. 1). A pair of sclerotized rods (AP2) extend from the anterior margin of the ovipositor lobes into the body cavity. The eighth segment is well developed. Anteriorly two heavily sclerotized rods (AP1) arise from a deep notch, and extend into the body cavity. The sclerotized portions of the seventh and eighth segments are separated by a wide membranous area. The ostium bursae (OS) which is the external opening of the bursa copulatrix, lies in an invaginated pocket in the ventral part of this membrane. A sclerotization of the membrane forms semicircular genital plates (GP), which surround the ostium bursae dorsally and ventrally.

SYNOPTIC TABLE OF ABBREVIATIONS APPLIED TO THE EXTERNAL ANATOMY EXCLUDING SETA AND SETAL PUNCTURES

ADF	Adfrontal sclerite
AE	Aedeagus
AE2	Mesothoracic anepisternum
AF	Antefrons
AL	Adnotale
AN	Adanale
ANF	Antennifer
ANU	Anus
AP1	Apophysis of abdominal segment VIII
AP2	Apophysis of abdominal segments IX and X
AT	Anterior tentorial invagination
1AX	First axillary sclerite
2AX	Second axillary sclerite
3AX	Third axillary sclerite
AXC	Axillary cord
BS1	Prothoracic basisternum
BS2	Mesothoracic basisternum
BS3	Metathoracic basisternum
C	Costal vein
CD	Cardo
CH	Cremastral hook
CL	Clasper
CO	Coxa
CP	Clypeus
CRE	Cremaster
CS	Coronal suture

CU1	First cubital vein
CU2	Second cubital vein
DT	Distitarsus
EP1	Prothoracic epimeron
EP2	Mesothoracic epimeron
EP3	Metathoracic epimeron
ES1	Prothoracic episternum
ES3	Metathoracic episternum
F	Frenulum
FCS	Frontoclypeal sulcus
FGS	Frontogenal sulcus
FM	Femur
FS	Frontal suture
FS2	Mesothoracic furcasternum
FS3	Metathoracic furcasternum
GA	Galea
GN	Gnathos
GO	Genital opening
GP	Genital plates
H	Hypostoma
HP	Humeral plate
JL	Lobe of Juxta
JX	Juxta
KE2	Katepisternum
LC	Lateral cervical sclerite
LM	Labrum
LP	Labial palpus

LPS	Socket of labial palpus
LS	Lateral sclerite of spinneret
M	Mentum
M1	First medial vein
M2	Second medial vein
M3	Third medial vein
MCS	Midcranial sulcus
MD	Mandible
ME	Meron
MP	Maxillary palpus
MS	Mesal sclerite of spinneret
O	Lateral ocellus
OP	Sulcus separating occipital and postgenal regions of head
OPS	Oviporus
OS	Ostium
P	Pilifer
PA	Postadanale
PC2	Mesothoracic postscutellum
PC3	Metathoracic postscutellum
PM	Prementum
PN	Pronotum
POS	Postoccipital sclerite
PP	Palpiger
PR	Precoxale
PRA	Prealare
PT	Patagia

PTB	Posterior tentorial bridge
PO	Pronotal arm
PWP	Pleural wing process
R1, R2	First, second radial veins
R3, R4	Third, fourth radial veins
R5	Fifth radial vein
RS	Radial sector
S2	Mesothoracic scutum
S3	Metathoracic scutum
SA	Subalare
SB	Subtegula
SC	Subcostal vein
SC+R1	Subcostal + first radial vein
SC2	Mesothoracic scutellum
SC3	Metathoracic scutellum
SCE	Scape
SM	Submentum
SN	Sternum of prothorax
SO	Socius
SP	Spinneret
SPI	Spiracle
SR	Basal sclerotic ring of spinneret
ST	Subtegula
STI	Stipes
SU	Suralare
T	Tibia
TA	Transtilla

TE	Tegumen
TG	Tegula
TN	Trochantin
TR	Trochanter
U	Uncus
V	Vinculum
VII	Seventh abdominal segment
VIII	Eighth abdominal segment
IX	Ninth abdominal segment
X	Tenth abdominal segment

SUMMARY

The synonymy of L. fiscellaria fiscellaria (Guenée) is outlined. The diagnostic characters of the two varieties of fiscellaria, lugubrosa and somniaria, which occur in the northern United States and Canada are discussed. L. fervidaria Hbn., described in 1831 as a distinct species, is considered by Capps (2) to be a variety of fiscellaria.

Four, severe, hemlock looper attacks occurred in Newfoundland from 1912 to 1950, at 8- to 15-year intervals. In each case heavy outbreak conditions lasted for about three years. Outbreaks occurred usually in pure stands of mature balsam fir.

This species overwinters as an egg. Hatching begins early in June and continues for the greater part of the month.

There are four larval instars in Newfoundland. These conform to "Dyar's Rule", that is, there is a fairly uniform rate of increase in head width from each instar to the succeeding instar. The total larval period ranges from 43 to 55 days, averaging 48.9 days. First, second, third and fourth instar larvae appear in the field about June 12, June 22, July 1 and July 14, respectively.

First instar larvae died when supplied with the following diets: 'old' foliage of balsam fir or white spruce; leaves of Cornus, raspberry, alder or mountain ash; sphagnum moss. They were reared successfully to pupation on new shoots of balsam fir or white spruce, or leaves of maple or birch. Second instar larvae died when fed 'old' white spruce or rasp-

berry foliage. Three of 20 second instar larvae supplied with old balsam fir needles survived and pupated.

First instar larvae lived only three or four days without food.

Severest defoliation occurred when larvae were in the third and fourth instars.

In a heavily infested area third and fourth instar larvae are unusually active. Movement in the first and second instars is not very apparent, although large numbers of first instar larvae have been seen crawling up the trunks of host trees. The first three instars react positively to light. This reaction is strong in starved larvae and enables them to find feeding sites at the branch tips. When suitable food is found the photic stimulus is weakened or is replaced by some other stimulus. Prior to the prepupal phase a photonegative reaction causes larvae to seek darkened, pupation sites.

The first pupae were collected on August 2. The pupal period ranged from 20 to 23 days and averaged 22 days. Preferred pupation sites are bark crevices, among lichens on the tree trunk, under loose bark and in dry decayed stumps.

Adult emergence started about August 21 and continued until September 17. The adult length of life ranged from 10 to 17 days for females and from 8 to 10 days for males, averaging 14.3 and 9.4 days respectively. Of the adults reared from field collected material 55.1 per cent were females and 44.9 per cent were males.

Adult females have a pre-ovipositional period of from three to five days. Eggs are usually laid singly on different sites ranging from moss on the forest floor to lichens and bark scales on the tree. Egg and oocyte counts were made on adult females collected in the late larval and pupal stages. The number per female ranged from 39 to 106 in 1950 and from 47 to 122 in 1951, averaging 63.1 and 67.6 respectively. Observations on the relationship between diet and fecundity also are discussed.

Information on the species. life histories, distribution and other hosts of parasites reared from the hemlock looper in the Maritime Provinces and Newfoundland is summarized. The two most important parasites in Newfoundland were *Aoplus velox* (Cress.) and *Apanteles* sp. near *flavovariatus* (Mues.).

A larval virus disease was the most important control factor in terminating recent outbreaks. Its effectiveness seems to be dependent on a high larval population.

A high mortality of first instar larvae from starvation occurred when eggs were deposited in areas where the host trees had been completely defoliated. Considerable mortality also occurs in the first instar when eggs are laid on the moss of the forest floor.

The eggs and the four larval instars are described. Structures of fourth instar larvae considered to have taxonomic significance are discussed. The external anatomy of the adult is described in detail.

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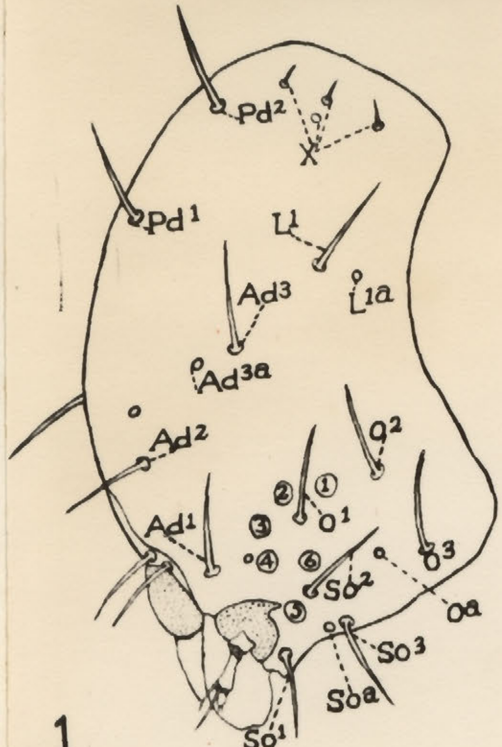
PLATE 1

Head of Fourth Instar Larvae

Fig. 1.--Lateral view of head showing setal pattern and arrangement of ocelli.

Fig. 2.--Setal pattern of genal region of head.

Fig. 3.--Frontal view of head showing setal pattern and other structures.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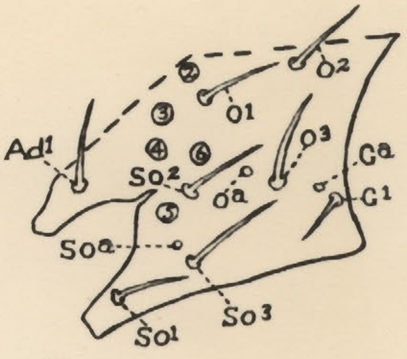
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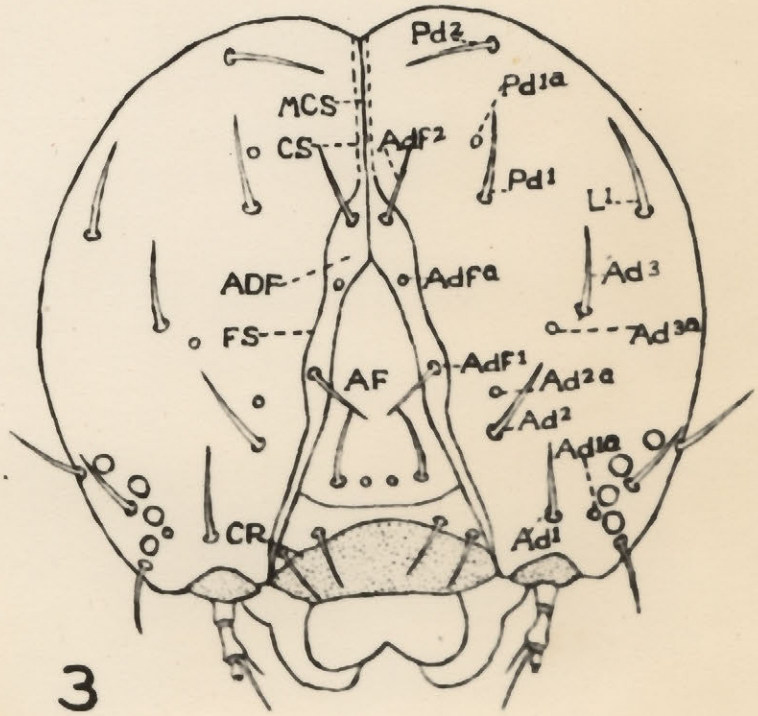
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Ad1a
Ad1
CR

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PLATE 2

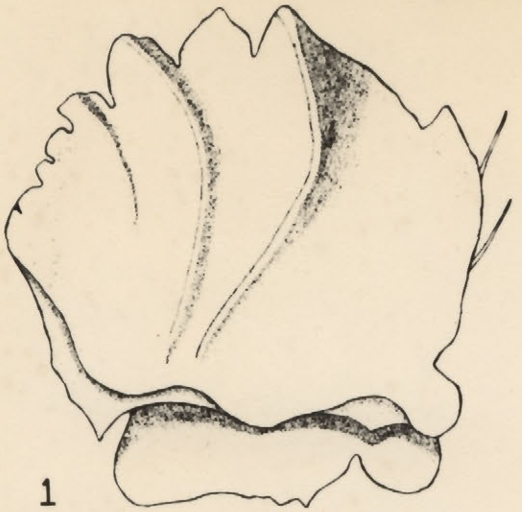
Mouthparts of Fourth Instar Larvae

Fig. 1.--The left mandible.

Fig. 2.--The maxillobabial-hypopharyngeal complex (ventral view).

Fig. 3.--The spinneret. A. Ventral view. B. Lateral view.

Fig. 4.--Setal pattern of the labrum.



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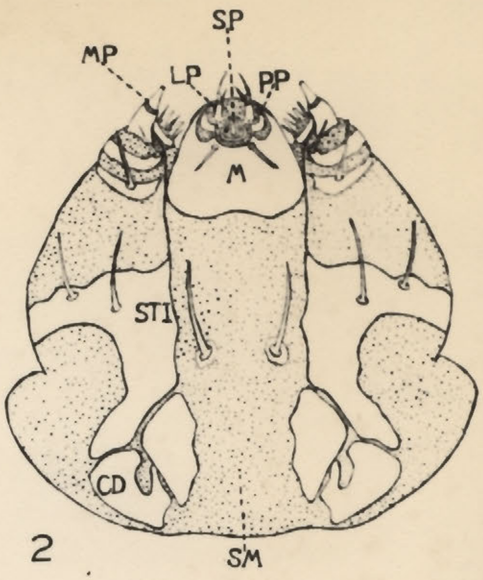

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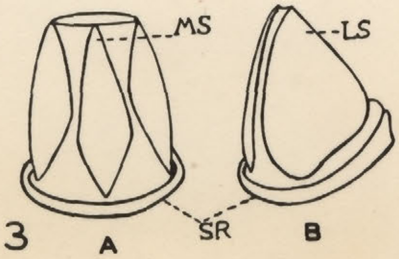

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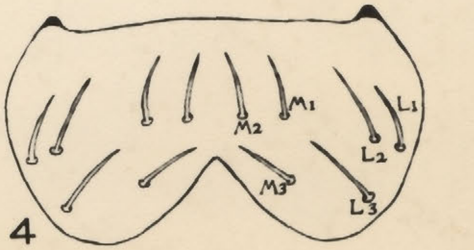

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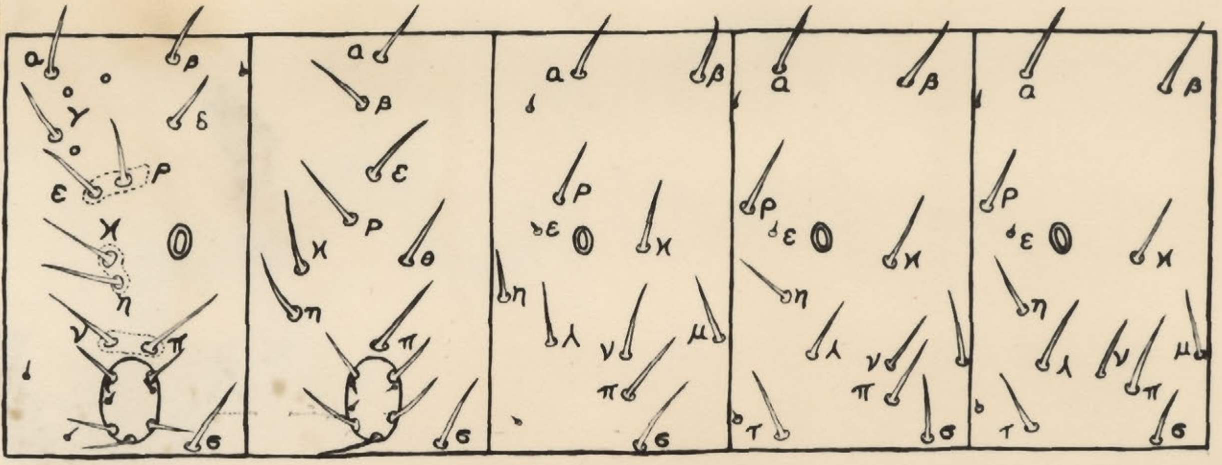
PLATE 3

Setal pattern of the thorax and abdomen

Fig. 1.--The prothoracic, mesothoracic, and first three abdominal segments.

Fig. 2.--Abdominal segments 6 - 10 inclusive.



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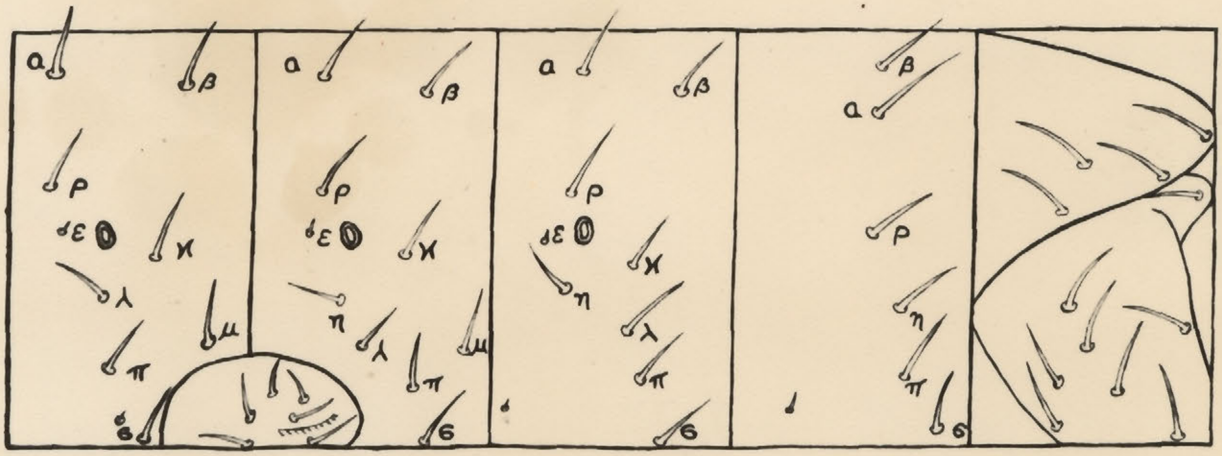

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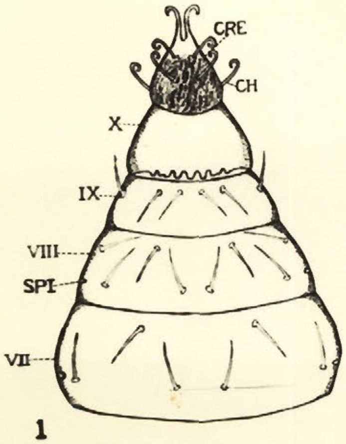
PLATE 4

Pupae--Posterior Segments

Fig. 1.--Dorsal view of pupa.

Fig. 2.--Ventral view of female pupa.

Fig. 3.--Ventral view of male pupa.



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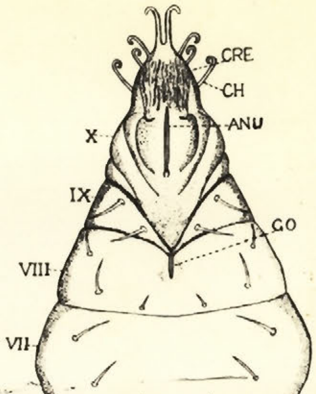

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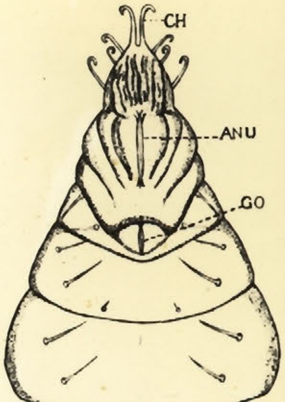


3 ♂

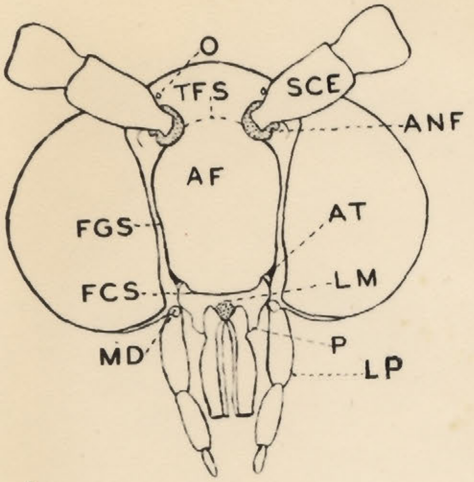
PLATE 5

Head of Adult

Fig. 1.--Anterior view of adult head.

Fig. 2.--Posterior view of adult head.

Fig. 3.--Posterior view of mouthparts.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ANF
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LM
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LP

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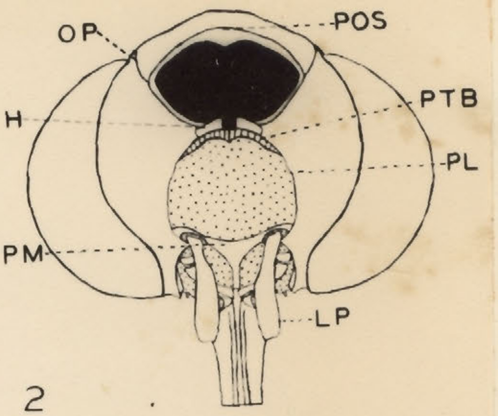
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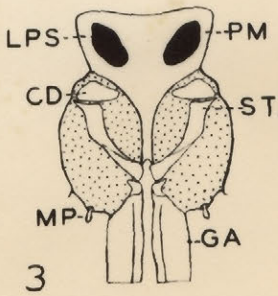

LPS
PM
CD
STI
MP
GA

3

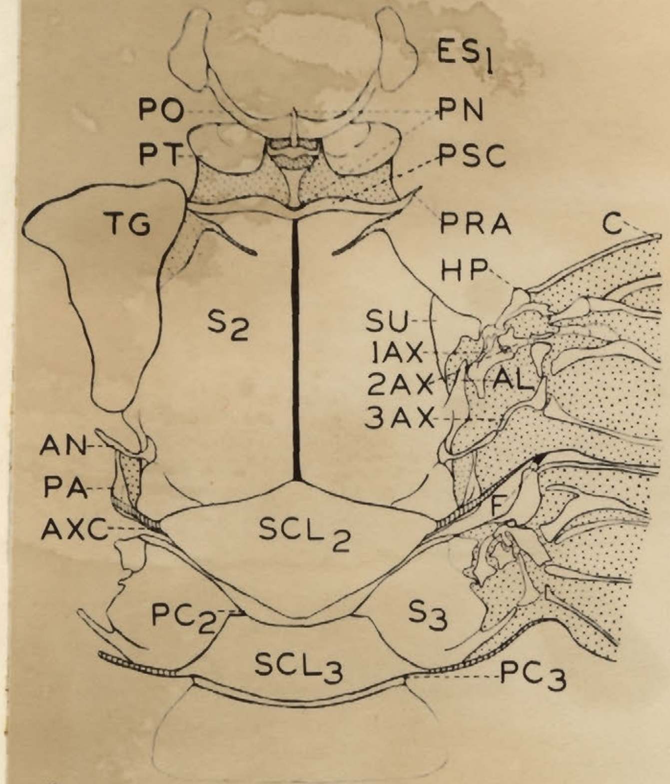
PLATE 6

Thoracic Segments of Adult

Fig. 1.--Dorsal view of thorax (right tegula and two left wings removed).

Fig. 2.--Ventral view of thorax.

Fig. 3.--Lateral view of thorax.



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PN
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PSC
TG
PRA
C
HP
S_2
SU
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AL
3AX
AN
PA
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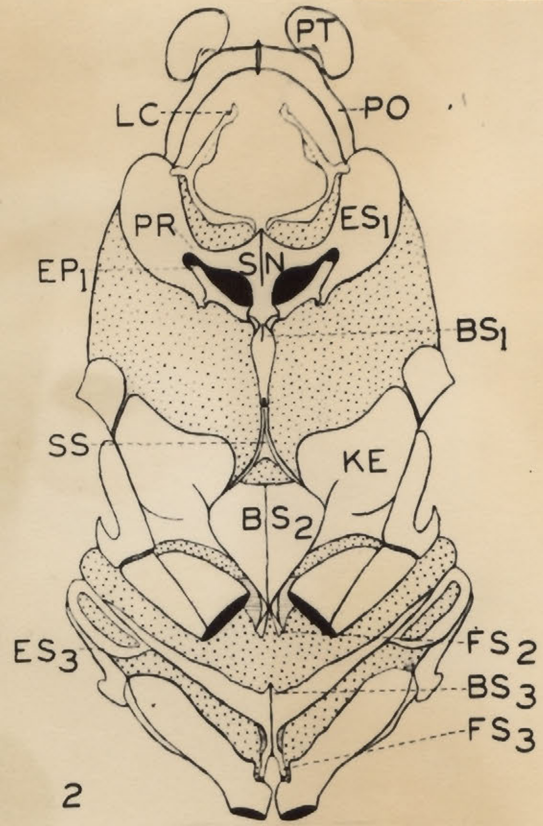
AXC
SCL_2
PC_2
S_3
SCL_3
PC_3

1



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LC
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PR
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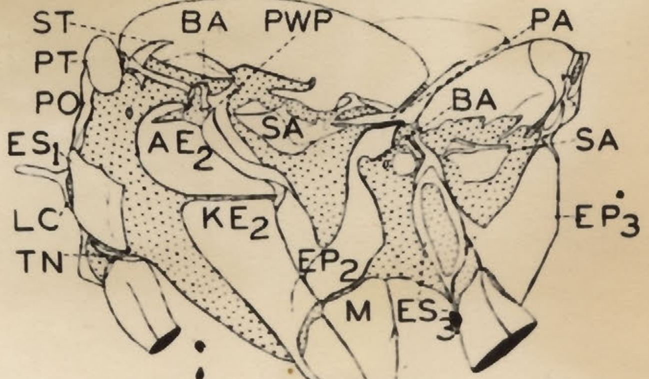
EP_1
SN
BS_1
SS
KE
BS_2
ES_3
FS_2
BS_3
FS_3

2



ST
BA
PWP
PA
PT
PO
BA
ES_1
AE_2
SA
SA
LC
KE_2
EP_3
TN
EP_2
M
ES_3
EC

3

PLATE 7

Thoracic Appendages of Adult

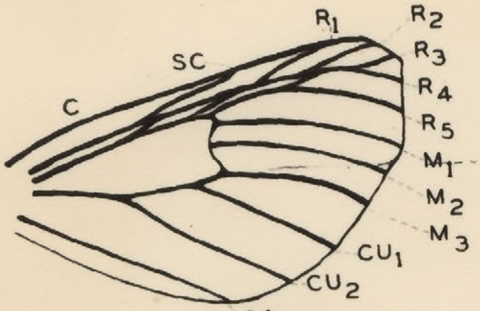
Fig. 1.--Fore-wing.

Fig. 2.--Hind-wing.

Fig. 3.--Prothoracic leg.

Fig. 4.--Mesothoracic leg.

Fig. 5.--Metathoracic leg.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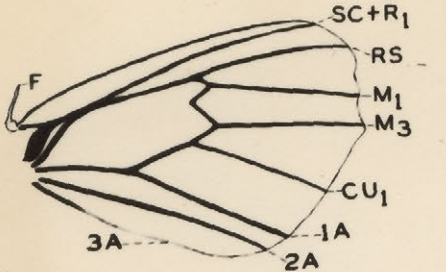
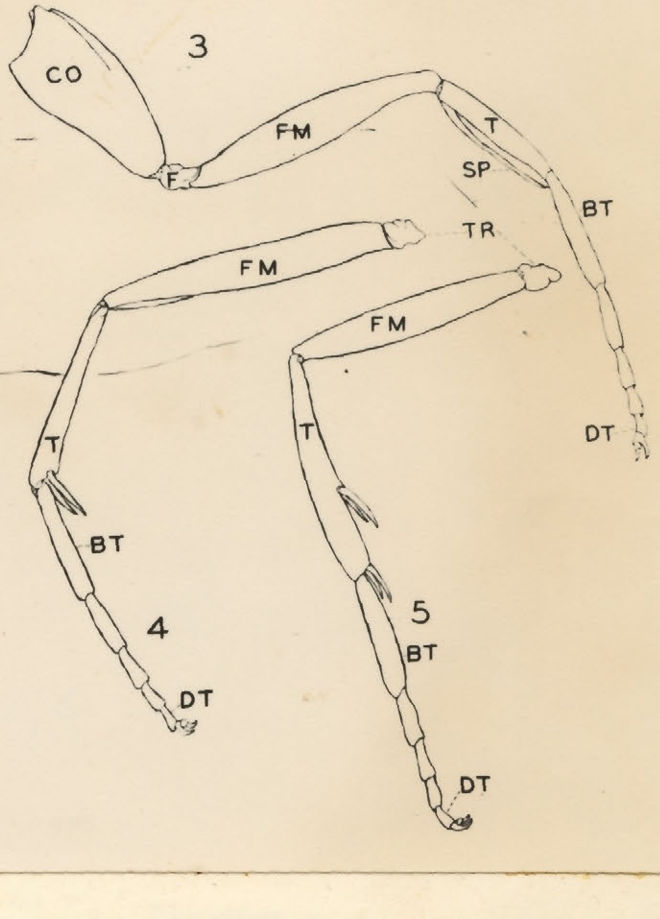
R3
SC
R4
C
R5
M1
M2
M3
CU1
CU2
2A

1


SC+R1
RS
F
M1
M3
CU1
1A
3A
2A

2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CO
FM
T
F
SP
BT
TR
FM
FM
DT
T
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5
BT
DT
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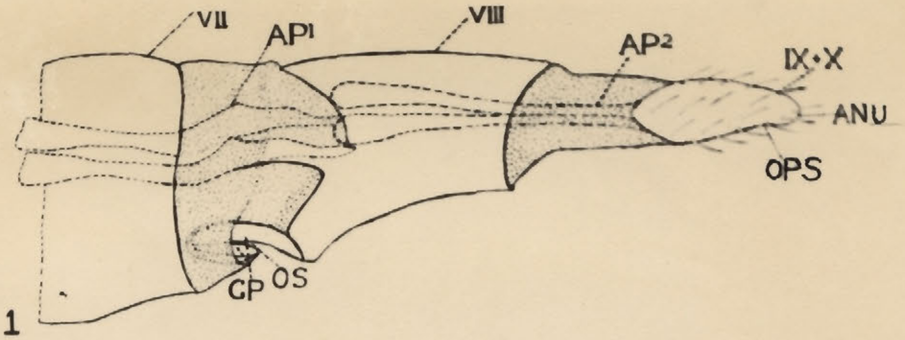
PLATE 8

External Genitalia of Adult

Fig. 1.--Lateral view of female genitalia.

Fig. 2.--Ventral view of male genitalia.

Fig. 3.--Dorsal view of male genitalia.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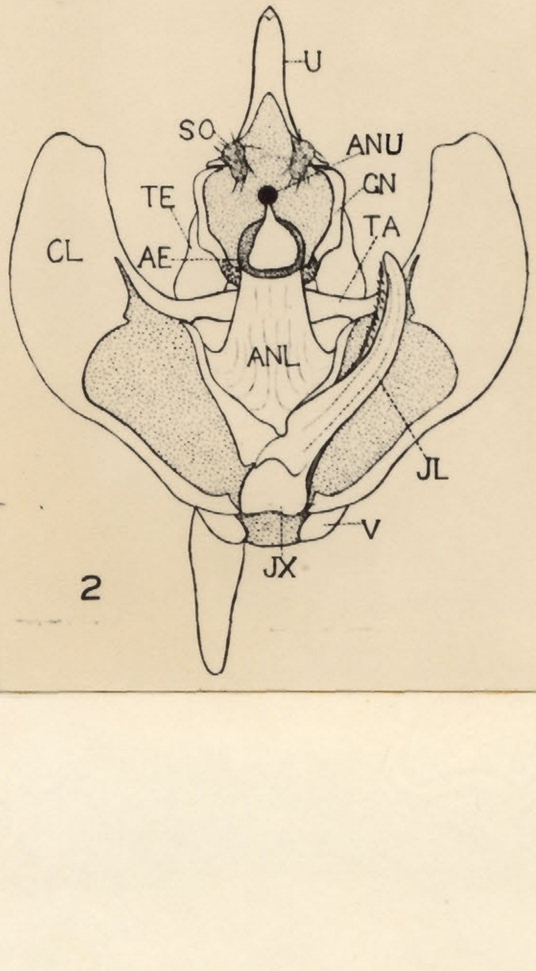
AP1
VIII
AP2
IX+X
ANU
OPS
CP
OS

1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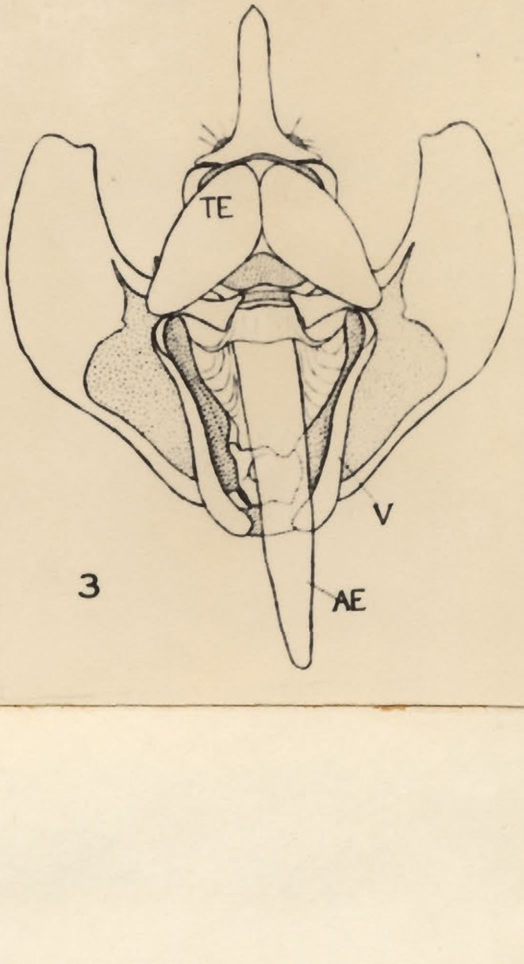
SO
ANU
TE
GN
TA
CL
AE
ANL
JL
V
JX

2


TE
V
AE

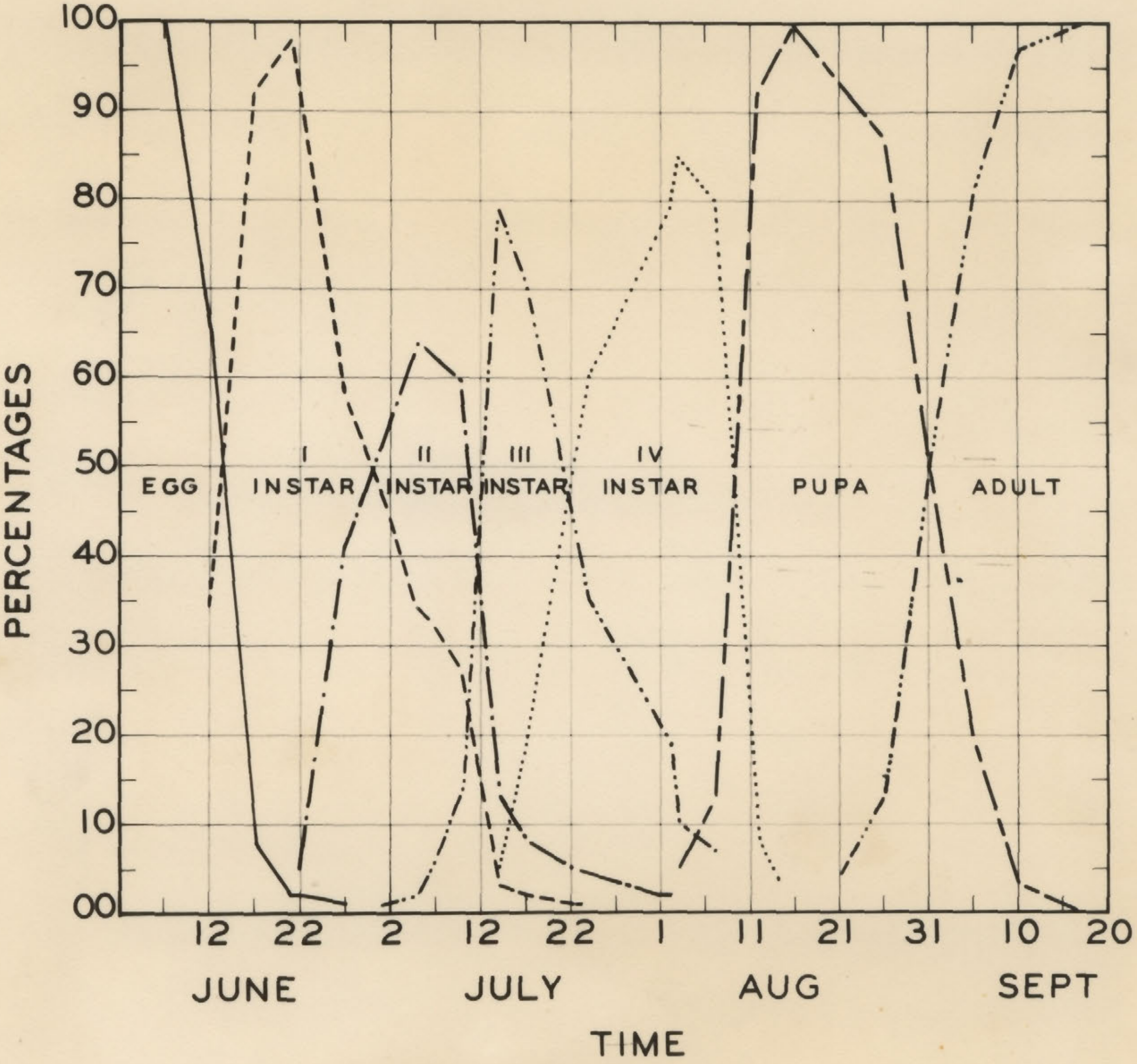
3

FIGURE 1

Mature balsam fir stand, near Lake St. George, Newfoundland. Severely damaged by *L. fiscellaria fiscellaria* (Guenée) in 1949.

FIGURE 2

Graph showing development of *L. fiscellaria fiscellaria* (Guenée) 1950.



100
90
80
70
60
50
40
30
20
10
00
PERCENTAGES
EGG
I INSTAR
II INSTAR
III INSTAR
IV INSTAR
PUPA
ADULT
12
22
2
12
22
1
11
21
31
10
20
JUNE
JULY
AUG
SEPT
TIME

FIGURE 3

L. fiscellaria fiscellaria (Guenée) eggs.

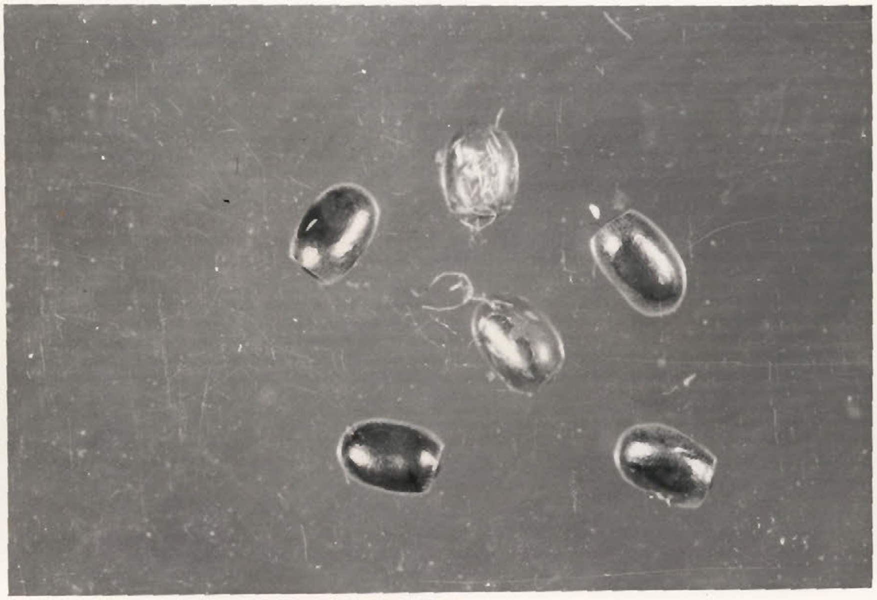
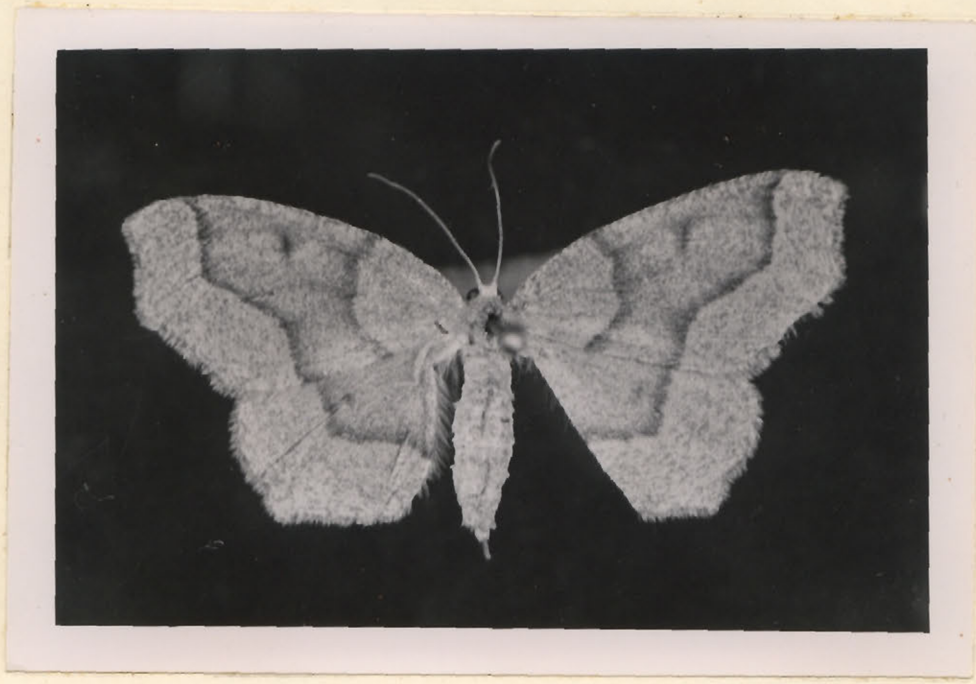


FIGURE 4

L. fiscellaria fiscellaria (Guenée). Adult male.

FIGURE 5

<u>L.</u> <u>fiscellaria</u> <u>fiscellaria</u> (Guenée). Adult female.



Short Title

BIOLOGY AND EXTERNAL MORPHOLOGY OF THE HEMLOCK LOOPER IN NFLD.

1039