CONTRIBUTIONS

to the

BIONOMICS of the SPRUCE BUDWORM,

Cacoecia Fumiferana Clem.,

in Southeastern Manitoba and Northwestern Ontario.

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CONTENTS

Note: Page references in the Text refer to typed pages in the Section under discussion, and not to the sequence page numbers.

The data to follow was obtained during the summer of 1938, while the writer was employed as Student Assistant to the Department of Agriculture of Canada, Science Service, Division of Entomology, Winnipeg Laboratory, Forest Insect Investigations.

This data has been liberated by the Department for thesis use, and grateful acknowledgement is hereby made.

INTRODUCTION

Systematic Position -

The Spruce Budworm, Cacoecia fumiferana Clem., is a member of the microlepidopterous family Tortricidae and appears to be indigenous to North America. Generically, it possesses considerable synonyny, being described in the literature variously as Tortrix, Archips and Harmologa fumiferana. The original description by CLEMENS ('65) designated the species as Tortrix fumiferana.

The moth occurs in two chief colour phases, one of which appears to occur most often in the Eastern section, feeding chiefly on Balsam fir and white spruce and predominantly grey in colour (GIBSON '25, CHAMBERS and THOMPSON '33); the other occurs most often on pines and in colour tends towards the copper shades (CHAMBERS and THOMPSON '33). GRAHAM ('35) has proposed that there is a biological race common to the central forested areas of North America and specifically adapted to feeding upon Jack Pine.

Distribution -

(1) This section aims merely to present a graphic picture of the widespread distribution of the pest, in a general way. No attempt is made to treat of the outbreaks from an historical or economic point of view. As the writer will indicate in several instances throughout the subsequent discussions, the solution of the epidemiology of this pest

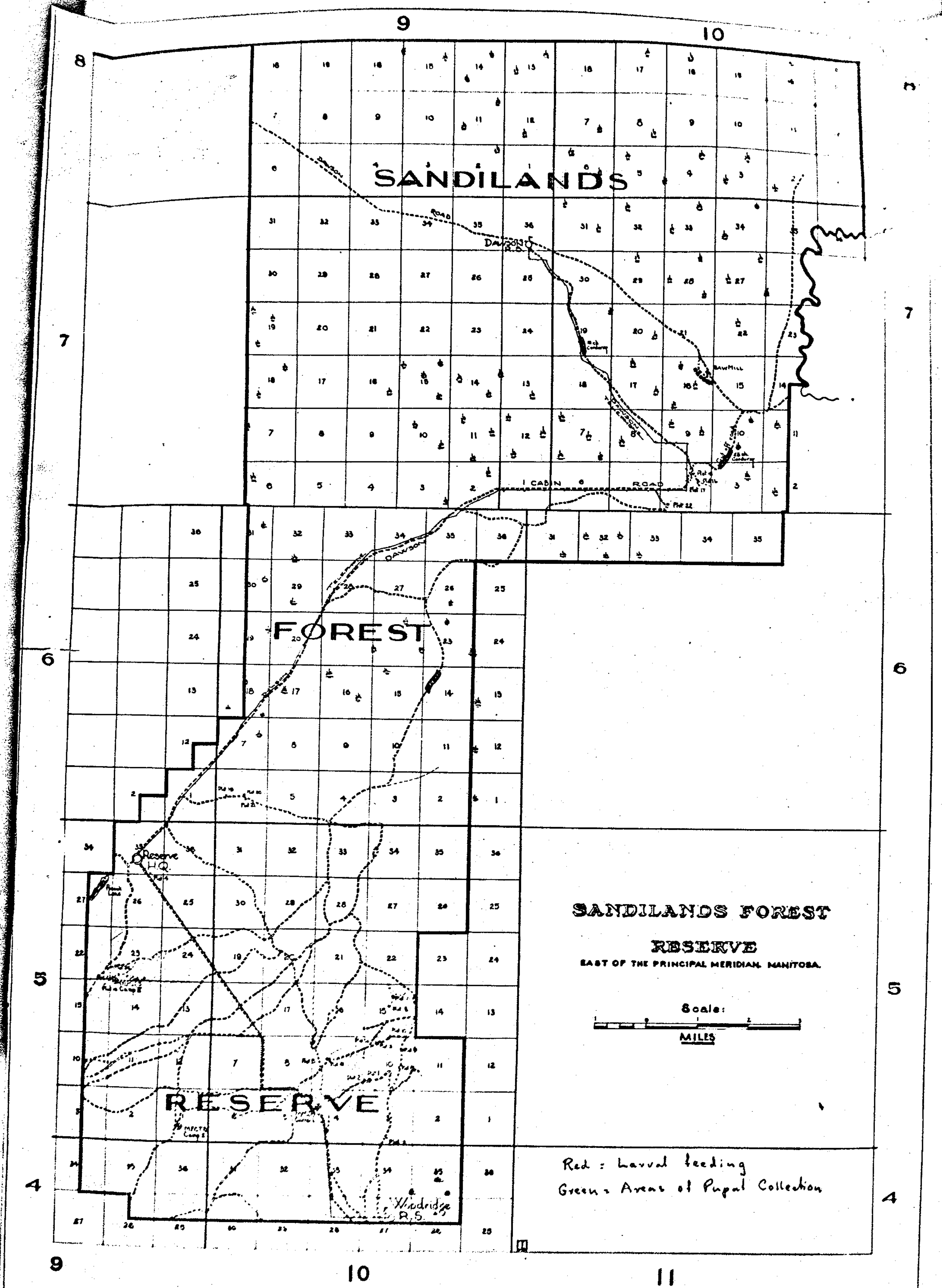
Cartocraft Desk Outline Map, North America

must ultimately rest upon co-operative undertakings.

The following is a list of territories affected by the Spruce Budworm at one time or another, the authority and date of his publication (see Literature Cited) following the territory mentioned. The accompanying map of North America indicates the approximate areas affected:-

AREA	AUTHORITY
British Columbia - Lillooet, Fort George, Barkerville	Johannsen ('13), Pierson ('23) Gibson ('25) Mathers ('24)
Connecticut -	Britton ('13)
Idaho - Northern Idaho	Hoffman ('24) Evenden ('25)
Maine - coastal	Packard ('90) Johannsen ('13) Pierson ('23)
Manitoba - Roblin Sandilands	Fletcher ('07) in Johannsen '13 Gibson ('25) Dunn ('35)
Massachusetts -	Robinson ('69)
Minnesota -	Ruggles ('22), Graham ('23)
Michigan -	McDaniel ('20)
New Brunswick -	Pierson ('23), Tothill ('18)
New Hampshire -	Pierson ('23)
New Jersey -	Pierson ('23)
New Mexico -	Perry ('24)
Nova Scotia -	Pierson ('23)
New York -	Felt ('06)

CANADIAN PACIFIC RAILWAY
CANADIAN NATIONAL RAILWAY
Brokenhead River
Whitemouth Lake
Whitemouth River
Rat River
Roseau River
Steinbach
Ste Anne
Dufresne
Lorette


SANDILANDS
FOREST
RESERVE
SANDILANDS FOREST
RESERVE
EAST OF THE PRINCIPAL MERIDIAN, MANITOBA.
Scale:
MILES
Red = Larval feeding
Green = Areas of Pupal Collection
DAWSON ROAD
Dawson R.S.
SAWMILL
CABIN ROAD
Reserve H.Q.
Woodridge R.S.

AREA		AUTHORITY
Ohio -		Robinson ('69)
Ontario -	E. Lake Huron	Swaine and Craighead ('24) Pierson ('23)
	N. Western	Tothill ('18) Dunn ('35)
Pennsylvania -		Robinson ('69)
Prince Edward Island -		Pierson ('23)
Quebec -	Gatineau E. Townships	Gibson ('25) Swaine and Craighead ('24) Pierson ('23)
Vancouver Island -		Johannsen ('13) Gibson ('25)
Vermont -		Pierson ('23)
Virginia		Clemens ('65)
Wisconsin -		Graham ('25) Chambers ('31)

(ii) The accompanying map shows the location of larval feeding by the Spruce Budworm during 1938, in the Sandilands Forest Reserve. The trend of infestation seems to be definitely south-easterly.

Résumé of Life History -

In central Canada, the eggs are laid during the middle of July. The egg when first laid is a very pale green in colour, becoming progressively more yellow as embryonation advances. The egg is flat beneath, moderately convex above, in shape oval to cylindrical, and the shell bears microscipially fine reticulations. The eggs are laid overlapping one another, much like scales on a fish, about one-third of the surface of each egg being exposed.

About ten days after oviposition the first instar larvae emerge, wander for a varying time and then spin silken hibernaculae around themselves in sites of their choice, usually near bud scales, in the axils of twigs or partly under large flakes of bark. Here they undergo a moult, overwinter and emerge in the spring, about the beginning of June, as second instar larvae.

The larvae feed ravenously on the needle bases of newly expanding terminal growth, and in staminate flowers, and by the end of June full-grown larvae are to be found in the field. Pupation occurs early in July, the larva first moving to the extreme tip of the twig it has been inhabiting, the silk of its larval tube serving to enmesh the hooks of the cremaster (see Plate V). The pupation appears to proceed postero-anteriorly. (It is interesting to note this as a possible axial gradient of development.) For some hours after the pupa is formed it is capable of violent jerking movements. The adults emerge in about nine days, mate approximately three days after emergence. Eggs are deposited by the female upon the needles of the host.

MATHERS ('24) reports a two-year life cycle in British Columbia.

<u>Economic Importance</u> -

The Spruce Budworm owes its importance to the habits of the larval stages. The larva spins about itself, and the needles upon which it feeds, a silken web inside of which it feeds upon the basal, succulent portions of the needles of the host, severing the needles from the twig. This action, when the incidence of larvae upon the host is high, results in acute and sometimes total defoliation of the tree. The foliage of such attacked trees presents a brick-red appearance due to the change of colour of the severed needles that are retained, together with feces of the larva, in the latter's silken tubelike web.

The resulting defoliation produces a marked loss of new growth to the host, since larvae favour the terminal and comparatively unexpanded spring buds. Migration to the old growth occurs when the former are destroyed. This defoliation produces a loss of increment in the tree, manifested by reduced size in the annual rings. In Central Canada this is exceedingly important to interests concerned with the production of kraft paper, railway ties, mine props, cordwood and rough lumber. In addition to loss of increment, the terminal portion of the crown of the tree may suffer killing for as much as ten feet, resulting in a stag-headed tree incapable of terminal growth. This presents a loss from several standpoints and in addition lays the tree open to the attacks of secondary forest insects such as bark beetles and wood borers, which in many instances doom trees which have been weakened by the Budworm but would otherwise recover; and by fungi. Still more important, it represents a potential menace from fires of the severest type - Crown fires. The cost of suppressing such fires must be charged against this pest.

The hosts of the Spruce Budworm in Central Canada are Jack Pine and Red Pine, with possibly casual feeding on Balsam, Spruce, and Larch. However, with regard to Balsam attack in Manitoba, Mr. Tunstall, Officer in Charge, Dominion Forest Service, Winnipeg, has records of a severe outbreak by the above pest on Balsam at Little Moose Island in 1924, while along the Winnipeg River in T 15-R 17 90% of advanced and mature growth had been killed; and in T 16-R 16 100% mortality was recorded on advanced growth and reproduction. An infestation was also reported at Sipiwesk Lake in 1928.

However, the chief and most favoured host in Central Canada during the current epidemic is the Jack Pine. Aerial reconnaissance in North-western Ontario has revealed thousands of sections of the best Jack Pine in Canada with reddened foliage due to the attack of the pest, while severe infestations obtain in South-western Manitoba, and sporadic attack occurs in Western Manitoba and Eastern Saskatchewan.

In addition to pulp and paper companies, tie operators, the railways and all those interested in forest products for their continued existence, hydro-electric power companies, the fur trade and tourist business are also affected by such infestations.

Spruce Budworm Epidemiology -

Epidemics of economically important insects are widespread over the earth's surface, affecting almost every variety of perishable produce of value to man.

Many attempts have been made to analyze the factors causing these epidemics, and much information has been collected to show that environmental factors are extremely important instruments in the phenomenon. Especially is this true of meteorological data.

These epidemics in many cases exhibit cyclic recurrences, often over widely scattered areas at the same time. These areas may be shown by future work to be part of a pattern of infestation, arising from some environmental change.

The Spruce Budworm is a forest insect of great importance, one that not only destroys large amounts of otherwise merchantable forest products, but alters the composition of subsequent forests, which replace the one destroyed. Little success has been met with in the attempt to analyze Budworm epidemics from the standpoint of physical environmental pressure. On the other hand little has been done to analyze the problem from any other angle. This view is summarized very concisely by SWAINE ('33):-

> "We are familiar with many of the factors which affect the course of these epidemics, (i.e., of Defoliating insects): parasites, predators, climatic conditions, food supply - all play a prominent part and in many cases provide sufficient explanation of the results; but in

other instances the situation is not be explained by any apparent cause. A sudden loss of vitality or vigour, as evidenced by a lack of fertility in the females or an unthrifty condition in the larvae, has been apparent in some instances and it is not inconceivable that sudden changes in the biotic potential may be the immediate cause of the sudden rise or fall of many insect outbreaks. The subject of changes in the biotic potential and their causes deserves much more attention than it has yet received."

GRAHAM ('35) advanced the hypothesis that Spruce Budworm epidemics upon Jack Pine forest were primarily related to the availability of staminate cones, with their pollen content the dominant factor. He stated that open stands, and defoliated stands, were predominantly staminate and the interaction of food and defoliation was visualized by him as follows:-

In an open stand there is greater root growth of the individual trees, making available more nitrogenous material for plant use. At the same time the leaf (needle) surface was comparatively luxuriant but expressed in terms of the relation of carbon (C) (from photosynthetic sources) to the nitrogenous intake of the roots (N) it was:-

C:N, less than equality.
Nitrogen high.

Under these conditions the plant was able to produce a relatively great quantity of staminate flowers.

In dense stands on the other hand he believes the reverse relation to exist, since root competition is very intense, the crown at the same time being also restricted but in the relation:-

C:N, more than equality.
Carbon high.

Less cones, comparatively few in fact, are produced.

This conception is complicated by the fact that when the larvae of the Spruce Budworm defoliate trees they cause the relation of C:N to be upset in favour of the root (N) system, hence there is a still further production of staminate flowers, in stands already predominantly staminate. This increases the larval vigour and adult fecundity, GRAHAM believes, and the population then reaches epidemic proportions.

No definite data has been gathered with respect to the above hypothesis of Graham, as yet. Circumstances of transportation and other facilities rendered the attempt to open the question during the 1938 season impossible.

The following thesis presents conceptions and data contributing to the general bionomics of the Spruce

Budworm in the hope that certain of the points in Spruce Budworm epidemiology may be rendered less obscure. It is essentially a contribution to the Biotic Potential of the Species. The treatment of the problem has attempted to approximate the ideal of GRAHAM ('29a):-

> "Much of the information now available is not of the maximum possible value because the basic data are often not comparable. In order that biotic information may be of the maximum value it must be expressed in accurate, comparable terms."

1. BIONOMIC DATA

A. Sex-Ratios.

SEX-RATIOS

Definition:

GRAHAM ('29) indicates, as others have done previously, that sex-ratio is the ratio of females to the total population, determined by dividing the number of females in a given group by the total number of individuals in that group. Thus equality of sexes produces a ratio of 0.5, while 100% parthenogenicity produces a ratio of 1.0. A ratio toward a lesser value than 0.5 is decreasingly low, one toward a higher value is increasingly high, and the writer wishes to point out what does not appear to have been indicated formerly, that if a low ratio obtains there is produced an imbalance which will affect the subsequent population unless the females are exceedingly fecund and little egg mortality occurs. On the other hand an imbalance also obtains when a high ratio is found and will also affect the subsequent population, unless the males be polygamous. For the Spruce Budworm the latter point is unknown, and as the following data will attempt to explain, it seems of the utmost importance that it be determined at the earliest opportunity.

Indroductory Remarks:

It is of interest to note that sex-ratios are little discussed in the literature. GRAHAM ('29), and CHAPMAN ('31) mention the significance of sex-ratio almost in passing, accrediting it with an integral part in Biotic Potential, but tending to place the emphasis on egg production and oviposition. As mentioned above, the sex-ratio when in imbalance has much deduced significance, such that its use in the epidemiology of economic insects is a very fruitful field for investigation. GRAHAM ('35) has mentioned this aspect in connection with the Spruce Budworm.

A careful search of the literature reveals but a few references that anticipate any use being made of sex-ratios in this connection. GARMAN and SCHREAD ('31) acknowledge that the sex-ratio of parasites is one of the limiting factors in maintaining sufficient populations of Trichogramma and Macrocentrus for use against the Oriental Fruit Moth. Refrigeration, they found, varied the ratio and they conclude the latter to be "an easily variable ratio", and take the view that there is a considerable fluctuation in the normal ratio in the field, influenced by locality and climate, "which may even affect abundance or natural distribution". While these statements refer to Trichogramma and Macrocentrus they appear generally applicable to the phenomenon of sex-ratios in general.

CHAPMAN ('31) mentions that Holdaway, in an unpublished thesis, "found evidence that under certain environmental conditions there may be a change of sex-ratio in Tribolium confusum".

Only one reference other than that of GRAHAM ('35) has been found to date whose authors saw the significance of sex-ratio in epidemiology of insects and applied it. This is found in the work of TSAI and CHUNG-NI ('35) working in China on Rice stem borers. Unfortunately their article is in Chinese and only a very brief English summary is available. They state that from the literature it would appear that sex-ratio is influenced by weather - especially temperature and humidity (cf. GARMAN and SCHREAD ('31)), nutrition (cf. GRAHAM ('35), BRANDT ('37), HERMS ('28)) and time of maturity of the insects. (Data will be submitted in the following pages which it is believed will expand knowledge of this point.) They found from the Rice borer that high sex-ratio can be expected to give rise to an epidemic the following year, but if the sex-ratio decreases in the autumn due to unfavourable weather conditions or cultivation practice, then the danger of epidemic decreases.

Previous work, even of ecological nature, has only considered the adult sex-ratios. However, a method of differentiating the sexes of the pupae of the Spruce Budworm was described by GRAHAM ('35). Equally as important and in certain instances of even greater value is the determination of the sexes of Budworm larvae. Although no mention of this is apparent in the literature, the writer discovered and studied a simple method for distinguishing the sex of the larvae and both of these methods are described in the following text. That immature stages have not been utilized for this purpose previously is no doubt due to the difficulties attending such differentiation. These immature stages, in the Budworm at least, and in other forms to be dealt with shortly, undoubtedly possess sexual difference, and this may safely be assumed to possess physiological significance. These sexual differences have been little considered and even where recorded have previously attracted but the most academic of interest.

Thus PETERSON ('12) examined "numerous specimens for gonads", and eventually found "two white, opaque, ovate bodies on each side adjacent to the heart in the 5th abdominal segment. Difficulty was experienced in locating these organs on account of their close similarity to adipose tissue and their being embedded in same. It was impossible to determine the sex of the glands on account of the limited material at hand." He notes that tracheation is from the 5th abdominal segment, a fact independently established in the case of Cacoecia fumiferana.

BRANCH ('22), working with Trichopterous larvae and therefore phylogenetically applicable for comparison here, found, "within the species (Platyphylax interrupta) two shapes of gonads occur. Some are elongate and flat; others are spherical. This seems to point to a sex differentiation, the elongate ones probably destined to become female organs and the spherical ones male organs." In the light of the evidence given below, the writer believes that if BRANCH had reared such larvae to the adult state he would have found the reverse to be true, that is, the "elongate ones" male and the "spherical ones" female.

Sex Differentiation in Budworm Stadia:

An independent observation made by the writer during the 4th week in July, 1938, in the Sandilands Forest Reserve led to the separation of the sexes in Budworm larvae. Larvae had been noted in which an ovoid dark area showed very prominently through the dorsal body wall in the region of the 5th abdominal segment. This was at first thought to be due to the presence of an endoparasite, and accordingly a number of dissections were made revealing instead of a parasite the male gonad; dorso-lateral paired testes, lying below the fat body on either side of the heart. Thus the possibility of utilizing this character in segregating the sexes of larvae suggested itself and accordingly dissections were made of other larvae not exhibiting this area. Such examinations revealed the anlage of the adult ovaries. They are also laterally arranged, paired and lying beneath the fat body. Indeed they are so intimately associated with the latter that they are found with difficulty on dissection.

The implications of a larval sex-ratio are as follows:-

(1) A study of the seasonal developmental differences of the sexes. This would be part of a long term project.

(2) Correlated with other phenomena, (1) above would provide a phenological indicator of environmental effects upon gonad development and potentiality.

(3) A potential use in the prediction of fluctuations of population density.

(4) Relative mortality of the sexes in the larval

stadium, it having been possible up to the present to distinguish sex difference and mortality in pupae and adults only.

(5) Relative susceptibility of the larval, pupal and adult males and females to parasitism.

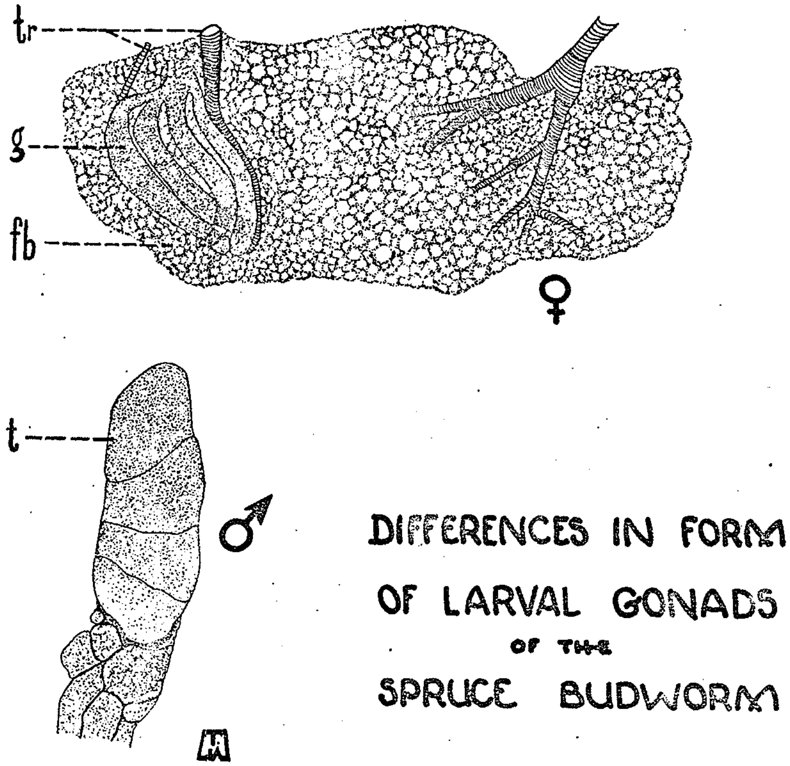
(6) Susceptibility of sexes as in (5) above could be extended to each larval instar.

(7) Effects of factors other than parasitism, gauged by their operation by instar and by sex.

Recently BRANDT ('37) showed that for the Nun Moth, in Germany, the early larvae have a sex-ratio of 0.5. The original article not being accessible, it is unknown to the writer how Brandt obtained his sex-ratios. However, in the first instar the female has an increased mortality over the male if food is scarce, the atmospheric humidity is too low, or the temperature too high. Unquestionably, much good work remains to be done on sex-ratio phenomenon.

The larval gonads of the Spruce Budworm are illustrated in Plate I, reproduced approximately X15 in the case of the male, and X25 in the case of the female. In the latter the tracheation is illustrated (tr), arising from the main trachea of the fifth abdominal spiracle as a dorsal branch (cf. PETERSON ('12)). The gonads (g) in the female are found more or less completely embedded in the dorsolateral portion of the fat body (fb), one on each side of the dorsal heart. Lying thus, and because of their high degree of translucency, they are difficult to discern at superficial dissection, considerable care being necessary in order not to overlook them completely and thus discard them in the fat-body. KERKIS ('31), working with Drosophila,

PLATE 1



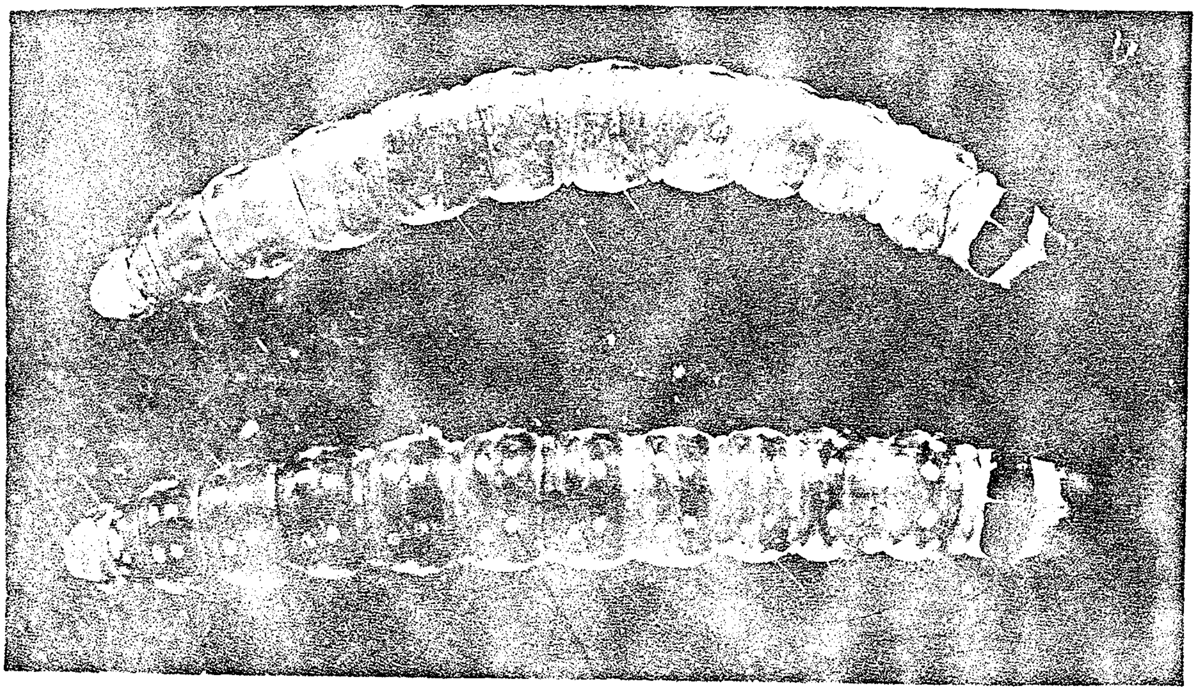
tr..... Tracheal branches

g ..... Gonad

fb ..... Fat body

t ..... Testis

PLATE 2



Larval gonads of male (above) showing plainly through the dorsal cuticle. Not visible in female, (below).

notes, "the young female gonads are so small that it is difficult to measure them as accurately as the male gonads." It would be of interest to determine how widespread is this discrepancy in size of immature gonads amongst insects. The gonad varies in shape from oval, through ovoid to elliptical, but there is not a marked increase in size from instar to instar in the later larval stages.

Unlike the female, the gonad of the male is very conspicuous, so much so as to be discernible through the dorsal body wall (Plate II). In this plate the comparison between male and female larvae is very conspicuous, the male glands standing out separately. Dorsally it is much flattened, not rounding off until near the margins of its flattish surface. Ventrally it is much more convex, the whole gland thus appearing hemispherical in transverse section. It is not so completely embedded in the fat-body, being free in most cases on the dorsal and median margins, and attached anteriorly and posteriorly to the fat-body. Note division into four chambers containing spermatic tubules, as illustrated in Plate I. It is to be noted that these glands are visible in very small and early larvae, and the latter can therefore be sexed without dissection in most cases, the exceptions being when the larval fat-body is very rich in reserve material, covering the dorsal surface of the gonad. Correct lighting or superficial dissection will serve to rapidly overcome this difficulty. KERKIS ('31) noted, for Drosophila, "In the six hour larvae the gonads are so large that they begin to be seen through the body wall of the living larvae. This fact gives the possibility to determine the sex of the larvae without dissection. The accuracy of such determinations has been checked by the classifying of such larvae on this basis and raising the males and females in separate bottles. The sex of the mature flies which appeared in these bottles was in accord with the expectations."

By rearing twenty-six female and thirteen male larvae, differentiated on the base of his assumption, the present writer verified the correctness of his own deductions. Plate VI shows the larval, pupal and adult males and females. Plate III illustrates the male gonads appearing through the dorsal cuticle of the fifth abdominal segments as dark areas, no such areas being observable in the case of the female larvae illustrated on the same plate.

A point of considerable importance with potential possibilities seems fairly evident from these dissections. Briefly, it is found that for male and female larvae of the same head capsule measurement, the gonad of the female will be decidedly smaller than that of the male, and that this difference in size expressed as a ratio remains relatively constant from one instar to another. The following data show quantitatively what a large series of observations provided qualitatively, viz, that there is an appreciable increase in size of the male gonads, as regards their length and width, over those of the female of the same head capsule width. Thus:

LARVAL GONAD SIZE COMPARISONS

Head Capsule	Sex	Gonad Length	Gonad Width
1.690 mm.	Male	1.950 mm.	0.815 mm.
1.690 mm.	Male	1.625 mm.	0.815 mm.
1.690 mm.	Male	1.950 mm.	0.815 mm.
1.690 mm.	Male	1.950 mm.	0.866 mm.
1.690 mm.	Male	1.820 mm.	0.780 mm.
		9.295 mm.	4.091 mm.

Mean gonad length, male $\frac{9.295}{5}$ .... 1.859 mm.

Mean gonad width, male $\frac{4.091}{5}$ .... 0.818 mm.

1.690 mm.	Female	0.568 mm.	0.328 mm.
1.690 mm.	Female	0.568 mm.	0.328 mm.
1.690 mm.	Female	0.466 mm.	0.318 mm.
1.690 mm.	Female	0.424 mm.	0.352 mm.
1.690 mm.	Female	0.530 mm.	0.282 mm.
		2.556 mm.	1.608 mm.

Mean gonad length, female $\frac{2.556}{5}$ .... 0.511 mm.

Mean gonad width, female $\frac{1.608}{5}$ .... 0.321 mm.

The ratio of the lengths, and widths, of the gonads of the two sexes is given below for comparison:-

Ratio of lengths $\frac{0.511}{1.859}$ 1:3.6

Ratio of widths $\frac{0.321}{0.818}$ 1:2.5

Thus the larval male gonad is 3.6 times as long as that of the female and 2.5 times as wide, when a series of five of each sex is examined in the same head capsule range. The variations in this limited series, the extension of which would appear to be but to labour the point, show that there is a valid conclusion to be drawn, viz; that the male gonad is, in the same stadium as a given female, longer and wider by 3.6 times and by 2.5 times respectively. MACHIDA ('26) stated that for the silkworm (Bombyx mori) "the ovary is always smaller than the testis in the larva." In doing so he is merely mentioning the fact in passing on to histological detail, and furnishes no quantitative data. This size ratio may be assumed to accompany physiological differences and a discussion of this question is given in the section following the presentation of the data relative to Stadial Sex-Ratios, Page 12. In order to supply a check upon the figures tabulated above a similar series of measurements was made of male and female larval gonads in a different head capsule width class. These follow:-

Head Capsule	Sex	Gonad Length	Gonad Width
1.300 mm.	Male	1.516 mm.	0.650 mm.
1.300 mm.	Male	1.465 mm.	0.520 mm.
1.300 mm.	Male	1.300 mm.	0.520 mm.
1.300 mm.	Male	1.515 mm.	0.650 mm.
1.300 mm.	Male	1.300 mm.	0.650 mm.
		7.096 mm.	2.990 mm.

Mean gonad length, male $\frac{7.096}{5}$ .... 1.419 mm.

Mean gonad width, male $\frac{2.990}{5}$ .... 0.598 mm.

Head Capsule	Sex	Gonad Length	Gonad Width
1.300 mm.	Female	0.380 mm.	0.212 mm.
1.300 mm.	Female	0.380 mm.	0.212 mm.
1.300 mm.	Female	0.530 mm.	0.282 mm.
1.300 mm.	Female	0.212 mm.	0.212 mm.
1.300 mm.	Female	0.324 mm.	0.144 mm
		1.826 mm.	1.062 mm.

Mean gonad length, female $\frac{1.826}{5}$ .... 0.365 mm.

Mean gonad width, female $\frac{1.062}{5}$ .... 0.212 mm.

The ratios of the lengths, and widths, of the gonads of the two sexes is given below for comparison:-

Ratio of lengths $\frac{0.365}{1.419}$ 1:3.8

Ratio of widths $\frac{0.212}{0.598}$ 1:2.8

It will be noted that these ratios compare very favorably with the ones given following the first set of data, and would appear to still more securely validate the conclusion drawn therefrom.

The foregoing serves to illustrate that not only are the gonads themselves little known in larval stages, but also that where they are known even passably the significance of the sex-ratio is not yet seen by other observers, with the exception of BRANDT ('37). This thesis therefore presents empiric evidence to demonstrate sex-ratio in Tortricid larvae and indicates its potential application to epidemiology.

It is anticipated that this method might be utilized to establish a more accurate and comprehensive estimation of the specific sex-ratio, i.e., the sex-ratio of the Budworm could be expressed as the summation of the larval, pupal and adult sex-ratios, on the average. This is given from the available data below, for the 1938 season in the Sandilands Forest Reserve, as 0.605. The yearly variations between these three stadial ratios might be of use in prediction of outbreaks, or subsidence of same. That matter will be discussed more fully later on.

Stadial Sex-Ratios:

(a) Larval -

By means of the method described above, involving dissections wherever the sexual differences were not obvious, (and in most cases the females were so determined), eight hundred and sixteen larvae were examined under a binocular microscope in the laboratory. These larvae were collected at various intervals during the previous summer in the Sandilands Forest Reserve. Unfortunately, time did not permit the examination for sex-ratio of a much more extensive series of several thousand larvae collected at Hawk Lake, Ontario, throughout the period of larval activity. This collection is available, however, for future reference, and it would be of great value as a means of expanding the sex-ratio theme if these larvae were differentiated at the earliest opportunity. This value arises from observations made in the field, which indicate a south-easterly spread of the Budworm infestation. Thus sex-ratio data would become available for all stages of an epidemic and apparently very virile population.

The following table gives the information secured from the above mentioned larval examinations:-

Date	Females	Males	Sex-Ratio	Total
June 14- 1	11	6	0.647	17
June 16- 2) - 3) - 5)	257	223	0.535	480
June 17- 4) - 6)	75	101	0.426	176

PLATE 3

Females Males

(Table Cont'd)

Date	Females	Males	Sex-Ratio	Total
June 21- 9) -10)	19	18	0.513	37
June 24-11)	23	29	0.442	52
June 26- 7	19	21	0.475	40
July 10- 8	13	1	0.928	14
	417	399	0.511	816

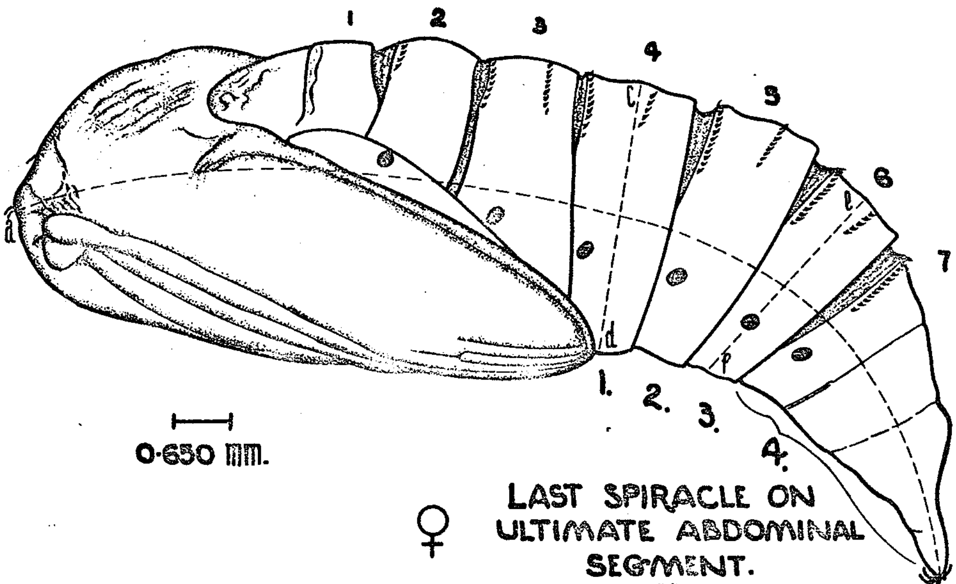
It will be noted that there is noticeable variation between the daily sex-ratios, but since the average for the whole population is almost equality, it may be assumed that these irregularities are due to the varying numbers of larvae involved in each group. An exception to this is the ratio for July 10th, 0.928, because at this date pupae had been found in the field for several days. This is significant, since it will be shown below that male pupae are in the majority at the onset of the pupal period, i.e., the sex-ratio is <u>low</u>. Consequently one would expect to find a <u>high</u> larval sex-ratio at this time, i.e., a majority of the larvae will be females. (Refer to Page 1). This explains the high ratio for July 10th in the table just presented.

(b) Pupal Sex-Ratios -

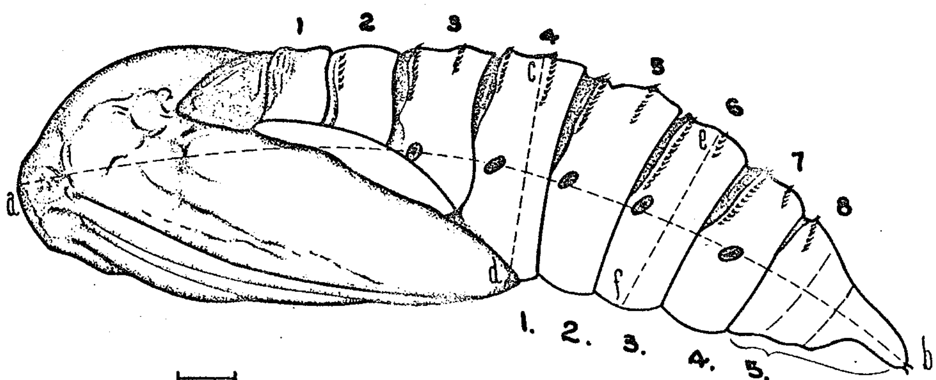
During the month of July, 1938, 33,315 pupae of the Spruce Budworm were collected in the Sandilands Forest Reserve through the co-operation of the Manitoba Forest Service, its officers, and personnel of the Manitoba Forest

PLATE 4

AN ILLUSTRATION OF GRAHAM'S METHOD
of DETERMINING SEX of
PUPAE of THE SPRUCE BUDWORM
- by -
EXTERNAL SEXUAL DIFFERENCES.



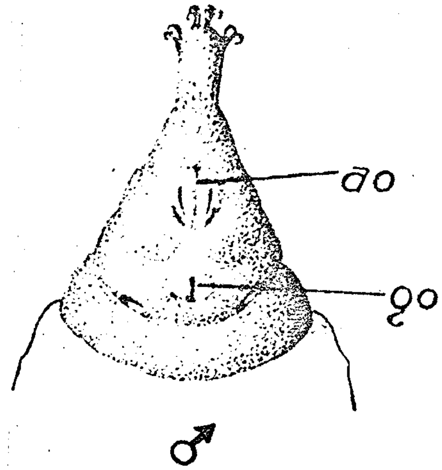
♀ LAST SPIRACLE ON ULTIMATE ABDOMINAL SEGMENT.
⊡



♂ LAST SPIRACLE ON PENULTIMATE ABDOMINAL SEGMENT.
⊡

LTJ

PLATE Va



ao ..... Anal opening

go ..... Genital opening

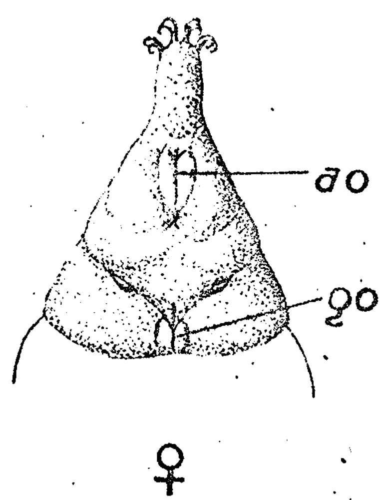


PLATE Vb

Conservation Training Camps Nos. 2 and 3. Pupal collections began on July 7th, and terminated on July 18th. By the latter date the emergence of adult moths as well as adult parasites from these pupae made further collections impracticable.

Sex determinations of 19,158 of these pupae, made at random assortment are aggregated in the following table:

Before presenting this data it will be necessary at this point to describe the method employed in arriving at these figures. Plates IV and V_a and V_b illustrate the pupae of the Spruce Budworm, male and female as indicated.

The former plate shows in lateral view the arrangement of the abdominal segments below the wing covers, four in the female and five in the male. Actually the total number of segments is the same, but the male has one more free segment than the female. In the female pupa a spiracle is found on the ultimate segment, whereas in the male the last spiracle occurs on the penultimate segment. This is the method employed by GRAHAM ('35) in Michigan forests. (The plate however is original.)

The latter plates, V_a and V_b, reproduced from GIBSON ('25) illustrate the sexual characters of the ventral, posterior region of the male and female pupae respectively and serve to corroborate the method of GRAHAM already mentioned, insofar as they offer a check on the relation between the segmentation and the morphological appearance of the ultimate segments of the abdomen, ventrally. A further check is provided on the former method by Plate VI, which is an actual photographic representation of lateral views of the male and female larvae, pupae and adult Budworm. Finally, by rearing through such pupae the sex-ratio of the adults is found to coincide exactly (in the absence of mortality) with that found by these methods, the former of which, i.e. Graham's, is the simpler, and the one employed in gathering the data below.

SEX-RATIO DETERMINATIONS

Date	Camp I Area: Pupae Exam'd	Camp I Area: S-R	Camp III Area: Pupae Exam'd	Camp III Area: S-R
July 7	-	-	1246	.519
7	-	-	1197	.556
8	858	.514	1041	.641
9	686	.515	1039	.619
11	873	.597	935	.663
12	647	.621	755	.783
13	583	.650	1171	.703
14	1198	.684	864	.735
15	1392	.584	758	.768
16	1450 (1595)	.664 (.658)	760 (826)	.703 (.691)
18	778 (881)	.683 (.677)	319	.709
18	-	-	212 (314)	- (.637)
	8445 (8693)		10297 (10465)	
			8445 (8693)	
		Grand Total:	18742 (19158)	

Average Sex-Ratio: 0.687

NOTE: Unbracketed figures represent the number of pupae examined prior to emergence of moths or parasites. In instances where partial emergence had occurred amongst the daily collection, cast skins were also examined for sex and in such cases the total of pupae plus cast skins is shown in brackets.

Of these 19,158 pupae determined as above, 18,725 were packed in screened containers and retained on ice according to instructions received from Dr. A. B. Baird of the Belleville Parasite Laboratory, pupae being packed the same day as collected. The entire collection was shipped to Belleville on July 19, 1938.

These data indicate very clearly that there is a progressive increase in the sex-ratio, i.e., the proportion of females to total population rises, as the period of pupation advances. However, GRAHAM ('35) believes the significant pupal sex-ratio obtains at the peak of pupation. One objection to this restriction is that unless pupae are very abundant over a wide area sampling on one day disturbs the sex-ratio balance, to the detriment of subsequent collections. The two sets of data presented above tend to overcome this difficulty to some extent, because from a statistical standpoint replication provides increased accuracy from random samplings. The map of the Sandilands Forest Reserve, to be found in that section of the Introduction dealing with Distribution, shows the two areas - M.F.C.T.S. Camps Nos. I and III - in which these collections were made.

In addition to field data, the following tabulation presents the results of sex-differentiation of 297 pupae reared in the insectory in similar equipment to that shown in Photo 2, Plate VII:-

PUPATION and SEX-RATIO
in
INSECTARY REARED SPRUCE BUDWORM LARVAE

Date		Male	Female	Sex-Ratio	Totals
July	5	66	36	.352	102
	9	31	37	.544	68
	12	26	43	.623	69
	14	3	3	.500	6
	15	7	12	.631	19
	18	4	15	.789	19
	22	5	9	.642	14
		142	155	.583	297

The sex-ratio derived from totals is 0.521 (cf. .583). The confined population showed a similar trend of fluctuation in sex-ratio over the period of pupation to that collected in the field. It will be noted, however, that there are irregularities in its distribution which it would seem reasonable to attribute to the smaller numbers involved. It is significant, however, that there is the trend from a low ratio to a high, increasing as time advances. Thus there seems to be certain incidental evidence to support the assumption made above, that the relatively slower development of the Spruce Budworm female has some Survival Potential import. This subject is expanded in the Discussion, below.

Unfortunately, no data regarding the sex-ratio of emerging adults is available from these insectary reared individuals, but the trend of pupation is such that a fluctuation similar to that found in the cage studies is to be expected.

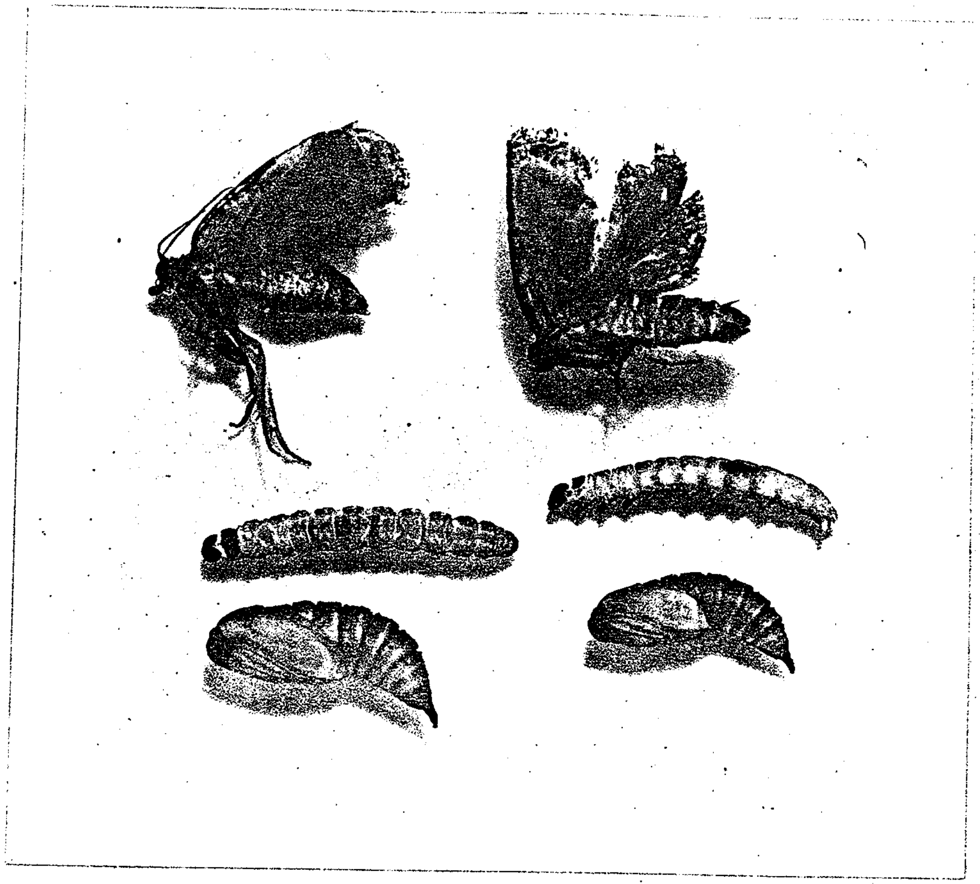
(c) Adult Sex-Ratios -

Some 9,426 pupae were confined in a rearing cage to determine such information as sex-ratio of emerging adults of the Budworm, period of adult moth emergence, the peak of emergence, as well as other data not pertinent here. The cage used was constructed originally for Bark Beetle population studies, and became available when they were terminated. The cage was of Factory Cotton, stretched upon a frame of scantling, the dimensions of the cage being 5' x 5' x 6'. It was fitted with a removable hatch at one of the lower corners, the whole structure being constructed in such a way as to be insect-proof. A board runway was laid on the floor of the cage and pupae were scattered between the boards, care being taken to prevent touching of the insects, one with another.

Pupae were accurately counted before being placed in the cage and daily observations and collections were made of all material that emerged. These specimens were all killed in cyanide bottles and packed dry for sexing. It might be mentioned in passing that in addition to the emerging moths of the Budworm there also emerged adult pupal parasites of Ichneumonid and Chalcid species, treated of in another thesis (R.R. Lejeune).

Sex differences in the adults are readily determined, the ovipositor of the female and the terminal portion of the male abdomen being very characteristic. These differences are shown in Plate VI.

PLATE VI



Female	Male
Adult	Adult
Larva	Larva
Pupa	Pupa

Introduction of Budworm pupae to this cage commenced July 8th and terminated July 15th, 1938. First emergence of adult moths was observed on July 11th, emergences no longer occurring after July 29th, 1938. The peak emergence occurred on July 18th, following which there was a marked decline in numbers emerging. The following table summarizes the emergence of Budworm moths:-

Date	Male	Female	Unsexed	Sex-Ratio	Totals
July 11	72	11	-	.133	83
12	76	19	-	.200	95
13	107	68	24	.384	199
14	131	158	-	.547	289
15	79	115	13	.593	207
16	137	179	-	.566	316
17	41	55	-	.573	96
18	137	198	-	.591	335
19	83	107	45	.563	235
20	25	34	-	.576	59
21	9	10	-	.526	19
22	10	12	-	.545	22
24	1	2	4	.666	7
26	1	2	7	.666	10
27	2	4	-	.666	6
29	0	0	-	.000	0
	911	974	93	.513	1978

It will be noticed that despite the wide variation in numbers available from date to date, that there is nevertheless a marked consistency in the shift of the Sex-Ratio from one of low potential to one of high, i.e. greater preponderance of females in the population. It will also be noted in the above tabulations that a significant change in sex-ratio occurs according to time, i.e., July 11, 1938, 0.133, July 27, 1938, 0.666. This coincides to a significant degree when compared to similar records derived from a field analysis of pupae, shown on Page 15, and is the more noteworthy in view of the relative totals involved between the two series. GRAHAM ('35) observed that "the males emerge somewhat ahead of the females so that in the early part of the flight males predominate, whereas at the end females predominate." He takes the sex-ratio obtaining at the peak of emergence as most significant, which is open to the same objection as that voiced for pupal peak ratios. However, on this basis the ratio in the Sandilands Forest Reserve during the 1938 season was 0.591.

It will be apparent that from a total of 9426 pupae introduced into the rearing cage a total of 1994 (1978 above plus 16 moths recovered when the cage was dismantled) emerged as adult moths. Thus the indicated mortality during the pupal period from all causes, may be computed as 78.84%.

Discussion:

A number of very interesting points arise from the above studies, and a potentially important hypothesis would appear to be tenable from the data at hand.

Figures have been presented to demonstrate a marked size difference between the male and female gonads in larvae of the Spruce Budworm. The significance of such figures can be conceived to be in the nature of a Protective Niche, a Time Niche. By Time Niche is meant a slower development of the female, resulting it may be assumed, from the relatively undifferentiated gonads in the larval female when compared to the glandular development of the larval male in the same age class. This lack of similarity in development has been shown to manifest itself as a gradual fluctuation in sex-ratio, from a low sex-ratio to a high in larvae, pupae and adults. It would seem quite reasonable to assume that such environmental forces as weather or food might operate in a sexually selective manner. As mentioned previously, BRANDT ('37) showed such adverse effects in the case of 1st instar Nun Moth larvae. The first instar larvae of the Spruce Budworm are so minute that their examination for a sex-ratio has not been possible due to the time factor. It appears to be of the utmost importance, however, that it be obtained as an indication of possible lack of equality in the sexes at this early stage. The marked size difference of gonads between the sexes presents the possibility of physiological difference between the sexes, the males being obviously more advanced in sexual development, for if a male gonad be dissected, the peritoneal sheath is found to surround a series of spermatic tubules, whereas the ovary is merely four ovariolar rudiments and undifferentiated exterially (refer to Plate I). These differences apply in all instars.

The conception of a Time Niche is substantiated to some extent by the variations in the sex-ratios of pupae and adults presented above, where it is seen that the male larvae not only pupate first but emerge first as adults. These facts raise two important questions, to which there are no answers as far as the writer is aware:-

(1) For what period after emergence are the adult

male moths able to fertilize female moths?

The importance of the reply to this question rests upon the fact that a low sex-ratio prevails amongst the adult moths during the first half of the period of adult emergence. All the males emerging will not have mates, and it is certain that if the male population assumes a condition of comparative impotency then the high sex-ratio which succeeds the earlier low ratio will find great numbers of female moths unfertilized, having an extremely detrimental effect upon the population density of the subsequent generations.

And: (2) How many female moths is a male capable of fertilizing?

The answer to this question is intimately related to both the question and answer of that first posed. This arises from the possibility that a high sex-ratio might obtain as regards emergence, the emerging females entering an environment along with few contemporary males, the male population of the environment containing merely impotent members of previous male emergences. If the fertile males available were polygamous, however, there would be greater opportunity for numbers of females to mate, oviposit, and so maintain a more even population density.

These points occurred to the writer after opportunity to gather data had passed. The answers to these questions will show how the population as a whole survives two adverse factors, viz. an adverse sex-ratio fluctuation, and sexually selective environmental resistance.

Since there has been found, from the increasing pupal sex-ratio, an excess of males in the population shortly after pupation commences, the idea was entertained that parasitism of Budworm pupae - the stadium apparently most subject to such attack - might be greatest amongst the male sex. It was thought that these male pupae might act in the nature of a "buffer" against parasitism of female pupae to any considerable extent, the male pupae absorbing a large proportion of the parasitic population, thus reducing the intensity of parasitism to which female pupae would be exposed. Through the courtesy of R. R. Lejeune the following substantiating data is made available. The figures present the number of parasites emerging from Budworm pupae, males and females for a 24-day period, and thus indicate the sex most frequently parasitized in the pupal stadium:-

Date	Male	Female	Data for 3-day intervals Male	Data for 3-day intervals Female	Sex-Ratio
July 20	2	0)			
21	1	0)			
22	4	0)	7	0	0.000
23	3	1)			
24	17	3)			
25	13	3)	33	7	0.175
26	26	9)			
27	20	7)			
28	16	1)	62	17	0.215
29	28	6)			
30	27	4)			
31	15	10)	55	20	0.266
Aug. 1	25	12)			
2	10	13)			
3	11	6)	46	31	0.402

Table Cont'd:

Date		Male	Female	Data for 3-day intervals Male	Female	Sex-Ratio
Aug.	4	10	3)			
	5	5	5)			
	6	14	10)	29	18	0.382
	7	3	0)			
	8	4	6)			
	9	1	6)	5	12	0.705
	10	1	0)			
	11	0	0)			
	12	3	1)	4	1	0.200

These figures become of more obvious significance when arranged as totals of three day periods, where it is to be seen that not only do the male pupae suffer most from parasitic attack, but that there is a marked fluctuation in the sex-ratios of pupae so attacked, indicating that females are attacked most heavily about three days following heavy attack upon males, until a peak is reached between August 1 - 3. Were pupae attacked proportionately, the "buffer" hypothesis would not appear tenable, but these data indicate that some environmental factors, probably physiological sex differences, discriminate against the male as regards parasitism, i.e., there may be a sexually selective predisposition to parasitism amongst males or it may result from unequal sex-ratio changes. At any rate it appears fairly obvious that female pupae are not parasitized to any degree corresponding to that affecting the males until the sex-ratio approximates equality. Thus for the 3-day period, July 23 - 25 the numbers of males attacked was revealed as 33, the number of females only 7, a sex-ratio of 0.175. Whereas from August 1 - 3 the sex-ratio was 0.402, the sexes being attacked more equally. The greater development of the gonad in the male larvae would lead the writer to assume that some physiological difference might be carried into the pupal state, predisposing male pupae to attack by parasites.

A further point in connection with the size difference of the gonads between the sexes is that the female, by maturing more slowly would possibly utilize most of her nutritive materials for gonad formation in the larval stadium, converting such excess into fat-body. Data is thus desirable on the relative richness of the reserve food resources of this organ in the two sexes. Although this point has yet to be established, the female may prove more passive than the male. It is apparent that a rapid development must take place in the pupal stage, and since this is a condition of almost complete inactivity a large proportion of the fat so stored would carry over into the adult stage to be utilized by the female in the further nourishment of the gonad and maturation of its contents. Observation of dissected females reveals a relatively abundant fat-body in the female moth, but data of a qualitative nature would be necessary to establish its relative richness when compared with that of the male.

To determine whether the pupae of the Budworm are subject to other sexually selective mortality than parasitism, two samples of 100 pupae each were taken at random from a collection of about 4000 of the pupae involved in the 78.84% mortality encountered in the cage as mentioned on Page 20. The causes of this mortality are obscure. The first sample produced 87 female and 13 male pupae or a sex-ratio of 0.870. The second sample produced 86 female and 14 male pupae or a ratio of 0.860. The average sex-ratio of the two samples is 0.865. This result is contradictory to the expected in the light of apparent predisposition of the male to parasitism, as just discussed on the last page. It thus appears additionally that an as yet unknown factor, or factors, discriminates heavily against female pupae, since parasitism is not in operation here at all. This mortality may be physiological weakness of strain, or a genetic lethal might be operating, or bacterial or other infection may have produced the resulting discrimination. Careful investigation is necessary to throw light upon the question at the earliest opportunity.

Conclusions -

(1) The literature concerning the separation of the sexes in Lepidopterous and other larvae is very meagre. Published reports regarding larval sex-ratios are rare, only one having been located (BRANDT '37) in a not readily obtainable journal. His methods are unknown to the writer.

(2) Separation of the sexes of larvae of the Spruce Budworm has been demonstrated, and sex-ratios derived, adding another method for obtaining such ratios in this species.

(3) The size of the male gonad appears to be uniformly

about three and a half times the female gonad in length and two and one-half times in width.

(4) The larval sex-ratios would appear to be more desirable than either pupal or adult, in the light of objections which arise to GRAHAM's ('35) selection of the peak ratios for pupation and adult emergence.

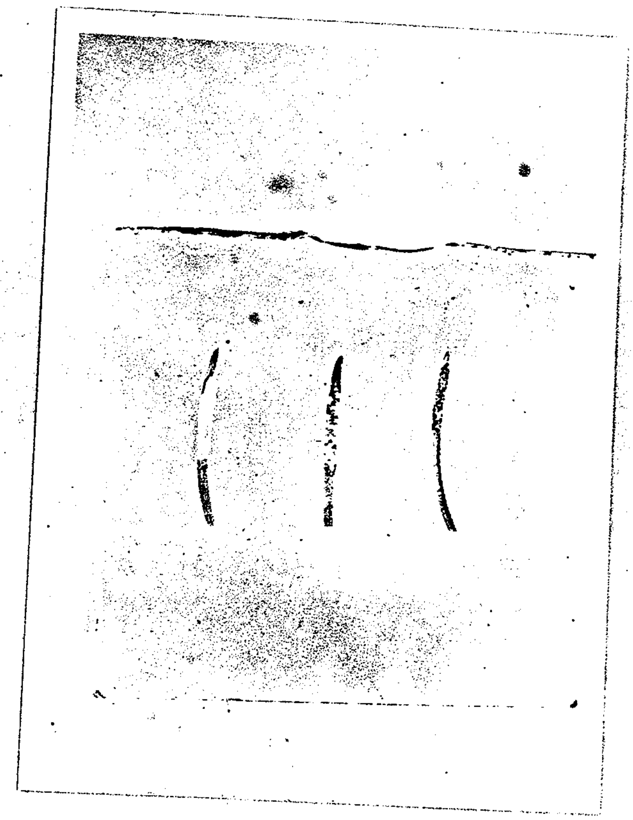
(5) In conjunction with pupal and adult sex-ratios, the larval ratio provides a means for studying the sexually selective operation of certain environmental factors. The three ratios provide a concrete estimate of the specific sex-ratio, i.e., the average summation of the stadial sex-ratios.

(6) The sex-ratio of 19,158 pupae collected in the field ranged from 0.514 at the outset, to 0.709 at the conclusion of the pupal collections. From the original counts of individuals of the various sexes, the average sex-ratio for all pupae examined was determined as 0.639. Pupae reared under insectory conditions, 297 in all, showed a similar shift in sex-ratio from 0.352 at the beginning of pupation to 0.642 at the end of the period, with an average ratio for the group of 0.583. Thus it is certain that male larvae do pupate in greater numbers than do female larvae, in the early part of the pupation period.

(7) The period of emergence of Budworm adults from con-

fined pupae extended from July 11th to July 27th, 1938. Peak emergence occurred on July 18th, following which there was a marked decline in the number of adults emerging.

(8) Sex-ratios of emerging adults varied from 0.113



to arise when the Time Niche factors conflict with the apparent predisposition of male pupae to parasitism, and the apparent female susceptibility to an as yet unknown mortality factor. This equalization is expressed as an average adult sex-ratio of 0.513.

In this manner a pupal sex-ratio of 0.639 was fined pupae extended from July 11th to July 27th, 1938. Peak emergence occurred on July 18th, following which there was a marked decline in the number of adults emerging.

(8) Sex-ratios of emerging adults varied from 0.113 on July 11th, to 0.666 on July 27th, 1938, with an average for all emergents of 0.513, and a ratio at the peak of emergence of 0.591. (vide GRAHAM '35).

(9) The average sex-ratio derived from a summation of the available data relating to the sex-ratios of all stadia - larval, pupal, and adult - is 0.605, which seems to indicate that the Survival Potential of females is slightly <u>higher</u> than that of males. The writer therefore assumes a physiological explanation, not yet determined, probably arising from the slower development of the female gonads. This constitutes the Time Niche discussed in the Introductory Remarks.

However, equalization of the sexes would seem to arise when the Time Niche factors conflict with the apparent predisposition of male pupae to parasitism, and the apparent female susceptibility to an as yet unknown mortality factor. This equalization is expressed as an average <u>adult</u> sex-ratio of 0.513.

In this manner a pupal sex-ratio of 0.639 was reduced to an adult ratio of 0.513.

(10) It would seem that those conditions which discourage the optimum development of the male will tend to affect the sex-ratio still more adversely, with its consequent effect upon the density of subsequent populations. The application of artificial increase of the parasitic population would seem most practicable. Thus if parasites were held in long term cold storage - there are 18,725 pupae of the Budworm, numbers of which are parasitized, in the cold storage rooms of the Belleville Parasite Laboratory at the time of writing - until field study revealed that <u>Larval Sex-ratios</u> are <u>high</u>, arrangements might be made to have the parasites shipped up to the infested area in time to cause a sexual imbalance, through selective parasitization of male pupae, which would appreciably decrease the numbers of females mated and consequently the numbers of eggs laid. In this connection it is imperative that the possible polygamity of the Budworm be investigated, for reasons discussed elsewhere.

(11) If the factors discriminating so adversely against female pupae were as controllable as parasitic material and could be stored indefinitely, then the <u>larval sex-ratio</u> would need to be <u>low</u> to indicate the most advantageous use of such methods.

One other possible, practical, application of the larval sex-ratio needs re-stating, and that is its potential use as an indicator of population trends, towards or away from epidemicity, and due to purely inherent tendencies in the species. This use requires more definite data on several points, namely, more knowledge of seasonal variation in larval sex-ratios themselves, the effect upon them of environmental factors, and the like, as presented on Page 5 as implications 1 to 7.

1. BIONOMIC DATA

B. Egg Data.

EGG DATA

(1) Field -

The following information was collected in the Sandilands Forest Reserve during the period indicated below. Co-operation in the collections was obtained through the generosity of officers of the Manitoba Forest Service and of the M.F.C.T.S. Camps Nos. I and III.

The objects for which these data were collected were essentially twofold; the elucidation of the numbers of eggs per mass being laid, on the average, during the season 1938; and the incidence of egg parasitism during the same period. Minor points are discussed in the following pages as they arise.

For the most part the female lays eggs on the adaxial surfaces of living, mature needles. In a few unusual instances egg masses were found laid other than on the adaxial surface of mature needles. Occasionally an egg mass would be found laid abaxially, or edgewise, or both surfaces of the same needle might be plastered with eggs. This latter instance made the masses very conspicuous. In one case an egg mass was located upon a completely dead fascicle. A very few were found laid on shorter, immature needles and the occasional one was found upon fascicles as yet unexpanded to any extent. The following table shows the distribution of egg masses from old and from very young fascicles, chosen at random in the field from the Top, Middle, and Bottom thirds of the crowns of freshly felled trees. (Such trees were chosen by striking the bole with an axe to disturb the adults on the foliage, those trees harboring the most moths being selected.)

	Number of Fascicles		Number of Egg Masses	
	Old Needles	New Needles	Old Needles	New Needles
TOP	2176	1638	2	-
MIDDLE	1839	196	2	-
BOTTOM	2598	266	1	-
	6613	2100	5	0

These figures would seem to indicate that oviposition upon new growth must be very infrequent in the field. For the older growth the ratio of egg masses to fascicles is as 1:1322.6.

(ii) Field Collections -

Egg masses were located in the field upon trees showing the greatest response of the adults when the bole of the tree was struck with an axe, as mentioned above. Trees so selected were felled and trimmed, the branches then being conveniently subdivided. The procedure thence was to examine every fascicle to note and collect any egg mass which might be found attached. In this manner 11 trees, ranging in height from 18½ ft. to 37 ft., were selected. The masses collected in the Top, Middle, and Bottom thirds of the tree were segregated, and were further subdivided into Parasitized (by Trichogramma minutum), and Unparasitized, (See Plate VIII). The following table presents the data so obtained:-

Date	Top P'd	Top Unp'd	Middle P'd	Middle Unp'd	Bottom P'd	Bottom Unp'd	Total
July 20	-	2	-	3	-	26	31
21	-	9	1	28	-	2	40
22	2	47	-	45	-	25	119
23	1	10	1	69	1	23	105
25	1	44	19	213	-	14	291
26/27	1	116	33	456	-	138	744
	5	228	54	814	1	228	1330

Total Masses Distribution:

			%
Top	233		17.5
% Parasitized		2.14%	
Middle	868		65.2
% Parasitized		6.22%	
Bottom	229		17.2
% Parasitized		0.43%	
Total Parasitization	1330	4.51%	

From the collections made above, 131 normal egg masses were examined for the number of eggs each contained. These were selected at random, and at different dates and thus there is observed to be an inequality in the number counted from the Middle third of the crown region. However, this is not thought to be significant in view of the greater accuracy a larger number of counts would be expected to give. The following tables present the variations in numbers of eggs per mass in the Top, Middle, and Bottom thirds of the crown:-

TOP THIRD OF CROWN

Egg Mass No.	No. Eggs	Egg Mass No.	No. Eggs
1.	43	20.	40.
2.	56	21.	94
3.	105	22.	99
4.	58	23.	84
5.	60	24.	79
6.	27	25.	33
7.	58	26.	40
8.	58	27.	63
9.	26	28.	17
10.	56	29.	43
11.	39	30.	72
12.	82	31.	33
13.	70	32.	72
14.	63	33.	102
15.	29	34.	20
16.	54	35.	52
17.	78	36.	91
18.	65	37.	58
19.	69	38.	53
	1094		1145

Total No. Egg Masses examined 38

Total No. Eggs counted 2239

Average No. Eggs / Mass $\frac{2239}{38}$ 58.9

MIDDLE THIRD OF CROWN

Egg Mass No.	No. Eggs	Egg Mass No.	No. Eggs
1.	6	28.	58
2.	95	29.	43
3.	43	30.	67
4.	45	31.	61
5.	35	32.	5
6.	66	33.	45
7.	72	34.	65
8.	88	35.	69
9.	77	36.	57
10.	47	37.	81
11.	75	38.	40
12.	55	39.	81
13.	80	40.	33
14.	95	41.	83
15.	91	42.	71
16.	15	43.	30
17.	114	44.	63
18.	90	45.	31
19.	42	46.	63
20.	48	47.	70
21.	87	48.	75
22.	15	49.	80
23.	68	50.	32
24.	14	51.	105
25.	37	52.	69
26.	90	53.	47
27.	46	54.	58
	1636		3218

Total No. Egg Masses examined...... 54

Total No. Eggs counted............. 3218

Average No. Eggs / Mass $\frac{3218}{54}$ 59.5

BOTTOM THIRD OF CROWN

Egg Mass No.	No. Eggs	Egg Mass No.	No. Eggs
1.	22	21.	81
2.	82	22.	56
3.	43	23.	79
4.	56	24.	41
5.	53	25.	70
6.	85	26.	77
7.	72	27.	98
8.	61	28.	56
9.	60	29.	62
10.	36	30.	89
11.	62	31.	39
12.	47	32.	30
13.	37	33.	40
14.	25	34.	74
15.	58	35.	25
16.	20	36.	31
17.	51	37.	103
18.	38	38.	82
19.	88	39.	41
20.	50		
	1044		1174

Total No. Egg Masses examined....... 39

Total No. Eggs counted.............. 2218

Average No. Eggs / Mass $\frac{2218}{39}$ 56.8

(Table Cont'd)

Egg Mass #	# Eggs	Egg Mass #	# Eggs	Egg Mass #	# Eggs
121.	51	161.	30	201.	63
122.	36	162.	44	202.	56
123.	67	163.	37	203.	85
124.	65	164.	73	204.	57
125.	79	165.	52	205.	42
126.	100	166.	101	206.	62
127.	80	167.	47	207.	50
128.	50	168.	33	208.	42
129.	25	169.	71	209.	75
130.	44	170.	72	210.	36
131.	41	171.	82	211.	80
132.	29	172.	101	212.	70
133.	34	173.	50	213.	41
134.	57	174.	34	214.	31
135.	54	175.	13	215.	23
136.	28	176.	43	216.	27
137.	46	177.	34	217.	36
138.	47	178.	56	218.	44
139.	76	179.	85	219.	44
140.	42	180.	49	220.	42
141.	50	181.	63	221.	40
142.	55	182.	53	222.	19
143.	30	183.	64	223.	61
144.	37	184.	53	224.	72
145.	32	185.	74	225.	85
146.	56	186.	63	226.	14
147.	65	187.	51	227.	78
148.	51	188.	57	228.	103
149.	1	189.	37	229.	31
150.	39	190.	27	230.	76
151.	46	191.	56	231.	20
152.	104	192.	52	232.	58
153.	43	193.	85	233.	42
154.	54	194.	69	234.	54
155.	32	195.	59	235.	28
156.	29	196.	51		
157.	60	197.	49		
158.	91	198.	59		
159.	58	199.	36		
160.	88	200.	61		
	2072		2226		1787

Total No. Egg Masses examined..... 235

Total No. Eggs counted............ 13,008

Average No. Eggs / Mass $\frac{13,008}{235}$ ... 55.3

(See Graph I overleaf)

G R A P H I

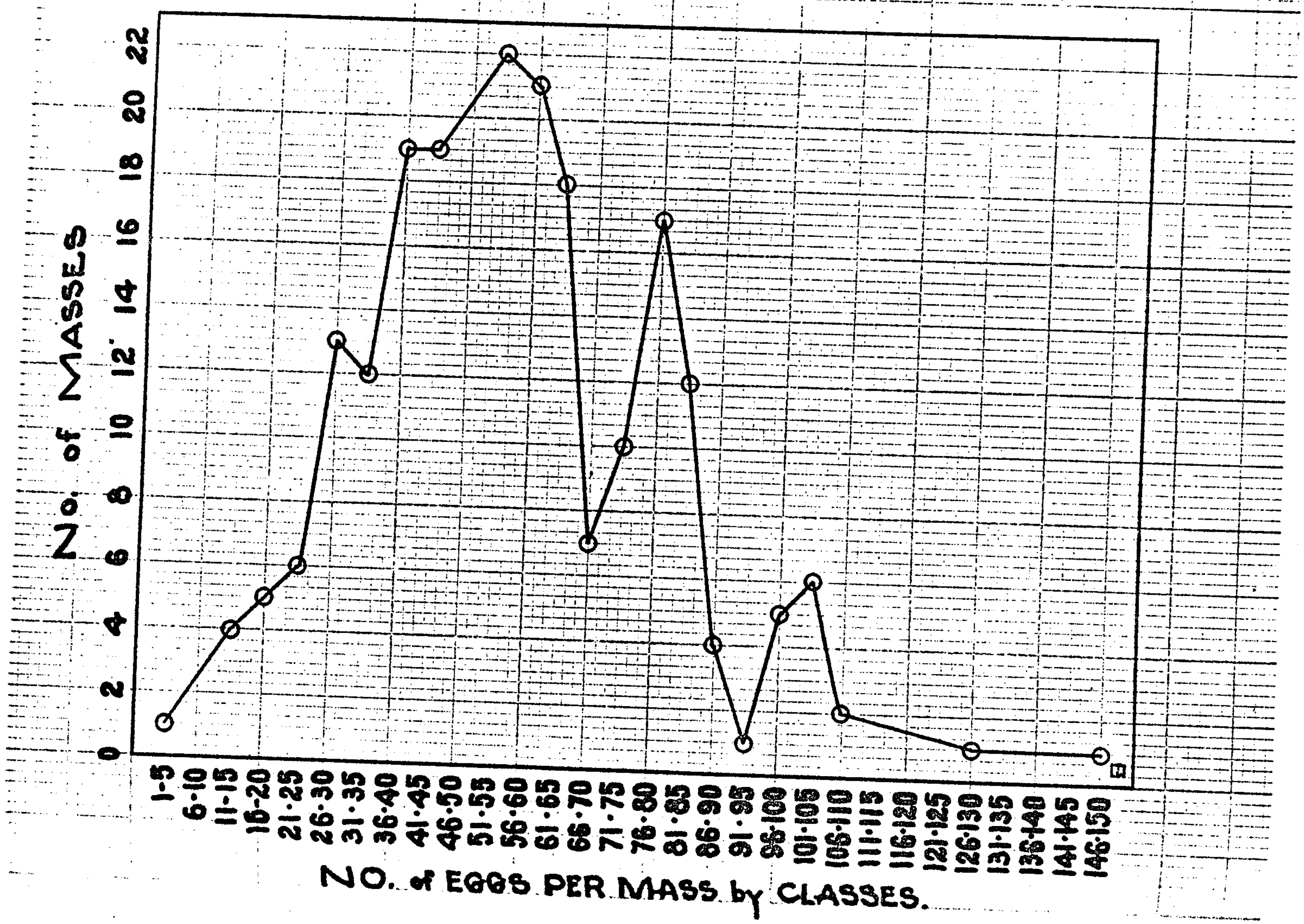
No. of Eggs per Mass by Classes, refers to the numbers of eggs actually counted.

No. of Masses, shows the number of masses giving rise to these eggs.

The graph therefore expresses the frequency distribution of numbers of eggs in proportion to number of masses containing them in small, medium or large numbers.

The graph illustrates that the mean is approximately 55 eggs per mass, a figure which is in close accord with that calculated from the preceding data (55.3). The curve thus has significance as an indication of frequency distribution. The smallest mass contained one egg, the largest contained 150 eggs.

DISTRIBUTION OF NUMBER OF EGGS PER MASS.
- NORMAL -



From the parasitized egg masses available, 49 were selected for examination, the number of normal eggs in the mass being noted as well as the parasitized eggs included. The accompanying Plate V111 illustrates, from left to right, a Normal egg mass, an egg mass with 50% parasitization and another mass with 100% parasitization of the eggs. The following figures represent the findings:-

Parasitized Egg Mass No.	No. Eggs in Mass	No. Eggs Parasitized
1.	92	2
2.	99	1
3.	98	1
4.	45	3
5.	47	14
6.	73	30
7.	79	1
8.	56	15
9.	52	51
10.	70	70
11.	42	21
12.	46	10
13.	86	52
14.	49	46
15.	61	33
16.	40	4
17.	55	53
18.	93	48
19.	94	40
20.	37	14
21.	110	105
22.	68	56
23.	50	31
24.	54	54
25.	60	31
26.	78	10
27.	60	46
28.	56	17
29.	68	3
30.	37	27
31.	82	7
32.	74	71
33.	75	10
34.	72	26
35	51	51
36.	44	43

(Table Cont'd)

Parasitized Egg Mass No.	No. Eggs in Mass	No. Eggs Parasitized
37.	16	16
38.	97	4
39.	98	35
40.	6	3
41.	74	2
42.	96	40
43.	41	4
44.	34	34
45.	65	26
46.	90	10
47.	98	5
48.	69	10
49.	55	5
49.	3192	1186

These comparisons would seem to indicate a lack of correlation between size of egg mass and degree of parasitization of egg mass. This is illustrated by the irregularity of the curve on Graph II, overleaf.

The percentage parasitization is, for the 49 masses:

$$\frac{1186}{3192} \times 100 = 37.1\%$$

It will be observed that in only 5 cases were egg masses of the host completely parasitized. These were Nos. 10, 24, 35, 37 and 44, and it is obvious that no relationship exists between these masses as regards numbers of eggs they contain. GRAPH III, following, illustrates this data.

GRAPH II

This graph shows the Host eggs by Numbers of Eggs per mass on the horizontal axis, and numbers of masses of each class parasitized on the vertical axis.

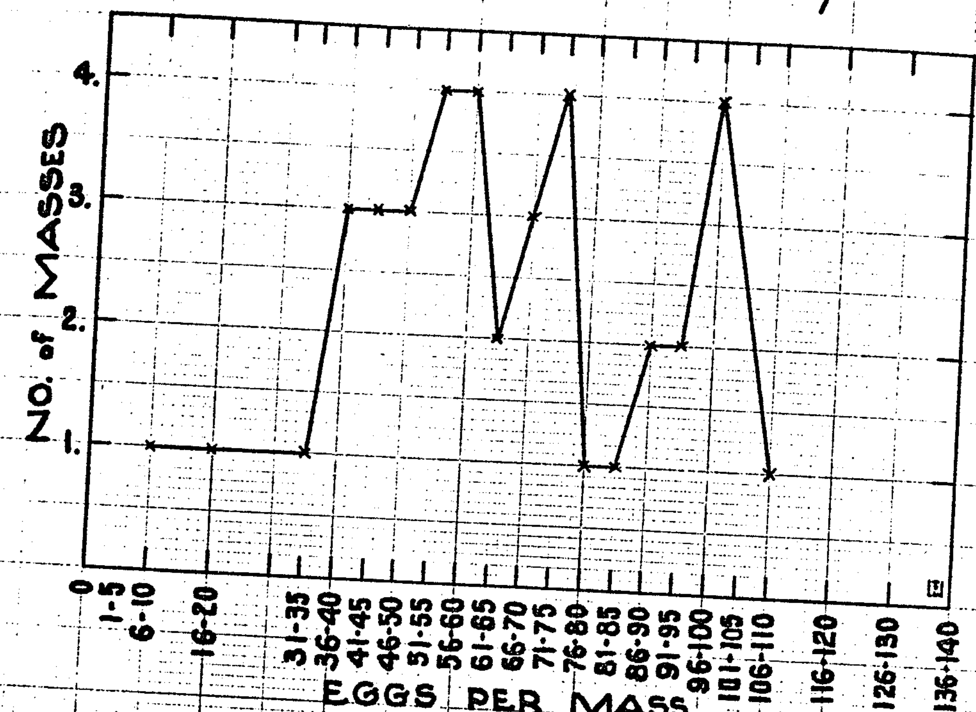
The graph illustrates the apparent versatility of the egg parasite in its choice of host material, from the standpoint of numerical egg content of such material.

GRAPH III

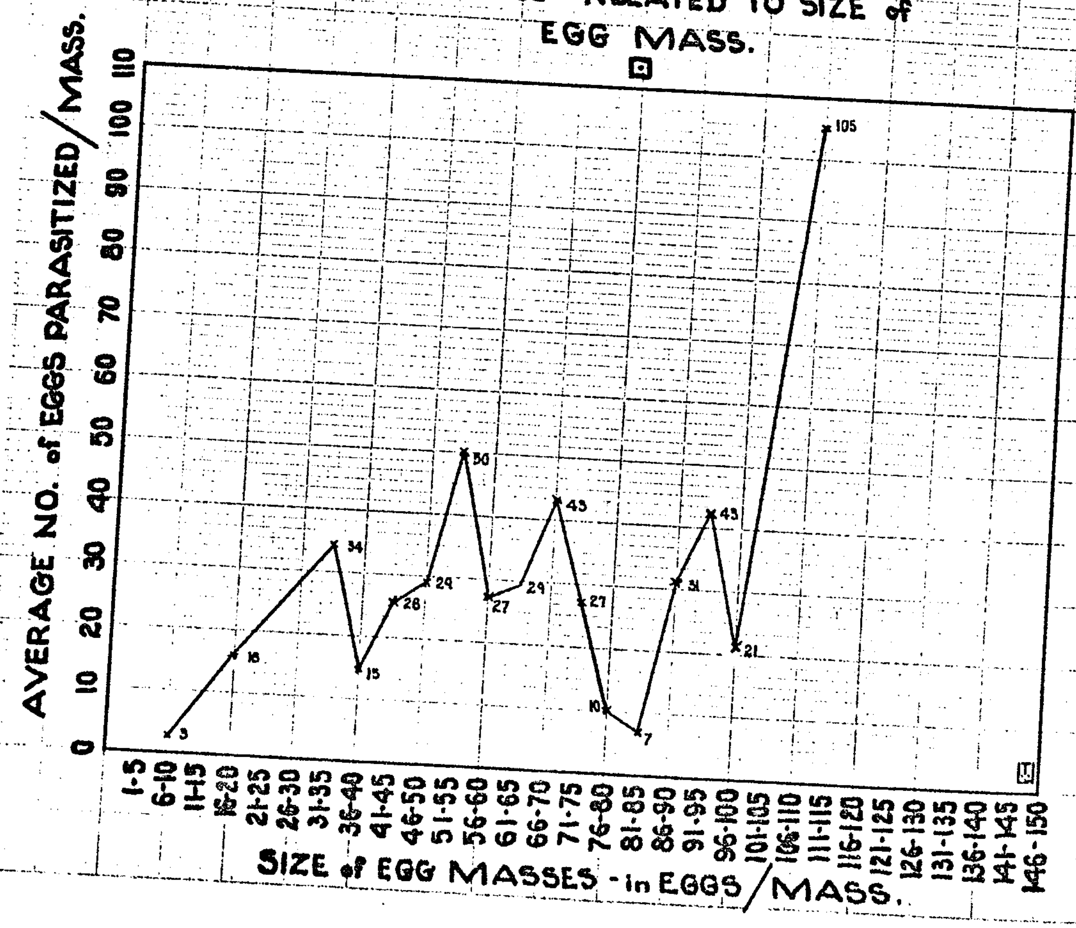
This graph shows the number of eggs parasitized in the host egg masses, compared with the numbers of available eggs in the masses.

It is seen that very little complete parasitization of host egg masses occurs, and that the most favoured masses fall in the classes with between 30 - 96 eggs per mass.

DISTRIBUTION of NO. of PARASITIZED EGGS / MASS.



AVERAGE NUMBER of PARASITIZED EGGS PER MASS – RELATED TO SIZE of EGG MASS.



No data is available concerning the biology of Trichogramma sp. infesting the eggs of the Spruce Budworm, except the incidence of such parasitization.

Attempts to carry Budworm eggs over at 32 degrees F., until adult Trichogrammids had emerged, were without success. The wasps moved rapidly and excitably over the surface of the egg masses, occasionally pausing, but no sign of either oviposition nor feeding at puncture holes was observed. It is more than likely that quite definite conditions of the environment must be favourable for these recently emerged wasps to infest other eggs of the Budworm, if indeed they do so at all.

This problem is complicated because there is a great probability of these minute egg-parasites having a series of alternate and seasonal hosts. The egg stage of the Spruce Budworm is very short - approximately 9 days, and one cannot assume the wasp to be specific to the Budworm, developing in the short period of about 9 days and inactive the rest of the summer season. But a series of collected eggs of Coccinellids, Aphids, Loopers, etc. revealed but one instance of egg parasitism, in eggs of a Looper of undetermined species.

While the total population of Trichogrammids would appear small, 5.05% parasitization in 23,975 eggs, the Spruce Budworm may be one of the less frequently selected hosts. The problem would be best pursued as an isolated entity, due to the large amount of rearings necessary for elucidation.

SUMMARY OF THE FOREGOING EGG DATA

Total Number of Masses with Normal Eggs only	366
Total Number of Masses with Parasitized eggs	49
Grand Total Number Masses of Both examined and counted	415
Total Number Normal Eggs counted	22,789
Total Number Parasitized Eggs counted	1,186
Grand Total Number counted eggs of Both classes....	23,975
Mean Number Eggs / Mass $\frac{23,975}{415}$	57.7
Average Number Normal Eggs / Mass $\frac{21,975}{366}$	60.0
Average Number Eggs / Parasitized Mass $\frac{3192}{49}$	65.1
Average Number Parasitized Eggs / Parasitized mass $\frac{1186}{49}$	24.2
% Parasitization of 49 masses, involving 3192 eggs, of which 1186 were parasitized $\frac{1186}{3192} \times 100$...	37.1
% Parasitization of 415 masses, involving 23,975 eggs of which 1186 were parasitized $\frac{1186}{23,975} \times 100$...	4.9

(iii) Insectary -

A. Object of Experiment.

This experiment was set up to collect data relative to the number of egg masses a female would lay on the average. From these egg masses the number of eggs per mass could be counted and the total number of eggs, together with the average number of eggs per female, in captivity, obtained.

B. Methods Employed.

Sixty-four females were confined with 55 males in screen wire cylinders enclosing fresh-cut twigs of Jack Pine, illustrated on Plate VII, Photo No. 1, overleaf. The screen cylinders are seen on the bench. The adults had been reared from larvae in Survey cans in the insectary, the usual method of providing a twig of host set in sand being employed. This equipment is illustrated in Photo No. 2, overleaf.

C. Results Obtained.

The following table represents the allocation and distribution of these adults, the number of egg masses deposited, the number of eggs per mass - maximum, minimum, and average - and the average number of egg masses per female.

PLATE VII

Photo 1.

Insectary, Sandilands Forest Reserve.

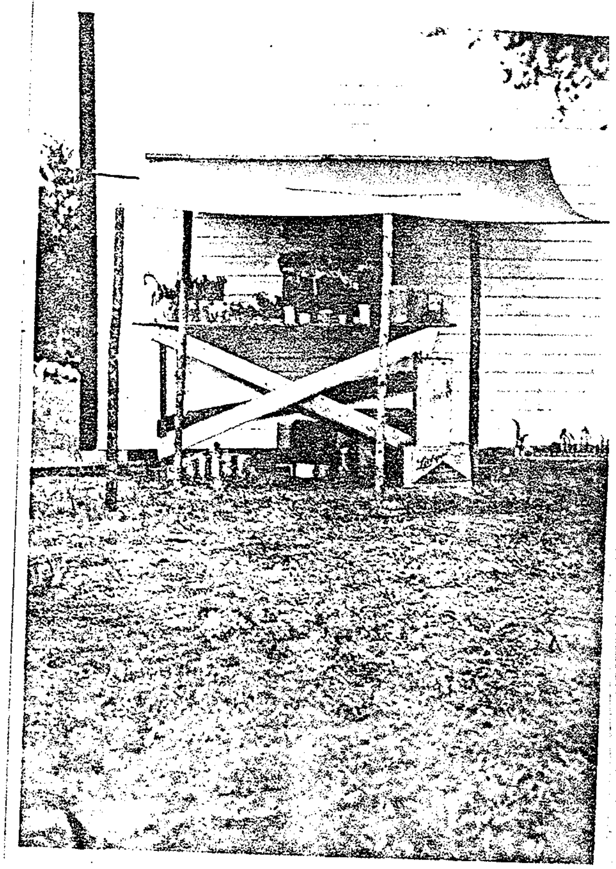


Photo 2.

Insect Survey Can, Lantern glass, and twig of Jack Pine.

Lot No.	No. Females	No. Masses	No. Males	No. Eggs / Mass	No. Masses / Fem.
A.	4	7	4	18-56; total 280; av.40	7/4, eq. 1.75
L.	9	42	7	1-48; total 517; av.13.6	42/7, " 6.0
M.	13	22	7	1-62; total 687; av.31.77	22/7, " 3.14
N.	11	32	13	1-64; total 811; av. (31) 26.16	32/11, " 2.9
O.	6	22	6	6-49; total 538; av.25.61	22/6, " 3.66
P.	12	19	8	2-70; total 634; av.33.37	19/8, " 2.37
Q.	5	15	6	1-66; total 404; av.26.9	15/5, " 3.0
R.	4	16	4	1-6; total 57; av. 3.56	16/4, " 4.0
	64	175	55		

Insofar as there were only 55 males employed, it is at present necessary to assume that only that number of females were involved in actual oviposition, because no data is available to indicate polygamy in the male of this species. On this basis, i.e., 55 males, the following figures summarize the table just presented:-

Probable number of mated females	55
Total number of egg masses laid	180
Total number of eggs laid	3928
Average number egg masses / female..................................	3.18
Average number eggs / mass	22.4
Average number eggs / female	71.4

Lowest number eggs / mass 1.0
Highest number eggs / mass 71.0

Females oviposited near the top of twigs provided, but on the old needles.

At Hawk Lake, Ontario, in the 1937 season, 66 females in confinement laid an average of 310 egg masses, an average of 4.7 per female.

(iv) <u>Miscellaneous</u> -

The following discussion covers a few general observations made during the hatching of Budworm larvae from the egg.

The first larval emergence from eggs kept in confinement in the laboratory occurred on the 24th of July, 1938. These egg masses were observed under the binocular microscope and the process of hatching noted. The young larva, in ovo, begins a rhythmic twisting of its body, bringing the head directly under the central portion of the shell. It begins to cut a crescentic piece of the shell away, working systemically around the shell. This cutting is done by the mandibles and the time involved in cutting this opening is quite variable. Some larvae observed rested at intervals. In vigourous appearing larva the time taken to emerge was approximately 4 minutes, these larvae immediately beginning a weaving motion with the fore part of the body as though seeking a definite stimulus, thence exploring over the surface of the egg mass and needle and finally the laboratory table. Before describing these habits further it is to be noted that some larvae only emerge from the shell to the extent of about one half their length and seem incapable of advancing further. This might be due to inherent lack of vigour - the larvae exhibiting this tendency are usually very small. This lack of activity would render them more susceptible to the attacks of predators such as Coccinellid and Chrysopid larvae, which are not uncommon on the foliage of Jack Pine. Active larvae would be able to drop on their silken threads.

The normal, active larvae move about restlessly, and in the laboratory if they come to a drop such as the edge of the table they descend from silken threads. The average primary descent, i.e., the length of the silk they let out before the first rest, is about four inches. This is based upon several score observations made while collecting such larvae into preservative. If the larval mouthparts are approached with a pencil or dissecting needle while the larva is at the end of its primary descent, it will break away from its first thread and descend from another which it attaches to the disturbing object and elongates by passing silk through its mouthparts. In this manner it will descend another 2-3 inches. Here it pauses again, and a repetition of the above procedure will produce a similar response upon the part of the larva, the additional thread being only approximately 1 inch in length. The larvae then appear to be exhausted and fall. A few fall immediately they are disturbed.

Discussion and Conclusions -

A survey of the available literature with regard to oviposition in the Spruce Budworm reveals several points of importance.

The average number of eggs per mass would not only appear very variable, but would tend to indicate that the Jack Pine variety of the Spruce Budworm possesses an egg capacity which is markedly higher than the Spruce-Balsam variety. Thus PACKARD ('90), JOHANNSEN ('13), PIERSON ('23) and CHAMBERS ('33) give the highest number of eggs found in any mass as thirty. The latter author definitely distinguishes these two varieties, based not only on their host plants but also upon minor colour differences. Despite his recognition of these varieties he has either found 30 eggs to be the maximum number, or what is more probable, has accepted the limit set by previous workers. Discussion centering about the colour varieties will be more fully dealt with subsequently.

Even lower average numbers of eggs per mass than 30 are reported by GIBSON ('25). He states that Tothill and Baird, in unpublished departmental manuscript, recorded that 25 egg masses totalled 465 eggs, an average of 18.6 eggs per mass. He also reports that G.E. Sanders in 1911 examined 184 egg masses, containing 2,024 eggs, an average of 11 eggs per mass. Field collections made at Maniwaki, Ontario, contained 1,192 eggs, or an average of 12.8 eggs per mass, according to Gibson. The largest mass contained 25 eggs.

The highest average found in the literature is given by GRAHAM ('35), as 43. This was obtained in Michigan on the Marquette Forest, but GRAHAM does not mention the extent of the observations from which this average was derived. An average closely approximating the one of Graham was obtained by R.R. LEJEUNE and the writer in the 1937 season at Hawk Lake, Ontario. This average was 45.9 eggs per mass, derived from a field collection of 525 masses comprising 24,023 eggs. No data from this area for 1938 is available, for comparison. However, during the 1937 season in the Sandilands Forest Reserve 212 masses were collected, and upon counting the eggs a total of 11,400 was reached, giving an average of 53.8 eggs per mass. Thus in South-Eastern Manitoba the highest average number of eggs per mass appears to have been recorded. This 1937 average has been found to be exceeded by that obtained in 1938, when, as indicated in the data above, 415 masses comprised 23,975 eggs, or an average of 57.7 eggs per mass. Egg masses exhibiting no parasitized eggs whatsoever themselves averaged 60.0 eggs, for 366 egg masses comprising 21,975 eggs. These comparisons, between South Eastern Manitoba and North Western Ontario, are very interesting, but as yet inexplicable. Unfortunately the weather data from the two areas has not yet been worked up, but the most noticeable differences between the two areas are related to moisture. The Sandilands and surrounding areas are excessively dry, less than four inches of rain falling during the 1938 season. The North Western Ontario area is on the other hand noted for the frequency and abundance of its rainfall. High relative humidities are also characteristic of the region. So much for the meteorological situation, as yet too indefinite to point to any conclusions. The most promising suggestion, if more speculative, arises from the fact that the infestation in the Sandilands is somewhat older than that in North Western Ontario, (DUNN, ('35)). This might conceivably indicate a very vigourous budworm population in the former area, which will subside first and the progress of general subsidence will take a south-easterly trend. To establish this point it would therefore seem of the utmost importance that large numbers of egg masses be collected from as many infested areas as possible, in Saskatchewan, Manitoba and North Western Ontario, in order to elucidate the focus of the general infestation based upon the relative numbers of eggs per mass. This type of study could, in the writer's opinion, be extended to all areas in which Budworm activity is severe; cooperative exchange of information thus obtained might prove very indicative in evaluating the status of the various infestations. Ideally, such a program should be repeated over a number of seasons, and be supplemented by sex-ratio information and meteorological data.

With regard to the maximum number of eggs oviposited by any given female, or by females on the average, little is known. GIBSON ('25) reports Tothill and Baird found one female laid 163 eggs; and that FERNALD stated a single female may lay as many as 125 eggs. Tothill, Gibson states, estimated females would lay an average of 150 eggs. GRAHAM ('35) reports 316, remarking, "this is an unusually large number and probably represents the result of excellent, although perhaps not perfect environmental conditions."

The following table records data derived by the writer from the dissection of eighteen female Budworm moths. The work was very tedious and time did not permit the expansion of this data, which would appear desirable:-

Female	No.Eggs	Female	No.Eggs
1.	250	10.	269
2.	242	11.	258
3.	42	12.	310
4.	240	13.	200
5.	167	14.	265
6.	176	15.	205
7.	154	16.	319
8.	275	17.	317
9.	288	18.	256
		18.	4233

This is an average of 235.1 eggs per female. The lowest number found was 42, the highest 319.

Assuming each female were to actually lay this average number of eggs, and dividing this number by the average number of eggs per mass as found in the data above (57.7), a theoretical average number of egg masses laid per female is found to be 7.3. It will be noted from the Insectary egg data recorded on Page 2 that an average of

4.7 masses per female obtained during the 1937 season at Hawk Lake, while during the season of 1938 in the Sandilands the average was 3.18. The latter average is comparable here to the theoretical, since all data were recorded from material collected in the Sandilands Forest Reserve. The difference between a theoretical average number of masses of 7.3, and an actual one under Insectary conditions of 3.2 is to be expected, since in the first place females would hardly be expected to mature all the eggs they contain, and in the second place, Insectary conditions are not ideal. It would seem, however, that this theoretical average number of masses is a legitimate technical symbolization, with valuable epidemiological potentialities.

Other conclusions arising from this data are as follows:-

(1) Normally, no oviposition occurs on immature fascicles of Jack Pine.

(2) The female moth is more partial to the upper two-thirds of the crown as a site for oviposition, although very little difference exists between the percentage of egg masses found in Top (17.5%) and Bottom (17.2%) thirds respectively. Also the average number of eggs per mass is slightly higher in the Top third (58.9 for 38 masses) than in the Bottom third of the crown (56.8 for 39 masses). GRAHAM ('35) found little difference between the top and bottom levels of the crown, but failed to

record any comparative data from the middle level. The above data has demonstrated that the middle level is most important.

(3) Parasitization of egg masses by Trichogramma minutum is greatest in the Middle third of the Crown (Top: Middle: Bottom:: 2.14%: 6.22%: 0.43%), where it is obvious the Budworm moth prefers to oviposit (see (2)).

(4) The low degree of parasitism of egg masses in the Bottom third of the tree is out of proportion to the difference in percentage of total egg masses laid there, when compared to the other two-thirds and especially the top; and is also inproportionate to the average number of eggs per mass found in the Bottom third. The possibility of phototropism, or greater attraction of host eggs in favoured portions of the crown is to be considered. Graph II seems to illustrate the absence of selection of host egg masses by the parasite, according to size of mass. Thus some physiological factor may be in operation, or else a certain definite stage in host embryonation is a limiting factor to parasitization.

Since the number of eggs per mass varies so extensively, either with locality, season, or biotic factors of an autecological nature, and probably the latter, it would seem that the averages for a reasonable series of masses from the two Budworm varieties, compared one season with another from various localities, would provide the possibility of indicating population density tendencies. This is an assumption all the more worthwhile when one considers its potential integration with the sex-ratio data previously presented.

11. BIOMETRIC DATA

A. Larval

LARVAL FOOD and POPULATION DATA together with LARVAL MEASUREMENTS

Since the rearing of larvae for the observation of differences produced by the two distinct food regimens - access to staminate cones containing pollen, and terminal leaf buds alone - was prevented from materialization, as described in the Introduction, the following collections were made to obtain the groundwork necessary for conducting such a project in a subsequent season.

The specific information obtained is given under the lot numbers following. The data below is of value at the present time as an indication of relative population densities, in staminate cones, and upon leaf buds.

GRAHAM ('35) has given the number of instars of the Spruce Budworm on Jack Pine as six, but does not give the mean width of the head capsule in each instar, nor any progression factor.

The following résumé serves to indicate that not only is the question as to the number of instars in the Spruce Budworm still open, but also that it is a complicated question of great potential importance to an enlightenment of Budworm epidemiology.

Measurement of the head capsule widths of 103 newly hatched (first instar) Budworm larvae gave a constant width throughout of 0.212 mm. GIBSON ('25) reports a width of 0.25 mm. for this stage. Both he and GRAHAM ('35) state that the first moult occurs in the over-winter hibernaculum, and the writer has found cast skins in such, together with the second stage larva. CRAIGHEAD ('24) observed that first instar larvae would moult in some cases before spinning the hibernaculum, and afterwards in others.

Measurement of the head capsule widths of 34 larvae that had emerged from hibernaculae on the same day collected were made and varied as follows:-

Head Capsule Width	No. Larvae
0.216 mm.	6
0.237 "	1
0.243 "	1
0.270 "	22
0.275 "	2
0.281 "	1
0.288 "	1
	34

The mean width from the larvae above is 0.2588 mm. which may be rounded off to 0.260 mm.

Using Dyar's Rule (Comstock '38), the progression factor is derived as follows:-

$$\frac{\text{Head Capsule Width 1st Instar}}{\text{Head Capsule Width 2nd Instar}},\quad \frac{0.212}{0.260}\ \ldots\ldots\ 0.81$$

On the basis of the above method, using the derived progression factor, the following mean head capsule widths are computed:-

0.212 mm.	0.260 mm.	0.319 mm.	0.379 mm.
0.465 mm.	0.576 mm.	0.706 mm.	0.866 mm.
1.029 mm.	1.263 mm.	1.550 mm.	1.902 mm.

This results in the production of 12 instars, double that given by GRAHAM ('35).

Still using Dyar's Rule, L. T. White of the Winnipeg Laboratory, applied the same method to the head capsules of larvae which, while being measured under the binocular, revealed that moulting would have taken place very soon had they not been preserved; and by measuring the head width, teasing out the new head capsule and measuring it, he determined a progression factor of 0.785. Applying this as above, the following mean head capsule widths are derived:-

0.212 mm.	(already	0.270 mm.	0.344 mm.
0.438 mm.	known)	0.558 mm.	0.711 mm.
0.906 mm.		1.154 mm.	1.470 mm.
1.870 mm.			

This produces ten instars, still four more than Graham indicates. The above series seems to be more valid, insofar as the head widths of four available prepupae averaged 1.868 mm. It will be observed at once that this is well within the probable range for the head capsule mean of the last instar derived in the second series, 1.870 mm.

At this time, however, it is apparent that a series of rearings must be undertaken to determine a definite answer to this problem. No work on the pollen question can be satisfactorily undertaken with a view to comparing vigour of larvae until it is settled, since the work of GAINES and CAMPBELL ('35) on the Corn Earworm indicates that food has a definite effect upon the number of instars. This leads one to expect similar effect elsewhere, perhaps in the Spruce Budworm.

Other workers would seem to have great difficulty in the satisfactory determination of the numbers of instars when Dyar's Rule is applied to head capsule widths of larvae collected from random field sampling. GAINES and CAMPBELL ('35) do not recommend its use, as they found it produces instars that do not exist. They reach these conclusions after an exhaustive analysis of the literature and offer experimental and statistical evidence for the Corn Earworm (Heliothis obsoleta (Fab.)) to support their views.

The whole problem concerned with dietary regimens is dependent to a marked degree upon definite instar determinations. The percentages of individuals in each instar at any one date and collected from one type of food would be presumably comparable to the point of significance with those obtained for the other food type. In the absence of a satisfactory solution to the establishment of these instars, the following data is presented, although admittedly of little present significance. The sex-ratio is given in each case, following the measurement data.

It has been observed, although not quantitatively, that there is a direct correlation between the size of the cone infested and the sizes of the larvae inhabiting it. To preserve each cone and its fauna separately would be laborious and so no attempt was made to analyze this situation.

In order to obtain a quantilative indication of Budworm incidence upon Jack Pine reproduction a sample strip 66' x 7', designated Plot A, was laid in an area where the Budworm had previously (1937) been of no apparent consequence. This area in 1938 was widely infested with larvae and signs of terminal (new growth) destruction were evident as early as June 13th.

Plot A -

This plot was laid out in the Sandilands Forest Reserve, on 10-5-10, about 400 feet East on the road from Sample Plot #1. It lies 116 feet in from the road, the corner post being 20° E of N.

The plot is laid in open reproduction with a stand density of 10% at noon. This area of reproduction is surrounded by mature trees at varying distances, from 8-50 feet. These latter trees have suffered former defoliation to a considerable extent. Under these trees in many cases the reproduction has been completely defoliated and thus the significance of this plot is that, being more distant from these trees, it has not suffered previous infestation to any appreciable extent, if any.

The purpose in laying out the plot was to secure data that would give a figure for the relative numbers of larvae present with respect to the numbers of leaf buds involved. Larvae collected were divided into two groups, 98 of which were selected at random and preserved in order to obtain instar information and sex-ratios. It was found that the work involved in completely covering the area of the plot as first laid out (66 x 66 feet) would be excessive and so a strip 66 x 7 feet was enclosed, all the young trees in the area being tagged and numbered for future reference and comparison; the numbers of buds of each were counted and the numbers of larvae recorded and then placed in a pint sealer for laboratory examination.

The following table shows the relation of tree, height of tree, number of leaf buds, and numbers of larvae found:-

Tree No.	No. Buds	Height	No. Larvae
201	119	4 ft.	18
2	33	1.5 "	00
3	308	6 "	12
4	247	7 "	2
5	165	5 "	4
6	190	5 "	26
7	70	2 "	3
8	100	3 "	3
9	198	5 "	11
210	104	3 "	3
11	36	1 "	4
12	31	2 "	3
13	139	3 "	9
14	286	6 "	19
15	875	11 "	37
16	579	10 "	58
17	379	5 "	27
18	3	3 "	00
18	3862		239

Of the larvae disinfested from their hosts, 98 were preserved for instar comparisons and sex-ratios. These were preserved under lot number 1:G_1 & N:1-VI.16.38-2 and the data is to be found therein, below.

From the tabulated data immediately above the following relations emerge:-

Average No. Buds / Tree $\frac{3862}{18}$ 214.5

However, since there is a wide range in height amongst these trees it seems better to place them into definite height ranges and thence obtain average figures for the number of buds.

Thus:

Range	No. Buds	No.Larvae	No. Trees
1- 5 ft.	1814	111	13
6-11 ft.	2048	128	5
	3862	239	18

This bears out the assumption, since it is obvious that there is a greater concentration of larvae where there are more buds available, and that there are more buds available where there is greater height. The first mentioned average is perhaps a figure of value for the population as a whole, as the following average is also:-

Average number of larvae per tree $\frac{239}{18}$ 13.2

In the 1-5 ft. class the average is $\frac{111}{13}$ 8.53

In the 6-11 ft. class the average is $\frac{128}{5}$ 25.6

Average number of buds per larva $\frac{3862}{239}$ 16.1

In the 1-5 ft. class the average is $\frac{1814}{111}$ 16.3

In the 6-11 ft.class the average is $\frac{2048}{128}$ 16.0

From this it would appear that there is an optimum concentration of larvae as compared to available buds irrespective of the height of the tree. Of course it is to be noted that there is only a 1:2 ratio between these heights, but by comparison there is a 5:13 ratio between the numbers of trees in the two classes. Buds being most abundant on the larger trees, the majority of the larvae were collected thence, but the population densities as shown above are as 16.0 to 16.3, between the two height classes. This seems to indicate the possibility that an optimum population density might obtain, a point worth more study in future projects.

In the height class itself there is wide discrepancy between the height, number of buds and numbers of larvae, as witness:-

Trees:	Nos.	5,	9,	17.
Buds :		165,	198,	379.
Larvae:		4,	11,	27.

1:G_1 & N(Y):1-V1.16.38-2

These larvae were collected from terminals in Plot A, and are comparable with respect to instar and sex-ratio to those in #3 and #4, following. They were preserved under the above lot number. The population density data and description is discussed under Plot A above.

FEMALE			MALE			UNSEXED		
No.	Head Capsule	Length	No.	Head Capsule	Length	No.	Head Capsule	Length
							0.322	3.542
							0.322	3.864
							0.322	2.683
						3 T.	0.966	10.089
						M.	0.322	3.363
						1	0.354	2.898
1	0.386	3.381	1	0.386	2.415		0.	
						1	0.402	2.683
1	0.429	2.254		0.429	4.025		0.429	4.186
				0.429	3.542		0.429	-
			2 T.	0.858	7.567	2 T.	0.858	4.186
			M.	0.429	3.7885	M.	0.429	4.186
	0.432	4.875	1	0.432	5.575		0.432	3.900
	0.432	4.225					0.432	3.900
	0.432	4.875					0.432	3.415
	0.432	4.875					0.432	4.875
	0.432	4.332					0.432	4.550
	0.432	4.875					0.432	4.982
	0.432	4.332					0.432	5.525
	0.432	5.200						
8 T.	3.456	37.389				7 T.	3.024	31.147
M.	0.432	4.6986				M.	0.432	4.4495
	0.450	2.790						
	0.450	3.220						
2 T.	0.900	6.010						
M.	0.450	3.005						
	0.483	3.434		0.483	4.186		0.483	3.220
	0.483	3.059		0.483	3.220		0.483	4.875
	0.483	3.542		0.483	3.542		0.483	2.898
				0.483	4.186		0.483	2.737
							0.483	-
							0.483	2.898
							0.483	3.864

FEMALE			MALE			UNSEXED		
No.	Head Capsule	Length	No.	Head Capsule	Length	No.	Head Capsule	Length
							0.483	2.898
3 T.	1.449	10.035	4 T.	1.932	15.134	8 T.	3.864	23.390
M.	0.483	3.345	M.	0.483	3.7836	M.	0.483	3.3414
	0.495	5.850		0.495	4.875			
	0.495	5.632		0.495	4.550			
	0.495	6.066		0.495	5.045			
	0.495	6.155		0.495	5.632			
	0.495	6.175						
	0.495	4.550						
	0.495	3.575						
	0.495	6.175						
	0.495	4.982						
9 T.	4.455	49.160	4	1.980	20.102			
M.	0.495	5.4622		0.495	5.0255			
	0.520	6.175		0.520	5.525	1	0.520	5.200
	0.520	3.682		0.520	6.500			
	0.520	6.175		0.520	4.875			
				0.520	6.500			
				0.520	6.066			
3 T.	1.560	16.032	5	2.600	29.466			
M.	0.520	5.344		0.520	5.8932			
			1	0.514	3.703			
	0.536	4.347				1	0.536	3.220
	0.536	3.381						
2 T.	1.072	7.728						
M.	0.536	3.864						
1	0.578	3.864						
	0.650	6.280		0.650	3.900			
	0.650	4.766		0.650	4.186			
2 T.	1.300	11.046	2 T.	1.300	8.086			
M.	0.650	5.523	M.	0.650	4.043			
	0.766	7.150						
	0.766	6.825						
2 T.	1.532	13.975						
M.	0.766	6.9875						
			1	0.780	4.116			
	0.815	6.066		0.815	6.500			
	0.815	9.750		0.815	6.500			
	0.815	4.550						
3 T.	2.445	20.366	2	1.630	13.000			
M.	0.815	6.7886		0.815	6.500			
	0.866	8.580		0.866	5.850			
	0.866	8.550		0.866	7.150			
	0.866	7.800		0.866	5.632			

FEMALE			MALE			UNSEXED		
No.	Head Capsule	Length	No.	Head Capsule	Length	No.	Head Capsule	Length
				0.866	4.766			
				0.866	8.666			
				0.866	6.825			
				0.866	5.200			
				0.866	6.825			
				0.866	5.200			
3 T.	2.598	24.930	9 T.	7.794	56.114			
M.	0.866	8.310	M.	0.866	6.2348			
1	0.975	7.475	1	0.975	6.932			

Sex-Ratio = .554

1:G_1 & N:1-V1.16.38-5

These larvae were collected at the same time and in the same manner as those in lot 1:G_1 & N:1-V1.16.38-3, from the vicinity of Plot A.

They were collected for instar comparisons with larvae in #2.

# Clusters / Cone	# Larvae	# Clusters / Cone	# Larvae
5	0	10	0
5	0	10	2
5	1	10	2
5	2	10	2
5	2	10	1
5	0	10	0
5	3	10	0
6	1	10	0
6	0	10	1
6	0	11	0
6	1	11	1
6	0	11	3
7	0	11	1
7	1	11	1
7	1	11	1
7	2	11	1
7	0	11	1
7	0	12	1
7	1	12	1
7	2	12	0
7	1	12	1
7	0	12	0
7	1	12	0
7	3	12	1
8	1	12	0
8	0	12	0
8	0	12	4
8	0	12	0
8	0	12	1
9	0	12	0
9	3	12	1
9	0	12	3
9	2	13	0
9	0	13	0
10	0	13	2
10	2	13	4
10	4	14	0

# Clusters / Cone	# Larvae	# Clusters / Cone	# Larvae
14	1	20	2
14	1	20	5
15	0	21	3
15	2	21	1
15	3	21	0
15	2	21	3
15	3	21	3
15	3	22	1
15	1	23	5
16	1	23	1
16	0	24	1
16	1	25	3
16	0	25	3
17	2	26	1
17	2	26	2
17	4	27	0
18	5	28	6
18	4	28	3
18	1	29	7
18	3	30	3
18	1	30	2
19	1	30	1
19	1	32	14
19	5	32	2
20	4	35	3
20	1	36	4
20	3	50	10

These data summarize as follows:-

Total number of cones	....	131
Total number of clusters	....	1912
Total number of larvae	....	218
Average number clusters / cone	$\frac{1912}{131}$	14.5
Average number clusters / larva	$\frac{1912}{218}$	8.7
Average number larvae / cone	$\frac{218}{131}$	1.6

As in previous collections of staminate flowers (cones), larvae were found free in the bottom of the container after all the contents had been examined. These were 70 in number and modify the above figures as follows:-

Total number of larvae, 218 plus 70		288
Average number Clusters / Larva	$\frac{1912}{288}$	6.6
Average number Larvae / Cone	$\frac{288}{131}$	2.1

The variation in average numbers of larvae / cone from 1.6 to 2.1 is to be expected in view of the considerable number of free larvae in the container.

When this data is arranged as above, in ranges, etc., it appears as follows:-

Range	# Cones	# Larvae
5-10	46	42
11-20	58	91
21-30	20	49

It will be noted that the largest group of larvae is to be found in the intermediate range of cone sizes, although proportionately there is a greater concentration in the 21-30 group, i.e., 49/20, or 2.4 per cone, as compared with 91/58, or 1.5 per cone in the intermediate range. It would appear from this data, unmodified by the finding of free larvae in the container, that the larvae are most often found in the larger cones, near the mean number of clusters.

No data is available to show whether or not there is a difference in size of head capsule correlated with the population density in cones, but the following figures show the Head Capsule distribution and sex differences for the above lot.

FEMALE			MALE			UNSEXED		
No.	Head Capsule	Length	No.	Head Capsule	Length	No.	Head Capsule	Length
			1	0.322	2.600			
	0.483	6.500						
	0.483							
	0.483							
	0.483							
	0.483							
	0.483							
6 T.	2.898	6.500						
M.	0.483	6.500						
				0.514	-			
				0.514				
			2 T.	1.028				
			M.	0.514				
1	0.536	4.116	1	0.536	3.381			
1	0.562	5.070	1	0.562	-	1	0.562	
	0.578	4.065		0.578	3.864	1	0.578	
	0.578	6.716		0.578	6.282			
	0.578	1.170		0.578	6.118			
	0.578	5.850		0.578	5.525			
	0.578	7.645		0.578	6.825			
	0.578	8.125		0.578	4.395			
	0.578	5.720		0.578	5.200			
	0.578	6.500		0.578	6.716			
	0.578	5.850		0.578	5.850			
	0.578	5.720		0.578	5.200			
	0.578	5.200		0.578	4.065			
	0.578	5.850		0.578				
	0.578	2.254		0.578				
	0.578	6.500		0.578				
	0.578	7.150		0.578				
	0.578	5.200		0.578				
	0.578	3.900		0.578				
	0.578	6.500		0.578				
	0.578	6.500		0.578				
	0.578	5.632		0.578				
	0.578	5.200						
	0.578	5.850						
	0.578	4.340						
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							

FEMALE			MALE			UNSEXED		
No.	Head Capsule	Length	No.	Head Capsule	Length	No.	Head Capsule	Length
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578							
	0.578	(23)			(11)			
51	T.29.478	127.437	30	T.17.340	60.040			
	M. 0.578	5.540		M. 0.578	5.458			
	0.650	4.116		0.650	7.150			
	0.650	4.550		0.650	5.850			
	0.650	4.766		0.650	6.240			
	0.650	3.575		0.650	4.982			
	0.650	4.550		0.650	6.500			
	0.650	4.875		0.650	3.900			
	0.650	6.500		0.650				
	0.650			0.650				
	0.650							
	0.650							
	0.650							
	0.650							
	0.650							
	0.650							
	0.650							
15 T	9.750	32.932	8 T	5.200	34.622			
M	0.650	4.704	M	0.650	5.770			
			1	0.715	4.550			
				0.765	8.450			
				0.765	9.100			
			2 T	1.530	17.550			
			M	0.765	8.775			
	0.780	6.282	1	0.780	6.500			
	0.780	7.475						
	0.780							
3 T	2.340	13.757						
M	0.780	6.878						

FEMALE			MALE			UNSEXED		
No.	Head Capsule	Length	No.	Head Capsule	Length	No.	Head Capsule	Length
	0.815	5.850		0.815	5.525			
	0.815	-		0.815	4.166			
				0.815	9.750			
				0.815	7.930			
				0.815	7.150			
				0.815	5.200			
				0.815	8.450			
				0.815				
				0.815				
				0.815				
				0.815				
				0.815	(7)			
				0.815				
2 T.	1.630	5.850	13 T.	10.595	48.171			
M.	0.815	5.850	M.	0.815	6.881			
	0.866	6.500		0.866	8.450			
	0.866	8.710		0.866	5.200			
	0.866	6.282		0.866	5.200			
	0.866	5.416		0.866	6.066			
	0.866	8.232		0.866	8.320			
	0.866	7.800		0.866	8.450			
	0.866	7.150		0.866	5.200			
	0.866	5.850		0.866	1.040			
	0.866	6.282		0.866	6.282			
	0.866	5.200		0.866	10.400			
	0.866			0.866	8.320			
	0.866			0.866	8.666			
	0.866			0.866	7.800			
	0.866			0.866				
	0.866			0.866				
	0.866			0.866				
	0.866			0.866				
	0.866			0.866				
	0.866			0.866				
	0.866			0.866				
	0.866			0.866				
	0.866			0.866				
				0.866				
				0.866				
				0.866				
				0.866				
		(10)		0.866	(13)			
				0.866				
22 T	19.052	67.422	28 T	24.248	89.394			
M	0.866	6.742		0.866	6.876			
1	0.880	7.150						

FEMALE			MALE			UNSEXED		
No.	Head Capsule	Length	No.	Head Capsule	Length	No.	Head Capsule	Length
	0.910	5.200		0.910	5.200			
	0.910	7.760		0.910	6.932			
	0.910	6.500		0.910	6.175			
	0.910	6.716		0.910	7.800			
	0.910	7.800		0.910	5.850			
	0.910	7.366		0.910	5.525			
	0.910	6.500		0.910	9.100			
	0.910	6.825		0.910				
	0.910	11.570		0.910				
	0.910	6.345		0.910				
	0.910	8.016		0.910				
	0.910	6.500		0.910				
	0.910			0.910				
	0.910			0.910				
	0.910			0.910				
	0.910			0.910				
	0.910			0.910				
	0.910	(12)			(7)			
	01910							
19 T	17.290	87.098	17 T	15.470	46.582			
M	0.910	7.258	M	0.910	6.654			
	0.975	5.200		0.975	9.100			
	0.975	8.775		0.975	9.750			
	0.975	6.175		0.975	6.716			
	0.975	8.016		0.975	7.150			
	0.975	7.800		0.975	7.150			
	0.975	7.150		0.975	7.670			
	0.975	7.475		0.975	8.775			
	0.975	6.175		0.975	7.150			
	0.975	9.100		0.975	9.915			
	01975	6.716		0.975	7.800			
	0.975	6.500		01975	8.882			
	0.975	6.175		0.975				
	0.975	11.050		0.975				
	0.975	7.150		0.975				
	0.975	4.550		0.975				
	0.975	8.775		0.975				
	0.975	6.500		0.975				
	0.975	7.800		0.975				
	0.975			0.975				
	0.975			0.975				
	0.975			0.975				
	0.975							
	0.975							
	0.975							
	0.975							
	0.975							
	0.975							
	0.975							

FEMALE			MALE			UNSEXED		
No.	Head Capsule	Length	No.	Head Capsule	Length	No.	Head Capsule	Length
	0.975							
	0.975	(18)			(11)			
30 T	29.250	131.082	21 T	20.475	90.058			
M	0.975	7.282	M	0.975	8.187			
	1.040	6.015		1.040	7.930			
	1.040	7.800		1.040	10.616			
	1.040	7.800		1.040	8.775			
	1.040	7.475		1.040	8.320			
	1.040			1.040	6.175			
	1.040			1.040	6.066			
	1.040			1.040				
				1.040				
7 T	7.280	29.090	8 T	8.320	47.882			
M	1.040	7.272	M	1.040	7.980			
1	1.070	4.332						
1	1.082	10.075		1.082	6.500			
				1.082	6.500			
				1.082	6.500			
				1.082	7.475			
				1.082	8.450			
				1.082	10.182			
				1.082	9.425			
				1.082	6.500			
				1.082	8.125			
				1.082				
				1.082				
				1.082				
				1.082	(9)			
				1.082				
			14 T	15.148	69.657			
			M	1.082	7.739			
			2	1.145				
				1.145				
			2 T.	2.290				
			M.	1.145				
				1.170	7.475			
				1.170	7.775			
				1.170				
			3 T.	3.510	15.250			
			M.	1.170	7.625			
			1	1.300	9.100			
			1	1.516	19.500			
1	1.625	16.900						
			1	1.795	15.925			

Sex-Ratio = 0.507

1:G_1 & N:1-V1.16.38-3

These larvae were collected from the vicinity of Plot A. They were collected from staminate flowers and are to be regarded as similar to lot 1:G_1 & N:1-V1.17.38-6, and combined with it are comparable to #4.

The staminate flowers (cones) were taken back into the laboratory in a pint sealer. The cones were carefully teased apart, the number of clusters per cone noted and the number of larvae per cone recorded. The larvae were preserved under the lot number heading this page. The following is a table showing the distribution of the larvae in the flowers:

#Clusters / Cone	# Larvae
4	1
5	2
6	1
6	1
7	1
7	0
8	1
8	0
8	0
8	2
9	1
10	0
10	1
10	0
10	2
10	1
10	0
10	1
11	1
11	1
11	1
12	0
12	1
13	1
13	0
13	3
13	3
13	1
13	0
13	0
13	0
14	2
14	1
14	0
14	1
14	1
14	1
14	1
14	1
15	1
15	1
15	1
15	1
15	0
16	1
17	2
17	1
17	1
17	1
18	1
18	0
19	1
19	2
20	1
21	0
21	2
21	1
21	2
21	3
22	3
22	2
23	3
24	1

#Clusters / Cone	# Larvae	#Clusters / Cone	# Larvae	#Clusters / Cone	# Larvae
		16	1		
		16	2		
		16	1		
		16	2		
		17	1		

These data summarize as follows:-

Total number of Staminate Cones 71
Total number of Cone Clusters 1234
Total number of Larvae in Cones 81

Average number Clusters / Cone $\frac{1234}{71}$ 17.3

Average number Clusters / Larvae $\frac{1234}{81}$ 15.2

Average number Larvae / Cone $\frac{81}{71}$ 1.1

Modification of these figures is necessary, since not only were there 81 larvae actually in the cones at the time of examination, but an additional 21 larvae were found free in the bottom of the pint sealer when all the cones were removed, having escaped from confinement after capture and collection. The modified summary table is then:-

Total number of Larvae, 81 plus 21 102

Average number Clusters / Larva $\frac{1234}{102}$ 12.0

Average number Larvae / Cone $\frac{102}{71}$ 1.4

It will be noted that these additional larvae do little to alter the relative figure representing the population per cone, that is, there is only the slight change from 1.1 to 1.4 larvae per cone. However, the finding of such free larvae does prevent the formation of a frequency curve to illustrate the distribution of larvae and cones made up of varying numbers of clusters. On the face of it though, it would seem that the larvae favour the intermediate cone sizes, as shown below:-

Range	# Cones	# Larvae
4-10	19	16
11-20	41	42
21-24	11	23

The following data shows the Head Capsule size distribution of the 102 larvae collected as above. It also shows the relation of this distribution to the sex of the larvae. These larvae were also measured for length, which while individually perhaps a little unreliable due to the differential action of the fixative, with its consequent elongation of some larvae and contraction of others, is on the average probably a fair enough indication of the mean length. When definite means become established for the instars these lengths would be of more value.

MALE		FEMALE	
Head Capsule	Length	Head Capsule	Length
		0.322 mm.	3.575 mm.
		0.483 "	5.045 "
		0.483 "	5.045 "
		0.514 "	3.900 "
		0.514 "	4.186 "
		0.514 "	5.045 "
		0.514 "	5.200 "
		0.514 "	4.875 "
		M. 0.514 "	4.641 "
0.536 mm.	4.550 mm.	0.536	3.703
		0.536	5.525
		0.536	4.332
		0.535	7.965
		M. 0.536	5.899

MALE

Head Capsule	Length
0.562 mm.	5.525 mm.
0.578	4.025
0.578	5.554
0.578	5.850
0.578	5.980
0.578	6.925
0.578	6.716
0.578	5.850
0.578	5.850
0.578	6.345
0.578	5.416
0.578	5.632
M. 0.578	5.831
0.644	6.010
0.644	3.864
M. 0.644	4.937
0.750	4.810
0.780	5.525
0.780	4.982
0.780	5.200

FEMALE

Head Capsule	Length
0.562 mm.	6.500 mm.
0.562	6.825
0.562	5.850
0.562	7.150
0.562	6.932
M. 0.562	6.651
0.578	6.825
0.578	5.695
0.578	5.632
0.578	5.796
0.578	4.225
0.578	5.070
0.578	7.150
0.578	6.875
0.578	3.381
0.578	7.150
0.578	5.045
0.578	5.850
0.578	6.282
0.578	6.015
0.578	5.200
0.578	5.525
0.578	6.825
0.578	7.582
0.578	5.850
0.578	7.475
0.578	4.875
0.578	4.550
0.578	3.250
M. 0.578	5.721
0.644	7.150
0.644	6.066
0.644	4.186
0.644	6.500
M. 0.644	5.975
0.650	6.500
0.712	3.900

MALE Head Capsule	MALE Length	FEMALE Head Capsule	FEMALE Length
0.815 mm.	0.000 mm.		
0.866	4.875	0.866 mm.	6.500 mm.
0.866	8.016	0.866	5.850
0.866	8.066	0.866	4.875
0.866	5.770	M. 0.866	5.741
0.866	6.175		
0.866	5.525		
0.866	5.850		
M. 0.866	6.323		
0.910	6.175	0.910	6.205
0.910	6.500		
0.910	6.066		
M. 0.910	6.247		
0.966	6.500		
0.975	5.525	0.975	10.075
0.975	5.850	0.975	9.425
0.975	5.632	M. 0.975	91750
0.975	5.632		
0.975	7.475		
0.975	6.995		
0.975	6.716		
0.975	5.200		
M. 0.975	6.128		
1.040	7.475	1.040	8.016
		1.073	6.601
		1.082	9.750

Sex-Ratio = 0.589

1:G_1 & N:1-V1.17.38-4

These larvae were collected in the early morning before they had become active. They may therefore be regarded as similar to those collected on July 16th. Collection was from terminals only adjoining Plot A (above). There is a reasonable assumption that they have had little, if any, access to staminate cones. These larvae were preserved under the above lot number, and are comparable with those in #2 and #3, as regards instar development, etc.

MALE

	Head Capsule	Length
	0.322 mm	4.550 mm.
	0.429	3.928
	0.429	5.313
M.	0.429	4.620
	0.483	5.474
	0.483	4.830
	0.483	4.025
	0.483	4.830
	0.483	3.381
	0.483	6.175
	0.483	4.715
	0.483	4.078
M.	0.483	4.688
	0.514	5.025
	0.578	6.118
	0.578	4.186
M.	0.578	5.152
	0.650	4.982
	0.650	5.040
M.	0.650	5.011
	0.780	4.875

FEMALE

	Head Capsule	Length
	0.322 mm	3.703 mm.
	0.322	3.300
M	0.322	3.501
	0.429	3.059
	0.483	5.313
	0.483	3.703
	0.483	4.550
	0.483	4.952
	0.483	3.745
	0.483	4.065
M.	0.483	4.388
	0.536	5.850

(Table Cont'd)

The following larvae were unsexed:-

0.322	3.756
0.322	3.220
0.429	3.254
0.432	4.982
0.483	4.508

Sex-Ratio = 0.629

<u>1:G_1 & N:1-V1.17.38-6</u>

These larvae were collected from Staminate Cones showing signs of larval inhabitants, i.e., those which bore silken webs enmeshing larval frass and feces, etc.

In field respects they are similar to #3. They are to be correlated with #4 above. The larvae were preserved under the above lot number.

The following table presents the data obtained:-

# Clusters / Cone	# Larvae	# Clusters / Cone	# Larvae	# Clusters / Cone	# Larvae
5	0	15	3	19	2
5	2	15	0	19	2
6	0	15	1	19	2
8	1	15	1	20	1
8	0	15	1	20	1
9	3	15	0	20	2
9	0	15	0	20	3
9	0	16	2	21	1
9	0	16	2	21	2
10	1	16	1	21	2
10	2	16	1	21	0
10	0	16	2	21	2
10	1	16	0	22	2
10	0	16	1	22	1
10	0	16	1	22	2
11	1	17	1	24	2
11	1	17	1	24	0
11	1	17	1	24	2
11	1	17	1	24	0
12	1	17	1	24	3
12	1	17	0	24	0
12	1	17	2	25	0
12	1	18	1	25	2
12	0	18	1	25	1
12	3	18	2	25	0
13	1	18	3	26	1
13	1	18	0	26	1
14	1	19	1	27	1
14	1	19	1	27	1
14	2	19	1	27	1
14	3	19	0	29	2
				30	1
				31	2
				33	3

These data summarize as follows:-

Total number of Staminate cones............ 98

Total number of Cone Clusters 1687

Total number of Larvae in cones............ 112

Average number Clusters / Cone $\frac{1687}{98}$ 17.2

Average number Clusters / Larva $\frac{1687}{111}$ 15.5

Average number Larvae / Cone $\frac{111}{98}$ 1.1

Modification of these figures is necessary as in 1:G_1 & N:1-V1.16.38-3 since not only were there 112 larvae actually in cones, but an additional 40 were found free in the bottom of the pint sealer, having escaped from their cones after capture and collection. The modified summary table is then:-

Average number of Larvae, 111 plus 40 151

Average number Clusters / Larva $\frac{1687}{151}$ 11.1

Average number Larvae / Cone $\frac{151}{98}$ 1.5

The above data also reveals a decided preference of the larvae for the intermidiate cones sizes, and corroborate preference shown in other lots.

Range	# Cones	# Larvae
5-10	15	10
11-20	54	66
21-30	25	30
31	1	2
33	1	3

While many of the cones in the extreme ranges show no occupants, no doubt these making up the additional

40 free in the container, it might be assumed that they left these smaller and larger cones because they were not so completely adapted to them, or that the cones did not for some reason suit their full requirements and thus disturbance caused them to vacate.

The following data shows the Head Capsule size distribution of the 151 larvae collected above. It also shows the relation of this distribution to the sex of the larvae:-

	Male	Female
	0.483	0.483
	0.483	
	0.483	
M.	0.483	0.483
	(Unsexed	0.483)
	0.578	0.578
	0.578	0.578
	0.578	0.578
	0.578	0.578
	0.578	0.578
	0.578	0.578
	0.578	0.578
	0.578	0.578
	0.578	0.578
	0.578	0.578
	0;578	0.578
	0.578	0.578
	0.578	0.578
	0.578	0.578
	0.578	0.578
	0.578	0.578
	0.578	
	0.578	
	0.578	
	0.578	
	0.578	
	0.578	
	0.578	
	0.578	
	0.578	

Male	Female	Unsexed
0.910	0.910	0.910
0.910	0.910	
0.910	0.910	
0.910	0.910	
0.910		
0.910		
0.910		
0.910		
0.910		
0.910	0.910	
0.975	0.975	
0.975	0.975	
0.975	0.975	
0.975	0.975	
0.975	0.975	
0.975	0.975	
0.975	0.975	
0.975		
0.975		
0.975		
0.975		
0.975	0.975	
	1.040	
	1.040	
	1.040	
	1.040	
	1.040	
1.082	1.082	
1.082	1.082	
	1.082	
	1.082	
1.082	1.082	

	Male	Female
	0.578	
	0.578	
	0.578	
	0.578	
	0.578	
	0.578	
	0.578	
	0.578	
	0.578	
M.	0.578	0.578
	0.650	0.650
	0.650	0.650
	0.650	0.650
	0.650	0.650
	0.650	0.650
	0.650	
	0.650	
	0.650	
	0.650	
M.	0.650	0.650
	0.780	0.780
	0.780	0.780
	0.780	
M.	0.780	0.780
	0.815	0.815
	0.815	0.815
	0.815	
M.	0.815	0.815
	0.866	0.866
	0.866	0.866
	0.866	0.866
	0.866	0.866
	0.866	0.866
	0.866	0.866
	0.866	0.866
	0.866	0.866
	0.866	0.866
		0.866
		0.866
		0.866
		0.866
		0.866
		0.866
		0.866
M.	0.866	0.866

	Male	Female
	1.145	1.145
		1.145
		1.145
M.	1.145	1.145
	1.170	1.170
M.	1.170	1.170

Sex-Ratio = 0.436

Summary of Plot A Data:-

A total of 3862 buds were examined upon 18 trees of reproduction and the larvae removed where found. Such larvae totalled 239.

Average number of buds per tree	$\frac{3862}{18}$	214.5
Average number of larvae / tree	$\frac{239}{18}$	13.2
Average number of larvae / bud	$\frac{239}{3862}$	0.061
Percent buds infested $\frac{239}{3862} \times 100$	....	6.1%

Summary of: 1:G_1 & N:V1.16.38-3
1:G_1 & N:V1.16.38-5
1:G_1 & N:V1.17.38-6

Total number flowers examined	300
Total number clusters involved	4833
Total number larvae found	411
(there were an additional 126 larvae free in the container when the laboratory examination was made).........	126
Grand total larvae	537

Average number clusters / flower	$\frac{4833}{300} = 16.1$
Average number clusters / larva	$\frac{4833}{411} = 11.7$; $\frac{4833}{537} = 9.0$
Average number larvae / flower	$\frac{411}{300} = 1.3$; $\frac{537}{300} = 1.7$

Summary of Sex-Ratios:-

	Sex-Ratio
Larvae collected from leaf buds	
#2	0.554
#4	0.629
Mean Sex-Ratio.....	0.591

Larvae collected from staminate cones,

#3	....	0.589
#5	....	0.507
#6	....	0.436
Mean Sex-Ratio	....	0.510

Since the sex-ratio appears to be higher on leaf buds than in cones, it might indicate that the greater development of male larvae arises from more extensive pollen feeding. The discovery of larval sex-ratios opens up the possibility of more fully investigating this point.

CONCLUSIONS:-

(1) There is evidence to indicate that the Spruce Budworm, on Jack Pine in Southeastern Manitoba and Northwestern Ontario at least, has more than the accepted sex instars during its larval development. The solution to the question is obscure and requires elucidation. The probability that types of feeding may influence such development is to be entertained tentatively.

(2) Thirteen seedlings 1-5 feet in height bore 1814 leaf buds and were infested by 111 larvae of the Spruce Budworm. Five older trees 6-11 feet in height bore 2048 buds and 128 larvae. Thus there is a greater concentration of larvae where there are more buds available, and there are more buds available where there is greater height. In both instances there is an average number of buds per larva equal to 16.1. The percentage of buds infested was found to be 6.1%.

(3) Since the sex-ratio appears to be slightly higher on leaf buds than in cones, the possibility that males derive more advantage from staminate cones, and that such feeding is responsible for their faster development is worthy of investigation. The discovery of larval sex-ratios offers a promising meens for future enquiry.

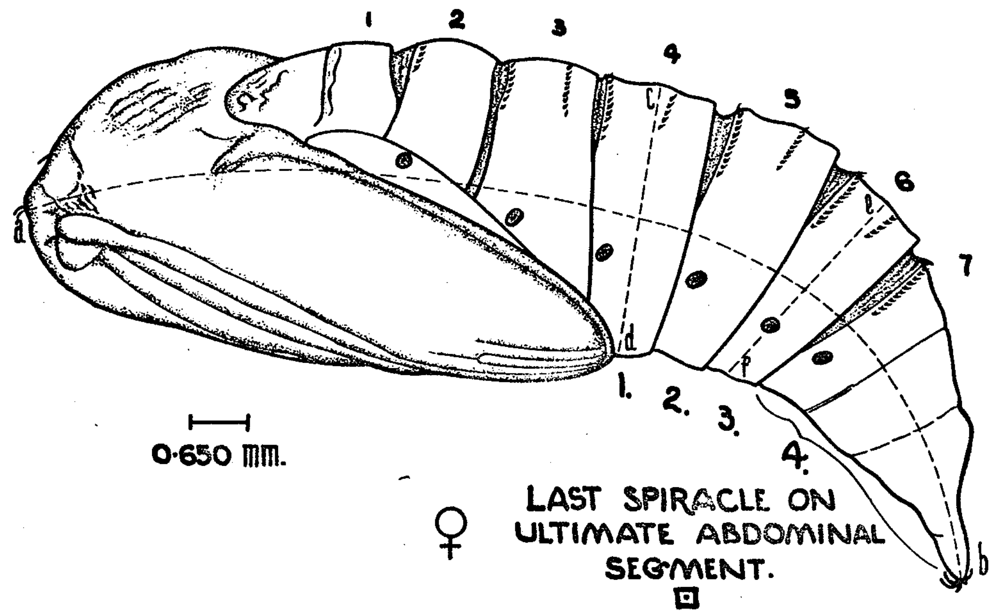
(4) The largest average number of larvae are to be found in the intermediate cone sizes.

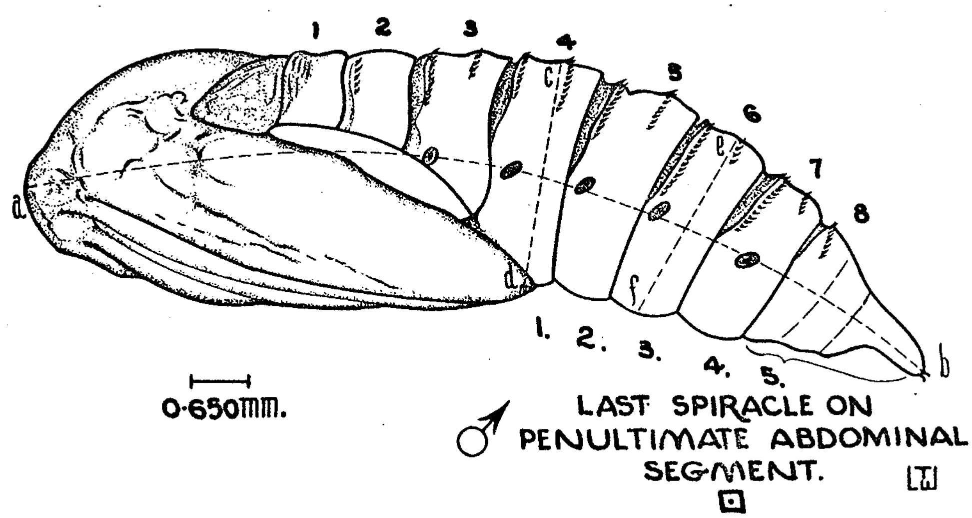
(5) The average number of clusters per staminate cone was found to be 16.1. The average number of larvae per cone was found as 1.7.

11. BIOMETRIC DATA

B. Pupal.

AN ILLUSTRATION OF GRAHAM'S METHOD
of DETERMINING SEX of
PUPAE of THE SPRUCE BUDWORM
- by -
EXTERNAL SEXUAL DIFFERENCES.





PUPAL MEASUREMENTS

From a large available series of pupae collected in the Sandilands Forest Reserve, commencing July 6th, and terminating July 18th, 63 female and 64 male pupae were selected at random for measurement. These pupae had been collected and segregated subsequently with reference to the type of stand the trees formed which provided the resting sites for the pupae.

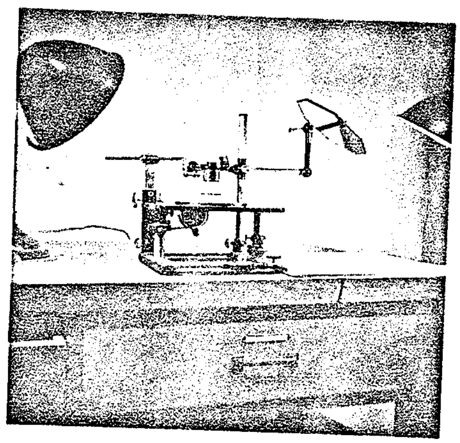
The method of sexing the pupae was based on the accompanying Plate which has been discussed under "Sex-Ratios". Briefly, it will be again noted that the female pupa has but four free abdominal segments visible vertrally, posterior to the wing-pods, and the last spiracle occurs on the ultimate segment; the male is seen to have five such free segments, with the last spiracle on the penultimate segment.

The dotted lines a--b, c--d, e--f are those along which measurements were taken, to be presented shortly, Thus:

- a--b extreme anterior margin of Frons to extreme posterior margin of Cremaster;
- c--d dorso-ventral median line of Abdominal segment #4;
- e--f dorso-ventral median line of Abdominal segment #6.

These measurements were similarly derived from both sexes.

The pupae were collected from Second Growth and



Mature types of stands of timber, and these types were again sub-divided into Open and Dense growth. From a forestry viewpoint Second Growth types of stands are those which have replaced virgin and uncut areas; mature trees may be, but are not necessarily, second growth in origin, the term here being confined to trees which are no longer increasing markedly in height or increment. Open stands are those where there is a predominance of straggling orchard type trees (see Introduction), with little or no crowding amongst the individual members of the stand; Dense stands are the reverse of the above, there being little tendency to straggle due to limited space. It is for the possible effect that site might have on pupal size that the pupae have been segregated from these sites, touching as this does the contention of S. GRAHAM ('35) that Staminate Cones, in relation to site are found in predominantly greater abundance on Open growing trees than upon those in Dense stands, and that such difference in stand and food supply influence Budworm phenomena. The measurements are therefore an attempt to draw inference from pupae which succeeded larvae whose food may have been lacking in pollen in Dense stands and with more or less pollen in Open stands.

Before presenting the tabulated data and conclusions, a brief description of the method of measurement employed will be given. The apparatus, a Mayer dissecting microscope and camera lucida, is illustrated in the accompanying photograph. Before it became available considerable difficulty was experienced in finding a suitable and rapid means of measurement. All data presented were accumulated by the following means:-

A millimeter rule was placed upon the stage of the dissecting microscope and its image superimposed upon Hughes-Owens' #315F graph paper, which has 20 lines equal to one inch. One millimeter on the scale was found to be the equivalent of 9 lines upon the graph paper. A simple calculation gave a value to each interval of the graph paper, as seen in the camera lucida, of 0.11 mm. The image of the pupa, by means of the camera lucida, thus became superimposed upon a ruled area, and a pencil was then used to mark lightly upon the graph paper the distances between the points a--b, c--d, and e--f, as described above. To do this, the pupae were disposed laterally in a Syracuse watch glass and extreme care taken to see that all measured points were on the same sagittal plane of the insect. It will be observed that the points a--b will rarely lie along a straight line - unless the pupae be straight - and this difficulty was overcome by using a length of light stiff copper wire which was then bent to conform to the pupal curvature, straightened after the points a--b had been noted upon it, and that distance measured in intervals of the graph paper and multiplied by 0.11 mm. to give the measurement.

Widths of Abdominal segments #4 and #6 were obtained directly. These were taken in the beginning in order to determine whether an index might be computed from them, thus either $\left(\frac{\text{Segt.}\#4}{\text{Segt.}\#6}\right) \div$ length, or $\left(\frac{\text{Segt.}\#6}{\text{Segt.}\#4}\right) \div$ length. A considerable series of calculations, where the correct values were substituted in the formulae, showed that this index yielded no correlation. It was therefore abandoned although the measurements were continued. WALLENSTEIN ('36) by "special measurement of pupal cases" of the Nun Moth in Germany predicted the number of eggs the resulting females would contain. The Revue of Applied Entomology furnished the above lead, too late to be consulted in time for use here.

T A B L E I

No.	Length	Sex	Width Abd. Segt. 4	Width Abd. Segt. 6	Stand
1.	13.31 mm.	Male	2.86 mm.	2.86 mm.	Dense 2d. Growth
2.	13.31 "	"	3.30 "	2.75 "	" " "
3.	12.65 "	"	3.13 "	2.75 "	" " "
4.	12.98 "	"	3.19 "	2.75 "	" " "
5.	12.65 "	"	3.19 "	2.86 "	" " "
6.	12.43 "	"	3.08 "	2.64 "	" " "
7.	12.98 "	"	3.41 "	2.64 "	" " "
8.	12.43 "	"	3.19 "	2.75 "	" " "
9.	12.54 "	"	3.30 "	2.97 "	" " "
10.	11.22 "	"	2.53 "	2.42 "	" " "
11.	11.99 "	"	2.53 "	2.31 "	" " "
12.	12.76 "	"	3.08 "	2.80 "	" " "
13.	12.21 "	"	3.30 "	2.70 "	" " "
13.	163.46 mm.	"	40.09 mm.	35.20 mm.	

Mean Length - 12.57 mm.

Mean Width #4 - 3.08 mm.

Mean Width #6 - 2.70 mm.

T A B L E II

No.	Length	Sex	Width Abd. Segt. 4	Width Abd. Segt. 6	Stand
1.	13.97 mm.	Female	3.96 mm.	3.41 mm.	Dense 2d. Growth
2.	13.97 m"	"	3.41 "	2.97 "	" " "
3.	13.53 "	"	3.63 "	2.97 "	" " "
4.	14.63 "	"	3.96 "	3.85 "	" " "
5.	15.40 "	"	3.63 "	3.19 "	" " "
6.	14.19 "	"	3.74 "	3.19 "	" " "
7.	16.83 "	"	3.63 "	3.19 "	" " "
8.	14.30 "	"	4.40 "	3.85 "	" " "
9.	14.33 "	"	3.85 "	3.41 "	" " "
10.	14.19 "	"	3.52 "	2.86 "	" " "
11.	14.30 "	"	3.85 "	3.41 "	" " "
12.	14.41 "	"	4.07 "	3.52 "	" " "
13.	15.18 "	"	3.74 "	3.41 "	" " "
14.	12.43 "	"	2.97 "	2.64 "	" " "
14.	201.66 mm.	"	52.36 mm.	45.87 mm.	

Mean Length - 14.40 mm.
Mean Width #4 - 3.74 mm.
Mean Width #6 - 3.27 mm.

T A B L E   III

No.	Length	Sex	Width Abd. Segt. 4	Width Abd. Segt. 6	Stand
1.	13.31 mm.	Male	3.08 mm.	2.42 mm.	Open 2d Growth
2.	11.22 "	"	2.86 "	2.75 "	" " "
3.	13.75 "	"	2.97 "	2.64 "	" " "
4.	10.34 "	"	2.97 "	2.53 "	" " "
5.	13.09 "	"	2.97 "	2.75 "	" " "
6.	9.68 "	"	2.64 "	2.20 "	" " "
7.	13.32 "	"	2.64 "	2.42 "	" " "
8.	12.43 "	"	3.08 "	2.75 "	" " "
9.	12.48 "	"	3.30 "	2.86 "	" " "
10.	12.59 "	"	3.19 "	2.75 "	" " "
11.	12.54 "	"	3.41 "	2.86 "	" " "
12.	12.59 "	"	2.86 "	2.53 "	" " "
13.	12.59 "	"	2.75 "	2.53 "	" " "
14.	12.76 "	"	3.08 "	2.64 "	" " "
15.	12.87 "	"	3.52 "	2.08 "	" " "
16.	12.54 "	"	2.97 "	2.53 "	" " "
17.	12.87 "	"	3.19 "	2.86 "	" " "
18.	12.87 "	"	3.30 "	2.97 "	" " "
19.	12.76 "	"	3.19 "	2.86 "	" " "
20.	11.33 "	"	2.75 "	2.31 "	" " "
21.	11.77 "	"	3.08 "	2.97 "	" " "
21.	259.70 "	"	63.80 "	56.21 "	

Mean Length - 12.36 mm.
Mean Width #4 - 3.03 mm.
Mean Width #6 - 2.67 mm.

T A B L E IV

No.	Length	Sex	Width Abd. Segt. #4	Width Abd. Segt. #6	Stand
1.	11.66 mm.	Female	3.08 mm.	2.64 mm.	Open 2d. Growth
2.	12.87 "	"	3.52 "	3.08 "	" " "
3.	12.76 "	"	3.30 "	2.97 "	" " "
4.	13.53 "	"	3.85 "	3.35 "	" " "
5.	13.20 "	"	3.19 "	2.97 "	" " "
6.	13.75 "	"	3.41 "	3.19 "	" " "
7.	13.97 "	"	3.74 "	3.08 "	" " "
8.	13.64 "	"	3.08 "	2.75 "	" " "
9.	13.53 "	"	3.30 "	2.97 "	" " "
10.	13.42 "	"	3.52 "	3.08 "	" " "
11.	13.24 "	"	3.63 "	3.30 "	" " "
12.	15.40 "	"	3.96 "	3.30 "	" " "
13.	16.28 "	"	3.74 "	3.19 "	" " "
14.	14.63 "	"	4.07 "	3.52 "	" " "
15.	14.19 "	2	3.63 "	3.41 "	" " "
16.	14.96 "	"	3.85 "	3.19 "	" " "
17.	14.19 "	"	3.85 "	3.35	" " "
18.	14.52 "	"	3.96 "	3.19 "	" " "
19.	14.85 "	"	3.74 "	3.41 "	" " "
20.	15.51 "	"	4.29 "	3.52 "	" " "
21.	14.63 "	"	3.74 "	2.97 "	" " "
22.	16.06 "	"	3.85 "	3.19 "	" " "
23.	14.30 "	"	3.19 "	2.86 "	" " "
23.	325.09 mm.	"	83.49 mm.	72.48 "	

Mean Length - 14.13 mm.
Mean Width #4 - 3.63 mm.
Mean Width #6 - 3.15 mm.

TABLE V

Nol	Length	Sex	Width Abd. Segt. 4	Width Abd. Segt. 6	Stand
1.	15.40 mm.	Male	3.52 mm.	2.97 mm.	Dense Mature
2.	13.75 "	"	3.19 "	3.08 "	" "
3.	13.97 "	"	3.30 "	2.97 "	" "
4.	12.65 "	"	3.24 "	2.42 "	" "
5.	12.75 "	"	2.86 "	2.53 "	" "
6.	12.76 "	"	3.41 "	2.97 "	" "
7.	12.54 "	"	3.41 "	2.86 "	" "
8.	12.87 "	"	2.97 "	2.69 "	" "
9.	12.65 "	"	2.91 "	2.53 "	" "
10.	12.54 "	"	3.08 "	2.86 "	" "
11.	11.66 "	"	2.64 "	2.53 "	" "
12.	11.99 "	"	3.08 "	2.75 "	" "
13.	11.33 "	"	3.19 "	2.86 "	" "
14.	11.77 "	"	2.86 "	2.53 "	" "
15.	11.55 "	"	2.75 "	2.42 "	" "
					"
15.	190.18 mm.	"	46.41 mm.	40.97 mm.	

Mean Length - 12.67 mm.
Mean Width #4 - 3.09 mm.
Mean Width #6 - 2.73 mm.

T A B L E   VI

No.	Length	Sex	Width Abd. Segt. 4	Width Abd. Segt. 6	Stand
1.	13.53 mm.	Female	3.63 mm.	3.19 mm.	Dense Mature
2.	13.09 "	"	3.30 "	2.86 "	" "
3.	13.75 "	"	3.74 "	3.19 "	" "
4.	13.20 "	"	3.52 "	3.19 "	" "
5.	13.42 "	"	3.63 "	3.19 "	" "
6.	14.19 "	"	3.85 "	3.52 "	" "
7.	14.96 "	"	3.74 "	3.08 "	" "
8.	14.52 "	"	3.83 "	3.19 "	" "
9.	15.78 "	"	3.96 "	3.35 "	" "
10.	14.41 "	"	3.85 "	3.30 "	" "
11.	12.76 "	"	3.52 "	2.97 "	" "
12.	12.98 "	"	3.41 "	2.86 "	" "
13.	11.99 "	"	3.30 "	2.75 "	" "
	"				
13.	178.58 mm.	"	47.28 mm.	40.64 mm.	

Mean Length - 13.73 mm.

Mean Width #4 - 3.63 mm.

Mean Width #6 - 3.12 mm.

TABLE VII

No.	Length	Sex	Width Abd. Segt. 4	Width Abd. Segt. 6	Stand
1.	13.31 mm.	Male	3.08 mm.	2.53 mm.	Open Mature
2.	13.31 "	"	3.08 "	2.75 "	" "
3.	13.09 "	"	3.41 "	2.86 "	" "
4.	12.10 "	"	2.75 "	2.53 "	" "
5.	12.11 "	"	3.30 "	2.75 "	" "
6.	12.98 "	"	2.86 "	2.42 "	" "
7.	12.43 "	"	2.86 "	2.42 "	" "
8.	12.48 "	"	3.19 "	2.86 "	" "
9.	12.54 "	"	3.19 "	2.97 "	" "
10.	11.33 "	"	3.08 "	2.75 "	" "
11.	11.88 "	"	3.08 "	2.53 "	" "
12.	11.44 "	"	3.08 "	2.75 "	" "
13.	11.77 "	"	3.08 "	2.53 "	" "
14.	11.00 "	"	2.97 "	2.53 "	" "
15.	10.45 "	"	2.75 "	2.42 "	" "
15.	182.22 mm.	"	45.76 mm.	39.60 mm.	

Mean Length - 12.14 mm.
Mean Width #4 - 3.05 mm.
Mean Width #6 - 2.64 mm.

TABLE VIII

No.	Length	Sex	Width Abd. Segt. 4	Width Abd. Segt. 6	Stand
1.	13.20 mm.	Female	3.52 mm.	3.08 mm.	Open Mature
2.	13.20 "	"	3.19 "	3.08 "	" "
3.	13.20 "	"	3.52 "	3.08 "	" "
4.	13.20 "	"	3.30 "	2.64 "	" "
5.	13.64 "	"	3.96 "	3.41 "	" "
6.	14.08 "	"	3.52 "	3.19 "	" "
7.	14.19 "	"	3.30 "	2.86 "	" "
8.	14.19 "	"	3.30 "	3.08 "	" "
9.	14.52 "	"	3.85 "	3.52 "	" "
10.	15.62 "	"	3.85 "	3.52 "	" "
11.	15.18 "	"	3.65 "	3.19 "	" "
12.	14.08 "	"	3.85 "	3.30 "	" "
13.	12.98 "	"	3.79 "	3.30 "	" "
13.	181.28 mm.	"	46.60 mm.	41.25 mm.	

Mean Length - 13.94 mm.
Mean Width #4 - 3.58 mm.
Mean Width #6 - 3.17 mm.

		Sex	No. Ind.	Total Length	Mean Length	Tot.Width Abd.Sgt.4	Mn.Width Abd.Sgt.4	Tot.Width Abd.Sgt 6	Mn.Width Abd.Sgt 6
OPEN	2d Gwth	Female	23	325.09	14.13	83.49	3.63	72.48	3.15
		Male	21	259.70	12.36	63.80	3.03	56.21	2.67
	Mature	Female	13	181.28	13.94	46.60	3.58	41.25	3.17
		Male	15	182.22	12.14	45.76	3.05	39.60	2.64
DENSE	2d Gwth	Female	14	201.66	14.40	52.36	3.74	45.87	3.27
		Male	13	163.46	12.57	40.09	3.08	35.20	2.70
	Mature	Female	13	178.58	13.73	47.28	3.63	40.64	3.12
		Male	15	190.18	12.67	46.41	3.09	40.97	2.73

NOTE: All measurements in millimetres.

This table summarizes the previous ones, relative to pupal measurements and type of stand.

From these data it appears that female pupae in Dense 2d Growth stands are slightly larger than those in Open 2d Growth. Females in Open mature stands are slightly larger than those in Dense mature stands. Males in Open 2d Growth are noticeably smaller than those in Dense 2nd Growth, but somewhat larger in Dense mature stands than males in Open mature ones.

The following condensed table serves to clarify the results according to whether the stand is Open or Dense:

Stand	Sex	Total	Total Length	Mean Length	Total Width Abd.4	Mean Width Abd.4	Total Width Abd.5	Mean Width Abd.6
OPEN	Male	36	441.92mm	12.27	109.56	3.04	95.81	2.66
	Female	36	506.37 "	14.06	130.09	3.61	113.73	3.15
DENSE	Male	28	353.64 "	12.63	85.50	3.08	76.17	2.72
	Female	27	380.24 "	14.08	99.64	3.69	86.51	3.20

This table reveals at once that pupae of both sexes are noticeably larger in Dense stands than in Open stands. The table aggregates the results from 2d growth and mature types of these stands.

These results are contrary to the expected, a fact for which no ready explanation is apparent. It may arise from an insufficient number of measurements having been taken or it may mean that larvae find conditions more advantageous in the denser stands. Factors such as insolation and evaporation would be expected to reach greater intensity in Open stands than in Dense, but no data is available.

Still further summarizing the above data, the following table presents biometrical data for male and female pupae of the Spruce Budworm, in the Sandilands Forest Reserve, during the season 1938. Similar measurements carried out over a period of years might conceivably afford data of significance in following trends in population density, and of use in forecasting:-

Sex Difference Data

Sex	No.Inds.	Mean Length	Mean Width Abd.4	Mean Width Abd.6
Male	64	12.43 mm.	3.06 mm.	2.68 mm.
Female	63	14.07 mm.	3.64 mm.	3.17 mm.

The female pupa thus appears to be the larger.

11. BIOMETRIC DATA

C. Adult.

ADULT MEASUREMENTS

During the course of dissections made upon 18 female moths, the measurements listed below were taken, and similar measurements were made of 18 male moths for the sake of comparison. While this data is too meagre to indicate much it is presented as a preliminary study of such data. The writer is of the opinion that measurements so presented fill a gap in the literature at least. All measurements were taken at the widest or longest straight distance; length of abdomen was taken from the anterior portion of the second abdominal segment to the posterior tip of the abdomen.

Right Fore Wing		Abdominal Width	Abdominal Length		
Length	Width	Ventral	Ventral	Sex	# Eggs
12.0 mm.	5.0 mm.	2.860 mm.	6.500 mm.	Female	250
10.0 "	4.0 "	2.600 "	4.550 "	Female	242
9.0 "	4.0 "	1.820 "	3.250 "	Female	42
9.0 "	4.0 "	1.950 "	3.250 "	Female	-
10.0 "	5.0 "	3.250 "	3.900 "	Female	240
9.0 "	4.0 "	2.600 "	3.575 "	Female	167
11.0 "	5.0 "	3.032 "	4.550 "	Female	176
12.0 "	4.0 "	2.600 "	5.200 "	Female	154
11.0 "	4.0 "	3.575 "	6.825 "	Female	288
12.0 "	5.0 "	3.900 "	6.500 "	Female	275
11.0 "	5.0 "	3.250 "	6.175 "	Female	258
12.0 "	5.0 "	3.900 "	7.582 "	Female	310
11.0 "	5.0 "	3.250 "	7.800 "	Female	200
12.0 "	5.0 "	3.900 "	6.500 "	Female	265
11.0 "	4.0 "	3.575 "	6.500 "	Female	205
12.0 "	5.0 "	3.575 "	6.825 "	Female	319
12.0 "	5.0 "	3.250 "	6.716 "	Female	317
12.0 "	5.0 "	3.900 "	6.175 "	Female	256
MEAN:					
11.0 "	4.6 "	3.143 "	5.688 "	18	

There would not appear to be any correlation between physical measurement and numbers of eggs, which seems to indicate that it is not the number of eggs that governs the size of female abdomen. WALLENSTEIN ('36) predicted the number of eggs females would be able to lay, from measurements of pupal cases of the Nun Moth in the field. Unfortunately his data and methods are unknown, due to the above statement being taken from the Review of Applied Entomology. Time did not permit the consultation of the original which is in German.

Right Fore Wing		Abdominal Width	Abdominal Length	
Length	Width	Ventral	Ventral	Sex
8.0 mm.	3.0 mm.	1.625 mm.	3.250 mm.	Male
10.0 "	4.0 "	3.575 "	4.550 "	Male
10.0 "	4.5 "	2.600 "	5.200 "	Male
9.5 "	4.0 "	2.600 "	5.200 "	Male
9.0 "	4.0 "	2.925 "	5.200 "	Male
10.5 "	4.0 "	3.250 "	5.850 "	Male
10.0 "	4.0 "	3.925 "	5.200 "	Male
10.0 "	4.0 "	2.925 "	3.575 "	Male
10.0 "	4.0 "	3.250 "	5.200 "	Male
10.0 "	4.0 "	2.600 "	5.200 "	Male
10.0 "	4.0 "	2.816 "	5.850 "	Male
10.0 "	4.0 "	2.925 "	5.525 "	Male
10.0 "	4.0 "	2.925 "	4.550 "	Male
9.0 "	4.0 "	2.816 "	5.850 "	Male
10.0 "	4.5 "	3.250 "	4.550 "	Male
10.0 "	4.0 "	2.382 "	3.900 "	Male
9.0 "	4.0 "	2.600 "	4.550 "	Male
10.0 "	5.0 "	1.950 "	4.550 "	Male
MEAN:				
9.7 "	4.0 "	2.774 "	5.041 "	18

This data summarizes as follows:-

Length of Right Fore Wing, Male .... 9.7 mm.
Expanse, 9.7 mm. x 2 .... 19.4 mm.
Length of Right Fore Wing, Female ..... 11.0 mm.
Expanse, 11.0 mm. x 2 .... 22.0 mm.

Width of Right Fore Wing, Male .... 4.0 mm.
Width of Right Fore Wing, Female ...... 4.6 mm.
Width of abdomen at widest part,
ventral, male .... 2.774 mm.
Width of abdomen at widest part,
ventral, female.................... 3.143 mm.
Length of abdomen, anterior margin
segment #2 to posterior extremity,.
male .... 5.041 mm.
Length of abdomen, anterior margin
segment #2 to posterior extremity,
female .... 5.688 mm.

There thus appears to be from the data available an increase in the length and width of the right fore wing, width and length of abdomen in the female, over similar measurements derived from the same number of males.

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