Holotype, male, allotype, female, and a series of paratypes, Boracea, Salesópolis, São Paulo, Brazil, 850 m., L. Travassos Filho and F. X. Rabello. Holotype, allotype and some paratypes in collection of Ministry of Agriculture, São Paulo, Brazil; several paratypes, No. 6817, C.N.C.

I take pleasure in naming this species for my generous and patient correspondent Dr. Lauro Travassos Filho, who collected the type series, and who has made it possible for me to study so much valuable material from Brazil.

Summary

The following new species and subspecies of *Palpita* are described: *P. kimballi*, Florida; *P. viettei*, West Indies; *P. forficifera*, South America; *P. persimilis*, South America; *P. trifurcata*, Brazil; *P. isoscelalis gourbeyrensis*, Guadeloupe; *P. braziliensis*, Brazil; *P. travassosi*, Brazil.

Acknowledgments

I am much indebted to the following colleagues for the loan of material: Mr. Harry K. Clench, Carnegie Museum, Pittsburgh, Pa.; Dr. Lauro Travassos Filho, formerly of the Ministry of Agriculture, São Paulo, Brazil; Mr. Pierre E. L. Viette, Museum of Natural History, Paris, France. The authorities of the British Museum (Natural History) permitted me to examine type material in their care, and Mr. E. L. Martin kindly dissected several types for me. The drawings were prepared by Mrs. Marie Spencer.

(Received March 24, 1959)

Estimation of Cocoon Populations of the Larch Sawfly, *Pristiphora erichsonii* (Hartig)[1]

By W. G. H. Ives and W. J. Turnock
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This paper is one in a series on techniques used in estimating populations of various stages of the larch sawfly (Ives, 1955b; Ives and Prentice, 1958). This insect spends most of the year in cocoons in the soil beneath the host tree. The objective of accurate estimation of the cocoon population is to provide a basis for the evaluation of mortality factors affecting this stage. Two methods of estimation are considered in this paper. One is based on soil sampling (Part I) and the other on the number of cocoons formed in traps for falling larvae (Part II).

I. SOIL SAMPLES

High intra-plot variability is a characteristic of most soil insect populations. Because of this variability, large samples are required to obtain statistically sound population estimates, and the removal of the insects from these samples requires a large labour force or considerable time.

To reduce variability, Prebble (1943) sampled adjacent squares of soil under the crowns of host trees on successive years to provide an index of the cocoon population of the European spruce sawfly, *Gilpinia hercyniae* (Htg.). Early workers at the Winnipeg Laboratory attempted to adapt this technique to the larch sawfly sampling problem, but the method proved basically unsound for estimating cocoon populations on an areal basis. These workers also noted a very high degree of variability in the distribution of cocoons in the soil and a tendency for the number of cocoons to decrease radially from the trunks of host trees.

[1]Contribution No. 565, Forest Biology Division, Research Branch, Department of Agriculture, Ottawa, Canada.

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Other problems in the estimation of larch sawfly cocoon populations from soil samples are: (1) newly-formed cocoons are indistinguishable from cocoons of the previous generation; (2) cocoon formation occurs from mid-July to late August; and (3) mortality factors may begin to destroy cocoons as soon as they are formed.

The inability to distinguish new cocoons limits the sample to cocoons containing living larvae. The samples thus include a small proportion of cocoons from the previous year containing larvae in prolonged diapause and excludes those cocoons of the current year in which the larvae died between cocoon formation and the sampling date. Because the amount of mortality is partially controlled by the duration of exposure, the delay in sampling caused by the long period of cocoon formation affects the results of sampling. The most important mortality factor, small mammal predation, may begin with the earliest cocoon formation, but does not destroy many cocoons before late August. The date providing the best compromise between cocoon formation and mortality is usually about mid-August. The selection of the date requires careful planning to provide data for accurate estimates of the population and comparisons between different areas and years.

During 1957 an intensive study was conducted in the Whiteshell Forest Reserve, Manitoba, to determine if statistically acceptable estimates of larch sawfly cocoon populations could be obtained from soil samples. The investigation covered the distribution of the cocoons in the soil, in relation to crown cover and topography and the estimation of the total cocoon population per unit area. The examination of old cocoons in the samples provided information on mortality factors during the cocoon stage.

Methods

The stand in which the study plot was located has been described (Buckner 1957, Plot 3). The plot measured 30 x 66 feet (1/22 acre) and contained 24 tamarack (density 528 per acre). It was divided into a grid with stakes at six-foot intervals. To provide a base for topographical measurements, the tops of these stakes were levelled with the device shown in Fig. 3. This consisted of a chick watering front and 50 feet of rubber hose. The hose was connected to a copper tube soldered over a hole in the fount, and a short piece of glass tubing was inserted in the other end. A jar of water was inverted on the fount on a stand in the middle of the plot. A constant level was obtained from the water in the glass tube after any air was eliminated from the hose. The stakes were driven to the level indicated in the glass tube. A jig was made to fit over the top of the stakes (Fig. 2) and divided the six-foot squares into 36 potential sampling units of one-square foot each, and also provided a guide for measuring (to the nearest half inch) from the level plane to the moss level in the centre of each unit. The plot contained 1,980 potential sampling units, of which 200 were selected at random. One-square foot samples of soil extending down to the limnic peat (the sampling units) were removed from August 21 to 23 from each randomly designated position and placed in plastic bags. Crown projections were mapped with the instrument described by Turnock and Ives (1957).

The 200 sample units were randomly separated into two equal groups. One group was sorted at the Whiteshell Field Station before September 10, and the other by Forest Biology Rangers at the Winnipeg Laboratory after October 1. The soil in each sample unit was carefully teased apart and all cocoons removed. This work had to be done by hand because the fibrous peat making up the soil could not be sifted. A check on the accuracy of the sorters was made by re-examining a portion of the samples.

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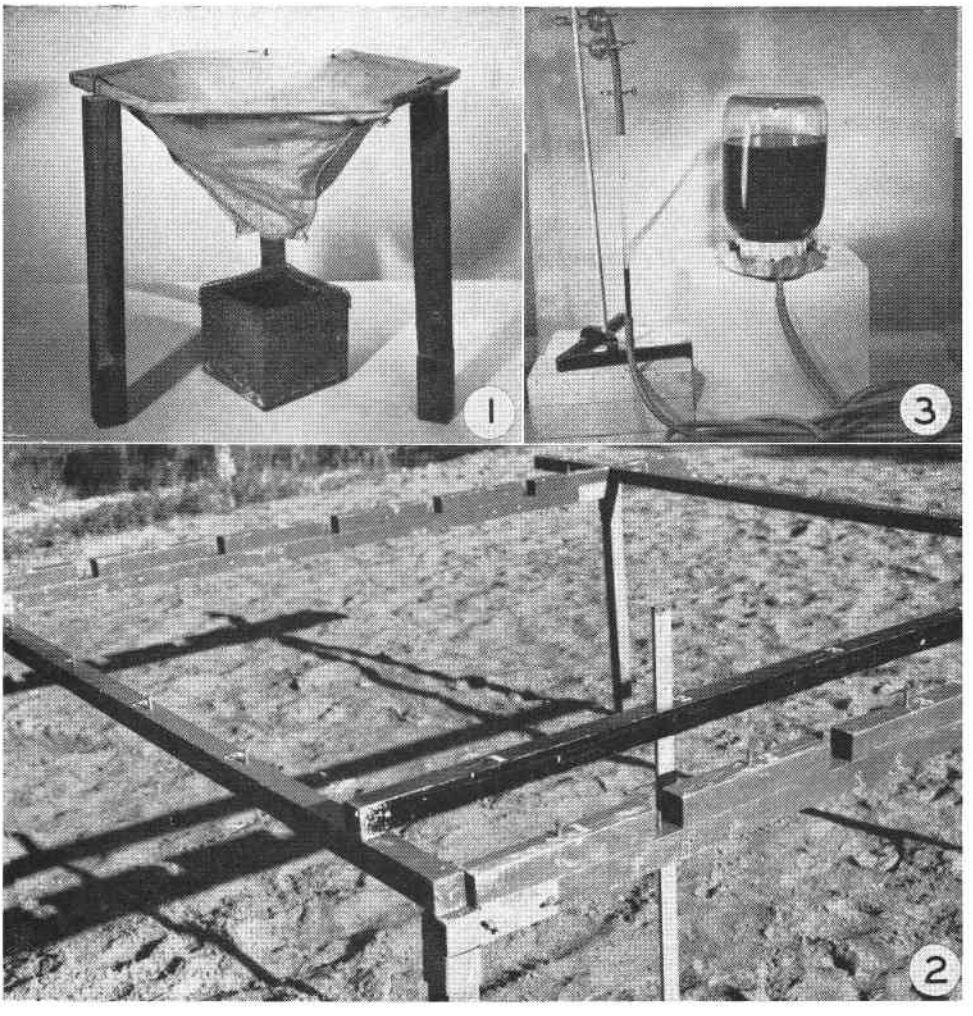


Fig. 1-3.—Apparatus used in connection with studies on sampling for cocoons of the larch sawfly. Fig. 1.—Trap for catching falling larvae. Fig. 2.—Jig for making topographical measurements. Fig. 3.—Apparatus for levelling tops of stakes.

The cocoons in each sample were examined and all apparently sound cocoons were opened. Cocoons containing living larvae were classified as 'sound'. The remainder, called "old cocoons", were classified into four groups: sawfly emerged; dead; killed by the tachinid parasite *Bessa harveyi* (Tnsd.); and eaten by small-mammal predators. The dead group included mortality attributable to the parasite *Mesoleius tenthredinis* (Morley), various insect predators, and disease organisms.

Results

Bases for stratification of the sample

The presence of openings in the canopy and the tendency for the number of cocoons per unit area to decrease from the trunk to the periphery of host trees suggested the use of strata based on crown cover. The stratification was based on the position of the sampling unit in relation to tree crowns. The

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TABLE I.

Distribution of mean number of cocoons per sampling unit in relation to crown cover and topography.

Crown cover	Cocoon classification	Topographic classification						
		0 – 6.5	7.0– 10.0	10.5– 13.5	14.0– 17.0	17.5– 20.5	21.0– 27.5	Totals
Under crown	Number of samples	3	5	5	4	1	0	18
	Sound cocoons	38.0	33.0	34.0	35.5	15.0	–	33.7
	Old cocoons	250.7	185.0	149.8	144.0	70.0	–	170.7
Edge of crown	Number of samples	4	17	26	15	15	8	85
	Sound cocoons	17.8	22.3	20.2	27.3	15.5	15.4	20.5
	Old cocoons	173.5	161.6	133.6	120.9	54.8	77.1	120.3
6″–24″ from crown	Number of samples	1	9	22	16	12	6	66
	Sound cocoons	18.0	11.1	12.9	19.1	9.9	8.8	11.1
	Old cocoons	182.0	120.5	83.8	84.9	30.1	29.3	75.8
Over 24″ from crown	Number of samples	0	6	12	4	6	3	31
	Sound cocoons	–	7.0	9.0	6.0	7.5	4.3	7.5
	Old cocoons	–	63.3	77.9	66.8	32.8	12.7	58.6
Totals	Number of samples	8	37	65	39	34	17	200
	Sound cocoons	25.4	18.5	16.7	18.9	12.1	11.1	16.6
	Old cocoons	203.5	138.9	107.7	102.9	44.3	48.9	100.6

shortest distances from the edges of the sample units to the crown projections were used in grouping the sample units into four categories:

(1) Under crown—at least six inches within crown projection;

(2) Edge of crown—less than six inches within crown to less than six inches beyond crown;

(3) Outside crown I—six to 24 inches from crown;

(4) Outside crown II—more than two feet from crown.

The distance in inches below the highest location recorded in the topographic mapping was also used to group the sample units as follows: 0-6.5; 7.0-10.0; 10.5-13.5; 14.0-17.0; 17.5-20.5; 21.0-27.5. The first and last groupings are larger because few samples fell into the extreme measurement classes. The results are recorded in Table I. The effect of crown cover and topography on the number of sound cocoons, using separate F tests, was as follows:

Source	Topographical effect			Source	Crown cover effect		
	d.f.	M.S.	F		d.f.	M.S.	F
Topography	5	431.28	3.17	Crown cover	3	3692.71	41.37
Error	194	136.17		Error	196	89.26	

These figures show that both factors contribute to significant differences in the number of cocoons per sampling unit. Similar results were obtained with old cocoons, the F values for topography and crown cover being 20.77 and 22.37, respectively.

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The effect of topography on the numbers of sound cocoons was not as marked as for the old cocoons. In both groups the largest number of cocoons were found in samples from hummocks and the smallest from depressions but the relative difference between the extreme numbers was much less. Larvae tend to avoid excessively dry or excessively wet locations when spinning cocoons (Ives, 1955a). During periods of moderate or heavy rainfall the hummocks are favourable sites for cocoon formation, while the hollows are relatively unfavourable, because of periodic flooding. During seasons with light rainfall the tops of hummocks are too dry and the depressions approach optimum conditions for cocoon formation. In 1957 the topographical effects were less pronounced because the July precipitation was only 18.6 per cent of the four-year average for 1955 to 1958. The agreement in the distribution of old and new cocoons in relation to crown cover is good. These results indicated that crown cover and topography provide suitable bases for stratification of the sample.

Estimation of cocoon populations

The grouping of sampling units (on the basis of crown cover and topography) was used for stratification of the sample. Some pooling of the data was required when less than two sample units were taken in a particular category. The number of possible sample units in each stratum was tallied. The estimated number of sound cocoons in the plot, the standard deviation, and the 95 per cent confidence interval for stratified and random sampling were:

Type of sampling	Numbers of sound cocoons	Standard deviation	95% confidence interval*
Stratified.....	33764	1299.96	$31216 < \mu < 36312$
Random.....	32828	1586.43	$29719 < \mu < 35937$

*Student's t with infinite degrees of freedom is used throughout this paper except where otherwise indicated.

Stratified sampling reduced the variance (and hence the required sample size for a given degree of accuracy) by 32.8 per cent. It reduced the standard deviation (and the width of the confidence interval) by 19.3 per cent. Either stratified or random sampling gives statistically satisfactory estimates with a sample size of 200.

Data on the relative magnitudes of the number of old cocoons probably give a better evaluation of average conditions than a single year's data. The estimated number of old cocoons, the standard deviation, and the 95 per cent confidence interval for stratified and random sampling were:

Type of sampling	Number of old cocoons	Standard deviation	95% confidence interval
Stratified.....	202271	6368.70	$189788 < \mu < 214754$
Random.....	199188	8667.53	$182200 < \mu < 216176$

The effects of stratification were greater for old cocoons than for sound cocoons. Stratification reduced the variance by 46.0 per cent and the standard deviation by 26.5 per cent. The average gain in efficiency obtained by stratification would be larger than obtained for sound cocoons in 1957.

Required sample size — By assuming that the variances for the different strata would remain constant at various levels of sampling intensity it is possible to

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TABLE II.
Comparison of estimated accuracy obtainable with different sample sizes using simple random sampling and stratified sampling with proportional allocation.

Sample Size	Stratified sampling		Random sampling	
	Standard deviation	$\frac{100 \lvert d \rvert}{\mu}$	Standard deviation	$\frac{100 \lvert d \rvert}{\mu}$
Sound cocoons				
50	2656	15.4	3346	19.4
100	2064	12.0	2366	13.7
150	1530	8.9	1932	11.2
200	1300	7.5	1586	9.2
Old cocoons				
50	13347	12.9	18283	17.7
100	9197	8.9	12928	12.5
150	7593	7.4	10556	10.2
200	6369	6.2	8668	8.4

*The sample of 200 is as sampling occurred, and is not strictly proportional. Calculations for standard deviation ignored the finite correction with the exception of the sample of 200. The half confidence intervals |d| were calculated for the 95 per cent confidence level based on Student's t for infinite degrees of freedon, and are expressed as percentages of the stratified estimate of the total sound or old cocoons, referred to as μ.

calculate the approximate degree of accuracy obtainable with samples of specified sizes (Table II). The stratified sample estimate of the total was used in these calculations as the best estimate of the true total. The estimated degree of accuracy is fairly good, even for samples of 50. However, these are only approximations, and there is a tendency to overestimate the accuracy of the smaller samples, because the calculations were based on Student's t with infinite degrees of freedom. Furthermore, there will be considerable sampling variation in the estimates of the total number of cocoons and its standard deviation when small samples are used. Samples of 100, using stratified sampling with proportional allocation, would probably be satisfactory for estimates of cocoon populations.

Recovery of cocoons from sampling units

The cocoons missed during sorting are a source of error in soil sampling. This error can be particularly serious in large series of sample units because the work is tedious and some workers may become bored and careless after a few days. This effect was overcome to some extent by a careful system of checks, but these were very time consuming.

In the present study the moss was sorted by two groups of workers. It was considered advisable to compare the numbers of cocoons recovered by each group. The crown cover grouping was retained to provide a basis for comparing the relative accuracies at different cocoon densities. The mean numbers of sound and old cocoons recovered by each group of workers were:

Worker group	Under crown		Edge of crown		Outside crown I		Outside crown II	
	Sound	Old	Sound	Old	Sound	Old	Sound	Old
I	41.6	213.6	20.3	130.6	11.4	82.4	6.0	57.0
II	28.6	143.4	20.8	105.5	10.9	69.2	8.1	58.9

The differences in the numbers of sound and old cocoons recovered by the two groups of workers for each crown cover classification were tested by analyses of

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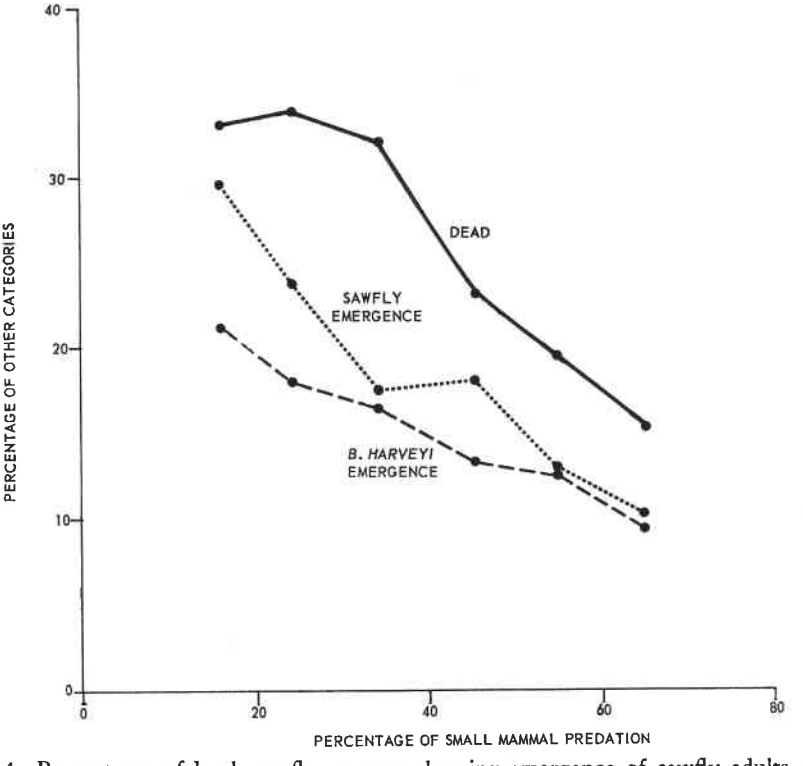


Fig. 4.—Percentages of larch sawfly cocoons showing emergence of sawfly adults, emergence of *B. harveyi*, and dead in relation to percentage predation by small mammals.

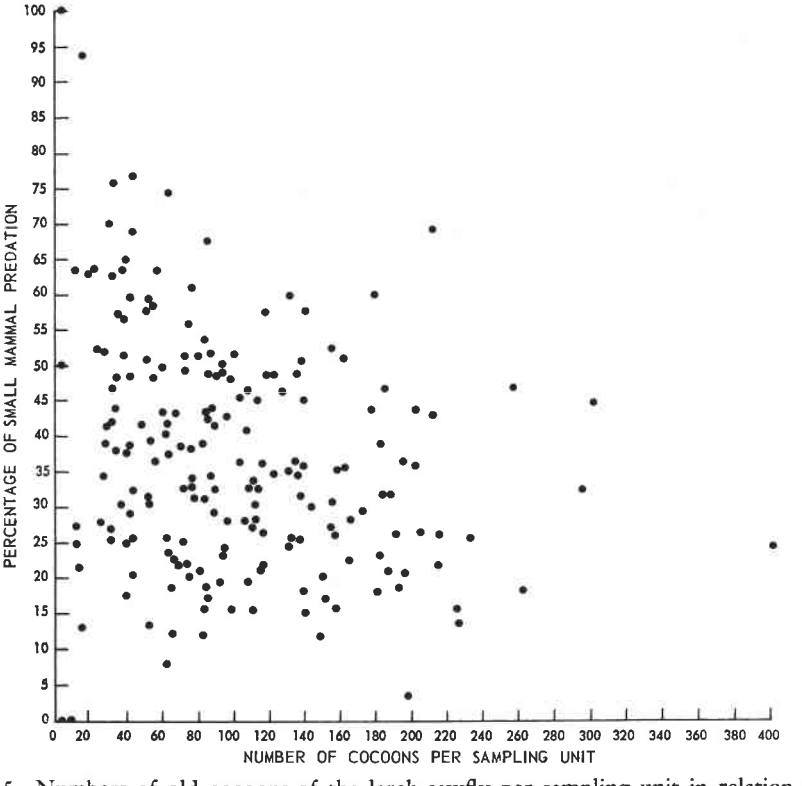


Fig. 5.—Numbers of old cocoons of the larch sawfly per sampling unit in relation to percentages of predation by small mammals.

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variance. There were no significant differences in the numbers of sound cocoons found by the two groups in any of the crown cover classifications. The number of old cocoons differed (at the .05 level) for the 'under crown' group.

Another check was provided by the re-examination of 57 sampling units. Only 18 sound cocoons (2.0 per cent of the total) were found in the check sorting. The level of accuracy in the first sorting was concluded to have been satisfactory.

Survival and mortality as estimated from old cocoons

Estimates of survival and mortality based on examination of old cocoons may be subject to errors arising from differential decomposition rates for various locations. However, these estimates provide information on the long-term effects of these factors under natural conditions.

Adult emergence and mortality data for the different crown cover and topographic groupings are shown in Table III. The only trend indicated is a possible inter-relationship between small-mammal predation and the other three factors. To examine this relationship the data were grouped according to the percentage of small mammal predation. The percentages of sawfly emergence, *B. harveyi* emergence, dead, and small-mammal predation for the grouped data are shown in Fig. 4.

Increased small-mammal predation was associated with decreases in the adult emergence, *B. harveyi* emergence, and dead classes. The decrease in the other mortality factors indicates overlapping between them and small-mammal predation. The predators apparently do not avoid cocoons containing larvae parasitized by *B. harveyi.* The principal small-mammal predator in the plot was *Sorex arcticus laricorum* Jackson, which does not discriminate against cocoons containing larvae parasitized by *B. harveyi* (Buckner, 1958). The decrease in *B. harveyi* emergence was not as great as in sawfly emergence, probably because some of these parasites emerge from the cocoons in the fall before predation occurs. Small mammals also apparently open cocoons containing dead or diseased larvae. However, predation begins in late summer (Buckner, 1953) and some of these larvae might have been alive when eaten but would later have died from other causes. Small-mammal predation is an important mortality factor affecting larch-sawfly cocoons but if "dead" as well as healthy larvae are eaten the impact on sawfly populations is less than if only healthy larvae are eaten.

Although there was apparently no relationship between topography or crown cover and the amount of small-mammal predation, cocoon density could influence the amount of predation. The numbers of old cocoons per sampling unit were plotted against the percentages of small mammal predation to determine if the two were related (Fig. 5). The results clearly indicate that predation was not related to density, and local concentrations of cocoons had little or no baiting effect.

II. TRAPPING FALLING LARVAE

The inherent weaknesses and large labour requirements of the soil-sampling method led to the consideration of an alternative technique for estimating the number of larch-sawfly cocoons formed per generation. The mature larvae fall freely from the host trees when feeding is completed.. The larvae falling on a standard area were channelled into a box containing a suitable cocooning medium (moist sphagnum moss).

This method had the following advantages: (1) The prolonged larval drop period is of no consequence, since the sampling units can be left out until larval drop is finished; (2) Only cocoons formed by the current generation are sampled; (3) Small-mammal predation does not affect the estimate; and (4) The labour

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TABLE III.
Percentage distribution of cocoon classifications within each crown cover and topographic category.

Crown cover	Cocoon classification	Topographic classification						
		0–6.5	7.0–10.0	10.5–13.5	14.5–17.0	17.5–20.5	21.0–22.5	Totals
Under crown	*Bessa* emerged	12.4	17.6	16.2	17.0	11.4	–	15.7
	Sawfly emerged	18.6	21.3	16.4	16.0	20.0	–	18.4
	Eaten by small mammals	37.8	26.4	32.8	36.6	38.6	–	32.9
	Dead	31.2	34.7	34.6	20.4	30.0	–	33.0
Edge of crown	*Bessa* emerged	15.0	15.8	17.3	20.6	17.1	11.3	17.0
	Sawfly emerged	20.6	24.4	24.5	18.4	16.6	14.3	21.8
	Eaten by small mammals	40.2	28.6	31.0	26.5	38.2	50.6	32.0
	Dead	24.2	31.2	37.2	34.5	28.1	23.8	29.2
6″–24″ from crown	*Bessa* emerged	11.5	15.6	17.2	16.1	11.9	9.7	15.7
	Sawfly emerged	23.1	19.2	21.3	15.5	17.7	8.0	18.6
	Eaten by small mammals	23.1	28.2	37.7	45.4	36.9	52.3	37.6
	Dead	42.3	37.0	23.8	23.0	34.4	30.0	28.1
Over 24″ from crown	*Bessa* emerged	–	16.3	16.6	11.2	17.8	13.2	15.8
	Sawfly emerged	–	21.6	22.8	12.7	16.8	15.8	20.3
	Eaten by small mammals	–	43.2	34.5	54.7	42.1	50.0	40.4
	Dead	–	18.9	36.1	21.4	23.3	21.0	23.5
Totals	*Bessa* emerged	13.4	16.1	17.1	18.0	15.7	11.1	16.4
	Sawfly emerged	20.0	22.5	22.6	16.7	17.1	13.0	20.4
	Eaten by small mammals	37.2	29.2	33.5	36.2	38.2	50.9	34.3
	Dead	29.4	32.2	26.8	29.1	29.0	25.0	28.9

required to separate the cocoons from the moss is greatly reduced. The method includes one source of error that may lead to over-estimation of the population. In the sampling units all mature larvae can form cocoons whereas under natural conditions some of them may fail to spin cocoons because of predation or drowning in open pools. Predation was not considered to be an important factor because the larvae quickly enter the ground and in the study area the water table was low so that no drowning occurred.

Methods

The sampling unit chosen (Fig. 1) was a funnel with a collecting area of two square feet that delivered the mature larvae into a six-inch-square metal box. This box had a screen bottom and the upper rim was incurved to prevent larvae from escaping. The sampling units were placed in the host stand in mid-June and removed after the larval drop was finished. The larval trap technique was tested for three years in one plot and one year in another.

Both study plots were situated in a pure tamarack stand in the Whiteshell Forest Reserve, Manitoba. Plot I measured 2 x 2.5 chains or 0.5 acres. This area was divided into four annual sampling units of 0.5 x 2.5 chains composed of five 0.5 x 0.5 chain subplots. The annual change in the sampling area within the plot was necessary because the ground vegetation in the bog forest deteriorated rapidly with trampling. The stand density and populations of larch sawfly in 1956, 1957, and 1958 were tested by analysis of variance and no significant differences between subplots could be detected.

Plot II was located about 100 yards east of Plot I and measured 2 x 2.25 chains (0.45 acres). The stand was similar but the trees were more widely spaced than in Plot I. This plot was sampled only in 1957.

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To obtain a random distribution of the sampling units, each plot was divided into numbered two-square-foot units and the required samples drawn at random. In Plot I each of the five subplots sampled annually contained 544.5 possible sample areas, of which 20 were selected. In 1957 a crown-cover map was made of four of the subplots. Plot II contained 10,178 possible sampling areas, of which 100 were selected. This plot was also mapped for crown cover.

Bases for stratification

With soil samples, stratification on the basis of crown cover reduced the variance of the estimated cocoon populations. It seemed logical to test this basis for stratifying larval trap samples. In Plot II the classification of the sampling areas was based on the distance from the centre of the sampling unit to the nearest crown periphery. The distances from the crown periphery to the centres of the larval traps in each of the eight categories of crown cover were:

Under Crown
1. more than 17 inches
2. from nine to 17 inches

Edge of Crown
3. from eight inches under to eight inches outside

Outside Crown
4. from nine to 17 inches
5. from 18 to 26 inches
6. from 27 to 35 inches
7. from 36 to 44 inches
8. more than 44 inches.

The effect of classification on the basis of crown cover was tested by analysis of variance. The differences between classes were highly significant ($F=5.17$ with seven and 92 degrees of freedom).

Stratification was also tested with data collected in 1957 from Plot I. The classification of the sampling areas on the basis of crown cover resembled that for Plot II but the number of categories was reduced to 'Under', 'Edge' and 'Outside' of crown. This broader classification was used because the tree crowns and crown openings were smaller than in Plot II. Classification on the basis of subplots, and on crown cover were tested with separate analyses of variance. Neither classification gave significant F values.

These results indicate that stratification on the basis of crown cover increases accuracy only in stands with large openings in the crown cover.

Estimation of cocoon populations

Estimates of cocoon populations were based on the number of cocoons found in each sample unit after the larval drop was complete. Because the differences between crown cover categories were significant in Plot II, the efficiency of stratification on this basis was compared with random sampling for the estimation of the total cocoon population.

The estimated cocoon population and the standard deviation for the 0.45 acre plot, based on both random and stratified sampling are given below:

Type of sampling	Number of cocoons	Standard deviation	95% confidence interval
Stratified	282,340	20,619	$241,927 < \mu < 322,753$
Random	292,210	22,467	$248,174 < \mu < 336,246$

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Stratification reduced the standard deviation by 8.23 per cent. This increase in efficiency is too small to justify the use of stratification in pure tamarack stands. In stands containing tree species other than tamarack or in open stands of tamarack, a stratification based on crown cover might be necessary to give the required degree of accuracy in estimating the total cocoon population.

Random sampling appeared to be a satisfactory method for estimating populations. In Plot I three years' sampling data were analysed to give the estimated population per 0.125 acre plot shown below:

Year	Degrees of freedom	Number of cocoons	Standard deviation	95% confidence interval
1956	99	98,527	4559	$89,487 < \mu < 107,567$
1957	99	118,510	6360	$105,898 < \mu < 131,122$
1958	49*	51,445	4024	$43,360 < \mu < 59,530$

*Only 50 sample units were available because 50 were overwintered in the plots.

Statistically these population estimates were satisfactory. In 1956 and 1957, with 100 sample units, the $\frac{1}{2}$ - 95 per cent confidence intervals were 9.2 and 10.6 per cent of the respective means. In 1958, with only 50 sample units, this percentage rose to 15.7.

Population estimates based on the larval trap method are larger than those made from soil samples. In Plot I both types of sampling were conducted in 1956 and 1957. Each year 50 one-square-foot soil samples were collected at random with 10 samples per subplot. The estimates of cocoon populations per acre for the two years, based on soil samples and larval traps were:

Type of sampling	n	Number of cocoons	Standard deviation
1956			
Soil	50	77,646	6720
Larval traps	100	98,527	4559
1957			
Soil	50	87,664	7484
Larval traps	100	118,510	6360

The difference between the two estimates was 21.2 per cent of the larger number in 1956 and 26.0 per cent in 1957. This emphasizes that the two methods do not estimate the same population. Soil samples provide estimates of the number of cocoons containing living larvae, while larval traps estimate the total number of cocoons formed.

The data presented in this paper lead to the conclusion that larval traps are the most practical method of estimating the larch sawfly cocoon population. In addition, estimates based on this method provide the most promising basis for evaluating mortality. A subsequent paper will discuss methods of evaluating mortality factors using the larval trap technique.

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References

Buckner, C. H. 1953. Small mammals as predators of the larch sawfly. *Can. Dept. Agric., Forest Biology Div. Bi-Monthly Prog. Rept.* 9(6): 2.

Buckner, C. H. 1957. Population studies on small mammals of southeastern Manitoba. *Jour. Mammalogy*. 38: 87-97.

Ives, W. G. H. 1955a. Effect of moisture on the selection of cocooning sites by the larch sawfly, *Pristiphora erichsonii* (Hartig). *Can. Ent.* 87: 301-311.

Ives, W. G. H. 1955b. Estimation of egg populations of the larch sawfly, *Pristiphora erichsonii* (Hartig). *Can. Jour. Zool.* 33: 370-388.

Ives, W. G. H., and R. M. Prentice. 1958. A sequential sampling technique for surveys of the larch sawfly *Can. Ent.* 90: 331-338.

Prebble, M. L. 1943. Sampling methods in population studies of the European spruce sawfly, *Gilpinia hercyniae* (Hartig) in eastern Canada. *Trans. Roy. Soc. Can.*, Third Series, Section V. 37: 93-126.

Turnock, W. J., and W. G. H. Ives. 1957. An instrument for measuring the radii of tree crowns. *For. Chron.* 33: 355-357.

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The Gypsy Moth and Some Possibilities of the Control of Insects by Genetical Means

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The screw worm, *Callitroga hominivorax* (Coquerel), can be sterilized by irradiation in such a way that the viability and sexual behaviour of the male are not seriously affected by the treatment. If such flies are released into a wild population, many of the males will mate with the native females which, since they mate only once, will become permanently infertile. Thus in proportion to the numbers released the numbers of fertile egg-masses produced by the population will be reduced; and if the numbers released are sufficient the population, failing rapid and extensive relief from a density-dependent controlling factor, could be eradicated in a few generations. This eradication has in fact been achieved on the island of Curacao; and the prognosis for the much larger undertaking now in progress in Florida is very favourable (see Lindquist and Knipling, 1957, for discussion and references).

It is obviously essential that the dosage of radiation required for sterilizing the insect should not seriously affect its ability to survive and mate. In the screw worm, fortunately, this condition is realized; but there seems to be no reason to suppose that it will be in every case.

Certain insects can probably be controlled or eradicated by a somewhat similar method that does not depend on artificial sterilization. For *Porthetria dispar* (L.), the gypsy moth, almost all the necessary basic information was obtained by Goldschmidt in his classical researches on sex-determination and geographic variation (summary in Goldschmidt, 1934), but the relevance of the facts to the problems of economic entomology does not seem to have been recognised.

In the gypsy moth, as in other Lepidoptera, the female is the heterogametic sex; the male determining factors lie in the X-chromosome while the female determining factors are conceived of as cytoplasmic. (The interpretation and terminology of Goldschmidt's review of 1934 will be used; other interpretations are possible but there is agreement as to the facts.) The species ranges from western Europe to Japan, and exists in a number of geographical races many of

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