

- Loew, H. 1861. Diptera Americae septentrionalis indigena. *Berl. Ent. Zeitschr.* 5: 307-359. (Centuria 1).
- Loew, H. 1864. Diptera Americae septentrionalis indigena. *Berl. Ent. Zeitschr.* 8: 40-104. (Centuria 5).
- Malloch, J. R. 1917. A preliminary classification of Diptera, exclusive of Pupipara, based upon larval and pupal characters. *Illinois Lab. Nat. Hist. Bull.*, Urbana, 12: 161-409, pls. 28-57.
- Melander, A. L. 1925. Diptera, Family Empididae; In Wytsman, *Genera Insectorum* 185: 1-434, pls. 1-8.

(Received March 6, 1959)

## The Assessment of Larch Sawfly Cocoon Predation by Small Mammals<sup>1</sup>

By C. H. BUCKNER

Forest Biology Laboratory, Winnipeg, Manitoba

### Introduction

Current investigations at the Forest Biology Laboratory, Winnipeg, are being directed towards the formulation of life tables for the larch sawfly, *Pristiphora erichsonii* (Htg.) (Lejeune, 1955). Because small mammal predation is a major factor in reducing cocoon populations of the sawfly (Buckner, 1953), an adequate method of assessing this source of mortality is desirable.

Five methods for estimating the amount of small mammal predation on larch sawfly cocoons were tested. A modification of the cocoon planting technique suggested by Graham (1928) provided the most useful means of assessing small mammal predation, from the standpoint of life table utilization. The usefulness of the other techniques for specific problems will be discussed.

### Methods and Results

#### *The Cocoon Planting Techniques*

Cocoon planting for the assessment of small mammal predation on larch sawfly cocoons was first used by Graham (1928), and later tested by Morris (1949) for the European spruce sawfly. These authors planted at regular intervals throughout the plot, 100 sets of five (later three) cocoons enclosed in small cotton bags. Periodic examination of these plantings showed the percentage of predation by small mammals. These authors found that the mammals chewed both cotton bags and cocoons beyond recognition, and so considered each set as a unit. The present author modified the technique so that each cocoon could be considered as a unit, and could be reclaimed for subsequent examination. This was accomplished by wiring apparently sound cocoons to three-inch tree tags. Two cocoons were placed about two inches apart on each tag. The cocoons were buried in tamarack bogs to a depth of approximately two inches, leaving about one inch of the tag projecting above the ground. One hundred sets were planted at intervals of about 40 feet in each bog. These were examined at intervals and the condition of each cocoon recorded. The technique is of advantage because each cocoon, rather than each set, can be recorded as a unit, and the order of the predator can be determined by the markings left on opened cocoons (Buckner, 1958).

During the period from 1952 to 1954, each cocoon opened by a small mammal was replaced as the sets were examined. Using the replacement modification,

<sup>1</sup>Contribution No. 522, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

TABLE I  
Comparison of cocoons on tags and loose cocoons opened by small mammals in cages

Predator	Cocoon type	Total	% Opened	Chi-square	d.f.	P.
<i>Sorex cinereus</i> (20)	Loose On tags	1560 800	91 94	.531	1	.5 approx.
<i>S. arcticus</i> (20)	Loose On tags	1560 800	97 89	16.3	1	less than .01*
<i>Clethrionomys gapperi</i> (10)	Loose On tags	780 400	73 68	802	1	.4 approx.
<i>Microtus pennsylvanicus</i> (2)	Loose On tags	78 40	72 78	.444	1	.5 approx.

\*Difference significant at less than one per cent level.  
Bracketed numbers indicate number of animals tested.

sets of cocoon plantings were examined at weekly intervals, at monthly intervals, and only once during the season, after small mammal predation had ceased. The various methods yielded essentially the same estimate of predation. On one plot during the late summer and fall of 1953 and the spring of 1954, the accumulated predation was 77 per cent when the sets were examined at weekly intervals, 72 per cent when examined at monthly intervals, and 79 per cent when examined only after predation had ceased. If the sets are examined at weekly intervals and the cocoons replaced as they are opened, a larger weekly sample is available. However, the replacement technique was abandoned in 1955 in order to gain additional information as explained later in this paper.

There is a possibility that cocoons on tags influence the feeding behaviour of small mammals by acting either as an attractant or repellent. To test this possibility, a cage with about 36 square feet of floor space was filled with sphagnum moss to a depth of about five inches, and cocoons on tags as well as loose cocoons were buried in the moss. Various small mammal predators were introduced and the numbers of opened tagged and loose cocoons were compared using pooled 2 x 2 Chi-square tests. The results are given in Table I. These data suggest that *Sorex cinereus cinereus* Kerr., the cinereous or masked shrew, *Clethrionomys gapperi loringi* (Bailey), the red backed vole, and *Microtus pennsylvanicus drummondii* (Audubon and Bachman), the meadow vole, are not influenced by the tags. The tags may repel *S. arcticus laricorum* Jackson, the saddle-backed shrew, to some extent.

Four replicates of the cocoon planting technique gave statistically consistent results.

Other uses for the cocoon planting technique include the determination of favourable and unfavourable locations for predation, and the effect of cocoon depth on predation (Buckner, 1958).

#### *The Collection Rate Technique*

The collection rate technique consists of collecting cocoons in an area at specified intervals of time before and after the period of small mammal predation. The numbers of sound cocoons collected per units of time in each sample are compared, and the differences between pre- and post-predation samples are attributed to small mammal predation. In this experiment 12 sampling points were established at 20-pace intervals, and cocoons were collected for five minutes at each station. Adjacent samples were taken after small mammal predation had

TABLE II

Small mammal predation on larch sawfly cocoons assessed by the collection rate technique and the cocoon planting technique

Date	Location	Cocoons collected per hour		% predation	% predation (Planting technique)
		Before predation	After predation		
1952	Telford Red Rock Lake	231	122	47	63
		287	158	45	48
1953	Telford Red Rock Lake	183	37	79	94
		329	53	84	98

ceased and the number of cocoons collected per man-hour was then compared with pre-predation collections. The results are recorded in Table II and are compared with estimates based upon the cocoon planting technique.

The collection rate technique is not considered to be an accurate means for determining the relative abundance of cocoons since the mood of the investigator, the meteorological conditions, and the type of terrain may tend to influence the efficiency of the collector. The technique may be adequate where only trends are considered and is less time consuming than other procedures for rating predation.

#### *The Cocoon Sampling Technique*

The cocoon sampling technique is a modification of the collection rate technique. Predetermined stations are sampled before and after predation and the numbers of sound cocoons compared. The difference is attributed to small mammal predation. In this experiment 20 sampling stations were chosen at the bases of large trees and a one-square-foot sample was taken in a direction chosen at random before and after predation. The results are recorded in Table III, and compared with estimates based on the cocoon planting technique.

This technique shows reasonable agreement with the cocoon planting technique and is not susceptible to the errors of judgment and mood of the collection rate technique. However, where predation is high and the insect population low, very large samples in the post-predation stage would be required to assess predation with confidence.

The locations of sampling points in this experiment were chosen to give the maximum number of cocoons. If the technique were to be used to assess cocoon populations as well, a random distribution of sampling effort would be required.

TABLE III

Comparison of predation of larch sawfly cocoons by small mammals derived from estimates using the cocoon sampling and cocoon planting techniques

Plot	Pre-predation cocoon sample	Post-predation cocoon sample	% predation by cocoon sampling technique	% predation by cocoon planting technique
1	37	13	65	54
2	25	6	76	76
3	134	12	91	92
4	55	10	82	87
5	10	4	60	43

### *The Saturation Trapping Technique*

The saturation trapping technique involves removing the entire small mammal population from an area by means of snap-back traps and comparing the emergence of adult sawflies on the mammal-free area with that on an area containing a normal complement of small mammals. A large, uniform tamarack bog was chosen for this experiment and two five-acre plots five chains apart were established. On one, the mammal population was removed by constant snap-back trapping, which began before mature larvae were falling from the trees and lasted until late October. The other plot retained its small mammal population and served as a control.

In the spring, 30 emergence cages were set out on each plot to sample the populations of surviving adults. Each of these cages covered an area of two square feet. The mammal-free plot yielded 222 adults, while on the undisturbed plot 102 were captured, indicating about 46 per cent predation on the plot containing mammals. Predation, as estimated by the cocoon planting technique, was 49 per cent. Although agreement between the two techniques was satisfactory, the results should be treated as indicative rather than conclusive, because the emergence cages in some instances allowed a proportion of the adults to escape.

Although the saturation trapping technique appears to provide a reliable estimate of small mammal predation on larch sawfly cocoons, it is not recommended for use in life tables. It is laborious and time consuming and requires a large uniform area that is usually unavailable in tamarack stands. Furthermore, the danger of permanently destroying the natural small mammal complement is high (Buckner, 1957), and this is not desirable in prolonged studies.

### *The Mammal Exclusion Cage Technique*

The mammal exclusion cage technique consists of exposing known numbers of larch sawfly cocoons to small mammal predation while a control is excluded from predation by mammal-proof cages. An experiment of this nature was tested in the 1955-1956 field season. Cylindrical fine-wire screen cages with open bottoms and cotton drawstring tops were buried in the moss deep enough so that the bottom of the cage lay below the water table. Ten cages were set out on each of three plots. Thirty-five larvae in post-feeding stages were set on top of the moss in the cages and allowed to spin. Eight cages on each plot were removed soon after cocoon formation by opening the drawstring, placing one hand inside to hold the moss in place, and sliding the cage upwards and free from the moss. The remaining cages were used to estimate the number of larvae that actually formed cocoons. After small mammal predation had ceased, the moss from the caged and uncaged areas was examined and the number of sound cocoons recorded. Predation was then estimated by determining the percentage of cocoons formed in the exclusion cages, and, considering this as the number available to small mammals in the exposed areas, calculating the number missing and presumably destroyed by small mammals. A comparison between the exclusion cage and cocoon planting technique for the same period is given in Table IV.

The exclusion cage technique is similar to that of the saturation trapping technique. However it is less laborious, and the exclusion cages are simpler and more easily constructed than the emergence cages.

The exclusion cage technique appears to give a reliable estimate of small mammal predation on larch sawfly cocoons. It is adaptable to life table studies but has an inherent anomaly that has not been assessed. Whereas the cocoon planting technique adds 200 cocoons to an area of about five acres, the exclusion

TABLE IV

Comparison of the results of the exclusion cage and cocoon planting technique in determining small mammal predation on larch sawfly cocoons

Plot	% larvae that formed cocoons in exclusion cage	% predation on exposed areas	% predation from planting technique
1	87	51	54
2	91	80	76
3	87	95	92

cage adds a concentration of cocoons to a very localized area. Especially at low prey populations, these "pockets" of cocoons could conceivably act as a bait for small mammals and hence lead to an overestimate of predation.

### Discussion

In the development of life tables for a forest insect, it is important to assess the mortality occurring in each age class or stage (Morris and Miller, 1954). Because small mammals have been shown to be important predators of larch sawfly cocoons, it is necessary to assess this source of mortality. Five techniques to assess small mammal predation on larch sawfly cocoons have been outlined in this paper, namely the cocoon planting, collection rate, cocoon sampling, saturation trapping, and exclusion cage techniques. Although it was not possible to test and replicate all five techniques simultaneously, series of comparable data were obtained for the cocoon planting and the remaining techniques individually. The results from each technique were compared with those from the cocoon planting technique and tested for significance using individual and pooled  $2 \times 2$  Chi-square tests. These are recorded in Table V. The results indicate that there is no agreement on the assessment of predation between the cocoon planting and collection rate techniques. It will be noted that in every case, the estimate of small mammal predation based upon the collection rate technique was lower than that of the cocoon planting technique, although one trial is not significantly different. Possibly this indicates an unconscious effort on the part of the investigator to search more diligently in the post-predation collection. This is further emphasized, since the results of the cocoon sampling and cocoon planting techniques agree in three of the five trials, and disagreement is significant only where the sample sizes are very small. Since the cocoon sampling trials represent the examination of 200 cubic feet of moss, time and labour limited further testing of the technique. Where sufficient cocoons were recovered to make reliable comparisons with the cocoon planting technique, agreement was highly significant. Similarly, the results from both the exclusion cage and saturation trapping techniques agree favourably with those from the cocoon planting technique. Ives (1959) also finds agreement between predation as assessed by the planting technique and by a cocoon sampling technique. From these data it may be concluded that:

1. The cocoon planting technique is a reliable means for assessing small mammal predation on larch sawfly cocoons.
2. The collection rate technique is not a reliable means of assessing this source of mortality.
3. The cocoon sampling technique is probably a reliable method of estimating small mammal predation on larch sawfly cocoons, but often low populations of the prey insect and labour shortages preclude the use of the method.

TABLE V

Evaluation of the cocoon planting technique for estimating small mammal predation on larch sawfly cocoons by comparing with other techniques, using individual and pooled 2 x 2 chi-square tests

Technique		Trials										Total
		1	2	3	4	5	6	7	8	9	10	
Cocoon planting	Per cent Sample	63 200	48 200	94 200	98 200	54 200	76 200	92 200	87 200	43 200	49 200	
Collection rate	Per cent Sample X <sup>2</sup>	47 231 12.10**	45 287 .40	79 183 15.05**	84 239 24.8**							1030 322**
Cocoon sampling	Per cent Sample X <sup>2</sup>					65 37 4.32*	76 25 2.78	91 134 .007	82 55 .99	60 10 4.49*		261 1.0
Exclusion cage	Per cent Sample X <sup>2</sup>					51 242 1.20	80 254 1.17	95 243 2.0				739 1.06
Saturation trapping	Per cent Sample X <sup>2</sup>										46 222 1.6	

\*difference significant at 5% level.

\*\*difference significant at 1% level.

4. The exclusion cage and saturation trapping techniques give reliable estimates of small mammal predation on larch sawfly cocoons.

The cocoon planting technique has been used almost exclusively to provide an estimate of small mammal predation for life tables of the larch sawfly. Earlier estimates were made by examining the sets at weekly intervals and replacing chewed cocoons at each examination. However, it was found that small mammals differentiate to varying degrees between sound and parasitized cocoons, and to measure this interacting factor, all subsequent trials were examined at weekly intervals but without cocoon replacement. The sets were left in the ground until the adult sawflies had ceased emerging the following summer and the cocoons were then examined and recorded as being opened by mice or shrews, having sawfly emergence holes, emergence holes of parasites, attacked by fungus, dead, or apparently sound. By comparing the numbers from which sawfly had emerged, the apparently sound cocoons and the number with parasite emergence holes with determinations of parasitism made at the time of larval drop, the interacting effect of small mammal selection is estimated.

A 1954-55 "pilot" life table study provides an interesting example of the usefulness of the technique. The initial cocoon plantings were set out on August 11. At this time a large proportion of the larval population was still feeding. Cocoon populations were estimated by trapping mature larvae as they fell from the trees and allowing them to spin cocoons in special receptacles. This estimate was checked by random cocoon sampling during the first week of September. The estimated cocoon population per tree using the larval drop technique was 1,263 cocoons, and 218 by the cocoon sampling technique (Turnock, 1956). However, by correcting the latter estimate for the 37 per cent small mammal predation which had occurred to the time of cocoon sampling, and by adding to this other mortality factors to the time of sampling, the initial cocoon

TABLE VI

Partial life table for the 1954-55 generation of the larch sawfly in the Telford bog,  
Whiteshell Forest Reserve  
(Abstracted from Turnock, 1956)

X Age interval	1x* No. alive at beginning of X	dxF Factor responsible for dx	dx No. dying during X	100 qx $\frac{dx}{1x} \times 100$
Cocoon (fall)	1263.2 (1030**)	parasites	128.2	10.1
		miscellaneous	533.8	42.3
		small mammal predators	475.0**	37.6**
		Total	1137.0	90.0
Cocoon (winter and spring)	126.2	unknown plus		
		holdover	32.8**	26.0**
		parasites	34.0**	27.0**
		Total	66.8**	53.0**
Adult	59.4**	males	0.25	0.4

\*Number per tree.

\*\*Estimates provided by the cocoon planting technique.

population was estimated as 1,030 per tree (Turnock, 1956). Thus, the cocoon planting technique aided greatly in dispelling the discrepancy between two interdependent estimates of the cocoon population. By the last week in October predation had ceased, and 79 per cent of the planted cocoons had been destroyed by small mammals; 43 per cent by shrews and 36 per cent by mice. Mechanical difficulties prevented the use of emergence cages to assess the surviving adult population. By allowing the cocoon plantings to remain in position until after the adult emergence period it was estimated that of the cocoons that escaped small mammal predation, 47 per cent produced adults in the spring of 1955, and the tachinid parasite, *Bessa harveyi* (Tnsd.) emerged from another 27 per cent. Thus the cocoon planting technique provided information in addition to mammalian predation. Table VI is a partial life table showing estimates provided by the cocoon planting technique.

The use of the cocoon planting technique exclusively for determining small mammal predation of larch sawfly cocoons may not be desirable, because total reliance on one technique without adequate checks may introduce errors. For example, it has been shown (Buckner, 1958) that under certain limited circumstances small mammal predation varies with cocoon depth. If the cocoon population were concentrated very close to the water table, small mammal activity would be inhibited and the cocoon planting technique would tend to give an overestimate of the percentage of cocoons destroyed by small mammals. Or, if the cocoon population were concentrated deeply, a rising water table could submerge and kill them. The predation on this population as estimated by the cocoon planting technique would give a good approximation for the remaining cocoons, but a false impression of the main mortality source. In order to avoid such errors, the cocoon planting technique should be supplemented.

The choice of a secondary technique could be made after a decision on the technique for estimating cocoon populations in the life table project has been reached. Current techniques used in the life table project include both larval drop and random cocoon samples. Random cocoon samples taken after predation

has ceased can be readily compared with cocoon samples taken during life table studies and thus provide a check against the planting technique.

### References

- Buckner, C. H. 1953. Small mammals as predators of the larch sawfly. *Can. Dept. Agr. For. Biol. Div. Bi-Monthly Prog. Rept.* 9(6): 2.
- Buckner, C. H. 1957. Population studies on some of the small mammals of southeastern Manitoba. *J. Mammal.* 38:87-97.
- Buckner, C. H. 1958. Mammalian predators of the larch sawfly in eastern Manitoba. *Proc. Tenth. Internat. Cong. Ent.* (4):353-361.
- Graham, S. A. 1928. The influence of small mammals and other factors upon the larch sawfly survival. *J. Econ. Ent.* 21: 301-310.
- Ives, W. G. H. 1959. Unpublished manuscript.
- Lejeune, R. R. 1955. Population ecology of the larch sawfly. *Can. Ent.* 87:111-117.
- Morris, R. F. 1949. Differentiation by small mammals between sound and empty cocoons of the European spruce sawfly. *Can. Ent.* 81:114-120.
- Morris, R. F., and C. A. Miller. 1954. The development of life tables for the spruce budworm. *Can. J. Zool.* 33:283-301.
- Turnock, W. J. 1956. Unpublished data, Forest Biology Laboratory, Winnipeg.

(Received February 2, 1959)

---

### **Joint Annual Meeting of Entomological Society of Canada Entomological Society of Ontario, and Entomological Society of America, Detroit, November 30 to December 3, 1959**

The Entomological Society of Canada, the Entomological Society of Ontario, and the Entomological Society of America will hold their annual meetings jointly at Detroit, Mich., Nov. 30 to Dec. 3, 1959.

The June issue of the Bulletin of the Entomological Society of America will present the highlights of the program and the call for papers; the October issue will contain the complete program. By arrangement between the societies, these issues will be distributed to all members of the Entomological Society of Canada.

Canadians have always been generously represented in the membership and offices of the Entomological Society of America. The combined meeting of the societies will be a fruitful continuation of this tradition of common interest.