SAMPLING WESTERN HEMLOCK LOOPER PUPAE (LEPIDOPTERA: GEOMETRIDAE) USING BURLAP TRAPS

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ABSTRACT

Burlap wrapped around western hemlock, *Tsuga heterophylla* (Raf.) Sarg., trees at breast height was used to trap pupae of the western hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst). The number of pupae in the traps was highly variable and was not related to tree diameter or the surface area of the trap. There was a significant relationship between the number of viable pupae per trap and the number of healthy western hemlock looper eggs subsequently laid on lichen in the trees. Sample size requirements are presented.

Key Words: *Lambdina fiscellaria lugubrosa*, Geometridae, defoliator, sampling, Lepidoptera, population index.

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INTRODUCTION

The western hemlock looper (WHL), *Lambdina fiscellaria lugubrosa* (Hulst) (Lepidoptera: Geometridae), is a periodic defoliating pest of coniferous trees, primarily western hemlock, *Tsuga heterophylla* (Raf.) Sarg., in Oregon, Washington and British Columbia. Epidemics are characterized by a rapid increase in insect numbers. Tree mortality can occur after only 1 year of severe defoliation. Outbreaks commonly last from 3 to 5 years (Hopping 1934; Carolin et al. 1964; Harris et al. 1982).

To predict when WHL outbreaks will occur, a population index is required. To date, sampling methods have concentrated on the egg stage (Richmond 1947; Kinghorn 1952; Thomson 1957, 1958; Carolin et al. 1964; Shepherd and Gray 1972). A predictive index based on the number of healthy WHL eggs per 100 grams of dry lichen, *Alectoria* spp., is used by the Forest Insect and Disease Survey of Forestry Canada in British Columbia (Shore 1985). This stage is difficult to sample as the eggs are laid singly in a variety of substrates such as bark, moss and lichens. Collection often involves tree-felling to obtain samples, and soaking with hot water, bleach or sodium hydroxide solutions to separate eggs from the substrate (Otvos and Bryant 1972; Shepherd and Gray 1972).

Otvos (1974) reported that a strip of burlap wrapped several times around a tree was an effective means of collecting pupae of the hemlock looper, *L. fiscellaria fiscellaria* (Guenée). He subsequently found that this method was also effective for WHL pupae (pers. comm.). Late instar WHL larvae may drop to the ground or lower branches and crawl into protected places such as bark crevices to pupate (Furniss and Carolin 1977). Apparently they find the burlap a favorable pupation site. The pupal stage occurs in August and September and would provide an earlier warning of high populations than the overwintering egg stage if pupal counts could be related to population levels or damage in the following year. Also, the burlap trap method could reduce the sampling effort from the present method based on eggs, and avoid the necessity of felling trees which is wasteful and increasingly unpopular due to the scarcity of the resource. This paper presents the results of a study in which the number of pupae caught in burlap traps was evaluated as an index of WHL population the following year, and presents some sampling characteristics associated with the use of burlap traps.

MATERIALS AND METHODS

Three widely separated locations experiencing WHL infestations were selected for study: Scotch Creek in the Kamloops Forest Region, Abbott Creek in the Cariboo Forest Region and Cranberry Creek in the Nelson Forest Region of British Columbia. These locations are separated by a minimum linear distance of 130 miles (209 km) and a maximum distance of 480 miles (772 km). In late July and early August 1984, prior to WHL pupation, 20 western hemlock trees at Scotch and Abbott creeks and 30 trees at Cranberry Creek were selected at random for sampling. Burlap was wrapped twice around the bole of each tree at breast height and secured with staples. The burlap was wrapped loosely enough to allow WHL larvae to crawl between the layers. The burlap was 50 cm wide on half of the trees selected at random at each location and 25 cm wide on the remainder. Diameter at breast height (DBH) was recorded for each tree. Mean diameters and standard deviations of the sample trees are given in Table 1.

Table 1. A comparison of the mean number of western hemlock looper pupae trapped in narrow (25 cm) and wide (50 cm) burlap wrapped twice around tree boles at breast height.

Burlap Width (cm)	Location	n*	Mean DBH†	S.D.	Mean # Pupae/ Tree‡	S.D.
25	Scotch Cr.	10	19.8	5.5	65.1	32.2
	Abbott Cr.	9	42.1	7.8	103.0	114.3
	Cranb. Cr.	15	24.5	6.4	3.2	7.0
50	Scotch Cr.	10	23.2	9.5	60.6	54.6
	Abbott Cr.	10	37.0	10.4	80.0	81.4
	Cranb. Cr.	15	23.9	5.8	2.7	3.7

* n = number of sample trees. One tree having an exceptionally large value (3135 pupae) was omitted from Abbott Cr. -25 cm.

† DBH did not differ significantly between burlap treatments within locations (Anova, $P > 0.67$).

‡ Mean number of pupae per tree did not differ significantly between burlap widths within locations (Anova, $P > 0.27$).

The traps were checked periodically and when pupation was at a peak (i.e. few new pupae and some emerged adults found) the traps were sampled. A drop cloth was spread around the base of the tree to catch any pupae falling to the ground when the burlap was removed. Numbers of pupae found in the burlap, on the bark under the burlap, and on the drop cloth were recorded separately. Samples of pupae from Scotch and Abbott creeks were reared through to emergence to determine survival and estimates of the number of viable pupae.

In early September, egg samples were obtained by filling 2-lb. (5 × 10 × 25 cm) polyethylene bags with lichen from 10 trees at each location. Sample trees were selected on the basis of accessibility of the lichen without felling the tree, and were not the same trees as those sampled for pupae. The eggs were removed from the lichen using a 2% bleach solution (Otvos and Bryant 1972). Defoliation of current year's foliage was assessed in the summer of 1985 based on ocular assessment of 10 trees per location.

Required sample sizes at the 80% probability level were calculated using the relationship between the variance and the mean from the location and burlap width samples (Table 1). The variance-mean relationship used was Taylor's power law: $s^2 = a\bar{x}^b$ (Taylor et al. 1978). The right hand side of this equation was then substituted into the sample size equations below and a sample size-mean relationship was developed. The sample size was presented two ways. To obtain a level of precision as a fixed percentage of the mean the sample size (n) required was estimated after Husch et al. (1972):

[1]
$$n = \frac{t^2 cv^2}{(AE)^2} \quad \text{or} \quad n = \frac{t^2 s^2}{(AE)^2 \bar{x}^2}$$

The sample size required to obtain a fixed level of precision in the same units as, but independent of, the mean (e.g. ± 10 pupae) was calculated after Freese (1962):

[2]
$$n = \frac{t^2 s^2}{(AE)^2}$$

where:
t = Student's t value at the required confidence level;
cv = the coefficient of variation expressed as a percentage;
s^2 = the variance;
AE = the allowable error expressed either as a percentage of the mean [1] or in the same units as the mean [2];
$\bar{x}$ = the mean.

RESULTS

The burlap traps were effective in catching WHL pupae; a maximum of 3135 pupae were trapped on one tree at Abbott Creek. Pupal populations were low at Cranberry Creek compared with the other two locations (Table 1).

There were no significant differences between the diameters of the trees selected for the wide and narrow burlap sample groups at each location (Table 1). The total number of pupae caught on the burlap, found on the bark under the burlap, and that dropped on removal of the burlap was not related to the diameter of the tree (covariance analysis, $F = 0.0$, $P > 0.96$). There was no significant difference between the number of pupae caught on the 25-cm-wide and 50-cm-wide burlap traps (Table 1). This, along with the insignificant relationship between

DBH and number of pupae suggests that it is not necessary to standardize pupal counts to a unit area of trap surface.

In the higher population areas, almost as many pupae were found on the bark under the burlap as were trapped in the burlap itself (Table 2), and there was a strong correlation in all three locations between the number of pupae on the bark and the number in the burlap. This relationship can be described by the linear relationship:

$$Y = 14.7 + 0.61\,X \tag{3}$$

where Y = number of pupae trapped per tree in the burlap

and X = number of pupae trapped per tree on the bark under the burlap.

($R^2 = 0.71$, $P = 0.0001$, $n = 69$; note: one large observation was removed from the analysis due to a strong positive influence on regression).

The number of pupae that dropped on removal of the burlap was related to the total number of pupae in the burlap and on the bark underneath the burlap. This relationship was best described through the range of pupal densities encountered in this study by the quadratic equation:

$$Y = 1.17 + 0.033747\,X - 0.0000039\,X^2 \tag{4}$$

where Y = number of pupae dropped on removal of the burlap

and X = number of pupae trapped in the burlap and on the bark underneath the burlap.

($R^2 = 0.88$, $P = 0.0001$, $n = 70$)

A comparison of three estimators: the number of pupae attached to the burlap, the number of pupae attached to the bark under the burlap, and the total number of pupae (which included the pupae on the burlap and bark as well as those that dropped on removal of the burlap) showed no clear advantage of any one estimator based on the coefficient of variation (Table 2). In two of the three locations the number of pupae on the burlap was less variable with respect to the mean than the total number of pupae and the number of pupae on the bark. The estimator based on pupae attached to the bark lacked sensitivity at very low populations as indicated by the near zero value for Cranberry Creek (Table 2). The number of pupae attached to the burlap was selected as the best estimator for the remaining analysis.

In order to obtain a larger sample size to compare the mean number of viable pupae trapped per tree with the subsequent number of healthy eggs per 100 grams of lichen and defoliation the following year, data from a sample of 20 trees at Cranberry Creek collected in 1983 were added to that from the other three locations (Table 3). There was a significant linear relationship between the number of viable pupae per burlap trap and the subsequent number of healthy eggs per 100 grams of lichen which can be described as:

$$Y = 0.368\,X \tag{5}$$

where: Y = number of healthy eggs per 100 grams lichen

X = number of viable pupae per burlap trap

($R^2 = 0.88$, $P = 0.017$, $n = 4$)

Table 2. A comparison of the mean number ($\bar{x}$) and variability of pupae caught on burlap traps, on the bark underneath the burlap and the total number trapped at three locations.

	Burlap*			Bark			Total†		
Location	$\bar{x}$	sd	cv‡	$\bar{x}$	sd	cv	$\bar{x}$	sd	cv
Scotch Cr.	62.8	43.7	69.5	80.6	49.8	61.8	150.0	95.0	63.3
Abbott Cr.	90.9	96.2	105.8	92.3	150.8	163.4	191.2	239.5	125.3
Cranb. Cr.	3.0	5.5	186.4	0.4	0.7	195.9	3.5	6.6	190.7

* Narrow (25 cm) and wide (50 cm) burlap data were combined as there was no significant width effect.

† Total includes number of pupae on burlap, on bark underneath burlap and those that dropped on removal of burlap.

‡ Coefficient of variation = (sd/$\bar{x}$) × 100.

Table 3. Mean numbers ± SE of viable western hemlock looper pupae per burlap trap and healthy eggs per 100 grams lichen, and predicted and actual defoliation occurring the following year at three locations in British Columbia.

Location	Year	Mean number of viable pupae per trap	Mean number healthy eggs/ 100 g lichen	Defoliation	
				Predicted*	Actual
Cranb. Cr.	1983	171.8 ± 42.3	56.2 ± 11.3	moderate	light
Scotch Cr.	1984	29.1 ± 6.6	1.2 ± 0.8	none	none
Abbott Cr.	1984	73.6 ± 19.4	47.0 ± 3.8	moderate	trace
Cranb. Cr.	1984	3.0 ± 1.0	10.7 ± 1.3	light	none

* Predicted defoliation based on number of eggs per 100 g lichen: < 5 = none, 5 − 26 = light, 27 − 59 = moderate, > 60 = severe. Defoliation categorized as 1 − 25% = light, 26 − 65% = moderate, and > 66% = severe (Shore 1985).

The predictive index based on the number of healthy eggs per 100 g of lichen appeared to overestimate the defoliation for three of the four location-years (Table 3). The WHL population apparently collapsed at Scotch Creek following the pupal stage; it had already declined at Cranberry Creek at the time of pupal sampling.

DISCUSSION

The surface area of burlap presented by the 25 cm width apparently provided all pupation sites required by the WHL population densities encountered in this study, because no increase in numbers was obtained by doubling the surface area.

There was considerable tree to tree variation in the number of pupae trapped within a location and this was unrelated to tree diameter and trap surface area. At Abbott Creek, one tree of average DBH (40 cm) had a total of 3135 pupae on the burlap and bark while several other surrounding trees of similar size and appearance had less than 50 pupae.

The number of pupae attached to the burlap is recommended as the best estimator because of its relatively low variability and the fact that it involves less sampling effort than the estimator based on total number of pupae in the burlap, on the bark and dropped on removal of the burlap.

The high variance and contagious distribution of sample estimates results in relatively large sample size requirements in order to obtain estimates within 20% of the mean at low population levels (Fig. 1). It is probably unrealistic and unnecessary to obtain this level of precision at very low means. Sampling to a fixed level of precision, such as ± 10 pupae, is an alternative. This method results in high sample sizes at high populations and low sample sizes at low populations (Fig. 1). Relatively high sample sizes may not be prohibitive because placing burlap on trees and counting pupae on the burlap are not overly labour-intensive or time-consuming activities.

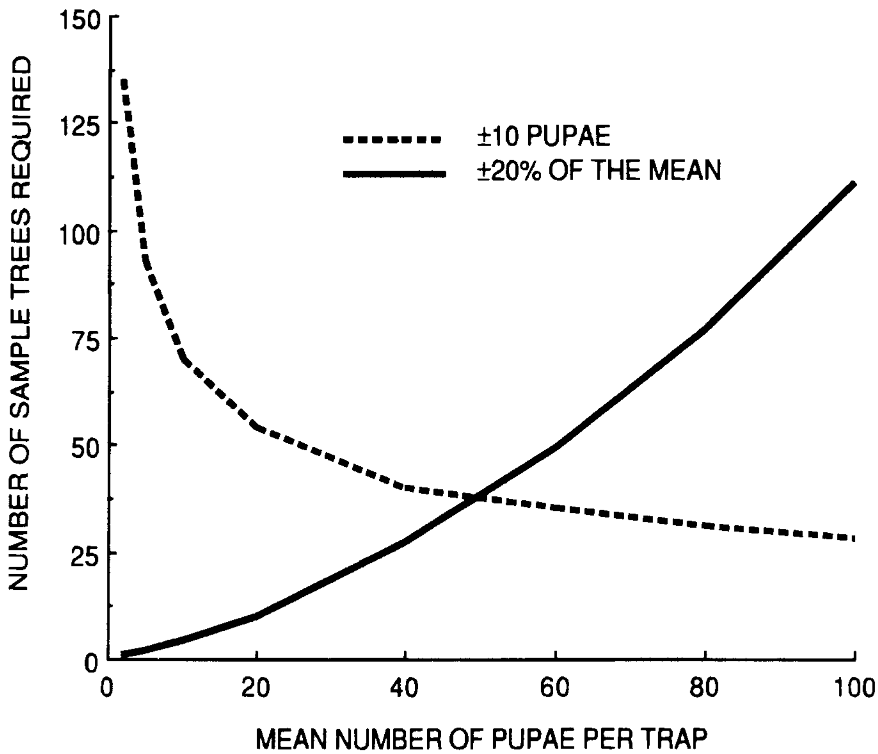

Fig. 1. The relationship between mean number of pupae per trap and the sample size required to obtain precision of ± 20% of the mean or ± 10 pupae. Based on the variance-mean regression $s^2 = 4.34\ \bar{x}^{1.59}$, ($R^2 = .94$), substituted into equations [1] and [2] in text.

The relationship between number of viable pupae per trap and the subsequent mean number of healthy eggs per 100 g of lichen (equation [5]) suggests that the number of pupae caught on burlap traps could be used successfully as a predictive index for WHL populations and defoliation the following summer. This relationship is based on a small sample of locations and therefore may require modification as more data become available. The relationship between pupal numbers obtained by this method and subsequent egg numbers and defoliation should be further investigated at a larger number of locations during the early stages of the next epidemic.

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