REQUIRED SAMPLE SIZE FOR EARLY INSTAR LARVAE OF SPRUCE BUDWORM, *CHORISTONEURA FUMIFERANA* (LEPIDOPTERA: TORTRICIDAE), IN NEWFOUNDLAND

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Abstract

Required sample size was determined for early instar (2nd to 4th instar) larvae of spruce budworm, *Choristoneura fumiferana* (Clem.). Larval counts on mid-crown 45 cm branch tips and whole branches of balsam fir, *Abies balsamea* (L.) Mill., were described in terms of the negative binomial distribution. The values of common k for the branch tip and whole branch sample units were 1.550 and 1.636, respectively. The required sample size at densities greater than or equal to one appears feasible. It is recommended that the 45 cm branch tip be used to estimate population density of early instar larvae in Newfoundland.

Résumé

La taille requise de l'échantillon pour les jeunes stades larvaires (2ᵉ à 4ᵉ) de la tordeuse des bourgeons de l'épinette, *Choristoneura fumiferana* (Clem.), a été déterminée. Les nombres de larves comptées au milieu de la cime sur les 45 derniers centimètres des branches et sur des branches entières du sapin baumier, *Abies balsamea* (L.) Mill., ont été exprimés suivant une distribution binominale négative. Les valeurs du k commun pour les échantillons de bouts de branches et de branches entières sont de 1,550 et 1,636 respectivement. Obtenir un échantillon de taille requise à des densités égales ou supérieures à 1 semble réalisable. Il est recommandé d'utiliser les 45 derniers centimètres des branches pour estimer la densité des populations des larves aux premiers stades à Terre-Neuve.

Introduction

The largest known outbreak of the spruce budworm, *Choristoneura fumiferana* (Clem.), in Newfoundland began in 1971 (Hudak and Raske 1981). By 1977, approximately 90% of the productive forest was severely infested (Otvos and Moody 1978). From 1978 to 1980 more than 1 million hectares of spruce–fir forest were being defoliated annually and the volume of dead trees reached 17,105,000 m³ (Clarke *et al.* 1980, 1981). The impact of this outbreak on the forests of Newfoundland has prompted intensive research on the biology and population dynamics of the spruce budworm. As part of this objective, a sampling plan for determining population density of early instar (2nd to 4th instar) larvae was required.

A single, mid-crown branch from a host tree was accepted as a suitable sample unit and insect density was expressed as number of insects per branch (Morris 1955). Either 45 cm branch tips, whole branches, or both are collected in eastern Canada (Sanders 1980). In this paper, we evaluate the fit of counts of early instar larvae to the negative binomial distribution for both the 45 cm branch tip and whole branch sample units. Required sample size to estimate population density was then determined for various levels of confidence and precision (Karandinos 1976).

Materials and Methods

Eight dominant or co-dominant balsam fir trees were arbitrarily selected from each sampling site across insular Newfoundland. There were five sites sampled in 1979, eight in 1980, and eight in 1981. One branch was collected from the mid-crown of each sample tree. Numbers of spruce budworm larvae were counted on the 45 cm tip and on the remaining foliated branch portion. Each year, samples of early instar larvae were collected

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in June when they are present at their feeding sites on the branches (Crummey and Otvos 1980).

Identification of the spatial distribution of an insect population is essential for the development of an effective sampling scheme (Morris 1955; Waters 1955; Waters and Henson 1959; Karandinos 1976). The nature of the spatial distribution can be deduced from the relationship between the variance and the mean of the insect counts per sample unit from samples collected at different plots and dates (Morris 1955; Bliss 1958). Departure from the theoretical distribution can be tested by the chi-square statistic (Lefkovitch 1966).

Of the several theoretical, contagious distributions, the negative binomial has been widely applied (Bliss and Fisher 1953; Southwood 1978). In the present study, the parameter k of the negative binomial was determined by the moment method of each plot-year (Anscombe 1949; Bliss and Fisher 1953) and a common k estimated by the weighted regression method (Bliss and Owen 1958). This method has been applied to develop sequential sampling plans for egg mass and late larval stages (5th to 6th instars) of spruce budworm (Morris 1954; Waters 1955).

Required sample size was defined as the smallest sample size needed to yield an estimate of population density for desired levels of precision and confidence (Karandinos 1976).

Results and Discussion

Figures 1 and 2 illustrate the relationship between the variance and the mean for the 45 cm branch tip and whole branch samples, respectively. The variance is greater than the mean which suggests a contagious type of spatial distribution. Ninety percent (19 of 21 plot-years) of the observed variances for both sample units did not depart from that expected by the negative binomial distribution as tested by chi-square (Lefkovitch 1966). The calculated curves represent the relationship found between the variance and the mean based on the negative binomial distribution ($S_{\bar{x}}^2 = \bar{x} + \bar{x}^2/k_c$).
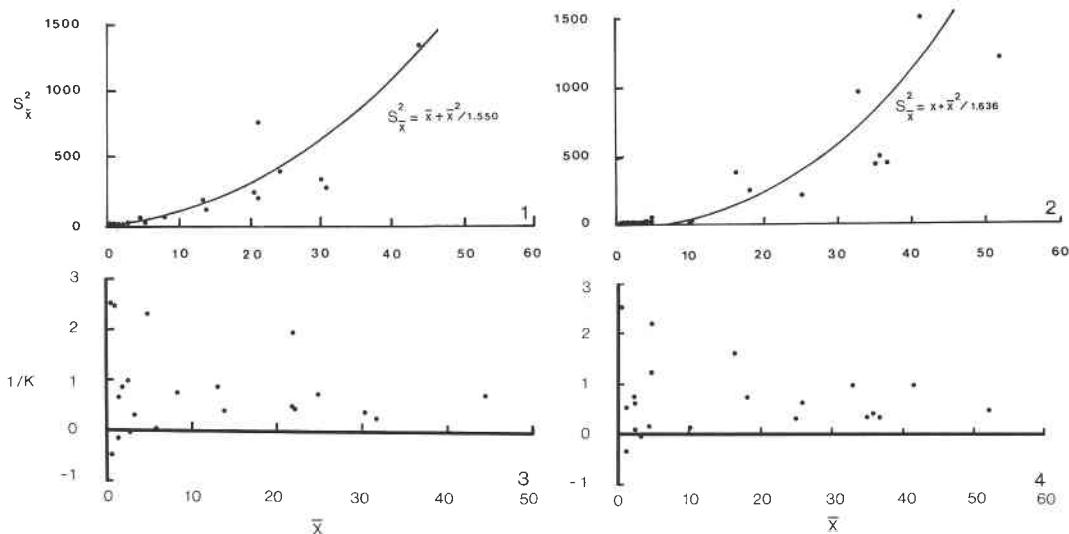
FIGS. 1–4. 1–2, the variance–mean relationship for counts of early instar larvae (2nd to 4th instars) of spruce budworm, *Choristoneura fumiferana* (Clem.), (1) on 45 cm mid-crown branch tips and (2) on whole mid-crown branches of balsam fir, *Abies balsamea* (L.) Mill. 3–4, relationship between the observed $1/k$ and the mean density, $\bar{x}$, of early instar larvae (2nd to 4th instars) of spruce budworm, *C. fumiferana*, (3) per 45 cm mid-crown branch tip and (4) per whole mid-crown branch of balsam fir, *A. balsamea*.

Table I. Required number of branch tip samples to estimate the population density of early instar (2nd to 4th instar) larvae of spruce budworm, *Choristoneura fumiferana* (Clem.)

Mean density (no. larvae/45 cm branch tip)	Confidence level (α)														
	0.90					0.80					0.70				
	Standard error of mean					Standard error of mean					Standard error of mean				
	0.10	0.15	0.20	0.25	0.30	0.10	0.15	0.20	0.25	0.30	0.10	0.15	0.20	0.25	0.30
0.01	34819	15475	8705	5571	3869	20149	8955	5037	3224	2239	12602	5601	3151	2016	1400
0.10	3683	1637	921	589	409	2131	947	533	341	237	1333	592	333	213	148
1.00	569	253	142	91	63	329	146	82	53	37	206	92	52	33	23
10.00	258	115	64	41	29	149	66	37	24	17	93	41	23	15	10
20.00	240	107	60	38	27	139	62	35	22	15	87	39	22	14	10
30.00	235	104	59	38	26	136	60	34	22	15	85	38	21	14	9
40.00	232	103	58	37	26	134	60	34	21	15	84	37	21	13	9

Plots of the inverse of k ($1/k$) against the mean density for each plot-year for both the 45 cm branch tip and whole branch sample units suggested that k was fairly constant (Figs. 3, 4). Therefore, the calculation of a common k was feasible (Southwood 1978). A common k of 1.550 for the 45 cm branch tip and 1.636 for the whole branch sample units was determined. A chi-square test and analysis of variance, as outlined by Bliss and Owen (1958), indicated homogeneity of k from the different samples ($P = 0.05$).

Similar results have been reported by Bliss (1958) based on data from Waters (1955) for late instar larvae (5th to 6th instars) of spruce budworm on balsam fir. Bliss computed a valid common k of 1.44 which applied to a wide area of forest and included a large range of variation as with our data. In general, enlarging the sampling area introduces new sources of heterogeneity and overdispersion becomes more pronounced and k_c becomes smaller (Bliss 1958). Waters (1959) has summarized numerous factors that influence k_c and its possible biological interpretation.

The required sample size for the 45 cm branch tip is presented in Table I. Similar sample sizes were estimated for the whole branch sample unit. Since the 45 cm branch tip is widely used and easily collected, it is recommended that this sample unit be used for density estimates of the spruce budworm in Newfoundland.

Miller *et al*. (1972) reported smaller required sample sizes to estimate 3rd instar larval density of the spruce budworm in New Brunswick. The larger sample sizes calculated by us is most likely attributable to the larger sampling variance associated with the wide geographic distribution of our sample plots. Similar results were reported by Morris (1955), however it is difficult to make a direct comparison because Morris expressed population density as number of larvae per 10 sq. ft of branch surface and calculated a k value of 8.217. Ruesink (1980) points out that a common k may not be appropriate because k is often density-dependent. Calculation of sample sizes based on a density-dependent k as outlined by Ruesink (1980), however, did not differ from the present sampling plan. Nonetheless, the sample sizes calculated by us should be feasible at population densities greater than or equal to one.

Acknowledgments

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