SEQUENTIAL SAMPLING OF ADULT *COCCINELLA SEPTEMPUNCTATA* L. IN WHEAT FIELDS

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Abstract

A sequential sampling program was designed for *Coccinella septempunctata* L. adults in wheat fields, based on a rapid visual counting method. This program takes into account the spatial heterogeneity of coccinellids and the efficiency of the counting method. The relationship between the mean and variance of the numbers sampled was described by Taylor's power law.

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Résumé

Une procédure d'échantillonnage séquentiel des adultes de *Coccinella septempunctata* L. en cultures de blé, basée sur une méthode visuelle rapide de dénombrement, a été concue. Elle tient compte à la fois de l'hétérogénéité des répartitions spatiales des coccinelles et de l'efficacité de la méthode de dénombrement. La relation entre moyenne et variance des échantillons s'appuie sur la loi puissance de Taylor.

Introduction

The awareness of the importance of aphids as pests of cereals has heightened in Europe since 1968 (Carter *et al.* 1980). Natural enemies, including coccinellids, especially *Coccinella septempunctata* L., are thought to be efficient agents limiting cereal aphid abundance. Including the effect of coccinellids in predictive population models requires quantification of their impact and development of sampling methods with a known efficiency that are also quick and simple enough to be used in large areas. A sequential sampling plan, associated with a rapid counting technique, would allow regional studies of the variability of predator abundance and efficiency.

Kuno (1969) developed a sequential sampling method to estimate population numbers with a fixed level of precision, using the following relationship:

$$n = s^2 / (D^2 \bullet m^2) \quad [1]$$

where n is the number of samples, D the desired precision (ratio of the standard error to the mean), s the estimate of the standard deviation, and m the estimate of the mean density.

There are many examples of sequential sampling programs for insect pests, including aphids (Ba-Angood and Stewart 1980; Ekbom 1985; Elliott and Kieckhefer 1986), but none was developed specifically for natural enemies.

In the case of *C. septempunctata*, estimates of s and m depend on the method used to count beetles in the field. Two methods were used to count adults in 25-m² plots of a wheat field (Lapchin *et al.* 1987): one method was very precise but time consuming and the other was rapid but less precise. This paper deals with the possibility of using the rapid method in a sequential sampling plan when the precise method is used to determine the relationship between mean and variance.

Methods

Data were collected in an experimental field (4125 m²) of winter wheat (var. Gala), in the Var Valley of southeastern France (5°E, 43°N). The field was divided into 165 plots of 25 m² each, marked by stakes. Both predator counting methods were used at weekly intervals from tillering to harvest (April to mid-July, 1983–1986).

In the detailed visual method (DVM), 16–32 plots were examined on each sampling date. Two observers worked successively through each plot, scanning the full height of wheat plants and collecting the predators. The duration of each observation was 20–30 min per plot. De Lury's method (in Laurent and Lamarque 1974) was used to estimate the

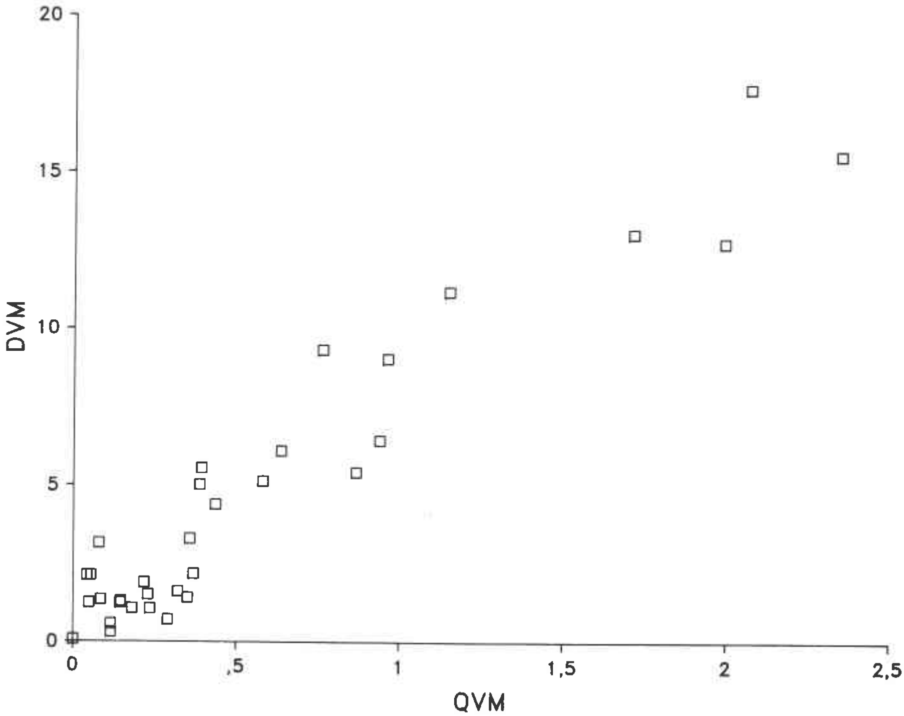

FIG. 1. Relationship between numbers of *Coccinella septempunctata* adults per 25-m² plot assessed by the quick visual method (QVM) and the detailed visual method (DVM).

density of predators in each plot. The results of this sampling procedure can be considered as unbiased estimates of adult *C. septempunctata* numbers in each plot (Lapchin *et al.* 1987).

In the quick visual method (QVM), an observer walked within each of the field plots for 2 min and counted adult coccinellids seen.

Average daily temperatures and daily rainfalls between successive sampling dates were obtained from a neighbouring meteorological station. Phenological stages of wheat were noted according to the classification of Zadocks *et al.* (1977).

Results

Estimation of Mean Density. The correlation between the mean densities of adult coccinellids estimated from both methods was high ($r = 0.95$; $n = 33$; $p < 0.001$) and the relationship was linear in the interval studied (Fig. 1):

$$\text{DVM} = a + b\,\text{QVM} \quad [2]$$

with $a = 0.640$; variance $a = 0.116$; $b = 7.159$; variance $b = 0.164$.

Estimation of the Variance. Taylor's power law (Taylor 1961) was used to relate the common logarithm of the variance of the numbers found with DVM at each sampling date to the logarithm of the mean (Fig. 2). A test of comparison of regression coefficients between years was not significant ($P > 0.05$); thus, coefficients of Taylor's power law were calculated from all sampling dates. The relationship between mean and variance with the DVM was:

$$s^2_{\text{DVM}} = c\,\text{DVM}^d \quad [3]$$

with $c = 2.400$; variance $(\log c) = 0.00243$; $d = 1.327$; variance $d = 0.00538$.

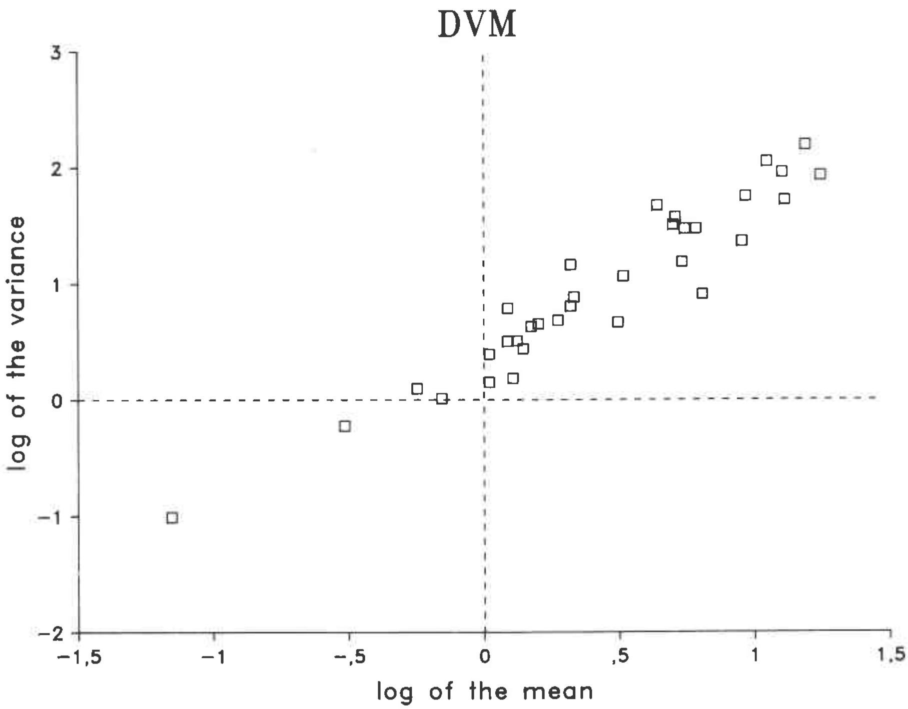

FIG. 2. Relationship between spatial variance and mean density (log scale) of *Coccinella septempunctata* adults for each sampling date, using the detailed visual method.

Sequential Sampling Plan. The sequential sampling plan using Eq. 1 was developed from Eqs. 2 and 3:

$$n = \frac{1}{D^2} \cdot \frac{2.400 \cdot (0.640 + 7.159\ \text{QVM})^{1.327}}{(0.640 + 7.159\ \text{QVM})^2}. \qquad [4]$$

Figure 3 presents "stop sampling curves" associated with different values of D, where n is the number of 25-m² plots.

Discussion and Conclusion

The precision of the estimation of n depends on the variability of the parameters a, b, c, and d. After verification of the normality of the residuals of both linear regressions, 200 simulations in which n was computed were made for a set of combinations of D (0.05, 0.10, 0.20, and 0.40) and QVM (0.5, 2, and 4). For each simulation, random values of the parameters were computed, with a normal distribution, using their mean and variance. Figure 4 presents frequencies of the estimates of n for each combination of D and QVM. These simulations demonstrate that stop curves give only the most probable precision for given values of n and QVM. If the user wants to assure a minimum precision, he must use a value of n corresponding, for instance, to 95% of the cumulative frequency distribution of n: for $D = 0.05$ and QVM $= 4$, $n = 170$ whereas $n =$ only 100 from stop curves; for $D = 0.20$ and QVM $= 0.50$, the cumulative frequency distribution of n gives 30 (level 95%), whereas the stop curves give 20.

The estimation of the variance of the DVM from the QVM depends on the efficiency of the QVM. As this method depends on seeing the beetles in the field, the influence of different parameters on the relationship between the results of QVM and DVM was tested,

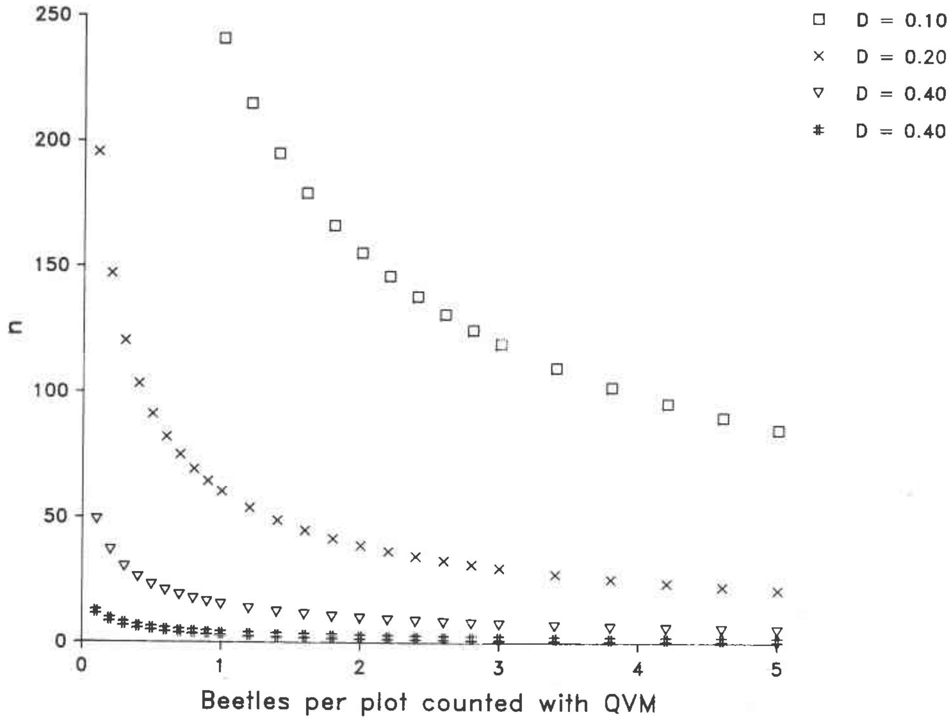

FIG. 3. Sample size curves for 25-m² plots sampled with the quick visual method, for different precision levels, D, of the assessment of adult *Coccinella septempunctata* density.

by computing partial correlations. No significant result was obtained for temperature (partial correlation: p.c. = 0.05), time (phenological stage of wheat) (p.c. = −0.05), or prey density (p.c. = 0.22).

The feasibility of sequential sampling depends on the reliability of the relationship between the variance and mean of the sampling data. The relationship illustrates the aggregation pattern of the population: a higher value of the slope of the correlation of log-variance and log-mean of the sample (here d) indicates a more aggregated population. Taylor (1984) considered this coefficient as ''dependent of the interaction between species' behavior and environment.'' Taylor and Woiwod (1982) fitted Taylor's power law to several hundred sets of field data. The value of the coefficient is often near 2, especially with aphid species. Except for plant species, the values of the coefficient are always greater than 1 (Taylor *et al.* 1978; Taylor and Woiwod 1982; Taylor *et al.* 1983). The value calculated here for *C. septempunctata* (1.33) is lower than that for most insects studied. However, few data are available for entomophagous insects and none for predators. Similar low values have been obtained for parasites: i.e. 1.27 for *Ooencyrtus kuvanae* Howard, a parasite of *Lymantria dispar* L. (Brown and Cameron 1982), and 1.4 for parasitized aphids in strawberries (Trumble and Oatman 1984).

Taylor and Woiwod (1980) determined that this parameter is largely independant of sampling method, local environmental and annual variation. It is actually constant for *C. septempunctata* adults from one year to another in wheat fields. However, even if the power law is fitted to QVM data (and not DVM), the correlation remains high (r = 0.981; n = 31; $p < 0.001$) but the value of d (1.15) seems to be different, although not significantly.

The sequential sampling program proposed for *C. septempunctata* adults, using either the most probable value of the precision or the minimum precision, includes both the

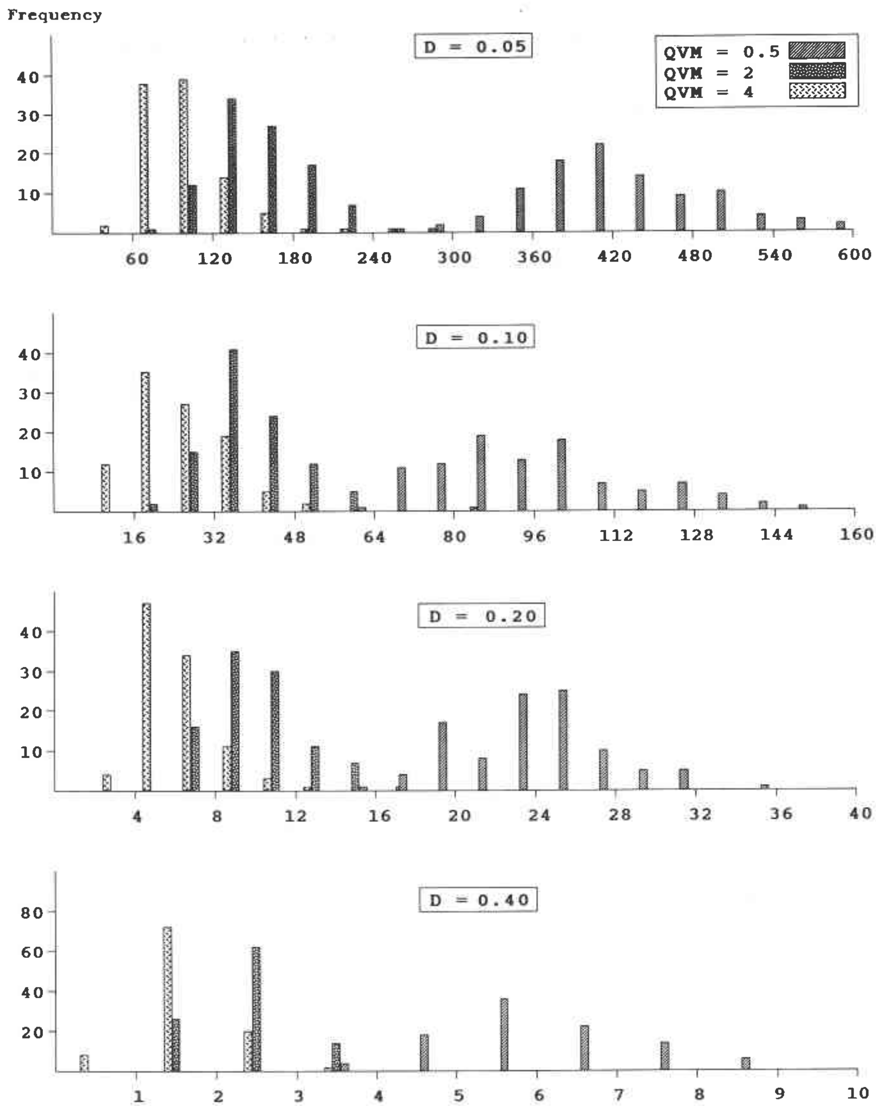

FIG. 4. Distribution of frequencies of the number, n, of plots to sample to obtain a given precision, D, for a given density observed with QVM, after simulation of the coefficients a, b, c, and d (see Eqs. 2 and 3).

variability due to spatial heterogeneity and the variability in efficiency of the visual counting method (QVM). The speed and simplicity of the QVM enables one to estimate population densities on a large scale, and to obtain field data to study predator–prey interactions.

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References

Ba-Angood, S.A., and R.K. Stewart. 1980. Sequential sampling for cereal aphids on barley in Southwestern Québec. *J. econ. Ent.* **73**: 679–681.

Brown, M.W., and E.A. Cameron. 1982. Spatial distribution of adults of *Ooencyrtus kuvanae* (Hymenoptera: Encyrtidae), an egg parasite of *Lymantria dispar* (Lepidoptera: Lymantriidae). *Can. Ent.* **114**: 1109–1120.

Carter, N., I.F.G. McLean, A.D. Watt, and A.F.G. Dixon. 1980. Cereal aphids: a case study and review. *Appl. Biol.* **5**: 271–348.

Ekbom, B.S. 1985. Spatial distribution of *Rhopalosiphum padi* (L.) (Homoptera: Aphididae) in spring cereals in Sweden and its importance for sampling. *Environ. Ent.* **14**: 312–316.

Elliott, N.C., and R.W. Kieckhefer. 1986. Cereal aphid populations in winter wheat: spatial distributions and sampling with fixed levels of precision. *Environ. Ent.* **15**: 954–958.

Kuno, E. 1969. A new method of sequential sampling to obtain the population estimates with a fixed level of precision. *Res. Popul. Ecol.* **11**: 127–136.

Lapchin, L., A. Ferran, G. Iperti, J.M. Rabasse, and J.P. Lyon. 1987. Coccinellids (Coleoptera: Coccinellidae) and Syrphids (Diptera: Syrphidae) as predators of aphids in cereal crops: a comparison of sampling methods. *Can. Ent.* **119**: 815–822.

Laurent, M., and P. Lamarque. 1974. Utilisation de la méthode des captures successives (De Lury) pour l'évaluation des peuplements piscicoles. *Ann. Hydrobiol.* **5**: 121–132.

Taylor, L.R. 1961. Aggregation, variance and the mean. *Nature* **189**: 732–735.

——— 1984. Assessing and interpreting the spatial distributions of insect populations. *Annu. Rev. Ent.* **29**: 321–357.

Taylor, L.R., R.A.J. Taylor, I.P. Woiwod, and J.N. Perry. 1983. Behavioral dynamics. *Nature* **303**: 801–804.

Taylor, L.R., and I.P. Woiwod. 1980. Temporal stability as a density-dependent species characteristic. *J. anim. Ecol.* **49**: 209–224.

——— 1982. Comparative synoptic dynamics. I. Relationships between inter- and intra-specific spatial and temporal variance/mean population parameters. *J. anim. Ecol.* **51**: 879–906.

Taylor, L.R., I.P. Woiwod, and J.N. Perry. 1978. The density-dependence of spatial behaviour and the rarity of randomness. *J. anim. Ecol.* **47**: 383–406.

Trumble, J.T., and E.R. Oatman. 1984. Dispersion analyses and resource utilization of aphid parasitoids in a non-depletable environment. *Res. Popul. Ecol.* **26**: 124–133.

Zadocks, J.C., T.T. Chang, and C.F. Konzak. 1977. Un code décimal pour les stades de croissance des céréales. *Phytiatrie-Phytopharmacie* **26**: 129–140.

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