

COMPARISONS OF SAMPLING METHODS FOR RECORDING
THE NUMBERS OF ROCKY MOUNTAIN WOOD TICKS
(*DERMACENTOR ANDERSONI*) ON CATTLE
AND RANGE VEGETATION DURING CONTROL EXPERIMENTS

BY P. R. WILKINSON¹ and J. D. GREGSON²

METHODS
OF
SAMPLING
TICKS
ON
CATTLE

ABSTRACT : Methods of sampling populations of adult *Derma-centor andersoni* were tested and compared as part of a 13-year experiment which began in 1959. Tick counts were made in four fields, two of which were stocked with cattle during the tick season for the first five years. Cattle in field A were untreated ; in field B, cattle were treated with acaricides or ticks were removed by hand-picking. Fixed quadrats were sampled in all fields. In the two stocked fields, randomly selected quadrats were also sampled. Two smaller fields were kept unstocked for 5 and 4 years respectively.

The counts of ticks on cattle were highly correlated to counts of host-seeking ticks on fixed quadrats in field A in 1959-63. Counts of ticks on fixed and randomly selected quadrats showed similar trends in fields A and B in 1963-68. However, the counts on the fixed quadrats needed division by about 4 in field A and by 17 in field B, to give a tick/unit area index comparable to the more extensive random samples. Stratification increased the efficiency of random sampling. The area sampled per day increased with size of quadrat, within the limits tested. Calculations based on six sizes tested in 1967 indicated that minimum standard error would be obtained with 279- m² quadrats.

For future use, stratified random sampling would be the preferred method of sampling ticks on vegetation, but the simpler fixed quadrats may sometimes be useful as indicators of annual trends in numbers, or when they occupy a high proportion of the area to be sampled. Counts of ticks on both cattle and random quadrats need transformation before analysis of variance.

Tick counts in the two unstocked fields declined only slowly during 1959-63, indicating that exclusion of stock, even for five years, may be ineffective in usefully reducing tick numbers.

TECHNIQUES
DE
RÉCOLTE
TIQUES
SUR
BÉTAIL

RÉSUMÉ : Les méthodes de récolte des populations de *Derma-centor andersoni* adultes ont été testées et comparées au cours d'une expérimentation de 13 années qui débuta en 1959. Les comptages de tiques ont été effectués dans quatre champs, dont deux enfermaient du bétail à la saison des tiques pendant les cinq premières années. Dans le champ A le bétail n'était pas traité ; dans le champ B il était traité par les acaricides ou bien les tiques étaient enlevées manuellement. Des quadrats fixes ont été mis en récolte dans tous les champs. Dans les deux champs occupés par du bétail, des quadrats vagabonds ont aussi été mis en récolte. Deux champs plus petits ont été maintenus innocupés pendant 5 ans et 4 ans respectivement.

1. Research Station, Research Branch, Agriculture Canada, Lethbridge, Alberta T1J 4B1.
2. 1594 Lorne Street East, Kamloops, British Columbia V2C 1X6.

Les quantités de tiques sur le bétail ont été hautement en corrélation avec celles des tiques se gorgeant sur l'hôte, dans les quadrats fixes du champs A, de 1959 à 1963. Les quantités de tiques dans les quadrats fixes et dans les quadrats vagabonds ont présenté les mêmes tendances dans les champs A et B, de 1963 à 1968. Cependant, les chiffres des quadrats fixes ont été divisés par 4 pour le champ A et par 17 pour le champ B pour que l'index tiques/unité de surface puisse se comparer avec celui des récoltes vagabondes, plus extensives. La stratification a accru l'importance des récoltes vagabondes. L'aire mise en récolte chaque jour s'accroissait avec la taille du quadrat, dans le cadre des limites testées. Les calculs basés sur six tailles testées en 1967 ont montré que l'erreur standard minimale devrait s'obtenir pour des quadrats de 279- m².

Dans l'avenir, des mises en récolte stratifiées vagabondes devraient constituer la méthode préférencielle de récolte de tiques sur la végétation, mais les quadrats fixes plus simples peuvent quelquefois se montrer d'utiles indicateurs des tendances quantitatives annuelles, ou bien quand ils occupent une forte proportion de l'aire à mettre en récolte. Les quantités de tiques sur le bétail et dans les quadrats vagabonds nécessitent une transformation avant l'analyse de variance.

Les quantités de tiques dans les deux champs vides ont diminué seulement lentement de 1959 à 1963, montrant que l'absence du bétail, même pendant cinq années, peut rester inefficace pour réduire utilement le nombre des tiques.

Although there are many texts on the theory of sampling field populations of plants and animals, little has been published on unbiased methods for sampling host-seeking, adult, three-host ticks over extensive areas of pasture. MILNE (1943) pioneered the theory and practice of sampling tick populations, but many authors have ignored the dangers of bias by using subjective or arbitrary selection of sampling sites, or they have sampled too few sites or counted ticks in relation to time taken instead of the more desirable relationship with unit area of terrain (cf. SOUTHWOOD, 1967 ; SAMPFORD, 1962).

In the bioclimatic zone described, *Dermacentor andersoni* Stiles tends to be a highly 'focal' (PAVLOVSKY, 1964) tick in that it is often concentrated around relatively small, shrubby, rock outcrops in extensive grasslands (WILKINSON, 1967 ; cf. CAREY *et al.*, 1980) used as spring range for beef cattle. If sampling methods could reveal the distribution of ticks in this terrain it might be possible to reduce contact between ticks and cattle or to alter the foci so that the necessity to treat the cattle with chemicals is reduced (WILKINSON, 1979). Sampling methods are also crucial in a wide variety of studies of tick populations, but more information is needed on practical methods of applying statistical concepts to field situations.

The present paper compares tick counts/unit area on fixed strip quadrats with counts on randomly selected strip and rectangular quadrats, with and without stratification, and with counts on cattle confined to the same fields. In addition to the discussion of the merits of various sampling methods, some tentative conclusions on the effects of spraying one herd of cattle with acaricides, and of excluding cattle from two small fields, are included.

METHODS

■ *Site and fencing.* The area (Fig. 1) is about 50 km by road south of Kamloops, British Columbia (lat. 50°24'N, long. 120°23'). It is in the *Pinus ponderosa-Agropyron spicatum* bioclimatic zone. The terrain includes steep, rocky, shrubby areas, aspen groves, and gently sloping grassland (WILKINSON, 1967 : Fig. 10). A and B fields were fenced from an existing large field in March to April 1959, and C₂ field was fenced from the same field in early 1960. C₁ field was fenced from an adjoining large field in early 1959. The fences consisted of 3-4 strands of barbed wire, designed to restrain cattle and horses. Hosts of adult ticks, such as deer and coyotes, were able to pass through the fences, and moose occasionally

broke through fences in the winter and early spring, before the entry of the cattle. The rodents *Erethizon dorsatum* L., *Marmota flaviventris avara* (Bangs), *Eutamias amoenus* (Allen), and *Peromyscus maniculatus* (Wagner) were present and considered to be the major hosts of the immature ticks. *E. dorsatum* is also a host of the adult ticks.

In April-May 1964, the new fences (broken

lines, Fig. 1) were removed. Thus, in part of the 1964 tick season and thereafter, fields A and B received the same treatment as regards livestock hosts of ticks. The owner then used the fields as winter and spring pasture for horses, and as spring pasture for varying numbers of cattle and sheep. Domestic livestock were excluded from fields C₁ and C₂ during 1959-63. Observations in fields C₁ and C₂ ceased in 1963.

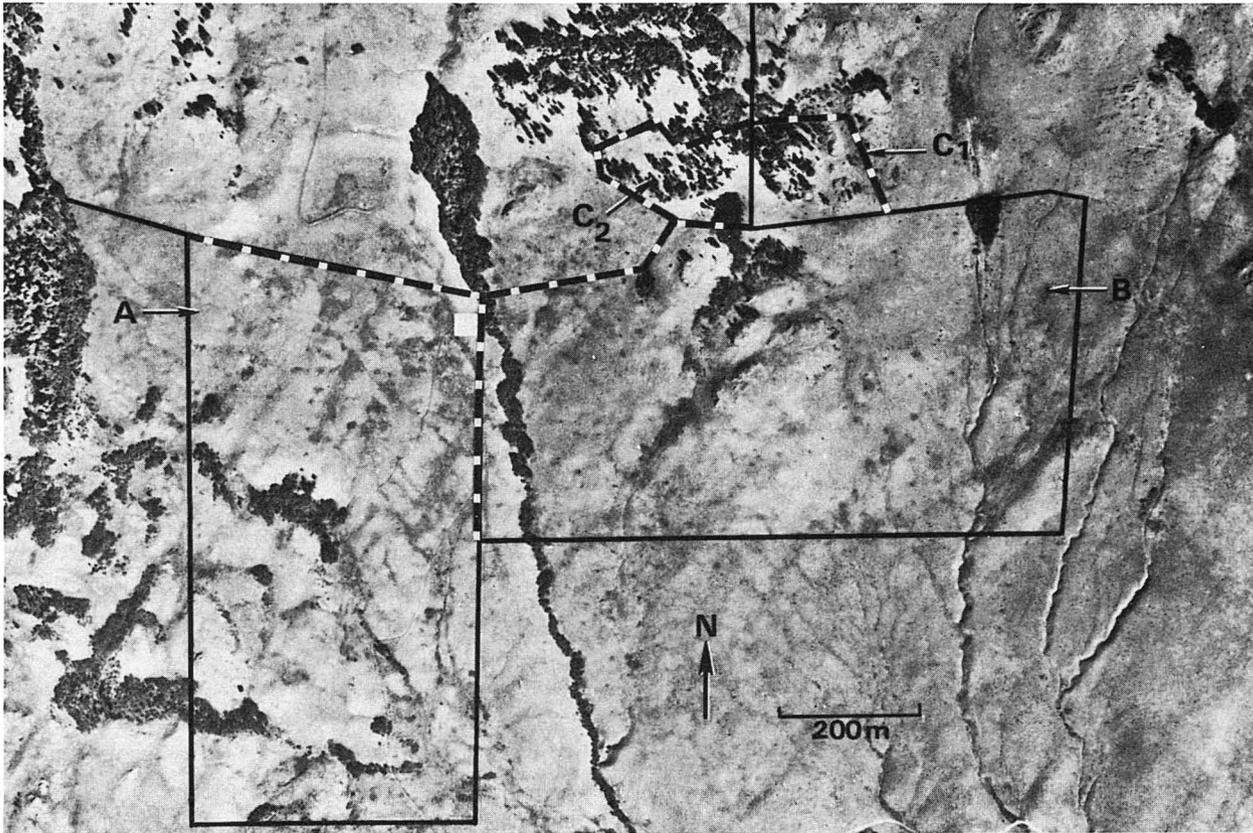


FIG. 1 : Aerial view of fields A, B and C. Solid lines indicate fences in 1959-71. Dotted lines indicate fences erected in 1959 (C₂ in 1960) and removed in April-May 1964. □ = corral for examination of cattle.

■ **Cattle.** Each tick season from 1959 to 1963, 20-24 yearling, commercial grade, Hereford cattle were admitted to each of fields A and B about mid-April. No other domestic stock were allowed in earlier in the calendar year or with the cattle. The cattle were usually examined for adult ticks at 5-day intervals to ensure that no unrecorded female ticks engorged and fell off between examinations. These cattle were removed

at the end of the tick season, about mid-May, and the gates were left open to allow other stock to graze the areas until winter, if required.

In 1959-62, cattle about to enter field B were sprayed on the poll, neck, and back with about 2 L BHC wettable powder (0.25 % gamma isomer) except that in 1959 half of the herd were sprayed with 0.5 % dieldrin emulsion. Any ticks found later on this herd were destroyed. The

cattle in field A were untreated and ticks found on examinations were left in place.

■ *Fixed quadrats.* Early in 1959, nine transects, each 31 m long, were pegged out irrespective of compass orientation in each of fields A and B. They were selected on the basis of preliminary flagging and qualitative knowledge of tick foci, with the expectation that 3 would be highly infested, 3 would be moderately infested, and 3 would have light infestation. The same methods and numbers of transects were used in each of fields C₁ and C₂. Each year the transects were traversed once a week in the season of adult tick activity, and the observer collected ticks along 31 × 3 m quadrats by sweeping a "flag" from side to side over the vegetation in front of him. This process was repeated for at least six weeks except in 1971 when only two flaggings were carried out. The flag used from 1963 onward was a 90 cm × 90 cm piece of cotton flannelette blanket, stapled to a wooden dowel rod 1.5 m long. Flags of similar materials and dimensions were used in 1959-62.

On a flat grassy area, the width of ground covered by the sweep of the flag was about 3 m, but it may have been less in some shrubby areas. On each sweep of the flag, the side that had contacted the vegetation on the previous stroke was exposed, then the operator checked for ticks and returned them near the place of capture. At the end of the traverse, number and sex of the ticks were recorded. One observer sampled the fixed quadrats in all the fields on the same day. From 1963 onward, the order of sampling fields A and B was determined by coin toss on the first day and by reversal of this order on the second day, the process being repeated for subsequent pairs of days. The C fields were sampled after sampling the A and B fields. J. D. G. supervised the observations in 1959-62, and P. R. W. in 1963-71.

■ *Random and stratified random quadrats in fields A and B.* A ground plan was prepared from an aerial photograph and measurements along the fences. Plots, 38 m × 38 m, were selected each year from a grid (Fig. 5), using

tables of random numbers, discarding numbers already chosen in the same year.

In 1963, selected fence posts were numbered, and each plot was found by pacing from the nearest marked post. In later years the first plot was located by pacing from the fence and subsequent plots were located by compass bearing and pacing. The first plot each day was indicated by the random numbers; the remaining plots were taken in the most convenient order. This corrected any tendency to start sampling in the same area each day and avoided wasted effort in backtracking. To sample a quadrat within a plot, a tape was laid out on the ground for the required distance (e.g., 18.3 m) and flagging proceeded adjacent to the tape (e.g., with 3 swaths on each side, covering an area of 18.3 m × 18 m). The tape was laid north-south unless major obstructions necessitated a deflection. The flagging procedure was the same as that used for the fixed quadrats. Except in 1963, square or near-square quadrats were used so that greater areas could be covered without the transect becoming unduly elongated, and also because a square is less susceptible to bias due to a selected compass orientation (SAMPFORD, 1962).

Fields A and B were sampled simultaneously, allocation of one observer to each field being decided by coin toss on alternate days, with reversal in the intervening day.

Contingency tests had indicated (WILKINSON, 1967) that ticks were associated with certain shrubs, and to a lesser degree with steep to moderate slopes. To avoid waste of sampling time in areas with few or no ticks (cf. Fig. 5), the fields were marked off in 1964 into strata of expected high, medium, and low tick counts, and more samples were taken in the high strata than in the low. Medium strata, used in 1964 and 1965, were merged with the low strata in 1966 to 1969 (Fig. 2), because of low tick counts in the medium strata.

For uniformity, high and medium strata were made of equal area in fields A and B, with low strata occupying the balance of the sampled area. Two quadrats per day were drawn from each of the medium and low strata and the balance of the

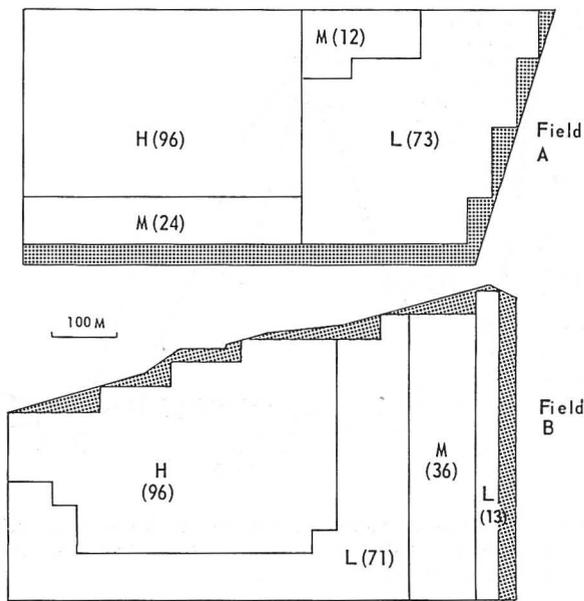


FIG. 2 : Stratification of fields A and B, 1964. Shaded areas, less than 38 × 38 m, were not sampled. Numbers in parentheses are numbers of 38 × 38 m squares in each stratum. (Cf. unstratified layout in Fig. 5). H = high, M = intermediate, L = low (tick count) strata.

planned number were placed in the high stratum (see discussion). Quadrat sizes and allocations to strata are summarized in Table 1.

Means of tick/unit area for the whole field were obtained by weighting for the proportions of

TABLE 1 : Details of quadrat size and allocation between strata 1964-68. There was no stratification in 1963.

Year	No. of quadrats per stratum per day			No. of sampling days	Approx. area (m ²) of each quadrat	Total area (m ²) sampled in each field
	High	Medium	Low			
1963	—	6	—	16	93	8 928
1964	6	2	2	12	93	11 160
1965	6	2	2	8	93	7 440
1966	6	2	2	7	372	20 832
1967	7	—	2	4	334*	12 024
1968	7	—	2	3*	334	9 018

* Sampling curtailed because of tick scarcity and entry of sheep.

* On day 1, a 595-m² quadrat (Fig. 5) was used but found impractical; for this day calculations for Table 2 are based on half of this area and multiplied by $\frac{334}{0.5 (595)}$

different strata in the whole field (SNEDECOR, 1956). Random sampling ceased from 1969 onwards because of low tick numbers.

■ *Tests of effect of quadrat size.* The number of days available for sampling was limited by the tick season and other commitments, and only about three hours each day could be conveniently spent in sampling procedures. Thus, it was important to investigate optimum quadrat size, which would give the lowest value of variance in relation to the mean, for the time spent sampling.

In 1967, records were kept on numbers of ticks in each of six 18.3 × 3 m 'sub-quadrats' comprising each of 21 quadrats, 18.3 × 18 m, in the high stratum of field A, to provide data for determining the optimum size of quadrat. In addition, on one day, records were kept of eight sub-quadrats, each 24.4 × 3 m, in each of eight quadrats.

■ *Conversion of units.* Areas and lengths quoted in this paper were rounded to the nearest decimal point after conversion from measurements in British units.

RESULTS

■ *Counts on cattle.* The mean annual counts of female ticks per animal per day, based on the three days of highest counts for each herd, are shown in Table 2. Counts of males are omitted, because they were more difficult to find on cattle. The field B counts in 1963 are of ticks removed by hand and later destroyed. The correlations with flagging counts are discussed later.

Confidence limits were calculated for the counts of 29 April 1963. Bartlett's test indicated the necessity for log (n + 1) transformation. Back transformed means and limits (P, 0.05) for cattle counts from the two fields were A, 22.1 (14.6 — 33.0) and B, 1.7 (0.7 — 3.2). The variance and mean of 2-day counts of ticks on cattle in field A in each year 1959-63 were calculated and log variance was plotted against log mean (TAYLOR, 1961). The slope of the straight line was 1.39, suggesting a cube root transformation for the

counts on cattle. This would give results close to those from the log transformation.

■ *Numbers of ticks recorded on fixed quadrats.* Table 2 summarizes the annual mean

TABLE 2 : The number of female ticks on cattle (per animal, mean of three highest days) and the number of host-seeking adult ticks (male and female) per 93 m² of area flagged in fields A and B, 1959-71. See text for correlations.

Year	Cattle		Fixed quadrats		Randomised quadrats	
	A	B	A	B	A	B
1959	24.1	1.0	8.4	16.7		
1960	3.0	0.0*	2.0	1.3		
1961	9.0	0.0	3.1	2.5		
1962	8.3	0.0	2.3	2.0		
1963	17.0	1.3	5.6	0.5	1.6	0.1
1964			7.3	1.7	1.7	0.1
1965			5.9	2.8	0.7	0.2
1966			3.1	2.7	0.9	0.1
1967			1.2	3.1	0.9	0.1
1968			1.0	1.4	0.2	0.1
1969			0.4	0.6		
1970			0.9	0.6		
1971			0.5	0.3		
Totals 1963-68			24.1	12.2	6.0	0.7

* 0.0 ≤ 0.04.

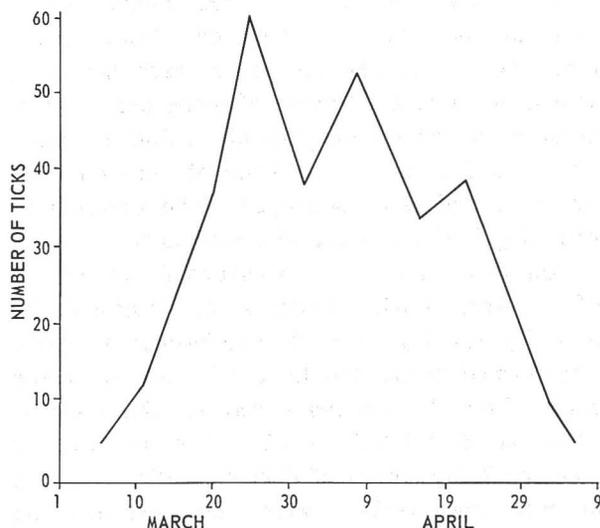


FIG. 3 : Seasonal incidence of ticks counted by 'flagging' on nine fixed transects, 3 × 31 m, in field A in 1963.

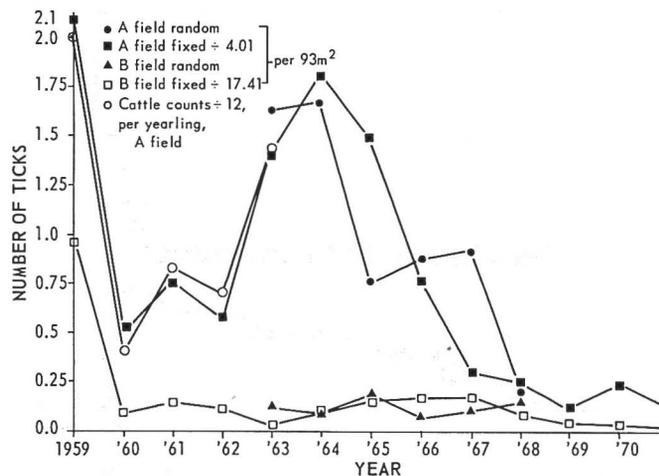


FIG. 4 : Trends of indices of numbers of host-seeking ticks in fields A and B, 1959-71, and numbers of ticks on cattle in field A, 1959-63.

number of both sexes of ticks per quadrat per day, for the three days with the highest totals, in fields A and B (two days only in 1971). This format gives an index of tick availability on the quadrats, which smooths variation between years in date and form of the seasonal peak in numbers, provided the weekly samples cover the season of activity. Fig. 3, based on counts on the fixed quadrats in field A in 1963, is an example of this seasonal peak. There was a high correlation ($r = 0.978$) between counts on cattle and counts on the fixed quadrats in field A in 1959-63.

In field C₁ annual means were 5.7, 4.9, 3.8, 2.3 and 2.9 ticks/93 m² for 1959-63 and in field C₂, 3.2, 2.1, 1.7 and 1.7 for 1960-63, using the same index as in fields A and B.

■ *Tick counts on random quadrats in fields A and B, and comparison with fixed quadrat and cattle counts.* Untransformed means from random samples of ticks/unit area, adjusted for stratification when this was used, showed year-to-year trends somewhat resembling those on the fixed quadrats ($r = 0.734$ for field A, 1963-68), but the value of ticks/unit area differed widely (Table 2).

Since the random samples were based on areas (Table 1) larger than the total area of the nine fixed quadrats in each field, and were randomly

distributed, their values of ticks/unit area for the whole field can be accepted as more realistic than those from the fixed quadrats. A comparison of totals for 1963-68 (Table 2) indicates that fixed quadrat counts should be divided by 4.0 for A field and by 17.4 for B field, and these have been entered in Fig. 4, along with cattle counts divided by 12 to approximate the same numerical scales.

To indicate the level of confidence limits for random samples, the counts from six 93- m² quadrats on each of 16 days between 18 March and 30 April 1963 were analysed after log transformation. Adjusted means and limits (i.e., anti-logs) were : field A, mean 1.09, confidence limits (P, 0.5) 0.79 — 1.45 ; field B, mean 0.15, limits 0.074 — 0.236. The appropriateness of log transformation was shown by a slope of 2 on the plot of log variance/log mean for the sampling days between 26 March and 19 April. The range of counts of ticks (both sexes) for individual quadrats was 0-31 in 1963.

In Fig. 5 the distribution of ticks collected in field A in 1963 has been mapped. The ticks tended to be concentrated in the shrubby, rocky areas in the southwest corner, with few ticks in the rolling grassland of the northern half, or in the aspen groves (see Fig. 1 ; also WILKINSON, 1967 : Fig. 10). These data were the basis for the stratifications in later years.

From the 1967 data on yields of ticks from different sizes and numbers of quadrats, hypothetical variances for yields of ticks from different sizes of quadrats were calculated. When these were combined with data on the number of different sizes of quadrats that could be sampled in three hours, it was determined that minimum standard error would be achieved with eight quadrats, each covering 280 m² (rounded figures, see Table 3). This approximated the quadrat size used in 1966-

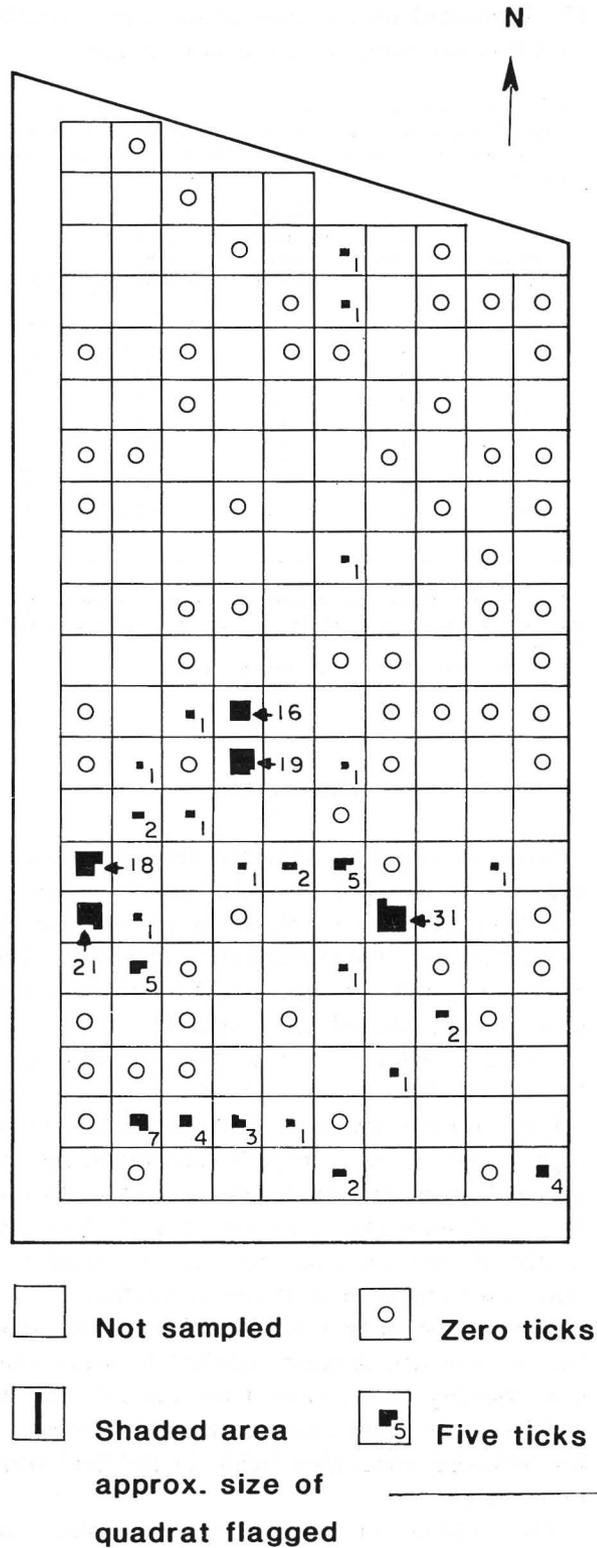


FIG. 5 : Spatial distribution of ticks in field A in 1963, as indicated by flagging 3 × 31 m quadrats within randomly selected plots. Each square of the grid is a 38 × 38 m plot. The plots were sampled between March 18 and April 25, during the main season of tick activity (see Fig. 3). Numbers of ticks are represented by shaded areas and figures, for each quadrat where ticks were found.

68, determined on the basis of the largest readily workable size using a central tape as marker.

TABLE 3 : Optimum size of quadrat (italics) to obtain minimum standard error of tick counts in relation to numbers of quadrats that can be sampled in 3 hours, based on 1967 results in 'high' stratum field A.

Size of quadrat (m ²)	Time to sample (min.) *	Number of quadrats sampled in 3 hr.	Approx. area sampled in 3 hr. (m ²)	S. E. +
56	18	10	560	.183
111	19	9.5	1 054	.158
167	20	9.0	1 503	.151
223	21	8.6	1 917	.148
279	22	8.2	2 288	.147
334	23	7.8	2 605	.149
390	24	7.5	2 925	.150
446	25	7.2	3 211	.151

* Based on 15 minutes for locating and walking, 1 minute to mark centre line, one minute for each 56 m² of area plus 1 minute for entering notes.

+ Standard error of number of ticks per 56 m².

DISCUSSION

Sampling of fixed quadrats may be a useful indicator of population trends, but the values of ticks/unit area may be biased by the selection of insufficient or unrepresentative quadrats. The preferred sampling procedures, randomization and stratification, should be applicable to studies using other methods, such as blanket dragging or CO₂ traps. For certain types of comparative control experiments where the fixed quadrats cover a high proportion of the experimental areas, the use of fixed quadrats may be justified (WILKINSON, 1977) and since they are easier to find than randomly selected quadrats, especially in rough terrain, less training of observers is needed.

Random sampling was discontinued after 1968 because low tick densities resulted in many quadrats yielding no ticks and it was decided that the less laborious fixed quadrats would be adequate for following population trends in the final years of the project.

The subject of allocation of numbers of samples between strata is discussed by SNEDECOR

(1956) and more recently by STEEL & TORRIE (1980). The ideal allocation is proportional to the standard deviation and cost (i.e., time, money or effort) of samples within each stratum, but Snedecor states these allocations need not be precise to effect an improvement. In the present work, estimates based on 1963 counts indicated that the theoretical allocation of quadrats to the low and medium strata would have been below the predetermined minimum of two each per day, so that the allocation of all the remainder to the high stratum was justified.

To obtain an index of the number of *D. andersoni* in a field there are both advantages and disadvantages to counting ticks on cattle as opposed to using flags or CO₂ traps. Except for areas that are too steep or rough for them, cattle will usually cover a field thoroughly at normal or high stocking rates, and less human labour may be involved in examining them than in walking the field to sample it. The disadvantages are the need for round-up and examination facilities, the cost of the cattle, and the lack of information on the exact localities in which the ticks are available on the vegetation. Large herds may break up into smaller herds, necessitating sub-sampling to cover the different ranges of the sub-herds (ARNOLD & DUDZINSKI, 1978). Counts of ticks on both cattle and vegetation need transformation before application of analysis of variance.

Only tentative explanations can be given for the population trends shown in Fig. 4, because the treatments and fields were not replicated. The high 1959 counts probably represent the progeny of high adult populations associated with the tick paralysis outbreak at the site in 1957 (GREGSON, 1958). The decline of tick numbers in both fields in 1960-62 was followed by high populations in field A in 1963-65, probably due to the availability of highly susceptible hosts (yearling Herefords, RICH, 1971) in 1959-63. Low tick populations that persisted in field B were probably maintained by wild hosts despite the death of adult ticks on the treated cattle. In 1964-71 the two fields were open to the same hosts of adult ticks, and counts in A field declined to the same level as in B field.

In C_1 and C_2 fields the populations declined slowly during the period of observation, probably due to the exclusion of livestock, but the results suggest that pasture vacation may be too slow a method of tick reduction to be economic, unlike the situation with one-host ticks (WILKINSON, 1979).

ACKNOWLEDGEMENTS

Thanks are due to Jean PROCTOR of the Statistical Research Service, Agriculture Canada, Ottawa, for helpful discussions and some calculations. Michael BINNS, also of the S.R.S., provided the calculation related to optimum quadrat size as a basis for Table 3. The field work for this study was carried out while both authors were at the former Entomology Section, Research Station, Agriculture Canada, Kamloops, British Columbia.

LITERATURE CITED

- ARNOLD (G. M.) & DUDZINSKI (M. L.), 1978. — Ethology of free-ranging domestic animals. — Elsevier Publishing Co., New York.
- CAREY (A. B.), McLEAN (R. G.) & MAUPIN (C. O.), 1980. — The structure of a Colorado Tick Fever Ecosystem. — *Ecol. Monog.*, **50** : 131-151.
- GREGSON (J. D.), 1958. — Tick paralysis in British Columbia in 1957. — *Proc. Ent. Soc. B.C.* **55** : 6-7.
- MILNE (A.), 1943. — The comparison of sheep-tick populations. — *Ann. Appl. Biol.* **30** : 240-250.
- PAVLOVSKY (E. N.), 1964. — Natural Nidality of Transmissible Diseases. — Translation, Levine (N. D.) and Plous (F. K.), 1966. — Univ. Illinois Press, Urbana, Illinois.
- RICH (G. B.), 1971. — Disease transmission by the Rocky Mountain wood tick, *Dermacentor andersoni* Stiles, with particular reference to tick paralysis in Canada. — *Vet. Med. Rev.* **1** : 3-26.
- SAMPFORD (M. R.), 1962. — An introduction to sampling theory. — Oliver and Boyd, Edinburgh and London.
- SNEDECOR (G. W.), 1956. — Statistical methods. — The Iowa State College Press, Ames, Iowa.
- SOUTHWOOD (T. R. E.), 1967. — Ecological Methods. — Methuen & Co., London.
- STEEL (R. G. D.) & TORRIE (J. H.), 1980. — Principles and procedures of statistics. — McGraw-Hill Book Co., New York.
- TAYLOR (L. R.), 1961. — Aggregation, Variance, and the Mean. — *Nature* **189** : 732-735.
- WILKINSON (P. R.), 1967. — The distribution of *Dermacentor* ticks in Canada in relation to bioclimatic zones. — *Can. J. Zool.* **45** : 517-537.
- WILKINSON (P. R.), 1977. — Effect of herbicidal killing of shrubs on abundance of adult *Dermacentor andersoni* (Acarina : Ixodidae) in British Columbia. — *J. Med. Ent.* **13** : 713-718.
- WILKINSON (P. R.), 1979. — Ecological aspects of pest management of ixodid ticks. — *Recent Advances in Acarology*, **2** : 25-33. Academic Press Inc., New York.

Paru en juillet 1985.