A study of the temporal and spatial relationships between small-mammals and the immature stages (larvae and nymphs) of the American dog tick, Dermacentor variabilis (Say) (Acari:Ixodidae) in an Aspen Parkland region near Birds Hill Park, Manitoba

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By

Vladimyr Ivan Burachynsky

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A STUDY OF THE TEMPORAL AND SPATIAL RELATIONSHIPS BETWEEN SMALL-MAMMALS AND THE IMMATURE STAGES (LARVAE AND NYMPHS) OF THE AMERICAN DOG TICK, DERMACENTOR VARIABILIS (SAY) (ACARI:IXODIDAE) IN AN ASPEN PARKLAND REGION NEAR BIRDS HILL PARK, MANITOBA

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ABSTRACT

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A study of the temporal and spatial relationships between small-mammals and the immature stages (larvae and nymphs) of the American dog tick, Dermacentor variabilis (Say) (Acari:Ixodidae) in an Aspen Parkland region near Birds Hill Park, Manitoba.

During a two year study on the relationships between small-mammals and D. variabilis larvae and nymphs, 739 captures of 427 individual animals were examined for ticks. Captures represented eleven species of mammals: Clethrionomys gapperi (Vigors), Lepus americanus Erxleben, Microtus pennsylvanicus (Ord), Mus musculus Linnaeus, Peromyscus maniculatus (Wagner), Sorex cinerius Kerr, Spermophilus franklinii (Sabine), Spermophilus tridecemlineatus (Mitchell), Tamias striatus (Linnaeus), Tamiasciurus hudsonicus (Erxleben) and Zapus hudsonius (Zimmerman). The most frequently captured species were C. gapperi, M. pennsylvanicus, P. maniculatus, S. franklinii and Z. hudsonius, and except for S. franklinii were also the most frequently infested with larvae and nymphs. The dominant host of D. variabilis larvae and nymphs was the red-backed vole, C. gapperi which produced 42.6% and 60.5% of all larvae collected in 1979 and 1980 respectively, and over 85% of all nymphs collected during both years.

Peak larval activity occurred between the last week of May and the middle of June and peak nymphal activity occurred in July. Peaks were four to five weeks apart.

C. gapperi populations fluctuated as a result of reproductive cycles.

Three periods of recruitment and subsequent population turnover were observed annually. Cycles represented new generations of voles, the beginning of each marked by greater proportions of immatures. Cycles were six weeks apart and roughly coincident with gestation and weaning periods as well as with the period between larval and nymphal activity peaks. Cycle peaks were two weeks earlier in 1980.

First cycle voles were predominantly infested with larvae, and individuals from the second cycle were infested with nymphs. Individuals caught between the two cycles infrequently carried small numbers of both larvae and nymphs. Third cycle voles were very rarely infested.

The area occupied by C. gapperi expanded during each cycle. In 1980, many individuals of the second and third cycles occupied sites outside of the preferred forest habitat. Several second cycle dispersers were infested with nymphs.

Larvae were spatially aggregated during both years. Larvae infested between 10 and 20% of the host population. Location of aggregates varied from year to year.

Nymphal aggregation was not as great as for larval aggregation. The distribution of nymphs overlapped that of larvae each year and occupied a greater area. The distribution of nymphs was highly correlated to that of C. gapperi. The prevalence of nymphal infestations in the C. gapperi population was always higher than for larval infestations. The intensity of nymphal infestations was similar to or less than that for larval infestations.

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DEDICATION

I would like to dedicate this thesis to my father, Roman Burachynsky , for having taught me the importance of knowledge above all things and to my uncle , Dmytro Negrych , who taught me that the love of nature requires discipline before it can lead to understanding.

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I am deeply indebted to my dearest friend and companion,Valerie who I was fortunate enough to marry before this project started, and without her faith and strength I might never have continued to the end.

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INTRODUCTION

Review of pertinent literature

The American dog tick, Dermacentor variabilis (Say), has aroused a great deal of interest during the last two decades in the eastern United States, where the incidence of Rocky Mountain spotted fever has steadily increased since 1958 (Burgdorfer 1975). This disease was formerly considered limited to the mountain areas of North America within the range of the vector, Dermacentor andersoni (Stiles). However, D. variabilis is now the most important vector of Rocky Mountain spotted fever in eastern and southeastern United States and the most likely to attack human beings (Burgdorfer 1975).

In Canada, D. variabilis has been reported from Nova Scotia (Hall and McKiel 1961; Dodds et al. 1969; Garvie et al. 1978), southern Ontario (Sholten 1977), Manitoba and Saskatchewan (Hearle 1938; Gregson 1956; Wilkinson 1967; Gkoroba 1980). The threat of this tick transmitting R.M.S.F. in Canada is evident with the discovery of positive sera from animals and humans (Newhouse et al. 1964; Campbell 1979) and a human case of the disease in Ottawa (Mackenzie et al. 1979).

Several major studies on the ecology and seasonal dynamics of D. variabilis have been conducted during the last twenty years along the eastern seaboard in Virginia (Sonenshine et al. 1966), Massachusetts (McEnroe 1974) and Nova Scotia (Garvie et al. 1978; Campbell 1979). Gkoroba (1980) conducted the first ecological study of D. variabilis in western Canada, the only one prior to this study.

Sonenshine et al. (1966) published the results of the most intensive

study on D. variabilis ecology up to that time. Their study was conducted at Montpelier, Virginia, over a period of three years. They found that larval activity began between March and April and declined to low levels in July, but small numbers were collected in August. Larvae were most frequently collected from small rodents. The peak abundance of nymphs occurred in May with an occasional peak occurring in late August and September following the second larval activity period. Nymphs were most frequently collected from small rodents. They concluded that the activity was bimodal for the two life-stages and that this was indicative of two distinct generations in a season (Sonenshine et al. 1966). The spring larval peak was composed of overwintered individuals while the summer larval peak was composed of individuals hatched the same summer (Sonenshine et al. 1966).

In 1968, Sonenshine and Stout published an analysis of the distribution of adult and immature stages of D. variabilis. The distribution of immature ticks was not correlated with host population densities. Hosts captured within the ecotone areas, dominated by woody shrubs, were more heavily infested with immature ticks than hosts caught in old fields or forest areas. The distribution of immature D. variabilis was positively correlated with habitats dominated by low, woody-deciduous vegetation (ecotone) (Sonenshine and Stout 1968). In addition they observed reduced hatch of D. variabilis eggs at R.H. <65%, and concluded that higher relative humidity in the ecotone and forests regions favoured survival more than in the old fields. Adult D. variabilis were observed to have a distribution different than that of immatures and apparently independent of conditions in the fields (Sonenshine and Stout 1968).

Sonenshine and Levy (1972) studied the distribution of immature and adult ticks in relation to vegetation types in greater detail. The capture frequency of immatures was highly aggregated in the old field-forest ecotone. Adult ticks were less aggregated than the immatures, though most frequently collected in the ecotone.

McEnroe and McEnroe (1973) and McEnroe (1974) observed that adult activity was bimodal in the drier, warmer regions of Massachusetts and unimodal in coastal areas and concluded that relative humidity and mean winter temperatures controlled seasonal activity and survival. McEnroe (1975) suggested that in areas where host populations are relatively stable overwinter mortality is the most important population regulator for ticks. McEnroe (1978a) reported that the distribution of D. variabilis in Massachusetts was limited by the average 0^{o}C winter (Dec., Jan., Feb.) isotherm.

Sonenshine (1979) suggested that the proposed climatic limitations of temperature and relative humidity did not apply to D. variabilis populations in western United States and Canada, some of which were recorded from prairie localities. He concluded his report with a recommendation for further study in this area of tick biology (Sonenshine 1979).

In Nova Scotia, D. variabilis was apparently introduced from the United States in the 1940's (Hall and McKiel 1961) and concern over the introduction of R.M.S.F. was raised. Dodds et al. (1969) reported that the range of this tick in Nova Scotia was expanding.

In 1973 a five year study on the field ecology and seasonal dynamics of D. variabilis was initiated in Nova Scotia by Garvie et al.

(1978). The range had increased since the work of Dodds et al. (1969) in spite of sub zero winter mean temperatures. The seasonal activity patterns of adults and nymphs were unimodal and larval activity was unimodal but occasionally bimodal. Larvae were most abundant in the forest habitats while nymphs and adults were most abundant in the field and ecotone areas (Campbell and McKay 1979).

In 1977, Gkoroba (1980) began a two year study on the field ecology and seasonal dynamics of D. variabilis in Manitoba, at Delta Marsh. He found that seasonal activity of all three life-stages was unimodal and that the abundance of both immature stages was highest in the forest while adults were most common in the ecotone and field.

The dominant hosts of immature ticks differ from study to study. The principal hosts were Peromyscus leucopus (Rafinesque) (Sonenshine 1972), Microtus pennsylvanicus (Ord) (Sonenshine et al. 1966; Campbell and MacKay 1979), Clethrionomys gapperi (Vigors) (Gkoroba 1980) and Peromyscus maniculatus (Wagner) (Stout 1978).

The seasonal dynamics and habitat associations of D. variabilis appear to be only slightly less variable than the dominant hosts of immature ticks. Sonenshine (1972) postulated a one year life cycle in Virginia, McEnroe (1975) a two year life cycle in Massachusetts, Garvie et al. (1978) a two to three year cycle in Nova Scotia and Gkoroba (1980) a two year cycle in Manitoba.

Historical review of Dermacentor variabilis (Say) in Manitoba

The earliest record of a problem with ticks in Manitoba is found in the journal of the famed explorer-fur trader, Alexander Henry. In

1801 he wrote in his journal that,

"Ever since April 25th we have been plagued with wood ticks (a species of Ixodes); and now that we are daily in the woods and grass, our clothes swarm with those troublesome and dangerous insects, which often get into the ear and cause inflammation. When they have time to get firm hold they cannot be removed without pulling the body from the head, which remains in the skin, and causes an itching which may last for several months. The bellies of our horses and dogs are covered with them; they adhere to the flesh until they have sucked themselves full of blood and are swelled nearly to the size of a musket ball, when they fall off of themselves. Their natural size is about that of a grain of barley, and in shape they are perfectly flat, with a tough, hard skin, of a chestnut colour. They continue to the end of July, when they suddenly disappear".[1]

In 1803, Henry was again beset by ticks while travelling from Fort Pembina to Portage la Prairie in late May,

"May 24th ... we camped; no wood; mosquitoes by the millions, and wood ticks" and then two days later he wrote "Camped at the beaver dam; wood ticks, mosquitoes, rain, and no covering".[1]

In 1910 Norman Criddle collected specimens of a tick identified as D. variabilis from Aweme, Manitoba (Hewitt 1915). Hewitt at this time reported that Criddle was engaged in limited research on the natural

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[1]From Elliot Coues (1897), The manuscript journals of Alexander Henry and David Thompson 1799-1814. Published by Ross and Haines, Minneapolis.

history of this tick. Criddle found that the peak of adult activity occurred in June and that the earliest captured specimens were taken on May 25th and the latest on July 17th, a much shorter season than reported by Henry over a 100 years earlier (Hewitt 1915). Dr. S. Hadwen attempted in 1910 to rear D. variabilis through its various life stages on rabbits, succeeding in 1911 and 1912. From these results he constructed the first life table for the species (Hewitt 1915).

In 1938 D. variabilis was reported to be abundant in Manitoba, parts of Saskatchewan and a few districts in Ontario (Hearle 1938). By 1950 the mention of D. variabilis in Manitoba dwindled to one record of two female specimens from an unknown contributor (Gregson 1956), though reports from Nova Scotia, Ontario and Saskatchewan were on the increase. By 1961 the only species of tick mentioned in R.D. Bird's Ecology of the Aspen Parkland was the winter moose tick, Dermacentor albipictus (Packard). However Wilkinson (1967) indicated, on a distribution map of D. variabilis for western Canada, ten records in Manitoba from as far north as Dauphin.

In 1977 Gkoroba (1980) began the first intensive field study on the ecology of D. variabilis in western Canada with observations on host preferences, seasonal dynamics and habitat preferences. In addition he estimated that adult D. variabilis population densities were 36,000 and 148,000 per acre in 1977 and 1978, respectively.

In 1978 a suspected case of D. variabilis induced paralysis of a horse was diagnosed at Virden, Manitoba (J.R. Allen, pers. comm.). Since that time a survey of rural veterinarians conducted by the author revealed that several veterinarians from across the province had diagnosed tick-induced paralysis in horses. In 1979 the author began studies on

D. variabilis ecology at Birds Hill Park, Manitoba.

Objectives

This study was initiated in response to several factors: a) the only other ecological study conducted in the province was in an area of marsh land and river bottom lands while the majority of complaints by rural and suburban residents come from the drier Aspen Parklands, b) unconfirmed reports of tick paralysis were beginning to come to our attention from veterinarians and farmers, c) the alarming increase of R.M.S.F. cases in the United States associated with D. variabilis and the high numbers of this species in Manitoba made us aware of the shortage of ecological data pertaining to Manitoba and d) the inconsistencies between the various ecological studies described earlier pointed out the need for more work in Manitoba.

The objectives of this study were: a) to determine the seasonal dynamics of D. variabilis immatures in an area of the province typical of the dominant forest region, the Aspen Parkland, b) to determine the host species infested by immature D. variabilis, c) to determine the distribution of tick populations with respect to vegetation and hosts, d) to examine dispersal of immature stages, and e) to examine temporal relationships between populations of immature ticks and host populations.

MATERIALS AND METHODS

General description of research plots

An area of land adjoining the southern boundary of Birds Hill Provincial Park (Fig. 1) was chosen as the site of two research plots. This area lies within the Aspen-Oak forest region as described by Rowe (1977).

Trembling aspen was the dominant tree species occurring in continuous and patchy stands, interspersed by prairie grasslands. Bur oak was sporadically dispersed within the dominant aspen stands. Aspen within the continuous stands grows to a greater height than aspen within patchy stands which tends to be quite shrubby (Rowe 1977).

The soils of this area are classified as members of the Leary series of well to excessively well drained Dark Grey soils (Degraded Chernozemic soils). Leary soils have developed on coarse, gravel beach and glacial outwash deposits. Commonly a thin sandy surface covers the coarser materials. The topography is level to very gently sloping. Soil permeability is rapid to very rapid resulting in low moisture retention (Canada-Manitoba Soil Survey 1975).

Plot one dimensions were 120m x 120m while plot two was 80m x 180m; both covered an area of 1.44 ha (3.6 acres).

The two plots, 400m apart, were oriented within this area to include the three major habitat types within their boundaries: forest, field and ecotone (Fig. 2). Habitats were mapped by visually evaluating vegetation type from each trap station on both plots. Habitat boundaries were mapped by pacing with a compass in addition to aerial photo interpretation of vegetation patterns.

The criteria for making habitat distinctions were based on the dominant vegetation characteristics. The field habitat was dominated by grasses and was free of trees and shrubs higher than .75m. The forest habitat was dominated by trees up to 10m in height. The forest floor was virtually free of grasses, due in part to the large amount of leaf litter and low light levels. The ecotone was dominated by shrubs and bushes up to 3m in height. Many woodland and field herbs and grasses were found in the ecotone.

Plant species lists for the two plots were basically similar, but plot two harbored a few species of orchids not seen on plot one. Plot two included some small areas, within the forest, that had a very dense canopy and deep leaf litter. See Appendix I for a complete list of plant species.

Trapping schedule

Plot one was staked out into a 7 station by 7 station grid and plot two into a 10 station by 5 station grid. Stations were 20m apart and a 3" x 3" x 10" live trap (Fig. 3), model no. 101, manufactured by the Tomahawk Live Trap Co. of Tomahawk, Wisconsin, was placed within 2m of the stake adjacent to any suitable cover or runway. One trap site, 9B, on plot two fell in the middle of a road and was abandoned resulting in 49 traps per plot. Occasionally a 6" x 6" x 19" live trap, Tomahawk model no. 202, was placed next to the smaller model to divert trap addicted ground squirrels whenever they were becoming a problem with the small traps.

Traps were set between 7:00 AM and 10:00 AM on two consecutive days every week on each plot. Traps were examined 24 hours later, captures

removed, traps scraped clean, bait replenished and the trap reset.

In 1979 trapping on plots one and two began on 8 and 17 May respectively and continued biweekly until 8 June and then once weekly until 7 September when all trapping ceased. In 1980 trapping on plots one and two began on 23 April and 1 May respectively, and continued biweekly on both plots until 22 August when all trapping ceased. If inclement weather posed a threat traps were closed and the schedule resumed normally when weather improved.

Traps were baited with rolled oats and peanut butter; carrots were added during hot weather to provide a source of water. Traps were covered by a shelter made of two pieces of 1/8" pressed board to provide protection from sun and rain (Fig. 3).

Mammal handling

All animals were transported to the laboratory and given food and water. Each animal was anaesthetized with ether in a large glass container and when unconscious placed on a white enamel tray under strong illumination. Animals were searched for parasites by brushing the pelage vigorously by hand followed by a systematic search of the animals' skin. All parasites were transferred to a vial containing 70% ethyl alcohol, and labelled with the host's capture history, status and background information.

All animals were sexed and given an identification number by clipping toes (Fig. 4). Age, weight and reproductive status were noted and histories of individual rodents compiled including their parasite burdens. When the animal had recovered consciousness it was returned to

a holding cage for the night with a supply of water and food.

Parasites collected from each host-capture were labelled and kept separate from all other material. All material was examined, sorted and processed. Ticks were identified to species and stage of development. Host and parasite data were recombined later using the individual host's date of capture and tag number to insure correspondence.

Animals were returned to the site of capture the next morning and released only after all the traps had been removed from the field. Animals caught over the second 24 hour period were processed in the same manner and returned the following day to the site of capture. Releases were conducted in this manner to avoid trapping the same individual twice in one week.

Rodent population dynamics: recruitment and turnover

To identify periods of population recruitment two criteria were employed. First, the population was monitored for the appearance of juveniles, which were identified on the basis of size and coloration. Secondly, since the juvenile pelage of cricetids (e.g. P. manicu-latus) changes quickly to the adult form, a large influx of previously unmarked individuals into a population was taken as a sign of recruitment. When the populations under examination are large, periods of high recruitment are easy to identify. However, at low population densities, these periods are not always obvious. As an indirect method of determining recruitment, population turnover or replacement of individuals was examined. Population recruitment and turnover periods were accepted as having occurred when no individuals

caught before a certain date remained in the population after a later date, even though the population size (M.N.A.) remained constant or increased. Population size was based on the minimum number of individuals known to be alive during a sampling period.

Host population size determination

Population size was estimated using the complete enumeration technique employed by Krebs (1966) and Krebs et al. (1969). By using a computer simulation of M. pennsylvanicus (Ord) populations based on actual data from capture-recapture studies, Hillborn et al. (1976) found that enumerated populations consistently underestimated actual populations by at least 10-20%. Population size was determined for each host species during the present study for two week periods as the minimum number of animals known to be alive or M.N.A. (Mihok 1979; Krebs et al. 1969; Hillborn et al. 1976).

Infestation parameters: Intensity and prevalence

The larval and nymphal infestation parameters of intensity and prevalence were tabulated for each of the host species by month for each plot.

Intensity of infestation is the measure of the average parasite burden of infested hosts,

$$\text{Intensity} = \frac{\text{total number of parasites collected}}{\text{number of infested captures}}$$

unlike the mean infestation which is the average number of parasites per host whether infested or not. Mean infestation figures will not be used in this paper.

Prevalence of infestation is a measure of the proportion of a sampled population infested by parasites,

$$\% \text{ Prevalence} = \frac{\text{number of infested captures}}{\text{total number of captures}} \times 100$$

Indices of dispersion for D. variabilis larval and nymphal distributions

The distribution patterns of D. variabilis larvae and nymphs were tested to determine departure from randomness. This measure is referred to as the index of dispersion by Greig-Smith (1964) and as the coefficient of dispersion by Southwood (1971).

The extent to which the distributions of larvae and nymphs conform to a random or Poisson distribution can be tested by a χ^2.

$$\chi^2 = \frac{S}{\bar{x}} \times (N-1)$$

where S = variance, N = number of trap sites and $\bar{x}$ = mean number of larvae or nymphs per site. If the χ^2 value calculated lies outside the limits 0.95 and 0.05 of the χ^2 for N-1 (48) degrees of freedom then the distribution is not random. The index of dispersion,- $\chi^2 \div (N-1)$ will be approximately equal to one for a random distribution. A value approaching zero is indicative of a regular distribution and a value significantly greater than one, as indicated by a χ^2 value outside of the 0.95 to 0.05 limits, implies an aggregated distribution (Southwood 1971; Greig-Smith 1964; Poole 1974).

Spatial distributions of ticks and hosts

Since there are no practical methods available for sampling free-living larvae or nymphs, the spatial distribution of feeding stages is interpreted from that of infested hosts. This approach, while the only