Effect of deer exclusion by fencing on abundance of Amblyomma americanum (Acari: Ixodidae) on Fire Island, New York, USA

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ABSTRACT: The effects of deer exclusion on northern populations of lone star ticks, Amblyomma americanum, were tested at the Lighthouse Tract, Fire Island, NY, USA, where densities of this species have increased recently. Game fencing was erected to exclude deer from two sites of roughly one ha each, and populations of nymphal and adult A. americanum within were compared with those at control sites outside the exclosures. Percent control of nymphs within vs. outside the exclosures averaged 48.4% in the four years post-treatment, compared to pre-treatment values. Percent control varied markedly in different years, suggesting that factors in addition to deer densities had strong effects on population densities of A. americanum. Exclosures of this size did not control adult A. americanum. Effects of deer exclusion in this recently expanded northern population of A. americanum were similar to those that have been reported for southern populations of this species. Journal of Vector Ecology 27(2): 215-221. 2002.

Keyword Index: Amblyomma americanum, deer exclusion, tick management.

INTRODUCTION

The lone star tick, Amblyomma americanum (L.), can cause substantial nuisance problems because of its aggressive host-seeking behavior and high population densities (Hair and Bowman 1986). This species has also been implicated in transmission of several pathogens, including Ehrlichia chaffeensis, which causes human monocytic ehrlichiosis (HME) (Walker and Dumler 1996).

A. americanum has been collected over most of the eastern United States, but high densities were formerly found only in southern parts of the range (Hair and Bowman 1986). Dense populations of this species appear to be spreading northward, with recent collections showing far higher densities than historic collections on eastern Long Island, NY (Ginsberg et al. 1991), and substantial populations currently on Prudence Island in Narragansett Bay, RI (Mather and Mather 1990). This expansion might be related to habitat changes resulting from human activities and to expanding populations of vetebrate hosts of A. americanum, including deer and wild turkeys (Haile and Mount 1987, Means and White 1997).

Deer exclusion has been used to manage A. americanum in the southern part of its range, both alone and in combination with other techniques such as vegetation management and pesticide application (Bloemer et al. 1986, 1990). Fencing a 2.43 ha area to exclude deer resulted in a 38% reduction in nymphal A. americanum (Bloemer et al. 1986), while fencing a 71 ha area resulted in up to 70% control (Bloemer et al. 1990). However, this approach has not been tested in the expanding northern portion of the range of this tick species. Differences between southern and northern tick populations in phenology (due to different seasonality), abundance of deer and other host species, and genetic structure (of older southern populations compared to the rapidly expanding northern population) could potentially influence the effect of deer exclusion on tick densities.

We report trends in populations of nymphal A. americanum on Fire Island, NY, in areas from which deer have been excluded by game fencing, compared to areas with free-ranging deer. Lone star ticks were not present in samples taken at our study site in 1986, while Ixodes scapularis Say was common (Ginsberg 1992). By 1995, however, A. americanum far outnumbered I. scapularis at this site (Ginsberg and Zhioua 1996).
Because of this recent population increase at our study site, our results provide a test of the efficacy of deer exclusion as a management method for expanding populations of *A. americanum* in the northern portion of this species’ range.

**MATERIALS AND METHODS**

Fire Island is a 55 km-long barrier island off the south shore of Long Island, New York, USA. The Lighthouse Tract is at the western end of Fire Island National Seashore, about 8 km from the western end of the barrier island. Deer exclosures were erected in two woodland types at the Lighthouse Tract. The western exclosure was a pitch pine (*Pinus rigida* Miller) woodland, with a roughly circular area of about 0.9 ha surrounded by game fencing. The eastern exclosure was longer and narrower in outline (approximately 1.2 ha) and included deciduous thicket-woodlands, primarily highbush blueberry, *Vaccinium corymbosum* L., chokeberry, *Aronia arbutifolia* (L.), and bayberry, *Myrica pensylvanica* Mirbel. Adjacent to each exclosure, one deciduous and one coniferous control (unfenced) site was selected (total of two fenced and four unfenced sample sites). Fencing was Gaucho Game Fence (Bekaert, Van Buren, AR), with three high-tension wires mounted above to a height of 2.4 m. The fence was mounted so that wide mesh (15 x 25.5 cm openings) was at ground level and narrow mesh (8.5 x 15 cm openings) was at the top. This allowed small and medium-sized mammals to pass easily through the fence (even some deer fawns), but excluded adult deer. The fences were erected during the summer of 1995.

Flagging samples were taken in each of the six sample sites each summer from 1994 through 2000. The flag was 1 x 0.5 m, made of white pinwale corduroy mounted on a wooden dowel. Flagging samples were taken so that the bottom portion of the flag was drawn through the leaf litter, and the top portion contacted vegetation up to 0.5 m above the ground. Samples were taken during periods of abundant adult and nymphal activity each year; on 22-23 June 1994, 16-17 June 1995, 9-11 June 1996, 30 June-7 July 1997, 22-29 June 1998, 27-28 June 1999, and on 3 July 2000. Fifteen samples, 1-min each, were taken in each of the six sample sites, with a total of 90 samples, 30 inside and 60 outside the exclosures each year (except for 1997 when 20 samples were taken per site, and 2000 when 10 samples were taken per site) for a total of 630 samples.

Tick abundances within vs. outside the exclosures were compared each year using hierarchical ANOVA, with subgroup effects (east vs. west and deciduous vs. coniferous) analyzed separately, by nesting within the main effect, inside vs. outside the exclosures. In all cases significance or lack of significance of the main effect was the same for both comparisons; to be conservative, the lower of the two *F* values were reported for significant comparisons. Data were analyzed using SPSS (SPSS 1999), general linear model function. Abundance data were tested for normality and homogeneity of variances and found to be right-skewed with heterogeneous variances. Therefore, data were transformed by log (x+1), which substantially lowered heterogeneity of variances in all years except 1997. Percent control was calculated using a modified Abbott’s formula (Mount 1981):

\[
\% \text{CONTROL} = 100 - ((\frac{T_{\text{after}}}{T_{\text{before}}})\frac{U_{\text{after}}}{U_{\text{before}}}) \times 100
\]

where: *T* = mean number of nymphs in treated area (within exclosures); *U* = mean number of nymphs in untreated area (outside exclosures).

**RESULTS**

Population trends in *A. americanum* nymphs are shown in Figure 1. Tick numbers inside did not differ significantly from outside the exclosure areas in 1994 (*P*>0.5), 1995 (*P*>0.2), or 1996 (*P*>0.16). In 1997, there were more *A. americanum* nymphs inside than outside the exclosures (*F*=7.912, *df*=1,117, *P*=0.006). Numbers of *A. americanum* nymphs were significantly lower inside than outside the exclosures in 1998 (*F*=48.271, *df*=1,187, *P*<0.0005), and 1999 (*F*=8.762, *df*=1,187, *P*=0.004), and were nearly significant in 2000 (*F*=3.771, *df*=1,57, *P*=0.057). Compared to the pretreatment values in 1994, percent control (inside the exclosure areas compared to outside) was 59.8 % in 1996 (the first year after the exclosures were built), -21.5 % in 1997, 87.3 % in 1998, 65.4 % in 1999, and 62.2 % in 2000. More nymphs were collected in deciduous than in coniferous woods most years (Figure 1B), but the differences were significant in only three years, and in one year (1999) nymphs were significantly more abundant in coniferous woods. Tick densities did not differ significantly in most years between eastern and western sites (Figure 1C).

Adult *A. americanum* were more commonly collected within the exclosures in 1996 (*F*=11.562, *df*=1,87, *P*=0.001) and 1997 (*F*=50.370, *df*=1,117, *P*<0.001), the two years after the exclosures were completed (Figure 2A), but not before or after this period (*P*>0.141 in all cases). In most years, numbers of ticks collected did not differ between deciduous and coniferous woods or between east and west sample sites (Figures 2B, C).
Figure 1. Population trends of nymphal *Amblyomma americanum* at the Lighthouse Tract, Fire Island, NY. A) inside vs. outside deer exclosures, B) in deciduous vs. coniferous woodlands, C) at sample sites in the eastern vs. western portions of the study area. Arrow indicates year that exclosures were placed. (* $P<0.05$; ** $P<0.01$)
Figure 2. Population trends of adult *Amblyomma americanum* at the Lighthouse Tract, Fire Island, NY. A) inside vs. outside deer exclosures, B) in deciduous vs. coniferous woodlands, C) at sample sites in the eastern vs. western portions of the study area. Arrow indicates year that exclosures were placed. (*P < 0.05; **P < 0.01)
Population trends of nymphal and adult *Amblyomma americanum* within the two exclosures are shown separately in Figure 3.

**DISCUSSION**

On Fire Island, adult and nymphal *Amblyomma americanum* are active from late spring through midsummer, and larvae are most common in mid-late August (Ginsberg, unpublished). Therefore, larvae take blood meals in late summer and are active as nymphs the following spring. Apparently, the nymphs take blood meals and are active as adults the following spring, resulting in a two-year life cycle. Therefore, deer exclusion by fencing in 1995 (the exclosures were not completed until after the adult activity season) would be expected to lower the number of adults dropping off of deer and laying eggs in the exclosure areas in 1996, thus reducing the density of larvae later that year. This should, theoretically, reduce the densities of nymphs in the exclosure areas (relative to controls) in 1997, and possibly the densities of adults in 1998. However, densities of *Amblyomma americanum* nymphs
in the exclosures were greater than outside in 1997 (Figure 1A), suggesting that some factor other than deer density regulated tick density that year. In subsequent years tick density was lower inside than outside the exclosures (1998, \(P=0.0005\); 1999, \(P=0.004\); 2000, \(P=0.057\)), indicating some measure of tick control resulting from deer exclusion. Percent control averaged 48.4% in the four post-treatment years, comparable to the results obtained by Bloemer et al. (1986), who found 38% fewer nymphs in a 2.43 ha enclosure area compared to a control area in western Kentucky.

Interestingly, adult numbers increased within the exclosures in 1996 and 1997 (the two years following exclusion), and subsequently did not differ from outside the fenced areas (Figure 2A). Thus fencing did not control adults at this site. Similarly, at the site where Bloemer et al. (1986) reported 38% control of nymphs in a 2.43 ha enclosure, they did not get significant control of adults. Presumably, movement of larvae on birds and other mobile hosts erodes the effects of fencing on nymphal abundance, and movement of nymphs on these same hosts further erodes the potential for control of adults by fencing. Thus, deer exclusion from 1 ha plots in our study gave comparable control of the newly expanded northern population of *A. americanum*, as was obtained with southern populations of this species.

The inconsistency of nymphal control both from year to year (1997 compared to 1998-2000) and from site to site (see Figure 3A, showing differential yearly fluctuations in nymphal densities within the two exclosures) suggests that other factors in addition to deer densities influence tick population sizes at this site. Immature *A. americanum* attach to a variety of hosts other than deer, including small mammals and birds (Hair and Bowman 1986), and are themselves highly mobile (Ginsberg and Ewing 1989). Therefore, factors other than deer distribution can influence nymphal distribution at the local level. The greater level of control (70%) achieved by Bloemer et al. (1990) when they fenced a 71 ha area supports this interpretation because local variability would cause less fluctuation over a large area than over small local sites. Furthermore, the well-established relationship between microhabitat characteristics (e.g., those that influence humidity levels) and *A. americanum* behavior and survival (Semtner et al. 1971, Hair et al. 1975, Robertson et al. 1975) suggests that varying local conditions could result in yearly changes in tick distribution independent of the effects of host abundance.

The importance of varying local conditions can be seen in the varying abundance of nymphs in different habitat types (Figure 1B) and in different physical locations (Figure 1C). Nymphs were significantly more abundant in deciduous than in coniferous woods in some years, but not in others, and they were more abundant in coniferous woods in 1999. Nymphs were significantly more abundant in eastern than western sites in 1995 and 1998, but not in other years. Thus tick distribution varies from year to year, but not in response to any one of the factors studied in this analysis. Tick distribution might be responding consistently to some variable that we have not identified, but this seems unlikely because the importance of deer abundance and of microclimate are well established (Semtner et al. 1971, Hair et al. 1975, Robertson et al. 1975, Hair and Bowman 1986, Bloemer et al. 1990). More likely, the determinants of tick distribution vary from year to year, resulting in fluctuations of local numbers that respond to more than just one environmental variable.

Another possible explanation for the high densities of nymphs collected inside the exclosures in 1997 is that a large proportion of the nymphs present might have been questing (and thus available to flagging samples) because white-tailed deer, a primary host (Hair and Bowman 1986), had been excluded. Outside the exclosures, even though there might have been more nymphs present than inside, relatively few ticks were flagged because they had already found deer hosts, which were highly abundant at this site (Ginsberg and Zhioua 1999). The fact that adults were more common within than outside the exclosures in the two years after the exclosures were built (Figures 2A, 3B) supports this hypothesis. This phenomenon has been described at this same site for adult *Ixodes scapularis* (Ginsberg and Zhioua 1999), which also attach readily to deer. In the subsequent years (1998-2000), the number of *A. americanum* nymphs within the exclosures might have been reduced to the point that even without attaching to deer, fewer nymphs were available for flagging inside than outside the exclosures.

We conclude that in 1 ha plots exclusion of deer by fencing can potentially contribute to an integrated management program for lone star ticks in the northeastern United States, but that this technique by itself is unlikely to give consistent control. In the first year or two after deer exclusion, the number of questing ticks can actually increase. Studies on southern populations (Bloemer et al. 1986, 1990) suggest that larger exclosures would be expected to provide better control of lone star ticks.

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