VECTOR-BORNE AND ZOONOTIC DISEASES
Volume 9, Number 4, 2009

DOI: 10.1089/vbz.2008.0197

ORIGINAL ARTICLE

Acaricidal Treatment of White-Tailed Deer to Control *Ixodes scapularis* (Acari: Ixodidae) in a New York Lyme Disease-Endemic Community

Thomas J. Daniels,[1,2] Richard C. Falco,[3] Erin E. Mchugh,[1] James Vellozzi,[1] Theresa Boccia,[1] Anthony J. Denicola,[4] J. Mathews Pound,[5] J. Allen Miller,[5] John E. George,[5] and Durland Fish[6]

Abstract

The efficacy of topically treating white-tailed deer with an acaricide was evaluated in a Lyme disease–endemic community of southern New York State. Twenty-four 4-Poster feeders were placed in a 5.2 km^2 treatment area in Bedford, NY, while a site in Lewisboro, NY, 4.8 km distant, served as control. Treatment periods ran from 15 September to 15 December each fall from 1997 to 2001, and from 15 March to 15 May each spring from 1998 to 2002. Corn consumption averaged 15,779 kg in fall sessions and 9054 kg in spring sessions, and a mean of 89.6% of deer in the study area showed evidence of using the feeders. Deer densities, estimated by aerial snow counts, averaged 22 and 28 deer per km^2 in Bedford and Lewisboro, respectively, over a 3-year period. Significant reductions in tick numbers on deer captured in the treatment area were noted in fall 1999 compared to deer captured at the control site. Drag sampling for nymphal host-seeking ticks indicated 63.6% control in 2001, which dropped to 54.8% the following year, but reached 80% in 2003. Higher-than-normal acorn production in 2001 that likely caused a drop in deer visitation to the feeders may have reduced efficacy against larval ticks in 2002. The 4-Poster effectively reduced the density of *Ixodes scapularis*, though the level of control is dependent on environmental factors that affect feeding behavior of white-tailed deer.

Key Words: Acaricide—Blacklegged ticks—Control—4-Poster—*Ixodes scapularis*—Lyme disease—White-tailed deer.

Introduction

Lyme disease remains especially prevalent in the northeastern United States, where just four states (New York, Connecticut, Pennsylvania, and New Jersey) account for approximately three-quarters of all cases; New York alone accounted for 31.6% of reported cases in the decade 1991–2000 (CDC 2002) and for nearly one-quarter of all Lyme disease cases in 2005 (CDC 2007), the most of any single state. The 4-Poster device, designed to reduce the risk of Lyme disease by treating white-tailed deer with an acaricide to kill adult blacklegged ticks (*Ixodes scapularis*), was evaluated in five northeastern states (see other articles in this issue). The current article describes work conducted at the New York sites.

Materials and Methods

Study sites

Lyme disease is endemic in Westchester County, in the lower Hudson River valley, and reported cases routinely number in the hundreds each year. Risk of tick bites and infection is highest in the northern half of the county (Dister et al. 1993, Falco et al. 1993), where evaluation of the 4-Poster was

[1]Vector Ecology Laboratory, Louis Calder Center, Fordham University, Armonk, New York.
[2]Department of Family & Community Medicine, New York Medical College, Valhalla, New York.
[3]New York State Department of Health, c/o Louis Calder Center, Armonk, New York.
[4]White Buffalo, Inc., Moodus, Connecticut.
[5]Knipling-Bushland U.S. Livestock Insects Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Kerrville, Texas.
[6]Department of Epidemiology and Public Health, Yale School of Medicine, New Haven, Connecticut.

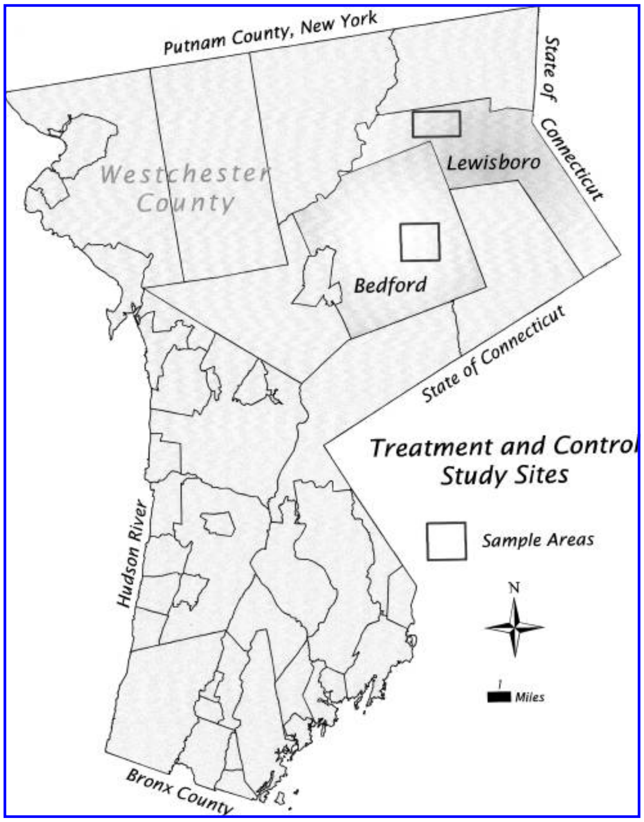

FIG. 1. Study sites in Westchester County, NY.

conducted (Fig. 1). The treatment site was located in Bedford, 64 km north of New York City, with a population of 16,000 in 101 km^2; at the time of the study Bedford had the highest incidence of Lyme disease reported from Westchester County. The core treatment area was approximately 5.2 km^2 (2 mi^2) consisting largely of private residential and commercial (a golf course) property. The control site was 4.8 km north of Bedford, in the town of Lewisboro, with a population of 11,500 in 75.1 km^2. The control site was approximately 7.8 km^2 (3 mi^2) in area consisting of private residential properties and two nature preserves. The additional 2.6 km^2 (1 mi^2) area in Lewisboro, relative to that in Bedford, assured an adequate number of residential properties for sampling. Homes in both sites typically were surrounded by maintained lawns, with many having landscaped islands of ornamental shrubs. Yards frequently abutted woodland a short distance from the home, forming ecotones that provided a suitable habitat for *I. scapularis* (Maupin et al. 1991) and their hosts. Abundant woodland habitat was mainly a mix of eastern deciduous trees (e.g., maples [*Acer* spp.] and oaks [*Quercus* spp.]), with a sparse understory of shrubs such as barberry (*Berberis vulgaris*), multiflora rose (*Rosa multiflora*), and wineberry (*Rubus phoenicolasius*).

Feeder placement

In fall 1997, twenty-five 4-Posters were placed in the 5.2 km^2 core area in Bedford. Properties were solicited by mail through a questionnaire that was sent to all (approximately 250) core area households. Feeder placement was determined on the basis of both owner response and location of the property within the core area. Although placement was not uniform in the core area, spacing was believed adequate to insure that all deer in the study area would encounter baited feeders and therefore be available for treatment. Subsequent changes in property ownership required the removal of one feeder in spring 1999 for a total of 24 operating in the Bedford study area (Fig. 2).

For budgetary and logistical reasons, additional 4-Posters that would have fed deer but not treat them were not placed in the Lewisboro site. Further, it was unlikely that we would have gotten permission to place them on residents' properties given concerns that simply feeding deer would exacerbate the tick problem.

Acaricide application

The treatment protocol (Pound et al., 2009a) called for feeders to be in operation for two periods each year, during spring (March 15–May 15) and fall (September 15–December 15). A 2% pour-on formulation of Amitraz (Point-Guard, Hoechst Roussel Vet, Warren, NJ) was applied manually with an applicator gun that had been customized with a PVC cup that fit snugly on the top of each roller. The original treatment regimen involved applying 20 mL of Point-Guard® to each roller once per week; however, this dose was deemed inadequate, and by fall 1999 treatment was increased to 40 mL Point-Guard per roller three times weekly.

Deer spotlighting

Efforts to determine the proportion of deer in the study area using the 4-Poster involved removing the acaricide-treated rollers and replacing them with rollers on which a mixture of petroleum jelly (fonoline), mineral oil, and powdered glass beads (3M Reflective Glass Elements; 3M, St. Paul, MN) had been smeared. Rollers were placed on the feeders for 2 days/one night before each spotlighting period. Spotlighting consisted of driving a predetermined route through the study area after dark, using a 400,000 candle power spotlight (Q-beam; Brinkmann, Dallas, TX) to scan for deer. All deer spotted were examined with binoculars for the presence of the marking, particularly on the head and neck; age and sex of deer were noted when possible. Because deer were frequently in woodland, each survey resulted in several individuals for which a good view was not obtained. Since observers could not determine if these deer were marked or not, they were excluded from calculations estimating the proportion of marked deer. To maximize acaricide application to deer during the treatment period, spotlighting surveys were conducted at the end of each treatment period.

Deer capture

Deer were captured by dart gun in late afternoon to early evening hours, using protocols described by Pound et al. (2009a). Upon capture, each deer was inspected for ticks. Ticks were collected and placed in individually labeled vials containing 70% ethanol. Labeled ear tags were applied to inform potential consumers (i.e., hunters or those recovering roadkills) to notify the appropriate agency before butchering as well as to prevent recapture during subsequent sampling periods. Swabs of the fur, using filter paper disks, were taken from deer captured in fall 1998 to determine the relative

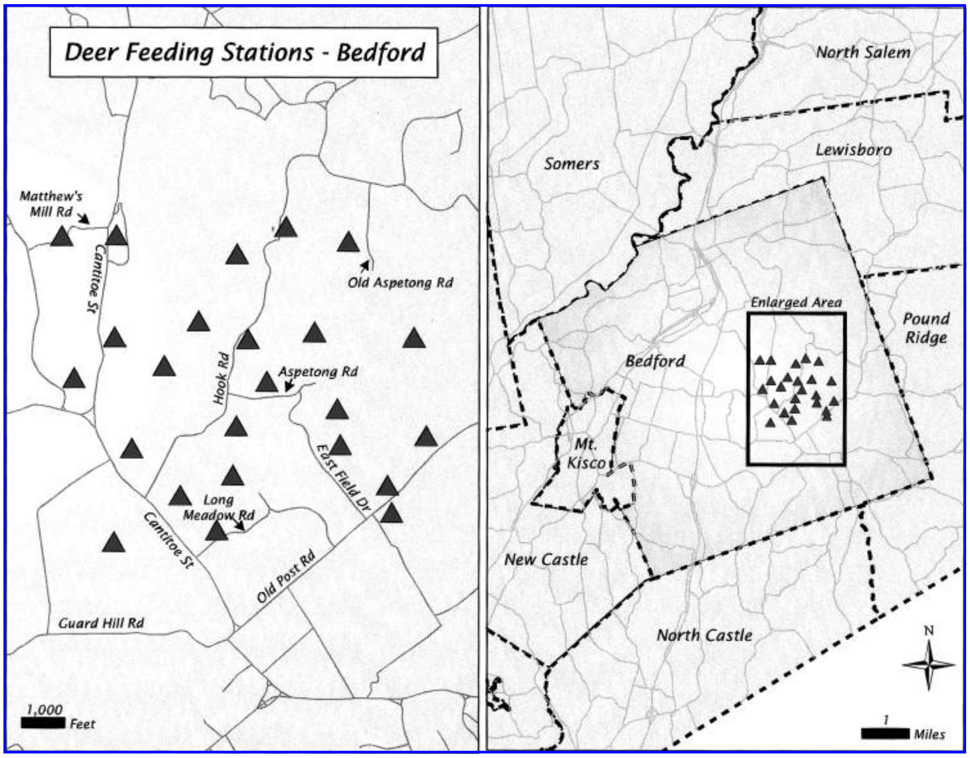

FIG. 2. 4-Poster locations, Town of Bedford, NY.

amount of amitraz present on different regions of the body (Stafford et al. 2009).

Aerial surveys

Deer population estimates were determined using helicopter snow counts when there was >10 cm of snow cover for visual contrast. The surveys were conducted by flying 183-m-wide transects, oriented north–south and covering the entire length of the study area, at an elevation of 60 m and at a speed of 32–40 kph. Two observers counted all deer out to 100 m from their respective side of the aircraft and recorded the number and distribution on an aerial photograph. There was a pilot and a navigator to ensure all transects were flown accurately. The navigator used a global positioning system (GPS) system with a moving map to verify the accuracy of all transects. Density was calculated as the number of deer counted per unit area surveyed. Based on work by Beringer et al. (1998), an average detection rate of 78.5% was assumed. Thus, counts were increased by 22.5% to permit more accurate density estimation.

Drag sampling

A 1 m^2 panel of white corduroy was pulled along the ground and over vegetation to collect host-seeking ticks (Falco and Fish 1992). Drag cloths were checked every 10–20 m, and all ticks found clinging to the cloth were removed with forceps, preserved in vials containing 70% ethanol, and stored until later identification and counting.

Individual properties were selected for sampling on a given day from a pool of properties for which permission had been obtained previously. Homeowners were again contacted by phone on the day of sampling (unless other arrangements had been made) to inform them of the visit and confirm permission to enter the property. Sampling consisted of dragging an average of 200 m^2 of woodland habitat on each property. Efforts were made to sample throughout the core treatment and control areas to provide a representative view of tick abundance. Over the course of a season, individual properties were sampled from one to four times. However, on those properties sampled more than once, each sample was collected along a series of randomly selected (start point and direction) transects in woodland that insured minimal chance of resampling the same spot.

Data analysis

Tick numbers vary over the course of each stage's activity period (e.g., Fish 1993), and all sampling cannot be conducted during the relatively short peak period. Thus, drag data collected in this study were adjusted upward if necessary on the basis of drag samples from a permanent grid site that has been sampled continually since 1987 (Daniels et al. 2000). This permitted standardization of the drag data to peak activity so that samples collected at different times of year could be compared. Briefly, once peak was identified, the proportion of ticks either not yet active (prepeak) or lost in the ensuing weeks due to host pick-up or death (postpeak) could be calculated. Actual drag data could be increased accordingly based on data for that specific week. By standardizing drag data to peak, we were able to pool data from an entire season and thus minimize sample size concerns. In addition, tick counts and density data frequently were not normally distributed. To facilitate analyses using standard parametric tests (e.g., analysis of variance [ANOVA]), data were log-transformed to help normalize them and to better meet the assumptions of ANOVA. In those cases where data were not normally distributed and did not meet the basic assumptions for parametric tests, nonparametric tests were used.

Abbott's (1925) formula was used to determine the percentage control achieved as a result of using the 4-Posters in which

% Control = 100 × (1 − number in treatment site after treatment/number in control site after treatment)

Results

Corn consumption by deer

Corn use averaged 9053 (±1322 SD) kg and 15,779 (±5497 SD) kg in spring and fall seasons, respectively, over the course of the 5-year treatment period (Table 1). Given differences in the length of spring and fall treatment seasons, corn usage per month was calculated and averaged just 4361 kg per month in spring compared to 5260 kg per month in fall.

Total corn consumption from 1 year to the next could be quite variable, as from spring 2000 to spring 2001 when a 35% increase in usage was observed. This subsequently dropped to more moderate levels in 2002. Likewise, corn consumption in the fall showed a 44% increase in 2000 compared to 1999, followed by a 59% decline in 2001. Within a season, corn consumption typically rose dramatically in the first 2 weeks of each treatment session, then tended to stabilize over the remainder of the treatment period.

Acaricide application

Initial amounts of Point-Guard applied to the 4-Poster rollers totaled just 16.4 L in fall 1997, and just 20.8 L the following spring. Step-wise increases in the amount of acaricide were made until fall 1999 when an application rate of 40 mL of Point-Guard per roller, three times per week, was decided upon. This regimen became the standard for the remaining treatment periods, and mean amounts of acaricide applied from then on were 89.7 and 141.6 L in spring and fall sessions, respectively.

Deer density

Aerial snow counts to evaluate deer density were conducted on three occasions: March 1999, February 2000, and February 2001. In addition to being restricted to winter months when leaves were off the trees, it was necessary to conduct these surveys after a snowfall of at least 10 cm so that the dark brown deer contrasted well with the white background. Aerial surveys in the winters of 1997/1998 and 2001/2002 could not be conducted because of the lack of snow cover.

Deer density was the same at both sites in 1999 (21 per km^2 in both towns), but rose nearly 50% in Lewisboro 1 year later (31 deer per km^2). Density in Bedford rose slightly to 23 deer per km^2 over the same period. No such changes were observed in 2001, with estimated deer densities of 22 and 31 per km^2 in Bedford and Lewisboro, respectively.

Given these independent measures of deer density, corn usage was evaluated as to the number of pounds per animal per day to determine if corn consumption could serve as an index of deer density. Ideally, the mean amount of corn used by each animal would remain consistent from one season to the next, but data for 3 years, 1999–2001, indicate that springtime corn consumption ranged from 1.30 (in 2000) to 1.81 (in 2001) kg per deer per day of treatment, while fall consumption ranged from 1.05 (2001) to 2.50 (in 2000) kg per deer per day.

Table 1. Total Corn Consumption (kg), New York

Year	*Spring*	*Fall*
1997	—	11,692
1998	7946	16,982
1999	8914	16,556
2000	8363	23,901
2001	11,324	9766
2002	8721	—
Mean	9053 (±1322 SD)	15,779 (±5497 SD)

Table 2. Percentage of Deer Using the 4-Poster Device

Season	*Number of deer observed*	*Percentage marked*[a]
Fall 1998	33	83
Spring 1999	37	97
Fall 1999	25	95
Spring 2000	53	86
Fall 2000	76	84
Spring 2001	40	90
Fall 2001	44	90
Spring 2002	46	92

[a]Excludes deer not seen clearly.

Deer use of the 4-Poster

Eight spotlighting surveys, one per treatment session, were conducted at the Bedford site from fall 1998 through spring 2002. A mean of 44 deer was seen per survey (range: 25–76), though an average of 19.8% of the deer spotted could not be observed well enough to determine marking status. Of those for which marking status could be ascertained, a mean of 89.6% showed evidence of feeding at the 4-Poster over the course of this study (Table 2).

Tick loads on deer

In spring 1998, four deer in Bedford and four in Lewisboro were captured by darting and examined. *I. scapularis* adults were found on two (50%) and three (75%) deer from Bedford and Lewisboro, respectively, with total numbers of ticks very low. Given the small sample size, this was followed in fall 1998 with the capture of an additional 12 deer (6 per study area). All deer hosted *I. scapularis*, and mean numbers of adult ticks on deer were higher than they had been in May 1998. However, comparison of tick numbers on deer from treatment and control properties revealed that means were not significantly different (Mann–Whitney *U*-test, $U = 0.97$, $p = 0.33$). Since successful tick reproduction requires that females attach and feed to repletion, we compared the number of attached female *I. scapularis* found on deer. When the numbers of attached females on deer from treatment and control properties were compared, differences in the means were more obvious, though still not significant (Mann–Whitney *U*-test, $U = 1.38$, $p = 0.16$).

By the fall 1999 season, several adjustments in the treatment regimen were made that included increasing the acaricide volume per application and increasing the height of the rollers to maximize chemical transfer to the deer. An effort to increase the number of deer sampled in both the treatment and control sites resulted in the capture of 40 deer, 20 in Bedford and 20 in Lewisboro, during the peak adult tick activity period in October 1999. On average, nearly sevenfold more ticks were found on untreated deer in Lewisboro compared to those from Bedford. Further, the proportion of ticks that was alive on deer was noticeably lower on deer from the treatment area than on those from the control site where virtually all ticks were alive (Table 3).

Significant treatment–control site differences included mean number of live ticks per deer (ANOVA: $F_{1,\ 38} = 63.1$, $p = 0$), number of live ticks attached to deer (ANOVA: $F_{1,\ 38} = 93.1$, $p = 0$), percentage of ticks alive on deer (Arcsine transformation and test of two percentages, $t_s = 3.42$, $p < 0.001$), percentage of ticks mating ($t_s = 4.66$, $p < 0.001$), and percentage of ticks alive on the head and neck ($t_s = 2.4$, $p < 0.05$).

Host-seeking ticks

Drag sampling was conducted regularly at both treatment and control sites from April through November, weather permitting. Efforts were made to sample a number of different properties in each study site throughout the year and to avoid sampling patches that had been sampled previously.

Because the study was initiated in fall 1997, drag sampling was limited that year to just 27 (4400 m^2) and 23 (4600 m^2) samples in Bedford and Lewisboro, respectively. Subsequent sampling averaged 28,220 m^2 per year in Bedford and 23,217 m^2 in Lewisboro for the period 1998–2003 (Table 4).

Once tick numbers were seasonally adjusted, as described above, density (number of ticks collected per m^2 dragged) was calculated for each sample. Densities were log-transformed, and ANOVA was performed for each stage, in each year, to determine the effect of sample site (treatment vs. control) on tick number (Table 5). A significant difference in larval numbers was noted between the two sites in 1999. However, this was likely an artifact of the small number of samples from Lewisboro ($n = 8$) that year. No statistical differences were found between treatment and control sites for any life stage in 2000, though fewer individuals of all stages were collected in Bedford compared to Lewisboro in 2001. In 2002, significant differences in nymphal and adult density were noted between the two sites, but larval densities were equivalent. Larvae and nymphs in 2003 were again significantly more abundant in the control site of Lewisboro compared to the treatment site (Table 5).

Nymphal densities were compared using Abbott's (1925) formula to estimate the percentage control obtained by using the 4-Poster. In 2001, 63.6% control was achieved while in 2002, control was reduced to 54.8%. However, percentage control reached 80% in 2003.

Table 3. Deer Darting Results, Fall 1999

	Bedford	*Lewisboro*
Number of deer examined	20	20
Total *Ixodes scapularis*	99	683
Number of ticks alive on deer	70 (70.7%)	682 (99.9%)
Number of ticks live on head/neck	45 (64%)	415 (61%)
Number of attached females	21	450
Mean number of live ticks per deer	3.5	34.1
% Ticks mating	0	45.2

Table 4. Drag Sampling Effort

	Bedford		*Lewisboro*	
Year	*Number of Samples*	*m^2 Dragged*	*Number of Samples*	*m^2 Dragged*
1997	27	4400	23	4600
1998	79	15,800	82	16,400
1999	99	20,620	74	15,600
2000	122	25,080	93	18,600
2001	270	57,800	219	47,100
2002	115	24,420	103	22,200
2003	123	25,600	97	19,400

Discussion

Data collected in this study support the use of the 4-Poster device to reduce risk of exposure to *I. scapularis* ticks over a relatively large geographic area. Significant differences in tick abundance between treatment and control sites were observed in 2001 for all life stages, in 2002 for both nymphs and adults, and in 2003 for larvae and nymphs. A delay in suppressing the tick population until 2001 was likely the result of suboptimal treatment from fall 1997 to spring 1999, as the application rate was raised incrementally. A significant reduction in larval numbers was anticipated but not observed the following summer, in 2000, although a trend toward reduced numbers on treatment properties was evident. By spring 2001, however, nymphal numbers were significantly reduced on treatment properties, along with adult numbers that fall, indicating that the 2000 larval reduction was critical if not statistically significant. To the extent that larval *I. scapularis* feed on white-tailed deer (Telford et al. 1988), there may be an additive effect on nymphal populations most likely resulting from the spring treatment period when we typically observe a pulse of early larval activity in the region (e.g., Fish 1993).

The absence of larval suppression in 2002 likely resulted from natural fluctuations in food availability for white-tailed deer, specifically in the abundance of acorns. Oak tree species exhibit synchronous production of large seed crops periodically, referred to as masting, which is dependent on weather conditions and prior reproductive events (Sork et al. 1993). Because masting tends to be regional, with synchrony often observed between sites up to hundreds of kilometers apart (Koenig and Knops 2000), we evaluated corn consumption data in Bedford with respect to acorn data collected at the Louis Calder Center, approximately 10 km distant. The

Table 5. Summary of Analysis of Variance to Determine Treatment Effects on Adjusted Tick Densities

Year	*Larva*	*Nymph*	*Adult*
1997	—	—	$F_{1,\ 41} = 1.59$, $p = 0.214$
1998	$F_{1,\ 48} = 0.45$, $p = 0.506$	$F_{1,\ 105} = 3.23$, $p = 0.075$	$F_{1,\ 46} = 1.50$, $p = 0.227$
1999	$F_{1,\ 35} = 8.05$, $p = 0.008$[a]	$F_{1,\ 32} = 0.86$, $p = 0.356$	$F_{1,\ 44} = 2.87$, $p = 0.097$
2000	$F_{1,\ 46} = 2.27$, $p = 0.139$	$F_{1,\ 175} = 1.22$, $p = 0.271$	$F_{1,\ 53} = 0$, $p = 0.944$
2001	$F_{1,\ 83} = 25.63$, $p = 0$[b]	$F_{1,\ 388} = 88.22$, $p = 0$[b]	$F_{1,\ 83} = 9.11$, $p = 0.003$[a]
2002	$F_{1,\ 64} = 1.94$, $p = 0.169$	$F_{1,\ 119} = 6.12$, $p = 0.015$[c]	$F_{1,\ 61} = 27.19$, $p = 0$[b]
2003	$F_{1,\ 91} = 8.47$, $p = 0.005$[a]	$F_{1,\ 186} = 39.02$, $p = 0$[b]	$F_{1,\ 38} = 2.03$, $p = 0.162$

[a]$p < 0.01$.
[b]$p < 0.001$.
[c]$p < 0.05$.

volume of corn consumed in fall 2000 had reached a peak of 23,901 kg and coincided with a 5-year low number of acorns per sample at our Calder Center study site. This was followed in 2001 by a reversal in which record acorn density for the 5-year period (1997–2001) accompanied a decline of nearly 60% in corn consumption. Together, these data suggest an inverse relationship between corn consumption and acorn availability that may have important implications for treatment efficacy. Regional environmental conditions that affect feeder visitation therefore may be expected to impact treatment efficacy in areas with extensive oak deciduous woodland, as is characteristic of much of the eastern United States, and consideration of these events in future control programs utilizing the 4-Poster is discussed by Pound et al., (2009b).

With respect to nymphal control, the reduced efficacy that was observed in 2002 did not actually represent higher densities at the treatment site that year. In fact, nymphal density in Bedford declined from 0.047 ticks per m^2 in 2001 to 0.024 in 2002, a drop of 49%. Further, this constituted the fourth straight decline in nymphal numbers dating back to 1999, suggesting that the 4-Poster treatment regimen continued to be effective in reducing risk at the Bedford site. The drop in efficacy appears to be due entirely to an unexplained drop in nymphal numbers at the control site in Lewisboro. Thus, while the percentage control that was achieved in 2002 was lower than that in 2001, Bedford residents were no less safe that year than the previous year. A marked increase in efficacy was observed in 2003, up to 80% control, which would be the last year in which treatment effects were expected. Nymphal density changed little in Bedford from 2002 (0.02 nymphs per m^2 in 2003), while 2003 density rose to 0.1 in Lewisboro compared to 0.044 in 2002. Thus, the increased efficacy in 2003 reflects a substantial increase in nymphal density at the control site that did not occur at the treatment site. Annual fluctuations in nymphal abundance are the norm (Daniels et al. 2000), and therefore it is to be expected that percentage control will vary from year-to-year. This underscores the point that accurate evaluations of treatment efficacy at a particular site will rely on sampling untreated control sites as well.

Corn consumption was high throughout the study, even in those seasons when alternate food sources were available. Approximately five tons of corn was used per month to bait the 24 feeders, though this amount is likely to be site dependent, given differences in deer density, size of individuals, climate, and food availability. Even within a site, differences in consumption rates may be observed seasonally. On average, 907 more kg of corn was consumed per month in fall than in spring, no doubt reflecting greater energy demands on deer that accompany reproductive activity and acclimation to colder temperatures in fall. The cost of baiting with corn may vary seasonally, but is likely to remain a significant expense in future 4-Poster programs given the typically high deer densities in suburban and rural areas of the northeast. Modifications to the system, such as the use of acaricides with longer residual that would require less frequent visits to the feeders, could ultimately reduce the cost of baiting.

Efforts to validate corn consumption as an index of deer density were not successful. Aerial snow counts indicated that deer density in Bedford varied slightly over the period 1999–2001, ranging from 21 to 23 deer per km^2, while corn consumption varied not only from spring to fall seasons, but also from year-to-year. Clearly, other environmental conditions influenced feeding rates while deer density remained constant.

However, corn consumption rates did support our contention that supplemental feeding of deer in such a program would not affect local deer density. The belief that feeding deer with bait corn would provide sufficient resources to increase reproduction and/or enhance survival and allow the population to grow, has been a concern of some residents within the treatment area. If this was a problem, some change in deer density, which would track corn consumption, should have been observed. Data from Bedford suggest that such a relationship does not exist. Further, the marked increase in deer density noted between 1999 and 2000 in Lewisboro occurred independently of any project-related feeding, since no feeders or bait corn were used at that site. Studies addressing the effects of supplemental feeding on survival and ranging patterns of white-tailed deer (Lewis and Rongstad 1998, Kilpatrick 2002) have shown little effect and therefore, support this approach using bait to attract and treat deer.

The fact that it generally took 2 weeks before corn consumption was approximately at seasonal norms for each treatment session does not necessarily indicate that deer took up to 2 weeks to find the feeders and reacclimate themselves to using them. Within the first week, corn was being taken from all feeders, suggesting that resident deer had incorporated visits to the feeders into their foraging routines. Thus, it is possible that all deer that would ultimately feed at the 4-Posters were visiting the devices within a week of baiting. The additional volume being taken in the second week of feeding may represent a continuing change in food preference by deer as greater amounts of corn were being added to their diet, up to some maximum. Alternatively, some observational data suggest that fawns may have taken longer to become acclimated to the feeders than did adults that had previous experience with the devices. However, expected differences between spring and fall corn consumption patterns in those first weeks as a result of more fawns in one season (fall) than the other were not observed.

The distribution of ticks on deer, as determined in the fall 1999 darting campaign, did not coincide with published accounts of >80% occurring on the head/neck area (Schmidtmann et al. 1998). Just over 60% of the live ticks recovered from darted deer were on the head/neck area in this study. While this may reflect real differences in attachment site preferences among ticks from different populations, it may also reflect inefficient search and collection procedures while anesthetized live deer are being examined. In the latter case, the treatment protocol should be considered appropriate for treating deer hosting *I. scapularis* since the actual percentage of adult ticks on the head/neck area is likely to be above 80%. Otherwise, fewer ticks will be treated and a reduction or delay in efficacy will be expected. Data collected thus far suggest that our estimate of 60% of ticks on the head/neck region may be an underestimate.

While it is clear that the 4-Poster approach has reduced risk of exposure to *I. scapularis*, further work remains before conclusions can be drawn about its effect on Lyme disease incidence. Clearly, the difficulty that persists in accurately counting Lyme disease cases will impede this evaluation. A more appropriate measure will be the incidence of tick bites obtained in the treated area, and it is expected that this will decline in sites using the 4-Poster for long-enough periods of time to impact tick reproduction.

Acknowledgments

We thank the numerous summer research assistants from 1997 through 2003 who took part in this study. We are indebted to the residents of Bedford and Lewisboro who permitted access to their property for sampling, and especially to the homeowners who allowed us to put 4-Posters on their properties. Their commitment to the study was both necessary and gratifying; without it, this project could not have been conducted. We also thank an anonymous reviewer for helpful comments that improved the article.

This research was supported largely by a USDA-ARS Cooperative Agreement 58-0790-2-072. We are also grateful to researchers at the other four cooperative sites for their role in shaping this study. This article represents contribution no. 218 to the Louis Calder Center.

Disclosure Statement

No competing financial interests exist.

References

Abbott, WS. A method for computing the effectiveness of an insecticide. J Econ Entomol 1925; 18:265–267.

Beringer, JL, Hansen, P, Sexton, O. Detection rates of white-tailed deer with a helicopter over snow. Wildl Soc Bull 1998; 26:24–28.

CDC. Lyme disease—United States, 2000. MMWR 2002; 51:29–31.

CDC. Lyme disease—United States, 2003–2005. MMWR 2007; 56:573–576.

Daniels, TJ, Falco, RC, Fish, D. Estimating population size and drag sampling efficiency for the blacklegged tick (Acari: Ixodidae). J Med Entomol 2000; 37:357–363.

Dister, S, Beck, L, Wood, B, Falco, RC, et al. The use of GIS and remote sensing technologies in a landscape approach to the study of Lyme disease transmission risk. In: Proceedings, GIS'93: Geographic Information Systems in Forestry, Environmental, and Natural Resource Management. Vancouver, Canada, 1993.

Falco, RC, Fish, D. A comparison of methods for sampling the deer tick, *Ixodes dammini*, in a Lyme disease endemic area. Exp Appl Acarol 1992; 14:165–173.

Falco, RC, Smith, HA, Fish, D, Mojica, BA, et al. The distribution of canine exposure to *Borrelia burgdorferi* in a Lyme disease-endemic area. Am J Public Health 1993; 83:1305–1310.

Fish, D. Population ecology of *Ixodes dammini.* In: Ginsberg, H. ed. *Ecology and Management of Lyme Disease*. New Jersey: Rutgers University Press, 1993:25–42.

Kilpatrick, HJ. Effects of temporary bait sites on movements of suburban white-tailed deer. Wildl Soc Bull 2002; 30:760–766.

Koenig, WD, Knops, JMH. Patterns of annual seed production by northern hemisphere trees: a global perspective. Am Nat 2000; 155:59–69.

Lewis, TL, Rongstad, OJ. Effects of supplemental feeding on white-tailed deer, *Odocoileus virginianus*, migration and survival in northern Wisconsin. Can Field-Nat 1998; 112:75–81.

Maupin, GO, Fish, D, Zultowsky, J, Campos, EG, et al. Landscape ecology of Lyme disease in a residential area of Westchester County, NY. Am J Epidemiol 1991; 133:1105–1113.

Pound, JM, Miller, JA, George, JE. The United States Department of Agriculture northeast area-wide tick control project: History and protocol. Vector Borne Zoonot Dis 2009; 9:365–370.

Pound, JM, Miller, JA, George, JE. The United States Department of Agriculture northeast area-wide tick control project: Summary and conclusion. Vector Borne Zoonot Dis 2009; 9:439–448.

Schmidtmann, ET, Carroll, JF, Watson, DW. Attachment-site patterns of adult blacklegged ticks (Acari: Ixodidae) on white-tailed deer and horses. J Med Entomol 1998; 35:59–63.

Sork, VL, Bramble, J, Sexton, O. Ecology of mast-fruiting in three species of North American deciduous oaks. Ecology 1993; 74:528–541.

Stafford, KC III, DeNicola, AJ, Pound, JM, Miller, JA, et al. Topical treatment of white-tailed deer with an acaricide for the control of *Ixodes scapularis* (Acari: Ixodidae) in a Connecticut Lyme borreliosis hyperendemic community. Vector Borne Zoonot Dis 2009; 9:371–379.

Telford, SR III, Mather, TN, Moore, SI, Wilson, ML, et al. Incompetence of deer as reservoirs of the Lyme disease spirochete. Am J Trop Med Hyg 1988; 39:105–109.

Address correspondence to:
Thomas J. Daniels
Vector Ecology Laboratory
Louis Calder Center
Fordham University
P.O. Box 887
53 Whippoorwill Road
Armonk, NY 10504

E-mail: thdaniels@fordham.edu