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ORIGINAL ARTICLE

The Impact of 4-Poster Deer Self-Treatment Devices at Three Locations in Maryland

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Abstract

From 1998–2002 twenty-five deer self-treatment devices (4-Posters), using 2% amitraz, were operated at three locations in Maryland to determine their effectiveness in controlling blacklegged ticks, *Ixodes scapularis* Say, and lone star ticks, *Amblyomma americanum* (L.). Each treatment site was ≈518 ha and paired with a similar site lacking 4-Posters. Locations varied in deer density, tick abundance, and land use. Flagging for host-seeking ticks showed declines in tick populations at all treatment sites compared to control sites by the third year. By 2002, control of *I. scapularis* nymphs attributable to the 4-Poster intervention at the three sites was 69.0%, 75.8%, and 80%. Control of *A. americanum* nymphs at the two sites where they occurred was 99.5% and 95.3%. In 2003, the first posttreatment year, control of *I. scapularis* remained around 2001–2002 levels, but by 2004, an upward trend in nymphal numbers was detectable. Populations of *A. americanum* showed no increase posttreatment. These results demonstrate that control of these tick species is locally possible with 4-Poster intervention.

Key Words: *Amblyomma americanum*—Amitraz—Bait—*Ixodes scapularis*—White-tailed deer.

Introduction

As long ago as the early 1980s, human cases of Lyme disease were reported from Maryland (Schrock 1982), though few specimens of the blacklegged tick, *Ixodes scapularis* Say, the principal vector of the infective agent, had been identified from the state (Coan and Stiller 1986). By the 1990s Lyme disease cases and densities of *I. scapularis* populations in Maryland had increased dramatically (Amerasinghe et al. 1992, 1993). Using geographic information systems, Glass et al. (1995) mapped risk areas in Baltimore County, Maryland. Although the incidence of Lyme disease in Maryland is highest on the upper Eastern Shore (Frank et al. 2002), most cases reported annually are from a band of more populous counties that extends from the northeast corner of Maryland through the suburbs of Washington, DC (Breisch and Thorne 2000). Maryland has consistently been among the top 10 states for reported cases and incidence of Lyme disease in recent years (CDC 2002). Cases of Lyme disease per 100,000 persons (1998 population, Maryland Office of Planning figures) for Anne Arundel, Baltimore, and Prince George's Counties were 10.6, 12.8, and 7.9, respectively. The Baltimore and Prince George's County population figures included densely inhabited inner suburbs (more urbanized and not favorable for deer) of Baltimore City and Washington, DC, which dilute incidence at the county level. Frank et al. (2002) pointed out, that at the county level, Lyme disease risk was not notable for Baltimore County from 1993–1998, but when mapped at zip code level a high incidence of Lyme disease was apparent for the area north of Baltimore City (Loch Raven area).

The 4-Poster device of U.S. Department of Agriculture has been used previously in Maryland to dispense permethrin, and Solberg et al. (2003) reported a high level of control of *I. scapularis* and *Amblyomma americanum* within a fenced study site. Carroll et al. (2003) reported preliminary results of some aspects of the 5-year U.S. Department of Agriculture Northeast Area-wide Tick Control Project in Maryland. The present article presents the complete results of this study, including data on posttreatment tick population levels.

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Materials and Methods

Based on deer and tick abundance, land use, and deer hunting strictures, three areas (Loch Raven [LR], Beltsville Agricultural Research Center [BARC], and Gibson Island [GI]), each 518 ha, were selected as core treatment sites for the evaluation of 4-Poster technology. The treatment site near LR Reservoir, Baltimore County, included watershed property owned by Baltimore City, a golf course, wooded suburban home sites, cornfields, and a gun club. The LR control area was on the opposite side of the reservoir from the treatment area, and also included watershed property, a golf course, a police gun range, and suburban homes. Although hunting was not allowed at the LR treatment or control areas, watershed lands in both areas were heavily poached.

The BARC and GI sites differed from LR in that the former two had managed deer hunting and, in addition to *I. scapularis*, had populations of *A. americanum*. GI had marshlands and a lake, and was somewhat smaller ($\sim$3.1 km^2). The treatment area at BARC, Prince George's County, was extensively wooded and had many fields planted in corn, soybeans, alfalfa, and other agricultural crops. The control area paired with BARC was $\sim$5 km distant, at the North Tract of U.S. Geological Survey Patuxent Wildlife Research Center, which was heavily wooded with maintained meadows and some corn plantings for wildlife. The GI treatment area, Anne Arundel County, was composed of almost the entire island except for some marshland. The paired control area for GI was in and around John Downs Memorial Park, 3.2 km distant on the mainland, to which the island was connected by a gated causeway.

At each treatment area, twenty-five 4-Posters were placed where observations or signs (e.g., well-worn paths) indicated regular deer activity. Full operation of the devices at BARC began in April 1998 after 1 month of baiting without the use of the acaricide. The LR site became operational in May 1998 and GI in June 1998. The devices were operated from late February to the third week of December at BARC and GI. Because there was no *A. americanum* population at LR, operation of the 4-Posters there was suspended June–August with a period of baiting-only in September before acaricide applications resumed the first week of October. Corn bait was replenished weekly or semiweekly for devices that had considerable deer usage. A pour-on formulation of 2% amitraz (Point Guard®; Hoechst-Roussel, Somerville, NJ) was applied to the rollers on the 4-Posters according to the guidelines of the Northeast Area-wide Tick Control Project protocol (Pound et al. 2009). Each 4-Poster was equipped with a magnetic strip on the inside wall of the bin with 5 kg gradations giving the quantity of corn in the bin.

In 1998, deer numbers at BARC and GI, based on counts by wildlife managers and other personnel at these locations, were estimated at 23 and 20 deer/km^2 at the respective treatment areas, and 20 and 10 deer/km^2 at the respective control areas. At LR, the Maryland Department of Natural Resources conducted aerial forward looking infrared (FLIR) surveys in 1996 and 1999. In Zone 2 of the FLIR survey, which largely coincided with the LR treatment area, 38 and 17 deer/km^2 were observed in 1996 and 1999, respectively. In Zone 4, which corresponded roughly with the LR control area, 27 and 15 deer/km^2 were counted in 1996 and 1999, respectively. Our observations and those of local residents and workers, along with corn consumption data, suggest densities of 40–50 deer/km^2 in the treatment area during 1998–2002, and we believe that FLIR counts in Zone 4 were also underestimates.

Deer marking

To ascertain the percentage of deer using the 4-Posters at LR, a marking compound consisting of mineral oil, klerol (Ruger Chemical, Irvington, NJ), and reflective glass elements type B (3M, St. Paul, MN) was applied to all rollers on all the 4-Posters in May and November 2000. The compound was mixed to a consistency slightly thicker than honey at ambient temperatures. On each occasion all acaricide-impregnated rollers were removed from all 4-Posters and replaced with rollers coated with the marking compound. At night on the day following placement of the marking rollers, deer were spotlighted from a vehicle, and the numbers of marked and unmarked deer that were observed were recorded. The acaricide rollers were replaced the next day.

Flag sampling

Host-seeking populations of *I. scapularis* and *A. americanum* nymphs and adults were sampled annually by flagging at LR four times and at BARC and GI three times in late May through June. In each treatment and each control area, 15 sites for sampling were selected that appeared favorable for supporting *I. scapularis* (Ginsberg and Ewing 1989, Sonenshine 1993, Ostfeld et al. 1995, Lubelczyk et al. 2004) yet also captured some of the heterogeneity of each study area. Typically, the sample sites were in mesic, canopied, mixed hardwood forests (some pines present), having understories of shrubs, forbs, vines, and grasses in various combinations of species and densities, underlain with leaf litter. However, at LR about one third of both the treatment and control sample sites were in mature, white pine, *Pinus strobus*, plantations that exploratory flagging in 1997 revealed to have moderate to dense populations of *I. scapularis*. At LR treatment area, suitable tick habitats (hence sample sites) were more peripherally located than at the other locations. A 0.5 by 0.5 m flag of laminated flannel crib cloth was flip-flopped on leaf litter and low vegetation, as the operator walked slowly for 30 s, advancing $\approx$10 m, in a straight line, as obstructions allowed. This subsample was repeated 10 times at each of the sample sites. Ticks captured on the cloth were identified, counted, and returned to the route just flagged. On the last sample date of each year, $\leq$50 nymphs from each site were preserved in 70% isopropyl alcohol for later identification of tick-associated bacterial pathogens as described by Gatewood Hoen et al. (2009).

Adult *I. scapularis* were flagged once each year in November. Because adult *I. scapularis* often quest at greater heights on vegetation than nymphs or larvae, the flag was swept upward from the leaf litter to $\approx$1 m high when higher vegetation was present. Larvae of *I. scapularis* and *A. americanum* were sampled once annually in late July or August. All larvae were removed from the flag cloth after each 30-s walk by pressing a piece of clear tape against the cloth. The pieces of tape were affixed in notebooks, and larvae were identified and counted under magnification in the laboratory. Nymphs were sampled in posttreatment years 2003 and 2004, and *I. scapularis* larvae were sampled in 2004 at LR.

Tick burdens on deer

In November 1998 and 1999, white-tailed deer at LR treatment and control areas were darted, anesthetized, and examined for attached *I. scapularis* adults (Maryland Department of Natural Resources Permit SCO-27823). Deer were darted by rifle by White Buffalo, Inc. (Moodus, CT), and trained Agricultural Research Service personnel, and immobilized with an injection of ketamine and xylazine hydrochloride. Ear tags were attached to the deer before their release to identify deer and inform persons not to eat tagged deer.

At the BARC treatment area, deer presented at the hunter check-in station were examined for adult ticks in November, as were deer brought to the hunter check in station at Patuxent North Tract, its paired control area. Although managed hunting was allowed at GI, the number of deer taken was considered too small to be a representative sample.

Statistical methods

A prefatory explanation is needed to make clear the rationale for and advantages of our statistical treatment of the data collected in this study. The data of interest are counts of ticks at sample sites, each site sampled over many years, and, in the case of nymphs, each site sampled 3–4 times annually in late May–June. Summing such count data over dates and sample sites (within location) yields yearly counts, but those counts would be unlikely to follow a simple Poisson distribution since the sum would also contain site-to-site variation, seasonal effects, and weather effects, in addition to the sampling error associated with a Poisson distribution. Further, investigations of similar data (with [Schulze et al. 2001] and without [Ostfeld et al. 1996, Schulze et al. 2002] 4-Posters) suggest that host-seeking larvae and nymphs commonly occur in clusters and so are overdispersed relative to a Poisson distribution (which assumes individuals are distributed randomly in space). The Poisson distribution underlies many familiar tests of count data (e.g., χ^2) (Bishop et al. 1975). If one of these tests is used on overdispersed Poisson data, the calculated p-values are too small (i.e., the tests are too liberal; see Kramer and Schmidhammer 1992).

Two equivalent formulas often used to express percent control due to treatment are those given by Abbott (1925) and Henderson and Tilton (1955). To derive a statistical test for these expressions requires knowledge of the distribution of the sample counts. The typical distributions used are binomial or Poisson (Finney 1971), the latter often employed for counts in field data, like the data in this study. If the true distribution of the sample counts is overdispersed relative to a Poisson distribution, incorrect p-values would be calculated for reasons described above. If one accepts that the counts come from a distribution that can be modeled as an overdispersed Poisson, then both the mean and variance need to be estimated (in a Poisson distribution, the variance equals the mean). The variance of a quotient of two random variables (e.g., the expressions of Abbott [1925] and Henderson and Tilton [1955] involve quotients of random variables) often can only be approximated, typically with a low-order Taylor's series expansion (see, e.g., Mood et al. 1974). Statistical tests involving a quotient are thus especially sensitive to departures from their underlying assumptions because the accuracy of the test is determined both by how good the approximation is and by the quality of the estimates of the means and variances of the treatment and control distributions (as well as their covariance). Even if one assumes the covariance is zero, variances are typically poorly estimated for field data of this nature (adequate estimates would require at least 30 replicates).

We use a more robust approach, based on the class of mixed linear models, one that allows for seasonal, weather, and site-specific effects. Adjusting for these effects removes "noise" that could otherwise obscure real differences in how tick populations in the control and treatment sites changed over time. The dependent variable (the tick count at one site on 1 day) was square root transformed. Year, treatment, and their interaction were fixed effects, and sample site was a random effect. The model included two sets of covariates, seasonal effects modeled using ordinal day, and day-to-day variation captured using weather variables.

In this model framework, tests of (and contrasts involving) fixed effects are made using F or t statistics. The problem with estimating variances discussed above is resolved by transforming the dependent variable so that the homogeneity of variance assumption is satisfied, in which case only one (residual) variance parameter need be estimated for the whole data set.

Weather variables have been shown to predict *I. scapularis* and *A. americanum* activity (e.g., Clark 1995, Duffy and Campbell 1994, Schulze et al. 2001, Carroll and Kramer 2003). In a preliminary analysis of these data, we found that some previous day weather variables predicted tick nymph counts in some of the locations, so these were included in our models as appropriate. We also included ordinal day effects for nymphs, sometimes interacting with the year effect. This allows for a trend over time (within a sampling season), possibly differing from year to year. We considered site (within location) a random factor. Because sites were visited several times during the sampling period (for nymphs), we allowed for covariances due to this repeated measures aspect. A time series model was used where the magnitude of the covariance depended on how many days separated the samples.

Locations were modeled separately, as were the two tick species, resulting in five models (*A. americanum* was not present at LR) for nymphs. The models for adults and larvae were simpler because these life stages were sampled only once per year. To determine if there was an effect of the 4-Poster treatment, all models included both a treatment effect and a treatment by year interaction effect, the latter because we expected the treatment effect to increase over time, starting from essentially no difference. Due to the 2-year life cycle of these ticks, the year effect was not modeled as a trend (an alternative is to run two models for each location, each offset by a year, and model every other year in each as a trend). Instead, we created linear contrasts to test if the changes in counts in the treatment groups over time were significantly greater than those in the control groups, and in the direction indicating tick populations were decreasing in treated areas. There were five contrasts made for each species–location combination, 1998 with 2000, 2002, and 2004, and 1999 with 2001 and 2003.

Results

In May and November 2000, all rollers of all 4-Posters at LR were coated with reflective marking compound. Counts of unmarked deer and deer marked with reflective compound ≈ 32 h after its application showed that at least 60% of the deer

were using 4-Posters in May 2000 and 70% in November 2000. However, the principal indicator of usage of the 4-Posters by deer was corn consumption. Among the three locations, the quantities of corn consumed from 4-Posters varied considerably (Fig. 1). At GI, deer quickly began feeding from 4-Posters (within 1 month); thereafter, weekly consumption levels changed little. At LR there was upward trend in corn consumption over time (Fig. 1). GI had the lowest weekly consumption totals and LR the greatest. Deer at BARC were the slowest among the sites to adopt using the 4-Posters. At BARC and GI, where 4-Posters were operated through the summer, the greatest corn consumption occurred in June and July, whereas the peak corn consumption at LR was in the fall. At BARC in 1998 and 2000, and to a lesser extent in 1999, corn consumption fell to extremely low levels in September and October. In November 1999, corn consumption rose at BARC, but stayed minimal in 1998 and 2000. However, at GI, only in 1999 was there deeply depressed corn consumption in September and October. Corn consumption from individual devices where deer densities were high at LR sometimes exceeded 150 kg/week, requiring semiweekly replenishment.

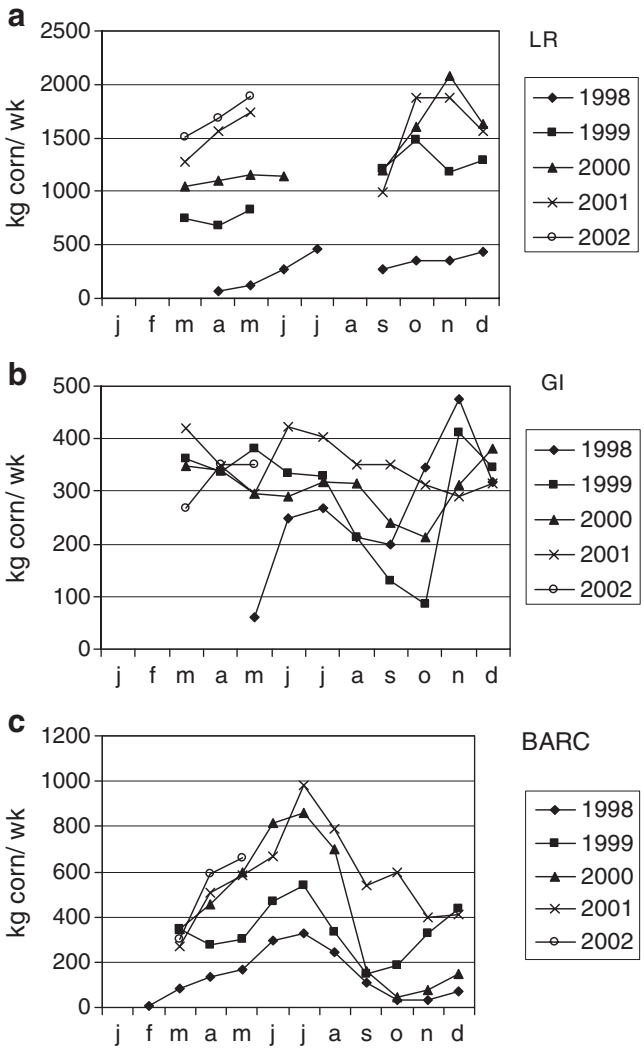

FIG. 1. Mean weekly corn consumption by month at the (**a**) Loch Raven (LR), (**b**) Gibson Island (GI), and (**c**) Beltsville Agricultural Research Center (BARC) sites. Operation of 4-Posters continued through the summer at BARC and GI because of the presence of *Amblyomma americanum*.

The 4-Poster intervention had a major impact on *I. scapularis* and *A. americanum* populations at all three locations. For nymphs at the BARC and GI locations, the fixed part of our models for *I. scapularis* included effects due to year, treatment, year by treatment interaction, and the covariates prior day minimum temperature, prior day average temperature, ordinal day by year interaction, and ordinal day squared. The LR model differed only in the addition of an indicator variable for habitat type, since sampling there was done in wooded areas and in suburban neighborhoods, and counts clearly differed between the habitats. Back-transformed least square means with upper and lower 95% confidence intervals for the different locations, years, and treatments, and at mean values for the covariates are shown in Figure 2. The relatively large decrease in nymph counts in treated areas when compared to control areas is obvious, and substantiated by results from testing contrasts, almost all of which were significant (Table 1). In 2003 and 2004 (posttreatment years), there was slight rebounding of nymphal numbers at treatment sites (Fig. 2). At the LR control area, numbers of *I. scapularis* nymphs fell drastically in 2004.

The model for *A. americanum* nymphs was slightly simpler; the fixed part included year, treatment, year by treatment interaction, and the covariates prior day maximum temperature, and ordinal day, with results summarized in Figure 3. The effect of the 4-Poster treatment was even more dramatic for this species (Table 1). There was no discernible recovery in nymphal numbers in treatment areas in the posttreatment years 2003 and 2004 (Fig. 3).

Results of analyzing other life stages of these species are summarized in Figures 4–7 and in Tables 2 and 3. In general and over time, response to the 4-Poster treatment was similar for all life stages (as it must be, since, other than the presumably small effects due to immigration/emigration we sampled from the same populations at different ages; differences could only result from differential attrition and sampling error).

In 1998, five deer from the LR treatment area and six from its control area were darted and examined for ticks, and in 1999 six deer each from treatment and control areas were examined. There was an average of 19.0 ± 13.0 female *I. scapularis* attached to the deer in the LR treatment area and 6.0 ± 1.6 female ticks attached to control deer (all does) in 1998. The following year 8.0 ± 4.5 females were found attached to deer in the treatment area and 12.5 ± 6.7 females attached to deer from the control area. In 1998, none of the hunter-killed deer examined at BARC were from the treatment area. In 1999, an average of 4.1 ± 1.4 and 16.0 ± 4.7 female *I. scapularis* were attached to deer from the BARC treatment and control areas, respectively ($n = 9$ each area). At BARC in 2000, 10.3 ± 7.2 female ticks were attached to deer ($n = 6$) from the treatment area and 4.4 ± 1.4 females on control deer ($n = 7$). No ticks were found on the only deer (a doe) examined from the BARC treatment area in 2001, whereas 7.6 ± 1.5 female ticks were attached to deer ($n = 5$) from the control area.

Discussion

Corn consumption at BARC and GI, where the 4-Posters were operated through the summer, peaked in June and July.

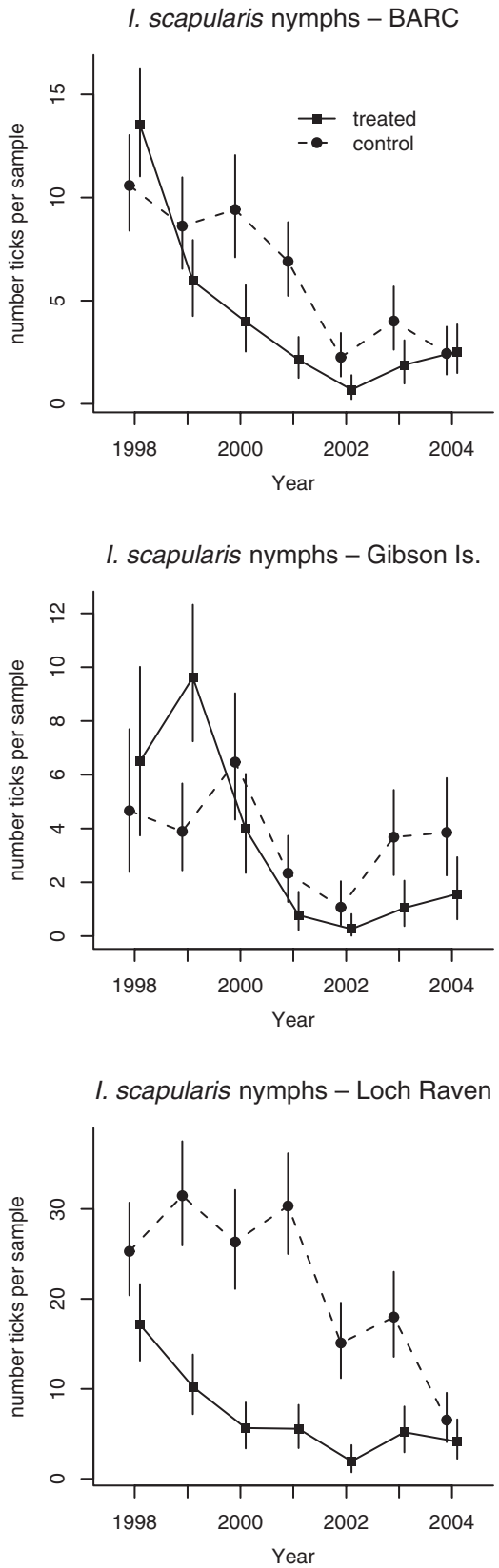

FIG. 2. Mean model estimates and 95% confidence intervals of numbers of *Ixodes scapularis* nymphs captured by flagging at LR, BARC, and GI treatment and control sites, back-transformed to the original scale for easier interpretation. Treatments stopped in 2002.

TABLE 1. TESTING CONTRASTS BETWEEN DENSITIES OF EVEN YEAR NYMPHAL COHORTS AND BETWEEN ODD YEAR NYMPHAL COHORTS REFLECT POPULATION DECREASES IN TREATMENT AREAS

	p-*Values*				
	2000–1998	*2001–1999*	*2002–1998*	*2003–1999*	*2004–1998*
Ixodes scapularis					
LR	<0.0001	0.0518	<0.0001	0.2647	0.3454
BARC	<0.0001	0.0302	<0.0001	0.6605	0.1523
GI	0.0199	<0.0001	0.0278	<0.0001	0.0091
Amblyomma americanum					
BARC	<0.0001	0.1002	0.0025	0.0026	0.0029
GI	<0.0001	0.0032	0.0009	<0.0001	<0.0001

Based on a 2-year life cycle, host-seeking nymphs of a given year were largely the offspring of nymphs seeking hosts 2 years earlier. Treatments stopped in 2002.

LR, Loch Raven; BARC, Beltsville Agricultural Research Center; GI, Gibson Island.

Fawning occurred in May and June, and probably accounted for the increased corn consumption in the late spring–early summer. Increased use of the 4-Posters during this period would expose *A. americanum* adults and nymphs and any *I. scapularis* nymphs and larvae feeding on deer to acaricide treatment. The minimal use of 4-Posters at BARC during three of the four autumns the devices were operated may have been due to the availability of corn and soybeans left in fields to dry for silage and subsequently dislodged during harvest. During the last fall of operation (2001), levels of corn consumption at BARC decreased from a summer peak but did not fall below 400 kg/week. In 1999 a severe drought caused crop failures at BARC, and the decline in corn consumption in the fall was brief. Mast crops may also have contributed to low corn consumption at BARC. At GI, where there were no large fields of agricultural crops, corn consumption was very low in the early fall of 1999. The LR site was heavily forested and contained a few corn fields, but corn consumption was always high. Oaks were not as abundant at LR, as they were at BARC and GI, and the deer density was high. At LR corn consumption tended to increase each year (Fig. 1), which may reflect the growing number of deer and each generation of fawns learning to use 4-Posters.

Based on serological data, ticks submitted by residents and interviews of residents, Armstrong et al. (2001) surmised that bite-induced lesions and a possible involvement of southern-tick-associated-rash illness rather than Lyme disease accounted for the preponderance of tick-related dermal manifestations on GI. They (Armstrong et al. 2001) suggested that GI residents' efforts to avoid *A. americanum* may have helped prevent Lyme disease. Armstrong et al. (2001) reported that of 1556 ticks submitted to them by GI residents 1994–1996, 95% were *A. americanum* and 3% *I. scapularis*. However, for the 2 years before the 4-Poster treatments (1998–1999) seriously affected the populations of host-seeking nymphs, densities of *I. scapularis* nymphs (based on flagging 15 sites on the island) were at least great as those of *A. americanum* (Figs. 2 and 3). As suggested by Armstrong et al.

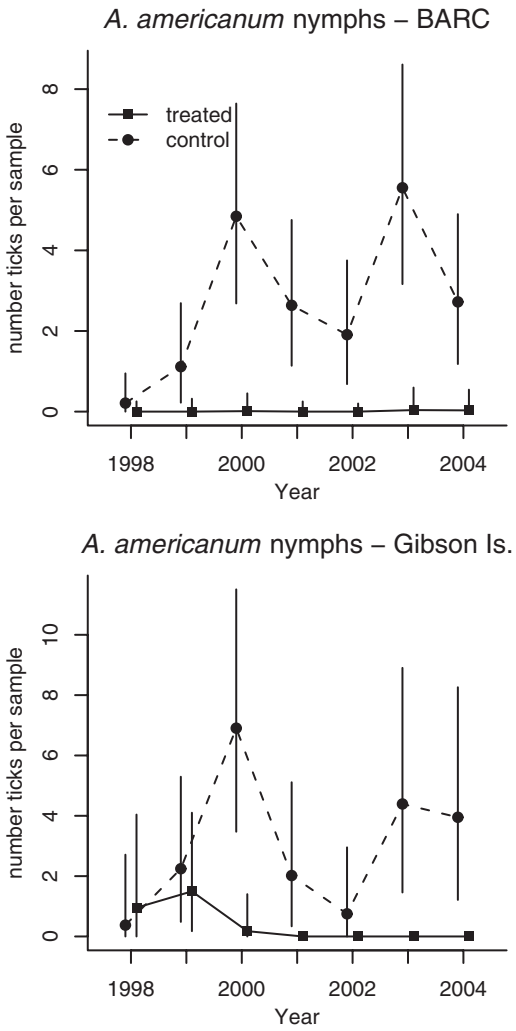

FIG. 3. Mean model estimates and 95% confidence intervals of numbers of *A. americanum* nymphs captured by flagging at BARC and GI treatment and control sites, back-transformed to the original scale for easier interpretation. Treatments stopped in 2002.

(2001), the active host-seeking behavior of *A. americanum* may make it more noticeable to humans. The greater efficacy of the 4-Poster treatments against *A. americanum* than *I. scapularis* observed at GI and possibly at BARC may be due to the use of deer as a major host by all feeding stages of *A. americanum* (Bloemer et al. 1988). Further, in warm weather, when larvae, nymphs, and adults of *A. americanum* are active, deer pelage is not thick. In contrast, most *I. scapularis* adults feed in the fall, winter, and early spring, when a deer's dense winter coat may shield some feeding ticks from topical acaricide treatments.

One interesting feature of the data set is the large variation over years seen in the control data, far outside the changes expected based on the within year 95% confidence limits. This makes the evaluation of the treatment effect more difficult, since one must know how much of the change in counts is due to the treatment (we used matched-population comparison). If the control population counts go to zero, it is not possible to detect a treatment effect. In 2002, at all treatment and control areas at all study locations, densities of both tick species

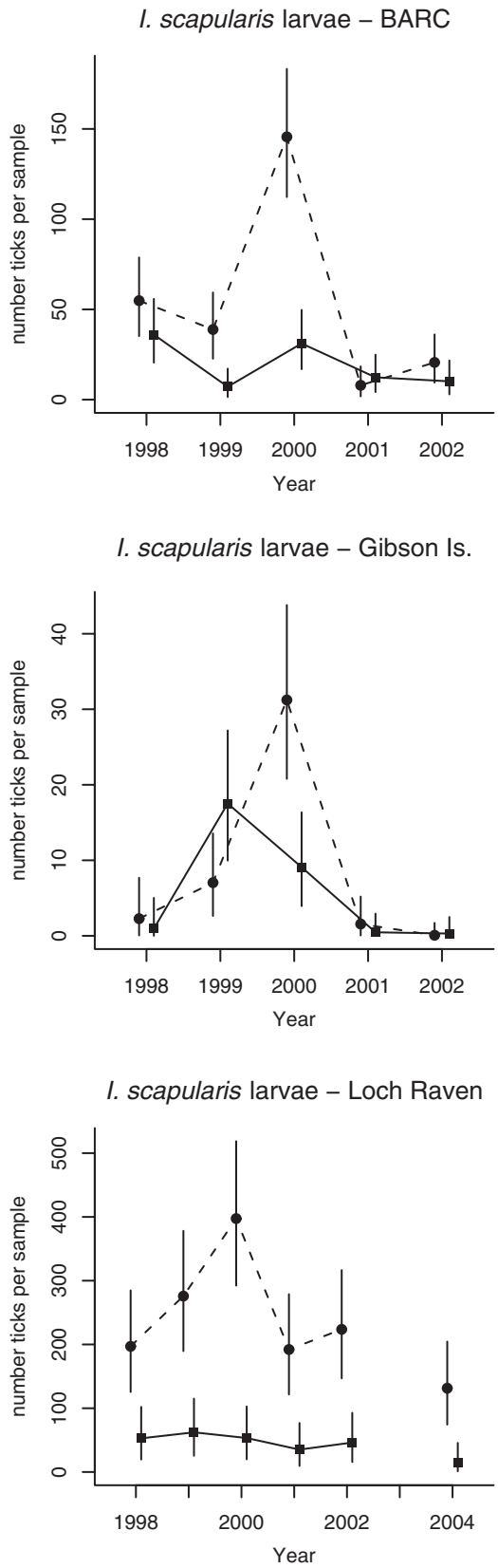

FIG. 4. Mean model estimates and 95% confidence intervals of numbers of *I. scapularis* larvae captured by flagging at LR, BARC, and GI treatment and control sites, back-transformed to the original scale for easier interpretation. Treatments stopped in 2002.

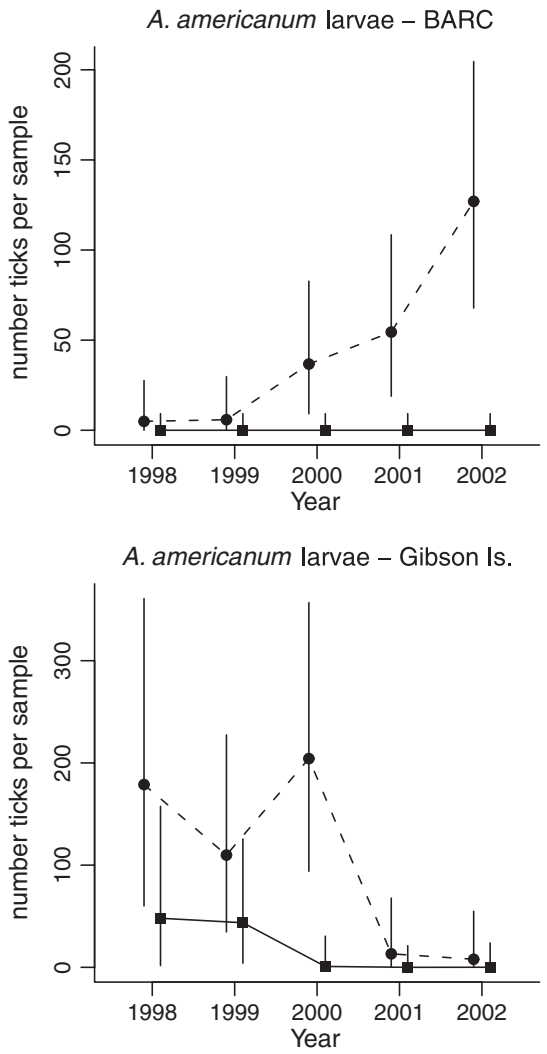

FIG. 5. Mean model estimates and 95% confidence intervals of numbers of *A. americanum* larvae captured by flagging at BARC and GI treatment and control sites, back-transformed to the original scale for easier interpretation. Treatments stopped in 2002.

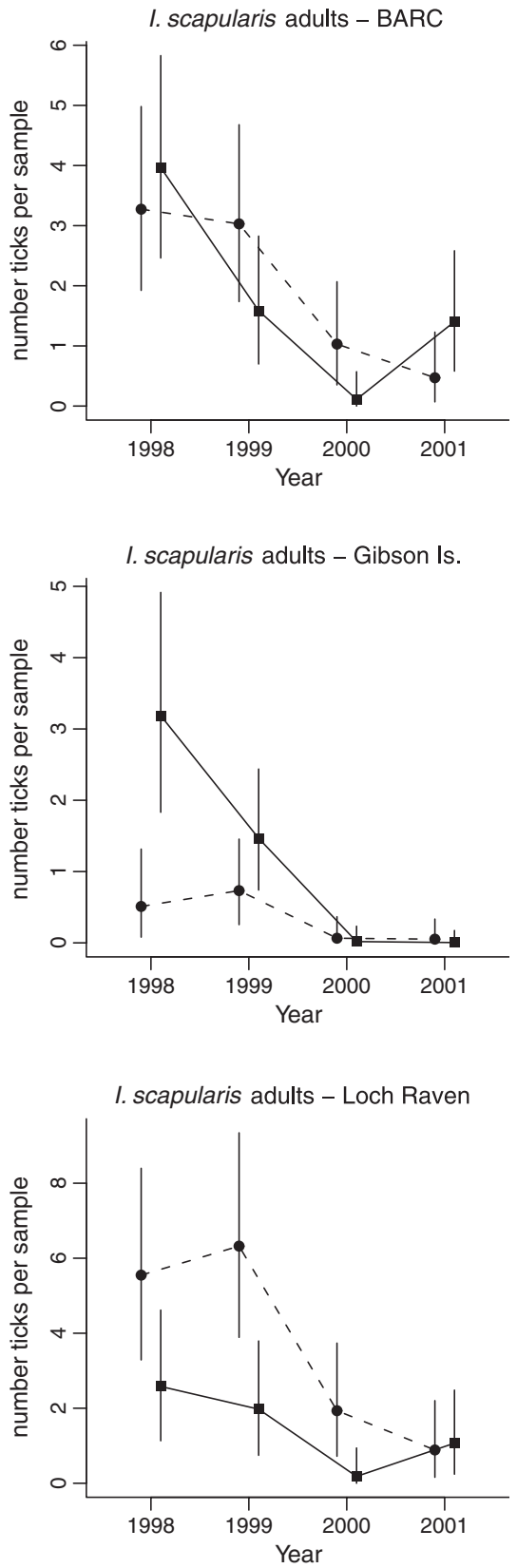

FIG. 6. Mean model estimates and 95% confidence intervals of numbers of *I. scapularis* adults captured by flagging at LR, BARC, and GI treatment and control sites, back-transformed to the original scale for easier interpretation. Treatments stopped in 2002.

declined sharply from 2001 levels. Extreme drought conditions occurred during the summer of 1999 and the fall of 2000. Low humidities are inimical to survival of *I. scapularis* (Stafford 1994), and Jones and Kitron (2000) found that summer drought predicts reduced numbers of *I. scapularis* larvae the following year. In 2002, while nymph densities of both species in treatment areas were 87–95% lower than 1998 levels, the low numbers of ticks in control areas masked the effects of the 4-Poster intervention. In the posttreatment year of 2003, numbers of *I. scapularis* nymphs in treatment areas rebounded slightly from those of 2002 to about 2001 levels, still much reduced from 1997 and 1998. In 2004, *I. scapularis* nymph populations increased slightly again at BARC and GI treatment areas, but declined slightly at LR. Many sample sites at LR were characterized by colonies of the invasive Nepal microstegium (Japanese stilt grass), *Microstegium vimineum* (Trinius) A. Camus (Carroll 2003). During the course of this study, the grass colonies gradually spread and merged until,

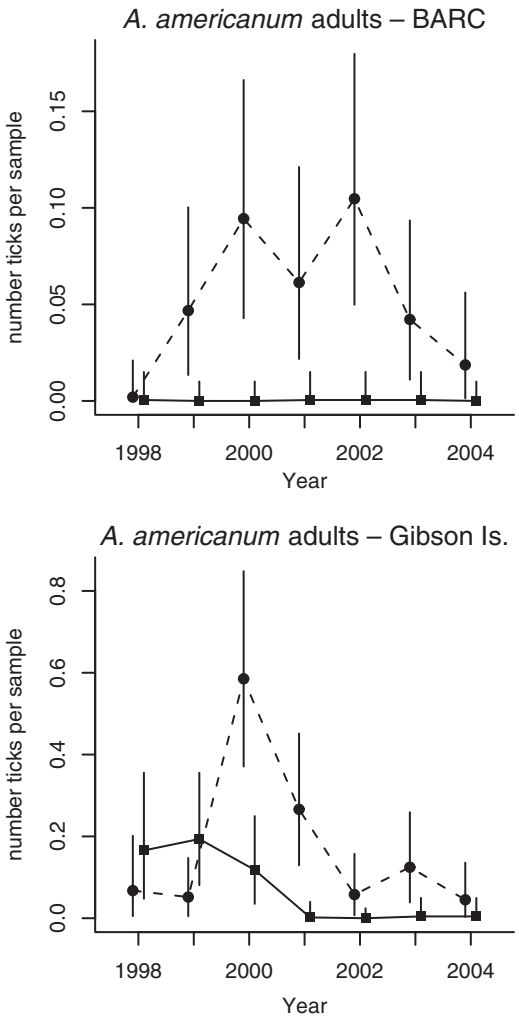

FIG. 7. Mean model estimates of numbers and 95% confidence intervals of *A. americanum* adults captured by flagging at BARC and GI treatment and control sites, back-transformed to the original scale for easier interpretation. Treatments stopped in 2002.

in 2004, several sample sites and surrounding forest floor, particularly in the control area, were nearly completely covered by dense colonies of grass. The grass grew to ≈ 0.3 m high, forming a moisture retentive canopy that remained wet days after a rain and made flag sampling of *I. scapularis* nymphs on the litter layer ineffective. The 2004 decline in LR *I. scapularis* nymphal numbers, particularly steep in the control area, may be attributable at least in part to the effects of *M. vimineum* on sampling effectiveness or unsuitability of dense colonies for *I. scapularis* larvae or nymphs or their hosts. In treatment areas, numbers of *A. americanum* nymphs did not show noticeable increases from their extremely low levels of 2001 and 2002 in the posttreatment years of 2003 and 2004, whereas control numbers rose sharply in 2003 and dropped some in 2004.

Much of the central portion of the LR treatment area was in open expanses (golf course, corn and hay fields, horse pastures, and meadows) that were unsuitable habitat for *I. scapularis*. Consequently, the 4-Posters and flagging sites were located peripherally, though it would have been preferable for the tick sampling sites to have been situated more to the interior surrounded to some degree by 4-Posters. Edge areas may have included intrusions of outlying deer home ranges that lacked 4-Posters. At LR, the sample sites that showed the smallest declines in near the tick numbers were those located near the boundary of the treatment area. The nearest 4-Poster to these sites was used minimally by deer and later relocated to augment another device that was very heavily used. Some deer herds at LR were large (>30 deer), and some 4-Posters required corn and acaricide twice a week. Possibly some deer did not get treated regularly in the large herds, because not all subdominant individuals may have had opportunities to feed at a 4-Poster before the herd moved elsewhere. Estimates of deer density based on FLIR counts in 1996 and particularly 1999 belied the numbers of deer we observed in the LR treatment area and the numbers of deer needed to eat the quantities of corn removed from 4-Poster there. If a 45-kg deer were to eat 0.7–0.9 kg corn/day, somewhat more than Texas deer (Pound et al. 1996), the deer densities at the LR treatment area would be calculated to be 50 deer/km^2 during this study.

Table 2. Testing Contrasts Between Densities of Even Year Larval Cohorts and Between Odd Year Larval Cohorts Reflect Population Decreases in Treatment Areas

	p-*Values*			
	2000–1998	*2001–1999*	*2002–1998*	*2004–1998*
I. scapularis				
LR	0.0086	0.7210	0.5293	0.7251
BARC	0.0006	0.0036	0.9724	
GI	0.0772	0.0427	0.4833	
A. americanum				
BARC	0.2075	0.1043	0.0034	
GI	0.1642	0.9566	0.4299	

Based on a 2-year life cycle, host-seeking larvae of a given year were largely the offspring of larvae seeking hosts 2 years earlier. Treatments stopped in 2002.

Table 3. Testing Contrasts Between Densities of Even Year Adult Cohorts and Between Odd Year Adult Cohorts Reflect Population Decreases in Treatment Areas

	p-*Values*				
	2000–1998	*2001–1999*	*2002–1998*	*2003–1999*	*2004–1998*
I. scapularis					
LR	0.6918	0.0281			
BARC	0.0431	0.0221			
GI	0.0031	0.1440			
A. americanum					
BARC	0.0026	0.9223	0.0032	0.7258	0.2259
GI	0.0006	<0.0001	0.0183	0.0007	0.0744

Based on a 2-year life cycle, host-seeking adults of a given year were largely the offspring of adults seeking hosts 2 years earlier. Treatments stopped in 2002.

Adult *I. scapularis* seek hosts during cooler times of the year, and in Maryland they seek hosts on many days in winter (Carroll and Kramer 2003). Depending on the weather, even in January large numbers of *I. scapularis* can sometimes be captured by flagging. Operation of the 4-Posters was suspended annually in late December and resumed in late February or early March. During these winter hiatuses, many *I. scapularis* adults may have fed on deer and escaped treatment. Possibly these winter-fed adults may account for a large portion of the *I. scapularis* remaining in core treatment areas throughout the study. Using a combination of weather-based and economic models, Carroll and Kramer (2003) found that ad hoc operation of 4-Posters during the winter (i.e., operate the devices only when weather variables favor tick activity) would provide satisfactory control.

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