Ability of 4-Poster Passive Topical Treatment Devices for Deer to Sustain Low Population Levels of *Ixodes scapularis* (Acari: Ixodidae) After Integrated Tick Management in a Residential Landscape

L. SCHULZE,[1,2] ROBERT A. JORDAN,[1,3] MARC C. DOLAN,[4] GABRIELLE DIETRICH,[4] SEAN P. HEALY,[5] AND JOSEPH PIESMAN[4]

J. Med. Entomol. 45(5): 899–904 (2008)

ABSTRACT In a recent study, the combined use of 4-Posters and Maxforce TMS bait boxes along with a barrier application of deltamethrin resulted in accelerated control of *Ixodes scapularis* Say by sequentially attacking each postembryonic life stage. We report the results of a follow-up study to test the ability of 4-Posters used alone to sustain the high levels of control achieved through the integrated tick management (ITM) approach after withdrawal of the bait boxes. In the first year after withdrawal, we observed declines in the level of control of larvae on small mammals, as well as of numbers of host-seeking larvae in the treatment area. There was no difference in the level of control of host-seeking adults in the treatment area after 2 yr. Within 2 yr, we observed a decline in control of subadult ticks infesting small mammals, but continued to see significant control of both host-seeking nymphs (85.9%) and larvae (89.0%) in the treatment area. The inconsistency that we observed between the apparent ability of 4-Posters to sustain high levels of control of host-seeking ticks, although having less effect on tick burdens on small mammal hosts, may be explained by the host-seeking ecology of immature *I. scapularis*.

KEY WORDS *Ixodes scapularis*, control, 4-Poster

A host-targeted approach to controlling *Ixodes scapularis* Say, the principal tick vector of the agents causing Lyme disease, human granulocytic anaplasmosis, and human babesiois, offers an attractive alternative to conventional habitat-targeted acaricide applications. In the northeast, the 4-Poster topical treatment device (USDA, Kerrville, TX) (targeted at deer) and Maxforce Tick Management System (TMS) bait boxes (Bayer Environmental Science, Montvale, ND) (targeted at rodents) have been used independently to control adult and subadult *I. scapularis*, respectively (Solberg et al. 2003, Dolan et al. 2004). However, because each technology targets only specific life stages within the 2-yr life cycle of *I. scapularis*, significant reduction in tick abundance may not be achieved until months or years after deployment. In a recent study, the sequential deployments of 4-Posters and Maxforce TMS bait boxes along with a barrier application of deltamethrin resulted in accelerated control of *I. scapularis* by targeting each postembryonic life stage (Schulze et al. 2007). This integrated tick management (ITM) approach led to 1-mo, 1-yr, and 2-yr postdeployment reductions of 92.7, 92.2, and 98.3%, respectively, of nymphal tick burdens on small mammals and 86.6 and 94.3% reduction in host-seeking nymphs after 1 and 2 yr.

Although an effective and environmentally sensitive approach, the commitment in resources needed for a community-wide integrated host-targeted tick control program may not be sustainable. For example, Schulze et al. (2007) reported that, under current manufacturer recommendations, the cost of the required two deployments of Maxforce TMS bait boxes per year was estimated to exceed \$2,000/ha, the approximate size of each property at the study site. In contrast, the annual cost of two typical 8-wk deployments of 4-Posters at the recommended deployment density of one 4-Poster/20 ha was estimated to be approximately \$80/ha (Solberg et al. 2003).

Because of the wide disparity in costs, we conducted a follow-up study to test the ability of 4-Posters used alone to sustain the high levels of control achieved through the ITM approach after withdrawal of the Maxforce TMS bait boxes.

Materials and Methods

Study Area. An ~66-ha residential community comprised of 48 single-family homes and 3 undeveloped

[1] Freehold Area Health Department, Municipal Plaza, Schanck Road, Freehold, NJ 07728.
[2] Terry L. Schulze, Inc., 9 Evergreen Court, Perrineville, NJ 08535.
[3] Corresponding author: 23 Running Brook Dr., Perrineville, NJ 08535 (e-mail: rajordanphd@msn.com).
[4] Bacterial Diseases Branch, Division of Vector-Borne Infectious Diseases, Centers for Disease Control and Prevention, Mail Stop P-02, 3150 Rampart Rd., Fort Collins CO 80521.
[5] Monmouth County Mosquito Extermination Commission, Wayside Rd., Tinton Falls, NJ 07724.

0022-2585/08/0899–0904\$04.00/0 © 2008 Entomological Society of America

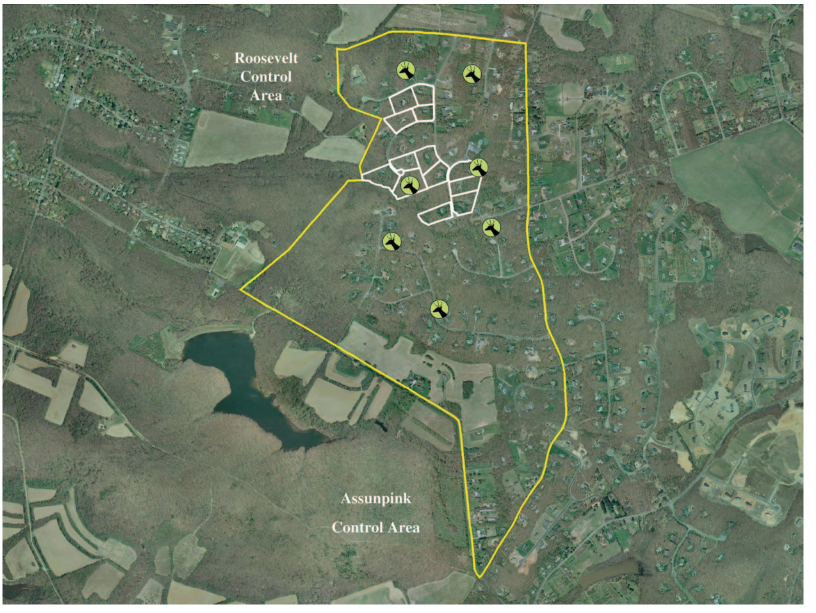

Fig. 1. Aerial photograph of the Millstone Township, NJ, study area showing locations of the bait box deployment sites (highlighted lots), locations of the 4-Poster devices (deer head symbols) and the untreated control area.

lots in Millstone Township, Monmouth County, NJ, served as the treatment area. Portions of nearby Assunpink Wildlife Management Area (WMA) located ~600 m from the treatment area and the adjacent Borough of Roosevelt served as the untreated control sites. Earlier studies conducted throughout this oak-dominated area showed *I. scapularis* populations to be statistically similar (Schulze et al. 1994, 2001, 2005a, b, 2007, Schulze and Jordan 1995).

4-Poster Deployment and Maintenance. Beginning in fall 2003, we deployed four 4-Posters distributed across the community as part of an integrated, host-targeted tick control program. Deployment site selection was based on observed deer activity, willingness of residents to host 4-Posters, and uniformity of spacing between devices to achieve a minimum density of one 4-Poster/20 ha. Three additional devices were deployed in a similar manner within an adjacent community located south of the study area to minimize the likelihood that deer from untreated properties would be drawn into the treatment area by bait corn. Where possible, 4-Posters were placed adjacent to wooded margins of the properties to facilitate routine maintenance, including the weekly or semiweekly provision of recleaned, whole kernel corn bait and recharging of acaricide applicator rollers with 2% amitraz (N′-(2,4-dimethylphenyl)-N-[[2,4-dimethylphenyl) imino]methyl]-N-methylmethanimidamide; Point-Guard; Hoechst Roussel Vet, Warren, NJ) at a weekly application rate of 40 ml Point-Guard/roller (160 ml Point-Guard/4-Poster). A second application at the same rate was made 3–4 d later to all 4-Posters exhibiting weekly corn consumption of ≥41 kg. The maximum weekly dosage for heavily used 4-Posters during the study was 80 ml Point-Guard/roller (320 ml Point-Guard/4-Poster). The 4-Posters were operated each fall between mid-October and mid-December and each spring during March and April, depending on weather conditions and observed tick activity. After four individual deployments of 350 bait boxes on 13 properties during spring and summer 2004 and 2005, use of the Maxforce TMS was terminated, whereas 4-Poster use continued through spring 2007.

Tick Collections. To assess the effectiveness of the 4-Posters to sustain low tick population levels within the community, we monitored burdens of subadult *I. scapularis* on live-captured small mammals and abundance of host-seeking larvae, nymphs, and adults from the treatment and untreated control areas. Small mammals were trapped using Sherman (7.6 by 8.9 by 30.5 cm) nonfolding box traps (H.B. Sherman, Tallahassee, FL) baited with cotton balls and rolled oats. Nymphal and larval tick burden data were obtained from single trapping events in June and August, the peak activity periods of *I. scapularis* nymphs and larvae, respectively (Schulze et al. 1986, 2005b). During each 2-d trapping event, 200 traps were set in both the treatment and control areas for 2 consecutive d. All traps were deployed by mid-afternoon and checked by mid-morning on the following day. Captured rodents were anesthetized with isoflurane or ethyl ether, examined for ticks, individually marked, allowed to recover from the anesthesia, and released at the point of capture. Tick burden data from small mammals recaptured on the second day were not collected.

We monitored numbers of host-seeking *I. scapularis* at 50 plots established among 13 properties in the treated area and at 20 plots located at the control sites (Fig. 1). Each of these 100-m^2 plots was placed in areas with patchy shrub layers to facilitate collection of

Table 1. Summary of corn consumption and Point-Guard applications, Millstone Township, NJ, 2005–2007

Deployment dates	Community	Weeks operational	Corn consumption (kg)		Point-Guard applied (liters)	
			Total	Weekly mean ± SE	Total	Weekly mean ± SE
20 Oct. to 8 Dec. 2005	Treatment	7	1090.5	155.8 ± 18.7	6.88	0.98 ± 0.09
	Adjacent	7	570.5	81.5 ± 6.2	4.48	0.64 ± 0.05
7 March to 27 April 2006	Treatment	7	1436.5	205.2 ± 9.9	8.32	1.19 ± 0.05
	Adjacent	7	784.2	112.0 ± 3.0	5.44	0.78 ± 0.02
13 Oct. to 22 Dec. 2006	Treatment	10	2113.8	211.4 ± 11.4	12.00	1.20 ± 0.04
	Adjacent	10	1154.7	115.5 ± 2.4	7.84	0.78 ± 0.02
12 March to 30 April 2007	Treatment	7	1586.5	226.6 ± 10.2	8.80	1.26 ± 0.02
	Adjacent	7	784.2	112.0 ± 1.4	5.60	0.80 ± 0.01

subadult ticks. A similar number of 100-m transects was established nearby in areas with denser shrub layers more likely to yield adult ticks. All stages of questing *I. scapularis* were collected using a combination of walking surveys and drag sampling (Ginsberg and Ewing 1989) to minimize biases of the individual sampling methods and those resulting from differences in questing behavior exhibited by developmental stage (Schulze et al. 1997). Treated properties and untreated control sites were sampled once during each of the peak activity periods of *I. scapularis* larvae, nymphs, and adults (Schulze et al. 1986). Adults were sampled in late October to early November, whereas nymphs and larvae were sampled in June and August, respectively. Ticks adhering to investigators' clothing and drags were removed at 20-m intervals (Schulze and Jordan 2001) and identified to species and stage.

Statistical Analysis. Differences in log-transformed numbers of subadult *I. scapularis* infesting captured small mammals were compared between trapping periods using separate one-way analysis of variance (ANOVA) for treatment and control areas, with Tukey's honest significant difference tests used for post hoc comparisons (Sokal and Rohlf 1981). We used Kruskal-Wallis tests to compare numbers of questing *I. scapularis* means between years. Separate tests were used for each stage and at control and treatment areas. Post hoc comparisons of mean ranks were performed following Siegel and Castellan (1988). An algebraic variation of Henderson's formula was used to calculate percentage control of ticks: percent control = 100 – (T/U × 100), where T and U are the mean after treatment/mean before treatment in treated plots and untreated plots, respectively (Henderson and Tilton 1955, Mount et al. 1976). All data are presented as untransformed means. All statistical tests were performed using Statistica analysis packages (StatSoft 2005).

Results

4-Poster Deployment and Maintenance. Mean weekly corn consumption and Point-Guard use did not differ among the 4-Poster deployments between fall 2005 and spring 2007 (Kruskal-Wallis tests: $H_{(3,62)} = 7.75$; $P = 0.07$ and $H_{(3,62)} = 7.56$; $P = 0.06$ for corn and acaricide, respectively), suggesting consistent use of the 4-Posters by deer over the course of the study (Table 1). Mean weekly corn consumption after withdrawal of the bait boxes (mean = 199.0 ± 14.9 [SE] kg) did not differ significantly from consumption during the concurrent deployment of both 4-Posters and Maxforce TMS (mean = 247.0 ± 5.2 kg; sign test, $P = 0.13$) (Schulze et al. 2007), indicating that treatment of deer was consistent between periods and that any difference in observed tick abundance was not the result of significant changes in deer use of the 4-Posters. Within the treatment area, weekly corn consumption varied among the four deployment sites from 31.8 to 72.7 kg, whereas in the adjacent buffer area, consumption ranged between 13.6 and 47.7 kg.

Tick Burdens on Rodents. After deployment of the 4-Posters in concert with bait boxes for 2 consecutive yr (2004–2005), subadult tick burdens on small mammals were significantly reduced at treated properties, suggesting >90% control of nymphal and larval ticks (Schulze et al. 2007) (Table 2). Bait boxes were withdrawn in August 2005. We expected to see any effects of the continuing use of 4-Posters reflected in larval burdens during August 2006 and 2007 and in nymphal burdens in June 2007. Nymphal tick burdens in the treatment area remained suppressed in 2006, reflecting control of larvae in the previous year (Table 2). However, mean larval burden at the treatment area in 2006 was significantly higher than that observed in 2005 before the withdrawal of the bait boxes, whereas larval burdens at the control sites did not differ between years. Mean 2007 nymphal burdens at the treatment site were significantly higher than burdens in 2006, whereas nymphal burdens at the control area declined significantly during the same period. In 2007, the mean larval tick burden in the treatment area did not differ from that observed in 2006, whereas the mean in the control area was significantly lower compared with 2006. The observed control of larvae infesting small mammals declined from 99.3% in 2005 to ≈60% in 2006 and ≈40% in 2007. Control of nymphs infesting small mammals exceeded 98% in 2006 but essentially ceased within 2 yr of withdrawing the bait boxes.

Host-seeking Ticks. The combined use of 4-Posters and bait boxes for 2 consecutive yr (2004–2005) seemed to provide 94.3% control of host-seeking nymphs over 3 yr and 90.6% control of host-seeking larvae over 2 yr. Similarly, numbers of host-seeking adults in the fall

Table 2. Subadult *I. scapularis* burdens (mean ± SE) on live-captured *P. leucopus* and *T. striatus* at Millstone Township, NJ treatment and control sites, 2003–2007

	Preintervention 2003		Pos-intervention 2005		2006		2007		ANOVA results[a]
	n	Burden	*n*	Burden	*n*	Burden	*n*	Burden	
Nymphs									
Control	25	1.5 ± 0.4 a	22	3.5 ± 0.7 b	31	4.1 ± 0.5 b	44	1.6 ± 0.5 a	$F_{(3,118)} = 6.33; P < 0.01$
Treatment	29	2.2 ± 0.5 a	40	0.4 ± 0.1 c (92.2%)[b]	76	0.1 ± 0.1 c (98.3%)	61	3.2 ± 0.7 a	$F_{(3,202)} = 12.41; P < 0.01$
Larvae									
Control	32	3.0 ± 0.6 a	34	5.9 ± 0.8 b	25	5.2 ± 0.7 b	24	2.9 ± 1.1 a	$F_{(3,111)} = 3.65; P = 0.01$
Treatment	52	2.9 ± 0.4 a	45	0.04 ± 0.03 b (99.3%)	39	2.0 ± 0.5 a (60.2%)	12	1.7 ± 0.8 a,b (39.4%)	$F_{(3,144)} = 10.79; P < 0.01$

[a] Means in the same row followed by the same letter are not significantly different (Tukey HSD).
[b] Represents percent control (modified Henderson's equation).

showed significant declines in all years, representing an 87.3% level of control (Schulze et al. 2007) (Table 3). In 2006, the abundance of host-seeking *I. scapularis* larvae in the treatment area was significantly greater than that observed before withdrawal of bait boxes in 2005, whereas numbers of questing larvae at the control sites did not differ between years. Numbers of host-seeking adults in the treatment and control areas were similar in both years. In 2007, nymphal abundance in the treatment area was similar to that observed in 2006, whereas numbers of host-seeking nymphs in the control area were significantly lower. The apparent level of larval control declined from 90.6% in 2005 to 74.3% in 2006 but rose to 89.0% in 2007, reflecting an increase in larval numbers in the control plots. During the same period, the level of control of adults remained similar (87.3% in 2005 and 89.5% in 2006), whereas the level of control of host-seeking nymphs in 2007 (85.9%) declined slightly from a high of 94.3% in 2006.

Discussion

Measured corn consumption at the 4-Poster devices during fall 2005 through spring 2007 suggested that deer were receiving acaricide treatment at a rate similar to that observed before withdrawal of bait boxes (Schulze et al. 2007). Consequently, we expected that any contribution of the 4-Poster to the observed reduction in *I. scapularis* abundance to be similar during both periods.

Both the 4-Poster and MaxForce TMS are designed to control specific life stages of *I. scapularis* and have shown direct and cumulative effects on tick populations. For example, a 2-yr deployment of bait boxes against nymphs and larvae seemed to significantly reduce tick burdens on small mammals, leading in turn to declines in abundance of host-seeking adults and nymphs in the subsequent fall and spring, respectively. Also, deployments of 4-Posters presumably resulted in reductions of adult tick burdens on deer, and we observed a decline in host-seeking larvae in subsequent years (Schulze et al. 2007). The abundance of host-seeking ticks on treatment area plots declined each year, suggesting that the effects were cumulative. After the withdrawal of bait boxes after the 2005 larval activity period, we expected that the only effect from the continued deployment of 4-Posters from fall 2005 forward should have been directly against adult burdens on deer and indirectly against larval populations in subsequent years (control of 2005 adults on deer would reduce larval populations in 2006 and control of adult burdens in 2006 would impact 2007 larvae). Any cumulative effects might be observed in numbers of nymphs and adults during the second year.

Table 3. Summary of host-seeking *I. scapularis* (mean ± SE) at the Millstone Township, NJ treatment and control study sites, 2003–2007

Location	Preintervention 2003	Postintervention 2005	2006	2007	Kruskal-Wallis test[a]
Nymphs					
Control	1.7 ± 0.5	3.4 ± 0.8	10.1 ± 2.1 a	5.3 ± 0.8	$H_{(2,70)} = 15.71; P < 0.01$
Treatment	4.1 ± 0.4 a	1.1 ± 0.4 (86.6%)[b]	1.4 ± 0.4 (94.3%)	1.8 ± 0.2 (85.9%)	$H_{(3,148)} = 28.51; P < 0.01$
Larvae					
Control	68.8 ± 32.5 a	197.4 ± 40.1 b	137.1 ± 26.9 a,b	143.6 ± 21.8 b	$H_{(3,70)} = 8.92; P = 0.03$
Treatment	124.3 ± 34.2 a	33.6 ± 10.1 b (90.6%)	63.6 ± 12.5 a,b (74.3%)	28.5 ± 5.9 b (89.0%)	$H_{(3,170)} = 13.96; P < 0.01$
Adults					
Control	6.0 ± 1.1	7.9 ± 1.7	5.7 ± 0.8		$H_{(3,60)} = 0.34; P = 0.95$
Treatment	3.0 ± 0.5 a	0.5 ± 0.2 (87.3%)	0.3 ± 0.2 (89.5%)		$H_{(3,70)} = 27.02; P < 0.01$

[a] Means in the same row followed by the same letter are not significantly different.
[b] Represents percent control (modified Henderson's equation).

However, in the first year after withdrawal of the bait boxes, and despite the continued deployment of 4-Posters in fall 2005 and spring 2006, we observed increased larval burdens on small mammals and increased numbers of host-seeking larvae in the treatment area. Numbers of host-seeking adults continued to be suppressed in the treatment area between 2005 and 2006. By spring 2007, we observed increased nymphal burdens on small mammals, but continued to see significant control (85.9%) of host-seeking nymphs in the treatment site. After the fall 2006 and spring 2007 deployments of 4-Posters, we observed no change in larval burdens on small mammals but an increase in the apparent level of control of host-seeking larvae (89.0%) during summer 2007.

This disparity between small mammal tick burdens and numbers of host-seeking ticks makes it difficult to draw any firm conclusion regarding the ability of the 4-Posters used alone to sustain the high levels of control achieved through the combined use of bait boxes and 4-Posters (Schulze et al. 2007). Although an earlier New Jersey study involving a 5-yr deployment of 4-Posters (Schulze and Jordan 2006) yielded 82.7, 77.3, and 94.2% control of host-seeking *I. scapularis* larvae, nymphs, and adults, respectively, that were similar to the results found in this study, no corresponding data on small mammal tick burdens were collected. However, Solberg et al. (2003) reported 70–95% reductions of subadult tick burdens on mice during a 3-yr deployment of 4-Posters in Maryland. The inconsistency that we observed between numbers of host-seeking nymphs and nymphal burdens on small mammals might be explained by activity of immature *I. scapularis* within the nests of some small mammal hosts. Previous research suggests that larvae acquired by rodents outside the nest may feed to repletion, detach, molt to nymphs, and reacquire a host, all without ever leaving the host nest (Mather and Spielman 1986, Matuschka et al. 1991). Although deployment of the Maxforce TMS apparently interrupts this nest-associated cycle (Schulze et al. 2007), tick burdens might be expected to rebound quickly after withdrawal of the bait boxes, as subadult ticks again become concentrated within rodent nests. If true, this intranest cycle may effectively amplify tick burdens, resulting in the observed discrepancy between nymphal burdens and the apparent numbers of questing nymphs as estimated by drag sampling and walking surveys. Nevertheless, because reductions in populations of host-seeking ticks may be a more important metric for evaluating the risk of human-tick encounters and, thus, disease transmission, these data suggest that the 4-Posters were able to sustain suppression of *I. scapularis* populations, although not at the level achieved by the combined use of both 4-Posters and bait boxes.

Results of this and a previous study (Schulze et al. 2007) showed that host-targeted approaches to tick control, particularly when used in concert, offer the promise of effectively reducing local tick populations while substantially reducing the amount of acaricides introduced into the environment by traditional habitat-targeted methods. However, we caution that our result, while promising, should be interpreted within its context and that the effective suppression of tick populations we observed in a single residential community, in a particular forest type, must be duplicated by more comprehensive, replicated studies conducted in different habitats to confirm the efficacy of host-targeted tick management. Nevertheless, our conclusions suggest that a host-targeted approach to tick control offers an alternative for health officials, managers of public lands, and the pest control community in response to the mounting threat of tick-borne diseases.

Acknowledgments

The authors thank the Millstone Township Committee and the participating residents for support. This work was supported by Cooperative Agreement U50/CCU219564-03,04 between the New Jersey Department of Health and Senior Services and the Centers for Disease Control and Prevention.

References Cited

Dolan, M. C., G. O. Maupin, B. S. Schneider, C. Denatale, N. Hamon, C. Cole, N. S. Zeidner, and K. C. Stafford III. 2004. Control of immature *Ixodes scapularis* (Acari: Ixodidae) on rodent reservoirs of *Borrelia burgdorferi* in a residential community of southeastern Connecticut. J. Med. Entomol. 41: 1043–1054.

Ginsberg, H. S., and C. P. Ewing. 1989. Comparison of flagging, walking, trapping, and collecting ticks from hosts as sampling methods for northern deer ticks, *Ixodes dammini*, and lone star ticks, *Amblyomma americanum* (Acari: Ixodidae). Exp. Appl. Acarol. 7: 313–322.

Henderson, C. F., and E. W. Tilton. 1955. Tests with acaricides against the brown wheat mite. J. Econ. Entomol. 48: 157–161.

Mather, T. N., and A. Spielman. 1986. Diurnal detachment of immature deer ticks (*Ixodes dammini*) from nocturnal hosts. Am. J. Trop. Med. Hyg. 35: 182–186.

Matuschka, F., D. Richter, and A. Spielman. 1991. Differential detachment from resting hosts of replete larval and nymphal *Ixodes* ticks. J. Parisitol. 77: 341–345.

Mount, G. A., R. H. Grothaus, J. T. Reed, and K. F. Baldwin. 1976. *Amblyomma americanum:* area control with granules or concentrated sprays of diazinon, propoxur, and chlorpyrifos. J. Econ. Entomol. 69: 257–259.

Schulze, T. L., and R. A. Jordan. 1995. Potential influence of leaf litter depth on effectiveness of granular carbaryl against subadult *Ixodes scapularis* (Acari: Ixodidae). J. Med. Entomol. 32: 205–208.

Schulze, T. L., and R. A. Jordan. 2001. Effects of habitat structure on the retention of *Ixodes scapularis* and *Amblyomma americanum* (Acari: Ixodidae) adults during drag sampling surveys. J. Med. Entomol. 38: 606–608.

Schulze, T. L., and R. A. Jordan. 2006. Assessment and management of vector tick populations in New Jersey: a guide for pest management professionals, land managers, and public health officials. Freehold Township Health Department, Freehold, NJ.

Schulze, T. L., G. S. Bowen, M. F. Lakat, W. E. Parkin, and J. K. Shisler. 1986. Seasonal abundance and host utilization of *Ixodes dammini* (Acari: Ixodidae) and other ixodid ticks from an endemic Lyme disease focus in New Jersey, USA. J. Med. Entomol. 23: 105–109.

Schulze, T. L., R. A. Jordan, L. M. Vasvary, M. S. Chomsky, D. C. Shaw, M. A. Meddis, R. C. Taylor, and J. Piesman. 1994. Suppression of *Ixodes scapularis* (Acari: Ixodidae) nymphs in a large residential community. J. Med. Entomol. 31: 206–211.

Schulze, T. L., R. A. Jordan, and R. W. Hung. 1997. Biases associated with several sampling methods used to estimate the abundance of *Ixodes scapularis* and *Amblyomma americanum* (Acari: Ixodidae). J. Med. Entomol. 34: 615–623.

Schulze, T. L., R. A. Jordan, R. W. Hung, R. C. Taylor, D. Markowski, and M. S. Chomsky. 2001. Efficacy of granular deltamethrin against *Ixodes scapularis* and *Amblyomma americanum* (Acari: Ixodidae) nymphs. J. Med. Entomol. 38: 344–346.

Schulze, T. L., R. A. Jordan, and A. J. Krivenko. 2005a. Effects of barrier application of granular deltamethrin on subadult *Ixodes scapularis* (Acari: Ixodidae) and nontarget forest floor arthropods. J. Econ. Entomol. 98: 976–981.

Schulze, T. L., R. A. Jordan, and C. J. Schulze. 2005b. Host associations of *Ixodes scapularis* (Acari: Ixodidae) in residential and natural settings in a Lyme disease endemic area in New Jersey. J. Med. Entomol. 42: 966–973.

Schulze, T. L., R. A. Jordan, C. J. Schulze, S. P. Healy, M. B. Jahn, and J. Piesman. 2007. Integrated use of 4-Poster passive topical treatment devices for deer, targeted acaricide application, and Maxforce TMS bait boxes to rapidly suppress populations of *Ixodes scapularis* (Acari: Ixodidae) in a residential landscape. J. Med. Entomol. 44: 830–839.

Siegel, S., and N. J. Castellan. 1988. Nonparametric statistics for the behavioral sciences, 2nd ed. McGraw-Hill, New York.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry. Freeman, New York.

Solberg, V. B., J. A. Miller, T. Hadfield, R. Burge, J. M. Schech, and J. M. Pound. 2003. Control of *Ixodes scapularis* (Acari: Ixodidae) with topical self-application of permethrin by white-tailed deer inhabiting NASA, Beltsville, Maryland. J. Vector Ecol. 28: 117–134.

StatSoft. 2005. STATISTICA, release 7, user's manual. StatSoft, Tulsa, OK.

Received 12 October 2007; accepted 20 March 2008.