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Research article



# Evaluation of the SELECT Tick Control System (TCS), a Host-Targeted Bait Box, to Reduce Exposure to *Ixodes scapularis* (Acari: Ixodidae) in a Lyme Disease Endemic Area of New Jersey

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## Abstract

We describe a 2-yr trial to evaluate the ability of SELECT Tick Control System (TCS) host-targeted bait boxes to reduce numbers of host-seeking *Ixodes scapularis* nymphs in a residential neighborhood. After four successive 9-wk deployments, nymphal and larval *I. scapularis* infestation prevalence and intensity were significantly reduced on target small mammals. In addition, these deployments resulted in 87.9% and 97.3% control of host-seeking nymphs in treatment sites at 1 yr and 2 yr postintervention, respectively. Installation of a protective metal cover around the SELECT TCS bait boxes eliminated nontarget wildlife damage to bait boxes that resulted in failure of previous bait box types. The results are discussed in the context of the residential environment and future research needs.

**Key words:** : SELECT TCS, bait box, tick control, *Ixodes scapularis*

Although conventional habitat-targeted acaricide applications have proven to be the most efficient and reliable means of suppressing host-seeking tick populations (Stafford and Kitron 2002; Schulze et al. 2005, 2008), the use of pesticides has met with growing public concerns over potential health issues and adverse environmental impacts (Ginsberg 1994, Schmidtmann 1994, Gould et al. 2008). Consequently, the development of effective and environmentally acceptable alternative tick control strategies has become an important public health initiative (Stafford and Kitron 2002, Hayes and Piesman 2003, Dolan et al. 2004).

Host-targeted tick control may offer an alternative to area application of acaricides (Schulze et al. 2007). In 1999, the Centers for Disease Control and Prevention (CDC) began testing a bait box to control subadult *Ixodes scapularis* Say on small mammal reservoir hosts to reduce the incidence of Lyme disease (Dolan et al. 2004). In 2002, a bait box incorporating the results of these experimental trials became commercially available as the Maxforce Tick Management System (TMS; Bayer Environmental Science, Montvale, NJ). However, poor performance of the original 2002 version of the bait box required changes in wick design and bait formulation. A trial of improved Maxforce TMS bait boxes in New Jersey during 2004–2005 resulted in 92.7% and 95.4% reduction in nymphal and larval tick burdens, respectively, on white-footed mice (*Peromyscus leucopus* Rafinesque) and eastern chipmunks (*Tamias striatus* L.), after single 4-wk deployments (Schulze et al. 2007).

Although results of this field trial were promising, between 36.4% and 92.0% of the bait boxes deployed were damaged by eastern gray squirrels (*Sciurus carolinensis* Gmelin; Schulze et al. 2007, T. L. Schulze, unpublished data), which compromised the child-resistant status of the boxes and often rendered the product label illegible. These problems were contributing factors in the eventual withdrawal of Maxforce TMS from the market in 2006. Subsequently, Tick Box Technology Corporation (Norwalk, CT) acquired the rights to manufacture and market the bait boxes as SELECT Tick Control System (TCS) in 2012. The new box was equipped with a two-piece metal protective covering to prevent squirrel damage. In this trial, we evaluated the ability of SELECT TCS to reduce the abundance of host-seeking *I. scapularis*, as well as the effect of the protective cover on acceptance and use by targeted small mammals and its ability to prevent or minimize damage and disturbance by nontarget wildlife.

## Materials and Methods

### Study Areas

SELECT TCS bait boxes were deployed on nine residential properties located in Plumsted Township, Ocean County, NJ, and three properties located in Millstone Township, Monmouth County, NJ. Each of the ≥0.4-ha properties was situated within oak- or oak and pine-dominated forests and consisted of lawn-landscaping immediately around the residence adjoined by woodland (± 10–70% of each property). The Assunpink Wildlife Management Area (Millstone Township) served as the control site. Earlier studies conducted in similar habitats and residential situations have shown *I. scapularis* and its small mammal hosts to be abundant (Schulze et al. 2001, 2005, 2007).

### Bait Box Description

SELECT TCS consists of a 19.05- by 13.97- by 6.35-cm child-resistant, injection-molded plastic box that houses a bait attractant and a fipronil-treated felt wick placed so that small mammals entering a box are passively treated by contacting the wick while attempting to reach the bait. In laboratory trials, a single topical treatment of 0.75% fipronil effectively protected mice from being bitten by *I. scapularis* nymphs for 4–6 wk (Dolan et al. 2004). SELECT TCS bait boxes were fitted with a two-piece, tightly fitting protective cover constructed of 0.032 gauge galvanized steel. The top and bottom sections of the protective cover and bait box were secured together at two opposite corners by means of 20.3-cm cable ties (Thomas & Betts Corp., Memphis, TN).

### Bait Box Deployment and Maintenance

We deployed 96 SELECT TCS bait boxes according to manufacturer recommendations at 12 residential properties in mid-May 2012 against nymphal *I. scapularis* for 9 wk. Deployment density ranged between 5 and 14 boxes per property, depending on the amount of wooded small mammal habitat present. Depending on the extent of habitat present at respective properties, bait boxes were deployed along one or two concentric rings, with the first located within the forest at ∼3 m from the lawn edge, with a ∼10-m interval between individual boxes. For those properties requiring additional bait boxes, a second similarly spaced row was placed at ∼10 m into the forest from the first ring of boxes. Wherever possible, boxes were placed in proximity to likely small mammal foraging or nesting sites. Because the combined weight of the bait box and protective covering exceeded 1,200 g and were judged too heavy to be easily displaced by nuisance wildlife, the boxes were not tethered (Schulze et al. 2007). Bait boxes were retrieved and replaced with new boxes in late July as a deployment against larvae. Boxes deployed against larvae were retrieved in late September 2012. In 2013, as a result of two property owners opting out of the study, 78 bait boxes were similarly deployed over 10 properties each during the nymphal and larval activity periods in mid-May and July, respectively.

During the first 4 wk of deployment in 2012, bait boxes were visited weekly and weighed in the field using a Scout *Pro* Balance (Ohaus Corporation, Pine Brook, NJ) to characterize small mammal acceptance and use of bait boxes. We considered any boxes exhibiting a loss in weight of ≥5.0 g as having been used by target small mammals. During initial bait palatability trials and a previous deployment of bait boxes (Schulze et al. 2007, and unpublished data), we found that 1) boxes placed in the environment initially gained weight (apparently through absorption of moisture) and 2) boxes opened at weekly intervals that exhibited weight loss of >5.0 g typically contained mouse or chipmunk droppings and baits with gnaw marks. Because at initial deployment boxes contained ∼200 g of bait, a box showing a weight loss of ∼200 g was considered emptied of bait. We used these same indicators of small mammal use of bait boxes in the present study. We also noted any change in box orientation or damage to boxes. Bait boxes were weighed again at the end of each deployment, opened, and inspected to assess the condition of remaining bait and wicks. In 2013, bait boxes were weighed only at the conclusion of the 9-wk deployments against nymphs and larvae.

### Small Mammal Trapping and Tick Burdens

We trapped small mammals to compare tick burdens on hosts between treated and untreated areas. Small mammals were collected using 7.6 by 8.9 by 30.5-cm Sherman nonfolding box traps (H.B. Sherman, Tallahassee, FL) baited with rolled oats and cotton balls. In 2012, preintervention small mammal nymphal tick burden data were obtained from a single trapping event conducted during 14–18 May, whereas postintervention tick burden data were collected 18–22 June, during the peak activity period of *I. scapularis* nymphs (Schulze et al. 1986, 2005, 2007). Trapping was repeated during 23–27 July, prior to deployment of bait boxes against larvae, and during 20–24 August, to coincide with the peak larval activity period. A similar trapping schedule was followed in 2013, with the exception that we did not trap in July. During each 3-d trapping event, we set 25 Sherman traps at each property and 100 traps at the Assunpink Wildlife Management Area untreated site. All traps were set during mid-afternoon and checked by mid-morning the following day. Traps remained open during the day and checked periodically until late afternoon. Captured rodents were transported to a central location and anesthetized with isoflurane prior to processing, which included examination for ticks, recording physical measurements, and marking with individual metal ear tags (Monel Model 1005-1 or 1005-3, National Band and Tag Company, Newport, KY). Captured animals were allowed to recover from the anesthetic and released at the point of capture. Ticks collected from small mammals were placed in discrete vials containing 100% ethanol and labeled with the corresponding ear tag number. Small mammals recaptured during a particular trapping event were not reprocessed.

### Tick Collections

Host-seeking *I. scapularis* nymphs were collected using a combination of dragging and walking methods (Ginsberg and Ewing 1989, Schulze et al. 1997) from a total of ten 100-m transects at both treatment and control sites. Collected nymphs were placed in discrete vials containing 70% ethanol for subsequent identification to species. Preintervention sampling for host-seeking *I. scapularis* nymphs was performed to coincide with trapping in May–June 2012, whereas the postintervention collections were made in May–June 2013 and 2014. All sampling was performed between 0800–1200 hours when vegetation was dry and wind was <10 km/h (Schulze and Jordan 2003).

### Statistical Analyses

Pre- and postdeployment tick burdens and numbers of host-seeking nymphal ticks were compared using Mann–Whitney U-tests or Kruskal–Wallis multiple comparisons tests, and infestation prevalence (percent of animals captured infested with at least one tick) was compared using contingency tables and chi-square tests (Sokal and Rohlf 1995).

A variation of Henderson's method was used to calculate percentage control of host-seeking ticks on treated properties: Percent

**Table 1.** Summary of small mammal use of SELECT TCS bait boxes deployed against subadult *I. scapularis* at Plumsted and Millstone Townships, NJ, May 2012–September 2013

| Year | Deployment | *n* | Weeks postdeployment | Boxes used (%)[a] | Boxes emptied (%)[a] |
|---|---|---|---|---|---|
| 1 | Nymphs | 96 | 1 | 16 (16.7) | 0 |
| | | | 2 | 36 (37.5) | 2 (2.1) |
| | | | 3 | 50 (53.2) | 6 (6.3) |
| | | | 4 | 42 (47.2) | 13 (13.7) |
| | | | 9 | 75 (91.5) | 58 (61.0) |
| | Larvae | 96 | 1 | 66 (68.8) | 0 |
| | | | 2 | 73 (76.0 | 14 (14.6) |
| | | | 3 | 82 (85.4) | 25 (26.0) |
| | | | 4 | 85 (88.5) | 44 (45.8) |
| | | | 9 | 87 (90.6) | 78 (81.3) |
| 2 | Nymphs | 78 | 9 | 60 (76.9) | 45 (57.7) |
| | Larvae | 78 | 9 | 69 (88.0) | 53 (68.0) |

[a] A loss of weight of ≥5.0 g was assumed to indicate measurable consumption of bait by target small mammals. A loss of weight >200 g indicated that a box was completely emptied of bait. Number in parentheses is the percentage of all deployed bait boxes either showing use or emptied of bait by small mammals.

control = 100 − ($T/U \times 100$), where $T$ and $U$ are the mean after treatment and mean before treatment in treated and untreated properties, respectively (Henderson and Tilton 1955, Mount et al. 1976). All statistical tests were performed using Statistica analysis packages (StatSoft, Inc. 2005).

## Results

### Small Mammal Acceptance and Use of SELECT TCS Bait Boxes

Rates of bait consumption suggested that the bait boxes equipped with protective covers were readily accepted and used by foraging small mammals. Following the first week of deployment in May 2012, 16.7% of bait boxes showed a decline in weight indicating use (Table 1). Box use increased through 3 wk and at the end of the 9-wk deployment against nymphs, 91.5% of the boxes demonstrated use. During the first 4 wk of deployment against larvae, bait box use steadily increased from 68.8% after 1 wk to 90.6% after 9 wk. In 2013, 76.9% and 88.0% of the bait boxes demonstrated use after the 9-wk deployments against nymphs and larvae, respectively.

### Bait Box Depredation

During 21,924 deployment days in 2012 and 2013, we observed no squirrel damage to the protective cover-equipped SELECT TCS bait boxes. During each of the four deployments, ≤14 boxes were disturbed per deployment, presumably by nuisance wildlife (e.g., flipped over, moved from original location, etc.), but were still functional, whereas one box could not be found after the 2012 deployment against nymphs.

### Small Mammal Trapping and Tick Burdens

Small mammal captures at both treated and untreated areas comprised primarily white-footed mice and eastern chipmunks, the primary *Borrelia burgdorferi* reservoir hosts in the study area (Schulze et al. 2005) and the hosts specifically targeted by the SELECT TCS deployments. Incidental captures (<2% of total captures) that were neither processed nor tagged included long-tailed weasel (*Mustela frenata* Licht.), meadow vole (*Microtus pennsylvanicus* Ord), southern flying squirrel (*Glaucomys volans* L.), northern short-tailed shrew (*Blarina brevicauda* Say), masked shrew (*Sorex cinereus* Kerr), and Virginia opossum (*Didelphis virginiana* Kerr).

Small mammals trapping in May 2012, prior to any bait box deployment, showed that mean *I. scapularis* nymphal infestation intensity (mean ticks per captured animal) on mice and chipmunks differed significantly between treated and untreated areas (Mann–Whitney $U_{(50,52)} = 1027.5$; $P = 0.04$), but there was no observable difference in infestation prevalence (proportion of captured animals carrying ticks) between areas ($\chi^2 = 0.61$; $P = 0.43$; Table 2). During trapping in June 2012, after the first 4 wk of bait box deployment, nymphal tick burdens were significantly lower in the untreated areas ($U_{(23,27)} = 127.0$; $P < 0.01$) and the proportion of captured animals carrying ticks was also reduced ($\chi^2 = 6.97$; $P < 0.01$), which may have reflected local conditions of high ambient temperatures and low rainfall that discouraged questing activity (Schulze and Jordan 2003). Nevertheless, we recovered no nymphs from any of the mice or chipmunks captured in the treated areas.

Prior to the 2012 deployment against larvae, larval burdens ($U_{(23,15)} = 12.50$; $P < 0.01$) and infestation prevalence ($\chi^2 = 7.17$; $P < 0.01$) on mice and chipmunks differed significantly between treated and untreated areas after 8 wk of bait box deployment (Table 2). Although larval burdens on captured small mammals in August 2012, after a second deployment of bait boxes, indicated a significant decrease in larval infestation intensity in the untreated areas ($U_{(23,22)} = 80.5$; $P < 0.01$), larval burdens in the treatment area continued to be depressed relative to the untreated area ($U_{(22,16)} = 41.0$; $P < 0.01$) and showed a continued decline from burdens observed in the previous month ($U_{(15,16)} = 113.0$; $P < 0.01$; Table 2).

Trapping in May 2013 showed that neither nymphal tick infestation prevalence ($\chi^2 = 1.24$; $P = 0.26$) nor intensity ($U_{(20,34)} = 257.0$; $P = 0.13$) on mice and chipmunks at the treated properties differed significantly from that at the untreated area (Table 3). After 4 wk of bait box deployment, infestation prevalence was significantly reduced at the treatment properties relative to the untreated area ($\chi^2 = 11.31$; $P < 0.01$). The apparently anomalous result that infestation intensity was higher in the treated areas ($U_{(21,33)} = 90.5$; $P < 0.01$) was accounted for by two chipmunks with very high numbers of ticks. However, larval infestation intensity was significantly less on animals captured during August in the treatment area ($U_{(12,21)} = 23.5$; $P < 0.01$), representing 89.7% reduction in larval tick burdens after 2 yr of bait box deployment.

### Host-Seeking Ticks

Prior to the first bait box deployment in May 2012, numbers of *I. scapularis* nymphs at the untreated (mean = 9.1 ± 5.0) and

**Table 2.** Infestation prevalence (number infested and total number trapped) and intensity (mean number of ticks ± SD per captured animal) of *I. scapularis* subadults on live-trapped small mammals before and after TCS bait box intervention, May–August 2012

| Treatment | Species | Deployment vs. Nymphs | | | | | | Deployment vs. Larvae | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | May[a] | | | June | | | July[b] | | | Aug. | | |
| | | *n* | Prevalence (%) | Intensity | *n* | Prevalence (%) | Intensity | *n* | Prevalence (%) | Intensity | *n* | Prevalence (%) | Intensity |
| Untreated | *P. leucopus* | 20 | 15 (75.0%) | 3.2 ± 3.2 | 24 | 8 (33.3%) | 0.9 ± 2.8 | 22 | 22 (100%) | 20.0 ± 13.9 | 21 | 20 (95.2%) | 5.4 ± 4.8 |
| | *T. striatus* | 3 | 3 (100%) | 5.7 ± 5.7 | 3 | 2 (66.7%) | 1.0 ± 1.0 | 1 | 0 | 0 | 1 | 1 (100%) | 1.0 |
| | All | 23 | 18 (78.3%) | 3.5 ± 3.5 | 27 | 10 (37.0%) | 0.9 ± 2.7 | 23 | 22 (95.6%) | 19.2 ± 14.2 | 22 | 21 (95.5%) | 5.2 ± 4.8 |
| TCS | *P. leucopus* | 18 | 11 (61.1%) | 1.4 ± 1.5 | 13 | 0 | 0 | 13 | 2 (15.4%) | 0.7 ± 1.9 | 14 | 3 (21.4%) | 1.0 ± 2.3 |
| | *T. striatus* | 10 | 7 (70.0%) | 2.9 ± 3.1 | 11 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 |
| | All | 28 | 18 (64.3%) | 1.9 ± 2.3 | 24 | 0 | 0 | 15 | 2 (13.3%) | 0.6 ± 1.8 | 16 | 3 (18.8%) | 0.8 ± 2.2 |

[a] Results of small mammal trapping before initial bait box deployment against nymphal ticks.
[b] Results of small mammal trapping prior to a second deployment against larval ticks made during July.

**Table 3.** Infestation prevalence (number infested and total number trapped) and intensity (mean number of ticks ± SD/captured animal) of subadult *I. scapularis* on live-trapped small mammals during the second year of TCS bait box intervention, May–August 2013

| Treatment | Species | Month | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | May[a] | | | June | | | Aug. | | |
| | | *n* | Prevalence (%) | Intensity | *n* | Prevalence (%) | Intensity | *n* | Prevalence (%) | Intensity |
| Untreated | *P. leucopus* | 16 | 11 (68.8%) | 3.1 ± 3.2 | 16 | 12 (75.0%) | 1.4 ± 1.3 | 10 | 10 (100%) | 7.5 ± 1.0 |
| | *T. striatus* | 4 | 4 (100%) | 13.5 ± 8.6 | 5 | 5 (100%) | 5.4 ± 3.9 | 2 | 2 (100%) | 3.5 ± 2.1 |
| | All | 20 | 15 (75.0%) | 5.2 ± 6.1 | 21 | 10 (81.0%) | 2.3 ± 2.7 | 12 | 12 (100%) | 6.8 ± 6.6 |
| TCS | *P. leucopus* | 10 | 2 (20.0%) | 1.3 ± 3.8 | 17 | 0 | 0 | 13 | 5 (38.5%) | 1.2 ± 1.9 |
| | *T. striatus* | 24 | 17 (71.0%) | 3.7 ± 4.8 | 16 | 2 (12.5%) | 6.4 ± 25.2 | 8 | 0 | 0 |
| | All | 34 | 19 (55.9%) | 3.0 ± 4.6 | 33 | 2 (6.1%) | 3.1 ± 17.6 | 21 | 5 (23.8%) | 0.7 ± 1.6 |

[a] Results of small mammal trapping before initial bait box deployment against nymphal ticks.

**Table 4.** Summary of questing *I. scapularis* nymphs (mean + SE; $n = 10$) at the Plumsted and Millstone Township study sites, 2012–2014

| Treatment[a] | Year | | | Kruskal–Wallis test |
|---|---|---|---|---|
| | 2012 | 2013 | 2014 | |
| Untreated[b] | 9.1 ± 5.0a | 10.1 ± 5.8a | 9.9 ± 4.1a | $H_{(2,30)} = 0.25$; $P = 0.88$ |
| TCS | 6.7 ± 1.7a | 0.9 ± 1.3b (87.9%)[c] | 0.2 ± 0.4c (97.3%) | $H_{(2,30)} = 22.09$; $P < 0.01$ |

[a] Values represent mean ticks ± SD/100-m$^2$. There were 10 randomly assigned plots in each treatment area. Values for 2012 are prior to any bait box deployment.
[b] Separate Kruskal–Wallis tests conducted for untreated and TCS sites. Values followed by different letters are significantly different (Dunn's test, $P < 0.05$).
[c] Percent control, after Henderson's equation (Henderson and Tilton 1955, Mount et al. 1976).

treated (mean = 6.7 ± 1.7) sites were statistically similar (Mann–Whitney $U_{(10,10)} = 36.5$; $P = 0.31$; Table 4), and tick abundance in the untreated area did not differ significantly during the following 2 yr. However, mean nymphal abundance in the treated area declined in both postdeployment years, representing 87.9% and 97.3% control of host-seeking ticks, respectively, after 1 yr (2013) and 2 yr (2014) of bait box deployment.

## Discussion

Deployment of SELECT TCS bait boxes resulted in significant declines in *I. scapularis* host infestation intensity and prevalence, as well as significant reduction in numbers of host-seeking nymphal ticks. After the initial 4 wk of deployment in June 2012, we failed to find a single nymph on small mammals captured on treatment properties, whereas small mammal captures in August 2012, after an additional 4 wk of exposure to bait boxes, showed significant reductions in both larval infestation prevalence and intensity compared with the untreated site. While small mammals using bait boxes in the treatment area were exposed to fipronil from mid-May through September 2012, there appeared to be some rebound in tick burdens in spring 2013 prior to the 2013 deployments. This may suggest that the effectiveness of fipronil treatment had dissipated over the intervening fall and winter. Dolan et al. (2004) showed that fipronil remains effective on treated small mammals for 42 d postapplication. Thus, while there were fewer nymphs in the treated areas because of treatment in 2012, those ticks that escaped treatment were apparently able to find untreated, or ineffectively treated, small mammal hosts. Alternatively, the apparent rebound in nymphal burdens may reflect immigration of untreated hosts into the treated area. This alternative explanation is supported by the presence of two trapped chipmunks on treated properties with inordinately high nymphal burdens. Nevertheless, as expected, trapping in June and August 2013 following additional bait box deployments showed continued decline in the infestation indices at treated properties. Consequently, successively fewer subadult ticks were presumably able to feed on infected small mammal hosts. In addition, two successive deployments of SELECT TCS each in 2012 and 2013 resulted in 97.3% control of host-seeking nymphs in 2014.

Small mammal acceptance and use of bait boxes in May–June 2012 was initially slow, but eventually increased to 91.5% of boxes being used after 9 wk of deployment. The second deployment made against larvae in late July demonstrated a much higher initial acceptance and more rapid increase in the rate of use. Similar rates of acceptance and use were observed in 2013. Although overall bait box use was lower and progressed more slowly in this study compared with an earlier study of Maxforce TMS bait boxes (Schulze et al. 2007), overall box use after 9 wk was similar, indicating that the protective cover did not interfere with box use by targeted hosts.

The steel cover completely protected bait boxes from squirrel damage, whereas as many as 92.0% of boxes deployed in an earlier study were damaged by squirrels (Schulze et al. 2007). Damage to bait boxes observed in the current study was limited to damage and removal of treated wicks from several boxes per deployment. We speculate that foraging mice may have removed the felt wicks for use as nesting material or that chipmunk damaged or removed wicks in an attempt to gain better access to bait blocks.

Few boxes were substantially disturbed at the end of this study. The added weight of the protective galvanized steel cover precluded the need to tether the bait boxes. In contrast, in an earlier deployment using the lighter weight, unprotected boxes, an average of 7 of 350 boxes per 4-wk deployment (range = 0–20 boxes per 4-wk deployment) were missing at the conclusion of the study and presumably removed from the study site by raccoons (*Procyon lotor* (L.); Schulze et al. 2007).

Bait box efficacy may be markedly affected by the density of boxes (i.e., the ability to adequately treat sufficient numbers of target hosts) as well as the potential for immigration of untreated hosts from adjacent areas. Further research is needed to determine a minimum box density that both treats sufficient small mammal hosts to be effective and makes the product cost-effective for the homeowner (Schulze et al. 2007, Eisen and Dolan 2016).

These results demonstrate that SELECT TCS may provide a significant reduction in exposure to host-seeking ticks, while reducing the use of pesticide compared with traditional area-wide chemical control. But, because the bait boxes target only specific life stages within the 2-yr life cycle of *I. scapularis* and kill only ticks that have already acquired a host, significant reduction of the tick population is not realized until months or years after deployment. This has important implications for host-targeted methods because their inherently delayed efficacy results in significant risk of exposure to *I. scapularis* nymphs well after initial deployment. Such lag-times may affect their widespread public acceptance and commercial use that requires that significant tick control must be achieved more rapidly (Schulze et al. 2007).

Nevertheless, bait boxes offer several other benefits. Because they reduce the number of subadult ticks feeding on reservoir competent hosts, the bait boxes have the potential to both reduce the force of infection (defined as the number of secondary infections arising from a focal infection, Eisen et al. 2012) and reduce infection prevalence in host-seeking ticks (Dolan et al. 2004).

More information is also needed to assess how the presence and abundance of alternate hosts (and alternate reservoir hosts) in residential situations may affect the efficacy of bait boxes (Eisen and Dolan 2016). For example, shrews are recognized reservoirs for *B. burgdorferi* and have been shown to use bait boxes (Ostfeld 2011), but are not effectively sampled by the methods employed here. Capture data indicate that such hosts are present and may be present in significant numbers (Schulze et al. 1986, 2005, 2007). Future research on host-targeted tick control should include efforts to examine mammal community composition and the roles played by reservoir and refractory hosts in residential situations. Also, any host-targeted approach to tick control that relies on attractive food baits effectively provides a supplemental food source to the host population, which may have consequences for local host density and, ultimately, disease transmission dynamics (Ostfeld et al. 2006).

SELECT TCS appears to offer an effective alternative, delayed efficacy notwithstanding, to the use of area application of acaricide in residential situations. Further research, to include analysis of disease infection prevalence in hosts and ticks, is required to verify the potential for tick-borne disease risk reduction indicated here. In addition, research is needed to determine what proportion of host small mammals using treated properties is actually treated by bait boxes. This may have important implications not only for efficacy, but also in determining cost of deployment. Ultimately, however, tick control efforts in residential areas, particularly any integrated tick control program that may combine multiple habitat and host-targeted methods, must consider the ecology of what remain as yet poorly understood suburban and ex-urban ecosystems in order to achieve comprehensive, reliable, and environmentally responsible reductions in tick-borne disease risk.

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