



Published in final edited form as:

J Med Entomol. 2025 March 17; 62(2): 236–276. doi:10.1093/jme/tjae155.

A scoping review of applied tick control research in North America: funding, implementation, and advancement

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Abstract

Geographic ranges of ticks and tick-borne pathogens within North America are shifting due to environmental changes and human-driven activities, with species of public health concern presenting a multifaceted risk to human health. Innovative strategies and continued collaboration to control tick populations are needed to combat this growing threat. We conducted a scoping review of the literature to describe the nature of applied tick control research conducted in North

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America (Canada, Mexico, and the United States) to date, with the goal of describing key concepts and identifying gaps in this research area. A total of 244 articles met our inclusion criteria and were reviewed for patterns in applied tick control authorship and funding, study location, target species, and control methodology. Most studies (83.6%) were conducted exclusively in the United States and 75% focused on ticks of public health concern, principally *Amblyomma americanum* (Linnaeus, Acari: Ixodidae), *Dermacentor variabilis* (Say, Acari: Ixodidae), *Ixodes scapularis* Say (Acari: Ixodidae), and *Rhipicephalus sanguineus* (Latreille, Acari: Ixodidae). The majority of funding was provided through US federal agencies, predominantly the Centers for Disease Control and Prevention and the United States Department of Agriculture. *Ixodes scapularis* was the target of over 50% of identified articles, with the majority of research conducted within 3 states in the Northeast region of the U.S. Only 8.2% of included studies evaluated integrated tick management interventions. We note gaps in tick control research regarding (i) non-*Ixodes* medically relevant tick species, (ii) endemic range coverage, and (iii) control methodologies evaluated.

Keywords

applied research; tick control; ticks; scoping review

Introduction

Ticks are nuisance pests and transmit multiple bacterial, viral, and protozoan pathogens affecting humans, domestic livestock, and wildlife (Jongejan and Uilenberg 2004). In North America, there are several tick genera of public health importance, given their ability to transmit pathogens to humans via an infectious bite and contribute to the allergic response alpha-gal syndrome. These tick genera include *Amblyomma* (Acari: Ixodidae) (ehrlichiosis, rickettsiosis, Rocky Mountain spotted fever [RMSF], tularemia, and alpha-gal syndrome), *Dermacentor* (Acari: Ixodidae) (Colorado tick fever, RMSF, and tularemia), *Ixodes* (Acari: Ixodidae) (anaplasmosis, babesiosis, ehrlichiosis, Lyme disease, and Powassan virus disease), and *Rhipicephalus* (Acari: Ixodidae) (RMSF) (National Center for Emerging and Zoonotic Infectious Diseases and Division of Parasitic Diseases and Malaria 2019, Sharma et al. 2024, U.S. Centers for Disease Control and Prevention 2024a).

In the United States, tick-borne disease (TBD) cases in humans have more than doubled from 2004 to 2019 (The U.S. Department of Health and Human Services, The U.S. Centers for Disease Control and Prevention. 2024). Lyme disease-causing agents, primarily *Borrelia burgdorferi* sensu stricto (Spirochaetales: Spirochaetaceae), are the most commonly acquired tick-borne pathogens in the United States (Rosenberg et al. 2018). Incidence of other TBDs, such as anaplasmosis and ehrlichiosis, have also increased, and new TBDs are emerging, including those caused by Heartland and Bourbon viruses (Rosenberg et al. 2018, Dupuis et al. 2023).

The geographic range of various tick species is shifting, and (re) emergence of tick-borne pathogens in new regions has occurred due to environmental changes, anthropogenic land-use changes, and host animal characteristics (Ogden et al. 2013, Eisen et al. 2016, Sonenshine 2018, Little et al. 2021, Rochlin et al. 2022, Eisen and Eisen 2023, Machtinger

et al. 2024). For example, the range of *Ixodes scapularis* Say, the blacklegged tick, has expanded into southern Canada and in 2017, an exotic and invasive tick species, *Haemaphysalis longicornis* Neumann (Acari: Ixodidae), was confirmed in the United States and is now a major veterinary pest concern (Levy 2017, Rainey et al. 2018, Animal and Plant Health Inspection Service 2024). Due to these changes, new communities are now facing increased risk of exposure to ticks and their associated pathogens (Sonenshine 2018, Deshpande et al. 2024).

There are various control strategies to decrease tick encounters, reduce tick abundance, prevent cases of tick-borne illness, and reduce the prevalence of TBD-causing agents in ticks (Stafford et al. 2017). Some of these measures include the application of acaricides to the environment, host-targeted acaricide application, biological control agents, habitat management (e.g., controlled burns, vegetation removal), and host reduction or exclusion (Stafford et al. 2017). In addition, integrated pest management (IPM), a strategy that uses multiple methods to reduce pest populations, can be applied to ticks (integrated tick management [ITM]) to effectively reduce the population and decrease human cases of TBDs (Stafford 2007, Beard and Strickman 2014).

Here, we conducted a scoping review of the applied tick control literature to determine trends in tick control practices, funding, and authorship over time. Scoping reviews are a valuable tool for rapidly mapping the key concepts underpinning a research area in terms of the volume, extent or range, and characteristics of available primary sources; scoping reviews are appropriate for exploring both existing and emerging literature and can often identify gaps that may exist (Pham et al. 2014, Mak and Thomas 2022). Our goal was to describe the trends in tick control applied research and identify opportunities that may be employed to expand the applied tick control portfolio that is responsive to the changing dynamics of TBD risk in North America.

Materials and Methods

Literature Search, Selection Criteria, and Review Process

We conducted a scoping review of the literature following the Arksey and O'Malley methodological framework, which includes 5 stages: (i) identifying a research question, (ii) identifying relevant studies, (iii) performing study selection, (iv) charting and collating, and (v) summarizing and reporting results (Arksey and O'Malley 2005). Our protocol was drafted using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols for Scoping Reviews and is detailed within this manuscript (Tricco et al. 2018). The PRISMA-ScR checklist associated with this review is available in Supplementary File 3.

A comprehensive search of the electronic databases PubMed and Web of Science was conducted for research pertaining to applied tick control. Searches were conducted using terms to identify studies on tick control in the environment, control of ticks on animals, evaluation of both field and laboratory acaricide efficacy, evaluation of acaricide resistance, and evaluation of ITM. The complete search terms and PubMed search strategy are outlined in Supplementary File 1-T1. Reference lists of articles identified through the database

searches were reviewed for additional relevant publications. Review articles were not included in the scoping review, but relevant primary sources identified from review articles were included. Articles were not limited by date of publication.

Searches of the databases were conducted on 4 March 2022 and 25 August 2023.

Research articles were included if they met the following criteria: (i) conducted in North America, including Mexico, United States, and Canada; (ii) empirical study; and (iii) explicitly included an assessment of any, or a combination of, the following: control of ticks in the environment, control of ticks on animals (livestock, domestic, wildlife), acaricide efficacy trials, ITM, acaricide resistance assays that report mortality metrics, repellency assays that report mortality metrics, or community-based assessments that directly address willingness to pay for tick control, acceptability of tick control interventions, and/or implementation of tick control services. Studies that did not meet any one of the above criteria were excluded from the scoping review.

The review process was conducted using Covidence systematic review software (Covidence, Veritas Health Information, Melbourne, Australia). After removing duplicates, each article was screened for inclusion by title and abstract by a single reviewing author (JG, EM, KM, or JP). The remaining articles underwent a full-text review and were screened by 2 reviewers independently (EM, JP, AL, or CW). Conflicts regarding article inclusion or exclusion were resolved and finalized by the reviewers.

Data Extraction and Key Outcomes

Authors EM and JP developed a project-specific data extraction template within Covidence (see Supplementary File 2). Characteristics of the included literature were documented within this template (authors EM, JP, AL) and exported as a database. Descriptive statistics of the exported literature characteristics were analyzed using Microsoft Excel and IBM SPSS Statistics (Version 28.0.0.0).

Articles included in this review were summarized based on several categorizations (Table 1). First, we divided articles by those focused on ticks of public health importance, which were defined as medically important tick species associated with the transmission of pathogens affecting human health within the genera *Amblyomma*, *Dermacentor*, *Ixodes*, and *Rhipicephalus*. The remainder of articles were classified as agricultural/wildlife, which was defined as articles that focused on evaluating tick control in the context of livestock or wildlife health. Second, we summarized the control interventions evaluated within the included articles by the following focus areas: environmental control using acaricides, habitat modification, host-targeted intervention, acaricide susceptibility trial, and community-based assessments. Definitions of these focus areas are further delineated in Table 1. Lastly, articles were grouped into climate regions according to the National Oceanic and Atmospheric Administration (NOAA) regional climate classification system. This system divides states in the contiguous United States into 9 climatically consistent regions based on current and historical conditions; these regions roughly align with the distributions of medically important tick species (Karl and Koss 1984, Eisen et al. 2017).

Results

As shown in the PRISMA flow diagram (Fig. 1), 3,727 references were imported to Covidence for screening. After duplicate removal, 3,289 unique studies remained for title and abstract screening; of these, 328 studies were screened for inclusion via full-text review. A total of 244 out of the 3,289 unique articles met the criteria for inclusion in this scoping review; of these 244 articles, most ($n = 183$, 75.0%) focused on tick vectors of public health importance, while the remaining studies focused on agricultural/wildlife tick control ($n = 61$, 25.0%). Table 2 provides additional summary details on the 244 included articles.

The primary focus of this scoping review was to summarize the nature of applied tick control research on tick vectors of public health importance; however, 61 studies on the control of ticks associated with agricultural and/or wildlife health did meet our inclusion criteria. Briefly, most of the research on agriculturally relevant ticks was conducted in Mexico ($n = 30$, 49.2%) and focused on control of *Rhipicephalus microplus* Canestrini ($n = 47$, 77.0%); further details and citations for the agriculture/wildlife studies are summarized in Supplementary File 1-T2. The remainder of the presented results will focus exclusively on the 183 articles investigating ticks of public health importance identified in this review.

The 183 articles focused on controlling ticks of public health importance largely reported on control of *Ixodes* ($n = 131$, 71.6%), followed by *Amblyomma* ($n = 59$, 32.2%), *Dermacentor* ($n = 29$, 15.9%), and *Rhipicephalus* ($n = 12$, 6.6%) ticks (Table 3). Thirty-nine studies (21.3%) evaluated more than one tick species concurrently; these studies are included in the genus-specific summaries presented below. The most common control focus of these studies was host-targeted interventions ($n = 74$, 40.4%), followed by environmental control based on acaricide application ($n = 59$, 32.2%), habitat modification ($n = 35$, 19.1%), and acaricide susceptibility assessments ($n = 33$, 18.0%); only 13 studies (7.1%) included community-based assessments (Table 2). A full listing of the 183 articles focused on controlling ticks of public health importance is available in Table 4, which provides details on target species, control intervention, location, funding, author background, and citation information for each study included in this review.

Funding and Authorship of Public Health Tick Control Studies

The earliest applied tick control study with a public health focus identified in this scoping review was published in 1944 and funded by the United States Department of Agriculture (USDA) (Smith and Gouck 1944) (Fig. 2A). Few applied tick control studies ($n = 11$) were published between 1940 and 1979. These studies focused largely on control of *Amblyomma* ($n = 7$, 64%), followed by *Dermacentor* ($n = 2$, 18%), and *Rhipicephalus* ($n = 1$, 9%); one study focused on *Amblyomma*, *Dermacentor*, and *Ixodes* concurrently (Smith and Gouck 1944). The 3 studies published prior to 1959 were supported exclusively through US federal funding (Smith and Gouck 1944, Smith et al. 1946, McDuffie et al. 1950) (Fig. 2B). Additional funding sources began to appear in published articles in the 1960s and 1970s and included nonprofit organizations (Nelson 1969) and state sources (Hoch et al. 1971). Thirty-six percent ($n = 4$) of the studies published between 1940 and 1979 did not report a funding source (Mount et al. 1968, 1976, Clymer et al. 1970, Wilkinson 1977).

Applied tick control research began to increase in the 1980s, with 172 articles published between January 1980 and August 2023. This period saw an increasing shift in focus to control of *Ixodes* ticks ($n = 128$, 60%) as compared to other tick species (see Fig. 2A). Additionally, funding from US Department of Health and Human Services (DHHS) agencies became more common beginning in the 1980s (Fig. 2C). However, it was not until the 1990s that a large increase in applied tick control research occurred due to increased funding from the US Centers for Disease Control and Prevention (CDC) (Fig. 2C). The increase in applied tick control was driven by a focus on *Ixodes* ticks, which remained the primary focus of applied tick control research until the late 2000s.

Overall, the majority of the applied tick control research conducted in North America received funding from US federal agencies ($n = 110$, 60%). US federal funding was provided by 16 different agencies, with the largest proportion of publications supported by the CDC ($n = 56$), USDA ($n = 24$), and the US Department of Defense (DOD; $n = 11$) (Table 4). Figure 2A–C provides a summary of applied tick control publications across time by (a) tick genera, (b) primary funding organizations, and (c) different US federal funding organizations. Figure 2A–C reports the number of publications assessing control of each listed tick genus and receiving funding from each listed entity. Some publications reported on more than one tick genus concurrently or received funding from more than one entity, which is not reflected in this figure.

Most articles included in this review were authored by researchers affiliated with only a public agency ($n = 72$, 39.3%) or affiliated only with an academic institution ($n = 51$, 27.9%). Of the articles conducted by researchers affiliated with only a public agency, the most common affiliations for studies focused on *Ixodes* ticks were the Connecticut Agricultural Experiment Station ($n = 18$), USDA ($n = 15$), Freehold Area Health Department (New Jersey, $n = 11$), CDC ($n = 8$), Monmouth County Mosquito Control Commission (New Jersey, $n = 8$), and the New Jersey Department of Health ($n = 7$); the most common affiliations for studies focused on metastriate ticks were the USDA ($n = 15$) and CDC ($n = 6$) (studies listed in Table 5). Public-only research affiliates received funding from the CDC, USDA, or did not report their funding source (Supplementary File 1-T3).

Academically affiliated researchers were associated with one of 24 separate academic institutions. Articles conducted by researchers affiliated with only an academic institution were most commonly located in New York State ($n = 13$), Rhode Island ($n = 5$), and Massachusetts ($n = 5$) for studies focused on *Ixodes* ticks and were most commonly located in Florida ($n = 5$) and Oklahoma ($n = 4$) for studies focused on metastriate ticks (Table 5). Academic-only research affiliates had the most diversity in funding sources, source but predominantly received funding from the CDC, academic institutions, nonprofit associations, or did not report their funding (Supplementary File 1-T3).

Twenty-eight studies (15.3%) were authored by a partnership of authors affiliated with public agencies and academic institutions. The most commonly observed partnerships included those between (i) universities and federal agencies ($n = 14$), and (ii) universities and state agencies ($n = 5$). Funding for these academic-public partnership studies most commonly came through federal agencies (excluding CDC or USDA), from the CDC,

from academic institutions, or were not reported. Only 10 studies (5.5%) were authored by researchers affiliated solely with private institutions, which included veterinary health and pharmaceutical companies ($n = 6$), independent contract research firms ($n = 6$), and agronomic service corporations ($n = 3$). The remaining 22 (12.0%) studies included a mixture of public agency, private agency, and academic author affiliations.

Location and Length of Public Health Tick Control Studies

The majority of articles included in this review conducted research at sites within the United States ($n = 174$, 95.1%), followed by sites in Canada ($n = 5$, 2.7%) and Mexico ($n = 1$, 0.55%); 3 (1.6%) studies were conducted in both the United States and another country (Table 4).

Of the studies conducted in the United States, the majority ($n = 98$, 53.6%) were conducted within NOAA Region I (Northeast). The states with the highest volume of studies conducted within them include New Jersey ($n = 29$), Connecticut ($n = 28$), and New York ($n = 25$), followed distantly by Texas ($n = 10$) and Oklahoma ($n = 9$). Tick control evaluations targeting *Ixodes* ticks predominated in NOAA Region I (Northeast), while Regions II (Southeast), IV (Ohio Valley), and V (South) had a higher proportion of studies targeting *Amblyomma* ticks. No applied tick control studies were identified with study sites located in NOAA Regions VI (Northern Rockies & Plains) or VIII (Northwest). Figure 3 portrays the distribution of applied tick control studies evaluating ticks of public health importance across the contiguous U.S. by NOAA region.

The length of time these studies were conducted was largely 1 year or less ($n = 52$, 28.4%), followed by 2 years ($n = 30$, 16.4%), 3 years ($n = 26$, 14.2%), and 4 years ($n = 16$, 8.7%) (Table 4). Twenty-six (14.2%) studies were conducted over 5 years or more. Thirty-three (18.0%) articles did not report the length of study. After the 1990s, when funding for tick control work increased, length of study did not increase.

Genus Summary: *Ixodes*

A total of 131 studies included in this review evaluated applied tick control interventions for *Ixodes* ticks. The most common vector targeted in the studies we identified was *I. scapularis*, which was assessed in 68.5% ($n = 126$) of the public health studies identified in this review; studies reporting control results for *I. dammini* were grouped with *I. scapularis* (Sanders 1998). Five studies focused on the western blacklegged tick, *Ixodes pacificus* Cooley & Kohls (Table 4).

Tick control interventions for *Ixodes* ticks predominantly focused on host-targeted approaches ($n = 56$, 42.7%) and environmental acaricide control approaches ($n = 37$, 28.2%), followed by acaricide susceptibility assessments ($n = 23$, 17.6%), habitat modification ($n = 20$, 15.3%), and community-based assessments ($n = 7$, 5.3%) (Table 4). Twelve studies (9.3%) incorporated multiple interventions, though only 5 of these were designed as ITM interventions (Stafford et al. 2003, Schulze et al. 2007, Williams et al. 2018, Mandli et al. 2021, Keesing et al. 2022). The most common length over which *Ixodes*-focused studies collected data was 1 year ($n = 36$, 27.5%), followed by 2 years ($n =$

22, 16.8%) and 3 years ($n = 18$, 13.7%); a large proportion of these studies ($n = 26$, 19.8%) did not report the period of data collection (Table 4).

Of the 57 studies evaluating host-targeted control interventions, the majority focused on white-tailed deer ($n = 25$, 43.9%) and/or rodents ($n = 24$, 42.1%); 7 (12.3%) studies focused on domestic pets, 2 (3.5%) on humans, and 1 (1.8%) on livestock. Deer-targeted interventions predominantly evaluated the 4-poster system ($n = 15$), while others evaluated deer exclusion ($n = 3$), deer removal ($n = 6$), and systemic treatments ($n = 1$). Rodent-targeted interventions predominantly evaluated acaricides delivered topically via nesting material ($n = 12$) and/or bait boxes ($n = 12$) and rodent removal ($n = 1$), while one study evaluated systemic treatments. Interventions targeting domestic pets exclusively evaluated tick control products delivered systemically or with spot treatments. Human-focused studies evaluated the impact of permethrin-treated clothing used during walking surveys (Table 5).

Of the 38 studies evaluating environmental acaricide control approaches, the majority focused on chemical acaricides ($n = 24$, 63.2%), followed by entomopathogenic fungi ($n = 10$, 25.6%) and naturally derived acaricides ($n = 9$, 23.7%); 2 (5.3%) studies evaluated control with parasitoids and 1 (2.6%) evaluated control with desiccant and insecticidal soap. The most commonly evaluated chemical acaricide classes were pyrethroids ($n = 13$) and carbamates ($n = 9$). The naturally derived acaricides consisted of botanically derived products ($n = 7$), nootkatone ($n = 6$), and 25(b) minimum risk products ($n = 5$). The US Environmental Protection Agency defines 25(b) minimum risk pesticides products as those containing active ingredients that are exempt from the Federal Insecticide, Fungicide, and Rodenticide Act; the 25(b) products evaluated in these studies included active ingredients such as rosemary oil, peppermint oil, and geraniol (U.S. Environmental Protection Agency 2024).

Most of the 20 studies evaluating habitat modifications focused on landscape management approaches ($n = 10$, 50.0%), while others evaluated controlled burns ($n = 6$, 30.0%) and invasive plant removal ($n = 4$, 20.0%). The focus of the 23 acaricide susceptibility studies was evenly distributed across chemical and naturally derived acaricides and entomopathogenic fungi. Of the 7 studies that included a community-based assessment component, 4 included assessments of acceptability regarding tick control interventions, 3 measured implementation of tick control through Knowledge, Attitudes, and Practices (KAP) surveys, and 1 measured use of private pest control services, prioritization of public tick control interventions, and willingness to pay for tick control, respectively (Table 5).

The majority of *Ixodes* research occurred in New Jersey ($n = 27$, 20.6%), Connecticut ($n = 26$, 19.9%), and New York ($n = 22$, 16.8%) (Table 4; Fig. 3). The counties in these states with the most *Ixodes* research included Monmouth County, NJ ($n = 23$), Westchester County, NY ($n = 11$), and Fairfield County, CT ($n = 10$). Most *Ixodes*-focused control interventions were conducted in residential settings ($n = 73$, 55.7%); of these, 63% ($n = 46$) were conducted in suburban settings, 35.6% ($n = 26$) in rural settings, and 1.4% ($n = 1$) in urban settings. Of the studies conducted in residential settings, most focused on host-targeted ($n = 45$) and environmental acaricide control ($n = 24$) interventions. Host-targeted interventions in rural residential areas focused almost exclusively on deer,

while host-targeted interventions conducted in suburban residential areas were more equally dedicated to deer and rodent-targeted interventions.

Other common study settings included parks ($n = 19$, 14.5%), wilderness areas ($n = 19$, 14.5%), and military bases ($n = 14$, 10.7%). Studies conducted in parks focused mostly on host-targeted interventions, and studies conducted in military bases focused mostly on environmental acaricide control interventions. Studies conducted in wilderness areas had an even distribution of environmental acaricide, host-targeted, and habitat modification interventions. The 23 studies evaluating acaricide susceptibility were conducted in laboratory settings (Table 4).

Funding for *Ixodes*-focused control studies was predominantly provided through CDC ($n = 51$, 38.9%), followed by non-profit funders ($n = 23$, 17.6%); 20.6% of *Ixodes*-focused control studies ($n = 27$) did not report a funding source. Most studies were supported exclusively by one funding source ($n = 69$, 52.7%), the majority of which were funded by a US federal agency ($n = 49$, 72.1%). Of these studies, exclusively CDC-supported work ($n = 35$) most often focused on environmental acaricide control ($n = 14$, 40.0%) followed by host-targeted interventions ($n = 8$, 22.9%), while most exclusively USDA-supported work ($n = 7$) focused on host-targeted interventions ($n = 5$, 71.4%) (Table 4).

Articles on control of *Ixodes* ticks were most frequently authored by researchers only affiliated with public agencies ($n = 50$, 38.2%), followed by authors only affiliated with academic institutions ($n = 34$, 26.0%), and partner authorships between public and academic institutions ($n = 20$, 15.3%). Authors affiliated with only public agencies most often researched environmental acaricide control approaches ($n = 14$, 28.0%) and host-targeted approaches ($n = 14$, 28.0%). Authors affiliated with only academic institutions largely researched host-targeted tick control interventions ($n = 14$, 41.2%), followed by environmental acaricide control ($n = 6$, 17.6%) and acaricide susceptibility assessments ($n = 6$, 17.6%). Research conducted in partnership with authors from public agencies and academic institutions most often researched host-targeted control ($n = 6$, 30.0%) and acaricide susceptibility assessments ($n = 5$, 25.0%) (Table 4).

Genus Summary: *Amblyomma*

Fifty-nine studies investigated tick control interventions for *Amblyomma* ticks; 53 (89.8%) of these studies investigated control of *Amblyomma americanum* (Linnaeus); 6 (10.2%) studies included both *A. americanum* and *A. maculatum* Koch; and one study (1.7%) included *A. americanum*, *A. maculatum*, and *A. cajennense* (Fabricius) (Table 4).

The majority of *Amblyomma*-focused control studies evaluated environmental acaricide interventions ($n = 24$, 40.7%), followed by host-targeted interventions ($n = 21$, 35.6%), habitat modifications ($n = 16$, 27.1%), acaricide susceptibility assessments ($n = 8$, 13.6%), with one community-based assessment (1.7%). The most common length over which *Amblyomma*-focused studies collected data was 1 year ($n = 14$, 23.7%), followed by 3 years ($n = 10$, 16.9%) and 2 years ($n = 9$, 15.3%); 18.6% of these studies ($n = 11$) did not report the period of data collection (Table 4).

Of the 24 studies focused on environmental acaricide interventions, most applied chemical acaricides to reduce tick populations in the environment ($n = 21$, 87.5%), followed by 4 (16.7%) studies evaluating naturally derived acaricides and 2 (8.3%) studies evaluating entomopathogenic fungi; 2 studies evaluated more than one acaricide type. The most commonly evaluated chemical acaricide classes were organophosphates ($n = 12$), followed by pyrethroids ($n = 6$) and carbamates ($n = 4$), while the most commonly evaluated natural acaricides were 25(b) minimum risk and other botanically derived products (Table 5).

Of the 21 studies focused on host-targeted evaluations, the majority ($n = 16$, 76.2%) focused on deer, followed by 4 (19.0%) studies that evaluated flea and tick control products for domestic pets delivered systemically or with spot treatments. The deer-targeted studies evaluated 4-poster systems ($n = 9$), with others focused on deer exclusion ($n = 4$) and topical and systemic acaricide treatment ($n = 3$, respectively). Of the 16 studies on habitat modifications, most conducted controlled burns ($n = 7$), followed by vegetation removal or thinning ($n = 5$). Two studies focused on the removal of invasive plant species, and 2 studies conducted landscape management to reduce tick populations. The community-based assessment measured willingness to pay for tick control services (Table 5).

Amblyomma-focused studies largely occurred in New Jersey ($n = 10$, 16.9%), Oklahoma ($n = 9$, 15.3%), and Texas ($n = 9$, 15.3%). The largest proportion of *Amblyomma*-focused studies was conducted in the wilderness setting ($n = 17$, 28.8%), followed by military bases ($n = 14$, 23.7%), and residential settings ($n = 13$, 22.0%). The wilderness-based studies were largely habitat modification trials, while studies conducted on military bases were mostly environmental acaricide interventions. Studies conducted in residential settings were predominantly focused on host-targeted interventions (Table 4).

Most research on the control of *Amblyomma* ticks was published from 1980–present ($n = 51$, 86.4%), with only 8 studies published prior to 1980. Funding for *Amblyomma*-focused control studies was provided by the USDA ($n = 15$, 25.4%), followed by the CDC ($n = 10$, 16.9%), and academic institutions ($n = 9$, 15.3%); 28.8% ($n = 17$) of *Amblyomma*-focused control studies did not report a funding source (Table 4).

Articles on control of *Amblyomma* ticks were most frequently authored by researchers only affiliated with public agencies ($n = 30$, 50.8%), followed by only academic institutions ($n = 15$, 25.4%), and public and academic partnerships ($n = 5$, 8.5%). Authors affiliated with only public agencies most often researched environmental acaricide control approaches ($n = 12$, 40.0%) and host-targeted approaches ($n = 8$, 26.7%). Authors affiliated with only academic institutions largely researched habitat interventions ($n = 6$, 40.0%), followed by acaricide susceptibility assessments ($n = 3$, 20.0%). Research conducted in partnership with authors from public agencies and academic institutions most often researched host-targeted control ($n = 2$, 40.0%) (Table 5).

Genus Summary: *Dermacentor*

Twenty-nine studies evaluated applied tick control interventions for *Dermacentor* ticks. Of these, 79.3% ($n = 23$) assessed *Dermacentor variabilis* (Say). Five studies included *D. occidentalis* Marx, and one study included *D. andersoni* Stiles (Table 4).

Most tick control interventions for *Dermacentor* ticks assessed host-targeted ($n = 15$, 51.7%) and habitat modification ($n = 9$, 31.0%) approaches, followed by acaricide susceptibility assessments ($n = 6$, 20.7%) and environmental acaricide control ($n = 5$, 17.2%); no studies for this genus incorporated community-based assessments (Table 5). Four studies (13.8%) incorporated multiple interventions, though only 2 of these were designed as ITM interventions (Bloemer et al. 1986, Zimmerman et al. 1988). The most common length over which *Dermacentor*-focused studies collected data was 1 year ($n = 7$, 25.0%), followed by 2 years ($n = 4$, 14.3%); 32.1% of these studies ($n = 9$) did not report the period of data collection (Table 4).

Of the 15 studies evaluating host-targeted control interventions, 40.0% ($n = 6$) evaluated tick control products for domestic pets delivered systemically or with spot treatments. Other host-targeted studies focused on deer ($n = 5$, 33.3%) or rodents ($n = 4$, 26.7%), with one (6.7%) study assessing permethrin-treated clothing used during walking surveys. Deer-focused studies evaluated 4-poster systems ($n = 3$) or deer exclusion ($n = 2$); the deer 4-poster studies were primarily designed as interventions for populations of *A. americanum* and/or *I. scapularis*, with *Dermacentor* ticks evaluated as a secondary target. Rodent-focused studies evaluated the use of acaricides delivered via nesting ($n = 2$), bait boxes ($n = 1$), bait cubes ($n = 1$), or rodent removal ($n = 1$) (Table 5).

Of the 9 studies evaluating habitat modification interventions, half ($n = 5$, 55.6%) evaluated the impact of controlled burns or natural fires. Other habitat modification interventions included landscape management approaches ($n = 2$, 22.2%), invasive plant removal ($n = 1$, 11.1%), and vegetation thinning/removal ($n = 1$, 11.1%). The 6 acaricide susceptibility trials evaluated active ingredients of pyrethroids, nootkatone, botanically derived pesticides, entomopathogenic fungi, and DEET. The 5 studies evaluating environmental acaricide control approaches evaluated active ingredients of organophosphates, pyrethrin, herbicides, and a variety of insecticides no longer available for use (Table 5).

Most research on the control of *Dermacentor* ticks was published from 1980 to present ($n = 26$, 89.7%), with only 3 studies published prior to 1980. Funding for *Dermacentor*-focused control studies was provided through CDC ($n = 6$, 20.7%), followed by academic institutions ($n = 5$, 17.2%), USDA ($n = 4$, 13.8%), private industry funders ($n = 4$, 13.8%), and other U.S. federal agencies ($n = 2$, 6.9%); 31.0% ($n = 9$) of *Dermacentor*-focused control studies did not report a funding source. CDC-funded studies focused primarily on habitat modification approaches ($n = 4$, 66.7%). USDA-supported work focused on environmental acaricide control approaches ($n = 2$ 50.0%), habitat modification ($n = 3$, 75.0%), and host-targeted approaches ($n = 2$, 50.0%). The majority of studies funded through private industry investigated host-targeted control methods for domestic pets ($n = 3$, 75.0%).

Articles on control of *Dermacentor* ticks were most frequently authored by researchers affiliated with only academic institutions ($n = 9$, 31.0%) and only public agencies ($n = 9$, 31.0%). Most authors at public agencies were affiliated with federal programs including USDA ($n = 4$) and CDC ($n = 2$). Authors affiliated with only academic institutions studied habitat interventions, host-targeted control, and acaricide susceptibility assessments ($n = 3$, 33.3%, respectively). Authors affiliated with only public agencies studied environmental

acaricide control approaches, host-targeted control, and use of multiple control approaches ($n = 2$, 22.2%, respectively). Research conducted in partnership with authors from public agencies and academic institutions ($n = 4$) focused on host-targeted control ($n = 2$), environmental acaricide control ($n = 1$), and habitat management ($n = 1$) (Table 5).

Most *Dermacentor*-focused studies were conducted in the United States ($n = 27$, 93.1%) followed by Canada ($n = 2$, 6.9%). The largest proportion of *Dermacentor*-focused studies were conducted in laboratory settings ($n = 11$, 37.9%). These lab-based studies were evenly distributed across host-targeted evaluations and acaricide susceptibility trials. Field-based studies were mostly conducted in wilderness settings ($n = 5$, 17.2%), parks ($n = 5$, 17.2%), residential areas ($n = 4$, 13.8%), or university experiment stations ($n = 5$, 17.2%). Studies conducted in wilderness settings were focused primarily on habitat modification, while studies conducted in other areas incorporated environmental acaricide and host-targeted control interventions. The states where *Dermacentor* was most frequently studied included California ($n = 6$, 20.7%), Texas ($n = 4$, 14.3%), and Virginia ($n = 4$, 14.3%).

Genus Summary: *Rhipicephalus*

Twelve studies evaluated applied tick control interventions for *Rhipicephalus* ticks, exclusively evaluating control of *Rhipicephalus sanguineus* (Latreille). Tick control interventions for *R. sanguineus* were mostly focused on host-targeted approaches ($n = 7$, 58.3%) and acaricide susceptibility trials ($n = 5$, 41.7%); no studies for this genus focused on habitat modification. Most *Rhipicephalus*-focused studies ($n = 8$, 66.7%) did not report the period of data collection (Table 4).

The largest proportion of *R. sanguineus* studies was conducted in laboratory settings ($n = 9$, 75.0%). These lab-based studies were evenly distributed across host-targeted evaluations and acaricide susceptibility trials (Table 4). Five susceptibility trials evaluated chemical acaricides (pyrethroids, organophosphates, and carbamates), naturally derived acaricides (nootkatone, pyrethrin), and entomopathogenic fungi. Four lab-based host-targeted studies evaluated tick control products for domestic pets delivered systemically or with spot treatments (Table 5).

Three studies incorporated multiple interventions and were designed as ITM studies to address RMSF outbreaks along the US-Mexico border (Drexler et al. 2014, Straily et al. 2016, Alvarez-Hernandez et al. 2020). These studies evaluated environmental acaricide control using pyrethroids, host-targeted treatment (domestic and free-roaming dogs) using Seresto collars (active ingredients include imidacloprid and flumethrin), and community education and outreach on bite prevention and control approaches for *R. sanguineus*. These studies were conducted in residential settings, including rural, urban, and suburban areas in Sonora, Mexico, and indigenous nation territory in the United States, and gathered data across the entire calendar year.

Funding for *Rhipicephalus*-focused control studies was provided through private industry ($n = 4$, 33.3%), CDC ($n = 2$, 16.7%), USDA ($n = 1$, 8.3%), and nonprofit funders ($n = 1$, 8.3%), or was not reported ($n = 5$, 41.7%). Of the studies supported by industry, most ($n = 3$, 75.0%) focused on host-targeted approaches. CDC supported 2 studies, one of which

focused on acaricide susceptibility and the other investigated multiple control methods for RMSF. USDA funded one study that investigated acaricide susceptibility (Table 4).

Most of the authors researching control of *Rhipicephalus* ticks were affiliated with academic institutions ($n = 4$, 33.3%) or private agencies ($n = 4$, 33.3%). Authors affiliated with only academic institutions exclusively studied acaricide susceptibility, while authors affiliated with only private organizations exclusively studied host-targeted approaches ($n = 4$, 100.0%, respectively). Research conducted in partnership with authors from public agencies and academic institutions ($n = 2$) focused on evaluating approaches that included multiple control methods ($n = 2$, 100.0%) (Table 5). The majority of *Rhipicephalus*-targeted studies occurred in the United States in Texas, Arizona, and Florida ($n = 8$, 66.7%). The remaining studies were conducted in both the United States and Mexico ($n = 3$, 25.0%) and Mexico only ($n = 1$, 8.3%).

ITM and Multi-Tick Evaluations

Fifteen studies (8.2%) conducted ITM evaluations (Table 4). Only 2 ITM studies evaluated more than one tick species concurrently (Bloemer et al. 1986, Zimmerman et al. 1988). These 2 studies evaluated *D. variabilis* and *A. americanum* using a combination of environmental acaricide control and deer-targeted interventions. One of these studies was funded by the USDA, and the other did not report a funding source. The remainder of the ITM studies evaluated *Amblyomma* ticks ($n = 5$), *Ixodes* ticks ($n = 5$), and *Rhipicephalus* ticks ($n = 3$). *Amblyomma*-focused ITM studies evaluated a combination of environmental acaricide control and habitat modification interventions, with 2 studies also including host-targeted approaches. These studies were funded by the USDA, Department of Commerce, state funders, or otherwise not reported. *Ixodes*-focused ITM studies evaluated a combination of environmental acaricide control and host-targeted interventions ($n = 4$) and habitat modification and host-targeted interventions ($n = 1$); the host-targeted interventions targeted deer and/or rodent hosts. These studies were funded by the CDC, USDA, academic institutions, nonprofit and private donors, and state funders. The 3 *Rhipicephalus*-targeted ITM studies addressed RMSF outbreaks along the US-Mexico border using environmental acaricide, host-targeted, and community-based assessments and were CDC-funded.

Thirty-nine (21.3%) studies evaluated control for more than one tick species concurrently (Table 4). Of these, 22 assessed 2-tick species, 60% of which paired *Ixodes* and *Amblyomma* ticks ($n = 14$), followed by *Amblyomma*-*Dermacentor* ($n = 4$) and *Ixodes*-*Dermacentor* ($n = 2$). Most of the 2-tick studies evaluated environmental acaricide control and host-targeted control interventions ($n = 9$, respectively), followed by habitat modification ($n = 5$). Eight of these 9 host-targeted interventions focused on deer. Six studies evaluated 3-tick species concurrently, 5 of which evaluated *Ixodes*, *Amblyomma*, and *Dermacentor* ticks; the remainder evaluated a mixture of *Dermacentor*, *Ixodes*, and *Rhipicephalus* ticks. Most of these 3-tick studies evaluated host-targeted interventions and acaricide susceptibility ($n = 3$, respectively); host-targeted interventions included deer, rodent, and human hosts. Seven (18.0%) studies evaluated 4 tick species concurrently, and 4 studies (10.3%) evaluated 5 tick species concurrently. These studies were dominated by host-targeted and acaricide susceptibility assessments; host-targeted assessments were

predominantly focused on flea and tick treatment for domestic pets. Multi-tick studies were predominantly CDC-funded ($n = 14$, 35.9%), followed by funder not reported ($n = 9$, 23.1%) and USDA-funded ($n = 5$, 12.8%).

Discussion

The results of this scoping review provide historical context on the major trends in applied tick control research in North America and highlight opportunities to expand our efforts in this important area of public health and disease prevention. Tick species range distributions are changing, and (re)emergence of tick-borne pathogens is a major public health concern (Ogden et al. 2013, Eisen et al. 2017, Sonenshine 2018, Little et al. 2021, Machtinger et al. 2024). Effective methods for controlling tick populations are necessary as is evaluating the effectiveness of control strategies. Our scoping review identified 244 articles reporting evaluations of applied tick control interventions in North America, the majority of which focused on tick vectors of public health importance and were conducted in the United States. Most interventions identified in this review focused exclusively on *I. scapularis*, were conducted at limited locations in the Northeast United States, and were supported through CDC funding increases beginning in the 1980s and 1990s. This trend in funding aligns with the increase in concern over Lyme disease and geographic areas of primary risk (Bacon et al. 2008). However, this historical pattern leaves several important gaps in our assessment of tick control strategies.

First, regional variations in tick-host associations, habitat usage, and host-seeking behavior are not well-reflected in the current control literature. These regional variations may have implications on the success of environmental acaricide, host-targeted, and habitat modification interventions in different ecological contexts (Arsnoe et al. 2015, Foster et al. 2022, Miller and Stafford 2022). Increasing the amount of tick control research conducted beyond the Northeast is of particular importance, as the distribution of ticks and their associated pathogens is shifting due to climate and land-use change (Sonenshine 2018, Bouchard et al. 2019, Alkishe et al. 2021). We note a lack of any studies conducted in NOAA regions VI (Northern Rockies & Plains) and VIII (Northwest) and a limited number of studies conducted in NOAA regions III (Upper Midwest), VII (Southwest), and IX (West). Ticks of public health importance are established in these regions and have been associated with an increased incidence of various TBDs in recent years (Straily et al. 2016, Alvarez-Hernandez et al. 2020, Fagre et al. 2024 Jul 9, Foley et al. 2024, U.S. Centers for Disease Control and Prevention 2024b, 2024c). Evaluating the effectiveness of tick control approaches in broadened geographies and ecosystems is a necessary next step in the progression of applied tick control research to protect public health.

Second, multiple tick species co-exist in shared environments, yet most studies we identified focused on the control of only one tick species (U.S. Centers for Disease Control and Prevention 2024b). Results from multi-tick control studies may provide valuable information for those seeking to implement cost-effective tick management practices in communities where multiple tick vectors co-exist. Future tick control evaluations should better reflect the realities of overlapping and expanding tick ranges by incorporating control outcomes for multiple tick vectors. In particular, evaluations that incorporate both *I. scapularis* and *A.*

americanum are needed, as the geographic ranges of these 2 species continue to expand in overlapping trajectories, magnifying the TBD risk (Cull 2022, Rochlin et al. 2022, Tardy et al. 2023). Our review identified 15 studies that evaluated control of both *I. scapularis* and *A. americanum* ticks through environmental acaricide application, habitat modification, and host-targeted approaches, 9 of which were conducted in New Jersey (see Table 4). Incorporating evidence from additional locations of current and projected species overlap, such as the Ohio Valley region, may provide additional evidence on control strategies that can optimally address the dual public health risk presented by these species (Eisen and Eisen 2023, Rochlin et al. 2023).

Third, only 8.2% of studies identified in this review implemented an explicit ITM approach to tick control. Incorporating ITM into tick management approaches aligns with the principles of IPM to use multiple strategies to control populations by the most economical means with minimal impact to the environment and nontarget organisms (U.S. Environmental Protection Agency 2015). However, recent cost assessments for ITM approaches highlight a mismatch between what individuals are willing to pay versus the actual cost of tick control (Schulze et al. 2023). Community feedback on acceptability and willingness to pay for various tick control strategies is an important consideration for the success of any community-based tick management plan (Eisen and Stafford 2021); however, we identified only a small number of studies that explicitly measured these factors. Studies measuring public sentiment have indicated that naturally derived products may have higher use and acceptability by the public compared to standard synthetic products (Eisen and Stafford 2021, Niesobecki et al. 2022, Cuaderna et al. 2023). Only 15 studies in this review evaluated applied tick control using naturally derived products, most of which were performed on *I. scapularis*. Research that identifies additional tools that can be incorporated into ITM approaches, such as the efficacy of naturally derived acaricide products on multiple tick species, may aid in the adoption of ITM practices.

Similarly, there is a need for greater adoption of an interdisciplinary One Health approach to tick control (Tiffin et al. 2022, Machtinger et al. 2024). One Health is a concerted approach that emphasizes the connection between environmental, human, and animal health and recognizes that the health and well-being of each sector are interconnected and require an integrated approach (Machtinger et al. 2024, The U.S. Department of Health and Human Services and The U.S. Centers for Disease Control and Prevention 2024, One Health). The US DHHS' National Strategy for the Prevention and Control of Vector-Borne Diseases in People calls for a collaborative effort that includes incorporating One Health (The U.S. Department of Health and Human Services and The U.S. Centers for Disease Control and Prevention 2024). In this review, only 3 studies incorporated a One Health approach (Drexler et al. 2014, Straily et al. 2016, Alvarez-Hernandez et al. 2020). Increasing collaborative research across interdisciplinary teams is necessary to address the complex systems that support the spread of ticks and TBD, and international collaboration is needed to effectively address threats posed by ticks and associated pathogens that cross jurisdictional boundaries (Tiffin et al. 2022, Foley et al. 2024).

Lastly, while funding for applied tick control research has steadily increased since the 1990s, the amount and pace of this funding has not matched the increasing threat presented by the

geographic expansion of tick vectors and increasing incidence of TBDs in North America (Rosenberg et al. 2018, Burtis et al. 2024). Studies that span the life cycle of tick vectors and connect entomological control strategies with epidemiological outcomes require multiyear investments and are costly to implement (Eisen and Stafford 2021). However, evaluating the connection between entomological outcomes (i.e., reduction of tick abundance or prevalence of infected ticks) and epidemiological outcomes (i.e., incidence of human disease) is vital to our development of effective, area-wide tick control strategies. The gap in evidence on epidemiological outcomes associated with tick control interventions is well recognized and has been described elsewhere (Poland 2001, Eisen et al. 2012, Eisen and Eisen 2016, Hinckley et al. 2016, Ostfeld and Keesing 2023). While our review did not directly assess this aspect of the literature, we emphasize the inclusion of human health outcomes in tick control studies as a necessary component of efficacy evaluation.

We recognize that both expertise and funding are needed to improve our repertoire of applied tick control strategies and expand development of new evidence-based control tools. Increased resources are also needed to ensure future studies encompass additional geographies, tick vectors, and human health outcomes. CDC funding has been the predominant source of support for applied tick control research on public health vectors in North America. Recent investments by CDC in extramural programs, including the Centers of Excellence, Teaching and Evaluation Centers, and Enhanced Laboratory Capacity programs, have been beneficial to both supporting broadened tick control research efforts and training the necessary workforce to conduct these evaluations (U.S. Centers for Disease Control and Prevention 2024d, 2024e). Increasing federal funding to both CDC and additional agencies, such as USDA and DOD, can enable the formation of an interdisciplinary, international, and epidemiologically focused approach to applied tick control in North America.

In conclusion, the volume of applied tick control research conducted in North America during the 20th and 21st centuries has provided valuable insights into strategies and approaches to manage tick populations and reduce the risk of TBDs. However, both within North America and internationally, the threat posed by ticks and their associated pathogens continues to increase, necessitating expanded approaches and increased collaboration to identify viable control strategies that will be effective across geographic and ecological contexts. The results of this review can serve as a platform from which gaps in our knowledge can be identified and pursued.

Limitations

There are limitations to this scoping review. First, while we did exclude duplicate articles in the review process, we did not track whether multiple articles reported segmented results from the same individual research study. Given this limitation, we may have included multiple publications reporting results from one research study. This effect was not accounted for in the summary statistics, and thus, our results reflect the number of publications on applied tick control research rather than the discrete number of studies conducted. Second, while we did include a small number of articles that incorporated community-based assessments (i.e., KAP surveys), tick bite prevention surveys and

community assessments did not generally fall within the primary focus of this review, and we expect that relevant articles were not captured in our search strategy. Thus, the results reported are not a comprehensive reflection of the broad KAP literature related to TBD knowledge or use of tick bite prevention and control strategies by the public. Third, assessment of the rigor of study design and relevance of measured outcomes to public and veterinary health were beyond the scope of this review. As such, we did not review the outcomes measured in tick control studies—such as density of infected ticks or human-tick encounters—nor the effect of tick control interventions on these outcomes. Additionally, we categorized each article's primary focus area as either public health or agriculture/wildlife; however, TBDs present a One Health issue. While a small number of studies fell within the One Health Framework, it was not a study characteristic targeted in our data extraction process. Lastly, while we made every effort to identify relevant applied tick control studies meeting our inclusion criteria, we may have overlooked relevant research that is not incorporated into the summary provided here.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

We would like to thank Dr. James Burtis and Dr. Lars Eisen for the valuable insight and expertise they provided throughout the systematic review process. We also thank Dr. Laura Harrington for the provision of support and resources to conduct this work within the Cornell Department of Entomology, as well as her valuable insight and expertise provided throughout this review. This research was conducted with support and resources provided by the Cornell Center for Social Sciences (CCSS) at Cornell University.

Funding

This work was supported by the Centers for Disease Control and Prevention (U01CK000509, U01CK000510, and U50CK000633) and National Institute of Allergy and Infectious Diseases (U01AI151801). This content is solely the responsibility of the authors and does not necessarily represent the official views of the Centers for Disease Control and Prevention or National Institute of Allergy and Infectious Diseases.

References

- Aenishaenslin C, Hongoh V, Cissé HD, et al. 2013. Multi-criteria decision analysis as an innovative approach to managing zoonoses: results from a study on Lyme disease in Canada. *BMC Public Health* 13:897. 10.1186/1471-2458-13-897 [PubMed: 24079303]
- Alkishe A, Raghavan RK, Peterson AT. 2021. Likely geographic distributional shifts among medically important tick species and tick-associated diseases under climate change in North America: a review. *Insects* 12:225. 10.3390/insects12030225 [PubMed: 33807736]
- Allan BF. 2009. Influence of prescribed burns on the abundance of *Amblyomma americanum* (Acari: Ixodidae) in the Missouri Ozarks. *J. Med. Entomol.* 46:1030–1036. 10.1603/033.046.0509 [PubMed: 19769033]
- Allan SA, Patrican LA. 1994. Susceptibility of immature *Ixodes scapularis* (Acari: Ixodidae) to desiccants and an insecticidal soap. *Exp. Appl. Acarol.* 18:691–702. 10.1007/BF00051536 [PubMed: 7555411]
- Allan SA, Patrican LA. 1995. Reduction of immature *Ixodes scapularis* (Acari: Ixodidae) in woodlots by application of desiccant and insecticidal soap formulations. *J. Med. Entomol.* 32:16–20. 10.1093/jmedent/32.1.16 [PubMed: 7869337]

- Allan BF, Dutra HP, Goessling LS, et al. 2010. Invasive honeysuckle eradication reduces tick-borne disease risk by altering host dynamics. *Proc. Natl. Acad. Sci. U.S.A.* 107:18523–18527. 10.1073/pnas.1008362107 [PubMed: 20937859]
- Alvarez-Hernandez G, Drexler N, Paddock CD, et al. 2020. Community-based prevention of epidemic Rocky Mountain spotted fever among minority populations in Sonora, Mexico, using a One Health approach. *Trans. R Soc. Trop. Med. Hyg.* 114:293–300. 10.1093/trstmh/trz114 [PubMed: 31819997]
- Animal and Plant Health Inspection Service. Asian longhorned tick (*Haemaphysalis longicornis*). Washington (DC): U.S. Department of Agriculture; 2024. Pest Alert Report No.: VS-21–001. <https://www.aphis.usda.gov/sites/default/files/alert-asian-longhorned-tick.508.pdf>.
- Arksey H, O'Malley L. 2005. Scoping studies: towards a methodological framework. *Int. J. Soc. Res. Methodol.* 8(1):19–32. 10.1080/1364557032000119616
- Arsnoe IM, Hickling GJ, Ginsberg HS, et al. 2015. Different populations of blacklegged tick nymphs exhibit differences in questing behavior that have implications for human Lyme disease risk. *PLoS One* 10:e0127450. 10.1371/journal.pone.0127450 [PubMed: 25996603]
- Bacon RM, Kugeler KJ, Mead PS; CDC. 2008. Surveillance for Lyme disease – United States, 1992–2006. *MMWR Morb. Mortal Wkly. Rep. Surveill. Summ.* 57:1–9.
- Baker CF, Hunter JS, McCall JW, et al. 2011. Efficacy of a novel topical combination of fipronil, amitraz and (S)-methoprene for treatment and control of induced infestations with four North American tick species (*Dermacentor variabilis*, *Ixodes scapularis*, *Amblyomma americanum* and *Amblyomma maculatum*) on dogs. *Vet. Parasitol.* 179:324–329. 10.1016/j.vetpar.2011.03.044 [PubMed: 21777734]
- Barile J, Braness G, Bao N, et al. 2005. A novel tick management system and its role in reducing the incidence of Lyme disease. In: Lee CY and Robinson WH, editors. *Proc. Fifth Int. Conf. Urban Pests. Malaysia*. <https://www.icup.org.uk/media/k5zpzsqb/icup057.pdf>.
- Barnard DR. 1986. Density perturbation in populations of *Amblyomma americanum* (Acari: Ixodidae) in beef cattle forage areas in response to two regimens of vegetation management. *J. Econ. Entomol.* 79:122–127. 10.1093/jee/79.1.122 [PubMed: 3950182]
- Beard C, Strickman D. 2014. Federal initiative: tick-borne disease integrated pest management white paper. In *Fed. Tick-Borne Dis. Integr. Pest Manag. Workgr* Washington, DC; p. 54. <https://www.epa.gov/pesp/federal-initiative-tick-borne-disease-integrated-pest-management-white-paper>
- Behle RW, Flor-Weiler LB, Bharadwaj A, et al. 2011. A formulation to encapsulate Nootkatone for tick control. *J. Med. Entomol.* 48:1120–1127. 10.1603/me10282 [PubMed: 22238870]
- Behle RW, Jackson MA, Flor-Weiler LB. 2013. Efficacy of a granular formulation containing *Metarhizium brunneum* F52 (Hypocreales: Clavicipitaceae) microsclerotia against nymphs of *Ixodes scapularis* (Acari: Ixodidae). *J. Econ. Entomol.* 106:57–63. 10.1603/ec12226 [PubMed: 23448015]
- Benjamin MA, Zhioua E, Ostfeld RS. 2002. Laboratory and field evaluation of the entomopathogenic fungus *Metarhizium anisopliae* (Deuteromycetes) for controlling questing adult *Ixodes scapularis* (Acari: Ixodidae). *J. Med. Entomol.* 39:723–728. 10.1603/0022-2585-39.5.723 [PubMed: 12349854]
- Bharadwaj A, Stafford KC. 2010. Evaluation of *Metarhizium anisopliae* strain F52 (Hypocreales: Clavicipitaceae) for control of *Ixodes scapularis* (Acari: Ixodidae). *J. Med. Entomol.* 47:862–867. 10.1603/me10020 [PubMed: 20939382]
- Bharadwaj A, Stafford KC. 2012. Susceptibility of *Ixodes scapularis* (Acari: Ixodidae) to *Metarhizium brunneum* F52 (Hypocreales: Clavicipitaceae) using three exposure assays in the laboratory. *J. Econ. Entomol.* 105:222–231. 10.1603/ec11169 [PubMed: 22420275]
- Bharadwaj A, Stafford KC, Behle RW. 2012. Efficacy and environmental persistence of Nootkatone for the control of the blacklegged tick (Acari: Ixodidae) in residential landscapes. *J. Med. Entomol.* 49:1035–1044. 10.1603/me11251 [PubMed: 23025184]
- Bharadwaj A, Hayes LE, Stafford KC. 2015. Effectiveness of garlic for the control of *Ixodes scapularis* (Acari: Ixodidae) on residential properties in western Connecticut. *J. Med. Entomol.* 52:722–725. 10.1093/jme/tjv044 [PubMed: 26335481]

- Bickerton M, McSorley K, Toledo A. 2021. A life stage-targeted acaricide application approach for the control of *Haemaphysalis longicornis*. Ticks Tick Borne Dis. 12:101581. 10.1016/j.ttbdis.2020.101581 [PubMed: 33075730]
- Bloemer SR, Snoddy EL, Cooney JC, et al. 1986. Influence of deer exclusion on populations of lone star ticks and American dog ticks (Acari: Ixodidae). J. Econ. Entomol. 79:679–683. 10.1093/jee/79.3.679 [PubMed: 3722591]
- Bloemer SR, Mount GA, Morris TA, et al. 1990. Management of lone star ticks (Acari: Ixodidae) in recreational areas with acaricide applications, vegetative management, and exclusion of white-tailed deer. J. Med. Entomol. 27:543–550. 10.1093/jmedent/27.4.543 [PubMed: 1696994]
- Bouchard C, Dibbernardo A, Koffi J, et al. 2019. Increased risk of tick-borne diseases with climate and environmental changes. Can. Commun. Dis. Rep. 45:83–89. 10.14745/ccdr.v45i04a02 [PubMed: 31285697]
- Brei B, Brownstein JS, George JE, et al. 2009. Evaluation of the United States Department of Agriculture Northeast Area-Wide Tick Control Project by meta-analysis. Vector Borne Zoonotic Dis. 9:423–430. 10.1089/vbz.2008.0150 [PubMed: 19650737]
- Bron GM, Lee X, Paskewitz SM. 2021. Do-It-Yourself tick control: granular gamma-cyhalothrin reduces Ixodes scapularis (Acari: Ixodidae) nymphs in residential backyards. J. Med. Entomol. 58:749–755. 10.1093/jme/tjaa212 [PubMed: 33107559]
- Brown JE, Miller TM, Machtinger ET. 2020. Tick tubes reduce blacklegged tick burdens on white-footed mice in Pennsylvania, USA. J. Appl. Entomol. 144:542–545. 10.1111/jen.12758
- Burridge MJ, Simmons L-A, Allan SA. 2003. Efficacy of acaricides for control of four tick species of agricultural and public health significance in the United States. J. Agric. Urban Entomol. 20:207–219.
- Burtis JC, Poggi JD, Payne B, et al. 2021. Susceptibility of Ixodes scapularis (Acari: Ixodidae) to permethrin under a long-term 4-poster deer treatment area on Shelter Island, NY. J. Med. Entomol. 58:1966–1969. 10.1093/jme/tjab054 [PubMed: 33822135]
- Burtis JC, Foster E, Eisen RJ, et al. 2024. Willingness and capacity of publicly-funded vector control programs in the USA to engage in tick management. Parasit. Vectors 17:316. 10.1186/s13071-024-06400-8 [PubMed: 39039577]
- Butler RA, Chandler JG, Vail KM, et al. 2021. Spray and pour-on acaricides killed Tennessee (United States) field-collected Haemaphysalis longicornis nymphs (Acari: Ixodidae) in laboratory bioassays. J. Med. Entomol. 58:2514–2518. 10.1093/jme/tjab115 [PubMed: 34197609]
- Carroll JF, Schmidtman ET. 1996. Silt Fencing as a Barrier to the dispersal of Ixodes scapularis (Acari: Ixodidae) into pastures. J. Med. Entomol. 33:921–925. 10.1093/jmedent/33.6.921 [PubMed: 8961640]
- Carroll JF, Maradufu A, Warthen JD. 1989. An extract of *Commiphora erythraea*: a repellent and toxicant against ticks. Entomol. Exp. Appl. 53:111–116. 10.1111/j.1570-7458.1989.tb01294.x
- Carroll JF, Allen PC, Hill DE, et al. 2002. Control of Ixodes scapularis and Amblyomma americanum through use of the ‘4-poster’ treatment device on deer in Maryland. Exp. Appl. Acarol 28:289–296. 10.1023/a:1025383408163 [PubMed: 14570143]
- Carroll JF, Hill DE, Allen PC, et al. 2009a. The impact of 4-poster deer self-treatment devices at three locations in Maryland. Vector Borne Zoonotic Dis. 9:407–416. 10.1089/vbz.2008.0165 [PubMed: 19650735]
- Carroll JF, Pound JM, Miller JA, et al. 2009b. Sustained control of Gibson Island, Maryland, populations of Ixodes scapularis and Amblyomma americanum (Acari: Ixodidae) by community-administered 4-poster deer self-treatment bait stations. Vector Borne Zoonotic Dis. 9:417–421. 10.1089/vbz.2008.0166 [PubMed: 19650736]
- Civitello DJ, Flory SL, Clay K. 2008. Exotic grass invasion reduces survival of Amblyomma americanum and Dermacentor variabilis ticks (Acari: Ixodidae). J. Med. Entomol. 45:867–872. 10.1603/0022-2585(2008)45[867:egirso]2.0.co;2 [PubMed: 18826028]
- Clymer BC, Howell DE, Hair JA. 1970. Environmental alteration in recreational areas by mechanical and chemical treatment as a means of lone star tick control. J. Econ. Entomol. 63:504–509. 10.1093/jee/63.2.504 [PubMed: 5441234]

- Cuaderna MKQ, Mader EM, Safi AG, et al. 2023. Knowledge, attitudes, and practices for tick bite prevention and tick control among residents of Long Island, New York, USA. *Ticks Tick Borne Dis.* 14:102124. 10.1016/j.ttbdis.2023.102124 [PubMed: 36764054]
- Cull B 2022. Monitoring trends in distribution and seasonality of medically important ticks in North America using online crowdsourced records from iNaturalist. *Insects* 13:404. 10.3390/insects13050404 [PubMed: 35621740]
- Cully JF. 1999. Lone star tick abundance, fire, and bison grazing in tallgrass prairie. *J. Range Manag.* 52:139–144. 10.2307/4003507
- Curran KL, Fish D, Piesman J. 1993. Reduction of nymphal *Ixodes dammini* (Acari: Ixodidae) in a residential suburban landscape by area application of insecticides. *J. Med. Entomol.* 30:107–113. 10.1093/jmedent/30.1.107 [PubMed: 8433317]
- Daniels TJ, Fish D. 1995. Effect of deer exclusion on the abundance of immature *Ixodes scapularis* (Acari: Ixodidae) parasitizing small and medium-sized mammals. *J. Med. Entomol.* 32:5–11. 10.1093/jmedent/32.1.5 [PubMed: 7869342]
- Daniels TJ, Fish D, Falco RC. 1991. Evaluation of host-targeted acaricide for reducing risk of Lyme disease in southern New York State. *J. Med. Entomol.* 28:537–543. 10.1093/jmedent/28.4.537 [PubMed: 1941916]
- Daniels TJ, Fish D, Schwartz I. 1993. Reduced abundance of *Ixodes scapularis* (Acari: Ixodidae) and Lyme disease risk by deer exclusion. *J. Med. Entomol.* 30:1043–1049. 10.1093/jmedent/30.6.1043 [PubMed: 8271246]
- Daniels TJ, Falco RC, Mchugh EE, et al. 2009. Acaricidal treatment of white-tailed deer to control *Ixodes scapularis* (Acari: Ixodidae) in a New York Lyme disease-endemic community. *Vector Borne Zoonotic Dis.* 9:381–387. 10.1089/vbz.2008.0197 [PubMed: 19650732]
- Davidson WR, Siefken DA, Creekmore LH. 1994. Influence of annual and biennial prescribed burning during March on the abundance of *Amblyomma americanum* (Acari: Ixodidae) in central Georgia. *J. Med. Entomol.* 31:72–81. 10.1093/jmedent/31.1.72 [PubMed: 8158633]
- Deblinger RD, Rimmer DW. 1991. Efficacy of a permethrin-based acaricide to reduce the abundance of *Ixodes dammini* (Acari: Ixodidae). *J. Med. Entomol.* 28:708–711. 10.1093/jmedent/28.5.708 [PubMed: 1941940]
- Deblinger RD, Wilson ML, Rimmer DW, et al. 1993. Reduced abundance of immature *Ixodes dammini* (Acari: Ixodidae) following incremental removal of deer. *J. Med. Entomol.* 30:144–150. 10.1093/jmedent/30.1.144 [PubMed: 8433321]
- Deshpande G, Beetch JE, Heller JG, et al. 2024. Assessing the influence of climate change and environmental factors on the top tick-borne diseases in the united states: a systematic review. *Microorganisms* 12:50. 10.3390/microorganisms12010050
- Dolan MC, Maupin GO, Schneider BS, et al. 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. 10.1603/0022-2585-41.6.1043 [PubMed: 15605643]
- Dolan MC, Dietrich G, Panella NA, et al. 2007. Biocidal activity of three wood essential oils against *Ixodes scapularis* (Acari: Ixodidae), *Xenopsylla cheopis* (Siphonaptera: Pulicidae), and *Aedes aegypti* (Diptera: Culicidae). *J. Econ. Entomol.* 100:622–625. 10.1603/0022-0493(2007)100[622:baotwe]2.0.co;2 [PubMed: 17461093]
- Dolan MC, Jordan RA, Schulze TL, et al. 2009. Ability of two natural products, Nootkatone and carvacrol, to suppress *Ixodes scapularis* and *Amblyomma americanum* (Acari: Ixodidae) in a Lyme disease endemic area of New Jersey. *J. Econ. Entomol.* 102:2316–2324. 10.1603/029.102.0638 [PubMed: 20069863]
- Dolan MC, Schulze TL, Jordan RA, et al. 2016. Evaluation of doxycycline-laden oral bait and topical fipronil delivered in a single bait box to control *Ixodes scapularis* (Acari: Ixodidae) and reduce *Borrelia burgdorferi* and *Anaplasma phagocytophilum* infection in small mammal reservoirs and host-seeking ticks. *J. Med. Entomol.* 54:403–410. 10.1093/jme/tjw194
- Drexler N, Miller M, Gerding J, et al. 2014. Community-based control of the brown dog tick in a region with high rates of Rocky Mountain spotted fever, 2012–2013. Yu X, editor. *PLoS One* 9:e112368. 10.1371/journal.pone.0112368 [PubMed: 25479289]

- Duffy DC, Downer R, Brinkley C. 1992. The effectiveness of helmeted guineafowl in the control of the deer tick, the vector of Lyme disease. *Wilson Bull.* 104:342–345.
- Dupuis AP, Lange RE, Ciota AT. 2023. Emerging tickborne viruses vectored by *Amblyomma americanum* (Ixodida: Ixodidae): Heartland and Bourbon viruses. *J. Med. Entomol.* 60:1183–1196. 10.1093/jme/tjad060 [PubMed: 37862097]
- Edwards K, Smith J, Bankert C, et al. 2016. A study report on the use of 4-poster deer treatment stations to control tick infestations on white-tailed deer (*Odocoileus virginianus*) in Fairfax County. Fairfax (VA): Fairfax County Police Department, Fairfax County Health Department; 2016. <https://www.fairfaxcounty.gov/wildlife/sites/wildlife/files/assets/documents/pdf/fairfax-county-4-poster-study-final-report.pdf>
- Eiden AL, Kaufman PE, Oi FM, et al. 2015. Detection of permethrin resistance and fipronil tolerance in *Rhipicephalus sanguineus* (Acari: Ixodidae) in the United States. *J. Med. Entomol.* 52:429–436. 10.1093/jme/tjv005 [PubMed: 26334817]
- Eisen L, Eisen RJ. 2016. Critical evaluation of the linkage between tick-based risk measures and the occurrence of Lyme disease cases. *J. Med. Entomol.* 53:1050–1062. 10.1093/jme/tjw092 [PubMed: 27330093]
- Eisen L, Eisen RJ. 2023. Changes in the geographic distribution of the blacklegged tick, *Ixodes scapularis*, in the United States. *Ticks Tick Borne Dis.* 14:102233. 10.1016/j.ttbdis.2023.102233 [PubMed: 37494882]
- Eisen L, Stafford KC. 2021. Barriers to effective tick management and tick-bite prevention in the United States (Acari: Ixodidae). *J. Med. Entomol.* 58:1588–1600. 10.1093/jme/tjaa079 [PubMed: 32372075]
- Eisen RJ, Piesman J, Zielinski-Gutierrez E, et al. 2012. What do we need to know about disease ecology to prevent Lyme disease in the Northeastern United States? *J. Med. Entomol.* 49:11–22. 10.1603/me11138 [PubMed: 22308766]
- Eisen RJ, Eisen L, Beard CB. 2016. County-scale distribution of *Ixodes scapularis* and *Ixodes pacificus* (Acari: Ixodidae) in the Continental United States. *J. Med. Entomol.* 53:349–386. 10.1093/jme/tjv237 [PubMed: 26783367]
- Eisen RJ, Kugeler KJ, Eisen L, et al. 2017. Tick-borne zoonoses in the United States: persistent and emerging threats to human health. *ILAR J.* 58:319–335. 10.1093/ilar/ilx005 [PubMed: 28369515]
- Elias SP, Lubelczyk CB, Rand PW, et al. 2013. Effect of a botanical acaricide on *Ixodes scapularis* (Acari: Ixodidae) and nontarget arthropods. *J. Med. Entomol.* 50:126–136. 10.1603/me12124 [PubMed: 23427661]
- Eller FJ, Vander Meer RK, Behle RW, et al. 2014. Bioactivity of cedarwood oil and cedrol against arthropod pests. *Environ. Entomol.* 43:762–766. 10.1603/EN13270 [PubMed: 24690252]
- Fagre A, Lehman J, Hills SL. 2024. Colorado tick fever in the United States, 2013–2022. *Am. J. Trop. Med. Hyg.* 111:598–602. 10.4269/ajtmh.24-0044 [PubMed: 38981504]
- Fischhoff IR, Keesing F, Pendleton J, et al. 2019. Assessing effectiveness of recommended residential yard management measures against ticks. *J. Med. Entomol.* 56:1420–1427. 10.1093/jme/tjz077 [PubMed: 31120510]
- Flor-Weiler LB, Behle RW, Stafford KC. 2011. Susceptibility of four tick species, *Amblyomma americanum*, *Dermacentor variabilis*, *Ixodes scapularis*, and *Rhipicephalus sanguineus* (Acari: Ixodidae), to Nootkatone from essential oil of grapefruit. *J. Med. Entomol.* 48:322–326. 10.1603/me10148 [PubMed: 21485368]
- Foley J, López-Pérez AM, Rubino F, et al. 2024. Roaming dogs, intense brown dog tick infestation, and emerging Rocky Mountain spotted fever in Tijuana, México. *Am. J. Trop. Med. Hyg.* 110:779–794. 10.4269/ajtmh.23-0410 [PubMed: 38377609]
- Foster E, Burtis J, Sidge JL, et al. 2022. Inter-annual variation in prevalence of *Borrelia burgdorferi* sensu stricto and *Anaplasma phagocytophilum* in host-seeking *Ixodes scapularis* (Acari: Ixodidae) at long-term surveillance sites in the upper midwestern United States: implications for public health practice. *Ticks Tick Borne Dis.* 13:101886. 10.1016/j.ttbdis.2021.101886 [PubMed: 34929604]

- Gaff HD, White A, Leas K, et al. 2015. TickBot: a novel robotic device for controlling tick populations in the natural environment. *Ticks Tick Borne Dis.* 6:146–151. 10.1016/j.ttbdis.2014.11.004 [PubMed: 25499615]
- Gage KL, Maupin GO, Monteneri J, et al. 1997. Flea (Siphonaptera: Ceratophyllidae, Hystrihopsyllidae) and tick (Acarina: Ixodidae) control on wood rats using host-targeted liquid permethrin in bait tubes. *J. Med. Entomol.* 34:46–51. 10.1093/jmedent/34.1.46 [PubMed: 9086710]
- Ginsberg HS. Ecology and management of ticks and Lyme disease at Fire Island National Seashore and selected eastern national parks. United States Department of the Interior, National Park Service; 1992. Report No.: NPS/NRSUNJ/NRSM-92/20. <http://npshistory.com/series/science/20/report.pdf>.
- Ginsberg HS, Butler M, Zhioua E. 2002. Effect of deer exclusion by fencing on abundance of *Amblyomma americanum* (Acari: Ixodidae) on Fire Island, New York, USA. *J. Vector Ecol.* 27:215–221. [PubMed: 12546457]
- Gleim ER, Conner LM, Berghaus RD, et al. 2014. The phenology of ticks and the effects of long-term prescribed burning on tick population dynamics in southwestern Georgia and northwestern Florida. *PLoS One* 9:e112174. 10.1371/journal.pone.0112174 [PubMed: 25375797]
- Gould LH, Nelson RS, Griffith KS, et al. 2008. Knowledge, attitudes, and behaviors regarding Lyme disease prevention among Connecticut residents, 1999–2004. *Vector Borne Zoonotic Dis.* 8:769–776. 10.1089/vbz.2007.0221 [PubMed: 18637724]
- Grear JS, Koethe R, Hoskins B, et al. 2014. The effectiveness of permethrin-treated deer stations for control of the Lyme disease vector *Ixodes scapularis* on Cape Cod and the Islands: a five-year experiment. *Parasit. Vectors* 7:292. 10.1186/1756-3305-7-292 [PubMed: 24965139]
- Greengarten PJ, Tuininga AR, Morath SU, et al. 2011. Occurrence of soil- and tick-borne fungi and related virulence tests for pathogenicity to *Ixodes scapularis* (Acari: Ixodidae). *J. Med. Entomol.* 48:337–344. 10.1603/me09116 [PubMed: 21485371]
- Hair JA, Howell DE. Lone star ticks; their biology and control in Ozark recreation areas. Oklahoma Agricultural Experiment Station; 1970. Report No.: 679. <https://hdl.handle.net/11244/331981>.
- Harmon JR, Hickling GJ, Scott MC, et al. 2011. Evaluation of 4-poster acaricide applicators to manage tick populations associated with disease risk in a Tennessee retirement community. *J. Vector Ecol.* 36:404–410. 10.1111/j.1948-7134.2011.00181.x [PubMed: 22129412]
- Hill DE. 1998. Entomopathogenic nematodes as control agents of developmental stages of the black-legged tick, *Ixodes scapularis*. *J. Parasitol.* 84:1124–1127. [PubMed: 9920301]
- Hinckley AF, Meek JJ, Ray JAE, et al. 2016. Effectiveness of residential acaricides to prevent Lyme and other tick-borne diseases in humans. *J. Infect. Dis.* 214:182–188. 10.1093/infdis/jiv775 [PubMed: 26740276]
- Hoch AL, Barker RW, Hair JA. 1971. Further observations on the control of lone star ticks (Acarina: Ixodidae) through integrated control Procedures. *J. Med. Entomol.* 8:731–734. 10.1093/jmedent/8.6.731 [PubMed: 5153597]
- Hoch AL, Semtner PJ, Barker RW, et al. 1972. Preliminary observations on controlled burning for lone star tick (Acarina: Ixodidae) control in woodlots. *J. Med. Entomol.* 9:446–451. 10.1093/jmedent/9.5.446 [PubMed: 5080432]
- Hodo CL, Forgacs D, Auckland LD, et al. 2020. Presence of diverse *Rickettsia* spp. and absence of *Borrelia burgdorferi* sensu lato in ticks in an East Texas forest with reduced tick density associated with controlled burns. *Ticks Tick Borne Dis.* 11:101310. 10.1016/j.ttbdis.2019.101310 [PubMed: 31704208]
- Hornbostel VL, Ostfeld RS, Zhioua E, et al. 2004. Sublethal effects of *Metarhizium anisopliae* (Deuteromycetes) on engorged larval, nymphal, and adult *Ixodes scapularis* (Acari: Ixodidae). *J. Med. Entomol.* 41:922–929. 10.1603/0022-2585-41.5.922 [PubMed: 15535622]
- Hornbostel VL, Ostfeld RS, Benjamin MA. 2005a. Effectiveness of *Metarhizium anisopliae* (Deuteromycetes) against *Ixodes scapularis* (Acari: Ixodidae) engorging on *Peromyscus leucopus*. *J. Vector Ecol.* 30:91–101. [PubMed: 16007961]

- Hornbostel VL, Zhioua E, Benjamin MA, et al. 2005b. Pathogenicity of *Metarhizium anisopliae* (Deuteromycetes) and permethrin to *Ixodes scapularis* (Acari: Ixodidae) nymphs. *Exp. Appl. Acarol* 35:301–316. 10.1007/s10493-004-5437-z [PubMed: 15969463]
- Hornbostel VL, Krell RK, Reid JJ, et al. 2021. *Spray Safe, Play Safe*: story-based films increase homeowner confidence about backyard tick management. *J. Med. Entomol.* 58:857–865. 10.1093/jme/tjaa230 [PubMed: 33225365]
- Hughes TH, Richardson AG, Hoel DF, et al. 2014. Suppression of *Amblyomma americanum* (Ixodida: Ixodidae) for short-term field operations utilizing cypermethrin and lambda-cyhalothrin. *J. Med. Entomol.* 51:709–712. 10.1603/me13034 [PubMed: 24897866]
- Hunter JS, Baggott D, Everett WR, et al. 2011. Efficacy of a novel topical combination of fipronil, amitraz and (S)-methoprene for treatment and control of induced infestations of brown dog ticks (*Rhipicephalus sanguineus*) on dogs. *Vet. Parasitol.* 179:318–323. 10.1016/j.vetpar.2011.03.042 [PubMed: 21777733]
- Jongejan F, Uilenberg G. 2004. The global importance of ticks. *Parasitology* 129:S3–14. 10.1017/S0031182004005967 [PubMed: 15938502]
- Jordan RA, Schulze TL. 2019. Ability of two commercially available host-targeted technologies to reduce abundance of *Ixodes scapularis* (Acari: Ixodidae) in a residential landscape. *J. Med. Entomol.* 56:1095–1101. 10.1093/jme/tjz046 [PubMed: 30984975]
- Jordan RA, Schulze TL. 2020a. Artificial accumulation of leaf litter in forest edges on residential properties via leaf blowing is associated with increased numbers of host-seeking *Ixodes scapularis* (Acari: Ixodidae) nymphs. *J. Med. Entomol.* 57:1193–1198. 10.1093/jme/tjaa033 [PubMed: 32186344]
- Jordan RA, Schulze TL. 2020b. Availability and nature of commercial tick control services in three Lyme disease endemic states. *J. Med. Entomol.* 57:807–814. 10.1093/jme/tjz215 [PubMed: 31794013]
- Jordan RA, Schulze TL, Jahn MB. 2007. Effects of reduced deer density on the abundance of *Ixodes scapularis* (Acari: Ixodidae) and Lyme disease incidence in a northern New Jersey endemic area. *J. Med. Entomol.* 44:752–757. 10.1603/0022-2585(2007)44[752:eorddo]2.0.co;2 [PubMed: 17915504]
- Jordan RA, Dolan MC, Piesman J, et al. 2011. Suppression of host-seeking *Ixodes scapularis* and *Amblyomma americanum* (Acari: Ixodidae) nymphs after dual applications of plant-derived acaricides in New Jersey. *J. Econ. Entomol.* 104:659–664. 10.1603/ec10340 [PubMed: 21510219]
- Kaplan ZD, Richardson EA, Kaufman PE, et al. 2020. Evaluation of fipronil susceptibility in the lone star tick (Acari: Ixodidae). *J. Med. Entomol.* 57:1314–1317. 10.1093/jme/tjaa028 [PubMed: 32076704]
- Karl T, Koss WJ. 1984. Regional and national monthly, seasonal, and annual temperature weighted by area, 1895–1983. National Climatic Data Center Historical Climatology Series 4–3. [accessed 2024 Jun 19]. <https://repository.library.noaa.gov/view/noaa/10238>.
- Keesing F, Mowry S, Bremer W, et al. 2022. Effects of tick-control interventions on tick abundance, human encounters with ticks, and incidence of tickborne diseases in residential neighborhoods, New York, USA. *Emerg. Infect. Dis.* 28:957–966. 10.3201/eid2805.211146 [PubMed: 35447066]
- Kirkland BH, Cho E-M, Keyhani NO. 2004a. Differential susceptibility of *Amblyomma maculatum* and *Amblyomma americanum* (Acari: Ixodidae) to the entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae*. *Biol. Control* 31:414–421. 10.1016/j.biocontrol.2004.07.007
- Kirkland BH, Westwood GS, Keyhani NO. 2004b. Pathogenicity of entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* to Ixodidae tick species *Dermacentor variabilis*, *Rhipicephalus sanguineus*, and *Ixodes scapularis*. *J. Med. Entomol.* 41:705–711. 10.1603/0022-2585-41.4.705 [PubMed: 15311464]
- Koloski CW, Duncan CAM, Rutherford PL, et al. 2020. Natural insensitivity and the effects of concentration on the repellency and survival of American dog ticks (*Dermacentor variabilis*) by DEET. *Exp. Appl. Acarol* 82:379–395. 10.1007/s10493-020-00550-x [PubMed: 33009647]

- Lane RS. 1989. Treatment of clothing with a permethrin spray for personal protection against the western black-legged tick, *Ixodes pacificus* (Acari: Ixodidae). *Exp. Appl. Acarol* 6:343–352. 10.1007/BF01193304 [PubMed: 2743839]
- Lane RS, Anderson JR. 1984. Efficacy of permethrin as a repellent and toxicant for personal protection against the Pacific Coast tick and the pajaroello tick (Acari: Ixodidae and Argasidae). *J. Med. Entomol.* 21:692–702. 10.1093/jmedent/21.6.692 [PubMed: 6502628]
- Lee X, Maxson G-A, Paskewitz S. 2023. Single mowing event does not reduce abundance of *Ixodes scapularis* (Acari: Ixodidae) and *Dermacentor variabilis* (Acari: Ixodidae) on recreational hiking trails. Fonseca D, editor. *J. Med. Entomol.* 60:228–234. 10.1093/jme/tjac164 [PubMed: 36308319]
- Leprince DJ, Lane RS. 1996. Evaluation of permethrin-impregnated cotton balls as potential nesting material to control ectoparasites of woodrats in California. *J. Med. Entomol.* 33:355–360. 10.1093/jmedent/33.3.355 [PubMed: 8667381]
- Lerman SB, D'Amico V. 2019. Lawn mowing frequency in suburban areas has no detectable effect on *Borrelia* spp. vector *Ixodes scapularis* (Acari: Ixodidae). Stevenson B, editor. *PLoS One* 14:e0214615. 10.1371/journal.pone.0214615 [PubMed: 30943238]
- Levy S. 2017. Northern trek: the spread of *Ixodes scapularis* into Canada. *Environ. Health Perspect.* 125:074002. 10.1289/EHP2095 [PubMed: 28743676]
- Linske MA, Williams SC, Stafford KC, et al. 2022. Integrated tick management in Guilford, CT: fipronil-based rodent-targeted bait box deployment configuration and *Peromyscus leucopus* (Rodentia: Cricetidae) abundance drive reduction in tick burdens. Ginsberg H, editor. *J. Med. Entomol.* 59:591–597. 10.1093/jme/tjab200 [PubMed: 34908136]
- Little S, Braff J, Place J, et al. 2021. Canine infection with *Dirofilaria immitis*, *Borrelia burgdorferi*, *Anaplasma* spp., and *Ehrlichia* spp. in the United States, 2013–2019. *Parasit. Vectors* 14:10. 10.1186/s13071-020-04514-3 [PubMed: 33407758]
- Lyon SM, Van Driesche R, Edman JD. 1998. Ecology of *Hunterellus hookeri* (Hymenoptera: Encyrtidae) and evaluation of its impact on *Ixodes scapularis* (Acari: Ixodidae) on Nonamesset Island in Massachusetts. *Environ. Entomol.* 27:463–468. 10.1093/ee/27.2.463
- Machtinger ET, Poh KC, Pesapane R, et al. 2024. An integrative framework for tick management: the need to connect wildlife science, one health, and interdisciplinary perspectives. *Curr. Opin. Insect Sci.* 61:101131. 10.1016/j.cois.2023.101131 [PubMed: 37866434]
- Mak S, Thomas A. 2022. Steps for conducting a scoping review. *J. Grad. Med. Educ.* 14:565–567. 10.4300/JGME-D-22-00621.1 [PubMed: 36274762]
- Mandli JT, Lee X, Bron GM, et al. 2021. Integrated Tick Management in south central Wisconsin: impact of invasive vegetation removal and host-targeted acaricides on the density of questing *Ixodes scapularis* (Acari: Ixodidae) nymphs. *J. Med. Entomol.* 58:2358–2367. 10.1093/jme/tjab131 [PubMed: 34397096]
- Mather TN, Ribeiro JMC, Spielman A. 1987. Lyme disease and babesiosis: acaricide focused on potentially infected ticks. *Am. J. Trop. Med. Hyg.* 36:609–614. 10.4269/ajtmh.1987.36.609 [PubMed: 3555140]
- Mather TN, Ribeiro JMC, Moore SI, et al. 1988. Reducing transmission of Lyme disease spirochetes in a suburban setting. *Ann. N. Y. Acad. Sci.* 539:402–403. 10.1111/j.1749-6632.1988.tb31885.x
- Mather TN, Duffy DC, Campbell SR. 1993. An unexpected result from burning vegetation to reduce Lyme disease transmission risks. *J. Med. Entomol.* 30:642–645. 10.1093/jmedent/30.3.642 [PubMed: 8510127]
- Maupin GO, Piesman J. 1994. Acaricide susceptibility of immature *Ixodes scapularis* (Acari: Ixodidae) as determined by the disposable pipet method. *J. Med. Entomol.* 31:319–321. 10.1093/jmedent/31.2.319 [PubMed: 8189426]
- McCall JW, Baker CF, Mather TN, et al. 2011. The ability of a topical novel combination of fipronil, amitraz and (S)-methoprene to protect dogs from *Borrelia burgdorferi* and *Anaplasma phagocytophilum* infections transmitted by *Ixodes scapularis*. *Vet. Parasitol.* 179:335–342. 10.1016/j.vetpar.2011.03.046 [PubMed: 21777736]
- McDuffie WC, Eddy GW, Clark JC, et al. 1950. Field studies with insecticides to control the lone star tick in Texas. *J. Econ. Entomol.* 43:520–527. 10.1093/jee/43.4.520

- McKay R, Talbot B, Slatculescu A, et al. 2020. Woodchip borders at the forest ecotone as an environmental control measure to reduce questing tick density along recreational trails in Ottawa, Canada. *Ticks Tick Borne Dis.* 11:101361. 10.1016/j.ttbdis.2019.101361 [PubMed: 31874797]
- Miller RJ, Stafford KC. Changing dynamics of tick ecology, personal protection, and control subcommittee report to the Tick-Borne Disease Working Group. Washington (DC): Office of the Assistant Secretary for Health; 2022. <https://www.hhs.gov/ash/advisory-committees/tickbornedisease/reports/changing-dynamics-tick-ecology-personal-protection-control-2022/index.html>.
- Miller NJ, Thomas WA, Mather TN. 2009. Evaluating a deer-targeted acaricide applicator for area-wide suppression of blacklegged ticks, *Ixodes scapularis* (Acari: Ixodidae), in Rhode Island. *Vector Borne Zoonotic Dis.* 9:401–406. 10.1089/vbz.2008.0164 [PubMed: 19650734]
- Mitchell EB, McCall JW, Theodore Chester S, et al. 2014. Efficacy of afoxolaner against *Ixodes scapularis* ticks in dogs. *Vet. Parasitol.* 201:223–225. 10.1016/j.vetpar.2014.02.015 [PubMed: 24685321]
- Mount GA. 1981. Control of the lone star tick in Oklahoma parks through vegetative management. *J. Econ. Entomol.* 74:173–175. 10.1093/jee/74.2.173 [PubMed: 7320314]
- Mount GA. 1983. Area control of larvae of the lone star tick (Acari: Ixodidae) with acaricides. *J. Econ. Entomol.* 76:113–116. 10.1093/jee/76.1.113 [PubMed: 6186711]
- Mount GA. 1984. Aerial application of diazinon granules for area control of the lone star tick (Acari: Ixodidae). *J. Econ. Entomol.* 77:1211–1213. 10.1093/jee/77.5.1211 [PubMed: 6512070]
- Mount GA, Hirst JM, McWilliams JG, et al. 1968. Insecticides for control of the lone star tick tested in the laboratory and as high- and ultra-low-volume sprays in wooded areas. *J. Econ. Entomol.* 61:1005–1007. 10.1093/jee/61.4.1005 [PubMed: 5662002]
- Mount GA, Grothaus RH, Reed JT, et al. 1976. *Amblyomma americanum*: area control with granules or concentrated sprays of diazinon, propoxur, and chlorpyrifos. *J. Econ. Entomol.* 69:257–259. 10.1093/jee/69.2.257 [PubMed: 57127]
- Murphy M, Garcia R, Karadzovska D, et al. 2017. Laboratory evaluations of the immediate and sustained efficacy of lotilaner (Credelio™) against four common species of ticks affecting dogs in North America. *Parasit. Vectors* 10:523. 10.1186/s13071-017-2476-y [PubMed: 29089057]
- National Center for Emerging and Zoonotic Infectious Diseases, Division of Parasitic Diseases and Malaria. DPDx - laboratory identification of parasites of public health concern: ticks. CDC - DPDx; 2019 [accessed 2024 Jun 21]. <https://www.cdc.gov/dpdx/ticks/index.html>.
- Nelson VA. 1969. Dursban® for control of the brown dog tick. *J. Econ. Entomol.* 62:719–720. 10.1093/jee/62.3.719
- Niesobecki S, Hansen A, Rutz H, et al. 2019. Knowledge, attitudes, and behaviors regarding tick-borne disease prevention in endemic areas. *Ticks Tick Borne Dis.* 10:101264. 10.1016/j.ttbdis.2019.07.008 [PubMed: 31431351]
- Niesobecki S, Rutz H, Niccolai L, et al. 2022. Willingness to pay for select tick-borne disease prevention measures in endemic areas. *J. Public Health Manag. Pract.* 28:E37–E42. 10.1097/PHH.0000000000001295 [PubMed: 33729199]
- Ogden NH, Mechai S, Margos G. 2013. Changing geographic ranges of ticks and tick-borne pathogens: drivers, mechanisms and consequences for pathogen diversity. *Front. Cell. Infect. Microbiol.* 3:46. 10.3389/fcimb.2013.00046. [accessed 2024 Mar 4]. <http://journal.frontiersin.org/article/10.3389/fcimb.2013.00046/abstract>. [PubMed: 24010124]
- Omodior O, Anderson KR, Clark W, et al. 2021. Preventing tick-bites among children in Indiana, USA: an analysis of factors associated with parental protective behaviors. *Ticks Tick Borne Dis.* 12:101647. 10.1016/j.ttbdis.2020.101647 [PubMed: 33445070]
- One Health. [accessed 2024 Jun 21]. <https://www.who.int/news-room/questions-and-answers/item/one-health>.
- Ostfeld RS, Keesing F. 2023. Does experimental reduction of blacklegged tick (*Ixodes scapularis*) abundance reduce Lyme disease incidence? *Pathogens* 12:714. 10.3390/pathogens12050714 [PubMed: 37242384]
- Padgett KA, Casher LE, Stephens SL, et al. 2009. Effect of prescribed fire for tick control in California chaparral. *J. Med. Entomol.* 46:1138–1145. 10.1603/033.046.0522 [PubMed: 19769046]

- Panella NA, Karchesy J, Maupin GO, et al. 1997. Susceptibility of immature *Ixodes scapularis* (Acari: Ixodidae) to plant-derived acaricides. *J. Med. Entomol.* 34:340–345. 10.1093/jmedent/34.3.340 [PubMed: 9151500]
- Panella NA, Dolan MC, Karchesy JJ, et al. 2005. Use of novel compounds for pest control: insecticidal and acaricidal activity of essential oil components from heartwood of Alaska yellow cedar. *J. Med. Entomol.* 42:352–358. 10.1093/jmedent/42.3.352 [PubMed: 15962787]
- Pascoe EL, Plourde BT, López-Perez AM, et al. 2020. Response of small mammal and tick communities to a catastrophic wildfire and implications for tick-borne pathogens. *J. Vector Ecol.* 45:269–284. 10.1111/jvec.12398 [PubMed: 33207067]
- Patrican LA, Allan SA. 1995a. Application of desiccant and insecticidal soap treatments to control *Ixodes scapularis* (Acari: Ixodidae) nymphs and adults in a hyperendemic woodland site. *J. Med. Entomol.* 32:859–863. 10.1093/jmedent/32.6.859 [PubMed: 8551510]
- Patrican LA, Allan SA. 1995b. Laboratory evaluation of desiccants and insecticidal soap applied to various substrates to control the deer tick *Ixodes scapularis*. *Med. Vet. Entomol.* 9:293–299. 10.1111/j.1365-2915.1995.tb00137.x [PubMed: 7548948]
- Pelletier J, Rocheleau J-P, Aenishaenslin C, et al. 2022. Fluralaner baits reduce the infestation of *Peromyscus* spp. mice (Rodentia: Cricetidae) by *Ixodes scapularis* (Acari: Ixodidae) larvae and nymphs in a natural environment. *J. Med. Entomol.* 59:2080–2089. 10.1093/jme/tjac106 [PubMed: 35980603]
- Pham MT, Rajić A, Greig JD, et al. 2014. A scoping review of scoping reviews: advancing the approach and enhancing the consistency. *Res. Synth. Methods* 5:371–385. 10.1002/jrsm.1123 [PubMed: 26052958]
- Piesman J 2006. Response of nymphal *Ixodes scapularis*, the primary tick vector of Lyme disease spirochetes in North America, to barriers derived from wood products or related home and garden items. *J. Vector Ecol.* 31:412–417. 10.3376/1081-1710(2006)31[412:ronist]2.0.co;2 [PubMed: 17249361]
- Poché DM, Dawson K, Tseveenjav B, et al. 2021. Efficacy of low-dose fipronil bait against blacklegged tick (*Ixodes scapularis*) larvae feeding on white-footed mice (*Peromyscus leucopus*) under simulated field conditions. *Parasit. Vectors* 14:459. 10.1186/s13071-021-04930-z [PubMed: 34493330]
- Poland GA. 2001. Prevention of Lyme disease: a review of the evidence. *Mayo Clin. Proc.* 76:713–724. 10.4065/76.7.713 [PubMed: 11444404]
- Pound JM, Miller JA, George JE, et al. 1996. Systemic treatment of white-tailed deer with ivermectin-medicated bait to control free-living populations of lone star ticks (Acari: Ixodidae). *J. Med. Entomol.* 33:385–394. 10.1093/jmedent/33.3.385 [PubMed: 8667385]
- Pound JM, Miller JA, George JE, et al. 2000. The ‘4-poster’ passive topical treatment device to apply acaricide for controlling ticks (Acari: Ixodidae) feeding on white-tailed deer. *J. Med. Entomol.* 37:588–594. 10.1603/0022-2585-37.4.588 [PubMed: 10916301]
- Pound JM, Miller JA, George JE, et al. 2009. The United States Department of Agriculture’s Northeast Area-Wide Tick Control project: summary and conclusions. *Vector Borne Zoonotic Dis.* 9:439–448. 10.1089/vbz.2008.0200 [PubMed: 19650739]
- Pound JM, Lohmeyer KH, Davey RB, et al. 2012. Efficacy of amitraz-impregnated collars on white-tailed deer (*Artiodactyla: Cervidae*) in reducing free-living populations of lone star ticks (Acari: Ixodidae). *J. Econ. Entomol.* 105:2207–2212. 10.1603/ec12219 [PubMed: 23356088]
- Prose R, Breuner NE, Johnson TL, et al. 2018. Contact irritancy and toxicity of permethrin-treated clothing for *Ixodes scapularis*, *Amblyomma americanum*, and *Dermacentor variabilis* Ticks (Acari: Ixodidae). *J. Med. Entomol.* 55:1217–1224. 10.1093/jme/tjy062 [PubMed: 29800259]
- Rainey T, Occi JL, Robbins RG, et al. 2018. Discovery of *Haemaphysalis longicornis* (Ixodida: Ixodidae) parasitizing a sheep in New Jersey, United States. *J. Med. Entomol.* 55:757–759. 10.1093/jme/tjy006 [PubMed: 29471482]
- Rand PW, Lacombe EH, Holman MS, et al. 2000. Attempt to control ticks (Acari: Ixodidae) on deer on an isolated island using ivermectin-treated corn. *J. Med. Entomol.* 37:126–133. 10.1603/0022-2585-37.1.126 [PubMed: 15218916]

- Rand PW, Lubelczyk C, Holman MS, et al. 2004. Abundance of *Ixodes scapularis* (Acari: Ixodidae) after the complete removal of deer from an isolated offshore island, endemic for Lyme disease. *J. Med. Entomol.* 41:779–784. 10.1603/0022-2585-41.4.779 [PubMed: 15311475]
- Rand PW, Lacombe EH, Elias SP, et al. 2010. Trial of a minimal-risk botanical compound to control the vector tick of Lyme disease. *J. Med. Entomol.* 47:695–698. 10.1093/jmedent/47.4.695 [PubMed: 20695287]
- Richards SL, Driver J, Dyer MC, et al. 2022. Assessing durability and safety of permethrin impregnated uniforms used by outdoor workers to prevent tick bites after one year of use. *J. Med. Entomol.* 59:615–622. 10.1093/jme/tjab216 [PubMed: 34958094]
- Roberts RH, Zimmerman JH, Mount GA. 1980. Evaluation of potential acaricides as residues for the area control of the lone star tick. *J. Econ. Entomol.* 73:506–509. 10.1093/jee/73.4.506
- Rochlin I, Egizi A, Lindström A. 2022. The original scientific description of the lone star tick (*Amblyomma americanum*, Acari: Ixodidae) and implications for the species' past and future geographic distributions. *J. Med. Entomol.* 59:412–420. 10.1093/jme/tjab215 [PubMed: 35024845]
- Rochlin I, Egizi A, Ginsberg HS. 2023. Modeling of historical and current distributions of lone star tick, *Amblyomma americanum* (Acari: Ixodidae), is consistent with ancestral range recovery. *Exp. Appl. Acarol* 89:85–103. 10.1007/s10493-022-00765-0 [PubMed: 36482230]
- Rosenberg R, Lindsey NP, Fischer M, et al. 2018. *Vital Signs*: trends in reported vectorborne disease cases—United States and Territories, 2004–2016. *MMWR Morb. Mortal. Wkly. Rep.* 67:496–501. 10.15585/mmwr.mm6717e1 [PubMed: 29723166]
- Rugg D, Hair JA, Everett RE, et al. 2007. Confirmation of the efficacy of a novel formulation of metaflumizone plus amitraz for the treatment and control of fleas and ticks on dogs. *Vet. Parasitol.* 150:209–218. 10.1016/j.vetpar.2007.08.035 [PubMed: 17923330]
- Sanders M 1998. *Ixodes dammini*: a junior synonym for *Ixodes scapularis*. *Emerg. Infect. Dis.* 4:132. 10.3201/eid0401.980125
- Sardelis MR, Neidhardt K, Perich MJ, et al. 1989. Reduction of the *Amblyomma americanum* (Acari: Ixodidae) population at Fort A. P. Hill, Virginia, by aerial application of diazinon granules: correlation of percentage control with received dose. *J. Med. Entomol.* 26:494–496. 10.1093/jmedent/26.5.494 [PubMed: 2795622]
- Schotthoefer A, Stinebaugh K, Martin M, et al. 2020. Tickborne disease awareness and protective practices among U.S. Forest Service employees from the upper Midwest, USA. *BMC Public Health* 20:1575. 10.1186/s12889-020-09629-x [PubMed: 33081728]
- Schulze TL, Jordan RA. 1995. Potential influence of leaf litter depth on effectiveness of granular carbaryl against subadult *Ixodes scapularis* (Acari: Ixodidae). *J. Med. Entomol.* 32:205–208. 10.1093/jmedent/32.2.205 [PubMed: 7608930]
- Schulze TL, Jordan RA. 2021. Synthetic pyrethroid, natural product, and entomopathogenic fungal acaricide product formulations for sustained early season suppression of host-seeking *Ixodes scapularis* (Acari: Ixodidae) and *Amblyomma americanum* nymphs. *J. Med. Entomol.* 58:814–820. 10.1093/jme/tjaa248 [PubMed: 33215212]
- Schulze TL, Jordan RA. 2023. Relative efficacy of high-pressure versus backpack sprayer applications of 2 natural product-based acaricides for control of host-seeking *Ixodes Scapularis* and *Amblyomma americanum* nymphs. *J. Med. Entomol.* 60:1131–1135. 10.1093/jme/tjad074 [PubMed: 37341185]
- Schulze TL, McDevitt WM, Parkin WE, et al. 1987. Effectiveness of two insecticides in controlling *Ixodes dammini* (Acari: Ixodidae) following an outbreak of Lyme disease in New Jersey. *J. Med. Entomol.* 24:420–424. 10.1093/jmedent/24.4.420 [PubMed: 3114494]
- Schulze TL, Taylor GC, Jordan RA, et al. 1991. Effectiveness of selected granular acaricide formulations in suppressing populations of *Ixodes dammini* (Acari: Ixodidae): short-term control of nymphs and larvae. *J. Med. Entomol.* 28:624–629. 10.1093/jmedent/28.5.624 [PubMed: 1941929]
- Schulze TL, Taylor GC, Vasvary LM, et al. 1992. Effectiveness of an aerial application of carbaryl in controlling *Ixodes dammini* (Acari: Ixodidae) adults in a high-use recreational area in New Jersey. *J. Med. Entomol.* 29:544–547. 10.1093/jmedent/29.3.544 [PubMed: 1625304]

- Schulze TL, Jordan RA, Vasvary LM, et al. 1994. Suppression of *Ixodes scapularis* (Acari: Ixodidae) nymphs in a large residential community. *J. Med. Entomol.* 31:206–211. 10.1093/jmedent/31.2.206 [PubMed: 8189411]
- Schulze TL, Jordan RA, Hung RW. 1995. Suppression of subadult *Ixodes scapularis* (Acari: Ixodidae) following removal of leaf litter. *J. Med. Entomol.* 32:730–733. 10.1093/jmedent/32.5.730 [PubMed: 7473629]
- Schulze TL, Jordan RA, Hung RW. 2000. Effects of granular carbaryl application on sympatric populations of *Ixodes scapularis* and *Amblyomma americanum* (Acari: Ixodidae) nymphs. *J. Med. Entomol.* 37:121–125. 10.1603/0022-2585-37.1.121 [PubMed: 15218915]
- Schulze TL, Jordan RA, Hung RW, et al. 2001a. Effects of an application of granular carbaryl on nontarget forest floor arthropods. *J. Econ. Entomol.* 94:123–128. 10.1603/0022-0493-94.1.123 [PubMed: 11233101]
- Schulze TL, Jordan RA, Hung RW, et al. 2001b. Efficacy of granular deltamethrin against *Ixodes scapularis* and *Amblyomma americanum* (Acari: Ixodidae) nymphs. *J. Med. Entomol.* 38:344–346. 10.1603/0022-2585-38.2.344 [PubMed: 11296847]
- Schulze TL, Jordan RA, Krivenko AJ. 2005. Effects of barrier application of granular deltamethrin on subadult *Ixodes scapularis* (Acari: Ixodidae) and nontarget forest floor arthropods. *J. Econ. Entomol.* 98:976–981. 10.1603/0022-0493-98.3.976 [PubMed: 16025588]
- Schulze TL, Jordan RA, Schulze CJ, et al. 2007. Integrated use of 4-poster passive topical treatment devices for deer, targeted acaricide applications, and Maxforce TMS bait boxes to rapidly suppress populations of *Ixodes scapularis* (Acari: Ixodidae) in a residential landscape. *J. Med. Entomol.* 44:830–839. 10.1603/0022-2585(2007)44[830:iuoppt]2.0.co;2 [PubMed: 17915516]
- Schulze TL, Jordan RA, Dolan MC, et al. 2008a. 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. *J. Med. Entomol.* 45:899–904. 10.1093/jmedent/45.5.899 [PubMed: 18826033]
- Schulze TL, Jordan RA, Schulze CJ, et al. 2008b. Suppression of *Ixodes scapularis* (Acari: Ixodidae) following annual habitat-targeted acaricide applications against fall populations of adults. *J. Am. Mosq. Control Assoc.* 24:566–570. 10.2987/08-5761.1 [PubMed: 19181066]
- Schulze TL, Jordan RA, Hung RW, et al. 2009. Effectiveness of the 4-poster passive topical treatment device in the control of *Ixodes scapularis* and *Amblyomma americanum* (Acari: Ixodidae) in New Jersey. *Vector Borne Zoonotic Dis.* 9:389–400. 10.1089/vbz.2008.0160 [PubMed: 19650733]
- Schulze TL, Jordan RA, Williams M, et al. 2017. 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. *J. Med. Entomol.* 54:1019–1024. 10.1093/jme/tjx044 [PubMed: 28399280]
- Schulze TL, Eisen L, Russell K, et al. 2023. Community-based integrated tick management programs: cost and feasibility scenarios. *J. Med. Entomol.* 60:1048–1060. 10.1093/jme/tjad093 [PubMed: 37540592]
- Sharma SR, Hussain S, Choudhary SK, et al. 2024. Identification of Alpha-Gal glycolipids in saliva of lone star tick (*Amblyomma americanum*). *Ticks Tick Borne Dis.* 15:102384. 10.1016/j.ttbdis.2024.102384 [PubMed: 39053323]
- Showler AT, Osbrink WL, Morris J, et al. 2017. Effects of two commercial neem-based insecticides on lone star tick, *Amblyomma americanum* (L.) (Acari: Ixodidae): deterrence, mortality, and reproduction. *Biopestic. Int.* 13:1–12.
- Six RH, Everett WR, Young DR, et al. 2016. Efficacy of a novel oral formulation of sarolaner (Simparica™) against five common tick species infesting dogs in the United States. *Vet. Parasitol.* 222:28–32. 10.1016/j.vetpar.2015.12.023 [PubMed: 26935819]
- Slowik TJ, Lane RS, Davis RM. 2001. Field trial of systemically delivered arthropod development-inhibitor (Fluazuron) used to control woodrat fleas (Siphonaptera: Ceratophyllidae) and ticks (Acari: Ixodidae). *J. Med. Entomol.* 38:75–84. 10.1603/0022-2585-38.1.75 [PubMed: 11268695]
- Smith CN, Gouck HK. 1944. Sprays for the control of ticks about houses or camps. *J. Econ. Entomol.* 37:85–87. 10.1093/jee/37.1.85

- Smith CN, Cole MM, Gouck HK. Biology and control of the American dog tick. Washington (DC): United States Department of Agriculture; 1946. Report No.: 905. <https://ageconsearch.umn.edu/record/169911/files/tb905.pdf>.
- Solberg VB, Neidhardt K, Sardelis MR, et al. 1992. Field evaluation of two formulations of cyfluthrin for control of *Ixodes dammini* and *Amblyomma americanum* (Acari: Ixodidae). *J. Med. Entomol.* 29:634–638. 10.1093/jmedent/29.4.634 [PubMed: 1495073]
- Solberg VB, Miller JA, Hadfield T, et al. 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. [PubMed: 12831136]
- Sonenshine D 2018. Range expansion of tick disease vectors in North America: implications for spread of tick-borne disease. *Int. J. Environ. Res. Public Health* 15:478. 10.3390/ijerph15030478 [PubMed: 29522469]
- Sonenshine DE, Haines G. 1985. A convenient method for controlling populations of the American dog tick, *Dermacentor variabilis* (Acari: Ixodidae), in the natural environment. *J. Med. Entomol.* 22:577–583. 10.1093/jmedent/22.5.577 [PubMed: 4045949]
- Sonenshine DE, Taylor D, Corrigan G. 1985. Studies to evaluate the effectiveness of sex pheromone-impregnated formulations for control of populations of the American dog tick, *Dermacentor variabilis* (Say) (Acari: Ixodidae). *Exp. Appl. Acarol* 1:23–34. 10.1007/BF01262197 [PubMed: 3870955]
- Sonenshine DE, Allan SA, Norval RAI, et al. 1996. A self-medicating applicator for control of ticks on deer. *Med. Vet. Entomol.* 10:149–154. 10.1111/j.1365-2915.1996.tb00721.x [PubMed: 8744707]
- Stafford KC. 1991a. Effectiveness of carbaryl applications for the control of *Ixodes dammini* (Acari: Ixodidae) nymphs in an endemic residential area. *J. Med. Entomol.* 28:32–36. 10.1093/jmedent/28.1.32 [PubMed: 1903451]
- Stafford KC. 1991b. Effectiveness of host-targeted permethrin in the control of *Ixodes dammini* (Acari: Ixodidae). *J. Med. Entomol.* 28:611–617. 10.1093/jmedent/28.5.611 [PubMed: 1941927]
- Stafford KC. 1992. Third-year evaluation of host-targeted permethrin for the control of *Ixodes dammini* (Acari: Ixodidae) in southeastern Connecticut. *J. Med. Entomol.* 29:717–720. 10.1093/jmedent/29.4.717 [PubMed: 1495085]
- Stafford KC. 1993. Reduced abundance of *Ixodes scapularis* (Acari: Ixodidae) with exclusion of deer by electric fencing. *J. Med. Entomol.* 30:986–996. 10.1093/jmedent/30.6.986 [PubMed: 8271257]
- Stafford KC. 1997. Pesticide use by licensed applicators for the control of *Ixodes scapularis* (Acari: Ixodidae) in Connecticut. *J. Med. Entomol.* 34:552–558. 10.1093/jmedent/34.5.552 [PubMed: 9379461]
- Stafford K Tick management handbook: an integrated guide for homeowners, pest control operators, and public health officials for the prevention of tick-associated disease. New Haven (CT): Connecticut Agricultural Experiment Station; 2007. Report No.: 1010. <https://portal.ct.gov/-/media/caes/documents/publications/bulletins/b1010pdf.pdf>.
- Stafford KC, Allan SA. 2010. Field applications of entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* F52 (Hypocreales: Clavicipitaceae) for the control of *Ixodes scapularis* (Acari: Ixodidae). *J. Med. Entomol.* 47:1107–1115. 10.1603/me10019 [PubMed: 21175060]
- Stafford KC, Ward JS, Magnarelli LA. 1998. Impact of controlled burns on the abundance of *Ixodes scapularis* (Acari: Ixodidae). *J. Med. Entomol.* 35:510–513. 10.1093/jmedent/35.4.510 [PubMed: 9701937]
- Stafford KC, Denicola AJ, Kilpatrick HJ. 2003. Reduced abundance of *Ixodes scapularis* (Acari: Ixodidae) and the tick parasitoid *Ixodiphagus hookeri* (Hymenoptera: Encyrtidae) with reduction of white-tailed deer. *J. Med. Entomol.* 40:642–652. 10.1603/0022-2585-40.5.642 [PubMed: 14596277]
- Stafford KC, Denicola AJ, Pound JM, et al. 2009. 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 Zoonotic Dis.* 9:371–379. 10.1089/vbz.2008.0161 [PubMed: 19650731]

- Stafford KC, Williams SC, Molaei G. 2017. Integrated pest management in controlling ticks and tick-associated diseases. *J. Integr. Pest Manag.* 8:1–7. 10.1093/jipm/pmx018. [accessed 2024 Jun 21].
- Straily A, Drexler N, Cruz-Loustaunau D, et al. 2016. Notes from the field: community-based prevention of Rocky Mountain spotted fever—Sonora, Mexico, 2016. *MMWR Morb. Mortal. Wkly. Rep.* 65:1302–1303. 10.15585/mmwr.mm6546a6 [PubMed: 27880753]
- Tardy O, Acheson ES, Bouchard C, et al. 2023. Mechanistic movement models to predict geographic range expansions of ticks and tick-borne pathogens: case studies with *Ixodes scapularis* and *Amblyomma americanum* in eastern North America. *Ticks Tick Borne Dis.* 14:102161. 10.1016/j.ttbdis.2023.102161 [PubMed: 36996508]
- The U.S. Department of Health and Human Services, The U.S. Centers for Disease Control and Prevention. 2024. The National Public Health Strategy to Prevent and Control Vector-Borne Diseases in People. Washington, DC: U.S. DHHS, CDC; p. 84. www.cdc.gov/VBD.
- Tiffin HS, Rajotte EG, Sakamoto JM, et al. 2022. Tick control in a connected world: challenges, solutions, and public policy from a United States border perspective. *Trop. Med. Infect. Dis.* 7:388. 10.3390/tropicalmed7110388 [PubMed: 36422939]
- Tricco AC, Lillie E, Zarin W, et al. 2018. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann. Intern. Med.* 169:467–473. 10.7326/M18-0850 [PubMed: 30178033]
- U.S. Centers for Disease Control and Prevention. 2024a. About ticks and tickborne disease. [accessed 2024 Jun 21]. <https://www.cdc.gov/ticks/about/index.html>.
- U.S. Centers for Disease Control and Prevention. 2024b. Where ticks live. [accessed 2024 Jun 21]. <https://www.cdc.gov/ticks/about/where-ticks-live.html>.
- U.S. Centers for Disease Control and Prevention. 2024c. Geographic distribution of tickborne disease cases [accessed 2024 Jun 21]. <https://www.cdc.gov/ticks/data-research/facts-stats/geographic-distribution-of-tickborne-disease-cases.html>.
- U.S. Centers for Disease Control and Prevention. 2024d. Regional training and evaluation centers. [accessed 2024 Jul 23]. <https://www.cdc.gov/vector-borne-diseases/what-cdc-is-doing/regional-training-and-evaluation-centers-1.html>.
- U.S. Centers for Disease Control and Prevention. 2024e. Centers of excellence in vector-borne diseases. [accessed 2024 Jul 23]. <https://www.cdc.gov/vector-borne-diseases/what-cdc-is-doing/centers-of-excellence-in-vector-borne-diseases.html>.
- U.S. Environmental Protection Agency. 2024. Minimum risk pesticides exempted from FIFRA registration. [accessed 2024 Jul 23]. <https://www.epa.gov/minimum-risk-pesticides>.
- U.S. Environmental Protection Agency. 2015. Integrated pest management (IPM) principles. [accessed 2024 Jun 21]. <https://www.epa.gov/safepestcontrol/integrated-pest-management-ipm-principles>.
- White DJ, Benach JL, Smith LA, et al. 1981. Control of *Dermacentor variabilis*. 3. An analytical study of the effect of low volume spray frequency on insecticide-stressed and nonstressed populations. *J. N. Y. Entomol. Soc.* 89:23–33. <https://www.jstor.org/stable/25009232>.
- Wilkinson PR. 1977. Effect of herbicidal killing of shrubs on abundance of adult *Dermacentor andersoni* (Acarina: Ixodidae) in British Columbia. *J. Med. Entomol.* 13:713–718. 10.1093/jmedent/13.6.713 [PubMed: 886564]
- Williams SC, Ward JS. 2010. Effects of Japanese barberry (Ranunculales: Berberidaceae) removal and resulting microclimatic changes on *Ixodes scapularis* (Acari: Ixodidae) abundances in Connecticut, USA. *Environ. Entomol.* 39:1911–1921. 10.1603/EN10131 [PubMed: 22182557]
- Williams SC, Ward JS, Worthley TE, et al. 2009. Managing Japanese barberry (Ranunculales: Berberidaceae) infestations reduces blacklegged tick (Acari: Ixodidae) abundance and infection prevalence with *Borrelia burgdorferi* (Spirochaetales: Spirochaetaceae). *Environ. Entomol.* 38:977–984. 10.1603/022.038.0404 [PubMed: 19689875]
- Williams SC, Linske MA, Ward JS. 2017. Long-term effects of *Berberis thunbergii* (Ranunculales: Berberidaceae) management on *Ixodes scapularis* (Acari: Ixodidae) abundance and *Borrelia burgdorferi* (Spirochaetales: Spirochaetaceae) prevalence in Connecticut, USA. *Environ. Entomol.* 46:1329–1338. 10.1093/ee/nvx146 [PubMed: 29029041]

- Williams SC, Stafford KC, Molaei G, et al. 2018. Integrated control of nymphal *Ixodes scapularis*: effectiveness of white-tailed deer reduction, the entomopathogenic fungus *Metarhizium anisopliae*, and fipronil-based rodent bait boxes. *Vector Borne Zoonotic Dis.* 18:55–64. 10.1089/vbz.2017.2146 [PubMed: 29173127]
- Williams SC, Stafford KC, Linske MA, et al. 2021. Effective control of the motile stages of *Amblyomma americanum* and reduced *Ehrlichia* spp. prevalence in adults via permethrin treatment of white-tailed deer in coastal Connecticut, USA. *Ticks Tick Borne Dis.* 12:101675. 10.1016/j.ttbdis.2021.101675 [PubMed: 33529986]
- Williams SC, Linske MA, Stafford KC. 2023. Orally delivered fipronil-laced bait reduces juvenile blacklegged tick (*Ixodes scapularis*) burdens on wild white-footed mice (*Peromyscus leucopus*). *Ticks Tick Borne Dis.* 14:102189. 10.1016/j.ttbdis.2023.102189 [PubMed: 37156086]
- Wilson ML. 1986. Reduced abundance of adult *Ixodes dammini* (Acari: Ixodidae) following destruction of vegetation. *J. Econ. Entomol.* 79:693–696. 10.1093/jee/79.3.693 [PubMed: 3722593]
- Wilson ML, Telford SR, Piesman J, et al. 1988. Reduced abundance of immature *Ixodes dammini* (Acari: Ixodidae) following elimination of deer. *J. Med. Entomol.* 25:224–228. 10.1093/jmedent/25.4.224 [PubMed: 3404540]
- Zhioua E, Lebrun RA, Ginsberg HS, et al. 1995. Pathogenicity of *Steinernema carpocapsae* and *S. glaseri* (Nematoda: Steinernematidae) to *Ixodes scapularis* (Acari: Ixodidae). *J. Med. Entomol.* 32:900–905. 10.1093/jmedent/32.6.900 [PubMed: 8551517]
- Zhioua E, Browning M, Johnson PW, et al. 1997. Pathogenicity of the entomopathogenic fungus *Metarhizium anisopliae* (Deuteromycetes) to *Ixodes scapularis* (Acari: Ixodidae). *J. Parasitol.* 83:815–818. 10.2307/3284273 [PubMed: 9379283]
- Zhioua E, Heyer K, Browning M, et al. 1999. Pathogenicity of *Bacillus thuringiensis* variety *kurstaki* to *Ixodes scapularis* (Acari: Ixodidae). *J. Med. Entomol.* 36:900–902. 10.1093/jmedent/36.6.900 [PubMed: 10593100]
- Zimmerman RH, McWherter GR, Bloemer SR. 1988. Medium-sized mammal hosts of *Amblyomma americanum* and *Dermacentor variabilis* (Acari: Ixodidae) at land between the Lakes, Tennessee, and effects of integrated tick management on host infestations. *J. Med. Entomol.* 25:461–466. 10.1093/jmedent/25.6.461 [PubMed: 3204625]

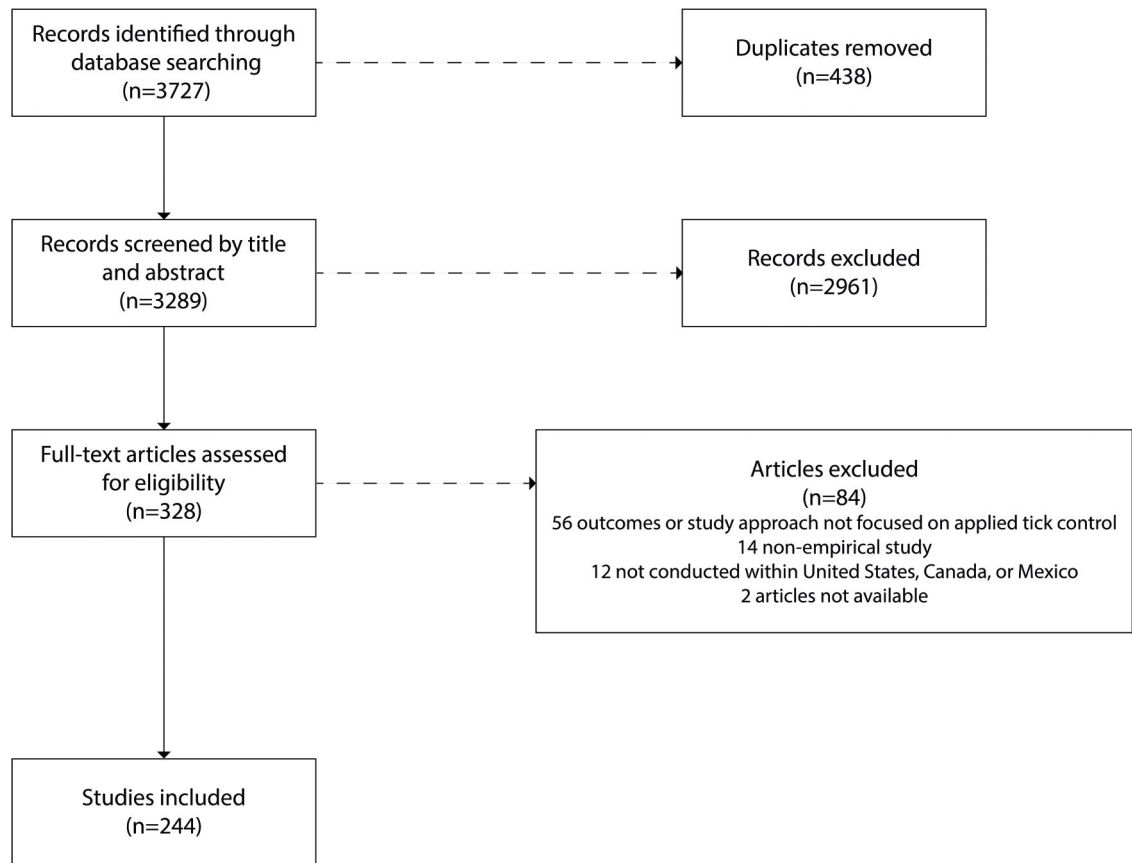
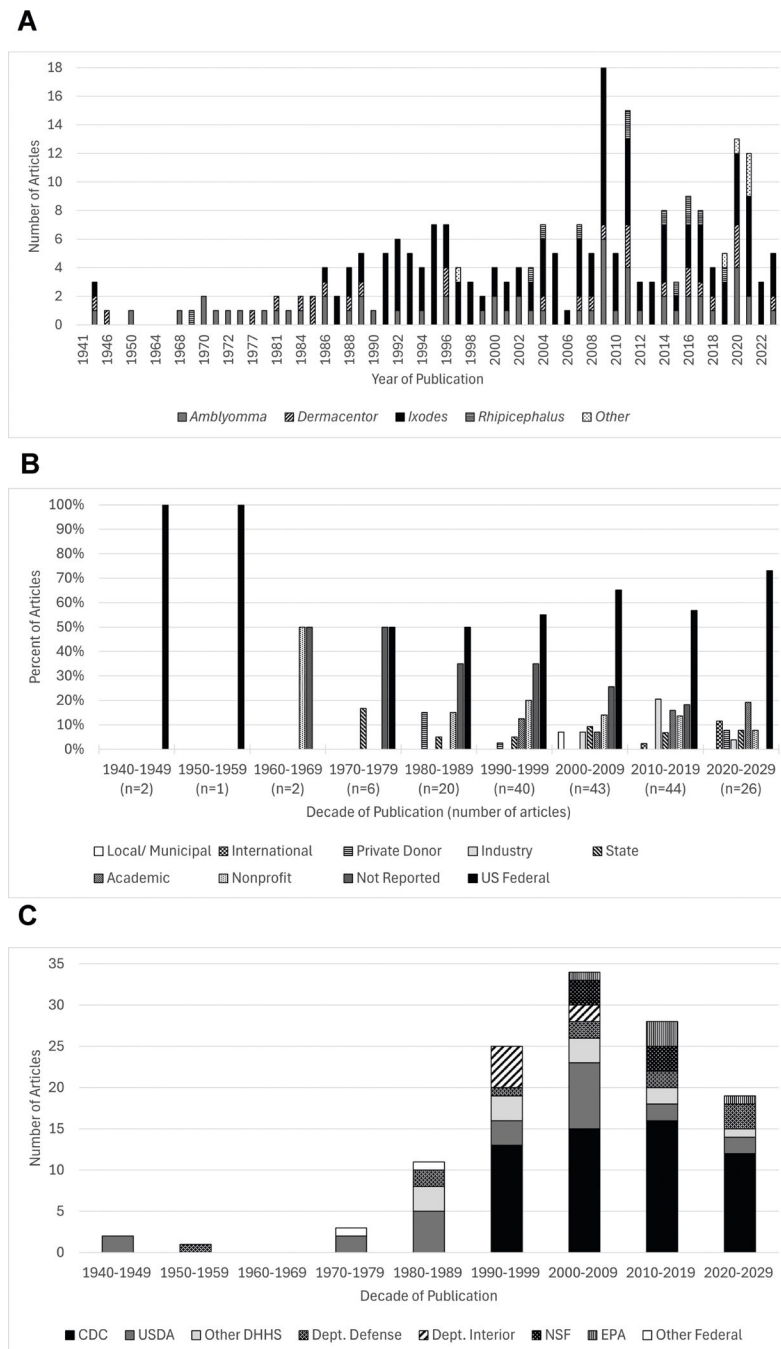


Fig. 1.
PRISMA flow diagram for article inclusion in scoping review (date of search: 13 August 2023).

**Fig. 2.**

A) Applied tick control article publication by year and tick genera; B) Applied tick control articles by decade of publication and funding organization; C) Applied tick control articles by decade and US Federal Funding Organization ($n = 183$; date of search: 13 August 2023).

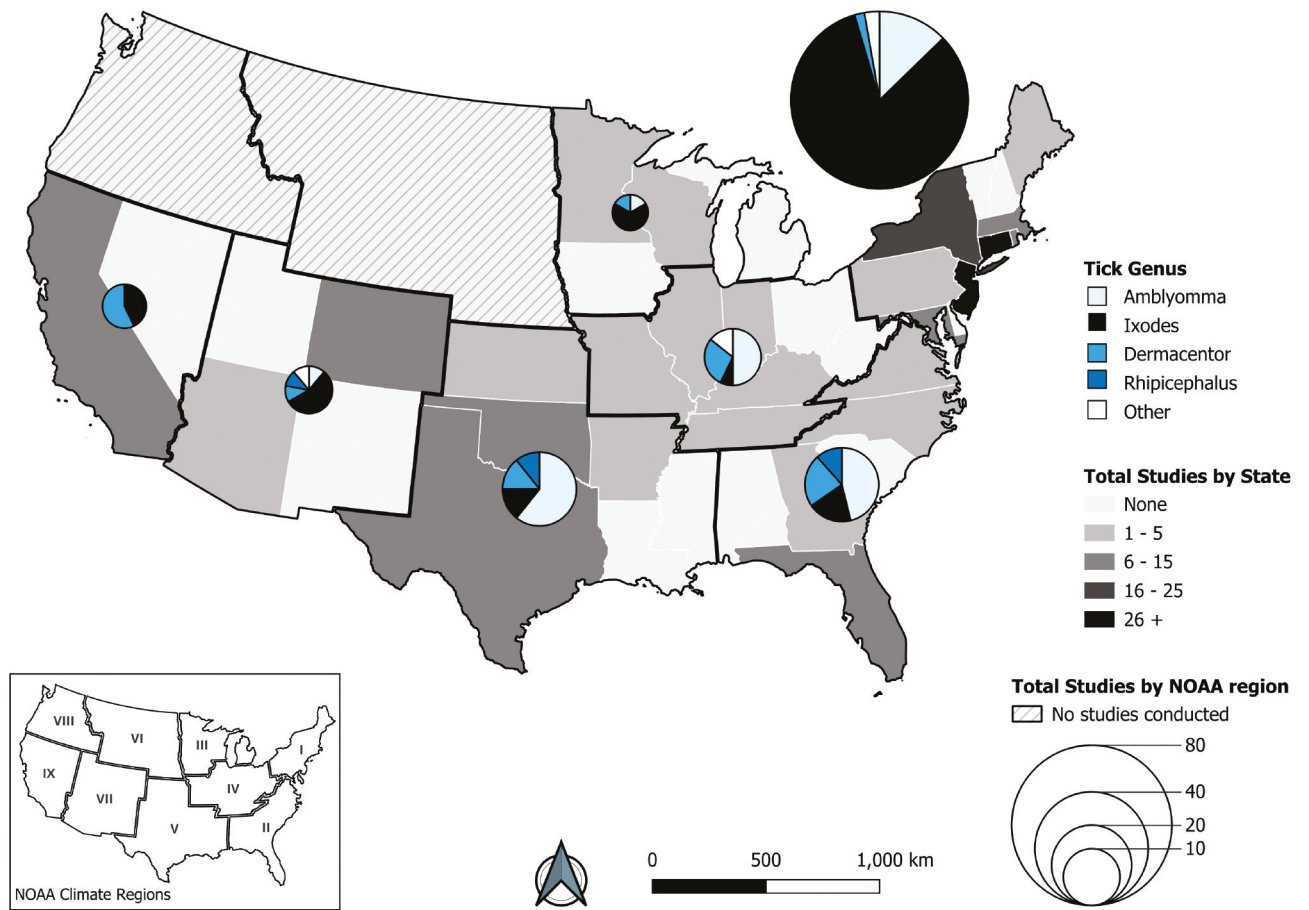


Fig. 3.
Applied tick control studies by tick genus and NOAA region ($n = 183$; date of search: 13 August 2023).

Table 1.

Scoping review key outcome definitions

Category area	Outcome	Definition
Ticks	Public Health Importance	Ticks associated with or evaluated in context of transmission of pathogens affecting human health in North America within the genera <i>Amblyomma</i> , <i>Dermacentor</i> , <i>Ixodes</i> , and <i>Rhipicephalus</i>
	Agriculture/Wildlife Health	Ticks associated with or evaluated in context of livestock and wildlife health
Control Focus Area	Environmental control	Use of acaricidal products to directly reduce tick populations in the environment. Products can include chemical and naturally derived acaricides, entomopathogenic fungi, and parasitoids.
	Habitat modification	Use of environmental modifications to alter habitats conducive to ticks. Strategies can include landscape management (mowing, xeric barriers, vegetation thinning, removal of host harborage), controlled and natural burning, and removal of invasive species.
	Host-targeted	Interventions applied to animal hosts associated with targeted tick species. Interventions can include topical application of acaricides (4-poster systems, rodent nesting material, rodent bait boxes, collars, spot treatments), systemic acaricides (treated bait), exclusion (fencing), removal (culling), introduction (predation), or use by humans of acaricide-treated products (clothing, textiles).
	Susceptibility trial	Evaluation of tick mortality after exposure to acaricidal products intended for field use in environmental control or host-targeted control interventions.
	Community-based assessments	Assessment of individual or community practices regarding tick control. Practices and perceptions include willingness to pay for tick control, acceptability of tick control interventions, implementation of tick control interventions or services, and prioritization of public tick control interventions.
	Region I: Northeast	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont
	Region II: Southeast	Alabama, Florida, Georgia, North Carolina, South Carolina, Virginia
	Region III: Upper Midwest	Iowa, Michigan, Minnesota, Wisconsin
	Region IV: Ohio Valley	Illinois, Indiana, Kentucky, Missouri, Ohio, Tennessee, West Virginia
NOAA Regional Climate Classification	Region V: South	Arkansas, Kansas, Louisiana, Mississippi, Oklahoma, Texas
	Region VI: Northern Rockies & Plains	Montana, Nebraska, North Dakota, South Dakota, Wyoming
	Region VII: Southwest	Arizona, Colorado, New Mexico, Utah
	Region VIII: Northwest	Idaho, Oregon, Washington
	Region IX: West	California, Nevada

Table 2.

Characteristics of applied tick control studies, North America (*n* = 244)

Study characteristics	<i>n</i> (%)	
	Agriculture/wildlife	Public health
Total Included Articles	61 (25.0%)	183 (75.0%)
Country		
United States	22 (35.1%)	174 (95.1%)
Canada	1 (1.6%)	5 (2.7%)
Mexico	30 (49.2%)	1 (0.5%)
US and Mexico	5 (8.2%)	1 (0.5%)
US and Other	0 (0.0%)	2 (1.1%)
Mexico and Other	3 (4.9%)	0 (0.0%)
Study Setting		
Field	20 (32.8%)	124 (67.8%)
Laboratory	28 (45.9%)	37 (20.2%)
Field and Laboratory	13 (21.3%)	14 (7.7%)
Not applicable	0 (0.0%)	8 (4.4%)
Control Intervention ^a		
Agricultural intervention	61 (100.0%)	0 (0.0%)
Nonagricultural host-targeted control	0 (0.0%)	76 (41.5%)
Environmental acaricide application	0 (0.0%)	60 (32.8%)
Habitat modification	0 (0.0%)	35 (19.1%)
Acaricide susceptibility trial	0 (0.0%)	33 (18.0%)
Community-based assessment	0 (0.0%)	13 (7.1%)
Target Species ^a		
<i>Amblyomma americanum</i>	3 (4.9%)	59 (32.2%)
<i>Amblyomma maculatum</i>	1 (1.6%)	6 (3.3%)
<i>Dermacentor variabilis</i>	1 (1.6%)	23 (12.5%)
<i>Haemaphysalis longicornis</i>	0 (0.0%)	2 (1.1%)
<i>Ixodes scapularis</i>	0 (0.0%)	126 (68.9%)
<i>Ixodes pacificus</i>	0 (0.0%)	5 (2.7%)

Study characteristics	n (%)	
	Agriculture/wildlife	Public health
<i>Rhipicephalus sanguineus</i>	0 (0.0%)	12 (6.6%)
<i>Rhipicephalus microplus</i>	47 (77.1%)	0 (0.0%)
Other	18 (29.5%)	19 (10.4%)
Life Stage		
Adult	10 (16.4%)	21 (11.5%)
Nymph	0 (0.0%)	32 (17.5%)
Larvae	24 (39.3%)	12 (6.6%)
Adult + Larvae	14 (23.0%)	2 (1.1%)
Adult + Nymph	0 (0.0%)	24 (13.1%)
Nymph + Larvae	1 (1.6%)	20 (10.9%)
All motile stages	6 (9.8%)	55 (30.1%)
Unspecified/NA	6 (9.8%)	17 (9.3%)

^aSome studies included multiple tick species and control interventions.

Table 3. Tick genera evaluated by control intervention, ticks of public health importance, North America (*n* = 183; date of search: 13 August 2023)

Tick control intervention evaluated ^a	Tick Genus Evaluated [n, (%)]				
	<i>Amblyomma</i> (<i>n</i> = 59)	<i>Dermacentor</i> (<i>n</i> = 29)	<i>Ixodes</i> (<i>n</i> = 131)	<i>Rhipicephalus</i> (<i>n</i> = 12)	<i>Other</i> (<i>n</i> = 6)
Environmental Acaricide	24 (50.7%)	5 (17.2%)	38 (29.0%)	3 (25.0%)	1 (16.7%)
Habitat Modification	16 (27.1%)	9 (31.0%)	20 (15.3%)	0 (0.0%)	0 (0.0%)
Host-Targeted	21 (35.6%)	15 (51.7%)	57 (43.5%)	7 (58.3%)	1 (16.7%)
Community-Based Assessments	1 (1.7%)	0 (0.0%)	7 (5.3%)	3 (25.0%)	3 (50.0%)
Acaricide Susceptibility	8 (13.6%)	6 (20.7%)	23 (17.6%)	5 (41.7%)	1 (16.7%)

^a 25 studies assessed multiple control interventions.

Table 4. Summary of applied tick control studies for ticks of public health importance, North America (n = 183; date of search: 13 August 2023)

Tick species	Country (State, NOAA region ^d)	Control intervention/s	Study site location	ITM	Funding source/s	Author/s affiliation	Length of study (years) ^b	Reference
<i>A. americanum</i>	US (MO, IV)	Habitat modification	Wilderness/preserve	No	Federal (NSF) Federal (EPA)	Academic	1	(Allan 2009)
<i>A. americanum</i>	US (MO, IV)	Habitat modification	Wilderness/preserve	No	Federal (NSF) Federal (EPA) Academic Nonprofit	Academic	1	(Allan et al. 2010)
<i>A. americanum</i>	US (TX, V)	Environmental acaricide Habitat modification Host-targeted	Farm paddocks/pastures	Yes	Not reported	Public	4	(Barnard 1986)
<i>A. americanum</i>	US (TN, IV)	Environmental acaricide Habitat modification Host-targeted	Rural park	Yes	Federal (USDA)	Public	4	(Bloemer et al. 1990)
<i>A. americanum</i>	US (OK, V)	Environmental acaricide Habitat modification	Wilderness/preserve	Yes	Not reported	Academic	2	(Clymer et al. 1970)
<i>A. americanum</i>	US (KS, V)	Habitat modification	Wilderness/preserve	No	Not reported	Public Academic	3	(Cully 1999)
<i>A. americanum</i>	US (GA, II)	Habitat modification	Wilderness/preserve	No	Federal (USDA)	Academic	5	(Davidson et al. 1994)
<i>A. americanum</i>	US (VA, II)	Environmental acaricide	Wilderness/preserve	No	Academic	Academic	1	(Gaff et al. 2015)
<i>A. americanum</i>	US (NY, I)	Host-targeted	Wilderness/preserve	No	Federal (USGS) Federal (NPS) Academic	Public Academic	7	(Ginsberg et al. 2002)
<i>A. americanum</i>	US (OK, V)	Environmental acaricide Habitat modification	Wilderness/preserve	Yes	Federal (DOC)	Academic	4	(Hair and Howell 1970)
<i>A. americanum</i>	US (OK, V)	Environmental acaricide Habitat modification	Wilderness/preserve	Yes	State Federal (USDA)	Academic	4	(Hoch et al. 1971)
<i>A. americanum</i>	US (OK, V)	Habitat modification	Wilderness/preserve	No	Federal (USDA)	Academic	2	(Hoch et al. 1972)
<i>A. americanum</i>	US (FL, II)	Environmental acaricide	Military base	No	Federal (DOD)	Public	1	(Hughes et al. 2014)
<i>A. americanum</i>	US	Acaricide susceptibility	Laboratory	No	Federal (CDC)	Academic	NR	(Kaplan et al. 2020)
<i>A. americanum</i>	US (TX, V)	Environmental acaricide	Military base	No	Federal (DOD)	Public	3	(McDuffie et al. 1950)
<i>A. americanum</i>	US (NC, FL-, II)	Acaricide susceptibility Environmental acaricide	Laboratory Military base	No	Not reported	Public	5	(Mount et al. 1968)
<i>A. americanum</i>	US (NC, II)	Environmental acaricide	Military base	No	Not reported	Public	2	(Mount et al. 1976)
<i>A. americanum</i>	US (OK, V)	Habitat modification	Park/recreation zone— suburban Rural park	No	Federal (USDA)	Public	2	(Mount 1981)

Tick species	Country (State, NOAA region ^d)	Control intervention/s	Study site location	ITM	Funding source/s	Author/s affiliation	Length of study (years) ^b	Reference
<i>A. americanum</i>	US (OK, V)	Environmental acaricide	Rural park	No	Federal (USDA)	Public	3	(Mount 1983)
<i>A. americanum</i>	US (OK, V)	Environmental acaricide	Suburban park	No	Federal (USDA)	Public	3	(Mount 1984)
<i>A. americanum</i>	US (TX, V)	Host-targeted	Wilderness/preserve	No	Not reported	Public	3	(Pound et al. 1996)
<i>A. americanum</i>	US	Host-targeted	Fenced pasture	No	Federal (USDA)	Public	1	(Pound et al. 2000)
<i>A. americanum</i>	US (TX, V)	Host-targeted	Wilderness/preserve	No	Not reported	Public	7	(Pound et al. 2012)
<i>A. americanum</i>	US (NC, FL, OK, II)	Environmental acaricide	Military base	No	Federal (USDA) Federal (DOD)	Public	2	(Roberts et al. 1980)
<i>A. americanum</i>	US (VA, II)	Environmental acaricide	Military base	No	Federal (DOD)	Public	1	(Sardelis et al. 1989)
<i>A. americanum</i>	US (TX, V)	Acaricide susceptibility	Laboratory	No	Academic Federal (NIH)	Public Academic	NR	(Showler et al. 2017)
<i>A. americanum</i>	US (CT, I)	Host-targeted	Wilderness/preserve	No	Federal (HATCH) Federal (DOD)	Public	3	(Williams et al. 2021)
<i>A. americanum</i> <i>A. cajennense</i> <i>A. maculatum</i> <i>R. sanguineus</i>	US (FL, II)	Acaricide susceptibility	Laboratory	No	Not reported	Academic	NR	(Burridge et al. 2003)
<i>A. americanum</i> <i>A. maculatum</i>	US (FL, II)	Acaricide susceptibility	Laboratory	No	Not reported	Academic	NR	(Kirkland et al. 2004a)
<i>A. americanum</i> <i>A. maculatum</i> <i>D. variabilis</i> <i>I. brunneus</i> <i>I. scapularis</i>	US	Host-targeted	Laboratory	No	Industry	Private	NR	(Baker et al. 2011)
<i>A. americanum</i> <i>A. maculatum</i> <i>D. variabilis</i> <i>I. brunneus</i> <i>I. scapularis</i>	US (FL, II)	Habitat modification	Wilderness/preserve	No	Federal (CDC) Academic	Public Academic Private	2	(Gleim et al. 2014)
<i>A. americanum</i> <i>A. maculatum</i> <i>D. albipictus</i> <i>D. variabilis</i> <i>I. scapularis</i>	US (VA, II)	Host-targeted	Suburban park	No	Not reported	Public	4	(Edwards et al. 2016)
<i>A. americanum</i> <i>A. maculatum</i> <i>D. variabilis</i> <i>I. scapularis</i> <i>R. sanguineus</i>	US (AR, TX, CA, V)	Host-targeted	Laboratory	No	Industry	Private	NR	(Six et al. 2016)
<i>A. americanum</i> <i>D. albipictus</i> <i>I. scapularis</i>	US (NC, II)	Host-targeted	Residential—urban Farm paddock	No	Academic	Academic	2	(Sonenshine et al. 1996)

Tick species	Country (State, NOAA region ^d)	Control intervention/s	Study site location	ITM	Funding source/s	Author/s affiliation	Length of study (years) ^b	Reference
<i>A. americanum</i> <i>D. variabilis</i>	US (TN, IV)	Environmental acaricide Host-targeted	Rural park	Yes	Not reported	Public	6	(Bloemer et al. 1986)
<i>A. americanum</i> <i>D. variabilis</i>	US (IN, IV)	Habitat modification	Wilderness/preserve University preserve land	No	Federal (USDA) Federal (NSF)	Academic	1	(Civitello et al. 2008)
<i>A. americanum</i> <i>D. variabilis</i>	US (TN, IV)	Host-targeted	Residential—suburban	No	Academic	Academic	1	(Harmon et al. 2011)
<i>A. americanum</i> <i>D. variabilis</i>	US (KY TN, IV)	Environmental acaricide Habitat modification Host-targeted	Rural park Campground	Yes	Federal (USDA)	Public	3	(Zimmerman et al. 1988)
<i>A. americanum</i> <i>D. variabilis</i> <i>I. scapularis</i>	US	Acaricide susceptibility	Laboratory	No	Federal (DOS)	Public	NR	(Carroll et al. 1989)
<i>A. americanum</i> <i>D. variabilis</i> <i>I. scapularis</i>	US (TX, V)	Habitat modification	Wilderness/preserve	No	Academic	Academic	1	(Hodo et al. 2020)
<i>A. americanum</i> <i>D. variabilis</i> <i>I. scapularis</i>	US (CO, VII)	Acaricide susceptibility	Laboratory	No	Not reported	Public	NR	(Prose et al. 2018)
<i>A. americanum</i> <i>D. variabilis</i> <i>I. scapularis</i>	US	Environmental acaricide	Military base	No	Federal (USDA)	Public	3	(Smith and Gouck 1944)
<i>A. americanum</i> <i>D. variabilis</i> <i>I. scapularis</i> <i>R. sanguineus</i>	US	Acaricide susceptibility	Laboratory	No	Federal (CDC)	Public	NR	(Flor-Weiler et al. 2011)
<i>A. americanum</i> <i>D. variabilis</i> <i>I. scapularis</i> <i>R. sanguineus</i>	US (AR, GA, TX, V) Ireland Switzerland	Host-targeted	Laboratory	No	Industry	Private	NR	(Murphy et al. 2017)
<i>A. americanum</i> <i>D. variabilis</i> <i>I. scapularis</i> <i>R. sanguineus</i>	US (OK, AR, TX, V)	Host-targeted	Laboratory	No	Not reported	Private	NR	(Rugg et al. 2007)
<i>A. americanum</i> <i>I. scapularis</i>	US (MD, I)	Host-targeted	Residential—suburban Residential—rural	No	Not reported	Public	5	(Carroll et al. 2002)
<i>A. americanum</i> <i>I. scapularis</i>	US (MD, I)	Host-targeted	Residential—suburban Residential—rural	No	Not reported	Public	10	(Carroll et al. 2009b)
<i>A. americanum</i> <i>I. scapularis</i>	US (MD, I)	Host-targeted	Residential—suburban Residential—rural Wilderness/preserve	No	Not reported	Public	6	(Carroll et al. 2009a)

Tick species	Country (State, NOAA region ^d)	Control intervention/s	Study site location	ITM	Funding source/s	Author/s affiliation	Length of study (years) ^b	Reference
<i>A. americanum</i> <i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Residential—suburban	No	Federal (CDC) Federal (DOD)	Public Academic Private	3	(Dolan et al. 2009)
<i>A. americanum</i> <i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Suburban park Military facility	No	Federal (CDC) Federal (DOD)	Public Private	2	(Jordan et al. 2011)
<i>A. americanum</i> <i>I. scapularis</i>	US (NJ, I)	Habitat modification	Residential—suburban	No	Federal (CDC)	Public	3	(Jordan and Schulze 2020a)
<i>A. americanum</i> <i>I. scapularis</i>	US (NY, MD, NJ, CT, RI, I)	Host-targeted	Residential—suburban Residential—rural Agricultural plots	No	Federal (USDA)	Public Academic	6	(Pound et al. 2009)
<i>A. americanum</i> <i>I. scapularis</i>	US (WI, III)	Community assessment	Northern Wisconsin	No	Academic Private donor	Public Academic	1	(Schotthoefer et al. 2020)
<i>A. americanum</i> <i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Military base	No	Federal (CDC)	Public	1	(Schulze et al. 2000)
<i>A. americanum</i> <i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Residential—suburban	No	Federal (CDC)	Public	1	(Schulze et al. 2001b)
<i>A. americanum</i> <i>I. scapularis</i>	US (NJ, I)	Host-targeted	Military base	No	Federal (USDA)	Public Private	8	(Schulze et al. 2009)
<i>A. americanum</i> <i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Military base	No	Federal (CDC)	Public	1	(Schulze and Jordan 2021)
<i>A. americanum</i> <i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Military base	No	Federal (CDC)	Public Private	1	(Schulze and Jordan 2023)
<i>A. americanum</i> <i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Military base	No	Federal (DOD)	Public	2	(Solberg et al. 1992)
<i>D. andersoni</i>	Canada	Environmental acaricide Habitat modification	Wilderness/preserve	No	Not reported	Public	8	(Wilkinson 1977)
<i>D. occidentalis</i> <i>D. variabilis</i> <i>I. pacificus</i> <i>I. spinipalpis</i> <i>I. woodi</i>	US (CA, IX)	Habitat modification	Wilderness/preserve	No	Federal (CDC) Academic	Academic	8	(Pascoe et al. 2020)
<i>D. occidentalis</i> <i>I. pacificus</i> <i>I. spinipalpis</i> <i>I. woodi</i>	US (CA, IX)	Host-targeted	Rural park Extension field station	No	Industry	Public Academic	2	(Slowik et al. 2001)
<i>D. occidentalis</i> <i>I. neotomae</i> <i>I. pacificus</i> <i>I. woodi</i>	US (CA, IX)	Host-targeted	University field station	No	Federal (CDC)	Academic	2	(Leprince and Lane 1996)

Tick species	Country (State, NOAA region ^d)	Control intervention/s	Study site location	ITM	Funding source/s	Author/s affiliation	Length of study (years) ^b	Reference
<i>D. occidentalis</i> <i>I. pacificus</i>	US (CA, IX)	Habitat modification	University field station	No	Federal (CDC)	Public Academic	2	(Padgett et al. 2009)
<i>D. occidentalis</i> <i>O. confusus</i>	US (CA, IX)	Acaricide susceptibility Host-targeted	University field station	No	Not reported	Academic	1	(Lane and Anderson 1984)
<i>D. variabilis</i>	Canada	Acaricide susceptibility	Laboratory	No	International federal	Academic	1	(Koloski et al. 2020)
<i>D. variabilis</i>	US (MA, I)	Habitat modification Host-targeted	Residential—suburban	No	Federal (USDA)	Public	4	(Smith et al. 1946)
<i>D. variabilis</i>	US (VA, II)	Host-targeted	Laboratory	No	Federal (NIAID)	Academic Private	NR	(Sonenshine et al. 1985)
<i>D. variabilis</i>	US (VA, II)	Host-targeted	Residential—suburban Laboratory	No	Not reported	Public Academic	4	(Sonenshine and Haines 1985)
<i>D. variabilis</i>	US (NY, I)	Environmental acaricide	Field plots	No	Not reported	Public Academic	1	(White et al. 1981)
<i>D. variabilis</i> <i>I. scapularis</i>	US (MN, III)	Habitat modification	Rural park	No	Federal (CDC)	Public Private	1	(Lee et al. 2023)
<i>D. variabilis</i> <i>I. scapularis</i> <i>R. sanguineus</i>	US (FL, II)	Acaricide susceptibility	Laboratory	No	Not reported	Academic	NR	(Kirkland et al. 2004b)
<i>H. longicornis</i>	US (NJ, I)	Environmental acaricide	Urban park	No	Federal (CDC) Federal (USDA)	Public Academic	1	(Bickerton et al. 2021)
<i>H. longicornis</i>	US (TN, IV)	Acaricide susceptibility	Laboratory	No	Nonprofit Federal (HATCH)	Academic Private	1	(Butler et al. 2021)
<i>I. pacificus</i>	US (CA, IX)	Acaricide susceptibility Host-targeted	Laboratory Suburban park	No	Nonprofit	Academic	2	(Lane 1989)
<i>I. scapularis</i>	Canada	Community assessment	Stakeholder engagement Laboratory	No	International federal	Academic	3	(Aenishaenslin et al. 2013)
<i>I. scapularis</i>	US (NY, I)	Acaricide susceptibility	Laboratory	No	Federal (CDC) Federal (FWS)	Academic	NR	(Allan and Patrican 1994)
<i>I. scapularis</i>	US (NY, I)	Environmental acaricide	Wilderness/preserve	No	Federal (CDC)	Academic	1	(Allan and Patrican 1995)
<i>I. scapularis</i>	US (MA CT NJ, I)	Host-targeted	Residential—suburban Suburban park	No	Not reported	Public Private	6	(Barile et al. 2005)
<i>I. scapularis</i>	US (IL, IV)	Acaricide susceptibility	Laboratory	No	Federal (CDC)	Public	NR	(Behle et al. 2011)
<i>I. scapularis</i>	US	Acaricide susceptibility	Laboratory	No	Not reported	Public Private	NR	(Behle et al. 2013)
<i>I. scapularis</i>	US (NY, I)	Acaricide susceptibility Environmental acaricide	Laboratory Wilderness/preserve	No	State Nonprofit	Academic	1	(Benjamin et al. 2002)

Tick species	Country (State, NOAA region ^d)	Control intervention/s	Study site location	ITM	Funding source/s	Author/s affiliation	Length of study (years) ^b	Reference
<i>I. scapularis</i>	US (CT, I)	Environmental acaricide	Residential—suburban Residential—rural	No	Federal (CDC) State Industry	Public	1	(Bharadwaj and Stafford 2010)
<i>I. scapularis</i>	US (CT, I)	Environmental acaricide	Residential—suburban Residential—rural	No	Federal (CDC)	Public	3	(Bharadwaj et al. 2012)
<i>I. scapularis</i>	US (CT, I)	Acaricide susceptibility	Laboratory	No	Federal (CDC)	Public	NR	(Bharadwaj and Stafford 2012)
<i>I. scapularis</i>	US (CT, I)	Environmental acaricide	Residential—suburban Residential—rural	No	Federal (CDC)	Public	3	(Bharadwaj et al. 2015)
<i>I. scapularis</i>	US (NY, MD, NJ, CT, RI, I)	Host-targeted	Residential—suburban Residential—rural	No	Federal (USDA)	Public Academic	8	(Brei et al. 2009)
<i>I. scapularis</i>	US (WI, III)	Environmental acaricide	Residential—suburban Residential—rural	No	Federal (CDC)	Academic	1	(Bron et al. 2021)
<i>I. scapularis</i>	US (PA, I)	Host-targeted	Wilderness/preserve	No	Industry	Academic	1	(Brown et al. 2020)
<i>I. scapularis</i>	US (NY, I)	Acaricide susceptibility	Laboratory	No	Federal (DOD) Federal (CDC)	Public Academic	1	(Burtis et al. 2021)
<i>I. scapularis</i>	US (MD, I)	Environmental acaricide Habitat modification	Laboratory Horse paddock	No	Not reported	Public	4	(Carroll and Schmidtmann 1996)
<i>I. scapularis</i>	US (NY, I)	Environmental acaricide	Residential—suburban	No	Federal (PHS) Federal (CDC)	Academic	1	(Curran et al. 1993)
<i>I. scapularis</i>	US (NY, I)	Host-targeted	Residential—suburban Suburban park	No	Nonprofit	Academic	3	(Daniels et al. 1991)
<i>I. scapularis</i>	US (NY, I)	Host-targeted	Suburban park Private estate	No	Federal (CDC) Nonprofit	Academic	NR	(Daniels et al. 1993)
<i>I. scapularis</i>	US (NY, I)	Host-targeted	Suburban park	No	Federal (CDC) Nonprofit	Academic	1	(Daniels and Fish 1995)
<i>I. scapularis</i>	US (NY, I)	Host-targeted	Residential—suburban	No	Federal (USDA)	Public Academic Private	6	(Daniels et al. 2009)
<i>I. scapularis</i>	US (MA, I)	Host-targeted	Suburban park Rural park	No	Not reported	Private	3	(Deblinger and Rimmer 1991)
<i>I. scapularis</i>	US (MA, I)	Host-targeted	Wilderness/preserve	No	Federal (NIH) Nonprofit	Academic Private	9	(Deblinger et al. 1993)
<i>I. scapularis</i>	US (CT, I)	Host-targeted	Residential—suburban	No	Federal (CDC)	Public Private	2	(Dolan et al. 2004)
<i>I. scapularis</i>	US (CO, VII)	Acaricide susceptibility	Laboratory	No	Not reported	Public	NR	(Dolan et al. 2007)
<i>I. scapularis</i>	US (NJ, I)	Host-targeted	Residential—suburban	No	Federal (CDC)	Public Academic	3	(Dolan et al. 2016)

Tick species	Country (State, NOAA region ^d)	Control intervention/s	Study site location	ITM	Funding source/s	Author/s affiliation	Length of study (years) ^b	Reference
<i>I. scapularis</i>	US (NY, I)	Host-targeted	Residential—suburban	No	Nonprofit	Private	1	(Duffy et al. 1992)
<i>I. scapularis</i>	US (ME, I)	Environmental acaricide	Residential—rural	No	Nonprofit	Academic Private	2	(Elias et al. 2013)
<i>I. scapularis</i>	US	Acaricide susceptibility	Laboratory	No	Not reported	Public	NR	(Eller et al. 2014)
<i>I. scapularis</i>	US (NY, I)	Habitat modification Host-targeted	Residential—suburban	No	Nonprofit	Academic	1	(Fischhoff et al. 2019)
<i>I. scapularis</i>	US (NY, I)	Host-targeted	Residential—suburban Suburban park	No	Federal (NPS)	Academic	1	(Ginsberg 1992)
<i>I. scapularis</i>	US (CT, I)	Community assessment	Residential—suburban	No	Federal (CDC)	Public	6	(Gould et al. 2008)
<i>I. scapularis</i>	US (MA, I)	Host-targeted	Residential—suburban	No	Federal (EPA)	Public Academic	5	(Gear et al. 2014)
<i>I. scapularis</i>	US (NY, I)	Acaricide susceptibility Environmental acaricide	Laboratory Wilderness/preserve	No	Academic Federal (EPA) Federal (NIH) Federal (NSF)	Public Academic	2	(Greengarten et al. 2011)
<i>I. scapularis</i>	US	Acaricide susceptibility	Laboratory	No	Not reported	Public	NR	(Hill 1998)
<i>I. scapularis</i>	US (CT, MD, NY, I)	Environmental acaricide Community assessment	Residential—suburban	No	Federal (CDC)	Public Academic	2	(Hinckley et al. 2016)
<i>I. scapularis</i>	US (NY, I)	Environmental acaricide	Wilderness/preserve	No	Federal (NIH) State Local	Academic	1	(Hornbostel et al. 2004)
<i>I. scapularis</i>	US (NY, I)	Host-targeted	Laboratory Institute field station	No	Local Federal (NSF) Federal (NIH)	Academic	2	(Hornbostel et al. 2005a)
<i>I. scapularis</i>	US (NY, I)	Acaricide susceptibility Environmental acaricide	Laboratory Wilderness/preserve	No	Federal (NIH) Local Nonprofit	Public Academic	2	(Hornbostel et al. 2005b)
<i>I. scapularis</i>	US (CT, I)	Community assessment	Residential—suburban	No	Federal (EPA)	Public Academic	3	(Hornbostel et al. 2021)
<i>I. scapularis</i>	US (NJ, I)	Host-targeted	Residential—rural	No	State Federal (CDC)	Public	5	(Jordan et al. 2007)
<i>I. scapularis</i>	US (NJ, I)	Host-targeted	Residential—suburban	No	Federal (CDC)	Public	3	(Jordan and Schulze 2019)
<i>I. scapularis</i>	US (NY, I)	Environmental acaricide Host-targeted	Residential—suburban	Yes	Nonprofit Federal (CDC) State Private donor	Public Academic	4	(Keesing et al. 2022)
<i>I. scapularis</i>	US (MA, I)	Habitat modification	Residential—suburban	No	Federal (NSF)	Public	2	(Lerman and D'Amico 2019)

Tick species	Country (State, NOAA region ^d)	Control intervention/s	Study site location	ITM	Funding source/s	Author/s affiliation	Length of study (years) ^b	Reference
<i>I. scapularis</i>	US (CT, I)	Host-targeted	Residential—suburban	No	Federal (USDA) Federal (HATCH)	Public	3	(Linske et al. 2022)
<i>I. scapularis</i>	US (MA, I)	Environmental acaricide	Wilderness/preserve Laboratory	No	State Academic Nonprofit Private donor	Academic	3	(Lyon et al. 1998)
<i>I. scapularis</i>	US (WI, III)	Habitat modification Host-targeted	Suburban park	Yes	Federal (HATCH) Academic	Academic	5	(Mandli et al. 2021)
<i>I. scapularis</i>	US (MA, I)	Host-targeted	Residential—rural	No	State Nonprofit Federal (NIH) Private donor	Academic	1	(Mather et al. 1987)
<i>I. scapularis</i>	US (MA, I)	Host-targeted	Residential—suburban	No	Not reported	Academic	2	(Mather et al. 1988)
<i>I. scapularis</i>	US (NY, I)	Habitat modification	Rural park	No	Federal (CDC) Federal (NIH) State	Academic	1	(Mather et al. 1993)
<i>I. scapularis</i>	US (CO, VII)	Acaricide susceptibility	Laboratory	No	Not reported	Public	NR	(Maupin and Priesman 1994)
<i>I. scapularis</i>	US	Host-targeted	Laboratory	No	Not reported	Academic Private	NR	(McCall et al. 2011)
<i>I. scapularis</i>	Canada	Habitat modification	Urban park	No	International federal	Public Academic	1	(McKay et al. 2020)
<i>I. scapularis</i>	US (RI, I)	Host-targeted	Residential—rural	No	Federal (USDA) Nonprofit	Academic	6	(Miller et al. 2009)
<i>I. scapularis</i>	US	Host-targeted	Laboratory	No	Industry	Private	NR	(Mitchell et al. 2014)
<i>I. scapularis</i>	US	Acaricide susceptibility	Laboratory	No	Federal (USDA)	Public Academic	NR	(Panella et al. 1997)
<i>I. scapularis</i>	US (CO, VII)	Acaricide susceptibility	Laboratory	No	Not reported	Public Academic	NR	(Panella et al. 2005)
<i>I. scapularis</i>	US (NY, I)	Environmental acaricide	Wilderness/preserve	No	Federal (CDC)	Academic	1	(Patrican and Allan 1995a)
<i>I. scapularis</i>	US	Acaricide susceptibility	Laboratory	No	Federal (CDC)	Academic	NR	(Patrican and Allan 1995b)
<i>I. scapularis</i>	Canada	Host-targeted	Wilderness/preserve	No	Academic International federal	Public Academic	3	(Pelletier et al. 2022)
<i>I. scapularis</i>	US (CO, VII)	Habitat modification	Laboratory	No	Not reported	Public	1	(Priesman 2006)
<i>I. scapularis</i>	US	Host-targeted	Laboratory	No	Federal (CDC)	Private	1	(Poiché et al. 2021)
<i>I. scapularis</i>	US (ME, I)	Host-targeted	Residential—rural	No	Nonprofit Industry Academic	Academic	4	(Rand et al. 2000)

Tick species	Country (State, NOAA region ^d)	Control intervention/s	Study site location	ITM	Funding source/s	Author/s affiliation	Length of study (years) ^b	Reference
<i>I. scapularis</i>	US (ME, I)	Host-targeted	Residential—rural	No	Federal (CDC)	Academic	14	(Rand et al. 2004)
<i>I. scapularis</i>	US (ME, I)	Environmental acaricide	Residential—rural	No	Nonprofit	Academic Private	1	(Rand et al. 2010)
<i>I. scapularis</i>	US (NC, II)	Host-targeted Community assessment	Residential—suburban Residential—rural Laboratory	No	Federal (NIOSH)	Academic	1	(Richards et al. 2022)
<i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Military base	No	Not reported	Public Private	1	(Schulze et al. 1987)
<i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Military base	No	Not reported	Public Academic Private	2	(Schulze et al. 1991)
<i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Suburban park Military base	No	Not reported	Public Academic Private	2	(Schulze et al. 1992)
<i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Residential—suburban	No	Federal (CDC)	Public	1	(Schulze et al. 1994)
<i>I. scapularis</i>	US (NJ, I)	Habitat modification	Residential—suburban	No	Federal (CDC)	Public	1	(Schulze et al. 1995)
<i>I. scapularis</i>	US (NJ, I)	Environmental Habitat modification	Residential—suburban	No	Federal (CDC)	Public	1	(Schulze and Jordan 1995)
<i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Residential—suburban Military base	No	Federal (CDC)	Public	1	(Schulze et al. 2001a)
<i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Residential—suburban	No	Federal (CDC)	Public	1	(Schulze et al. 2005)
<i>I. scapularis</i>	US (NJ, I)	Environmental acaricide Host-targeted	Residential—suburban	Yes	Federal (CDC)	Public	4	(Schulze et al. 2007)
<i>I. scapularis</i>	US (NJ, I)	Host-targeted	Residential—suburban	No	Federal (CDC)	Public	3	(Schulze et al. 2008a)
<i>I. scapularis</i>	US (NJ, I)	Environmental acaricide	Military base	No	Federal (CDC)	Public	3	(Schulze et al. 2008b)
<i>I. scapularis</i>	US (NJ, I)	Host-targeted	Residential—suburban	No	Federal (CDC)	Public	3	(Schulze et al. 2017)
<i>I. scapularis</i>	US (MD, I)	Host-targeted	Wilderness/preserve Military base	No	Academic Nonprofit Federal (CDC) Federal (DOD)	Public	4	(Solberg et al. 2003)
<i>I. scapularis</i>	US (CT, I)	Environmental acaricide	Residential—rural	No	Not reported	Public	1	(Stafford 1991a)
<i>I. scapularis</i>	US (CT, I)	Host-targeted	Residential—suburban Residential—rural	No	Not reported	Public	2	(Stafford 1991b)
<i>I. scapularis</i>	US (CT, I)	Host-targeted	Residential—suburban Residential—rural	No	Not reported	Public	1	(Stafford 1992)
<i>I. scapularis</i>	US (CT, I)	Host-targeted	Residential—rural	No	Not reported	Public	3	(Stafford 1993)

Tick species	Country (State, NOAA region ^d)	Control intervention/s	Study site location	ITM	Funding source/s	Author/s affiliation	Length of study (years) ^b	Reference
<i>I. scapularis</i>	US (CT, I)	Community assessment	Paper-based surveys	No	Federal (CDC)	Public	2	(Stafford 1997)
<i>I. scapularis</i>	US (CT, I)	Habitat modification	Rural park	No	Not reported	Public	1	(Stafford et al. 1998)
<i>I. scapularis</i>	US (CT, I)	Environmental acaricide Host-targeted	Suburban park Rural park	Yes	Federal (CDC) Federal (HATCH)	Public Private	10	(Stafford et al. 2003)
<i>I. scapularis</i>	US (CT, I)	Host-targeted	Residential—suburban Residential—rural	No	Federal (USDA)	Public Private	8	(Stafford et al. 2009)
<i>I. scapularis</i>	US (CT, I)	Environmental acaricide	Residential—rural	No	Federal (CDC)	Public	4	(Stafford and Allan 2010)
<i>I. scapularis</i>	US (CT, I)	Habitat modification	Wilderness/preserve	No	Industry State Nonprofit	Public Academic	2	(Williams et al. 2009)
<i>I. scapularis</i>	US (CT, I)	Habitat modification	Wilderness/preserve	No	Nonprofit Academic Industry State	Public	4	(Williams and Ward 2010)
<i>I. scapularis</i>	US (CT, I)	Habitat modification	Residential—suburban Residential—rural Wilderness/preserve	No	Nonprofit Industry Federal (USDA) State	Public	10	(Williams et al. 2017)
<i>I. scapularis</i>	US (CT, I)	Environmental acaricide Host-targeted	Residential—suburban Residential—rural	Yes	Federal (CDC)	Public	4	(Williams et al. 2018)
<i>I. scapularis</i>	US (CT, I)	Host-targeted	Wilderness/preserve	No	Federal (DOD) Federal (HATCH) State	Public	2	(Williams et al. 2023)
<i>I. scapularis</i>	US (MA, I)	Habitat modification	Residential—suburban	No	Private donor Federal (NIH)	Academic	NR	(Wilson 1986)
<i>I. scapularis</i>	US (MA, I)	Host-targeted	Residential—rural	No	Nonprofit Private donor	Academic	6	(Wilson et al. 1988)
<i>I. scapularis</i>	US (RI, I)	Acaricide susceptibility	Laboratory	No	Nonprofit Academic Federal (USGS)	Public Academic	NR	(Zhioua et al. 1995)
<i>I. scapularis</i>	US (RI, I)	Acaricide susceptibility	Laboratory	No	Academic Federal (USGS)	Public Academic	NR	(Zhioua et al. 1997)
<i>I. scapularis</i>	US (RI, I)	Acaricide susceptibility	Laboratory	No	Academic Federal (USGS) Nonprofit	Academic	NR	(Zhioua et al. 1999)
<i>R. sanguineus</i>	Mexico	Environmental acaricide Host-targeted Community assessment	Residential—urban Residential—suburban	Yes	Not reported	Public Academic	1	(Alvarez-Hernandez et al. 2020)

Tick species	Country (State, NOAA region ^d)	Control intervention/s	Study site location	ITM	Funding source/s	Author/s affiliation	Length of study (years) ^b	Reference
<i>R. sanguineus</i>	US (AZ, VII)	Environmental acaricide Host-targeted Community assessment	Indigenous nation territory	Yes	Federal (CDC) Industry	Public Academic Private	2	(Drexler et al. 2014)
<i>R. sanguineus</i>	US (FL TX, II)	Acaricide susceptibility	Laboratory	No	Federal (USDA)	Academic	4	(Eiden et al. 2015)
<i>R. sanguineus</i>	US South Africa	Host-targeted	Laboratory	No	Industry	Private	NR	(Hunter et al. 2011)
<i>R. sanguineus</i>	US	Acaricide susceptibility	Laboratory	No	Nonprofit	Academic	NR	(Nelson 1969)
<i>R. sanguineus</i>	US, Mexico	Environmental acaricide Host-targeted Community assessment	Residential—suburban Residential—rural	Yes	Not reported	Public Academic	1	(Straily et al. 2016)
Other: not specified	US (CO, VII)	Host-targeted	Wilderness/preserve	No	Not reported	Public	2	(Gage et al. 1997)
Other: Community assessment	US (NJ, PA, NY, I)	Community assessment	Survey participants in NJ, NY, PA	No	Federal (CDC)	Public	3	(Jordan and Schulze 2020b)
Other: Community assessment	US (MD, CT, I)	Community assessment	Residential—urban Residential—suburban	No	Federal (CDC)	Public Academic	2	(Niesobecki et al. 2019)
Other: Community assessment	US (IN, IV)	Community assessment	Residential—urban Residential—suburban Residential—rural	No	Academic	Academic	1	(Omodior et al. 2021)

^a NOAA regions: I—Northeast, II—Southwest, III—Upper Midwest, IV—Ohio Valley, V—South, VI—Northern Rockies & Plains, VII—Southwest, VIII—Northwest, IX—West.

^b NR, not reported.

Table 5. Control focus area and author affiliation for studies on the control of ticks of public health importance, North America (n = 183, date of search: 13 August 2023)

Tick species	Control focus area				Author affiliation			Reference
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public	Private
<i>A. americanum</i>	Controlled burn					WashU		(Allan 2009)
<i>A. americanum</i>	Invasive plant removal					WashU, UMSL, UW		(Allan et al. 2010)
<i>A. americanum</i>	Controlled burn	Bovine (exclusion)	Benzidine				USDA	(Barnard 1986)
<i>A. americanum</i>	Vegetation management	Deer (exclusion)	Organophosphate				USDA, TVA, PAHO	(Bloemer et al. 1990)
<i>A. americanum</i>	Vegetation management		Organophosphate			OU		(Clymer et al. 1970)
<i>A. americanum</i>	Controlled burn Bison grazing					KSU	USGS	(Cully 1999)
<i>A. americanum</i>	Controlled burn					UGA		(Davidson et al. 1994)
<i>A. americanum</i>			Pyrethroid			ODU, VMI, UKN, UNC		(Gaff et al. 2015)
<i>A. americanum</i>		Deer (exclusion)				URI	USGS	(Ginsberg et al. 2002)
<i>A. americanum</i>	Vegetation management		Organophosphate			OU		(Hair and Howell 1970)
<i>A. americanum</i>	Vegetation management		Organophosphate			OU		(Hoch et al. 1971)
<i>A. americanum</i>	Controlled burn					OU		(Hoch et al. 1972)
<i>A. americanum</i>			Pyrethroid				CDC, USDA, US Navy	(Hughes et al. 2014)
<i>A. americanum</i>				Phenothrin		UF		(Kaplan et al. 2020)
<i>A. americanum</i>			Pyrethrin, Other				USDA	(McDuffie et al. 1950)
<i>A. americanum</i>			Carbamate, Organophosphate, Other	Carbamate, Organophosphate, Other			USDA, US Navy	(Mount et al. 1968)

Tick species	Control focus area				Author affiliation			Reference
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public	Private
<i>A. americanum</i>			Carbamate, Organophosphate				USDA, US Navy	(Mount et al. 1976)
<i>A. americanum</i>	Vegetation management						USDA	(Mount 1981)
<i>A. americanum</i>			Organophosphate				USDA	(Mount 1983)
<i>A. americanum</i>			Organophosphate				USDA	(Mount 1984)
<i>A. americanum</i>		Deer (acaricide impregnated feed)					USDA, Texas Parks and Wildlife Dept.	(Pound et al. 1996)
<i>A. americanum</i>		Deer (4-poster device)					USDA	(Pound et al. 2000)
<i>A. americanum</i>		Deer (acaricidal collar)					USDA	(Pound et al. 2012)
<i>A. americanum</i>			Carbamate, Organophosphate, Pyrethroid				USDA, US Navy	(Roberts et al. 1980)
<i>A. americanum</i>			Organophosphate				US Army	(Sardelis et al. 1989)
<i>A. americanum</i>				IGR		UTX	USDA	(Showler et al. 2017)
<i>A. americanum</i>		Deer (4-poster device)					CAES, CT-DEEP	(Williams et al. 2021)
<i>A. americanum</i>				Carbamate, IGR, Organophosphate, Phenylpyrazole, Pyrethroid, Pyrethrin, Other				(Burridge et al. 2003)
<i>A. americanum</i>				Ent. fungi		UF		(Kirkland et al. 2004a)
<i>A. americanum</i>								(Baker et al. 2011)
<i>A. americanum</i>		Domestic pet (topical)						Meril Limited, TRS Labs, Young Veterinary Research Services, Nu-Era Farms, BerTek Inc, Meril S.A.S.
<i>A. americanum</i>								(Gleim et al. 2014)
<i>A. maculatum</i>	Controlled burn					UGA	CDC	Joseph W. Jones Ecological Research Center
<i>D. variabilis</i>								
<i>I. scapularis</i>								

Tick species	Control focus area				Author affiliation			Reference
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public	Private
<i>I. brunneus</i>								
<i>I. scapularis</i>								
<i>A. americanum</i>		Deer (4-poster device)					Fairfax Co. Police Dept., Fairfax Co. Health Dept.	(Edwards et al. 2016)
<i>A. maculatum</i>								
<i>D. albipictus</i>								
<i>D. variabilis</i>								
<i>I. scapularis</i>								
<i>A. americanum</i>		Domestic pet (oral administration)						(Six et al. 2016)
<i>A. maculatum</i>								
<i>D. variabilis</i>								
<i>I. scapularis</i>								
<i>R. sanguineus</i>								
<i>A. americanum</i>		Deer (selfmedicating applicator)				ODU, UF		(Sonenshine et al. 1996)
<i>D. albipictus</i>								
<i>I. scapularis</i>								
<i>A. americanum</i>		Deer (exclusion)	Organophosphate				TVA	(Bloemer et al. 1986)
<i>D. variabilis</i>								
<i>A. americanum</i>	Invasive plant removal					IU		(Civitello et al. 2008)
<i>D. variabilis</i>								
<i>A. americanum</i>		Deer (4-poster device)				UT		(Harmon et al. 2011)
<i>D. variabilis</i>								
<i>A. americanum</i>	Yard management	Deer (exclusion)	Organophosphate				TVA	(Zimmerman et al. 1988)
<i>D. variabilis</i>								
<i>A. americanum</i>				Botanically derived			USDA, Tropical Pesticides Research Institute	(Carroll et al. 1989)
<i>D. variabilis</i>								
<i>I. scapularis</i>								
<i>A. americanum</i>	Controlled burn					A&M		(Hodo et al. 2020)
<i>D. variabilis</i>								
<i>I. scapularis</i>								
<i>A. americanum</i>				Pyrethroid			CDC	(Prose et al. 2018)
<i>D. variabilis</i>								
<i>I. scapularis</i>								
<i>A. americanum</i>			Pyrethrin, Other				USDA	(Smith and Gouck 1944)
<i>D. variabilis</i>								
<i>I. scapularis</i>								
<i>A. americanum</i>				Nootkatone			CAES, USDA	(Flor-Weiler et al. 2011)
<i>D. variabilis</i>								
<i>I. scapularis</i>								
<i>R. sanguineus</i>								

Tick species	Control focus area				Author affiliation			Reference
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public	Private
<i>A. americanum</i> <i>D. variabilis</i> <i>I. scapularis</i> <i>R. sanguineus</i>		Domestic pet (oral tablet)						Elanco Animal Health
<i>A. americanum</i> <i>D. variabilis</i> <i>I. scapularis</i> <i>R. sanguineus</i>		Domestic pet (spot-on treatment)						Fort Dodge Animal Health, Nu-Era Farms, AgResearch Consultants, Stillmeadow Inc.
<i>A. americanum</i> <i>I. scapularis</i>		Deer (4-poster device)					USDA	(Carroll et al. 2002)
<i>A. americanum</i> <i>I. scapularis</i>		Deer (4-poster device)					USDA	(Carroll et al. 2009b)
<i>A. americanum</i> <i>I. scapularis</i>		Deer (4-poster device)					USDA	(Carroll et al. 2009a)
<i>A. americanum</i> <i>I. scapularis</i>			Nootkatone, Botanically derived			OSU	CDC, FAHD	Legacy BioDesign LLC
<i>A. americanum</i> <i>I. scapularis</i>			Nootkatone, Botanically derived				CDC, FAHD	Terry L. Schulze, Ph.D., Inc.
<i>A. americanum</i> <i>I. scapularis</i>	Yard management						MCMCD	(Jordan and Schulze 2020a)
<i>A. americanum</i> <i>I. scapularis</i>		Deer (4-poster device)				E, URL, YSM	USDA, NYSDOH, CAES	(Pound et al. 2009)
<i>A. americanum</i> <i>I. scapularis</i>					Assessment of willingness to pay for and use tick prevention strategies	MCRI, UMN	USFS	(Schotthoefer et al. 2020)
<i>A. americanum</i> <i>I. scapularis</i>			Carbamate				NJDOH, FAHD	(Schulze et al. 2000)
<i>A. americanum</i> <i>I. scapularis</i>			Pyrethroid				NJDOH, FAHD, MCMCD	(Schulze et al. 2001b)

Tick species	Control focus area				Author affiliation			Reference	
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public		Private
<i>A. americanum</i> <i>I. scapularis</i>		Deer (4-poster device)					FAHD	R.W. Hung Environmental Resources Inc.	(Schulze et al. 2009)
<i>A. americanum</i> <i>I. scapularis</i>			Ent. Fungi, 25(b), Pyrethroid				MCMCD	Terry L. Schulze, Ph.D., Inc.	(Schulze and Jordan 2021)
<i>A. americanum</i> <i>I. scapularis</i>			Ent. Fungi, 25(b)					Terry L. Schulze, Ph.D., Inc.	(Schulze and Jordan 2023)
<i>A. americanum</i> <i>I. scapularis</i>			Pyrethroid					US Army, US Navy, Uniform Services Univ.	(Solberg et al. 1992)
<i>D. andersoni</i>	Vegetation management		Benzidine					Agriculture Canada Research Station	(Wilkinson 1977)
<i>D. occidentalis</i> <i>D. variabilis</i> <i>I. pacificus</i> <i>I. spinipalpis</i> <i>I. woodi</i>	Natural fire					UC- Davis			(Pascoe et al. 2020)
<i>D. occidentalis</i> <i>I. pacificus</i> <i>I. spinipalpis</i> <i>I. woodi</i>		Rodent (bait cube)				UC- Berkeley	CA-DOH		(Slowik et al. 2001)
<i>D. occidentalis</i> <i>I. pacificus</i> <i>I. neotomae</i> <i>I. woodi</i>		Rodent (acaricide-treated nesting cotton)				UC- Berkeley			(Leprince and Lane 1996)
<i>D. occidentalis</i> <i>I. pacificus</i>	Controlled burn					UC- Berkeley	CA-DPH		(Padgett et al. 2009)
<i>D. occidentalis</i> <i>O. coriaceus</i>		Humans wearing permethrin-impregnated clothes		Pyrethroid		UC- Berkeley			(Lane and Anderson 1984)
<i>D. variabilis</i>				DEET		BU			(Koloski et al. 2020)
<i>D. variabilis</i>	Controlled burn	Roden (cull), Domestic pet (acaricidal application)					USDA		(Smith et al. 1946)

Tick species	Control focus area				Author affiliation			Reference	
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public		Private
<i>D. variabilis</i>		Domestic pet (acaricidal application)				ODU		Pet Care Products—AH Robins Company	(Sonenshine et al. 1985)
<i>D. variabilis</i>		Rodent (tick tube)				ODU	Fairfield Co. Health Dept.		(Sonenshine and Haines 1985)
<i>D. variabilis</i>			Organophosphate			SUNY SB	NYS-DOH		(White et al. 1981)
<i>D. variabilis</i> <i>I. scapularis</i>	Trail mowing					UW-Madison		Mississippi Headwaters Audubon Society	(Lee et al. 2023)
<i>D. variabilis</i> <i>I. scapularis</i> <i>R. sanguineus</i> <i>H. longicornis</i>				Ent. fungi		UF			(Kirkland et al. 2004b)
			Pyrethroid			RU	Bergen Co. Dept. of Health Services		(Bickerton et al. 2021)
<i>H. longicornis</i>				IGR, Organophosphate, Pyrethroid		UT		Central Life Sciences	(Butler et al. 2021)
<i>I. pacificus</i>		Humans wearing permethrin-impregnated clothes		Pyrethroid		UC			(Lane 1989)
<i>I. scapularis</i>					Acceptability of Lyme disease prevention strategies	Geisel, UdeM, UQAM			(Aenishaenslin et al. 2013)
<i>I. scapularis</i>				Organophosphate, Pyrethrin, Other		CU			(Allan and Patrican 1994)
<i>I. scapularis</i>			Pyrethroid, Organophosphate			CU			(Allan and Patrican 1995)
<i>I. scapularis</i>		Rodent (bait box)					CDC	Bayer Environmental Science	(Barile et al. 2005)
<i>I. scapularis</i>				Nootkatone			CAES, USDA		(Behle et al. 2011)
<i>I. scapularis</i>				Ent. fungi			USDA	Marrone Bio Innovations, Inc.	(Behle et al. 2013)

Tick species	Control focus area				Author affiliation			Reference
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public	Private
<i>I. scapularis</i>			Ent. fungi	Ent. fungi		Cary, Kent, URI		(Benjamin et al. 2002)
<i>I. scapularis</i>			Ent. fungi				CAES	(Bharadwaj and Stafford 2010)
<i>I. scapularis</i>			Nootkatone				CAES, CT Dept. of Emergency Services, USDA	(Bharadwaj et al. 2012)
<i>I. scapularis</i>				Ent. fungi			CAES	(Bharadwaj and Stafford 2012)
<i>I. scapularis</i>			25(b)				CAES	(Bharadwaj et al. 2015)
<i>I. scapularis</i>		Deer (4-poster device)				HMS, F, URI, YSM	CAES, USDA	(Brei et al. 2009)
<i>I. scapularis</i>			Pyrethroid			UW-Madison		(Bron et al. 2021)
<i>I. scapularis</i>		Rodent (tick tubes)				PSU		(Brown et al. 2020)
<i>I. scapularis</i>				Pyrethroid		CU	Shelter Island Police Dept., Suffolk Co. Dept. Health Services	(Burtis et al. 2021)
<i>I. scapularis</i>	Silt fencing		Pyrethroid				USDA	(Carroll and Schmidtman 1996)
<i>I. scapularis</i>			Carbamate, Organophosphate, Pyrethroid			NYMC		(Curran et al. 1993)
<i>I. scapularis</i>		Rodent (tick tubes)				NYMC		(Daniels et al. 1991)
<i>I. scapularis</i>		Deer (exclusion)				NYMC		(Daniels et al. 1993)
<i>I. scapularis</i>		Deer (exclusion)				NYMC		(Daniels and Fish 1995)
<i>I. scapularis</i>		Deer (4-poster device)				F, NYMC, Yale	NYSDOH, USDA	(Daniels et al. 2009)
<i>I. scapularis</i>		Rodent (tick tubes)					White Buffalo Inc.	(Deblinger and Rimmer 1991)
							Trustees of Reservations (MA)	

Tick species	Control focus area				Author affiliation			Reference
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public	Private
<i>I. scapularis</i>		Deer (cull)			HSPH			Trustees of Reservations (MA) (Deblinger et al. 1993)
<i>I. scapularis</i>		Rodent (bait boxes)					CAES, CDC	Bayer Environmental Science (Dolan et al. 2004)
<i>I. scapularis</i>				Botanically derived			CDC	(Dolan et al. 2007)
<i>I. scapularis</i>		Rodent (bait boxes)			CSU		CDC, MCMCD	Terry L. Schulze, Ph.D., Inc. (Dolan et al. 2016)
<i>I. scapularis</i>		Guineafowl (predation)						Lyme Disease Research Project, Applied Biomathematics, Gelfand, Rennert and Feldman (Duffy et al. 1992)
<i>I. scapularis</i>			Pyrethroid, 25(b)			MMCRI, UMaine, USM		Atlantic Pest Solutions (Elias et al. 2013)
<i>I. scapularis</i>				Botanically derived			USDA	(Eller et al. 2014)
<i>I. scapularis</i>	Yard management	Domestic pet				BC, Cary		(Fischhoff et al. 2019)
<i>I. scapularis</i>		Rodent (tick tubes)				RU		(Ginsberg 1992)
<i>I. scapularis</i>					Evaluation of tick bite prevention implementation		CDC, CT-DPH	(Gould et al. 2008)
<i>I. scapularis</i>		Deer (4-poster device)				CCCE	EPA	(Grear et al. 2014)
<i>I. scapularis</i>			Ent. fungi	Ent. fungi		F	NYSDOH	(Greengarten et al. 2011)
<i>I. scapularis</i>				Parasitoid nematodes			USDA	(Hill 1998)

Tick species	Control focus area				Author affiliation			Reference
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public	
<i>I. scapularis</i>			Pyrethroid		KAP assessment of tick control	WCSU, Yale	CDC, MD-DOH, NYSDOH	(Hinckley et al. 2016)
<i>I. scapularis</i>			Ent. fungi			Cary, IP		(Hornbostel et al. 2004)
<i>I. scapularis</i>		Rodent (ent. fungi-treated nesting cotton)				Cary		(Hornbostel et al. 2005a)
<i>I. scapularis</i>			Ent. fungi, Pyrethroid	Ent. fungi, Pyrethroid		Cary, IP, URI	USGS	(Hornbostel et al. 2005b)
<i>I. scapularis</i>					KAP assessment of tick control	WCSU	Ridgefield Health Dept.	(Hornbostel et al. 2021)
<i>I. scapularis</i>		Deer (removal)					FAHD	(Jordan et al. 2007)
<i>I. scapularis</i>		Rodent (tick tubes, bait boxes)					MCMCD	(Jordan and Schulze 2019)
<i>I. scapularis</i>		Rodent (bait boxes)	Ent. fungi			BC, Cary	CDC, Dutchess Co. Dept. Behavioral and Community Health	(Keesing et al. 2022)
<i>I. scapularis</i>	Yard management						USDA	(Lerman and D'Amico 2019)
<i>I. scapularis</i>		Rodent (bait boxes)					CAES, USDA	(Linske et al. 2022)
<i>I. scapularis</i>			Parasitoid wasp <i>I. hookeri</i>			UMass-Amherst		(Lyon et al. 1998)
<i>I. scapularis</i>	Invasive plant removal	Rodent (tick tubes)				UW-Madison		(Mandli et al. 2021)
<i>I. scapularis</i>		Rodent (acaricide-treated nesting cotton)				HU		(Mather et al. 1987)
<i>I. scapularis</i>		Rodent (tick tubes)				HU		(Mather et al. 1988)
<i>I. scapularis</i>	Controlled burn					URI		(Mather et al. 1993)

Tick species	Control focus area				Author affiliation			Reference
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public	Private
<i>I. scapularis</i>				Carbamate, Pyrethroid			CDC	(Maupin and Piesman 1994)
<i>I. scapularis</i>		Domestic pet (spot-on treatment)			URI			T RS Labs, Meril Limited, Meril S.A.S.
<i>I. scapularis</i>	Wood chip borders along trail systems				UoFO		National Capital Commission	(McKay et al. 2020)
<i>I. scapularis</i>		Deer (4-poster device)			URI			(Miller et al. 2009)
<i>I. scapularis</i>		Domestic pet (oral tablet)						(Mitchell et al. 2014)
<i>I. scapularis</i>				Botanically derived	OSU		CDC	(Panella et al. 1997)
<i>I. scapularis</i>				Nootkatone, Botanically derived	OSU		CDC	(Panella et al. 2005)
<i>I. scapularis</i>					CU			(Patrican and Allan 1995a)
<i>I. scapularis</i>			Pyrethrin	Pyrethrin, Other	CU, UF			(Patrican and Allan 1995b)
<i>I. scapularis</i>		Rodent (bait stations)			UdeM		Public Health Agency of Canada	(Pelletier et al. 2022)
<i>I. scapularis</i>	Yard management						CDC	(Piesman 2006)
<i>I. scapularis</i>		Rodent (oral acaricide bait)						(Poché et al. 2021)
<i>I. scapularis</i>		Deer (acaricide-treated corn)			MMCRI			(Rand et al. 2000)
<i>I. scapularis</i>		Deer (cull)			MMCRI			(Rand et al. 2004)
<i>I. scapularis</i>			Pyrethroid, 25(b)		MMCRI			(Rand et al. 2010)
<i>I. scapularis</i>	Humans wearing permethrin-impregnated clothes				KAP assessment of tick control			(Richards et al. 2022)

Tick species	Control focus area				Author affiliation			Reference	
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public		Private
<i>I. scapularis</i>			Carbamate, Organophosphate				NIDOH, USA MEDDAC	Environmental Connection Inc.	(Schulze et al. 1987)
<i>I. scapularis</i>			Carbamate, Organophosphate				NIDOH, NYSDOH, USA MEDDAC	Environmental Connection Inc.	(Schulze et al. 1991)
<i>I. scapularis</i>			Carbamate			RU	Monmouth Co. Health Dept., NIDOH, USA MEDDAC	Environmental Connection Inc.	(Schulze et al. 1992)
<i>I. scapularis</i>			Carbamate				NIDOH, FAHD, MCMCD		(Schulze et al. 1994)
<i>I. scapularis</i>	Yard management						NIDOH, FAHD		(Schulze et al. 1995)
<i>I. scapularis</i>	Yard management		Carbamate				NIDOH, FAHD		(Schulze and Jordan 1995)
<i>I. scapularis</i>			Carbamate				NIDOH, FAHD		(Schulze et al. 2001a)
<i>I. scapularis</i>			Pyrethroid				NIDOH, FAHD		(Schulze et al. 2005)
<i>I. scapularis</i>		Rodent (bait boxes), Deer (4-poster device)	Pyrethroid				CDC, FAHD, MCMCD		(Schulze et al. 2007)
<i>I. scapularis</i>		Deer (4-poster device)					CDC, FAHD, MCMCD		(Schulze et al. 2008a)
<i>I. scapularis</i>			Pyrethroid				FAHD, MCMCD		(Schulze et al. 2008b)
<i>I. scapularis</i>		Rodent (bait boxes)					CDC, MCMCD		(Schulze et al. 2017)
<i>I. scapularis</i>		Deer (4-poster device)					US Armed Forces, USDA, Walter Reed		(Solberg et al. 2003)
<i>I. scapularis</i>			Carbamate				CAES		(Stafford 1991a)
<i>I. scapularis</i>		Rodent (tick tubes)					CAES		(Stafford 1991b)

Tick species	Control focus area				Author affiliation			Reference	
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public		Private
<i>I. scapularis</i>		Rodent (treated nesting cotton)				CAES			(Stafford 1992)
<i>I. scapularis</i>		Deer (exclusion)				CAES			(Stafford 1993)
<i>I. scapularis</i>					Assessment of pesticide use by licensed applicators	CAES			(Stafford 1997)
<i>I. scapularis</i>	Controlled burn					CAES			(Stafford et al. 1998)
<i>I. scapularis</i>		Deer (cull)	Parasitoid wasp <i>L. hookeri</i>			CAES, CT-DEEP		White Buffalo Inc.	(Stafford et al. 2003)
<i>I. scapularis</i>		Deer (4-poster device)				CAES, USDA		White Buffalo Inc.	(Stafford et al. 2009)
<i>I. scapularis</i>			Ent. fungi			CAES, USDA			(Stafford and Allan 2010)
<i>I. scapularis</i>	Invasive plant removal					UConn	CAES		(Williams et al. 2009)
<i>I. scapularis</i>	Invasive plant removal						CAES		(Williams and Ward 2010)
<i>I. scapularis</i>	Invasive plant removal						CAES		(Williams et al. 2017)
<i>I. scapularis</i>		Rodent (bait boxes), Deer (population reduction)	Ent. fungi				CAES		(Williams et al. 2018)
<i>I. scapularis</i>		Rodent (bait boxes)					CAES		(Williams et al. 2023)
<i>I. scapularis</i>	Controlled burn, Yard management					HSPH			(Wilson 1986)
<i>I. scapularis</i>		Deer (removal)				HSPH			(Wilson et al. 1988)
<i>I. scapularis</i>				Parasitoid nematodes		URI, UN	USGS		(Zhioua et al. 1995)
<i>I. scapularis</i>				Ent. fungi		URI	USGS		(Zhioua et al. 1997)
<i>I. scapularis</i>				Ent. fungi		URI			(Zhioua et al. 1999)

Tick species	Control focus area				Author affiliation			Reference
	Habitat modification	Host (method)	Environmental Acaricide AI class	Susceptibility Acaricide AI class	Community assessment	Academic	Public	Private
<i>R. sanguineus</i>		Domestic pet (acaricidal collar)	Pyrethroid		Assessment of community tick control practices	USN	CDC, Ministry of Public Health Sonora	(Alvarez-Hernandez et al. 2020)
<i>R. sanguineus</i>		Domestic pet (acaricidal collar), Domestic and free-roaming dogs (spay-neuter campaign)	Pyrethroid, Other		Evaluated tick bite prevention practices		AZ-DOH, CDC, Indian Health Service	(Drexler et al. 2014)
<i>R. sanguineus</i>				Phenothrin, Pyrethroid		UF		(Eiden et al. 2015)
<i>R. sanguineus</i>		Domestic pet (spot-on treatment)						(Hunter et al. 2011)
<i>R. sanguineus</i>				Organophosphate				Merial Limited, Merial Animal Health Limited, BerTek Inc., ClinVet International Ltd., Merial S.A.S
<i>R. sanguineus</i>		Domestic pet (acaricidal collar)	Pyrethroid		Evaluated tick bite prevention practices	PSU	CDC, Secretariat of Public Health Mexico	(Nelson 1969)
Other: not specified		Rodent (tick tubes)				USN	CDC	(Straily et al. 2016)
Other: Community Assessment					Survey of pest control company tick control services			(Gage et al. 1997)
Other: Community Assessment					Assessment of personal tick control strategies	YSPH	MCMCD	(Jordan and Schulze 2020b)
Other: Community Assessment					Assessment of willingness to use tick bite prevention methods	IU, PSU, UNF	MD-DOH, CDC	(Niesobecki et al. 2019)
Other: Community Assessment								(Omodior et al. 2021)

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Abbreviations: 25(b), minimum risk pesticide product; AI, active ingredient; A&M, Texas A&M University; BC, Bard College; BU, Brandon University; CAES, Connecticut Agricultural Experiment Station; Cary, Cary Institute of Ecosystem Studies; CCCE, Cape Cod Cooperative Extension; CSU, Colorado State University; CU, Cornell University; Dept., Department; DOH, Department of Health; DPH, Department of Public Health; ECU, East Carolina University; Ent., entomopathogenic; FAHD, Freehold Area Health Department; F, Fordham University; Geisel, Geisel School of Medicine at Dartmouth; HMS, Harvard Medical School; HSPH, Harvard School of Public Health; HU, Harvard University; IGR, insect growth regulator; IP, Institut Pasteur; IU, Indiana University; KAP, Knowledge, Attitudes, and Practices; Kent, Kent School; KSU, Kansas State University; MCRI, Marshfield Clinic Research Institute; MCMCD, Monmouth County Mosquito Control Division; MMCRI, Maine Medical Center Research Institute; NYMC, New York Medical College; ODU, Old Dominion University; OSU, Oregon State University; OU, Oklahoma State University; PAHO, Pan American Health Organization; PSU, Pennsylvania State University; RU, Rutgers University; SUNY SB, SUNY Stony Brook; TVA, Tennessee Valley Authority; UC, University of California; UConn, University of Connecticut; UdeM, University of Montreal; UF, University of Florida; UGA, University of Georgia; UKN, University of KwaZulu-Natal; UMaine, University of Maine; UMass, University of Massachusetts; UMN, University of Minnesota; UMSL, University of Missouri-St. Louis; UN, University of Neuchâtel; UNC, University of North Carolina; UNF, University of North Florida; UofO, University of Ottawa; UQAM, University of Quebec; URI, University of Rhode Island; USA MEDDAC, U.S. Army Medical Department Activity; USF, University of South Florida; USFS, United States Forest Service; USGS, United States Geological Survey; USM, University of South Maine; USN, University of Sonora; UT, University of Tennessee; UTX, University of Texas; UW, University of Wisconsin; VMI, Virginia Military Institute; WashU, Washington University in St. Louis; WCSU, Western Connecticut State University; Yale, Yale University; YSM, Yale School of Medicine; YSPH, Yale School of Public Health.