KNOWLEDGE, ATTITUDES, AND PRACTICES REGARDING TICKBORNE DISEASES IN LONG ISLAND, NEW YORK

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ABSTRACT

Most vector-borne disease cases in the USA are transmitted through the bite of ticks. In the Northeast, tickborne infections are a major public health concern and a source of significant morbidity. Human-centric factors that influence tickborne disease risk include the knowledge, attitudes, and practices of individuals and communities. My study focused on Long Island, New York, a northeast region with high endemicity of ticks and tickborne diseases (TBDs). Through a knowledge, attitudes, and practices (KAP) survey, I identified several knowledge gaps related to Lyme disease treatment, age groups most at risk, and chronic Lyme disease. Knowledge of ticks and tick-borne diseases was positively but very weakly associated with increased use of protective behaviors. Overall, residents were concerned about TBDs. Those with more significant concern for ticks were more likely to pay for private and public tick control. Individuals who saw ticks last summer or have someone in the household diagnosed with a TBD were more likely to pay for private tick control. Those who had a tickborne disease in their household were also more likely to practice tick control and seek medical care overall. Residents who were bitten by ticks before were less likely to seek medical care. Pet owners were more concerned about ticks compared to non-pet owners and practiced more precautionary behaviors. This study will inform future public health campaigns in Long Island to reduce the burden of tickborne diseases in the area.

Key words: KAP survey, Lyme disease, Long Island, ticks

BIOGRAPHICAL SKETCH

Mervin Keith was born in a small city in Northern Mindanao, Philippines. He immigrated to the United States and his family when he was twelve years old after his mother was hired to teach middle school in Maryland. Although he initially wanted to study human genetics at the University of Maryland – College Park, that soon changed when he found a job posting related to maintaining lab mosquito colonies at Dr. Megan Fritz's lab in the first week of classes. He soon became interested in medical entomology as he learned more about the *Culex pipiens* colonies he maintained and mosquitoes in general. As an undergraduate lab assistant in the Fritz Lab, he also performed independent research to understand whether host preference in *Cx. pipiens* mosquitoes were due to how different host blood influenced mosquito fecundity. His experience at the Fritz lab inspired him to pursue a career in medical entomology. As he was nearing the end of his undergraduate career, he found out about Cornell University's MS in Entomology: Vector-Borne Disease Biology degree program. He officially joined Dr. Laura Harrington's lab in the fall of 2019. In her lab, he became more of a well-rounded medical entomologist. He trained and took coursework in public health, entomology, vector surveillance, and data science for two years. He wants to develop his skills further to become a future public health leader in medical entomology and use his expertise to fight against vector-borne diseases in the Philippines, which cause significant mortality and morbidity in the country.

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CHAPTER 1: LITERATURE REVIEW

Introduction

Tickborne infections are the most important vector-borne diseases in the United States, with Lyme disease being the most commonly reported vector-borne disease (R. J. Eisen et al., 2017). Annually, there approximately 30,000 cases of Lyme borreliosis reported. However, the CDC estimates that there may be close to 300,000 annual cases due to underreporting (Hinckley et al., 2014; Nelson et al., 2015). Between 2010 to 2018, approximately 476,000 patients were diagnosed and treated for Lyme disease annually (Kugeler et al., 2021). Three ticks predominantly transmit pathogens to humans in the Northeast region: *Ixodes scapularis, Amblyomma americanum,* and *Dermacentor variabilis*. A recently introduced species, *Haemaphysalis longicornis*, also may become an important human and animal vector regionally, as it is in parts of Japan and South Korea (Fujikawa et al., 2021; Kim et al., 2018). In this review of the current literature regarding tickborne diseases in the U.S., the biology, ecology, and human risk factors for these tick species will be discussed.

Additionally, human-related factors that impact individual tick bite risk, such as knowledge, attitudes, and practices, are explored. Healthcare cost and utilization are assessed to determine the economic and public health impact of tickborne diseases, especially Lyme disease. Finally, a One Health perspective of tickborne diseases will be examined and current control/prevention measures used in a public health setting.

Ixodes scapularis

Important Pathogens

Ixodes scapularis, known as the blacklegged tick or the deer tick, is the primary vector of *Borrelia burgdorferi* sensu stricto, the causative agent of Lyme disease in the United States (CDC, 2020b). The blacklegged tick also transmits other pathogens such as *B. burgdorferi* s.l.

complex, *Anaplasma phagocytophilum*, *Babesia microti*, *Borrelia miyamotoi*, *Ehrlichia muris eauclairensis*, *Borrelia mayonii,* and deer tick virus lineage of Powassan encephalitis virus (R. J. Eisen et al., 2017).

Host Associations

The blacklegged tick is a three-host tick, feeding on a wide range of animals such as humans, deer, rodents, lizards, and birds (R. J. Eisen et al., 2017). Immature stages often feed on small mammals and other animals, while adult ticks primarily feed on medium to large-sized mammals. Humans and deer are “dead-end” hosts, as they do not contribute, or minimally contribute, to the transmission cycles of the known pathogens transmitted by *I. scapularis*. For certain TBDs transmitted by *I. scapularis*, such as babesiosis and anaplasmosis, cases of person-to-person transmission usually occur via blood transfusions or through vertical transmission (CDC, 2019a, 2020a). For Lyme disease, important northeast reservoirs include the white-footed mouse (*Peromyscus leucopus*), chipmunks (*Tamias striatus*), short-tailed shrew (*Blarina brevicauda*), and Eastern gray squirrels (*Sciurus carolinensis*) (Brisson et al., 2008; R. J. Eisen et al., 2017).

Questing Behavior

Research on questing (host-seeking) behavior has focused mainly on nymphs. They are thought to be responsible for most human disease cases due to their smaller, less conspicuous size than adult ticks, enabling them to stay attached unnoticed on human hosts more frequently than adults (CDC, 2020b). In a modeling experiment, the questing probability depended on a combination of different temperature and humidity scenarios (McClure & Diuk-Wasser, 2019). In laboratory settings, reduced humidity and higher temperature were correlated with lower questing activity. However, field studies on the abiotic factors influencing questing have been inconclusive (McClure & Diuk-Wasser, 2019). The human risk from biting nymphs varies and can differ in the southern part of the *I. scapularis* range compared to the northern range (Ginsberg et al., 2017). The variability of human risk across the two regions could be related to differences in nymphs' questing behavior, host feeding patterns, infection rates, and genetics and interacting environmental conditions (Kiffner et al., 2011; Rosà et al., 2007; Xu et al., 2020).

Habitat and Range

Blacklegged ticks in the Northeast live in areas of dense brush, deciduous forest habitats, and transition zones between northern coniferous and southern deciduous forests (CDC, 2020b; Ostfeld et al., 1995). In Long Island, *I. scapularis* is abundantly distributed, especially in woodlands, forest edges, leaf litter, residential shrubbery, and hiking trails (SCDHS, 2015).

Life Cycle

I. scapularis have a two-year life cycle, which can vary depending on climatic conditions and host availability (Mullen & Durden, 2019). Mating and adult feeding occur in the fall before ticks enter quiescence for the winter. The following spring, adult females become active and lay their eggs. The larvae hatch and obtain a blood meal in the summer before overwintering. In late spring and early summer, the nymphs become active and seek another host. Finally, in the summer of the second year, the nymphs molt into adults and begin the cycle again (R. J. Eisen et al., 2016).

Human Risk Factors

Significant risk factors for human tick bites include white-tailed deer abundance, high levels of forest fragmentation, a more significant area of herbaceous edge, and pet or domestic animal ownership (Allan et al., 2003; Alverson et al., 1988; Daniels et al., 1993; Jones et al., 2018; Kugeler et al., 2016).

Amblyomma americanum

Important Pathogens

Amblyomma americanum, commonly known as the lone star tick, is the primary vector of *Francisella tularensis*, *Ehrlichia chaffeensis*, *Ehrlichia ewingii,* and Heartland virus, as well as a suspected vector for Bourbon virus (R. J. Eisen et al., 2017; Savage et al., 2017).

Host Associations

The lone star tick is a generalist, feeding on a wide range of hosts such as foxes, wild turkeys, raccoons, and deer (Kollars Jr et al., 2000). Humans are accidental hosts across all life stages, not contributing to the listed pathogens' transmission cycle. The white-tailed deer is the main disease reservoir for pathogens transmitted by this tick (R. J. Eisen et al., 2017). The lone star tick is an aggressive biter, actively questing for hosts (Childs & Paddock, 2003). Adult ticks mainly feed on medium to large mammals, while nymphs and larvae feed on ground-dwelling birds, medium-large mammals, and sometimes small mammals. Though they have a broad host range, lone star ticks depend on large mammalian hosts such as the white-tailed deer for all life stages.

Questing Behavior

Questing behavior is affected by changes in temperature and humidity (Robertson et al., 1975). As temperature increases and humidity decreases, tick activity decreases. Photoperiod impacts the pattern of feeding and dropping off a host, which helps synchronize ticks with the behavioral patterns of their host and ensure that replete ticks drop off in habitats suitable for development and reproduction (Mullen & Durden, 2019). Unlike blacklegged ticks, lone star ticks can tolerate hotter and drier conditions (Rynkiewicz & Clay, 2014).

Habitat and Range

The lone star tick range encompasses the southeastern and northeastern United States in woodland habitats and young second-growth forests with dense underbrush (CDC, 2020b; Childs & Paddock, 2003; SCDHS, 2015).

Life Cycle

Like *I. scapularis*, the lone star tick has a two-year life cycle, varying depending on climatic conditions. Adults quest during late spring to early summer; peak abundance in northern states occurs between March and July (R. J. Eisen et al., 2017). After a blood meal, females fall off the host and lay eggs in leaf litter or mulch (NCIPMI, 1998). The nymphal stage typically overlaps with the adult stage. In the Northeast, the nymphal peak occurs in late spring, sometime in June (R. J. Eisen et al., 2017). Larval abundance peaks in early fall. Unfed larvae, nymphs, and adults overwinter until spring (Childs & Paddock, 2003; R. J. Eisen et al., 2017). In spring, the larvae will quest and then molt into nymphs to begin the cycle again. The activity and peak of both nymphs and adults in Long Island overlap each other, peaking between May to June. The larval peak for Long Island occurs in mid-August (SCDHS, 2015).

Human Risk Factors

Risk factors for lone star tick bites include entering and spending time in forested habitat, especially during active tick season, increased density of brush (in particular Amur honeysuckle, *Lonicera maackii*), increased white-tailed deer population, and localities with hot and dry microclimates (Allan et al., 2010; Rynkiewicz & Clay, 2014).

Dermacentor variabilis

Important Pathogens

Dermacentor variabilis, commonly known as the American dog tick, is a North American vector of several pathogens, including *Francisella tularensis*, *Rickettsia rickettsii*, and Colorado tick fever virus (Dergousoff et al., 2013).

Host Associations

Like *I. scapularis* and *A. americanum*, the American dog tick is a three-host tick. Larvae attach and feed on smaller mammals such as mice. Nymphal and adult stages feed on larger mammals, including raccoons, dogs, and rabbits (Paterini, 2013). Adults may feed on humans, though humans are accidental hosts and do not contribute to the transmission cycle of diseases transmitted by the American dog tick, especially tularemia (*F. tularensis*) and Rocky Mountain spotted fever. Important reservoirs for *F. tularensis* are rabbits (*Sylvilagus spp.*), hares (*Lepus spp.*), and rodents (Bennett et al., 2014; Parola & Raoult, 2001). Mammalian reservoirs of *R. rickettsii* include rodents such as mice, voles, squirrels, and chipmunks (Warner & Marsh, 2002). Tick populations maintain the pathogen transmission cycle transovarially and transstadially (Raoult & Roux, 1997).

Questing Behavior

Adult and immature American dog tick behavior is dependent on various factors during their questing period, such as humidity, seasonality, and temperature (Harlan & Foster, 1986; James et al., 2015; Monello & Gompper, 2007). American dog ticks exhibit variable host-seeking behavior based on temperature. Larval activity is low at temperatures below 10°C and gradually increases with temperature, peaking at approximately 15°C (Harlan & Foster, 1986). Adult tick activity ceases in temperatures below 12°C and above 32°C. However, some investigators have reported adult activity ranging between 5-40°C (Micher & Rockett, 1993). Adult ticks seek areas with 84-85% relative humidity when the ambient air is dry (Hair et al., 1975). However, adults are less sensitive to changes in humidity than other ticks, such as *H. longicornis* or *I. pacificus* (Heath, 2016; MacDonald, 2018).

Habitat and Range

The American dog tick range in the United States includes all states east of the Rocky Mountains and limited areas of the Pacific Coast states, including California and Oregon (CDC, 2020c). In Long Island, the American dog tick is established and abundantly distributed in Nassau and Suffolk counties (Tokarz et al., 2018). The ticks live in forest edges, fields, and grasslands adjacent to beaches or salt marshes (Benach et al., 1977). While immature stages of the American dog tick favor areas with higher humidity levels, adults prefer more open areas that are grassy, brush-covered, and near a forest to field transition zone (Bishopp & Trembley, 1945; Burg, 2001; MacDonald, 2018).

Life Cycle

Depending on the geography and host availability, *D. variabilis* completes its life cycle within a few months or up to two or more years, depending on whether adults can feed and reproduce in the same year (Mullen & Durden, 2019). The complex life cycle of the ticks largely depends on the local climate, especially on favorable temperatures. In the Northeast, females that successfully obtain a blood meal during the summer will lay eggs and produce larvae that overwinter until early spring (McEnroe, 1979). Adults unsuccessful in obtaining a blood meal during the summer will diapause in the fall and then obtain their blood meal sometime in the spring. Increasing spring temperatures encourage larval activity, which peaks around May. During spring, the larval ticks will obtain their first blood meal and molt into nymphs during the summer. Around the same time, larvae from the adults that did not obtain a blood meal from the previous summer will start to become active. Blood-fed summer nymphs will molt into adults during fall and enter diapause until late April of the following year. Blood-fed summer larvae will molt into nymphs during the fall and enter diapause until sometime during the early spring of the following year. The spring nymphal ticks will molt into a summer adult tick upon obtaining a blood meal (McEnroe, 1979).

Human Risk Factors

Risk factors include spending time in forest edges, fields, or grasslands adjacent to beaches or salt marshes where these ticks are found during active tick season.

Haemaphysalis longicornis

Important Pathogens

Haemaphysalis longicornis, commonly known as the Asian longhorned tick, is a tick that was recently introduced to the United States in 2017 (Beard et al., 2018). It is a vector of various livestock pathogens such as *Theileria luwenshuni*, *Theileria orientalis, Babesia ovata*, *Anaplasma bovis*, and *Borrelia burgdorferi sensu lato* (Dinkel et al., 2021; Doan et al., 2013; J.-G. Kang et al., 2016; Li et al., 2007; Oakes et al., 2019; Sivakumar et al., 2014). This species is capable of transmitting human pathogens, including *Rickettsia japonica*, Powassan virus, Severe Fever with Thrombocytopenia Syndrome virus, and Huaiyangshan virus in other parts of the world (Dobler, 2010; Kenji et al., 2011; Kim et al., 2018; Lu et al., 2013; Luo et al., 2015). *H. longicornis* is not considered a vector of Lyme disease (Breuner et al., 2020). Recent laboratory studies have demonstrated their competence to transmit Rocky Mountain spotted fever bacteria (*R. rickettsii*) (Stanley et al., 2020).

Host Associations

In 2019, researchers found a virulent strain of *Theileria orientalis* (Ikeda genotype) in cattle in Virginia (Dinkel et al., 2021; Oakes et al., 2019). Asian longhorned ticks have a broad host range, including cattle, sheep, hare, and rabbits (Heath et al., 1987). Public health monitoring of *H. longicornis* is vital due to its status as a vector of Severe Fever with Thrombocytopenia Syndrome virus (SFTSv). This potentially fatal human pathogen was recently recognized in China and has been detected in South Korea and Japan (Fujikawa et al., 2021; Kim et al., 2018; Luo et al., 2015). The USDA Situation Report of *H. longicornis*, which is updated monthly, highlights where the ticks have been found and from which hosts (USDA, 2021). While the disease ecology is still unclear, it appears that the *H. longicornis* can serve as both the vector and the reservoir of SFTSv (Luo et al., 2015). Domestic animals such as goats and feral cats may also serve as reservoirs (Aguilar & Silvas, 2017). While Asian longhorned ticks in Asia do bite humans, there have been very few cases of human bites occurring in the United States (Bickerton & Toledo, 2020; Breuner et al., 2020). However, laboratory studies demonstrated that US field-derived *H. longicornis* ticks have a propensity for avoiding humans and white-footed mice (Ronai et al., 2020; Sherpa, 2020). In Staten Island, the ticks are often associated with medium and large mammals such as raccoons, opossums, and white-tailed deer (Tufts et al., 2021).

Questing Activity

The questing activity of Asian longhorned ticks depends on various factors, including the tick size, previous tick infestations of the host, and whether males and females are present on the same host (Kang, 1981). In New Zealand, the tick readily feeds on what is available potentially at any time of day (Heath, 2010; Myers, 1924; Yoshida, 1979). Questing behavior is affected by temperature and humidity. Activity decreases at temperatures between 11-15°C, and ticks typically begin to overwinter at 13°C (Shiraishi et al., 1989). The ticks have a preferred temperature range around 20-30°C; temperatures 40°C and above are considered lethal (Heath, 2016). Asian longhorned ticks are highly sensitive to humidity levels. Different life stages have different optimal humidity thresholds, which may depend on the tick's feeding status. Unfed questing ticks may actively seek places with higher humidity levels. In contrast, the survival of engorged ticks largely depends on where they drop off and the host location's humidity levels (Heath, 2016).

Habitat and Range

The tick has been found in moist leaf litter, manicured grass, shaded lawns, and tall grass areas (Tufts et al., 2019). In the United States, the current range of the Asian longhorned tick encompasses eastern states, including Virginia, West Virginia, Pennsylvania, North Carolina, South Carolina, Tennessee, New York, New Jersey, Maryland, Delaware, Kentucky, Arkansas, Ohio, Rhode Island, and Connecticut (USDA, 2021). Recent models estimate that the ticks can invade and establish populations in a broader swath of southeastern and northwestern states in the United States (Raghavan et al., 2019).

Life Cycle

The seasonality of the Asian longhorned tick is not well described in the United States. In New Zealand, where the tick is well established, a single generation usually takes around 12 months to complete (Heath et al., 1987). Overwintering periods for eggs and unfed ticks of all life stages in New Zealand last from May to June (Heath, 2016). From June to October, overwintered nymphs resume activity and obtain blood meals, with nymphal activity peaking in August. From October to January, nymphs molt from nymphs to adults, and adults begin obtaining the third blood meal with adult activity peaking in early December. In the same period, adults lay their eggs as well. In between January to March, larvae hatch from eggs, with peak larval activity occurring in February. From late March to early May, a second nymphal peak occurs from late active larval feeding (Heath, 2016).

Human Risk Factors

Risk factors for *H. longicornis* bites include proximity to tick-infested animals and tick habitat, including moist leaf litter or vegetation, manicured grass, shaded lawns, and tall grass.

Table I. Important Northeast tick vectors, habitats, and risk factors.

Species Name	Characteristics	Human Risk Factors	Human Diseases	Important Disease Reservoirs in North America	Distribution
Ixodes scapularis (Blacklegged tick or deer tick)	Present in woodlands, forest edges, leaf litter, residential shrubbery, and hiking trails; two-year life cycle	Increased deer abundance, high forest fragmentation, a significant area of herbaceous edge, pet ownership	Lyme disease, Powassan virus, anaplasmosis, babesiosis, ehrlichiosis	White-footed mouse, chipmunks, short-tailed shrew, Eastern gray squirrels	States across the eastern part of the United States.
Amblyomma americanum (Lone star tick)	Generalist; aggressive biter; questing behavior affected by changes in temperature and humidity	Forested habitats, high density of brush, increased deer abundance, hot and dry microclimates	Tularemia, Heartland virus, ehrlichiosis (suspected Bourbon virus)	White-tailed deer	Southeastern and eastern states
Dermacentor variabilis (American dog tick or wood tick)	Mainly bite dogs; disease transmission cycle, other than tularemia, maintained within populations either transstadially or transovarially; questing behavior affected by humidity, seasonality, and temperature	Being near forest edges, fields, and grasslands adjacent to beaches or salt marshes; High humidity levels; pet ownership	Tularemia, Colorado tick fever virus, rickettsiosis, anaplasmosis	Rodents such as mice, voles, squirrels, and chipmunks	States across the eastern part of the United States as well as some areas on the Pacific coast
Haemaphysalis longicornis (Asian longhorned tick)	Mainly feeds on medium and large mammals and has an aversion to white-footed mice; Questing activity depends on the size of the tick, previous tick infestations of a host, and whether males and females are present in the same host; exhibits parthenogenesis	Proximity to tick-infested animals; Moist leaf litter or vegetation, manicured grass, shaded lawns, and tall grass	Rickettsiosis, Powassan virus, Huaiyangshan virus, SFTS virus	Domestic animals such as goats, cattle, pigs, sheep, dogs, chicken, and potentially feral cats (disease transmission for SFTS virus is also maintained within tick populations)	Northeastern, eastern, and potentially northwestern states of the United States

Knowledge, Attitudes, and Practices (KAP) Regarding Tickborne Diseases

Human knowledge, beliefs, and practices can play a role in how tickborne diseases, especially Lyme disease, impact individuals and communities in the Northeast as they can modulate behaviors that make individuals more susceptible to tick bites (Armstrong et al., 2001; Malouin et al., 2003; Smith et al., 2001). Therefore, understanding where knowledge and behavioral gaps exist and addressing them is essential in reducing tickborne disease cases in Northeastern communities. Knowledge, attitudes, and practices (KAP) surveys are one tool public health organizations use to understand barriers to behavior change for a particular public health problem in a community. They can also be used to determine important knowledge gaps, such as awareness about new ticks or pathogens in the U.S. Eleven studies have been conducted to assess the tickborne disease knowledge, attitudes, and practices of community members and healthcare providers in Northeastern states (including Connecticut, Delaware, Maine, Vermont, Rhode Island, Maryland, Massachusetts, New Hampshire, Virginia, and New Jersey) (Butler et al., 2016; Conant et al., 2018; Gould et al., 2008; Gupta et al., 2018; Hallman et al., 1995; Heller et al., 2010; Herrington et al., 1997; Hu et al., 2019; Magri et al., 2002; Malouin et al., 2003; Niesobecki et al., 2019). However, some reports are more than 20 years old, have limited sample sizes, and may not reflect the current state of knowledge, attitudes, and practices regarding tickborne diseases of all communities. Additionally, states where tickborne disease incidence is high, such as Pennsylvania and New York, have not assessed their residents' knowledge, attitudes, and practices regarding tickborne diseases.

The majority of the KAP surveys conducted in areas where ticks and tickborne diseases are endemic assessed knowledge related to Lyme disease, how to identify symptoms of Lyme disease, and whether ticks were a threat in their respective geographic area of interest (Gould et al., 2008; Gupta et al., 2018; Hu et al., 2019; Niesobecki et al., 2019). In tick-endemic areas within Connecticut and Maryland, Niesobecki and others (2019) found that most individuals knew what Lyme disease was but were unfamiliar with other tickborne diseases such as babesiosis, anaplasmosis, and Rocky Mountain spotted fever. They also found that knowledge regarding tickborne diseases was positively associated with education level. Gupta and others (2018) found that Delaware residents did not think tickborne diseases were a threat, consistent with results from Gould and others (2008) on the efficacy of tick awareness campaigns in increasing knowledge and perceived seriousness of Lyme disease in Connecticut. Hu and others (2019) found that English as a primary language was significant in predicting whether individuals can identify vectors and Lyme disease symptoms, suggesting a public health need to provide tickborne disease education to non-native English populations.

Beliefs, such as perceived susceptibility, regarding tickborne diseases can also influence behavior. Heller and others (2010) found that outdoor workers in Massachusetts were more likely to practice tick preventative behaviors as they believed they were at greater risk of tick bites. Additionally, behavior can vary across locations and demographic groups. A follow-up of the Heller et al. (2010) study conducted by Butler and others (2016) found that among Connecticut residents, tick checks were the most common preventative measure and insect repellent use was the least common. In St. Louis, Missouri, the most common preventative behaviors were walking the center of trails, performing tick checks, and using an insect repellent (Bayles et al., 2013). However, the least common were tucking pants into socks and wearing long pants or long-sleeved shirts. Hu and others (2019) note that the most common preventative behavior of Hispanics living in Virginia and Maryland was showering after being outdoors. Tick checks or wearing repellents were the least common among this population. These studies attempt to assess standard tick preventative practices, but they also highlight how different demographics and communities differ in tick preventative behaviors. Therefore, understanding the knowledge, attitudes, and practices of more communities in the Northeast is vital in decreasing Lyme disease cases regionally.

Economic Impact of Tickborne Diseases

The impact of tickborne diseases on human health in the United States is better understood than the impact on healthcare spending. However, the economic impact of tickborne diseases related to healthcare utilization, productivity loss, and testing in the Northeast has not received much attention. Understanding the economic impact of tickborne diseases can help address policy questions related to how the diseases can contribute to loss in household wages due to loss of productivity, management of disease, and comorbidities. Most studies on the economic impact on ticks relate to livestock production, focusing on profit losses due to tick infestation and tick diseases such as cattle fever (Grisi et al., 2014; Ocaido et al., 2009; Pérez de León et al., 2012; Rodrigues & Leite, 2013). Nonetheless, a small number of studies have estimated the healthcare cost of tickborne diseases, primarily Lyme disease, in the United States.

Overall National Cost of Lyme Disease

In 1998, researchers tried to estimate the economic impact of Lyme disease cases by calculating the direct costs (outpatient visits, hospitalizations, emergency room visits, home health care, and prescription medication) and indirect costs (productivity losses resulting from the illness and long-term complications of the disease) based on age group and disease severity (Maes et al., 1998). Maes and others (1998) based their direct cost data estimates from Diversified Pharmaceutical Services and two publications focusing on treatment cost-effectiveness for Lyme disease prevention and sequelae (Lightfoot, 1993; Maes et al., 1998;

Magid et al., 1992). They obtained indirect costs using estimates from the 1993 and 1994 National Health Interview Survey. These authors also estimated the probabilities of certain direct cost items, such as performing testing procedures and developing more severe symptoms either through consultation by a panel of Lyme disease experts or as an assumption. Adjusting for 2019 US dollars, the estimated cost to prevent Lyme disease sequelae reported in Maes et al. (1998) would have totaled $821 million annually for five years, assuming an annual Lyme incidence rate of 4.73 cases per 100,000 population. It is worth noting that the annual Lyme incidence rate for 2018, the latest year reported, was 7.2 cases per 100,000 population, which could mean that the estimated cost to prevent Lyme disease sequelae is higher currently, although this assumes that treatment costs have not changed much (CDC, 2020d).

Zhang et al. (2006) analyzed Lyme disease's total cost in five Maryland Eastern Shore counties using charge data provided by a healthcare organization (Delmarva Health Plan) (Zhang et al., 2006). Office-based healthcare providers in Kent County provided direct costs (physician visits, serology, procedure, therapy, and other related costs). They used a patient survey to estimate indirect costs from productivity loss (Zhang et al., 2006). In 2019 dollars, they expected that the average cost attributable to Lyme disease was $2,960.16 (median cost = $423.81) per patient. For clinically defined early-stage patients, the average cost attributable to Lyme disease was $1,973.44 (median cost = $598.06). For clinically defined late-stage patients, the mean cost was $24,402.83 (median cost = $1,390.44). However, they found that the average cost of a Lyme disease patient in their study, regardless of the stage of the disease, was $12,310.64 ($4474.13 in direct costs plus $7836.51 in indirect medical costs, nonmedical costs, and productivity losses) (Zhang et al., 2006).

From 2013-2018, the CDC reported 131,836 confirmed Lyme disease cases with an average incidence of 8.3 cases per 100,000 population (CDC, 2020d). Using Zhang and others' estimates of each Lyme disease case's total cost, Lyme disease's national economic burden accounting for direct and indirect medical costs between 2013-2018 can be estimated to be approximately $1.62 billion or $325 million annually on average. Even though the incidence rate is almost twice as high in Zhang et al. (2006) compared to Maes et al. (1998), the average annual cost is significantly lower than the initial estimates. Lyme disease's actual economic burden may be higher than these estimates due to underreporting (Kuehn, 2013; Nelson et al., 2015; White et al., 2018). However, one caveat of these estimates is that extrapolating Lyme disease's total national cost based on a study of healthcare costs in one state may lead to an inaccurate picture of the actual economic burden of Lyme disease across broader geographies. Other states may charge for the same billable procedure differently, and different states have different healthcare spending rates (Fisher et al., 2009; Newhouse & Garber, 2013). Regardless, estimating the economic impact of Lyme disease is essential in assessing how preventative measures can benefit individuals living in the U.S. economically.

Adrion et al. (2015) studied the impact of Post-Treatment Lyme disease Syndrome (PTLDS) on Lyme disease cost. PTLDS is the persistence of Lyme disease symptoms after treatment that lasts for more than six months (Adrion et al., 2015). These authors analyzed the total costs attributed to inpatient, pharmacy, and outpatient costs by looking at medical claims data from IMS (Intercontinental Medical Statistics) Health LifeLink Health Plan Claims Database. Adjusted for 2019 using the average inflation between 2015 and 2019 (1.54%), they found that the presence of one or more PTLDS-related symptoms costs a patient $3,155.10 (adjusted using negative binomial regression analysis) more on average per treatment period (defined as accrued costs over twelve months following diagnosis) compared to a patient that has Lyme disease without any PTLDS symptoms. For patients with Lyme disease, irrespective of whether they have PTLDS or not, the mean total cost was estimated to be $8,722.22 (2019 dollars).

A recent study by Schwartz et al. (2020) determined the direct costs of Lyme disease-related hospitalizations among patients with employer-sponsored health insurance. The study was conducted to understand Lyme disease case costs for those that manifest with carditis, meningitis, arthritis, and facial palsy. The costs included all payments made by patients and insurance companies for services during an inpatient stay. The average cost of all Lyme disease-related hospitalizations was $16,561.03 per patient, with a median cost of $12,377.88 (Schwartz et al., 2020). Median costs of Lyme disease cases with carditis, meningitis, arthritis, and facial palsy ranged between $11,110.23 to $18,491.63 (Schwartz et al., 2020). Although the median cost estimated by Schwartz et al. (2020) was close to the estimated average cost of Lyme disease cases in the United States by Zhang et al. (2006), it did not account for indirect costs related to productivity loss or travel to the hospital. Therefore, the total attributable cost of Lyme disease-related cases may be higher than the estimates provided by Schwartz and others (2020).

Cost of Testing

The cost of diagnostic testing contributes significantly to the overall healthcare cost of Lyme disease, which is a cost paid by insurance companies, Medicare/Medicaid, the patient, or medical centers (Hinckley et al., 2014). Understanding the cost of testing is important in assessing how alternative or new Lyme disease tests/procedures can reduce the overall national cost of testing, which also benefits both individuals and organizations alike economically. In 2008, 3.4 million Lyme disease tests were conducted across seven commercial laboratories in the

United States at the cost of $596 million (2019 dollars, 1.75% average inflation rate) (Hinckley et al., 2014). The researchers estimated costs using median costs gathered by Wormser et al. (2013) for whole-cell ELISA/EIA ($153.84), C6 ELISA/EIA ($218.04), IgM, and IgG Western blot tests ($319.80 combined) (Hinckley et al., 2014; Wormser et al., 2013). Western blot tests were most frequently performed for one-tiered serological approaches, followed by whole-cell ELISA/EIA. For two-tiered serological approaches, the most common approach was whole-cell ELISA/EIA with a Western blot, followed by a C9 Peptide ELISA with a Western blot.

In 2008, tickborne diseases other than Lyme disease contributed to $11.7 million (2019 dollars, 1.75% average inflation rate) in testing costs, with panels detecting *Anaplasma* (HGA) and *Ehrlichia (*HGE*)* costing a total of $129,190.54 (Connally et al., 2016). These costs did not consider Powassan virus testing, as no data on costs was available for this pathogen at the time of the study. The researchers estimated costs using the national limit for reimbursement of the 2008 clinical diagnostic laboratory fee schedule from the Centers for Medicare and Medicaid Services for *Babesia, Anaplasma* or *Ehrlichia* microscopy detection, *Babesia* indirect fluorescent antibody, *Babesia* or *Anaplasma* PCR, *Anaplasma* or *Ehrlichia* indirect fluorescent antibody HGA/HME concurrent panel and RMSF indirect fluorescent antibody (Connally et al., 2016).

Healthcare Access and Utilization

Tickborne diseases, especially Lyme disease, are the most reported arthropod-borne diseases in the United States. Therefore, understanding barriers to healthcare access and utilization is vital to reducing the burden of tick-related illnesses since access to healthcare can reduce disease severity and prevent death. Several papers have highlighted barriers to appropriate healthcare for Lyme disease, including difficulty obtaining treatment, long commutes, and health insurance status (Brett et al., 2014; Cameron, 2007; Hirsch et al., 2018;

Johnson et al., 2011, 2014). Johnson and others (2011) conducted a survey among Lyme disease patients with symptoms lasting six months or more and reported that 76% of patients had to see four doctors or more to get a Lyme diagnosis from the onset of symptoms. They also reported that 60% of patients also had to travel more than 50 miles to treat Lyme disease.

Patients that experience delays in early treatment may develop more severe symptoms as the disease progresses (Johnson et al., 2011). In a quality-of-life survey conducted by Johnson et al. (2014), they found that patients clinically diagnosed with Lyme disease that had persistent symptoms lasting six months or more had a significantly lower quality of life than patients with other chronic diseases. These patients reported worse mental and physical health more often and had more considerable activity limitations. However, these studies have a limitation in that the studies looking into patient experiences did not use a robust inclusion criterion: a confirmed history of Lyme disease was based on self-reported diagnoses. A qualitative study by Hirsch and others (2018) interviewed a small sample of patients (n= 26) regarding their experience obtaining Lyme disease treatment. The researchers attributed the delay in Lyme diagnosis to misperceptions regarding the bull's eye lesion (erythema migrans) and misattributing symptoms by caregivers. Health insurance status also influenced when patients decided to seek help and act on their symptoms. Ten of the 26 patients interviewed went to urgent care, which may have caused treatment delay since misdiagnosis was common in that setting (Hirsch et al., 2018). Even though the experiences of this small number of patients studied are certainly not representative of the country, this study does provide qualitative information about why treatment delays occur that may not be detectable by looking at numbers alone.

Brett and others (2014) analyzed a survey completed by health practitioners regarding their experience treating Lyme disease and found that most healthcare providers (89%)

empirically prescribed oral antibiotics to patients with a bulls-eye lesion (Brett et al., 2014). However, prescribing antibiotics as Lyme disease prophylaxis in the low-incidence states was high (26%), suggesting a need for education regarding the appropriate use and limitations of prophylaxis for Lyme disease (Brett et al., 2014). Administering tick bite prophylaxis is recommended only in highly endemic regions with consideration of other circumstances such as whether prophylaxis can be started within 72 hours of tick removal, whether doxycycline is contraindicated, and if the attached tick can be identified as an adult or nymphal *I. scapularis* tick (CDC, 2019e). The study defined low-incidence states as those other than Delaware, Connecticut, New Hampshire, Massachusetts, Maine, New Jersey, Vermont, Pennsylvania, Wisconsin, Maryland, New York, Minnesota, Rhode Island, Virginia, and the District of Columbia. However, the article did not discuss the motivations of doctors prescribing prophylaxis, as doctors may have prescribed it appropriately if a patient traveled from a high-incidence state to a low-incidence state. In the same survey, responses by healthcare providers regarding the treatment of Rocky Mountain spotted fever showed that only 35% of the respondents correctly identified doxycycline as the most appropriate treatment for children age eight or younger and may be one factor that contributes to the higher pediatric fatality rates for this disease (Zientek et al., 2014).

Another issue related to healthcare utilization and cost is chronic Lyme disease. Chronic Lyme disease is a term used somewhat confusingly by medical professionals and individuals to describe illness in people, which can occur long after initial infection with Lyme disease and post-antibiotic treatment (Feder et al., 2007). It lacks a proper clinical definition and is not supported by any laboratory studies or controlled treatment trials. Four broad categories of illness have been attributed to chronic Lyme disease: 1) cases where there is no clinical evidence of the *Borrelia* bacteria and diagnosis that is based on nonspecific symptoms, 2) an identifiable illness or syndromes other than Lyme disease that is misdiagnosed as Lyme disease, 3) no clinical findings consistent with Lyme disease but samples contain antibodies against the *Borrelia* bacteria, and 4) symptoms associated with post-treatment Lyme disease syndrome (described in the next paragraph) (Feder et al., 2007). Patients in these categories incur higher costs and increased healthcare utilization due to improperly prescribed treatment regimens. In each of these cases, prolonged antibiotic treatment is often prescribed, despite the lack of evidence demonstrating active *B. burgdorferi* infection and no benefit to prolonging the usual antibiotic treatment course of 21 days or less (Krupp et al., 2003; NIAID, 2018). In 2020, the Infectious Diseases Society of America (IDSA), American Academy of Neurology (AAN), and American College of Rheumatology (ACR) jointly published a guideline that recommends a standard antibiotic course duration between 7-14 days depending on the antibiotic used, and 28 days of oral antibiotic therapy for patients with Lyme arthritis (Lantos et al., 2020).

The medical community does recognize post-treatment Lyme disease syndrome (PTLDS). This syndrome is associated with patients experiencing persistent symptoms such as pain, fatigue, or difficulty thinking for more than six months after laboratory-confirmed Lyme bacterial infection and antibiotic treatment (CDC, 2019d). PTLDS cases include a range of symptoms that some patients may feel after the infection itself is gone (CDC, 2019d). There is no current explanation for why PTLDS occurs. However, some researchers suggest that it may be caused by tissue damage or acute infection with *B. burgdorferi* that triggers an auto-immune response (CDC, 2019d). Patients experiencing PTLDS may request, or healthcare practitioners may recommend an extended antibiotic treatment regimen. This not only contributes to the overuse of antibiotics but may also contribute to higher healthcare utilization. Prolonged antibiotic treatment (that is, using antibiotics longer than 30 days) for Lyme disease can increase morbidity and mortality (Berende et al., 2016; Goodlet & Fairman, 2018; Patel et al., 2000). Thus, not only does prolonged use of antibiotics increase healthcare utilization, but it may also inadvertently cause increased harm to patients and increased healthcare costs due to adverse patient outcomes.

One Health and Tickborne Diseases

Tickborne disease cases have increased steadily in the United States (Rosenberg et al., 2018). The spread of tickborne diseases has no singular cause but involves several parameters: humidity, temperature, host abundance, and seasonality (Randolph, 2009). While rising temperatures may not directly influence tick abundance, they can impact the yearly patterns of when people are at the most risk for tick bites by enabling warmer winters and hotter summers (Gray et al., 2009). The pattern of warmer winters and hotter summers in the more northern regions of the United States may also increase the geographic range of various tick species. However, the successful establishment of any tick population will also depend on other factors such as vegetation and the presence of suitable hosts (Sonenshine, 2018). Climate change may also indirectly impact tick risk by changing the area's vegetation to be more suited for ticks. For example, a warming climate could lead to the replacement of deciduous trees with coniferous trees, whereby the fallen leaves of coniferous trees provide a habitat with a microclimate suitable for the immature ticks (Gray et al., 2009).

On a less global scale, human development can result in habitat fragmentation, which is vital in tickborne disease risk (Allan et al., 2003; Estrada-Peña et al., 2010). Human activity in an area may impact wildlife, especially host and reservoir populations, which impacts tick risk. Human activity may also impact host abundance and biodiversity, and as a result, impact tickborne disease risk. Some researchers showed that an increase in the population of less competent disease reservoirs in a tick habitat could divert infectious tick bites from more competent reservoirs, a phenomenon called the host dilution effect (Linske et al., 2018; Schmidt & Ostfeld, 2001). However, an argument against the host dilution effect theory is that increasing host diversity may lead to more risk if host abundance increases with host diversity (Levi et al., 2016). Linske and others (2018) demonstrated that the overall abundance of alternative hosts, rather than species richness itself, contributes to pathogen dilution (Linske et al., 2018). The dilution effect seems to be more critical for generalist ticks, and that the extent of the effect depends on the particular host species removed in a tick habitat (Krasnov et al., 2007; Levi et al., 2016).

Lastly, the interaction between humans and the animal population also plays a role in spreading disease. For example, increases in important Lyme disease reservoir populations (such as white-footed mice) contribute to the increased risk of Lyme disease infections in ticks due to the greater availability of this disease reservoir. Increases in white-tailed deer populations (which are reproductive hosts to blacklegged and other medically important ticks) can expand the distribution of ticks as deer move to areas that may not be tick endemic previously. Increases in the deer population also increase the risk of ehrlichiosis infections since they are the main reservoir for *E. chaffinesis* and *E. ewingii* (Yabsley et al., 2002). Increasing the deer population may also contribute to lone star tick success due to their primary host's increased availability.

Although understanding the role of the wild animal population in the spread of tickborne diseases is important, understanding the role domestic animals play in disease epidemiology is also essential. Outdoor pets can serve as a proxy for estimating the tickborne disease risk of their owners. For example, one farm dog in Mississippi presented severe symptoms that suggested an

Ehrlichia infection (Elchos & Goddard, 2003). Despite treatment, the dog succumbed to its sickness. However, the veterinarian never submitted the blood sample from the dog for testing. Eight days later, a second dog from the same owner died that exhibited similar symptoms. A few weeks later, the owner reported severe headaches, fever, severe back pain, and decreased appetite. Doctors diagnosed the patient with lower back sprains and acute cystitis-urinary tract infection. However, the patient's condition worsened, and the patient later died. After performing a biopsy, doctors determined Rocky Mountain spotted fever (RMSF) as the cause of death. Upon further investigation, health department personnel found that the dogs on the farm had antibody titers of the disease agent (*R. rickettsii)* (Elchos & Goddard, 2003).

Between 2003 and 2017, there was an outbreak of Rocky Mountain spotted fever in tribal lands of Arizona. In this area, cases were primarily attributed to the bite of *Rhipicephalus sanguineus* (brown dog tick), which is a vector of RMSF (Drexler et al., 2014). Dogs, the primary host of this tick species, were implicated as an amplifying host of *R. rickettsii* in the area since they demonstrated high bacteremia. To reduce disease cases, an integrated tick management program called RMSF Rodeo demonstrated the importance of tick control on domestic dogs in reducing tick infestations in communities and, therefore, human cases of RMSF (Drexler et al., 2014). These two scenarios demonstrate the interconnectedness between veterinary health and human health. Doctors and veterinarians alike must recognize potential connections between disease symptoms in animals to human disease risk and inform pet owners of these potential health risks.

Combating the threat of tickborne diseases requires understanding the connection between nature, human health, and animal health. Without addressing all the factors that influence tickborne disease risk, the threat will continue to grow. Therefore, public health officials, health care providers, veterinarians, tick control organizations, epidemiologists, and others must work together to reduce the number of tickborne diseases across the United States.

Prevention and Control Measures

The ever-increasing prevalence of tickborne diseases in the Northeast requires multiple preventative and control strategies that address each factor in the epidemiological triad involving the host, vector, disease agent, and the environment. Preventative and control strategies can be viewed at the individual and community levels. The identification of a community's knowledge, attitudes, and current practices regarding tick bites is the first step in reducing tickborne diseases in a community, which helps with identifying attitudes (such as not being concerned about ticks) or behaviors (such as not using insect repellents in a tick habitat) that can put people at risk, which can be addressed through public health campaigns. On an individual level, personal protective behaviors such as performing tick checks, wearing tick repellents, walking on the center of trails, avoiding brush, tucking pants into socks, and showering right after being in a tick-infested habitat are simple ways of minimizing tick bites and some of these behaviors are protective against Lyme disease (Connally et al., 2009; Vázquez et al., 2008). Awareness of seasonal patterns of changes in tick populations and knowing how to identify tick habitat are equally important, as ticks are present more prominently in some months compared to other months (R. J. Eisen et al., 2016). In habitats where ticks are endemic, individuals are generally aware that ticks pose a problem in their community and are generally aware of certain tickborne diseases such as Lyme disease (Gould et al., 2008; Gupta et al., 2018; Niesobecki et al., 2019). Individuals have also reported practicing some of the preventative behaviors outlined above. However, preferred practices differ across communities due to differences in the overall community's knowledge, attitudes, and current practices against tick bites. Another individual-level prevention practice would be vaccination, though there are currently no human vaccines available for Lyme disease or the other tickborne diseases endemic to the United States. In 1998, the United States Food and Drug Administration approved a Lyme disease vaccine. However, the vaccine manufacturer phased it out due to a lack of consumer demand (Shen et al., 2011). Nonetheless, a vaccine may become available again in the future since trends in Lyme cases have steadily increased in the past two decades.

Researchers and public health officials have implemented several methods for community-wide control strategies. Tick awareness and education campaigns are one such method, which has been implemented in multiple states, including Delaware, Rhode Island, New York, and Connecticut (Gould et al., 2008; Gupta et al., 2018; NYIPM, n.d.; RIDOH & RIDEM, 2020). However, evaluated education campaigns have only marginally increased knowledge and perceived seriousness of tickborne diseases. Tickborne disease prevention campaigns that did not produce the desired impact on their community may be due to not using the best communication channel for the community, or that the campaign may have just reinforced behaviors rather than promoting behavior changes (Gupta et al., 2018). Therefore, approaches in all campaigns regarding tickborne disease need to be modified to address additional factors that influence behavior change, such as perceived susceptibility, perceived benefits, self-efficacy, and cues to action.

Additionally, for tickborne disease public health campaigns to be effective, communities must be willing to accept and act on recommended behaviors (Hayes et al., 1999). Involving the community through outreach, community fairs, partnerships with local schools, targeted interventions, or even the development of campaign materials are ways that public health organizations can increase participation in tick preventative behaviors (Haldane et al., 2019).

Outlets of information also need reevaluation to see whether these channels are effective in reaching their intended audiences.

Another community-wide approach that focuses on tick vectors is the area-wide application of acaricides. The application of acaricides may significantly reduce nymphal populations of several tick species, such as *I. scapularis*, *D. variabilis,* and *A. americanum* (Dolan et al., 2004; Elias et al., 2013; Flor-Weiler et al., 2011; Kirkland et al., 2004; Schulze et al., 2000, 2001; Stafford III & Allan, 2010). Some strategies involved in the application of acaricides utilize baited pesticide treatment stations for target host animals, woodland barrier applications, and ground and air applications to shrub layers as well as forest buffers (Schulze et al., 1994, 2001, 2007; Solberg et al., 2003; D. E. Sonenshine & Haines, 1985; Stafford III et al., 2009). However, the long-term efficacy of application treatments is unclear. Another consideration is that certain highly effective acaricides, such as carbaryl, are toxic to humans and beneficial insects like honey bees (Bond et al., 2016).

Environmental control strategies are also useful in reducing tick populations. Allan and others (2010) demonstrated that reducing invasive honeysuckle reduced the risk of *A. americanum*-associated tickborne diseases by altering white-tailed deer behavior. Since white-tailed deer preferred habitats with invasive honeysuckles, areas with abundant honeysuckle vegetation also contained many ticks. Similarly, for *I. scapularis*, reducing invasive Japanese barberries reduces tick abundance (Williams et al., 2017). However, since invasive plant life may rebound after time, monitoring vegetation density is equally vital in the long-term control of tick densities.

Culling deer populations is another control strategy that public health organizations and researchers are exploring. In some studies, culling deer populations did not significantly reduce the overall tick population (Jordan et al., 2007; Wilson et al., 1984). However, other studies show that culling deer populations does reduce tick populations over time (Stafford III & Williams, 2014). These studies showing significant differences in tick populations after deer reduction had a time frame greater than three years, which could mean that deer reduction is a long-term strategy. Although the strategy has demonstrated success, community members may not be open to this tick reduction strategy (Kilpatrick et al., 2007; Kilpatrick & LaBonte, 2003).

Finally, there are control strategies that focus on vaccinating amplifying hosts, such as white-footed mice. In both laboratory and field studies, oral vaccinations have reduced infections in small mammal reservoirs and *I. scapularis* ticks (Meirelles Richer et al., 2011; Richer et al., 2014; Scheckelhoff et al., 2006; Stafford III et al., 2020). A cost analysis study showed the strategy to be cost-effective in areas with high human Lyme disease risk (Carrera-Pineyro et al., 2020). Although researchers are still conducting additional field studies, administering an oral vaccine seems to reduce the likelihood of *Borrelia* infections in mice and *I. scapularis* populations.

Tickborne diseases have a complex transmission cycle, contributing to their increasing prevalence in the Northeast. Nonetheless, researchers are developing and refining multiple control strategies that target different aspects of the epidemiological triad. Through a combination of these control measures, the Northeast may slow or reverse the upward trend in human tickborne disease cases.

CHAPTER 2: KNOWLEDGE, ATTITUDES, AND PRACTICES REGARDING TICKBORNE DISEASES IN LONG ISLAND, NEW YORK

[formatted for submission to the Journal of Ticks and Tickborne Diseases]

Introduction

Tickborne infections account for most of the vector-borne disease cases in the United States. Annually, an average of 30,000 Lyme borreliosis cases is reported. However, the Centers for Disease Control and Prevention (CDC) estimates that there may be close to 300,000 annual cases due to underreporting (Hinckley et al., 2014; Nelson et al., 2015). Between 2010 to 2018, approximately 476,000 patients were diagnosed with and treated for Lyme disease annually during those years (Kugeler et al., 2021). While tick biology, ecology, and control measures are essential in reducing future Lyme disease cases, individual knowledge, attitudes, and practices (KAP) can also impact individual risk to tick exposure and Lyme disease (Armstrong et al., 2001; Malouin et al., 2003; Smith et al., 2001). Therefore, identifying and addressing knowledge and behavioral gaps is crucial to inform interventions designed to decrease Lyme disease cases throughout the United States.

Throughout the United States, tickborne disease knowledge, attitude, and behavioral gaps can vary between communities, regardless of how endemic ticks may be in an area (Butler et al., 2016; Heller et al., 2010; Niesobecki et al., 2019). Many studies have focused on Lyme disease in areas of high endemicity, such as the Northeast and the Mid-Atlantic region. Various KAP surveys conducted in these regions highlight the nonuniformity of attitudes toward ticks and tick preventative behaviors. In one survey conducted in Connecticut and Maryland, six in ten respondents perceived Lyme disease as very severe overall (Niesobecki et al., 2019), but with notable differences in perceptions of how common Lyme disease is between these two endemic states. The majority (80%) of Connecticut residents viewed Lyme disease as common, compared to only 54% of Maryland residents. Differences in how common Lyme disease cases are in each state may have influenced views regarding the severity of Lyme disease since the two states have different incidence rates (CDC, 2020d). However, even within an endemic state, views, and utilization of preventative behaviors may also vary between counties (Gupta et al., 2018). This means that public health messages should be tailored to their audiences.

Beliefs regarding tickborne disease prevention can also influence behavior. In a survey conducted in southwestern Connecticut between June and September 2014, most residents believed that tick preventative behaviors effectively reduced the risk of tickborne diseases (Butler et al., 2016). Perceived effectiveness of a tick preventative behavior, such as performing tick checks, was also highly correlated with performing that behavior among southwestern Connecticut residents (Butler et al., 2016). Heller and others (2010) reported that tick preventative behaviors were associated with the perceived susceptibility of getting a tick bite among outdoor workers. In another study conducted in tick endemic areas of Maryland and Connecticut, perceived severity, prevalence, and the likelihood of contracting tickborne diseases were significantly associated with performing a tick check (Niesobecki et al., 2019). In a New York park study, beliefs related to the perceived probability of encountering a tick also increased the odds of performing tick preventative behaviors such as tick checks (Hassett, 2020). Throughout different endemic areas, the perception of increased risk due to ticks appeared to be associated with residents of these communities to practice tick preventative behaviors.

Understanding perceptions regarding ticks and tickborne diseases and highlighting gaps in tick preventative behaviors are advantages of conducting a KAP survey. Researchers use KAP surveys to identify knowledge gaps, attitudes, and barriers to behavior change to determine focus areas in future public health interventions. In Long Island, New York, a historically tick-endemic area, no studies have been conducted that assess the knowledge gaps, perceptions of ticks and tickborne diseases, and tick preventative practices of residents. I focused on two counties at the most significant risk within New York State (NYS) for medically important ticks: Nassau and Suffolk. Suffolk County, which encompasses eastern Long Island, is more rural and more tick endemic, with a more extended history of tickborne diseases than Nassau County. In recent years, ticks have started to expand from Suffolk County to the more urbanized Nassau County, and as a result, Lyme disease and other tickborne diseases have emerged (Yeh, 2003). Other than differences in urbanization and tickborne disease history, the two counties differ in median income, with the median household income (2019 dollars) of Suffolk County residents being $101,031 and Nassau County residents being $116,100 (United States Census Bureau, 2019). Educational attainment between the two counties is similar, with close to 90% of residents aged 25+ years completing high school. More Nassau County residents ages 25+ years (46%) have a bachelor's degree compared to Suffolk County residents ages 25+ years (36%) (United States Census Bureau, 2019). This research focused on identifying the knowledge, attitudes, and practices regarding tickborne diseases in residents of these two counties to inform the priorities for interventions related to knowledge, attitudes, and practices. The insights from this study will be used to inform future public health campaigns to address gaps in tickborne disease knowledge and behaviors and identify opportunities for decreasing Lyme disease incidence on the island.

Materials and Methods

Survey Development

The 55-item questionnaire (see **Appendix 1**) with multiple responses, multiple-choice, Likert scale, and free-response questions was developed using the online survey platform Qualtrics (Qualtrics, Provo, Utah). The questionnaire was divided into five sections that assessed demographic information; tickborne disease knowledge, attitudes, practices; and tickborne disease history, including questions incorporated from previous KAP surveys (Herrington, 2004;

Hook et al., 2015; Hu et al., 2019; Niesobecki et al., 2019). A pilot test of the survey was distributed to entomologists for technical comment and review and non-technical reviewers to ensure that the survey questions were understandable to a lay audience. Within the survey, several definitions were given to explain tick-related key terms:

- **Tickborne diseases:** diseases are spread through the bite of infected ticks. Ticks can spread bacteria, viruses, and parasites through their bites, including the bacteria that cause Lyme disease.
- **Pesticides:** substances used to kill pests such as ticks and mosquitoes. They can be man-made chemicals or natural products. They are often applied in yards to control pests.
- **Chronic Lyme disease:** a more permanent and long-lasting condition caused when the germ cannot be killed inside the body.

After creating the final questionnaire, the survey questionnaire was translated into Spanish due to the significant Hispanic or Latino population present in both Nassau and Suffolk counties, representing close to 20% of the combined county population (United States Census Bureau, 2019).

Response Collection

Qualtrics was engaged to select individuals from their existing survey panel. Eligible participants must self-report that they resided in Long Island at the time of the survey and were at least 18 years old. Qualtrics was responsible for providing participants compensation for taking the survey as part of their survey panel program. Quotas were placed to ensure the survey reflected Suffolk and Nassau Counties' income, population, and age distribution based on 2019 U.S. Census data (SimplyAnalytics, 2020) **(Table 1)**. For 2019, 52% of Long Island residents lived in Suffolk County, while 48% lived in Nassau County (SimplyAnalytics, 2020). The collected surveys aligned with these quotas until 800 responses were collected.

The online survey was sent to panelists that were eligible to take the survey. Informed consent was obtained before participants could take the survey. Survey collection was conducted between June 4, 2020 through August 10, 2020. This study was granted an exemption from review under criterion three by the Cornell University Institutional Review Board (IRB).

Data Analysis

Quality control checks were employed to remove responses from bots, individuals who had already completed the survey, straight-lined responses (respondents that chose the same answer for all or most of the questions), nonsensical responses, or surveys completed significantly faster than expected. Forced responses were not implemented except for some willingness to pay questions. Incomplete surveys were excluded from the analysis. Data were analyzed in R version 4.0.2 (R Core Team, 2020). For all statistics, a p-value less than 0.05, unless otherwise specified, was considered statistically significant. For Likert scale questions, a Chi-square test of independence was implemented to determine whether responses to questions and demographic variables were related. For multiple response questions, a multiple marginal test of independence from the "MCRV" package version 0.3-3 (Koziol & Bilder, 2014) was performed with respondents' demographic variables. For the multiple marginal test of independence, a modified Pearson statistic was estimated by approximating the Chi-square distribution using bootstrapping with 1999 resamples (Bilder & Loughin, 2004). In cases where there are no significant differences between groups, results are reported to describe the whole dataset. Otherwise, response percentages were reported for each group.

Knowledge scores were calculated for question items within the knowledge section. For multiple response questions, responses that indicated “None” or “Don’t know” were scored zero points. Each correct choice for the multiple response questions was scored one point. Not choosing an incorrect choice was also scored one point. Therefore, for a question with five total response options, two of which are correct, respondents who select only the two correct options will be given five total points, whereas respondents choosing all the five options will be awarded two total points. For the four-point Likert questions, one point was given for correctly agreeing or disagreeing with a statement. For multiple-choice questions, one point was given for choosing the correct answer. In total, the knowledge section was scored out of 20 points.

Exploratory factor analyses using principal component analysis (PCA) for attitudes and practices questions were performed using the packages' “psych” version 2.0.9 (Revelle, 2020), “GPArotation” version 2014.11-1 (Bernaards & Jennrich, 2014), and “corpcor” version 1.6.9 (Schafer et al., 2017). Two separate PCAs with no rotation were performed using the number of questions in each of the respective sections as the number of factors. Eigenvalues of all components were then graphed to a scree plot. Significant factors had an eigenvalue of one or greater. The number of factors in the component solution was determined by the number of eigenvalues above this minimum threshold. After obtaining the number of eigenvalues in the unrotated PCA, a second PCA was performed using an oblimin rotation. Factor scores were then extracted from the second PCA. Cronbach’s alpha was used to assess the factor scores' internal consistency, with an alpha less than 0.50 considered an unreliable scale for scores (Goforth, 2015). The same PCA procedure was followed for the tick precaution section. Pearson correlation was performed using the *stats* package version 4.0.2 in base R. Strengths of the absolute value of the correlation coefficient were described as 0-0.19 as very weak, 0.2-0.39 as weak, 0.4-0.59 as moderate, 0.6-0.79 as strong, and 0.8-1 as very strong (Swinscow, 1997).

Multinomial logistic regressions were implemented using the “nnet” package version 7.3-14 (Ripley & Venables, 2020). Relative risks were obtained from the multinomial logistic regressions model by exponentiating the coefficients. Multivariate linear regression and binomial logistic regression models were built using the glmmTMB package (Magnusson et al., 2020). Multicollinearity between independent variables was first evaluated using the “psych” package, with variable pairs having a correlation coefficient greater than or equal to 0.90 considered collinear. In cases of collinearity, only one of the variables was included in the model. Univariable linear regressions between the dependent variable and each of the independent variables were used as an initial screen for variable significance, with a p-value less than 0.20 considered significant, to allow for confounding (Bursac et al., 2008; Mickey & Greenland, 1989). After the initial screening, a model was built using the significant variables from the univariable linear regressions. The initial minimum adequate model was obtained through backward selection. Non-significant variables were added back to the initial minimum adequate model and assessed individually to determine if non-significant variables were confounders. Using a change-in-estimate criterion, a 10% change in any of the coefficients of variables in the initial minimum adequate model after the addition of the non-significant variables was considered significant confounding (Lee, 2014b, 2014a; Mickey & Greenland, 1989; VanderWeele, 2019). If confounding variables were found, those variables were added back for the final minimum adequate model. The model's residuals were then assessed using the “DHARMa” package version 0.3.3.0 (Hartig, 2020), implementing the Kolmogorov-Smirnov test for uniformity DHARMa non-parametric dispersion test, and the DHARMa bootstrapped outlier test.

Results

Survey demographics.

A total of 1201 responses were collected. The number of responses that passed the screening process and met our quota was 803. There were 404 responses from Nassau County (50.3%) and 399 from Suffolk County (49.7%). Response distribution per county population, age, gender, education, and income variables is presented in **Table 1**. Several key results were found with this study. Each result is summarized in a separate section below.

Long Island respondents were generally knowledgeable about ticks but less informed about Lyme disease.

Suffolk County respondents were more likely to have some or a lot of knowledge regarding Lyme disease than Nassau County respondents ($\chi2 = 12.887$, df = 3, p-value < 0.005). Given an image showing five arthropod species, most Nassau County respondents (68%) and Suffolk County respondents (74%) correctly identified a larval tick by visual inspection **(Table 2)**. However, respondents from both counties were less likely to identify the adult tick representative, with 38% from Nassau County and 49% from Suffolk County correctly identifying it. Significantly more Suffolk County respondents identified ticks correctly compared to Nassau County respondents (modified $\chi2 = 16.02$, resamples = 1979, bootstrap p = 0.02).

Most survey respondents (68%) correctly identified summer as the season when people are at most significant risk for tick bites, and differences between counties were not significant. Few survey respondents (28%) correctly identified older adults as a group with the highest risk for Lyme disease (CDC, 2019b). Likewise, less than half of survey respondents (37%) correctly identified children as the second-highest risk group (CDC, 2019b). No significant differences in responses regarding risk groups were found between the two Long Island counties.

Half of the survey respondents (52%) incorrectly chose long-term antibiotics as the usual treatment for Lyme disease instead of the correct answer "treatment with a short round of antibiotics." No significant difference was detected in Lyme disease treatment responses between counties.

Survey respondents were asked their level of agreement to the false statement 'if an infected tick is not removed within 15 minutes, then in most cases, the ticks will transmit Lyme disease'. Most Nassau County respondents (74%) and Suffolk County respondents (64%) agreed (somewhat or strongly) with this statement. The differences between counties were statistically significant ($\chi 2 = 14.364$, df = 3, p = 0.002). Approximately nine out of ten (86%) respondents correctly agreed (somewhat or strongly) that Lyme disease can be cured. However, Nassau County respondents were less certain about their answer, with fewer responding that they strongly agreed compared to Suffolk County respondents ($\chi 2 = 13.885$, df = 3, p = 0.003).

Approximately two out of three respondents in Nassau County (63%) and Suffolk County (58%) incorrectly agreed (somewhat or strongly) that most ticks are infected with the agent of Lyme disease. However, the responses between the two counties were not significantly different. Finally, approximately nine out of ten survey respondents (89%) agreed (somewhat or strongly) incorrectly when asked, "there is a chronic form of Lyme disease (a more permanent and long-lasting condition caused when the germ can't be killed inside the body)." Responses between the two counties were not statistically different.

The knowledge questions were totaled and were used to create a knowledge score (Cronbach's $\alpha = 0.18$). The average knowledge score of a Suffolk County resident was 9.8 out of

20, while the average knowledge score of a Nassau County resident was 9.01 out of 20 ($t = -3.8123$, $df = 610.54$, $p = 0.0002$). Scores were similar regardless of home ownership, age, gender, ethnicity, income, education, and age.

Long Island respondents were concerned about ticks, but the level of concern varied by county.

More Suffolk County respondents (58%) compared to Nassau County respondents (37%) agreed (somewhat or strongly) that tickborne diseases were common in their area ($\chi^2 = 51.084$, df = 4, p-value < 0.0001) **(Table 3)**. A larger portion of Suffolk County respondents (76%) compared to Nassau County respondents (62%) also agreed (somewhat or strongly) that they were concerned about being bitten by ticks in their area ($\chi^2 = 38.003$, df = 4, p-value < 0.0001).

More Suffolk County respondents (53%) than Nassau County respondents (32%) agreed (somewhat or strongly) that they were concerned about being bitten by ticks near their home ($\chi^2 = 44.354$, df = 4, p-value < 0.001). Significantly more Nassau County respondents (57%) compared to Suffolk County respondents (45%) disagreed (somewhat or strongly) that one of their family members would likely get a tickborne disease within the next year ($\chi^2 = 13.89$, df = 4, p-value < 0.01).

Nearly half of survey respondents (45%) agreed (somewhat or strongly) that tickborne diseases have negatively affected their feelings about the outdoors. Nassau County respondents (48%) were more negatively affected compared to Suffolk County respondents (41%) ($\chi^2 = 11.704$, df = 4, p = 0.02).

The perceived risk of tickborne diseases may also impact the desire to visit nature parks, with nearly half of respondents (44%) agreeing (somewhat or strongly) that they were less likely to go to nature parks for fear of contracting a tickborne disease. No differences in response were detected by county.

Residents in both counties have similar patterns of wearing precautionary clothing and insect repellents but differ in other precautionary behaviors.

Respondents were asked to indicate how often they took certain precautionary measures (wearing long-sleeved shirts or long pants, tucking pants into socks, wearing insect repellent) to avoid tick bites when outdoors. Overall, there were no significant differences in each of the precautionary measures between counties **(Table 4)**. Half of the survey respondents (49%) indicated that they often or always wore insect repellent, and half (53%) also indicated that they often or always wore long pants. However, only a third of survey respondents (32%) said that they wore long-sleeved shirts. A small portion of respondents (24%) often or always tucked their pants into socks.

Suffolk County respondents were more likely to use precautionary behaviors (tick checks, walking in the center of hiking trails to avoid brush, showering within two hours of engaging in outdoor activities in a tick habitat) to avoid tick bites. Significantly more Suffolk County respondents (50%) compared to Nassau County respondents (30%) said they often or always performed tick checks ($\chi^2 = 36.207$, df = 4, p-value < 0.001). Most respondents (68%) indicated that they often or always walked in the center of hiking trails to avoid brush. Significantly more Suffolk County respondents (70%) indicated they often or always walked in the center of hiking trails compared to Nassau County respondents (67%) ($\chi^2 = 15.388$, df = 4, p = 0.004). Nearly half of the respondents (49%) indicated that they often or always showered within two hours of engaging in outdoor activities in a tick habitat, with no noted significant differences between the two counties.

Residents were willing to pay for tick control.

Close to four out of ten respondents (44%) were willing to pay for a private pest control company's tick control service, while 23% were not. However, 33% of residents were unsure whether they wanted to pay for private tick control. When asked about paying taxes to support tick control near their home (public tick control), 39% were willing to do so, while 25% were not. However, a nearly equal number of residents (36%) were unsure whether they wanted to pay taxes to support public tick control. There were no differences between the two counties regarding willingness to pay for private and public tick control.

Overall, Long Island residents were willing to pay modest amounts for tick control. On two separate questions, residents were asked how much they were willing to pay for private and public tick control. For private tick control, 54% were willing to pay between $40.00 to $159.00 annually **(Figure 2)**. For public tick control, a quarter of survey respondents (28%) were willing to pay between $10.00-$20.00 annually **(Figure 3)**. Fewer respondents were willing to pay higher amounts of $50.00 annually (16%) or the maximum amount listed in the survey ($100.00) annually (19%) for public tick control. Responses from both counties about public tick control were not significantly different.

The variables that influenced a resident's willingness to pay for private tick control (after adjusting for confounder "age") included "history of tickborne disease in the household" and "seeing a tick last summer" **(Table 5)**. Respondents who said someone in their household was diagnosed with a tickborne disease, which represented 11% (n=86) of the total responses, were 9.41 times more likely to say "yes" to private tick control compared to those that did not. Respondents who saw a tick last summer were 2.29 times more likely to say "yes" to private tick control compared to those that did not. Among the different age groups, with ages 18-24 as the reference group, respondents aged 25-34 were 3.13 times more likely to say "yes" to private tick control, and those aged 55-64 were 0.36 times more likely to say "yes" to private tick control. However, these odds were not statistically significant.

Significant variables for residents who were willing to pay for public tick control (after adjusting for confounders "age," "education," and "having a pet") included "gender," "income," "history of tickborne disease in the household," and "seeing a tick last summer" **(Table 6)**. The only significant variable was gender, with respondents identifying as male 1.89 times more likely to say "yes" to public tick control compared to female respondents.

Tick removal practices and where residents seek medical care after a tick bite were different between counties.

When given a choice to select all methods that an individual could take to remove an embedded tick, most respondents overall (68%) would remove a tick embedded in their body by using fine-tipped tweezers **(Figure 4)**. In Nassau County, visiting a medical professional was the second most popular choice for tick removal (29%). Putting alcohol/hand sanitizer on the tick was the second most popular choice among Suffolk County residents for tick removal (29%). More people in Nassau County (10%) were unsure how to remove a tick compared to Suffolk County respondents (4%). Choices of how ticks were to be removed differed significantly between counties (modified $\chi^2 = 24.77$, resamples = 1999, bootstrap $p < 0.0005$).

Significantly more Nassau County respondents (75%) than Suffolk County respondents (69%) indicated they would seek medical care if bitten by a tick ($\chi^2 = 8.2282$, df = 2, $p = 0.02$)**.** Those who did not indicate "not sure" when asked if they would seek medical care if bitten by a tick, a follow-up question was asked to select all that apply regarding where residents would seek medical care if a tick bit them. Overall, seven out of ten survey respondents indicated they would visit their primary care provider for this care **(Figure 5)**. The second most common choice overall was visiting an emergency room. Only 10% of Nassau County residents and 15% of Suffolk County residents reported that they would seek medical care if they felt sick after a tick bite. Choices of where respondents would seek medical care if a tick bit them were significantly different between the two counties (modified $\chi^2 = 16.85$, resamples = 1999, bootstrap p = 0.03).

Variables important for seeking medical care if bitten by a tick (adjusted for confounder "finding a tick crawling on oneself previously") included "income" and "having been previously diagnosed with a tickborne disease" (**Table 7**). Compared to those making less than $25,000 a year, residents who indicated that they made between $25,000-$49,999 a year were significantly more likely to seek medical care (OR = 3.83, p = 0.045), as well as those making above $150,000 a year (OR = 2.89, p = 0.041). Those that were previously diagnosed with a tickborne disease were also significantly more likely to seek medical care than those who were not (OR = 18.72, p = 0.005). However, those who have found a tick bite their body previously were significantly less likely to seek medical care than those who have not previously had a tick bite (OR = 0.21, $p < 0.0001$).

Yard-based control measures differed by county of residence.

More Nassau County respondents (39%) did not implement any control measures in their yard compared to Suffolk County respondents (25%) **(Figure 6)**. A large proportion of Nassau County respondents (39%) used control measures beyond those listed in the survey. These included burning citronella candles and applying tea tree oil to door posts, regular mowing, having a landscaper perform tick control measures, and reducing grass-covered areas in the yard with pavement or bricks. In Nassau County, the second most common approach was spraying natural pesticides (27%). The most common form of tick control in Suffolk County was removing brush or leaves (37%), followed by spraying natural pesticides (33%). Choices of control measures implemented were significantly different between the two counties (modified χ^2 = 95.85, resamples = 1999, bootstrap $p < 0.0005$).

Significant variables for practicing some form of tick yard control (adjusted for confounders “education,” “having been previously diagnosed with a tickborne disease,” and “race/ethnicity”) included “county,” “home ownership status,” “age,” “having someone in the household with a history of tickborne disease,” and “pet ownership” (**Table 8**). Suffolk County residents were significantly more likely to practice yard control than Nassau County residents (OR = 1.57, p = 0.026). Residents who were renting a house were significantly less likely to practice yard control than homeowners (OR = 0.53, p = 0.017). Compared to residents between the ages of 18 to 24, residents that were in older age groups were less likely to practice tick control (25-35 OR = 0.33, p = 0.076; 35-44 OR = 0.18, p = 0.005; 45-54 OR = 0.18, p = 0.004; 55-64 OR = 0.10, p < 0.001; ≥65 OR = 0.21, p = 0.008). Residents that had someone in their household with a history of tickborne disease were significantly more likely to practice tick control (OR = 19.38, p = 0.004). Finally, those who had outdoor pets were more likely to practice some form of tick control than those who did not have outdoor pets (OR = 2.48, p < 0.0001).

Most residents were willing to use pesticides to control ticks, but a significant portion did not spray pesticides in their yards during warm months.

Most respondents (69%) agreed (somewhat or strongly) with the idea of using pesticides on their yards to control ticks. However, reflecting on what they have done in the past, half of the respondents (54%) were unsure if they have ever hired someone to spray pesticide on their property and only a few individuals in the two counties (10%) responded that they did.

During warm months, which typically have the most tick activity during the year, a significant number of respondents (40%) did not spray pesticides in their yards **(Figure 7)**. Monthly (20.03%) was the next common choice, followed by twice a year (17%), yearly (12%), weekly (8%), and then every few years (4%). No significant differences between the frequency of spraying were noted between the two counties.

Suffolk County residents have more personal tickborne disease history compared to Nassau County residents.

Most Nassau County respondents (95%) and Suffolk County respondents (88%) had not been diagnosed with a tickborne disease **(Table 9)**. However, of those reporting a personal history of tickborne disease, a significantly higher proportion lived in Suffolk County (10.10%) compared to Nassau County (3%) ($\chi^2 = 15.51$, df = 2, p-value < 0.001). Similarly, while most respondents (86%) did not have someone in their household diagnosed with a tickborne disease, a significantly larger proportion of Suffolk County respondents (15%) compared to Nassau County respondents (7%) indicated that they did ($\chi^2 = 13.816$, df = 2, p = 0.001).

A significantly higher proportion of Suffolk County respondents saw a tick last summer (47%) compared to Nassau County respondents (13%) ($\chi^2 = 72.782$, df = 2, p-value < 0.001). Similarly, a significantly higher proportion of Suffolk County respondents (37%) compared to Nassau County respondents (13%) have found a tick biting them before ($\chi^2 = 60.297$, df = 2, p-value < 0.001).

Perceived tick bite susceptibility was correlated with reduced outdoor behavior.

The six attitude questions loaded strongly into two factors after a principal component analysis **(Supplementary Table 1)**. Four of the questions related to perceptions of tickborne diseases (how common ticks are in the area, likelihood of family getting a tickborne disease within a year, concern about being bitten by ticks near home, concern about ticks in the area) loaded into one factor (henceforth called *perceived tick bite susceptibility score*). The other two questions (less likely to go to hiking or nature trails and having negative feelings about the outdoors because of ticks) loaded into the other factor (henceforth called *reduced outdoor behavior score*). Factor scores were then created for perceived tick bite susceptibility (Cronbach's $\alpha = 0.83$) and outdoor behavior (Cronbach's $\alpha = 0.82$). There was a positive, moderate correlation between perceived tick bite susceptibility and reduced outdoor behavior due to tickborne diseases ($t = 12.954$, $df = 682$, $p < 0.0001$, $r = 0.44$).

After running a linear regression for tick bite susceptibility score, significant variables for increased tick-borne disease severity scores included "county," "having been previously diagnosed with a tickborne disease," "having someone in the household with a history of tickborne disease," "seeing a tick last summer," and "finding a tick crawling on oneself previously" **(Table 10)**. After running a linear regression for the reduced outdoor behavior score, significant variables included "county," "gender," "income," "having been previously diagnosed with a tickborne disease," "having someone in the household with a history of tickborne disease," and "seeing a tick last summer" **(Table 11)**. Suffolk County residents were associated with lower reduced outdoor behavior scores. Male respondents were also associated with lower reduced outdoor behavior scores compared to female respondents. Similarly, having a higher income was associated with lower scores. Those diagnosed with a TBD previously, saw ticks last summer, and those who have someone in their household diagnosed with a TBD previously were associated with higher reduced outdoor behavior scores.

Knowledge of ticks and tickborne diseases and perceived tick bite susceptibility is positively associated with increased use of protective behaviors.

The seven protective behavior questions loaded strongly in one factor (henceforth called *protective behavior score*) (Cronbach's $\alpha = 0.80$) **(Supplementary Table 2)**. Although the correlation between knowledge scores and the protective behavior factor was significant, it was only very weakly positive ($t = 3.33$, $df = 697$, $p = 0.001$, $r = 0.125$). The perceived tick bite susceptibility score was significantly positively and weakly correlated with the protective behavior score ($t = 9.63$, $df = 572$, p-value < 0.0001, $r = 0.37$). The reduced outdoor behavior score was significantly positively and weakly correlated with the protective behavior score ($t = 7.38$, $df = 572$, p-value < 0.0001, $r = 0.29$).

Variables important for the protective behavior score included "race/ethnicity," "having been diagnosed with a tickborne disease previously," "having someone in the household with a history of tickborne disease," and "seeing a tick last summer" **(Table 12)**. Compared to Asian respondents, White respondents had significantly lower protective behavior scores ($p = 0.034$). Those who were previously diagnosed with a tickborne disease had significantly greater protective behavior scores ($p = 0.007$), and residents that had someone in their household with tickborne disease history had greater protective scores ($p < 0.0001$) compared to respondents without these histories. Lastly, residents who saw a tick last summer also had greater protective behavior scores than residents who did not see a tick last summer ($p < 0.0001$).

There is a relationship between tick concern and willingness to pay.

Increases in the perceived tick bite susceptibility score were associated with a relative risk ratio of 2.36 for saying "yes" to the willingness to pay for private tick control question **(Table 13)**. Increases in the perceived tick bite susceptibility score were associated with a relative risk ratio of 1.81 for saying "yes" to the willingness to pay for public tick control question.

Pet owners' attitudes and practices.

Out of 802 responses, 333 respondents (42%) indicated having a pet that went outdoors. Overall, pet owners were more concerned about ticks compared to non-pet owners. More pet owners (75%) compared to non-pet owners (64%) agreed (somewhat or strongly) that they were concerned about being bitten by ticks in the area ($\chi^2 = 21.019$, df = 4, p = 0.0003). More pet owners (59%) compared to non-pet owners (39%) agreed (somewhat or strongly) that tickborne diseases were common in the area ($\chi^2 = 39.666$, df = 4, p-value < 0.0001). A larger percentage of pet owners (24%) compared to non-pet owners (11%) agreed (somewhat or strongly) that one of their family members will likely get a tickborne disease within the next year ($\chi^2 = 35.215$, df = 4, p-value < 0.0001). Lastly, more pet owners (50%) compared to non-pet owners (37%) agreed (somewhat or strongly) that they were concerned about being bitten by ticks near their home ($\chi^2 = 34.789$, df = 4, p-value < 0.0001). However, no significant differences were detected regarding ticks negatively affecting respondents' desire to go outdoors, willingness to visit nature parks due to tickborne diseases, and feelings about visiting a tick-endemic vacation destination between pet owners and non-pet owners.

Pet owners were more likely to wear precautionary clothing or engage in precautionary behavior to avoid ticks than non-pet owners. Fifty-five percent of pet owners compared to 46% of non-pet owners indicated that they often or always used insect repellents ($\chi^2 = 16.068$, df = 4, p = 0.003). More pet owners (39%) compared to non-pet owners (28%) indicated they often or always wore long-sleeved shirts ($\chi^2 = 18.345$, df = 4, p = 0.001). When it came to tick checks, more pet owners (50%) compared to non-pet owners (33%) indicated that they often or always performed this behavior (χ^2 = 36.602, df = 4, p-value < 0.001). More pet owners (74%) compared to non-pet owners (64%) indicated they often or always walked in the center of trails (χ^2= 16.42, df = 4, p = 0.003). More pet owners (29%) compared to non-pet owners (21%) indicated they often or always tucked their pants into their socks (χ^2 = 19.815, df = 4, p = 0.0005). More pet owners (53%) compared to non-pet owners (46%) indicated that they often or always showered within 2 hours of being in a tick habitat (χ^2 = 11.672, df = 4, p = 0.02). The only non-significant difference was the frequency of wearing long pants, where 53% of both pet owners and non-pet owners often or always wore long pants.

A significantly higher proportion of Suffolk County respondents (49%) compared to Nassau County respondents (34%) have pets that go outdoors (χ^2 = 18.792, df = 1, p-value <0.001) **(Table 9)**. This result may be due to differences in urbanization between these two counties, as Suffolk County's rural setting may suit more outdoor pets than Nassau County's more urban setting. Of these outdoor pet-owning respondents, more Suffolk County respondents (60%, n = 117) compared to Nassau County respondents (30%, n = 41) have seen a tick crawling on their pet (χ^2 = 30.213, df = 2, p-value <0.001). Likewise, a significantly larger proportion of Suffolk County respondents (51%, n = 99) have found a tick biting their pets than Nassau County respondents (21%, n = 29). Significantly more Nassau County respondents reported never seeing a tick on their pets during the summer (64%, n = 87) compared to Suffolk County respondents (42%, n = 82) (χ^2 = 19.306, df = 4, p = 0.001). Thirty-six percent (n = 71) of Suffolk County respondents and 19% (n = 26) of Nassau County respondents reported having seen a tick on their pets once a week.

Discussion and Conclusions

This is the most extensive study to date conducted in the Northeast examining knowledge, attitudes, and practices regarding tickborne diseases. The results of the study highlighted several knowledge gaps within Long Island. Additionally, the study also measured the attitudes towards tickborne diseases, control measures, willingness to pay for private and public tick control. Furthermore, it described the patterns related to tick control practices and healthcare utilization. The study also quantified differences between pet owners and non-pet owners on the island. Moreover, it presented a validated measure for perceived susceptibility to tick bites, reduced outdoor behavior due to tickborne diseases, and personal protection from tick bites.

Resident Knowledge Gaps

Overall, Long Island residents had insufficient knowledge regarding tickborne diseases. The only significant demographic variable was the county of residence, with Suffolk County residents being slightly knowledgeable about tickborne diseases compared to Nassau County residents. However, regardless of county or demographic variables, the average knowledge scores indicate inadequate knowledge regarding tickborne diseases. This pattern of insufficient knowledge regarding tickborne diseases is similar to the findings of previous studies that quantified overall tickborne disease knowledge among residents in endemic areas (Butler et al., 2016; Valente et al., 2015). While residents were knowledgeable about what season they were most at risk for tick bites, what a larval tick looked like, and that Lyme disease is treatable, most lacked knowledge in other important areas. For example, only 10% of the respondents correctly identified that chronic *Borrelia burgdorferi* infection (chronic Lyme disease) was not possible, only a few residents correctly identified the age groups that were most at risk for Lyme disease, and about 50% of the respondents incorrectly chose long-term antibiotics as the usual Lyme disease treatment. Future public health campaigns should address treatment options, misconceptions about Lyme disease infection, and age groups most at risk to improve education and tickborne disease prevention in the region. These knowledge gaps have also been documented previously in other states and are thus worth exploring further (Butler et al., 2016; Valente et al., 2015). However, these should not be the only areas of focus if the goal is to increase the use of tick preventative practices and tick bite precautionary behaviors.

While knowledge was positively correlated with practicing precautionary behavior, the correlation was very weak. Knowledge improvement alone is unlikely to motivate people to practice protective behavior, as individuals may know what to do but choose not to do it for many reasons, such as inconvenience, not having the resources to implement the activity, or not having the opportunity to practice skills recently learned. Similarly, knowledge does not address other factors that influence behavior, such as motivation and norms regarding ticks and tickborne diseases, which are important components in understanding barriers to adopting tick preventative practices (Miller & Prentice, 2016; Patrick & Williams, 2012). Other campaigns that focused on the information deficit model, which is a model that assumes new knowledge generates new behavior, have repeatedly failed to achieve their expected behavior change (Marteau et al., 2002). The information deficit model relies on the passive dissemination of knowledge, such as the mailing of educational materials, which are ineffective in causing behavior change (Grimshaw et al., 2002).

Social cognition models such as the Health Belief Model, Social Cognitive Theory, and the Theory for Planned Behavior have been developed to address the deficiencies of the information deficit model (Marteau et al., 2002). These models assert that how people think about a situation or behavior determines what they do. They typically focus on three components that increase the likelihood of practicing health-promoting behaviors: 1) perceived benefits weighed against perceived barriers, 2) perceptions of attitudes from other individuals regarding the behavior, 3) self-efficacy (Marteau et al., 2002). There are empirical evidence for using the Health Belief Model to understand the decision process regarding health-related behavior (Janz & Becker, 1984). The Health Belief Model addresses six dimensions: perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy (Sadeghi et al., 2018). In their review of the literature that utilized the Health Belief Model, Janz et al. (1984) found that addressing perceived barriers, perceived susceptibility, and perceived benefits were positively associated with the use of preventative health behavior outcomes. Recent successful implementations of the Health Belief Model include educating nurses on observing standard precautions, increased self-care behaviors among diabetes patients, the promotion of healthy eating habits, and increasing colorectal cancer screening (Deshpande et al., 2009; Rakhshanderou et al., 2020; Sadeghi et al., 2018; Shabibi et al., 2017). Thus, an effective public health campaign for tick bite prevention should focus not only on addressing knowledge gaps but also on other barriers to behavior change, such as lack of motivation. Additionally, public health campaigns must also consider the stage of readiness individuals are when it comes to formulating messaging as part of this campaign. The transtheoretical model (also known as the stages of change model) states that individuals move in stages when adopting a healthy behavior (LaMorte, 2019). The stages in the transtheoretical model are: 1) pre-contemplation 2) contemplation 3) preparation 4) action 5) maintenance 6) termination (LaMorte, 2019). Different interventions can be used in each of the stages to move individuals from one stage to the next.

Within Nassau County, educational materials regarding ticks and tickborne diseases are lacking. There have also been no tick awareness campaigns in the county. Yuan et al. (2020) found that adult *I. scapularis* ticks in the schools and parks within the county had a prevalence rate of 50% for *B. burgdorferi*, the causative agent of Lyme disease (Yuan et al., 2020). Although rates were much lower than in Suffolk County, there are still cases of Lyme disease reported every year (CDC, 2019c). It is also unclear where public health messaging regarding ticks exists in the county. The Nassau County Department of Health website does not have any pages dedicated to ticks and tickborne diseases, which presents a gap in public health outreach. Data from Nassau County in this study can be used to inform educational materials and future public health outreach activities within the county.

The Suffolk County Department of Health Services (SCDOHS) website contains information about ticks and tickborne diseases, such as their biology, species information, guidelines to personal protection, and a link to a tick management handbook (SCDHS, n.d.). They launched a tick bite prevention education campaign in 2019 targeted towards children (which is an age group most at risk for Lyme disease), on top of their seasonal outreach activities (Suffolk County Government, 2019). In addition to the current outreach activities conducted by the SCDOHS, insights from my study can also inform strategies related to addressing knowledge and behavioral gaps within the Suffolk County community.

Attitudes Towards Ticks and Tickborne Diseases

Unlike the knowledge scale, the measures for perceived tick bite susceptibility and reduced outdoor behavior were more reliable, with a Cronbach's α of 0.83 and 0.82, respectively, indicating high internal consistency. Most residents were concerned about ticks. Those who lived in Suffolk County, had been previously diagnosed with a tickborne disease or saw a tick last summer had much higher perceived tick bite susceptibility scores. Thus, individuals who have a history of tickborne disease or are in a tick endemic area may be more aware of the threat tickborne diseases pose. Most residents also expressed that ticks have affected their feelings regarding the outdoors, contributing to reduced outdoor behavior. These insights also suggest that ticks and tickborne diseases may play a role in lessening the quality of life for Long Island residents. Access to green spaces and natural outdoor environments have been associated with better general and mental health (Triguero-Mas et al., 2015). If residents are less encouraged to explore natural parks due to tickborne diseases, it may reduce their general and mental health. However, further studies are required to explore the link between tickborne diseases and reduced quality of life among Long Island residents.

In the survey, residents with a history of tickborne diseases in their household and those who saw a tick last summer were more likely to pay for private tick control. This trend, as well as the positive relationship between increases in tick bite susceptibility scores and willingness to pay for any forms of tick control may be further explained by the Health Belief Model, which states that individuals are more likely to participate in behavior change when they perceive a threat (Champion & Skinner, 2008). However, perceived susceptibility is only one factor contributing to the likelihood of individuals practicing preventative health behaviors. An effective public health campaign focused on tick bite prevention should also address other Health Belief Model components, such as increased perceived benefits of practicing preventative tick control (such as wearing the appropriate clothing in tick habitats). It would be especially beneficial to focus on subgroups that already have high perceived susceptibility, such as those with a history of tickborne diseases, since they may be more likely to perform a preventative health behavior if they are aware of how it can lower their perceived susceptibility. By showing the benefits of practicing tick prevention, which includes less worrying about tick bites and tickborne diseases, individuals are more likely to engage in the desired preventative health behavior. Increased self-efficacy (showing the simple steps an individual can take to prevent tick bites) is also important. It reduces barriers related to hesitancy in practicing the behavior due to its difficulty of being implemented. Increasing the perceived severity of tickborne diseases (by demonstrating serious health implications) and cue to action (posting signs to remind residents to practice tick bite prevention) will also likely increase practicing preventative health behaviors.

Tickborne Disease Prevention Practices

Although more Suffolk County residents were worried about tickborne diseases than Nassau County residents, they were less likely to seek medical care if bitten by ticks. This might be due to the normalization of ticks and tickborne diseases in this more rural county than the more urban Nassau County. However, whether it is for this reason remains unclear since the questionnaire does not directly address why individuals choose not to seek medical care following a tick bite. It is not always necessary for individuals to go to a health care provider if they get bitten by a tick. The CDC recommends only seeing a healthcare provider when symptoms such as fever or a rash appear after a tick bite. However, only 10% of Nassau County residents and 15% of Suffolk County residents would seek medical care if they felt sick following a tick bite. Additional studies can address why people are unwilling to seek medical care after symptoms associated with a tick bite. Although, the survey does not address the motivation as to why we see such a pattern (perhaps due to a lack of good healthcare access or perceived non-seriousness of symptoms). Nonetheless, public health practitioners should emphasize the threat of tickborne diseases and offer concrete examples of when individuals should seek medical after a tick bite. This suggestion applies more to Suffolk County, which had a lower proportion of residents than Nassau County, indicating they would seek medical care after a tick bite.

Overall, those bitten by a tick previously were 79% less likely to seek medical care if they were bitten by a tick again. Individuals who were bitten by ticks once and did not contract a tickborne disease may be more likely to treat the tick bite as innocuous. Similarly, those who get bitten by ticks often may become jaded, or they may have learned that promptly removing ticks minimizes the risk for Lyme disease transmission. Also, individuals with lower income were less likely to seek medical care, which may be due to issues related to healthcare access. Therefore, public health practitioners need to conduct tickborne disease prevention outreach to low-income communities and work with community leaders outside of the healthcare setting.

Tick Control Measures

Support for and use of control measures varied by county, which may be due to differences in geography and tick densities in the area. Suffolk County is much more rural and has a longer history of ticks and tickborne diseases than Nassau County. Although Nassau County is more urbanized, Lyme disease and other tickborne diseases have emerged in the area (Yeh, 2003). In Suffolk County, the most common form of tick control was removing brush or leaves followed by the spraying of natural pesticides. For Nassau County, the most common form of tick control is through other means, including yard work, regular mowing, and reducing grass-covered areas in the yard, followed by the spraying of natural pesticides. Property management measures such as removing leaf litter, cleaning trash from yards, removing wood piles, or mowing grassy areas can effectively reduce tick densities in the area (Fischhoff et al., 2019). Removing areas where ticks or tick reservoirs can reside near or around the house can be a practical way of reducing tick densities near homes, especially since they do not require contracting a company to spray acaricides. Residential acaricides have been shown to significantly reduce tick abundance in yards (Hinckley et al., 2016).

Nonetheless, even when used as recommended, residential acaricides may not significantly reduce the risk of tick exposure or incidence of tickborne diseases (Hinckley et al., 2016). Empirical evidence regarding the efficacy of tick control measures on decreasing tick densities varies widely. Some measures having robust evidence (such as using rodent-targeted acaricides, deer fencing), and others are limited (such as the removal of leaf litter and landscaping) (L. Eisen & Stafford III, 2020). However, empirical evidence on whether these control measures effectively reduce tickborne disease incidence in the area is lacking. Educating the public about the efficacy of using acaricides in a domestic setting, especially since spraying natural pesticides was the second most common yard control measure, may be another avenue a public health tickborne disease campaign can address. Educating Long Island residents about the efficacy of acaricides in a domestic setting may also influence how receptive residents are towards public tick control, which they prefer less than private tick control.

Tick control in residential yards was positively influenced by the tickborne disease history of the residents. This means that residents are more likely to practice tick control if they know someone or have themselves been impacted by ticks. Thus, another potential strategy for promoting tick control and personal prevention is to highlight testimonials of community members who have encountered ticks and discuss why it is important to practice tick bite prevention and control in a highly endemic area. In addition, pairing guidance on which strategies have the best evidence of reducing the likelihood of getting tickborne diseases.

Limitations

A knowledge score was used to determine the overall measure of knowledge residents had based on the questions asked in the survey, similar to other studies conducted in the past (Butler et al., 2016; Valente et al., 2015). Additional analysis such as regressions with demographic and tickborne disease history became possible by creating a knowledge score. Although the knowledge score was a convenient measure to calculate and may have been a good proxy for the overall knowledge of tickborne diseases in the survey, one caveat is that it had poor reliability when it came to its Cronbach's α of 0.18. This could be for various reasons, including not having the same question formats, not having enough questions to measure knowledge, and the score measuring different aspects of tickborne disease knowledge. Analyzing each question is another way of getting insights as it can reveal which specific questions respondents had trouble with and is thus another way of identifying knowledge gaps. Specific topics, such as other diseases transmitted by ticks, overestimating the percentage of ticks that carry the *B. burgdorferi*, appropriate treatment for Lyme disease, and tick habitats, have been documented to be areas where knowledge gaps existed (Butler et al., 2016; Valente et al., 2015).

Another limitation of the study is the lack of zip code level data. As Suffolk and Nassau Counties represent roughly two-thirds of Long Island, there may be variations within each county regarding geography and tickborne disease incidence. A finer resolution may have resulted in more informative and targeted recommendations tailored to each county. In the questionnaire, benefits related to tick control and results of studies related to the efficacy of residential control were not described, which may have influenced the response regarding willingness to pay for tick control. The questionnaire also did not describe the actions that constituted public versus private tick control. In the questionnaire, upon further examination, the image representing "adult ticks" in the question that asked to identify arthropod specimens that were ticks was ambiguous and thus may not be representative of how well residents could identify adult tick specimens. Some of the questions (such when respondents were asked to respond to the statement "I am less likely to go to nature parks or hiking trails because I do not want to get a tickborne disease" and "tickborne diseases have negatively affected my feelings about the outdoors") could be phrased better to be more neutral and reduce bias in responses. Lastly, the survey identified areas for future public health interventions. However, it did not necessarily address why barriers to behavior change exist (such as access to healthcare, beliefs about the effectiveness of interventions). Further studies are required to address the root causes of these barriers to inform public health tickborne disease prevention campaigns in Nassau and Suffolk counties.

Contribution to the Literature

This is the largest study conducted in the Northeast examining knowledge, attitudes, and practices regarding tickborne diseases. My results validated several attitudes and practices questions as reliable measurements regarding anxiety related to tick bites, reduced outdoor activity due to ticks, and precautionary behavior in response to ticks. Previous KAP surveys have examined the frequency of certain precautionary behaviors, such as tucking pants into socks, wearing insect repellents, and wearing long-sleeved shirts. However, none of the previously published studies assessed whether questions about these precautionary measures accurately measured the construct of personal protection from tick bites. In some surveys, multiple questions are asked to create a measure of certain latent (or inferred) variables. Principal component analysis allows researchers to take these questions and convert them into latent factors, such as how individuals feel about ticks and tickborne diseases in general. However, to be an accurate measure of the latent variable of interest, the scale on which the factor scores are assessed must be reliable. Previous KAP surveys have tried to assess certain latent factors such as knowledge about tickborne diseases, feelings of respondents regarding tickborne diseases, and preparedness against tick bites. However, these surveys did not measure or validate whether their questions truly captured the latent constructs they were interested in. The large sample size of my study allowed me to conduct this assessment through greater statistical power and confidence that my questions about precautionary behaviors and attitudes toward ticks captured latent constructs of tick anxiety and personal protection.

The insights gleaned from this study will help identify educational and outreach strategies for reducing tickborne diseases in Long Island, NYS. My study identified several potential target areas that can form the basis of additional research and outreach strategies, including knowledge gaps in treatment options, misconceptions about Lyme disease, and those who are most at risk for getting Lyme disease. Perceptions about tickborne diseases, such as perceived tick bite susceptibility or reduced outdoor behavior due to tickborne diseases, can be incorporated in the implementation of outreach programs to tailor programming in different subgroups of the Long Island population. Patterns in healthcare access can also be used to inform communication channels for outreach. Identifying demographic and tickborne disease history factors that impact knowledge, attitudes, and practices can further tailor messages regarding tickborne diseases. This study could serve as a baseline to see the effect of future educational outreach within Long Island, especially regarding the knowledge gaps and practices this study has identified. Incorporating the insights from my study and interacting directly with residents to further understand barriers to behavior change in their communities will increase the likelihood of implementing a successful public health campaign to reduce the tickborne disease burden throughout Long Island NYS.

FIGURES

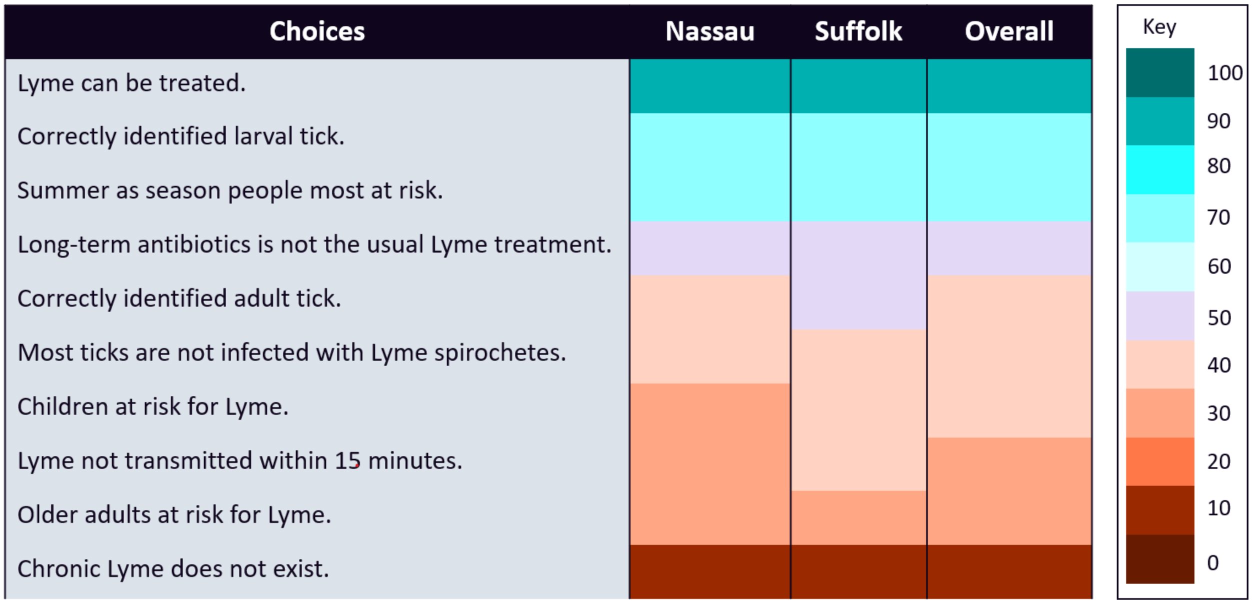

Figure 1. Degree of knowledge per knowledge question for survey respondents from Nassau and Suffolk Counties, NYS. Colors indicate the percentage of respondents who chose the correct response listed in the "Choices" column.

Figure 2. The distribution of the maximum range residents were willing to pay for private tick control annually in Nassau County and Suffolk County.

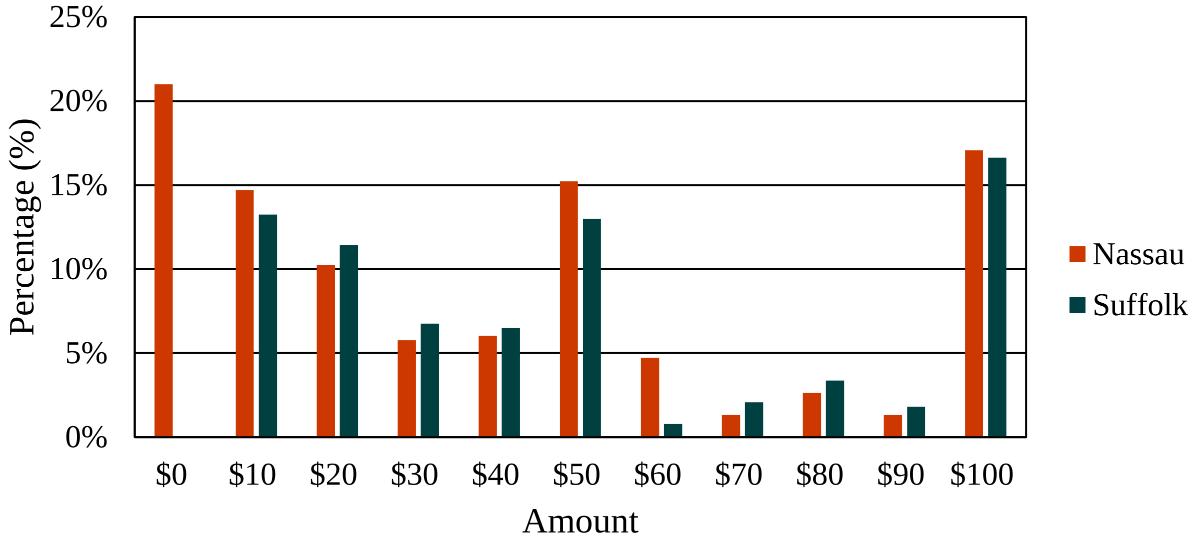

Figure 3. The distribution of the maximum amount residents were willing to pay in taxes annually for public tick control in Nassau County and Suffolk County.

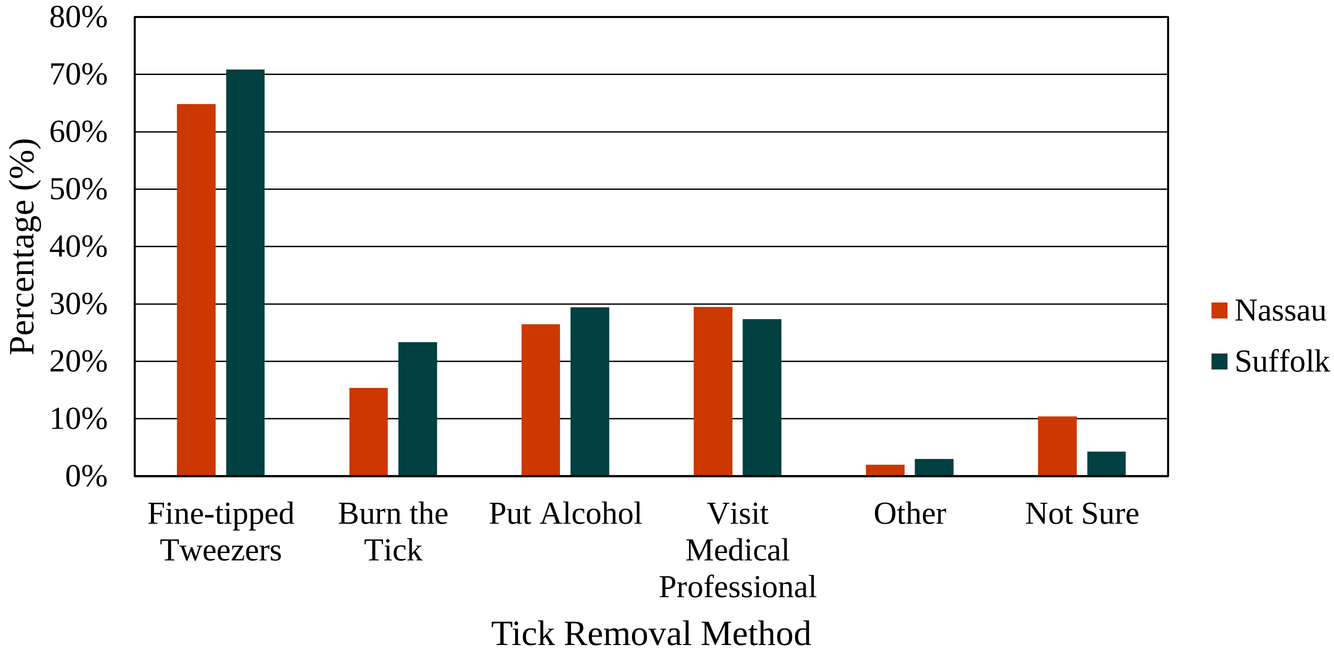

Figure 4. Nassau County and Suffolk County resident methods for removing ticks embedded in their skin (modified $\chi2 = 24.77$, resamples = 1999, bootstrap $p < 0.0005$).

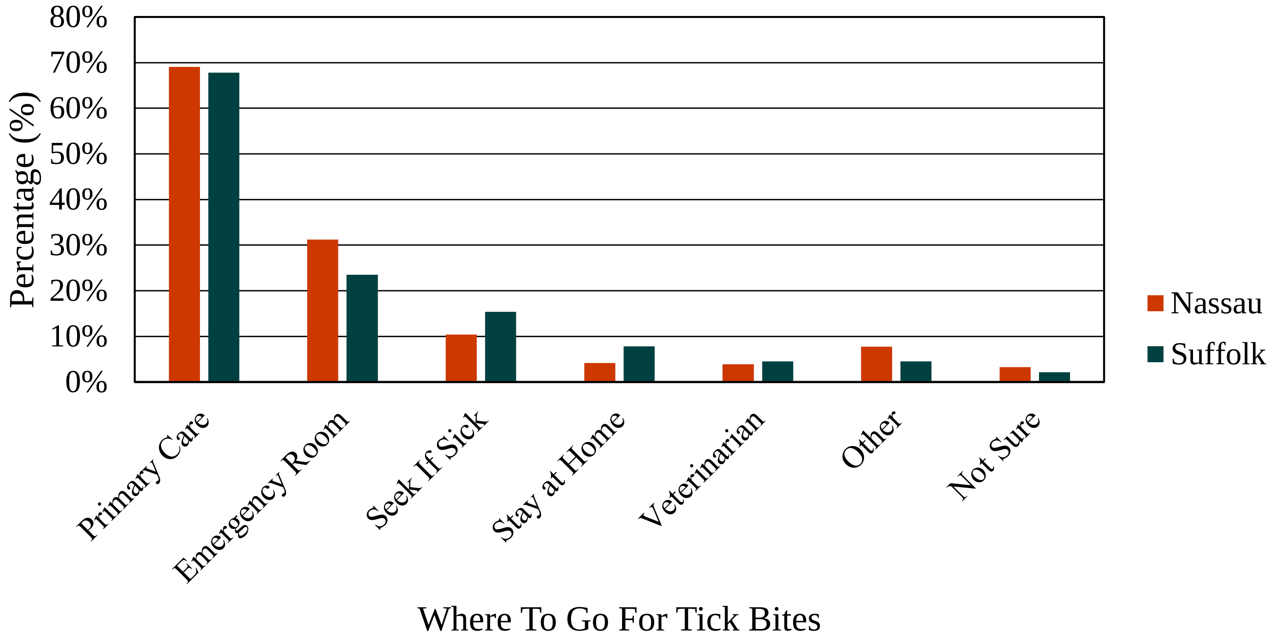

Figure 5. Distribution of responses to the question, "If I ever get bitten by a tick, I would go to: (select all that apply)." Health clinics and other places where Nassau County and Suffolk County residents seek help in relation to tick bites (modified $\chi 2 = 16.85$, resamples = 1999, bootstrap $p = 0.03$).

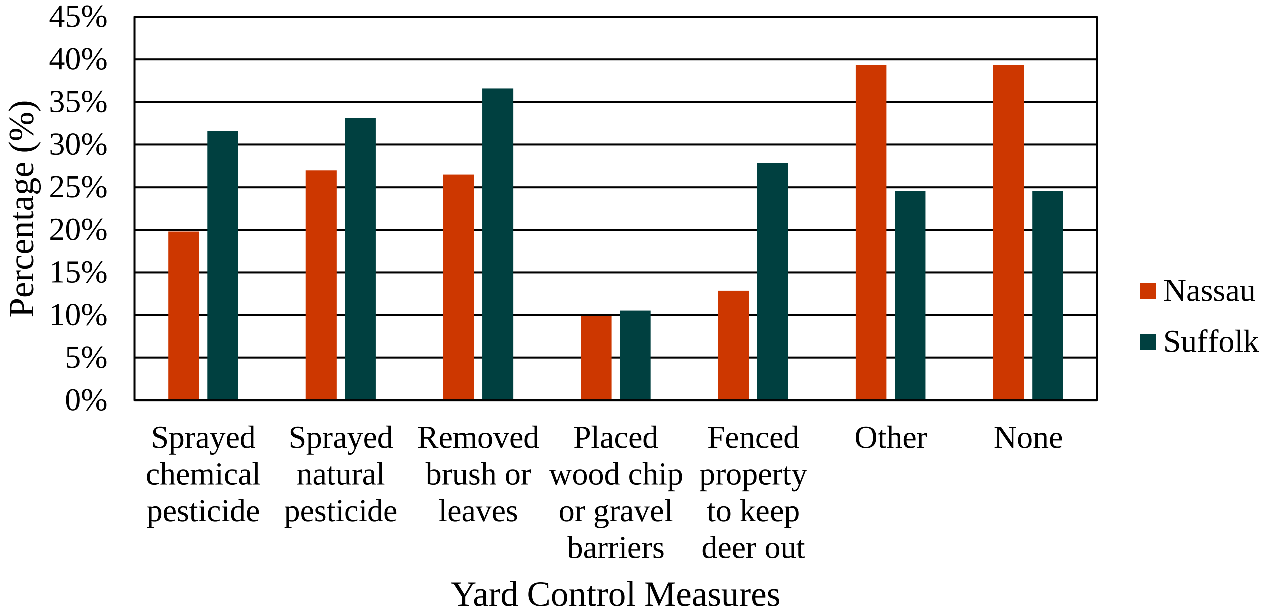

Figure 6. Yard control measures implemented by residents in Nassau County and Suffolk County (modified $\chi2 = 95.85$, resamples = 1999, bootstrap $p < 0.0005$). For Suffolk County, other means of control included keeping grass short, using homemade tick tubes, having chickens, and using plants that are natural insect repellent. For Nassau County, other means of control included burning citronella candles and applying tea tree oil to door posts, regular mowing, having a landscaper perform tick control measures, and reducing grass-covered areas in the yard with pavement or bricks.

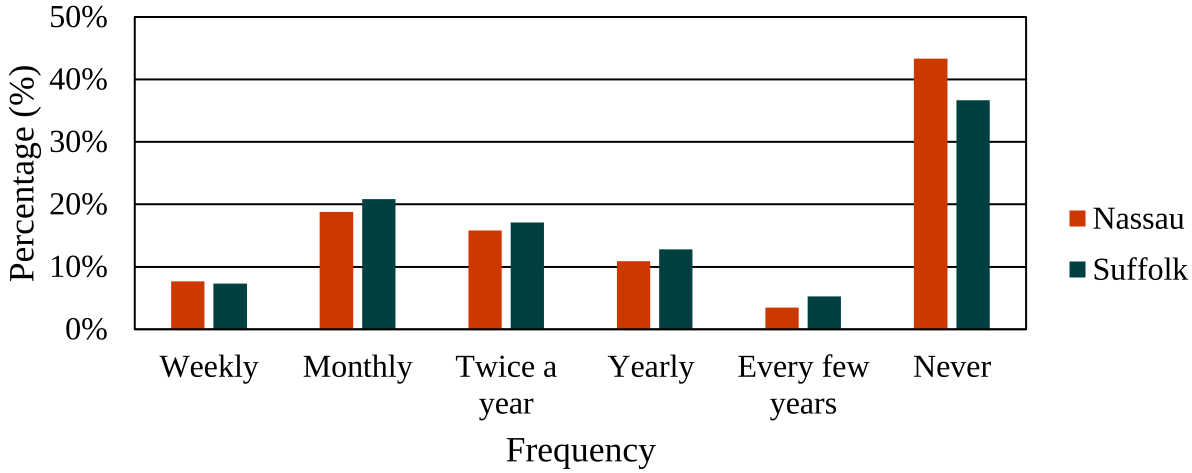

Figure 7. Frequency of spraying pesticide in a domestic setting among residents in Nassau County and Suffolk County.

TABLES

Table 1. Demographics of survey respondents from Nassau County and Suffolk County.

		Nassau County	Suffolk County	Sample Total	Expected (%)
Total		404 (50.31%)	399 (49.69%)	803 (100%)	52%, 48%
Age					
	18-24	49 (12.22%)	41 (10.49%)	90 (11.36%)	11%
	25-34	65 (16.21%)	58 (14.83%)	123 (15.53%)	15%
	35-44	69 (17.21%)	70 (17.90%)	139 (17.55%)	17%
	45-54	65 (16.21%)	90 (23.01%)	155 (19.57%)	19%
	55-64	75 (18.70%)	72 (18.41%)	147 (18.56%)	18%
	65 or older	78 (19.45%)	60 (15.35%)	138 (17.42%)	20%
Gender					
	Female	246 (61.19%)	245 (62.03%)	491 (61.61%)	
	Male	152 (37.81%)	149 (37.72%)	301 (37.77%)	
	Other	4 (1.00%)	1 (0.25%)	5 (0.63%)	
Race/Ethnicity					
	Asian	23 (5.81%)	15 (3.85%)	38 (4.83%)	
	Black/African American	32 (8.08%)	29 (7.44%)	61 (7.76%)	
	Hispanic/Latinx	32 (8.08%)	20 (5.13%)	52 (6.62%)	
	White	302 (76.26%)	317 (81.28%)	619 (78.75%)	
	Other	7 (1.77%)	9 (2.31%)	16 (2.04%)	
Income					
	$24,999 or less	33 (8.38%)	33 (8.59%)	66 (8.48%)	8%
	$25,000 - $49,999	41 (10.41%)	49 (12.40%)	90 (11.57%)	11%
	$50,000 - $99,999	88 (22.34%)	92 (23.96%)	180 (23.14%)	22%
	$100,000 - $149,999	84 (21.32%)	88 (22.92%)	172 (22.11%)	21%
	$150,000 or greater	148 (37.56%)	122 (31.77%)	270 (34.70%)	38%
Education					
	High School or Less	46 (11.59%)	71 (18.25%)	117 (14.89%)	
	College Student	67 (16.88%)	69 (17.74%)	136 (17.30%)	
	College Graduate	145 (36.52%)	148 (38.05%)	293 (37.28%)	
	Graduate or Above	139 (35.01%)	101 (25.96%)	240 (30.53%)	
Home Status					
	Homeowner	304 (81.28%)	289 (78.53%)	593 (79.92%)	
	Renter	70 (18.72%)	79 (21.47%)	149 (20.08%)	

Table 2. Accuracy of Nassau and Suffolk County residents visually assessing ticks from different life stages from non-tick insects.

County	Bed Bug	Tick Larvae	Flea	Adult Tick	Deer Ked	None	Sample Size
Nassau	133 (38.44%)	235 (67.92%)	92 (26.59%)	130 (37.57%)	107 (30.92%)	1 (0.29%)	346 (48.53%)
Suffolk	122 (33.24%)	270 (73.57%)	89 (24.25%)	178 (48.50%)	106 (28.88%)	4 (1.09%)	367 (51.47%)

Table 3. Responses from Nassau County and Suffolk County residents to questions related to concern about ticks and tick bites and overall feelings regarding the outdoors.

			Nassau	Suffolk	χ^2 Statistics
Statements					
	I am concerned about being bitten by ticks in the area.				$\chi^2 = 38.00$, df = 4, **$p < 0.0001$**
		Strongly disagree	29 (7.20%)	13 (3.27%)	
		Somewhat disagree	63 (15.63%)	26 (6.55%)	
		Neither agree nor disagree	63 (15.63%)	55 (13.85%)	
		Somewhat agree	154 (38.21%)	146 (36.78%)	
		Strongly agree	94 (23.33%)	157 (39.55%)	
		Total	403 (50.38%)	397 (49.63%)	
	Tickborne diseases have negatively affected my feelings about the outdoors.				$\chi^2 = 11.70$, df = 4, **$p = 0.02$**
		Strongly disagree	46 (11.47%)	52 (13.07%)	
		Somewhat disagree	74 (18.45%)	89 (22.36%)	
		Neither agree nor disagree	87 (21.70%)	93 (23.37%)	
		Somewhat agree	141 (35.16%)	97 (24.37%)	
		Strongly agree	53 (13.22%)	67 (16.83%)	
		Total	401 (50.19%)	398 (49.81%)	
	I am less likely to go to nature parks or hiking trails because I do not want to get a tickborne disease.				$\chi^2 = 5.04$, df = 4, $p = 0.3$
		Strongly disagree	40 (9.95%)	49 (12.31%)	
		Somewhat disagree	73 (18.16%)	86 (21.61%)	
		Neither agree nor disagree	108 (26.87%)	89 (22.36%)	
		Somewhat agree	118 (29.35%)	104 (26.13%)	
		Strongly agree	63 (15.67%)	70 (17.59%)	
		Total	402 (50.25%)	398 (49.75%)	
	Tickborne diseases are				$\chi^2 = 51.08$,

common in my area.				df = 4, **$p < 0.0001$**
	Strongly disagree	35 (8.68%)	17 (4.27%)	
	Somewhat disagree	100 (24.81%)	48 (12.06%)	
	Neither agree nor disagree	118 (29.28%)	102 (25.63%)	
	Somewhat agree	105 (26.05%)	127 (31.91%)	
	Strongly agree	45 (11.17%)	104 (26.13%)	
	Total	403 (50.31%)	398 (49.69%)	
One of my family members will likely get a tickborne disease within the next year.				$\chi^2 = 13.89$, df = 4, **$p = 0.008$**
	Strongly disagree	107 (26.62%)	75 (18.89%)	
	Somewhat disagree	123 (30.60%)	105 (26.45%)	
	Neither agree nor disagree	118 (29.35%)	141 (35.52%)	
	Somewhat agree	30 (7.46%)	35 (8.82%)	
	Strongly agree	24 (5.97%)	41 (10.33%)	
	Total	402 (50.31%)	397 (49.69%)	
I am concerned about being bitten by ticks near my home.				$\chi^2 = 44.35$, df = 4, **$p < 0.0001$**
	Strongly disagree	72 (17.87%)	38 (9.55%)	
	Somewhat disagree	119 (29.53%)	79 (19.85%)	
	Neither agree nor disagree	82 (20.35%)	69 (17.34%)	
	Somewhat agree	91 (22.58%)	122 (30.65%)	
	Strongly agree	39 (9.68%)	90 (22.61%)	
	Total	403 (50.31%)	398 (49.69%)	
I would not want to visit a vacation destination if they have a tick problem.				$\chi^2 = 8.53$, df = 4, $p = 0.07$
	Strongly disagree	19 (4.70%)	22 (5.53%)	
	Somewhat disagree	24 (5.94%)	43 (10.80%)	
	Neither agree nor disagree	64 (15.84%)	71 (17.84%)	
	Somewhat agree	135 (33.42%)	112 (28.14%)	
	Strongly agree	162 (40.10%)	150 (37.69%)	
	Total	404 (50.37%)	398 (49.63%)	

Table 4. Responses from Nassau County and Suffolk County residents regarding precautionary clothing and behavior against tick bites.

Statements		Nassau	Suffolk	χ^2 Statistics
I apply insect repellent.				
	Never	20 (4.95%)	25 (6.28%)	$\chi^2 = 6.10$, df = 4, p = 0.2
	Rarely	57 (14.11%)	50 (12.56%)	
	Sometimes	143 (35.40%)	118 (29.65%)	
	Often	114 (28.22%)	114 (28.64%)	
	Always	70 (17.33%)	91 (22.86%)	
	Total	404 (50.37%)	398 (49.63%)	
I wear long pants.				
	Never	8 (1.99%)	8 (2.02%)	$\chi^2 = 3.51$, df = 4, p = 0.5
	Rarely	30 (7.44%)	40 (10.10%)	
	Sometimes	152 (37.72%)	138 (34.85%)	
	Often	129 (32.01%)	139 (35.10%)	
	Always	84 (20.84%)	71 (17.93%)	
	Total	403 (50.44%)	396 (49.56%)	
I wear long-sleeved shirts.				
	Never	20 (4.96%)	18 (4.55%)	$\chi^2 = 0.41$, df = 4, p = 0.98
	Rarely	71 (17.62%)	73 (18.43%)	
	Sometimes	182 (45.16%)	176 (44.44%)	
	Often	86 (21.34%)	89 (22.47%)	
	Always	44 (10.92%)	40 (10.10%)	
	Total	403 (50.44%)	396 (49.63%)	
I perform tick checks.				
	Never	62 (15.38%)	40 (10.05%)	$\chi^2 = 36.21$, df = 4, **p < 0.0001**
	Rarely	107 (26.55%)	64 (16.08%)	
	Sometimes	114 (28.29%)	96 (24.12%)	
	Often	58 (14.39%)	95 (23.87%)	
	Always	62 (15.38%)	103 (25.88%)	
	Total	403 (50.31%)	398 (49.69%)	
I walk in the center of hiking trails to avoid brush				
	Never	32 (7.92%)	40 (10.08%)	$\chi^2 = 15.39$, df = 4, **p = 0.004**
	Rarely	20 (4.95%)	19 (4.79%)	
	Sometimes	83 (20.54%)	61 (15.37%)	
	Often	147 (36.39%)	112 (28.21%)	
	Always	122 (30.20%)	165 (41.56%)	
	Total	404 (50.44%)	397 (49.56%)	

	I tuck my pants into my socks.				
		Never	122 (30.20%)	111 (27.89%)	χ^2 = 4.48, df = 4, p = 0.34
		Rarely	89 (22.03%)	88 (22.11%)	
		Sometimes	101 (25.00%)	97 (24.37%)	
		Often	51 (12.62%)	43 (10.80%)	
		Always	41 (10.15%)	59 (14.82%)	
		Total	404 (50.37%)	398 (49.63%)	
	I shower within two hours of engaging in outdoors activities in a tick habitat.				
		Never	36 (8.91%)	34 (8.54%)	χ^2 = 9.21, df = 4, p = 0.06
		Rarely	62 (15.35%)	39 (9.80%)	
		Sometimes	125 (30.94%)	113 (29.39%)	
		Often	95 (23.51%)	101 (25.38%)	
		Always	86 (21.29%)	111 (27.89%)	
		Total	404 (50.37%)	398 (49.63%)	

Table 5. Minimum adequate model for binomial logistic regression on willingness to pay for private tick control (significant values highlighted in bold).

Conditional Fixed Effects			
	Estimate	Std. Error	p-value
(Intercept)	0.28	0.46	0.55
Household TBD Yes	**2.07**	**0.76**	**0.01**
Saw Tick Last Summer Yes	**0.73**	**0.32**	**0.02**
Age 25-34	1.14	0.67	0.09
Age 35-44	0.06	0.54	0.90
Age 45-54	-0.58	0.54	0.28
Age 55-64	-1.01	0.58	0.08
Age 65 or older	-0.69	0.55	0.21
AIC	BIC	Residuals DF	
303.8	332.1	246	

Table 6. Minimum adequate model for binomial logistic regression on willingness to pay for private tick control.

Conditional Fixed Effects			
	Estimate	Std. Error	p-value
(Intercept)	0.13	-0.79	0.87
Gender Male	0.63	0.31	**0.04**
Income $25K-$49,999	1.43	0.8	0.07
Income $50K-$99,999	0.24	0.64	0.70
Income $100K-149,999	0.21	0.64	0.74
Household TBD Yes	1.11	0.61	0.07
Saw Tick Last SummerYes	0.58	0.34	0.09
Education College Student	-0.38	0.47	0.42
Education Graduate/Above	-0.04	0.37	0.90
Education High School or Less	-0.86	0.49	0.08
Age 25-34	0.77	0.72	0.28
Age 35-44	-0.31	0.61	0.60
Age 45-54	-0.85	0.6	0.16
Age 55-64	-1.15	0.65	0.08
Age 65 or older	-0.66	0.62	0.29
Have Outdoor Pet Yes	0.47	0.32	0.14
AIC	BIC	Residuals DF	
316.3	376.4	237	

Table 7. Minimum adequate model for binomial regression for factors impacting likelihood to seek medical care when bitten by a tick.

Conditional Fixed Effects			
	Estimate	Std. Error	p-value
(Intercept)	1.72	0.47	< 0.001
Income $25,000-$49,000	**1.34**	**0.67**	**0.05**
Income $50,000-$99,000	0.97	0.55	0.08
Income $100,000-$149,000	0.78	0.53	0.15
Income >$150,000	**1.06**	**0.52**	**0.04**
Diagnosed with TBD Yes	**2.93**	**1.05**	**0.01**
Found Tick Biting on Self Yes	**-1.57**	**0.39**	**<0.0001**
Found Tick Crawling on Self Yes	-0.71	0.39	0.07

AIC	BIC	Residuals DF
334.0	367.4	470

Table 8. Minimum adequate model for binomial regression for factors impacting the likelihood of practicing yard control.

Conditional Fixed Effects			
	Estimate	Std. Error	p-value
(Intercept)	1.79	0.74	0.02
County Suffolk	**0.45**	**0.2**	**0.03**
Home Renter	**-0.64**	**0.27**	**0.02**
Age 25-34	-1.10	0.62	0.08
Age 35-44	**-1.70**	**0.61**	**0.01**
Age 45-54	**-1.74**	**0.6**	**0.004**
Age 55-64	**-2.34**	**0.59**	**<0.0001**
Age 65 or older	-1.58	0.6	0.01
Household TBD History Yes	**2.96**	**1.04**	**0.004**
Have Outdoor Pet Yes	**0.91**	**0.21**	**<0.0001**
Education College Student	0.50	0.38	0.19
Education College Graduate	0.45	0.31	0.15
Education Graduate/Above	-0.01	0.32	0.98
Diagnosed with TBD Yes	0.72	0.69	0.30
Race Black or African American	0.20	0.62	0.75
Race Hispanic/Latinx	0.25	0.63	0.70
Race White	-0.22	0.46	0.63

AIC	BIC	Residual DF
654.0	728.3	568

Table 9. Tickborne disease history among Nassau County and Suffolk County residents and their household.

			Nassau	Suffolk	χ^2 Statistics
Statements					
	I have been diagnosed with a tickborne disease.				
		No	383 (94.80%)	347 (87.63%)	χ^2 = 15.51, df = 2, **p = 0.0004**
		Yes	13 (3.22%)	40 (10.10%)	
		Not sure	8 (1.98%)	9 (2.27%)	
		Total	404 (50.50%)	396 (49.50%)	
	Someone in my household has been diagnosed with a tickborne disease.				
		No	363 (90.07%)	328 (82.41%)	χ^2 = 13.82, df = 2, **p = 0.001**
		Yes	27 (6.70%)	59 (14.82%)	
		Not sure	13 (3.23%)	11 (2.76%)	
		Total	403 (50.31%)	398 (49.69%)	
	I saw a tick last summer.				
		No	289 (71.53%)	188 (47.12%)	χ^2 = 72.78, df = 2, **p-value < 0.0001**
		Yes	77 (19.06%)	189 (47.37%)	
		Not sure	38 (9.41%)	22 (5.51%)	
		Total	404 (50.31%)	399 (49.69%)	
	I have found a tick biting me before.				
		No	330 (81.68%)	234 (58.65%)	χ^2 = 60.30, df = 2, **p-value < 0.0001**
		Yes	54 (13.37%)	148 (37.09%)	
		Not sure	20 (4.95%)	17 (4.426%)	
		Total	404 (50.31%)	399 (49.69%)	
	I have found a tick crawling on me before.				
		No	304 (75.43%)	186 (46.62%)	χ^2 = 77.26, df = 2, **p-value < 0.0001**
		Yes	76 (18.86%)	190 (47.62%)	
		Not sure	23 (5.71%)	23 (5.76%)	
		Total	403 (50.25%)	399 (49.75%)	
	I have a pet that goes outdoors.				
		No	267 (66.09%)	202 (50.75%)	χ^2 = 18.79, df = 1, **p-value < 0.0001**
		Yes	137 (33.91%)	196 (49.25%)	
		Total	404 (50.37%)	398 (49.63%)	

Table 10. Minimum adequate model for linear regression for factors important for perceived tick bite susceptibility score.

Conditional Fixed Effects			
	Estimate	Std. Error	p-value
(Intercept)	-0.49	0.05	< 0.0001
County Suffolk	**0.30**	**0.08**	**0.0001**
Diagnosed with TBD Yes	**0.49**	**0.17**	**0.003**
Household TBD History Yes	**0.47**	**0.14**	**0.001**
Saw Tick Last Summer Yes	**0.51**	**0.09**	**< 0.0001**
Found Tick Crawling on Self Yes	**0.31**	**0.09**	**0.001**

AIC	BIC	Residual DF
1494.6	1525.2	572

Table 11. Minimum adequate model for linear regression for factors important for reduced outdoor behavior score.

Conditional Fixed Effects			
	Estimate	Std. Error	p-value
(Intercept)	-0.49	0.16	0.04
County Suffolk	**-0.21**	**0.08**	**0.01**
Gender Male	**-0.18**	**0.08**	**0.03**
Income $25,000-$49,000	-0.06	0.20	0.78
Income $50,000-$99,000	-0.24	0.17	0.16
Income $100,000-$149,000	**-0.37**	**0.18**	**0.04**
Income >$150,000	**-0.5**	**0.17**	**0.003**
Diagnosed with TBD Yes	**0.56**	**0.18**	**0.002**
Household TBD History Yes	**0.46**	**0.15**	**0.002**
Saw Tick Last Summer Yes	**0.21**	**0.09**	**0.02**
AIC	BIC	Residual DF	
1608.0	1655.9	568	

Table 12. Minimum adequate model for linear regression for factors important for protective behavior scores.

Conditional Fixed Effects			
	Estimate	Std. Error	p-value
(Intercept)	0.05	0.17	0.76
Black or African American	-0.10	0.22	0.65
Hispanic/Latinx	-0.33	0.22	0.14
White	**-0.36**	**0.17**	**0.03**
Diagnosed with TBD	**0.47**	**0.17**	**0.007**
Household TBD History	**0.56**	**0.14**	**<0.0001**
Saw Tick Last Summer	**0.54**	**0.08**	**<0.0001**
AIC	BIC	Residual DF	
1552.7	1587.6	572	

Table 13. Multinomial logistic regression relationship between tick concern and willingness to pay.

Type of Control	Items	Coefficient	Std. Error
Private			
	Maybe	0.35	0.10
	Yes	0.86	0.16
	Residual Deviance:	1401.21	
	AIC:	1409.21	
Public			
	Maybe	0.22	0.10
	Yes	0.60	0.11
	Residual Deviance:	1446.13	
	AIC:	1454.13	

SUPPLEMENTARY TABLES

Supplementary Table 1. Factor Loadings for the two-factor principal component analysis in the attitudes section.

Items	Factor Loadings for perceived tick bite susceptibility	Factor Loadings for reduced outdoor behavior	Communalities	Uniqueness
Tickborne diseases are common in my area	0.93		0.74	0.26
I am concerned about being bitten by ticks near my home	0.79		0.75	0.25
I am concerned about being bitten by ticks in the area	0.76		0.65	0.35
One of my family members will likely get a tickborne disease within the next year	0.68		0.57	0.43
I am less likely to go to nature parks and hiking trails because I do not want to get a tickborne disease.		0.93	0.85	0.15
Tickborne diseases have negatively affected my feelings about the outdoors		0.88	0.83	0.17
Sum of Square Loadings	2.60	1.79		
Proportion Variance	0.43	0.30		
RMSR	0.08			
Empirical Chi-Square	160.82 with probability < 0.0001			
Fit based upon off diagonal values	0.97			

Supplementary Table 2. Factor loadings for the one-factor principal component analysis in the precaution section of the survey.

Items	Factor Loadings	Communalities	Uniqueness
Wear Long-Sleeve Shirts	0.75	0.56	0.44
Tuck Pants Into Socks	0.75	0.56	0.44
Perform Tick Checks	0.7	0.49	0.51
Apply Insect Repellent	0.67	0.45	0.55
Wear Long Pants	0.66	0.44	0.56
Shower Within Two Hours	0.64	0.41	0.59
Walk in Center of Trails	0.57	0.33	0.67
Sum of Square Loadings	3.21		
Proportion Variance	0.46		
RMSR	0.12		
Empirical Chi-Square	725.56 with probability < 0.0001		
Fit based upon off diagonal values	0.96		

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APPENDIX 1. FULL SURVEY QUESTIONNAIRE

Start of Block: Consent Page

We are requesting your participation in a research study titled "Knowledge, Attitudes, and Practices Regarding Tick-Borne Diseases in Long Island, New York." This study is led by Mervin Keith Cuadera, from the Department of Entomology at Cornell University and is an initiative of the CDC-funded Northeast Regional Center of Excellence in Vector-Borne Diseases. The Faculty Advisor for this study is Dr. Laura Harrington, from the Department of Entomology at Cornell University.

What the study is about

The purpose of this research study is to identify the knowledge, attitudes and practices regarding ticks and tick-borne diseases of individuals living in Long Island, New York. You were invited to participate in our study because you indicated that you resided in Long Island.

What we will ask you to do

We will ask you to complete an online survey questionnaire truthfully and to the best of your ability. While taking the survey, please do not use any aids to answer the questions. The survey will take about 10 minutes of your time. In order for the survey results to be useful to our study team, we need you to answer all questions in the survey, especially a few questions that we've indicated as "required".

Risks and discomforts

We do not anticipate any risks or discomforts from participating in this research. We anticipate that your participation in this survey will present no greater risk to you than everyday use of the Internet.

Benefits

While you will not receive any direct benefits from participating in this research study, your responses will help determine areas of focus for public health programming in Long Island, New York regarding tick-borne diseases, which is a major regional public health concern.

Compensation for participation

There is no compensation for participation in this research other than what is provided by Qualtrics for being in their survey panel.

Privacy/Confidentiality/Data Security

Your responses will be anonymous and the researcher will not collect any identifying personal information about you. Your survey answers will be stored in a password protected electronic format. Qualtrics does not collect personal information such as your name, email address or IP address. Data resulting from this process is called "de-identified".

Sharing De-identified Data Collected in this Research

De-identified data from this study may be shared with the research community at large to advance science and health. We will remove or code any personal information that could identify you before files are shared with other researchers to ensure that, by current scientific standards and known methods, no one will be able to identify you from the information we share. Despite these measures, we cannot guarantee anonymity of your personal data.

Taking part is voluntary

Your participation in this survey is voluntary. You may refuse to participate before the study begins or discontinue at any time. However, in order to participate, you must answer the required questions in the survey. The results of the survey will not be useful to us if you do not answer the required questions and will be less useful if you do not answer all of the questions. If you do not want to answer all of the questions, you may decline to participate now.

Required Questions

The required questions in the survey will not be linked to any identifiable information. We will be asking you a mixture of questions related to your understanding of tick-borne diseases, your views on tick control practices and how important tick control is to you.

If you have questions

The main researcher conducting this study is Mervin Keith Cuadera, a graduate student at Cornell University. Please ask any questions you have now at mc2658@cornell.edu. If you have questions before, during, or after the survey, you may contact Mervin at mc2658@cornell.edu or via telephone at 301-281-3595. If you have any questions or concerns regarding your rights as a subject in this study, you may contact the Institutional Review Board (IRB) for Human Participants at 607-255-5138 or access their website at http://www.irb.cornell.edu. You may also report your concerns or complaints anonymously through Ethicspoint online at www.hotline.cornell.edu or by calling toll free at 1-866-293-3077. Ethicspoint is an independent organization that serves as a liaison between the University and the person bringing the complaint to ensure anonymity.

Clicking on the "Agree" button indicates that:

- You have read the above information.
- You voluntarily agree to participate.
- You are 18 years of age or older.

Please select your choice below.

- o Agree
- o Disagree

End of Block: Consent Page

Start of Block: Demographic Questions

Which county do you live in?

- o Suffolk County
- o Nassau County
- o Prefer not to answer

Are you a homeowner or a renter?

- o Homeowner
- o Renter
- o Prefer not to answer

What is your age?

- 18 - 24
- 25 - 34
- 35 - 44
- 45 - 54
- 55 - 64
- 65 or older
- Prefer not to answer

What is your gender?

- Male
- Female
- Non-Binary/Other
- Prefer not to answer

What is your race/ethnicity?

- White
- Black or African American
- Hispanic/Latinx
- American Indian or Alaska Native
- Asian
- Native Hawaiian or Pacific Islander
- Multi-ethnic/ Other Race/Ethnicity: ____
- Prefer not to answer

What is the highest education you've attained?

- High School or Less
- College Student
- College Graduate
- Graduate/Above
- Prefer not to answer

What is your household income?

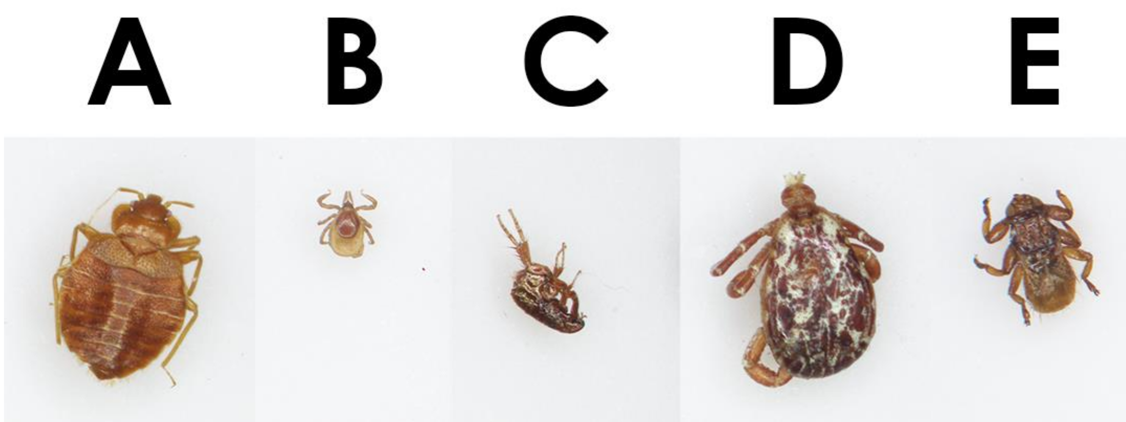
- < $15,000
- $15,000-24,999
- $25,000-34,999
- $35,000-49,999
- $50,000-74,999
- $75,000-99,999
- $100,000-124,999
- $125,000-149,999
- $150,000-199,999
- >$200,000
- Prefer not to answer

End of Block: Demographic Questions

Start of Block: Knowledge Section

Please rate your knowledge about Lyme Disease.

- A lot
- Some
- A little
- None



Which of the above choices show a tick? (Check all that apply)

- ▢ A
- ▢ B
- ▢ C
- ▢ D
- ▢ E
- ▢ None
- ▢ Don't know

Name a unique symptom of Lyme disease.

- o Symptom: ____
- o Don't know

Majority of ticks are infected with Lyme disease.

- o Strongly agree
- o Somewhat agree
- o Somewhat disagree
- o Strongly disagree

In most cases, infected ticks will transmit Lyme disease if they are not pulled off within 15 minutes.

- o Strongly agree
- o Somewhat agree
- o Somewhat disagree
- o Strongly disagree

Lyme disease can be treated.

- o Strongly agree
- o Somewhat agree
- o Somewhat disagree
- o Strongly disagree

How is Lyme disease usually treated? (Select all that apply)

- ▢ Short-term antibiotic treatment
- ▢ Long-term antibiotic treatment
- ▢ Natural therapy (acupuncture, herbal remedies)
- ▢ No effective treatment is available
- ▢ Other: ____
- ▢ Not sure

There is a chronic form of Lyme disease (a more permanent and long lasting condition caused when the germ can't be killed inside the body).

- o Strongly agree
- o Somewhat agree
- o Somewhat disagree
- o Strongly disagree

Generally speaking, which age group(s) are at highest risk for getting Lyme disease? (select all that apply)

- ▢ Children (0-12)
- ▢ Teens (13-17)
- ▢ Young Adults (18-35)
- ▢ Middle Aged Adults (36-60)
- ▢ Older Adults (>60)
- ▢ Not Sure

What season are people most at risk of being bitten by ticks?

- o Spring
- o Summer
- o Fall
- o Winter
- o Not sure

End of Block: Knowledge Section

Start of Block: Attitudes Section

Tick-borne diseases are spread through the bite of infected ticks. Ticks can spread bacteria, viruses and parasites through their bites, including the bacteria that causes Lyme disease. Please let us know your attitudes regarding the following sentences about ticks and tick-borne diseases.

I am concerned about being bitten by ticks in the area.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Tick-borne diseases have negatively affected my feelings about the outdoors.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

I am less likely to go to nature parks and hiking trails because I do not want to get a tick-borne disease.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Tick-borne diseases are common in my area.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

One of my family members will likely get a tick-borne disease within the next year.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

I am concerned about being bitten by ticks near my home.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

I would not want to visit a vacation destination if they have a tick problem.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

End of Block: Attitudes Section

Start of Block: Practices Section: Precautions

Please let us know how often you take the following precautions to avoid tick bites when outdoors.

I apply insect repellent.

- Always
- Often
- Sometimes
- Rarely
- Never

I wear long pants.

- Always
- Often
- Sometimes
- Rarely
- Never

I wear long-sleeved shirts.

- Always
- Often
- Sometimes
- Rarely
- Never

I perform tick checks.

- Always
- Often
- Sometimes
- Rarely
- Never

I walk in the center of hiking trails to avoid brush.

- Always
- Often
- Sometimes
- Rarely
- Never

I tuck my pants into my socks.

- Always
- Often
- Sometimes
- Rarely
- Never

I shower within two hours of engaging in outdoor activities in a tick habitat.

- Always
- Often
- Sometimes
- Rarely
- Never

Other precautions I take: ____

End of Block: Practices Section: Precautions

Start of Block: Practices: Tick Bites

The following questions will ask about how you respond when coming into contact with a tick.

Please let us know how you would respond when encountering a tick.

If I find a tick biting me, I plan on removing it by: (select all that apply)

- ▢ Pulling it out using fine-tipped tweezers
- ▢ Burning the tick by using a flame
- ▢ Kill the tick by putting alcohol/hand sanitizer on it
- ▢ Visiting a medical professional
- ▢ Other: ____
- ▢ Not sure

If I ever get bitten by a tick, I would seek medical care.

- Yes
- No
- Not sure

If I ever get bitten by a tick, I would go to: (select all that apply)

- ▢ Primary Care Provider
- ▢ Veterinarian
- ▢ Emergency Room
- ▢ Stay at Home
- ▢ Only seek medical care if I feel sick
- ▢ Other: ____
- ▢ Not sure

End of Block: Practices: Tick Bites

Start of Block: Practices Section: Pesticide Use

Pesticides are substances used to kill pests such as ticks and mosquitoes. They can be man-made chemicals or natural products. They are often applied in yards to control pests. The following questions will ask about your attitudes and use of pesticides to control ticks.

I approve of using pesticides on my yard to control ticks.

- o Strongly agree
- o Somewhat agree
- o Neither agree nor disagree
- o Somewhat disagree
- o Strongly disagree

(if not) Why do you not approve of using pesticides on your yard? __________________

How often do you spray pesticides on your yard to control ticks during warm months?

- o Weekly
- o Monthly
- o Twice a year
- o Yearly
- o Every few years
- o Never

What control measures have you used to reduce the number of ticks in your yard? (select all that apply)

- ▢ Sprayed a chemical pesticide
- ▢ Sprayed a natural pesticide
- ▢ Removed brush or leaves
- ▢ Placed wood chip or gravel barriers
- ▢ Fenced property to keep deer out
- ▢ None
- ▢ Other: ____

Do you hire someone to spray pesticide on your property?

- ○ Yes
- ○ Maybe
- ○ No

I am willing to pay for tick control services provided by a private pest control company.

- ○ Yes
- ○ Maybe
- ○ No

I am willing to pay taxes to support tick control near my home.

- ○ Yes
- ○ Maybe
- ○ No

The most I am willing to pay for a private pest control company to provide tick control services **each year** is:

- $0
- $1-39
- $40-79
- $80-119
- $120-159
- $160-199
- $200-239
- $240-279
- $280-319
- $320-359
- >$360

The most I am willing to pay for tick control in taxes **each year** is:

- $0
- $10
- $20
- $30
- $40
- $50
- $60
- $70
- $80
- $90
- $100

End of Block: Practices Section: Pesticide Use

Start of Block: Tick Disease History

Tick-borne diseases are spread through the bite of infected ticks. Ticks can spread bacteria, viruses and parasites through their bites, including the bacteria that causes Lyme disease. The next questions ask about your personal experience with tick-borne diseases.

I have been diagnosed with a tick-borne disease.

- Yes
- No
- Not Sure

Someone in my household has been diagnosed with a tick-borne disease.

- Yes
- No
- Not Sure

I saw a tick last summer.

- Yes
- No
- Not Sure

I have found a tick biting me before.

- Yes
- No
- Not Sure

I have found a tick crawling on me before.

- Yes
- No
- Not Sure

I have a pet that goes outdoors. (Pets that are either outdoor for most of the year or are allowed to go outside)

- Yes
- No

(If yes to previous question) Have you ever found a tick crawling on your pet before?

- ○ Yes
- ○ No
- ○ Not Sure

Have you ever found a tick biting your pet before?

- ○ Yes
- ○ No
- ○ Not Sure

How often have you seen a tick on your pet during summer months?

- ○ Daily
- ○ 4-6 times a week
- ○ 2-3 times a week
- ○ Once a week
- ○ Never

What type of pet do you have? (select all that apply)

- ▢ Dog
- ▢ Cat
- ▢ Horse
- ▢ Other: ____

End of Block: Tick Disease History
