# ASSESSMENT AND MANAGEMENT OF VECTOR TICK POPULATIONS IN NEW JERSEY

**Terry L. Schulze and Robert A. Jordan**

## A Guide for Pest Management Professionals, Land Managers, and Public Health Officials

**FREEHOLD TOWNSHIP HEALTH DEPARTMENT**

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*Cover:* Female blacklegged tick, *Ixodes scapularis*, courtesy of Terry L. Schulze

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# Introduction

Ticks have long been known as major nuisance pests of man and animals, but it was not until fairly recently that human tick-borne diseases in New Jersey were recognized as a significant public health threat. The emergence of tick-borne diseases began in 1975, when a cluster of what appeared to be juvenile arthritis cases was identified in the towns of Lyme, Old Lyme, and East Haddom, Connecticut. By the end of the 1970s, epidemiologic investigations led to the identification of a separate clinical entity, termed Lyme disease, and the discovery that a tick was responsible for transmission of the as yet unknown causative agent or pathogen. Over the next few years, Lyme disease became recognized in several other coastal northeastern and mid-Atlantic states, including New Jersey, but it was not until the early 1980s that a new species of spirochete, a type of bacterium, was isolated from ticks. The discovery of the causative agent resulted in a dramatic increase in Lyme disease and other tick-borne disease-related research that produced much of the information included in this manual.

Over the last two decades, Lyme disease has become the most frequently reported vector-borne illness in the United States, with over 181,000 confirmed cases reported to the Centers for Disease Control and Prevention (CDC) between 1990 and 2002. During the same period, New Jersey ranked fourth with respect to Lyme disease reporting, with over 21,000 cases or 11.6% of the national total. While the importance of Lyme disease cannot be overstated, several other tick-borne illnesses are now known to occur in New Jersey, including human babesiosis, human granulocytic anaplasmosis, and human monocytic ehrlichiosis. Others will likely be identified in the future. The transmission cycles of these diseases are extraordinarily complex, so that a complete understanding of the biology, behavior, and ecology of each tick vector and its hosts is essential to the design of effective, site-specific tick management strategies.

This manual provides technical information on the assessment and management of vector tick populations, including an overview of the tick-borne diseases of New Jersey. Detailed information on tick identification, biology, behavior, and ecology will serve as the basis for discussions on assessing risk and categorizing the currently available tick control technologies, their relative effectiveness, advantages and disadvantages, and potential roles in integrated tick control strategies. A list of references used in preparation of this manual is also included and the reader is encouraged to access these materials for more detailed information about specific subjects.

# Tick-borne Diseases of New Jersey

The decision to initiate control efforts against any pest species is normally triggered by an over-abundance of the pest that is perceived to cause unacceptable impacts on human well-being. In most situations, low to moderate pest populations are considered below an economic threshold when efforts to reduce pest numbers are deemed impractical, too costly or result in collateral environmental impacts that cannot be justified. The exception to this principle is when public health is threatened. This is particularly true in the case of Lyme disease, where the presence of even moderate populations of the blacklegged tick, *Ixodes scapularis* (formerly *Ixodes dammini*), poses substantial risk of transmission by virtue of the fact that the degree to which the tick population is infected (infection prevalence) is so high, often exceeding 50%, and exposure to infected ticks occurs most often in residential settings. In such cases, the cost of suppressing pest populations must be weighed against the medical, emotional, and productivity costs associated with the disease. Although a detailed discussion is beyond the scope of this manual, an overview of tick-borne diseases encountered in New Jersey may provide useful insight into the history, complexity, and magnitude of this significant public health problem and may help illustrate the importance of tick control in reducing the risk of disease transmission.

**Rocky Mountain Spotted Fever**

Bruce J. Marlin and Cirrus Digital Imaging

Rocky Mountain spotted fever (RMSF) was first made reportable to New Jersey public health officials in 1961. RMSF is caused by the bacterium *Rickettsia rickettsii* and is transmitted primarily by the American dog tick, *Dermacentor variabilis*. The percentage of infected ticks in New Jersey is unknown. The brown dog tick, *Rhipicephalus sanguineus*, has recently been implicated as a secondary vector. Transmission occurs through the bite of an infected tick or by contact with crushed tissue or feces of the tick through breaks in skin or mucous membranes. The principal source of the pathogen in nature (reservoir host) is the meadow vole, *Microtus pennsylvanicus*, although the infection is also maintained between tick life stages (transstadial transmission) and from females to eggs (transovarial transmission). Following an incubation period of 3-14 days, the disease is marked by sudden onset of fever, which may persist for several weeks in untreated cases, malaise, muscle pain, severe headache, chills, and conjunctivitis. A spotted rash may appear on the palms and soles in about 50% of cases, and may spread rapidly to other parts of the body. The fatality rate may reach 15-20% in untreated cases. An average of 10 confirmed cases of RMSF are reported annually in New Jersey.

**Lyme Disease**

Michael R. Patnaude

First made reportable in New Jersey in 1981, Lyme disease is a multi-systemic, inflammatory disorder caused by the spirochete *Borrelia burgdorferi* that is transmitted primarily through the bite of an infected nymphal blacklegged tick, known more familiarly as the deer tick. About 50% of adult and 25% of nymphal blacklegged ticks are infected with Lyme disease spirochetes. The white-footed mouse, *Peromyscus leucopus*, and Eastern chipmunk, *Tamias striatus*, are the primary reservoir hosts. The infection is maintained transstadially in the tick, but transovarial passage is infrequent. Within 3-30 days following tick bite, Lyme disease is often, but not always, characterized by a distinctive skin lesion known as *erythema migrans* (EM), which first appears as a red, raised area that expands in size over time and may develop central clearing. Single or multiple lesions are usually preceded or accompanied by a variety of other symptoms, including headache, fever, fatigue, malaise, joint pain, stiff neck, and nausea. If untreated, neurological and cardiac symptoms may develop within weeks or months of the appearance of EM. Finally, individuals may develop swelling and pain in the large joints. In both the early and advanced phases of Lyme disease, symptoms are often recurrent and may become chronic in untreated individuals. During the last 5 years, over 2,500 confirmed Lyme disease cases have been reported annually in New Jersey.

Terry L. Schulze

Charles Stephen

**Human Babesiosis**

Human babesiosis is a malaria-like illness caused by the protozoan *Babesia microti* transmitted by nymphal blacklegged ticks. White-footed mice and meadow voles are the principal reservoirs. A study in northern New Jersey showed that 5% of blacklegged ticks were infected with *B. microti*. Symptoms may be mild to severe and include fever, chills, headache, muscle pain, fatigue, and anemia, which may persist from several days to months. Asplenic, immunocompromised, and elderly individuals are at increased risk of infection. The time between pathogen transmission and onset of illness (incubation period) is 1-8 weeks, but individuals may be asymptomatic for up to 1 year. Although the first case of babesiosis in New Jersey was not confirmed until 1997, over 50 cases are now reported annually.

**Human Granulocytic Anaplasmosis**

Human granulocytic anaplasmosis (HGA), formerly referred to as human granulocytic ehrlichiosis (HGE), is caused by the bacterium *Anaplasma phagocytophilum*. Recent studies in New Jersey have shown the infection prevalence in the blacklegged tick vector to be between 6-17%. The white-footed mouse is the probable reservoir. Non-specific symptoms, which normally occur within 1-2 weeks following tick bite, may be mild to severe and include fever, chills, malaise, headache, muscle aches and pain, and nausea. Although reportable in New Jersey since 1995, the first case of HGA was not reported until 1997 and about 5 cases are reported annually.

**Human Monocytic Ehrlichiosis**

Human monocytic ehrlichiosis (HME) is a rickettsial disease characterized by fever, headache, muscle aches and pain, anorexia, abdominal pain, and confusion occurring 1-3 weeks following the bite of an infected lone star tick, *Amblyomma americanum*. The probable reservoirs are the white-tailed deer, *Odocoileus virginianus*, and wild rodents. Infection prevalence of the causative agent *Ehrlichia chaffeensis* in lone star ticks is about 12%, while the prevalence of *E. ewingii*, a similar ehrlichial pathogen, is approximately 8%. The American dog tick is considered a secondary vector of *E. chaffeensis*. Over 10 cases of HME have been reported annually in New Jersey since 1995.

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**Southern Tick-Associated Rash Illness**

Southern tick-associated rash illness (STARI) is clinically indistinguishable from Lyme disease in its early stages. It has been suggested that STARI is caused by the spirochete *B. lonestari* that is transmitted by lone star ticks. The reservoirs are unknown, but likely include white-tailed deer. Because of its similarity to Lyme disease, the extent to which STARI occurs in New Jersey has not been determined. However, studies in New Jersey have shown that the infection prevalence of *B. lonestari* in lone star ticks is 4-9%.

**Co-infectivity**

Potentially complicating the diagnosis and treatment of these diseases is the fact that ticks may be infected with more than one agent. Recent research has shown blacklegged ticks in New Jersey to be simultaneously co-infected with disease agents for both Lyme disease and HGA (2.7-6.0%), Lyme disease and human babesiosis (2.0%), and HGA and human babesiosis (2.0%). Lone star ticks have been shown to be co-infected with the infectious agents of HME (4.1%) and both STARI and HME (0.8%).

**Tick Paralysis**

In rare instances, a toxin produced by the American dog tick after feeding for 5-7 days causes an ascending, symmetrical paralysis that begins with the lower limbs and progresses within several hours to the torso, upper limbs, and head, causing loss of coordination, irregular breathing, and slurred speech. Although death may result through respiratory failure, complete recovery usually occurs within 24 hours following removal of the tick.

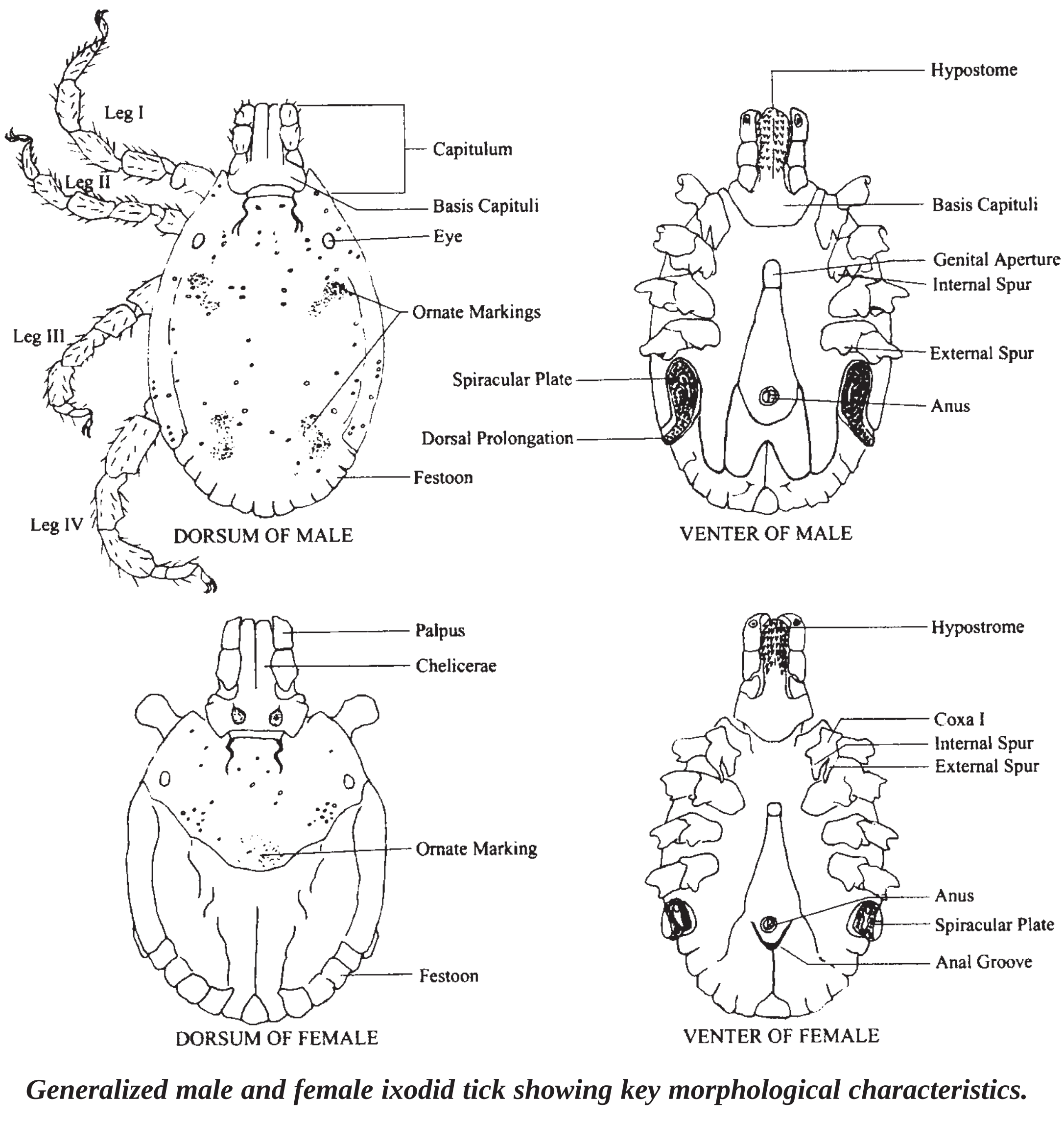
**Tick-borne Diseases of Domestic Animals**

In addition to its importance in human disease transmission, blacklegged ticks are also involved in transmitting the Lyme disease spirochete to dogs, cats, and certain livestock species, most notably horses and cattle. The brown dog tick, lone star tick, and American dog tick have been variously implicated in the transmission of canine ehrlichiosis and canine babesiosis. The American dog tick is also responsible for causing tick paralysis in dogs. The extent to which tick-borne diseases affect livestock and wildlife in New Jersey is unknown.

# Tick Morphology and Identification

Ticks are not insects, but are more closely related to spiders and mites. There are two families of ticks that occur in New Jersey--the soft ticks (Argasidae) and the hard ticks (Ixodidae), the latter deriving their name from the large shield-like scutum located on the dorsal or upper surface of the tick. However, since all of the ticks of medical and veterinary importance in New Jersey are hard (ixodid) ticks, they will be the focus of this manual.

The body of the medically important ixodid ticks considered here is flattened dorsoventrally (top to bottom) and is readily distinguished from that of insects by the presence of only two body regions, the gnathosoma and idiosoma, that appear undivided, while insects have three body segments (head, thorax, and abdomen). Nymphal and adult ticks have 4 pair of legs, while larvae have 3 pair. Insects always have 3 pairs of legs. Ticks are classified to genus and species by the characteristics of several key anatomical structures that include their presence or absence, size, shape, and/or number. For example, the mouthparts, which constitute the




USDA adapted from Strickland et al. 1976

*Generalized male and female ixodid tick showing key morphological characteristics.*

gnathosoma, are located at the front (anterior) end of the tick on a structure called a capitulum and consist of a basis capitulum, paired palps, paired chelicerae, and a hypostome. The length of the mouthparts, shape of the basis capitulum, and the number of recurved teeth on the hypostome are among these key characteristics. The shield-like structure located on the dorsal (top) surface of the tick behind the capitulum, known as a scutum, covers a portion of the idiosoma in the larvae, nymphs, and females. In males, the scutum covers most of the idiosoma. In adults of some species, the scutum is ornate and characteristic markings are often used in identification. The presence or absence of festoons, eyes, anal plates, an anal groove or the number and configuration of spurs on the legs are also used in tick identification. However, some of these structures cannot be observed in engorged ticks.

In discussions about Lyme disease, mention is often made of the small size of immature blacklegged ticks. In fact, the subadult stages of all ticks are quite small, making identification difficult to the untrained eye. In contrast, the identification of the adult stage of ticks discussed in this manual is relatively simple. For example, the mouthparts of blacklegged ticks are relatively long with broad, paddle-shaped palps. The scutum is uniformly dark brown to black in color, while the idiosoma of females is a characteristic brick-red color. Eyes and festoons are absent. The lone star tick is somewhat larger, brown in color, and rounder in appearance than the blacklegged tick. Its mouthparts are quite long and slender. Eyes and festoons are present. The lone star tick derives its name from the characteristic white spot on the posterior margin of the scutum in the female. Faint white markings may be observed on festoons along the posterior margin of the abdomen. The largest of the ticks discussed here is the American dog tick, whose mouthparts are relatively short compared to those of the blacklegged and lone star tick. Eyes and festoons are present. The scutum is ornate and characterized by mottled white markings throughout, while the idiosoma is chestnut-brown in color. The brown dog tick is uniformly brown in color with relatively short mouthparts and an inornate scutum. Eyes and festoons are present. In all ixodid ticks, females are noticeably larger than males.

## Tick Distribution, Biology, Behavior, and Ecology

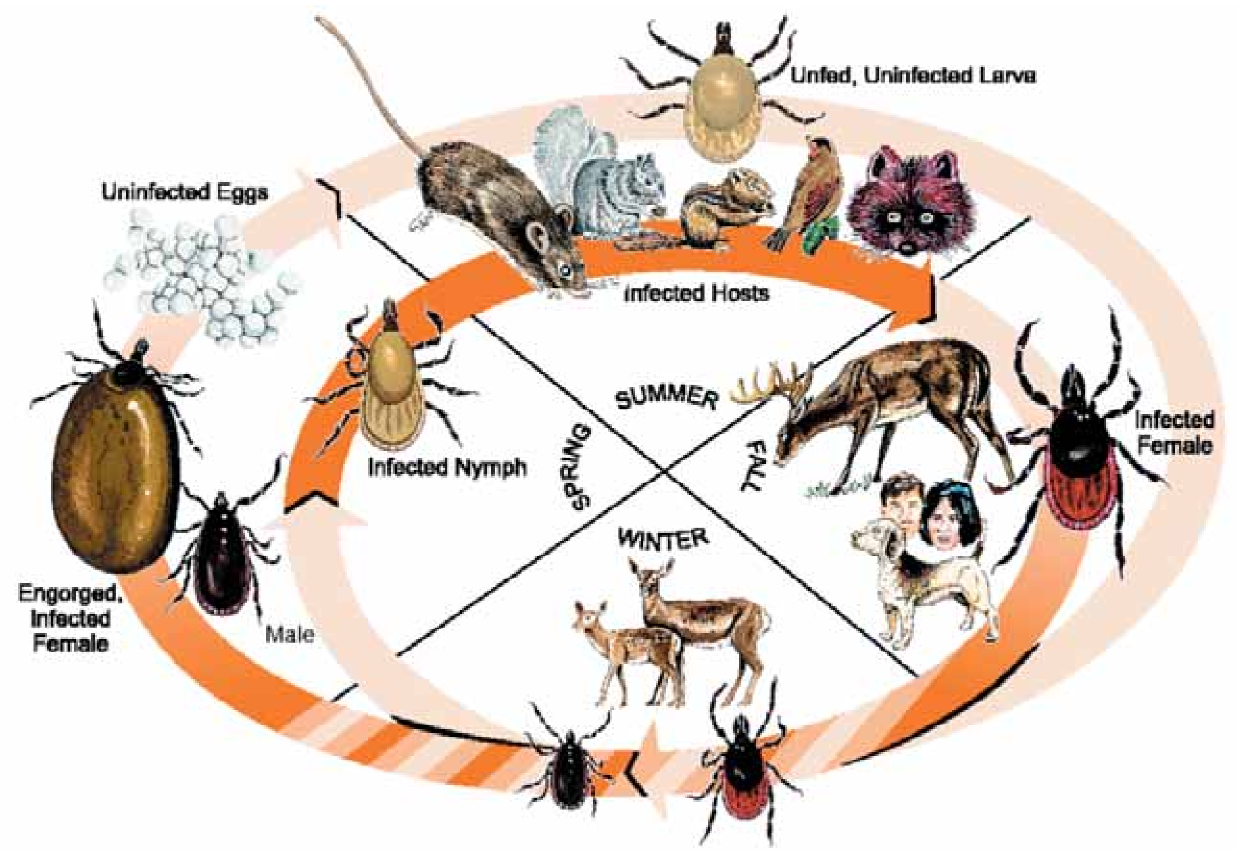
Ticks belonging to the family Ixodidae pass through 4 stages of development: egg, larva, nymph, and the sexually differentiated adult. The ticks discussed here are all 3-host ticks, meaning that they must locate and feed upon 3 different hosts in order to complete their life cycle. Animals that provide a bloodmeal are termed hosts. With the possible exception of the brown dog tick, none of these ticks is host-specific and, thus, will feed on a variety of vertebrates, including mammals, birds, and reptiles. Human are incidental hosts. Although important hosts, most bird species are not considered significant reservoirs of tick-borne pathogens and are more important for their ability to rapidly disperse ticks to new geographical areas. The manner in which ticks attempt to acquire hosts is called questing or host-seeking behavior and largely determines the type animal parasitized. Because of its importance as the vector of Lyme disease, human babesiosis, and HGA, the blacklegged tick will receive the greatest emphasis, but major differences in the biology, behavior, and ecology of the other tick species will be noted.

**The Blacklegged Tick,** ***Ixodes scapularis*** **Say**

Daniel Markowski, MCMEC

***Left to right: Male, female, nymph and larva of the blacklegged tick,*** **Ixodes scapularis** ***(smaller ticks represent actual size).***

The blacklegged tick is found throughout the eastern portion of the United States and several upper mid-western states. Despite its extensive geographical distribution, most Lyme disease cases are found in coastal northeastern and mid-Atlantic states. In New Jersey, the blacklegged tick and the diseases it transmits are most common in rural and suburban wooded areas throughout the State.




Ronald E. Schulze

***Two-year life cycle of the blacklegged tick.***

In New Jersey, the life cycle of the blacklegged tick requires about 2 years to complete. Adults are active in the fall, during the winter when temperatures rise above freezing, and in the spring. After mating and feeding on a host, usually a large- to medium-sized mammal, the engorged female drops off the host, finds a secluded location, digests the bloodmeal, and eventually produces an eggmass containing up to several thousand eggs. These eggs hatch into uninfected larvae during the summer. There is little transovarial passage of spirochetes from infected females to eggs. The larvae typically quest at ground level in the leaf litter. This host-seeking behavior favors the location and feeding upon small mammals and certain birds. After feeding for several days, larvae will drop off the host, overwinter, and molt to nymphs the following spring. If a larval tick fed on an infected host, it will become infected and carry the pathogens through the molt (transstadial transmission) to become infected nymphs. Nymphs also quest at or near ground level and tend to feed on the same small mammals and birds as larvae. After feeding for 3-4 days, the nymphs will leave the host, digest the blood, and molt to adults in the fall of the same year. If the nymph was infected by feeding on an infected host (reservoir) as a larva, it now has the opportunity to transmit the spirochetes to the next host upon which it feeds. Nymphs that were not infected have another chance to obtain spirochetes from the second feeding. Spirochetes are also transstadially passed from the nymphal to the adult stage. Unlike the immature stages, adults frequently quest on shrub layer vegetation and, therefore, tend to encounter larger animals as hosts, particularly white-tailed deer. In fact, deer are such an important host for the reproductive stage of the blacklegged tick, that significant populations rarely occur in areas where deer are absent. After locating a host, females will mate and feed for 5-7 days, thus completing the life cycle.

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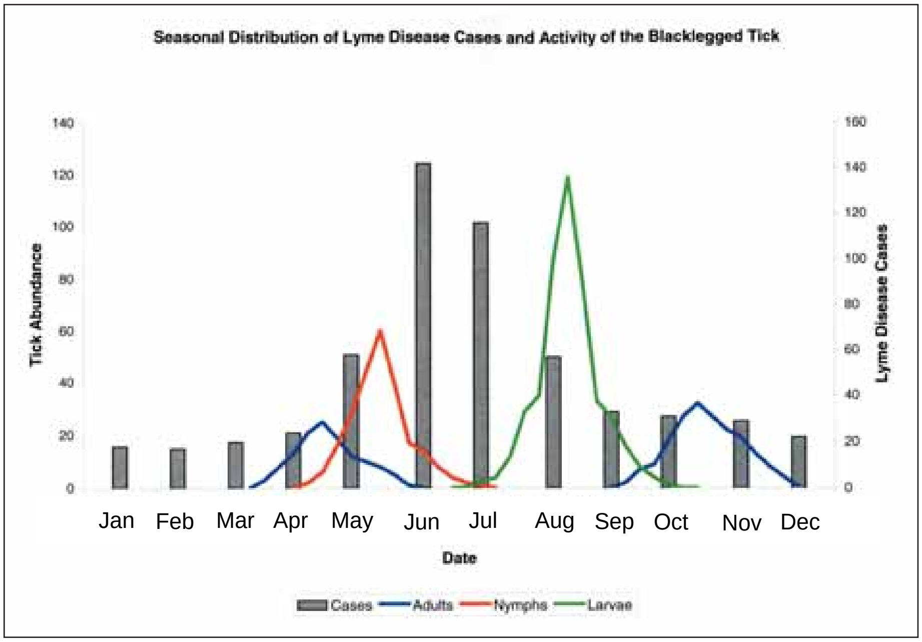
Several important points bear emphasis. First, although different generations are involved, the activity period of nymphs precedes that of larvae during any given year. As a result, nymphs have the opportunity to feed upon and infect an array of small mammals that will serve as hosts for larvae 6-8 weeks later. This phenomenon is largely responsible for the inordinately high infection prevalence of Lyme disease spirochetes in nymphal and adult blacklegged ticks. Secondly, adults normally become inactive as temperatures drop below freezing during winter and resume activity as temperatures increase in spring, giving the appearance of a bimodal activity period. However, unlike lone star and American dog ticks, adult blacklegged ticks will resume host-seeking activity during winter when temperatures rise above freezing. As a result, the risk of exposure to infected adult ticks may occur even during winter months.

Since most cases of Lyme disease occur between May and July, transmission appears to be epidemiologically linked to the activity period of nymphal blacklegged ticks. People tend to be more active in tick habitat during this time and since nymphs are quite small, many feed to




Robert A. Jordan, FAHD

become fully engorged with blood without ever being noticed. However, some Lyme disease cases have been reported with a month of onset between October and April. Therefore, transmission during the fall, winter, and early spring can only result from exposure to infected adults. Although adults have a much higher spirochete infection prevalence than nymphs, fewer Lyme disease cases occur during this period because adult ticks are less abundant, fewer people are active in tick habitats, and those people who are active generally wear multiple layers of clothing. Hunters, hikers, bird watchers, and others who engage in outdoor recreational activities are generally more knowledgeable about tick bite prevention. Finally, adult ticks, because they are much larger than nymphs, are more easily seen and removed before they transmit disease pathogens.

**The Lone Star Tick, *Amblyomma americanum* (L.)**

Although lone star ticks may be found along coastal areas of some northeastern states, central New Jersey marks the northern extent of significant populations of this species. It is found as far south as Florida and west to Texas. Throughout its range, the lone star tick may be quite abundant and, coupled with its aggressive behavior, is considered a serious pest of humans, livestock, and wildlife. In New Jersey, it is common in wooded rural and suburban areas from Monmouth to Cape May Counties.

Daniel Markowski, MCMEC

***Left to right: Male, female, nymph and larva of the lone star tick,* Amblyomma americanum *(smaller ticks represent actual size).***

The life cycle of the lone star tick is similar to that of the blacklegged tick, with several notable differences. Unlike blacklegged ticks, which acquire hosts passively through ambush (questing on vegetation or in the litter awaiting a passing host), the lone star tick is also a hunter and will actively pursue hosts by moving towards a carbon dioxide gradient or responding to changes in their environment, such as temperature gradients, variations in light intensity, and perhaps the presence of animal scents (kairomones). To avoid desiccation, ticks maintain water balance by moving within the litter or shrub layers as ambient conditions change. Because the lone star tick seems more tolerant of hot, dry conditions than other tick species, larvae and nymphs also quest above ground on vegetation. In lone star tick-infested areas, it is common to brush against vegetation and acquire one or more clusters of several hundred or more larvae or "seed ticks." Again, this questing behavior increases the chances of encountering larger mammal hosts. Consequently, although the lone star tick is known to feed on a variety of small mammals and birds, it most often feeds on white-tailed deer.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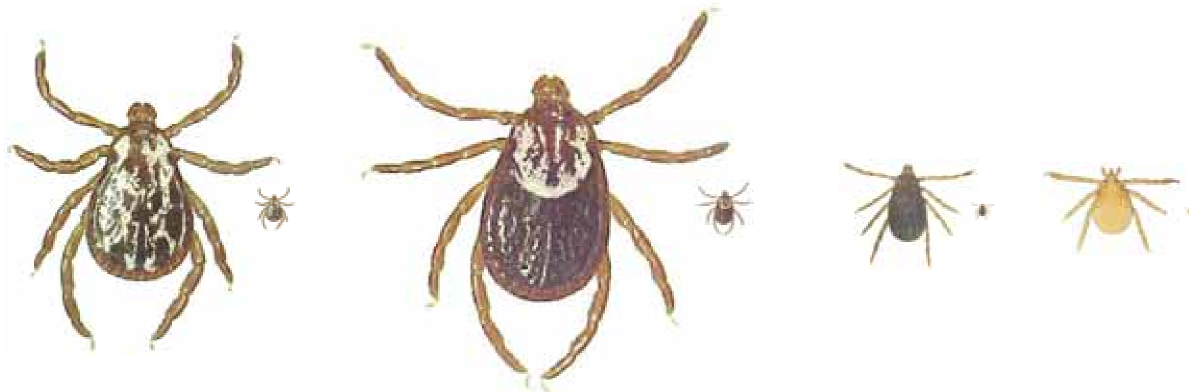
***Ear of a white-tailed deer infested with subadult lone star ticks.***

The seasonal distribution of lone star ticks is similar to that of blacklegged ticks, except there is no fall adult activity peak. The peak activity period of lone star tick adults is mid-April through mid-June, lagging behind that of adult blacklegged ticks by several weeks. Nymphs of both species are most active between mid-May and mid-July, while larvae appear in significant numbers beginning in late July through September. The activity periods of the lone star tick tend to be of longer duration compared to blacklegged ticks, and during their respective activity peaks, lone star ticks are typically more abundant than blacklegged ticks within the same areas. It should also be noted that adult and nymphal lone star ticks are also active during the principal Lyme disease transmission season. Because of its activity during a period of known disease transmission risk, combined with its large numbers and very aggressive behavior, the lone star tick may achieve greater public health significance as more is learned about the extent of HME, *E. ewingii* infection, and STARI in New Jersey.

### The American Dog Tick, *Dermacentor variabilis* (Say)

The American dog tick is found throughout much of the eastern United States. It is found throughout New Jersey in rural and suburban areas, but is more common in overgrown fields and wooded edges than in forests. In urban areas, American dog ticks may be locally abundant in vacant lots, rights-of-way, or similar areas where vegetation is not maintained.



Daniel Markowski, MCMEC

***Left to right: Male, female, nymph and larva of the American dog tick,* Dermacentor variabilis *(smaller ticks represent actual size)*.**

Immature American dog ticks tend to feed on voles, mice, and other small mammals, while adults feed on a variety of medium- and large-sized mammals. Adults first appear in March and may be encountered through the spring and summer. Larvae and nymphs are most abundant in spring and summer months, respectively. In New Jersey, the typical life cycle takes 2 years to complete, but each stage can survive for extended periods without feeding.

### The Brown Dog Tick, *Rhipicephalus sanguineus* (Latrielle)

The brown dog tick is found throughout much of the United States. Although occasionally biting humans, this species differs from the other 3-host ticks of medical or veterinary importance in that it normally parasitizes domestic dogs in all active life stages. In more northern climates, this tick can become established indoors and is often found associated with kennels, households, and other areas frequented by dogs. Under ideal conditions, the brown dog tick can complete its life cycle within 1 year.

Daniel Markowski, MCMEC

***Left to right: Male and female of the Brown Dog Tick,* Rhipicephalus sanguineus.**

## Assessment of Transmission Risk

### Emergence of Tick-borne Diseases

The precise reasons for the rapid emergence of Lyme disease and other tick-borne illnesses over the last 25 years are not completely understood. Early theories linked disease emergence to the rapid rebound of white-tailed deer populations since their virtual elimination at the end of the 19th century. However, the resurgence of the deer population, in response to reforestation and significant reduction in hunting pressure in the Northeast, occurred much earlier than the emergence of Lyme disease as a serious public health problem. A more likely explanation for

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***Low risk and high risk residential communities.***

the emergence of Lyme disease in New Jersey involves what has been termed "suburban sprawl" and the accompanying changes in how we develop the landscape. Over the last 50 years or so, there has been a tendency for people to leave cities to live in more rural areas. Initially, suburban communities were often created by clear-cutting of forests prior to the construction of homes. However, in the 1970s, many county and local governments responded to a growing environmental sensitivity by changing zoning laws to increase lot size and requiring developers to retain as much of the natural vegetation as possible during construction. This shift in development strategy had the unintended consequence of placing more and more people at risk of encountering ticks.

Examining the Lyme disease model can demonstrate how development of residential communities within forested habitats may contribute to the emergence of these tick-borne diseases. Maintaining significant amounts of natural vegetation to serve as buffers and greenbelts creates a patchwork of interconnected woodland. Because of firearm discharge restrictions, these wooded patches within residential developments serve as islands of refuge for deer and other wildlife during hunting season or during development of adjacent lands. Also, as surrounding forest land is lost to development, these areas tend to concentrate deer, the principal host for the reproductive stage of the blacklegged tick. Other mammals, such as raccoons, opossums, squirrels, and chipmunks readily adapt to new residential environments. Woodpiles, brush piles, stone walls, landscaping ties, and outbuildings provide cover and nesting sites for a variety of small mammal hosts of immature blacklegged ticks. The use of bird feeders and introduction of companion animals and, in some cases livestock, also provide additional hosts. People moving into these types of wooded rural environments from more urbanized areas are generally uninformed about ticks and tick-transmitted diseases and less aware of preventive measures. Concentration of ticks and their hosts in proximity to a human

Terry L. Schulze

***Common rodent harborages, including wood piles, brush piles, and stone walls.***

population with low awareness of the risk of tick-borne disease may well have contributed to the emergence of Lyme disease and other tick-borne illnesses.

Although most cases of Lyme disease are acquired from exposure to ticks at or near the home, similar risk factors are present in other settings. In some recreational areas, wooded camp sites, picnic areas, nature trails, and fitness courses may pose substantial risk for encountering ticks, while use of athletic fields and courts, where tick habitat is generally lacking, results in little risk. Frequent exposure to ticks may be common with certain outdoor occupations that routinely place people within tick-infested areas. Consequently, the ability to recognize tick habitats is of paramount importance.

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***High risk areas in a recreational setting.***


***High, moderate, and low risk areas in a residential setting.***

## Recognizing Tick Habitats

Although the ideal habitats for each of the tick species discussed in this manual vary, they all must provide environmental conditions that are conducive to survival, host acquisition, and reproduction. For the blacklegged tick, which is prone to desiccation, the ideal habitat consists of a forested area with a dense shrub layer and deep litter layers. The shrub layer vegetation and litter provide moist, cool conditions, while providing cover and food resources for a variety of hosts. In general, as the density of the shrub layer and depth of the leaf litter declines, so do tick numbers. Further, since hosts seem to be more abundant along forest edges, ticks tend to be more abundant at the margins of woodlands compared to forest interiors. In residential settings, the majority of blacklegged ticks will be found within woods and associated edges, while about 10% occur in landscaped areas, particularly those with dense groundcover plantings. Because of the unfavorable microclimate, ticks are rarely found on lawns beyond a few feet from wooded edge. Wetlands provide poor habitat.

Lone star ticks coexist with blacklegged ticks in these types of forested habitats. However, the lone star tick does not appear to have the same moisture restrictions and survives well in areas with sparse shrub layers and minimal litter.

Since immature American dog ticks feed primarily on meadow voles and other small mammals, it is more frequently encountered in old-field environments, along trails and paths, pastures, and along the wooded margins of forested areas. Along forest edges, it is not uncommon to collect adult American dog, lone star, and blacklegged ticks in a single survey in spring. In more urbanized settings, the American dog tick inhabits overgrown areas, such as vacant lots and rights-of-way, where adults tend to feed primarily on dogs.

The brown dog tick is unique among the medically important ticks of New Jersey in that it has adapted to indoor environments. In colder climates, it completes its entire life cycle indoors and can become a serious pest in kennels and residences, using dogs as the host for all active life stages. Cracks and crevices in these structures provide protected areas during molting or oviposition. Because of favorable conditions within the structures and the ready availability of hosts, the life cycle may be completed in several months.

**Categorizing Risk**

In addition to the presence of suitable tick habitat, any assessment of the risk of encountering ticks must also take into account the quality, amount, and accessibility of the habitat at the subject site, as well as the target human population that will use the site. For example, a park that is comprised almost exclusively of ideal tick habitat and where people are encouraged to access tick habitat (wooded campsites or picnic areas) provides considerably more risk than a park of equal size that has a small amount of marginal habitat and limited public access. There may also be substantial differences in risk within a particular site. Using the same park analogy, people playing basketball on paved courts or baseball on well-maintained athletic fields, for example, are at minimal risk compared to the others who spend several days living at a wooded campsite. Park employees who routinely enter tick habitats as part of their job may be considerably more at risk. The manner in which people use different areas must be considered when evaluating potential risk.


Terry L. Schulze

***High and low risk recreational activities.***

Ticks are not uniformly distributed in nature and even in seemingly ideal habitats may be scarce or absent. Therefore, assessment of actual risk can only be determined by surveying suspect areas for ticks. The most efficient and cost-effective way to accomplish these

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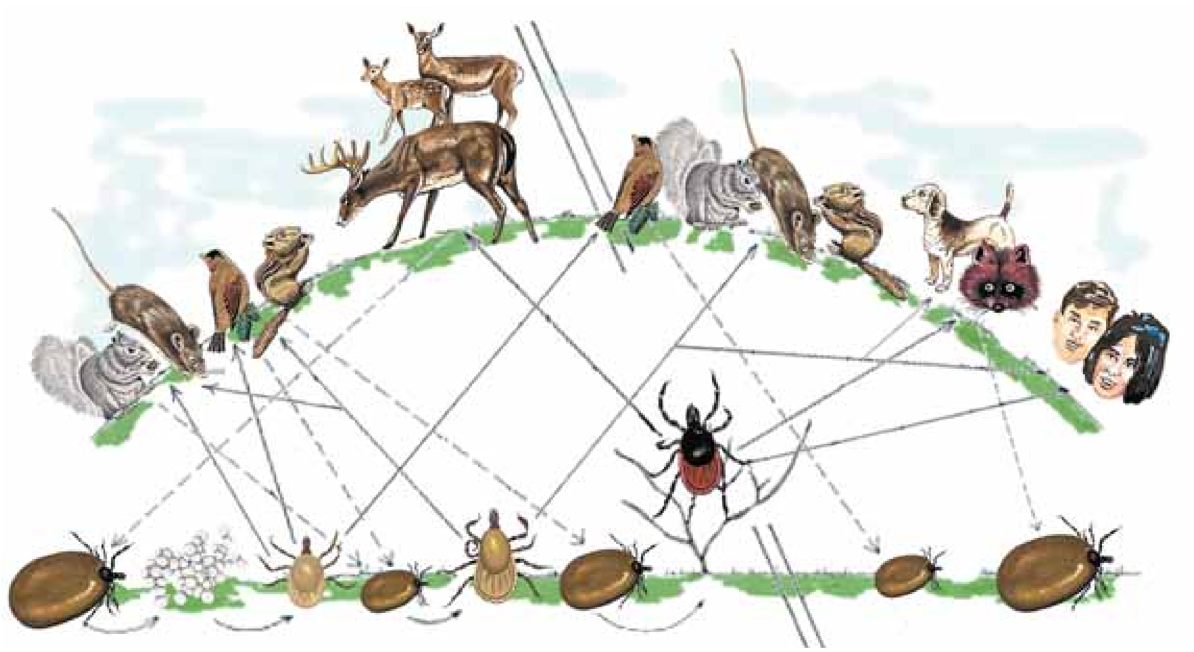
***Drag sampling for adult and subadult blacklegged ticks.***

assessments is by conducting dragging and/or walking surveys. Tick drags or flags are constructed of a piece of light-colored cloth attached at both ends to wooden dowels. A rope handle is attached to both ends of the leading dowel to facilitate working of the drag across vegetation or leaf litter for a measured distance or length of time and then counting ticks adhering to the drag. Alternately, an estimate of tick abundance can be made by simply walking through potentially tick-infested habitat and counting ticks adhering to clothing over a prescribed distance or time period. Individuals who perform drag sampling surveys are, in reality, also conducting walking surveys. The use of protective clothing is strongly advised when considering either sampling technique. Light-colored, long-sleeved, full-length coveralls duct taped to rubber boots provide the best protection.

The use of either or both survey techniques requires a complete understanding of the differences in seasonal activity periods and questing behavior exhibited by different tick species and/or stages. For example, walking surveys are ideal for estimating the abundance of ticks



Ronald E. Schulze/Sean P. Healy, MCMEC

***Questing behavior and typical host associations of the blacklegged tick.***

that quest above ground on shrub layer vegetation (all stages of lone star ticks and adults of blacklegged and American dog ticks), but are of little value in sampling the species whose immature stages quest at or near ground level (blacklegged and American dog ticks). Similarly, the use of drags in dense vegetation will not accurately estimate populations of immature blacklegged and American dog ticks because shrubs will prevent the drag from reaching the ground. In such instances, adjacent areas with patchy shrub layers should be sampled instead.

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Populations can also be monitored by counting ticks on live-trapped small mammals. However, because this technique is labor-intensive, requires permits, extensive experience, and safety training, it should only be considered if there is some unique need. Carbon dioxide-bait trapping works well for lone star ticks, but is of little value in sampling blacklegged tick populations.

Edward M. Bosler

## Prevention and Personal Protection

As stated earlier, recognition and avoidance of tick-infested areas is the principal means of preventing exposure to ticks and decreasing the potential for disease transmission. If such areas cannot be avoided, several personal protection measures should be considered, including wearing light-colored clothing, tucking pant legs into socks, judicious use of personal and/or clothing repellents, frequent self-examinations, and the prompt removal of attached ticks. Wearing light-colored clothing simply makes it easier to see ticks. Tucking pant legs into socks and shirttails into pants forces ticks to crawl on the outside of clothing where they can be more easily seen and removed. Duct tape or lint rollers can be quite useful in removing ticks from clothing. Appropriate dress can be augmented by the proper use of repellents. Read product labeling carefully before use. Personal repellents, particularly those containing the active ingredient DEET, may be applied to skin or clothing. Permethrin-based repellents have proven very effective, but should only be applied to clothing. A single treatment with permethrin-based repellent will remain effective for many days. Individuals who have frequent occupational or recreational exposure to ticks should consider wearing a dedicated pair of permethrin-treated coveralls or similar clothing each time they enter tick habitat. After leaving tick habitat or certainly at the


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***Mouthparts of the blacklegged tick.***

end of every day, individuals should examine themselves for ticks and properly remove them. Recent studies have shown that blacklegged ticks must be attached and feeding for at least 24 hours before Lyme disease spirochetes can be transmitted, and the risk of transmission increases proportionally over time. However, since other tick-borne pathogens may be transmitted earlier in the feeding process, more frequent inspections are recommended.

Proper tick removal is key in reducing disease transmission. Unlike mosquitoes and biting flies, which bite almost immediately, ticks require a relatively long time to insert their mouthparts and begin feeding. The hypostome is gradually inserted into the skin and the recurved teeth located on the hypostome help anchor the tick to the host during feeding. In some species, the tick secretes a cement-like material around the mouthparts, attaching it more securely to the host. Therefore, popular tick removal methods, such as smothering the tick in petroleum jelly or applying noxious chemicals or a heat source to the tick, simply do not work. Proper removal involves grasping the mouthparts with a fine-pointed forceps or tweezers as close to the skin as possible and slowly applying backward pressure until the tick becomes dislodged. If deeply imbedded, the mouthparts may break off and may have to be teased out. After removal, the site of the bite should be treated with a local antiseptic. Localized reactions to the tick bite are common.


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Since the identity and stage of the tick may provide useful information if disease transmission is suspected, removed ticks should be retained. For example, removal of a blacklegged tick would rule out RMSF as a diagnosis, since this tick is not a vector of *R. rickettisia*. Similarly, a diagnosis of Lyme disease would be contraindicated if only blacklegged tick larvae were removed from a patient, since this stage is rarely infected. The value of testing ticks for the presence of disease pathogens is problematic. Identification of a tick-borne pathogen within a particular tick does not mean that transmission has occurred, since the duration of attachment is seldom known. In reality, it is usually the tick that you do not find or test that is involved in transmission!

## Tick Management Strategies

Although recognition and avoidance of tick-infested areas and the use of the preventive measures discussed earlier will dramatically reduce the risk of transmission, there are situations when controlling tick populations is warranted. In general, tick control strategies fall into 4 basic categories: host reduction, biological control, habitat management (mechanical control), and chemical control.

### Host Reduction

The motivation behind host reduction is that tick abundance will be substantially suppressed following the reduction of a significant number of hosts. For example, the reduction of several major hosts of blacklegged ticks has been proposed, although the only actual host reduction research focused on the removal of white-tailed deer from an island ecosystem. After attempts to live-trap deer proved impractical, hunting was used to cull the herd. Removal of 70% of deer did not markedly reduce tick abundance. The failure to reduce tick numbers in the short-term can be explained if ticks used alternate hosts or if the density of ticks increased on the remaining deer. In a subsequent study, the virtual eradication of deer eventually resulted in significant reduction of the tick population. Not withstanding the partial success of these studies, the use of host reduction as a means to reduce tick populations has ecological, sociological, and political drawbacks.

The first problem with the deer reduction studies was that they were conducted in geographical isolation. Compared to mainland situations, islands often lack the diversity and abundance of alternative hosts. Aside from the many logistical obstacles to implementing a control program, maintaining reduced local deer populations in mainland situations, where recolonization by deer from surrounding areas is typically rapid, may not be practical. Even if moderately successful, culling programs are often limited by municipal ordinances prohibiting discharge of firearms or by public opposition to lethal removal methods, as evidenced by the negative public response to several municipally sponsored deer reduction efforts in New Jersey. Given the politically, and often emotionally, charged climate surrounding urban deer management, the widespread destruction of this important game animal is not a viable option to reducing tick populations and disease transmission.

### Biological Control

Biological control refers to the use of predators, parasitoids, or pathogens to reduce populations of a particular pest. The degree to which predators and parasitoids naturally regulate the abundance of medically important ticks is unknown. Flocks of helmeted guineafowl have been reported to reduce populations of blacklegged ticks in penned areas. However, since most predators, including guineafowl,

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***Helmeted guineafowl.***

feed on a variety of species, it is unlikely that impact on tick populations would be significant. Further, the establishment of free-ranging flocks of guineafowl in residential communities would be undesirable, if not impractical.


**Ixodiphagus hookeri.**

Surveys of several islands off the New England coast identified a wasp, *Ixodiphagus hookeri*, parasitizing up to 40% of blacklegged tick nymphs. Despite this high rate of parasitism, tick populations on these islands remain high. Subsequent studies have shown the abundance of this wasp and the rate of parasitism to be relatively low in mainland environments. Therefore, the use of this parasitoid wasp in an integrated tick control program will be limited.


***Engorged female blacklegged tick parasitized by nematodes.***

Certain nematodes are parasites of ticks. However, the nematodes studied to date are only effective against engorged female blacklegged ticks that have already fed on and possibly infected a host, and their inability to survive at colder temperatures makes them of limited value as a viable biological control agent against ticks.


***Blacklegged tick parasitized by fungus.***

Offering greater promise as an effective biological control agent are pathogenic fungi. Although commercially available formulations of specific fungi have been successful in controlling blacklegged ticks in limited trials, additional research is needed.

**Habitat Management**

Habitat management refers to rendering existing habitats unattractive, inhospitable, and/or inaccessible to ticks and/or their hosts. This can be accomplished using a variety of techniques. For blacklegged ticks, one of the simplest and most effective methods to reduce exposure to ticks is vegetation management. In residential landscapes, this may include frequent mowing, trimming back overhanging shrubs or tree branches, and removal of leaf litter, particularly at the lawn-forest interface and in high use areas. Each of these techniques has the dual function of reducing cover and food resources for hosts, while creating dryer conditions that affect the survivability of ticks. Another landscape modification technique involves the elimination or reduction of small mammal cover and nesting sites. The removal of woodpiles,

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brush piles, stumps and fallen trees, and other harborages will tend to keep rodent populations at a minimum. The use of deer resistant ornamental vegetation, in combination with these other techniques, may discourage deer from entering residential properties and decrease browse damage. Use of dense groundcover plantings should be discouraged, since they provide ideal tick habitat and cover for rodent hosts. In addition to feeding birds, bird feeders also provide food for many of the small mammal hosts for immature ticks. Therefore, the use of bird feeders should be limited to winter months or placed over areas that are inhospitable to tick survival, such as lawns. Habitat management can include host exclusion. Studies have shown that installation of deer fencing dramatically reduced blacklegged tick abundance within the protected property. However, deer fencing is quite expensive, does not exclude small or medium-sized hosts, and tends to increase deer density on neighboring properties.

***Low risk areas in a recreational setting following habitat management.***

Many of the principals of habitat management can also be applied to recreational areas and parks. The removal of shrub layer vegetation and leaf litter from around campsites, fitness trails, and picnic areas can dramatically reduce potential exposure to ticks. Similarly, widening exercise or hiking trails and pruning overhanging vegetation will reduce human-tick encounters. Posting signs in high-risk areas that advise park visitors of potential risk and precautions to use when entering tick-infested areas may also reduce exposure. Controlled burns, used primarily as a forestry management tool, have been shown to suppress tick populations, if performed regularly. However, such practices may increase tick populations in the long-term by improving deer browse, as well as food resources and cover for small mammal hosts.

**Habitat-targeted Chemical Control**

Habitat-targeted chemical control refers to the application of an acaricide (a pesticide that kills ticks and related organisms) to the environment in an effort to suppress or manage tick populations. It is the most effective and least expensive way to control ticks in small- or moderately-sized areas. However, the use of habitat-targeted or area-wide chemical control is often perceived by the public as having undesirable environmental effects. This view undoubtedly stems from the widespread use of persistent chlorinated hydrocarbon insecticides (e.g. DDT, chlordane, heptachlor) that were in common use during the late 1940s through the 1970s. This class of pesticides not only lasted a long time in the environment, but also tended to bioaccumulate within the food web. During the 1970s, many of these pesticides were banned or had their use significantly regulated. They were replaced by classes of pesticides known as the organophosphates (e.g. diazinon, chlorpyrifos, propoxur) and organocarbamates (e.g. carbaryl) that were more biodegradable (less persistent) than the chlorinated hydrocarbons, but generally more toxic to mammals. By the late 1990s, many of the organophosphate acaricides were no longer available for tick control and have largely been replaced by synthetic pyrethroids (e.g. bifenthrin, cyfluthrin, deltamethrin, λ-cyhalothrin, permethrin) and natural pyrethrins. The advantages of the pyrethroid compounds are that they are generally less persistent in the environment and exhibit low mammalian toxicity, compared to organophospates. However, the acaricides currently available are still broad-spectrum and, as such, can have significant impacts on a variety of non-target organisms.

The ultimate goal of any habitat-targeted control program is to kill the greatest number of ticks, while minimizing adverse environmental effects, by using the least amount of acaricide. In part, this can be achieved by limiting treatment to just those areas with high probability of human-tick encounters. Rather than treating large expanses of woodland, barrier applications to vegetation in areas with significant human activity will dramatically reduce exposure to ticks while minimizing the potential for unwanted environmental impacts. Studies in New Jersey involving barrier acaricide applications have shown that impacts to non-target organisms may be significant, but short-lived.

A thorough knowledge of tick biology, behavior, and ecology can reduce acaricide use by eliminating unnecessary multiple applications and by targeting only those habitats capable of supporting ticks. The three most important factors in the development of a successful and environmentally sound habitat-targeted tick reduction strategy are the seasonal activity, habitat preference, and questing behavior of the tick species to be controlled. For example, applications to control blacklegged tick nymphs should be conducted during their peak activity period in late May and concentrated in the litter layer where they quest. A single application made at the right time and location can control 90-100% of nymphs in the target area, thus

eliminating the need for repeated applications. Similarly, applications intended to suppress adult blacklegged ticks should be made around late October and directed toward shrub layer vegetation where they quest. A single application of carbaryl directed at fall populations of adult blacklegged ticks adults resulted in 95-100% control and because few ticks are available to overwinter, control is maintained during the subsequent spring. However, such applications do not seem to have an impact on other stages of blacklegged ticks or other tick species, which are inactive in the fall. The larval stage is the most difficult to control because hatching of eggmasses occurs over a protracted period and the distribution of larvae is extremely patchy. Although blacklegged tick larvae do not pose a public health threat, control may be achieved with a late July-early August application directed at the litter layer.

Although sharing the same type of habitat as blacklegged ticks, efforts to control the lone star tick require modifications in both timing and location of the application. Since there is no fall activity peak, any control of adult lone star ticks must be confined to spring. However, seasonal activity patterns of lone star tick nymphs and larvae are similar to those of the blacklegged tick. In general, the duration of activity of the various stages of the lone star tick is longer than that of the blacklegged tick and since all active stages of the lone star tick quest both at ground level and in the shrub layer, both areas need to be treated. Differences in activity periods and habitat must also be taken into consideration when attempting to control American dog ticks. Because of its host associations, control of this species will be most effective when directed at tall grasses and shrubs in fields, along trails, rights-of-way, and woodland edges. Since the brown dog tick is primarily an indoor pest, timing of any application is less critical.

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***Habitat-targeted application of granular and liquid acaricide formulations.***

Seasonality, habitat affinity, and questing behavior also affect the selection of acaricide formulations. For example, adult blacklegged ticks quest in shrub layer vegetation in both fall and spring when deciduous foliage is absent. In such situations, the use of liquid sprays applied to shrubs would be the obvious choice. In contrast, since the immature stages of this tick quest on or within the leaf litter during the growing season, the application must penetrate the foliage and reach the litter layer to be effective. Granular formulations are ideally suited

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for this purpose, but liquid formulations can be just as effective providing that sufficient pressure is used to penetrate the foliage and physically disturb the leaf litter. Chest-mounted cyclone spreaders or modified mist blowers have been used successfully to apply granular acaricides, while high-pressure hydraulic sprayers are best suited to apply liquid formulations. Other considerations affecting the selection of formulation include availability of equipment, size of the area to be treated, density of vegetation, and cost. Aerial applications have been successfully used to control blacklegged tick adults and nymphs, but high cost and regulatory considerations make this approach impractical in all but unique situations.

**Host-targeted Chemical Control**

In response to concerns over the potential environmental impacts associated with area-wide acaricide applications, several host-targeted tick control technologies have been developed. The goal of the host-targeted approach is to kill ticks on hosts that have been self-treated with acaricide. Since no acaricide is applied directly to the environment, non-target effects are minimized. However, in addition to considering seasonal activity, habitat preference, and questing behavior of ticks, the successful tick management professional or land manager must also possess knowledge of host behavior and ecology when considering the use of host-targeted strategies.

**Small Mammals**

The first attempt to employ a host-targeted approach involved the distribution of permethrin-treated cotton in cardboard tubes, commercially available under the trade name Damminix®, in wooded areas to control immature blacklegged ticks on white-footed mice. Separate spring and summer applications are required. The premise of this approach is that mice become self-treated with the acaricide after harvesting the cotton for use as nesting material and that immature ticks on mice and in mouse nests will be killed, ultimately reducing the number of host-seeking nymphs and transmission risk. Early studies in Massachusetts showed significant reduction of tick burdens on mice and the number of questing ticks within the treatment area. However, subsequent research in Connecticut and New York reported no difference in the number of host-seeking nymphs and adults between treated and untreated areas after several years of use and concluded that the reduction of tick burdens on mice was insufficient to reduce the risk of human-tick encounters. These conflicting results may be explained by differences in the availability of alternate nesting materials and/or the diversity, composition, and abundance of hosts.

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In the mid-1990s, the Centers for Disease Control and Prevention, Bayer Environmental Sciences (formerly Aventis Environmental Sciences), and scientists from several states developed and tested a bait box technology that targets certain small mammal hosts of immature blacklegged ticks. The child-proof bait box consists of two entry portals and a central corridor that leads to an overhanging acaricide-treated wick at the entrance to the paired bait chambers. Initial laboratory bioassays showed that the active ingredient fipronil killed immature blacklegged ticks for over 42 days following a single treatment. Early field studies in Connecticut resulted in a significant reduction of tick burdens on mice during the first year of deployment and reduction in the number of host-seeking nymphs and adults after the second year. This technology also interrupts the natural tick-mouse transmission cycle of Lyme disease spirochetes by killing the majority of spirochete-infected blacklegged tick nymphs before transmission can occur. Subsequent testing in New Jersey has shown over 93% reduction of nymphal and larval blacklegged tick burdens on target small mammals following separate deployments in spring and summer. By the second year of treatment, the level of control of host-seeking nymphs and larvae exceeded 86% and 90%, respectively. The bait box technology is commercially available under the trade name Maxforce™ Tick Management System.

Although the bait boxes appear to provide more consistent and reliable control, both rodent-targeted technologies share common limitations. Both techniques are considerably more expensive than habitat-targeted approaches by virtue of increased product and labor costs. Both technologies require manual deployment and retrieval of the product during each treatment period. Efficacy of rodent-targeted approaches is also affected by the diversity and composition of the small mammal community. Since the blacklegged tick lacks host-specificity, an abundance of hosts that are not treated by these products will negatively impact efficacy. For example, the Eastern gray squirrel, *Sciurus carolinensis*, an important host of immature blacklegged ticks that is often quite abundant in residential environments, is not treated by either device. Damminix®, for example, appears to be effective only in habitats dominated by white-footed mice. Finally, the efficacy of both technologies is limited to only those tick species whose immature stages feed on small mammals. Consequently, reduction of lone star ticks, which feed primarily on deer in all active stages, will not be achieved by the sole use of these rodent-targeted technologies.

## White-tailed Deer

### *Topical Applications*

The United States Department of Agriculture has developed and tested a passive topical treatment device designed to control ticks that parasitize white-tailed deer. The device consists of a bait bin that will accommodate up to 250 pounds of whole kernel corn. Feeding ports on both sides of the bin are flanked by vertical application rollers, hence the name "4-poster." Deer are treated as they rub their head, ears, and neck against acaricide-laden rollers while

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***Treatment and use of a prototype 4-Poster.***

Wayne Ryan, USDA, ARS

***Commercially available 4-Poster.***

feeding on corn. The acaricide is dispersed to other parts of the deer by self-grooming. Deployment of the 4-poster treated with 2% amitraz (Point-Guard®) within a fenced pasture resulted in 92-97% control of lone star ticks on deer that regularly used the device. In another study, 4-posters treated with 10% permethrin, deployed in a fenced facility over a 3-year period, resulted in 100% control of blacklegged ticks on deer after 2 years, 91-100% reduction of all stages of host-seeking ticks from sampled plots, and 70-95% reduction in nymphal and larval tick burdens on mice. A more comprehensive New Jersey study involving deployment of 25 4-posters treated with 2% amitraz yielded levels of control of 82.7%, 77.3%, and 94.2% for host-seeking blacklegged tick larvae, nymphs, and adults, respectively. Control of host-seeking lone star ticks peaked at 99.2%, 89.5%, and 96.9% for larvae, nymphs, and adults, respectively, during the 5-year treatment period. Tick burdens were also significantly reduced on deer from the treatment area.

Although these studies demonstrated the effectiveness of the 4-poster technology as an alternative to habitat-targeted acaricide applications, several factors may affect its efficacy and widespread use. The availability of acorns during the fall of any given year will dramatically affect the efficacy of the 4-poster by providing an alternate and attractive food source for deer. Another factor is host preference. Although neither blacklegged nor lone star ticks are host-specific, blacklegged ticks tend to feed on deer primarily as adults, while deer are a major host of all stages of the lone star tick. This may explain the somewhat higher levels of control of lone star ticks in the New Jersey study. Economics is a third factor. In addition to its initial purchase price and costs for acaricide, corn, rollers, and periodic maintenance, the use of the 4-poster technology is labor intensive. Where deer are abundant, the 4-posters may require semi-weekly visits to replace corn and recharge rollers. The United States Environmental Protection Agency has approved the registration of 10% permethrin (Y-TEX® 4-Poster™ Tickicide) for use on 4-posters. Current labeling restrictions prohibit the deployment of any 4-poster within 100 yards of a residence or other area where children might be present without adult supervision. This requirement restricts the use of 4-posters in many residential communities with small lot sizes and poses significant logistical problems in servicing the devices.  Further, 4-Poster™ Tickicide can only be applied in New Jersey by licensed applicators.  A final impediment to the widespread use of this technology involves restrictions on feeding deer that may affect approval by some state regulatory agencies.  That being said, research has shown that a single 4-poster is able to treat the majority of deer within an area of 50 acres or more, all while introducing virtually no acaricide into the environment.

***Systemics***

Systemic acaricides are those that when topically applied or fed to animals, move through body tissue or fluids in sufficient concentrations to stop ticks from feeding.  In an island community in Maine, ivermectin-treated corn was fed to white-tailed deer.  On deer that had adequate serum levels of ivermectin, adult blacklegged ticks were significantly less abundant compared to animals with low serum levels.  However, no consistent differences were noted in the number of host-seeking ticks or tick burdens on small mammal hosts.  Failure to reduce the number of host-seeking ticks resulted from an underestimation of the size of the deer herd and its distribution, which led to the provision of an inadequate amount of treated corn to a portion of the herd.  Deer dominance at the feeding sites and seasonal availability of other food resources also affected the inadequate or inconsistent consumption of corn and, thus, ivermectin serum levels.  A final concern with this strategy is the substantial withdrawal period for ivermectin before consumption of venison is permitted.  Since the fall peak activity period for adult blacklegged ticks and the deer hunting season coincide, this restriction alone will limit the use of this strategy only to areas where deer are not hunted and consumed.  Currently, there are no systemic acaricides registered for use in deer.

J. Mathews Pound, USDA, ARS

**Miscellaneous Chemical Control Strategies**

Other formulations, such as desiccants and insecticidal soaps, have also been used to provide more environmentally sensitive alternatives to conventional chemical control programs.  In general, desiccants contain silica-based compounds that kill ticks through the adsorption of the lipid layer of the cuticle, essentially drying them out.  In trials to control blacklegged ticks, the commercially available desiccant Drione®, which contains 1% pyrethrin, silica gel, and ammonium fluorosilicate, provided short-term control.  However, the efficacy of desiccants is diminished following rainfall or under conditions of high humidity.  Some soaps dissolved in water at sufficient concentrations can provide insecticidal activity, but soaps have been more often used as emulsifiers, spreaders, wetting agents, and stabilizers to enhance the effectiveness of certain insecticide formulations.  Field trials of Safer's Insecticidal Soap® (0.2% pyrethrin) also provided significant short-term control of blacklegged ticks. The lack of residual activity may require repeated applications of these products.


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Fipronil-based veterinary products (e.g. Frontline® and Top Spot™) are effective in controlling external arthropod parasites on dogs and cats. They are topically applied and eventually spread over the body and concentrate in sebaceous glands and hair follicles of the animal, where they provide long-term control of ticks and fleas.

**Selecting a Tick Control Program**

The overall approach to suppressing tick populations should be an integrated one that employs education on preventive measures, selected habitat alterations, and the use of acaricides. Recognition and avoidance of likely tick-infested areas, wearing appropriate clothing, use of repellents, frequent self-examination, and prompt removal of ticks are the best ways to reduce human-tick encounters and risk of disease transmission. Trimming vegetation, mowing lawns and weedy areas, removal of leaf litter, eliminating or reducing rodent harborages and nesting sites, planting of deer-resistant plants, and installation of deer fencing are examples of successful habitat modification techniques. Personal protection recommendations should be followed when engaged in habitat modification activities. Where appropriate, the use of habitat- and/or host-targeted chemical control can be a safe and effective means of reducing tick populations.

Review of the scientific literature suggests that at this time, host reduction, biological control, and some habitat management techniques are either unavailable or impractical for widespread use. Habitat-targeted chemical control has been shown to be the most reliable, efficient, and cost-effective method of reducing tick populations in limited geographical areas. Because of potential environmental impacts, applications should be confined to those areas with significant human activity. In general, large expanses of tick habitat need not be treated. Lawns, athletic fields, and similar areas are poor tick habitats that do not require treatment, except where they abut woodland edge. Selection of an appropriate acaricide formulation and application method requires knowledge of the biology, behavior, and habitat preference of the target tick species. Acaricides applied to appropriate habitats at the proper time will provide excellent control of ticks and eliminate the need for repeated applications, all resulting in a dramatic reduction of acaricide use. Some of the host-targeted approaches show great promise in an integrated tick control program. They are generally more expensive, may be of limited value in controlling certain tick species or stages, require knowledge of host biology and behavior to insure proper deployment of the product, and have an inherent delay in their effectiveness. For this reason, clients should be apprised of this lag time and advised to consider interim measures, such as the use of barrier acaricide applications. Since no control program will ever eradicate the tick population, clients should be urged to continue the use of preventive measures. Design of any integrated tick control program should be site-specific and in complete conformance with labeling requirements.

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# NOTES

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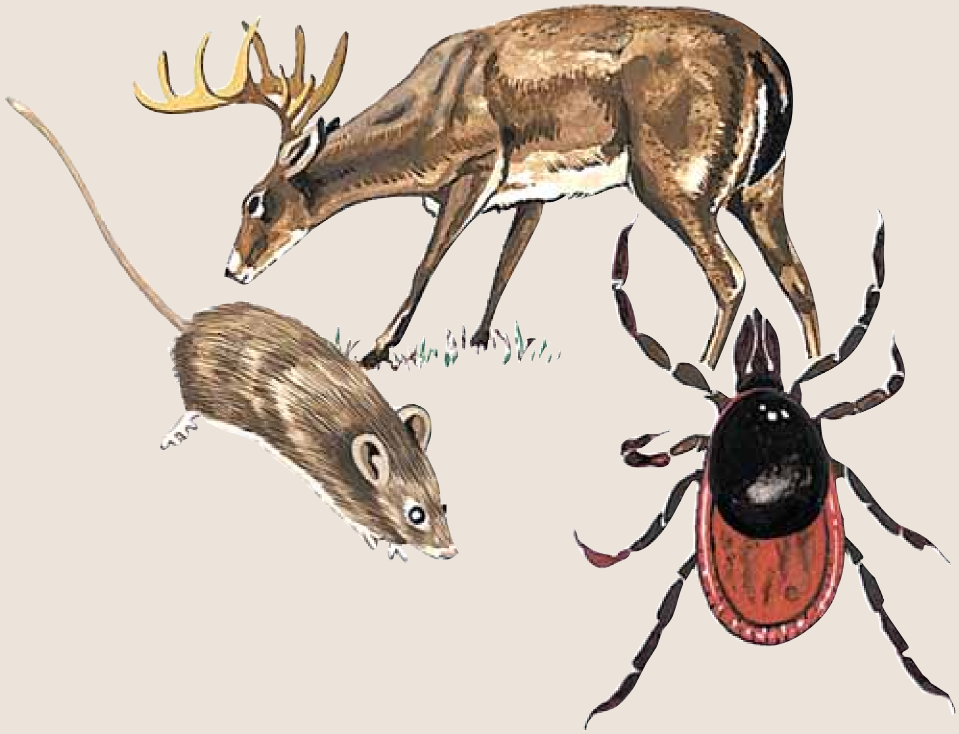
*Back cover:* Artwork by Ronald E. Schulze



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