Tick Management Handbook

An integrated guide for homeowners, pest control operators, and public health officials for the prevention of tick-associated disease

Revised Edition

Prepared by:

Kirby C. Stafford III, Ph.D.
Vice Director, Chief Entomologist
Connecticut Agricultural
Experiment Station, New Haven

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Table of Contents

Introduction 1

Ticks of the Northeastern United States 3
Tick biology and behavior 4
Tick morphology 6
How a tick feeds 7
Tick sampling 8
Blacklegged tick, *Ixodes scapularis* 9
American dog tick, *Dermacentor variabilis* 13
Lone star tick, *Amblyomma americanum* 15
Other ticks 16

Tick-Associated Diseases 20
Lyme disease 21
Southern tick-associated rash illness 26
Human babesiosis 27
Human granulocytic anaplasmosis 28
Human monocytic ehrlichiosis 29
Rocky Mountain spotted fever 30
Tick paralysis 32
Tularemia 32
Powassan encephalitis 33
Tick-borne relapsing fever 33
Colorado tick fever 33
Bartonella infections 33
Lyme disease in companion animals 34

Personal Protection 35
Tick bite prevention 35
Tick removal 37
Topically applied insect repellents 39
Human Lyme disease vaccine 43

Integrated Tick Management 44
Landscape management 46
Organic land care practices 50
Environmentally friendly lawns and backyard wildlife programs 50
Management of host animals 52
Prevention of tick-associated disease in companion animals 62

Area-wide Chemical Control of Ticks 63
Acaricides used for tick control 64
Homeowner application of acaricides for tick control 65
Commercial application of acaricides 66
An acaricide primer 68
Additional sources of information about pesticides 69

Biological Control of Ticks 70

Selected Bibliography and References 71

Preface

The original 2004 edition was published as part of a community-based program for the prevention of tick-borne illness supported through a cooperative agreement with the Centers for Disease Control and Prevention (CDC). Of the 10,000 copies originally printed, very few remained after wide distribution through Connecticut, New England and elsewhere. The publication was also available online from The Connecticut Agricultural Experiment Station's website (www.ct.gov/caes) and a link through the CDC. In 2006 alone, 117,000 copies were downloaded from the Experiment Station's website. Nevertheless, there continues to be demand for printed copies. This reprinting of a revised tick management handbook in 2007 was made possible with the support of the Connecticut Office of Policy and Management and the Connecticut General Assembly.

The information in this publication depends not only on the research conducted by scientists at The Connecticut Agricultural Experiment Station, but on that of many other fellow scientists and their published findings as well as disease statistics compiled by the CDC and state health departments. The research and community outreach by The Connecticut Agricultural Experiment Station on ticks and tick-associated diseases would not have been possible without the collaboration and support of the Connecticut Department of Public Health and local health departments, particularly the Westport Weston Health District, the Torrington Area Health District, and the Ledge Light Health District. As this publication is intended as a general guide for the public, pest control operators, and public health officials, citations are not directly provided in the text. A selected bibliography of references is listed at the end for those who wish to pursue specific topics further or consult original publications. While the reference list is fairly comprehensive, the scientific literature related to ticks, Lyme disease, and other tick-associated diseases is extensive. There are many excellent papers that could not be listed. Some other sources of information, such as government internet sites, are provided in several specific sections of the handbook.

Surveys have consistently shown that most residents in Lyme disease endemic areas consider the disease an important or very important issue that poses a high risk to members of their family. Children are particularly at risk. An estimated three quarters of all Lyme disease cases are acquired from ticks picked up during activities around the home. The withdrawal of the human Lyme disease vaccine (LYMErix™) in 2002 has essentially brought the control of the disease back to managing tick bites and methods to suppress the local tick population or prevalence of pathogen infection in the ticks. A few precautions and the management of infected ticks in the residential or recreational landscape can substantially reduce the risk of Lyme disease and other tick-associated illnesses. Prompt recognition of infection and treatment can prevent more serious manifestations of disease. Therefore, education is important in preventing or mitigating disease, but it is only the first step. Landscape and host management practices combined with the judicious use of an acaricide can provide excellent tick control with minimal risk or impact to the environment or other wildlife. This handbook provides the homeowner, pesticide applicator, health professional, and others some basic information necessary to manage ticks and prevent Lyme disease. Much still needs to be learned. Implementation of some of the concepts presented in this handbook can reduce ticks and the risk of Lyme disease. If this publication succeeds in helping families prevent tick-borne illness, then it will have met its goal.

Kirby C. Stafford III

To these I must add the wood lice [ticks] with which the forests are so pestered that it is impossible to pass through a bush or to sit down, though the place be ever so pleasant, without having a whole swarm of them on your clothes.

Pehr Kalm, 18 May 1749
Raccoon [Swedesboro], New Jersey

Introduction

Ticks have become an increasing problem to people and animals in the United States. Ticks are obligate blood-feeders that require an animal host to survive and reproduce. They feed on a wide variety of mammals, birds, reptiles, and even amphibians. While most ticks feed on specific host animals and are not considered to be of medical or veterinary importance, several ticks have a wide host range and attack people, pets, or livestock. Ticks can be a nuisance; their bites can cause irritation and, in the case of some ticks, paralysis. Severe infestations on animals can cause anemia, weight loss, and even death from the consumption of large quantities of blood. Ticks can also transmit many human and animal disease pathogens, which include viruses, bacteria, rickettsiae, and protozoa.

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The association between ticks and disease was first demonstrated when Theobald Smith and Fred Kilbourne proved in 1893 that Texas cattle fever (cattle babesiosis) was caused by a protozoan transmitted by an infected tick. In the late 1800s, Rocky Mountain spotted fever was the first human tick-borne disease identified in the United States, and for many years, was the major tick-associated disease in this country. Although first recognized from the virulent cases in the Bitterroot Valley of Montana, it eventually became evident that most cases were distributed through the eastern United States. Lyme disease was first recognized as a distinct clinical entity from a group of patients with arthritis in the area of Lyme, Connecticut, in 1975, although it became evident that this disease had an extensive history in Europe throughout the twentieth century. Today, Lyme disease is the leading arthropod-associated disease in the United States with nearly 24,000 human cases reported to the Centers for Disease Control and Prevention (CDC) in 2005. This may represent only about 10% of physician-diagnosed cases. Surveys have found that up to a quarter of residents in Lyme disease endemic areas have been diagnosed with the disease and that many residents perceive the disease as a serious or very serious problem. Without an effective intervention strategy, the steadily increasing trend in Lyme disease case reports is likely to continue.

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In the northeastern United States, the emergence of Lyme disease can be linked to changing landscape patterns. A Swedish naturalist named Pehr Kalm recorded in his journal of his travels in the United States in 1748-1750 that ticks were

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abundant and annoying. Over a century later in 1872, entomologist Asa Fitch noted that ticks were nearly or quite extinct along the route that Pehr Kalm had traveled. During this time, the land had been cleared for agriculture and white-tailed deer in many areas were drastically reduced or virtually eliminated due to habitat loss and unregulated hunting. With the reestablishment of forested habitat and animal hosts through the latter half of the twentieth century, ticks that may have survived on islands off the southern New England coast were able to increase and spread. The blacklegged tick, *Ixodes scapularis*, which is commonly known as the "deer" tick, and the principal vector for Lyme disease or Lyme borreliosis, was present on Naushon Island, Massachusetts, in the 1920s and 1930s. Some *I. scapularis* from Montauk Point, Long Island, New York, that were collected in the late 1940s and early 1950s were found infected with Lyme disease bacteria. The risk of human infection increased through the 1960s and 1970s until the recognition of the disease from the cluster of cases in Lyme, Connecticut, in 1975. Indeed, the disease was not new and cases had occurred in Europe through the 20th century under different names.

The rising incidence of Lyme disease is due to a number of factors including:

- Increased tick abundance
- Overabundant deer population
- Increased recognition of the disease
- Establishment of more residences in wooded areas
- Increased potential for contact with ticks.

With the steady increase in the incidence and geographic spread of Lyme disease, there is a need for homeowners, public health officials, and the pest control industry to learn how to manage or control the tick problem. The purpose of this handbook is to provide basic information on ticks and their biology, basic information on the diseases they carry, methods to reduce the risk of exposure to these parasites, and most importantly, information on how to reduce or manage tick populations, and therefore risk of disease, in the residential landscape.

Ticks: the foulest and nastiest creatures that be. Pliny the Elder, 23-79 A.D.

Ticks of the Northeastern United States

Ticks are not insects but are arthropods more closely related to mites, spiders, scorpions, and harvestmen. There are about 80 species of ticks in the United States (~ 865 species worldwide). However, only about 12 or so in the U.S. are of major public health or veterinary importance with a few others that occasionally attack humans. The ticks discussed in this handbook belong to the family Ixodidae or hard ticks. The principal hard ticks recovered from humans in the mid-Atlantic and northeastern United States are the blacklegged (i.e., deer) tick, *Ixodes scapularis*, the American dog tick, *Dermacentor variabilis*, and the lone star tick, *Amblyomma americanum*. Other tick species recorded as feeding on humans in the eastern U.S. include *Ixodes cookei*, *Ixodes dentatus*, and the brown dog tick, *Rhipicephalus sanguineus*. The Argasidae or soft ticks form the other major group of ticks. Soft ticks are generally nest inhabitants that are associated with rodents, birds, or bats. Several species of soft ticks attack humans and can transmit disease organisms, mainly in western states, but are not the focus of this handbook. One species, *Carios (Ornithodoros) kelleyi*, a bat tick, has been recovered from states in the northeast, including Connecticut.

Table 1. Important ticks of the northeastern states and some other major ticks of medical importance in the United States.

Tick	Common name	General Distribution
Hard Ticks		
Ixodes scapularis	Blacklegged tick	Northeastern, southeastern & mid-western U.S.
Ixodes pacificus	Western blacklegged tick	Pacific coast & parts Nevada, Arizona, Utah
Ixodes cookei	A woodchuck tick	Eastern United States & northeast Canada
Ixodes dentatus	A rabbit tick	Eastern United States
Amblyomma americanum	Lone star tick	Southeastern U.S., Texas to S. New England
Dermacentor variabilis	American dog tick	Eastern U.S. & parts of the west coast
Dermacentor andersoni	Rocky Mountain wood tick	Rocky Mountain states south to NM & AZ
Dermacentor albipictus	Winter tick	Canada, United States south to Central America
Dermacentor occidentalis	Pacific coast tick	California, Oregon, northern Baja peninsula
Rhipicephalus sanguineus	Brown dog tick	All U.S. and worldwide
Soft Ticks		
Ornithodoros species ticks	Relapsing fever ticks	Western United States
Carios kelleyi	A bat tick	A bat tick

Scientific Names and a Few Terms

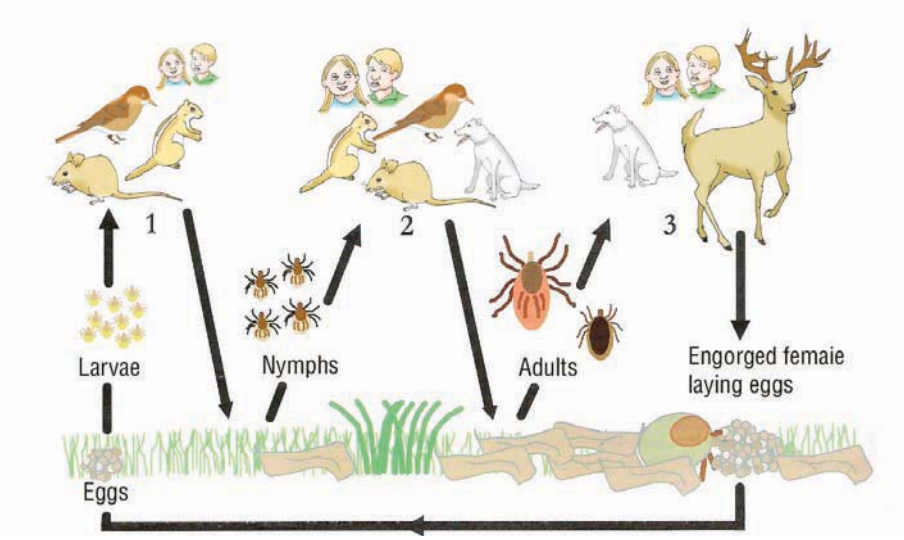
The scientific name of ticks, like other organisms, is given in two parts: genus (capitalized, often abbreviated by the first letter, e.g. *I. scapularis*) and species (not capitalized) sometimes followed by the name of the person who described the organism (given in parenthesis if the genus name is later changed). The name Linneaus is abbreviated L. Common names like deer tick can vary regionally and some organisms may have no common name. The common names used in this guide follow those officially recognized by scientific societies. Several terms are used to define the cycles of animal, tick and pathogen.

- Pathogen: the microorganism (i.e., virus, bacteria, rickettsia, protozoa, fungus) that may cause disease.
- Parasite: An animal that lives in or on a host for at least part of their life and benefits from the association at the expense of the host (from the Greek, literally para - beside and sitos - food).
- Vector: An insect or other arthropod, like a tick, that carries and transmits a disease pathogen. Diseases associated with pathogens transmitted by a vector are called vector-borne diseases.
- Host: An animal infected by a pathogen or infested with a parasite.
- Reservoir: An animal host that is capable of maintaining a pathogen and serving as a source of infection.
- Zoonoses: A disease caused by a pathogen that is maintained in vertebrate animals that can be transmitted naturally to humans or domestic animals by a vector or through other means (e.g. saliva, feces).
- Endemic disease: A disease that is established and present more or less continuously in a community.

Tick Biology and Behavior

Ticks, like many mite species, are obligate blood-feeders, requiring a host animal for food and development. Ticks have four stages in their life cycle: egg, the 6-legged larva (seed ticks), and 8-legged nymph and adult (male or female). Larvae and nymphs change to the next stage after digesting a blood meal by molting or shedding the cuticle. Most of the ticks mentioned in this handbook have a 3-host life cycle, whereas each of the three active stages feed on a different individual host animal, taking a single blood meal. Larvae feed to repletion on one animal, drop to the ground and molt to a nymph. The nymphs must find and attach to another animal, engorge, drop to ground and molt to an adult. The adult tick feeds on a third animal. A replete or engorged (blood filled) female tick will produce a single large batch of eggs and then die. Depending upon the species of tick, egg mass deposited can range roughly from 1,000 to 18,000 eggs.

3-host tick life cycle



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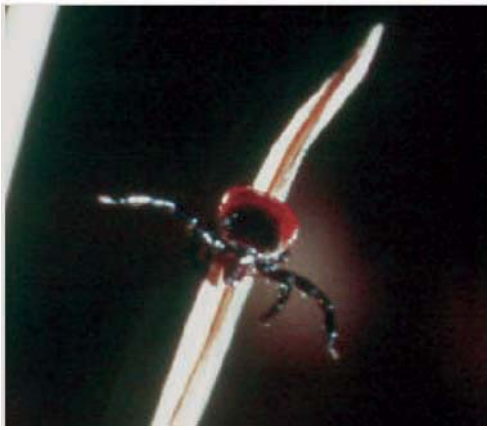

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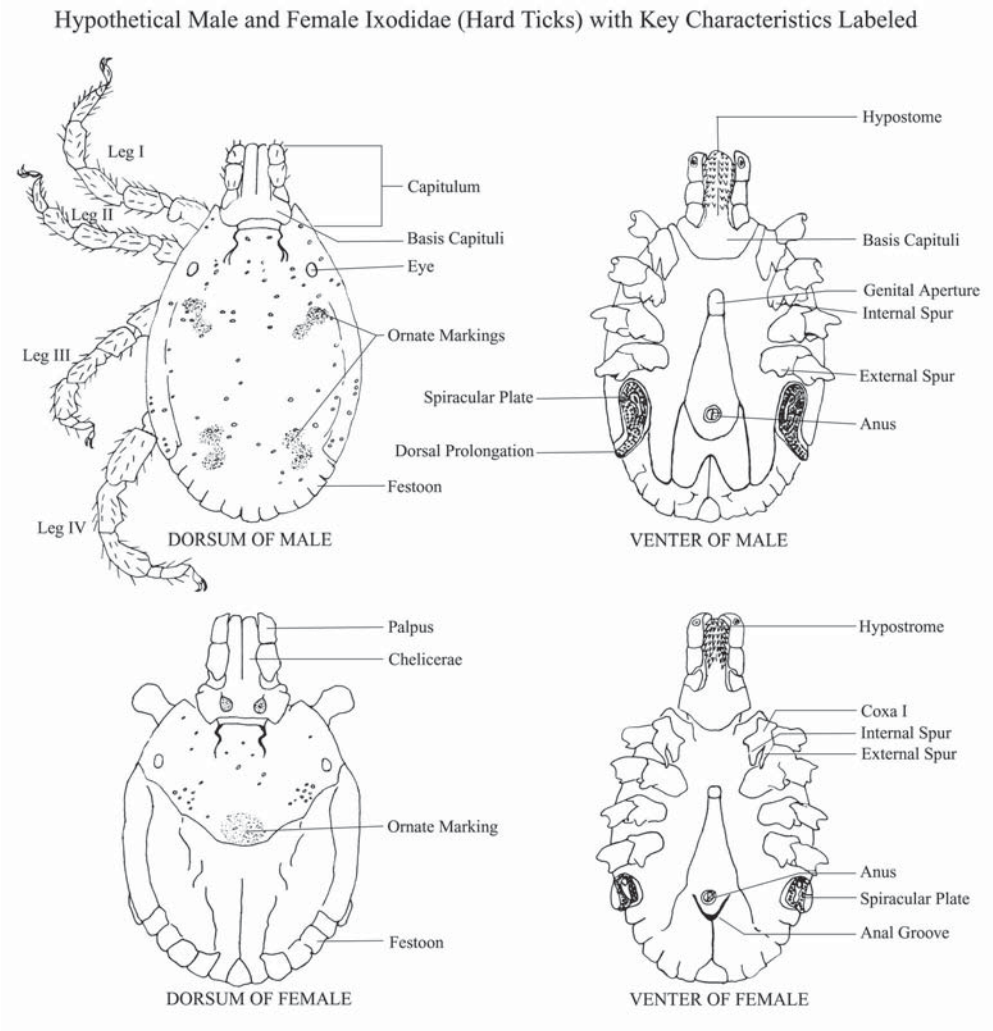
The larvae and nymphs generally feed on small to medium-sized hosts, while adult ticks feed on larger animals. Some ticks may have one-host (all stages staying and feeding on only one animal host before the female drops off) or other multi-host lifecycles. Depending upon the tick, the life cycle may be completed in 1, 2 or even 3 years, while a one-host tick may have more than one generation per year. Feeding for only a few days, the majority of the life of a tick is spent off the host in the environment either seeking a host, molting or simply passing through an inhospitable season (e.g., hot summers or cold winters). Soft ticks have a multi-host life cycle with multiple nymphal stages; each stage feeds briefly, and adults take multiple small blood meals, laying small egg batches after each feeding. As nest and cave dwellers, often with transient hosts, some argasid ticks may survive many years without a host. However, most hard ticks do not successfully find a host and perish within months or a year or two at best.

Larval ticks will be clustered on the egg mass after hatching and when ready to feed, ascend blades of grass or similar vegetation to await a host. Ticks assume a questing position by clinging to the leaf litter or vegetation with the third and fourth pair of legs, and hold the first pair outstretched. Due to differences in susceptibility to desiccation and host preference, immature ticks generally remain in the low vegetation, while adult ticks may seek a host at a higher level in the vegetation. Ticks detect their hosts through several host odors (including carbon dioxide, ammonia, lactic acid, and other specific body odors), body heat, moisture, vibrations, and for some, visual cues like a shadow. When approached by a potential host, a tick becomes excited - waving the front legs in order to grab the passing host. Ticks cannot fly or jump; they must make direct contact with a host. Once on a host a tick may attach quickly or wander over the host for some time. Some ticks attach only or principally on certain areas like the ear or thin-skinned areas, while other species may attach almost anywhere on the host. The ticks feed slowly, remaining on the host for several days, until engorged with blood (see following section on tick feeding). Male ticks feed intermittently, take small blood meals, and may remain on a host for weeks. For most ticks mating occurs on the host, as the male tick also requires a blood meal. However, male *Ixodes* ticks do not need to feed prior to mating and mating may occur on or off the host.

Tick Morphology

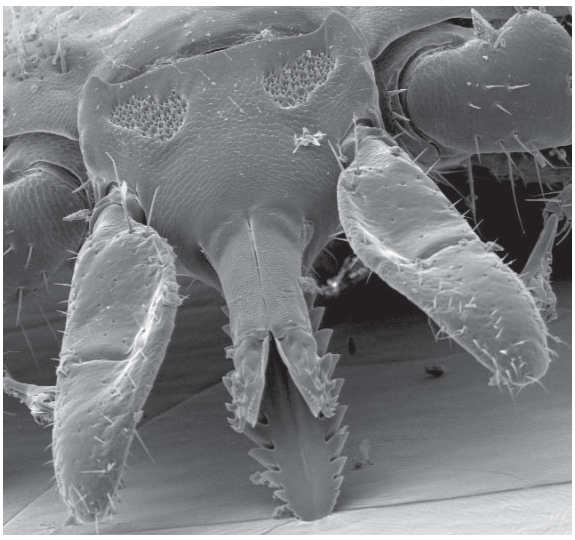
The body of a tick consists of a "false head" (the capitulum) and a thorax and abdomen fused into a single oval, flattened body. A larval tick has six legs, while nymphs and adults have eight legs present. The basal segment of the leg, the coxa, may have spurs that help in identification. An adult tick will have a genital aperture on the ventral surface, located roughly between the second pair of legs. The respiratory system is evident by spiracular plates located ventrolaterally behind the fourth pair of legs in the nymphs and adults. These plates may be oval, rounded, or comma-shaped. Hard ticks get their name from a tough dorsal shield or plate called the scutum present on all mobile stages of the tick. The scutum on the larva, nymph, and female tick covers the dorsal anterior third to half of the body. By contrast, the scutum on a male tick covers almost the entire dorsal surface and expansion during feeding is very limited. The scutum differs in shape and others characteristics (i.e., presence or absence of simple eyes) between tick genera. In some ticks, ornate or patterned markings may be present that can aid in identification. A distinct semicircular anal groove curves around the front of the anal opening in *Ixodes* ticks. In all other ticks, the anal groove is behind the anus or absent. Many ticks, but not *Ixodes*, have rectangular areas separated by grooves on the posterior margin of the tick body called festoons. Festoons, if present, may not be visible on fully engorged females. Argasid ticks are leathery, wrinkled and grayish in appearance. The capitulum of soft ticks is located on the underside of the body and cannot be seen from above.



The capitulum in hard ticks is visible dorsally in all stages. The capitulum holds the mouthparts consisting of a base (basis capituli), two palps, paired chelicerae, and the median ventral hypostome, which is covered with denticles or recurved teeth. The shape of the basis capituli, length of the palps, number of denticles, and other characteristics of the mouthparts are used to help identify tick genera and species. While the adults of some common ticks can be easily identified with a little training because of distinctive markings or color, the identification of most ticks and the immature stages requires the services of a trained entomologist and the use of keys developed by tick taxonomists. These keys are designed to specifically identify adults, nymphs or larvae.

Above right: Mouthparts of *I. scapularis* nymphs showing hypostome with rows of denticles (center) and two pair chelicerae (palps are partially visible).

13



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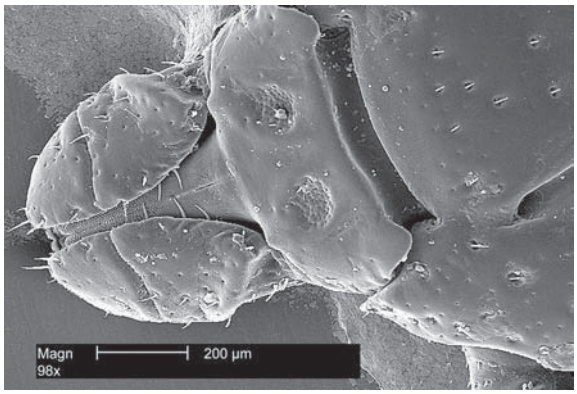

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How a Tick Feeds

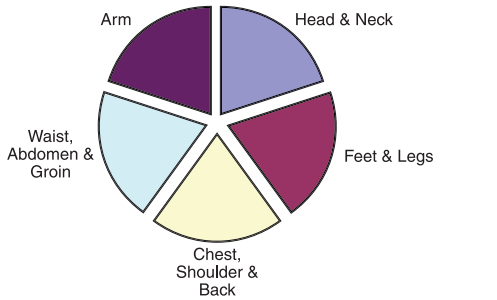
The term tick bite may be misleading as ticks do not bite and depart or feed rapidly like a mosquito. Ticks attach and feed gradually over a period of several to many days. Once a tick has found a suitable place to feed, it grasps the skin, tilts the body at a 45-60° angle, and begins to cut into the skin with the paired chelicerae. The palps lay outwards on the skin surface. After the chelicerae and hypostome penetrate the skin, they become encased in “cement” secreted by the tick. The cement serves to hold the mouthparts in place while the tick feeds. Mouthparts on larval and nymphal ticks are small with less penetration and produce a smaller host reaction. Adult *Ixodes* and *Amblyomma* ticks have long mouthparts that can reach the subdermal layer of skin, produce a larger reaction, and make the tick harder to remove. Insertion of the mouthparts often takes around 10-30 minutes, but can take longer (1-2 hours). The reaction to a feeding tick may make the tick appear imbedded, but only the slender mouthparts actually penetrate the skin.

Scanning electron micrographs of the mouthparts of the blacklegged tick (top) and American dog tick (bottom). On the top picture the two palps are spread apart showing the upper two chelicerae and the lower hypostome bracketing the oral cavity.

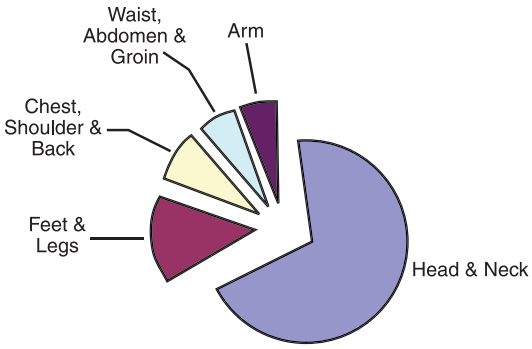
Physical and enzymatic rupture of tissue creates a lesion or cavity under the skin from which blood is imbibed. A variety of pharmacologically active compounds that aid the feeding process and possibly increase pathogen transmission are introduced in the tick's saliva (e.g., blood platelet aggregation inhibitors, anticoagulants, anti-inflammatory and immunosuppressive agents, enzymes, and vasodilators to increase blood flow). Feeding is not continuous and most of the blood meal is taken up during the last 12-24 hours of feeding. The body weight of a feeding female tick can increase 80-120 times. Male ticks are intermittent feeders, take smaller amounts of blood, and do not change appreciably in size (male *I. scapularis* do not need to feed and are rarely found attached).

Ticks may attach and feed anywhere on the body, but there are differences depending upon exposure and species of tick. The distribution of the blacklegged tick is relatively uniform. However, over a third of *I. scapularis* were from the legs and arms and another third were from the back up through the shoulders, neck and head. By contrast, most American dog ticks are removed from the head and neck region.

Proportion of *Ixodes scapularis* (A) and *Dermacentor variabilis* (B) submitted to The Connecticut Agricultural Experiment Station recovered from various regions of the body.



A. *Ixodes scapularis*



B. *Dermacentor variabilis*

Tick Sampling

A "tick drag" or "tick flag" may be used to determine if ticks are present. To construct a tick drag, attach one edge of a square yard piece of white, heavy flannel or corduroy material to a 3 foot long wooden dowel and tie a rope to each end of the wooden dowel. Curtain weights can be attached to the opposite end to help hold the cloth to the ground. Drag the cloth over the lawn and leaves and check for ticks. A "tick flag", which is easier to use on vegetation, is similar to a tick drag, but is built just like a flag. Only a small proportion of the ticks present will be picked up this way, so several drags should be done before concluding there are few or no ticks. Tick drags will not work when the grass or vegetation is damp or wet. **Precautions to avoid tick bites should be taken when sampling for ticks.**

The Blacklegged Tick or "Deer" Tick, *Ixodes scapularis* Say

Blacklegged tick is the correct common name for the tick popularly known as the "deer" tick (the terms are not used together, it is not called the blacklegged deer tick). *Ixodes* (pronounced x-zod-ease) *scapularis* transmits the causal agents of three diseases; Lyme disease, human babesiosis, and human granulocytic anaplasmosis (HGA). The northern range of the tick includes southern portions of Canada and coastal Maine through the mid-Atlantic states into Maryland, Delaware and northern parts of Virginia and in several north central states, particularly Wisconsin and Minnesota, extending down through Illinois and into Indiana. This tick is also found throughout the southeastern United States west to southcentral Texas, Oklahoma, southern Missouri, and eastern Kansas. However, few *I. scapularis* in the southeast have been found infected with the bacterium that causes Lyme disease, the spirochete *Borrelia burgdorferi*. Therefore, the risk for Lyme disease from this tick in the southeastern United States is considered relatively low.

16

Above: left to right: larva, nymph, male and female *I. scapularis*. Below top: unfed and engorged female. Below bottom: female with egg mass.

17

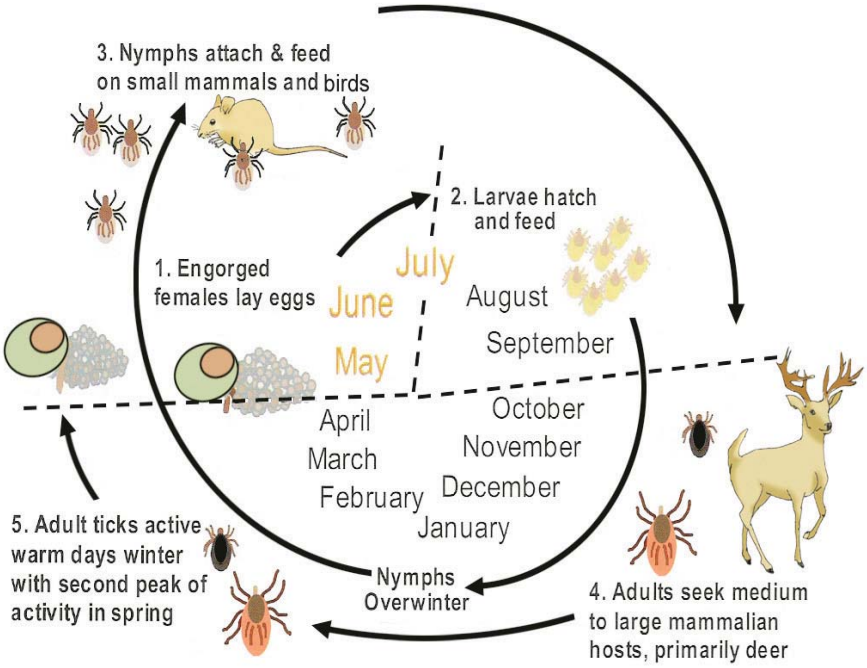
18

Unfed female *I. scapularis* have a reddish body and a dark brown dorsal scutum (plate) located behind the mouthparts. Length of the female tick from the tip of the palpi to the end of the body is about 3 to 3.7 mm (about 1/10 of an inch). Male *I. scapularis* are smaller (2 – 2.7 mm) than the female and are completely dark brown. Nymphs are 1.3 to 1.7 mm in length, while larvae are only 0.7 to 0.8 mm. Female blacklegged ticks become fairly large when engorged with blood and, consequently, are sometimes confused with engorged female American dog ticks.

Blacklegged ticks feed on a wide variety of mammals and birds, requiring 3-7 days to ingest the blood, depending on the stage of the tick. Larvae and nymphs of *I. scapularis* typically become infected with *B. burgdorferi* when they feed on a reservoir competent host. The white-footed mouse is the principal reservoir (source of infection) for *B. burgdorferi*, the protozoan agent of human babesisois, *Babesia microti*, and can serve as a reservoir for the agent of human granulocytic ehrlichiosis. Birds are also a major host for immature *I. scapularis* and have been implicated in the long-distance dispersal of ticks and *B. burgdorferi*. White-tailed deer, *Odocoileus virginianus* (Zimmerman), are the principal host for the adult stage of the tick, which feeds on a variety of medium- to large-sized mammalian hosts. An engorged female tick may typically lay around 2,000-3,000 eggs.

The Lyme disease spirochete in northern states is maintained, in part, by the two-year life cycle of the tick. Eggs are laid by the female in May. Larvae hatch from those eggs in mid- to late July with August being the peak month for larval tick activity. After feeding, the larvae drop from the host and molt to nymphs, which will appear the following year in late spring. May, June and July are peak months for nymphal tick activity in the northeast. Therefore, the nymphs precede larvae seasonally and can infect a new generation of animal hosts. Larvae active later in the summer then become infected when feeding on reservoir host animals. The nymphal ticks will molt to adults after feeding and appear in the fall of the same year. Adult *I. scapularis* do not hibernate and may be active on warm winter days and the following spring. Adults of *I. scapularis* are more heavily infected with *B. burgdorferi* than the nymphs because the tick has had two opportunities to become infected, once as a larva and once as a nymph.

Two-year Life Cycle for *Ixodes scapularis*



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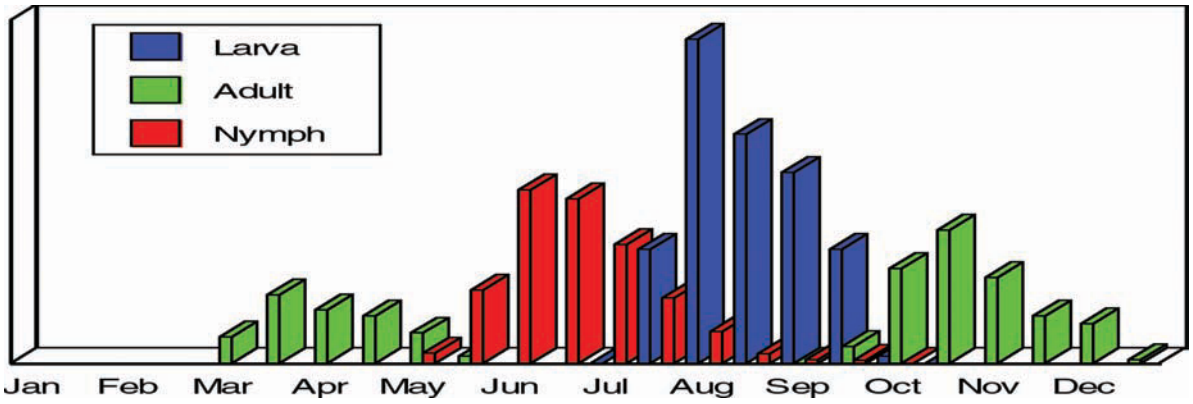
Seasonal activity of *Ixodes scapularis* larvae, nymphs, and adults



Top row: Nymphal *I. scapularis* in the hand and close-up of an *I. scapularis* nymph (fingerlike projections of the tick mid-gut where the Lyme spirochetes are found are visible through the tick cuticle); Middle row: nymphal *I. scapularis* on finger and female and nymph *I. scapularis* on finger; Bottom row: paired *I. scapularis* nymph dorsal and ventral views.

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Below left: Dorsal and ventral view female *I. scapularis*; dorsal view male *I. scapularis*; right is male, female and engorged female with straight pin for size comparison.

26

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27

Basic Seasonal Guide to Major Ticks Affecting Humans in Connecticut
(Also see seasonal graph for *I. scapularis*)

Fall (October-November)
Adult *Ixodes scapularis* active

Winter (December-February)
Adult *Ixodes scapularis* active during periods of warm weather (the ticks do not hibernate)

Early Spring (March-April)
Adult *Ixodes scapularis* (second peak of activity)
Adult *Dermacentor variabilis* appear late April
Adult *Amblyomma americanum* appear mid-April
(lone star ticks still are not common in CT)

Late Spring (May)
Adult *Ixodes scapularis* are disappearing
Nymphal *Ixodes scapularis* appear about mid-May
Nymphal *Amblyomma americanum* appear mid-May
(lone star ticks still are not common in CT)

Early Summer (June-July)
Nymphal *Ixodes scapularis* peak period activity
Adult *Dermacentor variabilis*
Nymphs *Amblyomma americanum*
(lone star ticks still are not common in CT)

Late Summer (August-September)
Larval *Ixodes scapularis peak*
A few nymphs of *Ixodes scapularis* &
adults of *Dermacentor variabilis* may still be present

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

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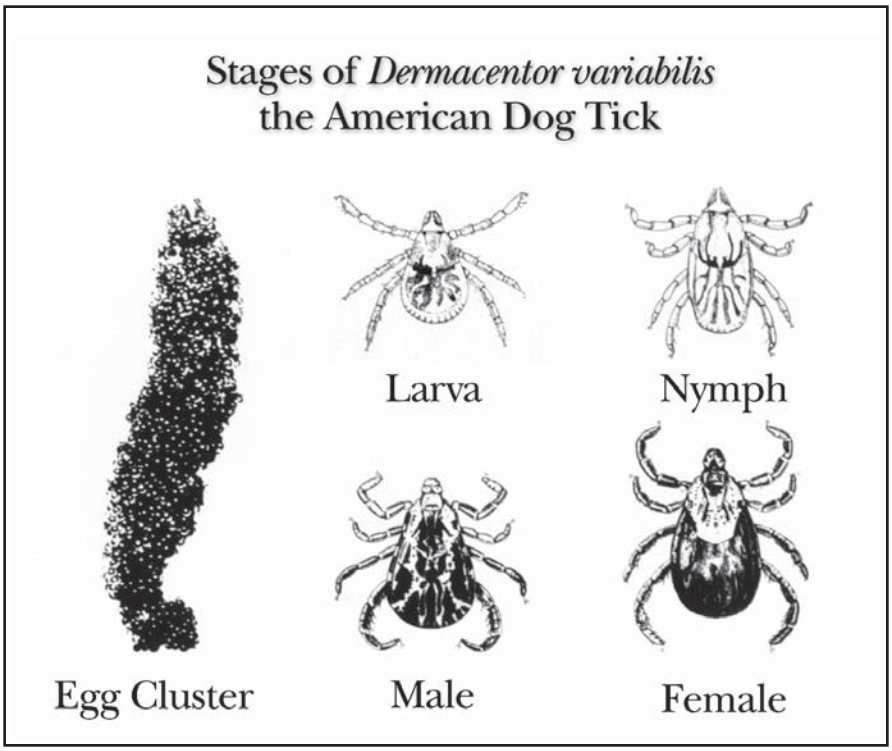
31

The American dog tick, *Dermacentor variabilis*, is the primary vector of the causal agent of Rocky Mountain spotted fever in the eastern United States and is also a vector for the agent of tularemia. This tick does not transmit Lyme disease spirochetes and recent studies have indicated that it is not a vector for the agent of human granulocytic ehrlichiosis. The American dog tick, known by some people as the wood tick, is one of the most widely distributed and common ticks in the eastern and central United States, found from Nova Scotia to the Gulf Coast as far west as Texas, Kansas and the Dakotas. It is also found in parts of California, Oregon, eastern Washington, and northern Idaho. Only adults of the American dog tick feed on people and their pets – records of nymphs from humans are rare.

Adult American dog ticks are reddish brown in color with silvery-gray or whitish markings on the back or upper body. They are almost 6.4 mm (¼ inch) in length. The palps are short. The ornate marking is on the scutum of the female, which on the male, extends over the entire back. Female ticks increase dramatically in size as they obtain their blood meal from a host animal. Fully engorged females may reach ½ inch in length (13 mm long by 10 mm wide) and resemble a dark pinto bean. Male ticks do not change notably in size as they feed. The scutum or plate does not change in size and the white markings are readily visible on a blood-fed tick. Adult dog ticks can be distinguished from adult *I. scapularis* by their larger size and the white markings on the dorsal scutum. In the northeast, adults of both tick species are active during the spring.

Dogs are the preferred hosts of adult ticks, but they also feed readily on other medium to large mammals. These include opossums, raccoons, skunks, fox, coyote, bobcat, squirrel, cattle, sheep, horses and people. Larvae and nymphs of the American dog tick feed on meadow voles (*Microtus pennsylvanicus*), white-footed mice (*Peromyscus leucopus*), and other rodents. In New Jersey, adult ticks are active from mid-March to mid-August. In Connecticut and Massachusetts, adults become active about mid-April to early May, peak in June, and may remain a nuisance until mid-August. Mating occurs on the host. A female tick will feed for 10-12 days. Once she is engorged with blood, she drops off the host, and may deposit about 3,000 to 7,000 eggs (average around 5,000). Males continue to ingest small amounts of blood from the host. In the northeast, the American dog tick probably requires 2 years to complete its life cycle as opposed to one year in the southern parts of its range. American dog ticks can live for extended periods without feeding, more than two years to almost three years, if suitable hosts are not available. Larvae, nymphs, and adults may live up to 540, 584, and 1,053 days, respectively, although typically survival will be much less.

American dog ticks are most numerous along roadsides, paths, marshy areas and trails in brushy woodlands or meadows with tall grass or weeds. Meadow voles are found in fields, pastures, fresh and saltwater marshes and meadows, borders of streams and lakes, and open and wooded swamps. Consequently, large numbers of American dog ticks may be encountered in these areas. People or their pets may bring these ticks from outdoors into the home, where they can survive for many days. However, the tick will not become established indoors. The Brown dog tick is the species that may cause household infestations.



32

American Dog Tick, *D. variabilis*; top row female; Dorsal view (left), Ventral View (right); lower row, male, Dorsal view (left), Ventral View (right)

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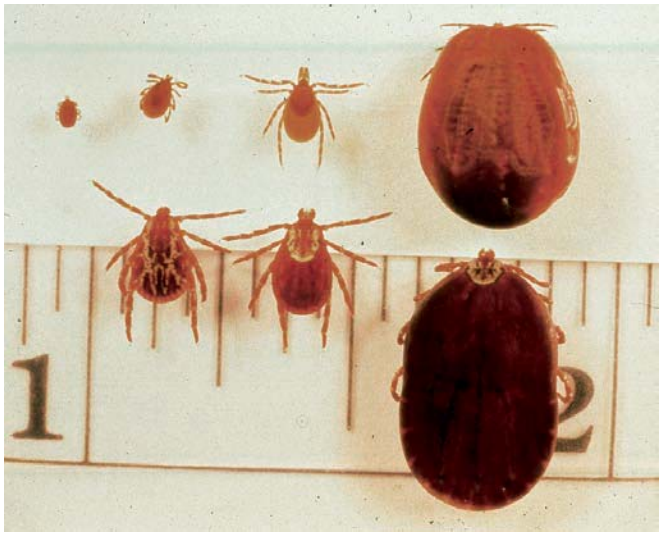

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Comparison between the blacklegged tick and American dog tick (above). Top row left to right: nymph, male, female, and engorged female *I. scapularis*. Note engorged female is nearly as large as the engorged female American dog tick. Bottom row left to right: male, female, and engorged female *D. variabilis*. Note the white markings on the scutum of *D. variabilis* can help distinguish between the two engorged ticks.

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

38

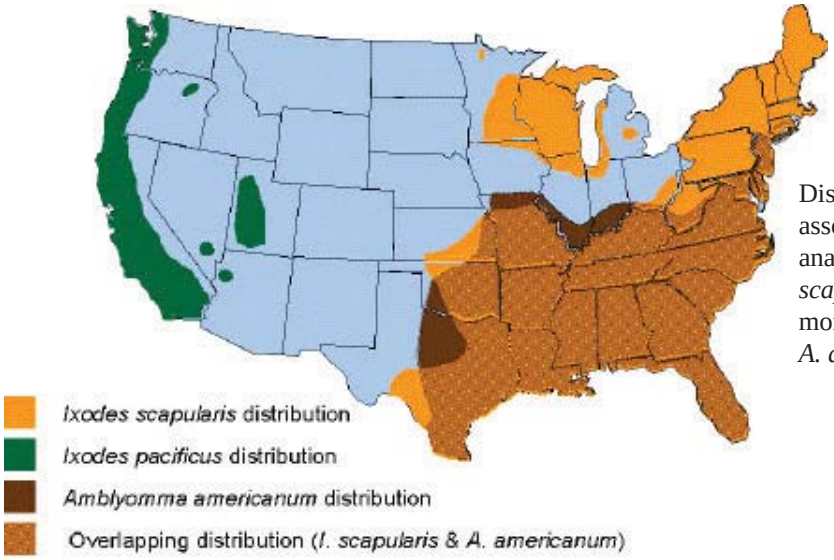
The lone star tick, *Amblyomma americanum*, is named from the conspicuous spot on the end of the scutum of the female tick. This tick is the vector for *Ehrlichia chaffeensis*, the agent of human monocyctic ehrlichiosis (HME). The tick does not transmit the Lyme disease bacterium, *B. burgdorferi*, but has been linked with a Lyme-like illness with a rash and other symptoms resembling Lyme disease called southern tick-associated rash illness or STARI. Possibly caused by another species of spirochete, attempts to culture the organism from skin biopsies at the rash or obtain serological evidence of Lyme disease from affected patients have not been successful thus far. A new spirochete, *B. lonestari*, has been described from lone star ticks based on a DNA analysis. It has been detected in both a tick and associated rash, but it is yet not clear if it is the agent of the Lyme-like illness.

39

The lone star tick is widely distributed through the southeastern United States as far west as Texas and north to southern parts of Iowa, Illinois, Indiana, Ohio, and Pennsylvania. Along the Atlantic coast, its northern range extends to New Jersey and Long Island, New York, and it is also abundant on Prudence Island, Rhode Island. Lone star tick populations in Connecticut are sparse, but these ticks are occasionally recovered from residents in many parts of the state, predominately in coastal communities in Fairfield and New Haven Counties.

Lone star ticks are reddish brown in color and about 3 to 4 mm long. The palps of *Amblyomma* ticks are long. Female ticks have a conspicuous spot on the end of the scutum. Male ticks have faint white markings at the edge of the body. Nymphs are more circular in shape than *I. scapularis* nymphs and reddish in tint. Adults are active in the spring, while nymphs are active from April through the mid-summer. Larvae are active in the late summer and early fall.

The lone star tick has a wide host range, feeding on virtually any mammal. All stages will feed on people. On wild hosts, feeding occurs principally in and on the ears and the head. The bite of this tick can be painful because of the long mouthparts and attached ticks can caused great irritation. All stages are active during the summer months. Female ticks can deposit 1,000 to 8,000 eggs with an average of around 3,000 eggs. Deer and other large to medium-sized animals are hosts for the adults and nymphs. Heavy infestations of this tick have been known to result in blindness and death of fawns of white-tailed deer. In some localities, this tick may also be known as the "deer" tick. Larvae and nymphs commonly feed on large and medium-sized and mammalian hosts such as raccoon, skunk, rabbit, opossum, and fox. Larval ticks also feed on many species of birds. Rodents do not appear to be important hosts for immature *A. americanum*.



Distribution of the tick species associated with human granulocytic anaplasmosis (HGA), *I. scapularis*, *I. pacificus*; and human monocytotropic ehrlichiosis (HME), *A. americanum* (CDC).

Other Ticks

Ixodes cookei Packard

Ixodes cookei, sometimes referred to as the "woodchuck tick", is found throughout the eastern half of the United States and Canada. It is primarily a parasite of medium-sized mammals such as woodchucks, opossums, raccoons, skunks, and foxes. In a New York study, it was the second most abundant tick on medium-sized mammals behind *I. scapularis*. All stages of *I. cookei* will feed on humans, though reports in southern New England and New York are uncommon. It appears to be a more frequent human parasite in northern New England and Ontario, Canada. After the American dog tick, *I. cookei* was the second most common tick removed from humans in Maine from 1989-1990 (*I. scapularis* was third). Lyme disease spirochetes have been detected in this tick, but based upon laboratory studies, it does not appear to be a good vector for *B. burgdorferi*. However, *I. cookei* is the principal vector for the Powassan virus, which can cause severe or fatal human encephalitis.

Rocky Mountain Wood Tick, *Dermacentor andersoni* Stiles

40

The Rocky Mountain Wood tick, *Dermacentor andersoni*, is found in western North America from British Columbia and Saskatchewan south through North Dakota to northern New Mexico and Arizona and California. The immature stages prefer to feed on a variety of small mammals such as ground squirrels, chipmunks, meadow mice, woodchucks, and rabbits, while the adults feed mainly on larger animals like cattle, sheep, deer, elk, dogs, and humans. Adults become active in February or March, peak in April and May, and decline by July. The normal life cycle requires 1 or 2 years. Unfed adult ticks may survive for 66 days. The female tick can lay up to 7,400 eggs. This tick is the vector for Rocky Mountain spotted fever and Colorado tick fever in western Canada and the northwestern United States as well as tularemia and Q fever.

Pacific Coast Tick, *Dermacentor occidentalis* Marx

This 3-host tick is distributed along the Pacific coast west of the Cascade range and Sierra Nevada Mountains in Oregon and California as well as northern Baja California, Mexico. The immature stages prefer to feed on a variety of small mammals such as ground squirrels, chipmunks, meadow mice, and wood rats, while the adults feed commonly on cattle, horses, deer, and humans. This tick is a vector for Rocky Mountain spotted fever and tularemia and bites are very irritating to humans. Adult ticks are active all year, but are most abundant in April and May.

Brown Dog Tick, *Rhipicephalus sanguineus* (Latreille)

41

The brown dog tick or kennel tick, *Rhipicephalus sanguineus*, is a three-host tick found almost worldwide and throughout the United States. The tick is more abundant in the southern states. This is the only species of this genus in the U.S. Domestic dogs are the principal host for all three stages of the tick, especially in the United States, although the tick feeds on other hosts in other parts of the world. Adult ticks feed mainly inside the ears, head and neck, and between the toes, while the immature stages feed almost anywhere, including the neck, legs, chest, and belly. People may occasionally be attacked.

This tick is closely associated with yards, homes, kennels and small animal hospitals where dogs are present, particularly in pet bedding areas. In the North, this tick is found almost exclusively indoors. Brown dog ticks may be observed crawling around baseboards, up the walls or other vertical surfaces of infested homes seeking protected areas, such as cracks, crevices, spaces between walls or wallpaper, to molt or lay eggs. A female tick can deposit between 360 to 3,000 eggs. Under favorable conditions, the life cycle can be completed in about two months. This tick is the vector for canine ehrlichiosis (*Ehrlichia canis*) and canine babesiosis (*Babesia canis* or *Babesia gibsoni*) and may possibly be associated with the transmission of *Bartonella vinsonii* in dogs. Brown dog ticks infected with the agent for Rocky Mountain spotted fever were recovered in Arizona where an outbreak of the disease had occurred.

Brown dog tick, *R. sanquineus*, female dorsal view (left) and ventral view (right). Note hexagonal shape of the basis capituli behind the mouthparts.

42

43

Winter Tick, *Dermacentor albipictus* (Packard)

The winter tick, *Dermacentor albipictus*, is a one-host tick found commonly on moose (*Alces alces*), elk (*Cervus elaphus*), and deer. Hunters will encounter this tick (as well as *I. scapularis*) on harvested deer, moose, and elk during the hunting season. Heavy tick infestations can cause anemia and other problems and death of the animal. Larval ticks infest animals in the fall and then develop into nymphs and adults without leaving the host. Engorged females will drop off the host animal in the spring. This tick is broadly distributed from Canada to Central America. This tick will occasionally feed on humans.

Western Blacklegged Tick, *Ixodes pacificus* Cooley and Kohls

Although outside the scope of this handbook, readers should note that the western blacklegged tick, *Ixodes pacificus*, is the principal vector for Lyme disease to humans in the western United States. It looks just like the blacklegged tick in the east and only a specialist could tell them apart. It is found along the Pacific Coast in the western half of Washington and Oregon, almost all of California, and in parts of Utah, Arizona, and New Mexico. Infection rates with *B. burgdorferi* are generally low, 5-6% or less, because many of the immature *I. pacificus* ticks feed on the western fence lizard (*Sceloporus occidentalis*), a reservoir incompetent host for *B. burgdorferi* whose blood also contains a borreliacidal factor that destroys spirochetes in *I. pacificus* nymphs. Several rodents (mainly woodrats) and a nest dwelling tick, *I. spinipalpis*, maintain the enzootic cycle of Lyme disease in California and other western states.

Carios (Ornithodoros) kelleyi Cooley and Kohls

This tick feeds on bats and is found in homes, bat colonies, and other areas where bats may be found. It may occasionally bite humans whose dwellings are infested by bats. Records from the northeast include Pennsylvania, New York, and Connecticut.

44

Imported ticks

Travelers abroad have found exotic ticks on themselves after returning to the United States. Other ticks may be imported on pets and other animals. Some of these ticks are potential vectors of pathogens of domestic livestock and introduction and establishment of these ticks would have serious consequences for the livestock industry. For humans, there are a number of bacterial and rickettsial pathogens and encephalitis and hemorrhagic fever viruses carried by ticks in Europe, Asia, Africa and Australia. For example, cases of boutonneuse fever, also called Mediterranean spotted fever, have occurred in travelers returning to the U.S. Boutonneuse fever is distributed through Africa, countries around the Mediterranean, southern Europe, and India. Other spotted fever diseases are African tick-bite fever, Siberian tick typhus, and Queensland tick typhus.

45

Amblyomma hebraeum, one exotic species that has been imported into the U.S. Found throughout southern Africa, it is a vector for *Rickettsia conori*, the agent of boutonneuse fever. (J. Occi).

Several tick-borne encephalitis viruses, as well as Lyme disease spirochetes, are transmitted by *Ixodes ricinus* ticks in the British Isles, central and Eastern Europe, and Russia and by *Ixodes persulcatus* from central Europe, Russia, parts of China, and Japan. The following ticks have been documented from traveler's returning to the northeast (destination, origin): *Amblyomma cajennense* (CT, Jamaica), *A. hebraeum* (CT, South Africa), *A. variegatum* (NY, Kenya), *Rhipicephalus simus* (CT, Kenya), *Dermacentor auratus* (ME, Nepal), and *Hyaloma marginatum* (CT, Greece). The Connecticut travelers returning from South Africa and Kenya were diagnosed with boutonneuse fever. Tick bite prevention measures should be taken by travelers to potentially tick infested areas abroad. Physicians should consider exotic tick-associated diseases in the differential diagnosis for a patient with a travel history outside the United States.

Louse Flies of Deer May Be Confused with Ticks

These flies are tick-like, blood-feeding parasitic flies (family Hippoboscidae), which may be confused with true ticks. The adult flies are dorsally flattened like a tick, with six legs. Several species are common parasites of white-tailed deer in the U.S. and are frequently seen by hunters or others in close association with deer. One species, *Lipoptena cervi* is known as the "deer ked" and was imported from Europe. It occasionally will bite humans. Other "deer keds" are native to the U.S. The female fly retains the larvae, nourishing them internally, and then lays mature larvae, which promptly pupate. The hippoboscid flies associated with deer have wings when they emerge, but lose them once they find a host.

46

During the 1960s and 1970s, my husband, four children, and I were periodically plagued with mysterious symptoms. In time, I came to suspect that these ailments were somehow linked.

Polly Murray, 1996
The Widening Circle:
A Lyme Disease Pioneer Tells her Story

Tick-Associated Diseases

There are at least eleven recognized human diseases associated with ticks in the United States, seven or eight of which occur in the mid-Atlantic or northeastern states. Each of the diseases is highlighted in this section of the handbook. The greatest attention is given to Lyme disease, anaplasmosis (ehrlichiosis), and babesisois. Although each is a zoonotic vector-associated disease, not all are caused by an infectious agent or are exclusively tick transmitted. A toxin causes tick paralysis, tularemia can be transmitted through contaminated animal tissue or other materials, and babesisois and anplasmosis can be transmitted perinatally and through blood transfusion. Tick associations with other pathogens like *Bartonella* or *Mycoplasma* are not yet clearly defined. The causative agents transmitted to humans by the tick are maintained in a reservoir host. *Ixodes* ticks can be infected with more than one agent and co-transmission and infection can occur. Alternatively, multiple infections can occur from multiple tick bites. In a Connecticut and Minnesota study, 20% of Lyme disease patients also had serological evidence of exposure to another tick-borne agent.

Table 2. Tick-associated diseases in the United States.

Disease	Pathogen or causal agent	Tick Vector
Anaplasmosis, granulocytic	*Anaplasma phagocytophilum*	*I. scapularis, I. pacificus*
Babesiosis	*Babesia microti*	*I. scapularis, I. pacificus*
Colorado tick fever	CTF virus (Retoviridae)	*D. andersoni*
Ehrlichiosis, monocytic	*Ehrlichia chaffeensis*	*A. americanum*
Lyme disease	*Borrelia burgdorferi*	*I. scapularis, I. pacificus*
Southern rash illness	*Borrelia lonestari* (?)	*A. americanum*
Powassan encephalitis	Powassan virus	*I. cookei*
Rocky Mountain spotted fever	*Rickettsia rickettsia*	*D. variabilis, D. andersoni*
Tick-borne Relapsing Fever	*Borrelia* species	*Ornithodoros* species ticks
Tularemia	*Franciscella tularensis*	*D. variabilis, A. americanum*, others
Tick paralysis	Toxin	*D. variabilis, D. andersoni*

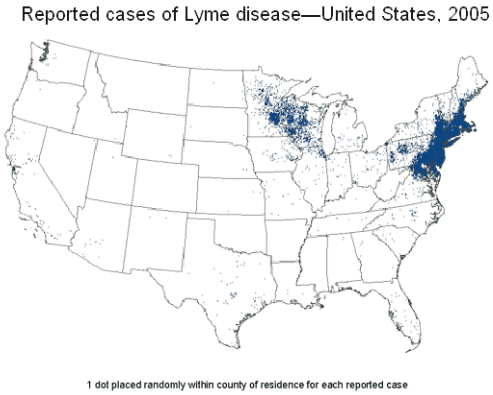
Lyme disease, monocytic ehrlichiosis and granulocytic anaplasmosis, Rocky Mountain spotted fever, and tularemia are nationally reportable diseases. The amount and quality of surveillance data provided to state health departments and then to CDC is quite variable. Most surveillance is passive, dependent upon physician reporting. Most diseases are greatly underreported. Active surveillance or laboratory-based reporting may also exist in some states or areas. Case reports are based on a standardized surveillance case definition, which is not meant to be the basis for diagnosis. An increase in case reports can represent a true increase in disease or increased awareness of the disease and increased reporting. Conversely, a decrease may represent a change in reporting or a lack of reporting, rather than a true decrease in the incidence of disease. Nevertheless, surveillance case reports generally provide valuable long-term tracking of disease trends and may influence the allocation of resources to monitor, study and prevent disease.

Lyme Disease (Lyme Borreliosis)

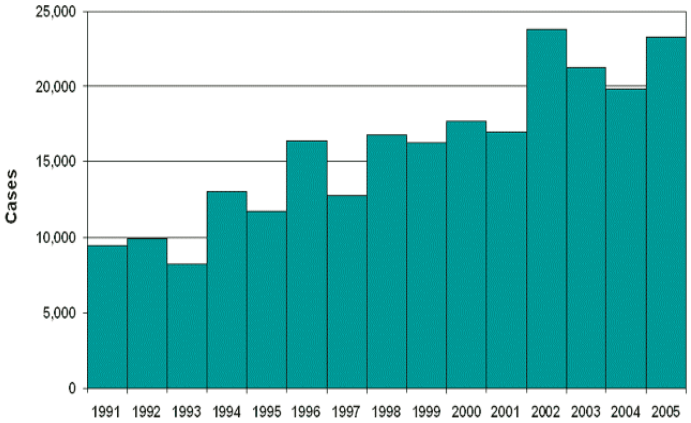
Lyme disease is the leading arthropod-associated disease in the United States and is caused by the spirochete *Borrelia burgdorferi*, a corkscrew-shaped bacterium. It is associated with the bite of certain *Ixodes* ticks, particularly the blacklegged tick, *I. scapularis*, in the northeastern and north-central United States and the western blacklegged tick, *Ixodes pacificus*, on the Pacific Coast. Other *Ixodes* ticks spread the disease in Europe and Asia. The disease has been reported from 49 states, as well as parts of Canada, and across Europe and Asia.

The spirochete *Borrelia burgdorferi* (CDC)

Lyme disease was first recognized as a distinct clinical entity in a group of arthritis patients from the area of Lyme, Connecticut in 1975. In 1981, Dr. Willy Burgdorfer and co-workers discovered spirochetes in the mid-gut of some *I. scapularis* ticks from Long Island, New York and the bacterium was later named after him. A Lyme disease testing program by The Connecticut Agricultural Experiment Station and Connecticut Department of Public Health found the greatest prevalence in Connecticut in 1984 and 1985 was in towns east of the Connecticut River. The distribution of the tick and the risk of disease have since expanded dramatically from early foci in Connecticut, New York and Cape Cod, MA. Nationally, human case reports have been running around 20,000 to 24,000 cases annually. There were 23,305 cases reported in 2005, 19,804 cases reported in 2004, 21,273 cases in reported in 2003 and 23,763 cases were reported in 2002. Twelve states accounted for 95% of reported cases. In order of incidence (per 100,000 population) in 2002 they were Connecticut, Rhode Island, Pennsylvania, New York, Massachusetts, New Jersey, Delaware, New Hampshire, Wisconsin, Minnesota, Maine, and Maryland. Lyme disease is underreported, and these numbers may represent only 10-20% of diagnosed cases.



National statistics are available through the CDC website, www.cdc.gov and local statistics may be available through state public health departments or on their websites. Lyme disease affects all age groups, but the greatest incidence of disease has been in children under 14 and adults over 40 years of age. In most cases, Lyme disease symptom onset occurs during the summer months when the nymphal stage of the blacklegged tick is active.



Reported cases of Lyme disease in the United States, 1991-2005.

Clinical signs and symptoms of Lyme disease

Lyme disease is a multisystem disorder with diverse cutaneous, arthritic, neurologic, cardiac, and occasional ocular manifestations. Symptoms that occur within days or weeks following the tick bite reflect localized or early-disseminated infection. Late manifestations can become apparent months or years after infection. Early diagnosis and treatment is important to resolve current signs and symptoms, eliminate *B. burgdorferi* infection, and prevent later complications. The major signs and symptoms provided below do not cover all those associated with infection by *B. burgdorferi*. Those who want additional information can consult the literature provided in the bibliography including treatment and prevention guidelines published in 2006 by the Infectious Diseases Society of America.

Localized infection

- The dormant spirochetes in the tick midgut multiply as blood feeding begins and migrate to the tick salivary glands. The spirochetes alter the expression of outer surface proteins from OspA in the midgut to OspC in the salivary glands, which is required for infection of a mammalian host.
- Lyme disease is characterized in the majority of patients (70-80%) by an expanding red rash at the site of the tick bite called primary erythema migrans (or EM). The rash serves as a clinical marker for early disease, although the presence of a rash may go unrecognized. A rash should be > 5 cm in diameter for a firm diagnosis. The CDC specifies that an EM rash must be 2.5 inches or greater in diameter for a surveillance case definition, but this definition should not be used as a diagnostic criterion!
- Erythema migrans may appear within 2 to 32 days (typically 7-14 days) after the tick has detached. The rash gradually expands over a period of days to a week or more at a rate of ½ to ¾ inch per day and should not be confused with the transient hypersensitivity reaction (< 5 cm) to a tick bite that disappears within 24-48 hours.
- Rashes vary in size, shape, and appearance. They may occur anywhere on the body, although common sites are the thigh, groin, trunk, and axilla. Many rashes reach about 6 inches in diameter, but some can expand to 8-16 inches or more.
- An EM may be warm to the touch, but it is usually not painful and is rarely itchy. The rash may be uniformly red, have central clearing, or a “bull’s eye” appearance. Swelling, blistering, scabbing occur occasionally (5% cases). The "bull’s-eye" appearance is not common and is characteristic of older rashes. The EM will resolve spontaneously without treatment.
- Mild nonspecific systemic symptoms may be associated with the rash in about 80% of cases and include fatigue, muscle and joint pain, headache, fever, chills, and stiff neck. Flu-like symptoms may occasionally occur in the absence of an identified rash and be identified as ‘summer flu.’ Respiratory or gastrointestinal complaints may occur, but are infrequent.

47

48

49

51

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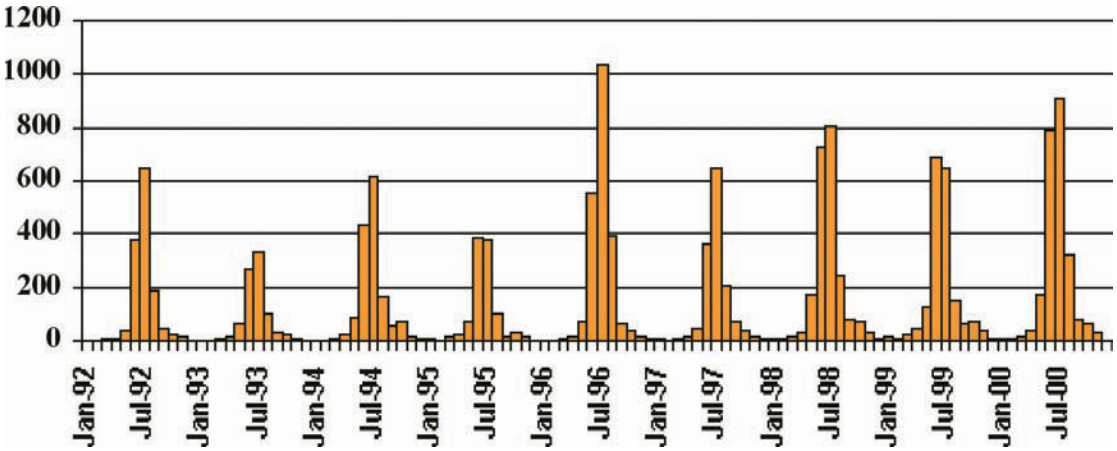
52

Previous page: Lyme rash without clearing (left) and bull's eye EM (right). This page: rash on the top left showing central clearing is the same EM illustrated on the previous page (bottom left). Lyme rash (EM) 5 days (bottom right) and 10 days (top right) on antibiotic treatment.



Above: Month of onset of Lyme disease symptoms over a 9-year period in Connecticut. The pattern is relatively consistent from year to year with the greatest number of cases occurring in the summer months when nymphs of the blacklegged tick are active (CT DPH).

Early disseminated infection

Lyme disease spirochetes first multiply locally in the tick bite site and then disseminate widely within days to weeks through the skin, lymph, or blood to various organ systems, particularly skin, joint, nervous or cardiac tissue. Signs and symptoms may be intermittent, migratory and

changing. Nonspecific viral-like symptoms generally mark early-disseminated infection and up to a fourth of patients may develop multiple secondary rashes. Days or weeks after the bite of an infected tick, migratory joint and muscle pain (also brief, intermittent arthritic attacks), debilitating malaise and fatigue, neurologic or cardiac problems may occur. The symptoms appear to be from an inflammatory response to active infection. Multiple EM, headache, fatigue, and joint pain are the most common clinical manifestations noted in early-disseminated disease in children. Multiple components of the nervous system can be affected by *B. burgdorferi*. Early neurologic symptoms develop in 10-15% of untreated patients and these include cranial neuropathies, the most common manifestations (e.g., Bell's palsy or paralysis of facial muscles), radiculoneuropathy (pain in affected nerves and nerve roots, can be sharp and jabbing or deep), and meningitis (fever, stiff neck, and severe headache). Children present less often with facial palsy and more commonly with fever, muscle and joint pain, and arthritis (primarily the knee). Lyme carditis (various degrees of intermittent atrioventricular heart block) and rhythm abnormalities may occur in 4-10% of untreated patients and require hospitalization. Ocular manifestations are uncommon and may include conjunctivitis and other inflammatory eye problems. Infection produces an active immune response and antibodies to *B. burgdorferi* are detectable in the vast majority of patients during these manifestations. The immune response appears to eradicate most *B. burgdorferi* and symptoms may resolve even without antibiotic treatment. However, the organism may still survive in localized sites.

Late disseminated and persistent infection

Detection and treatment for Lyme disease early after infection appears to have reduced the incidence of later arthritic and late neurologic manifestations of disease. Lyme arthritis is an intermittent chronic arthritis that typically involves swelling and pain of the large joints, especially the knee. If not treated, episodes of arthritis may last weeks to months with spontaneous remissions over a period of several years. Approximately 50-60% of untreated individuals may develop arthritis and about 10% of these may have chronic joint inflamation. Joint swelling may persist after complete or near complete elimination of the spirochete from the joint with antibiotic therapy. Late neurologic Lyme disease may present as numbness or tingling of the extremities, sensory loss, weakness, diminished reflexes, disturbances in memory, mood or sleep, cognitive function deficits. Late encephalomyelitis may be confused with multiple sclerosis.

53

The course and severity of Lyme disease is variable. Mild symptoms may go unrecognized or undiagnosed and some individuals may be asymptomatic (no early illness). The EM rash or subsequent arthritic, cardiac or nervous system problems may be the first or only sign of Lyme disease. Most symptoms eventually disappear, even without treatment, although resolution may take months to over a year. The disease can also be chronic and debilitating with occasional permanent damage to nerves or joints. Chronic Lyme disease or post-Lyme disease syndromes, similar to chronic fatigue syndrome and fibromyalgia, are a controversial and unclear constellation of symptoms related to or triggered by infection with *B. burgdorferi*. Both persistent infection and infection-induced autoimmune processes have been proposed to account for ongoing problems despite antibiotic therapy. Disease persistence might be due to a slowly resolving infection, residual tissue damage, inflammation from remains of dead spirochetes, immune-mediated reactions in the absence of the spirochete, co-infection with other tick-borne pathogens, or an alternative disease process that is confused with Lyme disease.

Diagnosis and treatment of Lyme disease

A physician should be consulted if Lyme disease is suspected. Only the rash is distinctive enough for a clinical diagnosis without laboratory confirmation. In the absence of an EM rash, Lyme disease may be difficult to diagnose because its symptoms and signs vary among individuals and can be similar to those of many other diseases. Conversely, other arthritic or neurologic diseases may be misdiagnosed as Lyme disease. Lyme disease is probably both over-diagnosed and under-diagnosed with groups of patients, some of whom without Lyme disease convinced they have it while other patients with the disease being told they do not have it. A blood test to detect antibodies to Lyme disease spirochetes (serological testing) can support or confirm the clinical diagnosis of the disease. Antibodies to *Borrelia* antigens (parts of the bacteria recognized by the immune system) usually cannot be detected until 3-4 weeks after onset of disease. Therefore, tests are not reliable enough to be used as the sole criterion for a diagnosis during the early stages of the disease. Tests can give false-negative and false-positive results. Newer tests are more specific, greatly reducing false positive reactions. Reliability of the test improves dramatically in the later stages of the disease as serological reactivity increases, although inaccurate results may still occur. Patients with neurologic or arthritic Lyme disease almost always have elevated antibody concentrations.

54

Two stage serological testing for Lyme disease is suggested by many public health organizations:

- Stage One: A relatively sensitive screening method by enzyme-linked immunosorbent assay (ELISA) or indirect fluorescent antibody (IFA) test. If negative, no further testing is done. Testing at the time of the Lyme disease rash is unnecessary as many will be negative. Antibiotic treatment early in infection may abrogate the antibody response. An ELISA provides a quantitative measure of antibody levels (measurable color reaction) and for rapid testing of large numbers of samples. An ELISA measures the reaction to all the antigens in disrupted *Borrelia* or to recombinant antigens, but does not allow identification of which antigens are being bound by antibody and can yield false positives from cross-reactive antibodies. ELISA using the C6 peptide of the VslE protein antigen, another surface protein of *B. burgdorferi* that elicits a strong response by the immune system, may be as sensitive and selective as the two-stage testing procedure.
- Stage Two: If the first test is positive or equivocal, a more specific Western immunoblot test is performed to simultaneously demonstrate an antibody response to several *B. burgdorferi* antigens (i.e., proteins recognized by the immune system), which show up as bands on the blot. The Lyme disease spirochete has numerous immunogenic proteins including outer surface proteins (OspA, OspB, and OspC), the 41 kDa antigen on the internal flagellum, and at least 9 other prominent antigens. The Western blot is labor intensive and requires a subjective interpretation of the results. Although there is an established criterion for a positive blot, there is some disagreement on the number and specific “bands” required for a positive test.

Lyme disease can be treated with one of several types of antibiotics, including tetracyclines, most penicillins, and many second- and third-generation cephalosporins (e.g., doxycycline, amoxicillin,

cefuroxime axetil, penicillin, ceftriaxone, or cefotaxime). Doxycycline is also effective against the agent of human granulocytic anaplasmosis. The standard course of treatment generally is for 14-28 days, depending upon clinical manifestation and drug, though a physician may elect a longer course of treatment. Tetracyclines should be avoided for pregnant or lactating women and children >8 years of age. Patients treated in the early stages of the disease usually recover rapidly and completely with no subsequent complications. While a few patients (<10%) fail to respond to antibiotic therapy, re-treatment is rarely needed. Oral antibiotics are effective in treating most cases of Lyme disease.

Intravenous antibiotics are indicated for central nervous system involvement and for recurrent arthritis. Full recovery is likely for patients treated in the later stages of the disease. Development of other Lyme disease symptoms after a course of antibiotics may require re-treatment with the appropriate antibiotic. However, resolution of some symptoms may take weeks or months even after treatment due to the inflammatory processes and damage associated with *B. burgdorfer*i infection, which does not appear to be altered by an initial longer course of antibiotics. Post-Lyme syndrome is not well defined and most researchers feel there is insufficient convincing evidence for persistent infection by *B. burgdorferi*.

Persistence of some symptoms and inability to directly determine if the bacteria are eliminated can make decisions on the length of treatment controversial. Courses of antibiotics may have health consequences due to the disruption of the normal intestinal bacteria, allergic reactions, increased sun sensitivity (with doxycycline), gall bladder problems (with ceftriaxone), and infection risks with catheters (extended intravenous antibiotics). Treatment failure may result from incorrect treatment, long delay before treatment, misdiagnosis (not Lyme disease), poor treatment compliance by the patient (did not finish the full course of antibiotics), and infection or co-infection with other tick-borne agents (i.e., *Babesia* or *Anaplasma*). Concurrent babesiosis or anaplasmosis should be considered in patients with a flu-like illness, particularly fever, chills, and headache, that fails to respond to antibiotic therapy for *Borrelia*. Reinfection can occur from subsequent tick bites, especially in patients treated with antibiotics early in the illness. Antibody levels generally will decline after treatment, although they may persist for many months or even years in some patients after symptoms have resolved.

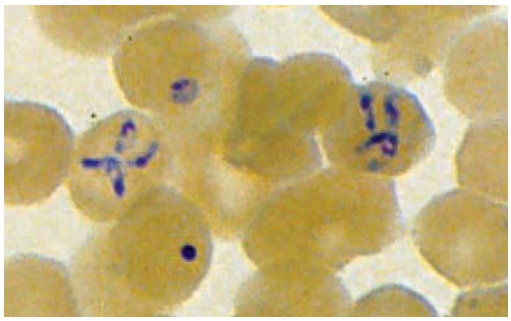
The economic impact of Lyme disease can be considerable. A recent study found a Lyme disease patient (clinically defined early and late stage) cost $2,970 in direct medical costs plus $5,202 in indirect medical costs, nonmedical costs, and productivity losses. The estimated costs varied considerably depending, in part, on dealing with clinical early or late Lyme disease or a tick bite, but the data suggested that a small number of patients accounted for a large proportion of total costs. Direct medical costs of Lyme disease include physician visits, referrals for consultations, serologic testing, medical procedures, treatment, hospitalization or emergency room visit charges, and other costs. The figures also included other expenses related to Lyme disease like suspected disease or similar complaints and tick bite. While more information on the social costs of tick-associated disease is needed, tick bite prevention, tick management, and early diagnosis and treatment for infection are important in reducing the individual, social and economic impact of Lyme disease.

Southern Tick-Associated Rash Illness (STARI)

A Lyme-like rash has been noted following the bite of the lone star tick, *A. americanum*, in south central and southeastern states and given the name Southern tick-associated rash illness (STARI). The rash is indistinguishable from the rash caused by *B. burgdorferi*. Associated symptoms include fever, headache, fatigue, muscle and joint pain. Little is known about this illness. While spirochetes have been observed in about 1-3% of lone star ticks, the bacteria cannot be cultured in the media used for *B. burgdorferi*. A spirochete named *Borrelia lonestari* has been identified in *A. americanum* and at least one patient with STARI.

Human Babesiosis

Human babesiosis is a malaria-like illness that is caused by a protozoan organism found in the red blood cells of many wild and domestic animals. Babesiosis is caused by *Babesia microti* in the northeast and upper mid-west United States. *Babesia microti* is a parasite of white-footed mice, as well as voles, shrews, and chipmunks. Other species or variants of *Babesia* are associated with human disease in other parts of the United States (i.e., California and Missouri), Europe, and Asia. Human babesiosis has been recognized since the early 1970's in parts of Massachusetts (particularly Nantucket Island), Block Island, Rhode Island, and the eastern parts of Long Island, New York. Most reported cases of babesiosis have been from New York, Massachuetts, Connecticut, and Rhode Island. The first Connecticut case of human babesiosis was reported from Stonington in 1988. The majority of cases continue to be reported from the southeastern portion of that state, although recent evidence indicates that the organism has become more widely distributed in inland areas. Most cases in Rhode Island are reported from the southern coastal regions. The number of confirmed cases has increased in New Jersey in recent years, which may represent increased risk or increased awareness. The number of reported cases is probably only a small fraction of clinically diagnosed cases with many other subclinical or mild cases going undetected and unreported. Nevertheless, the distribution and number of reported cases of babesiosis appears to be increasing.



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Babesia microti in red blood cells (CDC).

The white-footed mouse is the primary reservoir for *B. microti*, which is transmitted by *I. scapularis*. While data on the prevalence of infection in *P. leucopus* and particularly in *I. scapularis* are limited to a few studies, babesial parasites have been observed in up to 41% of mice and over 90% can carry antibodies to this agent in endemic areas. Infection in mice may be life long. Infections in ticks generally appear to be lower than that of *B. burgdorferi*, but in highly endemic areas, tick infection may be equally prevalent. Maintenance of the parasite seems to require moderate to high tick densities. Most human cases occur during the summer months when nymphs of the blacklegged tick are active. *Babesia* also can be transmitted through blood transfusions from asymptomatic donors.

56

White-footed mouse, *Peromyscus leucopus*.

A mouse (or other reservoir competent rodent host, such as the meadow vole) and the blacklegged tick are required to complete different aspects of the *Babesia* lifecycle. Larval or nymphal ticks acquire the parasites when feeding on an infected mouse. In the tick gut, male and female gametes unite to form zygotes. Subsequently, a stage of the parasite reaches the salivary glands and becomes dormant until the tick feeds again. The parasite is passed to the next stage of the tick (transstadial transmission). Upon tick attachment, infectious sporozoites are formed and shed in the saliva of the tick. It may require as many as 54 hours of attachment before transmission occurs. Adult *I. scapularis* also can transmit the parasite. During transmission, the sporozoites enter red blood cells, reproduce asexually, and emerge to

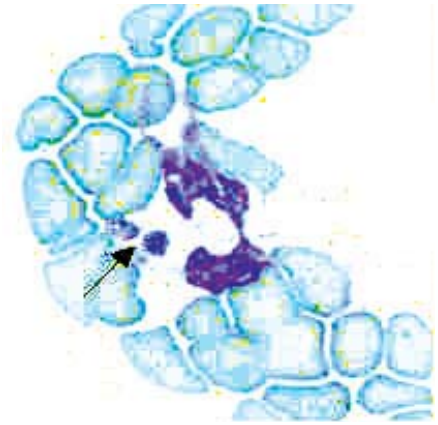
invade new cells, destroying the infected cells in the process. Introduction of *B. microti* into another mouse perpetuates the cycle. A female tick does not transmit this parasite to her eggs (transovarial transmission).

The clinical presentation of human infection ranges from subclinical to mild flu-like illness, to severe life-threatening disease. Infection often is accompanied by no symptoms or only mild flu-like symptoms in healthy children and younger adults. The disease can be severe or fatal in the elderly, the immune suppressed (HIV infection or use of immunosuppressive drugs), and people without spleens. The greatest incidence of severe disease occurs in those older than 40 years of age. Symptoms of babesiosis include fever, fatigue, chills, sweats, headache, and muscle pain beginning 1-6 weeks after the tick bite. Gastrointestinal symptoms (nausea, vomiting, diarrhea, abdominal pain), respiratory symptoms (cough, shortness of breath), weight loss, dark urine, and splenomegaly also may occur. Complications such as acute respiratory failure, congestive heart failure and renal failure have been associated with severe anemia and high levels of infected cells (parasitemia). Up to 80% of red blood cells can be infected in a splenectomized patient, although 1-2% parasitemia is typical in those with intact spleens. Illness may last weeks to months and recovery can take many months. Co-infection with *B. microti* and *B. burgdorferi* can result in overlapping clinical symptoms, a more severe illness, and a longer recovery than either disease alone.

A specific diagnosis of babesiosis can be made by detection of the parasites in Giemsa-stained blood smears and confirmed serologically by an indirect fluorescent antibody (IFA) test. A complete blood count (CBC) is useful in detecting the hemolytic anemia and/or thrombocytopenia (decrease in blood platelets) suggestive of babesiosis. Liver enzymes may be elevated. The parasite can also be detected by polymerase chain reaction (PCR) assay for the DNA of the *Babesia* agent. The drugs of choice in the treatment of babesiosis are oral clindamycin plus quinine sulfate or a combination of oral azithromycin and atovaquone. Adverse effects (i.e., tinnitus, vertigo, lower blood pressure, gastrointestinal upset) are commonly associated with clindamycin and quinine use and some patients cannot tolerate the treatment. The combination of azithromycin and atovaquone is better tolerated. At times, severely ill patients may receive intravenous clindamycin and quinine and benefit from an exchange blood transfusion. Following drug treatment, the parasites usually are eliminated and there is no recurrence of disease. In immunocompromised individuals, however, parasitemia may persist for months and possibly years following recovery from illness and relapse may occur. Currently, individuals who have ever been diagnosed with babesisois are excluded from donating blood.

Human Granulocytic (Granulocytotropic) Anaplasmosis

Human granulocytic anaplasmosis (HGA), formerly human granulocytic ehrlichiosis, is caused by a small gram-negative bacterium, *Anplasma phagocytophilum*. The HGA agent is transmitted by the bite of infected *Ixodes* ticks (*I. scapularis* and *I. pacificus*) and is usually found where Lyme disease is also endemic, particularly the northeast and upper mid-west. This pathogen belongs to a group of bacteria with several species known to cause disease in cattle, sheep, goats, and horses. These bacteria invade neutrophils, a type of white blood cell (leucocyte), forming colonies (morulae) that may be observed in a stained peripheral blood smear. HGA was first described from patients with an acute febrile illness, sometimes severe, in Wisconsin and Minnesota in 1994. The organism was first grouped in the genus *Ehrlichia* with the agent for human monocytic ehrlichoisis. Based on



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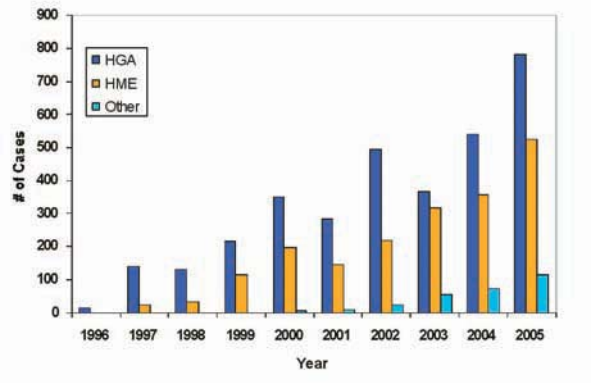
Morulae of *A. phagocytophilum* in cytoplasm of neutrophil (CDC).

a DNA analysis, the pathogen was reclassified as an *Anaplasma* species and HGE became HGA. Surveillance for HGA is sparse in most states; it was added to the national list of reportable diseases in 1998 (along with human monocyctic ehrlichiosis). HGA is less common than Lyme disease, but the number of reported cases has been increasing. In Connecticut, there have been 883 confirmed cases of HGA reported from 1995-2005, with cases distributed across all eight Connecticut counties. States with the majority of HGA cases include New York, Connecticut, Rhode Island, Massachusetts, Minnesota and Missouri.



Number of national reported cases of human anaplasmosis and ehrlichiosis (CDC).

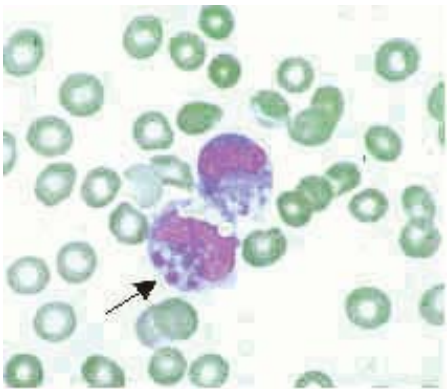
The blacklegged tick is the principal vector for the HGA agent in the northeastern and upper mid-western United States. The western blacklegged tick is the vector in northern California. Most cases of HGA occur in May, June, or July with 80-90% of cases occurring between April and September. This corresponds to the activity of nymphal *I. scapularis*. The white-footed mouse appears to be the primary small mammal reservoir. Unlike *B. burgdorferi*, infection appears transient in most mice, with a few possibly more persistently infected individuals. However, any potential role other animals that have been found seropositive or PCR positive as reservoirs for *A. phagocytophilum* remains unclear. Co-infection with *B. burgdorferi* in ticks appears to be generally low (<10%), but relatively high (~25-33%) rates have been noted in a few localities. Transmission of both *B. burgdorferi* and *A. phagocytophilum* from a single tick bite has been documented. Laboratory studies indicate transmission may occur within 24 hours of tick attachment and possibly within 8 hours.

Clinical manifestations for HGA are non-specific and are not clinically distinctive. Illness may be characterized by fever, headache, muscle pain, nausea, vomiting, and malaise. Initial symptoms appear 5-21 days after the tick bite. Most cases are mild and self-limiting, resolving without treatment within 30 days, but cases may also be moderate or severe. Some cases require hospitalization and there have been a few fatalities, although the death rate is very low. The number of clinical cases increases with age. The highest rates have been observed for patients 50 years of age or older. Severe cases and fatalities have been reported across all age groups. Laboratory findings may show a decrease in white blood cell (leukopenia) and blood platelet (thrombocytopenia) counts and an increase in liver enzyme levels. Chronic infections in humans have not been reported. A diagnosis of HGA should be considered for patients with a febrile illness in tick endemic areas. Co-infections by the agents of HGA and Lyme disease have been reported and may result in more severe disease. A diagnosis of HGA can be confirmed by observing the organism in white-blood cells, culturing the organism, amplification of the DNA of the organism by polymerase chain reaction (PCR), or by a serological test. Serological tests may be negative in the early stages of acute disease and are more reliable in specimens obtained during the third week of illness. The drug of choice for the treatment of HGA is doxycycline (tetracycline may also be effective). Response to antibiotic therapy is rapid with clinical improvement in 24-72 hours. Rifampin has been used successfully when doxycycline cannot be used.

Human Monocytic (Monocytotropic) Ehrlichiosis

Human monocytotropic ehrlichiosis (HME) is caused by *Ehrlichia chaffeensis*. Lone star ticks are the vector for *E. chaffeensis* in south central and southeastern regions of the country where most cases of HME occur. Veterinarians have known about canine ehrlichiosis, caused by *E. canis* and

transmitted by the Brown dog tick since 1935. HME was first recognized in the United States in 1986 in a patient who was bitten by a lone star tick in Arkansas. The organism, closely related to *E. canis*, was isolated from another patient at the Fort Chaffee Army Base and named *E. chaffeensis*. This pathogen is associated with monocytes, another type of white blood cell. The DNA of *E. chaffeensis* has been detected in lone star ticks from Connecticut and Rhode Island, so cases of HME may occur in southern New England. Unlike HGA, white-tailed deer rather than mice are the likely reservoir for *E. chaffeensis*.



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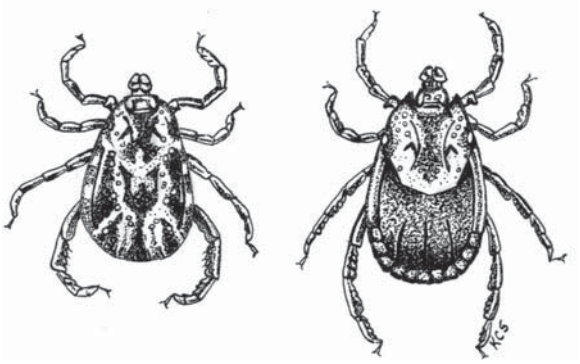
Morulae of *E. chaffeensis* in cytoplasm of monocyte (CDC).

Clinically, HME resembles HGA with similar non-specific viral-like symptoms appearing a few days to a couple of weeks after the tick bite and range from mild to severe. Subclinical cases may be relatively common. And like HGA, patients usually will develop leucopenia, thrombocytopenia and elevated liver enzymes. HME has been confused with other diseases including Rocky Mountain spotted fever (RMSF). Before *Ehrlichia* was linked with the disease, cases may have been included in what was called "Rocky Mountain spotless fever". A skin rash is uncommon in adults (< 10%), but is more common in children even though cases in children are less common (<10% of reported cases) than in adults. Diagnosis is based on the observation morulae in monocytes or macrophages in stained blood smears, PCR assays, or on serological tests. The antibiotic of choice is doxycycline, but rifampin is sometimes chosen when tetracyclines are contraindicated. Human infections by *Ehrlichia ewingii*, the agent of canine granulocytic ehrlichosis, also have been recently reported. Like the HGA agent, these bacteria occur in neutrophils. The ecology is probably similar to that of *E. chaffeeensis* as the lone star tick appears to be the vector and white-tailed deer appear to be the reservoir animal.

Rocky Mountain Spotted Fever

Rocky Mountain spotted fever (RMSF), caused by *Rickettsia rickettsii*, a type of bacterium, is widely distributed throughout the continental United States, southern Canada, Mexico and Central America and parts of South America. Although the disease was first recognized in 1896 from virulent cases in Idaho and Montana, the name is somewhat misleading as only a relatively small proportion of current cases are reported from the Rocky Mountain region. In the U.S., most cases of RMSF occur in the southeastern and south central states, particularly Oklahoma, Arkansas, Tennessee, North Carolina and South Carolina, which account for more than half of reported cases. Until recently, there were only 300-800 cases reported each year, but 1,000-2,000 case reports were received annually from 2003-2005. The majority of RMSF cases are associated with the American dog tick. In the western U.S., the vector is the Rocky Mountain wood tick, *D. andersoni*. Recently, the brown dog tick, *R. sanguineus*, has been implicated as a vector for RMSF in parts of Arizona.



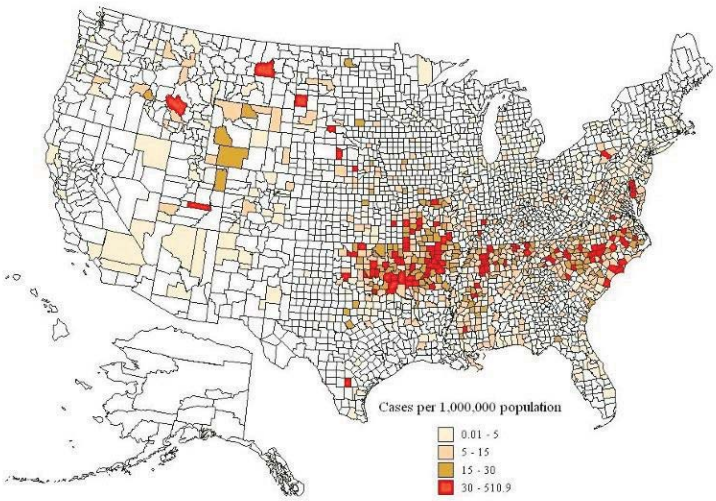
59

RMSF is relatively uncommon in New England. Between 1997 and 2002, based on figures in the CDC's Morbidity and Mortality Weekly Report (MMWR), 3,520 human cases were reported in the United States, of which 28 (less than one percent) were from New England. In Massachusetts,

RMSF is most often reported from Cape Cod and the surrounding islands. The mid-Atlantic States accounted for < 7 % of the U.S. total. Few ticks are infected. Scientists at The Connecticut Agricultural Experiment Station found that less than 1% of 3,000 American dog ticks examined in Connecticut, some of which were collected in the backyards of patients, were infected. Some spotted fever group rickettsiae are not infectious to humans.

Children are particularly at risk for RMSF with two-thirds of the cases in patients under 15 years of age. Like Lyme disease, the highest rate in children is in the 5 to 9 year-old age group. Symptoms usually appear within 2 to 9 days after a tick bite. Early disease is difficult to diagnose. Patients experience a variety of symptoms including sudden fever (90%), severe headache (89%), muscle pain (83%), and rash (78%). The rash may include the palms (50%) and soles of the feet. The rash may not be present or faint when a physician initially examines a patient as the classic spotted rash of RMSF appears after about six days.

RMSF incidence by county, 1997-2002 (CDC).



Below: Examples of spotted fever rash (CDC). Left to right: early (macular) rash on sole of foot, late (petechial) rash on palm and forearm, and rash on hand of a child.

60-62

The majority of patients receive an alternate diagnosis on their first visit for medical care, particularly early in the course of disease before distinct symptoms appear. Some patients (10-15%) never develop a rash. RMSF can be fatal in 20-30% of untreated cases and clinical progression may be rapid (median time to death about 8-10 days). Therefore, delays in diagnosis or treatment because of the absence of the rash or no knowledge of a tick bite could be dangerous. Prompt

antibiotic treatment is important for suspected cases. The tetracyclines are the drug of choice with chloramphenicol an alternative in some cases. RMSF is made more severe with inadvertent use of sulfonamides. In recent years, about 1-4% of cases in the U.S. have been fatal. A clinical diagnosis may be confirmed by molecular tests or serologically by an indirect fluorescent antibody (IFA) test, but antibodies may not yet be present when a physician sees a patient early in the illness (85% of patients lack diagnostic titers the first week after illness and 50% lack diagnostic titers 7-9 days after onset of illness).

Tick Paralysis

A toxin produced by certain *Dermacentor* ticks during feeding can cause a progressive, ascending paralysis, which is reversed upon removal of the tick. Recovery is usually complete. Paralysis begins in the extremities of the body with a loss of coordination and inability to walk. It progresses to the face with corresponding slurred speech, and finally shallow, irregular breathing. Failure to remove the tick can result in death by respiratory failure. Cases appear more frequently in young girls with long hair where the tick is more easily overlooked. Most cases of tick paralysis are caused by the Rocky Mountain wood tick (*Dermacentor andersoni*) in northwestern states. The American dog tick also has been known to cause tick paralysis.

Tularemia

The bacterium, *Francisella tularensis*, that causes tularemia (Rabbit Fever or Deer Fly Fever) is transmitted by bites from deer flies and horse flies and from several species of ticks. The American dog tick, *D. variabilis* is one of the principal vectors for *F. tularensis*. Other ticks associated with tularemia include the lone star tick, *A. americanum*, Rocky Mountain wood tick, *D. andersoni*, and certain *Ixodes* ticks. Most cases occur during the summer (May-August), when arthropod transmission is common. The disease also may be contracted while handling infected dead animals (particularly while skinning rabbits), eating under cooked infected meat, or by an animal bite, drinking contaminated water, inhaling contaminated dust, or having contact with contaminated materials. Transmission does not occur between people. Natural reservoirs of infection include rabbits, hares, voles, mice, muskrats, water rats, and squirrels. A recent study conducted in Connecticut showed that cats carried antibodies to the pathogen. Tularemia was removed from the list of reportable diseases after 1994, but was reinstated in January 2000 because of its potential as a bioterrorism agent.

Tularemia occurs throughout the United States as well as Europe, Russia, and parts of the Middle East, northern coast of Africa, Asia, China and Japan. There have been fewer than 200 cases reported each year during the first half of the 1990s, and again in 2000-2001, and less than 100 in 2002. Most cases have been reported from the central states of Missouri, Arkansas, and Oklahoma. With the exception of outbreaks of pneumonic tularemia on Martha's Vineyard that appear related to gardening or mowing activities that may have stirred up contaminated dust, reports of this disease are not common in New England, although sporadic cases do occur.

63

All persons are susceptible to tularemia. The clinical symptoms of tularemia depend upon the route of infection. With infection by a tick, an indolent ulcer often occurs at the site of the bite followed by swelling of the regional lymph nodes and usually a fever. Fever is the most commonly reported symptom. Diagnosis usually is made clinically and confirmed by an antibody test. Antimicrobials with demonstrable clinical activity against *F. tularensis* include the fluorinated

quinolones such as ciprofloxacin as well as streptomycin and gentamicin. While tetracycline or chloramphenicol also may be used, they are less effective and relapses occur more frequently.

Powassan Encephalitis

Powassan virus, a *Flavivirus*, is the sole member of the tick-borne encephalitis (TBE) group present in North America. The disease is named after a town in Ontario, Canada where it was first isolated and described from a fatal case of encephalitis in 1958. Documented cases of Powassan encephalitis (POW) are rare, but the disease may be more common than previously realized. While there were only 27 known cases in North America between 1958-1998 (mainly in Canada and New York state), four additional cases were identified in Maine and Vermont from 1999-2001 as a result of increased testing for West Nile virus. Surface antigens of these two viruses are similar, thus allowing cross-reactivity in antibody testing. The ages of these recent New England cases ranged from 25 to 70 years. Previously, the latest recognized symptomatic cases occurred in New York in 1978 and Massachusetts in 1994. POW presents as meningitis or meningoencephalitis progressing to encephalitis with fever, convulsions, headache, disorientation, lethargy, with partial coma and paralysis in some patients. The disease has a fatality rate of 10-15% and may result in severe long-term disability in the survivors. The principal tick vector appears to be *Ixodes cookei* with cases occurring from May through October. Patients generally have a history of tick bite, or a history of exposure to tick habitat or exposure to hosts such as squirrels, skunks, or woodchucks. The blacklegged tick is a competent vector of Powassan virus in the laboratory. A virus very closely related to and apparently a separate subtype of the Powassan virus has been isolated from *I. scapularis*, but the prevalence and public health significance of this virus are unknown.

Tick-borne Relapsing Fever

Soft ticks of the genus *Ornithodoros* transmit relapsing fever, caused by *Borrelia hermsi*, or a group of tick-adapted strains of the spirochete. Disease is characterized by cycles of high fever and is treated with antibiotics. Relapsing fever ticks are found in rodent burrows, nests, and caves through the western United States. They can live for many years without feeding. Human cases are often associated with people staying in shelters or cabins infested with these ticks.

Colorado Tick Fever

Colorado tick fever, caused by a virus, occurs in mountainous areas of the western United States and Canada. There are 200-400 cases each year. Scientists believe that cases are underreported. The virus is transmitted by female Rocky Mountain wood ticks. Symptoms begin with an acute high fever, often followed by a brief remission, and another bout of fever lasting 2-3 days. Other symptoms included severe headache, chills, fatigue, and muscle pain. Illness may be mild to severe, but is self-limited and not fatal. Treatment is symptomatic. Recovery occurs over several weeks but occasionally may take months.

Bartonella Infection

The genus *Bartonella* includes at least 16 species of vector-associated, blood-borne bacteria that infect a wide variety of domestic and wild animals, including rodents. Several are known human pathogens. These cause cat scratch disease (*B. henselae*), trench fever (*B. quintana*), Oroya fever (*B. bacilliformis*), and endocarditis (*B. elizabethae*). For example, *Bartonella henselae*, the agent of cat scratch disease, is transmitted to cats by fleas and generally to humans by bites or scratches from infected cats. *Bartonella*-specific DNA has been detected in *I. scapularis* and *I. pacificus* ticks, clearly ingested during feeding. A high percentage of *I. ricinus* ticks in Europe also have been reported to be infected with *Bartonella henselae*. A novel *Bartonella* species has been found with *B. burgdorferi* and *B. microti* in the white-footed mouse. At this time, there is no convincing evidence

that *Bartonella* can be transmitted to humans by a tick bite. The ability of ticks to transmit these bacteria in the laboratory or field still needs to be determined.

Lyme Borreliosis in Domestic and Companion Animals

Swollen joints in a dog with Lyme disease (Levy).

Domestic animals (dogs, cats, horses, cows, and goats) can become infected with *B. burgdorferi* and develop clinical Lyme borreliosis. Lameness and swollen joints, fever, lymph node enlargement, reduced appetite, and a reluctance to move are the usual symptoms in these animals. Disease is more common in dogs and relatively less frequent in cats. Most dogs (47-73% of unvaccinated animals) in a Lyme disease endemic area will eventually become infected (based on positive serology) due to their high exposure to ticks and about 5% will develop disease each year. Limb and joint arthritis is the most frequent sign in canine Lyme borreliosis; cardiac, neurological, ophthalmic, and a unique renal involvement is less common. Lyme nephritis in dogs often results in the death of the animal, even with aggressive treatment. Animals are treated with antibiotics (tetracycline or penicillin-group) and nonsteroidal anti-inflammatory drugs for relief of Lyme arthritis. Most dogs' arthritis responds dramatically to antibiotic treatment within days, followed by a complete recovery. Chronic disease appears rare, and a lack of response to therapy may suggest another diagnosis. Other disease processes, which should be ruled out, include rheumatoid arthritis, infectious arthritides, and other tick-borne diseases such as Rocky Mountain spotted fever and ehrlichiosis. However, studies have shown that infection and antibody titers may persist in dogs after efficacious treatment. It is not clear if a reoccurrence of disease is due to another tick exposure or from the initial infection. Some data suggest that treatment in the absence of clinical disease for seropositive dogs may be indicated. Prevention in companion animals is covered in the host management section.

Additional sources of information about tick-associated diseases

The Centers for Disease Control and Prevention, National Center for Infectious Diseases, Division of Vector-Borne Infectious Diseases, P.O. Box 2087, Fort Collins, Colorado, 80522 and Division of Viral and Rickettsial Diseases, 1600 Clifton Road, NE, MS G-13, Atlanta, Georgia 30333 (404-639-1075). The CDC provides details on the natural history, epidemiology, reported cases, signs & symptoms, diagnosis, treatment, prevention & control for several zoonotic diseases, including Lyme disease (www.cdc.gov/ncidod/dvbid/lyme/index.htm).

State health departments can provide information on the incidence of Lyme disease and other tick-borne illnesses in the state. There is usually a division or department that handles Lyme disease and other vector-borne diseases. Statistics are sometimes available on a department's web site.

Lyme disease foundations or groups can provide information or patient support. These include the American Lyme Disease Foundation, Inc. (ALDF), www.aldf.com and the Lyme Disease Foundation (LDF), www.Lyme.org.

Additional information related to tick-associated diseases, tick bite prevention, tick testing results for Connecticut, and the electronic version of this handbook are available on The Connecticut Agricultural Experiment Station's website, www.ct.gov/caes.

Personal Protection

Tick Bite Prevention

Personal protection behaviors, including avoidance and reduction of time spent in tick-infested habitats, using protective clothing and tick repellents, checking the entire body for ticks, and promptly removing attached ticks before transmission of *Borrelia* spirochetes can occur, can be very effective in preventing Lyme disease. While surveys and the continuing incidence of disease suggest that few people practice these measures with sufficient regularity, studies suggest that tick checks are the most effective method for the prevention of tick associated disease. Preventive measures are often considered inconvenient and, in the summer, uncomfortable. Despite the efficiency of tick repellents, particularly with DEET applied to skin and permethrin applied to clothing, they are under-utilized.

Checking for ticks and prompt removal of attached ticks is probably the most important and effective method of preventing infection!

65

Important points to consider in tick bite prevention and checking for ticks include:

Tick Behavior & Risk of Exposure

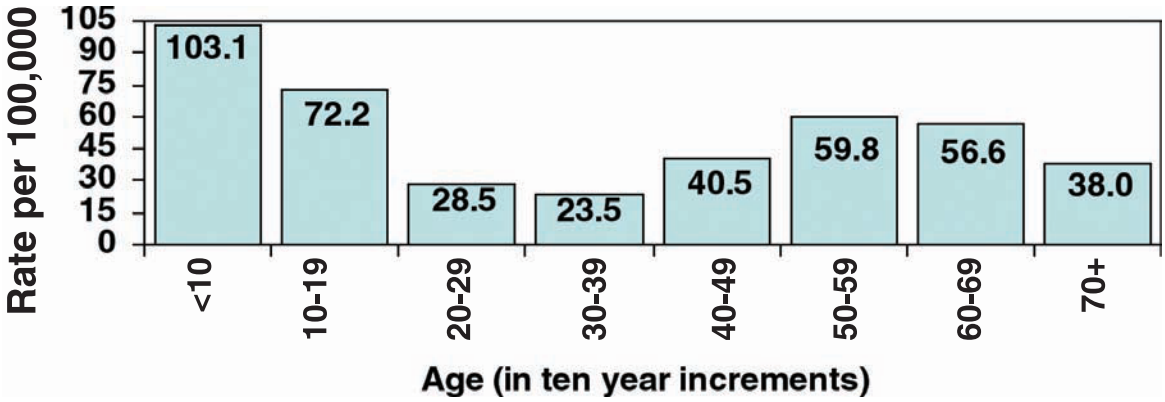
- Most (about 98%) Lyme disease cases are associated with the bite of the nymphal stage of the blacklegged tick, of which 10-36% may be infected with Lyme disease spirochetes.
- Nymphal blacklegged ticks are very small (about the size of a pinhead), difficult to spot, and are active during the late spring and summer months when human outdoor activity is greatest. The majority (about 75%) of Lyme disease cases are associated with activities (play, yard or garden work) around the home.
- Adult blacklegged ticks are active in the fall, warmer days in the winter, and in the spring when outdoor activity and exposure is more limited. They are larger, easier to spot, and therefore associated with fewer cases of Lyme disease (even though infection rates are higher).
- Ticks do not jump, fly or drop from trees, but grasp passing hosts from the leaf litter, tips of grass, etc. Most ticks are probably picked up on the lower legs and then crawl up the body seeking a place to feed. Adult ticks will, however, seek a host (i.e., deer) in the shrub layer several feet above the ground, about or above the height of children.
- Children 5-13 years of age are particularly at risk for tick bites and Lyme disease as playing outdoors has been

66

identified as a high-risk activity. Take notice of the proximity of woodland edge or mixed grassy and brushy areas from public and private recreational areas and playing fields. While ticks are unlikely to be encountered in open fields, children chasing balls off the field or cutting through woods to school may be entering a high-risk tick area.

- Pets can bring ticks into the home, resulting in a tick bite without the person being outdoors. A veterinarian can suggest methods to protect your pets. Engorged blacklegged ticks dropping off a pet will not survive or lay eggs in the house, as the air is generally too dry.

Lyme disease incidence (per 100,000 population) by ten year age groups for Connecticut, 2006. The pattern has been consistent each year. The incidence of Lyme disease is highest in children and middle-aged adults, related to outdoor activity and exposure to ticks (CT DPH).



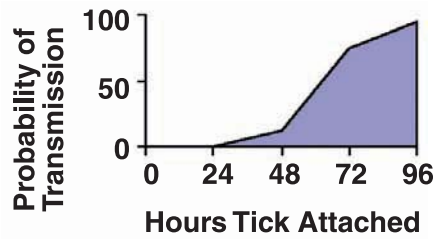
Prevention

- Wear light-colored clothing with long pants tucked into socks to make ticks easier to detect and keep them on the outside of the clothes. Unfortunately, surveys show the majority of individuals never tuck their pants into their socks when entering tick-infested areas. It is unclear just how effective this prevention measure is without the addition of a repellent. Larval and nymphal ticks may penetrate a coarse weave sock. Do not wear open-toed shoes or sandals.
- DEET or permethrin-based mosquito and tick repellents may be used, which can substantially increase the level of protection (see section on repellents). This approach may be particularly useful when working in the yard, clearing leaves, and doing other landscaping activity with a high risk of tick exposure. A separate set of work or gardening clothes can be set aside for use with the permethrin-based clothing tick repellents.
- When hiking, keep to the center of trails to minimize contact with adjacent vegetation.
- Carefully inspect the entire body and remove any attached ticks (see below). Ticks may feed anywhere on the body. Tick bites are usually painless and, consequently, most people will be unaware that they have an attached tick without a careful check. Also, carefully inspect children and pets. A hypersensitivity reaction to a tick bite may aid detection in a few individuals, but most people will be unaware that a tick is attached and feeding.

- Unattached ticks brought in on clothing can potentially result in a later tick bite. Blacklegged ticks can survive for many days in the home depending upon the humidity. In the laboratory, nymphal *I. scapularis* can survive for over 6 months at 93-100% relative humidity (RH), but over half will die in less than 4 days at 65% RH. On returning home, remove, wash and dry the clothing. Many blacklegged ticks and lone star ticks can survive a warm or hot water wash, but they cannot withstand one hour in a hot dryer.

Transmission

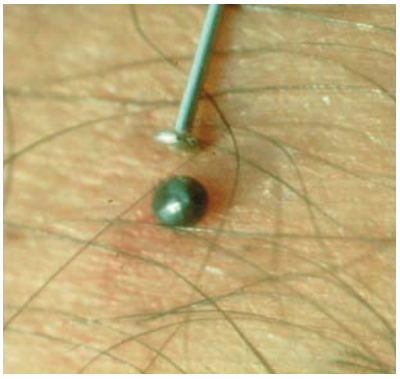
- It takes 36-48 hours or more for transmission of *B. burgdorferi* or *B. microti* to occur from an attached tick and not all ticks are infected. Therefore, a tick bite does not necessarily mean a person will get infected. Prompt removal of an attached tick will reduce the chance of infection. However, transmission of the agent of ehrlichiosis can occur within 24 hours.
- The probability of transmission of Lyme disease spirochetes increases the longer an infected tick is attached (0% at 24 hours, 12% at 48 hours, 79% at 72 hours, and 94% at 96 hours in one recent study). The estimated average time for attachment before detection and removal was 30 hours for nymphs and 10 hours for adult ticks, nymphal ticks were twice as likely as adult ticks to be partially engorged.



- Lyme disease may result from an unrecognized tick rather than the tick that was detected and removed, as the primary Lyme disease rash is sometimes found at a different location than the detected tick. It is not unusual to have more than one tick attached at one time.
- In some areas, tick-testing services for the presence of Lyme disease spirochetes may be available from a government or commercial laboratory. The detection of spirochetes in a tick does not necessarily indicate transmission and an estimate of risk is difficult without a measure or estimate of length of attachment.

Tick Removal

To remove a tick, use thin-tipped tweezers or forceps to grasp the tick as close to the skin surface as possible. Pull the tick straight upward with steady even pressure. This should remove the tick with the mouthparts intact. Commercial tick removal devices have been shown to vary widely in their efficacy for removing nymphal blacklegged ticks: some worked in every attempt, some failed in every attempt, some were in between. Tick removal devices that have been shown to successfully remove *I. scapularis* nymphs attached for 48 hours in all attempts in a recent study include #4 forceps, Original Tick Kit (Tick Kit, Inc.), Pick-Tick (Encepur, Chiron), Pro-Tick Remedy (SCS, Ltd.), and the Nick Nipper (Josyln Designs, Inc.).



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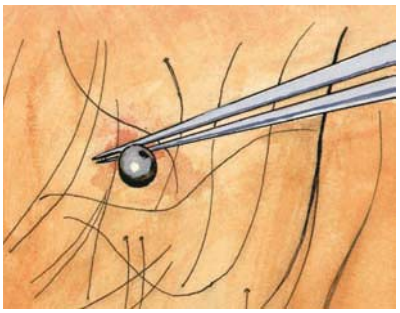

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The mouthparts of larval and nymphal ticks will seldom be left in the skin. With proper removal, they usually come out intact. Adult ticks are more difficult to remove intact because of the longer mouthparts. If the mouthparts break off, it will not change the chance of getting Lyme disease. Spirochetes in the

mouthparts or cement plug, and therefore the feeding lesion, means the tick was removed too late and transmission has already occurred. Do not use other methods of tick removal (e.g. petroleum jelly to suffocate the tick, heat from matches to make the tick back out or gasoline or other chemicals); they are not effective and may potentially increase the risk of pathogen transmission.

70

71

After removing the tick:

- Disinfect the area with rubbing alcohol or another skin disinfectant; a topical antibiotic also may be applied.
- Save the tick for reference and, in some cases, testing (if available). A live tick can be placed in a crush proof container with a blade of grass to keep it alive (a sealable plastic bag also will work). A small plastic vial is best. Dead ticks are tested by DNA methods and should be held dry in a crush proof container. For long-term storage, ticks are held in 70-80% ethyl alcohol (rubbing alcohol will work). Avoid placing ticks in black film containers or using cellophane tape to mount the tick to paper, a note card or a slide if it needs to be identified or tested. Ticks under cellophane tape are difficult to handle. If the tick is removed by a health professional, ask to keep the tick for future reference or testing.
- Note the site and date of the bite.
- Watch for signs and symptoms of Lyme disease or other tick-associated diseases for 30 days or consider prophylactic treatment if the tick is engorged or infection rates are high (see below). Watch for evidence of secondary infection.

Localized tick bite reactions develop rapidly and can sometimes resemble a small Lyme disease rash, but these transient reactions generally disappear in 24-48 hours and do not continue to expand like a characteristic erythema migrans rash. Mouthparts left in the skin may cause irritation as the body attempts to absorb or reject the foreign tick tissue (analogous to a minute splinter that is difficult to remove) with a slight risk of secondary bacterial infection. A foreign body granuloma may persist for weeks, especially if the mouthparts remain. A physician should be consulted if there is evidence of infection.

Tick Bite Prophylaxis

The prophylactic use of antibiotics following a tick bite has not generally been recommended by most medical authorities in the U.S. as the chance of Lyme disease from a known tick bite with *I. scapularis* appears low (< 5%; 0% with flat ticks, 10% with engorged ticks in one study). Only 14-32% of patients diagnosed with Lyme disease remember a feeding tick.

Factors against prophylactic treatment:

- Tick bites in endemic areas are very common.
- Local infection rates in nymphal ticks may be low (< 20%) with a low risk of infection (<5%) from a detected, attached tick (most people who get Lyme disease do not notice the tick).

- The infection status and degree of engorgement of the tick, and therefore the risk of infection, are generally not known. Routine testing of unengorged (flat) ticks attached < 24-36 hours is not necessary.
- Not infrequently, ticks submitted for identification or testing turn out not to be a tick (i.e., a scab, beetle, spider , etc.) or a tick that is not a vector for Lyme disease (better training of physicians or clinic staff to recognize major tick species is important).
- There may be a risk of an adverse reaction to the antibiotic.
- The value of antibiotic prophylaxis for HGA or babesiosis is unknown.

Factors in favor of prophylactic treatment:

- A single 200 mg dose of doxycycline within 72 hours for adults or children ≥ 8 years of age (4 mg/kg up to 200 mg) following a tick bite can prevent Lyme disease. A single dose is less likely to stain teeth in children or produce adverse reactions.
- For a partly or fully engorged blacklegged tick, the risk of infection may be high. It can equal the prevalence of infection in the tick, which may be > 30% for a nymphal tick and greater than 60% for an adult tick (though usually lower).
- Patient reports on the period of attachment usually underestimate actual time of attachment.
- If a tick is infected (determined by testing at a proficient laboratory) and the tick is engorged, infection by Lyme disease spirochetes is highly likely and treatment may be seriously considered. However, results from tick testing may not be available in time for prophylactic treatment or Lyme disease symptoms may already be evident.

Topically Applied Insect Repellents

Insect (and tick) repellents applied to skin and/or clothing can be broadly grouped as synthetic-chemical or botanical chemical-based compounds. The effectiveness of a repellent against mosquitoes does not indicate how effective a product will be against ticks, but may provide a broad indication of repellency potential as data for efficacy against ticks are limited. An ideal repellent would provide complete protection for several hours under different environmental conditions, protect against all biting arthropods, be non-toxic, non-irritating, be harmless to clothing, be cosmetically acceptable with no unpleasant odor or oily feel to the skin, be easy to apply and inexpensive.

Insect repellent compounds currently in use include:

- DEET (N,N-diethyl-m-toluamide, also known as N,N-diethyl-3-methylbenzamide).
- IR3535 (Ethyl Butylacetylaminopropionate or 3-[N-Butyl-N-acetyl]-aminopropionic acid, ethyl ester).
- Picaridin (1-piperidinecarboxylic acid, 2-(2-hydroxy)ethyl)-, 1-methylpropylester).
- MGK-326 (di-n-propyl isocinchomeronate), used in conjunction with DEET in composite formulation.
- MGK-264 (N-octyl-bicycloheptene dicarboximide), used in conjunction with DEET in composite formulation.
- Oil of Lemon Eucalyptus (PMD; p-Mentane-3,8-diol).
- Citronella, Soybean, Peppermint, and other plant essential oils.

DEET

The primary active ingredient in most insect/tick repellents today is DEET (N,N-diethyl-3-methylbenzamide, also known as N,N-diethyl-m-toluamide). DEET is the most effective, broad-spectrum repellent ever discovered, effective against mosquitoes, biting flies, chiggers, fleas and ticks. The U.S. Environmental Protection Agency (EPA) estimates that over one-third of the U.S. population will use a DEET-based product. There are approximately 230 products containing DEET registered with the EPA (e.g., *Cutter, Off, Repel, Muskol, Ben's, Sawyer, and others*). Products range in concentration from 5% to 100% DEET and are available as an aerosol can, pump spray bottle, stick, lotion, cream, or towelette for application to skin or clothing. For any repellent, all active ingredients and their concentrations are listed on the product label.

DEET is effective for one to several hours and must be reapplied periodically. There are few firm guidelines on the concentration a consumer should use. The effectiveness of DEET on the skin is influenced by the concentration of DEET, absorption through the skin, evaporation, sweating, air temperature, wind, abrasion of the treated surface by rubbing or washing and the arthropod for which protection is desired. Higher concentrations generally provide longer protection, but increasing the concentration does not proportionally increase protection time. A recent study comparing the efficacy of insect repellents against bites of the mosquito *Aedes aegypti* found that a 23.8% DEET formulation provided an average of 5 hours of complete protection, while 6.65% DEET provided slightly under 2 hours of protection. Several controlled-release or extended-release DEET formulations have been developed which decrease skin absorption and increase protection time. These products may provide longer protection similar to products with a higher concentration of DEET.

DEET and Ticks

DEET will repel ticks and decrease the chances of tick bite, but depending upon the concentration, it may not provide total protection against the blacklegged tick. Not all products with DEET are labeled for ticks. Little is known about the effectiveness of different concentrations of DEET against *I. scapularis*. Concentrations of DEET that might prevent tick attachment may not deter a tick from walking across the skin to unexposed and untreated areas. Some protection against tick attachment appears to come from the oily nature of some products. When applied to clothes, 30% and 20% DEET were found to be 92% and 86% effective against *I. scapularis*, respectively, but skin applications were reported to be only 75 to 87% effective against crawling ticks in a second study. These studies suggest that, for blacklegged ticks, DEET concentrations around 30 to 40% may be necessary for adequate protection, although the effectiveness of higher (>50%) and lower (<20%) concentrations against *I. scapularis* needs to be examined more closely. Concentrations above 50% will probably provide the user with little additional protection. When applying a repellent against ticks, particular attention should be given to the shoe tops, socks, and lower portion of pants.

Composite DEET Repellents with MGK-326 and MGK-264

The MGK Repellent 326 and MGK Repellent 264 are only used together with DEET in composite repellent formulations for human use in the United States. Composite repellents are labeled for use against biting flies, fleas, chiggers, and ticks. The EPA has determined that MGK-326 poses no unreasonable adverse effect on human health when properly used, but MGK-326 was classified as a probable human carcinogen in 1993. To mitigate risk, the EPA has limited total production and use of MGK-326, set a maximum concentration of 2.5% in repellent products, and the label may limit the number of applications per day of MGK-326 on children twelve and under to limit overexposure in young children.

Permethrin-based Repellents

Several products contain 0.5% permethrin (e.g., *Duranon Tick Repellent, Repel Permanone, Cutter Outdoorsman Gear Guard, Sawyer's Permethrin Tick Repellent, Sawyer's Clothing Insect Repellent, 3M Clothing and Gear Insect Repellent, No Stinkin' Ticks*), which is for use only on clothing or other fabrics such as mosquito netting or tents. A synthetic pyrethroid insecticide rather than a traditional repellent, permethrin works primarily by killing ticks on contact with the clothes, although it has some repellency. It can provide high levels of protection against ticks (and chiggers and mosquitoes). Permethrin is available as an aerosol spray or pump, mainly in lawn and garden centers or sports and camping stores. Permethrin has a relatively low mammalian toxicity, is poorly absorbed through the skin and is quickly metabolized and excreted by the body, although the EPA does list it as a potential carcinogen. Permethrin can cause mild skin and eye irritation, but reactions appear uncommon. Important points in the safe use of a permethrin repellent include: **72**

- Follow the directions and precautions given on the repellent label.
- Apply to CLOTHING ONLY. Do not apply to skin. Immediately wash with soap and water if you get material on the skin.
- Do not apply to clothing while it is being worn. Apply before you put the clothing on.
- Apply in a well-ventilated area outdoors protected from the wind.
- Lightly moisten the fabric, do not saturate. Allow drying for 2 hours (4 in humid conditions).
- Allow clothing to dry prior to before wearing.
- Do not treat the clothing more than once every two weeks. Launder treated clothing at least once before retreating.
- Permethrin can be used in conjunction with an insect repellent labeled for use on skin for additional protection.

IR3535 and Picaridin

Classified by the EPA as a biopesticide (it is structurally very similar to the amino acid B-alanine), the synthetic compound IR3535 has been used as an insect repellent in Europe for 20 years with no notable adverse effects and was approved for use in the United States in 1999. Several formulated products with varying concentrations of IR3535, including a spray, an aerosol, a towelette, and a lotion and spray with sun block, are currently available in the United States (e.g., *Skin-So-Soft Bug Guard Plus Insect Repellent*). They are labeled for use against deer ticks, mosquitoes, and several other biting flies. IR3535 is not a skin irritant or sensitizer, but it is a strong eye irritant. There is some information on the efficacy of IR3535® against the blacklegged tick and other ticks. Industry-sponsored evaluations of IR3535 against *I. scapularis* suggest that 15% IR3535 is as effective as 30% DEET and 30% IR3535 is as effective as 60% DEET against the blacklegged tick. After 2 hours, >85% repellency was observed with both 15% IR3535 and 60% DEET on treated human fingers. Another study showed a 7.5% IR2535 lotion provided protection against blacklegged ticks for about 3 hours.

The Centers for Disease Control and Prevention (CDC) recently added a Picaridin-based insect repellent and oil of lemon eucalyptus-based repellent (see below) to DEET as recommended repellents for the prevention of mosquito bites. Several published studies of the use of picaridin repellents against mosquitoes has shown the compound to be as effective or slightly more effective than similar concentrations of DEET, depending on the mosquito species. It is claimed to have more pleasant cosmetic properties than DEET. The chemical name for picaridin is 1-piperidinecarboxylic acid, 2-(2-hydroxyethyl)-, 1-methylpropyl ester. It is also known as KBR2030 or Bayrepel® (a trademark of Bayer AG) and has been available in Europe and Australia under the Autan® brand

(S.C. Johnson and Sons, Inc.) since 1988. There is one brand currently available in the United States at two concentrations (5.75 and 7%) *(Cutter® Advanced*) and others should become available. Picaridin is labeled for protection against biting flies, chiggers, fleas, gnats, mosquitoes and no-see-ums, but is not labeled for use against ticks. One study against nymphs of an African *Amblyomma* tick species found that 20% KBR2030 was much less effective than 20% DEET. Unlike DEET, this repellent has no adverse affect on plastics and synthetics.

Botanical, Herbal, and Natural-based Repellents

Botanical, herbal or natural-based repellents include one or several plant essential oils. Some new products are refinements of these essential oils or synthetic versions of the active ingredient in the natural oil. These oils are considered safe by the EPA at the low concentrations used, but provide a limited duration of protection against mosquitoes (< 3 hours). There is virtually no published data on the efficacy of plant-based repellents against ticks and most are not labeled for use against ticks. Citronella is often the principal and sometimes only active ingredient in many plant-based insect repellents. Oil of lemon eucalyptus, soybean oil or geraniol is the sole active ingredients in some products. Available in several brands or formulations, oil of lemon eucalyptus provides protection against mosquitoes similar to low concentrations of DEET. Two products containing oil of eucalyptus or its primary compound provided the most protection against mosquitoes with protection ranging from 60 to 217 minutes, better than 7-15% DEET. The compound p-menthane-3,8-diol occurs naturally in the oil of the lemon eucalyptus plant. It was originally isolated from waste distillate of lemon eucalyptus oil extract, but the synthetic compound is used. The EPA recognizes general use of p-Mentane-3,8-diol as safe for both children and adults as the toxicity of p-Mentane-3,8-diol is very low. However, the label states it should not be used on children under the age of three. At least one brand is labeled for use against ticks and some repellency has been reported against the tick *I. ricinus*, the vector for Lyme disease in Europe. A 2% soybean oil-based repellent has been reported to provide an average of 1.5 hours of protection against mosquito bites, while other botanical repellents tested provided only short-term protection with a mean protection time of only 3 to 20 minutes. There are no published data on repellency against mosquitoes for many of the other oils incorporated into repellent products. Other essential oils used in these natural-product based repellents include peppermint, lemongrass, lavender, cedar, canola, rosemary, pennyroyal, geranium and cajeput among others. In summary, most plant-derived repellents are not labeled for ticks and are unlikely to provide much protection against ticks.

Safe Use of DEET

DEET has been used by millions of Americans for at least 40 years and has a remarkable safety record. The incidence of adverse reactions is extremely low with fewer than 50 cases of serious effects documented in the medical literature since 1960. The Environmental Protection Agency (EPA) conducted a review of DEET and believes that normal use of DEET does not present a health concern to the general population when used according to label directions (Reregistration Decision document available from the EPA). Some allergic, toxic, and neurological reactions to DEET have been reported in medical literature, but toxic encephalopathic reactions are rare. Reported adverse reactions appear to have involved high concentrations of DEET, over application of product contrary to label directions, or ingestion of product. Repeated applications have occasionally produced tingling, mild irritation or contact dermatitis. Important points in the safe use of DEET include:

- Follow the directions and precautions given on the repellent label.
- Apply DEET sparingly to exposed skin, and spray on clothing when possible.
- Do not use DEET under clothing or over cuts, wounds, or irritated skin.
- Use the lowest concentration necessary for protection and estimated time of needed

protection. Minimize the use of higher concentrations on the skin. Lower concentrations, such as 10% DEET, will provide approximately 2 hours of protection (but may be less effective against ticks), while a concentration of 24% will provide about 5 hours of protection.

- A concentration of DEET up to 30% for adults and children over 2 years of age is the maximum concentration currently recommended by the American Academy of Pediatrics (AAP).
- The AAP does not recommend the use of DEET on children under 2 months of age. Apply sparingly to small children.
- AAP precautions suggest DEET should not be used in a product that combines the repellent with a sunscreen as sunscreens are often reapplied periodically. DEET is not water-soluble and will last many hours. Reapplications of DEET may increase the possibility of a toxic reaction to DEET.
- Apply the product to a child yourself. Repellent on a child's hands can end up in the eyes or mouth.
- Wash the hands with soap and water after applying DEET.
- People with certain skin conditions should be cautious about the use of DEET.
- Wash off the repellent with soap and water when returning indoors.
- DEET generally won't harm cotton, wool or nylon. DEET can damage some synthetic fabrics (acetate, rayon and spandex), plastics (watch crystals and eyeglass frames), and car and furniture finishes.
- If you suspect a reaction to DEET (or any other repellent), stop using the product, wash the treated skin, and call a poison control center (CT 1-800-222-1222) or contact your physician.

Other Repellent Options

Avon's moisturizing Skin-So-Soft bath oil has been widely touted as a mosquito repellent, but provides less than 10-30 minutes of protection against mosquitoes and is unlikely to offer any protection against ticks. Ingested compounds like garlic and vitamin B1 and ultrasonic sound devices do not repel mosquitoes and probably do not repel ticks. Wrist-bands impregnated with either DEET or citronella provided no protection against mosquitoes and would not protect against ticks either. Protection is provided only around where the repellent is actually applied.

Medical and safety information about the acive ingredients in an insect repellent is available from:

National Pesticide Information Center by telephone (1-800-858-7378) from 6:30 a.m. to 4:30 p.m. Pacific Standard Time or 9:30 a.m. to 7:30 p.m. Eastern Standard Time, 7 days week, except holidays. Additional information is available at their website (http://npic.orst.edu/).

Human Lyme disease vaccine

The Food and Drug Administration (FDA) approved a human Lyme disease vaccine, LYMErix (GlaxoSmithKline), which contained recombinant outer-surface protein A (OspA) of *B. burgdorferi*, in December 1998. However, the manufacturer took the vaccine off the market in February 2002 because of declining sales. In clinical trials, vaccine efficacy was 49% after 2 doses for those with definite Lyme disease and 76% after the third dose. Protection in an immunized individual was provided when levels of antibody to OspA in the blood were high enough to neutralize the spirochetes inside a feeding tick before transmission occurred. Protection in vaccinated individuals will wane after a year or two, so protection against Lyme disease in previously vaccinated people will be nonexistent.

Integrated Tick Management

73

Integrated pest management (IPM) basically involves the selection and use of several methods to reduce, rather than eliminate, a pest population with expected ecological, economic, and sociological costs and benefits. For ticks, this may involve the use of landscape practices to reduce tick and host animal habitat adjacent to the home, management or treatment of host animals, targeted applications of least-toxic pesticides to high-risk tick habitat – all in conjunction with tick checks and other personal protective measures to either reduce the number of infected ticks and number of tick bites. The ultimate goal, of course, is to reduce the number of human cases of disease as much as possible with the resources available. A decision has to be made on how much one is willing to spend and what ecological impact one is willing to tolerate to reduce the risk of a tick-borne illness. An integrated management approach does not necessarily preclude the use of pesticides, for example, but seeks to use chemicals effectively and responsibly in order to minimize and reduce exposure and use. Research and computer models have shown that pesticides are the most effective way to reduce ticks, particularly when combined with landscaping changes that decrease tick habitat in often-used areas of your yard.

Tick Distribution and Creating a Tick Safe Zone in the Residential Landscape

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Tick abundance is related to landscape features of the suburban residential environment that provide a suitable environment for the tick and its animal hosts, particularly white-tailed deer and white-footed mice. While there is a lot of variation in tick numbers between homes, larger properties are more likely to harbor ticks because they are more likely to have woodlots. The blacklegged tick is found mainly in densely wooded areas (67% of total sampled) and ecotone (22%), which is unmaintained transitional edge habitat between woodlands and open areas. Fewer ticks are found in ornamental vegetation (9%) and lawn (2%). Within the lawn, most of the ticks (82%) are located within 3 yards of the lawn perimeter particularly along woodlands, stonewalls, or ornamental plantings. Tick abundance in manicured lawns is also influenced by the amount of canopy vegetation and shade. Groundcover vegetation can harbor ticks. Woodland paths also may have a high number of ticks, especially adults, along the adjacent grass and bushes.

The lawn perimeter, brushy areas and groundcover vegetation, and most importantly, the woods, form the high-risk tick zone. The idea for residential tick management is to create a tick managed area around your home that encompasses the portions of the yard that your family uses most frequently. This includes walkways, areas used for recreation, play, eating or entertainment, the mailbox, storage areas and gardens.

Table 3. Tick management strategies for the control of *Ixodes scapularis*.

Personal Protection	Tick-bite prevention, tick checks, and tick removal.
Landscape Management	Vegetative modifications to render the environment less suitable for tick survival and for tick hosts.
Management of Host Abundance	Exclusion of hosts by fencing, host reduction, and host reduction by management of the host habitat.
Host-targeted Acaricides	Treatment of white-footed mice, chipmunks or deer through passive topical application devices.
Area Application Acaricides	Spraying chemical insecticides to control ticks
Biological & Natural Control	Use of fungal pathogens and plant extracts as biopesticides to control ticks.

Some actions to consider in an integrated management approach include:

- Keep grass mowed.
- Remove leaf litter, brush and weeds at the edge of the lawn.
- Restrict the use of groundcover, such as pachysandra in areas frequented by family and roaming pets.
- Remove brush and leaves around stonewalls and wood piles.
- Discourage rodent activity. Cleanup and seal stonewalls and small openings around the home.
- Move firewood piles and bird feeders away from the house (see section on small mammals and birds).
- Manage pet activity, keep dogs and cats out of the woods to reduce ticks brought back into the home.
- Use plantings that do not attract deer or exclude deer through various types of fencing.
- Move children's swing sets and sand boxes away from the woodland edge and place them on a wood chip or mulch type foundation.
- Trim tree branches and shrubs around the lawn edge to let in more sunlight.
- Adopt hardscape and xeriscape (dryer or less water demanding) landscaping techniques with gravel pathways and mulches. Create a 3-foot or wider wood chip, mulch, or gravel border between lawn and woods or stonewalls.
- Consider areas with decking, tile, gravel and border or container plantings in areas by the house or frequently traveled.
- Widen woodland trails.
- Consider a least-toxic pesticide application as a targeted barrier treatment.

Landscape management

76

Residential landscapes are designed for a variety of aesthetic or environmental reasons and "tickscape" practices can be a part of the landscape in Lyme disease endemic areas. Landscape modifications can create an environment unattractive to primary tick hosts and may decrease the abundance of ticks that are present in parts of the yard. Fewer ticks have been found on well-maintained lawns, except on areas adjacent to woodlands, stonewalls, or heavy groundcover and ornamental vegetation. Deer-browse resistant exotic-invasive understory vegetation is associated with greater tick abundance. This section provides some ideas on how to incorporate tick management into the landscape. Clearing leaf litter and woodchip barriers have been documented to help reduce ticks on the lawn. However, landscape practices to create a lower risk tick zone will not directly eliminate many ticks and you may need to consider integrating other tick control practices into the overall program. Landscape work may also be expensive, not acceptable to some residents, and must be done by residents on their own property. In computer simulations of a hypothetical community of 10,000 individuals, a 90% habitat reduction on lawns, 80% habitat reduction in ecotone, and 10% reduction in forested areas by nearly half the residents resulted in the prevention of only 94 Lyme disease cases in comparison to 156 with the application of acaricides or 121-272 with the treatment or removal of deer. Landscape management alone may not reduce disease incidence, as the undetected bite of only one infected tick is required for transmission of *B. burgdorferi*.

Woodland edge and leaf litter are high-risk areas for nymphal blacklegged ticks!

77

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In most cases, alterations will be made to an existing landscape, although landscape architects and designers should also incorporate tick safe landscaping concepts into major renovations or new

construction. There are several basic interrelated concepts in modifying the landscape to create an area with fewer ticks and environmentally acceptable management practices.

- Open up the land to direct solar exposure, and include that part of the landscape used or traveled frequently by family members to reduce tick and small mammal habitat and cover. Bright, sunny areas are less likely to harbor ticks.
- Isolate areas used by the family or public (i.e., lawns, play areas, recreational or ball fields) from tick habitat or tick hot spots (i.e., woods, dense vegetation, groundcover, stonewalls).
- Use hardscape and xeriscape landscaping (i.e., brick, paving, decking, gravel, container plantings, low water requirement plantings) in areas immediately around the house that are frequently used.
- In cases where environmentally acceptable alternatives to large tracts of open lawn or only small lawn areas are desired, consider butterfly gardens, vegetable gardens, formal herb gardens, colonial style gardens, wildflower meadows and hardscapes. See the section on Environmentally Friendly Lawns and Backyard Wildlife Programs. Elimination of woodland and all wildlife habitats is not necessary or environmentally desirable. Some evidence suggests a lack of biodiversity and a landscape that specifically favors deer and mice increases tick abundance and transmission of *B. burgdorferi*. The key factor appears to be the presence and abundance of deer.
- Avoid invasive plant species and plantings that are inappropriate for where they will be growing. Several guides and listings of invasive plants and native alternatives are available. Some nurseries are helping to assess invasiveness and introducing alternative cultivars.

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Reducing tick habitat

Altering the landscape to increase sunlight and lower humidity may render an area less hospitable to ticks. Management of the habitat should focus on the areas frequently used by the family, not necessarily the entire property. To reduce ticks

adjacent to homes, prune trees, mow the lawn, remove leaf litter accumulations around the house and lawn perimeter, and cut grass, weeds, and brush along edges of the lawn, stonewalls, and driveways. Plants can be pruned to provide open space between the ground and base of the plant. Individual shade trees, with the exception of fruit trees like crab apple that are attractive to deer, and small ornamental stands in the open lawn will probably not contribute to the tick numbers unless surrounded by groundcover.

A. Yard before landscape intervention.

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B. Yard after landscape intervention.

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Ticks also may be found in groundcover such as *Pachysandra*. Restrict the use of groundcovers to less frequently used areas of the yard. Clean up the vegetation around or even seal stonewalls near the house. The removal of leaf litter has been shown to reduce the number of *I. scapularis* nymphs on some properties. Mowing and removing cover vegetation around the house also will discourage rodent hosts. Leaf litter and other plant debris can be raked or blown out from under shrubs and bushes. Composting or removal by appropriate bagging is an acceptable method of disposing leaf litter. Leaves should not be simply moved to another part of the property. Some communities will compost collected leaves and provide the compost to residents for free or a nominal charge.

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Move swing sets and playground areas out or away from the woodland edge!

Play activity can be a high-risk activity for tick exposure, and children have some of the highest rates of Lyme disease.

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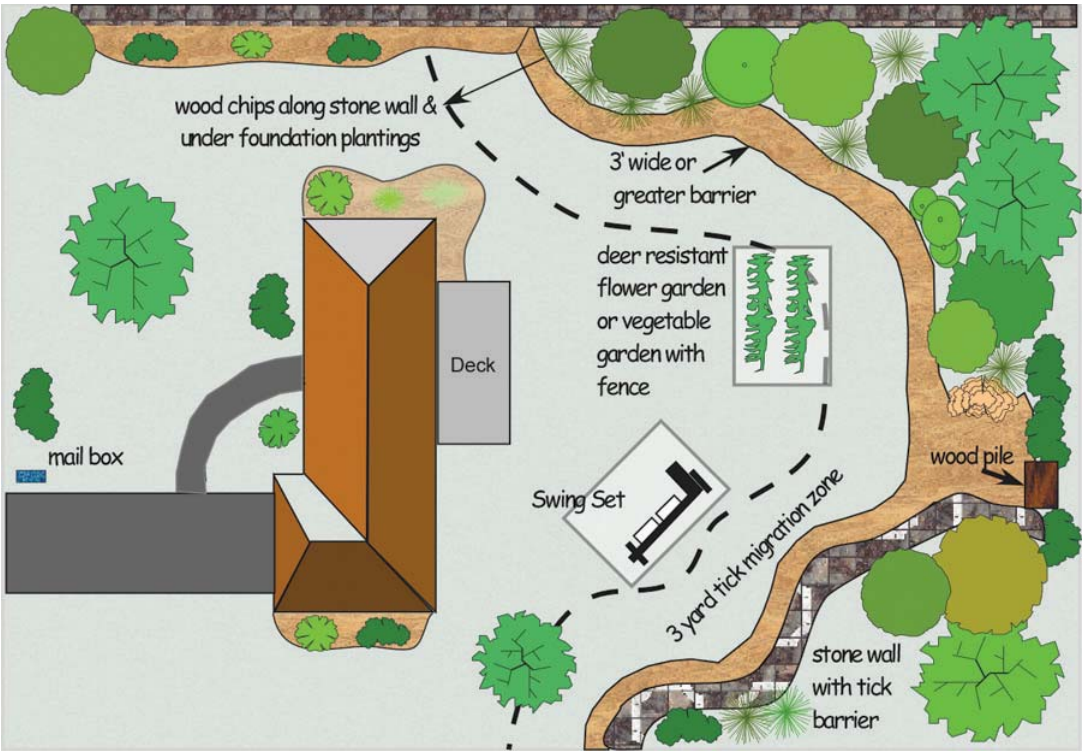

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The use of hardscapes, mulches, and xericape landscaping techniques can help reduce tick habitat and isolate parts of the yard from tick hot spots. Hardscapes refer to nonliving features of the landscape like patios, decks, and paths. Mulches are used to suppress weeds and help retain soil moisture, but also can help reduce tick movement. In the laboratory, landscape materials have been shown to deter tick movement and around homes, a three-foot wide or broader woodchip barrier may help reduce tick abundance on the lawn, although results vary widely from home to home and from year to year depending upon other factors (i.e. density of woods, amount of shade, initial tick densities). Mulches are often organic materials like bark chunks or shredded bark, but can also be small stones or gravel. Wood chip and tree bark, gravel, or similar landscaping materials between woods or stonewalls and lawn as a buffer or barrier can help reduce the number of ticks on the lawn and delineate the tick zone. Quality of the landscape material may also influence results as wood chips from chipped trees, especially if it contains leaves, quickly degrade and may soon become no different than leaf litter. Properly maintained each year, the barrier may allow fewer ticks to migrate from the woodlands into the lawn. It also serves as a reminder that people who cross the barrier may be at higher risk of getting ticks. The application of a barrier or buffer will be easiest where there is a sharp delineation between the woods and lawn. A pesticide application can be focused on the landscape barrier or buffer zone to increase the effectiveness of the barrier. Move swing sets and sandboxes away from the woodland edges and place on a covering of smooth bark, mulch or other suitable material.

Xeriscaping is the application of water conserving landscape practices. This approach reduces habitat cover; helps isolate frequently used areas, can provide an attractive focal area in the yard or garden and reduce maintenance and water, fertilizer, and chemical use. Many drought resistant plants are also deer resistant. Landscapes can incorporate formal or informal designs around play, eating, or pool areas. Landscape materials such as laid brick, wood decking, stone paving, raked gravel or pea gravel (set down slightly from bordering bricks, stone, or paved areas), and concrete (exposed aggregate can provide varying attractive colors and textures and edged with brick or tile) can be used to create a patio and paths. Gravel can be laid over a layer of crushed stone covered with black plastic to discourage weed growth. Some plantings can be in raised beds or containers.

Organic Land Care Practices

Standards for organic land care practices for design and maintenance of ecological landscapes have been developed and published by the Connecticut and Massachusetts chapters of the Northeast Organic Farming Association (NOFA). Tick IPM practices are covered under pest and wildlife management guidelines (*NOFA Standards for Organic Care*). Practices that are preferred to manage ticks would include personal protection measures, making the environment unsuitable for the pest (i.e., landscape modifications as reviewed in this section), deer resistant plantings (the use of native plants is generally encouraged), fencing against deer, and herbal-based deer repellents (reviewed in the next section on host management). Ammonia or hot sauce based deer repellents are allowed. The use of arthropod pathogens like entomopathogenic fungi (fungi that kill insects), diatomaceous earth, insecticidal soaps and botanical insecticides are allowed under the standards. However, botanicals cannot be formulated with EPA List 1 inert ingredients (i.e., inert ingredients of toxicological concern). Prohibited under the organic standards are all synthetic insecticides and piperonyl butoxide as an insecticide synergist, rodenticides containing warfarin, predator urine (due to collection practices), and products containing sewage sludge (e.g., Milorganite). Two other NOFA resource publications are the *NOFA Guide to Organic Land Care: Directory of Accredited Organic Land Care Professionals* (2007 Edition) and *The NOFA Lawn and Turf Handbook* (www.organiclandcare.net).

Environmentally Friendly Lawns and Backyard Wildlife Programs

A residential lawn of pure, carefully manicured grass has been the standard American suburban landscape for many decades. Lawns provide valuable areas for play and recreation and are esthetically pleasing to many communities. With increased environmental awareness, the focus for many backyards has been to provide a more natural or organic landscape (sometimes retaining the manicured front lawn for community relations), with reduced inputs of energy, water, pesticides, fertilizer and labor, and increased wildlife habitat. An alternative landscape may involve a lawn of mixed grasses and low-lying plants like clover, reducing the amount of lawn, or replacing the lawn entirely. Some shrubs and other plants are selected for their wildlife value due to the berries, fruit and cover they provide for birds and small mammals. Many resources are available to help create backyard wildlife habitats.

How can the desire to have a more natural, environmentally friendly habitat be balanced with the need to reduce contact with animals carrying ticks and the creation of a tick safe zone? The presence of deer and rodents can result in the presence of ticks. This is an area that has not been adequately explored and little information is available on how to best integrate the two different objectives. Open lawns harbor fewer ticks and wildlife that carry potentially infected ticks. There is limited evidence that increased animal diversity may reduce the rate of transmission of tick-associated disease, resulting in fewer infected ticks. However, the fragmented woodland and ecotone environment of suburbia favors the deer and mice most involved in the maintenance and transmission of tick-associated diseases.

What kind of organic landscape, alternative habitat, or wildlife program could be set up within or adjacent to the tick safe zone? While deer-browse resistant exotic-invasive understory vegetation is associated with greater tick abundance, little is known about relative tick densities in various alternative landscapes to turf like wildflower meadows, gardens, and butterfly gardens. It is not known what specific plants or plant groupings may be associated with more or fewer ticks or if it makes much difference. Some plants used in butterfly gardens are more attractive to deer, while most herbs are highly resistant to deer browsing. If a property is large enough, a separate wildlife and tick-managed zone could be maintained. Fencing against deer will allow greater landscape flexibility. Certain activities such as xeriscaping, mulching, removing invasive exotics, and planting native deer resistant plants can conserve resources and fit into a tick reduction program. Use a grass variety that requires little additional water, pesticide, and fertilizer and allow the lawn to go dormant in the hot summer. The proper selection of plants may help support a diversity of butterflies and other insects, bats, hummingbirds, salamanders, toads, and turtles, but not encourage deer or key small mammals. Possible alternatives to increasing lawn area might include mulched or gravel paths, a meadow or prairie patch, vegetable, herb or butterfly garden, or hard landscaping as previously discussed. Choosing plantings can get complicated when native versus non-native or invasive species, deer susceptible versus deer resistant plants, aesthetic, and wildlife values are considered.

Reducing ticks in a “naturalscape” will require higher level of management of the landscape and visiting wildlife. Consider consulting a specialist on natural landscapes and ask them to incorporate tick management concepts into your design. The objective of a tick management program is to discourage activity of several key tick hosts and create a barrier between woodland habitat and areas the family uses most frequently.

Possible Landscape Options

- Butterfly gardens in large open sunlit areas may make an attractive alternative to an open expanse of manicured lawn. Nectar plants are placed in sunny areas protected from wind by shrub nectar sources and trees and selected to provide continuous bloom for the adult butterflies. Clumping nectar sources is more attractive to butterflies. Clumps of nectar flowers can be separated from tick habitat by gravel or mulch paths or strips of lawn to reduce its potential for harboring ticks. A much larger separation also would minimize any impact from targeted use of pesticides for tick control. Butterfly gardens also can be placed in sunny flower borders, along walkways, in containers on patios, or in a small wildflower meadow, which attracts the most butterflies. Some nectar plants are deer browse resistant.
- Colonial style gardens are formal layouts of herbs, vegetables, and flowers surrounded by fieldstone, gravel or lawn walks. The sunny, warmer landscape, separated from woodland habitat, should harbor few ticks.
- Native wildflower and grass meadows require no fertilizer, little or no supplemental water, and only annual mowing, once established. A small wildflower meadow is very attractive to butterflies. While data are limited, meadows appear to harbor few blacklegged ticks except along narrow edges with woodlands, dense vegetation and stonewall. Native grasses, which usually grow in small clumps, provide cover for meadow birds and certain butterflies (particularly skippers) and are deer resistant.
- Ferns may be an option in more shady portions of the landscape. In some cases, fewer ticks have been recovered in stands of fern, except adjacent to stonewalls or woodland. However, another study found nymphal ticks to be more abundant in moist fern habitat than open understory, deciduous litter habitat. Ferns are deer browse resisant.

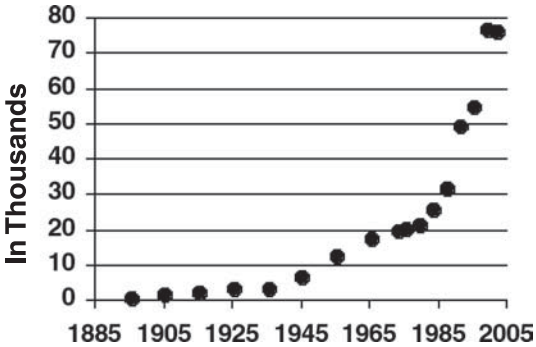
Management of Host Animals

Food and shelter are essential requisites for wildlife. The residential landscape can be particularly attractive to white-tailed deer and conducive to mice and chipmunks, important hosts in the prevalence of ticks and Lyme disease. One component of a tick management strategy is managing deer and small rodent activity in your yard. Some landscaping practices discussed in the previous section can also help manage key animals in the landscape. Stonewalls, woodpiles, and dense vegetation can harbor rodents.

White-tailed Deer, *Odocoileus virginianus* (Zimmerman)

90

In the northeast from New Jersey and New York to Maine, the deer population is estimated at 1,918,000 animals. In Connecticut, the number of deer has increased from about 12 in 1896 to over 76,000 today. Overabundance of deer is associated with problems such as deer/vehicle collisions, agricultural damage, lack of forest regeneration, detrimental impacts on other wildlife (especially birds), damage to residential landscapes, spread of seeds of invasive plants, and the rising incidence of Lyme disease. The fault is not in the animal. Who has not appreciated the thrill of a glimpse of these animals in the meadow or grazing in our landscapes? The problem is in their numbers. There only need be fewer of them. Mature, shaded forests with poor forage and browse support low densities of deer and fewer ticks. A mosaic of light fragmented woodland and woodland edges, clearings and abundant shrubs, berries, grass, and forbs and a lack of predators are ideal for deer. Fencing out deer can allow greater landscape options favorable to other wildlife.



Historical estimates for white-tailed deer abundance in Connecticut (Data: CT DEP).

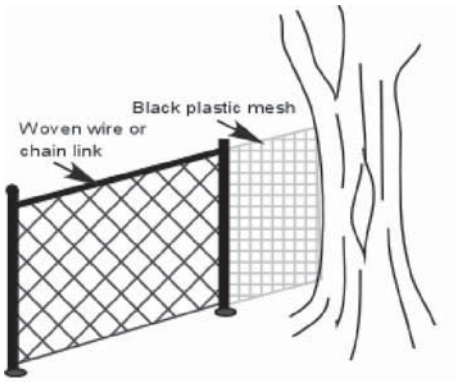
The abundance and distribution of *I. scapularis* has been related to the size of the deer population. It has been estimated that over 90% of adult ticks feed on deer, each laying ~3,000 eggs. Therefore, deer are the key to the reproductive success of the tick. Deer transport blood-engorged female ticks into the property where they can lay thousands of eggs, increasing the number of larval ticks available to feed on small animals. Reservoir incompetent, deer do not infect feeding ticks with Lyme disease bacteria. Larvae of *I. scapularis* pick up the spirochetes when they feed on small animals, especially mice, which are reservoir competent hosts. Island or peninsular communities with extremely high deer densities (ca. > 100/mi^2) have superabundant tick populations. Conversely, islands without deer do not appear to support *I. scapularis* or *B. burgdorferi*. Deer management options include deer fencing, repellents, and deer resistant landscape plantings. Dogs also may help deter deer, but to be effective, the animal may have to be active both day and night, something a family pet may not do.

Deer Fencing: Fencing is the most effective method to control access by deer to a property. Fences can keep deer from large garden beds or small to moderate sized home lots. The exclusion of deer from areas of 15 to 18 acres with a slant high-tensile electric fence was shown to reduce the abundance of *I. scapularis* nymphs by as much as 84% and larval ticks by 100% approximately 70 yards or greater inside the fence as fencing would need to enclose an area large enough to exceed the range of smaller animal hosts. A deer fence does not inhibit small animal movement and tick movement. Fencing of smaller areas also may be beneficial, but tick management practices within the enclosure and the use of an insecticide at the fence perimeter may also be needed. Barrier fencing can be used to protect individual trees, shrubs or other plantings from deer.

There are many types of deer fences and selection will depend upon deer pressure, area to be protected, and site characteristics. The most common choice for a fence is a plastic or wire mesh vertical structure. An electric fence is another option. A number of companies specialize in providing deer fencing and can provide the fencing materials or install the fence. However, many communities have local restrictions or ordinances on the type and height of fencing allowed – check with your local authorities.

91

Non-electric fence: The fence may be vertical or three-dimensional. A vertical fence requires the least space and a wide variety of fence materials and designs are available. Increasingly, a black polypropylene plastic fence-like mesh or steel mesh is being used instead of a chain-link for vertical fences because of reduced cost, low maintenance, long life, and near invisibility, an attractive feature in the residential landscape. The plastic material comes in rolls of various lengths and 7.5 feet wide and can be fastened to existing trees or several different types of posts. White flags should be attached at around 4 feet to signal the presence of the fence. While deer can jump a vertical fence of eight feet from a standing position, they rarely do so and are more likely to try and push under fencing. Proper anchoring or staking of the fence along the ground is important. Single or multiple electric strands also can be placed along the top of a vertical wire or mesh fence. Another option is a slant deer fence set at an angle of 45 degrees for use in areas with moderate to high deer densities, but it requires more space (about 6 feet of horizontal space). Deer cannot clear both the height and width of the fence and often find themselves under the top outer wire. Solid 5- to 6-foot fences are also effective. Access gates, driveway gates (can be remotely controlled in more expensive systems), or in ground driveway deer grates (similar to cattle guards) will be needed to completely enclose the area and still allow owner and vehicle access.



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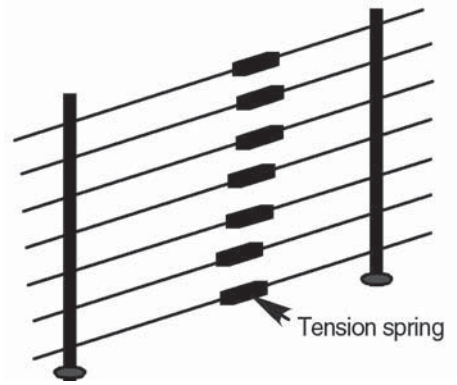

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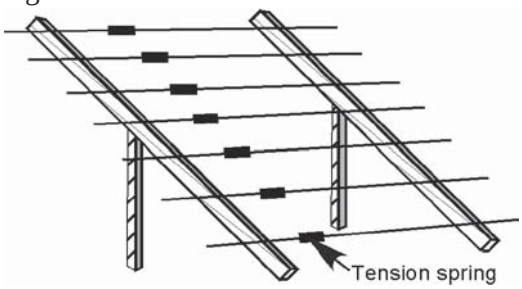
Electric fence: An electric fence requires maintenance, proper grounding, and may not be appropriate in many residential settings. A vertical or slant seven-strand, high-tensile electric fence is very effective for larger areas where deer densities are high.



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Deer Repellents: The use of deer repellents may reduce damage to plants and help defer the animals elsewhere, but by itself will not impact tick abundance unless deer consistently avoid the property entirely. Repellent performance is highly variable depending upon the product (most are either odor or taste-based), rain, frequency of application, and the availability of other food sources for deer. Nevertheless, some repellents are fairly effective with low to moderate deer densities.

95

Deer Resistant Plantings: Substituting less palatable landscape plants may discourage browsing around the home, reduce damage to ornamental plants and may help make the yard less attractive to deer, though deer will also readily graze on lawns. The use of deer resistant plantings may have no impact on ticks unless deer consistently avoid the property and the use of these plants specifically as part of tick management has not been examined. It simply seems to make sense to make your yard and plantings less attractive to deer.

No plant is completely browse resistant and susceptibility depends upon deer density, food availability, and food preferences, which can vary regionally. Plant selection will depend partly upon the type of terrain you have: a sunny, moist yard, a dry, sunny garden, a dry shady garden, or a wet, shady yard, proximity to streams or ponds and effect desired (e.g., fragrance, foliage color, seasonal color, showy borders, etc.). Use of native shrubs and trees is encouraged and the use of invasive plantings is discouraged. Non-native invasive plants, some of which are very resistant to deer browse damage, can crowd out natives. Examples include Japanese barberry, multiflora rose, Asiatic bittersweet, and several non-native honeysuckles. Many states prohibit or restrict the selling, movement or planting of certain invasive plants or noxious weeds. For example, Connecticut prohibits importing, selling, buying, cultivating, distributing or transplanting of 81 listed invasive plant species (some are aquatic). Massachusetts bans the importation and sale of more than 140 plants identified as either noxious and/or invasive. Lists of banned and invasive species and alternative plantings are usually available from state agencies, universities, or environmental groups in each state.

A rating of deer browse damage to many plants was compiled at The Connecticut Agricultural Experiment Station (CAES) from a survey of Connecticut gardeners. A comprehensive list of the survey results with plants ranging from very susceptible to highly resistant to browse damage is available in CAES Station Bulletin 968 (online at www.ct.gov/caes). Information is also available on deer resistant plantings and deer proofing from a variety of books and handouts. Many nurseries and garden centers can provide a suggested list of deer resistant plantings.

Groundcovers like pachysandra and myrtle, while browse resistant, have been found to harbor ticks and may not be the most appropriate choice near heavily used areas around the house, porch, or mailbox. In general, ornamental grasses and ferns are browse resistant and may be good choices in sunny and moist shady areas, respectively. A number of medicinal herb varieties, ornamental

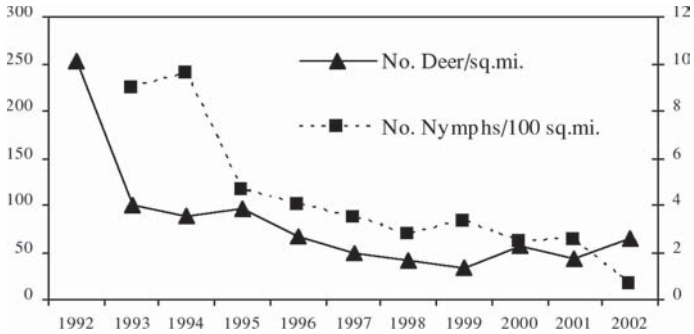
herbs, and butterfly garden plants are resistant to deer browse. The most browse resistant plantings can be placed at the edges and entrances of the property and the most browse susceptible plants closer to the house or areas frequented by people and pets. Susceptible plants can be surrounded by less palatable species. Clean up fruits and other produce from under trees or crop plants. While eliminating cover like mixed tall grass and brush may help discourage deer from bedding near the home, deer will bed wherever they consider it safe – even open lawn. In a study of tick egg-laying, female ticks from deer were found to survive in field bedding areas and lay eggs from which larvae successfully hatched. However, larval survival in the field was shorter than in the woods and they are less likely to be picked up by a rodent host.

Deer Reduction and Management

Some communities have explored the reduction of white-tailed deer through regulated hunting or controlled hunts to reduce problems associated with deer overabundance, particularly related to Lyme disease. A major question has been how far deer densities must be lowered to reduce tick exposure and human disease. The incremental removal, reduction or elimination of deer has clearly been shown to substantially reduce tick abundance in many studies. Observational studies and computer models suggest that a reduction of deer densities to less than twenty deer per square mile may significantly reduce tick bite risk, while lower levels (~8 deer/mi^2) would interrupt the enzootic cycle of Lyme disease and transmission of *B. burgdorferi* to wildlife and humans. Fewer ticks have been reported at deer densities less than 18 animals/mi^2 in one study. Because of issues related to locations where most deer reduction studies have been conducted and limited human case reports, data on the impact on human disease are more limited. However, reductions in human tick-associated disease with the lowering of deer densities have been reported.

Select Deer Reduction Studies on the Blacklegged Tick and Lyme Disease

- The reduction of deer on Great Island (a peninsula on Cape Cod, MA) by 97% from an estimated 32 deer to 1 animal from 1982 to 1984 (52 deer in all) resulted in ~80 and ~55% average reductions in larvae and nymphs on mice in the 3 years following the intervention. Continued maintenance of a density >6 deer/mi^2 has reduced tick-borne disease incidence from 16% of a community of 220 people to only 3 cases since 1986 (Telford 2002; Wilson et. al. 1988).
- In the coastal community of Ipswich, MA, removal of deer over a 7-year deer period from 160 deer/mi^2 to 27 deer/mi^2 (~83%) reduced the average number of larval and nymphal *I. scapularis* on mice by 50 and 41%, respectively (Deblinger et. al. 1993).
- In Connecticut, deer were reduced from over 200/mi^2 to ~30/mi^2 (~84%) at the Bluff Point Coastal Preserve and a geographically isolated tract in Bridgeport (see figure below) producing a substantial (>90%) decline in tick abundance from 9-12 nymphal *I. scapularis* per 100 m^2 to ~1.0/100m^2 (Stafford et. al. 2003).



- In Mumford Cove, a residential community in Groton, Connecticut, the deer population was reduced 92% from ~100/mi^2 to ~12/mi^2 and the number of Lyme disease cases was reported to have dropped from 30 to less than 5 within three years. Although part of this reduction was due to a regional decrease in tick activity and in reported Lyme disease cases during the same period, tick abundance was reduced and a regional increase in tick numbers and reported Lyme disease cases in 2005 was not reflected in the Mumford Cove community (Kilpatrick & LaBonte 2003; Stafford, unpublished data).
- Deer were completely eliminated from Monhegan Island, Maine over a 28-month period resulting in the steady disappearance of *I. scapularis* from the island (Rand et. al. 2004).
- Computer simulations with a program called LYMESIM suggest that a 70% reduction in deer density and maintenance level of 19 deer per square mile (7.5/km^2) would achieve ~40% reduction in infected nymphs within 4 years. The virtual elimination of deer would result in a 99% reduction in infected nymphs (Mount et. al. 1997).

While adult ticks also feed on opossums, raccoons, coyotes, and skunks, it doubtful that *I. scapularis* can be maintained in significant numbers just from feeding on these medium-sized alternate animal hosts. They are less abundant than deer and, in the case of raccoons, ticks are frequently removed while grooming. Some ticks still may continue to be introduced into an area on migrating birds, even with the complete removal of deer. A few adult ticks have been recovered from deer-free islands. Interestingly, the number of adult ticks on remaining deer and the 'apparent' adult tick host-questing abundance will increase for several years following deer reductions as questing adult ticks, many of which would have fed on deer, become available to other hosts. The prevalence of *B. burgdorferi* in the ticks will initially rise as a greater proportion of immature ticks feed on reservoir competent hosts before dropping in subsequent years. The time that is required for reductions in the questing tick population is due, in part, to the 2 year life cycle of the tick.

Although deer and tick reductions have been successfully carried out on some islands, peninsulas or some other defined geographical tracts, it is not clear if a deer population can be reduced sufficiently to achieve a satisfactory level of tick control in more densely populated areas on the mainland. Conversely, unregulated deer populations may potentially lead to an increasing tick population. Lethal management options for deer are effective, though controversial, while the use of anti-fertility agents remains experimental and labor intensive. A community that wishes to implement a deer management program, especially in densely populated urban and suburban areas must deal with hunting restrictions, real or perceived safety or liability concerns, and conflicting attitudes on managing wildlife. Since most land in the northeast is privately held, homeowner views and hunter access are important to deer management. Any deer population control program would require an initial reduction phase to lower high densities of deer and a maintenance phase to keep the deer population at the desired targeted level. Deer capacity for reproduction is high and deer herds can potentially double in size in one year. Management would be an ongoing process.

Host-Targeted Chemical Tick Control for White-tailed deer

The U.S. Department of Agriculture, Agricultural Research Service (ARS), developed passive self-treatment methods for white-tailed deer through both systemic (i.e. ivermectin-treated corn) and topical application technologies to kill ticks feeding on deer. A device termed a '4-Poster' was designed for the application of topical acaricides to white-tailed deer to prevent the successful feeding of adult ticks. It consists of a feeding station with four paint rollers that hold the pesticide. Deer self treat themselves when, because of the design, they are forced to brush against the rollers as they feed on whole kernel corn. Computer simulations of various intervention scenarios

suggested that acaricide applied to white-tailed deer (assuming 90% of deer are treated and 90% tick mortality on these deer) would prevent more cases of human Lyme disease except perhaps for the best use scenario of a Lyme disease vaccine.

Because white-tailed deer are the keystone species for adult blacklegged ticks and lone star ticks, the '4-Poster' was evaluated on free-ranging deer in a multi-year (5 years treatment plus 2 additional years tick sampling) project in the northeastern United States for the control of both tick species at seven 2-mi^2 sites in 5 states (MD, NJ, NY, CT, RI). Approximately one device was placed per 51 acres, although some minimally used 4-posters were redeployed near heavily used devices to increase host access. Treatments utilized a 2% oily formulation of amitraz and reduced blacklegged tick abundance by up to 81% and lone star ticks up to 99.5% in the treated communities in comparison with untreated areas after 3 or more years of use. Similarly, the application of 10% permethrin to a 600-acre fenced population of deer resulted in a 91-100% reduction of larval, nymphal, and adult questing blacklegged ticks at the Goddard Space Flight Center, MD. While usage of the devices by deer was generally high (> 90 to 100%), utilization of the devices by deer can be low or sporadic when alternative food sources were available such as heavy acorn mast. Maintenance of the feed and topical insecticide through the tick season is labor intensive. Nevertheless, according to computer simulations, this approach, in principal, could provide the greatest reduction in Lyme disease with the least direct community involvement (i.e. number of direct participating households) and may be an alternative to the application of area-wide acaricides and the maintenance of drastically reduced deer populations.

96

The '4-Poster' Deer Treatment Bait Station is licensed to the American Lyme Disease Foundation of Lyme, CT (www.aldf.com) and manufactured by C. R. Daniels, Inc. of Ellicott City, MD (www.crdaniels.com). The U.S. Environmental Protection Agency (EPA) has registered an oily 10% permethrin formulation of ready to use tickicide (Y-TEX '4-Poster' Tickicide□, Y-TEX Corporation, Cody, WY) especially for application to deer via the '4-Poster Deer Treatment Stations to control *I. scapularis* and *A. americanum*. Permethrin is the chemical used as a tick repellent on clothing and as an acaricide in some louse and scabies mite treatment products for human use. According to the 'Tickicide' label, the acaricide is not to be used less than 100 yards from any home, apartment, playground, or other place children might be present without adult supervision. States may impose more restrictive requirements than the federal label. State pesticide registrations have been obtained in 47 of the 48 contiguous states except for New York, which has strict regulations against feeding deer. Approval requirements or regulations for use by state wildlife officials vary from state to state and use of the device raises some concerns among some state wildlife agencies. Although no cases have been observed in New England and only a single isolated occurrence in New York, Chronic Wasting Disease (CDW) has been shown to be transmitted via blood and saliva of infected deer, primarily in Michigan and other north central states. The use of the 4-poster will probably be most practical as part of a neighborhood or community coordinated program to reduce ticks and the risk of Lyme disease, managed under state use regulations, and combined with some form of a deer management program.

97

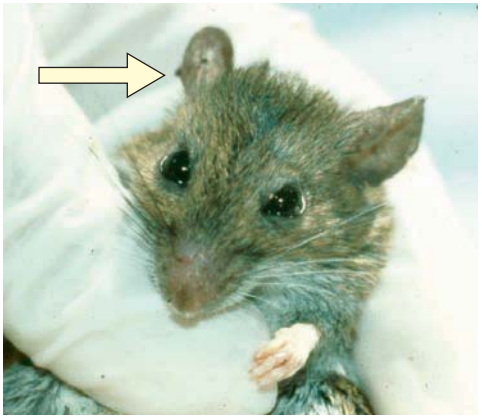
Small Mammals and Birds

Rodents and birds can infect ticks with *B. burgdorferi* and transport these ectoparasites onto your property. The importance of these animals in the dynamics of Lyme disease depends on the abundance of the animal host, number of ticks feeding on the host, and the host's ability to infect feeding ticks with the Lyme disease spirochete (i.e., the reservoir potential). In other words, what animals are contributing infected ticks to your property? Some animals may have a lot of ticks, but these hosts may not be able to infect their ticks with spirochetes.

Rodents

While different rodent and bird species may predominate in certain years and locations, white-footed mouse, *Peromyscus leucopus*, is generally the most abundant and efficient animal reservoir for the Lyme disease bacteria. They contribute more infected ticks than eastern chipmunks or meadow voles do. White-footed mice also are reservoirs for the causal agents of anaplasmosis and babesisois. Over 90% of white-footed mice will be infected with *B. burgdorferi* in many areas and up to half have been found to carry all three pathogens in some areas. In one study, a single mouse was estimated to infect as many ticks as 12 chipmunks or 221 voles. Meadow voles, *Microtus pennsylvanicus*, which are most abundant in fields, pastures, orchards, harbor few *I. scapularis*. Although they harbor fewer ticks, short-tailed shrews, *Blarina brevicauda*, with their high reservoir potential, may contribute to the maintenance of both *B. burgdorferi* and *B. microti* in some areas, especially when mouse numbers are low. By contrast, squirrels have a lower Lyme disease reservoir potential. One study indicated that squirrels might reduce or dilute the number of infected ticks in the landscape. Although not quantified, this author has noticed mouse populations drop dramatically (based on trapping success) with resultant declines in the tick population at a sample site where a fox family or snakes have taken up residence in or near the stone walls. Mice have relatively small home ranges. Dense vegetation and ground cover plants like pachysandra adjacent to homes provide cover for rodents as they forage for food. Shaded stonewalls overgrown with grass and brush can harbor many mice and chipmunks.

98



99

100

White-footed mice (top, middle) and Eastern chipmunk (bottom). Note the engorged larval ticks(arrow) feeding on the ears and around the eyes of the white-footed mouse in the middle picture. Larval ticks become infected with B. burgdorferi and other pathogens while feeding on an infected mouse or chipmunk.

White-footed Mouse
Peromyscus leucopus (Rafinesque)

The white-footed mouse is the principal animal carrying the pathogens that cause Lyme disease, human anaplasmosis (i.e., ehrlichiosis) and human babesisois. White-footed mice are found throughout most of eastern and Midwestern United States, except in Florida and

northern Maine. This mouse is difficult to distinguish from the deer mouse, *P. maniculatus*.

White-footed mice have a home range of generally 0.1 to 0.5 acre, sometimes larger. This woodland and brushy area dwelling animal nests in stonewalls, tree cavities, abandoned bird or squirrel nests, under stumps, logs, and stacked firewood. Mice may readily enter and nest in buildings, especially during the winter months and may line the nest with fur, feathers or shredded cloth. These nocturnal animals are omnivorous and feed on acorns, seeds (including newly planted gardens), fruits, insects, snails, tender young plants, and carrion.

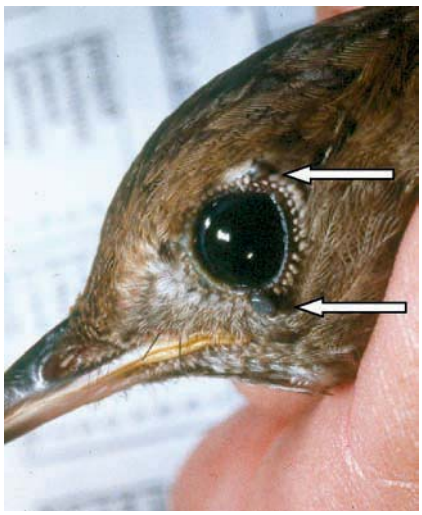
Mouse densities usually are around 1-10 per acre but can be higher (15 per acre) and may go relatively unnoticed until they enter homes that are not rodent proof. Breeding spring through fall, a female mouse typically has 3-4 young after a gestation period of 22-25 days. The mice reach sexual maturity in 6-7 weeks. There are no ticks on the mice during the winter and, inside buildings, they do not pose a risk for the transmission of Lyme disease. Folded hardware cloth (1/4-inch mesh) may be used to exclude mice from buildings, flowerbeds, and garden plots. Cleaning up small black droppings and urine-contaminated areas in confined areas can pose a risk for exposure to hantavirus.

Eastern Chipmunk *Tamias striatus* L.

Eastern chipmunks are found in most states east of the Mississippi River, except along the southeastern coastal region. They are often the second most important rodent in the maintenance of Lyme disease and may even be the principal reservoir in some areas. Solitary by habit and active during the day, chipmunks feed on seeds, grains, fruits, nuts, bulbs, mushrooms, insects, carrion and may prey on young birds and eggs. They can climb trees to gather seeds, fruit and nuts and store food throughout the year. They hibernate during the winter, but may become active for brief periods on sunny warm days. Requiring ample vegetative cover, chipmunks are found in deciduous woodlands with undergrowth, old logs, stonewalls, and in brushlands. Their home range is small, typically less than 100 yards in diameter and females defend a 50-yard radius around the home. A small (2 inch), inconspicuous entrance leads to a complex burrow system. There are typically 2 to 4 chipmunks per acre, but densities may be higher with adequate food and cover. There are 1 or 2 litters each year. Hardware cloth (1/4-inch mesh) may be used to exclude chipmunks from buildings and flowerbeds.

Birds

Birds are frequent hosts for immature stages of the blacklegged tick. In a Connecticut woodland study, 26% of 5,297 individual birds were infested with ticks, 41.4% of 87 bird species were infested, and 94% of 4,065 specimens collected from the birds were *I. scapularis*. In a Maine study, a similar proportion of bird species were infested (39% of 64) with blacklegged ticks and immature *I. scapularis* were recovered from 86.9% of the 1,972 birds examined. At times, the number of individual ticks on birds exceeded that found on white-footed mice.



Note the ticks (arrows) feeding around the eyes of this veery (J. Occi).

While some bird species can infect feeding ticks with *B. burgdorferi* (i.e., American robin, veery, grackle, common yellowthroat, Carolina wren, house wren), other species (i.e., gray catbird, woodthrush) do not. Due to variability in bird species composition, population, and reservoir

competence, it is uncertain how many ticks birds actually contribute to an individual residential landscape. One study found that American robins, a reservoir competent bird, were likely contributors to the nymphal tick population found in some suburban residential landscapes. However, based on another study, most birds probably contribute few infected ticks and may actually dilute pathogen transmission, at least in comparison to mice. Bird feeders were not found to be a risk factor for Lyme disease in a recent study, possibly because birds that frequent feeders in the summer have less exposure to ticks on the ground. Adult ticks, which are active in the fall, winter and spring months, do not feed on birds.

It is unknown what impact summer or winter fruit-bearing trees and shrubs for birds have on the prevalence of ticks as related to mouse and chipmunk activity. Seeds and fruits can also serve as a food source for these animals.

Many berry plants, however, are important to fall migrants, and the berries are quickly consumed. Deer resistant bird favorites include bayberry (*Myrica pensylvanica*) and Virginia creeper (*Parthenocissus*) and highbush blueberry (*Vaccinium corymbosum* – produces summer berries); cedars and certain holly cultivars, however, are subject to heavy deer browsing. Common winterberry (*Ilex verticillata*) is also fairly susceptible to heavy deer browse damage. It requires both female and male plants to produce winterberries for birds. Native viburnums will suffer only occasional to minimal damage from deer and are good bird plants. Japanese barberry (*Berberis thunbergii*) is considered invasive. Both nymphs and adults of the blacklegged tick have been reported to be around twice as abundant in areas dominated by deer-browse resistant exotic invasive plants, particularly Japanese barberry, than areas dominated by native shrubs. Lower small mammal species diversity, increased densities of white-footed mice, and therefore increased tick abundance and Lyme disease risk have been linked to habitat with higher density woody understory with more leaf litter and good soil moisture. The Connecticut Agricultural Experiment Station publication *Alternative for Invasive Ornamental Plant Species* is available on the CAES website (www.ct.gov/caes).

Possible small animal and bird management strategies include:

- Keep potential mouse nesting sites in stonewalls and woodpiles near the residence free of brush, high grass, weeds, and leaf litter.
- Seal or rework stonewalls near or under the home to reduce harborage.
- Move firewood away from the house.
- Place the birdhouses and feeders away from the house. However, it is unknown if this will decrease risk of exposure to ticks. Clean up spilled feed (spilled bird feed can also attract mice).
- Set up bird feeders in fall and winter when natural foods are scarce (and the immature stages of *I. scapularis* are not present on birds).
- Seal foundations. For example, a garden shed on cement blocks can harbor raccoons, skunks, or woodchucks. This can be avoided through a proper foundation or use of hardware cloth buried at least two feet beneath the ground. A poorly sealed building or old garden shed can harbor mice.
- Select or replace exotic-invasive shrubs with native shrubs.

A fitted stonewall (right) is unlikely to harbor rodents and ticks, compared to the old stonewall with leaf litter and other vegetative cover (left)

102 103

Host-Targeted Chemical Tick Control for Rodents

The first rodent-targeted product was a cardboard tube of cottonballs treated with the insecticide permethrin (Damminix® Tick Tubes). The product is aimed at larvae and nymphs of *I. scapularis* feeding on white-footed mice. The effectiveness of this product is dependent upon the mice collecting the cotton as nesting material from cardboard tubes distributed throughout the mouse habitat. Although reductions in tick numbers were reported in a couple of Massachusetts studies, evaluations in Connecticut and New York failed to show any reduction in the number of infected, host-seeking *I. scapularis* nymphs when this product was used for a three-year period in woodland and residential areas of about 4 acres or less. Lack of control may be due to failure by the mice in some areas to collect the cotton or the presence of alternative tick hosts, such as chipmunks, an important secondary tick host and spirochete reservoir. Reductions in tick numbers were reported in an 18-acre tract study conducted in Massachusetts.

Another approach, using bait boxes for the topical treatment of rodents with fipronil, was first successfully evaluated for the control of *I. scapularis* on wild white-footed mice on Mason's Island, Connecticut, where the prevalence of infection of *B. burgdorferi* in the mice dropped dramatically after one year and nymphal tick populations were substantially reduced after only two years of use. Fipronil is the active ingredient in topical or spray flea and tick control products (Frontline®). In the laboratory, a single topical application to a mouse can kill all ticks on the animal for 4-6 weeks. A commercial version called the Maxforce Tick Management System that was available through licensed pesticide applicators consisted of a sealed, ready to use, child resistant box containing nontoxic food blocks and an applicator wick impregrated with 0.70% fipronil. Due to added costs from a metal shroud required to prevent squirrels from chewing into the boxes, the Maxforce Tick Management System is no longer being manufactured by Bayer Environmental Science.

Prevention of Tick-Associated Disease in Companion Animals

104

Engorged female *I. scapularis* on a domestic cat (Pfizer).

The prevention of Lyme disease and other tick-associated diseases in dogs relies on avoiding tick habitat, reducing ticks on the animal, daily tick checks, and use of one of the canine Lyme disease vaccines available (whole-cell killed bacterins or recombinants based on outer surface protein A - OspA - of *B. burgdorferi*). Vaccination early, prior to tick exposure, will provide better protection, but vaccination after treatment can help reduce future infection. Electronic fencing systems can help confine a pet in an area where the animal is less likely to pick up ticks or where other tick control measures have been implemented. If the pet is not allowed to freely roam into the wooded areas, it is less likely to pick up ticks. Animals can carry ticks into the home. However, studies to determine whether pet owners may be at increased risk of Lyme disease have been inconclusive. Ticks, once attached or fed, will not seek another host. Dogs and cats should be checked daily for ticks, but the immature stages may be virtually impossible to detect on longhair or dark-hair animals. Outdoor activities with animals also may increase the exposure of pet owners to ticks and their habitat.

A veterinarian should be consulted about the prevention and treatment of Lyme disease in your animals. A variety of products can repel and/or kill ticks on the animal. Some are available over the counter (OTC), while others require the assistance of veterinarians. Chemical products to protect dogs from ticks are available as spot-ons, sprays, collars, powders, and dips. Ingredients include several insecticides such as pyrethrin, permethrin, permethrin and imidacloprid, amitraz, or fipronil (see section on chemical control). Fipronil is the only option for cats. Some products are combined with an insect growth regulator to help control flea eggs. Follow label directions to minimize the chances for an adverse reaction to the product in your pet and do not combine products without the advice of your veterinarian. Different products can contain the same or similar ingredients, which could result in an overdose of the animal.

105

Although the risk of clinical disease is low, the canine Lyme disease vaccines can provide high levels of protection for dogs living in or traveling to endemic areas with a likely exposure to ticks. Depending upon the vaccine, an initial dose can be given as early as 9 or 12 weeks of age with a second required dose several weeks later. An annual booster is recommended by the manufacturer.

Area-Wide Chemical Control of Ticks

Insecticides, or as termed for ticks, acaricides, are the most effective way to reduce ticks, particularly when combined with the landscaping changes to decrease tick habitat reviewed earlier in this handbook. These measures provide consistent control, are relatively easy to apply, and are relatively inexpensive. Only small amounts of an acaricide applied at the right time of year are necessary. Chemical intervention should focus on early control of nymphal *I. scapularis* ticks, the stage most likely to transmit Lyme disease, by spraying once in May or early June. A fall application in October may be used to control adult blacklegged ticks (or in the spring if no fall application was made). Targeting lawn and woodland edges and perimeter areas near tick "hot-spots" or along the "tick zone" can minimize exposure. Some general points to consider if you spray for ticks:

106

107

108

109

- Applications can be made by the homeowner or by a commercial applicator.
- Spray once in the late spring or early summer for control of *I. scapularis* nymphs. For American dog ticks, an application can be made anytime after the adults emerge in the spring.
- A single application of most ornamental-turf insecticides will provide 85-90% or better control with some residual activity so multiple applications are rarely necessary. Some organic pesticide products are less effective, breakdown rapidly, and multiple applications may be required.
- Focus treatment on tick habitat. Spray areas where the lawn meets the woods, stonewalls, or ornamental plantings. Spray several yards into bordering woodlands, area of greatest tick density. Spray groundcover vegetation like *Pachysandra* near the home or walkways. Spray perimeter of areas of the yard often used by people (play areas, gardens, outside storage areas, walkways or paths to neighbors or mailboxes). Avoid herb, vegetable, and butterfly gardens.
- In parks and school athletic fields, restrict any applications to high-risk tick habitat. Spraying of open fields and lawns is not necessary.

- Use a product specifically labeled for controlling ticks. Some products are packaged as fertilizer-pesticide mixtures or mixtures of different pesticides (e.g., herbicide and insecticide) or target just garden insects.

Acaricides Used for Tick Control

There are several factors that will influence the selection or use of a specific chemical product. All pesticides sold must be registered with the U.S. Environmental Protection Agency (EPA) and the appropriate state pesticide agency for use within that state.

- The product must be labeled for area-wide tick control (see Table 4). Some products are General Use Pesticides and others are classified as Restricted Use Pesticides for commercial use only, available only to licensed applicators. Some products are labeled for brown dog ticks only or for ticks on surfaces, indoors, as a building foundation or perimeter treatment and are not labeled for use on ornamentals or turf. Check the label and ask for assistance. A licensed commercial applicator often will have a preferred acaricide that is used most frequently.
- The toxicity and environmental impact of the chemical. Chemicals differ in their toxicity to humans, wildlife, aquatic organisms and beneficial insects. While some general information is provided in this handbook, more detailed information can be obtained from sources listed at the end of chemical control section.
- The type of formulation and method of application. Both liquid and granular formulations have been reported effective against *I. scapularis* with somewhat better control usually obtained with liquid formulations. Sufficient spray volume and pressure should be used for thorough coverage and penetration of the vegetation and leaf litter. A small hand pump sprayer is unlikely to provide the coverage needed for good tick control and, at a minimum, some type of garden hose sprayer is indicated for an adequate application. A homeowner who wishes to apply a granular material with a fertilizer spreader for tick control may not be able to treat woodland margins effectively and the product may be labeled for lawn use only.
- Effectiveness in controlling ticks. Blacklegged ticks and American dog ticks are readily killed by almost all ornamental and turf insecticides labeled for tick control. With the withdrawal of the organophosphate insecticides chlorpyrifos and diazinon from residential use (the U.S. Environmental Protection Agency cancelled registration of these compounds for residential area-wide use), the synthetic pyrethroid insecticides are the most commonly used tick control agents. Pyrethroids are particularly effective at rates 6-45 times less than the now cancelled organophosphate insecticides and the carbamate insecticide carbaryl. In the laboratory, nymphal *I. scapularis* crawling on landscape stones treated with pyrethrin-based desiccants and insecticidal soaps suffered high (> 88%) mortality. However, natural pyrethrin with the synergist piperonyl butoxide provided limited tick control in the residential landscape in several trials. By contrast, synergized pyrethrin was more effective when combined with insecticidal soap or as part of a silicon dioxide (from diatomaceous earth) product. Silicon dioxide acts as a desiccant. Thorough coverage appears particularly important with pyrethrin and insecticidal soap products. With the exception of a desiccant, there is little residual activity. At least two applications may be required.

- Site use restrictions. Many states, including Connecticut, regulate, restrict, or ban the use of pesticides in school buildings or on school grounds. In some cases, applications may be permitted under an approved integrated pest management (IPM) plan or for a health emergency. As these laws or regulations change, the state pesticide regulatory agency can be consulted to determine current requirements and restrictions.

Table 4. Acaricides with products labeled for the control of ticks in the residential landscape.

Chemical	Some brand or common names*	Chemical type and usage
Bifenthrin	Talstar® Ortho® product	Pyrethroid insecticide. Available as liquid and granular formulations. Products available for homeowner use and commercial applicators.
Carbaryl	Sevin®	Carbamate insecticide. A common garden insecticide for homeowner use, some products are for commercial use only.
Cyfluthrin	Tempo® Powerforce™	Pyrethroid insecticide. Available for commercial and homeowner use with concentrates and ready to spray (RTS) products.
Deltramethrin	Suspend® DeltaGard® G	A pyrethroid insecticide for commercial applicators.
lambda-cyhalothrin	Scimitar® Demand®	A pyrethroid insecticide for commercial applicators.
Permethrin	Astro® Ortho® products Bonide® products Tengard® SFR Others	Pyrethroid insecticide. There are concentrates and ready to spray (RTS) products. Most are for homeowner use, a few are for commercial use.
Pyrethrin	Pyrenone® Kicker® Organic Solutions All Crop Commercial & Agricultural Multipurpose Insecticide®	Natural pyrethrins with the synergist piperonyl butoxide (PBO) or insecticidal soap provide limited tick control. A combination of pyrethrin and PBO with either insecticidal soap or silicon dioxide (from diatomaceous earth) was found effective against ticks in one trial.

*Active ingredients and brand names frequently change as new products are registered and others discontinued. New formulations for homeowner use may become available. Mention of a product is for information purposes only and does not constitute an endorsement by the Connecticut Agricultural Experiment Station.

Homeowner Application of Acaricides for Tick Control

One option is for the homeowner to make the pesticide application. Anyone applying pesticides to their own property should be familiar with how to read a pesticide label, how to correctly mix the pesticide, and follow the listed precautions in handling and applying the material. The pesticide label provides information on the active chemical ingredients, formulation, pests and sites for which it can be legally used, directions for use, precautions, hazards to humans, wildlife and the environment, and first aid instructions. Always read and follow pesticide label directions and precautions. It is a violation of federal law to use a pesticide in a manner inconsistent with the label. The label will provide an indication of how hazardous a pesticide is by the signal word on the label. Signal words are based on the EPA toxicity class and must be included on pesticide labels.

- Danger-Poison means highly toxic or poisonous through oral or dermal exposure

- Danger means highly toxic, but may include severe skin or eye irritants
- Warning means moderately toxic or hazardous
- Caution means slightly toxic or hazardous
- No signal word means practically nontoxic

Not all brands of a particular pesticide chemical will be labeled for area tick control. Some products may be for application in or on building and their immediate surroundings. Check the label. Homeowner products come in three forms.

- Ready-to-use (RTU) is premixed and applied directly from the existing container. They are used for spot treatments, treatments of individual plants, or treatment of small areas. Some RTU products, for example, are used to control dog ticks indoors or around a dog's bedding. Ready-to-spray (RTS) products are used for treating larger areas. The container attaches directly to a garden hose for automatic mixing of the water with the concentrate. For example, a ready spray of 2.5% permethrin or 0.75% cyfluthrin is available as a hose end sprayer for the control of *I. scapularis* and will cover about 5,000 square feet.
- Concentrates require mixing the product with water and using your own sprayer (pump-up style, hose-end style, or other type sprayer). Homeowner products may contain carbaryl, cyfluthrin, or permethrin.
- Granules are designed for lawn applications with a hand held or broadcast spreader. The chemical is usually released with addition of water, so granules generally must be watered in. Granules for tick control on the lawn may contain bifenthrin or carbaryl.

Appropriate protective gear as directed on the label should be used when applying pesticides. Surveys have shown many individuals fail to take precautions while applying pesticides. Pesticides should be stored in a cool, dry, secure place. Keep them out of the reach of children. An EPA survey found 85% of households had at least one pesticide on the property and 47% with young children (under age 6) stored them within reach of the child. Keep a pesticide in its original container; do not store diluted spray. Either use up the product or properly depose of leftover product through a community household hazardous waste program. Pesticides should never be poured down the sink or toilet. Empty containers should be triple rinsed and placed in the trash. For more information on handling, applying, storing and deposing of pesticides, readers may refer to the EPA's Citizen's Guide to Pest Control and Pesticide Safety (available at www.epa.gov).

Commercial Application of Acaricides

Another option is to have a licensed commercial pesticide applicator apply the acaricide. Most companies offering tick control services are lawn care, landscape, or tree care companies, but may include some pest control operators (PCOs) in some states, depending upon what licenses the operator has obtained. A survey of commercial applicators in Connecticut in the mid-1990s found that about 16% offered tick control services. The application of pesticides for tick control comprised less than 5% of their business for most companies. Nevertheless, most companies reported that tick control business had increased and a few companies have specialized solely in providing tick control. A follow-up survey by the author in 1999 indicated that 53% were now offering tick control services. A number of companies provide organically oriented pest management services.

A company offering commercial application of pesticides must be registered with the state or states in which they conduct business. A pesticide license is required for the commercial application

of pesticides or the application of restricted use materials in the area. There must be at least one commercial supervisory pesticide applicator certified in the type of application being made. In Connecticut, for example, a license for ornamental and turf application from the Department of Environmental Protection is required for applying pesticides for tick control in the landscape. Some tree service companies (arborists) also treat for ticks. Although arborists are tested and licensed by the state specifically for arboriculture services, they must also possess an ornamental and turf license to spray for ticks. Consumers should employ individuals who are licensed to spray for ticks and may request to see the license or license number or check with the agency responsible for the state pesticide program to see if the firms are properly registered and licensed. A commercial company should provide a consumer the name of the pesticide product to be used, the active ingredient in the product, the reentry period (the time before family members can safely reenter the treated area), and the form of the pesticide and type of equipment to be used. In most states, companies are required to provide copies of the label and material safety data sheets (MSDS). With this information, additional information can be obtained over the Internet, from local Cooperative Extension offices, state agencies and pesticide alternative groups. Tips on hiring an applicator are available from EPA's Citizen's Guide to Pest Control and Pesticide Safety (available at www.epa.gov). Some general guidelines about a pesticide application that homeowners and commercial applicators should be aware of include:

- Many states (including all New England states, New York, New Jersey, Pennsylvania) have notification laws that require customers or adjacent residents receive written notice prior to an urban pesticide application. Usually this notification is provided only to those who request it through a registry.
- Pesticides should not be applied on windy days (greater than 10 mph) to avoid drift to non-target areas.
- Before the spraying, the windows and doors of the home should be closed.
- Pesticides should be kept away from plants and play areas that you do not want treated. Most tick control pesticides are for ornamental and turf use only and are not labeled for use on plants meant for human consumption. Most of these chemicals are toxic to bees and should not be applied to areas with foraging bees.
- Pesticides should not be applied near (within 25 feet) wetlands (i.e. lakes, reservoirs, rivers, streams, marshes, ponds, estuaries, and commercial fish farm ponds) or near (within 100 feet) coastal marshes or streams. Even organic pesticides are toxic to fish and aquatic invertebrates.
- Family members and pets, especially cats, should be kept off the treated area for 12-24 hours or other specified reentry interval following the treatment (generally until a spray thoroughly dries).
- Do not water the lawn after the application of a pesticide to avoid run off (there are a few exceptions with some granular products which must be watered in). Do not apply within 24 hours of rain to avoid run-off. Pesticides typically reach streams via run-off when rains hit a recently applied area or flush treated soil or other matter into the water body. Once the pesticide has dried, however, some materials bind tightly to the soil or vegetation and do not readily move or wash off. They will breakdown with exposure to sunlight and soil microbes.
- Avoid pesticide applications near a wellhead. The shaft of the well should be tightly sealed and the well water source should be isolated from surface water source. Most acaricides used for tick control are water insoluble and pose little risk to wells by leaching through the soil, but direct exposure should be avoided.

- Many states (including all New England states, New York, New Jersey, Pennsylvania) have laws that require signs to be posted after an urban treatment is made.

An Acaricide Primer

The purpose of this section is to serve as a reference for some basic, general material on the major classes of chemicals used in tick control. More detailed information is available from the EPA, the Cooperative Extension Service, state pesticide agencies, and independent groups, particularly over the Internet. Some sources of information are listed at the end of this section. Acaricides belong to a variety of chemical classes, which differ in their chemistry, mode of action, toxicology, and environmental impacts. They also contain "inert ingredients," chemicals that carry or enhance the application or effectiveness of the active ingredient (i.e., the actual acaricide). A variety of pesticides are also used in products to control ectoparasites on pets. Some pet care products are available over the counter and others through a veterinarian.

- **Organophosphates.** There were two organophosphate insecticides commonly used for area-wide tick control, chlorpyrifos (i.e., Dursban) and diazinon. The EPA cancelled the residential use and some agricultural uses of chlorpyrifos and cancelled the registration of diazinon for lawn, garden, and other residential outdoor use. Residential applications accounted for nearly 75% of the use of diazinon. Products with these chemicals are no longer used for tick control.
- **Carbamates.** Carbaryl (Sevin□) is the carbamate used in the control of ticks. Carbaryl is a broad-spectrum compound used for a wide variety of pests on the lawn, on pets, and in the home. Carbaryl in animals is readily broken down and excreted. It does not appear to cause reproductive, birth, mutagenic, or carcinogenic effects under normal circumstances, but it is a suspected endocrine disrupter. Carbaryl is extremely toxic to bees and beneficial insects, is moderately toxic to fish, but is relatively nontoxic to birds.
- **Pyrethrins.** Pyrethrum is a natural insecticide extracted from certain chrysanthemum plants. Natural pyrethrins are a group of six compounds that form the insecticidal constituents of the natural pyrethrum, which is highly unstable in light and air. Natural pyrethrins are considered knockdown agents because they rapidly paralyze insects, but many insects can detoxify the compound and recover. Therefore, pyrethrins are sometimes combined with a synergist. A synergist is a compound that enhances the toxicity of an insecticide, but is not an insecticide itself. The most common synergist used with pyrethrin is piperonyl butoxide, which inhibits the enzymes that break down pyrethrin. Pyrethrins also may be combined with insecticidal soaps, spreader sticker agents, silicon dioxide (desiccant) and other agents to enhance the effectiveness of the product. Pyrethrins have little residual effect, being quickly broken down by exposure to light, moisture, and air.
- **Pyrethroids.** Synthetic pyrethroids are derivatives of the natural compounds, chemically modified to increase toxicity and stability. Most of the chemicals used for area-wide tick control are pyrethroids. The pyrethroids are less volatile than the natural compounds and photostable, which provides some residual activity and greater insecticidal activity. Both pyrethrins and pyrethroids are highly toxic to fish and other aquatic organisms, but generally are much less toxic to mammals, birds and other wildlife. Pyrethroids can be skin and eye irritants. Many concentrated pyrethroid formulations are restricted to commercial use by licensed applicators because of their potential impact on aquatic organisms. However, low concentration, ready-to-use products are available for homeowner use.
- **Inert ingredients**. They may be solvents, propellants, spreaders, stickers, wetting agents, or carriers for the active pesticide chemical. Because these compounds are not the active chemical, they are labeled "inert ingredients" or sometimes "other ingredients". These

compounds often make up the major part of a pesticide formulation. In some cases, the inert ingredients may be more toxic than the active ingredient. A few examples of inerts include napththalene, petroleum distillates, and the organic solvents xylene and toluene.

- **Acaricides for control of ticks on pets**. Carbaryl, the pyrethroid permethrin and imidacloprid are used in several flea and tick control products for dogs. Studies have indicated that use of permethrin and permethrin/imidacloprid products (i.e., K9 Advantix□, Kiltix□) can prevent the transmission of *B. burgdorferi*. Both are topical products applied to spots along or on the back of the animal. They are not for use on cats, as cats are particularly susceptible to pyrethrin poisoning. Fipronil, a phenypyrazole, is the only commercial insecticide of this chemical type and may be used on cats. Formulated pet products are available as a spray or topical spot application (Frontline□, Frontline□ Top Spot□, Frontline□ Plus) for long-term control of fleas and ticks on dogs and cats. Fipronil dissolves in the oils on the skin, spreads over the body, and collects in sebaceous glands and hair follicles for long-term reapplication. It is not affected by bathing or water immersion. Skin irritation may occur. Fleas are killed from 1-3 months, while ticks are killed for about a month. Trizapentadiene or formanidene compounds include one currently used material, amitraz. In livestock, it is used to control ticks, mites, and lice. It is not a skin irritant, is not readily absorbed into tissue, and degrades rapidly in the environment. Amitraz is used in a tick prevention collar for dogs (Preventic□), and one study indicated it could prevent transmission of *B. burgdorferi*. An amitraz product was one of the compounds initially evaluated for the topical treatment of deer to control *I. scapularis*.

Additional sources of information about pesticides

Environmental Protection Agency (EPA) Public Information Center (telephone 202-260-2080), National Center for Environmental Publications and Information (telephone 513-489-8190), EPA booklets or the EPA web site (www.epa.gov).

National Pesticide Information Center (NPIC) (formerly the National Pesticide Telecommunications Network) is a cooperative effort of Oregon State University and the U.S. Environmental Protection Agency (EPA). The toll-free service is staffed 6:30 am – 4:30 pm Pacific time (9:30 a.m. – 7:30 p.m. Eastern time) 7 days week, except holidays (telephone 1-800-858-7378). Information provided by the NPIC includes pesticide information, information of recognizing and managing pesticide poisonings, safety information, health and environmental effects, referrals for investigation of pesticide incidents and emergency treatment information, and cleanup and disposal procedures. Pesticide related fact sheets and other information are available at the web site, a source of factual chemical, health, and environmental information about more than 600 pesticide active ingredients incorporated into over 50,000 different products registered for use in the United States since 1947 (http://npic.orst.edu/). Their address is NPIC, Oregon State University, 33 Weniger Hall, Corvallis, Oregon 97331-6502.

Extension Toxicology Network (EXTOXNET) is a cooperative effort of University of California-Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho. Primary files are maintained and archived at Oregon State University. Pesticide Information Profiles (PIPs) and Toxicology Information Briefs (TIBs) provide information on pesticide trade names, regulatory status, acute and chronic toxicological effects, signs and symptoms of poisoning, ecological effects and environmental fate, physical properties, manufacturer, and references (http://ace.orst.edu/info/extoxnet/).

State pesticide regulatory agencies can provide information on the laws and regulations governing the application of insecticides, certification of pesticide applicators, and which products

are registered for use in the state. Depending upon the state the agency may be associated with the state Department of Agriculture, Consumer Protection, or Environmental Protection.

Biological Control of Ticks

Ticks have relatively few natural enemies, but the use of predators, parasites, and pathogens has been examined for tick control. Tick predation is difficult to document and observations are sporadic. Most arthropod predators are non-specific, opportunistic feeders and probably have little impact on ticks. Anecdotal reports suggested that guinea-fowl or chickens may consume ticks and impact local tick abundance. However, there is no good evidence to support this, and turkey foraging was not found to reduce the local density of adult ticks. A minute parasitic wasp, *Ixodiphagus hookeri*, parasitizes blacklegged ticks in a few geographically isolated tracts in New England with superabundant deer and tick populations. However, my studies indicate that the usefulness of this wasp to control *I. scapularis* is very limited. The wasp disappears at deer and tick densities typical of most mainland areas. Insect parasitic nematodes have been studied as possible biological control agents. Engorged female *I. scapularis* are susceptible to certain types of nematodes, but these nematodes are too sensitive to the colder autumn temperatures when the ticks are present.

The application of insect pathogenic fungi, however, is a promising approach for controlling ticks. Several fungi, such as *Beauveria bassiana* and *Metarhizium anisopliae* have been shown to be pathogenic to *I. scapularis* in the laboratory and field. A perimeter treatment of existing commercial formulations of the fungus *Beauveria bassiana* and *Metarhizium anisopliae* at residential sites has been shown to control *I. scapularis* in small experimental trials. *Metarhizium* is a naturally occurring soil fungus that is considered nonpathogenic to mammals. The fungus infects host insects (and ticks) when conidia (spores) attach to the host cuticle, germinate, penetrate the cuticle and hyphae (filaments) grow. *Metarhizium* also produces insect toxic secondary metabolites. The green muscardine fungus *M. anisopliae* Strain 52 is being developed as a tick control biopesticide by Novozymes Biologicals Inc., Salem, VA. Additional residential trials with this fungus in Connecticut and New Jersey in 2007 provided good control of nymphal *I. scapularis* and a limited launch under the Tick-Ex™ label is anticipated in 2008. A granular product is also under development. This fungus posses minimal risk to non-target organisms and does not harm many beneficial insects such as honey bees, green lacewings, lady beetles, parasitic Hymenoptera or earthworms at rates used. The *Metarhizium* spores, applied like a traditional pesticide, may become an option in future tick management programs and could readily meet organic standards.

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Illustrations top to bottom: Adult of H. hookeri, engorged nymph of I. scapularis showing parasitoid emergence hole, female I. scapularis showing infestation by M. anisopliae (two pictures).

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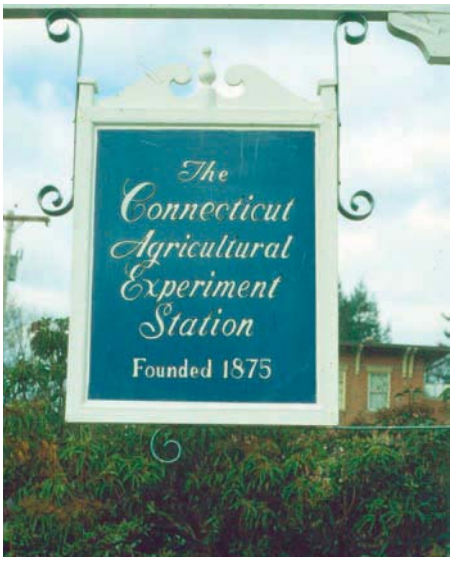
About the Author

Dr. Kirby Stafford is a medical-veterinary entomologist whose research focuses on the ecology and control of the blacklegged tick. He received his B.S. in entomology and M.S. in veterinary entomology from Colorado State University and Kansas State University, respectively, and his Ph.D. in medical/veterinary entomology from Texas A&M University in 1985. After working at Penn State, he joined The Connecticut Agricultural Experiment Station in 1987. Dr. Stafford is currently Vice Director, Chief Entomologist and State Entomologist of The Connecticut Agricultural Experiment Station.



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