Biology and Control of Ticks Infesting Dogs and Cats in North America*

Michael W. Dryden, DVM, PhD
Patricia A. Payne, DVM, PhD

Department of Diagnostic Medicine/Pathobiology
College of Veterinary Medicine
Kansas State University
Manhattan, KS

CLINICAL RELEVANCE

At least 15 different infectious agents and diseases are transmitted or produced by ticks parasitizing dogs and cats in North America. Those infectious agents and diseases are distributed among eight different tick species that commonly infest dogs and cats. All but one of these species are hard ticks with a three-host development cycle in which each motile stage (larva, nymph, and adult) feeds on a different host after molting. Tick species, disease occurrence, and peak activity of each tick life stage can vary dramatically depending on geographic and climatic conditions. Gaining an understanding of tick distribution, tick ecology, and seasonal occurrence of different tick life stages can help with the management of tick infestations and reduce the incidence of tick-transmitted diseases in dogs and cats. Control should be based on an understanding and management of ecologic factors responsible for tick infestations and selection of appropriate acaricides. Occasionally, topical acaricides will appear not to have prevented tick infestations. This lack of control may be real or perceived based on reinfestation rates and/or pet owner expectations of product performance.

Controlling tick infestations is important not only because ticks are nuisance parasites of dogs, cats, and humans but also because they are vectors of a variety of bacterial and protozoal diseases. Prevention and control of tick infestations should begin with an understanding of the basic biology of ticks. Tick infestations may be prevented by decreasing hosts and habitats for juvenile tick life stages and through the judicious use of acaricides to kill larvae, nymphs, and adult ticks. The control of ticks and tick-transmitted diseases is often difficult due to multiple tick species with different life histories, prolonged tick life cycles, high reproductive capacity, numerous wildlife hosts, immature tick life stages in the environment, and large numbers of questing adult ticks.

*Publication of this article is being funded by an educational grant.

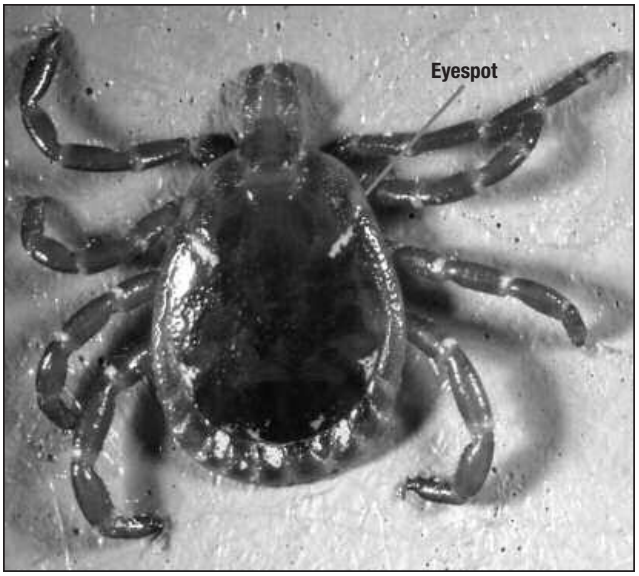

Figure 1. *Male* Amblyomma americanum *(lone star tick). Note the white to yellow lines on the edge of the scutum and one of the two eyespots.*

This article focuses on the characteristics of the various species of ticks, including their life cycles, questing behavior, habitats, preferred hosts, and feeding patterns. It also discusses the diseases ticks can transmit to their hosts. Research on products to control ticks is reviewed, as are measures veterinarians and home owners can take to prevent tick infestation in the first place.

CHARACTERISTICS OF HARD TICKS

Ticks infesting dogs and cats are divided into two primary families, Argasidae (soft ticks) and Ixodidae (hard ticks). The ticks of most importance to dogs and cats and their owners in North America are the Ixodidae. This family of ticks is characterized by a hardened dorsal shield (scutum) and a head (capitulum) that extends in front of the body. Some of these species also have eyespots on the scutum (Figure 1) and posterior indentations called *festoons* (Figure 2) that can be used to aid in identification. The hard ticks commonly found on dogs and cats in North America are all three-host ticks, with each motile stage (larva, nymph, and adult) feeding on a different host after molting.[1,2]

The six-legged larva stage hatches from the egg within days to months, depending on environmental conditions. The larva remains on the ground or on low vegetation while waiting for a host, which for many tick species is usually a small rodent or bird. After feeding on the host for a few days, the engorged larva drops to the ground and molts into an eight-legged nymph. The nymph then finds an appropriate host and feeds for several days to a week. Once the nymph has engorged, it drops to the ground and molts into the eight-legged adult, which then must find a third, and final, host.

Most tick species infesting dogs and cats will exhibit host-seeking behavior only during certain periods of the year when climatic conditions favor development and reproduction. Most ticks infesting dogs and cats use an ambush technique, although *Ixodes* spp may employ both ambush and hunter tactics.[2] Ticks that use the ambush strategy climb onto weeds, grasses, bushes, or other leafy vegetation and wait for passing hosts to brush against the vegetation. When stimulated by the presence of a host, the tick extends its forelegs, which contain a sensory apparatus called the *Haller's organ*; this is referred to as *questing*. The Haller's organ is believed to have gustatory, thermosensory, and mechanosensory functions.[2] When the host brushes against the plant, the tick immediately releases from the vegetation and crawls onto the host. Ticks do not jump onto

hosts or drop out of trees. An animal may encounter one to several thousand ticks as it moves through tick-infested vegetation. Ambushing ticks are usually found just a few centimeters to 1 m off the ground. Ticks that exhibit a hunter strategy run or crawl to attack hosts and are usually associated with animals occupying dens.[2]

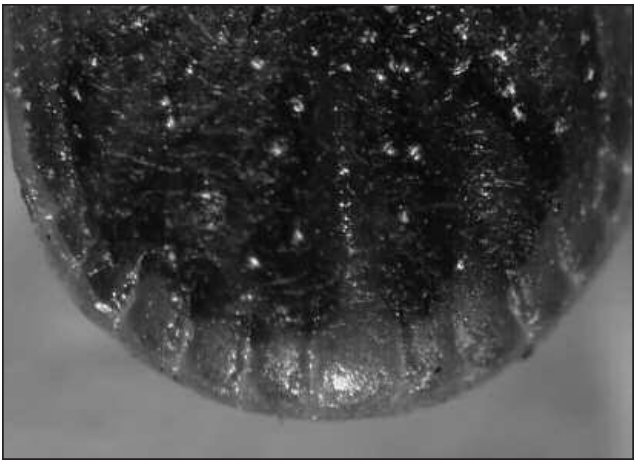

Figure 2. *Festoons on the posterior abdomen of a male* Rhipicephalus sanguineus *(brown dog tick).*

Ticks in the genera *Amblyomma, Dermacentor,* and *Rhipicephalus* mate on the host after feeding. Certain *Ixodes* spp often mate off the host before feeding but may mate while on the host.[3] Once a tick has acquired a potential host, the tick detects appropriate host cues that enable it to determine whether to attach and feed or to drop off and resume seeking another host. Attachment and feeding by ixodid ticks occurs in three phases. In the preparatory phase,[4] ticks may crawl on the host for only a few minutes or for several days in search of a suitable site to attach and feed.[2] Little or no ingestion of blood takes place during the first 24 to 36 hours after attaching to the host.[4] During this period ticks use their chelicerae to cut the epidermis and insert their hypostome, which serves as an anchor and feeding apparatus. Backward-directed spines that prevent easy removal of the attached tick cover the hypostome. After inserting the hypostome, many ticks then reinforce their attachment by secreting a cement-like substance from their salivary glands. This material hardens around the chelicerae and the bite wound.[2,5] Once the feeding site is established, the tick begins the second, or slow-feeding, phase. In females, larvae, and nymphs, this occurs during the first 7 or more days on the host.[4,5] Immature stages and adult ixodid female ticks each take a single continuous blood meal. Most male ticks feed sparingly, except for the nonfeeding males of some species of *Ixodes.*[2,3]

An animal may encounter one to several thousand ticks as it moves through tick-infested vegetation.

During the slow-feeding phase, the weight of the female tick may increase 10-fold; the female tick expands and actually grows new cuticle to accommodate the massive blood meal. The slow-feeding phase is followed by the rapid-feeding phase, which occurs 12 to 36 hours before detachment. During this phase, the size of the mated female tick may increase to 100 times her unfed body weight.[4,5] The final engorged weight of a female tick is actually less

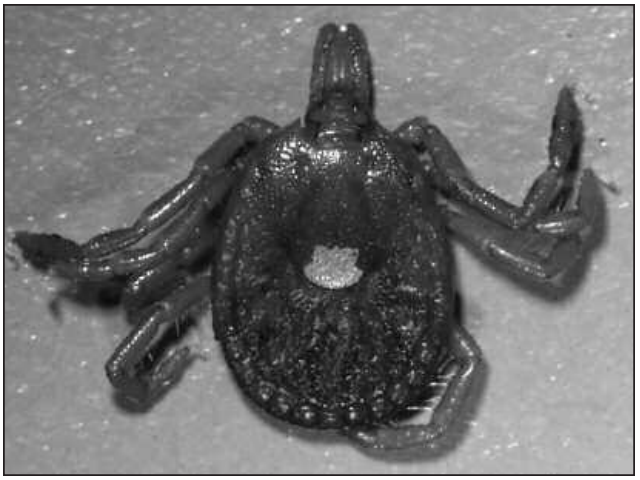

Figure 3. *Female* Amblyomma americanum *(lone star tick). Note the characteristic white spot on the dorsal shield of this tick. Compare with the male of the species (Figure 1).*

than the total amount of blood consumed.[5] A considerable amount of the fluid consumed by the tick is excreted back into the host via the salivary glands.

Typical attachment and engorgement times range from as few as 2 days for larvae to up to 6 to 14 days for females.[5,6] Once the female has completed feeding, she drops off and deposits her eggs in the environment. Female hard ticks then die after taking days or weeks to deposit an egg mass typically numbering in the thousands.[2]

Research has identified and characterized a variety of pharmacologically active compounds in tick salivary gland secretions in addition to the cement-like substance used to seal the attachment site. These salivary components aid in blood feeding, facilitate evasion of the host's immune system, and can aid pathogen transfer. Not all ticks contain the same complexity of salivary compounds, but the range of pharmacologically active compounds is impressive. Compounds with antiplatelet, vasodilatory, anticoagulant, immunosuppressive, and antihistamine-like properties have been identified.[2]

TICK SPECIES INFESTING DOGS AND CATS

The tick species that most commonly infest dogs in North America are *Amblyomma americanum* (lone star tick), *Amblyomma maculatum* (Gulf Coast tick), *Dermacentor variabilis* (American dog tick), *Dermacentor andersoni* (Rocky Mountain wood tick), *Ixodes pacificus* (western black-legged tick), *Ixodes scapularis* (black-legged tick), and *Rhipicephalus sanguineus* (brown dog tick) (Table 1). Other tick species may occasionally be recovered from dogs, including the soft tick *Otobius megnini* (spinose ear tick). While perhaps not as commonly infested as dogs, cats can be parasitized by ticks, including *A. americanum, D. variabilis,* and *I. scapularis.*

Amblyomma spp

A. americanum is named for the characteristic and easily recognizable single white spot on the dorsal shield of the female (Figure 3). The males also are ornate but have several white to yellow lines on the edge of their scutum instead of the single white spot (Figure 1). *A. americanum* is also characterized by long palpi, a long hypostome, eyespots, and festoons.

The range of *A. americanum* appears to be increasing across the southern, midwestern, and eastern states. Its geographic range, once considered to be primarily in the south with southern New Jersey being its most northern edge, has expanded.[7] Focal populations now occur in many northern states, including Connecticut, Maine, Massachusetts, Michigan, New Jersey, and New York.[7–11] Survey data from New York State demonstrate the geographic expansion of this species. The first es-

TABLE 1. Hosts and Disease Transmission of Common Hard Ticks Infesting Dogs and Cats in North America

Tick Species	*Hosts*	*Infectious Agents and Diseases Transmitted or Produced*
Dermacentor variabilis	**Larvae:** Voles, mice **Nymphs:** Cats, dogs, opossums, rabbits, raccoons **Adults:** Cats, coyotes, dogs, cattle, horses, raccoons, other large mammals (including humans)	*Cytauxzoon felis*, *Francisella tularensis*, *Rickettsia rickettsii*, tick paralysis
Dermacentor andersoni	**Larvae:** Voles, mice **Nymphs:** Cats, dogs, opossums, rabbits, raccoons **Adults:** Bears, coyotes, dogs, cattle, deer, horses, sheep, humans	*R. rickettsii*, *F. tularensis*, tick paralysis
Amblyomma americanum	**Larvae and Nymphs:** Bobwhite quail, turkey, wrens, numerous mammals such as cats, coyotes, white-tailed deer, dogs, red fox, rabbits, squirrels, raccoons, humans **Adults:** Cats, cattle, coyotes, white-tailed deer, dogs, horses, raccoons, sheep, humans	*Borrelia lonestari*, *Ehrlichia chaffeensis*, *Ehrlichia ewingii*, *F. tularensis*
Amblyomma maculatum	**Larvae:** Small rodents, ground-dwelling birds **Nymphs:** Small rodents, ground-dwelling birds, dogs **Adults:** Horses, cattle, pigs, goats, dogs, bears, birds, bobcats, coyotes, rabbits, rodents, deer, humans	*Hepatozoon americanum*
Rhipicephalus sanguineus	**Larvae:** Dogs, rodents **Nymphs:** Dogs, rabbits **Adults:** Dogs	*Anaplasma platys*, *Babesia canis*, *Babesia gibsoni*, *Ehrlichia canis*
Ixodes scapularis	**Larvae:** Various rodents such as white-footed mice and shrews, other small mammals, birds, lizards **Nymphs:** Birds, cats, chipmunks, mice, opossums, raccoons, various rodents, skunks, shrews, squirrels, humans **Adults:** Bobcats, cattle, coyotes, dogs, foxes, white-tailed deer, opossums, raccoons, other wildlife	*Anaplasma phagocytophilum*, *Babesia microti*, *Borrelia burgdorferi*, tick paralysis
Ixodes pacificus	**Larvae and Nymphs:** Lizards, small rodents, birds **Adults:** Large mammals (commonly deer), canids, horses, humans	*A. phagocytophilum*, *E. chaffeensis* (?), *B. burgdorferi*

Figure 4. *Female* Dermacentor variabilis *(American dog tick). Note the white markings covering the scutum, festoons on the posterior abdomen, eyespots, and short palpi.*

tablished populations of *A. americanum* in New York were reported in Long Island in 1972.[8] Tick specimens collected in 1988 indicated *A. americanum* was present in three of New York's 62 counties.[10] By 1996, specimens had been collected from 46 counties.[10]

Several factors have contributed to the increased range of *A. americanum*, including its increased habitat and wide host range, which includes deer, small mammals, birds, and humans.[7] This tick is found most commonly in woodland habitats with dense underbrush. Reforestation in urban and rural areas has provided increased areas of habitat for survival of these ticks.[7] The white-tailed deer is considered a preferred host for *A. americanum*, and all life stages will successfully feed on white-tailed deer.[7] The wild turkey is another host that uses similar habitats and is an excellent host for larvae and nymphs.[7,12,13] Areas with high white-tailed deer and wild turkey populations can have remarkably large populations of *A. americanum.* This aggressive tick can parasitize many other animals. Immature stages can be found on a variety of birds, including bobwhite quail, turkeys, and wrens, as well as numerous mammals, including red fox, rabbits, squirrels, raccoons, dogs, cats, coyotes, deer, and humans.[2,7,13]

Nymphs are found from March through September, and larvae are frequently encountered from late summer to fall.[13] Larvae and nymphs engorge over a period of 3 to 9 days.[7] Adult ticks can also feed on a variety of hosts, including cattle, coyotes, horses, sheep, raccoons, dogs, cats, deer, and humans.[2,7,13] Adults are often encountered from late February through early June and can engorge within 9 days but may take longer.[7,13] It is important to note that peak seasonal activity can vary widely by geographic region.

Similar to other ixodid ticks, unfed adult *A. americanum* may survive for more than 400 days if hosts are unavailable. Fully engorged females can deposit up to 8,000 eggs. Similar to what is seen in other three-host ticks in temperate climates, the *A. americanum* life cycle often takes 2 years to complete; however, it can be completed within 1 year in warmer coastal climates.[6]

While *A. americanum* is considered a major nuisance parasite, it is also a vector of *Ehrlichia chaffeensis* (human monocytic ehrlichiosis) and

Ehrlichia ewingii.[7] *A. americanum* also transmits *Borrelia lonestari,* which causes a Lyme disease–like infection called southern tick–associated rash illness.[1,14,15] It has also been implicated in the transmission of *Francisella tularensis* (tularemia).[1,16] While not as common, *A. maculatum* will infest dogs and carries *Hepatozoon americanum*, the etiologic agent of American canine hepatozoonosis. Transmission of this disease is unique in that dogs need to ingest the engorged adult female tick to become infected.[17] *A. maculatum* has also been documented to cause tick paralysis.[18]

***Dermacentor* spp**

D. variabilis is an ornate Ixodidae. The scutum, which covers the entire dorsal surface of the male and the anterior third of the unengorged female, is covered with white markings. It also has festoons on the posterior abdomen, eyespots, and short palpi (Figure 4).

Dermacentor spp ticks were historically one of the most widespread and common ticks infesting dogs and cats in North America. *D. variabilis* are found in the eastern United States from Florida to southern New England and from the Atlantic coast to the eastern sections of the plains states.[19] Populations also occur along the Pacific coast. This tick is commonly found on small mammals in grassy meadows and young forests as well as along roadways and trails.[19]

In the typical development cycle of *D. variabilis,* the larva remains on the ground or low vegetation before finding a suitable small mammal host such as various voles and mice. In the southern United States, some of the larvae hatching from eggs laid during the early summer will begin questing in late summer.[19] However, most larvae will enter diapause in the fall and will not seek hosts until early the following year.[19] In the southern United States, larvae can begin questing as early as February and will continue this activity for 2 to 3 months.[19] As previously noted, seasonal tick activity varies widely by geographic region. In the northern areas of the United States and Canada, peak larvae activity may occur until late May or June. Once attached, larvae can take 3 to 12 days to engorge (average: 4 days).[19]

The molt from larva to nymph can occur within 32 days during the spring and early summer as soil temperatures warm.[19] Nymphal questing activity therefore quickly follows larval activity. Nymphs can be found feeding on cats, dogs, opossums, rabbits, raccoons, and other medium- to small-sized mammals. Nymphs can take 3 to 11 days to engorge (average: 6 days).[19–21]

Dermacentor *spp ticks were historically one of the most widespread and common ticks infesting dogs and cats in North America.*

Once molting is complete, the unfed adult may live more than 2 years without feeding if hosts are not available.[19] The prolonged off-host survival increases the chances ticks will find a suitable host on which to feed. Adults may seek hosts that same summer after molting but often overwinter and begin questing the following spring.[19] Hosts for adult *D. variabilis* include cats, dogs, cattle, horses, and other large mammals, including humans. Male *D. variabilis* feed sparingly and do not engorge. Females engorge markedly on blood and often increase in size more than 100-fold. Fully engorged female *D.*

Figure 5. *Female* Rhipicephalus sanguineus *(brown dog tick). This tick species does not have the white dorsal markings seen on* D. variabilis *and* A. americanum. *Note the hexagonal shape of the basis capitulum and the presence of eyes and festoons.*

variabilis drop from their hosts within 4 to 10 days.[20] Once off the host, engorged *D. variabilis* females will deposit between 4,000 and 6,500 eggs.[20] The entire life cycle can be completed in as little as 3 months in the southern United States but may take up to 2 years in more northern climates.[19]

D. andersoni are found in the Rocky Mountain states and southwestern Canada. The life cycle of this three-host tick often takes 2 to 3 years. The larvae and nymphs of *D. andersoni* attack the same sort of small mammals as *D. variabilis* and feed for 3 to 5 days.[22] Similar to *D. variabilis*, adult *D. andersoni* obtain their blood meals from large mammals, including horses, cattle, dogs, sheep, deer, bears, coyotes, and humans.[20] This tick can also survive for prolonged periods without feeding, with larvae and nymphs surviving for more than a year without a host and adults for 2 years or more.[20,22] It is similar in appearance to *D. variabilis*, but adults of *D. andersoni* in general have paler coloring and larger goblets on the spiracular plates.

Dermacentor spp ticks are important vectors of disease. *D. variabilis* can transmit cytauxzoonosis, an often fatal infection in cats caused by the blood parasite *Cytauxzoon felis*.[2,21] Both *D. variabilis* and *D. andersoni* are the primary vectors of Rocky Mountain spotted fever (caused by *Rickettsia rickettsii*) in dogs and humans.[2] Both species are also most commonly associated with tick paralysis in North America[1,18] and can transmit *F. tularensis*.[16]

Rhipicephalus sanguineus

Rhipicephalus spp (Figure 5) are reddish brown in color and are not ornate, lacking the white dorsal markings seen on *D. variabilis* and *A. americanum*. The basis capitulum is hexagonal, and eyes and festoons are present.

R. sanguineus is the only species of tick that infests human dwellings and kennels in North America. It is a three-host tick but is unique because all feeding life stages can infest dogs. It appears to be intolerant to cold and persists only in temperate regions within kennels and homes. Infestations can occur in heated buildings any time of the year. These ticks often crawl up walls in homes and kennels[22] and can be found in false ceilings.

Up to 4,000 eggs are deposited in cracks and crevices along floors, behind dog cages, or even in ceilings.[20,22] In kennels, eggs can hatch within 20 to 30 days; larvae rapidly find and feed on puppies or mature dogs. While preferring to feed on dogs, larvae will also feed on rodents

and nymphs on rabbits.[2] Larvae engorge over a period of 2 to 4 days, while nymphs feed for 4 to 9 days.[22] Larvae and nymphs are commonly distributed along the back and neck of dogs. Adult ticks are found most commonly in the ears or between the toes of dogs and feed for 6 to 9 days.[20,22] The life cycle may be completed in as little as 3 months, which allows for a rapid increase in tick populations. Infestations of homes or kennels can be extremely difficult to eradicate. *R. sanguineus* is the vector of *Ehrlichia canis* (canine monocytic ehrlichiosis) and *Babesia canis* (canine babesiosis).[2] It also may be a vector of *Anaplasma platys*[23] (formerly *Ehrlichia platys*) and *Babesia gibsoni*.[24]

Figure 6. *Female* Ixodes scapularis *(black-legged tick). Note the two-tone appearance. The inornate dorsal shield covers the anterior third of the body but leaves the posterior area exposed.*

***Ixodes* spp**

I. scapularis, also referred to as the deer tick or Lyme disease tick, is an inornate tick without eyes or festoons. Larvae are small, about 0.5 mm long, flat, six-legged, and nearly translucent, making them extremely difficult to see.[25] Nymphs are approximately 1 mm long and darker in color. Adults also are small, with unfed males about 2 mm long and unfed females about 2.5 mm long.[25] Males appear dark brown, almost black, since the inornate dorsal shield covers the entire dorsal surface. Females appear two-toned, with the inornate dorsal shield covering the anterior third of the body and leaving the orange-brown posterior area of the body exposed (Figure 6).

I. scapularis is widely distributed in the eastern and central United States and is found in at least 35 states.[26] The area of distribution runs from Maine south to Florida, west into central Texas, and then north to Minnesota. Similar to *A. americanum,* the distribution of *I. scapularis* is linked to the distribution and abundance of the white-tailed deer.[25,27]

While seasonal activity can vary by geographic region, larval activity is generally highest in August and September, when larvae attach and feed on a wide variety of small mammals, birds, and lizards.[27] The white-footed mouse is of particular importance in the tick life cycle and disease transmission because it serves as a good host for larval *I. scapularis* and is a major reservoir of *Borrelia burgdorferi*.[27–29]

The immature ticks typically engorge for 2 to 4 days before dropping off to molt in moist protected areas, such as under leaf litter in forested habitats.[30] Larvae overwinter and then

Figure 7. *Ventral view of an engorged larva of* Otobius megnini *(spinose ear tick); note the bulbous body and small legs.*

molt into nymphs in the spring. Nymphs will feed for 3 to 4 days on a variety of hosts, including mice, squirrels, chipmunks, raccoons, opossums, shrews, cats, and humans.[25–28] Nymphs occur primarily from May through July in northern regions and January through September in the southern United States.[25,30] Similar to larvae, engorged nymphs detach and drop to the forest floor, where they molt into the adult stage.

Adults occur most commonly from October through December, with those not finding a host questing again the next spring, typically from March to May.[27] Adults feed for 5 to 7 days primarily on white-tailed deer and occasionally on cattle, coyotes, dogs, opossums, raccoons, and other wildlife.[25,29]

I. scapularis is the vector of *B. burgdorferi* (Lyme disease) in the central, upper midwest, and northeast United States. It is also the vector of *Anaplasma phagocytophilum* (human granulocytic ehrlichiosis) and *Babesia microti* (human babesiosis).[2] *I. scapularis* may also cause tick paralysis.[18]

Transmission of *B. burgdorferi* differs between the western and northeastern United States. *I. pacificus* is the vector of *B. burgdorferi* to humans and dogs in the western part of the country, whereas *Ixodes neotomae* can serve as the vector in parts of the Rocky Mountains.[29] *I. pacificus* is not directly involved in maintaining the natural disease cycle. Immature stages of *I. pacificus* commonly feed on the western fence lizard, which is an incompetent reservoir for *Borrelia.*[31] *Ixodes spinipalpis* is involved in maintaining the natural cycle in the west and parasitizes the dusky-footed wood rat and kangaroo rat, which are the rodent reservoirs of the bacteria.[32,33] However, larvae or nymphs of *I. pacificus* can acquire *B. burgdorferi* when they feed on infected rodents. The nymphs and adults that have acquired the *Borrelia* through transstadial transmission then transmit the bacteria to dogs, other domestic animals, and humans.[34]

Transmission of *B. burgdorferi* in the southeastern United States also differs from the pattern seen in the northeast, which may account for the extremely low level of disease in the southeast.[35] In the southeast, *Ixodes affinis* and *Ixodes minor,* which rarely bite humans, appear to maintain the enzootic cycle of *B. burgdorferi* in the cotton mouse, hispid cotton rat, and eastern woodrat.[35] *Borrelia* infection rates were considerably higher in *I. affinis* and *I. minor* than in *I. scapularis.*[35]

Soft Ticks

O. megnini is the only soft tick that commonly parasitizes dogs in North America.[36] Soft ticks have no dorsal shield, and in their adult stage, the capitulum is positioned under the body and does not extend anterior to the body when the tick is viewed dorsally. The mouthparts do project anterior in the larval and nymph stages. *O. megnini* is unusual in that only the larvae and nymphs are parasitic. Larvae, which look like small shriveled grapes (Figure 7), infest the ears of livestock and occasionally dogs and cats.[22] Larvae feed for 5 to 10 days before molting into the nymph stage on the host.[22] There are two nymphal stages, and both have a spiny cuticle from which the tick's name is derived. After molting, nymphs reattach to the ear, suck blood, and remain in the ear for several weeks or months.[36] Engorged nymphs drop from the host and crawl into cracks and crevices, under stones, or under the bark of trees, where they develop into adults.[36] Adults do not feed, and mating occurs in the environment. Eggs are laid over a period of a few weeks to several months, and up to 1,500 eggs are deposited into the environment.[36]

TICK CONTROL ON DOGS AND CATS

If a dog or cat has only a few ticks, they can be removed manually. The tick should be grasped as close to the skin as possible with fine forceps or tweezers. The tick is then extracted straight out using slow, steady pressure. The tick should not be crushed, twisted, or jerked out of the skin; such actions may cause the head to become detached and left in the skin, which may lead to infection or granuloma formation.[37] However, the rate of occurrence of infections or granulomas in dogs or cats following incorrect tick removal is unknown.

Regular application of acaricides is often necessary to protect dogs or cats from ticks and the diseases they transmit. Several studies evaluating the efficacy of various acaricides against ticks infesting dogs and were recently summarized by Kidd and Breitschwerdt.[38] Differences in study design make comparison of the results difficult. The study design differences include the time after infestation or treatment in which live–dead assessments were conducted, tick species used, laboratory versus field study, size or hair coat density of the dogs, and unknown acaricide susceptibility of tick isolate.

Three topically administered acaricides appear to have the greatest activity against ticks: amitraz (impregnated collar), fipronil (spray and spot-on formulations), and permethrin (spray and spot-on formulations).[39–43] Published data also indicate that selamectin kills *R. sanguineus* and *D. variabilis* on dogs,[44] but the slower speed of kill of selamectin may not be clinically acceptable in heavy tick infestations. Amitraz, fipronil, and permethrin spot-ons can be used safely on dogs, but only fipronil is approved for use on cats. Amitraz, fipronil, and permethrin may help prevent tick attachment and cause tick death within 24 to 48 hours.[39,45] Certain permethrin formulations may also produce repellent-like activity.[46]

Rapid tick kill or prevention of attachment and feeding is important in the prevention of tick-transmitted disease. A few studies have been conducted, although none using dogs, to determine the time from tick attachment until transmission of various pathogens. Results varied depending on the organism, host, tick species, numbers of ticks used, and other factors.[38] While it is generally accepted that killing ticks within 24 to 48 hours will prevent disease transmission, this may not always be accurate. However, it is true that following host acquisition, some time is needed for tick attachment, feeding, and pathogen activation and then excretion. If ticks can be repelled, prevented from attaching, or killed outright during this period, disease trans-

mission may be prevented. More research is needed to determine the exact transmission times of the various pathogens to dogs and cats.

Only a few studies have evaluated the performance of various acaricides in the prevention of tick-transmitted diseases.[47–49] When dogs were infested with adult *I. scapularis* containing *B. burgdorferi* 7 days after placement of amitraz-impregnated collars, none of the dogs seroconverted to *B. burgdorferi*.[47] Fipronil spray prevented transmission of *B. burgdorferi* when dogs were exposed to adult *I. scapularis* 7 and 28 days after treatment.[48] A permethrin–imidacloprid combination spot-on prevented seroconversion to *B. burgdorferi* when dogs were exposed to infected adult *I. scapularis* ticks 7 days after treatment.[49]

To date only one study has been published investigating the efficacy of an acaricide in preventing *R. sanguineus* from transmitting *E. canis* to dogs.[50] A year-long prospective study in Africa was conducted to evaluate the ability of fipronil spot-on to prevent transmission of *E. canis*. Two groups of French army dogs in Djibouti and Dakar were used in the study. Control dogs were native pet and police dogs. The area in which the study was conducted was highly endemic for both the tick vector (*R. sanguineus*) and the pathogen (*E. canis*), demonstrated by seroprevalence in untreated control groups ranging from 21.7% to 100%. Dogs receiving monthly applications of fipronil spot-on had seroprevalence rates of 2.7% in Djibouti and 5.5% in Dakar.[50]

While the above studies demonstrate considerable efficacy against ticks and prevention of disease transmission, pet owners should be advised that a particular acaricide might not completely prevent disease transmission. Too many variables exist once a particular product has been dispensed. Bathing and swimming can decrease insecticide levels of all topically applied products.[51–55] Several studies have been conducted to evaluate the effects of bathing or water exposure on acaricide performance.[51–55] These studies often produce differing results depending on the duration of water exposure, types of shampoos used, and frequency and timing of shampoo application after treatments. In addition, results of the various studies may be difficult to apply directly to clinical situations because of the previously mentioned variables as well as differences in hair coat length and density and the duration of shampooing and rinsing.

Educating pet owners about reasonable expectations for product performance can prevent client frustration.

In addition, potential differences in susceptibility among various tick species and genetic variability within a particular species indicate that none of the currently available residual tick products is 100% effective.[39–44] Even with the extended intervals allowed between applications with the new tick control products, infrequent product application commonly occurs as a result of poor pet owner compliance with the label or with veterinarian's instructions. While the first dose of an acaricide product is likely applied in a veterinary clinic, pet owners administer subsequent doses or attach collars themselves. It must be remembered that veterinarians have little control over what a client may or may not do in the timing or diligence of product application.

Occasionally, topical acaricides will not appear to control the problem even when ap-

plied according to label recommendations. This lack of control may be real or perceived based on reinfestation rates and/or pet owner expectations of product performance. Pet owner perceptions of the success of tick control are often more adamant than those for flea control. This is primarily related to visual recognition of engorging ticks. If a dog treated with a flea product 3 weeks previously enters a flea-infested environment and the product's efficacy is still 95%, often only an astute pet owner will notice a few surviving fleas. However, the same is often not true when the dog walks through a tick-infested area. One or two surviving ticks engorging on a dog are readily noticeable to many pet owners, even though the product may be performing as expected—that is, killing 95% of the ticks encountered by the dog. In such situations, the pet owner often considers the product a failure. Educating pet owners about reasonable expectations for product performance can prevent client frustration.

If additional measures are deemed necessary, clients should be informed and notations made in a pet's record before extra-label use of acaricides is recommended. If additional control measures are needed, products may be combined, frequency of application may be increased, or an attempt can be made to eliminate ticks in the environment.

ELIMINATING TICKS IN THE ENVIRONMENT

If possible, start by destroying tick and alternative host habitats. Cutting or removing grass, weeds, and brush piles between fences and along property lines and buildings will increase tick desiccation and decrease protective harborage for wild animals that can also serve as hosts for ticks. Controlled burning of forest canopy or grasslands has produced at least short-term reduction in populations of *A. americanum* and *I. scapularis*[56,57] but is not practical or acceptable in many situations.

If *R. sanguineus* are encountered in buildings, acaricides such as cyfluthrin and permethrin should be sprayed into cracks and crevices, behind and under cages, and along the boards in the ceiling. Effective compounds for outdoor premises tick control include carbaryl, cyfluthrin, permethrin, and s-fenvalerate.[58–60] Outdoor applications of acaricides can have a significant effect on tick populations. Liquid cyfluthrin applied in New Jersey during the spring at 0.41 kg/hectare was effective in reducing populations of nymphal *I. scapularis* and *A. americanum* for up to 1 year.[58] The freshly applied acaricide should be allowed to dry before animals or humans are permitted back onto the premises.

Regulatory approval of acaricides can vary from year to year and among different states. Before having pet owners apply acaricides onto the premises, it is recommended to contact a local or state entomology extension service. However, it is often best to have a licensed pest management specialist (exterminator) apply indoor and outdoor premises acaricides.

CONCLUSION

Ticks produce disease by consumption of blood, injection of salivary proteins, and transmission of infectious agents. Reactive treatments to eliminate existing infestations are frequently too late to prevent disease and distress. Many dogs and cats would benefit by being placed on preventive tick control products throughout the year.

Even with application of tick control products, however, continued reinfestation is a common problem for many pets. It should be remembered that ticks typically engorge and drop from animals within 7 to 14 days. Therefore, if ticks are observed on a dog 2 to 3 weeks after acaricide application, the fact that these

are likely not the same ticks observed on the dog during the initial visit needs to be explained to the pet owner. If ticks continue to be a problem, restricting a pet's access to tick-infested environments, such as tall grass, weeds, and forested areas, may be necessary.

Since substantial geographic differences occur in tick prevalence and seasonality, prevention programs should be tailored accordingly.

REFERENCES

1. Kettle DS: Ixodida–Ixodidae (hard ticks), in Mullen G, Durden L (eds): *Medical and Veterinary Entomology.* Wallingford, UK, CAB International, 1990, pp 423–448.
2. Sonenshine DE, Lane RS, Nicholson WL: Ticks (Ixodida), in Mullen G, Durden L (eds): *Medical and Veterinary Entomology.* Amsterdam, Academic Press Elsevier Science, 2002, pp 517–558.
3. Kiszewski AE, Matuschka FR, Spielman A: Mating strategies and spermiogenesis in ixodid ticks. *Annu Rev Entomol* 46:167–182, 2001.
4. Sonenshine DE: The midgut, in *Biology of Ticks,* vol 1. New York, Oxford University Press, 1991, pp 159–176.
5. Kaufman WR: Tick-host interaction: A synthesis of current concepts. *Parasitol Today* 5:47–56, 1989.
6. Teel PD: Ticks, in Williams RE, Hall RD, Broce AB, Scholl PJ (ed): *Livestock Entomology.* New York, John Wiley & Sons, 1985, pp 129–150.
7. Childs JE, Paddock CD: The ascendancy of *Amblyomma americanum* as a vector of pathogens affecting humans in the United States. *Annu Rev Entomol* 48:307–337, 2003.
8. Good NE: Ticks of Eastern Long Island: Notes on host relations and seasonal distribution. *Ann Entomol Soc Am* 66:240–243, 1973.
9. Keirans JE, Lacombe EH: First records of *Amblyomma americanum*, *Ixodes* (Ixodes) *dentatus*, and *Ixodes* (Ceratixodes) *uriae* (Acari: Ixodidae) from Maine. *J Parasitol* 84:629–631, 1998.
10. Means RG, White DJ: New distribution records of *Amblyomma americanum* (L.) (Acari: Ixodidae) in New York State. *J Vector Ecol* 22:133–145.
11. Merten HA, Durden LA: A state-by-state survey of ticks recorded from humans in the United States. *J Vector Ecol* 25:102–113, 2000.
12. Mock DE, Applegate RD, Fox LB: Preliminary survey of ticks (Acari: Ixodidae) parasitizing wild turkeys (Aves: Phasianidae) in Eastern Kansas. *J Med Entomol* 38:118–121, 2001.
13. Kollars TM, Oliver JH, Durden LA, Kollars PG: Host associations and seasonal activity of *Amblyomma americanum* (Acari: Ixodidae) in Missouri. *J Parasitol* 86:1156–1159, 2000.
14. Bacon RM, Gilmore Jr RD, Quintana M, et al: DNA evidence of *Borrelia lonestari* in *Amblyomma americanum* (Acari: Ixodidae) in southeast Missouri. *J Med Entomol* 40:590–592, 2003.
15. Faulk-Stegall T, Clark DC, Wright SM: Detection of *Borrelia lonestari* in *Amblyomma americanum* (Acari: Ixodidae) from Tennessee. *J Med Entomol* 40:100–102, 2003.
16. Sonenshine DE: Tick-borne bacterial diseases, in *Biology of Ticks*, vol 2. New York, Oxford University Press, 1993, pp 255–319.
17. Ewing SA, Panciera RJ: American canine hepatozoonosis. *Clin Microbiol Rev* 16:688–697, 2003.
18. Sonenshine DE: Tick paralysis and other tick-borne toxicosis, in *Biology of Ticks,* vol 2. New York, Oxford University Press, 1993, pp 320–330.
19. Sonenshine DE: Ecology of non-nidocolous ticks, in *Biology of Ticks*, vol 2. New York, Oxford University Press, 1993, pp 3–64.
20. Harwood RF, James MT: Ticks and tick-associated diseases, in *Entomology in Human and Animal Health,* ed 7. New York, Macmillian Publishing, 1979, pp 371–416.
21. Blouin EF, Kocan AA, Kocan KM, Hair J: Evidence of a limited schizogonous cycle for *Cytauxzoon felis* in bobcats following exposure to infected ticks. *J Wildl Dis* 23:499–501, 1987.
22. Soulsby EJL: Arthropods, in *Helminths, Arthropods and Protozoa of Domestic Animals,* ed 7. Philadelphia, Lea & Febiger, 1982, pp 357–504.
23. Sanogo YO, Davoust B, Inokuma H, et al: First evidence of *Anaplasma platys* in *Rhipicephalus sanguineus* (Acari: Ixodida) collected from dogs in Africa. *Onderstepoort J Vet Res* 70(3):205–12, 2003.
24. Higuchi S, Kuroda H, Hoshi H, et al: Development of *Babesia gibsoni* in the midgut of the nymphal stage of the tick, *Rhipicephalus sanguineus. J Vet Med Sci* 61(6):697–699, 1999.
25. Keirans JE, Hutcheson HJ, Durden LA, Klompen JS: *Ixodes* (Ixodes) *scapularis* (Acari: Ixodidae): Redescription of all active stages, distribution, hosts, geographical variation, and medical and veterinary importance. *J Med Entomol* 33:297–318, 1996.
26. Dennis DT, Nekomoto TS, Victor JC, et al: Reported distribution of *Ixodes scapularis* and *Ixodes pacificus* (Acari: Ixodidae) in the United States. *J Med Entomol* 35(5):629–638, 1998.
27. Lane RS, Piesman J, Burgdorfer W: Lyme borreliosis:

Relation of its causative agent to its vectors and hosts in North America and Europe. *Ann Rev Entomol* 36: 587–609, 1991.
28. Anderson JF, Magnarelli LA: Vertebrate host relationships and distribution of ixodid ticks (Acari: Ixodidae) in Connecticut, USA. *J Med Entomol* 17:314–323, 1980.
29. Fritz CL, Kjemtrup AM: Lyme borreliosis. *JAVMA* 223:1261–1270, 2003.
30. Wilson ML, Spielman A: Seasonal activity of immature *Ixodes dammini* (Acari: Ixodidae). *J Med Entomol* 22:408–414, 1985.
31. Casher L, Lane R, Barrett R, Eisen L: Relative importance of lizards and mammals as hosts for ixodid ticks in northern California. *Exp Appl Acarol* 26:127–43, 2002.
32. Brown RN, Lane RS: Lyme disease in California: A novel enzootic transmission cycle of *Borrelia burgdorferi. Science* 256:1439–1442, 1992.
33. Lanes RS, Brown RN: Wood rats and kangaroo rats: Potential reservoirs of the Lyme disease spirochete in California. *J Med Entomol* 28:299–302. 1991.
34. Lane RS, Lavoie PE: Lyme borreliosis in California. Acarological, clinical, and epidemiological studies. *Ann NY Acad Sci* 539:192–203, 1988.
35. Oliver Jr JH, Lin T, Gao L, et al: An enzootic transmission cycle of Lyme borreliosis spirochetes in the southeastern United States. *Proc Natl Acad Sci USA* 100(20):1642–1645, 2003.
36. Kettle DS: Ixodidae-argadisae (soft ticks), in *Medical and Veterinary Entomology*. Wallingford UK, CAB International, 1990, pp 406–422.
37. Habif TP: Infestations and bites, in Habif TP (ed): *Clinical Dermatology*, ed 3. St. Louis, Mosby, 1996, pp 463–475.
38. Kidd L, Breitschwerdt EB: Transmission times and prevention of tick-borne diseases in dogs. *Compend Contin Educ Pract Vet* 25:742–751, 2003.
39. Estrada-Pena A, Ascher F: Comparison of an amitraz-impregnated collar with topical administration of fipronil for prevention of experimental and natural infestations by the brown dog tick (*Rhipicephalus sanguineus*). *JAVMA* 214:1799–803, 1999.
40. Hunter JS, Tanner P, Keister M, Jeannin P: Residual efficacy of Frontline® Top Spot™ for the control of fleas and ticks in the dog. *Proc 42nd Annu Meet Am Assoc Vet Parasitol*:97, 1997.
41. Hunter JS: Efficacy of Frontline spray and Frontline Topspot. *Compend Contin Educ Pact Vet* 19(suppl): 15–16, 1997.
42. Endris RG, Hair JA, Anderson G, et al: Efficacy of two 65% permethrin formulations against induced infestations of *Ctenocephalides felis* (Insecta:Siphonaptera) and *Amblyomma americanum* (Acari: Ixodidae) on beagles. *Vet Ther* 4:47–55, 2003.
43. Cruthers L, Slone R, Arther RG: K9 Advantix (imidacloprid plus permethrin) for controlling ticks and mosquitoes on dogs. *Compend Contin Educ Pact Vet* 25(suppl 5A):15–18, 2003.
44. Jernigan AD, McTier TL, Chieffo C, et al: Efficacy of selamectin against experimentally induced tick (*Rhipicephalus sanguineus* and *Dermacentor variabilis*) infestations on dogs. *Vet Parasitol* 91:359–375, 2000.
45. Epe C, Coati N, Stanneck D: Efficacy of the compound preparation imidacloprid 10%/permethrin 50% spot-on against ticks (*I. ricinus, R. sanguineus*) and fleas (*Ct. felis*) on dogs. *Parasitol Res* 90(suppl 3): S122–S124, 2003.
46. Young DR, Arther RG, Davis WL: Evaluation of K9 Advantix vs. Frontline Plus topical treatments to repel brown dog ticks (*Rhipicephalus sanguineus*) on dogs. *Parasitol Res* 90(suppl 3):S116–S118, 2003.
47. Elfassy OJ, Goodman FW, Levy SA, Carter LL: Efficacy of an amitraz-impregnated collar in preventing transmission of *Borrelia burgdorferi* by adult *Ixodes scapularis* to dogs. *JAVMA* 219:185–189, 2001.
48. Hunter JS, McCall JW, Alva R, et al: The use of frontline spray treatment to prevent transmission of *Borrelia burgdorferi*, the causative agent of Lyme disease, from infected black-legged ticks, *Ixodes scapularis*, to dogs. *Proc 47th Annu Meet Am Assoc Vet Parasitol*:42, 2002.
49. Spencer JA, Butler JM, Stafford KC, et al: Evaluation of permethrin and imidacloprid for prevention of *Borrelia burgdorferi* transmission from blacklegged ticks (*Ixodes scapularis*) to *Borrelia burgdorferi*–free dogs. *Parasitol Res* 90(suppl 3):S106–S107, 2003.
50. Davoust B, Marie JL, Mercier S, et al: Assay of fipronil efficacy to prevent canine monocytic ehrlichiosis in endemic areas. *Vet Parasitol* 112:91–100, 2003.
51. Tanner PA, Hunter JS, Keister DM: An investigative study to evaluate the effect of bathing of laboratory dogs on the efficacy of fipronil spray. *Proc 41st Annu Meet Am Assoc Vet Parasitol*:20, 1996.
52. Arther RG, Cunningham J, Everett R: Evaluating the effects of shampooing or repeated water exposure on the residual efficacy of Advantage (imidacloprid) for flea control on dogs. *Proc Fourth Intl Symp Ectoparasites of Pets*:73, 1997.
53. Tanner PA, Romano MN, Jeannin PH: An investigative study to evaluate the effect of water immersion or shampooing on the efficacy of Frontline Topspot. *Proc 42nd Am Assoc Vet Parasitol*:35, 1997.
54. Young DR, Ryan WG: Comparison of Frontline Top

Spot, Preventic collar alone or combined with Advantage in control of flea and tick infestations in water immersed dogs. *Proc Fifth Intl Symp Ectoparasites of Pets*:95, 1999.

55. Ascher F, Boyd JP, Elfassy O: Effect of water immersion on the residual efficacy of an amitraz collar. *Proc Fifth Intl Symp Ectoparasites of Pets*:97, 1999.
56. Davidson WR, Siefken DA, Creekmore LH: Influence of annual and biennial prescribed burning during March on the abundance of *Amblyomma americanum* (Acari: Ixodidae) in central Georgia. *J Med Entomol* 31:72–81, 1994.
57. Stafford KC, Ward JS, Magnarelli LA: Impact of controlled burns on the abundance of *Ixodes scapularis* (Acari: Ixodidae). *J Med Entomol* 35:510–513, 1998.
58. Solberg VB, Neidhardt K, Sardelis MR, et al: Field evaluation of two formulations of cyfluthrin for control of *Ixodes dammini* and *Amblyomma americanum* (Acari: Ixodidae). *J Med Entomol* 29:634–638, 1992.
59. Curran KL, Fish D, Piesman J: Reduction of nymphal Ixodes dammini (Acari: Ixodidae) in a residential suburban landscape by area application of insecticides. *J Med Entomol* 30:107–113, 1993.
60. Stafford KC: *Tick Control*. New Haven, CT, The Connecticut Agricultural Experiment Station, 2001. Available at: www.caes.state.ct.us/FactSheetFiles/ForestryHorticulture/Tick%20Control01.pdf; accessed March 2004.