Title
Ixodid Ticks on Feral Swine and Other Mammals in South-Central Florida

Journal
Proceedings of the Vertebrate Pest Conference, 27(27)

ISSN
0507-6773

Authors
Merrill, Mary M.
Lord, Cynthia C.
Turner, E. Lynn
et al.

Publication Date
2016

DOI
10.5070/V427110536

Poster Presentation

Ixodid Ticks on Feral Swine and Other Mammals in South-Central Florida

Mary M. Merrill
Department of Environmental and Global Health, College of Public Health and Health Professions, University of Florida, Gainesville, Florida
Cynthia C. Lord
Florida Medical Entomology Laboratory, University of Florida, Vero Beach, Florida
E. Lynn Turner
State of Florida Department of Health, Brevard County Health Department - Epidemiology, Merritt Island, Florida, and College of Public Health and Health Professions, University of Florida, Gainesville, Florida
Raoul K. Boughton, **Felipe A. Hernández**, and **Samantha M. Wisely**
Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, Florida

ABSTRACT: Feral swine in the United States are known to harbor both native and exotic Ixodid ticks. The expanding range, broad habitat use, high population potential, and large movements of feral swine may increase the distribution and density of certain tick species and tick-borne pathogens that can infect humans, livestock, and wildlife. This preliminary study was conducted to determine which tick species are present on feral swine as well as other mammals sympatric with feral swine in south-central Florida. We trapped large-, medium-, and small-bodied mammals at two study sites, Kissimmee Prairie Preserve State Park and MacArthur Agro-ecology Research Center, from February to May of 2014. We examined mammals for ticks and conducted drags for host-seeking ticks. We trapped five mammal species (feral swine, Florida mouse, marsh rice rat, Virginia opossum, and northern raccoon). From these animals we identified four native tick species (*Amblyomma americanum, A. maculatum, Dermacentor variabilis,* and *Ixodes scapularis*) and one exotic to the United States (*A. auricularium*). We also obtained carcasses of nine-banded armadillos in Brevard County, on which we found *A. auricularium*. This is the first report of *I. scapularis* in Okeechobee County and *A. auricularium* in Brevard and Highlands Counties. All four native tick species are known disease vectors. These data reiterate that many mammals that share habitat with livestock and commonly contact humans are hosts to many ticks of medical and veterinary importance. Coupled with the population, distribution potential, and movement of feral swine, the diversity of ticks found in this study highlights the need for further research on the ability of feral swine to host and distribute ticks and tick-borne pathogens among wildlife, livestock, and humans.

KEY WORDS: ectoparasites, feral swine, Florida, invasive species, public health, *Sus scrofa*, ticks, wild pig

Proc. 27th Vertebr. Pest Conf. (R. M. Timm and R. A. Baldwin, Eds.)
Published at Univ. of Calif., Davis. 2016. Pp. 190-194.

INTRODUCTION

Feral swine (*Sus scrofa*) are large-bodied, invasive mammals capable of harboring multiple species of native and exotic Ixodid ticks. These hard ticks can carry multiple pathogens that affect the health of livestock, wildlife, and humans. For example, the American dog tick (*Dermacentor variabilis*) has been found on feral swine in multiple states, and is known to transmit the causative agents of Rocky Mountain spotted fever and tularemia (Greiner et al. 1984, Allan et al. 2001, Sanders 2011). *Dermacentor* spp. can also transmit the causative agent of bovine anaplasmosis to domestic ruminants, causing mortality between 29-49% in previously unexposed adult cattle (Aubry and Geale 2011). Anaplasmosis is a costly livestock disease; the average cost of each clinical case of bovine anaplasmosis in Texas is $425, and the total annual cost to the United States beef industry is estimated to be more than $300 million (McCallon 1973, Alderink and Dietrich 1983, Kocan et al. 2010). The blacklegged or deer tick (*Ixodes scapularis*) has also been found on feral swine (Greiner et al. 1984, Allan et al. 2001, Sanders 2011) and is capable of transmitting the causative agents of Lyme disease, human babesiosis, and human anaplasmosis (Spielman et al. 1985, Barbour and Hayes 1986, Telford et al. 1996). The role of swine in pathogen transmission is uncertain, but swine may be contributing to the maintenance of tick populations and tick dispersal.

In addition to endemic ticks and tick-borne pathogens, multiple foreign animal diseases, such as heartwater (caused by *Ehrlichia ruminantium*) and East Coast fever (caused by *Theileria parva*) are tick-borne. Heartwater is a disease of ruminants that can cause up to 67% mortality in naïve cattle (Mahan et al. 2001, Allsopp 2015). Survey data from eight countries in southern Africa suggest that vector control and other costs related to heartwater in cattle and small ruminants exceed $44 million per year (Minjauw and McLeod 2003). The primary vector for heartwater, the tropical bont tick (*Amblyomma variegatum* Fabricius), is not endemic to the United States. However, another competent vector, the Gulf Coast tick (*A. maculatum* Koch), is endemic to the southeastern United States and has been found in large numbers on feral swine (Greiner et al. 1984, Allan et al. 2001, Sanders 2011). If a disease such as heartwater were introduced, wildlife vector hosts with a broad distribution and sometimes large home range, such as feral swine, could make vector and pathogen control efforts difficult or impossible.

Vertebrate host composition and host species movement are mechanisms that contribute to tick abundances and community composition differences across habitats (Ostfeld et al. 1995, Ostfeld et al. 1996). Adult ticks are usually found on large vertebrate hosts such as white-tailed deer (*Odocoileus virginianus*) and feral swine where they will feed, mate, and then drop off of the host to lay eggs. Thus, local movement by individual hosts during tick mating seasons may influence where female ticks ultimately lay their eggs, consequently influencing larval densities in the local landscape. Because some tick-borne pathogens such as spotted fever group *Rickettsia* can be transmitted from female ticks to their offspring (Sonenshine 1991), host movement influences the local distribution of infected larvae and may influence risk of certain tick-borne diseases. Feral swine are habitat generalists that utilize multiple habitats within their home range, sharing habitat with other wildlife, domestic livestock, and humans, and thus may introduce or increase densities of infected larval ticks in areas where feral swine have invaded.

Additional risks exist for hunters, land managers, and wildlife professionals who may come into close contact with feral swine either recreationally or for population control purposes. Ticks attached to a harvested animal may soon begin to seek a live host; therefore, people who handle harvested feral swine may become the next hosts to their tick vectors. Thus, to better estimate risk and protect humans and livestock, it is important to understand the potential role of feral swine in maintaining and distributing ticks and tick-borne pathogens.

The goal of this study was to determine which tick species are present on feral swine and co-occurring wildlife in south-central Florida. This study updates Greiner et al. (1984) and Allan et al. (2001) and expands the survey to mammalian wildlife sympatric with feral swine on an active cattle ranch. In addition, we report new county records for two species, *I. scapularis* and *A. auricularium* (Conil 1878).

METHODS

Between February and May 2014, a variety of small-, medium-, and large-bodied mammals were trapped and examined for ticks at two study areas in south-central Florida: MacArthur Agro-ecology Research Center (MAERC) in Highlands County, and Kissimmee Prairie Preserve State Park (KPPSP) in Okeechobee County. Trapping was conducted as part of a larger study comparing effects of supplemental feeding on interactions between wildlife and cattle. Six sites were trapped at MAERC, and three were trapped at KPPSP; each trap site was located at least 750 m from other sites. Small and medium mammals were trapped at both areas, while large mammals were trapped only at MAERC. Small mammals were trapped at each site (n = 100 trap locations per site) using small box-style Sherman live traps (H. B. Sherman, Inc., Tallahassee, FL) baited with birdseed. Medium mammals were trapped (n = 25 trap locations per study area) using medium box-style live traps (Tomahawk Live Trap Company, Tomahawk, WI) baited with canned cat food and raisins. Feral swine were trapped (n = 15 traps at each study area) in handcrafted large corral or box-style live traps baited with fermented corn. All traps were set in the evening and checked early the following morning, at which point any mammals trapped were anesthetized following species-appropriate procedures described in the Handbook of Wildlife Chemical Immobilization (Kreeger and Arnemo 2012). When sample collection was completed, reversal drugs were administered if necessary, and animals were released at the point of capture. Ticks were also collected from carcasses of nine-banded armadillos (*Dasypus novemcinctus*) in Brevard County; these animals were salvaged from wildlife nuisance trappers and checked for ticks during 2015.

In addition to mammal trapping at each study area, host-seeking tick surveys were conducted by dragging a 1-m^2 corduroy cloth for 100 m through vegetation adjacent to trap sites and in nearby tree cover in order to collect questing ticks. Transects were dragged weekly (during mammal trapping), and the drag cloth examined for ticks every 10 m. Ticks removed from animals and drag cloths were stored in ethanol and identified to species using taxonomic keys (Keirans and Litwak 1989, Keirans and Durden 1998, Martins et al. 2010, Guzman-Cornejo et al. 2011, Martins et al. 2014).

RESULTS

Northern raccoons (*Procyon lotor*), Virginia opossums (*Didelphis virginiana*), Florida mice (*Podomys floridanus*), and marsh rice rats (*Oryzomys palustris*) were trapped and examined for ticks at both MAERC and KPPSP, and feral swine (*Sus scrofa)* at MAERC. Table 1 displays the total number of each species trapped at each study area. Each mammal species was host to at least one tick species. Overall, five species of ticks (*Amblyomma americanum*, *A. auricularium*, *A. maculatum*, *D. variabilis*, and *I. scapularis*) at two life stages (nymph and adult) were collected from mammals and drags (Table 2). Armadillos from Brevard County were host to adult *A. auricularium* only.

DISCUSSION

All tick species collected in this study are native to the region, except for *A. auricularium*, which is exotic to the United States. *Amblyomma auricularium* is primarily found in South and Central America (Guglielmone et al. 2003), but has been reported on multiple animal species throughout south Florida and is now believed to be established (Lord and Day 2000, Allan et al. 2001, Burridge 2011 and references therein, Mertins et al. 2016). The distribution of *A. auricularium* was recently extended through South Florida (Mertins et al. 2016). Our collections at MAERC (Highlands County) were contiguous and on the northern edge of this range, while the Brevard county collections are farther north and slightly separated from the known distribution. *A. auricularium* is predominately associated with armadillos, although it will feed on a variety of mammals and birds and has been found unattached on humans (Guglielmone et al. 2003, Burridge 2011, Cohen et al. 2015, Lugarini et al. 2015, Mertins et al.

Table 1. Number of each mammal species surveyed per study site.

Mammal Species	Number Surveyed
Brevard County	
Nine-banded armadillos	8
Kissimmee Prairie Preserve State Park, Okeechobee County	
Eastern harvest mouse	6
Marsh rice rat	16
Opossum	8
Raccoon	8
MacArthur Agro-ecology Research Center, Highlands County	
Eastern harvest mouse	42
Marsh rice rat	10
Opossum	7
Raccoon	14
Feral swine	16

Table 2. Species and life stages of ticks removed from mammalian hosts and drag cloths in south-central Florida from February-May 2014.

Tick Species	Tick Life Stage	Hosts
Kissimmee Prairie Preserve State Park		
Amblyomma maculatum	Nymph	Marsh rice rat
Dermacentor variabilis	Nymph	Florida mouse
Dermacentor variabilis	Adult	Human*, opossum, raccoon, drag
Ixodes scapularis	Adult	Human*, opossum
Ixodes spp. (damaged)	Adult	Opossum
MacArthur Agro-ecology Research Center		
Amblyomma americanum	Adult	Feral swine
Amblyomma sp.	Nymph	Opossum
Amblyomma auricularium	Adult	Feral swine, raccoon
Amblyomma maculatum	Nymph	Drag
Amblyomma maculatum	Adult	Feral swine
Dermacentor variabilis	Nymph	Marsh rice rat
Dermacentor variabilis	Adult	Feral swine, opossum, raccoon

* Human = ticks found on researchers during trapping or dragging efforts

2016). *Amblyomma auricularium* is not known to be associated with disease; however *Rickettsia* spp. of unknown pathogenicity have been detected in this tick species (Cohen et al. 2015, Lugarini et al. 2015, Saraiva et al. 2015). These are the first reported collections of *A. auricularium* in Highlands and Brevard Counties (FL).

The remaining tick species collected are all known vectors of at least one human or veterinary pathogen within the United States. In this study, we found that many tick species were shared among small, medium, and large mammals in south-central Florida. *Dermacentor variabilis*, which can vector the causative agents of Rocky Mountain spotted fever and tularemia, was found on all mammal species sampled, and the exotic *A. auricularium* was found on two mammal species.

Small mammals hosted nymphs of two species of ticks, *D. variabilis* and *A. maculatum*. Not much is known about the ability of either the marsh rice rat or Florida mouse to amplify tick-borne pathogens. Antibodies to *Borrelia burgdorferi*, the causative agent of Lyme disease, have previously been found in marsh rice rats (Oliver et al. 1999), although we did not find *I. scapularis*, a vector of *B. burgdorferi*, on marsh rice rats in this study.

Medium-sized mammals (raccoons and opossums) hosted three of the five tick species found during this study. Though we did not perform pathogen tests, raccoons have been shown to be competent reservoirs for tick-borne pathogens such as *B. burgdorferi*, *Anaplasma phagocytophilum*, and *Babesia microti* (Fish and Daniels 1990, Levin et al. 2002, Hersh et al. 2012). We did not find *I. scapularis*, the primary vector of these pathogens, on raccoons during our study. However, our sampling area was localized and confined to the spring season, so it is possible we missed tick species that we might have found with greater sampling effort. We did find *I. scapularis* on opossums and humans at KPPSP. Interestingly, opossums can serve to reduce tick abundance in habitat patches through self-grooming, and have been shown to remove between 83-96% of larval *I. scapularis* that attempted to feed on them (Keesing et al. 2009). *Ixodes scapularis* has been reported from most counties in Florida on a variety of hosts (Forrester 1992, Wehinger et al. 1995, Forrester et al. 1996, Cilek and Olson 2000, Durden et al. 2000, Allan et al. 2001, Fang et al. 2002, Forrester and Spalding 2003, Clark 2004, Oliver et al. 2008, Yabsley et al. 2009). However, there have been gaps in the recorded distribution, and this study is the first reported collection of *I. scapularis* in Okeechobee County, FL (recently reported as unpublished data in Eisen et al. 2016).

Feral swine harbored adults of every tick species collected from MAERC, which is the only site where swine were successfully trapped. Although no *I. scapularis* were found at MAERC or attached to swine in this study, previous studies have found this species on feral swine in Florida (Greiner et al. 1984, Allan et al. 2001). The broad habitat use and large home ranges of feral swine may contribute to the diversity of tick species found parasitizing them, and may make them a valuable species to survey for ticks and tick-borne pathogens in a diversity of habitat types. Feral swine in Texas have been shown to have antibodies to *Borrelia* spp., *Rickettsia* spp., and *Ehrlichia* spp., as well as evidence of circulating *Borrelia* spp. (Sanders 2011).

The wide distribution, high densities, variable home range, and ability of feral swine to utilize many habitats may contribute to the distribution of exotic and native tick species throughout the state. In addition, feral swine may legally be trapped and transported throughout Florida to private game reserves, approved holding facilities, or for slaughter, which may also facilitate the redistribution of ticks and tick-borne diseases. Therefore, more research is needed to determine what role feral swine play in tick and tick-borne disease spread as well as if feral swine are competent reservoirs for tick-borne pathogens.

ACKNOWLEDGEMENTS

We thank our funding agencies, the United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center (Cooperative Agreement Number No. 12-7412-0896-CA); the University of Florida Institute of Food and Agricultural Sciences Department of Wildlife Ecology and Conservation; the University of Florida College of Public Health and Health Professions; and the MacArthur Agro-ecology Research Center (MAERC), a division of Archbold Biological Station. We thank Hilary M. Swain, Elizabeth H. Boughton, and Gene Lollis for their support and the opportunity to conduct this research at MAERC. We thank Kissimmee Prairie Preserve State Park for their support and the opportunity to conduct this research. We thank all who helped with feral swine trapping, especially Tyler Campbell, Eric Tillman, and Michael Milleson. We thank Andrew Satterlee and David Cleveland for conducting large-, medium-, and small-mammal trapping as well as tick dragging. David Cleveland was supported by a research internship from MacArthur Agro-ecology Research Center. We thank Kyle Huston, wildlife nuisance trapper in Brevard County, for his assistance in collecting armadillos. Field methods were approved by the University of Florida's Institutional Animal Care and Use Committee (Protocol numbers 201308160 and 201508785).

LITERATURE CITED

Alderink, F.J. and Dietrich, R.A. 1983. Economic and epidemiological implications of anaplasmosis in Texas beef cattle herds. Bulletin B-1426, Texas Agricultural Experiment Station, College Station, TX. 16 pp. http://hdl.handle.net/1969.1/150031

Allan, S. A., L. A. Simmons, and M. J. Burridge. 2001. Ixodid ticks on white-tailed deer and feral swine in Florida. J. Vector Ecol. 26:93-102.

Allsopp, B. A. 2015. Heartwater - *Ehrlichia ruminantium* infection. Rev. Sci. Tech. 34:557-568.

Aubry, P., and D. W. Geale. 2011. A review of bovine anaplasmosis. Transboundary and Emerg. Dis. 58:1-30.

Barbour, A. G., and S. F. Hayes. 1986. Biology of *Borrelia* species. Microbiol. Rev. 50:381-400.

Burridge, M. J. 2011. Non-Native and Invasive Ticks. Threats to Human and Animal Health in the United States. University Press of Florida, Gainesville, FL. 292 pp.

Cilek, J. E., and M. A. Olson. 2000. Seasonal distribution and abundance of ticks (Acari : Ixodidae) in northwestern Florida. J. Med. Entomol. 37:439-444.

Clark, K. 2004. *Borrelia* species in host-seeking ticks and small mammals in northern Florida. J. Clin. Microbiol. 42: 5076-5086.

Cohen, E. B., L. D. Auckland, P. P. Marra, and S. A. Hamer. 2015. Avian migrants facilitate invasions of neotropical ticks and tick-borne pathogens into the United States. Appl. Environ. Microbiol. 81:8366-8378.

Conil, P. A. 1878. Description d'une nouvelle espèce d'ixode *Ixodes auricularius*. Acta Acad. Nac. Cienc. Exactas (Argentina) 3:99-110.

Durden, L. A., R. J. Hu, J. H. Oliver, and J. E. Cilek. 2000. Rodent ectoparasites from two locations in northwestern Florida. J. Vector Ecol. 25:222-228.

Eisen, R. J., L. Eisen, and C. B. Beard. 2016. County-scale distribution of *Ixodes scapularis* and *Ixodes pacificus* (Acari: Ixodidae) in the continental United States. J. Med. Entomol. doi: http://dx.doi.org/10.1093/jme/tjv237

Fang, Q. Q., T. R. Mixson, M. Hughes, B. Dunham, and J. Sapp. 2002. Prevalence of the agent of human granulocytic ehrlichiosis in *Ixodes scapularis* (Acari : Ixodidae) in the coastal southeastern United States. J. Med. Entomol. 39: 251-255.

Fish, D., and T. J. Daniels. 1990. The role of medium-sized mammals as reservoirs of *Borrelia burgdorferi* in southern New York. J. Wildl. Dis. 26:339-345.

Forrester, D. J. 1992. Parasites and Diseases of Wild Mammals in Florida. University Press of Florida, Gainesville, FL. 480 pp.

Forrester, D. J., G. S. McLaughlin, S. R. Telford, G. W. Foster, and J. W. McCown. 1996. Ectoparasites (Acari, mallophaga, anoplura, diptera) of white-tailed deer, *Odocoileus virginianus*, from southern Florida. J. Med. Entomol. 33:96-101.

Forrester, D. J., and M. G. Spalding. 2003. Parasites and Diseases of Wild Birds in Florida. University Press of Florida, Gainesville, FL. 1152 pp.

Greiner, E. C., P. P. Humphrey, R. C. Belden, W. B. Frankenberger, D. H. Austin, and E. P. J. Gibbs. 1984. Ixodid ticks on feral swine in Florida. J. Wildl. Dis. 20:114-119.

Guglielmone, A. A., A. Estrada-Peña, C. A. Luciani, A. J. Mangold, and J. E. Keirans. 2003. Hosts and distribution of *Amblyomma auricularium* (Conil 1878) and *Amblyomma pseudoconcolor* Aragão, 1908 (Acari : Ixodidae). Exper. Appl. Acarol. 29:131-139.

Guzman-Cornejo, C., R. G. Robbins, A. A. Guglielmone, G. Montiel-Parra, and T. M. Perez. 2011. The Amblyomma (Acari: Ixodida: Ixodidae) of Mexico: identification keys, distribution and hosts. Zootaxa 2998:16-38.

Hersh, M. H., M. Tibbetts, M. Strauss, R. S. Ostfeld, and F. Keesing. 2012. Reservoir competence of wildlife host species for *Babesia microti*. Emerg. Infect. Dis. 18:1951-1957.

Keesing, F., J. Brunner, S. Duerr, M. Killilea, K. LoGiudice, K. A. Schmidt, H. Vuong, and R. S. Ostfeld. 2009. Hosts as ecological traps for the vector of Lyme disease. Proc. Royal Soc. B-Biol. Sci. 276:3911-3919.

Keirans, J. E., and L. A. Durden. 1998. Illustrated key to nymphs of the tick genus Amblyomma (Acari : Ixodidae) found in the United States. J. Med. Entomol. 35:489-495.

Keirans, J. E., and T. R. Litwak. 1989. Pictorial key to the adults of hard ticks, family Ixodidae (Ixodida, Ixodoidea), east of the Mississippi River. J. Med. Entomol. 26:435-448.

Kocan, K. M., J. de la Fuente, D. L. Step, E. F. Blouin, J. F. Coetzee, K. M. Simpson, S. G. Genova, and M. J. Boileau. 2010. Current challenges of the management and epidemiology of bovine anaplasmosis. The Bovine Practitioner 44(2):93-102.

Kreeger, T. J., and J. M. Arnemo. 2012. Handbook of Wildlife Chemical Immobilization. Terry J. Kreeger, publ. 448 pp.

Levin, M. L., W. L. Nicholson, R. F. Massung, J. W. Sumner, and D. Fish. 2002. Comparison of the reservoir competence of medium-sized mammals and *Peromyscus leucopus* for *Anaplasma phagocytophilum* in Connecticut. Vector-Borne Zoonot. Dis. 2:125-16.

Lord, C. C., and J. F. Day. 2000. First record of *Amblyomma auricularium* (Acari : Ixodidae) in the United States. J. Med. Entomol. 37:977-978.

Lugarini, C., T. F. Martins, M. Ogrzewalska, N. C. T. Vasconcelos, V. A. Ellis, J. B. Oliveira, A. Pinter, M. B. Labruna, and J. C. R. Silva. 2015. Rickettsial agents in avian ixodid ticks in northeast Brazil. Ticks Tick-Borne Dis. 6: 364-375

Mahan, S. M., G. E. Smith, D. Kumbula, M. J. Burridge, and A. F. Barbet. 2001. Reduction in mortality from heartwater in cattle, sheep and goats exposed to field challenge using an inactivated vaccine. Vet. Parasitol. 97:295-308.

Martins, T. F., V. C. Onofrio, D. M. Barros-Battesti, and M. B. Labruna. 2010. Nymphs of the genus Amblyomma (Acari: Ixodidae) of Brazil: descriptions, redescriptions, and identification key. Ticks Tick-Borne Dis. 1:75-99.

Martins, T. F., M. B. Labruna, A. J. Mangold, M. M. Cafrune, A. A. Guglielmone, and S. Nava. 2014. Taxonomic key to nymphs of the genus Amblyomma (Acari: Ixodidae) in Argentina, with description and redescription of the nymphal stage of four Amblyomma species. Ticks Tick-Borne Dis. 5: 753-70.

McCallon, B. R. 1973. Prevalence and economic aspects of anaplasmosis. Pp. 1-3 *in*: E. W. Jones (Ed.), Proceedings of the 6th National Anaplasmosis Conference. Heritage Press, Stillwater, OK.

Mertins, J. W., S. L. Vigil, and J. L. Corn. 2016. *Amblyomma auricularium* (Ixodida: Ixodidae) in Florida: new hosts and distribution records. J. Med. Entomol. Advance online publication. doi:10.1093/jme/tjw159

Minjauw, B., and A. McLeod. 2003. Tick-borne diseases and poverty: the impact of ticks and tick-borne diseases on the livelihoods of small-scale and marginal livestock owners in India and eastern and southern Africa. Research report, DFID Animal Health Programme, Centre for Tropical Veterinary Medicine, University of Edinburgh, UK. 124 pp.

Oliver, J. H., L. A. Magnarelli, H. J. Hutcheson, and J. F. Anderson. 1999. Ticks and antibodies to *Borrelia burgdorferi* from mammals at Cape Hatteras, NC and Assateague Island, MD and VA. J. Med. Entomol. 36:578-587.

Oliver, J. H., L. H. Gao, and T. Lin. 2008. Comparison of the spirochete *Borrelia burgdorferi* s. l. isolated from the tick *Ixodes scapularis* in southeastern and northeastern United States. J. Parasitol. 94:1351-1356.

Ostfeld, R. S., O. M. Cepeda, K. R. Hazler, and M. C. Miller. 1995. Ecology of Lyme disease: habitat associations of ticks (*Ixodes scapularis*) in a rural landscape. Ecol. Appl. 5(2): 353-361.

Ostfeld, R. S., C. G. Jones, and J. O. Wolff. 1996. Of mice and mast: ecological connections in eastern deciduous forests. Bioscience 46(5):323-330.

Sanders, D. M. 2011. Ticks and tick-borne pathogens associated with feral swine in Edwards Plateau and Gulf Prairies and Marshes Ecoregions of Texas. PhD dissert., USAF School of Aerospace Medicine, Dayton, OH. 73 pp.

Saraiva, D. G., F. A. Nieri-Bastos, M. C. Horta, H. S. Soares, P. A. Nicola, L. C. Pereira, and M. B. Labruna. 2013. *Rickettsia amblyommii* infecting *Amblyomma auricularium* ticks in Pernambuco, northeastern Brazil: isolation, transovarial transmission, and transstadial perpetuation. Vector Borne Zoonotic Dis. 13:615-618.

Sonenshine, D. E. 1991. Biology of Ticks, Vol. 2. Oxford University Press, New York, NY. 465 pp.

Spielman, A., M. L. Wilson, J. F. Levine, and J. Piesman. 1985. Ecology of *Ixodes dammini*-borne human babesiosis and Lyme disease. Ann. Rev. Entomol. 30:439-460.

Telford, S. R., J. E. Dawson, P. Katavolos, C. K. Warner, C. P. Kolbert, and D. H. Persing. 1996. Perpetuation of the agent of human granulocytic ehrlichiosis in a deer tick-rodent cycle. Proc. Nat. Acad. Sci. USA 93:6209-6214.

Wehinger, K. A., M. E. Roelke, and E. C. Greiner. 1995. Ixodid ticks from panthers and bobcats in Florida. J. Wildl. Dis. 31:480-485.

Yabsley, M. J., T. N. Nims, M. Y. Savage, and L. A. Durden. 2009. Ticks and tick-borne pathogens and putative symbionts of black bears (*Ursus americanus floridanus*) from Georgia and Florida. J. Parasitol. 95:1125-1128.