A REVIEW OF TICKS (ACARI: IXODIDA), SURVEILLANCE AND COMMON TICK-BORNE DISEASES OF SOUTH DAKOTA, USA

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ABSTRACT

The scope of literature concerning tick-borne disease in South Dakota (SD) is limited primarily to case reports by public health officials. Published records of ticks occurring in the state are scarce and are mostly limited to reports of ticks opportunistically collected from wildlife, with little focus on surveillance for ticks themselves or potential pathogens. There exists only one published record with a compilation of the ticks of South Dakota (1983). Here, the current literature on the ticks of South Dakota, the pathogens they may carry, and their relevance and history in South Dakota are reviewed. Three new tick species documented in the state since the last publication are included herein, bringing the total number of tick species in the state to 21. I review and update past reports to include new county records and identification of pathogens previously undetected in the state and include some information on ongoing research involving ticks and tick-borne disease in the state. This manuscript and the projects referenced within were conducted with the goal of drawing attention to the need for tick surveillance in South Dakota.

Keywords

South Dakota, ticks, tick-borne disease, Lyme disease

INTRODUCTION

South Dakota (SD) is a Midwestern state consisting primarily of prairie habitat, with less than 4% of its total land area made up of forested lands (Walters 2016). Ticks are potential inhabitants of these and other terrestrial habitats existing throughout the state. The most thorough description of ticks in South Dakota was given by Easton (1983) in a compilation based on prior publications that mostly focused on ticks from hosts (Bishopp 1911; Ulrich and Vaughn 1963; Boddicker and Hugghins 1965, 1969; Anderson and Jones 1971; Wilson 1978; Keirans and Clifford 1983), and on data associated with tick collections housed at the Rocky Mountain Laboratory (now The Smithsonian collection).

Prior studies describing ticks in South Dakota focused primarily on either tick-borne diseases of humans or are compilations of reports of ticks from wildlife such as birds, deer, or rodents (Banks 1908; Cooley and Kohls 1945; Keirans and Clifford 1978; Durden and Keirans 1996). Several researchers have surveyed for human infection with the agents of tularemia (*Francisella tularensis*) and Rocky Mountain spotted fever (*Rickettsia rickettsii*) in Native American communities (a group that is likely to come into contact with ticks because of cultural and environmental factors) in South Dakota (Markowitz et al. 1985; Demma et al. 2006; CDC 2017), although few records for pathogen screening of ticks exist in the state. There is substantial need for an improved understanding of tick ecology and public health risk associated with tick-borne disease within the state.

In this manuscript, a hybrid approach (utilizing a mixture of review and original research) is used to review published tick research and report new records occurring after 1983, post Easton (1983). This project was a part of an *I. scapularis* surveillance study (Maestas et al. 2016; Maestas et al. 2018). Data were obtained from multiple sources: local biologists were asked to collect ticks from their wildlife studies and pets, additional ticks were collected from swift foxes (Nevison 2017), from skunks from a local trapper (Maestas et al. 2018), by South Dakota Department of Game Fish and Parks (Maestas et al. 2018), and from small mammals (Maestas and Britten 2017).

ARGASIDAE OF SOUTH DAKOTA

***Argas cooleyi* (Kohls and Hoogstraal 1960)**, the swallow tick, is primarily a parasite of cliff swallows (*Petrochelidon pyrrhonota* (Viellot)) (Cook, 1972; Kohls and Hoogstal 1962), but has been identified from other bird species (Cook 1972). *Argas cooleyi* is not considered a tick of medical importance because of its host specificity and lack of records of human feeding (Golnar et al 2019). However, it is of note that an Orbivirus (Chenuda virus) has been isolated from *A. cooleyi* (Bowman and Nuttal, 2008; Yunker et al. 1972). Records exist of *A. cooleyi* from Custer, Jackson, Oglala Lakota (previously Shannon), Pennington, and Jackson (previously Washabaugh) counties (Easton et al 1983).

***Carios concanensis* (Cooley and Kohls 1941) (previously *Ornithodoros*)** is a parasite primarily of cliff swallows, bats, and raptors, though it has been associated with human hosts (Golnar et al. 2019; Cook, 1972). I am unaware of any potential medical or veterinary associations of *C. concanensis*. Records exist of *C. concanensis* in Custer, Stanley and Jackson (Washabaugh) counties (Easton 1983).

***Carios kelleyi* (Cooley and Kohls 1944) (previously *Ornithodoros*)**, the bat tick is primarily a parasite of bats, but evidence of human feeding does exist (Gill et al. 2004). While there are no known disease associations with *C. kelleyi*, Schwan et al. (2009) have isolated Candidatus *Borrelia johnsonii*, and Loftis et al (2005) have isolated several bacterial agents closely related to known pathogenic agents. Currently, no evidence of vector competence for *B. johnsonii* by *C. kelleyi* exists. Records for detection of *C. kelleyi* exist in Harding, Pennington and Todd counties. Here we report a new county record for *C. kelleyi,* which was collected on two separate occasions in 2015, once from a home with roosting bats, and again from a dog (*Canis familiaris* (Linnaeus)), in Clay County, SD (L. Maestas unpublished).

***Otobius megnini* (Duges 1884)**, the spinose ear tick, is a one-host tick that feeds on a wide range of domestic and wild mammals and occasionally has been found on people (Eads and Campos 1984). It was documented by Cooley and Kohls (1944) on the ears of cattle in Haakon and Falls River counties (Easton 1984). This species has been widely disseminated by the shipment of infested animals (Keirans and Pound 2000; Eads and Campos 1984), and the lack of detections and establishment in SD and neighboring states indicates that the ticks reported by Cooley and Kohls (1944) may have been travel-related cases (Easton 1984). There is no current medical association of this tick, though it has been attributed to the morbidity and mortality of livestock (Rich 1957).

IXODIDAE OF SOUTH DAKOTA

***Amblyomma americanum* (Linnaeus 1758)**, the lone star tick, is an aggressive host-seeking species with only two reported records in South Dakota, one from an unknown host in McCook County (1993); and a second record reporting populations in Clay and Yankton counties, as well as an established population (considered by the CDC to be six or greater individuals, or two life stages) (Dennis et al. 1998) in Union County (from non-host environmental collections) (Springer et al. 2014; Black and Britten 2019). South Dakota is considered the northwestern limit of the range of *A. americanum* (Springer et al. 2014). This species primarily inhabits wooded areas with thick vegetation (Springer et al. 2014; Kuklok et al. 2017) and is associated with deer and wild turkeys in other parts of its range (Kollars et al. 2000). *Amblyomma americanum* is recognized as an important tick vector in the eastern United States (Springer et al. 2014). It is known to be the primary vector of the agent of human monocytic ehrlichiosis (HME), *Ehrlichia chaffeensis*, and a vector of the agents of tularemia, *Francisella tularensis,* and spotted fever rickettsiosis, *Rickettsia* spp., in the US. This species is also likely involved in the emergence of southern tick-associated rash illness (STARI) (Bowman and Nuttal 2008; Sonenshine and Roe 2013), and has recently been implicated as a vector of Heartland and Bourbon viruses (Raghavan et al. 2019; Savage et al. 2018). The development of a red meat allergy to the alpha-gal protein of non-primate mammalian meats and meat products has also been associated with the bite of *A. americanum* (Commins et al. 2016).

***Dermacentor albipictus* (Packard 1869)**, the winter tick, is a one-host tick that is primarily a parasite of North American cervids, though it regularly parasitizes domestic ungulates (Sonenshine 1993). In South Dakota, it has been documented from mule deer (*Odicoileus hemionus* (Rafinesque)), mountain goat (*Oreamnos americanus* (Blainville)), and North American elk (*Cervis canadensis* (Erxleben)) (Easton 1983), as well as from off-host environmental collections and unreported hosts (Bishopp and Trembley 1945). Reports are from Custer, Bon Homme, Harding and Lawrence counties. Here, we report *D. albipictus* from mule deer in Brule County, SD (L. Maestas unpublished), which represents a new county record. There are no current significant medical or veterinary concerns aside from death by desanguination and hair loss syndrome in moose (Drew and Samuel 1985).

***Dermacentor andersoni* (Stiles 1908)**, the Rocky Mountain wood tick, is widely distributed in western North America and is found in the Black Hills region of western South Dakota (James et al. 2006). In South Dakota, *D. andersoni* has been documented on black-tailed prairie dogs (*Cynomis ludovicianus* (Ord)) (Kietzmann 1987), mountain goats (*Oreamnos americanus*) (Boddicker et al. 1971), and least chipmunks (*Eutamias minimus* (Bachmann)) (Easton 1983). It has been reported from Butte, Custer, Falls River, Harding, Jackson, Lawrence, Oglala Lakota, and Pennington counties. In the US, *D. andersoni* is an important vector for the agents of Colorado tick fever virus (*Coltivirus*), tularemia (*F. tularensis*), and Rocky Mountain spotted fever (RMSF) (*Rickettsia rickettsii*) (Sonenshine and Roe 2013; Wolbach 1919). This species is also the most frequent cause of tick paralysis in the US (Drummond 2008). *Dermacentor andersoni* typically inhabits rocky slopes with a mix of grass, brush, and conifers at elevations greater than 2,300 meters (Eisen et al. 2007) and can be found in rough, cutover mountainous areas and in sage brush-dominated regions near streams (Bishopp and Trembley 1945).

***Dermacentor variabilis* (Say 1821)**, the American dog tick, is considered to be the principal vector of RMSF in North America (Sonenshine 1993). It is also an important vector of other tick-borne pathogens in the US and can cause tick paralysis (Bowman and Nuttal 2008; Sonenshine and Roe 2013). This tick is common in eastern and northern South Dakota, and narrowly overlaps in range with *D. andersoni* (Drummond 2008). In South Dakota, *D. variabilis* has been documented from dogs, coyotes (*Canis latrans* (Say)), porcupine (*Erethizon dorsatum* (Linnaeus)), swift fox (*Vulpes velox* (Say)) (Easton 1983; Maestas 2018) and from the following small mammal species: hispid pocket mouse (*Chaetodipus hispidus* (Baird)), northern grasshopper mouse (*Onychomys leucogaster* (Wied-Neuwied)), meadow vole (*Microtus pennsylvanicus* (Ord)), deer mouse (*Peromyscus maniculatus* (Wagner)), western harvest mouse (*Reithrodontomys megalotis* (Baird)), and plains harvest mouse (*Reithrodontomys montanus* (Baird)) (Maestas 2018). This species is found primarily in grassy and brush covered areas, with fewer ticks in heavily forested areas, and seems to be limited by low levels of humidity (Bishopp and Trembley 1945). *Dermacentor variabilis* is widely distributed in South Dakota, being found in 31 of 66 counties (Lehane et al. 2019; Maestas 2018; Easton 1983): Brookings, Butte, Clark, Clay, Codington, Davison, Day, Deuel, Fall River, Grant, Gregory, Haakon, Hamlin, Hand, Hughes, Jackson, Kingsbury, Lawrence, Lincoln, Lyman, Marshall, Meade, Minnehaha, Oglala Lakota, Pennington, Perkins, Roberts, Spink, Stanley, Union, and Ziebach.

***Haemaphysalis chordeilis* (Packard 1869),** the bird tick, is a native North American tick with no significant medical or veterinary associations (Egizi et al 2019). This species is not commonly collected, but is thought to have a broad North American distribution (Egizi et al 2019, Bishopp and Trembley 1945). Its role as a specialist on birds has led to a dearth of information available on this species; as such. there has been only one report of *H. chordeilis* from South Dakota. Boddicker and Hugghins (1965) reported this species from a sharp-tailed grouse (*Tympanuchus phasianellus* (Linnaeus)) in one of four South Dakota counties: Haakon, Jackson (Washabaugh), and Mellette (Easton 1983).

***Haemaphysalis leporispalustris* (Packard 1869)**, the rabbit tick, like *H. chordeilis* and *D. albipictus*, is a specialist feeder typically collected from lagomorphs (Egizi et al 2019; Sonenshine 1993) and is occasionally collected via off-host environmental collections (Maestas, personal observations), or from ground feeding birds (Sonenshine 1993). Although this species is not thought to be important in human transmission of disease, it is important in sylvatic cycling of pathogens such as SFGR and *F. tularensis* (Sonenshine 1993; Egizi et al 2019; Bowman and Nuttal 2008). Documented county records for *H. leporispalustris* in South Dakota all occur west of the Missouri River, in Fall River, Bennett, and Lawrence counties (Turner, 1974; Easton 1983).

***Ixodes angustus* (Neumann, 1899),** is a parasite of small mammals, some mid-sized animals and humans. Keirans and Clifford (1978) have reported the presence of *I. angustus* from South Dakota in unpublished records from Rocky Mountain Laboratories, not including county data. There are several instances where *I. angustus* has been linked to Lyme disease with the suggestion of transmission by this species.

***Ixodes cookei* (Packard 1869)**, the groundhog tick, is primarily a parasite of carnivores and small to medium-sized mammals, but is known as an occasional parasite of humans (Durden and Kierans 1996). *Ixodes cookei* is a known vector of Powassan virus in the New England states and in Canada (Hermance and Thagamani 2017; Durden and Kierans 1996; Main et al. 1979). Several other pathogens have been isolated from *I. cookei*, though it is an inefficient vector of *B. burgdorferi* (Ryder et al. 1992), and vector competency of SFGR and *F. tularensis* are unconfirmed (Artsob et al. 1984; Magnarelli and Swihart 1991). The only known record of this tick in South Dakota was from an unspecified small mammal in Brooking County (Easton 1983). Here we additionally report the presence of *I. cookei* from swift foxes in Pennington County, and from striped skunks (*Mephitis mephitis* [Schreber]), Brule County, SD (L. Maestas, unpublished).

***Ixodes eastoni* (Keirans and Clifford 1983)** is reported from small mammals and insectivores in the Black Hills region of South Dakota, in Lawrence, Harding and Pennington counties (Robbins and Keirans 1992; Easton 1983). There are currently no medical or veterinary associations for this species, although its geographical range overlaps with human cases of both Powassan and Colorado tick fever viruses (Durden and Keirans 1996).

***Ixodes kingii* (Bishopp 1911)** has a wide host range, including carnivores and small mammals in South Dakota, and has been reported from Brule, Fall River, Harding, Jackson, Perkins, Oglala Lakota, and Mellette counties (Easton 1983). Since Easton's original review, Harris et al. (2014) have reported *I. kingii* from black-footed ferrets (*Mustela nigripes* (Audubon and Bachman)). Here we additionally report *I. kingii* from swift foxes in, Pennington County, and from *Ictidomys tridecemlineatus* (Mitchill), *C. hispidus*, *P. maniculatus*, and *O. leucogaster* in Lyman County, SD. Though uncommon, *I. kingii* has been recovered from humans and may be involved in sylvatic maintenance of tularemia (Durden and Keirans 1996).

***Ixodes muris* (Bishopp and Smith 1937)** is a parasite of small mammals and several species of birds (Durden and Keirans 1996) and has been reported from Bennett and Roberts counties (Easton, 1983). Although not definitive, *I. muris* is thought to be a vector of *Babesia* spp., causing disease in humans and potentially other animals (Scott and Scott 2018; Durden and Keirans 1996; Spielman et al. 1984).

***Ixodes ochotonae* (Gregson, 1941),** is primarily a parasite of pikas and woodrats, though records exist from other small and mid-size animals. Keirans and Clifford (1978) have reported the presence of *I. ochotonae* from South Dakota in unpublished records from Rocky Mountain Laboratories, with no associated county data. There are no known medical or veterinary associations with this tick (Durden and Keirans 1996).

***Ixodes scapularis* (Say 1821**), the blacklegged tick, is the primary vector of *Borrelia burgdorferi*, the primary agent of Lyme disease in the eastern US. This species primarily inhabits deciduous forests with dense vegetation and high levels of humidity (Maestas 2018). *Ixodes scapularis* has only recently been found to have established populations in Clay, Day and Lincoln counties, SD, and has been reported in Marshall, Roberts, and Union Counties (Maestas et al. 2016; Maestas et al. 2018; Black and Britten 2019). Previous reports of *I. scapularis* exist describing the detection of this tick from a deer in Brookings County, and later from a dog in Codington County (McDaniel and Hildreth 1992). *Ixodes scapularis* is an important vector known to be capable of causing tick-borne paralysis and transmitting the following disease agents: *Anaplasma phagocytophilum* (anaplasmosis), *Babesia microti* (babesiosis), *Borrelia burgdorferi* senso lato (Lyme borreliosis), *Borrelia miyamotoi* (relapsing fever), deer tick virus (Powassan encephalitis), *F. tularensis* (tularemia), and possibly others (Durden and Keirans 1996; Sonenshine and Roe 2013).

***Ixodes sculptus* (Neumann 1904)**, the sculptured tick, has been reported from ground dwelling rodents and carnivores in Custer, Harding, Hyde, Jackson, and Brookings Counties (Easton 1983). Harris et al. (2014) has reported *I. sculptus* from black-footed ferrets (*Mustela nigripes*), and here we report them from swift foxes in Pennington County, SD (Maestas 2018). We additionally report *I. sculptus* from *I. tridecemlineatus, C. hispidus*, *P. maniculatus*, and *O. leucogaster* in Lyman County (L. Maestas unpublished). There are no known medical or veterinary associations with this tick.

***Ixodes spinipalpis* (Hadwen and Nuttall 1916)** has been reported from rodents in Lawrence, Custer and Fall River Counties, SD (Easton 1983). This species is not known to be of medical or veterinary importance, but is an important component in the sylvatic cycles of Lyme borreliosis (Maupin et al. 1994), and potentially Powassan virus (Durden and Kierans 1996; Keirans and Clifford 1983).

***Ixodes texanus* (Banks 1909)**, the raccoon tick, is a parasite of primarily carnivores, especially raccoons (*Procyon lotor* Linnaeus), and occasionally parasitizes humans and domestic animals (Durden and Kierans 1996). We recorded the first detection of *I. texanus* in South Dakota from swift foxes in Pennington County (Maestas 2018). There are no significant medical or veterinary associations of this tick, although there is circumstantial evidence that it could be a vector of raccoon babesiosis (Anderson et al. 1981). Additionally, Anderson et al. (1986) isolated *Rickettsia rickettsii* from an *I. texanus* nymph.

***Rhipicephalus sanguineus* (Latreille 1806)**, the brown dog tick, is a non-native tick that primarily is a specialist of dogs, though it will parasitize other animals, including humans (Occi et al. 2019). In South Dakota, only two records of *R. sanguineus* exist: from Beadle and Lake Counties (Nelson 1968; Nelson 1966). This dearth in detections has been suggested to be a product of the inability of this species to overwinter outdoors in South Dakota (Easton 1983). The brown dog tick is of considerable medical importance regionally, being involved in human cases of SFGR in the Southwestern US and in Central America (Demma et al. 2006) and is associated with various pathogens worldwide (Dantas-Torres et al. 2008).

***Some Commonly Reported Tick-borne Diseases of South Dakota*—**The most commonly reported tick-borne diseases in South Dakota are Lyme disease, RMSF, and tularemia (CDC 2017). The scope of literature concerning tick-borne diseases in South Dakota is severely restricted to case reports through the US Centers for Disease Control and Prevention and the state Public Health Department. Here we briefly discuss the ecology of these diseases and summarize the literature on tick-borne disease ecology in South Dakota. It is important to note that this list of diseases is not exhaustive, but focuses on the three most commonly reported tick-borne diseases in the state.

Lyme Disease

Lyme borreliosis (LB) is the most prevalent tick-borne disease in North America. Lyme disease is caused by the bacterial group *Borrelia burgdorferi* senso stricto and has recently also been attributed to *Borrelia mayonii* in North America (Pritt et al. 2016). It is one of the most increasingly recognized diseases and is the most common tick-borne disease in the Northern Hemisphere (AFPMB 2001). It occurs, in the US, at a 3-year average incidence of 8.7 cases per 100,000 in population (2008-2017); in South Dakota, there have been a total of 47 human Lyme disease cases reported from 2008-2017 (CDC 2017; Schwartz et al. 2017) with the greatest number of cases being reported in 2015-2017(South Dakota Department of Health 2017). Prior to the report of McDaniel and Hildreth (1992) and documentation of an established population by Maestas et al. (2016), *I. scapularis* was not thought to occur in SD, and LB was not expected outside of travel cases (Maestas et al. 2016; Huntington and Allison 2017). Maestas et al. (2018) have recently documented the first instance of *B. burgdorferi* senso stricto from a tick from SD.

Spotted Fever Group *Rickettsia*

Rocky Mountain spotted fever is a potentially fatal bacterial disease caused by *R. rickettsii*. It is the most severe rickettsial disease in humans (Demma et al. 2006) and just one member of the SFGR complex. There are a number of other tick-associated SFGR species whose status as pathogens is currently unknown (Mays et al. 2016), though recently emerging pathogens such as *R. parkeri* associated with *Amblyomma maculatum* (Koch) in coastal regions of the southern and southeast US are being recognized. Cross-reactivity of serological tests complicate medical diagnosis and distinction between RMSF and other SFGR, while the non-specificity of common PCR assays makes species-level identification of SFGR difficult without sequencing (Paddock et al. 2004; Mays et al. 2016). Three vectors of SFGR have been documented within the state: *A. americanum*, *Dermacentor andersoni*, and *D. variabilis* (Easton 1983; Springer et al. 2014). The earliest cases of RMSF in South Dakota were documented in 1915 (Wolbach 1919), and continue with a reported incidence of 2.3-6.6 human cases per million in population per year and a 5 year median (2014-2018) of 6 cases per year (CDC 2017; South Dakota Department of Health 2018). I found reports of only RMSF from the SFGR complex in South Dakota. In one study, SFGR was detected in nine percent of 100 immature *D. variabilis* from small mammals on the Lower Brule Indian Reservation (LOBR), Lyman County, SD; positive ticks were not sequenced (Maestas 2018; L. Maestas, Spilger, N., and Britten, H. unpublished).

Tularemia

Francisella tularensis is the bacterial agent of tularemia, a re-emergent zoonotic disease of varying pathogenicity (Petersen and Schriefer 2005). Two disease cycles of tularemia have been described, terrestrial (Type A) and aquatic (Type B), with the pathogen strain associated with aquatic cycles being less virulent; both types are present in SD (Staples et al. 2006). Ticks are thought to be the ecological drivers of tularemia, serving as both vector and reservoir for the causative agent *F. tularensis*. In the eastern US, *D. variabilis* is thought to be the main vector, whereas in the western US, tabanid flies and *D. andersoni* are thought to be the main vectors of tularemia (Friend 2006). Rabbits and rodents are considered the main reservoirs for tularemia (Farlow et al. 2005; Petersen et al. 2009); however, *F. tularensis* is highly virulent in lagomorphs and rodents, indicating that they may not be the true reservoirs (Friend 2006). In the US, long-term maintenance of tularemia is accomplished through maintenance cycles involving ticks, rodents, and rabbits, coupled with augmentation by tabanids. South Dakota reported a five-year median of 7 cases for the years of 2012-2016; though in 2015, there were 20 cases of tularemia reported in SD (South Dakota Department of Health). South Dakota is one of the top five states for incidence of tularemia in humans (0.84 reported cases per 100,000 persons/year from 2001-2010) (Morbidity and Mortality Report 2013)). In 2015, the mean number of tularemia cases experienced a 186% increase within SD (Morbidity and Mortality Report 2015). Tularemia outbreaks have been associated with *D. variabilis* in South Dakota (Saliba et al. 1966; Markowitz et al. 1985). Neither I, nor my technicians detected *F. tularensis* from 100 immature *D. variabilis* from small mammals in Lyman County, SD, in 2017 (L. Maestas unpublished).

CONCLUSIONS AND FUTURE DIRECTIONS

Within the state of South Dakota, 21 tick species (Table 1) have been documented (Keirans and Clifford 1978; Easton 1983; McDaniel and Hildreth 1992; Maestas et al. 2016). Included among the Ixodidae reported in South Dakota are

A. americanum, D. andersoni, *D. variabilis*, and *I. scapularis*, which are known to serve as reservoirs and vectors of several pathogens of wildlife and people. We found no evidence for the presence of any confirmed vectors of human disease among the records of the Argasidae of South Dakota (Anderson and Jones 1971; Wilson 1978; Easton 1983; Goodman et al. 2005; Sonenshine and Roe 2013).

The risk of tick-borne diseases to the people of South Dakota is apparent, with human cases of Lyme disease, RMSF, and tularemia being reported annually. The risk of potential encroachment by new tick and pathogen species remains high, especially in forested areas along rivers and streams where human recreational activities are at their peak. Few studies have been conducted within the state to survey for ticks and tick-borne pathogens. Surveillance for the presence of ticks and tick-borne disease is imperative for alerting the public, as well as physicians and veterinarians, within the state to the presence of these potential vectors. We recommend the development or extension of tick surveillance systems in the central lowland region of eastern South Dakota, particularly in the Couteau de Prairies region along the Minnesota River, and extending along the James River into the Missouri River Valley for the presence of both *I. scapularis* and *A. americanum*.

I revise the report of Easton (1983) to include the presence of three new tick species: *A. americanum* (Springer et al. 2014; Black and Britten 2019), *I. texanus* (established population) (Maestas 2018), and *I. scapularis* (established populations) (McDaniel and Hildreth 1992; Maestas et al. 2016; Black and Britten 2019). I report additional county and/or host records for *C. kelleyi, D. albipictius*, *D. variabilis, I. cookei*, and *I. kingii*, and *I. sculptus*. Some of these species may play a role in the sylvatic maintenance of tick-borne diseases. It must be noted that there have been other studies reporting on ticks in South Dakota, but without identification to species; some of these ticks are unavailable for review, e.g. Herreman (1937). Additionally, the incursion or expansion of new ticks into the state must be considered.

Here I use *I. scapularis* and *A. americanum* as a model for the spread of ticks. Maestas et al. (2018) suggest that influxes of ticks on wide-ranging hosts from neighboring states could lead to the establishment of tick populations in neighboring counties and states. In neighboring Minnesota, *I. scapularis* is widespread, but western and southwestern counties nearest to South Dakota were not predictive of suitable habitat, except in one model; and in Iowa the greatest number of established populations of *I. scapularis* are from far eastern counties (Hahn et al. 2016). Similarly, most reports of *I. scapularis* in Nebraska occur along its southeastern border (Hahn et al. 2016; NDHH 2019), following the Missouri river, which may act as a corridor similar to what is seen in the Ohio River Valley. Recent climatological changes have allowed for further expansion of tick populations into regions where they were not historically present (Ogden et al. 2008). Potential range expansion for *A. americanum* is further supported by Raghavan et al. (2019), with models predicting that with climatological shifts, populations *of A. americanum* will move into northern Nebraska and Iowa, closer to South Dakota. Additionally, *A. americanum* has been reported recently in two North Dakota counties, though it is also unclear whether these were locally acquired (Kuklok et al. 2017). The geographic range expansion of *A. americanum* to include neighboring Nebraska (Springer et al. 2014; Stromdahl et al. 2018) and

Iowa (Lingren et al. 2005) highlights the possibility for *A. americanum* range expansion in SD, and the necessity for establishing tick surveillance programs in the state.

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Table 1. Updated list of tick species reported or established in South Dakota with commonly associated diseases reported nation-wide and common hosts in South Dakota.

Tick Species	Family	Established/ Reported	Diseases of Concern	Host Species in South Dakota
Amblyomma americanum	Ixodidae	Established	Human monocytic ehrlichiosis, tularemia, spotted fever group rickettsiosis, Southern tick-associated rash illness	Unknown
Dermacentor albipictus	Ixodidae	Established	None known	Mule deer
Dermacentor andersoni	Ixodidae	Established	Colorado tick fever, tularemia, Rocky Mountain spotted fever, tick-borne paralysis	Small mammals, and humans
Dermacentor variabilis	Ixodidae	Established	Rocky Mountain spotted fever, ehrlichiosis, tularemia, tick-borne paralysis	Canids, small mammals, and humans
Haemaphysalis chordeilis	Ixodidae	Reported	None known	Sharp-tailed grouse
Haemaphysalis leporispalustris	Ixodidae	Reported	Tularemia	Rabbits
Ixodes angustus	Ixodidae	Reported	Potential Lyme Disease	Small mammals and oppossums

Ixodes cookei	Ixodidae	Reported	Powassan virus	Striped skunks, and small mammals
Ixodes eastoni	Ixodidae	Reported	Potential maintenance of Powassan virus, Colorado tick fever virus, and an unknown rickettsial agent	Small mammals
Ixodes kingi	Ixodidae	Established	Potentially involved in maintenance of Tularemia	Small mammals, black-footed ferrets, and foxes
Ixodes muris	Ixodidae	Reported	Babesiosis	Small mammals
Ixodes ochotonae	Ixodidae	Reported	None known	Pikas, and small mammals
Ixodes scapularis	Ixodidae	Established	Lyme borreliosis, tick paralysis, tularemia, babesiosis, anaplasmosis, Powassan virus, and relapsing fever	Dog, deer, and humans
Ixodes sculptus	Ixodidae	Established	None known	Rodents, black-footed ferrets, and foxes
Ixodes spinipalpis	Ixodidae	Established	Potentially Powassan virus, maintenance of Lyme borreliosis	Small mammals
Ixodes texanus	Ixodidae	Reported	Raccoon babesiosis, potentially involved in RMSF maintenance in nature	Swift fox
Rhipicephalus sanguineus	Ixodidae	Reported	Rocky Mountain spotted fever, Spotted fever group rickettsias	Dog
Argas cooleyi	Argasidae	Reported	None known	Cliff Swallows
Carios concanensis	Argasidae	Reported	None known	Birds
Carios kelleyi	Argasidae	Reported	None known	Bats
Otobius megnini	Argasidae	Reported	Physical irritation of animals, and potentially Q fever	Cattle