County Scale Distribution of *Amblyomma americanum* (Ixodida: Ixodidae) in Oklahoma: Addressing Local Deficits in Tick Maps Based on Passive Reporting

ANNE W. BARRETT,[1] BRUCE H. NODEN,[2] JEFF M. GRUNTMEIR,[1] TAYLOR HOLLAND,[1] JESSICA R. MITCHAM,[2] JACLYN E. MARTIN,[2] EILEEN M. JOHNSON[1] AND SUSAN E. LITTLE[1,3]

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ABSTRACT Geographic distribution records for the lone star tick [*Amblyomma americanum* (L.)] in the peer-reviewed literature are incomplete for Oklahoma, preventing accurate disease risk assessments. To address this issue and document the presence of *A. americanum* in available habitats throughout the state, county-scale tick records published in U.S. Department of Agriculture–Cooperative Economic Insect Reports and specimens maintained at the K.C. Emerson Entomology Museum, Oklahoma State University, were reviewed. In addition, dry ice traps and tick drags were used to collect adult and nymphal *A. americanum* from throughout the state. Review of published USDA reports and the local museum collection documented *A. americanum* in 49 total counties (35 and 35, respectively). Active surveillance efforts confirmed the presence of this tick in 50 counties from which this species had not been previously reported to be established, documenting *A. americanum* is established in 68 of the 77 (88.3%) counties in Oklahoma. Taken together, these data verify that *A. americanum* ticks are much more widespread in Oklahoma than reflected in the literature, a phenomenon likely repeated throughout the geographic range of this tick in the eastern half of North America.

KEY WORDS active surveillance, *Amblyomma americanum*, geographic distribution, lone star tick

Amblyomma americanum (L), the lone star tick, is the most common tick species found infesting humans and domestic animals in the southern United States (Felz et al. 1996, Kollars et al. 2000, Goddard 2002). Although *A. americanum* readily feeds on a number of different animals, white-tailed deer serve as the primary wildlife host for all life stages (Childs and Paddock 2003, Paddock and Yabsley 2007). Populations of lone star ticks are currently established throughout the majority of the eastern half of the United States, extending as far north as southwestern Maine, and are known to transmit multiple veterinary and human disease agents including *Rickettsia* spp., *Ehrlichia* spp., tularemia, Heartland virus, and *Cytauxzoon felis* (Paddock and Yabsley 2007, Jiang et al. 2010, McMullan et al. 2012). Accurate understanding of the geographic distribution of this tick is critical for developing useful risk assessments and appropriate control methods.

A recent publication summarized *A. americanum* populations throughout the United States on a county-scale using reports in the peer-reviewed literature and selected museum collections (Springer et al. 2014). In Oklahoma, only 17 counties were classified as having established populations of *A. americanum*, a finding most likely because of incomplete collection records based on passive surveillance. Active surveillance is known to be a more accurate means of documenting presence of both vectors and vector-borne disease agents (Springer et al. 2014). Indeed, a previous review of published data suggests that, compared with active surveillance, passive reporting underestimates the rate of *A. americanum*-transmitted human ehrlichiosis infections by ≥10-fold (Paddock and Childs 2003). Our objective for this study was to provide a more complete, accurate depiction of the distribution of *A. americanum* in Oklahoma.

Materials and Methods

***A. americanum* Records from Oklahoma.** To complement reports summarized from the peer-reviewed literature (Springer et al. 2014), we reviewed all issues of the U.S. Department of Agriculture's 1951–1974 (USDA) Cooperative Economic Insect Reports (CEIR), published weekly from January 1951

[1] Department of Veterinary Pathobiology, Center for Veterinary Health Sciences, Oklahoma State University, 250 McElroy Hall, Stillwater, OK 74078
[2] Department of Entomology and Plant Pathology, Oklahoma State University, College of Agricultural Sciences and Natural Resources, 127 Noble Research Center, Stillwater, OK 74078
[3] Corresponding author, email: Susan.little@okstate.edu

to December 1975 (USDA 2014). We further expanded our database by compiling *A. americanum* collection records of the specimens from the K. C. Emerson Entomology Museum, Oklahoma State University, which archives specimens collected from the 1940s to present.

Active Collection of *A. americanum*. Active tick surveillance was conducted in counties not known to have established populations of *A. americanum* based on the published peer-reviewed literature (Springer et al. 2014). Adult and nymphal stages of *A. americanum* were collected from March–July 2014 in wooded areas with substantial underbrush (Bishopp and Trembley 1945). Ticks were collected via standard dry ice trap and by dragging and flagging. Briefly, dry ice-baited cardboard and cloth squares, with masking tape around the perimeter (cardboard), were used to collect adult and nymphal *A. americanum* from the environment, as previously described (Lockhart et al. 1997, Savage et al. 2013). In addition, dragging (roughly 9 square feet of muslin cloth weighted at both ends) or flagging (36 × 27in flannel flags attached to poles) was used to collect questing adults and nymphs from leaf litter and small foliage. Ticks were identified by morphologic comparison to standard keys (Kierans and Litwak 1989, Kierans and Durden 1998).

Data Summation. Counties were classified as *A. americanum* established or *A. americanum* reported, as previously described (Dennis et al. 1998). Briefly, *A. americanum* was considered 1) established in a county if six or more ticks, or more than one life stage was collected or reported at one time period, or 2) reported in a county if less than six ticks, or only one life stage was collected at one time period. Counties described in the USDA-CEIR were considered to have established *A. americanum* if enumeration meeting the above standards was provided. Distribution maps of *A. americanum* in Oklahoma were plotted using MapViewer 7 (Golden Software, Inc. Golden, CO).

Results

The USDA-CEIR contain 354 county-scale references of *A. americanum* in Oklahoma (USDA 2014). Of these, 35 counties were mentioned as having *A. americanum* present on animals or in the environment, including 14 counties that were not included in the peer-reviewed literature (two established, 12 reported). The K. C. Emerson Entomology Museum, Oklahoma State University, also had specimens from 35 counties in Oklahoma dating from 1941–2012, 19 of which were not included in the peer-reviewed literature (six established, 13 reported). Active surveillance was completed in all 60 counties in Oklahoma where *A. americanum* was not reported as established (Springer et al. 2014). Of these, 50 (83.3%) had established populations of *A. americanum* that were not represented in the peer-reviewed literature (Table 1). In total, *A. americanum* ticks are established in 68 of the 77 (88.3%) Oklahoma counties (Fig. 1).

Discussion

Active surveillance for populations of *A. americanum* in Oklahoma revealed a fourfold increase in the number of counties with established lone star tick populations compared with that previously described in the peer-reviewed literature (68 vs. 17, respectively; Fig. 1). This change, although dramatic, was achieved using only a small team of trained personnel in a single tick collection season, and documents that *A. americanum* populations actually span most of the state (Fig. 1). The data in the present paper also indicate an apparent westward spread of *A. americanum* from its historic range (Childs and Paddock 2003). The far western counties were surveyed in late June and early July, after the peak activity time for adult *A. americanum* (Hair and Howell 1970, Davidson et al. 1994), a factor which may have prevented detection in some areas, particularly in the southwestern region of the state. Indeed, we suspect isolated populations of lone star ticks are likely present in this area. Although lack of precipitation and suitable habitat likely limit further expansion to the west, additional collection attempts using both dry ice and tick drags should be made in these western counties earlier in the year to more accurately ascertain the full extent of *A. americanum* populations in this region.

Distribution maps of *A. americanum* based on the peer-reviewed literature alone underestimated the distribution of this tick in Oklahoma. This shortcoming is likely true in other states as well because of underreporting inherent in passive surveillance methods (Paddock and Childs 2003, Springer et al. 2014). Even when active surveillance is used, tick distribution maps may underestimate the presence of ticks owing to variation in collection techniques and timing, seasonal phenology shifts in tick activity, and the different methods required to collect ticks from disparate habitats. Including historic USDA reports and a local museum collection improved, but did not completely correct, the deficiencies of reviewing only the literature and limited national collections. Applying active surveillance efforts similar to those used in the present study to other states where *A. americanum* and the infectious agents it transmits are common, such as Kansas, Missouri, Mississippi, Alabama, Georgia, western Texas, and northern Louisiana, could correct local and regional deficits in tick distribution maps that may contribute to underestimation of the public and veterinary health importance of tick-borne infections (Davidson et al. 1994, Burkot et al. 2001, Castellaw et al. 2010, Berrada et al. 2011, Brown et al. 2011, Cortinas and Spomer 2013, Leydet Jr and Liang 2013, Springer et al. 2014). Coordinating surveillance efforts across the United States and then providing these data at a national level would be useful, particularly if passive and active data could be combined. Accurate distribution maps for *A. americanum* will be increasingly important as lone star ticks continue to expand their range and the repertoire of infections known to be transmitted by this tick, and thus the need for surveillance efforts, grows.

Table 1. Counties in Oklahoma where *A. americanum* are established [or reported]

Counties	Peer-reviewed literature[a] no. of references	National museum records[a] no. of records	VectorMap[a] no. of records	USDA-CEIR no. of reports	K.C. Emerson Entomology Museum No. of ticks	Active collection in 2014 no. of ticks	Current status of county
Adair	5	0	0	[2]	0	ND	Established
Alfalfa	0	0	0	0	0	>6A, >6N	Established
Atoka	1	2	0	23	>6A	ND	Established
Beaver	0	0	0	0	0	0	
Beckham	0	0	0	0	0	0	
Blaine	0	0	0	0	0	>6A, >6N	Established
Bryan	2	2	0	[6]	0	ND	Established
Caddo	0	0	0	0	0	>6A, >6N	Established
Canadian	0	0	0	0	[1A]	>6A, >6N	Established
Carter	1	2	0	[1]	[1A]	ND	Established
Cherokee	74	8	1	61	>6A, >6N	ND	Established
Choctaw	1	2	0	[24]	0	ND	Established
Cimarron	0	0	0	0	0	0	
Cleveland	0	0	0	[1]	1A, 1N	>6A, >6N	Established
Coal	0	0	0	[3]	0	>6A, >6N	Established
Comanche	2	2	16	[1]	0	ND	Established
Cotton	0	0	0	0	0	6A, 2N	Established
Craig	0	0	0	[1]	2A, 3N	>6A, >6N	Established
Creek	[1]	0	0	0	3A, 2N	>6A, >6N	Established
Custer	0	0	0	0	0	6A, 1N	Established
Delaware	[1]	0	2	[3]	10N	>6A	Established
Dewey	0	0	0	0	0	5A, 1N	Established
Ellis	0	0	0	0	0	0	
Garfield	[1]	0	1	0	0	>6A, 3N	Established
Garvin	0	0	0	0	0	>6A, 1N	Established
Grady	0	0	0	0	[1A]	>6A, >6N	Established
Grant	[1]	0	0	0	0	>6A, >6N	Established
Greer	0	0	0	0	0	0	
Harmon	0	0	0	0	0	>6A, 6N	Established
Harper	0	0	0	0	0	0	
Haskell	[1]	0	0	[11]	0	>6A, >6N	Established
Hughes	0	0	1	[3]	0	>6A, 1N	Established
Jackson	0	1	2	0	0	1A, 1N	Established
Jefferson	0	0	0	0	0	>6A	Established
Johnston	0	1	0	6	1A, 1N	ND	Established
Kay	[1]	0	0	0	2A, 1N, 1L	>6A, >6N	Established
Kingfisher	0	0	0	0	[1A]	5A, 3N	Established
Kiowa	0	0	0	0	0	0	
Latimer	3	0	0	12	0	ND	Established
Le Flore	46	1	0	[7]	1A, 1N	ND	Established
Lincoln	[1]	0	0	[1]	>6A	>6A, >6N	Established
Logan	[1]	0	0	0	0	>6A, 1N	Established
Love	0	0	0	1	0	5A, 1N	Established
Major	0	0	0	0	0	3A, 4N	Established
Marshall	0	1	0	[12]	[1A]	>6A, 1N	Established
Mayes	[1]	0	0	24	>6A, >6N	>6A, >6N	Established
McClain	0	0	0	0	0	>6A	Established
McCurtain	5	17	0	31	>6A, 1N	ND	Established
McIntosh	8	0	0	[1]	0	ND	Established
Murray	[1]	0	0	[1]	0	>6A, 5N	Established
Muskogee	8	5	1	22	0	ND	Established
Noble	0	0	0	0	4A, 2N, 2L	>6A	Established
Nowata	0	0	0	0	[1A]	1A, 2N	Established
Okfuskee	0	0	0	[1]	0	>6A, 6N	Established
Oklahoma	1	0	1	0	>6A, >6N, 7L	ND	Established
Okmulgee	0	0	0	0	[2A]	>6A, >6N	Established
Osage	2	0	0	0	[2A]	ND	Established
Ottawa	0	0	0	[1]	[1A]	>6A, >6N	Established
Pawnee	0	0	0	[1]	[2A]	>6A	Established
Payne	14	0	0	[6]	>6A, >6N, >6L	ND	Established
Pittsburg	7	2	14	[8]	5A, 2N	ND	Established
Pontotoc	0	1	0	[6]	0	>6A, >6N	Established
Pottawatomie	0	1	0	0	0	>6A	Established
Pushmataha	[2]	0	0	59	2A, 3L	>6A, 3N	Established
Roger Mills	0	0	0	0	0	1A, 1N	Established
Rogers	0	0	0	0	[2A]	>6A	Established
Seminole	0	0	0	0	[2A]	>6A, >6N	Established
Sequoyah	[2]	0	1	9	>6A	5A, 1N	Established

(*Continued*)

Table 1. (continued)

Counties	Peer-reviewed literature[a] no. of references	National museum records[a] no. of records	VectorMap[a] no. of records	USDA-CEIR no. of reports	K.C. Emerson Entomology Museum No. of ticks	Active collection in 2014 no. of ticks	Current status of county
Stephens	0	0	0	[1]	[2A]	5A, 1N	Established
Texas	0	0	0	0	0	0	
Tillman	0	0	0	0	0	1A, 1N	Established
Tulsa	0	1	0	0	[2N]	>6A, >6N	Established
Wagoner	0	0	0	[3]	[5A]	>6A, >6N	Established
Washington	0	0	0	[1]	3A, 1N	5A, 5N	Established
Washita	0	0	0	0	0	>6A, >6N	Established
Woods	0	0	0	0	>6A	0	Established
Woodward	0	0	0	0	0	0	
Total Established	17	0	0	10	20	50	68
Total Reported	18	16	10	25	15	0	0

[a] As summarized in Springer et al. 2014.
A, adult ticks; N, nymphal ticks; L, larval ticks; ND, not determined.

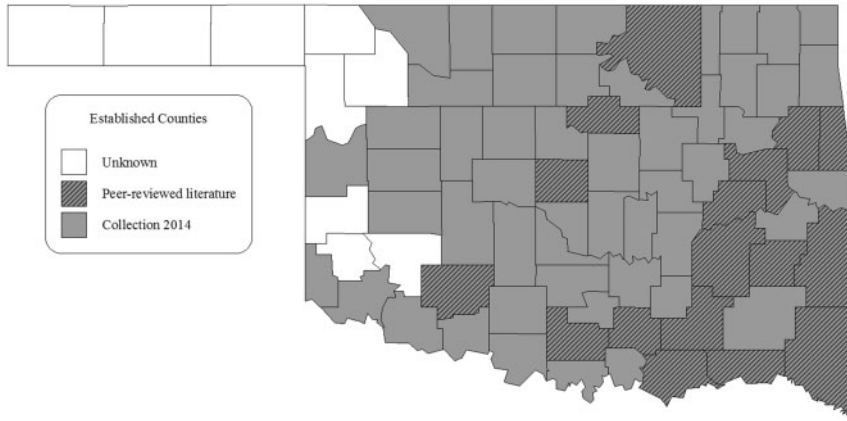

Fig. 1. Map of counties in Oklahoma where *Amblyomma americanum* are established based on summary of the peer-reviewed literature and surveillance completed in the present paper.

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