Check List the journal of biodiversity data

LISTS OF SPECIES

Check List 12(4): 1935, 29 July 2016 doi: http://dx.doi.org/10.15560/12.4.1935
ISSN 1809-127X

A checklist and assemblage comparison of ants (Hymenoptera: Formicidae) from the Wichita Mountains Wildlife Refuge in Oklahoma

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Abstract: We present a checklist of 47 ant species (Hymenoptera: Formicidae) from the Wichita Mountains Wildlife Refuge in Oklahoma, USA. Surveys conducted in 2015 recaptured 67% of all historically collected species and add 12 new county records including the new state records of *Pheidole tetra* and *Solenopsis aurea*. We demonstrate the importance of sampling multiple habitats for species inventories as forests and grasslands contained compositionally unique ant assemblages. We also report an absence of the invasive red imported fire ant, *Solenopsis invicta,* at all sampling locations despite its occupation of the surrounding area and the southern half of the state. Combined, these results highlight the importance of protected land in conserving regional fauna and add to our understanding of the biodiversity in Oklahoma.

Key words: biodiversity; Central Great Plains; conservation; native species

INTRODUCTION

The state of Oklahoma is at the crossroads of numerous ecoregions with diverse biotas (Bruner 1931; Hoagland 2000). While most of the area is made up of the Central Great Plains, anthropogenic sources have converted large portions of this once lush grassland to row crop agriculture (Pogue and Schnell 2001; Drummond et al. 2012; Sohl et al. 2012). As a result, over 15% of Oklahoma is now considered cropland (Diamond and Elliot 2015), which is worrisome given that native species richness has been shown to decrease in agriculturally dominated areas (Matson et al. 1997; Krebs et al. 1999; Hendrickx et al. 2007). To combat these changes, government agencies such as the United States Fish and Wildlife Service have created programs to protect the environment for future generations.

One such program built to conserve, manage, and if needed, restore the native flora and fauna of designated areas across the United States is the National Wildlife Refuge System. Created in the early 1900s, this system now exists in all 50 states and US territories (Meretsky et al. 2006). Oklahoma hosts nine refuges including the Wichita Mountains Wildlife Refuge (hereafter WMWR) located in the southwestern part of the state. At the WMWR, species lists exist for amphibians, birds, mammals, plants, and reptiles. Yet an updated list for one notable taxon, ants (Hymenoptera: Formicidae), is missing.

Ants are abundant, diverse, and ecologically important (Lach et al. 2010). From forests to grasslands, ants are ecosystem engineers (Del Toro et al. 2012), nomadic armies (Kaspari and O'Donnell 2003), and devastating invasive species (Tschinkel 2006; Holway et al. 2002). They are organized into a variety of castes that contain a range of phenotypes that differ in body size, life span, societal role, and reproductive output (Hölldobler and Wilson 1990). Compiled species lists (Smith 1935; Young and Howell 1964; Smith 1979; Wheeler and Wheeler 1989; Albrecht 1995) and data from the Global Ant Biodiversity Informatics Project (GABI 2016) report between 87–125 native species for the state of Oklahoma. However, only thirty of these species have been previously collected at the WMWR (Wheeler and Wheeler 1989).

Here we present the first updated species list of ants from the WMWR in 25 years. As major taxonomic revisions at the species and genus level have occurred during this time (Bolton 1995; Bolton et al. 2006), we have updated the nomenclature of previous records. Furthermore, since the mid-1980s, the invasive red imported fire ant, *Solenopsis invicta* Buren 1972, was reported from the neighbouring town of Lawton, Oklahoma causing concern about their possible spread

into the WMWR. As most of the previous species records occur prior to this invasion, we systematically resurveyed ants in the WMWR during the summer and fall months of 2015. In doing so, we (1) recaptured 67% of previously collected ant species, (2) add 12 new county and two new state locality records, (3) highlight the importance of sampling multiple habitat types, and (4) report an absence of *S. invicta* at all of our surveyed locations.

MATERIALS AND METHODS

Study site

The WMWR contains 59,020 acres of protected land located in the southwestern portion of Oklahoma (Figure 1). Within this area, there are over 806 plant, 240 bird, 55 reptile, 50 mammal, 36 fish, and 19 amphibian species (WMWR Species Lists 2016). The flora is primarily mixed grass prairie with forest fragments in the middle of an igneous rock formation (Chase et al. 1956). Woody vegetation is dominated by eastern redcedar (*Juniperus virginiana* L.), American elm (*Ulmus americana* L.), netleaf hackberry (*Celtis reticulate* (Torr.) L.D. Benson), sugar maple (*Acer saccharum* Marshall), pecan (*Carya illinoinensis* (Wangenh.) K. Koch), blackjack oak (*Quercus marilandica* Münchh.), and post oak (*Quercus stellata* Wangenh.) (Buck 1964; Diamond and Elliot 2015). The climate is variable with an average coldest month minimum temperature of –3.28°C (January), an average warmest month maximum temperature of 35.33°C (July), and a mean annual precipitation of 806.45 mm (OCS 2016).

Data collection

We surveyed ants at fifteen locations across the WMWR from May to September 2015 (Table 1). At 10 sites that were spaced approximately 2.5 km apart along the latitudinal median of the WMWR, we set out 20 pitfall traps spaced 10 m apart along a 200-m transect oriented in a north to south direction for three days. Pitfall traps were 50 ml centrifuge tubes filled with a solution of propylene glycol, ethanol, and fragrance-free detergent. We also opportunistically collected ants by hand and when appropriate, extracted ants from leaf litter using a Winkler sifter (Bioquip Products, CA, USA) to generate the overall species list.

Specimens were identified using taxonomic references found in Creighton (1950), DuBois (1986), Fisher and Cover (2007), Kallal and LaPolla (2012), Mackay and

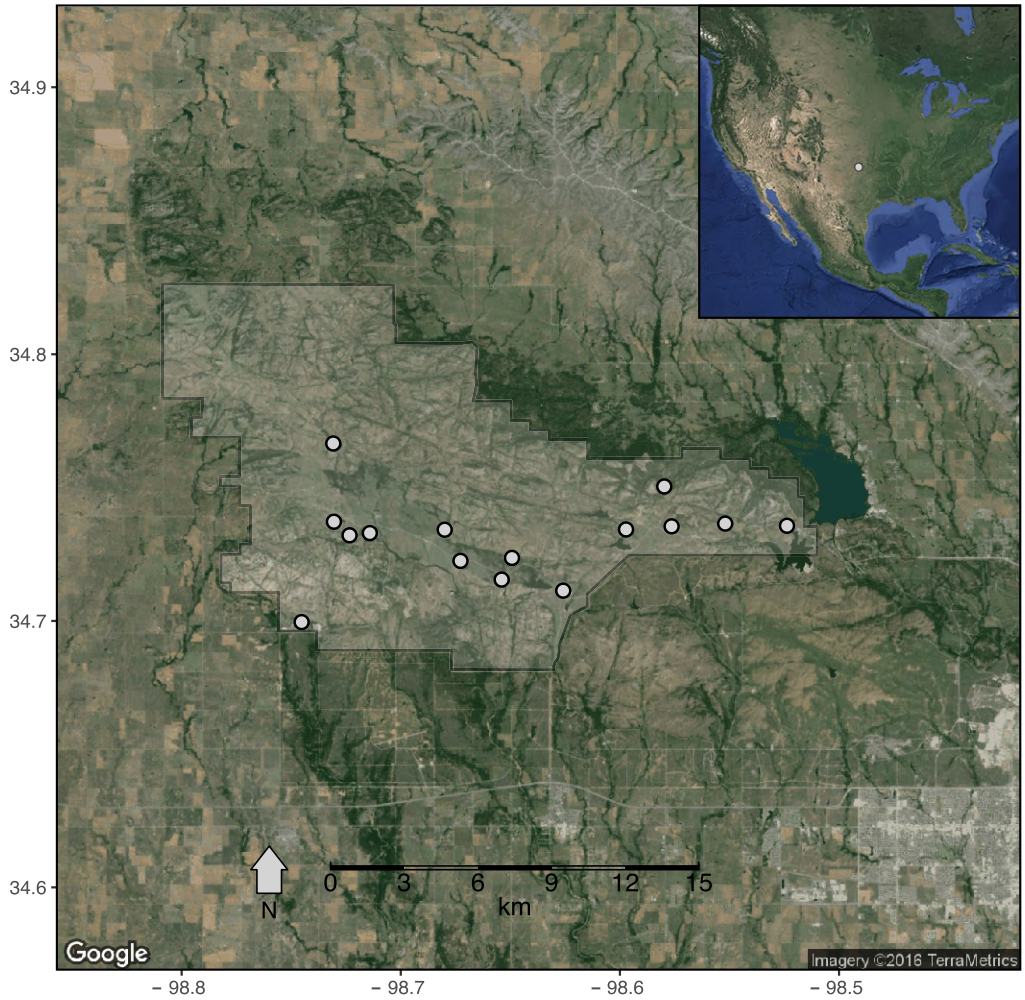

Figure 1. Map of the Wichita Mountains Wildlife Refuge. The fifteen sampling locations are denoted by grey points. The inset shows the location of the refuge in North America.

Table 1. Sampling locations at the Wichita Mountains Wildlife Refuge. The closest landmark is listed as location with latitude and longitude coordinates in decimal degrees and elevation in meters for the actual site of collection. Habitat is classified as grassland (absence of woody vegetation) or forest (presence of woody vegetation) and collection method is listed as H = hand, P = pitfall, or W = Winkler Sifter.

Location	Latitude	Longitude	Elevation	Habitat	Method
Apache Lake	34.7342°	-098.6800°	486 m	Forest	H,P,W
Buford Lake	34.7226°	-098.6727°	457 m	Grassland	H
Caddo Lake	34.7372°	-098.7305°	552 m	Grassland	H,P
Comanche Lake	34.7666°	-098.7308°	572 m	Grassland	H
Elmer Thomas Lake	34.7357°	-098.5237°	436 m	Grassland	H,P
Holy City	34.7355°	-098.5764°	496 m	Grassland	H,P
Jed Johnson Lake	34.7343°	-098.5972°	502 m	Forest	H,P,W
Job Corps Center	34.6996°	-098.7452°	453 m	Forest	H,P,W
Osage Lake	34.7155°	-098.6539°	464 m	Forest	H,W
Parallel Forest	34.7504°	-098.5798°	489 m	Forest	H
Quanah Parker Lake	34.7237°	-098.6492°	468 m	Forest	H,P,W
Quetone Point	34.7365°	-098.5519°	476 m	Grassland	H,P
Refuge Headquarters	34.7330°	-098.7141°	518 m	Forest	H,P,W
Sunset Park	34.7321°	-098.7234°	514 m	Forest	H
Visitor Center	34.7114°	-098.6259°	456 m	Grassland	H,P

Mackay (2002), Rabeling et al. (2007), Snelling (1995), Snelling and Snelling (2007), Taber (1998), Trager (1991), Trager et al. (2007), Ward (2005) and Wilson (1955, 2003) with nomenclature changes implemented to follow Bolton's New Catalogue of Ants (2006). Digital color images of new distributional records were taken using a Leica EC3 digital camera mounted on a Leica S8 APO stereo microscope with FireCam software version 3.4.1 (Leica Microsystems Inc., Wetzlar, Germany). Images were compiled using Helicon Focus version 4.2.7 (Helicon Soft Ltd.) with scale bars added in Adobe Photoshop CS3 version 10.0.1 (Adobe Systems Inc., San Jose, CA, USA). All samples were collected in accordance with Wichita Mountains Wildlife Refuge Research and Monitoring Special Use Permit #21670–15–046 issued to Karl A. Roeder. Voucher specimens are deposited in the K. A. Roeder collection and duplicates, when available, will be deposited in the Sam Noble Oklahoma Museum of Natural History.

Data analysis

For each pitfall transect, Chao2 sample-based rarefaction was used to estimate if sampling had gone to completion after 100 randomizations in the program EstimateS 9.1.0. Transects were categorized as forest or grassland based on the presence or absence of woody vegetation, and compared using the inverse Simpson diversity index. We then assessed compositional differences of the ten ant assemblages using non-metric multidimensional scaling (NMDS) with a Bray-Curtis dissimilarity as the distance parameter in the R package 'vegan'.

RESULTS

Ecological surveys

A total of 4428 individuals from 25 species were collected in the 10 pitfall transects. Abundance (N) and species richness (S) varied across traps (N_{range} = 0 to 352; S_{range} = 0 to 8) and transects (N_{range} = 79 to 1735; S_{range} = 6 to 11). Chao2 estimates suggest that pitfall sampling had approached completion at all but one of the sites (Figures 2–5). At the Job Corps Center, an asymptote was not reached as single individuals were observed for the species: *Aphaenogaster texana* Wheeler 1915, *Forelius pruinosus* (Roger 1863), *Nylanderia terricola* (Buckley 1866), *and Prenolepis imparis* (Say 1836). For *P. imparis* this may have been an artifact of temporal sampling as the species only appears above ground in the cooler months (Tschinkel 1987), and the Job Corps Center was the last sampled transect. Moreover, *P. imparis* was hand collected throughout the WMWR in September at locations where it had not been previously observed during May, June, or July.

Estimates of the inverse Simpson index (D) suggest that forest sites were more diverse than grassland sites (Inverse Simpson Index: D_{Forest} = 3.71 ± 0.59; $D_{Grassland}$ = 2.46 ± 0.42) primarily due to a lower mean abundance (N_{forest} = 293.4 ± 97.3; $N_{grassland}$ = 592.2 ± 296.3) and higher mean species richness (S_{forest} = 9.8 ± 0.4; $S_{grassland}$ = 7.8 ± 0.7). Additionally, sites clustered according to habitat type in NMDS ordination space (Figure 6) because 16 of the 25 collected species were exclusively observed in either forests or grasslands. Of these, the majority were unique to forests (S_{forest} = 11; $S_{grassland}$ = 5). These results combined with hand collecting and Winkler sifting resulted in 37 collected ant species at the WMWR during the summer and fall months of 2015 (Table 2; *see Taxon information portion*).

Taxon information

Aphaenogaster fulva Roger, 1863

Aphaenogaster fulva Roger (1863): 190. — Mayr (1886b): 445.
Aphaenogaster fulva var. *rubida* Enzmann (1947): 147. — Brown (1949): 49.

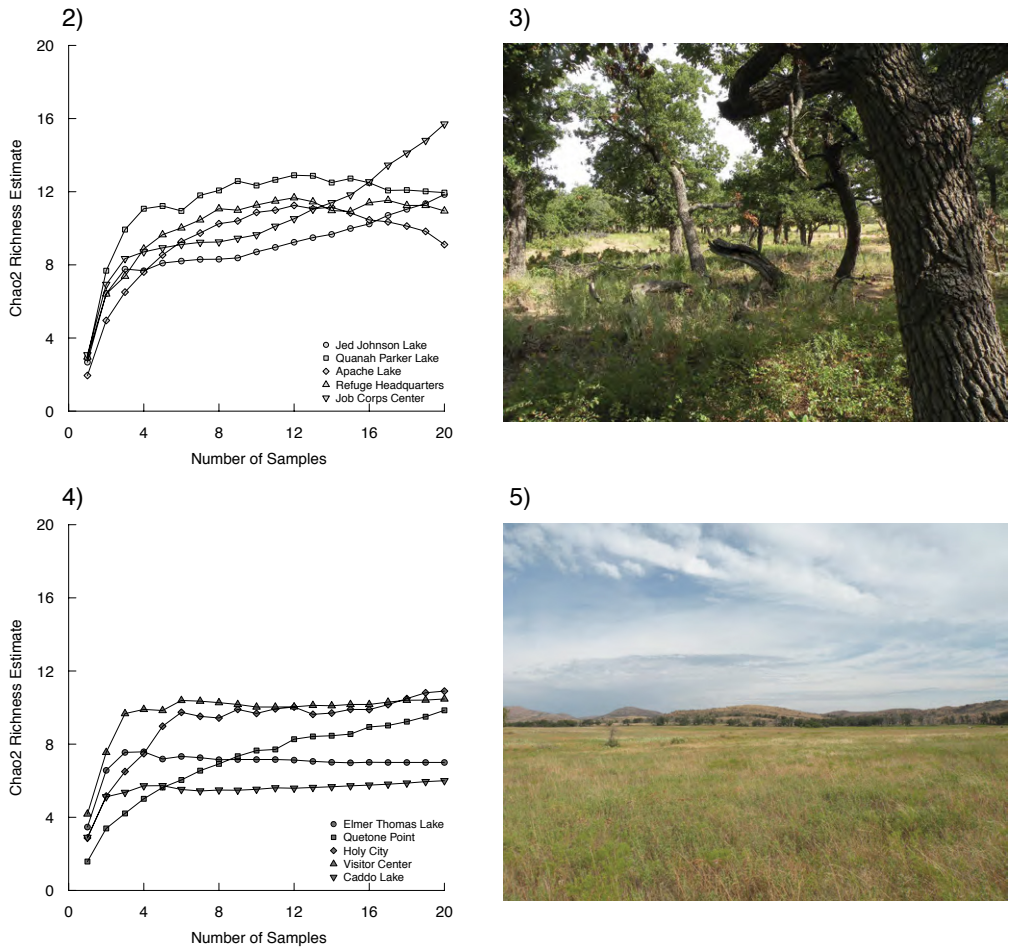

Figure 2–5. Sample-based rarefaction of ant richness in different habitat types. **2:** Chao2 estimates of forest sites. **3:** Oak forest at Quanah Parker Lake. **4:** Chao2 estimates of grassland sites. **5:** Mixed-grass prairie at the Holy City.

Material examined: KAR155; Figure 7; Table 2.

Coloration is variable. An abruptly raised mesonotum with an elevated anterior edge separates this species from many others found in the genus *Aphaenogaster* (Mackay and Mackay 2002). Specimens were found in only one location, the leaf litter at Osage Lake, potentially as a host for the parasitic *Aphaenogaster tennesseensis*.

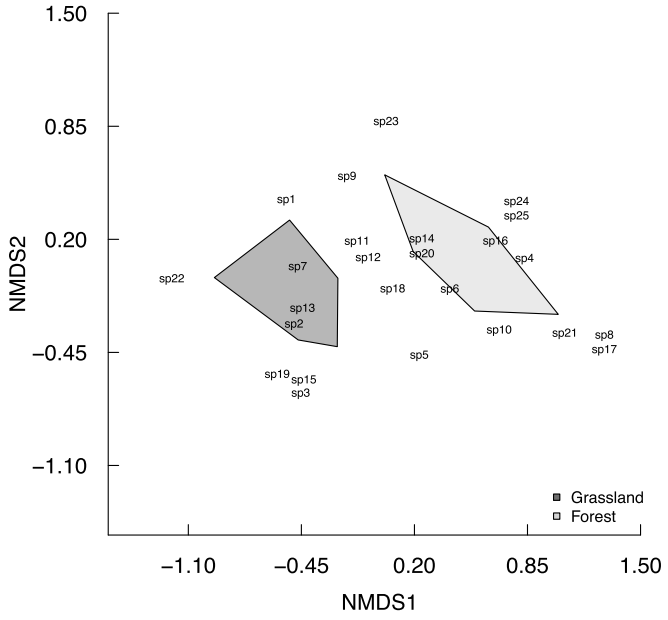

Figure 6. Non-metric multidimensional scaling (NMDS) ordination of the different ant assemblages from the pitfall transects. Sites of similar habitat are grouped using convex hulls.

Aphaenogaster tennesseensis (Mayr, 1862)

Atta tennesseensis Mayr (1862): 743. — Wheeler and Wheeler (1953c): 61.

Myrmica subrubra Buckley (1867): 336. — Mayr (1886b): 365.

Stenamma (*Aphaenogaster*) *tennesseense* var. *ecalcaratum* Emery (1895): 301. — Creighton (1950): 151.

Material examined: KAR156; Figure 8; Table 2.

Workers are red and heavy bodied. A diagnostic trait of this species is its long, curved propodeal spines. Specimens were collected at only one location, Osage Lake, and may have been parasitizing a colony of *Aphaenogaster fulva* that was collected in the same leaf litter sample.

Aphaenogaster texana Wheeler, 1915

Aphaenogaster texana Wheeler (1915): 412. — Wheeler and Wheeler (1953c): 62.

Aphaenogaster (*Deromyrma*) *silvestrii* Menozzi (1929): 282. — Creighton (1950): 152.

Material examined: KAR157; Figure 9; Table 2.

Coloration is brown. Head is elongate, and approximately one-third longer than broad with coarse rugae

Table 2. Checklist of native ants for Comanche County and the Wichita Mountains Wildlife Refuge (WMWR). Legend: – = absent, x = present, * = new county record, ** = new state record.

Taxa	Comanche County	WMWR	WMWR (2015 survey)	Voucher number
Dolichoderinae				
Dorymyrmex flavus McCook, 1879	x	x	x	KAR141
Dorymyrmex insanus (Buckley, 1866)	x	x	-	-
Forelius mccooki (McCook, 1879)	x	x	x	KAR142
Forelius pruinosus (Roger, 1863)	x	x	x	KAR143
Tapinoma sessile (Say, 1836)	x	x	x*	KAR144
Ecitoninae				
Neivamyrmex nigrescens (Cresson, 1872)	x	x	x	KAR145
Neivamyrmex punctaticeps (Emery, 1894)	x	-	-	-
Formicinae				
Brachymyrmex depilis Emery, 1893	x	x	x*	KAR146
Camponotus americanus Mayr, 1862	x	x	x	KAR147; KAR150
Camponotus decipiens Emery, 1893	x	x	x	KAR148
Camponotus discolor (Buckley, 1866)	x	-	-	-
Camponotus nearcticus Emery, 1893	x	-	-	-
Camponotus pennsylvanicus (De Geer, 1773)	x	x	x	KAR149
Camponotus semitestaceus Snelling, 1970	x	x	-	-
Formica dolosa Buren, 1944	x	x	-	-
Formica pallidefulva Latreille, 1802	x	x	x	KAR151
Lasius interjectus Mayr, 1866	x	x	-	-
Lasius latipes (Walsh, 1863)	x	x	-	-
Lasius neoniger Emery, 1893	x	x	x	KAR152
Myrmecocystus melliger Forel, 1886	x	x	-	-
Nylanderia terricola (Buckley, 1866)	x	x	x*	KAR153
Prenolepis imparis (Say, 1836)	x	x	x	KAR154
Myrmecinae				
Aphaenogaster fulva Roger, 1863	x	x	x*	KAR155
Aphaenogaster tennesseensis (Mayr, 1862)	x	x	x*	KAR156
Aphaenogaster texana Wheeler, 1915	x	x	x*	KAR157
Aphaenogaster tretae Forel, 1886	x	x	-	-
Carebara longii (Wheeler, 1903)	x	-	-	-
Crematogaster laeviuscula Mayr, 1870	x	x	x	KAR158
Crematogaster lineolata (Say, 1836)	x	x	x	KAR159
Crematogaster minutissima missuriensis Emery, 1895	x	x	x	KAR160
Monomorium minimum (Buckley, 1867)	x	x	x	KAR161
Myrmecina americana Emery, 1895	x	x	x*	KAR162
Pheidole bicarinata Mayr, 1870	x	x	x	KAR163; KAR164
Pheidole cockerelli Wheeler, 1908	x	x	x*	KAR165; KAR166
Pheidole dentata Mayr, 1886	x	x	x	KAR167; KAR168
Pheidole hyatti Emery, 1895	x	x	x	KAR169; KAR170
Pheidole pilifera (Roger, 1863)	x	x	x*	KAR171; KAR172
Pheidole soritis Wheeler, 1908	x	x	x	KAR173; KAR174
Pheidole tetra Creighton, 1950	x	x	x**	KAR175; KAR176
Pheidole sp. 1	x	x	x	KAR177
Pogonomyrmex barbatus (Smith, 1858)	x	x	x	KAR178
Pogonomyrmex desertorum Wheeler, 1902	x	x	-	-
Pogonomyrmex imberbiculus Wheeler, 1902	x	x	-	-
Solenopsis aurea Wheeler, 1906	x	x	x**	KAR179
Solenopsis molesta (Say, 1836)	x	x	x*	KAR180
Solenopsis xyloni McCook, 1879	x	x	x	KAR181
Temnothorax pergandei (Emery, 1895)	x	x	x	KAR182
Temnothorax schaumii (Roger, 1863)	x	x	x	KAR183
Temnothorax texanus (Wheeler, 1903)	x	x	-	-
Trachmyrmex septentrionalis (McCook, 1881)	x	x	x	KAR184
Ponerinae				
Hypoponera opacior (Forel, 1893)	x	x	x	KAR185
Species richness	51	47	37	

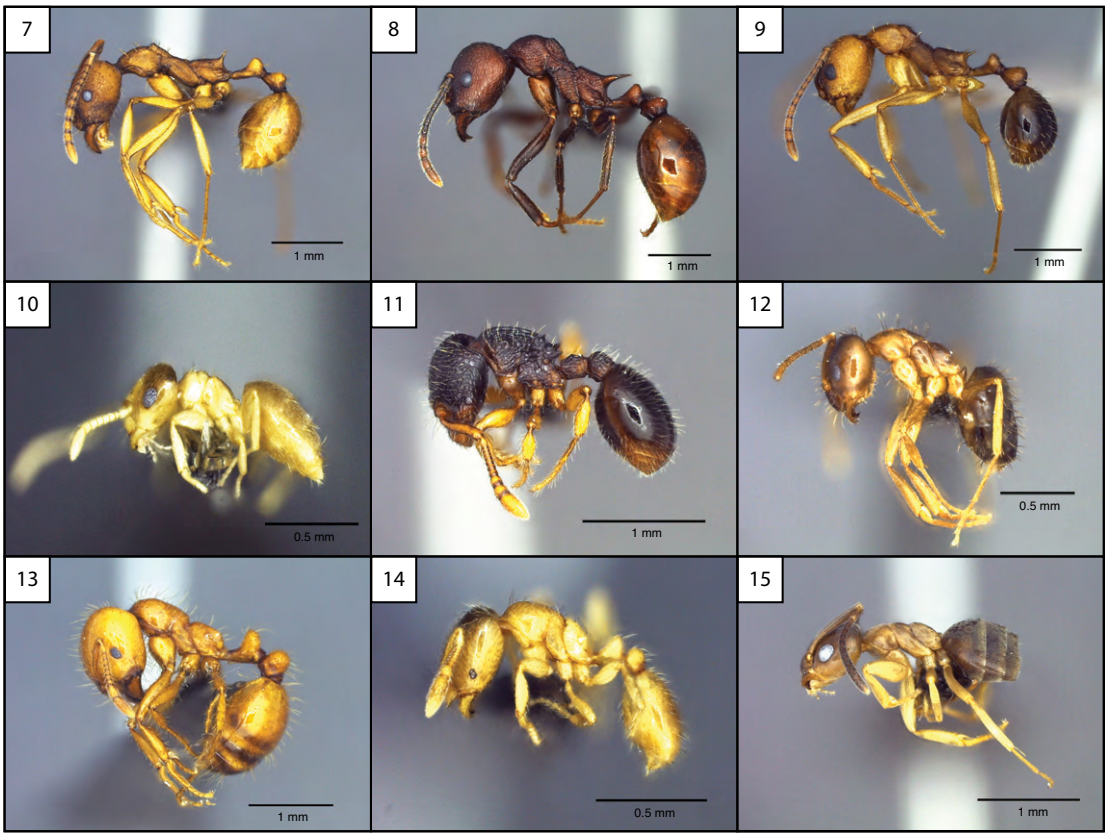

Figure 7–15. Photographs of ants with new distributional records at the Wichita Mountain Wildlife Refuge. **7:** *Aphaenogaster fulva.* **8:** *Aphaenogaster tennesseensis.* **9:** *Aphaenogaster texana.* **10:** *Brachymyrmex depilis.* **11:** *Myrmecina americana.* **12:** *Nylanderia terricola.* **13:** *Solenopsis aurea.* **14:** *Solenopsis molesta.* **15:** *Tapinoma sessile.*

on the dorsum (Mackay and Mackay 2002). Specimens were collected in the leaf litter of an Oak forest at the Job Corps Center.

Brachymyrmex depilis Emery, 1893

Brachymyrmex heeri subsp. *depilis* Emery (1893): 635. — Wheeler and Wheeler (1953a): 139.
Brachymyrmex nanellus Wheeler (1903a): 102. — Creighton (1950): 359.
Brachymyrmex depilis subsp. *flavescens* Grundmann (1952): 117. — Cole (1953): 266.

Material examined: KAR146; Figure 10; Table 2.

A minute species, coloration yellowish brown. Members of this genus are easily distinguished from other formicines by their 9-segmented antennae (Mackay and Mackay 2002). Specimens were collected in Winkler samples from leaf litter at Osage Lake.

Camponotus americanus Mayr, 1862

Camponotus americanus Mayr (1862): 661. — Emery (1893): 674; Wheeler and Wheeler (1968): 216.
Camponotus castaneus st. *rufinasis* Santschi (1936): 204. — Creighton (1950): 365.

Material examined: KAR147 and KAR150; Table 2.

While variable in color, specimens are generally yellow to brown with a black head. Nests were found in rotting logs or stumps. This species was collected at four of the five forest pitfall transects and Sunset Park. A large colony was found at the Refuge Headquarters at the base of a dead tree and contained a large number of major workers.

Camponotus decipiens Emery, 1893

Camponotus marginatus var. *decipiens* Emery (1893): 676. — Wheeler (1910): 227.
Camponotus fallax subsp. *rasilis* Wheeler (1910): 227. — Snelling (1988): 66.

Material examined: KAR148; Table 2.

Coloration is generally red to brown with a black gaster. Specimens of this species were collected by hand on trees at Jed Johnson Lake and the Refuge Headquarters.

Camponotus pennsylvanicus (De Geer, 1773)

Formica penslyvanica De Geer (1773): 603. — Wheeler and Wheeler (1953b): 187.
Camponotus herculeanus var. *herculeanopennsylvanicus* Forel (1879): 57. — Creighton (1950): 367.

Material examined: KAR149; Table 2.

A common, large black ant that is found in the eastern United States. Long, erect hairs are abundant on the gaster. While observed in various forest locations across the WMWR, only one of our forest pitfall transects, Apache Lake, contained workers from this species.

Crematogaster laeviuscula Mayr, 1870

Crematogaster laeviuscula Mayr (1870): 993. — Wheeler (1908): 480; Petralia and Vinson (1980): 383.

Ocecodoma (*Atta*) *arborea* Buckley (1867): 349. — Smith (1951): 809.
Crematogaster clara Mayr (1870): 993. — Creighton (1950): 210; Johnson (1988): 322.

Material examined: KAR158; Table 2.

Workers have a smooth and shining red body with a black gaster. Propodeal spines are well developed and the dorsum of the pronotum is finely sculptured (Mackay and Mackay 2002). Workers were collected by hand and in a pitfall trap at two oak forests: Sunset Park and Jed Johnson Lake.

Crematogaster lineolata (Say, 1836)
Myrmeica lineolata Say (1836): 290. — Wheeler and Wheeler (1952): 250.
Myrmica (*Monomorium*) *columbiana* Buckley (1867): 340. — Mayr (1886b): 462.
Myrmica (*Monomorium*) *marylandica* Buckley (1867): 339. — Mayr (1886b): 462.
Myrmica novaeboracensis Buckley (1867): 337. — Mayr (1886b): 462.

Material examined: KAR159; Table 2.

Rather dull in appearance with dark red to blackish coloration. Hairs are present on the dorsal portion of the pronotum, mesonotum, and propodeum, and with rough sculpturing on the lateral portion of the mesosoma. Abundant and present at all transects except Quanah Parker Lake. This species reached especially high numbers in grasslands in the interior of the refuge, such as the Visitor Center.

Crematogaster minutissima missuriensis Emery, 1895
Crematogaster victima subsp. *missuriensis* Emery (1895): 287. — Wheeler and Wheeler (1952): 260.

Material examined: KAR160; Table 2.

Light yellow in appearance with dark-edged terminal tergites. Compared to the other *Crematogaster* collected, this species appears less robust and has shorter propodeal spines. Behaviorally, individuals seem timid and dominated by *Pheidole* at baits. This species is currently a subspecies of *Crematogaster minutissima* (Creighton 1950). Collected in three of the five grassland transects as well as by hand at Sunset Park.

Dorymyrmex flavus McCook, 1879
Dorymyrmex flavus McCook (1879): 188. — Cockendolpher and Franke (1984): 349; Johnson (1989): 190; Snelling (1995): 5.

Material examined: KAR141; Table 2.

Pale yellow to brown with a slightly darker head compared to their body. The propodeum has a single vertical tooth (Fisher and Cover 2007) distinguishing this genus from others in the Dolichoderinae subfamily. Specimens were collected by hand at the Refuge Headquarters, and on dirt roads in the special use area.

Forelius mccooki (McCook, 1879)
Iridomyrmex mccooki McCook (1879): 187. — Buckley (1866): 167; Cuezzo (2000): 249.
Forelius maccooki r. *andrei* Forel (1912): 44. — Smith (1979): 1419.

Material examined: KAR142; Table 2.

Coloration is light yellow with a small petiolar node. Distinguishable from *Forelius pruinosus* by the presence of erect hairs on the antennal scape. Specimens were collected at only one location, Apache Lake, near a dirt road.

Forelius pruinosus (Roger, 1863)
Tapinoma pruinosum Roger (1863): 165. — Wheeler and Wheeler (1951): 185.
Tapinoma anale André (1893): 148. — Ward (2005): 9.
Iridomyrmex pruinosus var. *testaceus* Cole (1936): 121. — Cuezzo (2000): 261.

Material examined: KAR143; Table 2.

Similar in appearance to *Forelius mccooki* but lacking erect hairs on the antennal scape. This species was present in high abundance at every grassland location and sometimes in tree gaps at forested sites. Individuals were observed foraging at high temperatures at Elmer Thomas Lake.

Formica pallidefulva Latreille, 1802
Formica pallidefulva Latreille (1802): 174. — Mayr (1866): 889; Emery (1893): 657.
Formica pallidefulva var. *nitidivenris* Emery (1893): 656. — Trager, MacGown, and Trager (2007): 625.
Formica pallidefulva var. *succinea* Wheeler (1904): 369. — Creighton (1950): 550.
Formica pallidefulva var. *delicata* Cole (1938): 369. — Creighton (1950): 551.

Material examined: KAR151; Table 2.

A large, yellow to orange conspicuous ant that is regularly found in a variety of habitats. Three ocelli are present and well developed in workers of this genus (Fisher and Cover 2007). Specimens were collected under a cluster of small trees in the middle of the Holy City site, foraging on the ground.

Hypoponera opacior (Forel, 1893)
Ponera trigona var. *opacior* Forel (1893): 363. — Emery (1895): 268; Wheeler and Wheeler (1964): 454.

Material examined: KAR185; Table 2

Small, dark and variable in color. Colonies of this species routinely inhabit forests and prey on small soil invertebrates. Distinguishable from the genus *Ponera* by the lack of a complex subpetiolar process (Fisher and Cover 2007). Specimens were found in the forest transects of Apache Lake and Quanah Parker Lake.

Lasius neoniger Emery, 1893
Lasius niger var. *neoniger* Emery (1893): 639.

Material examined: KAR152; Table 2.

Brown, with large eyes (Mackay and Mackay 2002). This species is common and widespread in the United States. Specimens were collected by hand and pitfall traps in the grass at Jed Johnson Lake.

Monomorium minimum (Buckley, 1867)
Myrmica (*Monomorium*) *minima* Buckley (1867): 338. — Emery

(1895): 274; Wheeler and Wheeler (1955): 122; Crozier (1970): 116.
Mrymica (*Monomorium*) *atra* Buckley (1867): 342. — Emery (1895): 274.
Monomorium metoecus Brown and Wilson (1957) 239. — Ettershank (1966): 90.

Material examined: KAR161; Table 2.

Small, black and shiny. Members of this genus have 12-segmented antennae with a 3-segmented antennal club and a bicarinate clypeus (Dubois 1986). This species is present in almost every habitat and was found at every location.

Myrmecina americana Emery, 1895
Myrmecina americana Emery (1895): 271. — Wheeler and Wheeler (1954): 130.
Myrmecina californica Smith (1948): 239. — Brown (1967): 236.
Myrmecina americana subsp. *brevispinosa* Creighton (1950): 249. — Brown (1967): 236.

Material examined: KAR162; Figure 11; Table 2.

Small, dark red and brown. A subcylindrical to subquadrate petiole with an absent dorsal node and two sets of propodeal teeth help distinguish this genus from other myrmicine ants (Fisher and Cover 2007). This species is a predator of soil invertebrates, specifically oribatid mites (Fisher and Cover 2007). Specimens were only found in sifted leaf litter from one location, Osage Lake.

Neivamyrmex nigrescens (Cresson, 1872)
Labidus nigrescens Cresson (1872): 194. — Wheeler (1900a): 563; Smith (1942): 551; Wheeler and Wheeler (1984): 273.
Eciton (*Acamatus*) *schmitti* Emery (1895): 261. — Smith (1938): 160; Borgmeier (1955): 494.

Material examined: KAR145; Table 2.

Army ants with simple tarsal claws (Snelling and Snelling 2007). Coloration can be variable and the two raiding columns observed had workers that ranged from light to dark reddish brown. Workers were collected early in the morning during raids on a *Pheidole* species at the Holy City.

Nylanderia terricola (Buckley, 1866)
Formica (*Tapinoma*) *terricola* Buckley (1866): 168
Prenolepis melanderi Wheeler (1903a): 104. — Trager (1984): 81.

Material examined: KAR153; Figure 12; Table 2.

Yellow to brown, with head and gaster generally darker than the mesosoma (Kallal and LaPolla 2012). Long, coarse setae are conspicuous on the dorsal side of the mesosoma. Specimens were collected in pitfall traps at Quanah Parker Lake, the Refuge Headquarters, the Job Corps Center, and the Visitor Center.

Pheidole bicarinata Mayr, 1870
Pheidole bicarinata Mayr (1870): 989.
Pheidole vinelandica var. *longula* Emery (1895): 292. — Wilson (2003): 561.
Pheidole hayesi Smith (1924): 251. — Creighton (1950): 171.

Material examined: KAR163 and KAR164; Table 2.

Small, and variable coloration based on geography. In majors, the anterior clypeal margin is bidentate and the basal face of the epinotum is covered with transverse striae (Wilson 2003).

Pheidole cockerelli Wheeler, 1908
Pheidole cockerelli Wheeler (1908): 464.

Material examined: KAR165 and KAR166; Figures 16–17; Table 2.

Red to brown. Pronotal rugae of majors are reticulate (Mackay and Mackay 2002). Found only in the grasslands at the Visitor Center and Holy City.

Pheidole dentata Mayr, 1886
Pheidole morrisi var. *dentata* Mayr (1886b): 457. — Forel (1901): 351; Wheeler and Wheeler (1953c): 71; Crozier (1970): 117.
Pheidole commutata Mayr (1886b): 459. — Creighton (1950): 178.

Material examined: KAR167 and KAR168; Table 2.

Minors are bicolored with dark head and gaster. The mesonotum of major workers is depressed below the pronotum forming a step between the pronotum and the propodeum. This species is common, widespread and occupies a variety of habitats. Specimens were collected at every forest transect and three of the five grassland transects.

Pheidole hyatti Emery, 1895
Pheidole hyatti Emery (1895): 295. — Wheeler (1908): 463; Wheeler and Wheeler (1953c): 74; Wheeler and Wheeler (1972): 244; Taber and Cockendolpher (1988): 95.
Pheidole vaslitii Pergande (1896): 883. — Ward (2000): 94.

Material examined: KAR169 and KAR170; Table 2.

Light yellow to brown. Majors have long antennal scapes that are flattened near the base (Mackay and Mackay 2002). This location represents one of the northernmost occurrences in the eastern part of *Pheidole hyatti*'s range. Specimens were collected in grasslands at Elmer Thomas Lake and Quetone Point as well as in tree gaps at the Refuge Headquarters and Quanah Parker Lake.

Pheidole pilifera (Roger, 1863)
Leptothorax pilifer Roger (1863): 180. — Emery (1895): 290; Wheeler and Wheeler (1953c): 79.
Pheidole pennsylvanica Roger (1863): 199. — Emery (1895): 290.

Material examined: KAR171 and KAR172; Figures 18–19; Table 2.

Minors and majors dark brown, often with a reddish head. The antennal scape of major workers does not reach the occipital angles and is not bent at the base, nor flattened. This species is widespread and occupies a variety of habitats (Wilson 2003). Specimens were collected on a dirt road near Comanche Lake.

Pheidole soritis Wheeler, 1908
Pheidole soritis Wheeler (1908): 439.
Pheidole sitarches Wheeler (1908): 440. — Wilson (2003): 598.

Material examined: KAR173 and KAR174; Table 2.

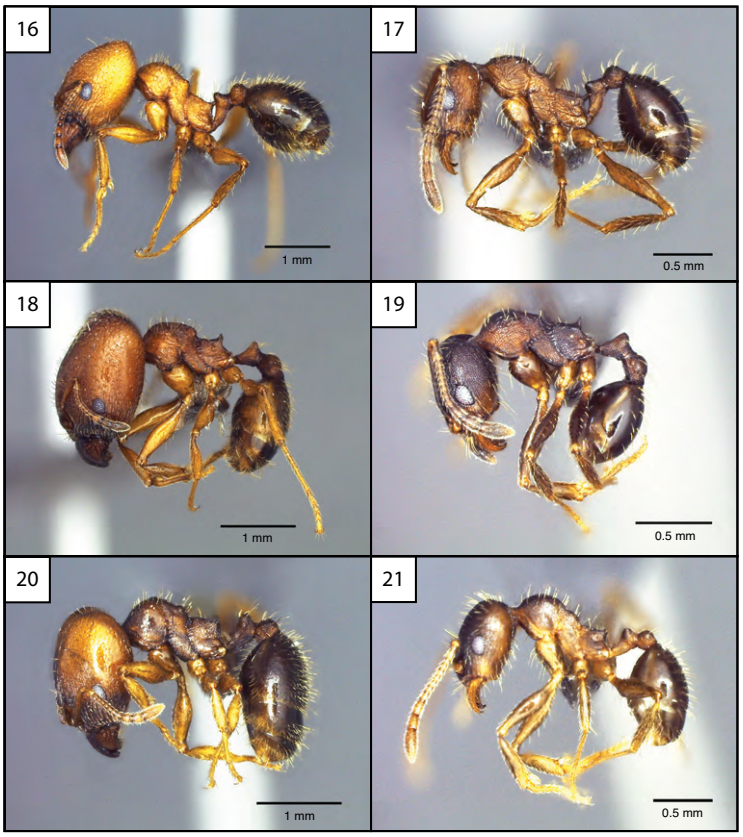

Figure 16–21. Photographs of ants with new distributional records at the Wichita Mountain Wildlife Refuge. **16:** Major of *Pheidole cockerelli*. **17:** Minor of *Pheidole cockerelli*. **18:** Major of *Pheidole pilifera*. **19:** Minor of *Pheidole pilifera*. **20:** Major of *Pheidole tetra*. **21:** Minor of *Pheidole tetra*.

Light to dark brown. Majors with short, not bent antennal scapes. Minors have hairs on the dorsum of the mesosoma that are blunt tipped (Mackay and Mackay 2002). Specimens were collected in every grassland transect, but never found in any forested location.

***Pheidole* sp. 1**

Material examined: KAR177; Table 2.

Small and yellow. Workers have 12-segmented antennae with a 3-segmented club. The pronotum and mesonotum are smooth and humped until reaching the propodeum where small, short spines are present. Only a couple of minor workers from *Pheidole* sp. 1 were collected at the Quanah Parker Lake, Jed Johnson Lake, Apache Lake, and Job Corps Center forest transects. As majors were never found, this species cannot currently be assigned an official name. However, minors from this species are morphologically distinct from all of the other *Pheidole* minors collected at the WMWR.

Pheidole tetra Creighton, 1950

Pheidole crassicornis subsp. *tetra* Creighton (1950): 176. — Wilson (2003): 161.

Material examined: KAR175 and KAR176; Figures 20–21; Table 2.

Small size with coloration that is reddish brown. In majors, the base of the scape is flat with a slightly concave dorsal surface (Mackay and Mackay 2002). Only a few specimens were collected on dirt roads and pitfall traps at Quanah Parker Lake and the Holy City.

Pogonomyrmex barbatus (Smith, 1858)

Myrmica barbata Smith (1858): 130. — Mayr (1870): 971; Mayr (1887): 610; Wheeler (1900b): 20; Taber, Cokendolpher and Franke (1988): 51.

Myrmica (*Atta*) *molefaciens* Buckley (1860): 445. — Mayr (1886a): 365.

Material examined: KAR178; Table 2

Large, red and conspicuous. This species clears vegetation around their large nests, and regularly places small rocks around the nest entrance. While the only transect to contain this species was outside the Visitor Center, individuals were regularly observed in most grasslands and Prairie dog towns on the refuge.

Prenolepis imparis (Say, 1836)

Formica imparis Say (1836): 287. — Wheeler (1930): 16; Wheeler and Wheeler (1953a): 142; Hauschteck (1962): 219.

Formica (*Tapinoma*) *wichita* Buckley (1866): 169. — Dalla Torre (1893): 178; Wheeler (1930): 15.

Prenolepis nitens var. *americana* Forel (1891): 94. — Emery (1893): 635; Dalla Torre (1893): 178.

Prenolepis imparis var. *minuta* Emery (1893): 636. — Creighton (1950): 414.

Prenolepis imparis var. *testacea* Emery (1893): 636. — Creighton (1950): 414.

Prenolepis imparis var. *californica* Wheeler (1930): 23. — Wheeler and Wheeler (1986): 14.

Prenolepis imparis var. *pumila* Wheeler (1930): 21. — Creighton (1950): 414.

Material examined: KAR154; Table 2.

Brown to dark brown. Only one species in this genus is currently recognized from North America (Fisher and Cover 2007). Specimens were collected by hand in September at Sunset Park and a single individual was collected in a pitfall trap at the Job Corps Center. This species is commonly found in forested areas during cooler months (Tschinkel 1987).

Solenopsis aurea Wheeler, 1906

Solenopsis geminate var. *aurea* Wheeler (1906): 336. — Snelling (1963): 6; Crozier (1970): 116.
Solenopsis huachucana Wheeler (1915): 393. — Trager (1991): 170.

Material examined: KAR179; Figure 13; Table 2.

Yellow to light brown. Some specimens from Buford Lake were light yellow. Distinguishable from *Solenopsis xyloni* by morphological characteristics such as fewer eye facets and tergites margined with brown (Trager 1991). Most large workers had carinal teeth, relatively abundant pilosity, and dark-edged tergites. Specimens were primarily collected near a dirt road at Quanah Parker Lake.

Solenopsis molesta (Say, 1836)

Myrmica molesta Say (1836): 293. — Wheeler and Wheeler (1955): 134; Petralia and Vinson (1980): 383; Crozier (1970): 116.
Myrmica minuta Say (1836): 294. — Emery (1895): 277.
Myrmica (*Tetramorium*) *exigua* Buckley (1867): 342. — Emery (1895): 277.
Solenopsis debilis Mayr (1886b): 461. — Emery (1895): 277.

Material examined: KAR180; Figure 14; Table 2.

Small, light yellow. Thief ants belong to the same genus as fire ants and have 10-segmented antennae with a 2-segmented apical club. This species is common and abundantly present at every site throughout the refuge.

Solenopsis xyloni McCook, 1879

Solenopsis xyloni McCook (1879): 188. — Wheeler (1915): 396; Wheeler and Wheeler (1955): 133; Taber and Cokendolpher (1988): 95.

Material examined: KAR181; Table 2

Red to dark brown with a black gaster. This is a native North American ant species that is commonly referred to as the southern fire ant. Although similar in appearance to the invasive fire ant, *Solenopsis invicta*, this species has smaller colonies, lacks a median clypeal tooth, and is less aggressive. Specimens were collected under logs and rocks or in the soil at most locations that were near a lake or a man-made structure.

Tapinoma sessile (Say, 1836)

Formica sessilis Say (1836): 287. — Emery (1895): 333; Wheeler and Wheeler (1951): 196; Crozier (1970): 119; Taber and Cokendolpher (1988): 95.
Tapinoma boreale Roger (1863): 165. — Creighton (1950): 353.
Formica gracilis Buckley (1866): 158. — Emery (1895): 337; Wheeler (1902): 20.
Formica parva Buckley (1866): 159. — Mayr (1886b): 434.
Bothriomyrmex dimmocki Wheeler (1915): 417. — Shattuck (1992): 153.

Material examined: KAR144; Figure 15; Table 2.

Widespread and common in a variety of habitats. This ant species has a vestigial petiolar node with the fifth gastral tergite reflexed ventrally (Fisher and Cover 2007). Only a single specimen was collected by hand at Buford Lake.

Temnothorax pergandei (Emery, 1895)

Leptothorax (*Dichothorax*) *pergandei* Emery (1895): 323. — Wheeler (1903b): 257; Wheeler and Wheeler (1960): 23.
Leptothorax (*Dichothorax*) *floridanus* Emery (1895): 324. — Mackay (1993): 289.
Leptothorax (*Dichothorax*) *manni* Wesson (1935): 208. — Wesson (1939): 180.

Material examined: KAR182; Table 2

Dark brown head and gaster with lighter mesosoma, sculpturing, and size with a 12-segmented antennae and 3-segmented apical club (Mackay 1993). Propodeal spines are small and appear to extend directly upwards. Only three individuals were collected in a pitfall trap at the Refuge Headquarters.

Temnothorax schaumii (Roger, 1863)

Leptothorax schaumii Roger (1863): 180. — Mayr (1886b): 451; Wesson and Wesson (1940): 95; Wheeler and Wheeler (1960): 23.
Leptothorax fortinodis Mayr (1886b): 452. — Creighton (1950): 271.

Material examined: KAR183; Table 2

Small, dark brown to black, with 11-segmented antennae and small propodeal spines. Individuals were observed foraging solitarily on oak trees in forested locations.

Trachmyrmex septentrionalis (McCook, 1881)

Atta septentrionalis McCook (1881): 362. — Wheeler (1907): 707; Wheeler (1949): 673.
Oecodoma virginiana Buckley (1867): 346. — Wheeler (1902): 29.

Material examined: KAR184; Table 2

Light red to light yellow-brown. Tubercles present on head, mesonotal dorsum, petiole and postpetiole dorsum, and gaster (Rabeling et al. 2007). A somewhat common and widespread fungus gardening ant. Specimens were collected in pitfall traps and by hand at Quetone Point and Jed Johnson Lake.

DISCUSSION

Fifty-one native ant species from 22 genera are now known from Comanche County, Oklahoma (Table 2). Forty-seven of these reside in the WMWR with inconsistencies occurring due to an absence of *Camponotus discolor* (Buckley 1866), *Camponotus nearcticus* Emery 1893, *Carebara longii* (Wheeler 1903), and *Neivamyrmex punctaticeps* (Emery 1894). This new list represents a 38% increase in species richness over Wheeler and Wheeler's list (1989) due to 12 new county records including the new state records of *Pheidole tetra* and *Solenopsis aurea* (Figures 7–21). In addition to adding to the checklist of the WMWR, the 2015 surveys also recaptured 20 of the 30 previously collected species, only failing to find

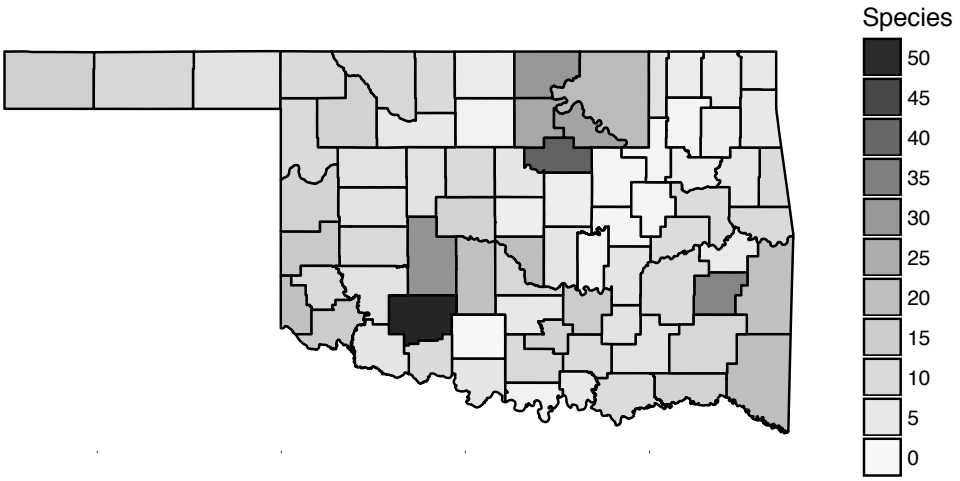

Figure 22. Species richness of ants across the 77 counties of Oklahoma.

Aphaenogaster treatae Forel 1886, *Camponotus semitestaceus* Snelling 1970, *Dorymyrmex insanus* (Buckley 1866), *Formica dolosa* Buren 1944, *Lasius interjectus* Mayr 1866, *Lasius latipes* (Walsh 1863), *Myrmecocystus melliger* Forel 1886, *Pogonomyrmex desertorum* Wheeler 1902, *Pogonomyrmex imberbiculus* Wheeler 1902, and *Temnothorax texanus* (Wheeler 1903).

When compared to the last compiled ant checklist for the state of Oklahoma (Wheeler and Wheeler 1989), the WMWR astonishingly supports 68% (21 of 31) of the known genera and 54% (47 of 87) of the known species. In stark contrast, the adjacent Oklahoma counties of Caddo, Cotton, Grady, Kiowa, Stephens, and Tilman appear depauperate containing only 31, 10, 19, 7, 0, and 6 native ant species. Expanding this comparison to all of Oklahoma suggests that the WMWR may be the most speciose area in the entire state as the next richest counties report only 41, 34, and 31 ant species respectively (Wheeler and Wheeler 1989; Albrecht 1995). Though this new checklist highlights the importance of the WMWR in conserving the native ant fauna, it also illuminates a problem.

Oklahoma has historically been ignored by myrmecologists. Of the 77 counties in the state, 66% (51 of 77) have reported 10 or fewer species of ants (Figure 22). Scaling up the assessment to Oklahoma and its adjacent states reveals that Texas (337 species), New Mexico (328 species), Colorado (226 species), Arkansas (147 species), Missouri (144 species), and Kansas (125 species) all appear to be more speciose (GABI 2016). Undeniably, factors such as habitat modification and the introduction of non-native species can contribute to lower levels of ant diversity (Sanders et al. 2003; Andersen and Majer 2004; Tillberg et al. 2007), yet the discrepancy is likely due to low sampling effort. As an example, new state records at both the genus and subfamily level have recently been reported for ants in Marshall County, Oklahoma (Roeder and Roeder 2015; Roeder et al. 2015). Despite these findings and the county's potential for high species richness, previous published records include a paltry checklist of only five ant species (Wheeler and Wheeler 1989).

One approach towards resolving the sampling effort conundrum is the use of survey methods that are repeatable across habitat types (Agosti et al. 2000; Gotelli et al. 2011). Pitfall traps, while limited in sampling the arboreal ant fauna, are useful in capturing ground foraging insects in forests and grasslands (Andersen 1991; Steiner et al. 2005). We found that across 10 different sites, pitfall traps accounted for 68% (25 of the 37) of all ant species from our 2015 survey. Moreover, pitfall traps provide snapshots of ant abundance that may be useful in determining dominant or keystone species (Porter and Savignano 1990; Human and Gordon 1997; Resasco et al. 2014). For example, *Crematogaster lineolata*, a common acrobat ant with potentially large colonies (Whitford and Gentry 1981), was responsible for the majority of the observed difference in ant abundance between habitat types. This species made up 35% of all individuals in pitfall traps, but was disproportionally collected in grasslands (*C. lineolata* abundance: N_{Forest} = 84; $N_{Grassland}$ = 1478). As invasive species management is a priority for wildlife refuges, *C. lineolata* is of particular interest as a previous study found its abundance was negatively correlated with the invasive *S. invicta* (Stuble et al. 2009).

Ant diversity from the WMWR highlights the role of protected areas such as National Wildlife Refuges in conserving regional fauna. Not only have most of the historically collected species from the past 100 years been conserved, but the area has resisted, to date, one of the most notorious invasive species, *S. invicta*. Given the variety of ecoregions and environmental gradients found in Oklahoma, we suggest that more species inventories should be conducted, especially in the numerous under-sampled areas of the state.

ACKNOWLEDGEMENTS

We thank D. T. McDonald for help with obtaining a permit to collect ants at the Wichita Mountains Wildlife Refuge and M. Kaspari for laboratory space. We would also like to thank everyone that encouraged us during this project. This work was funded by a University of Oklahoma Graduate Student Senate research grant awarded to K. A. Roeder.

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Author contributions: KAR and DVR collected the data, KAR identified the specimens, KAR and DVR wrote the text, and KAR performed the analyses.

Received: 22 February 2016
Accepted: 6 July 2016
Academic editor: Aline Barcellos