PROCEEDINGS
of the
OKLAHOMA ACADEMY OF SCIENCE
Volume 96
2016

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The Official Organ of
the

OKLAHOMA ACADEMY OF SCIENCE

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Publication Date: January 2017

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PROCEEDINGS OF THE OKLAHOMA ACADEMY OF SCIENCE

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Patterns of Carnivore Distribution and Occurrence in the Oklahoma Panhandle

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Carnivore distributions in the Oklahoma panhandle were determined through the use of baited, stainless steel tracking plates and verified with infra-red triggered cameras. Tracking plates were operated for two years covering four seasons (October 1995-February 1997). Six species of carnivores were detected in sufficient numbers to permit analyses during tracking efforts in the Oklahoma panhandle (Swift fox (*Vulpes velox*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), spotted skunk (*Spilogale putorius*), striped skunk (*Mephitis mephitis*), and badger (*Taxidea taxus*)). In general, Oklahoma panhandle carnivores were not distributed evenly across panhandle counties or habitats. Canid distributions were skewed toward Cimarron County, however individual canid species exhibited separate habitat preferences within counties. Mustelids and mephitids were distributed evenly across the broader panhandle landscape, but demonstrated clear habitat preferences when detection data were combined at the Family level. Carnivores were also sensitive to the presence of other carnivores within panhandle habitats. This response was most pronounced between the canid species.

Introduction

In western Oklahoma, few comprehensive investigations of carnivores have been undertaken (Glass 1956; Kilgore 1969). Most of the information on carnivores in the state has occurred in conjunction with and ancillary to projects focused on other vertebrates (Shackford et al. 1989; Shackford and Tyler 1991; Peoples and DeMaso 1996). This study had three objectives. The first was to survey carnivores of the Oklahoma panhandle. Historically, the Oklahoma panhandle has supported a diverse carnivore community. Carnivores from the region include 17 species in five families (Caire et al. 1989; Table 1). Four species, gray fox (*Urocyon cinereoargenteus*), western spotted skunk (*Spilogale gracilis*), hog-nosed skunk (*Conepatus mesoleucus*) and ringtail (*Bassariscus astutus*), are thought to be restricted to a small mesa region in the northwestern corner of the Oklahoma panhandle (Caire et al. 1989). The badger (*Taxidea taxus*), black-footed ferret (*Mustela nigripes*), swift fox (*Vulpes velox*) and coyote (*Canis latrans*) are thought to be associated with prairie dog (*Cynomys ludovicianus*) towns (Shackford and Tyler 1991). These and the remaining panhandle carnivores (Table 1) are also more widely distributed and may be found throughout the panhandle.

The second objective was to determine the distributions of carnivores in the Oklahoma panhandle with respect to major habitats. Presently, there exist four broadly classified types of habitat in the Oklahoma panhandle. Mesa habitat extends into New Mexico and Colorado, where it is found more extensively. Mesa habitat is dominated by sand sagebrush (*Artemisia filifolia*), juniper (*Juniperus*

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Table 1 – Carnivores of the Oklahoma panhandle (from Shackford and Tyler 1991; Caire et al. 1989). * Indicates species extirpated from the Oklahoma panhandle.

Scientific Name	Common Name
Family Mustelidae	
Taxidea taxus	Badger
Mustela nigripes	Black-footed ferret
Mustela frenata	Long-tailed weasel
Family Mephitidae	
Mephitis mephitis	Striped skunk
Spilogale putorius	Eastern spotted skunk
Spilogale gracilis	Western spotted skunk
Conepatus mesoleucus	Hog-nosed skunk
Family Canidae	
Vulpes velox	Swift fox
Vulpes vulpes	Red fox
Urocyon cinereoargenteus	Gray fox
Canis latrans	Coyote
*Canis lupus**	Wolf
Family Felidae	
Lynx rufus	Bobcat
Felis concolor	Cougar
Family Procyonidae	
Procyon lotor	Raccoon
Bassariscus astutus	Ringtail
Family Ursidae	
Ursus americanus	Black bear

scopulorum) and two-needle pinyon (*Pinus edulis*). Large, conspicuous riparian areas are also evident in the panhandle. Several riparian areas run predominantly west-east through the Oklahoma panhandle and are dominated by large eastern cottonwoods (*Populus deltoides*), shrubs and taller grasses. Grassland/range areas are dominated by a variety of native and introduced grass species. Grassland/range areas all experience some degree of grazing by domestic cattle. The final major habitat type, agriculture, has come to prevail across several parts of the panhandle. The dominant crops in the panhandle are wheat, winter wheat, corn, and milo. As these agricultural areas can be extensive and uniform, they cannot be ignored as potential habitat for Oklahoma carnivores.

The third objective was to examine whether carnivore distributions and habitat affinities are influenced by the distributions or presence of other carnivore species. Specifically, do different carnivore species (particularly closely-related carnivore species) in the Oklahoma panhandle occur together regionally or in specific habitats more or less than would be expected by chance? We examined not only the effects of large scale factors such as habitat on carnivore distributions, but also how local processes influence where carnivores occur. This approach provides for a better, more comprehensive understanding of carnivore interactions and distributions in the Oklahoma panhandle.

A previous publication (Shaughnessy 2003) on panhandle carnivores compared detection method efficacy and examined swift fox distributions alone, using tracking plate detection frequencies instead of total number of detections. The use of tracking plates was determined to be more effective at detecting carnivores than dirt tracking, spotlighting or the use of infrared cameras (Shaughnessy 2003). Swift fox distributions in the panhandle, as determined by detection frequencies, were examined independently of other carnivore detection data (Shaughnessy 2003). No analyses examining the panhandle carnivore community distributions were presented (Shaughnessy 2003). Detection frequencies were also used, instead of total number of detections, to examine any interactions between swift foxes and coyotes (Shaughnessy 2003). This current work expands the analyses of swift fox distributions by including swift fox total detection data with that of the other panhandle carnivores, presenting power analyses to examine the strength of the applied statistics and interpreting results in conjunction with data from the broader mesocarnivore community.

Study Area

Research on carnivores was conducted in the Oklahoma panhandle, a strip of land about 267 km long (east-west) and 55 km wide (north-south) adjacent to the northwestern-most part of the body of the state. The panhandle region is comprised of three counties, each of about equal size. The counties (from east to west) are Beaver (470,172 hectares), Texas (527,855 hectares), and Cimarron County (475,506 hectares).

Historically, the panhandle consisted primarily of shortgrass prairie (Duck and Fletcher 1943) and was dominated by blue grama (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*) and prairie three-awn (*Aristida oligantha*). Prairie dog towns also covered much of the panhandle, occurring in all habitat types (Shackford and Tyler 1991; Shackford et al. 1989). Presently, the landscape has been altered. While the historical habitat types persist, their quality and quantity has changed. The grassland, mesa and riparian areas now are grazed by domestic cattle. The severity of this grazing varies among habitats and locations. Prairie dog towns have been reduced in number and size due to the combined effects of periodic plague (*Yersinia pestis*) episodes and concentrated eradication efforts. Agricultural areas, present since at least 1893, cover a substantial area. These extensive monocultures have had a profound impact on the composition of the vegetation in the panhandle.

Methods

The distribution of carnivores was determined primarily through the use of baited tracking plates at pre-established tracking stations and supplemented with infrared photography. Tracking plates were made of sheets of stainless 26-gauge steel about one square meter in size and sprayed with a mixture of carpenter's chalk and isopropyl alcohol (G.M. Fellers, Biological Resources Division, USGS, pers. comm.). These materials were selected over traditional sand tracking techniques for two reasons. First, tracks in the chalk tended to persist longer and were clearer than tracks in sand under the typical high wind conditions of the panhandle. Second, plate and chalk stations were easier to establish and less expensive to operate repetitively than sand stations. Each plate had a one-inch (2.5 cm) hole drilled through its center, allowing it to be placed directly over a stake that permanently marked the tracking station (Shaughnessy 2003). Canned mackerel and beef scraps were then placed in the center of each plate or on the stake to serve as bait (Shaughnessy 2003). The plates were checked for tracks and recovered after three nights (Egoscue 1956; Hatcher 1978; Pocatello Supply Depot progress report 1981; Orloff et al. 1986; Paveglio and Clifton 1988).

Ninety permanent tracking stations were established throughout the panhandle according to a stratified design (Shaughnessy 2003). Tracking stations were distributed first according to county size. Stations were then distributed across habitats based upon estimates of the total area habitats covered in the panhandle. The minimum number of permanent tracking stations established in any habitat was 12 in each of the mesa and riparian habitats. The most stations (43) were placed in range/grassland habitat (Shaughnessy 2003). Four carnivore tracking surveys, covering each season of the year, were completed from January 1995 to February 1997.

Infrared-triggered cameras were also used in order to detect and verify carnivore presence. The camera units were set at tracking plate stations so that the infrared trigger and the camera were aimed at the center of the station. Ten cameras operated during each sampling trip at tracking stations. Cameras were placed at stations based upon the prior tracking history of the station and a qualitative judgment of the potential of the habitat to produce carnivore detections. Cameras were also placed at stations that appeared to be in areas of high carnivore densities or high quality carnivore habitat that had not tracked carnivores to that point. While cameras were useful for a few novel detections of carnivores, the cameras functioned primarily for verifying carnivore tracks at tracking plates (Shaughnessy 2003).

Statistical Methods

Carnivore landscape distributions were analyzed through chi-square analyses (Zar 2010). Data were compiled by detections within panhandle counties. The panhandle counties are conveniently oriented in-line from west to east and are of roughly equal in size. Chi-square was used to analyze these data according to their distributions across counties to determine if differences existed in gross distributions of carnivores across the panhandle. These data were analyzed for all carnivores, groups of carnivores based on taxonomic relationships and for individual carnivore species.

A second series of tests analyzed carnivores in habitats. Data were compiled for the four major pre-defined habitat types. Chi-square analyses were used to determine if carnivore distributions and occurrences were random across these habitats. These analyses were performed for all carnivores, groups of carnivores, and all individual carnivore species.

Finally, a third chi-square analysis was performed. A chi-square contingency table was used to analyze interspecific associations between carnivores within habitats. In particular, associations between taxonomically related carnivores were examined within Oklahoma panhandle habitats. This test was used to determine if carnivores within certain taxonomic groups were interacting with each other across the broader panhandle landscape. These interactions, if present, could then be used to further explain overall patterns of carnivore occurrence within habitats. This analysis was completed for all carnivores, canids and mustelids/mephitids.

Sample sizes during this project were not large. As a result, power analyses were conducted and reported on all non-significant chi-square results in order to determine the likelihood of the commission of Type II errors. Power values were computed using Cohen (1977) as a reference and evaluated as to their strength according to recent literature (Greenwood 1993; Taylor and Gerrodette 1993; Thompson and Neill 1993; Thomas and Juanes 1996; Zielinski and Stauffer 1996; Marshal and Boutin 1999). These values were used in the further interpretations of non-significant statistical results.

Results

Six carnivores (no distinction was made between western and eastern spotted skunks) were detected in sufficient numbers to permit statistical analysis. These carnivores represent four families (Canidae, Felidae, Mephitidae and Mustelidae) of six possible families reported present in the Oklahoma panhandle. Because of their close taxonomic affiliation, similar sizes, and habitats, data for mustelids and mephitids are combined.

Sampling Effort

Tracking plates were operated for 850 plate nights in the Oklahoma panhandle (Table 2). A plate night is defined as one tracking plate, baited and coated with chalk, set out for one night. Cimarron County recorded the most plate nights, while Beaver County accounted for the least number of plate nights (Table 2). Tracking plate nights were established in range/grassland areas most. The fewest tracking plates were located in mesa and riparian areas (Table 2). These numbers reflect the proportions that habitats and counties occupy within the total area of the Oklahoma panhandle.

Analyses

The results of chi-square analysis of carnivore occurrences across counties is highly statistically significant ($X^2 = 26.90$, df = 2, $p \leq 0.001$; Figure 1). Chi-square analysis of carnivore distributions among habitats also reveals significant differences in the occurrence of carnivores in the habitats ($X^2 = 12.11$, df = 3, $p \leq 0.01$; Figure 2).

Two canid species were detected with sufficient regularity to permit analyses. Swift fox and coyote were detected in all habitats and during all sampling periods. Analyses of swift fox in the Oklahoma panhandle are dealt with more extensively in Shaughnessy (2003), yet in all cases, swift fox distributions are significantly different from expected frequencies or occurrences. Chi-square analysis of swift fox distributions across counties is highly significant ($X^2 = 27.04$, df = 2, $p \leq 0.001$; Figure 3). Swift fox distributions among habitats are similarly uneven. Chi-square analysis shows significant differences in the numbers of detections of swift foxes between habitats ($X^2 = 12.02$, df = 3, $p \leq 0.01$; Figure 4).

The analyses for coyotes produced similar results. Coyotes are not evenly distributed between the three counties of the Oklahoma panhandle ($X^2 = 10.49$, df = 2, $p \leq 0.01$; Figure 5). Additionally, coyotes are not distributed evenly among the broadly defined habitats. Chi-square analysis revealed significant differences in coyote detections across the habitats ($X^2 = 18.94$, df = 3, $p \leq 0.001$; Figure 6).

In general, the results are the same when the data for the two canid species are combined. The chi-square analysis indicates that canids are not evenly distributed across the three counties ($X^2 = 24.35$, df = 2, $p \leq 0.001$). Canids are not evenly distributed among the major habitats of the panhandle either ($X^2 = 16.28$, df = 3, $p \leq 0.001$).

One mustelid and two mephitid species were detected during the course of this study. The spotted skunk, striped skunk, and badger were detected with tracking plates and incidentally. The spotted skunk was detected most frequently. Chi-square analysis examining spotted skunk occurrence among counties reveals no significant differences in spotted skunk occurrences among the counties ($X^2 = 4.21$, df = 2, $p > 0.05$). Power for this test is high ($U_{0.05} = 2$, w = 0.5962, Power = 0.75). Similarly, chi-square analysis shows no significant differences in spotted skunk detections between major habitats ($X^2 = 2.53$, df = 3, $p > 0.05$). Statistical power for this test is high as well ($U_{0.05} = 3$, w = 0.5821, Power = 0.70).

Chi-square analysis of badger detections between panhandle counties is also not significant. Badgers exhibit no significant differences between the counties ($X^2 = 1.71$, df = 2, $p > 0.05$). Statistical power for this test is comparatively high ($U_{0.05} = 2$, w = 0.6429, Power = 0.71). Badgers also are not detected in any habitat more often than expected ($X^2 = 3.54$, df = 3, $p > 0.05$). Power for this test is marginal ($U_{0.05} = 3$, w = 0.5379, Power = 0.54).

The final mephitid species examined was the striped skunk. Results are not significant for striped skunk occurrences between counties ($X^2 = .017$, df = 2, $p > 0.05$). Statistical power for this test is very low, however ($U_{0.05} = 2$, w = 0.1414, Power = 0.02). Chi-square analysis does reveal that striped skunks are not detected evenly among habitats ($X^2 = 9.93$, df = 3, $p \leq 0.025$).

The mustelid and mephitid data were grouped and analyzed to determine if any differences are manifested at higher mesocarnivore levels. The chi-square analysis of mustelid/mephitid occurrences across counties shows that these small mesocarnivores do occur evenly between counties ($X^2 = 3.68$, df = 2, $p > 0.05$). Power for this test is also low ($U_{0.05} = 2$, w = 0.3209, Power = 0.43). The chi-square analysis of mustelid/mephitid occurrences between habitats reveals that collectively the three species do not occur evenly in all habitats ($X^2 = 7.8225$, df = 3, $p \leq 0.05$; Figure 7).

One felid was detected during this study, the bobcat. Chi-square analysis indicates that bobcats occur evenly between the counties and therefore across the panhandle in general ($X^2 = 3.29$, df = 2, $p > 0.05$). Power for this test is relatively high ($U_{0.05} = 2$, w = 0.6165, Power = 0.61). Analysis of bobcat occurrence among habitats is also insignificant ($X^2 = 6.91$, df = 3, $p > 0.05$). Statistical power for this test is low ($U_{0.05} = 3$, w = 0.4472, Power = 0.32).

Our final analyses attempt to examine potential interspecific associations occurring between carnivores in the panhandle. These results may be used to understand patterns in occurrence and detections among panhandle habitats. Chi-square contingency table analysis reveals that a significant interaction exists between the two canid species ($X^2 = 13.62$, df = 3, $p \leq 0.005$; Figure 8). For mustelids and mephitids, chi-square contingency table analysis reveals that no significant interactions occur between species ($X^2 = 8.60$, df = 6, $p > 0.05$). Statistical power for this test is marginal ($U_{0.05} = 5$, w = 0.4351, Power = 0.54). Intraorder level interactions are present among all canids and mustelids as well, at significant levels throughout the panhandle ($X^2 = 34.06$, df = 12, $p \leq 0.001$).

Discussion

This current work demonstrates that carnivores are not distributed evenly across the Oklahoma panhandle in counties or in habitats. Carnivores are detected most often in Cimarron County and less often than expected in either Texas or Beaver counties. These data imply a gradual decline in carnivore occurrence from west to east in the Oklahoma panhandle.

Carnivores also exhibit non-random trends in occurrence within specific habitats. Carnivores are detected more often than expected in the mesa and agricultural areas. Carnivores are detected as often as expected in riparian areas, but are underrepresented in grassland/range areas. These patterns likely reflect occurrence trends in individual carnivore species.

Canids

Occurrence and distribution patterns in

Table 2 - Sampling effort in counties and habitats of the Oklahoma panhandle expressed as functional plate nights, January 1995 - February 1996.

	Cimarron County	Texas County	Beaver County	Total
Agriculture	13	108	80	201
Mesa	136	0	0	136
Range	104	132	140	376
Riparian	43	51	43	137
Total	296	291	263	850

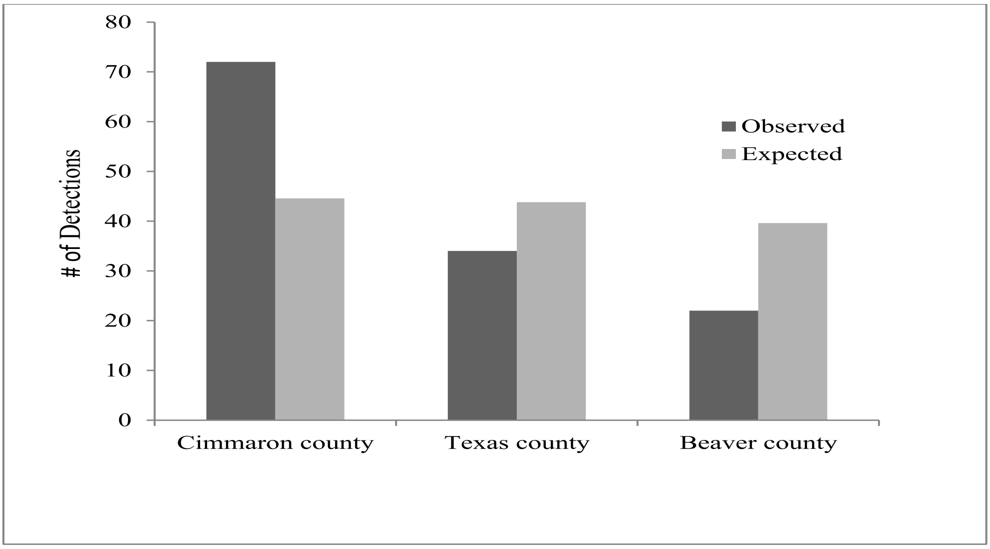

Figure 1 - All carnivore detections across the Oklahoma panhandle counties (p < 0.001).

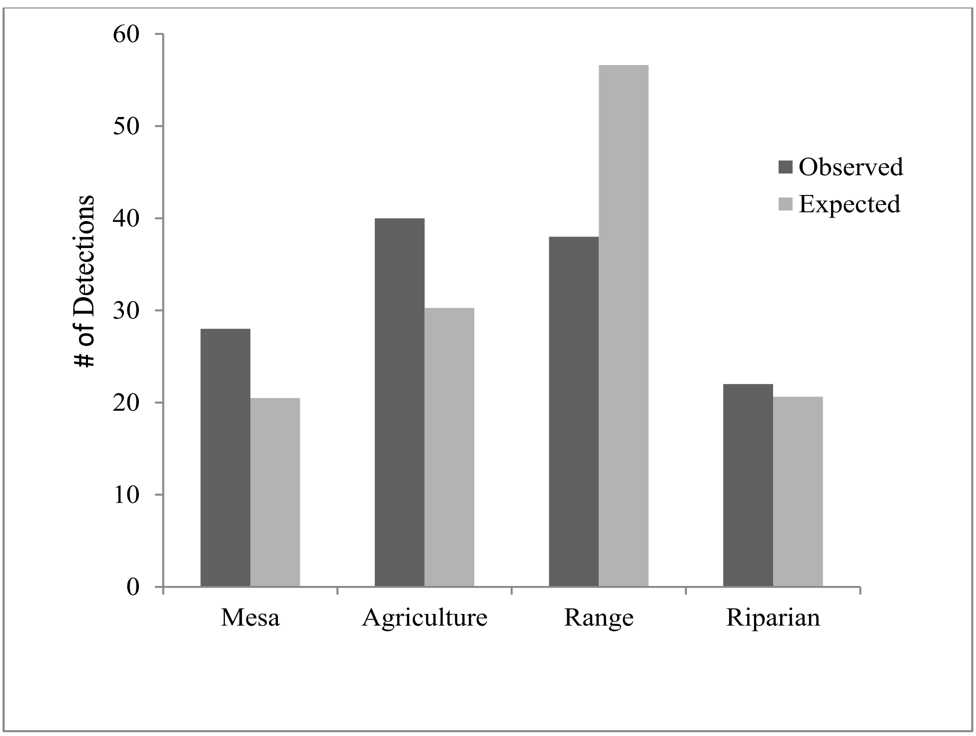

Figure 2 - All carnivore detections across habitats of the Oklahoma panhandle (p < 0.01).

swift foxes over the course of this study are discussed more extensively in Shaughnessy (2003). However, it is important to note that the swift fox is not detected in all counties or habitats equally. Swift foxes are detected more often in the westernmost parts of the Oklahoma panhandle and specifically in Cimarron County. Foxes are not detected as often as expected in

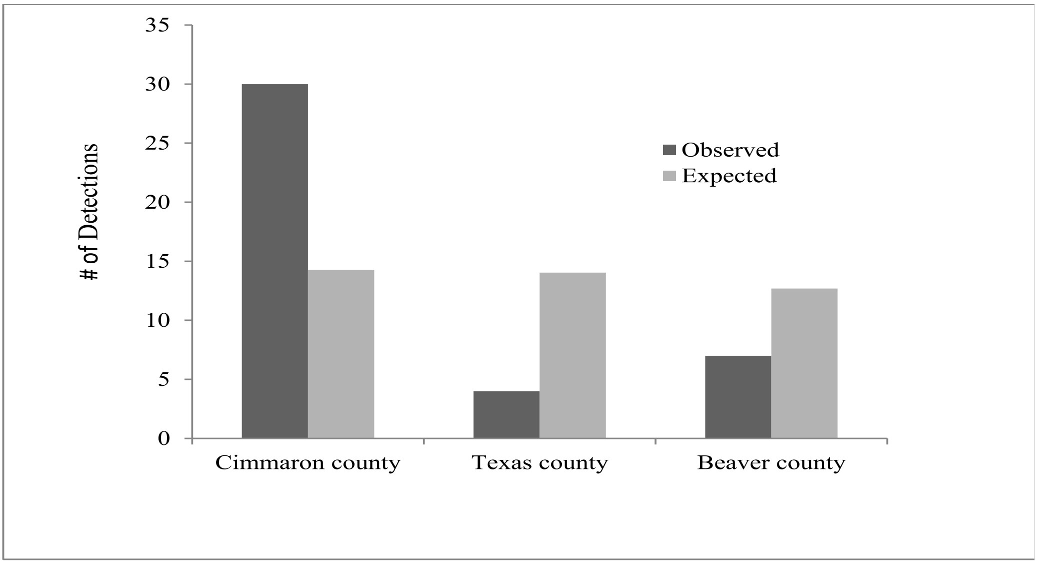

Figure 3 - Swift fox (*Vulpes velox*) detections across the Oklahoma panhandle counties ($p < 0.001$).

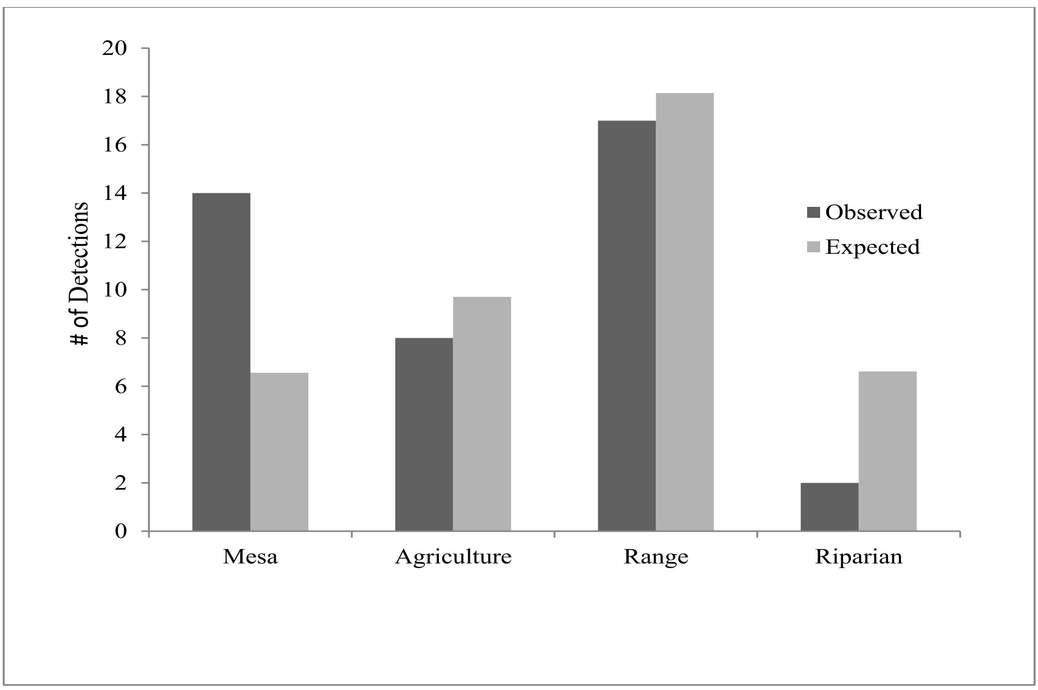

Figure 4 - Swift fox (*Vulpes velox*) detections across habitats of the Oklahoma panhandle ($p < 0.01$).

either Texas or Beaver counties. Additionally, swift foxes also demonstrate a clear preference for the westernmost physiographic regions of the panhandle (mesa and northwestern mesa/riparian) and are absent in the more centrally located regions of the panhandle (north/central agriculture and central mixed agriculture and range).

Patterns in coyote occurrence in the panhandle

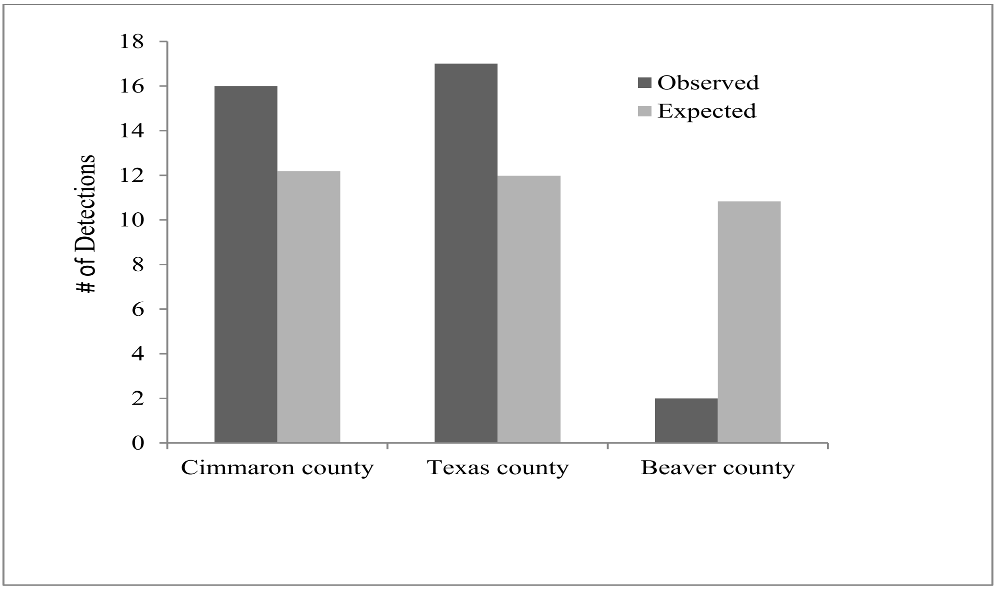

Figure 5 - Coyote (*Canis latrans*) detections across the Oklahoma panhandle counties ($p < 0.01$).

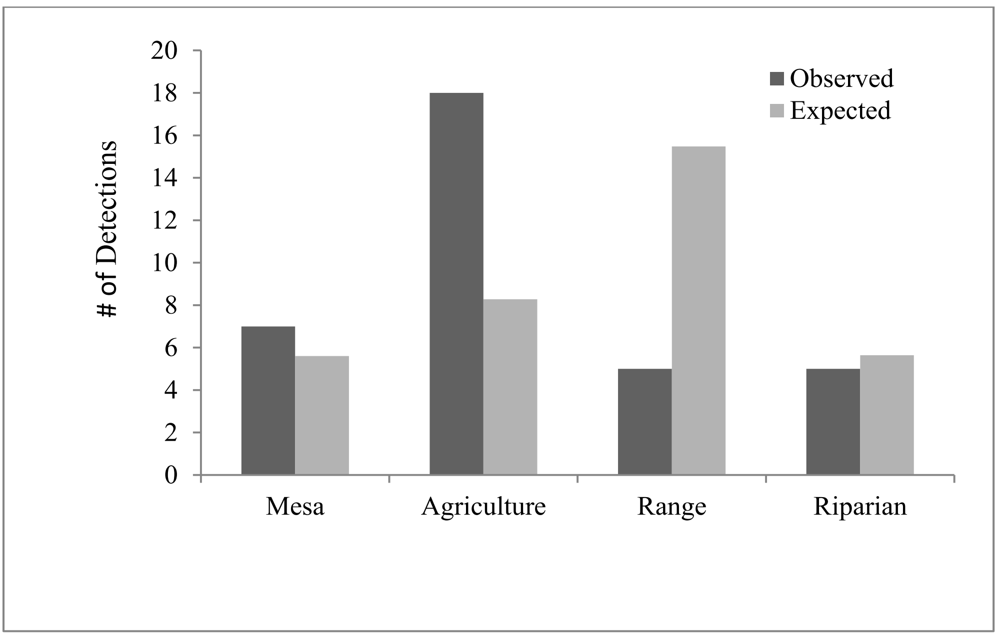

Figure 6 - Coyote (*Canis latrans*) detections across habitats of the Oklahoma panhandle ($p < 0.001$).

are similarly uneven. Coyotes are detected most often in Texas County. They are only rarely detected in Beaver County and they are detected about as often as expected in Cimarron County. Coyotes in Cimarron County are detected outside of the mesa region. Physiographically, coyotes prefer the north/central agricultural region of the panhandle far above any other panhandle region.

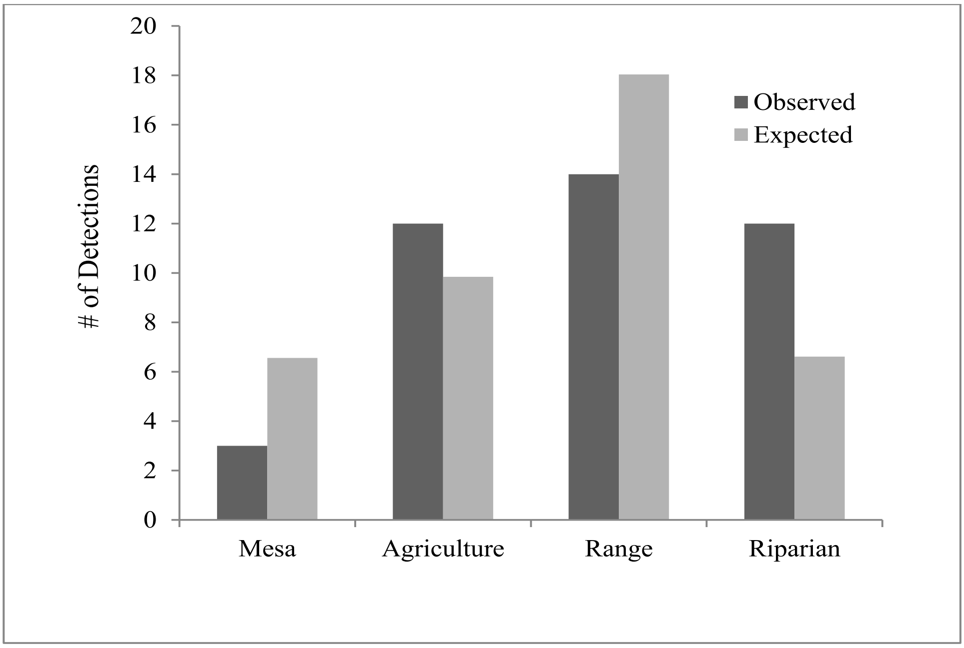

Figure 7 - Detections of mustelids and mephitids across habitats of the Oklahoma panhandle ($p < 0.05$).

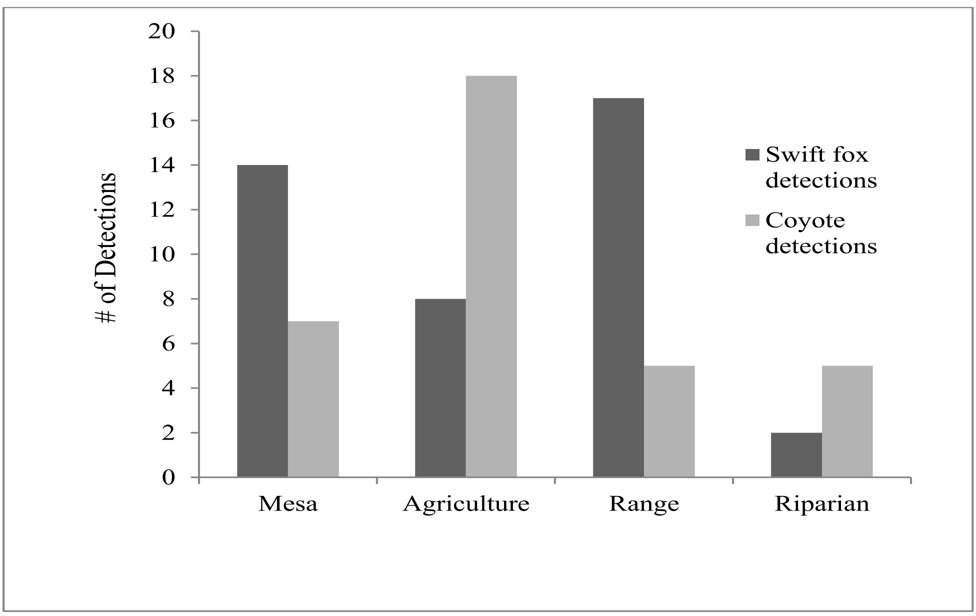

Figure 8 - Detections of swift foxes (*Vulpes velox*) and coyotes (*Canis latrans*) across habitats of the Oklahoma panhandle ($p < 0.005$).

They also occur regularly in the southwestern grassland region of the panhandle. Coyotes avoid the northwestern mesa/riparian region as well as the northeastern riparian/range area of the panhandle.

In habitats, coyotes prefer agricultural areas over all other areas. They are detected in agricultural areas more than twice as often as predicted (Figure 6). Coyotes are detected in riparian areas about as often as expected, but they apparently avoid mesa and range areas and are only recorded in these areas about half as much as expected (Figure 6). Given these habitat affinities for coyotes, it is not surprising that coyotes are detected most often in Texas County. Texas County is predominantly an agricultural county. Cimarron and Beaver counties are much less devoted to agricultural practices.

Canids as a group are also not distributed evenly across the panhandle, between counties or among macrohabitats. Canids are detected much more often than expected in Cimarron County and much less than expected in Beaver County. Canids display decreases in occurrence from west to east in the Oklahoma panhandle. Canids also show a preference toward the mesa and agricultural areas of the panhandle while exhibiting an aversion towards riparian and range areas. This result is probably due to the strong positive individual responses of swift foxes and coyotes toward each of these areas respectively.

Canid occurrences in the panhandle were determined to be governed at least in part by a strong interaction between the two species (Shaughnessy, 2003). Where coyotes occurred in abundance, swift foxes were conspicuously absent (Figure 8). Swift foxes are present in abundance only in those areas where coyotes are detected infrequently, most notably the mesa region (Figure 8). This strong negative interaction has been documented among other canid species (Carbyn 1982; Rudzinski et al. 1982; Sargeant et al. 1987; Harrison et al. 1989; Bailey 1992; Thurber et al. 1992; Peterson 1995; Johnson et al. 1996; Dayan and Simberloff 1996). Coyotes and other larger canids have been documented as significant sources of mortality for smaller canids and swift foxes, specifically in the prairie environment (Carbyn 1982; Rudzinski et al. 1982; Sargeant et al. 1987; Harrison et al. 1989; Bailey 1992; Peterson 1995; Johnson et al. 1996; Dayan and Simberloff 1996). This interaction between swift foxes and coyotes in the Oklahoma panhandle is, therefore, not surprising.

While the presence or absence of coyotes undoubtedly affects swift fox habitat selection in the Oklahoma panhandle, the interaction is probably not the sole determining factor in swift fox distribution. Swift foxes tend to be highly sensitive to predation from many potential predators, not only larger canids (Egoscue 1956, 1962, 1979). This susceptibility to predation also is inferred by the swift fox's heavy reliance on den sites and subterranean tunnels (Egoscue 1962, 1979; Moehrenschlager 2003). Tall grass areas may inhibit the ability of the swift fox to detect predators because of the fox's small size (Allardyce pers. comm.). Tall grass areas also may limit the ability of the fox to find a suitable escape route underground when confronted with a predator (Allardyce pers. comm.). Swift foxes may be avoiding tall grass areas to facilitate predator detection and escape (Allardyce pers. comm.).

The mesa areas are dominated by shorter grasses that the foxes may prefer because they allow them to more easily detect predators and locate escape routes underground. Additionally, agricultural areas are only seasonally planted and often left fallow, with only low ground plants covering them. Swift foxes may be using agricultural areas because their normally low vegetation aids them in predator avoidance, and persisting in agricultural areas during the short periods of time when crops are tall. Conversely, range/grassland areas are often a mix of tall grass areas, short grass areas, and areas that are barren due to overgrazing. The absence of coyotes in these areas (Figure 6) may be attractive to swift foxes, but the heterogeneous nature of the habitat, particularly the presence of tall grasses, may discourage selection of this habitat by swift foxes. This may explain the slightly depressed occurrence frequency of swift foxes in range/grassland areas (Figure 4). Finally, swift foxes are absent from riparian areas. These areas are often overgrown with tall grasses, shrubs, bushes, and trees. In addition, coyotes are found in abundance riparian areas (Figure 6). It is not surprising then, that swift foxes are uncommon in riparian areas.

Coyote occurrence patterns are not easily explained. Coyotes exhibit no aversion to riparian areas and an overwhelming preference for agricultural areas (Figure 6). Coyotes are among the largest terrestrial predators in the Oklahoma panhandle and are the largest carnivores detected during this study. Riparian areas often serve as travel corridors for a variety of panhandle vertebrates. Coyotes may be frequenting riparian areas to increase the probability of encountering potential prey. Agricultural areas may support higher numbers of small and medium-sized mammals. Rodent populations may be higher in agricultural areas than in the surrounding grasslands due to the seasonal abundance of seed resources. Coyotes may prefer agricultural areas because of their potential for higher rodent resource bases.

Coyote habitat selection may also be influenced by human factors in the Oklahoma panhandle. Coyotes did not occur often in mesa or range/grassland areas (Figure 6). Much of the range/grassland and mesa areas of the panhandle are used for cattle production (Shaughnessy 2003). Coyotes are considered significant predators on livestock by the ranchers in the Oklahoma panhandle and substantial effort is invested in coyote control in the primary cattle production areas (Shaughnessy 2003). Coyote populations may be reduced in these areas due to these control efforts, and coyotes may be selectively avoiding these areas in response to the control efforts (Shaughnessy 2003).

An additional historical component may be at work in the dynamics of panhandle canid populations. The wolf (*Canis lupus*) historically occupied the Oklahoma panhandle (as well as the body of the state). Antagonistic interactions between coyotes and wolves are well documented (Carbyn 1982; Thurber et al. 1992; Peterson 1995). It is possible that the wolf historically structured the panhandle canid community by eliminating coyotes from local areas and limiting their populations regionally. If this were the case, the interaction would have benefitted swift foxes and other smaller canids. With the extirpation of wolves, however, coyote numbers have not only increased, but coyotes have invaded habitats from which they were previously excluded by wolves. As a result, it is likely that coyotes now eliminate swift foxes locally and swift foxes are only able to thrive in those habitats that coyotes do not prefer.

Mustelids/Mephitids

Of the three mustelid species that were detected during the course of this study, spotted skunks were detected most often. Overall, spotted skunks were detected most often in Cimarron County and least often in Texas County. However, these differences are not statistically significant. Physiographically, spotted skunks also occur evenly among all designated regions. While power for the habitat test was low, power for the county test was high. Given that the two tests agreed, the probability of the commission of a Type II error seems remote. As a result, we conclude there are no regional biases in spotted skunk detections throughout the panhandle.

Badgers were detected regularly throughout the course of the study as well, but not with the frequency of spotted skunks. Badgers were detected much more often in Cimarron County than in any other panhandle county, however these differences are not significant. Power for this test was high as well, so although there are detection differences between counties, no regional preference exists.

Striped skunks were detected least often over the course of this study. Striped skunks are distributed very evenly across the three panhandle counties. Statistical power is low, however, for this test, so these results should be interpreted with caution. Striped skunks show significant habitat preferences within the counties. Striped skunks markedly prefer riparian areas over all other panhandle habitats. They also occur regularly in the mesa and agricultural areas, but are under-represented in grassland/range areas.

Mustelids and mephitids in general are distributed evenly across the entire panhandle, although power is low for this test. Due to the low power, results should again be interpreted with caution and trends in occurrences should be examined. Mustelids/mephitids were detected more often in Cimarron County than in either Texas or Beaver counties. Mustelids/mephitids were detected in Cimarron County twice as often as they were detected in Texas County and nearly twice as often as they were detected in Beaver County. Mustelids/mephitids exhibit clear habitat preferences in the Oklahoma panhandle. Mustelids/mephitids prefer riparian and agricultural areas over other habitats in the panhandle (Figure 7). They do not appear to avoid the mesa area, but do show a clear aversion to the range/grassland areas of the panhandle. Mustelids and mephitids also do not demonstrate any significant intra- or interfamilial interactions.

Mustelid/mephitid distribution patterns in the Oklahoma panhandle are more difficult to explain due to the lack of intra- and interfamilial interactions. Intraorder level interactions are present among all canids and mustelids/mephitids, however. Mustelids/mephitids tend to avoid those habitats which support higher numbers of swift foxes and are generally more abundant in areas with higher coyote occurrences. Although swift foxes are generally larger than the these mesocarnivores, it seems unlikely that the dynamics defining swift fox/coyote interactions and distributions are at work between swift foxes and badgers/skunks owing to the defensive adaptations of skunks and the generally aggressive disposition of badgers. It seems more likely to us that mustelids and mephitids, like coyotes, are simply selecting areas that may support larger small-mammal and, in particular, rodent populations such as agricultural areas.

Small canids tend to be more generalized in their food habits than larger canids (or mustelids) and are able to persist on a less strictly carnivorous diet (Cutter 1958; Johnson et al. 1996). If coyotes exclude swift foxes from areas of high rodent densities, swift foxes should be able to persist in less optimal areas (in terms of rodent densities) by expanding their diet to include a wider variety of foods. Mustelids and mephitids, by virtue of their defenses and smaller size, are probably not viewed by coyotes as being strong food resource competitors. Mustelids/mephitids are also more strictly carnivorous than canids (Feldhamer et al. 1999). They would be predicted to select areas with the highest prey bases available. This may explain the similar habitat selections by coyotes, badgers and skunks if agricultural areas do indeed support higher small mammal populations than surrounding habitats.

Felids

The final carnivore detected during this study was the bobcat. Bobcats were only detected infrequently. Bobcats are distributed evenly among counties. In the panhandle, bobcats are also distributed evenly among habitats. The relative scarcity of data for cats in general underscores the need for further research on the role of felids in the Oklahoma panhandle carnivore community.

Discussion

Overall, carnivores are not distributed evenly throughout the panhandle or among habitats. Panhandle distributions may be indirectly related to human populations and activities. Carnivores were overwhelmingly detected more often in the western third of the panhandle (Cimarron County), with detections tending to decrease eastward through the panhandle. Cimarron County is the least populated and developed county in the Oklahoma panhandle. Human populations steadily increase eastward to Guymon, Oklahoma, which is located in the center of Texas County, in the very middle of the panhandle. Human populations then slightly decrease through Beaver County, which may also explain some of the far eastern distributional peaks in carnivore occurrences. Carnivore habitat preferences are often also dependent upon the presence or absence of other carnivores and may be dependent upon relative densities of small mammals within habitats. However, more research in the form of small mammal surveys in the major panhandle habitats is needed to properly address this hypothesis.

Acknowledgments

We would like to thank Drs. Larry Toothaker, Nicholas Czaplewski, Mark Jakubauskas, and Kathryn Pandora for their guidance and comments over the course of this research. We are indebted to Dr. David Legates as well, for his contributions to the statistical analyses and designs in this project. We acknowledge, with thanks, the Oklahoma Department of Wildlife Conservation for providing the Section 6 funding (to MJS) for this project. We also thank the many panhandle landowners for providing access to their land in the Oklahoma panhandle, as well as an anonymous reviewer for comments on the manuscript.

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Received April 15, 2016 Accepted November 21, 2016

Biological and Water Quality Monitoring at Tallgrass Prairie Preserve in Oklahoma

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Abstract: From 2013 to 2015, aquatic monitoring was conducted at the Tallgrass Prairie Preserve (TGP) in Pawhuska, Oklahoma. Biological monitoring consisted of fish and macroinvertebrate Index of Biotic Integrity (IBI). Ten streams are located on the TGP with 21 fish species and 14 macroinvertebrate orders. The overall fish IBI score was 39 which indicates a good fishery. The overall macroinvertebrate IBI score was 37 which indicates a good macroinvertebrate community. Water quality consisted of water temperature, dissolved oxygen, conductivity, pH, sodium, and chloride parameters. Conductivities ranged around 0.3 ms/cm with water temperatures varying from 13 Celsius in the spring to 38 Celsius in the summer. Dissolved oxygen ranged from 7mg/L to 14mg/L. Overall, streams on the preserve have good diversity based on the IBI with an abundant number of fish species and macroinvertebrate taxa represented.

Introduction

Tallgrass Prairie Preserve is a 40,000-acre conservation preserve owned by The Nature Conservancy (TNC) in the northeast portion of Oklahoma. The preserve was acquired in 1989 and consists of tallgrass prairie rangeland, with scattered crosstimber woodlands and riparian corridors along stream courses. The preserve is managed with the use of prescribed fire, invasive species control, and seasonal grazing by cattle leases and a permanent herd of about 2,000 bison. The preserve is located in the upper reaches of the Sand Creek watershed (Figure 1). The property has been maintained in native grassland, with habitat for target species such as greater prairie-chicken, Henslow's sparrow, upland sandpiper, short-eared owl, rough-legged hawk and the American burying beetle. In the 1990's, an inventory was conducted of the fauna and flora of the TGP which included fish surveys of all the streams and ponds on the preserve. Stewart et al. 1999 found 23 fish species at 11 sites on the preserve. Bass 1994 sampled macroinvertebrates and water quality at three of the 10 stream sites that TNC researched. Bass 1994 found 134 taxa represented at six stream sites.

Aquatic monitoring started in 2013 to gather data for the preserve since there was a 22-year gap in aquatic data collection. This data will assist in detecting future declines in fish and macroinvertebrate populations. It also provides information to the preserve director about the streams and what stream improvements can be undertaken to improve the water quality and biology.

Methods

1. Biology

Fish were collected at 10 stream sites using backpack shockers and 10-foot seine nets with a five-person field crew. IBI methods were used for sampling fish, which includes sampling all macrohabitats including riffles, pools and runs over a 300-meter stream reach. Macrohabitats were sampled using the depletion method until

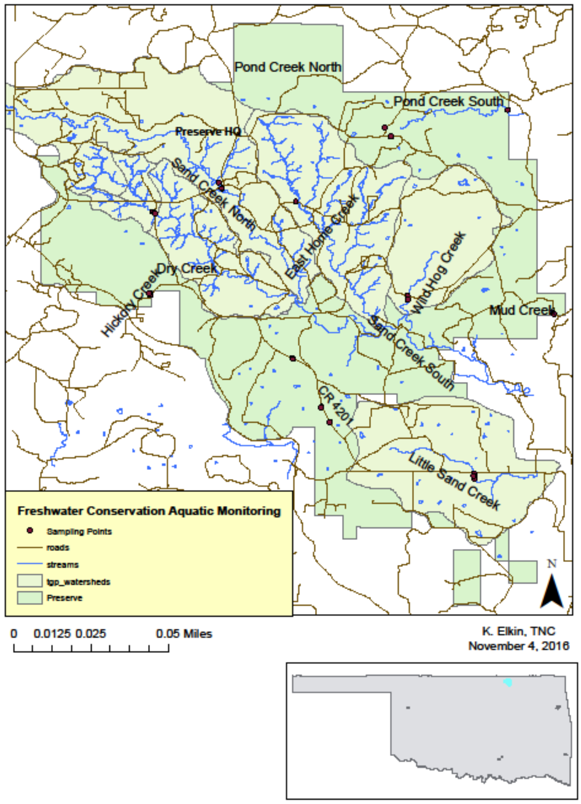

Figure 1. Tallgrass Prairie Preserve study area

no new species were collected in the riffles, pools and runs. The depletion method samples all fish species in a reach of stream until no new fish species were collected. If a new species were collected, the depletion method started over for that macrohabitat until no new species were sampled. The IBI were designed to include a range of attributes for fish assemblages (Karr 1986). The 12 measures or metrics fall into three broad categories: Species Composition, Trophic Composition, and Fish Abundance and Condition (Karr 1986). Fish were identified to species in the field and released back into the stream. Unidentified fish species were preserved in 10% formalin and identified to species at the Pontotoc Ridge Preserve (PRP) Environmental Research Facility in Stonewall, Oklahoma.

Macroinvertebrates were sampled using D-frame aquatic dip-nets. Riffles, pools and runs were sampled over a 300-meter stream reach. Field crews of seven to eight people consisting of Oklahoma State University (OSU), TNC and Brigham Young University (BYU) staff collected for a specified amount of time based on the number of people collecting. Staff were positioned within the 300-meter stream reach to sample the different macrohabitats. Macroinvertebrates were preserved in 70% denatured ethyl alcohol for identification to order, family and genus at the PRP Environmental Research Facility located in Stonewall, Oklahoma.

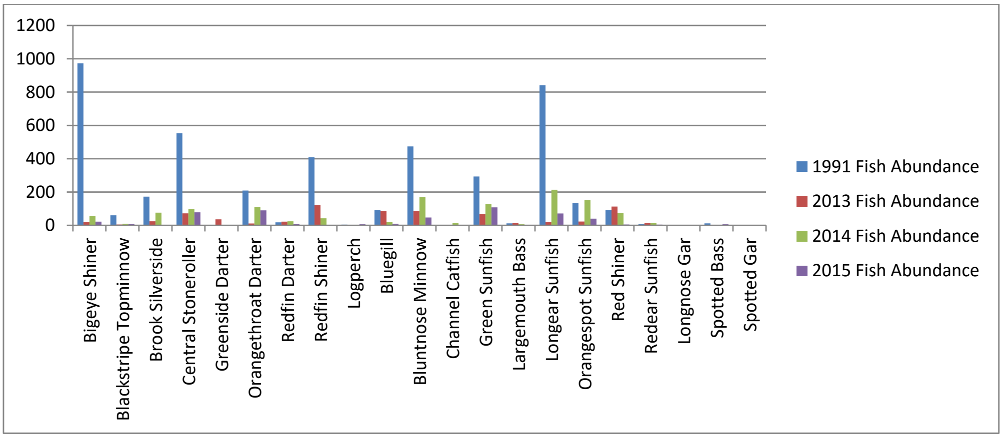

Figure 2. Fish abundance at Tallgrass Prairie Preserve

Table 1. Overall fish IBI score for 10 streams on the Tallgrass Prairie Preserve

Fish IBI indicated a good fishery based on nine metrics. Metrics based on Karr 1986 were modified to fit Oklahoma ecoregions (Monty Porter, Oklahoma Water Resources Board (OWRB) personal communication). Nine metrics were used to evaluate the streams on the preserve. Scores were divided into a value of five, three and one point per metric based on the value calculated for each metric.

Watershed Size	Metric	Score of 5	Score of 3	Score of 1
<100 sq.miles	Total # of species		21	
	# of species comprising >75% of sample	8		
	Shannon's Diversity based on #	10.7		
	# of sunfish	4		
	# of intolerant sp.	8		
	% of tolerant sp.		42%	
	% of lithophils		25%	
	% of DELT anomalies	0%		
	Fish # (total individuals)	1394		
	Total Score			**39**

2. Water Quality

Water quality measurements were collected with a Hach Hydrolab DS5 water quality meter. Parameters measured included water temperature, conductivity, pH and dissolved oxygen. Riffles, pools and runs were sampled over a 300-meter stream reach. Sodium and chloride samples were taken to determine sodium and chloride concentrations. Samples were taken from pools in the stream and analyzed by the OSU Soil, Water and Forage Analytical Laboratory.

Results

Fish abundance at TGP indicated 21 different species were found on the preserve (Figure 2). Darters, minnows, shiners, stonerollers, catfish, sunfish, bass and gar were all present during fish surveys. The largest population numbers found were the Centrachidae (sunfish) and Cyprinidae (minnow) families. Fish abundance was higher in 1991, and this could be due to the amount of time spent seining and angling fish. From 2013-2015, streams were sampled until no new species

Table 2. Macroinvertebrate taxa from 10 streams on the Tallgrass Prairie Preserve. Macroinvertebrates were represented by 14 orders with the most abundant orders represented by Gastropoda, Ephemeroptera and Decapoda.

Total #	Order	Family	Genus
1	Diptera	Tipulidae	Triogma
2	Annelida	Oligochaeta	
123	Ephemeroptera	Potomanthidae	Anthopotamus
23	Gastropoda	Hydrobiidae	Pyrgulopsis
9	Gastropoda	Viviparidae	Viviparous
5	Gastropoda	Pleuriceridae	Leptotoxis
38	Decapoda	Cambarinae	Orconectes
2	Decapoda	Cambarinae	
7	Decapoda	Orconecteidae	Orconectes
9	Trichoptera	Helicopsychidae	Heliopsyche
1	Ephemeroptera	Leptophlebiidae	Hydrosmilodon
6	Hemiptera	Gerridae	Gerris
4	Oligochaeta		
40	Gastropoda	Hydrobiidae	Tryonia
1	Diptera	Chironimidae	
1	Odonata	Libellulidae	Libellula
2	Odonata	Calipotergyidae	
1	Hemiptera	Corixidae	
3	Ryhnchobdellida	Piscicolidae	Piscicola
3	Gastropoda	Planorbidae	Planorbula
15	Mollusca	Corbiculidae	Corbicula
1	Diptera	Tipulidae	Tipula
5	Trichoptera	Glossiphoniidae	Placobdella
81	Ephemeroptera	Heptageniidae	Stenacron
1	Coleoptera	Dytiscidae	
9	Diptera	Chironomidae	
2	Diptera	Simulidae	
10	Trichoptera	Leptoceriidae	Oecetis
8	Trichoptera	Leptoceriidae	Leptocerus
2	Plecoptera	Perlidae	Perlesta
3	Coleoptera	Dytiscidae	
1	Tipulidae	Tapaniidae	
1	Coleoptera	Elmidae	

were found in each macrohabitat. Some streams were sampled faster than other streams due to the number of species present while sampling and based on stream order. Fish IBI indicated a good fishery (Table 1).

Macroinvertebrate diversity consisted of 14 orders found on TGP (Table 2). Macroinvertebrate IBI indicated a good macroinvertebrate community (Table 3). Decapoda (crayfish) Gastropoda (snail), and Ephemeroptera (mayfly) were the most dominant macroinvertebrate orders present.

Dissolved oxygen concentration ranged from seven to 14 mg/L in various streams (Figure 3). Water temperature ranged over 25 degrees Celsius between streams (Figure 4). Multivariate regression analysis depicted no relationship between dissolved oxygen, conductivity and pH (Table 4). Sodium concentrations ranged from four to 45 ppm (Figure 5), while chloride concentrations ranged from three to 75 ppm (Figure 6).

Table 3. Overall macroinvertebrate IBI score for 10 streams on the Tallgrass Prairie Preserve of Oklahoma.

The macroinvertebrate IBI score represents a good macroinvertebrate community. Taxa abundance was high in streams sampled at the preserve. Eleven metrics were used to calculate the macroinvertebrate IBI score. Metrics were developed by OWRB to represent the ecoregions of Oklahoma. A score of five, three or one were given to each metric to develop an overall IBI score. These metrics were established by OWRB to represent the ecoregions of Oklahoma.

Metric	**5**	**3**	**1**
Total Taxa		16	
# EPT Taxa		7	
% EPT- % Hydropsychidae			0%
% Scrapers		20%	
% Clingers		55%	
% Diptera	3.4%		
% Chironomidae	2.8%		
% Isopoda	0.0%		
% Tolerant Organisms			25%
HBI		5.10	
% Intolerant Organisms	56.0%		
Total IBI Score			**37**

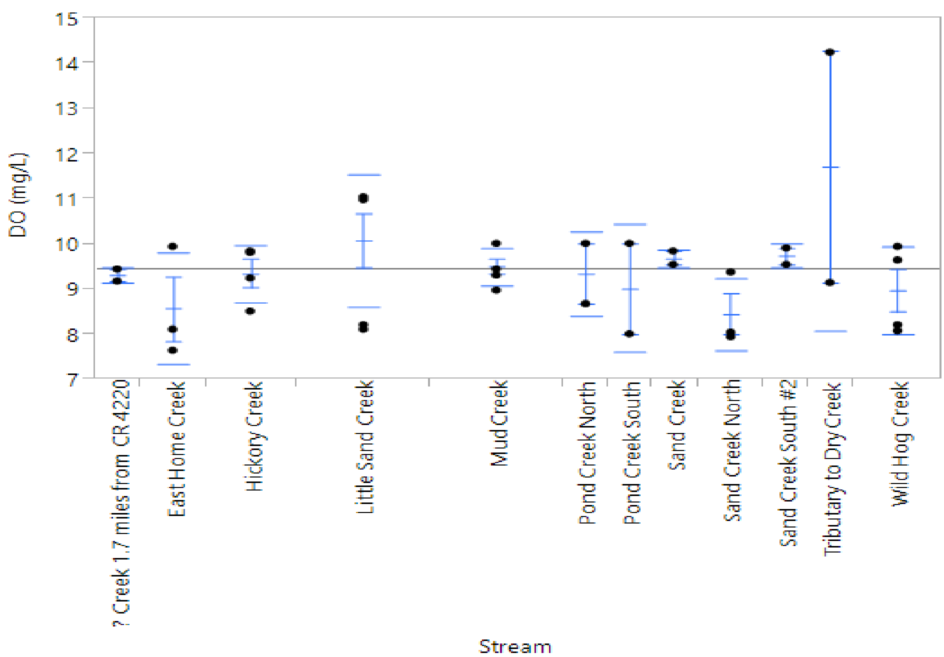

Figure 3. One-way ANOVA of dissolved oxygen concentrations.

Dissolved oxygen concentrations varied from 7.0 mg/L in the early morning to 14.0 mg/L in the late afternoon. Dissolved oxygen fluctuates with temperature, salinity and pressure changes in the aquatic environment. Dissolved oxygen concentrations vary in prairie stream systems due to the shallow depths encountered in these stream systems. Small order streams had shallower macrohabitat and higher dissolved oxygen levels.

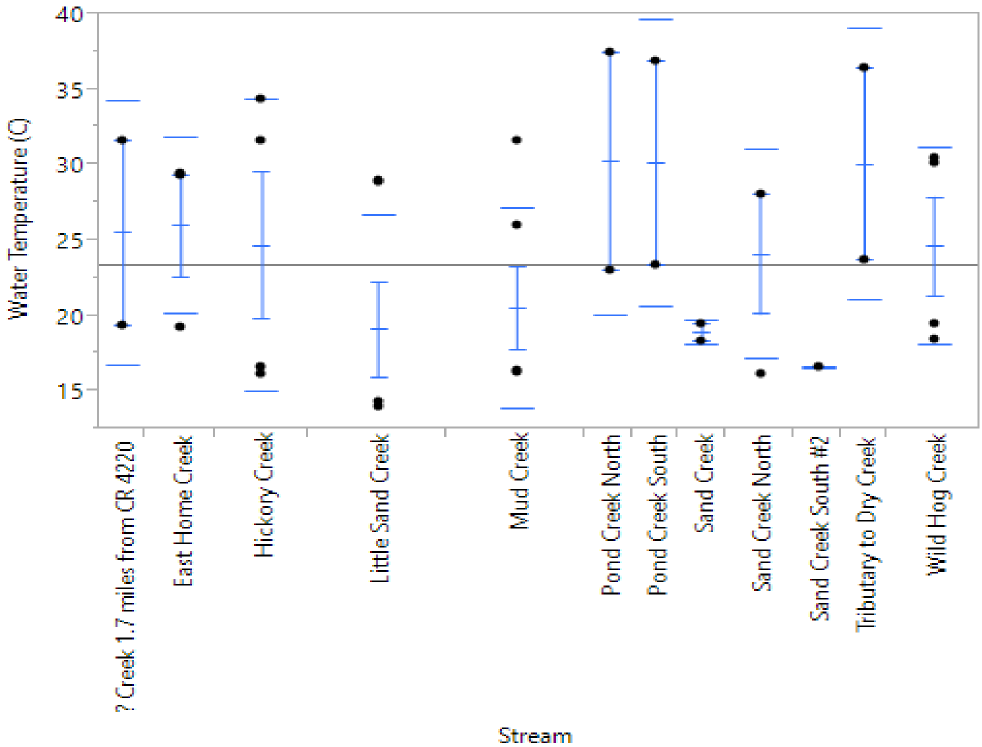

Figure 4. One-way ANOVA of water temperatures.

Water temperatures ranged from 13 Celsius in the early morning to 38 Celsius in the late afternoon. Small order streams had higher water temperatures due to the smaller depths encountered.

Table 4. Water quality multi-variate regression analysis

R-squared values show a weak correlation between dissolved oxygen, conductivity and pH. Dissolved oxygen concentrations varied depending on the time of day the measurements were taken and based on stream order. Conductivity values were consistently around 0.3 ms/cm.

Summary of Fit

RSquare	0.310062
RSquare Adj	0.121898
Root Mean Square Error	1.878919
Mean of Response	25.67
Observations (or Sum Wgts)	15

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	17.452109	5.81737	1.6478
Error	11	38.833691	3.53034	**Prob > F**
C. Total	14	56.285800		0.2351

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-1.111521	30.70841	-0.04	0.9718
LDO (mg/L)	-0.284572	0.233808	-1.22	0.2490
Conductivity (ms/cm)	10.434446	5.763814	1.81	0.0976
pH	2.4768387	3.076296	0.81	0.4378

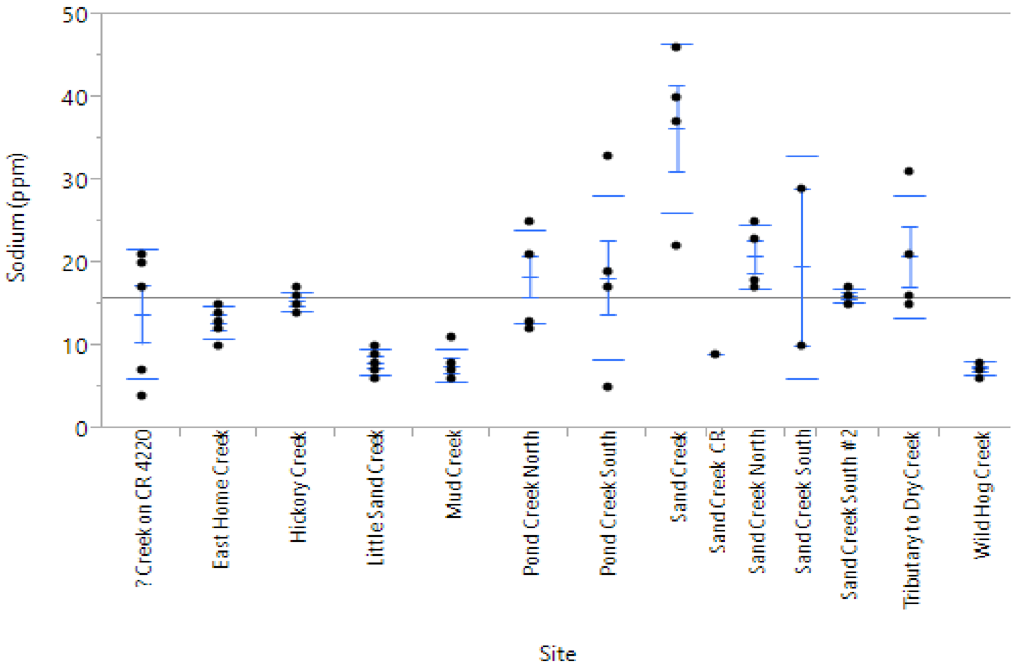

Figure 5. Sodium concentrations for streams on the Tallgrass Prairie Preserve.
Sodium occurs naturally in streams on the preserve due to the limestone substrate present in the streams. Sodium reached as much as 45 ppm in some streams with four ppm in other streams.

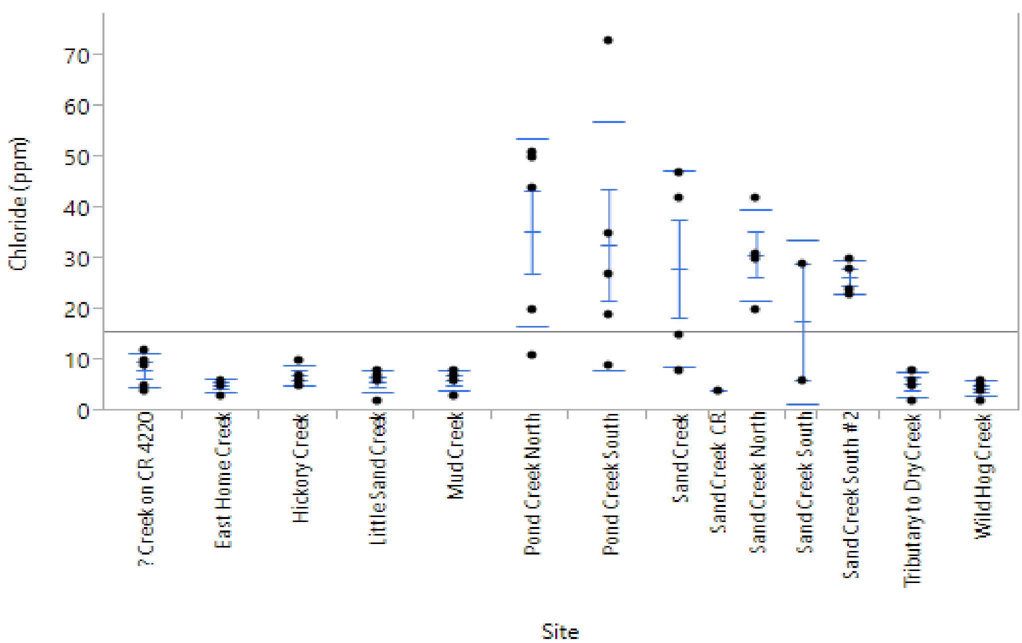

Figure 6. Chloride concentrations for streams on the Tallgrass Prairie Preserve
Chloride concentrations ranged from three ppm to 75 ppm in streams located on the preserve. Natural sources of chloride occur in these streams due to the geologic deposits, soils and saline groundwater.

Discussion

Biological integrity is the capability of supporting and maintaining a balanced, integrated and adaptive community of organisms having a species composition, diversity and functional organization comparable to that of the natural habitat of the region (Hawkins 2006). The natural habitat of the tallgrass prairie indicates that these fish species and macroinvertebrate orders were representative of this prairie ecoregion. This preserve has 40,000 acres with several streams that were protected from major anthropogenic factors. Stream fish assemblages are influenced indirectly by natural and anthropogenic landscape features acting through intermediate factors like flow and temperature regimes and water quality and physical habitat (Gido and Jackson 2010). The fish found on the TGP appear to be of high quality based on the IBI.

TGP has one main stream, Sand Creek, which flows across the preserve with several tributaries. Fish were sampled in 1991 after TNC's purchase of the TGP at Sand Creek and several of the tributaries. The overall fish IBI score for 10 streams indicated a good fishery.

The overall macroinvertebrate IBI score indicates a good macroinvertebrate community. Fish and macroinvertebrate IBI scores are used to assess the environmental quality of streams (Hotz 2010). Based on the IBI score for fish and macroinvertebrates, streams on the TGP were still of high quality.

Overall, TGP offers a unique look at several different tributary streams and one mainstem stream that provides biological and water quality data from a prairie ecoregion.

Acknowledgments

TNC would like to thank Tony Brown and Perry Collins of the Tallgrass Prairie Preserve for assistance in the field. TNC would like to thank Tawnda Hopper and Kay Krebbs for assistance during overnights at the preserve. TNC would like to thank Jim Burroughs, Donnie King, Darren Rythe, Jeanne Odonell, Buck Ray and Curtis Tackett of the Oklahoma Department of Wildlife Conservation (ODWC) for assistance during fish surveys. TNC would like to thank Sarah Hogden and Kaleb Thayer of Oklahoma State University (OSU) for assistance in the field.

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Submitted May 24, 2016 Accepted November 30, 2016

A New Record of and Additional Notes for the River Otter, *Lontra canadensis,* from Logan County, Oklahoma

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River otters, *Lontra canadensis*, were at one time found across most of Oklahoma. What little is known about the historical distribution in the early 1800s and 1900s in Oklahoma has been summarized by Blair and Hubbell (1938), Duck and Fletcher (1944), Bissonette and Maughan (1978), Hatcher (1984), Caire et al. (1989), Oklahoma Department of Wildlife Conservation (2008), Barrett (2008) and Barrett and Leslie (2010). The Oklahoma Game and Fish Department (1952) reported that otters were very rare or had been extirpated in most areas of Oklahoma by 1952 (Caire et al., 1989). Early historical reports are scarce and scattered across the state but include the Red River (Marcy, 1854), Muskogee County (Foreman, 1926), Comanche County (Conover, 1927), Caddo County (Nice, 1931), Woodward County (Blair, 1939) and Kiowa County (Halloran and Glass, 1964). In an attempt to reestablish the river otter in Oklahoma, on 21 March 1984, 5 male and 5 female otters were released into the Wister Wildlife Management Area in LeFlore County and in April 1985 seven otters (4 males and 3 females) were released into the McGee Creek Wildlife Management Area in Atoka County by the Oklahoma Department of Wildlife Conservation (Barrett, 2008). Over a two-year period in the mid-late 1990s, 22 river otters were reintroduced into the Wichita Mountains Wildlife Refuge in Comanche County (Barrett, 2008). Other reports (Hatcher, 1984; Base, 1986; White and Hoagland, 1997; Barrett, 2008) suggest the reintroductions have been successful and that the river otter distribution in Oklahoma is spreading westward, with specimens from Cleveland County preserved in the Sam Noble Museum of Natural History collections. A map in Barrett and Leslie (2010) suggests the presence of river otters in Kingfisher County based on USDA Animal and Plant Health Inspection Service capture reports for 2004. On 13 February 2016, an adult male river otter, *L. canadensis*, was found dead on Oklahoma State Highway 33, 0.8 km N of Coyle. The coordinates of the specimen location are 35°57’50.1”N 97°14’10.3”W; elevation 265 m. From where the otter was found dead on the road to the western edge of the Cimarron River is 0.5 km. The habitat along the river near this locale is dominated by willow (*Salix*), cottonwood (*Populus deltoides*) and tamarisk (*Tamarix*).

This is the first record of an otter from Logan County and in north central Oklahoma. There are no reports of otters being taken from Logan County from 2008 to 2016 (ODWC). The nearest known reports are from Cleveland County (Barret and Leslie, 2010).

The male otter is deposited in the University of Central Oklahoma Natural History Museum (UCONHM 7158). External measurements were total length, 119 cm; length of tail, 47 cm; length of body, 72 cm; length of hind foot, 12.5 cm; length of ear, 2.3 cm; weight, 10.6 kg. In addition to skin and skeletal remains, internal organs and contents were preserved in alcohol and tissue samples (lung, kidney, heart, muscle) were preserved in the UCONHM frozen tissue collection. The animal had been run over by a vehicle, the back broken and the skull completely crushed.

Reproductive data for river otters in Oklahoma is scant. This scrotal male specimen had testes lengths of 52 mm (right) and 55 mm (left). Hamilton and Eadie (1964) used the length of the testes to estimate the age of otters in New York. Length of testes of males 3 years or older are reported to range from 30–36 mm during March and April and 35–50 mm in November and December and based on these values, this otter would have been at least 3 years old. Friley (1949) separated males into four age groups based on the baculum size. The baculum measured 100 mm in length, and weighed 7.4 g., which placed it in Friley's (1949) older adult male category.

Barrett and Leslie (2012) noted that the age of river otters decreased from east-to-west and colonizing populations to the west had a higher proportion of younger individuals. Not having a large sample of otters or any data as to how long this otter had been in Logan County precludes discussion of whether this was an established resident or an older instead of younger colonizing individual.

Descriptions of the internal anatomy of river otters from Oklahoma are few. The length of river otter trachea has been described as intermediate between that of terrestrial carnivores and marine mammals and a shorter trachea facilitates air exchange and increases lung ventilation in diving mammals (Tarasoff and Kooyman, 1973b). The mean tracheal length of river otters is reported as 15.3 cm, or 23.2% of the body length (Tarasoff and Kooyman, 1973b; Lariviere and Walton, 1998). However, the length of trachea in this river otter was 21.1 cm (measured from the top of the forking of the branching of the bronchi to the rim of the trachea below the bottom of epiglottis). This is 29.2% of the body length and considerably longer than reported for river otters elsewhere (Lariviere and Walton, 1998). We know of no other measurements of tracheal length of river otters from Oklahoma. The lobes of the lungs match the descriptions presented in the literature (Tarasoff and Kooyman, 1973a). They are triangular in shape, and there are four lobes in the right lung (cranial, middle, caudal, and accessory) and two in the left (cranial and caudal). After combing and brushing the fur, the only ectoparasites found were several sucking lice. However, Kimber and Kollias (2000) indicated ectoparasites on river otters are rare. The length of the small intestine was 35 cm and the large intestine was 26.6 cm. The kidneys were reniculated and similar in gross morphology as reported by Baitchman and Kollias (2000).

Fish have been reported as a common diet item of river otters (Knudsen and Hale, 1968; Reid et al., 1994). Hatcher (1984) reported the stomach and intestine contents of two otters from Latimer County contained crayfish, newts (*Notophthalmus viridescens*), an unidentified fish, and a gastropod. Shackelford and Whitaker (1997) reported piles of fish scales at river otter feeding sites in Oklahoma. We examined the stomach and intestinal contents of this otter and it contained numerous fish scales (Centrarchidae).

Acknowledgments

We thank Jerrod Davis, furbearer biologist, Oklahoma Department of Wildlife Conservation, for information about otter harvest in Oklahoma.

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Submitted June 14, 2016 Accepted November 21, 2016

A Comparison of Lead Lengths for Mini-Fyke Nets to Sample Age-0 Gar Species in Lake Texoma

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Abstract: Mini-fyke nets are often used to sample small-bodied fishes in shallow (<1 m depth) water, especially in vegetated shoreline habitats where seines are ineffective. Recent interest in gar (Lepisosteidae) ecology and conservation led us to explore the use of mini-fyke nets to capture age-0 gar and specifically how capture is affected by lead length of the fyke net. In the summers of 2012, 2013, and 2015, mini-fyke nets with two different lead lengths (4.57 m and 9.14 m) were set at random sites in backwaters and coves of the Red River arm of Lake Texoma, Oklahoma. Mean CPUE (catch-per-unit-effort; number per net night) was significantly lower for mini-fyke nets with short leads (0.52) compared to those with long leads (1.51). Additionally, Spotted Gar (*Lepisosteus oculatus)* were captured at a higher rate than the other three gar species present in Lake Texoma, although this could have been an artifact of sampling location. We found that differences in length-frequency of captured gar between gear types were nearly significant, with total length ranging from 47mm to 590mm. Mini-fyke nets with longer leads increased the efficiency of sampling for age-0 gar by increasing catch rate without affecting estimates of other population parameters and appear to be useful for this purpose.

Introduction

Gar are found in North America, Central America and Cuba, have a long-standing history of being considered a "trash" fish, and are often perceived by anglers and management biologists as a potential predator or competitor (Helfman et al. 1999, Pflieger 1997, Robertson et al. 2008, Scarnecchia 1992). As a result, many gar species have been the target of eradication efforts in lakes and rivers (Binion 2015, Scarnecchia 1992). Recently, however, there has been an increased interest in conservation of these species (O'Connell et al. 2007), resulting in a greater need to understand the ecological role of these predators in their native ecosystems and a greater need for research on sampling protocols.

With declining populations and changes in public perception, most conservation has been directed towards alligator gar (*Atractosteus spatula*), which grows large (up to 2.4 m) and has garnered a relatively high popularity among anglers (Buckmeier 2008). Spotted gar (*Lepisosteus oculatus*) has received renewed conservation interest in Canada since it was listed as threatened (COSEWIC 2005) and Florida gar (*L. platyrhincus*) has gained attention in that state due to habitat loss within their limited distribution (Glass et al. 2011, Gray et al. 2012, Murie et al. 2009). Because many gar species have been sampled as by-catch with gear types intended to target sportfish, little is known about gar densities, especially gear types useful to capture them. Additionally, most of the sampling information on gar has been collected for adults using: multifilament gillnets (Binion 2015, Robertson et al. 2008), monofilament gillnets (Howland et al. 2004, O'Connell et al. 2007), electrofishing (Glass et al. 2011, Murie et al. 2009), trawls (O'Connell et al. 2007), trammel-nets (Brinkman 2008), seines (O'Connell et al. 2007), jug lines (Buckmeier et al 2013, Dibenedetto 2009), and rod and reel (Buckmeier et al 2013). There is a paucity of information regarding the collection of age-0 gar, which is needed to better understand the early life-history of these species.

Most sampling methodologies that have been used to collect young-of–the-year (YOY) gar are limited to active gear (electrofishing; Echelle 1968 and seining; Inebnit 2009), which can be ineffective in shallow, vegetated habitats where this life stage occurs (Snow and Long 2015). Age-0 gar have been found floating at the surface along with twig fragments and leaf debris (Moore et al. 1973), which clogs net sampling gear or reduces detectability by the netter, reducing sampling effectiveness. Alternatively, passive gear types may be more effective in these habitats, but variation in their construction and deployment may affect capture efficiency (Kubecka et al.2012). Brinkman (2008) deployed mini-fyke nets with 4.57 m leads to successfully capture juvenile Alligator gar in Lake Texoma, Oklahoma, although catch was minimal. In a subsequent study, Snow and Long (2015) reported that mini fyke-nets with a long lead (9.14 m) caught more YOY alligator gar than nets with the 4.57 m lead, although this was not specifically tested. The ability to consistently sample age-0 gar species will give management biologists a better understanding of early life history requirements of these species (e.g., recruitment, growth, food habits). The purpose of this study was to compare catch per unit effort (CPUE) and length-frequencies of YOY gar species captured with mini-fyke-nets of differing lead lengths (4.57 m and 9.14 m).

Methods

Sampling Site – The area for this study was the river-reservoir interface section of the Red River arm of Lake Texoma, which is composed largely of backwater habitat and encompasses 33.56 km² (Figure 1). The typical sample site was less 1m in depth and surrounded by aquatic or terrestrial vegetation and woody debris.

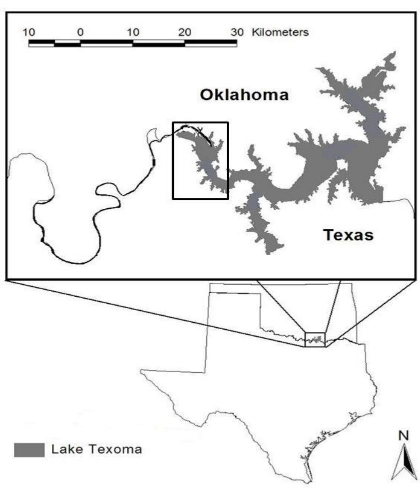

Figure 1. Location of Lake Texoma in south central Oklahoma where age-0 gar were sampled with mini fyke nets during the summer months of 2012, 2013, and 2015. The black outlined box represents the sampling area which encompasses 33.56 km² of Lake Texoma.

Lake Texoma is a 36,000-ha reservoir on the Oklahoma-Texas border. During normal flow, the Red River is constrained within a river channel, cut off from adjacent flood plains where terrestrial vegetation colonizes (Patton and Lyday 2008), creating suitable substrate for the adhesive eggs and developing larvae of gar (Moore et al. 1973). However, these sites are not accessible to adult spawning gar until flooding from the Red River reconnects adjacent floodplain environments.

In the summer of 2012, 2013, and 2015 mini-fyke nets (0.6 m x 6.35 m; with 3.18 mm mesh, 0.6 m x 1.92 m rectangular cab, and 510 mm metal throat) with two different lead lengths (4.57 m and 9.14 m) were set perpendicular towards the shoreline. In 2012 and 2013, sampling sites were chosen with an adaptive random cluster sampling design (Tompson 1990) to maximize detection of alligator gar. In 2015, sites were chosen at random in backwater areas and coves where herbaceous vegetation and woody debris were abundant (Brinkman 2008). All gar collected were identified using preserved specimens, dichotomous keys (Pflieger 1997; Miller and Robison 2004), and a guide to identification from cleithra (Traynor et al. 2010). Gar were measured to the nearest mm, and verified as young-of-year by examining the sagittae and lapilli otoliths for annual rings (Buckmeier et al. 2012, Long and Snow 2016).

Lepisosteus spp. less than 125 mm total length (TL) (Echelle and Riggs 1972) were problematic to identify in the field, so fish were frozen until they could be identified in the laboratory. We based our identifications of these individuals mostly from morphology of cleithra (Traynor et al. 2010), which are the paired bones of the pectoral girdle that form the frame of the body wall directly posterior to the opercular cavity (Scharf et al. 1998). For reference, we compared cleithra of wild fish to those from known-age, hatchery reared specimens of spotted gar (15-185 mm TL [Snow et al. *In Press*]), shortnose

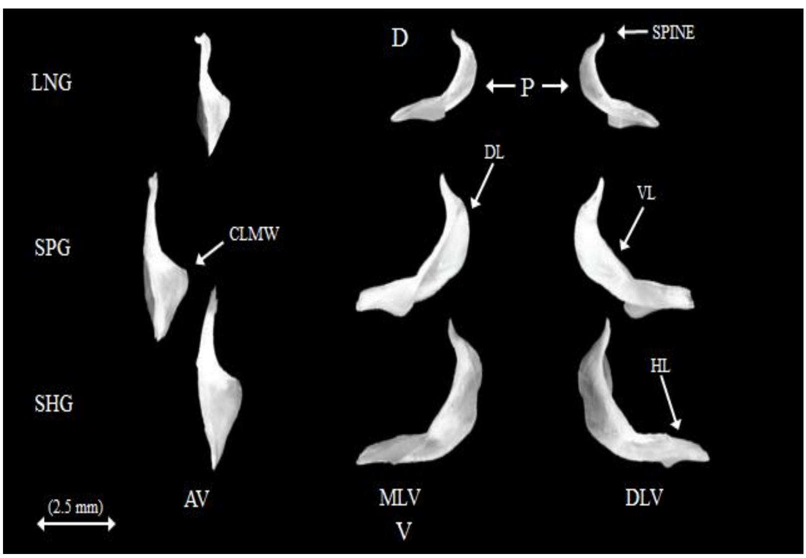

Figure 2. Cleithra morphology of three *Lepisosteus* spp (longnose gar [LNG; 109 mm TL], spotted gar [SPG; 103 mm TL], and shortnose gar [SHG; 117 mm TL]) according to 3 viewpoints: anterior view (AV), mesial lateral view (MLV), and distal lateral view (DLV). Shown here are the structure of the cleithra are cleithrum medial wing (CLMW), dorso-posterior lobe (DL), horizontal limb (HL), vertical limb (VL), and spine. Ventral (V), dorsal (D) and posterior (P) labels note orientation of the structure.

gar (57-192 mm TL [Snow and Long *In Review*]), and wild longnose gar >150 mm TL (this study). From 13 individuals ranging from 103 - 125 mm TL, cleithra were soaked in a 3:1 dilute bleach solution for 2 minutes, picked clean of flesh under a dissecting microscope, and rinsed with water until the cleithrum was clean. Based on shape from multiple viewpoints, the morphology of cleithra was used to distinguish among species (Figure 2). In anterior view (AV), the spine of cleithra from longnose gar protrudes farther from the midline and the cleithrum medial wing (CLMW) is less pronounced than shortnose gar and spotted gar. From the mesial lateral view (MLV), the dorso-posterior lobes of cleithra from shortnose gar and spotted gar were more robust than from longnose gar. In distal lateral view (DLV), the spines on the cleithra from longnose gar and shortnose gar had a more pronounced curve than from spotted gar. Shortnose gar and spotted gar cleithra were very similar when viewed in DLV and AV, but the horizontal limb extended over the dorso-posterior lobe and combined to form the spine when viewed in MLV. The horizontal limb of cleithra from shortnose gar folds and runs vertically, forming the spine at a much shallower depth compared to spotted gar. Also, the vertical and horizontal limbs of cleithra from spotted gar were disproportionate to each compared to longnose gar and shortnose gar whose limbs were more equal in proportion.

Two-way analysis of variance (ANOVA) was used to determine differences in CPUE (number of gar caught per net night) between lead length and gar species. All data were $\log_{10}+0.01$ transformed to conform to the assumptions of normality and tests were performed at a significance level of $P \leq 0.05$. Post-hoc tests of significant ANOVA results were conducted with the lsmeans pdiff option in SAS. The coefficient of variation (CV) was calculated as a measure of precision for CPUE estimates (Cyr et al. 1992, Patterson 2014). A Kolmogorov-Smirnov Test was used to determine differences in length frequency of gar collected between lead lengths. A length frequency histogram was added for visual interpretation. All statistical analyses were conducted with SAS 9.4 software (SAS Institute, Cary, North Carolina).

Results

Over the entire study period, 76 nights of netting captured 86 gar in nets with long leads compared to 61 nights of netting and 24 gar caught in nets with short leads (Table 1). Fyke nets with long leads caught 1.5 fish per net night on average, which were approximately 3X the number caught by fyke nets with short leads (0.5). Mean CPUE of gar was affected by species ($F_{3,540} = 3.89$, $P < 0.01$) and lead length ($F_{1,540} = 21.15$, $P < 0.01$), but no interaction was evident between the two ($F_{3,540} = 0.40$, $P = 0.75$). Furthermore, nets with long leads produced more precise estimates of mean CPUE (i.e., lower CV estimates; 0.14) than nets with short leads (CV = 0.25). Post hoc test reveal that among species, spotted gar were captured at a higher rate than the other three species (Figure 3).

Lead length did appear to affect sizes of gar captured somewhat, producing nearly similar length frequency histograms (Kolmogorov-Smirnov, P = 0.058, Figure 4). Mean total length of gar captured in nets with long leads was 237 (11.1) mm compared to 220 (17.4) mm in nets with short leads. Both net types captured gar ranged in size from 47 mm TL to 590 mm TL.

Table 1. Summary of age-0 gar capture (n) for each year, net nights, CPUE with standard error (S.E.) and coefficient of variation ($CV\bar{x}$) for each lead type (long = L and short = S) from the river-reservoir interface section of the Red River arm of Lake Texoma.

Year	Lead Type	Net Nights	*n*	CPUE (S.E)	$CV\bar{x}$
2012	L	9	12	2.11 (.97)	0.46
	S	21	5	0.32 (.21)	0.66
2013	L	27	23	0.96 (.14)	0.15
	S	13	6	0.56 (.24)	0.43
2015	L	41	51	1.74 (.33)	0.19
	S	27	13	0.66 (.22)	0.34
All year combined	L	77	86	1.51 (.21)	0.14
	S	61	24	0.52 (.13)	0.25

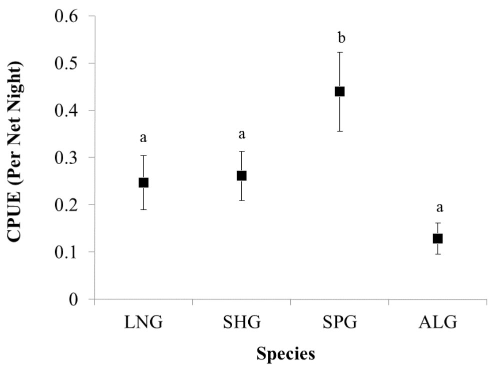

Figure 3. Post-hoc test results comparing mean CPUE among species of gar (LNG = longnose gar, SHG = shortnose gar, SPG = spotted gar, and ALG = alligator gar) sampled with mini fyke nets during the summer months of Lake Texoma in south central Oklahoma in 2012, 2013, and 2015. Different letters indicate significant differences of the post-hoc test (a being significantly different than b). Error bars represent ±1 SD.

Discussion

Doubling the lead length from 4.57 m to 9.14 m tripled the catch rates and improved precision, demonstrating the utility mini fyke nets with long leads to catch YOY gar. Also, lead length appeared to exert an influence on total length (mm) of fish captured, although a greater sampling effort would be needed to confirm this nearly-significant result. Additionally, we found differences in catch among species, which we attribute to the habitats sampled. The sampling area consisted of backwater and littoral zones of the river reservoir interface, which are used by all four species for spawning and nursery cover, but differences among relative abundance of species still likely existed. Longnose gar is the most widely distributed of the four gar species in Oklahoma (Miller and Robison 2004), so the lack of their predominance in our study area was intriguing. However, longnose gar often spawn over rocky habitat (Echelle 1968, Echelle and Riggs 1972), which was rare in our study area and would offer a partial explanation of our findings. We speculate that sampling in habitats with a greater preponderance of rocky substrate, such as the dam face, would result in a greater catch of longnose gar. Spotted gar, in contrast, was the most commonly captured species in our study, and this species seems to remain in backwater and littoral habits throughout life, moving in and across the floodplain depending on water level (Sneddan et al. 1999). Such backwater and littoral habitats were abundant in our study area.

The ability to efficiently capture YOY gar has many implications. For example, it has been suggested that juvenile alligator gar exhibit site fidelity, making them more prone to recapture (Sakaris et al. 2003). In Lake Texoma, alligator gar are relatively rare, reducing the probability of their capture, thus hindering studies that could investigate their site fidelity. Sampling of rare YOY alligator gar could be improved by deploying long-lead mini-fyke nets. Furthermore, this gear could help investigators better determine differences in habitat use or preference. Regardless of the species, having more efficient gear would improve sample sizes, leading to better estimates of numerous population-level metrics (e.g., age, growth, mortality; Snow and Long 2015).

For studies where sampling mortality is critical, it should be noted that access to surface air could be important. During our study, we sometimes observed dead individuals during retrieval. During periods of high temperature and low dissolved oxygen gar break the surface of the water to use their large vascularized swim-bladder to breathe air (Moyle and Cech 1982, De Roth 1973, Saksena 1975). These conditions are prevalent in shallow, backwater coves of southern reservoirs thru the summer months. To alleviate trap mortality, nets could be checked more often, or set such that captured gar would always have access to surface air for respiration (e.g., set shallower, or elevated in the water column with floats or a platform).

The use of cleithra to identify *Lepisosteus* gar < 125 mm may prove beneficial to biologist investigating early life history of gar (YOY

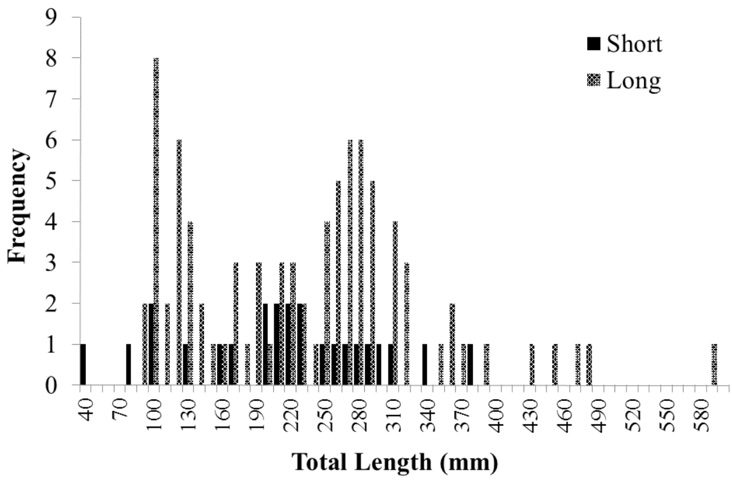

Figure 4. Length frequency histogram for all gar species sampled with mini fyke nets during the summer months of Lake Texoma in south central Oklahoma in 2012, 2013, and 2015 combined for both lead types.

alligator gar are easily identifiable from their dorsal stripe). While we used reference specimens to aid our identification and place high confidence on our results, a more formal examination of cleithra as an identification aid (e.g., shape analysis *sensu* Lombarte et al. 2006) would be beneficial. The cleithrum is the first structure to appear in the pectoral girdle, around 17-20 mm (Jollie 1984) making it potentially very useful for identifying and studying very early life stages of *Lepisosteus* gar. Although validation of cleithra is a need for further research, the differences noted in this manuscript make a compelling case for using this structure.

While we found that mini-fyke nets were efficient at capturing YOY gar, but may be biased toward catching fish >100 mm TL. Using active gear, approximately one-half of gar captured were < 100 mm TL (Echelle 1968: 53% and Echelle and Riggs 1972: 46%). In contrast, only 5% of the gar we captured were < 100 mm TL, suggesting that age-0 gar are not recruiting to the type of mini fkye nets we used in this study until after 100 mm TL. Speculatively, active gear may be better at capturing gar <100 mm because their body movement is limited to the use of their notochord appendage (Carpenter 1975). The notochord appendage is in the process of being absorbed as the gar grows beyond 150 mm TL, and is generally absent by 300 mm TL (Carpenter 1975). With limited movement capability, YOY gar < 100 mm TL may not encounter passive sampling gears very often, limiting catch, whereas these fish would also not easily be able to escape an active gear, resulting in increased catch rates. However, sampling large areas of backwater and flooded coves of reservoirs is not conducive to most active gears that could collect small fishes (e.g., backpack electrofishing and seining). In these cases, mini-fyke nets with long leads seem to be an efficient option.

Acknowledgments

The authors thank those individuals that assisted with laborious field work including Clayton Porter, Amie Robison, Conrad Aaron, Nate Copeland and Steve O'Donnell. We thank K. Kuklinski (ODWC) for reviewing an early draft of this manuscript. Financial support was provided by the Oklahoma Department of Wildlife Conservation and the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma State University, Oklahoma Department of Wildlife Conservation, U.S.

Geological Survey, U.S. Fish and Wildlife Service, and Wildlife Management Institute, cooperating). Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Submitted June 30, 2016 Accepted November 21, 2016

Comparison of Long Lead Versus Short Lead Mini-Fyke Net for Sampling Shallow Backwater Habitats

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Abstract: We evaluated catch of mini-fyke nets of two lead lengths (long lead =9.14 m vs. short lead= 4.57 m) for comparing species richness and abundance estimates of fish captured using both approaches. The sampling area consisted of shallow backwater coves in the river-reservoir interface of Lake Texoma in Oklahoma. During high water events, the Red River reconnects to adjacent flood plains and isolated oxbow lakes, and inundates terrestrial vegetation. These dynamic habitats are colonized by a host of fish for spawning, nursery cover, foraging, and movement purposes. Fish were collected from 28 long lead nets and 20 short lead nets. A total of 38 species were captured, representing 13 families, and totaling 3,893 individuals. The mean species diversity represented in long lead was 17.4 (± 9.45) compared to 15.7 (± 9.21) for short lead nets, but the difference was not statistically significant. There was no significant difference in species richness between lead lengths, however there was a difference detected in abundance between lead lengths (long 99.6 and short 55.2).

Introduction

Sampling fishes in riverine and lentic systems has been a common activity among managers, and identifying the most appropriate methodology estimating abundance and other community is always a goal (Guy et al. 2009, Miranda and Boxrucker 2009). Some sampling gears select for certain species or sizes, and the relative number caught may not reflect true proportions of fishes in the assemblage (Weaver et al. 1993), making gear selection a vital component to managers.

A single sampling gear usually provides only a limited representation of a fish assemblage and cannot capture all species and size classes (Ruetz III et al. 2007, Murphy and Willis 1996). A multiple gear approach is almost always necessary to gain reliable estimates of community aspects and size structure (Fisher and Quist 2014, Ruetz III et al. 2007). Additionally, sampling gears are dependent upon habitats present and different gears to target specific species. When sampling in the river-reservoir interface water depth, rocks, macrophytes, logs, tree branches, and dead terrestrial vegetation accrue, which could interfere or prevent an accurate representation of densities and relative abundance when sampling with seines, gillnets, and electrofishing boats.

Sedimentation within the river-reservoir interface creates an artificial marsh or floodplain habitat (Patton and Lyday 2008), which can provide nursery refuge habitats for juvenile and small body fishes (Buckmeier et al. 2014). Clark et al. (2007) showed that in areas of inundated vegetation, fyke netting was the most effective means of collection for overall species richness and abundance. The use of mini-fyke nets for sampling fishes has been shown to be an effective passive collection method for small bodied fishes (Krueger et al. 1998, Hubert 1996, Fargo 1998).

For this project, we compared mini-fyke nets with two different lead lengths (long lead and short lead) for differences in species richness and abundance. It has been shown that fyke nets are preferred when collecting fishes in shallow areas less than 1m in depth in heavy vegetative and large amounts of woody debris (Clark et al. 2007, Bonvechio et al. 2014). We use fyke nets for these reasons: 1) Electrofishing can be biased by shocking select fish (size and species) along with netter bias, 2) Fyke nets are a smaller versions of traps nets and have been shown to collect broader size ranges and more species of fish, and 3) Gill netting accounts for high mortality rates.

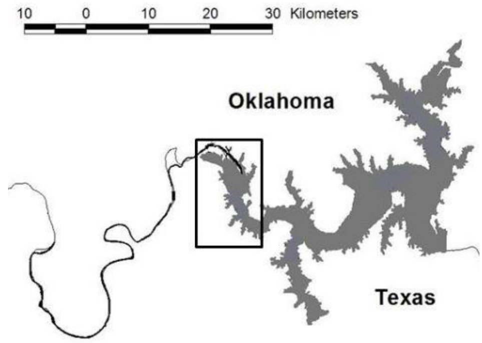

Figure 1. Location of Lake Texoma in south central Oklahoma where sampling occurred. The black outlined box represents the sampling area used in the Red River arm of Lake Texoma.

Study Area

Our study area was located on the southern border of Oklahoma on the Red River arm of Lake Texoma (Figure 1), a 36,000-ha reservoir on the Oklahoma-Texas border, impounding the Red and Washita Rivers. The Red River drainage encompasses 81,199km^2. Sampling occurred in the Red River and Lake Texoma interface where siltation and fragmentation caused by sediment loading has created habit in the river-reservoir interface that function as a floodplain (Buckmeier et al. 2014; Patton and Lyday 2008). This functional floodplain creates spawning habitat and cover for a multitude of species (Buckmeier et al. 2014).

Methods

We deployed mini-fyke nets (0.6 m x 6.35 m; with 3.18 mm mesh, 4.57 m lead, 0.6 m x 1.92 m rectangular cab, and 510 mm metal throat, and 0.6 m x 6.35 m; with 3.18 mm mesh, 9.14 m lead, 0.6 m x 1.92 m rectangular cab, and 510 mm metal throat) in the river-reservoir interface of Lake Texoma in the Red River arm during August and September of 2015. Due to historical flooding and inflows, nets were not deployed between May and July 2015. A 100-m gridded map of all backwaters and shallow-water coves in the river-reservoir interface was used to randomly select initial sample sites. Nets were anchored with a T-Post on the lead end and pulled tight by a 9.1 kg kedge style anchor on the cod end. Nets were set perpendicular to the shore in water less than 1m in depth and run the next morning. All fish collected were identified and measured to the nearest (mm). Any individuals that could not be identified in the field were preserved on ice and brought back to the laboratory for further identification using a dichotomous key (Miller and Robison 2004), clethra guide (Traynor et al. 2010), and pharyngeal teeth key (Miller and Robison 2004).

Data were analyzed using R and tests were performed at a significance level of $P \leq 0.05$ (R Core Team 2015). A Shapio-Wilk test was used to test for normality (P = 0.08). A T-Test was used to compare the number of species captured between the lead types, and to test differences in total individual captured by each lead type.

Results

A total of 3,893 fish were collected 48

combined net nights which consisted of 28 long lead net nights (N = 2,846) and 20 short lead net nights (N =1,047) of sampling. The mean species diversity represented per net night in long lead nets was 17.4 (± 9.45) compared to 15.7 (± 9.21) for short lead. There was no significant difference between lead type (T_{42} = 0.62, P = 0.27), however there was a difference detected with the abundance of individuals sampled in each net (long = 99.6 and short = 55.2) (T_{44} = 2.77, P = 0.01). The combined total of Bluegill (*Lepomis macrochirus*), White Crappie (*Pomoxis annularis*), and Silverside species (*Menidia ssp.*) made up 75.9% of the catch in long lead nets and 70.5% of the catch in short lead nets, respectively (Table 1).

Discussion

We found that both long and short lead mini fykes were able to collect a large number of fish from the littoral zone of the river-reservoir interface of Lake Texoma. Samples exhibited high species richness, yielding a total of 38 species with no difference detected between lead length. Clark et al. (2007) reported in fourty-six net nights in the White River system, Arkansas they collected 46 species and Ruetz III et al. (2007) reported similar results from sampling Muskegon Lake, Michigan (collecting 33 species).

Mini Fyke nets tend to collect smaller more mobile fish (Fago 1998, Bonvechio et al. 2014). We found that longer leads collected a significantly larger number of fish. This is a result of the lead being in more fishable water allowing for more of the littoral zone to be sampled. However, both lead lengths seemed to collect some species at a higher rate than others. For example, in the long lead net Bluegill represented 21% of the total catch, while in short lead bluegill comprised 37% of species sampled (Table 1). Similar results were presented in Clark (2007) where nearly 40% of fish captured were Bluegill. It has been speculated that age-0 fish seek cover or protection in or around the net, a behavioral occurrence that was documented (Gritters 1994).

The ability to sample Menidia ssp. in long lead mini fyke nets at such a high abundance may benefit management biologist when assessing the importance of Menidia species as a forge fish. An alternative gear to collect Menidia species in large numbers (1,015 individuals representing 36% of fish collected in 28 net nights of sampling), long lead mini fyke nets could act as a valuable gear for managers (Hubert 1996, and Ruetz et al. 2007). In a lake where physical sampling obstacles exist which may snag or hinder one from seining, mini fyke net would give managers the option to collect abundance data on Menidia species using a passive gear.

Mini-fyke net design includes a 5.2 cm excluder ring placed before the cod portion of the net to prevent predatory species from entering net. These excluder rings are problematic when catch data are compromised by an adult gar blocking the funnel. On average this occurred in 8.3% of net sets in our study. Bonvechio et al. (2014) described Florida gar being caught in 6.7 % of nets set, causing entanglement in the excluder ring which prevented the gear from fishing properly. Further research should be done on a small excluder ring which may prevent the cod portion from being obstructed, but also could have a negative impact on species and individuals sampled.

Mini-fyke nets could be a viable alternative to electrofishing or seining should shallow areas and obstacles (e.g. woody debris, vegetation or jagged rocks) exist when sampling. Mini-fyke nets also have the potential to reduce man-hours and effort required to collect sufficient quantities of fish compared to active gears (electrofishing and seining). Bonvechio et al. (2014) recommended that min fyke nets be used to monitor long term collection of fish communities because this gear type was able to detect 80% of species represented in a lake, and Eggleton et al. (2010) reported that mini fyke nets captured the largest number of unique species. We recommend the use of mini-fyke nets in a sampling protocol targeting small bodied fishes in river-reservoir interface or back water areas. Specifically, the use of long lead

Table 1. Total catch was measured to the near (mm) TL (± SD) and individuals counted (N) from 28 long-lead nets (L) and 20 short-lead net (S) net nights from the RRI of the Red River.

	N		% Catch		Mean TL mm (SD)	
Species	L	S	L	S	L	S
Largemouth Bass (*Micropterus salmoides*)	5	3	0.18	0.29	105 (55)	122 (10)
Spotted Bass (*Micropterus punctulatus*)	1	1	0.04	0.10	118	114
White Crappie (*Pomoxis annularis*)	504	138	17.71	13.18	107 (40)	99 (24)
Black Crappie (*Pomoxis nigromaculatus*)	96	15	3.37	1.43	98 (27)	116 (43)
White Bass (*Morone chrysops*)	18	20	0.63	1.91	107 (16)	101 (13)
Striped Bass (*Morone saxatilis*)	2	1	0.07	0.10	97 (2)	89
Saugeye (*Stizostedion vitreum X Stizostedion canadense*)	2	-	0.07	-	125 (2)	-
Channel Catfish (*Ictalurus punctatus*)	-	1	-	0.10	-	93
Blue Catfish (*Ictalurus furcatus*)	-	1	-	0.10	-	546
Bluegill Sunfish (*Lepomis macrochirus*)	600	387	21.08	36.96	59 (37)	51 (26)
Longear Sunfish (*Lepomis megalotis*)	14	6	0.49	0.57	65 (17)	61 (5)
Orangespot Sunfish (*Lepomis humilis*)	8	7	0.28	0.67	74 (3)	83 (2)
Redear Sunfish (*Lepomis microlophus*)	-	1	-	0.10	-	148
Green Sunfish (*Lepomis cyanellus*)	5	16	0.18	1.53	51 (16)	51 (20)
Warmouth Sunfish (*Lepomis gulosus*)	91	2	3.20	0.19	66 (24)	74 (9)
Hybrid Sunfish (*Lepomis hybrid*)	-	1	-	0.10	-	77
Yellow Bullhead (*Ameiurus natalis*)	-	1	-	0.10	-	31
Common Carp (*Cyprinus carpio*)	1	1	0.04	0.10	378	756
Freshwater Drum (*Aplodinotus grunniens*)	22	8	0.77	0.76	147 (77)	188 (88)
Smallmouth Buffalo (*Ictiobus bubalus*)	11	12	0.39	1.15	119 (27)	147 (30)
Bigmouth Buffalo (*Ictiobus cyprinellus*)	2	2	0.07	0.19	154 (11)	158 (2)
Black Buffalo (*Ictiobus niger*)	1	3	0.04	0.29	428	126 (18)
River Carpsucker (*Carpiodes carpio*)	2	4	0.07	0.38	110 (4)	172 (80)
Highfin Carpsucker (*Carpiodes velifer*)	13	-	0.46	-	182 (131)	-
Flathead Catfish (*Pylodictis olivaris*)	2	-	0.07	-	305 (202)	-
Alligator Gar (*Atractosteus spatula*)	6	1	0.21	0.10	294 (141)	347
Longnose Gar (*Lepisosteus osseus*)	14	4	0.49	0.38	367 (154)	279 (101)
Shortnose Gar (*Lepisosteus platostomus*)	23	12	0.81	1.15	316 (128)	307 (105)
Spotted Gar (*Lepisosteus oculatus*)	32	10	1.12	0.96	304 (109)	284 (117)
Gizzard Shad (*Dorosoma cepedianum*)	198	63	6.96	6.02	113 (33)	121 (127)
Threadfin Shad (*Dorosoma petenense*)	55	4	1.93	0.38	44 (17)	61 (32)
Golden Shiner (*Notemigonus crysoleucas*)	1	-	0.04	-	98	-
Bluntnose Minnow (*Pimephales notatus*)	2	-	0.07	-	48 (9)	-
Mosquito Fish (*Gambusia affinis*)	86	66	3.02	6.30	30 (4)	35 (6)
Red River Shiner (*Notropis bairdi*)	3	-	0.11	-	48 (21)	-
Logperch (*Percina caprodes*)	1	-	0.04	-	74	-
Red Shiner (*Cyprinella lutrensis*)	5	3	0.18	0.29	57 (16)	61 (16)
Silverside species (Atherinidae)*	1015	253	35.66	24.16	72 (14)	69 (16)
Totals	2846	1047	100%	100%		

*Inland Silversides and Brook inland Silverside combined mini-fyke nets for sampling Pomixis, Menidia, and some Lepomis species is recommended.

Acknowledgments

The authors thank those individuals that assisted with laborious field work including Amie Robison and Jeff Tibbits. We thank K. Kuklinski (ODWC) and Tim Patton (SE) for reviewing an early draft of this manuscript. Financial support was provided by the Oklahoma Department of Wildlife Conservation.

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Submitted August 5, 2016 Accepted November 21, 2016

A New Geographic Record for *Brachycybe lecontii* (Diplopoda: Platydesmida: Andrognathidae) from Oklahoma

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Much has been published on the millipeds (Diplopoda) of Oklahoma since the turn of the century (Lewis 2002; McAllister et al. 2002, 2005, 2013; McAllister and Shelley 2003a, 2003b, 2005, 2008, 2010; Shear 2003; Shelley et al. 2005a, 2005b, 2006; McAllister and Robison 2011; Lewis and Slay 2012; Shelley and Snyder 2012). However, there are still gaps in the distribution of many species. Here, we continue to help fill some of those gaps with a noteworthy county record of an uncommon milliped of the state. Additionally, we provide an updated distribution for this species in Oklahoma and surrounding states.

On 1 April 2016, MBC collected two millipeds from a cave/spring outflow site off county road 660 at Flint, Delaware County (36° 12' 27.83"N, 94° 42' 15.78'W). They were taken off the ground near the cave entrance. Specimens were placed in a vial containing 70% (v/v) ethanol and, following preliminary identification, were sent to CTM for verification of identification and deposition of voucher specimens in the Sam Noble Oklahoma Museum of Natural History (SNOMNH, Acc. No. 1579), Norman.

Based on morphological characters, the millipeds fit the description of *Brachycybe lecontii* Wood, 1864 using the key to species of *Brachycybe* of Gardner (1975), modified by Shelley et al. (2005b). Our specimens displayed a bright pinkish-red paranota which is typical of *B. lecontii* in the western part of its range (McAllister et al. 2002). We did not record sexes because this milliped is the only representative of the Platydesmida in the state that can be authentically identified with either sex and/or with juveniles.

This milliped had been previously reported from only two counties, Le Flore and McCurtain (Appendix) in the southeastern corner of the state on the Ouachita uplift. It is typically found under decaying hardwood logs or under the bark of those logs but as yet not under pine logs or bark. The current location (Flint) is important as it is on the Ozark Plateau of Oklahoma, which extends northward and ends in southeastern Kansas in the vicinity of Galena, Cherokee County (see Shelley et al. 2005b, Fig. 19 showing the outlined projected range for "population 2" of *B. lecontii*). The potential Kansas location (Fig. 1) would be geographically important because the authors and others, have attempted to find *B. lecontii* there at Schermerhorn Park (3.7 km S of Galena off St. Hwy 26) in typical habitat (moist upland deciduous woods) on several occasions but were unsuccessful. The reason for these failures remain an enigma but we suggest continued surveying in this region as its collection would be a new state record for Kansas.

Interestingly, a recent molecular study of *Brachycybe* (Brewer et al. 2012) did not recognize multiple species within the *B. lecontii* clade. In addition, "populations 2, 3" of Shelley et al. (2005b), which included specimens from Le Flore and McCurtain counties (Appendix), represented a genetically divergent lineage that shows considerable internal geographic structuring (Brewer et al. 2005).

Brachycybe lecontii has a large range that occupies a north to south area extending from southern West Virginia, central Kentucky, and southern Missouri to the southern periphery of Georgia, southcentral Louisiana, southeastern Texas, and possibly southeastern Kansas (Gardner 1975; McAllister et al. 2003b; Shelley et al. 2005b, see Figs. 18–19; Youngsteadt and McAllister 2014). In Arkansas, it occurs along the northwestern tier of counties (Benton, Crawford and Washington) along the Oklahoma state line (McAllister et al. 2003b) (Fig. 1). Here, we officially extend it into northeastern Oklahoma with deposition of genuine voucher specimens, which constitutes a new county record, and, most importantly, a noteworthy extension of the northwest range distribution of the species in North America.

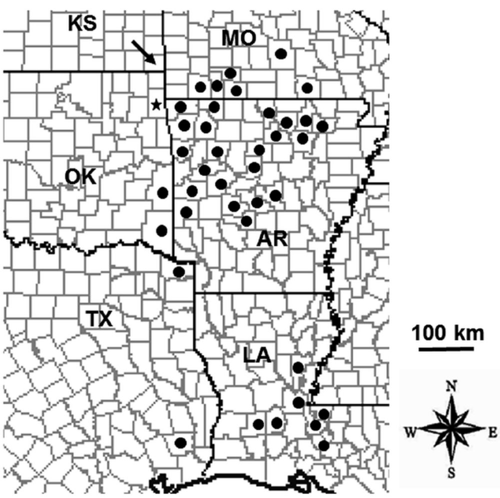

Figure 1. Distribution of *Brachycybe lecontii* in Arkansas, Louisiana, Missouri, Oklahoma and Texas. Dots = previous records; star = new record. Arrow denotes potential occurrence in Cherokee County of southeastern Kansas.

Acknowledgments

The Oklahoma Department of Wildlife Conservation provided a scientific collecting permit to CTM. We thank Dr. Jason E. Bond (Auburn University) for assistance in locating some records.

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Submitted August 9, 2016 Accepted November 21, 2016

Appendix. Summary of collection data on *Brachycybe lecontii* from Oklahoma.

Delaware County

(1) Vicinity of Flint off county road 660, 1 Apr. 2016, M.B. Connior (SNOMNH).

Le Flore County

(1) 11.2 km NE Talihina at Bear Den Cave, 29 Apr. 1971, J.H. Black (FSCA) (see Black 1971).

(2) Choctaw Nation Historic site at junction of St. Hwy 1 and AR St. Hwy 88, 27 Sept. 2002 & 13 Aug. 2003, C.T. McAllister (NCSM).

(3) Off US 259, ~9.7 km N of St. Hwy 144 junction. No date. J.E. Bond (AUM).

(4) Ouachita National Forest on US 59, ~12.9 km E of US 259 junction near Oklahoma welcome sign. No date. J.E. Bond (AUM).

McCurtain County

(1) Beavers Bend State Park, 16 Jun. 1970, 11 June 1985, D.C. Arnold (OKSU).

(2) Beavers Bend State Park, David Boren Trail, 29 Dec. 2003, C.T. & R.A. McAllister (NCSM).

(3) 4.8 km N of Tom, 7 Feb. 2004, Z.D. Ramsey (NCSM).

(4) Halibut Bay Road, Hochatown. 15 Nov. 2015, C.T. McAllister (author's collection).

(5) Off US 259, ~9.7 km SW of St. Hwy 4 junction. No date. J.E. Bond (AUM).

Museum acronyms: AUM = Auburn University Museum of Natural History, Auburn, Alabama; FSCA = Florida State Collection of Arthropods, Gainesville; NCSM = North Carolina State Museum of Natural Sciences, Raleigh; OKSU = Department of Entomology and Plant Pathology, Oklahoma State University, Stillwater; SNOMNH = Sam Noble Oklahoma Museum of Natural History, Norman.

Age and Size of Spotted Gar (*Lepisosteus oculatus*) from Lake Thunderbird Reservoir in Central Oklahoma

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Abstract: We report the body size and population age structure of Spotted Gar from the Lake Thunderbird reservoir, OK. We collected 90 Spotted Gars ranging between 348 – 846 mm total length, and aged gars by examining annuli from the sagittal otoliths. Annuli were counted on both browned and not browned sagittal otoliths to compare the efficacy of both methods. Gars ranged between 1 and 14 years old, and percent agreement of age within one year between readers was comparable for both the browned and not browned otoliths. Back-calculated growth indicated that Spotted Gar grow quickly during the first year of life, and approach maximum size by year 4.

Introduction

The Spotted Gar (*Lepisosteus oculatus*) is one of four species of gar (Family: Lepisosteidae) that occur in Oklahoma. While globally secure, the Spotted Gar is a species of conservation concern at the northern edge of its range and is critically imperiled in Canada (Glass et al. 2011; Statton et al. 2012; David et al. 2015; NatureServe 2016), critically imperiled in Kansas, Ohio, and Pennsylvania, and is thought to be extirpated in New Mexico (Staton et al. 2012; NatureServe 2016). The basic biology of this species and other gars remains largely understudied, due in part to the reputation gars hold as nuisance fish throughout much of their range (Scarnecchia 1992). This lack of information concerning Spotted Gar holds true for Oklahoma, where few studies have focused on this species. Echelle and Riggs (1972) described early life history of gars, including Spotted Gar, in Lake Texoma. Tyler and Granger (1984) reported on size, diet, and spawning behavior of Spotted Gar from Lake Lawtonka, and Frenette and Snow (2016) described spawning behavior in Spotted Gar from Lake Thunderbird. This study describes population age using sagittal otoliths and body size of Spotted Gar in the Lake Thunderbird reservoir.

Methods

Study Area Description

The Lake Thunderbird reservoir is a man-made impoundment located in the Cleveland and Oklahoma counties in central Oklahoma, USA (Figure 1; Simonds 1999). The reservoir was build and put into operation between 1962 and 1965, and is located approximately 16km from the city of Norman, OK (Simonds 1999). Lake Thunderbird impounds the Little River, a tributary to the Canadian River, and provides water for Oklahoma City, Norman, Midwest City, Del City, and the Tinker Air Force Base (Simonds 1999). Historic and contemporary sampling did not detect Spotted Gars or other species of Lepisosteidae in the Little River and its tributaries surrounding Lake Thunderbird (Franssen and Tobler 2013). However, sampling methods from this study may not have been

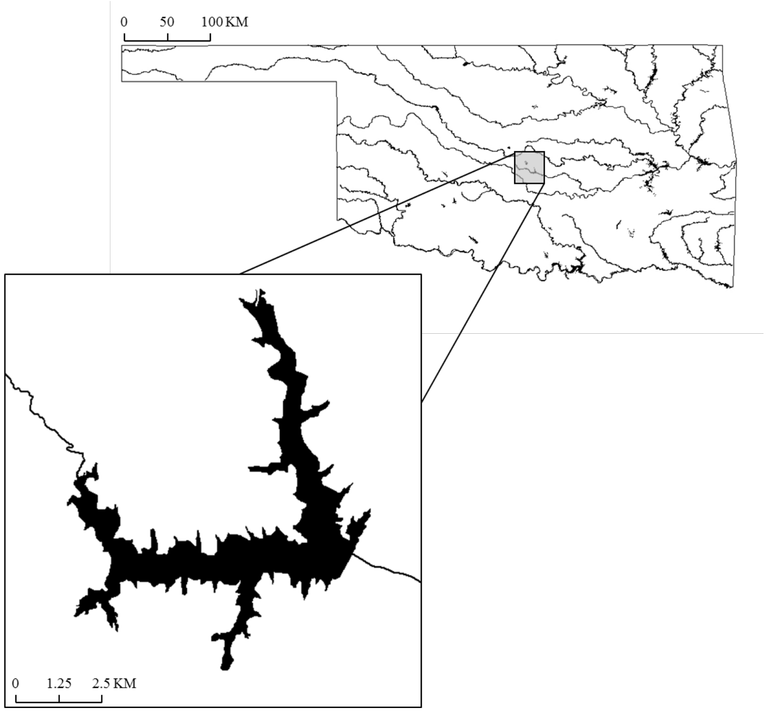

Figure 1.—Map of the Lake Thunderbird reservoir in central Oklahoma.

sufficient to efficiently capture large-bodied fishes like Gars (Franssen and Tobler 2013; M. Tobler, Kansas State University, personal communication). It was hypothesized that flooding in the late 1990's allowed Spotted Gar to migrate into Lake Thunderbird from Lake Stanley Draper to the north; Spotted Gar were not detected by sampling in Lake Thunderbird until the mid-2000's (K. Thomas, Oklahoma Department of Wildlife Conservation, personal communication).

Sampling and Data Collection

Sampling on April 25 and May 2, 2014 in the Hog Creek arm of Lake Thunderbird captured 90 adult Spotted Gar. Collections were made using boat electroshocking in areas where gar densities were high, presumably due to the spawning season. Fish were transported to the Aquatic Research Facility (ARF) at the University of Oklahoma, where they were held in a 0.04 ha holding pond until being processed for this study.

Sex identification and morphometric measures.—Prior to measuring, fish were placed into an ice bath to induce torpor. Fish were measured in mm for total length (TL) using a measuring board (±1 mm). Calipers were used to measure both head length (HL) and snout length (SnL) in mm. HL was measured from the tip of the snout to the posterior portion of the opercle. SnL was measured from the tip of the snout to the anterior start of the orbital. Both HL and SnL were measured alongside the snout on the left side of the body. Fish were weighed in kg using a digital scale. Sex of Spotted Gars was determined by examining the gamete release pathways following a standardized procedure for determining sex in Lepisosteids (Ferrara and Irwin 2001).

Otolith aging.—Paired sagittal otoliths were removed from Spotted Gar through the ventral side of the brain case. Otoliths were then cleaned and dried before processing. One otolith from each pair was browned at 104°C using a hot plate to increase the contrast between the accretion and discontinuous zones (Figure 2; Secor et al. 1992; Long and Snow 2016). Both otoliths (browned and not browned) were processed following Buckmeier et al. (2012),

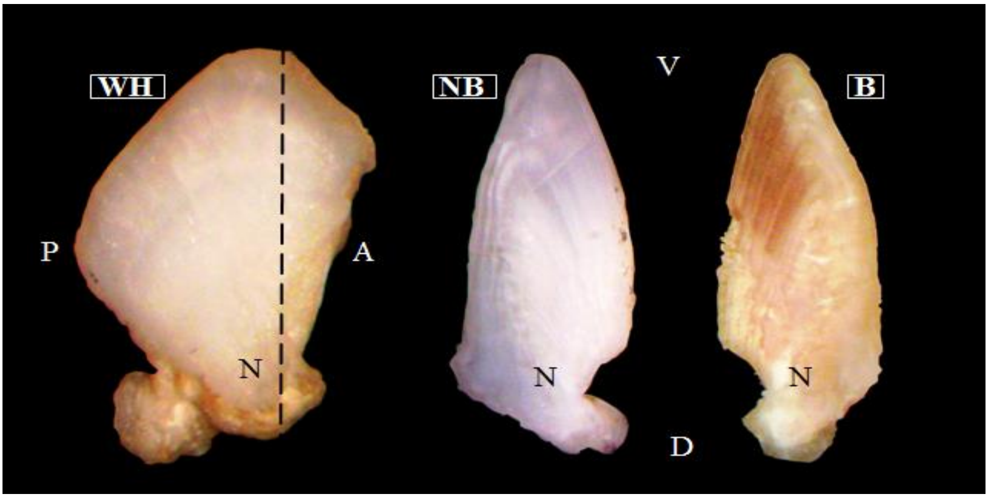

Figure 2.—Whole (WH) sagittal otolith view to the left with not browned (NB) and browned (B) ground otoliths in a transverse plane from a 653 mm spotted gar, noting orientation (P = posterior, A = anterior, V = ventral, D = dorsal). The dashed line represents the portion of the otolith that was removed starting from the anterior (A) side. The nucleus (N) is located in the dorsal region of the otolith, with annuli being estimated in the ventral (V) portion of the otolith.

where otoliths were ground in a plane transverse to the nucleus (Figure 2) using a rotary tool fixed with a grinding bit (#85422, Dremel, Racine WI). The rotary tool was attached to a table, and forceps coated in Tool Dip (Plasti Dip Internation, Blaine MN) were used to securely hold the posterior portion of the otolith during the grinding process. Sagittal otoliths were ground by placing the anterior portion of the otolith on the grinding bit and removing material until the nucleus was even with the apex of the ventral portion of the otolith (Figure 2). Otoliths were then polished using wetted 1600 grit sand paper.

Two readers independently examined the otoliths to estimate ages (Hoff et al. 1997) using an optic-mount digital camera attached to an Olympus dissection microscope (Olympus Corporation, Lake Success NY) and displayed on a high-resolution monitor. Otoliths were selected at random with the readers having no reference to fish length, weight, or sex to reduce bias. Otoliths were then placed in clay and submerged in water to reduce glare. A fiber optic filament with an external light source was used to illuminate annuli. Annuli were first counted from the nucleus margin to the outer edge, and then repeated to verify the first count. If needed, otoliths were polished multiple times to increase the clarity of and to clearly interpret the outer-most annuli (Buckmeier et al. 2012). After otoliths were estimated independently, readers estimated and agreed on ages for both browned and not browned sagittal otoliths. Independently aged otoliths were compared to agreed ages for both browned and not browned sagittal otoliths.

Statistical analyses.—Browned and not browned otoliths were compared using age bias plots to determine if precision was higher using either technique (Campana et al. 1995). Percent agreement (PA) and coefficient of variation (CV) between readers was calculated for both otolith types (Campana et al. 1995). A length frequency histogram was created to visualize the length distribution of Spotted Gar. A von Bertalanffy growth equation (Beverton 1994) was used to model back-calculated total length-at-age using non-linear regression. Non-linear regression was used to describe the weight-length relationship of the population. Due to sample size being low, data for both male and female Spotted Gar were pooled.

Results and Discussion

We collected 24 female and 66 male Spotted Gars, ranging in size between 348 – 846 mm TL (average = 601.1 ± 82.5 mm), from the Lake Thunderbird reservoir (Table 1). Sex ratios were not 1:1 across all ages sampled. This is likely a relic of sampling time and methodology, as gars were targeted during the spawning season. Spawning aggregations of gars typically consist of a greater ratio of males than females (Echelle and Grande 2014; Frenette and Snow 2016). The length-frequency distribution of Spotted Gar appeared to be bimodal, with fewer large (730 - 760 mm TL) individuals than smaller (530 - 630 mm TL) individuals (Figure 3). Gars are known to be sexually dimorphic in body size, with females being larger, on average, than males (Love 2002; McGrath and Hilton 2012; McDonald et al. 2013). In our sample from Lake Thunderbird, female Spotted Gars where, on average, larger (651.7 ± 124.2 mm TL) than males (582.7 ± 48.9 mm TL). The modelled von Bertalanffy growth curve indicates that Spotted Gar from Lake Thunderbird approach maximum length quickly (K = 0.81), with individuals in the population growing to half of their expected TL in the first year of life and approaching infinity (L_∞ = 609 mm) by age 4 (Figure 4). The weight-length relationship suggests that Spotted Gar experience positive isometric growth (Figure 5). It is worth noting that, since sexes were pooled to calculate growth, any sex-specific differences in growth are masked. However, because the sample size of females was low, the difference in back-calculated growth was minimal compared to when females were excluded from the analysis. Nonetheless, the results hold with the knowledge that gars, including Spotted Gar, grow rapidly during the first year of life (Matthews et al. 2012; David et al. 2015).

Ages assigned using both techniques (not browned and browned) ranged from 1 to 14 years (Table 1). Exact agreements for browned otoliths were 55.4% for reader 1 and 32.1% for reader 2, whereas PA within 1 year was 84.7% for reader 1 and 63.3% for reader 2. CV estimates for browned otoliths were 6.5% for reader 1 and 11.1% for reader 2. Results for not browned otoliths were similar, with exact agreements of 57.1% for reader 1 and 30.7% for reader 2. PA within 1 year for not browned otoliths was 81.3% for reader 1 and 65.1% for reader 2, and CV estimates were 6.1% for reader 1 and 10.6% for reader 2. Age bias plots for both techniques provided similar age estimates and did not consistently under- or overestimate ages (Figure 6), however readers felt that annuli were more clearly visible in browned otoliths. Caution should be used, however, when estimating ages using browned otoliths of Spotted Gar, as false annuli are more defined using this technique and, without experience, are harder to eliminate during estimations.

This study represents the first report of age and size structure of Spotted Gar from the Lake Thunderbird reservoir, and contributes to our understanding of the basic biology of this species in Oklahoma.

Table 1.—Average (± 1 SD) and range (minimum - maximum) of morphometric measurements and age for Spotted Gar from Lake Thunderbird. Measurements are reported for males, females, and for pooled sexes. TL = total length; HL = head length; SnL = snout length; W = weight; A = age.

	Pooled		Female		Male	
	Mean	Range	Mean	Range	Mean	Range
TL (mm)	601.1 ± 82.5	348 - 846	651.7 ± 124.2	356 - 846	582.7 ± 48.9	348 – 674
HL (mm)	143.4 ± 27.5	85 - 240	164 ± 41.7	85 - 240	135.9 ± 13.7	88 – 162
SnL (mm)	96.7 ± 21.2	60 - 173	112.5 ± 30.8	60 - 173	91 ± 11.9	62 - 121
W (kg)	0.82 ± 0.4	0.11 – 2.45	1.14 ± 0.6	0.11 – 2.45	0.70 ± 0.19	0.11 – 1.32
A (yr)	7.1 ± 2.1	1 - 14	6.8 ± 1.8	1 - 9	7.2 ± 2.2	2 - 14

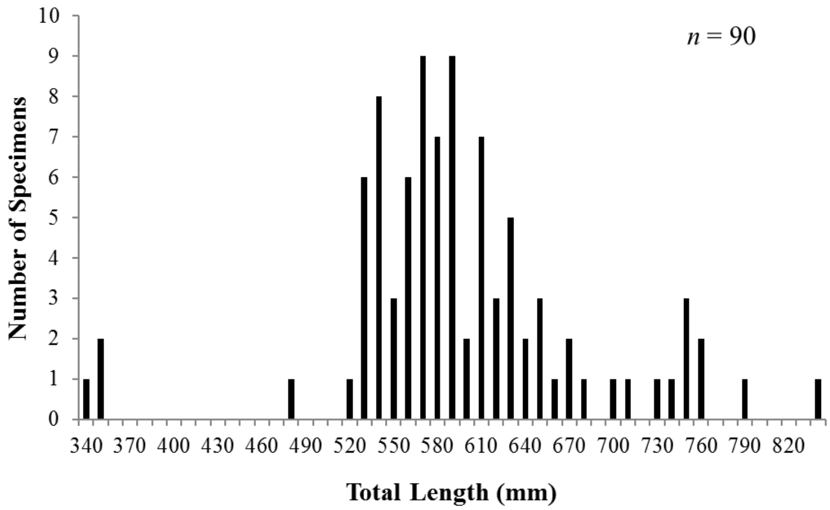

Figure 3.—Length-frequency (TL in mm) histogram for Spotted Gar captured from Lake Thunderbird during spring of 2014.

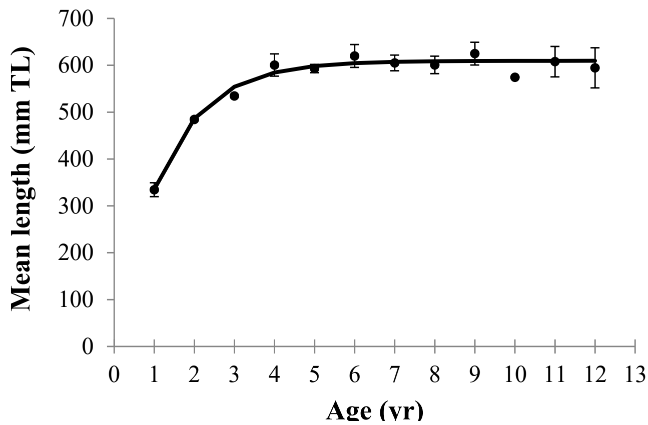

Figure 4.—Length and age for Spotted Gar collected from Lake Thunderbird during spring of 2014. The solid line represents the modeled von Bertalanffy growth curve. Error bars represent SE.

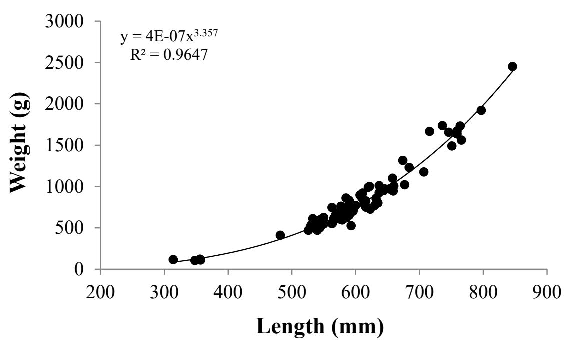

Figure 5.—Length-weight relationship for Spotted Gar captured from Lake Thunderbird during spring of 2014. The solid line represents the fit between L-W.

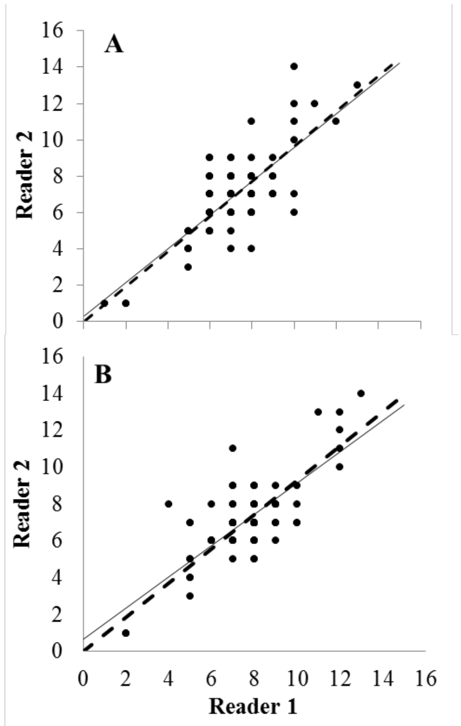

Figure 6.—Age bias plots between readers for (A) browned and (B) not browned sagittal otoliths of Spotted Gar from the Lake Thunderbird reservoir. The dashed line represents a 1:1 relationship between readers 1 and 2. Bias between readers is represented by the solid line.

Acknowledgments

The authors thank those individuals that assisted with collection of specimens, lab work, and forage collection including Clayton Porter, Donnie King, Jeff Tibbets, Amie Robison, and Michael Hollie; Kurt Kuklinski (ODWC) for reviewing an early draft of this manuscript; the University of Oklahoma's ARF steering committee for allowing the use of the holding ponds; and Edie-Marsh-Matthews for providing direction during the project. The Oklahoma Department of Wildlife Conservation provided financial support. This project was approved by IACUC no. R13-003 from the University of Oklahoma.

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Received August 14, 2016 Accepted November 21, 2016

Aethycteron moorei (Monogenoidea: Dactylogyrida: Ancyrocephalidae) from the Fantail Darter, *Etheostoma flabellare* (Perciformes: Percidae): New distributional records for Arkansas and Oklahoma

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Little is known about monogenean parasites of fishes in Oklahoma (see McAllister et al. 2015). Members of the ancyrocephalid genus *Aethycteron* Suriano and Beverley-Burton, 1982, have been reported on the gills of various darters (*Ammocrypta*, *Etheostoma*, and *Percina* spp.) from Alabama, Arkansas, Mississippi, New York, North Dakota, Tennessee, and Ontario, Canada (see Hoffman 1999; Hanson and Stallsmith 2013; Cloutman and McAllister 2017). To our knowledge, nothing has been published on any species of *Aethycteron* in Oklahoma, and a single species, *A. robisoni*, was only recently described from Arkansas (Cloutman and McAllister 2017).

Here, we report new distributional records for a species of *Aethycteron* from the Fantail Darter, *Etheostoma flabellare* Rafinesque, in Arkansas and Oklahoma. *Etheostoma flabellare* is a morphologically variable species of the subgenus *Catonotus* which some authors suggest is a complex of species (Blanton and Schuster 2008). Page and Burr (2011) consider *E. flabellare* to comprise three subspecies. *Etheostoma flabellare* is widely distributed in rocky riffles of small and medium streams in eastern North America from Atlantic, Great Lakes, and Mississippi River basins from southern Quebec to Minnesota, and south to the Pee Dee basin in northern South Carolina, northern Alabama, and northeastern Oklahoma (Page and Burr 2011).

Between June 2013 and June 2015, 28 *E. flabellare* were collected by seine (3.7 m, 1.6 mm mesh) or backpack electrofisher from: **ARKANSAS:** *Benton Co.,* Flint Creek at Gentry, 36º14'33.8"N, 94º29'14.5"W (*n* = 1) and Flint Creek at Springtown, 34º15'9.9"N, 94º26'25.8"W (*n* = 1); *Franklin Co.,* N. Fork White Oak Creek, 35º33'20"N, 93º51'44"W (*n* = 10) and Spirits Creek, 35º38'17.65"N, 93º56'16.84"W (*n* = 4); *Johnson Co.,* Washita Creek, 35º39'16.80"N, 93º35'37.16"W (*n* = 2); *Izard Co.,* Little Strawberry River, 36º19'27.31"N, 91º51'27.98"W (*n* = 4); *Randolph Co.,* Eassis Creek at St. Hwy 90, 36º20'30.77"N, 91º08'46.87"W (*n* = 1); **OKLAHOMA:** *Mayes Co.,* Snake Creek, 36º09'51.90"N, 95º09'25.61"W (*n* = 5). Fish were placed in containers with cool aerated water from their collection site, measured for total length (TL) and necropsied, excepting the gills, within 24 hr. We followed accepted guidelines for the use of fish in research (AFS, 2004); specimens were overdosed by immersion in a concentrated chloretone (chlorobutanol) solution and preserved in 10% formalin. The preserved gills of all the fish were examined under a stereomicroscope for monogeneans, and when found, they were picked with minuten nadeln directly from the gills. Monogeneans were mounted in Gray and Wess medium stained with Gomori's trichrome (Kritsky et al. 1978). Measurements of haptoral sclerites, in micrometers (µm), were made as presented by Beverley-Burton and Suriano (1980) and Suriano and Beverley-Burton (1982); means ± 1SD are followed by ranges in parentheses. The curved male copulatory organ was measured as a straight line extending between the two most distant points of such structures (Harrises and Vickery 1970). Voucher specimens were deposited in the Harold W. Manter Laboratory of Parasitology (HWML), Lincoln, Nebraska. Host voucher specimens were deposited in the Henderson State University Collection (HSU), Arkadelphia, Arkansas.

Seven of 28 (25%) of the *E. flabellare* were found to be infected with a species of monogenean identifiable as *A. moorei* (Mizelle, 1940), Suriano and Beverley-Burton, 1982 (Figs. 1 and 2). These included two of four (50%, mean ± 1SD intensity = 1.5 ± 0.7, range 1–2) from Spirits Creek, Franklin Co., Arkansas, 35º38'17.65"N, 93º56'16.84"W (HWML 102073, 2 specimens), and five of five (100%, 6.4 ± 5.5, range 1–13) from Snake Creek, Mayes Co., Oklahoma, 36º09'51.90"N, 95º09'25.61"W (HWML 102074, 3 specimens). Host mean total length was 43.8 ± 3.8, range 40–49 mm and 42.6 ± 2.8, 38–45 mm, respectively. Measurements of the sclerites of the five specimens above of *A. moorei* are: dorsal anchor length 39 (34–44); dorsal bar length 48 (43–54); ventral anchor length 44 (43–47); marginal hooks 15 (14–16); male reproductive organ 40 (36–44); accessory piece 16 (14–17). The distal portion of the male reproductive organ of *A. moorei* is flexible and often strongly curves back on itself as shown in our Fig. 1B and in Fig. 29 in the original description by Mizelle (1940), or appears as a shepherd's hook as shown in our Fig. 2 and in Fig. 14 in a redescription by Suriano and Beverley-Burton (1982).

Aethycteron moorei has previously been reported on two species of darters: Rainbow Darter, *Etheostoma caeruleum* Storer, and *E. flabellare* (Table 1). Based on the typically

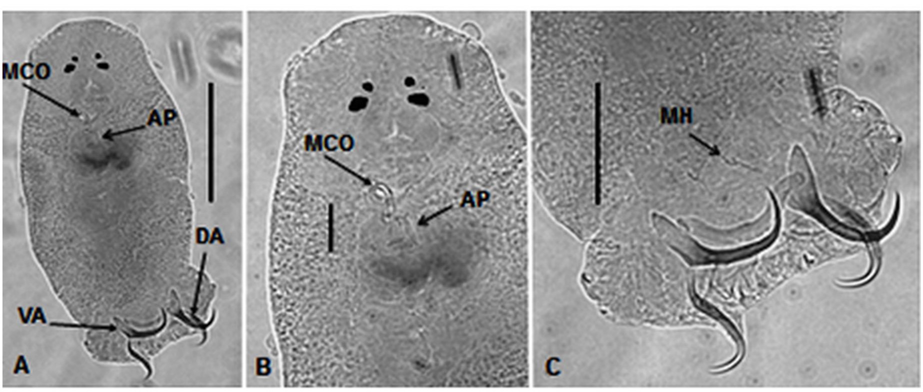

Figure 1. *Aethycteron moorei* (HWML 102074, slide DGC 7212-4) from *Etheostoma flabellare*. A. Entire specimen showing male copulatory organ (MCO) and accessory piece (AP); dorsal anchor and dorsal bar (DA); ventral anchor and ventral bar (VA). Scale bar = 100 µm. B. View showing close-up of male copulatory organ (MCO) and accessory piece (AP). Scale bar = 30 µm. C. Closer view showing marginal hooks (MH). Scale bar = 40 µm.

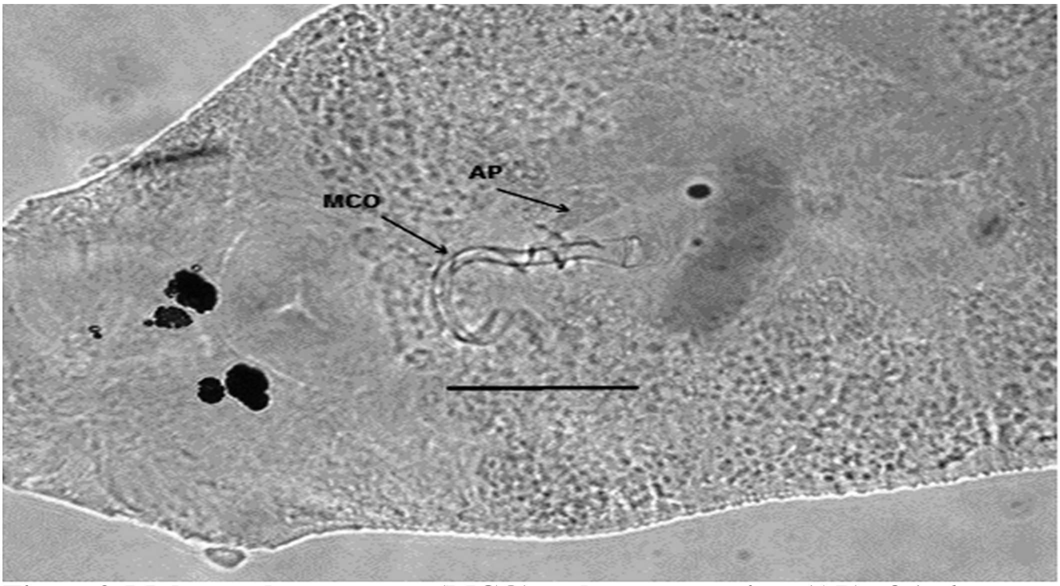

Figure 2. Male copulatory organ (MCO) and accessory piece (AP) of *Aethycteron moorei* (HWML 102074, slide DGC 7212-7) from *Etheostoma flabellare*. Scale bar = 30 µm.

high host specificity suggested by Suriano and Beverley-Burton (1982) for species of *Aethycteron*, we suspect that the record of *A. moorei* from *E. caeruleum* (no voucher specimens are available for examination) by Kozel and Whitaker (1982) represents *A. caerulei* Suriano and Beverley-Burton, 1982. Kozel and Whitaker (1982) reported this record (as *Urocleidus moorei*) almost simultaneously with Suriano and Beverley-Burton's (1982) original description of the genus *Aethycteron* and of *A. caerulei*. We suspect that both pairs of authors were unaware of the others' work, as neither cited the others' papers. Furthermore, Kozel and Whitaker (1982) used the genus *Urocleidus*, which was standard taxonomic practice until Suriano and Beverley-Burton (1982) partially synonymized *Urocleidus* (from darters) with *Aethycteron*. *Aethycteron caerulei* and *A. moorei* are morphologically very similar (Suriano and Beverley-Burton 1982; Cloutman and McAllister 2017); in fact, Suriano and Beverley-Burton (1982) compared the two species in their original description of *A. caerulei*. Thus, it is understandable that Kozel and Whitaker (1982) identified the monogenean on *E. caeruleum* as *Urocleidus moorei*.

Excluding the report of *A. moorei* from *E. caeruleum* discussed above, all records of *A. moorei* (Table 1) are from *E. flabellare*, and based on geographic distribution (Page and Burr 2011), the subspecies *E. f. flabellare* Rafinesque, in particular. The specimens reported herein extend the range of this widely distributed parasite into the far western portion of the range of *E. flabellare* (Page and Burr 2011) and represent the first records of *A. moorei* from west of the Mississippi River and from Arkansas and Oklahoma.

Numerous species of *Etheostoma* (including several in the subgenus *Catonotus*) have been described in recent decades, largely the result of splitting what were previously considered to be widely distributed species (including *E. flabellare*). Robins et al. (1980), Robins et al. (1991), Nelson et al. (2004), and Page et al. (2013) provide an overview and references of these taxonomic developments. Research concerning monogeneans on darters is in its infancy (Cloutman and McAllister 2017), as studies of parasites have not kept pace with those of their hosts. As a prime example, *E. flabellare* is only one of two of the 24 described species of *Catonotus* (Page and Burr 2011, Martin and

Table 1. Reports of hosts and localities of *Aethycteron moorei.*

Host	Locality	Reference
Etheostoma caeruleum	Tennessee	Kozel and Whitaker 1982*
Etheostoma flabellare	Tennessee	Mizelle 1940†
	Ontario, Canada	Suriano and Beverley-Burton 1982
	Arkansas‖, Oklahoma‖	This study

*Most likely represents *A. caerulei* (see text for discussion).

†Reported as *Urocleidus moorei*, a synonym of *A. moorei*.

‖New distributional records.

Page 2015) to have a monogenean reported from it (Hoffman 1999; Hanson and Stallsmith 2013). Hanson and Stallsmith (2013) reported an unidentified species of *Aethycteron* from the Stripetail Darter, *Etheostoma kennecotti* (Putnam) in Alabama. Much research is needed to determine the species diversity, host specificity, geographic distribution, intensity, prevalence, and harmfulness of monogenes on species of *Catonotus*, including the other two subspecies of *E. flabellare* not yet studied. Moreover, the same can be said for numerous other species of darters.

Acknowledgments

The Arkansas Game and Fish Commission and Oklahoma Department of Wildlife Conservation issued Scientific Collecting Permits to CTM. We thank Drs. Scott L. Gardner (HWML) and Renn Tumlison (HSU) for expert curatorial assistance. We further acknowledge Matthew B. Connior (Northwest Arkansas Community College, Bentonville, AR), Dr. David A. Neely (Tennessee Aquarium, Chattanooga, TN), and Uland Thomas (Chicago, IL) for help in collecting. Dr. William J. Stark and Andrew Karlin (Fort Hays State University, Hays, KS) provided laboratory facilities and assistance in taking digital images to DGC.

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Submitted August 24, 2016 Accepted November 21, 2016

Natural History Notes on Select Fauna (Decapoda, Actinopterygii) from Southeastern Oklahoma

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Abstract: Oklahoma is rich in biodiversity, mostly due to the vast differences in the various eco- and physiographic regions of the state that support that fauna. In particular are the distinctive fish assemblages found in the southeastern corner of the state in the coastal plain and upland streams of the Ouachita highlands in Le Flore and McCurtain counties. However, our knowledge of their ecology and natural history, as well as the geographic distribution of many species, is still not well understood. Here, we report some new information on select aspects of the natural history of a crayfish and several native fishes of the state.

Introduction

Although there have been seminal publications on various fauna of Oklahoma, including those on crayfishes (Creaser and Ortenburger 1933; Reimer 1968; Morehouse and Tobler 2013), and fishes (Miller and Robison 2004), our knowledge of the geographic distribution, ecology and natural history of many of these organisms in the state is not well documented. A series of articles on the natural history of Arkansas' crayfishes and fishes have been reported over the last decade (Tumlison et al. 2016 and references therein). Here, in a similar manner, we provide a noteworthy report on aspects of the natural history of a crayfish and several native fishes of Oklahoma.

Methods

A single crayfish was collected by hand and preserved in 70% (v/v) ethanol. Fishes were taken with 3.1 × 1.8 m or 6.1 × 1.8 m seines (3.2 mm mesh) and/or with a backpack electrofisher, preserved in 10% formalin and stored in 45% (v/v) isopropanol. Total length (TL) of fishes was also measured and all specimens examined for reproductive characters. Observations were made on specimens from Cherokee, Delaware, Le Flore, and McCurtain counties with specific localities reported as GPS (latitude and longitude) coordinates. Voucher specimens are deposited in the Henderson State University (HSU) Collection, Arkadelphia, Arkansas.

Results and Discussion

The collections described herein represent important records of geographic distribution or previously unknown observations of their natural history and are reported below in an annotated format as follows.

Decapoda: Cambaridae (cambarid crayfishes)

Orconectes neglectus neglectus (Faxon, 1885) – ringed crayfish. On 2 April 2016, a female *O. n. neglectus* "in berry" with 129 ova (1.2–1.5 mm in diameter, wet weight = 0.9 g) was collected from the outflow of an unnamed cave off county road 660 in vicinity of Flint, Delaware County (36°12'27.83"N, 94°42'15.78'W). Creaser and Ortenburger (1933) and Reimer (1968) did not report on reproduction of *O. neglectus* in the state nor did Williams (1954) in adjacent Arkansas. However, a female in berry was reported in late April from a subterranean stream in January-Stansberry Cave, Delaware County, but the number of eggs were not reported (Fenolio et al. 2013). In Arkansas, 15 females in berry were collected by Reimer (1963, *unpublished thesis*) in May from burrows near the edge of a clear, fast-moving stream. Also, females in berry have been reported in March and April from introduced populations in the Spring River drainage of Arkansas and Missouri (Magoulick and DiStefano 2007; Larson and Magoulick 2008). Pflieger (1996) reported females in berry in Missouri from March through June with 18 females carrying 54 to 505 eggs (mean 245). This is the first time ova have been quantified from an *O. n. neglectus* in Oklahoma.

Actinopterygii: Petromyzontiformes: Petromyzontidae (lampreys)

Ichthyomyzon gagei Hubbs and Trautman, 1937 – Southern Brook Lamprey. A gravid female *I. gagei* (164 mm TL) was collected by CTM on 31 January 2016 from Yashau Creek off the US 70 bridge, just S of Broken Bow, McCurtain County (33° 59' 14.3952"N, 94° 44' 36.6174"W). This specimen was taken using a backpack electrofisher near the upper end of a riffle in gravel and sandy substrate. It contained ~6,000 ova (wet weight = 3.0 g); however, unyolked eggs were not considered in this count and some may regress before spawning, thus reducing the count. In an Alabama population of *I. gagei*, number of oocytes ranged from 820 to 2,485 (William and Beamish 1982). In addition. Beamish et al. (1994) noted that females produce on average about 1,500 eggs and Etnier and Starnes (1993) reported from 800–2,500 eggs. Nothing has been previously reported on reproduction of *I. gagei* in Oklahoma (Miller and Robison 2004).

The Southern Brook Lamprey is listed as vulnerable (S3) in Oklahoma (NatureServe 2015). This current specimen is also important as it represents a new distribution record. Miller and Robison (2004, p. 47) shade the distribution just north of the current locale in the Ouachita uplift so we extend the distribution southward into the Little River drainage.

Ichthyomyzon castaneus Girard, 1858 – Chestnut Lamprey. In Oklahoma, spawning of *I. castaneus* has been observed by HWR in the upper Mountain Fork River, Le Flore County, over a nest in coarse gravel substrate. Five individuals (two males and three females) were observed spawning approximately 1.2 m from shore in swift water, 0.5 m deep, over a large excavated gravel nest ca. 0.61 m long × 0.15 m wide on a coarse gravel bottom 0.15 m deep on 23 April 1984. Water temperature was 17.8°C.

An adult (139 mm TL) *I. castaneus* was collected by a local fisherman (Michael Hill) on 2 April 2016 attached to an adult Walleye (*Sander vitreus*) at Broken Bow Lake, McCurtain County (34° 10' 49.8612"N, 94° 41' 29.5722"W). Although there are unpublished and anecdotal accounts of infestation of "lampreys" from the Great Lakes on Walleye (although most of these appear to be from Silver Lampreys, *Ichthyomyzon unicupis*), this is the first time, to our knowledge, *I. castaneus* has been documented from a Walleye with a representative voucher specimen.

Cypriniformes: Cyprinidae (carps and minnows)

Campostoma spadiceum (Girard, 1856) – Highland Stoneroller. Populations representing this species in Oklahoma were formerly assigned to *Campostoma anomalum pullum* with *C. spadiceum* recognized as a distinct species and redescribed by Cashner et al. (2010). Two gravid *C. spadiceum* (116, 119 mm TL) were collected by CTM on 13 February 2016 from Yashau Creek off US 70 bridge, just S of Broken Bow, McCurtain County (33° 59' 14.3952"N, 94° 44' 36.6174"W). Nothing has been reported previously on reproduction in Oklahoma *C. spadiceum*.

Lythrurus snelsoni (Robison, 1985) – Ouachita Mountain Shiner. Miller and Robison (2004) reported spawning of *L. snelsoni* occurred from late May to mid-July in Oklahoma. Robison and Buchanan (1988) quoted field notes taken by Drs. George A. Moore and Frank B. Cross on 30 May 1948 of the reproduction of *L. snelsoni* below the dam on Mountain Fork River, McCurtain County. We report observations of *L. snelsoni* spawning from four different years: namely 14 May 1982, 27 May 1985, 3 June 1990, and 15 June 1994 in the upper Mountain Fork River at Smithville, Le Flore County (34° 27' 40.6008"N, 94° 38' 9.4452"W). Observations by HWR while snorkeling revealed that the Ouachita Mountain Shiner is a midwater, schooling species that feeds from the surface and the water column. Feeding from the surface was observed numerous times. In each of the four years observed (1982, 1985, 1990, and 1994), tuberculate males and gravid females were present at the Smithville site. Breeding males developed red coloration dorsally on the head from the top of the snout to the occiput, and on the chin, and the anterior third of the gular area (Robison 1985). Our observations of courtship were similar to those of Moore and Cross in that females and males swam together in schools in pools where water depth was approximately 0.9–1.2 m just off beds of water willow (*Justicia americana*). Water temperature in the pools ranged from 18.3–25°C. Courtship began when a male would pursue a female and appeared to nudge or bump her side. Aggressive tendencies were shown by males if another male came close to the area of interaction as the first male would dart out and drive the other male away. After these brief encounters, the first male would always return to the side of the original female he seemed to be guarding. Such behavior was repeated numerous times. Unfortunately, actual spawning was not observed and no eggs were ever collected. Tuberculate males have been taken by HWR as early as 10 May from the Smithville locality and gravid females have been collected there into early July.

Siluriformes: Ictaluridae (catfishes)

Ameiurus natalis (Lesueur, 1819) – Yellow Bullhead. An adult *A. natalis* was collected on 10 October 2015 from the Little River at Cow Creek Crossing, McCurtain County (33° 56' 38.2122"N, 94° 37' 53.7342"W). This specimen was found to have an unusual forked maxillary barbel (Fig. 1). The barbel might have been injured or split which resulted in the abnormal growth. Forked barbels have been previously reported in other catfishes (Rao and Reddy 1984); however, to our knowledge, this is the first report in a North American Yellow Bullhead.

Noturus exilis Nelson, 1876 – Slender Madtom. One of seven (14%) *N. exilis* (female with eggs, 60 mm TL) collected on 5 June 2015 from a tributary of the Illinois River, Cherokee County (36° 07' 16.2006"N, 94° 48' 21.3732"W) was found to have a leech in its stomach. *Noturus exilis* usually feeds on aquatic insect larvae, crustaceans, nematodes, and gastropods (Curd 1960; Mayden and Burr 1981). There is no previous report of leeches eaten by this madtom.

Esociformes: Esocidae (pikes)

Esox americanus vermiculatus Lesueur, 1846 – Grass Pickerel. On 13 February 2016, a 90

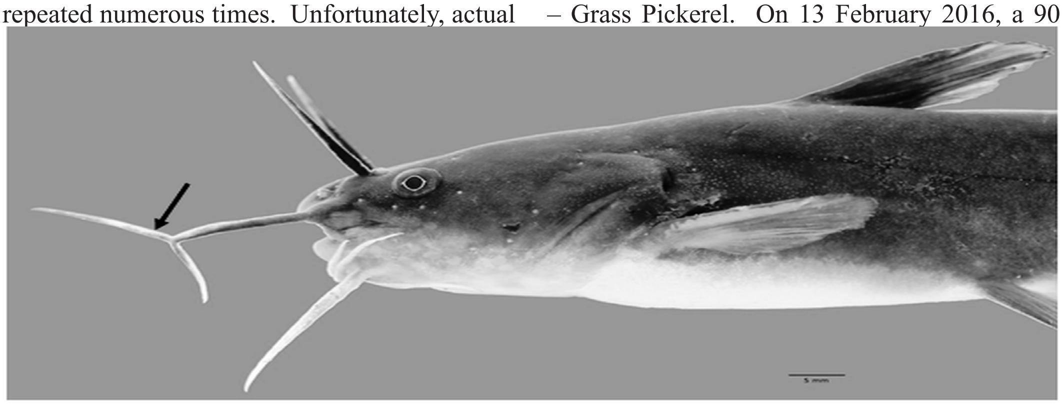

Figure 1. Yellow Bullhead from Little River with forked maxillary barbel (arrow).

mm TL female *E. a. vermiculatus* with eggs was collected by CTM from Yashau Creek at Airline Drive, McCurtain County **(**34° 01' 8.0184"N, 94° 45' 24.2634"W**)**. This fish was previously known to spawn from late February through early March in Oklahoma (Miller and Robison 2004).

Perciformes: Aphedoderidae (pirate perches)

Aphredoderus sayanus (Gilliams, 1824) – Pirate Perch. A gravid *A. sayanus* (75 mm TL) was collected by CTM on 13 February 2016 from Yashau Creek at Airline Drive, McCurtain County **(**34° 01' 8.0184"N, 94° 45' 24.2634"W**)**. Two additional *A. sayanus* (93 and 105 mm TL) with eggs were collected on 28 February 2016 from the same locale. In Arkansas, Tumlison et al. (2015) reported collecting a male running milt on 6 April 2014 from Floyd, White County. Tiemann (2004) reported that two sizes of eggs were present in ovaries (mature and immature) of *A. sayanus*, with a mean of 78 and 124 eggs, respectively. In Oklahoma spawning occurs in spring (Miller and Robison 2004).

Percidae (perches)

Etheostoma artesiae (O. P. Hay, 1881) – Redspot Darter. An adult male (64 mm TL) *E. artesiae* was found in breeding color (with bands of blue, white, and red [proximally] on its median fins) on 13 February 2016 at Yashau Creek at the US Hwy 70 bridge just S of Broken Bow, McCurtain County (33° 59' 14.3952"N, 94° 44' 36.6174"W). In addition, a female (71 mm TL) with eggs was collected at the same site on the same date. Miller and Robison (2004) reported that *E. artesiae* spawned in the spring but little else is known about its biology in Oklahoma.

Etheostoma squamosum (Distler, 1968) – Plateau Darter. Four of nine (44%) female *E. squamosum* (42–53 mm TL) were found with eggs as well as two adult males (47, 55 mm TL) in breeding color (with 8-9 brilliant bars on their sides with more or less bright orange between them) collected on 2 April 2016 from Flint Creek, Delaware County (36° 11' 55.734"N, 94° 42' 27.0504"W). Spawning of *E. squamosum* (formerly *E. spectabile squamosum*) in Oklahoma occurs from late February to May (Miller and Robison 2004).

In summary, Oklahoma contains a tremendous variety of fauna, including 30 species of crayfishes (Morehouse and Tobler 2011) and 180+ species of fishes (Miller and Robison 2004). Much can be gained by reporting novel natural history information on both invertebrates and vertebrates of the state. Here, we report reproductive information on a crayfish and several fishes from Oklahoma, as well as other natural history data. Additional documentation of similar natural history is warranted.

Acknowledgments

The Oklahoma Department of Wildlife Conservation issued a scientific collecting permit to CTM. We thank Dr. Renn Tumlison (HSU) for expert curatorial assistance, Mike Hill (Broken Bow) for providing an *I. castaneus*, Dr. Dennis J. Richardson (Quinnipiac University, Hamden, CT) for use of the electroshocker, and Nikolas H. McAllister (Lukfata Elementary, Broken Bow) and Dr. David A. Neely (Tennessee Aquarium, Chattanooga, TN) for assistance in collecting.

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Submitted August 24, 1016 Accepted November 21, 2016

Parasites (Coccidia, Trematoda, Acari) of Tri-Colored Bats, *Perimyotis subflavus* (Chiroptera: Vespertilionidae): New Geographical Records for Oklahoma

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Abstract: The tricolored bat, *Perimyotis subflavus* has been the subject of several surveys on parasites from various parts of its range. However, few populations have been studied west of the Mississippi River and there are apparently no reports of parasites from this bat in Oklahoma. On examination of two *P. subflavus* from a cave near Flint, Delaware County, we found coccidia, *Eimeria macyi*, digenean trematodes, *Ochoterenatrema breckenridgei*, and chiggers, *Perissopalla flagellisetula*. Although these parasites have been reported previously from *P. subflavus* from various locales in other states, all three are reported as new state records from Oklahoma. In addition, we provide, for the first time, photomicrographs of endogenous stages of *E. macyi* as well as a summation of *O. breckenridgei* records from bats of the Western Hemisphere.

Introduction

The tricolored bat (formerly, eastern pipistrelle), *Perimyotis subflavus* F. Cuvier is a small vespertilionid bat that occurs in forested regions from Nova Scotia to Minnesota and southward to the Yucatán Peninsula (Reid 2006).

In Oklahoma, *P. subflavus* is very abundant in the eastern third of the state, but uncommon in the central and western parts (Caire et al. 1989). This bat hibernates in caves or abandoned mines and typically selects a site with high humidity whereas it is mostly found in trees in the warmer months.

Although information is available on parasites of *P. subflavus* from various states (see Fujita and Kunz 1983; Sparks and Choate 2000; Walters et al. 2011), including adjacent Arkansas (McAllister et al. 2004, 2011a, b, 2014), nothing, to our knowledge has been published on any parasites of this bat from Oklahoma. Here, we report new distributional records for three parasites of *P. subflavus* from northeastern Oklahoma.

Methods

Two adult *P. subflavus* were collected by hand from a cave in the vicinity of Flint, Delaware County (36°12'27.83"N, 94°42'15.78'W). They were taken to the laboratory and, following recommendations for care of mammals (Gannon et al. 2007), killed with an intraperitoneal injection of sodium pentobarbital (Nembutal®). The pelage was examined for ectoparasites by brushing the hair over a white enamel pan as well as a superficial examination of the body with a stereomicroscope. Chiggers were collected with fine forceps and placed in a vial containing 70% (v/v) ethanol; they were cleared in lactophenol and slide-mounted in Hoyer's medium (Walters and Krantz 2009). A midventral incision was made from mouth to anus to expose the gastrointestinal tract and fresh feces were collected from the rectum, placed in vials containing 2.5% (w/v) aqueous potassium dichromate ($K_2Cr_2O_7$) and examined for coccidia by light microscopy using an Olympus BX compound microscope equipped with Nomarski interference-contrast (DIC) optics after flotation in Sheather's sugar solution (sp. gr. 1.20). One positive sample was allowed to complete sporulation in a Petri dish containing a shallow layer of 2.5% $K_2Cr_2O_7$ for five days at room temperature (23 C). Sporulated oocysts were again isolated by flotation (as above) and were photographed and measured using Olympus Microsuite© software. Measurements were taken on 30 oocysts and reported in micrometers (μm) using a calibrated ocular micrometer and reported in micrometers (μm) with means followed by the ranges in parentheses; photographs were taken using DIC optics. Oocysts were 141 days old when measured and photographed. To examine endogenous stages of the coccidian, tissue from the small intestine was fixed in 10% neutral buffered formalin (NBF) and we used routine histological techniques to prepare them for light microscopy and employed paraffin embedding methods found in Presnell and Schreibman (1997). We dehydrated portions of the intestine and accompanying tissues in a graded series of increasing ethanol solutions (50–100%, v/v), cleared with xylene, and infiltrated and embedded in paraffin wax for 8 hr. We trimmed paraffin/tissue blocks of excess wax, serially sectioned them into ribbons 6 μm thick using a rotary microtome, and affixed sections to microscope slides using Haupt's adhesive while floating on a 2% NBF solution. Tissues were stained using Harris hematoxylin followed by counterstaining with eosin (H & E). For photomicroscopy, we utilized a Nikon Eclipse 600 epi-fluorescent light microscope with a Nikon DXM 1200C digital camera (Nikon Instruments Inc., Melville, NY). Trematodes were removed from the intestine and fixed in nearly boiling water without coverslip pressure, placed in 70-95% (v/v) DNA grade ethanol, stained with acetocarmine, dehydrated in a graded ethanol series, cleared in xylene, and mounted in Canada Balsam. Photovouchers of sporulated oocysts and slide-mounted trematodes were accessioned into the Harold W. Manter Laboratory (HWML) of Parasitology, University of Nebraska, Lincoln. Voucher specimens of chiggers are deposited in the General Ectoparasite Collection in the Department of Biology at Georgia Southern University, Statesboro, Georgia (accession no. L3794). Voucher hosts are deposited in the Henderson State University (HSU) collection, Arkadelphia, Arkansas as HSU 947–948.

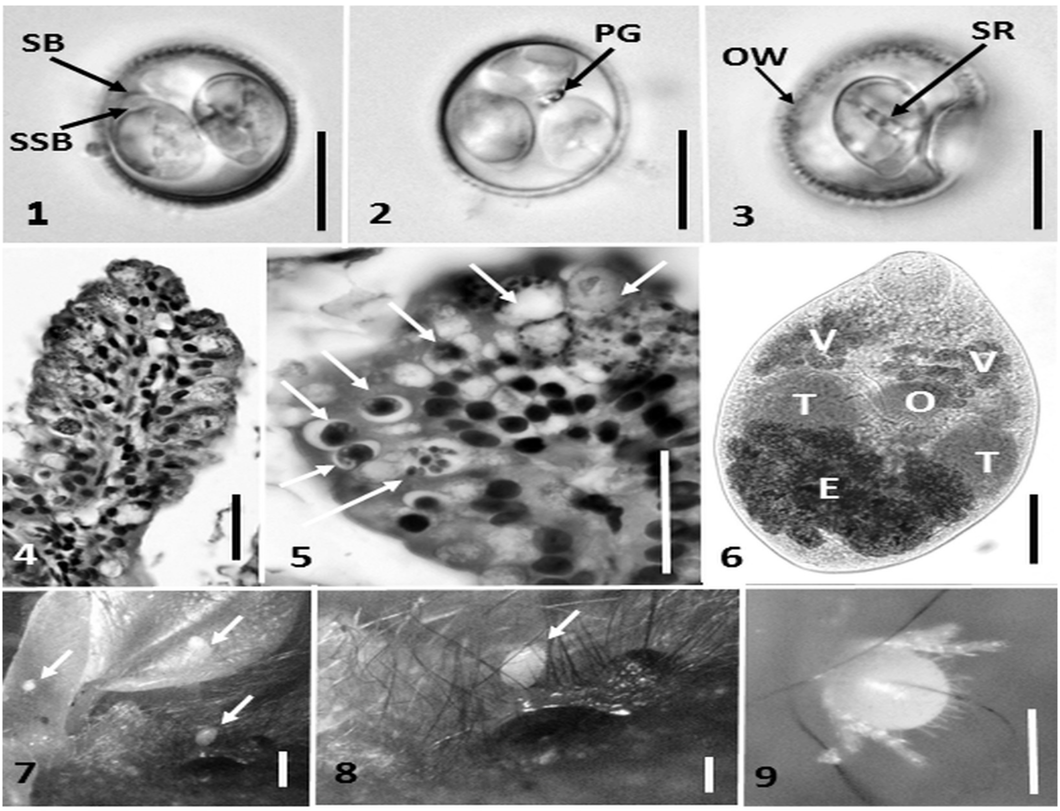
Results and Discussion

Both *P. subflavus* were found to be parasitized, including one harboring a coccidian (HWML 102084) and the other with a digenean trematode (HWML 102051) and a chigger. Data on each species are provided below.

Apicomplexa: Eimeriidae
***Eimeria macyi* Wheat, 1975 (Figs. 1–5)**

One of two *P. subflavus* was found to be passing oocysts of a coccidian that fit the description of *Eimeria macyi* (Wheat 1975; McAllister et al. 2001). This coccidian was originally described from *P. subflavus* from Clarke County, Alabama (Wheat 1975). McAllister et al. (2001) provided a redescription of *E. macyi* including the first photomicrographs of the coccidian. We report *E. macyi* from Oklahoma for the first time, and it represents only the third coccidian reported from any bat in the state. McAllister et al. (2012) reported *E. catronensis* Scott and Duszynski and *E. tumlisoni* McAllister, Seville and Roehrs from northern long-eared myotis, *Myotis septentrionalis* from Le Flore County.

We also provide, for the first time, photomicrographs of the endogenous development of this coccidian in the small



Figures 1-9. Parasites of *Pipistrellus subflavus* from Oklahoma. 1–3. Sporulated oocysts of *Eimeria macyi*. Abbreviations: OW (oocyst wall); PG (polar granule); SB (Stieda body); SSB (substieda body); SR (sporocyst residuum). Scale bars = 10 µm. 4. Endogenous stages (H&E) of *Eimeria macyi* in small intestine. Scale bar = 50 µm. 5. Higher magnification of endogenous stages showing various developmental stages (arrows). Scale bar = 50 µm. 6. *Ochoterenatrema breckenridgei*. Abbreviations: E (eggs); O (ovary); T (testes); V (vitellaria). Scale bar = 100 µm. 7. Three *Perissopalla flagellisetula* chiggers, two on right ear, one above right eye (arrows). Scale bar = 2 mm. 8. Close-up view of single chigger above right eye (arrow). Scale bar = 1 mm. 9. Higher magnification of chigger. Scale bar = 1 mm.

intestine which shows several stages (Figs. 4–5). We also report comparative measurements of three isolates of *E. macyi* (Table 1) which shows some variability in the size of oocysts but we believe all represent this coccidian.

Trematoda: Digenea: Lecithodendridae
***Ochoterenatrema breckenridgei* (Fig. 6)**

One of the *P. subflavus* harbored >50 trematodes in the intestine that fit the description of *Ochoterenatrema breckenridgei* (Macy) Lotz and Font (Macy 1936). In the life cycle, anopheline mosquitoes and snails serve as intermediate hosts, and the adult trematode develops in the intestinal tract of bats, which have most likely ingested mosquitoes (Abdel-Azim 1936). This digenean has been reported previously from *P. subflavus* from Arkansas, Indiana, and Minnesota as well as from other bats in five families and various localities (see Table 2). This is the first time *O. breckenridgei* has been reported from Oklahoma.

Acarina: Trombiculidae
***Perissopalla flagellisetula* (Figs. 7–9)**

Six larval chiggers, *Perissopalla flagellisetula* Brennan and White were found attached to the ears on one of two *P. subflavus*. This chigger was originally described from *P. subflavus* from Alabama (Brennan and White 1960). It has not, as far as we can tell, been reported from additional *P. subflavus* or any other host (Walters et al. 2011). We therefore document a new distributional record for *P. flagellisetula* and only the second time this chigger has been reported since the original description over 46 yr ago. The most frequently recorded chigger from *E. subflavus* is *Euschoengastia pipistrelli* Brennan which has been reported from this host or from other species of bats from the states of Alabama, Arkansas, Illinois, Indiana, Kansas, Kentucky, Missouri, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee and West Virginia (Walters et al. 2011). There is also a record of *Euschoengastia staffordi* Brennan and White from *P. subflavus* in Alabama (Brennan and White 1960). Members of the genus *Euschoengastia* have a pair of distinctive balloon-shaped central scutal setae whereas *P. flagellisetula* has a pair of elongate, plumose central scutal setae.

In summary, little is known about the parasites of Oklahoma bats, and much of what is known concerns their ectoparasites (Reisen et al., 1976; OConner and Reisen 1978, Whitaker et al. 2007), most notably, bat flies from the cave myotis, *Myotis velifer* (Smith 1934; Kessel 1952; Kohls 1954; Zeve 1959, 1960; Caire and Hornuff 1982, 1986; Veal 1983; Caire et al. 1981, 1985). Additional surveys are certainly warranted on parasites of the other 19 species of bats known from the state (Caire et al. 1989) and we expect that additional new host and

Table 1. Comparison of mensural characters of different isolates of *Eimeria macyi* from *Perimyotis subflavus*.

Isolate*	Oocysts (L × W) L/W range	Sporocysts (L × W) L/W range	Reference
Alabama	19.0 × 17.6; 1.1 (16–21 × 15–19); 1.0–1.2	11.0 × 7.0; 1.6 (10–12 × 6–8); 1.5–1.7	Wheat (1975)
Arkansas	22.2 × 20.5; 1.1 (19–25 × 18–24); 1.0–1.2	12.4 × 8.3; 1.5 (11–14 × 7–10); 1.3–1.7	McAllister et al. (2001)
Oklahoma	18.1 × 15.8; 1.1 (16–21 × 13–17); 1.0–1.3	10.1 × 6.4; 1.6 (9–12 × 6–8); 1.5–1.7	This study

*All isolates possessed a polar granule(s), Stieda and substieda bodies, and sporocyst residua without a micropyle and oocyst residuum.

Table 2. Hosts and localities of *Ochoterenatrema breckenridgei*.

Family/Host	Locality	Reference
Molossidae		
Mormopterus minutus	Cuba	Groschaft and Valle, 1969†; Odening, 1969‡; Zdzitowiecki and Rutkowska, 1980‡
Nyctinomops laticaudatus	Cuba	Zdzitowiecki and Rutkowska, 1980‡
Tadarida brasiliensis	Cuba	Zdzitowiecki and Rutkowska, 1980‡
	Florida	Foster and Mertins, 1996
Mormoopidae		
Molossus molossus	Cuba	Odening, 1969‡
	Cuba	Zdzitowiecki and Rutkowska, 1980‡
Mormoops blainvillii	Cuba	Odening, 1969‡; Zdzitowiecki and Rutkowska, 1980‡
Natalidae		
Nyctiellus lepidus	Cuba	Zdzitowiecki and Rutkowska, 1980‡
Phyllostomidae		
Artebius jamaicensis	Cuba	Perez Vigueras, 1940*
Phyllonycteris poeyi	Cuba	Groschaft and Valle, 1969†
Vespertilionidae		
Eptesicus fuscus	Cuba	Groschaft and Valle, 1969†; Zdzitowiecki and Rutkowska, 1980‡
	Indiana	Pistole, 1988
	Minnesota	Lotz and Font, 1983, 1985, 1991, 1994
	Wisconsin	Lotz and Font, 1985, 1991, 1994
Myotis keenii	Indiana	Pistole, 1988
Myotis lucifugus	Indiana	Pistole, 1988
Myotis sodalis	Indiana	Pistole, 1988
Perimyotis subflavus	Arkansas	McAllister et al. 2001
	Indiana	Pistole, 1988
	Minnesota	Macy, 1936; Lotz and Font, 1983
	Oklahoma	This study

* Originally reported as *Lecithodendrium pricei*, a synonym of *O. breckenridgei* (per Lotz and Font, 1983).
†Originally reported as *Lecithodendrium vivianae* (fide Odening, 1973).
‡Originally reported as *O. pricei*, a synonym of *O. breckenridgei* (per Lotz and Font, 1983).

distributional records would be discovered.

Acknowledgments

The Oklahoma Department of Wildlife Conservation issued Scientific Collecting Permits to CTM and MBC. We thank Scott L. Gardner (HWML) and Renn Tumlison (HSU) for expert curatorial assistance. We also thank Mr. Whitmire for allowing us to access his property. This publication was made possible in part by an Institutional Development Award (IDeA) from the National Institute of General Medical Sciences of the National Institutes of Health under Grant # 2P20GM103432. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of NIH.

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Submitted September 1, 2016 Accepted November 21, 2016

Argulus spp. (Crustacea: Branchiura) on Fishes from Arkansas and Oklahoma: New Geographic Distribution Records

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The genus *Argulus* Müller contains about 129 species and subspecies that are ectoparasites, primarily on fishes in freshwater or marine habitats (Poly 2008). However, there has not been a good taxonomic treatment of *Argulus* in the U.S. since Cressey (1972) and the genus is badly in need of revision. Most species are pan-continental in North and South America, Africa, and Eurasia.

There are only a few reports of *Argulus* spp. infesting fishes in Arkansas and Oklahoma. In Arkansas, Spotted Gar (*Lepisosteus oculatus*) has been reported as a host of *A. nobilis* Thiele (Hoffman 1999), and Warmouth (*Lepomis gulosus*), Bluegill (*L. macrochirus*), and Largemouth Bass (*Micropterus salmoides*) have been reported as hosts for *A. mississippiensis* C. B. Wilson (Becker and Cloutman 1975; Cloutman 1975; Becker et al. 1978). In Oklahoma, there is a report of *A. flavescens* C. B. Wilson on Common Carp (*Cyprinus carpio*) from Lake Texoma (Roberts 1957) and *Argulus* sp. were found in the stomachs of four of 176 White Crappie (*Pomoxis annularis*), as well as on Flathead Catfish (*Pylodictis olivaris*) and White Bass (*Morone chrysops*) in Lake Carl Blackwell, Payne County (Spall 1970). Here we provide new distributional records for some *Argulus* spp. on native fishes from Arkansas and Oklahoma.

During October 2015, a single adult (not measured) Bowfin (*Amia calva*) was collected with a backpack electrofisher from Dorcheat Bayou at US 82 bridge, Columbia County, Arkansas (33.358811°N, 93.413554°W). Between February and March 2016, an adult (640 mm total length [TL]) *P. olivaris* and an adult (380 mm TL) *M. salmoides* were collected by MKH with fishing gear from Broken Bow Lake, McCurtain County, Oklahoma (34.3347°N, 94.5864°W). Lice immediately observed on the body of each fish were collected and placed in individual vials containing 70% (v/v) ethanol. Specimens were forwarded to WJP and DGC for identification. Voucher specimens of fish lice are on deposit in the collection of the California

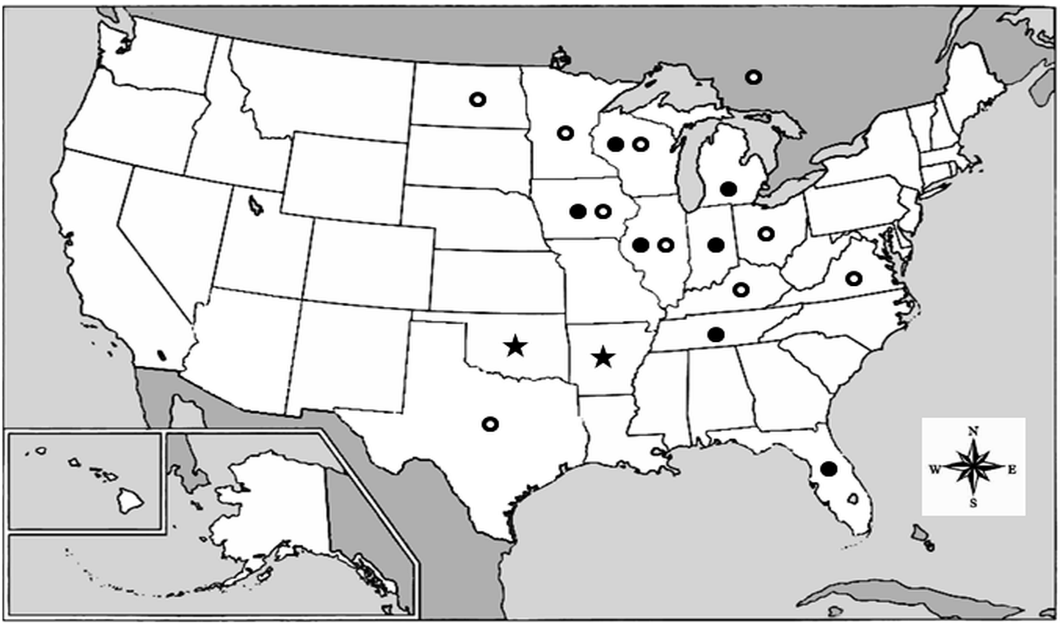

Figure 1. Records of *Argulus americanus* (solid dots) and *A. appendiculosus* (open dots) in North America. Stars = new records.

Academy of Sciences (CAS), San Francisco, California.

Fishes were found to harbor *Argulus* spp., as follows:

***Argulus americanus* C. B. Wilson, 1902**

A single adult female *A. americanus* infested *A. calva*. This louse has been reported previously from *A. calva* as well as other fishes, including those in the genera *Cyprinus, Ictalurus, Lepomis*, and *Umbra* from Florida, Illinois, Indiana, Iowa, Michigan, Tennessee, and Wisconsin (Fig. 1) and is a frequent host/parasite association (Wilson 1916; Meehean 1940; Bangham and Venard 1942; Shimura and Asai 1984; Poly 1998a; Hoffman 1999). We report *A. americanus* from Arkansas for the first time.

***Argulus appendiculosus* C. B. Wilson, 1907**

One adult female *A. appendiculosus* was taken from *P. olivaris*. It has been found previously on Flathead Catfish (Poly 1998a, b) and other hosts including a variety of fishes in the families Catostomidae, Centrarchidae, Clupeidae, Ictaluridae, Lepisosteidae, Percidae, and Sciaenidae from Illinois, Iowa, Kentucky, Minnesota, North Dakota, Ohio, Texas, Virginia, and Wisconsin and Ontario, Canada (Fig. 1) (see Hoffman 1999). It has been erroneously reported in Great Britain according to Fryer (1982). We document a new geographic record for *A. appendiculosus* in Oklahoma.

***Argulus* sp.**

An adult female *Argulus* sp. was found on *M. salmoides*. However, it could not be identified to species. There are several previous reports of *Argulus* spp. on Largemouth Bass, including *A. appendiculosus*, *A. flavescens*, and *A. mississippiensis* (Hoffman 1999).

In summary, we document two new distributional records for a species each of *Argulus* in Arkansas and Oklahoma. These would bring to three each, the number of *Argulus* spp. reported from fishes of Arkansas and Oklahoma. With 167 native species of Oklahoma fishes (Miller and Robison 2004), it is obvious that additional studies are warranted on the fish lice of the state. From such research, we would predict additional new distributional records as well as new host records and the possibility of discovery of new species.

Acknowledgments

The Arkansas Game and Fish Commission and Oklahoma Department of Wildlife Conservation issued Scientific Collecting Permits to CTM and HWR. We acknowledge Dr. David A. Neely (Tennessee Aquarium, Chattanooga) and Uland Thomas (Chicago, IL) for assistance in collecting the bowfin.

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Submitted September 5, 2016 Accepted November 21, 2016

Eimeria chelydrae Ernst, Stewart, Sampson, and Fincher, 1969 (Apicomplexa: Eimeriidae) from the Common Snapping Turtle, *Chelydra serpentina* (Reptilia: Testudines: Chelydridae): First Report from Oklahoma

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The state of Oklahoma supports 19 species and subspecies of turtles in four families (Sievert and Sievert 2011). Although there is a good deal of information on their helminth parasites (see references in McAllister et al. 2015a), little is known about their coccidian (Apicomplexa) parasites (Duszynski and Morrow 2014). The only study, to date investigating Oklahoma turtle coccidians, was performed by McAllister et al. (2015b) on *Eimeria ornata* McAllister and Upton, 1989 from three-toed box turtles, *Terrapene mexicana triunguis* (=*T. c. triunguis*). Here, we report a coccidian in common snapping turtles (*Chelydra serpentina*), for the first time, in Oklahoma.

During May 2013, April 2015 and again between April and May 2016, four adult *C. serpentina* were collected by hand off roads in McCurtain County, Oklahoma. They were measured for carapace length (CL) and fresh fecal samples from captive turtles were placed in individual vials containing 2.5% (w/v) aqueous potassium dichromate ($K_2Cr_2O_7$). Samples were examined for coccidia by brightfield microscopy first after flotation in Sheather's sugar solution (specific gravity = 1.30). However, because oocysts wrinkled in this concentrated solution, it was diluted 50:50 with distilled water, then samples were centrifuged at low speed. The oocysts were pipetted from the top few mm of the flotation medium and resuspended in 0.5 ml distilled water. Measurements were taken on 30 sporulated oocysts (except 10 measurements on oocyst wall thickness and anterior and posterior refractile bodies) from a single turtle using a calibrated ocular micrometer and reported in micrometers (µm) with the ranges followed by the means in parentheses; photographs were taken using brightfield optics. Oocysts were *c.*60 days old when measured and photographed. A host photovoucher was accessioned into the Arkansas State University Museum of Zoology (ASUMZ) Herpetological Collection, State University, Arkansas. Photovouchers of sporulated oocysts were accessioned into the Harold W. Manter Laboratory of Parasitology (HWML), Lincoln, Nebraska.

Oocysts of a coccidian matching the description of *E. chelydrae* (Ernst et al. 1969) were found in two turtles and are described below.

Apicomplexa: Eimeriidae

***Eimeria chelydrae* Ernst, Stewart, Sampson, and Fincher, 1969 (Figs. 1-3)**

Oocysts subspheroidal, 12.5 × 11.3 (11–15 × 10–13) with smooth, thin wall ~ 0.7 (0.5–0.8) thick that wrinkles easily in sucrose solution; shape index (L/W) 1.1 (1.0–1.3). Micropyle, oocyst residuum, and polar granule absent. Sporocysts ellipsoidal, 7.6 × 5.3 (6–10 × 4–7); L/W 1.5 (1.3–1.8). Distinct nipple-like Stieda body present, substieda and parastieda bodies absent. Sporocyst residuum compact and rounded in 2 of 30 (7%) sporocysts, otherwise scattered within the sporocyst. Each sporozoite (not measured) contains a spheroidal anterior refractile body, 1.8 (1.5–2.0) and a spheroidal posterior refractile body, 2.5 (2.0–3.0). Nucleus not evident.

Host: Common snapping turtle, *Chelydra serpentina* (Linnaeus, 1758), (Reptilia: Testudines: Chelydridae) (adult male, 190 mm CL, photovoucher ASUMZ 33585, collected 29 May 2016).

New locality: Off US 259, 6.4 km N of Broken Bow, McCurtain County, Oklahoma (34° 5' 10.593"N, 94° 44' 27.7944"W).

Type-host and locality: *C. serpentina*, farm pond near Tifton, Tift County, Georgia (Ernst et al. 1969).

Other hosts and localities: *C. serpentina*, Arkansas (McAllister et al. 1990, 1994); Texas (McAllister et al. 1994).

Material deposited: Photovoucher deposited in the HWML 102962.

Prevalence: In 2 of 4 (50%) *C. serpentina*.

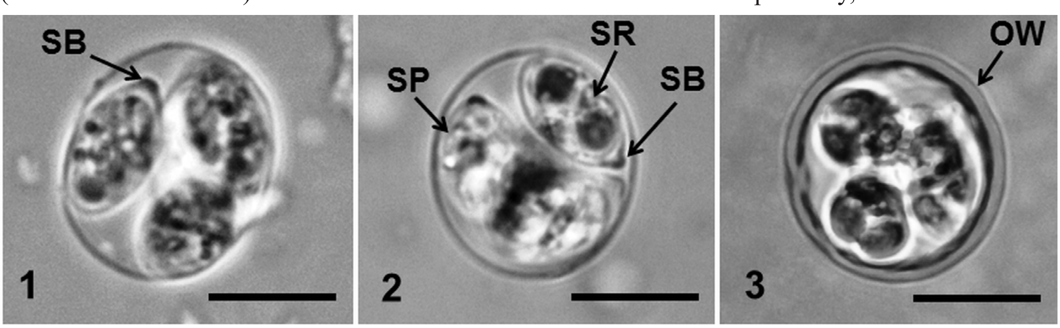
Sporulation time: Exogenous. All oocysts were passed unsporulated or partially sporulated and fully sporulated within 5 days at *c.*23°C.

Site of infection: Unknown; oocysts passed in feces.

Remarks

Although oocysts and sporocysts of our isolate of *E. chelydrae* were smaller (*vs.* 15.2 × 14.4 μm, L/W = 1.0 and 9.6 × 5.6 μm, L/W = 1.7) and the Stieda body was more distinct than that in the original description which was described as "small", all other morphologies (including L/W ratios) matched those of *E. chelydrae* provided by Ernst et al. (1969). In addition, McAllister et al. (1990, Figs. 7–8) provided photomicrographs of *E. chelydrae* from *C. serpentina* from Arkansas and Texas and those clearly showed sporocysts with a prominent Stieda body.

In summary, we provide the first report of *E. chelydrae* documented from aquatic turtles found in Oklahoma. As other aquatic turtles from surrounding states (Arkansas, Texas) have been reported as common hosts of coccidians (McAllister and Upton 1989; McAllister et al. 1994), additional surveys could result in new distributional records as well as new host records. More importantly, the likelihood of



Figures 1–3. Sporulated oocysts of *Eimeria chelydrae* from *Chelydra serpentina* from Oklahoma. 1. Subspheroidal oocyst showing Stieda body (SB). 2. Another oocyst with SB, sporocyst (SP) and sporocyst residuum (SR). 3. Spheroidal oocyst showing oocyst wall (OW). Scale bars = 5μm.

discovering new species of coccidia is also a distinct possibility.

Acknowledgments

The Oklahoma Department of Wildlife Conservation issued a Scientific Collecting Permit to CTM. We also thank Drs. Scott L. Gardner (HWML) and Stanley E. Trauth (ASUMZ) for expert curatorial assistance.

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Submitted September 7, 2016 Accepted November 21, 2016

New Host and Distributional Records for Helminth Parasites (Trematoda, Cestoda, Nematoda) from Amphibians (Caudata, Anura) and Reptiles (Testudines: Ophidia) of Oklahoma

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Abstract: Between April 2012 and September 2016, 28 amphibians and seven reptiles from Delaware, Latimer, and McCurtain counties, Oklahoma, were examined for helminth parasites, including 10 Oklahoma salamanders, *Eurycea tynerensis*, two Fowler's toads, *Anaxyrus fowleri*, five crawfish frogs, *Lithobates areolatus*, two spring peepers, *Pseudacris crucifer*, nine Cajun chorus frogs, *Pseudacris fouquettei*, two eastern cooters, *Pseudemys concinna***,** and one each black racer, *Coluber constrictor priapus*, western mud snake, *Farancia abacura reinwardti*, plain-bellied watersnake, *Nerodia erythrogaster*, broad-banded watersnake, *Nerodia fasciata confluens*, and western ratsnake, *Pantherophis obsoletus*. A total of 11 helminths, including six trematodes (*Dasymetra conferta, Glypthelmins* sp., *Haematoloechus complexus*, *Renifer ellipticus*, *Renifer* sp. metacercaria, *Telorchis corti*), two cestodes (*Oochoristica eumecis*, *Ophiotaenia* sp.), and three nematodes (*Cosmocercoides variabilis*, *Omeia papillocauda*, *Oswaldocruzia pipiens*) were harbored by these hosts. Although we document six new host and two new distributional records, the total parasite fauna of Oklahoma's herpetofauna is probably underestimated, particularly from potential hosts in the western and panhandle regions of the state.

Introduction

The state of Oklahoma with its diverse habitats support at least 58 species and subspecies of amphibians and 99 species and subspecies of reptiles (Sievert and Sievert 2011). In the last decade, a great deal of information has been published from our collaborative community effort in a series of papers on the helminth parasites of Oklahoma's herpetofauna (McAllister and Bursey 2007, 2012; McAllister et al. 2010, 2011, 2014 a, 2014b, 2014c, 2015a, 2015b). Here, we augment some of that void by reporting new host and distributional records for select amphibians and reptiles from three counties of the state.

Methods

Between April 2012 and September 2016, the following herpetofauna (amphibians, n = 28; reptiles, n = 7) were collected and examined for helminth parasites–Caudata: 10 Oklahoma salamanders, *Eurycea tynerensis*; Anura: two Fowler's toads, *Anaxyrus fowleri*, five crawfish frogs, *Lithobates areolatus*, two spring peepers, *Pseudacris crucifer*, nine Cajun chorus frogs, *Pseudacris fouquettei*; Testudines: two eastern cooters, *Pseudemys concinna*; Ophidia: one each black racer, *Coluber constrictor priapus*, western mud snake, *Farancia abacura reinwardti*, plain-bellied watersnake, *Nerodia erythrogaster*, broad-banded watersnake, *Nerodia fasciata confluens*, and western ratsnake, *Pantherophis obsoletus*. They were collected by hand, aquatic dipnet or snake tong from Delaware, Latimer, and McCurtain counties, measured for snout-vent length (SVL) or carapace length (CL), and examined for helminths. Specimens were placed in collection bags, placed on ice, and taken to the laboratory for necropsy within 24 hr. They were killed by prolonged immersion with a concentrated chloretone® (chlorobutanol) solution (amphibians) or by intraperitoneal injection of sodium pentobarbital (reptiles). A bone saw was used to detach the plastron from turtles to expose the viscera which was removed, placed in a Petri dish, and its contents scanned using a stereomicroscope. The gastrointestinal tract was split lengthwise and examined as well as other organs, including the lungs, liver, and gonads. For other herpetofauna, a mid-ventral incision was made to expose the viscera and the entire gastrointestinal tract and other organs were examined for helminths in a similar manner. Trematodes and cestodes were fixed in hot tap water without coverslip pressure, stained with acetocarmine, dehydrated in a graded ethanol series, cleared in methyl salicylate or xylene and mounted in Canada balsam. Nematodes were fixed in hot tap water and studied as temporary mounts on a microscopic slide in a drop of glycerol. Parasites were either retained for future DNA studies or deposited in the Harold W. Manter Laboratory of Parasitology (HWML), University of Nebraska-Lincoln. Host voucher specimens are deposited in the Arkansas State University Herpetological Collection (ASUMZ), State University, Arkansas, or the Henderson State University Herpetological Collection (HSU), Arkadelphia, Arkansas.

Results and Discussion

A total of 11 helminths, including six trematodes, two cestodes, and three nematodes were harbored by 16 hosts (10 amphibians, six reptiles). An annotated list of the helminths found and the host data follows.

Trematoda: Digenea: Plagiorchiida: Haematoloechidae

***Haematoloechus complexus* (Seely, 1906) Krull, 1933**

One *H. complexus* (HWML 99910) was taken from the lung of one of five (20%) adult (90 mm SVL) *L. areolatus* collected on 13 March 2016 from 14.5 km E of Jay, Delaware County (36° 26' 44.65"N, 94° 37' 46.15'W). *Haematoloechus* is one of the most common genera of trematode found in the lungs of frogs. *Haematoloechus complexus* has been previously reported from Cope's gray treefrog, *Hyla chrysoscelis,* northern leopard frog, *Lithobates pipiens,* southern leopard frog, *L. sphenocephalus utricularius*, wood frog, *L. sylvaticus*, green frog, *L. clamitans*, plains leopard frog, *L. blairi*, *P. crucifer*, and Woodhouse's toad, *Anaxyrus woodhousii* (Bolek and Janovy 2007). In experimental life cycle studies, amphipods, chironomids, and dragonfly larvae served as intermediate hosts of *H. complexus* (Bolek and Janovy 2007). It is a common eastern species and has already been reported from Oklahoma in *L. s. utricularius* (Vhora and Bolek 2015).

This ranid frog is one of the few in the genus rarely reported as a host of helminths. Harwood (1932) lists *L. areolatus* from Texas as a host of the trematode *Megalodiscus temperatus* and the nematode *Cosmocercoides variabilis* (as *C. dukae*). Parris and Redmer (2005) erroneously lists *L. areolatus* as a host of trematodes and nematodes based on previous studies of Kuntz (1941) and Walton (1949). *Haematoloechus complexus* becomes only the third helminth ever reported from *L. areolatus*.

Macroderoididae

***Glypthelmins* sp.**

One of nine (11%) adult (31 mm SVL) *P. fouquettei* collected on 22 February 2016 from Hochatown, McCurtain County (34° 09' 55.152"N, 94° 45' 35.8776"W) harbored three immature *Glypthelmins* sp. in its intestines. In addition, two *P. crucifer* (male 28 mm, female

33 mm SVL) collected on 13 March 2016 from 14.5 km E of Jay, Delaware County (36° 26' 44.65"N, 94° 37' 46.15'W) were found to harbor two and four immature (HWML 99895) *Glypthelmins* sp. in their intestinal tract. Since no eggs were present in any trematode from either host it was not possible to assign a species designation. This is the first time this digenean has been reported from Oklahoma specimens of *P. crucifer* and the initial report of *Glypthelmins* sp. from the Cajun chorus frog.

The northern spring peeper has rarely been surveyed in the state and they have only been reported to previously harbor larval *Physaloptera* sp. in Oklahoma (Morgan 1941). *Glypthelmins pennsylvaniensis* Cheng, 1961 has been previously reported from this frog in Arkansas (McAllister et al. 2008), Michigan (Muzzall and Peebles 1991), Pennsylvania (Cheng 1961), West Virginia (Joy and Dowell 1994), and Wisconsin (Coggins and Sajdak 1982; Yoder and Coggins 1996). Another, *Glypthelmins quieta* (Stafford, 1900) Stafford, 1905 has been reported from American bullfrog, *Lithobates catesbeianus* and *L. s. utricularius* from Oklahoma (Trowbridge and Hefley 1934; Brooks 1979) and *P. crucifer* from Ohio (Odlaug 1954).

McAllister et al. (2015a) examined 20 *P. fouquettei* from the same Oklahoma site reported herein and, although several helminths were found, they did not report a single *Glypthelmins* sp. In addition, another survey of *P. fouquettei* in Arkansas and Texas did not report this digenean (McAllister et al. 2013). The prevalence is obviously low for this trematode in southern populations of *P. fouquettei*. Indeed, it would be difficult to predict if *Glypthelmins* might be more common during other parts of the year because this frog is rarely taken outside of the breeding season (Feb.-Mar.) that our specimens herein were collected.

Ochetosomatidae
***Renifer ellipticus* Pratt, 1903**

Twenty-one *R. ellipticus* (HWML 99907) were taken from the esophagus and oral cavity of an adult (740 mm SVL) *C. c. priapus* collected on 20 April 2016 from off of US 259 in Hochatown, McCurtain County (34° 09' 55.152"N, 94° 45' 35.8776"W). *Ochetosoma ellipticus* was originally described by Pratt (1903) from specimens found in the mouth of an eastern hognose snake, *Heterodon platirhinos* (locality not given). It has been reported previously from blue racer, *Coluber constrictor foxi* from Illinois (Dyer and Ballard 1989) as well as other colubrid snakes in North America, including *Coniophanes* sp., indigo snake, *Drymarchion corais,* northern speckled racer, *Drymobius margaritiferus,* common kingsnake, *Lampropeltis getula,* northern cat-eyed snake, *Leptodeira septentrionalis, Micrurus* sp., *N. erythrogaster,* diamondback watersnake, *Nerodia rhombifer,* blackneck garter snake, *Thamnophis cyrtopsis,* and eastern ribbonsnake, *Thamnophis sauritis* from Arizona, New Mexico, South Dakota, and Tabasco, México (see Ernst and Ernst 2006). We document a new host record in the southern black racer as well as the first report of *R. ellipticus* from Oklahoma.

***Renifer* sp. metacercaria**

Seven ochetosomatid metacercaria (*Renifer* sp.) were found in the intestinal tract of an adult (1,190 mm SVL) *F. a. reinwardti* collected on 8 April 2012 from Yashau Creek at Broken Bow, McCurtain County (34° 01' 08.2878"N, 94° 45' 17.4852"W). This is the first time *Renifer* sp. has been reported from this subspecies. *Renifer aniarum* has been reported previously from eastern mud snake, *Farancia abacura abacura* from an unknown locality by MacCallum (1921) (see McAllister and Bursey 2008).

***Dasymetra conferta* Nicoll, 1911**

Five *D. conferta* (HWML 99891) were taken from the esophagus of an adult (660 mm SVL) *N. erythrogaster* collected on 23 August 2016 from Hochatown, McCurtain County (34° 10' 12.4926"N, 94° 45' 01.1442"W). Although this digenean has been previously reported from *N. erythrogaster* (Ernst and Ernst 2006), this is the first time it has been found in a plain-bellied watersnake from Oklahoma. McAllister and Bursey (2012) previously reported *D. conferta* from *N. rhombifer* from McCurtain County.

Telorchiidae

Telorchis corti Stunkard, 1915

Two *T. corti* (HWML 99892) were found in the intestinal tract of an adult (290 mm CL) *P. concinna* collected from the vicinity of Bengal, Latimer County (34° 49' 58.3608"N, 95° 03' 42.861"W). This fluke has been reported from a number of turtles, including common snapping turtle, *Chelydra serpentina*, red-eared slider, *Trachemys scripta elegans*, and Mississippi mud turtle, *Kinosternon subrubrum hippocrepis* from Oklahoma (see McAllister et al. 2015b). We document a new host record for *T. corti*.

Cestoda: Cyclophyllidea: Linstowiidae

Oochoristica eumecis Harwood, 1932

A single adult (1091 mm SVL) *P. obsoletus* collected on 19 April 2016 from 14.5 km E of Jay, Delaware County (36° 26' 44.65"N, 94° 37' 46.15'W) was infected in its small intestine with two *O. eumecis* (HWML 99893). This is the first report of *O. eumecis* from a snake and from Oklahoma. Previous hosts include five-lined skink, *Plestiodon fasciatus* (type host) from Texas, western spiny-tailed iguana, *Ctenosaura pectinata* from México, and Madrean alligator lizard, *Elgaria kingii* from Arizona (Harwood 1932; Flores-Barroeta et al. 1958; Goldberg et al. 1999). However, Brooks et al. (1999) has suggested that all reports of *Oochoristica* in *C. pectinata* refer to *O. acapulocoensis* Brooks, Pérez-Ponce de León, and García-Prieto. We agree and document a new host and a new distribution record for *O. eumecis* as well as the third host of this tapeworm. We also provide comparative measurements of our specimens of *O. eumecis* with those in the original description by Harwood (1932) (Table 1). There is some variability in measurements; however, reproductive characters are very similar and we feel confident our specimens are *O. eumecis*.

Ophiotaenia sp.

Two gravid proglottids of an *Ophiotaenia* sp. was found in the small intestine of an adult (223 mm SVL) *N. f. confluens* collected on 30 June 2013 from Yashau Creek at Broken Bow, McCurtain County (34° 00' 42.0336"N, 94° 44' 57.9186"W). Two cestodes, *Proteocephalus faranciae* and *Ophiotaenia perspicua* has been reported previously from *N. fasciata* (Ernst and Ernst 2006).

Nematoda: Ascaridida: Cosmocercidae

Cosmocercoides variabilis (Harwood, 1930) Travassos, 1931

A single *P. crucifer* (male 28 mm) collected on 13 March 2016 from 14.5 km E of Jay, Delaware County (36° 26' 44.65"N, 94° 37' 46.15'W) was infected with a single male *C. variabilis* (HWML 99894) in its rectum. Muzzall and Peebles (1991) reported *Cosmocercoides* sp. from this host in Michigan, and Yoder and Coggins (1996) reported *C. dukae* (more likely *C. variabilis*) from *P. crucifer* from Wisconsin. This common nematode has been reported from a plethora of herpetofauna from the Nearctic and Neotropical regions (see Bursey et al. 2012) and, in Oklahoma, from a salamander, four anurans, and a colubrid snake (see McAllister et al. 2015a, 2015b). This is the first time this parasite has been reported from Oklahoma specimens of *P. crucifer*.

Seuratoidea: Quimperidae

Omeia papillocauda Rankin, 1937

Three of 10 (30%) adult (36–42 mm SVL) *E. tynerensis* collected on 15 May 2015 from Flint Cave, Delaware County (36° 12' 27.83"N, 94° 42' 15.78'W) were infected in their intestines with seven (3 males, 4 females) *O. papillocauda* (HWML 99896) nematodes. *Omeia papillocauda* has previously been reported from *E. tynerensis* from nearby Arkansas (McAllister et al. 2014c). This is the first time *O. papillocauda* has been reported from Oklahoma *E. tynerensis*.

Strongylida: Molineidae

Oswaldocruzia pipiens Walton, 1929

One of two *A. fowleri* (91 mm SVL) collected on 12 September 2016 from Hochatown, McCurtain County (34° 09' 55.152"N, 94° 45' 35.8776"W) was infected with 11 (3 male, 8 female) *O. pipiens* (HWML 99874) in its small intestine. Previous hosts in Oklahoma include *A. a. americanus*, Rocky Mountain toad (*A. woodhousii woodhousii*), *L. s. utricularius*, and Hurter's spadefoot (*Scaphiopus hurterii*) (see McAllister et al. 2014a). This is another nematode that shows little host specificity as it

Table 1. Comparison of *Oochoristica eumecis* Harwood with current specimens.

Character	Harwood (1932) (*n* = 1)	Current specimens (*n* = 2)
Length	103 mm	100–110 mm
Scolex	500 µm	497–510 µm
Suckers	220 × 260 µm	204 × 255 µm
Neck	350 × 2000 µm	408 × 1472–2176 µm
Immature segments	not given	832–960 × 320–960 µm
Mature segments	800–900 long × 1180–1200 µm wide	1150–1340 long × 768–960 µm wide
Gravid segments	absent	absent
Genital pore	anterior fourth or fifth	end of first quarter
Cirrus sac	260–180 long × 60–70 µm wide	224–178 long × 89–96 µm wide
Testes number	40–55 (1 field)	45–52 (1 field)
Testes size	not given	26 µm (in diameter)
Ovary	400 µm wide	384 µm wide
Vitellaria	not given	triangular 192 × 192 µm
Egg	no gravid proglottids	no gravid proglottids

has been reported from other anurans as well as various North American reptiles (McAllister et al. 2014b). We document a new host record for *O. pipiens*.

Several new host and distributional records are documented herein. Additional surveys are recommended, particularly on those amphibians and reptiles in the western and panhandle parts of the state where the ecoregions (and its herpetofauna) differ considerably from those in eastern Oklahoma. Furthermore, exposure of this fauna to its parasite's life cycles, which include vastly different intermediate hosts, will likely portend additional new host and geographic distribution records, including the possibility of discovering new species.

Acknowledgments

The Oklahoma Department of Wildlife Conservation issued a Scientific Collecting Permit to CTM and MBC. Drs. Scott L. Gardner (HWML) and Stanley E. Trauth (ASUMZ) provided expert curatorial assistance. We thank Dr. Norman O. Dronen (Texas A&M University-College Station) for identification of *Glypthelmins* sp. from *P. fouquettei*.

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Submitted September 14, 2016 Accepted November 21, 2016

New Records of Helminth Parasites (Trematoda, Cestoda, Nematoda) from Fishes in the Arkansas and Red River Drainages, Oklahoma

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Abstract: Between November 2014 and November 2016, 85 individual fishes (13 taxa from seven families) were collected from four sites in the Arkansas River drainage and three sites in Red River drainage of Oklahoma and examined for helminth parasites. Eighteen endoparasites (six trematodes, five cestodes, seven nematodes) were found in 32 of 85 (38%) fish including: *Alloglossidium progeneticum* in Black Bullheads (*Ameiurus melas*), *Clinostomum marginatum* in Slendar Madtoms (*Noturus exilis*), *Crepidostomum* sp. in a Plateau Darter (*Etheostoma squamosum*), *Caecincola* sp. in Slenderhead Darters (*Percina phoxocephala*), *Posthodiplostomum minimum* in a Redspot Chub (*Nocomis asper*), unknown metacercariae in a Slim Minnow (*Pimephales tenellus*), *Bothriocephalus claviceps* in a Banded Sculpin (*Uranidea carolinae*) and a Cardinal Shiner (*Luxilus cardinalis*), *Essexiella fimbriatum* in a Yellow Bullhead (*Ameiurus natalis*) and in an *A. melas*, *Proteocephalus ambloplitis* in a Western Creek Chubsucker (*Erimyzon claviformis*), *Proteocephalus* sp. in an *E. squamosum* and Grass Pickerels (*Esox americanus*), *Schyzocotyle acheilognathi* in *E. claviformis*, *Rhabdochona cascadilla* in *L. cardinalis*, *Spinitectus micracanthus* from largemouth bass (*Micropterus salmoides*), *Dichelyne robusta* and *Spinitectus macrospinosus* in a channel catfish (*Ictalurus punctatus*), *Spiroxys* sp. in *E. claviformis*, *Textrema hopkinsi* from a *M. salmoides*, and unknown larval nematodes in an *E. americanus*. Thirteen new host and six new geographic distributional records are documented.

Introduction

Since the seminal publication of Hoffman (1999), which summarized various parasites of North American fishes, including citing those studies from Oklahoma, more than a decade of neglect occurred in our knowledge of helminth parasites of the state's fish fauna. However, in the past few years, our collaborative community effort has helped us better understand the diversity of parasites in a variety of non-game fishes of the state (McAllister and Bursey 2011, 2013; McAllister et al. 2014b, 2015a, 2015b, 2015c, 2016; Kasl et al. 2015; Fayton et al. 2016). Here, in a similar manner, we continue to expand that information by documenting new host and distributional records for helminth parasites of select fishes from the Arkansas and Red River drainages of Oklahoma.

Methods

Between November 2014 and November 2016, 85 individual fishes (13 taxa from seven families) were examined for helminths including: **Catostomidae:** 13 Western Creek Chubsuckers (*Erimyzon claviformis*); **Centrarchidae:** four Largemouth Bass (*Micropterus salmoides*); **Cyprinidae:** two Cardinal Shiners (*Luxilus cardinalis*), four Redspot Chubs (*Nocomis asper*), three Slim Minnows (*Pimephales tenellus*); **Cottidae:** one Banded Sculpin (*Uranidea carolinae*); **Esocidae:** 15 Grass Pickerels (*Esox americanus*); **Ictaluridae:**19 Black Bullheads (*Ameiurus melas*), three Yellow Bullheads (*Ameiurus natalis*), six Slender Madtoms (*Noturus exilis*), one Channel Catfish (*Ictalurus punctatus*); **Percidae:** seven Plateau Darters (*Etheostoma squamosum*) and seven Slenderhead Darters (*Percina phoxocephala*). They were collected by dipnet, backpack electrofisher, or 3.7 m (1.6 mm mesh) seine from seven sites in four counties of Oklahoma (Fig. 1) including, ***Cherokee County*:** tributary of the Illinois River off St. Hwy 10 (36° 07' 16.2006"N, 94° 48' 21.3732"W); ***Delaware County*:** Flint Creek at Flint (36° 11' 55.734"N, 94° 42' 27.0504"W); ***Mayes County*:** Little Saline Creek (36° 17' 4.833"N, 95° 05' 22.74"W) and Snake Creek off St. Hwy 82 (36° 09' 51.8976"N, 95° 09' 25.614"W); ***McCurtain County***: Yanubbee Creek at Currence Road in Broken Bow (34° 02' 45.5568"N, 94° 43' 19.7394"W); Yashau Creek at Airport Road in Broken Bow (34° 01' 7.8996"N, 94° 45' 24.1668"W); Cow Creek Crossing on the Little River (33° 57' 14.3568"N, 94° 35' 37.3446"W). Fish were placed in aerated habitat water, taken to the laboratory for necropsy within 24 hr, killed by prolonged immersion in a concentrated chloretone® (chlorobutanol) solution, and measured for total length (TL). A mid-ventral incision was made to expose the viscera and the entire gastrointestinal (GI) tract and other organs were placed in Petri dishes containing 0.6% saline, and examined for helminths. The GI tract was split longitudinally and its contents examined under a stereomicroscope. Trematodes

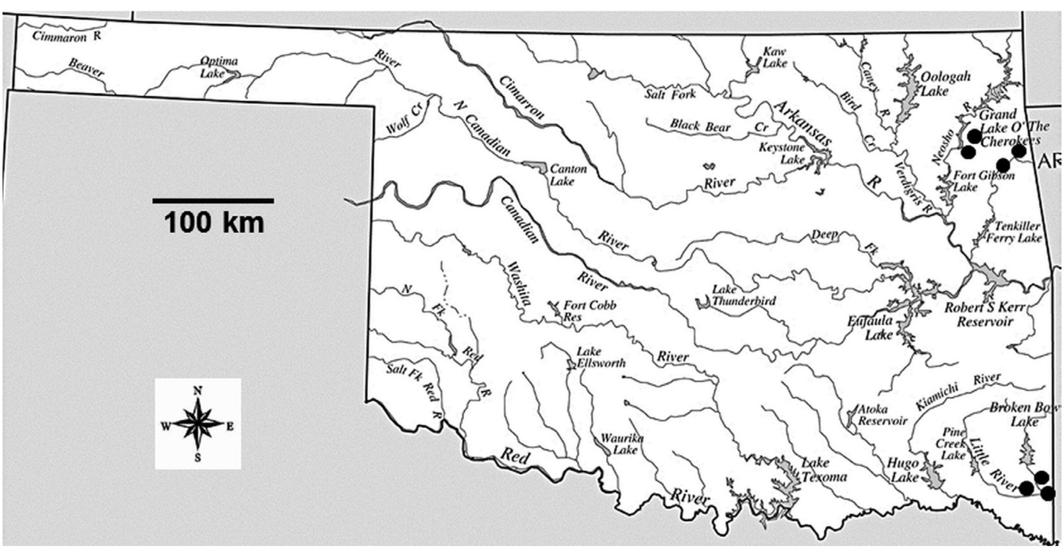


Figure 1. Map of Oklahoma showing major watersheds. Dots represent approximate location of study sites.

and cestodes were fixed in near boiling tap water without coverslip pressure, stained with acetocarmine, dehydrated in a graded ethanol series, cleared in methyl salicylate or xylene, and mounted in Canada balsam or damar gum. Nematodes were fixed in a similar manner, preserved in 70% (v/v) ethanol, and studied as temporary mounts in glycerol. To examine tissues containing suspected helminths, sections from the liver and mesenteries were fixed in 10% neutral buffered formalin (NBF). We used routine histological techniques to prepare them for light microscopy and employed paraffin embedding methods found in Presnell and Schreibman (1997). Dehydrated tissues were placed in a graded series of increasing ethanol solutions (50–100%, v/v), cleared with xylene, and infiltrated and embedded in paraffin wax for 8 hr. We trimmed paraffin/tissue blocks of excess wax, serially sectioned them into ribbons 6 µm thick using a rotary microtome, and affixed sections to microscope slides using Haupt's adhesive while floating on a 2% NBF solution. Tissues were stained using Harris hematoxylin followed by counterstaining with eosin (H & E). For photomicroscopy, we utilized a Nikon Eclipse 600 epi-fluorescent light microscope with a Nikon DXM 1200C digital camera (Nikon Instruments Inc., Melville, NY).

Voucher specimens of parasites were were either retained for DNA studies or deposited in the Harold W. Manter Laboratory of Parasitology (MWML), Lincoln, Nebraska. Host voucher specimens were deposited in the Henderson State University Collection (HSU), Arkadelphia, Arkansas.

Results and Discussion

Thirty-two of 85 (38%) fish harbored helminths; infected fish came from all six sites in both drainages. The helminths found are presented below in annotated format.

Trematoda: Digenea: Strigeatida: Diplostomidae

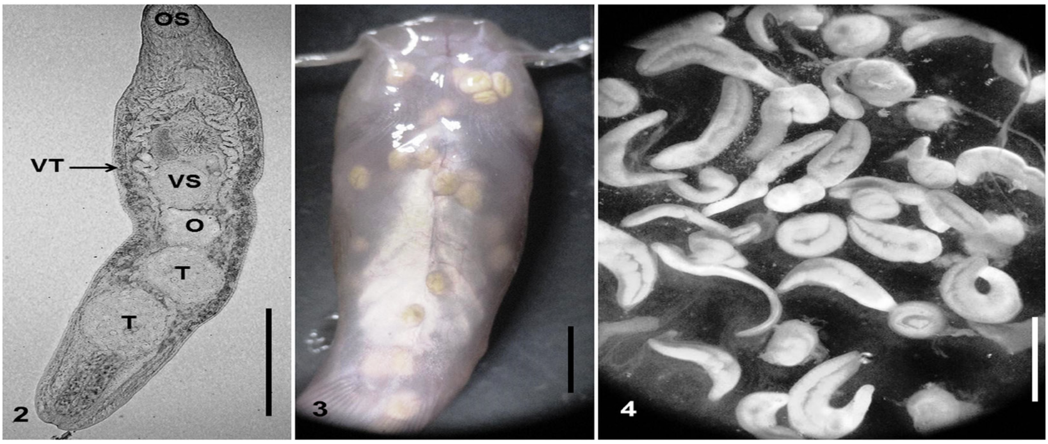
***Posthodiplostomum minimum* (MacCallum, 1921)**

One of four (25%) *N. asper* (96 mm TL) collected on 5 June 2015 from a tributary of the Illinois River, Cherokee County harbored *P. minimum* metacercaria. White grub has been reported from various fishes from North America (see Hoffman 1999). Physid snails serve as first intermediate hosts and natural infections of *Posthodiplostomum* have been reported from piscivorous birds of the Orders Ciconiiformes, Charadriiformes, and Pelecaniformes (Bedinger and Meade 1967; Dubois 1970). Metacercariae of strigeiforms that mature in these fish-eating birds are common and widely distributed. We document a new host record for *P. minimum*.

Clinostomidae

***Clinostomum marginatum* Rudolphi, 1819**

Three of six (50%) *N. exilis* (66, 74, 84 mm TL) collected on 2 April 2016 from Flint Creek, Delaware County harbored metacercariae of *C. marginatum* (yellow grub). One of these *N. exilis* (66 mm TL) had a hyperinfection of 44 individual worms (Figs. 3–4) but the other two had one and two metacercaria, respectively. Daly et al. (1991) reported hyperinfection of Smallmouth Bass (*Micropterus dolomieu*) in Arkansas with up to 2,500 individual worms of *C. marginatum*. In the life cycle, embryonated eggs pass in the feces of the definitive host, which are various piscivorous birds (herons, egrets, herring gulls, and bitterns), and miracidia hatch and penetrate feces of snail first intermediate hosts (Bullard and Overstreet 2008; Caffara et al. 2014). Sporocysts and two generations of rediae develop producing cercariae that eventually encyst as metacercaria (yellow grub) in fishes or amphibian second intermediate hosts (Hopkins 1933; Hunter and Hunter 1933). This digenean is a very common fish trematode that is cosmopolitan in distribution (Lane and Morris 2000); however, this is the first time it has been reported from *N. exilis*. McAllister et al. (2015c) did not find any *C. marginatum* in a large sample (n = 43) of *N. exilis* from Arkansas. In Oklahoma, yellow grub has been reported previously from other non-game fishes, including Pirate Perches, *A. sayanus* (Hopkins 1933; McAllister and Bursey 2013), Carp, *Cyprinus carpio* (Spall 1969) and Striped Shiner, *Luxilus chrysocephalus* (McAllister et al. 2014).



Figures 2–4. 2. Ventral view of adult *Alloglossidium progeneticum* from *Ameiurus melas*. Locations of oral sucker (OS), ovary (O), testes (T), ventral sucker (VS), and vitellaria (VT) are indicated. Scale bar = 400 µm. 3. Ventral view of *Noturus exilis* with hyperinfection of encysted metacercaria of *Clinostomum marginatum*. Scale bar = 5 mm. 4. Some of the same metacercaria after removal from their cysts. Scale bar = 2 mm.

Plagiorchiida: Alloglossiidae

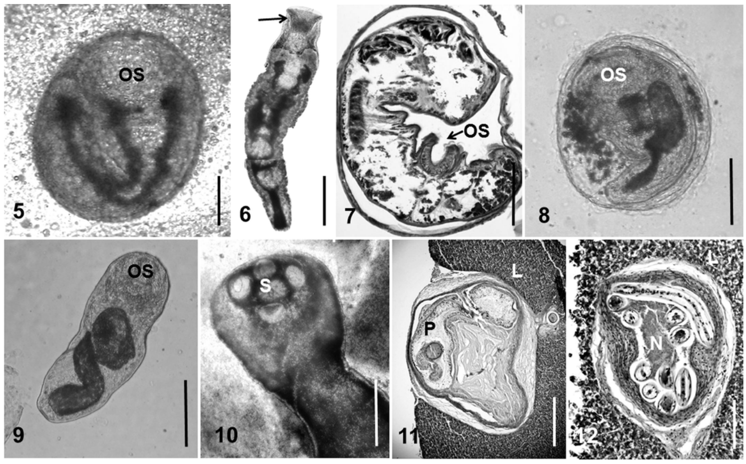
***Alloglossidium progeneticum* (Sullivan and Heard, 1969) Font and Corkum, 1975**

Four of 19 (21%) *A. melas* (138.5 ± 38.3, range 100–195 mm TL) collected on 25 June 2015 from Yashau Creek, McCurtain County harbored a total of five *A. progeneticum* (Fig. 2) in their small intestine. Specimens (Fig. 2) fit the description of those *A. progeneticum* described from a nonprecocious population (see Kasl et al. 2015). Interestingly, this fluke has a facultative progenetic life cycle in which the worms are able to reach sexual maturity in either a crayfish (2-host) or *Ameiurus* spp. (3-host) final host. In those exhibiting a 2-host life cycle, eggs are produced while still encysted in the antennal gland of crayfishes whereas those utilizing a 3-host life cycle are found as adults in the intestine of fishes (Kasl et al. 2015). *Alloglossidium progeneticum* has been reported from Yellow Bullheads, *Ameiurus natalis* in Alabama, Arkansas, Georgia, Louisiana, Oklahoma, and Texas (Kasl et al. 2015). Previous reports of *Alloglossidium corti* (Lamont) Van Cleave and Mueller from *A. melas* and *A. natalis* (Hoffman 1999) most likely represent *A. progeneticum*. We document a new host record herein for *A. progeneticum*.

Allocreadiidae

***Crepidostomum* sp.**

Three specimens of this digenean were found in two (33, 47 mm TL) *E. squamosum* collected on 5 June 2015 from Little Saline Creek, Mayes County. This is the first time *Crepidostomum* sp. has been reported from the Plateau Darter. Several *Etheostoma* spp. have been previously reported to harbor *Crepidostomum* spp. (Hoffman 1999), including Orangebelly Darter, *Etheostoma radiosum* from the Blue River at Connerville, Johnston County, Oklahoma, with *C. cooperi* S. H. Hopkins (Scalet 1971). In addition, *C. cooperi* has also been reported in Oklahoma centrarchid fishes (McDaniel and Bailey 1966). McAllister and Bursey (2013) previously reported *C. isostomum* S. H. Hopkins from *A. sayanus* from McCurtain County, Oklahoma. In the life cycle, oculate xiphidiocercaria occur in clams with metacercaria in mayflies and crustaceans (see Hoffman 1999). *Crepidostomum* has a high number of species parasitizing freshwater fishes of North America among the many trematode genera represented in these hosts in North America (Choudhury et al. 2016). Indeed, undocumented diversity persists in the genus and the specific identity of this form will be examined in a subsequent publication. Nevertheless, *E. squamosum* is a



Figures 5-12. 5. *Caecincola* sp. metacercaria from *Percina phoxocephala*. Oral sucker (OS). Scale bar = 50 µm. 6. Same *Caecincola* sp. removed from cyst. Arrow shows characteristic cup-shaped oral sucker. Scale bar = 100 µm. 7. *Caecincola* sp. metacercaria from mesenteries of *P. phoxocephala* showing OS. Scale bar = 50 µm. 8. Unknown metacercaria in cyst from *Pimephales tenellus* showing OS. Scale bar = 50 µm. 9. Same metacercaria removed from cyst showing OS. Scale bar = 100 µm. 10. *Proteocephalus* sp. plerocercoid from *Esox americanus* showing suckers (S). Scale bar = 500 µm. 11. Plerocercoid (P) from *E. americanus* in liver (L) tissue. Scale bar = 500 µm. 12. Unknown larval nematodes (N) in cysts of *E. americanus* liver (L). Scale bar = 500 µm.

new host record for this helminth.

Opisthorchiida: Cryptogonimidae
***Caecincola* sp.**

Four of seven (57%) *P. phoxocephala* (53.5 ± 6.6, 48–63 mm TL) collected on 10 October 2015 from Cow Creek Crossing on the Little River, McCurtain County, harbored immature *Caecincola* sp. in the liver and mesenteries (Figs. 5–7). This is the initial helminth parasite reported from *P. phoxocephala* and the first time *Caecincola* sp. has been reported from any Percidae as well as, in so far as we know, the first report from Oklahoma. The geographic range of the genus now includes Arkansas, Florida, Georgia, Illinois, Louisiana, Michigan, Mississippi, New York, Oklahoma, Tennessee, Texas, Wisconsin, and Ontario and Lake Huron, Canada (McAllister et al. 2015c; this report). Other fish hosts include several species of centrarchids and ictalurids (McAllister et al. 2015c). In the life cycle, pleurolophocercous cercaria are found in amnicolid snails with metacercaria in *Lepomis* spp. (Greer and Corkum 1980).

***Textrema hopkinsi* Dronen, Underwood, and Suderman, 1977**

A single *T. hopkinsi* was found in the intestine of one of four (25%) *M. salmoides* (103 mm TL) collected on 18 September 2016 from Yanubbee Creek, McCurtain County. This trematode has been previously reported from various centrarchids from Louisiana and Texas, including *M. salmoides* (Dronen et al. 1977; Greer and Corkum 1979, 1980; Underwood and Dronen 1984). We document a new geographic record for *T. hopkinsi* in Oklahoma as well as adding to a molecular database on cryptogonimids (A. Choudhury, *pers. comm.*).

Unknown metacercariae

One of three (33%) *P. tenellus* (64 mm TL) collected on 10 October 2015 from Cow Creek Crossing on the Little River, McCurtain County, was infected with unknown metacercariae encapsulated in various tissues (Figs. 8–9). This fish species has not been reported previously to harbor any parasite so we document the initial report of a digenean from this host.

Cestoda: Bothriocephalidea: Bothriocephalidae

***Bothriocephalus claviceps* (Goeze, 1782) Rudolphi, 1810**

A single (130 mm) *U. carolinae* collected on 6 June 2015 from Snake Creek, Mayes County harbored a single *B. claviceps* (HWML 99886) in its intestine. In addition, one *L. cardinalis* collected on 5 June 2015 from a tributary of the Illinois River, Cherokee County was also infected with a single *B. claviceps* (HWML 99887). Both fish represent new host records for *B. claviceps* as well as the first records of this tapeworm from the Cottidae and Cyprinidae. More importantly, this is the initial parasite reported from *L. cardinalis*. McDaniel (1963) previously reported immature *B. claviceps* from bluegill (*Lepomis macrochirus*) and longear sunfish (*Lepomis megalotis*) from Lake Texoma, Oklahoma. This cestode is distributed in six Canadian provinces as well as eight US states (Scholz 1997) with the life cycle typical of the genus (Jarecka 1959). Interestingly, we surveyed (McAllister et al. 2014a) a large sample of *U.* (syn. *Cottus) carolinae* from Arkansas (some from Flint Creek, Benton County) and did not find any to be infected with *B. claviceps*.

***Schyzocotyle acheilognathi* (Yamaguti, 1934) Brabec, Waeschenbach, Scholz, Littlewood, and Kuchta, 2015**

A larval *S.* (syn. *Bothriocephalus*) *acheilognathi* was collected from one of 13 (8%) *E. claviformis* (99 mm TL) taken on 30 October 2016 from Yanubbee Creek, McCurtain County. The Asian fish tapeworm has been reported from western mosquitofish, *Gambusia affinis* from McCurtain County (McAllister et al. 2015b). This is the only the second time, to our knowledge, it has been reported from any fish of the family Catostomidae (*Minytrema melanops*, see McAllister et al. 2015b), and the first report from *E. claviformis*. In the life cycle, procercoids occur in copepods, with smaller fishes acting as "carriers", and the adult is found in the intestine of teleost fishes (see Hoffman 1999). This tapeworm is a known pathogen having a potential negative impact on many fishes, particularly cyprinids (Salgado-Maldonado and Pineda-Lopez 2003); however, the effect of *S. acheilognathi* on fishes in Oklahoma is unknown.

Proteocephalidea: Proteocephalidae

***Essexiella fimbriatum* (Essex, 1927) Scholz, de Chambrier, Mariaux, and Kuchta, 2011**

Scholz et al. (2011) erected a new genus *Essexiella* for *Corallobothrium fimbriatum*. A single *E. fimbriatum* (HWML 103024) was found in the small intestine of one of three (33%) *A. natalis* (153 mm TL) collected on 10 October 2015 from Cow Creek Crossing at the Little River, McCurtain County. In addition, eight specimens of *E. fimbriatum* (HWML 99888, 103025) were taken from the intestinal tract of *A. melas* collected on 5 August 2016 from Yashau Creek, McCurtain County. Adult *E. fimbriatum* occur in various members of the Ictaluridae with the procercoid in *Cyclops* and plerocercoid in minnows (*Notropis* spp.) and other fishes (Hoffman 1999). Although *E. fimbriatum* has been previously reported from both bullheads (Hoffman 1999) and from Oklahoma in Flathead Catfish (*Pylodictis olivaris*) and *I. punctatus* (Spall 1968), this is the first time this tapeworm has been reported from Oklahoma non-game fishes.

***Proteocephalus ambloplitis* (Leidy, 1887) Benedict, 1900**

A plerocercoid of *P. ambloplitis* was collected from one of 13 (8%) *E. claviformis* (99 mm TL) taken on 30 October 2016 from Yanubbee Creek, McCurtain County. The "bass tapeworm" is a common helminth of many fishes and has been reported from several US states and southern Canada (Hoffman 1999). McDaniel and Bailey (1974) reported *P. ambloplitis* in the Little River (Cleveland County) and Lake Texoma, Oklahoma. This tapeworm has also been reported from the related Lake Chubsucker (*Erimyzon sucetta*) from Wisconsin (Amin 1990). In the life cycle, procercoids are found in the hemocoel of copepods, plerocercoids occur in the viscera of small fishes and basses mainly serve as definitive hosts (Hunter and Hunter 1929). It can be a major concern in fish culture because plerocercoids can cause fibrosis in gonads of bass, sometimes rendering them sterile (Hoffman 1999). We report *P. ambloplitis* for the first time from *E. claviformis*.

Proteocephalus sp.

A single plerocercoid of *Proteocephalus* sp. (HWML 99889) was found in the intestinal tract of one of seven (14%) *E. squamosum* (55 mm TL) collected on 6 June 2015 from Little Saline Creek, Mayes County. No cestodes have been previously reported from this darter (Hoffman 1999), so we document a new host record here. However, this genus of tapeworm has been commonly reported from various fishes, including several from Oklahoma (see McAllister et al. 2014).

Three of 15 (14%) *E. americanus* (135, 148, 190 mm TL) collected on 20 November 2014, 13 February, and 17 July 2015 from Yashau Creek, McCurtain County, had *Proteocephalus* plerocercoids in their liver (Figs. 10–11). Three species of *Proteocephalus*, as adults, have been reported previously from *E. americanus*, including *P. pearsei* La Rue, *P. perplexus* La Rue and *P. pinguis* La Rue, although none of these have been reported to date from any fish in Oklahoma. *Proteocephalus ambloplitis* (Leidy) Benedict plerocercoids have been documented from centrarchid fishes from the state (Spall 1969) as well as *E. claviformis* herein. This is the first time encapsulated plerocercoids have been reported from *E. americanus*.

Nematoda: Ascaridida: Cucullanidae

Dichelyne robusta (Van Cleave and Mueller, 1932) Petter, 1974

A single *D. robusta* was found in the intestine of *I. punctatus* (345 mm TL) collected on 30 October 2016 from Yanubbee Creek, McCurtain County. This nematode has been previously reported from several ictalurids (including *I. punctatus*) from Arkansas, Kansas, New York, North Dakota, Ohio, Tennessee, Texas, and Wisconsin (Hoffman 1999; Dutton and Barger 2015). To our knowledge, the life cycle has yet to be determined. We document the first report of *D. robusta* from Oklahoma.

Spirurida: Gnathostomatidae

Spiroxys sp. (larvae)

Larval *Spiroxys* sp. (1 or 2 each) were found in the mesenteries of five of 13 (38%) *E. claviformis* (96.8 ± 14.2, range 71–111 mm TL) taken on 30 October, 20 November, and 27 November 2016 from Yanubbee Creek, McCurtain County. This nematode has been reported from at least 23 genera of freshwater fishes from numerous states and Canada (Hoffman 1999). The adult of *Spiroxys* is found in the stomach of turtles and intestines of amphibians and the experimental life cycle has shown the first intermediate host is *Cyclops* (Hedrick 1935). This is the first time *Spiroxys* sp. has been reported from *E. claviformis*.

Cystidicolidae

Spinitectus macrospinosus Choudhury and Perryman, 2003

Seven female *S. macrospinosus* were collected from the large intestine of an *I. punctatus* (345 mm TL) taken on 30 October 2016 from Yanubbee Creek, McCurtain County. This nematode was originally described from *I. punctatus* from the Assiniboine and Red rivers, Winnipeg, Manitoba, Canada, and also reported from Blue Catfish (*Ictalurus furcatus*) from Kentucky Lake, Tennessee (Choudhury and Perryman 2003). The authors also noted that *S. macrospinosus* was taken from an "*I. lacustris*" (= *I. punctatus*) from Lake Texoma, Oklahoma and Texas. As the middle of the reservoir is roughly situated on the southern and northern borders of both states and, more importantly, a specific collection locale was not given, we provide the first definitive report of *S. macrospinosus* from Oklahoma.

Spinitectus micracanthus Christian, 1972

Four *S. micracanthus* were collected from the intestine of two of four (50%) *M. salmoides* (82, 103 mm mm TL) taken on 18 September 2016 from Yanubbee Creek, McCurtain County. Previous records of *S. micracanthus* are primarily from centrarchids, including *Lepomis* spp. and *Micropterus* spp. from Alabama, Indiana, Ohio, Pennsylvania, and Texas (Hoffman 1999). In the life cycle, larval *Spinitectus* use larval mayflies as intermediate hosts (Gustafson 1939). This is the first report of *S. micracanthus* from Oklahoma.

Rhabdochonidae

***Rhabdochona cascadilla* Wigdor, 1918**

Two *L. cardinalis* (not measured) collected on 5 June 2015 from a tributary of the Illinois River, Cherokee County harbored 12 (2 male, 10 female) and 14 (1 male, 13 female) *R. cascadilla* (HWML 99890), respectively. This nematode shows little host specificity as it has been previously reported from more than 38 genera and 12 families of North American freshwater fishes (Hoffman 1999; Moravec 2007, 2010; Moravec and Muzzall 2007). In the life cycle, larval members of the genus develop in mayflies and the adult is parasitic in the intestine of freshwater fishes (Byrne 1992; Moravec 2010). We document a new host as well as a new distributional record for *R. cascadilla*.

Unknown larval nematodes

Unidentified larval nematodes were found encapsulated in the liver of one of 15 (7%) *E. americanus* (190 mm TL) collected on 13 February 2015 from Yashau Creek, McCurtain County (Fig. 12). There are numerous nematodes reported from *E. americanus* (Hoffman 1999). However, this is the first time larval nematodes have been documented from tissue of a Grass Pickerel.

In summary, we have provided several new host and geographic distributional records for fishes from Oklahoma. As noted by Scholz and Choudhury (2013) and reiterated here, there is still considerable work to be done to have a better understanding of the diversity of fish helminths of the state. More exploratory and opportunistic surveys on fishes are urgently needed throughout Oklahoma from other hydrologic units, including those in the western part and panhandle where we know very little about their helminth parasites.

Acknowledgments

The Oklahoma Department of Wildlife Conservation issued a Scientific Collecting Permit to CTM. We thank Scott L. Gardner (HWML) and Renn Tumlison (HSU) for expert curatorial assistance, Thomas J. Fayton (GCRL, Gulfport, MS) for technical assistance, Anindo Choudhury (St. Norbert College, De Pere, WI) for identification of some helminths, and Dennis J. Richardson (Quinnipiac University, Hamden, CT) for use of the electrofisher. T. J. Fayton, James T. McAllister, III (University of Texas, Dallas, TX), Nikolas H. McAllister (Lukfata Elementary, Broken Bow, OK), Dave Neely (Tennessee Aquarium, Chattanooga, TN), and Uland Thomas (Chicago, IL) assisted with collections.

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Submitted September 14, 2016 Accepted November 30, 2016

First Report of *Bothriocephalus rarus* (Bothriocephalidea: Bothriocephalidae) from a Cave Salamander, *Eurycea lucifuga* and Grotto Salamanders, *Eurycea spelaea* (Caudata: Plethodontidae) from Oklahoma, with a Summary of Helminths from these Hosts

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The cave salamander, *Eurycea lucifuga* Rafinesque, 1822, as its name implies, is restricted to moist woodlands, cliff fissures, and damp limestone caves in the Central Highlands of North America from western Virginia and central Indiana southward to northern Georgia and west to eastern Oklahoma (Powell et al. 2016). In Oklahoma, *E. lucifuga* is restricted to karst systems in the northeastern portion of the state (Sievert and Sievert 2011).

The grotto salamander, *Eurycea spelaea* (Stejneger) is, as an adult, a troglobitic species that occurs in darker zones of caves, underground streams and sinkholes in the Salem and Springfield plateaus in the Ozark region of southwestern Missouri to southeastern Kansas and adjacent areas from northern Arkansas to northeastern Oklahoma (Powell et al. 2016). Larval grotto salamanders can be found outside of caves in surface springs and in the entrance zone of caves but can also be found living deeper in cave systems (Fenolio et al. 2004; Trauth et al. 2004). In Oklahoma, *E. spelaea* is restricted to limestone caves and adjacent springs and seeps in the extreme northeastern corner of the state

(Sievert and Sievert 2011).

Although a moderate amount of information is available on the natural history of *E. lucifuga* (Juterbock 2005) and *E. spelaea* (Fenolio and Trauth 2005), comparatively little is known about their helminth parasites. Several studies have reported helminth parasites of *E. lucifuga* from some of its range, including Dyer and Brandon (1973) in Illinois, Dyer and Peck (1975) from several localities in the southeastern USA, Castle et al. (1987) in Kentucky, McAllister et al. (1991, 2007) in Arkansas and Tennessee, respectively, and McAllister and Bursey (2004) in Arkansas. The two largest studies, to date on *E. spelaea*, were by Dyer (1975) who examined over 100 specimens from Missouri, and McAllister et al. (2006) from a survey of 48 larval and adult grotto salamanders from Arkansas and Missouri. Additional reports of endoparasites from *E. spelaea* include those of Reeves (1949), Schaefer and Self (1978), Bonett et al. (2011) and McAllister et al. (2011) in Oklahoma, and Smith (1948) and Fenolio et al. (2013) in Missouri. Here we report a new host and distributional record for a tapeworm collected from *E. lucifuga* and *E. spelaea* from northeastern Oklahoma, and provide a first summary of helminths (Table 1) known from these hosts.

On 31 March 2016, six larval *E. spelaea* (mean ± 1SD snout-vent length [SVL] = 38.7 ± 3.4, range 33–43 mm) were collected by dipnet from Adair Cave (Christian School Cave), Adair County (latitude and longitude not given to protect location). In addition, three *E. lucifuga* were collected on 15 November 2015 and nine (five adult and four larval, 45.9 ± 7.1, 38–58 mm SVL) were collected on 2 April 2016 from Flint Cave, Delaware County (36°12’27.83”N, 94°42’15.78’W). They were placed in cave water and transported to the laboratory for necropsy. Salamanders were killed by immersion in a concentrated Chloretone solution and measured for SVL. A midventral incision was made from the cloaca to throat and the tissue placed in a Petri dish containing 0.6% NaCl where it was split lengthwise and examined for helminths using a stereomicroscope. The liver, gonads, and other organs were examined similarly. Tapeworms found in the small intestine were heat-fixed in near boiling water without coverslip pressure. They were transferred to 70–85% (v/v) ethanol, stained in acetocarmine, and mounted entire in Canada Balsam. Nematodes were fixed similarly, preserved in 70% (v/v) ethanol, and studied as temporary mounts in glycerol. Voucher specimens of salamanders were deposited in the Arkansas State University Museum of Zoology (ASUMZ), State University, Arkansas, and voucher specimens of parasites were either retained for future DNA analyses or deposited in the Harold W. Manter Laboratory of Parasitology (HWML), University of Nebraska State Museum, Lincoln, Nebraska.

Two of six (33%) *E. spelaea* (37 and 43 mm SVL) were found to harbor three tapeworms fitting the description of *Bothriocephalus rarus* Thomas (Thomas 1937). In addition, one of 12 (8%) *E. lucifuga* ([larvae], 41 mm SVL) was also infected with a single *B. rarus*. This cestode has been reported from several states (Fig. 1) and a variety of hosts (see McAllister et al. 2015); however, this is the first time it has been documented in *E. lucifuga* and *E. spelaea*. *Bothriocephalus rarus* has also been reported from two freshwater fishes, bluegill (*Lepomis macrochirus*) from Virginia and banded killifish (*Fundulus diaphanus*) from Maine (Meyer 1954; Bogitsh 1958); however, because this tapeworm has not been reported for over more than half a

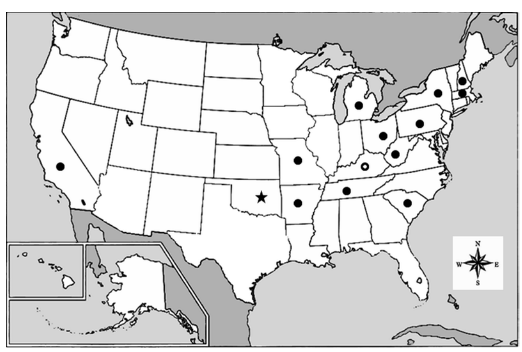

Figure 1. States with geographic records of *Bothriocephalus rarus*. Dots = previous records; open dot = unpublished thesis record; star = new record.

Table 1. Summary of helminth parasites of *Eurycea lucifuga* and *Eurycea spelaea*.

Host and Parasite	Locality	Prevalence*	Reference
	Eurycea lucifuga		
Trematoda			
Brachycoelium sp.	Illinois	1/17 (6%)	Dyer and Brandon (1973)
	SE USA†	24/255 (9%)	Dyer and Peck (1975)
B. salamandrae	Kentucky	14/74 (19%)	Castle et al. (1987)
Cainocreadium pseudotritoni	SE USA†	1/255 (0.4%)	Dyer and Peck (1975)
Clinostomum complanatum	Tennessee	1/549 (0.2%)	McAllister et al. (2007)
Sphyranura euryceae	Arkansas	10/10 (100%)	McAllister et al. (1991)
Cestoda			
Batrachotaenia cryptobranchi	SE USA†	1/255 (0.4%)	Dyer and Peck (1975)
Bothriocephalus rarus	Oklahoma	1/12 (8%)	This study
Nematoda			
Amphibiocapillaria tritonipunctati	Kentucky	49/74 66%)	Castle et al. (1987)‡
	SE USA†	13/255 (5%)	Dyer and Peck (1975)‡
Batracholandros magnavulvaris	Kentucky	7/74 (9%)	Castle et al. (1987)¶
	SE USA†	2/255 (1%)	Dyer and Peck (1975)¶
Cosmocercoides dukae‖	Illinois	3/17 (18%)	Dyer and Brandon (1973)
	SE USA†	62/255 (24%)	Dyer and Peck (1975)
C. variabilis	Arkansas	1/5 (20%)	McAllister and Bursey (2004)
Omeia papillocauda	SE USA†	1/255 (0.4%)	Dyer and Peck (1975)
	Oklahoma	1/12 (8%)	This study
Oswaldocruzia euryceae	Arkansas	1/5 (20%)	McAllister and Bursey (2004)
	Oklahoma	1/12 (8%)	This study
O. pipiens	Kentucky	26/74 (35%)	Castle et al. (1987)
	SE USA†	25/255 (10%)	Dyer and Peck (1975)
Oxysomatium sp.	Illinois	1/17 (6%)	Dyer and Brandon (1973)
Rhabdias sp.	SE USA†	1/255 (0.4%)	Dyer and Peck (1975)
Spirurid cysts	SE USA†	6/255 (2%)	Dyer and Peck (1975)
Trichoskrjabinia sp.	Kentucky	26/74 (35%)	Castle et al. (1987)
	Eurycea spelaea		
Trematoda			
B. salamandrae	Missouri	2/119 (2%)	Dyer (1975)
Clinostomum marginatum	Oklahoma	1/12 (8%)	Bonett et al. (2011)
Plagioporus gyrinophili	Missouri	1/38 (3%)	McAllister et al. (2006)
Sphyranura sp.	Missouri	1/1 (100%)	Ashley (2004)
S. euryceae	Oklahoma	1/12 (8%)	McAllister et al. (2011)
Strigeoid metacercaria	Arkansas	8/8 (100%)	McAllister et al. (2006)
	Missouri	1/1 (100%)	Fenolio et al. (2013)

Table 1. Continued

Cestoda			
B. rarus	Oklahoma	2/6 (33%)	This study
B. typhlotritonis	Oklahoma	2/3 (67%)	Reeves (1949)
	Arkansas	3/40 (8%)	McAllister et al. (2006)
Ophiotaenia sp.	Missouri	9/31 (29%)	Smith (1948)
Nematoda			
A. tritonipunctati	Missouri	7/119 (6%)	Dyer (1975)‡
	Arkansas	4/13 (31%)	McAllister et al. (2006)
Falcaustra catesbeianae	Missouri	1/119 (1%)	Dyer (1975)
Omeia papillocauda	Arkansas	1/40 (3%)	McAllister et al. (2006)
Oswaldocruzia sp.	Missouri	2/119 (2%)	Dyer (1975)
Acanthocephala			
Fessisentis vancleavei	Arkansas	1/40 (3%)	McAllister et al. (2006)
	Oklahoma	1/12 (8%)	McAllister et al. (2011)

*Number infected/number examined = %.

†SE U.S.A. = sites in Alabama, Georgia, Illinois, Kentucky, Missouri, Tennessee, Virginia, and West Virginia.

‡Originally reported as *Capillaria inequalis* Walton, 1935, a synonym of *A. tritonipunctati* (see Moravec 1982).

¶Originally reported as *Thelandros magnavulvaris*; genus now referred to *Batracholandros* Freitas and Ibáñez, 1965.

‖Most likely a misidentification as *C. dukae* occurs in snails and *C. variabilis* is found in amphibians.

century in any other fish, we suspect that these findings could be misidentifications as several other *Bothriocephalus* spp. naturally occur in North American fishes (see Hoffman 1999) or represent pseudoparasites passing through the digestive tract from prey (newts?) naturally infected with *B. rarus*.

Interestingly, a similar tapeworm, *Bothriocephalus typhlotritonis* Reeves has been reported in grotto salamanders from Oklahoma (Reeves 1949) and Arkansas (McAllister et al. 2006). Another species, *Bothriocephalus eurycienis* Schaefer and Self was reported from five of five (100%) dark-sided salamanders, *Eurycea longicauda melanopleura* from the same cave site in Adair County (Schaefer and Self 1978) where we collected *E. spelaea*. In fact, we collected specifically from this type locality in search of *B. eurycienis*. However, surveys on *E. l. melanopleura* in Arkansas (McAllister and Bursey 2004; McAllister et al. 2015) failed to find any infected with *B. eurycienis* although several *B. rarus* were found in two of 13 (15%) and eight of 47 (17%) of specimens, respectively. *Bothriocephalus eurycienis* remains an enigma of sort as it has not been reported in any host since its original description nearly 40 yr ago. Although these three cestodes are currently differentiated using morphological characters (e.g., size and scolex shape), additional work is needed to help unravel differences between *B. rarus*, *B. typhlotritonis* and *B. eurycienis* using more powerful molecular techniques previously used on other Bothriocephalidea (Brabec et al. 2015).

A single *E. lucifuga* (58 mm SVL) collected on 2 April 2016 harbored one female (HWML 99911) *Omeia papillocauda* Rankin, 1937. It has previously been reported from *E. lucifuga* from the SE USA (Dyer and Peck 1975). This nematode has also been reported from several other members of the genus *Eurycea* as well as *Desmognathus* and *Gyrinophilus* from Alabama, North Carolina, Ohio, and Tennessee (see McAllister and Bursey 2010). We document a new state record for *O. papillocauda*.

Another *E. lucifuga* (43 mm SVL) collected on 15 November 2015 harbored two female *Oswaldocruzia euryceae* Reiber, Byrd and

Parker, 1940. This nematode has previously been reported from *E. lucifuga* from Arkansas (McAllister and Bursey 2004) and from Rich Mountain salamander (*Plethodon ouachitae)* from Oklahoma as well as several other plethodontids from Georgia and Arkansas (McAllister and Bursey 2012).

A summary of the helminth parasites of *E. lucifuga* and *E. spelaea* is provided in Table 1. Seventeen helminths, including five trematodes, two cestodes, and 10 nematodes have been reported from *E. lucifuga* whereas a total of 14 helminths have thus far been found to infect grotto salamanders from Arkansas (five species), Missouri (eight species), and Oklahoma (five species), including six trematodes, three cestodes, four nematodes, and an acanthocephalan. Examination of larval specimens of *E. spelaea* from the only county in Kansas known to support them (Cherokee County, see Collins et al. 2010) would complete a parasite survey within its range and possibly provide new host and distributional records. However, *E. spelaea* is listed as endangered and critically imperiled (S1) in that state (NatureServe 2015) so only examination of limited museum specimens should be done.

Acknowledgments

We thank Drs. Scott L. Gardner and Gabor A. Racz (HWML) for expert curatorial assistance. We also thank Shea Hammond (Deputy Wildlife Manager, U.S. Fish and Wildlife Service, Ozark Plateau National Wildlife Refuge, Colcord, OK) who collected the larval *E. spelaea*. Specimens of *E. lucifuga* were collected under Oklahoma Department of Wildlife Conservation Scientific Collecting Permits issued to MBC and CTM.

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Submitted September 14, 2016 Accepted November 21, 2016

First Report of the Plant Bug *Collaria oculata* (Reuter, 1871) (Hemiptera: Miridae) from Oklahoma

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Collaria oculata (Reuter, 1871) (Hemiptera: Miridae: Mirinae) is a grass-feeding plant bug (Knight 1941) previously reported from 23 U.S. States and three Provinces of Canada (Fig. 1) (the Alberta literature record was questioned by Maw et al. [2000]; we follow their listing) (Henry and Wheeler 1988; Maw et al. 2000; Chordas et al. 2011). A report of *C. oculata* from neighboring Arkansas (Chordas et al. 2011) prompted our search for specimens in Oklahoma because the presence of this species was considered probable for the state. Here, we document *C. oculata* as a new state record.

During August 2016, various hemipterans were observed by CTM below a night light at a residence in Hochatown, McCurtain County. Specimens were collected with fine forceps and placed in individual vials containing 70% (v/v) ethanol. They were subsequently shipped to

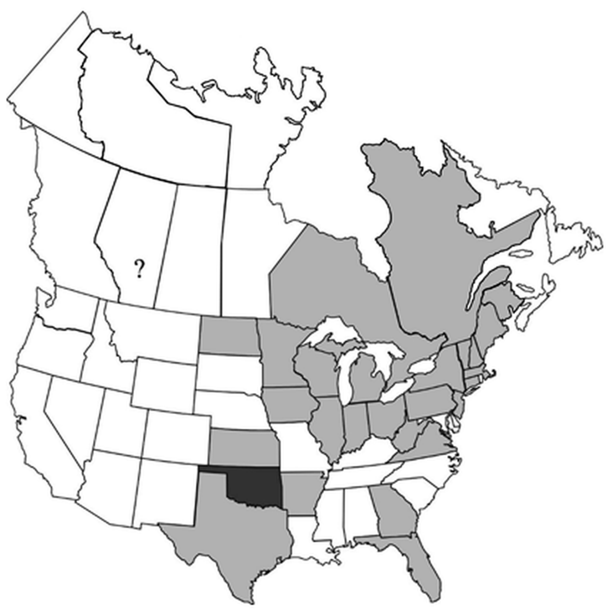

Figure 1. Distribution of *Collaria oculata* in North America north of Mexico. Light shade = prior literature records (Henry and Wheeler 1988; Maw et al. 2000; Chordas et al. 2011); dark shade = new state record.

SWC for identification. Our single specimen of *C. oculata* was deposited in the C.A. Triplehorn Collection at The Ohio State University, Columbus, Ohio, as a voucher specimen.

We collected a single female specimen of *C. oculata* with the following collection data: ***Oklahoma***: McCurtain County, off Halibut Bay Road in Hochatown (34° 10' 17.0286"N, 94° 45' 5.7414"W); 21 VIII 2016; C. T. McAllister, collector (unique museum specimen code: OSUC 620934). Surrounding habitat consisted of various hardwoods (*Quercus* spp.) and pines (*Pinus* spp.) in Ouachita uplands. Several other Hemiptera species were also collected, including *Jalysus spinosus* (Say, 1824), *Myodocha serripes* Oliver, 1811, *Ozophora picturata* Uhler, 1871, and *Ptochiomera nodosa* Say, 1832. All four species have been previously reported from Oklahoma.

Collaria oculata has two distinctive dark ovoid spots on the posterior lateral aspect of the pronotum (see color Fig. 16 of this species in Chordas et al. [2011]). This plant bug had not previously been documented for Oklahoma. With additional fieldwork, many other hemipteran species recorded from surrounding states (see Chordas et al. 2011) probably can be added to the mirid fauna of Oklahoma.

Acknowledgments

We thank the Oklahoma Department of Wildlife Conservation for issuing a Scientific Collecting Permit to CTM.

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Submitted September 15, 2016 Accepted November 21, 2016

Habitat Selection, Nest Box Usage, and Reproductive Success of Secondary Cavity Nesting Birds in a Semirural Setting

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Abstract: As urban areas continue to grow and erode rural landscapes, it is critical to characterize essential habitats for all wildlife in order to set aside protected areas in an attempt to maintain diversity. We constructed and monitored 30 nest boxes for usage by secondary cavity-nesting birds each year from 2014-2016 at the John Nichols Scout Ranch located in southeast Canadian County, Oklahoma. At each of six sites, five nest boxes were situated along a transect at 15m intervals with a central box located at an abrupt edge between a wooded habitat and a grassland habitat. We measured 77 habitat variables around each nest box at 2 sampling scales, $1m^2$ and $10m^2$. We used these habitat variables and sites in which nesting occurred in a principal components analysis. Eastern Bluebirds and Carolina Chickadees nested in grassland habitats with little to no overhead canopy cover. Carolina Wrens nested in woodland areas with high amounts of litter ground cover and overhead canopy cover. Results at both spatial scales were similar. We used the simplified Morisita index to calculate niche overlap at both spatial scales. Overlap varied substantially depending on sampling scale.

Introduction

As urban areas continue to encroach on rural landscapes, it is often difficult to delineate one land use type from another due to the fragmented nature of urban development and its associated construction (habitat destruction). These dynamic zones between urban and rural landscapes are referred to as semirural. Such areas represent a challenge for birds and other animals that are adapted to native landscapes, as opposed to those adapted to urban settings. Avian abundance in urban and suburban landscapes can be higher than in surrounding rural landscapes, while species diversity in the larger contiguous landscape tends to decrease overall as urban landscapes become dominated by only a few species (Reale and Blair 2005, Saarikivi and Herczeg 2014). Additionally, bird tolerance of human disturbance may increase in some species (Clucas and Marzluff 2012). Urbanization can produce new habitat types resulting in new species' presence, but it also typically reduces the number and size of large habitat patches when compared to rural and semirural areas (Gilbert 1989, Luck and Wu 2002). Many birds require these larger patches for breeding (Vickrey et al. 1994). Semirural areas may represent the last available source of nesting sites for non-urban adapted birds over long, unsuitable urban distances (Wiens 1989, Sanström et al. 2006). Because habitat in urban and suburban areas is hyper-managed relative to rural and semirural areas, characters within the urban and suburban habitats tend to be more uniform. This includes manicured landscapes with similar characters such as tree height, a distinct lack of snags and tree cavities, canopy cover, monocultures, herbaceous vegetation type and height, etc. (Berthier et al. 2012). These more homogeneous habitats preclude occupation and breeding by birds that require specific habitat structure, including secondary cavity-nesting birds (Jackson et al. 2013). As urban areas sprawl into and eventually consume rural areas, it is critical that ecologists have an inventory of species that will most likely be displaced and the specific habitat requirements of these species so that at a minimum, quality remnants of suitable size can be set aside and reserved as refugia.

Studies of cavity-nesting birds have been conducted in both urban and rural areas (Conner and Adkisson 1977, Pogue and Schnell 1994, Jackson et al. 2013, Saarikivi and Herczeg 2014). Most of these studies assess habitat relative to some life strategy such as foraging or reproduction. In this study, we associate nest box selection (reproduction) with habitat sampled in a $1m^2$ and $10m^2$ area around each nest.

Methods

Study Area

The John Nichols Scout Ranch (JNSR, 97-ha) is located in the extreme southeast corner of Canadian County, Oklahoma (35.349987 N, 97.672389 W), and as such is included in the cross timbers physiognomic region (Duck and Fletcher 1945, Oklahoma Department of Wildlife Conservation). The JNSR is bordered on the south by the Canadian River (and Grady County) and to the east by Cleveland County. A 250 hectare housing development is currently under construction less than 1km to the east of JNSR. Various cultivated fields lie between this development and JNSR. Across the river to the south is pasture and cross timber forest. To the west and north is pasture and wheat fields. Habitat types at JNSR include riparian, intermittent streams, woodlands, and mixed-grass prairie. Mowing of camp areas occurs at irregular intervals. The JNSR serves as a summer camp for scouts of all ages. Human occupancy ranges from high (hundreds) to none throughout the year. Occupancy is heavy in the late spring and early summer due to Boy Scout camping and events and tapers down to low or no occupancy through the fall and winter.

Nest Box Monitoring

We established nest boxes at 6 separate sites in the fall of 2013. Nest boxes are constructed of ¾" rough cedar with a finished inner surface. Nest box dimensions are 9" tall x 5½" wide x 5½" deep. The entrance hole has a diameter of 1½" and is located 6½" above the floor of the box. All nest boxes are affixed to an 8ft t-post by a U-bolt at a bottom height of 6ft with the entrance facing due east.

Each site consists of a distinct woodland and a distinct grassland with an abrupt edge (ecotone) between the two. Five of the grassland habitats undergo periodic mowing, but at different frequencies. The woodland areas are not manicured in any way.

We placed one nest box at the abrupt edge between the woodland and grassland habitats. This box was designated as the C (center) box. We placed 2 boxes at 15m intervals into the woodland (C+1 and C+2) and 2 boxes into the grassland at 15m intervals (C-1 and C-2) along a 60m transect set perpendicular to the edge.

We monitored nest boxes for nesting activity on a weekly basis beginning in February and continuing through August of each year from 2014-2016. Nest boxes were classified as being used for reproduction after the nest was complete and egg laying had begun. We removed all nesting materials after fledging or nest abandonment.

Habitat Sampling

We sampled 77 habitat variables using quadrats at 2 spatial scales, $1m^2$ and $10m^2$, around each nest box location. These variables include ground cover, canopy cover, vertical structure, major vegetation type, and various distance measures (Table 1). Cover was measured using a $1m^2$ PVC sampling frame. We measured vertical structure using a 1m rod marked with 1dm increments. We used a convex densiometer to measure canopy cover at the t-post for $1m^2$ and at each of the 4 corners and t-post for the $10m^2$ scale. We recorded the average of these 5 readings as the $10m^2$ canopy cover. Distance measures were made using a Leica Rangemaster 1600-B laser range finder. We measured tree heights using a Suunto PM-5/1520 clinometer. All site transects and individual nest boxes were georeferenced using a Trimble Juno 3B.

Statistical Analysis

We used these habitat variables and nest box usage data in various statistical analyses to provide general descriptive associations between bird species and the habitats that they occupied. Initially, we used the 77 habitat variables in a principal components analysis (PCA) to characterize general trends along habitat gradients from a rectangular data matrix of 30 nest box sites by habitat variables. These data were mean-centered and correlations were calculated among the variables. We then projected standardized data onto eigenvectors extracted from the correlation matrix. In this type of analysis, principal component 1 (PC1) explains the maximum character variance and each subsequent PC explains the maximum remaining variance.

We also constructed a rectangular matrix of nesting bird species by habitat variable averages and subjected this matrix to PCA. Projections of these species onto principal component axes indicates species habitat preferences (Stancampiano and Schnell 2004).

Niche overlap was evaluated at both scales using the simplified Morisita index (Ecological Methodology ver. 7.2). This measure of niche overlap ranges from 0.0 (no resources in common) to 1.0 (complete overlap).

Results

Seventeen clutches were laid at 5 of the 6 transects between March of 2014 and September of 2016. The Greenbriar transect had 6 nests, Bermuda Triangle 4, Council Ring 4, Creaking Cabin 2, and Walnut Grove had 1 nest. Eastern Bluebirds (*Sialia sialis*) utilized 11 boxes and Carolina Chickadees (*Poecile carolinensis*) and Carolina Wrens (*Thryothorus ludovicianus*) nested in 3 boxes each. Eastern Bluebirds and Carolina Chickadees only used boxes in grassland habitat while Carolina Wrens only used boxes in the woodlands (Fig. 1). The mean clutch size and mean number of fledglings was similar for all species (Fig. 2). Carolina Wrens chose wooded areas that were near the abrupt edge. In 2 of the 3 nesting instances they occupied the C+1 nest (closest to the edge). Eastern Bluebirds used the C+2 boxes (furthest from the edge) for 6 of the 11 nestings and Carolina Chickadees used C+2 boxes in 2 out of 3 instances. Nest boxes located at the abrupt edge between woodlands and clearings were not utilized at any of the 6 study sites.

Principal Components Analysis

We constructed a rectangular matrix of 77 habitat variables by 30 nest box sites at both the $1m^2$ and $10m^2$ scale for principal components analysis. Twenty-nine invariant habitat variables were eliminated in the $1m^2$ analysis and 25 were eliminated in the $10m^2$ analysis. The first 3 components in the $1m^2$ PCA explained 37.4% of the total variance in the habitat variables. Projections and character loadings indicate that PC I (19.3% of total variance) represents a gradient from high annual cover and low canopy cover to low annual cover and high canopy cover. This describes the transition from grassland into the woodland at each transect. PC II represents a gradient from sites with rocky and annual ground cover to sites with litter and no cover. Most nest box sites had very low loadings (positive and negative) or high positive loadings for this component.

The first 3 components in the $10m^2$ PCA of habitat variables versus nest box sites explained 35.6% of the total variance in the habitat

Table 1. Habitat variables and variable codes used in principal components analysis.

6-10	CA00-20 - CA81-100	Annual Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
11-15	CL00-20 - CL81-100	Litter Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
16-20	CR00-20 - CR81-100	Rock Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
21-25	CS00-20 - CS81-100	Shrub Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
26-30	CT00-20 - CT81-100	Basal Tree Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
31-35	CM00-20 - CM81-100	Moss Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
36-40	COC00-20 - COC81-100	Overhang Canopy Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
41-47	MHA00-2 - MHAgt10	Mean Annual Height 0-2dm, 2-4dm, 4-6dm, 6-8dm, 8-10dm, >10dm
48-51	MHS00-5 - MHSgt20	Mean Shrub Height 0-5dm, 6-10dm, 11-20dm, >20dm
52-55	MHT00-15 - MHTgt85	Mean Tree Height 0-15dm, 16-40dm, 41-85dm, >85dm
56-59	VegA, VegT, VegS, VegN	Annuals are major vegetation, Trees are major vegetation, Shrubs are major vegetation, No major vegetation
60-63	DHA00-10 - DHAgt30	0-10m distance from human activity, 11-20m distance, 21-30m distance, greater than 30m distance from human activity
64-67	DW00 - 10 - DWgt30	0-10m distance from permanent water source, 11-20m distance, 21-30m distance, greater than 30m distance from permanent water source
68-71	DDH00-10 - DDHgt30	0-10m distance from different habitat, 11-20m distance, 21-30m distance, greater than 30m distance from different habitat
72-78	DT00-5 - DTgt30	0-5m distance to closest tree, 6-10m distance, 11-15m distance, 16-20m distance, 21-25m distance, 26-30m distance, 31-35m distance, greater than 35m distance to closest tree

variables. Projections and character loadings indicate that PC I (17.5% of total variance) represents a gradient from low annual cover, high litter cover, and high canopy cover to sites dominated by annual vegetation that are near a different habitat type (edge). Component II represents a gradient from low annual and high litter cover with moderate overhead canopy

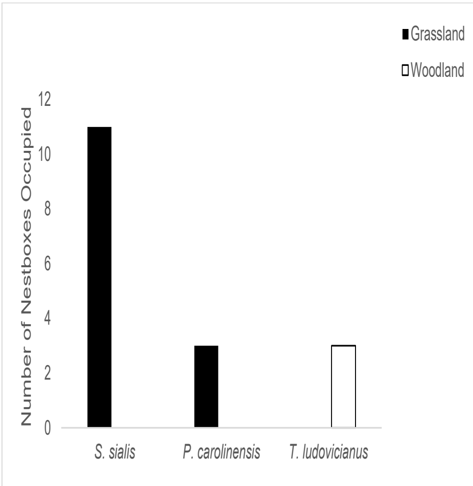

Figure 1. Nest box usage in grassland and woodland per species.

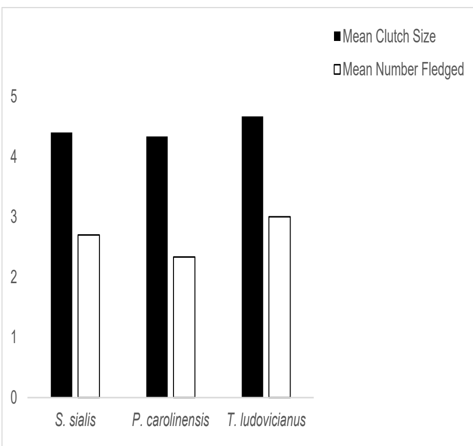

Figure 2. Mean clutch size and mean number of fledglings per species.

cover to sites with very high annual cover and little canopy cover. These 2 components accurately represent the woodland to grassland transition.

We calculated the mean value for each of the 77 habitat variables at both the 1m^2 and 10m^2 scale for each of the 17 nesting sites. Fifty-one invariant habitat variables were eliminated in the 1m^2 analysis and 45 were eliminated in the 10m^2 analysis of the nesting bird species by habitat variables PCA.

In the 1m^2 analysis, the first 2 components explained 100% of the total variance in the habitat variables. Projections and character loadings show that PC I (71.38% of the total variance) represents a gradient from short, intermediate annual cover, presence of shrubs, greater tree density and overhead canopy cover to taller, almost total annual cover, and low canopy cover. Component II represents a gradient from habitat with some rocky cover, abundant litter cover, intermediate height annuals, and relatively longer distances to different habitat type (negative loadings) to habitat with relatively shorter distance to different habitat type and very short annual vegetation (Fig. 3).

The first 2 components of the 10m^2 PCA (nest species by habitat variables) also explain 100% of the total variance in the habitat variables. Component I describes a gradient from habitat with less than 80% annual cover, high litter cover, moderate shrub cover, high tree density and overhead canopy cover to areas with greater than 80% annual cover and little canopy cover. Component II had very few high loading positive loadings, such as low annual vegetation height and low percentage of areas with no ground cover. Negative loadings included habitat with

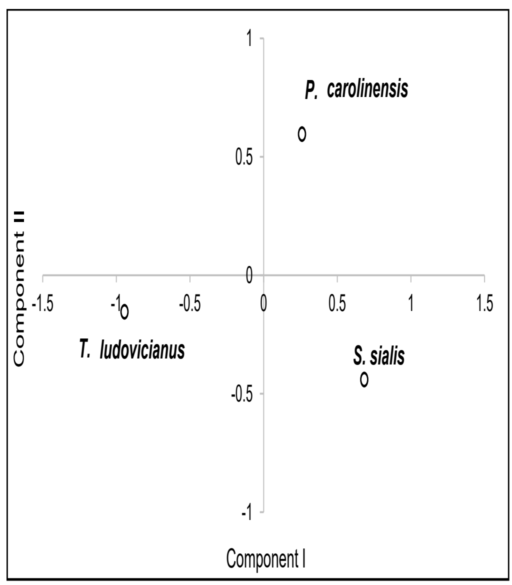

Figure 3. Projections of *T. ludovicianus, P. carolinensis,* and *S. sialis* based on the 1m^2 habitat variables onto principal components I and II.

some shrub cover, moderate areas of no ground cover, and moderate overhead canopy cover (Fig. 4).

Nesting species niche overlap varied widely from the 1m² scale to the 10m² scale analysis (Table 2). At both scales, the 2 species that utilized grassland areas for nesting had a high degree of overlap. At the 1m² scale, both Eastern Bluebirds and Carolina Chickadees had relatively high overlap with Carolina Wrens.

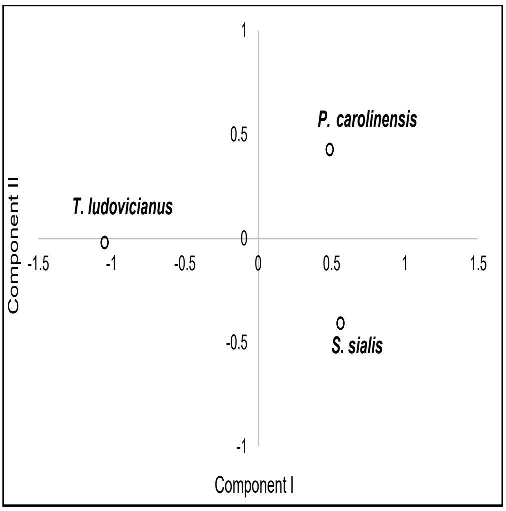

Figure 4. Projections of *T. ludovicianus, P. carolinensis,* and *S. sialis* based on the 10m² habitat variables onto principal components I and II.

However, at the 10m² scale there was reduced overlap between the grassland nesters and Carolina Wrens.

Discussion

Principal components analysis of nesting sites versus habitat variables suggests that these 3 species perceive their habitat in terms of ground cover, vertical structure, horizontal structure, and neighborhood type. The 1m² and 10m² PCA produced very similar results and as such, neither scale provided unique habitat characters that help to reveal habitat preferences. The PCA did, however, support the importance of diversity in habitat and landscape structure in providing quality nesting habitat for multiple species.

Although the 1m² scale niche overlap index suggests substantial overlap among all 3 species, the 10m² scale niche overlap values reveal that overlap drops dramatically between the 2 grassland nesting species and the Carolina Wren. Sampling at an even larger scale to include landscape measurements may reveal additional insight into why habitat that appears similar in structure and composition may not equally support nesting activity. This information is important as developers and city planners consider requirements for incorporating/preserving native habitats in newly developed areas.

We expected secondary cavity-nesting birds to utilize nest boxes to a greater extent than they did. Based on observations of the avian fauna at JNSR, we also expected a higher diversity of birds using the boxes. Other secondary cavity-nesting birds seen at JNSR, but not utilizing nest boxes include the Tufted Titmouse (*Baeolophus bicolor*) and Bewick's Wren (*Thryomanes bewickii*). Despite JNSR's proximity to encroaching housing development, we only saw House Sparrows and European Starlings in very low numbers, typically only along county roadsides. Additionally, over the course of the study, 4 clutches were abandoned prior to incubation indicating either predation threats or that mated pairs had multiple nests. Although there was no ecotone at any of our sites due to the abrupt edge, we expected C-0 nest boxes (edge effect) to be used at least as frequently as the other boxes. We found the opposite to be true as edge nest boxes were the only location where no boxes were used for nesting over the course of all 3 years.

These facts indicate to us that 1) natural cavities are abundant at this time on JNSR 2) JNSR currently has a sufficient rural buffer around it to minimize invasion by naturalized invasive species such as House Sparrows and European Starlings, commonly associated with urban environments, and 3) with regard to our study, edge effect has little influence when choosing nest box sites for the 3 species. It is

Table 2. Niche overlap between bird species using the simplified Morisita index of overlap.

	1m^2			10m^2		
Species	1	2	3	1	2	3
1 *Sialia sialis*	1.000			1.000		
2 *Poecile carolinensis*	0.987	1.000		0.967	1.000	
3 *Thryothorus ludovicianus*	0.879	0.866	1.000	0.219	0.199	1.000

important to characterize nesting habitat for native species in the absence of competition with these introduced species. This provides a more accurate evaluation of habitat affinities with regard to reproductive adaptations of native species.

Acknowledgments

We would like to thank the Boy Scouts of America Last Frontier Council and Jim Taylor for the use of the John Nichols Scout Ranch. We also thank Troy Woodson, store manager at Lowe's Home Improvement Store #2540 for construction materials. This study was supported, in part, by a 2014 CAIRS OCU Undergraduate Research Grant. We thank the Dean's Office in the Petree College of Arts and Science and the Department of Biology at OCU for use of a field vehicle and financial support of the field crew. This study would not have been possible without field assistance from Cassandra Velasco and Dylan Smith-Sutton.

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Submitted September 15, 2016 Accepted November 21, 2016

Impact of Hand Washing Instructions on Hand Hygiene Practices at the University of Central Oklahoma

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Abstract: Washing hands with soap and water has long been considered an effective way to reduce the spread of infectious disease, yet hand washing compliance has historically been low, even in health care institutions. Studies conducted in health care institutions have shown that compliance can be improved with intervention, principally through the potential for punishment. In a public setting, the threat of punishment is not a viable option; therefore other methods are employed to promote hand washing compliance. Over a period of two months hand washing practices were observed in various restrooms on the UCO campus before and after hand washing instructions were placed in the restrooms. The percentage of subjects who washed their hands for at least 30 seconds, which is the Centers for Disease Control (CDC) recommendation, improved from 23% to 27% after hand washing instructions were placed in designated restrooms. This improvement was not statistically significant and indicates that placing signs in restrooms is not sufficient to improve hand washing practices on the UCO campus.

Introduction

Washing hands with soap and water has long been considered an effective way to reduce the spread of infectious disease. In 1861 Semmelweis was the first to demonstrate the role of hand hygiene in reducing the risk of transmitting disease from person-to-person (Wiese 1930). Since that time there have been several studies that have demonstrated the benefits of hand washing to inhibiting the spread of disease. For example, several studies demonstrated that a variety of hand washing approaches in areas of low income or limited access to piped water were effective at reducing the level of coliform contamination from hands (Hoque 1991, Hoque 1995, Burton, 2011). Hand washing has also been suggested to potentially reduce the risk of spreading diarrheal diseases (Ejemot 2008) and according to the Centers for Disease Control and Prevention (CDC) poor handwashing practices contributes to almost 50% of all foodborne illness outbreaks (Mead et al., 1999). A meta-analysis of hand washing studies by Aiello and colleagues in 2008 found that the incidence of respiratory illness was reduced by an average of 21% in various environments (Aiello et al, 2008). A field study conducted in Tanzania demonstrated that hand washing with soap reduced the presence of *E. coli* and fecal streptococci by 0.50 and 0.25 log per hand, respectively (Pickering et al. 2010). A study published in 2011 demonstrated that hand washing with water alone reduced the prevalence of bacteria on the hands of study volunteers by 21%, whereas washing with soap and water reduced the prevalence of bacteria by 36% (Burton 2011). Mortimer and colleagues demonstrated that hand washing reduces

Staphyloccocus aureus transmission several fold. They found that the transmission rate of *S. aureus* from nurses to babies when nurses did not wash their hands was 43%, while the transmission rate was only 14% when nurses did wash their hands (Mortimer 1962).

Self-reporting of hand washing practices in the U.S. tends to be exaggerated. Surveys conducted in 2009 and 2010 involving approximately 3,500 people indicated that about 95% of those surveyed stated that they always wash their hands after using public restrooms (QSR Magazine 2009, Harris Interactive 2010). However, actual studies of handwashing practices conducted by The American Society for Microbiology and the American Cleaning Institute in public restrooms across the country showed that roughly 85% of the observed adults washed their hands to some degree after using a public restroom. (Harris Interactive 2010). The Center for Disease Control (CDC) recommends and publishes guidelines for hand washing using soap and water for at least thirty seconds (CDC 2015). The number of people who actually wash their hands following these guidelines is likely very low. Indeed one report in which roughly 3,300 subjects were observed washing their hands after using the restroom, only 6% washed their hands for at least 15 seconds (Borchgrevink et al. 2013). The impact of washing time on the reduction of bacteria from the hands has been studied. For example, Rotter and colleagues demonstrated that hand washing with plain soap and water for 15 seconds reduced bacterial counts by 0.6-1.1 $\log_{10}$, whereas washing for 30 seconds reduced counts by 1.8-2.8 $\log_{10}$ (Rotter 1999) while Fuls et al. demonstrated that washing hands with nonantibacterial soap for 15 or 30 seconds specifically reduced the level of *Shigella flexneri* by approximately 1.7 $\log_{10}$/hand (Fuls et al. 2008).

The purpose of this study was to determine the impact of placing hand washing instructions in UCO restrooms on the hand hygiene practices of people on the UCO campus. The hypothesis was that placing instructions in the rest rooms would significantly improve hand washing practices.

Methods

Data collection. This study was carried out as part of an active learning exercise in a Microbiology for Majors course in the fall of 2012 after students had completed the NIH training for Protecting Human Research Participants and under UCO IRB approval. After using the rest rooms, subjects were observed as to how they washed their hands before exiting the rest room. Student researchers used a data collection sheet to mark a box corresponding to how the subjects washed their hands. Hand washing practices were recorded into five categories: nothing, rinse with water and dry, wash with soap and water and dry, but $<$ 30 seconds, wash with soap and water and dry $>$ 30 seconds, and alcohol based hand gel. Hand washing practices were observed before and after instructions were posted in the rest rooms. Before and after data was collected in the same rest rooms for a period of 4 to 5 weeks respectively. Student researchers did not interact with the rest room users in any way.

Statistical analysis. Two sample t-tests between percents were used to determine if there were statistically significant differences between hand washing practices between groups before and after placing instructions in the designated restrooms.

Results and Discussion

Before hand washing instructions were placed in restrooms a total of 312 adult subjects (157 males and 155 females) were observed for their hand washing practices. After hand washing instructions were placed in restrooms at total of 219 adult subjects (115 males and 104 females) were observed for their hand washing practices. Prior to instructions being placed in the designated restrooms 13.5% of all subjects did not wash their hands after using the restroom, 70.8% of all subjects washed their hands with soap and water to some degree, and only 22.8% of all subjects washed their hands with soap and water for at least 30 seconds per CDC recommendations (Figure 1).

These results are not too dissimilar from

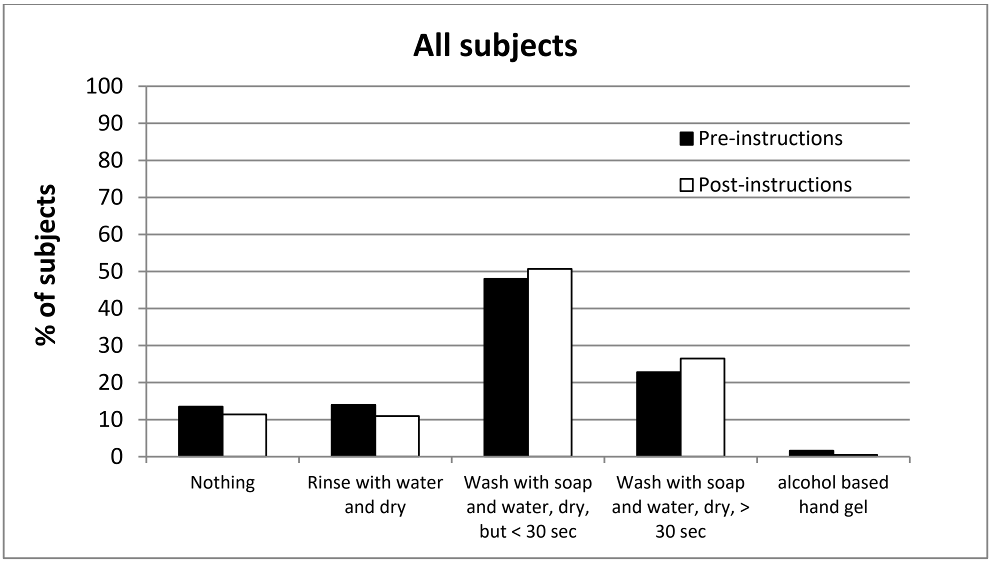

Figure 1. Hand washing results for all male and female subjects pre and post-instructions. Pre-instructions n = 312. Post-instructions n = 219.

a study of hand washing practices in public restrooms in a Michigan college town. The authors of that study found that approximately 11% of subjects did not wash their hands at all, and when they did wash their hands, approximately 64% used soap and water to some degree (Borchgrevink et al. 2013). We also found that in general women tend to exhibit better hand washing practices than males. Prior to instructions being placed in the restrooms, 19.7% of males did not wash their hands at all, while only 7.1% of the females did not wash their hands at all (Figures 2 and 3). This too is in agreement with previous reports (Judah et al. 2009, Borchgrevink et al. 2013).

After placing instructions in the designated bathrooms, the percentage of all subjects who did not wash their hands dropped to 11.4%, those who washed their hands with soap and water to some degree increased to 77.2%, and the percentage of subjects who washed their hands for at least 30 seconds increased to 26.5%. These changes in hand washing practices were not statistically significant (Figure 1). In fact there were no significant differences in any of the hand washing practices of all the subjects. The percentage of subjects who only rinsed their hands with water dropped from 14.0% to 11.0% ($p = .308$). The percentage of subjects who used soap and water for less than 30 seconds rose from 48% to 50.7% ($p = .496$). A previous study to evaluate the efficacy of various electronic messages in public restrooms to improve hand washing practices found that these forms of intervention only modestly improved hand washing practices and was dependent on the type of electronic message being used (Judah et al. 2009).

In our study, males demonstrated no significant changes in hand washing behavior after instructions were posted (Figure 2). The percentage of males who washed their hands with soap and water for at least 30 seconds increased only 2%. The percentage of males who did nothing or just rinsed with water was essentially unchanged. The percentage of males who washed their hands with soap and water for less than 30 seconds dropped from 38.2% to 33.9%. The percentage of males who used soap and water for some period of time went from 64.3% to 62.6%.

Unlike males, females did demonstrate some significant changes in hand washing behavior

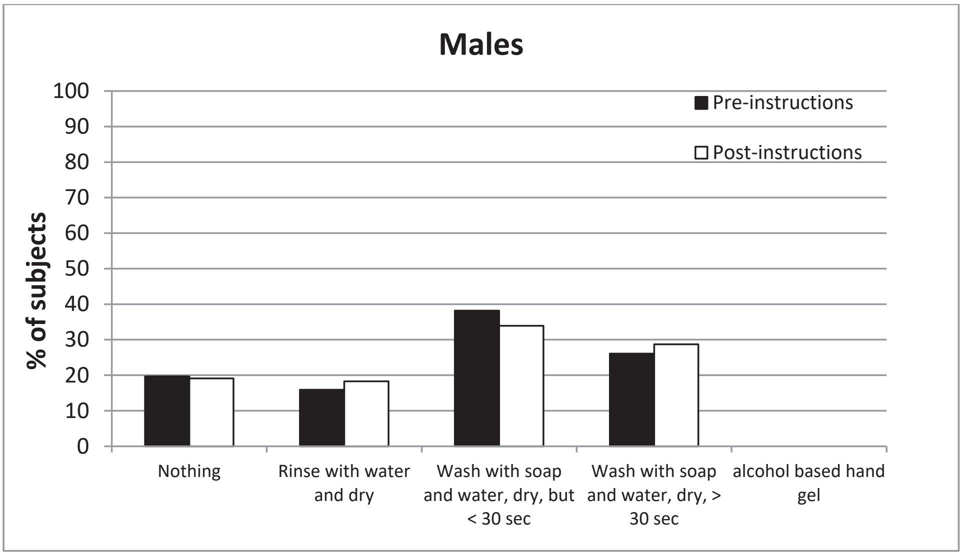

Figure 2. Hand washing results for all male subjects pre and post-instructions. Pre-instructions n = 157. Post-instructions n = 115.

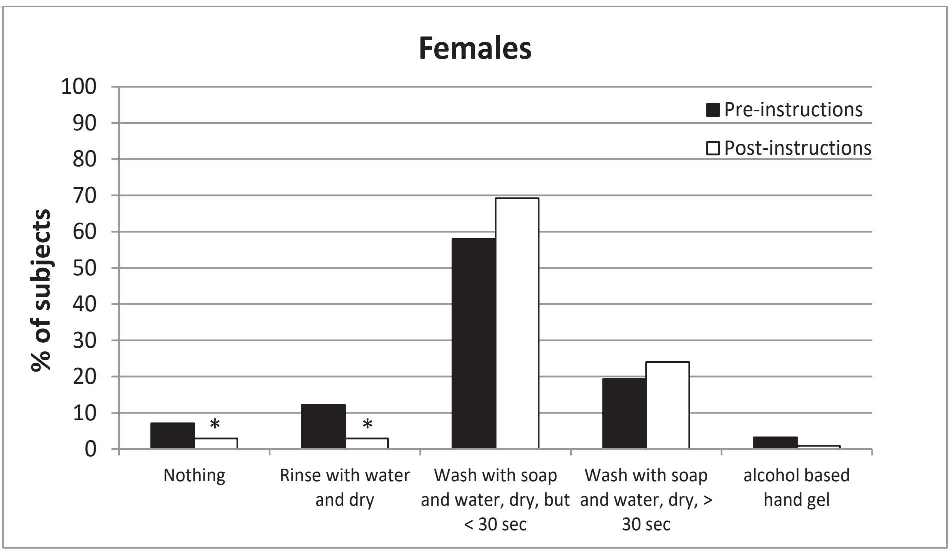

Figure 3. Hand washing results for all female subjects pre and post-instructions. Pre-instructions n = 155. Post-instructions n = 104.

after instructions were posted (Figure 3). The percentage of females who washed their hands with soap and water for at least 30 seconds increased 4.7%. The percentage of females who did nothing or just rinsed with water dropped significantly from 7.1% down to 2.9% ($p < 0.05$). The percentage of females who washed their hands with soap and water for less than 30 seconds increased from 58% to 69.2%. The percentage of females who used soap and water for some period of time significantly increased from 77.3% to 93.2%.

Although placing hand washing instructions in the restrooms did not significantly improve the percentage of people washing their hands according to CDC recommendations, there was a slight improvement in the percentage of people using soap and water. A similar study conducted on the campus of Pennsylvania State University approximately a decade earlier reported that in general hand washing practices were better in the presence of signs (Johnson et al. 2003). However, the authors of that study did not determine the length of hand washing time, which makes it impossible to know if the hand washing that did take place before or after signage was placed in the restrooms was in accordance with CDC recommendations. Therefore, our study provides a more in depth look at the quality of hand washing. Our findings that females in general demonstrated better hand washing practices then males and showed the greatest improvement in hand washing practices after signs were posted is consistent with previous studies (Judah et al. 1999, Johnson et al. 2003, Borchgrevink et al. 2013). While this study was intended to evaluate the impact of placing hand washing signs in restrooms on hand washing practices, we did not take into consideration the design, size, or number of signs placed. Additionally we did not survey individuals exiting the restrooms to determine whether or not they even saw the signs. Therefore we are not able to make any comparisons between the way men and women respond to hand washing signs in restrooms. In order to better understand the impact of signage on hand washing practices, these factors would need to be taken into consideration in future research.

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Submitted May 2, 2016 Accepted November 21, 2016

Abstracts of the
105th Oklahoma Academy of Science Technical Meeting
November 4th, 2016

Oklahoma State University Center for Health Sciences – Tulsa

12-HETRE EXERTS ITS ANTITHROMBOTIC EFFECTS THROUGH THE PROSTACYCLIN RECEPTOR

Zitha R. Isingizwe, Oklahoma Christian University, Edmond, OK

Benjamin E. Tourdot, Reheman Adili, Meral Abraham, & Michael Holinstat, University of Michigan, Ann Arbor, MI

Theodore R. Holman, University of California, Santa Clara, CA

Best Undergraduate Paper of the Academy and Outstanding Undergraduate Paper in the Biomedical Sciences Section.

Thrombotic diseases such as myocardial infarction and stroke remain the major contributor of cardiovascular related deaths. Our lab recently discovered that the antithrombotic effects of dihomo-γ-linolenic acid (DGLA) are predominantly mediated by the 12-lipoxygenase (12-LOX) derived metabolite 12-hydroxyeicosatetrienoic acid (12-HETrE). 12-HETrE was shown to inhibit platelets activation by stimulating a yet to be identified Gαs-coupled receptor. We hypothesize that 12-HETrE functions through one of the known prostanoid receptors (IP, DP1, EP2 or EP4). To determine whether 12-HETrE inhibits platelets through the known prostanoid receptors, platelets were incubated with a pharmacological inhibitor to one of the prostanoid receptors prior to treating platelets with 12-HETrE. The IP receptor antagonist partially blocked the inhibitory effects of 12-HETrE, suggesting that 12-HETrE signals at least in part through the IP receptor. IP receptor deficient mice were utilized to further characterize the role of the IP receptor in 12-HETrE-mediated platelet inhibition. 12-HETrE was unable to inhibit platelet aggregation in the IP receptor deficient mice, which further supports that 12-HETrE exerts its antiplatelet effects predominantly through the IP receptor. The understanding of DGLA-mediated platelet inhibition in this study will help to identify new therapeutic targets to control aberrant platelet activation, hence limiting the risk of unwanted clotting.

EFFECTS OF FIRE INTENSITY ON SMALL MAMMAL COMMUNITIES— 5 YEARS POST FIRE

Laura E. Jardine, Adam K. Ryburn, & Anthony J. Stancampiano, Oklahoma City University, Oklahoma City, OK

Outstanding Undergraduate Paper in the Biological Science-Botany Section.

We assessed the recovery and current status of small mammal populations in 3 mixed grass prairie habitats 5 years post burn in the Wichita Mountains Wildlife Refuge, Indiahoma, Oklahoma. These sites represent 3 burn treatments: moderate burn, intense burn, and unburned. We sampled the small mammal fauna at each site using a Y-shaped array of Sherman and pitfall traps for a total of 800 trap nights/site. We used a modified point-intercept method to sample 80 habitat variables at 280 points at each site. These abundance-weighted data were subjected to principal components analysis to assess mammal affinities for habitat structure among the 3 sites. We also calculated mammal species diversity for each treatment. Component I represents a gradient from short, low density forbs and grasses, lichen covered cobble and boulders, and water disturbance to areas of taller grasses and

forbs with herbaceous litter ground cover. Component II represents a gradient from short forbs, tall herbaceous litter, and no disturbance to areas with tall forbs and grasses, short herbaceous litter, bare ground cover, and ungulate and human disturbance. Four species, Peromyscus maniculatus, Cryptotis parva, Sigmodon hispidus, and Chaetodipus hispidus clustered tightly on the positive loadings of PC I. Neotoma floridana occurred on the extreme opposite (negative) end of PC I and P. leucopus intermediate to these 2 groups. PC I explained 59.58% of the variation in the dataset. Neotoma floridana, P. maniculatus, P. leucopus, and S. hispidus clustered closely near the center of PC II while Chaetodipus hispidus was projected onto the negative end of PC II and Cryptotis parva onto the extreme positive end. Using the Shannon-Wiener Diversity Index, we determined that the moderate burn site had the greatest species diversity, the intense burn site had the second highest species diversity, and the unburned site had the lowest species diversity.

EFFECTS OF FIRE INTENSITY ON HABITAT RECOVERY IN A MIXED GRASS PRAIRIE ECOSYSTEM

Laura E. Jardine & Anthony J. Stancampiano, Oklahoma City University, Oklahoma City, OK

Outstanding Undergraduate Paper in the Applied Ecology and Conservation Section.

We assessed the recovery and current status of 3 mixed grass prairie habitats 5 years post burn in the Wichita Mountains Wildlife Refuge, Indiahoma, Oklahoma. These sites represent 3 burn treatments: moderate burn, intense burn, and unburned. We used a modified point-intercept method to sample 80 habitat variables at 280 points at each site. These data were subjected to principal components analysis to assess trends in habitat structure among the 3 sites. The first 2 components explained 100% of the variation in the dataset. Component I represents a gradient from short, low density forbs and grasses, herbaceous litter vertical cover, lichen covered cobble, and low disturbance to areas of tall, dense forbs and grasses, and animal disturbance. Component II represents a gradient from bare soil, moss, algae, gravel, shrubs, and graminoid crowns to areas with tall forbs, water disturbance cover, and boulders. Projections of the burn treatment sites onto principal components I and II indicate that the moderate and unburned sites cluster closely on component I (negative loadings) but are widely distinct along component II. The intense burn had the highest positive loadings along component I and is intermediate with respect to component II. High intensity fire results in more complete nutrient cycling from accumulated litter. This leads initially post fire to dense grass cover then increasing forb cover in the following years. Such an increase in forage density attracts large herbivores which inflict higher levels of disturbance to ground cover.

SMALL MAMMAL ASSEMBLAGE COMPOSITION AND HABITAT USAGE IN A SEMIRURAL LANDSCAPE

Cassandra Velasco & Anthony J. Stancampiano, Oklahoma City University, Oklahoma City, OK

Outstanding Undergraduate Paper in the Biological Science-Zoology Section.

During the summer of 2016, we studied the small mammal fauna at John W. Nichols Scout Ranch in extreme southeast Canadian County, Oklahoma. Six species of small mammals, including Peromyscus leucopus, P. maniculatus, Neotoma floridana, Sigmodon hispidus, Reithrodontomys fulvescens, and Didelphis virginiana, were represented in 52 captures. The habitat preferences for these species were then assessed using species' abundance and 21 habitat variables from 10 randomly selected plots. These data were subjected to principal components and niche overlap analysis. Peromyscus leucopus, P. maniculatus, N. floridana, and D. virginiana exhibited the highest degree of niche overlap, occurring mostly in habitats with large amounts of woody litter and overhead canopy. Sigmodon hispidus and R. fulvescens were found in open grasslands with high grass and forb cover. In this landscape, woodland habitat exhibits higher mammal species diversity probably

due to a greater amount of vertical structure.

TIME RESOLVED UV-VIS SPECTROSCOPY FOR MONITORING PEROXIDE VAPORS

Meagan E. Bobo, Oklahoma Christian University, Edmond, OK

Nicholas Materer & Allen Apblett, Oklahoma State University, Stillwater, OK

Outstanding Undergraduate Paper in the Physical Sciences Section.

The reaction of dark blue nanometric suspension of molybdenum or tungsten hydrogen bronze particles with nitrobenzene, hydrogen peroxide, or triacetone triperoxide results in a dramatic color change. Bronzes are formed from the trioxides by the incorporation of hydrogen into open channels present in WO3 or between the sheets of MoO3. Hydrogen ions are attached to oxygen atoms in the channels. The electrons are delocalized giving an electrically conductive and highly colored material. In this project, spectroscopy was used to further confirm the mechanism of color change. Reflectance spectra were taken over a period of time at regular intervals to confirm the reaction is first order. The absorbance at each of the designated time intervals was recorded and plotted versus time to determine the rate of the reaction.

PERCEPTIONS OF MULTI-LEVEL MARKETING WITH MBA STUDENTS

Olivia Sharp & Robert Mather, University of Central Oklahoma, Edmond, OK

Outstanding Undergraduate Paper in the Social Sciences Section.

Multi-level marketing organizations (MLMs) are rapidly growing and is the business practice of selling products or services through independent agents who are financially compensated for their sales. These organizations account for 75 percent of goods and services sold via direct channels (the Direct Selling Association 2003). The ethics of such marketing and Ponzi schemes have been the topic of recent discussion. However, there is no empirical research regarding the social cognitive factors that affect the receptiveness of a multi-level marketing target to a persuasive message. Testing MBA students will give a unique vantage point on the receptiveness of schemes, compared to previous studies (Mather et al., 2016). Attitudes will be measured by individual difference measures. Participants will then read a scenario in which they are at a career fair and are solicited to arrange a meeting to discuss a multi-level marketing opportunity. MBA students may be found to be more or less receptive to multi-level marketing. The findings from this study will contribute to the limited knowledge on multi-level marketing and reward mechanisms (Emek et al., 2011) of multi-level marketing.

CHARACTERIZATION OF PLANT PATHOGENIC *DIAPORTHE* SPECIES INFECTING MELONS IMPORTED FROM CENTRAL AMERICA

Matthew Broge, C. Biles, A. Howard, K. Karki, & B. Bruton, East Central University, Ada, OK

Outstanding Undergraduate Paper in the Microbiology Section.

Interior rot of melon fruit (*Cucumis melo* L. var. *cantalupensis* Naudin) is caused by fungi of the *Diaporthe* species. Plant pathogens such as *Diaporthe* spp. enter the surface of the melon fruit early in development and remain latent until fruit maturity. While ripe fruit is harvested and imported with no external evidence of *Diaporthe* spp., internal fruit rot from *Diaporthe* spp. becomes evident as the fruit matures. The objective of this study was to characterize melon-infecting *Diaporthe* spp. in melon imported from Central America. Isolates were cultured from sunken surface lesions from melons imported from Costa Rica, Honduras, and Guatemala. Four *Diaporthe* spp. were isolated

from melons imported from Guatemala, six *Diaporthe* spp. isolates were found in melons imported from Costa Rica and none were isolated from melons imported from Honduras. The majority of the Costa Rican isolates were similar in spore type to *D. melonis* and *D. ueckerae*, whereas the Guatemalan isolates were similar to *D. sojae* and *D. curcurbitae*. Deoxyribonucleic acid (DNA) was extracted from fungal hyphae and purified polymerase chain reactions (PCR) products were sent for Sanger DNA Sequencing. Sequencing analysis demonstrated that our isolates were a 100% match of 509 base pairs for *Phomopsis* sp. ENS505 (Sequence ID: KM977662.1), a *Diaporthe* species native to Panama. Our finding of pathogenic *Diaporthe* spp. from Panama in melons imported from other Central American countries suggest that plant pathogens are carried across international borders and imported into the United States.

HERMITE POLYNOMIALS

Maranda Robin Clymer, East Central University, Ada, OK

Outstanding Undergraduate Paper in the Mathematics, Statistics, & Computer Science Section.

I investigate the n-dimensional Hermite polynomials. Beginning with the general multivariate normal, I will build the most general Hermite Polynomials. This process starts by taking partial derivatives. Once we have taken partial derivatives, we are able to define the Hermite polynomials. Then, I am able to calculate for different values of n. If I take n partial derivatives, I then get one entry for an n-tensor. I examine multiple properties of the polynomials, such as their orthogonality and symmetry. Finally, I restrict the Hermite polynomials to one-dimension. With the assumption of mean zero and standard deviation one, I recover the traditional Hermite Polynomials. With this information, I was able to help build the foundation of the Edgeworth Expansion.

UPTAKE OF ARSENIC BY IRON HYDROXY CARBONATE (CHUKANOVITE): IMPLICATIONS FOR GROUNDWATER TREATMENT USING GRANULAR IRON REACTIVE BARRIERS

Morgan Mackey, East Central University, Ada, OK

Richard T. Wilkin, Environmental Protection Agency, Ada, OK

Outstanding Undergraduate Paper in the Environmental Sciences Section.

Chukanovite ($Fe_2(OH)_2CO_3$), an iron hydroxy carbonate mineral, is a prevalent secondary mineral precipitate in granular iron permeable reactive barriers (PRB) used to treat contaminated groundwater. The buildup of secondary precipitates in PRBs, like chukanovite, can change the rate and efficiency of contaminant removal. Our goal is to determine what role chukanovite plays in controlling the efficiency and lifespan of PRBs. Chukanovite was synthesized based on previously developed methods, and confirmed through X-ray diffraction analysis. Batch sorption experiments were performed to determine how chukanovite controlled arsenic levels (arsenite and arsenate) in water samples. Experiments show that chukanovite can rapidly (<1 h) reduce arsenic levels in water and arsenic remains bound to chukanovite for extended periods of time. Equilibrium concentrations of arsenic were typically below 10 μg/L at loadings of 2.3 g/L and initial arsenic concentrations of 1000 μg/L. Studying different concentrations of arsenite under varying pH conditions shows chukanovite can incorporate up to 0.049 mol As/kg, and uptake is optimal at higher pH. Future studies will further characterize chukanovite using Fourier Transform-Infrared (FTIR) Spectroscopy, Scanning Electron Microscopy (SEM), and will test arsenate interactions with chukanovite under variable conditions.

A NEW SPINYPOD FROM NORTHEAST TEXAS, *MATELEA HIRTELLIFLORA* AND A SYNOPSIS OF IT'S RELATIVES

Angela McDonnell, Oklahoma State University, Stillwater, OK

Best Graduate Paper of the Academy.

A new species of spinypod milkweed vine, *Matelea hirtelliflora*, has been described recently from Northeastern Texas. We distinguish this new species from it's closest relatives in Oklahoma and the Southeastern United States. A synopsis of the species, comparison to relatives, phylogenetic placement, and distribution are discussed.

FINDING FLOW FOR FREE: THE FLOW EXPERIENCE IN VOLUNTEERISM

Jonathan D. Becker & Jennifer L. Kisamore, University of Oklahoma, Norman, OK

Best Graduate Poster of the Academy.

This study examined flow experiences in professional work and volunteer activities. Flow experiences were expected to be more frequent the higher the perceived importance of the task and the higher the level of social interaction of the activity involved. Participants for this study were recruited from local non-profit organizations and the researcher's personal and professional networks. The online survey that was used assess flow and other relevant variables. Results of this study showed that people experience more flow in volunteer activities than in paid professional activities when age was controlled. Additionally, there was some evidence that people perceived volunteer activities as somewhat more important than work activities, although the results were not statistically significant. With a more robust measure of perceived importance, this may be an opportunity for future research. Finally, there was a statistically significant correlation between the level social interaction in volunteer activity and the level of flow experience in volunteer activity which suggests individuals experience more flow in volunteer work and that the level of flow experienced may be positively influenced by social interaction.

OPTIMIZATION OF QUANTUM CELLULAR AUTOMATA: REINFORCEMENT LEARNING

Patrick Harrington, Department of Mathematics and Computer Science, Northeastern State University, Tahlequah, OK.

Quantum Cellular Automata (QCA) are vulnerable to manufacturing errors that change circuit polarization. Analysis and correction of these errors has been done using Bayesian, Markovian, or neural network methodologies. Our work uses intelligent agents to improve evaluation and correction of Gaussian error using partially observable Markov Decision Processes in a multi-objective environment.

DOMINANCE RELATIONSHIPS IN JUVENILE FIVE-LINED SKINKS (*PLESTIODON FASCIATUS*): DOES SMALL SIZE MATTER?

Mark Paulissen, Department of Natural Sciences, Northeastern State University, Tahlequah, OK

I studied aggressive behavior of neonate Common Five-Lined Skinks (*Plestiodon fasciatus*). Two neonates of differing sizes were placed on opposite sides of a divided observation chamber for 48 hours. Then the partition was removed and a single retreat was placed in the center of the observation chamber, and the behaviors of the two neonates were recorded for 60 min. During an encounter, one lizard typically displayed aggressive behavior (lunging at or biting the other lizard) while the other lizard displayed submissive behavior (avoidance/fleeing/tail-wiggling); though in 24% of

encounters the two lizards showed no reaction to each other. Scoring of behaviors made it possible to determine which lizard was dominant and which was subordinate in each trial. The larger of the two lizards was dominant in 75% of the trials, and the smaller of the two lizards was dominant in 25% of trials. In trials in which the smaller lizard was dominant, the dominant lizard "won" barely over 50% of encounters compared to over 70% in trials in which the dominant was larger. In all trials, the two lizards spent significantly more time on opposite sides of the observation chamber than on the same side because the subordinate almost always fled from the dominant, often to the opposite side of the chamber. Nonetheless, the two lizards often used the retreat simultaneously.

EFFECT OF SALT (NACL) AND SALT SUBSTITUTIONS ON DOUGH RHEOLOGY AND BREADMAKING

Zorba J. Hernández-Estrada, & Patricia Rayas-Duarte, Robert M. Kerr Food & Agricultural Products Center, Biochemistry and Molecular Biology Department, Oklahoma State University, Stillwater, OK

Bread is a staple food worldwide and is responsible of 30% of the daily salt intake. High daily sodium intake has been widely associated with hypertension as well as numerous cardio-vascular diseases and other health problems. The effect of salt content and salt substitution using a potassium chloride based salt (NTS 24510) on mixing behavior, absorption properties, shelf-life (1, 3, and 7 days after baking), and sensory evaluation of white pan bread were investigated. The treatments included no salt (negative control), 0.5, 1.0 to 2.0% salt and substitutions of 33% and 40% salt with NTS 24510. Consumer acceptance was performed with 100 untrained panelists. Significant effects (Tukey; $P=0.05$) were found in water absorption, development time and stability of dough, and wet gluten and elastic recovery of gluten (0%-2% salt). Salt substitutions and 2% salt treatments were similar ($P>0.05$) suggesting that salt can be reduced up to 40% and have similar rheological properties. Crumb firmness evaluated with a Texture Analyzer TA.XT2i revealed softer crumb in the substituted treatments (9 to 30% softer, $P<0.05$) compared to the control. However, consumers did not detect any effect of the treatments in bread firmness. No significant effects ($P<0.05$) on white bread perception of saltiness, texture and seven other sensory attributes were observed when comparing the two substitution treatments with the control within 1 and 7 days after baking. Potassium chloride salt NTS 24510 at 33% substitution does not affect critical quality characteristics of white pan bread appreciated by bakers and consumers.

LATENT PLANT PATHOGENIC *DIAPORTHE* SPECIES IN MELONS IMPORTED FROM CENTRAL AMERICA

Matt Broge, Charlie L. Biles, Alisha Howard, & Keshav Karki, East Central University, Department of Biology, Ada, OK

Benny D. Bruton, United States Department of Agriculture, Agricultural Research Service, Lane OK

Phomopsis rot of melon fruit (*Cucumis melo* L. var. *cantalupensis* Naudin) is caused by fungi of the *Diaporthe* species. Plant pathogens such as *Diaporthe* spp. enter the surface of the melon fruit early in development and remain latent until fruit maturity. While ripe fruit is harvested and imported with no external evidence disease, internal fruit rot from *Diaporthe* spp. becomes evident as the fruit matures. The objective of this study was to characterize pathogenic *Diaporthe* spp. in melon imported from Central America. Isolates were cultured from sunken surface lesions from melons imported from Costa Rica, Honduras, and Guatemala. Fungal pycnidia and spores were examined microscopically to separate *Diaporthe* spp. from other fungi. Deoxyribonucleic acid (DNA) was extracted from fungal hyphae. Primers slightly inset of the traditionally barcoding ITS1 and ITS4 primers were used in the DNA amplification reaction. Purified polymerase chain reaction (PCR)

products were sent for Sanger DNA Sequencing.

Four *Diaporthe* spp. were isolated from melons imported from Guatemala, six *Diaporthe* spp. isolates were found in melons imported from Costa Rica, and none were isolated from melons imported from Honduras. Three of the Costa Rican isolates were similar in spore type to *D. melonis* and *D. ueckerae,* and three were similar to *D. sojae* and *D. curcurbitae*. Three of the Guatamalan isolates were also similar in spore type to *D. sojae* and *D. curcurbitae* and one was similar in spore type to *D. melonis* and *D. ueckerae,*. Sequencing analysis demonstrated that one of the isolates was a 100% match of 509 base pairs for *Phomopsis* sp. ENS505 (Sequence ID: KM977662.1), a *Phomopsis* species native to Panama. Of note, this species of fungi is currently taxonomically classified as belonging to the *Valsaceae* family versus that of the *Diaporthaceae* family. However, genetic analysis of the fungi demonstrated marked resemblance to *D. melonis*

Isolation and characterization of pathogenic *Diaporthe* spp. from Panama in melons imported from other Central American countries suggest that plant pathogens are carried across international borders and imported into the United States. Further, the Valsaceae family classification of a species with a marked genetic resemblance to a Diaporthaceae family member suggests the need to reconsider current taxonomic classification of this group of fungi.

HTLV-1 PROMOTOR COMPLEX TAX/PCREB INTERACTION WITH MED15 "KIX-LIKE" BINDING DOMAINS

Josh Hardage, Morgan Mackey, & Alisha Howard Department of Biology, East Central University, Ada, OK

Human T-Cell Leukemia Virus type 1 (HTLV-1), is a retrovirus that has been shown to cause adult T-Cell leukemia/lymphoma (ATLL) or HTLV-1-associated myelopathy (HAM) in approximately 5% of infected individuals. Tax, an HTLV-1 encoded transcription factor, recruits host CREB to the viral promoter. CREB, a transcription factor found to activate a large number of genes, becomes active when phosphorylated at serine 133 (pCREB). Tax promotes recruitment of pCREB to the HTLV integrated promoter at enhancer sites known as viral CREs. Together the Tax/pCREB/promoter DNA complex then recruit the ubiquitous host coactivator paralogs p300/CBP to the HTLV-1 promotor, leading to high transcriptional activation of the provirus. The KIX domain of CBP/p300 has been identified to interact with Tax and pCREB through two separate binding pockets. This interaction is believed to be the main interaction tethering the coactivator to the viral promoter. Interestingly, several so called "KIX-like" domains have been recently identified through structural and functional analysis. One such KIX-like domain has been proposed to reside in a mediator subunit known as MED15 or ARC105. We are investigating possible interaction between the Tax/CREB activator complex and the KIX-like domain of MED15 in order to determine whether Tax may recruit other transcriptional coactivators, such as the mediator complex, to the HTLV promoter.

ADHERENCE TO PEDIATRIC GUIDELINES FOR THE DIAGNOSIS AND MANAGEMENT OF ACUTE OTITIS MEDIA

Aaqil Shihab, Meredith Proctor, Oklahoma State University Center for Health Sciences, Tulsa, OK

Krista S. Schumacher, & Shrie Raam Sathyanarayanan, Oklahoma State University Center for Health Sciences & Oklahoma State University Center for Health Systems Innovation, Tulsa, OK

William D. Paiva, Oklahoma State University Center for Health Systems Innovation, Tulsa, OK

Acute otitis media (AOM), or ear infection, is one of the most common reasons for children to be prescribed antibiotics. Doctors may tend to overprescribe antibiotics for AOM, and there has been much debate over whether steps are being taken to address this issue. Overprescribing antibiotics is a problem because after a certain period of time the targeted bacteria strain can become resistant to the antibiotic, rendering it useless. In June 2004, the American Academy of Pediatrics released AOM treatment guidelines that included a recommended observation period of 48-72 hours for children with non-severe AOM or uncertain diagnosis. Our objective was to determine if the establishment of clinical quality standards had an impact on the prescribing rates of antibiotics for AOM treatment among children from infancy to age 12. Using data from the Cerner Health Facts data warehouse of electronic medical records, we conducted chi-square analyses on over 200,000 patient encounters to compare antibiotic prescription rates before and after guidelines for teaching/non-teaching hospitals and for urban/rural hospitals. We found teaching hospitals to be half as likely as non-teaching hospitals to prescribe antibiotics after guideline implementation. Although antibiotic prescribing rates decreased for urban hospitals post guidelines, rates increased for rural hospitals. These findings suggest that efforts targeting non-teaching and rural hospitals may be needed to increase awareness of AOM treatment guidelines and the risks of overprescribing antibiotics. Further research is needed to more fully understand the factors contributing to differential antibiotic prescribing patterns for children suffering from AOM.

SPATIO-TEMPORAL VARIATIONS IN MIRNA, MRNA AND PROTEIN EXPRESSION IN PERIPHERAL NERVE INJURY

Yerokhin, Vadim, Das, Subhas, Miller, & Kenneth, Oklahoma State University, Center for Health Sciences, Tulsa, OK

Peripheral nerve injury (PNI) affects approximately 20 million Americans annually, costing the healthcare system over $150 billion each year. Although current therapies attempt to promote nerve regeneration, only 50% of persons fully regain motor and sensory function. Injured peripheral axons can regenerate, but this is rarely complete due to the slow rate of regeneration. Clearly, a new therapeutic approach for accelerating peripheral nerve regeneration is needed. Although miRNA and anti-miRNA therapy has proved fruitful in normalizing dysregulated protein expression in other diseases, clinical use of this therapeutic modality in pain and PNI has yet to be realized. The absence of translational application of miRNA therapeutics stems mostly from our limited understanding of the molecular mechanisms underlying nerve injury and regeneration. Because nerve regeneration requires a complex coordination of finely regulated events, understanding these molecular mechanisms is key for designing an effective bio-pharmacological intervention. In this study, we present novel findings of spatial and temporal expression of miRNA let-7a and 23b post-PNI in the spinal cord (SC), and elucidate their relationship with Nerve Growth Factor (NGF) and Glutaminase (GLS) expression. Sciatic nerve crush injury was performed in male adult rats. Lumbosacral SC was divided into 4 quarters and miRNA let-7a and 23b, NGF and GLS mRNA expression was measured at 1, 4 and 7 days. Expression in partial SC section was compared to the whole SC. Spatio-temporal patterns of miRNA, mRNA and protein expression were detected in partial sections of the SC, as well as the whole SC, suggesting presence of site-specific expression changes. These findings shed light on the molecular relationship during PNI, contributing to the knowledgebase required for the development of a novel therapeutic approach to peripheral nerve injury and regeneration.

PRELIMINARY STUDY: APPLYING OSTEOPATHIC MANIPULATIVE TECHNIQUES IN REDUCING SOFT TISSUE ABUSE IN VOCALISTS

Breanna Anderson & Susan Goldman-Moore, University of Tulsa School of Music, Tulsa, OK
Kent Smith, Oklahoma State University Center for Health Sciences, Office for the Advancement of American Indians in Medicine and Science, Tulsa, OK

Leslie Ching, Oklahoma State University Center for Health Sciences, OMM Department, Tulsa, OK

Osteopathic Manipulative Medicine may prevent vocal abuse and contribute to the overall health of the soft tissues associated with singing. Many singers are treated by physicians for ailments they develop over the course of their singing career (i.e. polyps, cysts, nodules, ulcers). These conditions can be mild to severe and create difficulties in a singer's life that may lead to phonomicrosurgery and post-surgery vocal therapy. Although this is a successful treatment, less invasive and preventive methods, such as osteopathic manipulation, would benefit the singer and produce a longer and more productive singing career. Singing improperly or for long durations can result in straining of the vocal folds and tension near the hyoid bone in the neck. Thus, select osteopathic manual manipulations may be advantageous in diagnosing and treating patients suffering from muscle tightness or joint strain. Herein, we will study the effects of select osteopathic manual manipulation techniques that decrease tension in the neck and shoulders and their effectiveness in contributing the overall health and performance of vocalists.

ECOLOGICAL ASSESSMENT OF NUTRIENT AVAILABILITY IN SUBTERRANEAN STREAMS TO DETERMINE HABITAT SUITABILITY FOR CAVEFISH IN THE ARBUCKLE MOUNTAINS, OKLAHOMA

Kevin W. Blackwood, Britney J. Temple, Stacy I. Blackwood, Lainee A. Sanders, & Kaitlyn S. Beard, East Central University, Ada, OK

The Arbuckle Mountains ecoregion is underlain by thick sequences of carbonate rock, which has undergone significant karstification and cave development. The anisotropy of the karst groundwater flows is largely controlled by fracture networks and cave systems with a dominating lateral component near the water table. Surface derived nutrients are carried by flowing water into the cave systems primarily through inputs such as ponors and sinkholes, but also from leaching through discrete fractures. Nutrient availability is dependent on many factors such as basin characteristics, season, precipitation and discharge, as well as anthropogenic activities. Cavefish are rare in Arbuckle Mountain caves, known only from the largest and most studied cave systems. However, lesser known cave systems, discovered more recently, may have the potential to host a suitable habitat with sufficient nutrient availability to constitute a food web that may sustain populations of cavefish. This investigation uses cave streams with known cavefish populations as analogs to assess various parameters, such as nutrient availability and discharge, as well as abundance of prey in determining the conditions most suitable for cavefish habitat. These results may be used as a baseline to determine whether other Arbuckle Mountain cave systems might host cavefish populations, which may then be further investigated using environmental DNA sampling.

Erratum:

In the article "Additional Distribution Records of Scolopendromorph Centipedes in Oklahoma," by Bass, Tedford, Harlin, and Shelley, of Vol. 95, 2015 *POAS*, an incorrect figure was published for Figure 2 on page 94. The correct photo that should have appeared is shown here, along with the accompanying Figure 2 label. The error was also corrected on the online copy of the manuscript, available at http://ojs.library.okstate.edu/osu/index.php/OAS/article/view/6921/6383.

Figure 2. *Scolopendra heros* at Lake Hefner Dam, 24 July 2014.

The Editor and the Editorial Staff deeply regret the error.

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REVENUES COLLECTED		
Contributions		
Donations	100.00	$ 100.00
Membership Dues and assessments		
Dues	3,180.00	3.180.00
Investment Income		
Interest Earned	71.96	71.96
Other Income		
POAS Income	6,248,00	
Woody Plants	190.70	6,438.70
Meetings		
Registration - Spring Meeting	2,018.00	
Registration - Fall Meeting	6,273.00	
Registration - Technical Meeting	5,587.02	13,878.02
Total revenue collected		$23,568.68
EXPENSES PAID		
Stipends and Other Compensation		
Stipends	6,141.24	
Social Security	824.60	
Medicare	192.84	7,158.68
Professional Fees		
Audit	500.00	
Tax Preparation	995.00	1,495,00

STATEMENT OF REVENUES COLLECTED AND EXPENSES PAID FOR THE YEAR ENDED DECEMBER 31, 2015 (Continued)

Other Expenses		
Spring Meeting	2,290.00	
Fall Meeting	4,100.94	
Technical Meeting	1,775.32	8,176.26
Insurance	583.00	583.00
Dues	1,700.00	
AAAS	99.00	
NAAS		
POAS	3,555.64	
OTHER	201.85	5,556.49
Total Expenses		$22,969.43
Revenues Collected over Expenses Paid		**$ 599.25**

OKLAHOMA ACADEMY OF **SCIENCE**

STATEMENT OF ASSETS, LIABILITIES AND FUND BALANCE ARISING FROM CASH TRANSACTIONS DECEMBER 31, 2015

ASSETS

Cash:			
	OAS Checking Account	25,789.78	
	Savings account	1,287.50	
	Savings account	3,274.76	$30,352.04
Investments:			
	Certificate of Deposit	60,000.00	$60,000.00
Total Assets			$90,352.04

LIABILITIES AND FUND BALANCE

Liabilities		0.00
Fund balance:		
	Beginning operation fund balance	89,187.70
	Excess revenues collected over expenses	599.25
		$ 90,352.04

INDEPENDENT AUDITORS' REPORT

Executive Committee
The Oklahoma Academy of Science

I have audited the accompanying statements of assets, liabilities, and fund balance arising from cash transactions of the Oklahoma Academy of Science as of December 31, 2015, and the related statements of revenue collected and expenses paid for that year. These financial statements are the responsibility of the Company's management. My responsibility is to express an opinion on these financial statements based on the audit.

I have conducted an audit in accordance with generally accepted auditing standards. This audit was conducted to obtain reasonable assurance about whether the financial statements are free of material misstatement and examining, on a test basis evidence supporting the amounts and disclosures in the financial statements. These financial statements were prepared on the basis of cash receipts and disbursements and this report prepared only for the internal use of the Executive Committee of the Oklahoma Academy of Science.

I find the financial statements referred to above present fairly, in all material respects, the assets, liabilities and fund balance arising from cash transactions of The Oklahoma Academy of Science as of December 31, 2015 and its revenue collected and expenses paid during that year.

E. Pace, Retired
Assistant County Auditor

OKLAHOMA ACADEMY OF SCIENCE

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All manuscripts must be refereed critically. The *POAS* Editors have an obligation to the membership of the Academy and to the scientific community to insure, as far as possible, that the *Proceedings* is scientifically accurate. Expert refereeing is a tested, effective method by which the scientific community maintains a standard of excellence. In addition, expert refereeing frequently helps the author(s) to present the results in a clear, concise form that exceeds minimal standards.

The corresponding author is notified of the receipt of a manuscript, and the Editor sends the manuscript to at least two reviewers, anonymous to the author(s). After the initial review, the Editor either accepts the manuscript for publication, returns it to the author for clarification or revision, sends it to another referee for further review, or declines the manuscript.

A declined manuscript will have had at least two reviews, usually more. The Editors examine such manuscripts very carefully and take full responsibility. There are several grounds for declining a manuscript: the substance of the paper may not fall within the scope of the *Proceedings*; the work may not meet the standards that the *Proceedings* strives to maintain; the work may not be complete; the experimental evidence may not support the conclusion(s) that the author(s) would like to draw; the experimental approach may be equivocal; faulty design or technique may vitiate the results; or the manuscript may not make a sufficient contribution to the overall understanding of the system being studied, even though the quality of the experimental work is not in question.

A combination of these reasons is also possible grounds for declining to publish the MS. In most cases, the Editors rely on the judgment of the reviewers.

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We thank the reviewers who contribute so much to the quality of these *Proceedings*. They must remain anonymous to assure their freedom in making recommendations. The responsibilities or obligations of these reviewers are

- Because science depends on peer-reviewed publications, every scientist has an obligation to do a fair share of reviewing.
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Prospective authors should note carefully the policy statement "Policies of the *Proceedings*" on page ii.

The Editors review the MS and carefully select other reviewers as described in "Editorial Policies and Practices" (see p. 131); all referee and editorial opinions are anonymous. Send a resubmitted and/ or revised manuscript and a point-by-point response to the reviewers'/Editor's comments.

All authors should approve all revisions (the corresponding author is responsible for insuring that all authors agree to the changes). A revised paper will retain its original date of receipt only if the revision is received by the Editor within two months after the date of the letter to the author(s).

B. Types of Manuscripts.

A manuscript may be a paper (report), review, note (communication), a technical comment, or a letter to the editor.

Paper (a report; traditional research paper). A Paper may be of any length that is required to describe and to explain adequately the experimental observations.

Review. The Editor will usually solicit review articles, but will consider unsolicited ones. The prospective writer(s) of reviews should consult the Editor; in general, the Editor needs a synopsis of the area proposed for review and an outline of the paper before deciding. Reviews are typically peer- reviewed.

Note (Communication). The objective of a *Note* is to provide an effective form for communicating new results and ideas and/ or describing small but complete pieces of research. Thus, a *Note* is either a preliminary report or a complete account of a small investigation. *Notes* must not exceed four printed pages including text, figures, tables, and references. One journal page of standard text contains about 600 words; hence, there is space for presentation of considerable experimental detail. *Notes* are peer-reviewed.

Technical Comment. Technical comments (one journal page) may criticize material published in an earlier volume of *POAS* or may offer additional useful information. The author(s) of the original paper are asked for an opinion on the comment and, if the comment is published, are invited to reply in the same volume.

Letter to the Editor. Letters are selected for their pertinence to materials published in *POAS* or because they discuss problems of general interest to scientists and/or to Oklahomans. Letters pertaining to material published in *POAS* may correct errors, provide support or agreements, or offer different points of view, clarifications, or additional information.

Abstract. You may submit an abstract of your presentation at the OAS Technical Meeting. For specific instructions, contact the Editor. Even though abstracts are not peer-reviewed, they must align with the policies and scope of the Proceedings. The quality or relevance of work may not be in question, but the printed material is still subject to scientific accuracy.

The same guidelines that apply to manuscripts and notes submitted for peer-review, also apply to abstracts submitted for print. Just as manuscripts and notes are subject to thorough testing, so are comments written in abstracts (supported by data). The Proceedings understands that all disciplines are in a search for a deeper understanding of the world some of which are through creative expression and personal interpretation. Science is a system by which one discovers and records physical phenomena, dealing with hypotheses that are testable. The domain of "science" while working within nature is restricted to the observable world. There are many valid and important questions to be answered but lie outside the realm of science.

C. Manuscript Organization.

1. General organization.

For papers (reports), the subsections should typically include the following: Abstract, Introduction, Experimental Procedures (or Methods), Results, Discussion, Acknowledgments (if any), and References. In the case of notes or short papers, you may combine some headings, for example, "Results and Discussion":

I. The title should be short, clear, and informative; it should not exceed 150 characters and spaces (three lines in the journal), and include the name of the organism, compound, process, system, enzyme, etc., that is the major object of the study.

II. Provide a running title of fewer than 60 characters and spaces.

III. Spell out either the first or second given name of each author. For example, Otis C. Dermer, instead of O.C. Dermer, or H. Olin Spivey, instead of H.O. Spivey.

IV. Every manuscript (including Notes) must begin with a brief Abstract (up to 200 words) that presents clearly the plan, procedure, and significant results of the investigation. The Abstract should be understandable alone and should provide a comprehensive overview of the entire research effort.

V. The Introduction should state the purpose of the investigation and the relationship with other work in the same field. It should not be an extensive review of literature, but provide appropriate literature to demonstrate the context of the research.

VI. The Experimental Procedures (or Methods) section should be brief, but adequate for repetition of the work by a qualified experimenter. References to previously published procedures can reduce the length of this section. Refer to the original description of a procedure and describe any modifications.

VII. You may present the Results in tables or figures or both, but note that it is sometimes simpler and clearer to state the observations and the appropriate experimental values directly in the text. Present a given set of results *in only one form:* in a table, or figure, or the text.

VIII. The Discussion section should interpret the Results and how these observations fit with the results of others. Sometimes the combination of Results and Discussion can give a clearer, more compact presentation.

IX. Acknowledgments of financial support and other aid are to be included.

X. References are discussed below.

1. References

POAS uses the name-year system for citing references. Citations in the text, tables and figure legends include the surname of the author or authors of the cited document and the year of publication. The references are listed alphabetically by authors' surnames in the reference list found at the end of the text of the article. Below are given several examples of correct formats for citing journal articles, books, theses and web resources. For Additional information regarding the name- year system, consult the CBE Manual [Scientific *Style and Format: The CBE Manual for Authors, Editors, and Publishers,* 6th edition]. Abbreviate journal names according to the *International List of Periodical Title Word Abbreviations.*

If it is necessary to refer to a manuscript that has been accepted for publication elsewhere but is not yet published, use the format shown below, with the volume and page numbers absent, the (estimated) publication year included and followed by the words *in press* for papers publications and *forthcoming* for all other forms (CBE 30.68). If the materials are published before the manuscript with that reference is published in *POAS,* notify the Editor of the appropriate volume and page numbers and make the changes as you revise.

Responsibility for the accuracy of bibliographic references rests entirely with the author(s); confirm all references through comparison of the final draft of the manuscript with the original publications. *We expect that the only changes in galley proof will be for typographical errors.* Any mention of *manuscript in preparation, unpublished experiments,* and *personal communication* should be in parenthesis. Use of *personal communication* should be with written permission of the communicator and should be entered only in the text, not in the Reference list.

Examples of References in CBE Style and Format

Journal Articles

Miller LF, Chance CJ. 1954. Fishing in the tail waters of TVS dams. Prog Fish-Cult 16:3-9.

Ortenburger AI, Hubbs CL. 1927. A report on the fishes of Oklahoma, with descriptions of new genera and species. Proc Okla Acad Sci 6:123-141.

Books

Book with Authors:

Miller RJ, Robison HW. 1980. The fishes of Oklahoma. Stillwater (OK): Oklahoma State University Press. 246 p.

Book with Editors:

Gilman AG, Rall TW, Nies AS, Taylor P, editors. 1990. The pharmacological basis of theraputics. 8th ed. New York: Pergamon. 1811 p.

Book with Organization as Author: International Union of Pure and Applied Chemistry, Physical Chemistry Division. 1993. Quantities, units, and symbols in physical chemistry. 3rd. Oxford (UK): Blackwell Science. 166 p.

Chapter in Book with Editors:

Hamilton K, Combs DL, Randolph JC. 1985. Sportfishing changes related to hydro- power generation and non-generation in the tailwater of Keystone Reservoir, Oklahoma. In: Olsen FW, White RG, Hamre RH, editors. Proceedings of the symposium on small hydropower and fisheries. Bethesda (MD): American Fisheries Society. p 145-152.

Theses: Knapp MM. 1985. Effects of exploitation on crappie in a new reservoir [MSc thesis]. Stillwater (OK): Oklahoma State University. 84 p. Available from: OSU Library.

Internet: Oklahoma Climatological Survey. 2003. Climate of Oklahoma [online]. Available from: http://climate.ocs.ou.edu. (Accessed August 15, 2005).

D. Review Process.

The Editors review the MS and carefully select reviewers for all submitted manuscripts. All referee and editorial opinions are anonymous. A decision to accept, revise, or reject the manuscript is made by the editor after careful consideration of reviewers' comments and recommendations. If a "revise" decision is reached, the authors will be allowed to resubmit a revised version of the manuscript within a given time window. The authors are considered to address all reviewers' comments and concerns, or provide compelling reasons to explain why they chose not to do so. A point-by-point rebuttal letter is required with each revised manuscripts, which clearly indicates the nature and locations of corrections within the revised manuscript. All authors should approve all revisions, with the corresponding author being responsible for insuring that all authors agree to the changes.

E. Page Charges

The OAS will publish accepted MSs with the implicit understanding that the author(s) will pay a charge per published page. Page charges are billed at the cost per page for the given issue: current rates of $90 per page for nonmembers of the Academy and $35 for members. All authors are expected to honor these page charges. Billing for page charges and receipt of payment are handled by the

Business Manager, who is also the Executive Secretary and Treasurer for the Academy.

Under exceptional circumstances, when no source of grant funds or other support exists, the author(s) may apply, at the time of submission, for a waiver of page charges.

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