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REPORTS

A. Applied Ecology & Conservation

Composition of Fish Communities on and off Mussel Beds in the Kiamichi River, Oklahoma

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Abstract: Fishes and mussels are prominent organisms in streams of eastern North America. Fish communities have large effects on mussel communities because mussels disperse as ectoparasitic larvae on fish hosts. Mussel communities influence the abundance and composition of algae and macroinvertebrates in streams by providing shell habitat and nutrient subsidies from their excreta, possibly influencing fish communities through these same mechanisms. To begin addressing this question, we asked if fish composition varied on and off mussel beds in the Kiamichi River in Southeastern Oklahoma. We also asked how any observed variation in fish composition between mussel and non-mussel sites was related to fish feeding and nesting traits. We quantitatively sampled 10 sites in summer 2013, including five with and five without large mussel beds. We found no significant differences in fish abundance, richness, or feeding guilds between mussel and non-mussel sites. However, mussel sites had a significantly higher proportion of nest building fish than non-mussel sites. Our study was limited by sample size, methodology and timing. To robustly address the question of whether mussel communities influence fish communities, we encourage further work that samples more sites, employs a variety of sampling methods, and includes behavioral observations.

Introduction

Freshwater fishes and mussels (Bivalvia: Unionidae) are dominant consumers in streams of eastern North America. Adult mussels are sedentary and mussel dispersal occurs largely through the movement of mussel larvae, which are obligate ectoparasites on fish (Barnhart et al. 2008; Vaughn 2012). Because of this host-parasite relationship, fish community structure can have a large influence on mussel community structure (Vaughn and Taylor 2000; Schwalb et al. 2013). However, little is known about how mussels in turn might influence the composition and abundance of fish communities. There is anecdotal evidence that fish prefer sections of experimental tanks with mussels more than areas without mussels (Moy and Sparks 1991). Recently, American shad (*Alosa sapidissima*) have been found to deposit eggs in the body cavities of mussels (Wisniewski et al. 2013) and pacific lamprey grow faster in the presence of mussels (Limm and Power 2011).

Mussels typically occur as patchily distributed, dense, multispecies aggregations called mussel beds. Mussel beds have been shown to influence the distribution of other

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organisms primarily through two mechanisms. First, nutrients excreted by mussels fertilize algae (Allen et al. 2012) that is then consumed by primary consumer invertebrates (Atkinson et al. 2014), fish (Sansom, unpublished data), and even riparian spiders (Allen et al. 2012). Second, mussels provide structural habitat for benthic organisms both through the biogenic habitat provided by their shells and by altering sediment properties by their shells increasing surface roughness and/or through bioturbation (Spooner and Vaughn 2006; Vaughn et al. 2008; Allen and Vaughn 2011; Sansom et al. 2017). Mussels might influence the composition of fish communities by one or both of these mechanisms. Increased standing crops of benthic algae and higher abundances and richness of benthic macroinvertebrates resulting from mussel fertilization might lead to increased abundances of fish herbivores and insectivores. Increased substrate complexity provided by mussel shells can offer refuge from predation (Moy and Sparks 1991), and more stable stream sediment might provide preferential spawning and nesting habitat. For example, in previous field studies we have often observed centrarchid nests within mussel beds (C. Vaughn, personal observation).

To begin addressing the question of whether mussels might influence fish communities we asked two questions: (1) does fish composition and abundance vary on and off mussel beds and (2) how is variation in fish composition on and off mussel beds related to their feeding and nesting traits?

Methods

We conducted our study in the Kiamichi River, a major tributary of the Red River in southeastern Oklahoma with high mussel (31 species) and fish (86 species) biodiversity (Vaughn et al. 1996; Matthews et al. 2005). Based on previous knowledge of mussel distribution in the river (Galbraith et al. 2008) we selected 10 river reaches, five with large mussel beds and five with similar environmental conditions (Table 1), but without mussel beds (Fig. 1). All sites were a minimum of 500 m apart.

In the summer of 2013 we sampled fish, water quality and physical habitat variables at each site. Fish were collected with a backpack electroshocker (Smith-Root, Inc. Model 12-B) using pulsed direct current. Electrofishing began at the most downstream portion of the reach and continued upstream, going from bank-to-bank in a zigzag pattern. The shocking effort (cumulative time the shocker was engaged) was recorded and used to determine catch per unit effort (CPUE). Immediately after electroshocking, all fish were euthanized in MS222 and preserved in 80% ethanol for later identification.

We measured current velocity, water chemistry, and substrate heterogeneity along five transects at each site. Transects were located at the most downstream location of the site, 25%, 50%, and 75% of the site reach, and the most upstream location. Current velocity was measured in 1 m intervals along each transect, at 0.6 depth of the water column (March-McBirney FloMate). Dissolved oxygen, temperature, pH, and conductivity were measured at the right bank, river center, and left bank along each transect using a Hach meter (Hach, HQ36d: dissolved oxygen and temperature) and a PCSTestr Multi-Parameter (Oakton Instruments, PCSTestr 35 model WD-35425-10; pH, and conductivity). Finally, we conducted pebble counts of 20 pebbles per transect (Kondolf et al. 2003), pooled the substrate data from each transect per site, and used these data to derive sediment texture distribution and heterogeneity

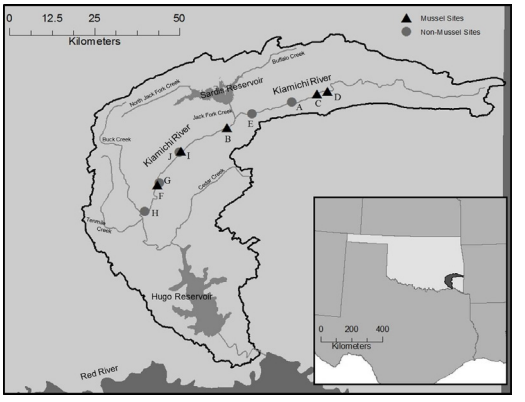

Figure 1. Kiamichi River watershed showing the site locations that were sampled during 2013.

Table 1. Abiotic parameters measured for each site in the Kiamichi River, Oklahoma.

	Site	Effort (minutes)	Site Length (m)	Mean Site Width (m)	Mean Temperature (C)	Mean pH	Mean Conductivity (uS)	Mean Total Dissolved Solids (ppm)	Mean Salinity (ppm)	Mean Dissolved Oxygen (mg/L)	Mean Dissolved Oxygen (%)	Substrate Heterogeneity	D50 (mm)	Mean Velocity (m/s)	Mean Depth (m)
Mussel	B	29	75	19.5	31.0	7.2	51.9	37.0	32.1	7.0	96.2	4.1	80	0.24	0.44
	C	32	70	20.6	27.8	7.3	55.2	39.2	32.8	5.9	76.4	7.0	50	0.06	0.40
	D	37	100	31.4	30.0	7.4	55.8	39.7	33.5	7.0	94.4	4.5	80	0.04	0.51
	F	30	70	38.8	29.5	7.5	53.5	38.0	32.5	7.6	100.0	3.3	70	0.07	0.45
	I	26	50	19	28.0	7.5	54.3	38.5	32.4	7.2	91.7	4.0	40	0.03	0.47
Non-Mussel	A	29	100	22.6	30.7	7.7	46.4	33.0	29.8	8.1	109.8	4.0	80	0.29	0.34
	E	30	80	34.2	28.8	7.7	54.2	38.5	32.6	8.4	109.9	4.0	60	0.06	0.45
	G	20	64	24.8	30.0	7.5	53.6	38.1	32.6	7.4	99.2	4.0	70	0.16	0.32
	H	36	80	29.8	30.6	7.9	59.7	42.4	35.0	8.1	108.3	7.0	60	0.06	0.42
	J	23	40	10.7	29.5	7.5	54.3	38.6	32.7	7.6	100.0	4.0	80	0.16	0.36
Mean[a]	Mussel Sites	30.8	73	25.9	29.3 A	7.4 A	54.1	38.5	32.7	6.9 A	91.7	4.6	64	0.08 A	0.46 A
	Non-mussel Sites	27.6	72.8	24.4	30.0 B	7.6 B	52.8	37.5	32.2	7.9 B	106.3	4.6	70	0.13 B	0.39 B

[a]If applicable, total mean values obtained from average of entire data per mussel and non-mussel sites, not the average values per site seen above. Heterogeneity and D50 means were averaged from totals per site. Different letters indicate means are statistically different (alpha = 0.05).

Table 2. The fish species collected in the Kiamichi River, Oklahoma grouped according to family[a], trophic guild, and spawning activity.

Species[b]	Family Group	Trophic Guild	Nest Builder
Lepomis cyanellus	Centrarchidae	General Invertivore	Yes
Lepomis gulosus	Centrarchidae	General Invertivore	Yes
Lepomis humilis	Centrarchidae	General Invertivore	Yes
Lepomis macrochirus	Centrarchidae	General Invertivore	Yes
Lepomis megalotis	Centrarchidae	General Invertivore	Yes
Micropterus dolomieu	Centrarchidae	Piscivore	Yes
Campostoma anomalum	Cyprinidae	Herbivore/Detritivore	No
Cyprinella whipplei	Cyprinidae	Surface/Water Column Invertivore	No
Notropis boops	Cyprinidae	Surface/Water Column Invertivore	No
Notropis suttkusi	Cyprinidae	Benthic Invertivore	No
Pimephales notatus	Cyprinidae	Omnivore	Yes
Noturus spp	Ictaluridae	Benthic Invertivore	No
Pylodictis olivaris	Ictaluridae	Piscivore	Yes
Etheostoma maculatum	Percidae	Benthic Invertivore	Yes
Etheostoma nigrum	Percidae	Benthic Invertivore	Yes
Etheostoma radiosum	Percidae	Benthic Invertivore	No
Percina caprodes	Percidae	Benthic Invertivore	No
Percina copelandi	Percidae	Benthic Invertivore	No
Percina maculata	Percidae	Surface/Water Column Invertivore	No
Percina phoxocephala	Percidae	Benthic Invertivore	No
Percina sciera	Percidae	Benthic Invertivore	No
Aplodinotus grunniens	Other	Benthic Invertivore	No
Lepisosteus oculatus	Other	Piscivore	No
Moxostoma erythrurum	Other	Benthic Invertivore	No

[a]The family group "Other" was used to group fish species that did not have more than two species in a family.
[b]Fish species do not include the singleton species removed from the analysis.

(D_{90} / D_{50}) within each site (Williams 1980).

We estimated CPUE by dividing the total number of fish caught at each site by the time (in minutes) spent electrofishing. We first compared total fish abundance and species richness between mussel and non-mussel sites. We then classified fish by taxonomy, feeding guild, and nesting behavior and compared the abundance of these groups on and off mussel beds. We used non-parametric tests to analyze data as they did not meet normality requirements. We compared total abundance, total richness, and nesting behavior with the Wilcoxin signed-ranks test and differences among fish families and feeding groups with a Kruskal-Wallis test.

Fish families were Percidae, Cyprinidae, Centrarchidae, Ictaluridae, and 'other fish' (consisting of fish that did not have more than two species in a family). We assigned fish to feeding guilds (benthic invertivore, general invertivore, herbivore/detritivore, omnivore, piscivore, surface/water column invertivore according to Poff and Allan (1995), Taylor and Warren (2001), Miller and Robison (2004), Gido and Franssen (2007), and Frimpong and Angermeier (2009; Table 2). Fish were classified as nest builders or non-nest builders following Frimpong and Angermeier (2009; Table 2). Singleton species, those species in which only one individual was found across all sites, were tallied, but were not used in further statistical analyses to avoid rare species bias (Cao et al. 1998; Cao et al. 2001).

Results

All sites were sampled in riffle-run reaches during summer low-flow conditions. Overall, mussel and non-mussel sites had similar environmental conditions (Table 1). On average, sites were 72.9 m in length and 25.1 m in width. Minor but statistically significant differences were observed between mussel and non-mussel sites in mean temperature (0.7 ºC), mean pH (0.2 pH units), mean dissolved oxygen (1.0 mg/L), mean current velocity (0.05 m/s) and mean

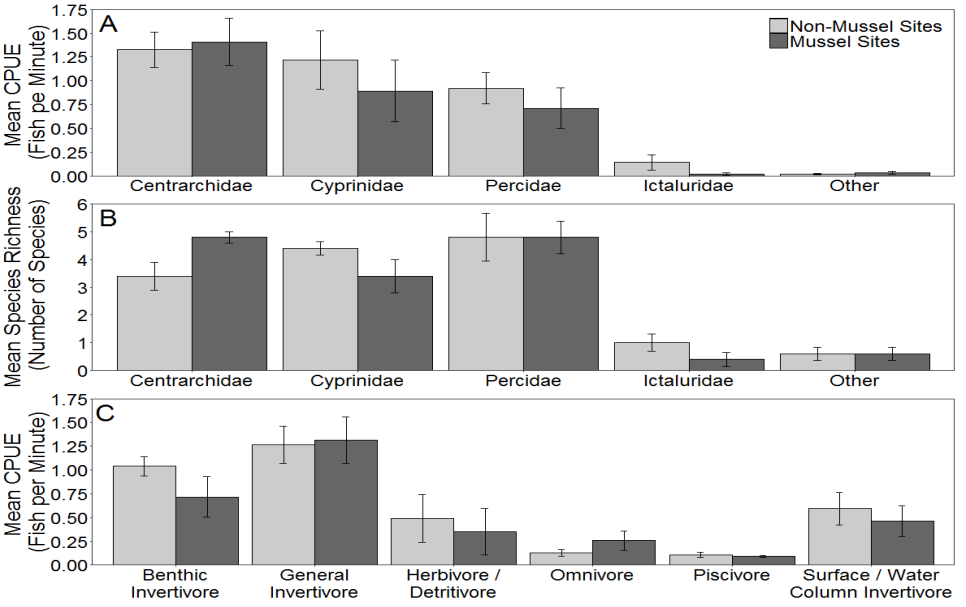

Figure 2. Mean CPUE for each fish family between mussel and non-mussel sites (A). Mean species richness for each fish family between mussel and non-mussel sites (B). Mean CPUE for each feeding guild between mussel and non-mussel sites (C). Error bars on each panel represent ± SE.

depth (0.07 m) (Table 1).

We collected a total of 964 fish across 34 species. Ten of the 34 species occurred as singletons and were removed from further analyses (i.e. 10 singleton species). Neither total fish abundance (mussel = 3.06 ± 0.43, non-mussel 3.63 ± 0.43, W = 2806, P = 0.1862) or species richness (mussel = 14.0 ± 0.63, non-mussel 14.2 ± 0.97, W = 317.5, P = 0.9292) varied significantly between mussel and non-mussel reaches.

The abundance and species richness of fish families, and the abundance of fish feeding guilds also did not vary significantly between mussel and non-mussel sites (Fig. 2). Ten of the 24 species analyzed were classified as nest builders (Table 2). Mussel sites had a significantly higher proportion of nest building fish than non-mussel sites. On average, 50% ± 0.02 of the fish species found at mussel sites were nest builders, while only 41% ± 0.03 of the fish found at non-mussel sites were nest builders (W = 2.5, P = 0.0439).

Discussion

It is well known that fish communities impact the abundance and species composition of mussel communities (Vaughn and Taylor 2000; Vaughn 2012; Schwalb et al. 2013). We asked if mussels, in turn, influence fish community composition. We found a significantly higher proportion of nest building fish on mussel sites as opposed to non-mussel sites. However, we found no significant differences in overall fish abundance, species richness, taxonomic composition, or feeding guilds between mussel and non-mussel sites. Thus, with the exception of potential effects on nesting behavior, we detected no effects of mussels on the abundance and composition of fish in the Kiamichi River.

Our finding of no influence of mussel communities on fish communities could be because there is indeed no effect, because of improper site selection, or be due to sampling error (time of sample collection and small sample size). Fish assemblages are greatly influenced by environmental and landscape factors (Marsh-Matthews and Matthews 2000; Porter and Patton 2015), and these are likely the primary controls on fish composition in the river. To account for this, we attempted to minimize differences in environmental variables among mussel and non-mussel sites. We did, however, observe slight differences in water temperature, pH, dissolved oxygen, current velocity and depth among mussel and non-mussel sites (Table 1). Temperature, pH, and dissolved oxygen are typically spatially homogenous in a stream at any given time, and therefore not likely to influence fish community structure. Increases in water depth and in stream complexity associated with higher current velocity are both associated with an increases in fish species richness (Sheldon 1968; Taylor et al. 1993; Marsh-Matthews and Matthews 2000). However, both species richness and species composition were similar between mussel and non-mussel sites in our study (Figure 2). We don't think that the slight differences in depth (0.07 m) and velocity (0.05 m/s) that we observed between mussel and non-mussel sites influenced fish species composition.

Further, our study was conducted during a single field season and each site was only sampled one time, thus our results represent a static "snapshot in time", while highly mobile fishes move in and out of habitats temporally. Finally, our data indicate that we under sampled some components of the fish community. The Kiamichi River supports a diverse fish fauna of 86 species, but many of these species are relatively rare (Pyron et al. 1998; Matthews et al. 2005). During our limited survey of 10 sites using electrofishing, we collected 34 species or approximately 40% of the known fauna. We know that we under sampled some fishes because of their size or habitat preferences. For example, we visually observed freshwater drum (*Aplodinotus grunniens*) and spotted gar (*Lepisosteus oculatus*) at most of the sites, but failed to capture many individuals because of our sampling method. However, the majority of species we sampled are considered to be ubiquitous throughout the Kiamichi River (15 out of 24 species analyzed; Porter and Patton 2015), and we are confident that we sampled the majority of common species that were found in

mussel and non-mussel sites.

We found more species of nest building fish in mussel sites compared to non-mussel sites. Mussel shells provide biogenic habitat and mussel aggregations may act to stabilize stream sediments during high flow events (Strayer 1999; Zimmerman and De Szalay 2007). This alteration to the benthic habitat may be attractive to fish that need firm substrate in which to construct their dish-like nests (Danylchuk and Fox 1996). All of the Centrarchidae collected in our study were nest builders, and centrarchid nests are commonly seen within mussel beds in the Kiamichi River and other nearby rivers (C. Vaughn, personal observation). While not statistically significant, we did find slightly more species of Centrarchidae in mussel sites (mussel = 4.8 ± 0.2, non-mussel = 3.4 ± 0.5). As discussed above, we don't think that the slight differences in depth and velocity observed among mussel and non-mussel sites influenced the distribution of nest-building fish.

Do mussel communities influence fish communities? With the exception of differences in the number of nest building species, we found no influence of mussel communities on the composition and abundance of fish in the Kiamichi River. However, our study was limited by sample size, methodology and timing. To robustly address this question we suggest further work should be done examining more sites, employing methods beyond electrofishing, and sampling fishes seasonally. Additionally, observational studies of fish movement and behavior on and off mussel beds would be useful.

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First Evidence of Blue Catfish Natural Reproduction in Canton Reservoir, Oklahoma

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Abstract: Blue catfish (*Ictalurus furcatus*) is the largest member of Ictaluridae and is the second largest fish in Oklahoma. Oklahoma Department of Wildlife Conservation (ODWC) has introduced Blue Catfish to many Oklahoma reservoirs due to their popularity among anglers. In 1983, Blue Catfish were stocked into Canton Reservoir in hopes of creating a self-staining population, but to date, no natural recruitment of Blue Catfish has been observed in Canton Reservoir. However, in 2016 seven juvenile Blue Catfish were collected in Canton Reservoir, Oklahoma. Fish were collected during electrofishing and experimental gill-net surveys. All of these fish were estimated to be age-1 using the lapilli otoliths (one of the three pair of ear stones that comprise the inner ear of fish), suggesting that Blue Catfish successfully spawned in Canton Reservoir in 2015. Blue Catfish spawn in late spring to early summer in Oklahoma. Conditions during spring 2015 consisted of high flow events from the North Canadian River resulting in an increase of pool elevation in Canton Reservoir. Prior to the increase in pool elevation, Canton Reservoir was experiencing low water levels due to an extended drought (2012-2015). During this drought, herbaceous and woody vegetation established in the dry reservoir bottom, however when inundated during spring 2015, it provided habitat which may have been utilized for spawning by adult Blue Catfish and as nursery habitat by juveniles. Understanding environmental conditions that lead to successful spawn and year-class formation of Blue Catfish in Canton Reservoir will aid in future management decisions for this species.

Introduction

Blue catfish (*Ictalurus furcatus*) are the largest member of Ictaluridae and are native to the Arkansas and Red River systems in Oklahoma. The Oklahoma Department of Wildlife Conservation (ODWC) has introduced Blue Catfish into many Oklahoma reservoirs outside their native river basins (Miller and Robinson 2004). Currently, they are found in reservoirs and river systems throughout Oklahoma. The accessibility and trophy potential of Blue Catfish has helped make this species popular among Oklahoma anglers (Kuklinski and Patterson 2011). Blue Catfish has gone from the ninth most preferred species in 1985 to the fourth most preferred species during 2001– present by anglers in Oklahoma (Summers 2009; Jager 2015).

Due to Blue Catfish popularity among Oklahoma anglers, ODWC wanted to create a sport fishery in Canton Reservoir by stocking Blue Catfish. A total of six stocking events

occurred over the span of 24 years (1983-2007) in repeated attempts to establish a Blue Catfish population in Canton Reservoir. However, Blue Catfish were never observed in sampling efforts following these stocking events (unpublished data ODWC). Despite not ever being caught in ODWC annual sampling, anglers have reported encounters with Blue Catfish in Canton Reservoir since the late 1980's, with recent accounts referencing large fish (John Stahl, Oklahoma Department of Wildlife Conservation, personal communication). For example, on September 28, 2015 a 27.7 kg Blue Catfish was harvested by an angler and is the current lake record for Canton Reservoir. However, there has never been reports of small Blue Catfish being caught until recently.

During an annual electrofishing survey in July 2016, ODWC northwest region fisheries staff collected four juvenile Blue Catfish. Then in October 2016 fall standardized gillnet surveys, three juvenile Blue Catfish were captured. The following year in May during a tagging event for the walleye rodeo fishing tournament, 5 more individuals were collect (via electrofishing). The purpose of this study is to estimate age of the Blue Catfish captured during these surveys and back-calculate spawning year to evaluate the environmental conditions which contributed to the first documented spawning success of Blue Catfish in Canton Reservoir.

Methods

Study area - Canton Reservoir is a 3,201-ha impoundment located in Blaine and Dewey Counties in northwest Oklahoma (Figure 1). Canton Reservoir has a maximum depth of 10.7 m and average depth of 4.6 m. It was built in 1948 to serve as flood control for the North Canadian River, which is the major tributary that flows into the lake. However, the reservoir also serves as a municipal water supply for the city of Oklahoma City.

Sampling - Blue Catfish were collected from Canton Reservoir in July of 2016, using

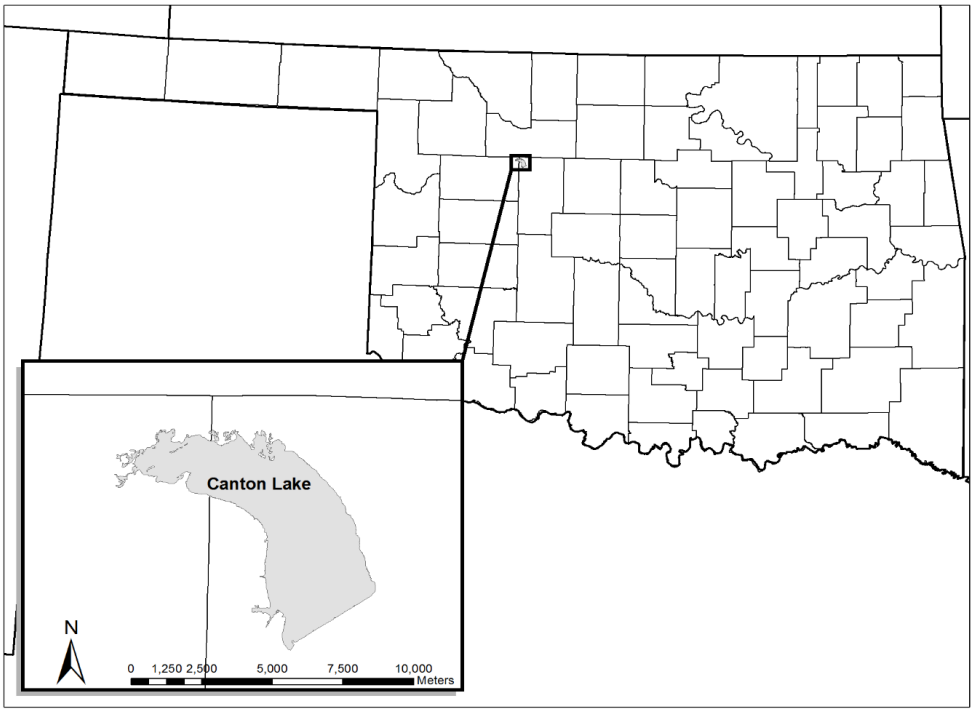

Figure 1. Canton Reservoir is located in Blaine and Dewey in northwest Oklahoma, near the towns of Longdale and Canton.

electrofishing (ETS MBS-1DP-SR-7200, 15 pulse/sec, set for optimal power; Miranda 2009, Bodine et al. 2011). Electrofishing sites were chosen at random and each site consisted of a five-minute unit of effort during daylight hours. In October of 2016, gillnetting was performed following standard protocols recommended by Miranda and Boxrucker (2009). Gillnets were bottom-set perpendicular to shore at depths ranging from 1.8 to 4.6 m. Experimental gill nets used were 61 m long x 1.8 m tall and constructed of eight 7.6 m panels (12.7, 15.9, 19.1, 25.4, 38.1, 50.8, 63.5, and 76.2 mm bar mesh).

Otolith aging - Following capture, each fish was measured for total length (TL; mm) and lapilli otoliths were removed for age estimation. Otoliths were dried for a period > 24 hours. After drying, lapilli otoliths were browned at 104°C on a hot plate to increase contrast between accretion and discontinuous zones (Secor et al.1992, Long and Snow 2016). After browning, otoliths were embedded in Loctite 349 (Mauck and Boxrucker 2004) and sectioned with a low speed IsoMet® saw (127 mm x 0.4 mm). To estimate age, the otolith was positioned sectioned-side up in modeling clay, covered with immersion oil to enhance annuli, and viewed with a dissecting microscope (4-45x) using a fiber optic light source. Annuli, which appeared as dark rings on a light background, were counted to assign an age estimate to each fish. Each otolith was evaluated by two independent readers (Hoff et al. 1997).

Descriptive statistics – Mean length-at-age was calculated to compare average growth rate from Canton Reservoir Blue Catfish to other Oklahoma Blue Catfish populations. The back-calculated spawning year was calculated for each Blue Catfish using age estimates from lapilli age estimates, and those spawning years were compared against lake condition for those years with pool elevation data for Canton Reservoir at (U.S. Army Corps of Engineers) and river discharge for the North Canadian River upstream of Canton Reservoir (USGS gage #07238000).

Results and Discussion

Seven juvenile Blue Catfish ranging from 220 – 291 mm in total length were collected in July and October 2016 with 5 addition fish collected in May of 2017. All fish were estimated to be age-1 in 2016 and age-2 in 2017 (Figure 2), suggesting that Blue Catfish successfully spawned in spring 2015. Because these fish are not age-0, back-calculation of spawning date is not possible as daily growth increments are no longer visible on otoliths. However, Blue Catfish spawn in late spring to early summer in Oklahoma (Miller and Robinson 2004). We surmise that spawning occurred in June 2015 in Canton Reservoir, because prior to the spawning event, Canton Reservoir was at its lowest pool elevation in recorded history. During this drought (November 2011 through April 2015) herbaceous and woody vegetation colonized the dry portion of lake bed and exposed shoreline. Then during April- July 2015, the pool elevation quickly increased by 2.74 m (Figure 3). By June, the terrestrial vegetation was entirely inundated. It is likely that Blue Catfish utilized this new habitat for spawning (Graham 1999) or as nursery areas for young fish.

Blue catfish are highly migratory, and have been found to move upstream in the spring in response to river flow (Garrett and Rabeni 2011) and water temperature increase (21 - 25ºC) in search of spawning sites (Graham 1999; Sublette et al. 1990). The North Canadian River that

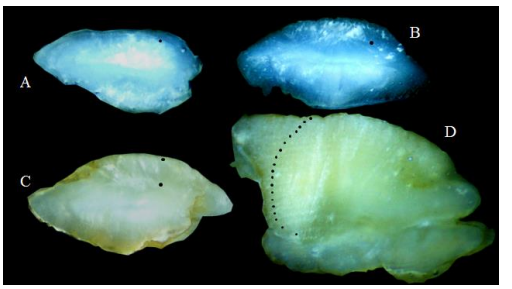

Figure 2. Photograph depicting annuli on lapilli otoliths of Blue Catfish from Canton Reservoir, Oklahoma A) Age-1 fish 228 mm TL collected July 2016; B) Age-1 fish 278 mm TL collected October 2016; C) Age-2 fish 282 mm TL collected May 2017; D) Age-19 fish 988 mm TL collected May 2017).

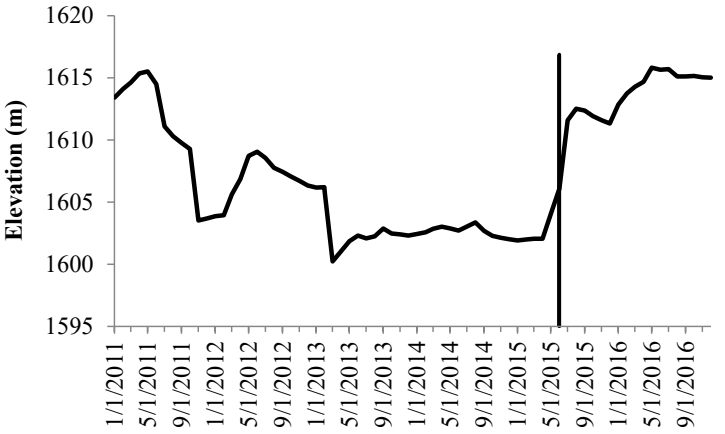

Figure 3. Canton Reservoir pool elevation from 2011 – 2016 using data from the U.S. Army Corps of Engineers. We speculate that spawning occurred in June based on knowledge of historical Blue Catfish spawning times in Oklahoma (Miller and Robinson 2004), which is represented by the vertical bar.

flows into Canton Reservoir is a shallow, prairie stream that on occasion will flood, but does not function like a large river system. High flow events starting in April 2015 and lasting through June 2015 (U.S. Geological Survey gage # 07238000), may have triggered a spawning run of Blue Catfish. By June, the pool elevation had almost returned the lake to normal pool conditions (Figure 4), which may have allowed Blue Catfish to find spawning sites in the newly established vegetation around the perimeter of the lake. Because daily increments have been validated for Blue Catfish (Sakaris et al. 2011), it is possible to back-calculate spawning dates of age-0 fish that are sampled in the future, which may allow us to better understand conditions leading to the timing of reproduction and the potential successful recruitment of Blue Catfish. Little information exists in the literature describing the environmental variables contributing to spawning success and recruitment of Blue Catfish and is a need of further research.

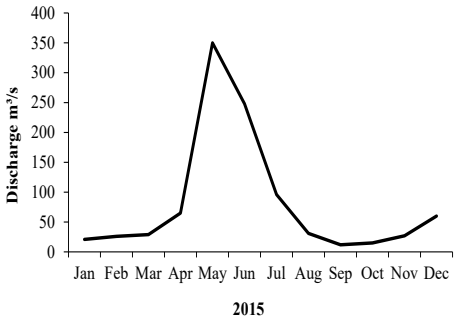

Figure 4. Spring river conditions of the North Canadian River (USGS gage #07238000) during 2015 when successful Blue Catfish reproduction occurred in Canton Lake.

A side effect of a flood event, especially after a prolonged dry period, is a large pulse of nutrients entering the system. This increased nutrient loading can lead to increased species richness, diversity and overall system productivity (Bayley 1995; Robertson et al. 2001). Blue Catfish populations in Texas have shown to be influenced by surface area, growing season, and productivity (Bartram et al. 2011). Furthermore, Bartram et al. (2011) found that stocking Blue Catfish into larger reservoirs with poor productivity yielded poor returns of stocked fish. Canton Reservoir is considered a hypereutrophic lake, however during the drought period (2011 – 2015) no runoff occurred from the agricultural land that dominates the watershed. Besides the increased spring flows and habitat abundance, it is possible that runoff from upstream agricultural sources increased productivity in Canton Reservoir assisting in conditions favorable to the formation of a Blue Catfish year class. However, without pre- and post-drought water quality data this is merely

speculation. Blue Catfish may have spawned annually with no observed recruitment due to comparatively low productivity. A long-term water quality monitoring program in Canton Reservoir would be beneficial to determine if reservoir productivity is critical to reproduction and recruitment of Blue Catfish.

Unfortunately, we could only speculate which Blue Catfish stocking event contributed to this reproduction event in Canton Reservoir. Only two adult Blue Catfish have been captured and verified by ODWC personnel from Canton Reservoir since stocking was initiated in 1983 (Table 1), although anglers have reported catching Blue Catfish through the years. The first fish is the current lake record, however the age is unknown preventing us the ability to back calculate the year of stocking. More recently, a large Blue Catfish was caught and weighed in at the Canton Lake Walleye Rodeo in May 2017. This fish measured 988 mm TL, weighed 13.7 k g, and the estimated age of this fish was 19 (Figure 2). This fish likely came from the 2007 stocking event when 163 fish from Ellsworth Lake were stocked into Canton Reservoir. These fish averaged 305 mm TL at stocking, and based on previous Blue Catfish age data, ranged in age from 7-9 years old (Kuklinski and Patterson 2011). The longevity of Blue Catfish in Oklahoma is around 20 years old, however fish have been estimated to be 32-year-old from R. S. Kerr Reservoir (Boxrucker and Kuklinski 2006; Kuklinski and Patterson 2011). Assuming that Blue Catfish longevity similar to R. S. Kerr Reservoir then Blue Catfish stocked after 1984 could have contributed to the reproduction success of Blue Catfish in 2015.

Table 1. Year, number of fish stocked, total length, and stocking rates of Blue Catfish stocked in Canton Reservoir, Oklahoma.

Year	Number Stocked	Length (mm)	Density (fish/ha)
1983	41,070	119	12.83
1989	74,889	79	23.39
1991	21,717	114	6.78
1992	27,200	152	8.49
1993	89	Adults	0.02
2007	163	305	0.05

Otolith analysis of Blue Catfish in Canton Reservoir reveals fast growth rates. Blue Catfish grew an average of 229 mm in the first year in Canton Reservoir. In comparison to other studied populations of Blue Catfish in Oklahoma, the Canton population growth rate was faster than 84.6% of other systems sampled during 2004 – 2007 (Boxrucker and Kuklinski 2006; Kuklinski and Patterson 2011; Table 2). Considerable growth continued as age-2 fish gained 45 mm in their second year (274 mm mean TL). Mean length at age of 2-year-old Blue Catfish was greater than 75% of Oklahoma populations, with similar growth rates to Arcadia, Keystone and Sardis Reservoirs (Table 2). Growth of Blue Catfish in reservoirs is dependent on several variables such as length of the growing season, lake fertility, fish density, forage density and water temperature (Graham 1999). Canton Reservoir is a hypereutrophic system with adequate forage, however the fish community is comprised of a high abundance of predators which could lead to interspecific competition and growth effects.

If Blue Catfish spawning coincides with increased spring flows and a rise in pool elevation that inundates terrestrial vegetation to provide spawning and nursery habitat, this information could be used by fisheries managers to predict when a Blue Catfish year class may be formed. It may be possible to manipulate pool elevation in reservoirs to attempt to produce a year class of Blue Catfish if the pool elevation was drawn down for an extended period to allow herbaceous vegetation to colonize the littoral areas of the reservoir. This is an unrealistic approach for Canton Reservoir since this is a municipal water source for downstream Oklahoma City, however it could be possible in other medium to small impoundments where establishing a Blue Catfish population is desirable. Furthermore, if no age-1 Blue Catfish are sampled in 2017 but age-2 individuals are, one could conclude that a pulse of water is more important in spawning success than just a rise in pool elevation that inundates spawning habitat. Conversely, if age-1 and age-2 Blue Catfish are collected and there was no extreme spring flow event or increase in pool elevation, then it is merely a function of habitat,

Table 2. Comparison of age 1 Blue Catfish mean total length (mm) and standard error from Oklahoma Reservoirs. Data from **Boxrucker and Kuklinski (2006) and *Kuklinski and Patterson (2011). Bold lettering represents study lake.

			Age 1		Age 2	
Lake	Year Sampled	Suface Acres (ha)	N	Length (mm)	N	Length (mm)
Arcadia	2006	737	45	205 (±5)	54	283 (±5)
Canton	**2016**	**3,201**	**4**	**229 (±3)**	**5**	**274 (±3)**
Ellsworth**	2004	2,258	2	166 (±18)	32	186 (±3)
Eufuala**	2005	45,540	48	156 (±4)	41	203 (±4)
Fort Gibson*	2005	8,053	7	174 (±7)	35	202 (±3)
Hugo**	2005	5,343	721	168 (±1)	212	223 (±2)
Kaw**	2004	6,871	21	174 (±2)	75	232 (±2)
Keystone**	2005	9,520	98	195 (±3)	57	277 (±5)
Oologah*	2006	11,736	283	188 (±1)	141	247 (±3)
R.S Kerr*	2006	17,401	172	185 (±2)	126	229 (±2)
Sardis*	2007	5,811	1	269	10	293 (±3)
Texoma**	2003	35,600	30	172 (±3)	21	253 (±10)
Waurika**	2004	4,073	22	184 (±3)	278	194 (±2)

which could be addressed by fishery managers. An electrofishing survey was conducted in July 2017 and resulted in 0 age-1 Blue Catfish being caught, however 38 age-2 (verified by aging 13 individuals) with a mean TL 342 mm (±3.4 SE) were captured, leading us to believe that the pulse of water experienced in spring 2015 queued fish to spawn, which resulted in a successful reproduction event of Blue Catfish in Canton Reservoir.

We will continue to monitor Blue Catfish in Canton Reservoir into the future in an attempt to determine which environmental factors (or combination of factors) lead to reproduction and recruitment of Blue Catfish. Because the adult Blue Catfish in Canton Reservoir are reaching the maximum longevity (~20 years) for this species in Oklahoma (Kuklinski and Patterson 2011), a stocking program may need to be developed and implemented to maintain a population of sexually mature adult Blue Catfish in this system if successful Blue Catfish reproduction does not continue.

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First Report of *Mesocestoides* sp. Tetrathyridia (Cestoda: Cyclophyllidea) from the American Bullfrog, *Rana catesbeiana* (Anura: Ranidae)

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Abstract: A single adult American bullfrog, *Rana* (=*Lithobates*) *catesbeiana* collected from McCurtain County, Oklahoma, was found to harbor tetrathyridia of *Mesocestoides* sp. Specimens representing the non-proliferating type of *Mesocestoides* occurred in the mesenteries as well as encapsulated in the liver, spleen, and gastrointestinal tract. This discovery is rare and, most interesting, because many surveys of large numbers of *R. catesbeiana* have failed to report this cestode in American Bullfrogs from throughout its range in North America. Although seven other species of ranid frogs from Arkansas, Iowa, Kansas, Michigan, Nebraska, New York, South Dakota, Texas, and Wisconsin have been reported to harbor *Mesocestoides* sp., we report it for the first time from the largest species of North American frog.

Introduction

Over 25 yr ago, McAllister and Conn (1990) were the first to provide a summary of North American anuran hosts of *Mesocestoides* sp. Noticeably absent from that host list was the largest North American frog, the American Bullfrog, *Rana* (=*Lithobates*) *catesbeiana* Shaw, 1802. More recently, McAllister et al. (2014) updated that list to include all North American amphibian hosts of this tapeworm. In their list, seven species of frogs of the family Ranidae were reported as hosts of *Mesocestoides* sp. collected from Arkansas, Iowa, Kansas, Michigan, Nebraska, New York, South Dakota, Texas, and Wisconsin. Again, *R. catesbeiana* was not on this list. The reason for this absence is an enigma as its ecology is very similar to other ranid frogs (Stebbins et al. 1995; Casper and Hendricks 2005), including northern and southern leopard frogs (*Rana pipiens* and *R. sphenocephalus*), who have previously been commonly reported as hosts (McAllister et al. 2014). Indeed, a summary of parasites of *R. catesbeiana* was provided by Andrews et al. (1992) and Mata-López et al. (2010), and, although they collectively list at least 10 species of cestodes from native and non-native populations of this host, neither lists *Mesocestoides* sp. Many surveys utilizing hundreds of specimens of *R. catesbeiana* have been reported from numerous North American localities; however, none, to date (Harwood 1932; Trowbridge and Hefley 1934; Brandt 1936; Odlaug 1954; Najarian 1955; Campbell 1968; Lank 1971; Hollis 1972; Brooks 1976; Lemke et al. 1982; Muzzall 1991;

Andrews et al. 1992; McAlpine 1997; Yoder and Gomez 1997; Goldberg et al., 1998; McAlpine and Burt 1998; Goldberg and Bursey 2002; Conn et al. 2002; Mata-López et al. 2010; and others) have reported this frog as a host of this tapeworm. Here, we document the first report of *Mesocestoides* sp. from *R. catesbeiana*.

Between May 2013 and September 2016, 18 juvenile and adult American bullfrogs (mean ± 1SD snout-vent length [SVL] = 65.3 ± 38.1, range 35–102 mm) were collected by hand or dipnet from Little River (n = 7) and Polk (n = 7) counties, Arkansas, and McCurtain (n = 4) County, Oklahoma. Specimens were placed in individual collection bags on ice and following the guidelines for the human treatment of research animals (HACC 2004) were overdosed by immersion in a concentrated chloretone (chlorobutanol) solution. A mid–ventral incision was made from throat to cloaca and the viscera and body cavity examined for *Mesocestoides* sp. When suspected encapsulated cestodes were observed, they were excised with a bit of tissue and preserved in 10% neutral buffered formalin. Other specimens were teased from mesenteries and preserved in 70–90% (v/v) DNA grade ethanol. For light microscopy, we used standard histological techniques to prepare the tissue preserved in 10% neutral-buffered formalin for light microscopy following Presnell and Schreibman (1997). For photomicroscopy, we used a Nikon Eclipse 600 epifluorescent light microscope with a Nikon DXM 1200C digital camera (Nikon Instruments Inc., Melville, NY). A host voucher specimen was deposited in the Arkansas State University Herpetological Museum (ASUMZ), State University, Arkansas. Voucher specimens of *Mesocestoides* sp. were deposited in the Harold W. Manter Laboratory of Parasitology (HWML), University of Nebraska, Lincoln, Nebraska. We follow Yuan et al. (2016) in the taxonomic use of the genus *Rana* (rather than *Lithobates*) for North American ranid frogs.

Results and Discussion

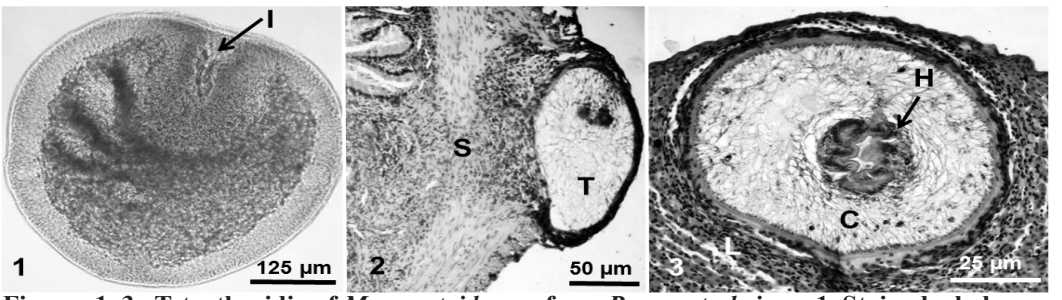
One of 18 (6%) *R. catesbeiana* was found to be infected with encapsulated and free tetrathyridia of *Mesocestoides* sp. as follows.

Cestoda: Cyclophyllidea: Mesocestoididae
***Mesocestoides* sp. Vaillant, 1863 (Figs. 1–3)**

***Host and locality*:** American bullfrog, *Rana catesbeiana* (ASUMZ 33580, 102 mm SVL, adult male) collected on 29 June 2016 from Yanubbee Creek off county road N4680 at Broken Bow, McCurtain County, Oklahoma (34° 02’ 45.6426” N, 94° 43’ 19.761” W).

Prevalence and intensity: 1/18 (6%) overall; 1/4 (25%) McCurtain County, Oklahoma; tetrathyridia too numerous to count.

***Site of infection*:** Free tetrathyridia in body cavity (Fig. 1); encapsulations in intestinal tract (Fig. 2), liver (Fig. 3), and spleen.



Figures 1–3. Tetrathyridia of *Mesocestoides* sp. from *Rana catesbeiana*. 1. Stained whole mount of free tetrathyridium from body cavity showing invaginated scolex and deep invagination canal (I). 2. Low power microscopic view showing stained histological section of encapsulated tetrathyridium (T) on serosal surface (S) of intestinal tract. 3. Higher power microscopic view of stained histological section of tetrathyridium in host-derived fibrotic capsule in liver. Note the solid hindbody characteristic of tetrathyridia of *Mesocestoides*. Abbreviations = calcareous corpuscles (C); scolex holdfast (H).

Morphological and histological features: Tetrathyridia possessed characteristic individual features of a single invaginated scolex, a generally deep invagination canal (Fig. 1), calcareous corpuscles, and a solid hindbody (Figs. 1–3). No tetrathyridium possessed a divided scolex, somatic bud, or any tegumental or excretory anomalies such as those reported rarely from tetrathyridia in some aberrant acephalic tetrathyridia from other host species (Conn et al. 2010; see also recent review by Conn et al. 2011).

Additional Oklahoma records: Caudata: Sequoyah slimy salamander, *Plethodon sequoyah* Highton, 1989 (McAllister and Bursey 2004); Anura: Hurter's spadefoot, *Scaphiopus hurterii* Strecker, 1910, and plains spadefoot, *Spea bombifrons* (Cope, 1863) (McAllister et al. 2005).

Additional reports, anurans: see summary by McAllister et al. (2014).

Other reported herpetofauna: See recent summary by Bursey et al. (2012) which includes a variety of hosts, including amphibians and reptiles from the Asian, Australo-Papuan, Ethiopian, Nearctic, Neotropical, and Palearctic regions.

Geographic range: The genus is cosmopolitan (Schmidt 1986).

Type species, type host and type locality: *Mesocestoides ambiguous* (Mammalia: Carnivora), small-spotted genet, *Vivera genetta*, Africa (Vaillant 1863).

Specimens deposited: HWML 102076–102077 (slides).

The life cycle of *Mesocestoides* spp. has been and remains an enigma. Current thought of most researchers is that it requires at least three hosts (i.e., a vertebrate definitive host, a vertebrate second intermediate host, and a supposed arthropod first intermediate host) (Rausch 1994), though this has not been verified and the putative first-intermediate host is not known. Indeed, it is not unusual to find encapsulated and free tetrathyridia in the body cavity and various organs of amphibians, reptiles and rodents (Padgett and Boyce 2004) as well as some birds (Skirnissonet al. 2016), all of which have been assumed to be second-intermediate hosts. In our sample, there was no morphological, histological or other evidence of asexual proliferation. Thus, these findings are consistent with the absence of asexual reproductive capacity reported in our earlier studies (for example, see McAllister et al. 1989, 1992, 2005, 2013a, b, 2014, 2015; Conn and McAllister 1990; McAllister and Conn 1990), and corroborate the rarity of asexuality for tetrathyridia in general (Conn 1990; Conn et al. 2011).

We cannot offer any explanation for the absence of *Mesocestoides* in *R. catesbeiana* from all previously published surveys. This frog has been reported to prey on a great diversity of invertebrate and vertebrate fauna (see Table SP-3 of Casper and Hendricks 2005). The study site noted herein (Yanubbee Creek) is not unlike other watersheds in Arkansas or Oklahoma where we have collected *R. catesbeiana* in the past. Perhaps some unknown intermediate host occurs at that site and additional research will be required to investigate this unusual finding in a common, widely-ranging, anuran.

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Parasitic Acari from Four Oklahoma Vertebrates (Aves, Mammalia), Including New State Records for Mites (Laelapidae, Listrophoridae, Macronyssidae)

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Over the last decade, our community collaborative efforts have provided several new records for mites (including chiggers), ticks, lice, and fleas parasitizing Oklahoma vertebrates (McAllister et al. 2013b, c, 2014a, b, 2015; Connior et al. 2015). To that end, we report additional ectoparasite records for a bird and three mammalian hosts from the state.

Collections were made between July 2014 and April 2017 from sites in McCurtain County and hosts and/or their nests were examined for ectoparasites as follows: a road-killed eastern gray squirrel, *Sciurus carolinensis* was taken on 2 July 2014 from Broken Bow off Memorial Drive (34° 00' 41.8566"N, 94° 44' 53.7972"W); a nuisance adult Virginia opossum (*Didelphis virginiana*) was killed on 7 March 2016 by a local landowner in Idabel off Chico Road (33° 53' 12.2028"N, 94° 54' 48.5598"W); three southern short-tailed shrews (*Blarina carolinensis*) were collected by hand on 29 November 2016 from Hochatown on Halibut Bay Road (34° 10' 16.2114"N, 94° 45' 7.6278"W); and a barn swallow (*Hirundo rustica*) nest was examined on April 2017 from the same locale in Hochatown. Mites and ticks were collected and placed in vials containing 70% ethanol and shipped to the junior author for specific identification. Ectoparasites were processed and identified using appropriate guides (Whitaker 1982; Benton 1983; Keirans and Litwak 1989; Keirans and Durden 1998). Voucher specimens of ectoparasites were deposited in the General Ectoparasite Collection in the Department of Biology at Georgia Southern University, Statesboro, Georgia. Voucher hosts were deposited in the Henderson State University (HSU) collection, Arkadelphia, Arkansas.

Acari: Laelapidae

***Echinonyssus blarinae* (Herrin) – No common name (NCN)**. Seven female *E. blarinae* (accession no. L-3800A) were collected from two of three *B. carolinensis*. This mite has previously been reported from seven species of soricomorphs (including *B. carolinensis*) and from at least 17 States and Canadian Provinces (Whitaker and Wilson 1974; Ritzi et al. 2005; Whitaker et al. 1994, 2007; Nims et al. 2008; Sylvester et al. 2012; Connior et al. 2014). However, this is the first record from Oklahoma.

Listrophoridae

***Olistrophorus blarina* (Fain and Hyland) – NCN.** Six adult *O. blarina* (L-3800B) was collected from two of three *B. carolinensis.* This is a very small fur mite which has previously been collected from northern short-tailed shrew (*B. brevicauda*), *B. carolinensis*, and Elliot's short-tailed shrew (*B. hylophaga*), and has been reported from eight U.S. States (Whitaker and Wilson 1974; Whitaker et al. 1994, 2007; Ritzi et al. 2005; Nims et al. 2008; Connior et al. 2014). However, we document the first record of this mite from Oklahoma.

Macronyssidae

***Ornithonyssus bursa* (Berlese) – tropical fowl mite.** Hundreds of *O. bursa* (males, females, and larvae, L-3805) were found in a nest of *H. rustica*. The tropical fowl mite is almost entirely restricted to warm tropical and subtropical regions of most biogeographical realms. It is a hematophagous mite commonly found on a variety of wild and domestic birds, including canaries, caracara, chickens, common sparrow, ducks, English and European starlings, kingbird, meadowlark, pigeons, red-eyed vireo, turkey, and wood thrush, and other wild birds; they also occasionally bite humans (Denmark and Cromroy 2015). It is rarely found on mammals, but where infested birds are nesting in close proximity to humans, these mites may enter homes and bite its inhabitants. This is the first time, to our knowledge, that *O. bursa* has been reported from Oklahoma.

***Ornithonyssus wernecki* (Fonseca)** – NCN. Two female *O. wernecki* (L-3740) were found on *D. virginiana*. This mite is primarily an ectoparasite of New World marsupials and has been recorded from the eastern U.S., Brazil, Panama, Surinam, and Venezuela (Fonseca, 1948; Micherdzinski, 1980). Although there is a record from northern raccoon (*Procyon lotor*) and a few records from rodents, the latter hosts are likely considered accidental (Yunker et al. 1990). In the U.S., this mite has been reported previously from *D. virginiana* from Georgia, New Jersey, Tennessee, and West Virginia (Whitaker et al. 2007) (Fig. 1). We provide the first record of *O. wernecki* from west of the Mississippi River and, as such, this also represents a new state record for Oklahoma.

Ixodidae

***Amblyomma americanum* (Linnaeus) – Lone star tick.** A single nymphal *A. americanum* (L-3724) was taken from *S. carolinensis*. This is one of the most abundant tick species in the eastern United States and adults parasitize a variety of medium to large-sized mammals, especially white- tailed deer (*Odocoileus virginianus*), whereas immatures feed on various birds and mammals (Cooley and Kohls 1944; McAllister et al. 2016). There is a record of *A. americanum* from an eastern fox squirrel (*Sciurus niger*) in Arkansas (McAllister et al. 2016) and Durden et al. (2004) reported this tick from *S. carolinensis* in Georgia. However, this is the first time this tick has been reported from *S. carolinensis* in Oklahoma.

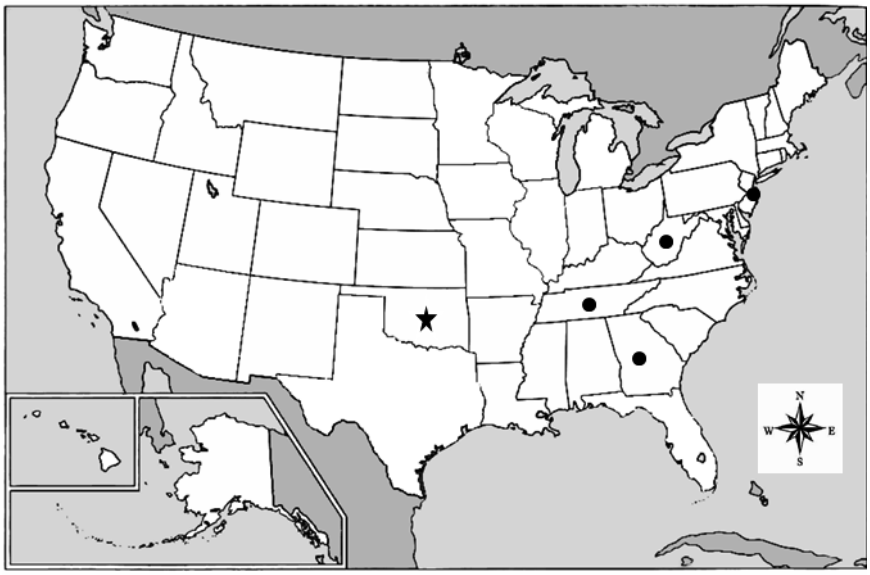

Figure 1. Records of *Ornithonyssus wernecki* from five states. Dots = previous records; star = new state record.

***Dermacenter variabilis* (Say) – American dog tick.** An unengorged female *D. variabilis* (L-3724) was taken from *S. carolinensis*. This tick is widely distributed in the eastern United States and in some western states (Strickland et al. 1976; McAllister et al. 2016). Adult *D. variabilis* usually infest dogs, raccoons, foxes, opossums, and humans; however, it is unusual to find this tick on a squirrel. McAllister et al. (2013a) reported one larval and two male *D. variabilis* on *S. niger* from Arkansas, but here, we document a new host record for *S. carolinensis*.

Oklahoma supports at least 106 species of mammals with nearly half of these being rodents (Caire et al. 1989). Although we have provided several new host and distributional records over the last decade, progress can be made when surveying additional potential hosts with the distinct possibility of discovering new ectoparasite records.

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Noteworthy Natural History and Ecological Information on Crayfishes (Decapoda) and Fishes (Actinopterygii) from Oklahoma

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Abstract: Here, in our second contribution on the subject, we include several noteworthy observations on the natural history and ecology of four cambarid crayfishes and five native fishes of Oklahoma. Information is given on reproduction, food habits, deformities, and other miscellaneous aspects of their biology. Our purpose is to help complement and fill gaps in our limited biological knowledge of this biota that should help in future studies conducted in the state.

Introduction

Although biological knowledge has been summarized on the 31 species of crayfishes (Morehouse and Tobler 2013; Taylor and Robison 2016) and over 180 species of fishes (Miller and Robison 2004) of Oklahoma, additional data on the natural history and ecology of select species is important to fill gaps in knowledge. Here, we provide noteworthy facts on several aspects of the natural history of four species of crayfishes and five taxa of native fishes of the state.

Methods

Crayfishes were collected by hand from various locales in McCurtain County and preserved in 70% isopropyl alcohol. Measurements on crayfishes were made using a Vernier caliper following Wang et al. (2011). We follow the classification scheme of Crandall and De Grave (2017) for the taxonomy of the crayfish family Cambaridae.

Fishes from a site in Adair County (35° 57' 28.44"N, 94° 46' 46.056"W), the Illinois River in Cherokee County (35° 57' 34.149"N, 94° 46' 30.8202"W), and locales at Lukfata (34° 03' 10.0866"N, 94° 48' 11.2536"W), Yanubbee (34° 02' 45.618"N, 94°43'19.7328"W), and two sites on Yashau (34°01'8.0112"N, 94°45' 24.5088"W and 33° 59' 14.496"N, 94° 44' 36.5712"W) creeks, McCurtain County. Fishes were collected 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% isopropanol. Total length (TL) was measured on all fishes, and specimens were examined for reproductive characters, and their eggs measured. Highland Stonerollers (*Campostoma spadiceum*) and Green Sunfishes (*Lepomis cyanellus*) were examined for ciliates following McAllister et al. (2016). All localities are reported as GPS (latitude and longitude) coordinates. Crayfish voucher specimens are deposited in the Southern Arkansas University (SAU) Collection, Magnolia, AR., and voucher fishes are deposited in the Henderson State University (HSU) Collection, Arkadelphia, AR.

Results and Discussion

The collections listed herein represent important records of observations of their natural history and are reported below in an annotated format and phylogenetic order.

Crustacea: Decapoda: Cambaridae (Cambarid crayfishes)

***Cambarus ludovicianus* Faxon, 1884 – Painted Devil Crayfish.** To date, ovigerous females of *C. ludovicianus* have not been reported from Oklahoma (Morehouse and Tobler 2013). On 4 December 1999, an ovigerous female with 104 ova (1.0–1.5 mm in diameter) was collected by hand from a roadside burrow off St. Hwy 3, 4.0 km SE of Haworth, McCurtain County (33° 49' 22.4898"N, 94° 36' 58.917"W). To our knowledge, no one has discussed reproduction of *C. ludovicianus* in the state (Creaser and Ortenburger 1933; Reimer 1968; Morehouse and Tobler 2013). In Louisiana, Penn and Marlow (1959) reported ovigerous females in December and January, whereas Walls (2009) revealed gravid females in that state were most likely to be found during the winter and spring. This is the first time ova have been quantified from an ovigerous *C. ludovicianus* from Oklahoma.

***Fallicambarus fodiens* (Cottle, 1863) – Digger Crayfish.** Creaser (1931) reported copulations of *F. fodiens* occurring in the fall and early spring. Morehouse and Tobler (2013) noted other studies corroborated this report with the collection of form I males, ovigerous females, and females with young from February through May, and August through November, depending on the latitude (Creaser 1931; Bovbjerg 1952; Page 1985; Jezerinac et al. 1995; Pflieger 1996; Taylor and Schuster 2004). In Louisiana, Walls (2009) found females with eggs and young during the cooler months of the year from November to March. On 15 April 2000, an ovigerous female *F. fodiens* with 138 ova (1.5–2.0 mm in diameter) was dug from a burrow in a roadside ditch on St. Hwy. 3, *ca.* 5.1 km N of Tom, McCurtain County (33° 47' 36.4272"N, 94° 34' 22.5114"W). To our knowledge, the present report is the first documented occurrence of an ovigerous female of *F. fodiens* in Oklahoma. In Arkansas, Hobbs and Robison (1989) reported egg masses of three ovigerous females with 177, 190, and 196 eggs, and diameters ranged from 1.9–2.0 mm. They noted ovigerous females were collected in February, April, and November, whereas females carrying young were taken in January, February, and March. In Ohio, Norrocky (1991) revealed *F. fodiens* bred in late spring or early summer and by October most mature females were carrying eggs containing embryos in an advanced stage of development: each female carried an average of 115 eggs and/or 74 young.

***Faxonius* (=*Orconectes*) *palmeri longimanus* (Faxon, 1898) – Western Painted Crayfish.** An unusually large male *F. p. longimanus* with extremely large chela (Fig. 1) was collected on 17 January 2014 by CTM from the Mountain Fork River at Beavers Bend State Park, McCurtain County (34° 08' 17.6994"N, 94° 41' 17.2032"W). Measurements (in mm) of this specimen are as follows: left chelae length (L) and width (W), 45.4 and 14.6, right chelae L and W, 53.6 and 17.5; body (carapace) L, W, and depth (D), 38.1, 24.2, and 22.2, respectively; abdomen L, 51.2, W, 20.2, and D, 14.3. Neither Williams (1954) for Arkansas specimens, Reimer (1968) for Oklahoma specimens, or Pflieger (1996) for Missouri specimens gave a maximum size for this crayfish. Because our specimen has a TL of 89.3 mm, and Morehouse and Tobler (2013) stated that this crayfish in Oklahoma rarely exceeds 80 mm in TL, we document a record size for the subspecies.

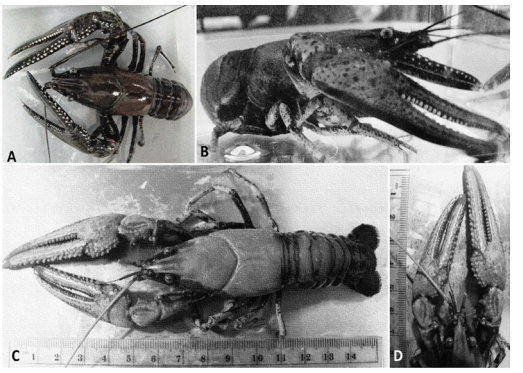

Figure 1. Large *Faxonius palmeri longimanus* from Mountain Fork River, McCurtain County, Oklahoma. A. Dorsal view of live specimen. B. Lateral view of same. C. Same specimen (preserved), showing its total length; note scale ruler. D. Same, showing large chelae; note scale ruler.

***Procambarus curdi* Reimer, 1975 – Red River Burrowing Crayfish.** Reimer (1975) originally described *P. curdi*, and listed several collecting localities in southern Oklahoma, including three near Idabel, McCurtain County. Unfortunately, no natural history information was included in his original description. McAllister et al. (2011) found 16 adult (including Form I and II males, females) and many juvenile and subadult *P. curdi* on the Eastern Oklahoma State Campus just N of Idabel, McCurtain County. More recently, Morehouse and Tobler (2013) revealed males (Form I and II) and females have been collected year round in Oklahoma from burrows. However, to our knowledge, no ovigerous females or females with young have been reported in Oklahoma. On 16 April 2000, a single ovigerous female with 121 ova (1.1–1.6 mm in diameter) was collected in a burrow from a roadside ditch on U.S. Hwy. 70 (259) *ca.* 8.5 km NE of Idabel, McCurtain County (33° 56' 27.1536"N, 94° 45' 30.2754"W).

Actinopterygii: 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). On 10 November 2017, an adult female (77 mm TL) *C. spadiceum* was collected from Yashau Creek, McCurtain County, which possessed an unusual white growth on its mid-body region and dorsal fin (Fig. 2A). Examination of biopsies of this growth using light microscopy revealed live colonies (Figs. 2B-C) comprising various numbers of individuals, with a branched and smooth, noncontractile stalk and partially to fully expanded zooids. *Epistylus* spp. are ciliates and present as sessile peritrichous organisms (Hoffman 1999; Dias et al. 2006; Lynn 2008). If these ciliates are present in large colonies, attachment sites can cause lesions that get inflamed, necrotic, and ulcerated, leaving the fish susceptible to secondary infection (Hoole et al. 2001). There are previous reports of *Epistylis* in other cyprinids, including two of 18 (11%) Common Carps (*Cyprinus carpio*) and two of five (40%) Golden Shiners (*Notemigonus crysoleucus*) (Miller and Chapman, 1976), one of 95 (1%) *N. crysoleucus* and two of 670 (0.3%) Whitefin Shiners (*Cyprinella nivea*) (Lewis et al., 1978), and one of 23 (4%) *N. crysoleucus* (Cloutman et al., 1978), all collected from North Carolina; additional minnows and shiners were examined in these studies and did not harbor *Epistylis*. Interestingly, we have collected over 100 *C. spadiceum* from various McCurtain County watersheds (including Yashau Creek) and have never seen one individual with a similar condition. Thus, based on the prevalence noted above, cyprinids appear to be rare hosts of *Epistylis*. Here, we document the first report of *Epistylis* sp. from *C. spadiceum*, and to our knowledge, the first time from Oklahoma.

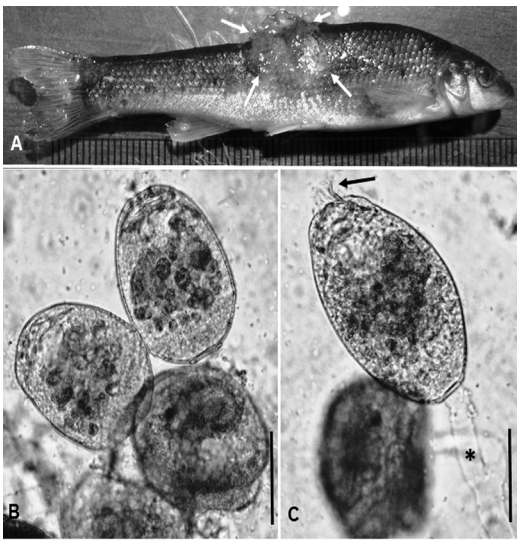

Figure 2. Highland Stoneroller (*Campostoma spadiceum*) from Yashau Creek, McCurtain County, with *Epistylis* sp. A. Gross lateral view of infested fish with whitish growth (arrows) on mid-body and covering dorsal fin. B. Wet mount of colony of partially expanded *Epistylis* zooids. C. Wet mount of single fully expanded zooid showing cilia (arrows) and stalk (*). Scale bars = 25 µm.

***Luxilus cardinalis* (Mayden, 1988) – Cardinal Shiner.** Previously, Moore and Paden (1950) and Miller (1967) noted spawning of *L. cardinalis* (=*Notropis pilsbryi*) in the Illinois River and Spavinaw Creek, respectively,

in northeastern Oklahoma. Herein, we supplement their observations with those of one of us (HWR) of *L. cardinalis* spawning on two separate dates four years apart: namely 24 April 1979 and 5 May 1983 in the Baron Fork of the Illinois River at Proctor, Adair County.

Observations in the Illinois River in Arkansas while snorkeling revealed the Cardinal Shiner is a midwater, schooling species that feeds from the surface and the water column. Tuberculate males and gravid females were present at the Proctor site. Breeding males developed brilliant, crimson red coloration on the underside of the head from the top of the snout to the occiput, and on the chin, and the anterior third of the gular area (Robison and Buchanan 1988); the snout region was a powder blue color. In addition, red coloration was well developed on the lower sides and on the base of the anal fin and all fins also had red pigment. Males exhibited intensely dark, broad lateral bands and were highly tuberculate with prominent tubercles showing on the head region.

Our observations of the breeding activities of *L. cardinalis* were similar to those noted by Miller (1967) who witnessed spawning of *L. cardinalis* over Creek Chub (*Semotilus atrocaudalis*) nests in deep water (1.2 m) pool situations, whereas Moore and Paden (1950) had earlier observed their breeding activities in 2.5 to 3.8 cm of water. In field observations on both dates and years noted herein, HWR observed a mass aggregation of male and female *L. cardinalis* schooling in pools where water depth was approximately 0.7 to 1.2 m deep, clear, and with a moderate current. Water temperatures in the pool areas ranged from 19.1 to 20.6°C while air temperatures ranged from 21.5 to 22.3°C on the two occasions of observations. Miller (1967) had previously noted a close correlation between water temperature and timing of breeding in this species.

Initially, nest building activities of *S. atromaculatus* attracted the attention of HWR who was seining fishes from the stream. He later stopped to observe three to five large *S. atromaculatus* picking up stones in their mouths and depositing them upstream of their nest area. Interestingly, at the same time, an aggregation of 30 to 50 individuals (mostly males) of *L. cardinalis* was seen initially congregating over the rear of the *Semotilus* nest area. This breeding aggregate of *L. cardinalis* constantly moved back and forth over the cleared nest, but seemed to stay primarily in the posterior portion of the nest area. They only moved toward the center portion of the pit when *Semotilus* males were either distracted or carried pebbles upstream to the front of the nest area, thereby leaving the center of the nest unguarded. Male *L. cardinalis* appeared to line up over the pit facing upstream only 2.5-5.0 cm above the substrate while females tended to remain above and behind them in the water column. Courtship in *L. cardinalis* began when a male would pursue a female and appeared to nudge or bump her side. Individuals remained just above the cleared substrate and often moved toward the center of the pit. Such behavior was repeated numerous times. Unfortunately, HWR did not observe clasping in *L. cardinalis*, but did observe males rolling from side to side as reported by Moore and Paden (1950). Miller (1964) suggested that it is possible this species does not utilize a clasp. Rolling side to side is also typical of courtship behavior in the Common Shiner, *L. cornutus* (Miller 1967), a relative of *L. cardinalis*. 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. Numerous brilliantly colored males jockeyed for position near less brilliantly colored females and aggressive males were seen twice to engage in parallel swimming. This is the first documentation of parallel swimming in *L. cardinalis*. Following field observations, a small hand screen was used to collect eggs of *L. cardinalis* from the gravel.

Percopsiformes: Aphredoderidae

***Aphredoderus sayanus* (Gilliams, 1824) – Pirate Perch**. An anomalous 80 mm TL *A. sayanus* was collected on 31 May 2017 from Yanubbee Creek, McCurtain County. Deviation of the spine on the coronal or frontal planes (scoliosis) was noticed (Fig. 3A). Seven other *A. sayanus* collected from the same site did not

possess this anomaly nor did 19 others from nearby Yashau Creek, McCurtain County. Fish affected by this deformity do not usually swim efficiently, are less capable of acquiring food, are at a greater risk of predation, as well as being more susceptible to physiological imbalances (Silverstone and Hammel 2002). This is the first time, to our knowledge, that this deformity has been documented in *A. sayanus*.

Percidae: Centrarchidae

***Lepomis cyanellus* Rafinesque, 1819 – Green Sunfish.** A 145 mm TL *L. cyanellus* collected on 6 November 2016 from Yanubbee Creek, McCurtain County, had lordosis or swayback (Fig. 3B). Although this type of deformation is considered rare in wild fish populations (Boglione et al. 2001), spinal malformations represented by dorso-ventral deviation (kyphosis and lordosis) or curvature in the coronal plane (scoliosis) are the most frequent types. Lordosis remains the utmost diffused type of backbone deformity and is one of the most severe skeletal deformities observed in fish (Chatain and Dewavrin 1989). When fish are affected, the backbone shows a typical V shape with a more or less pronounced angle.

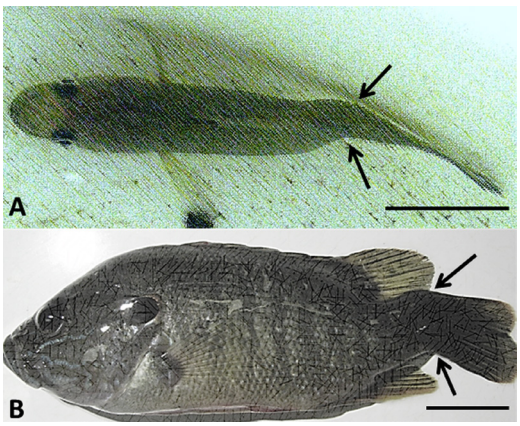

Figure 3. Pirate Perch (*Aphredoderus sayanus*) and Green Sunfish (*Lepomis cyanellus*) from Yanubbee Creek, McCurtain County, Oklahoma, with skeletal deformities. A. Dorsal view of Pirate Perch showing deviation of caudal spine (scoliosis, arrows). B. Lateral view of Green Sunfish with lordosis (arrows). Scale bars = 20 mm.

Although these deformities can be caused by a number of environmental factors (temperature, infectious diseases, malnutrition, and exposure to pollutants), researchers have found that the genetics of the parents can also play an important role as well (Evans and Neff 2009). This affected fish was the only one of 15 from Yanubbee Creek affected with this disorder and three others from Yashau Creek appeared normal. To the best of our knowledge, occurrence of spinal deformations in *L. cyanellus,* a common centrarchid in Oklahoma, had not previously been reported.

Five of 20 (25%) *L. cyanellus* (109.0 ± 40.7, 76–175 mm) collected on 9 October (2 of 6 [33%]), 6 November (1 of 2 [50%]), 11 November (1 of 3 [33%]), and 27 November 2016 (1 of 1 [100%]) from Yanubbee Creek were found to be infested with an *Epistylis* sp. (Fig. 4). McAllister et al. (2016) recently reported a similar *Epistylis* from *L. cyanellus* from Arkansas; however, this is the second report of this ciliate from any Oklahoma fish.

Perciformes: Percidae

***Etheostoma radiosum* (Hubbs & Black, 1941) – Orangebelly Darter.** A 55 mm TL female with eggs was collected on 24 June 2015 from Yashau Creek, McCurtain County. Spawning in *E. radiosum* in Oklahoma occurs between the middle of March and the middle of April but can begin as early as February (Scalet 1973; Miller and Robison 2004). This extends the known breeding season of the species in Oklahoma.

Another *E. radiosum* (41 mm TL male) collected on 24 November 2015 from Lukfata Creek, McCurtain County, was found to have two unidentified species of water mites (Acari: Hydrachnidae) in its stomach. We are not aware of any reports of this darter feeding on water mites. In Oklahoma, young *E. radiosum* feed primarily on crustaceans, and adults on mayflies and other insect larvae (Scalet 1972).

Scorpaeniformes: Cottidae

***Cottus carolinae* (Gill, 1861) – Banded Sculpin.** A 117 mm TL female with eggs was

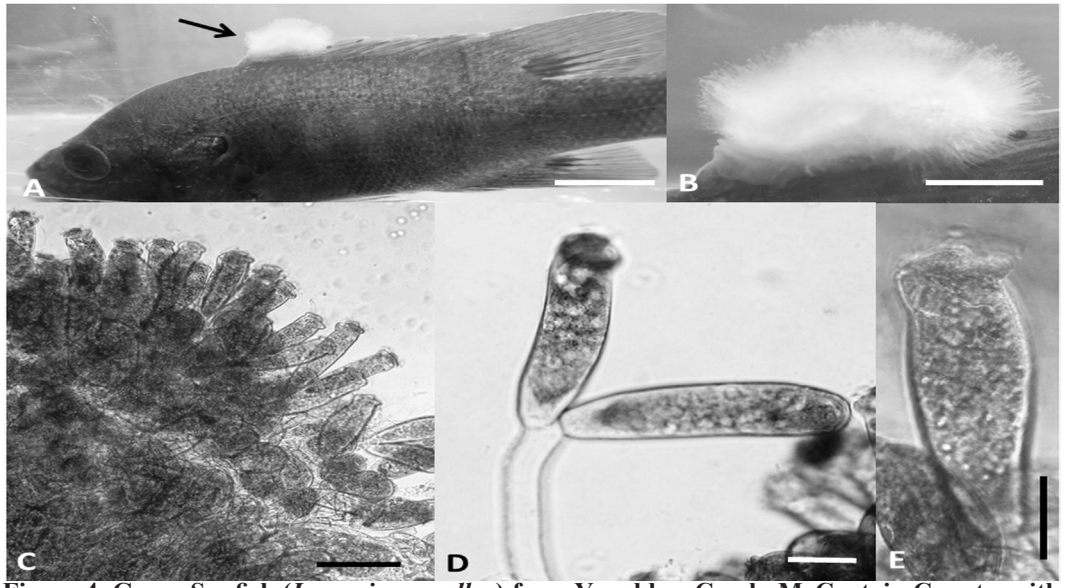

Figure 4. Green Sunfish (*Lepomis cyanellus*) from Yanubbee Creek, McCurtain County, with *Epistylis* sp. A. Gross lateral view of infested fish with whitish growth (arrow) on anterior part of dorsal fin. B. Close-up of same growth. C. Colony of *Epistylis* zooids. D. Pair of *Epistylis* zooids showing stalk. E. Microscopic view of single *Epistylis* zooid. Scale bars A = 30 mm; B = 10 mm; C = 100 µm; D–E = 50 µm.

collected on 13 March 2017 from the Illinois River, Cherokee County. The Banded Sculpin spawns in late winter and early spring (Miller and Robison 2004). However, this is the first time a female with eggs has been reported from Oklahoma.

In conclusion, Oklahoma supports a great variety of biota in its vast ecoregions. Biologists can gain novel natural history information on both invertebrates and vertebrates of the state by providing updated data as we document herein. This represents our second contribution (McAllister and Robison 2016) on the subject as we continue to develop additional articles to update the state of knowledge of the natural history of Oklahoma's fauna. Documentation of similar natural history is warranted in other ecoregions, particularly in the Great Plains of the western and Panhandle regions of the state where observations on several species are sorely needed.

Acknowledgments

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An Evaluation of Tiger Muskellunge Introduced into Lake Carl Etling, Oklahoma

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Abstract: Tiger Muskellunge (Muskellunge *Esox masquinongy* x Northern Pike *Esox lucius*) were stocked into Lake Carl Etling in the northwestern tip of Oklahoma's panhandle in Cimarron County. This lake sustained a population of Northern Pike from 1966 – 1976, with natural reproduction maintaining the population until 1986. However, after 1986, periods of drought affecting the lake level and water temperature negatively impacted the Northern Pike population. In 2004, Lake Carl Etling's surface area was reduced to approximately 4 ha by drought, which negatively affected the sportfish populations. Salt Cedar (*Tamarix ramosissima*) and other herbaceous vegetation colonized the dry lakebed before rainfall in the summer of 2013 filled Lake Carl Etling to normal elevation. Nongame fish populations became over abundant and Tiger Muskellunge were stocked as biological control and to potentially create a unique trophy fishery. However, through extensive sampling efforts only 1 adult and 76 juveniles (of the 2,656 individuals stocked) were caught. Tiger Muskellunge recruitment was affected by high turbidity and high water temperatures. A combination of increasing turbidity levels and water temperatures, post-stocking, likely resulted in increases in Tiger Muskellunge metabolism. Relative weights (Wr) decreased monthly after stocking in 2016 and 2017, with no fish observed in sampling efforts after July of 2016. These conditions likely required Tiger Muskellunge to forage more frequently. As an ambush predator that depends on sight to forage, they had little foraging success in turbid water, which ultimately led to starvation and death.

Introduction

Oklahoma lakes typically get too warm to sustain populations of cold-water fishes, but Lake Carl Etling, Cimarron County Oklahoma is an exception. Historically, this lake has sustained a population of Northern Pike (*Esox Lucius*) following an initial introduction of 64,000 25-mm fingerlings and 3,151 76.2 mm advanced fingerlings stocked by ODWC on April 9, 1966. Maintenance stockings averaging 2,148 76.2-mm pike continued annually until 1976, however past that year, stocking was discontinued. Limited recruitment was observed during annual electrofishing surveys conducted by ODWC until 1986 (Stahl 1986),

however no individuals were found during annual surveys thereafter. It was hypothesized that reduced water elevations lead to increased water temperature during periods of drought surpassed the Northern Pike thermal maxima of 27.8 ºC (Casselman 1978). Other reports of Northern Pike die-off have been documented in lakes following several very warm days where water temperatures ranged from 32° C at the surface to 24° C in the lower epilimnion (Inskip 1982).

In 2004, the surface area of Lake Carl Etling was reduced to approximately 4 ha as a result of prolonged drought, which negatively affected the sportfish populations. Salt Cedar (*Tamarix ramosissima*) and other herbaceous vegetation colonized the dry lakebed before rainfall in the summer of 2013 filled Lake Carl Etling to normal elevation. Consequently, the inundated Salt Cedar created nursey habitat for the remaining fish community. This resulted in increased densities of nongame species (not commonly pursued or consumed by anglers), such as Common Carp (*Cyprinus carpio*), Gizzard Shad (*Dorosoma cepedianum*), and Green Sunfish (*Lepomis cyanellus*).

In an attempt to reduce the abundance of nongame species via biological control, ODWC attempted to establish a population of Tiger Muskellunge (Muskellunge *Esox masquinongy* x Northern Pike *Esox lucius*) in Lake Carl Etling. Tiger muskellunge are highly piscivorous and have been stocked throughout the United States to successfully control populations of fish species (e.g. White Sucker, *Catostomus commersonii*, and Black Crappie *Pomoxis nigromaculatus*, Siler and Beyerle 1986; Yellow Perch, *Perca flavescens*, Monroe 2013; Brook Trout, *Salvelinus fontinalis*, Koeing et al. 2015; etc.). Biological control offers some advantages over other methods, including reduced labor, no chemical pesticides, little specialized equipment, and a low cost/benefit ratio when the action is effective (Hoddle 2002, Koenig et al. 2015). In addition, Tiger Muskellunge are sterile F_1 hybrids (they do not reproduce), which allow managers to control population size or even stop stocking if they later do not want this species present in the lake.

ODWC began stocking Tiger Muskellunge in Lake Carl Etling in the fall 2014 and continued for four years. It was hypothesized by ODWC that the stocked Tiger Muskellunge would primarily forage on over abundant nongame species, which would have two positive impacts on the lake. First, a reduction in the nongame species could potentially free up resources for other sport-fish species to utilize. Secondly, Tiger Muskellunge grow rapidly and may create a unique trophy fishery. However, during the course of this evaluation, only one adult fish was captured, suggesting recruitment failure of the stocked fish. Due to the lack of recruitment, this study focuses on food habits and environmental factors that affected juvenile Tiger Muskellunge to attempt to ascertain why stocking efforts in Lake Carl Etling failed.

Methods

Study Area

South Carrizo Creek, a tributary of the Cimarron River, was impounded in 1958 to form Lake Carl Etling. It is in the northwestern tip of Oklahoma's panhandle (Cimarron County), which is encompassed by the diverse Mesa de Maya/ Black Mesa ecoregion. Lake Carl Etling is 159 surface acres at normal pool elevation, with 8 kilometers of shoreline (Figure 1). It is a hyper-eutrophic lake with a mean depth of 1 meter and maximum depth of 5.5 meters. The lake is managed by the ODWC, and is surrounded by Black Mesa State Park, which is managed by Oklahoma Department of Tourism and Recreation. This area provides recreational opportunities such as fishing, camping, hiking, and wildlife viewing. The lake has historically been a popular Largemouth Bass (*Micropterus salmoides*) and Walleye (*Sander vitreus*) fishery. Prey species include Gizzard Shad, Bluegill (*Lepomis macrochirus*), Green Sunfish (*Lepomis cyanellus*), and Redear Sunfish (*Lepomis microlophus*). White Suckers, Plains Killifish (*Fundulus zebrinus*), Black Bullheads (*Ameiurus melas*), and Common Carp. White Suckers are introduced during trout stocking and are not seen past the summer months. In

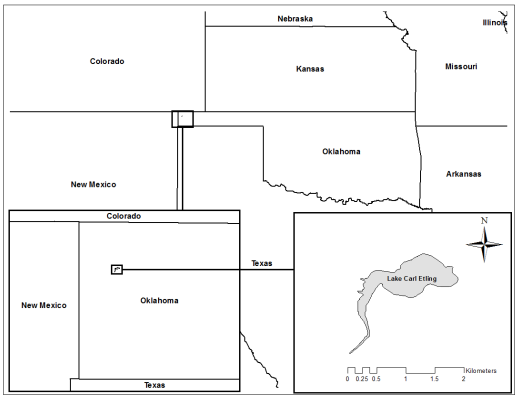

Figure 1. Study site, where Tiger Muskellunge stockings occurred in Oklahoma. Lake Carl Etling is a 64.3 ha impoundment found within the Black Mesa State Park in Cimarron County located in the far northwestern tip of Oklahoma. Lake Carl Etling was built in 1958, impounding South Carrizo Creek, a tributary of the Cimarron River.

addition, ODWC stocks Lake Carl Etling with Channel Catfish (*Ictalurus punctatus*) in the summer and during wintertime trout are stocked for additional winter angling opportunities.

Stocking

Stocking of Tiger Muskellunge in Lake Carl Etling occurred yearly at varying rates, depending on hatchery production (Table 1). Tiger Muskellunge were obtained from both Speas Fish Hatchery in Casper, Wyoming and Wray Fish Hatchery in Wray, Colorado. Tiger Muskellunge stocked in 2014 and 2015 had a mean total length < 250 mm. To reduce predation on stocked Tiger Muskellunge in 2016 and 2017, fish were transported to the Byron State Fish Hatchery in Burlington, Oklahoma and allowed to grow out until mean length exceeded 250 mm. Fish were stocked haphazardly throughout the lake in 2014, 2015, and 2016. In 2017, fish were stocked at the boat ramp in the upper portion of the lake.

Sampling

Tiger Muskellunge sampling was conducted monthly starting in July of 2015. Tiger Muskellunge were sampled using electrofishing gear during the day and night. After initial electrofishing samples failed to sample many Tiger Muskellunge, fyke nets (.91 m x 3.05 m; with 12.7 mm mesh, .91 m x 1.83 m rectangular cab, 152.4 mm throat and a 20.12 m lead), mini fyke nets (0.6 m x 6.35 m; with 3.18 mm mesh, 0.6 m x 1.92 m rectangular cab, 60 mm metal throat and a 9.14 m lead), and floating fyke nets (add floats to the cab and hoops to both fyke nets and short lead fyke nets) were also used to increase the number of Tiger Muskellunge captured. Additionally, experimental gill nets (24.4 m long by 1.8 deep and composed of eight, 3-m panels [12.7, 15.875, 19.05, 25.4, 38.1, 50.8, 63.5, and 76.2 mm bar mesh]) were used in May of 2017 to ensure that Tiger Muskellunge were not avoiding electrofishing and trap-net gears. All nets were set haphazardly to avoid the herbaceous and woody vegetation that surrounds the lake. The entire perimeter of the lake was sampled via boat electrofishing during each monthly sample. Temperature and dissolved oxygen (DO) profiles were recorded monthly using a YSI Professional Series 1020 meter. Secchi turbidity measurements were recorded monthly using a turbidity tube as outlined in Myre and Shaw (2006).

After capture, all Tiger Muskellunge were measured (mm), weighed (g), and stomach contents removed by gastric lavage techniques outlined by Fowler and Morris (2008). Stomach contents were place into a zip-lock bag marked with a corresponding number to each individual fish and placed on ice until they could be frozen. In the laboratory, food items were thawed, weighed (g) and volumetric displacement was measured (ml). Food items were categorized into 4 groups: fish, aquatic vegetation, invertebrates, and other prey. Items were identified to species when possible using scientific taxonomic

Table 1. Stocking dates, number, rates, and total length (mm) for Tiger Muskellunge at Lake Carl Etling in Oklahoma.

Date Stocked	*n*	*#/ha*	Mean Total Length (mm)
10/08/2014	166	2.5	206
10/20/2015	805	12.5	193
2/10/2016	205	3.2	236
5/06/2016	1200	18.7	319
2/16/2017	280	4.4	252

keys to identify aquatic invertebrates (Merrit et al. 2008), fish fillets and scales (Oats et al. 1993), clethra guide (Traynor et al. 2010), and dichotomous key (Miller and Robison 2004). Stomach samples were analyzed by percent of empty stomachs, frequency of occurrence (O_i), percent composition by number (N_i), percent composition by volume (V_i), and index of relative importance (IRI) (Bowen 1996, Chipps and Garvey 2007).

Results & Discussion

A total of 2,656 Tiger Muskellunge were stocked from 2014 through 2017 (Table 1). During monthly sampling events, 76 juveniles and 1 adult Tiger Muskellunge were captured from July 2015 through May 2017. Daytime electrofishing captured 95% (73 of 77) of the individuals sampled (Table 2) during 66.83 h of pedal time. Fyke nets and mini fyke nets combined captured the remaining 5% (4 of 77) of Tiger Muskellunge sampled. Gillnets were used in May 2017 to attempt to capture Tiger Muskellunge, however no individuals were caught. A total effort for all gear types combined was 2,442.6 h.

Most fish were captured as juveniles within 2-3 months post-stocking, and juveniles were not present in monthly surveys after November in 2015 (fish stocked in October), after July in 2016 (fish stocked in February and May), and after May in 2017 (fish stocked in February). After no age-1+ tiger Muskellunge were sampled by late summer 2016, it was hypothesized that the mean total length of fish at stocking was too small (Table 1), and fish were being preyed upon by resident predators (Largemouth Bass, Walleye) shortly after stocking. This resulted in Walleye stocking to be discontinued. Stein et al. (1981) found that 95% of Tiger Muskellunge stocked ≤180 mm were preyed upon within 40 days after stocking and recommended that tiger muskellunge be stocked after they are > 250 mm, TL to reduce predation by Largemouth Bass, Walleye, and other Tiger Muskellunge. Therefore, in 2016 and 2017 fish were held in hatchery ponds at the Bryon State Fish Hatchery and were not stocked until their mean length was ≥250 mm. Despite efforts to grow fish to larger sizes prior to stocking, Tiger Muskellunge still were not observed in samples > 3 months from the time of stocking, suggesting stocking failure.

Table 2. Number of Tiger Muskellunge captured in Lake Carl Etling for each sampling method during 2015-2017.

Year	Method	Number Captured	Net Nights	Effort (hhh:mm)
2015	Electrofishing (Daytime)	8	-	23:10
	Electrofishing (Nighttime)	0	-	13:40
	Fyke Nets	0	55	770:00
	Mini Fyke Nets	0	36	468:00
2016	Electrofishing (Daytime)	54	-	31:10
	Electrofishing (Nighttime)	0	-	14:50
	Fyke Nets	2	42	504:29
	Mini Fyke Nets	2	29	319:22
	Floating Fyke Nets	0	12	168:17
2017	Electrofishing (Daytime)	11	-	12:30
	Gill-nets	0	9	117:08

Following stocking each year, mean relative weight (W_r) of juvenile Tiger Muskellunge decreased each month until they were no longer detected in monthly samples (Figure 2). Relative weight at the time of stocking was 94 – 112 and declined to < 75 in three to four months, with the lowest W_r being 46 in July of 2016 (2 months after the May stocking). Relative weight remained highest for February-stocked fish. All fish stocked in spring had rapid drops in W_r from May to July (Figure 3). During this May to July time period, water temperature increased, which may have caused sub-lethal stress to Tiger Muskellunge, ultimately resulting in stocking failure via delayed mortality.

The likely cause of stocking failure was exposure to high temperatures. In a laboratory experiment, Snow et al. (*in-press*) exposed Tiger Muskellunge to a range of acclimation temperatures and found as acclimation temperature increased, mean lethal thermal maxima response variable temperatures increase as well. Based on these results, Tiger Muskellunge should be able to survive during the hottest part of the year in Lake Carl Etling. However, Snow et al (*in-press*) also found thermal stress responses were 2-3^{0}C lower for starved fish than for fed fish in the 28^{0}C acclimation treatment. There was a span of 20 days in Lake Carl Etling during the summer of

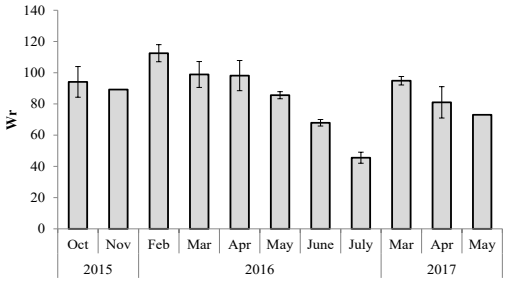

Figure 2. Mean relative weight (Wr) of Tiger Muskellunge (>240 mm TL) collected monthly during 2015-2017 from Lake Carl Etling, Oklahoma. Error bar represent standard error. Months without error bar indicate only 1 individual was captured in that month.

2015 that exceeded the thermal maximum of Tiger Muskellunge if fish were not foraging, that could have resulted in death. Water temperatures were also exceedingly warm during June and July 2016 (29.9 to 33.4^{0}C from the dam to the creek mouth), which would have likely resulted in death of juvenile tiger muskellunge regardless of their foraging return. The mean water temperature on July 6, 2016 was 32.1^{0}C, high enough to exceed the upper thermal limits of a juvenile Tiger Muskellunge, especially if they were not able to forage. Not only did Tiger Muskellunge disappear from monthly samples, but anglers also reported the inability to catch Tiger Muskellunge past July 2016.

Tiger Muskellunge are an ambush predator, which depend on sight when foraging (Andersen et al. 2008). Lake Carl Etling is highly turbid at times due to suspended solids. High turbidity levels could affect the ability for Tiger Muskellunge to detect prey, which could result in reduction of foraging return and ultimately starvation. In a laboratory study, a secchi depths $\leq$ 26 cm (increased turbidity levels) reduced the foraging success and selectivity of juvenile Tiger Muskellunge (Snow et al. *in review*). The mean monthly secchi depth at Lake Carl Etling was 23.4 cm from October 2015 through May 2017. Therefore, a combination of increasing turbidity levels and high water temperatures likely resulted in increases in Tiger Muskellunge metabolism making them expend more energy foraging with little success, thus leading to starvation and death.

Out of all Tiger Muskellunge sampled, 76.6% had empty stomachs (no food items present), which may explain the overall poor condition (Figure 3) of juvenile Tiger Muskellunge and supports the plausible scenario that the fish were not able to forage efficiently under the conditions experienced in Lake Carl Etling. The remaining 23.4% of Tiger Muskellunge contained 5 species of fish and 1 species of invertebrate (Table 3). Gizzard shad composed the bulk of the diet, representing 43.8% of the food eaten (V_i) and was the most important diet item (56% IRI). Bluegill represented the second most important species consumed by Tiger Muskellunge at 15.1% (IRI), just ahead of Green Sunfish 7.2% (IRI). Both Gizzard Shad and Common Backswimmer (*Notonecta glauca*) were the most numerically abundant item consumed 25% (N_i), however Common Backswimmers ranked

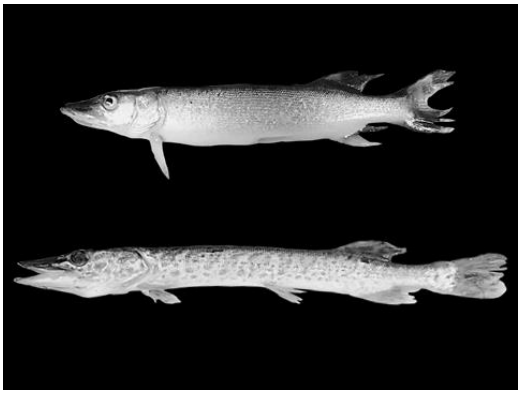

Figure 3. Tiger Muskellunge that were stocked in May 2016 into Lake Carl Etling, Oklahoma. The top photograph is an average size/condition Tiger Muskellunge at time of stocking (284 mm TL, 125 g, and relative weight = 108). The bottom photograph is a Tiger Muskellunge that was captured in Lake Carl Etling during the July 2016 electrofishing survey. This fish shows the effects of high temperature and increased turbidity on condition of juvenile Tiger Muskellunge (337 mm TL,100 g, and relative weight = 49)

Table 3. Percent composition by number (N_i), percent composition by volume (V_i), frequency of occurrence (O_i), and Index of Relative Importance (IRI) of prey items consumed by Tiger Muskellunge in Lake Carl Etling from 2015 - 2017.

Prey	%N_i	%V_i	%O_i	%IRI
Fish:				
Bluegill Sunfish	15	22.2	18.75	15.1
Gizzard Shad	25	43.8	37.5	56.0
Green Sunfish	10	16.4	12.5	7.2
Plains Killifish	5	9.6	6.25	2.0
Invertebrate:				
Common Backswimmer	25	4.8	6.25	4.1
Other:				
Unknown	22.2	3.2	31.25	15.6

4.1% (IRI) in importance because of their small size (Table 3). Unknown diet items occurred in 31.25% (O_i) of diets, but only made up 3.2% by volume (Table 3).

Lake Carl Etling has experienced drastic changes in temperature regime through time, with resulting changes in species composition. In May 1959, a Rainbow Trout (*Oncorhynchus mykiss*) fishery was created from an initial stocking of 52,800 fingerlings (Houser 1961). This resulted in a year-round trout fishery from 1959 - 1961. However, after 1963, trout could no longer survive year-round in Lake Carl Etling, leading ODWC to create a winter time fishery for trout in 1989 (ODWC unpublished data). Bennett (1979) describes Lake Carl Etling as a highly vegetated, clear water lake (secchi depth of 48 cm) with marginal dissolved oxygen (DO) levels below 6 m and a main pool surface and bottom temperature of 22.5^{0}C and 21.5^{0}C, respectively in August. This is considerably different than main pool mean temperature from 2015-2016 in August of 28.7^{0}C (surface) and 24.6^{0}C (bottom) with anoxic condition below 3.4 m and a mean secchi measurement of 31 cm (high turbidity levels). Furthermore, there is a substantial difference in maximum depth (9.8 m) recorded in 1992 (Stahl 1992) and in 2014 (5.7 m).

We hypothesize that changes in land practices and sedimentation via stream flow or dust storms has affected the natural spring flowing into Lake Carl Etling. Historically, it is likely that flowing springs were used as thermal refuge by cold water species during the summer months in Lake Carl Etling. Koch and Steffense (2013) found that Northern Pike in Kingsman Lake in Southcentral Kansas become vulnerable to anglers when fish congregate on cold water springs during the hottest months of the year. In the early 1980's, ODWC attempted to excavate a natural spring in the bottom of Lake Carl Etling that was thought to be plugged with silt and organic matter. Despite hitting ground water, this attempt was unsuccessful as water flow from the spring was not initiated (John Stahl, Oklahoma Department of Wildlife Conservation, personal communication). Lake Carl Etling is located near the High Plains aquifer, which includes Beaver, Cimarron, Ellis, Harper, Texas and Woodward Counties in Northwestern Oklahoma. Water level in this aquifer has decreased 3.4 m from predevelopment to 2011 (McGuire 2012). The main reason for the reduction of the High Plains aquifer is the increase in the number of large capacity wells (> 100 gal min; < 50 in the 1950's to an estimated 2,400 in 1999) used mostly for agricultural purposes (Luckey and Becker 1999). We speculate that Lake Carl Etling's elevation is higher than the current elevation of the water table of the High Plains aquifer, resulting in a cut off of flow to the natural springs. Furthermore, the main substrate in the area is sand, which allows water to permeate quickly making it difficult for Lake Carl Etling to maintain normal pool level.

Stocking fish at the fringe of its geographic range can be risky as small changes in habitat or annual environmental variation could make the habitat unsuitable for stocking success. For example, Northern Pike stocking efforts were successful in the 1970's in Lake Carl Etling. Because of the success of the Lake Carl Etling introductions, ODWC attempted to create a sport fishery for Northern Pike in Watonga Lake located within Roman Nose State Park, Blain County, Oklahoma. Fish were stocked from 1970 to1976 with no observed recruitment of Northern Pike. A single Northern Pike (838 mm Tl, 2408 g) was captured during an annual gill-net survey in 1980, four years after the last stocking (ODWC unpublished data). No other Northern

Pike were caught in surveys conducted during and after stocking, similar to efforts targeting Tiger Muskellunge in Lake Carl Etling. During the time that stocking was occurring, fertilizer was being added to Watonga Lake each spring to offset poor primary productivity and promote phytoplankton growth. Fertilizing would cause phytoplankton-induced turbidity, which has shown to decrease population densities of Northern Pike (Cassleman and Lewis 1996). Furthermore, Craig and Babaluk (1989) described poor condition of Northern Pike caused by turbid water conditions that affected their ability to forage, leading to decreased prey consumption. Northern Pike have lower lethal thermal maxima than Tiger Muskellunge, which if Northern Pike react similar through periods high temperature and starvation, it could have affected the ability of Northern Pike to recruit in Watonga Lake. These results suggest that it is critical to understand reservoir conditions (i.e. predator abundance, forage availability, water turbidity, water temperature) prior to stocking a new species as this may determine how successful an introduction will be.

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Macroinvertebrate Community Structure and Physicochemical Conditions of Desperado Spring

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Abstract: Desperado Spring is a small rheocrene spring located in south-central Oklahoma that emerges from a rocky outcrop and flows into the nearby Blue River. Macroinvertebrate collections and water quality measurements were taken seasonally for an annual period at the springhead and in the springbrook. A total of 16,410 individuals representing 49 taxa were collected in Surber net samples while an additional four species were collected using a dip net. This spring fauna was dominated by insects, especially midges (Chironomidae). Shannon's species diversity values at the springhead differed significantly from those in the springbrook during all four seasonal collections, probably due to increasing levels of oxygen in the springbrook.

Introduction

Springs are described as naturally occurring sources of emerging groundwater that have unique properties unto themselves, such as discrete habitats with relatively constant conditions with respect to temperature, dissolved oxygen concentration, and flow (van der Kamp 1995). Investigations of springs are limited and only a few ecological studies of these unique environments have occurred in Oklahoma. Matthews et al. (1983) attempted to determine whether macroinvertebrate community compositions could be useful indicators of groundwater quality, but low similarities between the springs in the study led to inconclusive results. Varza and Covich (1995) concluded limited food availability and predation by crayfish limited macroinvertebrate abundance in Buckhorn Spring. Bass (2000) reported a combined total of 39 taxa of macroinvertebrates from two springs in the Pontotoc Ridge Nature Preserve sampled only once during 1995. Based on samples of invertebrates from springs along a southeast to northwest gradient across Oklahoma, Gaskin and Bass (2000) concluded a unique spring fauna was generally not present in Oklahoma and the spring inhabitants were associated with populations from other nearby stream habitats. Rudisill and Bass (2005) reported 64 taxa, dominated by dipteran larvae, during a year-long investigation from three adjacent springs in Roman Nose State Park. Graening et al. (2006) compiled a checklist of all amphipods known from Oklahoma, including *Allocrangonyx* sp., from Desperado Spring. In another annual study, Brown and Bass (2014) collected 114 invertebrate taxa, dominated by the species complex *Hyalella azteca* and *Tanytarsus*, from three springs in south-central Oklahoma.

The macroinvertebrate community of Desperado Spring was previously sampled by Gaskin and Bass (2000). Desperado Spring is a rheocrene spring located in the Blue River Wildlife Management Area of south-central Oklahoma in Johnston County (34.3319°N, 96.5993°W) (Fig. 1). The spring emerges from a rocky outcrop and flows approximately 15 meters before draining into the Blue River. The

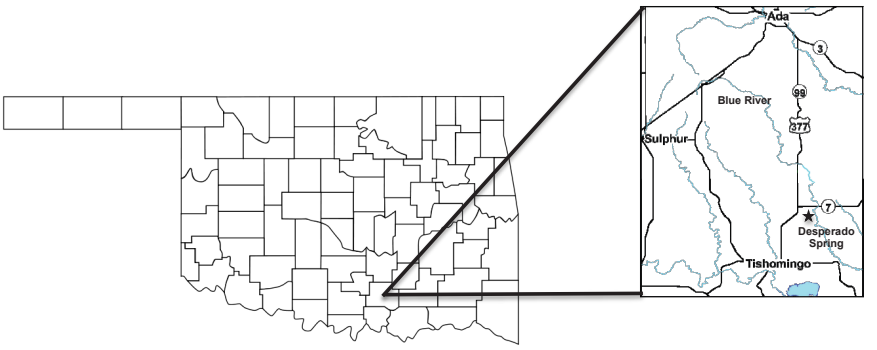

Figure 1. Map showing location of Desperado Spring in Johnston County, Oklahoma.

substrate of this spring is composed primarily of cobble, gravel, and sand with an abundance of aquatic vegetation (Gaskin and Bass 2000).

Purposes of the current investigation were to 1) describe the macroinvertebrate community composition of Desperado Spring over an annual period, 2) compare composition of these communities to previously collected data on this and other springs, and 3) determine selected physicochemical conditions of Desperado Spring.

Methods

Desperado Spring was sampled seasonally (October, January, April, and July) beginning in 2002. Both physicochemical and macroinvertebrate samples were collected during each quarterly visit.

Two sampling sites (springhead and 12 m downstream in springbrook) were established within the springbrook and three Surber net samples were collected from each site. Qualitative samples were also collected, by examining microhabitats, to capture species that may have been missed by the Surber net. All samples were washed in a number 60 (0.250mm) U.S. standard sieve bucket, and preserved with a 10% mixture of formalin and Rose Bengal dye. The preserved macroinvertebrates were returned to the laboratory to be sorted, identified, and counted. Identification of macroinvertebrates was determined primarily using keys by Wiederholm (1983), Epler (1995), Smith (2001), Merritt et al. (2008), and Thorp and Covich (2009). All specimens were deposited in the Invertebrate Section of the University of Central Oklahoma Natural History Museum.

Shannon's (1948) diversity index was calculated for springhead samples and the springbrook samples for each spring for each collection period. Sorenson's index of similarity (Brower et al. 1997) was used to make comparisons between the species present at springhead and springbrook sites for each collection. Chi-square contingency analyses were performed to determine if there was a relationship in number of individuals between the springhead and springbrook during the different seasons. Furthermore, a Hutcheson *t*-test was used to compare species diversity between the springhead and springbrook samples. The Hutcheson *t*-test is a median test with a distribution-free procedure that assumes the two populations or samples have the same shape. It is a modified version of the classic *t*-test that provides a way to compare samples using Shannon's diversity index values (Zar 2010).

Water temperature, dissolved oxygen concentration, and pH were measured at both collecting sites within the springbrook, while alkalinity and flow were measured only at the springhead. In addition, a water sample collected from the head of each spring was used to determine turbidity, conductivity, and concentrations of ammonia, nitrites, nitrates,

Table 1. Physicochemical conditions for near the springhead in Desperado Spring, Blue River Wildlife Management Area, Johnston County, Oklahoma. Values in parentheses describe conditions in springbrook.

Parameter/Collection	Oct. 2002	Jan. 2003	Apr. 2003
Water Temp °C	17.9 (17.6)	17.1 (16.7)	16.6 (16.7)
Dissolved Oxygen (mg/l)	4.5 (4.8)	6.6 (9.4)	5.3 (8.2)
DO Percent Saturation (%)	45 (48)	66 (95)	53 (83)
pH	6.5 (6.5)	7.2 (7.2)	7.2 (7.6)
Alkalinity (mg/l)	463	486	380
Turbidity (JTU)	1	1	1
Specific Conductivity (μmhos/cm)	630	486	397
Ammonia (mg/l)	0.62	0.38	0.43
Nitrates (mg/l)	0.11	0.04	0.11
Nitrites (mg/l)	2	2	2
Orthophosphates (mg/l)	0.22	0.1	0.04
Flow (m/sec)	0.4	0.4	0.4

and orthophosphates in the laboratory using a Bausch & Lomb Spectrophotometer 20 (Hach 1987).

Results & Discussion

Results from the analysis of these physicochemical conditions indicated whether the water quality would be sufficient to support aquatic macroinvertebrates (Table 1). Both dissolved oxygen concentration and percent oxygen saturation values increased between the springhead and springbrook sites as atmospheric oxygen diffused into the water below the emergence point (van der Kamp 1995). The values of most other parameters were relatively constant.

A total of 16,410 individuals representing 49 species were collected in the Surber net samples during the four seasonal sampling periods from Desperado Spring (Table 2). Four additional species of hemipterans and coleopterans were collected only in the qualitative samples, so they were not included in the statistical analyses. Hexapods made up 94.4% of the individuals and 34 taxa, while non-hexapods formed 5.6% of the individuals and 15 species. This overwhelming dominance by hexapods is a different finding than what was reported by Brown and Bass (2014) in nearby Pontotoc Ridge springs where non-hexapods were the most abundant group. Although it is well known that many springs often support more non-insects than insects (Webb et al. 1995, Brown and Bass 2014), hexapods were much more abundant in Desperado Spring. This is most likely due to the close proximity of the Blue River, an environment only about 15 meters from the springhead, that supports many aquatic insects. Blue River fauna may also colonize the spring run during periods of flooding. Over half of the insect species found in Desperado Spring were previously reported in an investigation of invertebrate drift occurring in the Blue River by Matzinger and Bass (1995).

Four genera of Chironomidae larvae dominated the Desperado Spring macroinvertebrate community making up 81.8% of the individuals present in the collections. These included *Sublettea* (33.7%), *Eukiefferiella* (24.3%), *Paratendipes* (13.0%), and *Corynoneura* (10.7%). *Sublettea*, *Eukiefferiella*, and *Corynoneura* always occurred in higher numbers at the springhead, while *Paratendipes* was usually more abundant in the springbrook (Table 2). It is possible these distributions reflected preferences for different microhabitats – the springhead substrate was composed primarily of cobble and gravel, while the springbrook substrate contained more sand and leaf debris overlying rock.

Comparisons of the species present at the springhead and those present at the springbrook sites using Sorensen's index of similarity ranged from 0.40 - 0.62 during the four collection periods. Specifically, those values were 0.50 during October, 0.52 during January, 0.62 during April, and 0.40 during July. Although some overlap of species did occur at both sites, other species were limited to either the springhead or

Table 2. Macroinvertebrates collected in Desperado Spring, Blue River Wildlife Management Area, Johnston County, Oklahoma.

Taxa	Oct. 2002 Springhead	Oct. 2002 Springbrook	Jan. 2003 Springhead	Jan. 2003 Springbrook	Apr. 2003 Springhead	Apr. 2003 Springbrook	Jul. 2003 Springhead	Jul. 2003 Springbrook	Totals
Platyhelminthes									
Unknown Turbellaria	1		8		14	2	112	3	140
Nematoda									
Unknown Nematoda		1		1		7			9
Oligochaeta									
Branchiura sowerbyi		1	1	3		13			18
Dero sp.				1		2		2	5
Limnodrilus sp.	30	28	9	25	17	166	1	52	328
Lumbriculus sp.	4								4
Pristina sp.						1		1	2
Bivalvia									
Sphaerium sp.						1		1	2
Crustacea									
Caecidotea sp.	6		107		33		5	1	152
Cladocera				2					2
Harpacticoida	1	4		7		5	16	44	77
Hyalella azteca complex					1				1
Ostracoda			4		38	2	25		69
Procambarus sp.		1		6		3		13	23
Acarina									
Hydrachnidae	2		3	16	14		17		52
Collembola									
Isotomidae	2			1	2	3	96		104
Semicerura sp.								1	1
Ephemeroptera									
Baetidae	1			2					3
Odonata									
Argia sp.	25	8	85	19	16	7	265	2	427
Brechmorhoga sp.			1						1
Unknown Zygoptera			1				6		7
Trichoptera									
Hydroptila sp.			2						2
Metrichia sp.	7		30	2	2	1	5		47
Hemiptera									
Aquarius sp.								1	1
Neocorixa sp.*									*
Rhagovelia sp.								1	1
Trepobates sp.*									*
Trichocorixa sp.								8	8
Trichoptera									
Hydroptila sp.			2						2
Metrichia sp.	7		30	2	2	1	5		47
Coleoptera									
Dineutus sp.*									*
Laccophilus sp.*									*
Diptera									
Atrichopogon sp.			1						1
Chironomus sp.						3		34	37
Conchapelopia sp.				2					2
Corynoneura sp.	67	24	1147	161	74	57	126	116	1772
Cricotopus sp.	21		38	22	48	26			155
Dasyhelea sp.	14		92	2				1	109
Dixa sp.							9		9
Ephydridae							1		1
Eukiefferiella sp.	31	2	688	22	3090	131	54		4018
Georthocladius sp.	18	8	15		181	13	563		798
Hemerodromia sp.			1						1
Larsia sp.						23	35	13	71
Limnophila sp.						1			1
Ormosia sp.			1						1
Paratendipes sp.	15	3		96	19	207		1813	2153
Rheotanytarsus sp.					11				11
Simulium sp.				2					2
Stictochironomus sp.	1		9	14		41		17	82
Sublettea sp.	43	2	58	38	368	224	4833		5566
Tanytarsus sp.	3			2				3	8
Tipula sp.		1			2		42	32	77
Number of Individuals	299	83	2333	448	3932	940	6216	2159	16,410
Species Richness	20	12	23	23	18	24	19	21	49 + (4*)
Species Diversity	2.437	1.834	1.516	2.116	0.912	2.102	0.957	0.777	

*** indicates taxa were not present in Surber net samples; found only in quantitative samples.**

the springbrook.

Results from the chi-square analyses indicated there was a statistically significant relationship between the number of individuals in the springhead and springbrook collections for all four seasons (χ^2 contingency test, $p<0.001$). Shannon's diversity values at the springhead ranged from 0.912 - 2.437 while these values in the springbrook were 0.777 - 2.116 (Table 2). Species diversity between the springhead and springbrook was significantly different during each collection month (Hutcheson *t*-test, October $t=4.88$, $p<0.001$, January $t=9.47$, $p<0.001$, April $t=29.39$, $p<0.001$, July $t=5.01$, $p<0.001$. This was expected because dissolved oxygen concentrations increased, presumably from atmospheric diffusion, as water flowed from the springhead into the springbrook, thus allowing the springbrook to support more species of macroinvertebrates.

Placement of taxa into trophic categories, based on information from Merritt et al. (2008) and Thorp and Covich (2009), revealed collectors dominated at the spring sites. Collectors were composed of 31 taxa, 66% of the species, and made up 94.6% of the individuals present. Predators (14 species, 4.5% of the individuals) and detritivores (two species, 0.9% of the individuals) composed the remaining trophic groups present. It should be noted that some of these species have different trophic roles as they grow and mature, so these proportions may change through time.

A large fraction of insect nymphs and larvae were found in the samples (Table 2). Gaskin and Bass (2000) also observed many immature insects were present in Desperado Spring and suggested that much reproduction must have been occurring there. This may be the case, but there is another possibility to be considered. Individuals making up the spring populations may have originated in the river and later moved into the springbrook, using it as a refuge from predators, such as larger fishes that would have difficulty existing in the spring's shallow water. It is unknown which, if either, of these hypotheses correctly explains the high number of immature individuals in Desperado Spring, but they are both possibilities.

Conclusion

Springs are unique and often over-looked aquatic environments. While many springs are reported to contain fauna found nowhere else, the Desperado Spring invertebrate community is mostly composed of species also found in the nearby Blue River. Non-insects are the dominant groups in many springs, but insects are the prevalent group in Desperado Spring, most likely due to its close proximity to the Blue River. Results of the physicochemical conditions in Desperado Spring indicate the water quality is capable of supporting a diverse biota, and this was confirmed by the intolerant taxa present in the samples.

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Two New State Records for Hemiptera (Miridae, Reduviidae) from Oklahoma

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The true bugs (Hemiptera) are likely one of the most recognized groups of any of the major orders of insects in Oklahoma. Over the last half decade, new geographic distributional records for hemipterans from the state have been provided by our community collaborative effort (Chordas and McAllister 2012, 2016; Chordas et al. 2017). Here, we continue to add new state records for two true bugs not previously reported from the state.

Between May and August 2017, various hemipterans were collected below a night light at a private residence in Hochatown, McCurtain County (Fig. 1). Specimens were collected with fine forceps and placed in individual vials containing 70% (v/v) ethanol. They were subsequently shipped to Stephen W. Chordas, III (The Ohio State University) for identification and deposition of vouchers in the C.A. Triplehorn Collection (OSUC) at The Ohio State University, Columbus, Ohio.

We collected a single specimen of the mirid, *Eustictus necopinus necopinus* Knight, 1923 with the following collection data: ***Oklahoma***: McCurtain County, off Halibut Bay Road in Hochatown (34° 10' 17.0286"N, 94° 45' 05.7414"W; 257 meters elevation); 30 V 2017; C. T. McAllister, collector (unique museum specimen code: OSUC 620943). In addition, a single horned or Red Bull assassin bug *Repipta taurus* (Fabricius, 1803) (Reduviidae), was also collected from the same site; 12 VIII 2017; C. T. McAllister, collector (OSUC 620942). Surrounding habitat consisted of various hardwoods (*Quercus* spp.) and pines (*Pinus* spp.) in Ouachita uplands.

Numerous other hemipterans were also collected from the same site, including: **Coreidae**, *Acanthocephalus declivis* (Say, 1832), *A. terminalis* (Dallas, 1852); **Miridae**, *Collaria oculata* (Reuter, 1876); *Jalysus spinosus* (Say, 1824), *Myodocha serripes*

Figure 1. Location of Hochatown (dot), McCurtain County, Oklahoma, where bugs were collected.

Oliver, 1811, *Ozophora picturata* Uhler, 1871; *Phytocoris sp.*; **Pentatomidae**, *Proxys punctulatus* (Palisot de Beauvois, 1818); **Reduviidae**, *Microtomus purcis* (Drury, 1782); *Oncocephalus geniculatus* (Stal, 1872); *Rasahus hamatus* (Fabricius, 1781); *Stenopoda spinulosa* Giacchi, 1969; *Triatoma sanguisuga* (Leconte, 1856); **Rhopalidae**, *Arhyssus lateralis* (Say, 1823); *Arhyssus nigristernum* (Signoret, 1859); **Rhyparochromidae**, *Myodocha serripes* Oliver, 1811; *Neopamera bilobata* (Say, 1852); *Ozophora picturata* (Uhler, 1871); *Pseudopachybrachius basalis* (Dallas, 1852); *Pseudopachybranchius vinctus* (Say, 1832); *Ptochiomera nodosa* Say, 1832. All of these 21 taxa (within six families) have been previously reported from Oklahoma (Drew and Schaefer 1962; Arnold and Drew 1988; Henry and Wheeler 1988; and others).

Eustictus necopinus necopinus is a brown bug with a light yellowish brown head, and brown striations; adults measure about 5.0–7.5 mm in length (see color Fig. 20 of this species in Chordas et al. [2011]). This hemipteran is distinguished by the shiny and glabrous appearance, vertical head with prominent eyes, and by the striate frons (Kelton 1980). It is transcontinental in distribution in Canada and has also been reported from Arkansas, Connecticut, Massachusetts Missouri, Mississippi, New York, Virginia, and México (Ward et al. 1977; Henry and Wheeler 1988; Maw et al. 2000; Chordas et al. 2011). This plant bug had not previously been documented for Oklahoma.

Repipta taurus is a small (11–13 mm) red and black assassin bug that is a stealthy predator of insects and other arthropods. It has been previously reported from Colorado, Florida, Georgia, Illinois, Louisiana, Mississippi, North Carolina, Pennsylvania, Texas, and México, Cuba, El Salvador, Guatemala, Honduras, Nicaragua, and Panama (Maldonado 1990; Shuh and Slater 1995; Taber and Fleener 2003; Swanson 2011; Martin-Park et al. 2012). We document *R. taurus* from Oklahoma for the first time and only the third report from a state west of the Mississippi River. There are likely several species of Hemiptera in Oklahoma that have not yet been collected so with extensive effort, including the use of flight-interceptor traps, discovery of additional records in the state is expected.

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Noteworthy Records of Helminth (Monogenoidea, Cestoda, Nematoda) and Crustacean (Copepoda) Parasites from Pealip Redhorses, *Moxostoma pisolabrum* (Catostomidae), from Oklahoma

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Abstract: Parasitic examination of two Pealip Redhorses, *Moxostoma pisolabrum* collected in March 2017 from the Illinois River, Cherokee County, Oklahoma, yielded a variety of taxa. Found were a new species of monogene, *Dactylogyrus* sp., a plerocercoid of the tapeworm, *Proteocephalus ambloplitus*, a nematode, *Rhabdochona milleri*, and a copepod, *Ergasilus megaceros*. We document four new host and three new geographic distributional records for these parasites, and the first time, to our knowledge, that this fish has been reported as a host.

The Pealip Redhorse, *Moxostoma pisolabrum* Trautman and Martin is a large catostomid that occurs in the Ozark uplands and adjacent areas of southeastern Kansas, Missouri, Oklahoma, and Arkansas (Robison and Buchanan 1988; Cross and Collins 1995; Pflieger 1997; Miller and Robison 2004). In Oklahoma, *M. pisolabrum* is found in the northeastern third of the state with two disjunct populations further west and south where it inhabits clear, gravel-bottomed large streams and rivers, often in riffle areas (Miller and Robison 2004). To our knowledge, nothing is known about the parasites of the Pealip Redhorse. We recently had the opportunity to examine *M. pisolabrum* for parasites and the results are reported herein.

On 12 March 2017, two adult *M. pisolabrum* (350 and 390 total length [TL]) were collected using a boat electrofisher from two sites in the Illinois River, Cherokee County (35.958345°N, 94.869452°W and 35.942909°N, 94.912282°W). They were placed on ice and necropsied within 24 hr. Gills were removed, fixed in 10% formalin, and examined under a stereomicroscope for monogeneans and crustaceans. When found, they were picked with minuten nadeln directly from the gills. Monogeneans and copepods were mounted in Gray and Wess medium, stained with Gomori's trichrome, and coverslip ringed with fingernail polish. 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. A single cestode was fixed in near boiling tap water without coverslip

pressure, stained with acetocarmine, dehydrated in a graded ethanol series, cleared in methyl salicylate, and mounted in Canada balsam. Nematodes were fixed in a similar manner, preserved in 70% (v/v) ethanol. Nematodes were cleared by placing them in a mixture of 5% or 10% glycerin in 70% ethanol in an uncovered dish, and allowing the ethanol (and water) to evaporate. Cleared nematodes were studied as temporary mounts in glycerol.

Voucher specimens of select parasites were deposited in the Harold W. Manter Laboratory of Parasitology (MWML), University of Nebraska, Lincoln, Nebraska. A host photovoucher specimen was deposited in the Henderson State University Collection (HSU), Arkadelphia, Arkansas, as HSU 3620.

Results and Discussion

Both fish harbored parasites, including a monogenean, tapeworm, nematode, and a copepod. The parasites found are presented below in annotated format.

Monogenoidea: Monopisthocotylea: Dactylogyridae

***Dactylogyrus* sp.**

One *M. pisolabrum* (390 mm TL) was found to harbor four specimens of an undescribed species of *Dactylogyrus* on its gills. This unknown species morphologically resembles *Dactylogyrus apos* Mueller, 1938, *D. atripinnei* Timmons and Rogers, 1977, *D. duquesnei* Mueller, 1938, and *D. niger* Rogers and Mizelle, 1966, all parasitizing species of catostomids (Hoffman 1999), by possessing a robust, sickle-shaped male copulatory organ. It differs from these and all other North American species of *Dactylogyrus* by possessing two unique wing-like projections opposite each other on the proximal portion of the accessory piece. A description of this new species is forthcoming in a separate report.

Cestoda: Proteocephalidea: Proteocephalidae

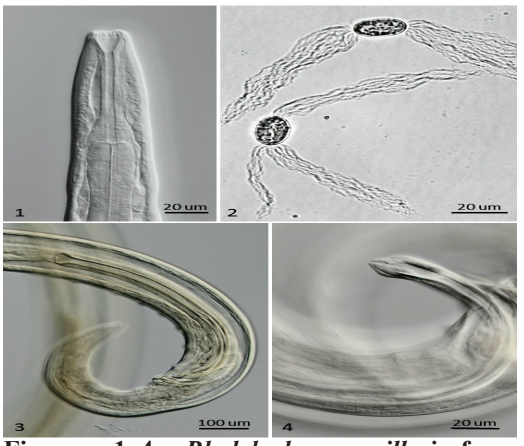
***Proteocephalus ambloplitis* (Leidy, 1887) Benedict, 1900**

A single plerocercoid of *P. ambloplitus* was found in the body cavity of one of the *M. pisolabrum*. In addition, several mature *P. ambloplitus* were found during this survey of other fishes from the same Illinois River locale in the anterior intestine of three Largemouth Bass (*Micropterus salmoides*). 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). 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) found *P. ambloplitis* in centrarchids from the Little River (Cleveland County) and Lake Texoma, Oklahoma. Concerning other catostomids, Amin (1990) reported *P. ambloplitis* from Common Carp (*Cyprinus carpio*), Lake Chubsucker (*Erimyzon sucetta*), and Golden Redhorse (*Moxostoma erythrurum*) from Silver and Tichigan Lakes, Wisconsin, and Hoffman (1999) documents *P. ambloplitis* from Smallmouth Buffalo (*Ictiobus bubalus*). We report *P. ambloplitis* for the first time from *M. pisolabrum*, and only the second time from the fishes of the genus *Moxostoma*.

Nematoda: Ascaridida: Rhabdochonidae

***Rhabdochona milleri* Choquette, 1951 (Figs. 1–4)**

Nematodes (HWML 110365-110366) closely resembling *R. milleri* were found in the small intestine of both *M. pisolabrum*. In essential (taxonomically relevant) features, such as 14 prostomal "teeth" with paired lateral ones, eggs with conspicuous polar filaments, male papillar pattern, and shape and size of spicules, the species found in *M. pisolabrum* is similar to *R. milleri* of Moravec and Arai (1971) and Moravec et al. (2011). However, the distal end of the long spicule is similar to that illustrated by Moravec and Arai (1971) from *R. milleri*, but different from that in Moravec et al. (2011). It also appears that the distal end of the long spicule



Figures 1–4. *Rhabdochona milleri* from *Moxostoma pisolabrum*. 1. Anterior end of female. 2. Eggs with polar filaments in ribbon form. 3. Long spicule of male in situ. 4. Distal free end of long spicule.

is partially membranous. The membranous folds may remain compressed against the distal end of the spicule or unfurl when needed, which may explain the variability seen in this feature in different descriptions (see also discussions by Moravec and Arai, 1971, and Moravec et al., 2011). This membranous region is also difficult to see when the spicule is retracted, which may further contribute to the apparent differences in the other accounts. *Rhabdochona milleri* appears to be the typical *Rhabdochona* species in *Moxostoma* spp. It was originally described from the Shorthead Redhorse, *Moxostoma macrolepidotum* (as *M. aureolum*) in Québec, Canada (Choquette 1951). It has been reported from *M. macrolepidotum* in Ontario, Canada (Dechtiar 1972), South Carolina (Moravec et al. 2011), Virginia, and elsewhere in the U.S. (Moravec and Arai 1971; Hoffman 1999). It is also common in the same host in Manitoba, Canada (AC, *unpubl*.).

Moravec et al. (2011) synonymized *R. milleri* with two other *Rhabdochona* species described (or redescribed) from catostomids, *R. catostomi* Kayton, Kritsky, and Tobias, 1979 from two *Catostomus* spp. in Alberta, Canada, and Idaho, and *R. ovifilamenta* Weller, 1938, originally described from Yellow Perch, *Perca flavescens* (arguably an incidental host) and later redescribed from two *Catostomus* spp. in Alberta (Moravec and Arai 1971). Moravec et al. (2011) argued that the differences between *R. milleri*, *R. catostomi* and *R. ovifilameta* can be attributed to intraspecific variation, and concluded that *R. milleri* and *R. catostomi* are junior synonyms of *R. ovifilamenta*. However, it is uncertain whether notable differences in the prostomal "teeth" pattern and differences in the egg filaments between *R. milleri* and *R. ovifilamenta* (Moravec and Arai 1971; Moravec et al. 2011) can be accepted as 'intraspecific' variation until *Rhabdochona* spp. from *Moxostoma* and *Catostomus*, from both the same and different locations, are studied using morphological and molecular data. Therefore, we feel it prudent to keep the three nominal species separate for the moment, and assign the nematodes from *M. pisolabrum* to *R. milleri*. The presence of *R. milleri* in *M. pisolabrum* is a new host and geographic record.

Crustacea: Copepoda: Ergasilidae

***Ergasilus megaceros* Wilson, 1916**

Both *M. pisolabrum* were infested on their gill filaments with one each *E. megaceros* (HWML 139374). This copepod has been reported from several hosts in the families Catostomidae, Centrarchidae, Cyprinidae, and Ictaluridae, primarily east of the Mississippi River in Alabama, Florida, Iowa, Massachusetts, Michigan, Mississippi, New York, and North Carolina (Hoffman 1999). The following catostomids have been reported as hosts, including White Sucker (*Catostomus commersonii*), Blue Sucker (*Cycleptus elongatus*), *E. sucetta*, and Blacktail Redhorse (*Moxostoma poecilurum*) from Alabama and Florida (Roberts 1970; Johnson and Rogers 1973). We document a new host and geographic record for *E. megaceros*.

In summary, we have provided four new host and three new geographic distributional records for parasites of *M. pisolabrum* from Oklahoma. As our sample size was limited, additional surveys are warranted on this fish from Oklahoma as well as other parts of its range.

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Seasonal Diet Composition of Black Bullhead (*Ameiurus melas*) in Lake Carl Etling, Oklahoma

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Abstract: Black Bullhead (*Ameiurus melas*) is the most common of the three species of *Ameriurus* present in Oklahoma. They range across the state and inhabit any aquatic eco-system. However, little is known about their feeding habits. Food habits of Black Bullheads (95-318 mm total length) collected from June 2015 through May 2016 at Lake Carl Etling revealed a broad range of prey items. The total food volume of the 408 stomachs examined was comprised of sixteen different prey items (5 fish species, 5 crustacean species, 3 species of insects, and 3 plant species). No significant difference was found between seasons. Overall, fish had the highest index of relative importance (IRI; 88.5) with crustaceans having the lowest IRI (2.1), while insects and plants had similar IRI (5.8 and 5.5). Gizzard Shad were found to be the most frequent diet item consumed. Black Bullheads exhibit a mixed feeding strategy with varying degrees of specialization. Fish were most important prey item of Black Bullheads, while bullheads occasionally consumed crustaceans, insects or plants showing a higher between-phenotype component. It appears that Black Bullheads are highly piscivorous in Lake Carl Etling. Due to this finding, consideration of diet overlap and fish forage availability is critical when fisheries managers are considering management strategies for other top predators or when contemplating the introduction of a new species into an aquatic system containing Black Bullhead.

Introduction

Black Bullhead (*Ameiurus melas*) is one of three species of *Ameriurus* native to Oklahoma and has a wide distribution across the midwestern United States (Miller and Robison 2004; Mork et al. 2009). Their ability to survive under conditions of poor water quality with high nutrient concentrations has allowed Black Bullhead to adapt to virtually any aquatic ecosystem throughout their range (Pflieger 1997). As a result, many fisheries managers have considered Black Bullhead a pest species and most studies have been directed towards their removal (Houser and Grinstead 1961; Hanson et al. 1983) or studying how they negatively impact water quality (Braig and Johnson 2003; Fisher et al. 2013). However, few studies have examined their role in the ecosystem, particularly their trophic status in the aquatic communities.

The studies that have examined prey use by Black Bullheads are dated and have focused on prey preference. These studies have shown selectivity for a variety of macroinvertebrates (Raney and Webster 1940; Williams 1970) from a wide range of zones including limnetic, littoral, and benthic (Repsys et al. 1976).

Currently, there exists a lack of diet information in the literature and no studies to our knowledge describing feeding habits of Black Bullhead in Oklahoma. The objective of this study was to examine the diet composition of Black Bullhead in Lake Carl Etling in Oklahoma on the western extent of their natural range, and to describe their feeding patterns and the effect of season on diets.

Methods

Study Area

Lake Carl Etling is 64.3 ha at normal pool elevation, with approximately 8 km of shoreline. It was created in 1958 by impounding South Carrizo Creek, a tributary of the Cimarron River in the northwestern tip of Oklahoma's panhandle in Cimarron County.

Sampling

Black Bullheads were collected monthly from June 2015 through May 2016 using boat electrofishing to sample the entire shoreline. Fish were placed on ice immediately after capture, and processed at the Oklahoma Fisheries Research Lab in Norman, Oklahoma. Fish were measured for total length (nearest mm) and weight (nearest g). Stomachs were extracted, prey items were removed and identified, enumerated, and individual prey items weighed to the nearest gram. All prey items were identified to species when possible using scientific taxonomic keys to identify aquatic invertebrates (Merrit et al.2008), fish fillets and scales (Oats et al. 1993), clethra (Traynor et al. 2010), and fish dichotomous keys (Miller and Robison 2004) to identify fish prey items.

Analysis

One-way ANOVAs were performed to determine differences between TL and weight of Black Bullheads between seasons. Tukey HDS post-hoc tests were used when ANOVA indicated significant differences existed. Stomach samples were analyzed by percentage of empty stomachs, frequency of occurrence (O_i), percent composition by number (N_i), percent composition by weight (W_i), and index of relative importance (IRI) (Bowen 1996; Chipps and Garvey 2007). Different prey items were pooled into four categories (Fish, Crustacean, Insect, and Plant). Diet composition (excluding fish with empty stomachs) between seasons (Spring - from March 1 to May 31, Summer - from June 1 to August 31, Fall - from September 1 to November 30, and Winter - from December 1 to February 28) was assessed using a chi-square test (Sokal and Rohlf 1981; Bascinar and Saglam 2009). All statistical analyses were conducted at a significance level of $P \leq 0.05$.

The graphical model of Amundsen et al. (1996) was used to depict feeding strategy (specialized or generalized), relative prey importance (dominant or rare), and niche variation (individual versus population pattern based on the distribution of individual prey items) by plotting prey specific abundance against frequency of occurrence for each prey type. Prey specific abundance is calculated by taking in account only those predators in which the actual prey occurs ($Pi=(\Sigma S_i/\Sigma S_{ti}) \times 100$; where Pi is the prey-specific abundance of prey i, Si is the stomach content (volume, weight or number) comprised of prey i, and S_{ti} is the total stomach content in only those predators with prey i in their stomach (Amundsen et al. 1996).

Results

Of the 408 specimens collected between June 2015 through May 2016, 40% had empty stomachs (N = 162). Black Bullheads ranged in TL from 95-318 mm (mean = 201 mm), and from 10-525 g in weight (mean = 127 g). No significant difference was detected between total lengths ($F_{3, 405} = 0.44$, $P = 0.72$) and weights ($F_{3, 405} = 0.16$, $P = 0.92$) seasonally (Table 1). Diets of these fish were fairly diverse, including sixteen different prey items (5 fish, 5 crustaceans, 3 insects, and 3 plant species; Table 2).

Black Bullheads had empty stomachs most frequently in summer samples (O_i = 49.4), followed by fall (43.5), spring (33.0), and winter (28.9). Overall, fish had the highest IRI (88.5) with crustaceans having the lowest IRI (2.1), while insects and plants had similar IRI (5.8 and 5.5; Table 2). Of all prey items, Gizzard

Table 1. Total number, mean total length (±SE), and mean weight (±SE) of Black Bullheads captured during each season from Lake Carl Etling, Oklahoma.

Season	*N*	Total Length (mm)	Weight (g)
Winter	97	201 ± 5.5	126 ± 9
Spring	91	197 ± 5.6	124 ± 8.8
Summer	77	201 ± 6.1	132 ± 9.9
Fall	145	204 ± 4.6	128 ± 7.8

Shad had the highest O_i during summer, fall and winter. However, in the fall Bluegill had a higher IRI = 45.9 than Gizzard Shad (IRI = 39.4, Table 2). The two *Lepomis* species had a combined O_i 14.13 (spring) and 15.15 (winter) in diets, however in winter and summer O_i was three times less. During spring, unidentified fish had the highest O_i, N_i, and IRI of all prey species.

A Chi-square test revealed no significant differences among Black Bullhead stomach contents (the four diet categories) by season (χ^2 = 13.19, P = 0.15). Because no statistical difference occurred among seasons, all items were pooled into four main prey item groups (fish, crustaceans, insects and plant) for the entire year to graphically depict feeding strategy.

Analysis of feeding strategy, based on the Amundsen et al. method (1996), showed that Black Bullheads exhibit a mixed feeding strategy with varying degrees of specialization based on different prey groups (Figure 1). In terms of prey importance, fish were most important among individual bullheads based on habitat, but Black Bullheads also occasionally consumed crustaceans, insects or plants (having a higher between-phenotype component).

Discussion

Fish, but more specifically Gizzard Shad, were found most frequently in the diets of Black Bullheads from Lake Carl Etling. A transition from a Gizzard Shad dominated diet to alternate prey sources may be due to changes in environmental conditions, prey availability, or species habitat shifts, which could be a driving the seasonal presences of *Lepomis* species in diets of Black Bullheads. A preference for fish prey has not been documented in previous *Ameiurus* diet studies, instead Arthropoda and Crustacea were the most frequently consumed diet items in those studies (Raney and Webster 1940; Williams 1970). Repsys et al. (1976) suggested that prey consumed by Black Bullheads was based on habitat and availability of prey. The shoreline habitat in Lake Carl Etling is fairly homogenous consisting of inundated dead terrestrial vegetation and remnant debris from recent years of drought, large rock outcroppings, and a mixed sand/gravel substrate. Gizzard Shad are the most abundant fish species in Lake Carl Etling with electrofishing catch rates in the spring ranging from 216-341 fish/hr, and in the fall ranging from 1593-1752 fish/hr (ODWC unpublished data). Fish importance in the winter diet of Black Bullhead, particularly the Gizzard Shad component, is likely driven by the overall abundance of Gizzard Shad in Lake Carl Etling. High Gizzard Shad abundance is also likely driving total annual fish consumption values for Black Bullhead in this system.

A novel finding was the spike in unidentified fish that were found in spring diets of Black Bullhead. Lake Carl Etling is stocked annually in the fall with hatchery raised Rainbow Trout (*Oncorhynchus mykiss*) to create a winter time fishery. We speculate that during the winter months when surface water temperatures are low (ranging from 1.7 – 5.6 ºC; unpublished data 2016), Gizzard Shad movements are reduced, which has been shown to effect other *Clupeidae* winter movements (Hurst 2007). High densities of stocked trout and other resident predators in Lake Carl Etling are more effectively able to feed on Gizzard Shad in winter months. Furthermore, Lake Carl Etling freezes over for a brief period of time annually. This usually results in the observation of winter time Gizzard Shad kill. Gizzard Shad succumb once water temperatures decrease below 4 ºC (Porath 2006). Both events could result in lowering of density of Gizzard Shad shown in the decreased catch rates from fall to spring. Alternatively, when water warms to 21-26ºC (Cherry et al. 1977; Currie et al. 1998), the critical thermal maxima of Rainbow Trout, death occurs. While examining Black Bullhead stomach samples in early June 2015,

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Table 2. Frequency of occurrence (O_i), percent composition by number (N_i), percent composition by weight (W_i), and index of relative importance (IRI) for seasonal diet composition of Black Bullheads collected from June 2015 through May 2016 from Lake Carl Etling,Oklahoma. Bold values indicates the overall annual combined group (fish, crustaceans, insects, plant and empty) values.

Diet Item	Winter				Spring				Summer				Fall			
	O_i	W_i	N_i	IRI	O_i	W_i	N_i	IRI	O_i	W_i	N_i	IRI	O_i	W_i	N_i	IRI
Fish	**39.6**	**89.5**	**47.1**	**88.5**												
Bluegill Sunfish (*Lepomis macrochirus*)	2.92	7.35	1.75	0.77	7.61	38.5	11.6	15.8	1.73	17.9	1.94	1.94	11.7	51.6	29	45.9
Green Sunfish (*Lepomis cyanellus*)	0.69	2.8	0.88	0.07	6.52	13.8	8.7	6.1	3.46	26.8	4.85	6.17	3.45	9.69	6.54	2.72
Gizzard Shad (*Dorosoma cepedianum*)	29.4	64.3	22.8	74	2.17	3.35	2.9	0.56	19.5	34.8	32	73.4	14.6	28.5	27.1	39.4
Common Carp (*Cyprinus carpio*)	0	0	0	0	0	0	0	0	2.6	0.21	1.94	0.32	0	0	0	0
Black Bullhead (*Ameiurus melas)*	2.06	1.16	0.88	0.12	1.09	9.23	1.45	0.48	9.16	12.6	7.77	10.5	2.07	1.93	2.8	0.48
Unidentifiable	8.76	7.25	3.95	2.83	26	19.1	40.6	64.5	1.3	0.18	0.97	0.08	3.62	3.51	5.61	1.61
Crustaceans	**2.3**	**0.87**	**8.5**	**0.21**												
Anostaca	0	0	0	0	1.52	1.25	2.9	0.26	0	0	0	0	0	0	0	0
Copepoda	0.82	0	8.77	0.21	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0	1.62	0.78	13.6	1.31	0	0	0	0
Ostracoda	0.1	0	0.44	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentifiable Crayfish Species	0	0	0	0	1.09	2.23	1.45	0.17	0	0	0	0	0	0	0	0
Unidentifiable	0	0	0	0	2.17	0.61	2.9	0.32	0	0	0	0	2.07	0.21	2.8	0.3
Insects	**4.4**	**3.9**	**33.3**	**5.8**												
Odonata	0	0	0	0	1.09	0.5	1.45	0.09	2.53	5.46	1.94	1.06	2.07	0.06	5.61	0.57
Orthoptera	0	0	0	0	0	0	0	0	1.3	0.03	1.94	0.14	0	0	0	0
Diptera	8.35	9.35	53.5	15.2	0	0	0	0	0	0	0	0	0	0	0	0
Unidentifiable	0	0	0	0	0	0	0	0	2.6	0.12	29.1	4.28	0.69	0.01	1.87	0.06
Plant	**12.5**	**5.7**	**11.1**	**5.5**												
Cladophora	16	7.77	7.02	6.83	1.41	0.2	4.35	0.27	1.3	0.62	0.97	0.12	1.72	1.5	2.8	0.36
Maize	0	0	0	0	0	0	0	0	0	0	0	0	0.52	0.3	0.93	0.03
Myriophyllum	0	0	0	0	9.78	10.5	13	9.59	3.57	0.49	2.91	0.68	9.93	2.74	15	8.55
Unidentifiable	0	0	0	0	4.73	0.7	8.7	1.85	0	0	0	0	0	0	0	0
Empty	**38.5**															
Empty	28.9				33				49.4				43.5			

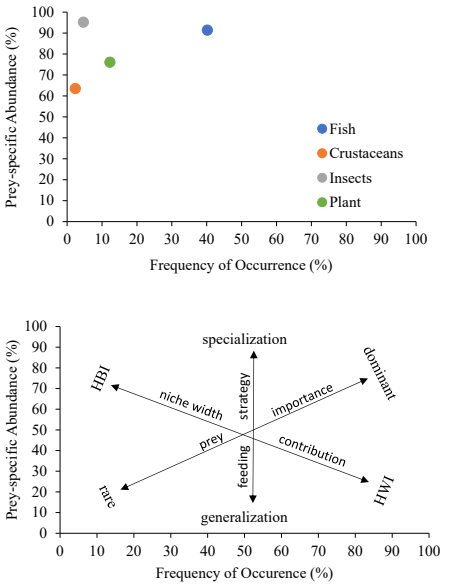

Figure 1a. Feeding strategy plot for Black Bullheads using methods described in Amundsen et al. (1996). Figure 1b. Graphic representation of feeding strategy, niche width contribution, and prey importance, as proposed by Amundsen et al. (1996; HBI = high between individuals; HWI = high within individuals).

observations of distinct fish organs (e.g. gill arches, pieces of intestines, stomachs, and pyloric caeca) were noted during analysis. However, it was not until May 2016 during an electrofishing survey that we developed a potential theory as to why we frequently observed unidentified fish parts in Black Bullhead diets during spring months. In May 2016, we sampled numerous Black Bullheads and Channel Catfish *Ictalurus punctatus* that were actively foraging on and were stuck within the body cavities of dead Rainbow Trout (Figure 2). Coinciding with the winter decline in Gizzard Shad abundance and an increase in dead or dying rainbow trout, we believe that Black Bullheads shifted to a scavenging foraging behavior, hence the observations of distinct fish organs in their diets during spring.

It appears that in certain aquatic systems Black Bullheads are highly piscivorous, but their impacts on other sport fish populations within the same system are unknown. Based on these results, it seems that Black Bullheads in Lake Carl Etling are likely competing with other top predators (Largemouth Bass *Micropterus salmoides*, Walleye *Sander vitreus*) based on the dominance of fish in their diets. This could be problematic if dietary overlap and resource availability is not considered in systems where Black Bullheads are established and a fisheries manager is trying to stock additional predators to create angling opportunities.

Although Black Bullheads are a native species in North America, they are considered invasive in Europe (Nowak et al. 2010; Rutkayova et al. 2013; Copp et al. 2016). Most studies have focused on species identification and factors affecting reproduction (Ruiz-Navarro et al 2015), but little is known about their impact on the native fishes. Similar to our results, Ruiz-Navarro et al. (2015) found through stable isotope analysis of a population of Black Bullheads in Europe that fish contributed to the long term assimilated diet, more so than macroinvertebrates. It appears that if Black Bullhead range continues to expand in Europe, the result could be negative for native predatory species based on competition, predation, or the

Figure 2. A photograph taken during an electrofishing survey in late May 2016 at Lake Carl Etling, Oklahoma showing a live Channel Catfish actively foraging on a recently deceased Rainbow Trout.

displacement of native fish species.

Results from this study show the importance of fish in the diets of Black Bullhead. Furthermore, it introduces the question of how to deal with Black Bullhead populations in situations where they are highly piscivorous and function similarly to a top predator in the system. Considerations of diet overlap and fish forage availability are critical when fisheries managers are considering management strategies for other top predators or when contemplating introduction of a new species into an aquatic system. Further research is needed on a larger scale (multiple systems) to determine the full impacts of Black Bullheads on sportfish populations.

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Recruitment of Two Non-native River-Spawning Fishes in Lake Texoma, Oklahoma and Texas

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Abstract: The impoundment of a river alters environmental conditions to the extent that some important life history requirements of lotic-adapted fishes are disrupted; changes in requisite conditions for reproduction can interfere with spawning and recruitment. Water movement stimulates spawning migration as well as providing buoyancy to maintain eggs in suspension during development. These requirements can be met for reservoir populations if the fish can access adequate flowing water conditions in tributaries. Two non-native river-spawning fishes, Grass Carp (*Ctenopharyngodon idella*) and Striped Bass (*Morone saxatilis*) have become established in Lake Texoma; both have spawned in the Red and Washita Rivers and have been recruiting in the lake environment. Based on relative abundance of each species in the 2017 samples, we consider that both produced a strong year class. Successful reproduction for the exotic Grass Carp might be expected in some of the other 10 inland reservoirs where Striped Bass spawning occurs.

Introduction

Reproduction and survival of a non-native fish determines whether a population will be naturalized in the new aquatic habitat. Requisite physico-chemical conditions for lotic spawners are not present within reservoirs, however, some in-flowing tributaries can provide suitable habitat for reproduction. The anadromous Striped Bass (*Morone saxatilis*) has been widely stocked in large impoundments of North America since 1965 following the development of artificial propagation techniques (Stevens 1984); however, natural reproduction and recruitment have occurred in only about ten of the over 450 stocked reservoirs. Setzler et al. (1980) provide a biological review for the Striped Bass including reproductive biology and Bonn et al. (1976) and Harrell et al. (1990) published details of hatchery-based propagation.

Grass Carp (*Ctenopharyngodon idella*) were imported from Asia in 1963 and hatchery spawned in 1966; they were first collected in open waters within the U.S. in 1971 (Kelly et al. 2011), becoming widespread and common by 1974-1976 (Plieger 1978). Stanley et al. (1978) summarized the reproductive requirements of this river-spawning cyprinid and speculated on the likelihood of recruitment in North America. Yolk-sac larvae were reported at water temperatures from 23-28^{0}C (Brown and Coon 1991; Zimpfer et al. 1987). Naturalization was widely established by 1990 (Raibley et al. 1995). Shireman and Smith (1983) and Chilton and Muoneke (1992) review the biology of the Grass Carp and summarize the reproductive requirements and Opuszynski and Shireman (1995) describe important details of artificial propagation.

Grass Carp stocking in Oklahoma is permitted only in private waters, but collection from public waters tributary to Lake Texoma has been reported (Wagner et al. 1983). While Grass Carp have spawned and have become naturalized in North America and natural spawning of Striped Bass is known from only a few of the stocked reservoirs, reproduction and

recruitment within the same system has not been reported. Here, the reproductive requirements for these two rheophilic species are compared within the context of known recruitment in Lake Texoma.

Striped bass were introduced into Lake Texoma between 1965 and 1974 through stocking over 1 million juveniles; they established a self-sustaining population through natural reproduction, which was reported in 1973 and 1975 and continues to the present (Mauck 1991; Harper and Namminga 1986; Lamprecht et al. 2013). The specific localities of Striped Bass spawning in both major tributaries in 2001-2004 were identified by Baker et al. (2009) and Ryan (2004).

Striped Bass are anadromous in their Atlantic Coast range; they migrate far enough up the coastal rivers so that the current will suspend the semi-buoyant eggs throughout incubation and early larval development. The reproductive biology for Grass Carp, although totally occurring in freshwater, is quite similar relative to upstream spawning migration. Both seek suitable environmental conditions to stimulate spawning and the eggs of both must have sufficient flowing water conditions to maintain the developing eggs in the water column until hatching and until the swimbladder develops in larvae (Table 1).

Both species migrate upstream comparable distances to spawn at similar temperatures. The current velocity to maintain water-hardened eggs in suspension is similar, however, spawning in Lake Texoma presents conditions which are quite different from their native spawning habitats. Both the Red and Washita Rivers have high total dissolved solids (TDS) from natural sources; this high salinity reduces the post-fertilization swelling of the eggs which results in smaller eggs with greater density (Combs 1980). In contrast, eggs swell to a proportionately greater size in water with low dissolved solids (Bergey et al. 2003). Various studies present confounding information on the relationship of water quality and the extent of post-spawning egg swelling (Gonzal et al. 1987; Spade and Bristow 1999); is it a factor of the components of Total Hardness (Calcium & Magnesium) or Alkalinity (Carbonates & Bicarbonates) or the total array relative to osmolality (Total Dissolved Solids - Conductivity)? Water hardened eggs of grass carp in water of low TDS (ca 40 µmhos/cm) have 16-18 eggs/mL (W. Shelton, Unpublished data, Auburn University) compared to about 65/mL at 800-1,000 µmhos/cm (Rothbard et al. 2000). Both Grass Carp and Striped Bass eggs have a relatively thin non-adhesive limiting membrane which are similar in initial diameter, and developmental periods are very similar at comparable temperatures and further, both are similarly affected by the ionic level of water relative to the extent of swelling during water hardening (Table 1). Consequentially, smaller eggs will require a greater minimum velocity to keep them in suspension, thus, will travel further prior to hatching at any particular temperature.

Methods

Natural spawning and recruitment for each species in Lake Texoma have been previously reported, however, the present report documents reproduction and high survival for both within the same year, suggesting similar environmental conditions were effective. The two sampling efforts had different objectives; the ODWC program was directed toward documenting survival of recently stocked age-0 Alligator Gar (*Atractosteus spatula*) in the river-reservoir interface section of the Red River arm of Lake Texoma during the summer of 2017. Alligator gar are native to the Red River drainage, but have not been common since the impoundment of Lake Texoma. Sampling has been designed to evaluate the effectiveness of stocking to supplement natural spawning. Mini-fyke nets (0.6 m x 6.35 m; with 3.18-mm mesh, 0.6 m x 1.92-m rectangular cab, 510-mm metal throat and with a 9.14-m lead) were deployed perpendicular to the shoreline in water less than 1- m deep and surrounded by aquatic or terrestrial vegetation and woody debris (per protocol referenced in Snow et al. 2016). Grass Carp and Striped Bass juveniles were captured incidentally. Secondly, fish were collected during the Freshwater Fish Ecology

Table 1. Characteristics of spawning-related parameters for grass carp and striped bass.

Parameter	Grass Carp	Literature	Striped Bass	Literature
Temperature (^{0}C)				
Migration:	15-17	1,2	13-15	7,8
Spawning:	18-22	1,3,16	14-18	7,8
Current Velocity (m/s)	0.2-1.8	1,2,3	0.3-2.0	7,8,13
			0.5-0.8*	11
Egg Size				
Initial (#/mL)	800-1000	1,5,14	900-1000	7,9,10,15
Initial diameter (mm)	1.2-2.0	1,5	1.2-1.8	9
*Water hardened (mm)	4.2-5.3 (+1-2h)	1,5,17	2.9-4.6 (+1.0-1.5h)	6,9,10
			1.7-2.0; 1.5-1.8	11,12
*Water hardened (#/mL)	16-18 to 65-85	5,14	117	15
Incubation Period (h)	23-33 @ 21-25°C	1,5	26-40 @ 20-25°C	9,10
**Drift Distance (km)	28-100	1-4,6	30-150	7,8
			60-160	11,12,13
Yolk-sac larvae –Swim-up	+ 3d; ca 5 mm TL	1,5	+ 4 d; ca 6 mm TL	7,8

* Smaller eggs have greater specific gravity, therefore greater current is required to maintain buoyancy; swelled size (water hardened) is affected by total dissolved solids [smaller in water with high conductivity e.g. **Striped Bass** - Red River @ 2380-5460 µmho/cm (1.55 mm); Washita @ 449-1811 µmho/cm (1.7 mm); larger in low conductivity water e.g. **Striped Bass** - Santee-Cooper @ 100-120 µmho/cm (2.0-3.0 mm), **Grass Carp** – 16-18 eggs/mL (4-5 mm) @ ca. 40 µmho/cm vs. 65-85/mL (4.0-mm) @ 800 µmho/cm (11, 12, 13, 14).

**drift distance depends on temperature and current velocity.

1)Shireman & Smith 1983; 2) Chilton & Muoneke 1992); 3). Stanley et al. 1978; 4) Leslie et al. 1982; 5) Opuszynski and Shireman 1995; 6) Bergey et al. 2003; 7) Setzler et al. 1980; 8) Crance 1984; 9) Bonn et al. 1976; 10) Harrell et al. 1990; 11) Combs 1980; 12) Baker et al. 2009; 13)Lamprecht et al. 2013; 14) Rothbard et al. 2000; 15) Spade and Bristow 1999; 16) George & Chapman 2015; 17) Rach et al. 2010.

(BIOL 4433/5533) course at the University of Oklahoma Biological Station (UOBS) in May of 2014 and August of 2017. The objectives of these efforts were intended to demonstrate the usefulness of seine-sampling reservoir fishes. Juvenile fishes were collected by seining along the south perimeter of the biological station. Multiple daytime and nighttime seine samples were made with standard 3-m seines, a 6-m bag seine and a 30-m seine.

Results and Discussion

A fresh specimen of an adult Grass Carp (ca. 50 cm TL) was found in 2014 during a class field trip; it appeared to have been killed by a bow hunter. Presence of adult Grass Carp indicated the potential for reproduction. In fact, juvenile Grass Carp had been reported from collections in 1999 and 2000 in both the Red River and Washita River areas, respectively (Hargrave and

Gido 2004); no other published reports have been made. Grass Carp were not collected during class sampling in May of 2014, but juvenile Striped Bass were abundant. On 7 August 2017, the class seine sampled for about two hours along the shoreline area south of UOBS. In one seine series, 40-50 Striped Bass fingerlings (5 to 12-cm TL) and 20-30 Grass Carp fingerlings (8.5 to 10-cm TL) were collected using a 6-m bag seine. A second seine series was repeated on 8 August using both a 6-m and a 30-m bag seine; multiple hauls were made during the day and after dark. Striped Bass juveniles were again common as well as a few juvenile White Bass (*Morone chrysops*), however, no grass carp juveniles were collected. These young-of-the-year Striped Bass and Grass Carp presumably were spawned in the Red River based on the netting in that region of the reservoir.

The mini-fyke netting by Oklahoma Department of Wildlife Conservation (ODWC) personnel in the river-reservoir interface section of the Red River arm collected 66 juvenile Grass Carp during 216 net-nights of effort (Table 2). Most Grass Carp (92.4%) were captured from 19 June through 14 July 2017. Only five individuals were captured after 14 July. No juvenile Grass Carp were captured at the end of June 2017 within the mid-lake reservoir proper during seine sampling by ODWC personnel of the Southcentral Management Region (Cliff Sager, ODWC, Personal Communication). The five Grass Carp collected from 31 July through 4 August were of two distinct size groups, one individual was 113 mm TL and the other four averaged 44 mm (Table 2). During the post-nursing period, larger juveniles probably disperse into the reservoir; we speculate that by the time Grass Carp have reached about 100 mm TL, they will have left the nursery habitat in the river-reservoir interface and moved down lake to alternative habitat and/or food sources. This transition could account for the size of Grass Carp collected by the class at UOBS, about one month after frequent capture of smaller fish in the upper reaches of the reservoir. Daily age estimation of individual otoliths for these four Grass Carp will need to be completed before any conclusive results are made.

Previous ODWC mini-fyke netting from May through June of 2012 and June through July of 2013, captured 8 and 12 juvenile Grass Carp, respectively (ODWC unpublished data); no juvenile Grass Carp were collected during 2015 netting (Porter and Snow 2016). Regarding Striped Bass year-class recruitment, average year class sizes were produced in both 2012 and 2013, but 2015 and 2017 year classes were considered strong (Cliff Sager, ODWC, Personal Communication). Even though a good year class of Striped Bass was formed in 2015, no Grass Carp were collected; however, sampling was in August through September (Porter and Snow 2016), so the juvenile Grass Carp may have already moved down lake,

Analyzing otolith daily growth increments for both Grass Carp and Striped Bass will allow management biologist to better understand environmental factors influencing recruitment. Proper daily growth increment estimates will allow managers to back-calculate fish ages at hatching, and possibly correlate the environmental variables (river flows, water

Table 2. Summary of age-0 Grass Carp capture (N) for each sample date, net-nights, CPUE with standard error (S.E.), coefficient of variation (CV$\bar{x}$), mean total length (mm) and mean weight (g) from the river-reservoir interface section of the Red River arm of Lake Texoma.

Year	Date	Net Nights	*N*	CPUE (S.E.)	CV$\bar{x}$	Total Length (mm)	Weight (g)
2017	June 19-23	48	24	0.52 (0.17)	0.43	52 (1.7)	1.6 (0.16)
2017	July 10-14	64	37	0.63 (0.18)	0.47	76 (1.2)	5.2 (0.3)
2017	July 31- Aug 4	64	5	0.08 (0.05)	0.82	58 (13.8)	3.9 (0.3)
2017	Aug 21-25	40	0	0 (0)	0	None	None

temperatures, etc.) associated with those hatch dates. A better understanding of these factors could allow management biologist to use one species as a proxy to understand whether any specific impoundment could be suitable for the natural reproduction of the other species. Thus, a reservoir with successful recruitment of Striped Bass might suggest the potential for naturalization of Grass Carp. The capability for a manager to predict recruitment potential of either Grass Carp or Striped Bass in a reservoir based on the level of recruitment success of the other species is a novel idea that is in need of further research. For example, Lake Keystone on the Arkansas River has similar chemico-physical conditions to Lake Texoma and also has a self-sustaining Striped Bass population (Combs 1978); therefore, based on the comparable reproductive requirements of Grass Carp and Striped Bass, we should expect that spawning of Grass Carp will occur in this impoundment and possibly some of the other ten inland reservoirs where Striped Bass spawn.

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Diet of Invasive White Perch in Sooner Lake, Oklahoma

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Abstract: White Perch *Morone americana* are native to the Atlantic Coast of North America. Outside of their native range, White Perch quickly dominate fish communities, and they can compete with native fish species. White Perch were discovered in Sooner Lake, Oklahoma in 2006. However, little has been done to understand the potential impacts of White Perch in Sooner Lake. Therefore, from April 2015 – June 2016 White Perch were collected monthly from Sooner Lake to analyze food habits. White Perch diets were described seasonally (spring, summer, fall, winter) and by size classes (sub-stock, stock, quality, preferred, memorable) using percent composition by number, percent weight, and frequency of occurrence. In spring, White Perch diets were dominated by zooplankton. During summer, White Perch consumed primarily invertebrate prey, however, White Perch transitioned to a predominately fish diet in fall and winter. Sub-stock sized fish ate mostly invertebrates and zooplankton. However, as fish size increased White Perch consumed larger amounts of fish, which became the predominate prey at quality and preferred size classes. The shift in diet (seasonally and by size) from zooplankton to invertebrates and fish suggests that White Perch may compete with resident sport fishes for these resources in Sooner Lake.

Introduction

White Perch *Morone americana* populations have become established in inland lakes and reservoirs in many states outside of its native range through intentional (Zuerlein 1981) or unintentional movements (Wong et al. 1999; Harris 2006; Kuklinski 2007). White Perch is native to the Atlantic Coast of North America where it inhabits estuarine, freshwater, and marine environments (Scott & Crossman 1973). In its native range, the White Perch is a commercially and recreationally valuable species (Manuseti 1961). Because of its importance as a sportfish in its native range and the habitat suitability for this species in several Nebraska reservoirs, White Perch were introduced by Nebraska Game and Parks Division to create additional recreational fishing opportunities (Zuerlein 1981). However, these populations were quickly dominated by a high density of small-bodied White Perch.

Upon establishment, White Perch tend to become overabundant in inland lakes and reservoirs, resulting in slow growing, stunted populations (Kuklinski 2007; Gosch et al. 2010; Bethke et al. 2014). Because of the small average size of fish in stunted populations, it typically has little or no recreational value (Kuklinski 2007; Gosch et al. 2010). Furthermore, White Perch reach reproductive maturity at age-1 and tolerates a variety of habitats, which results in quick establishment in some aquatic systems with the potential to dominate or alter fish communities (Zuerlein 1981). White Perch can affect native fish populations following introduction (Kuklinski 2007). In a study evaluating interactions between White Perch and Yellow Perch *Perca flavescens* in Lake

Erie, Parrish and Margraf (1990) concluded that invasion of White Perch had negatively affected Yellow Perch populations, especially in the western basin of the lake. Furthermore, Madenjian et al. (2000) suggested that invasion of White Perch in Lake Erie has reduced White Bass *Morone chrysops* recruitment through interaction during the early life history of these species. Schaeffer and Margraf (1987) found that adult White Perch may affect Walleye *Sander vitreus* and White Bass recruitment via egg predation, as eggs comprised a large percentage of White Perch diets in April and May. In reservoir systems, diet investigations suggest that White Perch feed primarily on invertebrates, which may affect early life stages of sport fish species through competition for these resources (Harris 2006, Kuklinski 2007, Gosch et al. 2010), resulting in poor survival and recruitment.

In Oklahoma, Kuklinski (2007) investigated potential consequences of White Perch invasion on native species in Kaw Lake, Oklahoma. White Perch were discovered in Kaw Lake in 2000 as a result of emigration from populations in Nebraska and Kansas to Oklahoma through the Arkansas River system (Kuklinski 2007). It was determined at low population abundance, White Perch do not appear to be negatively impacting White Bass or White Crappie *Pomoxis annularis* populations (Kuklinski 2007). However, there was high diet overlap between White Perch and juvenile White Bass. Competition for food resources could affect White Bass population levels if White Perch abundance increases through time.

Since the initial discovery in Kaw Lake, White Perch has been found in Keystone Lake (2004) and Sooner Lake (2006; Oklahoma Department of Wildlife Conservation, unpublished data). White Perch abundance in Sooner Lake has been increasing since establishment. Conversely, Largemouth Bass *Micropterus salmoides*, White Bass, Channel Catfish *Ictalurus punctatus*, and hybrid Striped Bass *Morone saxitilis x M. chrysops* abundances have decreased in Sooner Lake (Copeland 2016). Although White Perch are present at a high abundance, the Sooner Lake population is characterized as a non-stunted population with fish reaching 8 years in age and exceeding 300 mm total length (Porta and Snow 2017). Porta and Snow (2017) found disparities among condition values when evaluating White Perch by size classes. Smaller fish (<200 mm TL) had lower mean relative weights, whereas larger fish (>200 mm TL) had higher mean relative weights, suggesting that intraspecific competition may be high and that larger fish may outcompete smaller fish for food resources or there may be differences in food items consumed. In this scenario, it would be beneficial to know if differences in diet are driving differences in condition among size classes of White Perch in this population.

Besides the initial investigation by Kuklinski (2007) following the introduction of White Perch into Kaw Lake, little has been done to understand potential impacts of White Perch invasion on other aquatic systems in Oklahoma. Therefore, our objectives are to evaluate food habits of White Perch in Sooner Lake, Oklahoma. Also, because diet information was collected from the subsample of White Perch used to evaluate Sooner Lake population characteristics (Porta and Snow 2017), it may be possible to determine whether diet differences contributed to differences in size-specific condition observed in that study. Finally, because the Sooner Lake White Perch population is non-stunted, we can compare White Perch diets from this population to observations in Kuklinski (2007) for a stunted White Perch population in Kaw Lake, Oklahoma.

Methods

Study area

Sooner Lake is a 2,185 ha reservoir located in north central, Oklahoma that is owned and operated by Oklahoma Gas and Electric Company. The Sooner Lake water level is maintained by pumping water from the Arkansas River, which allowed White Perch to enter the reservoir.

Study design

White perch were collected from Sooner Lake

monthly from April 2015-June 2016 (with the exception of May 2016 because of equipment breakdown), using boat-mounted electrofishing (pulsed DC, high voltage, Smith Root 7.5 GPP) and experimental gillnets (61 m long x 1.8 m deep and constructed of eight 7.6 m panels [12.7 mm, 15.9 mm, 19.1 mm, 25.4 mm, 38.1 mm, 50.8 mm, 63.5 mm, and 76.2 mm bar mesh]). A multi-gear approach was implemented to ensure that all size classes of white perch were represented in the sample (Kuklinski 2007, Feiner et al. 2012, Bethke et al. 2014), and day and night surveys were conducted to ensure no diel differences in size structure. Each monthly sample consisted of twelve electrofishing transects (600 sec/transect; 7,200 sec of total pedal time) and four experimental gill nets set perpendicular to the shoreline at various depth contours. Sites were chosen randomly by laying a 300 m^2 grid over the map of the lake in ArcGIS, individually numbering each grid square and using a random number generator to select the grid to be sampled. New electrofishing and gillnetting sites were randomly selected monthly (Porta and Snow 2017).

Following capture, each fish was measured for total length (TL; mm) and weight (g). Fish were placed on ice until they could be processed in the laboratory. In the laboratory, stomach contents from fish were removed, identified to the finest taxonomic level possible (order or family for invertebrates, species for fish), and enumerated. Percent occurrence (the percentage of stomachs in the sample containing a particular diet item), percent composition by number (number of individuals of a given prey type divided by the total number of prey items counted from a given predator stomach), and percent weight (weight of individuals of a given prey type divided by the total weight of prey items from a given predator stomach) of prey items (Bowen 1996) were calculated for White Perch by season (spring =March-May, summer=June-August, autumn =September-November, winter =December-February) and size class (sub-stock =<130 mm, stock=130-199 mm, quality=200-249 mm, preferred= 250-299, memorable=300-379 mm, trophy=>380 mm; Gabelhouse 1984).

Results

A total of 574 White Perch ranging from 56-308 mm TL were collected from Sooner Lake for diet analysis (Table 1 and 2). Diets of White Perch were diverse, consuming 29 different prey items. Of the 574 fish collected for diet analysis, 150 had empty stomachs (26%). Dipterans (29.97%) dominated White Perch diets by percent occurrence, followed by amphipods (18.12%), cladocerans (13.59%), copepods (12.02%), and ephemeropterans (10.28%). All other prey items contributed <10% by occurrence. Zooplankton comprised 96.24% of all diet items by percent total number (70.01% and 26.22% for cladocerans and copepods, respectively). However, fish dominated White Perch diets by percent total weight (47.62%). Threadfin Shad *Dorosoma petenense* (18.96%), Gizzard Shad *Dorosoma cepedianum* (13.27%), and Inland Silversides *Menidia beryllina* (10.03%) contributed most to total fish weight. All other fish represented 5.36% by total weight. Invertebrates comprised a substantial portion of the total weight of prey items (37.75%), with ephemeropterans (13.23 %) and dipterans (10.42 %) contributing the bulk of invertebrate prey items. Zooplankton contributed to 11.19% of the total percent by weight.

A total of 142 sub-stock sized fish were evaluated for diet analysis, and 30 (21.13%) had empty stomachs (Table 1). Sub-stock sized White Perch consumed mostly zooplankton by number (98.37%), however invertebrate prey items comprised slightly more of the diet by weight (52.69%) followed by zooplankton (45.94%). Dipterans occurred most frequently in diets of sub-stock sized White Perch (44.37%), followed by copepods (28.87%), cladocerans (20.42%), and amphipods (19.01%). Sub-stock sized White Perch rarely ate fish. A total of 183 stock sized fish were evaluated for diet analysis, and 51 (27.87%) had empty stomachs. Stock sized White Perch consumed mostly zooplankton by number (94.40%), however this comprised only 13.36% by weight. Invertebrates dominated stock sized White Perch diets by weight (57.59%), followed by fish (28.79%). Dipterans (27.87%) and amphipods (27.32%)

Table 1. Size-specific diets of White Perch collected from Sooner Lake, Oklahoma from April 2015 – June 2016.

	Size														
	Substock (N=142)			Stock (N=183)			Quality (N=115)			Preferred (N=132)			Memorable (N=2)		
Diet Item	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence
Zooplankton															
Cladocera	67.818	26.305	20.420	60.449	7.385	8.200	84.941	5.250	9.570	85.876	8.150	16.670	99.190	44.100	20.42
Copepoda	30.547	19.640	28.870	33.948	5.974	10.930	5.585	0.820	4.350	10.015	0.516	2.270			
Total Zooplankton	**98.365**	**45.944**		**94.398**	**13.359**		**90.526**	**6.070**		**95.890**	**8.666**		**99.190**	**44.100**	
Fish															
Bluegill							0.008	1.420	0.870						
Gizzard Shad				0.013	14.466	2.730	0.041	10.270	4.350	0.058	16.048	7.580			
Inland Silverside	0.003	1.253	1.410	0.028	12.916	4.370	0.107	10.600	8.700	0.077	9.828	9.090			
Largemouth Bass							0.060	7.110	3.480						
Threadfin Shad							0.099	13.170	6.090	0.116	31.307	9.090	0.270	55.660	50.00
White Perch							0.008	1.420	0.870	0.029	3.395	2.270			
Unidentified Fish				0.015	1.412	2.730	0.017	1.010	1.740	0.019	0.813	3.030			
Total Fish	**0.003**	**1.253**		**0.056**	**28.794**		**0.340**	**45.000**		**0.299**	**61.390**		**0.270**	**55.660**	
Fish Eggs							0.040	0.110	0.870						
Invertebrates															
Amphipoda	0.400	6.211	19.010	2.080	8.071	27.320	1.458	2.720	13.040	0.796	1.459	9.090			
Anostraca	0.009	5.496	1.410	0.010	1.057	0.550	0.115	2.270	0.870						
Arachnida				0.003	0.021	0.550				0.068	0.144	1.520			
Coleoptera	0.004	0.028	0.700	0.008	0.835	1.640									
Corbicula							0.017	6.140	0.870						
Crayfish				0.008	2.748	1.640				0.005	4.565	0.760			
Diptera	0.788	20.366	44.370	2.377	14.521	27.870	4.251	7.810	24.350	1.674	9.322	21.970	0.405	0.180	50.00
Dreissena	0.026	0.612	4.930	0.073	3.722	4.370	0.058	0.014	0.870	0.068	0.094	2.270			
Ephemeroptera	0.020	13.085	4.930	0.371	16.957	14.210	0.873	17.140	9.570	0.569	10.724	11.360			
Gastropoda							0.010	0.001	0.870						
Hemiptera				0.010	0.761	1.090	0.148	0.330	0.870	0.077	0.174	1.520			
Hymenoptera										0.043	0.099	1.520			
Isopoda	0.001	0.243	0.700	0.015	0.486	1.090									
Megaloptera				0.005	0.012	1.090									
Nematoda				0.005	<0.001	0.550							0.135	0.060	50.00
Odonata	0.121	2.616	7.750	0.457	5.010	14.750	0.445	2.390	6.960	0.024	0.023	3.790			
Ostracoda	0.228	3.700	3.520				0.536	1.550	1.740						
Plecoptera	0.003	0.165	0.700	0.028	3.182	3.830	0.585	1.340	2.610						
Trichoptera	0.030	0.173	1.410	0.040	0.213	1.640	0.469	0.360	2.610	0.439	0.479	3.030			
Total Invertebrates	**1.630**	**52.693**		**5.489**	**57.593**		**8.964**	**42.065**		**3.763**	**27.084**		**0.540**	**0.240**	
Unknown Items	0.001	1.099	0.700	0.058	0.254	1.090	0.132	6.750	9.570	0.048	2.861	6.820			
Empty			**21.13**			**27.87**			**26.96**			**28.79**			

occurred most frequently in diets of stock sized White Perch, followed by odonata (14.80%) and ephemeroptera (14.21%). A total of 115 quality sized fish were evaluated for diet analysis, and 31 (26.96%) had empty stomachs. Quality sized White Perch consumed mostly zooplankton by number (90.53%), but this made up only 6.07% of prey weight. Fish comprised the highest prey weight (45.00%) of quality sized White Perch. Dipterans (24.35%) and amphipods (13.04%) occurred most often in quality sized White Perch diets. All other prey items occurred in <10% of quality sized White Perch diets. A total of 132 preferred sized fish were evaluated for diet analysis, and 38 (28.79%) had empty stomachs. Preferred sized White Perch consumed mostly zooplankton by number (95.89%), but this made up only 8.67% of prey weight. Fish dominated

Table 2. Seasonal diets of White Perch collected from Sooner Lake, Oklahoma from April 2015 – June 2016.

Diet Item	Season											
	Spring (N=140)			Summer (N=108)			Fall (N=168)			Winter (N=158)		
	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence
Zooplankton												
Cladocera	87.137	47.134	45.710				98.074	2.271	7.740	7.751	0.100	0.630
Copepoda	8.366	6.846	16.430	14.650	0.054	2.780				86.899	6.488	27.220
Total Zooplankton	**95.503**	**53.980**		**14.650**	**0.054**		**98.074**	**2.271**		**94.650**	**6.588**	
Fish												
Bluegill				0.230	1.392	0.930	0.002	1.782	0.600			
Gizzard Shad				1.370	6.786	5.560	0.014	27.911	4.760	0.018	14.106	3.800
Inland Silverside	0.003	0.441	0.710	2.970	6.815	9.260	0.022	14.191	7.140	0.036	15.986	5.700
Largemouth Bass				1.600	6.961	3.700						
Threadfin Shad				0.920	2.439	3.700	0.016	21.776	4.760	0.061	49.923	5.060
White Perch				1.370	4.063	2.780	0.002	1.782	0.600			
Unidentified Fish	0.023	3.902	5.710	0.460	0.835	1.850				0.003	0.055	0.630
Total Fish	**0.025**	**4.342**		**8.920**	**29.291**		**0.056**	**67.442**		**0.118**	**80.069**	
Fish Eggs	0.010	0.212	0.710									
Invertebrates												
Amphipoda	0.822	9.093	27.140	0.687	0.015	0.930	0.533	2.954	12.500	1.983	3.780	27.850
Anostraca				5.490	3.898	3.700						
Arachnida							0.024	0.255	1.790			
Coleoptera				1.140	0.323	2.780	0.002	0.140	0.600			
Corbicula				0.460	6.014	0.930						
Crayfish				0.460	1.103	1.850	0.002	7.662	0.600	0.003	0.445	0.630
Diptera	2.387	18.258	50.710	31.810	14.898	22.220	0.726	6.852	22.620	2.050	3.377	24.680
Dreissena	0.040	0.276	3.570	0.230	0.006	0.930	0.067	2.258	5.950	0.023	0.151	1.900
Ephemeroptera	0.312	7.150	14.290	30.200	36.756	17.590	0.017	0.528	2.380	0.299	1.378	10.130
Gastropoda							<0.001	0.001	0.600			
Hemiptera							0.060	1.120	2.980			
Hymenoptera							0.014	0.166	1.190			
Isopoda	0.015	0.528	1.430				0.002	0.032	0.600			
Megaloptera										0.005	0.008	1.270
Nematoda	0.003	0.001	0.710							0.005	<0.001	0.630
Odonata	0.050	0.213	6.430	1.370	0.564	2.780	0.219	4.437	11.900	0.410	1.263	12.030
Ostracoda	0.305	1.405	2.860				0.103	1.736	1.190	0.092	0.014	0.630
Plecoptera				1.830	1.632	5.560	0.014	1.165	1.790	0.171	0.474	1.270
Trichoptera	0.462	2.296	8.570									
Total Invertebrates	**4.395**	**39.220**		**73.677**	**65.207**		**1.782**	**29.305**		**5.041**	**10.889**	
Unknown Items	0.010	2.245	2.860	2.750	5.448	5.560	0.011	2.775	4.170	0.069	2.454	3.800
Empty			**16.43**			**26.85**			**29.76**			**30.38**

the prey weight (61.39%) of quality sized White Perch. Dipterans (21.97%), cladocerans (16.67%), and ephemeropterans (11.36%) occurred most often in preferred sized White Perch diets. All other prey items occurred in <10% of preferred sized White Perch diets. Only 2 memorable sized White Perch were captured for diet analysis and both contained diet items. Fish comprised the bulk of memorable sized White Perch diets (55.66%), followed closely in weight by zooplankton (44.10%).

White perch were collected across all seasons for diet analysis (Table 2). During spring, 140 White Perch were collected for diet analysis. Of these fish, 23 (16.43%) had empty stomachs. White Perch containing diet items consumed 15 different prey items. Zooplankton dominated

the spring diets by number (95.50%) and weight (53.98), although invertebrates, particularly dipterans (18.26%), amphipods (9.09%), and ephemeropterans (7.15%) contributed substantially by weight. Dipterans occurred most frequently in the spring diets of White Perch (50.70%), followed by cladocerans (45.71%), ephemeropterans (27.14%), copepods (16.43%) and amphipods (14.30%). Fish eggs were rarely consumed by White Perch in spring. In summer, 108 White Perch were collected, of which 29 (26.85%) were empty. White Perch consumed 19 different prey items during summer. Summer diets were dominated by invertebrates by number (73.68%) and weight (65.21%). Dipterans and ephemeropterans dominated summer White Perch diets by number (31.81% and 30.20% for dipterans and ephemeropterans, respectively) and weight (36.76% and 14.90% for ephemeropterans and dipterans, respectively). Dipterans occurred most frequently in the summer diets of White Perch (22.22%), followed by ephemeropterans (17.60%). During fall, 168 White Perch were collected of which 50 (29.76%) were empty. White Perch consumed 20 different prey items during fall. Zooplankton dominated White Perch diets by number (98.07%), however contributed little to weight (2.27%). Fish comprised the highest percentage by weight (67.44%), consisting mostly of Gizzard Shad (27.91%) and Threadfin Shad (21.78%). Invertebrates contributed to 29.31% by weight to fall diets, consisting mostly of crayfish (7.66%), dipterans (6.85%), and odonates (4.44%). Dipterans occurred most frequently in the fall diets of White Perch (22.62%), followed by amphipods (12.50%) and odonata (11.90%). During winter, 158 White Perch were collected for diets analysis and 48 (30.38%) were empty. White Perch consumed 17 prey items during winter. Zooplankton dominated White Perch diets by number (94.65%), however contributed little to weight (6.59%). Fish comprised the highest percentage by weight (80.07%), consisting mostly of Threadfin Shad (49.92%), Inland Silversides (15.99%), and Gizzard Shad (14.11%). Amphipods occurred most frequently in the winter diets of White Perch (27.85%), followed by copepods (27.22%) and dipterans (24.68%).

Discussion

White Perch are adaptive predators that switch feeding patterns to cope with changing prey availability (St-Hilaire et al. 2002). Previous research suggests that White Perch diets can be variable, making this species very adaptable to different environments and habitat types. In Sooner Lake, White Perch transitioned to different prey items depending on season. During spring, White Perch consumed large amounts of zooplankton, transitioning to predominately invertebrates by summer. Couture and Watzin (2008) also documented a transition from zooplankton to invertebrates, which occurred when zooplankton densities declined during summer. In Sooner Lake, White Perch transitioned to a fish dominated diet (65-80% by weight) in fall and winter. Stein (2001) found that dipterans dominated White Perch diets during spring, summer, and fall, but switched to primarily fish during winter. Similarly, Elrod et al. (1982) found that adult White Perch consumed dipterans in spring and summer, but ate fish during fall. Schaeffer and Margraf (1986) found that cladocerans and chironomids were important to White Perch in Lake Erie during June and July, but transitioned to Gizzard Shad during August and September.

White Perch in this study consumed a substantial amount of fish, particularly at larger sizes. In Sooner Lake, quality (200-249 mm) and preferred (250-299 mm) sized White Perch had diets dominated by fish (45-61%). Gosch et al. 2010 found that White Perch began consuming fish between 130-160 mm. Similar to our results, Stein (2001) found that White Perch in Browning Oxbow, Kansas exhibited differences in diet among life stages, with small fish (young-of-the-year) feeding heavily on zooplankton, whereas adults (age-l and older) consumed primarily aquatic insects and fish. At small sizes (sub-stock and stock size classes), White Perch in Sooner Lake consumed mostly zooplankton and invertebrates. The transition from zooplankton and invertebrates to fish prey may explain the differences in size specific

condition of White Perch in this population (Porta and Snow 2017).

The Sooner Lake White Perch population is characterized as a non-stunted population (Porta and Snow 2017). Gosch et al. 2010 found that stunted and non-stunted populations of White Perch in Nebraska had very similar diets (both consuming primarily invertebrates), and suggested that shifting from a stunted to non-stunted state will not change food habits of these populations. Similarly, Kuklinski (2007) found that stunted White Perch in Kaw Lake, Oklahoma consumed primarily insects. However, we found that Sooner Lake White Perch transition from zooplankton and invertebrates to fish seasonally and by size classes. The transition to fish prey may influence growth of White Perch in Sooner Lake and may be why this population is currently in a non-stunted state (Porta and Snow 2017).

White Perch in Sooner Lake rarely consumed fish eggs. White Perch can be voracious egg predators in systems that they invade (Schaeffer and Margraf 1987). The consumption of eggs by White Perch may affect recruitment of other species in those systems (Schaeffer and Margraf 1987; Madenjian et al. 2000). It appears unlikely that fish egg consumption by White Perch will affect fish recruitment in Sooner Lake, Oklahoma. However, White Perch may compete directly with the resident sportfish in Sooner Lake for forage resources.

The shift in diet from zooplankton to invertebrates and fish suggests that White Perch may compete with resident sport fishes for these resources. Sooner Lake White Perch consume considerable amounts of zooplankton, invertebrates, and fish. This may explain why Largemouth Bass, White Bass, Channel Catfish, and hybrid Striped Bass abundances have decreased in Sooner Lake since establishment of White Perch (Copeland 2016). Previous research suggests that White Perch can affect native fish species following introduction. Parrish and Margraf (1990) discovered that White Perch had negatively affected Yellow Perch populations in Lake Erie following introduction of White Perch. Similarly, Madenjian et al. (2000) linked a reduction in White Bass recruitment with invasion of White Perch in Lake Erie, suggesting that competition at early life stages is driving this relationship. Future research should be directed toward understanding trophic relationships between White Perch and resident species in Sooner Lake to determine if competition or predation lead to species declines in this system.

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Eimeria dericksoni Roudabush, 1937 (Apicomplexa: Eimeriidae) from the Pallid Spiny Softshell, *Apalone spinifera pallida* (Reptilia: Testudines: Trionychidae): Initial Report from Oklahoma and a Summary of the Coccidia from North American Softshell Turtles

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The pallid spiny softshell, *Apalone spinifera pallida* (Webb, 1962) is a large turtle that ranges from southern Arkansas and westcentral Oklahoma south to the eastern coast of Texas (Powell et al. 2016). In Arkansas, *A. s. pallida* occurs primarily in the Gulf Coastal Plain of the extreme southwestern part of the state (Trauth et al. 2004), and in Oklahoma, it is found in the southern one-third of the state in the Red River drainage (Sievert and Sievert 2011). It prefers sites with sandy or soft substrates such as rivers, streams, lakes, and ponds where it feeds on a variety of invertebrates (crayfish, insects, mollusks, earthworms) and vertebrates (fish, amphibians), and even carrion.

Five species of coccidian parasites (Apicomplexa) have been reported from this turtle, including *Eimeria amydae* Roudabush, 1937, *E. dericksoni* Roudabush, 1937, *E. pallidus* McAllister, Upton, and McCaskill, 1990, and *E. spinifera* McAllister, Upton, and McCaskill, 1990 from Texas, and *E. apalone* McAllister, Upton, and McCaskill, 1990, from Arkansas and Texas (see Duszynski and Morrow 2014). There are no previous reports of any coccidians from softshell turtles from Oklahoma. Here we document a new distributional record for an eimerian from *A. s. pallida* from the state and provide a summation of the eimerians from North American softshell turtles (Trionychidae).

During April 2013 and April 2017, two adult (150, 155 mm carapace length [CL]) eastern spiny softshells, *A. s. spinifera* (Le Sueur, 1827) were collected by hand from Anderson's Minnow Farm, Lonoke County, Arkansas (34° 45' 36.3954"N, 91° 57' 14.1114"W), and Crow Creek at Madison, St. Francis County, Arkansas (35° 00' 45.144"N, 90° 44' 16.8246"W), respectively; a single adult (360 mm CL) *A. s. pallida* was collected in a similar manner in September 2017 from Yashau Creek, McCurtain County, Oklahoma. 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). Measurements were taken on 10 sporulated oocysts from a single turtle using a calibrated ocular micrometer and reported in micrometers (μm) with the means followed by the ranges in parentheses; photographs were taken using brightfield optics. Oocysts were 20 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 as ASUMZ 33744. Photovouchers of sporulated oocysts were accessioned into the Harold W. Manter Laboratory of Parasitology (HWML), University of Nebraska, Lincoln, Nebraska.

Oocysts of a coccidian matching the description of *E. dericksoni* (Roudabush 1937) were found in one turtle and are described below.

Apicomplexa: Eimeriidae

***Eimeria dericksoni* Roudabush, 1937 (Figs. 1-2)**

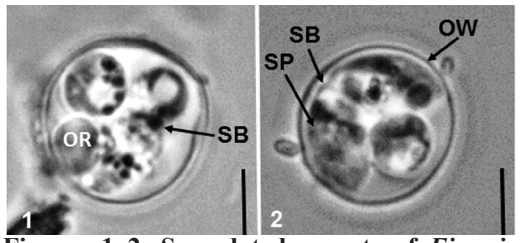
Oocysts subspheroidal, 12.4 × 11.2 (11–14 × 10–12) with smooth, thin wall prone to collapsing in sucrose solution; shape index (L/W) 1.1 (1.1–1.2). Micropyle absent but oocyst residuum 3.6 × 3.4 (3–4 × 3–4; n = 5) present; a polar granule was present in 3 of 10 (30%) sporulated oocysts. Sporocysts ellipsoidal, 8.3 × 5.2 (7–10 × 4–6); L/W 1.6 (1.3–1.8). Stieda body present, substieda and parastieda bodies absent. Sporocyst residuum scattered within the sporocyst. Each sporozoite (not measured) contains a spheroidal posterior refractile body. Nucleus not evident.

Host: Pallid spiny softshell, *Apalone spinifera pallida* (Webb, 1962) (Reptilia: Testudines: Trionychidae) (adult female, collected 23 September 2017).

New locality: Yashau Creek off West Sherry Lane, Broken Bow, McCurtain County, Oklahoma (34° 2’ 27.0018”N, 94° 45’ 21.8046”W).

Type-host and locality: *A. s. spinifera* (Le Sueur, 1827), Ames, Story County, Iowa (Roudabush, 1937).

Other hosts and localities: Western spiny softshell, *A. s. hartwegi* (Conant and Goin, 1948), Iowa (Wacha and Christiansen 1977); *A. s. pallida*, Dallas and Johnson counties, Texas (McAllister et al. 1994).



Figures 1–2. Sporulated oocysts of *Eimeria dericksoni* from *Apalone spinifera pallida* from Oklahoma. Abbreviations: OR (oocyst residuum); OW (oocyst wall); SB (Stieda body); SP (sporocyst). Scale bars = 5µm.

Material deposited: Photovoucher of sporulated oocyst deposited in the HWML 102962.

Prevalence: In 1 of 3 (33%) overall; 1 of 1 (100%) *A. s. pallida*.

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

Site of infection: Unknown; oocysts passed in feces.

Remarks

A total of seven eimerians have been reported from two subspecies of *A. spinifera* from Arkansas, Iowa, Oklahoma, and Texas (Table 1). Oocysts of our isolate of *E. dericksoni* are smaller than those reported in the original description (14.6 × 12.9 µm, L/W = 1.1) (Roudabush 1937); sporocyst measurements were not given in the original description. However, in a redescription of *E. dericksoni* by Wacha and Christiansen (1977), measurements of oocysts and sporocysts were provided, respectively, as follows: 10.8 × 10.0 µm, L/W = 1.1 and 6.8 × 4.0 µm, L/W = 1.7. These authors, in the same report, also included measurements of the oocysts and sporocysts from a different isolate of *E. dericksoni* as follows: 13.0 × 12.0 µm, L/W = 1.1 and 8.4 × 5.2 µm, L/W = 1.6. Taken together, the mensural data of Roudabush (1937) and Wacha and Christiansen (1977) suggest that the oocysts and sporocysts of *E. dericksoni* can vary somewhat in size. The dimensions of the oocysts and sporocysts of

Table 1. Summary of coccidian parasites of North American trionychid turtles.

Eimeria spp.	Host	Locality	Prevalence*	Reference
E. amydae	*Apalone spinifera pallida*	Texas	1/9 (11%)	McAllister et al. (1990)
	A. s. spinifera	Iowa	1/1 (100%)	Roudabush (1937)
E. apalone	*A. s. pallida*	Texas	5/9 (56%)	McAllister et al. (1990)
			5/10 (50%)	McAllister et al. (1994)
	A. s. spinifera†	Arkansas	1/3 (33%)	McAllister et al. (1994)
E. dericksoni	*A. s. pallida*	Texas	3/7 (43%)	McAllister et al. (1990)
			3/10 (30%)	McAllister et al. (1994)
		Oklahoma	1/1 (100%)	This report
	A. s. spinifera	Iowa	1/1 (100%)	Roudabush (1937)
E. mascoutini	*A. s. pallida*	Texas	3/10 (30%)	McAllister et al. (1994)
	A. s. spinifera	Iowa	2/5 (40%)	Wacha and Christiansen (1976)
			1/1 (100%)	Wacha and Christiansen (1977)
E. pallidus	*A. s. pallida*	Texas	4/9 (44%)	McAllister et al. (1990)
			4/10 (40%)	McAllister et al. (1994)
E. spinifera	*A. s. pallida*	Texas	3/9 (33%)	McAllister et al. (1990)
			3/10 (30%)	McAllister et al. (1994)
E. vesticostieda	*A. s. spinifera*	Iowa	not given	Wacha and Christiansen (1977)

*Prevalence = number infected/number examined (%).

†Host originally reported as *A. s. hartwegi* from Conway County, Arkansas (McAllister et al. 1994); only *A. s. spinifera* occurs in central Arkansas.

our isolate are similar to those reported for *E. dericksoni* by Wacha and Christiansen (1977). In addition, the morphological characters of our isolate (smooth, thin oocyst wall prone to collapsing in Sheather's solution, presence of oocyst residuum and polar granule) match those of Wacha and Christiansen's (1977) specimens. Consequently, we consider the coccidian described herein to be *E. dericksoni*.

In summary, we provide the first report of *E. dericksoni* documented from a trionychid turtle from Oklahoma. This also represents only the third report of a coccidian from any turtle in the state (McAllister et al. 2015; McAllister and Hnida 2016). Since the midland smooth softshell, *A. mutica* (Le Sueur, 1827) also occurs in the state (Sievert and Sievert 2011), and in adjacent Arkansas (Trauth et al. 2004) and Texas (Dixon 2013), it should also be examined for coccidia as the species has never been reported as a host (Duszynski and Morrow 2014). Indeed, finding any coccidian would result in a new host record and possibly geographic records.

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(1921–2016), former curator of the Stovall Museum, OU faculty member (1952–1982), and herpetologist extraordinaire of Oklahoma and beyond.

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First Report of a *Hepatozoon* sp. (Apicomplexa: Adeleina: Hepatozoidae) from Midland Water Snake, *Nerodia sipedon pleuralis* (Ophidia: Colubridae), from Missouri

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Intraerythrocytic hematozoans of the genus *Hepatozoon* (Miller, 1908) occur in the gamont stage in birds, mammals, and all groups of reptiles (Telford 2009). For example, one group of reptiles, the North American watersnakes of the genus *Nerodia*, are important hosts of a variety of these parasites (Gibbons and Dorcas 2004). The northern watersnake, *Nerodia sipedon sipedon* (Linnaeus, 1758) has been previously reported to harbor *He. sipedon* Smith, Desser, and Martin, 1994 from Ontario, Canada (Smith et al. 1994; Smith and Desser 1998). However, another widely ranging subspecies, the midland watersnake, *N. s. pleuralis* (Cope, 1892), has not previously been reported as a host nor has any snake, to our knowledge, been reported from Missouri with these hemoparasites. Here, we document, with photomicrographs and select measurements, the first report of a *Hepatozoon* sp. in *N. s. pleuralis*, as well as documentation, to our knowledge, from any ophidian host in Missouri. In addition, a summary of intraerythrocytic hematozoans of North American watersnakes and swampsnakes is provided.

Between April 2012 and June 2016, 10 *N. s. pleuralis* were collected by hand or with snake tong from Franklin (n = 1), Fulton (n = 1), Garland (n = 1), Independence (n = 5), Marion (n = 1), and Montgomery (n = 1) counties, Arkansas; they were overdosed with an intraperitoneal injection of sodium pentobarbital (Nembutal®). In addition, a single specimen of *N. s. pleuralis* found recently dead (no petrification) was collected on 11 June 2017 from Franklin County, Missouri. A midventral incision was made on each snake to expose the heart and blood was obtained by puncturing the ventricle with a .22 gauge needle, with samples being drawn into an ammonium heparinized (75 mm long) capillary tube. Thin films were air-dried, fixed for one minute in absolute methanol, stained for 20–30 minutes with Wright-Giemsa stain, and rinsed in neutral-buffered phosphate buffer (pH = 7.0). Slides were scanned at 100× or 400× and when infected cells were found, photographs were taken and length and width (L × W) measurements of gamonts were made of intraerythrocytic parasites (n = 20) using a calibrated ocular micrometer under oil immersion lens at 1,000×. A host voucher was deposited in the Henderson State University (HSU) collection, Arkadelphia, Arkansas, as HSU 1950. A voucher slide of a hematozoan was deposited in the Harold W. Manter Laboratory of Parasitology (HWML), University of Nebraska, Lincoln, Nebraska.

One of 11 (9%) of the *N. s. pleuralis* (adult, 425 mm snout-vent length [SVL]), collected from Little Indian Creek, Franklin County,

Missouri (38° 14' 07.008"N, 90° 56' 23.1792"W) was found to harbor an intraerythrocytic hematozoan (HWML 139358); all of the 10 snakes from Arkansas were negative. Less than 0.5% of the erythrocytes contained elongate-shaped (unrecurved) thin gamonts (Figs. 1A–C) thought to belong to the genus *Hepatozoon*. Measurements are as follows: L ± 1SD (range) × W 1SD (range) = 19.5 ± 1.0 (19–21) × 4.0 ± 0.6 (3.4–5.0) µm. These measurements and morphologies are similar to those provided by Smith et al. (1994) for *He. sipedon*; these authors also reported a parasitemia of 0.2% in naturally-infected host snakes that is similar to our observed prevalence in erythrocytes.

Smith (1996) considered all hemogregarines of snakes to be members of the genus *Hepatozoon*. However, specific identification of these hematozoans is difficult as the complete life cycle including developmental stages in hematophagus invertebrates must be known (Jacobson 2007; Smith and Desser 1997). *Hepatozoon sipedon* uses culcine vectors, *Culex pipiens* and *C. territans* (Smith et al. 1994); unfortunately, these vectors were not examined in this study.

Several species of North American watersnakes, including at least eight species/subspecies of *Nerodia* and the North Florida swampsnake, *Liodytes* (=*Seminatrix) pygaea pygaea* (Cope, 1871) host these parasites, most identified as "haemogregarines" (Table 1). To date, there have been no hematozoans reported from three species of watersnakes, *N. clarkii* (Baird and Girard, 1853), *N. cyclopion* (Duméril, Bibron, and Duméril, 1854), and *N. harteri* (Trapido, 1941), two species of crayfish snakes, *Regina grahamii* Baird and Girard, 1853, and *R. septemvittata* (Say, 1825) or two species of swampsnakes, *L. alleni* (Garman, 1874), and *L. rigida* (Say, 1825). Without life cycle data, the inclusion of molecular characterization (DNA sequences) would be particularly helpful in the identification of some hematozoans (see Allen et al. 2011; Cook et al. 2014; Maia et al. 2014) which have limited morphological traits.

As far as we can tell, the only previous report of hemoparasites from any Missouri reptile is that of Smith et al. (1983) who reported a *Haemogregarina* sp. from a red-eared slider, *Trachemys scripta elegans* (Wied, 1838) from Bollinger County. We therefore document a *Hepatozoon* sp. from *N. s. pleuralis* and, in Missouri, for the first time.

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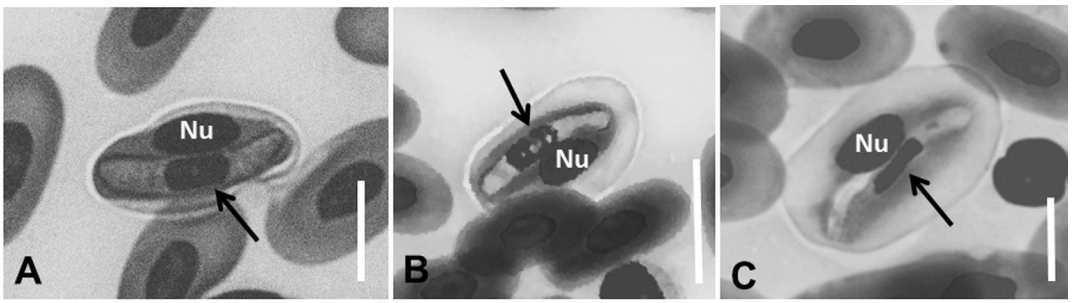

Figures 1A–C. Photomicrographs of a *Hepatozoon* sp. from *Nerodia sipedon pleuralis* from Missouri. A–B. Typical banana-shaped gamonts from two separate erythrocytes. C. Slender more attenuated gamont morph. Abbreviation: Nu (nucleus of host rbc). Scale bars = 10 µm.

Table 1. Reports of hematozoans from North American watersnakes and swampsnakes.

Host	Parasite	Prevalence*	Locality	Reference
Liodytes pygaea pygaea	*He. floridana*	1/4 (25%)	FL	Telford et al. (2001)
	He. seminatrici	1/4 (25%)	FL	Telford et al. (2001)
Nerodia erythrogaster	*He. serpentium*	1/11 (9%)	TX	Hilman and Strandtmann (1960)
	"Haemogregarine"	10/20 (50%)	LA	Lowichik and Yaeger (1987)
N. fasciata confluens	"Haemogregarine"	25/26 (96%)	LA	Lowichik and Yaeger (1987)
N. f. pictiventris	*Hepatozoon* sp.	1/1 (100%)	FL	Wozniak et al. (1998)
	Haemogregarina floridana	1/3 (33%)	FL	Telford et al. (2001)
	He. fasciatae	3/5 (60%)	FL	Telford et al. (2001)
	He. pictiventris	8/10 (80%)	FL	Telford et al. (2001)
N. floridana	*He. floridana*	3/4 (75%)	FL	Telford et al. (2001)
N. rhombifer	"Haemogregarine"	1/1 (100%)	AR	Daly et al. (1984)
		1/1 (100%)	LA	Lowichik and Yaeger (1987)
N. sipedon pleuralis	*Hepatozoon* sp.	1/1 (100%)	MO	This report
N. s. sipedon	*Haemogregarina* sp.	1/2 (50%)	CA†	Fantham and Porter (1954)
	"Haemogregarine"	8/29 (28%)	OH	Hull and Camin (1960)
	He. sipedon	18/26 (69%)	CA§	Smith et al. (1994)
N. taxispilota	"Haemogregarine"	1/1 (100%)	UN‖	Roudabush and Coatney (1937)
Nerodia sp.#	"Haemogregarine"	3/5 (60%)	IL	Marquardt (1966)

*Number infected/number examined (%).

†Quebec, Canada.

§Ontario, Canada.

‖Unknown; locality not given.

#Species not identified; *N. erythrogaster*, *N. rhombifer*, *N. s. pleuralis*, and *N. s. sipedon* all occur in Illinois (see Powell et al. 2016).

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Some Parasites (Apicomplexa, Trematoda, Nematoda, Acanthocephala, Phthiraptera) of the Common Great Horned Owl, *Bubo virginianus virginianus* (Aves: Strigiformes: Strigidae), from Southeastern Oklahoma

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Abstract: A common great horned owl, *Bubo virginianus virginianus* was found dead on the road near Idabel, McCurtain County, Oklahoma; it was salvaged and examined for parasites. The following parasites were found: a coccidian, *Eimeria megabubonis*, a trematode, *Neodiplostomulum* sp., ova of a nematode, *Capillaria* sp., an acanthocephalan, *Centrorhynchus spinosus*, and a chewing louse, *Colpocephalum brachysomum*. All parasites are reported from Oklahoma for the first time. More importantly, it shows that utilizing select road-killed specimens that could otherwise not be collected alive because of state and federal regulations is worthwhile for parasitological examination, and can yield new scientific information.

Introduction

The common great horned owl, *Bubo virginianus virginianus* (Gmelin) is one of the largest strigiform birds and possesses an extremely large range, being the most widely distributed owl in the Americas (Lynch 2007). It ranges from the tree limit in Alaska and two-thirds of Canada to Tierra del Fuego, Chile (Peterson and Peterson 2002). In Oklahoma, according to Sutton (1967), it is a largely non-migratory owl, but some shifting of populations probably takes place in winter. This owl has been reported to feed on a great diversity of prey in Oklahoma, including insects, crayfish, snakes, a lizard, and 16 bird and 30 mammal species (Kittridge et al. 2006).

Although there are several reports on the coccidian (Cawthorn and Stockdale 198; Upton et al. 1990) and helminth parasites of *B. virginianus* (Ramaligam and Samuel 1978; Nickol 1983; Richardson and Nickol 1995; Kinsella et al. 2001; Bolette 2007; Richardon and Kinsella 2010), no parasites, to our knowledge, have been reported from this owl in Oklahoma. Here, we document several parasites from a salvaged *B. v. virginianus* from southeastern

Oklahoma and document new distributional records for its parasites.

Methods

An adult *B. v. virginianus* was found dead on 12 September 2017 off the road at the intersection of US 259 and Farley Road in Idabel, McCurtain County (33° 54' 36.3672"N, 94° 46' 48.6408"W) and brought to the laboratory for parasitic examination; it was not examined for subcutaneous helminths or *Trichinella* sp. The specimen appeared to be recently killed and the body showed no sign of petrification. The feathers were brushed for ectoparasites and those found were placed in a vial of 70% (v/v) ethanol; specimens were cleared in 10% potassium hydroxide, dehydrated through an ethanol series, further cleared in xylene, and slide-mounted in Canada balsam (Price et al. 2003). A midventral incision was made to expose the viscera and a blood sample was taken from the heart, smeared onto a microscopic slide and allowed to dry, then fixed in absolute methanol, stained in Giemsa, and rinsed in neutral buffered phosphate saline. The gastrointestinal (GI) tract from the throat to cloaca was removed, rinsed in 0.9% saline, and placed in a Petri dish. Feces from the rectum was collected and placed in a vial containing 2.5% (w/v) potassium dichromate ($K_2Cr_2O_7$) and, after flotation in Sheather's sugar solution (sp. gr. 1.30), examined for coccidia by brightfield microscopy. The sample contained unsporulated oocysts which were 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 measured using a calibrated ocular micrometer. Measurements on 10 oocysts/sporocysts are reported in micrometers (µm) with the means followed by ranges in parentheses; photographs were taken using brightfield optics. Oocysts were 14 days old when measured and photographed. Several 100 mm sections of the GI tract were cut, split lengthwise, and examined under a stereomicroscope for endoparasites. Trematodes were rinsed in saline, fixed in hot tap water without coverslip pressure, preserved in 70% ethanol, stained in acetocarmine, cleared in methyl salicylate, and coverslip mounted in kleermount. Nematode ova from the fecal flotation was placed on a microscopic slide, coverslip mounted, and photographed as above. Acanthocephalans were prepared, examined, and measurements (provided in µm) were made as described by Richardson (2005, 2006).

A photovoucher host was deposited in the Henderson State University (HSU) collection, Arkadelphia, Arkansas. Voucher specimens of ectoparasites were deposited in the General Ectoparasite Collection in the Department of Biology at Georgia Southern University, Statesboro, Georgia under accession no. L-3809. The coccidian (photovoucher), trematodes, and nematodes (photovoucher) were deposited in the Harold W. Manter Laboratory (HWML) of Parasitology, University of Nebraska, Lincoln, Nebraska. Voucher specimens of acanthocephalans were deposited in the Sam Houston State University Invertebrate Collection (SHSU), Sam Houston State University, Huntsville, Texas, and assigned accession numbers (SHSUINVRT000240 - SHSUINVRT000247).

Results and Discussion

The owl was infected or infested with several parasites, including a coccidian, trematode, nematode ova, an acanthocephalan, and a chewing louse; the blood smear was negative. The parasites recovered are presented below in annotated format.

Apicomplexa: Eimeriidae

***Eimeria megabubonis* Upton, Campbell, Weigel, and McKown, 1990.**–Oocysts (Figs. 1A–C, HWML 139369) matching the description of *E. megabubonis* were found to be passing in feces of *B. virginianus*. Measurements are as follows: subspheroidal oocysts, 28.6 × 25.0 (26–30 × 23–26), L/W ratio = 1.2 (1.0–1.3), bilayered (smooth outer) wall 1.2 (1.0–1.5), micropyle and oocyst residuum absent, 1–4 polar granules present; ellipsoidal-elongate sporocysts, 15.7 × 8.7 (14–17 × 8–10), L/W = 1.8 (1.5–2.1), Stieda and substieda bodies present, parastieda body absent, large sporocyst residuum present; each

sporozoite with three residual bodies.

This eimerian was originally described by Upton et al. (1990) from a single *B. virginianus* from Kansas. Another eimerian, the considerably smaller *E. bubonis* Cawthorn and Stockdale, has been reported from *B. virginianus* from Saskatchewan, Canada (Cawthorn and Stockdale 1981). We document a new distributional record for *E. megabubonis* as well as only the second time in over 25 years that this coccidian has been reported from a great horned owl.

Trematoda: Digenea: Neodiplostomidae

***Neodiplostomum* sp.–**Three specimens (HWML 139370) of an unknown *Neodiplostomum* (Fig. 1D) were found in the small intestine of this host. These digeneans possessed vitelline follicles restricted to the forebody (Fig. 1D) but lacked a genital cone, both morphological features of the Neodiplostominae (Dronen et al. 1995). Five species of *Neodiplostomum* have been previously reported from *B. virginianus*, including *N. cochleare* (Krause) La Rue, from Minnesota (Penrod 1947) and Wisconsin (Chandler and Rausch 1947), *N. americanum* Chandler and Rausch from Connecticut (Richardon and Kinsella 2010), Florida and Mississippi (Kinsella et al. 2001; Woodyard et al. 2017), *N. delicatum* Chandler and Rausch from Wisconsin (Chandler and Rausch 1947), *N. reflexum* Chandler and Rausch from Florida (Kinsella et al. 2001), Michigan (Chandler and Rausch 1947), and Brazil (Gallas and Silveira 2013), and *N. buteonis* Dubois and Rausch from owls from Ontario, Canada (Pearson 1960). Species of *Neodiplostomum* parasitize avian definitive hosts with the majority in the orders Falconiformes

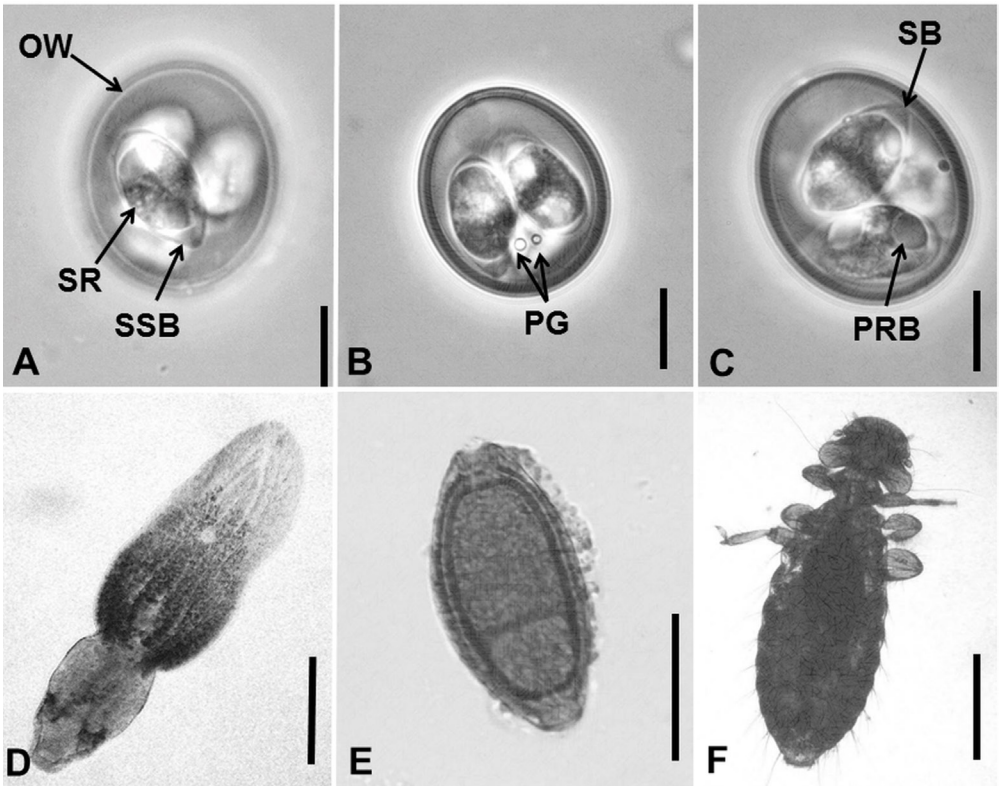

Figure 1. Parasites collected from *Bubo virginianus* from Oklahoma. A–C. Brightfield photomicrographs of sporulated oocysts of *Eimeria megabubonis*. Scale bars = 10 µm. D. *Neodiplostomum* sp. Scale bar = 25 µm. E. Ova of *Capillaria* sp. Scale bar = 25 µm. F. *Colpocephalum brachysomum* female. Scale bar = 500 µm. Abbreviations: OW (oocyst wall), PG (polar granule), PRB (posterior refractile body), SB (Stieda body), SSB (substieda body), SR (sporocyst residuum).

or Strigiformes but the orders Ciconiiformes, Coarciiformes, Cuculiformes, Passeriformes, and Piciformes are also represented (Dubois 1938, 1944, 1962). This is the first time this parasite has been reported from Oklahoma.

Nematoda: Trichurida: Capillariidae

***Capillaria* sp.**–Ova of a *Capillaria* sp. (Fig. 1E, HWML 139369) were recovered from the feces of *B. v. virginianus*. Two capillarid species have previously been reported from great horned owls, including *C. falconis* (Rudolphi) from Florida and Alberta, Canada, and *C. tennissima* (Rudolphi) from Florida (Ramalingam and Samuel 1978; Kinsella et al. 2001) and Connecticut (Richardson and Kinsella 2010). *Capillaria* spp. have also been previously reported from other vertebrates of Oklahoma (Williams 1953; Morrison and Gier 1979; Criffield et al. 2009); however, this is the first time ova of *Capillaria* sp. has been reported from an owl from the state.

Acanthocephala: Paleoacanthocephala: Polymorphida: Centrorhynchidae

***Centrorhynchus spinosus* (Kaiser, 1893) Van Cleave, 1924.**–Ten specimens (3 males, 7 females) of *C. spinosus* were collected from the small intestine representing a new geographic distribution record for this parasite. In accordance with Nickol (1983), the specimens were identified as *C. spinosus* based primarily on trunk shape, the most important character distinguishing individuals of this species from the morphologically similar congener, *Centrorhynchus kuntzi* Nickol, 1983. All specimens lacked the characteristic anterior inflation of the trunk associated with *C. kuntzi*.

Centrorhynchus spinosus was originally described as *Echinorhynchus spinosus* by Kaiser (1893) from an unknown host in Florida. Van Cleave (1916) described *C. spinosus* from a great blue heron, *Ardea herodias* (as *Herodias egretta*) from an undetermined locality. Van Cleave (1924) examined specimens from the Leidy collections supposedly collected from a great gray owl (*Strix nebulosa*) from Florida. Van Cleave (1924) concluded that the specimens were conspecific with *C. spinosus*, ascribed them as *C. spinosus* (Kaiser, 1893) and listed *C. spinosus* Van Cleave, 1916 as a junior synonym, thus establishing the current correct taxonomic designation *C. spinosus* (Kaiser, 1893) Van Cleave, 1916. The known range of *S. nebulosa* lies far north of Florida (Johnsgard 1988). Thus, the host of the Leidy specimens listed as being from *S. nebulosa* should be considered to be from an "unknown host," although it is likely that it was some kind of owl. Van Cleave (1940) reported acanthocephalans collected from an undetermined "Galapagos hawk" collected from the Galapagos Islands that were morphologically similar to *C. spinosus* but they possessed a longer proboscis and exhibited an anterior inflation of the trunk. Subsequently, Schmidt and Neiland (1966) described *C. kuntzi* from a roadside hawk, *Rupornis magnirostris* (as *Buteo magnirostris*), collected in El Recreo, Rio Escondido, Nicaragua. *Centrorhynchus kuntzi* was not reported from North America until Nickol (1983) reported *C. kuntzi* from three species of hawks in southern Louisiana. Nickol (1983) observed the fact that Van Cleave did not recognize the Galapagos specimens as distinct from *C. spinosus,* and may have permitted the occurrence of *C. kuntzi* to go unnoticed in North America. Nickol (1983) reexamined all available specimens of *C. kuntzi* in an attempt to correct previous misidentifications.

Centrorhynchus spinosus has been reported only rather sporadically throughout North America with the majority of reports being from owls in Florida and Louisiana, *B. virginianus*, barred owls (*Strix varia*), and eastern screech owls (*Megascops asio*) (Nickol 1983; Kinsella et al. 2001). Kinsella et al. (2001) reported prevalences of 78, 82, and 22% for *C. spinosus* from barred owls, great horned owls, and eastern screech owls, respectively, with intensities as high as 340 individual worms. Likewise, Nickol (1983) found six of eight (75%) barred owls to be infected with *C. spinosus*. Aside from owls, small numbers of specimens identified as *C. spinosus* have been reported from a potpourri of other hosts. Nickol (1969) reported five specimens of *C. spinosus* from three of 53 (6%) red-bellied woodpeckers, *Melanerpes carolinus* (as *Centurus carolinus*) from southern

Louisiana. A single specimen conforming to the description of *C. spinosus* was collected from a Cooper's hawk (*Accipiter cooperi*) in Connecticut (Nickol, 1983). Taft et al. (1993) reported two of 16 (13%) broad-winged hawks (*Buteo platypterus*) to be infected with *C. spinosus,* although these specimens have not been subsequently confirmed. Coulson et al. (2010) reported one salvaged nestling swallow-tailed kite (*Elanoides forficatus*) from southern Mississippi or Louisiana to be infected with *C. spinosus*, although voucher specimens were not referenced. Single immature individuals of *C. spinosus* were reported from an opossum (*Didelphis virginiana*) and raccoon (*Procyon lotor*) in Georgia (Ellis et al. 1999; Richardson 2014). Interestingly, Read (1950) demonstrated that *C. spinosus* did mature in an experimentally infected rat (*Rattus*), which had been fed cystacanths taken from the body cavity of an eastern garter snake (*Thamnophis sirtalis*) collected in Texas. Additionally, Vogel and Bundy (1987) indicated that cystacanths of *C. spinosus* were common in Jamaican gray anoles (*Anolis lineatopus*). The relatively high prevalence and intensity of *C. spinosus* among owls in Florida and Louisiana supports the assertion of Richardson and Nickol (1995) that *C. spinosus* is primarily a parasite of raptors of the order Strigiformes (owls).

Morphological analysis of the collected specimens revealed some apparent ambiguities, suggesting that the morphological distinctions previously used to distinguish between *C. spinosus* and *C. kuntzi* may not be as pronounced as previously thought. Nickol (1983) found that the number of large rooted hooks on the anterior proboscis differed between *C. spinosus* and *C. kuntzi*. Nickol (1983) also reported that *C. spinosus* bears eight to 11 large rooted hooks whereas *C. kuntzi* bears seven to nine, with the usual numbers of large rooted hooks being nine and 10 in females and males of *C. spinosus*, respectively, and eight in both sexes for *C. kuntzi*. The three males collected in this study that provided good hook counts exhibited nine to 10 (usually nine), large rooted hooks and the four females that provided reliable hook counts exhibited seven to nine large rooted hooks. Nickol (1983) further indicated that the proboscis of *C. kuntzi* is longer than that of *C. spinosus*, in contrast to the report of Schmidt and Neiland (1966) who stated that *C. spinosus* possesses a longer proboscis. The proboscides of female *C. spinosus* were frequently less than one mm long and averaged only 1,014 in length and that the proboscides of males averaged only 963 long according to Nickol (1983). In the current study, the proboscides of three males measured 1,050, 1,110, and 1,130 long × 300, 330, and 300 wide, respectively. The proboscides of three females measured 1,220, 1,250, and 1,250 long × 450, 440, and 410 wide, respectively. Nickol (1983) also indicated and figured a difference in proboscis shape between the two species with *C. kuntzi* exhibiting a pronounced swelling at the level of insertion of the proboscis receptacle that is lacking in *C. spinosus*. One specimen in the current study exhibited a pronounced swelling of the proboscis at the level of the insertion of the proboscis receptacle, similar to that figured by Nickol (1983) for *C. kuntzi*. The other proboscides either exhibited a proboscis shape like that figured by Nickol (1983) for *C. kuntzi*, or a slight swelling that was intermediate between the two species.

Centrorhynchus kuntzi has been reported from hawks throughout North America (Richardson and Kinsella 2010), as well as two *H. leucocephalus* from Florida (Kinsella et al. 1998), a groove-billed ani (*Crotophaga sulcirostris*) in Veracruz, México (Richardson et al. 2010), and in low numbers from great horned owls in Florida (Nickol 1983; Kinsella et al. 2001).

Although there appears to be some ambiguity in morphological characters previously thought to be unambiguous between *C. kuntzi* and *C. spinosus*, trunk shape, along with host affiliation, clearly support the validity of the view that *C. kuntzi* and *C. spinosus* are distinct species. Nevertheless, given the ambiguities revealed by the present specimens, further analysis, including molecular characterization of both species, is warranted as new material becomes available.

Arthropoda: Insecta: Phthiraptera: Menoponidae

***Colpocephalum brachysomum* Kellogg and Chapman, 1902.–**One male, 17 females, and one nymph of *C. brachysomum* (Fig. 1F) were found on the road-killed *B. virginianus*. Emerson (1940) did not include this species in his list of chewing lice recorded from Oklahoma. Peters (1936) reported three species of chewing lice from *B. virginianus* in the eastern United States, namely, *Strigiphilus oculatus* (Rudow) (listed under the synonym *Eustrigiphilus bubonis* Osborn), *Strigiphilus cursor* (Burmeister) (listed under the synonym *Philopterus cursor* Burmeister), which typically parasitizes the short-eared owl, *Asio flammeus*, and *Kurodaia subpachygaster* (Piaget), which typically parasitizes the barn owl, *Tyto alba.* Emerson (1972) listed the following four species of chewing lice as ectoparasites of *B. virginianus* in North America: *C. brachysomum, Kurodaia magna* Emerson, *Strigiphilus syrnii* (Packard) (listed under the synonym *Strigiphilus acutifrons* Emerson) and *S. oculatus*. Price et al. (2003) listed six species of chewing lice as true ectoparasites of *B. virginianus* namely *C. brachysomum, K. magna, S. oculatus, S. syrnii, Strigiphilus elutus* Carricker, and *Strigiphilus chilensis* Carricker, with the last two listed species apparently being restricted to the neotropical part of the range of *B. virginianus.*

Peters (1936) also recorded the ectoparasitic louse fly *Lynchia americana* Leach from *B. virginianus* in six eastern states, and Boyd (1951) reported a single great horned owl with more than 100 louse flies (which were not identified to species).

In conclusion, we document several new distributional records for parasites of *B. virginianus*. This survey, albeit based on a single host specimen, illustrates the significance of salvaging road-killed owls which can yield knowledge on their parasites that could not be obtained otherwise because of state and federal restrictions on collecting and euthanizing live birds, all in the spirit of conservation.

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A CLOSER LOOK AT A TEA TREE OIL-SELECTED *STAPHYLOCOCCUS AUREUS* SMALL COLONY VARIANT

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Best Graduate Paper of the Academy

Staphylococcus aureus small colony variants (SCV) are associated with chronic and recurring infections that are recalcitrant in antimicrobial therapy. SCVs demonstrate: slower growth rates; defective metabolism and electron transport; and reduced antimicrobial susceptibility. Tea tree oil (TTO) kills bacteria by denaturing proteins and disrupting membrane structure and TTO reduced-susceptibility (TTORS) *S. aureus* mutants exhibit an "unique" SCV phenotype. Similar to previously described SCVs, all TTORS SCVs investigated were less susceptible to both the cell wall antibiotics vancomycin and oxacillin. A TTORS SCV mutant (TTORS-1) harbored numerous mutations, including a mutation within acpP which encodes the acyl carrier protein (ACP) essential for fatty acid biosynthesis. Comparative proteomics revealed that TTORS-1 demonstrated increases in 39 proteins and decreases in 74 proteins compared to parent strain SH1000. In TTORS-1, the fatty acid biosynthesis proteins FabF (3-oxoacyl-synthase) and FabD (malonyl CoA-acyl carrier protein transacylase) and the bifunctional phosphopantothenoylcysteine decarboxylase/phosphopantothenate-cysteine ligase were found in greater abundance. This latter enzyme is required for the synthesis of 4'-phosphopantetheine, which when linked to ACP acts as the anchor on which fatty acid biosynthesis takes place. Furthermore, RT-PCR analysis revealed that 4 genes involved with de novo fatty acid biosynthesis as well as one phospholipid biosynthetic gene were also up-regulated in TTORS-1. *S. aureus* SCVs can result from the deletion of menB or cold shock protein cspB, and menB SCVs demonstrate a decrease in citric acid cycle activity. TTORS-1 harbored less menaquinone biosynthetic protein MenB (1,4-dihydroxy-2-naphthoyl-CoA synthase), cold shock proteins CspB and CspC, ATP synthase subunit gamma, and proteins involved with the citric acid cycle. Collectively our data indicates that fatty acid biosynthesis is altered in TTORS-1, as would be expected in an acpP mutant. We also demonstrate the reduced synthesis of certain proteins in TTORS-1 mirroring what has been observed in previously described SCV phenotypes.

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THE EFFECTS OF TEMPERATURE ON THE ATTENUATION COEFFICIENT OF ULTRASOUND

Maranda Robin Clymer, East Central University

Best Undergraduate Paper of the Academy and Outstanding Undergraduate Paper in Physical Sciences Section

Attenuation is an important property of ultrasound that needs to be known in its many different applications, such as food processing, sanitizing, extraction, and imaging in medicine. This property factors in the amount of energy lost with distance traveled (Williams, 2017). I observed the effects of temperature on the attenuation coefficient of ultrasound. Due to the diverse physiochemical properties of oils, I expected to see a clear connection between temperature and the attenuation of ultrasound within different oils. With the results, I hope to inform future research and users of ultrasound of an important factor that should be considered and noted when determining a medium's attenuation coefficient. Using an Ultrasonic Echoscope, a 1 MHz frequency transducer, and a computer with A-Scan software, I obtained different values of factors found within Beer's law. I repeated this at a range of depths and temperatures to solve for multiple attenuation coefficient values, αF. With Graphical Analysis, I plotted multiple attenuation coefficient vs temperature graphs at small temperature intervals. Once I collected all my data and composed the graphs, I observed that though there is a connection between the attenuation coefficient and temperature, there needs to be a broad range of temperatures for this to be seen. These graphs helped me achieve equations that show a relationship between the ultrasound attenuation coefficient and temperature for the mediums I used. I accomplished this by using three different oils: sunflower oil, coconut oil, and corn oil.

EVALUATION OF THE BLUE RIVER FOR PRESENCE OF *CAMPYLOBACTER JEJUNI*

Gunner Parent and April Nesbit, East Central University

Best Undergraduate Poster of the Academy

Campylobacter jejuni is a known bacterial species associated with cattle and poultry, along with other species. *C. jejuni* is known to cause campylobacteriosis, an intestinal infection that can have severe effects on young animals and humans. The Blue River is a water source for many people and livestock in Southeast Oklahoma, and the Oka' Yanahli preserve includes one mile of the Blue River near the headwaters. Prior to being a preservation, cattle occupied the land and today a chicken plant resides next to the river, and either of these activities could lead to contamination of the Blue Rive by *C jejuni*. For the safety and health humans and animals, I sampled for the presence of *C. jejuni* in the portion of the Blue River contained in the Oka' Yanahli preserve. Sediment and water samples were collected from six locations along the Blue River. Water samples were diluted using serial dilution protocols and placed on *C. jejuni*, BD *Campylobacter* Bloodfree Selective Medium, petri plates. Plates were grown at 42^{o}C for 24 hours. Eleven bacterial colonies of interest were isolated followed by gram staining and eight biochemical tests. Results were collected and deciphered using Bergey's Manual. Based on initial results, none of the eleven isolated colonies are *C. jejuni*. Future work includes testing additional colonies using standard microbial techniques and 16S bar coding studies to confirm bacteria species.

RE-GROWTH AFTER FIRE IN A CROSS-TIMBERS FOREST IN OKLAHOMA

Haylee Story, Sonya Ross, and Stanley A. Rice, Southeastern Oklahoma State University

Outstanding Undergraduate Paper in Biological Science-Botany Section

We counted the number of sprouts of woody plant species that grew after a 2011 fire near the Blue River in south central Oklahoma over the course of six years. One of the transects was in a cross timbers forest; the other one was along the Blue River. We found that some woody plant species re-sprouted quickly and maintained a relatively unchanged density of sprouts, while in other species, the number of sprouts increased over time.

TEMPERATURE REGULATES FORAGING BEHAVIOR IN THE RED HARVESTER ANT, *POGONOMYRMEX BARBATUS*

Anna Parakevopoulos, Karl Roeder, and Diane Roeder, Cameron University

Outstanding Undergraduate Paper in Biological Science-Zoology Section

All organisms require nutrients for survival, growth, and reproduction. These nutrients are acquired in varying quantity when animals forage for food. The abiotic conditions that animals experience can either constrain or provide windows of opportunity for foraging activity. Here we examine how daily fluctuations in abiotic conditions regulate foraging activity of the red harvester ant, *Pogonomyrmex barbatus*. We examine 1) colony differences in time spent foraging and distance traveled per trip, 2) the effect of temperature on travel speed, and 3) the effect of temperature on the time spent engaged in each component of a foraging trip (i.e. outbound trip, foraging duration, return trip). We tracked 20 individual foragers at each of nine colonies and recorded distance to foraging area, time spent travelling and foraging, and temperature during each trip. Ants foraged in the morning at surface temperatures ranging from 25-60ºC. Colonies foraged at different distances from the nest, which was reflected in travel time to and from the foraging area. Controlling for differences between colonies, travel speed for both outbound and return trips increased with temperature. Likewise, search time was constrained to shorter bouts. Despite increased travel speed, ants foraged in the same location throughout the day, suggesting that distance to foraging areas was not influenced by temperature. Our results highlight the importance of daily temperature cycles in regulating foraging behaviors, which may limit nutrient intake.

ENHANCING STUDENT LEARNING USING COGNITIVE SCIENCE

Shi Rui Yeoh, Tiara Travis, Paul Cook, Nesreen Alsbou, and Samuel Lawrence, University of Central Oklahoma

Outstanding Undergraduate Paper in Social Sciences Section

Our goal for this project is to study the thinking process of college students when they are learning and in the process enhance the way they think using cognitive science. We focus on the think-aloud strategy and the advantage and disadvantage of this method. The think-aloud strategy requires the learner to verbalize his or her thinking when solving a given problem. Our group contains of 6 students and 2 Professors. At the beginning of the research, our task was to review academic journals regarding to the think-aloud strategy. After that, each of us was required to design a case study which focus on the application of the think-aloud strategy to students related to our respective major. As for now, each of us has completed our preliminary case studies. The initial experiments only focused on a scale of one student and we plan to expand the scale of the experiment and hopefully help students improve the way they learn.

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MOLECULAR CHARACTERIZATION OF FOODBORNE PLANT PATHOGENS IMPORTED FROM CENTRAL AMERICA.

Matt Broge, J Grimm, C Soden, K Karki, C Biles, A Howard, and B Bruton, East Central University

Outstanding Undergraduate Paper in Microbiology Section

Plant pathogens are often carried into other countries through insects, animals, farm machinery, or plant transmission. Latent plant pathogens, such as *Diaporthe* sp., enter the surface of the melon fruit (*Cucumis melo* L. var. *cantalupensis* Naudin) early in development. The fruit is picked at maturity and then sent to market. The fruit continues to mature and at this time the pathogen quickly causes interior fruit rot often discovered by the consumer when cutting the fruit open. The purpose of this research is to investigate whether *Diaporthe* species imported on melons from Central America are the same as those already identified in melons grown in Oklahoma. Four *Diaporthe* spp. have recently been taxonomically classified that attack melon; *D. cucurbitae*, *D. melonis*, *D. sojae*, and *D. ueckerae*. Melons from Costa Rica, Honduras, and Guatemala were purchased at local grocery stores and melons were taken from fields throughout Oklahoma. The melons were washed in 10% bleach, dried and stored on a dry bench. After 4-10 days, sunken surface lesions were detected and the melons dissected using a sterile knife. Samples of the diseased tissue was placed on an agar plate containing either potato dextrose or malt extract. After 4-10 days, the fungus growing from the tissue was subcultured to another agar plate. After 7 to 14 days, the fungal pycnidia were examined microscopically for alpha and beta spores characteristic of *Diaporthe* species. Fungal hyphae was then separated from agar and DNA was extracted. Polymerase chain reactions (PCR) were performed using ITS tagged M13 Primer sequence and products were confirmed using agarose gel electrophoresis. Purified PCR products were sent to Eurofins Scientific for Sanger DNA Sequencing. *Diaporthe* spp. were isolated from melons imported from Guatemala, Costa Rica, Honduras, and from those grown in Oklahoma.

DYNAMIC RESPIRATORY PHANTOM

Amjad Barghouthi, University of Central Oklahoma

Outstanding Undergraduate Paper in Engineering Science Section

In our research we are planning to design a 3D platform and a lung phantom that has different cancerous tumor sizes. The goal is to use the phantom to detect motion artifacts in CT. We will be using motion modeling to model the respiration motion of the patients which produces image artifacts during the scanning process. These artifacts cause erroneous calculations of the volume and characterization of the tumors and critical structures in treatment planning and variations in the CT-number values and the associated densities of the associated tissues. This phantom will be made of foam substance that mimics lung tissue and gel like substance that has a density equivalent to water and normal tissues. This phantom system is compatible and safe to be used under x-rays of the cancer treatment devices. The design and reconstruction of this phantom system is still in process. This phantom moves in 3D using three mobile platforms that are driven by different stepper motors which will allow complicated motions that can simulate the lung movement. When we complete our project and research successfully we will be investigating image artifacts induced by phantom motion and develop techniques that enhance CT image quality thereby allowing radiotherapy planners to accurately calculate the volume of the tumors and reduce the uncertainty in CT numbers

MTORC1 IS NECESSARY AND SUFFICIENT TO STIMULATE GLS ACTIVITY IN OSTEOBLASTS

Joshua C. Hardage, East Central University and Duke University
Yilin Yu and **Courtney M. Karner,** Duke University

Outstanding Undergraduate Paper in Biochemisty and Biophysics Section

Osteoblasts are secretory cells whose primary function is to produce and secrete Type 1 Collagen and other proteins that comprise and mineralize the bone matrix. Metabolically, how osteoblasts generate biomass and energy to sustain matrix production is not well understood. Previously, we identified glutamine metabolism as a critical regulator of WNT-induced osteoblast differentiation and bone formation by entering the TCA cycle to alleviate the energy deficit associated with WNT-induced bone formation. WNT stimulates glutamine metabolism by activating the enzyme glutaminase (GLS) which catalyzes the first, rate limiting step in glutamine metabolism. How WNT regulates GLS activity and glutamine metabolism is unknown. Here we present data demonstrating the mammalian target of rapamycin complex 1 (mTORC1) pathway is both necessary and sufficient to stimulate GLS activity during osteoblast differentiation. We used the active site mTOR inhibitor Torin1 to inhibit all mTOR activity during osteoblast differentiation. Torin1 treatment completely eradicated both GLS activation and osteoblast differentiation in response to WNT. Conversely, disinhibition of the mTOR pathway by deletion of the Tsc2 gene in calvarial osteoblasts greatly increased GLS protein expression and activity. Moreover, pharmacological activation of mTOR with three distinct small molecules that activated the upstream kinases PI3K (PI3K activator) or AKT (SC79) or mTORC1 directly (MYH1485) was sufficient to increase GLS protein expression and activity in vitro. Mechanistically, quantitative PCR and Phos-tag western blot analyses indicated that GLS is not regulated transcriptionally rather it may be the result of direct phosphorylation by mTOR. Finally, we evaluated SC79 for efficacy in vivo. Two-month old C57Bl/6 female mice were injected intraperitoneally for 4 hours with SC79. This regimen stimulated mTORC1 activity and increased GLS protein levels in bone extracts. Collectively, our data suggest targeting mTOR activity may be a viable strategy to modulate GLS activity and stimulate osteoblast differentiation and bone formation in vivo.

UTILIZING XLSFORM AND FORM-HUB TO DIGITIZE THE DATA FOR PONTOTOC ANIMAL WELFARE SOCIETY

Billy Andrew, East Central University

Outstanding Undergraduate Paper in Math, Statistics, & Computer Science Section

Pontotoc Animal Welfare Society (PAWS) in Ada Oklahoma still collects data on paper. With a PetSmart grant and help form McNair Scholars Program, we have obtained equipment and developed specialized form for data entry utilizing an open source program, Form-Hub. Creating a working and efficient form will be the key in making this a viable methodology for data transfer and entry for PAWS, other humane societies and small businesses. For non-profit organizations and small businesses, it is crucial to have the least operating cost as possible. For Form-Hub to work there needs to be a server, these are expensive devices. To keep it on a small budget, ideas like using Amazon Web services and the use of a micro-server like a Raspberry PI 3 B will be explored.

EXTRACELLULAR VESICLES TARGET T-CELL FUNCTION IN B CELL CHRONIC LYMPHOCYTIC LEUKEMIA

Whitney Hall, Oklahoma Christian University
H. Mahmud, **G. Maiti, and A. Mille,** Stephenson Cancer Center
A. Ghosh, Stephenson Cancer Center, University of Oklahoma Health Sciences Center
Outstanding Undergraduate Paper in Biomedical Science Section

B-cell chronic lymphocytic leukemia (CLL) is still incurable despite aggressive therapies. While various microenvironmental factors are known to influence CLL progression, exploring the role of extracellular vesicles (EVs) in CLL pathobiology has just begun. We now know that CLL plasma contain elevated levels of EVs including microvesicles (MVs; 0.1–1.0μm) and exosomes (Exos; 30–<100nm). While our earlier work shows the ability of CLL MVs to activate CLL bone marrow stromal cells, their interactions with T-cells remain largely undefined. Of relevance, CLL patients are also known to have T-cell dysfunction. Thus, we studied the impact of CLL EVs on T-cell function. MVs/Exos were purified from CLL plasma or used culture media of CLL B-cells and Meg-01 (megakaryocytes) cells by differential centrifugations. Levels of MVs/Exos were determined by estimating protein content. Primary T-cells from normal peripheral blood mononuclear cells and CLL B-cells from CLL patients' blood were purified using specific kits. A human T-cell line (Jurkat) was also cultured for few experiments. Fluorescent microscopic observations suggest that EVs from CLL plasma, CLL B-cells, and Meg-01 cells are able to integrate into the T-cells. Interestingly, different T-cell types show specific affinity towards MVs, Exos, or both. On the other hand, CLL B-cell derived EVs show more affinity towards T-cells than EVs from other sources. Importantly, circulating EVs from certain CLL patients inhibited normal T-cell activation in vitro. Our initial studies suggest that circulating EVs in CLL are likely to target T-cells which may contribute significantly in CLL pathogenesis.

REDEFINING HTLV AND HOST PROTEIN-PROMOTER INTERACTIONS IN MAGNETIC PROMOTER PULL-DOWN ASSAYS

Conner Anderson and Alisha Howard, East Central University

Human T-cell leukemia virus type 1 (HTLV-1) is the oldest known human retrovirus affecting over 20 million people worldwide. HTLV-1 is a causative agent of Adult T-cell leukemia/lymphoma (ATL/L) for which there is currently no known cure for. This project investigated amplification of the viral promoter utilizing different polymerase samples (Thermus aquaticus). The amplicon was also designed to attach to magnetic beads upstream of the HTLV-1 promoter region facilitating protein-DNA interaction identifications. Various polymerase samples and assorted buffers were obtained through several companies or generated in house (ECU). A plasmid, coding for Taq polymerase was transformed into BL21 (DE3) pLysS and expressed. Expression was monitored with SDS-PAGE and purified similar to established protocols. Amplification in controlled PCRs allowed comparison of reaction efficiencies. An analysis of various streptavidin coated magnetic beads was also conducted. Results indicated that Taq-Pol expressed in the lab was suitable for promoter amplification via PCR, making large volume production feasible. Results of the project also indicated that magnetic beads vary significantly in binding efficiency to the biotinylated promoter region. Based on the results, streptavidin coated magnetic beads provide the ability to isolate the promoter region of HTLV via magnetic pull-down assays. Utilizing this method will help us to understand viral-host protein-DNA and protein-protein interactions. These interactions are suspected to play an important role in the activation of the HTLV retrovirus in humans. Understanding of this process helps our comprehension, not only of viral life cycle and patient prognosis, but overall understanding of dynamic regulation in endogenous genes as well.

CULTIVATION OF FASTIDIOUS ANAEROBIC ORGANISMS FROM THE EQUINE GUT MICROBIOME USING THE ICHIP DEVICE FOR NON-TRADITIONAL CULTIVATION

Shaylin Daji, Nisha Patel, and Paul Lawson, University of Oklahoma

Cultivation is an invaluable tool in microbiology that allows for the characterization of an organism's morphological, physiological, biochemical, and chemotaxonomic traits. Currently, only a small fraction of all microorganisms have been identified and described. The Ichip diffusion device is a non-traditional cultivation method developed to recover "uncultivable" organisms in situ in an aerobic environment. In this study, a culture-dependent approach will be used to grow anaerobic fastidious organisms in situ using a modified Ichip device protocol in order to identify novel bacteria from the equine gastrointestinal tract. In the laboratory, organisms often fail to grow due to their specific growth substrates not being provided. The principle behind this approach is that organisms are encouraged to grow on the material they naturally inhabit and vital nutrients will migrate into the agar present in the Ichip device thus further increasing the probability of continued growth when transferred to a range of substrates present in agar plate growth experiments. The Ichip device will be inoculated with a diluted equine fecal sample and the Ichip will be placed in a fecal slurry grown at physiological conditions in the anaerobic chamber. Candidate novel isolates identified (below 97% 16S rRNA sequence similarity), will be subjected to a panel of morphological, physiological, biochemical, chemotaxonomic (fatty acid, polar lipids, peptidoglycan), and more in depth phylogenetic analysis. In this approach, we envision that underrepresented microbes in equine intestinal microbiome will be further characterized and studied to determine their health function in horses. Using the Ichip diffusion device, a greater range of organisms located in different phylogenetic groups will be recovered from the equine gut microbiome by providing organisms with natural growth conditions compared to traditional isolation methods.

CLONING, SEQUENCING, AND IDENTIFICATION OF UNKNOWN *SALMONELLA* OR EHEC (ENTEROHEMORRHAGIC *E. COLI*) BACTERIOPHAGE 3

Raina Hahn, Owasso High School
Riley Pritzlaff, Bixby High School
B.J. Reddig and E.L. Blewett, Oklahoma State University – Center for Health Sciences
P.K. Litt, Oklahoma State University

Bacteriophages are a common type of viruses that infect and kill bacteria. *Salmonella* and enterohemorrhagic *E. coli* [EHEC] bacterial infections are a common cause of foodborne illnesses. Bacteriophages were isolated from the environment and shown to kill both of these pathogens. Preparations of these bacteriophages can be sprayed onto food processing machinery and leafy greens in order to reduce bacterial contamination thus preventing foodborne illness. In this project we cloned DNA fragments from one of the bacteriophages, Phage 3, and sequenced the DNA. We sequenced more than 2,000 bp and used this DNA sequence data and phylogeny software to compare our phage with existing phage in GenBank. We identified Phage 3 as a Salmonella-type phage and inferred it's relationship with other bacteriophage.

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A PUTATIVE PHYTASE, CARP, IS DIFFERENTIALLY REGULATED BY MULTIPLE PROMOTERS AND PLAYS AN IMPORTANT ROLE IN CA2+ RESPONSE OF *PSEUDOMONAS AERUGINOSA*.

Michelle King and **Marianna A. Patrauchan,** Oklahoma State University
Mariette Barbier, West Virginia University

Pseudomonas aeruginosa is an opportunistic pathogen that causes severe acute and chronic infections in humans, particularly, in cystic fibrosis (CF) patients. Our group has shown that calcium (Ca2+) induces virulence and antibiotic resistance in *P. aeruginosa*. Earlier we identified a Ca2+-regulated protein, CarP, which was predicted to form a 5 bladed β-propeller structure with a phytase-like domain and a putative Ca2+ binding site in the center of the propeller. We have characterized its role in Ca2+-induced production of virulence factors: pyocyanin and pyoverdine, and cell tolerance to elevated Ca2+. To further characterize the role of CarP in Ca2+-regulated virulence and adaptation to host, we aim to identify the host factors that control the expression of carP. Based on RNA seq data analyses of carP transcription profile, we predicted two promoter regions located at -52 and +6. To study the potential role of these promoters in regulation of carP transcription, we cloned three fragments harboring P1 (-321 to -1), P2 (-212 to +100), or both P1P2 (-321 to +36) into a vector with promoterless lux operon. Overall, P1 promoter showed increased activity during late log and stationary growth phases. However, elevated Ca2+ induced its activity during early log, and decreased it during later phases. Growth at 5% CO2 reduced P1 activity and abolished the growth phase-dependent Ca2+ effect. Furthermore, we studied the role of CarP in *P. aeruginosa* pathogenicity by using Galleria mellonella and mouse virulence models. Disruption of carP reduced worm killing by 60% and decreased survival of *P. aeruginosa* in mice by 30%. These data reveal that CarP plays an important role in the pathogen's virulence and survival within a host and advance our knowledge of the molecular mechanisms of Ca2+ regulation of P. aeruginosa virulence and fitness in response to host environments with elevated levels of Ca2+.

RAISING AWARENESS FOR AN ENDANGERED SPECIES (THE SEASIDE ALDER) THROUGH PRODUCT MARKETING

Andrea Lashley and Stanley A. Rice, Southeastern Oklahoma State University

The seaside alder (Betulaceae: *Alnus maritima*) is an endangered species. One of its three populations occurs in southern Oklahoma. An endangered plant species can be protected by the Fish and Wildlife Service or rescued by planting in a botanical garden. Another way of protecting an endangered plant species is to create an economic value for its sustainable use. An extract from the twigs of the seaside alder, which can be sustainably harvested, has strong antibiotic properties. The extract, when incorporated into a lotion, can create a clear zone of dead bacteria on an agar plate. This demonstrated antibiotic activity can help to sell the product, some of the revenues from which can be used for conservation of the alder.

IMPORTED SPECIES OF PATHOGENIC *FUSARIUM* SPECIES FROM CENTRAL AMERICA DIFFER FROM *FUSARIUM* SPECIES IN OKLAHOMA

Cierra Soden, Matt Broge, Alisha Howard, Benny Burton, and Charles Biles, East Central University

Plant pathogenic *Fusarium* causes disease on a large range of food crops around the world. This project is investigating the various *Fusarium* isolates that are being brought into the United States from Central America on cantaloupes. Symptoms that occur before harvest include a green margin around the area of infection, large fissions in the netted epidermal tissues, along with the infected lesion area turning tan to brown. White mycelium can occur on the surface when stored at high humidity and warm temperatures. Lesions that develop postharvest and without the external preharvest symptoms, also develop interior spongy, white lesions. Melons (*Cucumis melo* L. var. *cantalupensis* Naudin) imported from Mexico were purchased from a local grocery store, surface disinfected with bleach and stored on disinfected table tops for 7 days. The melons were dissected with a sterile knife and small infected fruit tissue pieces were placed on Potato Dextrose Agar (PDA). On PDA, the colonies appeared peach colored. Microscopic examination indicated that the isolates were *Fusarium* spp. They were placed in 15% glycerol and stored at -70°C until molecular analysis could be conducted. The isolates stored at -70°C were thawed and 50 µl of the spore suspension transfer to a PDA plate. A small portion of the hyphae was removed from the Petri dish and used for DNA extraction. ITS primers were used to isolate DNA sequences from the different isolates. The DNA analysis confirmed that they were *Fusarium* species. GenBank blast search indicated that the isolates from Mexico were a 100% match with Fusarium sp. ALO-IIHR. Costa Rica isolates were either *F. proliferatum* var. *proliferatum* or *F. subglutinans*. Oklahoma isolates were *Fusarum solani*. The *F. proliferatum* and *F. subglutinans* have not been reported as pathogens on cantaloupe. This is the first report of *Fusarium* Fruit Rot in Costa Rica and Mexico.

DESIGN AND SYNTHESIS OF COLLYBOLIDE PROBES FOR DEVELOPING NON-ADDICTIVE PAINKILLERS

Rhonda H. Weigand, Redlands Community College
Nicholas P. Massaro and Indrajeet Sharma, University of Oklahoma

Opiates, such as morphine are prescribed and used by millions of patients each year for the treatment of moderate to severe pain. However, opioid analgesics cause addiction and subsequent abuse that affects the health, social, and economic environment of all societies. Studies suggest that selective kappa-opioid receptor (kOR) agonists biased towards G-protein signaling could be novel therapeutics for treating pain with reduced side effects. In the quest for biased kOR ligands, we have identified collybolide a non-nitrogenous sesquiterpene natural product from the mushroom *Collybia maculata*. Deciphering the structural requirements essential for kOR selectivity through collybolide probes, is the first step in developing selective- and biased-kOR ligands. Therefore, we have developed a novel three components coupling approach for the efficient synthesis of diverse biocores of collybolides. All of the starting materials required for the three components coupling have been synthesized at gram scale. During the process, various synthetic and analytical skills including the Schlenk techniques, low- and high-temperature reactions, column chromatography, thin-layer chromatography (TLC), High-Pressure Liquid Chromatography (HPLC), as well as Infrared (IR), nuclear magnetic resonance (NMR) and Mass spectroscopy were applied. The resulting analogues will be submitted for the High-throughput screening at the NIMH Psychoactive Drug Screening Program against 50 CNS receptors to find new hits. Identified high-affinity collybolide probes will be advanced for in vivo use for the development of potential non-addictive painkillers.

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USING ULTRASOUND TO ANALYZE CALIBRATED ABSORBERS

Karen A. Williams, East Central University

Two sets of lead absorbers seemed to produce different results when used to attenuate gamma rays. In an attempt to determine if the absorbers were different or there was other error, I used ultrasound to examine them to determine if the absorbers were different. Examination of the velocity of sound determined if the absorbers were different. My findings showed there was a 332 m/s difference between the average velocities of the two lead absorber kits. The square lead absorbers have some other metal (Al) on the back and their velocity appears slightly higher as expected. Since the mass absorption coefficient of these absorbers was calibrated at the manufacturer, my use of a one-point attenuation coefficient determination was used to examine the relationship between the ultrasound attenuation coefficient and the mass absorption coefficient for x-rays. I was surprised to find a moderately strong correlation between these two quantities even with the one-point attenuation errors inherit in the method. The ultrasound attenuation at 1MHz in lead data appears to be linearly correlated with the mass attenuation coefficient. The slope = 54,140 (dB/cmMHz)/(cm^2/mg), r = .953 for round lead; while the slope = 11,300 (dB/cmMHz)/(cm^2/mg), r = .995 for square lead. This finding was only with five and four absorbers, respectively. The smaller slope for the aluminum-backed lead graph was logical as aluminum is not as good a gamma attenuator as lead is. The sound attenuation versus the mass attenuation for aluminum absorbers also exhibited a linear relationship (slope = 7,062 (dB/cmMHz)/(cm^2/mg), r = .906). More data from calibrated materials should be examined before there can be confidence that the sound attenuation coefficient is strongly linearly correlated to the mass absorption coefficient.

HIGH TEMPERATURE SYNTHESIS OF TITANITE

Austin Walker and Dwight L. Myers, East Central University

Titanite (sphene) is a mineral which commonly forms where calcium, silicon, and titanium are all present together. Since titanium oxide is present in high temperature applications in turbomachinery, titanite is one possible reaction product when calcium and silicon bearing minerals are ingested into a gas turbine. A study of the reaction of calcium carbonate with silicon dioxide (quartz) and titanium dioxide (rutile) is described in this study. Titanite is observed to form on heating for 24 hour intervals at temperatures of approximately 1300°C and above. Reaction progress over multiple heating cycles shows increasing amounts of titanite by X-ray diffraction. Calcium titanate (perovskite) is observed to form at these temperatures as well. The significance of these reactions with regard to corrosion in gas turbines will be discussed.

COMPUTATIONAL INVESTIGATIONS OF BROMINE OXIDES

Daniel McInnes and Aljan Ranjit. East Central University.

Structural isomers of bromine oxides with the formulas BrO_2, Br_2O, and Br_2O_2 have been characterized at the HF/6-31G level of theory. This work expands on a previous investigation of the analogous iodine oxides. An understanding of the properties and reactivity of halogen oxides is important in atmospheric chemistry, among other areas. How these species act as intermediates in the ozone depletion process is of particular interest. Methods of making, storing and analyzing reactive compounds have improved over the years; as a result, halogen oxides can be synthesized, their properties can be studied, and their environmental fate can be determined.

OKLAHOMA ACADEMY OF SCIENCE

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OKLAHOMA ACADEMY OF SCIENCE

STATEMENT OF REVENUES COLLECTED AND EXPENSES PAID
FOR THE YEAR ENDED DECEMBER 31, 2016

REVENUES COLLECTED

Contributions:		
Donations	$100.00	$100.00
Membership Dues and Assessments:		
Dues	$1,994.00	$1,994.00
Investment Income:		
Interest Earned	$54.48	$54.48
Other Income:		
POAS Income	$6,005.99	$6,005.99
Professional Fees	$140.00	$140.00
Miscellaneous	$1,893.06	$1,893.06
Meetings:		
Registration - Spring Meeting	$2,471.00	$2,471.00
Registration - Fall Meeting	$7,599.39	$7,599.39
Registration - Technical Meeting	$9,411.91	$9,316.91
Total Revenue Collected		**$29,574.83**

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	$1,055.00	$1,555.00
Meeting Expenses:		
Spring Meeting	$2,267.76	
Fall Meeting	$5,457.04	
Technical Meeting	$2,561.07	$10,285.87
Insurance	$742.00	$742.00

STATEMENT OF REVENUES COLLECTED AND EXPENSES PAID
FOR THE YEAR ENDED DECEMBER 31, 2016 (Continued)

Dues:		
AAAS	$281.00	
NAAS	$753.07	$1,034.07
POAS	$3,737.68	$3,737.68
Others	$216.00	$216.00
Miscellaneous:		
NAAS Mileage	$103.07	
Catering & Speaker	$2,198.40	
Flight for AAAS/NAAS Meeting	$467.14	
Office Assistants	$20.00	$2,788.61
Total Expenses Paid		**$27.414.84**
Revenues Collected Over Expenses Paid		**$2,159.99**

OKLAHOMA ACADEMY OF SCIENCE
STATEMENT OF ASSETS, LIABILITIES AND FUND BALANCE
ARISING FROM CASH TRANSCATIONS
DECEMBER 31, 2016

ASSETS

Cash:		
Checking Account	$27,897.07	
Savings Account	$1,287.74	
Endowment Savings Account	$3,260.43	$32,445.24
Investments:		
Certificate of Deposit	$60,000.00	$60,000.00
Total Assets:		**$ 92,445.24**

LIABILITIES AND FUND BALANCE

Liabilities:	$0.00	
Fund balance:		
Beginning operation fund balance	$90,285.25	
Excess revenues collected over expenses	$2,159.99	
Total Funds:		**$92,445.24**

INDEPENDENT AUDITOR'S REPORT

Executive Committee
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, 2016, and the related statements of revenue collected and expenses paid for the year than ended. 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. An audit 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, 2016 and its revenue collected and expenses paid during the year then ended.

E. Pace, Retired
Assistant County Auditor

OKLAHOMA ACADEMY OF SCIENCE

Name_____Affiliation _____
Last First Middle

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_____ B Geology _____F Geography_____J Biochemistry/Biophysics_____N Biomedical Sci.
_____ C Physical Sciences_____G Fish and Wildlife_____K Microscopy_____Y Collegiate Acad.
_____ D Social Sciences_____H Microbiology_____L Mathematics/Computer Sci_____Z Junior Academy

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Mail completed form and payment to: Dr. David Bass, Executive Director, Oklahoma Academy of Science, University of Central Oklahoma, Campus Box 90, Edmond, OK 73034.

Members, please photocopy this form and give that to a non member colleague or student. Help strengthen OAS by recruitment!

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Make tax deductible donations in memory or honor of a family member, friend, or colleague. All donated fund are placed as principle into the OAS Endowment Account and the interest generated funds the Academy's programs.

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Editorial Policies and Practices

The *Proceedings of the Oklahoma Academy of Science* is published by the Oklahoma Academy of Science. Its editorial policies are established by the Editor and Associate Editors, under the general authority of the Publications Committee. The Editor is appointed by the Executive Committee of the Academy; Associate Editors are appointed by the Publications Committee in consultation with the Editor. The suitability for publication in the *Proceedings* of submitted manuscripts is judged by the Editor and the Associate Editors.

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.

Reviewer's Responsibilities

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.
- A reviewer who has a conflict of interest or a schedule that will not allow rapid completion of the review will quickly return the manuscript; otherwise, the review will be completed and returned promptly.
- A reviewer shall respect the intellectual independence of the author(s). The review shall be objective, based on scientific merit alone, without regard to race, religion, nationality, sex, seniority, or institutional affiliation of the author(s). However, the reviewer may take into account the relationship of a manuscript under consideration to others previously or concurrently offered by the same author(s).
- A reviewer should not evaluate a manuscript by a person with whom the reviewer has a personal or professional connection if the relationship could reasonably be perceived as influencing judgment of the manuscript.
- The manuscript is a confidential document. If the reviewer seeks an opinion or discusses the manuscript with another, those consultations shall be revealed to the Editor.
- Reviewers must not use or disclose unpublished information, arguments, or interpretations contained in a manuscript under consideration, or in press, without the written consent of the author.
- Reviewers should explain and support their judgments and statements, so both the Editor and the author(s) may understand the basis of their comments.

Brief Instructions to Authors

The instructions to authors wishing to publish their research in the Proceedings of the Oklahoma Academy of Science are listed below. We ask the authors to recognize that the intent is not to establish a set of restrictive, arbitrary rules, but to provide a useful set of guidelines for authors, guidelines that, in most cases, are also binding on the Editors in their task of producing a sound and respected scientific journal.

A. Submission Process.

Manuscripts for the *Proceedings* should be submitted electronically via electronic mail (email) to:

poas@okstate.edu

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. 107); 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.

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