Occurrence of Harris mud crab *Rhithropanopeus harrisii* in Oklahoma (Lake Texoma),the furthest inland report to date.

Tim Patton
Department of Biological Sciences, Southeastern Oklahoma State University, 1405 Nth 4th Ave., PMB 4054, Durant, OK 74701.

Christina Newman
Department of Biological Sciences, Southeastern Oklahoma State University, 1405 Nth 4th Ave., PMB 4054, Durant, OK 74701.

Cliff Sager
Oklahoma Department of Wildlife Conservation, 2021 Caddo Hwy, Caddo, OK 74729

Matt Mauck
Oklahoma Department of Wildlife Conservation, 2021 Caddo Hwy, Caddo, OK 74729

Harris mud crabs *Rhithropanopeus harrisii* are believed to be native to the east Coast of North America but have been introduced to coastal areas throughout much of the old and new worlds. By the middle of the 20th century, they had become established in inland habitats in California, and since the mid 1990's, in several reservoirs in Texas. In 2008, a specimen reported to be from lake Texoma, Oklahoma, was provided by an angler. In 2008 and 2009, we conducted trapping and visual surveys and followed-up on reports from the general public to confirm the presence and describe the distribution of this potentially invasive species in Lake Texoma. We collected 24 specimens from sites along much of the longitudinal gradient in Lake Texoma, in the Red and Washita River arms. Ours is the first confirmed report of this species in Oklahoma, and the furthest inland report of which we are aware. Harris mud crabs are apparently widespread and reproducing in Lake Texoma, though densities appear to be low at this time, and the potential ecological and mechanical impacts of this species in Oklahoma are unknown.

INTRODUCTION

Harris mud crab *Rhithropanopeus harrisii* (Gould, 1841) (Crustacea: Decapoda, Panopeidae), is believed to be native to coastal waters from the southwest Gulf of Saint Lawrence, Canada, extending south through the Gulf of Mexico to approximately Vera Cruz, Mexico, where it inhabits fresh to brackish waters along coastlines (Williams, 1984), and occurs well out to sea (Perry, 2009). Over a time period spanning the late 1800's through the 20th century, it invaded brackish waters, estuaries, coast lines, and inland seas throughout much of Europe, the Middle East, Panama, and Venezuela (Rodriguez & Suarez, 2001; Roche & Torchin 2007), and along the west coast of the United States (Perry, 2009). Grosholz and Ruiz (1996) describe this species as among the most widely distributed brachyuran invaders world-wide. In 1998, it was discovered in inland reservoirs in Texas, and since that time, has been confirmed in a total of 10 Texas reservoirs (Boyle, Keith, & Pfau, 2010). It was also reported from one additional reservoir (Lake Braunig) but has not been confirmed (Boyle et al., 2010). Thus, the northward inland expansion of this species across Texas occurred rapidly. In this paper, we report the presence of *R. harrisii* in Lake Texoma, Oklahoma, making it the furthest inland population in North America of which we are aware.

Also referred to as the white-fingered crab (Keith, 2005), Harris mud crab is small, with a carapace width typically less than 26 mm (Williams, 1984; Roche & Torchin, 2007). Physical description, derived from Rathbun (1930, cited in Perry, 2009) and Williams (1984) is as follows: front almost straight, slightly notched; frontal margin transversely grooved, appearing double when viewed from the front; chelipeds unequal and dissimilar, major chela with short fixed finger and strongly decurved dactyl; minor chela with longer fixed finger and relatively straight dactyl; dactyls light in color; carpus of chelae in juveniles rough with lines and granules; walking legs slender and somewhat hairy, color brown to olive green. A photograph is provided (Fig. 1). *R. harrisii* is typically associated with some form of cover, shelter, or coarse substrate, including oyster reefs, vegetation, and various types of debris, including pipes associated with water intakes (Williams, 1984; Keith, 2005).

On September 19, 2008, a decapod specimen was brought into the Oklahoma Department of Wildlife Conservation Fisheries Division office in Caddo, Oklahoma, by a local construction diver, and was reported to be from the waters near a dock construction site in the Cross Point area of Lake Texoma, south of Kingston (Fig. 2). Identification of the specimen as *R. harrisii* was made initially via a photograph provided to Brenda Bowling, Texas Parks and Wildlife, Dickinson Marine Laboratory, and later via a physical specimen provided to Dr's. Russell Pfau and Keith Todd, Tarleton State University. Due to the invasive nature of this species, we sought to (1) verify the presence of *R. harrisii* in Lake Texoma, (2) provide a tentative description of the distribution of *R. harrisii* on the Oklahoma side of Lake Texoma, and (3) test various methods for detecting *R. harrisii* that may be used for monitoring or searching inland waters.

Figure 1. Photograph of a Harris mud crab *Rhithropanopeus harrisii* captured from Lake Texoma, Marshall and Bryan Counties, Oklahoma, September 3, 2009. Numbered scale units are cm.

METHODS

Study Sites

Lake Texoma is a 36,000 hectare reservoir on the Oklahoma-Texas border, impounding the Red and Washita Rivers (Fig. 2), and has a drainage area of 101,362 km^2, including 81,999 km^2 in the Red River drainage and 19,363 km^2 in the Washita River drainage (Matthews, Gido, & Gelwick, 2004; Matthews & Marsh-Matthews, 2007). We established seven study sites (and recorded additional sites from which the general public reported specimens of *R. harrisii*) along the longitudinal gradient in which to conduct surveys for *R. harrisii* (Fig. 2), including the site from which the original specimen had been reported.

Survey Methods

We utilized two types of traps, two types of visual surveys, and reports from the general public for capture or detection of *R. harrisii*. Traps included (1) a standard cylindrical minnow trap (funnel trap) 40 cm long x 22 cm diameter, made of welded wire with a 5 mm mesh, and having a 38 mm opening within cones at each end of the trap; and (2) a length of polyvinyl chloride (PVC) pipe, 35 cm long by 50 mm inside diameter, with a cap covering one end of the pipe (under the premise that crabs would inhabit the pipe). Traps were weighted to keep them

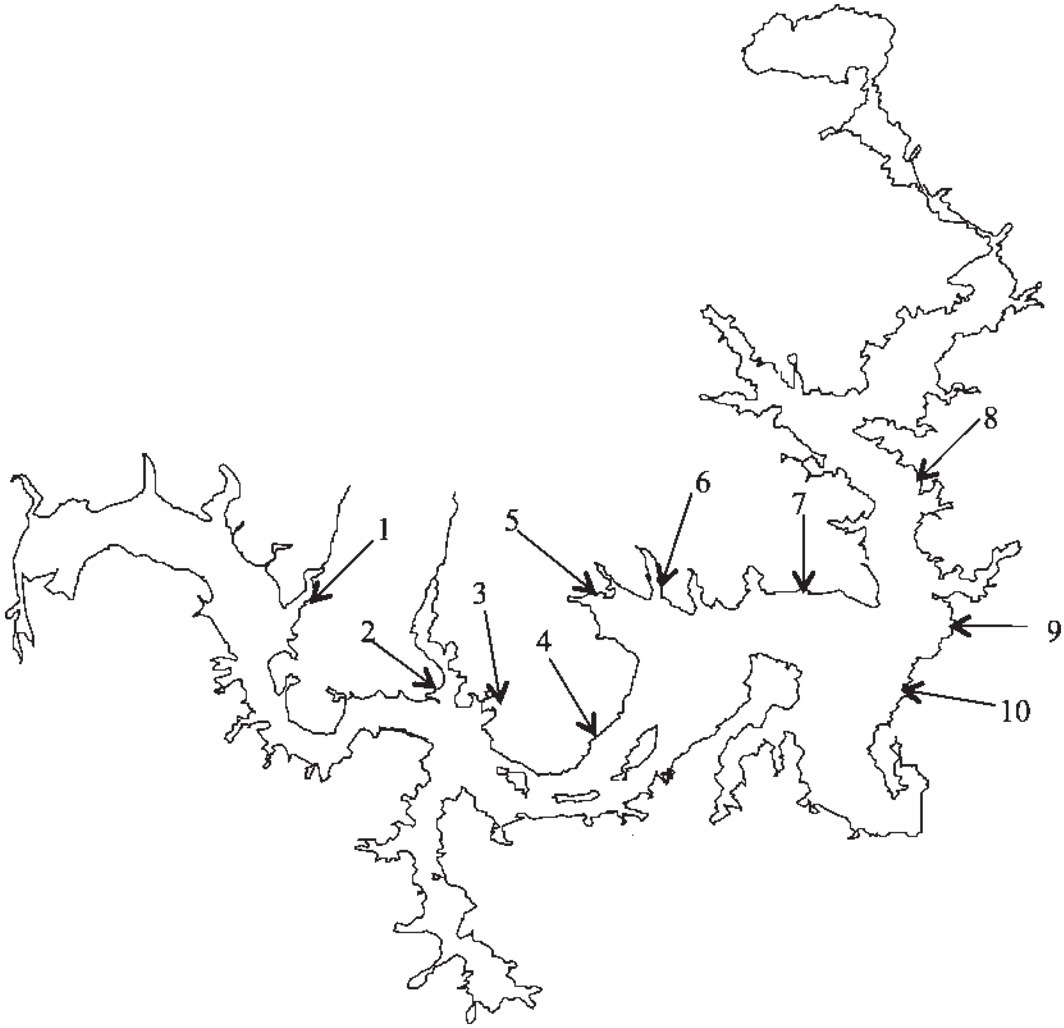

Figure 2. Locations (arrows) in which we have searched for Harris mud crab *Rhithropanopeus harrisii*, and sites from which they have been reported by anglers and other members of the general public, in Lake Texoma, Marshall and Bryan Counties, Oklahoma, during 2008 and 2009. Search methods included trapping and visual encounter surveys. Locations are: (1) Fobb Bottom, (2) Buncombe Creek, (3) Cardinal Cove, (4) Sandy Beach, (5) Cross Point Camp, (6) Caney Creek, (7) McLaughlin Creek, (8) Willow Springs, (9) Platter Flats, and (10) Willafa Woods. *R. Harrisii* was detected at all sites except 1, 4, and 9.

in place, floats were attached via rope for locating and retrieving the traps, bait in the form of dead fish was placed in the funnel traps but not in the pipe traps, and all traps were set in 0.5 – 1.3 m of water along the shorelines. Where substrate variability existed, trap sets were stratified by substrate type, with a portion of them set over fine (silt or sand) and coarse substrates (gravel, cobble, or boulder), respectively. Visual surveys were conducted (1) by snorkeling, and (2) utilizing visual encounter surveys. Snorkeling was conducted by two or more people along shorelines in 0.3 – 1.0 m of water, examining the bottom and overturning rocks and debris in an effort to detect crabs. Visual encounter surveys included two or more people wading along shorelines in 0.1 – 1.0 m of water and picking up rocks or debris and examining the surfaces thereof and substrate beneath.

Table 1. Numbers of Harris mud crabs *Rhithropanopeus harrisii*, organized by locations searched and methods of detection, from 10 sites on Lake Texoma, Marshall and Bryan Counties, Oklahoma, September – November, 2008, and June – September, 2009. Locations correspond to those shown in Figure 2. Detection methods include capture in funnel traps (FT), capture in polyvinyl chloride pipe traps (PT), visual encounter surveys (VE), and reports/specimens provided by the general public (GP). Included are all sites we surveyed, and all sites from which specimens were reported by the general public.

	Detection methods				
Location	FT	PT	VE	GP	Total
Fobb Bottom					
Buncombe Creek				2	2
Cardinal Cove				1	1
Sandy Beach					
Cross Point	1	2	11	1	15
Caney Creek			1	2	3
McLaughlin Creek		1			1
Willow Springs				1	1
Platter Flats					
Willafa Woods				1	1
Total	**1**	**3**	**12**	**7**	**24**

During September – November, 2008, funnel traps, snorkeling, and visual encounter surveys were used at Cross Point and Buncombe Creek sites (Fig. 2). During June – September, 2009, funnel traps and pipe traps were used at all seven sites, whereas snorkeling and visual encounter surveys were used only at the Cross Point and Caney Creek sites (Fig. 2). All crabs captured or detected were returned to the laboratory in the Department of Biological Sciences at Southeastern Oklahoma State University, where they were weighed, measured, and either frozen or placed in isopropyl alcohol.

We made no effort to solicit reports of sightings from the public, but made note of all reports that were submitted. Reports were typically submitted either to the Oklahoma Department of Wildlife Conservation, or to the Department of Biological Sciences at Southeastern Oklahoma State University. When reports were submitted, we noted the location, approximate number seen, and we sought to confirm reports by examining specimens or photographs of specimens.

RESULTS AND DISCUSSION

A total of 24 specimens of *R. harrisii* were detected among all methodologies. During 2008, we trapped 900 trap-nights and captured one specimen of *R. harrisii*, we conducted snorkeling surveys for one person-hour and detected no specimens, and we conducted 20 person-hours of visual encounter surveys (10 at Cross Point and 10 at Buncombe Creek) and detected no specimens (Table 1). During 2009, we trapped 490 trap-nights (70 trap-nights in each of 7 sites) and captured three specimens, we conducted snorkeling surveys for approximately one person-hour at Caney Creek and Cross Point and detected no specimens, and we conducted 20 person-hours of visual encounter surveys (10 hours at Caney Creek and 10 hours at Cross Point) and captured 12 specimens of *R. harrisii* (Table 1).

We are aware of no reports of *R. harrisii* by the public during 2008 except for the initial specimen that prompted this survey. We are aware of seven reports of crabs from the general public during 2009 (Table 1), and verified all but one of these with either a specimen or a photograph of a specimen. In two cases, reports were of several individual specimens from a single location. Among reports made by the public, crabs were found by overturning rocks, attached to debris removed from the lake, and in one case, from the stomach of a blue catfish *Ictalurus furcatus* caught by an angler. Locations of reports made by the public included three sites included in our search efforts, as well as three additional sites (Table 1).

Among all methods of detection, we confirmed the presence of *R. harrisii* at seven locations in Lake Texoma (Table 1, Figure 2). Our trapping efforts were standardized by effort, and we captured or detected crabs at three of seven sites (frequency of occurrence = 43% of sites). Crabs were found at a total of seven of nine sites, including those reported by the public, but visual encounter surveys and public reports did not include equal search effort. *R. harrisii* appear to be present along nearly the entire longitudinal gradient of Lake Texoma Fig. 2), within both the Red and Washita River arms, and it is likely that they are present on the Texas side of the reservoir as well. Our observations are consistent with that reported in the literature with respect to substrate; most crabs were detected on coarse substrates or debris. However, visual encounter surveys do not lend themselves well to fine substrates, and some crabs were captured in traps placed over silt and sand substrates.

Among the various detection methods we employed, visual encounter surveys produced the highest number of crabs (Table 1) with the least amount of effort (fewest person-hours) and expense (e.g., supplies, wages, fuel costs). Snorkeling was not effective for us; however, winds were high at the times of our snorkeling attempts, resulting in rough surface waters and waves in littoral areas that increased turbidity and reduced visibility. We suspect that snorkeling in calm conditions and clear water would result in detection of *R. harrisii*. Among our trapping methods, we captured three crabs in pipe traps and one crab in a funnel trap. Further, pipe traps are cheaper than funnel traps (made from inexpensive material acquired from the hardware store), easy to construct, require no bait, and (in our study) were less likely to be lost due to theft or vandalism. Our sample sizes among the two trap types are low, and additional comparisons are needed to determine the relative efficiency of these two trap types. However, our overall trapping effort was high and our results suggest that visual encounter surveys are the most efficient way to collect specimens. It should be noted that *R. harrisii* exhibit very cryptic coloration and behavior, and are somewhat difficult to detect. The most effective means we found was to pick up rocks and debris and search carefully within small cracks and crevices. Development of a search image and the use of experienced searchers (although it does not take long to develop a search image and gain adequate experience) increases detection rates considerably. Further, our experience suggests that reliance on reports from the public, even when not solicited, can result in numerous sightings and locations of *R. harrisii*, though we suggest that verification of specimens be included in such reports. For example, one report of crabs "all over the campground" was determined to be crayfish.

We captured specimens of *R. harrisii* that ranged from 8.6 – 9.6 mm carapace width (mean = 13.8 mm), including one ovigerous female, and captures spanned much of the reservoir. This suggests that *R. harrisii* is successfully reproducing in Lake Texoma. With these observations, three important questions are apparent: what are the potential impacts, what is the source, and what is the potential for expansion of *R. harrisii*?

Several species of crustaceans in general have been reported to be highly invasive and potentially impactful (Rodriguez &

Suarez, 2001). *R. Harrisii* has been reported to cause fouling problems with water intake pipes in the Caspian Sea (Roche & Torchin, 2007) and in Texas Reservoirs (Perry, 2009; Boyle, 2009). Ecologically, it has been reported to compete with native crabs (Cohen & Carlton, 1995), and possibly compete with, prey upon, or displace native organisms such as crayfish (Perry, 2009), which may play an important role in the diet of fishes. And, while it is not our intention to suggest that introduction of this species may be beneficial in any way, *R. harrisii* may serve as a food source for some species, e.g., some detections described by anglers on Lake Texoma (this study) and in Texas (Boyle, 2009; Boyle et al., 2010) were reported to be from the stomachs of catfish (*Ictalurus* spp.). However, any value as forage would likely be negated if *R. harrisii* displaces native prey species such as crayfish. We are aware of no research that has addressed what physical, ecological, or economic impacts may be incurred by the presence of *R. harrisii* in any inland reservoir.

The spread of *R. harrisii* from its native range in the western Atlantic and Gulf of Mexico to various other parts of the world was likely through ship ballast water and commercial oyster shipments, and it was first documented along the west coast of North America in 1937 (Rodriguez & Suarez, 2001). The first report in any inland reservoir of which we are aware is in Possum Kingdom Reservoir, Texas, in 1998 (Howells, 1998; Boyle, 2009). The method by which this species has spread across Texas is unclear. Howells (2001) described two possible mechanisms by which *R. harrisii* may have been introduced into inland waters: (1) accidental introductions made while stocking marine fish (e.g., striped bass) into freshwaters, and (2) accidental introductions by transport of water via bait buckets or live-wells of fishermen. Once populations were established in one or more reservoirs, reservoir-to-reservoir transfers may have occurred via travel down rivers, bait buckets, live wells, or water transport systems (Boyle, 2009; Boyle et al. 2010). In an effort to address possible sources of introduction and expansion in Texas waters, Boyle (2009; Boyle et al., 2010) tested the plausibility that (1) crabs may have been introduced along with fish stocked from hatcheries (tested by examining hatchery records), (2) crabs may have been bait-bucket or live-well introductions (tested by examining survival rates of crabs placed in buckets over 7-day trial periods), and (3) crabs may move between reservoirs via rivers (tested by searching for evidence of crabs in the Brazos River, which connects two reservoirs in which they occur). Additionally, Boyle (2009; Boyle et al., 2010) conducted genetic analyses of specimens from four reservoirs in an effort to provide insight on the source of introduction. It is important to note that no attempt was made to identify the actual mechanism of introduction in Texas reservoirs, but rather, to examine the plausibility of mechanisms. Boyle (2009; Boyle et al., 2010) concluded that none of these hypotheses could be ruled out; he found hatchery records that show common stocking by some hatcheries among the affected reservoirs, high seven-day survival rates of crabs placed in buckets, and evidence that crabs are present in the Brazos River. Genetic analyses also did not provide insight on the source of introduction. It is plausible that this species invaded Lake Texoma by any of the same potential methods described by Boyle (2009; Boyle et al., 2010), including riverine transport from an upstream reservoir source, as Lake Texoma is down-stream and within the same drainage (Red River) as Lake Nocona (which has confirmed reports of *R. harrisii*).

Based on the rapid movement of *R. harrisii* in Texas, the potential to spread into other waters ostensibly seems high. The adults are euryhaline, with reported salinity tolerances of 0.5 – 41% (Costlow, Bookhout, & Monroe, 1966), although Turoboyski (1973) reported that most adults could not survive for more than two days in fresh water without physiological problems. Minimum estimates of salinity values required for hatchling and larval survival are lower, with reported minimum values ranging from 1 – 4 % ,(Costlow et al., 1966; Turoboyski, 1973; Christiansen & Costlow, 1975). Such a wide range of salinity tolerances suggests that *R. harrisii* exhibits a high level of genetic plasticity, as would be expected of an estuarine species that experiences freshwater and saltwater conditions (Boyle, 2010). Further, the larvae pass through four zoeal stages and a postlarval or megalopal stage that are all planktonic, and exhibit vertical migration (Forward, 2009). Given the relatively euryhaline nature of this species and the ostensible ease at which planktonic larvae or postlarvae could be accidentally taken up and transported, it is plausible that *R. harrisii* could be spread to other waters with acceptable salinity ranges.

We conclude that *R. harrisii* are present and wide-spread in Lake Texoma, although densities appear to be relatively low at this time, and that detections can be made relatively efficiently through the use of visual encounter surveys and reports provided by the general public. The existing literature indicates that the source of introduction of *R. harrisii* into freshwaters in Texas (and thus, Oklahoma) is uncertain, expansion of this species through means such as transport of fish and water or alluvial transport are all plausible, they are euryhaline, and they have planktonic life stages. These factors suggest that continued expansion of *R. harrisii* in Oklahoma and other inland waters is highly plausible.

ACKNOWLEDGEMENTS

We thank the following Southeastern Oklahoma State University students for assisting with field efforts: Raymond Bettinger, Heather Hoedebeck, Adam James, Sara Noel, Chase Philips, Clayton Porter, Lonny Robertson, Chisum Schreibvogel, and Kash Weil, and Jared Wood. We are grateful to those individuals that provided reports of sightings or collections of *R. harrisii*. Discussions with Russell Pfau, Donald Keith, and Terrence Boyle, as well as a review of an early version of this manuscript by James Morel and Mark McKinstry, resulted in the improvement of this manuscript. Funding for this work was provided by the Louis Stokes- Oklahoma Alliance for Minority Participation, the Oklahoma Department of Wildlife Conservation fisheries division, and the Department of Biological Sciences at Southeastern Oklahoma State University.

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Received: September 8, 2010; Accepted January 30, 2011.