Morphometric Analysis of the Harris Mud Crab (*Rhithropanopeus harrisii*) in Lake Texoma

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Abstract: Harris mud crab, *Rhithropanopeus harrisii,* is a small crab native to the brackish waters of the Atlantic coast of North America. Today, *R. harrisii* exists well beyond its native range and in a wide variety of habitats, including freshwater reservoirs. *R. harrisii* was discovered in Lake Texoma in 2008 and is thought to have originated from Texas estuaries. The objectives of this study were to gather and describe the morphometrics of *R. harrisii* from Lake Texoma and document sex ratio, carapace size distributions, and handedness. Individuals were collected from August 2019 to August 2021 from six sampling sites located along the Oklahoma side of Lake Texoma. Various morphometrics were recorded from 1,326 crabs. Most crabs in the study were right-handed and they were smaller than crabs reported from other locations. Small size could be result from stressful conditions or early fatality. While there was no significant difference in average carapace size between males and females, males made up the highest percentage of large size classes. Males were also more numerous in the population and often attained larger claw sizes than the females. This is thought to be beneficial in intraspecific competition for females.

Introduction

Harris mud crab, *Rhithropanopeus harrisi*, is a small decapod crustacean belonging to the family Panopeidae (formally Xanthidae) (Marco-Herrero et al. 2014). Harris mud crabs possess a short abdomen hidden under the thorax and four pairs of walking legs (Ryan 1956). The chelipeds are often curved and unequal (Hegele-Drywa et al. 2014). *R. harrisii* are distinguished by a subquadrate carapace and four pairs of anterolateral teeth (Ryan 1956, Turoboyski 1973).

Harris mud crabs originate from the Atlantic coast of North America, ranging from Miramichi Estuary, Canada, to Veracruz, Mexico (Boyle Jr. et al. 2010). Today, *R. harrisii* occurs far beyond its native range, and is described as one of the most widely distributed brachyuran invaders (Grosholz & Ruiz 1996, Roche & Torchin 2007). The crabs are found in 82 locations worldwide (Fowler et al. 2013), including several US reservoirs throughout Texas and Oklahoma (Boyle Jr. et al. 2010, Patton et al. 2010).

In 2008, Patton et al. (2010) collected 24 crabs from Lake Texoma and documented the furthest inland occurrence of Harris mud crabs to date. Virtually no research was conducted on the Texoma population until Huebner et al. (2021) performed genetic analyses and determined the founding individuals were most likely from Texas estuaries. The purpose of the following project is to describe the morphometrics of this Harris mud crab population in Lake Texoma.

Methods

R. harrisii specimens were collected monthly during the warm seasons and every other month during the cool seasons from August 2019 to August 2021. Six sites were established on the Oklahoma side of Lake Texoma. At each site, two 1m^2 plots were randomly selected within a submerged transect along the shoreline. A 13.5 cm by 18.0 cm scoop was used to dredge the entire benthic area within the plots and the

substrate was washed through sieve buckets having a 0.5 mm mesh bottom. Visual surveys were conducted in addition to dredging if fewer than 10 crabs were found in the plots. Specimens were preserved in 70% ethanol and returned to the laboratory at the University of Central Oklahoma. Water temperature, salinity, and specimen count from each site were recorded.

A stereo microscope was used to determine sex and perform morphometric analyses. The following measurements to the nearest 0.01 mm were taken using a micrometer: carapace length (CL), from between eyes to the posterior margin of the carapace; carapace width (CW), greatest distance across the carapace; claw lengths (LCL, RCL), including the dactyl and propodus; and claw widths (LCW, RCW), left and right respectively. Crabs with unequally sized claws were labeled as "left-handed" or "right-handed," as commonly used in decapod research (Abby-Kalio 2008, Czerniejewski 2009). The data obtained was tested for normality using the Shapiro-Wilk test and then subjected to either the appropriate chi-square or Mann-Whitney tests.

Results and Discussion

A total of 1,326 crabs were collected in 18 sampling trips. Of the crabs analyzed, 420 (31.7%) were female, 524 (39.5%) were male, 341 (25.7%) were immature, and 41 (3.1%) were too damaged to determine sex. Results from a two-proportion z-test indicated that the number of males and females differed from an expected 1:1 (male:female) ratio ($p<0.001$). Male-dominated sex ratios have been observed in other populations of Harris mud crab, including a 1.3:1 in the Dead Vistula (Normant et al. 2004) and 2.4:1 in Vistula Lagoon (Rychter 1999 as cited in Normant et al. 2004).

The range of carapace width was larger in males than in females. The largest male measured 17.85 mm wide, while the largest female was 15.6 mm (Table 1). Although *R. harrisii* are sexually dimorphic and males usually attain larger sizes (Czerniejewski & Rybczyk 2008, Hegele-Drywa et al. 2014), there was no significant difference between the mean size of males and females according to a Mann-Whitney U Test (U = 111,722, p = 0.4455). Average carapace widths were also similar between the sexes when confidence intervals were compared (Fig. 1). To analyze size distribution of males and females, the individual crabs were assigned to 1 mm-wide carapace size classes and compared using chi-square tests. The test results showed multiple size classes with an unequal sex ratio of males and females. The following carapace width (CW) size classes differed significantly from expected (1:1): 6.00-6.99mm CW ($\chi 2 = 6.20$, df = 1, p = 0.0128), 10.00-10.99mm CW ($\chi 2 = 5.26$, df = 1, p = 0.0218), 11.00-11.99mm CW ($\chi 2 = 6.53$, df=1, p = 0.0106), 12.00-12.99mm CW ($\chi 2 = 9.00$, df = 1, p = 0.0028), and 13.00-13.99mm CW (χ 2= 7.14, df = 1, p = 0.70546) (Fig. 2). All size classes with disproportionate sex ratios

Table 1. Mean carapace width, carapace length, and major chela length of the 524 male and 420 female *Rhithropanopeus harrisii* adults from Lake Texoma, Oklahoma.

	Carapace width (mm)		Carapace length (mm)		Major chela length (mm)	
	Range	Mean ± std	Range	Mean ± std	Range	Mean ± std
Males (524)	4.00 - 17.85	7.51 ± 2.60	3.00 - 12.6	5.71 ± 1.90	1.65 - 14.70	5.49 ± 2.44
Females (420)	4.00 - 15.60	7.24 ± 2.16	3.15 - 11.65	5.48 ± 1.53	1.65 - 10.15	4.61 ± 1.47

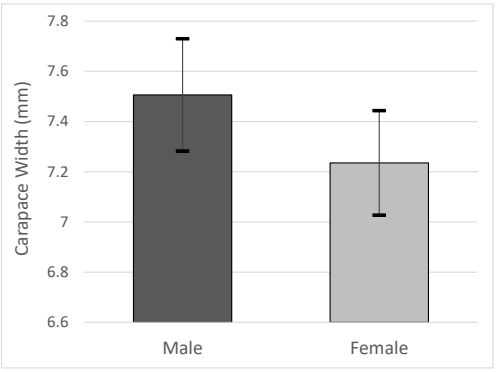

Figure 1. Carapace width (mm) averages for adult male and female *R. harrisii* crabs collected throughout the entire sampling period. Error bars display 95% confidence intervals.

were skewed towards male. Males also made up the majority of several large size classes (>10.00mm) (Fig. 2). As stated earlier, it is common in brachyuran crabs for males to reach larger sizes, and the trend has been documented in *R. harrisii* from Poland (Czerniejewski & Rybczyk 2008). However, there was a notable difference in overall carapace size between the crabs from Lake Texoma and the European crabs. The Lake Texoma crabs were smaller, averaging 12mm narrower than the Polish crabs. Additionally, *R. harrisii* in other locations are often larger than the maximum size (17.85 mm) observed in Lake Texoma (Turoboyski 1973, Normant et al. 2004, Czerniejewski & Rybczyk 2008). For example, Ryan (1956) reported a crab as large as 26.1mm, and Turoboyski (1973) determined the maximum size for the species is 27 mm.

A possible explanation for the reduced body size is the stressful conditions in Lake Texoma. Lake Texoma is a freshwater reservoir with low salinity (<1 PPT) and wide-ranging seasonal changes in water temperature (9-35 °C). Because Harris mud crab is native to brackish coastal waters, these conditions in

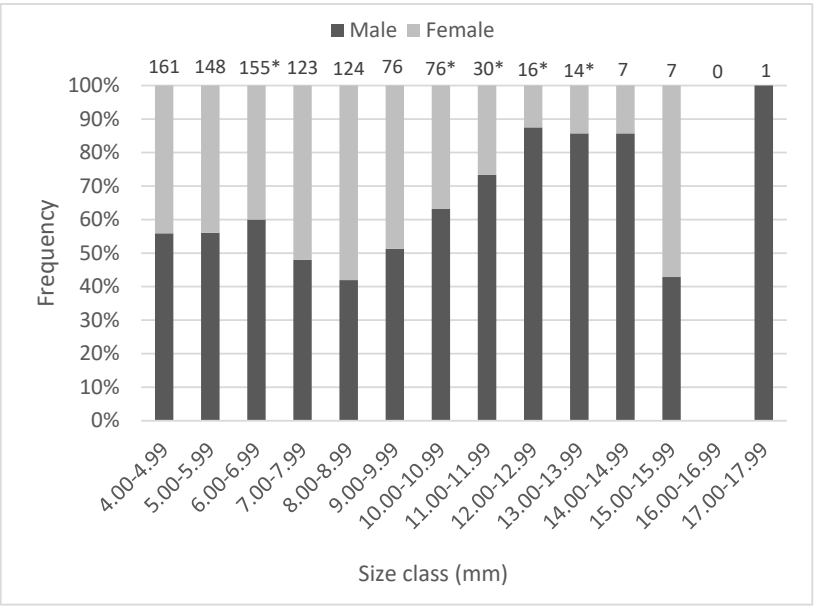

Figure 2. Sex ratio of *R. harrisii* adult male and females by carapace width (mm) size class, sampled from August 2019 to August 2021 from Lake Texoma, Oklahoma. Crabs larger than 4.0mm are considered adults. The sample size is denoted at the top of each class and an asterisk (*) indicates statistical difference from the expected 1:1 (male:female) sex ratio in each size class. Size classes with fewer than 2 observations were omitted from statistical analyses due to small sample sizes.

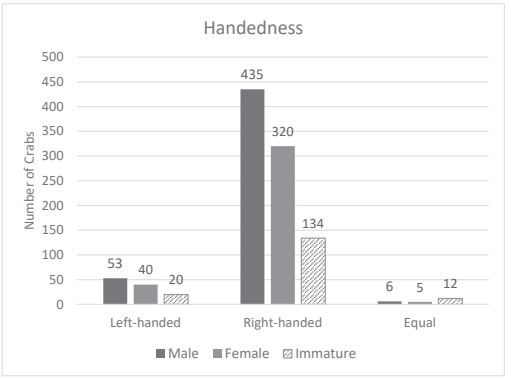

Figure 3. Bar graph showing the number of male, female, and immature *R. harrisii* crabs displaying dominant-right, dominant-left, or equally-sized claws

Lake Texoma likely hinder the growth and development of Harris mud crab. Another factor to consider is fatality. Without knowing the age of the crabs, it is difficult to determine whether the crabs are growing slower than expected or dying before a larger body size is reached. In addition, a constantly fluctuating water level in the reservoir can affect the survival of Harris mud crabs. Two massive fatality events were witnessed as a result of rapidly dropping lake levels leading to hundreds of crabs being stranded and desiccating on the shoreline at the sampling sites. Fatality events likely occur more often than observed, impacting the number of crabs surviving multiple years and attaining larger sizes.

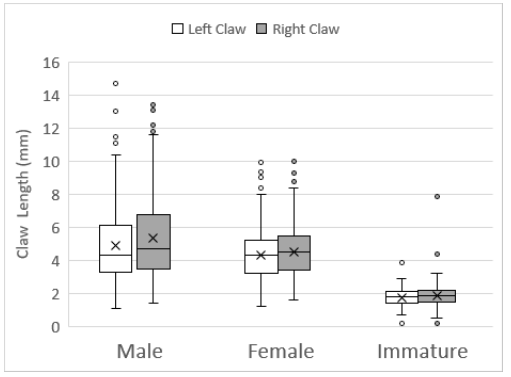

Figure 4. Left and Right claw length (mm) ranges for *R. harrisii* male, female, and immature crabs collected from Lake Texoma, Oklahoma throughout the 2019-2021 sampling period. Bars indicate the five-number summary of the data including the minimum, first quartile, median, third quartile, and maximum. Means are represented with an "x."

Results from a chi-square test show an unequal distribution of claw length ($\chi 2$ = 1329.65, df = 2, $p<0.001$). Heterochely was observed in male, female, and immature crabs (Fig. 3). Approximately 86.73% of crabs were right-handed, 11.02% were left-handed, and 2.24% of crabs were homochelous. These results are consistent with the literature stating Harris mud crabs are right-handed (Hegele-Drywa et al. 2014). When a Mann-Whitney U test was used to compare the dominant claws of adult male and female crabs (>4.0mm), claw lengths differed significantly ($U=61605$, $p<0.001$). Despite majority of crabs having a dominant right claw, the largest claw was a male's left claw measuring 14.7mm long (Table 1). However, this measurement was an outlier far beyond the upper quartile range (Fig. 4). Lastly, a positive linear relationship between major chela length (mm) and carapace width (mm) was observed in males, females, and immature crabs (Fig. 5). Males displayed a higher rate of change as major chela length (mm) and carapace width (mm) increased (Fig. 5). This could be because larger claws are advantageous for males in intraspecific competition for females (Jesse 2001, Czerniejewski & Rybczyk 2008).

Acknowledgments

We thank the University of Central Oklahoma Office of Research and Sponsored Programs for supplies and travel support. We also thank the University of Oklahoma Biological Station, U.S. Army Corps of Engineers, and Texoma State Park for allowing access and permission to collect. Dr. Wayne Lord and Dr. Chad King reviewed earlier drafts of this manuscript.

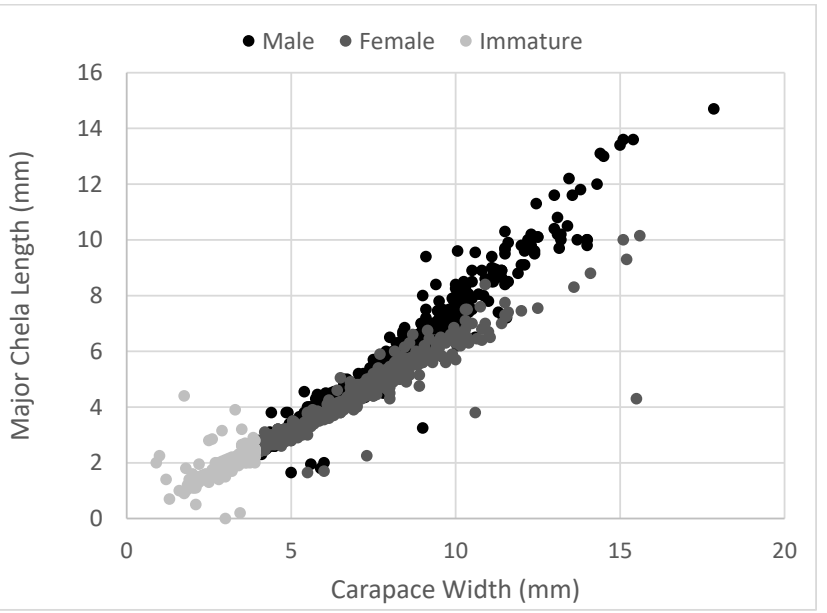

Figure 5. Carapace width (mm) versus major chela length (mm) for male, female, and immature *R. harrisii* crabs collected from Lake Texoma, Oklahoma during the 2019-2021 sampling period.

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Submitted August 15, 2022 Accepted October 22, 2022