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Research Article

Population Biology of *Manningis arabicum* (Jones & Clayton, 1983; Decapoda: Brachyura, Ocypodidae) from Umm SA Mangrove Swamps, Qatar

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Abstract

Population parameters including body size, size frequency distribution, reproductive period and sex ratio of *Manningis arabicum* were studied in samples collected from intertidal zone of Umm SA mangrove. Sampling was carried out during the period October 2013 to September 2014. Carapace width data indicated that the recruitment of this species was continuous throughout the year. Asymptotic length (L_∞) of the von Bertalanffy growth function was 12.08 mm and the growth coefficient (K) was 2 year^{-1}. Carapace width-individual weight measurements showed males heavier than females. The smallest sized crab observed bearing eggs was 3.8 mm in CW during October.

Keywords: Crab; Length-weight relationship; Mangrove swamp; *Manningis arabicum*; Population structure, Qatar

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Introduction

Brachyuran crabs are a key component of the macrofauna inhabiting tropical and subtropical intertidal zones, including the Red Sea and Arabian Gulf. The importance of brachyuran crabs lies in energy transfer, as they support a large number of invertebrates, fish, and birds [1,2]. One of such crabs is *Manningis arabicum*, an endemic species from the Arabian Gulf, recorded only from coastal habitats of Qatar, Saudi Arabia, and Kuwait [3]. *M. arabicum* are small deposit feeders found on sandy to muddy shores, salt marshes, and mangrove swamps. They typically dwell in burrows located between mean high and mean low tide, where they tend to hide during the day [3,4].

Studies involving brachyuran crabs from the Arabian Gulf region have mostly focused on taxonomy. Early studies from the Arabian Gulf were reported by Stephensen [5] and Tirmizi [6]. Jones & Clayton [3], reported 17 species of tropical burrowing crabs along the coast of Kuwait and Al-Khayat & Jones [7], reported on new Brachyurans from the genera *Manningis* and *Leptochryseus*. Crabs were of the families Grapsidae and Ocypodidae, including 2 new species of the genera *Cleistostoma* and *Paracleistostoma*.

Although taxonomic studies have demonstrated the high diversity of brachyuran crabs along the coasts of the Arabian Gulf, few attempts have been made to examine the dynamics of their population. Population biology studies are of immediate importance, as brachyurian crabs in the Arabian Gulf inhabit mangrove swamps and intertidal mud flats, largely threatened environments [8]. An understanding of trends of crab populations in such environments may serve well in using *M. arabicum* as indicators of habitat health.

Of the few studies of Gulf of Arabia crab biology, Jones & Clayton [3], examined ecological relations among crabs of the genera *Cleistostoma* and *Paracleistostoma* on Kuwait mudflats. Clayton & Al-Kindi [9], studied the population structure and dynamics of *Scopimera crabricauda* in Omani estuaries. Similarly, Snowden et al. [10], studied the population biology of *Ilyoplax stevensi*, also on mudflats in Kuwait. Our research will provide additional information on Brachiuran crab population biology for environmental conservation efforts.

This study is the first for characterizing the population biology of *M. arabicum* from Qatar mangroves. Analyses of selected biological aspects of the crab *M. arabicum* were evaluated to better understand the interplay between this species and its environment. Such understanding may assist in developing future indices of habitat health using this species as an indicator.

Materials and Methods

Monthly random samples of *M. arabicum* were collected from intertidal areas of Umm SA mangrove swamps between October 2013 and September 2014 (Figure 1). Swamps located in the study area are predominated by *Avicennia marina* (grey mangrove) and secondarily by *Rhizophora mucronate*, which provide nursery ground and cover for a vast array of fish, sea snakes, turtles, and birds.

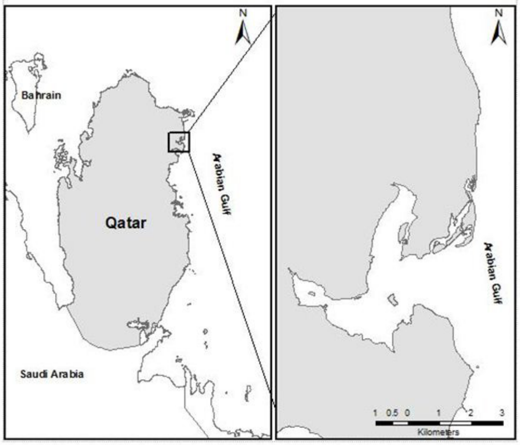

Figure 1: Sampling location in the Umm SA mangrove swamps, Qatar.

Air and surface water temperatures were recorded monthly using a mercury bulb thermometer. Salinity was determined using a portable salinometer and pH with a portable meter. Samples of the top 5 cm of sediment were collected for analysis of grain size, organic matter, and moisture content. Grain size was determined according to Buchanan [11]. Organic matter content was determined measuring the weight loss after 6hrs at 450°C.

Crabs were collected during low tide from their burrows using a shovel. Crabs were sexed from their abdominal morphology and number of pleopods. Egg bearing females were recorded. Carapace width to the nearest 0.05 mm was measured with a Vernier caliper (CW=greatest Cephalothorax Width), and individual weights recorded to the nearest 0.001g.

Descriptive data on abundance and size by season and gender were recorded to examine crab population size structure. Sex ratios and proportion of egg-bearing females were determined to infer reproductive season and potential.

Carapace width data was grouped into 5 mm classes for estimation of population growth parameters. The von Bertalanffy Growth Function (VBGF) was used to describe growth. Growth parameters were estimated using FiSAT II [12] and ELEFAN-1 [13]. Estimated parameters were the asymptotic length (L_∞) and the growth coefficient (K), the latter estimated using the K-scan routine to determine reliable estimate of the K value. The estimates of L_∞ and K were used to estimate the φ› growth performance index [14] of *M. arabicum*, based on the equation $\varphi› = 2 \log_{10} L_\infty + \log_{10} K$.

Crab carapace Width-Individual Weight Relationships (W-W) were calculated to describe body allometry as an indicator of population condition [15-18]. Estimates of W-W were obtained by gender and season. To assess allometry, the linear form of the length-weight relation power function was used [19-21]. The power function is of the form

$$W = a\,L^b \qquad (1)$$

Where is the intercept parameter, or shape coefficient, and b the allometric parameter. The linearized equation of (1) is of the form

$$\ln(W) = \ln(a) + b*\ln(L) \qquad (2)$$

Parameter estimates and fit of (2) were done using ordinary linear least square regression. The parameter W in equation (2) for this study was the individual crab weight (g), and the parameter L the total carapace width (mm).

Results

Physical data

All physical data followed seasonal norms during the period of sampling. Air temperature values varied from 23 to 43°C during the study period (Figure 2). The highest air temperature was recorded in July (43°C) and the lowest in January (23°C). Surface water temperature reached its minimum in January (18°C) and February (19°C) and its maximum in August (33°C). Salinity regimes followed the same as that for temperature. The maximum surface salinity was in July and August (between 44.1 and 44.51‰) and the minimum between November and February (between 41.1‰ and 41.5‰).

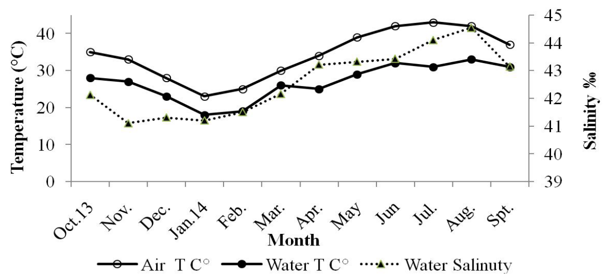

Figure 2: Air and surface sea water temperatures (ºC) and salinity (‰) at Umm SA (October 2013 to September 2014).

Substrate at the collection site comprised mostly of clay (45.14 percent±0.4 SEM), followed by silt (37.36 percent±0.4 SEM) and sand (17.50 percent±0.4 SEM), with a mean grain size of 0.11 mm±0.01 SEM. Mean organic matter was at 3.71 percent±0.43 SEM, pH at 7.53±0.12 SEM, and moisture at 25.88 g±1.05 SEM.

Population structure

Seven hundred and forty-five *M. arabicum* were collected, of which 367 were males (49.33%), 190 non-ovigerous females (25.5%), and 188 (25.2%) ovigerous females. The highest value recorded was 53 individuals/m^{-2}, in May at the mid intertidal zone. The lowest value was during December and January, with 20 and 15 individuals/m^{-2}, respectively (Figure 3).

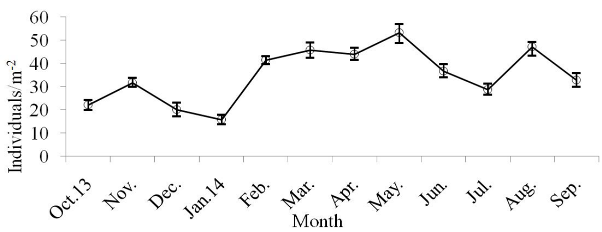

Figure 3: Monthly average of population abundance/m^{-2}, for *M. arabicum* collected from Umm SA, October 2013-December 2014. Vertical bars are standard error of the mean.

Carapace width varied from 3.2 to 11.5 mm for males and from 3.8 to 11.7 mm for females. Mean size of females (8.4±0.08 mm) was not significantly different from that of males (7.8±0.09 mm; t-test, $p>0.05$). The size classes of 9.0 to 9.5 mm and 9.5 to 10.0 mm had the largest numbers of individuals for males and females, respectively. Most of the ovigerous individuals were between 3.8 and 11.7 mm CW (Figure 4).

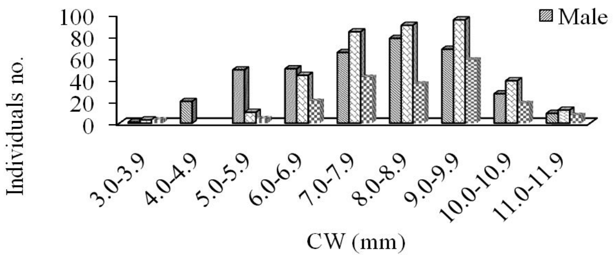

Figure 4: Carapace width frequency distributions for male and female *Manningis arabicum* collected from Umm SA mangrove swamp between October 2013 and September 2014.

Population growth

M. arabicum VBGF asymptotic length was 12.08 mm and the growth coefficient was 2 year^{-1} (Figure 5). The observed maximum length was 11.7 mm and the predicted maximum length was 11.86 mm. The 95 percent confidence interval of the predicted maximum length ranged between 11.38 and 12.34 mm. Growth performance index was estimated at 2.465.

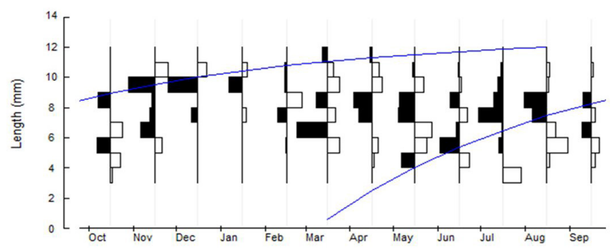

Figure 5: Restructured length-frequency (W-W) distribution with superimposed growth curves for *Manningis arabicum* collected from Umm SA mangrove swamp between October 2013 and September 2014.

Carapace width-individual weight relationships

The relationship between carapace width and body weight for *M. arabicum* showed both, males and females with negative allometric growth. Females showed to have a higher negative allometric growth than males (Table 1).

Comparisons of the weight loss showed variation according to seasons (Table 2). Males of *M. arabicum* for a fixed width were heavier than females in the fall and winter. Both males and females lost weight during autumn and spring and gained weight during winter and summer. Males added 42 percent weight from fall to winter, dropped 36 percent from winter to spring and dropped 17 percent from spring to summer. Similarly, females added 30 percent weight from fall to winter, dropped 16 percent from winter to spring and dropped 6 percent from spring to summer (Table 2).

	N	R	a	SEM_a	b	SEM_b	p-Value a	p-Value b
				Males				
Fall	71	0.337	2.94	0.388	-1.337	0.449	0.231	0.004
Winter	81	0.678	<0.01	0.939	2.446	0.299	<0.001	<0.001
Spring	91	0.969	<0.01	0.245	2.992	0.081	<0.001	<0.001
Summer	124	0.8	<0.01	0.498	2.457	0.167	<0.001	<0.001
				Females				
Fall	82	0.163	0.45	0.531	-0.85	0.575	0.133	0.143
Winter	82	0.758	<0.00	0.71	2.304	0.222	<0.001	<0.001
Spring	104	0.93	<0.00	0.339	2.819	0.11	<0.001	<0.001
Summer	110	0.67	<0.00	0.688	2.084	0.222	<0.001	<0.001

Table 1: Carapace width-individual weight relationships by season for males and females of *Manningis arabicum* collected from Umm SA mangrove swamp collected between October 2013 and September 2014.

Season Mean Water Temperature °C±SE	N	Mean Weight Males	SEM	N	Mean Weight Females	SEM
Fall 28.67±1.2	71	0.268	0.019	82	0.226	0.01
Winter 20.00±1.2	81	0.379	0.018	82	0.293	0.012
Spring 26.67±1.2	91	0.242	0.017	104	0.245	0.013
Summer 32.00±0.5	124	0.201	0.014	110	0.231	0.012

Table 2: Seasonal changes in mean weight for males and females of *Manningis arabicum* collected from Umm SA mangrove swamp between October 2013 and September 2014.

Sex ratio

Sex ratios by sampling months were examined for individuals ranging from 3.0 to 11.7 mm carapace width. Chi-squared tested ratios showed a significant and highly significant deviation from 1:1 favoring males in October and females in November, respectively. Sex ratios by carapace width ranging over all month were also examined. Chi-squared tested ratios showed a skew toward males for widths between 5.5 and 6.0, and 6.5 and 7.0 mm. Females were more abundant for widths between 6.0 and 6.5, 7.0 and 7.5, and 9.5 and 10.0 mm. All other size ranges showed non-significant deviations from 1:1 ratio (Table 3).

Reproductive season

The smallest female crab bearing eggs was found at 3.8 mm and the largest at 11.7 mm carapace width. The highest percentage of ovigerous females was at 9.5 mm. Ovigerous females occurred in the population mostly from October 2013 to May 2014. Major egg-bearing peaks were in December and January, the period of high breeding activity (100 percent), and the lowest, still above zero, in May, with 10.8 percent egg-bearing females (Figure 6).

Months	Males	Females	Total	Males %	Females %	Sex Ratio	Chi Square
October	38	23	61	62.3	37.7	1.0:0.61	3.69*
November	33	59	92	35.9	64.1	1.0:1.79	7.35*
December	30	32	62	48.4	51.6	1.0:1.07	0.06
January	21	20	41	51.2	48.8	1.0:0.95	0.02
February	30	30	60	50	50	1.0:1.0	0
March	29	32	61	47.5	52.5	1.0:1.10	0.15
April	33	35	68	48.5	51.5	1.0:1.06	0.06
May	29	37	66	43.9	56.1	1.0:1.28	0.97
June	33	29	62	53.2	46.8	1.0:0.88	0.25
July	27	26	53	50.9	49.1	1.0:0.96	0.02
August	35	28	63	55.6	44.4	1.0:0.8	0.78
September	29	27	56	51.7	48.2	1.0:0.93	0.07
Total	367	378	745	49.3	50.7	1.0:1.02	13.42

A: Sex ratio by month

Note: Test of heterogeneity: df (df=1, P<0.05)

Sum of 12 Chi-squares 11:13.42

Pooled Chi-square: 0.16

Size-Group (mm)	Males	Females	Total	Males %	Females %	Sex Ratio (M:F)	Chi Square (χ^2)
3.0-0.5	1	0	1	100			
3.5-4.0	0	3	3	100			
4.0-4.5	8	0	8	100			
4.5-5.0	12	0	12	100			
5.0-5.5	15	0	15	100			
5.5-6.0	34	10	44	77.27	22.73	1:0.29	13.09*
6.0-6.5	12	25	37	32.43	67.57	1:2.08	4.57*
6.5-7.0	38	20	58	65.52	34.48	1:0.53	5.59*
7.0-7.5	25	43	68	36.76	63.24	1:1.72	4.76*
7.5-8.0	40	41	81	49.38	50.62	1:1.03	0.03
8.0-8.5	35	47	82	42.70	57..30	1:1.34	1.75
8.5-9.0	43	43	86	50.00	50.00	1:1.00	0.00
9.0-9.5	50	38	88	56.80	43.20	1:0.76	1.64
9.5-10.0	18	57	75	24.00	76.00	1:3.17	20.28*
10-10.5	16	16	32	50.00	50.00	1:1.14	0.00
10.5-11	11	23	34	32.35	67.75	1:1.09	1.16
11-11.5	6	9	15	40.00	60.00	1:1.26	9.69*
11.5-12	3	3	6	50	50	1:1.00	0
Total	367	378	745	49.26	50.74		62.56

B: Sex ratio by carapace width.

Table 3: Sex ratio of *M. arabicum* collected from Umm SA mangrove swamp between October 2013 and September 2014.

Note: Test of heterogeneity: df (df=1, P<0.05)

Sum of 14 Chi-squares 13:62.56

Pooled Chi-square: 0.16

*asterisks indicate significant differences (p<0.05; χ^2 test) from the 1:1 ratio.

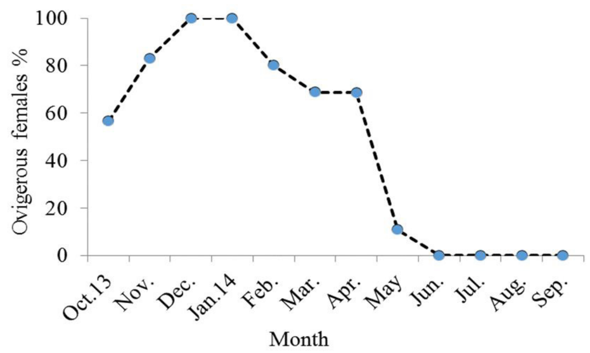

Figure 6: Percentage of ovigerous females *M. arabicum* collected from Umm SA mangrove swamp between October 2013 and September 2014.

Discussion

Even though the environment was relatively constant in term of the variables measured in this study, crab population characteristics varied more widely, enabling resource managers and conservationist to hone and improve conservation measures by including crab populations when implementing habitat protection regulations.

Size frequency distribution is usually a population trait that varies throughout the year, due to varied reproduction times and wide-ranging larvae recruitment rates [22]. Size frequency distribution of *M. arabicum*, however, suggested that the recruitment was continuous throughout the year, not showing any intra-annual patterns. Recruitment for this species favored males.

Estimates of crab growth rates and performance from this study provide a baseline for future studies on growth trends for this species. Examples of such studies include assessing mud crab growth as indicators of habitat health or the effectiveness of mangrove rehabilitation programs [23]. Growth patterns from carapace width-body weight relationships, on the other hand, was consistent with other Brachyurans, according to Hartnoll [24-26]. In our study, the values for the exponent b, the allometric parameter, ranged from 2.08 to 2.30, which suggests negative allometric growth (organism becomes slenderer as it becomes longer). Moreover, male allometric parameter was estimated to be higher than that of females, indicating that the overall negative allometric growth for the population is even more pronounced for the latter. Similar results were found for crabs of the species *Uca rapax* in Brazil, indicating a general trend toward negative allometry for Ocypodidae crabs [27].

Seasonally, there was also a difference in the allometric parameter by gender of crabs examined in this study. Inconclusive data was observed for body allometry in the fall. The most pronounced difference was observed in spring for both genders, with the highest value for that parameter. Various factors may be responsible for observed differences, such as species density, shore level, temperature, salinity, food quantity and quality, sex, time of year and stage of maturity [28,29]. We surmise that the differences were mostly as a consequence of weight gains during the spring, potentially due to higher food availability from the higher rains during that season. Such data should be considered, when implementing conservation practices based on time-of-year.

Crab weight measurements indicated that males were heavier than females during the fall and summer, with females being heavier in the winter and spring. This should be expected, as *M. arabicum* does not show sexual dimorphism in chelae size. As *M. arabicum* have similar sized chelae, the observed differences could be due to differences in carapace density. Seasonal carapace weight differences were also observed, showing higher values for the spring. This could be explained by a loss of water starting in April and extending through October, as water salinity during this period was highest. Salinity values were below 20‰ during the winter and mid spring, rising to as high as 57‰ in the summer and fall. Water losses from high salinity waters has also been observed elsewhere [30].

Sex ratio of brachyuran crabs is usually close to unity [25,31,32], with some variations according to populations and year within the same population being reported by Sastry [33], Johnson [34], and Varisco & Vinuesa [35]. Sex ratios close to unity in ocypodids have also been reported by Simons and Jones [36] and Snowden et al, [10]. Sex ratios for crabs in this study favored males in October and females in November. Ratios by carapace width favored males over smaller widths and females over larger widths. As there is no evidence that these species change sex, behavioral differences related to breeding might be one explanation for the observed results. It is possible that either non-ovigerous females remain at deeper levels in burrows outside the breeding season, or males remain on the surface to exhibit territorial displays [37]. Ovigerous females may also have spent prolonged periods underground and, when on the surface, foraged closer to water sources, creating spatial separation from foraging males [38].

Most ovigerous females from this study were observed from October to April, with peaks in December and January. No ovigerous females were observed from June to September. Studies on the reproductive cycles of family Ocypodidae are very limited in the Gulf region. Apel [39], reported that the longest breeding period was of 10 months for *M. depressus* in Saudi Arabia.

The majority of tropical species tend to breed continuously throughout the year or have prolonged breeding seasons compared to species at higher latitudes [40], with some seasonality present in subtropical regions [41]. As latitude increases, breeding seasons tend to match periods of higher water temperature [33,42-44], with breeding starting later in the season [45]. Although temperature is most likely the controlling factor [46-49], showed that for species which spawn throughout the year, low breeding coincides with the SW monsoon season, possibly due to a low in food availability for crab larvae during that period. Similarly, Pillay & Nair in a study of the breeding biology of brachyuran crabs from the southwest coast of India, found that availability of food for the young during the planktotrophic life was a critical cue for breeding season timing, most likely determining the length of the planktonic phase and, therefore, risk of predation [50-53]. No information is available on size at sexual maturity for males *M. arabicum*. It is not unreasonable to assume that the size at first maturity, as for females in this study, occurs when individuals are small.

This study constitutes the first account on the population biology of *M. arabicum*. We provide baseline data to support and further conservation efforts of coastal and estuarine habitats, one of the most threatened, yet ecologically and economically important ecosystems. The data from this study may complement studies using mud crab density as indicators of habitat health [23], by offering data on growth and reproduction, as these latter parameters may more closely indicate habitat health than single estimates of number of individuals. Our information, thus, may be preferred for the often multidisciplinary and multifaceted studies on mangrove restoration and preservation [54].

Conclusion

To further understand the implications of human alterations to mangrove ecosystems, extending investigations beyond assessment of single population parameters may be necessary. Studies on the interactions of *M. arabicum* with other prey and predator species may be needed for a better understanding of the various ecological linkages supporting large-scale conservation of key ecosystems, such as the one from this study.

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