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Sexual Differences in Foraging Behavior of Fiddler Crab, *Uca sindensis* (Decapoda: Ocypodidae)

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Abstract

Fiddler crab females have two small feeding claws while males have only one; the other is enlarged and used as a weapon as well as a mate attraction signal. The study was conducted on the small intertidal fiddler crab *Uca sindensis* in the Abi estuary near Bandar Abbas on the Persian Gulf. Data were collected from September 2007 to August 2008 in order to cover a wide range of ecological conditions experienced by these crabs over the duration of a year. We considered whether males *Uca sindensis* have behaviorally or morphologically compensated for the loss of one feeding claw. Therefore we measured the sex ratio of surface-active crabs; the size of the feeding claws the amount of food processed and the feeding effort (male and female). We showed that males scoop up handfuls of sediment at approximately half the rate of females, but spend more time feeding than do females (70.41%). Males are slightly larger than females, but the relationship of feeding claw to carapace size is not linear: small females have relatively large feeding claws for their size, while large males have relatively large feeding claws for their size. Males and females process equivalent amounts of food on a daily basis. In order to compensate for the loss of one feeding claw, males need to spend a greater amount of time feeding.

Keywords*: Uca sindensis, Foraging behavior, Fiddler crab, Persian Gulf*

1. Introduction

Sexual dimorphism is a common phenomenon in the animal kingdom. Males may be brightly colored while females are dull (e.g. bird, Butcher 1984; Slagsvold, 2000). Males may be smaller (e.g. spiders, Elgar, 1991) or larger (e.g. most birds, reptiles and mammals, Abouheif and Fairbairn, 1997; Andersson 1994; Blanckenhorn, 2005; Dubey et al., 2009) than females or may possess exaggerated appendages that are absent in females (e.g. stag beetle, Armin, 2006; Brittany et al., 2008). There are many studies examining sexual dimorphisms in terms of sexual selection and reproductive fitness, but far fewer have examined the effect of sexually selected dimorphisms on the non-reproductive aspects of animal life, for example, its effect on foraging behavior and efficiency. An extreme case of a sexually selected dimorphism affecting feeding is found in the fiddler crab. These animals feed on algae, bacteria and decaying plant and animal matter in the mud surrounding their burrows (Caravello and Cameron, 1987; Teal, 1958). They use their feeding claws to scoop up a small amount of sediment and put it into their mouth (Icely and Jones 1978; Miller, 1961; Ono, 1965; Yamaguchi, 2000). Females have two small

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feeding claws that they use in alternation, scooping sediment into their mouth at a rapid rate (Crane, 1975). Males, however, have only one feeding claw. The other has been greatly enlarged into a sexually selected 'major claw' that functions in combat with other males and is waved to attract females for mating. The loss of a feeding claw must have a profound effect on the feeding behavior of males and on their feeding efficiency. In other fiddler crab species, males can partly compensate for the loss of a feeding claw.

In this study, we examined foraging behavior in a species of fiddler crab, *Uca sindensis*, in order to determine whether males have behaviorally or morphologically compensated for the loss of one feeding claw. We investigated whether males and females differed in the amount of time they spent feeding; the rate at which they collected food (per feeding claw); the total amount of food processed in a day and the relative size of the feeding claws of males and females. To detect seasonal differences in feeding behavior, the study was conducted over both the breeding and non-breeding seasons.

2. Materials and Methods

2.1. Study Area

The study was conducted on the small intertidal fiddler crab *Uca sindensis* in the Abi estuary (27º11'N 56º24'E) near Bandar Abbas on the Persian Gulf (Fig. 1). Data were collected from September 2007 to August 2008 in order to cover a wide range of ecological conditions experienced by these crabs over the duration of a year.

2.2. Sex Ratio of Feeding Crabs

In order to determine the relative ratio of surface-active, feeding males to females, demarcated 108 plots (50 × 50cm) randomly throughout the 1000 m^2 study site (Fig. 2). For each plot, were counted the number of surface-active males and females that were feeding. The reading was taken three times during the day: at one hour before the lowest tide level; at the time of the lowest tide level; and at one hour after the lowest tide level. The data were collected over the 14 day activity cycle of the species and at different times of the year (two days per month for 12 months). The air temperature was measured daily at a point 30 to 40 Cm above the surface of the study site.

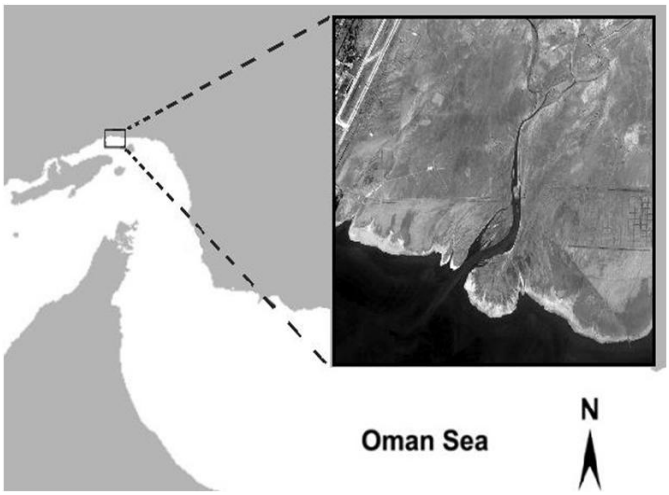

Fig. 1: Abi estuary located on south of Bandar Abbas (27º 11' N and 56º 24' E).

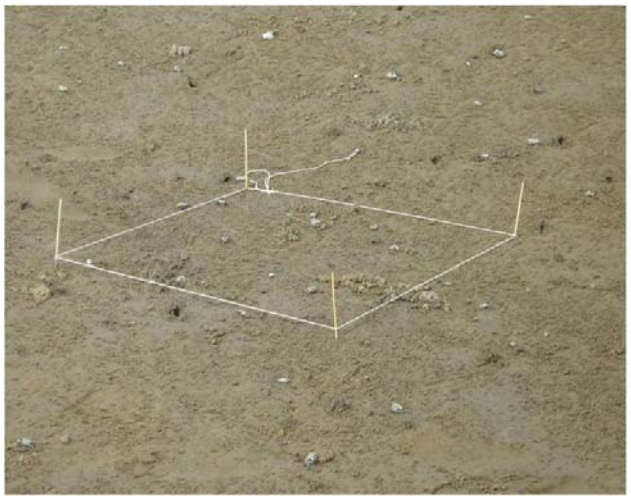

Fig. 2: Plot used to determine the sex ratio of feeding fiddler crabs (50 × 50 Cm).

2.3. Feeding Rate

Feeding rate of males and females measured by counting the number of times the feeding claw (males) or claws (females) were lifted to the mouth in a 1 min interval (Figs. 3 and 4). For this, crabs

selected throughout the study site randomly and collected the data over 20 days (n = 84 of each sex). The temperature of the air was measured daily at a point 30 to 40 Cm above the surface of the study site.

Fig. 3: Male of *Uca sindensis*

Fig. 4: Female of *Uca sindensis.*

2.4. Total Feeding Effort

At one hour before the tide covered the mudflats, all of the feeding pellets that a crab had produced over the duration of the day were collected (n = 50 males and 50 females). To ensure that only the pellets from the focal crab were collected, the burrows of the surrounding crabs were blocked to prevent them from emerging and feeding in the area (Figs. 5, 6 and 7). The pellets were then heated at 500 °C for 24 hr (Valiela et al., 1974) and their dry mass recorded. This measure of feeding effort accommodates breaks in feeding behavior over the day.

Fig. 5: Feeding pellets around the burrow.

Fig. 6: The feeding pellets mixed between neighbouring burrows.

Fig. 7: Method of blocking the burrows of the surrounding crabs in order to collect the feeding pellets of the target crab.

2.5. Feeding Claw Size

A total of 68 males and 116 females were randomly caught and measured (Fig. 8): carapace width and the length of the feeding claws (dactyl length) using vernier calipers (to nearest 0.01mm).

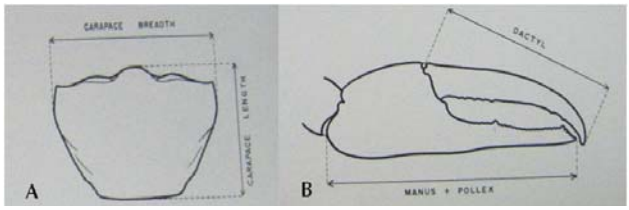

Fig. 8: Measurment of the carapace width (A) and dactyl length (B)

3. Results

3.1. Sex Ratio of Feeding Crabs

There was great variation in the number of males and females foraging at different times of the year; at different times of the 14 day activity cycle and at different times of the day (relative to the low tide). However, males were always feeding in greater numbers than females. Of the 1531 feeding crabs monitored, 70.41% were males.

Both sexes were more likely to feed in before lowest tide level. Feeding males were present in greatest numbers before the lowest tide level (x = 5.12 ± 2.93, n = 554) with fewer present at the lowest tide level (x = 3.68 ± 2.66, n = 398) and least after the lowest tide level (x = 1.16 ± 1.25, n = 126). The same pattern holds for females: before the lowest tide level: (x = 2.26 ± 1.46, n = 248); at the lowest tide level: x = 1.44 ± 1.51, n = 156) and after the lowest tide level: (x = 0.45 ±0.74, n = 49). Although there were always more males than females feeding (F = 113.30; P <0.001, n = 324), the relative proportion of males to females remained relatively constant throughout the day (Mean ± SD; n= number of individuals).

The number of foraging crabs varied over the year. The ratio of feeding males to females was far more pronounced during the breeding season (late February – early September). The ratio of males to females was 0.76 during the breeding season, but dropped to 0.57 out of the breeding season.

Temperature also had a significant effect on the number of crabs feeding. More crabs were present when the temperatures were higher: rP = 0.514, P < 0.001, n = 324. Figure 9 shows the effect of temperature on the number of feeding crabs. The feeding rates of both sexes were affected by temperature (males: rP = 0.609, P < 0.001; females:rP = 0.198, P < 0.001, n = 324), but male feeding were more closely correlated with temperature than females, especially at higher temperatures.

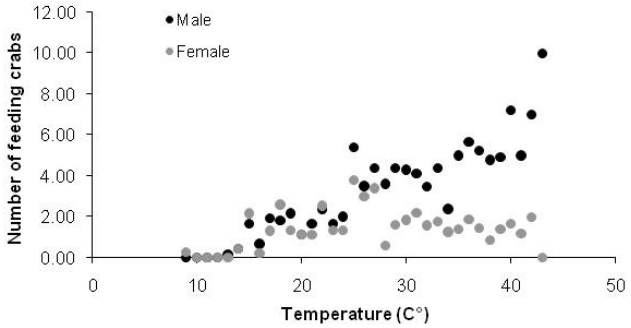

Fig. 9: The effect of temperature on the number of crabs feeding at different times of the year.

3.2. Feeding Rate

The rate at which crabs delivered food to their mouthparts differed significantly between the sexes. Males fed at about half the rate of females (males = 66.26 ± 22.9 scoops per minute, n = 84; females = 129.98 ± 47.56 scoops per minute, n = 84, t = -21.80, P<0.001)(Mean ± SD). This result is clearly due to the fact that females have two feeding claws while males have only one. Temperature had a profound effect on feeding rate, with both males and females feeding faster at higher temperatures (males: rP = 0.89, P < 0.001, n = 84; females: rP = 0.94, P < 0.001, n = 84) (Fig. 10).

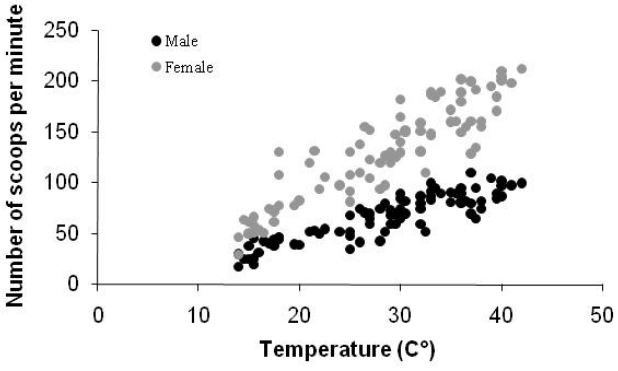

Fig.10: Relationship between feeding rate and temperature.

3.3. Total Feeding Effort

Males produced, on average, 49.1 ± 24.45g dry mass of feeding pellets over the duration of a single day. In contrast, females produced, on average, 31.05 ± 11.05g dry mass of feeding pellets over a single day (Mean ± SD). This difference is significant ($t = 6.86$, $P < 0.001$, $n = 50$). Larger crabs produced a greater mass of feeding pellets (Fig. 11).

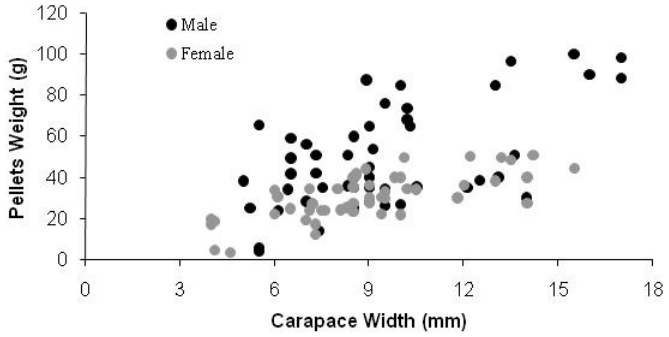

Fig.11: Total dry weight (g) of sand pellets by male and female carapace widths.

3.4. Feeding Claw Size

Males have feeding claws that are, on average, 3.76 ± 1.54 mm long ($n = 68$) and females have feeding claws that are 3.27 ± 1.17 mm long ($n = 116$) (Mean ± SD). Males and females have different relationships between the size of the feeding claw and the size of the crab (ANCOVA Interaction: $F = 20.539$, $P < 0.001$). At carapace widths smaller than 10 mm, females have larger feeding claws for their body size than do males. In larger crabs (carapace widths over 10 mm), males have larger feeding claws for their body size than do females.

4. Discussion

Feeding in the fiddler crab *Uca sindensis* involves scooping sediment into the mouth using the small feeding claws. Crabs spend long periods of time feeding on the sediments surrounding their burrows. Most feeding occurs early in the six-hour daily diurnal the lowest tide level period but some crabs feed throughout the lowest tide level. At all times of the day, however, there are more feeding males than females. The skewed ratio of feeding males to females was far more pronounced during the breeding season (late February – early September), when 76% of feeding crabs were male. During the non-breeding season this dropped to 57%. It is possible that females were less common during the breeding season because they remained underground while incubating their eggs, a behavior common among many fiddler crab species (Crane, 1975). Temperature also had a significant effect on feeding behavior with more crabs feeding when the temperatures were higher. This pattern was particularly pronounced for males.

Male *Uca sindensis*, like all other fiddler crabs, have an enlarged feeding claw that is sexually selected for use in combat with other males and is waved to attract females for mating (Crane, 1975). They are therefore left with a single feeding claw compared to the two functional feeding claws found in females. Results showed males feed at about half the rate of females. There are two other fiddler crab species in which this has been investigated. In *U. panacea*, males fed at higher rates than female (Caravello and Cameron, 1987). In *U. pugnaxmales* did not feed at a higher rate than females (Valiela et al., 1974). Results also showed, in *U. sindensis,* both males and females fed faster, when temperatures were higher.

Although males were more likely than females to be surface feeding, they fed at about half the rate of females. Apparently, there is a difference in the total daily feeding effort between the sexes. In fiddler crabs, the food is extracted from the sediment by complex mouthparts and the flooding of the buccal cavity. The 'clean' sediment is then spat out as a small pellet of sand. Larger crabs produce larger feeding pellets. Males produced a significantly greater mass of feeding pellets over the duration of a day than did females. This may be because they are larger than females and so each feeding pellet is larger; because they scoop up more sediment per handful than do females of the same size; or because

they take more scoops with their single claw than females take with both claws.

Results of this study showed males' feeding claws were significantly larger size primarily because of their larger size. When controlling for body size, small female crabs have larger feeding claws than small males. In carapace width of larger than 10 mm, however, males have larger feeding claws than females. In the two other studied fiddler crabs, males had larger feeding claws for their body size than did females (Caravello and Cameron 1987; Valiela et al., 1974).

Within the daily activity period, males produced a greater mass of feeding pellets than females partly because of their larger size and feeding claws than females and spending more time feeding. In *U. pugnax,* males and females produced the same mass of feeding pellets (Valiela et al., 1974).

Male fiddler crabs have clearly been able to overcome the disadvantage of having only a single feeding claw differently. Results of this study showed in *U. sindensis*, the advantage of having an enlarged, sexually selected claw outweighed the disadvantage of having to spend more time feeding. Further consideration for future studies is to investigate the potential difference in energy acquisition between the sexes. It is possible that males and females are different in thire efficiency which, they extract energy from the food source.

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