

# Feeding ecology and bioturbation of fiddler crab *Uca princeps* (Smith, 1870) (Brachyura, Ocypodidae) in a peri-urban wetland in an arid region

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# Abstract

Fiddler crabs are essential to understanding tropical coastal wetlands' dynamics and analyzing carbon budgets because they are the primary epibenthic biomass. They have a high consumption of detritus/bacterial biomass and generate high rates of bioturbation in sediments, affecting storage and export carbon budgets. In the present study, we analyzed the feeding ecology and bioturbation of *Uca princeps* with field experiments (i.e., daily food intake) and laboratory/analysis. This study estimated the daily food intake, evacuation rates, organic matter/carbon content, and bioturbation rate by feeding this species in two seasons (cold and warm). We found that the percentage of daily intake of *U. princeps* measured in dry weight in November 2008 was 16.2% and 17.4% for females and males, while in April, the food intake was much higher with 38.4% and 41.6%, respectively. The average bioturbation of this species through their feeding activities was  $\sim 0.3 \text{ Mg ha}^{-1} \text{ day}^{-1}$ . The results suggest that the females are more selective in their feed. The evacuation rate was  $0.84 \text{ h}^{-1}$  for females and  $0.87 \text{ h}^{-1}$  for males. Therefore, *U. princeps* plays a vital role within the peri-urban ecosystem by removing/altering high quantities of organic matter from the sediments, transforming them into biomass, and influencing biophysical modifications in the peat.

## 1. Introduction

Fiddler crabs are the dominant epifauna in many tropical and subtropical coastal wetlands (Koch & Wolff, 2002; Kristensen et al., 2008), including mangrove forests, salt marshes, and mudflats (Kristensen et al., 2008; Alongi, 2009). Fiddler crabs are essential in trophic networks because they connect detritus and bacterial production with higher trophic levels (Koch et al., 2005). Most fiddler crabs are active at low tide during the day when they forage and repair their burrows (Crane, 1975; Montague, 1982). They use their burrow during the day to prevent desiccation, protect themselves from high temperatures, and at night or at high tides to protect themselves from predators such as other crustaceans, fish, birds, and mammals (Montague, 1980; Warren, 1990). The fiddler crabs can influence the shape and functions of tropical coastal wetlands, regulating the structure and biomass of vegetation (e.g., mangroves; McKee, 1995); and helping stimulate and maintain productivity through bioturbation (Aschenbroich et al., 2017; Ferreira et al., 2019).

These crabs play a crucial role in the carbon dynamics in coastal ecosystems due to the high biomass in the intertidal epibenthos of tropical wetlands (Koch et al., 2005; Kristensen et al., 2008; Alongi, 2009; Canicci et al., 2009; Atwood et al., 2015). Fiddler crabs contribute significantly to the total epibenthic production and are responsible for significant energy and nutrient transfer in coastal wetlands (Koch & Wolff, 2002; ). They affect coastal wetlands' carbon dynamics through their feeding and burrowing activities (e.g., Kristensen et al., 2008; Ferrerira et al., 2019; Xiao et al., 2020; Sarker et al., 2021; Agosto et al., 2022; Grow et al., 2022).

The sediment carbon stock (i.e., quantity/quality) and their dynamic are related to the biomass of fiddler crabs due to bioturbation (e.g., Atwood et al., 2015; Xiao et al., 2020; Agosto et al., 2022; Grow et al.,

2022). The lack of predators and the increased number of fiddler crabs can be critical for the coastal carbon budget due to the high oxidation of organic matter (e.g., blue carbon; Atwood et al., 2015). Likewise, the high biomass of fiddler crabs in wetlands significantly increases food demand and affects other epibenthic and meiofauna biodiversity (Peer et al., 2016).

These organisms are generally critical in intertidal ecosystems (e.g., blue carbon ecosystems: mangroves, seagrasses, and salt marshes) due to modified physicochemical conditions and metabolism/community microbial (Fusi et al., 2022). In salt marshes and mangroves, carbon fluxes by bioturbation (e.g., daily organic matter intake) are underestimated due to a lack of observations/data, introducing uncertainties in coastal carbon budgets (Kristensen et al., 2008; Atwood et al., 2015; Xiao et al., 2020). The magnitudes (e.g., consumption rates, biomass) of the fiddler crabs' contribution to carbon dynamics is relevant in coastal wetlands because these ecosystems are vital in the coastal carbon cycle and under global warming. The bioturbation of crabs increases the flow of CO<sub>2</sub> and CH<sub>4</sub> significantly (Xiao et al., 2020; Agosto et al., 2022; Grow et al., 2022).

The bioturbation can modify the microbiomes and biogeochemistry of the sediments (Booth et al., 2019; Fusi et al., 2022). High consumption/bioturbation rates for these organisms also contribute to the carbon flux to adjacent ecosystems (i.e., dissolved/particulate organic carbon). CO<sub>2</sub> fluxes are detectable in burrows within two hours after cessation of bioturbation activities (i.e., excavation burrows); on the other hand, CH<sub>4</sub> emissions are detectable for up to 24 h (Grow et al., 2022). Xiao et al. (2020) found that the concentration of CO<sub>2</sub> is six times higher in the burrows of crabs than in the atmosphere. Studies have concluded that bioturbation modifies blue carbon budgets and significantly impacts sequestration (Xiao et al., 2020; Sarker et al., 2021; Agosto et al., 2022).

*Uca princeps* has one of the most extensive distribution ranges of fiddler crabs in the Neotropic (Rosenberg, 2018) and is the most abundant species with the highest biomass in an arid peri-urban wetland of southwest of the Gulf of California (Fig. 1 and Fig. 2a). This study analyzed the feeding ecology and bioturbation through the daily food intake of the giant Mexican fiddler crab. Furthermore, we hypothesize that a) their peak feeding will be during the day/low tide with specificity in food for females (i.e., animal detritus/bacterial biomass), and b) their consumption and bioturbation rates are higher than other fiddler crabs in the Neotropic due to their larger size.

## 2. Material And Methods

### 2.1 Study area

Chametla's mudflat (24 ° 06' 23.7" N, 110° 24' 51.0 W) is located southwest of La Paz Bay, Mexico (Fig. 1). This mudflat has 3.8 km in length and a width of 0.7 km, with an area of ~ 13.3 km<sup>2</sup> (Leija-Tristan et al., 1990). The beach is less than 3 meters deep, with a slight slope and low-energy waves, and is an important site a feeding area for migratory birds (Brabata & Carmona, 1998). This Ramsar site is

peri-urban to La Paz City and close to the sewage drain of a water treatment plant (Brabata & Carmona, 1998).

The tidal regime is mixed semidiurnal, and the intertidal zone is exposed from 100 to 500 meters (Leija-Tristan et al., 1990). The marsh can be up to 1.5 km wide into the mudflat (Leija-Tristan et al., 1990; Brabata & Carmona, 1998). The predominant vegetation in the mudflat is black mangrove (*Avicennia germinans*), followed by red mangrove (*Rhizophora mangle*), and in the high intertidal *Salicornia* sp. (Leija-Tristan et al., 1990; Brabata & Carmona, 1998) (Fig. 2bc). The substrate is the clay-silty type with a high content of mollusk shells. The region's climate is arid in a transitional latitude of tropical to temperate, with a tropicalization process in mangroves (Ochoa-Gómez et al., 2021).

The macrofauna most conspicuous in the wetland are the fiddler crabs *Uca crenulata* and *U. princeps*. The zonation of both is well delimited due to arid conditions in the high (*U. crenulata*) and low (*U. princeps*) intertidal of the mudflat (Brabata & Carmona, 1998; Precoma de-la Mora, 2012) (Fig. 2bc).

## 2.2 Diet

In April 2009, 40 adult organisms (20 females and 20 males) of similar sizes and characteristics (i.e., no ovigerous, both chelas) were randomly captured in the study area during the day at low tide and in a feeding peak. Likewise, the average depth of the burrow where they were captured was estimated with a flexometer ( $\pm 1$  cm), and visual censuses for the square meter ( $N = 20 \text{ m}^2$ ) were realized in the study area to estimate the burrows' density. The collected crabs were separated/labeled into groups A ( $N = 20$  crabs) and B ( $N = 20$  crabs) and transferred to the Ecology laboratory of the Autonomous University of Baja California Sur (UABCS).

The crabs were measured (carapace width; Fig. 2a) and weight in the laboratory with a vernier caliper ( $\pm 0.01$  cm) and analytical balance ( $\pm 0.001$  g); subsequently, they were tagged and frozen ( $\sim -10^\circ\text{C}$ ).

In group A, The gastrointestinal content (GIC = cardiac and pyloric stomach) was extracted in the laboratory (ten females and ten males), and the GIC was washed (with 1 ml of distilled water), mixing the GIC and the distilled water. After, an aliquot of 0.5 ml of GIC content was obtained. In total, 20 aliquots were obtained (10 females and 10 males), and each one was placed on a slide to observe the abundance (i.e., percentage of coverage per observation field) of each type of food using an optical microscope (Leica DM2500) at a resolution of 40x. An average percentage ( $\pm$  standard deviation) of the abundance of each type of food was obtained for females and males. In the other group (B), the ICG (except feces) was extracted and filtered using a vacuum pump (GF/C filters). The GCI was dried at  $70^\circ\text{C}$  in a stove for 48 h and weighed on an analytical balance.

Finally, 20 GIC sample slides from each sex were stained using the Gram method, and the abundance of Gram (+) and Gram (-) bacteria was determined (i.e., percentage of coverage per observation field) at 100x resolution with an optical microscope (Leica DM2500).

## 2.3 Organic matter in GIC and sediment's surface

In the zonation (low intertidal), well marked for *U. princeps* were collected ten sediment samples of the surface (to 2 cm depth; 2–3 g dry weight) for estimated the percentage of organic matter in the surface substrate in summer (April 2009). Likewise, the average organic matter percentage in GIC of 20 fiddler crabs was obtained (see section 2.2) (group B). For estimated organic matter, all samples were processed with the calcinated/ignition method (i.e., muffle at two hours at 500°C).

## 2.4 Model to estimate dry weight for *U. princeps*

In the warm season (April 2009), 27 males and 23 females were captured randomly in the study area. All the individuals presented both chelas with different sizes, and none of the females was in an ovigerous state. The crabs were transferred to the laboratory's UABCS in a freezer (-10°C). The organisms were tagged, measured with a vernier caliper ( $\pm 0.01$  cm), and weighed (wet weight) on an analytical balance ( $\pm 0.001$  g). Subsequently, the crabs were placed in a drying oven at 70°C for 48 h. Then, all the organisms were weighed again in an analytical balance ( $\pm 0.001$  g) to obtain their dry weight. The wet weight vs. dry weight was correlated in linear/multiple regression for estimated the dry weight and generated the model's equation (confidence > 95%) for females and males with significant parameters ( $p < 0.05$ ). The multiple correlations with the carapace width were not considered because they were not significant ( $p > 0.05$ ).

## 2.5 Food periodicity, daily intake, and bioturbation

Field experiments in the study area were conducted during two 24-h cycles at the start of the warm season and at the end of the winter seasons (27–28 April 2009 and 07–08 November 2008, respectively); in the transition of water/air temperatures. The experiment was carried out to determine the food consumption and the periodicity with which the crabs feed. Seven samples were taken during each 24-h cycle. The samples were collected in periods of four hours, each one with 15 females and 15 males.

The carapace's width of the crabs was measured with a vernier caliper ( $\pm 0.01$  cm), placed in bags labeled with the collection time, and stored in a cooler at  $\sim -10^\circ\text{C}$  to stop digestion during their transfer to the laboratory's UABCS. All crabs were weighed (wet weight) on an analytical balance ( $\pm 0.001$  g). Subsequently, the GIC was extracted and filtered using a vacuum pump (GF/C filters). The filters had been previously dried (100°C) and weighed ( $\pm 0.001$  g). All GIC contents (N = 210 GIC) were dried at 100°C in an oven for 24 h. Likewise, the predictive model for estimating the dry-weight males and females was used (see section 2.3). The feeding periodicity was represented with graphs that relate the GIC to the time of day and tidal cycle.

The Elliott (1972) and Jobling (1981) models were used to estimate the evacuation rate, which considers the evacuation rate (ER) the steepest negative slope of the GIC. The model is following:

$$ER = \ln GIC_j - \ln GIC_{j+1} / t_{j+1} - t_j$$

$GIC_j$  and  $GIC_{j+1}$  are the gastrointestinal content at time  $t_j$  and  $t_{j+1}$ , respectively. The ER was estimated per hour. The daily intake (DI) was calculated with the Eggers (1977) model:

$$DI = (24h)(GIC)(ER)$$

In Eggers' model, GIC is the average of the gastrointestinal contents during 24 hours in the percentage of the dry weight of the crab. This model applies to various diets and is statistically robust (Boisclair & Leggett, 1988).

The average daily food intake estimated the bioturbation by sex (expressed as percentage dry weight) multiplied by the average number of burrows by area. Bioturbation will be estimated with the average daily food intake between males and females to obtain an adequate estimate of bioturbation by the specie (*U. princeps*).

## 2.5 Statistical analysis

The a priori tests of normality of Kolmogorov-Smirnoff and equality of variance (hypothesis test for the ratio of variances) were performed. The data were normal and homoscedastic. Hypothesis tests were performed to analyze whether there were differences between the means of two populations (female and male). The ANOVA test was realized to compare weight among sex (males vs. females). The tests were conducted on the diet, evacuation, and consumption rate (daily food intake). All tests were performed at 95% confidence ( $\alpha = 0.05$ ).

## 3. Results

### 3.1 Size weight-Relationship

*U. princeps* measured (carapace width) in average  $2.3 \pm 0.6$  cm (females) and  $3.6 \pm 0.4$  cm (males) (females range: 1.3 to 3.4 cm; males range: 2.7 to 4.3 cm). The linear regression models for estimating wet vs. dry weight had a high correlation coefficient in females and males (Table 1). Males weigh up to ~ 30 g wet weight (~ 10 g dry weight), and females up to ~ 11 g wet weight (~ 7.5 g dry weight). The enlarged chela of males provides an essential part of their weight. The average dry weight for females was 3.3 g ( $\pm 2.6$  g) and 5.9 g ( $\pm 2.4$  g) for males; significant differences were found ( $F = 13.2$ ;  $p < 0.00$ ).

Table 1  
Model for estimating the dry weight of *U. princeps*.

Equations	r <sup>2</sup>	p-value
<i>Females</i> Dry weight= -0.2039 + 0.7679*(wet weight)	0.93	0.00
<i>Males</i> Dry weight= 0.3167 + 0.3112*(wet weight)	0.90	0.00

## 3.2 Burrows, biomass, and diet

The average burrow density of *U. princeps* was 16 burrows  $\text{m}^{-2}$  ( $\pm 6$  burrows  $\text{m}^{-2}$ ). The burrowing depth of this class of individuals (adults) averages  $41 \pm 8$  cm. The females and males of *U. princeps* measured on average 3.6 cm ( $\pm 0.3$  cm) and 3.9 cm ( $\pm 0.3$  cm), respectively. Their average dry weight range was 3–6 g, and the average biomass concerning the average number of burrows was 50–80  $\text{g m}^{-2}$ . The diet composition of males and females was based mainly on organic matter and bacteria (Fig. 3). Animal and plant detritus are covered by bacterial biomass.

The average percentage of organic matter within the stomach of females and males was 85.2% ( $\pm 11.7$ ) and 87.0% ( $\pm 7.3$ ), respectively. No significant differences were found in the organic matter of the GIC between males and females ( $t_{g,l21} = -0.49$ ;  $p > 0.05$ ). ~80% of the diet of both males and females was organic matter covered with bacterial biomass. The percentage of organic matter on the soil's surface was ~7% ( $\pm 1.4$ ).

Plant detritus was the second item in females and males, followed by diatoms (Fig. 2). Significant differences ( $t_{g,l18} = 2.6$ ;  $p < 0.05$ ) were found in the ingest of plant detritus between sexes; males ingest more plant detritus compared to females. The most abundant bacteria in females and males were cocci and bacilli type Gram (-) (> 60%). The similar daily intake in females and males indicates no significant difference in consumption, although females found significant differences ( $t_{g,l18} = 2.6$ ;  $p < 0.05$ ) in the selectivity of the food.

## 3.3 Food periodicity and daily intake

The feeding of *U. princeps* occurs mainly at daytime low tides. In spring tides, most *U. princeps* activity occurs around the middle of the morning at low tides and decreases as the tide rises in the afternoon (Fig. 2ac). The consumption rate was higher in April 2009 compared to November 2008. No significant differences (Males  $t_{g,l12} = -1.016$ ;  $p > 0.05$ ) (Females  $t_{g,l12} = -0.90$ ;  $p > 0.05$ ) were found in the GIC between sexes of both seasons (November 2008 vs. April 2009).

The percentage of daily intake of the dry weight of the crab changed from the winter season (November) to the warm season (April) for females and males. In November 2008, it was 16.2% and 17.4% for females and males, while in April, it was 38.4% and 41.6%, respectively (Fig. 4). The evacuation rate for females was  $0.84 \text{ h}^{-1}$  in November 2008 and April 2009. In males, it was  $0.92 \text{ h}^{-1}$  in November 2008 and  $0.81 \text{ h}^{-1}$  in April 2009.

## 3.4 Bioturbation rate

*U. princeps* had an average daily consumption daily rate of ~38% dry weight for females and 41% for males in April 2008. The average bioturbation (with the average weight of this species in this study) of females and males was 1 and 2.4 g per day of sediment, respectively. The model to estimate the dry

weight of this species can help estimate/calculate bioturbation rates in different seasons (Table 1), considering the number of burrows and the average weight of the species of the study site.

The average bioturbation of this species was  $\sim 1.7$  g dry weight per day of sediment. The average sediment removal rate per square meter per day for *Uca princeps* was  $\sim 28$  g ( $\sim 0.3$  Mg ha<sup>-1</sup>) of bioturbated sediments in the warm season in this study area; annually, it could be up to  $\sim 110$  Mg ha<sup>-1</sup>.

## 4. Discussion

Fiddler crabs are opportunistic species that select/alternate food sources (plant or animal detritus), and consumption rates depend on environmental conditions (Meziane et al., 2002). The nutrient input by wastewater treatment plants could be related to the quality of organic matter inside the crabs' stomachs; the main bacteria (Gram-negative) in *U. princeps* are highly pathogenic in animals (Tune et al., 1993). The higher bacterial biomass is Gram (-), an indicator of the water quality discharged, or that arrives by runoff.

The sediment from the study site contained an average of 7% organic matter, which is higher than other marshes with 1-3.5% surface organic matter (Reinsel, 1994; Wolfrath, 1992). This high value could indicate organic matter input from anthropogenic impact (e.g., the treatment plant and other sources from La Paz city). Cannicci et al. (2009) have reported that wastewater positively affects the biomass and richness of fiddler crabs. In the case of *U. princeps*, the organic matter content in the stomach was  $\sim 80\%$  higher than that found in *U. pugilator* (i.e., 40%; Reinsel, 1994).

Temperature plays a crucial role in intertidal organisms such as fiddler crabs (da Silva Vianna et al., 2020). During the seasons of the study area, no substantial difference was observed between the average annual air temperature between November ( $22.2^{\circ}\text{C}$ ) and April ( $22.7^{\circ}\text{C}$ ) (CONAGUA, 2022). However, there is an essential difference in the water temperature reported between these months, with April being the coldest month (April:  $20^{\circ}\text{C}$  and November:  $22.5^{\circ}\text{C}$ ; Herrera-Cervantes et al., 2014). Other authors (i.e., Hernández et al., 2010; Guevara-Guillen et al., 2014) mentioned that the year 2008 was atypical, influenced by the ENSO (El Niño-Southern Oscillation) due to anomalies in the sea surface temperature of up to  $1.8^{\circ}\text{C}$  lower than the average recorded in the last 25 years.

The results suggest that the change among seasons of  $2.5^{\circ}\text{C}$  in water temperature was essential in the consumption rate of *U. princeps*. It has been reported that other decapods (e.g., *Crangon crangon*) increase consumption rates by up to 6% for a change of  $1^{\circ}\text{C}$  (Pihl & Rosenberg, 1984). Other crabs (*Cancer polyodon*) increase the consumption rate from winter to summer from 2.8–4.4% of the dry weight of the crab (Wolff & Cerda, 1992).

The consumption of *U. princeps* was higher in April due to the low temperature of the water in this month and because winter ended, when the amplitude of the tides was more extensive, and the metabolic activity went from lower to higher due to the increase in temperature (Da Silva Vianna et al., 2020). That is, the short time they had to feed during the cold season, coupled with the amplitude of the tides,



impulsed their metabolic rate and increased their consumption at the beginning of the warm season (i.e., April).

In this sense, the results suggest that in April, the population of *U. princeps* was coming out of a hibernation/dormancy process (Burger et al., 1991; Wolfrath, 1992) driven by local circadian rhythms (Kellmeyer and Salmon, 2001; Stillman and Barnwell, 2003), which generated a potential increase in the consumption in males and females. Moreover, these circadian tidal cycles drive the reproduction process (Kellmeyer and Salmon, 2001).

The daily food intake of *U. princeps* (~ 40%) was slightly up to *Uca maracoani* (30.6%), and this is above the range reported for species such as *Uca vocator* (22.1%) and *Uca rapax* (32.2%) (Koch, 1999; Koch et al., 2005). The metabolic requirements of females and males in *U. princeps* are similar, although sometimes females can ingest more food during reproductive periods, and their consumption is in a short time, contrary to males, where their consumption is in more extended periods (Valiela et al., 1974; Weissburg, 1992; Koch, 1999). Females have been reported to have slightly higher selectivity in food quality because they may have more chemosensory fibers in their maxillipeds (Weissburg & Derby, 1995; Weissburg, 1993).

The evacuation rate is directly related to consumption and was higher than other species in tropical regions, such as *Uca rapax* and *Uca annulipes*, which have an evacuation rate of  $0.59 \text{ h}^{-1}$  and  $0.79 \text{ h}^{-1}$ , respectively (Koch, 1999; Peer et al., 2016). The high evacuation rates of *U. princeps* ( $0.85 \text{ h}^{-1}$ ) indicate high metabolic activity and are directly related to the assimilation efficiency of organic matter (Koch and Wolf, 2002; Peer et al., 2016). The lower evacuation rate of females suggests being associated with this efficiency in selecting food quality.

The dominance of *U. princeps* in the Neotropics and its actual extension in the distribution range (Rosenberg, 2018) could be the cause of the greatest bioturbation due to its large biomass and high consumption rate compared to other fiddler crabs species. The number of burrows is an estimation of the number of fiddler crabs and could be used to estimate the average bioturbation in coastal wetlands for this species considering their dry weight (see Table 1) and daily food intake. However, it is crucial to consider that the burrow size and excavation rate are related to the fluxes of  $\text{CO}_2$  and  $\text{CH}_4$ , respectively (Grow et al., 2022). In another study, sediments  $\text{CO}_2$  and  $\text{CH}_4$  flux rates are significantly and positively correlated with crab burrow density, organic matter content, and vegetation types. Specifically, higher sediment organic matter content and crab burrow density significantly increased soil heterotrophic respiration in a marsh (Agusto et al., 2022).

The bioturbation related to the density/depth of burrows is relative since variables such as population dynamics and the species' biology must be considered, as well as the number/depth/shape of burrows in a given area and others (e.g., quality/quantity of organic matter, canopy) (Mouton & Felder, 1996; Chen et al., 2017; Li et al., 2015; Agusto et al., 2022). Some species remove between 7–48% of the surface sediment (depth 0–15 cm) annually (Katz, 1980; McCrauth et al., 2003). In this case, the adults of *U.*

*princeps* had a burrow twice as deep ( $38 \pm 8$  cm). In the same study area, Precoma de-la Mora (2012) reported that the species coexisting (i.e., *U. crenulata*) with *U. princeps* in the high intertidal of the same study site has a higher average burrow density ( $\leq 88$  burrows  $m^{-2}$ ) than *U. princeps*, but with less biomass ( $\leq 29.7$  g  $m^{-2}$ ; Précoma-de la Mora, 2012). It has been reported that the drainage of sewage/contaminated water decreases bioturbation due to the construction of burrows of fiddler crabs increases (Penha-Lopes et al., 2009).

The bioturbation rates are important to analyze organic carbon dynamics in sediments (Kristensen et al., 2008), helping to understand carbon fluxes in blue carbon ecosystems (Atwood et al., 2015; Macradie et al., 2017; Agosto et al., 2022; Grow et al., 2022). However, it is a complicated measurement due to multiple biophysical interactions and the complexity of the sediments (e.g., meiofauna). In the tropics, the high biodiversity of benthic organisms causes bioturbation (e.g., amphipods, penaeid shrimp, bivalves), and their impacts on carbon budgets should be considered (Sarker et al., 2021).

Finally, the fiddler crabs are the main benthic macrofauna, it is essential to analyze blue carbon fluxes, as they are an essential trophic link of these systems with the detritus chain (Koch & Wolff, 2002). Moreover, carbon assimilation for critical species and their population dynamics is essential for analyzing the carbon dynamics in blue carbon ecosystems and other coastal wetlands (Kristensen et al., 2008; Koch et al., 2005).

## Conclusions

*U. princeps* is one of the fiddler crabs with the highest daily food intake of diverse organic matter (mainly organic matter/bacteria). Multiple species-site-specific variables condition the magnitude of mechanical bioturbation of carbon in the soil. Bioturbation by feeding is essential in understanding the role of the superficial carbon dynamic in wetlands and the coastal carbon budgets. The ecology-social dynamics (e.g., the input of wastewater) and geomorphology/physiography must be thoroughly studied to understand the processes of carbon fluxes within this type of wetlands.

## Declarations

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## Figures

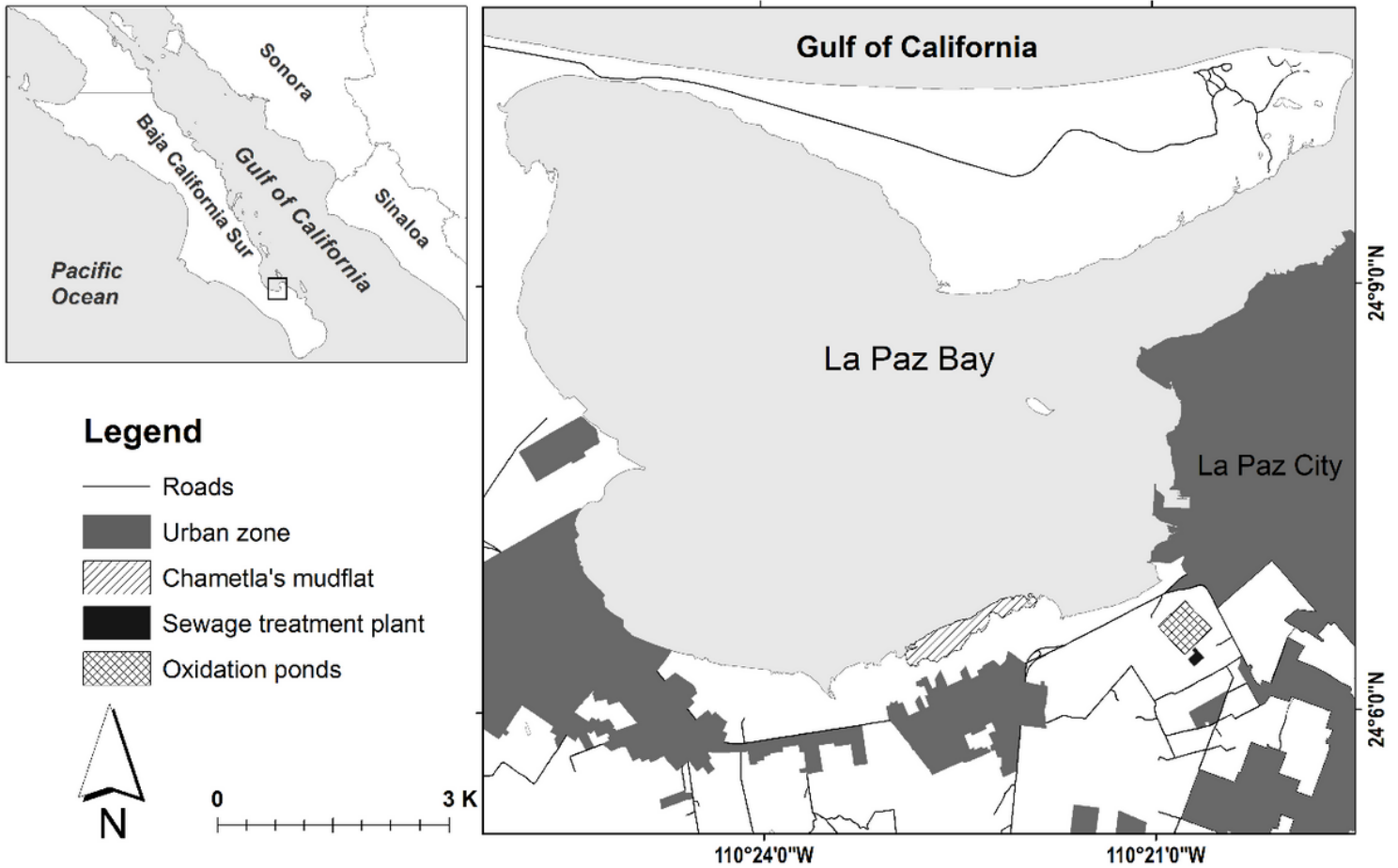


Figure 1

Study area in La Paz Bay, Mexico.

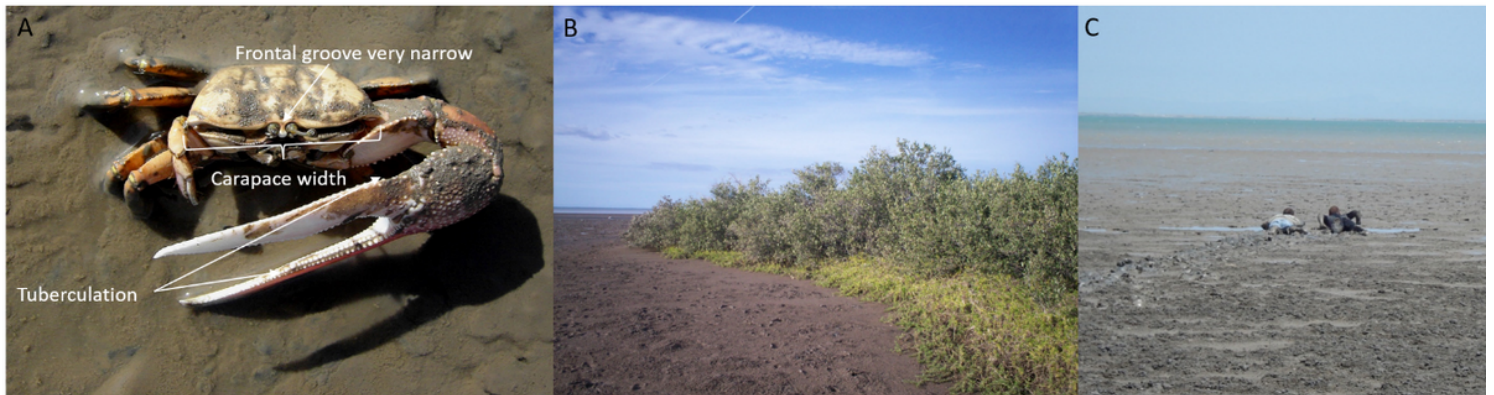


Figure 2

Photos in the study site. A) Some diagnostic characteristics of *Uca princeps* (Photo: Steven Mlodinow) B) Mudflat wetland with mangroves patches C) Collecting samples/organisms in the zonation of *U. princeps* in the mudflat.

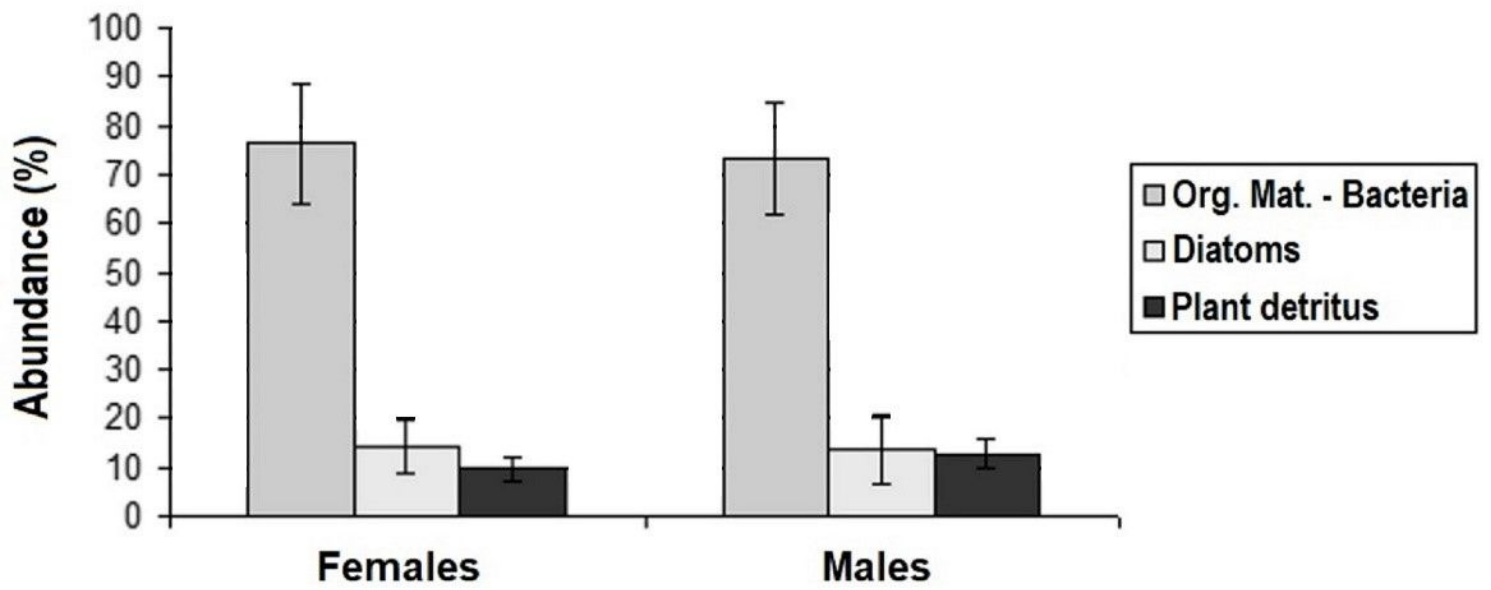


Figure 3

Percentage ( $\pm$ SD) of abundance in composition of the *Uca princeps* diet (Org. Mat.= Organic Matter).



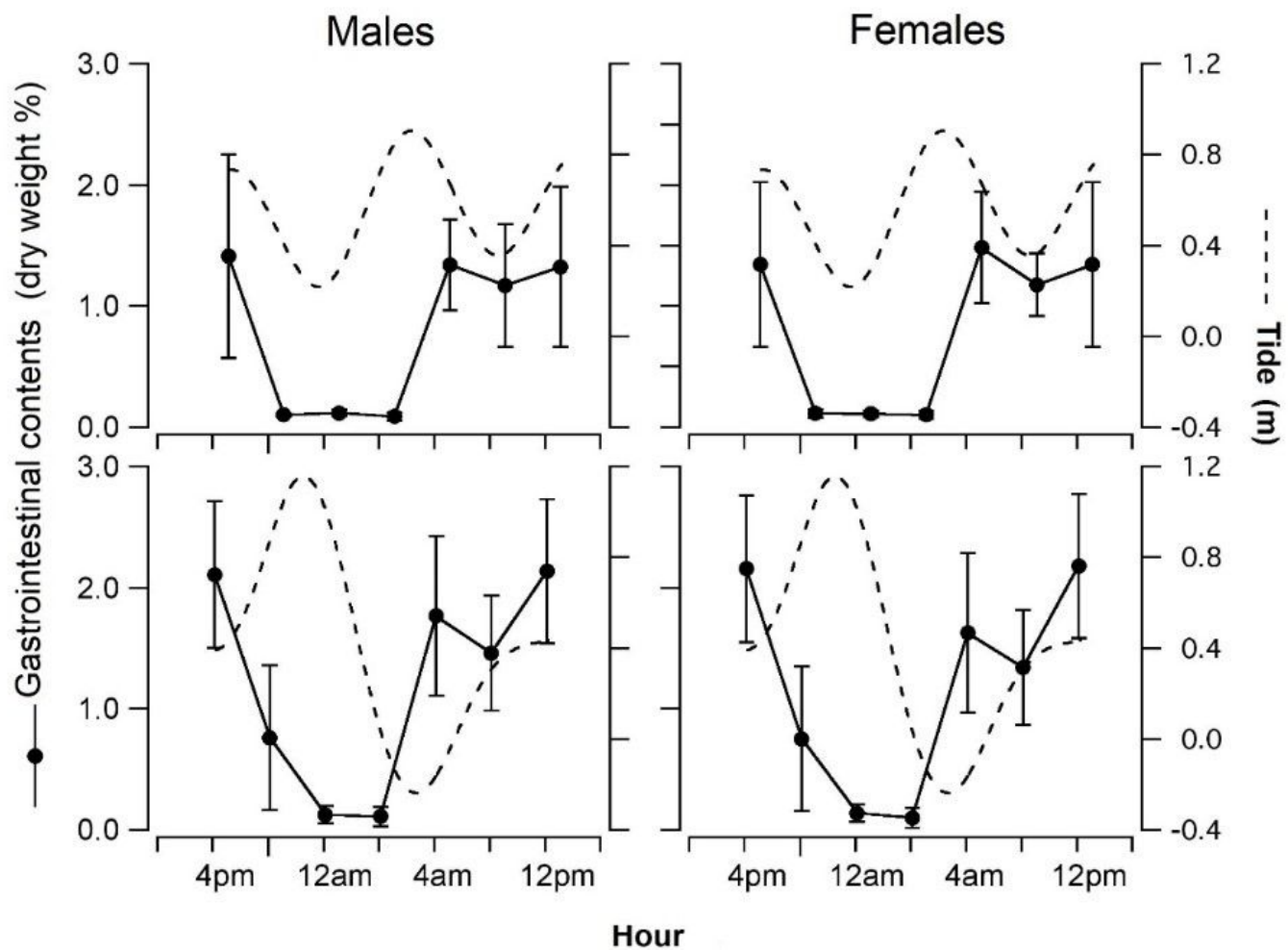


Figure 4

Periodicity and food daily intake by *U. princeps*.