ORIGINAL RESEARCH

Behavior and diet composition of fiddler crabs in Guang-guang, Dahican, Mati City, Davao Oriental, Philippines

Ivy M. Nallos[1, 2] and Edison D. Macusi[1, 2, *]

[1]Fisheries Catch Assessment Project, Davao Oriental State University, Mati, Philippines. [2]Faculty of Agriculture and Life Sciences (FALS), Davao Oriental State University, Mati, Philippines. ORCID *Ivy M. Nallos* https://orcid.org/0000-0003-3752-4847, *Edison D. Macusi* https://orcid.org/0000-0002-9714-1074

ABSTRACT. This paper aims to provide information about the behavior and diet composition of fiddler crabs. The large percentage of sediments present in the stomach of fiddler crabs proves that fiddler crabs play an important role in aerating the soil, which would help in the growth of mangrove and wetland plants. Observations were done in sandy, muddy, and coralline substrates for four months. Thirty fiddler crabs were collected for laboratory test of their diet composition. Sediments had the highest percentage in the stomach content of the fiddler crabs (60%), followed by chum (25%), and leaf particles (15%). The analysis of the fullness of their stomach showed that it was highly significant (df = 2, MS = 2.09, F = 34.34, p = 0.001). While the fiddler crabs ate all three colors of mangrove leaves, it preferred to forage on yellow leaves (n = 104) followed by the brown leaves (n = 78) and the green leaves (n = 77), proving that nutrient recycling occurs in the mangrove area. The existence of the fiddler crabs contributes to a more stable mangrove ecosystem. In addition, this study is the first assessment of fiddler crabs documented in Mindanao, Philippines. Results of the study can be used as a baseline for the protection of mangrove ecosystem species.

Key words: Antagonistic behavior, bioturbation, mangrove, sediments, soft-bottom ecosystem.

Comportamiento y composición de la dieta del cangrejo violinista en Guang-guang, Dahican, Mati City, Davao Oriental, Filipinas

RESUMEN. Este trabajo tiene como objetivo proporcionar información sobre el comportamiento y la composición de la dieta de los cangrejos violinistas. El gran porcentaje de sedimentos presentes en el estómago de los cangrejos violinistas demuestra que los cangrejos violinistas juegan un papel importante en la aireación del suelo, lo que ayudaría al crecimiento de las plantas de manglares y humedales. Las observaciones se realizaron en sustratos arenosos, fangosos y coralinos durante cuatro meses. Treinta cangrejos violinistas fueron recolectados para estudiar en de laboratorio la composición de su dieta. Los sedimentos tuvieron el porcentaje más alto en el contenido estomacal de los cangrejos violinistas (60%), seguidos de la carnada (25%) y las partículas de hojas (15%). El nivel de llenado del estómago mostró que era altamente significativo (df = 2, MS = 2,09, F = 34,34, p = 0,001). Si bien los cangrejos violinistas comieron los tres colores de las hojas de mangle, prefirieron alimentarse de las hojas amarillas (n = 104), seguidas de las hojas marrones (n = 78) y las hojas verdes (n = 77), lo que demuestra que el reciclaje de nutrientes ocurre en la zona de manglares. Los cangrejos violinistas contribuyen a mantener un ecosistema de manglar más estable. Además, este estudio representa la primera evaluación de cangrejos violinistas documentada en Mindanao, Filipinas. Los resultados se pueden utilizar como referencia para la protección de las especies del ecosistema de manglares.

Palabras clave: Comportamiento antagonista, bioturbación, manglar, sedimentos, ecosistema de fondos blandos.

Marine and Fishery Sciences MAFIS

OPEN ACCESS

*Correspondence:
edison.macusi@dorsu.edu.ph

Received: 16 January 2023
Accepted: 16 March 2023

ISSN 2683-7595 (print)
ISSN 2683-7951 (online)

https://ojs.inidep.edu.ar

Journal of the Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP)

INTRODUCTION

The Genus *Uca* contains about 100 species of semi-terrestrial marine crabs which includes fiddler crabs, sometimes called 'calling crabs' (Rosenberg 2019). Fiddler crabs are members of the Family Ocypodidae of brachyuran crabs, marine animals that recently invaded the land. They are active on the surface at low tide, feeding on soil debris, bacteria, and algae (Zeil et al. 2006). Sandy beaches, mudflats, mangrove areas, and salt marshes are all locations where fiddler crabs can be found. Fiddler crabs rely on the sediment which they use for food, burrowing, and for collecting bacteria, debris, and benthic macroalgae (Ribeiro and Iribarne 2011). The intertidal zone and the nearby marine and terrestrial habitats are connected by fiddler crabs, which are recognized as ecosystem engineers and significant connectors of energy flow. According to a recent study, fiddler crabs are the primary food source for some fish and may be more important than was previously thought as food for predators (Grande et al. 2018).

Fiddler crabs are recognized for having extraordinary claws. Male claws are much larger compared to those of females, who have claws of the same size. They stay close to their burrows to quickly escape from predators, as well as find shelter from the heat and water loss (Macintosh et al. 2002). Male fiddler crabs use their minor claw for feeding and the major claw for displaying and fighting. Major claws are typically brightly colored and four to five times longer than minor claws, making up around one-third of the total body mass of the crab. Female fiddler crabs have two tiny claws almost always cryptic (Rosenberg 2001). Fiddler crabs can tolerate a wide range of salinities, high temperatures, and low levels of oxygen (Nagelkerken et al. 2008). Fiddler crabs attract a female for mating by waving their enlarged claw. Courtship activity of male fiddler crabs peaks semi-monthly and coincides with the peak in the temporal distribution of receptive female fiddler crabs. A female fiddler crab mate once a month, 4-5 days prior to one of the semi-monthly spring tides. The relationship between the timing of reproduction and tide cycles may represent an adaptation to maximize the likelihood that the last stage of planktonic larvae will be carried by tidal currents to substrates suitable for adults (Swanson et al. 2013). They protected themselves against other fiddler crabs or predators using their enlarged claws (Bergey and Weis 2006). Burrows are the most crucial resource for the reproduction and survival of fiddler crabs, and males must defend them for females to be attracted to them. Each fiddler crab concentrates its territorial defenses on a single burrow (Mautz et al. 2011). Research on the behavior of fiddler crabs is critical to understanding when and how much sediments impact and how they affect the overall functioning of ecosystems. As with other intertidal invertebrates, their activity is significantly influenced by tides. According to several studies, fiddler crabs only engage in surface behaviors including feeding, burrowing, and mating during low tide and stay in their burrows during high tide (Reinsel 2004; Sanford et al. 2006; Zeil and Hemmi 2006; Dugaw et al. 2009). Fiddler crabs can significantly influence the ecology of mangrove communities, acting as ecological engineers by adjusting resources accessible to marsh plants and by changing the physical, chemical, and biological characteristics of these communities of soft sediments (Smith et al. 2009). Fiddler crab bioturbation would improve the oxygenation of the sediments and promote the growth of mangrove saplings (Macusi and Tipudan 2021). Various species of fiddler crabs, each have different behaviors like feeding, mating, walking, etc., can be found in the same habitat in many tropical environments (Nordhaus et al. 2009; Shih 2012).

Because there are few studies of fiddler crabs in the Philippines, this paper provides a new understanding of the species. The objective of this study was to provide information about the behavior and diet composition of fiddler crabs in Guang-guang, Dahican, Mati City, Davao Oriental. Findings of this study will be used as a reference for anyone interested in studying fiddler crabs in the Philippines, particularly in Mindanao, and will provide additional information to assist in the development of a conservation strategy for various marine species.

MATERIALS AND METHODS

Study area

The study area was located in the mangroves of Guang-guang, Barangay Dahican under the municipality of Mati City, Province of Davao Oriental. The study area is situated at 60° 55′ N and 126° 15′ E. The area is characterized by sandy, sandy-muddy, sandy coralline and muddy substrate with different species of seagrasses thriving in it. The Guang-guang mangrove area is part of the National Integrated Protected Areas System (NIPAS) as Protected Landscape/ Seascape under Proclamation No. 451 dated July 31st, 1994 of the Philippine government with an approximate area of 168 km^2 (Abreo et al. 2020) (Figure 1).

Data collection

The study focused on observing the behavior and the diet composition of fiddler crabs in relation to low tide in Guang-guang, Dahican, Davao Oriental. Three sampling stations of 10 × 10 m quadrats each were established on the shoreline

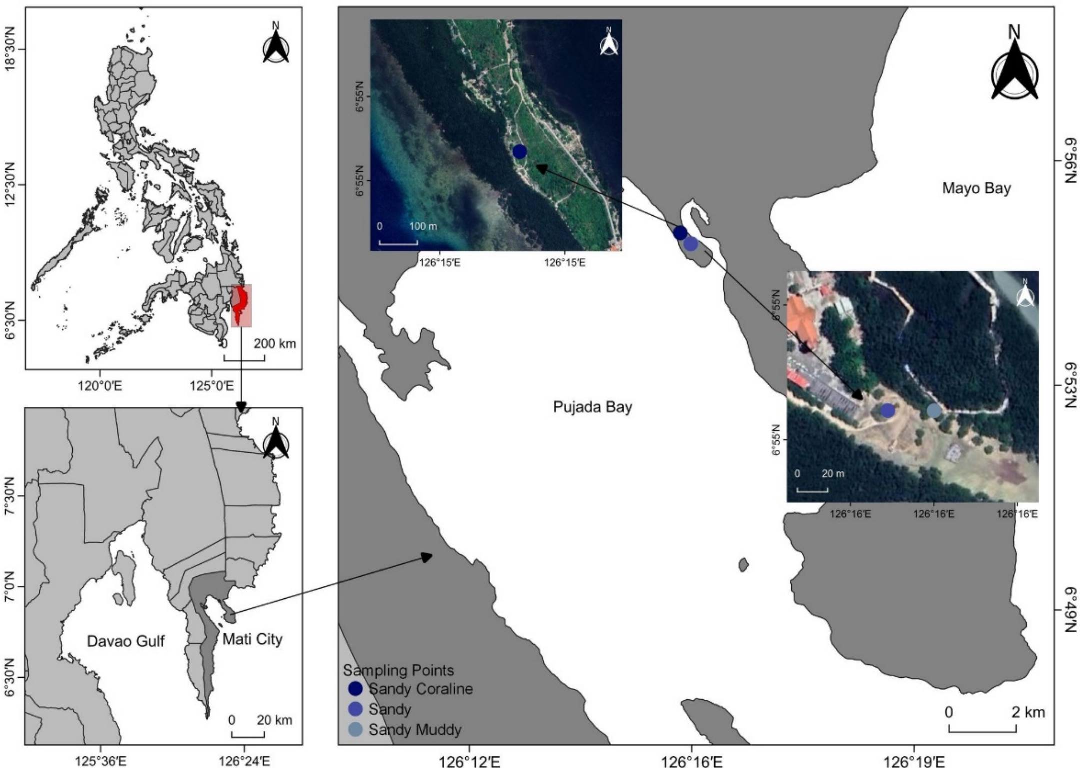

Figure 1. Study area in Guang-guang Dahican, Mati City, indicating different substrates (blue colors).

of Guang-guang: sandy, muddy, and sandy coralline. Each station had four quadrats for easier observation on their behaviors with a minimum distance of 100 m from each other to maintain independence and prevent one station from being influenced by the others. The behavior of fiddler crabs was assessed according to their sex, whether they perform courting, defending burrows, fencing or predation, waving, enhancing their burrows, walking/grasping or foraging. Foraging activities of fiddler crabs were also categorized as either collecting leaves (grasping the item and retreating to the burrow) or foraging (slow walking, associated with tapping or tasting sediment or litter). In each station, fiddler crabs and their burrows were counted and burrows were examined for leaf taking. The duration of the observation and counting of fiddler crabs took one hour during low tide and these activities were photographed for documentation. The regularity of the observation in the three stations were thrice a week for four months. Three different hues of leaves (green, yellow, and brown) were tied with a thread, anchored by a bamboo stick, and placed close to the burrows for determining the preferred color. Scoring and observation were carried out by evaluating the leaves that were eaten or missing and scored positive when fiddler crabs had bite marks on that particular leaf color or if leaves were missing. Ten randomly selected burrows from each of the three stations were used in the experiment. Each station was observed for one hour during low tide. The experiment was repeated four times and then after the fourth test, crab burrows were sampled for leaf coloration in each of the three stations.

Laboratory work

Species identification and diet composition of fiddler crabs

Fiddler crab species were identified by morphological characteristics from Rosenberg (2019) and by using the following taxonomic references: the *Austruca annulipes* (Milne Edwards, 1837), *Gelasimus vocans* (Linnaeus, 1758), *Tubuca capricornis* (Crane, 1975), *Tubuca urvillei* (Milne Edwards, 1852), *Paraleptuca crassipes* (White, 1847) and *Tubuca alcocki* (Shih, Chan and Ng 2018). Thirty male and female fiddler crabs from each of the three stations were sampled for diet composition. These samples were collected in the field and placed immediately in 70% ethanol and brought to the laboratory. Fiddler crabs were injected with 10% formalin solution to stop the digestion process and then they were photographed. Next, fiddler crabs were dissected and stomach contents were washed with distilled water, transferred to a solution of 10% formalin, and stained with safranin red (this stain was used because it was the only one that could be found in the laboratory during the study). Contents were classified into distinguishable food categories, e.g. leaf, algae, and sediments. Stomach fullness, percentage of the total volume visible contributed by each of the food categories, and frequency of occurrence of different food categories were determined. To get the percentage of the stomach fullness the following values were $D_0 = 0\%$, $D_1 = 25\%$, $D_2 = 50\%$, $D_3 = 75\%$ and $D_4 = 100\%$.

Categorizing food Items from crab stomachs

By using a dissecting microscope, food items in the stomach of each crab were classified as sediment, leaves, or algae. There were also stomach samples in which no leaf fragments were found. Foraging behaviors of fiddler crabs were also classified according to whether they forage (slow walking, associated with tapping or tasting sediment and litter) or collect leaves (grasping the item and retreating into the burrow).

Data analysis

All count data were first checked for normal distribution before comparisons were made. If data were not normally distributed, they were $\log_{10}$ transformed and checked again for normal data distribution and homogeneity of variance using Kolmogorov-Smirnov test. Once the requirement of ANOVA was satisfied, then all tests were considered statistically significant at $p \leq 0.05$. *Post hoc* analyses using Tukey's HSD test and the modified Tukey's HSD test for unequal sample N were performed. The Kruskal-Wallis test was used to analyze the frequency of various behaviors and the diet composition of fiddler crabs in order to compare them when data transformation did not work out for normal distribution and homogeneity of variance.

RESULTS

Species composition

Family Ocypodidae is the family of fiddler crabs found in different stations: the muddy, sandy coralline, and sandy muddy substrate in the study area. Six species were identified from samples: *Austruca annulipes* (Edwards, 1837), *Gelasimus vocans* (Linnaeus, 1758), *Tubuca capricornis* (Crane, 1975), *Tubuca urvillei* (Edwards, 1852), *Paraleptuca crassipes* (Adams and White, 1848), and *Tubuca alcocki* (Shih, Chan and Ng 2018). In species identification, the genus level was used due to a lack of exact information about their species composition. Pictures taken during the sampling period were compared to descriptions from Rosenberg (2014) (Figure 2).

Behavior of fiddler crabs

There were different behaviors of fiddler crabs observed in the study area. They consisted of antagonistic, walking, foraging, waving, and burrow enhancement. The frequency of these activities during the observation days were analyzed using Kruskal-Wallis test and no significant differences in terms of the walking (df = 2, H = 2.65, p = 0.266), foraging (df = 2, H = 0.36, p = 0.834),

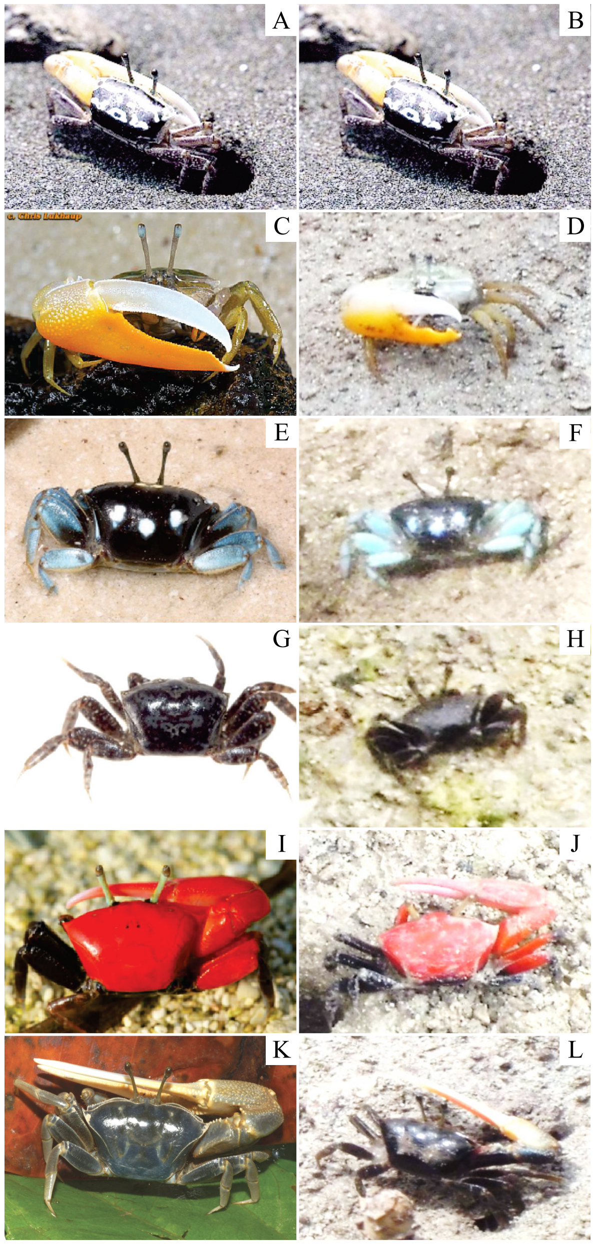

Figure 2. Side by side, comparison of species found in the study area together with published photos from Rosenberg (2014) and their corresponding names. *Austruca annulipes* (Edwards, 1837) (A and B), *Gelasimus vocans* (Linnaeus, 1758) (C and D), *Tubuca capricornis* (Crane, 1975) (E and F), *T. urvillei* (Edwards, 1852) (G and H), *Paraleptuca crassipes* (Adams and White, 1848) (I and J), and *T. alcocki* (Shih, Chan and Ng 2018) (K and L).

antagonistic (df = 2, H = 0.36, p = 0.834) and burrow enhancement activities of the various fiddler crabs (df = 2, H = 5.71, p = 0.058) were detected. Observations were done in three different substrates (muddy, coralline, and sandy substrates) for three days to assess their behaviors. Waving and antagonistic activity were two patterns of activity that only male fiddler crabs were able to perform more actively than female fiddler crabs (Figure 3).

The various behaviors of fiddler crabs observed included courting (waving), defending burrows (antagonistic), and burrow enhancement mostly performed by *Paraleptuca crassipes* (Figure 4 A, D, and E). A waving behavior was usually performed by *Paraleptuca boninensis* (Figure 4 B), while fencing/predation behavior was performed by *Tubuca dussumieri* (Figure 4 C), and foraging behavior was performed by *Tubuca capricornis* (Figure 4 F). In addition, walking was performed by *Gelasimus tangeri* (Figure 4 G), and foraging was also performed by *Paraleptuca chlorophthalmus* (Figure 4 H).

Diet composition

Fiddler crabs were collected to identify their stomach content. Most of stomach samples contained sediment, leaf fragments, and algae. The *post hoc* comparison showed that sediments comprised 34% of stomach contents followed by 12% of chum and 10% of leaf particles. Comparison of sediment contents of stomachs from the various substrates showed no significant differences (df = 2, H = 1.19, p = 0.551), and the same was observed for chum (df = 2, H = 2.17, p = 0.339) and leaf contents (df = 2, H = 1.38, p = 0.501) when compared to those in the sandy, muddy, and coralline area.

Mangrove leaf preference

During the three-day experiment regarding leaf preference of fiddler crabs, the most eaten leaves were the yellow ones with a total count of n = 104. In the muddy substrate, yellow leaves were the most eaten among the three colors (n = 27), while green leaves were the least consumed (n = 23). The highest count of total leaves eaten in the coralline substrate was yellow leaves (n = 37), while brown leaves were the least eaten (n = 21). For the sandy muddy, the highest count of eaten leaves were also yellow leaves (n = 40), while green leaves were also less consumed (n = 29) (Figure 5 A). On the third day of the experiment, some leaves were missing in each station, both green and yellow leaves. In the muddy station, the number of leaves missing for the three colors were the same (2). In coralline areas, yellow leaves had two missing leaves (2) compared to the others, one for the green (1) and none for the brown (0). For sandy areas, green and yellow leaves had the same number of missing leaves (6) while brown leaves had the lowest number (5) (Figure 5 B).

DISCUSSION

Females invested more time feeding and fed 50% faster than males. For example, *Uca vocans* (Rumphius, 1705) was the most dominant fiddler crab species on sandy beaches and was particularly active, feeding at approximately twice the rate of other species (Weis and Weis 2004). Composition of the substrate is also significantly altered by foraging and burrowing activities (Posey 1987) and could affect biological processes like meiofauna reproduction (Ólafsson and Ndaro 1997) and growth of young mangrove plants (Macusi and Tipudan 2021). Foraging activity was the most frequently performed activity by female fiddler crabs compared to males, followed by walking. To increase the size of their arms out of proportion to the growth of their bodies, large male fiddler crabs engage in grabbing and pinching structures. Even crab mating can be utilized

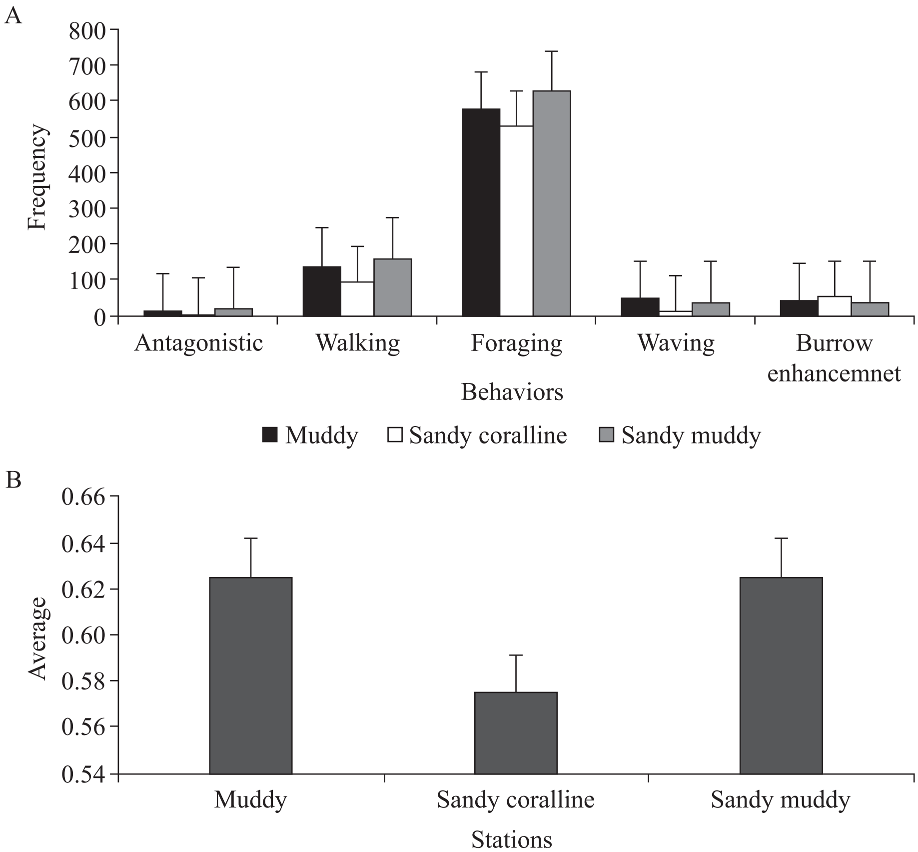

Figure 3. Total count of various behaviors of fiddler crabs observed in the three different substrates (A). Male fiddler crabs performed both antagonistic and waving activities more actively. Percentage of stomach contents of fiddler crabs (B).

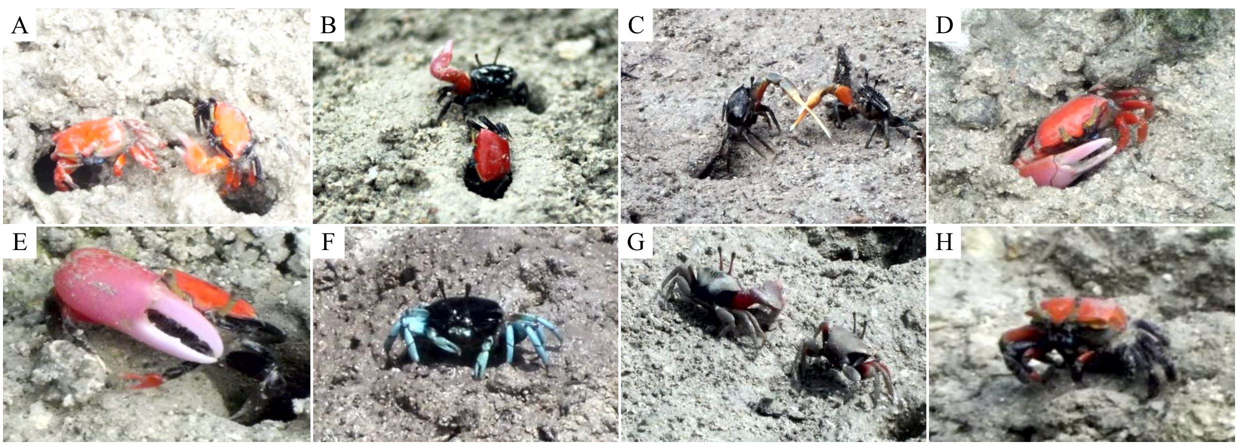

Figure 4. The various behaviors of fiddler crabs displayed in the three stations (muddy, sandy, and coralline). A, D, and E) *Paraleptuca crassipes*. B) *P. boninensis*. C) *Tubuca dussumieri*. F) *T. capricornis*. G) *Gelasimus tangeri*. H) *P. chlorophthalmus*.

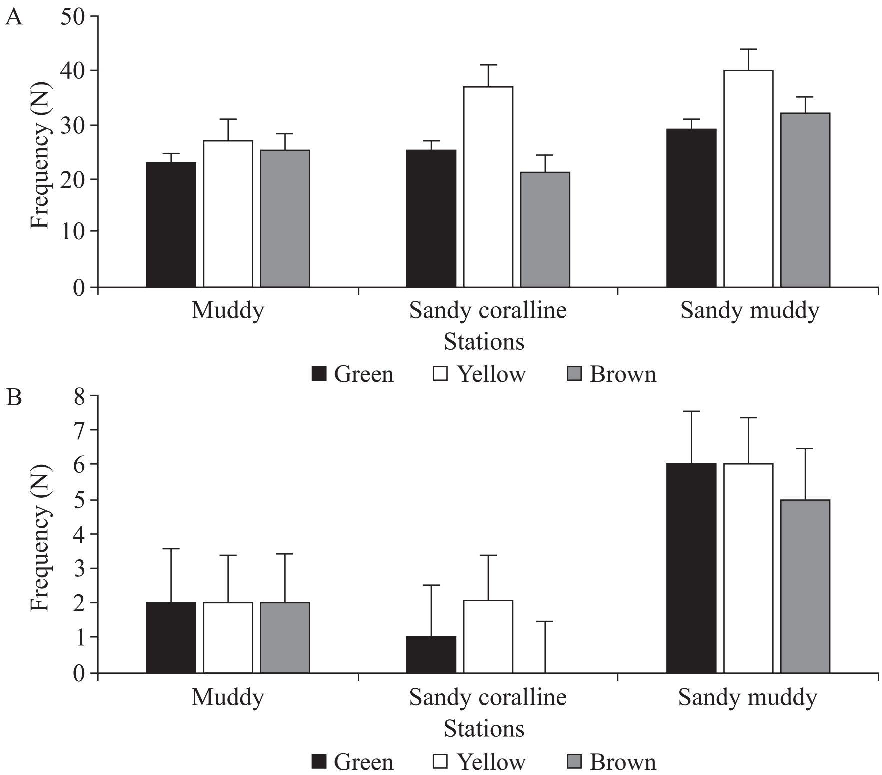

Figure 5. Total count of eaten (A) and missing (B) mangrove leaves.

as a predation technique. Males of 'directing' or 'herding' fiddler crab species trap stressed females between their body and their major claw before pushing and pulling them into burrows (Zucker 1986). The bioturbation carried on by fiddler crabs through burrowing, feeding and ventilation is crucial for coastal wetlands worldwide (Stieglitz et al. 2013; Xiao et al. 2017). Crab burrows become waterlogged occasionally as a result of tidal flushing, which results in material exchange between the burrow water and overlying water across the sediment-water interface (Xie et al. 2019). Burrow flushing creates asymmetric distributions of dissolved oxygen along burrow walls and surrounding sediments, and bioturbation can significantly increase dissolved oxygen uptake (Liu et al. 2019).

Stomach contents of fiddler crabs consisted of sediments, chum, and leaf particles. When observed under the microscope, sediments and chum were consistently more prevalent than leaf particles in the stomach of fiddler crabs. At each station, some leaves were tied near their burrows and after some time they disappeared, while some leaves bore a scratch mark and others were eaten, indicating that leaves were also part of the diet of the species. Since energy is much more readily available in plants than in animals, the low nitrogen concentration of plants can prove to be a significant limiting nutrient for herbivores (Boyd and Goodyear 1971). Although having a greater expected mass and availability than animal meals, plants are less nutrient-dense than those used for food by herbivores (Wolcott and O'Connor 1992).

Mangrove forest sediments contain large numbers of active bacteria (Alongi et al. 2005). These bacterial communities break down organic debris, including leaf litter, and incorporate remineralized nutrients into mangrove sediments, making them available to plants and detritivores (Koch and Wolff 2002). Fiddler crabs, together with other detritivores, consume between 20% and 80% of the carbon from mangrove leaf litter. They are the most active and noticeable detritivores in the mangrove forest (France 1998; Bouillon et al. 2008; Kristensen et al. 2008). By utilizing these resources, detritivores contribute more to the cycling of nutrients in mangrove systems than any other trophic group by mass per unit of time (Koch and Wolff 2002). This concept, however, had been questioned, and even pointed out that partially degraded mangrove leaves are likely insufficient to support crab growth (Bouillon et al. 2004). When gut samples of fiddler crabs were viewed under the microscope and analyzed, 60% of their content was sediment. Fiddler crabs are specialized sediment consumers. They use their mouthparts to extract organic material from the sand or mud sediments. Excess inorganic sediments are later released as tiny pellets, which typically cover the ground near burrows. Because male crabs only have one feeding claw, it is helpful to identify crab species by its gender. Therefore, they feed longer and scoop more quickly than female crabs. After the primary claw reaches a particular size, it becomes useless as a feeding instrument (Moruf and Ojetayo 2017).

CONCLUSIONS

This study was conducted due to the lack of information about the behavior and diet composition of fiddler crabs. Subsequent studies could benefit from additional data collection to better understand their roles in the mangrove ecosystem. Firstly, a similar study involving the recording of digital video cameras for their various behaviors ought to be carried out. Secondly, Rose Bengal staining should have been used to determine the gut contents of the fiddler crabs and additional burrow sampling should have been used to assess the diets of fiddler crabs. Lastly, identifying the species of fiddler crabs could be done at the molecular level.

ACKNOWLEDGEMENT

The authors would like to thank PENRO/CENRO staffs who assisted and allowed the study to be conducted in Guang-guang, Dahican, Mati City. We thank Mr Mike Bersaldo for making the map for this study.

REFERENCES

Abreo NAS, Siblos SVK, Macusi ED. 2020. Anthropogenic Marine Debris (AMD) in Mangrove Forests of Pujada Bay, Davao Oriental, Philippines. J Mar Island Cultures. 9: 38-53.

Alongi DM, Pfitzner J, Trott LA, Tirendi F, Dixon P, Klumpp DW. 2005. Rapid sediment accumulation and microbial mineralization in forests of the mangrove *Kandelia candel* in the Jiulongjiang Estuary, China. Estuar Coast Shelf Sci. 63: 605-618. DOI: https://doi.org/10.1016/j.ecss.2005.01.004

Bergey L, Weis JS. 2006. Immobility in five species of fiddler crabs, genus *Uca*. J Crustac Biol. 26 (1): 82-84. DOI: https://doi.org/10.1651/C-2587.1

Bouillon S, Borges A V, Castan E, Diele K, Dittmar T, Duke NC, Kristensen E, Lee SY, Marchand C, Middelburg JJ, et al. 2008. Mangrove production and carbon sinks: a revision of global budget estimates. Global Biogeochem Cycles. 22: 1-12. DOI: https://doi.org/10.1029/2007GB003052

BOUILLON S, MOENS T, OVERMEER I, KOEDAM N, DEHAIRS F. 2004. Resource utilization patterns of epifauna from mangrove forests with contrasting inputs of local versus imported organic matter. Mar Ecol Prog Ser. 278: 77-88. DOI: https://doi.org/10.3354/meps278077

BOYD CE, GOODYEAR CP. 1971. Nutritive quality of food in ecological systems. Arch für Hydrobiol. 69 (2): 256-270.

DUGAW CJ, HONEYFIELD R, TAYLOR CM. VERZI DW. 2009. Modeling activity rhythms in fiddler crabs. Inf Healthc. 26 (7): 1355-1368. DOI: https://doi.org/10.3109/07420520903421872

FRANCE R. 1998. Estimating the assimilation of mangrove detritus by fiddler crabs in Laguna Joyuda, Puerto Rico, using dual stable isotopes. J Tropical Ecol. 14 (4): 413-425. DOI: https://doi.org/10.1017/S0266467498000315

GRANDE FR DE, COLPO KD, QUEIROGA H, CANNICCI S, COSTA TM. 2018. Contrasting activity patterns at high and low tide in two Brazilian fiddler crabs (Decapoda: Brachyura: Ocypodidae). J Crustac Biol. 38: 407-412. DOI: https://doi.org/10.1093/jcbiol/ruy030

KRISTENSEN E, BOUILLON S, DITTMAR T, MARCHAND C. 2008. Organic carbon dynamics in mangrove ecosystems: a review. 89: 201-219. DOI: https://doi.org/10.1016/j.aquabot.2007.12.005

KOCH V, WOLFF M. 2002. Energy budget and ecological role of mangrove epibenthos in the Caeté estuary, North Brazil. Mar Ecol Prog Ser. 228: 119-130.

LIU J, DIAO Z, XU X, XIE Q, NI Z. 2019. In situ arsenic speciation and the release kinetics in coastal sediments: a case study in Daya Bay, South China Sea. Sci Total Environ. 650: 2221-2230. DOI: https://doi.org/10.1016/j.scitotenv.2018.09.389

MACINTOSH DJ, ASHTON EC, HAVANON S. 2002. Mangrove rehabilitation and intertidal biodiversity: a study in the Ranong mangrove ecosystem, Thailand. Estuar Coast Shelf Sci. 55: 331-345. DOI: https://doi.org/10.1006/ecss.2001.0896

MACUSI ED, TIPUDAN CD. 2021. Effects of bioturbation of fiddler crabs in relation to the growth of mangrove saplings (*Rhizophora apiculata*) in a mangrove reforested area. J Mar Island Cult. 9 (2): 76-85. DOI: https://doi.org/10.21463/jmic.2020.09.2.06

MAUTZ B, DETTO T, WONG BBM, KOKKO H, JENNIONS MD, BACKWELL PRY. 2011. Male fiddler crabs defend multiple burrows to attract additional females. Behav Ecol. 22 (2): 261-267. DOI: https://doi.org/10.1093/beheco/arq207

MORUF O, OJETAYO T. 2017. Biology of the West African fiddler crab, *Uca tangeri* (Eydoux, 1835) (Decapoda: Ocypodidae) from a mangrove wetland in Lagos, Nigeria. Int J Aquat Biol. 5 (4): 263-267.

NAGELKERKEN I, BLABER SJM, BOUILLON S, GREEN P, HAYWOOD M, KIRTON LG, MEYNECKE JO, PAWLIK J, PENROSE HM, SASEKUMAR A, et al. 2008. The habitat function of mangroves for terrestrial and marine fauna: a review. Aquat Bot. 89 (2): 155-185. DOI: https://doi.org/10.1016/j.aquabot.2007.12.007

NORDHAUS I, DIELE K, WOLFF M. 2009. Activity patterns, feeding and burrowing behaviour of the crab *Ucides cordatus* (Ucididae) in a high intertidal mangrove forest in North Brazil. J Exp Mar Biol Ecol. 374 (2): 104-112.

NORDHAUS I, WOLFF M, DIELE K. 2006. Litter processing and population food intake of the mangrove crab *Ucides cordatus* in a high intertidal forest in northern Brazil. Estuar Coast Shelf Sci. 67 (1-2): 239-250. DOI: https://doi.org/10.1016/j.ecss.2005.11.022

ÓLAFSSON E, NDARO SGM. 1997. Impact of the mangrove crabs *Uca annulipes* and *Dotilla fenestrata* on meiobenthos. Mar Ecol Prog Ser. 158 (1): 225-231. DOI: https://doi.org/10.3354/meps158225

POSEY MH. 1987. Influence of relative mobilities on the composition of benthic communities. Mar Ecol Prog Ser. 39: 99-104. DOI: https://

doi.org/10.3354/meps039099

Reinsel KA. 2004. Impact of fiddler crab foraging and tidal inundation on an intertidal sandflat: season-dependent effects in one tidal cycle. J Exp Mar Biol Ecol. 313(1): 1-17. DOI: https://doi.org/10.1016/j.jembe.2004.06.003

Ribeiro PD, Iribarne OO. 2011. Coupling between microphytobenthic biomass and fiddler crab feeding. J Exp Mar Bio Ecol. 407 (2): 147-154. DOI: https://doi.org/10.1016/j.jembe.2011.05.030

Rosenberg MS. 2001. The systematics and taxonomy of fiddler crabs: a phylogeny of the genus *Uca*. J Crustac Biol. 21 (3): 839-869. DOI: https://doi.org/10.1163/20021975-99990176

Rosenberg MS. 2014. Contextual cross-referencing of species names for fiddler crabs (Genus *Uca*): an experiment in cyber-taxonomy. PLoS ONE. 9 (7): e101704. DOI: https://doi.org/10.1371/journal.pone.0101704

Rosenberg MS. 2019. A fresh look at the biodiversity lexicon for fiddler crabs (Decapoda: Brachyura: Ocypodidae). Part 1: taxonomy. J Crustac Biol. 39 (6): 729-738. DOI: https://doi.org/10.1093/jcbiol/ruz057

Sanford, Eric, Holzman, Samuel, Haney, Robert, Rand, David, Bertness M. 2006. Larval tolerance, gene flow, and the northern geographic range limit of fiddler crabs. Ecol Soc Am. 87 (11): 2882-2894.

Shih HT. 2012. Distribution of fiddler crabs in East Asia, with a note on the effect of the Kuroshio Current. Kuroshio Sci. 6 (1): 83-89.

Smith NF, Wilcox C, Lessmann JM. 2009. Fiddler crab burrowing affects growth and production of the white mangrove (*Laguncularia racemosa*) in a restored Florida coastal marsh. Mar Biol. 156: 2256-2266.

Stieglitz TC, Clark JF, Hancock GJ. 2013. The mangrove pump: the tidal flushing of animal burrows in a tropical mangrove forest determined from radionuclide budgets. Geochim Cosmochim Acta. 102: 12-22. DOI: https://doi.org/10.1016/j.gca.2012.10.033

Swanson BO, George MN, Anderson SP, Christy JH. 2013. Evolutionary variation in the mechanics of fiddler crab claws. BMC Evol Biol. 13: 137.

Weis JS, Weis P. 2004. Behavior of four species of fiddler crabs, genus *Uca*, in southeast Sulawesi, Indonesia. Hydrobiologia. 523 (1-3): 47-58. DOI: https://doi.org/10.1023/B:HYDR.0000033093.84155.1d

Wolcott DL, O'Connor NJ. 1992. Herbivory in crabs: adaptations and ecological considerations. Integr Comp Biol. 32 (3): 370-381. DOI: https://doi.org/10.1093/icb/32.3.370

Xiao K, Li H, Wilson AM, Xia Y, Wan L. Zheng C, Ma Q, Wang C, Wang X, Jiang X. 2017. Tidal groundwater flow and its ecological effects in a brackish marsh at the mouth of a large sub-tropical river. J Hydrol. 555: 198-212. DOI: https://doi.org/10.1016/j.jhydrol.2017.10.025

Xie M, Simpson SL, Wang WX. 2019. Bioturbation effects on metal release from contaminated sediments. Environ Pollut. 250: 87-96. DOI: https://doi.org/10.1016/j.envpol.2019.04.003

Zeil J, Hemmi JM. 2006. The visual ecology of fiddler crabs. J Comp Physiol. 192: 1-25. DOI: https://doi.org/10.1007/s00359-005-0048-7

Zeil J, Hemmi JM, Backwell PRY. 2006. Quick guide fiddler crabs. Current Biol. 16 (2): 40-41.

Zucker N. 1986. On courtship patterns and the size at which male fiddler crabs (genus *Uca*) begin to court. Bull Mar Sci. 38 (2): 384-388.