Nauplius
The Journal of The Brazilian Crustacean Society

e-ISSN 2358-2936
www.scielo.br/nau
www.crustacea.org.br

Short Communication

The burrow structure of *Minuca osa* (Brachyura: Ocypodidae) from the eastern Montijo Gulf, Panamanian Pacific

Roberto C. Lombardo[1,2,3]

1 Sistema Nacional de Investigación (SNI), SENACYT Ciudad del Saber. Provincia de Panamá, Panamá.

2 Centro de Capacitación, Investigación y Monitoreo de la Biodiversidad (CCIMBIO). Provincia de Veraguas, Panamá

3 Universidad de Panamá, Departamento de Biología Marina y Limnología, Centro Regional Universitario de Veraguas. Provincia de Veraguas, Panamá

RCL email: roberto.lombardo@up.ac.pa

ZOOBANK: http://zoobank.org:pub:5659A205-FA76-457F-8330-8F7C6C2E5FAF

ABSTRACT

Between November 2022 and March 2023, thirty-seven *Minuca osa* burrow plaster casts were poured while simultaneously collecting biometric data of the occupants in Ponuga, eastern Montijo Gulf, Panamanian Pacific. Casts revealed a highly variable structure with straight and spiral sections, reaching depths down to 122 cm (mean ± SD = 73.20 ± 28.66 cm). Burrow depth and length did not differ between sexes; however, males exhibited larger burrow diameter (25.9 ± 4.61 mm) compared to females (19.48 ± 1.65 mm; Mann-Whitney, $P < 0.001$). Male carapace width (23.4 ± 2.15 mm) surpassed that of females (18.42 ± 1.73 mm; Mann-Whitney, $P < 0.001$). Female carapace length ($r^2 = 0.793$) and male chela length ($r^2 = 0.769$) were correlated to diameter. This study presents the first description of *M. osa* burrow structure, providing valuable insights into this understudied species.

KEYWORDS

Burrow diameter, carapace, fiddler crabs, mangrove, plaster cast, water table

Due to their burrowing activity, fiddler crabs play a crucial role in sediment mixing and bioturbation, with substantial implications for various soil physicochemical processes, thereby influencing a diverse array of species (Kristensen, 2008; Aschenbroich et al., 2016; Agusto et al., 2021). In general, fiddler crab burrows are an essential resource that serves as refuge from predators, a source of water during low tide, and a site for reproduction (Mautz et al., 2011; Pardo et al., 2020).

Minuca osa (Landstorfer and Schubart, 2010) is a burrow-building fiddler crab species. It was originally described in Golfo Dulce on the Pacific coast of Costa Rica (Landstorfer and Schubart, 2010) and recently

Corresponding Author
Roberto Lombardo
roberto.lombardo@up.ac.pa

Submitted 04 June 2023
Accepted 09 April 2024
Published 24 February 2025

DOI 10.1590/2358-2936e20250519

reported in the Ponuga River, Panamanian Pacific (Lombardo, 2022). Observations indicate that *M. osa* constructs burrows in high-mangrove areas with sandy-muddy sediments. These are maintained and defended by the resident crabs (Lombardo, 2023). While burrow structure has been studied in different fiddler crab species (see Qureshi and Saher, 2012; Sen and Homechaudhuri, 2016; Chen et al., 2017; Min et al., 2023), the internal structure of *M. osa* burrows remains unknown. Thus, the objective of this study was to examine the structure of *M. osa* burrows using replica casting techniques to characterize their features.

The study site is located in the Ponuga River (07°51'51"N 81°0'52"W) in Veraguas, Panamanian Pacific. During rainy season (April–December), the substrate is covered by the highest monthly tides and sequentially exposed during low tide. During the dry season (January–April), the river level drops and flooding is infrequent (Lombardo, 2022; 2023). From November 2022 to March 2023, 27 focal males and 10 females were selected using binoculars (Bushnell 10×42 mm). Focal individuals were identified by their size and coloration (Lombardo, 2022: fig. 1b, c), as well as their digging activity. Observation of *M. osa* individuals coincided with diurnal ebbing tides to facilitate burrow ownership assessment while crabs first emerged. The casting mixture consisted of plaster gypsum and water in a 1:0.5 ratio. The mixture was poured slowly, ensuring it filled the burrow completely, forming a solid cast, without voids. During pouring of the plaster mixture, any crabs attempting to escape from the burrow were captured by hand. Crab carapace width (CW), length (CL), chela length (ChL), height (ChH), and total weight (TW) were measured using a Vernier caliper (0.01 mm) and a digital scale (0.01g). Processed crabs were kept for reference in 4% formaldehyde solution, and burrow casts were left to cure for four days. During cast excavation, soil profiles were exposed, allowing the cast to rest on the sediment. Soil profile details such as the total burrow depth (TBD) and water table depth (WTD) were inspected and recorded. In the lab, the burrow length (BL) was registered with a flexible measure tape. As diameter within casts varied along their length, the site for

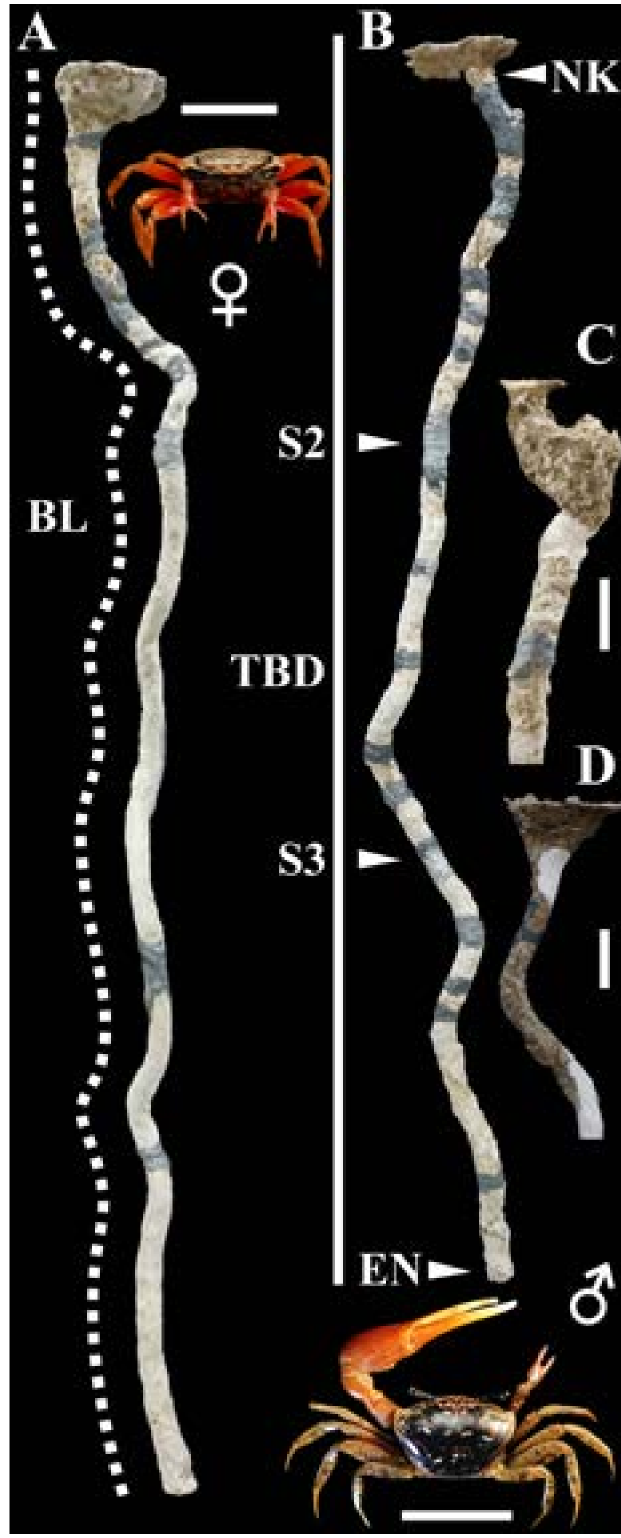

Figure 1. *Minuca osa* burrow structure from Ponuga, Veraguas, Panama. **A**. Female burrow length (BL; dotted line, 97 cm). **B**. Male total burrow depth (TBD, solid vertical bar, 104 cm). Sections: neck = NK, second S2 and third S3 sections, and end = EN. **C**, **D**. Detail of male burrow variation with chamber (scale = 55 mm) and funnel shape (scale = 60 mm). Male and female crab scale bars are 20 mm and 15 mm, respectively.

measuring diameter was standardized by dividing each cast into four segments according to their BL (neck = NK, second and third sections = S2 and S3, and end = EN; Fig. 1). Burrow morphology was compared based on sex, size, and rainy (Nov–Dec) versus dry (Jan–Mar) seasons using the Mann-Whitney and Moods median tests, while simple regression was applied to explore the relationships between burrow diameter, WTD, TBD, BL, and crab biometrics.

Seven male and two female burrow casts were unrecoverable, and one male and one female could not be captured for biometry. Twenty-six complete burrow casts revealed a structure with straight and spiral sections, reaching depths down to 122 cm. Burrow depth and water table depth were positively correlated in both sexes (♂, $r^2 = 0.964$, $F_{(1,12)} = 350.92$, $P < 0.001$; ♀, $r^2 = 0.954$, $F_{(1,4)} = 104.53$, $P = 0.001$). The males exhibited greater size and weight compared to females (Tab. 1). There was no statistical difference among burrow section diameters (Moods median test, d.f. = 3, $\chi^2 = 4.80$, $P = 0.187$); however, male burrow cast sections NK, S2, and S3 exhibited wider diameters compared to the females. In the dry season, the water table was farther away from the surface (dry = 93 cm, rainy = 72 cm, $U = 108$, $P = 0.004$), and the burrows were deeper compared to the rainy season (dry = 92 cm, rainy = 59 cm, $U = 122.5$, $P = 0.028$); no differences between medians were detected in the rest of the burrow features versus season. In contrast, there was no difference in WTD, TBD, BL, or EN between male and female burrows (Tab. 2). Five male biometric variables demonstrated a positive correlation with cast diameter (S2 and NK). Among the females, only CW and CL exhibited significant association with burrow diameter S2 (Fig. 2). Biometric variables showed no discernible correlations with WTD, TBD, or BL (Tab. 3).

Table 1. Descriptive statistics and comparison of biometric variables between sexes in *Minuca osa* from Ponuga, Veraguas, Panamanian Pacific. Carapace width (CW), length (CL), chela length (ChL), height (ChH), and total weight (TW). All measurements are reported in millimeters, except for total weight (TW) which is reported in grams.

Biometric variable	♂ Median ± SD Min.–Max.	♀ Median ± SD Min.–Max.	Mann-Whitney test
CW	22.99 ± 1.99; 18.64–27.61	18.84 ± 1.31; 17.02–20.95	U = 342, P = 0.001
CL	15.45 ± 1.07; 13.09–17.51	13.21 ± 0.74; 12.63–14.84	U = 260, P = 0.003
TW	5.76 ± 1.29; 2.91–8.14	2.73 ± 0.45; 2.10–3.33	U = 270, P < 0.001
ChL	35.44 ± 6.47; 19.51–43.56		
ChH	12.85 ± 1.32; 8.71–15.08		

Table 2. Comparison of burrow features between male and female *Minuca osa* from Ponuga, Veraguas, Panamanian Pacific. Water table depth (WTD), total burrow depth (TBD), burrow length (BL), burrow diameters: neck (NE), second section diameter (S2), third section diameter (S3), and end diameter (EN). Depth and length are given in centimeters, while diameter is in millimeters.

Burrow features	♂ Median ± SD Min.–Max.	♀ Median ± SD Min.–Max.	Mann-Whitney test
WTD	80.3 ± 23.95; 18–120	81.75 ± 29.02; 30–115	U = 286, P = 0.859
TBD	74.6 ± 28.06; 18–122	67.3 ± 32.44; 27.80–114	U = 304.5, P = 0.476
BL	79.47 ± 29.03; 24.1–119.4	69.71 ± 34.05; 24.5–113.2	U = 303, P = 0.525
NE	27.18 ± 5.72; 15.95–40.19	20.08 ± 2.36; 17.3–24.61	U = 352, P = 0.002
S2	25.9 ± 4.61; 19.38–35.23	19.48 ± 1.65; 16.93–22.06	U = 360.5, P < 0.001
S3	26.23 ± 6.45; 17.83–39.27	20.04 ± 4.26; 15.04–27.56	U = 338, P = 0.016
EN	24.13 ± 5.32; 13.72–34.23	21.83 ± 2.55; 18.69–25.58	U = 313, P = 0.252

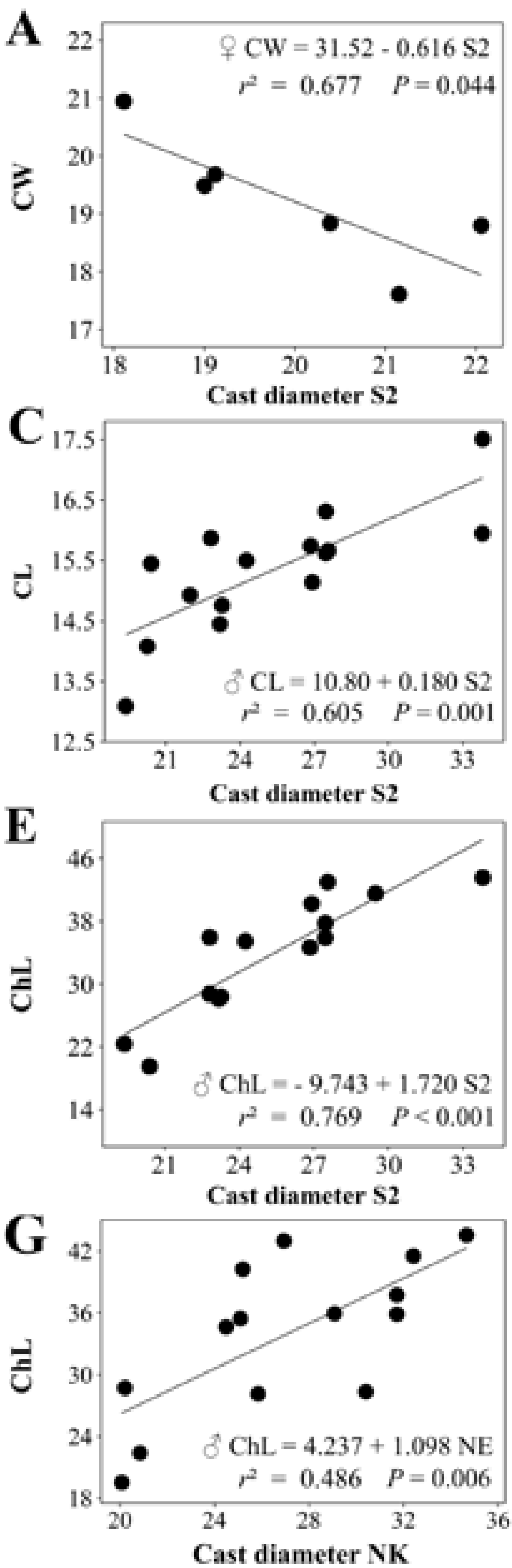

Figure 2. Relationship between biometrical variables and burrow cast diameters of *Minuca osa* from Ponuga, Veraguas, Panama. **A**, **B**. Female and **C**–**G**. Male regressions. Burrow neck diameter (NK) and second section diameter (S2). Carapace width (CW), length (CL), chela length (ChL), height (ChH), and total weight (TW). All measurements are given in millimeters, except for total weight (TW), which is reported in grams.

Table 3. Relationships between burrow features and the biometry of male and female *Minuca osa* from Ponuga, Veraguas, Panamanian Pacific. Water table depth (WTD), total burrow depth (TBD), burrow length (BL), burrow diameters: neck (NK), second section diameter (S2), third section diameter (S3), and end diameter (EN). Carapace width (CW), length (CL), chela length (ChL), height (ChH), and total weight (TW).

Burrow features	Biometrics							
	♂CW	♂CL	♂ChL	♂ChH	♂TW	♀CW	♀CL	♀TW
WTD	$r^2 = 0.2678$ $F_{(1,7)} = 2.56$ $P = 0.154$	$r^2 = 0.0502$ $F_{(1,13)} = 0.69$ $P = 0.422$	$r^2 = 0.210$ $F_{(1,12)} = 3.19$ $P = 0.099$	$r^2 = 0.072$ $F_{(1,12)} = 0.94$ $P = 0.352$	$r^2 = 0.2112$ $F_{(1,12)} = 3.21$ $P = 0.098$	$r^2 = 0.0378$ $F_{(1,4)} = 0.16$ $P = 0.712$	$r^2 = 0.033$ $F_{(1,4)} = 0.01$ $P = 0.913$	$r^2 = 0.1984$ $F_{(1,4)} = 0.99$ $P = 0.376$
TBD	$r^2 = 0.2806$ $F_{(1,7)} = 2.73$ $P = 0.142$	$r^2 = 0.1755$ $F_{(1,13)} = 2.77$ $P = 0.120$	$r^2 = 0.1838$ $F_{(1,12)} = 2.70$ $P = 0.126$	$r^2 = 0.1119$ $F_{(1,12)} = 1.51$ $P = 0.242$	$r^2 = 0.3943$ $F_{(1,12)} = 7.81$ $P = 0.016$	$r^2 = 0.2373$ $F_{(1,4)} = 1.24$ $P = 0.327$	$r^2 = 0.1474$ $F_{(1,4)} = 0.69$ $P = 0.452$	$r^2 = 0.00$ $F_{(1,4)} = 0.00$ $P = 1.00$
BL	$r^2 = 0.3056$ $F_{(1,7)} = 3.08$ $P = 0.123$	$r^2 = 0.2207$ $F_{(1,13)} = 3.68$ $P = 0.077$	$r^2 = 0.2283$ $F_{(1,12)} = 3.55$ $P = 0.084$	$r^2 = 0.2206$ $F_{(1,12)} = 3.40$ $P = 0.090$	$r^2 = 0.4219$ $F_{(1,12)} = 8.76$ $P = 0.012$	$r^2 = 0.2880$ $F_{(1,4)} = 1.62$ $P = 0.272$	$r^2 = 0.2086$ $F_{(1,4)} = 1.05$ $P = 0.363$	$r^2 = 0.049$ $F_{(1,4)} = 0.02$ $P = 0.895$
NK	$r^2 = 0.0136$ $F_{(1,7)} = 0.10$ $P = 0.765$	$r^2 = 0.3652$ $F_{(1,13)} = 7.48$ $P = 0.017$	$r^2 = 0.4858$ $F_{(1,12)} = 11.34$ **$P = 0.006$***	$r^2 = 0.4307$ $F_{(1,12)} = 9.08$ $P = 0.011$	$r^2 = 0.3634$ $F_{(1,12)} = 6.85$ $P = 0.002$	$r^2 = 0.0469$ $F_{(1,4)} = 0.20$ $P = 0.680$	$r^2 = 0.014$ $F_{(1,4)} = 0.01$ $P = 0.945$	$r^2 = 0.1780$ $F_{(1,4)} = 0.87$ $P = 0.405$
S2	$r^2 = 0.4342$ $F_{(1,10)} = 7.67$ $P = 0.020$	$r^2 = 0.6050$ $F_{(1,13)} = 19.91$ **$P = 0.001$***	$r^2 = 0.7689$ $F_{(1,12)} = 39.92$ **$P < 0.001$***	$r^2 = 0.5773$ $F_{(1,12)} = 16.39$ **$P = 0.002$***	$r^2 = 0.7358$ $F_{(1,12)} = 33.43$ **$P < 0.001$***	$r^2 = 0.6770$ $F_{(1,4)} = 8.38$ **$P = 0.044$***	$r^2 = 0.7929$ $F_{(1,4)} = 15.32$ **$P = 0.017$***	$r^2 = 0.4565$ $F_{(1,4)} = 3.36$ $P = 0.141$
S3	$r^2 = 0.1606$ $F_{(1,7)} = 1.34$ $P = 0.285$	$r^2 = 0.2711$ $F_{(1,13)} = 4.83$ $P = 0.047$	$r^2 = 0.3023$ $F_{(1,12)} = 5.20$ $P = 0.042$	$r^2 = 0.2059$ $F_{(1,12)} = 3.11$ $P = 0.103$	$r^2 = 0.3218$ $F_{(1,12)} = 5.69$ $P = 0.034$	$r^2 = 0.1199$ $F_{(1,4)} = 0.54$ $P = 0.501$	$r^2 = 0.2241$ $F_{(1,4)} = 1.16$ $P = 0.343$	$r^2 = 0.0190$ $F_{(1,4)} = 0.08$ $P = 0.794$
EN	$r^2 = 0.260$ $F_{(1,7)} = 0.02$ $P = 0.896$	$r^2 = 0.1427$ $F_{(1,13)} = 2.16$ $P = 0.165$	$r^2 = 0.0149$ $F_{(1,12)} = 0.18$ $P = 0.678$	$r^2 = 0.1192$ $F_{(1,12)} = 1.62$ $P = 0.227$	$r^2 = 0.076$ $F_{(1,12)} = 0.99$ $P = 0.339$	$r^2 = 0.020$ $F_{(1,4)} = 0.00$ $P = 0.979$	$r^2 = 0.0816$ $F_{(1,4)} = 0.36$ $P = 0.583$	$r^2 = 0.001$ $F_{(1,4)} = 0.00$ $P = 0.985$

The size of crabs is typically proportional to the depth and size of their burrows, with larger crabs constructing larger and more spacious burrows (Ens et al., 1993; Lim and Diong, 2004; Qureshi and Saher, 2012). This correlation might not hold entirely in *M. osa* because WTD, TBD, and BL seem independent of crab size and sex. Contrastingly, wider burrow diameter has been attributed to the larger carapace length to width ratios, implying such crabs require wider burrows for comfortable movement (Lim, 2006; Qureshi and Saher, 2012). Mangrove and floodplain tree root biomass decreases with soil depth. This is especially relevant since burrow segments NE and S2 are located in the upper soil layers where roots are abundant. Crabs likely adapt to such root obstacles by excavating tunnels with acute-angle turns (Dembowski, 1926; Lim and Diong, 2004); thus, a large asymmetrical claw would require wider tunnels to pass through. This seems to be the case in *M. osa*, particularly in male crabs, where the relationship between ChL and burrow diameter (S2) was strongest.

The moisture content of the substrate influences the depth of burrows (Dembowski, 1926) and said moisture is dependent on rain, tides and water table dynamics (Laio et al., 2009). The correlation between BL and WTD, as well as the similarities in WTD, TBD, and BL between male and female *M. osa*, emphasize the importance of accessing water to prevent desiccation (Thurman, 1998; Yoder et al., 2005). This is in line with *M. osa* adaptive behavior in response to variation in WTD, resulting in burrow depth variability between rainy and dry seasons. Similar behavior has been reported in other fiddler crabs, for example, in tidal flats with shallow WTD, crabs dig burrows 10–40 cm deep. This behavior may prevent unnecessary energy expenditure on further excavation (Kristensen, 2008; Chen et al., 2017). In contrast, when confronted with increasing WTD and greater distances from the water source, fiddler crabs tend to construct deeper burrows, 90–180 cm (Thurman, 1984; Klaassen and Ens, 1993; Chen et al., 2017; Tina et al., 2017). This behavior, possibly aimed at mitigating desiccation, provides a plausible explanation for the deep burrows constructed by *M. osa*, particularly in this site, where the WTD reached depths of 120 cm.

This is the first study describing the burrow structure of *M.* osa, where relationships were found between burrow diameter and crab phenotypic traits under sexual selection. Interestingly, burrow depth and length appear independent of crab size and sex, providing valuable insights for future research on the response to environmental fluctuation in this understudied species.

ACKNOWLEDGEMENTS

Our gratitude goes to Arilis Peralta and Héctor Santos for their assistance during field work. We also thank the anonymous reviewers for their comments to improve the manuscript.

REFERENCES

Agusto LE; Fratini S; Jimenez PJ; Quadros A and Cannicci S 2021. Structural characteristics of crab burrows in Hong Kong mangrove forests and their role in ecosystem engineering. *Estuarine, Coastal and Shelf Science*, 248: 106973. https://doi.org/10.1016/j.ecss.2020.106973.

Aschenbroich A; Michaud E; Stieglitz T; Fromard F; Gardel A; Tavares M and Thouzeau G 2016. Brachyuran crab community structure and associated sediment reworking activities in pioneer and young mangroves of French Guiana, South America. *Estuarine, Coastal and Shelf Science*, 182: 60–71. https://doi.org/10.1016/J.ECSS.2016.09.003.

Chen TY; Hwang GW; Mayfield AB; Chen CP and Lin HJ 2017. The relationship between intertidal soil composition and fiddler crab burrow depth. *Ecological Engineering*, 100: 256–260. https://doi.org/10.1016/j.ecoleng.2016.12.011.

Dembowski JB 1926. Notes on the behavior of the fiddler crab. *The Biological Bulletin*, 50(3): 179–201. https://doi.org/10.2307/1536668.

Ens BJ; Klaassen M and Zwarts L 1993. Flocking and feeding in the fiddler crab (*Uca tangeri*): Prey availability as risk-taking behaviour. *Netherlands Journal of Sea Research*, 31(4): 477–494. https://doi.org/10.1016/0077-7579(93)90060-6

Klaassen M and Ens BJ 1993. Habitat selection and energetics of the fiddler crab (*Uca tangeri*). *Netherlands Journal of Sea Research*, 31(4): 495–502. https://doi.org/10.1016/0077-7579(93)90061-V.

Kristensen E 2008. Mangrove crabs as ecosystem engineers; with emphasis on sediment processes. *Journal of Sea Research*, 59(1–2): 30–43. https://doi.org/10.1016/j.seares.2007.05.004.

Laio F; Tamea S; Ridolfi L; D'Odorico P and Rodriguez-Iturbe I 2009. Ecohydrology of groundwater-dependent ecosystems: 1. Stochastic water table dynamics. *Water Resources Research*, 45(5): W05419. https://doi.org/10.1029/2008WR007292.

Landstorfer RB and Schubart CD 2010. A phylogeny of Pacific fiddler crabs of the subgenus *Minuca* (Crustacea, Brachyura, Ocypodidae: *Uca*) with the description of a new species from a tropical gulf in Pacific Costa Rica. *Journal of Zoological Systematics and Evolutionary Research*, 48(3): 213–218. https://doi.org/10.1111/j.1439-0469.2009.00554.x.

Lim SSL 2006. Fiddler crab burrow morphology: How do burrow dimensions and bioturbative activities compare in sympatric populations of *Uca vocans* (Linnaeus, 1758) and *U. annulipes* (H. Milne Edwards, 1837)? *Crustaceana*, 79(5): 525–540. https://doi.org/10.1163/156854006777584241.

Lim SSL and Diong CH 2004. Burrow-morphological characters of the fiddler crab, *Uca annulipes* (H. Milne Edwards, 1837) and ecological correlates in a lagoonal beach on Pulau Hantu, Singapore. *Crustaceana*, 76(9): 1055–1069. https://doi.org/10.1163/156854003322753411.

Lombardo RC 2022. First record of the fiddler crab, *Minuca osa* from the eastern Montijo Gulf, Panama. *Revista Ciencias Marinas y Costeras*, 14(2): 27–35. https://doi.org/10.15359/revmar.14-2.2.

Lombardo RC 2023. Behavior and activity pattern of *Minuca osa* (Brachyura: Ocypodidae) from Ponuga, Veraguas, Panama. *Biología, Ciencia y Tecnología*, 16: 1194–1210. https://doi.org/10.22201/fesi.20072082e.2023.16.85678.

Mautz B; Detto T; Wong BBM; Kokko H; Jennions MD and Backwell PRY 2011. Male fiddler crabs defend multiple burrows to attract additional females. *Behavioral Ecology*, 22(2): 261–267. https://doi.org/10.1093/beheco/arq207.

Min WW; Kandasamy K and Balakrishnan B 2023. Crab species-specific excavation and architecture of burrows in restored mangrove habitat. *Journal of Marine Science and Engineering*, 11(2): 310. https://doi.org/10.3390/jmse11020310.

Pardo JCF; Stefanelli-Silva G; Christy JH and Costa TM 2020. Fiddler crabs and their above-ground sedimentary structures: a review. *Journal of Ethology*, 38(2): 137–154. https://doi.org/10.1007/s10164-020-00647-1.

Qureshi NA and Saher NU 2012. Burrow morphology of three species of fiddler crab (*Uca*) along the coast of Pakistan. *Belgian Journal of Zoology*, 142(2): 114–126. https://doi.org/10.26496/bjz.2012.152

Sen S and Homechaudhuri S 2016. Comparative burrow architectures of resident fiddler crabs (Ocypodidae) in Indian Sundarban mangroves to assess their suitability as bioturbating agents. *Proceedings of the Zoological Society*, 71(1): 17–24. https://doi.org/10.1007/s12595-016-0178-7.

Thurman CL 1984. Ecological notes on fiddler crabs of south Texas, with special reference to *Uca subcylindrica*. *Journal of Crustacean Biology*, 4(4): 665–681. https://doi.org/10.2307/1548080.

Thurman CL 1998. Evaporative water loss, corporal temperature and the distribution of sympatric fiddler crabs (*Uca*) from south Texas. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 119(1): 279–286. https://doi.org/10.1016/S1095-6433(97)00424-8.

Tina FW; Jaroensutasinee M and Jaroensutasinee K 2017. Burrow excavation and mudballing behaviour of the fiddler crab *Uca annulipes* (H. Milne Edwards, 1837) from southern Thailand. *Crustaceana*, 90(6): 735–743. https://doi.org/10.1163/15685403-00003694.

Yoder JA; Reinsel KA; Welch JM; Clifford DM and Rellinger EJ 2005. Herding limits water loss in the sand fiddler crab, *Uca pugilator*. *Journal of Crustacean Biology*, 25(1): 141–145. https://doi.org/10.1651/C-2517.

ADDITIONAL INFORMATION AND DECLARATIONS

Competing interests

There are no competing interests to declare.

Data availability

All data generated and analyzed during this study are presented in this article.

Funding and grant disclosures

There were no external funding sources for this study.

Study association

The research presented here was not part of the acquisition of an academic degree.

Study permits

The methods were compliant with Panamanian law.