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BURROWS ARCHITECTURE OF THE CRAB *Ucides cordatus* (LINNAEUS, 1763) (CRUSTACEA, DECAPODA, UCIDIDAE) IN A MANGROVE SWAMP OF BRAZIL

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ABSTRACT

In mangrove forests, several species of crabs dig and keep burrows in the sediment. Among them, stands out *Ucides cordatus* (Linnaeus, 1763). The aim of this study was to describe the architecture of burrows of *U. cordatus* at the mangrove around the Mundaú/Manguaba Lagunar Complex (CELMM), Northeast Brazil. A total of 735 galleries were opened and grouped into five categories, taking into account the number of openings and dead-ends. Length varied from 10 to 144 cm (70.2 ± 30.9 cm). Each crab usually occupies its own burrow, and covers the openings with mud for the high tide periods. Many built their burrows around mangrove trees and their roots for protection. Burrows diminish the effect of extreme temperatures and serve as water reservoirs, allowing regular immersion to humidify the gill chambers.

Keywords: Brachyura, ecosystem engineers, burrowing organisms, Alagoas State.

RESUMO

Em florestas de manguezais, várias espécies de caranguejos cavam e mantem tocas no sedimento. Entre elas, destaca-se *Ucides cordatus* (Linnaeus, 1763). O objetivo desse estudo foi descrever a arquitetura das tocas de *U. cordatus* no manguezal ao redor do Complexo Estuarino Lagunar Mundaú/Manguaba (CELMM), Alagoas, nordeste do Brasil. Um total de 735 galerias foram abertas e agrupadas em cinco categorias, levando em conta o número de abertura e fundo-cego. O comprimento variou de 10 a 144 cm (70,2 ± 30,9 cm). Cada caranguejo usualmente ocupa sua própria toca, e fecha a abertura com lama durante a maré alta. Muitos constroem suas tocas ao redor das árvores de manguezal e suas raízes para proteção. Tocas diminuem o efeito de temperaturas extremas e servem como reservatórios de água, permitindo a imersão regular para umedecer as câmaras branquiais.

Palavras-chave: Brachyura, engenheiros de ecossistema, organismos escavadores, Estado de Alagoas.

INTRODUCTION

In mangrove forests, the macrozoobenthos is dominated by several species of decapods, standing out the Sesarmidae and Ocypodoidea crabs. These herbivores recycle litter and microalgae mats by retaining, burying and ingesting them (EMMERSON; MCGWYNNE, 1992; KRISTENSEN, 2008). With these activities, such organisms prevent nutrients loss and promote decomposition. Moreover, they dig and keep burrows in the sediment to serve as refuges when environmental conditions at the sediment surface are unfavorable or from predators. In many occasions, burrows also provide food storage places (GIDDINS et al., 1986; DITTMANN, 1996; KRISTENSEN, 2008) and are fundamental to many intra- and interspecific interactions, including the choice of reproductive areas (BLISS et al., 1978) and parental care (GOSHIMA; KOGA; MURAI,

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1996).

An important ecological feature is how burrows affect the substratum topography and composition by altering the particle size distribution, drainage and organic matter, and availability of nutrients (BOTTO; IRIBARNE, 2000). Thus, crabs are responsible for creating much of the visible topographic features that are typical for mangroves soil profiles (WARREN; UNDERWOOD, 1986), being considered ecosystem engineers.

According to Jones; Lawton; Shachak (1994, 1997), physical ecosystem engineers are organisms that modify, create or sustain habitats by causing changes to the physical state of biotic and abiotic elements that inflect resources availability for organisms, either directly or indirectly. The burrowing activity of crabs, for example, increases the productivity of some swamps, marshes and mangroves (SMITH et al., 1991).

Among the Ocypodoidea that burrows in the intertidal zone of mangroves, *Ucides cordatus* (Linnaeus, 1763) (Ucididae) is highlighted. It is popularly known as 'caranguejo-uçá' or true crab. According to Melo (1996), this crab constructs wide and relatively shallow burrows in wetland environments of brackish water, between the roots of mangrove trees.

Although there are some studies that mention the physical, chemical and geological features of burrows, such as temperature, salinity of water in the interior and location in the mangrove (OLIVEIRA, 1950), substrate texture (COELHO et al., 2004), depth (IVO; GESTEIRA, 1999), number (PINHEIRO; FISCARELLI, 2001) and diameter of openings (SANTOS; PINHEIRO; HATTORI, 2009), as well as the burrowing behavior (NORDHAUS; DIELE; WOLFF, 2009), the morphotypes of galleries built by *U. cordatus* were never elucidated. The aim of this study was to survey and describe the different types of burrows architecture constructed by this crab in a tropical mangrove forest, at South American coast.

STUDY AREA

The Mundaú/Manguaba Lagunar Complex (CELMM) is a tropical estuary at the Brazilian coast, formed by two large coastal lagoons: Mundaú and Manguaba (Figure 1). These are interconnected by canals, and converge to a single inlet. It is the most important estuarine complex of the state of Alagoas (35°42'30", 35°57'30"W and 9°35'00", 9°45'00"S), and one of the most important of the Northeast Brazil. According to Andrade; Lins (1970), the region shows two well defined seasons, the rainy season (March to August) and the dry season (September to February).

MATERIAL AND METHODS

The same burrows opened by Araújo; Calado (2008) for *U. cordatus* population studies had their architectures drawn. In that study, the samplings were accomplished through the 'braceamento' technique, where a fisherman introduces his arm in the burrow of the crab until he finds the animal, which is manually removed. Between August/2005 and July/2006, the illustrations were taken to the field, and in a spreadsheet the burrow architecture and length, the sex and number of inhabitants per burrow were noted. The openings were checked to see whereas there was sedimentary structure, tracks, or mud plugs. Water samples from burrows and from the main creek were collected with plastic bottles for salinity determination. Temperature from burrows and main creek water, and air were also obtained. The texture of the sediment was observed and classified as sandy, muddy sand, and muddy.

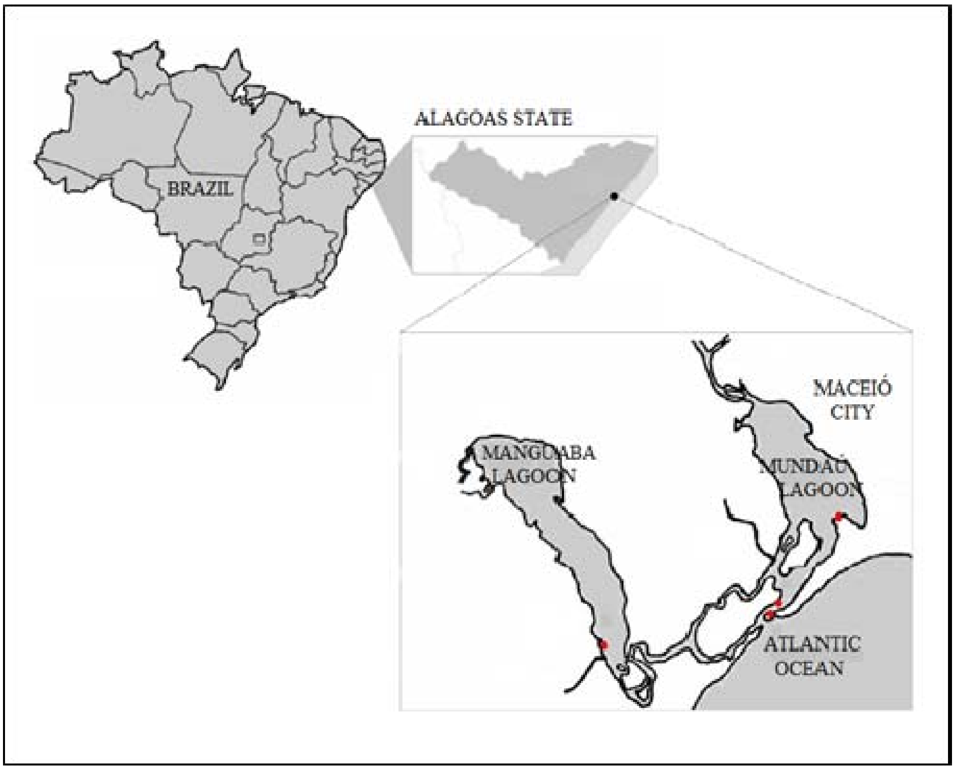

Figure 1 – Map of the sampling area, the Mundaú/Manguaba Lagunar Complex, Alagoas State, Brazil.

The burrows with similar morphology were grouped into categories that took into account the number of openings and dead-ends. A one way analysis of variance (ANOVA) was applied to compare the salinity between burrows and main creek water, the temperature among burrows, main creek water and air, each of these abiotic parameters between rainy and dry periods, and lengths of burrows between males and females. When the ANOVA indicated significant differences, the Bonferroni *a posteriori* test was applied. In the cases where data was heterocedastic, the Kruskal-Wallis non-parametric analysis was applied, followed by Student-Newman-Keuls *a posteriori* test. All statistical tests were performed at α =0.05.

RESULTS

Abiotic data

Water temperature in the burrows ranged from 24 to 32°C (mean±sd: 28.3±2.0°C). In the main creek it ranged from 24 to 38°C (29.2±2.6°C). Air temperature in the mangrove ranged from 22 to 38°C (29.2±2.8°C). These values varied throughout the sampling year (Fig. 2), and significant differences between rainy and dry periods were detected (p < 0.05). No significant difference among the water temperature of the burrows, main creek and air was detected (p = 0.15). However, the annual amplitude of the burrows temperature (8°C) was lower than the annual amplitude of the main creek (14°C) and air temperature (16°C). Besides, in August, when air and water temperatures reached 38°C, the burrow temperature was 10°C lower.

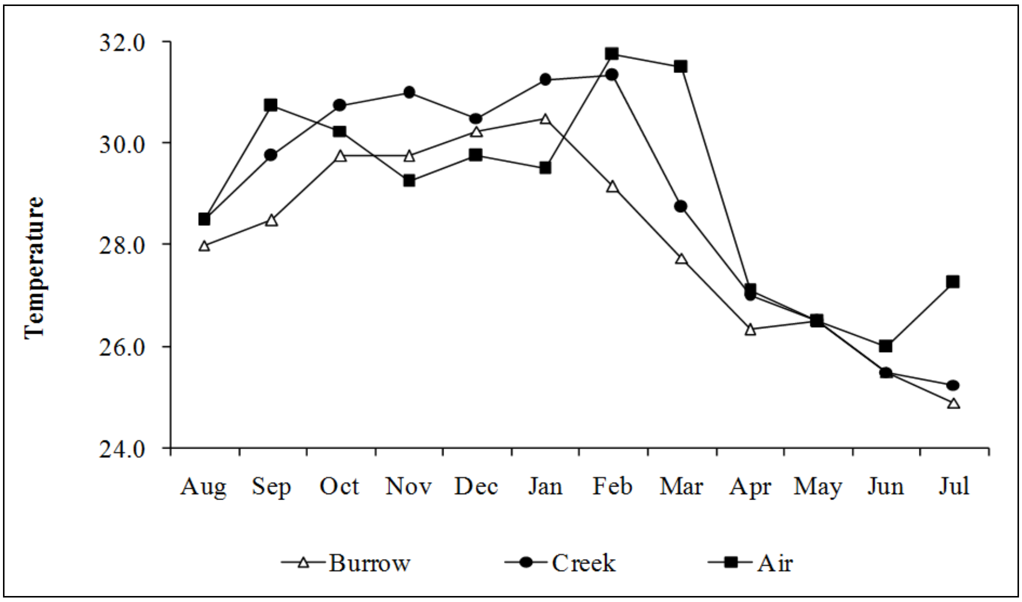

Figure 2 – Burrow, creek and air temperature at the Mundaú/Manguaba Lagunar Complex, Alagoas State, Brazil.

The salinity of the burrows water ranged from 1.5 to 34.5 (20.1±9.6), and the salinity of the main creek water ranged from 0.0 to 28.9 (14.4±9.6). These values also fluctuated throughout the sampling year (Fig. 3), with significant differences between rainy and dry periods ($p < 0.05$). There were significant differences between the salinity of the burrows and main creeks ($p < 0.05$), with the salinity of burrows being higher.

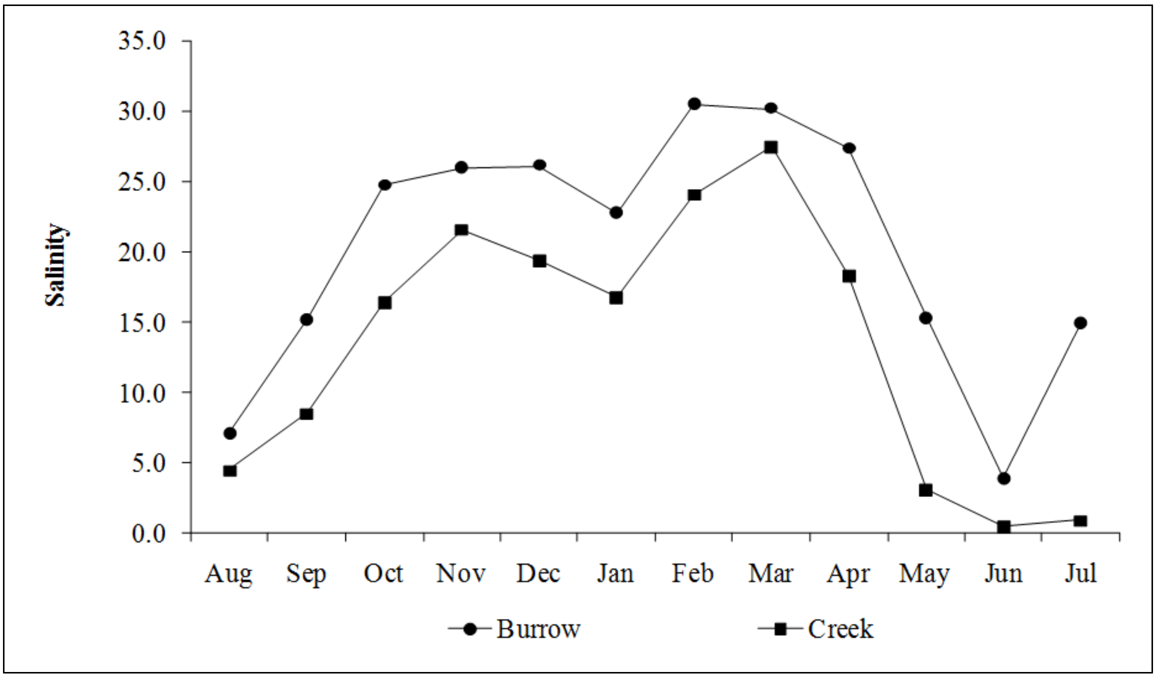

Figure 3 – Burrow and creek water salinity at the Mundaú/Manguaba Lagunar Complex, Alagoas State, Brazil.

Burrows

In the present study, 735 galleries of *U. cordatus* were opened, being 359 of males and 376 of females. These burrows had varying architecture (number of openings, branches and dead-ends), and could be grouped into five categories, namely: A – burrows as a single tube, I-shaped, straight or curved, vertical, inclined or parallel to the surface, with a single opening and a single dead-end (Fig. 4); B – burrows with a single opening and two dead-ends, λ-shaped, although in some types the secondary branching head to the surface, but does not open up overseas (Fig. 5); C – burrows with two openings and a dead-end, Y-shaped (Fig. 6); D – burrows with two openings and no dead-end, U-shaped, parallel to the surface (Fig. 7); and E – burrows with three openings and a dead-end (Fig. 8).

The category 'A' was the most frequent, corresponding with more than 85% of the samples (Table 1). It can be noted that the frequency of each burrow category is similar between the sexes. Length varied from 10 to 144 cm (70.2 ± 30.9 cm) (Table 1). Regarding the mean length, no significant difference was detected between the sexes ($p = 0.66$). However, due to the low number of burrows in categories C, D and E, a comparative test among the mean length of each category could not be performed.

Table 1 – Minimum, mean ± standard deviation (sd) and maximum length, and frequency (%) of *Ucides cordatus* burrows by sex and categories.

Categories	Males				Females			
	Min.	Mean ± sd	Max.	%	Min.	Mean ± sd	Max.	%
A	10	67.1±11.0	133	87.2	10	69.3±19.8	137	88.0
B	10	67.8±14.2	112	7.5	50	64.0±17.0	112	7.4
C	41	65.7±16.2	112	2.8	25	78.5±28.6	89	3.5
D	30	60.5±43.1	91	1.9	25	64.0±55.1	103	0.8
E	61	101±56.6	141	0.6	-	41.0	-	0.3

All burrows from category 'E' were occupied by juveniles and found in sandy sediment, in zones of higher grounds, and the other burrows, mainly occupied by adults, were found in muddy sediment, in zones of intermediary and low grounds. Each *U. cordatus* usually occupies its own burrow. However, it was possible to find more than one specimen per burrow in few cases.

The burrows had ellipsoid or circular openings. No sedimentary structure, such as towers, mounds and hoods, were found near the burrow opening, but tracks indicating recent activity in the burrow could be observed. Crabs quickly retreated into the burrows when noticed movement, even at a distance of some meters. However, during the 'andada' phenomenon, they were found wandering through the mangrove forest, with no reaction to the human present, being easily captured. The 'andada', which means "wandering around", is the behaviour observed in these crabs during the reproductive period, when they leave their burrows searching for a reproductive partner (ARAÚJO; CALADO, 2008).

Burrows were opened during the low tide, but crabs covered the openings with mud during the rising tide. Many *U. cordatus* built their burrows around the mangrove trees and their roots, especially of *Rhizophora mangle* L. These burrows had, in many cases, curves along their length. Meanwhile, straight burrows occurred mainly in areas of mud, bare of vegetation.

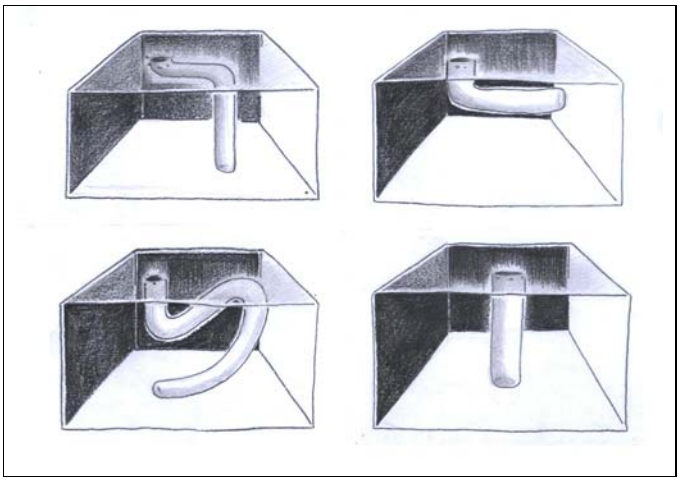

Figure 4 – Example of *Ucides cordatus* burrows belonging to the category 'A'.

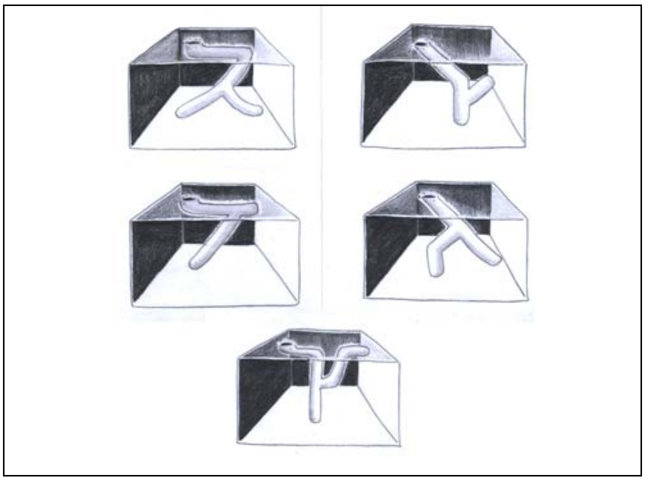

Figure 5 – Example of *Ucides cordatus* burrows belonging to the category 'B'.

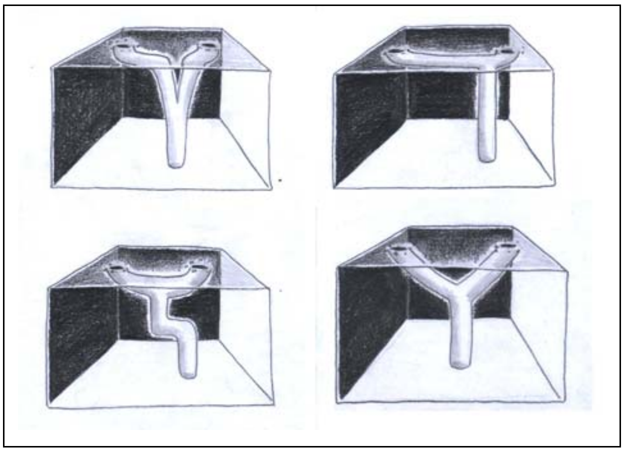

Figure 6 – Example of *Ucides cordatus* burrows belonging to the category 'C'.

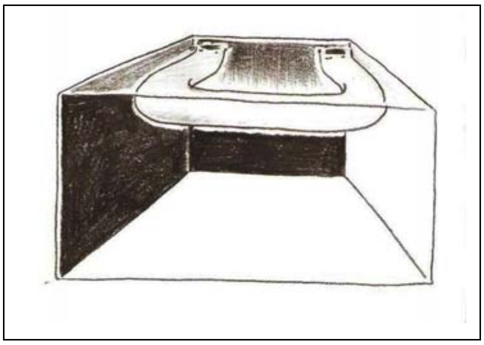

Figure 7 – Example of *Ucides cordatus* burrow belonging to the category 'D'.

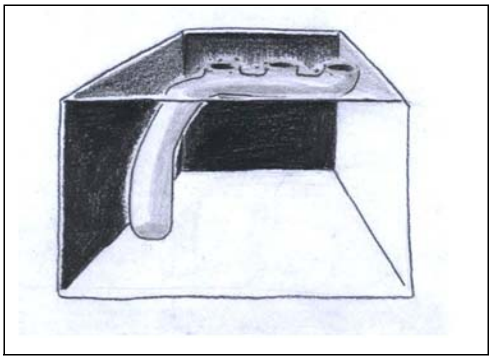

Figure 8 – Example of *Ucides cordatus* burrow belonging to the category 'E'.

DISCUSSION

The high values of temperature found in CELMM are typical of tropical regions, where small annual amplitude is observed (PASSAVANTE; FEITOSA, 2004). The thermal stability of this lagoon complex had already been observed by Melo-Magalhães et al. (1996). The small annual oscillation demonstrates a thermal uniformity that allows the development of constant biological processes. The main factors for the diffusion of salt in CELMM are the ebb and flow of tides (OLIVEIRA, 1996). The CELMM channels have a reduced water movement which controls the distribution of salinity for both lakes. Unlike the behavior of temperature, water salinity in the region is an extremely variable parameter, in both temporal and spatial scales (MARQUES, 1991). Thus, *U. cordatus* can be considered a euryhaline and eurythermic species, occurring in wide amplitude of salinity, as well as in waters with variable temperatures.

During the sampling of *U. cordatus*, the burrows always had water within, and the annual amplitude of the burrows temperature was lower than the annual amplitude of the main creek and air temperature, phenomenon already observed by Herreid (1963) for *Cardisoma guanhumi* Latreille, 1828. Burrows not only give protection to crabs, but also modify the extreme temperatures and serve as water reservoirs, due to the need for regular immersion to humidify the gill chambers.

The occurrence of *U. cordatus* under both low and high salinity regimes had been predicted by Coelho et al. (2004). According to them, among brachyuran species found in Brazilian mangroves, *Uca (Uca) maracoani* (Latreille, 1803) was mentioned in all environments, except in areas where salinity at high tide is usually below 5. On the other hand, *Goniopsis cruentata* (Latreille, 1803), *Uca (Leptuca) leptodactyla* Rathbun, 1898, *Uca (Minuca) rapax* (Smith, 1870), *Uca (Minuca) burgesi* Holthuis, 1967, *Uca (Minuca) thayeri* Rathbun, 1900 and *Ucides cordatus* has been collected under all regimes of salinity.

Due to evaporation of water from the burrows when they are exposed at low tide and to the salt exclusion of tree roots (PASSIOURA; BALL; KNIGHT, 1992), salinity from the crab burrows waters can be higher than the main creek water, as observed herein. Such phenomenon was also found in *Episesarma versicolor* (Tweedie, 1940) in Thailand (THONGTHAM; KRISTENSEN, 2003). In addition, the salinity in the interstitial water of mangroves is higher than in surface water, fact that can also explain the observed differences. It is known that the urinary production of *U. cordatus* is higher in brackish water, when compared to sea water (SANTOS, 1987). Thus, these salinity variations probably exert a great influence in these species population, but due to its euryhaline characteristic, it can survive in this unstable environment.

Burrows commonly observed in macrofaunal burrows are the U-shaped, Y-shaped and I-shaped, also were observed in this study. This demonstrates the existence of a pattern in the construction of burrows, being possible to compare their general structure. According to Kristensen (2008), the burrows of fiddler crabs (*Uca*) are very simple and usually consist of a vertical tube extending within the sediment. Burrows consisting of a single tube are very common in *Ocypode quadrata* (Fabricius, 1787) (ALBERTO; FONTOURA, 1999), *O. ceratophthalmus* (Pallas, 1772) (CHAN; CHAN; LEUNG, 2006) and, in the present study, *U. cordatus.* Sesarmidae burrows vary considerably in morphology, from simple and straight burrows with little ramifications, as observed in *U. cordatus*, to complex labyrinth structures with more than five openings, as observed in *E. versicolor* (THONGTHAM; KRISTENSEN, 2003). In some species, as *Uca (Leptuca) pugilator* (Bosc, 1802), *Sesarmoides longipes* (Krauss, 1843), *Cardisoma carnifex* (Herbst, 1796) and *Macrophthalmus (Macrophthalmus) parvimanus* Guérin, 1834, the single tube burrows are temporary, being only refuges during high tide (BRAITHWAITE; TALBOT, 1972; CHRISTY, 1982).

At large, crab burrows present single openings and tubes. Studying a *U. cordatus* population from Southern Brazil, Santos; Pinheiro; Hattori (2009) only observed burrows with a single opening. However, three of the five categories of burrows described here presented more than one opening. Cowles (1908), studying *O. quadrata*, proposed that the second opening of the burrow is not used as entry, since it is narrower, and surmised that probably it has the task of ventilating the burrows, making it cooler. However, Thongtham; Kristensen (2003) reported that the multiple entrances of *Episesarma versicolor* burrows probably provide quick access to shelter from predators. Probably, the second entries of *U. cordatus* present both functions, since the thermal range of the burrows was smaller than the air and main creek water. Besides, all openings had approximately the same diameter.

Pinheiro; Fiscarelli (2001) cited that the *U. cordatus* juvenile burrows have up to five openings. In the present study, juvenile burrows had three openings. A differential spatial distribution of burrows according to age was reported by Costa (1972) and Pinheiro; Fiscarelli (2001) either.

One of the five categories of burrows described here for *U. cordatus* presented more than one dead-end. The branching of burrows can provide extra shelter for crabs from predation or have reproductive purposes (CHAN; CHAN; LEUNG, 2006). Besides, the ramifications that go to the surface (but fail to open) can be used on the need to escape, preventing body injuries (COWLES, 1908). *O. quadrata* digs the exhaust passage almost to the surface without breaking it, thus leaving the exit place closed.

U. cordatus is very sensitive to the substratum vibration (NORDHAUS; DIELE; WOLFF, 2009), which explains the rapid retraction into the burrow when in the human presence. The fact that crabs close the burrow openings during flood tide is probably due to catfish predation, as *Sciades herzbergii* (Bloch, 1794) (GIARRIZZO; SAINT PAUL, 2008). The crabs probably detect the rising tide by changes in water level inside the burrows, since they reach down the water table (NORDHAUS; DIELE; WOLFF, 2009). Each burrow was occupied by a single crab, which characterizes the territoriality of the species. Nevertheless, temporary visitors were found, probably seeking refuge from predators (THONGTHAM; KRISTENSEN, 2003) or for reproductive purposes, mating and combats between males.

The 'andada' phenomenon, observed in populations of *U. cordatus* and *Cardisoma guanhumi*, is characterized by the presence of crabs walking through the mangrove substratum, moving away from their burrows in all directions. The 'andada' has a reproductive function, and during this period, the crabs lose their protection and defense instinct (ALCÂNTARA-FILHO, 1978; NASCIMENTO, 1993). In this period the crabs can be easily captured. Araújo; Calado (2008) reported that the 'andada' phenomenon at CELMM occurs in the month of February.

According to Oliveira (1950), the land crab looks for places among the shadows of *Avicennia* to build their burrows. However, Schories et al. (2003) and Nordhaus; Diele; Wolff (2009) reported that the highest densities of *U. cordatus* burrows occurred between aerial roots of *Rhizophora mangle* L., which is corroborated by the present study. The vegetation provides shade, soft humid soil and shelter against predators, probably a more stable construction of burrows, and a leaf fall that is much higher than the forest on average (NORDHAUS; DIELE; WOLFF, 2009).

CONCLUSION

The knowledge on the burrows of *U. cordatus* is limited, and the present study brings new light to this ecological feature of this socially important species. However, more studies are still needed, especially on the Northeastern coast of Brazil, where its economical importance contrasts with the lack of peer reviewed papers about it.

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REFERENCES

ALBERTO, R.M.F.; FONTOURA, N.F. Distribuição e estrutura etária de *Ocypode quadrata* (Fabricius, 1787) (Crustacea, Decapoda, Ocypodidae) em praia arenosa do litoral sul do Brasil. **Revista Brasileira de Biologia**, v. 59, n. 1, p. 95–108, 1999.

ALCÂNTARA-FILHO, P. Contribuição ao estudo da biologia e ecologia do caranguejo-uçá *Ucides cordatus cordatus* (Linnaeus, 1763) (Decapoda, Brachyura) no manguezal do Rio Ceará (Brasil). **Arquivos de Ciências do Mar**, v. 18, n. 1/2, p. 1–41, 1978.

ARAÚJO, M.S.L.C.; CALADO, T.C.S. Bioecologia do caranguejo-uçá *Ucides cordatus* (Linnaeus) no Complexo Estuarino Lagunar Mundáu/Manguaba (CELMM), Alagoas, Brasil. **Revista da Gestão Costeira Integrada**, v. 8, n. 2, p. 169–181, 2008.

BLISS, D.E.; VAN MONTFRANS, J.; VAN MONTFRANS, M.; BOYER, JR. Behaviour and growth of the land crab *Gecarcinus lateralis* (Fréminville) in southern Florida. **Bulletin of the American Museum of Natural History**, v. 160, p. 111–152, 1978.

BOTTO, F.; IRIBARNE, O. Contrasting effects of two burrowing crabs (*Chasmagnathus granulata* and *Uca uruguayensis*) on sediment composition and transport in estuarine environments. **Estuarine and Coastal Marine Science**, v. 51, p. 141–151, 2000.

BRAITHWAITE, C.J.R.; TALBOT, M.R. Crustacean burrows in the Seychelles, Indian Ocean. **Palaeogeography, Palaeoclimatology, Palaeoecology**, v. 11, p. 265–285, 1972.

CHAN, B.K.K.; CHAN, K.K.Y.; LEUNG, P.C.M. Burrow architecture of the ghost crab *Ocypode ceratophthalma* on a sandy shore in Hong Kong. **Hydrobiology**, v. 560, p. 43–49, 2006.

CHRISTY, J.H. Burrow structure and use in the sand fiddler crab, Uca pugilator (Bosc). **Animal Behavior**, v. 31, p. 687–694, 1982.

COELHO, P.A. Os crustáceos decápodos de alguns manguezais pernambucanos. **Trabalhos do Instituto Oceanográfico da UFPE**, v. 7/8, p. 71–90, 1965/66.

COELHO, P.A.; BATISTA-LEITE, L.M.A.; SANTOS, M.A.C.; TORRES, M.F.A. O Manguezal. In: ESKINAZI-LEÇA, E.; NEUMANN-LEITÃO, S.; COSTA, M.F. (Org.). **Oceanografia**: Um Cenário Tropical. Recife: Bagaço, 2004, p. 641–688.

COSTA, R.S. **Fisiologia do caranguejo-uçá, *Ucides cordatus* (Linnaeus, 1763) - Crustáceo, Decápode - do nordeste brasileiro**. 1972. 121f. Tese (Doutorado em Oceanografia), Universidade de São Paulo, São Paulo. 1972

COWLES, R.P. Habits, reactions, and associations in *Ocypode arenaria*. **Papers from the Department of Marine Biology of the Carnegie Institution of Washington**, v. 2, p. 1–41, 1908.

DITTMANN, S. Effects of macrobenthic burrows on infaunal communities in tropical tidal flats. **Marine Ecology Progress Series**, v. 134, p. 119–130, 1996.

EMMERSON, W.D.; MCGWYNNE, L.E. Feeding and assimilation of mangrove leaves by the crab *Sesarma meinerti* De Man in relation to leaf-litter production in Mgazana, a warm-temperate southern African mangrove swamp. **Journal of Experimental Marine Biology and Ecology**, v. 157, p. 41–53, 1992.

ESKINAZI-LEÇA, E. **Taxonomia e distribuição das diatomáceas (Bacillariophyceae) na laguna Mundaú (Alagoas-Brasil)**. 1976. 87f. Dissertação (Mestrado em Botânica), Universidade Federal Rural de Pernambuco, Recife, 1976.

GIARRIZZO, T.; SAINT-PAUL, U. Ontogenetic and seasonal shifts in the diet of the pemecou sea catfish *Sciades herzbergii* (Siluriformes: Ariidae), from a macrotidal mangrove creek in the Curuçá estuary, Northern Brazil**. Revista de Biologia Tropical**, v. 56, n. 2, p. 861–873, 2008.

GIDDINS, R.L.; LUCAS, J.S.; NEILSON, M.J.; RICHARDS, G.N. Feeding ecology of the mangrove crab *Neosarmatium smithi* (Crustacea: Decapoda: Sesarmidae). Marine Ecology Progress Series, v. 33, p. 147–155, 1986.

GOSHIMA, S.; KOGA, T.; MURAI, M. Mate acceptance and guarding by male fiddler crabs *Uca tetragonon* (Herbst).. **Journal of Experimental Marine Biology and Ecology**, v. 196, p. 131–143, 1996.

HERREID, C.F. Observations on the feeding behavior of the Cardisoma guanhumi (Latreille) in Southern Florida. **Crustaceana**, v. 5, n.3, p.176–180, 1963.

IVO, C.T.C.; GESTEIRA, T.C.V. Sinopse das observações do Caranguejo uçá, *Ucides cordatus cordatus* (Linnaeus, 1763) capturado em estuários de sua ocorrência no Brasil. **Boletim Técnico Científico Cepene**, v. 7, n. 1, p. 9–51, 1999.

JONES, C.G.; LAWTON, J.H.; SHACHAK, M. Organisms as ecosystem engineers. **Oikos**, v. 69, p. 373–386, 1994.

JONES, C.G.; LAWTON, J.H.; SHACHAK, M. Positive and negative effects of organisms as physical ecosystem engineers. **Ecology**, v. 78, p. 1946–1957, 1997.

KRISTENSEN, K. Mangrove crabs as ecossystems engineers; with emphasis on sediment process. **Journal of Sea Research**, v. 59, p. 30–43, 2008.

MARQUES, J.G.W. **Aspectos ecológicos da etnoictiologia dos pescadores no Complexo estuarino-lagunar Mundaú/Manguaba, Alagoas.** Campinas, 1991. 292 f. Tese (Doutorado em Ecologia) Universidade Estadual de Campinas.

MELO, G.A.S. Manual de Identificação dos Brachyura (caranguejos e siris) do Litoral Brasileiro. São Paulo, **Plêiade**, 1996. 604p.

MELO-MAGALHÃES, E.M.; MAFALDA-JUNIOR, P.O.; LYRA, M.C.A.; SILVA, J.J. Chaetognatha planctônico do Complexo Estuarino Lagunar Mundaú Manguaba, Alagoas. **Boletim de Estudos de Ciências do Mar**, v. 9, p. 63–88, 1996.

NASCIMENTO, A.S. **Biologia do caranguejo-uçá (Ucides cordatus)**. Aracajú, ADEMA, 1993. 45p.

NORDHAUS, I.; DIELE, K.; WOLFF, M. Activity patterns, feeding and burrowing behaviour of the crab *Ucides cordatus* (Ucididae) in a high intertidal mangrove forest in North Brazil. **Journal of Experimental Marine Biology and Ecology**, v. 374, p. 104–112, 2009.

OLIVEIRA, L.P.H. Levantamento biogeográfico da Baía de Guanabara. Memórias do Instituto Oswaldo Cruz, v. 48, p. 362–391, 1950.

OLIVEIRA, A.M. Salinity diffusion in the estuarine channels of the Manguaba Lagoon, Brazil. **Boletim de Estudos de Ciências do Mar**, v. 9, p. 33–38, 1996.

PASSAVANTE, J.Z.O.; FEITOSA, F.A.N. Dinâmica da Produtividade Fitoplanctônica na Zona Costeira. In: ESKINAZI-LEÇA, E.; NEUMANN-LEITÃO, S.; COSTA, M.F. (Org.). **Oceanografia**: Um Cenário Tropical. Recife: Bagaço, 2004, p. 425–439.

PASSIOURA, J.B.; BALL, M.C.; KNIGHT, J.H. Mangroves may salinize the soil and in so doing limit their transpiration. **Functional Ecology**, v. 6, p. 476–481, 1992.

PINHEIRO, M.A.A.; FISCARELLI, A.G. **Manual de apoio à fiscalização do caranguejo-uçá (*Ucides cordatus*)**. Florianópolis, UNESP/IBAMA/CEPSUL, 2001. 43p

SANTOS, C.M.H.; PINHEIRO, M.A.A.; HATTORI, G.Y. Orientation and external morphology of burrows of the mangrove crab Ucides cordatus (Crustacea, Brachyura, Ucididae). **Journal of the Marine Biological Association of the United Kingdom**, v. 89, n. 6, p. 1117–1123, 2009.

SANTOS, M.C.F. Regulação osmótica e iônica no caranguejo de mangue *Ucides cordatus* (Linnaeus, 1763). In: SIMPÓSIO SOBRE ECOSSISTEMAS DA COSTA SUL E SUDESTE BRASILEIRA – SÍNTESE DOS CONHECIMENTOS, 1987, Cananéia. **Anais**. Cananéia: ACIEP, 1987, p.149.

SCHORIES, D.; BARLETTA-BERGAN, A.; BARLETTA, M.; KRUMME, U.; MEHLIG, U; RADEMAKER V. The keystone role of leaf-removing crabs in mangrove forests of north Brazil. **Wetlands Ecology Management**, v. 11, p. 243–255, 2003.

SMITH, T.J.; BOTO, K.G.; FRUSHER, S.D.; GIDDINS, R.L. Keystone species and mangrove forest dynamics: the influence of burrowing by crabs on soil nutrient status and forest productivity. **Estuarine, Coastal and Shelf Science**, v. 33, p. 419–432, 1991.

STRICKLAND, J.D.H.; PARSONS, T.R. A manual of sea water analysis. **Bulletin of the Fisheries Research Board of Canada**, v. 125, p. 1–185, 1960.

THONGTHAM, N.; KRISTENSEN, E. Physical and chemical characteristics of mangrove crab (*Neoepisesarma versicolor*) burrows in the Bangrong mangrove forest, Phuket, Thailand with emphasis on behavioral response to changing environmental conditions. **Vie Milieu**, 53:141–151. 2003.

WARREN, J.H.; UNDERWOOD, A.J. Effects of burrowing crabs on the topography of mangrove swamps in New South Wales. **Journal of Experimental Marine Biology and Ecology**, v. 102, p. 223–235, 1986.