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Spatial distribution of juveniles of the mangrove crab *Ucides cordatus* (Linnaeus, 1763) (Crustacea, Brachyura, Ucididae) from Guaratuba Bay, southern Brazil

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Abstract: The distribution of the juvenile stages of *Ucides cordatus* was analyzed in the Cabaraquara mangrove area, Guaratuba Bay, Paraná State, Southern Brazil (25º49'S - 48º34'W). Two sampling sites were established: Pinheiros River mangrove (PRM) and Ponta do Cavalo tidal flat (PC). Muddy sediment and the surface of adult crab galleries were sampled on transects perpendicular to the river in PRM, from June/2007 to April/2008. At PC, 50x50x50cm samples were collected in searching for older juveniles. Fifty juveniles were collected at PRM (48 in the galleries and two in the muddy substratum) and 95 at PC. A total of 137 adult galleries were analyzed from PRM, ranging from 2.33 to 152.20 m from the riverbank, and measuring from 0.38 to 11.97 m^2. No differences were observed in juvenile crab densities in varied distances from the riverbank, nor in relation to gallery size at PRM. The galleries constructed by adult crabs shelter most of the early juveniles until they reach up to 10 mm carapace width. These results confirm the importance of adult galleries in the recruitment of *U. cordatus*, and the conservation of these galleries in recovery programs of its populations.

Keywords: juvenile crabs, mangrove swamps, substrate preferences, adult gallery

Resumo: Distribuição espacial de juvenis do caranguejo-do-mangue, *Ucides cordatus* (Linnaeus, 1763) (Crustacea, Brachyura, Ucididae), na Baía de Guaratuba, Paraná, Brasil. A distribuição de juvenis de *Ucides cordatus* foi analisada na área de manguezal do Cabaraquara, Baía de Guaratuba, Paraná, Brasil (25º49'S - 48º34'W). Dois locais de coleta foram selecionados: Manguezal do Rio Pinheiros (MRP) e Baixio da Ponta do Cavalo (BPC). Amostras de sedimento puro e da superfície de galerias de caranguejos adultos foram coletadas em transecções perpendiculares ao rio em MRP, de junho/2007 a abril/2008. Em BPC amostras de 50x50x50 cm de sedimento foram coletadas na procura por juvenis mais velhos. Cinquenta juvenis foram coletados em MRP (48 em galerias e 2 no substrato puro) e 95 em BPC. Um total de 137 galerias de adultos foram amostradas em PRM, variando de 2,33 e 152,2 metros de distância do rio, medindo entre 0,38 e 11,97 m^2. Não foram observadas diferenças na densidade dos juvenis em relação as distâncias do rio ou tamanho de galeria em MRP. As galerias escavadas por adultos abrigam juvenis até atingirem o tamanho de 10 mm de largura de carapaça. Estes resultados confirmam a importância das galerias de adultos no recrutamento de *U. cordatus*, assim como da necessidade de conservação destas galerias em programas de recuperação populacional desta espécie.

Palavras-chave: juvenis, manguezal, preferência por substrato, galeria de adulto

Introduction

The mangrove crab *Ucides cordatus* (Linnaeus, 1763) is a semi-terrestrial decapod that lives in burrows dug in the muddy ground of mangrove areas. This species is restricted to the American Atlantic coast, from Florida, USA, to southern Brazil (Melo, 1996). *Ucides cordatus* plays an important ecological role in the energy flux of mangroves, as it is the main consumer of leaf litter and mangrove trees` propagules in this ecosystem (Schories *et al*., 2003; Christofoletti *et al*., 2013). In addition, this species constitutes the second most profitable fishery resource for native coastal fisherman communities in Brazil (Abrunhosa *et al*., 2002; Hattori & Pinheiro, 2003; Diele *et al*., 2005).

According to Pinheiro & Fiscarelli (2001) the embryonic development of *U. cordatus* lasts about 19±1 days (at 27ºC) and occurs attached to pleopods of the ovigerous female; after that, the zoea larvae are released in the estuarine water adjacent to the mangrove area. These larvae undergo five to six stages of zoea and one of megalopa, with this last larval stage returning to the mangroves to settle and metamorphose into a juvenile crab (Rodrigues & Hebling, 1989).

Larviculture techniques with larvae obtained from wild ovigerous females of *U. cordatus* have been developed in an attempt to aid in the recovery of natural populations, through repopulation of mangrove areas with megalopa and juvenile crabs. However, little is known about the spatial distribution of the *U. cordatus* juveniles in their natural environment, from the megalopa stage to the one-year-old juvenile. Schmidt & Diele (2009) reported the occurrence of *U. cordatus* recruits co-inhabiting burrows of conspecifics; however, they stated that more studies are necessary in order to compare juvenile numbers inside and outside the burrows. The present work aims to study the spatial distribution of the *U. cordatus* juveniles after the megalopa colonization.

Material and methods

Study area: Guaratuba Bay is about 15 km long, with an area of 45 km^2, and it is connected to the Atlantic Ocean through a 500m wide channel (Maack, 1968). It is the second largest estuarine system of Paraná state and is located inside the Environmental Protected Area (EPA) of Guaratuba. The present study was conducted at two sites within the Cabaraquara mangrove area, Guaratuba Bay, Paraná state: Pinheiros River mangrove (PRM) (25º49'S - 48º34'W) and Ponta do Cavalo tidal flat (PC) (Fig. 1).

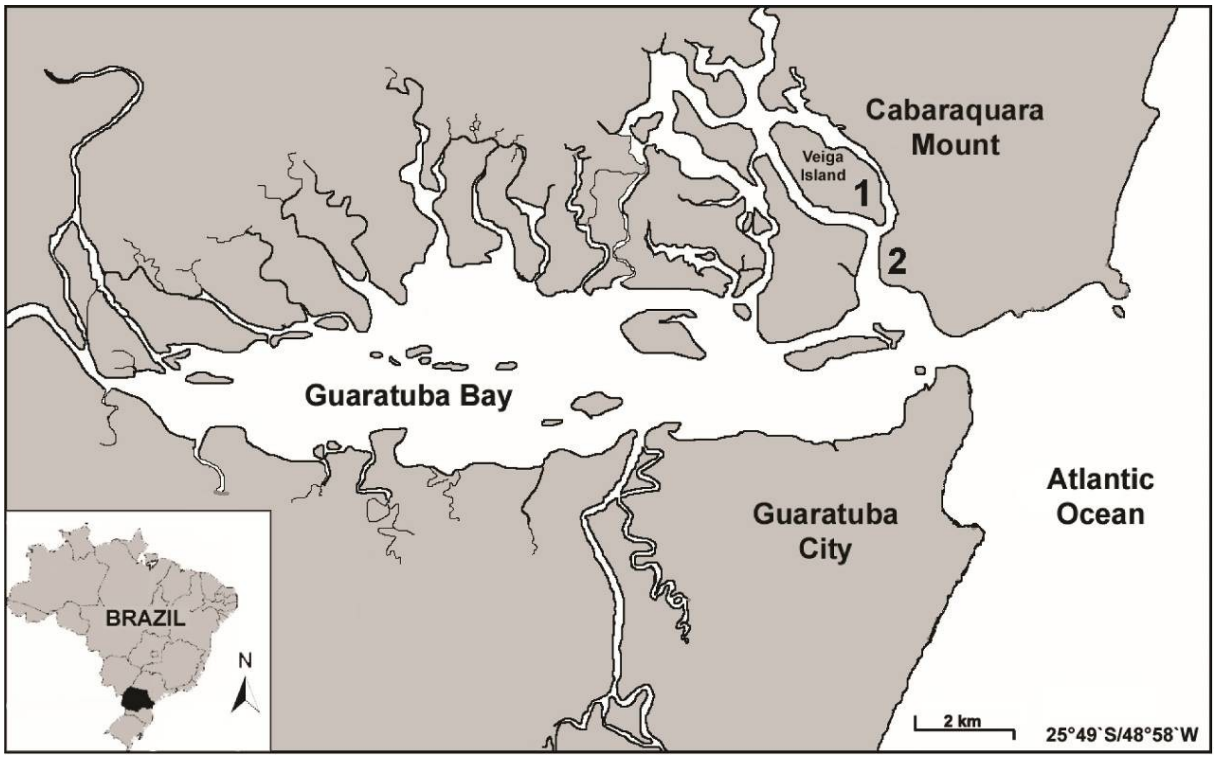

Figure 1: Guaratuba Bay, Paraná State, Brazil. 1 – Pinheiros River mangrove; 2 – Ponta do Cavalo tidal flat.

Sampling: *Ucides cordatus* burrows are composed by a tunnel protected by an elevated roof: this tunnel can divide into several branches, forming a typical gallery of tunnels. Usually, only one mangrove crab lives in each branched burrow and, therefore, males separated from females, sexually mature or immature. The area constructed by adult crabs, composed of the main burrow, tunnels and secondary openings is usually elevated from the ground and easily distinguished from the mangrove ´s muddy area. We designated here this kind of area of high influence from adult crabs as "gallery complex", or simply, "gallery".

Preliminary sampling: In order to check possible substrates preferences, a previous sampling at Pinheiros River mangrove (PRM), 26 samples of muddy sediment and 39 of other substrata were collected. Among the last samples, 17 were obtained from adult crab galleries (four from the main burrow cavity, seven from the main burrow roof and six from the secondary burrows roof), 14 from the rhizosphere, two from areas with large numbers of small openings of fiddler crabs burrows, two from the base of mangle trees, three from the "apicum", an ecotone area between mangle and terrestrial forest, and one from the drainage brooks. These samples measured approximately 12 x 12 cm.

Based on the obtained data, samplings were carried out only in the muddy substratum and over the gallery roofs of adult crabs, in between 2007 and 2008 (June/07, August/07, October/07, November/07, December/07, February/08 and April/08). All collections were carried out during the daytime in low spring tides.

Pinheiros River Mangrove: Two transects were established perpendicular to Pinheiros River, along which sediment surface samples of 12 x 12 cm (0.0144 m^2) were collected with a small shovel in a depth of 10 cm. From the first transect, only muddy sediment was sampled, at an average 7.7m interval, totaling 10 samples on each collection month. From the second transect, samples were taken from the surface of 15 to 25 different galleries. In addition, the sides of each sampled gallery were measured for posterior total area estimation, and the relevant items associated to it (such as large trees or logs) were reported. All samples were kept in plastic bags and properly labeled.

Ponta do Cavalo tidal flat: In order to dig deeper in search for larger juveniles, a different sampling design was performed in Ponta do Cavalo tidal flat (PC). This area is known by local fisherman as a nursery ground for mangrove crabs. Also, the soil in this area is easier to dig due to the absence of entangled roots. Twenty-eight samples of 50 x 50 x 50 cm were dug with a large shovel, either from vegetated and non-vegetated areas. These sampling sites were chosen according to the presence of freshly dug burrow entrance, a clear evidence of existing crabs. All juvenile crabs were manually collected from the samples. and the remaining volume was filtered in a 0.6 mm mesh. As a different sampling protocol was used, these individuals were not included in the statistical tests with the PRM samples, only in the morphometry analysis.

Each sample from PRM was carefully dissolved inside a bucket containing freshwater and filtered through 0.6mm mesh nets. The retained material was kept in plastic bags and frozen until processing. All samples were sorted under stereo microscope and the animals were preserved in 75% alcohol, including juveniles of *U. cordatus*. These were identified by comparison with juvenile specimens spawned and reared in the laboratory of Integrated Aquaculture Group of Federal University of Paraná – GIA/UFPR.

The carapace width (CW) of the juvenile crabs was measured with a digital caliper (0.01mm). Those crabs smaller than 0.9 cm CW were photographed under a stereo microscope with a coupled digital camera, and measured using SigScan Pro 5 software package. After that, the CW values were distributed into 1.0 mm range classes.

The distances between the galleries and the riverbank at PRM were distributed into classes of 10.0 m each. Also, the galleries were distributed into classes of 1.00 m^2 area. Due to the experimental design, only galleries up to 80 m from the riverbank were used in the statistical analysis. The abundance of juveniles per gallery was calculated in relation to the total area of the respective gallery.

Kolmogorov-Smirnov test was performed in order to verify if the data distribution differed from a normal distribution and the homogeneity of variances was tested with a Bartlett test. As these assumptions were not accurate, non-parametric test were performed. The difference in crab frequencies occurring in muddy substratum and in galleries was tested using the Mann-Whitney U test. The distribution of the juveniles among distance classes and gallery size classes was tested using Kruskall-Wallis test. All statistical procedures were evaluated considering 5% of significance level. Also, the correlation between the distance to the river and the number of juveniles was tested by Pearson's correlation test.

Results

In the previous sampling, juveniles of *U. cordatus* were only found in the muddy substratum (n=2) and in the sediment from the gallery roofs (n=6). No early juvenile was obtained from other searched substrates (rhizosphere, area with fiddler crabs burrows, base of mangrove trees, "apicum" and drainage brooks)

Ninety-six muddy sediment samples and 137 gallery samples of *U. cordatus* were collected from PRM, comprising up a total area of 1.38m^2 and 1.97m^2, respectively. Fifty early juveniles of *U. cordatus* were obtained, among them, two from the muddy sediment and 48 from the gallery surfaces with mean densities of 1.45 ind.m^{-2} and 24.36 ind.m^{-2}, respectively (Z= 3.70).

The absolute number of early juveniles living in each gallery sample varied from one to four individuals, corresponding to density values from 69.44 ind.m^2 to 277.78 ind.m^2 However, most galleries (n=104) did not harbor any juvenile crab followed by those with one juvenile (n=22) and two juveniles (n=5). Only one gallery showed three juveniles and three galleries, four juveniles.

The distance of the galleries from riverbank ranged from 2.33m up to 152.20 m. They were found along all transect, but their distribution was not uniform, varying from one gallery in the 111-120 m class to 24 galleries in the 31-40m class (X^2 = 62.36; p <0.01). Juveniles were found up to 152 meters from the riverbank, however we tested only galleries up to 80 meters from the riverbank due to the experimental design. On this experiment, no significant differences on the number of juveniles was found along the distances from the riverbank (H = 5; p = 0.2747), and no correlation was found either (r = -0.1203; p > 0.05). (Fig. 2). The class of the highest frequency of early juveniles coincided with the highest frequency class of galleries (31-40 m). There was a positive correlation between these two parameters (r = 0.8022; p < 0.01) (Fig. 3).

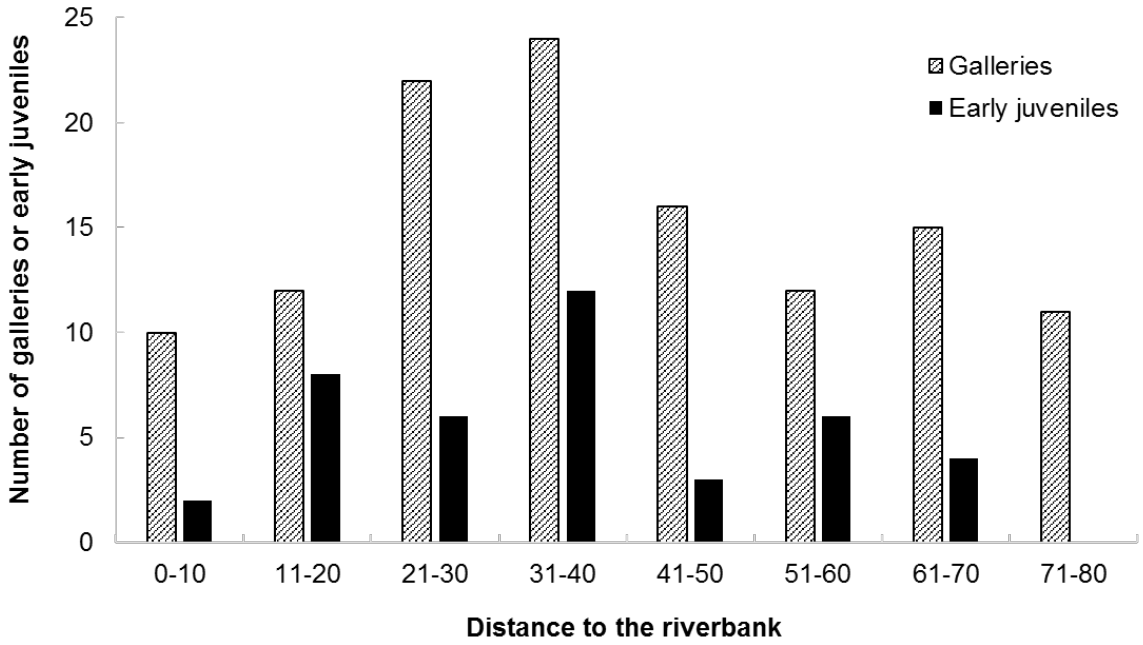

Figure 2: *Ucides cordatus* from Pinheiros River mangrove. Distribution of the number of galleries of adult crabs and of early juveniles into classes of distance from the riverbank.

The smallest gallery measured 0.038 m^2 and the largest one 11.97 m^2. The highest frequencies were observed in the first four classes of gallery area (from 0.00 to 0.40 m^2), whose values were always equal or more than 14 (X^2 = 79.1; p <0.01). Similarly, the number of galleries harboring early juveniles was higher in the same four classes, and the smallest gallery harboring them measured 0.053 m^2 and the largest one 3.63 m^2 (Fig. 4). There was a positive correlation between these two parameters (r = 0.8343; p < 0.01) (Fig. 5).

Most galleries were associated with the basal area of large size trees (65.12 %), others with juvenile plants (6.2 %), small roots (3.9 %), macroalgae (1.6 %) and the remaining (23.1 %) were isolated without any association to the surrounding vegetation. This vegetation frequency occurrence was statistically different from the

expected (H=22.291; p <0.05).

A total of 28 galleries were sampled at PC, where 95 juveniles were found. No juvenile in early stages was obtained from the surface sediment in this collection site. Juveniles obtained from PRM measured from 2.15 to 9.94 mm CW, while those coming from PC, from 10.02 to 45.8 mm CW (Fig. 6).

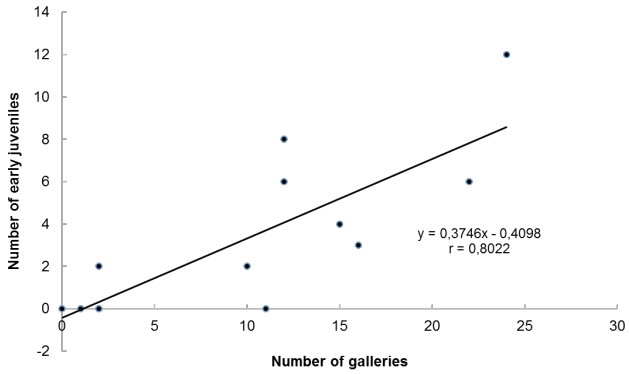

Figure 3: *Ucides cordatus* from Pinheiros River mangrove. Relationship between the number of galleries and the number of early juveniles occurring in the classes of distance from riverbank.

Discussion

The strong dominance of early juveniles of *Ucides cordatus* associated to adult crab galleries, in the present work, is in accordance with Schmidt & Diele (2009) who also found juvenile crabs co-inhabiting burrows of conspecific adults in Carnavieras Bay, Bahia State, northeastern Brazil. These results may indicate a preference for settlement site by the megalopa larvae that could be attracted to the adult living site through some intrinsic or extrinsic factors, prior to their metamorphosis to the first juvenile stage. This assumption is based on the experimental analysis of the effect of conspecific odor in the substrate carried out by Diele & Simith (2007). These authors reported that megalopae cultivated in a natural muddy substrates or with adult odors have their development time greatly reduced. They also observed that merging these two factors resulted on a more powerful effect on the megalopae development. Therefore, *U. cordatus* megalopae are likely to settle near adult burrows in the field where they will moult to crab 1, which was confirmed by the observations of Schmidt & Diele (2009) and by the present study.

The megalopae response to specific signals coming from the adult habitat, influencing the settlement and metamorphosis period, has also been reported for the grapsoid crab *Chasmagnathus granulata* (Dana) (Gebauer *et al*. 1998, 2003). Additionally, a strong influence of chemical signals from conspecific and congeneric adults was observed in another grapsoid *Sesarma curacaoense* de Man, 1982 (Gebauer *et al*., 2002).

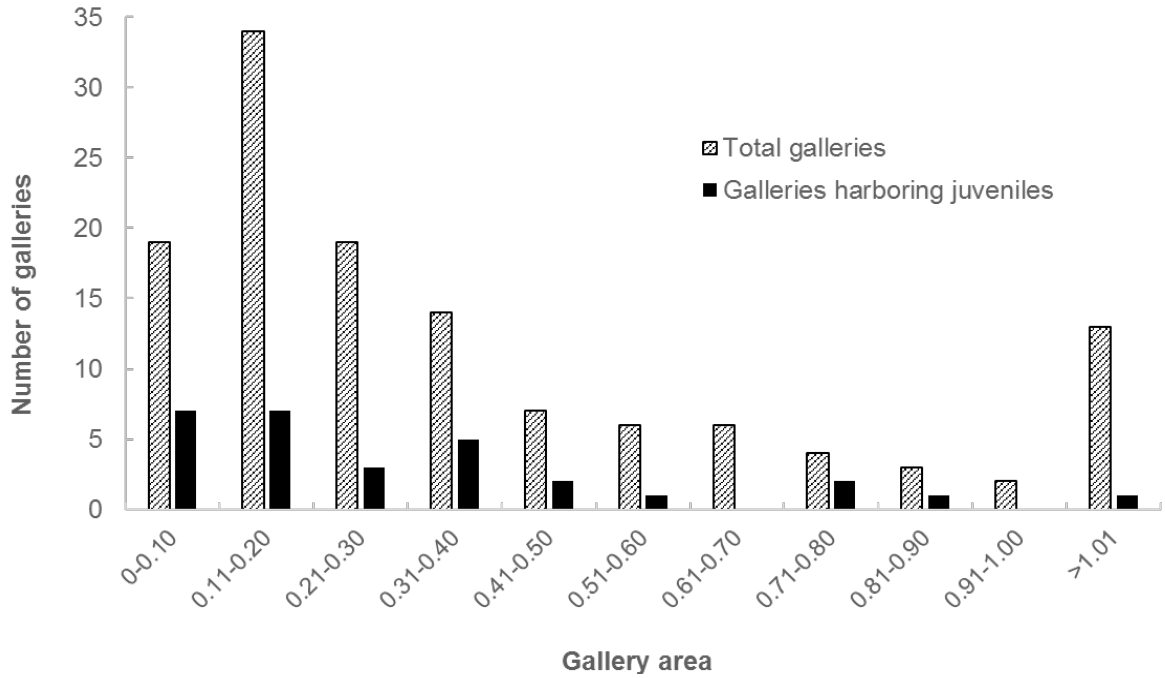

Figure 4: *Ucides cordatus* from Pinheiros River mangrove. Total number of galleries (dashed bars) and galleries harboring juveniles (filled bars).

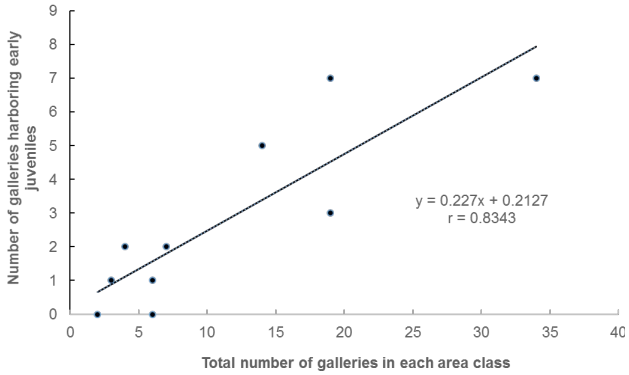

Figure 5: *Ucides cordatus* from Pinheiros River mangrove. Number of galleries with early juveniles and the total number of galleries.

Furthermore, Christy (1989) reported the positive influence of substrates removed from the adult's site of *Uca pugilator* in the development phase of its megalopae. Therefore, it is clear that the chemical factors coming from adults of semiterrestrial decapods have an important influence on the timing and settlement of the conspecific megalopae.

Other possible reasons and advantages for early juveniles of *U. cordatus* in sharing adult galleries could be the inclusion of entangled mesh of fine roots, during the construction of the elevated roof entrance by adult crabs. This entangled mesh is filled with very fine sediment, giving a spongy texture for the tunnel walls of the gallery entrance. Certainly, this mesh construction provides a stable structure that prevents an eventual collapse of the early juvenile's burrows. The absence of early juvenile stages in the barren area at PC, where no elevated roof entrance was present, supports this assumption.

The importance burrows as protection against predation was demonstrated by Warren (1990) with the ocypodid *Heloecius cordiformis* (H. Milne Edwards, 1837). According to this research, crabs outside or in shallow burrows were more frequently victims of subtidal predators. Surely, the adult crab galleries of *U. cordatus* have also this role for early juveniles. Furthermore, this stable substrate constitutes a protection against strong tidal currents and a source of other vital needs such as food and thermic stability.

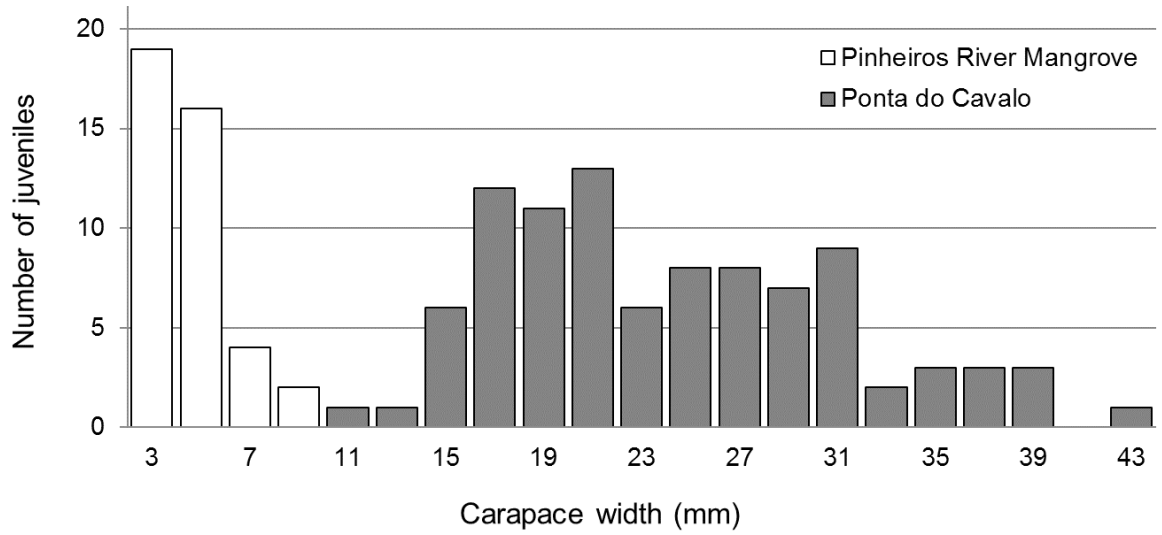

Figure 6: *Ucides cordatus.* Distribution of juveniles coming from Pinheiros River mangrove (open bars) and Ponta do Cavalo tidal flat (filled bars) into carapace width classes (2 mm).

The natural diet of *U. cordatus* adults is mainly composed of fallen leaves of mangrove trees, which are yellowish or brownish, a clear sign of some degree of decomposition (Nordhaus & Wolff, 2007; Christofoletti *et al*, 2013). These adults carry the leaves into their burrows and feed there. Early juveniles that settle near adults may share the food the adults bring in. However, we suppose that the fine root branches composing the gallery structure could be a sufficient food source for these delicate juveniles.

Our results indicate that there is no zonation on this species juveniles in this mangrove. In contrast, Warner (1969) reported a distribution of the crab fauna in five different zones at a Jamaican mangrove. He observed that *U. cordatus* adults were present throughout the mangrove but that their density increased, as he got closer to land. Pinheiros

River Mangrove has a relatively level ground and therefore, a foreseen simultaneous inundation of high tide water, which could lead to a uniform distribution of the young crabs. As we focused on a mangrove area closer to the river (up to 80 meters), the level ground could be an explanation to the absence of zonation reported. Future studies reaching deeper into to the mangrove might prove the preference of this young crabs to colonize areas closer to the river.

According to Macnae & Kalk (1962), the mangrove benthic fauna does not show clear zonation, but it displays a preference for particular microhabitats. Their distribution is most likely controlled by the following factors: water loss resistance, demand for protection from sun exposure, water table depth at the habitat and consolidation degree of the sediment and the availability of food resources, such as microfauna, microflora and organic matter.

The predominance of galleries located near or under large trees (about 65%) at PRM is probably a consequence of extraction activities by human catchers of crabs. In these places, entangled roots of mangrove trees prevent the crab catchers to reach deeper depths where the large crab is taking shelter. On the other hand, adult crabs that were living in areas without robust roots (far away from large trees) were already captured. This assumption is also based on the absence of large adult crabs at PC, where digging to deeper depths is easily performed.

The present work confirms the importance in preserving adult galleries of *Ucides cordatus* for recruitment of its own juveniles. It enhances the necessity of the preservation not only the mangroves, but also the adult crab population, at least, partly.

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References

Abrunhosa, F. A., Neto, A. A. S., Melo, M. A. & Carvalho, L. O. 2002. Importância da alimentação e do alimento no primeiro estágio larval de *Ucides cordatus cordatus* (Linnaeus 1763) (Decapoda: Ocypodidae). **Revista Ciência Agronômica**, 33: 5-12.

Christofoletti, R. A.; Hattori, G. Y. & Pinheiro, M. A. A. 2013. Food selection by a mangrove crab: temporal changes in fasted animals. **Hydrobiologia**, 702: 63-72.

Christy, J. H. 1989. Rapid development of megalopae of the fiddler crab *Uca pugilator* reared over sediment: implications for models of larval recruitment. **Marine Ecology Progress Series**, 57: 259-265.

Diele, K., Koch, V. & Saint-Paul, U. 2005. Population structure, catch composition and CPUE of the artisanally harvested mangrove crab *Ucides cordatus* (Ocypodidae) in the Caeté estuary, North Brazil: Indications for overfishing? **Aquatic Living Resources**, 18: 169-178.

Diele, K. & Simith, D. J. B. 2007. Effects of substrata and conspecific odour on the metamorphosis of mangrove crab megalopae, *Ucides cordatus* (Ocypodidae). **Journal of Experimental Marine Biology and Ecology**, 348: 174-182.

Fiscarelli, A. G. & Pinheiro, M. A. A. 2002. Perfil sócio econômico e conhecimento etnobiológico do catador de caranguejo-uçá, *Ucides cordatus* (Linnaeus, 1763), nos manguezais de Iguape (24º41'S), SP, Brasil. **Actualidades Biologicas**, 24: 129-142.

Gebauer, P., Paschke, K. & Anger, K. 2002. Metamorphosis in a semiterrestrial crab, *Sesarma curacaoense*: intra and interspecific settlement cues from adult odors. **Journal of Experimental Marine Biology and Ecology**, 268: 1-12.

Gebauer, P., Paschke, K. & Anger, K. 2003. Delayed metamorphosis in decapod crustaceans: evidence and consequences. **Revista Chilena**

de História Natural 76: 169 -175.

Gebauer, P., Walter, I. & Anger, K. 1998. Effects of substratum and conspecific adults on the metamorphosis of *Chasmagnathus granulate* (Dana) (Decapoda: Grapsidae) megalopae. **Journal of Experimental Marine Biology and Ecology**, 223: 185-198.

Hattori, G. Y. & Pinheiro, M. A. A. 2003. Fertilidade do caranguejo de mangue *Ucides cordatus* (Linnaeus) (Crustacea, Brachyura, Ocypodidae), em Iguape (São Paulo, Brasil). **Revista Brasileira de Zoologia**, 20: 309-313.

Maak, R. 1968. **Geografia física do Estado do Paraná**. Universidade Federal do Paraná, Curitiba, PR.

Macnae, W. & Kalk, M. 1962. The ecology of the mangrove swamps at Inhaca Island, Mocambique. **Journal of Ecology**, 50: 19-34.

Melo, G. A. S. 1996. **Manual de identificação dos Brachyura (caranguejos e siris) do litoral brasileiro**. São Paulo, Editora Plêiade, 604 pp.

Nordhaus, I. & Wolff, M. 2007. Feeding ecology of the mangrove crab *Ucides cordatus* (Ocypodidae): food choice, food quality and assimilation efficiency. **Marine Biology**, 151: 1665–1681.

Pinheiro, M. A. A. & Fiscarelli, A. G. 2001. **Manual de apoio à fiscalização do caranguejo-uçá (*Ucides cordatus*)**. Jaboticabal, IBAMA/CEPSUL, 43 pp.

Rodrigues, M. D. & Hebling, N. J. 1989. *Ucides cordatus cordatus* (Linnaeus, 1763) (Crustacea: Decapoda). Complete larval development under laboratory conditions and its systematic position. **Revista Brasileira de Zoologia**, 6: 147-166.

Schmidt, A. J. & Diele, K. 2009. First field record of mangrove crab *Ucides cordatus* (Crustacea: Decapoda: Ucididae) recruits co-inhabiting burrows of conspecific crabs. **Zoologia,** 26 (4): 792-794.

Schories, D., Barletta-Bergan, A., Barletta, M., Krumme, U., Mehlig, U. & Rademake, V. 2003. The keystone role of leaf-removing crabs in the mangrove forests of North Brazil. **Wetlands Ecology and Management**, 11: 243-255.

Warner, G. F. 1969. The occurrence and distribution of crabs in a Jamaican mangrove swamp. **Journal of Animal Ecology**, 38: 379-389.

Warren, J. H. 1990. Role of burrows as refuges from subtidal predators of temperate mangrove crabs. **Marine Ecology Progress Series**, 67: 295-299.

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