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Original Article

# Biology, trophic chain, and ethnobiological calendar of the mangrove crab, *Ucides cordatus* (Linnaeus, 1763) (Brachyura, Ocypodidae), according to the perception of catchers in Itanhaém, São Paulo, Brazil

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## Abstract

Ethnobiology helps to better understand research processes involving humans and nature. It produces important information for the management of ecosystems and their natural resources. The mangrove crab (*Ucides cordatus*) is an endemic mangrove crustacean that lives in close association with arboreal vegetation and whose distribution extends throughout this ecosystem along the Brazilian coast. It plays an important role in ecosystem processes, actively participating in sediment bioturbation and the flow of organic matter and energy, affecting the entire trophic chain of coastal environments. This study compiles ethnobiological data from catchers in the Itanhaém River Estuary (state of São Paulo) on the biology of the mangrove crab according to morphotype (male and female), biological cycle (growth and reproductive period), fishing season, and its participation in the trophic chain of mangroves. Thus, this study serves as a basis for education and environmental management actions. The authors conducted interviews using the snowball technique and applied a semi-structured questionnaire with open and closed questions for catchers. We submitted the data to qualitative and quantitative analysis and compared it with data from the available literature. We interviewed the entire sample universe of catchers in the study area. Ethnobiological data referring to the periods of growth and reproduction coincided with literature data in the following proportions:

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66.8 % for Brazil and 82.5 % for the southeast-south region. The results reinforce the relevance and accuracy of local ecological knowledge in the interpretation of data from nature. Moreover, the results show gaps in compliance with the norms for the protection of this species.

## Keywords

Artisanal fishery, collective subject discourse, fishermen, food chain, local ecological knowledge.

## Introduction

Ethnobiology is a field of comparative human biology that aims to assist research processes involving humans and nature (Schwidetzky, 1955; Frake, 1962), where ethnozoology is one of its approaches, involving the interactions between human cultures and animals (Alves and Souto, 2010; 2011; 2015; Alves, 2012). In this perspective we have ethnocarcinology focusing on the interactions between humans and crustaceans (Alves and Souto, 2011). Regardless of the type of traditional science knowledge they are an important tool for the management of ecosystems and their natural resources, and they promote relevant information about biological communities (Posey, 1987). It relies on the intrinsic relationship between these communities and their use and dependence on natural resources (Johannes, 1989; Begossi, 2012). Quintas (2005) argues that environmental problems must be analyzed from a multidisciplinary approach, considering economic, social, and ecological aspects. This is because humans act as an integral part of nature, as holders of knowledge/values, and as builders/transformers of historical processes.

The scientific community has reached a consensus that the Earth's ecosystems have been suffering many anthropogenic impacts that often cause irreversible damage to ecosystems and their biota. Mangroves are one such highly impacted ecosystem. Their conservation depends on efforts that involve the scientific community, NGOs, public authorities, and organized civil society. In Brazil, this ecosystem spreads along the entire coast from Amapá to Santa Catarina States (Spalding *et al.*, 2010), offering several ecosystem services. Some examples of these services are: protection of the coastline (Losada *et al.*, 2018; Hochard *et al.*, 2019), carbon sequestration (Donato *et al.*, 2011), being a breeding and spawning site for numerous aquatic species, being a geochemical barrier to countless pollutants, being a relevant source of fishing resources, and providing nutrients to the marine environment (Alcântara-Filho, 1978; Schaeffer-Novelli, 1995; Cunha-Lignon *et al.*, 2011; Carrasquilla-Henao and Juanes, 2017). These ecological services may reach trillions of dollars annually (Costanza *et al.*, 2014), with the recovery of estuarine areas impacted by anthropogenic action being very costly (Motta, 1997; Losada *et al.*, 2018), and therefore partly reflecting the relevance of these services.

*Ucides cordatus* (Linnaeus, 1763), is an endemic mangrove crab that lives in close association with arboreal vegetation and has great ecological, economic, and fishing importance. The first reports of this importance date back to the 14$^{th}$ century (Melo, 1996). This species is relevant in mangrove processes, mainly regarding sediment bioturbation. It converts leaf litter to organic matter, alters sediment biochemistry, and promotes the flow of nutrients and energy along the food chain (Koch and Wolff, 2002; Christofoletti *et al.*, 2013; Sarker *et al.*, 2020). This mangrove crab has a significant role in the mangrove trophic chain and thus, impacts and/or changes in such a close association between crabs and the mangrove may affect the entire trophic chain and the ecosystem balance.

According to Pinheiro and Fiscarelli (2001), the life cycle of this crab comprises two well-defined seasons, one for fattening/growth and another for reproduction, each lasting six months. These authors also mention that the warmest months correspond to the reproductive season of the species, with longer photoperiod and significant rainfall (December to May). The other months correspond to the growing

and fattening season (June to November). A peculiar phenomenon called 'andada' ('walking') or 'carnaval' ('carnival') occurs during the reproductive period of the mangrove crab, from December to April (Alcântara-Filho, 1978; Nordi, 1994; Pinheiro and Fiscarelli, 2001; Wunderlich *et al.*, 2008; Sant'Anna *et al.*, 2014). During this occasion, crabs abandon their burrows and actively walk through the mangrove, even in the presence of humans, for males to perform courtship, sexual pairing, and copulation (Sant'Anna *et al.*, 2014). Decapod crustaceans generally have growth and reproduction as antagonistic biological events (Sastry, 1983; Hartnoll, 2001) since they use glycogen as an energy source (Kyomo, 1988), which is stored in the perigastric organ (Cervellione *et al.*, 2017).

The mangrove crab is used as human food because it is a high-protein source, and is captured and traded by traditional fishing communities (*e.g.*, 'caiçaras') along the Brazilian coast (Pinheiro and Fiscarelli, 2001; Abrunhosa *et al.*, 2002; Diele *et al.*, 2005; Pinheiro *et al.*, 2015). The strong exploitation of this species, coupled with the lack of observance of its biological cycle (*e.g.*, reproductive and growing seasons) and the introduction of illegal and high impact catch techniques (*e.g.*, netting), have decreased natural stocks (IBAMA, 1994). For this reason, legal instruments, such as IBAMA ordinances No. 34/2003 (IBAMA, 2003a) and No. 52/2003 (IBAMA, 2003b), respetively for N-NE and SE-S, enable more effective conservation with better management conditions and sustainable use of the mangrove crab. This species has support from the guidelines for fisheries management by Decree No. 60.133/2014 (São Paulo, 2014), with licenses issued for catchers according to the SMA Resolution No. 64/2015 (São Paulo, 2015). However, since 2018 (São Paulo, 2018), the mangrove crab is no longer considered as threatened in the red list of the São Paulo State, with its capture being allowed again.

Ethnobiological data on the mangrove crab in Itanhaém city (São Paulo State) are lacking. This study aims to complement the information published by Namora *et al.* (2009) and Souza and Pinheiro (2020; 2021). According to the first authors, catchers are anglers who do not own a vessel (Namora *et al.*, 2009). In turn, Souza and Pinheiro (2020; 2021) describe the socioeconomic profile in this ecosystem, as well as perceptions about its conservation status and the mangrove crab resource in Itanhaém city. This current research will add information on the biological aspects of the species from the perspective of one of the last groups of traditional fishermen, called 'caiçaras', in São Paulo State.

This survey of the empirical knowledge of catchers on the biology and ecology of the mangrove crab, in addition to the available information about the ecology of mangroves, are factors that may affect the conservation status of this resource and the ecosystem it occupies. The government should not only control the exploitation of natural/fishery resources, but should also contextualize the catchers knowledge and consider the most diverse aspects about this exploited species. Currently, regulatory legislation for the use of these resources often ignores these aspects (Barboza *et al.*, 2008). Hence, there is a clear need for a deeper knowledge of this artisanal and traditional fishing activity aimed at integrated environmental management of this species (Cortês *et al.*, 2014).

Therefore, this study compiles ethnobiological data on the mangrove crab, in particular its morphotype (differentiation between males and females), biological cycle (growth and reproductive periods), and the closed fishing season of this species. The study also addresses the participation of the mangrove crab in the trophic chain, providing information for future education and environmental management.

## Material and Methods

This study was structured in two stages: 1) bibliographic survey on the biology and closed fishing season of the mangrove crab — these data were subsequently compiled in tables and compared with those of the present study; and 2) survey of ethnobiological knowledge (biology, trophic chain, and biological calendar) from catchers in the Itanhaém Estuarine System (IES), São Paulo State, Brazil.

### *Survey of ethnobiological data*

The ethnobiological survey was authorized by the Ethics Committee on Human Research of the State University of São Paulo - UNESP - 'Presidente Prudente' Campus (CAAE: 69239817.8.0000.5402). The study was registered in the National System for

the Management of Genetic Heritage and Associated Traditional Knowledge (SisGen: A894D3A).

Data were obtained from interviews carried out by applying a semi-structured questionnaire (Selltiz, 1974; Boni and Quaresma, 2005) containing 58 open and 49 closed questions based on previous forms prepared by Fiscarelli and Pinheiro (2002) and Machado *et al*. (2018). Qualitative variables were analyzed from the perspective of the Collective Subject Discourse (CSD) (Lefévre *et al*., 2000; Minayo, 2006; Dictoro *et al*., 2016), allowing perceived social representations (SR) and environmental perceptions of catchers in relation to the study goals. Key expressions and literal transcriptions of part of the testimonies and central ideas were assessed using CSD to reconstruct a collective and opinionated entity in the form of a subject of discourse with a collective and amplified content (Lefévre and Lefévre, 2006; Dictoro *et al*., 2016).

Aiming to interview as many catchers as possible, the sample '*n*' was maximized by the snowball method, as recommended by Hudelson (1994) and Bernard (2005), in association with the local mediator method (Albuquerque *et al*., 2010). The secretary of the 'Z-13' Fishermen's Community 'Padre José de Anchieta', initially acted as a key informant by randomly appointing one of the registered catchers (local mediator) to make referrals for new contacts. Each person added to the process was asked about other people from their own personal network that had the study's desirable characteristics. This expanded the sample size successively at each interview (Bernard, 2005). The cycle ended with information saturation due to repetition of the names given, and without adding new information to the analysis framework.

The interviews were conducted from July to September 2017 in a place previously set by the catcher. These interviews addressed two thematic axes about the mangrove crab: 1) biology, reproductive season, and closed fishing season; and 2) ethnobiological calendar.

*Data analysis*

The research approach was qualitative and quantitative since the data and information complement each other. Quantitative data allow understanding of the scope of the phenomena since they classify, order, and measure variables and seek to establish relationships. Qualitative information, on the other hand, provides knowledge of the meaning attributed to the phenomena. The researcher surveys the beliefs, opinions, and meanings in the participants' words, but always maintains a due neutrality (Vieira, 2008).

To represent the qualitative variables, we used direct quotes from the catchers, as well as phrases obtained by using the Collective Subject Discourse (CSD), key expressions, and the main idea. Verbal data were organized and tabulated, with CSD phrases evaluated using the DSCSOFT 2.0 software (Lefévre *et al*., 2000). These data were compared with those from the available scientific literature whenever possible. Quantitative data were entered into electronic spreadsheets, organized by theme, tabulated, and displayed graphically. Whenever necessary, they were also statistically analyzed based on the percentage, minimum, maximum, means, standard deviation, and coefficient of variation (Siegel and Castellan, 1988; Ihaka and Gentleman, 1996; Sokal and Rohlf, 2003).

For the preparation of the ethnobiological calendar, we considered the indication of the occurrence of the seven biological events related to growth and reproduction, namely: 'shell exchange' (molting), recording of 'milk'-crabs (post-ecdysis), copulation season, male fighting and foaming next to their burrows (reproductive events to select and attract females, respectively), 'andada' (migration during the reproduction) and occurrence of ovigerous females. The data were tabulated, with subsequent calculation of the frequency of monthly occurrence of each event based on the interviews of all catchers. The association between biological events was also assessed using Pearson's linear correlation coefficient at a 5 % significance level.

The authors compiled scientific and ethnobiological information about the frequency of biological events to prepare a calendar referring to the growth and reproduction periods of the mangrove crab. Based on this information, data was arranged and the monthly occurrence frequency (FR) was calculated, both nationally and per Brazilian region: north-northeast (N-NE) and southeast-south (SE-S). Then, months with record of a monthly frequency ≥ 30 % (MO) were calculated. Subsequently, to compare the data of the present study with those used as a reference, the matching percentage (MP) was calculated in relation to the MO.

Some thematic axes presented multiple, but not exclusive, responses. This generated a sum that surpassed 100 % for some of the subjects evaluated.

*Study site*

The Itanhaém River Estuary (23°50' – 24°15'S, 46°35' – 47°00'W) (Fig. 1) is on the limits of Itanhaém city (Souza-Pereira and Camargo, 2004) in São Paulo State, Brazil. At this site, virtually the entire estuarine region is surrounded by an urban network, suffering the influence of various anthropogenic impacts. These include contamination by untreated domestic waste (Souza-Pereira and Camargo, 2004) and petroleum hydrocarbons (Pinto *et al.*, 2015), in addition to the suppression of vegetation for real estate expansion, and degradation of riparian forests and silting of tributary rivers (Alves and Quinões, 2013).

## Results

The nine professionals that make up the universe of catchers who work in the IES attended the interviews (Souza and Pinheiro, 2020). This number surpassed the initial estimate of the 'Z-13' Fishermen's Colony by 80 % and went far beyond the two traditional fishermen indicated by the Fishery Institute of São Paulo State for this region. Despite the low sample size, the ethnological information presented qualitatively allows us to know the meaning attributed to the phenomena, which often cannot be expressed quantitatively.

This study evaluated traditional knowledge about the biology, biological cycle, and closed fishing season of the mangrove crab, as well as its participation

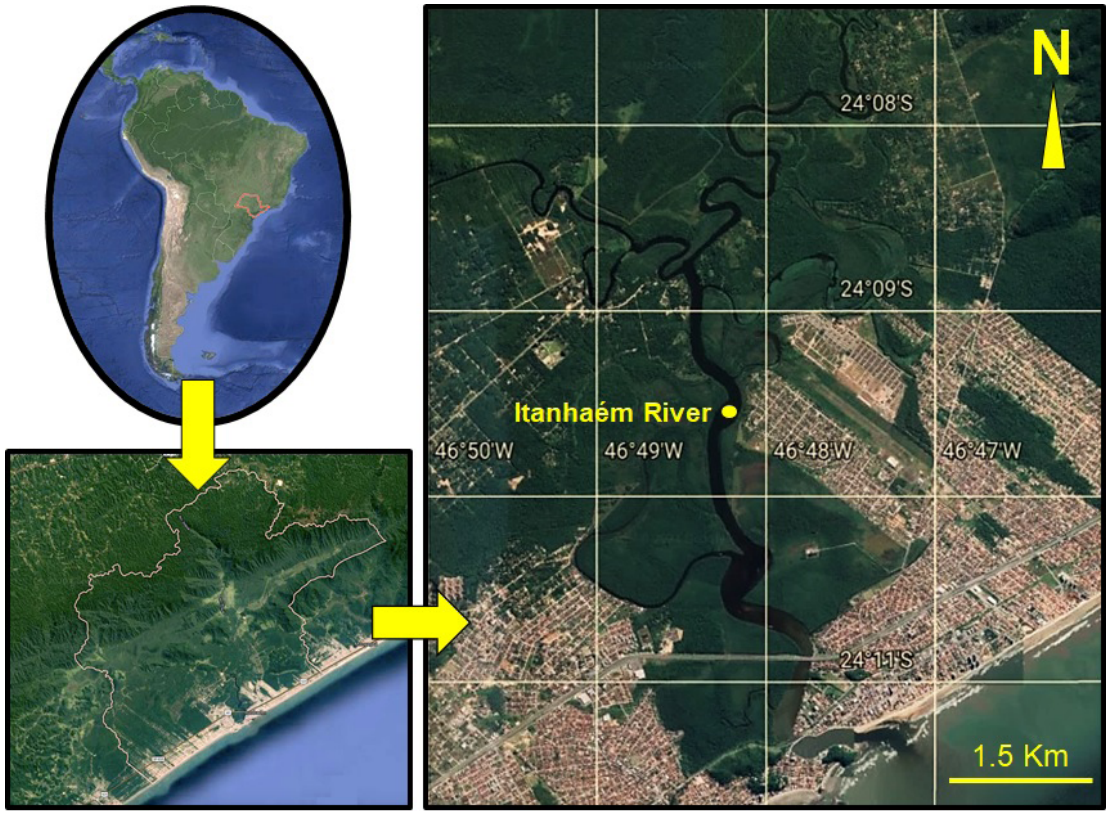


**Figure 1.** Photographic maps of the Itanhaém River Estuary (São Paulo State, southeastern Brazil). Source: Modified from Google® Maps 2020 - Image from 19 Mar 2021.

in trophic chains. Based on this information, the authors made a representative diagram of a fragment of the trophic chain of *U. cordatus*, as well as an ethnobiological calendar of the species according to the perception of catchers.

*Biology of the mangrove crab*

This part of the survey comprised 16 open, two closed, and three mixed questions. Qualitative data corresponded to sentences of the Collective Subject Discourse (CSD) and/or direct quotes from the answers, and quantitative data relied on percentage values and mean values.

Knowing the abdominal morphology of the mangrove crab is an important requirement for sex identification. Regarding this topic, catchers were asked if they could establish the sex of the specimens based only on the characteristics of the crab's burrow. Most catchers (67 %) reported that this is possible by observing the tracks left by the animals and/or the size/shape of the burrow opening. The other 33 % of catchers establish crab sex only when they catch the animal. The central idea corresponds to an experience related to touch and recognition based on signs left by the animal in the sediment (*e.g.*, tracks, feces etc.). The CSD is:

> *"Recognition by touch, experience with the animal, and the type of burrow. The footprint of the male is bigger and thicker; the feces and the burrow are also bigger. The track of the male is wide and long. The footprint of the female is smaller and thinner, the feces and the burrows are also smaller. The track of the female is thin and without hair traces."* — **seven catchers**.

> *"I only identify them when I catch them. The female has a large abdomen, and the male has a thin, narrow one."* — **two catchers**.

Regarding the higher incidence of closed burrows and the explanation for that, in addition to issues concerning the identification of biological events (molting, growth, and records of 'milk'-crabs), 89 % of catchers reported these occurred during the winter. Some mentioned that closed burrows occur for 'shell exchange' (33 %), while others mentioned that it is due to the animal's fattening period (11 %), mating (11 %), or care of hatchlings (11 %), but 33 % did not know the reason why.

> *"Because of the shell exchange."* — **three catchers**.

> *"Because of the cold, the animal gets stuck, putting on weight."* — **one catcher**.

When asked about the period during which the crabs 'exchange their shell' (molting), 67 % of the catchers mentioned spring (September to December), although 22 % said it occurs in the winter (June to September), and another 11 % did not know. In addition, the majority of catchers (67 %) mentioned that both sexes undergo changes at the same time. Others reported that changes occur at different times (11 %), and 22 % of catchers did not know.

The months indicated as having the highest occurrence of 'milk'-crabs were October and November (50 % and 25 %, respectively). Of all catchers, 56 % said they know the reason for the name 'milk'-crab; the remaining 44 % of catchers did not know its meaning. As the central idea of the CSD in this axis, 'milk' means the white-colored liquid that comes out of the crab.

> *"Because it turns pale, whitish, a white liquid as milk comes out, it is changing the shell, it is poisonous."* — **five catchers**.

As for the marketing of the 'milk'-crab, 89 % of catchers do not sell this product, and only 11 % of catchers sell them. The central idea of the CSD correlates to aspects of health.

> *"It is bad, it causes stomachache. It tastes bad, you can't eat it, it is weird."* — **six catchers**.

Regarding having eaten the 'milk'-crab, 89 % of catchers denied this. They know it is bad for their health and may even cause reactions, such as the eruption of 'lumps' on the skin. One catcher reported that he had eaten a 'milk' crab and that the taste is terrible, but he did not feel bad afterwards.

Regarding seeing dense aggregations of females with eggs on the margins of the mangrove, 78 % of

catchers said they had already seen it, and 22 % of catchers had never witnessed this phenomenon. The central idea of the CSD in this axis is spawning:

*"To release the eggs, they eat, walk back and forth. With their paws they pull the eggs from the abdomen."* — **seven catchers.**

Regarding the time required for the crab to reach a commercial size (80 mm carapace width - CW), 46 % of catchers said they did not know this information, while the remaining 54 % of catchers indicated a significant age contrast, including one year (33 % of catchers), ten years (11 %), and two months (11 %).

All catchers reported having knowledge of the closed fishing season law concerning crabs and 89 % correctly identified the period but the remaining 11 % did not know. The catchers mostly indicated the months of October and November (70 % and 35 %, respectively), although some cited September and December (12 % each), as well as August (6 %).

According to 56 % of catchers, the most cited form of access to the closed season law was through the Fishermen's Community, but access to information also occurred through fellow anglers (22 %), television (11 %), and when the sanitary inspection agents fined them for not having the General Fisherman's Registry ('Registro Geral de Pescador - RGP') (11 %). These same 56 % of catchers mentioned meeting people who catch crabs during the closed season, and only 33 % of catchers mentioned meeting people who paid a fine. One of the interviewed catchers revealed that he has already been fined for not complying with the closed season provided for by the legislation in force. The fine was R$ 174 (~US$ 34).

Most catchers (56 %) agreed with the existence of the closed season. They did not see a need to change it. Three of them (33 %) indicated that this season is important and proposed extending the period from the time of 'milk'-crabs (October) until February, covering spawning and 'walking' ('andada') events. Catchers claim that the crabs are very vulnerable during 'walking' and thus can be easily caught by people who disregard the legislation. Another aspect to be considered is the need for greater inspection activity by the authorities; a fact mentioned by one of the catchers.

Questions on the eating habits of the crabs and participation of *U. cordatus* in the mangrove food chain resulted in all catchers (n = 9) mentioning that the species feeds on 'mangrove' leaves. Catchers also mentioned other food elements, such as roots (22 %), vegetation in general (22 %), and 'fruits' (22 %). Therefore, the CSD is as follows:

*"Leaves that fall from trees, fruits, and roots of the mangrove."* — **nine catchers**.

In addition to its role in the dynamics of nutrient cycling, the mangrove crab participates as a relevant and iconic species in the food chain of the mangrove ecosystem. According to the catchers, the animals that feed on crabs are the following: crab-eating raccoon (n = 8); crab-eating fox (n = 8); tiger heron (n = 7); otter (n = 5); slaty-breasted wood rail (n = 3); puffer fish (n = 1); capybara (n = 1); marine turtle (n = 1); egret (n = 1); and snakes (n = 1). Table 1 shows a synthesis of the species mentioned, their common and scientific names with respective taxonomic authorities, as well as their area of occurrence.

*"Raccoons eat the traps."* — **one catcher**.

*"Puffer fish eat at high tide."* — **one catcher**.

Figure 2 shows a fragment of the mangrove crab trophic chain according to the knowledge of the Itanhaém catchers.

Sixty-seven percent of catchers mentioned that the crab-eating raccoon (*Procyon cancrivorus*) as one of the predators of the mangrove crab. According to them, the animal always uses the paws for this purpose. The central idea of the CSD is as follows:

*"It puts its paw in the burrow, pulls the crab, steps on it, kicks, breaks the shell, and then eats and leaves the shell on the side of the burrow. It also eats trapped crabs."* — **six catchers**.

The catchers mention that if they take too long to check their traps, the crabs are likely to have already been eaten by the time they return. When asked about the crab-eating raccoon catching crabs using its tail, 67 % said this is not true. The same percentage of

**Table 1.** Summary of the faunal species cited by the catchers (by common name) as possible predators of the mangrove crab (*Ucides cordatus*) in Itanhaém city (São Paulo State, Brazil) and its area of occurrence and distribution based on the literature.

| Class | Common name | | Species name | Area of occurrence and distribution |
|---|---|---|---|---|
| **Pisces Osteichthyes** | Baiacu-liso | Oceanic puffer | *Lagocephalus lagocephalus* (Linneaus, 1758) | Circumglobally: tropical/subtropical to temperate seas[5]. |
| | Baiacu-pintado | Checkered puffer | *Sphoeroides testudineus* (Linneaus, 1758) | Western Atlantic to Southwest Atlantic: Rhode Island, USA to Southeastern Brazil[6]. |
| **Reptilia** | Tartaruga-marinha | Loggerhead sea turtle | *Caretta caretta* (Linnaeus, 1758) | Circumglobally: temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans[7]. |
| | Cobra-d'água | Military ground snake | *Erythrolamprus miliaris orinus* (Linnaeus, 1758) | Brazil, Uruguay, Paraguay, Bolivia, Peru, Colombia, French Guiana, Guyana, Venezuela, Argentina. Brazil, Uruguay, Paraguay, Bolivia, Peru, Colombia, French Guiana, Guyana, Venezuela, Argentina. Inhabits estuary and mangrove areas.[4,8] |
| **Birds** | Garça-branca-pequena | Snowy egret | *Egretta thula* (Molina, 1782) | Brazil and from the southern United States and the Antilles to almost all of South America. Inhabits the edges of lakes, rivers, wetlands, and near the sea. Common in mangroves, estuaries, and mud puddles on the coast.[9] |
| | Garça-moura | Cocoi heron | *Ardea cocoi* (Linnaeus, 1766) | Brazil, Panama to Chile and Argentina, and the Malvinas Islands. Associated with estuaries, rivers, and coastal regions.[9,14] |
| | Garça-azul | Little blue heron | *Egretta caerulea* (Linneaus, 1758) | Present throughout the Brazilian coast, Pantanal, and Amazon Basin. From the southern United States and Central America to Colombia, Peru, Chile, and Uruguay.[9,11] |
| | Saracura-do-mato | Slaty-breasted wood rail | *Aramides saracura* (Spix, 1825) | Southeastern Brazil, Paraguay, Uruguay, and Argentina. It inhabits forests and woods, preferring swampy and swampy areas.[9,15] |
| | Saracura-três-potes | Grey-cowled wood rail | *Aramides cajanea* (Muller, 1776) | Brazil and from Mexico to Argentina. Inhabits the ground in areas flooded with dense vegetation, mangroves, riverbanks, and ponds.[9,18] |
| | Saracura-lisa | Uniform crake | *Amaurolimnas concolor* (Gosse, 1847) | Belize, Bolivia, Brazil, Cayman Islands, Colombia, Costa Rica, Ecuador, French Guiana, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Peru, Puerto Rico, Venezuela, and possibly Jamaica. Low-lying humid subtropical or tropical forests, subtropical or tropical swamps, and highly degraded secondary forests.[9,12] |
| | Saracura-sanã | Blackish rail | *Pardirallus nigricans* (Vieillot, 1819) | Brazil, from Pará to Rio Grande do Sul. Also found in Guyana, Venezuela, Peru, Colombia, Bolivia, Paraguay, and Argentina. Typical of wetlands, swamps, and grassy lakes.[9,17] |
| | Socó-boi | Rufescent tiger heron | *Tigrisoma lineatum* (Boddaert, 1783) | Central America to Bolivia and Argentina and throughout Brazil. Lives in humid areas, such as swamps and footpaths, and also forest regions.[9,16] |
| | Socózinho | Striated heron | *Butorides striata* (Linnaeus, 1758) | Brazil and in hot climate regions around the planet in America, Africa, Asia, Australia, and islands in the western Pacific Ocean. It can be found almost anywhere where there is water, both inland and in mangroves.[9,13] |
| **Mammalia** | Cachorro-do-mato | Crab-eating fox | *Cerdocyon thous* (Linnaeus, 1766) | Endemic to South America, it occurs in northern Colombia, Venezuela, most of Brazil (except for the Amazon), throughout Paraguay, in northern Argentina, in almost all of Uruguay, and in Bolivia to the east of the Andes (up to 2,000 m altitude), with few records in Suriname and Guyana. Recently recorded in Panamá.[1] |
| | Mão-pelada Guaxinim | Crab-eating raccoon | *Procyon cancrivorus* (Cuvier, 1798) | Central and South America. It inhabits mangroves, beaches, bays and lagoons[3]. |
| | Lontra | Otter | *Lontra longicaudis* (Olfers, 1818) | Circumglobally: tropical/subtropical to temperate seas[2,10] |

[1]Beisiegel *et al.* (2013); [2]Cheida *et al.* (2006); [3]Cheida *et al.* (2013); [4]Duarte *et al.* (2014); [5]Fishbase (2021a); [6]Fishbase (2021b); [7]MarineBio (2021); [8]Marques and Souza (1993); [9]Piacentini *et al.* (2015); [10]Rodrigues (2013); [11]Wikiaves (2018a); [12]Wikiaves (2018b); [13]Wikiaves (2018c); [14]Wikiaves (2020a); [15]Wikiaves (2020b); [16]Wikiaves (2020c); [17]Wikiaves (2021a); [18]Wikiaves (2021b).

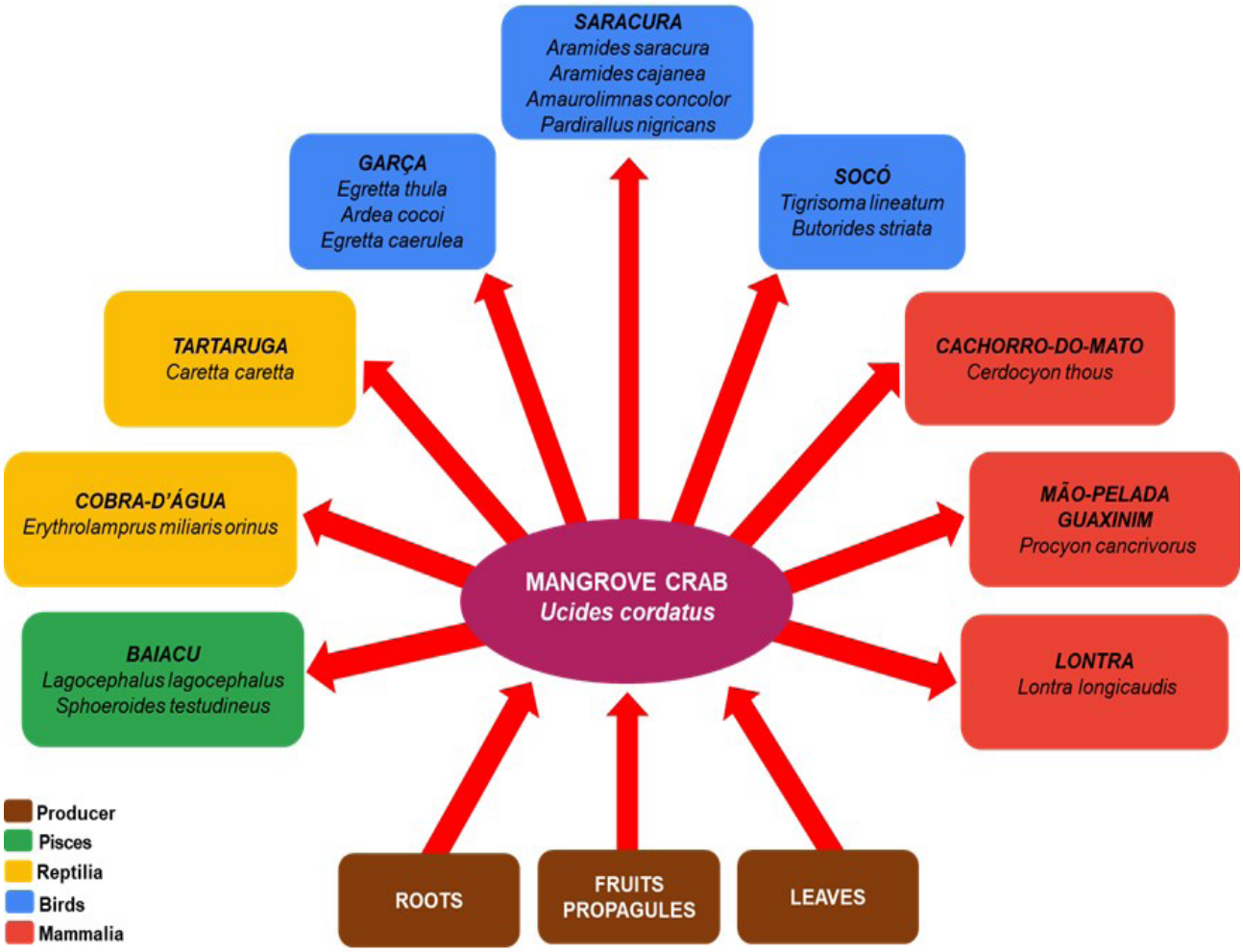


**Figure 2.** Representation of a fragment of the mangrove crab trophic chain according to the knowledge of catchers in the Itanhaém-SP mangrove.

catchers also said that the raccoon has a solitary habit in the mangroves, but 33 % reported that they walk in groups of two to three individuals.

*Ethnobiological calendar of the mangrove crab*

According to the catchers, the molting season of the mangrove crab occurs in October (26 %) and November (37 %), percentages similar to those of the months with the highest occurrence of 'milk'-crabs (40 and 33 %, respectively). These periods are shortly before the reproductive period of the species (December to March), when the following biological events occur: 1) 'andada' (86 %), which is characterized by the emergence of crabs from their burrows; 2) fights between males for the possession of females (100 %); 3) males foaming next to their burrows (92 %); 4) sexual pairing and copulation (91 %); and 5) occurrence of ovigerous females (100 %) (Fig. 3).

The biological stages of crab growth (molting and the occurrence of 'milk'-crabs) correlated positively and significantly with each other ($r = 0.87$; $p < 0.05$) (Tab. 2). Conversely, Tab. 2 also shows a negative association between growth variables and reproductive biological stages ($r < -0.57$) despite the absence of statistical significance for all cases ($p > 0.05$). The biological stages linked with reproductive events correlated positively and significantly with each other ($r \geq 0.92$; $p < 0.05$).

Table 3 shows a calendar with the distribution of biological events of growth and reproduction periods of the mangrove crab. The data obtained are presented together with literature data, including ethnobiological data. Considering the months of occurrence of biological events with a monthly record frequency ≥ 30 %, the percentage of correspondence for all events ranges from 57 to 100 %.

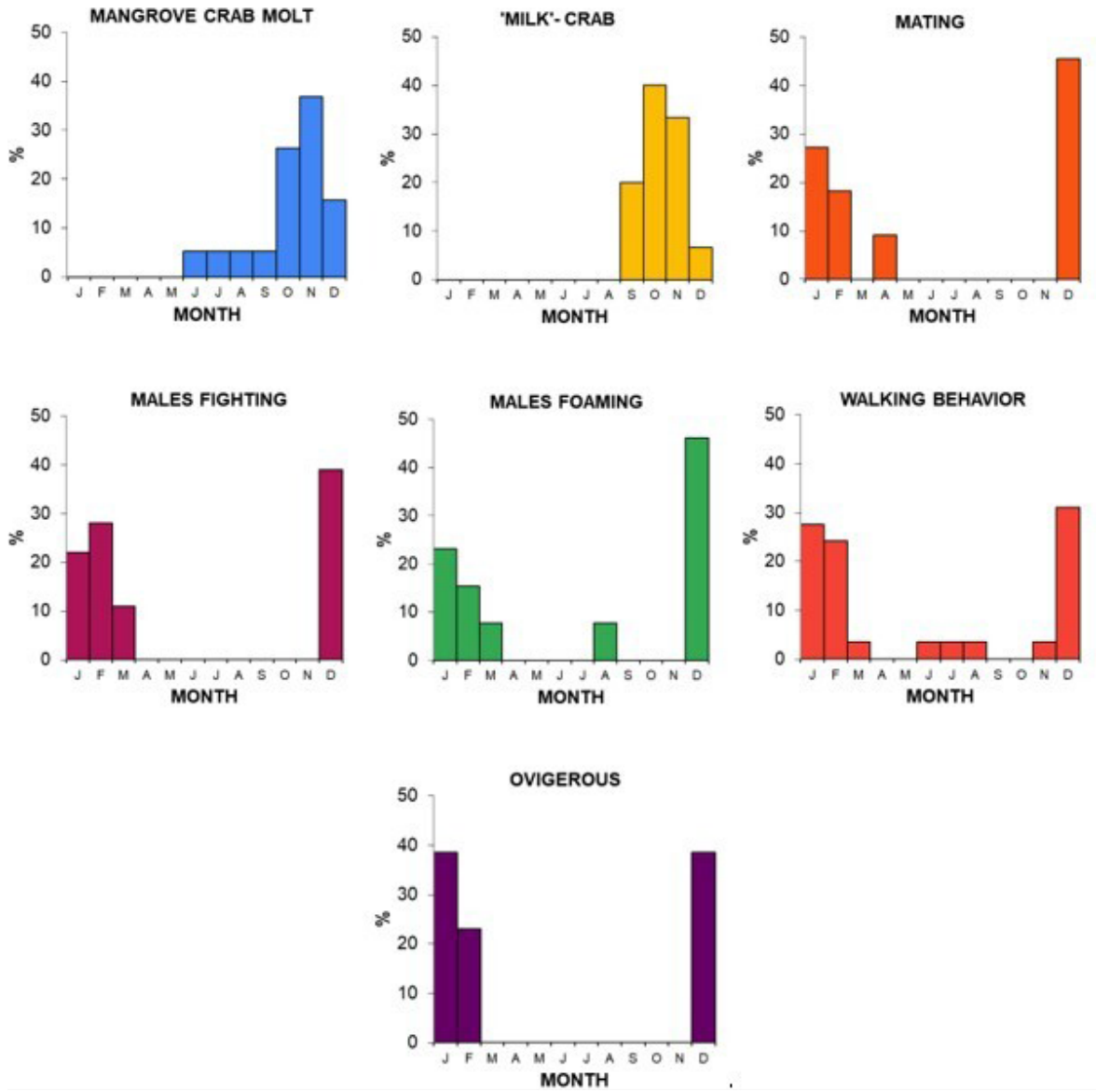


**Figure 3.** Ethnobiological calendar of the mangrove crab (*Ucides cordatus*) showing the months of occurrence of its biological events according to interviews conducted in 2017 with catchers of the mangrove swamp of the Itanhaém River in Itanhaém city (São Paulo State, Brazil).

**Table 2.** Pearson's linear correlation coefficient for variables of biological events (growth and reproduction) of the mangrove crab (*Ucides cordatus*) during interviews conducted in 2017 with catchers in the Itanhaém River, Itanhaém city (São Paulo State, Brazil). Values in bold are significant at 5 % ($p < 0.05$).

| **Biological Events (%)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Pearson's Coefficient** | **Growth** | | **Reproduction** | | | | |
| | **MO** | **MI** | **MA** | **FI** | **FO** | **WA** | **OV** |
| Mangrove crab Molt (MO) | 1,00 | | | | | | |
| 'Milk'-crab (MI) | 0,87 | 1,00 | | | | | |
| Mating (MA) | -0,06 | -0,23 | 1,00 | | | | |
| Males Fighting (FI) | -0,12 | -0,26 | **0,92** | 1,00 | | | |
| Males Foaming (FO) | -0,03 | -0,23 | **0,95** | **0,93** | 1,00 | | |
| Walking Behaviors (WA) | -0,10 | -0,27 | **0,92** | **0,95** | **0,91** | 1,00 | |
| Ovigerous (OV) | -0,11 | -0,23 | **0,95** | **0,92** | **0,91** | **0,98** | 1,00 |

**Table 3.** Monthly frequency (FR) of each biological event of the mangrove crab (*Ucides cordatus*) in relation to growth (molt and 'milk'-crab) and reproduction (walking behavior, males fighting / foaming, mating and ovigerous registry), based on scientific literature compared with ethnological data obtained in present study. Where: MO%, monthly occurrence percentage/year; MP%, match percentage between data of the present study and MO%.

| Biological events | | Locate | Period | | | | | | | | | | | | MO % | MP % | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | J | F | M | A | M | J | J | A | S | O | N | D | | | |
| Growth | mangrove crab molt 'Milk'-crab | N - NE | | | | | | | | | | | | | 50,0 | – | 1,5, 7 |
| | | SE - S | | | | | | | | | | | | | 58,3 | 100,0 | 8,13,12,15, 19 |
| | | Brazil | | | | | | | | | | | | | 58,3 | 83,3 | same as above |
| Reproduction | walking behavior | N - NE | | | | | | | | | | | | | 50,0 | – | 1,2,4,5,7,11, 17 |
| | Males fighting | SE - S | | | | | | | | | | | | | 41,7 | 80,0 | 3,6,8,9,12,13,14,15,18, 19 |
| | Males foaming | Brazil | | | | | | | | | | | | | 41,7 | 66,7 | same as above |
| | Mating | N - NE | | | | | | | | | | | | | 66,7 | – | 1,5,7, 17 |
| | | SE - S | | | | | | | | | | | | | 33,3 | 75,0 | 3,6,8,13,14,15, 19 |
| | | Brazil | | | | | | | | | | | | | 58,3 | 57,1 | same as above |
| | Ovigerous | N - NE | | | | | | | | | | | | | 41,7 | – | 1,5,7, 10 |
| | | SE - S | | | | | | | | | | | | | 33,3 | 75,0 | 3,8,13,14,15,16, 19 |
| | | Brazil | | | | | | | | | | | | | 41,7 | 60,0 | same as above |

FR ≤ 30 % | 30 % < FR < 70 % | FR ≥ 70 %

[1]Alcântara-Filho (1978); [2]Botelho *et al.* (1999); [3]Branco (1990); [4]Castro (1986); [5]Costa (1979); [6]Dalabona *et al.* (2005); [7]Diele (2000); [8]Fiscarelli and Pinheiro (2002); [9]Goes *et al.* (2010); [10]Mota-Alves (1975); [11]Nascimento *et al.* (1982); [12]Oliveira (1946); [13]Pinheiro and Fiscarelli (2001); [14]Pinheiro and Fransozo (2002); [15]Present estudy; [16]Rodrigues and Hebling (1989); [17]Vasconcelos *et al.* (1999); [18]Vergara-Filho and Alves (1992); [19]Wunderlich *et al.* (2008).

## Discussion

The present study describes the ethnobiological knowledge of a community of catchers on the biology of the mangrove crab and its performance profile throughout the life cycle of the species. This may be the only, and perhaps the last, report on this traditional fishing community ('caiçaras') in the region.

Nevertheless, other ethnocarcinology studies have already recorded information on traditional knowledge about *U. cordatus* (*e.g.*, see Fiscarelli and Pinheiro, 2002; Capistrano and Lopes, 2012; Freitas *et al.*, 2015; Machado *et al.*, 2018; Souza and Pinheiro 2020; 2021), either contrasting with or complementing the present study. Therefore, the recording of this information allows the safeguarding of cultural richness and different human perceptions, which may vary among the interviewed catchers.

The traditional 'caiçara' people were formed by the miscegenation of indigenous peoples (already extirpated), colonizing Europeans, and 'quilombola' peoples (Ramires and Barrella, 2003). They formed a mosaic of social groups, often living in some isolation on the coastline between the sea and the mountains, from the south of Paraná State to the central region of Rio de Janeiro State, Brazil. With urban development, many of these communities have lost their peculiar characteristics, with an expressive cultural loss in terms of fishing and ethnobotany.

Identification by catchers of the morphotype (male/female) and other factors are elements of local ecological knowledge (LEK), used as an informally established management measure. The use and incorporation of LEK is an important component of participatory management approaches (Berkes *et al.*, 2001; Berkes, 2004). Most catchers (67 %) say they know how to differentiate between the sexes only by their traces and the knowledge acquired over years of experience. Alves *et al.* (2005) and Machado *et al.* (2018) corroborate this statement. These authors found a similar proportion of positive responses: 69 % in Cubatão city, São Paulo State, and 75 % in the Mamanguape River estuary, Pernambuco State, in northeastern Brazil.

The other catchers declared they needed contact with the animal to differentiate between sexes. Empirical knowledge has a close association with scientific knowledge since both use species morphology for such a differentiation. In males, the abdomen is elongate and triangular, with the presence of a dense fringe of bristles on the ventral surface of the second to fifth pair of pereiopods (walking legs). Females, on the other hand, have a semicircular abdomen and few bristles on their legs (Pinheiro and Fiscarelli, 2001). Therefore, males sometimes leave bristle marks in the mud (Santos *et al.*, 2009). It is important to emphasize here that the loss of the cultural transmission of this traditional knowledge has led new generations of crab catchers to use predatory techniques, such as 'redinha' (Nascimento *et al.*, 2012; 2016). The 'redinha' (little net) is a popular trap (fishing gear), but prohibited by law, which are handcrafted by crab gatherers using plastic fibers (raffia sacs) and branches of mangrove trees, placed in the opening of the galleries to capture the crabs (see Pinheiro and Fiscarelli, 2001). These different techniques represent a break with traditional patterns of extraction of the species and may represent a threat to its further conservation (Alves *et al.*, 2005).

Sex differentiation is extremely important for the conservation of the species, especially with regard to the closed season for the southeast region. This region has a restriction on the capture of females throughout the month of December, although the capture of males is allowed (IBAMA, 2003b). Corroborating Capistrano and Lopes (2012), crab gatherers can provide very accurate information about the bioecology of *U. cordatus*, although there may be some limitations regarding specifics.

Most catchers do not market 'milk'-crabs. More than half of the catchers reported knowing the reason for why they are called this, that is, the time of ecdysis, or 'shell exchange'. The association made by the catchers from Itanhaém city (SP) differs in part from that made by catchers from Iguape city (São Paulo State). In the latter, according to Fiscarelli and Pinheiro (2002), some catchers related the 'milk' to the breastfeeding of juvenile crabs and even to religious aspects. This ethnocarcinological information showed a good association (44 %) with scientific information. Greenaway (1993) mentions that during pre-molt the calcium and magnesium must be reabsorbed from the exoskeleton and stored in hemolymph and soft tissues in some land crabs to prepare specimens for the molting process. This phenomenon is remarkable

for the crab *U. cordatus*, where a great amount of Ca (calcium) and Mg (magnesium) promote a whitish coloration in hemolymph and all tissues before ecdysis, that is peculiar to this species (Pinheiro and Fiscarelli, 2001) and necessary for the stiffening of the new carapace.

The mangrove crab takes one year to reach a commercial size (~ 6–8 cm CW), according to 33 % of the catchers, although the mean age mentioned is 2.6 years. *Ucides cordatus* has a slow growth rate, taking about three years to reach sexual maturity (~ 5 cm CW) and around ten years to reach 8–10 cm CW (Pinheiro and Fiscarelli, 2001; Pinheiro *et al.*, 2005). This age of sexual maturity is four times the age corresponding to the best marketing period indicated by catchers for crabs with an 8 cm CW. A significant percentage of these professional catchers is unaware of this information. Some authors have observed a decrease in the size of the catch and point to the use of predatory catching techniques and noncompliance with legislation as probable causes (Jankowsky *et al.*, 2006). Due to the slow growth rate of the species, and the intense extraction to which it is subject, mainly in the North and Northeast regions of Brazil, more frequent inspection is needed and a more adequate management of the natural populations of *U. cordatus* should be made (Pinheiro and Fiscarelli, 2001; Capistrano and Lopes, 2012; Freitas *et al.*, 2015).

Respect for environmental legislation is also of fundamental importance for proper management of this species. Most catchers reported that they hunt crabs throughout the year and only 44 % of catchers reported respecting the closed fishing season established for the southeast-south region by IBAMA Ordinance No. 52/2003. The closed fishing season is a strategy towards sustainable management of this species, aiming to ensure their reproduction and the maintenance of natural stocks. Compliance with the legislation aims to ensure resources are available to present and future generations. After meeting some prerequisites, anglers can access a closed fishing season insurance and therefore comply with the prohibition period. The duty of the public authorities is to monitor the catchers compliance with the law.

Although all catchers declared knowing about the closed season law for managing the mangrove crab resource, the period of prohibition they indicated was not always the same as that of the actual legislation (IBAMA, 2003b). Out of 89 % of catchers who indicated knowing of the period, 44 % of them correctly identified October and November as the main period of prohibition stipulated in the current legislation (closed fishing season applied to males and females of *U. cordatus*), but made wrong answers for December (when the prohibition falls only on females of this species).

Fiscarelli and Pinheiro (2002) found a different percentage (32 %) of catchers made the correct association for the closed period. This discrepancy indicates a possible failure in communication between the catchers and the Fishermen's Community, as well as in the inspection mechanism by the responsible agents. This difference in compliance with the legislation can put the management of the species at risk, also affecting the entire mangrove ecosystem, considering the close relationship between them. It is important to note that the current legislation prohibits the catch and commercialization of ovigerous females at any time of the year for the coastal-center region of São Paulo State.

The empirical knowledge about crab eating habits and the participation of *U. cordatus* in the trophic chain positively correlates with scientific data. Through observation and interaction with the species and its habitat, catchers mention with great precision the elements of the crab's diet, as well as crab predators, reinforcing the importance of the mangrove crab to the ecosystem.

The mangrove crab is food for several animals that live in, or frequent, the mangroves, such as: the puffer fish (Fishbase, 2021a; 2021b); the reptiles *C. caretta* (see Bugoni *et al.*, 2003) and *E. miliaris orinus* (see Duarte *et al.*, 2014); the ciconiform birds such as egrets and tiger-herons (Sick, 1997); and the mammals *P. cancrivorus* (see Emmons and Feer, 1990), *C. thous* (see Montgomery and Lubin, 1978), and *L. longicaudis* (see Helder and Ker de Andrade, 1997). Among them, the empirical knowledge was greatest regarding the crab-eating racoon (called 'mão-pelada'). This intimate knowledge is built by extensive field experience and a greater frequency of sightings, allowing catchers to know various facts, which prevail over the myths at the study sites. Animals mentioned in the present study

coincided 60 % with those presented by Fiscarelli and Pinheiro (2002) and 36 % with those in Souto (2007).

The catchers mentioned mangrove leaves, roots, and fruits as sources of food for crabs, with the latter source being considered synonymous with propagules. According to this perspective, Fig. 3 shows a fragment of the trophic relationships of the mangrove crab.

The catchers did not associate the color of the crab's exoskeleton with the pre-molt and post-molt phases. The only mention of color was in relation to the 'milk'-crab. As for the identification of biological events related to molting, animal growth, and the 'milk'-crab, the periods of occurrence mentioned by the catchers for the events are July to September, July to December, and September to December, respectively and longer than those in the literature. However, when considering the period of greatest occurrence of all these events, the percentage of correspondence with scientific/ethnobiological data is 100 % for the south and southeast and 83.3 % for all Brazil.

Considering all events related to the reproductive period ('andada', male fighting, males foaming in the burrow, and presence of ovigerous females), the scientific and ethnobiological data coincided 76.7 % of the time for the SE-S region and 61.3 % for Brazil. Thus, the ethnobiological data highlights an important issue for the life cycle of this species, namely that crab growth/fattening periods diverge from the reproductive period. This confirms the antagonism mentioned in other studies (Mota-Alves, 1975; Alcântara-Filho, 1978; Costa, 1979; Maneschy, 1993; Botelho *et al.*, 1999; Ivo *et al.*, 2000; Hartnoll, 2001; Pinheiro and Fiscarelli, 2001; Dalabona *et al.*, 2005; Wunderlich *et al.*, 2008; Silva *et al.*, 2009; Sant'Anna *et al.*, 2014) and Tab. 3 shows this antagonism between both periods for this study.

Similarly for other crabs, the size at maturity of *U. cordatus* varies with geographic latitude. Crabs are smaller in the north than in the south (Pinheiro and Fiscarelli, 2001; Diele, 2005) due to the higher, more constant temperatures near the equator, which allows an early maturation of the population. Therefore, the distribution of biological events differs between Brazilian regions (Tab. 3) and reproductive events are distributed with a greater intensity and with longer periods in these regions than in the SE-S regions. This information is important for species management, especially for supervisory bodies. For the SE-S of Brazil, the size at sexual maturity is from 6 cm CW (see IBAMA Ordinance No. 52/2003). In addition to following federal guidelines, the periods during which the catching of this species is closed throughout the Brazilian territory also follows closely the uniqueness of each region, which may be even more restrictive.

## Final Considerations

The participation of *U. cordatus* in the mangrove trophic chain denotes the importance of this species for ecosystem balance. It serves as food for various animals, including species under different degrees of extinction threat. These include otters (*L. longicaudis*) and sea turtles (*C. caretta*), which are almost threatened with extinction and threatened with extinction, respectively. In addition, this crab species actively participates in the recycling of leaf litter and organic matter genesis, which contributes to the exuberance of mangrove forests.

The 'caiçara' population of Itanhaém (São Paulo state), formed from the miscegenation of Portuguese settlers, with 'Guarani' Indians and post-abolition black people, developed a particular way of life closely associated with the sea, estuaries, and adjacent environments, such as the Atlantic Forest (Begossi *et al.*, 2001; Hanazaki, 2003). Their activities and daily habits were adapted to the resources provided by these coastal ecosystems, where the traditional knowledge of crab catchers is very close to that obtained through the scientific method, but with limitations due to several factors. Ethnocarcinological studies though indicate high percentages of correspondence to scientific knowledge, as found in the present study (Alves and Nishida, 2002; Fiscarelli and Pinheiro, 2002; Freitas *et al.*, 2015; Machado *et al.*, 2018; Souza and Pinheiro, 2020; 2021). Considering all the events evaluated regarding the growth and reproduction of this species, the correspondence to scientific data is 66.8 % for Brazil and 82.5 % for the SE-S regions of Brazil. The traditional knowledge of crab catcher communities in the SE-S regions of Brazil differs from that presented by traditional communities originating

from the indigenous peoples of the N-NE regions (*e.g.*, 'Tremembé' Indians, among others). This fact may be associated with several elements, such as: 1) greater conservation and transfer of knowledge over generations in the N-NE regions, due to the lower segregation of these natives in relation to the SE-S regions; 2) a more intrinsic relationship of these natives with the mangrove, due to the larger area of this ecosystem in the N-NE regions; 3) a greater dependence of these indigenous peoples of the N-NE regions on seafood items (*e.g.*, mollusks, crustaceans, etc.) for their survival, favoring greater contact with the species and the mangrove; and 4) by the insertion (or suppression) of new cultural habits by the 'caiçaras' of the SE-S regions.

The ethnocarcinological knowledge of crab catchers about the biology and ecology of the mangrove crab throughout its life cycle (*e.g.*, growth and reproduction) highlights the intimate man-mangrove-crab interactions, enabling support for the establishment of conservation strategies. These strategies will allow this species to continue to provide environmental services to the ecosystem and to humans, mainly as a fishery resource.

This study shows how the performance profile of catchers may affect the conservation of the mangrove crab. This information is extremely valuable for lawmakers, who can deliberate with greater propriety on legal instruments aimed at protecting this resource and the ecosystem and, on the regularization/inspection of this artisanal fishing activity in this part of the coastal-center region of São Paulo State. The ultimate aim is sustainable exploitation of the resource.

The ethnobiological data discovered in this research corroborates the scientific literature, stressing the relevance and accuracy of local ecological knowledge by human perception in the interpretation of data from nature. However, the catching of crabs in disregard for the closed fishing season puts at risk the proper management, not only of the 'uçá'-crab, but also of the ecosystem, given the close association of this species with the mangroves.

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