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Research Article

Biological responses in gills and hepatopancreas of *Ucides cordatus* (Crustacea, Decapoda, Ocypodidae) as indicative of environmental contamination in mangrove areas in Maranhão State, Brazil

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ABSTRACT. This study aimed to identify alterations in gills and hepatopancreas of the crab *Ucides cordatus* as indicative of environmental contamination in mangrove areas subject to chemical effluents from port activities in Maranhão, Brazil. Samples of gills and hepatopancreas were removed from each animal and fixed in Davidson's solution until the procedure of histological technique. The biometric data (means and standard deviations) of the specimens collected in the study areas indicated that the crabs in the reference area are significantly ($P < 0.05$) higher and heavier than the crabs collected in the potentially impacted area (port area). Gill alterations (rupture of pilaster cells, dilation of the marginal channel, cuticle rupture and necrosis) and hepatopancreas alterations (abnormal lumen, vacuolized B cells, pycnotic nuclei and necrosis) were significantly ($P < 0.05$) more frequent in crabs collected in the port area than crabs collected in the reference area. These data indicate that the health of crabs is compromised due to the pollutants present in the mangroves that surround the port area in São Marcos' Bay.

Keywords: *Ucides cordatus*; uçá crab; biomonitoring; biomarkers; port area; alterations; xenobiotic

INTRODUCTION

Crustaceans are part of the life and economy of many families, especially those who use the organisms as a means of subsistence (Nudi *et al*., 2007). Crustaceans easily accumulate pollutants present in the aquatic environment, as well as through biomagnification by the trophic chain, representing an important route of contamination to public health (Pinheiro *et al*., 2013). Thus, these organisms present high sensitivity to the xenobiotics available in the environment (Carvalho-Neta *et al*., 2019; Oliveira *et al*., 2019).

Ucides cordatus (Linnaeus, 1763) is considered an excellent biomonitor in the identification of mangrove pollution once it can respond to several types of changes under the influence of xenobiotics (Pinheiro *et al*., 2013). Also, it is an endemic species of Brazilian mangroves and plays a unique ecological role in nature (Nordhaus *et al*., 2006). However, the effects of xenobiotics from port activities in Maranhão on this species are still poorly understood. There are already records of heavy metals in water, sediment and mangrove in the São Luís port region (the area used in this study) that make clear the impacts of chemical po-

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llution in this region (Furtado, 2007; Sousa, 2009; Carvalho Neta *et al*., 2012). As the crab is an animal that feeds on mangrove vegetation and is in direct contact with the sediment (Pinheiro *et al*., 2012), we chose to study this organism, as according to the literature they organisms bioaccumulating metal and respond easily to xenobiotics contaminated environment (Pinheiro *et al*., 2012; Duarte *et al*., 2016). Thus, the investigation of the effects on the health of this organism is of great relevance to the ecosystem and to the health of the people that use it for subsistence.

The histological analysis of gills and hepatopancreas of crustaceans has been increasingly recognized as a valuable tool for the evaluation of the impacts of pollutants on crustaceans (De Freitas-Rebelo *et al*., 2000; Maharajan *et al*., 2015; Negro, 2015; Carvalho-Neta *et al.*, 2019). The gills are characterized as the first organ to get in contact with environmental pollution; this organ is highly sensitive to chemicals (Negro, 2015), which can lead to severe problems for the organism. The hepatopancreas of crustaceans is a very dynamic organ mainly related to the digestive functions, being responsible for most of the detoxification activity (Maharajan *et al*., 2015) responding with intensity to toxic substances.

The use of morphological alterations in gills and hepatopancreas (as biomarkers) of *U. cordatus* can provide information about the toxicity of chemical compounds in the environment, contributing in a fast and effective way for the monitoring of mangrove systems and port regions. They provide economically and short-term information on the effects produced by exposure to xenobiotics (De Freitas-Rebelo *et al*., 2000; Maharajan *et al*., 2015; Negro, 2015). Biomarkers are defined as the biochemical, morphological, physiological or behavioral responses of organisms to xenobiotic present in the environment (Walker *et al*., 2010).

In the estuarine system, mangroves occupy an extensive area and are considered an important ecosystem (Davanso *et al*., 2013), also participating in the recycling of biological nutrients and primary productivity. Also, mangroves serve as a nursery for many species of ecological and economic importance (Bayen, 2012). In this context, mangroves in Maranhão (Brazil) is home to several species of crustaceans, where the effects of impacts from the port complex in São Marcos' Bay on these aquatic organisms have already been reported (Carvalho-Neta *et al.*, 2012, 2019; Sousa *et al.*, 2013; Oliveira *et al*., 2019), which requires a thorough investigation of the impacts in this region (Carvalho-Neta *et al*., 2012, 2019; Sousa *et al*., 2013; Oliveira *et al*., 2019). This study aimed to identify alterations in gills and hepatopancreas of crabs as indicative of environmental contamination in mangroves areas subject to chemical effluents from port activities in Maranhão, Brazil.

MATERIALS AND METHODS

Study area

São Marcos' Bay (02°43'13"S, 44°21'39"W), located in the Maranhense Gulf, is classified as one of the most important estuarine area on the Brazilian coast, due to the implantation of the port complex of the State of Maranhão (1960), where about 30 companies operate the economy of the state (Souza-Filho, 2005). Therefore, it requires more detailed studies about the impacts these companies can cause in the environment and consequently in the organisms. Thus, this area was chosen and characterized in our study as a port area considered a "potentially impacted area" (Fig. 1).

The Facão Island, municipality of Raposa, is located in São José' Bay (02°25'13"S, 44°05'12"W) about 30 km far from São Luís, and it presents a mangrove ecosystem with rich fauna and flora (Santos *et al*., 2011). There are no major port installations or residences on the island. Therefore, it was used as a reference area in this study.

Crabs samples

Bimonthly collections of *Ucides cordatus* crabs were taken in the field during the dry and rainy seasons between 2016 and 2017. Only the rainy (January to June) and dry (July to December) seasons are set as default for the region (INMET, 2017). The capture of crabs was authorized by SEMA (Secretaria de Estado de Meio Ambiente e Recursos Naturais) collection permit (#18208/2014) issued by the State Department of Natural Resources and Environment. During the collections, it was obtained 50 individuals of crabs per area (port and reference areas) with a total of 100 individuals. In order to standardize, it was chosen to capture only sexually mature males in the intermolt phase, avoiding any effects of molting and sex (Pinheiro *et al*., 2012).

With the help of artisanal fishermen, the crabs were collected using the braiding ("braceamento") technique, consisting of the catching of the crabs from the holes using the arm (Nordi, 1995). After that, the crabs were kept in thermal boxes and taken to the Laboratory of Biomarkers in Aquatic Organisms of the State University of Maranhão for laboratory procedures.

Sediment collection

Samples of mangrove sediments (a triplicate sampling in each area) were obtained for chemical analysis through acid digestion in a microwave oven (method 3051 USEPA, 2007). The digested solutions were filtered and analyzed by inductively coupled plasma optical emission spectrometry (ICP-IOS Optima 8300-Perkin Elmer) for the analysis of arsenic, cadmium,

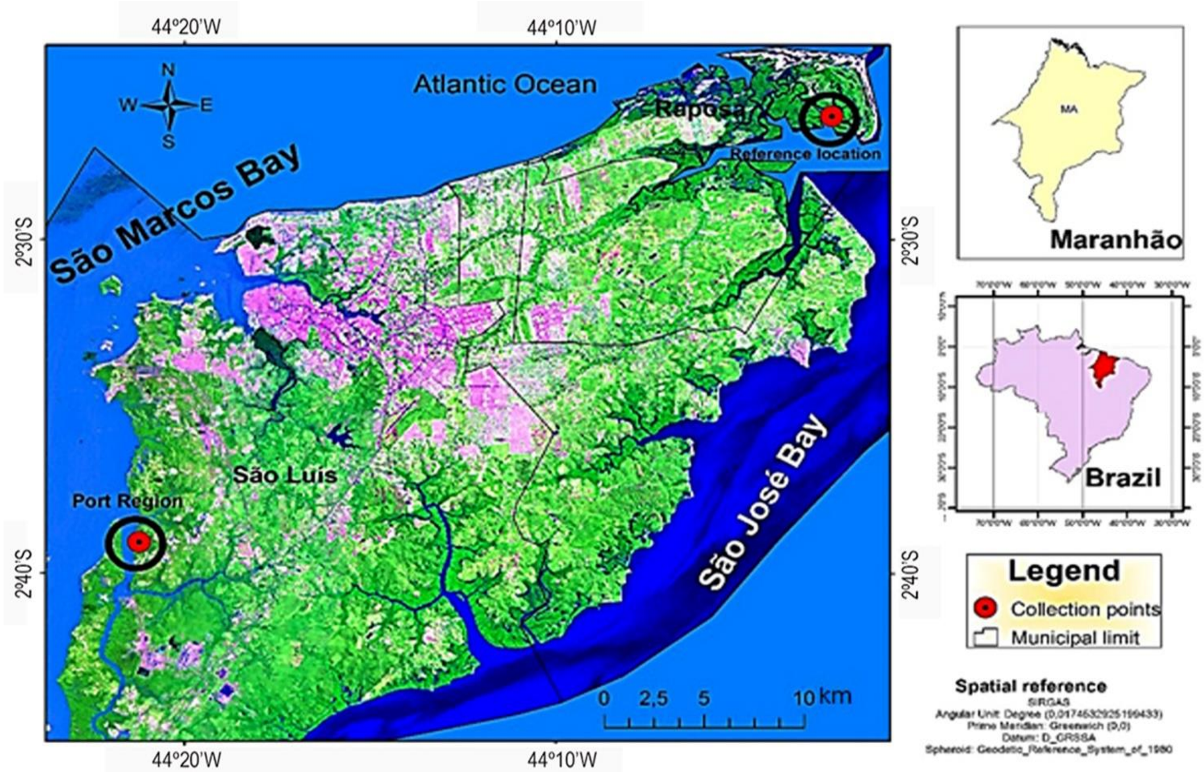

Figure 1. Location map representing sampling sites of *Ucides cordatus* crabs: Port Region - São Marcos' Bay; Reference area - Island of Facão, Raposa, São José' Bay, Maranhão, Brazil.

lead, copper, chromium, nickel and zinc content and by cold vapor atomic absorption spectrometry (CVAAS-Buck 400A) to analyze the concentration of mercury. The detection limits calculated as three times the standard deviation of the reagent blanks and given in mg kg^{-1} for HCl and HNO_3 extracts, respectively, were: Cd: 0.005 and 0.017; Ni: 0.054 and 0.018; Pb: 0.036 and 0.210; Cu: 0.022 and 0.054; Zn: 0.3 and 1.2. Samples of water from the crab collection sites were collected for physical and chemical analysis, such as temperature (°C), saturated dissolved oxygen (%), pH and salinity.

Biometrics data of *U. cordatus* collected in the port and reference areas

According to Pinheiro & Fiscarelli (2001), biometric data such as carapace width (CW) and length (CL) were taken with the aid of a precision pachymeter (0.1 cm). After that, the total weights (TW) of each specimen of crab were measured on a precision scale (0.1 g).

The histological procedure of gills and hepatopancreas samples

In the laboratory, the specimens of *U. cordatus* were immediately dissected. Samples of hepatopancreas and gills were removed with the help of sterilized scissors. Then, the samples were fixed in Davidson's solution for 24 h (Arockia-Vasanthi *et al*., 2014) in vials adequately identified and sealed. After 24 h, the samples were washed and stored in 70% ethanol.

Afterward, the hepatopancreas and gills were dehydrated in increasing series of ethanol, diaphanized in xylol and impregnated with paraffin. Cross-sections of approximately 5 μm thick, were stained with hematoxylin and eosin. In light microscopy, the cuts were analyzed for each organ of each animal. The modifications were photo-micrographed with an Axioskop-Zeiss microscope and quantified, according to specialized literature (De Freitas-Rebelo *et al*., 2000; Maharajan *et al*., 2015; Negro, 2015).

Statistical analyses

The biometric data were expressed as the mean and standard deviation, submitted to the normality test and were compared between the regions and between the seasons of the year by Student's *t*-test in order to verify significant differences ($P < 0.05$) in the alterations found and in the biometric data between the groups (in potentially impacted and reference areas).

The results of the alterations in the gills and hepatopancreas were expressed in percentages. A total of 20 hepatopancreas tubules per slide were analyzed, in which the percentage of the total number of tubules and total tubules affected were obtained. Concerning the gills, the total number of secondary lamellae and the total of each affected secondary lamella were analyzed and quantified.

RESULTS

Chemical analysis of sediment

The values of the heavy metals concentrated in the sediments of the areas analyzed in this study were different when compared between areas (Table 1), since in the port area the data of concentration of heavy metals are higher than in the area which is not influenced by the port activity (reference area). On the other hand, these values are within the standards allowed by Brazilian legislation (CONAMA Resolution 454/2012).

Biometric data

The biometric data of the specimens of *Ucides cordatus* analyzed in the potentially impacted area (port area) presented significantly lower values ($P < 0.05$), in both periods (dry and rainy season), when compared to the crabs collected in the reference area (Table 2).

Morphological biomarkers and gill alterations

Different types of alterations were observed in the gills of *U. cordatus* (Fig. 2). In the port area, the number of alterations identified was higher than those found in the reference area. The percentage of branchial alterations in *U. cordatus* sampled between the seasonal (rainy and drought) periods are included in Table 3. For the rainy season, there was a higher percentage of branchial alterations in the port area. The most important alterations in the gills of crabs caught in the potentially impacted area were the rupture of the pilasters (dry season 26.4%; rainy season 63.8%), necrosis (dry season 19.7%; rainy season 49.4%) and deformation of the marginal canal (dry season 26.9%; rainy season 43.1%).

Alterations observed in the hepatopancreas

Observations indicated that the percentage of the alteration in the hepatopancreas of *U. cordatus* in the port area was higher than in the crabs collected in the reference area (Fig. 3; Table 4). The percentage of alterations in the hepatopancreas of *U. cordatus* indicated that the alterations were more frequent in crabs caught in the port area for both rainy and dry periods. However, the occurrence of alterations in the hepatopancreas of crabs varied between the rainy season and dry season for the port area ($P < 0.05$). The most important alterations in the hepatopancreas of crabs caught in the potentially impacted area were the abnormal lumen (dry season 88%; rainy season 94%), vacuolized B cells (dry season 77%; rainy season 69%), necrosis (dry season 65%; rainy season 51%) and pycnotic nuclei (dry season 59%; rainy season 66%).

Table 1. Values of heavy metals in sediments (mg kg^{-1}) from the sampling sites. LD: limits of detection. *Indicates significant differences between areas ($P < 0.05$). Port area: impacted area, Reference area: low-impacted area Brazilian Law (CONAMA #454/2012).

Metal	Heavy metal (mg kg^{-1})		Value area (min.-max.)
	Port area	Reference area	
Arsenic	5.9 ± 0.2*	2.0 ±0.1*	19-70
Cadmium	<0.6	<LD (0.6)	1.2-7.2
Lead	7.9 ± 0.2*	2.4 ± 0.3*	46.7-218
Cooper	9.1 ± 0.5*	2.5 ± 0.2*	34-270
Chrome	18.2 ± 0.8*	5.3 ± 0.3*	81-370
Mercury	<0.05	<0.05	0.3-1.0
Nickel	7.1 ± 0.2*	1.9 ± 0.1*	20.9-51.6
Zinc	27 ± 1.0*	10 ± 1.0*	150-410

Comparison of alterations in gills and hepatopancreas

The alterations observed in crabs were much more frequent in gills than in hepatopancreas of *U. cordatus* (Fig. 4). Besides, in the port area, branchial alterations were more frequent when compared to the reference area.

DISCUSSION

The values of the concentration of heavy metals found in sediments indicated that the *Ucides cordatus* species might be bioaccumulating these components in their tissues, which can lead to the appearance of the defensive responses as the appearance of alterations in their organs and the diminution of their body size. Also, in this region, past studies have identified contaminations by heavy metals in water samples, mangrove sediments, vegetation and leaf dust (Carvalho-Neta *et al*., 2012; Silva *et al*., 2016), confirming the exposure of aquatic biota, contaminants such as heavy metals.

In Maranhão, mainly in the port region, a study about fish and crab biometrics showed significant differences in the sizes and weights of the individuals collected in the port area concerning a reference area

Table 2. Means and standard deviation of the biometric data of *Ucides cordatus* collected during the dry and rainy seasons in the port area and in the reference area, respectively. *Indicates significant differences between sites and periods (rainy and dry) ($P < 0.05$). Total number of crabs = 100 (50 per area). CW: carapace width, CL: carapace length, TW: total weight.

Biometric data	Dry season		Rainy season	
	Port area	Reference area	Port area	Reference area
TW	115.00 ± 2.82*	142.50 ± 3.53*	130.00 ± 1.41*	190.50 ± 17.67*
CW	6.65 ± 0.07*	6.50 ± 0.42*	7.30 ± 0.42*	7.65 ± 0.35*
CL	4.65 ± 0.49*	4.85 ± 0.49*	5.20 ± 0.28*	5.10 ± 0.24*

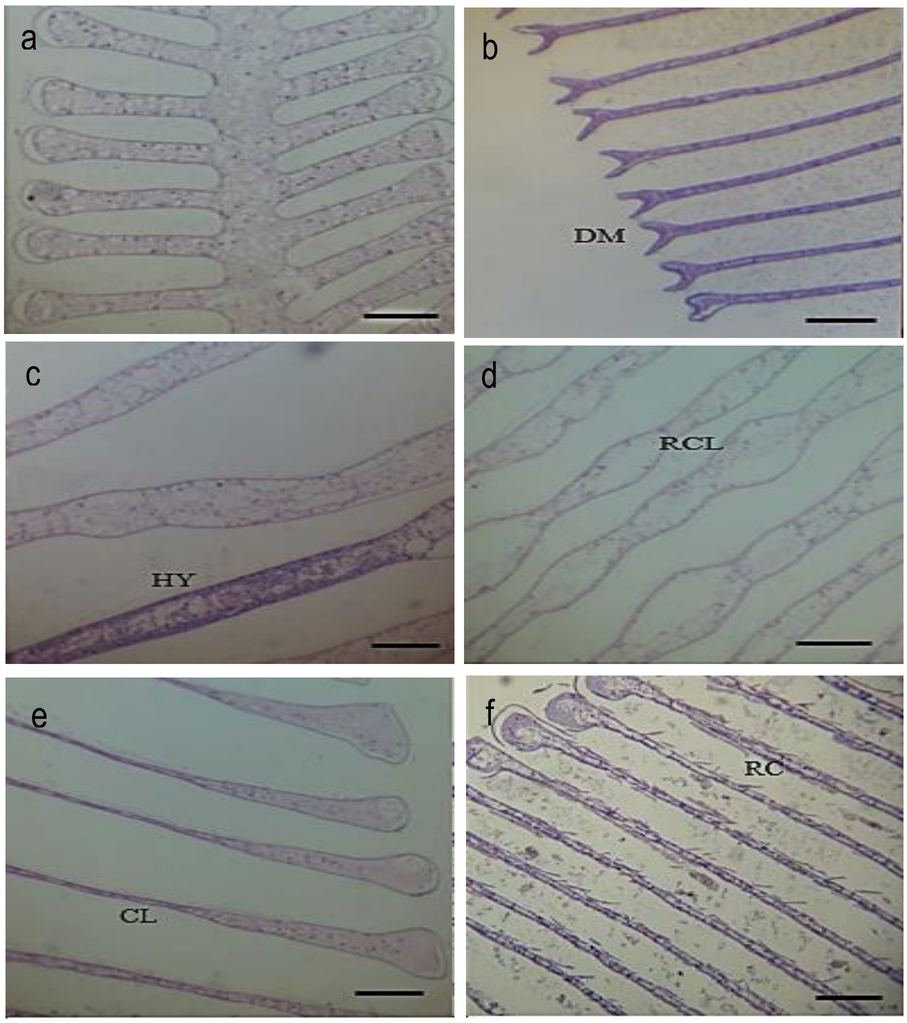

Figure 2. a) Normal gill of *Ucides cordatus* showing the primary lamella in the middle and the lateral lamellae, b) dilation of the marginal channel (DM), c) hyperplasia (HY), d) rupture of pilaster cells (RCP), e) lamellar collapse (CL), f) cuticle rupture (RC). Bar: 100 µm.

(Carvalho-Neta *et al*., 2014, 2019; Oliveira *et al*., 2019). Benetti & Negreiros-Fransozo (2004), observed similar results, studying crabs collected in a mangrove impacted by anthropic actions, where it was observed that the crabs presented smaller sizes than those collected in less impacted areas. Moureaux *et al*. (2011) emphasize that the ability to deal with stress influences the amount of energy that is used in the growth of benthic invertebrates and leading to a consequent reduction in the body size of the individual. Thus, this study suggests that individuals from the port area are showing responses to stress due to the presence of xeno-

Table 3. Percentage of lamellae alterations in the gills of *Ucides cordatus* collected in estuarine environments.

Gill alterations	Dry season		Rainy season	
	Port area (%)	Reference area (%)	Port area (%)	Reference area (%)
Lamellar colapse	0.3	0	8.0	0
Lamellar colapse and tissue swelling	0.3	0	1.3	0
Hyperplasia	0.5	0	1.2	0
Hemocyte infiltration	0.5	0	0.5	0
Melanized nodules	0.6	0	0.5	0
Cuticle rupture	9.9	7.6	35.4	6.2
Detached cuticle	10.0	5.8	13.3	11.9
Necrosis	19.7	0	49.4	0
Rupture of pilaster cells	26.4	16.7	63.8	27
Dilation of the marginal channel	26.9	11.1	43.1	17.7

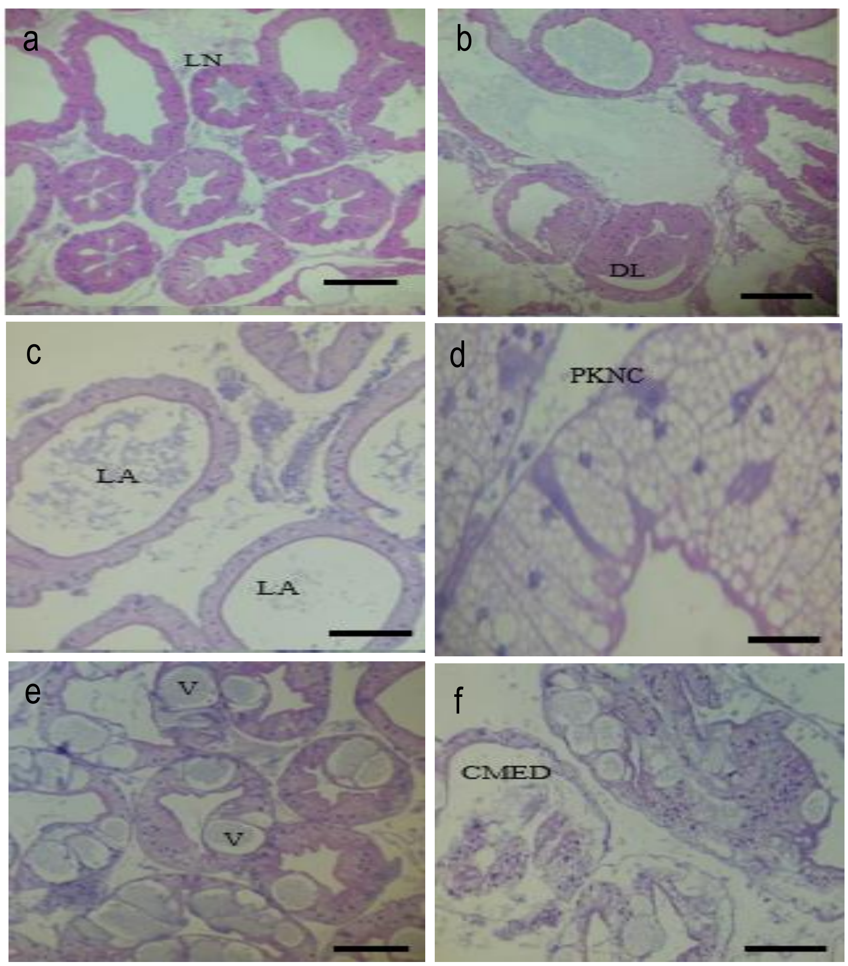

Figure 3. a) Histology of the normal hepatopancreas of *Ucides cordatus* demonstrating the normal star shape of the lumen (LN), b) epithelial delamination (DL), c) abnormal lumen (LA), d) pycnotic nuclei (PKNC), e) vacuolated B cells (V), f) damaged myoepithelial layer (CMED). Bar: 100 µm.

biotics, which may be affecting the development of crabs in the port area.

The most frequent alterations in gills of *U. cordatus* observed in this study, such as rupture of pilaster cells, marginal canal deformation and necrosis, were also

Table 4. Percentage of alterations in the hepatopancreas of *Ucides cordatus* collected in estuarine environments.

Hepatopancreas alteration	Dry season		Rainy season	
	Port area (%)	Reference area (%)	Port area (%)	Reference area (%)
Hemocytic infiltration	13	0	8	0
Apoptose	25	4	13	6
Delamination of the epithelia	36	10	33	8
Vacuolized B cells	77	23	69	38
Damaged myoepithelial layer	32	23	42	27
Necrosis	65	24	51	35
Pycnotic nuclei	59	41	66	41
Abnormal lumen	88	55	94	56

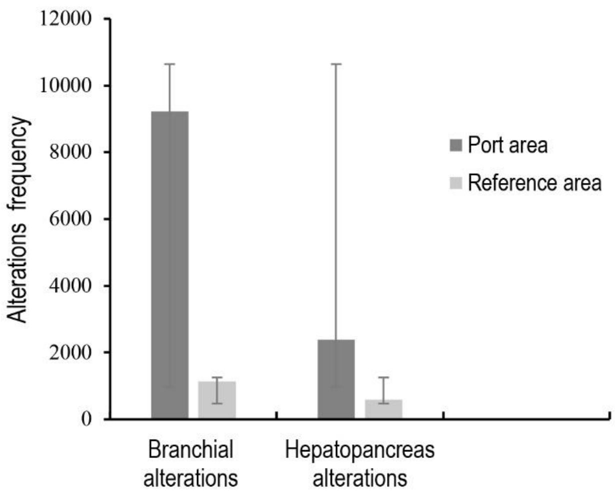

Figure 4. Comparison of alterations frequency observed in gills and hepatopancreas of *Ucides cordatus* in the port area (São Marcos' Bay) and in the reference area (São José' Bay).

found in gills of crustaceans analyzed by De Freitas-Rebelo *et al*. (2000). The most important alteration in both study areas was the rupture of the pilaster cells. This type of alteration is defined as the cell break, resulting in cell death, which leads to necrosis (De Freitas-Rebelo *et al*., 2000). When this structure shows a normal pattern, the pilaster cells attach to epithelial cells, which will have a T-shape in the secondary lamellar.

Carvalho-Neta *et al*. (2012) and Oliveira *et al*. (2019) analyzing the sediment in the study area identified high levels of heavy metals. Also, Sousa *et al*. (2013) using biomarkers in catfish, Oliveira *et al*. (2019) and Carvalho-Neta *et al*. (2019), using biomarkers in crabs collected in São Marcos' Bay, identified significant histopathological responses in the gills of these organisms. These data suggest that the port area in São Marcos' Bay, which is an important habitat for crabs, is being influenced by the impacts caused by the port activities in that region. Alterations, such as hyperplasia, necrosis and rupture of pilaster cells together, can cause greater damage to the branchial tissue resulting in lamellar collapse and functional loss of the organ. According to De Freitas-Rebelo *et al*. (2000), such alteration is characterized as the reduction of hemolymph space, resulting in the collapse of the lamellar.

The gills play a significant role for the species that depend on it for respiration, osmoregulation, excretion of ions and other functions; however, when the gills perform other activities than those that have already been performed, such as the detoxification of heavy metals or pesticides, their structure may get damaged (De Freitas-Rebelo *et al*., 2000; Negro, 2015). Moreover, the gills are the first organs to get in contact with the aquatic environment; thus, they are subject to stress caused by contaminants present in the water. Therefore, gills have been of great importance for the study of biomonitoring being an excellent biomarker of pollution (Negro, 2015).

The alterations identified in *U. cordatus* show that the study areas on the coast of Maranhão have been impacted. However, when comparing the two environments presented here, it is observed that in the reference area, the impact is lower than in the port area. In the port area, which is considered the second largest port complex in Brazil in cargo handling, several industries may be releasing daily industrial effluents that are harmful to aquatic organisms.

In the literature, there are several reports on the histopathological effects of pollutants on crustacean gills (Bhavan & Geraldine, 2000; Arockia-Vasanthi *et al*., 2014; Maharajan *et al*., 2015; Negro, 2015). However, are still few studies about the effects of pollutants in *U. cordatus*, especially in the state of Maranhão (Carvalho-Neta *et al*., 2019; Oliveira *et al*., 2019). Thus, detailed biomonitoring studies in the port areas are extremely necessary, especially about the specific role of each type of crab gill.

Regarding the alterations observed in the hepatopancreas (Fig. 3) of *U. cordatus* collected in the study areas, a significant difference was observed in the frequency of alterations, with the port area presenting the higher alterations in crabs. These data corroborate with the results observed for gill alterations in the same crabs analyzed in the port region (Carvalho-Neta *et al*., 2019; Oliveira *et al*., 2019). Therefore, it is inferred that the alterations observed in different organs of crabs from the port area are due to chronic chemical contamination in the environment. Hepatopancreas of crustaceans play important roles in several metabolic processes, and exposure to chemical contaminants may lead to structural alterations (Bhavan & Geraldine, 2000). The same types of hepatopancreas alterations observed in crabs from the port region in this study were also observed in studies carried out by Maharajan *et al*. (2015) for *Paratelphusa jacquemontii*. In this study, the abnormal lumen alteration (Fig. 3) was the most frequent alteration in the crabs collected in the analyzed areas. It is characterized by morphological alterations of the tubular epithelial cells, since the cell decreases in height, from normal columnar cells to cuboidal cells (Maharajan *et al*., 2015). Also, an increase of vacuolized B cells was observed (Fig. 3), which means that there was a proliferation of these cells. That may be related to the high rate of excretion of hepatopancreas, which is a storage and detoxification organ, so that it is possible to eliminate xenobiotics by increasing the number of F cells and converting them to B cells (Maharajan *et al*., 2015). Such alterations directly affect the tissue and cause damage to the cells. Thus, the alterations cited here are considered severe.

Alterations considered severe indicate irreversibly damage to cells and tissues (Bernet *et al*., 1999). Alterations in hepatopancreas tubule observed in crabs in the port area suggest that the integrity of the tissue may be affected by the exposure to contaminants. Studies testing different types of contaminants show that alterations in the tissues of the hepatopancreas of some crustaceans are due to their exposure to chemical contaminants (Maharajan *et al*., 2015; Negro, 2015). The consequences are the severe alterations identified in the present study, indicating the exposure of crabs to a polluted environment.

When comparing the frequencies of alterations observed in the gills and hepatopancreas of *U. cordatus* collected in the study areas, it was noted that the gills presented a higher frequency of alterations. Thus, it is considered a more sensitive organ than the hepatopancreas (Negro, 2015). The gills are characterized as the best organ to analyze the biomarkers (or biological responses altered due to the presence of xenobiotics) since it is sensitive, and when in direct contact with the water and contaminants, the gills respond with different structural alterations (Carvalho-Neta *et al*., 2019). However, it is relevant to consider that hepatopancreas has also been used as an important organ in studies with biomarkers in crustaceans of chronic contamination, and it is of fundamental importance for the metabolism of organisms (Negro, 2015). Besides that, there are four possible ways to expose crabs to a contaminant: gills, food, ingested water and skin (Galloway *et al*., 2002; Van Der Oost *et al*., 2003). Thus, even if the size of the xenobiotic molecule is larger than the exchange area in the gill, the crab will be susceptible to exposure by other metabolic pathways. Generally, in aquatic contamination studies, it is observed that in acute exposure, the gill responses are the most evident since the gills are directly exposed to xenobiotics present in the environment, responding quickly and significantly to the effects of xenobiotics (Van Der Oost *et al*., 2003).

On the other hand, hepatopancreas responds more slowly to the effects of xenobiotics (Carvalho-Neta *et al*., 2019) on the environment because they need to metabolize these compounds (and the onset of effects is later). Thus, changes in hepatopancreas are considered chronic effects changes about the acute effects changes found in gills. Therefore, both organs can be used in methodologies for the biomonitoring of port areas.

Nevertheless, there is a need to improve the knowledge about contaminants that are interfering in the physiological needs and causing histological alterations in crabs that live under the influence of the port complex activities, such as the one studied here. Besides that, the rainy season contributes to the development of changes in both organs (gills and hepatopancreas), because at this time of year, pollutants are more easily leached from the continent to the aquatic environment (Carvalho-Neta *et al*., 2019). Also, during this rainy season, xenobiotics present in harbor sediments (such as heavy metals) may be remobilized and bioavailable. This situation of xenobiotic bioavailability in this rainy season may influence the increase of organ changes in organisms exposed to the contaminated environment (Sousa *et al*., 2013). In addition, when aquatic organisms are subjected to abiotic variations (*e.g.*, low salinity in the rainy season), they develop defensive mechanisms to maintain themselves in environments with significant variations, whether environmental or anthropic (Romano & Zeng, 2012; Paital & Chainy, 2013).

These data corroborate with other data of crustaceans and fish collected in the port area that is subject to stress caused by xenobiotics (Sousa *et al*., 2013; Carvalho-Neta *et al*., 2014). In other words, the smaller size of the crabs in the port area could indicate a decrease in the growth rate, as it has already been reported for crabs in other areas (Diele *et al*., 2005). A population that lives in a rich environment with food resources will have their individuals growing faster (De Oliveira *et al*., 2013). On the other hand, if there are not sufficient food resources (and if there are anthropogenic impacts on the area), the population may suffer from this impact due to lack of food and stress. Therefore, the port area in São Marcos Bay, which is a region of intense port activity, may influence the quantity of food available and, consequently, the maintenance of the crab populations of that ecosystem.

CONCLUSIONS

The frequency and types of alterations in gills and the hepatopancreas in the *Ucides cordatus* collected in the port area, and analyzed in this study, indicate that the organisms are submitted to stress caused by some contaminant, which leads to the appearance of alterations.

The biometric differences of the crabs between the study areas indicated that the crustaceans from the port area are suffering from the impacts caused by alterations in the environment, once they were smaller and less heavy when compared to the crabs collected in the area reference. Also, the comparison of alterations in gills and hepatopancreas showed that the alterations in these two organs were more extensive and significant in the crabs collected in the port area.

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