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Original Article

Aquatic pollutants are associated with reproductive alterations and genotoxicity in estuarine fish (*Sciades herzbergii* - Bloch, 1794) from the Amazon Equatorial Coast

Poluentes aquáticos estão associados a alterações reprodutivas e genotoxicidade em peixe estuarino (*Sciades herzbergii* - Bloch, 1794) da Costa Equatorial Amazônica

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Abstract

Estuaries are constantly subject to continuous environmental impacts of human activities, such as fisheries, port or industry, and domestic sewage, with fish being one of the most affected aquatic animals, reflecting the impacts directly on their bodies. Thus, the aim of this study was to carry out the biomonitoring of an estuary located on the Amazonian Equatorial Coast through analysis of PAHs (Polycyclic Aromatic Hydrocarbons) in the water, in addition to trace metals, histopathological alterations and analysis of erythrocyte micronuclei in *Sciades herzbergii. S. herzbergii* was used as a model species, due to its estuarine-resident behavior. Gonad and gill samples were subjected to histopathological evaluations. The quantification of trace metals was performed in samples of skeletal muscles of the animals collected, where concentrations of Lead (Pb), Copper (Cu), Zinc (Zn), Cadmium (Cd), Magnesium (Mg), Iron (Fe) and Aluminum (Al) were found. Except for Cadmium (Cd), all the concentrations were above the recommended limits. The PAHs analysis revealed the presence of Naphthalene and Acenaphthene in the water samples Histopathological and genotoxic analyses revealed of lesions in 100% of the study specimens. Thus, the histological and genotoxic alterations found in 100% of *S. herzbergii* specimens captured in São José Bay-MA are potentially associated with PAH concentrations present in the water. These results are potentially associated with the presence of PAH and trace metals, both in water and in animal tissues, inferring a general scenario of environmental contamination which directly implies a risk to the health and survival of the local biota. This study shows the relevance of continuous biomonitoring of estuarine ecosystems, in order to guide authorities regarding sewage management and ensure the evolutionary development of estuarine species, especially fishes of importance in the local cuisine, therefore related to human food security.

Keywords: biomonitoring, ecotoxicology, chemical compounds, trace metals, polycyclic aromatic hydrocarbon.

Resumo

Os estuários estão constantemente sujeitos a impactos ambientais de atividades antropogênicas, como pesca, movimentação portuária, indústria ou esgoto doméstico, onde os peixes são um dos animais aquáticos mais atingidos, sendo capazes de refletir os impactos diretamente em seu organismo. Assim, o objetivo desse estudo foi realizar o biomonitoramento de um estuário da Costa Equatorial Amazônica por meio de análises de PAHs (Hidrocarboneto Policiclico Aromáticos) na água, além de metais traços, alterações histopatológicas e análises de micronúcleos eritrocitários em *Sciades herzbergii*.. O *S. herzbergii* foi utilizado como espécie modelo, devido seu comportamento estuarino residente. Amostras de gônadas e brânquias foram submetidas a avaliações histopatológicas. A quantificação de metais traços foi realizada em amostras de músculos esqueléticos dos animais coletados, onde foram encontrados teores de Chumbo (Pb), Cobre (Cu), Zinco (Zn), Cádmio (Cd), Magnésio (Mg), Ferro (Fe) e Alumínio (AL), e foram encontradas em concentrações acima dos limites recomendados, à exceção do Cádmio (Cd). A análise dos PAHs revelou a presença de Naftaleno e Acenafteno nas amostras de água. Análises

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histopatológicas e genotóxicas revelaram lesões em 100% dos espécimes estudados, resultados estes, potencialmente associados à presença de PAH e de metais traços, tanto na água quanto nos tecidos animais, comprovando um cenário geral de contaminação ambiental implicando diretamente em risco à saúde e sobrevivência da biota local. Esse estudo mostra a relevância do biomonitoramento contínuo dos ecossistemas estuarinos, afim de nortear autoridades no manejo de efluentes e assegurar o desenvolvimento evolutivo de espécies estuarinas, sobretudo dos peixes de importância na culinária regional, diretamente relacionados à segurança alimentar humana.

Palavras-chave: biomonitoramento, ecotoxicologia, contaminantes químicos, metais traços, hidrocarboneto policíclico aromático.

1. Introduction

Estuaries are coastal environments located between the mainland and the sea, in the transition zone (Kennish, 1992). Due to their location, estuaries are subject to industrial and domestic pollution, accumulating excessive amounts of chemical elements (Meng and Liu, 2010). In the island of Maranhão, located on the Equatorial Coast of the Brazilian Amazon, estuaries are influenced by contaminants as trace metal, fuel oils, ores released by activities in the port region (González-Gorbeña et al., 2015), and by domestic sewage (França et al., 2013). Which can be harmful to animal and human health.

Trace metals and PAHs in aquatic environments might bioaccumulate in the fish organism, due to direct contact with water and also through food, after consuming smaller organisms that inhabit that environment (van der Oost et al., 2003). Their ingestion in large quantities may cause chronic poisoning (Oliveira and Poletto, 2020). Considered priority pollutants (Martins et al., 2015) the PAHs (Polycyclic Aromatic Hydrocarbons), are composed of fused benzene rings originated from petroleum (Douben, 2003). These compounds are known to be carcinogenic, immunotoxic, teratogenic and mutagenic, posing a risk to human health (Martins et al., 2015) and marine life (Silva et al., 2006).

Fish are one of the vertebrate superclasses most affected by contaminants. *Sciades herzbergii*, is an abundant species on the North-Northeast coast of Brazil, being an important food resource for traditional fishing communities in the region (Sousa et al., 2013). It is a species of demersal habits that, throughout its biological cycle, resides in the estuary (non-migratory) where it grows and reproduces (Giarrizzo and Saint-Paul, 2008). According to Krumme and Matthias (2008), the diet of *S. herzbergii* is based on benthic invertebrates and crustaceans which makes them have greater contact with estuarine substrates.

Histological analysis is considered one of the most efficient techniques to investigate contamination of the aquatic environment. It is very sensitive in diagnosing toxic effects that directly affect animal tissues (Albinati et al., 2009). Cellular genotoxic biomarkers are also important bioindicators of contamination, as the presence of micronuclei in erythrocytes from aquatic animals can prove the occurrence of a genetic mutation (Souza and Fontanetti, 2006).

Considering the increase in human activities close to estuarine environments and the continuous need to monitor these regions due to their importance for the ecosystem and public health, in this work we aim to quantify PAHs and histological and genotoxic biomarkers in *Sciades herzbergii* in an estuary on the Amazon Equatorial Coast. Our hypothesis is that resident estuarine fish may present histological and genotoxic damage due to the presence of chemical contaminants in the water and, in addition, they serve as reference indicators for biological damage resulting from environmental pollution".

2. Material and Methods

2.1. Port areas and sampling

The study area is located near the main artisanal fishing ports in the island of Maranhão, an island of great importance along the Amazonian Coast, where the largest Brazilian port complex is located (2°31'51.30"S 44° 5'24.40"W) (See Figure 1). The catches were carried out with a trap made of wood covered by a polyethylene mesh, popularly known as manzuá or covo. During sampling, in-situ physical and chemical data were obtained, including water temperature, salinity, pH, and dissolved oxygen. The multiparameter kit was used *in situ* (Asko®, modelo AK 88).

2.2. Experimental draw

This is a descriptive cohort study of 68 individuals of *Sciades herzbergii* (44 females and 24 males), length between 25 and 40 cm were collected in São José Bay, Island of Maranhão, Amazonian Equatorial Coast, in 4 stages, between the years 2020 and 2021. After collection, the following parameters were measured: total weight (TW), eviscerated weight (EW), total length (TL), partial length (PL) and furcal length (FL). Then the specimens were anesthetized with benzocaine (1.0g/10L in estuary water), previously diluted in ethanol (Ferreira et al., 1984), and blood samples were taken from the branchial vasculature (about 4 mL) using 0.7 x 25 mm needles and insulin syringes lightly moistened with anticoagulant (Liquemine®, Roche) (Santos et al., 2009), immediate preparation of whole blood smear on microscopy slides, in order to evaluate the presence of micronuclei in erythrocytes (Fenech, 2000).

After blood collection, the specimens were again submerged in water containing 3% Benzocaine for the cessation of opercular movements, loss of skin sensitivity and death (Santos et al., 2009), and transported in thermal boxes with ice to the Laboratory of Technology Applied to the Reproduction and Production of Nektonic Organisms (TARPON) of the Federal University of Maranhão (UFMA). In the laboratory, the specimens were eviscerated. After characterization, the gonads were weighed on an analytical balance with a precision of 0.01 grams to calculate the Gonadosomatic Index (GSI). Then, the gonads were fixed in Bouin's solution (75 mL of saturated picric acid solution,

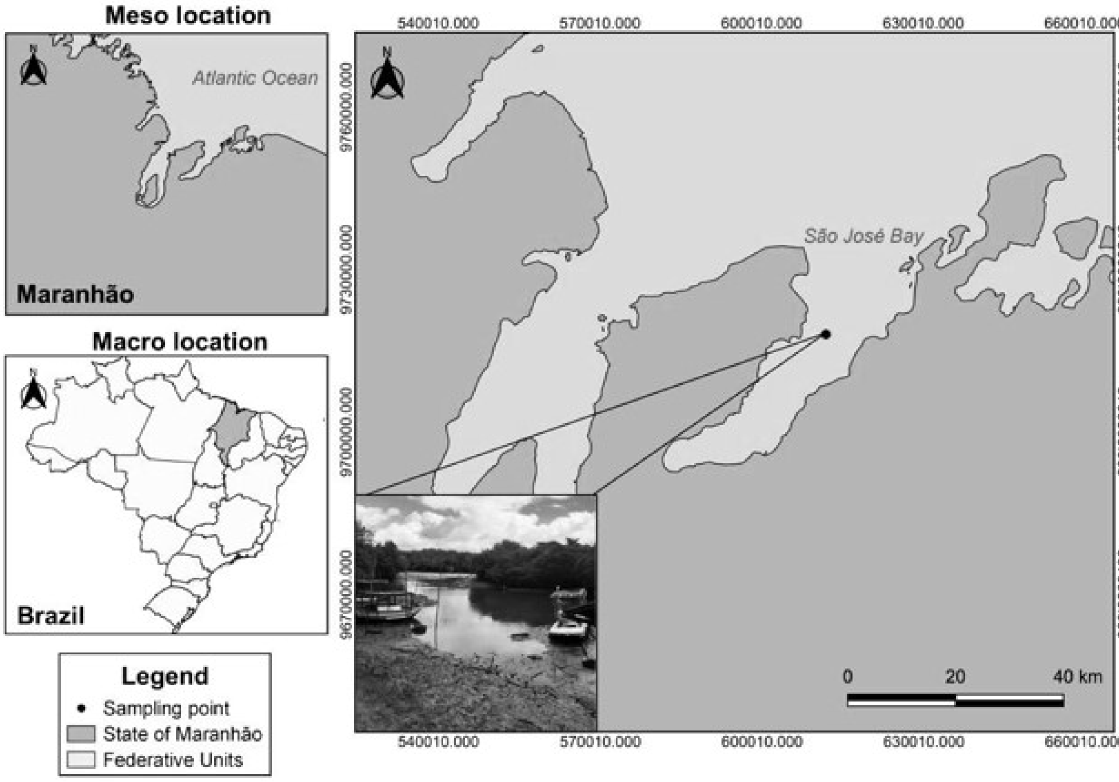

Figure 1. Sampling site: São José Bay, in the Island of Maranhão, Brazil.

20 mL of 37-40% formaldehyde and 5 mL of glacial acetic acid). The gill arches were fixed in 10% formalin for 24 hours and then decalcified in 10% nitric acid for 6 hours (Poleksic and Mitrovic-Tutundzic, 1994). After fixation, the medial portion of the gonads of both ovaries and the second gill arches were removed to be subjected to usual histological routine Louiz et al. (2009).

2.3. Analysis of metals in fish muscles

Muscle samples were collected from the 68 captured specimens and dried in an oven at 50ºC., macerated and stored in propylene bottles. Approximately 1 to 2 grams (dry weight) was used to determine trace elements, by the EPA 3050 B method – SMEWW 23rd Edition - Method - 3130B. Soon after, acid digestion was carried out with nitric acid HNO3 (65%, Merck®) and hydrogen peroxide (37%, Merck®). Trace elements (Cu, Zn, Fe, Mg, Al, Pb and Cd) were determined using inductively coupled plasma optical emission spectrometry. (ICP-OES Optima 8300, Perkin Elmer®). The recommended standard for trace elements in fish muscle is showed in Table 1, according to Decree (Brasil, 1965); Brasil (2005a, 2013, 2021) and FAO (1983, 2003).

2.4. Chemical analysis of water

Polycyclic Aromatic Hydrocarbons were analyzed according to CONAMA (Resolution N° 454/2012). The water was collected directly in amber bottles previously washed by immersion in a 5% neutral laboratory detergent (Extran® MA 02, Merck Millipore). The samples were stored on ice and transported to the Research Laboratory in Analytical Chemistry (LPQA) of the Federal University of Maranhão (UFMA). Then, the electroanalytical technique of differential pulse voltammetry (DPV) (Mota, 2019), was used to identify the Polycyclic Aromatic Hydrocarbons (PAHs). The voltammetric experiments were carried out in a potentiostat (µautolab-II, Ecochemie®), coupled to a computer equipped with a GPES interface (Metrohm-Autollab®). For adjustments of the hydrogenic concentration, a pH meter model Analyzer model pH 300® with coupled glass electrode, calibrated with commercial buffers of pH 4.7 and 10 was used. (Merck®). For the electroanalytical procedure, Britton Robinson (BR) buffer solution with a concentration of 0.2 mol/L and with pH 2.0 previously standardized with sodium hydroxide (NaOH) 0.1 mol/L^{-1} was used. The electrochemical experiments were performed in an electrochemical cell made of Pyrex glass (10ml) containing the electrodes: Ag/AgCl containing 3.0 mol/L^{-1} KCl, as reference electrode, platinum electrode (Pt) as auxiliary electrode and glassy carbon eletrode (GCE), as working electrode. The area of GCE is 0.123 cm^2, to evaluate the presence of naphthalene and acenaphthene in the water. The PAHs values were compared with Brasil (2012, 2005b) and NOAA (2015) resolutions.

2.5. Biomarkers analysis

Histological analysis of reproductive/gonadal damage in females were performed according to Louiz et al. (2009)

and Vigano et al. (2010). In males, characterizations were performed according to Louiz et al. (2009). The histological alterations of the gills were classified according to (Poleksic and Mitrovic-Tutundzic, 1994). Histological readings were performed with the aid of a light microscope with 10x and 40x objectives.

Erythrocytes analyzes were performed by reading 2000 cells from each fish, using a 100x objective, where the presence or absence of micronucleus-type anomalies was identified (Fenech, 2000). The photomicrographs of the lesions were captured in a photomicroscope (AXIOSKOP®, Zeiss).

2.6. License and ethics declaration

The research protocol was approved by the Ethics Committee for the Use of Animals (CEUA) of the Federal University of Maranhão, in accordance with Law N° 11794, of October 8, 2008, Decree N° 6899, of July 15, 2009, and with the rules issued by the National Council for the Control of Animal Experimentation (CONCEA), registered under protocol number 23115.030805/2018-23. The SISBIO/ICMBio license protocol was also obtained (number 65479-1).

2.7. Statistical analysis

The relationship between the variables was studied through the principal component analysis (PCA) method, using the Statistica 7.1 (TIBCO Software Inc., California, USA) (Statsoft, Inc. Statistica) data analysis software (StatSoft, 2007), producing a two-axis graph to illustrate the importance of the main components in the total variation.

3. Results

3.1. Chemical analysis of water

During the sampling, the physicochemical characteristics of the water were within the recommended by resolutions nº 357/2005 and 430/2011 of the National Council for the Environment - CONAMA (pH 7.08; temperature 29.3 °C; salinity 18.32%), except for dissolved oxygen (4.1 mg/L), which was below the standard established for brackish water (≥ 5 mg/L) (Brasil, 2005b).

Regarding the PAHs, the values found for Acenaphthene and Naphthalene were 0.678mg/L and 0.024mg/L respectively (See Figure 2).

3.2. Analysis of metals in fish muscle

The concentrations of metals (as shown in the Table 1). Lead, Zinc, Iron, Magnesium concentrations are above those recommended by the guidelines and legal limits established by the NATIONAL HEALTH SURVEILLANCE AGENCY (ANVISA), resolutions RDC 42/2013 and DC No. 88 OF 03/26/2021, Decree No. 55,871 (March 26, 1965), and by the Food and Agriculture Organization of the United Nations (FAO) 1983 and 2003. FAO does not establish limit

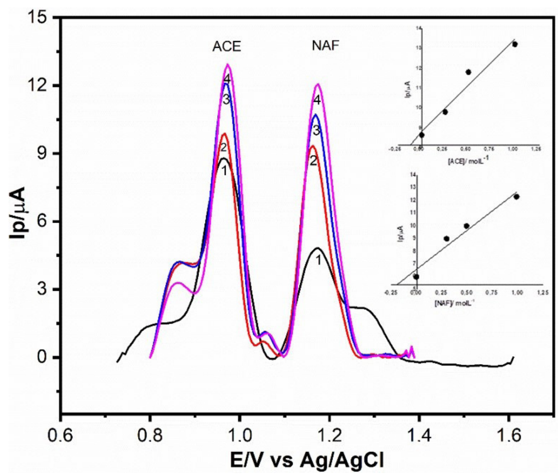

Figure 2. Differential Pulse Voltamograms using ECV/CoPc at different concentrations of Acenaphthene and Naphthalene respectively (1) real sample; (2) 0.0383 mg/L and 0.0319 mg/L (0.249 µmol L^{-1} and 0.249 µmol L^{-1}); (3) 0.0766 mg/L and 0.0637 mg/L (0.497 µmol L^{-1} and 0.497 µmol L^{-1}); (4) 0.0152 mg/L and 0.0126 mg/L (0.99 µmol L^{-1} and 0.99 µmol L^{-1}) of buffer solution BR 0.2 mol L^{-1}, pH 2, v = 0.025 V s^{-1}.

Table 1. Mean and standard error of metals monitored in the surface waters of São José Bay, Brazil.

	Bay of São José-MA mg/Kg	REFERENCE / BRAZIL	FAO	LQ Mg/Kg
Al (Total)	384.98 (SE±6.63)	---	---	0.10
Pb (Total)	1.17 (SE±0.06)	0.30 mg/Kg *	0.5 mg/Kg*****	0.10
Cd (Total)	< 0.100	0.05 mg/Kg *	0.1 mg/Kg*****	0.100
Cu (Total)	3.16(SE±0.42)	30.0 mg/Kg **	30 mg/Kg****	0.20
Zn (Total)	50.62 (SE±9.94)	50.0 mg/Kg **	30 mg/Kg****	0.01
Fe (Total)	152.55(SE±3.06)	14 mg/day***	---	0.05
Mg (Total)	840.15 (SE±16.77)	260 mg/day***	---	0.10

Al = Aluminum; Pb = Lead; Cd = Cadmium; Cu = Copper; Zn = Zinc; Fe = Iron; Mg = Magnesium; SE = standard error; --- No limit concentration for aluminum consumption in foods in the Brazilian legislation. *ANVISA RDC42/2013 and ANVISA/Decree Nº 88, March 26, 2021 (Brasil, 2013, 2021); **Decree nº 55.871, March 26, 1965 (Brasil, 1965); ***Resolution-RDC Nº 269, SEPTEMBER 22, 2005 (Brasil, 2005a); ****FAO. Heavy Metals Regulations Legal Notice No 66/2003 (FAO, 2003); *****FAO. Compilation of legal limits for Hazardous substance in fish and fishery products (FAO, 1983).

concentrations for Aluminum, Iron and Magnesium in fish meat. Also, there is not a limit concentration established for Aluminum in fish meat in the Brazilian resolutions.

3.3. Biomarkers analysis

Total weight average was 345.82 ± 26.94g (ranging from 117 to 1200g), and total length average was 32.01 ± 0.57 cm (ranging from 24 to 43 cm). The GSI average was 1.34 ± 0.27 g (ranging from 0.03 to 12 g).

The histological analysis of the gonads and gills showed several alterations which were detected in all specimens (see Figure 3).

The following alterations in the reproductive organs of the fish were observed: Melanomacrophages, found in the ovaries and testicles of all individuals, with a frequency (males and females) of 4.81%, SE 0.52; Atretic oocytes and cytoplasmic Retraction, alterations found only in ovaries, with frequencies of 2.88%, SE 0.61, and 5.69%, SE 1.13 respectively.

Alterations in the gill morphology were: Hyperplasia with frequency of 16.11±1.89%, Displacement the lamellar epithelium (40.76±3.08%), Congestion (6.51±0.87%) and Lamellar fusion (6.51±1.07%). The micronucleus frequency reported in this study represent basal rates (2.95±0.19%).

The association between Gonadossomatic Index and genotoxic biomarkers on the Ovaries and Gills was investigated through Principal Component Analysis (PCA) (as shown in Figure 4).

Results have shown that the two main components, altogether, explained 41.48% of total data variation. GED was the most representative variable in Component 1, since they presented longer-length vectors that were closer to 1 the Component 1 axis. GHL and GLF were the variables that mostly contributed to Component 2. They were highly inversely related to each other, but they were not related to ovarian histopathologic biomarkers nor with GSI. MN, MMC and RET have shown strong association

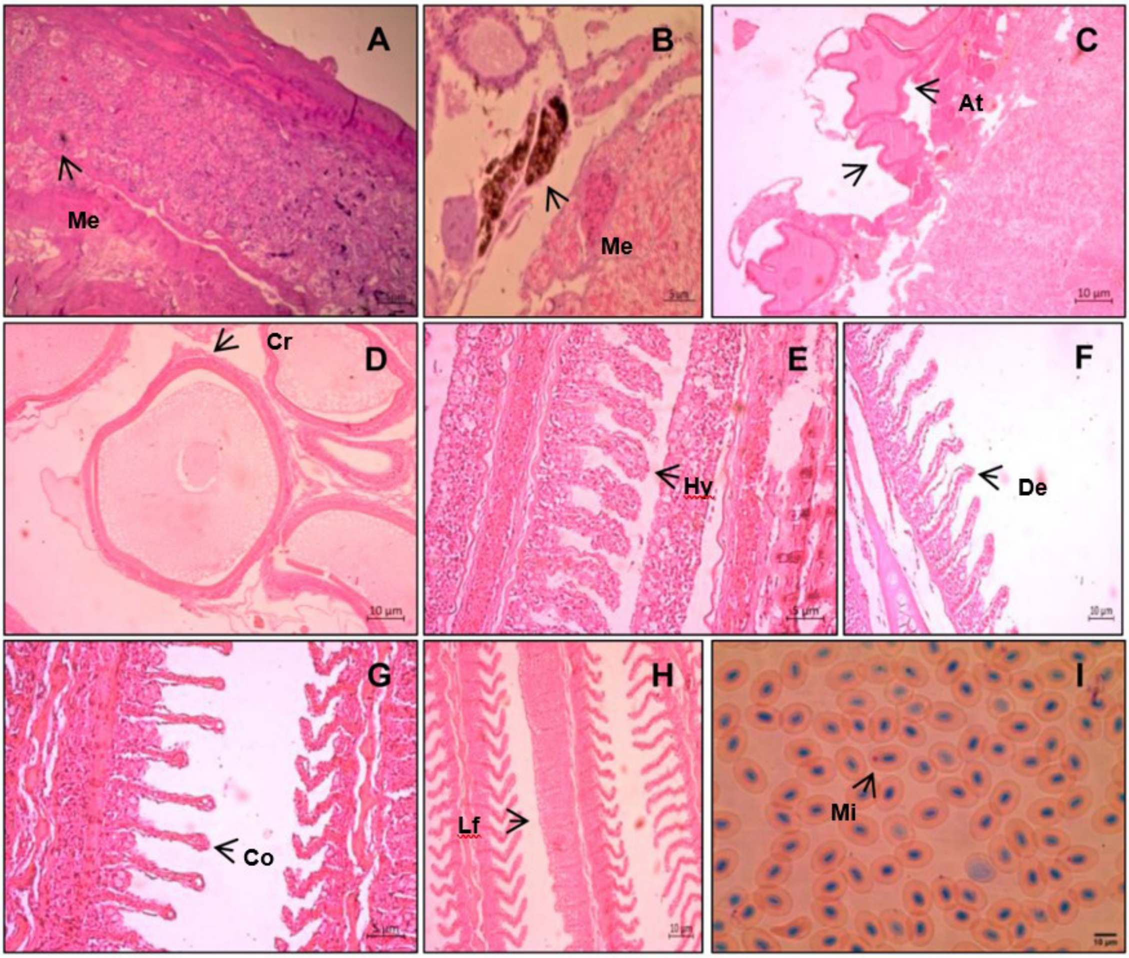

Figure 3. Main cellular damage in *Sciades herzbergii* collected in the community of Pau Deitado, São José Bay-MA, in 2020 and 2021. (S.E=Standard Error). (A) (40x) Gonad-Melanomacrophages of males (Me/arrow); (B) (40x) Gonad: Melanomacrophages of females (Me/arrow); (C) (20x) Gonad-Atretic oocytes (At/arrow); (D) (20x) Gonad-Cytoplasmic retraction (Cr/arrow); (E) (40x) Gill-Hyperplasia (Hy/arrow); (F) (20x) Gill-Displacement of the epithelium (De/arrow); (G) (20x) Gill-Congestion (Co/arrow); (H) (40x) Gill-Lamellar fusion (Lf/arrow); (I) (100x) Blood-Micronucleus (Mi/arrow).

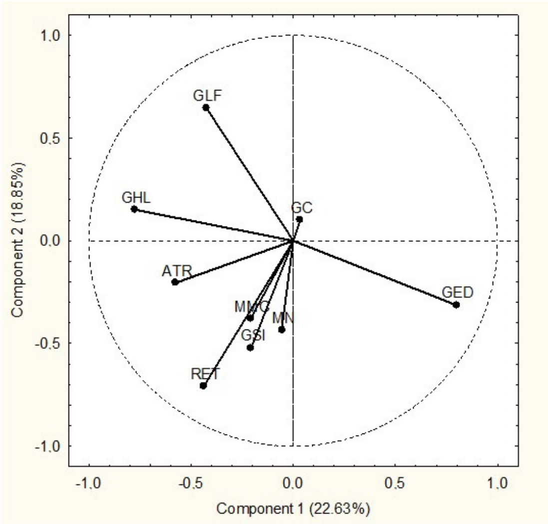

Figure 4. Biplot of Principal Component Analysis (PCA) applied to the association between variables, Gonadossomatic Index and genotoxic biomarkers on the Ovaries and Gills in *S. herzbergii* at São Jose Bay. GSI = gonadossomatic index; ATR = atresic ovarian follicles; MMC = ovarian melanomacrophagus; RET = oocyte cytoplasmatic retraction; MN = micronucleus; GHL = gill hyperplasia; GLF = gill lamellar fusion; GC = gill lamelar congestion; GED = gill epithelium displacement.

with each other and with GSI, since they formed acute angles between their respective vectors.

4. Discussion

Initially, this research highlights it is worth that when dealing with biological research associated with wild fish in their natural habitat, characteristics such as selectivity for fishing gear, local fishing pressure, time of year, and effluent leaching, etc., can be determinants of significant biological variation between different studies. Nevertheless, in our research, we have presented scientific evidence that the pollutants affected the development and reproduction potential of *Sciades herzbergii* under conditions presented in the methodology.

The physicochemical analysis of São José Bay waters indicated dissolved oxygen below the limits allowed by the regulatory agencies. Dissolved oxygen is an indicator of environmental conditions, since organic matter from domestic sewage and released into the aquatic environment causes changes in the oxygen balance (Cunha et al., 2011). Cantanhede et al. (2016) in previous studies reported low oxygen saturation in estuarine waters after histological and genotoxic study in *Centropomus undecimalis* (Bloch, 1792) around the Island of Maranhão.

Chemical analyses (PAHs) of the water were also performed, and the results are in disagreement with the regulatory agencies. The CONAMA (Conselho Nacional do Meio Ambiente), through the resolution n°454 2012 does not establish minimum values for Acenaphthene and Naphthalene in brackish waters. However, when the lowest reference value of PAHs is observed in the resolution (0.052 mg/L), the values found in this study are above the suggested for other PAHs (Brasil, 2005b). On the other hand, if we consider the values recommended by NOAA (National Oceanic and Atmospheric Administration) that allow up to 2.35mg/L for Naphthalene, and 0.0097 mg/L for Acenaphthene (NOAA, 2015), we observe that Naphthalene concentrations are below and Acenaphthene concentrations are above the recommended by NOAA, which indicates that the study area has low PAHs concentrations, although it shows a low level of contamination. Pinheiro-Sousa et al. (2021) when analyzing estuaries in the North of the Brazilian Amazon, identified trace elements and PAHs in sediments in the region, which explains the changes in the lamellar structure of the gills and also the increasing oxidative stress in the specimens collected. Considering anthropogenic activities such activities may cause an increase in chemical/organic compounds in the environment, which can affect the aquatic organisms that live there, and also human health.

The analysis of metals showed that the muscles analyzed are suffering some level of environmental contamination, once the results showed concentrations above those allowed by national and international resolutions, which are the maximum limits for detection and consumption of this meat. The resolutions establish maximum values for Pb of 0.30 mg/Kg (Brasil, 2013) and 0.5 mg/Kg by FAO, Cu 30 mg/Kg (Decree No. 55.871 of 1965) and 30 mg/Kg (FAO, 2003), Zn 50 mg/Kg (Decree No. 55,871 of 1965) and 30 mg/Kg (FAO, 2003), Cd of 0.05 mg/Kg (Brasil, 2013) Cd of 0.1mg/Kg (FAO, 2003) for fish meat, showing that the results of Pb, Cu and Zn are above those allowed by the agencies. Cd is within the limits. Although ANVISA and FAO do not establish maximum limits of Mg, Fe and Al in fish muscle, ANVISA does recommend a daily intake (RDI) of 260 mg per day for adults and 14 mg/day for children (Brasil, 2005a).

Altered metal levels were previously found in São José Bay by Noleto et al. (2021), and Ribeiro et al. (2020) when studying metals in oysters of the *Cassostrea* genus (Sacco, 1897). Barbieri et al. (2010), also found accumulation of trace metals in the muscle of *Cathorops spixii* (Agassiz, 1829), in an estuary located in Aracajú-SE, characterizing direct connection with the life cycle and feeding habits of the catfish to a higher incidence of contaminants in its organism. Masood et al. (2021) studying *Ctenopharyngodon idella* (Valenciennes, 1844) observed that high concentrations of zinc might cause mortality, showing that human fishing activity and the disposal of domestic effluents in the region may be causing contamination. According to von Sperling (1996) sewage is made up of organic and inorganic matter, such as sugars, oils, proteins, fats, microorganisms, organic salts, components of sanitizing products (such as soap, detergents, disinfectants), salts formed by chlorides, sulfates, nitrates, phosphates, sodium, calcium, potassium, iron and magnesium (von Sperling, 1996).

According to the biometric averages found for the animals in this study, these values may be directly affected by the level of contaminants found in the aquatic environment (Noleto et al., 2021). According to Ribeiro et al.

(2012) species that inhabit impacted areas use the energy stock available to grow to perform detoxification. It is known that animals that live in contaminated environments are likely to have inadequate maturation of the gonads (Vazzoler, 1996) due to the inhibition of estrogen-induced by pollutants (Kime, 1995). Excess of some contaminants in aquatic environments might directly affect the reproductive system of fish, affecting the continuity of the specie (Kime, 1995).

Contaminants are also capable of causing several histological changes in animals. In this study, some of these alterations were observed, such as the appearance of melanomacrophages, which are cells belonging to the nonspecific immune system (Louiz et al., 2009) and are closely associated with chronic inflammatory processes. Furthermore, the presence of this inflammation in the individual is related to the level of stress it is experiencing, often due to exposure to chemicals (Marty et al., 2003). The presence of melanomacrophages was also identified by Marty et al. (2003) when analyzing fish organs that had direct contact with an aquatic environment contaminated with PAHs. Other alterations in the reproductive level also found in this study area, oocyte atresic and cytoplasm retention, which can be found naturally in their ovaries (Louiz et al., 2009; Dutta and Maxwell, 2003) or may appear and increase under the interference of contaminants causing a decrease in the reproduction rates of the individuals (Louiz et al., 2009), also identified in *Gobius Niger* from the Bizerta-Tunisia lake by Louiz et al. (2009).

About the gill alterations, hyperplasia, displacement of the lamellar epithelium, congestion, and lamellar fusion, were observed. These alterations are due to the attempt of the organism to defend itself against pollutants. However, it is a process carried out by the gills, which affects the respiration and survival of organisms, as they cause derangements in their blood flow structures (Camargo and Martinez, 2007). These changes may be reversed with the improvement of water quality or may be progressive in cases of persistent exposure (Poleksic and Mitrovic-Tutundzic, 1994). Some of these alterations were also found by Castro et al. (2018) when analyzing catfish of the species *Sciades herzbergii* in estuarine environments, seeking to identify the impact of anthropization in the aquatic environment. Medeiros et al. (2020), also identified lamellar changes in gills of *Geophagus iporangensis* fish (Haseman, 1911), subjected to different concentrations of zinc and cadmium. Barbieri et al. (2016) identified changes in *Oreachomis niloticus* (Lineus, 1759) when exposed to lead and carbon, proving that the association of these metals, even at low concentrations, interfered with the respiratory capacity of the individuals studied.

In this study, all organisms showed some level of the alteration as a result of DNA damage. Cantanhede et al. (2016) studied *Centropomus undecimalis* (BLOCH, 1792) two different estuaries in the Southeast region of Brazil and, in both, the presence of metals interfered not only with the genetics, but also with the biochemistry and morphology of aquatic organisms.

This work, as well as other studies carried out previously with specimens of *Sciades herzbergii* in estuaries belonging to the North Amazon coast (Pinheiro-Sousa et al., 2021; Castro et al., 2018) indicates that contaminants present in these environments lethal or chronically alter the health of animals that live there. It can then be suggested that the organisms of São José Bay are under some influence of chemicals. Thus, the histological and genotoxic alterations found in 100% of *S. herzberg* specimens captured in the São José Bay-MA are potentially associated with the concentrations of PAHs found in the water and metals found in the muscles of the animals collected. Thus, it is necessary to systematize the biomonitoring in the region, to mitigate the harmful effects on the environment and food riverside communities. It is concluded that *S. herzbergii* is a good bioindicator of estuarine pollution, because due to its sensitivity, life cycle and food, its body can respond to an environment with the presence of metals and PAHs.

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