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Impact of the Jamapa River Basin on the Gulf of Mexico

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and Fabiola Lango-Reynoso*

Abstract

The Jamapa River basin is located in the central region of the State of Veracruz, it is born in the Pico de Orizaba and connects with the Veracruz Reef System in the Gulf of Mexico, both protected natural areas. The lower part of the basin has the contribution of two important effluents, Arroyo Moreno, which is a protected natural area, strongly impacted due to municipal discharges from the metropolitan cities Veracruz-Boca del Río-Medellín. And the Estero, which is part of a complex aquatic system that discharges its waters from the Lagunar Mandinga system to the Gulf of Mexico. Currently, there is a diversity of chemical and biological compounds that the basin receives from different sources of freshwater pollution, such as industrial waste, sewage, agricultural and urban runoff, and the accumulation of sediments. The climatic seasons are the determining factors in the composition of its sediments, due to the force exerted on the bottom of the river by the increase in rainfall, the force of the winds mainly in the north wind season, where the greatest quantity of polluting materials.

Keywords: basin, Jamapa River, anthropogenic activities, reef system

1. Introduction

The basins have an altitudinal function, that is to say, being made up of territories that are at different altitudes; the problems of the higher parts may directly affect the lower parts, such as the mouth and deposition, this, by interconnecting the geographical spaces formed by the flow of water, matter and energy [1]. The Jamapa River basin is the link between three protected natural areas of great economic, social and environmental importance for the sustainable development of the state of Veracruz. These areas are the Pico de Orizaba National Park or Cilaltépetl with 19,750 ha, Arroyo Moreno Protected Natural Area (ANPAM) with 287 ha and the National Park of the Veracruz Reef System (PNSAV) with 65,516.47 ha [2].

Human settlements and the economic activities that take place in the surroundings have strongly impacted the basin, from the highest part wastewater is discharged without treatment or with poor treatment that allows all pollutants and nutrients to reach its main effluents. It is considered that only the large cities that are in this basin have wastewater treatments such as Veracruz, Boca del Río, Córdoba, Huatusco and Coscomatepec. However, there are more than a thousand rural agricultural, livestock, aquaculture and fishing communities that do not treat their wastewater. Due to the variety of pollutants that are constantly dumped into

the basin and that converge in four important natural areas due to their ecosystem functions, it is a priority to know the interactions that take place in the different components of these systems in order to find solutions to this problem. The research question has its origin in knowing what is the impact that the Jamapa River basin receives from the Arroyo Moreno protected natural areas and lagoons connected with the basin, and whose final destination is the natural resources of the Gulf of Mexico?

Works such as that of Ortiz [3] who carried out a *“Modification in the provision of environmental services due to the change in environmental heterogeneity in the Jamapa River Basin, Veracruz, Mexico.”* whose main objective was to analyze the modification in the provision of environmental services due to the effect of the change in environmental heterogeneity in the Jamapa River Basin.

The results of the study conclude that the anthropic activity throughout the basin, caused by the increase in agricultural and urban areas, is the cause of the reduction, fragmentation and detriment of primary coverage. These changes in the coverage of the basin have modified the provision of environmental services, a decrease in land areas provided by those associated with “Support” functions, and an increase in the percentage of land provided by those related to the functions of “Provision”, mainly food.

Castañeda-Chávez et al., [4] carried out a water quality study in the lower basin of the Jamapa River, by analyzing the relationship between dissolved oxygen and temperature. The investigation showed that the dissolved oxygen levels in the different sampling sites and by season did not have significant differences; However, this parameter remained above that established in the national standards for water bodies, the temperature results showed significant differences in the north wind season. Salas-Monreal et al., [5] carried out the *annual variation of the hydrographic parameters at the confluence of the Río Jamapa and Arrollo Moreno (Mexico)*. They evaluated the quality of the aquatic environment at the mouth of the Río Jamapa, by monitoring the environmental parameters of dissolved oxygen, total nitrogen, chlorophyll, temperature and salinity in different climatic seasons. The results showed a variation of dissolved oxygen, total nitrogen, temperature and salinity in the different climatic seasons, while chlorophyll remained constant. Both authors point out the importance and need to carry out constant monitoring of these parameters in sites adjacent to the main sources of contamination, due to the possible effects of population growth and the increase in productive activities in the study area.

On the other hand, the impact that anthropic activities have on the aquatic environment of the Jamapa River basin is shown in the studies carried out in the Arroyo Moreno Protected Natural Area (ANPAM) by García-Villar et al., [6], where the temporal variation of the composition of fish species in the area, with the historical information collected with the fishermen and various statistical tools, they concluded that in the last two decades the richness, abundance and sizes of the fish species have decreased; particularly those used as a fishery resource, this effect is attributed to the use of this stream as a drainage of wastewater, which is a consequence of urban growth in the area and the lack of environmental management of this protected natural area.

The variation of species due to anthropogenic activity was confirmed by Rodríguez et al., [7]; evaluated the gross primary productivity (PPB) and planktonic respiration (PR) in the National Park of the Veracruz Reef System (PNSAV), characterized the area and identified the function of the organic metabolism of the ecosystem. The values indicated that the north zone had a difference with the south zone of the study area, being Playa Norte the most productive site in the system. The northern area presented a greater anthropogenic influence, due to a wastewater treatment plant, while the southern area is subject to the influence of the discharge

from the Jamapa River during the rainy season. In contrast, the Cabezo reef was the least productive; this site is the farthest from the coast and therefore suffers less from the influence of the Jamapa River.

The impact that human activities have on water quality is not limited to surface waters, it also affects groundwater, as demonstrated by Landeros-Sánchez et al., [8] in their work entitled: “*Assessment of Water Pollution in Different Aquatic Systems: Aquifers, Aquatic Farms on the Jamapa River, and Coastal Lagoons of Mexico*” where the concentrations of nitrates, total coliforms (TC) and *Vibrio* sp., temperature, salinity, dissolved oxygen, and pH in groundwater of shallow wells in aquatic farms located along the river, and in lagoon systems, located in the state of Veracruz, Mexico. The results showed that agricultural effluents had total coliforms (TC) levels higher than 2419 NMP 100 mL⁻¹ and the dissolved oxygen was at a minimum value of 1.7 mg L⁻¹, concentrations beyond those established in the Official Mexican Standards. They also identified the presence of *Vibrio* sp. in lagoon systems, for which they concluded that the impact of productive activities leads to health risks. However, derived from population growth and as a consequence the increase in the contribution of pollutants and nutrients from the Jamapa River to the Veracruz Reef National Park (PNSAV), it is vitally important to continue monitoring these pollutants in order to preserve the public health, since currently emerging pollutants such as antibiotics, hormones, microplastics, among others, are compounds that are discharged directly from this basin to the Gulf of Mexico.

With the above, it seeks to substantiate the importance of knowing the influence that the Jamapa River basin exerts on the center of the Gulf of Mexico, whose purpose is in the first instance the preservation of coastal marine ecosystems, the care of public health, as well as the proposal of possible mitigation measures with the development of environmentally friendly activities. With the aim of analyzing the impact of pollutants in the Jamapa River basin in the center of the Gulf of Mexico.

2. Study area

The Jamapa River Basin is located on the slope of the Gulf of Mexico, and occupies an area of 3, 918 km², and it is made up of the states of Veracruz Puebla; and the municipalities that comprise it are 31 from the state of Veracruz and 3 from the state of Puebla. Among the main cities are Córdoba, Huatusco, Coscomatepec, Atoyac, Cuitlahuac, Paso del Macho, Medellín, Soledad de Doblado, Fortín and Medellín. The eastern part of the basin is located on the southern Gulf coastal plain, and the western part is located on the neovolcanic axis (Mexican volcanic belt) [9].

The upper basin is the highest altimetric portion, with the steepest slope in the entire basin, with flow-erosive characteristics. The middle basin is a transition zone between the upper and lower basin, the slope is less steep than the upper basin. The lower basin is the deposition and discharge zone of the basin, the slope is softer or nul, is the exit area, composed of the flood plains [10].

The prevailing climates for 10 years are: **E (T)CH (w2)ig** (Very cold with rain regime in summer with ganges and isotherms type gait) It is located in the region of the peak of Orizaba; **Cb' (w2)igw** (Semi-cold with rains in summer with heatwave, Ganges-type gait and isotherms); **C(m)(f)igw** (Humid temperate with rains all year round with heat waves, Ganges-type gait and isotherms); **C(w1)ig** (Temperate with rains in summer with Ganges-type gait and isotherms); **C(w2)ig** (Temperate with rains in summer with ganges and isotherms, the most humid of the sub humid) [11].

To highlight the levels of sociocultural importance in the lower part of the Rio Cotaxtla and Rio Jamapa basins, with an area of 500km², lies in the location

of 132 sites with monumental architecture of rammed earth, as testimony of pyramidal and monumental squares, they have been used to collect chronological information on archeological events, as an example, the Conchal Norte and La Joya are considered (Figure 1) [12].

2.1 Methodological description

A review and inclusion of the research results was carried out in the lower basin of the Jamapa River, to know what is the impact of anthropogenic activities that are having an impact on fresh and salt water, in addition to knowing what would be the impact of these activities on the aquatic organisms that are present in the lower Jamapa basin and the implications for the impact of pollution in the Gulf of Mexico. Some research results are also presented, where the presence of pollutants such as heavy metals and pesticides in the water is manifested, which is important to note

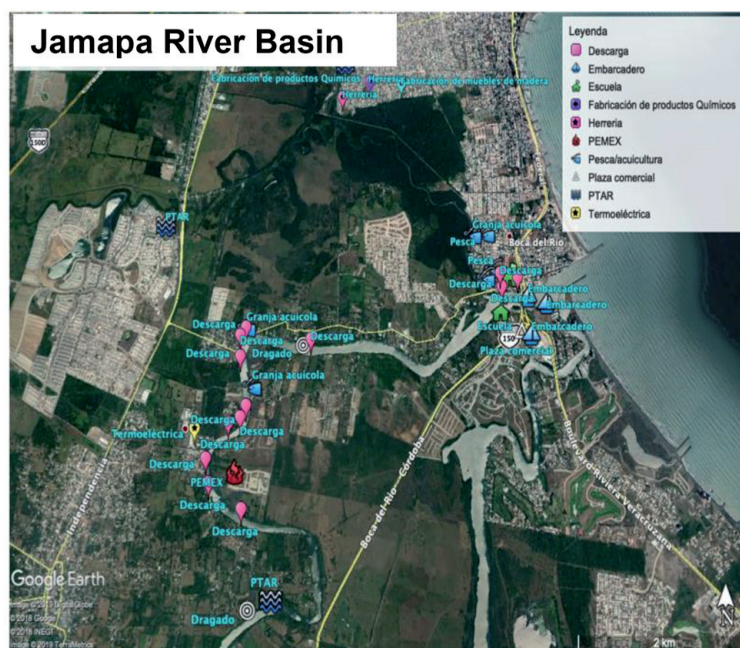
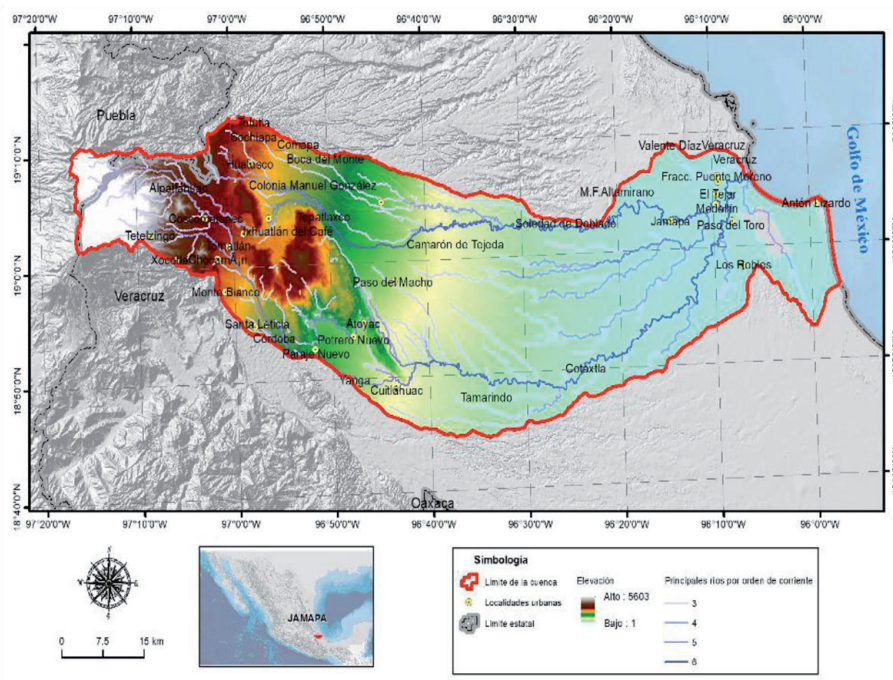


Figure 1. Representative location of the lower basin of the Jamapa River.

that its importance lies in its massive use and recently introduction to the market of the agricultural sector. It was divided as main topics to address: Anthropogenic activities in the region; Contaminants in water, soil, sediment and organisms; Impacts on the Veracruz Reef System; Impact on the Gulf of Mexico.

2.2 Anthropogenic activities in the region

The character of the Jamapa River basin is heterogeneous, it encompasses present coverage, related to orography, and human activities in the region. That is, in the upper part of the basin, erosive flow conditions are associated, it links a vegetation of mountainous regions, with river slopes, associated with water flows. In the middle part of the basin, the vegetation and the slope (does not exceed 1%), allows the development of agricultural activities and pastures, that is, the development of the agricultural sector, begins to displace the primary vegetation and its alteration, otherwise In the lower part of the basin where anthropic activities occur in greater proportion as urbanization product of a softer or no slope, it is the area with the greatest deposition and discharge of the basin, an example of this is the metropolitan area of Veracruz and Boca del Rio [13]. The activities carried out in the coastal lagoons that influence the lower Jamapa basin, activities are carried out in areas with open and closed systems, in cages and ponds, for the production of marine and freshwater organisms. [14]. In the upper part of the Jamapa river basin, rainfall that is between the ranges of 1200 to 1300 mm per year, represents 19.4% of the Jamapa basin, where pine forest communities such as oak, pine and the oyamel [15].

In development areas in the basin, the negative effects upstream will have direct impacts on the lower part of the basin, that is, they influence the coastal and marine ecosystems, they affect the capacity of the system on meteorological phenomena, increasingly violent and unpredictable. CONANP (National Commission of Protected Natural Areas) and its civil allies, companies and the settled population, carry out activities for the ordering, conservation and adaptation of productive activities, protection of natural resources, because, in terms of water, the shortage of 2.5 million people in the states of Puebla and Veracruz [16]. The extreme impacts of climate change in the Pacific and Gulf of Mexico, such as cyclones Ingrid and Manuel, are the product of the climatic variability of our environment, it is estimated that there is an area of high vulnerability in the north of the state of Veracruz, mainly where begins the slope towards the Gulf of Mexico (Figures 2 and 3) [17].

The anthropic activities that are carried out in the region of the Jamapa River basin could not only negatively impact the population, but also change the habitat of some species that nest in said area, such as the red-billed tropical bird (*Phaethon aethereus*) that feeds on various species of fish (*Loliolopsis diomedae*, *Engraulidae*, *Clupeidae*, *Exocoetidae*, *Hemiramphidae*, *Carangidae*, *Gerreidae* y *Scombridae*) in the Gulf of Mexico [18]. Anthropic causes and the magnitude of climate change threaten the basic elements of human life, such as water supply, food production, health, land use, and the environment [19]. The Mandinga Lagoon System, located in the town of Mandinga; Alvarado; Veracruz is a body of water that receives water from the Jamapa River basin and the Gulf of Mexico tide, and its main activity is fishing; But the facts and social phenomena are articulated in different dimensions through the territory, the conception of humanity and nature have given rise to environmental and social problems, combined with historical aspects, such is the case of disputes between the conceived space and the local territory, which is more than a cultural aspect [20]. Since this system has direct influence from four municipalities Alvarado, Boca del Río, Medellín and Tlaxiacoan.

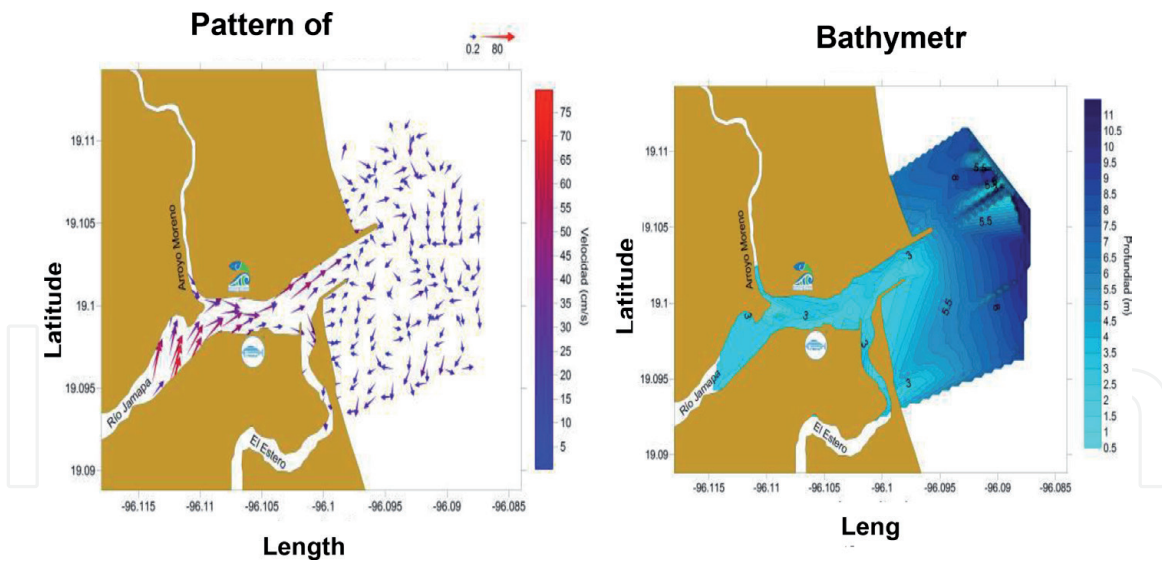


Figure 2. Current pattern (left) and bathymetry (right), studies from august 2016.

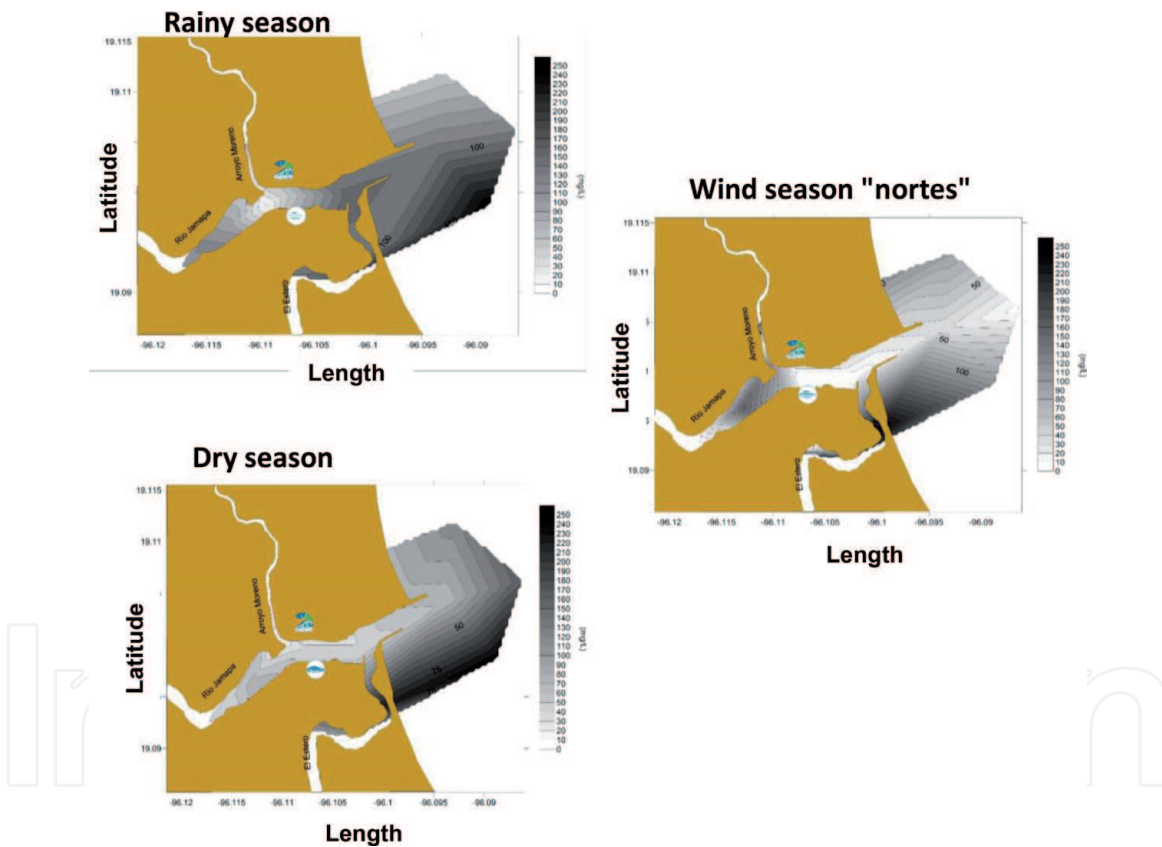


Figure 3. Behavior of the suspended particles per season, in the water column at the mouth of the Jamapa River, Veracruz.

The Mandinga Lagoon System has been impacted by the high logging of the mangrove and fishing deterioration, by the decrease in some environmental services that the lagoon system provides to the inhabitants, such as artisanal fishing, in addition to the change of activities employment from construction, trucking and migration with a negative effect [21].

A study in three municipalities vulnerable to hydrometeorological phenomena in the state of Veracruz, showed that young people from Tlacotalpan, La Antigua and Cotaxtla are the ones who can become agents of change towards their families

and the rest of the population, mainly because they know the uses and customs of the community and are proactive, this allows to identify natural leadership, to link intra-community and inter-community civil protection and strengthen solidarity and reciprocity (Figure 4) [22].

2.3 Pollutants in water, soil, sediment and organisms

In a study of surveys carried out among residents and users of the Jamapa basin, contamination was detected as the biggest problem at the municipal level, among which the contamination of the river, soil, improper handling and burning of garbage, factory waste stand out [23].

In Table 1, as part of the agricultural activities and watersheds that take place in the Jamapa River, neonicotinoid pesticide residues were found at different sampling points along the river route, the maximum values were 0.163 mg L^{-1} of thiamethoxam and mean values of 0.0417 mg L^{-1} of thiamethoxam, In the north wind season that begins in the month of November to February, the highest concentrations of this pesticide were recorded [24].

The Mandinga Lagoon System is associated with the Jamapa River basin, which is born with the melting of the Orizaba peak and travels 150 km, in this lagoon system there are different sources of point and diffuse contamination with the presence of *Vibrio cholerae*. The main factors of alteration and contamination of the lagoon are the change of land use, population increase and migration to the coast, the uncontrolled use of pesticides, and industrial waste (oil), little water treatment of waste, immoderate logging, desiccation of swamps for agricultural purposes. In 40 sampling sites of the lagoon system, a variation of the concentrations of *Vibrio cholerae*, and the highest concentrations were found in the round lagoon, higher than 1000



Figure 4. River Jamapa Basin, Veracruz. A) Mouth of arroyo Moreno, B) arroyo Moreno, C) mouth of the Jampa River, D) mouth of the estuary of the Mandinga lagoon system and E) estuary of the Mandinga lagoon system.

| Main riverbed | Slopes built-in | Activities / Establishments |
|---------------------------|-----------------------------------|---|
| Jamapa River | Jamapa River Cotaxtla River | Discharge of urban and industrial wastewater and transport of chemical pollutants in soils pesticides, herbicides, heavy metals, emerging and microbiological pollutants. |
| Arroyo Moreno | Laguna Real, river and Channel | Domestic / industrial wastewater discharges La Zamorana canal of the municipalities of Veracruz, Boca del Río- Medellin |
| Mandinga Lagoon System | Mandinga Lagoon | Discharges of Wastewater from El Dorado, Discharge of Wastewater from the domestic areas of the towns of Mandinga, El Conchal, Alvarado and Veracruz. |

Table 1.
Main point and non-point sources in the Gulf of Mexico with an impact on the Jamapa River basin.

NMP/100 ml of water; Also, it was determined that the main source of contamination are discharges from homes and restaurants. Another important factor regarding the seasons, the greatest contamination is in the dry season, followed by the rainy season and the north wind season [25]. The presence of high densities of bacteria and organic matter generates the ideal characteristics for the development of parasites in wild populations of *Macrobrachium acanthurus* from the lower basin of the Jamapa River; in a diagnosis carried out in 2007 to 2008, five species of parasites were found: *Epistylis* sp., *Acineta* sp., *Lagenophrys* sp., gregarines and a ciliate (**Figure 5**) [26].

The dry river sub-basin, located in the center of Veracruz, is a part of the hydrological region “X Golfo Centro” and the Jamapa River basin, which is home to more than 200,000 people, who live in urban areas, and the 30% in rural areas, this river is used for agriculture, for the provision of drinking water and environmental support; at present it is heavily contaminated by organic matter, nitrogen and fecal matter [27]. Also, water erosion has been estimated in the Jamapa River Sub-basin,



Figure 5.
Point pollution sources in the Estero area, of the de Mandinga lagoon system, Veracruz.

with precipitation data of 10 years from 1990 to 2008, finding that is lost a total of 7787.8 ton/10 years and the month of July is when the highest average specific degradation in 10 years of 27.7 t. ha^{-1} [28].

In **Figure 6**, the concentrations of paraquat herbicide particles in water are shown in the lower basin of the Jamapa River in the rainy season, high residual concentrations were found mainly in the sampling site called Las Gualdras, these concentrations have as diffuse sources of contamination the crops established on the banks of the Jamapa River, such as crops of pineapple (*Ananas comosus*), watermelon (*Citrullus lanatus*), papaya (*Carica papaya* L.) and rice (*Oryza sativa*). On the other hand, the management of systemic insecticides with high mobility such as neonicotinoids, especially thiamethoxam, cause water pollution.

In **Figure 7**, it is shown that the Cotaxtla and Jamapa rivers bifurcate in the Gulf of Mexico, they present residuality of thiamethoxam exceeding the maximum residuality limit of the FAO of 0.01 mg/L, It was also observed that the highest concentrations were found in the Cotaxtla River, which crosses the municipalities of the center of Veracruz, such as Cotaxtla and Medellín de Bravo, a place of high agricultural activity.

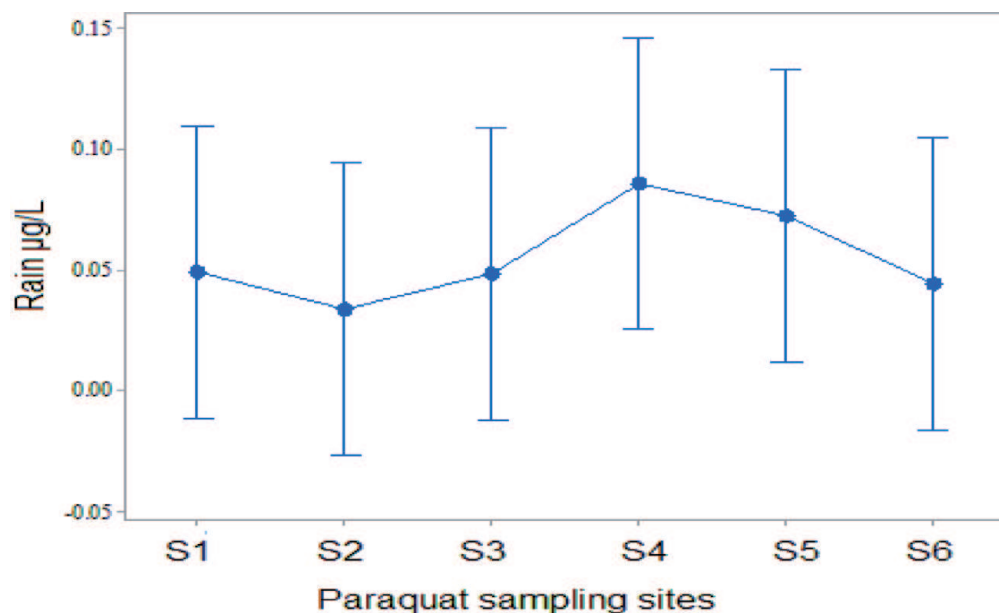


Figure 6. Paraquat concentrations in the rainy season at six surface water sampling sites (ANOVA: $\alpha = 0.05$), in the sub-basin of the port of Veracruz and Río Jamapa, S = water sampling site. S1(dos Bocas 1), S2(dos Bocas 2), S3(La Rayana), S4(las Gualdras), S5(arroyo Moreno), S6(La Bocana).

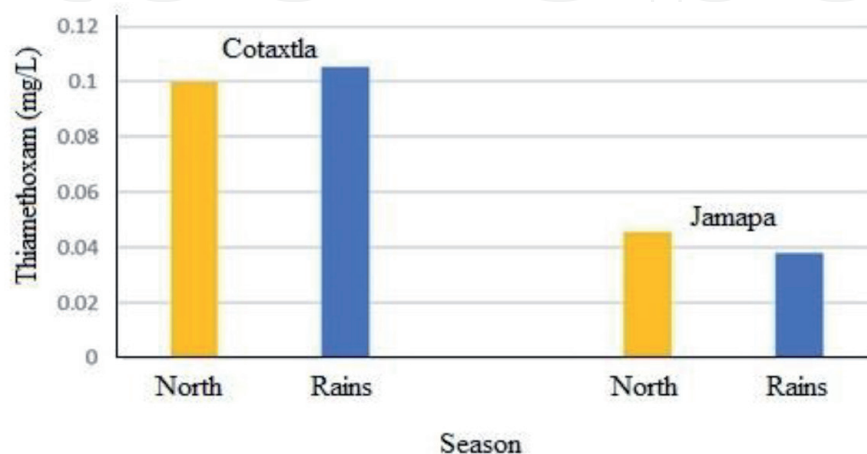


Figure 7. Thiamethoxam concentrations in the Cotaxtla and Jamapa rivers in the north wind and rainy seasons.

2.4 Impacts on the Veracruz reef system

In the Veracruz Reef system, the variation in temperature was studied between the period of March 2011 to March 2012, it was found that the highest values in temperature occur in the months of August and September; With respect to the salinity of the water there is little variability because the concentrations are presented in a constant way. In the variation of oxygen, the values found were in a range of 2 to 5 ml L⁻¹, and nitrogen concentrations were observed low values in the months of August and September with 8.2 ml L⁻¹ and high values greater than 9.0 ml L⁻¹, These variations are caused by the accumulation of sediments from the Jamapa River basin, in addition, a scenario is visualized by the microbiotic activity and an area of hypoxia is identified [29].

It is indicated that after the floods of the Jamapa River and the cold water intrusions that affected the Veracruz Reef System in the 1970s, the populations of *Acropora palmara* are recovering, because in 2007 and 2013 they have been found in 11 reefs north and on all southern reefs, mainly in shallow waters along the reef edge [30].

The presence of various pollutants of anthropic origin has been detected, Zamudio-Alemán et al., [31] in his research work: "Heavy metals in marine sediment of the National Park Veracruz Reef System (PNSAV)" had the objective of identifying the concentration of Cu, Cd and Zn in the sediments of the PNSAV, associated with the main sources of contamination, that influence the lower basin of the Jamapa River using atomic absorption spectrophotometry obtained concentrations of Cu, Cd and Zn of 0.1392; 0.001 and 2.3606 mg kg⁻¹.

Montoya-Mendoza et al., [32] determined the concentrations of cadmium (Cd), lead (Pb), vanadium (V) and zinc (Zn) in the muscle of 30 specimens of *Pterois volitans*, in the National Park Veracruz Reef System (PNSAV), Veracruz, México, using spectrophotometry atomic absorption (AAS), after microwave digestion. Due to their proximity to the coast, and to the Veracruz port, they have suffered numerous severe impacts from human activity, industry, and the carry of sediments from the rivers of Jamapa, Papaloapan and Antigua; causing a set of disturbances by heavy metals, hydrocarbons and coliforms. Studies in 2007 of macrocrustaceans in this reef park, found the existence of more than 20 reef banks with different degrees in development and accretion, the presence of two groups of macrocrustaceans, located in the northern part and another in the southern part of the reef system, as a result of the presence of two oceanic gyres in front of the Jamapa River, which generate a physical barrier in this protected natural area [33].

The expansion works in the Veracruz Reef System National Park have generated negative changes in the ecosystems of the coral reefs; For example, in the Blanquilla reef, it was observed that the algae cover tends to decrease temporarily and increase the groups of invertebrates, also the reefs tend to increase like the *Agaricia* in the Blanquilla and in others the opposite happens like *Agaricia* in the Galician; In addition, there were diseases such as coral bleaching, which has been the disease with the highest percentage of mortality in 2017; On the other hand, the decrease in biomass and density of piscivores and fish of commercial interest is also attributed to the expansion of the port [34].

The environmental and socioeconomic problems currently being experienced in the PNSAV, requires a change in the work scheme that allows to recover the trust and participation of the different actors in favor of the maintenance of environmental services, since its declaration as a National Park, Ramsar site, Biosphere Reserve. So, from 1992 to date it has been working, without any management program since its name as ANP. On the other hand, despite the fact that there are several involved from researchers, authorities, with multidisciplinary scientific capacity and quality

research institutions, a fisheries management program is required, in the area in synchrony with the park management program, to contribute the conflict facing the PNSAV, with economic activities including port activity, tourism and fishing, with impact work on the conservation of reefs, flora and fauna since its expansion of the port area to correct space problems [35].

2.5 Impact on the Gulf of Mexico

The pollution indices on the coast of the Gulf of Mexico, coming from the Jamapa River, found heavy metals as Al, V, Cr, Co, Ni, Cu, Zn, As, Cd and Pb, but the highest values are for Al₂O₃ higher than 120 µg g⁻¹. The geoaccumulation index of metal concentrations in the area of the upper continental crust of the Jamapa are As (3.76), Cu (2.47), Zn (1.38), the determining factor of chemical concentrations is coming from anthropic activities and their distribution of the Jamapa River [36].

A study of eutrophication on the coast of the lower part of the Jamapa River, found in six sampling sites values of dissolved oxygen between the ranges of 3.41 to 6.19 mg L⁻¹, total nitrogen between ranges of 2.732 to 4.596 mg L⁻¹ and temperatures of 27.67 to 30.30 °C, these values influence the water quality [37]. Local fishermen from the Jamapa river hydrological basin, in the Boca del Río municipality and field findings, indicate that species richness, abundance, fish sizes and their commercial use have decreased, as a result of the growth of the urban area, and the deterioration of the body of water and the negative effects on the fish population is also evident, in addition to that the characteristics of the water have been modified, mainly due to its poor quality [38].

The trend of the decrease in salinity in the large Mandinga lagoon between the city of Boca del Río and the town of Mandinga, in rainy or dry periods, is due to the contribution of the flow of the volume of water from the Jamapa River, which dilutes the concentration of salt; In the two-dimensional analysis carried out under low water conditions, the values ranged from zero to 0.5 km upstream from the border with the sea [39].

| Matriz | Cd | Pb | Región | Referencia |
|-----------------------|-------------|-------------|---|------------|
| Sedimento marino | 1.0–13.9 | 0.9–37.7 | Placa continental de Tabasco, Tamaulipas y Veracruz | [41] |
| Sedimento superficial | — | 5.3–42.4 | Isla de Sacrificios, PNSAV | [42] |
| Sedimento superficial | 0.02–0.2 | 5.0–22.0 | Costa central de Veracruz | [43] |
| Sedimento marino | <0.0–0.37 | — | PNSAV | [44] |
| Sedimento superficial | — | 53.1–107.3 | PNSAV | [45] |
| Sedimento | 0.01–5.27 | 0.02–2.3 | Sistema Lagunar de Alvarado | [46] |
| Sedimento marino | — | 2.90–16.6 | Costa central de Veracruz | [31] |
| Núcleo de sedimento | <0.00–0.016 | 31.86–40.36 | Sistema Lagunar de Alvarado | [47] |
| Sedimento marino | — | 10.0–27.0 | Costa de Tamaulipas | [48] |
| Núcleo de sedimento | — | 0.1–26.2 | Región sur del Golfo de México | [49] |
| Sedimento marino | 2.9–33.33 | 0.0–11.72 | PNSAV | [50] |

Table 2. Reported concentrations for cadmium and lead in sediments in the Gulf of Mexico. Concentrations in mg kg⁻¹.

There is evidence of metal contamination in water and sediment matrices in coastal and marine areas; such is the case of the presence of Lead in sediments (Pb), in the lagoons near Laguna Verde of $77.2 \mu\text{g g}^{-1}$, Salada of $78.8 \mu\text{g g}^{-1}$ and the Mancha of $81.1 \mu\text{g g}^{-1}$. It must be considered that lead is volatile and tends to be deposited in areas other than its origin, this could be influenced by the wind patterns that predominate in the Gulf of Mexico. In addition, in some metals the chromium in sediments present in the Laguna de Ostión with concentrations of $140.7 \mu\text{g g}^{-1}$ and in the Alvarado lagoon of $159.7 \mu\text{g g}^{-1}$ in the state of Veracruz, in addition, it tends to accumulate in sediments and increases its level in these areas. In the case of total Nickel (Ni) in the sediments of the coastal areas of the Gulf of Mexico, with a concentration pattern of $26.29 \mu\text{g g}^{-1}$ in the Mandiga lagoon, in the Jamapa and Actopan rivers, Papaloapan Veracruz, with concentrations below $100 \mu\text{g g}^{-1}$ [40]. **Table 2** shows the concentrations for cadmium and lead in sediments in the Gulf of Mexico.

3. Discussion

The presence of pollutants in the water in the Jamapa River basin, and the concentration of organisms that come from fecal matter such as total and fecal coliforms, have their origin from human activities, animal husbandry, agricultural activity and aquaculture, it was found that there is a variation in the chemical parameters (oxygen, nitrates and nitrites) in the quality of groundwater and surface water (lagoon water systems); An indicator of contamination in the Jampa River basin is the presence of *Vibrio* sp., there is also evidence of the negative impact of the extraction of water from the aquifer and of chemical and microbiological contaminants, such as the presence of the enteropathogenic bacteria *E. coli*, which is the cause of diarrhea syndromic diseases in adults and children, and some *E. coli* batteries that cause internal bleeding [51].

It is evident that all the discharges that the Jamapa River basin receives are the result of the runoff and infiltration processes of the lagoon systems that ultimately go to the Jamapa River, in addition to impacting the Gulf of Mexico, mainly the coral reef area, is a concentration of pathogenic bacteria from organic matter and anthropogenic activities among those identified are *Aurantimonas coralicidae*, *Halofolliculina corallasia*, *Helicostoma nonatum*, *Oscillatoria* sp., *Phormidium coral-lyticum*, *Phormidium valderianum*, *Serratia marcescens* and *Vibrio* spp. [52]. Among the indicator parameters of eutrophication on the lower coast of the Rio de Jamapa, they were found in the municipalities of Boca del Rio, Medellín and Alvarado in six analyzed sites (Medellín, Tejar, San José, Playa de Vacas, Arroyo Moreno, Boca del Rio) maximum temperatures of $30.3 \text{ }^\circ\text{C}$, and dissolved oxygen of 5.83 mg L^{-1} , and the maximum means and total nitrogen were 4.59 mg L^{-1} and 4.28 mg L^{-1} . This causes alterations in nitrogen concentrations, an increase in temperature and high concentrations of nutrients in the water. [53]. On the other hand, synthetic pollutants present in the Gulf of Mexico such as banned organochlorine pesticides such as Endosulfan, when concentrated in the water, can be present in aquatic organisms such as mollusks, crustaceans and fish; organisms in which they have been detected in maximum concentrations of $99.48 \pm 16.21 \text{ ng g}^{-1}$, which could be a potential risk to public health and food trade in tourist areas such as Veracruz-Boca Río [54]. Among other organochlorinated pesticides identified in sediments in the Alvarado lagoon system, some concentrations were aldrin (46.05 ng / g), dieldrin (22.13 ng / g) and endrin (21.23 ng/g), these concentrations are reported and originate from the agricultural activities [55].

Faced with this problem, it is important to generate agricultural, livestock and aquaculture production schemes with sustainable approaches, to mitigate the

effects caused by pollution and greenhouse gases; For example, in the case of the management of pesticides of chemical and synthetic origin, combine production for pest control with products of plant or biological origin. Minimize the use of pesticides in agriculture and livestock, it is evident that aquaculture and fisheries production activities are having a negative impact. Ecosystems require sustainability strategies for the protection of their resources, the local participation of producers, the formation of networks, disseminating clear norms, building trust and credibility in transparent processes [56]. Consider that human settlements and conurbation areas need to strengthen wastewater treatment, improve solid waste treatment, and that municipal governments improve processing plants, prohibit construction on the banks of the Jamapa River [57].

4. Conclusion

The Jamapa River basin is the link of three protected natural areas, receives a significant impact from the sources that flow into the basin and which has a consequence in the Gulf of Mexico. Due to anthropogenic activities, many of the physical, chemical and biological pollutants are deposited in water, sediments and marine organisms, mainly in the reef area of the Gulf. It is necessary to seek strategies to mitigate the environmental impact generated by human activities, from the organization at the national, state and municipal level and the organization with the key actors participating in the different links of the agri-food chains, in addition to applying regulations and laws for the regulation and care of the environment.

In Mexico, 1471 hydrographic basins have been delimited that, for administrative purposes, the National Water Commission (CONAGUA) has grouped into 731 basins, which in turn make up 37 hydrological regions, again grouped into 13 economic-administrative regions.

The Jamapa River Basin is an example of the complexity that occurs in the basins of Mexico, where sustainable development faces the challenges of combining and harmonizing economic, social and environmental development in favor of growth and the preservation of different habitats to achieve an adequate quality of life and mitigate climate change.

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Conflict of interest

The authors certify that they have no conflict of interest during preparation of this chapter.

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