The Use of Wetlands by Fishermen in the Region of the Lower Papaloapan River Basin (Veracruz, Mexico)

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ABSTRACT

The inhabitants of the Papaloapan River's lower basin have been devising strategies for adjusting to nature since prehistoric times, utilizing the diverse species found in the wetlands. Currently, commercial fishing is an economic activity that has been developed throughout the lagoon system (Alvarado Lagoon System, ALS). In areas with less saline influence, sugar cane is grown, and extensive livestock farming is practiced. Moreover, for local consumption and trade, freshwater turtles and blue crabs (*Cardisoma guanhumi*) are caught. Additionally, the "naca" fish (*Dormitator maculatus*) is obtained for a brief period during the rainy. Human activity has had a negative impact on the wetland complex and the species that inhabit them, due to factors such as agricultural expansion, the extraction of species, and water pollution. Through our field activities, we observed that the population living along the lower basin of the Papaloapan River has developed a symbiotic relationship with the river, which has permeated their daily life, traditions, and festivities. Despite the recognition of the wetlands as a Ramsar site, the degradation of the ecosystem has not been halted. Therefore, it is imperative to develop alternative strategies aimed at safeguarding and conserving it.

INTRODUCTION

In the lower basin of the Papaloapan River (Veracruz, Mexico), there is a complex set of wetlands, rivers, and coastal lagoons known as the Alvarado Lagoon System (ALS). This system covers more than 314,000 hectares. This wetland complex is the third largest in Mexico and has the largest area of mangrove in the state of Veracruz. It is also the second largest in the Gulf of Mexico (Rodríguez-Luna et al. 2011). Additionally, the system includes other freshwater wetlands, such as marshes, flooded palm groves, flooded forests, sandy beaches, and coastal dunes. In the ALS, there also exist livestock and farming systems, mainly consisting of flooded pastures for cattle and sugar cane plantations. Due to its significance, it has been designated as a Ramsar site since 2004 (Ramsar site 1355, Sistema Lagunar de Alvarado, https://rsis.ramsar.org/es/ris/1355). The extensive surface area of wetlands allows for a high diversity of aquatic fauna, especially birds. It is estimated that the system serves as a habitat for more than 300 species of birds, both resident and migratory (Berlanga et al. 2008), as it is situated within the Central Flyway. This is why the Important Bird Area 'Humedales de Alvarado' is also located within this system (BirdLife International 2023). The ALS also serves as the habitat for the threatened manatee (*Trichechus manatus*) and a diverse range of species that are exploited commercially or locally, including the blue crab (*Cardisoma guanhumi*), the fat sleeper (*Dormitator maculatus*, locally referred to as *naca*), and seven species of freshwater turtles, all of which are deemed threatened species by the NOM-059-SEMARNAT-2010 in Mexico (Cázares Hernández 2015). The region's wetlands have been used by people since pre-Hispanic times. Despite having distinct categories of biological conservation, the ALS nonetheless exhibits significant impacts due to the alteration in land use within the basin, hydraulic works such as dams, industrial activities, oil, agricultural and livestock activities, among other factors. In this article, we will document the natural history of the region, the records of the historical use of its wetlands, their current use, and the environmental problems in the area.

THE PAPALOAPAN RIVER BASIN

Because of its size (47,600.51 km^2), the Papaloapan River Basin (PRB) is the second-largest hydrological system in Mexico (Andrade Galindo and González Solano 2003; Figure 1). The upper zone of the basin (130 – 160 km from the coast) is located mainly in the north of the state of Oaxaca (Sierra Juárez), where it reaches an altitude of 2,970 meters a.s.l. Additionally, it includes an eastern portion of the state of Puebla, at an altitude of 2,619 meters a.s.l. This region is located between 130 and 160 km from the coastal zone and receives rainfall almost all year round, with annual accumulations greater than 3000 mm of rain or fog (CNA 1992; García 1987). The geomorphology of this mountain area has an abrupt descent, since the plain is located at a distance of between 20 and 30 km from the ridge tops. The two dams, "Miguel Alemán" (also known as the "Temascal" dam, in 1959) and "Miguel de la Madrid" (also known as the "Cerro de Oro" dam, in 1988), were constructed at elevations ranging from 50 to 150 meters above sea level, at a distance of between 100 and 120 km from the coastal area. From here, an extensive plain is formed that borders the Papaloapan River and its tributaries. Approximately one third of the basin corresponds to low areas of the coastal plain. This basin contains a potential water reserve equivalent to 18.9% of the country's total potential reserves.

This basin receives the 12% of Mexico's total precipitation, making it one of the most significant freshwater re-

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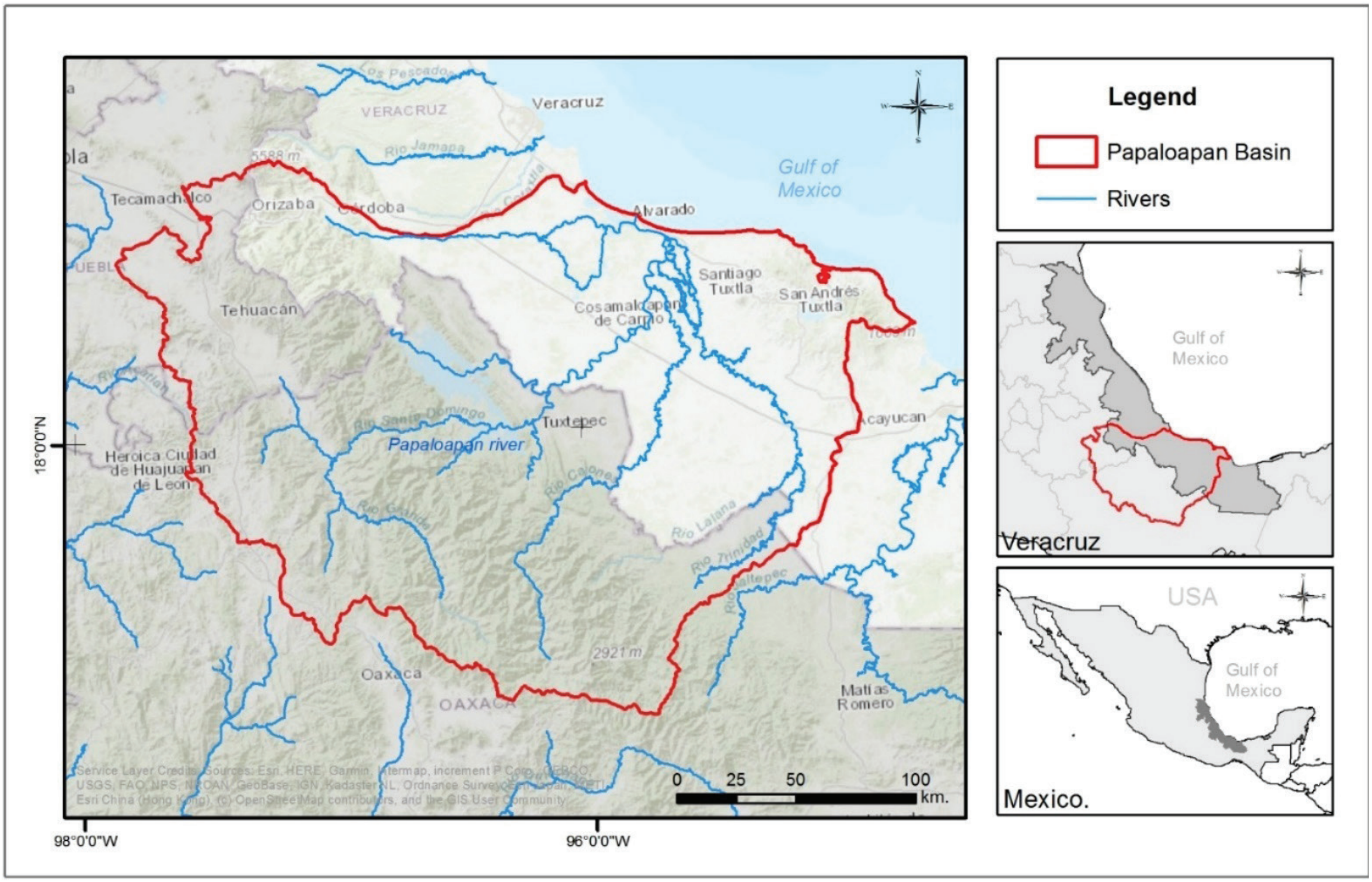

Figure 1. Map showing the delimitation of the Papaloapan River Basin (PRB) and its location in the states of Veracruz, Puebla and Oaxaca in Mexico (Elaborated by Roberto C. Monroy Ibarra).

serves in the country (CNA 2011). Due to the large amount of water that flows down the basin, a complex system of coastal lagoons, rivers, and wetlands formed on the coastal plain of the ALS. This is an intertidal system of freshwater and brackish environments, that supports a high diversity of aquatic fauna.

The Alvarado Lagoon System (ALS)

The ALS contains the second-largest area of mangrove in the Gulf of Mexico. The mangrove covers close to 20% of the total surface of the area. The species are red mangrove (*Rhizophora mangle*), white mangrove (*Laguncularia racemosa*), and black mangrove (*Avicennia germinans*). In brackish or freshwater environments, large surfaces are formed with marshes dominated by cattail (*Typha domingensis*), reed (*Phragmites australis*), alligator flag (*Thalia geniculata*), Mexican papyrus (*Cyperus giganteus*), or spike-rushes (*Eleocharis* spp.) (Figure 2). There are still remnants of flooded forests dominated by money tree (*Pachira aquatica*) or flooded groves dominated by Mexican sabal palm (*Sabal mexicana*) (Rodríguez-Luna et al. 2011). Large areas of wetlands have been replaced by grasses of African origin, such as Pará grass (*Brachiaria mutica*) or Antelope grass (*Echinochloa pyramidalis*) (López Rosas et al. 2013).

Figure 2. Example of an oligohaline marsh dominated by a spike-rush *Eleocharis* sp. An isolated seedling of white mangrove (*Laguncularia racemosa*) is observed. The mangrove community mixed with palms of *Sabal mexicana* can be seen in the background. (Photo by Adrián López Espejel)

This large area of wetlands is a priority site for bird conservation. A total of 337 bird species have been recorded, which corresponds to 32.6% of the bird species found in the country. Migratory birds are important in these systems; they constitute 49% of the total recorded for the area. Out of this, 45 are classified as being at some risk per the established Mexican Official Norm (Berlanga et al. 2008; Portilla-Ochoa 2003).

HISTORICAL USE OF WETLANDS

In ancient Mesoamerica, the use of wetlands has a long cultural history. The Olmec people in the Coatzacoalcos River floodplain, temporarily cut off from other towns due to river fluctuations, developed community improvement strategies. Wetland use reflected risk management and adaptation, granting resource control vital for survival (Cyphers et al. 2013). In the Central Altiplano, evidence shows wetlands utilization in hunting, fishing plant collection, and craft (Sugiura and Serra Puche 1983). In western Mexico, pre-Spanish, commercial exchange via water routes aided the Purépecha Empire's development (Williams 2015). Wetlands offered abundant nutrition, including algae, insects, fish, plants, reptiles, and birds (Parsons 2005; Sugiura 2015; VanDerwarker 2006; Williams 2009). They remain integral to cultural identity, seen in Xochimilco's chinampas (a pre-Hispanic cultivation system comprised the placement of wooden stakes around a raft-shaped islet), and Mexica Empire founding myths in Lake Texcoco.

One of the most relevant wetland landscapes since pre-Hispanic times up to the present is the lower basin of the Papaloapan River. This culturally multi-ethnic region has evidence of human occupation and settlement dating back to the Mesoamerican Formative Period (1200 BC to 200 AD) (Medellín 1960; Stark 1989), highlighting its long history of human use.

In 1908, Leopoldo Batres published "Prehistoric Civilization of the Banks of the Papaloapan and Sotavento Coast." This work highlights the strategic geographic location that facilitated interaction between settlements both inside and outside the basin. The basin's geographic location and water communication networks drove population movements, migrations, and the creation of new settlements, fostering trade. During the 1940s, Gonzalo Aguirre Beltrán described the colonization of human settlements like La Campana, El Tiesto, El Zapotal, El Cocuite, La Mojarra, and Tío Primo. He emphasized the ecological conditions of the Papaloapan and referred to this region as La Hoya (The Hollow) due to its basin-like geographical characteristics (Ortiz 1987). Since the late 20th Century, this region has been studied by both foreign and domestic researchers, expanding our understanding of the lifestyles of communities settled in flood-prone areas and their relationship with water (Guadarrama Olivera 2005, Pool et al. 2023, Velasco Toro and Ramos Pérez 2011).

Figure 3. The remains of pre-Hispanic settlements are represented by mounds located in wetlands in Costa de San Juan, Alvarado (Veracruz). Stark and Ossa (2005) consider that the mounds were intended for residential use. During the flood season, the dwelling was safeguarded, and upon the receding of the flood, the low areas were utilized as orchards. (Photo by Hugo López Rosas)

Some of the present-day villages along the banks of the Papaloapan River are built upon ancient settlements, strategically positioned to foster cultural continuity and showcase the ongoing use of the river and wetlands. For instance, archaeological studies of sites near the river in the Tlacojalpan and Otatitlán areas during the Classic Period (200-900 AD) have discovered obsidian utensils used for fish scaling (Jiménez Lara y León Estrada 2010). Towards Tlacotalpan and Alvarado, there's significant importance noted in the river networks, coastal dunes, and wetlands for fishing associated with mangroves (Stark 2008). Aquatic resources in the ALS were highly valued because the scarcity of arable land meant ancient inhabitants of the mangroves subsisted on them. Evidence indicates that, since pre-Hispanic times, these floodplains were transformed for human settlements, as mounds of rammed earth from that period can still be observed (Figure 3).

The PRB holds significant importance in Mesoamerican cultural history due to the La Mojarra stele, a monolith found on the banks of the Acula River, which feeds into the Alvarado lagoon (Diehl 2011). This area, characterized by compacted earth mounds amid waters and bordered by mangroves, is notable for the stele, which, according to Justeson and Kaufman (2008) represents one of the oldest pieces of evidence of glyphic writing in Mesoamerica, featuring a historical narrative in a pre-Protozoque language.

During the Postclassic period (900-1521 AD), the lower PRB was part of the Tochtepetl province (Aguirre Beltrán 1992), which paid tribute to the Mexica Empire with cotton blankets, diverse fish, and multicolored birds, showcasing the region's biodiversity of the region, as documented in the Mendoza Codex. Subsequently, the Spanish explored the area by both water and land. According to Bernal Díaz del Castillo's account, 500 years ago, Captain Pedro de Alvarado ventured through a river known to the indigenous people as Papaloapa, where abundant fish products were found. He also narrates an encounter with indigenous fishermen who claimed to be "natives of a town called Tacotalpa" (Díaz del Castillo 1974: 22). During the colonial era in the 16th century, fisheries were established. Fishing became a traditional activity among the indigenous population, Spanish settlers, mulattoes, and mestizos (Velasco 2003: 127). However, gradually, cattle farming became a more important than fishing (Thiébaut 2013).

The natural and cultural characteristics of the wetland landscape in the lower basin of the Papaloapan River are also reflected in common language. Papaloapan derives from the Nahuatl words *papalotl* (butterfly) and *apan* (river), meaning "river of the butterflies"; while Tlacotalpan, one of the main cities in the lower Papaloapan basin, owes its name to the Nahuatl words *tlacotl* (reed, rod), *tlalli* (land), and *pan* (on top of...) (Thouvenot 2014); thus, it would literally translate to a place of reeds on the land or green rods on the land. This refers to the characteristic cattail (*Typha domingensis*) formations, that grow along the riverbanks. Another example is Otatitlán, a village situated on the banks of the Papaloapan River. In Nahuatl, Otatitlán is derived from *otatl* (giant cane), *ti* (under), *tlan* (place), translating to "place under the giant canes" (Melgarejo Vivanco 1950:30), which refers to the bamboo-like plants of the *Otatea* genus growing along the riverbanks, streams, and commonly found in wetland areas.

Through the historical utilization of wetlands, we can observe how it refers to an ecosystem and encompasses "an entire social fabric and the implications that come with its occupation and use (...) within a cultural context in which the ecosystem is just one influential part that enables symbiotic relationships" (León Estrada and Wilson 2020:188).

CURRENT USE OF WETLANDS

There are multiple activities in the lower basin of the Papaloapan River contributing to its economic progress, spanning across a salinity gradient from the intertidal zone to areas without saline influence. Commercial fishing is conducted throughout the lagoon system, including the river and streams. In areas with lower saline influence, the primary economic activity is agriculture, primarily focused on sugarcane cultivation, followed by extensive cattle farming (Figure 4). Traditionally, for local consumption and trade, freshwater turtles and blue crabs (*Cardisoma guanhumi*) are harvested. Turtles are captured in the wetlands, primarily during the dry season when they are estivating; turtle hunters set fires to force the turtles out of the mud. Meanwhile, the capture of blue crabs mainly occurs during the rainy season, when females migrate from the wetlands to the sea for spawning (Figure 5). Another less commercial fishing activity is for the "naca" fish (*Dormitator maculatus*), occurring only for a few days during the rainy season (September-October) when females migrate along the river, from freshwater wetlands to saline environments. This is a massive migration in which many specimens can be caught quickly, which is not possible during the dry season, when this species is estivating in the mud. It is also difficult to catch outside of migration because the fishes are dispersed in the wetlands, where they are difficult to catch. All these activities have had negative impacts on the wetland com-

Figure 4. In the ALS, large areas of freshwater and oligohaline wetlands have been displaced by grasslands, with exotic grasses, for the practice of extensive cattle ranching. In the process of land use change, ranchers first burn native wetland vegetation to later plant forage grasses. (Photo by Hugo López Rosas)

Figure 5. In the rainy season, from July to September, female blue crabs (*Cardisoma guanhumi*) migrate from the freshwater and oligohaline wetlands to the beaches to spawn in the sea. On their migratory route, many specimens are captured for human consumption before they can spawn. (Photo by Verónica E. Espejel González)

Figure 6. Farmers in field with planted mangroves. In the last decade, the National Forestry Commission of Mexico has promoted the Environmental Compensation Program due to change of land use in forest land. Small landowners, farmers of communal lands or fishermen, from the Alvarado Lagoon System have benefited from this program, with economic incentives for mangrove reforestation. (Photo by Ignacio C. Sánchez Luna)

plex and the populations of these aquatic species. More recently, mangrove reforestation activities have been practiced (Figure 6), along with beekeeping (Figure 7), producing mangrove honey (a blend of pollen from *Laguncularia racemosa*, *Rhizophora mangle*, and *Avicennia germinans*) and "estribo" honey from Brown's indian rosewood (*Dalbergia brownei*), a legume woody shrub or vine inhabiting riverbanks and freshwater channels.

The PRB is also one of the main agricultural production centers in Veracruz, primarily for sugarcane, but for maize, tropical fruits, and vegetables in non-flood zones. It stands as Mexico's most significant sugarcane-producing region, with 10% of the national land devoted to this crop situated within this basin (CONADESUCA 2023). Due to the high demand for sugar and the maintenance of prices, the area allocated for sugarcane cultivation increases annually, leading to changes in land use or the replacement of other crops with lower demand. This situation negatively impacts wetlands as they increasingly receive excess residues of fertilizers and pesticides.

Extensive cattle farming also has a major impact on wetlands as vast expanses of mostly freshwater wetland have been replaced by flooding grasslands featuring exotic grass species originating from Asia and Africa (López Rosas et al. 2013). This pattern repeats in other flood-prone areas in southern and southeastern Mexico. However, in the Papaloapan basin, since 1970, cattle production has exceeded the national average (Rodríguez-Luna et al. 2011). This pattern of land use change to allocate land for extensive cattle ranching persisted for more than 30 years, and by 2003, this activity already occupied 50% of the lower basin. In the past 20 years, due to low cattle ranching pro-

Figure 7. In recent decades, the commercial production of honey from wetlands in the Alvarado lagoon system began. This honey is obtained from both mangrove species and freshwater species, mainly the legume *Dalbergia brownei*. (Photos by Carlos J. Cardoso Martínez)

ductivity, these lands have been abandoned, reducing their extent to 30% of the lower basin, allowing for the recovery of secondary vegetation (Alavez-Vargas et al. 2023).

Commercial fishing is artisanal (traditional and subsistence fishing) and stands as the third most important economic activity in the area. Within the ALS, 82 fish species have been recorded, of which only 32 are utilized for local sale and consumption, while another 10 are used as bait (Portilla-Ochoa 2003). Apart from catching fish such as bass and snapper, it is a significant area for harvesting shrimp, crabs, oysters, and clams.

In the ALS, fisheries are declining due to overexploitation, the use of prohibited fishing gear, an increase in unregulated fishermen, alongside diminishing water quality and ecosystem health resulting from inadequate land use/ water management practices in the basin (Portilla-Ochoa 2003). Deforestation and soil erosion due to land-use changes, excessive pesticide and fertilizer application, dam construction, and water extraction for irrigation and domestic use pose significant threats to the region's water and wetland resources. Surprisingly, this system still maintains a high fish biodiversity. However, it is recommended to establish conservation and reforestation programs to preserve key habitats crucial for the breeding and sustenance of fish populations within the system.

HUMAN IMPACTS

The Ramsar Site 1355 Alvarado Lagoon System faces many of the wetland issues seen across the country, but its main threat is land-use change for agricultural and livestock activities, leading to the loss of natural ecosystems, habitats for aquatic fauna, and overall biodiversity. Large expanses of mangroves were converted into low-productivity pastures for extensive cattle farming, as the saline soils aren't suitable for high-yield pasture production for livestock. Additionally, mangroves were affected by logging for fence posts in livestock areas and charcoal production. In 2007, Mexico decreed mangrove protection in the General Wildlife Law and, since then, mangrove logging has been illegal. This law, together with the abandonment of livestock lands and reforestation programs, has allowed a slow recovery of these ecosystems in the area. However, there isn't similar regulation for the conservation of other wetlands, such as flooded forests or herbaceous wetlands, which are the ecosystems most affected by agricultural and livestock practices.

Agricultural Expansion

As of 2022, agricultural and livestock activities covered 63% of the land in the municipality of Alvarado (SEFIPLAN 2022). Before the decree of the General Wildlife Law, expansion of agricultural frontiers, primarily for sugarcane cultivation, cattle farming, and forestry practices, resulted in the loss of coastal vegetation, including the mangrove forest (Moreno-Casasola et al. 2016). By 1976, there was a recorded mangrove area solely within the ALS of 211.50 km², a size that decreased to 148.97 km² by 2010 (Vásquez-Lule et al. 2009).

The expansion of agricultural and livestock activities brings with it basic needs fulfilled by the natural resources present in the area. For instance, farmers and ranchers require posts for fencing their fields, leading to mangrove logging (PRONATURA 2015). Another need is space for cultivation or livestock enclosures, sometimes addressed by deliberate fires in certain plant communities. These fires occasionally spiral out of control, spreading through roots and canopy, as local communities lack necessary staff and equipment to address these emergencies. This situation has resulted in the loss of extensive wetland areas (PRONATURA 2015). To date, there is no record of the area affected by fires, but when they occur, they spread rapidly. For example, in 2011, there was a fire that destroyed more than 200 hectares of mangrove (López-Rosas, 2018). Furthermore, the use of agrochemicals has led to their presence in soils, rivers, coastal lagoons, estuaries, and organisms. Various chemicals have been found in the tissues of organisms, many of which are part of the local communities' diets, as well as in commercially significant fish (Moreno-Cassola et al. 2016).

Extraction of Species

Given the biocultural heritage of local communities, many species, both flora and fauna, are used for sustenance and as an economic resource for these human populations. However, the very ways in which these resources are exploited can lead to a series of impacts on the species themselves and the ecosystem as a whole. In this section, we will discuss two specific cases: the extraction of naca fish (*Dormitator maculatus*) roe, and the capture of freshwater turtles, clear examples of how traditional extraction processes can significantly impact the habitats of these ecosystems.

*Naca Roe***.** Naca (*Dormitator maculatus*) is a demersal fish primarily found in fresh or oligohaline water. During the breeding season, it migrates to saline environments for spawning, whereas during the dry season, this species buries itself in the sediment of wetlands (to minimize its metabolism).

The "Naca" is utilized by artisanal fisheries for a period of one to two weeks per year, between September and October, when mature individuals migrate massively from wetlands to spawn in the Alvarado Lagoon (Figure 8). According to Franco-López et al. (2020), an estimated average of 150 tons are caught annually exclusively for the use of the gonads (female ovaries), discarding the rest of the organism. This activity is mainly carried out by women, youngsters, and children who set nets in the channels near their homes. The nets fill quickly, and males are separated from females. The males are returned to the river, while the females have their gonads (Naca roe) extracted. The highly

Figure 8. Harvest and processing of “Naca” fish. During the rainy months, the “Naca” fish migrate from freshwater or oligohaline wetlands to more saline areas. During their migration, the females are captured for the use of their gonads, which are a Veracruz delicacy. (Photos by María del Socorro Aguilar Cucurachi)

valued roe is sold to local merchants. This practice exerts significant pressure on the fish population, as it hinders the spawning. Nevertheless, the species’ habitat in the area is extensive, and it is quite resilient to disturbances, with locals reporting no noticeable decline in abundance, except during years with low rainfall. Franco-López et al. (2020) report that in the 1980s and early 1990s, the maximum quantity of collected roe was 250 tons, but it has recently decreased to less than 100 tons. So, it appears that the practice is having an impact on fish reproduction.

Turtles

The extraction of turtles is another example of the negative consequences of exploiting species inhabiting wetlands. In the state of Veracruz, there are 13 species of freshwater turtles (Cázares Hernández 2015), which are subject to traditional use by human communities. Exploiting turtles represents a significant additional income for farmers, ranchers, and fishermen. Their exploitation is even linked to their use as “goods” exchanged for obtaining other consumable goods during economically challenging periods. Unlike other organism groups that have been bred in captivity, commercially traded turtles come from their natural habitat, invariably placing them in the informal market. This results in little or no information regarding their consumption. While there is not consistent record-keeping of turtle populations and their uses in the state of Veracruz, some studies indicate that worldwide populations remain low due to being utilized as food, pets, and even for traditional medicine (Bárcenas-García et al. 2022; del Toro et al. 1979; Turtle Conservation Fund 2002). Additionally, their habitats are increasingly fragmented, destroyed, urbanized, and contaminated.

In the wetlands of the ALS, as well as in other regions in southern Veracruz, Tabasco, Campeche, and Chiapas, the capture of freshwater turtles is highly destructive to wetlands. During the dry season, these species go into dormancy (estivation) by burying themselves in wetland

Figure 9. Cattail (*Typha domingensis*) regrowth after a fire. One of the main impacts to the wetlands of the Alvarado lagoon system are accidental or arson fires. In livestock management, grass is burned during the dry season, but careless management can cause the fire to escape into the wetlands. While the capture of freshwater turtles is a prohibited practice, it continues to be practiced by locals. During the dry season, turtle hunters set fires to force the turtles to come out of their estivation and thus capture them. (Photo by Hugo López Rosas)

Figure 10. Plastic pollution causes serious concern. Plastic products are thrown into the effluents and the currents carry them to the coast, where they become stuck in the roots of mangroves. Excess plastic pollution is manifesting itself in the form of microplastics in foods from wetlands. (Photo by Hugo López Rosas)

sediment. At this time, turtle hunters start fires to force them out of dormancy and to the surface (Figure 9). Despite being illegal, this practice is ongoing and causes fires across extensive areas of herbaceous wetlands that spread to mangroves, resulting in massive loss of ecosystems and their biodiversity.

Water Contamination

The wetlands of the ALS are impacted by runoff from the basin, changes in land use, industrial waste, deforestation in the upper part of the basin, as well as domestic human waste. Among these factors, it's noteworthy that Alvarado's populations lack the necessary infrastructure for treating urban wastewater, resulting in frequent gastrointestinal, skin, and ocular diseases among the population. Furthermore, communities within the lagoon complex lack public services, leading to the majority of waste being discharged directly into water bodies. Barrera-Escorcia and Wong Chang (2005) mention that wastewater contains microorganisms that pose a potential risk to human health.

Various studies of water contamination in Alvarado have been revealed contamination from metals to microorganisms. For instance, Guzmán-Amaya et al. (2005) identified high concentrations of cadmium, copper, chromium, nickel, lead, and zinc in sediment and in the Eastern oyster (*Crassostrea virginica*) from the lagoons of Alvarado, Mandinga, and Tamiahua. They pointed out that the recorded concentrations could lead to adverse biological effects, as high cadmium concentrations in the marine environment can affect the survival of larvae and juveniles of various organisms. Furthermore, Castañeda-Chávez et al. (2018) found organochlorine pesticides in the ALS, specifically hexachlorocyclohexanes, cyclodiene, methoxychlor, and heptachlor in the sediments. These substances are highly toxic to public health and their presence indicates their illegal use in Mexico, despite being internationally banned. The sediments serve as a habitat for various aquatic organisms like crustaceans and bivalve mollusks that become contaminated and when consumed by individuals, they could pose a public health risk. Beltrán et al. (2005) mention that the waters of the main coastal lagoons where oysters are cultivated, such as in Alvarado, show bacterial contamination levels that exceed the permissible limits for mollusk cultivation areas.

In recent years there is increasing concern about the presence of microplastics in aquatic environments (Figure 10). Peralta-Peláez et al. (2022) demonstrated a presence of plastics in the tissues and organs of living organisms, in water, and in the air. They found that the beaches of Alvarado, located south of the Jamapa River's mouth, exhibit the highest plastic pollution along the central coastal zone of Veracruz. This type of pollution can originate from items related to fishing activities (e.g., nets), agricultural practices (e.g., boats, agrochemical containers), industrial pellets, caps, straws, cigarette butts, among others. These fragmented and degraded items find their way into various ecosystems, eventually reaching the sea.

FINAL REMARKS

The lower basin of the Papaloapan River, located in the state of Veracruz, Mexico, constitutes a ecological environment of great importance. This region, characterized by the presence of the extensive Papaloapan River and its tributaries, harbors a natural wealth that impacts both local biodiversity and the lives of people dependent on its resources. Its rivers, lagoons and wetlands are crucial habitats for numerous species of flora and fauna, some of which are endemic and endangered (Table 1). The interconnection of aquatic and terrestrial ecosystems in this basin creates a delicate balance that sustains wildlife and contributes to the overall health of the environment. In addition to its ecological value, the lower basin of the Papaloapan River plays a vital role in the lives of surrounding communities. Local populations have developed a symbiotic relationship with the river, depending on its waters for agriculture, fishing, and transportation. Over the centuries, these communities have woven their cultural identity around the Papaloapan river, reflected in their traditions, festivals, and daily practices. Despite its importance, the lower basin of the Papaloapan river faces grave threats. Land use change, extraction of endangered species, fires, and water pollution negatively impact the health of the system. Although there is already an internationally recognized wetland resource (the Ramsar site 1355, Sistema Lagunar de Alvarado), its presence has not been sufficient to prevent ecosystem degradation. We think it is important and necessary to protect this system through other conservation designations, such as a Biosphere Reserve or a Flora and Fauna Protection Area.

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Table 1. Lists of endemic and endangered species in Alvarado Lagoons System — extract from Vásquez-Lule et al. (2009).

Group	Family	Scientific name	Category NOM-059-SEMARNAT-2001	Category IUCN Red List
Plants	Combretaceae	*Conocarpus erectus*	Subject to special protection	
	Combretaceae	*Laguncularia racemosa*	Subject to special protection	
	Palmae	*Roystonea dunlapiana*	Subject to special protection	EN B1+2c ver2.3(1994)
	Palmae	*Roystonea regia*	Subject to special protection	
	Rhizophoraceae	*Rhizophora mangle*	Subject to special protection. Endemic	
	Verbenaceae	*Avicennia germinans*	Subject to special protection	
Fungi	Boletaceae	*Boletus edulis*	Endangered	
Fish	Ariidae	*Potamarius nelsoni*	Subject to special protection. Endemic	
	Atherinopsidae	*Atherinella marvelae*	Endemic to the Papaloapan River basin	
	Centropomidae	*Centropomus poeyi*	Endemic to the Gulf of Mexico W	
	Cichlidae	*Vieja fenestrata*	Endemic oh the Veracruz rivers	
	Pimelodidae	*Rhamdia guatemalensis*	Subject to special protection. Endemic	
	Poeciliidae	*Priapella compressa*	Endangered. Endemic	
	Pristidae	*Pristis pectinata*	Endangered	EN A1bcd+2cd ver2.3(1994)

Table 1 (continued). Lists of endemic and endangered species in Alvarado Lagoons System — extract from Vásquez-Lule et al. (2009).

Group	Family	Scientific name	Category NOM-059-SEMARNAT-2001	Category IUCN Red List
Herpetofauna	Anguidae	*Abronia taeniata*	Subject to special protection. Endemic	
	Boidae	*Boa constrictor*	Endangered	
	Cheloniidae	*Chelonia mydas*	In danger of extinction	EN A1bd ver 2.3 (1994)
	Cheloniidae	*Lepidochelys kempii*	In danger of extinction	CR A1ab ver 2.3 (1994)
	Chelydridae	*Chelydra serpentina*	Subject to special protection	
	Crocodylidae	*Crocodylus moreletii*	Subject to special protection	LR/cd ver2.3(1994)
	Colubridae	*Imantodes cenchoa*	Subject to special protection	
	Colubridae	*Leptophis mexicanus*	Endangered	
	Dermatemydidae	*Dermatemys mawii*	In danger of extinction	EN A1abcd+2bcd, B1+2cde ver2.3(1994)
	Emydidae	*Trachemys scripta*	Subject to special protection	LR/nt ver2.3(1994)
	Iguanidae	*Ctenosaura acanthura*	Subject to special protection. Endemic	
	Kinosternidae	*Kinosternon acutum*	Subject to special protection	LR/nt ver 2.3 (1994)
	Kinosternidae	*Kinosternon integrum*	Subject to special protection. Endemic	
	Kinosternidae	*Kinosternon leucostomum*	Subject to special protection	
	Plethodontidae	*Bolitoglossa platydactyla*	Subject to special protection. Endemic	
	Ranidae	*Rana pustulosa*	Subject to special protection. Endemic	
	Rhinophrynidae	*Rhinophrynus dorsalis*	Subject to special protection	
	Staurotypidae	*Claudius angustatus*	In danger of extinction	LR/nt ver 2.3 (1994)
	Staurotypidae	*Staurotypus triporcatus*	Subject to special protection	LR/nt ver2.3(1994)
Birds	Ardeidae	*Tigrisoma mexicanum*	Subject to special protection	
	Podicipedidae	*Tachybaptus dominicus*	Subject to special protection	
	Psittacidae	*Amazona oratrix*	In danger of extinction	EN A1acd ver2.3(1994)
	Psittacidae	*Aratinga holochlora*	Endangered	
Mammals	Cebidae	*Ateles geoffroyi*	In danger of extinction	
	Felidae	*Leopardus wiedii*	In danger of extinction	
	Mustelidae	*Lontra longicaudis*	Endangered	DD ver2.3(1994)
	Trichechidae	*Trichechus manatus*	In danger of extinction	VU A2d ver2.3(1994)

REFERENCES

Aguirre Beltrán, G. 1992. Pobladores del Papaloapan: Biografía de una Hoya. CIESAS, Mexico, D.F., Mexico.

Alavez-Vargas, M., G. González-Celada, C. Birkel, R. Fonseca, and J. A. Breña-Naranjo. A. 2023. Estimated potential erosion in the Papaloapan River: Modeling efficiency and uncertainty. *Tecnología y Ciencias del Agua*, 14(4): 349-407.

Andrade Galindo, J. and M. González Solano. 2003. La ex comisión del Papaloapan y la recuperación de su memoria histórica. *Boletín del Archivo Histórico del Agua* 25(8): 42-49.

Bárcenas-García, A., F. Michalski, W.H. Morgan, R.K. Smith, W.J. Sutherland, J.P. Gibbs, and D. Norris. 2022. Impacts of dams on freshwater turtles: a global review to identify conservation solutions. *Tropical Conservation Science* 15: 1-21.

Barrera-Escorcia, G., and I. Wong Chang. 2005. Contaminación por microorganismos en zonas costeras. In A. V. Botello, J. Rendón-von Osten, G. Gold-Bouchot, and C. Agraz-Hernández (eds). *Golfo de México Contaminación e Impacto Ambiental: Diagnóstico y Tendencias*, second edition. Universidad Autónoma de Campeche, Universidad Nacional Autónoma de México, Instituto Nacional de Ecología, Campeche, México. Pages 475-486.

Beltrán, J., A. Villasol, A. V. Botello, and F. Palacios. 2005. Condición actual del ambiente marino-costero de la región del Gran Caribe. In A. V. Botello, J. Rendón-von Osten, G. Gold-Bouchot, and C. Agraz-Hernández (eds) *Golfo de México Contaminación e Impacto Ambiental: Diagnóstico y Tendencias*, second edition. Universidad Autónoma de Campeche, Universidad Nacional Autónoma de México, Instituto Nacional de Ecología, Campeche, México. Pages 1-24.

Berlanga, H., V. Rodríguez-Contreras, A. Oliveras de Ita, M. Escobar, L. Rodríguez, J. Vieyra, and V. Vargas. 2008. AICA 41, Humedales de Alvarado. AVESMX, CONABIO, México, D.F. http://avesmx.conabio.gob.mx/lista_region

BirdLife International. 2023. Important Bird Area factsheet: Humedales de Alvarado. http://datazone.birdlife.org/site/factsheet/humedales-de-alvarado-iba-mexico

Castañeda-Chávez, M.R., F. Lango-Reynoso, and G. Navarrete-Rodríguez. 2018. Hexachlorocyclohexanes, cyclodiene, methoxychlor, and heptachlor in sediment of the Alvarado lagoon system in Veracruz, Mexico. *Sustainability* 10(1):76. https://doi.org/10.3390/su10010076

Cázares Hernández, E. 2015. Guía de las Tortugas Dulceacuícolas de Veracruz. Instituto Tecnológico Superior de Zongolíca, Mexico.

CNA [Comisión Nacional del Agua]. 1992, Isoyetas normales de la República Mexicana 1931-1990. Comisión Nacional del Agua, Mexico.

CNA [Comisión Nacional del Agua]. 2011. Identificación de Reservas Potenciales de Agua para el Medio Ambiente en México. Comisión Nacional del Agua, Mexico.

CONADESUCA [Comité Nacional para el Desarrollo Sustentable de la Caña de Azúcar].2023. 10° Informe Estadístico del Sector Agroindustrial de la Caña de Azúcar en México, zafras 2013-2014 / 2022-2023. SEDARPA, Mexico.

CONAPESCA [Comisión Nacional de Acuacultura y Pesca]. 2021. Anuario Estadístico de Acuacultura y Pesca de la Comisión Nacional de Acuacultura y Pesca. SEDARPA, Mexico.

Cyphers, A., J. Zurita Noguera, and M. Lane Rodríguez. 2013. Retos y Riesgos en la Vida Olmeca. Instituto de Investigaciones Antropológicas, UNAM, Mexico.

Dávila Camacho, C.A. and I. Galaviz-Villa. 2021. Basic biological aspects of *Dormitator maculatus* "Naca" (Bloch, 1792) from the Alvarado lagoon in Veracruz, Mexico. *IOP Conference Series: Earth and Environmental Science*: 690(1). https://doi.org/10.1088/1755-1315/690/1/012063

del Toro, M.A., R.A. Mittermeier, and J.B. Iverson. 1979. River turtle in danger. *Oryx* 15(2): 170-173.

Díaz del Castillo, B. 1974. Historia de la Conquista de Nueva España. Porrua, Mexico.

Diehl, R. 2011. The La Mojarra Chronicle: An Illustrated Account of an Archaeological Investigation in Veracruz, Mexico. FAMSI, Washington.

Franco-López, J., C.M. Bedia-Sánchez, E. Peláez-Rodríguez., J.L. Viveros-Legorreta, M.A. Ortiz-Touzet, and H. Vázquez-López. 2020. Ecological aspects of *Dormitator maculatus* Bloch, 1792 in the Alvarado Lagoon, Veracruz, Mexico. *Turkish Journal of Fisheries and Aquatic Sciences* 20(1): 51-60.

García, E. 1987. Modificaciones al Sistema de Clasificación Climática de Kóppen. Instituto de Geografía, UNAM, Mexico.

Guadarrama Olivera, H. 2005. Historia del bajo Papaloapan, historia en construcción. In J. Velasco Toro, and L. A. Montero García (eds) Economía y Espacio en el Papaloapan Veracruzano. Siglos XVII -XX, Editora de Gobierno del Estado de Veracruz, Xalapa, Mexico. Pages 187-193

Guzmán-Amaya, P., S.F. Villanueva, and A.V. Botello. 2005. Metales en tres lagunas costeras del estado de Veracruz. Pages 361-372 in A. V. Botello, J. Rendón-von Osten, G. Gold-Bouchot, and C. Agraz-Hernández (eds) Golfo de México Contaminación e Impacto Ambiental: Diagnóstico y Tendencias, second edition. Universidad Autónoma de Campeche, Universidad Nacional Autónoma de México, Instituto Nacional de Ecología, Campeche, Mexico.

Jiménez Lara, P. and X.A. León Estrada. 2010. El patrón de asentamiento y la obsidiana en el Bajo Papaloapan-Veracruz Central, México. *Clío Arqueológica* 25(1): 51-95.

Justeson, J.S. and T. Kaufman. 2008. The epi-olmec tradition at Cerro de las Mesas in the Classic period. Pages 159-194 in P. J. Arnold III and C. A. Pool (eds). *Classic Period Cultural Currents in Southern and Central Veracruz*. Dumbarton Oaks Pub., Washington.

León Estrada, X.A., and N.D. Wilson. 2020. Isla Tenagre y Teotepec. Asentamientos lacustres en la sierra de Los Tuxtlas. In L. Budar and S. Ladrón de Guevara (eds). *Uso y representación del Agua en la Costa del Golfo*. Universidad Veracruzana, Xalapa, Mexico. Pages 187-206

López-Rosas, B. 2018. Comunidad San Juan restaura 112 hectáreas de mangle en laguna de Alvarado. Televisa.news. https://noticieros.televisa.com/ultimas-noticias/comunidad-san-juan-restaura-hectareas-mangle-alvarado/

López Rosas, H., V.E. Espejel González, and P. Moreno-Casasola. 2013. Zacate alemán (*Echinochloa pyramidalis*): planta invasora de humedales costeros del sureste mexicano. *Investigación Ambiental Ciencia y Política Pública* 5(2): 53-63.

Medellín, A. 1960. Monolitos inéditos olmecas. La Palabra y El Hombre 16: 75-97.

Melgarejo Vivanco, J.L. 1950. Toponimia de los Municipios Veracruzanos. EDITIV, Mexico.

Moreno-Casasola, P., J.L. Rojas Galaviz, D. Zárate Lomelí, M.A. Ortiz Pérez, A.L. Lara Domínguez, and T. Saavedra Vázquez. 2016. Diagnóstico de los manglares de Veracruz: distribución, vínculo con los recursos pesqueros y su problemática. *Madera y Bosques* 8: 61-88.

Ortiz, P. 1987. Las investigaciones arqueológicas en Veracruz. *La Palabra y El Hombre* 64: 57-95.

Parsons, J.R. 2005. The aquatic component of Aztec subsistence: hunters, fishers, and collectors in an urbanized society. *Michigan Discussions in Anthropology* 15(1): 49-89.

Peralta-Peláez, L.A., J. Santander-Monsalvo, O.O. Rivera-Garibay, and O. Garelli-Ríos. 2022. Amenaza Plástica: un Problema en las Costas Veracruzanas. Greenpeace México, Tecnológico Nacional de México campus Veracruz, Mexico.

Pool, C. A., T. M. Peres, and M. L. Loughlin. 2023. Settlement and the exploitation of aquatic resources in the Eastern Lower Papaloapan Basin, Veracruz, Mexico. *The Journal of Island and Coastal Archaeology*, 1-19. https://doi.org/10.1080/15564894.2022.2162635

Portilla-Ochoa, E. 2003. Sistema Lagunar Alvarado. Fichas Informativas de los Humedales Ramsar. CONANP, Mexico. https://rsis.ramsar.org/RISapp/files/RISrep/MX1355RIS.pdf

PRONATURA. 2015. Plan de Manejo de las Áreas Privadas de Conservación “Cañón Bajo, Isletas Pataratas, La Flota y Necxtle o Lechería” Municipio de Alvarado, Veracruz. PRONATURA Veracruz A.C., Mexico.

Rodríguez Luna, E., A. Gómez-Pompa, J.C. López Acosta, N. Velázquez Rosas, Y. Aguilar Domínguez, M. Vázquez, and M. Vázquez Torres. 2011. Atlas de los Espacios Naturales Protegidos de Veracruz. Gobierno el Estado de Veracruz, Secretaría de Educación de Veracruz, Universidad Veracruzana, Xalapa, Mexico.

SEFIPLAN [Secretaría de Finanzas y Planeación de Veracruz]. 2022. Alvarado. Gobierno del Estado de Veracruz-Llave, SEFIPLAN, CEIEG, Xalapa, Mexico.

Stark, B.L. 1989. Patarata Pottery: Classic Period Ceramics of the South-central Gulf Coast, Veracruz, Mexico. Anthropological Papers of the University of Arizona no. 51. University of Arizona Press, Tucson, AZ.

Stark, B.L. 2008. Polity and economy in the western lower Papaloapan Basin. In P. J. Arnold III and C. A. Pool (eds). *Classic Period Cultural Currents in Southern and Central Veracruz*. Dumbarton Oaks Pub., Washington. Pages 85-119.

Stark, B. L., and A. Ossa (2005). Los asentamientos urbanos de jardines-huertos en la planicie costera de Veracruz. *Anales de Antropología* 39(1): 39-49.

Sugiura, Y. 2015. Vivir entre volcanes, bosques y agua: los antiguos isleños de Santa Cruz Atizapán. *Anales de Antropología* 49(1): 185-221.

Sugiura, Y. and M. C. Serra Puche. 1983. Notas sobre el modo de subsistencia lacustre, La Laguna de Santa Cruz Atizapán, Estado de México. Anales de Antropología 20: 9-26.

Thiébaut, V. 2013. Paisaje e identidad. el río Papaloapan, elemento funcional y simbólico de los Paisajes del sotavento. *LiminaR. Estudios Sociales y Humanísticos*, 11(2): 82-99.

Thouvenot, M. 2014. Diccionario náhuatl-español. Basado en los diccionarios de Alonso de Molina con el náhuatl normalizado y el español modernizado. Universidad Nacional Autónoma de México, Instituto de Investigaciones Históricas/Fideicomiso Felipe Teixidor y Monserrat Alfau de Teixidor. Mexico.

Turtle Conservation Fund. 2002. A Global Action Plan for Conservation of Tortoises and Freshwater Turtles. Strategy and Funding Prospectus 2002-2007. Conservation International and Chelonian Research Foundation, Washington, DC.

Valadez-Rocha, V. 2013. Evaluación de la vulnerabilidad de las playas ante los efectos no deseados por la construcción de obras de protección costera en la Zona Metropolitana de Veracruz. PhD Thesis. Instituto de Ciencias Marinas y Pesquerías, UV, Boca del Río, Mexico.

VanDerwarker, A.M. 2006. *Farming, Hunting, and Fishing in the Olmec World*. University of Texas Press, Austin.

Vásquez-Lule, A.D., M.T. Rodríguez-Zúñiga, and P. Ramírez-García. 2009. Caracterización del sitio de manglar, Sistema lagunar de Alvarado, Veracruz. In CONABIO (ed). Sitios de Manglar con Relevancia Biológica y con Necesidades de Rehabilitación Ecológica. CONABIO, Mexico. Pages 1-19

Velasco, J. 2003. Tierra y Conflicto Social en los Pueblos del Papaloapan Veracruzano (1521-1917). Universidad Veracruzana, Xalapa, Mexico.

Velasco Toro, J., and G. Ramos Pérez. 2011. Agua: símbolo de vida y muerte en el bajo Papaloapan. In L. A. Monterro (ed) Mariposas en el Agua. Historia y Simbolismo en el Papaloapan. Universidad Veracruzana, Xalapa, Mexico. Pages 21-46.

Williams, E. 2009. The exploitation of aquatic resources at lake Cuitzeo, Michoacán, Mexico: an ethnoarchaeological study. *Latin American Antiquity* 20(4): 607-627.

Williams. E. 2015. El modo de vida lacustre: etnografía de las cuencas lacustres de Michoacán. *Arqueología Iberoamericana* 28: 29-39