REVISTA BIO CIENCIAS
http://revistabiociencias.uan.edu.mx
https://doi.org/10.15741/revbio.12.e1749
ISSN 2007-3380

Artículo original/ Original article

Perception of the ecological and socioeconomic problems of the invader sailfin catfish *Pterygoplichthys* spp. (Siluriformes: Loricariidae) by fishermen in Altamira, Tamaulipas, Mexico

Percepción de la problemática ecológica y socioeconómica del pez diablo invasor *Pterygoplichthys* spp. (Siluriformes: Loricariidae) por pescadores en Altamira, Tamaulipas, México

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Please cite this article as/Como citar este artículo: Balderas Mancilla, U. J., Cipriano Anastasio, J., Azuara Domínguez, A. (2025). Perception of the ecological and socioeconomic problems of the invader sailfin catfish *Pterygoplichthys* spp. (Siluriformes: Loricariidae) by fishermen in Altamira, Tamaulipas, Mexico. *Revista Bio Ciencias*, 12, e1749. https://doi.org/10.15741/revbio.12.e1749

Article Info/Información del artículo
Received/Recibido: October 16th 2024.
Accepted/Aceptado: December 30th 2024.
Available on line/Publicado: March 04th 2025.

ABSTRACT

The invasion of the sailfin catfish has caused serious ecological and socioeconomic problems in diverse global ecosystems. This study evaluates the impact of this invasive species in the Champayán Lagoon System (CHLS), considering ecological and socioeconomic aspects as well as the perception of local fishermen. Semi-structured interviews were conducted to gather information on the socioeconomic conditions and perception of the impact of the sailfin catfish. According to the results, fishermen report a high abundance of sailfin catfish, associated with a notable decrease in the catch of commercial fish. In addition, habitat alterations (water quality and erosion), damage to fishing equipment, and negative effects such as physical injuries and mental stress on fishermen were identified. These findings highlight the urgent need to develop and implement management and control strategies to mitigate the impact of this invasive species in order to improve the quality of life of the inhabitants of the affected fishing communities.

KEY WORDS: Fishermen, ecological impact, invasive species, socio-economic impact, lagoon system.

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RESUMEN

La invasión del pez diablo ha causado serios problemas ecológicos y socioeconómicos en diversos ecosistemas globales. Este estudio evalúa el impacto de esta especie invasora en el Sistema Lagunar Champayán (SLCH), considerando tanto aspectos ecológicos y socioeconómicos como la percepción de los pescadores locales. Se realizaron entrevistas semiestructuradas para recopilar información sobre las condiciones socioeconómicas y la percepción del impacto del pez diablo. De acuerdo con los resultados, los pescadores reportan una alta abundancia del pez diablo, asociada a una notable disminución en la captura de peces comerciales. Además, se identificaron alteraciones en el hábitat (calidad del agua y erosión), daños en los equipos de pesca y efectos negativos como lesiones físicas y estrés mental en los pescadores. Estos hallazgos destacan la urgente necesidad de desarrollar e implementar estrategias de manejo y control para mitigar el impacto de esta especie invasora para mejorar la calidad de vida de en los pobladores de las comunidades pesqueras afectadas.

PALABRAS CLAVE: Pescadores, impacto ecológico, especie invasora, impacto socioeconómico, sistema lagunar.

Introducción

Invasive exotic species represent a serious threat to ecosystems after the habitat degradation, causing significant damage because they contribute to various biological changes in native organisms (Capps & Flecker, 2013; Rubio *et al.,* 2024) affecting negatively in their behavior (Chaichana *et al.,* 2013; Mallick *et al.,* 2024).

Several species of armed catfish from the Neotropical family locariidae, belonging to the genera *Hypostomus* and *Pterygoplichthys*, have become invasive organisms, causing problems worldwide in aquatic ecosystems (Hoover *et al.,* 2004; Dmitry & Yến, 2023) one of them is the fishing activity (Sumanasinghe & Amarasinghe, 2014; Raj *et al.,* 2020; Aida *et al.,* 2022). These organisms have biological characteristics that allow them to have successful survival, such as high fertility rate, early reproduction (Hoover *et al.,* 2004; Gibbs *et al.,* 2008) and high adaptability to environmental variables (Escalera-Vázquez *et al.,* 2019; Elfidasari *et al.,* 2020[a], 2020[b]). In addition, they have physical defeneses that protect them from predation, such as a hard shell covered in spines (Ebenstein *et al.,* 2015).

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To properly manage the water bodies affected by these species, it is crucial to reduce their populations with: 1) control programs during reproductive seasons (Ludlow & Walsh, 1991); 2) increasing their market value (Cagauan, 2007); 3) organizing fishing tournaments (Malpica-Cruz *et al.,* 2016); 4) involving fishermen in monitoring and control (Cen-López & Aguilar-Perera, 2020); 5) taking advantage of the empirical knowledge of fishermen to improve scientific strategies (Sagarin & Pauchard, 2010; Tesfamichael *et al.,* 2014).

This species of sailfin catfish *Pterygoplichthys* spp. was first detected in Mexico in 1995 in the Mezcala River, Guerrero (Guzmán & Barragán, 1997). Since then, this invasive species has spread to various aquatic ecosystems in the country, including Michoacán, Chiapas, Tabasco (Usumacinta River), Morelos (Balsas River), Baja California (Colorado River) and Tamaulipas (Tamesí River and Champayán Lagoon System) (Mendoza *et al.,* 2007; Mejía-Mojica *et al.,* 2014; Amador-del-Ángel *et al.,* 2014; Ruiz-Campos *et al.,* 2014). The presence of the sailfin catfish has generated one of the greatest threats to aquatic biodiversity, negatively affecting native communities and the ecosystems it inhabits (Mendoza *et al.,* 2007), as is the case in the Champayán Lagoon System (CHLS), located in the south of the state of Tamaulipas, since species such as Tilapia and Common Carp, essential for the local economy, have experienced a decreased in the catches due to overexploitation, environmental changes and the invasion of the sailfin catfish (Diario Oficial de la Federación, 2014; SAGARPA, 2012; Singh & Welfare, 2017).

Since the sailfin catfish represents a significant threat to aquatic biodiversity and has contributed to the reduction of catches of economically important species, it is crucial to address these impacts in a comprehensive manner. Furthermore, although the sailfin catfish has no economic value, it is considered an ecological danger, and possible uses for this intrusive species are being explored, such as its incorporation into the production of agricultural inputs and food (Mendoza *et al.,* 2009). This perspective suggests that, despite its adverse effects, controlled management of the sailfin catfish could offer opportunities to mitigate its impacts of ecosystems and benefit local fishers.

Therefore, this study focused on analyzing the ecological and socioeconomic impact of the sailfin catfish in the CHLS. Also, understanding these impacts will allow the development of effective management and conservation strategies that not only control the proliferation of the sailfin catfish but also take advantage of its potential in a sustainable form. The information obtained will contribute to the formulation of the policies and practices that promote the recovery of aquatic biodiversity and strengthen local fishing activities.

Material and Methods

Study Area

The CHLS is a body of water fed by the Guayalejo-Tamesí River, with an area of approximately 213 km^2 and an average depth of 1.5 m. This complex hydraulic network serves as a communication route for fishing populations. Moreover, it is the main source of water for

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domestic and industrial uses in the urban areas of Altamira, Ciudad Madero and Tampico (Figure 1). The system also provides direct benefits such as drinking water supply, aquaculture and fishery production, the latter consisting of aquatic species of economic importance such as the Cinnamon River Shrimp (*Macrobrchium acanthurus*), Bigclaw River Shrimp (*Macrobrachium carcinus*) and Crabs (*Callinectes* spp.) and fish fauna with a predominance of the following native fish species of fishing importance: Rio Grande Cichlid (*Herichthys cyanoguttatus*), Lowland Cichlid (*Herichthys carpintis*), Alligator Gar (*Atractosteus spatula*). Likewise, the existence of the following introduced species: Blue Tilapia (*Oreochromis aureus*), Common Carp (*Cyprinus carpio*), Channel Catfish (*Ictalurus punctatus*) and Florida Bass (*Micropterus salmoides*) (Diario Oficial de la Federación, 2014), however, these species have become a source of income for fishermen (Rodríguez-Castro *et al.,* 2010).

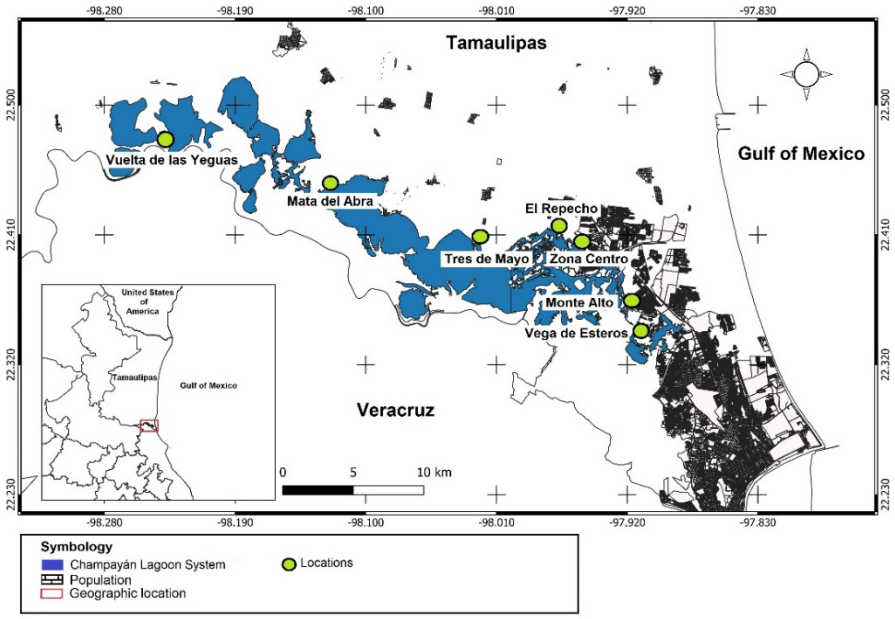

Figure 1. Location of the Champayán Lagoon System (CHLS), Altamira, Tamaulipas.

Source: own elaboration based on Qgis 3.38 Grenoble version

Data collection

Semi-structure interviews were conducted with fishermen, mainly adult men and women, with the purpose of investigating the impact of the sailfin catfish on their livelihoods in fishing and how it has affected their family economy. Before each interview, they were explained that the use of the information would be exclusively for academic purposes, without profit or political purposes.

The interview consisted of 25 open questions organized into four sections: 1. General

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information of the interviewee (sex, age, and socioeconomic level); 2. Experience of the interviewee as a local fisherman, this in order to provide greater participation and an environment of trust; 3. Ecological impacts (on biodiversity and habitat), 4. Socioeconomic impacts. The fishermen's perceptions were synthesized and classified according to the type of impact according to Schoenbeck *et al*. (2023).

To determine the number of interviewees, data was obtained from fishermen registered in the fishing department of the municipality of Altamira. Later, the snowball technique (Bernard, 1996) was used to select key actors, as recommended in previous studies (Albuquerque *et al.,* 2014). This technique allows us to identify individuals who have relevant information on the topic, respecting their cultural and local identity, and establishing a relationship of trust between the researcher and the informants. The inclusion criteria were being of legal age and having more than 10 years of experience as a fisherman.

The sample size was determined using the equation recommended for qualitative sampling (Vivanco, 2005):

(Equation 1)

$$n = \frac{NZ^2_{\alpha/2}\, p}{Nd^2 + Z^2_{\alpha/2}\, p}$$

Where N: Population size (236); Zα/2: 95% reliability (1.96); p=0.5; d=precision (0.1)

The sample size was defined as 68 interviews as shown in the following table (Table 1).

Table 1. Localities and number of interviews conducted in fishing populations located adjacent to the CHLS

Locality	Number of interviews
Vuelta de las Yeguas (VY)	9
Mata del Abra (MB)	7
Tres de Mayo (TM)	8
El Repecho (ER)	9
Zona Centro (ZC)	14
Monte Alto (MA)	5
Vega de Esteros (VE)	16
Total	68

Source: Own elaboration

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Results and Discussion

A total of 68 people were interviewed, aged between 30 and 60 years, all of whom had been living in the area for more than 10 years. Interviews were conducted in six locations: Vega de Esteros (VE), Monte Alto (MA), Zona Centro (ZC), El Repecho (ER), Tres de Mayo (TM) and Mata del Abra (MB), including both men and women. In Vuelta de las Yeguas (VY), all interviewees were women. The majority of interviewees depend entirely on fishing as a full-time livelihood (FT), while a smaller number work part-time (PT) of recreational fishing (RT) (Figure 2).

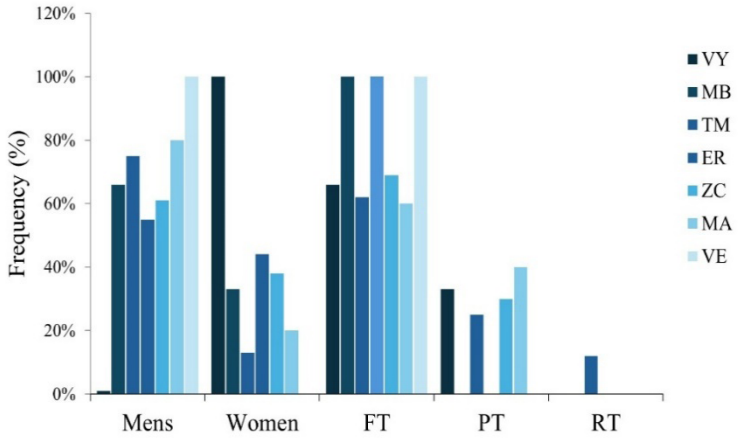

Figure 2. Frequency of some socioeconomic aspects of the fishers of the CHLS. Source: own elaboration based on Microsoft Excel

Overall, fishermen from the seven CHLS sites have been in contact with the sailfin catfish for more than 10 years. However, the problem has increased in the last five years, causing various ecological and socioeconomic impacts according to their perception (Figure 3).

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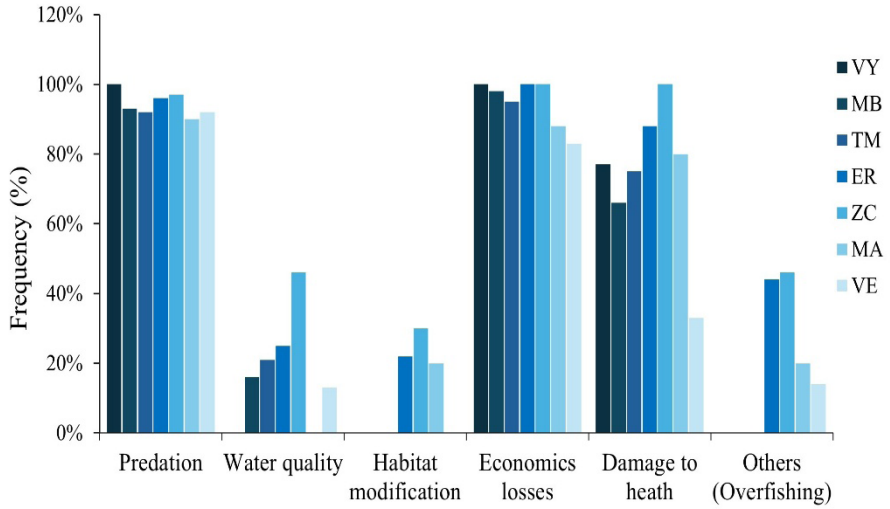

Figure 3. Frequency of ecological and socioeconomic impacts of sailfin catfish perceived by fishers of the CHLS.

According to the interviewees, one of the main perceived ecological problems (Table 2) in the decreasing in the abundance of commercial fish in the area (e.g. Tilapia, Common Carp and the Lowland Cichlid). They also mention that the sailfin catfish displaces these species due to its invasive behavior. Furthermore, they mention the formation of sailfin catfish colonies in certain areas, where native fish are notably absent. Fishermen avoid these places to carry out their activities, which leads them to look for more remote sites in search of the resource. Thus, this study highlights the growing problem of the sailfin catfish in various regions of Mexico, particularly on the Champayán Lagoon System (CHLS) and the Tamesí River in Tamaulipas, where it was first reported in 2014 (Amador del Ángel *et al*., 2014).

Although this species has been present in these places for more than a decade, our results indicate that its impact has increased significantly in the last five years. According to the interviewees, nowadays, more sailfin catfish are caught than other fish of commercial interest, this possibly generation an ecological problem due to its invasive behavior (Chaichana *et al*., 2013; Sumanasinghe & Amarasinghe, 2014; Raj *et al*., 2020; Aida *et al*., 2022; Dmity & Yến, 2023; Mallick *et al*., 2024). Some research has documented the magnitude of the ecological impact of this invasive organism in different regions of Mexico, for example, Mendoza *et al*. (2007) report that the sailfin catfish constitutes between 70 and 80 % of the catch in El Infiernillo dam, Michoacán. Similarly, Wakida-Kusunoki & Amador del Ángel (2011) point out that these fish represent 32.57 % of the total biomass captured in the Palizada River, Campeche. Furthermore, Barba-Macías (2013) describes a significant impact of the fisheries of Tabasco, where the capture of sailfin

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catfish reaches between 60 and 70% of the total catch, likewise, in 2017, Barba-Macías *et al*. (2017) report a dramatic increase in the capture of these fish, from 240 to 500 specimens per fishing day.

This increase in the sailfin catfish population and its dominance in catches not only affects local biodiversity but also poses economic challenges for fishers in the CHLS, who see populations of commercial species decline. Additional studies reinforce this concern, pointing to the need for management and control strategies to mitigate the impact of this invasive species (Chaichana *et al*., 2013; Sumanasinghe & Amarasinghe, 2014; Raj *et al*., 2020; Aida *et al*., 2021; Dmitry & Yến, 2023; Mallick *et al*., 2024). On the other hand, the interviewees mention that the sailfin catfish preys on and ingest native fish of commercial interest (e.g. Tilapia, Common Carp and the Lowland Cichlid), which could be the cause of the population decline of the fisheries in the CHLS; however, the feeding habits of special of the genus *Pterygoplichthys* are based mainly on plants and detritus, ingesting food high in organic matter (Stolbunov *et al*., 2021; Lozada-Gómez & Pérez-Reyes, 2024) and benthic invertebrates, so the ingestion of fish larvae and eggs has only been described incidentally (Stolbunov *et al*., 2021). In another context, only a few interviewees mentioned that the use of illegal nets (trawls) is the main cause of the population reduction of fish of commercial interest, since this capture method presents a low selectivity, since not only the fish or crustaceans that are the target of fishing enter the net, but also many other species that are essential for ecosystem (Gorelli *et al*., 2016; De Juan *et al*., 2020). Some surveillance operations have been carried out by federal authorities in the CHLS, where they have confiscated illegal nets, as well as the application of fines, however, the omission to report complaints by the authorities and the lack of surveillance, cause those who were fined to return to their activities. According to CONAPESCA (2022) and Torres-Alfaro *et al*. (2023) The period 2019-2021, the highest number of reports of illegal fishing was recorded, which is related to the SARS-CoV-2 (Covid-19) pandemic event, since cases of this illicit activity increased in the country, due to the absence of federal authorities, with Tamaulipas being one of the states with the highest rate of reports of illegal fishing in the Gulf region (Torres-Alfaro *et al*., 2023).

One of the behaviors of the sailfin catfish that those interviewed have observed is the high abundance of this organism in sites close to residential areas or places where there are discharges of wastewater or domestic water, which go directly to the CHLS. According to Escalera-Vásquez *et al*. (2019) these discharges of contaminated water promote a greater abundance of the sailfin catfish, since various studies have correlated the high density and survival of the sailfin catfish with poor water quality, due to the fact that they present physiological modifications that allow them to adapt in waters with little dissolved oxygen (Elfidasari *et al*., 2020[a],2020[b]; Aida *et al*., 2022; Putri *et al*., 2024).

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Table 2. Perceived ecological impacts caused by sailfin catfish, reported by fishers from the CHLS

Type of impact	Impact perceived by fishers	Description
Impacts of biodiversity	1.Decline in native species	Predation of eggs and fry of Tilapia *Oreochromis spp*., Common Carp *Cyprinus carpio* and the Lowland Cichild *Herichthys carpintis*
	2. Displacement of native species	The sailfin catfish shows invasive behavior when it moves in schools or “spots” causing the dispersion of other native species to other sites.
	3. Overexploitation of native species	The low fishing productivity of native species is mainly due to overfishing.
Impacts on habitat	4. Changes in water quality	The sailfin catfish causes changes in water quality such as turbidity, erosion and removes bottom sediments
	5.Conglomeration of sailfin catfish near the city	The sailfin catfish concentrates in schools or spots very close to wastewater discharges or areas close to the urban area, otherwise, the abundance of the sailfin catfish decreases in inland waters in CHLS.

Source: Own elaboration

Other aspects that the interviewees have mentioned is the turbidity of the water, since they mention that these organisms congregate in “patches” as they call it, causing modifications in the sediment making it softer, this is because they dig holes to protect themselves and reproduce (Lienart *et al*., 2013). These sites where sailfin catfish congregate, mentioned by the interviewees, are usually individual colonies consisting of a few to perhaps dozens of adult fish burrows, which has contributed to problems such as excess sediment and erosion (Elfidasari *et al*., 2020[b]) and sites with high dissolved nutrient content due to excretions, causing chemical changes in water quality (Capps & Flecker, 2013; Rubio *et al*., 2016).

Currently, it is difficult to estimate the economic losses caused by the capture of the sailfin catfish due to the lack of specific studies that evaluate the quantitative impact on fisheries (Table 3). One of the most common economic losses is damage to fishing nets or gear, since when the sailfin catfish gets caught, it breaks them due to its very rough and rigid fins. Likewise, the fishermen mentioned that before the appearance of the sailfin catfish, a fishing net had a useful

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life of up to six months, however, today, the useful life of this same net is one to two months due to the intense capture of this species, which has affected them economically (Mendoza *et al*., 2007; Barba-Macías, 2013; Barba-Macías *et al*., 2017). Likewise, this problem is related to the mental stress and effort of the fisherman that represents the high abundance of the sailfin catfish, because the fishermen mention that when high densities are captured, it is better to remove it by taking the net to dry land than to remain in the lagoon. The above mentioned represents economic losses since, for them, it is a day of work lost when removing these organisms from the nets. Physical damage is also another problem that fishermen have expressed, due to the fact that the sailfin catfish has strong spines on its pectoral fins and scales or rigid spiny dermal shields, which cause damage and cuts to their hands when removing the fish from the nets, so they must use gloves to avoid injuries that may affect their health.

Currently, this species has no commercial value, only some fishermen use it as bait to catch fish and crustaceans, and others as occasional food. Fishermen are more than willing to learn how to use this organism and to establish opportunities to create collaboration between fishermen and municipal and state authorities to control this fish or try to obtain economic benefits from this species. However, fishermen feel abandoned by government authorities, as they do not have a proposal plan for the use, management or commercialization of this species.

Table 3. Perceived socioeconomic impacts caused by sailfin catfish were reported by fishers in the CHLS

Impact perceived by fishers	Description
Economic losses from fishing	The capture of commercial species has decreased since the overpopulation of the sailfin catfish in the CHLS. As a result, the economic income of fishermen has decreased.
Increased fishing time	The capture of large quantities of sailfin catfish in fishing gear (gill nets or cast nets) implies a loss of time in removing them, which translates into a lost day of work, causing economic losses.
Damage to fishing gear	Fishing gear is damaged by the sailfin catfish's spiny fins, so fishermen have to spend time repairing their nets, and sometimes the nets are completely unusable.
Physical damage to fishermen	The sailfin catfish's spiny fins and armored body cause injuries to fishermen's hands when they try to remove them from fishing nets.
There is no market for sailfin catfish	The capture of numerous sailfin catfish increases fishing effort and reduces commercial fish catches. They mention that since there is no market for sailfin catfish, the sailfin catfish return to the lagoon, that in biological terms these fish return to their life cycle and their overpopulation continues.

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Source: Own elaboration

The little or no knowledge of the life cycle and ecology of this organism has resulted in the invasion of aquatic systems in southern Tamaulipas with a consequent deterioration in the biological processes in the CHLS. This knowledge acquired by fishermen is of utmost importance to carry out future research in relation to the sailfin catfish (e.g. population structure, reproductive season, feeding habits and habitat characteristics), with the purpose of creating alternatives and programs for the control and eradication of this species. Likewise, technical assistance is suggested to guide fishermen and their involvement in this type of programs, since this would benefit the ecosystem and fishing, which is the livelihood of many families and a key factor for food security in the area.

Conclusions

The sailfin catfish or pleco of the genus *Pterygoplichthys* has successfully established itself throughout the CHLS causing a negative impact on the fishing activities of residents who live in the different localities. The impacts perceived by fishermen have been ecological and socioeconomic. It is currently difficult to quantify the degree of impact caused by this invasive organism on native and commercially interesting species, due to the lack of biological, ecological and fishery studies that evaluate the current situation in the CHLS. Fishermen are willing to seek alternatives to give it an economic value, as well as establish collaboration to implement programs to control or eradicate the sailfin catfish, however, the lack of government support hinders the implementation of an effective action plan. Without an adequate strategy that includes the control of this species and community participation, fishing activity in the area faces an uncertain future.

Authors contribution

Conceptualization of the work: B.M.U.J., A.D.A., C.A.J; Field trip, writing and preparation of the manuscript: A.D.A., C.A.J; Editing and review: A.D.A.

Funding

This research was funded with own funds.

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Acknowledgements

We deeply thank all the fishermen from the different localities for the valuable information provided for this study.

Conflict of interest

The authors declare that they have no conflict of interest.

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