Bangladesh J. Zool. ***51****(3): 371-396, 2023*

ISSN: 0304-9027
eISSN: 2408-8455

Review Article

INVASIVE SUCKERMOUTH CATFISHES (SILURIFORMES, LORICARIIDAE) IN BANGLADESH WETLANDS: PRESENT STATUS AND CHALLENGES

Md. Masud Rana, Shakik Mahmud[1], Md Kamrul Siam[2], Hasan Ahmmed Chowdhury[3], Subrata Ranjan Das[4], Mehady Islam[5], Marufa Sultana[6], A.H.M. Shafiullah Habib[7], Eruban Shawdiv Naser[8], Tonima Mustafa[7], Samia Saif[9], Momin Momin[10] and Md. Niamul Naser[11*]

Faculty of Resource Science and Technology, University Malaysia Sarawak, Malaysia and Department of Fishing and Post Harvesting Technology, Sher-e-Bangla Agricultural University, Bangladesh

ABSTRACT: The suckermouth catfish (SMF) is an invasive species in Bangladesh that has had a huge negative impact on ecosystems including rivers, lakes and wetlands. Several SMFs had been introduced as aquarium fish in the early 80's. The first report of this fish in Bangladesh was recorded in 2008; more recently, it has been banned in September 2022 due to its alarming adverse impact on flora and fauna of inland waterbodies. This review explores the complex ecological, economic, and social dynamics triggered by several species of SMFs. The information on SMF's rapid proliferation, adaptability, and destructive capacity on inland waterbodies were underscored, as well as the resulting challenges significant to the indigenous aquatic flora and fauna, habitats, and livelihoods of the wetland-dependent communities. However, the eradication of SMFs from inland waterbodies would be a major challenge. Moreover, a cautious yet prospective plan for either exploitation or eradication, along with inflexible ecological safeguards, are recommended. Technological supports such as environmental DNA (eDNA) techniques, together with the integration of image processing, machine learning, and robotics, may be favorably used in detecting the presence of SMFs. Additionally, identifying habitat, distribution, and hotspot should be considered for needful action. This review highlights a multifaceted narrative of SMF in Bangladesh, emphasizing a complex balance between ecological conservation, economic gains, and technological innovations. Therefore, the illustrated information of SMFs could be helpful to enhance the current knowledges which may lead our nation towards ecological resilience and sustainable harmony against future aquatic invasions. This review suggests advanced action plan and collaboration among different fisheries stakeholders, government authorities and policy makers for eradication or sustainable management of SMFs in inland waterbodies.

Key Words: Invasive suckermouth catfishes, Inland waterbodies, Loricariidae

**Author for correspondence:* <mnnaser@du.ac.bd>*; [1]Japan-Bangladesh Robotics and Advanced Technology Research Center, Bangladesh; [2]Colorado School of Mines, Golden, Colorado, USA; [3]Department of Fisheries (DoF)-JICA-INTEM Fisheries Development Advisors Project, FiLEP, MoFL, Government of the People's Republic of Bangladesh (GoB); [4]ACI Motors Limited, ACI Centre, Tejgaon Industrial Area, Dhaka, Bangladesh; [5]ACI Animal Health, ACI Centre, Tejgaon Industrial Area, Dhaka, Bangladesh; [6]Wildlife Ecology and Management, Faculty of Environment and Natural Resources, University of Freiburg, Germany; [7]Department of Zoology, Jagannath University, Dhaka, Bangladesh; [8]Department of Oceanography, and Hydrography, Bangladesh Maritime University, Dhaka, Bangladesh; [9]Counter Wildlife Trafficking Specialist, Bangladesh; [10]Department of Aquaculture, Faculty of Fisheries, Ataturk University, Türkiye; [11]Department of Zoology, University of Dhaka, Dhaka.*

 DOI: https://doi.org/10.3329/bjz.v51i3.72105

INTRODUCTION

The Sucker mouth catfish was introduced in Bangladesh as aquarium fish in the 80's. Now they become invasive fish of the country by adapting to the natural waterbodies (Figure 1; Hossain *et al.* 2008; Galib 2015; Parvez *et al.*, 2023). The Government of the People's Republic of Bangladesh banned the Suckermouth catfishes in September 2022 through a gazette under Section 18 of the Protection and Conservation of Fish Act, 1950. The ban also emphasized that the import, breeding, culture, handling, transporting, selling, storing, and marketing are all prohibited by law.

Suckermouth catfish (SMF), a remarkable species within the family Loricariidae, are native to the diverse freshwater ecosystems of Central and South America. Characterized by their distinctive armored bodies and specialized mouths, these fish exhibit a fascinating example of evolutionary adaptation (Mori and Nakamura, 2021). Over the years, the international aquarium trade has increasingly exploited the exotic allure of the SMF, catapulting them from the tranquil waters of their native habitats into the global spotlight (Page and Robins, 2006). The journey of the SMF from obscurity to popularity dates back to its mid-20th-century debut in the aquarium trade. Enthusiasts worldwide have been captivated by their unique appearance, along with their pragmatic algae-cleaning abilities (Guillén-Sánchez *et al.*, 2021). Beyond their aesthetic and practical value in aquariums, these catfish contribute significantly to their native aquatic ecosystems. Their feeding habits naturally curtail algae blooms, fostering a balanced, biodiverse environment (Seshagiri *et al.*, 2021).

Figure 1. Suckermouth catfish (*Pterygoplichtys disjunctivus*) collected from the River Buriganga, Dhaka, Bangladesh (Photograph: *T. Mustafa*)

However, a concerning trend lurks beneath the surface of their popularity and ecological contributions. The rapid proliferation of the SMF,

propelled by the aquarium trade, has precipitated their invasive status in numerous ecosystems globally. Fuller *et al.* (1999) underscored the consequences of their unregulated release, revealing the dark underbelly of their proliferation. The resilience and adaptability that once underscored their appeal are now forces of ecological disruption. Despite their role in mitigating algae blooms, the introduction of the SMF into non-native ecosystems has unfurled a tapestry of challenges. Their increasing population, unrestrained by the natural checks and balances of their indigenous habitats, is ringing alarm bells in the corridors of environmental conservation. The catfish's aggressive territorial behavior and voracious appetite are not only tilting the ecological scales but are also triggering a precipitous decline in native fish populations (Hasrianti *et al.*, 2022). Very few reviews on the SMF of Bangladesh were done (Hossain *et al*, 2018 and Sarkar *et al.*, 2023). As we investigate deeper into the complicated ballet between the SMF's ecological contributions and the emerging threats to biodiversity, several questions of understanding are imperative. This study aims to unpack the complex narrative of the SMF, weaving through their current status, challenges for the urgent quest for sustainable management strategies, and eradication aspects of the invasive species in general.

MATERIAL AND METHODS

A detailed literature review was conducted on the subject to identify the problem. The local distribution and spreading history were assessed from scientific reports and news media records. Some preliminary laboratory-based work from the author was included in the documents. Other perspectives, like global and illegal trades, were also included to ensure an exclusive understanding of the issue.

RESULTS AND DISCUSSION

Invasive species and global perspective

According to the IPBES (2023), invasive alien species are one of the primary causes of biodiversity loss worldwide. Moreover, it is found to be the second most common threat following climate change across the natural World Heritage sites (Osipova *et al.*, 2020). More than 3,500 invasive alien species with documented impacts have been reported globally (IPBES, 2023). 25% of the reported impacts were found in Asia Pacific, and one-quarter of the documented negative impacts have been reported from aquatic realms. Over the last few decades, this increase in invasive alien species has become dramatic and is now drastically threatening human health, food security, and livelihoods. It is identified as a threat to the global economy, with an estimated cost of over $423

billion in 2019, which increased fourfold every decade (IPBES, 2023). Universally, invasive aquatic species out-compete the native species (Havel *et al.*, 2015). It causes disruption in the natural food web owing to the alteration in the species-specific interaction, competition, and predation (Thomaz *et al.*, 2015). There is also an indication of the risk of new diseases and parasite transmission from the invasive species to native aquatic fauna (Conn, 2014). The consequences can ultimately negatively affect the provision of food for humans and economic loss in the fisheries sector. It is thus suggested to integrate the following objectives: prevention and preparedness, early detection, eradication, containment and control, ecosystem restoration, public understanding, and engagement, to manage biological invasions within terrestrial and closed water systems or marine and connected water systems (IPBES, 2023).

The Kunming Montreal Global Biodiversity Framework (GBF) has already adopted target 6- "Reduce rates of introduction and establishment of invasive alien species by 50 percent" to reduce/mitigate the impacts of invasive alien species on biodiversity and ecosystem services (CBD, 2022 & 2023). To achieve this target, it is, however, essential to first understand the current patterns of invasive alien species distribution and their consequences at the local scale. Policy interventions are necessary to support decision-makers in advancing management opportunities. Furthermore, it is crucial to promote multidisciplinary collaboration across different countries to address the issues in implementing management actions in alignment with the GBF goals.

Taxonomy and diversity of Suckermouth catfish

Classification and identification of species: The Loricariidae family of order Siluriformes catfishes includes 80 genera and over 680 species of diverse groups of fish (Reis *et al.*, 2003). These catfish are easily identifiable by their distinct armored plates and suckermouths, adaptations that have equipped them to thrive in fast-flowing aquatic environments. Adriaens *et al.* (2009) provided an exhaustive classification, detailing the various species within this family and emphasizing their distinctive dermal plates and intricate jaw structures. Page and Robins (2006) documented three species of suckermouth catfish from *Pterygoplichtys* genera in Southeastern Asia. Hosein *et al.* (2008) first reported the Suckermouth catfish from Bangladesh waters, and it was identified as Orinoco sailfin catfish (*Pterygoplichtys multiradiatus*). Later, Galib (2015) also reported common or spotted pleco (*Hypostoms placostomus*) from the Brahmaputra River system. Hossain *et al.* (2018) again reported Amazon sailfin catfish (*Pterygoplichtys paradalis*) from local waterbodies. Recently, Parvez *et al.* (2023) reported Vermiculated sailfin catfish (*Pterygoplichtys disjunctivus*) from 17 rivers across Bangladesh. Further presence of various suckermouth catfishes

in the water bodies has been reported by Hanif *et al.* (2015), Abdullah Al Mamun *et al.* (2023) and Afrin *et al.* (2023). As most of these are morphologically identified (Figure 2), we suspect there is two to three species in nature. The identification may be misleading due to hybrid or sexual dimorphism or the age of the fish. Genetical tools need to be used to confirm the SMF species complex in Bangladesh.

Examination of Morphological and Physiological Adaptations: The morphological and physiological traits of SMF are intricate and attributed to their survival in diverse ecosystems. These adaptations underscore their resilience, including specialized mouthparts for adhering to surfaces and armored bodies for protection (Adriaens *et al.*, 2009). Their unique jaw structure and dentition are specialized for scraping algae, as shown in Figure 2, and their gill morphology facilitates respiration in hypoxic environments (Adriaens *et al.*, 2009). These physical adaptations make them efficient algae grazers and equip them with the tools to dominate varied habitats, leading to concerns about their invasive potential.

Orinoco sailfin catfish (*Pterygoplichtys multiradiatus*)

Common or spotted pleco (*Hypostoms placostomus*)

Vermiculated sailfin catfish (*Pterygoplichtys disjunctivus*)

Amazon sailfin catfish (*Pterygoplichtys paradalis*

Figure 2. Some common aquarium Suckermouth catfishes (Images from online source)

In summarizing the taxonomy and diversity of the SMF, a deeper dive into the nuances of their classification, geographic distribution, and morphological adaptations are critical. These aspects, though intricate, provide

insights into the species' ecological roles, adaptive strategies, and the accompanying challenges that emerge amidst their proliferative spread across global water bodies.

Distribution of Suckermouth catfish in home and abroad

Geographical distribution and habitat preferences: SMF is indigenous to the freshwater rivers and streams of Central and South America, with a concentration in the Amazon Basin (Lewis, 2003). They exhibit remarkable adaptability and survive in varied environmental conditions – a trait that has facilitated their invasive spread to non-native ecosystems. The catfish's preferences for substrate-laden, fast-flowing waters with abundant algae and organic matter have been well-documented (Mori and Nakamura, 2021). However, their pervasive spread has sparked ecological concerns, prompting investigations into their adaptive capacities and impacts on biodiversity in invaded habitats.

Distribution in Bangladesh waterbodies: The suckermouth catfish was first observed at Gulshan Lake in the mid 80's (pers. Obs. M N Naser) but was not reported. Hossain *et al.* (2008) identified Suckermouth fish as Orinoco sailfin catfish (*Pterygoplichthys multiradiatus*) from Kahalu Upazila of Bogura. Over time, several media reports have shown the presence of SMF in various categories of water bodies found all across Bangladesh. With a specific focus on the type of water bodies and the location of said water body in one of four major regions of Bangladesh (Tables 1-4), a visual has been produced (Figure 3). The regions are Greater Dhaka, which comprises the administrative divisions Dhaka and Mymensingh, i.e., the Central-Northern part of Bangladesh; Greater Chattogram, which combines Chattogram and Sylhet, i.e., the Eastern part of Bangladesh; Greater Rajshahi, combining Rajshahi and Rangpur, i.e., the Northwestern part of Bangladesh; and Greater Khulna, which combines the Southern-Southwestern part of Bangladesh. Moreover, looking at the water body types, it became apparent that SMFs have great adaption capabilities. The water bodies, which include ponds, rivers, lakes, riverlets, haors, beel or open waters, khals or ditches, and paddy fields, each have differences in terms of size and depth, types of water flow, seasonal variations in flow or water volume or sediments influx/efflux, etc. However, as long as they have fresh water in them, SMFs are able to thrive. Fig. 3 also shows that Greater Chattogram has the most varied water bodies for SMF to grow in, then Greater Khulna, then Greater Dhaka, whereas Greater Rajshahi has the least variety in terms of habitat. A detailed overview of all reported sightings of SMF had been conducted and the results have been enlisted in the following tables: Table 1 through 4, each showcasing the districts/areas in which SMF has been sighted along with other

specificities such as time, water body and source, under each of the four greater regions of Bangladesh mentioned earlier.

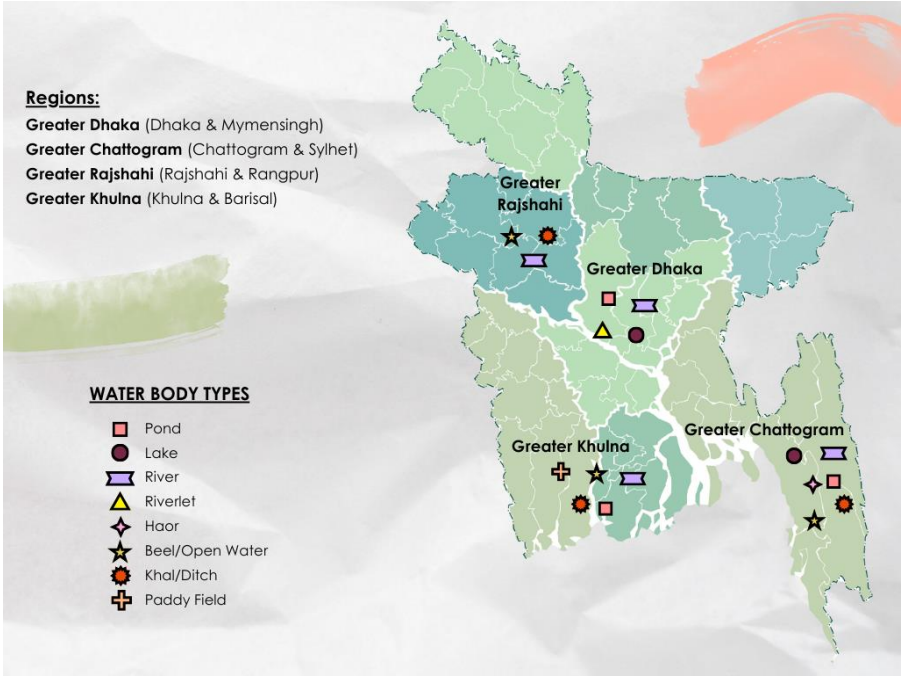

Figure 3. Suckermouth catfish have been reported over the years 2009-2023 in different habitats across Bangladesh (Original map modified; used under CC BY-SA license)

According to the Bangladesh Fisheries Research Institute (BFRI), 22 percent of the country's fish production is in the district of Mymensingh. Suckermouth catfish has been found numerous times in various water bodies of Mymensingh in the last 3 months. It's also been found in Netrakona, Jamalpur, Sherpur, Tangail, Kishoreganj, Jessore, Sylhet, Khulna and Bangladesh Agricultural University (BAU) water reservoirs. It's even been seen in a pond of the Fisheries Research Institute located in Mymensingh. While fishing in a river or a reservoir, many people have seen this 'terrible' fish. Previously, different native species of fish were always available from the river, but now the 'unfamiliar' SMF is being caught in the nets of many fishers. Fisheries researchers fear that native species of fish will be threatened if SMF spreads widely.

The SMF are now often caught in Bakrbir reservoirs. They're seen more in the lake and water bodies adjacent to the Isha Khan Hall. Recently, in Sanchur village of Phulpur upazila of Mymensingh, a SMF weighing more than one kg was caught in the pond of Mohammad Habibur Rahman.

Table 1. Media reports on Suckermouth catfish from Dhaka and Mymensingh division with waterbody types, sources and date of reporting

Dhaka and Mymensingh Division	Water body types	Media Source	Date of reporting
Mymensingh, Gouripur	Ponds	Barta	25 March 2020
Dhaka, Shahbagh	National Museum Pond	BBC	31 March 2021
Dhaka	Buriganga River	Prothom Alo	19 November 2021
Rajbari	Padma, Dauladia, Rajbari	Prothom Alo	24 November 2021
Rajbari, Goalanda	Padma	Jugantor	24 November 2021
Mymensingh	BAU, Ponds	Amader Orthoneeti	26 November 2021
Jamalpur, Dewanganj	Brahmaputra River	Dainik Odhikar	24 December 2021
Narayanganj Sadar	Shitalakshya River	The Daily Star	2 February 2022
Dhaka	Turag River	Deutsche Welle Bengali	6 April 2022
Dhaka	Gulshan Lake	Deutsche Welle Bengali	6 April 2022
Dhaka	Buriganga River	Dhaka Mail	3 August 2022
Mymensingh	Rivers channels, ponds	Dhaka Mail	3 August 2022
Gazipur Sreepur	Shitalakshya	risingbd.com	28 May 2023
Munsiganj	Dhalesear River	Prothom Surjadoy	24 July 2023
Mymensingh	Ishwarganj Ponds	Desh Rupantor	23 October 2023

Upon closer examination of the reporting list, a certain trend was noticed. The reporting rate generally increased from 2009 to 2023, with some minor fluctuations (Table 1 to 4). The highest record of reports occurred in 2022, the second highest in 2021. The rest of the years have a medium to low number of reports. Rashidar Rahman, the owner of a pond in Aushia village of Shailkupa, Jhenaidah, said that a strange fish had come to the pond 3-4 years ago with other fish fries, according to the BFRI. Now he's fed up with the plight brought by this fish. There's no way to exterminate the fish from the pond. It's also seen in abundance in various local canals and rivers. Apart from this, it is known that the fish has spread in ponds and open water bodies in various districts including Naogaon, Pirojpur, Tangail, Natore, Chittagong, Narsingdi, Chuadanga, and Cumilla. Md. Khalilur Rahman, Director of Fisheries Research Institute, regarding the spread of this fish in Bangladesh had said, "I first got the news of getting this fish in Gulshan Lake of the capital." The media coverage since 2009 indicates that the mass distribution occurred after 2020 (Figure 4 & 5). It also shows the spreading time of several decades for the invasion of the exotic species. As stated above, since 2009, the media reporting on the fish were compiled from eight districts of Bangladesh (Fig. 5). Major cities like Chattogram (23.73%), Dhaka (18.64%), Barisal (15.25%) and, to some extent, Khulna

Table 2. Media reports on Suckermouth catfish from Chattogram and Sylhet divisions with waterbody types, sources and date of reporting

Chattogram and Sylhet Division	Water body types	Media Source	Date of reporting
Moulvibazar	Hakaluki Haor	Daily Jugantor	29 September 2017
Sunamganj	Surma River	Bangla Tribune	6 January 2018
Moulvibazar, Sreemangal	Bilas River	Prothom Alo	21 June 2018
Chattogram, Satkania	Sangu River	Suprobhat	21 May 2020
Chattogram, Satkania	Sangu River	Cvoice 24	21 May 2020
Habiganj, Shayestaganj	In a Local Beel	Sylhet Mirror	14 July 2020
Habiganj	Ponds	BBC	31 March 2021
Chattogram, Satkania	Sangu River	Daily Bangladesh	29 July 2021
Rangamati Kaptai	Karnaphuli River	Sonalil News	3 January 2022
Sylhet Bishwanath	Pond	inews.zoombangla	27 March 2022
Chattogram	Halda River	Deutsche Welle Bengali	6 April 2022
Rangamati, Longadu	Kaptai Lake	Ajker Patrika	12 April 2022
Rangamati, Longadu	Kaptai Lake	Cvoice 24	12 April 2022
Chandpur	River	Dhaka Mail	3 August 2022
Brahmanbaria Sarail	Meghna	Jugantor	12 August 2022
Lakshmipur	Meghna River, Khal, Beel, Open water	Amar Sangbad	20 October 2022
Chattogram	Halda River	bdnews24	16 November 2022
Noakhali- Feni	Khal	Cumillar Dhoni	19 December 2022
Feni, Sonagazi	Pond	Cumillar Dhoni,	19 December 2022
Cumilla, Sadar	Pond	Kaler Kantho	24 March 2023

Table 3. Media reports on Suckermouth catfish from Rajshahi and Rangpur division with waterbody types, sources and date of reporting

Rajshahi and Rangpur Division	Water body types	Media Source	Date of reporting
Rajshahi, Durgapur	Beel/ Open water	Amar Rajshahi	27 January 2022
Bogura, Dhunat	Jamuna River	Kaler Kantho	23 April 2022
Lalmonirhat, Hatibandha	Teesta River	Bahannonews	13 May 2022
Lalmonirhat, Hatibandha	Teesta River	Jagonews24	14 May 2022
Bogura, Nandigram	Ditch	Dainik Jamalpur	3 July 2022
Rangpur, Pirgacha	Rivers	Dhaka Mail	3 August 2022
Kurigram	Dharola	bdnews24	5 June 2023

(11.85%) were the most cited areas. This strongly hints at the introduction of invasive fish in nature from these urban areas. Dhaka and Chattogram aquarists and aquarium shops may be the key seed sources for this exotic fish. From the above observation, it can be commented that almost two

decades the species became invasive after introduction to the natural waters of Bangladesh.

Table 4. Media reports on Suckermouth catfish from Khulna *and* Barishal division with waterbody types, sources and date of reporting

Khulna and Barishal Division	Water body types	Media Source	Date of reporting
Jeshore	Pond	Taiyabs Wordpress	18 April 2009
Jhenaidah, Kaliganj	Chitra River	Sylhet Today 24;	15 August 2016
Pirojpur	Baleshwar River	Prothom Alo	11 November 2017
Pirojpur, Mothbaria	Khal	Kaler Kantha	4 June 2018
Chuadanga Sadar	Pond	Jugantor	19 October 2019
Bagerhat, Sharankhola	Paddy field	Kaler Kantha	29 August 2020
Barguna Patharghata	Pond	Patharghata News	2 August 2021
Bhola, Lalmohon	Pond	News 24	15 January 2022
Barguna, Betagi	Bishkhali River	Kaler Kantha	8 February 2022
Pirojpur, Indurkani	Pond	Kaler Kantha	10 April 2022
Satkhira	Rivers, ponds	Dhaka Mail	3 August 2022
Meherpur	Bhairab River, Tegharia Beel, Chand Beel, Tuplar Beel, Pirinir Khal, Ponds	Bhorer Kagoj;	17 September 2022
Pirojpur	Baleshwar River	Daily Hathazarir Sangbad	8 November 2022
Bhola Sadar	Pond	Dhaka Post	31 March 2023
Jhenaidah Shailakupa	Pond	Akkbd;	Not found

Eco-biology and behavior of Suckermouth catfishes

Feeding habits and ecological roles: The SMF epitomizes adaptability and resilience, which are profoundly mirrored in their feeding habits and roles within their ecological niches. Specialized morphological adaptations enable these catfish to effectively graze on algae, a predominant component of their diet (Angulo-Olmos *et al.*, 2023). Their sucker-like mouths, intricate jaw structures, and dentition are precisely evolved to scrape algae from substrate surfaces, roots, and rocks (Adriaens *et al.*, 2009).

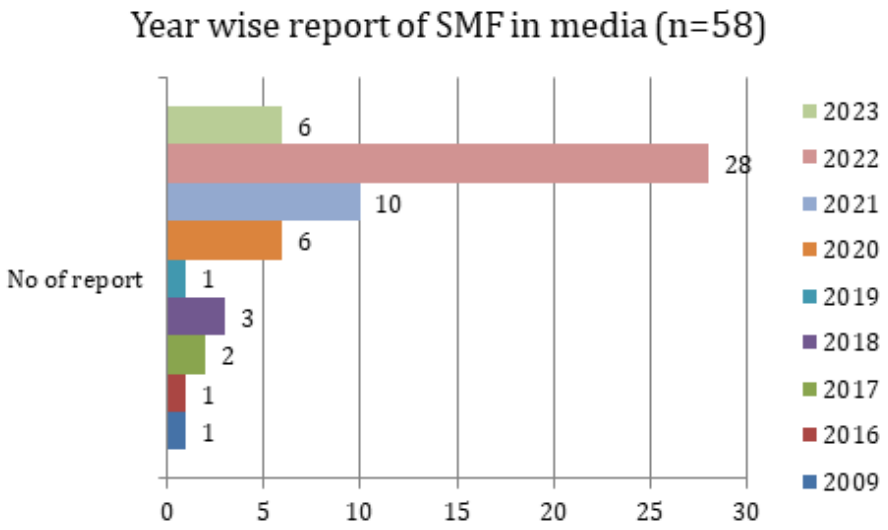

Figure 4. Media reports on Suckermouth catfish in Bangladesh between 2009 to 2023

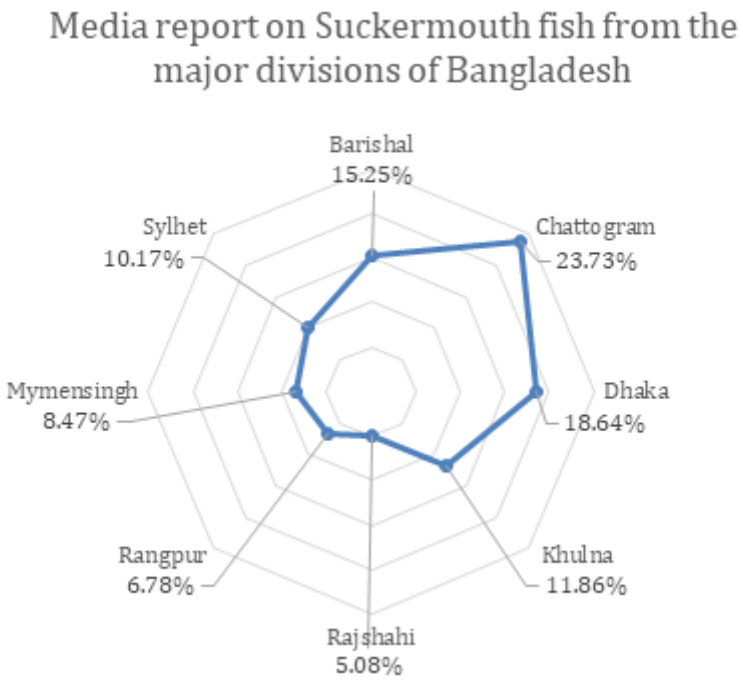

Figure 5. Media reports on Suckermouth catfish from major divisions of Bangladesh during 2009 to 2023

Their feeding behavior transcends mere sustenance; it is an ecological service that significantly influences the structural and functional dynamics of aquatic ecosystems. By consuming algae, SMF contributes to the control of algae blooms, influencing water quality and the distribution and abundance of other aquatic species (Hay *et al.*, 2022). Their role as efficient algivores highlights an intricate balance of promoting biodiversity while potentially unsettling ecosystem equilibrium.

Social behaviors of SMF and interactions within the habitats: SMF weaves intricate patterns through their social behaviors and interactions in the complex tapestry of aquatic ecosystems. They are territorial creatures, often displaying aggressive behaviors to defend their domains, particularly during the breeding season (Woods, 2022). Males are known to guard nesting sites tenaciously, an attribute that reveals a complex behavioral repertoire intertwined with environmental cues and ecological contexts. The catfish's nocturnal nature adds another layer to their behavioral complexity. Their night-time activities minimize predation risks and optimize feeding efficiency, a testament to their adaptive strategies for survival (Lowe-McConnell, 1987).

Impact on native species and ecosystems: While the SMF are esteemed for their algae-grazing abilities (Wu *et al.*, 2011), their introduction into non-native ecosystems has precipitated a series of ecological consequences. In environments where natural predators and competitors are absent, their populations burgeon uncontrollably, leading to significant impacts on native species and ecosystems (Fuller *et al.*, 1999).

Their robust feeding habits, while beneficial in their native habitats, can lead to the overgrazing of aquatic vegetation in invaded ecosystems. This not only diminishes food resources for native species but also alters habitat structures, impacting species that rely on this vegetation for shelter and breeding (Zaret, 1980). Furthermore, the aggressive territorial behaviors of the SMF often result in the displacement of native species, exacerbating the impacts of habitat degradation and fragmentation. The cumulative effects of these interactions cascade through the ecosystem, altering biodiversity, community structure, and ecological processes (Pérez-Flores, 2020).

Aquarium trade and invasiveness: The global aquarium trade has been a conduit for the widespread distribution of the SMF, a species known for its distinct morphology and ecological roles. The allure of these fish in the aquarium trade is significantly influenced by their striking appearance and algae-cleaning abilities (Matamoros *et al.*, 2016). Enthusiasts value them for their capacity to thrive in varied environmental conditions, a trait that emphasizes their adaptability but also foreshadows their potential invasiveness.

Their presence in non-native ecosystems stems from the aquarium trade, wherein the intentional and accidental releases of these species into the wild have escalated. The adaptability of SMF becomes a double-edged sword when evaluated against the backdrop of ecological conservation. In habitats beyond their native range, these fish demonstrate an alarming resilience, characterized by rapid population growth and territorial expansion (Fuller *et al.*, 1999).

A closer look at established populations in regions such as Florida and Southeast Asia unveils a narrative of ecological disturbance and adaptation. In Florida, SMF has transformed local ecosystems, and a lack of natural predators and favorable environmental conditions facilitates their proliferation. Similarly, in Southeast Asian water bodies, the catfish exhibit robust adaptability, altering ecological dynamics and biodiversity (Sarkar *et al.*, 2023).

Reproduction and life-cycle: The reproductive ecology of the SMF is as intricate as its behavioral repertoire. Males are renowned for their territoriality, especially during breeding seasons, when they guard nesting sites with unwavering tenacity (Secutti and Trajano, 2009). Their reproductive strategies are finely tuned to environmental cues, and breeding behaviors are often synchronized with seasonal changes, ensuring the survival and growth of offspring. These stages reflect an evolutionary adaptation designed to optimize survival in dynamic aquatic environments. Environmental factors, including water temperature, flow, and availability of food resources, play a pivotal role in shaping the catfish's life cycle and influencing reproductive success.

The intertwined narratives of the SMF in the aquarium trade, their invasiveness in non-native ecosystems, and the nuances of their reproductive ecology present a complex tableau. Each facet, from their allure in aquariums to their adaptability and reproductive strategies, is a piece of a larger puzzle. Unraveling this complexity is pivotal for balancing the conservation and management of these enigmatic creatures, ensuring that their ecological roles are maintained without compromising the integrity of the ecosystems they inhabit.

Threats posed by the Suckermouth catfish in Bangladesh

Impact on aquatic ecosystem and habitat: The suckermouth catfish (SMF) invasion in Bangladesh's waterbodies represents an ecological crisis underlined by disrupted biogeochemical cycles and compromised ecosystem functionality (Rubio *et al.*, 2016). The catfish's rapid proliferation drives a narrative of ecological disarray, marked by premature shifts in nutrient dynamics and diminished nutrient availability for primary consumers (Werner, 1982).

In the intricate ecosystems of Bangladesh, these catfish have become notorious for their destructive tendencies. They are equipped with thick bony

plates, acting as phosphorus sinks and leading to reduced primary and secondary productivity in oligotrophic environments (Englund, 2000). The excavation behaviors of SMF have adverse impacts; they uproot aquatic plants and create surface covers, reducing sunlight penetration into water bodies and impacting photosynthesis (Hubilla *et al.*, 2007).

The rapid maturation and population density of SMF allow domination over other aquatic life forms (Englund, 2000). Their presence in Bangladesh's water bodies is marked by physical disturbances and reduced food availability due to excessive grazing on algae and detritus (Hoover *et al.*, 2014). Furthermore, their burrowing behaviors, notably along river banks, have resulted in erosion, altered benthic habitats, and increased siltation, threatening the structural integrity of aquatic ecosystems (Nico, 2000).

The inherent aggressiveness and competitive nature of SMF have profound implications for native species. In Bangladesh, a country marked by its rich aquatic biodiversity, the introduction of SMF has been linked to the displacement of native species and the endangerment of keystone predator populations (Hoover, 2004). Their competitive advantage over smaller, short-lived, and less tolerant fish species raises alarms about declining biodiversity and disrupted ecological balance (Hubbs *et al.*, 1978).

The defensive spine-erection of SMF also threatens shorebirds, impacting the broader ecological network (Bunkley-Williams *et al.*, 1994). The fishing industry, a vital component of Bangladesh's economy and food security, is not immune to the invasive catfish. The presence of SMF leads to unintentional entanglement in commercial gillnets, affecting the capture of target fish species and livelihoods (Wijesinghe *et al.*, 2021).

As SMF continues to establish and expand its populations, the existence of native and small indigenous species (SIS) of fish in Bangladesh is threatened, and the sustainability of fish production hangs in the balance. With sixty-four freshwater fishes already under threat in the country (IUCN, 2015), the invasive effects of SMF exacerbate the vulnerability of these species and their habitats.

In the face of this impending ecological crisis, urgent and comprehensive management measures are paramount. The intersecting threads of ecological, economic, and social impacts necessitate a multifaceted approach to mitigate the destructive influence of SMF in Bangladesh's aquatic ecosystems. The preservation of biodiversity, recovery of impacted habitats, and safeguarding of livelihoods dependent on these ecosystems emerge as pressing imperatives in the wake of the SMF invasion.

Value products from Suckermouth fish and consumption perspectives

The proliferation of suckermouth catfish (SMF) has undoubtedly cast a shadow over Bangladesh's aquatic ecosystems, spawning environmental,

economic, and biodiversity concerns. However, in an environment where challenges and opportunities coexist, the prospect of utilizing SMF to balance some economic losses is worth exploring.

Fillet and animal feed: The SMF fillet and product like animal feed can be a alternative use of the fish (Figure 6). Precaution should be taken to utilize the fish from good water sources, as they are also found from highly polluted waterbodies in Bangladesh.

Skin leather: Skin from larger sized fish can be used to produce leather (Federico *et al.*, 2020). That could be further used for making various expensive things such as pencil boxes, ornament boxes, handbags, purses, and even shoes.

Some largest Suckermouth catfishes collected from the river Buriganga, Bangladesh

Fish processed for animal feed processing

Dry fish meat processed for animal feed

Suckermouth catfish fish fillet

Figure 6. Fish fillet and animal feed from Suckermouth catfishes (Photograph: M. M. Rana)

Nutritional contents: Despite their invasive nature, SMFs possess nutritional values compared to many other common freshwater fish (Table 5). They boast a protein content that is competitive with catfish and eel, albeit varying based on species, body size, and environmental conditions (Badal and Mihir, 2015). Such protein richness presents an opportunity for consumption or animal feed production, besides being heavily regulated to avoid promoting their propagation. In addition, the health risk of heavy metal accumulation from polluted water fish sources must be considered before preparing fish meal for human consumption.

Table 5. Proximate contents of two size groups of Suckermouth Catfish (*Pterygoplichthys pardalis* (Hasrianti *et al.*, 2022)

	Suckermouth Catfish (*Pterygoplichthys pardalis)*	
Parameter	**Fishes smaller than 22 cm**	**Fishes larger than 40 cm**
Arsenic (As)	0.09	0.21
Crude Protein (%)	14.58	14.52
Total Fat (%)	0.52	0.49
Water content (%)	82.83	83.87
Ash value (%)	1.0	0.91

Environmental management: Beyond nutrition, SMFs can play a role in environmental management, particularly wastewater biotreatment. Their proven efficacy in reducing total dissolved solids, biochemical oxygen demand, and other pollutants from industrial effluents suggests a potential utility in this sphere (Karthiga *et al.*, 2019). However, extreme caution and rigorous monitoring are essential to mitigate unintended ecological repercussions.

Heavy metal content: While the protein content is a boon, the heavy metal content in SMFs necessitates caution (Table 6). Though generally within safe thresholds, continuous consumption of SMFs can potentially impact human health due to the bioaccumulation of heavy metals (Orfinger and Goodding, 2018). Hence, thorough research and stringent guidelines are imperative to safeguard public health.

Table 6. Heavy metal contents of meat and scales of Suckermouth catfish (*Pterygoplichthys pardalis* (Hasrianti et al. 2022)

Elements	**Fish meat (µg/g)**	**Fish armour/fins (µg/g)**
Arsenic (As)	0.01	0.01
Cadmium (Cd)	<0.01	<0.01
Mercury (Hg)	<0.0005	<0.0005
Lead (Pb)	<0.01	<0.01

As Bangladesh grapples with the SMF invasion, a multifaceted approach integrating control, management, and utilization can offer a holistic solution. While exploitation for nutritional and environmental management purposes is plausible, it should be approached with stringent regulations, comprehensive

research, and an unwavering commitment to ecological preservation. Balancing the need for economic relief and environmental integrity will be the cornerstone of this utilization strategy.

Policy adoption and community engagement for invasive fish control

The recent ongoing debate on the invasion of Suckermouth catfish (SMF) in aquatic ecosystems of Bangladesh evolved an urgent necessity for a Policy and regulatory framework addressing the impacts of SMF on native species, aquatic ecosystems, and the intricate balance of biodiversity. These issues urge for multi-dimensional interventions emphasizing ecological conservation, technological innovations, and exploring the opportunity for economic benefits. The SMF's quick adaptability in open inland water habitat, their rapid distributions, proliferations, abundance in nature, and invasiveness indicate significant threat to the biodiversity and aquatic habitat. So, it has become a time-bound case and demands urgent dialogues to develop well-defined policy and regulatory measures on SMF's management, control, and utilizations.

The government has already prohibited SMF by amending the Rules on 15 January 2023, adding a clause to section 18*(2)* in "Protection and Conservation of Fish Rules, 1985, under the jurisdiction of delegated power by the Protection and Conservation of Fish Act, 1950 (Act No. XVIII of 1950), Sectio-3 where stated: "*No person shall import, breed, culture, carry, sell, receive or take, market, stock, expose and (possess of any species of fish of 'Suckermouth catfish' group."* Now, it is important to decide on policy, plan, and program for implementation of this regulation under relevant well explained rules, directives, and Terms of References (ToR) for the regulatory bodies, implementing actors/partners and beneficiaries where a balanced approach should work out to strictly control the entering/imposing, dissemination, and proliferation of new SMF from imported/native sources. The existing SMF stocks could not completely withdraw from nature (whether it is harmful or beneficial). However, a stringent policy, management strategy, and National Action Plan must be developed how to prevent/reduce the spread of stocks from different natural habitat to protect aquatic ecosystems and biodiversity. Furthermore, it is also necessary to observe and control any genetic pollution that occurs by SMF with native similar species.

There are important necessities for policy decisions and required investment to engage more study and research on the life cycle and distribution of SMF in Bangladesh's environment/natural habitat, dispersion pattern, food & feeding habit; predation pattern & efficiency, impacts in the food chain; sources & routes of contamination (spread over) from one habitat to another, SMF's breeding biology & genetics, proximal compositions including

pollutant/contaminants residues at different selected habitats. As a consequence of the research results of this study, the outcomes of those mentioned earlier fundamental/action research and activities will generate information to facilitate the identification of causative factors behind the rapid invasiveness of SMF. Based on that, developing a management action plan with defined prevention and control measures for their gradual eradication from the closed and open water ecosystem of Bangladesh and a transformation toward environment resilient, productive, economic, and sustainable approaches may be expected. Besides, the potential utilization of SMFs as pollutant removal agents in nature, as sources of nutrients to be used in food/feed ingredients (both for human & non-human uses), product/byproduct development, and other relevant studies necessitating innovative and immediate actions to identify SMF as a potential avenue for economic alleviation and livelihood enhancement options for fisheries.

The government may initiate immediate policy decision to develop a National Action Plan (NAPA) and Road Map (RM) to identify SMF distributions, management, control, and utilization. Strong collaboration and coordination between the concerned agencies/ministries (especially, MoFL. MoFECC, MoHome, MoCommerce, MoPA, MoShipping, MoICT, MoSTC), active engagement of research/academic institutions and relevant stakeholders are the pre-requisite conditions for developing and effective implementation of such NoPA & RM. First, a multi-disciplinary National Expert Working Group (EWG) on SMF could be formed to develop NoPA/RM as an utmost necessity to outline the policy, plan & program framework. A Scientific Advisory Group on SMF should be formed consisting of academia, researchers, and limited concerned representatives from policy and implementation groups to identify research needs, conduct reviews, surveys, research/studies, organize dialogues on specific issues, and deliver time to time reports, publications and advise the National EWG for policy decision making via suggested agendas. International collaboration for exploring technical assistance in education, research, and innovation is also of prime importance to precede the actions related to the topics.

Based on the identified beneficial utilization of SMF, public-private partnership, employment generation, and SME/large-scale industrial investment could be encouraged at a limited level, observing the sustainability of the proposed utilization along with strict regulatory monitoring and control on the process safeguarding economic, environmental, and social aspects. For withdrawal/collection of the SMF as a harmful agent from nature, stocking genetically sterile (Gynogenetic or triploid progeny) new stocks in nature can be attempted to observe their performances in hybridization with fertile SMF

stocks. Provisions of attractive incentives for the fisherman might be considered effective tools to encourage them to catch SMF from natural habitats and sell them in preferred collection centers supervised by local extension workers. Collected SMF could be linked to the industry for beneficial utilization (if any) following the other fisheries value chain modalities. For each case, skilled human resources are the driving factors for managing, controlling, and utilizing the SMF value chain. Policy level and institutional support and the required investment are also necessary for research, education, and capacity building of the actors/ beneficiaries at each step for successfully dealing with SMF issues. The use of modern technologies (IoT, GIS, GPS) and advanced technological interventions, as suggested in earlier chapters, requires government policy support to access the existing facilities in the public/private sector and intervene in new systems for research, study, and innovations.

Lack of importation-control encourage illegal trades: The illegal trafficking in protected species of wild flora and fauna and biological resources, are profitable areas for organized criminal groups (WLFC, 2013). The lack of control over the identification of imported or exported exotic animals opens up other avenues of trade. The emergence of financial uplift usually encourages the exotic animal trade in many countries. This could lead Bangladesh as the route for the illegal trading of wild animals in or from neighboring countries. Regional cooperation and surveillance by trained officials from a zoological background could help to identify the species and prevent this issue.

Internet of Things (IOT) technological intervention to mitigate the impact

The proliferation of suckermouth catfish (SMF) in Bangladesh has necessitated innovative and technology-driven solutions to mitigate their adverse impacts on aquatic ecosystems. Combining traditional measures with modern technological interventions can amplify the effectiveness of efforts to control and possibly eradicate the threat of this invasive species (Gao *et al.*, 2021).

Integration of technology: Implementing cutting-edge technologies like Image Processing, the Internet of Things (IoT), Machine Learning, and Robotics can enhance the precision, speed, and efficiency of identifying and eradicating SMF. These technologies can facilitate real-time catfish population monitoring, identification, and management (Ishikawa and Fukuda, 2022).

Identification and monitoring: Image processing and machine learning can be pivotal in identifying and monitoring SMF populations. Algorithms can be developed to analyze underwater images and videos to identify SMFs, assess their population size, and monitor their movement and behavior in real-time. Utilizing IoT, continuous data can be relayed to central monitoring stations for

analysis, enabling swift decision-making and action (Usha and Mahesh, 2022; Siam *et al.*, 2023).

Environmental DNA technology (eDNA): Environmental DNA (eDNA) is a protocol used for rapid, cost-effective, and standardized data collection on any species in the environment. Identification of SWF species using eDNA can help in providing information about the status, distribution, and habitat requirements of the species. In aquatic environments, eDNA is diluted and distributed by currents, and other hydrological processes only last about 7–21 days, depending on environmental conditions (Darling and Mahon, 2011; Dejean *et al.*, 2011, 2012). eDNA may also be an effective tool for early detection of aquatic invasive species in a wetland. The application of eDNA methods may also be used for monitoring invasive species and may provide a means of confirming the eradication of all invaders.

Robotics and automated eradication: Underwater robots equipped with machine learning algorithms can be deployed to identify and eradicate SMF efficiently. These robots can be designed to navigate aquatic environments, identify SMFs with high precision, and eradicate them, ensuring minimal impact on other aquatic species and the ecosystem (Han *et al.*, 2020).

Geographic information systems: GIS technology can aid in mapping out invaded areas and assessing the level of risk and susceptibility. Combining GIS with machine learning can facilitate predictive modeling to foresee the potential spread and impacts of SMF, allowing for pre-emptive actions.

Incentive mechanisms: An incentive mechanism can be effective, leveraging a reward system for fishermen who catch and ethically destroy invasive species. Additionally, exploring the economic utilization of SMFs, like converting them into value-added products or by-products, can turn a challenge into an opportunity and ensure economic and ecological benefits.

A synergistic approach, intertwining technology, policy, and community engagement, is paramount to address the SMF invasion in Bangladesh. The government's restrictions on the import and sale of SMF (MoFL, 2023) should be rigorously enforced, coupled with public awareness campaigns by institutes and universities like Department of Fisheries, GoB, Bangladesh Fisheries Research Institute, University of Dhaka, Jahangirnagar University, Jagannath University, Bangladesh Agricultural University, Sher-e-Bangla Agricultural University, Sylhet Agricultural University, Bangladesh Maritime University, etc,. Community-based teams can be empowered with technology to monitor, report, and address SMF invasions. The integration of image processing, IoT, machine learning, and robotics can amplify the effectiveness, precision, and speed of eradication efforts, safeguarding the aquatic biodiversity and ecosystems of

Bangladesh. These technological interventions, supported by robust policies and community participation, can weave a comprehensive strategy to mitigate the impacts of SMF and restore ecological balance.

CONCLUSIONS

The invasion of suckermouth catfish (SMF) in Bangladesh's aquatic ecosystems has prompted an urgent need for multifaceted interventions. This research has unveiled the ecological and economic impacts of SMF, illuminating a path fraught with challenges but not devoid of opportunities. Their adaptability and invasiveness threaten biodiversity and habitat quality, necessitating innovative and immediate actions. Utilization of SMFs, while controversial, emerges as a potential avenue for economic alleviation. Strict regulations and a balanced approach are crucial to exploit their nutritional and environmental management capabilities without exacerbating the invasion. Technology, particularly the integration of image processing, IoT, machine learning, and robotics, is identified as a pivotal ally in this battle, offering precision and efficiency in both containment and exploitation strategies. In conclusion, the SMF invasion in Bangladesh is a call to action that demands an intricate balance between control and utilization, immediate actions, and long-term sustainability. The resolution lies in a harmonious blend of technology, policy, and community engagement, illuminating a path defined by innovation, collaboration, and ecological guardianship.

Acknowledgements: The writing of this review was originated after a media- talk show organized by the ACI motors. The speakers Dr Md. Niamul Naser and Md. Masud Rana are the initiator of theme of the review writing. The other authors are collectively contributed on the different aspects on the script. The talk show is available at,
https://www.facebook.com/share/r/gXTsVL4a5LR2Y7W4/?mibextid=lRVMka

LITERATURE CITED

ABDULLAH AL MAMUN, S., HOSSAIN, M.S. and CAPPS, K.A. 2023. Promoting community-based surveillance of economically important invasive species in lower-income economies: a case study of the suckermouth catfish (*Pterygoplichthys pardalis*) in Bangladesh. *Biol Invasions* **25**, 1285–1290 (2023). https://doi.org/10.1007/s10530-022-02993-2

ADRIAENS, D., GEERINCKX, T., VLASSENBROECK, J., VAN HOOREBEKE, L., and HERREL, A. 2009. Extensive Jaw Mobility in Suckermouth Armored Catfishes (Loricariidae): A Morphological and Kinematic Analysis of Substrate Scraping Mode of Feeding. Physiological and Biochemical Zoology, **82**(1), 51-62. https://doi.org/10.1086/594378

AFRIN, R., RAKHI, R.F., SULTANA, A., SHAHARIAR, M.A., HOSSAIN, M.S., ALAM, M.S. and ALAM, M.S., 2023. Domestication and Inter-Species Interaction of Bangladeshi Native and Exotic Ornamental Fishes in the Captive Condition. **27**(1): 349- 367. DOI: 10.21608/EJABF.2023.287414

ANGULO-OLMOS, G., ÁLVAREZ-PLIEGO, N., SÁNCHEZ, A.J., FLORIDO, R., SALCEDO, M.Á., GARRIDO-MORA, A. and CRUZ-RÁMIREZ, A.K. 2023. Microfibers in the gut of invasive armored catfish (Pterygoplichthys spp.) (Actinopterygii: Siluriformes: Loricariidae) in an urban lake in the floodplain of the Grijalva River basin, Mexico. Acta Ichthyologica et Piscatoria **53**, 81–88. https://doi.org/10.3897/aiep.53.102643

BADAL D and MIHIR D. 2015. Fat content of an Indian Major Carp, *Catla catla*, in relation to age and size for optimizing harvesting period. International Journal of Fisheries and Aquatic Studies 2015; **2**(6): 386-390.

BUNKLEY-WILLIAMS, L., WILLIAMS JR, E.H., LILYSTROM, C.G., CORUJO-FLORES, I.., ZERBI, A.J., ALIAUME, C., and CHURCHILL, T.N. 1994. The South American sailfin armored catfish, *Liposarcus multiradiatus* (Hancock), a new exotic established in Puerto Rican fresh waters. Caribbean Journal of Science **30**:90–94.

CBD. 2022. CONFERENCE OF THE PARTIES TO THE CONVENTION ON BIOLOGICAL DIVERSITY Fifteenth meeting – Part II Montreal, Canada, 7-19 December 2022 Agenda item 9A. https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf

CBD. 2023. Convention on Biological Diversity. *The Kunming-Montreal Global Biodiversity Framework (GBF).* https://www.cbd.int/gbf/targets/6/

CONN, D.B., 2014. Aquatic invasive species and emerging infectious disease threats: A One Health perspective. *Aquatic Invasions*, ***9***(3): 383- 390. doi: http://dx.doi.org/10.3391/ai.2014.9.3.12

DARLING, J.A., and MAHON, A.R., 2011, From molecules to management—Adopting DNA-based methods for monitoring biological invasions in aquatic environments. Environmental Research, **111**(7): 978–988, doi:10.1016/j.envres.2011.02.001.

DEJEAN, T., VALENTINI, A., DUPARC, A., PELLIER-CUIT, S., POMPANON, F., TABERLET, P., and MIAUD, C., 2011, Persistence of environmental DNA in freshwater ecosystems: PLoS ONE, v. **6**, no. 8, e23398, doi:10.1371/journal. pone,0023398.

DEJEAN, T., VALENTINI, A., MIQUEL, C., TABERLET, P., BELLEMAIN, E. and MIAUD, C., 2012, Improved detection of an alien invasive species through environmental DNA barcoding—The example of the American bullfrog *Lithobates catesbeianus*: Journal of Applied Ecology, v. **49**, iss. 4, p. 953–959, doi: 10.1111/j.1365-2664.2012.02171.x.

ENGLUND, R.A. 2000. Nonindigenous freshwater and estuarine species introductions and their potential to affect sportfishing in the lower stream and estuarine regions of the south and west shores of Oahu, Hawaii. Final Report. Bishop Museum Technical Report No. 17, Honolulu, Hawaii.

FEDERICO, E., VERENDIA, A.D., VIDAL, R.J. and GARCIA, E. 2020. Potentials of Invasive *Pterygoplichtys disjunctivus* (Janitor Fish) Rind as Fish Skin Leather. LPU-Laguna Journal of Arts and Sciences, **3**(3): 67- 73.

FULLER, P.L., NICO, L.G., and WILLIAMS, J.D. 1999. Nonindigenous Fishes Introduced into Inland Waters of the United States. A*merican Fisheries Society, Special Publication 27.*

GALIB, S.M. 2015. Fish fauna of the Brahmaputra River, Bangladesh: richness, threats and conservation needs. *Journal of Fisheries*, **3**(3), 285-292. https://doi.org/10.17017/j.fish.46

GAO, M., BAI, Y., LI, Z., LI, S., ZHANG, B., and CHANG, Q. 2021. Real-Time Jellyfish Classification and Detection Based on Improved YOLOv3 Algorithm. *Sensors (Basel, Switzerland), **21***.

GUILLÉN-SÁNCHEZ, E.J., PACHECO-AGUILAR, R., SCHEUREN-ACEVEDO, S.M., CARVALLO-RUIZ, M.G., NAVARRO-GARCÍA, G., and RAMÍREZ-SUÁREZ, J.C. 2021. Shelf-life of loricariid catfish (*Pterygoplichthys disjunctivus* (Weber, 1991) roe stored in ice. *Food Science and Technology International,* **41,** 311-318.

HAN, F.L., YAO, J., ZHU, H.T., and WANG, C. 2020. Underwater Image Processing and Object Detection Based on Deep CNN Method. *J. Sensors, **2020***, 6707328:1-6707328:20.

HANIF, M.A., SIDDIK, M.A.B., CHAKLADER, M.R., NAHAR, A., and MAHMUD, S. 2015. Fish diversity in the southern coastal waters of Bangladesh: present status, threats and conservation perspectives. Croatian Journal of Fisheries, **73**, 148-161. DOI: 10.14798/73.4.84

HASRIANTI, SURIANTI, PUTRI, A.R., DAMIS, RAJAB, R.A., and AKBAR, A.H. 2021. The Effect of Suckermouth Catfish (*Pterygoplichthys* sp.) Population Explosions on the Effectiveness of Fishing and the Sustainability Status of Sidenreng Lake Waters. *Proceedings of the 3rd KOBI Congress, International and National Conferences (KOBICINC 2020).*

HASRIANTI, H., ARMAYANI, M., SURIANTI, S., PUTRI, A.R.S., and AKBAR, A.H. 2022. Analysis of nutritional content and heavy metals of suckermouth catfish (*Pterygoplichthys pardalis*) in Lake Sidenreng, South Sulawesi, Indonesia. Biodiversitas, **23**(7). https://doi.org/10.13057/biodiv/d230729

HAVEL, J.E., KOVALENKO, K.E., THOMAZ, S.M., AMALFITANO, S., and KATS, L.B. 2015. Aquatic invasive species: challenges for the future. Hydrobiologia **750**, 147–170. https://doi.org/10.1007/s10750-014-2166-0

HAY, A.A., RIGGINS, C.L., HEARD, T.C., GAROUTTE, C., RODRIGUEZ, Y., FILLIPONE, F., SMITH, K.K., MENCHACA, N., WILLIAMSON, J., and PERKIN, J.S. 2022. Movement and mortality of invasive suckermouth armored catfish during a spearfishing control experiment. *Biological Invasions, **24***, 3119 - 3131.

HOOVER, J.J. 2004. Suckermouth catfishes: threats to aquatic ecosystems of the United States? Aquatic Nuisance Species Research Program Bulletin **4**(1):1–13.

HOOVER, J.J., MURPHY, C.E., and KILLGORE, K.J. 2014. Ecological impacts of suckermouth catfishes (Loricariidae) in North America: A conceptual model. Aquatic Nuisance Species Research Program Bulletin **14**(1):1–20

HOSSAIN, M.Y., RAHMAN, M.M., AHMED, Z.F., OHTOMI, J., and ISLAM, A.B.M.S. 2008. First record of the South American sailfin catfish *Pterygoplichthys multiradiatus* in Bangladesh. Journal of Applied Ichthyology, **24**:718–720. DOI:10.1111/j.1439-0426.2008.01117.x

HOSSAIN M.Y, VADAS R, RUIZ-CARUS R, and GALIB S.M. 2018 Amazon sailfin catfish *Pterygoplichthys pardalis* (Loricariidae) in Bangladesh: a critical review of its invasive threat to native and endemic aquatic species. Fishes **3**:14. doi.org/10.3390/fishes3010014

HUBBS, C., LUCIER, T., GARRETT, G.P., EDWARDS, R.J., DEAN, S.M., MARSH, E., and BELK, D. 1978. Survival and abundance of introduced fishes near San Antonio, Texas. Texas Journal of Science **39**:369–376.

HUBILLA, M., KIS, F., and PRIMAVERA, J. 2007. Janitor fish *Pterygoplichthys disjunctivus* in the Agusan marsh: a threat to freshwater biodiversity. Journal of Environmental Science and Management **10**(1):10–23. http://hdl.handle.net/10862/3519

IPBES. 2023. Summary for Policymakers of the Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Roy, H. E., Pauchard, A., Stoett, P., Renard Truong, T., Bacher, S., Galil, B. S., Hulme, P. E., Ikeda, T., Sankaran, K. V., McGeoch, M. A., Meyerson, L. A., Nuñez, M. A., Ordonez, A., Rahlao, S. J., Schwindt, E., Seebens, H., Sheppard, A. W., and Vandvik, V. (eds.). IPBES secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.7430692

ISHIKAWA, W., and FUKUDA, S. 2022. Application of YOLOv5 and MASK R-CNN for diurnal activity monitoring of freshwater fish. *2022* Joint 12th International Conference on Soft Computing and Intelligent Systems and 23rd International Symposium on Advanced Intelligent Systems (SCIS&ISIS), 1-4.

IUCN. 2015. Red list of Bangladesh volume 5: freshwater fishes. International Union for Conservation of Nature (IUCN), Bangladesh Country Office, Dhaka, Bangladesh.

KARTHIGA, D., APPASAMY, S., and ANTONY, J.T. 2019. Biotreatment of sugar industry effluent using the tank cleaner, *Pterygoplichthys pardalis*. World Journal of Advanced Research and Reviews **1**:14–27

LEWIS, R. 2023. Amazon River Fish: Best known species - Rainforest cruises. Rainforest Cruises. https://www.rainforestcruises.com/guides/amazon-river-fish-best-known-species.

LOWE-MCCONNELL, R.H. 1987. Ecological Studies in Tropical Fish Communities. Cambridge University Press.

MATAMOROS, W.A., MCMAHAN, C.D., MEJIA, C., HOUSE, P., ARMBRUSTER, J.W., and CHAKRABARTY, P. 2016. First Record of The Non-Native Suckermouth Armored Catfish *Hypostomus* CF. Niceforoi (Fowler 1943) (Siluriformes: Loricariidae) From Central America. Occasional Papers of the Museum of Natural Science, Louisiana State University.

MOFL. 2022. Protection and Conservation of Fish Rules, 1985, Rules modification of 18.2. Notified on 25th Sept 2022 and Amended on 15 January 2023. Ministry of Fisheries and Livestock (MOFL), Government of the Peoples Republics of Bangladesh. 983-984.

MORI, S., and NAKAMURA, T. 2021. An evolutionarily conserved Odontode gene regulatory network underlies head armor formation in suckermouth armored catfish. bioRxiv preprint doi: https://doi.org/10.1101/2021.06.21.449322

NICO, L. 2000. *Pterygoplichthys multiradiatus* (Hancock 1828). Nonindigenous aquatic species fact sheet 768. United States Geological Survey.

ORFINGER AB, and GOODDING DD. 2018. The global invasion of the suckermouth armored catfish genus *Pterygoplichthys* (Siluriformes: Loricariidae): Annotated list of species, distributional summary, and assessment of impacts. Zool Stud **57**: e7.

OSIPOVA, E., EMSLIE-SMITH, M., OSTI, M., MURAI, M., ÅBERG, U., and SHADIE, P. 2020. IUCN World Heritage Outlook 3: A conservation assessment of all natural World Heritage sites, November 2020. Gland, Switzerland: IUCN. x + 90pp.

PAGE, L.M., and ROBINS, R.H. 2006. Identification of sailfin catfishes (Teleostei: Loricariidae) in Southeastern Asia. The Raffles Bulletin of Zoology **54**:455–457.

PARVEZ, M., LUCAS, M., HOSSAIN, M., CHAKI, N., MOHSIN, A., SUN, J., and GALIB, S.M 2023. Invasive vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*) has an impact on highly valued native fish species. Biological Invasions, **25**(6), 1795-1809. https://doi.org/10.1007/s10530-023-03012-8

REIS, R. E., S. O. KULLANDER and C. J. FERRARIS, JR., 2003. Check List of the Freshwater Fishes of South and Central America. EDIPUCRS, Porto Alegre. xi + 729 pp.

PÉREZ-FLORES, J. 2020. Injuries caused by the invasive armoured suckermouth catfish *Pterygoplichthys* sp. in three captive Antillean manatees *Trichechus manatus manatus*. Hidrobiologica, **30**, 173-176.

REIS, R.E., KULLANDER, S.O. and FERRARIS, J.R.C.J, 2003. Check List of the Freshwater Fishes of South and Central America. EDIPUCRS, Porto Alegre. xi + 729 pp.

RUBIO, V.Y., GIBBS, M.A., WORK, K.A., and BRYAN, C.E. 2016. Abundant feces from an exotic armored catfish, *Pterygoplichthys disjunctivus* (Weber, 1991), create nutrient hotspots and promote algal growth in a Florida spring. Aquatic Invasions **11**:337–350. http://dx.doi.org/10

SARKAR, A., RANA, S., BHOWMIK, P., HASAN, M.N., SHIMUL, S.A., and NAHID, S.A. 2023. A Review of Suckermouth Armoured Catfish (Siluriformes: Loricariidae) Invasion, Impacts and Management: Is Its Invasion a Threat to Bangladesh's Fisheries Sector? *Asian Fisheries Science* **36**(3): 128-143. https://doi.org/10.33997/j.afs.2023.36.3.002

SECUTTI, S., and TRAJANO, E. 2009. Reproductive behavior, development, and eye regression in the cave armored catfish, *Ancistrus cryptophthalmus* Reis, 1987 (Siluriformes: Loricariidae), breed in the laboratory. Neotropical Ichthyology, **7**(3):479-490. https://doi.org/10.1590/S1679-62252009000300016

SESHAGIRI, B., SWAIN, S.K., PILLAI, B.R., SATYAVATI, C., SRAVANTI, Y., RANGACHARYULU, P.V., RATHOD, R., and RATNAPRAKASH, V. 2021. Suckermouth armoured catfish (*Pterygoplichthys* spp.) menace in freshwater aquaculture and natural aquatic systems in Andhra Pradesh, India. *International Journal of Fisheries and Aquatic Studies*. **9**(1): 375-384

SIAM, M.K.H., TASNIA, N., MAHMUD, S., HALDER, M., and RANA, M.M. 2023. A Next-Generation Device for Crop Yield Prediction Using IoT and Machine Learning. In T. D. Nguyen, E. Verdú, A. Le,N and M. Ganzha (Eds.), *Intelligent Systems and Networks* (pp. 668-678). Springer Nature Singapore.

THOMAZ, S.M., KOVALENKO, K.E., HAVEL, J.E. and KATS, L.B. 2015. Aquatic invasive species: general trends in the literature and introduction to the special issue. Hydrobiologia **746**, 1–12. https://doi.org/10.1007/s10750-014-2150-8

USHA, S., and MAHESH, H.B. 2022. Monitoring and Analysis of Agricultural Field Parameters in Order to Increase Crop Yield through a Colored Object Tracking Robot, Image Processing, and IOT. *Engineering, Technology & Applied Science Research*. **12**(4): 8791-8795 https://doi.org/10.48084/etasr.5028

WERNER, D. 1982. Review of man, fishes, and the amazon. Human Ecology **10**:151–153. http://www.jstor.org/stable/4602640

WLFC. 2013. Report on the implementation of the Toolkit in Bangladesh. Wildlife and Forest Crime (WLFC). Department of Forest, Dhaka, Bangladesh. 71p.

WIJESINGHE, S.K.D., ABEYRATHNE, E.D.N.S., VIDANARACHCHI, J.K., and RAJAPAKSE, R.P.N.P. 2021. Bioactive properties of fish protein hydrolysates from Amazon sailfin catfish (*Pterygoplichthys pardalis*) from the Victoria Reservoir in Sri Lanka. Tropical Agricultural Research **32**:219–228

WOODS, R 2022. Plecostomus care Guide, Facts & Species Profile. Fishkeeping World. https://www.fishkeepingworld.com/plecostomus/ Accessed on 22nd November 2023.

WU, LW., LIU, C.C., and LIN, S.M. 2011. Identification of exotic sailfin catfish species (*Pterygoplichthys*, Loricariidae) in Taiwan based on morphology and mtDNA sequences. Zoological Studies **50**:235–246.

ZARET, T.M. 1980. Predation and freshwater communities. Yale University Press. 208p.

(Manuscript received on 01 November 2023 revised on 28 November 2023)