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Research Article

Invasive Amazon sailfin catfish in Bangladesh: wild distribution, environmental and perceived socio-economic consequences

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Abstract

Amazon sailfin catfish are native to Latin Arica (Siluriformes: Loricariidae: *Pterygoplichthys*) and are popular around the world as ornamental fish. It is well-documented that these species are highly successful invaders and very prone to forming new geographical ranges. However, once established, eradicating a new population is a very challenging task. In Bangladesh, species of the genus *Pterygoplichthys* are expected to spread widely and have a severe detrimental impact on ecosystem health, biodiversity and economics. Here we provide new information on the future probable establishment of non-native populations of these species in the wild using a climate-matching analysis and highlight their potential area of occurrence. The potential socio-economic consequences are also discussed, as are the public perception of these species and probable economic damages caused. Control of the import of similar species, their culture and intentional or unintentional release into open water is urgently required.

Key words: *Pterygoplichthys*, fish, biological invasion, modelling, climate matching, Asia

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Introduction

Biological invasions cause huge environmental and socio-economic losses worldwide (Bang et al. 2022). In freshwaters, numerous invasive fish species have been introduced via various pathways such as culture for human consumption, ornamental aquaculture and the pet trade, and pest control (Faulkner et al. 2020). Tropical countries are especially suitable for the establishment of new populations of many fish species such as the well-known invasive Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) and common carp *Cyprinus carpio* Linnaeus, 1758, as well as species paradoxically endangered in their native ranges such as the giant arapaima *Arapaima gigas* (Schinz 1822), as reported by Marková et al. (2020) and Zam-

brano et al. (2006). In the case of catfish, several species of Amazon sailfin catfish *Pterygoplichthys* spp. have been recognized in tropical, subtropical and warm-water regions as invasive (Nico et al. 2012; Rao and Sunchu 2017; Hossain et al. 2018; Orfinger and Goodding 2018; Patoka et al. 2020; Saba et al. 2020; Yen 2021).

Amazon sailfin catfishes (Siluriformes: Loricariidae: *Pterygoplichthys*) are native to Latin America and are very popular worldwide as ornamental species (Burgess 1989; Hoover et al. 2004; Novák et al. 2022). They are transported around the planet in huge quantities and released accidentally by irresponsible owners or even intentionally by producers for culture in new localities outside their native ranges (Hoover et al. 2014). They can quickly establish new populations where suitable climatic conditions exist and then spread and multiply rapidly (Orfinger and Goodding 2018).

Various biological and ecological characteristics allow certain Amazon sailfin catfishes species to be highly successful invaders: parental care and large eggs that generate strong hatchlings that can escape predators; nesting; extended spawning seasons; high fecundity; rapid growth; lifespans of more than five years; ability to gulp air and extract oxygen through the gut lining in hypoxic environments; and a capacity to survive several hours of desiccation in simple burrows (Armbruster 1998; Hoover et al. 2004; Gibbs and Groff 2014; Hossain et al. 2018). Their scales are hard, and their fins are equipped with sharp hard spines that are effective deterrents against predators (Quan et al. 2020; Peplinski et al. 2021). For this reason, species such as *Pterygoplichthys disjunctivus* (Weber, 1991) and *P. pardalis* (Castelnau, 1855), as well as their hybrids, are currently spreading intercontinentally as invaders in the tropics, subtropics and warm-water regions (Hill and Sowards 2015; Hossain et al. 2018; Patoka et al. 2020). Although the most non-native populations originate from aquarium releases or escapes from fish cultures, the possibility of introduction for human consumption cannot be ignored (Patoka et al. 2020). Where these species have been introduced by a combination of several pathways, they can be referred to as 'polyvectic' *sensu* Carlton and Ruiz (2005).

Invasive *Pterygoplichthys* species can become locally dominant fish species as they have the capacity to outcompete native species by altering the dynamics of food webs (Page and Robins 2006) and by exploiting similar trophic niches (Meena et al. 2016). Various negative impacts on habitats in invaded ranges are also known, including increased water turbidity, bank erosion and instability (Nico et al. 2009a). The grazing and burrowing behaviour of *Pterygoplichthys* spp. also greatly damages populations of aquatic macrophytes (Hoover et al. 2004; Nico et al. 2009b; Gibbs et al. 2010). Once a new population is established, these fish are very difficult to eradicate (Hill and Sowards 2015; Orfinger and Goodding 2018).

In Bangladesh, *Pterygoplichthys* spp. were imported for ornamental purposes in the 1980s but escaped into the wild during the 1990s as a result of both intentional and unintentional releases (Hossain 2020). However, no *Pterygoplichthys* spp. were recorded in Bangladesh until their first appearance in 2007 in northern Bangladesh (Hossain et al. 2008). Recently established wild populations (Parvez et al. 2023) and numerous records at different waterbodies have now been reported (Parvez et al. 2023; Mamun et al. 2023). Before banning all types of activities related to *Pterygoplichthys* spp. (suckermouth catfishes) in 2023 (Ahamad 2023), there were no legislative restrictions banning imports of these fish into Bangladesh by aquarium traders or other vectors. Explicit permission from the Bangladesh Department of Fisheries, Ministry of Fisheries and Livestock is, nevertheless, required for importing these species (MoFL 2018) and these fish are perceived as a 'conditional' species. Conditional non-native species are those that are thought to endanger the environment, native biota and/or humans. However, this regulation seems to be totally ineffective (a so-called 'dead letter'; Patoka et al. 2018) as

aquarium traders import and breed these fish commercially in huge quantities in local hatchery facilities without permission (Hossain 2021). These irresponsible activities and intentional or unintentional ranching in the wild may have led to these species becoming widespread in Bangladesh.

Therefore, these species are expected to become well-established in many areas of Bangladesh and to have had significant negative impacts on biodiversity, ecosystem functioning and economics. To date, the only data on the abundance and wild establishment of *Pterygoplichthys* spp. in Bangladesh are reports by local people and frequent newspaper articles (Mamun et al. 2023). Therefore, we decided to (i) update information on the occurrence of these fish species in Bangladesh by evaluating the establishment of non-native populations in the wild using a climate-matching model; and to (ii) observe and evaluate human attitudes towards these fish.

Material and methods

Collection of data on wild occurrence

Records of the occurrence of *Pterygoplichthys* spp. were collected from the national and local daily Bangladesh newspapers (The Daily Prothomalo, The Daily Star, The Bangladesh Post, The NEWAGE, The Daily Jugantor, The Daily Sun, The Daily Bangladesh, The Daily Ittefaq, The Daily Somokal, The Daily Karatoa, The Daily Kalerkontho etc.). To do so, we used the Google search engine with keywords such as 'sucker fish', 'rare fish caught in Bangladesh', 'sucker fish/rare fish in Buriganga Rivers/Turag', River/Kaptailake/floodplain/beels/haors/pond', 'birol mach' or 'danob mach'. Similar methods were used by Mamun et al. (2023). During searches, we also used the names of different localities and major rivers as key words. Since most of the reports were originally published in Bengali, we searched in both Bengali and English. Occurrence records obtained from personal communications and via social media (Facebook) reports were also collated. We included reports that were confirmed by experts and also by viewing photos and videos shared in news and social media. During data collection from newspapers, social media or personal communications, fish capture date, location (city/district etc.), fish size (weight), number caught, and water body type were all recorded. The GPS coordinates of reported locations were obtained using Google Earth Pro based on the description in news reports and social media stories/descriptions. All raw data are summarized in Suppl. material 1: table S1. These data were analysed to obtain the percentage of invaded districts, open waters or ponds, size and weight range of caught fish individuals, and the year-wise percentage of occurrence.

Climate match analysis

Bioclimatic factors from the WorldClim database were used to simulate the distribution of these species (v.2.0; https://www.worldclim.org; Fick and Hijmans 2017) at a spatial resolution of 30 seconds (~1 km^2). Bioclimatic variables are essential characteristics derived from monthly temperatures and rainfall data that reflect the yearly patterns, seasonality and extremes that are crucial for species survival. The distribution pattern of aquatic species and environmental factors, particularly temperature, have been discovered to be linked (Jeschke and Strayer 2008; Gallardo et al. 2012). These environmental layers were assembled in QGIS 3.30.1 *'s-Hertogenbosch*' and released on 31.03.2023 (https://qgis.org/en/site/) in an ASCII format for use with the MaxEnt algorithm (Phillips 2017), a maximum entropy model that is ideal for mapping species distributions (Phillips and Dudik

2008). The MaxEnt model is commonly used to predict alien species dispersion since it represents a continuous probability surface of habitat suitability in the target region (Ward 2007; Giovanelli et al. 2008; Yonvitner et al. 2020; Akmal et al. 2022). We calculated nine bioclimatic variables for *Pterygoplichthys* spp. (Table 1) representing temperature and precipitation averages, extremes and variations, all variables that are widely used in ecological niche modelling. MaxEnt was trained using all nine bioclimatic variables with default features and regularization multipliers (Default model), which are based on empirical tuning studies (Phillips and Dudik 2008). As a cumulative output, a continuous map was generated and visualised in QGIS 3.30.1 *'s-Hertogenbosch'*.

Table 1. Bioclimatic variables used in the variable selection strategy to build a climate similarity model for *Pterygoplichthys* spp. in Bangladesh.

	Bioclimatic variables
BIO1	Annual Mean Temperature
BIO2	Mean Diurnal Range (Mean of monthly max temp - min temp)
BIO3	Isothermality (BIO2/BIO7) (×100)
BIO4	Temperature Seasonality (standard deviation ×100)
BIO5	Max. Temperature of Warmest Month
BIO6	Min. Temperature of Coldest Month
BIO7	Temperature Annual Range (BIO5–BIO6)
BIO8	Mean Temperature of Wettest Quarter
BIO9	Mean Temperature of Driest Quarter
BIO10	Mean Temperature of Warmest Quarter
BIO11	Mean Temperature of Coldest Quarter
BIO12	Annual Precipitation
BIO13	Precipitation of Wettest Month
BIO14	Precipitation of Driest Month
BIO15	Precipitation Seasonality (Coefficient of Variation)

Sample collection and identification, and interviews with stakeholders

Pterygoplichthys spp. were sampled from the Turug River (GPS coordinates 23°58'57.9"N, 90°19'49.9"E, 23°53'30.8"N, 90°21'35.3"E, 23°53'09.6"N, 90°23'33.0"E) and household outdoor ponds in Gazipur (24°01'23.9"N, 90°23'30.6"E, 24°01'22.5"N, 90°23'16.7"E) and Mymensingh (24°37'59.3"N, 90°23'52.4"E) districts (Bangladesh) using a cast net (4-m diameter, 1-cm mesh size). A few individuals were also collected from aquarium markets and owners. Captured fish were taken alive to the laboratory of the Faculty of Fisheries, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh for identification using the colouration and patterning on the ventral part of the body, as described by Page and Robins (2006), Hossain et al. (2018) and Wu et al. (2011). Specimens were measured with digital slide calliper to the nearest 1 mm and weighed on an electric scale to the nearest 0.1 g.

Ninety-seven stakeholders including local residents (businessmen, students, employees, lawyers, politicians etc.), riverside workers, fish farmers, pet shop owners, fishermen, and fish-sellers were asked about *Pterygoplichthys* spp. to gather information, specifically, about:

- the local name of the species;
- its potential as food for human consumption;
- the economic significance of the species;
- the community perception of the species;
- the environmental consequences of their presence.

The respondents from different districts/locations were selected randomly. Some of the interviewees were chosen based on personal communication from the lead author. We asked 17 questions (Suppl. material 1: table S2) during in-person interviews. We only analysed answers from respondents who were familiar with the fish under study.

Results

Wild occurrence and distribution pattern

Based on newspaper reports and personal communications, *Pterygoplichthys* spp. were recorded 65 times during the period 2014–2021 in 34 national districts (out of a total of 65 districts) in Bangladesh (Figs 1, 2). In most cases, the fish (~200) were caught by fishermen or laypeople in open water, household ponds or culture ponds. The collected fish ranged from 10 to 30 cm in body length and weighed from 0.2 to 2.0 kg. Most of the newspapers reported them as 'rare fish found in rivers/ponds' and included pictures and descriptions. Some newspapers and local people and authorities identified these fish as 'sucker fish' or 'armoured catfish'. The majority of the southern district of Bangladesh and most major rivers have been invaded by *Pterygoplichthys* spp. (Suppl. material 1: table S1, Fig. 3). In total, 69% of records were from open waters including rivers and floodplains, while 31% were from culture or household ponds. The lowest frequency occurred in 2014 and highest prevalence was from between 2020 and 2021 (Fig. 2).

Climate suitability

As a cumulative output, a continuous map was generated and visualised in QGIS 3.30.1 *'s-Hertogenbosch*'. MaxEnt calculated a threshold value for Amazon sailfin catfishes of 8.714. If the value of the climate match reached or exceeded this threshold, this was interpreted as indicating that there was no evidence of any climatic constraints on the survival of these species and is shown in red on the map (Fig. 3). The value of the area under the receiver operator curve (AUC) was 0.982, which means there is a 98% probability that a random selection of records of the presence of Amazon sailfin catfish will have a model score greater than a random selection of absence records (Ward 2007). Climate matching analysis showed a high probability that *Pterygoplichthys* spp. will become established in new localities in Bangladesh if introduced into those novel areas. The distribution of detected populations matches perfectly the predicted suitable areas. *Pterygoplichthys* spp. populations are probably well-established in almost all suitable climate-matched areas of Bangladesh. Climate-match analysis showed that part of Satkhira and Sunamgonj and part of Chittagong Hill Tracks districts are less favourable for these fish. The unsuitable or unfavourable regions are categorized as Ganges Tidal Floodplain or Northern and Eastern Hills based on agroecological zone classification (BARC 1988).

Figure 1. *Pterygoplichthys* spp. captured in a net (**a**), a fish close to its burrow (**b**), and an example of a locality (Turag River, Gazipur) where *Pterygoplichthys* spp. are present (**c**). Photographs Mir Mohammad Ali (**a**), Abu Hanif (**b**) and Md Shakhawate Hossain (**c**).

Identification of species and exploitation by humans

Morphometric and meristic data of sampled specimens were recorded (Table 2) and ventral body colouration patterns were observed. Based on these analyses, the species were identified as either *P. disjunctivus* or *P. pardalis* or as hybrids of these two species. The former was identified by the worm-like pattern of dark spots on a light background, stout pectoral fins with rough surfaces resembling coarse sandpaper, and an inferior disc-like protrusible mouth. *P. pardalis* was identified by the dotted dark spots on the ventral side (Fig. 4a); hybrids showed intermediate forms (Fig. 4c, d). We also found an albino phenotype in two ponds (Fig. 4e).

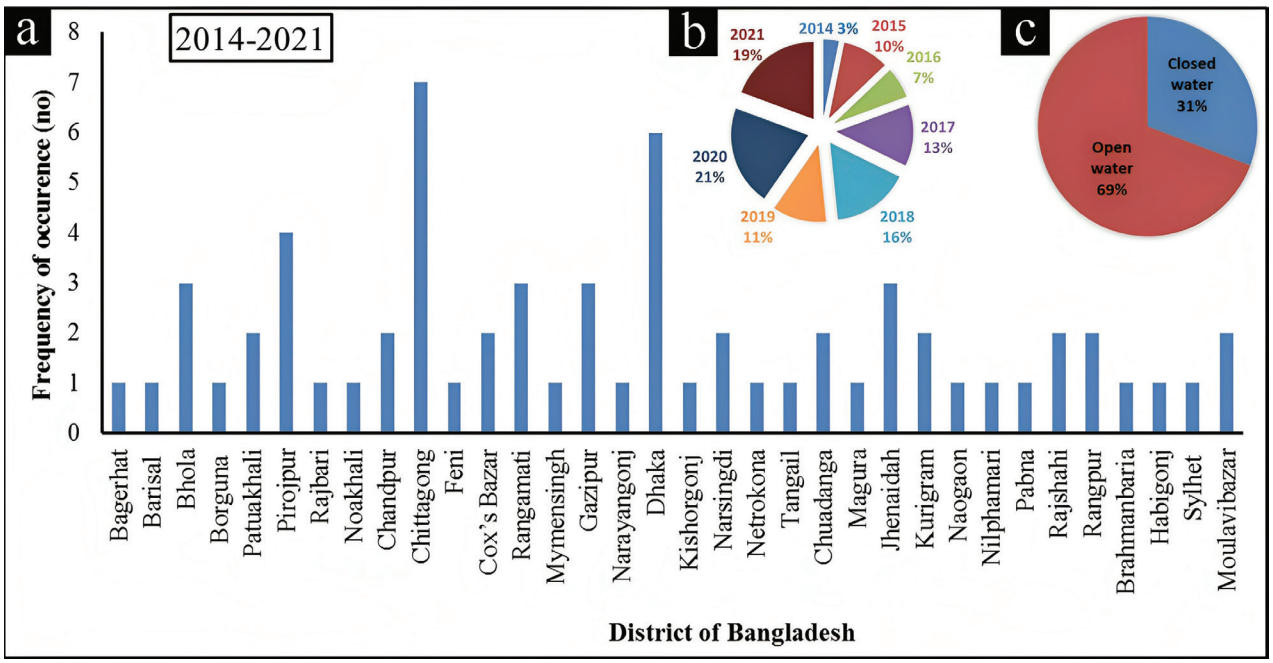

Figure 2. Frequency of *Pterygoplichthys* spp. captured in different districts in Bangladesh (**a**), year-wise occurrence (%) (**b**), and occurrence (%) in open waters (rivers and floodplains) or closed waters (ponds) (**c**) based on newspaper reports from 2014–2021.

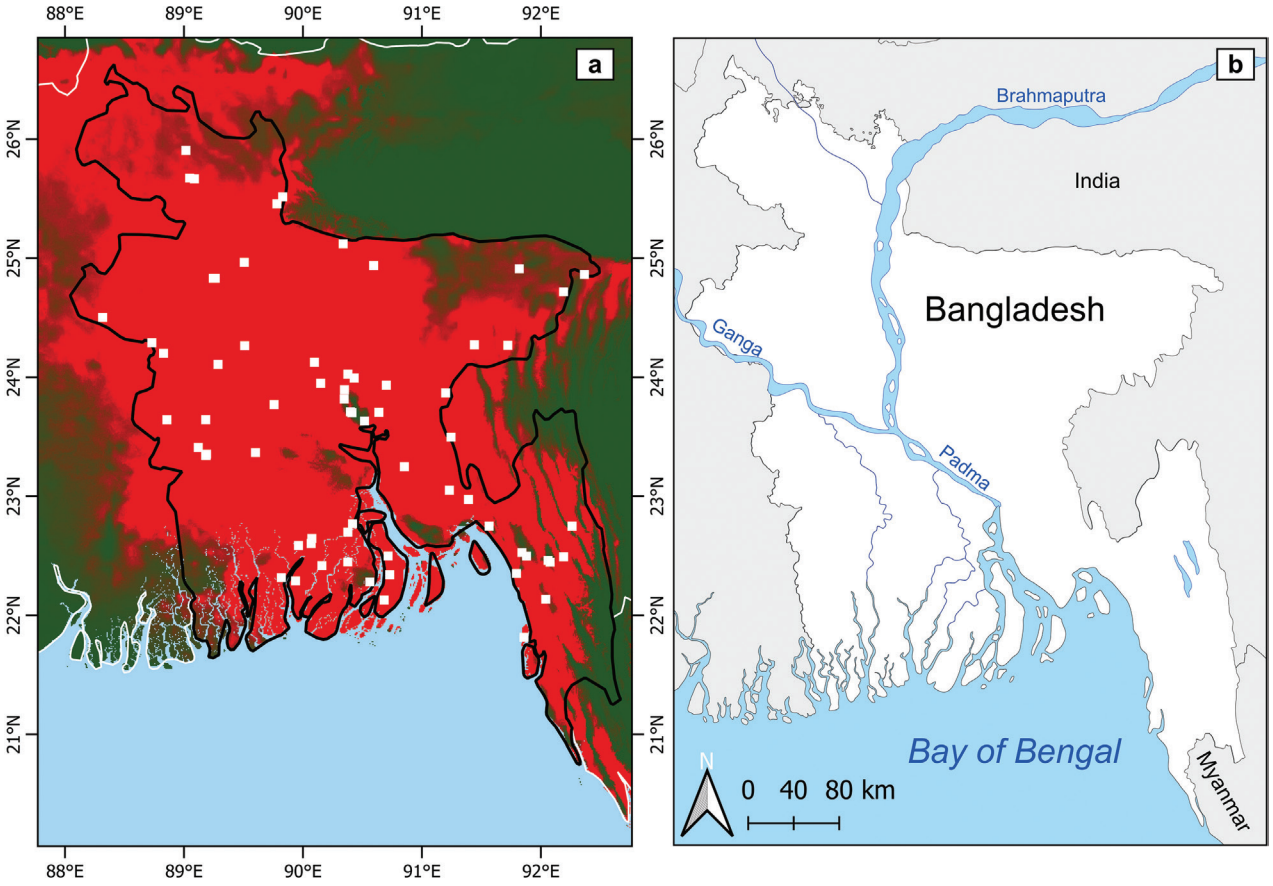

Figure 3. Records of *Pterygoplichthys* spp. in Bangladesh shown by white squares. The red colour indicates the area where the establishment of new populations is probable based on climate matching (**a**); map of Bangladesh showing main rivers and national borders (**b**).

Table 2. Morphometric and meristic characteristics of *Pterygoplichthys* spp. collected from different localities in Bangladesh.

Morphometric characters	Average	Range	Meristic characters	Range
Weight (g)	332.22 ± 161.94	90–540	Dorsal Fin Ray (DF)	12–13
Total length (TL; cm)	21.22 ± 3.29	17.78–26.16	Anal Fin ray (AF)	4–5
Standard length (SL; cm)	18.40 ± 3.16	14.22–23.37	Caudal Fin ray (CF)	15–6
Predorsal length (PDL; cm)	6.21 ± 1.14	4.06–7.62	Pectoral Fin ray (PF)	5–7
Head length (HL; cm)	3.44 ± 0.73	2.03–4.83	Pelvic Fin ray (PVF)	5–8
Snout length (SnL; cm)	1.41 ± 0.42	0.76–2.03	Lateral Plate (LP)	25–29
Mouth length (ML, cm)	1.07 ± 0.25	0.76–1.27		
Barlel length (BL; cm)	0.58 ± 0.19	0.25–0.76		
Pectoral spine length (PSL; cm)	3.75 ± 0.79	2.29–4.57		
Pelvic spine length (PVSL; cm)	1.67 ± 1.11	0.05–3.05		
Anal fin spine length (ANSL; cm)	2.48 ± 1.34	0.76–4.32		
Dorsal spine length (DSPL; cm)	3.47 ± 0.44	2.54–4.06		
Head depth (HD; cm)	3.47 ± 0.85	2.29–4.32		
Mouth width (MW; cm)	0.99 ± 0.35	0.51–1.52		

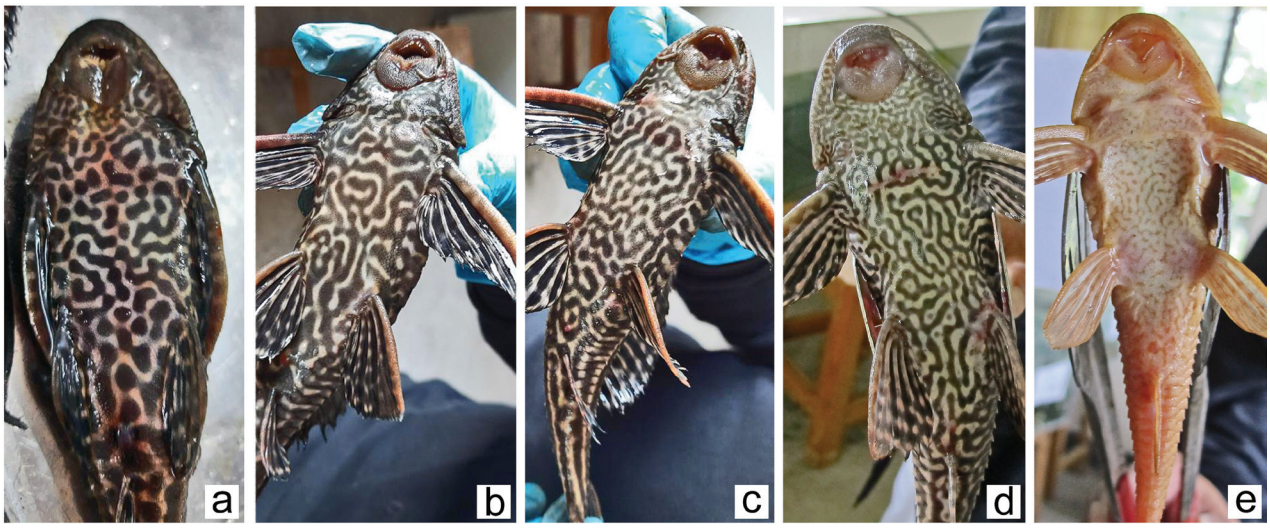

Figure 4. Variation in ventral colouration and pattern of *Pterygoplichthys* spp. collected from different locations in Bangladesh. *Pterygoplichthys pardalis* (**a**), *P. disjunctivus* (**b**), intermediate form (**c, d**) and albino (**e**). Photographs by Md Shakhawate Hossain.

Among the respondents, half was not familiar with these fish. Local people who know these fish are very aware of the presence of mentioned bizarre species and have various interesting names for them including 'tiger fish', 'sucker fish', 'thousand-spine fish', 'chaca', 'helicopter fish', 'rohinga fish', 'kotkoti', 'cot fish' or 'fighter'. They usually harvest these fish indirectly as bycatch when attempting to catch other fish by cast netting or seine nets, or by draining water bodies. Most respondents (63%) were very anxious about the presence of these fish in culture ponds and open waters and mentioned their possible negative impact on native fish production. Affected fish farmers have tried to eradicate them from their ponds by draining and sun-drying given that they have no economic value and can damage their nets. They recognized that these attempts all failed but did not know why. Some farmers claimed that there might be dormant eggs in the mud from where they recolonize ponds. People who once bathed in the invaded rivers mentioned that they are now too scared to bathe in the river (river Buriganga) because of the

possibility of being injured by the hard spiny fins of these catfish. All the interviewed fishermen (100%) confirmed that their fishing gear had been damaged and/or that they had suffered or were scared of physical injury when fishing due to the presence of these invasive fish at the Turag and Buriganga rivers. They also claimed that there had been a decline in fish production in invaded waters. About 71% of fish farmers agreed that these fish damage dykes when burrowing and increase the turbidity of ponds or reduce the total fish production from ponds.

The majority of collectors (fishermen/farmers) throw these catfish back into the water body when they catch them or throw them on the bank to kill them. About 88% of respondents suggested these fish could be eradicated by killing, burning or burying after they are caught. However, there were also cases mentioned where homeless and extremely poor people collect these fish for their own consumption and/or sell them on the street for about US$1.2–2.0/kg. Despite this, these fish are not popular and most respondents (about 70%; 34 out of 49) rejected eating *Pterygoplichthys* spp. due to their hard body armour. On the other hand, about 81% think they are edible. However, some respondents among the fishermen and boat labour (about 10%) did say that they had cooked the fish with spices and oil after peeling off the skin and hard shield (as shown in Suppl. material 1: fig. S1).

Discussion

We found *Pterygoplichthys* spp. to be widely spread throughout Bangladesh. Given the recent attention focused on invasive fish species in general and on the illegal releases of *Pterygoplichthys* spp. in particular by both the general public and the Bangladesh government (Hossain 2020), we recommend that these findings be transmitted to all key stakeholders involved in the sustainable exploitation and conservation of the ichthyofauna of the country.

It is foreseeable that *Pterygoplichthys* spp. will establish populations in suitable water bodies throughout Bangladesh. Based on the climate-matching maps, we believe that further detailed monitoring is required in the regions indicated as threatened to update current knowledge of the distribution and spread of these catfish in Bangladesh, and to improve the management of water bodies. The climate analysis shows a good climate match for these species for most of Bangladesh. Judging from reports in newspapers and observations by local people, these species are now widespread in the wild in Bangladesh. However, no scientific literature other than the first record from 2007 (Hossain et al. 2008) and a recent invasion note (Mamun et al. 2023 and Parvez et al. 2023) has reported their widespread occurrence in this country or studied habitat suitability via climate-match analysis. *Pterygoplichthys* spp. in the Indian subcontinent and southern Asia have become established as an invasive population (Patoka et al. 2020; Sinha et al. 2010; Rao and Sunchu 2017; Saba et al. 2020) and the climate analysis and pattern of wild establishment show the suitability of habitats in Asia (Patoka et al. 2020; this study). Little geographical climate difference across the country and high aqueous connectivity through river channels and floodplains during the monsoon and flooding periods have facilitated the spreading and establishment of these species in favourable climatic conditions. The highest occurrence pattern was in 2020–2021 and in open waters (69%), which also indicates that these species are spreading in the wild. Repeated occurrence in the same or nearby localities in consecutive years could be related to well-established populations. Year-wise fluctuations might be due to the reporting pattern of individual cases.

The pathways of introduction into Bangladeshi waters include both intentional and unintentional releases from aquariums that mirror reports from other countries (Page and Robins 2006; Samat et al. 2016). For instance, in Indonesia

Pterygoplichthys spp. were introduced to control the invasive water hyacinth (Patoka et al. 2020), while in Bangladesh and the Philippines they were introduced for ornamental purposes by the pet trade (Cagauan 2007). In Bangladesh, introductions mostly derive from ornamental culture facilities in households or commercial pet shops. According to newspaper reports and shop owners' information, illegal breeding and fry production in Bangladesh (Mobin 2022) probably represents another pathway of introduction into the wild due to surplus production. Another possible pathway of the *Pterygoplichthys* spp. introduction into Bangladeshi waters was from India during monsoon along connected major river channels (the Gangas and the Brahmaputra rivers) (Hussan et al. 2016). Water connectivity during monsoon, the altitudinal difference from north to south, and the major river channels also facilitate the occurrence of these species in all favourable regions, as well as in those that lie outside the suitable climate-match regions in Bangladesh.

Local people, fishermen and farmers assume that these fish will compete with other indigenous fish and predate on their eggs and larvae. Fishermen and farmers mentioned the reduction in fish availability and total fish production in invaded habitats. This finding also corroborates the statements mentioned by Mamun et al. (2023) and the findings of Parvez et al. (2023). Damage to fishing nets by these catfishes has been also reported. Some interviewees also suspected that native fish species were displaced, and habitat was destroyed by *Pterygoplichthys* spp. The environmental impact of *Pterygoplichthys* spp. has been reported by several scientists from other continents (Hoover et al. 2004; Chavez et al. 2006; Wakida-Kusunoki et al. 2007; Cook-Hildreth 2008; Krishnakumar et al. 2009; Chaichana et al. 2013) and in Bangladesh they seem to possess all the characteristics of a successful invader threatening native fish populations (Hoover et al. 2004; Liang et al. 2005; Nonogaki et al. 2007; Wakida-Kusunoki et al. 2007; Krishnakumar et al. 2009; Mendoza et al. 2009). These negative impacts have also been reported by Parvez et al. (2023) via a mesocosm study and highlighted by Mamun et al. (2023) through expert opinions.

Aside from its environmental impact, the *Pterygoplichthys* spp. invasion has also had a socio-economic effect on local communities. Fishermen are suffering economic losses due to damage to their fishing gear and poorer catches (Chavez et al. 2006; Wakida-Kusunoki et al. 2007; Krishnakumar et al. 2009; Orfinger et al. 2019). This biological invasion of both artificial ponds and open waters reduces fish production, which ultimately affects fish farmers' and fishermen's livelihoods. Moreover, there is an obvious related burden on fish farmers caused by the extra cost of pond management due to, for example, the need for dyke repair and pond drainage aimed at eradicating these invaders.

Eradication attempts are not successful because these fish can survive in extremely dry conditions, grow quickly and have high fecundity (Hoover et al. 2004; Chaichanaa and Jongphadungkiet 2012; Hill and Sowards 2015; Hussan et at. 2021). In invaded habitats they destroy ponds' potential as food sources by sequestrating the majority of the nitrogen and phosphorus and hamper primary production in water bodies (Capps et al. 2009), factors that have led directly to economic losses. People are also frightened of these fish because of the hard armoured shields and spines on the dorsal fin that can cause injury. They are even afraid of bathing in invaded waterbodies, which in turn creates unnecessary stress on people who live near these rivers and ponds and depend on them for bathing and other daily activities. Simply put, the many human activities tied to certain waterbodies are negatively affected by the invasive *Pterygoplichthys* spp.

In our study, the local people who catch these fish in rivers or other waterbodies throw them onto the bank or release them back into the water. Today, however, the Bangladeshi government is taking note of these invasive fish and is trying to raise aware-

ness amongst the general public and stakeholders regarding the risks and negative consequences of this invasion. For instance, government officials have made several official announcements and came to fish the Buriganga River. All the *Pterygoplichthys* spp. they caught were officially buried on the bank to encourage people to follow this approach.

The invasive *Pterygoplichthys* spp. have easily occupied and established themselves in Bangladesh as a tropical region (climate-match result) and can withstand extreme conditions (Hossain et al. 2018). Therefore, both the mass media and government need to work continuously to create greater public awareness regarding the negative impact of these invasive species and to stop intentional releases or unintentional escapes into water bodies (Novoa et al. 2017). Adult fish, eggs and juveniles should be caught/killed in invaded regions periodically by netting or draining wherever possible. Invaded areas could be separated by net-blocking or embankments from uninvaded waters (Hussan et al. 2021) and imports for any purpose of these species should be banned by the government.

However, illegal import and breeding hamper initiatives set up by concerned people. Along with eradication and control strategies, any control measures must consider other aspects of the invasion by *Pterygoplichthys* spp. In our study, we found that low income and homeless people eat these fish despite the fact that pollution from contaminated rivers and streams can accumulate in their flesh (Elfidasari et al. 2020). However, pollution-free grown *Pterygoplichthys* spp. could be used to manufacture fish meal, poultry, and cattle feed (McLaughlan et al. 2014; Ragaza et al. 2021). Some researchers also suggest that their skin could be used in handicrafts (Cagauan 2007) and their body parts for making soap, biofuel, enzymes, collagen or natural coagulants to control water turbidity (CEC 2009; Medellín Castillo et al. 2022).

Finally, we should also state that the situation of *Pterygoplichthys* spp. may in fact be worse in Bangladesh than we observed. The detected frequency of occurrence of these species could be just the tip of the iceberg. The established breeding populations might be present in more localities and open waters than we observed. Thus, based on the climate-matching maps, we suggest that further monitoring of the regions highlighted as suitable for these taxa be performed to update current knowledge of the occurrence, distribution and spread of these fish species in Bangladesh. Moreover, as necessary further steps, the control of imports, culture and releases – whether they be intentional or unintentional – of similar species into open waters is urged. There is hope that the Bangladesh government will ban all types of activities related to the catching, sale, importation, breeding, and production these fish in the country (Ahamad 2023). Nevertheless, strict official monitoring of illegal culture and breeding within the country is needed to stop further spread. Currently, the effective strategy for eradication of these species from the wild still needs to be developed. In addition, the negative impacts discussed in this article and elsewhere (Hossain et al. 2008; Mamun et al. 2023; Parvez et al. 2023) focus on either *P. pardalis* or *P. disjunctivus* but not on putative hybrids. In future it will be important to clarify whether both species and hybrids have similar effects on local ecology, social life, and ecosystems. The farmers or fishermen could play a crucial role in eradication through killing unwanted fish or larvae and/or by destroying fish eggs on farms or in open waters whenever found.

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Authors' contributions

Conceptualization: MSH and JP Methodology: MSH; SGA Formal analysis and investigation: MSH, SGA; Writing - original draft preparation: MSH, JP, SGA; Writing - review and editing: MSH, JP, SGA, MB; Funding acquisition: JP, MSH; Supervision: MSH, JP.

Ethics approval and consent to participate

The study did not involve any endangered or protected species. No specific permission was required for the locations and activities involved in this study. All experimental manipulations (rearing, capture and measurements) were conducted according to the principles of the Ethical Committee of Bangabandhu Sehikh Mujibur Rahman Agricultural University, Bangladesh, and the National Research Ethics Committee (NREC) of Bangladesh.

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References

Ahamad R (2023) Sucker fish banned as it poses threat to water species in Bangladesh. NewAge Bangladesh. https://www.newagebd.net/article/192682/sucker-fish-banned-as-it-poses-threat-to-water-species-in-bangladesh [Accessed: 28 March 2023]

Akmal SG, Jerikho R, Yulianda F, Wardiatno Y, Novák J, Kalous L, Slavík O, Patoka J (2022) Culture, trade and establishment of *Polypterus senegalus* in Indonesia with first record of wild populations. Aquaculture Environment Interactions 14: 127–133. https://doi.org/10.3354/aei00433

Armbruster JW (1998) Modifications of the digestive tract for holding air in loricariid and scoloplacid catfishes. Copeia 3: 663–675. https://doi.org/10.2307/1447796

Bang A, Cuthbert RN, Haubrock PJ, Fernandez RD, Moodley D, Diagne C, Turbelin AJ, Renault D, Dalu T, Courchamp F (2022) Massive economic costs of biological invasions despite widespread knowledge gaps: a dual setback for India. Biological Invasions 24: 2017–2039. https://doi.org/10.1007/s10530-022-02780-z

BARC [Bangladesh Agriculture Research Council] (1988) Land resources appraisal of Bangladesh for agricultural development. BARC, Dhaka.

Burgess WE (1989) An atlas of freshwater and marine catfishes. A preliminary survey of the Siluriformes. T.F.H. Publications, Inc., Neptune City, New Jersey (USA), 784 pp.

Cagauan AG (2007) Exotic aquatic species introduction in the Philippines for aquaculture-A threat to biodiversity or a boon to the economy. Journal of Environmental Science and Management 10(1): 48–62.

Carlton, JT, Ruiz GM (2005) Vector science and integrated vector management in bioinvasion ecology: conceptual frameworks. In: Mooney HA, Mack RN, McNeely JA, Neville LE, Schei PJ, Waage JK (Eds) Invasive alien species: a new synthesis. Island Press, Covelo, California, 36–58.

Capps KA, Flecker AS, Rodiles-Hernández R (2009) August. COS 45-8: Exotic fishes alter nutrient dynamics in tropical streams. In: 94th ESA Annual Meeting Summary, August 2-August 7, 2009, Albuquerque Convention Centre, Albuquerque, New Mexico. http://eco.confex.com/eco/2009/techprogram/P16502.HTM

CEC [Commission for Environmental Cooperation] (2009) Trinational Risk Assessment Guidelines for Aquatic Alien Invasive Species: Test Cases for the Snakeheads (Channidae) and Armored Catfishes (Loricariidae) in North American Inland Waters. CEC Publications: Montreal, Canada, 98 pp. http://www.cec.org/publications/trinational-risk-assessment-guidelines-for-aquatic-alien-invasive-species/

Chaichana R, Jongphadungkiet S (2012) Assessment of the invasive catfish *Pterygoplichthys pardalis* (Castelnau, 1855) in Thailand: ecological impacts and biological control alternatives. Tropical Zoology 25(4): 173–182. https://doi.org/10.1080/03946975.2012.738494

Chaichana R, Pouangcharean S, Yoonphand R (2013) Foraging effects of the invasive alien fish *Pterygoplichthys* on eggs and first-feeding fry of the native *Clarias macrocephalus* in Thailand. Agriculture and Natural Resources 47(4): 581–588.

Chavez JM, De LA, Paz RM, Manohar SK, Pagulayan RC, Vi JRC (2006) New Philippine record of south american sailfin catfishes (Pisces: Loricariidae). Zootaxa 1109(1): 57–68. https://doi.org/10.11646/zootaxa.1109.1.6

Cook-Hildreth SL (2008) Exotic armored catfishes in Texas: reproductive biology and effects of foraging on egg survival on native fishes (*Etheostoma fonticola*, endangered and *Dionda diaboli*, threatened). Master of Science, Texas State University, San Marcos, 62 pp.

Faulkner KT, Hulme PE, Pagad S, Wilson JRU, Robertson MP (2020) Classifying the introduction pathways of alien species: are we moving in the right direction? NeoBiota 62: 143–159. https://doi.org/10.3897/neobiota.62.53543

Elfidasari D, Wijayanti F, Muthmainah HF (2020) Habitat characteristic of suckermouth armored catfish *Pterygoplichthys pardalis* in ciliwung river, Indonesia. International Journal of Fisheries and Aquatic Studies 8(3): 141–147.

Gallardo B, Errea MP, Aldridge DC (2012) Application of bioclimatic models coupled with network analysis for risk of the killer shrimp, *Dikerogammarus villosus*, in Great Britain. Biological Invasions 14: 1265–1278. https://doi.org/10.1007/s10530-011-0154-0

Gibbs MA, Groff BW (2014) Patterns of aerial respiration by *Pterygoplichthys disjunctivus* (Loricariidae) in Volusia Blue Spring, Florida. Florida Scientist 77(2): 53–68. https://doi.org/10.3391/ai.2013.8.2.08

Gibbs M, Futral T, Mallinger M, Martin D, Ross M (2010) Disturbance of the Florida manatee by an invasive catfish. Southeastern Naturalist 9: 635–649. https://doi.org/10.3391/ai.2013.8.2.08

Giovanelli JGR, Haddad CFB, Alexandrino J (2008) Predicting the potential distribution of the alien invasive American bullfrog (*Lithobates catesbeianus*) in Brazil. Biological Invasions 10: 585–590. https://doi.org/10.1007/s10530-007-9154-5

Hill JE, Sowards J (2015) Successful eradication of the non-native loricariid catfish *Pterygoplichthys disjunctivus* from the Rainbow River, Florida. Management of Biological Invasions 6(3): 311–317. https://doi.org/10.3391/mbi.2015.6.3.11

Hoover JJ, Killgore KJ, Cofrancesco AF (2004) Suckermouth catfishes: threats to aquatic ecosystems of the United States. Aquatic Nuisance Species Research Program Bulletin 4(1): 1–9. https://doi.org/10.21236/ADA422109

Hoover JJ, Murphy CE, Killgore J (2014) Aquatic Nuisance Species Research Program. Ecological Impacts of Suckermouth Catfishes (Loricariidae) in North America: A Conceptual Model. Volume 14-1, March 2014. Engineer Research and Development Center, Vicksburg MS Aquatic Nuisance Species Program, 20 pp.

Hossain E (2020) Alien fish threatens Bangladesh aquatic ecology. NewAge Bangladesh. https://www.newagebd.net/article/122634/alien-fish-threatens-bangladesh-aquatic-ecology [Accesed: 29 May 2022]

Hossain E (2021) Commercial production of suckermouth catfish in Bangladesh causes concern. NewAge Bangladesh. https://www.newagebd.net/article/135124/commercial-production-of-suckermouth-catfish-in-bangladesh-causes-concern [Accesed: 31 May 2022]

Hossain MY, Rahman MM, Ahmed ZF, Ohtomi J, Islam ABMS (2008) First record of the South American sailfin catfish *Pterygoplichthys multiradiatus* in Bangladesh. Journal of Applied Ichthyology 24(6): 718–720. https://doi.org/10.1111/j.1439-0426.2008.01117.x

Hossain MY, Vadas RL, Ruiz-Carus R, Galib SM (2018) Amazon sailfin catfish *Pterygoplichthys pardalis* (Loricariidae) in Bangladesh: a critical review of its invasive threat to native and endemic aquatic species. Fishes 3(1): 1–12. https://doi.org/10.3390/fishes3010014

Hussan A, Choudhury TG, Das A, Gita S (2016) Suckermouth sailfin catfishes: A future threat to aquatic ecosystems of India. Aquaculture Times 2(6): 20–22.

Hussan AJMAL, Mandal RN, Hoque F, Sundaray JK, Das A, Chakrabarti PP, Adhikari S, Udit UK, Choudhury G, Pillai BR (2021) Strategies to control invasion of Sailfin Armoured Catfish, *Pterygoplichthys* spp. in wastewater-fed aquaculture bheries of East Kolkata Wetland, India with suggestion of a modified barrier based on the biological and behavioural characteristics. International Journal of Aquatic Biology 9(3): 187–199.

Fick SE, Hijmans RJ (2017) World Clim 2: new 1km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37(12): 4302–4315. https://doi.org/10.1002/joc.5086

Jeschke JM, Strayer DL (2008) Usefulness of bioclimatic models for studying climate change and invasive species. Annals of the New York Academy of Sciences 1134(1): 1–24. https://doi.org/10.1196/annals.1439.002

Krishnakumar K, Raghavan R, Prasad G, Bijukumar A, Sekharan M, Pereira B, Ali A (2009) When pets become pests-exotic aquarium fishes and biological invasions in Kerala, India. Current Science 97(4): 474–476.

Liang SH, Wu HP, Shieh BS (2005) Size structure, reproductive phenology, and sex ratio of an exotic armored catfish (*Liposarcus multiradiatus*) in the Kaoping river of southern Taiwan. Zoological Studies 44(2): 252–259.

McLaughlan C, Rose P, Aldridge DC (2014) Making the best of a pest: The potential for using invasive zebra mussel (*Dreissena polymorpha*) biomass as a supplement to commercial chicken feed. Environmental Management 54(5): 1102–1109. https://doi.org/10.1007/s00267-014-0335-6

Mamun SAA, Hossain MS, Capps KA (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. Biological Invasions 25: 1285–1290. https://doi.org/10.1007/s10530-022-02993-2

Marková J, Jerikho R, Wardiatno Y, Kamal MM, Magalhães ALB, Bohatá L, Kalous L, Patoka J (2020) Conservation paradox of giant arapaima *Arapaima gigas* (Schinz, 1822) (Pisces: Arapaimidae): endangered in its native range in Brazil and invasive in Indonesia. Knowledge and Management of Aquatic Ecosystems 421(47): 1–10. https://doi.org/10.1051/kmae/2020039

Medellín Castillo NA, Aguilera Flores MM, Ávila Vázquez V, González García R, García Torres J (2022) Evaluation of the Devilfish (*Pterygoplichthys* spp.) Natural Coagulant as a Treatment for the Removal of Turbidity in Fish Farm Wastewater. Water, Air, and Soil Pollution 233(5): 1–16. https://doi.org/10.1007/s11270-022-05652-3

Meena M, Sundaramanickam A, Kumar TTA (2016) Occurrence of a *Pterygoplichthys disjunctivus* (Weber, 1991) population in Cauvery River System, Tamil Nadu, South India. International Journal of Fisheries and Aquaculture 8(6): 62–66. https://doi.org/10.5897/IJFA2015.0526

Mendoza RE, Cudmore B, Orr R, Balderas SC, Courtenay WR, Osorio PK, Mandrak N, Torres PA, Damian MA, Gallardo CE, Sanguines AG (2009) Trinational Risk Assessment Guidelines for Aquatic Alien Invasive Species. Commission for Environmental Cooperation. 393, rue St-Jacques Ouest, Bureau 200, Montréal (Québec), Canada, 98 pp.

Ministry of Fisheries and Livestock (MoFL) (2018) Motsha Songgonirod Iyn 2018. https://mofl.gov.bd/sites/default/files/files/mofl.portal.gov.bd/law/c811e447_7fcf_4f0c_9526_7b50de1fdf5b/%E0%A6%B8%E0%A6%99%E0%A7%8D%E0%A6%97%E0%A6%A8%E0%A6%BF%E0%A6%B0%E0%A7%8B%E0%A6%A7%20%E0%A6%86%E0%A6%87%E0%A6%A8,%20%E0%A7%A8%E0%A7%A6%E0%A7%A7%E0%A7%AE%E2%80%99%E2%80%99.pdf [Accessed on: 24 March 2023]

Mobin AM (2022) Sucker-mouth catfish: A recipe for disaster. The Daily Observer. https://www.observerbd.com/details.php?id=377113 [Accessed: 22 October 2022]

Nico LG, Jelks HL, Tuten T (2009a) Non-native suckermouth armored catfishes in Florida: description of nest burrows and burrow colonies with assessment of shoreline conditions. Aquatic Nuisance Species Research Program Bulletin 9(1): 1–30.

Nico LG, Loftus WF, Reid JP (2009b) Interactions between nonnative armored suckermouth catfish (Loricariidae: *Pterygoplichthys*) and native Florida manatee (*Trichechus manatus latirostris*) in artesian springs. Aquatic Invasions 4: 511–519. https://doi.org/10.3391/ai.2009.4.3.13

Nico LG, Butt PL, Johnston GR, Jelks HL, Kail M, Walsh SJ (2012) Discovery of South American suckermouth armored catfishes (Loricariidae, *Pterygoplichthys* spp.) in the Santa Fe River drainage, Suwannee River basin, USA. BioInvasions Records 1(3): 179–220. https://doi.org/10.3391/bir.2012.1.3.04

Nonogaki H, Nelson JA, Patterson WP (2007) Dietary histories of herbivorous loricariid catfishes: evidence from δ13C values of otoliths. Environmental Biology of Fishes 78(1): 13–21. https://doi.org/10.1007/s10641-006-9074-8

Novák J, Hofmann J, Hohl D, Magalhães ALB, Patoka J (2022) Enigmatic armoured catfishes (Siluriformes: Callichthyidae and Loricariidae) in ornamental aquaculture: A new insight into Neotropical fish diversity. Aquaculture 547: e737460. https://doi.org/10.1016/j.aquaculture.2021.737460

Novoa A, Dehnen-Schmutz K, Fried J, Vimercati G (2017) Does public awareness increase support for invasive species management? Promising evidence across taxa and landscape types. Biological Invasions 19(12): 3691–3705. https://doi.org/10.1007/s10530-017-1592-0

Orfinger AB, 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. Zoological Studies 57: e7.

Orfinger AB, Lai QT, Chabot RM (2019) Effects of nonnative fishes on commercial seine fisheries: Evidence from a long-term data set. Water 11(6): 1–11. https://doi.org/10.3390/w11061165

Page LM, Robins RH (2006) Identification of sailfin catfishes (Teleostei: Loricariidae) in southeastern Asia. The Raffles Bulletin of Zoology 54(2): 455–457.

Patoka J, Magalhães ALB, Kouba A, Faulkes Z, Jerikho R, Vitule JRS (2018) Invasive aquatic pets: failed policies increase risks of harmful invasions. Biodiversity and Conservation 27(11): 3037–3046. https://doi.org/10.1007/s10531-018-1581-3

Patoka J, Takdir M, Aryadi H, Jerikho R, Nilawati J, Tantu FY, Bohatá L, Aulia A, Kamal MM, Wardiatno Y, Petrtýl M (2020) Two species of illegal South American sailfin catfish of the genus *Pterygoplichthys* well-established in Indonesia. Knowledge and Management of Aquatic Ecosystems 421: 28. https://doi.org/10.1051/kmae/2020021

Parvez M, Lucas MC, Hossain M, Chaki N, Mohsin AB, Sun J, Galib SM (2023) Invasive vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*) has an impact on highly valued native fish species. Biological Invasions 13: 1–5. https://doi.org/10.1007/s10530-023-03012-8

Peplinski J, Malone MA, Fowler KJ, Potratz EJ, Pergams AG, Charmoy KL, Rasheed K, Avdieiev SS, Whelan CJ, Brown JS (2021) Ecology of Fear: Spines, Armor and Noxious Chemicals Deter Predators in Cancer and in Nature. Frontiers in Ecology and Evolution 9: 1–18. https://doi.org/10.3389/fevo.2021.682504

Phillips SJ (2017) A brief tutorial on MaxEnt. http://biodiversityinformatics.amnh.org/open_source/maxent/ [Accessed on 22 March 2023]

Phillips SJ, Dudík M (2008) Modelling of species distributions with MaxEnt: new extensions and a comprehensive evaluation. Ecography 31: 161–175. https://doi.org/10.1111/j.0906-7590.2008.5203.x

Quan H, Yang W, Tang Z, Ritchie RO, Meyers MA (2020) Active defense mechanisms of thorny catfish. Materials Today 38: 35–48. https://doi.org/10.1016/j.mattod.2020.04.028

Rao KR, Sunchu V (2017) A report on *Pterygoplichthys pardalis* Amazon sailfin suckermouth Catfishes in Freshwater tanks at Telangana state, India. International Journal of Fisheries and Aquatic Studies 5(2): 249–254.

Ragaza JA, Hossain MS, Kumar V (2021) The Potential of Invasive Alien Fish Species as Novel Aquafeed Ingredients. In: Lorenzo JM, Simal-Gandara J (Eds) Sustainable Aquafeeds CRC Press, 57–76. https://doi.org/10.1201/9780429331664-3

Saba AO, Rasli NF, Ismail A, Zulkifli SZ, Ghani IFA, Muhammad-Rasul AH, Azmai Amal MN (2020) A Report on Introduced Amazon Sailfin Catfish, *Pterygoplichthys pardalis* in Gombak Basin, Selangor, with Notes on Two Body Patterns of the Species. Pertanika Journal of Tropical Agricultural Science 43(4): 693–703. https://doi.org/10.47836/pjtas.43.4.19

Samat A, Yusoff FM, Arshad A, Gaffar MA, Nor SM, Magalhaes ALB, Das SK (2016) Reproductive biology of the introduced sailfin catfish *Pterygoplichthys pardalis* (Pisces: Loricariidae) in Peninsular Malaysia. Indian Journal of Fisheries 63(1): 35–41. https://doi.org/10.21077/ijf.2016.63.1.44937-05

Sinha RK, Sinha RK, Sarkar UK, Lakra WS (2010) First record of the southern sailfin catfish, *Pterygoplichthys anisitsi* Eigenmann & Kennedy, 1903 (Teleostei: Loricariidae), in India. Journal of Applied Ichthyology 4(26): 606–608. https://doi.org/10.1111/j.1439-0426.2010.01474.x

Wakida-Kusunoki AT, Ruiz-Carus R, Amador-del-Angel E (2007) Amazon sailfin catfish, *Pterygoplichthys pardalis* (Castelnau, 1855) (Loricariidae), another exotic species established in southeastern Mexico. The Southwestern Naturalist 52(1): 141–144. https://doi.org/10.1894/0038-4909(2007)52[141:ASCPPC]2.0.CO;2

Ward DF (2007) Modelling the potential geographic distribution of invasive ant species in New Zealand. Biological Invasions 9: 723–735. https://doi.org/10.1007/s10530-006-9072-y

Wu LW, Liu CC, Lin SM (2011) Identification of exotic sailfin catfish species (*Pterygoplichthys*, Loricariidae) in Taiwan based on morphology and mtDNA sequences. Zoological Studies 50(2): 235–246.

Yen MD (2021) Status and Management of Invasive Alien Species (IAS) in Vietnam. In: Pullaiah T, Ielmini MR (Eds) Invasive alien species: observations and issues from around the world. John Wiley & Sons, 226–243. https://doi.org/10.1002/9781119607045.ch23

Yonvitner Y, Patoka J, Yuliana E, Bohatá L, Tricarico E, Karella T, Kouba A, Reynolds JD (2020) Enigmatic hotspot of crayfish diversity at risk: invasive potential of non-indigenous crayfish if introduced to New Guinea. Aquatic Conservation 32: 219–224. https://doi.org/10.1002/aqc.3276

Zambrano L, Martínez-Meyer E, Menezes N, Peterson AT (2006) Invasive potential of common carp (*Cyprinus carpio*) and Nile tilapia (*Oreochromis niloticus*) in American freshwater systems. Canadian Journal of Fisheries and Aquatic Sciences 63(9): 1903–1910. https://doi.org/10.1139/f06-088

Supplementary material 1

Records of *Pterygoplichthys* spp., sample questions asked to different stakeholders and pieces of filleted *Pterygoplichthys* spp.

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Data type: docx

Explanation note: **table S1.** Records of *Pterygoplichthys* spp. based on newspaper reports from 2014–2021 from different regions of Bangladesh, with locality, GPS coordinates and names of water bodies. **table S2.** Sample questions asked to different stakeholders. **fig. S1.** Pieces of filleted *Pterygoplichthys* spp. (a) and flesh cooked with different vegetables and spices (b), (c).

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