



Dominance of Intergrades of Invasive Suckermouth Armoured Catfishes *Pterygoplichthys* spp. (Siluriformes: Loricariidae) in Coastal Wetlands of West Bengal, India

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Unauthorized introduction of South American suckermouth armoured catfishes (Loricariidae) of the genus *Pterygoplichthys* into the waste water beries of East Kolkata Wetland, West Bengal has led to their noticeable naturalization in this ecosystem. A total of 439 specimens collected during this study were externally evaluated for affirming the species identity. Morphometric traits of the specimens were found to have unimodal distribution, but pattern of body colouration, especially of the belly (the main diagnostic character for the species identification of this genus) were found to be very diverse. Abdominal patterns analysis revealed that 27% specimens were closely related to *Pterygoplichthys pardalis* or *Pterygoplichthys disjunctivus* and remaining 73% have intermediary coloration pattern of unknown identity. Forty one specimens were identified as *P. disjunctivus* with abdominal pattern including light and dark vermiculations formed as a result of coalescence of spots and seventy seven has discrete black spots on the ventral side of the body identical to *P. pardalis*. All the 22 sampling localities were found to be dominated by intermediary forms, which are possibly the introgressive hybrids between *P. pardalis* and *P. disjunctivus*, or specific *Pterygoplichthys* species with varied abdominal pattern as they have significant plasticity to change the colour. To affirm the species identity it is recommended that multiple molecular tools be used in future studies.

(**Keywords:** East Kolkata Wetlands, *Pterygoplichthys*, Intergrades, Abdominal colour pattern)

Deliberated or accidental introduction of exotic fishes is one of the major causes of erosion or devastation of the native fish biodiversity in freshwater ecosystems worldwide (Singh and Lakra, 2011; De Silva *et al.*, 2009; Garcia-Berthou, 2007). When exotic species naturalize in an ecosystem it not only mischaracterizes the ecological niches, but also impose high economic costs to the society through predation or competition of native species, spreading parasites or pathogens or causing unexpected hybridization (Ribeiro and Leunda, 2012; McCrary *et al.*, 2007). The genus *Pterygoplichthys* belonging to the family Loricariidae (armoured catfishes), are among one of the exotic fish groups most seriously threatening tropical and subtropical freshwater regions (Chavez *et al.*, 2006; Liang *et al.*, 2005). Inhabited to freshwater habitats of the South and Central America, these catfishes begun to appear outside of their native range in the second half of the 20th century first in Central America (Bunkley-Williams *et al.*, 1994), southern states of the USA (Nico and Martin, 2001) and in the Pacific Islands (Hoover *et al.*, 2004). Later, with growing popularity as aquarium pets due to their attractive appearance (Wu *et al.*, 2011), these fishes

accidentally or intentionally got introduced and subsequently established in inland water bodies of many countries across the world (Table 1). All four common species of this genus, viz., *Pterygoplichthys pardalis*, *P. multiradiatus*, *P. anisisti* and *P. disjunctivus* has also been reported from inland water bodies of India (Table 2).

Excellent tolerability to highly polluted water, tolerability to low oxygen concentrations or desiccation (up to 20 hours) (Armbruster, 1998), ability to down regulate metabolism during periods of scarcity of food (German *et al.*, 2010), multiple-spawning reproduction, nest construction and parental care (Tello *et al.*, 1992); lack of predators of adults in invaded areas due to spiny fins and hard external 'armour' (Liang *et al.*, 2005) ameliorated its invasion in wide parts of the world. They can be found in highland streams to lowland rivers and stagnant water bodies (Gestring *et al.*, 2010), acidic to alkaline waters (pH 5.5 to 8.0) (Mendoza *et al.*, 2009), pure water to polluted waters (Chavez *et al.*, 2006). Even some species of this genus are salt tolerant (Mendoza *et al.*, 2009) and some species can thrive at elevations of up to 3,000 m (Wakida-Kusunki *et al.*, 2007).

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Table 1. Invasion records of Suckermouth Sailfin Catfishes (*Pterygoplichthys* spp.) in the world

Continent	Country	Authors
Native range:		
South America	Brazil & Peru	Weber, 2003; Page and Robins, 2006
Invaded to:		
Asia	Bangladesh	Hossain <i>et al.</i> , 2008
	India	Krishnakumar <i>et al.</i> , 2009; Panikkar <i>et al.</i> , 2015; Bijukumar <i>et al.</i> , 2015; Mogalekar <i>et al.</i> , 2017
	Indonesia	Kottelat <i>et al.</i> , 1993, Page and Robins, 2006
	Israel	Golani and Snovsky, 2013
	Japan	Golani and Snovsky, 2013;
	Malaysia	Page and Robins, 2006; Samat <i>et al.</i> , 2008
	Philippines	Nakabo, 2002; Chavez <i>et al.</i> , 2006
	Turkey	Ozdilek, 2007
	Taiwan	Liang <i>et al.</i> , 2005; Wu <i>et al.</i> , 2011
	Singapore	Page and Robins, 2006
	Sri Lanka	Sumanasinghe and Amarasinghe, 2013
	Vietnam	Levin <i>et al.</i> , 2008; Zworykin and Budaev, 2013
Europe	Italy	Piazzini <i>et al.</i> , 2010
	Poland	Keszka <i>et al.</i> , 2008
North America	Mexico	Wakida-Kusonoki <i>et al.</i> , 2007; Capps <i>et al.</i> , 2011
	USA	Capps, 2008; Gibbs <i>et al.</i> , 2008; Pound <i>et al.</i> , 2011
	Puerto Rico	Bunkley-Williams <i>et al.</i> , 1994

Table 2. *Pterygoplichthys* reported from different inland water bodies of India

Species	Distribution	Reference
<i>P. pardalis</i>	Manimuthar dam on river Tambaraparani in southern Tamil Nadu Cauvery river system of peninsular India Freshwater tanks of Jangaon, Telangana	Mogalekar <i>et al.</i> , 2017 Murugan <i>et al.</i> , 2015 Rama Rao and Sunchu, 2017
<i>P. disjunctivus</i>	Cauvery river system of peninsular India Gomti river	Panikkar <i>et al.</i> , 2015 NBFGR, 2009
<i>P. multiradiatus</i>	Vembanad lake, Kerala Akkulam lake, Kerala	Krishnakumar <i>et al.</i> , 2009 Baiju, 2009
<i>P. anisisti</i>	River Ganga near Patna and Gomti near Lucknow, North India	Singh and Lakra, 2011
<i>P. disjunctivus</i> and <i>P. pardalis</i> (both)	Drainages of Thiruvananthapuram city, Kerala Vellayani lake, Kerala	Bijukumar <i>et al.</i> , 2015 Reenamole and Ambili, 2016
Intermediary forms of <i>Pterygoplichthys</i>	Drainages of Thiruvananthapuram city, Kerala Vellayani lake, Kerala	Bijukumar <i>et al.</i> , 2015 Reenamole and Ambili, 2016

Within the genus *Pterygoplichthys* four species viz. *Pterygoplichthys anisisti*, *P. multiradiatus*, *P. pardalis* and *P. disjunctivus* have closely related character and are distinguished mainly based on their ventral spot patterns (Armbruster and Page, 2006; Weber, 1992). While *P. disjunctivus* has reticulate dark pattern on the ventral

surface, *P. pardalis* has a spotted pattern (Armbruster and Page, 2006). Occurrences of these two species in wide parts of the world were extensively reported (Hussan, 2016; Murugan *et al.*, 2015; Sumanasinghe and Amarasinghe, 2013; Golani and Snovsky, 2013; Zworykin and Budaev, 2013; Ozdilek, 2007). But in

recent time reports of coexistence of large number of intermediate forms of these two species (Zworykin and Budaev, 2013; Jumawan *et al.*, 2011; Wu *et al.*, 2011), possibly due to natural or artificial hybridization (Nico *et al.*, 2012; Wu *et al.*, 2011; Hoover *et al.*, 2004), further complicated the identification of these fishes to species level. In India occurrence of intermediary forms of *Pterygoplichthys* of unknown identity together with *P. disjunctivus* and *P. pardalis*, from the drainages of Thiruvananthapuram city, Kerala (Bijukumar *et al.*, 2015) and from Vellayani Lake, Kerala (Reenamole and Ambili, 2016) were reported. This paper documents the extensive occurrence of intermediary forms of *Pterygoplichthys* together with specific species, *Pterygoplichthys aff. pardalis* and *Pterygoplichthys aff. disjunctivus* in the bheries of East Kolkata Wetlands (EKW).

MATERIALS AND METHODS

Description of the Study Area

East Kolkata Wetlands (EKW), a complex of natural and man-made wetlands with rich biodiversity lying approximately between 22° 25' – 22° 40' North latitude and 88° 20'– 88° 35' East longitude, is the only Ramsar site in West Bengal and largest among the 26 Ramsar sites in India (Ramsar, 2013).

Sampling, identification and analysis

Fishes were collected from the bheries of Jagrasisha and Bantala area under EKW, using drag net during the period July to December, 2017. A total of 439 adult specimens of *Pterygoplichthys* were collected from 22 bheries (sampling localities) covering approx 31 ha water body. Specimens collected were identified based on keys provided by Zworykin and Budaev (2013), Jumawan *et al.* (2011) and Wu *et al.* (2011). As colouration pattern of the belly, represents the key character for the species identification of many catfishes of the genus *Pterygoplichthys* (Zworykin and Budaev, 2013; Jumawan *et al.*, 2011; Wu *et al.*, 2011; Armbruster and Page, 2006; Weber, 1992). We photographed the dorsal part of the body of all 439 specimens under standard condition using Canon EOS 30D digital camera equipped with the Canon EF macro lens, 100 mm F/2.8 and then images were carefully compared with images provided by Zworykin and Budaev (2013); Jumawan *et al.* (2011) and Wu *et al.* (2011). Morphometric and meristic characters of the specimens were also examined following the methods suggested by Weber (1992), Armbruster (2003) and Armbruster and Page (2006).

Measurements were taken with digital caliper to the nearest 0.1 mm and weight to the nearest 0.01 g using a digital balance.

RESULTS AND DISCUSSIONS

Species delineation within the genus *Pterygoplichthys* (Fig. 1) is hard, primarily because the four closely related species such as *P. anisitsi*, *P. multiradiatus*, *P. pardalis* and *P. disjunctivus*, which are distinguished only based on the nature of their abdominal spots and patterns (Nico *et al.*, 2012; Armbruster and Page, 2006; Chavez *et al.*, 2006; Page and Robins, 2006). In EKW, among the total 439 specimens evaluated, we found forty one specimens (9%) has abdominal colour pattern resembling to *P. disjunctivus* (Fig. 2) with light and dark vermiculations formed as a result of coalescence of spots and seventy seven (17%) seven has discrete black spots on the ventral side of the body identical to *P. pardalis* (Fig. 3). Weber (1991, 1992) concluded that both *P. disjunctivus* and *P. pardalis* possess a pattern of coalesced dark spots on a light background in the abdominal region and difficult to identify from dorsal view. Altogether these two species contributed only about 27% of the population of these fishes in EKW and remaining population (73%) with intermediate abdominal patterns (Fig. 4), not fully

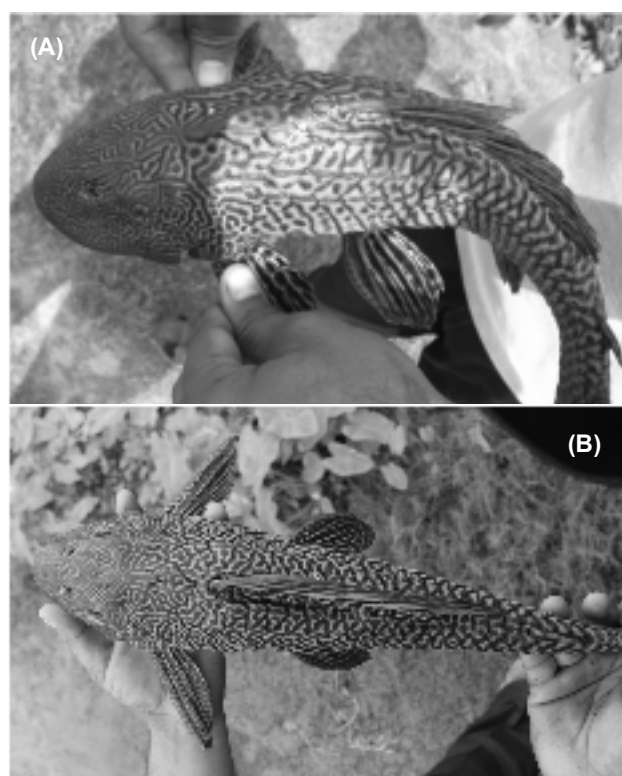


Fig. 1. Adult specimen identified as (A) *Pterygoplichthys aff. pardalis* and (B) *Pterygoplichthys aff. disjunctivus*



Fig. 2. *Pterygoplichthys* aff. *disjunctivus* from EKW (Based on Wu *et al.* 2011)



Fig. 3. *Pterygoplichthys* aff. *pardalis* from EKW (Based on Wu *et al.* 2011)



Fig. 4. Series of intergrades of *Pterygoplichthys* found in EKW, West Bengal

resembling with any specific species of *Pterygoplichthys*, as identified based on the abdominal markings (Zworykin and Budaev, 2013; Jumawan *et al.*, 2011; Wu *et al.*, 2011) might be the groups of species *P. pardalis* or *P. disjunctivus* or hybrid population of these two species. Nico *et al.* (2012) noted extensive variations among introduced populations of *Pterygoplichthys* and described the individuals' characters not identical to any specific species as "hybrid swarms". Wu *et al.* (2011) hypothesised possibility of hybridization between introduced/invaded *Pterygoplichthys* species. Jumawan *et al.* (2011) though inferred the possibility of hybridization between *P. pardalis* and *P. disjunctivus* resulting individuals with intermediary color pattern in

Marikina river, Philippines; they also not discounted the likelihood of presence of the same *Pterygoplichthys* species with variable abdominal patterns in that River. Variations in the abdominal patterns noticed in the intermediary forms during present study (Fig. 4), may be results of the significant plasticity of these species to change their coloration. Zworykin and Budaev (2013) from the experience of the local fishermen of Vietnam reported that *Pterygoplichthys* have significant ability to change their colouration. These fishes when transferred from river to ponds for growing, they become darker, light stripes and spots become narrower and often completely disappear on the head, flanks and the back. Chavez *et al.* (2006) also reported significant variability of colouration patterns in armoured catfishes.

The morphometric and meristic characters of the specimens though affirm the occurrence of the genus *Pterygoplichthys* in EKW (Table 3 & 4), however no significant difference in these characters among the specimens with different abdominal color pattern was recorded. Our findings are consistent with the findings of Zworykin and Budaev (2013), Armbruster and Page (2006) and Chavez *et al.* (2006) who noted coinciding modal values for most of morphometric and meristic traits between *P. pardalis* and *P. disjunctivus*. Dorsal pattern of the specimens were found to have limited variability (Fig. 5). Specimens looking alike from dorsal side were found to have different abdominal coloration and vice versa.

All 22 sample localities contained individuals with intermediate abdominal pattern. They occupied >80% of the *Pterygoplichthys* populations in 7 localities, and > 85% in 2 localities. Sixteen of the 22 sample localities presented the coexistence of *P. pardalis*, *P. disjunctivus* and intermediary forms. But *Pterygoplichthys pardalis* was not recorded in 4 localities of Bantala area; while

Table 3. Meristic counts of *Pterygoplichthys* collected from EKW

Sl. No.	Characters	Counts
1.	Dorsal fin rays (DFR)	13-15
2.	pectoral fin rays (PCFR)	6-7
3.	Pelvic fin rays (PLFR)	6
4.	Anal fin rays (AFR)	5
5.	Caudal fin rays (CFR)	14-16
6.	Lateral line plates (LLP)	28-31
7.	Abdominal plates (AP)	6-7
8.	Dorsal plates (DP)	3-5



Fig. 5. Dorsal view of *Pterygoplichthys* specimens collected from EKW

P. disjunctivus was absent in two localities of Jagrasisha area. Grosholz (2002) indicated that, exotic populations can gain higher genetic variation if multiple invasions or hybridization occurs. Superiority of hybrids in terms of higher growth and swimming endurance of the native Pecos pupfish (*Cyprinodon pecosensis*) and the invasive Sheephead minnow (*Cyprinodon variegatus*) was reported from North America (Rosenfield *et al.*, 2004). In case of *Pterygoplichthys*, though Wu *et al.* (2011) speculated “hybrid superiority” of *P. pardalis* x

P. disjunctivus over these species, increasing the fitness of offspring of hybrids in novel environments. Jumawan *et al.* (2010, 2011) reported no significant differences in the reproductive phenology patterns, fecundity and gonad characteristics of the intergrades (possible hybrids) compared to *P. pardalis* and *P. disjunctivus*. But *Pterygoplichthys*, regardless of “hybrid” or not was reported to possess very high tolerance to poor water conditions and often dominating the ichthyofauna of polluted, hypoxic waters with rich organic load (Jumawan *et al.*, 2011). Large quantities of dead and dried *Pterygoplichthys* recorded in the pond embankment of East Kolkata Wetland during present study and also as reported by Hussan *et al.* (2016) indicated the severity of invasion of these fishes in EKW. Colloquially called as the “Kidneys of Kolkata”, this “Wetland of International Importance” which supplies about 15000 MT of fish per annum from its 264 functioning aquaculture ponds, locally called bheries (East Kolkata Wetlands Newsletter, 2010) with an yield of 3 to 5 t ha⁻¹ year⁻¹ (Bunting *et al.*, 2002), is under severe

Table 4. Morphometric measurements of *Pterygoplichthys* collected from EKW

Sl. No.	Characters	Range (mm)	Mean ± SD (in mm)
1.	Total length (TL)	255 - 426	352.1 ± 58.1
2.	Fork length (FL)	231 - 386	320.4 ± 53.1
3.	Standard length (SL)	207 - 335	273.4 ± 45.5
4.	Head length (HL)	35 - 61	49 ± 8.5
5.	Head Depth (HD)	26 - 39	33.1 ± 4.6
6.	Body depth (BD)	33 - 55	43.4 ± 7.7
7.	Mouth length (ML)	20 - 29	25.3 ± 3.0
8.	Mouth width (MW)	23 - 39	32.4 ± 4.8
9.	Eye diameter (ED)	8 - 12	10 ± 1.3
10.	Snout length (SNL)	21 - 35	28.3 ± 4.9
11.	Barbel length (BL)	13 - 22	17.7 ± 3.2
12.	Dorsal fin base length (DFBL)	74 - 116	94.8 ± 12.2
13.	Pectoral fin base length (PFBL)	16 - 24	19.2 ± 3.0
14.	Anal fin base length (AFBL)	10 - 18	13.4 ± 2.6
15.	Caudal peduncle depth (CPD)	17 - 37	25.8 ± 6.4
16.	Dorsal spine length (DSL)	46 - 70	58.3 ± 8.3
17.	Pectoral spine length (PCSL)	59 - 93	76.7 ± 10.2
18.	Pelvic spine length (PESL)	39 - 65	52.9 ± 8.2
19.	Anal fin spine length (AFSL)	30 - 49	41.4 ± 6.4
20.	Adipose spine length (ASL)	12 - 19	15.9 ± 2.2
21.	Length of first caudal fin ray (LFCFR)	54 - 87	73.5 ± 9.8
22.	Length of last caudal fin ray (LLCFR)	51 - 81	68.1 ± 10.8

threat from the fishes of the genus *Pterygoplichthys*, as mass reproduction of these catfishes are reported to cause noticeable threat on the ecosystem and biodiversity (Zworykin and Budaev, 2013; Hoover *et al.*, 2004). In the Chacamax river, population of these fishes reportedly attained a biomass two orders of magnitude larger than native fishes, and substantially altered the amount of N and P stored in the system (Wakida-Kusunoki *et al.*, 2007). The environmental and ecological effects of the *Pterygoplichthys* sp. include disruption of food web by overgrazing on the benthic algae and detritus, creating floating mats that shade the benthos from sunlight, decline in abundance of native species due to competition and egg destruction, changes in pond bottom and dyke due to ploughing and burrowing habit, damages to the fishing gears and mortality of aquatic birds (Mendoza *et al.*, 2009; Hoover *et al.*, 2004). A constant declining trend in native fish species yield due to high invasion of *Pterygoplichthys* spp. in the drainages of Thiruvananthapuram city, Kerala was reported by Bijukumar *et al.* (2015). Displacement of several species of minnow including the Federally threatened and 'Vulnerable (VU)' Devils river minnow (*Dionda diabolii*) in Texas was reported (Mendoza *et al.*, 2009). *P. pardalis* has been reported to contribute about 21% of the commercial fishery of the Pologolla reservoir of Sri Lanka, largely displacing the native cichlid fisheries of the reservoir (Sumanasinghe and Amarasinghe, 2013).

It is unknown whether the population of *Pterygoplichthys* that established in the EKW is a result of single penetration or separate population invasions or got unintentionally introduced in EKW system. It is also not clear whether the intergrades population that at present dominate the population of *Pterygoplichthys* in EKW are individual species or hybrid of the species that are identified as *Pterygoplichthys* aff. *pardalis* and *Pterygoplichthys* aff. *disjunctivus*. Whatsoever the species be, it is clear from the study that *Pterygoplichthys* has invaded extensively the EKW ecosystem with self-sustaining populations and are affecting aquaculture scenario of this ecosystem.

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REFERENCES

- Armbruster, J. W. (1998). Modifications of the digestive tract for holding air in loricariid and scoloplacid catfishes. *Copeia* **3**: 663-675. <https://doi.org/10.2307/1447796>
- Armbruster, J. 2003. The species of the *Hypostomus* cochliodon group (Siluriformes: Loricariidae). *Zootaxa* **249**: 1-60.
- Armbruster, J. W. and Page, L. M. (2006). Redescription of *Pterygoplichthys punctatus* and description of a new species. *Neotropical Ichthyology* **4**: 401-409.
- Baiju, P. T. (2009). Population status of exotic catfish *Pterygoplichthys multiradiatus* (Hancock) in the feeder canals of Akkulam lake, Thiruvananthapuram, Kerala. *Dissertation, University of Kerala, India*.
- Bijukumar, A., Smrithy, R., Sureshkumar, U. and George, S. (2015). Invasion of south american suckermouth armoured catfish *Pterygoplichthys* spp (Loricariidae) in Kerala, India- a case study. *Journal of Threatened Taxa* **7**(3): 6987-6995.
- Bunkley-Williams, L., Williams Jr, E. H., Lilystrom, C. G., Corujo-Flores, I., Zerbi, A. J. and Aliaume, C. (1994). The south american sailfin armored catfish, *Liposarcus multiradiatus* (Hancock), a new exotic established in Puerto Rican fresh waters. *Caribbean Journal of Science* **30**(1-2): 90-94.
- Bunting, S. W., Kundu, N. and Mukherjee, M. (2002). *Situation Analysis: Production Systems and Natural Resource Management* in PU Kolkata. Institute of Aquaculture, University of Stirling, UK.
- Capps, K. (2008). The impacts of sailfin catfish (Siluriformes: Loricariidae) on invaded freshwater ecosystems. Abstracts of *Annual Meeting of American Ichthyologist and Herpetologist Society*, July 23-28, 2008, Montreal, Canada.
- Capps, K. A., Nico, L. G., Mendoza-Carranza, M., Arevlo-Frias, W., Ropicki, A. J., Heilpern, S. A. and Rodiles-Hernandez, R. (2011). Salinity tolerance of non-native suckermouth armoured catfish (Loricariidae: *Pterygoplichthys*) in south-eastern Mexico: implications for invasion and dispersal. *Aquatic Conservation: Marine and Freshwater Ecosystems* **21**: 528-540. <https://doi.org/10.1002/aqc.1210>
- Chavez, M. J., De La Paz, R. M., Manohar, S. K., Pagulayan, R. C. and Vi, C. (2006). New Philippine record of south american sailfin catfishes (Pisces: Loricariidae). *Zootaxa* **1109**: 57-68.

- De Silva, S. S., Nguyen, T. T., Turchini, G. M., Amarasinghe, U. S. and Abery N. W. (2009). Alien species in aquaculture and biodiversity: a paradox in food production. *Ambio* **38**: 24-28.
- East Kolkata Wetlands Newsletter Volume I, (2010). New Delhi, India, 24 p.
- Garcia-Berthou, E. (2007). The characteristics of invasive fishes: what has been learned so far? *Journal of Fish Biology* **71**(Suppl. D): 33-55.
- German, D. P., Neuberger, D. T., Callahan, M. N., Lizardo, N. R. and Evans, D. H. (2010). Feast to famine: the effects of food quality and quantity on the gut structure and function of a detritivorous catfish (Teleostei: Loricariidae). *Comparative Biochemistry and Physiology* **155**: 281-293.
- Gestring, K. B., Shafland, P. L. and Stanford, M. S. (2010). Status of the exotic Orinoco sailfin catfish (*Pterygoplichthys multiradiatus*) in Florida. *Florida Scientist* **73**: 122-137.
- Gibbs, M. A., Shields, J. H., Lock, D. W., Talmadge, K. M. and Farrell, T. M. (2008). Reproduction in an invasive exotic catfish *Pterygoplichthys disjunctivus* in Volusia Blue Spring, Florida, U.S.A. *Journal of Fish Biology* **73**: 1562-1572.
- Grosholz, E. (2002). Ecological and evolutionary consequences of coastal invasions. *Trends in Ecology and Evolution* **17**: 22-27.
- Golani, D. and Snovsky, G. (2013). Occurrence of suckermouth armored catfish (Siluriformes, Loricariidae, *Pterygoplichthys*) in inland waters of Israel. *BioInvasions Records* **2**(3): 253-256. <https://doi.org/10.3391/bir.2013.2.3.13>
- Hoover, J. J., Killgore, K. J. and Cofrancesco, A. F. (2004). Suckermouth catfishes: threats to aquatic ecosystems of the United States? Aquatic Nuisance Species Research Program. Engineers Research and Development Center, Vicksburg, MS. *ANSRP Bulletin* **4**(1): 1-13.
- 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.
- Hussan, A., Choudhury, T. G., Das, A. and Gita, S. (2016). Suckermouth sailfin catfishes: a future threat to aquatic ecosystems of India. *Aquaculture Times* **2**(6): 20-22.
- Jumawan, J. C., Herrera, A. A. and Jacinto, S. D. (2010). Length-weight and gonado-morphometric characterization in the janitor fish *Pterygoplichthys disjunctivus* (Weber, 1991) from Marikina river, Philippines. In: *Transactions of the National Academy of Science & Technology*, R. Dolores (ed.), NAST-Philippines, Manila, 32: 80.
- Jumawan, J. C., Vallejo, B. M., Herrera, A. A., Buerano, C. C. and Fontanilla, K. C. (2011). DNA barcodes of the suckermouth sailfin catfish *Pterygoplichthys* (Siluriformes: Loricariidae) in the Marikina river system, Philippines: Molecular perspective of an invasive alien fish species. *Philippines Science Letter* **4**(2): 102-113.
- Keszka, S., Panicz, R. and Tanski, A. (2008). First record of the leopard pleco, *Pterygoplichthys gibbiceps* (Actinopterygii, Loricariidae) in the Brda river in the centre of Bydgoszcz (northern Poland). *Acta Ichthyologica Et Piscatoria* **38**: 135-138. doi.org/10.3750/AIP2008.38.2.08
- Krishnakumar, K., Raghavan, R., Prasad, G., Bijukumar, A., Sekharan, M. and Periera, B. (2009). When pets become pests-exotic aquarium fishes and biological invasions in Kerala, India. *Current Science* **97**: 474-476.
- Kottelat, M., Whitten, A. J., Kartikasari, S. N. and Wirjoatmodjo, S. (1993). *Freshwater Fishes of Western Indonesia and Sulawesi*, Periplus Editions, Hong Kong, 259 p.
- Levin, B. A., Phuong, P. H. and Pavlov, D. S. (2008). Discovery of the amazon sailfin catfish *Pterygoplichthys pardalis* (Castelnau, 1855) (Teleostei: Loricariidae) in Vietnam. *Journal of Applied Ichthyology* **24**: 715-717.
- Liang, S. H., Wu, H. P. and Shieh, B. S. (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.
- McCrary, J. K., Murphy, B. R., Stauffer Jr., J. R. and Hendrix, S. S. (2007). Tilapia (Teleostei: Cichlidae) status in Nicaraguan natural waters. *Environmental Biology of Fishes* **80**: 78-100.
- Mendoza, R. E., Cudmore, B., Orr, R., Balderas, S. C., Courtenay, W. R., Osorio, P. K., Mandrak, N., Torres, P. A., Damian, M. A., Gallardo, C. E., Sanguines, A. G., Greene, G., Lee, D., Orbe-

- Mendoza, A., Martinez, C. R. and Arana, O. S. (2009). *Tri-National Risk Assessment Guidelines for Aquatic Alien Invasive Species*. Commission for Environmental Cooperation 393, rue St-Jacques Ouest, Bureau 200, Montréal (Québec), Canada.
- Mogalekar, H. S., Jawahar, P., Srinivasan, A., Karal Marx, K., Sujathkumar, N. V., Canciyal, J. and Sudhan, C. (2017). Discovery of the Amazon sailfin catfish *Pterygoplichthys pardalis* (Castelnau, 1855) (Teleostei: Loricariidae) from Manimuthar dam, Tamiraparani river system. *Journal of Entomology and Zoology Studies* **5**(4): 1229-1231.
- Murugan, M., Kaliappan, M. and Muthukaruppan G. (2015). Extended distribution of the invasive sucker catfish *Pterygoplichthys pardalis* (Pisces: Loricariidae) to Cauvery river system of peninsular India. *International Journal of Aquatic Biology* **3**(1): 14-18.
- Nakabo, T. (ed.) (2002). *Fishes of Japan with Pictorial Keys to The Species* (English edition). Tokai University Press, Tokyo. 1474 p.
- NBFR, (2009). First record of the southern sailfin catfish, *Pterygoplichthys disjunctivus* from India. In: *NBFR News* **7**: 4.
- Nico, L. G. and Martin, T. R. (2001). The south american suckermouth armored catfish, *Pterygoplichthys anisitsi* (Pisces: Loricariidae), in Texas, with comments on foreign fish introductions in the American Southwest. *The Southwestern Naturalist* **46**(1): 98-104. DOI:10.2307/3672381
- Nico, L. G., Butt, P. L., Johnson, G. R., Jelks, H. L., Kail, M. and Walsh, S. J. (2012). Discovery of the south american suckermouth armoured catfish (Loricariidae, *Pterygoplichthys* spp.) in the Santa Fe river drainage, Suwannee river basin, USA. *BiolInvasions Records* **1**: 179-200. dx.doi.org/10.3391/bir.2012.1.3.04
- Ozdilek, S. Y. (2007). Possible threat for middle east inland water: an exotic and invasive species, *Pterygoplichthys disjunctivus* (Weber, 1991) in Asi river, Turkey (Pisces: Loricariidae). *Egyptian Journal of Aquatic Biology and Fisheries* **24**(3-4): 303-306.
- Page, L. M. and Robins, R. H. (2006). Identification of sailfin catfishes (Teleostei: Loricariidae) in south-eastern Asia. *Raffles Bulletin of Zoology* **54**: 455-457.
- Panikkar, P., Jagadeesh, T. D., Rao, D. S. K., Sarkar, U. K. and Naska, M. (2015). First record of non-native loricariid catfish, *Pterygoplichthys disjunctivus* (Weber, 1991) (Siluriformes, Loricariidae) in Cauvery river of peninsular India. *The Bioscan* **10**: 1659-1663.
- Piazzini, S., Lori, E., Favilli, L., Cianfanelli, S., Vanni, S. and Manganelli, G. (2010). Invasion note: a tropical fish community in thermal waters of southern Tuscany. *Biological Invasions* **12**: 2959-2965. <https://doi.org/10.1007/s10530-010-9695-x>
- Pound, K. L., Nowlin, W. H., Huffman, D. G. and Bonner, T. H. (2011). Trophic ecology of a nonnative population of suckermouth catfish (*Hypostomus plecostomus*) in a central Texas spring-fed stream. *Environmental Biology of Fishes* **90**: 277-285. <http://dx.doi.org/10.1007/s10641-010-9741-7>
- Rama Rao, K. and 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.
- Ramsar Secretariat, (2013). *The List of Wetlands of International Importance*. The Secretariat of the Convention on Wetlands, Gland, Switzerland.
- Reenamole, G. R. and Ambili, T. (2016). Occurrence of suckermouth armoured sailfin catfishes in Vellayani fresh water lake, Kerala, southwest coast of India. *International Journal of Scientific Research* **5**(3): 1142-1145.
- Ribeiro, F. and Leunda, P. M. (2012). Non-native fish impacts on Mediterranean freshwater ecosystems: current knowledge and research needs. *Fisheries Management and Ecology* **19**: 142-156.
- Rosenfield, J. A., Nolasco, S., Lindauer, S., Sandoval, C. and Kodric-Brown, A. (2004). The role of hybrid vigor in the replacement of Pecos pupfish by its hybrids with sheepshead minnow. *Conservation Biology* **18**: 1589-1598.
- Samat, A., Shukor, M. N., Mazlan, A. G., Arshad, A. and Fatimah, M. Y. (2008). Length-weight relationship and condition factor of *Pterygoplichthys pardalis* (Pisces: Loricariidae) in Malaysia peninsula. *Research Journal of Fisheries and Hydrobiology* **3**: 48-53.
- Singh, A. K. and Lakra, W. S. (2011). Risk and benefit assessment of alien fish species of the aquaculture and aquarium trade into India. *Reviews in Aquaculture* **3**: 3-18.

- Sumanasinghe, H. P. W. and Amarasinghe, U. S. (2013). Population dynamics of accidentally introduced Amazon sailfin catfish, *Pterygoplichthys pardalis* (Siluriformes, Loricariidae) in Pologolla reservoir, Sri Lanka. *Sri Lanka Journal of Aquatic Sciences* **18**: 37-45. doi.org/10.4038/sljas.v18i0.7040
- Tello, J. S., Montreuil, V. H., Maco, J. T., Ismino, R. A. and Sanchez, H. (1992). Bioecología de peces de importancia económica de la parte inferior de los ríos Ucayali y Marañon, Peru. *Folia Amazonica* **4**: 87-107.
- Wakida-Kusunoki, A. T., Ruiz-Carus, R. and Amador-del-Angel, E. (2007). Amazon sailfin catfish, *Pterygoplichthys pardalis* (Castelnau, 1855) (Loricariidae), another exotic species established in southeastern Mexico. *The Southwestern Naturalist* **52**: 141-144. doi:10.1894/0038-4909(2007)52[141:ASCPPC]2.0.CO;2
- Weber, C. (1991). Nouveaux taxa dans *Pterygoplichthys sensu lato* (Pisces, Siluriformes, Loricariidae). *Revue suisse de Zoologie* **98**: 637-643.
- Weber, C. (1992). Revision du genre *Pterygoplichthys sensu lato* (Pisces, Siluriformes, Loricariidae). *Revue Francaise d'Aquariologie Herpetologie* **19**: 1-36.
- Weber, C. (2003). Loricariidae - Hypostominae (Armored catfishes). In: *Checklist of the Freshwater Fishes of South and Central America*, R.E. Reis; S.O. Kullander; and C.J. Ferraris Jr. (eds.), Porto Alegre: EDIPUCRS, Brasil. pp 351-372.
- Wu, L. W., 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.
- Zworykin, D. D. and Budaev, S. V. (2013). Non-indigenous armoured catfish in Vietnam: invasion and systematic. *Ichthyological Research* **60**(4): 327-333. dx.doi.org/10.1007/s10228-013 0356-9.