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Suckermouth armoured catfish (*Pterygoplichthys* spp.) menace in freshwater aquaculture and natural aquatic systems in Andhra Pradesh, India

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Abstract
Suckermouth armoured catfish (*Pterygoplichthys* spp.) which is popularly called “Devil fish” in Andhra Pradesh, was recorded in 93.33% of fish ponds out of 600 ha surveyed in Krishna and West Godavari districts including mesohaline ponds wherein salinity ranges from 2 to 20‰. *Pterygoplichthys* spp. have ranged from 150 to 600 kg/ha that accounts to 2.01-7.50% of total biomass of fish harvested in aquaculture ponds leading to escalation of feed conversion ratio by 25.76%. Consequently, carp production has diminished by 18.88% to 22.92% leading to economic losses to fish farmers up to 13.40%. Food chain disruption by this alien fish is not only confined to benthic algae and periphyton but also foraging on supplementary feeds leaving primary fishes deprived from availing feed. Abundance of *Pterygoplichthys* spp populations in culture ponds as also in canals was high in monsoon season when compared to winter. Invasion and abundance of *Pterygoplichthys* spp in various river systems in Andhra Pradesh has become major concern for fishers causing extensive damage to nets and gears as also retarded catch per unit effort resulting in minimization of their income by 30%. Efforts to extract fish hydrolysate from *Pterygoplichthys* spp were futile due to intense bony skeleton and poor recovery rate which projected utilization of this fish for allied activities to minimum. Abundance of *Pterygoplichthys* spp is increasing in confined and open water bodies due to their tolerance and ability to grow and breed in variety of aquatic habitats including polluted environments as also lack of effective predators thus poses a high risk and threat to native freshwater species in any ecosystem in which they get established.

Keywords: *Pterygoplichthys* spp, invasive magnitude, freshwater aquaculture, natural waters, production and economic loss

1. Introduction
Introduction of exotic species in India has an early record with exotic carps being introduced in aquaculture for increasing the fish yield (Vishnubhat and Singh, 2014) [1]. In the past few decades, non-native fish species were introduced in India either purposefully, or by chance for the purpose of improving aquaculture productions, filling vacant niches in natural ecosystems (Singh, 2014; Strayer, 2010) [2,3], aquarium trade, therapeutic value, research and biological control (Singh and Lakra 2011) [4]. In several instances, various considerations such as the impact of alien species on the environment, economic, biodiversity and chances of disease transmission were not evaluated before importation (Singh and Lakra, 2006) [5]. Most of the alien fishes are having the advantage of the aquarium business and one third of the global aquatic intrusive species are of aquarium or ornamental fishes (Markusknight, 2010) [6].
Suckermouth armoured catfish (*Pterygoplichthys* spp.), a native to South America and a popular aquarium species was initially captured in West Bengal along with other native species and further spread into open waters in several states like Andhra Pradesh (Singh and Lakra, 2011) [4], Bihar (Singh, 2014) [2], Kerala (Krishnakumar *et al*., 2009; Bijukumar *et. al*., 2015) [7, 8], Tamil Nadu (Panikkar *et. al*., 2015; Moorthy *et al*., 2016) [9, 10], Telangana (Laxmappa, 2016; Ramarao and Venugopal, 2017) [11, 12]. These catfish have a hard external armor and are highly tolerant to low dissolved oxygen with no value as a food fish besides no established predation pressure (Ghosal, 2018, Karunarathna *et al*., 2008) [13, 14].

Pterygoplichthys spp which is popularly called "Devil fish" in Andhra Pradesh has been identified as a great threat to freshwater diversity because; this species will not only out-compete the native algae consumers, but have the ability to alter physico-chemical parameters (Hoover *et al.*, 2004; Pandit and Raul, 2017) [15,16]. The Present study is aimed to assess the degree of invasion of devil fish (Suckermouth armoured catfish; *Pterygoplichthys* spp.) into freshwater aquaculture ponds and river systems in Krishna-Godavari Delta due to which fish production not only declined drastically but resulted in inferior feed conversion ratio as well as under production.

2. Materials and Methods

Members of the family Loricariidae (Order: Siluriformes) which belong to genus *Pterygoplichthys* inhabit freshwater habitats in tropical America, are commonly referred to as sailfin catfish or common pleco or suckermouth armoured catfishes (Page and Robins, 2006) [17] and have become popular as pets in aquarium because of their ability to remove the algae (Wu *et al*., 2011) [18]. Most of the loricariids are characterized by a depressed body, covered by armoured and flexible bony plates, radiating lines on the head, leopard patches on the body, unique pair of maxillary barbells and ventrally placed suctorial mouth (Nico *et al*., 2014) [19]. Majority of the species in this family are often hybridized among stocks for better varieties for aquarium trade and hence, more often the identity of individual species is uncertain and ambiguous (Krishnakumar *et al*., 2009) [7].

South American suckermouth armoured catfish (*Pterygoplichthys* spp) populations have established populations globally in tropical and subtropical freshwater systems and have become one of the worst invading fishes in the nations where they have registered accidentally or through other processes (Ramarao and Venugopal, 2017) [12]. The Present study was based on a field survey (Cresswel, 2013; Glasow, 2005) [20,21] carried out in freshwater aquaculture ponds located in Krishna and Godavari Districts during September 2016 to August 2017 following reports published in newspapers (Akbar, 2016; Manasa, 2016) [22,23] and representations received from fish farmers. Eight experimental sites (ES-1 to ES-8) *viz*., Ilaparru (ES-1; 16.5617° N, 81.0599° E), Polukonda (ES-2; 16.5199° N, 81.0789° E), Pallevada (ES-3; 16.5777° N, 81.2890° E) and Bhavadevarapalli (ES-4; 15.9618° N, 80.9595° E) in Krishna District and Akividu (ES-5; 16.5823° N, 81.3784° E), Kalla (ES-6; 16.5374° N, 81.4087° E), Pedapadu (ES-7; 16.6370° N, 81.0334° E) and Dosapadu (ES-8; 16.7405° N, 81.2009° E) in West Godavari District were selected for conducting a survey to assess the degree of menace by *Pterygoplichthys* spp. in fish ponds. Experimental sites were selected based on their location nearer to open water channels that supply water to aquaculture ponds as also where devil-fish (*Pterygoplichthys* spp) menace was complained to be high. Data was collected from 40 farms measuring 10-20 ha extending in a total area of 600 ha were surveyed using open ended questions (Gendall *et al*., 1996) [24]. Out of eight experimental stations, two stations *viz.*, Bhavadevarapalli (ES-4) and Kalla (ES-6) were located in low and mesohaline coastal areas (salinity range 2 to 20‰) in order to document *insitu* occurrence of non-native *Pterygoplichthys* spp. in coastal water culture systems.

Presence of *Pterygoplichthys* spp in River Krishna and canals was substantiated through face to face interviews (Mathers *et al*., 2007) [25] with active fishermen living in Ferry (ES-9; 16.58003° N, 80.51475° E), Tummalapalem (ES-10; 16.57060° N, 80.52918° E), Prakasam barrage, Sitanagaram (ES-11; 16.49979° N, 80.60056° E) and Penamaluru (ES-12; 16.46959° N, 80.749958° E) landing centres during study period (Fig. 1).

3. Results and Discussion

Results comprised in the present study have accrued from 600 ha of aquaculture ponds located in Krishna and Godavari Districts (ES-1 to ES-8) which were predominantly performing carp culture involving Rohu (*Labeo rohita*) and Catla (*Catla catla*) with an average fish production ranging from 9000-10000 kg^{-1ha} per year (Ramakrishna *et al*. 2013) [26] as also data pooled from active fishermen who are depending on River Krishna for fishing (ES-9 to ES-12).

3.1 Effect on Carp Production

Early records of presence of *Pterygoplichthys pardalis* in natural water bodies as well as aquaculture ponds in Andhra Pradesh were found in 2014 (Singh, 2014) [2]. Subsequently, it has established to breed profusely in wetlands as well as aquaculture ponds wherein large numbers of live specimens were captured (Muralidharan *et al*., 2015) [27]. The presence of *Pterygoplichthys* spp. was recorded in 560 ha (93.33%) of fish ponds out of 600 ha surveyed during the present study in Krishna and West Godavari districts including Bavadevarapalli (ES-4) wherein fish pond salinity ranges from 2 to 20‰. In a previous study, it was reported that 83% of fish farms in East Kolkata Wetlands were invaded by *Pterygoplichthys* spp. which may be primarily be due to the convivial environment (Hussan *et al*., 2019) [28] and primary feed abundance (Ozedilek, 2007) [29].

In the current study, *Pterygoplichthys* spp. (Fig. 2) have registered a biomass ranging from 150 to 600 kg/ha that accounts to 2.01-7.50% of total biomass of fish harvested in various experimental stations. Consequently, carp production was affected by 18.88% to 22.92% in different experimental stations due to invasion of suckermouth armoured catfish (Fig. 3). Carp production was affected to lowest order (18.88%) in ponds located in Bhavadevarapalli (ES-4) wherein suckermouth armoured catfish (*Pterygoplichthys* spp) recorded minimum biomass representing 2.01% of carp production. This could be because of salinity stress and low rate of survival and multiplication of this non-native fish in saline ponds. The highest incursion of suckrmouth armoured catfish (7.50%) resulting in maximum drop-down of carp production (22.92%) was observed in ponds located in Pedapadu (ES-5) limiting the carp production to 7400 kg/ha against a real-time production of 9600 kg/ha in this region. Overall biomass (Mean±SEM) of *Pterygoplichthys* spp (suckermouth armoured catfish) in carp culture ponds was estimated to be 366.87±50.37 kg/ha (4.63%) limiting carp production to 7487.5 ± 51.25 kg/ha against a normal production of 9412.50±81.91 kg/ha and thus recorded 20.43% reduction in carp production (Table-1).

Mean annual fish harvest data in East Kolkata Wetlands revealed that *Pterygoplichthys* spp. constituted 4.83% of total fish catch (Suresh *et al*. 2019) [30] that almost conforms to 4.63% in the current study. However, Moorthy *et al* (2016) [10] recorded very high degree invasion of *Pterygoplichthys* spp up to 80% of the total fish community harvested in River Cauvery, India thus alarming about invasive pressure on native species. There were similar instances of *P. pardalis* had become established by over 70% of fishes harvested in countries like Thailand (Chaichana *et al*. 2011) [31], Taiwan (Wu *et al*., 2011) [18], Vietnam (Zworykin and Budaev, 2013) [32]. The abundance of *Pterygoplichthys* spp. in East Kolkata Wetlands up to 22 individuals per ha corresponding to the production of 450 kg/ha per year (Hussan *et al*., 2019) [28]. *Pterygoplichthys* spp. populations have the ability to withstand low dissolved oxygen content (Ambruster, 1998) [33], minimized metabolic rates (MacCormack *et al.*, 2003) [34], hostile feeding habit (Molur *et al*., 2016) [35], rapid growth (Hussan *et al*., 2019) [28], ability to breed in a variety of environments (Chaichana and Sirapat, 2012) [36] and less vulnerability to predation (Zworykin and Budaev, 2013) [32] as also withstanding poor water conditions (Welcomme and Vidthayanom, 2003) [37]. Although, Hussan *et al*. (2019) [28] has suggested multi-layer screening of the inlet water into the ponds is most suitable solution for control but, invasion of the *Pterygoplichthys* spp into fish culture ponds could not be arrested even by screening of inlet waters with monofilament screen (100 mesh/inch), thus the possible way in which they register in an ecosystem seems to be intricate. Voracious grazing on benthic algae and periphyton by *Pterygoplichthys* spp reduces food cover available for other similar fishes and aquatic insects and thus, disrupts the food web (Hoover *et al*., 2014) [38]. Observations recorded in the current study divulges that food chain disruption is confined not only through benthic algae and periphyton but also foraging on supplementary feeds leaving primary fishes deprived of availing feed. This phenomenon was substantiated from the fact that 70% of these fishes were caught near feed bags during sampling. Thus, substantiating the assumption that *Pterygoplichthys* spp. displaces local fishes by way of competition for food (Hubilla *et al*. 2008) [39] and space (Mendoza-Alfaro *et al*. 2009) [40].

Tolerance to salinity is one of the significant physiological parameters that determine the rate of invasion success, stabilization and the pattern of dispersal of invasive species in the aquatic environment (Ashton *et al*., 2007) [41]. Although *Pterygoplichthys* spp is an inhabitant of freshwater but reported to exist in saline habitats (Bijukumar et. al., 2018) [42]. The current study revealed that *Pterygoplichthys* spp. have exhibited low survival and multiplication in low and medium saline culture systems (ES-4) and furthermore, their presence was not recorded in brackish water ponds containing full salinity of 35‰. Exposure studies of Kefford *et al*. (2004) [43] in the laboratory revealed that *Pterygoplichthys* spp exhibited tolerance to low and medium salinity ranging from 2 to 10‰ and recorded 100% survival. But, acclimation increased the salinity tolerance levels up to 16‰. Survival of *Pterygoplichthys* spp was inversely proportional to salt concentrations and exhibited 100% mortality at 30‰ salinity (Brion *et al*., 2013) [44]. Thus, the toxicity of higher salinities might inhibit its migration to estuarine waters limiting the existence to freshwater (Bijukumar *et al*., 2018) [42] but, Bringolf *et al.* (2005) [45] hypothesized that the armor plate cover of these catfishes provide impermeability to saltwater and helps in dispersal to differently originated freshwater systems through marine coastal route. This hypothesis cannot be disputed since, *Pterygoplichthys* spp. has registered its presence in all river systems and their tributaries in Andhra Pradesh (Akbar, 2016) [22] and Telangana (Laxmappa, 2016) [11] further aggravated by Godavari-Krishna river linking (Akbar, 2017; Teja, 2017) [46, 47] probably utilizing estuaries and coastal waters as 'bridges' for dispersing from one coastal river system to another (Capps *et. al*., 2010) [48]. Human activity including aquaculture may also facilitate the movement of species across traditional barriers and outside of native distributions (Casal, 2006) [49]. However, the fish limits itself to suitable salinities because of the stress exerted on osmoregulation and the phenomenon becomes a vital aspect in bio-geographic distribution of this alien species (Brion *et. al*., 2013) [44].

3.2 Effect on Feed Conversion Ratio (FCR)

Feed expense constitutes the majority cost of production in aquaculture system. The underperformance of fish growth in terms of Feed Conversion Ratio (FCR) is a foremost concern in aquaculture as it intensely affects the profitability in fish farming (Eriegha and Ekokotu, 2017) [50]. Feed utilization in ponds invaded by suckermouth armoured catfish (*Pterygoplichthys* spp) was severely affected resulting in elevated FCR that ranged from 4.00 to 4.32 against a normal FCR of 3.12 to 3.48 (Fig. 4). As a result, overall mean pond FCR was affected by 25.76% for a normal fish production of 9,000 to 9,600 kg/ha/year in these experimental stations. Carp production in these areas typically ranged from 8,000 to 10,000 kg/ha/year with FCR of 2.5 and 3.2 (Ramakrishna *et al*., 2013) [26]. The Present study revealed that economic losses incurred by farmers ranged from 12.29% (ES-2) to 15.40% (ES-7) with a mean economic loss of 13.40% (Table-2). Escalation of FCR indicates dissimilarity among the best and worst-performing farms (Rana and Hassan, 2013) [51] leading to heavy economic losses due to sluggish growth and inefficient feed conversion ratio (Mengistu *et al*., 2020) [52]. *Pterygoplichthys* spp that alter food webs by rapidly utilizing nutrients and reduce algal and invertebrate standing thereby curtailing primary as well as secondary productivity resulting in inhibition of growth of primary fish and other aquatic organisms that feed on plant and animal plankton (Hoover *et al*., 2014) [38]. Although loricariids lack territorial behaviour and do not confront with native fish physically, their predominant behaviour of adhering to objects, scraping and vacuuming the food zones of fishes having similar feeding habits were proved to be highly disruptive in small tanks and ponds (Nico, 2010) [53].

Although high mineral content of calcium and phosphorus in *Hypostomus plecostomus* has prompted few researchers to suggest as a good source of minerals for eggshell formation in duck and poultry (Asnawi et. al., 2014) [54] but heavy metal content in these fishes should not be ignored (Purnamasari and Asnawi, 2011) [55]. Notwithstanding the fact, Asnawi et. al. (2015) [56] have recorded that 78% of farmers in Mataram (Indonesia) were incorporating sapu-sapu (*Hypostomus luteus*) in duck feed. However, efforts to extract fish hydrolysate from *Pterygoplichthys* spp were futile in the present study owing to intense bony skeleton (Fig. 5) and economically infeasible recovery rate.

3.3 Harvest Trend and Seasonal variation

The occurrence of *Pterygoplichthys* spp among natural catches in River Krishna was substantiated by fishermen who live in Ferry (ES-9), Tummalapalem (ES-10) and Prakasam barrage, Sitanagaram (ES-11) landing centres and Penamaluru (ES-12) wherein fishermen catch fish in Bundar Canal that is made from River Krishna to meet agriculture and drinking water demands. This alien fish was first recorded in 2014 in River Krishna near Prakasam barrage reservoir (Akbar, 2016) [22] and the situation has worsened after interlinking of

Godavari and Krishna Rivers by means of Pattiseema lift irrigation and increased in its magnitude within one year causing extensive damage to nets and gears as also significantly affected catch per unit effort (Teja, 2017) [47]. Although Froese and Pauly (2014) [57] have observed that loricariid catfishes are usually non-migratory but Hoover *et al*. (2014) [38] reported that they pass and enter new habitats wherein they can quickly colonize. Each fisherman in Prakasam barrage reservoir was harvesting 5-10 kg food fish daily which was drastically reduced to 4-8 kg due to entangling of *Pterygoplichthys* spp in the nets, thus reducing the unit catch by 20%. It has not only minimized the daily income of an active fisherman from INR 500 to 350 but also resulted in diminished daily gross annual income by 30%. This has been further perturbed by damage caused to nets by *Pterygoplichthys* spp to INR 5000 annually which constituted to be 4.5% of annual income as against incurring of 1.8% expenditure in normal course (Manasa, 2016) [23].

The abundance of *Pterygoplichthys* spp populations in culture ponds was high during monsoon starting from July through September with biomass that varied from 420 to 600 kg/ha. They were harvested in low numbers (195 to 245 kg/ha) during winter i.e., December to February. *Pterygoplichthys* spp catches were low in Krishna River and canals during winter, but the peak for maximum harvest extended from April to June (Fig. 6). This may be due to the reason that fish from loricariidae family have low chance to survive in the cold climates (Maciaszek, *et al*., 2019) [58]. Hoover *et al*. (2014) [38] marked that low temperature is one of the limiting factors that restrict the natural dispersal of *Pterygoplichthys* catfishes, but Bijukumar *et al*. (2015) [8] recorded that presence of young and juvenile fishes throughout the year in drainage systems is an indication that they breed all year round. It was observed that incidence of *Pterygoplichthys* spp has increased enormously during last four years since it was first recorded in natural waters in Andhra Pradesh (Akbar, 2016; Mallick, 2019) [22, 59]. It was recorded that *Pterygoplichthys* has populated in river basins as also in main streams of rivers within 2–3 years of their first appearance in countries like Vietnam (Gusakov *et al*., 2018) [60]. Chaichana *et al*. (2011) [31] recorded average density of Pterygoplichthys in canals in Eastern Thailand was 88 ± 9.3 individuals/100 m^2 weighing about 20 kg while Bijukumar *et al*. (2015) [8] recorded 1023 specimens/50 m^2 from a drain in Kerala which were most abundantly distributed in urban downstream region of the canal. Abundance of *Pterygoplichthys* spp. was enormously high among total fish catch netted out in East Kolkata Wetlands (Hussan et. al. 2019) [28], Kerala (Suresh *et al*. 2019) [30], Tamilnadu (Sandilyan, 2019) [61]. In the present study, invasion of *Pterygoplichthys* spp was assessed in terms of biomass registered in carp culture ponds as well as canal and river systems. Pterygoplichthys catfishes are known to survive even in disturbed habitats and also able to proliferate through various seasons indicating possible batch spawning (Dmitry and Budaev, 2013) [62] and have the ability to move into river basins and water bodies that are remotely located from the places of their first discovery surpassing natural and manmade barriers indicating its effective invasive potential (Gusakov *et al*., 2018) [60]. Nico *et al*. (2012) [63] has marked that subterranean (hypogeal) pathway is also possible for sailfin catfishes. The alarming rate at which the aquatic habitats are getting invaded raises concern and urges for a consolidated effort to combat the invasion by alien species across the globe (Bijukumar *et al*., 2015; Panlasigui *et al*., 2018) [8,64]. Expansions of armoured catfishes into irrigation channels and feral water bodies are also worsened by dispersal because of flash floods (Hossain *et al*., 2018) [65]. Concurrently the fact has established that heavy rains and floods in Andhra Pradesh have increased *Pterygoplichthys* spp invasion in canals and aquaculture farms enormously and adversely affected the fish yields by 15-20% in 2020. Floodwaters have proved to be one of the indispensable routes for the spread of invasive species globally and, therefore, a precautionary approach is warranted to prevent their entry into floodplains (Cuda *et al*., 2017) [66]. An evaluation of the consequences of the floods on water bodies revealed the invasion of alien species immensely into native water bodies, thus indicating possible threat to the endemic aquatic environs and biodiversity (Havel *et al*., 2015; Nandkumar, 2018) [67,68].

Researchers do not exclude the possibility of introgressive hybridization among various *Pterygoplichthys* spp (Nico *et al*., 2012) [19] and the hybrids of *Pterygoplichthys* spp fishes are much vigorous in establishing in the new sites (Hussan *et al*., 2018) [69] causing the extensive damages to the systems and biodiversity which can be identified by using molecular markers (Bijukumar *et al*., 2018) [42]. Thus, species-specific eDNA technique needs to be integrated to manage and restrict the naturalization of this non-native species (Ghosal, 2018) [13]. There were incidences of releasing of this strange fish that had been caught by fisherman back into the same aquatic systems which could amplified opportunities of its distribution, spread and colonization (Gusakov *et al*., 2018) [60]. In few instances, they were used to experiment for excoriating the algae deposited in the fish cages in the reservoirs (Edwin, 2020) [70].

Table 1: Effect of Armoured Suckermouth catfish, *Pterygoplichthys* spp. on carp production

Exp. Station	Production (kg)		Total kg	% SMAC*	Carp Production (kg)			
	Carps	SMAC			Realtime Production*	Yield affected	% yield affected	economic loss (%)
ES-1	7600	420	8020	5.24	9400	-1800	-19.15	12.67
ES-2	7600	410	8010	5.12	9400	-1800	-19.15	12.29
ES-3	7500	325	7825	4.15	9600	- 2100	-21.87	13.69
ES-4	7300	150	7450	2.01	9000	-1700	-18.88	12.44
ES-5	7600	360	7960	4.52	9500	- 1900	-19.99	13.06
ES-6	7300	250	7550	3.31	9200	- 1900	-20.65	13.99
ES-7	7400	600	8000	7.50	9600	- 2200	-22.92	15.40
ES-8	7600	420	8020	5.24	9600	- 2000	-20.83	13.69
Mean	7487.50	366.87	7854.37	4.63	9412.50	1928.57	-20.43	13.40
±SEM	±51.25	±50.37	±86.72		±81.91	±73.46		

*Average production in last three years was considered as real-time production

Table 2: Effect of Armoured Suckermouth catfish, *Pterygoplichthys* spp. on carp FCR

Exp. Station	Production (kg)		Feed Consumed* (kg)	FCR	Normal Production		% FCR affected	Economic loss (%)
	Carps	SMAC			Carps	FCR		
ES-1	7600	420	32000	4.21	9400	3.40	-23.82	12.67
ES-2	7600	410	31000	4.08	9400	3.29	-24.01	12.29
ES-3	7500	325	30000	4.00	9600	3.12	-28.11	13.69
ES-4	7300	150	31000	4.24	9000	3.44	-23.25	12.44
ES-5	7600	360	32000	4.21	9500	3.37	-24.92	13.06
ES-6	7300	250	32000	4.38	9200	3.48	-25.86	13.99
ES-7	7400	600	32000	4.32	9600	3.33	-29.73	15.40
ES-8	7600	420	32000	4.21	9600	3.33	-26.42	13.69
Mean	7487.50	366.87	31500	4.21	9412.50	3.34	-25.76	13.40
±SEM	±51.25	±50.37	±285.71	±0.04	±81.91	±0.04		

*suckermouth armoured catfish biomass was not taken into consideration while computing FCR.

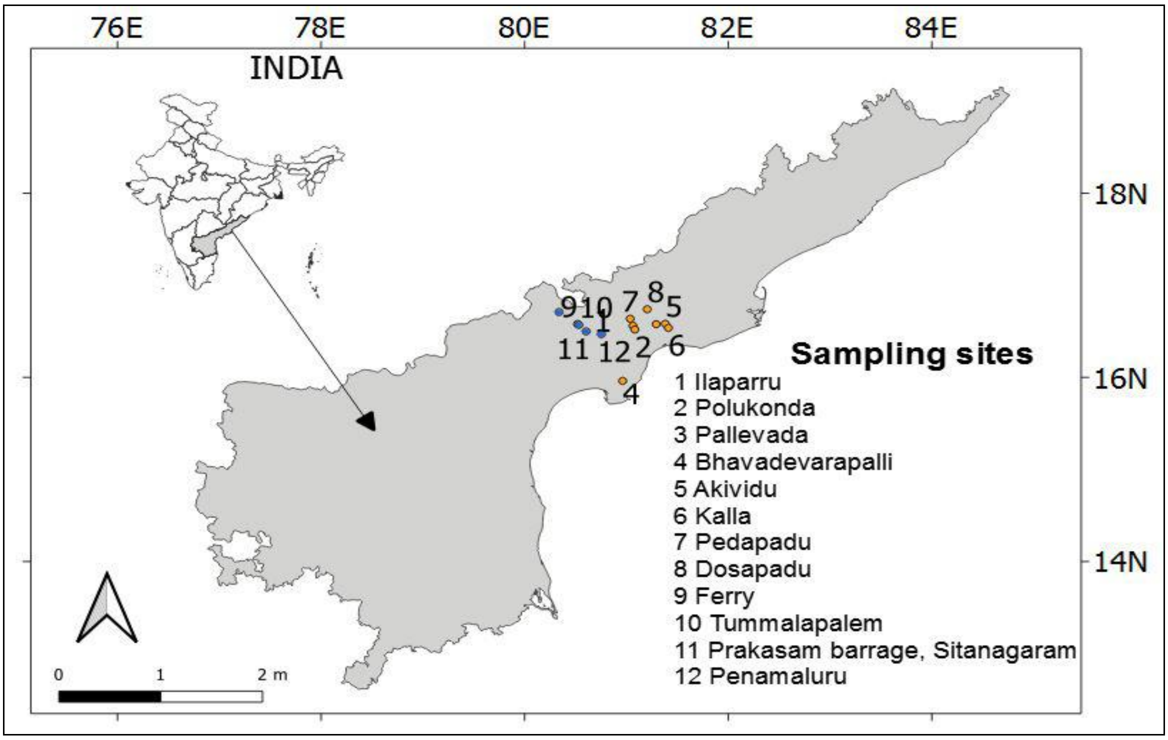

Fig 1: Location of Experimental stations that are surveyed to assess impact of *Pterygoplichthys* sp. on carp production in Krishna-Godavari Delta.

Fig 2: *Pterygoplichthys* sp. harvested from carp culture ponds in Krishna-Godavari Delta, Andhra Pradesh

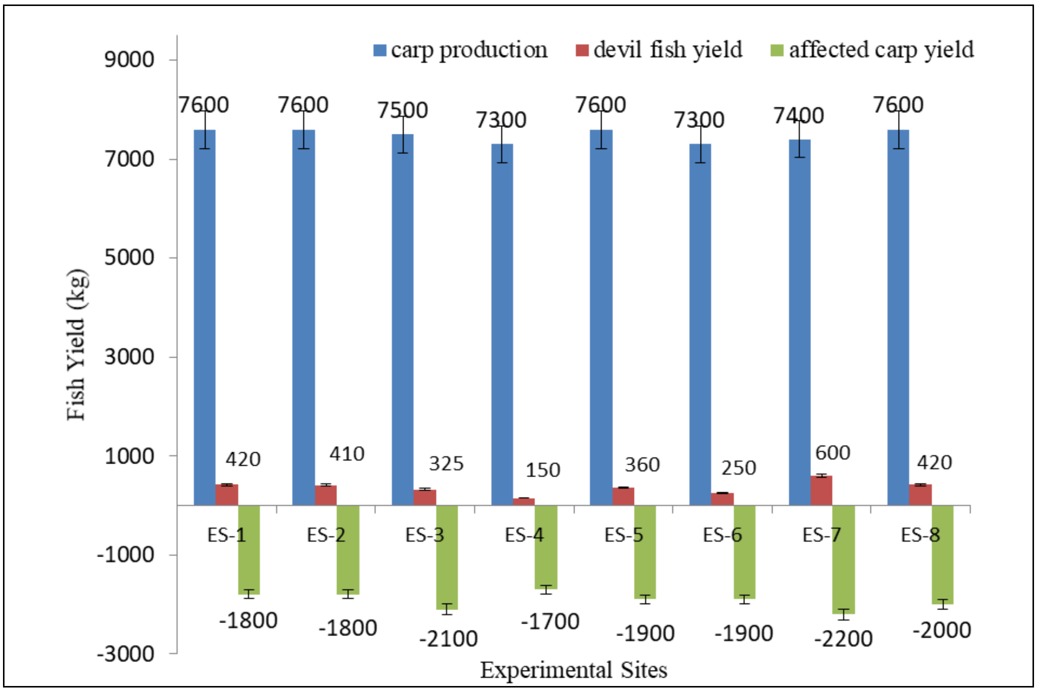

Fig 3: Histogram showing effect of *Pterygoplichthys* sp. on carp production in Krishna-Godavari Delta.

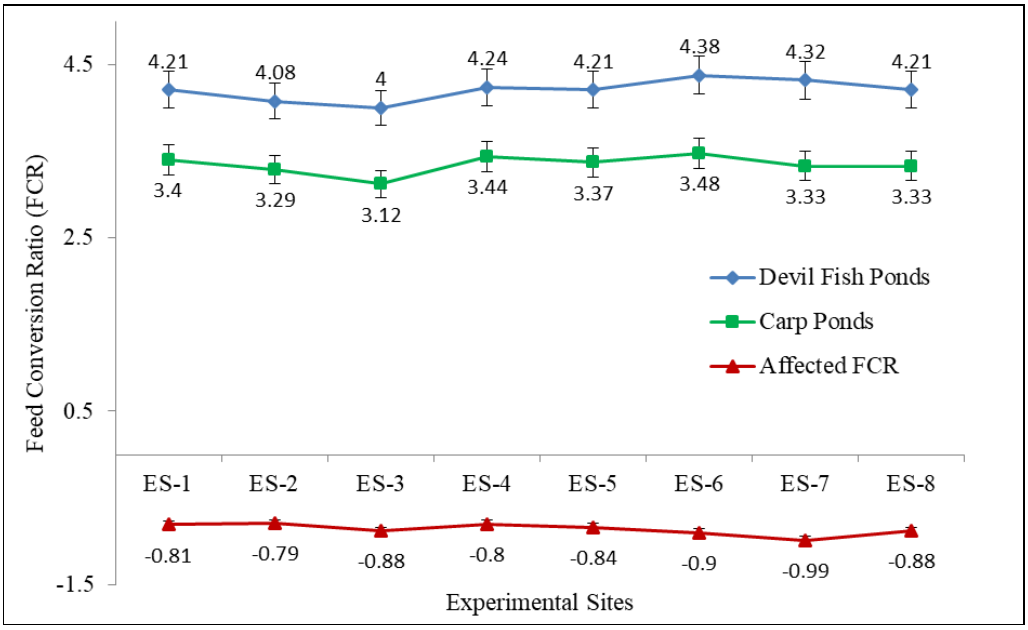

Fig 4: Line drawing showing effect of Pterygoplichthys sp. on FCR in carp culture ponds in Krishna-Godavari Delta.

Fig 5: Bony skeletons of *Pterygoplichthys* spp. that are discarded on bunds of carp culture systems in Krishna-Godavari Delta, Andhra Pradesh

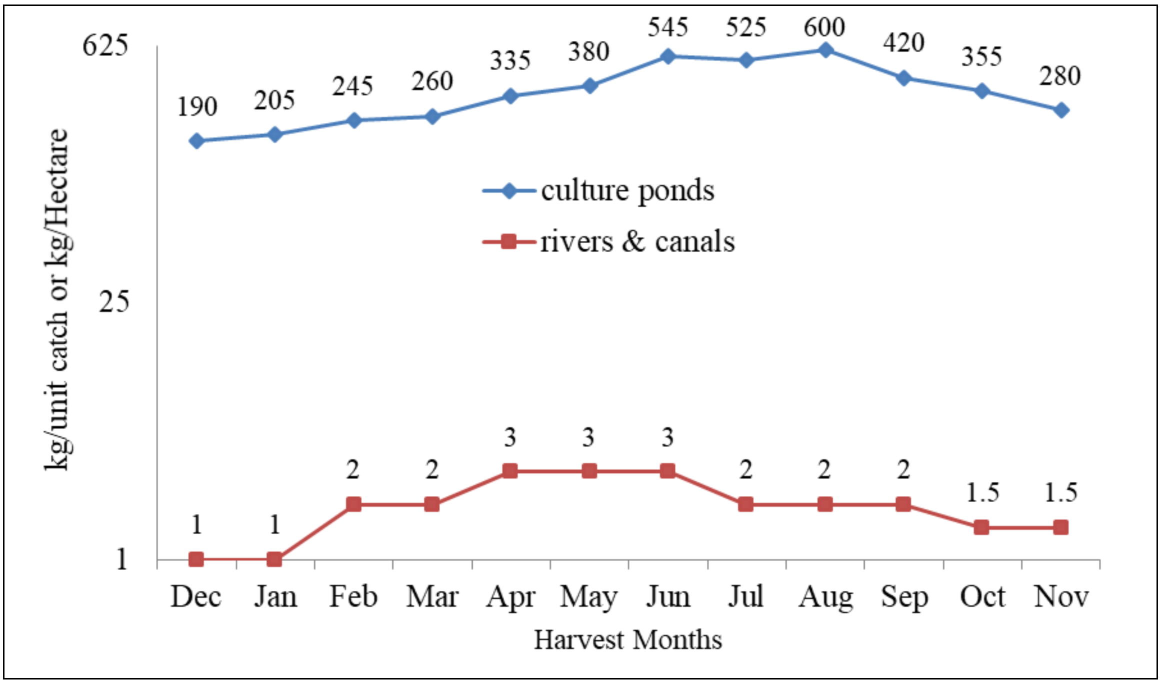

Fig 6: Line drawing showing seasonal variation in harvest of sucker mouth catfish in carp culture systems and natural water bodies in Krishna-Godavari Delta.

4. Conclusion

Pterygoplichthys spp. is one of the fast dispersing species in the invaded countries, resulting in extreme ecological and economic consequences. The abundance of *Pterygoplichthys* spp in aquaculture ponds as well as rivers and canals could be attributed to the fact that the invaded habitats characteristically similar to those of its origin in addition to their forbearance to a variety of aquatic habitats and tolerance to adverse conditions. The lack of effective predators also contributes to the natural abundance of this catfish in feral water bodies. Eradication or control of *Pterygoplichthys* catfishes which are extremely resilient and invasive may pose a high risk and become a menace to the native species in any ecosystem in which they get established. Further, the lack of documented history of the introduction of *Pterygoplichthys* spp. in Indian waters and issues related to socio-economic and ecological impact remains a debated issue.

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