Ichthyol Res (2013) 60:327–333
DOI 10.1007/s10228-013-0356-9

FULL PAPER

Non-indigenous armoured catfish in Vietnam: invasion and systematics

Dmitry D. Zworykin · Sergey V. Budaev

Received: 4 September 2012 / Revised: 16 May 2013 / Accepted: 2 June 2013 / Published online: 30 July 2013

Abstract The occurrence of non-indigenous armoured catfish *Pterygoplichthys* aff. *pardalis* from the Dinh River basin (Khan Hoa Province, Vietnam) is reported. We provide data indicating that this may be a naturalised population and present information on the fish reproduction, which points to possible batch spawning. Potential threats posed by the armoured catfish to the native habitat are discussed. Morphometric traits do not form discrete clusters, patterns of the body colouration (the main diagnostic character of these species) are very diverse and largely embrace those of different species. We suggest that the systematics of the genus should be revised.

Keywords *Pterygoplichthys* · Invasive species · Morphometric traits · Colour patterns

Introduction

Invasions by alien species have been recognised as an important global problem for more than 50 years. Starting from the classical work by Elton (1958) they are known to cause significant ecological and economic damage. For example, invasive species can significantly change communities and ecosystems, seriously contributing to extinction of native species (United Nations 1992). They cause millions of dollars in financial costs annually in the USA alone (Pimentel et al. 2005). The study of non-indigenous species in Vietnam is in its onset. The existence of invasive fishes in Vietnam can be expected, although their possible role in natural habitats of this country remains poorly understood. Preliminary reports indicated that at least nine alien species have been naturalised in the Mekong River basin alone (Welcomme and Vidthayanom 2003; Cacot and Lazard 2009).

Several fishes have been introduced into the country as objects of commercial aquaculture. These include the North African catfish (*Clarias gariepinus*), pacu (*Colossoma brachypomum*), Nile tilapia (*Oreochromis niloticus*), Mozambique tilapia (*Oreochromis mossambicus*), and blue tilapia (*Oreochromis aureus*). Some species, such as the guppy (*Poecilia reticulata*) and the armoured catfishes (*Pterygoplichthys* sp.) could have been introduced by the aquarium trade. The western mosquitofish (*Gambusia affinis*) has been used in government programmes for malaria control whereas Alluaud's Haplo (*Astatoreochromis alluaudi*) has been used for controlling gastropod snails that are the intermediate hosts for schistosoma. The ways other non-indigenous species (e.g. pirahna, arapaima) were introduced in Vietnam are even less clear. Most probably they were brought there as objects of exotic decorative aquaculture.

The armoured catfishes (Loricariidae) represent a large family of the order Siluriformes including more than 700 species (Ferraris 2007) that inhabit freshwater habitats of the South and Central America. Many species have a characteristic attractive appearance that makes them popular for aquarium keeping. They 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; Wakida-Kusunoki et al. 2007; Sandoval-Huerta et al. 2012) and southern states of the USA (Nico and Martin 2001). Later, they were introduced into the islands of the Pacific and the Indian Ocean, including Hawaii (Eldredge 2000),

D. D. Zworykin (✉) · S. V. Budaev
Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, 33 Leninsky Prospect, 119071 Moscow, Russia
e-mail: d.zworykin@gmail.com

S. V. Budaev
e-mail: sbudaev@gmail.com

the Philippines (Joshi 2006; (Hubilla et al. 2007), Japan (Nakabo 2002), Taiwan (Chen et al. 2003; Liang et al. 2005; Wu et al. 2011), as well as Indonesia, Malaysia and Singapore (Page and Robins 2006). Now they occur also in Eurasia (Özdilek 2007; Knight 2010; Piazzini et al. 2010; Chaichana et al. 2011). The source of these invasions is probably aquarium keepers, suppliers and breeders of exotic aquarium fishes (Eldredge 2000; Liang et al. 2005; Joshi 2006; Page and Robins 2006).

The first report of armoured catfishes (*Pterygoplichthys plecostomus*) in the Mekong River delta of Vietnam appeared in 2003 (Welcomme and Vidthayanom 2003). Serov (2004) reported a capture of a non-indigenous catfish, identified as *Pterygoplichthys multiradiatus*, in southern Vietnam. Another catfish, identified as *Pterygoplichthys pardalis*, was caught in northern Vietnam in 2006 (Levin et al. 2008). The first of these studies reported a naturalised population, while separate individuals were captured in the other cases.

In January 2010 we found a new population of the armoured catfish in the Dinh River (Khanh Hoa Province, Central Vietnam), with subsequent discoveries in January 2012 and February 2013. This South American species has never been recorded either in the Dinh River basin or in this area of Vietnam. We found several fish with a wide range of body sizes and this suggests that a self-maintaining population had become established in the Dinh River. In this work, we analysed this population of the armoured catfish from the Dinh River and assessed the degree of its naturalisation. We also considered the problem of species identification of armoured catfishes and their taxonomy.

Materials and methods

The Dinh River is the largest in the Ninh Hoa District of Khanh Hoa Province, with a length of approximately 50 km and a catchment area of 985 km^2. Local fishermen typically catch the armoured catfish and other fishes using fixed gill nets. Small specimens are transferred to ponds where they are successfully maintained for growing.

We studied two catfish groups. The first group (group 1, 34 individuals) was obtained between October and December 2010, and the second group (group 2, 10 individuals) in January 2012. All fish were caught in the main channel of the Dinh River (N12°29´34´´, E109°07´55´´) by local fishermen. Specimens from both groups were dissected to determine their sex and the gonad maturity stage, but for logistical reasons we did not conduct a full biological analysis of specimens from the second group. The gonadosomatic index (GSI) was determined only for females at the stage IV ($n = 5$). GSI was calculated as the mass of the gonads divided by the total body mass of the fish (%). We used an electronic scale with an accuracy of 0.01 g.

Morphometric analysis was conducted following Boeseman (1968), Weber (1992) and Armbruster and Page (2006). We identified fish based on the keys in Armbruster (2001) and Armbruster and Page (2006). Table 2 presents the 17 morphometric characters analysed. We also analysed the relative area of the background at the ventral side of the body. All morphometric characters (except for the predorsal length) were expressed as a percentage of the predorsal length.

The pattern of colouration, especially of the belly, represents the key character used for the species identification of many catfishes of the genus *Pterygoplichthys* (Weber 1992; Armbruster 2001; Armbruster and Page 2006). To analyse the patterns found on the dorsal part of the body we photographed all 34 specimens from group 1 under standard conditions (standard natural illumination 25,000–30,000 lx, white background, Canon EOS 30D digital camera equipped with the Canon EF macro lens, 100 mm F/2.8). To analyse colour patterns we defined a rectangular area on the ventral part of the body limited by the bases of

Fig. 1 Location of the area on the dorsal part of the body used for the analysis of colouration patterns of the armoured catfish, *Pterygoplichthys* aff. *pardalis*, from the Dinh River basin, southern Vietnam

the pectoral and pelvic fins (Fig. 1). The images were converted to the 8-bit grayscale and then to black and white. The grayscale was reduced to the black and white such as to retain the optimal rendering of the edges of the colouration spots. This was done using a k-means clustering (Chen et al. 1998) of the 8-bit grayscale, after which we calculated the relative area of the white background. To assess the accuracy of this method, we re-analysed the data for ten randomly chosen specimens. Both measurements were highly correlated (Spearman correlation coefficient $r_s = 0.84$, $p = 0.004$).

We used the Anderson–Darling test for normal distribution, and calculated coefficients of skewness and kurtosis to check for possible departures from perfect symmetry, such as "peakedness" or "flatness" (e.g. bimodality) of the distributions (skewness is zero whereas kurtosis is three for the normal distribution). We also calculated the D'Agostino test for skewness and the Anscombe-Glynn test of kurtosis. Principal component analysis (PCA) was also conducted to reduce the dimensionality of the data. Here the optimal number of factors was determined using Horn's parallel analysis (Horn 1965). Because biological interpretation of the factors was not the main aim of this PCA, rotation was not used. We also conducted a model-based cluster analysis of the morphometric data (Fraley and Raftery 2002). The R software system (version 2.15.0) was used for the statistical analysis.

Results

Naturalisation of armoured catfishes of the Dinh River basin. Our data are consistent with the hypothesis that the armoured catfishes of the genus Pterygoplichthys have naturalised in the Dinh River basin. These fish are not only occasionally found in the river, but are quite abundant there. They are commonly caught by the local fishermen which is possible only if a sustained population has established in the river. Sex and the maturity stage in 20 fish examined (Table 1) indicated that 10 were mature females and capable of spawning (i.e. maturity stages IV and VI–III, see Fig. 2). Eight of the remaining fish were males whose testes were at the stages III–IV and also ready for spawning. The single remaining fish was at stage II and its gender could not be determined.

The differences between groups 1 and 2 are also interesting. Catfish in the first group spawned between October and December while those in the second group spawned also in January. In addition, batch spawning in group 2 was indicated because five of the six females examined had maturity stages VI–III. Intermittent spawning is supported also by the fact that the gonads of all females at this maturity stage contained eggs of different sizes (1–3 mm in diameter). The GSI of the females ranged from 6.59 to 15.77 % (median = 8.88).

Table 1 The sex and maturity stage of two groups of armoured catfish, *Pterygoplichthys* aff. *pardalis*, from the Dinh River basin, southern Vietnam

Sex and maturity stage	Group 1	Group 2
Unsexed, II	0	1
Females, III	0	1
Females, IV	5	0
Females, VI–III	0	5
Males, III–IV	5	3

Fig. 2 Ventral view of group 1 female of *Pterygoplichthys* aff. *pardalis* at maturity stage IV

Phenotypic variability and the problem of the species. A group of species that are distinguished only by subtle patterns of their colouration is defined within the genus *Pterygoplichthys*. They include *Pterygoplichthys anisitsi*, *P. multiradiatus*, *P. pardalis* and *Pterygoplichthys disjunctivus*, and usually referred to as adventive in the literature. In the Dinh River basin, we found individuals whose colouration coincided with the description of distinct species, such as *P. pardalis* (Fig. 3a) and *P. disjunctivus* (Fig. 3b). There were fish with intermediate patterns and those that were very different from published descriptions (see Fig. 3c, d). Importantly, all these fish were caught at the same time in the same area. This diversity of colour patterns, the main diagnostic trait of *Pterygoplichthys*, led us to analyse the differences between these fish in greater detail.

All morphometric characters had unimodal distribution, in most cases not significantly different from the normal. There was also no significant skewness or kurtosis (Table 2). Inspection of the histograms and probability plots (not presented here to save space) confirmed the near-normality of the distributions. The PCA conducted to reduce the dimensionality of the data resulted in a two-factor solution, in which four components had eigenvalues >1, the Horn's parallel analysis, however, revealed only a single non-random factor so we made a compromise decision to extract two factors (see Table 3). The relative area of the background at the ventral side of the body did not correlate with any of the morphometric characters ($r < 0.26$, $p > 0.13$) and was excluded. Inspection of the PCA plot did not reveal any clear groups (Fig. 4). A more formal assessment of possible discrete groups using the model-based clustering of the principal component scores revealed a single multivariate normal distribution. The value of the Bayesian Information Criterion (BIC) reached its maximum for the single distribution model (diagonal multivariate normal model with a single component, Fig. 5). Thus, we were unable to distinguish any discrete clusters in our sample of the fish based on the morphometric traits. This is consistent with the hypothesis that our fish came from a single population of the same species.

Analysis of the colouration patterns also failed to reveal distinct groups. The relative area of the background at the ventral side of the body had a distribution not significantly different from normal (Table 2). The configurations of the coloured spots differed across individuals without discrete subgroups. We analysed the configurations of the spots on the head and the caudal peduncle with the same result. Because the pattern of the spots is the main diagnostic trait for the identification of these adventive species, our data may indicate that *P. pardalis*, *P. disjunctivus* and a few others may represent a single variable species.

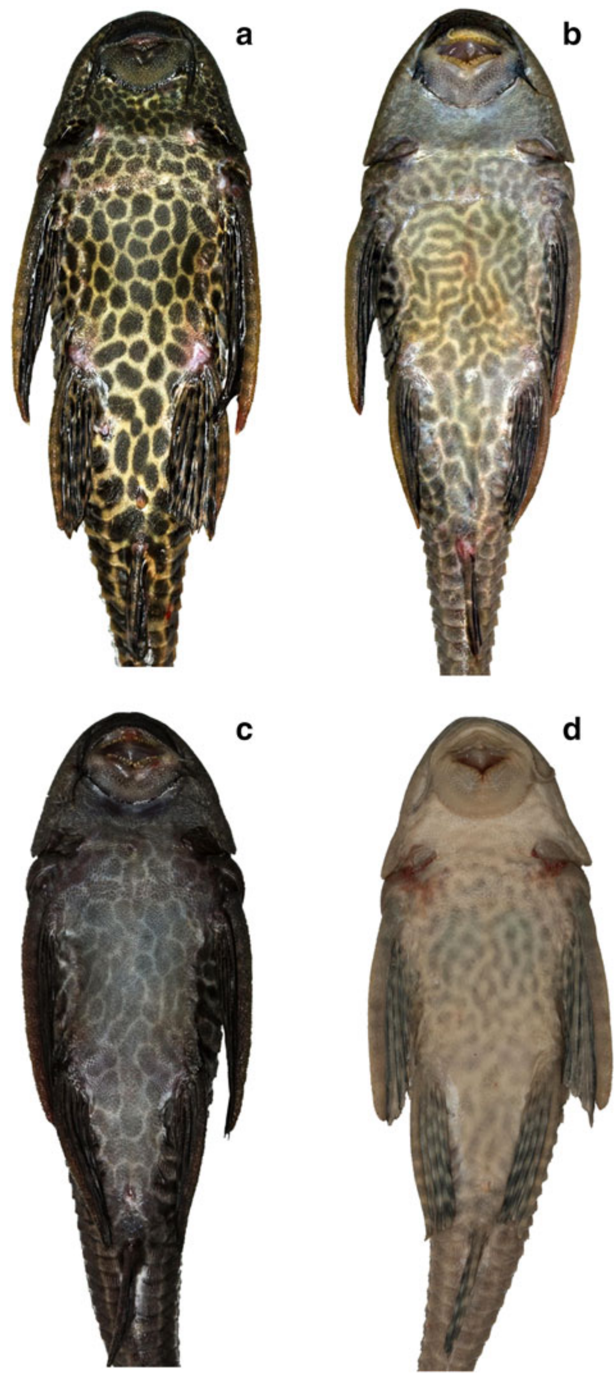

Fig. 3 Examples of different colouration patterns in group 1 armoured catfish, *Pterygoplichthys* aff. *pardalis*. Specimen numbers are: **a** 1–32, **b** 1–03, **c** 1–09 and **d** 1–16. See text for explanations

Discussion

Armoured catfish spread rapidly in tropical and subtropical freshwater bodies globally and established naturalised populations across its invasive range. This process is facilitated by several factors. These catfish are eurybiont, can withstand water pollution (Welcomme and Vidthayanom 2003), and can tolerate insufficient oxygenation due to their ability to accessory respiration with diverticula of the gastrointestinal tract (Armbruster 1998). Their eggs can develop normally even at low water levels, the only condition being that they should be covered with water (Hoover et al. 2004). *Pterygoplichthys* feed on periphyton and detritus, which are usually abundant, and there is little competition. Spiny fins and a hardened external morphology make these fish not much vulnerable to predators. Finally, they are characterised

Table 2 Characteristics of morphological characters of *Pterygoplichthys* aff. *Pardalis* in group 1

Morphometric characters	Skewness[a]	Kurtosis[b]	*A*	*p*
Predorsal length	0.77	4.00	0.80	0.034*
Head length	0.10	2.63	0.11	0.991
Distance between distal tips of cleithra	0.26	2.65	0.16	0.940
Head depth	0.02	2.79	0.19	0.891
Snout length	0.17	2.90	0.18	0.915
Eye diameter	0.38	2.70	0.30	0.556
Interorbital width	0.14	2.47	0.29	0.592
Depth of first dorsal fin	0.13	3.47	0.22	0.831
Length of first dorsal fin base	−0.16	3.40	0.27	0.657
Distance between dorsal fins	0.10	2.30	0.27	0.642
Distance between pectoral and anal fins	−0.20	3.39	0.34	0.477
Length of pectoral fin	−0.20	2.57	0.27	0.646
Distance between pelvic and anal fins	0.34	3.91	0.27	0.665
Length of pelvic fin	0.31	2.49	0.19	0.900
Length of caudal peduncle	0.65	3.87	0.25	0.719
Depth of caudal peduncle	−0.71	3.06	0.93	0.016*
Relative area of background at ventral side of body	0.37	2.08	0.49	0.2021

A is the Anderson–Darling test statistic; significantly non-normal distributions ($p < 0.05$) are marked with asterisks

[a] D'Agostino test for skewness is non-significant ($p > 0.19$) in all cases

[b] Anscombe-Glynn test of kurtosis is non-significant ($p > 0.15$) in all cases. Kurtosis for normal distribution should be equal to three

Table 3 Principal component analysis of morphometric traits of *Pterygoplichthys* aff. *pardalis* in group 1

Morphometric character	PC1	PC2
Predorsal length	−0.30	0.07
Head length	−0.32	−0.04
Distance between distal tips of cleithra	−0.32	0.10
Head depth	−0.30	0.05
Snout length	−0.30	−0.05
Eye diameter	−0.24	−0.04
Interorbital width	−0.31	0.00
Depth of first dorsal fin	−0.16	−0.25
Length of first dorsal fin base	−0.03	−0.43
Distance between dorsal fins	0.15	0.13
Distance between pectoral and anal fins	0.13	−0.50
Length of pectoral fin	−0.14	−0.37
Distance between pelvic and anal fins	0.17	−0.49
Length of pelvic fin	−0.27	−0.27
Length of caudal peduncle	−0.10	−0.10
Depth of caudal peduncle	−0.28	0.06
Eigenvalue	2.86	1.45

PC1 and *PC2* are the first and second principal components. *PC1* seems to involve overall body size, *PC2* might be linked with sizes of fins

by a prolonged reproductive period, batch spawning and active parental care (Cruz and Langeani 2000; Hoover et al. 2004; Liang et al. 2005). These traits promote successful invasion.

The effects of these non-indigenous catfishes on the indigenous species and communities are poorly understood. We were unable to find any published data on this issue. In our opinion, this can be explained by the very specific ecological niche occupied by the armoured catfishes not competing directly with native species. Nonetheless, mass reproduction of the armoured catfishes growing up to 50 cm in length could represent a noticeable threat (Hoover et al.

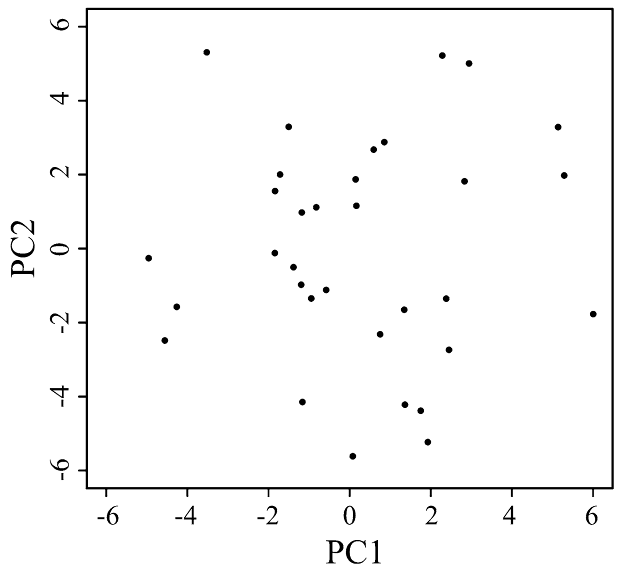

Fig. 4 Scatterplot of the principal component analysis of morphological data from armoured catfish, *Pterygoplichthys* aff. *pardalis*, collected from the Dinh River basin of southern Vietnam

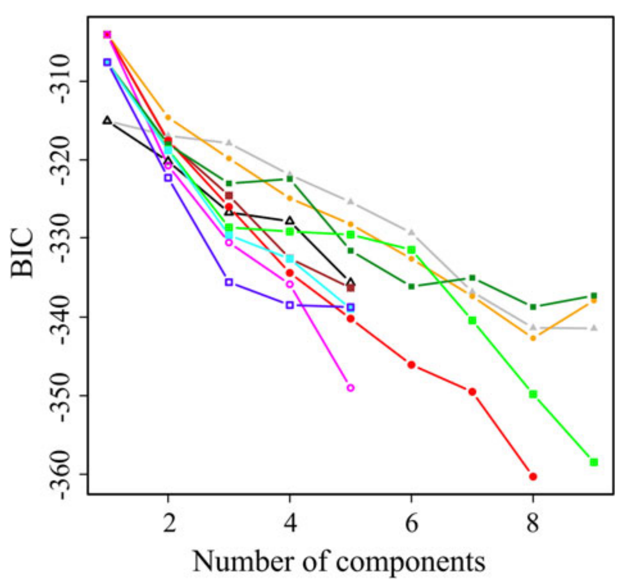

Fig. 5 Bayesian information criterion (BIC) for a range of models (different colour) postulating different number of clusters resulting from principal component analysis of morphological data. Note that BIC reaches its maximum value for the single distribution (no-mixture) models

2004; Joshi 2006). Armoured catfishes can eat up demersal eggs of autochthonic species while consuming the bottom periphyton, and dig and destroy the bottom substrate which may change the composition of the bottom vegetation. Males of these fish dig long holes (exceeding 1 m in length) for deposition of eggs in the underwater part of the river bank. Moreover, these holes are frequently located close to each other and form a kind of colonial aggregation, resulting in significant erosion of the river bank (Nico et al. 2009a). There were reports of piscivorous birds dying after trying to swallow these very well armoured fish. For example, several protected pelicans (*Pelecanus occidentalis*) died in such a way in Puerto Rico (Bunkley-Williams et al. 1994). Catfish, as well as certain indigenous fishes, can damage fishing nets (Joshi 2006). In some cases invasion may have certain positive consequences, such as development of new symbiotic relationships. For example, in some water bodies of Florida catfishes developed mutualistic relationships with the American manatee *Trichechus manatus latirostris* (see Nico et al. 2009b).

It has been suggested (e.g. Liang et al. 2005) that armoured catfishes could be characterised by batch spawning, although we are unaware of any data showing this unambiguously. Our results provide further support, even though more conclusive evidence should be based on data covering the whole complete annual cycle. The value of the GSI in females agrees with data published previously (Liang et al. 2005; Gibbs et al. 2008).

Our data on phenotypic variability suggest that distinguishing valid species based solely on subtle characteristics of the colouration pattern, especially in the absence of well-defined discrete groups, is insufficient. Significant variability of colouration patterns has already been reported in armoured catfishes (e.g. Chavez et al. 2006). Furthermore, no statistically significant differences in morphometric or meristic characters have been found between *P. pardalis* and *P. disjunctivus*, even the modal values for most traits coincide in these species. In addition, modal values of several traits determined by (Chavez et al. 2006) differ from those published by Weber (1992). Another reason to question the validity of species based on colouration patterns is their significant plasticity. As mentioned above, local fishermen transfer small individuals that get to their nets to ponds for growing. The fish change their colouration significantly after few weeks in these ponds. Usually they become darker, light stripes and spots become narrower and often completely disappear on the head, flanks and the back. The systematics of this genus appears to be quite arbitrary and requires more research (J. Armbruster, personal communication).

We conclude that a population of non-indigenous armoured catfish inhabits the Dinh River. It has not been described previously and is probably self-recruiting. Until the taxonomy of these fish is more clear, they should be identified preliminarily as *Pterygoplichthys* aff. *pardalis*.

Acknowledgments We are grateful to Đinh Thị Hải Yến and Võ Thị Hà (Coastal Branch of Vietnam–Russian Tropical Centre) for their help in the collection of the materials and organisation of the field-work, Kirill F. Dzerzhinsky for assistance in processing of the materials, and Terry J. Donaldson for numerous valuable comments on the manuscript. This study was supported by the Research Programme Ekolan E-3.2, "Taxonomic diversity, ecology and behaviour of fresh-water hydrobionts", Tropical Research and Technology Centre.

References

Armbruster JW (1998) Modifications of the digestive tract for holding air in loricariid and scoloplacid catfishes. Copeia 1998:663–675

Armbruster JW (2001) The Loricariidae. http://www.auburn.edu/academic/science_math/res_area/loricariid/fish_key/lorhome/index.html. Accessed 14 August 2012

Armbruster JW, Page LM (2006) Redescription of *Pterygoplichthys punctatus* and description of a new species of *Pterygoplichthys* (Siluriformes: Loricariidae). Neotrop Ichthyol 4:401–409

Boeseman M (1968) The genus *Hypostomus* Lacépède, 1803, and its Surinam representatives (Siluriformes, Loricariidae). Zoologische Verhandelingen 99:1–89

Bunkley-Williams L, Williams EHJ, Lilystrom CG, I C-F, Zerbi AJ, Aliaume C, Churchhill TN (1994) The South American sailfin armored catfish, Liposarcus multiradiatus (Hancock), a new exotic established in Puerto Rican fresh waters. Caribb J Sci 30:90–94

Cacot P, Lazard J (2009) La domestication des poissons du Mékong: les enjeux et le potentiel aquacole. Cah Agric 18:125–135

Chaichana R, Pouangcharean S, Yoonphand R (2011) Habitat, abundance and diet of invasive suckermouth armored catfish (Loricariidae *Pterygoplichthys*) in the Nong Yai Canal, East Thailand. Trop Zool 24:49–62

Chavez JM, La Paz RM De, Manohar SK, Pagulayan RC, Carandang Vi JR (2006) New Philippine record of south american sailfin catfishes (Pisces: Loricariidae). Zootaxa 1109:57–68

Chen CW, Luo J, Parker KJ (1998) Image segmentation via adaptive k-mean clustering and knowledge-based morphological operations with biomedical applications. IEEE Trans Image Process 7:1673–1683

Chen R-T, Ho P-H, Lee H–H (2003) Distribution of exotic freshwater fishes and shrimps in Taiwan. Endemic Species Res 5:33–46

Cruz AL, Langeani F (2000) Comportamento reprodutivo do cascudo *Liposarcus anisitsi* (Eigenmann & Kennedy, 1903) (Ostariophysi, Loricariidae, Hypostominae) em cativeiro. Comunicações do Museu de Ciências e Tecnologia da PUCRS, Série Zoologia 3:109–115

Eldredge LG (2000) Non-indigenous freshwater fishes, amphibians, and crustaceans of the Pacific and Hawaiian islands. In: Sherley G (ed) Invasive species in the Pacific: a technical review and draft regional strategy. South Pacific Regional Environment Programme, Apia, Samoa, pp 173–190

Elton CS (1958) The ecology of invasions by animals and plants. Methuen, Methuen

Ferraris CJ (2007) Checklist of catfishes, recent and fossil (Osteichthyes: Siluriformes), and catalogue of siluriform primary types. Zootaxa 1418:1–628

Fraley C, Raftery A (2002) Model-based clustering, discriminant analysis, and density estimation. J Am Stat Assoc 97:611–631

Gibbs MA, Shields JH, Lock DW, Talmadge KM, Farrell M (2008) Reproduction in an invasive exotic catfish *Pterygoplichthys disjunctivus* in Volusia Blue Spring, Florida, USA. J Fish Biol 73:1562–1572

Hoover JJ, Killgore KJ, Cofrancesco AF (2004) Suckermouth catfishes: threats to aquatic ecosystems of the United States? Aquat Nuisance Species Res Bull 04–1:1–9

Horn JL (1965) A rationale and test for the number of factors in factor analysis. Psychometrika 30:179–185

Hubilla M, Kis F, Primavera J (2007) Janitor fish *Pterygoplichthys disjunctivus* in the Agusan Marsh: a threat to freshwater biodiversity. J Environ Sci Manage 10:10–23

Joshi RC (2006) Invasive alien species (IAS): concerns and status in the Philippines. In: Proceedings of the International Workshop on the Development of Database (APASD) for Biological Invasion. FFTC, Taichung, Taiwan, China, pp 1–23

Knight JDM (2010) Invasive ornamental fish: a potential threat to aquatic biodiversity in peninsular India. J Threat Taxa 2:700–704

Levin BA, Phuong PH, Pavlov DS (2008) Discovery of the Amazon sailfin catfish *Pterygoplichthys pardalis* (Castelnau, 1855) (Teleostei: Loricariidae) in Vietnam. J Appl Ichthyol 24:715–717

Liang S-H, Wu H-P, 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. Zool Stud 44:252–259

Nakabo T (ed) (2002) Fishes of Japan with pictorial keys to the species, English edition. Tokai University Press, Tokyo

Nico LG, Martin RT (2001) The South American suckermouth armored catfish, *Pterygoplichthys anisitsi* (Pisces: Loricaridae), in Texas, with comments on foreign fish introductions in the American Southwest. Southwest Nat 46:98–104

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. Aquat Nuisance Species Res Bull 9:1–30

Nico LG, Loftus WF, Reid JP (2009b) Interactions between non-native armored suckermouth catfish (Loricariidae: Pterygoplichthys) and native Florida manatee (*Trichechus manatus latirostris*) in artesian springs. Aquat Invasions 4:511–519

Özdilek SY (2007) Possible threat for Middle East inland water: an exotic and invasive species, *Pterygoplichthys disjunctivus* (Weber, 1991) in Asi River, Turkey (Pisces: Loricariidae). Ege J Fish Aquat Sci 24:303–306

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

Piazzini S, Lori E, Favilli L, Cianfanelli S, Vanni S, Manganelli G (2010) Invasion note: a tropical fish community in thermal waters of southern Tuscany. Biol Invasions 12:2959–2965

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecol Econ 52:273–288

Sandoval-Huerta ER, Madrigal-Guridi X, García-Meraz A, Dimas-Mora NI, Domínguez-Domínguez O (2012) Nuevo registro de *Pterygoplichthys disjunctivus* (Actinopterygii: Loricariidae) en la desembocadura del río Coahuayana, Coahuayana, Michoacán, México. Revista Mexicana de Biodiversidad 83:294–297

Serov D (2004) Harnischwelse in Südostasien. DATZ 2:18–19

United Nations (1992) Convention on biological diversity. Alien species that threaten ecosystems, habitats or species [Article 8 (h)]. http://www.cbd.int. Accessed 10 June 2013

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. Southwestern Nat 52:141–144

Weber C (1992) Révision du genre *Pterygoplichthys* sensu lato (Pisces, Siluriformes, Loricariidae. Revue Française d'Aquariologie Herpétologie 19:1–36

Welcomme RL, Vidthayanom C (2003) The impacts of introductions and stocking of exotic species in the Mekong Basin and policies for their control. MRC Technical Paper No. 9. Mekong River Commission, Phnom Penh

Wu L-W, Liu C-C, Lin S-M (2011) Identification of exotic sailfin catfish species (*Pterygoplichthys*, Loricariidae) in Taiwan based on morphology and mtDNA sequences. Zool Stud 50:235–246