

Invasion of the Indo-Pacific blenny *Omobranchus punctatus* (Perciformes: Blenniidae) on the Atlantic Coast of Central and South America

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We examined 308 specimens of the Indo-Pacific blenniid *Omobranchus punctatus* deposited in four museum collections, and analyzed data on their collection locations to assess its invasion on the Atlantic coast of Central and South America. This species occurs in shoreline estuarine and marine habitats in the Indo-West Pacific. Previous sampling and recent records in the Tropical West Atlantic from 1930 to 2004 produced 20 records for: Panamá, Colombia, Venezuela, Trinidad and Brazil. In this work, we provide data on 17 new records for the Gulfs of Venezuela and Paria in Venezuela, as well as four records for Maranhão and Pará states in NE Brazil. The temporal pattern of collections (1930 - 2009) and the proximity of most localities to ports and zones of ship traffic indicate that *O. punctatus* was initially introduced to the Atlantic by ships travelling from India to Trinidad. Within Brazil the introduction is linked to shipping connected to petroleum platforms. In Maranhão and Pará the introduction may have occurred as a result of fish sheltering in fouling on hulls of ships moving between ports around the mouth of the Amazon River. Alternatively, the spread of this species along of the American coast may reflect the expansion of the range of *O. punctatus* through larval dispersal in northward flowing currents. We recommend monitoring of this introduced species, and studies of its ecology in West Atlantic areas.

Nós examinamos 308 espécimes do blenídeo *Omobranchus punctatus*, de origem Indo-Pacífica, depositados em coleções de quatro museus. Os dados de distribuição foram analisados com o objetivo de avaliar a invasão das águas costeiras do Oceano Atlântico nas Américas do Sul e Central. Em sua área de distribuição original, *O. punctatus* ocorre em ambientes marinhos e estuarinos. Amostras datadas de 1930 e de 2004 produziram 20 registros da espécie no Atlântico Oeste tropical, incluindo amostras do Panamá, Colômbia, Venezuela, Trinidad e Brasil. Neste trabalho nós apresentamos 17 novos registros em áreas da Venezuela e nordeste do Brasil. O padrão temporal dos dados (1930-2009) e a proximidade da maioria das áreas de amostragem a regiões portuárias indicam que a espécie foi inicialmente introduzida no Atlântico pela água de lastro de navios navegando na rota Índia-Trinidade. No Brasil, a introdução parece estar associada ao movimento de navios em torno das plataformas de petróleo. No Maranhão e no Pará, a introdução está associada ao movimento de navios entre os portos próximos à foz do rio Amazonas. Alternativamente, a expansão de área desta espécie ao longo da costa da América pode ter acontecido através de dispersão larval, acompanhando as correntes em direção ao norte. Nós recomendamos o monitoramento desta espécie, bem como o desenvolvimento de estudos sobre sua ecologia em ambientes do Atlântico ocidental agora ocupados por ela.

Key words: Bio-invasions, Distributional data, Exotic marine fishes, New records.

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Introduction

Biological invasions are closely related to the history of humanity (Cavalcante & Major, 2006) and are among the main agents of environmental changes in the world (Occhipinti-Ambrogi, 2007). There is a relationship between environments altered by mankind and the existence of invasive species (Sax & Brown, 2000). Among marine environments, estuaries are among the ecosystems most altered by anthropogenic actions and are the sites of the greatest number of records of invasions (Moyle *et al.*, 1999).

Wonham *et al.* (2000) proposed that the invasion of a new environment by an exotic species includes three phases: dispersion, introduction and settlement. These phases, along with the survival capacity of the species to its new environment, influence its success as an invader. According to these authors, Blenniids, Gobiids, and Pleuronectids dominate the records of introductions to exotic locations via ballast water because such water provides conditions resembling normal habitats used by them.

The blennies (Blenniidae), comprised about 360 species in 56 genera, are cosmopolitan in tropical and subtropical marine habitats (Nelson, 2006). The natural geographic range of *Omobranchus punctatus* (Valenciennes, 1836) spans from the northern Indian Ocean to the Western Pacific Ocean. In the 1960s, records of specimens collected in the Atlantic began to be reported, and currently the species is known from the Caribbean and eastern Africa (Cervigón, 1966; Springer & Gomon, 1975; Cervigón, 1994), Suez Canal and Mediterranean Sea (Bath, 1980; Golani, 2004) and Brazil (Gerhardinger *et al.*, 2006). *Omobranchus punctatus* is regarded as an exotic species introduced in the Atlantic.

This work was aimed to elucidate the historical information on records of *O. punctatus* on the Central and South Western Atlantic coast, adding new information in order to understand the process of invasion by this species in the region.

Material and Methods

Two approaches were selected in order to determine the invasion of *O. punctatus*: (1) field work collections and (2) Museum analyses. For (1) various samplings were done using different fishing methods, such as hand nets and, in some cases, fish poison (Rotenone and Mentol). For (2) an exhaustive bibliographic survey was conducted along with recisions of fish collections of the following Venezuelan museums such as: Museo de Historia Natural La Salle, Caracas (MHNLS); Museo Oceanológico Hermano Benigno Román, Isla de Margarita, Nueva Esparta State (MOBR-EDIMAR), and Museo de Ciencias Naturales de Guanare, Guanare, Portuguesa State (MCNG). In addition, the following fish collections were reviewed in Brazil: Departamento de Oceanografia e Limnologia, Universidade Federal de Maranhão, Maranhão (CPDOL-UFMA); Grupo

de Ecologia Aquática, Pará (GEA/UFPA), and Museu Nacional, Rio de Janeiro (MNRJ). The following collections of fishes from the United States were consulted via internet: Academy of Natural Sciences of Philadelphia, Philadelphia, (ANSP); National Museum of Natural History, Smithsonian Institution, Washington (USNM); Natural History Museum of Florida, Gainesville, Florida (UF); Oceanography Institute Scripps, La Jolla, California (SIO); Laboratory of Coastal Investigations of the Gulf Ocean Springs, Mississippi (GCRL); American Museum of Natural History, New York (AMNH), and Natural History Museum, London (BMNH). The other institutional abbreviations mentioned in this essay follow Leviton *et al.* (1985), except MHNLS, MOBR-EDIMAR, EBRG, CPDOL-UFMA and Laboratório de Biologia Pesqueira, Universidade Federal do Pará (LBP-UFPA). Other acronyms mentioned in this paper correspond to the ones from Institute of Investigations and Natural Museum Senckenberg (SMF), Frankfurt, Germany and from Hebraic University of Jerusalem (HUJ), Jerusalem, Israel.

Results and Discussion

A description of *Omobranchus* genus can be found at Williams (2002). *Omobranchus punctatus* (Fig. 1) is characterized by having a very elongate rounded head lacking a longitudinal crest on its top; almost always 3 (2-4) pores between the eyes; lateral line with 2-8 double-pored tubes; the gill opening is restricted to above the level of the pectoral fin; dorsal fin XII (XI-XIII), 19-24; anal fin II, 20-26, 1 or both spines imbedded, not visible externally; tail fin with 13 (11-14) segmented rays, none filamentous; a pale-edged dark bar across the nape, a little before the origin of the dorsal fin, about 11 dark saddles across the top of the back; 3 dark bars on the lower part of the head and another on the pectoral fin base; and 4-5 slender dark stripes along the upper side of the front half of the body.

The natural range of *O. punctatus* includes the northern Indian Ocean and western Pacific, from the Persian Gulf (Iraq) to India, Japan, the northern Australian coast and the Fiji Islands (Springer & Gomon, 1975).

In the Caribbean, the first records of *O. punctatus* was in 1930, when Fowler (1931) described a new species of blenny, *Poroalticus sewalli*, with specimens captured on the western coast of Trinidad (Brighton beach, Gulf of Paria) (Table 1). In 1975, this species was recognized as a synonym of *O. punctatus* (Springer & Gomon, 1975). In 1961, Cervigón (1966) recorded *O. punctatus* (as *O. dasson*), at the Guiria on the Venezuelan coast of the same Gulf. After Fowler's initial record (1931), more specimens were collected from Trinidad in 1933, and between 1960 and 1968 (Table 1) for both the Atlantic and Paria coasts of that Island, and the western coast of the Gulf of Paria (Figs. 2a and b).

In Central America, this species has been recorded from Panama, with records of collections between 1967 and 1974 (Fig. 2a, Table 1). All records of the species in Panama come



Fig. 1. *Omobranchus punctatus* in natural habitat (tide pools) in Brazil. Photos by J. Nunes.

from the Caribbean entrance of the Panama Channel. Fish collections made between 1935 and 1937 at the Pacific side of the Channel (Miraflores locks) by Hildebrand (1939) yielded no specimens of *O. punctatus*. Also, the species was not recorded in these areas by McCosker & Dawson (1975). To date, there is no evidence of its occurrence on the Pacific coast of Panama. The Channel first began operation in 1914. The first record of *O. punctatus* in Trinidad dates from the 1930s. The first records of *O. punctatus* in Panama, at the Caribbean entrance to the canal, are from 1967, much later than the first record from Trinidad (1930) (Table 1). Springer & Gomon (1975) and Carlton (1985) suggested that it is likely that specimens of muzzled blenny from Panama originate via shipping movements from the population at Trinidad. This hypothesis was supported by strong similarities in the morphology of specimens collected from those two countries.

The Caribbean coast of Colombia has been intensively sampled over the past 30 years, and as a consequence its shore-fish fauna is well known. Intensive sampling by Garzón-Ferreira (1989) on the Colombian coast revealed no specimens of *O. punctatus*. To date, the only record of this species (Table 1) on that coast of Colombia is a single specimen from Portete Bay, on Guajira Peninsula, in the eastern end Colombia, just west of the Gulf of Venezuela (Fig. 2c).

There are various records of *O. punctatus* collected in the Gulf of Venezuela, adjacent to the east of Guajira Peninsula (Fig. 2c, Table 1). These include the Gulf itself, and several sites in the channel connecting lago de Maracaibo to the Gulf of Venezuela. Such specimens were

captured between 1978 and 2007 and represent new records from this study. The first record of *O. punctatus* from eastern Venezuela was taken by Cervigón (1966) from the Gulf of Paria in 1961 (Table 1). Subsequently, Lasso *et al.* (2004) collected specimens from a rocky beach of the Orinoco Delta river, in 2002 (Table 1). Other new records from Venezuela are five lots (36 specimens) collected at that same site and a nearby sandy beach in 2004 and 2006 (Table 1). An additional specimen was found in the mouth of Caño Macareo (68 km east of the previous location) in 2008 (Table 1), together with 14 specimens from four locations from the eastern end of South coast of the Paria Peninsula. (Fig. 2a; Table 1). One of us (RR), while snorkeling at one of the latter sites, saw dozens of *O. punctatus* darting around a rocky point within 1 m of the surface of the water. Most recently (April 2009), a specimen was captured inside the shell of a dead barnacle attached to the hull of the ship Boca Grande, 7 km north of the outfall from Caño Macareo.

The two regions of Venezuela where the populations of *O. punctatus* evidently are established, the (western) Gulf of Venezuela and the (eastern) Gulf of Paria include the most extensive and important estuary areas of the northern coast of South America. Extensive sampling using small rotenone stations of shallow estuarine and marine habitats between Paria Peninsula and the Gulf of Venezuela by JP, JVT and DRR, between 2005 and 2008 failed to record any specimens of *O. punctatus*. The entrance of lago de Maracaibo and the Gulf of Paria were the only two locations in which *O. punctatus* was collected.

In Brazil, the records of *O. punctatus* date from 2002 and 2008 (Figs. 1 and 2d, Table 1). In 2002, 90 specimens were captured in the Bahia State (Gehardinger *et al.* 2006). In 2004, Gehardinger *et al.* (2006) found two specimens in Rio de Janeiro State, and six specimens were collected from fouling organisms on the hull of a ship in Santa Catarina State (Table 1). Here we report new records from the vicinity of the mouth of the Amazon River in 2005 and 2006 (Figs. 1 and 2d Table 1). Most recently, a population was found in Pará State (Fig. 2d, Table 1).

Springer & Gomon (1975), on the basis of a morphological and historical analysis of the species in the west Atlantic concluded that the populations of *O. punctatus* are the result of an introduction to Trinidad via shipping from India between 1538 and 1914 that transported immigrant workers to Trinidad Island. They thought that ballast water or hull fouling organisms were involved in supporting *O. punctatus* individuals during the voyages.

Information we presented and summarized here, based on collections of *O. punctatus* at additional sites in the Central and NE South American coast also implicates shipping movements in subsequent expansions of that species range. All new collection sites are at or very near to, ports and seaways that support heavy shipping activity: the Gulf of Venezuela and Lago de Maracaibo and the sites in NE Colombia. In this regard, the absence of records of *O.*

Table 1. Records of *Omobranchus punctatus* from Trinidad (T), Panama and Colombia (PC), Venezuela (V) and Brazil (B). References from: 1 - Fowler (1931), 2 - Springer & Gomon (1975), 3 - Garzón-Ferreira (1989), 4 - Cervigón (1966), 5 - Lasso *et al.* (2004), 6 - Gerhardinger *et al.* (2006), 7 - Loebmann *et al.* (2010), and 8 - Soares *et al.* (2011).

Collection	Date	Site	Source
T1	1930	Brighton beach, Gulf of Paria	1, 2 ANSP 2 lots
T2	1933	Trinidad, Gulf of Paria	2, BMNH 1 lot
T3	1960	Salt Bay, east coast of Trinidad	BMNH 1 lot
T4	1961	Mayaro, Rodix Point, east coast of Trinidad	2, USNM 1 lot
T5	1961	Salt Bay, east coast of Trinidad	2, USNM 1 lot
V1	1961	Guiria, Sucre state, Gulf of Paria	4, MOBR-EDIMAR 1 lot
T6	1963	Chaguaramas Bay, Gulf of Paria	2, UF 2 lots
PC1	1966	Limón Bay, Atlantic coast, Panamá	2, USNM 1 lot
PC2	1967	Limón Bay, Atlantic coast, Panamá	2, USNM 1 lot
T7	1968	Salt Bay, east coast of Trinidad	BMNH 3 lots
T8	1968	Mayaro, Rodix Point, east coast of Trinidad	BMNH 3 lots
PC3	1970	Limón Bay, Atlantic coast, Panamá	2, SIO 1 lot
PC4	1971	Limón Bay, Atlantic coast, Panamá	2, SIO 1 lot
PC5	1972	Gatún locks, Atlantic coast, Panamá	2, GCRL 2 lots
PC6	1974	Gatún locks, Atlantic coast, Panamá	2, GCRL 2 lots
V2	1978	Paraguaipoa, Zulia state, Gulf of Venezuela	FLMNH 1 lot
V3	1978	Zapara Island, Zulia state	MCNG 1 lot
V4	1978	El Tablazo Bay, Zulia state	MCNG 1 lot
PC7	1981	Portete Bay, Peninsula de La Guajira, Colombia	3, INV - PEC 1 lot
V5	2002	Pedernales beach, caño Manamo, Orinoco Delta, Delta Amacuro state	5, MHNLS 4 lots
B1	2002	Todos os Santos bay, Bahia	6, MNRJ 1 lot
V6	2004	Pedernales beach, caño Manamo, Orinoco Delta, Delta Amacuro state	MHNLS 1 lot
B2	2004	Ilha Grande bay, Rio de Janeiro	6, LNEP-UFF 1 lot
B3	2004	Babitonga bay, Santa Catarina	6, MHNLI 2 lots
V7	2006	Pedernales beach, caño Manamo, Orinoco Delta, Delta Amacuro state	MHNLS 1 lot
V8	2006	Pedernales beach, caño Manamo, Orinoco Delta, Delta Amacuro state	MHNLS 1 lot
V9	2006	Pedernales beach, caño Manamo, Orinoco Delta, Delta Amacuro state	MHNLS 1 lot
V10	2006	Cotorra island, Orinoco Delta, Delta Amacuro state	MHNLS 1 lot
B4	2006	Araçagy beach, Maranhão	CPDOL 1 lot
B5	2006	Calhau beach, Maranhão	CPDOL 1 lot
B6	2006	São Marcos beach, Maranhão	CPDOL 1 lot
V11	2007	Santa Cruz, El Tablazo bay, Zulia state	MHNLS 1 lot
V12	2007	Palmarejo, Estrecho of Lago de Maracaibo, Estado Zulia	AMNH 1 lot
V13	2007	Isla de Pájaros, Estrecho of Lago de Maracaibo, Estado Zulia	AMNH 1 lot
V14	2008	Punta Pescador beach, caño Macareo, Orinoco Delta, Delta Amacuro state	MHNLS 1 lot
V15	2008	Cariaquito inlet, Paria Peninsula, Sucre state	MHNLS 1 lot
V16	2008	South of Cariaquito inlet, Paria Peninsula, Sucre state	MHNLS 1 lot
V17	2008	Lagoon, Patao inlet, Paria Peninsula, Sucre state	MHNLS 1 lot
V18	2008	Patao Point, Paria Peninsula, Sucre state	MHNLS 1 lot
B7	2008	Ilha da Romana, Pará	LBP-UFPA 1 lot
B8	2008	Luís Correia, Piauí	7, UFBA 1 lot
B9	2008, 2010	APA Algodão-Maiandua, Pará	8, MPEG 8 lot
V19	2009	Boca Grande Ship, 7 km North Punta Pescador, caño Macareo, Orinoco Delta, Delta Amacuro state	MHNLS 1 lot

punctatus on the Venezuelan coast between the Gulfs of Paria and Venezuela, on the Panama coast, east of the Panama Channel, and along most of the coast of Colombia are particularly revealing. Gerhardinger *et al.* (2006) and Hostim *et al.* (2002) linked recent records of this species at sites on the east coast of Brazil to ship movements and shipping supply of offshore oil platforms. On the NE coast of Brazil, the collection sites reported here support heavy shipping. However, some expansion of the geographic range of *O. punctatus* through larval dispersal on nearshore ocean currents may well be involved in expansions along the eastern coast of South America: the south Equator Current flowing across the Atlantic bifurcates when it meets the hump of Brazil, with the North Brazil Current flowing along the coast to the

Caribbean, and the South Brazil current flowing south to about the tropic of Capricorn. These currents are thought to be important in promoting dispersal of reef fishes (*e.g.* Rocha, 2003). The former could be involved in spreading *O. punctatus* along the NE coast of Brazil and the latter in spreading it along the southern Brazilian coast.

Although it is hard to know the natural distribution of *O. punctatus* (Jeffrey Williams, personal communication, 2009), there are records of likely introductions of this species elsewhere in the world. Springer & Gomon (1975) noted that specimens captured at Mozambique in 1951 and 1970 likely came from a population introduced by ballast water. Subsequent captures at Kenya (USNM 293027) and the southern tip of South Africa (BMNH 1979.3.23.57) likely

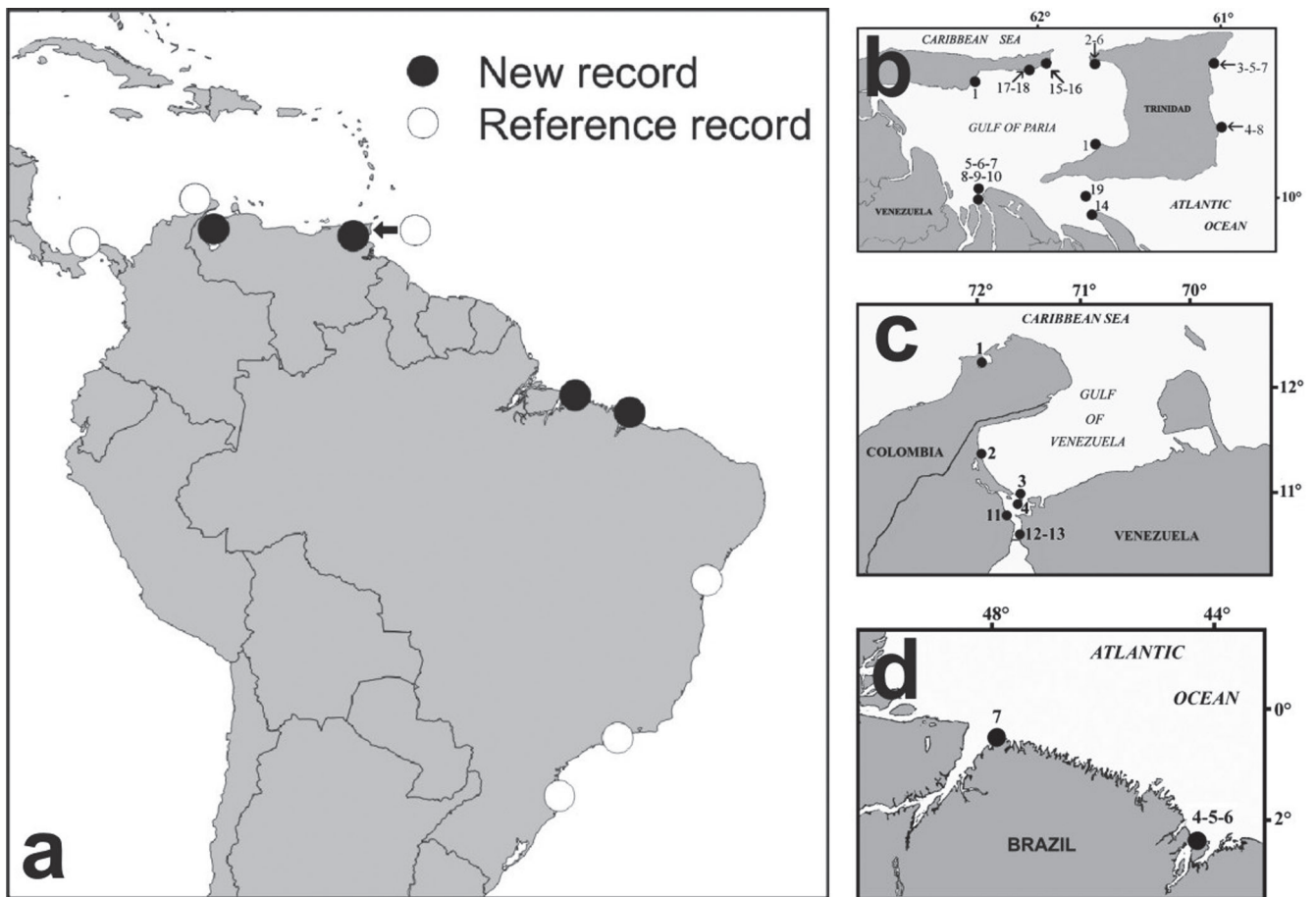


Fig. 2. Distribution of *Omobranchus punctatus* in Central and South American coasts. **a)** Full circle represents new records and open circle represents records from literature; **b)** Catch sites of *Omobranchus punctatus* in the eastern coast of Venezuela (Gulf of Paria) and Trinidad (see Table 1); **c)** Localities with records of *Omobranchus punctatus* in western Venezuela (Gulf of Venezuela) and Colombia (Guajira Peninsula) (see Table 1) and **d)** Localities with records of *Omobranchus punctatus* from Maranhão and Pará states, northern Brazil (see Table 1).

resulted from the same or later introductions. Bath (1980) recorded *O. punctatus* (SMF 15218) captured in 1979, within the Suez Canal, between the Mediterranean Sea and the Red Sea, while Golani (2004) records it (HUJ 18977), on the Mediterranean coast of Israel.

In addition to *O. punctatus*, introductions of three other members of the same genus have been recorded: *O. elongatus* in Hawaii in 1951 (Walford & Wicklund, 1973), and subsequently, in Guam in 1992 (Eldredge, 1994), *O. obliquus* in Hawaii and Kiribati (Myers, 1991) and *O. ferox* (Herre, 1927) in continental waters from the United States since 1998 (Bartley, 2006). All those introductions are regarded as having led to the establishment of resident populations, potentially leading to competition with native species (Albins & Hixon, 2008).

Other exotic species have been introduced to the southern Caribbean Sea. Pezold & Cage (2002) found *Eleotris picta* (Eleotridae), from western Venezuela. Its natural distribution encompasses the Pacific coast of the America

between Mexico and Ecuador. Lasso-Alcalá *et al.* (2005a) and Lasso-Alcalá *et al.* (2005b) found the eleotrid *Butis koilomatodon* and the gobiid *Gobiosoma bosc*, near the capture points of *O. punctatus* on the north side of the Orinoco Delta River. *Butis koilomatodon*, which naturally occurs from east Africa to the West Pacific (Papua New Guinea) (Dawson, 1973; Miller & Wongrat, 1990), had also been collected from the Pacific side entrance (Miraflores locks) to the Panama Channel (Dawson, 1973), Western Central Atlantic: Port Harcourt, Nigeria (Miller *et al.*, 1989), Boffa, Guine (Harrison *et al.*, 2003) and mouth of Ndian river in Cameroon (Stiassny *et al.*, 2008). The natural range of *Gobiosoma bosc* is the north west Atlantic, from the western Gulf of México to Massachusetts, on the Atlantic coast of the US (Bohlke & Robins, 1968; Castro-Aguirre *et al.*, 1999; Williams, 2002).

In the last ten years, the Indo-Pacific lionfishes *Pterois volitans* (Linnaeus, 1758) and *P. miles* (Bennett, 1828) have been recognized as the most alarming cases of introduction

and invasion in the Western Atlantic (Schofield, 2009). From 1999 to 2010, the dispersion of *Pterois volitans* is confirmed on the east coast of US (New York to Florida), Bermuda, North Caribbean (Bahamas to US Virgin Islands), Gulf of México (Florida and Yucatán Peninsula), Western Caribbean (México, Belize, Honduras, San Andrés and Providencia Archipelago, Costa Rica, Panama) and South Caribbean Sea (Colombia coast, Curaçao and Bonaire islands) (Whitfield *et al.*, 2002; Chevalier *et al.*, 2008; Guerrero & Franco, 2008; González *et al.*, 2009; Schofield, 2009; USGS-NAS, 2010; Aguilar-Perera & Tuz-Sulub, 2010). In Venezuela, this species has been recently observed and collected in 18 locations at the coast and islands of the central region (Lasso-Alcalá & Posada, 2010).

In Brazil, Caires *et al.* (2007) found the batrachoidid *Opsanus beta*, in several sites in southern Brazil (in São Paulo and Paraná States), to where it is thought to have been introduced in ship ballast water.

We recommend performing research focused on inventories of coastal regions near port and aquaculture facilities or with intense maritime traffic to seek other introduced species in Central and South America. Monitoring and studying the bio-ecology of the introduced species and already established populations of *Omobranchus punctatus* is also recommended. In addition, studies on population dynamic (population structure, reproduction, diet, age and growth), macroecology, behavior, competition with native species, habitat use and genetic variation will provide informations to a complete monitoring of the *O. punctatus*.

Material Examined. *Omobranchus punctatus*. **Brazil:** Maranhão: CPDOL 6612, 6613, 6614, 6615, 6616, 6617, 6618, Araçagy beach, tidepool, São Luís Municipality; CPDOL 6619, 6620, 6621, São Marcos beach, tidepool, São Luís Municipality; CPDOL 6622, 6623, 6624, Calhau beach, tidepool, São Luís Municipality. Pará: GEA 1255, Ilha da Romana, tidepool, Curuçá Municipality. **Venezuela:** Delta Amacuro: MHNL 17216, 17217, 17218, 17219, 17220; 20728, 21460, 21277, Playa de Perdernales, tidepool; MHNL 21470, Playa Arenosa, tidepool. MHNL 22768, Playa Punta Pescador, tidepool. Zulia: MHNL 22483, Santa Cruz, tidepool. AMNH 241423, Palmarejo, tidepool. AMNH 241438, Isla de Párajos, tidepool. MHNL 24615, Casco Del Barco Boca Grande, tidepool. Sucre: MHNL 24525, 24526, Enseada de Cariaquito, tidepool. MHNL 24523, Laguna, tidepool. MHNL 24524, Punta Patao, tidepool.

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