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Rapid Communication

First report of the non-native gulf toadfish *Opsanus beta* (Goode & Bean, 1880) on the coast of Rio de Janeiro – Brazil

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Abstract

Biological invasions are considered an extreme risk to biodiversity, resulting in serious ecological and economic problems. Marine species have been introduced mainly through ballast water in estuaries, bays and inland waters, those bodies are historically threatened by intense urbanization making them highly susceptible to invasions. The gulf toadfish, *Opsanus beta* has been reported as an invasive species that commonly inhabits shallow water bodies, such as coastal bays and estuaries. Its native distribution range from Belize to Palm Beach – Florida (Gulf of Mexico). The first occurrence of *O. beta* on the Brazilian coast was in Santos estuarine area, Southeastern region, and the second was further south, in the estuarine complex of Paranaguá, Southern region. Here we report the first occurrence of a single *O. beta* in Rio de Janeiro coast, which was caught in October 2017, using a beach seine in Bica Beach, a polluted sandy beach located in Guanabara Bay – RJ. Considering the similarities among Guanabara Bay and other areas in Brazil, there is a potential for the establishment of *O. beta* populations in Guanabara Bay in a near future.

Key words: bioinvasion, non-indigenous species, estuary, southwest Atlantic, reef fish

Introduction

Since the facility of traveling across geographical barriers has been growing with the globalization in the past 200 years, one of the most serious ecological and economic problems has been the introduction of non-native species (Perrings et al. 2005; Seebens et al. 2017). Biological invasions, characterized by the establishment of introduced species and their subsequent impacts over the ecosystem, are considered an extreme risk to biodiversity (Vitousek et al. 1997; Sala et al. 2000). In the marine realm, species have been introduced mainly by ballast water worldwide along the take up and release of these waters in estuaries, bays and inland waters, spreading non-native species to these environments. A great part of these

water bodies are historically threatened by intense urbanization (e.g. the Guanabara Bay in Rio de Janeiro) and, consequently, water degradation, making them highly susceptible to invasions (Carlton and Geller 1993; Ruiz et al. 1997; Williams and Grosholz 2008).

The gulf toadfish *Opsanus beta* (Goode & Bean, 1880) (Batrachoididae) has been reported as an invasive species that commonly inhabits seagrass beds and rocky shores in shallow water bodies, such as coastal bays and estuaries (Robins and Ray 1986). Its native distribution ranges from Belize to Palm Beach – Florida (Gulf of Mexico) (Collette 2002). Here we report the first occurrence of *O. beta* on Rio de Janeiro coast, Southeastern Brazil. This paper is part of a long-term and broad study that aims to address the spatial changes of fish assemblages along the estuarine gradient of Guanabara Bay.

Materials and methods

Guanabara Bay, the second largest bay in Brazil, is a highly impacted estuarine system located on the coast of the State of Rio de Janeiro, one of the most populated urban areas of the world, home to circa 11 million people. Covering a surface area of 381 km² and 22 islands (Fistarol et al. 2015), Guanabara Bay harbors one of the most important ports in Brazil, handling over 5 million tons cargo in 2017 (ANTAQ 2017).

This study was conducted in nine beaches along Guanabara bay and was sampled bimonthly from October 2017 to July 2019. A single gulf toadfish was caught at Bica Beach (22°49′31″S; 43°10′06″W – Figure 1), a polluted sandy beach (~ 1 km long) located in the south of Governador Island, one of the most degraded areas in Guanabara Bay, located within a region of poor water quality (Fistarol et al. 2015). Fish were surveyed using a beach seine with a bag (20 m width × 2 m height; 7 mm mesh size). The beach seine was set parallel to the coast and hauled perpendicularly to the shore by a distance of 20 m (up to 3 m depth), resulting in an approximately 400 m² fishing area. Before the seine haul, water temperature, dissolved oxygen, salinity and pH were measured using a multi-parameter probe Hanna HI 9828 and transparency was assessed through a Secchi disk.

Opsanus beta was dissected in the Laboratory of Theoretical and Applied Ichthyology at the Ecology and Marine Resources Department of the Federal University of the State of Rio de Janeiro (UNIRIO). The fish was measured for total length (cm; TL) and total weight (g), of which gonads and stomach were weighed and preserved in 10% buffered formalin. The stage of gonad maturation was macroscopically classified following Núñez and Duponchelle (2009).

Results

The single sampled individual of *Opsanus beta* was captured in October 2017 and measured 19.4 cm (TL) and weighed 136.31g (Figure 2). In order

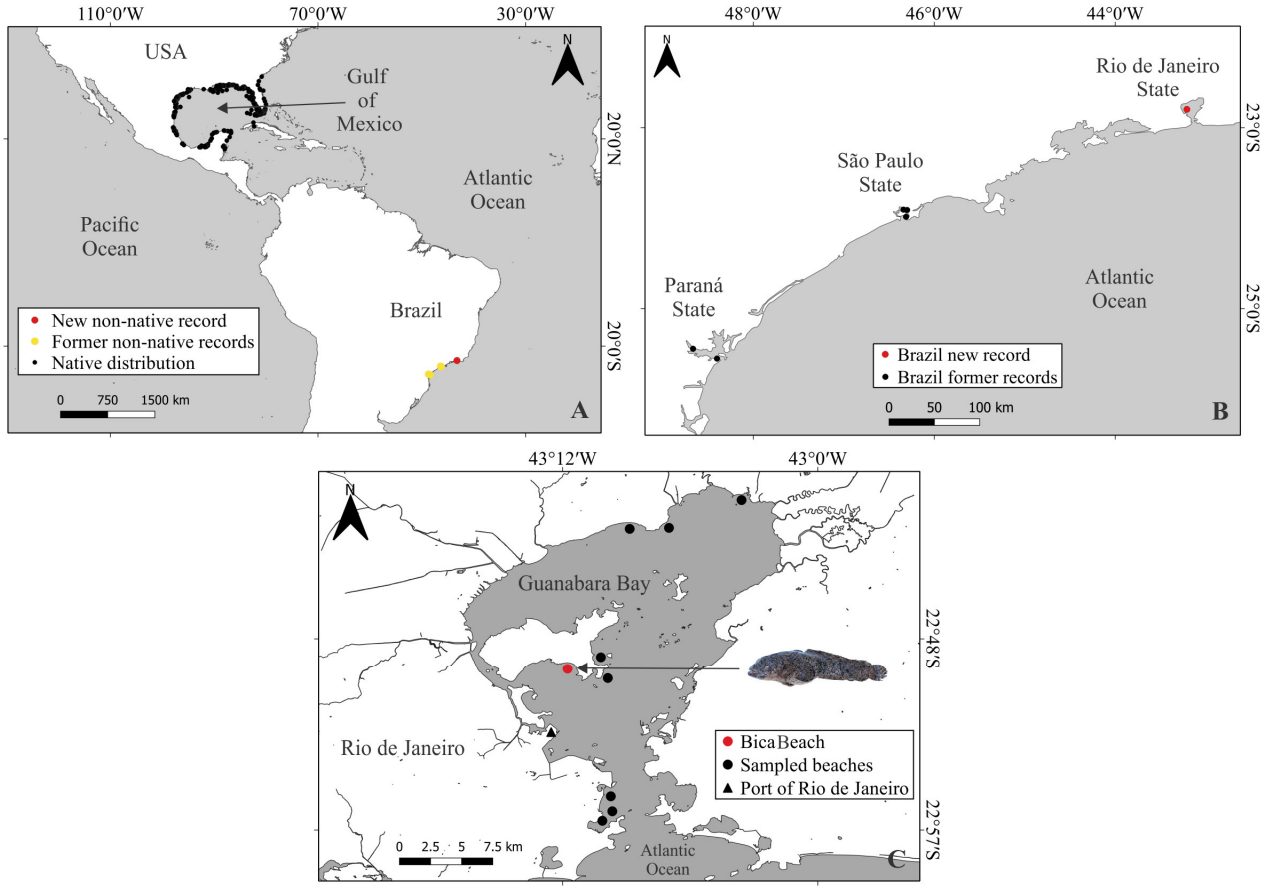

Figure 1. (A) Native distribution (as available in GBIF 2019), former and new non-native records of *O. beta* throughout the world; (B) Brazilian former and new records of *O. beta*; (C) the nine beaches currently surveyed at Guanabara Bay, highlighting the Bica Beach, which was the site where *O. beta* was recorded in the present study.

Figure 2. *Opsanus beta* (19.4 cm total length), from Bica Beach, Guanabara Bay, RJ. Photo: AAB.

to confirm the taxonomy, the morphometric characteristics of the fish were taken and compared with the results of other studies in both native and non-native ecosystems (Table 1).

The gonads of the captured individual weighed 5.69 g and were of a recently spawned female since they were still relatively large and flaccid with remaining spaces and oocytes (Figure 3). This stage is characterized by the presence of developing yellow (vitellogenic) oocytes of different sizes and intense vascularization at the distal part, which may indicate the beginning of new spawning cycles until the end of the breeding season.

Table 1. Morphometric characteristics of the single *Opsanus beta* specimen sampled in Guanabara Bay compared to North Atlantic (Florida, United States), South Atlantic (Paraná, Brazil)—examined material in Caires et al. 2007 study—and literature data (Collette 2001). Standard length (mm) and counts of fish body parameters in raw data, other body measurements as given proportions in thousandths of standard length (‰ SL) (Adapted from Caires et al. 2007).

	(Guanabara Bay – present study)	(Florida-USA)	(Paraná-Brazil)	(literature)
		Max–Min		
Standard length (mm)	165	30.3–126.6	107.3–200.5	77.5–200.0
Dorsal fin rays	26	25–26	25	24–25
Anal fin rays	20	22	21	20–22
Pectoral fin rays	19	18–19	19	18–19
Dorsal lateral line papillae	26	25–28	23–25	25–29
Ventral lateral line papillae	24	23–26	21–22	22–25
Pectoral axil glands	8	8–12	10–11	6–12
‰ SL				
Head length (mm)	348.6	297.8–387.4	360.0–390.9	367.0–412.0
Maximum head width (mm)	340.8	229.2–297.4	268.8–292.4	246.0–324.0
Maximum head height (mm)	177.1	83.6–228.6	191.6–221.3	
Eye diameter (mm)	53.3	49.5–104.5	49.8–64.0	63.0–92.0
Interorbital width (mm)	89.6	37.6–52.3	54.5–57.1	54.0–86.0
Predorsal (mm)	377.8	437.0–584.8	351.3–478.1	471.0–486.0
Preanal (mm)	517.0	533.1–585.5	576.6–612.7	551.0–600.0
Pectoral fin (mm)	219.9	203.1–253.2	222.9–224.4	196.0–223.0
Pelvic fin (mm)	152.4	149.0–213.3	157.4–173.3	160.0–182.0

Figure 3. *Opsanus beta*'s female gonad, in advanced development stage. Photo: AAB.

Two genera of brachyuran *Acantholobulus* sp. and *Achelous* sp. (Figure 4) were observed within stomach contents, weighing in total 1.901 g, beyond 1.273 g of non-identified organic material. In addition, there was plastic and hair fragments inside the stomach (Figure 4).

The abiotic conditions at Bica Beach measured at the moment wherein the specimen was captured were: water temperature 24.37 °C, dissolved oxygen 1.6 mg/L, salinity 32.98 PSU, pH 8.30 and transparency 80 cm.

Discussion

Identifying which species has the highest potential to establish itself and the most susceptible sites for invasion are fundamental questions for the study

Figure 4. Stomach contents of *O. beta*, among series of chelae of two brachyuran genera, *Acantholobulus* sp. and *Achelous* sp. plastic and hair. Photos: AAB.

of bioinvasions (Mack et al. 2000). Such information could provide more effective prevention actions, while on the other hand, once established, it takes larger efforts and costs to control and mitigate its impacts (Kolar and Lodge 2001). The probability that a species survives and spreads depends on the interaction of a series of factors, involving the environmental conditions and biotic resistance (e.g. community diversity, tolerance thresholds, predators and competitor abundances) (DeRivera et al. 2005). In addition, if the non-native species is a dissimilar predator to native ones, it will likely not be recognized as menace by native prey and, as a prey, to native top predators (Sih et al. 2010).

The first occurrence of *O. beta* along the Brazilian coast (see Rotundo et al. 2005) occurred in Santos estuarine area (23°58′56″S; 46°17′22″W). Although Rotundo et al. (2005) erroneously described it as a new species named *O. brasiliensis*, Caires et al. (2007) concluded that it was a junior synonym of *O. beta* and registered the first occurrence further south, in the estuarine complex of Paranaguá (25°29′07″S; 48°26′15″W), in the State of Paraná (Figure 1). It is also suggested that, since the records of this species

are close to port areas, ballast water might be responsible for its introduction. Tomás et al. 2012 concluded that *O. beta* is probably already established in Santos estuary and can be considered a severe threat to native diversity not only at this place but to any other estuarine system.

Opsanus beta is an ambush predator of many groups including fishes and invertebrates, in both native and non-native environments (Tomás et al. 2012; López et al. 2017). The crab genus *Achelous* found in the stomach contents in this study is considered commercially valuable in Guanabara Bay (Moreira et al. 2011), a fact that can amplify the future impacts of this hypothetical invasion. Furthermore, two species of fishes (*Citharichthys spilopterus* Günter, 1862 and *Gobionellus oceanicus* Pallas, 1770) that were found in stomach contents of *O. beta* at its native area (López et al. 2017), can also be found in Guanabara bay (Silva et al. 2016). The occurrence of plastic and hair fragments in the stomach emphasizes the voracious nature of this predator, probably ingested while preying on the crabs.

Reproduction of *O. beta* starts when male specimens nest and attempt to attract females with courtship vocalization, and after fertilization males guard the nest (Barimo et al. 2007; López et al. 2017). The type of spawning ranges from batch (Florida, USA (Barimo et al. 2007) and Paraná, Brazil (Nagata 2013)) to single spawning in Florida (Malca et al. 2009). Another difference found in literature was the period of spawning. Barimo et al. (2007) detected winter and spring as spawning seasons and López et al. (2017) observed spawning during summer (Veracruz, México) in its native area (Florida, USA), while Nagata (2013) described *O. beta* as an all-year-long spawning species. Those differences might be attributed to different seasonal abiotic variations among the studied areas and show *O. beta* ability to adapt to different environments.

According to Breder (1941), the length at first maturity of this species is 9.5 cm, which indicates that the captured individual is an adult able to reproduce, also evidenced by the developed gonads. Since the macroscopic stage of maturity of the gonads was classified as spawned, it is possible to infer that the species has been spawning in Guanabara Bay.

Several studies showed that *O. beta* is adapted to a wide range of conditions regarding water temperature (18.9 to 32 °C), salinity (8 to 39 PSU) and dissolved oxygen (4.1 to 11.4 mg/L), occurring in costal water bodies, such as bays and estuaries, with spatial and seasonal variations (Serafy et al. 1997; Barimo et al. 2007; López et al. 2017). Male toadfish can take advantage of pollution by using human waste (cans, plastic containers) as shelter when guarding the nest (Ryder 1886; Gill 1907).

Finally, considering the similarities among Guanabara Bay and other areas in Brazil where the species is considered established (see Tomás et al. 2012), the potential establishment of *O. beta* in Guanabara Bay raises concern. Therefore, actions to avoid the arrival and spread of other individuals, leading to further population establishment and massive

invasion in this highly disturbed system are extremely important. However, to be sure of the establishment and its potential impacts, which are key factors to assign this species as invasive, further studies focusing on the ecology of this species are needed, thus requiring larger numbers of individuals, not recorded through our surveys. It is important to mention that our sampling method (beach seine) is not the most appropriate, neither our aim, to catch *O. beta*, since, beaches are not the common habitat of this species (Robins and Ray 1986).

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References

ANTAQ (2017) ANTAQ Sistema de Informações Gerenciais (SIG). http://portal.antaq.gov.br/index.php/sistema-de-informacoes-gerenciais-sig/ (accessed 12 July 2018)

Barimo JF, Serafy, JE, Frezza PE, Walsh PJ (2007) Habitat use, urea production and spawning in the gulf toadfish *Opsanus beta*. *Marine Biology* 150: 497–508, https://doi.org/10.1007/s00227-006-0356-7

Breder CM (1941) On the reproduction of *Opsanus beta*, Goode & Bean. *Zoologica* 26(21): 229–232

Caires RA, Pichler HA, Spach HL, Ignácio JM (2007) *Opsanus brasiliensis* (Rotundo, Spinelli and Zavalla-Camin, 2005) (Teleostei: Batrachoidiformes: Batrachoididae), a junior synonym of *Opsanus beta* (Goode and Bean, 1880), with notes on its occurrence in the Brazilian coast. *Biota Neotropica* 7: 136–139, https://doi.org/10.1590/S1676-06032007000200015

Carlton JT, Geller JB (1993) Ecological roulette: the global transport of nonindigenous marine organisms. *Science* 261: 78–82, https://doi.org/10.1126/science.261.5117.78

Collette BB (2001) *Opsanus dichrostomus*, a new toadfish (Teleostei: Batrachoididae) from the western Caribbean Sea and southern Gulf of Mexico. *Occasional Papers of the Museum of Zoology the University of Michigan* 731: 1–16

Collette BB (2002) Batrachoididae. In: Carpenter KE (ed), The Living marine resources of the Western Central Atlantic. Volume 2: Bony Fishes part 1 (Acipenseridae to Grammatidae). FAO Species Identification Guide for Fishery Purposes American Society of Ichthyologists and Herpetologists Special Publication Number 5, FAO, pp 1026–1042

DeRivera CE, Ruiz GM, Hines AH, Jivoff P (2005) Biotic resistance to invasion: native predator limits abundance and distribution of an introduced crab. *Ecology* 86: 3364–3376, https://doi.org/10.1890/05-0479

Fistarol GO, Coutinho FH, Moreira APB, Venas T, Cánovas A, Paula Jr. SER, Coutinho R, de Moura RL, Valentin JL, Tenenbaum DR, Paranhos, R, do Valle RAB, Vicente ACP, Amado Filho GM, Pereira RC, Kruger R, Rezende CE, Thompson CC, Salomon PS, Thompson FL (2015) Environmental and sanitary conditions of Guanabara Bay, Rio de Janeiro. *Frontiers in Microbiology* 6: 1232, https://doi.org/10.3389/fmicb.2015.01232

GBIF (2019) GBIF Occurrence Download. https://doi.org/10.15468/dl.lv6dqg (accessed 02 December 2019)

Gill T (1907) *Opsanus*. In: Life histories of toadfishes (Batrachoidids), compared with those of weevers (Trachinids) and stargazers (Uranoscopids). *Smithsonian Miscellaneous Collections* 48: 391–401

Kolar CS, Lodge DM (2001) Progress in invasion biology: predicting invaders. *Trends in Ecology & Evolution* 16: 199–204, https://doi.org/10.1016/S0169-5347(01)02101-2

López JF, Santes González AG, Arenas LGA, Sánchez CB, Escorcia HB, Pérez JAM, Rodríguez EP, Legorreta JLV (2017) Ecología y reproducción de *Opsanus beta* (Actinopterygii: Batrachoididae) en la Laguna de Alvarado, Veracruz, México. *Revista de Biología Tropical* 65: 1381–1396, https://doi.org/10.15517/rbt.v65i4.27239

Mack RN, Simberloff D, Lonsdale WM, Evans H, Clout M, Bazzaz FA (2000) Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications* 10: 689–710, https://doi.org/10.1890/1051-0761(2000)010[0689:BICEGC]2.0.CO;2

Malca E, Barimo JF, Serafy JE, Walsh PJ (2009) Age and growth of the gulf toadfish *Opsanus beta* based on otolith increment analysis. *Journal of Fish Biology* 75: 1750–1761, https://doi.org/10.1111/j.1095-8649.2009.02426.x

Moreira FN, Vianna M, Lavrado HP, Silva-Junior DR, Keunecke KA (2011) Survival and physical damage in swimming crabs (Brachyura, Portunidae) discarded from trawling fisheries in an estuarine ecosystem in southeastern Brazil. *Crustaceana* 84: 1295–1306, https://doi.org/10.1163/156854011X596937

Nagata JK (2013) Biologia reprodutiva e alimentar da espécie exótica *Opsanus beta* (Teleostei: Batrachoididae) no Complexo Estuarino de Paranaguá, Paraná, Brasil. MSc Dissertation, Federal University of Paraná, Curitiba, Paraná, Brazil, 47 pp

Núñez J, Duponchelle F (2009) Towards a universal scale to assess sexual maturation and related life history traits in oviparous teleost fishes. *Fish Physiology and Biochemistry* 35: 167–180, https://doi.org/10.1007/s10695-008-9241-2

Perrings C, Dehnen-Schmutz K, Touza J, Williamson M (2005) How to manage biological invasions under globalization. *Trends in Ecology & Evolution* 20: 212–215, https://doi.org/10.1016/j.tree.2005.02.011

Robins CR, Ray GC (1986) A field guide to Atlantic coast fishes of North America. Houghton Mifflin Company, Boston, USA, 354 pp

Rotundo MM, Spinelli M, Zavala-Camim LA (2005) Descrição de uma nova espécie de *Opsanus* (Teleostei-Batrachoididae) no Litoral do Estado de São Paulo. *Revista Ceciliana* 23: 93–99

Ruiz GM, Carlton JT, Grosholz ED, Hines AH (1997) Global invasions of marine and estuarine habitats by non-indigenous species: mechanisms, extent, and consequences. *American Zoologist* 37: 621–632, https://doi.org/10.1093/icb/37.6.621

Ryder JA (1886) The development of the toadfish. *American Naturalist* 20: 77–80, https://doi.org/10.1086/274152

Sala OE, Chapin FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL, Sykes MT, Walker BH, Walker M, Wall DH (2000) Global biodiversity scenarios for the year 2100. *Science* 287: 1770–1774, https://doi.org/10.1126/science.287.5459.1770

Seebens H, Blackburn TM, Dyer EE, Genovesi P, Hulme PE, Jeschke JM, Pagad S, Pyšek P, Winter M, Arianoutsou M, Bacher S, Blasius B, Brundu G, Capinha C, Celesti-Grapow L, Dawson W, Dullinger S, Fuentes N, Jäger H, Kartesz J, Kenis M, Kreft H, Kühn I, Lenzner B, Liebhold A, Mosena A, Moser D, Nishino M, Pearman D, Pergl J, Rabitsch W, Rojas-Sandoval J, Roques A, Rorke S, Rossinelli S, Roy HE, Scalera R, Schindler S, Štajerová K, Tokarska-Guzik B, Kleunen M, Walker K, Weigelt P, Yamanaka T, Essl F (2017) No saturation in the accumulation of alien species worldwide. *Nature Communications* 8: 14435, https://doi.org/10.1038/ncomms14435

Serafy JE, Hopkins TE, Walsh PJ (1997) Field studies on the ureogenic gulf toadfish in a subtropical bay. I. Patterns of abundance, size composition and growth. *Journal of Fish Biology* 50: 1258–1270, https://doi.org/10.1111/j.1095-8649.1997.tb01651.x

Sih A, Bolnick DI, Luttbeg B, Orrock JL, Peacor SD, Pintor LM, Preisser E, Rehage JS, Vonesh JR (2010) Predator-prey naïveté, antipredator behavior, and the ecology of predator invasions. *Oikos* 119: 610–621, https://doi.org/10.1111/j.1600-0706.2009.18039.x

Silva Jr DR, Paranhos R, Vianna M (2016) Spatial patterns of distribution and the influence of seasonal and abiotic factors on demersal ichthyofauna in an estuarine tropical bay. *Journal of Fish Biology* 89: 821–846, https://doi.org/10.1111/jfb.13033

Tomás ARG, Tutui SDS, Fagundes L, Souza MR (2012) *Opsanus beta*: an invasive fish species in the Santos estuary, Brazil. *Boletim do Instituto de Pesca* 38(4): 349–355

Vitousek PM, Mooney HA, Lubchenco J, Melillo JM (1997) Human domination of Earth's ecosystems. *Science* 277: 494–499, https://doi.org/10.1126/science.277.5325.494

Williams SL, Grosholz ED (2008) The invasive species challenge in estuarine and coastal environments: marrying management and science. *Estuaries and Coasts* 31: 3–20, https://doi.org/10.1007/s12237-007-9031-6