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Distribution extension of invader Palometa *Serrasalmus maculatus* (Kner, 1858) and first record of *Pygocentrus nattereri* (Kner, 1858) (Characiformes: Serrasalmidae) at the Patos Lagoon System, Rio Grande do Sul State, Brazil

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ABSTRACT

This study documents the southern expansion of *Serrasalmus maculatus* and the first record of *Pygocentrus nattereri* in the central portion of Patos Lagoon, Brazil. Four individuals of *S. maculatus* were caught in the central and southern areas of the lagoon, whereas one sexually mature *P. nattereri* was found in its central region. Both species occur naturally in the Uruguay River basin and are considered allochthonous in the Patos Lagoon. Their presence in this lagoon could have been facilitated by artificial water channels associated with agricultural activities and exacerbated by high rainfall and river discharge, which are triggered by the *El Niño* phenomenon. Such predatory species pose a potential threat to local biodiversity due to their adaptable diets and the lagoon's habitat diversity, which is potentially suitable for such invaders.

Keywords: Invasive species, Biological invasions, Aquaculture, *El Niño*, Freshwater

The Serrasalmidae Family has approximately 101 recognized species (Fricke et al., 2023). The fish in this Family generally inhabit lentic environments, which typically occur in lakes and reservoirs, and feed mainly on fish (Agostinho and Júlio Júnior, 2002; Ferreira et al., 2014). The genus Serrasalmus Lacepède, 1803, popularly known as "piranhas" or "palometas" (in Portuguese) consists of 33 valid species, which have a wide distribution in the main drainage basins of South America. Palometas are commonly found in shoals and widely distributed throughout South American basins such as the Amazon, Orinoco, and Uruguay basins (Bertaco and Azevedo, 2013; Gimênes Júnior and Rech, 2022; Loureiro et al., 2023). There are two species of piranha in the Rio Grande do Sul State: *Serrasalmus maculatus* Kner, 1858 and *Pygocentrus nattereri* Kner, 1858, which are natives to the Uruguay River basin.

Recently, *S. maculatus* was identified as an invasive species in Patos Lagoon, occupying the northern region of the system (Bertaco et al., 2022). Therefore, this study aims to document the southern expansion of *S. maculatus* in this lagoon, as well as to record the occurrence of *P. nattereri* near its central area.

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The Patos Lagoon (Figure 1), located in southern Brazil, is the largest coastal lagoon in Latin America (~10,000 km²) and a favorable environment for the colonization of invasive species due to its great heterogeneity. This system is home to a wide variety of natural habitats, flooded fields, marshes, lakes, rivers, and an extensive estuarine region (~1,000 km²), which provides abundant food, favorable conditions for spawning, growth, and refuge for more than one hundred fish species (Fontoura et al., 2016; Mai and Possamai, 2022; Vieira et al., 2010). Studies have shown the vulnerability of this system to the establishment of invasive fish species (e.g., Garcia et al., 2004a; Troca and Vieira, 2012).

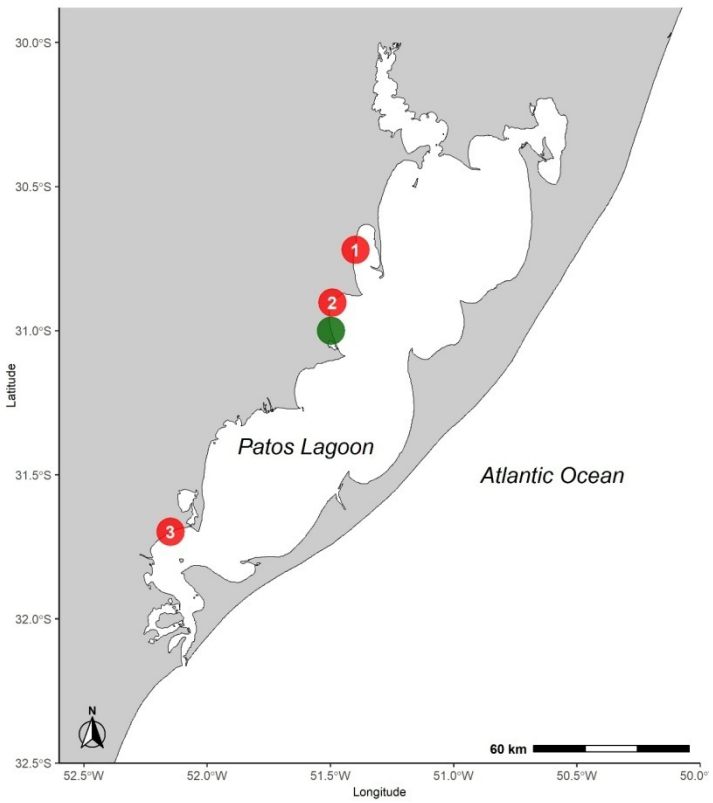

Figure 1. Map showing the location of the Patos Lagoon in South America. The red dots correspond to the occurrence of *Serrasalmus maculatus* (red dot 1 – individual A; red dot 2 – individuals B, C; red dot 3 – individual D). The green dot corresponds to the *Pygocentrus nattereri*.

The individuals were caught by local artisanal fishermen between October 2023 – May 2024 using gillnets and later given to the researchers for analysis. They were immediately preserved on ice for analysis at the Federal University of Rio Grande (FURG) at the Laboratory of Ichthyology. Each specimen was measured for weight and length using a caliper. Table 1 shows details of the morphometric and meristic data. The fish were identified according to Gimênes Júnior and Rech (2022) and Loureiro et al. (2023). One main morphological feature distinguishing both species is the shape of their head, *S. maculatus* has a concave-shaped head, whereas *P. nattereri* has a convex one. Gimênes Júnior and Rech (2022) also point out that *S. maculatus* has three to five teeth on the palate, whereas *P. nattereri* adults are toothless, as well as the number of spines on the ventral keel, *S. maculatus* has 21-24 and *P. nattereri* has 13-21, followed by six to ten post-pelvic (Gimênes Júnior and Rech,2022).

Table 1. Morphometric and meristic data of the palometa specimens *Serrasalmus maculatus (*A, B, C and D), and *Pygocentrus nattereri (*E*)* caught in Patos Lagoon.

	A	B	C	D	E
Weight (gr)	220.5	116.3	171.1	357.7	586.4
Morphometric data					
Total length	194	165	185	238	254
Standard length	150	130	140	186	207
Head length	50	43	47	65	70
Dorsal fin base	34	26	28	38	41
Adipose fin base	8	5	8	11	12
Caudal peduncle length	12	10	11	15	16
pre-orbital distance (snout)	8	7	10	10	12
Eye diameter	6	5	6	9	9
Post-orbital distance	28	22	27	28	30
Maximum body height	95	76	88	110	123
Caudal peduncle height	13	11	11	18	19
Pectoral fin length	29	25	30	42	47
Anal fin base	59	47	52	73	76
Upper jaw length	15	13	14	20	23
Head height	52	37	41	49	63
Pectoral fin base	5	2	4	6	8
Pre-dorsal distance	79	75	72	99	105
Pre-caudal portion (trunk)	106	92	94	115	128
Caudal portion	43	36	35	41	48
Caudal fin length	31	21	34	60	69
Mouth width	14	12	10	20	23
Interorbital distance	18	14	16	22	28
Meristic data					
Dorsal	I+17	I+15	I+15	I+15	I+16
Pectoral	12	11	13	14	14
Anal	II+33	II+33	I+33	II+33	II+33
Pelvic	7	6	7	6	7
Lateral line scales	85	79	80	85	79
Scales dorsal base to lateral line	35	32	34	35	36
Adipose base scales up to lateral line	10	8	9	10	10
Gill rakers 1st upper branchial arch	8	8	8	8	8
Gill rakers 1st lower branchial arch	7	7	7	7	7
Ventral keel spines	26	26	29	29	29
Pre-pelvic ventral keel spines	18	19	21	20	21
Post-pelvic ventral keel spines	8	7	8	8	7
Spines around the anus	4	6	6	4	2
Pre maxillary teeth	6	6	6	6	6
Palate teeth	10	12	10	10	0
Dentary teeth	7	7	7	7	7

The gonads of *P. nattereri* were removed and histologically processed according to the protocol by Beçak and Paulete (1976) and the total fecundity was estimated using a gravimetric method (Vazzoler, 1996). The specimens are preserved in the scientific collection of the Laboratory of Ichthyology, FURG (*Serrasalmus maculatus*: CIFURG #2956, #2957, #2958, #2959; *Pygocentrus nattereri*: CIFURG #2960).

Four individuals of *S. maculatus* were caught (Figure 2), in which one was in the municipality of Tapes (S 30' 39.084' W 51º 23.113) (Figure 2A), two were in the municipality of Arambaré (S 30' 55.411' W 51º 29.589') (Figure 2B, 2C), and one was in the municipality of Pelotas (S 31°41' W 52º 08') (Figure 2D). *Pygocentrus nattereri* was caught in Arambaré (S 30' 55.411' W 51º 29.589') (Figure 2E).

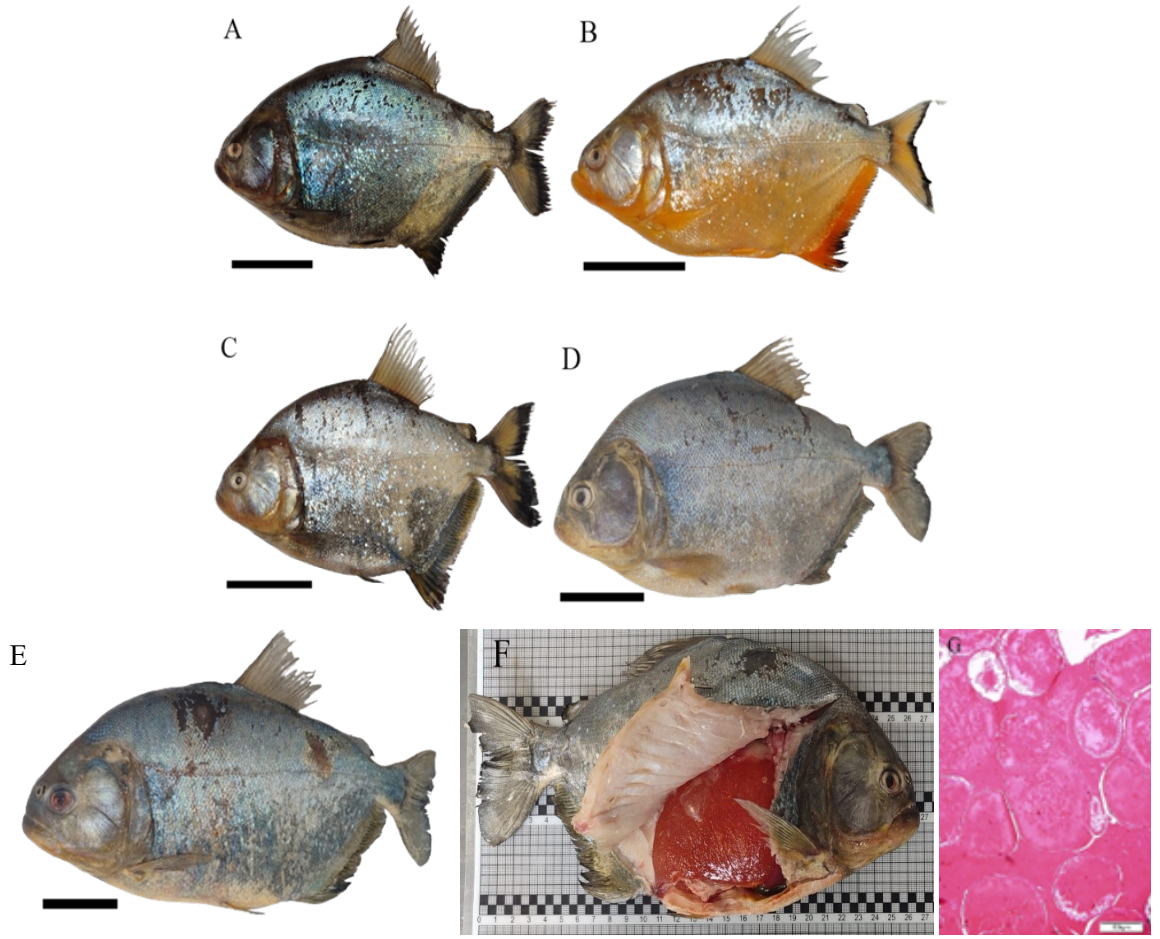

Figure 2. Individuals of *Serrasalmus maculatus* caught in Patos Lagoon system, in southern South America: (A) Tapes, (B,C) Arambaré, (D) Pelotas. Scale bar: 50mm. (E) Individual of *Pygocentrus nattereri* caught in Arambaré, Patos Lagoon system, in southern South America, (F) macroscopic detail of mature gonads and (G) histological section of ovary showing high frequency of oocytes with complete vitellogenesis (Hematoxylin-Eosin). Scale bar: 50mm.

The macroscopic and histological analysis revealed the *P. nattereri* ovaries were in an advanced stage of development with numerous vitellogenic follicles (Figure 2F, 2G). The fecundity of *P. nattereri* was 31,779 oocytes (TL = 254mm, TW = 586,4g and gonad weight = 114g).

Both species (*S. maculatus* and *P. nattereri*), which were recorded in this work for the first time within the central and southern portion of Patos Lagoon, are native to the Uruguay River basin (Nion et al., 2016). Hence, their presence in Patos Lagoon characterizes them as allochthonous

species, which have already invaded the Patos Lagoon, such as *Acestrorynchus pantaneiro* (Saccol-Pereira et al., 2006). Studies assessing the impact of exotic species cultivated in the vicinity of Patos Lagoon have identified the presence of species that are already considered allochthonous to this ecosystem, such as the *Hoplias lacerdae* (Troca, 2013; Troca and Vieira, 2012).

Fish farming and artificial water channels are two hypotheses that should be considered to explain the presence of such species in this lagoon system. Fish farming is particularly vulnerable to incidents when they escape into nearby waterways, especially during periods of intense rainfall associated with *El Niño* (Fontana and Berlato, 1997; Garcia et al., 2004a). For instance, in 2007 there was a case in which fish raised in artificial ponds in the municipality of Cristal were swept into the Camaquã River (Troca, 2009). However, artificial water connections built for agricultural and water supply purposes can promote artificial links between small tributaries within the drainage basin favoring fish dispersion. In 2015, three individuals of the banjo *Pseudobunocephalus iheringii* were caught in an artificial irrigation channel that connects the Tramandaí basin to Patos Lagoon (Silveira et al., 2017), which suggests that such water channels made by humans may facilitate the invasion of species to another basin.

When exotic species, such as *S. maculatus* and *P. nattereri*, are found in an aquatic system, their spread may be influenced by factors such as the absence of natural predators (Latini et al., 2016). The dispersion of exotic fishes into Patos Lagoon may be favored by the hydrological effects associated with *El Niño*. During such climatic events, higher rainfall occurs in southern Brazil and consequently increases river discharges into Patos Lagoon (Garcia et al., 2004b; Grimm et al., 2000), which favors the displacement of freshwater fish towards the estuarine region in its southern portion (Garcia et al., 2003; Possamai et al., 2018). Hence, it seems plausible to assume that the dispersion of palometa towards the southern portion of the lagoon was favored by the hydrological conditions associated with the 2023-2024 *El Niño* episode (Climate Prediction Center/ NOAA, 2024). This could explain why Palometa *S. maculatus* invaded Patos Lagoon from the north and quickly spread southward, reaching the northern reaches of its estuarine region.

Several authors showed that the presence or expansion of an invasive species can change the dynamics of local ecosystems (e.g. Bernery et al., 2022; Omondi and Merceline, 2023; Peller and Altermatt, 2024). For example, *S. maculatus* and *P. nattereri* are predatory species and have feeding habits that vary from smaller fish and invertebrates to occasional plants (Andrade and Braga, 2005; Behr and Signor, 2008; Ferreira et al., 2014; Miguel et al., 2022). This varied diet combined with the high habitat heterogeneity of Patos Lagoon provides favorable conditions for the species' adaptation to new environments and exerts potentially significant pressure on available local food resources. Such scenario could result in direct competition with native species, which can have serious implications for biodiversity and the ecological balance of the region.

In summary, this work reports, for the first time, the occurrence of Palometa *S. maculatus* in three locations of Patos Lagoon, from its central area (Tapes municipality; S 30' 39.084' W 51º 23.113) to its estuarine region in the southern reaches of the lagoon (Pelotas municipality; S 31°41' W 52º 08'). Palometa *S. maculatus* has been currently recorded in the Jacuí river basin, in the Patos Lagoon system (Bertaco et al., 2022), but there are no studies regarding the occurrence of this species in aquatic environments from coastal river basins of Rio Grande do Sul, mainly for the Patos Lagoon estuary. The first individual of *P. nattereri* with mature gonads in the central portion of the lagoon is reported (Arambaré municipality; S 30' 55.411' W 51º 29.589'). Considering the invasive capacity of these species, the presence of sexually mature individuals, and the characteristics of Patos Lagoon with a diverse mosaic of habitats suitable for freshwater fishes, preventive measures are important to avoid an invasive process, which could have serious ecological and economic consequences for the Patos Lagoon system and its rich biodiversity.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Supplementary material

No supplementary material is associated with this article.

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Author contributions

A.M.G., A.S.V., F.C., V.M.L., Y.G.G.: Conceptualization, Investigation; Writing – original draft; Writing – review & editing.

Conflicts of interest

The authors declare no conflicts of interest.

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