Bioinvasiones (1) 2026
DOI: https://doi.org/10.67154/BIN.v9.2026.47
Original Research

Checklist and status of non-native marine and estuarine species in Southern Brazil

Fernanda Araujo Casares*[1], Marcia Regina Aguieiras[1], Natasha Thomaz Lopes[1], Vithória Rodrigues de Melo[1], Caio Barros Brito do Bem, Raquel Godoi Mata Virgem[1], Laura Sol Aranda[1] & Joel Christopher Creed[1].

1. Departamento de Ecologia, Instituto de Biologia Roberto Alcântara Gomes, Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier 524, 20550-900, Rio de Janeiro, RJ, Brazil.

* Corresponding author: Fernanda Araujo Casares (fernanda.araujo.casares@gmail.com)

Special issue: Lists of alien taxa in the Caribbean and Latin America: current status and proposed solutions

Abstract

To prevent the introduction, control or eradicate non-native species (NNS), an essential first step is to compile and maintain regional up-to-date lists of NNS. With the aim of contributing to a review of the marine biodiversity of southern Brazil (Paraná, Santa Catarina and Rio Grande do Sul states) for marine spatial planning, we compiled regional records of all marine NNS from the literature up to September 2024, created an updated checklist with the status of each species and analysed spatial, temporal, ecological and habitat use patterns by taxonomic group. For southern Brazil, we found 1,678 records of 104 NNS in marine or estuarine habitats, of which 43 species (41%) were considered invasive. These fell into 23 classes, with Malacostraca, Teleostei, Ascidiacea, Polychaeta and Bivalvia most speciose. Zoobenthic species were most frequent (70%) then nekton (15%). The ragworm *Alitta succinea*, the pacific oyster *Magallana gigas*, the muzzled blenny *Omobranchus sewalli*, and the copepod *Temora turbinata* had the highest number of records (> 100). Species detection rate increased from 1997 and yearly records increased from 2004 to the present (~3 additional species and mean of 64 records per year). Species and records were not evenly distributed. Although Santa Catarina (SC) had more NNS (n=67) than Paraná (PR, n=60) or Rio Grande do Sul (RS n=32), PR was relatively much more invaded (PR=6.1 species.10km^{-1} coastline vs. SC=1.3 and RS=0.5). Significantly less species and records are found south of 28°S (south of Santa Catarina Island), and records are concentrated in Paranaguá Bay, Babitonga Bay, Florianópolis/Santa Catarina Island and Rio Grande, where there are ports, shipping and major coastal urban infrastructure (about one third of records were in artificial habitats, especially marine farms). Estuaries and rocky reefs are the most invaded ecosystems. We predict that the region will have approximately 200 NNS in 30 years.

Keywords: invasive species, alien, checklist, occurrence records, management of biological invasions

Introduction

More than three billion people depend on the goods and services provided by coastal marine ecosystems for their livelihoods and survival (United Nations 2025). These systems provide essential goods and services for human society (Barbier *et al*. 2017), while contributing to atmospheric oxygen production and climate regulation of the planet. However, the great majority of these ecosystems are facing global crises due to the combination of local and global pressures (Pandolfi 2003, Halpern *et al*. 2015) caused by the unsustainable use of natural resources. The introduction of non-native species (NNS – species that occur outside their native range as a result of anthropogenic activities) represents one of the greatest threats to biodiversity and ecosystem functioning of marine ecosystems (Simberloff 2013). In addition, they can lead to high economic costs as well as damage to human health (Roy *et al.* 2024).

The main vectors of introduction of marine NNS are ballast water and ship biofouling (Bailey *et al.* 2020), although other intentional pathways and vectors, including the aquarium trade and the importation of NNS for mariculture are also of concern. Mariculture can contribute to species introductions either through the inadvertent transport of non-native species fouling the spat of the focal species or by the escape of the cultivated species into the natural environment (Lins and Rocha 2022). Considering the continuous increase in the global trade and transportation of goods through shipping activities, the number of introductions of marine species is expected to increase even further within the next decades (Sardain *et al*. 2019).

Invasive NNS affect organisms and populations of native species through competition, predation, herbivory, parasitism, disease transmission, hybridization, poisoning (or toxicity), and facilitation of other NNS (Kumschick *et al*. 2015), decreasing biodiversity, changing community structure, causing trophic changes, altering ecosystem processes (i.e. nutrient cycling) and even the structure of natural landscapes (Capel *et al*. 2020). Given the serious impacts caused by invasive NNS and that the costs of the control of biological invasions increase exponentially over time since introduction, while effectiveness decreases (Hobbs and Humphries 1995), it is widely recognized that it is necessary to be proactive (Lodge *et al.* 2016). Several legal instruments and public policies include the need to prevent, reduce and control the introduction of NNS, such as target six of the Convention on Biological Diversity, Article 196 of the United Nations Convention on the Law of the Sea, and the International Convention for the Control and Management of Ships Ballast Water and Sediments, which establishes guidelines for ballast water treatment (United Nations 1982, Lehtiniemi *et al.* 2015, Essl *et al*. 2020). Brazil is a signatory of most major international legal instruments, and numerous standards have been developed as a result of the country's adherence to global Conventions.

Prevention (risk analysis and vector control), early detection and rapid response are essential for successful NNS control or eradication programs. Due to the dynamic nature of the processes of biological invasion and the high rates of species detection (Seebens *et al.* 2017, 2018; Bailey *et al*. 2020), a first step to plan NNS management actions is the compilation, maintenance and dissemination of regional up-to-date lists, organized in NNS databases. In Brazil, a number of lists of non-native species have been published across different geographical scales, for example non-native species in the state of Rio de Janeiro (Bergallo *et al.* 2021), state-level governmental lists (e.g. Rio Grande do

Sul 2013, Paraná 2015 and Santa Catarina 2025), national inventories (Zenni *et al.* 2024), and databases (Instituto Hórus 2025). For the marine environment, Teixeira and Creed (2020) updated a previous study by Lopes et al. (2009), providing a detailed analysis of marine species records in Brazilian territory, although none of these studies attempted to compile or presented site specific records.

An important part of the preparation of NNS lists is the classification of species by their invasive status in order to identify the most troublesome species based on the best scientific knowledge available at the time. Over time and due to the accumulation of new scientific evidence on the occurrence, distribution and taxonomy of NNS, it is necessary to review the status of the already known species, as well as to include new species on the list. This information is essential so that management actions can be prioritized, given the high number of NNS and the limitation of human and financial resources (McGeoch *et al*. 2016). Moreover, when adequately made available, NNS lists play an important role in science communication, environmental education and societal engagement regarding biodiversity conservation.

The aim of the present study was to compile regional records of marine and estuarine NNS in the South region of Brazil from the literature, create an updated checklist and analyze spatial, temporal, ecological and habitat use patterns by taxonomic groups, as well as classify the status of each species. This will allow us to contribute to the current review of marine biodiversity in southern Brazil, as well as assess the potential impact of marine NNS. These data will be used for Marine Spatial Planning of the region, currently in development.

Material and Methods

Study area

This study comprises a detailed survey of marine and estuarine non-native species present in the South region of Brazil, which includes the states of Paraná (PR), Santa Catarina (SC) and Rio Grande do Sul (RS). We set the northern limit of the region to latitude 25.2ºS to enable the inclusion of NNS records from estuaries in the north of Paraná and the lower limit to latitude ~34.1ºS, marked by the Chuí stream.

The region is situated in two marine ecoregions (Southeastern Brazil and Rio Grande), within the Warm Temperate South Western Atlantic Province, according to the division by Spalding *et al.* (2007) (Figure 1). Two distinct oceanographic conditions are present: Between Paraná and the Cape of Santa Marta, in the state of Santa Catarina, the Brazil Current prevails, and typical characteristics of mid-latitude continental shelves are observed (Boltovsky and Valentin 2018). Moreover, the coast of SC is influenced by the upwelling of the South Atlantic Central Water (Acha *et al.* 2004), which generates peaks in the primary production mainly in Austral spring and summer. The southernmost sector is determined by the interaction between the Brazil Current and the Malvinas Current, as well as the discharge of the La Plata River and the Patos Lagoon (Boltovsky and Valentin 2018). In terms of coastal marine ecosystems, the region contains important estuaries, such as the Paranaguá Estuarine Complex situated in PR and the Lagoa dos Patos Estuary in RS, as well as coastal lagoons, rocky reefs, and sandy beaches, the latter being especially extensive in RS. Mangroves in the north transition to salt marshes further south, and tropical seagrasses are replaced by widgeon grass (*Ruppia maritima*) in the south. Some rocky reef species also reach their southern limit of distribution in the Atlantic Ocean in Santa Catarina (e.g. Anderson et al. 2015, Slivak *et al.* 2022). Due to the combination of oceanographical and ecological features, the region presents important benthic, planktonic and nektonic marine biodiversity, including endangered species, and a relatively high level of species endemism (Cord *et al.* 2022).

Data gathering and classification

To produce a list of NNS for the southern states of Brazil (Paraná, Santa Catarina and Rio Grande do Sul) and build a database with NNS occurrence records, we followed four steps: (i) taxon selection; (ii) literature search; (iii) data filtration and extraction; (iv) revision. The first step involved choosing a taxonomic group (phylum or class, usually) to direct the search effort. Afterwards we conducted a general literature search to compile all NNS of the group listed either in general (*e.g.* Rocha *et al.* 2013; Teixeira and Creed 2020) or more specific studies (*e.g.* Ajala-Batista *et al.* 2020) and annotated those present in Southern Brazil. Then we conducted a detailed search in Google Scholar using each species name AND "Brazil" as well as each species name AND "Paraná" OR "Santa Catarina" OR "Rio Grande do Sul" to compile occurrence records of NNS in the three southern states of Brazil, reported in scientific articles, undergraduate and master's dissertations, doctoral theses, abstracts presented at scientific events and technical reports. References were downloaded or obtained upon request, carefully read and filtered. For each chosen reference, the following information regarding NNS records was extracted: species, type of record (presence), date, source of information (reference), environment (natural or artificial), habitat, latitude, longitude, state and additional observations. The classes for artificial habitat were adapted and complemented from those in Lopes *et al*. (2009). Only references up to September 2024 were included in the present study.

When the required information was not available in the publication and could not be obtained from the authors, we made adjustments following established criteria. For instance, when no date was available for the first record of the NNS in the South of Brazil we used the first day of the first month of the year of publication. Similarly, we used the first day and/or the first month of the year when the study only informed the year of NNS occurrence. For studies carried out during a continuous period of sampling, we considered the middle date for the presence record. When no spatial coordinates were informed, we attributed the coordinates using Google Maps, estimated from any available map showing site sampling points, from the site name, or from information obtained from the authors (when possible). In a few cases, the reference reporting the occurrence of a NNS only mentioned the state where it was found with no coordinates detailing the site or region [for example in regional check lists such as Lana *et al*. (2006)]. These species were included in the species list, but not in the record list, and could not be considered in the data analyses. When not described in the references, habitats were deduced through species life histories and/or by visualization of the sampling site on Google Maps. The final step of data collection included a careful review of the data, specifically the spatial coordinates of the NNS records. To do this, point locations were displayed on a Google Earth image and inspected for mistakes that could then be tracked and corrected. All presence records were added to the database of the portal Bioinvasão Brasil (https://bioinvasaobrasil.org.br/).

We created an updated checklist of NNS as well as classified the status of each species. Species nomenclature was updated following WoRMS - World Register of Marine Species (Bernot *et al*. 2025). We did not include cryptogenic species (Carlton 1996). Species still unresolved taxonomically [species that are not (unidentified) or cannot yet be (unidentifiable) identified to a level permitting biogeographic assessment - Carlton 2009) were considered cryptogenic and hence were not included in the list. Although the list primarily focused on marine species, one non-marine species – the moth *Hyblaea puera* – was included in the list since it can cause substantial damage to mangrove trees (Faraco *et al*. 2019).

Species status was classified as either non-native or invasive. We considered a species invasive if there was at least one study that documented evidence of a negative ecological, socioeconomic or human health impact anywhere in the world within its introduced range. To obtain this information we conducted searches of the scientific literature using Google Scholar inserting as key words the species name AND "invasion impact evidence". Only studies that effectively quantified (and detected) the effect of NNS on native species, communities and/or ecosystems, on socioeconomic features or human health were considered as negative impact evidence (Supplementary Material - Table 1). It is important to highlight, however, that the absence of impact evidence does not imply that the non-native species is not causing negative impacts. Moreover, this categorization is dynamic and can change in the future. That is why we chose to list all non-native species in this study, drawing more attention to the species already acknowledged as harmful.

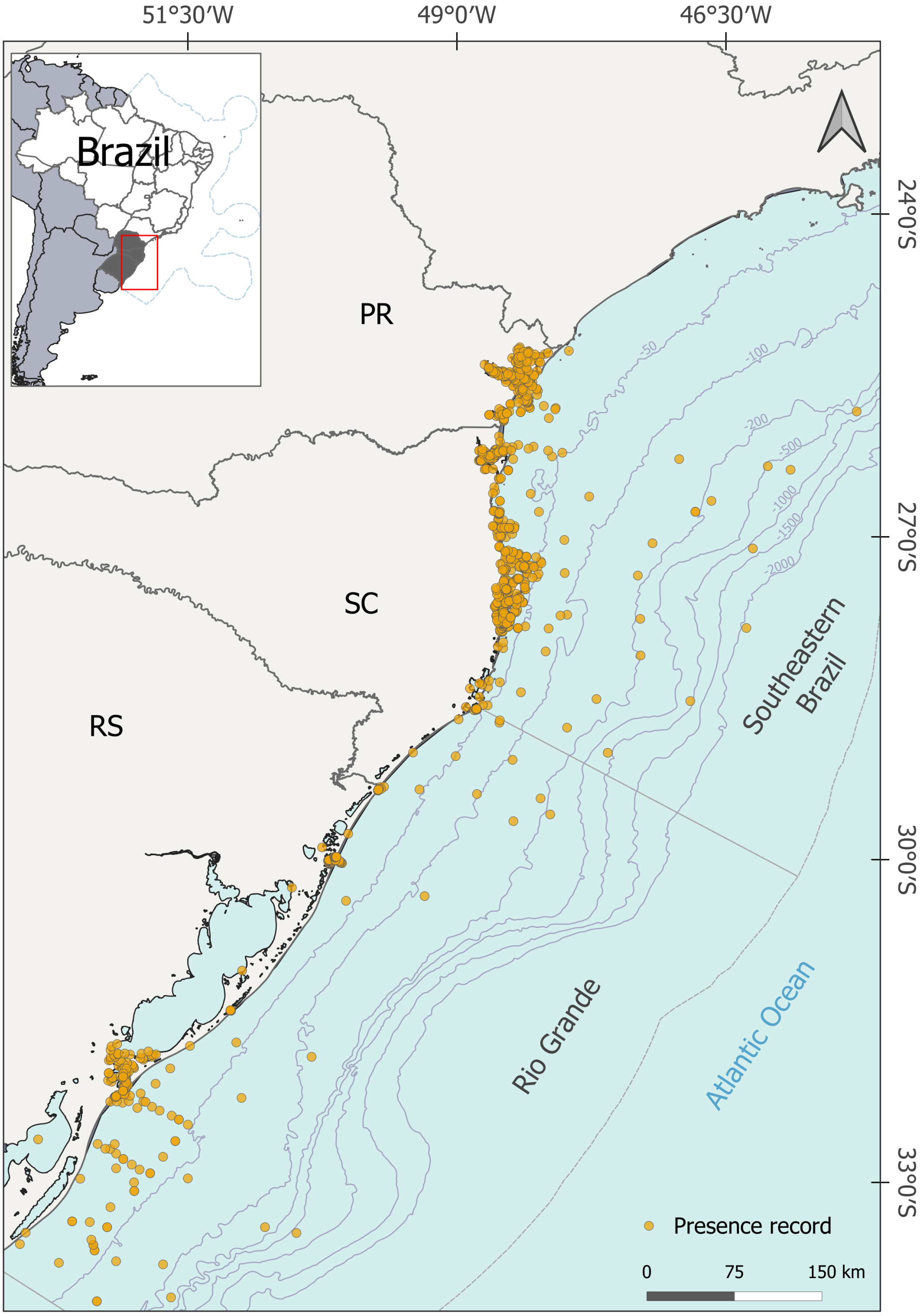

Figure 1. Map showing the Southern region of Brazil, with the states of Paraná (PR), Santa Catarina (SC) and Rio Grande do Sul (RS), the Marine Ecoregions of Rio Grande and Southeastern Brazil and the 50-2000m isobaths All the compiled records of occurrence of non-native species (NNS) are shown in orange. Notice that there might be more than one NNS found at the same point.

Data analysis

We extracted basic summary statistics: the number of non-native species present in Southern region of Brazil; the proportion of species that are invasive; the relative frequency of species from each taxonomic group and marine habitat; the total number of NNS records; the most widespread species. Temporal patterns were assessed by quantifying both the number of NNS and the presence records, and cumulative number of NNS reported over time, from 1867 until 2024. We also extracted information regarding NNS richness per year for each state and then inspected the distribution of NNS records among taxonomic and functional groups for each state and for the Southern region as a whole. Finally, we extracted information regarding habitat use patterns by evaluating the number of NNS records in natural and artificial habitats, as well as the type of ecosystem where they were found.

To better analyze patterns of NNS distribution over space, we quantified the number of NNS and number of presence records per state, per latitudinal class (from -25° to -34° in 0.5° steps) and mapped NNS records to identify hotspots (areas with higher concentrations of NNS). Maps were created in QGIS 3.34.15 software, using Bing Satellite and ESRI Satellite for raster data (in Feb/2025). Vector data (shapefile format) were obtained from the Instituto Brasileiro de Geografia e Estatística (IBGE) (2023), Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) (2025), Agência Nacional de Transportes Aquaviários (ANTAQ) (2024), and Marine Ecoregions of the World (WWF 2007). To assess impact in marine protected areas, NNS presence records were overlapped with a layer of federal protected areas.

Results

The complete list of NNS compiled for the Southern Region of Brazil and their detailed occurrence records are shown in Supplementary Material Tables 1 and 2. We found 1,678 records of 104 NNS in marine or estuarine habitats of the region (Figure 1), of which 43 (41%) were considered invasive. NNS fell into 14 taxonomic groups, with Crustacea, Osteichtyes, Ascidiacea, Bryozoa, Cnidaria, Polychaeta, and Mollusca being the most speciose (Figure 2). Zoobenthic species dominated (70%) the NNS, followed by nekton (15%), zooplankton (7%), phytobenthos (4%), phytoplankton (3%) and bacteria (1%). Sixty-seven percent of the presence records (n=1122) occurred in natural habitats while the rest were found in artificial habitats (Table 1). Overall, estuaries and rocky reefs were the most frequently invaded ecosystems with 347 and 344 records, respectively (Table 1). Within artificial habitats, marine farms had the highest number of records (n=216, Table 1).

In terms of the relative frequency of occurrence records in the southern region as a whole, most NNS exhibited relatively few records, with 76 NNS (73%) being reported 20 times or less. On the other hand, four species had more than 100 records each: the copepod *Temora turbinata,* the muzzled blenny *Omobranchus sewalli,* the ragworm *Alitta succinea*, and the pacific oyster *Magallana gigas* (with 146, 137, 104 and 101 records, respectively) (Figure 3). The red algae *Kappaphycus alvarezii* and the Pacific white shrimp *Penaeus vannamei* were only registered in captivity.

The dominance in the number of records per NNS varied among states. In PR *T. turbinata*, the diatom *Coscinodiscus wailesii* and the sessile hydrozoan *Calyptospadix cerulea (Garveia franciscana)* had the highest number of records (n=41, n=39 and n=38, respectively). In SC *O. sewalli*, *T. turbinata* and *M. gigas* dominated (n=133, n=96 and n=86, respectively), while in RS *A. succinea* and the mud crab *Rhithropanopeus harrisii* were the most frequently recorded NNS (n=73 and n=43, respectively).

The first NNS record we found for the region dates from 1867 and refers to the barnacle *Balanus trigonus* (described as *B. armatus* - Müller 1867 apud Zullo 1992). The next NNS was recorded almost a hundred years later (1959 for *A. succinea,* as *Neanthes succinea* - Nonato 1965) and ever since then all the forthcoming decades added records (Figure 4). Species detection rate has increased since 1997 in the region, reaching approximately three additional species per year (Figure 4). Assuming this rate remains constant, we predict that the region will have approximately 200 NNS within 30 years.

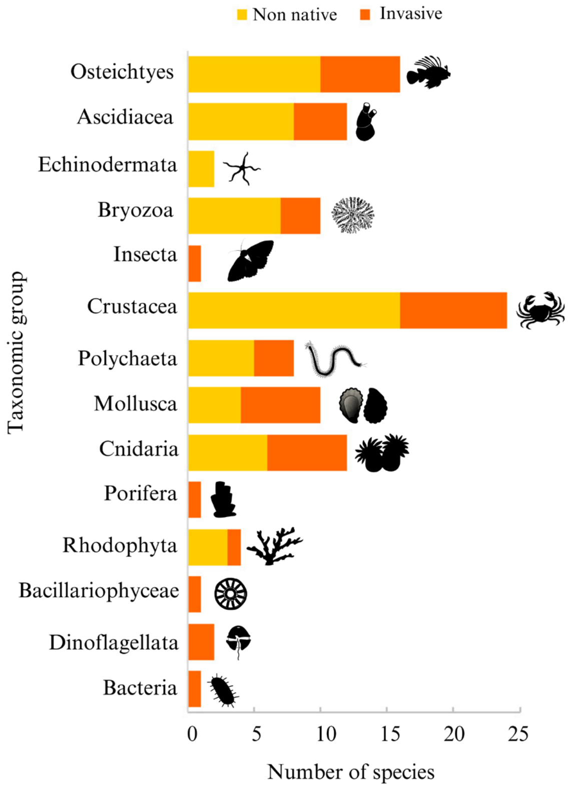

Figure 2. Total number of non-native species per taxonomic group in the Southern region of Brazil. The different colors of the bars represent the proportion of non-native and invasive species.

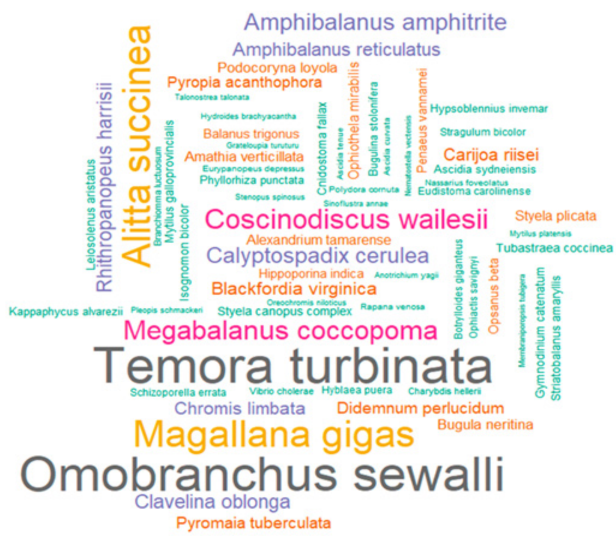

Figure 3. Word Cloud illustrating the non-native species with the highest number of records for Southern Brazil. The sizes of the name of the species are proportional to their frequency.

Table 1. Number of presence records of non-indigenous species per type of habitat (artificial or natural) and ecosystem for each functional group in Southern Brazil

Habitat	Ecosystem	Functional Group						
		Bacteria	**Nekton**	**Phytobenthos**	**Phytoplankton**	**Zoobenthos**	**Zooplankton**	**Total**
Artificial								
	Artificial reef		5			28		**33**
	Ballast water	2			1			**3**
	Experimental unit			12		164		**176**
	Floating buoy			2		25		**27**
	Marine farm	1	1	2	4	208		**216**
	Oil rig		1			1		**2**
	Pier			3		72		**75**
	Port structure					5		**5**
	Seawall			5		7		**12**
	Ship hull					6		**6**
	Shipwreck		1			3		**4**
	Total	**3**	**8**	**24**	**5**	**519**		**559**
Natural								
	Coral reef					1		**1**
	Estuary		159		10	96	82	**347**
	Mangrove					12		**12**
	Marism					2		**2**
	Pelagic	6	1		83	2	134	**226**
	Rhodolith			1		1		**2**
	Rocky reef		56	22		266		**344**
	Sandy beach			2		27	2	**31**
	Soft bottom				12	142		**154**
	Total	**6**	**217**	**25**	**105**	**550**	**218**	**1122**
	Grand Total	**9**	**224**	**49**	**110**	**1068**	**218**	**1678**

Despite some former years with high numbers of NNS occurrence records, the increase in yearly NNS records has been more pronounced since 2004, with mean rates of 64 records.year^{-1}) (Figure 4). Looking at each state separately, we observed that the number of NNS records was higher in RS in the 1980s and 1990s (n=36 and n=85, respectively) compared to PR (n=5 and n=66, respectively) and SC (n=8 and n=33, respectively) (Figure 5). From the 2000s on, SC assumed the dominant position in terms of number of NNS presence records (2000, n= 410; 2010, n=380 and 2020, n=77) compared to PR (n=149, n=259 and n=6, respectively) and RS (n=46 , n=102 and n=6, respectively) (Figure 5).

Species and presence records were not evenly distributed among nor within states (Figures 1, 6, 7, 8). Although Santa Catarina (SC) had more NNS (n=67) than Paraná (PR, n=60) or Rio Grande do Sul (RS n=32), PR was relatively much more invaded (PR=6.1 species.10km^{-1} coastline vs. SC=1.3 and RS=0.5). SC had the highest number of presence records (n=914), followed by PR (n=487) and RS (n=277). Again, PR had the most records when considering the number of NNS presence records per coastline extension - about 5 records.km^{-1} coastline, followed by SC (1.7 records.km^{-1} coastline) and RS (0.4 records.km^{-1} coastline). Less species and records were found south of 28°S (south of Santa Catarina Island, Figure 7), and records were more concentrated in Paranaguá Bay (PR), Babitonga Bay (SC), Florianópolis/Santa Catarina Island (SC) and the Patos Lagoon estuary (RS), which are areas with ports, shipping, coastal urban infrastructure and marine farms (Figures 6-8).

The maps of the states also highlighted the occurrence of 47 (45%) of NNS and 311 (18,5%) of presence records inside Federal Protected Areas. In PR, NNS occurred in the Área de Proteção Ambiental de Guaraqueçaba, Parque Nacional de Superagui, and in the Parque Nacional Marinho da Ilha dos Currais (Figure 6; Supplementary Material Table 3), with 30 (50%) of NNS and 182 (37%) presence records. In SC, 31 (46%) NNS and 124 (13,5%) presence records occurred within the Reserva Biológica do Arvoredo, the Área de Proteção Ambiental de Anhatomirim, the Estação Ecológica de Carijós, the Reserva Extrativista Marinha de Pirajubaé and the Área de Proteção Ambiental da Baleia Franca (Figure 7; Supplementary Material Table 3). In contrast, only five presence records of two species occurred in protected areas in RS: four presence records of the ragworm *Alitta succinea* in the Parque Nacional da Lagoa do Peixe, and one record of the Azores chromis *Chromis limbata* in the Refúgio da Vida Silvestre da Ilha dos Lobos (Figure 8; Supplementary Material Table 3).

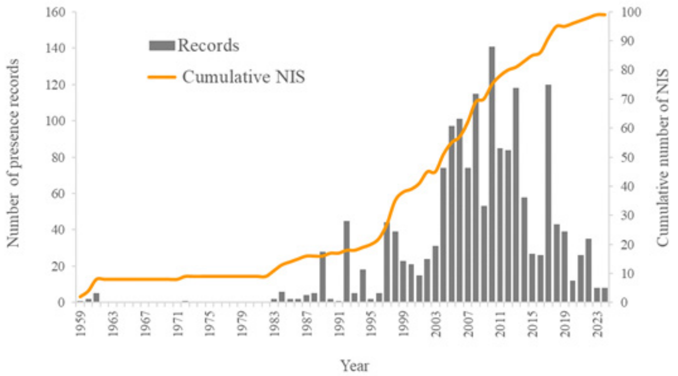

Figure 4. Number of presence records and accumulated number of non-native species per year in the Southern region of Brazil. For simplicity, the first non-native record for the region (from 1867) was omitted from the graph.

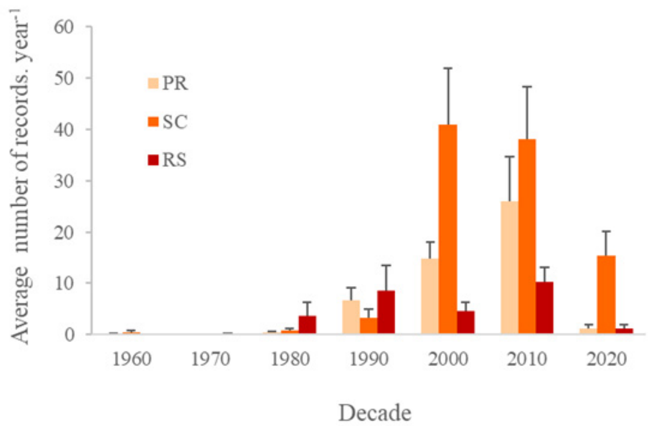

Figure 5. Average number of NNS records per year for each decade since the 1960s, for each state of Southern Brazil. PR = Paraná, SC = Santa Catarina and RS = Rio Grande do Sul. Bars represent the standard error.

Discussion

Comparison to other NNS lists

Our detailed compilation revealed a much greater number of species and records for the South of Brazil than previously recognized. While we found 104 estuarine and marine NNS for the southern states of Brazil (up to September 2024), Teixeira and Creed (2020), who also concentrated on marine species, listed 138 NNS for Brazil, 63 of which occurred in the Southern region (see detailed comparisons on species occurrences across studies in Supplementary Material Table 4). This higher number of marine NNS occurrences found can be explained by three main factors. Firstly, the present study may have been more detailed since it focused on compiling NNS occurrence records for only one specific region in Brazil. The second and third reasons are intrinsically related to the dynamic and additive nature of both science and the biological invasion process that leads to a direct relationship between NNS occurrences and time. Clearly, our study incorporated the additional scientific knowledge which became available from 2019 until 2024 by including new records that were published after the study by Teixeira and Creed (2020). As they themselves pointed out when comparing their study to the previous one by Lopes *et al.* (2009), not only do first records of new NNS appear, but past collections of biological material are identified as new NNS, so there is an intrinsic lag between arrival, recognition of a species, publication, compilation and synthesis which is reflected in the time series data. In fact, this might also be evident in our time series data, as both records and the cumulative species curve rates seem to slow down from 2018 to 2024 (Figures 4 and 5); if that is the case, three new species per year would be an underestimation of recent arrivals and invasion rates. Alternatively, this might represent a real reduction in invasion detection rates in southern Brazil, though this seems unlikely given predicted and actual global and regional trends (Schwindt and Bortolus 2017; Sardain *et al.* 2019; Bailey *et al.* 2020; Teixeira and Creed 2020). Finally, species are constantly being recategorized as a result of new taxonomical, molecular and ecological studies, so some species formerly considered cryptogenic or even native might now be considered non-native (for example the bryozoan *Schizoporella errata* - Lins and Rocha 2022).

In contrast, Zenni *et al.* (2024) listed only species considered invasive in marine, terrestrial and freshwater habitats. They listed 72 invasive marine species for Brazil as a whole and 42 for the South. We found 43 invasive species. However, the comparison between our study and Zenni et al. (2024) is not as straightforward, since the methodologies applied between the different studies varied somewhat as Zenni *et al.* (2024) used general keywords in their reference search and restricted their list to non-native invasive species (which they define as "species explicitly described as occurring outside their native range, spreading beyond the point of introduction, and having a prior history of invasion somewhere, with described known or potential negative environmental impacts"). Moreover, Zenni *et al.* (2024) relied on expert opinion (that may potentially underestimate NNS of understudied taxa) while this study included grey literature, often neglected and which contributed data for several NNS records. Furthermore, distinct studies differently classify species as marine, freshwater or terrestrial. Zenni *et al*. (2024) considered several species that we classified as marine, as freshwater and terrestrial (e.g. the mud crab *Scylla serrata*) (Supplementary Material Table 4).

At the state level, all three states have official lists of invasive species including some marine species, but most of them are rather outdated and somewhat subjective. According to these official lists, PR recognizes 34 invasive marine or estuarine species and the imminent risk of invasion of six others (three of which have now invaded - *Omobranchus punctatus*, *Alexandrium tamarense*, and *Ciona intestinalis*) (Paraná 2015). Santa Catarina recognizes 39 invasive marine or estuarine species (Santa Catarina 2025) and Rio Grande do Sul, 11 invasive NNS (Rio Grande do Sul 2013). In comparison to the species we consider invasive in our database these official state lists have 41% more (PR), 15% more (SC), and 39% less (RS) species than we found. This highlights the need for common criteria and frequent updates on lists.

Compared to the studies of Zenni *et al.* (2024) and Teixeira and Creed (2020), our study added six and 12 NNS respectively to the South region as a whole and extended the distribution of 17 and 13 NNS respectively for other states of the region (see Supplementary Material Table 4). For example, the snowflake coral *Carijoa riisei* was not previously recorded for the southern region but has been reclassified as invasive, with molecular analyses indicating a Pacific Ocean origin (Castro *et al.* 2010) and it is currently widely distributed in Paraná and Santa Catarina states, including in Federal Protected Areas.

The Pacific oyster *Magallana gigas* has been recorded for the southern region of Brazil by both lists, but only in the state of SC. Although its introduction to Brazil occurred intentionally for marine farming, Teixeira and Creed (2020) commented that it had escaped and established in the surroundings of marine farms. Our study identified 86 records of *M. gigas* for this state, three in the natural environment, including the Baleia da Franca Environmental Protection Area, as well as in Paraná with 15 records in the Paranaguá estuarine complex, most in protected areas such as the Guaraqueçaba Environmental Protection Area and Superagui National Park.

In contrast, other species that Zenni *et al.* 2024 and Teixeira and Creed 2020 listed for the South were not included here: two species reported in both studies (the sun coral *Tubastraea tagusensis* and the polychaete *Boccardiella bihamata*); five species listed only by Zenni *et al.* (2024) (the sea squirt *Bostrichobranchus digonas*, the orange-striped anemone *Diadumene lineata*, the red-rimmed melania *Melanoides tuberculata*, the red seaweed *Pyropia suborbiculata* and the red-rust bryozoan *Watersipora subtorquata*); three additional species listed only by Teixeira and Creed (2020) (the barnacle *Chirona amaryllis*, the hydrozoan *Cordylophora caspia* and the whitetip-reef shark *Triaenodon obesus*) (Supplementary Material Table 4).

The erroneous presence of *Tubastraea tagusensis* in the South likely results from a confusion originated by the study of Lopes *et al.* (2009), where they reported the geographic distribution of *Tubastraea tagusensis* in Brazil by indicating the occurrence of the genus *Tubastraea* in the states of Rio de Janeiro and Santa Catarina, making the information ambiguous. As a result, the record of *T. tagusensis* in SC spread to later citations (e.g., Rocha *et al.* 2013; Teixeira and Creed 2020; Zenni *et al.* 2024), although there is actually no record of this species in the South at least until the date of the survey for this study. Furthermore, despite some citations (originating with Silva and Barros 2011) we do not recognise that *Tubastraea* occurs in PR.

Teixeira and Creed (2020) erroneously listed *C. caspia* as an invasive marine NNS in PR. This species is of concern in aquatic environments in the region due to its occurrence on structures of a hydroelectric plant in the Iguaçu River Basin in PR (Oliveira Junior 2022), but we did not find any records of the species in marine or estuarine systems. In the case of *T. obesus* we considered it to be a cryptogenic species, and did not include it in our list due to it possibly being a vagrant (Bornatowski *et al*. 2018). Teixeira and Creed (2020) erroneously listed *Striatobalanus amaryllis* and *Chirona amaryllis* (an invalid synonym, according to WoRMS (Bernot *et al.* 2025).

Spatial patterns of NNS distribution

NNS are expected to be more frequent in areas and ecosystems that suffer from more intense disturbance from human activities and may reveal probable pathways and vectors of introduction. The South includes important cities and the human population of the three states is over 30 million people (IBGE 2024) so there are numerous pathways and vectors of introduction of marine NNS to the region. These include several ports, the port of Paranaguá (located in Paraná), which is the sixth largest of Brazil in terms of gross load (Antaq 2024). The region also harbors many marine farms, especially in Santa Catarina, which is the biggest producer of oysters and mussels in Brazil.

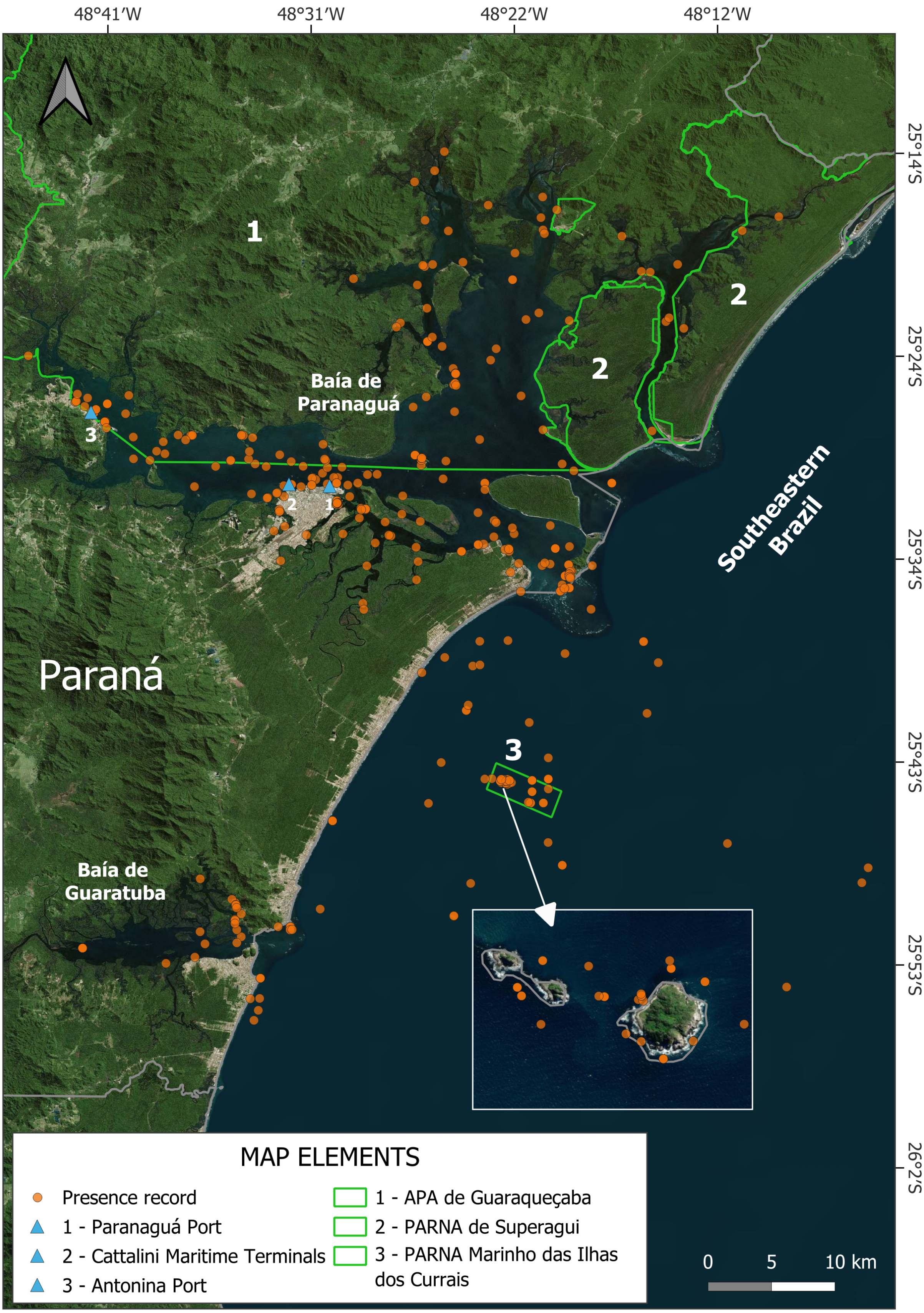

Figure 6. Map showing the presence records of estuarine and marine non-native species in the state of Paraná (PR), Southern Brazil. The busiest ports and the federal marine protected areas are also depicted. APA and PARNA refer to different categories of protected areas, Área de Proteção Ambiental and Parque Nacional, respectively. In detail is the marine protected area of Parque Nacional Marinho das Ilhas dos Currais. Note that there might be more than one NNS found at the same point.

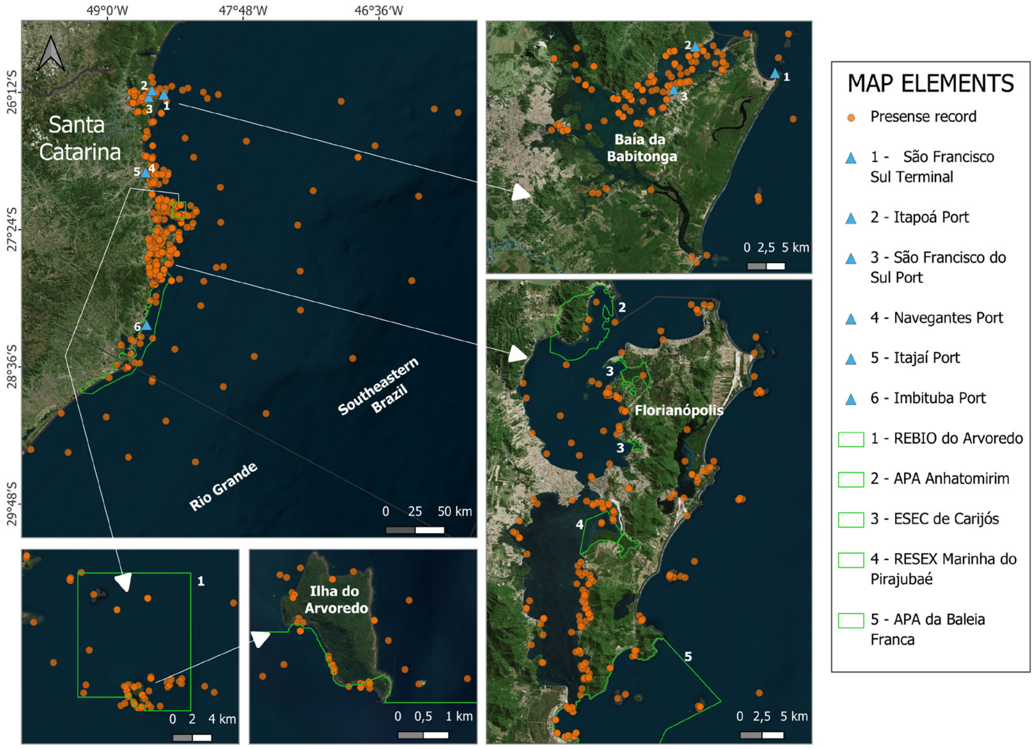

Figure 7. Map showing the presence records of estuarine and marine non-native species in the state of Santa Catarina (SC), Southern Brazil. The busiest ports and the federal marine protected areas are also shown. REBIO, APA, ESEC and RESEX refer to different categories of protected areas, Reserva Biológica, Área de Proteção Ambiental, Estação Ecológica and Reserva Extrativista, respectively. In detail are Babitonga Bay, Florianópolis island and Arvoredo Island, part of the marine protected area of the Reserva Biológica do Arvoredo. Note that there might be more than one NNS found at the same point.

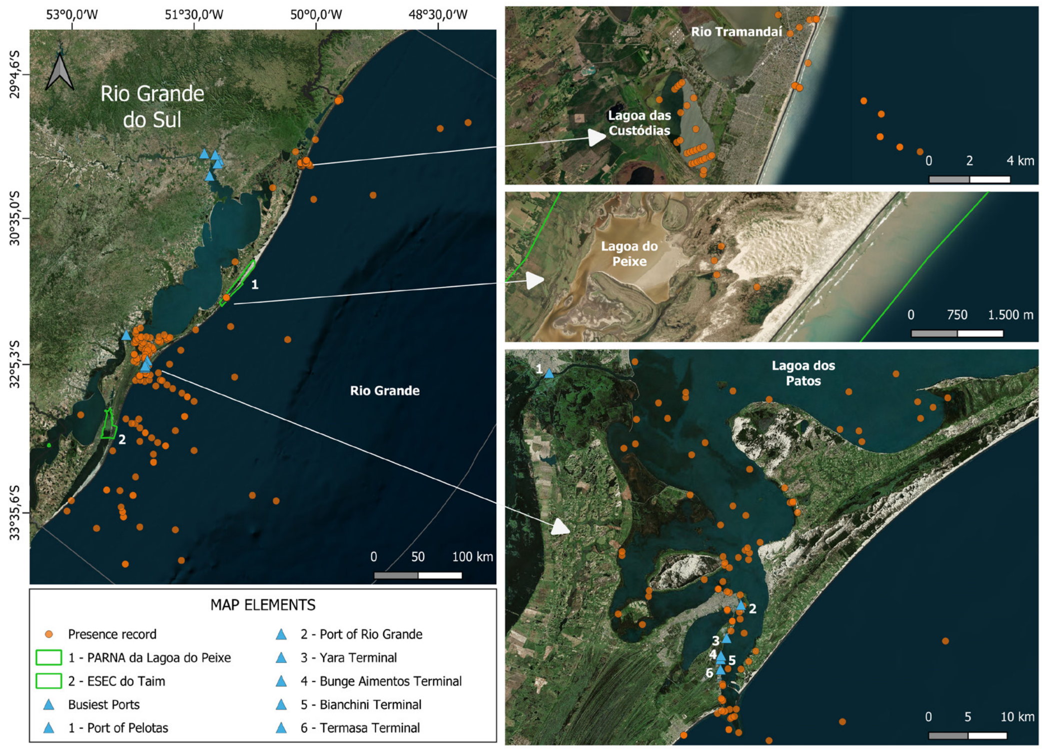

Figure 8. Map showing the presence records of estuarine and marine non-native species in the state of Rio Grande do Sul (RS), Southern Brazil. The busiest ports and the federal marine protected areas are also shown. PARNA and ESEC refer to different categories of protected areas, Parque Nacional and Estação Ecológica, respectively. In detail appear the Lagoons of Custódias, Peixes e Patos. Note that there might be more than one NNS found at the same point.

The NNS occurrence records were concentrated in areas with intense shipping activities, coastal urban infrastructure and marine farms, notably in Paranaguá Bay (PR), Babitonga Bay (SC), Florianópolis/ Santa Catarina Island (SC), and the Patos Lagoon estuary (RS). Bays and estuaries are recognized as areas with higher incidence of species introduction (Rocha *et al.* 2013; Bumbeer and Rocha 2012, Bumbeer and Rocha 2016) and there are some studies that specifically evaluated the role of such systems in the distribution of NNS in the South (e.g. Neves *et al.* 2007, Neves and Rocha 2008). Moreover, most records were found in natural habitats (estuaries and rocky reefs), although marine farms also showed a high proportion of occurrences.

Under the light of human impact and vector pressure we might expect that marine protected areas may be less invaded. Despite this, we found a high number of species and records in the ten federal protected areas in Southern Brazil (Supplementary Material Table 4). It is highly probable that protected areas are more studied than adjacent unprotected areas (as one of their functions is to promote scientific research), and the number of NNS species and records within these areas may reflect this bias. Notwithstanding, considering these are high priority areas for biodiversity conservation, this study contributes with valuable information that can be applied by local environmental managers and by the national environmental agency (Instituto Chico Mendes de Conservação da Biodiversidade) to plan conservation actions to monitor, prevent and control non-native species in these areas. For example, the cleaner shrimp *Lysmata uncicornis* is a species that could potentially be eradicated, considering its single record for the South in the Protected area Reserva Biológica do Arvoredo (SC) (Giraldes *et al.* 2018 - as *L. arvoredensis*). Additionally, the data presented in this study will be used in the Marine Spatial Planning that is being undertaken for Brazil.

Invasive species, most frequent NNS and call for attention

We classified species as either non-native or invasive, based on whether there is scientific evidence of impact on native populations, communities, ecosystems, socioeconomic activities or human health somewhere within their global introduced range. We adopted this classification following the definition of the Convention for Biological Diversity (UN 1992) to be practical, aiming at ranking NNS in order of concern to guide management actions. Therefore, species termed here as invasive, but without known local impacts, are potentially harmful, assuming that if they have already caused documented impacts elsewhere, they may cause them everywhere. In an analogy with the Environmental Impact Classification for Alien Taxa (IUCN 2020), non-native species would be either classified as Data Deficient or Minimal Concern, while invasive species would fall into one of the other categories (Minor, Moderate, Major or Massive). This more detailed classification fell beyond the scope of the present study, but would be an important contribution from future studies.

The species with the highest number of records in Southern Brazil were the copepod *Temora turbinata,* the muzzled blenny *Omobranchus sewalli,* the ragworm *Alitta succinea*, and the pacific oyster *Magallana gigas*, all with more than 100 presence records. While *T. turbinata* and *M. gigas* are harmful species, *O. sewalli* and *A. succinea* still have no documented impacts, despite being widespread along the Brazilian coast and other introduced regions worldwide (Supplementary Material Table 1). *T. turbinata* is a very abundant species that has competitively displaced its native congener *T. stylifera* on the southern coast of São Paulo State, Brazil (Ara 2002). *M. gigas* has been shown to compete with native oysters (Krassoi et al. 2008).

Out of the 43 invasive species listed in this study, we would like to highlight some that we think are the most worrisome species and deserve special attention. Firstly, some species affect marine farming activity and yield, threatening food security and local communities' livelihood and wellbeing. These include substantial fouling by the sponge *Paraleucilla magna* (Longo *et al.* 2007), the polychaetes *Hydroides dianthus* (Çinar et al. 2014) and *Polydora cornuta* (Neves and Rocha 2008), the bivalve *Mytilus galloprovincialis* (Lins *et al.* 2021), the barnacle *Megabalanus coccopoma* (Lins and Rocha 2022), the bryozoan *S. errata* (Lins and Rocha 2022), the ascidians *Bugula neritina* (Sá *et al.* 2007*)*, *Clavelina oblonga* (Ordoñez *et al*. 2016), *Didemnum perlucidum* (Lins and Rocha 2020) and *Ciona intestinalis* (Daigle and Herbinger 2009). The gastropod *Rapana venosa* is a voracious predator species that also poses a risk to native mollusk species, including those of economic value (Spotorno-Oliveira et al. 2020).

Also of special concern are some species that impact human health such as cholera (*Vibrio cholerae*) and the microalgae *Alexandrium tamarense*, *Coscinodiscus waillesi* and *Gimnodinium catenatum* (Hamasaki *et al.* 2003*, Kazmi et al.* 2021*,* Manabe and Ishio 1991). Others substantially alter ecosystem properties such as nutrient cycling and water quality (the fishes *Coptodon rendalli*, *Cyprinus carpio*, *Ctenopharyngodon idella* and *Oreochromis niloticus* - Badiou *et al.* 2011, Canonico *et al*. 2002, Cudmore and Mandrak 2004) or severely damage key species such as the teak defoliator moth *Hyblaea puera* (Faraco *et al.* 2019). The sun coral *Tubastraea coccinea* is a species with chemical and physical competitive strategies that can monopolise rocky reefs, affecting native species (Miranda *et al.* 2016), altering community structure (Lages *et al.* 2011) and even seascape dynamics (Capel *et al.* 2020, Merz *et al.* 2023). Sun corals (*Tubastraea* spp.) are so concerning that they are the only marine invasive species that have been the subject of a National Management Plan (MMA 2018). Specifically in Southern Brazil, management actions to control the spread of *T. coccinea* are carried out in the marine protected area Rebio Arvoredo (see Crivellaro *et al*. 2021), but managers face several challenges including technical limitations, scarcity of financial and human resources, as well as the constant arrival of contaminated vectors.

We also highlight the whiteleg shrimp *Penaeus vannamei* and the red algae *Kappaphycus alvarezii*, which until now are only found confined to marine farms or in experimental aquaria within laboratory facilities. *P. vannamei* is already present in natural environments in Southeastern Brazil, but *K. alvarezii* is not. Nevertheless, we chose to include them in this study as they are invasive species that have potential to cause impacts (Loebman *et al.* 2010, Arasamuthu *et al.* 2023) and must be kept outside natural areas of Southern Brazil.

We calculated that ~3 additional NNS have been added and 64 new presence records have been reported per year, on average, for Southern Brazil within the last decades. Considering global warming scenario and the southern creep of tropical species, as well as their known invasion biology we would predict that the Asian green mussel (*Perna viridis*), the sun coral *Tubastraea tagusensis*, and the Red lionfish (*Pterois volitans*) will all become highly invasive in the South (Akira-Umena *et al*. 2025, Ohanna *et al*. 2025 and Soares *et al*. 2025). It is very important to prevent further species introductions by focusing efforts on managing vectors and by activating effective early warning systems to avoid species spread, together with the control and monitoring of the NNS that are already present. In this age of open science, we believe that data sharing, local management plans aligned to global strategies, as well as societal awareness and engagement, are the best allies for combating biological invasions.

Conclusion

To prevent the introduction, control or eradicate non-native species an essential first step is the compilation and maintenance of regional up-to-date lists. This updated list of estuarine and marine NNS for Southern Brazil represents an important advance, adding several new species to the region in comparison with the most recent studies carried out. In addition to the species list, we provide the reported georeferenced records of NNS occurrences, resulting from a detailed compilation of available scientific studies, (including the grey literature), which constitute an important database.

The data presented here will contribute to the updating of the NNS lists of the states of PR and RS that were last reviewed in 2015 and 2013, respectively. Moreover, we present a list of the most worrisome NNS, known to have caused impacts either on the Brazilian coast or in other parts of its introduced range, in order to call the attention of local environmental managers and to support preventive and control actions.

This study is an important step towards understanding one of the important threats for marine biodiversity Brazil in the south of Brazil and as such to contribute to the data gathering process necessary to elaborate the National Marine Spatial Planning as well as contribute to management of the marine protected areas. Finally, this database can also be used for scientific communication as well as societal awareness and engagement in the control of biological invasions.

Supplementary Material

The Supplementary Material can be found on Casares FA, Aguieiras MR, Lopes NT, Melo VR, Bem CBB, Mata Virgem RG, Aranda LS, Creed JC. 2025. Dataset of records of non-native marine and estuarine species in southern Brazil [Data set]. Zenodo. https://doi.org/10.5281/zenodo.16912782 and includes 4 tables: Supplementary Material Table 1. Check list of non-native species for the Southern region of Brazil Supplementary Material Table 2. Presence records of non-native species in the Southern region of Brazil Supplementary Material Table 3. Occurrence of NNS inside Federal Protected Areas in Paraná, Santa Catarina and Rio Grande do Sul Supplementary Material Table 4. Comparison of the species found in this study with those listed by Teixeira and Creed (2020) and Zenni et al. (2024) for each state of the Southern region of Brazil.

Acknowledgements

We would like to thank the editors for the invitation to participate in this special issue. We are grateful to all authors that kindly responded to our requests and contributed either by sending publications or sharing data on species occurrences. We appreciate the support from Instituto Nacional de Ciência e Tecnologia da Biodiversidade da Amazônia Azul (BioAmazônia Azul). We thank the reviewers for providing important comments that contributed to manuscript improval. This article is no. 60 from the Projeto Coral-Sol.

Funding

This study was funded by Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro (E26/203.002/2017-PensaRio). FA Casares received a scholarship from Universidade do Estado do Rio de Janeiro (UERJ), MR Aguieiras received a research scholarship (process no. 385624/2024-7) from the Brazilian National Institute of Science and Technology (INCT) Biodiversidade da Amazônia Azul (CNPq proc. 405999/2022-4), VR de Melo, CBB do Bem and RG Mata Virgem received scholarships from CETREINA/UERJ and JC Creed received the support of FAPERJ - Proc. No. E-26/010.003031/2014 and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq- 313698/2021-0).

References

Acha EM, Mianzan HW, Guerrero RA et al. 2004. Marine fronts at the continental shelves of austral South America: Physical and ecological processes. Journal of Marine Systems 44:83-105. https://doi.org/10.1016/j.jmarsys.2003.09.005

Agência Nacional de Transportes Aquaviários (ANTAQ) 2024. Informações Geográficas. Available from https://dadosabertos.ana.gov.br/datasets/4c606c38ee534b84bffe70ca6c8552c6_0/aboutAcessed 2025-02-19.

Ajala-Batista L, Lins DM, Haddad MA. 2020. Diversity of estuarine and marine hydroids (Cnidaria, Hydrozoa) from subtropical ecosystems of Brazil. Marine Biodiversity 50:97. https://doi.org/10.1007/s12526-020-01133-0

Akira-Umeno, Marcos, Leonardo Cirillo, and Alexandre Ribeiro da Silva. 2025. The expansion of *Perna viridis* towards South Brazil: bridging the gap with traditional scientific surveys and citizen science. Austral Ecology 50:e70071. https://doi.org/10.1111/aec.70071

Anderson AB, Carvalho-Filho A, Morais RA et al. (2015). Brazilian tropical fishes in their southern limit of distribution: checklist of Santa Catarina's rocky reef ichthyofauna, remarks and new records. Check List 11:1688-1688. doi: http://dx.doi.org/10.15560/11.4.1688

Ara K. 2002. Temporal variability and production of *Temora turbinata* (Copepoda: Calanoida) in the Cananéia Lagoon estuarine system, São Paulo, Brazil. Scientia Marina 66:399-406. https://doi.org/10.3989/scimar.2002.66n4399

Arasamuthu A, Laju RL, Diraviya Raj K et al. 2023. Invasive red alga *Kappaphycus alvarezii* on the reefs of the Gulf of Mannar, India–a persistent threat to the corals. BioInvasions Records 12:151–166. https://doi.org/10.3391/bir.2023.12.1.13

Badiou P, Goldsborough LG, Wrubleski D. 2011. Impacts of the common carp (*Cyprinus carpio*) on freshwater ecosystems: a review. In: JD Sanders and SB Peterson (eds.) Carp: habitat, management and diseases. Nova Science Publishers, Inc, New York, USA, pp. 121-146.

Bailey SA, Brown L, Campbell ML et al. (2020). Trends in the detection of aquatic non-indigenous species across global marine, estuarine and freshwater ecosystems: A 50-year perspective. Diversity and Distributions 26:1780-1797. https://doi.org/10.1111/ddi.13167

Barbier EB. 2017. Marine ecosystem services. Current Biology 27:R507-R510. https://doi.org/10.1016/j.cub.2017.03.020

Bergallo HG, Silveira TB, Ziller SR 2021. Primeira lista de referência de espécies exóticas invasoras no estado do Rio de Janeiro – Brasil: implicações para pesquisas, políticas e manejo. Bioinvasiones 8:3 - 18.

Bernot J, Ahyong S, Boyko CB et al. 2025. World Register of Marine Species. Available from https://www.marinespecies.org at VLIZ. Accessed 2025-04-10. https://doi.org/10.14284/170.

Boltovskoy D, Valentin JL. 2018. Overview of the history of biological oceanography in the southwestern Atlantic, with emphasis on plankton. In: Plankton Ecology of the Southwestern Atlantic: From the Subtropical to the Subantarctic Realm (pp. 3-34). Springer International Publishing, Cham, Switzerland.Bornatowski H, Loose R, Sampaio CLS et al. (2018) Human introduction or natural dispersion? Atlantic Ocean occurrence of the Indo-Pacific whitetip reef shark *Triaenodon obesus*. Journal of Fish Biology 92:537-542. https://doi.org/10.1007/978-3-319-77869-3_1

Brasil. 2025. Decreto 12363 - Plano Setorial para os Recursos do Mar.

Bumbeer JA and Rocha RM. 2012. Detection of introduced sessile species on the near shore continental shelf in southern Brazil. Zoologia 29:126–134. https://doi.org/10.1590/S1984-46702012000200005

Bumbeer JA and Rocha RM. 2016. Invading the natural marine substrates: a case study with invertebrates in South Brazil. Zoologia (Curitiba) 33:e20150211. https://doi.org/10.1590/S1984-4689zool-20150211

Canonico GC, Arthington A, McCrary JK et al. 2005. The effects of introduced tilapias on native biodiversity. Aquatic Conservation: Marine and Freshwater Ecosystems 15:463-483. https://doi.org/10.1002/aqc.699

Capel KCC, Kitahara MV, Creed JC et al. 2020. Invasive corals trigger seascape changes in the southwestern Atlantic. Bulletin of Marine Science 85:217-218. https://doi.org/10.5343/bms.2019.0075

Carlton JT. 1996. Biological invasions and cryptogenic species. Ecology 77:1653–1655. https://doi.org/10.2307/2265767

Carlton J. 2009. Deep invasion ecology and the assembly of communities in historical time. In: Rilov G, Crooks J (eds) Biological Invasions in Marine Ecosystems, Book 204. Springer Berlin Heidelberg, pp.13-56. https://doi.org/10.1007/978-3-540-79236-9_2

Castro CB, Medeiros MS, Loiola LL. 2010. Octocorallia (Cnidaria:Anthozoa) from Brazilian reefs. Journal of Natural History 44:763-827. https://doi.org/10.1080/00222930903441160

Çinar ME, Arianoutsou M, Zenetos A et al. 2014. Impacts of invasive alien marine species on ecosystem services and biodiversity: a pan-European review. Aquatic Invasions 9:391-423. http://dx.doi.org/10.3391/ai.2014.9.4.01

Cord I, Nunes LT, Barroso CX et al. 2022. Brazilian marine biogeography: a multi-taxa approach for outlining sectorization. Marine biology 169: 61. https://doi.org/10.1007/s00227-022-04045-8

Crivellaro MS, Silveira TCL, Custódio FY et al. 2021. Fighting on the edge: reproductive effort and population structure of the invasive coral *Tubastraea coccinea* in its southern Atlantic limit of distribution following control activities. Biological Invasions 23:811-823. https://doi.org/10.1007/s10530-020-02403-5

Cudmore BMNE and Mandrak NE. 2004. Biological synopsis of grass carp (*Ctenopharyngodon idella*). Canadian manuscript report of fisheries and Aquatic Sciences 2705:1-44.

Daigle RM and Herbinger CM. 2009. Ecological interactions between the vase tunicate (*Ciona intestinalis*) and the farmed blue mussel (*Mytilus edulis*) in Nova Scotia, Canada. Aquatic Invasions 4:177–187. https://doi.org/10.3391/ai.2009.4.1.18

Ehler CN. 2021. Two decades of progress in Marine Spatial Planning. Marine Policy 132:104134. https://doi.org/10.1016/j.marpol.2020.104134

Essl F, Latombe G, Lenzner B et al. (2020) The Convention on Biological Diversity (CBD)'s Post-2020 target on invasive alien species–what should it include and how should it be monitored? NeoBiota 62:99-121. https://doi.org/10.3897/neobiota.62.53972

Faraco LFD, Ghisi CL, Marins M et al. 2019. Infestation of Mangroves by the Invasive Moth *Hyblaea puera* (Cramer, 1777)(Lepidoptera: Hyblaeidae). Brazilian Archives of Biology and Technology 62:e19170516. https://doi.org/10.1590/1678-4324-2019170516

Giraldes BW, Macedo TP, Brandão MC et al. (2018) *Lysmata arvoredensis* nov. sp. a new species of shrimp from the south coast of Brazil with a key to species of *Lysmata* (Caridea: Lysmatidae) recorded in the southwestern Atlantic. PeerJ 6:e5561. https://doi.org/10.7717/peerj.5561

Halpern BS, Frazier M, Potapenko J et al. 2015. Spatial and temporal changes in cumulative human impacts on the world's ocean. Nature communications 6: 7615. https://doi.org/10.1038/ncomms8615

Hamasaki K, Takahashi T, Uye S. 2003. Accumulation of paralytic shellfish poisoning toxins in planktonic copepods during a bloom of the toxic dinoflagellate *Alexandrium tamarense* in Hiroshima Bay, western Japan. Marine Biology 143:981-988. https://doi.org/10.1007/s00227-003-1131-7

Hobbs RT and Humphries SE. 1995. An Integrated Approach to the Ecology and Management of Plant Invasions. Conservation Biology 9:761-770.

Instituto Brasileiro de Geografia e Estatística (IBGE). 2023. Malha Municipal. Available from https://www.ibge.gov.br/geociencias/organizacao-do-territorio/malhas-territoriais/15774-malhas.html Acessed 2025-02-19.

Instituto Brasileiro de Geografia e Estatística (IBGE). 2024. Available from https://www.ibge.gov.br/cidades-e-estados/, Accessed 2025-03-01

Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio). 2025. Dados geoespaciais de referência da Cartografia Nacional e dados temáticos produzidos no ICMBio. Available from https://www.gov.br/icmbio/pt-br/assuntos/dados_geoespaciais/mapa-tematico-e-dados-geoestatisticos-das-unidades-de-conservacao-federais Acessed 2025-02-19.

Instituto Hórus. 2025. Base de Dados Nacional de Espécies Exóticas Invasoras. Disponível em https://bd.institutohorus.org.br/. Acesso em 30/04/2025.

International Union for the Conservation of Nature (IUCN). 2020. IUCN EICAT Categories and Criteria: The Environmental Impact Classification for Alien Taxa (EICAT). IUCN, Gland, Switzerland.

Kazmi SSUH, Rahman MS, Xu H. 2021. Use of biological trait analysis of periphytic protozoan assemblages for evaluating effects of harmful algal blooms on ecological quality status in marine ecosystem. Marine Pollution Bulletin 164:112083. https://doi.org/10.1016/j.marpolbul.2021.112083

Krassoi FR, Brown KR, Bishop MJ et al. 2008. Condition specific competition allows coexistence of competitively superior exotic oysters with native oysters. Journal of Animal Ecology 77:5–15. https://doi.org/10.1111/j.1365-2656.2007.01316.x

Kumschick S, Gaertner M, Vilà M et al. 2015. Ecological Impacts of Alien Species: Quantification, Scope, Caveats, and Recommendations. BioScience 65:55–63. https://doi.org/10.1093/biosci/biu193

Lages BG, Fleury BG , Menegola C et al. 2011. Change in tropical rocky shore communities due to an alien coral invasion. Marine Ecology Progress Series 438:85-96. https://doi.org/10.3354/meps09290

Lana PC, Santos CSG, Garraffoni ARS et al. 2006. Checklist of polychaete species from Paraná State (Southern Brazil). Check List 2:30-63. Lana PC, Santos CSG, Garraffoni ARS et al. 2006. Checklist of polychaete species from Paraná State (Southern Brazil). Check List 2:30-63.

Lehtiniemi M, Ojaveer H, David M, et al. (2015) Dose of truth—Monitoring marine non-indigenous species to serve legislative requirements. Marine Policy 54:26-35. https://doi.org/10.1016/j.marpol.2014.12.015

Lins DM and Rocha RM. 2020. Cultivated brown mussel (*Perna perna*) size is reduced through the impact of three invasive fouling species in southern Brazil. Aquatic Invasions 15:114–126. https://doi.org/10.3391/ai.2020.15.1.08

Lins DM and Rocha RM. 2022. Invasive species fouling *Perna perna* (Bivalvia: Mytilidae) mussel farms. Marine Pollution Bulletin 181:113829. https://doi.org/10.1016/j.marpolbul.2022.113829

Lins DM, Zbawicka M, Wenne R et al. 2021. Ecology and genetics of *Mytilus galloprovincialis*: A threat to bivalve aquaculture in southern Brazil. *Aquaculture 540*: 736753. https://doi.org/10.1016/j.aquaculture.2021.736753

Lodge DM, Simonin PW, Burgiel S et al. 2016. Risk Analysis and Bioeconomics of Invasive Species to Inform Policy and Management Annual Review of Environmental Resources 41:453–88. https://doi.org/10.1146/annurev-environ-110615-085532

Loebmann D, Mai ACG, Lee JT. 2010. The invasion of five alien species in the Delta do Parnaíba Environmental Protection Area, Northeastern Brazil. Revista de Biología Tropical 58:909-923.

Longo C, Mastrototaro F, Corriero G. 2007. Occurrence of *Paraleucilla magna* (Porifera: Calcarea) in the Mediterranean sea. Journal of the Marine Biological Association of the United Kingdom 87:1749-1755. https://doi.org/10.1017/S0025315407057748

Lopes RMC, Pombo L, Cunha VB et al. 2009. Informe sobre as espécies exóticas invasoras marinhas no Brasil. Ministério do Meio Ambiente/ Secretaria de Biodiversidade e Florestas, Brasília, 440p.

Manabe T and Ishio S. 1991. Bloom of *Coscinodiscus wailesii* and DO deficit of bottom water in the Seto Inland Sea. Marine Pollution Bulletin 23:181-184. https://doi.org/10.1016/0025-326X(91)90671-E

McGeoch MA, Genovesi P, Bellingham PJ et al. 2016. Prioritizing species, pathways, and sites to achieve conservation targets for biological invasion. Biological Invasions 18:299-314. https://doi.org/10.1007/s10530-015-1013-1

Merz E, Kitahara MV, Flores AAV. 2023. A legacy of invasive sun corals: Distinct mobile invertebrate assemblages at near-reef coral-dominated rubble. Marine Environmental Research 188:105974. https://doi.org/10.1016/j.marenvres.2023.105974

Ministério do Meio Ambiente (MMA). 2018. Plano Nacional de Prevenção, Controle e Monitoramento do Coral-Sol (*Tubastraea* spp.) no Brasil. Book 1. Ministério do Meio Ambiente - MMA, Brasília, 102 p.

Miranda RJ, Cruz ICS, Barros F. 2016. Effects of the alien coral *Tubastraea tagusensis* on native coral assemblages in a southwestern Atlantic coral reef. Marine Biology 163:1–12. https://doi.org/10.1007/s00227-016-2819-9

Müller F. 1867. Uber *Balanus armatus* und einen Bastard dieser Art und des *Balanus improvisus* var. *assimilis* D. Archiv für Naturgeschichte I:329-356.

Neves CS, Rocha RM, Pitombo FB et al. 2007. Use of artificial substrata by introduced and cryptogenic marine species in Paranaguá Bay, southern Brazil. Biofouling 23:319-330. https://doi.org/10.1080/08927010701399174

Neves CS and Rocha RM. 2008. Introduced and Cryptogenic Species and their Management in Paranaguá Bay, Brazil. Brazilian Archives of Biology and Technology 51:623-633. https://doi.org/10.1590/S1516-89132008000300025

Ohanna M, Silveira TC, Crivellaro MS et al. 2025. Charting the invasion: Predicting *Tubastraea* spp. next move into Brazilian marine protected areas. Marine Pollution Bulletin 217:118030. https://doi.org/10.1016/j.marpolbul.2025.118030

Oliveira Junior RB. 2022. Ferramentas moleculares aplicadas na identificação do hidróide invasor *Cordylophora caspia* (Pallas 1771). Masters dissertation, Universidade Federal de Minas Gerais, Belo Horizonte, MG, 57p.

Pandolfi JM, Bradbury RH, Sala E et al. 2003. Global trajectories of the long-term decline of coral reef ecosystems. Science 301:955-958. https://doi.org/10.1126/science.1085706

Paraná. 2015. Lista de Espécies Exóticas Invasoras do Paraná anexo Portaria IAP nº 59, de 15 de abril de 2015. In: IAP (ed) 59p.

Rio Grande do Sul. 2013. Secretaria de Estado de Meio Ambiente. Portaria Nº 79 de 31/10/2013.

Rocha RMD, Vieira LM, Migotto AE et al. 2013. The need of more rigorous assessments of marine species introductions: a counter example from the Brazilian coast. Marine Pollution Bulletin 67:241–243. https://doi.org/10.1016/j.marpolbul.2012.12.009

Roy HE, Pauchard A, Stoett PJ et al. 2024. Curbing the major and growing threats from invasive alien species is urgent and achievable. Nature Ecology & Evolution 8:1216-1223. https://doi.org/10.1038/s41559-024-02412-w

Santa Catarina. 2025. Resolução CONSEMA Nº 272 de 30/05/2025.

Sardain A, Sardain E, Leung B. 2019. Global forecasts of shipping traffic and biological invasions to 2050. Nature Sustainability 2:274-282. https://doi.org/10.1038/s41893-019-0245-y

Schwindt E and Bortolus A. 2017. Aquatic invasion biology research in South America: Geographic patterns, advances and perspectives. Aquatic Ecosystem Health & Management 20:322-333. https://doi.org/10.1080/14634988.2017.1404413

Seebens H, Blackburn TM, Dyer EE et al. 2017. No saturation in the accumulation of alien species worldwide. Nature Communications 8:14435. https://doi.org/10.1038/ncomms14435

Seebens H, Blackburn TM, Dyer EE et al. 2018. Global rise in emerging alien species results from accessibility of new source pools. Proceedings of the National Academy of Sciences of the United States of America 115:E2264–E2273. https://doi.org/10.1073/pnas.1719429115

Simberloff D, Martin J, Genovesi P et al. (2013). Impacts of biological invasions: what's what and the way forward. Trends in Ecology and Evolution 28:58-66. https://doi.org/10.1016/j.tree.2012.07.013

Silva EC and Barros F. 2011. Macrofauna bentônica introduzida no Brasil: lista de espécies marinhas e dulcícolas e distribuição atual. Oecologia Australis 15:326-344. https://doi.org/10.4257/oeco.2011.1502.10

Slivak NN, Lindner A, Romanowski HP. 2022. Echinoderms from Santa Catarina, southern Brazil: an update on biodiversity and distribution. Papéis Avulsos de Zoologia 62:e202262004. https://doi.org/10.11606/1807-0205/2022.62.004

Soares MO, Pereira PHC, Rabelo EF et al. 2025. Invasive lionfish spread through southwestern Atlantic marine protected areas. Marine Environmental Research 208:107099. https://doi.org/10.1016/j.marenvres.2025.107099

Spalding MD, Fox HE, Allen GR et al. 2007. Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. BioScience 57:573-583. https://doi.org/10.1641/B570707

Spotorno-Oliveira P, Lopes RP, Larroque A et al. 2020. First detection of the non-indigenous gastropod *Rapana venosa* in the southernmost coast of Brazil. Continental Shelf Research 194:104047. https://doi.org/10.1016/j.csr.2020.104047

Teixeira LM and Creed JC. 2020. A decade on: an updated assessment of the status of marine non-indigenous species in Brazil. Aquatic Invasions 15:30-43. https://doi.org/10.3391/ai.2020.15.1.03

United Nations. 1982. United Nations Convention on the Law of the Sea of 10 December 1982.

United Nations. 1992. Convention on Biological Diversity. New York.

United Nations. 2025. Department of Economic and Social Affairs, Sustainable Development, Oceans and Seas. Available from https://sdgs.un.org/topics/oceans-and-seas Accessed April 2025.

World Wide Fund for Nature (WWF). 2007. Marine Ecoregions of the World (MEOW). Available from https://www.worldwildlife.org/publications/marine-ecoregions-of-the-world-a-bioregionalization-of-coastal-and-shelf-areas Acessed February 2025.

Zenni RD, Ziller SR, da Rosa CA et al. 2024. Invasive non-native species in Brazil: an updated overview. Biological Invasions 26:2397-2405. https://doi.org/10.1007/s10530-024-03302-9

Zullo VA. 1992. *Balanus trigonus* Darwin (Cirripedia, Balaninae) in the Atlantic basin: an introduced species? Bulletin of Marine Science 50:66-74.