



The high biodiversity of benthic organisms in a coastal ecosystem revealed by an integrative approach

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Abstract: Increasing habitat modification and species loss demand consistent efforts to describe and understand biodiversity patterns. The BIOTA/FAPESP Program was created in this context and it has been a successful initiative to promote studies on biodiversity and conservation in Brazil. The BIOTA/Araçá is an interdisciplinary project that provided a detailed evaluation of the biodiversity of Araçá Bay, a coastal seascape located on the North coast of the state of São Paulo, Southeast Brazil. The bay encompasses multiple habitats, such as beaches, mangroves, rocky shores, and a tidal flat, and provides important ecosystem services. Unfortunately, the bay is the subject of complex social-environmental conflicts that oppose economic, social, and environmental demands (i.e., the expansion of neighboring harbor activities vs. small-scale artisanal fisheries and protection of biodiversity). The present study presents a survey of the benthic species occurring in the different habitats of Araçá Bay, including data obtained during the BIOTA/Araçá project and previous assessments of the area. The benthic species play an important role in marine environments and studying the diversity of these organisms that live associated with the bottom is indispensable for comprehending the environment’s functioning. The macrofauna, meiofauna, and microorganisms associated with soft and hard bottom were listed, and additional information, such as the habitat and geographical distribution, were provided for each species. The checklist includes 826 species, almost 70% recorded during the BIOTA/Araçá project. The most speciose taxa were the annelids (225 spp.), mollusks (194 spp.), and crustaceans (177 spp.). Seven benthic species are endemic to Araçá Bay, 14 are considered threatened, and seven are economically exploited. Furthermore, the bay is the type locality of many taxa, and 11 new benthic species were described based on specimens sampled during the project. This project shows the importance of Araçá Bay as a unique biologically rich environment and highlights the need for conservation efforts in light of the current threats.

Keywords: Araçá Bay; checklist; macrofauna; meiofauna; microorganism; conservation.

A alta biodiversidade de organismos bentônicos em um ecossistema costeiro revelada por uma abordagem integrativa

Resumo: O aumento da modificação dos habitats e da perda de espécies demanda esforços consistentes para descrever e compreender os padrões de biodiversidade. O programa BIOTA/FAPESP foi criado nesse contexto e é uma iniciativa de sucesso para promover estudos em biodiversidade e conservação no Brasil. O BIOTA/Araçá é um projeto interdisciplinar que promoveu uma avaliação detalhada da biodiversidade da Baía do Araçá, um ecossistema costeiro localizado ao Norte do estado de São Paulo, Sudeste do Brasil. A baía engloba múltiplos habitats, tais como praias, manguezais, costões rochosos, e uma planície de maré, e também fornece importantes serviços ecossistêmicos. Infelizmente, a baía está sujeita a conflitos sócio-ambientais complexos que contrastam demandas econômicas, sociais e ambientais (i.e. a expansão das atividades do porto vizinho vs. a pesca artesanal de pequena escala e a proteção da biodiversidade). O presente estudo apresenta um levantamento das espécies bentônicas que ocorrem nos diferentes habitats da Baía do Araçá, incluindo dados obtidos durante o projeto BIOTA/Araçá e de investigações realizadas anteriormente na área. As espécies bentônicas desempenham um papel importante no ambiente marinho, e estudar a diversidade desses organismos que vivem associados ao fundo é indispensável para compreender o funcionamento do meio ambiente. A macrofauna, meiofauna, e microorganismos associados aos fundos consolidado e inconsolidado foram listados, e informações adicionais foram fornecidas para cada espécie, tais como a distribuição geográfica e nos habitats. O checklist inclui 826 espécies, quase

70% registradas durante o projeto BIOTA/Araçá. Os taxa mais especiosos foram os anelídeos (225 spp.), moluscos (194 spp.), e crustáceos (177 spp.). Entre as espécies bentônicas listadas, sete são endêmicas da Baía do Araçá, 14 são consideradas ameaçadas de extinção, e sete são exploradas economicamente. A baía é a localidade tipo de vários taxa, e 11 novas espécies bentônicas foram descritas com base em espécimes amostrados durante o projeto. Este projeto mostra a importância da Baía do Araçá como um ambiente de riqueza biológica única e demonstra a necessidade de esforços para a sua conservação considerando as atuais ameaças.

Palavras-chave: Baía do Araçá; checklist; macrofauna; meiofauna; microorganismos; conservação.

Introduction

Over the past decades, the growing human population and the effects of climate change have accelerated extinction rates and significantly changed the structure and functioning of ecosystems (IPCC 2022). Estimates suggest that thousands of species disappear each year, many of them unknown to science (Pimm & Raven 2019, Cowie *et al.* 2022). To successfully protect our ecosystems in the long term, it is necessary to increase efforts in assessing biodiversity so that the available information is sufficient to identify key areas for conservation and improve management strategies (Amaral & Jablonski 2005). Unfortunately, a complete biodiversity assessment is usually precluded by the reduced number of taxonomic specialists and the time-consuming work to sample and identify organisms (Myers *et al.* 2000, Heino 2010, Corte *et al.* 2017). This situation is even more critical in developing countries like Brazil (Amaral *et al.* 2016a, Fernandes *et al.* 2017).

Brazil is considered one of the most biologically diverse countries in the world, presenting between 15 and 20% of the total number of known species (Joly & Bicudo 1999, Lewinsohn & Prado 2005). Nonetheless, due to anthropic environmental impacts, many species are lost day after day before being recognized (Miola *et al.* 2019). Considering this scenario, in 1999, the Program for the Characterization, Restoration and Sustainable Use of the Biodiversity (BIOTA/FAPESP Program – www.biota.org.br), was created with the support of the São Paulo Research Foundation (FAPESP). The main goal of the program is to support studies targeting the diagnose of the biological diversity from the state of São Paulo. The biological knowledge at the time was published in a series of seven books, named “Biodiversidade do Estado de São Paulo, Brasil: síntese do conhecimento ao final do século XX” (orgs., Joly & Bicudo, 1999), containing diagnoses, taxonomic, and distribution data of the biota from São Paulo. One of the volumes focused on marine invertebrates, and gathered a considerable knowledge of more than thirty known *phyla* from the state of São Paulo, highlighting that most of these taxa presented outdated data or had no active specialists (Migotto & Tiago 1999). Aside from the characterization of biodiversity, the BIOTA/FAPESP Program was designed to ensure the means for the theoretical and practical training of a significant number of young researchers and substantially improved the production of knowledge and scientific competence in studies on conservation and marine management in the state of São Paulo.

One of the initiatives supported by the program, the BIOTA/Araçá project, carried out from 2012 to 2017, was designed to assess and characterize the biodiversity of Araçá Bay, a seascape located on the northern coast of the state of São Paulo. This project brought together about 170 researchers from different scientific areas and institutions, allowing the integration of multiple dimensions, from ecological,

social, economic, and political points of view (Amaral *et al.* 2016b). The interdisciplinarity and high number of specialists in the project opened a realistic dialogue between scientists and decision-makers and allowed for a holistic assessment of the benthic biodiversity (Amaral *et al.* 2016b, Turra *et al.* 2016). The biodiversity data obtained was partially included in identification guides, such as the “Manual de Identificação dos Invertebrados Marinhos da região sudeste-sul do Brasil - Volume 2” (Steiner *et al.* 2021).

The Araçá Bay, located in the São Sebastião Channel, is part of the Marine Environmental Protection Area of the North Coast of the State of São Paulo and the Municipal Environmental Protection Area of Alcatrazes. The remarkable heterogeneity of this small bay, associated with its accessibility, allowed detailed documentation of its high biodiversity (Amaral *et al.* 2016b). The bay is locally and regionally important, providing important ecosystem services to society. In addition to harboring a high biological diversity, the bay is a stronghold of artisanal fishermen, provides shelter for vessels and access to the sea, hosts scientific and educational activities, and plays a relevant role in effluent depuration and carbon stocking (Amaral *et al.* 2016b, Carrilho & Sinisgalli 2018). However, due to its proximity to the urban area, it has been historically exposed to various anthropogenic disturbances, such as irregular occupations, sewage disposal, and harbor activities (Port of São Sebastião), including one of the most important oil terminals in Brazil (Terminal Aquaviário de São Sebastião). The bay has also been threatened with occupation by the expansion of the nearby port, which would likely severely compromise the ecosystem functioning and its biodiversity (Turra *et al.* 2017). These conflicts between environment and economic development mirror issues of complex resolutions typical of coastal regions worldwide (Gari *et al.* 2015).

In this context, this study presents a checklist of benthic species found in Araçá Bay, combining data obtained within the BIOTA/Araçá project with past data from previous assessments of the area. Also, the geographical and habitat distribution data were provided for each species, as well as information about material deposited in museum collections, the availability of molecular data, and the status according to the threatened species list. This work is a main outcome of the BIOTA/Araçá project and provides essential information to ensure the long-term sustainability of the bay.

Material and Methods

1. Study area

The Araçá Bay is located on the continental side of the São Sebastião Channel, a 25 km strait on the northern coast of the state of São Paulo, southeastern Brazil (Figure 1). The bay shelters beaches, mangrove

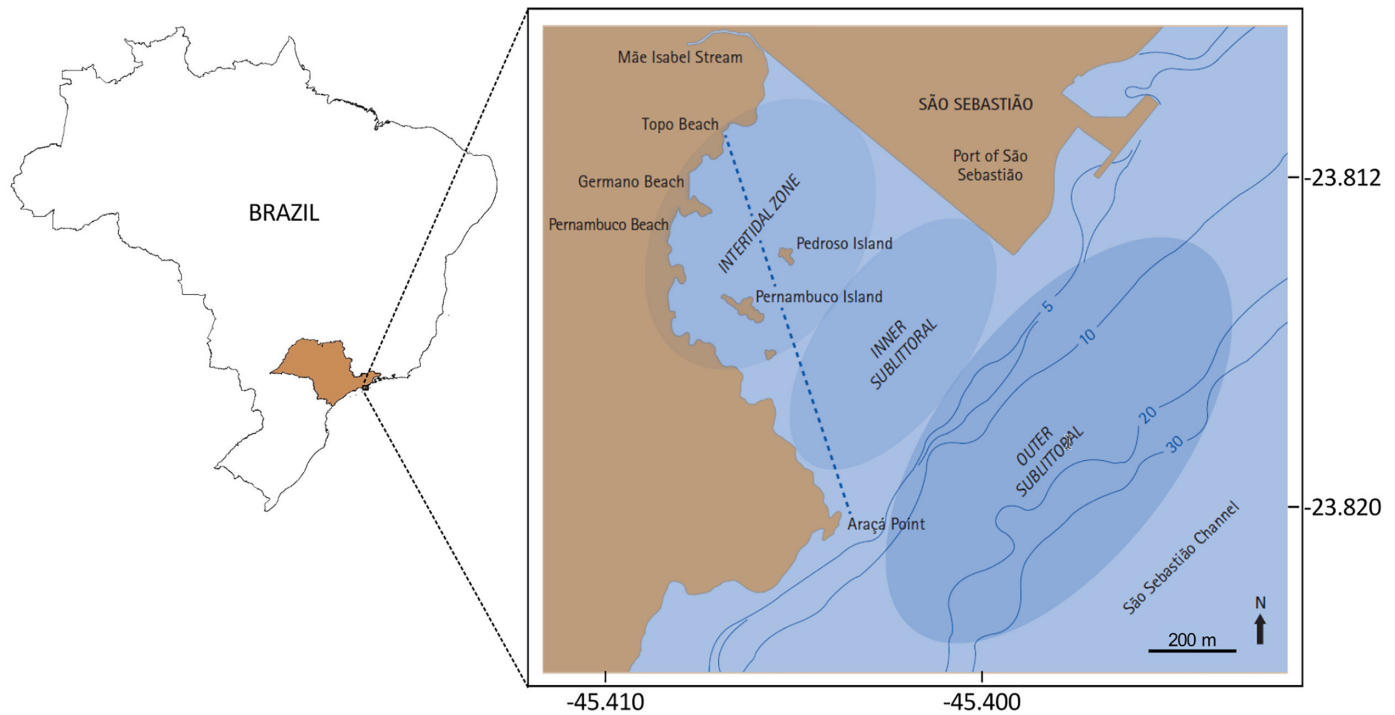


Figure 1. Map of the Araçá Bay, São Paulo state, Brazil. The blue dashed line represents the offshore sewage outfall. Adapted from Amaral *et al.* (2016b).

stands, rocky shores, and a tidal flat that can exceed 300 m in length. The bay also encompasses a sublittoral zone that reaches a maximum depth of 30 m in the São Sebastião Channel. Besides the anthropic impact, the interaction between physical, biological, and geological features makes the bay an area of special interest for different studies (Amaral *et al.* 2016b).

An exhaustive sampling effort was performed to assess the biodiversity and functioning of the bay. All the different habitats from Araçá Bay were identified and mapped according to the substrate type and their communities' composition. The sampling to investigate the benthic organisms from the soft and hard bottom was conducted as described in Amaral *et al.* (2017). The collaboration of taxonomists during samplings was mandatory for a more comprehensive description of the biodiversity, mainly because of specific sampling procedures that allowed adequate preservation of specimens and for the assessment of microhabitats that eventually would go unnoticed by non-specialist researchers.

2. Soft bottom

2.1. Sampling design

The soft bottom of the bay was sampled to assess the macrobenthic, meiobenthic, bacterial, and fungal biodiversity. Sampling was performed at four campaigns (October 2012, February, June, and September 2013). Thirty-seven sampling stations were established from the intertidal and sublittoral area at the bay (up to a depth of 25 m). Sampling stations were positioned to encompass habitat heterogeneity (*i.e.*, different sediment types and depths), and achieve a reasonable dispersion and spatial coverage. The same locations (± 1 m) were sampled during each campaign using a GPS. In the intertidal and

shallow sublittoral (< 3 m deep), four samples were taken using a corer of 10 cm diameter and 20 cm depth for the evaluation of macrofauna, and one sample of 2.5 cm in diameter and 5 cm depth for meiofauna at each station. The sampling was performed using the multi-corer (macro and meiofauna), van Veen (macrofauna), and rectangular Dredge (macrofauna) methods in depths ranging from 3 to 25 m. Sediment samples for microorganism analyses were collected in the 37 sampling stations at the bay, according to Zampieri *et al.* (2016) and Doi *et al.* (2018). Additional samples were taken at each station to evaluate environmental parameters.

2.2. Samples processing

Macrofauna samples were stored in plastic bags and posteriorly sieved with a 0.3 mm mesh. The fauna retained was sorted into taxonomic groups and fixed in 70% or absolute ethanol. The specimens were identified at the lowest level possible by the specialists of each group.

Meiofauna samples were immediately fixed in 4% formaldehyde, posteriorly washed through a 45 μ m mesh sieve, then extracted by flotation with Ludox TM 50 (specific density 1.18) (Heip *et al.* 1985). The retained material was stored in formaldehyde 4% and stained with Rose Bengal. The morphological identification of these tiny animals is time-consuming and demands high-quality microscopy and specialized knowledge (Giere 2009). Thus, the morphological identification of many taxa in the present study remained at higher taxonomical levels. Since there is no regional identification key for the meiofauna species, identification down to the species level was done based on the original descriptions.

Bacteria were isolated using the Pour Plate Method in Marine Agar 2216 (MA, Difco) and identified using 16S rRNA gene sequencing

(~1360 nucleotides). The Fungi were isolated using the Spread Plate Method in Potato Dextrose Agar (PDA) and identified using yeast NL1 and NL4 (Pagnocca *et al.* 2008). For filamentous fungi, two different nuclear DNA markers were amplified for phylogenetic analysis (LSU and ITS) (Möller *et al.* 1992). The Technique of Membrane Filtration was used to check the presence of the contaminant microorganism (*Candida* sp., *Escherichia coli*, and *Enterococcus* sp.).

3. Rocky Shore

3.1. Sampling design

The samplings on the rocky shores were carried out from the entrance to the bottom of the bay, near the mouth of the Mãe Isabel River, including those of Pernambuco Island, and the artificial substrate formed by boulders near the port (Figure 1).

The occurrence of common species in the hard bottom was registered and the macrofauna was sampled for later identification (Amaral *et al.* 2017). The qualitative (active search) and quantitative (20 parcels of 10 × 10 cm, Dias *et al.* 2018) sampling was carried out at different times, for almost two years (October 2012, February, July, November 2013, March, and June 2014), allowing ephemeral species with a short life cycle to be sampled. Additionally, the pebbles found at the interface with the hard substrate were visually inspected and the sessile and mobile organisms that occupied these microhabitats were collected.

3.2. Samples processing

Macrofauna specimens were anesthetized (MgCl₂ or menthol) and preserved in 70% ethanol, while macroalgal samples were fixed in 10% formalin with seawater. The sediment associated with the organisms sampled, mainly macroalgae, sponges, and arborescent bryozoans, was also examined under a stereomicroscope to obtain meiofaunal organisms while they were still alive. Afterward, the samples were divided into taxonomic groups and, when possible, in morpho-species for posterior identification.

To visualize the eyes of the macrofaunal Platyhelminthes, they were dehydrated in an ascending series of ethanol before clearing in clove oil. For observing the anatomical details, other samples were embedded in paraffin, sectioned at 7 µm, and transferred to glass slides coated with albumen-glycerine. Tissues were stained with the Mallory method modified by Canson (1950).

4. Collections

Most of the specimens collected in the different environments were deposited in the Museu de Diversidade Biológica, Instituto de Biologia, Universidade Estadual de Campinas (MDBio/IB-UNICAMP) and in the Museu de Zoologia, Universidade de São Paulo (MZUSP/USP). Material was also deposited in other collections in national and international museums. Much of the deposited material is cataloged and available at <https://specieslink.net/> and <https://sibr.gov.br>. A list with acronyms and full names of the museums is shown in Table 1.

5. Procedures for preparing the Araçá Bay checklist

The current survey of the species from Araçá Bay includes records from the previous assessments and new records consisting

of unpublished data obtained during the BIOTA/Araçá project. The checklist by Amaral *et al.* (2010) provided the starting point. The present review also includes species from scientific collections, previously sampled in the bay, and recently identified by the specialists. The validity of each taxa name was confirmed in specific databases, such as WoRMS (<http://www.marinespecies.org/aphia.php?p=search>) and TCBF - Taxonomic Catalog of the Brazilian Fauna (<http://fauna.jbrj.gov.br>). The checklist was divided into three sections (Macrofauna, Meiofauna, and Microorganism), and the phyla were listed in alphabetical order within each section.

When appropriate, the following symbols were used ahead of species names:

β – species sampled during the BIOTA/Araçá project;

® – species recorded in the Araçá Bay for the first time in the current checklist.

We provided relevant data about each species, such as the geographical and habitat distribution. The information was presented in the following sections:

Original name – when needed, the name originally given to the species was presented.

Record in Araçá Bay – for those species previously recorded in the bay, the publication reporting the species in the area was included (Amaral *et al.* 2010 or a study published thereafter). When the species had been reported with another name, it was indicated between parentheses.

Main taxonomic references – main references related to the taxonomy, phylogeny and/or functional anatomy of the species.

Habitat – information on the environments of occurrence of the species, not restricted to Araçá Bay (such as bathymetry, the type of substrate, and association with different species, among other pertinent information).

Geographical range – localities where the species is recorded, corresponding countries and information such as oceans and/or seas.

Deposited material – information on specimens from Araçá Bay deposited in the museum's collections. The museum acronym(s) were presented accompanied by a maximum of five lots or the interval between them (*e.g.*, ZUEC BIV 5119 – 5141). When over five registration numbers were available, only the acronym of the museum (s) was informed. Species with no deposit register were reported as NR (no record).

Molecular data – the information about the availability of nucleotide sequences deposited in GenBank was given as AV (available) when there was deposited material; or NR (no record) for species with no deposit register.

Conservation status – status of the species according to the “Red List (ICMBIO)” (<https://www.gov.br/icmbio/pt-br/centrais-de-conteudo/publicacoes/publicacoes-diversas/livro-vermelho/livro-vermelho-da-fauna-brasileira-ameacada-de-extincao-2018>) or “IUCN – The IUCN Red List of Threatened species” (<http://www.iucnredlist.org>). The species listed here were classified according to their risk status: Least concern (LR), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), or NR (no record) for unregistered species.

Table 1. Acronyms, full names and locations of the museums where specimens from Araçá Bay are deposited.

Acronym	Museum collection
CCDB/FFCLRP/USP	Crustacea Collection, Departamento de Biologia, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Universidade de São Paulo, Ribeirão Preto, Brazil
CZM	Zoological Museum, University of Sassari, Sassari, Italy
DZUP	Asciacea Collection, Departamento de Zoologia, Universidade Federal do Paraná, Curitiba, Brazil
MCZ:IZ	Collection Invertebrate Zoology, Museum of Comparative Zoology, Harvard University, Cambridge, USA
MNCN	Museo Nacional de Ciencias Naturales, Madrid, Espanha
MNHN	Muséum National d'Histoire Naturelle, Paris, France
MNRJ	Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil
MZUSP	Museu de Zoologia, Universidade de São Paulo, São Paulo, Brazil
UFPE	Museu de Zoologia, Universidade Federal de Pernambuco, Recife, Brazil
USNM	National Museum of Natural History, Smithsonian Institution, Washington DC, USA
ZMUC KIN	Kinorhyncha Collection, Natural History Museum of Denmark, Copenhagen, Denmark
ZUEC ASC	Asciacea Collection, Museu de Diversidade Biológica, Instituto de Biologia, Universidade Estadual de Campinas, Campinas, Brazil
ZUEC AST	Asteroidea Collection, Museu de Diversidade Biológica, Instituto de Biologia, Universidade Estadual de Campinas, Campinas, Brazil
ZUEC BIV	Bivalvia Collection, Museu de Diversidade Biológica, Instituto de Biologia, Universidade Estadual de Campinas, Campinas, Brazil
ZUEC CRU	Crustacea Collection, Museu de Diversidade Biológica, Instituto de Biologia, Universidade Estadual de Campinas, Campinas, Brazil
ZUEC ECH	Echinoidea Collection, Museu de Diversidade Biológica, Instituto de Biologia, Universidade Estadual de Campinas, Campinas, Brazil
ZUEC GAS	Gastropoda Collection, Museu de Diversidade Biológica, Instituto de Biologia, Universidade Estadual de Campinas, Campinas, Brazil
ZUEC HOL	Holothuroidea Collection, Museu de Diversidade Biológica, Instituto de Biologia, Universidade Estadual de Campinas, Campinas, Brazil
ZUEC OPH	Ophiuroidea Collection, Museu de Diversidade Biológica, Instituto de Biologia, Universidade Estadual de Campinas, Campinas, Brazil
ZUEC POL	Polychaeta Collection, Museu de Diversidade Biológica, Instituto de Biologia, Universidade Estadual de Campinas, Campinas, Brazil
ZUEC POR	Porifera Collection, Museu de Diversidade Biológica, Instituto de Biologia, Universidade Estadual de Campinas, Campinas, Brazil

Results and Discussion

During the five years of development of the BIOTA/Araçá project, unprecedented and invaluable results about the biodiversity of Araçá Bay were produced, surpassing studies carried out there between 1950 and 2010 (Amaral *et al.* 2010). These results revealed that the bay and the adjacent region (area of the São Sebastião Channel closer to the bay) sustain high biodiversity, with a total of 1177 benthic taxa identified (including identifications at the level of species, genera, or morphotypes). Among those, 276 were recorded for the first time at the Araçá Bay (®), and 11 new species were described (Table 2). Parallel to these results, several papers have been published exploring ecological,

social, and economic aspects, which together are generating subsidies for debates about the management and conservation of the bay (*e.g.*, Angelini *et al.* 2018, Checon *et al.* 2018, Dias *et al.* 2018, Stori *et al.* 2019, Gallucci *et al.* 2020, Kitazawa *et al.* 2021).

The current checklist includes 826 species, almost 70% (553 spp.) recorded during the BIOTA/Araçá project (Annex; Supplementary Material). Annelids (225 spp., including macro- and meiofaunal species), mollusks (194 spp.), and crustaceans (177 spp.) were the most speciose taxa. Among the meiofaunal organisms, the nematodes were the most abundant and diversified, however, they were identified only at the morphospecies level (195 morphospecies). The survey presented here reveals seven benthic species endemic to Araçá Bay,

Biodiversity of benthic organisms in Araçá Bay

Table 2. Number of taxa of the groups listed within this checklist. BIOTA: species sampled during the BIOTA/Araçá project; N. id.: taxa not identified at the species level; Reg.: new records; Depos.: species with material from Araçá Bay deposited in museum collections; Mol.: species with molecular data available; Threat.: threatened species; New sp.: species described based on individuals sampled during the BIOTA/Araçá project; Endm.: species endemic to Araçá Bay; Exot.: exotic species, nonnative or introduced to the bay; Econ.: economically exploited.

Taxon	Family	Genus	Species	BIOTA	N.id.	Reg.	Depos.	Mol.	Threat.	New sp.	Endm.	Exot.	Econ.
MACROFAUNA													
Annelida													
Polychaeta	37	128	211	127	58	28	134	97	2	8	2	1	–
Echiura	1	3	3	0	–	–	–	–	–	–	–	–	–
Sipuncula	3	6	8	5	2	1	8	7	–	–	–	–	–
Arthropoda													
Decapoda	33	77	124	92	19	65	66	112	–	–	–	1	2
Amphipoda	18	27	29	23	9	20	29	13	–	–	–	–	–
Isopoda	6	9	9	1	2	1	8	5	–	–	–	–	–
Tanaidacea	4	6	6	4	1	3	6	3	–	–	–	–	–
Stomatopoda	3	4	5	0	–	–	–	1	–	–	–	–	–
Cirripedia	4	4	4	2	–	–	–	4	–	–	–	2	–
Bryozoa	23	27	40	32	5	8	40	16	–	2	2	5	–
Chordata	10	20	29	26	7	11	27	23	–	–	–	10	–
Cnidaria	27	40	51	24	4	18	11	40	–	1	–	–	–
Echinodermata	17	24	32	23	1	14	26	18	5	–	–	–	–
Entoprocta	3	3	4	1	1	–	4	2	–	–	–	–	–
Hemichordata	2	3	4	–	–	–	–	1	1	–	1	–	–
Mollusca													
Bivalvia	28	69	86	77	3	28	85	40	6	–	–	–	5
Gastropoda	56	88	101	45	9	42	74	56	–	–	–	–	–
Polyplacophora	2	4	5	2	–	1	3	1	–	–	–	–	–
Scaphopoda	1	2	2	2	2	2	2	–	–	–	–	–	–
Nemertea	1	1	1	–	–	–	–	1	–	–	–	–	–
Phoronida	1	1	1	1	–	1	1	1	–	–	–	–	–
Platyhelminthes	5	7	7	7	18	7	7	6	–	–	–	–	–
Porifera	11	12	15	11	1	7	14	10	–	–	–	–	–
MEIOFAUNA													
Annelida	2	2	3	3	–	–	3	–	–	–	–	–	–
Gastrotricha	1	2	2	2	3	2	–	1	–	–	–	–	–
Gnathomulida	–	–	–	–	2	–	–	–	–	–	–	–	–
Kinorhyncha	2	2	4	4	4	1	3	4	–	–	2	–	–
Nematoda	–	–	–	–	195	–	–	–	–	–	–	–	–
Platyhelminthes	4	9	9	8	–	4	2	1	–	–	–	–	–
Tardigrada	1	1	1	1	1	1	–	1	–	–	–	–	–
MICROORGANISM													
BACTERIA	6	7	14	14	4	1	–	14	–	–	–	–	–
FUNGI	8	10	16	16	–	10	–	16	–	–	–	–	–
TOTAL	320	598	826	553	351	276	553	494	14	11	7	19	7

14 threatened species, and seven economically exploited species (see Table 2). Therefore, Araçá Bay shelters not only a diverse fauna but also presents endemism and houses threatened species, justifying the need for the protection of this environment.

More than half of the species listed here have molecular data available (60%) and/or material deposited in the museum's collections (67%). Those are valuable data sources for future studies in the fields of taxonomy, phylogeny, biogeography, and conservation biology. The results and discussions by groups of organisms sampled by the BIOTA/Araçá project, as well as from records in available literature (mainly Amaral *et al.* 2010) and from museum collections are presented below. The phyla with less than five species recorded (Entoprocta, Phoronida, Hemichordata, and Nemertea) were treated together in the section "Other groups" (1.18).

1. Macrofauna

1.1. Annelida – "Polychaeta"

Polychaetes are among the most diversified benthic organisms and were the most speciose taxa in Araçá Bay. A total of 211 macrofaunal species belonging to 37 families were included in the present checklist (Table 2). As a comparison, the previous survey of the species in the area listed 158 polychaetes identified at the species level (Amaral *et al.* 2010). There are about 1350 species reported in Brazil, more than 400 of which are found in the state of São Paulo (Amaral *et al.* 2023). Therefore, the number of species recorded in the bay represents more than half of the total polychaete diversity known to the state.

The family Syllidae presented the highest number of species (30), followed by Spionidae (21), Nereididae (14), and Eunicidae (12). In descending order, the most abundant species found during the project were: *Capitella nonatoi*, *Laeonereis acuta*, *Scoloplos (Leodamas)* sp. A, *Armandia hossfeldi*, *Isolda pulchella* and *Haploscoloplos* sp. A. Eight new species for science were described based on specimens sampled during the BIOTA/Araçá project (Fukuda & Nogueira 2014, Silva *et al.* 2017, Silva & Amaral 2019), seven classified in Capitellidae family (*Capitella aracaensis*, *C. biota*, *C. neoaciculata*, *C. nonatoi*, *Scyphoproctus paivai*, *S. profundus*, and *S. robustus*) and one Syllidae (*Exogone cebimar*).

Besides the eight new species to science, 28 were new records for Araçá Bay and 58 taxa were identified only at the genus level, which may indicate possible new records or new species for science. Additionally, the bay is the type locality of about 20 species of the group, which highlights the importance of the area. The species *Eunice sebastiani* and those of the *Diopatra cuprea* complex, found in the area, are classified as threatened, which is aggravated by the fact that they are collected and marketed as bait for recreational fishing.

1.2. Annelida – Echiura

Three echiuran species were registered for Araçá Bay. Two of them, *Arhynchite paulensis* and *Lissomyema exilii*, were first described based on material from the Brazilian coast.

1.3. Annelida – Sipuncula

The current list of Sipuncula from Araçá Bay includes eight species, representatives of three families: Sipunculidae, comprising large worms,

with trunk up to 35 cm in length; Golfingiidae, with a high degree of morphological diversity; Aspidosiphonidae with hardened structures called shields close to the anus (anal shield) and at the posterior end (caudal shield). The most abundant species collected during the BIOTA/Araçá project is *Thysanocardia catharinae*. A few specimens sampled during the project were only identified at the genus level, and according to their external anatomy, they were identified as *Nephasoma* sp. and *Phascalion* sp., the latter representing the first record of the genus for the São Sebastião Channel.

Amaral *et al.* (2010) registered ten species for the Araçá Bay, but *Sipunculus multisulcatus* should be excluded from this list because it is a junior synonym of *S. phalloides*, a species already listed for the bay. We could not find the specimens of *Sipunculus* sp. recorded by Jorge *et al.* (1969), but according to Ditadi (1982a) there are three species of *Sipunculus* in the area (*S. nudus*, *S. phalloides*, *S. polymyotus*). Considering that *S. phalloides* and *S. polymyotus* are already on the list of Amaral *et al.* (2010), Jorge *et al.*'s species can be one of the two previous ones. *Sipunculus* sp. in Kawauchi (2005) are confirmed as *S. nudus*. Thirty-nine species are reported from Brazil (Kawauchi 2005), and five have the type localities in the country. It is important to note, however, that the diversity of Sipuncula along the Brazilian coast is still poorly known (Schulze & Kawauchi 2021).

1.4. Arthropoda – Crustacea, Decapoda

The decapod crustaceans of Araçá Bay were represented by 124 species and 33 families. The composition was dominated by western Atlantic species typical from estuaries and mangroves. Most species are free-living, whereas others are obligate burrow-dwellers or live associated with other invertebrates including bryozoans, echinoderms, polychaetes, and sponges. The white shrimp *Litopenaeus schmitti* and the swimming crabs of the genus *Callinectes* are taxa of commercial importance registered in the area. One invasive taxon, *Charybdis (Charybdis) hellerii*, a nonindigenous portunid from the Indo-West Pacific, widespread in the western Atlantic Ocean (Tavares & Mendonça 1996, Tavares 2011), was also registered. There are no endangered species of decapods living in the bay currently.

Twelve species of hermit crabs were registered in Araçá Bay. Diogenidae is represented by nine species, while Paguridae by three species. All sampled species are restricted to the Western Atlantic (Melo 1996, 1999), however with wide latitudinal distribution from the southeastern US coast until southern Brazil or South America. The hermit crab species occur in the intertidal zone or shallow water up to 50 m deep, although *Petrochirus diogenes* can reach 130 m in depth. Gastropod shells are an important and limiting resource for hermit crabs, which they need to substitute as they grow (Turra *et al.* 2005, Turra & Denadai 2004). In this way, the high diversity and abundance of gastropod species in Araçá Bay, due to its high environmental heterogeneity (Denadai *et al.* 2005), make possible the co-occurrence of several hermit crab species in this area. Six new records were presented here (*Paguristes puncticeps*, *Paguristes tortugae*, *Pseudopaguristes calliopsis*, *Petrochirus diogenes*, *Pagurus brevidactylus*, and *Pagurus leptonyx*). However, three of them (*Paguristes tortugae*, *Petrochirus diogenes*, and *Pagurus brevidactylus*) were only visually recorded. Studies on hermit crabs in Araçá Bay are numerous due to the group's high diversity and abundance in this region. The species registered by Amaral *et al.*

(2010) are the most commonly found in the region and for which there are some studies on biology and ecology (Leite *et al.* 1998, Turra & Leite 2000, 2001, 2002, 2003, 2004, 2007, Turra & Denadai 2001, 2002, 2003, Nucci *et al.* 2001, Turra 2003, 2004, 2007, Dominciano *et al.* 2009, Sant'Anna *et al.* 2010, 2012a, 2012b, 2014, Turra & Gorman 2014, Gorman *et al.* 2014, 2015, 2016, Ribeiro *et al.* 2015, Souza *et al.* 2015, Ragagnin *et al.* 2016, 2018, Dahlet *et al.* 2019).

1.5. Arthropoda – Crustacea, Peracarida

The list of Peracarida species from Araçá Bay comprises 44 valid species distributed in three orders: Amphipoda, Isopoda, and Tanaidacea. The Amphipoda was the most diverse with 29 species, whereas Isopoda and Tanaidacea were represented by nine and six species, respectively. The knowledge about the composition of peracarid species in the bay increased with the register of new occurrences, such as the amphipods *Eudevenopus capuciatius* and *Ampelisca soleata*, registered for the first time for the state of São Paulo. In addition, five probable new species were recognized, two of the order Amphipoda (*Ampelisca* sp. and *Monocorophium* sp.) and three of Isopoda (*Natatolana* sp., *Discerciles* sp., and *Uromunna* sp.), which can further increase the known diversity of the group for the Brazilian coast. The species of amphipods *Elasmopus rapax*, *Leucothoe alada* and *L. spinicarpa*, and the isopod *Cirolana parva* previously recorded for Araçá Bay (Amaral *et al.* 2010) were not included in the present checklist, since recent taxonomic reviews (Senna & Souza-Filho 2011, White 2011, Paiva & Souza-Filho 2014) do not indicate the occurrence of these species in Brazil.

1.6. Arthropoda – Crustacea, Stomatopoda

Five species of Stomatopoda in three families were recorded in the Araçá Bay (Amaral *et al.* 2010). All species are broadly distributed in the Western Atlantic Ocean.

1.7. Arthropoda – Crustacea, Cirripedia

All four cirripeds species listed here were previously reported by Amaral *et al.* (2010). The barnacle *Chthamalus bisinuatus* dominated the supra-littoral stratum of the Araçá Bay rock shores, and the mid-littoral stratum is characterized by the presence of *Tetraclita stalactifera* (Dias *et al.* 2018).

1.8. Bryozoa

After the review of all specimens in different collections, as well as those reported by Amaral *et al.* (2010), 40 species of bryozoans are known from Araçá Bay, 15 of which classified in Ctenostomata, 24 in Cheilostomata, and one in Cyclostomata. Amaral *et al.* (2010) listed 40 bryozoan species from the area, but there are some misidentifications in that list (e.g., *Scrupocellaria bertholletii* is now recognized as *Cradoscrupocellaria atlantica*, see Vieira *et al.* 2013a), some duplicate entries (e.g., *Scrupocellaria regularis* and *Scrupocellaria* sp. refer to the same species: *Aspiscellaria piscaderaensis*), and also unnamed taxa (e.g., *Bugula* sp.). We have recognized five taxa that still require review (*Celleporaria* sp., *Microporella* sp.1, *Microporella* sp.2, *Parasmittina* sp. and *Schizoporella* sp.), which may refer to undescribed species. Particularly, ctenostomatous species are abundant and the most common bryozoans in shallow waters, with dominant species belonging to the genus *Amathia*.

1.9. Chordata – Ascidiacea

The list of ascidians found in Araçá Bay includes 29 species, 17 of which had been previously listed by Amaral *et al.* (2010). This number represents almost half of the total diversity known for the state of São Paulo (Rocha *et al.* 2011). The high diversity is surprising given the scarceness of hard substrates in the bay. The bay is the type locality of only one species, *Botryllus tabori*. The high number of introduced (10) and cryptogenic species of wide geographical distribution (13) found may be explained by the proximity to the São Sebastião port, which may be a source of larvae from nonindigenous species. None of those species is abundant inside the bay, but a few are quite common in the region of the São Sebastião Channel (e.g., *Clavelina oblonga*, *Didemnum psammotodes*, *Polyclinum constellatum*). *Ciona robusta*, *Ecteinascidia styeloides*, and *Molgula occidentalis* were new records in the area, probably very recently introduced in the bay. *Ciona robusta* is a harmful species for bivalve cultivation (Wilson *et al.* 2022) and its presence in the region is a threat to this economic activity. The other species are of tropical origin and their presence in the area highlights the dangers of seawater temperature elevation.

1.10. Cnidaria

Cnidarians are represented in the Araçá Bay by the polyp stages of species belonging to the classes Hydrozoa (34 spp.) and Anthozoa (17 spp., including sea anemones), totaling 51 species. Despite some large, noticeable hydroid colonies and polyps of a few sea anemones, most hydroids and anthozoans present in the bay are inconspicuous by their small size and habits, living in crevices or as epibionts of colonial invertebrates or macroalgae. Most cnidarians from the bay are associated with hard substrates. The ones collected by dredging, such as *Halecium* spp. and *Lytocarpia tridentata*, for instance, were attached to pebbles, vacant mollusk shells, and corals scattered on the surface of the soft sediment. *Dynamena crisioides* is one of the few hydroids that colonizes the intertidal zone; in Araçá Bay it is found on vertical rocky walls in the mid-littoral zone, covering large areas of the rock in the form of sparse, yellow colonies. Amaral *et al.* (2010) list 27 species of cnidarians, almost half of the species here reported, showing a considerable increase in the recognition of the diversity of Cnidaria in the area.

The present study has increased to eleven the number of species of sea anemones in Araçá Bay (Milanelli 2003, Amaral *et al.* 2010). The eleven species belong to ten genera and six families and include seven species recorded from other localities in the state of São Paulo (Silveira & Morandini 2011). Most species recorded here belong to the family Actiniidae (Milanelli 2003, Amaral *et al.* 2010), being predominantly large and conspicuous polyps that are often abundant in shallow water habitats. The bay is the type locality of two species of burrowing sea anemones: *Metapeachia schlenzae* and *Edwardsia migottoi* (Gusmão 2016, Gusmão *et al.* 2016). *Metapeachia schlenzae* is a burrowing halocladid species described from specimens collected in the Araçá Bay and Barequeçaba beach in São Sebastião as well as Monte Alto in Rio de Janeiro. *Edwardsia migottoi* was described using material collected by the BIOTA/Araçá project (Gusmão *et al.* 2016). This was the first record of the genus *Edwardsia* for the Southwestern Atlantic, highlighting the advantages of a long-term study to uncover the diversity of anemones with cryptic habits and small sizes.

The Taxonomic Catalog of the Brazilian Fauna records 684 species of cnidarians in Brazil (Oliveira 2017), 565 of which marine. Despite its extensive coastline, only 63 species of sea anemones have been recorded from Brazil (Gusmão & Rodríguez 2021), most of which exhibit large polyps and are abundant in rocky shores and shallow waters (Belém & Preslercravo 1973). Sea anemones are conspicuous members of benthic habitats on the Southeastern coast of Brazil with 22 species recorded for the state of São Paulo (Zamponi *et al.* 1998, Silveira & Morandini 2011, Fautin 2013, Gusmão & Rodríguez 2021).

1.11. Echinodermata

A total of 32 species, belonging to 24 genera, 17 families, and five classes of Echinodermata were recorded in the soft and hard bottom of Araçá Bay. Ophiuroidea was the most representative taxon with 16 species, followed by Asteroidea (7 spp), Holothuroidea (5 spp), Echinoidea (4 spp), and Crinoidea (1 spp). Ophiuroidea was sampled mainly in the intertidal zone up to 20 m deep and the most frequent species were *Ophiactis lymani*, *Microphiopholis subtilis*, *Ophioderma januarrii*, *Microphiopholis atra* and *Hemipholis cordifera*. *Luidia senegalensis* was the most abundant Asteroidea collected in the intertidal and subtidal zone. Among Echinoidea, the black sea urchin *Arbacia lixula* was the most abundant in the study area and *Protankyra benedeni* was the most frequent Holothuroidea collected in the intertidal and subtidal zone.

In Brazil, there are about 340 registered species of Echinodermata (Ventura *et al.* 2013), and in the state of São Paulo, nearly 120 species (Hadel *et al.* 1999, Borges *et al.* 2006, Borges & Amaral 2007). Despite the perimeter of the bay (3 km) amounting to only 0.03% of the length of the Brazilian coastline (8,500 km), the diversity of Echinoderms registered in Araçá Bay represented 8.3% of the species known in Brazil and 26% in the state of São Paulo (Alitto *et al.* 2016).

The present study includes 14 new records to the area (such as *Amphiura kinbergi*, *Amphiura princeps*, *Luidia alternata alternata*, *Ophioplocus januarrii*, *Ophiothela mirabilis*, and *Protankyra benedeni*), and five species in the Red List (ICMBIO), *Astropecten brasiliensis*, *Astropecten marginatus*, *Luidia clathrata*, *Luidia senegalensis*, *Lytechinus variegatus*. Therefore, the conservation of the bay is crucial to support the regional diversity of Echinodermata.

1.12. Mollusca – Bivalvia

Throughout the BIOTA/Araçá project, more than 1800 individuals of bivalves were sampled in hard (rocky shores, associated with rocks, shells, chunks of wood, mangrove roots) and soft bottom (mud, sand). They were identified into 77 species, and three taxa at higher levels. The list of bivalves also includes nine species previously sampled in the bay, totaling 86 species. Tellinidae (14 spp) and Veneridae (13 spp) were the most representative families, followed by Mytilidae (8 spp). This work provided 28 new records for the region, including some rare species such as the carnivorous bivalve *Cardiomya cleryana*, the endolithic bivalve *Lamychaena hians*, and also bivalves of the family Corbulidae, such as *Caryocorbula chittyana* and *Caryocorbula marmorata*.

For the Brazilian coast, there are about 510 valid species of bivalves recorded (Machado *et al.* 2023) of which about 190 have already been registered for the state of São Paulo (Ihering 1897a, b, Morretes 1949, Haas 1953, Klappenbach 1965, Narchi 1974, Lopes & Narchi 1993, Migotto *et al.* 1993, Simone 1997, Salvador *et al.* 1998, Machado *et al.* 2017). Amaral *et al.* (2010) and Tallarico *et al.* (2014) have further

expanded the number of species known to the state of São Paulo, mainly for the São Sebastião Channel. Although the total area of Araçá Bay is relatively small when compared to other nearby areas, the incredible biodiversity and the presence of rare bivalve species show its importance as a reservoir for Brazilian malacological knowledge.

1.13. Mollusca – Gastropoda

The gastropod fauna from Araçá Bay was very speciose (101 species), spanning species from all main groups and habits: herbivores (e.g., *Diodora cayenensis* and *Strombus pugilis*), detritivores, predators (e.g., *Siratus senegalensis*), ectoparasites (e.g., *Eulima mulata*) and even filter-feeders (e.g., *Crepidula protea*). There is a balance in species from hard and soft bottom habitats, and even a relatively good abundance of shell-lacking species (e.g., *Doris januarrii*). Despite the Araçá Bay being relatively well documented previously, the present survey resulted in 42 new reports for the area. On the other hand, *Cerithiopsis emersoni* and *Mangelia quadrilineata*, recorded by Amaral *et al.* (2010), were not sampled during the study. As these taxa are easily misidentified, and the previous samples could not be checked, their occurrence in the region remains doubtful.

1.14. Mollusca – Polyplacophora

The current overview showed two families, four genera, and five species of polyplacophores. One species, *Ischnoplax pectinata*, was recorded for the first time in the bay.

1.15. Mollusca – Scaphopoda

The register of the two first scaphopods species for Araçá Bay, *Paradentalium disparile* and *Pertusiconcha callithrix*, was made during the BIOTA/Araçá project. The low number of species and records of scaphopods in the area may be due to the type of soft bottom found in the bay, predominantly muddy sand, which restricts the occurrence of this group.

1.16. Platyhelminthes

A total of seven species of macrofaunal platyhelminths were identified, and another 18 taxa were identified at the genus level. A few species are potentially new to science. It is interesting to note that the Araçá Bay is included in or close to many type localities of the described Brazilian species, namely Ubatuba, São Sebastião, Ilhabela, Santos, and Guarujá (Marcus 1947, 1948, 1949, 1950, 1952), but it also houses taxa not previously recorded there. Among these taxa, one is a new record for Brazil (*Notoplana queruca*) and two others are most likely new species. This evidence leads to the presumption that this environment is characterized by a relatively rich diversity for the group.

Most of the existing data on Platyhelminthes diversity in Brazil results from collections from the coast of the state of São Paulo, very near the Araçá Bay (Marcus 1947, 1948, 1949, 1950, 1952, 1954, Corrêa 1949, du Bois-Reymond Marcus 1955, 1957, 1958, 1965, Smith 1960), and a few records from other regions (Corrêa 1958, du Bois-Reymond Marcus & Marcus 1968), totaling 66 species (Carbayo & Froehlich 2008). Recently, new studies on the fauna from the Northeastern coast of Brazil and Rio de Janeiro state augmented the number of reported species to 72 (Bulnes & Torres 2014, Bahia *et al.* 2012, 2014, 2015, Bahia & Schrödl 2018) and pointed to an underestimation of the polyclad fauna of the country.

1.17. Porifera

The present study listed 15 species, 12 genera, and 11 families of sponges (Porifera) found in the Araçá Bay. One species, *Haliclona* (*Soestella*) cf. *caerulea*, was registered for the first time on the southeastern coast of Brazil. Six species were registered for the first time in the area: *Callyspongia* (*C.*) *pallida*, *Chondrosia* aff. *reniformis*, *Lissodendoryx* (*L.*) *isodictyalis*, *Mycale* (*Carmia*) *microsigmatosa*, *Pachychalina alcaloidifera*, and *Suberites aurantiacus*. Most species registered were broadly distributed in the Western Tropical Atlantic (11 spp.). Three species are found only in Brazil: *Chondrosia* aff. *reniformis* (Saint Peter and Saint Paul Rocks, Rocas Atoll, from Pernambuco to São Paulo); *Halichondria* (*H.*) *sulfurea* (endemic to the state of São Paulo); and *Pachychalina alcaloidifera* (endemic to southeastern Brazil).

Large efforts are still needed to describe the diversity of marine sponges in Brazil, with only 563 species recorded to date (Muricy 2023). For the state of São Paulo, 146 marine species were listed (Custódio & Hajdu 2011 – including records from the gray literature). Sponges inhabiting the northern coast of the state of São Paulo, especially those from the rocky shores of the municipalities of Ilhabela and São Sebastião, proved to be unexpectedly rich (Hajdu *et al.* 1999, Custódio & Hajdu 2011).

1.18. Other groups

Four Entoprocta species were recorded in Araçá Bay, one sampled during the BIOTA/Araçá project (*Barentsia discreta*). The synopsis of the Entoprocta from Brazil, including species from Araçá Bay, was published by Vieira and Migotto (2011). Also, four species of hemichordates were registered, one originally described based on specimens from Araçá Bay, *Willeyia loya*. This species is endemic to the bay and is considered threatened.

One broadly distributed species of Nemertea was registered in the area, *Baseodiscus delineatus*, previously reported as *Baseodiscus curtus* (Amaral *et al.* 2010). Finally, a single species of phoronid, *Phoronis hippocrepi*, is here first reported for Araçá Bay.

2. Meiofauna

There were eight meiofaunal phyla recorded at the Araçá Bay: Annelida, Arthropoda, Gastrotricha, Gnathostomulida, Kinorhyncha, Nematoda, Platyhelminthes, and Tardigrada. Nematodes comprised the most abundant and diverse phylum, with 195 morphospecies. However, organisms that could not be identified at the species level were not included in this report. Here were included a total of 19 meiofaunal species: nine platyhelminths, four kinorhynch, two gastrotrichs, three polychaetes, and one tardigrade. Three kinorhynch species were first described based on specimens sampled in the Araçá Bay, *Echinoderes ajax*, *E. astridae*, and *E. marthae* (Sørensen 2014).

The marine meiofauna is an abundant and diverse group of animals, comprehending 24 of the 35 metazoan phyla, that can be found mainly inhabiting soft bottoms (Giere 2009). Although some species are cosmopolitan, local communities may contain hundreds of unknown species, allowing only a rough estimate of the total number of existing species (Robertson *et al.* 2000, Lamshead & Boucher 2003). The number of taxonomical studies along the Brazilian coast has expanded in the last decades. Nevertheless, these studies are still localized and there is a vast potential for revealing new species (Fonseca *et al.* 2014).

3. Microorganism

A total of 14 bacteria species were recorded herein for Araçá Bay. The genetic molecular analysis from the gene of the 16S rRNA subunit revealed the prevalence of *Bacillus* sp. out of the 50 strains isolated in this study. Quantitatively, only four species account for 75% of the bacteria identified for the Araçá Bay. *Bacillus pumilus* occurred most frequently in the samples (38%), followed by *Bacillus cereus* (18%), *Vibrio alginolyticus* (10%) and *Planococcus maritimus* (8%). The abundance of other bacteria varied from 2% (*Bacillus thuringiensis*, *Bacillus safensis* and *Bacillus boroniphilus*) to 3% (*Bacillus aerophilus*, *Enterobacter asburiae*, *Exiguobacterium* sp., *Micrococcus luteus*, *Staphylococcus aureus*, *Staphylococcus* sp., 2 *Staphylococcus epidermidis*, *Staphylococcus warneri*). Another important result is the elevated prevalence of *Enterococcus* sp. and *Escherichia coli*, which are used as an indicator of the water quality, showing that the bay has a high fecal contamination. Bacteria may be one of the most abundant and species-rich groups of organisms, and they mediate many critical ecosystem processes (Horner-Devine *et al.* 2004). However, the diversity of these microorganisms is little explored, especially in Brazil (Cury *et al.* 2011).

Sixteen fungi species were registered for Araçá Bay. The most frequent genera were *Candida*, *Aspergillus*, and *Penicillium*. Marine yeasts are generally associated with nutrient concentration, pollution, plankton blooms, and macroalgae, suggesting that fungi are also important saprotrophs in marine environments (Kohlmeyer & Kohlmeyer 1979). Phylogenetic analysis of environmental marine fungal sequences shows several sequences branching closely to known saprotrophic fungi, including *Aspergillus* (Richards *et al.* 2012).

Anthropogenic impacts on the marine environment have threatened microorganisms, altering their abundance and diversity. The study of marine microbial biodiversity is of vital importance to the understanding of the different processes of the ocean, which may present novel microorganisms for screening of bioactive compounds (Das *et al.* 2006).

Supplementary Material

The following online material is available for this article:
Supplementary - Checklist of benthic species from Araçá Bay.

Table S1 – List of the species recorded in the Araçá Bay and included in the present checklist. The table indicates the species sampled during the BIOTA/Araçá project (β) and those registered for the first time at the Araçá Bay in the present work (x).

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Conflicts of Interest

The author(s) declare(s) that they have no conflict of interest related to the publication of this manuscript.

Ethics

This study did not involve human beings and/or clinical trials that should be approved by one Institutional Committee.

Data Availability

Supporting data are available in <<https://doi.org/10.5281/zenodo.10909959>>.

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