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TECHNICAL SCIENTIFIC REPORT

1º SEMESTER 2023

OUR BLUE HANDS

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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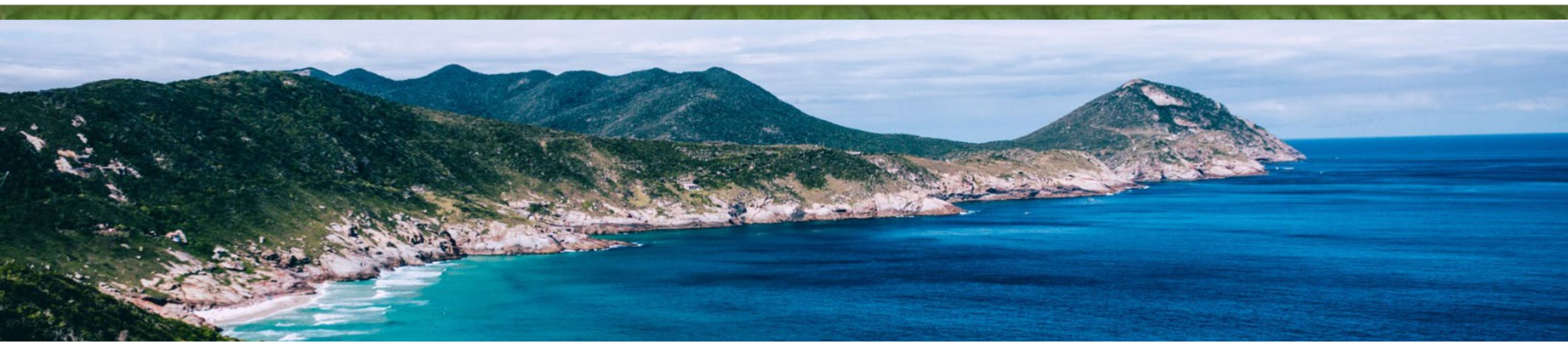
"Together we will make the world a better place"

Coast of Santa Catarina, Brazil

PROJECT IMPLEMENTATION

1° SEMESTER, 2023

SCIENTIFIC AND TECHNICAL REPORT



Preface and Executive Summary

The fight against plastic pollution represents one of the major challenges faced by modern societies, with complex mitigation and resolution. Throughout the production chain and life cycle, plastic products impact coastal and marine habitats and biodiversity, reaching all ecosystem compartments and from local to migratory species, and from food to humans. Marine litter has a large effect on traditional fishery communities, with direct impacts on the source of income. According to the 2030 Agenda and the Ocean Decade, a clean ocean should be a priority for research and action in order to sustain a healthy planet for the next generations and contribute to global equity.

From March to June 2023, the Our Blue Hands project in partnership with Instituto de Sustentabilidade de Itajaí (INIS), Fundação de Amparo ao Meio Ambiente de Bombinhas (FAMAB), Instituto do Meio Ambiente de Santa Catarina (IMA/SC), and Associação R3 Animal, carried out microplastic monitoring along the coast of Santa Catarina, Brazil, covering 5 municipalities [Garopaba, Imbituba, Florianópolis, Bombinhas and Itajaí] and 170 kilometers of shoreline and mobilizing 4 sampling teams in order to build a preliminary census of the occurrence, distribution, and abundance of this pollution in the Santa Catarina beaches. This pilot project was funded by the Social Good Labs program through the Experiment Platform, which resources supported training, data acquisition, and reporting, now presented in this document. The Our Blue Hands project (OBH) unites communication, implementation, and data transformation for the Ocean we want, using citizen science as a link between society and the university. This initiative showcased that it is possible to strengthen the means of implementation and revitalization of global partnerships for sustainable development (Agenda 2030 and its goals, SDGs), ensure quality inclusive and equitable education (SDG 17), promote lifelong learning for all (SDG 4) through the use of citizen science and ocean literacy tools for traditional communities, covering a representative portion of the various groups of society for the benefit of the Oceans (SDG 14; UN Ocean Decade vision).

Experiment is an online platform for discovering, funding, and sharing scientific research. It is based in New York City, where a team of scientists, designers, and technologists passionate about helping ideas grow in order to democratize science. The platform has funded 1164 projects with the support of 53,864 donors and $11,046,293 invested in science and innovation throughout the world. Experiment has boarded with us to in the journey of a Clean Ocean, supporting the on-going microplastics monitoring on beaches of Santa Catarina with the implementation of new observing sites. This funding was important not only to maintain data acquisition and provide longer view of environmental quality in terms of plastic pollution, but also to train and engage more people on the same pathway.

The sampling of microplastics alerts us to the problems associated with plastic degradation and accumulation on beaches around the world, and a particular emergency in coastal populated cities. The development of a collaborative network to gather information about marine pollution based on citizen science brings together the dialogue between academia, local communities, and environmental management. The project converges with the sustainable development goals (SDGs) when it holds on to partnerships, capacity building, co-design, consumer awareness, and prevention of pollution on beaches and oceans. The 4-month pilot project developed actions around the two main axes; monitoring using a standardized methodology to provide high-quality data about microplastic pollution in the environment (e.g., beaches), and data management to ensure that all the data cycle is covered and transformed into meaningful information for decision-making. All steps of the project are supported by training efforts and network engagement tools to potentiate the positive impacts of the project on all sectors involved as well as leverage a transparent and participatory process.

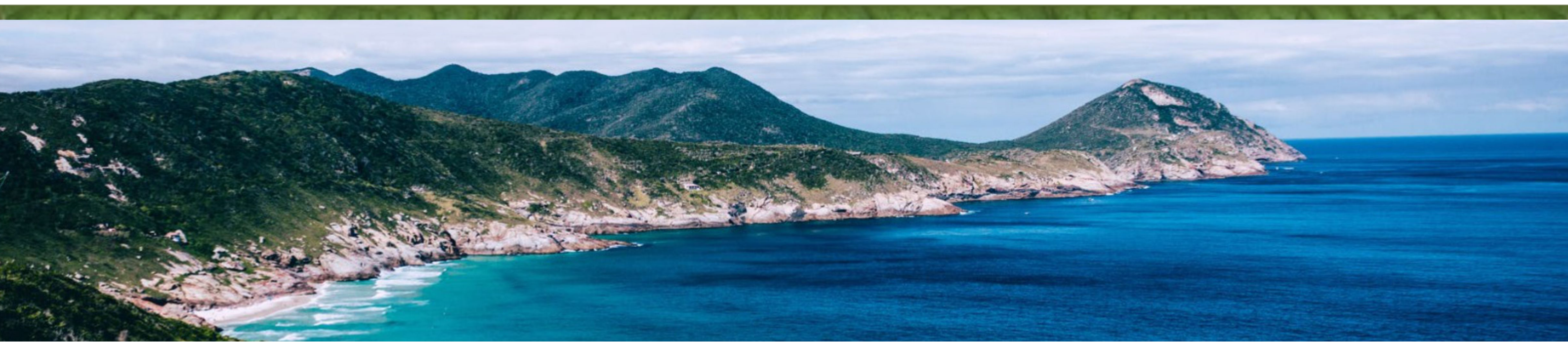
The cities in Santa Catarina, South coast of Brazil, have several initiatives focused on environmental conservation and marine spatial planning and, therefore, seek a solution to the waste that accumulates on their scenic and tourist beaches. The diverse anthropogenic drivers and environmental forcings are a great challenge to understand and mitigate marine pollution across the region, but also an opportunity to change reality through unified efforts and to develop partnerships between the different sectors of society that put pressure on the environment in a certain way. Considering that building sustainable Blue communities requires holistic assessment, the Our Blue Hands methodology also mapped the pressures and mitigation responses both locally and regionally. This phase of the project was built through many hands, uniting multiple technical stakeholders and experts, which have a more technical vision of the problem, and local residents of the islands, who follow development on a daily basis. As a result, the project produced matrixes of drivers and the impacts of marine litter in Santa Catarina and pointed out potential impacts on related marine ecosystem services.

The Marine Strategy Framework Directive (MSFD), an important reference guide for the Ocean, requires the European Member States to develop strategies that should lead to programmes of measures to achieve or maintain Good Environmental Status strategies. During 2011, the TSG-ML (Technical Subgroup on Marine Litter) focused on providing advice through the report "Marine Litter – Technical Recommendations for the implementation of MSFD requirements", which described the options and tools available for the monitoring of marine litter in the different environmental compartments. Thus, by supporting and engaging in the Our Blue Hands Project, the municipalities in Santa Catarina advanced in the sense of preparing to meet marine pollution regulatory targets, also anticipating data acquisition to understand and mitigate the related problems.

In the following chapters, you will find an overview of the six months since the implementation and expansion of the Our Blue Hands in Santa Catarina in 2023, covering the project's *phase 1 - Engaging and Monitoring* at 10 sites, as proposed. Phase 1 included the articulation of the Citizen Science network and associated stakeholders, capacity building and training, and a bi-monthly to monthly microplastics monitoring surveys project. Additionally, the project's *phase 2 - Data management and sharing* was partially implemented in order to provide a diagnosis of microplastic pollution patterns at the monitored sites and provide insights into potential sources of these plastics. The results show that there are significant amounts of micro and mesoplastics on the sandy beaches of Santa Catarina, with marked spatial variation and temporal differences, and various types of residue. According to these findings, the monitored beaches are susceptible to the impact of marine litter and plastic pollution, even on the smaller compartment, and effects on ecosystem services should be expected in the present and future if marine pollution is not mitigated. At the end of this report, the Our Blue Hands provides important recommendations for long-term actions considering the results until now.

Chapter 1

A FUTURE VISION OF THE OCEAN AND ITS TERRITORIES



Chapter 1 A future vision of the Ocean and its territories

1.1. 2030 AGENDA, MOVING TOWARDS A CLEAN OCEAN

Considering all the problems that currently affect the Ocean, marine pollution is one of the most challenging, for which there is not yet a simple solution. Marine pollution has numerous sources, therefore, it is understood that it requires a synergy between the various sectors and diverse stakeholders involved in order to build a new and more sustainable paradigm (Sandu et al., 2020; Willis et al., 2020). The actions that follow the plans and projects aiming to prevent and combat marine litter cover topics such as innovative research and investment with the replacement of raw materials and harmful chemicals to more natural and biodegradable ones, formulation of public policies with a regulatory system that reduces the use of plastic and other materials that affect human and marine life; and, evaluation of market instruments, monitoring programs and mitigation and restoring actions (Biondi et al., 2002).

The 2030 Agenda represents a global action plan, and serves as a guide for all actors interested in the sustainable development of their place of operation, whether as an individual or as part of a network. The SDGs - Goals for Sustainable Development are strategies that address seventeen key themes (17) for Earth's future and one hundred and sixty-nine goals (169) covering three pillars for Sustainable Development: social, economy, and environment (The Sustainable Development Goals Report, 2016). In this context, the Decade of the Oceans (UN Decade of Ocean Science for Sustainable Development 2021-2030) emerges as an initiative integrated into the 2030 Agenda with the purpose of raising awareness and engaging the population in favor of the conservation of the Oceans through SDG 14 - Life on the water (UNDP, 2016). It advocates the Ocean flag to achieve those SDGs and relies on the ocean science community to raise awareness and take action. In addition, with the aim of "accelerating" the development of actions of the 2030 Agenda, it was proposed unification of funding, mentoring, and support efforts, where the different groups will work synergistically to promote *common goals for synergistic actions.* It is important to mention that the initiatives of the Ocean Decade and 2030 Agenda differ in dimensions, and sectors of society and focus on specific themes, but they complement each other and integrate into a united global vision.

Considering this common global vision, a Clean Ocean is one of society's main targets for 2030 (UN Ocean Conference, 2022). Reducing marine pollution, particularly, marine litter is a major concern of individuals and nations (UNEP, 2022). It was estimated that in 2015 " 60% of all plastic ever produced had already become waste, a significant part of which has ended up in the ocean. Estimates vary widely, but it's thought that between 86-150 million metric tonnes of plastic have accumulated in the oceans by now, at a continuously increasing rate" (WWF, 2019). This data evidences the magnitude of the problem we are facing and highlights the planetary crisis already in course. Recycling, reduction, and reuse rates are still small compared to the plastic that becomes waste (Schnurr, et al. 2018). And as more people adopt a development style based on single-use plastic products, the scenario moment becomes even more challenging and dramatic.

The increase in microplastics in coastal environments and in the ocean is a direct consequence of the increase in the presence of plastic litter within the continental and marine biomes (GESAMP, 2015). It seems that both correct and incorrect plastic disposal can be a source of microplastics in the ocean, for instance, simple domestic washing of clothes releases an enormous amount of microplastics in the rivers and into the ocean (Falco et al., 2019). The largest sources of plastic fragments found in environments today are *microplastics from primary sources* used in cosmetics and nurdles (plastic resin), which in turn contain chemical additives that are extremely harmful to the environment and human health (Thompson, 2015). The choice to consume or not these products, in view of there being biodegradable alternatives on the market and informative information online (Hunt et al., 2020). The second largest source of microplastic in the environment is textile microfiber, the report Primary Microplastics in the Oceans (International Union for Conservation of Nature) pointed out that 6 kg of polyester (a washing machine) releases 496,000 microfibers, while acrylic releases 728,700 microfibers for every 6 kg of clothing, thus representing 35% of the microplastic in the oceans today. The recently released WHO report (2022) cites some of the most up-to-date research related to dietary and inhalation exposure to nano- and microplastic particles and potential implications for human health. They are all in unisonous to highlight an urgent need to unify efforts to prevent this plastic material from reaching degradation at sea or on the beaches.

The acquisition and measurement of ocean pollution-related data is a constant challenge and one of the primary data to be intensively acquired during the Ocean Decade. Many global initiatives and a network of partners are dedicated to building a large-scale marine litter information system, with clear aims and structure toward understanding the magnitude of the problem to guide efficient mitigation in the coming years (e.g., Global Partnership on Marine Litter). Communicating is key to fighting marine pollution and achieving the associated goals by 2030. It is crucial to make consumers aware of their purchasing power while the industry does not change the overall means of production (Okoe et al., 2023). High-quality information, a sense of belonging, and empowerment of people can be an efficient way to reduce marine litter and microplastics in the Ocean. There are several actions from local to global scales that have proved the potential of environmental change (Sandu et al., 2020). For instance, tools for raising awareness and disseminating using citizen science protocols to monitor strategic areas have been shown to be efficient for research by federal universities in Brazil. These initiatives also include society as part of the scientific approach and knowledge production, at the same time educating and communicating for sustainability and Ocean Culture (Cunha et al., 2017; Miranda et al., 2020).

Accessing and predicting changes in Ocean health from local to global scales is a high research priority and an urgent request from global communities (Ocean Panel, 2021a). Several marine observatories are incorporating marine pollution metrics to their current environmental monitoring programs in order to meet multiple-stakeholder needs (e.g., Borja et al., 2020). Easy-to-replicate protocols and science-based technology to improve and speed data collection are highlighted as strong solutions to assess coastal areas at large scales and with high temporal resolution. Finding current drivers of marine pollution across habitats will give us a better understanding of the patterns of environmental impacts and quality, and, in turn, guide us toward more efficient mitigation efforts (Ocean Panel, Jambeck et al., 2020). Projects like Our Blue Hands aim to provide structure, support, information, and tools for society to strengthen its participation, knowledge building, and transformation for a global change in behavior, development, and future vision. By collecting standardized high-quality data from coastal and marine areas and hydrographic basins, including beaches, rivers, and mangroves, Our Blue Hands and similar long-term monitoring programs not only provide essential information for decision-making, but communicate science in a tangible way, and promote deep public engagement.

It is certain that society will not advance into a sustainable Ocean without broad and massive investment (Ocean Panel, Sumalia et al., 2021). Along this pathway, crowdfunding is an innovative model to seed and democratize science across the globe. Experiment is a platform to fund scientific discoveries in order to unlock new knowledge and promote technological development. Different from traditional science funding agencies, backers directly fund the project scientists with no overhead involved. All projects are rigorously reviewed, provided feedback, and scientifically approved by the Experiment team. Scientists share progress, data, and results directly with backers, many widely available as open access and citeable.

1.2. A BRIEF OVERVIEW OF THE COASTAL CRISES

The Brazilian coastal zone extends for approximately 8 thousand kilometers of coastline and is totally embedded by the Atlantic Forest biome, a mosaic of rich and biodiverse ecosystems such as mangroves, estuaries, and "restingas", that benefit millions of people (SOS Mata Atlântica, 2021). 70% of the Brazilian population lives on the coast spread around 275 municipalities, which put significant pressure on the conservation of coastal and marine environments by multiple economic activities and the intensive use of watersheds and their natural resources. In order to reduce the impact of coastal cities around the world, such as in Brazil, and move the global mindset to sustainability, the Ocean Decade highlights the importance of increasing marine protected areas by up to 30% by 2030 (revised Treaty of the High Seas, UN 2023). According to experts, creating new reserves is an effective way of preserving biodiversity and contributing to nature restoration. Brazil currently has 125 national protected areas designated as Conservation Units according to national legislation, 23 of them in the south of Brazil, many within the coast of Santa Catarina (MMA). The main objectives of conservation units are to safeguard the biological heritage, geological characteristics, and water resources and to protect natural landscapes in the determined area. These coastal and marine protected areas and the conservation efforts around them are fundamental instruments to reduce human impacts, particularly efficient when dealing with increasing marine pollution.

According to the United Nations (2017) more than 8 million tons of plastic enter the ocean, beaches, and stomachs of marine animals annually. Found in all environmental compartments (Montagner et al., 2021), these residues are consequences of a complex series of phenomena happening along the production-consumption-disposal chain in modern societies (Turra et al., 2022). Recently, studies have focused on the role of river runoff as an important gateway for waste on beaches and oceans. The litter composition of each river is markedly associated with human influences along its course (Rech et al, 2014), such as land use and social-economic activities in the coastal or riverine area (Williams and Simmons, 1999). The Ocean Cleanup project showed that rivers with urbanized banks and intense use, such as agriculture, are major entries of solid waste into the sea, mainly plastic. Accordingly, Brazil has approximately 600 source entries for plastic waste through river basins, which represent critical sites and 67% of all plastic that can reach the coastal zone (Alencar et al, 2022). Of the thousand most polluted rivers in the world, ten of them are in the State of Santa Catarina and are responsible for the annual input of 2.3 tons of plastic into the ocean.

More than 95% of the waste found on Brazilian beaches is plastic, such as bottles, disposable cups, straws, cotton swabs, ice cream packaging, and fishing nets (IOUSP, 2020). Plastic is a rigid, durable, persistent material that is easy to transport from one place to another, that's why 80% of the waste that reaches beaches and oceans comes from terrestrial sources, often resulting from lack or inadequate management (IOUSP, 2020). Only in 2022 and in part of Santa Catarina Island (Florianópolis), 118.5 tons of waste were removed from touristic and wide beaches and the surrounding sea by volunteers (Ecosurf, 2023). In addition to domestic waste, several economic activities such as commerce, the port industry, and tourism play a fundamental role in the generation of marine pollution. Society shares responsibility for the problem when it promotes the incorrect destination of its waste that, many times, is deliberately thrown into the streets and rivers.

Once mega and macro plastic enter the coastal environment, they accumulate on beaches and underwater habitats and end up causing the most visible damage to the biota (entanglement and ingestion, and transport of encrusting invertebrates; Ivar & Costa , 2009; Moore 2008, Barnes et al. 2009). The accumulated plastics undergo successive processes of degradation and fragmentation mainly by photo-oxidation and weakening of the molecular structures releasing smaller particles (Barnes et al. 2009). Particle physical degradation leads to different forms of microplastics (e.g., fibers, fragments, films; Montagner et al., 2021), a slow process that can take hundreds of years to complete (Costa et al.2009). As the microplastic degrades, chemical additives such as dyes, stabilizers, flame retardants, pesticides, and even polychlorinated biphenyls (PCBs) are released and can cause severe physiological changes (hormonal changes, disturbances in the production of enzymes, reproduction, and growth) in marine and human species. The lower the water quality of estuaries and coastal marine areas, the greater the chances of contamination of marine biota. Microplastics have been observed everywhere, coastal habitats and oceanic areas, marine water and sediments, zooplankton, fish, whales, and humans (Zhuet al. 2018; Wieczorek, 2018; Piperagkas et al. 2019; Kazour et al. 2019; Zhang et al. 2019; Botterell et al, 2019).

Plastics are transported from populated areas to the coastal environment via rivers, wind, tides, extreme wave and rainfall events, and urban drainage. While environmental factors are responsible for the distribution and concentration of microplastics in the environment, anthropogenic factors are responsible for the accumulation of these residues in the environment (Brach et al., 2018). Due to sedimentation and accumulation, the abundance of microplastic tends to be higher in sediment samples (0.21 to <77,000 items per m^2) than water surface (0.022 to 8,654 items per m^3; reviewed by Hidalgo-Ruz et al (2012). This concentration is higher close to shore. In Santa Catarina, there is more floating microplastics in estuaries than further away from the coast, and the larger amounts are founf close to the river mouth (2.12 ± 2.01 items per m^3) corroborating the role of rivers as plastics exporters (Vandresen, 2017). In 2022, the first pilot monitoring of the Our Blue Hands project recorded 589 (total 2422 fragments) occurrences of microplastic and mesoplastic in 28 monitoring campaigns on 8 beaches of Santa Catarina, with an average of 70 units per sampling campaign. The study suggested that the microplastic was accumulated through the dynamics of winds, waves, and currents.

Understanding the composition of microplastics is also important. It can indicate the potential sources and chemical impacts on the environment. Therefore, in order to have a more complete environmental diagnosis, the monitoring the Our Blue Hands' network adds to the occurrence, abundance and distribution of microplastics information about size, shape (fibers, fragments, films, spheres or pellets), color and type (polymeric composition), origin (primary or secondary). This polymeric matrix provides an overview of the contamination and toxicity (Lithner, et al. 2011). The Plastic Pollution Research Group (http://dgp.cnpq.br/dgp/espelhogrupo/786476) coordinated by Prof. Walter Ruggeri Waldman is developing a low-cost and easily accessible system to extract more information about the types of polymers from the microplastics found by the Our Blue Hands. The system is based on the difference in density between the polymers most frequently used as plastic pollution, such as polypropylene, polyethylene and polystyrene, and use a saturated solution to separate them. The techinique is being validated and could be applied to analyze pellets (a format used for marketing between petrochemical companies and transformers) and fragments (originating from plastic products), improving the environmental assessment.

1.3. THE POTENTIAL OF LONG-TERM MONITORING AND CITIZEN SCIENCE

The importance that the Ocean represents to society has made its conservation a priority. In the pre-and post-pandemic world, the Ocean represents a route of trade and transport of goods and people, and now, an economic recovery with a Blue stamp. Marine environments are the primary source of income and subsistence for a major portion of the human population (FAO, 2014). Numerous are services and opportunities provided by the ocean, such as food and other resource supply, living habitat, economic enhancement, and sociocultural connection (Bindoff et al, 2019). The borders between the Ocean and the continents and islands are of intense historical use, where not only the most populated areas of the world are located but are common temporary spaces for the immense flux of tourism, leisure, and sports (IPCC, 2019). It is common sense that contaminating and polluting ocean waters has negatively impacted many communities and societies for decades. Thus, we are facing a moment in which decision-making requires high-resolution large-scale simultaneous data to formulate powerful public policies to reduce marine litter. Assuming accessibility to increasingly remote locations on the planet and the increase in purchasing power that consumption provides, the project understands that the reaction to this socio-cultural phenomenon not linked to the increase in campaigns and projects aimed at reducing litter at sea, will extend the problem rather than reduce it.

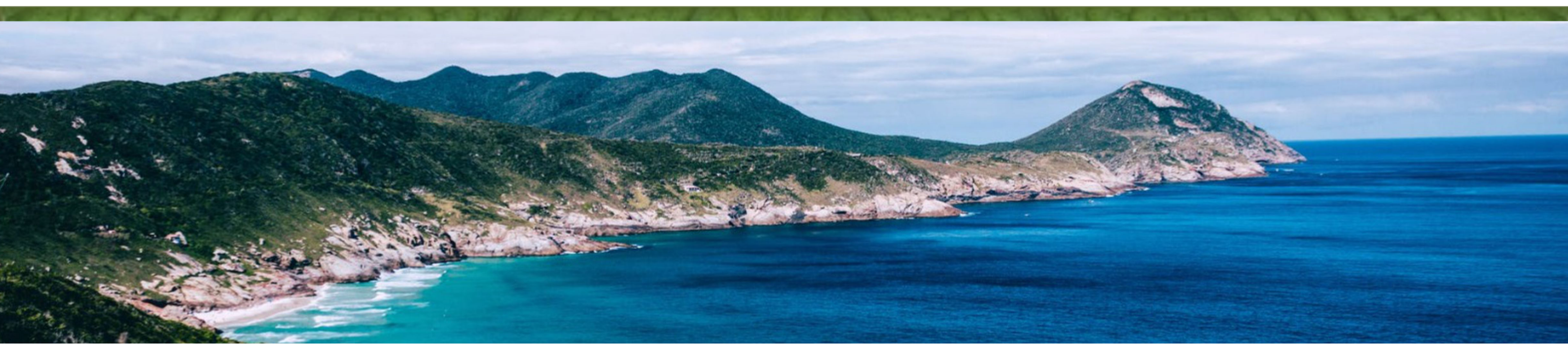
Citizen science has given voice to a movement that has existed for decades when the local and traditional groups have been responsible for the sustainable management of the environments in which they live. Traditional people and communities know environmental and local aspects in a profound way, which tends to be very beneficial for the management and monitoring of biodiversity in protected areas (Comandulli et al., 2015). Citizen Science produces a link of engagement by inserting methodological innovations to fight environmental problems that can be replicated by anyone anywhere in the world.

In order for this knowledge to be disseminated and applied in a fair way, there needs to exist a two-way flow of interactions, where both the local population and the scientific community benefit from this partnership. Besides, it is important that the structuring of the projects covers beyond the acquisition of data and the sampling effort to obtain them. These processes must add collaborative preparation and community empowerment, offering the necessary capacity-building activities, tools, and feedback, as well as provision of income and application of the knowledge built together whenever possible.

Initiatives such as the Our Blue Hands project point out that environmental communication and scientific dissemination are fundamental to combating this pollution and, therefore, achieving the goals of the 2030 Agenda. It is important to make consumers aware of their decision-making power. Involving them in the processes of generating high quality information is a way to stimulate a sense of belonging and empowerment, being an efficient form of education and attitude change. Tools for raising awareness and disseminating the use of Citizen Science protocols for monitoring strategic areas have proven to be efficient for research in Brazil and around the world. These initiatives include society as part of the scientific approach and knowledge production, while educating and communicating for ocean sustainability and culture (Our Blue Hands, 2023).

Chapter 2

THE OUR BLUE HANDS PROJECT



Chapter 2 The Our Blue Hands project

2.1. BACKGROUND

During the Ocean Decade regional preparation workshops, the local and international communities identified huge gaps in data, information, and knowledge about the Ocean that must be filled in order to achieve the sustainable development goals (SDGs), particularly SDG 14 and the vision of a Healthy, Clean, and Accessible Ocean. Across all the ocean science disciplines and blue economy and society sectors, it was highlighted that there should be an agreement on best practices and unified methodologies to monitor coastal and marine habitats, to provide inter-comparable indicators for decision-making. Simultaneously, the Our Blue Hands initiative has focused on disseminating a standardized and replicable framework to monitor the accumulation of microplastics on sandy beaches, using a network of engaged citizens as the core of data collection, public awareness, and solution co-creation. The project's best practices were built based on the methodology developed by the National Ocean and Atmospheric Administration of the United States of America (NOAA-USA), the European Marine Strategy Framework Directive (MSFD), and the Just One Ocean methodology developed by Portsmouth University (Jones, D., Mohamed, H.), adapted to local needs. Pilot sampling began on three coastal islands located between the Southeast and South of Brazil (São Sebastião Island, Santa Catarina Island, and Campeche Island) in order to understand the challenges and improvements required to sustain long-term monitoring relying on limited resources and diversified partnerships.

After three years, the Our Blue Hands project expanded the monitored sites to the mainland, adding Ubatuba (north coast of São Paulo State), Itajaí (northern coast of Santa Catarina State), and two islands in the Cape Verde archipelago (Santiago and Boa Vista). This marine plastic pollution monitoring network has been articulated and actively engaged, generating biweekly, monthly, or sporadic standardized high-quality data. Some pilot monitoring sites are still active, and new ones are being designed for the continuity of the project and the deepening of the analysis. A monitoring network was articulated and more than 20 organizations and institutes joined the project to observe the impact of microplastics on priority areas for conservation. The network was built with the premise that gathering data on microplastic and marine litter pollution will help locals, managers, and conservationists to move towards a Clean Ocean by taking action driven by information, engagement, and advocacy. The project understands that citizen science monitoring networks are one of the most efficient ways to raise awareness about the current environmental crises and that the products delivered by this type of project (e.g., as actions with schools, beach cleanings, and reports for managers) have a high impact on local reality.

2.2. SOLUTION

Considering the 2030 Agenda and the UN Decade vision of a Clean Ocean, the Our Blue Hands project aims to create a network of citizen scientists engaged in the monitoring of microplastic pollution and plastic waste, using low-cost infrastructure and easy-to-replicate methodology to acquire high-quality standardized data about different marine sites of the world. This standardized and adaptable methodology contributes to building a local and regional database of marine litter (focused on micro and mesoplastics) to be further analyzed and converted into marine pollution indicators of multiple uses in decision-making. The data library and documentation of best practices are planned to assist the management of urban waste, identification of temporal and spatial variation in pollution, assessment of environmental and social drivers, and guide change in consumer behavior, product use, and manufacturing (e.g., food and beverage packaging, fishing gear, civil construction supplies). By involving local communities, the network aims to promote engagement and co-design of creative applicable solutions to the problem of marine litter. The project has the potential to promote associated initiatives, build technical capacity, and generate income flux through partnership, work as a monitor, grants, and projects that can actively participate in the network. The Our Blue Hands project hopes to find in the managing bodies the guarantee of the applicability of this information in order to reduce marine litter and improve the environmental quality at the monitoring sites.

Figure 2.1. The Our Blue Hands solutions.

The project core consists of 5 solutions (Fig. 2.1), covering the entire data cycle with the co-design of actions meeting network objectives and local needs:

Solution 1. Training - Monitor Network

Empowerment is a way to engage citizens interested in being part of the solution. The core of this solution is to promote space for the exchange of knowledge and leveling of it, by providing courses, moments to share theoretical and practical experience, and a collaborative safe basis for the implementation of the pilot project. The project's theme is introduced months before the practical experience, creating an alert and conscious mind of the issue.

Solution 2. Data Acquisition

The acquisition of data about the abundance, occurrence, and distribution of micro and mesoplastics at marine habitats (e.g sandy beaches) during a predetermined period is the guide of this second solution. The data matrix is based on standardized methodologies applied at several sites around the world and is planned to provide enough information to answer basic marine pollution queries. The implementation and sustaining of these monitors in the long term allow a more complex time series and a better understanding of the problem and habitat dynamics, increasing markedly the possibility of resolution. In this phase, all previously acquired knowledge is put into practice, highlighting the importance of training for the quality of the data acquisition and successful articulation of partners.

Solution 3. Curation and Quality Control - Database

Standardized databases at multiple scales (local, regional, and global) solve a very important gap in Ocean research and decision-making toward sustainability. Ensuring that data from various parts of the world are being collected in the same way and safely stored, facilitates the comparison of information across different conditions, and thus, the development of indicators of high applicability and a baseline for marine microplastics. Based on this premise, this project includes a plan for data management, data curation, and quality control after the acquisition phase (solution 2). The local teams are responsible for taking action in the first phases of the data cycle from the field to the cloud, and may potentially engage in the more complex data system as he/she feels capacitated. The main product of solution 3 is to create a micro and mesoplastics database that will feed analytical proceedings to generate information. The archive is dynamically being prepared to integrate further international marine litter databases, as the project and partners agree on.

Solution 4. Information Transformation

The transformation of the database into meaningful information is one of the most valuable contributions that this project can offer. Through the various analyses and correlations with the management tools, it is possible to think about the response measures together with managers and the local population. Through science-based statistical analysis and visualization methodologies, the data is transformed into information that can be reproduced in environmental actions, infographics, and reports. This solution framework can be updated to meet local information needs and be compared to similar observatories around the world.

Solution 5. Decision-making

The information delivered by the other solutions generates indicators of plastics' source, site exposure to marine litter, and potential impact of micro and mesoplastics in the monitoring sites. This set of information and indicators must be aligned with current plans for combating and preventing litter in the Ocean. The core role of the Our Blue Hands monitoring is to create a baseline prior to the implementation of management and conservation regulations, defining key parameters that may interfere with the quality of that environmental compartment. In the longer term, this information can be used to evaluate the efficiency and effectiveness of the local and regional action plans.

Aims

The main objective of the Our Blue Hands Project is to create a network of citizen scientists engaged in monitoring microplastic pollution and plastic waste, using low-cost infrastructure and easily replicated methodology to acquire high-quality standardized data on different marine and coastal habitats and through this information, you will find the solutions that are more contextualized with the place in question.

In this first semester of 2023, the project focused on:

- Carrying out a diagnosis of microplastic pollution on the beaches of 5 municipalities of Santa Catarina state, Brazil;
- Creating a map of the environmental pressures using the DPSIR framework;
- Determining the composition of polymers found during beach monitoring;
- Implementing the basis for an integrated monitoring network involving different sectors of society.

2.3. CO-DESIGN AND PARTICIPATORY EVALUATION

Considering that plastic pollution in the Ocean is transboundary, tackling this problem requires the engagement and commitment of different sectors of society in coastal areas, and islands, as well as stakeholders living within the continents (Ocean Panel, Jambeck et al., 2020). The Our Blue Hands is an open space for collaboration, co-design, and partnership based on the premise that the network shares similar principles and works together for a Clean Ocean, particularly, for the monitoring and reduction of microplastics in marine and coastal habitats. Besides SDG 14 (Life in the water), Our Blue Hands contributes to SDG 17 which aims to strengthen the means of implementation and revitalize the global partnership for sustainable development. It implies that multi-sectoral partnerships are a potential strategy to mobilize solutions and share knowledge, experience, technology, and financial resources are the pieces that make the gear of the advance of SDGs. SDG 17 is of particular importance for developing countries, which rely on local, regional, and international partners to develop sustainable solutions (Leal Filho et al., 2022). The articulation of a network of stakeholders and parties allows each necessary function to be performed by multiple competent hands called focal points (nodes within the network), which communicate with each other through multiple pipelines supporting more decentralized harmonic governance. In Our Blue Hands, each focal point multiplies knowledge and carries out monitoring, and in turn, being both supporters and financiers. In general, all the partners involved have a sense of belonging to the place where they live or were born and are naturally attracted to this work as a way of preserving the coastal marine environment.

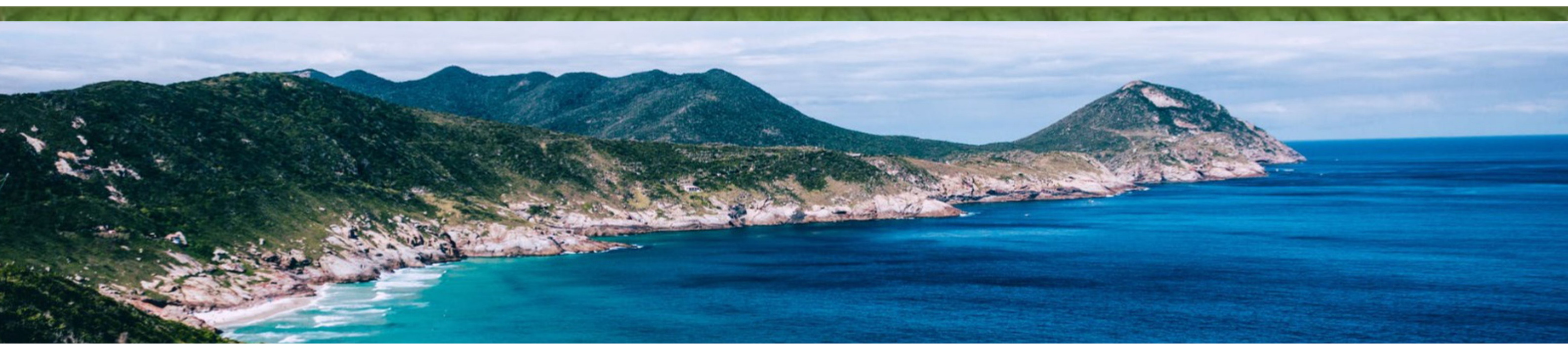
The main objective of the Our Blue Hands project in Santa Catarina was to enable a collaborative monitoring network to assess the occurrence, distribution, and abundance of microplastics at sites considered environmentally strategic by the population and managers across the region, and where it was feasible to start and continue observations in a longer basis. During the different steps of the project, the priority of understanding environmental and anthropogenic drivers and pressures on coastal pollution was evident. The use of the Driver-Pressure-State-Impact-Response (DPSIR; Abalansa, Samuel, et al.,2020) framework is of great value in validating the discussions and problems encountered during the face-to-face training and samplings. In addition to clarifying shifts in the ecosystem state, the DPSIR provides a diagnosis of the impact of human activities on ecosystem services and identifies the connections between possible solutions for marine litter based on national and regional legislation and mitigation actions already happening. The DPSIR is a dynamic tool that is closely linked to the environmental compartment to which it is applied. For instance, as the beach environment is subject to multiple meteo-oceanographic forcings, those are expected to influence the DPSIR outcomes, which, in turn, will require updates accordingly. These loops and new connections enable this framework to address both current and future environmental needs, in order to provide guidance to immediate actions as well as predictions. Overall, connecting monitoring and DPSIR builds the pathway to answer two questions: (1) What types and amounts of microplastic waste are currently found at the monitored sites? (2) How does the use of the beach impact the environment? The project schedule was divided into two phases according to the proposed activities: Phase 1, Engagement, communication, and training; and Phase 2 Data management and sharing.

The Our Blue Hands explores various aspects of plastic pollution. The partnership with universities brings a scientific knowledge basis and allows the exchange between students, researchers, and the local community. Despite being a work that applies a scientific methodology, it was extremely important to hear and understand the local context from the point of view of the residents of these beaches and professionals working in conservation in the region. These inputs provide deep knowledge and meaningful information about the local reality, engaging those who know and face the problem of marine pollution on a daily basis. Strengthening the dialogue between civil society and academia through the citizen science framework proved to be an opportune way to raise environmental awareness and local engagement surrounding the monitoring sites. The entire collaborative construction process, from the knowledge outreach, data acquisition, and information transformation, made it clear to all participants that it is possible to implement the marine litter mitigation plan at strategic and priority maintenance sites and communities.

Chapter 3

PROJECT IMPLEMENTATION

PHASE 1 - ENGAGING AND MONITORING



Chapter 3 Project Implementation

Phase 1 - Engagement, communication and training

3.1. CITIZEN SCIENCE NETWORK AND FACE TO FACE TRAINING

The project focused on creating the basis for an integrated collaborative network of different stakeholders engaged in developing solutions for reducing beach pollution. In Santa Catarina, the project engaged a network of citizen scientists from environmental agencies, civil society, students, technical professionals, local associations, and fishermen (Table 2.1). This network embraced participants from both the generation and management of waste, as well as the development of public regulations.

Table 3.1. List of partners of Our Blue Hands in Santa Catarina during the monitoring from March to June 2023.

Partner	*General mission and/or environmental targets*	Municipality, sector, jurisdiction	role in the project
Itajai Sustainable Institute (INIS) https://inis.itajai.sc.gov.br/	Work serving the community of the municipality of Itajaí, integrating the man-society-nature trinomial to guarantee the quality of life in the environment, for current and future generations.	Itajaí Governmental Local/Municipal	Monitoring Team and Support Point
Environment Support Foundation (FAMAB) https://bombinhas.sc.gov.br/estrutura/pagina-1055/	Carry out the environmental licensing of activities with a local impact and the collection of environmental fees,	Bombinhas Governmental Local/Municipal	Monitoring Team and Support Point
Environment Institute of Santa Catarina (IMA) https://www.ima.sc.gov.br/	Implement public policies to protect the environment, ensure the proper use of natural resources, conservation and recovery of ecosystems, contributing to sustainability and environmental quality.	Florianópolis Governmental Regional/State	Monitoring Team
R3 Animal Association https://r3animal.org/	Work towards the conservation of biodiversity through the rehabilitation of wild animals, research and awareness of society, seeking to recover the environment, minimizing human impact.	Florianópolis Non-governmental Organization Local	Monitoring Team
Z22 Fishery Colony https://mapaosc.ipea.gov.br/detalhar/410196	Support local traditional fishery community	Bombinhas Non-governmental Organization Local	Structure, support and monitoring
Charles Darwin Museum of Natural History https://www.facebook.com/MuseuCharlesDarwin/?locale=pt_BR	Science literacy and environmental conservation	Bombinhas Non-governmental Organization Local	Monitoring Team

Three municipalities had representatives participating in Our Blue Hands practical-theoretical training (8 hours each), with a total of 24 hours of knowledge leveraging and technical preparation to carry out unsupervised field samplings. The training content covered topics about marine pollution, the impact of microplastics in all environmental compartments, concepts and the standardized vocabulary defined by the Brazilian legislation and scientific community, and sampling methodology (OUR BLUE HANDS, 2021). According to the attendance lists, approximately 40 people were trained from which 15 were chosen for the sampling teams in Itajaí and Bombinhas (central-north coast), Florianópolis (Island of Santa Catarina), Garopaba, and Imbituba (south coast). The teams received a sampling kit at the end of the face-to-face training, had an assigned role within the network, and agreed to a specific site/area to continue monitoring.

The face-to-face meetings were very constructive in creating an opportunity to build trust, exchange information, and co-design solutions. These capacity-building activities had as their main objective to guarantee that the network of collaborators would have the minimum amount of information about the project, its background, the monitoring methodology, and the data flows. The activities required in-person training in order to increase standardization of monitoring surveys and to assure that the volunteer efforts would provide meaningful and reliable data about micro and macroplastic waste, supporting management and decision-making.

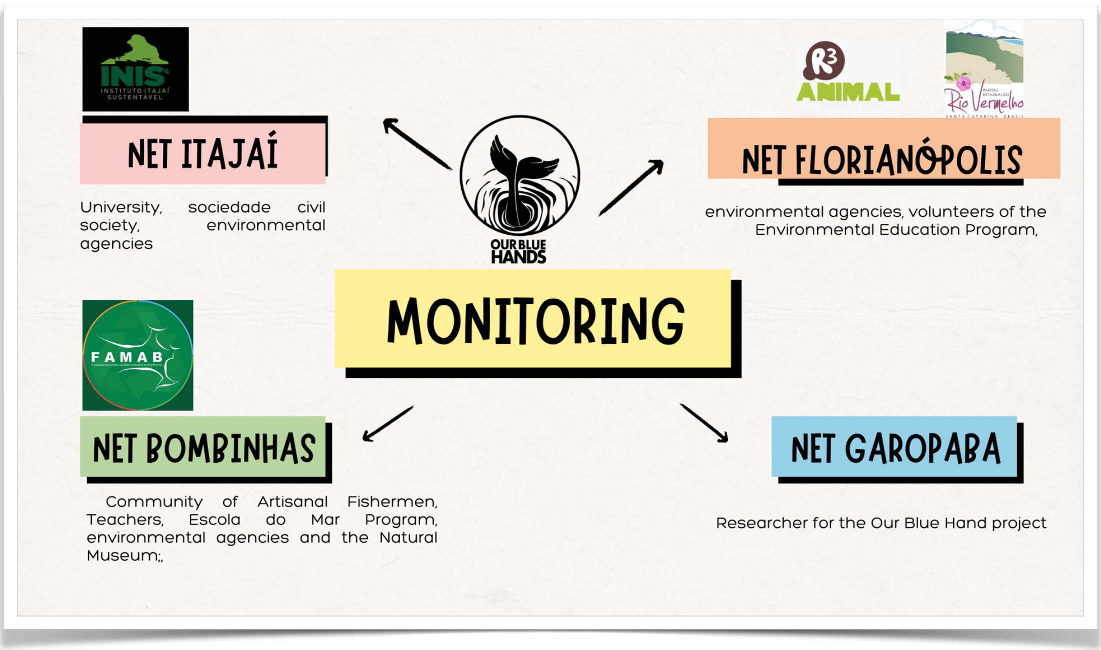


Figure 3.1. Network schema in Santa Catarina.

During these trainings, the Our Blue Hands monitoring methodology was replicated at the beach by the partner's team and supervised by the project's coordinator. It was an opportunity to identify the need for adaptations, gather a first diagnosis of the plastic waste at each site (e.g., types, abundance), and establish group goals. The group also sought to understand in a systematic way the main differences between the beaches studied, including the identification of the uses and major activities happening at each site, the flow of tourism, and the association with the increase or decrease of waste accumulation, and spatial variability of these patterns. Important concepts were introduced, such as recognition of the properties of plastic, strategic locations for data collection, types of sand grains, the influence of climatic factors, the different tide lines, paths from waste to arrival at sea, types of plastics found on the beach and, most importantly, how to collect and enter data into tables. Those conversations aimed to engage collaborators in observing their sites while conducting the monitoring. Information about natural and human-driven conditions is of high value in the interpretation of the monitoring results.

The main challenges encountered during the training were associated with the reduced resources and staff available to be trained and organized in a very short time. These challenges were overcome by concentrating some of the surveys under the project coordinator's responsibility, who ran the monitoring at the sites lacking collaborators. The team also recognized that there is an urgent need to adapt the scientific language to facilitate dialogue with the volunteers and collaborators from different sectors of society. The more everyone involved in the project knows the steps and protocols, the higher the quality of the data and the capacity of the network to evaluate larger coastal areas in the long-term. In this implementation, the project did not include training in data analysis, which is still a fallout in terms of generating self-sustained branches of the network. It also tends to overwhelm the coordination team that does not have the capacity (time) to run a deeper data assessment.

Figure 3.2. Our Blue Hands face-to-face training in Santa Catarina in 2023.

3.2. MONITORING SITES

The project focal points were coordinated by the Fundação de Amparo ao Meio Ambiente - Bombinhas (FAMAB) and the Colônia de Pesca Z22, Instituto Sustentável de Itajaí, Paerve/IMA (Parque Estadual do Rio Vermelho/ Instituto do Meio Ambiente Santa Catarina and Our Blue Hands. These partners were responsible for carrying out the monitoring and structuring teams, covering 170 km of coastline and 10 beaches in 5 municipalities (Table 3.2). The pilot project defined the sampling areas with the aim of implementing actions that encourage the integrated management of Conservation Units on the coast of Santa Catarina, considering both natural resources and biodiversity.

Table 3.2. The list of the Our Blue Hands monitoring sites from March to June 2023, including the municipality, coastal sector, geographical coordinates, morphodynamic classification (dissipative, reflective, or intermediate; according to Ribeiro et al, 2015), and exposure to wind and waves.

Municipality	Coastal Sector	Beach	Decimal Latitude	Decimal Longitude	Morpho-dynamics	Exposure
Itajaí	Central-north	Atalaia	-26.9	-48.6	Intermediate to Dissipative	South/ East exposed
Itajaí	Central-north	Brava	-26.9	-48.6	Intermediate	North and South exposed
Itajaí	Central-north	Cabeçudas	-26.9	-48.6	Reflective	
Bombinhas	Central-north	Praia de Zimbros	-27.2	-48.5	Intermediate	Sheltered
Bombinhas	Central-north	Canto Grande			Intermediate	East exposed
Bombinhas	Central-north	Tainha	-27.2	-48.5		
Florianópolis	Central	Moçambique (Canto das Aranhas)	-27.5	48.4	Dissipative	Southeast exposed
Florianópolis	Central	Moçambique (Barra da Lagoa)	-27.6	-48.4	Intermediate	Exposed
Garopaba	South	Ferrugem	-28.0	-48.4	Intermediate	East/Southeast exposed
Imbituba	South	Praia do Rosa	-28.1	-48.4	Intermediate	East/ Southeast exposed

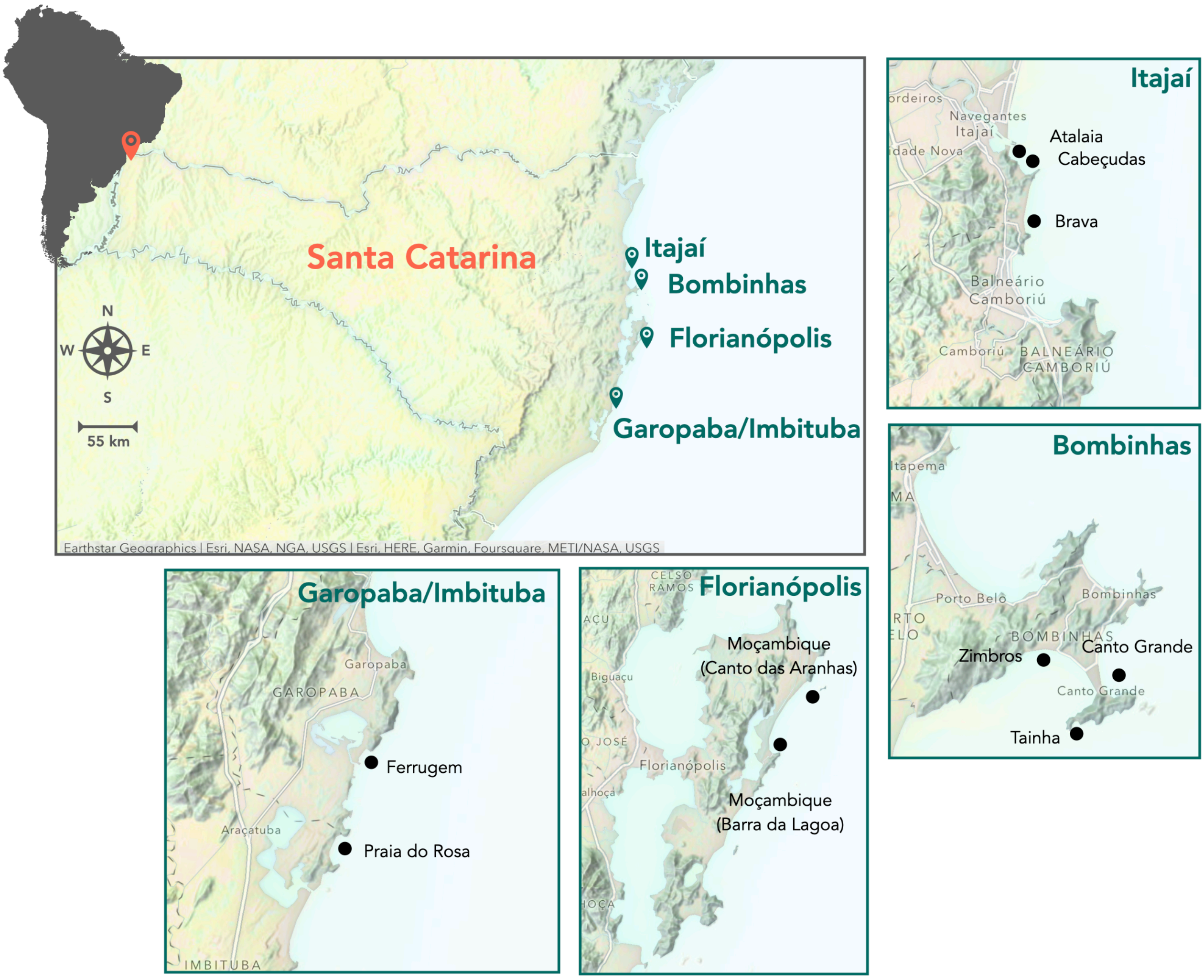


Figure 3.3. Our Blue Hands monitoring sites in Santa Catarina.

3.3. DPSIR - FRAMEWORK

The DPSIR, whose acronym refers to Driver-Pressure-State-Impact-Response (European Environmental Agency, 1999) is a methodological framework used to describe and analyze complex environmental problems in a conscious and strategic way, and yet it provides a simplified view of a cause-effect relationship between society and the environment, including the economy. This analytical framework is expected to link causes and consequences in the causal chain from the driving forces to the impacts on ecosystem services, establishing quantitative indicators for the different elements of the chain. DPSIR allows the evaluation and type of integrated monitoring for a given system, revealing temporal trends in the same area, or if standardized for application in other areas and comparison with other socio-environmental systems (Bandeira, 2021).

The Our Blue Hands project dedicated part of the online training and face-to-face moments in Santa Catarina to map these indicators in information matrixes based on CICES classification of environmental impacts. CICES was developed to standardize the use of the terminology of ecosystem services to improve the comparability of environmental accounting and ecosystem assessments. The classification was developed by the European Environment Agency (EEA). In CICES, ecosystem services are divided into three sections; provisioning, regulating and maintenance, and cultural services. In short, provisioning services are the tangible products that people obtain from ecosystems. These include food, water, raw materials, energy, and genetic resources. Regulating services consist of ecosystem processes that maintain environmental conditions favorable to life. Cultural ecosystem services are those "benefits" that we get from nature that we cannot touch: recreation, experiences, spiritual sustenance, a sense of place, and so on. At large, they refer to the significance of nature in our cultures and for our well-being. This exercise generated a focused and strategic diagnosis of the environmental situation at those habitats and human settlements.

Table 3.2. DPSIR matrixes of Santa Catarina. Note the codes referring to each municipality: Bombinhas (*B), Garopaba (*G), Itajaí (*I), Florianópolis (*F).

Driver

- Housing
- Disorderly mass tourism
- Fishing activity
- Vessel Repair (*B)
- Environmental factors (precipitation)
- Lack of planning of watersheds (*G, *I, *F)

Pressure

- Precipitation
- Frequency and intensity of extreme events
- Civil construction/real estate speculation
- Waste disposal and solid waste management

State

- Replacement of the front dunes and sandbanks by buildings and/or structures such as walkways, sidewalks and decks
- Occupations of permanent preservation areas
- Piping of watercourses
- Removal of riparian forest
- Lack of treatment of domestic effluents and proper disposal of solid waste
- Fragmentation of restinga/mangroves/forests
- Accumulation of solid waste on beaches
- Environmental contamination

Impact on Ecosystem Services

Section	Division	Group	Class	Code
Provisioning (Biotic)	Biomass	Land plants grown for nutrition, materials or energy	• Cultivated land plants (including fungi, algae) grown for nutrition	1.1.1.1
		Animals bred for nutrition, materials or energy	• Animals raised by in situ aquaculture for nutrition	1.1.4.1
		Wild animals (terrestrial and aquatic) for nutrition, materials or energy	• Wild animals (terrestrial and aquatic) used for food	1.1.6.1
	Water	Surface water used for nutrition, materials or energy	• Surface water for drinking	4.2.1.1
			• Surface water used as material (for non-potable purposes)	4.2.1.2
			• Freshwater surface water used as an energy source	4.2.1.3
Regulation and Maintenance (biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of waste or toxic substances of anthropogenic origin by living processes	• Filtration/sequestration/ storage/accumulation by microorganisms, algae, plants and animals	2.1.1.2

	Regulation of physical, chemical and biological conditions	Water conditions	• Regulation of the chemical condition of fresh water by living processes	2.2.5.1
			• Regulation of the chemical condition of salt water by living processes	2.2.5.2
Cultural (Biotic)	Direct, in situ and outdoor interactions with living systems that depend on their presence in the environment	Physical and experiential interactions with the natural environment	• Characteristics of living systems that enable activities that promote health, recovery, or pleasure through passive or observational interactions	3.1.1.2
Response				
Bombinas **Itajaí**	• Port Inspection - Transport, Handling • Coalition of Strategies to Combat Litter in the Sea of Watersheds • Onboard Selective Collection Program • Tourism Awareness Actions - holidays, vacations and off-season • beach cleaning • Single plastic use regulation • Inspection of implemented laws (*B)			
Florianópolis	• Encouraging Environmental Education in the areas of the Rio Vermelho State Park • Minimize possible initial fire outbreaks, monitor possible outbreaks (remnants of embers, remains of offerings from religious rituals; • Carry out programs and partnerships with Comcap (organ responsible for urban cleaning), cleaning, collection and informative and educational work; • Rio Vermelho monitoring project and citizen science Embrace the Rio Vermelho ECOPAERVE			
Garopaba	• Monitoring bathing on the beaches, especially during the summer • Strengthening of social organizations with the aim of guaranteeing decentralization in decision-making and information flows both horizontally, between the community itself, and vertically, to the various government levels • Inspection of fishing activities • Housing plans, more efficient homes, sewage collection and treatment systems, waste collection and final disposal			

Table 3.3. Pollution on water basins

Municipality	Hydrographic Basin	Pollution Focus
Itajaí	RH 07 - Itajaí Valley	• Drainage of urban-industrial centers, with diversified industrial facilities (textiles, fishing, metal-mechanics, paper, cellulose, etc.)
Bombinhas	RH 07 - Itajaí Valley	• Contribution of the polluting load through the Bay
Florianópolis	RH 08 - Central Coast	• Irregular occupation of riverbanks, release of domestic sewage and the industrial park in the municipality of Biguaçu (plastic industries, furniture and cement artifacts)
Garopaba	RH 09 - South of Santa Catarina	• Transport and port activity, industrial fishing, agribusiness sector.

Insights

The DPSIR framework is a model that needs to be constantly reassessed depending on the environmental constraints, especially when dealing with transition environments between land and sea (e.g., estuaries, mangroves, rivers, and beaches), as they tend to undergo multiple and highly variable natural and anthropogenic-driven changes. In addition, DPSIR result is modified as an effect of environmental mitigation, when conditions should evolve positively. Therefore, mapping these forcings is a strong instrument of marine spatial planning, and should be widely used for coastal management. Besides, DPSIR is markedly based on community participation, which enables more effective societal vigilance and awareness, together with a clearer view of the legal framework for implementing response actions. The DPSIR results of the Our Blue Hands initiative in Santa Catarina offered a baseline about the environmental reality based on the experiences and views of the local community, providing insights to plan actions for a more sustainable future.

Santa Catarina coast, like all coast of Brazil, has been historically impacted by real estate speculation, disorderly occupation, and unplanned economic development. These activities had a huge impact on the landscape, and as expected, were noticed and identified by the monitoring team in the DPSIR evaluation. It was also possible to map and contextualize punctual and diffuse sources of pollution that might be affecting water bodies along the coast as well as driving large amounts of plastics to the monitored beaches.

The monitoring group also noticed that these beaches have particular natural characteristics, for instance, with distinct exposure to waves and winds or position within the hydrographic basin. The north-center beaches are more influenced by river discharge, which, in turn, forces a large volume of freshwater to the nearshore areas and waste accumulation on sand. On the other hand, the beaches in the center and south are under higher wind and wave impact and have stronger sea currents, which tend to spread waste across more areas of the beach and more temporal variability in the abundance of microplastics.

Traditional fisheries, although expected to have less impact on the environment, were identified by the community as an important local source of plastics. Many fishermen use of the beach for repairing boats and nets, which tends to leave a trace of plastics on sand.

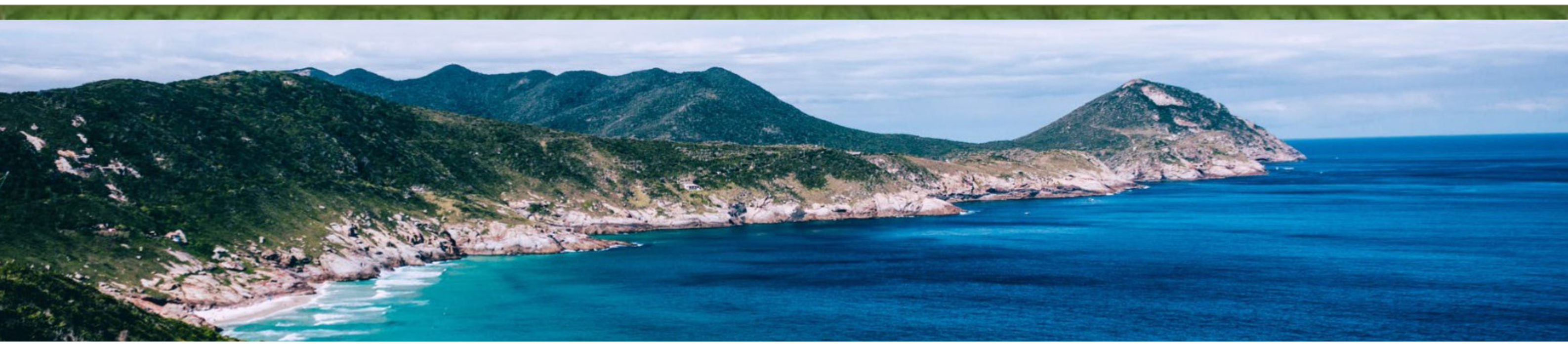
Port industry was recognized as a major threat to the environmental quality of the monitored beaches, and a source of specific types of microplastics. Between the region that comprises Imbituba to Itajaí, there are three ports in full activity (Imbituba, Itajaí, and Navegantes). These ports are equipped to receive several industrialized materials and goods, including plastic. It was evident during the DPSIR evaluation that there is an urgent need to develop plastic pollution control programs that include major sources and polluters. These ports are connected to 7 (or more) plastic transformer companies located in the north-center region of the state, and the pressure on the environment should be expected along the entire transport cycle. Mapping and monitoring the development of these activities is a shared responsibility between industry, government, and society. The group highlighted the importance of including multiple stakeholders, such as waste disposal companies, municipal managers, and cooperatives of collectors and recyclers. The prevention of litter at sea is an opportunity to strengthen partnerships and collaboration among the various sectors involved in the production-consumption-disposal chain, as a basis for implementing circular economic models.

DPSIR assessment identified that each coastal area within Santa Catarina provides important ecosystem services, but the accumulation of microplastics in beach sand directly interferes with the health of biodiversity and environmental quality. Most monitored sites are scenic beaches or conservation hotspots, where tourism is also allowed to be a major source of income for the region. Although sustainability depends on merging society development with environmental protection, the process is complex and requires constant vigilance and planned actions. Beach tourism in Santa Catarina generates a lot of single-use plastic and disposable waste, which accumulates on the sand during high season. Waste management is still being regulated by the state, therefore, the Our Blue Hands network highlighted that it is a unique opportunity to start joint efforts towards educating tourists and service providers on the fight against marine pollution. Local residents are key in the process by showcasing good examples and engaging visitors in hands-on activities. Co-designing and implementing a communication plan was also recognized by the network as a priority. Beach cleaning estimates and monitoring the potential entry points for waste might be a tool to quantify and control the amount of waste that reaches those beaches, and work as indicators of the effectiveness of municipal new waste management legislation of "less plastic".

Chapter 4

PROJECT IMPLEMENTATION

PHASE 2 - DATA MANAGEMENT AND SHARING



Chapter 4 Project Implementation

Phase 2 - Data management and sharing

4.1. AIMS AND SOLUTION

Understanding the impact of microplastics in the Ocean and its ecosystems and moving toward an effective solution requires long-term standardized data with broad coverage from local to global (Andrady et al., 2011; Napper & Thompson, 2020; Lamichhane et al., 2022). In this sense, the Our Blue Hands Project has included in its practices not just data acquisition, but robust analyses and indicators that provide a quali-quantitative comparative ground to assess microplastic pollution on sandy beaches. In the short-term, the Our Blue Hands data analysis rationale aims to develop a rapid census of microplastic pollution at the monitored sites, including information about the occurrence, abundance, and composition of plastic fragments and compare geographical and temporal differences in pollution impact. In the longer term, the information obtained from the microplastic occurrence time series can be used to determine trends in coastal pollution, including insights into potential sources and environmental drivers (e.g. Cole et al., 2011). This data is crucial to assess marine pollution impacts on coastal areas and it provides indicators to follow the efficiency of management and mitigation actions (Ogunola et al., 2018).

The analytical design, statistical techniques, and visualization tools applied to the microplastic data are endorsed by a long list of scientific literature from environmental and marine sciences (e.g., Balthazar-Silva et al., 2020; Jiang et al., 2020). The metrics and corresponding analyses were chosen in order to fit the database, accounting for variability among datasets, sites, and collaborators. Besides, this design allows robust comparison and identification of spatio-temporal differences according to the response variables (Underwood, A.J., 1992; Anderson & Walsh, 2013), in this case, related to micro and meso plastics in sandy beaches. At the bottom of the analytical chain is the data acquisition protocol, which is based on international standards (GESAMP, 2019).

In the following sections, you will find a brief description of the sampling protocol focused on data acquisition, detailed data analysis procedures, a description of the results of the monitoring until now, and insights discussing the main information acquired and recommendations for the next steps.

4.2. SAMPLING PROTOCOL

The Our Blue Hands monitoring protocol carried out on sandy beaches in Florianópolis acquired data by in situ samplings, which consisted of sieving sand along a standardized area of the beach (25m transect) looking for micro and meso plastic fragments. Along each transect, smaller areas were defined as the sand samples (1 m2, n = 5). The protocol was replicated approximately every 15 days at different coastal sites and municipalities, providing 1 to 6 sampling events until June 30th, 2023.

Fragments found in each quadrant were separated into micro or mesoplastics based on size, according to sieve mesh and/or manual measurements (micro 1 to 5 mm; meso 5 to 25 mm). Microplastics were then classified based on shape into primary microplastics (nurdles, or secondary microplastics (Expanded PolyStyrene EPS, and others). Mesoplastics were divided into fragments and other types (fiber, film, foam, or rubber).

The full monitoring protocol is published open access in the Ocean Best Practices System (OBPS-UNESCO) repository (Our Blue Hands, 2021), and the corresponding references from which it was adapted are cited in the text.

4.3. DATA ANALYSIS

The data obtained from the monitoring surveys provided the following response variables: (1) record, the number of micro/mesoplastic occurrences observed in the samples, considered as unique records for the different categorizations (type and color); (2) abundance, the amount of micro/mesoplastics fragments sampled per transect or per square; (3) composition, considering the multivariate matrix of micro/mesoplastic abundance for the different categories. We used two types of sampling units, transect (one per survey, n = 1 to 6 surveys depending on the beach) or square (n = 5, per transect per campaign). All comparative analyses were carried out including similar sample units.

Differences between beaches (sites), monitorings (surveys), and municipalities were evaluated by analysis of variance (ANOVA; Underwood, 1997) for record and abundance, and by univariate or multivariate permutational analysis of variance (PERMANOVA; Anderson, 2014) for composition. The analyzes tested the factors separately as the difference in the number of sampling units and monitoring replications still does not allow for multilevel hierarchical assessments for ANOVA and PERMANOVA. Specific contrasts were identified with Tukey's a posteriori tests (Tukey, 1977) and pairwise PERMANOVA (Anderson, 2014).

Data were transformed (log x+1; square root) when necessary to meet the assumptions of the analyzes (i.e., normality and homoscedasticity in ANOVA; linearity and null values in PERMANOVA). Graphic and analytical processing was performed by Numbers (Apple Inc.) for graphics and R environment (R core team 2023) for statistics.

4.4. MAIN RESULTS

The project surveys registered 691 records of different micro and meso plastics during the 36 monitoring campaigns on the coast of Santa Catarina from March to June 2022. A total of 1289 units of plastics were found on the 11 monitored beaches, with an average of 36 units per sampling campaign (Table 1). Most records were registered in April (n = 285) and May (181). Secondary microplastics were found more often on the sand than other sizes of fragments (46%; Fig. 1). Overall, the total abundance of primary microplastics and mesoplastics was similar (~190 units; Fig. 1). Larger amounts of microplastics were found in Atalaia in Itajaí, Canto Grande in Bombinhas, Moçambique in Florianópolis, and Rosa Norte in Garopaba (Table 1, Fig. 3). Tainha in Bombinhas was the least polluted according to these surveys, where only microplastics were registered (Table 1, Fig. 2 and 3).

The monitoring identified marked differences in the abundance, occurrence, and composition of micro and meso plastics among and within each municipality. In Itajaí beaches, the composition of plastic fragments was more diverse and relatively homogeneous (Fig. 2). In Bombinhas beaches, there was a higher occurrence of primary microplastics (>40%; Fig. 2). Secondary microplastics occurred more often in Florianópolis and Garopaba beaches (51 to 83%; Fig. 2).

Temporal patterns of micro and mesoplastics abundance were also very dependent on the site (Fig. 3). Itajaí showed the least variability among samplings, meaning that the amount of plastics does not differ significantly between 2 weeks to 1 month. At the other sites, there was at least a peak in plastics that was outstanding compared to the other ones. These maxima abundances were not synchronous either between closer beaches or the ones with similar geographical orientation or wave impact.

Table 1. Summary of micro and meso plastic observed during beach monitoring in Santa Catarina between March and June 2023.

State	Municipality	Site	Number of surveys	Records	Total abundance	Average abundance per survey
Santa Catarina	Itajaí	Atalaia	4	104	304	76
Santa Catarina	Itajaí	Cabeçudas	5	36	37	12
Santa Catarina	Itajaí	Brava	5	71	87	29
Santa Catarina	Bombinhas	Canto Grande	4	116	205	51
Santa Catarina	Bombinhas	Tainha	2	6	6	3
Santa Catarina	Bombinhas	Zimbros	6	127	180	30
Santa Catarina	Florianópolis	Barra da Lagoa	3	50	65	20
Santa Catarina	Florianópolis	Moçambique	2	45	120	60
Santa Catarina	Florianópolis	Ingleses	1	18	37	37
Santa Catarina	Garopaba	Ferrugem Sul	3	43	57	19
Santa Catarina	Garopaba	Rosa Norte	3	63	155	51

Table 2. ANOVA results assessing variations in the abundance of microplastics among sites.

	df	SS	MS	F	*p*
Site	10	7898	789.8	15.2	< 0.0001*
Residuals	169	8760	51.8		
	df	SS	MS	F	*p*
Municipality	3	67	22.3	0.2	0.871
Residuals	176	16591	94.3		
	df	SS	MS	F	*p*
Area	2	22	11.2	0.1	0.887
Residuals	177	16635	93.9		
	df	SS	MS	F	*p*
Survey	1	279	279.1	3.0	0.0833
Residuals	178	16379	92.1		

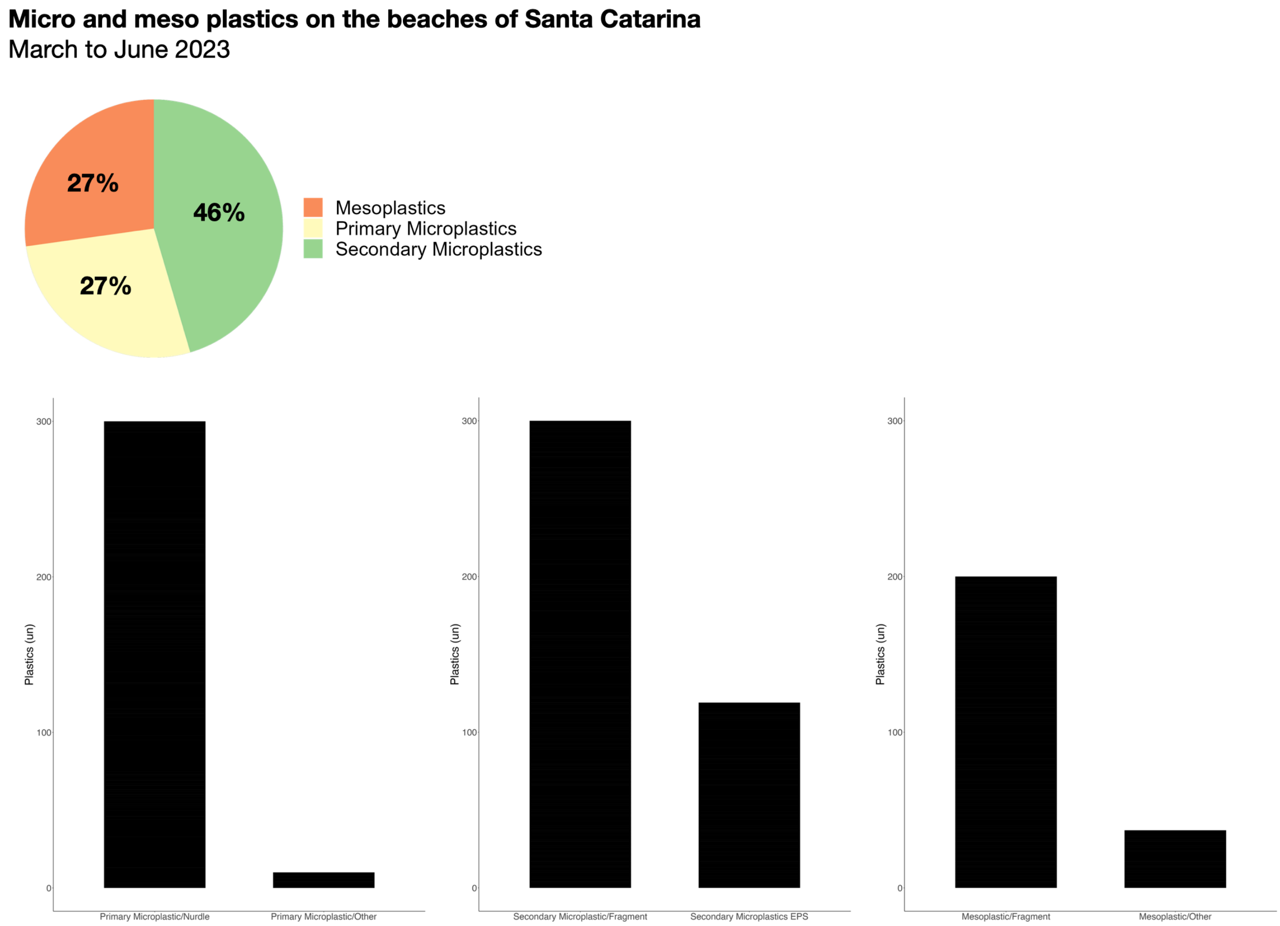


Figure 1. Total abundance (black bars) and occurrence records (pie chart) of micro and meso plastics on the beaches of Santa Catarina between March and June 2023.

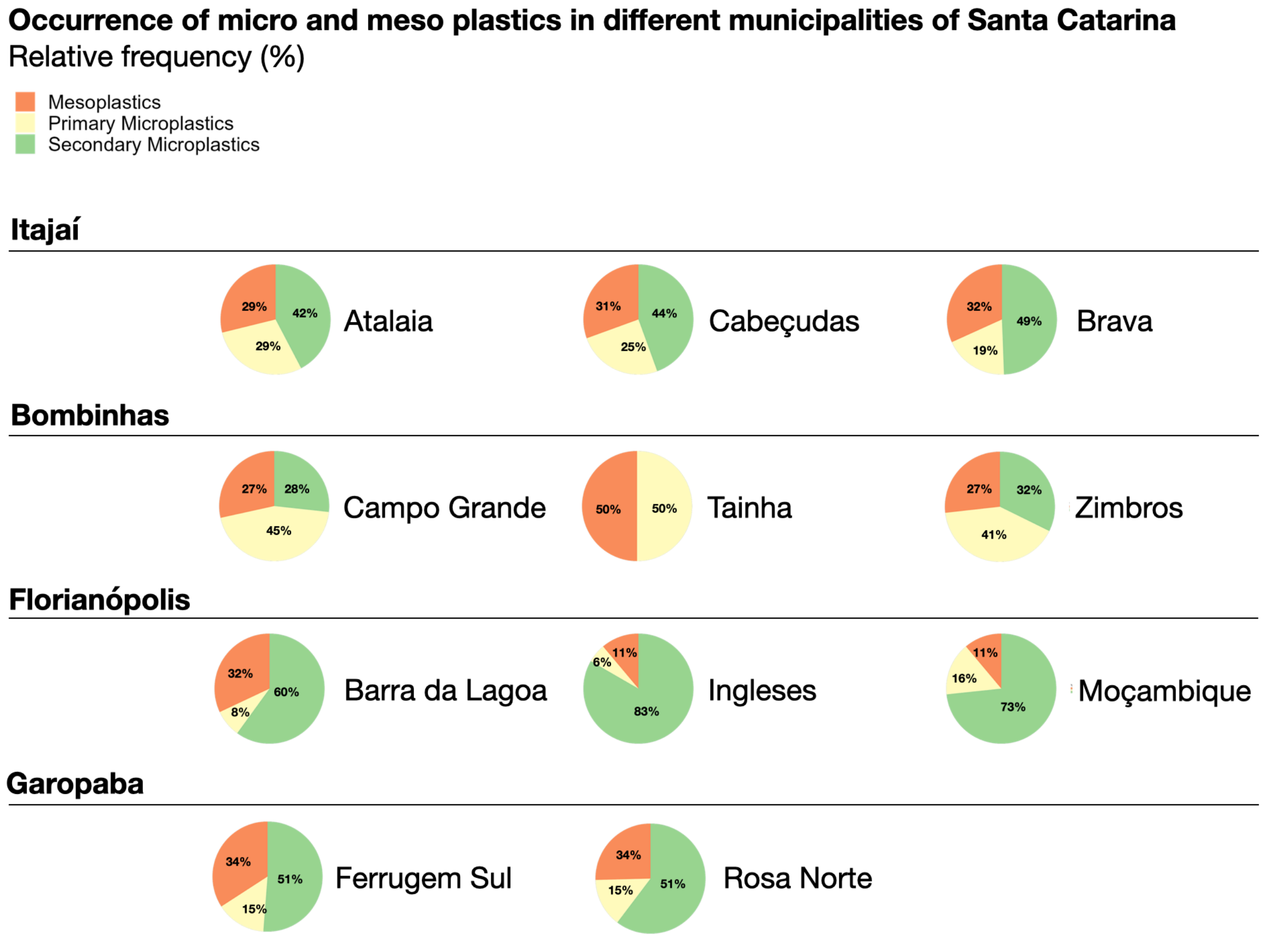


Figure 2. Occurrence of micro and meso plastics (relative frequency, % of records) on the beaches of different municipalities in Santa Catarina in March and June 2023.

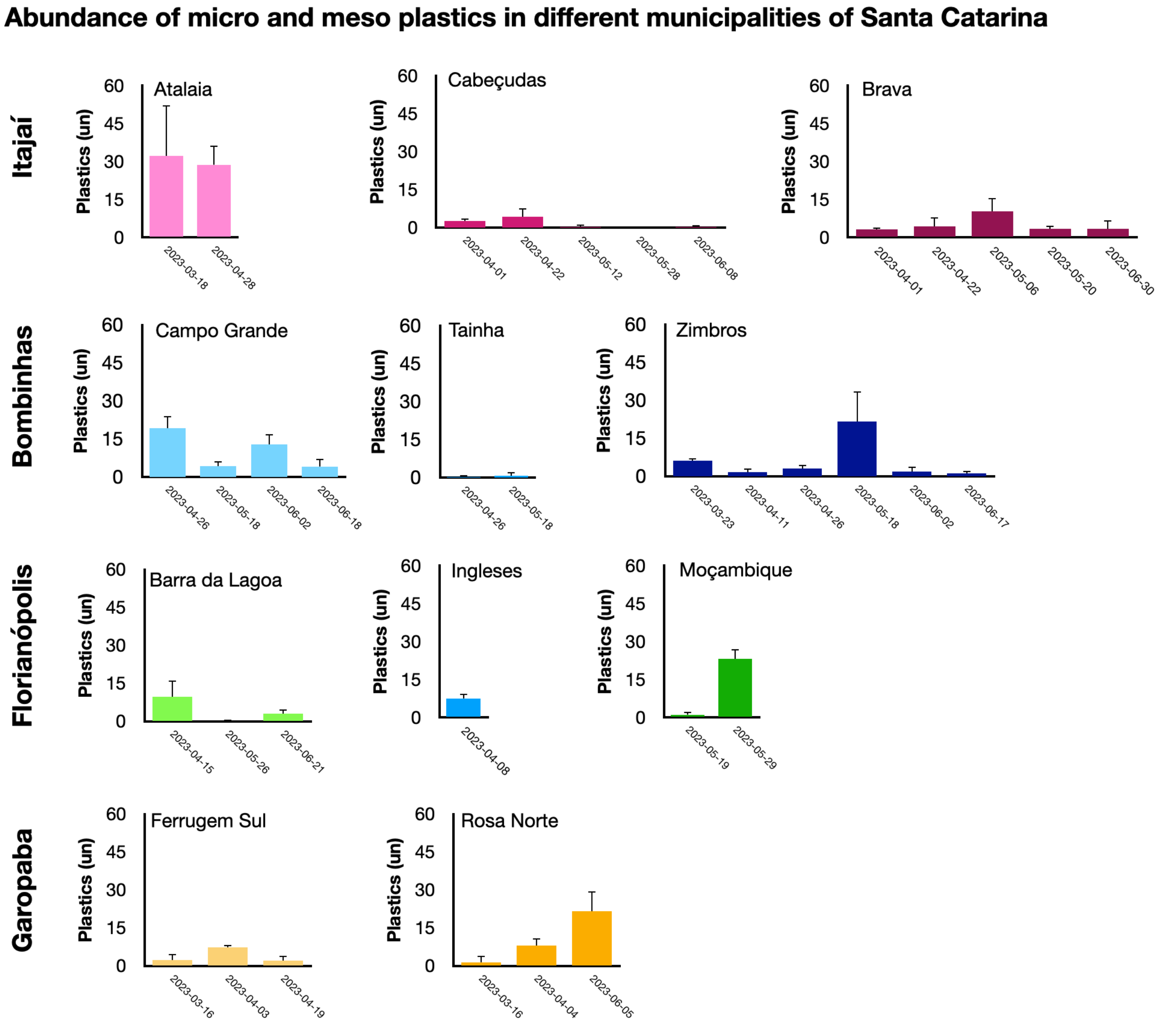


Figure 3. Abundance of micro and meso plastics (units per quadrat) on the beaches of different municipalities in Santa Catarina in March and June 2023. Note: average per quadrat in bars, standard deviation in error bars.

4.5. INSIGHTS

The Our Blue Hands monitoring built an important baseline to help understand the impacts of microplastic pollution on the beaches of Santa Catarina. The results showed that plastic fragments (micro and meso) are present in the sand of all the surveyed sites in significant numbers, indicating that these residuals are an important source of marine pollution across the region. Like many other coastal sites, Santa Catarina beaches reflect the serious problem that plastic pollution is posing to the health of our planet (Ocean Panel, Jambeck et al. 2020). Plastic fragments are found everywhere in the world, and, particularly, have been accumulated in the ocean for the past decades (Andrady et al., 2011). This plastic is not easily visible to humans but has a multivariate impact on sea life, habitats, and the services they provide to society. According to our findings, although there is spatiotemporal variability in the abundance and occurrence of plastics on monitored beaches, these fragments were present at all the surveys and indicate a constant pollution source.

There are several environmental and health risks associated with the presence of plastic fragments in sand or seawater. Plastic even in small pieces can be toxic to the organisms living in those marine compartments and magnify throughout the trophic web. Those effects are yet to be measured and require specific ecotoxicological. Monitoring data is fundamental to guide those efforts and to provide information on the type and amount of those plastic fragments. Cumulatively, the negative effects of microplastics on coastal and marine ecosystems are expected to pose serious harm to Ocean health. Many projects throughout the world are starting to evidence the impacts of those tiny plastics on the quality of seafood and water.

Overall, the monitoring registered more microplastics (63%; 27% primary, 46% secondary) than mesoplastics (27%), but this ratio was highly dependent on the area of the coast and municipality. For instance, sites in the Itajaí (central-north coast) tend to have more even quantities of primary microplastics, secondary microplastics, and mesoplastics. Beaches in Bombinhas (central-north) have more primary microplastics. Central and south beaches (Florianópolis and Garopaba/ Imbituba) have more secondary microplastics. Considering that often plastic pollution reflects land uses and sources, our results indicate that human pressure differs among the monitored sites and has a direct impact on beach environmental quality. These results are aligned with the community perception and the DPSIR matrixes and support previous studies that showed that the proximity to pollution sources and the position within the route of pollution transportation by ocean currents is a major force in the accumulation of microplastics on beaches (e.g., Sandu, C. et al. (2020).

The beach is an important coastal environment, which acts in the transition between land and ocean (Komar, 1998), numerous ecosystem services are provided for human well-being and biodiversity, for example, they serve as nurseries for some species that seek beach for spawning, coastal protection against high waves and storms, in addition to serving as a feeding environment for several species. The protection of this space is urgent, including the prevention of solid waste that reaches this environment. The occurrence of plastic waste on sandy beaches jeopardizes the quality of this ecosystem both at an environmental, economic, and social level (Andreussi, 2021; Ivar do Sul; Costa, 2007; Turra, 2011).

Regarding the economic aspect, it is known that the State of Santa Catarina is the second largest plastic producer in Brazil and accounts for 11% of the plastic product transformation. In 2020, up to 1,078 thousand tons of plastic products were processed. The sub-regions of the State of Santa Catarina are divided according to their specialty, the South is responsible for disposables, the West for packaging, and the North for civil construction and parts. According to the results, of the 1289 units found over the 36 campaigns on 11 monitored beaches, 46% were secondary microplastics, also known as expanded polystyrene and fragments. In addition to the high activity in the 1st sector, the State is home to 6 ports, the closest to the sampling region, Itajaí, Imbituba, and Navegantes, all of which operate with commercial operations and are equipped to receive all types of cargo. Despite not being the producer of the plastic resin itself, the State operates with a high intensity of plastic transformation activities, receiving the well-known pellet (primary microplastic) via ports. Responsible handling and shipping are two key factors in containing much of the resin dispersion in the aquatic and coastal environment.

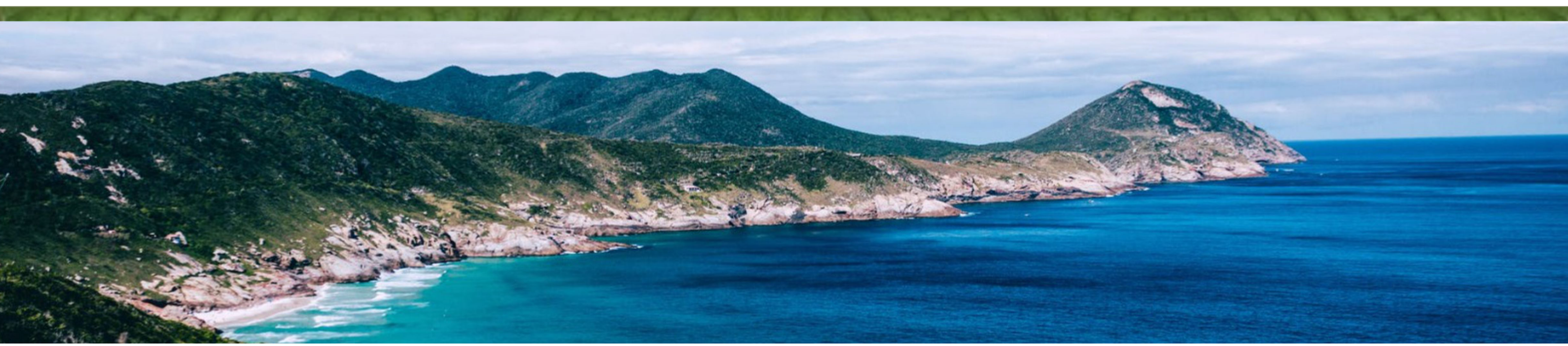
The beaches that recorded the highest occurrence of primary microplastics (>40%) were those located in the central-north sector, beaches that are influenced by the deposit of sediments corresponding to the alluvial plains of the Tijucas and Itajaí-Açu rivers (Fitzgerald et al, 2007), therefore they also contribute to all the polluting load that comes from the use of the Hydrographic Basin. According to a report by the Hydrographic Basin Committees, the polluting sources range from the drainage of urban-industrial centers, the very input of the polluting load that comes through the Bay, the irregular occupation of the riverbanks, in addition to the release of domestic sewage and the park industrial the municipality of Biguaçu, which in turn has at least 7 plastic industries

Microplastic is a direct consequence of the increased presence of plastic in coastal marine environments, whether due to environmental effects or anthropogenic effects (incorrect disposal and poor management of solid waste and even the lack thereof). Free et al (2014) suggest in their study that even places with low population density can be highly polluting through plastic consumption and lack of solid waste management in these regions. The presence of larger plastics or those in the process of fragmentation on the beaches may be related to land and sea deposits, in whichever way this waste reaches the beach, the fragmentation mechanisms are active and decompose this material over the months. The abundance of microplastic is related to the increase in precipitation rates, suggesting an increase in the flow of rivers and reaching the adjacent seas, the incorrect deposit of waste near rivers, estuaries, and even beaches and mangroves can also transport waste that when deposited on the beach sands, they are fragmented and persist there. The persistence of this material in the beach environment increases the availability of biota and makes biodiversity vulnerable.

Understanding the regional patterns of microplastic pollution in Santa Catarina will require data integration, with environmental, meteo-oceanographic, and demographic information. Even within a few days, the abundance of plastics on sand varied markedly between sampling surveys in most of the sites. Peaks in plastics on sand occur for various reasons and it is commonly associated with environmental drivers and/or seasonality of tourism. Santa Catarina coast is frequently (7 to 10 days average) influenced by the passage of cold fronts, which increase river discharge and wave and wind impact. Change in weather conditions is expected to be the main factor in either carrying more plastics to the beach or altering its composition, highlighting the relevance of seasonality on those patterns of marine litter (e.g., Balthazar-Silva et al., 2020).

The dynamics of accumulation of waste on beaches is related to the seasonality pattern in addition to the properties of the beach itself, such as the disposition of direction and exposure to environmental forcing (currents, winds, tide), and according to the results of this pilot, a greater occurrence of primary and secondary microplastics in the northern corner of the beaches of Mozambique (Florianópolis), Atalaia (Itajaí) and Rosa Norte (Imbituba) mainly in the months of April and May (autumn). According to Palma et al (2008), during the autumn and winter seasons, the dominance of marine currents incident in southern Brazil is directed towards the Northeast (NE) due to the greater action of the southwest (SW) winds. Despite the probability, the study time is still insufficient to corroborate the hypothesis that marine currents are the main driving force behind the accumulation of waste on beaches since this season also has a high rainfall rate.

FUTURE RECOMMENDATIONS AND PERSPECTIVES



Future recommendations and perspectives

Plastic pollution continues to accumulate in the oceans and fragment into different environmental compartments. There is a real probability, according to several scientific reports, that the harmful effects of plastic pollution will cross the threshold of an acceptable level and pose an unprecedented risk to society, species, and ecosystems. Solving the problem of marine litter consists of applying global, regional, and local systemic actions simultaneously to provide indicators for the management and improvement of environmental quality and ocean health. The Sustainable Development Goals play an extremely strategic part in this action plan, as it foster national and international alliances and partnerships and showcases the degradation or recovery of ecosystems.

Sharing information between local and regional stakeholders and citizens in Santa Catarina is extremely important for understanding the issue of litter at sea. Thus, the Our Blue Hands Project recommends that there is a continuous work of articulation and promotion of possible partnerships for monitoring actions aimed at the periodic provision of data on marine litter and microplastics. The organization of a monitoring program linked to the National Plan for Waste Management, in addition to strengthening a permanent communication channel between science and management, is fundamental to amplifying the impacts of the Our Blue Hands actions. In other words, it is important to target the implementation of this evaluation protocol with other existing public policies focusing on priority areas for conservation, where there is greater vulnerability.

We also strongly recommend building a collaborative plastic and microplastic pollution data platform and sustaining the ongoing engagement with the other municipalities, as well as active participation in collectively building the governance of plastic use and production. This implies common definitions, methods, standards, and regulations for an efficient system to combat plastic pollution throughout the life cycle of plastic. Besides, there should be an elaboration of an ongoing communication plan for environmental awareness with campaigns focused on waste and single-use plastic reduction, and stimulating medium and long-term attitudinal change.

Photo-gallery

Photo-gallery

Photo-gallery

Project Budget

2 cleaning prototypes	$348
Car and Gasoline Diaries	$135
Infrared Analysis	$100
Training	$200
Analysis of statistical data	$193
Fellowship	$400
Team supplies - consumables	$200
Extra training Team Santa Catarina Island	$150

Partner institutions:

IMA
Instituto do Meio Ambiente de Santa Catarina

FAMAB

DEEP BLUE
Ambiental

INIS
INSTITUTO ITAJAÍ SUSTENTÁVEL

R3 ANIMAL

PARQUE ESTADUAL DO Rio Vermelho
SANTA CATARINA . BRASIL

Digital resources

Website Our Blue Hands Project
www.ourbluehands.org

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