



Participatory Monitoring—A Citizen Science Approach for Coastal Environments

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In this article the authors share their experiences, results, and lessons learned during the creation of a coastal biodiversity participatory monitoring initiative. Throughout 2019, we delivered five training workshops to 51 citizen scientists. Data collected by the citizens scientists were validated by checking its similarities against that gathered by specialists. High similarity values were found, indicating that, if proper training is provided, there is a great potential for citizen scientists to contribute biodiversity data with high value. During this process a certain level of variation in data produced by specialists was found, drawing attention to the need for prior alignment among specialists who may offer training for citizens. In addition, despite overall similar results between specialists and participants, some differences emerged in particular parts of the habitat; for example, the bivalve zones presented higher complexity and hence greater challenge. Identifying key challenges for participants is key to developing appropriate citizen science protocols. Here it is provided preliminary evidence that supports the use of the monitoring protocol to obtain biodiversity data gathered by citizen scientists, assuring its scientific quality. Enhancing participation by the community and specialists is key to further validate the approach and to effectively expand such protocols, enhancing the level of biodiversity data collection. In order to promote participation, and maintain citizen scientist engagement in the initiative, it is recommended the development of new investigations that assess the interests and motivations of the public to take part. It is also fundamentally important to have an effective strategy to communicate the results of participants' monitoring and their applicability to local and global issues, thus maximizing the continuity of engagement of citizen scientists.

Keywords: citizen science, coastal ecosystems, biodiversity, community engagement, ocean literacy

INTRODUCTION

Among the ecosystems found on Earth, coastal marine environments are one of the most diverse and productive (Ray, 1996). Their vast biodiversity is responsible for many ecosystem services, including those that benefit humans (Nellemann et al., 2009). Despite this, biodiversity loss continues to accelerate (Brondizio et al., 2019), under pressure from a range of different sources including pollution, overexploitation, and climate change (Agardy, 2007). Concern regarding biodiversity loss in marine systems is such that the UN has proclaimed the Ocean Decade

for Sustainable Development (2021–2030) (United Nations, 2019)¹, a period to promote ocean science and support the efforts to overcome social environmental issues closely linked to marine ecosystems. For that, monitoring programs are essential, to establish the current status of biodiversity, detect its natural fluctuations and follow the consequences of different pressures over it. In this way appropriate management and conservation efforts may arise.

Biodiversity monitoring programs support researchers to detect changes in observed patterns and also to propose different investigation strategies. Such programs are essential to provide subsidies for public policies that are aligned with marine conservation and sustainable development. However, maintaining biodiversity monitoring schemes requires significant resources, which in many contexts can be a great challenge to overcome. As an alternative, many researchers have implemented citizen science initiatives as a tool for both acquiring biological data, but also approximating society to the academic realm and promoting environmental awareness (Stepenuck and Green, 2015). Citizen science was pointed as a key strategy to achieve the Aichi Biodiversity Target 18 in coastal zones after 2020 (Fajardo et al., 2021), stressing its important contribution to environmental and social sciences, while co-producing data that are fundamental for integrated management.

Citizen science is understood as the volunteer contribution to science made by members of society who lack formal scientific training (Bonney et al., 2009). Although citizen science has been evident for centuries (Miller-Rushing et al., 2012) it has grown considerably in recent times. As a consequence data that otherwise could not have been acquired has been gathered (Miller-Rushing et al., 2012), while engaging many members of the population in environmental issues and impacting management decisions (Chandler et al., 2017a). It is aligned with the concept of ocean science for the Ocean Decade (Intergovernmental Oceanographic Commission of UNESCO, 2020)² where the role of social and environmental sciences together is a key point. Also, citizen science is an important strategy to promote ocean and science literacy, by engaging layman people with ocean sciences (Kelly et al., 2019).

Different learning and educational outcomes can be achieved through citizen science: e.g., acquiring new knowledge about specific subjects (Brossard et al., 2005) or greater understanding and awareness of the scientific process (Ruiz-Mallén et al., 2016). Also, participating in a citizen science initiative can enhance people's sense of well-being due to its direct contact with natural spaces (Nellemann et al., 2010). Despite the broad impact that citizen science projects can have (Hecker et al., 2018; Shirk and Bonney, 2018), these initiatives still face challenges to reach their full potential. Integrating data that has been collected into official documents or scientific publications in peer-reviewed journals is a first barrier encountered (Delaney et al., 2008; Lukyanenko et al., 2016). As data is being collected by people with different

skills and knowledge, there is a need for scientific validation, to assure data quality. In this context, validation procedures to assess the accuracy and precision of data sampled by participants are necessary to enhance citizen science reach and acceptance by the scientific community (Lukyanenko et al., 2016; Aceves-Bueno et al., 2017).

THE SOCIAL-ECOLOGICAL CONTEXT

Brazil has a coastline of continental proportions, comprising 8.500 km of different ecosystems. Among those, rocky shores are used as models in the studies of marine biodiversity and in the determination of ecological patterns and processes between the planktonic and benthic environments (e.g., Kasten and Flores, 2013; López et al., 2014; Mazzuco et al., 2015). They are home to many different commercially important species such as the mussel *Perna perna* (da Silva et al., 2009; Casarini and Henriques, 2011). Moreover, rocky shores support many organisms that are already living in their extreme temperature tolerance (Foster, 1971; Firth and Williams, 2009), being much more sensitive to the effects of climate change and, thus, good biological models in climate change studies. In this way, rocky shores are key environments to be monitored when trying to understand and predict the responses of biodiversity to the different threats it suffers.

This study was developed in the “Baixada Santista” region which is home to the largest harbor of Latin America. It also includes a mosaic of natural reserves and protected areas. Local biodiversity is threatened by the consequences of intense industrial activity and urbanization processes on the region (Miloslavich et al., 2016), enhancing the need for monitoring protocols. In this urbanized region, rocky shores, sandy beaches, and mangroves form part of the natural backyards for the population.

Within this scenario, the authors outline an unprecedented citizen science project for coastal marine biodiversity monitoring on the southern coast of Brazil. The purpose of this study was to develop and validate the data from the citizen science program, considering the identity, culture, and social aspects of the volunteers involved. The objectives were: (i) to build and apply a monitoring protocol for coastal biodiversity (rocky shores being used as a model); and (ii) to validate data produced by volunteers following traditional scientific procedures, through tests of similarity. Also, we provide an overview of the profile of the people involved, their motivations to take part in the given initiative, providing baseline knowledge and information for the continuity of this initiative and other practitioners in similar contexts.

TRAINING WORKSHOPS, DATA VALIDATION, AND BIODIVERSITY PERCEPTION SURVEY

The rocky shore chosen for the field survey is the only natural rocky shore found at the study site (“Urubuqueçaba Island” at the

¹<https://www.oceandecade.org/>

²<https://www.oceandecade.org/news/72/Version-20-of-the-Ocean-Decade-Implementation-Plan-submitted-for-presentation-to-the-United-Nations-General-Assembly>

city of Santos). It is easily accessible by the public and anecdotal evidence suggests that Santos' inhabitants show an emotional connection to this place, a fact which could improve people's interest in the initiative.

Key partnerships were established with different institutions for the development and delivery of this initiative. A partnership with researchers at Bangor University, part of the Capturing Our Coast project (Garcia-Soto et al., 2017a) provided knowledge and strategy exchange before the development of the training workshop. The first author of this study had the opportunity to know and experience *in situ* different protocols of the 3-year citizen science project, established to gather data and to help understand the distribution of rocky shore species around Britain's coast, particularly within the context of climate change. Members of the this research team (PK and RC) were also trained by British Council's Active Citizen Program (British Council, 2021a,b),³ a social leadership program that equips members of the community to promote intercultural dialogue in the search for local solutions that are aligned to global challenges. Skills gained were fundamental as the authors were also interested in providing a training workshop that could promote environmental citizenship (Jørgensen and Jørgensen, 2020). From these experiences, the training workshop was designed to cater for the local context in Santos, Brazil, but also considering successful strategies used by the CoCoast team and applying the Active Citizens tools to engage our participants in the process. Also, the Secretary of Environment from Santos was a local partner essential for the divulgation of the initiative, using their official media channels and providing logistical assistance for the field surveys.

Training Workshops

Workshops were designed not only to coach participants into applying the monitoring protocol, but also to promote environmental awareness and citizenship. The workshops consisted of three parts: (i) contextualization of the project, group engagement, and reflection on the local community's role in the participatory monitoring scheme; (ii) theoretical concepts of rocky shore ecology and monitoring methodology; and (iii) practical activity in the field (applying the monitoring protocol).

Citizens were invited to enroll in the workshop through posts on social media by local groups of organized volunteers, students, associations, and others who shared an interest in the theme of the initiative. With the assistance of the Secretary of Environment of Santos, the invitation was promoted through their official channels and also broadcast the invitation through one of the local TV channel daily news programs. The only prerequisite to enroll in the workshop was to be older than 18 years old.

Contextualization of the Project and Group Engagement

During 2019, five training workshops were delivered. The research team received 123 registration of interest, 62 people participated only in the first two parts of the training (and

completed the Biodiversity Perception Survey), and 51 people were completely trained (participated in all three parts of the training). These were then part of our citizen science network. It consisted of an equal gender ratio (51% women and 49% men), with most aged between 18 and 33 years old (62%), but there were also participants (37%) between 34 and 42 years old or over 42. Participants' backgrounds ranged from undergraduate students and professionals from environmental fields (such as biology or geography), retirees, primary, and secondary teachers, environmental technicians, and managers to engineers and journalists.

The workshops began with a brief time-line of the development of the project, its objectives, and perspective of applicability of the data gathered. Then, participants were asked to share phrases or words that expressed their expectations about the workshop and the project. The same procedure was done to assess participants' skills and knowledge they believed they have and could be beneficial for the project's development. This activity was important to align the participants with the purpose of the project, and minimize any feelings of frustration regarding participants' expectations. Also, it created an atmosphere of well-being and trust among the group, as everyone could picture their role in the project and observe that each individual could contribute to the group effort.

Following the sharing of up to three words/sentences by participants to express their expectations of the project, the most used terms were calculated. People mostly expected to acquire knowledge (mentioned 36% of times), learn (22%) more about the environment (21%), and about rocky shores (14%, **Figure 1A**).

Interestingly, many of the words used to express their expectations were also used to express how participants could contribute to the project (**Figure 1B**). Participants considered they could contribute with knowledge (28%; both in environmental and scientific areas), experience (9%), time (5%), and commitment (9%). Other personal characteristics such as goodwill, willingness, and easygoing nature were often mentioned by the participants as ways of contributing to teamwork.

The research team wanted to engage participants in reflections and discussions on how citizenship, science, and decision-making related to each other, and then propose possible solutions for existing challenges. For that, the participants were divided into smaller groups and each received one or two sets of questions: (1) What do you understand by participative monitoring? How can citizens engage in environmental issues? What challenges are there in the relationship between citizens and decision-makers? (2) How do you think science and citizenship relate to each other? Which qualities of citizens can contribute to science and nature preservation? What challenges are there in the relationship between science and citizenship? Groups shared their ideas with the rest of the participants and further discussions were mediated by the research team. With this activity it was expected to awake in the participants their sense of environmental citizenship, understanding their roles both in the cause of some issues, but also as part of the solution, with their behaviors and actions.

³<https://active-citizens.britishcouncil.org/>

and fill in the same datasheet they used in the field, before submitting it to the responsible researcher.

Organisms Identification Similarity

The number of different organisms identified on each picture by the participants was compared to the number of organisms identified on that same picture by the specialists. With this procedure, it was possible to assess the degree of variation in the number of organisms identified between the participants and specialists. For this purpose, the Sørensen similarity index was calculated (Sørensen, 1948; Wolda, 1981) for each picture. The values of this index range from zero (no similarity) to one (complete similarity). The Sørensen similarity index can be calculated by the following formula:

$$S_s = \frac{2a}{2a + b + c}$$

where:

S_s = Sørensen similarity index

a = the number of organisms identified by the participants and the specialists

b = the number of organisms identified by the participants, but not by the specialists

c = the number of organisms identified by the specialists, but not the participants.

Percentage Cover Similarity

To evaluate the similarity of participants' organism counts compared to that of specialists, the Percentage Similarity (PS) value was calculated, as proposed by Renkonen (1938) (Wolda, 1981). The percentage cover of each organism identified by the participants and the specialists, for each picture analyzed were compared. To calculate the Percentage Similarity value proposed by Renkonen, the following formula is used:

$$PS = \sum_{\min}(P_{1i}, P_{2i})$$

where:

PS = percentage similarity between samples 1 and 2 (1 = specialists, 2 = participants)

P_{1i} = cover percentage of organism *i* in sample 1

P_{2i} = cover percentage of organism *i* in sample 2.

The values for this index range from zero (no similarity) to 100 (complete similarity) and, although it is a rather simple metric, this measure is one of the most efficient indices for quantitative similarity calculation (Wolda, 1981).

All 51 participants who completed the training workshop (three parts) were invited to participate in all the monitoring events and also to take part in the validation process. After the consultation, six participants (11.76%) agreed to analyze the pictures.

High values of similarity between species identifications made by participants and specialists were found (S_s = 0.74 ± 0.12 SD). When looking separately at the two main zones monitored in the rocky shore (cirripede zone, corresponding to the high intertidal; bivalve zone, corresponding to the medium/low intertidal), pictures from the cirripede zone resulted in higher values of similarity (S_s = 0.81 ± 0.03 SD) when

compared to the bivalve zone (S_s = 0.69 ± 0.13 SD; **Supplementary Figure 1**).

When comparing the frequency of times a specific organism was detected by the participants and the specialists (Student's *t*-test for independent variables for all pictures), a significant difference was only found in the frequency of detection of periwinkles; participants showed a significant reduction ($p < 0.05$; $t = 4.409$; $df = 7$; **Figure 2A**). The variation among observers detecting oysters, algae, and mussels was higher in the participants than in the specialists group. This difference was higher when considering percentage cover. This result indicates that the degree of concordance between specialists and participants can vary depending on the organism being monitored, and this must be considered for long-term plans (Cox et al., 2012).

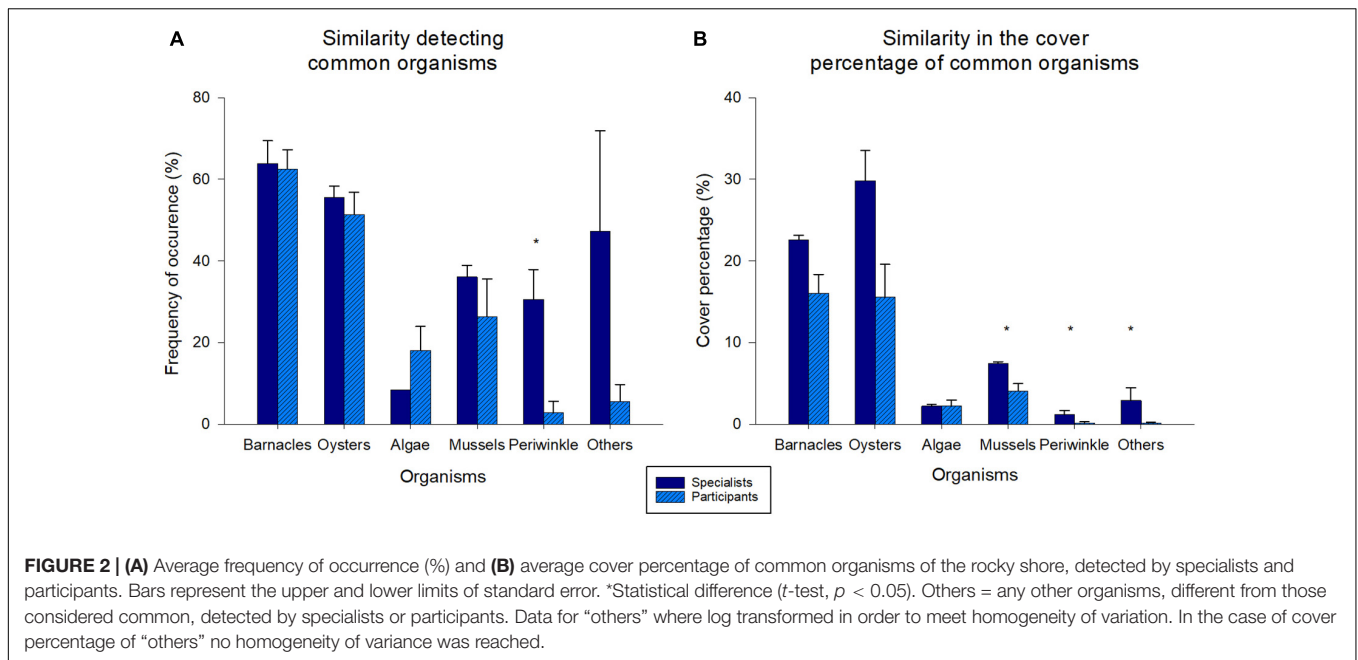
It is important to point out that, even after log transformations, no homogeneity was found in the variance within the specialists identification of "other" organisms, which did not allow further comparisons between the observers. Considerable variation among specialists identification of "other" organisms was detected (**Figure 2A**), which indicates that even among specialists discrepancies in identification data might emerge. This result draws attention to the necessity of a previous alignment among specialists who might offer future training in order to reduce great variability in data collection.

After testing for the similarity between observers counting of each organism (and thereafter their stipulated cover percentage), an overall percentage of similarity value of 77.88 ± 15.19 SD was obtained. As observed for the similarity in detecting the organisms in the different zones, participants' count of the animals in the cirripede zone was more similar to the count of specialists (PS = 94.09 ± 2.47 SD) in comparison to the counts of animals in the bivalve zone (PS = 66.30 ± 9.17 SD; **Supplementary Figure 2**).

When assessing statistical differences for the counts of each common organism, it was observed that specialists counted (Student's *t*-test), on average, more mussels ($p < 0.05$; $t = 2.60$; $df = 7$), periwinkles ($p < 0.05$; $t = 2.74$; $df = 7$), and other organisms than the participants ($p < 0.05$; $t = 2.59$; $df = 7$; **Figure 2B**). Here we observe again that, although no statistical significance was achieved, specialists tended to recognize and register a higher percentage cover of oysters present than the participants. During the validation process of the pictures, it was observed that participants had more difficulties distinguishing between live and dead oysters, which could result in this discrepancy. Also, participants had an expressive low count frequency of the organisms which were considered to be other than the main groups investigated (**Figure 2B**). This points to a limitation to our analysis, and further discussion regarding this result should be cautious.

Biodiversity Perception Survey

To assess participants' overall perception and knowledge of biodiversity, an environmental perception survey was applied (found at **Supplementary Material**). This was held after the participants had already introduced themselves and learned about the project's timeline. In total, 62 people took part



in this survey, with 50% of them female and most (61.2%) between 18 and 34 years old and the other 37.8% were between 35 and 64 years old. Virtually half of the participants had completed the secondary education degree (48.3%) or were undergraduates (50%).

When analyzing the results, it was perceived that the public involved in the workshop were already engaged in other environmental activities (such as environmental education projects or activism) and were well aware and informed about many of the biodiversity issues questioned in the survey. The majority of people knew what the term "biodiversity" is (77.42%), but less than half of respondents felt informed about biodiversity loss (37%). Most respondents perceived water and air pollution (98.4%), intense agriculture, deforestation and overfishing (96.7%), disasters caused by humans (91.9%), and climate change (62.9%) as great threats for biodiversity (**Supplementary Figure 3**). Also, the great majority (70.97%) responded they are already affected by biodiversity loss and about one-fourth (24.19%) believe they will be affected only in the future. Following a similar pattern, 72% of respondents indicated they already strive to protect biodiversity, but wish they could do more (**Supplementary Figure 4**). Such findings demonstrate the participant's concern about the present state and future of our biodiversity.

Participants were also questioned about which measures they agreed Brazil should take to protect its biodiversity. The great majority agreed that: citizens should be better informed about the importance of biodiversity (98.3%); more research about the impacts of biodiversity loss should be promoted (88.7%) and protected areas in Brazil should increase (80.7%). Most people also agreed that Brazil should allocate more financial resources for nature's protection (74.2%), create financial rewards for nature conservation (66.1%), and guarantee financial support for activities that

consider biodiversity protection in their practices (59.7%; **Supplementary Figure 5**).

DISCUSSION AND CONCLUSION

Throughout the first year of this participatory monitoring scheme, engaging with local citizens was successful. Participants were well informed and aware of different issues regarding biodiversity and were willing to dedicate their free time to discuss issues related to monitoring rocky shores. Such outcome is probably a consequence of the invitation strategy used, that could have narrowed the communication to groups of people already active in other environmental initiative, and, thus, who are prone to be more informed about the subject. In this initiative, a simple protocol to be used by citizen scientists was developed, tested and validated for the quality of the data gathered by participants. These findings provide evidence that this biodiversity monitoring scheme with a citizen science approach has great potential to be applied along the Brazilian coast, contributing with scientifically sound data, which, in turn, benefits not only the scientific community but also the engagement of citizens with marine sciences and conservation.

It has been shown that, when participants are properly trained to identify local marine organisms and to apply a monitoring protocol, data gathered by them are highly similar to those gathered by specialists, both in precision and accuracy. Nevertheless, the identification of benthic organisms at zones with a higher level of complexity (for example the bivalve zone) (Seed, 1996; Kovalenko et al., 2012) seems to be where further training is necessary. A discrepancy in the identification of uncommon organisms by citizen scientists and specialists is expected and has been previously documented (Cox et al., 2012; Forrester et al., 2015). One interesting finding was the

observed variability among the specialists in the identification of organisms other than the common groups targeted. Such findings draw attention to the necessity of an alignment between trainers before delivering workshops for general participants. Promoting continuous data quality assessment through the initiative (Balázs et al., 2021) is important to achieve robust data (Bonter and Cooper, 2012).

The successful development, implementation, and validation of this monitoring protocol was the first step to deliver a scientifically sound methodology with the potential to be applied along many rocky shores. Nevertheless, the next challenge to be faced to guarantee the quality of data gathered and the longevity of the initiative is in maintaining citizens involved in the project. People have different interests when participating in initiatives like this one and new participants might have expectations other than those already known. Combining the low response rate in the validation process (around 11%), along with the restricted number of participants who engaged in the monitoring days after the workshop, it is clear that interest or engagement with the initiative's goals is a limiting factor. Perhaps a possibility to have more participants involved in the validation process is to keep participants informed (and reminded) of the importance of this procedure for the applicability of the outcomes (Balázs et al., 2021). Also, it has been shown that communication about the application of the data gathered is fundamental to maintain participants engaged and interested (Schlappy et al., 2017). This stresses also the importance of an interdisciplinary team, where specialists in social sciences and communication could promote different strategies for engagement.

It is true that monitoring initiatives with a citizen science approach can greatly contribute to progress in ocean sciences (Couvret et al., 2008; Chandler et al., 2017b). Yet, this experience showed the importance of actually developing further the "citizen aspect" of these programs. Great care must be taken not simply to see the citizen science approach as a means to rapidly (and cheaply) gather high volumes of data. Implementation of Citizen Science initiatives in the marine realm is a grand opportunity to promote people's ocean literacy (UNESCO, 2017), develop the environmental citizenship of participants (Jørgensen and Jørgensen, 2020), and produce knowledge that is co-created (Garcia-Soto et al., 2017b). For that, researchers from the environmental fields could benefit if trained for conflict mediation and intercultural dialogue and apply such skills when designing their citizen science initiative. In this experience, the Active Citizen training allowed the incorporation of different activities in the workshop that resulted in group trust and environmental reflections that otherwise would not have emerged. Also, the collaboration among people of different backgrounds and experiences in participatory research is the proper path to co-create new scientific questions that are truly aligned with the community's needs (English et al., 2018).

As now the Ocean Decade begin (United Nations, 2019), great efforts are being made to promote a more inclusive and participative ocean science, that shares knowledge and information with a multitude of audiences. Citizen science monitoring programs for marine biodiversity such as the one

presented here have the potential to fulfill such demand while providing important evidence for many different ecological processes, essential for biodiversity conservation. Greater attention should be given to some topics before and during the training workshops: the alignment of identification skills among the specialists who are to provide training workshops, and more attention when training participants to identify organisms in complex regions of the environment. To maintain the enthusiasm and motivation of participants involved in the project, we recommend further assessment of people's expectations and interests and constant communication about the results that will be obtained and their usage. With the experience presented here and with further adjustments recommended, participatory monitoring of marine biodiversity through a citizen science approach can be the path for a more environmentally engaged society with a deeper understanding of the ocean.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The study was approved by the "Research Ethics Committee of the Universidade Federal de São Paulo (CEP/UNIFESP n:0852/2018), having obtained the informed consent of the participating adults. All subjects gave written informed consent in accordance with the Declaration of Helsinki.

AUTHOR CONTRIBUTIONS

PK contributed to the conception and design of the study, execution of workshops, and drafting and revising the manuscript critically. SJ contributed to the conception of the work and revising the manuscript critically. RC contributed to the conception and design of the study, supervision of activities, and drafting and revising the manuscript critically. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fmars.2021.681969/full#supplementary-material>

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