UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO
CENTRO DE CIÊNCIAS HUMANAS E NATURAIS
PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS BIOLÓGICAS

Comparison between an existing *ad hoc* Marine Protected Area (MPA) and a Marxan prioritization model

Natalia Brandao Vieira

Vitória, ES
Setembro, 2021

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Orientador: Dr. Agnaldo Silva Martins
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Dissertação submetida ao Programa de Pós Graduação em Ciências Biológicas (Biologia Animal) da Universidade Federal do Espírito Santo como requisito parcial para a obtenção do grau de Mestre em Biologia Animal.

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Once again, here, I am thankful to God's presence inside of me, for it is the only reason why I could manage for the past two years.

I dedicate this work to all people struggling with mental health issues, hence I do know how the challenge is much harder on us, and how those outside our sphere often misjudge.

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May life allow me to live the present moment, and keep bringing love to everything I do. May I not lose myself again, and if I do, may I know how to come back.

"Perceber no mar que o infinito não assusta, se estivermos dispostos a preenchê-lo."

Unknown Author

SUMMARY

RESUMO

Áreas Marinhas Protegidas (MPAs) são uma estratégia amplamente utilizada para garantir a conservação de ecossistemas e da biodiversidade. No entanto, a adoção de um método *ad hoc* no planejamento de MPAs pode diminuir a representatividade da biodiversidade conservada, por geralmente priorizar áreas com baixa ameaça e menor exploração de recursos. Desta forma, o avanço do Planejamento Espacial Marinho levou ao desenvolvimento de ferramentas de suporte à decisão específicas para realização do Planejamento Sistemático para Conservação (PSC), que demonstram resultados satisfatórios para seleção de áreas prioritárias para conservação. Este estudo faz uma comparação entre uma MPA, criada de forma *ad hoc*, existente em uma região importante ecológica e economicamente no sudeste do Brasil, e um modelo de priorização desenvolvido com o software Marxan, como um exercício de PSC dos habitats bentônicos da região, usados aqui como indicadores de biodiversidade. Os resultados demonstraram que a área de proteção existente não atinge a meta de conservação da maioria dos habitats, além de não incluir nenhuma fração do habitat de recife mesofótico. Adicionalmente, o polígono existente representa o local com o maior custo de conservação para a pesca, o que pode levar a uma diminuição da efetividade da área de proteção. Por outro lado, a melhor solução fornecida pelo modelo representa uma seleção de áreas que cumprem as metas dos alvos de conservação, dando preferência às unidades de planejamento com o menor custo para pesca. O modelo gerou também um mapa com a frequência de seleção de cada unidade de planejamento, promovendo flexibilidade para adoção de ações de conservação. Apesar das restrições dos habitats como alvos de conservação e das metas experimentais, os resultados indicam áreas importantes para ações de conservação mais representativas dos ambientes marinhos da região, além de fornecer um modelo organizado para receber incrementos de dados sobre biodiversidade e demais custos de conservação, permitindo o alcance de um efetivo planejamento sistemático para conservação marinha local, com as devidas discussões com *stakeholders* para evitar conflitos de uso e manter a sustentabilidade ambiental.

ABSTRACT

Marine Protected Areas (MPAs) have been a broadly used strategy to ensure ecosystem and biodiversity conservation. However, the adoption of *ad hoc* frameworks in the designing process of MPAs networks have been narrowing down their capacity of conservation by selecting non representative areas where exploitation is restrained and there is least need for protection. In this sense, advances in the Marine Spatial Planning field have led to development of specific decision support tools that help in the Systematic Conservation Planning (SCP) process, which have been demonstrated satisfactory outcomes for selecting priority areas for conservation. This study makes a comparison between an existing MPA, created in an *ad hoc* context, located in an economically and ecologically important region in South Eastern Brazil, and a prioritization model developed with the software Marxan as an SCP exercise in the same area, using benthic habitats as surrogates of biodiversity. The results showed that the current MPA fails in meeting conservation features' targets of most of the habitats used as surrogates of biodiversity and does not include any portion of mesophotic reefs representation. Additionally, this perimeter is the region with higher conservation costs for fisheries, which may interfere with the effectiveness of the MPA. On the other hand, the best solution provided by the model is a selection of areas that in the same time meets the conservation features' targets while aiming at planning units with the least possible conservation costs for fisheries. The results also include a map of the selection frequency of each planning unit, giving flexibility to possible conservation measures adopted. Despite restrictions that using habitats as surrogates for biodiversity and their respective arbitrary targets may bring, the results indicate important areas for more representative conservation measures for the marine region, besides providing a model organized to receive new data regarding ecological and economic matters. This way, it is possible to achieve an efficient SCP for the local biodiversity, with the proper discussions between stakeholders, so that they avoid conflicts in use, and at the same time maintain environmental sustainability.

1. Introduction

Over the past decades, economic development has led to an exponential increase of exploratory pressures in marine and coastal habitats related to natural resources (Reid et al. 2005). According to Jones et al. (2018), only 13.2% of the world’s oceans are evaluated as largely free of human impact, and approximately three quarters of the areas under national jurisdiction have evidenced biodiversity loss (Halpern et al. 2015). Therefore, the implementation of ecosystems and biodiversity conservation and restoration plans needs immediate attention. Considering this, international policy initiatives have set conservation targets, for instance The Convention on Biological Diversity (United Nations Environment Program 2010) which had agreed on conserve at least 10% of coastal and marine areas until 2020, as well as The Agenda for Sustainable Development (United Nations 2015), that determined this same goal for the short term.

For this matter, Marine Protected Areas (MPAs) have been a broadly used strategy (Edgar *et al.* 2014), seeing that their benefits include enhancement of recruitment, increase in stock abundance, restoration of healthy ecosystems, and even a subsequent spillover to adjacent areas, which may also help the fishing industry (Afonso *et al*. 2018; Roberts *et al*. 2005). Currently 7.65% of the oceans are under some sort of protection, distributed amongst 17,828 MPAs (UNEP-WCMC and IUCN 2021). However, fully and highly protected areas correspond to a small proportion of this number, and together with limitations in design, management and compliance, it strongly narrows down the capacity of reaching their conservation targets, reducing the quality of this network (Boonzaier and Pauly 2016). Additionally, there is a growing concern that in order to fulfill the proposed targets, countries have been establishing residual MPAs in areas where exploitation is restrained and there is least need for protection (Pressey *et al.* 2015). Thus, proper coastal and marine management planning, including both existing and new MPAs, is urgent and should focus on conservation goals and biodiversity traits based on scientific knowledge (Spalding *et al.* 2016).

In this sense, Marine Spatial Planning (MSP) has demonstrated satisfactory outcomes as a process for guiding the distribution of ocean space use, in which both conflicts and trade-offs are still minimized, and it prevents degradation of environmental significant and sensitive areas (Ehler and Douvere 2009; Stelzenmuller *et al.* 2013). The Systematic Conservation Planning (SCP) framework can potentially support the implementation of MSP, since it is an integrated and objective based approach that utilizes multiple datasets for identifying priority areas for biodiversity conservation (Margules and Pressey 2000). The SCP process has been applied globally (Álvarez-Romero *et al.* 2018) and it contemplates not only the necessity to protect a representative sample of ecosystems and their species, in a way that allows them to persist over time, but also the need for spatial efficiency and the economic importance of each region (Kukkala and Moilanen 2013).

The different phases of SCP may be assisted by decision support tools, such as the conservation planning software Marxan (Ball *et al.* 2009), which has been the most broadly used one in the world (Alvarez-Romero *et al.* 2018). This software helps the process of designing marine protected areas' networks, by setting conservation targets (e.g. a proportion of selected habitats, endangered species, etc.) to be achieved with the minimum possible cost, facilitating prioritization issues solving (Gandra *et al.* 2017). SCP and Marxan have been essential in providing an opposite path from an *ad hoc* and opportunistic approach, which lack scientific and technical criteria and are usually driven by conservation urgencies and favorable political and/or economic matters (Groves *et al*. 2002; Vilela and Bomfim 2014). Although publications using SCP and Marxan have significantly increased in the last ten years, there are still many gaps and challenges in transitioning from *ad hoc* patterns to a systematic planning approach, especially in regions with insufficient scientific data and where deficient communication between stakeholders and policy-makers prevent the awareness of existing conservation planning exercises (Alvarez-Romero *et al.* 2013; McIntosh *et al.* 2016).

The Brazilian Exclusive Economic Zone (EEZ) for instance has 26.8% of its extent officially under protected areas, however, 87.3% of this proportion still allow human economic activities (UNEP-WCMC and IUCN 2021). Most Brazilian MPAs have had an *ad hoc* approach, and since the fully protected areas are insufficient, many threatened species usually fall under the protection of least effective MPAs and trade-offs are not considered (Magris and Pressey 2018; Sala *et al.* 2018). Accordingly, the MPA network in Brazil fails to evenly represent the diversity of marine and coastal ecosystems (Soares *et al.* 2017). The majority of them have inadequate management and enforcement (Mills *et al.* 2020) and represent one of the world's greatest gaps in species protection (Giglio *et al.* 2018). The gap and lack of representativeness stand out in regions with limited information about ecosystem and species composition, such as the coast of the state Espirito Santo, located in Southeastern Brazil, which may again pose a serious threat to biodiversity conservation in view of the significant ecological and economic importance of this region (Soares *et al.* 2017). In spite of sheltering one of the greatest extensions of rhodolith beds of the Atlantic, various benthic and pelagic endemic species and important ecosystems such as mesophotic reefs, the state of Espirito Santo is the most critical area for conservation measures (Villaschi and Silva 2015; Vila-Nova *et al.* 2014).

In this context, not only is it essential to better plan new MPAs networks, but it is also urgent to review the ones created from *ad hoc* and opportunistic approaches in order to ensure that they are achieving conservation outcomes. For this matter, SCP exercises using Marxan may play an important role by establishing fair conservation targets, prioritizing the selection of more compact spaces with the least possible economic cost. In Espírito Santo's coastal and marine region's background, fishing is, at the same time, the most substantial economic activity and the major stoppable threat to marine species when a proper MSP process occurs (Vilar and Joyeux 2021). This way, an experimental SCP model can offer support to decision-makers while evaluating the efficiency of existing MPAs. Correspondingly, the aim of this study is to **assess the biodiversity representativeness and the conservation costs for fisheries in an existing MPA compared to a scenario modeled using Marxan in a region of SE Brazil**. In order to carry out this aim, the objectives are as it follows: 1 - Evaluate the representativeness (%) of conservation targets (habitats) in the existing conservation scenario (Environmental Protected Area of Setiba); 2 - Evaluate the conservation costs for fisheries in the existing conservation scenario; 3 - Evaluate the representativeness (%) of conservation targets (habitats) in the scenario modeled using Marxan; 4 - Evaluate the conservation costs for fisheries in the scenario modeled with Marxan; 5 - Compare the existing conservation scenario with the scenario modeled with Marxan.

2. Materials and Methods

2.1. Study Area

The study area is situated in the state of Espírito Santo in the southeast brazilian continental shelf, in whose marine area occurs the geographic transition from tropical to hot temperate area, being influenced by two marine currents, one of which is rich in nutrients (Horta 2001). These characteristics allow great biodiversity of algae, which has been related to habitat heterogeneity and high benthic richness (Aued *et al.* 2018).

With an approximate area of 1050 Km^2, the study region has as its north limit the location of Ponta da Fruta in the municipality of Vila Velha (40.3315260°W 20.4520653°S) and as its south limit the location of Meaípe in the municipality of Guarapari (40.5598069°W 20.7716585°S). The coastal line defines the west limit, and the region extends for 12 nautical miles east, which corresponds to the Territorial Sea length. The study area's depth ranges from 0 meters to 66 meters and it comprises benthic ecosystems formed by both consolidated bottoms (reef formations, calcareous algae/rhodolith beds) and unconsolidated ones (mud and sand). Besides, there is also a complex of coastal islands formed by the islands Escalvada, Rasas, the Archipel Três Ilhas, and other smaller ones, in addition to shipwrecks such as Bellucia and the artificial one Victory 8B (Figure 1). This region has been ecologically characterized by Teixeira *et al.* (2017), whose habitat distribution data provided the basis for the ecological dataset of the present study. Given the great biodiversity and richness of the region and the proximity to urban areas, many economic activities thrive on marine resources with the most significant one being fishing. This economic activity includes several fishing practices including troweling, line fishing, dive fishing, "mariscagem"[1] and net fishing, usually on a local fisheries scale.

[1] Mariscagem: artisanal fishing characterized by the activity of catching or collecting shellfish.

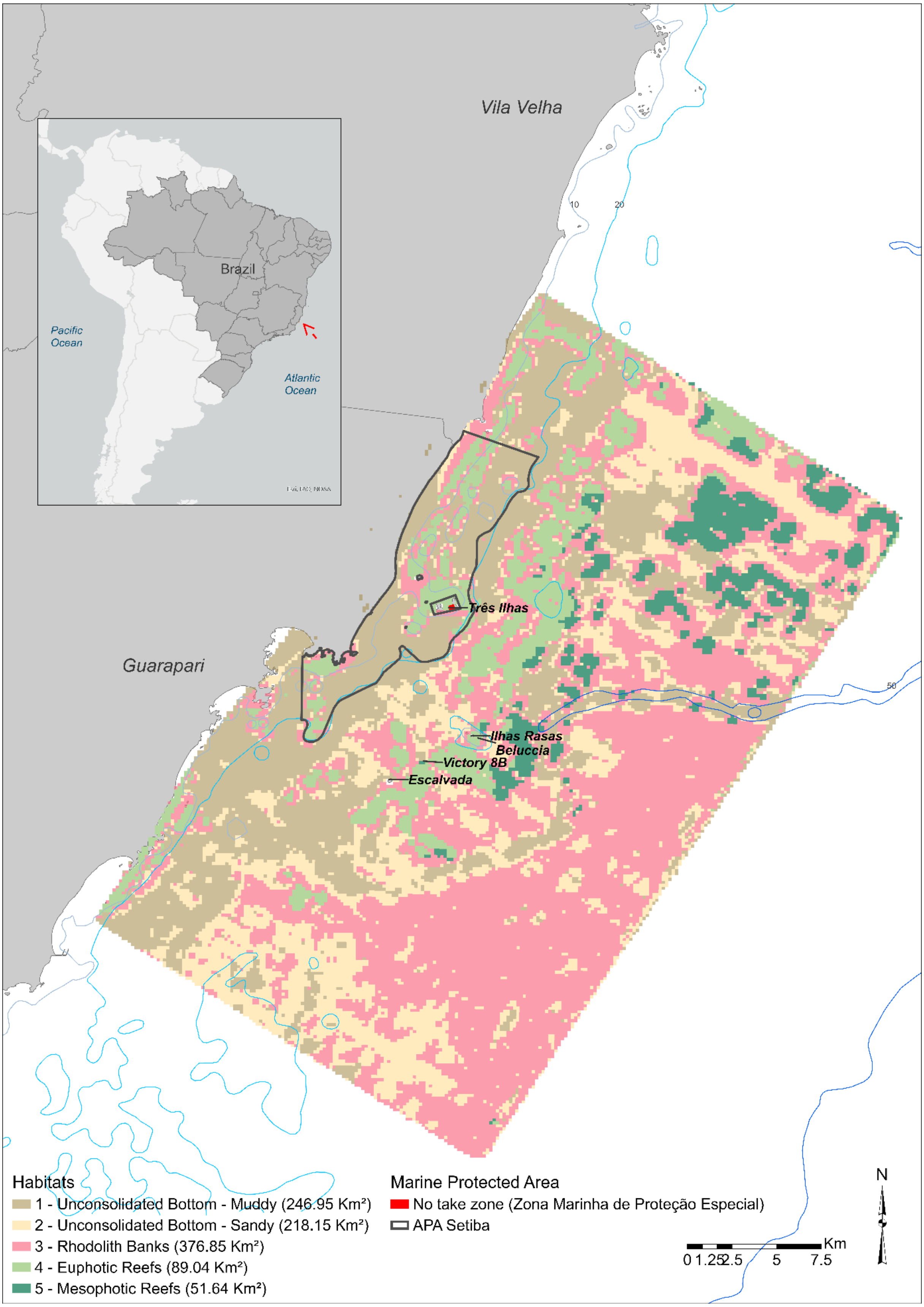

Figure 1 - Location of the study area, distribution of the different types of habitats and existing MPA.

2.2. Existing Marine Protected Area (MPA of Setiba)

In the planning area there is a conservation unit under Espirito Santo's jurisdiction that includes 69 Km² of marine territory. This Conservation Unit was first implemented by decree number nº 3.747-N in 1994 as "Área de Proteção Ambiental Três Ilhas" (Environmental Protected Area Três Ilhas), and in 1998 it became "Área de Proteção Ambiental de Setiba - APA de Setiba" (Environmental Protected Area of Setiba). According to the decree, following an *ad hoc* framework, initially the main objective of the APA de Setiba was to buffer possible impacts in the Paulo Cesar Vinha Park, which is part of its terrestrial portion, and to conserve and manage marine resources for the current economic activities. However, even within the upcoming management and zonation plans, there was never a rigorous evaluation of conservation effectiveness, considering habitat's representativeness and conservation targets. In addition to this gap in scientific knowledge, according to the current management plan of APA de Setiba, only 0.05% of the marine area covered fits into the full protection category (no-take zone), which is equivalent to 0,034 Km² from the total area of 69 Km². Hence, human activities are still allowed inside the area under protection. For this study, the existing MPA makes reference to the whole perimeter of the marine portion of APA de Setiba and disregards the possibility of human activities inside this selected region (Figure 1).

2.3. Spatial Datasets

In order to fulfill the objectives of the present study, the following datasets were considered:

2.3.1. Ecological Dataset

Taking into account information about the study area's habitat distribution (Figure 1) (Teixeira *et al.* 2017), conservation features (i.e. species or habitats of conservation interest) and their respective conservation targets were set. Hence, for this study, the habitats are used as surrogates of biodiversity.

The region of interest is characterized by both unconsolidated and consolidated bottoms (Figure 2). The unconsolidated bottoms (soft bottoms) include environments where the seabed consists of mud or sand, which store and recycle sand and sediment for other habitats, besides providing space for marine animals to forage, spawn and burrow (Snelgrove 2010). Additionally, since a great variety of life inhabit muddy and sandy bottom environments (e.g. worms, snails, clams, crabs, sea cucumbers, etc.), many other species also feed on them and on the macro and microalgae that grow there (Thrush *et al.* 2001). Therefore, they sustain multiple life forms, including some intrinsically related to economic activities, which gives them important ecological and economic roles (Cahoon 2017).

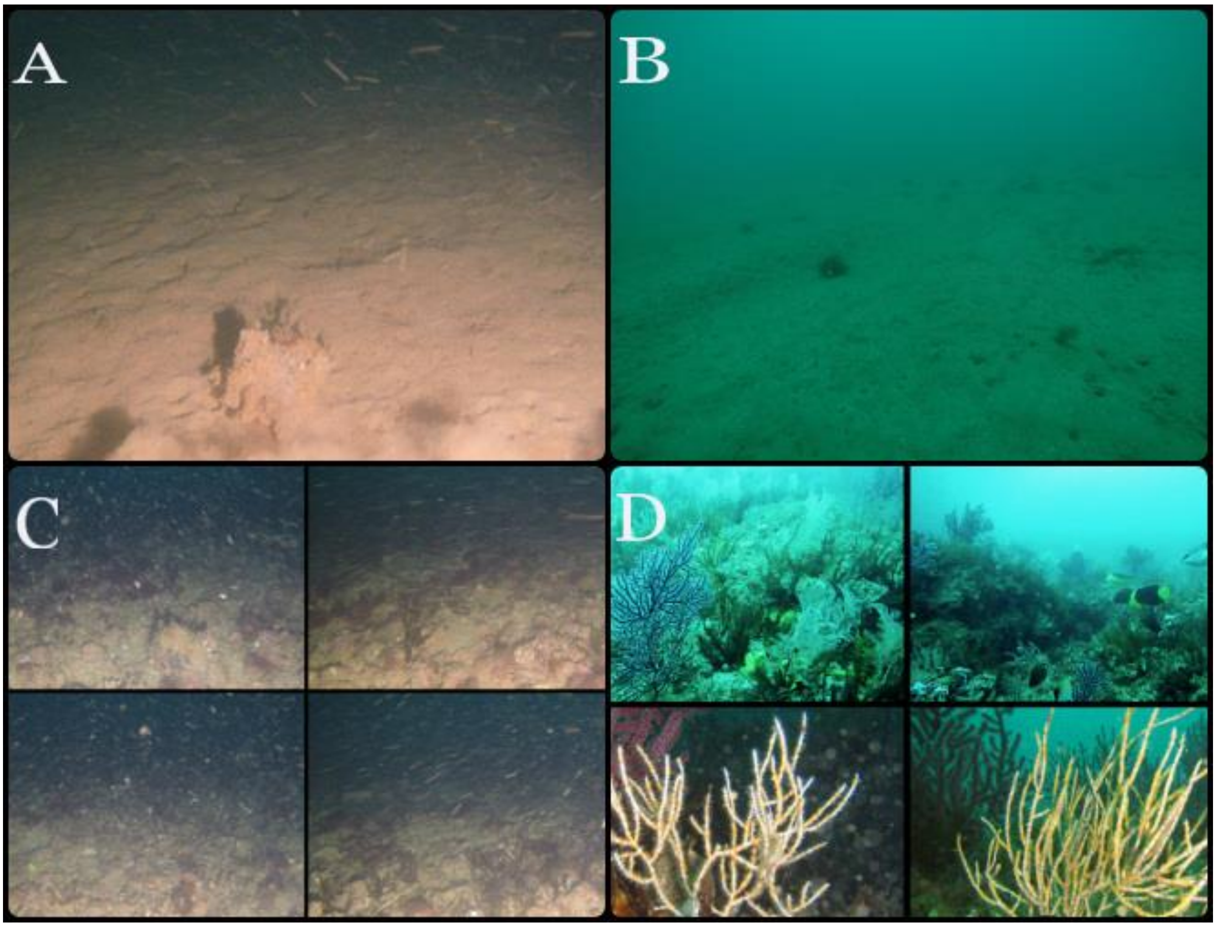

Figure 2 - Habitats of the study area. (Quadrant A: Unconsolidated Muddy Bottoms; Quadrant B: Unconsolidated Sandy Bottoms; Quadrant C: Consolidated Bottoms - Rhodolith Beds; Quadrant D: Consolidated Bottoms - Rocky and Biogenic Reefs). Source: Teixeira et al. 2017.

On the other hand, the consolidated bottoms include rhodolith beds, euphotic reefs and mesophotic reefs. Rhodoliths are nodules formed by calcareous marine algae with various morphological formats and free living forms, usually distributed over the continental shelf seafloor with moderate hydrodynamics (Amado-Filho et al. 2017). Rhodolith formations are one of the most important marine ecosystems in Brazil considering they provide a great number of ecosystems services for many species (e.g. shelter and nursery areas), even economically relevant ones, harboring rare and endemic fauna and flora (Riosmena-Rodriguez and Medina-Lopez 2010; Otero-Ferrer et al. 2019). At the same time, rocky and biogenic reef bottoms are distributed in euphotic (>30m) and mesophotic (<30m) zones, and also play an essential role in maintaining benthic and pelagic biodiversity, as the shallow ones act as nursery and the deep ones as reproductive aggregate areas for reef and commercial species (Teixeira *et al*. 2017).

Considering the distribution of these five habitats, the economic activities related to each of them, their sensibility to anthropogenic pressures and their ecological importance, arbitrary targets were set for each of them, in order to fulfill objectives 1, 3 and 5 (Table 1). For unconsolidated bottoms, the conservation target is to fully preserve 10% of the total habitats coverage, whereas for consolidated bottoms, the conservation target is to fully preserve 30% of the total habitats coverage, which is usually the ideal target (Ardron *et al.* 2010).

Table 1 - Conservation Features and Respective Targets.

Unconsolidated Bottoms		**Consolidated Bottoms**		
1 – Muddy	2 – Sandy	3 – Rhodolith Beds	4 – Euphotic Reefs	5 – Mesophotic Reefs
10%	10%	30%	30%	30%

2.3.2. Socioeconomic Dataset

Although many anthropogenic pressures affect this region, fishing activities are the most threatening ones, with a high relationship between fisheries and ecological damage. Therefore, this study considers conservation costs related to fisheries in order to evaluate the socioeconomic impact of the existing MPA and the possible cost for establishing fully protected MPAs. The present work uses data relative to the distribution of different types of fishing activities and the number of boats associated with each one of them, available in the management plan for the existing MPA de

Setiba. This way, the fishing effort spatial data makes reference to five categories: dive fishing (10 boats), “mariscagem” (18 boats), trawling (57 boats), net fishing (95 boats) and line and hook (206 boats) (Figure 3). Accordingly, the cost is relative to the expected number of boats per planning unit that would be affected if that region is no longer available for exploitation.

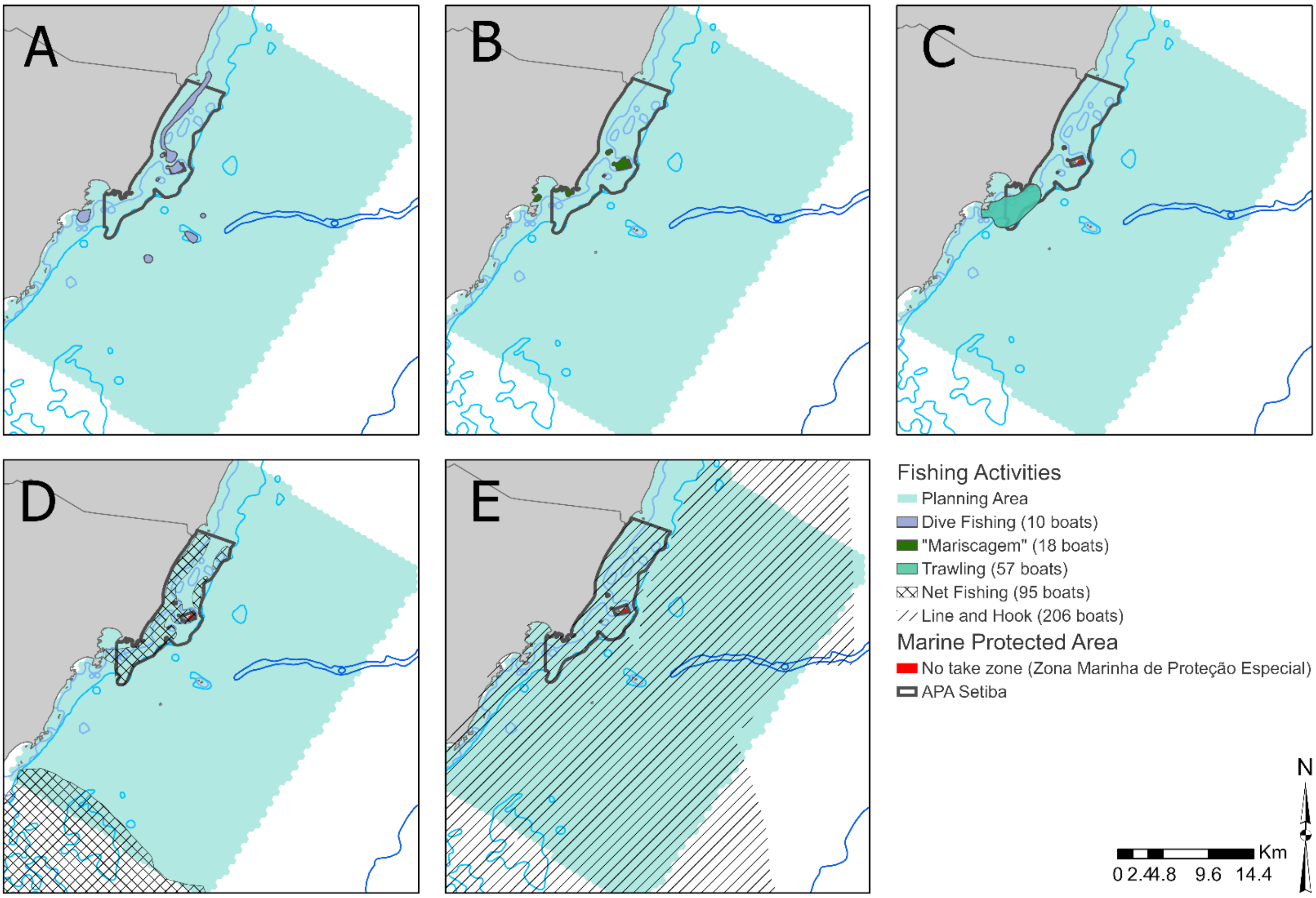

Figure 3 - Conservation costs related to fisheries: dive fishing (A), "mariscagem" (B), trawling (C), net fishing (D), line and hook (E).

2.4. Spatial Analysis

For the spatial analysis, the study region was segmented into planning units (PUs) with an hexagon shape and an area of approximately 0,5 Km² each. For both existing MPA and Marxan model contexts, the conservation features and respective targets were as stated above, as well as the conservation costs for fisheries.

In the Marxan model (Ball *et al.* 2009), the software calculates a *score* for each *planning unit*, taking into account three aspects: 1) the planning unit's cost; 2) the Species Penalty Factor (SPF), considering the achievement or not of conservation feature's targets; 3) Boundary Length Modifier (BLM), avoiding fragmented solutions, aiming for the connectivity principle. For the model development, both BLM and SPF parameters were well tuned according to the Marxan Good Practices Handbook (Ardron *et al.* 2010). After 500 runs, the model presents as final results the best solution, which means that within those 500 solutions, which one has the lowest *score,* and also a map with the selection frequency of each planning unit, making it possible to obtain certain flexibility from the decision support tool. In order to be able to compare the existing MPA and the Marxan model, the best solution was considered, but this study also presents the selection frequency map. It is already expected to be a discrepancy between the actual legal framework and the model's best solution, but the comparison between the scenarios may help visually demonstrate the differences to stakeholders and decision-makers.

3. Results

3.1. Biodiversity Representativeness

Even considering the existing MPA of Setiba as a fully protected area, it would still only fulfill the conservation target for the feature unconsolidated muddy bottom, covering 15.28% of the total distribution of this habitat. As for the other conservation features, the existing MPA includes 1.71% of the total coverage of unconsolidated sandy bottoms, 2.9% of the total area characterized by rhodolith beds and 18.33% of euphotic reefs. On top of failing to achieve the conservation targets for these three features, it also does not include any portion of mesophotic reefs (Figure 4).

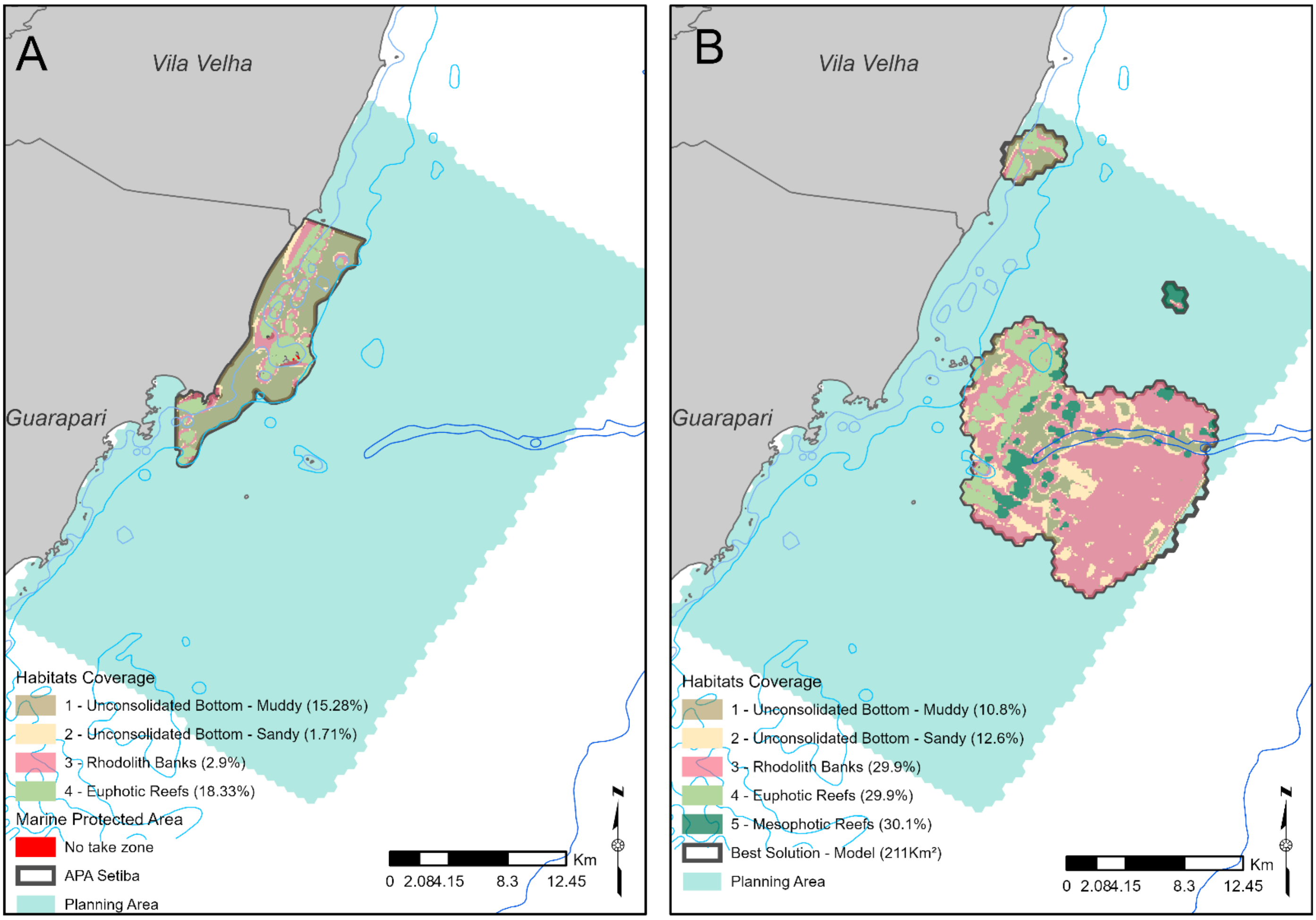

Figure 4 - Conservation features' distribution inside the existing MPA of Setiba (A) and inside proposed MPA by model's best solution (B).

On the other hand, the best solution given when running the model developed succeeds to reach all the conservation features targets in a selected area with the lowest possible cost. This region covers 10.8% of unconsolidated muddy bottoms, 12.6% of unconsolidated sandy bottoms, 29.9% of rhodolith beds, 29.9% of euphotic reefs and 30.1% of mesophotic reefs (Figure 4), which again, are not included in the actual MPA. It is also possible to notice that there was almost no intersection between the area proposed by the MARXAN model and the existing protected area.

3.2. Conservation Costs for Fisheries

Considering the existing MPA of Setiba as a fully protected area, the total conservation costs for fisheries would be 100,124 fishing boats affected. This region includes the planning units with the highest conservation costs for fisheries, which are the ones where multiple types of fishing happen, so if it were a no take region, it would impact the activity of more boats (Figure 5). For this reason, although the total area of the existing MPA is limited to 69 Km^2, it is a more costly zone, which makes the conservation cost for fisheries per planning unit the value of 592.4 per P.U..

On the other hand, the best solution given when running the model developed has a total conservation cost for fisheries of 179,492 fishing boats affected. This region includes planning units with lower conservation costs for fisheries, which are the ones with less or no fishing activities, therefore besides reaching the conservation features targets, it would also impact the activity of less boats (Figure 5). For this reason, the best solution includes a bigger area than the existing MPA (211 Km^2) but despite having a bigger total cost, the conservation costs for fisheries per planning unit would still be lower, with the value of 453.3 per P.U.

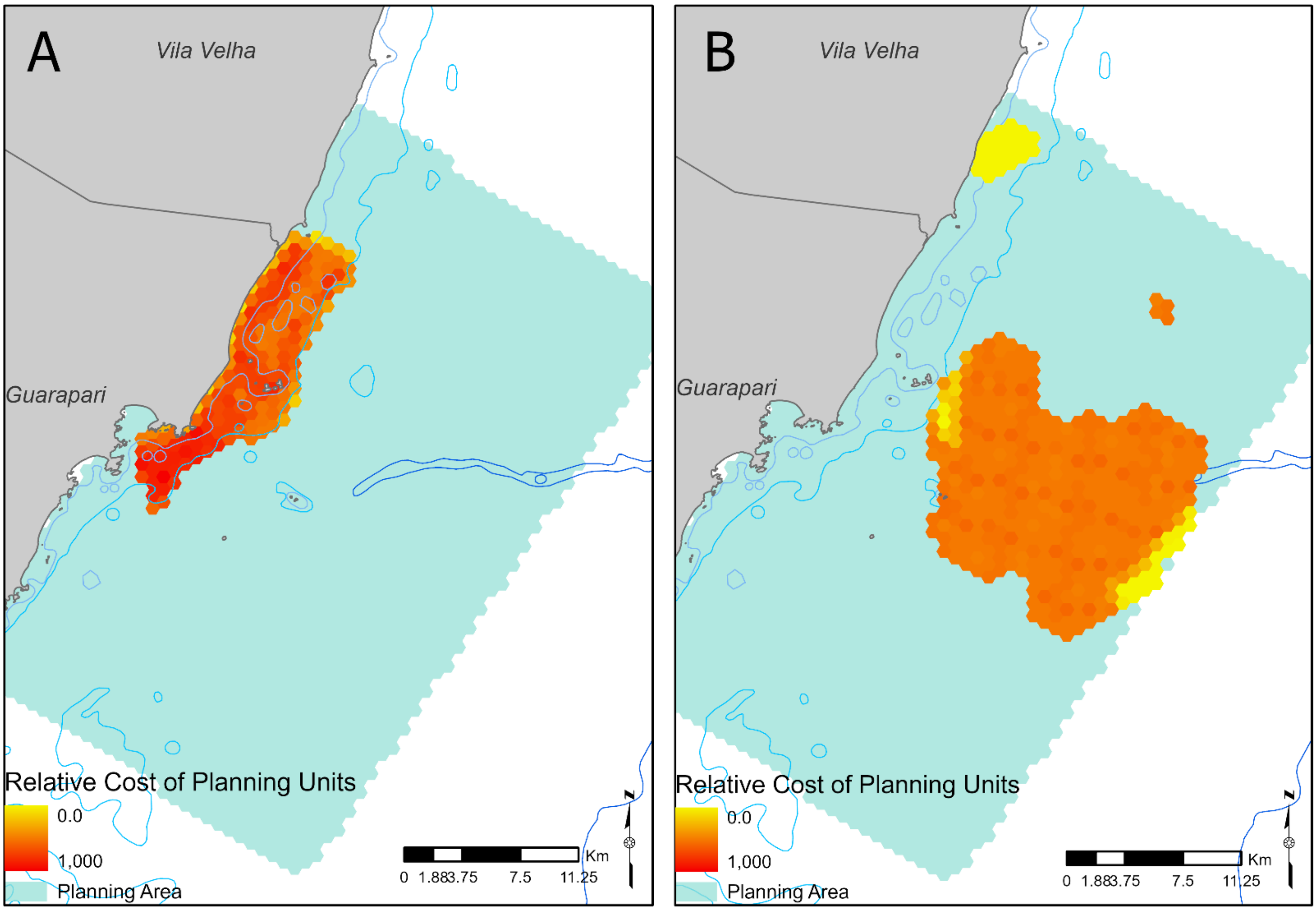

Figure 5 - Conservation Costs for Fisheries in existing MPA of Setiba (A) and in MPA Proposed by Model's Best Solution (B).

3.3. Flexibility of the Model

In addition to the best solution result, the model also provides this study with a map of the selection frequency of each planning unit (Figure 6), which would mean, how many of the 500 solutions given select each P.U. to be protected. According to this data, decision-makers could make trade-offs and still be able to accomplish conservation targets. It is interesting to notice that, again, the planning units with the highest frequency of selection are not included in the existing MPA region. In fact, with the exception of four P.U.s inside the current preserved area, the other ones were never selected in the model for any of the 500 solutions.

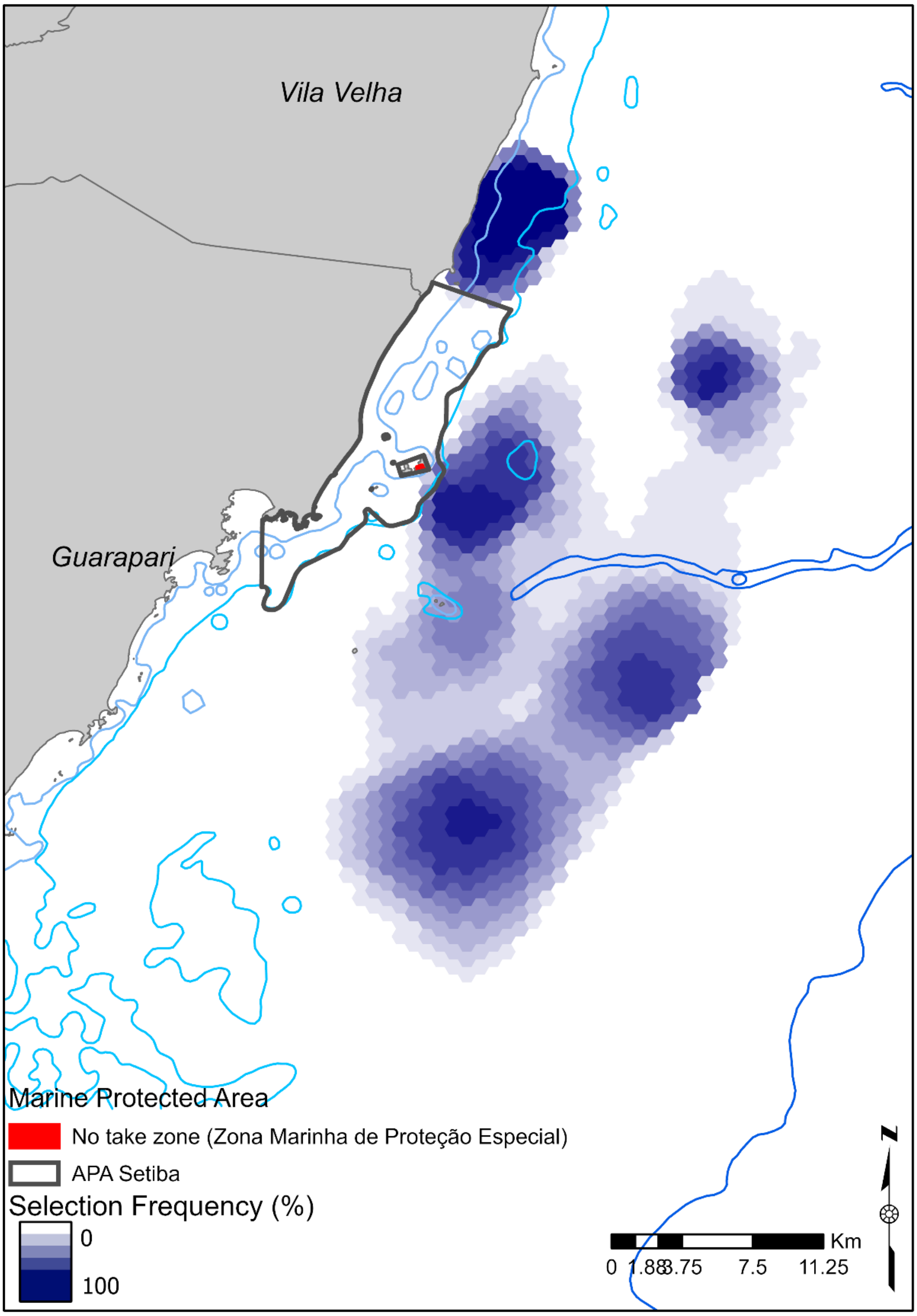

Figure 6 - Map of Selection Frequency of Each Planning Unit Considering the 500 Runs by the Model - Flexibility of Solutions.

3.4. Comparison between the Existing MPA of Setiba and Marxan's Best Solution

Table 2 - A summary of the comparison between the existing MPA of Setiba and MARXAN's best solution scenario

	Existing MPA of Setiba	MARXAN's Best Solution
Area	69 Km²	211 Km²
Unconsolidated Muddy Bottoms (target 10%)	15.28%	10.8%
Unconsolidated Sandy Bottoms (target 10%)	1.71%	12.6%
Rhodolith Beds (target 30%)	2.9%	29.9%
Euphotic Reefs (target 30%)	18.3%	29.9%
Mesophotic Reefs (target 30%)	0	30.1%
Total Cost (estimated number of boats)	100,124	179,492
Cost per Planning Unit	592.4	453.3

4. Discussion

The marine and coastal zone of the Southern area of the state of Espírito Santo comprehend a network of vital habitats such as muddy and sandy unconsolidated bottoms, rhodolith beds and reefs, and they support the highest algal diversity in the Southwestern Atlantic, including endemic ones (Amado-Filho *et al.* 2007). These habitats, used in this study as surrogates of biodiversity, are also hotspots for other endemic species and for threatened reef fish, so in view of their unique features, the region should be a national priority area for marine conservation (Vila-Nova *et al.* 2014). Nonetheless, the results of the present work have shown that the current area of the MPA of Setiba provides only partial protection for most habitats, and no protection at all for mesophotic reefs. More importantly, the actual management plan of the MPA still allows human activities inside almost all its range, preventing efficiency of the protection.

By doing a conservation prioritization exercise and developing a model to be used in a potential implementation of marine reserves, it was possible to simulate a best scenario for MPA's network. Within this best solution, all the conservation features' targets were met, which already represents a great evolution from the actual context, which contains a minimum portion of rhodolith beds coverage, for instance. By meeting the conservation target for rhodolith beds, one ensures the protection of this important hotspot for algal diversity of the Atlantic, and prevents the expanding damages inflicted on this habitat by mostly limestone overexploitation and trawling fisheries (Davies et al. 2007). Additionally, it also preserves the diversity of marine invertebrates and fish associated that sometimes is even bigger than in adjacent unconsolidated bottoms (Villas-Boas *et al.* 2014; Steller *et al.* 2003).

Another important aspect of the obtained results is the lack of coverage of mesophotic reefs in the existing MPA of Setiba, which has its conservation target met by the model's best solution. Although most studies regarding reef fauna assemblages have been conducted in shallow areas, the potential role of mesophotic reefs acting as refuges where climate change has affected other habitats has been calling attention to them (Rocha *et al.* 2018). Especially in regions where most fisheries resources are already overexploited (Martins *et al.* 2009), it is essential to preserve mesophotic reefs as reef fish may migrate to offshore deeper areas when they reach maturity and a bigger size (Verweij *et al.* 2007). Moreover, some economically and ecologically important species, such as groupers and snappers, form spawning aggregations in these deeper reefs, making this habitat fundamental for their reproduction (Aschenbrenner *et al.* 2016).

The use of a decision support tool such as MARXAN allows the incorporation of socio-economic aspects into the prioritization exercise. This study and the model developed use the most important economic activity of the region, which is fishing, as a conservation cost, so it creates a foundation for possible future trade-offs discussions with different stakeholders (Matos Ribeiro *et al.* 2020). It is important to say that other socioeconomic costs may be integrated into the model for an efficient planning process. It is interesting that either the best solution scenario or the planning units with higher selection frequency are both located outside of the existing MPA of Setiba area. This result is probably due to the high conservation costs for fisheries associated with the area inside the current perimeter under protection, where different types of fishing overlap, so this activity would be deeply affected. This is an example of how *ad hoc* marine protected areas are usually more costly than ones selected under a systematic conservation planning approach, besides also generally being ineffective on reaching conservation targets (Vieira *et al.* 2019).

The application of SCP exercise demonstrated herein has a few limitations that could be related to absence or low quality of information for the study area. More precisely, data on the specific distribution of endemic species and endangered ones such as groupers (IUCN 2021). The coast of Espírito Santo is one of the most diverse and less studied regions in Brazil, so habitat mapping and species monitoring efforts should be a priority (Teixeira *et al.* 2013), and this data may be added to the current model. This probably also represented a limitation during the creation of the existing *ad hoc* MPA in 1994, since there was even less information about habitat's distribution. Another limitation to this study may be that the targets were set arbitrarily, considering existing but non-sufficient data on habitat's vulnerability and conservation status. However, even though the conservation features' targets were arbitrary, they already showed that the existing MPA is not representative enough nor efficient in preserving biodiversity, and it was also possible to develop a model that could be adjusted accordingly. Moreover, the conservation aims were also based on global agreements such as the Aichi Targets, ensuring adequate implementation of MPA's protecting 10% of each habitat (UNEP 2010), and the 30% preservation target claimed by the 2016 IUCN World Conservation Congress (IUCN 2016). Therefore, the protection inconsistencies reported here and the SCP exercise may provide subsidies to improve new conservation actions and meet post-2020 international policy aims.

At last, this study was developed with the best current available information and it provides hefty support for spatial prioritization for conservation and management. The products presented here are a starting stage for the debate inside an appropriate approach for designing MPA networks not only in this specific region, but also in other ecologically and economically important zones. In view of new ecological and socioeconomic data, the model developed, once available for managers, allows reassessment and reconsideration, adapting conservation and management priority actions. It is viable, for instance, the incorporation of climate change refuges as conservation features, aiming at the persistence of species despite climate change events, which has been a global major concern (Groves *et al*. 2012). Therefore, results achieved through Marxan provide environmental authorities with near optimal solutions, so it is possible for them to lead various discussions between stakeholders, considering also their interests, in a way that avoids conflicts in the sea by integrating and managing different activities while still maintaining sustainability over time.

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