Final Evaluation Report

Your Details	
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Project Title	Coral Reef Mapping: Integrating Remote Sensing and Ecological Data for the First Coral Atlas in Brazil
Application ID	35581-1
Date of this Report	July 2023

1. Indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.

Objective	Not achieved	Partially achieved	Fully achieved	Comments
Bathymetric mapping of shallow reef environments of the MPA Costa dos Corais				High resolution mapping of shallow bathymetry is fundamental for the identification and characterisation of coastal environments (Kutser et al. 2020, Li et al. 2021, Roelfsema et al.2018), providing basis for mapping and monitoring benthic habitats, tracking fishing activity, planning actions in situations of environmental disasters, maritime operations and transport (Erdey-Heydorn 2008, Goes et al. 2019, Li et al. 2019, Rajendran et al. 2021, Xu et al. 2020, Zhao et al. 2014). Low spatial resolution sensors can lead to uncertainties in the land-water boundary and in the perception of features. In addition, they may have a low temporal frequency, resulting in a low supply of cloudless images, especially in tropical coastal regions (Li et al. 2021, Purkis 2017). In Brazil, other factors may limit the extraction of bathymetry by satellite, such as the high turbidity of coastal waters (Suggett et al. 2012) - limiting satellite mapping only to the period from late spring to late summer in the Southern Hemisphere, as well as by the scarcity of data on the physical conditions of the water column for modelling purposes. Shallow water bathymetry is fundamental for the characterisation of geomorphology. Mapping reef ecosystems helps understanding the morphological organisation of coral colonies, zoning areas of accumulation and removal of sediments, recognition of shallow lagoon flat top zones and preferential current paths (Greene et al. 1999; Harris 2012; Araujo and Seoane

				2016; Harris et al. 2018; Ferreira et al. 2012). Using a Sentinel-2 image mosaic, we derived a bathymetry with a spatial resolution of 10 m in shallow marine environments without field data calibration using the methodology of Li et al (2021) in the Marine Protected Area (MPA) Costa dos Corais region, in northeastern Brazil. After validation with field data (over 33,000 depth measurements), our bathymetry can be used with confidence to depths of up to 32 m.
Geomorphological mapping of shallow reef environments of the MPA Costa dos Corais				We also can associate several methodologies in the mapping of coral reefs, as in the present study, which used the bathymetry extracted by remote sensing with the Benthic Terrain Modeler (BTM) in ArcGIS to map the geomorphology. BTM is a suite of tools hosted on ArcMap (ESRI) that performs semi-automatic seafloor classification by combining depth, slope, and wide and fine-scale bathymetric position index (BPIs) information. In addition, we performed geomorphological mapping of the APACC by remote sensing. In processing the classification, we use the products generated by the GEE, such as the bathymetric model and the Sentinel-2 reflectance mosaic. The BTM, the representative points of the classes and the photointerpretation were the basis for training the classification scheme, in total 471 points were used (collected in the field in the region of Maragogi and Tatuamunha and by photointerpretation). The geomorphology classification clearly identified seven classes: Crest, Slope, Terrestrial Reef Flat, Reef Flat (flat reef), Plateau, Shallow Water and Deep Water.
Benthic mapping of shallow reef environments of the MPA Costa dos Corais				Benthic classification was also performed through digital processing of the Sentinel-2 mosaic in ArcGIS PRO. The classification was validated according to samples of georeferenced photos

				collected in the field in the region of Maragogi and Tatuamunha (Alagoas). Four classes were identified: sand, coral, gravel and seagrass.
Bathymetric mapping of mesophotic reefs of the MPA Costa dos Corais				Mesophotic reefs are poorly known worldwide despite their great ecological relevance and management importance for coral reef conservation strategies. To aid in filling this gap, we conducted a pioneering, large-scale survey, covering a total of around 315 miles in length, in the largest Brazilian coastal Marine Protected Area (MPA) Costa dos Corais. From the digital bathymetry model (30 to 50 m depth) generated by a multibeam echo sounder, we selected areas of greater geomorphological diversity for a detailed investigative expedition of mesophotic ecosystems. Various sampling techniques were used: single-beam echo sounders for detailing the relief, a remotely operated underwater vehicle (ROV) for habitat type investigation, baited remote underwater video (BRUV) for collecting images of the fish community, and scuba diving to perform transects describing the benthic and fish community. We analysed reef environments from 20 to 68 m deep. As a result, we present the mapping and geomorphological characterisation of two compartments of mesophotic reefs at 21–45 m depth and an image library of mesophotic ecosystems with the species description and indications of whether it is a new record in the region. Biodiversity data were collected covering eight species of sponges, with greater abundance for *Ircinia* spp., *Aplysina* spp., and *Xestospongia muta*: eight from corals, mainly *Siderastrea* spp. and *Montastrea cavernosa*; and 68 species of reef fish, with the Labridae family (including Scarinae—11 species) being the richest. Our results demonstrate the importance of mesophotic reefs for MPA Costa dos Corais reef biodiversity and, with that,

				the need to protect these areas through the application of local conservation strategies, such as the creation of "no-take zones". The results are available in the paper "Mesophotic Reefs of the Largest Brazilian Coastal Protected Area: Mapping, Characterization and Biodiversity" (Pereira et al. 2022, Diversity)
MPA Costa dos Corais reef atlas online				The MPA Costa dos Corais reef atlas is available: Below- The site is currently hosted on the ArcGIS PRO private licence, funded by funding provided by Rufford. We hope that soon the atlas can be accessed on an institutional website.
-Bathymetry + BTM: https://jcaon.maps.arcgis.com/apps/dashboards/57158942f9a246e1a0e74e044618c571 -Bathymetry + Object-oriented classification: https://www.arcgis.com/apps/dashboards/ad315c3bea3a47eab3fab3a9aaadbbaf				

2. Describe the three most important outcomes of your project.

a). First high-resolution coral reef atlas for the Brazilian coast. The unprecedented mapping presented bathymetric map (digital bathymetry model), geomorphological map (relief types) and benthic map (bottom types) for the shallow reefs of the MPA Costa dos Corais.

b). Maps and georeferenced information available online. Through ArcGIS PRO we make the results available through an online dashboard with an intuitive interface.

c). The reef atlas of the Coral Coast MPA is a document capable of assisting various research and conservation actions in the region. Through the maps it will be possible to identify areas of greatest interest for biodiversity conservation, facilitating the planning of monitoring actions, reviewing the limits of no-take areas and creating mitigation measures in situations of environmental stress, such as bleaching episodes and oil spills.

The most significant achievement of this work was to map the entire reef area of the Coral Coast MPA by remote sensing with freely available satellite images, validated with samples collected in the field. Despite the specificities of Brazilian corals, we were successful in the digital image processing and field stages. The methodology used was inspired by mapping carried out for other reef areas around the world, contributing to a common goal of global coral reef protection and conservation. This work can be seen as an incentive for mapping in other areas in Brazil and the creation of a coral reef health monitoring system.

3. Explain any unforeseen difficulties that arose during the project and how these were tackled.

Mapping coral reefs requires a lot of effort in logistics, specialised personnel and safety in the field stages. In addition, specialised software and hardware are required for the digital processing of satellite images. One of the initial difficulties of the project was the lack of funds to purchase a licence for specialised software in geoprocessing (Geographic Information Systems). The global Covid-19 pandemic also negatively impacted the project, postponing the field stages at various times. Regarding the satellite images used, initially we would use Planet images, but due to the particularities of the Brazilian coast we opted for the use of Sentinel-2A images. Planet images cover a smaller area per scene, which increases the variability of quality parameters (cloud occurrence, wave breaking and suspended material) in the study area, making it difficult to build a uniform image mosaic, necessary for quality mapping. A factor that is inherent to working in coastal areas and made the research difficult over time was the seasonality of the ideal conditions for data collection. Due to the better conditions of navigability and water transparency, we chose to carry out the expeditions during the summer period in the southern hemisphere. All the issues reported made it difficult to complete the work but were overcome by the support of the project partners.

4. Describe the involvement of local communities and how they have benefitted from the project.

Local communities were directly involved during the field stages through contact with fishermen and rafters in the region. They were often responsible for taking us into regions of highly preserved coral cover, which facilitated the mapping of habitat diversity. The choice of the areas mapped in detail was made in partnership with the management of the federal conservation unit, MPA Costa dos Corais (ICMBio - Ministry of the Environment), we chose priority areas for conservation in relation to the maintenance of coral cover, fishing stock and renewal and ecological importance. The mapping of coral reefs sought to identify patterns and spatial arrangements in the coastal area of the MPA Costa dos Corais, in addition to quantifying the coverage of reef structures, sand, gravel and seagrass. The availability of the data in an online manner and interactive interface facilitates the use by the local community, managers and other researchers. The mapping potentially benefits the local population in numerous ways, mainly through the knowledge of important areas for conservation, in the optimisation of inspection strategies, in the action in the face of disasters or environmental stresses, in the scientific dissemination and environmental education of children and tourism agents (guides, hotel chain, divers).

5. Are there any plans to continue this work?

After the finalisation of the reef atlas of the Coral Coast MPA, the main objective is to have the mapping hosted by a governmental website, so that it can be widely disseminated and used by interested parties. In addition, this project aims to encourage the application of the methodology in other reef areas in Brazil and to foster the creation of a system for monitoring the health of coral reefs in Brazil by

remote sensing. Monitoring by satellite imagery increases the spatial and temporal capacity of observation and could be used to predict new bleaching episodes.

6. How do you plan to share the results of your work with others?

The results will be shared through scientific articles in journals of the area and participation in events. However, the main method of dissemination is the availability of the mapping in an online dashboard, where anyone anywhere in the world can access and navigate the atlas of Brazilian reefs. The dashboard interface is interactive and presented in a way that facilitates user experience.

7. Looking ahead, what do you feel are the important next steps?

The next most important step is to publicize the mapping of coral reefs by remote sensing and to host the maps on an official website, either by some environmental agency (federal or state) or by the conservation unit itself. From this, we can think about the application in other conservation units. This work is a strong incentive for the creation of a mapping and monitoring network of Brazilian coral reefs by remote sensing, capable of mapping large areas on a metric scale.

8. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did the Foundation receive any publicity during the course of your work?

The Rufford Foundation logo was used only in academic presentations, at the II Brazilian Conference on Biodiversity Conservation Projects (Recife, Brazil) in April 2022 and in the completion stages of the PhD, as a thesis defence qualification.

9. Provide a full list of all the members of your team and their role in the project.

Prof. Dr. José Carlos Sicoli Seoane:
Full professor of geoprocessing and geological mapping at the Federal University of Rio de Janeiro. He was a doctoral advisor. He was present throughout the development of the project, academic guidance, assistance in the field stages and data processing and analysis.

Dr. Pedro Henrique Cipresso Pereira:
PhD co-supervisor and coordinator of the Reef Conservation Project (PCR). He was present throughout the development of the project, academic guidance and assistance in the field stages. Together with the PCR, he was fundamental for the realization of the field stages, mainly in the relationship with the management of the conservation unit and in the planning of the logistics of the expeditions.

MSc. Gislaine Vanessa de Lima:
Master in animal biology (Federal University of Pernambuco) was present throughout the project. She acted as a scuba diver in capturing photos of coastal habitats and other field activities, and also contributed to the writing and review of scientific articles currently under review.

Erandy Gomes da Silva:
Undergraduate student in oceanography (Federal University of Pernambuco) worked as a scuba diver in the investigation of reef habitats in unknown areas through taking videos and photos.

Luís Guilherme França Côrtes da Silva:
Undergraduate student in oceanography (Universidade Federal de Pernambuco) worked as a scuba diver in the investigation of reef habitats in unknown areas through taking videos and photos.

Antônio Vitor de Farias Pontes:
Undergraduate student in oceanography (Federal University of Pernambuco) acted as a scuba diver in the investigation of reef habitats in unknown areas by taking videos and photos.

MSc. Vitor Galazzo de Paiva:
Researcher at the National Institute for Space Research (INPE, Brazil). He worked on the collection of water for radiometric analysis during the Tatuamunha expedition in December 2022.

Dr. Thais Andrade Galvão de Medeiros:
Researcher at the National Institute for Space Research (INPE, Brazil). Worked on the radiometric analysis of seawater collected during the Tatuamunha expedition in December 2022.

10. Any other comments?