Setting a baseline for marine fish biodiversity in São Tomé and Príncipe using Baited Remote Underwater Video

Consultancy report for the Blue Action Project:
"Establishing a network of marine protected areas
across São Tomé and Príncipe through a co-management approach"

Two nurse sharks recorded with Baited Remote Underwater Video, one of them with a melanic phenotype (2019)

Report prepared by Guillermo Porriños (independent consultant, December 2019)

Version in Portuguese available here

TEAM **Guillermo Porriños** (Independent consultant for *Fauna & Flora International*)
Luisa Madruga (Project coordinator, *Fauna & Flora International*)
Manuel da Graça, "Lindo" (Príncipe, *Fundação Príncipe*)
Albertino Santos (São Tomé, *MARAPA*)
Lodney Nazaré (São Tomé, *Oikos*)
Márcio Guedes (São Tomé, Oikos)

Table of contents

This document has been structured in two independent reports: 1) report on the activities related to the implementation of Baited Remote Underwater Video surveys in São Tomé and Príncipe, conducted between the 15th of May and 28th of December as part of a consultancy contract between Fauna and Flora International and Guillermo Prieto Porriños; 2) Scientific report, with a detailed description of the methods, results, and recommendations.

List of figures and tables

FIGURES

ANNEXES

TABLES

Implementing Baited Remote Underwater Video surveys as a tool for monitoring fish diversity in São Tomé and Príncipe

ACTIVITIES REPORT

A. INTRODUCTION

Baited Remote Underwater Video surveys (BRUVs) are being implemented in São Tomé and Príncipe (STP) as part of the project "Establishing a network of marine protected areas across São Tomé and Príncipe through a co-management approach" (The Blue Action Project), led by *Fauna & Flora International* (FFI), in partnership with MARAPA (*MAR, Ambiente e Pesca Artesanal*), *Oikos* and *Fundação Príncipe*, and funded by *Blue Action Fund* and *Arcadia Fund*. BRUVs are a widely used, non-invasive technique to survey predatory fish species, consisting on placing a baited camera on the seafloor or the water column, which records uninterruptedly for a set time. Videos are later analysed by trained observers using a standardised method to record species' presence/absence, behaviours and relative abundance. In the Blue Action Project, BRUV surveys are being used to provide baseline data and better understand spatial variations in presence/absence of fish species of fisheries and conservation concern.

The Blue Action Project follows up on the activities of the projects Kike da Mungu (São Tomé) and Omali Vida Nón (Príncipe). The BRUV surveys' protocol and sampling strategy used on this study were developed for Príncipe by Dr. Ana Nuno, Dr. Phil Doherty and Guillermo Porriños (*University of Exeter*) during the Omali Vida Nón project (2016-2019, funded by Darwin Initiative, Halpin Trust and Africa's Eden). The sampling is limited to the area between the coastline and the line of 25 metres of depth, due to water visibility. The study area is divided in quadrants of approximately 15km^2 and 10 sampling points are randomly placed on each of them. For the Omali Vida Nón Project, this method was applied in Príncipe island twice, during July 2018 (Gravana, the colder season) and December 2018 (the end of the rainy season and the beginning of the warmest season), covering an area of 100 km^2 with 60 random sampling points per season. For the Blue Action project, a new BRUV sampling round was conducted in July 2019 in Príncipe, and the method was applied in São Tomé for the first time in September 2019, targeting the intervention area of the Kike da Mungú Project plus a buffer region around it (in total, the sampling area covers the southern half of the island, from Santana Islet to São Miguel). The total sampling area of São Tomé is comprised of 70 km^2 with 50 sampling points, plus extra 25 sampling points on five locations of interest for conservation and fisheries.

The activities and results reported in the present document were conducted as part of a consultancy contract between FFI and Guillermo Prieto Porriños.

B. OBJECTIVES

1) Training Fundação Príncipe's marine team to conduct BRUV sampling independently.
2) Adapting Principe's BRUV sampling method to São Tomé.
3) Training MARAPA's and Oikos team to conduct BRUV sampling independently.
4) Analysing newly and previously collected BRUV data to understand species' distribution in São Tomé and Príncipe.
5) Providing recommendations on priority areas for conservation and management based on knowledge of marine habitats and BRUV data.

C. OUTPUTS AND OUTCOMES

Output 1. Design and preparation

Output 1.1. Purchasing and building materials and transporting them to the country: including: **1)** Listing materials that need to be purchased out of the São Tomé and Príncipe, finding sellers online, building PVC frames for supporting the cameras underwater, and transporting the materials to the country

Output 1.2. Purchasing and building materials in the country: including identifying materials that need to be built or purchased in-country, identifying sellers and designing BRUV frames for conducting BRUV work in São Tomé (see Annex I, list of materials, in Portuguese, available here).

Output 1.3. Sampling design in Príncipe: using data digitised from a nautic chart during the project Omali Vida Nón, locating 60 random points on the area between the coastline and the 28 metre-deep-line. The total area (100 km^2) was divided in six sections (NE, NO, OO, SO, SE, EE) of approximately 15 km^2 each. On each of section, 10 random points were placed, separated at least 400 metres from each other.

Output 1.4. Sampling design in São Tomé: (August 2019, 5 days in total) including **1)** digitising a nautic chart with depth data and making a raster file with depth data for São Tomé; **2)** Dividing the area comprised between the coastline and the 28 metre-deep line in 5 polygons of approximately 15 km^2 each (EE, SE, S, SO). **3)** Locating 10 random points on each of the sections, separated at least 400 metres from each other (in total, 40 random points were sampled); **4)** Defining 7 transects of 5 BRUV sampling points each around known fishing grounds, which coordinates were provided by Frederic Airaud.

Output 1.5. Rapid assessment of software for reviewing BRUV footage, including potential for estimating fish abundance and estimated costs: July 2019, available here.

Output 2. Training

Output 2.1. Training needs assessment (in Portuguese and in English) available here.

Output 2.2. Guidelines of BRUV fieldwork, step by step (in Portuguese, available here).

Output 2.3. Briefing Fundação Príncipe's marine team and MARAPA and Oikos' teams on BRUV field work (June 2019)

Output 2.4. Field work training: conducted in parallel to the data collection. **1)** Príncipe: BRUV surveys were led by Manuel da Graça (Lindo) under the supervision of Guillermo Porriños. In total, 91 points were sampled in 14 field-work days, of which 12 were conducted by the marine team under the supervision of Guillermo Porriños, and 2 conducted by the marine team independently. **2)** São Tomé: In total, 83 sampling points were sampled over 8 days, all of them coordinated by Guillermo Porriños. Oikos and MARAPA's team received training during fieldwork: Márcio Guedes (Oikos) received 2 days of training, Albertino Santos (MARAPA) received 3 days of training and Lodney Nazaré (Oikos) received 1 day of training.

Output 2.5. Training observers: Marta García Doce, a BSc Biology student with funding from Erasmus + programme, was trained in analysing BRUV videos and species ID. Training was done over 32 hours, in which the student analysed 7 videos in the presence of the trainer (Guillermo Porriños).

Output 3. Data collection and processing

Output 3.1. Principe's BRUV fieldwork: Ninety-one points were sampled over 14 working days, of which 7 were points that failed and were repeated afterwards. Sixty-three points were sampled (60 random points around the island and 3 points at Tinhosas islets). Of the 60 random points, 20 points were sampled both in the morning and in the evening of the same sampling day, to detect any potential differences in fish assemblages related to the time of the day. Sampling both in the morning and in the evening of the same day was considered unfeasible and abandoned after the second sampling day, sampling exclusively in the morning period.

Output 3.2. São Tomé's BRUV fieldwork: 83 sampling points were sampled over 8 days, of which 8 were points that failed and were repeated afterwards.	
Output 3.3. Video analysis: Conducted by Marta García Doce from September 2019 to November 2019. In total, 68 videos from Principe's 2019 sampling were analysed.	
Output 3.4. Maps of species distribution (December 2019). Maxent algorithm was tested for mapping species distribution and abandoned (4 days). The general additive method Thin Plate Spline was used in the end for mapping species distribution (3 days). Full report available here.	
Output 4. Outreach	
Output 4.1. Environmental awareness events: four cinema sessions in São Tomé and two in Príncipe (approximately 15 minutes each) using BRUV videos from the Blue Action Project and Omali Vida Nón projects. Fishers, fish traders, children and other people attended the events. The communities in São Tomé were Porto Alegre (20 attendants), Malanza (15 attendants), Monte Mário (10 attendants), Ribeira Afonso (7 fishers and over 30 children). In Príncipe, the events were organised in Campanha (the whole community attended, approximately 30 people) and Abade (around 30 people including fishers, fish traders and children).	
Output 4.2. Presentation at the fisheries department: On November 19, 2019 the method and preliminary results of the project were presented at the fisheries department. Thirteen representatives of the fisheries directorate were present, including a representative of the head of the department. The presentation was mediated and introduced by Albertino Santos and Sinaida Espírito Santo (MARAPA) and Lodney Nazaré (Oikos-STP). The presentation (in Portuguese) can be downloaded here.	

Setting a baseline for São Tomé and Príncipe's fish diversity, distribution and abundance using Baited Remote Underwater Video

RESEARCH REPORT

INTRODUCTION

Baited Remote Underwater Video (BRUV) is a non-invasive technique for studying fish fauna (for example, their presence, relative abundance and behaviour), consisting on attracting fish species towards an underwater camera using a bait. Several different BRUVs systems exist that can be used for different purposes, such as estimation of biomass (using stereo-BRUVs) or using them in different environments (both demersal and pelagic BRUVs).

When compared to other methods, benefits include being a non-invasive technique (for example, scientific fishing requires harvesting) and field-work and data collection does not require intensive training or previous fish identification skills (for example, underwater visual census require experienced SCUBA divers and accurate identification of fish species underwater). In addition, it creates a permanent record of the sampling and the video material from BRUVs can be used for training students, technicians and researchers on fish identification, as well as being useful for outreach and environmental awareness activities.

BRUVs are being used in São Tomé and Príncipe to understand spatial patterns of fish abundance and create baseline information on Príncipe's marine environment for selected key species, as part of the project "Establishing a network of marine protected areas across São Tomé and Príncipe through a co-management approach", funded by Blue Action Fund (the "Blue Action Project").

METHODS

Study site

The archipelago of São Tomé and Príncipe is comprised of two islands of volcanic origin and several islets, including the Tinhosas islets, located approximately 20 km south of Príncipe. Coastlines facing the south are more exposed to waves, and have a relatively shorter distance (500-1000 m) to the deeper areas (below <25 km), whereas the northern coastlines have a wider shallow shelf (2-4 km) (see Cowburn, 2018). Three main habitat types can be found in Príncipe: *rocky reefs*, *sandy grounds* and *maerl beds* (Abreu *et al.*, 2016). Seagrass meadows also exist, with a higher density and abundance in São Tomé island than in Príncipe island (Alexandre *et al.*, 2017).

Sampling

The study was limited to a maximum depth of 28 metres, due to low visibility below that. In São Tomé, only the southern half of the island was sampled, from Ilheu Santana to São Miguel (see Figure 1). In Príncipe, all the area between the coastline and the 28-metre-deep line was sampled (see Figure 2). A small shallow platform (less than 1km^2) north of the biggest Tinhosas islet was also included in the study.

The sampling method was developed for Príncipe in 2018 by the project Omali Vida Nón (OVN, 2016-2019, see Nuno *et al.*, 2019). A front-facing baited underwater camera is deployed at the sampling point during the morning (09:00 to 11:00), except in São Tomé, where sampling happened between the morning and the afternoon period (09:00 to 14:00) due to time constrains. In Príncipe, twenty sampling points were sampled both in the morning and the afternoon of the same day, to see potential differences in the fish assemblages caught in the camera during both time periods. The camera sits on the bottom for an hour and a half (maximum battery life) and records uninterruptedly, and the device is retrieved after that. Depth is measured on the sampling point using a hand depth sounder.

The total sampled area was 100 km^2 in Príncipe and 85 km^2 in São Tomé. For both São Tomé and Príncipe, the study areas were divided in quadrants of approximately 15 km^2 and 10 random sampling points were located at each of them, setting a minimum distance between them of 400 metres. São Tomé's sampling area was divided in 4 quadrants (EE, SE, S, SO), with a total of 40 random sampling points; and Príncipe sampling area was divided in 6 quadrants (NE, E, SE, SW, W and NW), with a total of 60 random points. In addition, in São Tomé, 7 transects of 5 sampling points were conducted around areas of special interest for the artisanal fisheries.

Two sampling rounds of two phases each will be conducted for both islands. The first phase of the first sampling round was conducted both in São Tomé and Príncipe islands during *gravana* 2019 (the colder season, July to September). The second phase of the first sampling round will happen in both islands during January and February 2020, the warmest, driest season. Both sampling seasons will be used to create a baseline for fish diversity for São Tomé and Príncipe for the Blue Action Project. A second sampling round will happen at the end of the Blue Action Project, with a first phase in July-August 2022 for both islands and a second phase in January-February 2023. This second sampling round will be used to detect any potential differences related to the implementation of management measures and to set a second baseline for potential future projects.

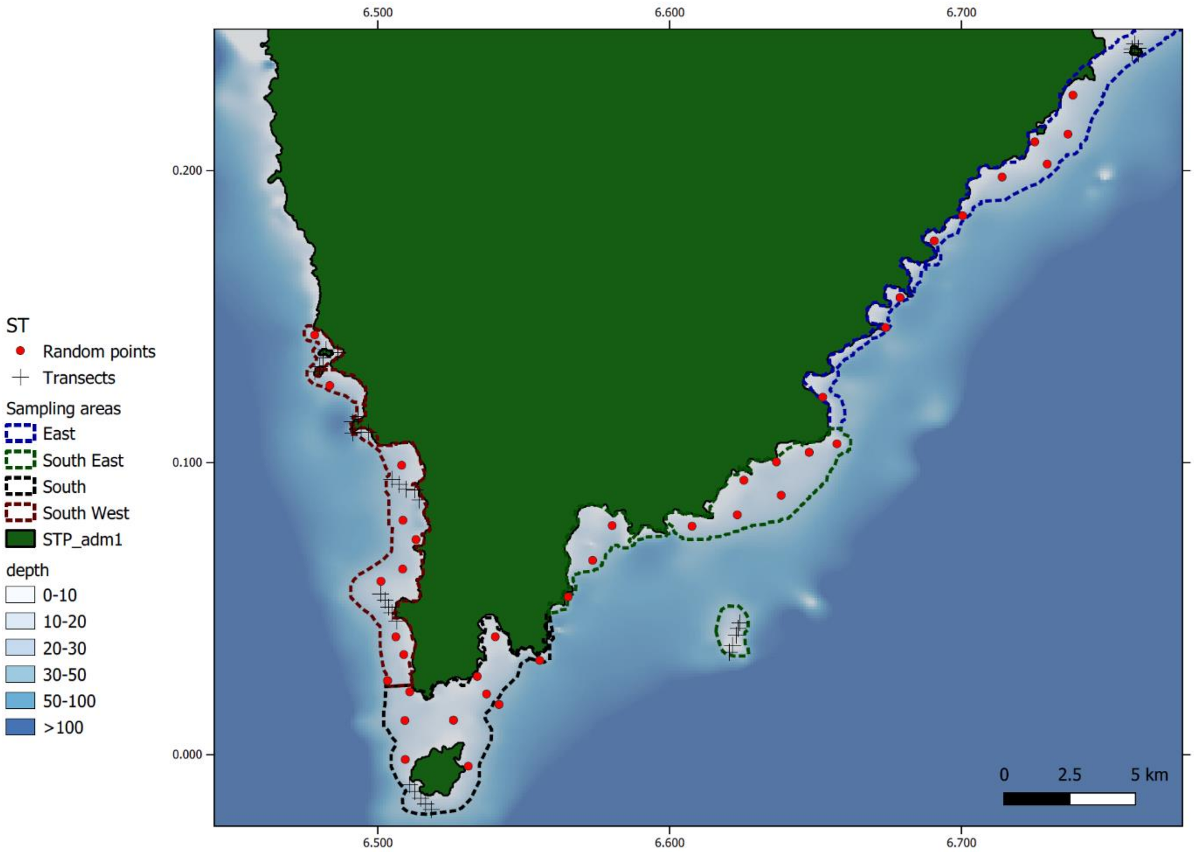

Figure 1: Sampling points in São Tomé.

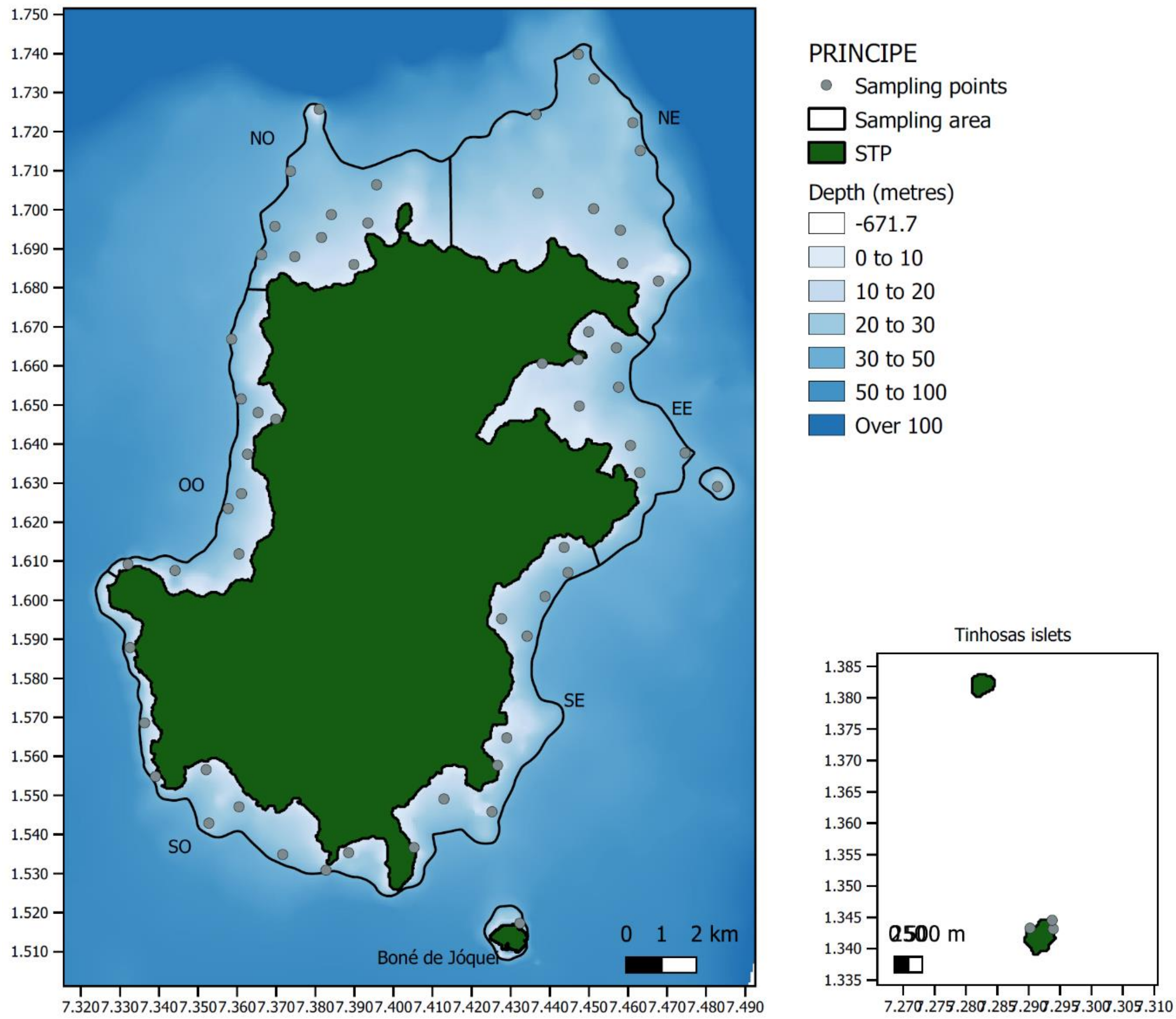

Figure 2: Sampling points in Príncipe and Tinhosas

Materials

The BRUV device consists on a frame holding a front-facing camera at 35 cm from the sea floor. GoPro cameras Hero5 and Hero7 were used. A bait cage is placed at 120 cm in front of the camera, using a 170-centimetre-long pole made of *muandi* wood (*Pentaclethra macrophylla*), which is attached to the frame using rubber bands made of discarded motorbike tire chambers. The bait cage was made by rolling a long, 30-cm wide piece of chicken wire into a 30-cm-long cylinder (see Figure I and Figure II of the Annex I). Two types of BRUV frames were used:

- *Prism-shaped frame*: it was first used in Príncipe for the project OVN and designed by Dr. Phil Doherty (see Doherty, 2018). It is a 70-centimetre-tall PVC frame with the shape of a prism with a triangular base, anchored by four 2-kg diving leads attached to its base. In the first field tests using this frame (project OVN, see Nuno *et al.*, 2019) the bait cage was located in front of the apex of the triangle, but it was later placed in front of the base of the triangle, to avoid the device falling backwards during the sampling (see Figure 3A).
- *Pyramid-shaped frame*: designed by Guillermo Porriños for the BRUV surveys in São Tomé. It is a 17-kg frame built by welding galvanized steel tubes into a pyramid-shaped structure that could be piled on top of each other in the boat (see Figure 3B).

Fifty-metre-long ropes of 10-12 mm of diameter were attached to the frames. Nylon ropes were used because of its buoyancy. At the other end of the rope, two buoys were attached, separated 1.5 metres from each other, in a way that if one of the buoys sinks because of the wave action, the other one stays in the surface, signalling the position of the device. For the PVC frames, a 6-kg weight acting as anchor was attached to the rope, 7 metres away from the frame. The weight is built by wrapping rocks around a piece of discarded fishing net and prevents the device from being moved by the action of the waves.

Chopped "*fulu fulu*" was used as bait (a small tuna of the species *Auxis thazard* and *Euthynnus alleteratus*, caught daily by local fishermen), and kept in a cooling box with ice during fieldwork.

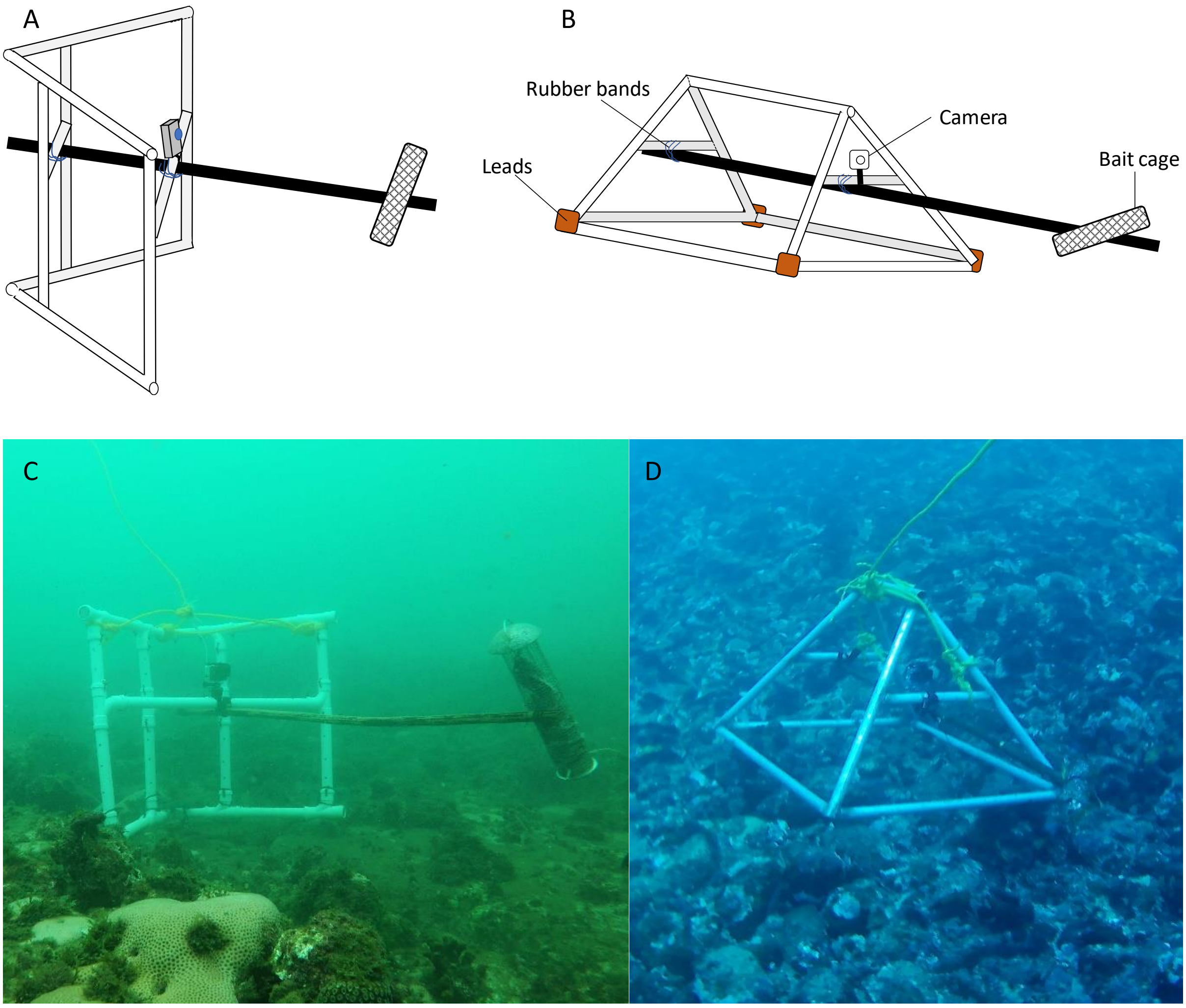

Figure 3: Top: schematic representation of the two BRUV frames used in this study; A) Prism-shaped frame and B) pyramid shaped frame; Bottom: Pictures of the frame underwater: C) Prism-shaped frame and D) Pyramid-shaped frame.

Fieldwork protocol

A maximum of ten BRUV devices were carried in the boat and deployed simultaneously (see Figure 4). The cameras are deployed during the morning period (09:00 to 11:00), and fieldwork is conducted by a crew of 3 to 4 people. Ropes bearing the buoys, BRUV frames and the poles bearing the bait cages are stored separately and only attached together before deploying the devices. Bait is kept frozen in a cooling box to maximise freshness, and only chopped immediately before deploying the devices. The cameras are stored safely in a box which prevents them from being accidentally started by the movement of the boat and kept away from the sun to avoid overheating. It is recommended to carry three to four extra charged batteries, and one extra *sd* card, keeping them in sealed box.

Figure 4: **BRUV fieldwork**. **A)** Fundação Príncipe's marine team, led by Lindo (front), departing to the sampling area. Up to 10 devices can be stored in the boat simultaneously. **B)** Lindo recording in the video depth, site, date and time information. **C)** Wilder preparing the bait cages. **D)** Quaresma, one of the sailors of São Tomé's marine team, tying the ropes to the devices before its deployment. All pictures by Guillermo Porriños.

Figure 5: **Marine team in São Tomé**: A) Bait was chopped on the paddle before putting it in the bait cages; B) Preparing the BRUV devices for their deployment included: attaching the ropes with the buoys and the poles bearing the bait cages to the devices; C) Five BRUV devices ready to be deployed. All pictures by Guillermo Porriños.

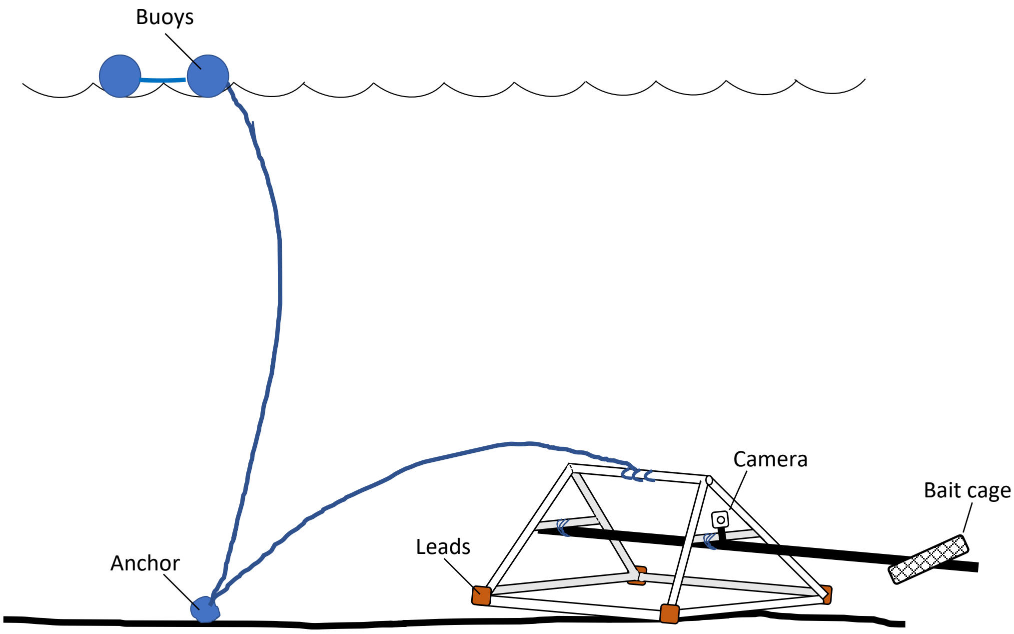

Figure 6: Schematic representation of the BRUV device underwater

Before reaching the first sampling point, the first two or three devices are prepared for its deployment (chopping the bait, attaching the ropes to the frame, preparing the ropes for their deployment to avoid entanglement, and attaching the poles with the bait cages to the frame using the rubber bands). Up to 10 BRUV devices can be deployed in 10 consecutive sampling points, and they retrieved after an hour and a half has passed since each device was deployed, generally starting by the first one that was deployed.

The protocol for deploying the camera consist on releasing the device slowly, by controlling its fall with the rope. One person controls the drop of the device from the boat, another one stays in the water to ensure that the device falls on the right position and a third one controls the engine of the boat. A fourth person can assist avoiding the entanglement of the rope. Date, time, sampling point and depth are recorded in the video by listing this information outloud and close to the camera.

Ideally, the device should be lined up with the current, with the bait pointing in the direction of the bottom current, so the smell plume is released from the front of the camera. To facilitate this, the boat can move in the opposite direction of the direction of the bottom current, to drag the device into the right position. However, although the direction of the bottom current can sometimes be inferred from the direction of the waves, it is challenging to estimate beforehand, and the device frequently falls perpendicular to the current, or against it.

Video analysis

Maximum number of individuals of each species per frame (MaxN) is recorded, identifying species to the lowest taxonomical level possible. All finfish species were recorded, plus sea turtles, octopuses, crabs and snails (although these were removed for the statistical analysis). For each species, MaxN was recorded, alongside the time in the video. The species was only registered again in a new entry if the number of individuals was higher than in the last data entry. When a species is unknown, they are labelled as "*Unknown*_n_*video_number*", and when a species cannot be assigned to any species or group, it is tagged with a dot at the beginning of the species identifier. Only sixty minutes of video are analysed, starting 5 minutes after the camera has settled in the bottom

By December 2019, only videos from Príncipe have been analysed. Video analysis was done by Marta Garcia Doce, a BSc Biology student who received 36 hours of training (7 videos). Data will need to be cleaned, validated and verified before it can be analysed. The validation method proposed is the analysis of 10 videos by an experienced viewer and comparison of the number of species recorded by the two observers, in order to validate the number of species and individuals spotted by the observer. The proposed verification analysis for the species ID will be done by reviewing every data entry.

Data analysis

Catch Per Unit Effort was defined as MaxN of a certain species or taxa per hour. Since BRUV videos from July 2019 have not been cleaned yet, the Omali Vida Nón BRUV database was used, consisting on two sampling rounds were conducted, one in July 2018 and one in January 2019. Distribution of species was mapped using habitat data produced by Dr. Benjamin Cowburn (2018) using remote sensing (see Table 1).

The statistical software R (v3.4.3) was used to perform all statistical analyses and calculations. ANOVA was used to detect differences in CPUE between habitat types. Post hoc comparisons using the Tukey correction were used to perform pairwise comparisons.

Table 1: data used for this study and authorship

Data	Authors
Habitat map	Dr. Benjamin C. Cowburn
Relative abundance of fish species measured using BRUVs	Guillermo Porriños, Dr. Ana Nuno, Dr. Phil Doherty, Dr. Liliana Colman, Dr. Kristian Metcalfe

Species distribution

Significant differences in fish abundance were found between habitat types for most groups (see Porriños and Nuno, 2019). Habitats were classified after Cowburn (2018) in rocky reefs, maerl beds and sand. Habitat was the only environmental variable used to predict species distribution. In order to simplify the analysis, depth was not considered. The species distribution model "Maximum Entropy" (maxent) was tested and abandoned.

Given the scarcity of environmental variables, it was considered that the most information source of information on species' abundance at a certain location was the CPUE values of the surrounding sampling points. Thus, in order to map species' abundance around the island, a generalised additive model was used to interpolate between data points. However, given that significant differences were found between habitat types, maerl, sand and rock data points were considered as three different distributions and standardised by subtracting the average CPUE per habitat and divided by the standard deviation of each habitat type.

A Thin Plate Spline (tps) regression model was used to predict CPUE values of specific taxa by interpolating information from 120 random sampling points. In order to eliminate the variability produced by the habitat type, CPUE of each point was divided by the species' average CPUE for the habitat type of the data point (note that, even after disaggregating by habitat, CPUE does not follow a normal distribution, so this standardisation might be a source of error). The resulting interpolated surface (relative abundance standardised by habitat type) was considered to represent differences in abundances generated exclusively by location. This was then corrected by the habitat type, multiplying each cells' value by the standard deviation of the CPUE of the habitat type of that cell, and then summing the average CPUE of the habitat type of that cell.

For the analysis, the following species (or genera) were considered: **1) great barracuda** (Figure 8, *Sphyraena barracuda*, reef-associated pelagic); **2) lutjanid snappers** (Figure 9, genus *Lutjanus*, ubiquitous but more frequently found on rocky habitats); **3) grey triggerfish** (Figure 10, *Balistes capriscus*, bottom-dwelling species, frequent in sandy habitats); **4) groupers and seabasses** (Figure 12, Epinephelinae, most abundant on rocky reefs); **5) flying gurnard** (Figure 11, *Dactylopterus volitans*, bottom dwelling species, frequent in sandy and maerl habitats).

Assessment of the validity of the model
The TPS model was chosen to compromise with the time available, although the following weaknesses in the method should be considered. The smoothing function of the TPS regression fills the gaps between the data points, so that the cells surrounding a certain data point will be given a value closer or equal to that point, and they will get more similar values to the cells surrounding as they approach to them. This is useful for data in which the observed value in a certain point is fixed (for example, altitude). However, in this case, higher values are given to cells surrounding an observation with higher CPUE, and values close to zero are given around points were the species was absent, creating the artifact that the species is absent at certain areas, even if a high CPUE value for the species was observed in a nearby point. Since some fish species (such as snappers) are highly mobile, the observed CPUE value at a certain point does not represent the abundance of the species at that specific point, and a different CPUE value might be observed if the same point was sampled in a different day. A model that calculates the probability of occurrence of the species should be considered instead.

RESULTS

In the Omali Vida Nón database, 92 different species were identified to species level, not being able to assign 12.5% of the data entries to any taxa. The most common fish family in terms of presence (number of species present at each sampling site) was Carangidae (jacks and pompanos), comprising 16% of all the observed species, with an average CPUE of 3.16 fish per hour and 6.2 of standard deviation. Catch Per Unit Effort (MaxN/total time) of carangids did not show significant differences between habitats not between areas ($p>0.1$). Snappers, barracudas, triggerfishes and seabasses showed significant differences between habitats.

CPUE for elasmobranchs was 0.04 sharks per hour and 0.06 rays per hour. Three different species of sharks were identified: nurse shark (*Ginglymostoma cirratum*), lemon shark (*Negaprion brevirostris*) and an unidentified hammerhead shark. Two different species of rays were identified, both belonging to Myliobatiformes: *Taeniura grabata* and *Daysatis pastinaca*.

Table 2: Average CPUE of sharks, stingrays and carangids

	Average CPUE (MaxN/h)	sd
Jacks and pompanos (Carangidae)	3.10	6.2
Sharks	0.07	0.3
Stingrays (Myliobatidae)	0.09	0.3

CPUE was largely dominated by predatory fish for all the habitat types (Figure 7). Herbivore fish are almost absent from sandy grounds and maerl beds, with small, medium and large tertiary consumers comprising 57% of the total MaxN in maerl and 61% in sand. CPUE of rocky habitats is significatively higher than sandy grounds and maerl beds, for all the trophic and size categories ($p<0.001$). Total MaxN for rocky habitats is comprised by medium and small herbivores (10%); by small, shoal-forming, medium and large secondary consumers (50%) and small, medium and large tertiary consumers (40%).

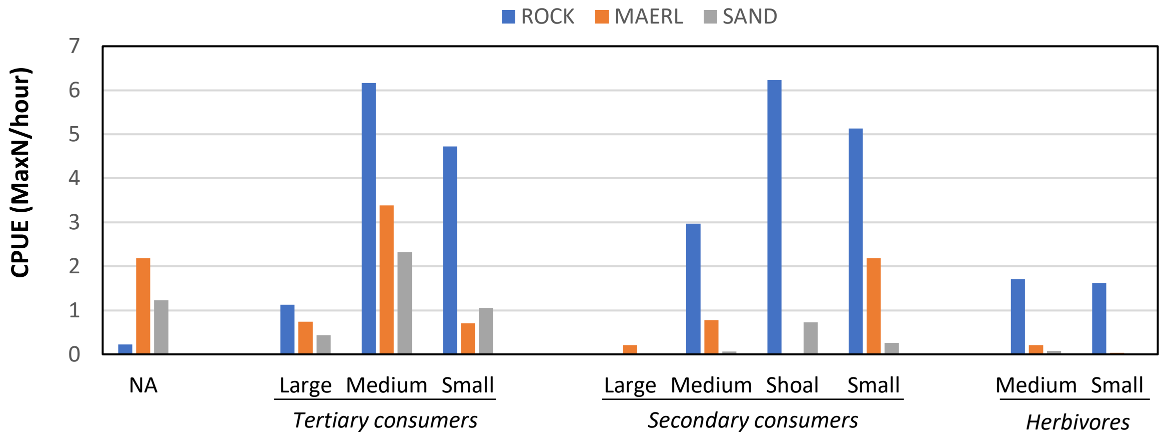

Figure 7: (from Porriños and Nuno, 2019) CPUE of the different trophic groups of finfish registered in the BRUVs: Large (max length =<90cm); Medium (max length between 30 and 89 cm); Small (max length <30cm); Shoal (shoal-forming species *Prionurus biafraensis* and *Paranthias furcifer*, below 30cm). For all the categories, CPUE was expressed in MaxN per hour, except for "shoal" (the unit for shoal forming species was 10 fish, so as to reduce the contrast).

As shown in Figure 8, the great barracuda, *Sphyraena barracuda* is most abundant in the south, with a few observations on the east and the west coasts. Most of the observations seem to concentrate around regions with high wave exposure, being absent in the northern platform (more sheltered). *Sphyraena barracuda*'s was more abundant in maerl and sand bottom than in rocky reefs (Tukey, $p<0.01$).

Snappers were found all around the island (see Figure 9) although they were much more abundant in the northern, more sheltered shore, and around the extensive rocky reefs in the south-east region known as "*pedra metade*". Snappers were most abundant in rocky reefs (Tukey, $p<0.01$), occurring in 80% of the points sampled on reef areas, but they were also observed in sandy habitats, some of them attacking the bait cage. This indicates that, although they might be most abundant in reef areas, they might leave the reefs for feeding. This might have consequences on the design of protected areas or no-take zones: even if rocky reef areas were protected, snappers might still be vulnerable to fishing if the sandy habitats around the reefs are unprotected.

The grey triggerfish (Figure 10) shows a similar distribution to the snappers, being more abundant in the northern coast. The grey triggerfish was actively attracted to the bait, and the species was feeding from the bait in all the observations. The species was mostly found in sandy areas, being completely absent from rocky reefs (Tukey, $p<0.01$).

As shown in Figure 12, groupers are ubiquitous, and they are present in virtually all sampled rocky reefs. However, most of the observations belong to two species: *Cephalopholis nigri* and *Cephalopholis taeniops*, two small to medium, highly resident seabass species found in almost all rocky reefs or isolated boulders. *Epinephelus adscensionis* (rock hind), another medium-sized species was observed three times in a rocky reef environment, and *Epinephelus aeneus*, a large species of grouper, was only captured on camera in two sampling points on a sandy habitat.

The bottom dwelling species *Dactylopterus volitans* (Figure 11) was most abundant in sandy habitats, being completely absent in rocky reefs (Tukey, $p<0.01$). Although it was found all around the island, it was most abundant in the northern platform (more sheltered from wave action), getting more abundant farther away from the coast.

Table 3: CPUE of *Sphyraena barracuda*, disaggregated by habitat

Habitat type	Average	SD	Max.	n
Maerl	0.12	0.331663	1	25
Rocky reef	0	0	0	16
Sand	0.21875	0.486932	2	64

Table 4: CPUE of snappers disaggregated by habitat

Habitat type	Average	SD	Max.	n
Maerl	0.24	0.52	2	25
Rocky reef	1.88	1.54	5	16
Sand	0.08	0.27	1	64

Table 5: CPUE of the grey triggerfish, disaggregated by habitat

Habitat type	Average	SD	Max.	n
Maerl	0.08	0.28	1	25
Rocky reef	0.00	0.00	0	16
Sand	0.17	0.81	6	64

Table 6: CPUE of groupers and seabasses (Epinephelinae), disaggregated by habitat

Habitat type	Average	SD	Max.	n
Maerl	0.08	0.4	2	25
Rocky reef	2	1.67332	5	16
Sand	0.046875	0.277728	2	64

Table 7: CPUE of snappers disaggregated by habitat

Habitat type	Average	SD	Max.	n
Maerl	0.40	0.58	2	25
Rocky reef	0.06	0.25	1	16
Sand	0.24	0.49	2	64

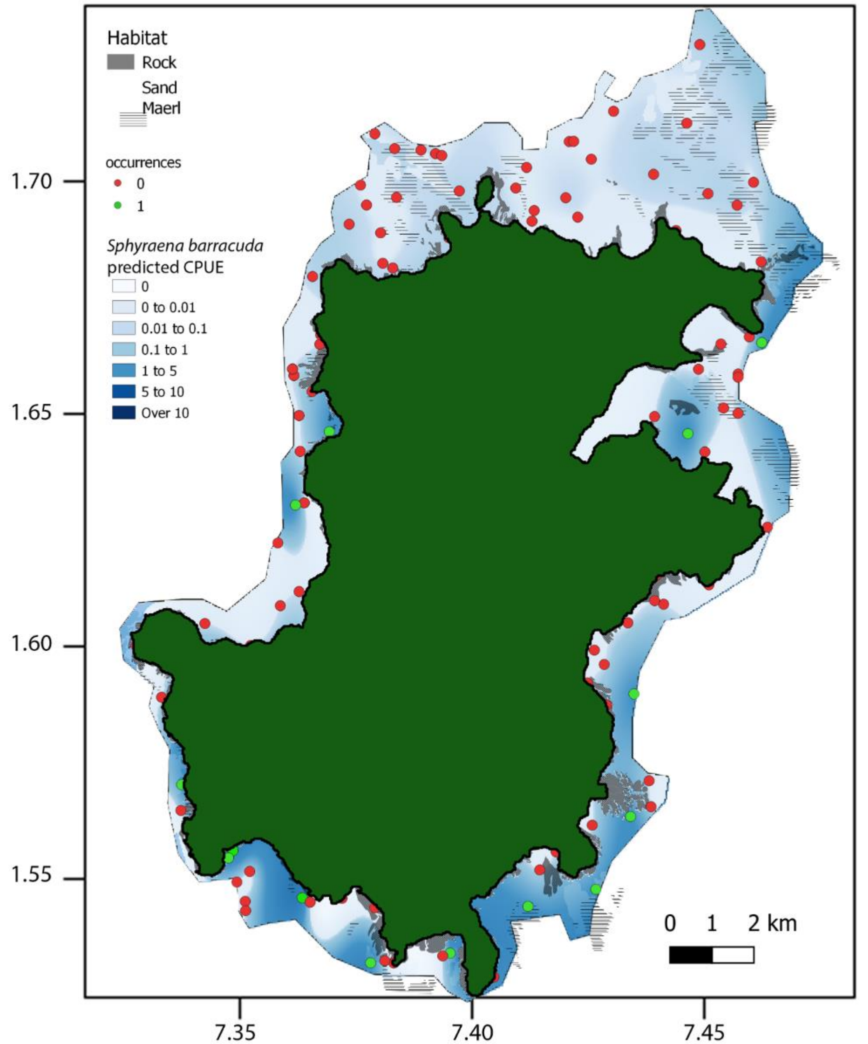

Figure 8: Distribution of *Sphyraena barracuda*'s CPUE measured using BRUVs and interpolated using a TPS regression model.

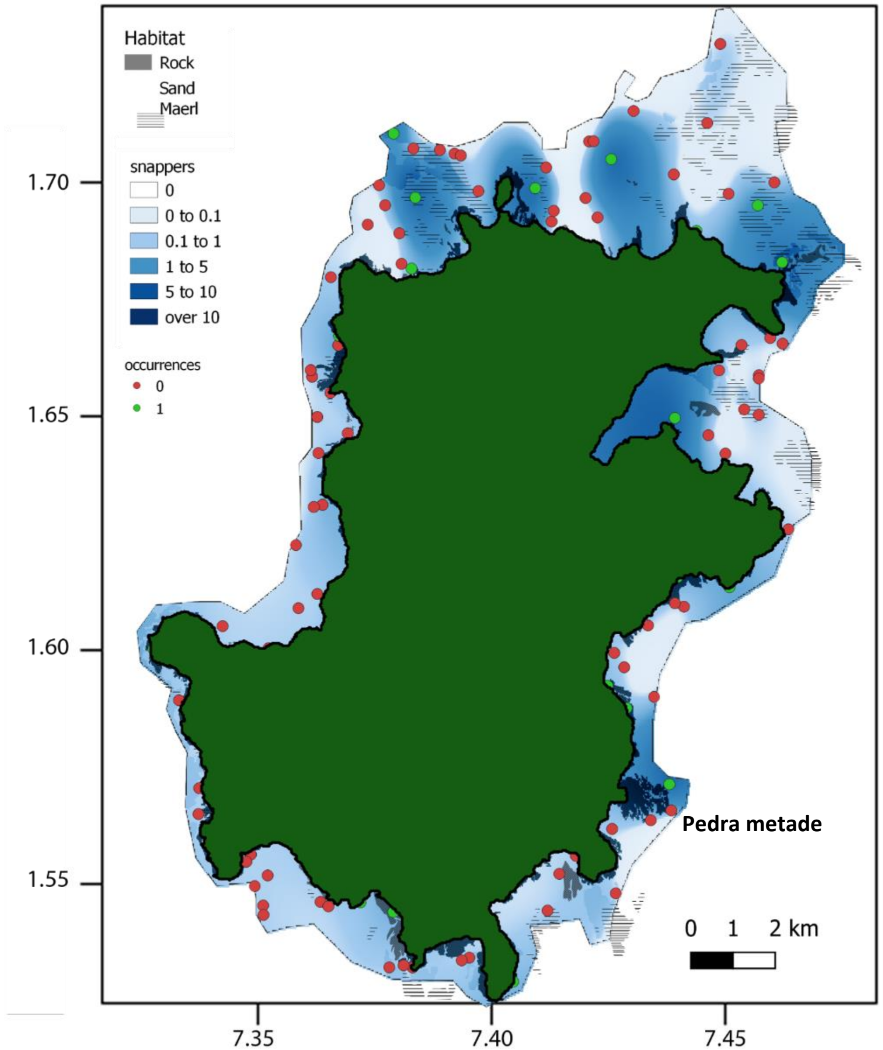

Figure 9: Distribution of CPUE of snappers of the genus Lutjanus measured using BRUVs and interpolated using a TPS regression model.

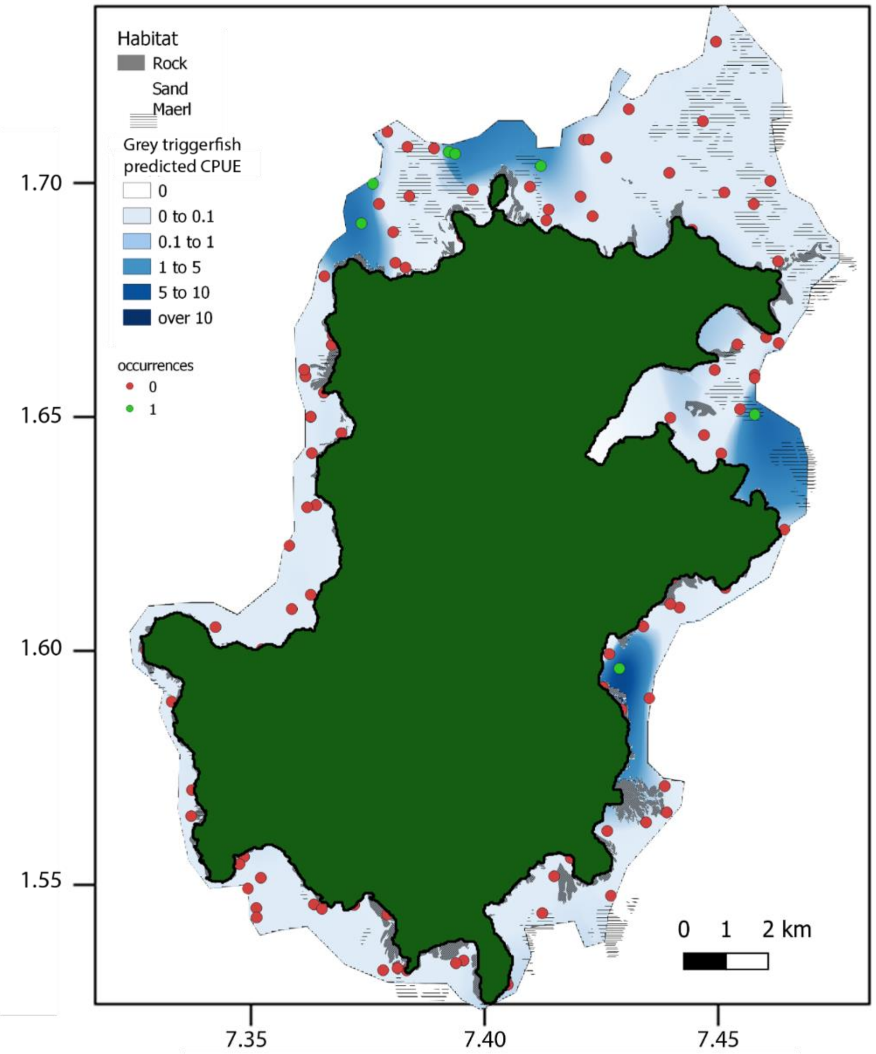

Figure 10: Distribution of the CPUE of the grey triggerfish (*Balistes capriscus*) measured using BRUVs and interpolated using a TPS regression model.

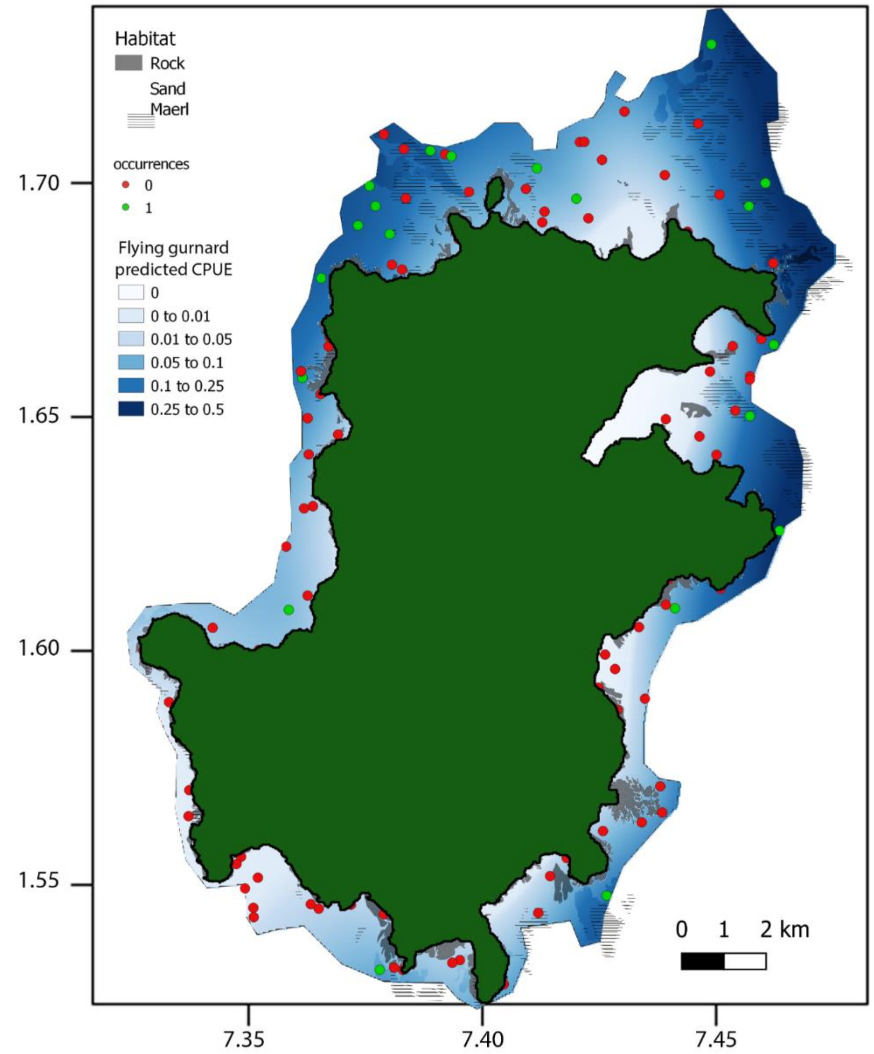

Figure 11: Distribution of the CPUE of the sand-bottom-dwelling species flying gurnard (*Dactylopterus volitans*) measured using BRUVs and interpolated using a TPS regression model.

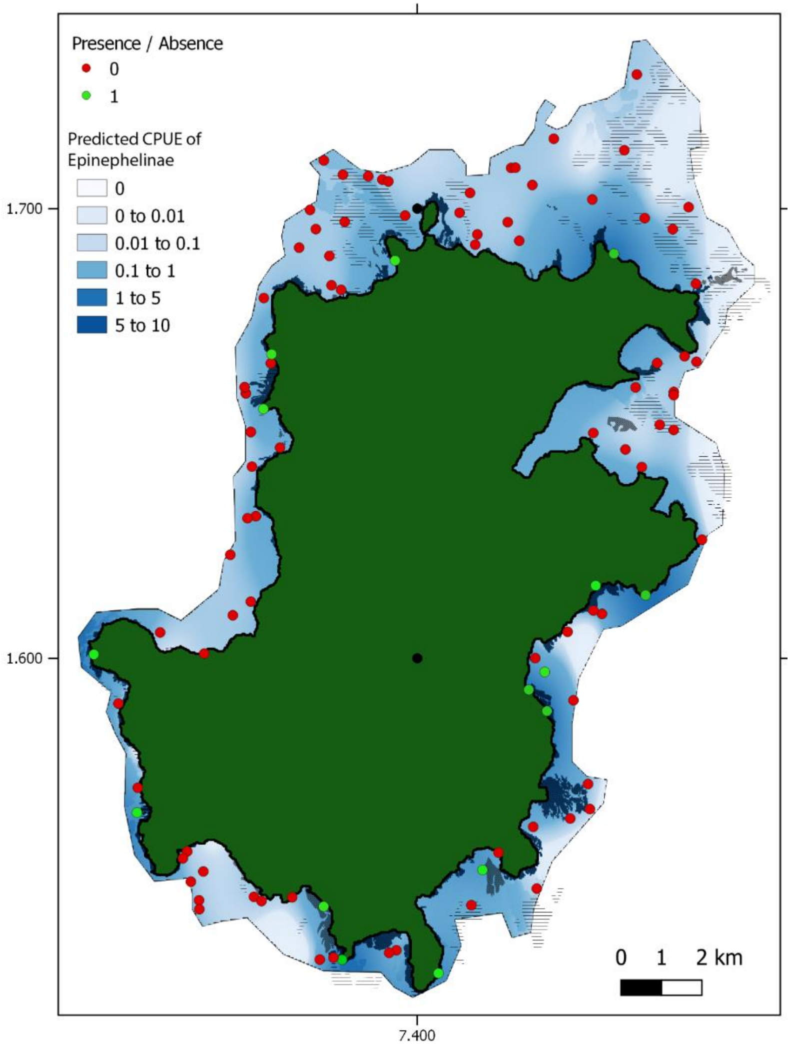

Figure 12: Distribution of the CPUE of the groupers and seabasses (subfamily Epinephelinae) measured using BRUVs and interpolated using a TPS regression model.

OUTREACH

Five cinema sessions in São Tomé and two in Príncipe (approximately 15 minutes each) using BRUV videos from the Blue Action Project and Omali Vida Nón projects. Fishers, fish traders, children and other people attended the events. The communities in São Tomé were Ilheu Rolas (7 attendants), Porto Alegre (20 attendants), Malanza (15 attendants), Monte Mário (10 attendants), Ribeira Afonso (7 fishers and over 30 children). In Príncipe, the events were organised in Campanha (the whole community attended, approximately 30 people) and Abade (approximately 30 people).

RECOMMENDATIONS

FUTURE TRAINING NEEDS:

- The marine team in Príncipe is ready to conduct fieldwork independently under Lindo's coordination.
- The crew who was hired in São Tomé (Quaresma, Juvéncio and Wilker) received between 4 and 8 days of training and are ready to conduct fieldwork independently. The coordination team in São Tomé (Márcio and Albertino) would benefit from having support, mostly for reading and handling the GPS.
- Both Principe's and São Tomé's team would benefit from having support on managing, labelling and copying the videos into the computer, as well as recording BRUV's metadata into the computer.

SAMPLING STRATEGY:

- Sampling should happen in two sampling rounds: the first one in 2019-2020 will provide baseline data for the design a potential network of Marine Protected Areas, whereas the second one, in 2022 and 2023 can be used to detect potential changes in fish assemblages as a consequence of the implementation management measures.
- Each round should have two seasons: the first season in *gravana*, the drier and colder season (July to September) and the second one in January – February, the warmer season between the two rainy seasons in November and March.

CLEANING AND VALIDATING BRUV DATA:

- Since BRUV videos will be analysed by different observers, it is recommended to perform a validation analysis. This validation analysis could be done by another observer (a "validator"), who would analyse a subsample of the videos analysed by each observer. The results of the analyses done by the validator would then be compared to the results of each of the observers, in order to have a common reference to detect whether any of the observers might be overestimating or underestimating the number of fish present in the video.
- A verification analysed could be done afterwards by an observer with good knowledge on São Tomé and Príncipe marine fish species. This could be done verifying every instance to detect potential mistakes in fish identification.

Figure 13: Screening of BRUV videos in Campanha (Príncipe, top), Porto Alegre (São Tomé, middle) and Ilheu Rolas (São Tomé, bottom)

REFERENCES

Abreu, A. D. *et al.* (2016) 'Final Report Scientific Expedition Bio-Principe 2016', *IU-ECOAQUA, Universidad de las Palmas de Gran Canaria, Spain*.

Alexandre, A. *et al.* (2017) 'First description of seagrass distribution and abundance in São Tomé and Príncipe', *Aquatic Botany*. Elsevier, 142(October), pp. 48–52. doi: 10.1016/j.aquabot.2017.06.008.

Cowburn, B. C. (2018) 'Marine Habitats of Príncipe , Eastern Tropical Atlantic – Description and Map', *Report for the project Omali Vida Nón (University of Exeter & Fundação Príncipe, funded by Darwin Initiative, Halpin Trust & Africa's Eden)*.

Doherty, P. (2018) *Schematic used for building Baited Remote Underwater Video frames*, *Report for the project Omali Vida Nón (University of Exeter & Fundação Príncipe, funded by Darwin Initiative, Halpin Trust & Africa's Eden)*. Available at: https://omaliprincipeen.weebly.com/uploads/2/5/6/2/25623460/bruvschematic.pdf.

Nuno, A. *et al.* (2019) *Omali Vida Nón - Summary of project activities and preliminary results*. Available at: https://omaliprincipeen.weebly.com/uploads/2/5/6/2/25623460/summary_finalen-compressed.pdf.

Porriños, G. and Nuno, A. (2019) 'Marine biodiversity assessment through baited underwater camera monitoring and maturity assessment of selected demersal fish species', *Report produced by The University of Exeter for Africa's Eden*, (April), pp. 1–30.

ANNEXES

Annex I: Schematics for building the BRUV devices

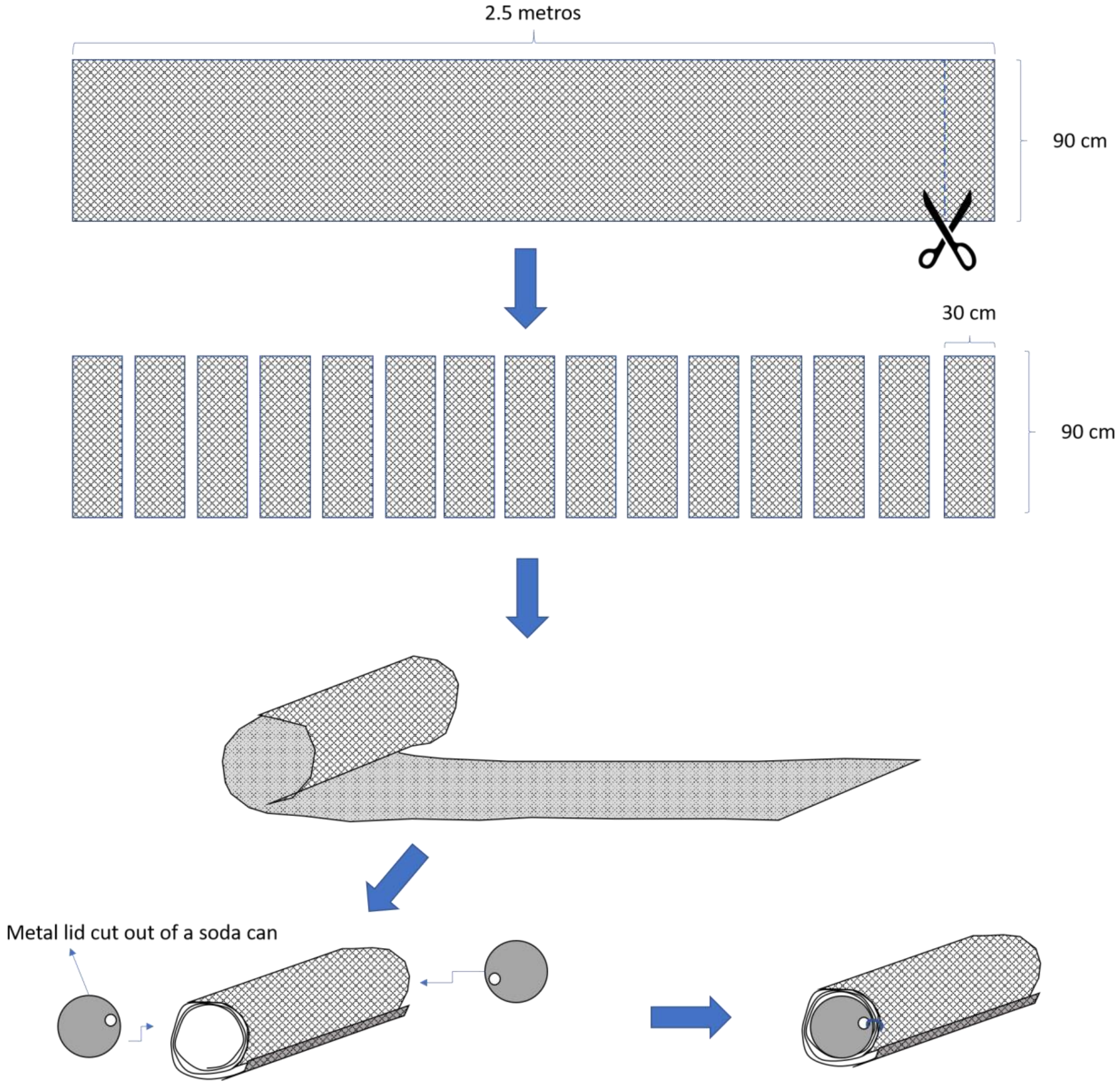

Figure I: Instructions for building a bait cage out of chicken wire.

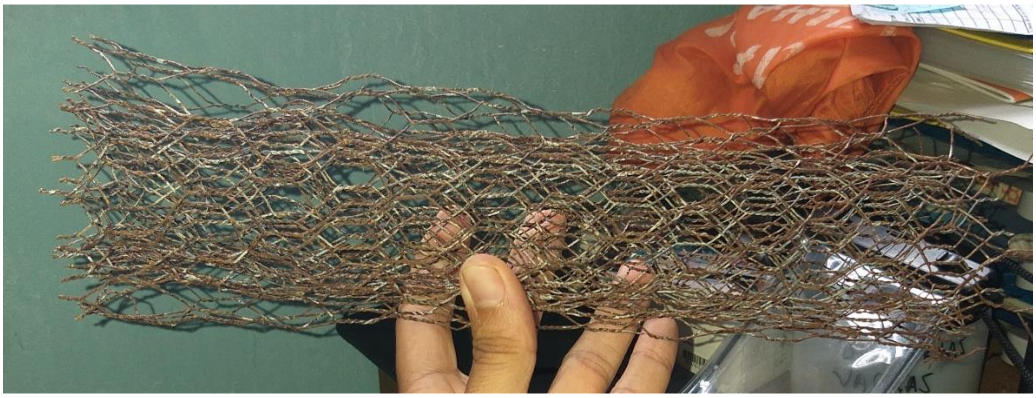

Figure II: Picture of a bait cage

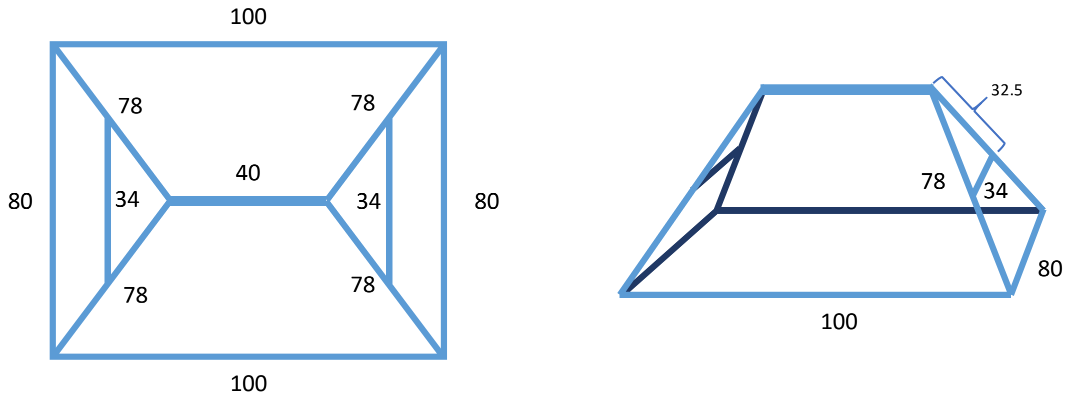

Figure III: Measurements of the BRUV frames used in São Tomé. Tope view (left) and side view (right)