Benthic Habitat Mapping in the coastal waters of Saba Dutch Caribbean

12/16/13

Internship Coastal Zone Management

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SUMMARY

In this research benthic habitats of the Saba Marine Park were mapped. There were several reasons for an updated benthic habitat map: (1) to compare the current situation to the baseline study carried out in 1992 and identify habitat changes in the past 21 years; (2) to review the zoning plan of the Saba Marine Park for which an accurate habitat map is required to identify suitable zones for marine reserves, anchoring, diving and fishing; (3) to support stratification in fisheries research such as lobster, conch and fish population studies; and (4) to produce value maps as part of the economic valuation study currently taking place on Saba and Sint Eustatius (What's Saba and Sint Eustatius Nature Worth?) for which habitat maps are necessary to assign monetary value at a spatial scale.
The research questions answered in this study were: (1) which benthic habitats are located where; (2) what are the rough species compositions in these habitats; and (3) what is the structural complexity in these habitats.

Data were collected from video images made with a HD camera, which was dropped from the marine park boat at 276 sample sites. A 150x150m grid was used to select sample sites at regular distances from the shore to the outer boundaries of the marine park. During data analysis three substrate types (sand, rubble and rock) and six benthic species groups (macro algae, sargassum, sea grass, corals, gorgonians and sponges) were identified and percentage coverage of these substrates and benthos were estimated. These percentage coverage were used to classify the samples into ten habitat types according to a pre-defined quantitative classification scheme based on the classification scheme of Caribbean coral reefs by Mumby PJ and Harborne AR (1999)

The resulting habitat map shows that of these ten habitat types only 7 occurred on Saba: bare sand, bare rock, diffuse patch reef, dense patch reef, coral reef, sea grass beds and algae fields. Sargassum fields did not occur, as this species of algae was not found on Saba. Gorgonian reef did not occur, although gorgonians were commonly present at other habitat types, i.e. patch and coral reefs. Bare rubble habitats did also not occur.

Besides the benthic habitat map, two other habitat maps were produced. A reef habitat map including the current zoning plan was produced to compare the zoning system of the Marine Park with the reefs identified in the study. A sand habitat map was produced to further specify the large number of sand habitats in two: bare sand and sand covered with algal and/or cyanobacteria mats. The sand habitat map revealed that sand habitats covered with algal and/or cyanobacteria mats were present around the entire island further ashore, of which the majority was at 30-50 meter depth.

1 Introduction

The Saba National Marine Park was established in 1987 with the objective to preserve and manage the marine resources in the coastal waters of Saba.

Saba is a Dutch Caribbean Island that used to be part of the Dutch Antilles islands and since 10 October 2010 is a special municipality of the Netherlands, as are Sint Eustatius and Bonaire (Figure 1A). Saba has 1800 inhabitants and has a rocky coast. It is 13 square kilometres and consists of a sleeping volcano with four lava domes and its highest point is 877 meters.

The Saba Marine Park was established to ensure the continued quality of the extraordinary marine resources. A zoning system was applied to get the best possible compromise between different uses of the marine environment [1]. In 1992 a baseline study was carried out to identify the benthic habitats in the coastal waters of Saba, which was the basis for the zoning plan of the Saba Marine Park (Van Beek, 2013).

The map of Saba (Figure 1B) shows the current zoning plan in the Marine Park (Wulf, 2013), which distinguishes mooring zones, no-take zones, recreational zones and multipurpose zones. This zonation was based on the benthic mapping of 1992. There was a need for an updated benthic habitat map for several reasons: (1) to compare the current situation to the baseline study carried out in 1992 and identify habitat changes in the past 21 years; (2) to review the zoning plan of the Saba Marine Park for which an accurate habitat map is required to identify suitable zones for marine reserves, anchoring, diving and fishing; (3) to support stratification in fisheries research such as lobster, conch and fish population studies; and (4) to produce value maps as part of the economic valuation study currently taking place on Saba and Sint Eustatius (What's Saba and Sint Eustatius Nature Worth?) for which habitat maps are necessary to assign monetary value at a spatial scale.

This research into an updated benthic habitat map for Saba has been based on recent research in Sint Eustatius carried out by (Timmer and Houtepen, 2013), which identified and mapped the benthic habitats in the Sint Eustatius Marine Park. The research by Houtepen and Timmer (2013) was similar to the habitat studies at the Spaanse Water in Curacao and in Lac Bay in Bonaire. However, these studies included only a part of the islands coastal waters, while in the current study of Saba, the entire coastal waters up to 60-meter depth have been covered. The objective of this research was to identify all different types of habitats present in the coastal waters of Saba, differently to the Curacao and Bonaire studies, where the focus was on seagrass species and algal beds.

[1] http://www.sabapark.org/about_scf/

Figure 1A: *Overview of the position of Saba in the Caribbean Sea*.

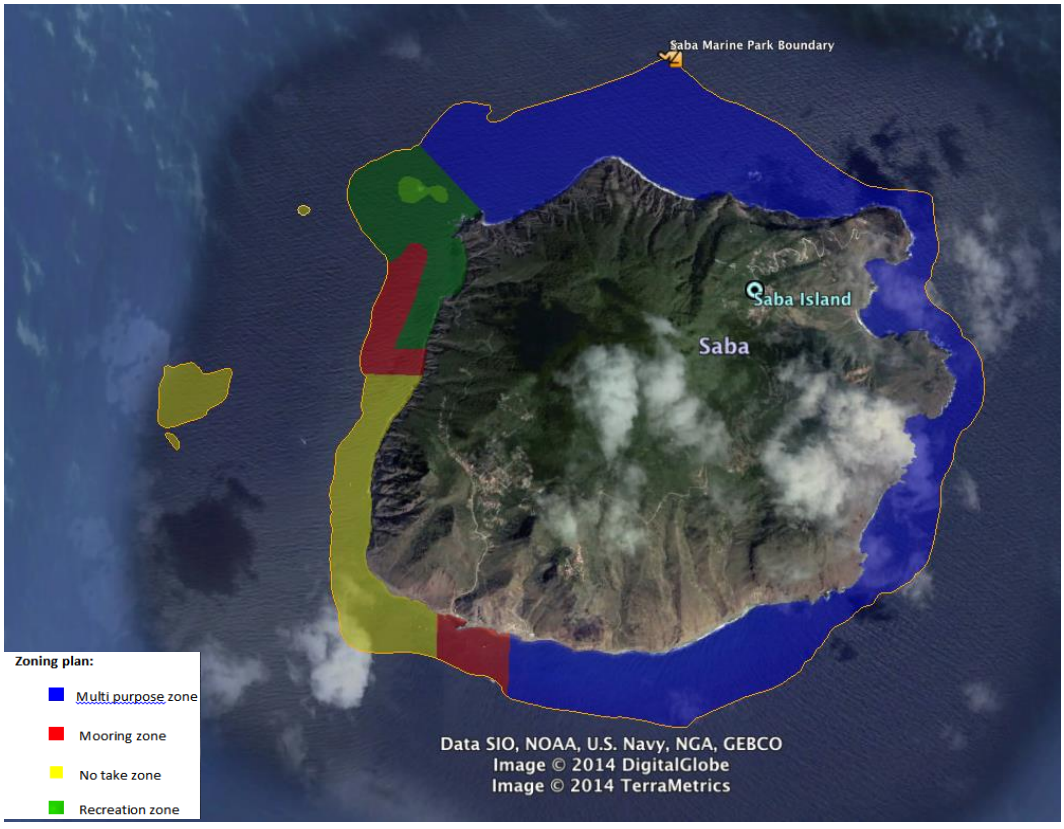


Figure 1B*: Close up of Saba Island, including the zoning plan and Marine Park boundaries (Wulf, 2013)*

1.1 Research questions

The objective of this research was to find out the benthic habitats present in the coastal waters of Saba. Our specific questions were: (1) which benthic habitats are located where; (2) what are the rough species compositions in these habitats; and (3) what is the structural complexity in these habitats. In order to answer these questions the research was divided in six phases: first, collecting video images to build up the benthic map by using a drop camera; second, identifying the different substrates and benthic compositions at each location; third, determining the rough percentage coverage of the substrates and benthos at each location; fourth, defining the structural complexity categories at each location; fifth, determining the habitat type of each location based on substrate and benthic coverage; and sixth, producing a habitat map of all locations.

1.2 Duration of research

This research was carried out from August 12th to January 12th, 2014. After a week of theoretical training and preparation in the Netherlands, the field training was done in St. Eustatius in August for 10 days from August 22nd to August 31st. The fieldwork was done in Saba from September 1st till December 1st. The data analysis was carried out in December in the Netherlands, followed by the report writing in January.

1.3 Site description

Saba has a pleasant climate throughout the year, with an average annual temperature of 27.5 ^{0}C (Willems). The trade winds blow throughout the year as well, from directions between east-northeast and east, causing humid air. The average sea temperature varies between 26 ^{0}C and 29 ^{0}C(Willems). Saba is situated in the hurricane zone and belongs to the windward Islands of the Dutch Caribbean. The hurricane season runs from July till November. The northern and eastern side of the island are exposed to strong wave impacts and currents; this area stretches from the northwest till the southeast. The other side of the island, from the west till the southeast is less exposed to strong wave impacts and currents. In this area you will find more swells and different surface and bottom currents. During the rainy season the average rainfall is 1080 millimetres (Willems) The volcano Mount Scenery is the highest point (877m) of the Dutch Caribbean. Because of its elevation and the frequent rainfall, Mount Scenery is a cloud forest. This is a rainforest that is frequently covered by clouds which leads to a reduction of sunlight, but high biomass because of its highly moisturous and geographic location.

The Saba Marine Park, as shown in Figure 1B, encompasses the waters and seabed encircling the whole island from the high water mark to 200 feet (60m). In total the Marine Park covers approximately 1300 hectare (13km^2). The current research took place in the waters of the Marine Park and was supported by the Saba Conservation Foundation (SCF). SCF boats were used to collect video images at the sample sites and SCF researchers, volunteers and interns contributed to and assisted with the fieldwork.

1.4 Acknowledgements

We would like to thank the following people for their kind assistance in gathering data, training, fieldwork, financing and other assistance:

Erik Boman from Agriculture, Livestock and Fisheries Department of Sint Eustatius, for providing a training with all the equipment which was used for the research, Kai Wulf, manager of Saba Conservation Foundation for supervising us during our stay, Dozlyn Pouchie and Laszlo Charles as captains of the boats used for the research and their knowledge of sea swells and currents and the best places to do the research drops and Jelle van der Velde as Saba Marine Park trainee who assisted us on the boat when help was needed.

Furthermore we would like to thank Susan Hurell for assisting us at the office during our research, Susan Burkhard for helping us with the financial information and payments for the boat and Shadan Lavia for helping us during our research when the frame needed to be pulled up manually.

2 Methods and Materials

2.1 Method

The methodology used was similar to the methods and materials used by Houtepen and Timmer (2013) at Sint Eustatius. A camera was dropped from the boat at regular distances from the shore to the outer boundaries of the marine park. A grid of 150 x 150m was used as a guideline to identify sample sites to drop the camera. Afterwards the videos were analysed to determine the different habitats and percentage cover of the substrate and benthos. The main differences of our method compared to the study of Houtepen and Timmer (2013) were the maximum depth of 60 meter instead of 30 meter, which are the Marine park boundaries at Saba and Sint Eustatius respectively, the use of an additional high definition camera for improved quality of the images and better identification of substrate and benthic cover, and a more quantitative approach to categorize habitats.

2.2 Materials

For the benthic habitat mapping a so-called drop camera was used to record the benthic habitats of the Marine Park. The underwater video camera, a SeaViewer type SEA-DROP 950, was connected to EyeTop LCD sunglasses and a 4k recording DVR. After a few drops, this method with the EyeTop LCD glasses was aborted and the camera was attached to a LCD screen, which was available from another research at SCF (Conch survey). The LCD screen prevented seasickness and provided a better life view of the water column and on the seafloor, thereby preventing damage to the seafloor. The other purpose of the use of the life feed was to have a first impression of the benthic substrate. A second camera, a GoPro Hero3 Black edition, was used to record the entire drop. The footage was made with the highest possible resolution of 1440 x 1080 pixels, in order to better identify substrate, benthos and percentage cover in the data analysis.

Both cameras were attached to a cylinder-form frame (figure 2) weighing approximately 5 kilogram, to give balance to both cameras and to ensure that the GoPro camera was facing straight down. In addition, the frame minimized the influence of currents on the position of the camera. The SeaViewer was placed such that it could see what the GoPro camera was recording and to ensure that the frame did not get stuck behind rocks. The GoPro was secured to the frame with a metal bar (figure 3).

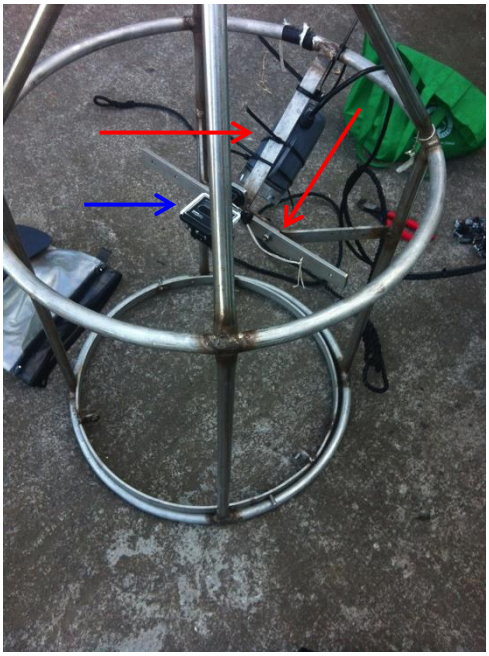


Figure 2: The mount of the two cameras on the frame. The red arrow indicates the attachment of the SeaViewer on the camera and the direction it is facing. The blue arrow indicates the GoPro camera.

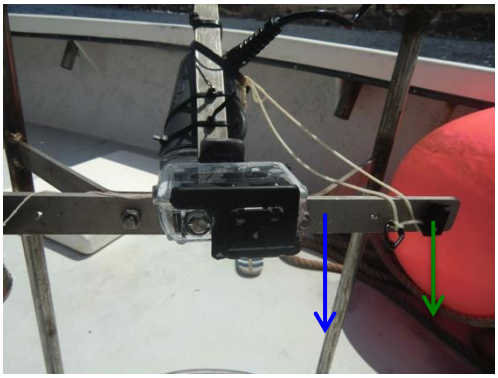


Figure 3: The metal bar where the GoPro camera was attached. The blue arrow indicates the direction in which the GoPro is facing for the recording. The green arrow indicates where the lamp was placed on the right side of the metal bar.

Because of light reduction in deeper water, two Light and Motion Sola 1200 video lamps were attached on each side of the same metal bar where the GoPro camera was attached. Both light beams were centred to the place where the GoPro camera would record the seafloor. The video lamps would facilitate better data recording and species identification. However, the screws of the lamps came loose in the third and fourth week of the study due to strong currents. This is the reason why the video lamps could not be used for the remaining drops. Surprisingly, the absence of the lamps did not influence the visibility for the recording and the SeaViewer as well as on the identification of the percentage cover of the habitats.

2.3 Sample site selection

Sample site selection in this study was similar to the method of Houtepen and Timmer (2013). Sample sites were selected using a 150 x 150 meter grid (Figure 4). The boat was driving transect lines perpendicular to the coast. The starting point for the transect line was at approx. five meter depth. This was as close as possible to the coastline while keeping the boat at a safe distance from the coast at the same time. From this depth the frame was dropped every 150 meter using a GarminGPS, model GPSMAP® 78. The GPS was also used to navigate in a straight line and to mark each site with a waypoint. The end point of the transect line was at a depth of 60 meter. When the 60 meter boundary was reached, the next transect line was started by going either 150 meter left or right and then back to shore. This was also done in a straight line and every 150 meter a drop was made until 5 meter depth. This created a rough 150 x150 meter grid. By making GPS waypoints the coordinates could be uploaded in Google Earth to create a habitat map. The depth was determined with the depth sonar on the boat. An automatic pulley was present on one of the boats to lift the frame up.

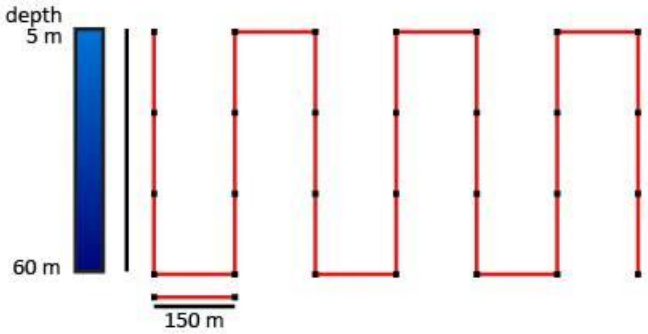


Figure 4: Every point is a drop. The grid is seen from above. Where 5 meter near the cost is.

2.4 Data collection

At each sample site, the following data were recorded, in addition to the video, in a logbook (Appendix I) of waterproof paper.

- The depth of the site;
- The video number of the recording on the GoPro;
- The waypoint number on the GPS;

The depth of the site was recorded to determine if a drop could be made or not. A drop could not be made if the depth was deeper than 180 feet or 55 meters.

Every site had a video recording, which was used in the data analysis to determine substrate, benthos, percentage cover, and ultimately the habitat type. Two stills were made from the video recording, at two different depths. The first still was a close-up of the sea floor and the second still was at five meters above the sea floor. The use of each still in the data analysis is explained in the next paragraph. The five meter was measured with a rope (of five meters) and a weight. When the weight reached the bottom it was seen on the camera. This method was aborted, because the weight could get stuck easily and it was not always visible when the weight reached the sea bottom. The second method used to

determine when the camera was five meters above the seafloor, was by manually pulling the rope up five arm-lengths to approximate five meter.

The video numbers of the sample sites were registered to use as unique identification number of each sample site and to determine which video, what depth and what waypoint corresponded with each sample site. These video numbers were also used to determine when to switch the battery and SD card in order to prevent data loss. The average number of videos that could be made with one battery with the GoPro was 10 videos of approximately 3 minutes per battery.

2.5 Data analysis

For the data analysis two stills were made from the recording of each drop. The first still, named “A”, was a screenshot of the frame when it was closest to the seafloor. The second still, named “B”, was a screenshot of an overview of the habitat, which was approximately five meters above the seafloor. To make the stills and to analyse the videos two laptops were used; a MSI GE70N and a MacBook Pro.

For the percentage cover of substrate and benthos and the habitat classification, still “B” was used to determine three different characteristics; substrate (sand, rock, rubble), dominant species (macro algae, sargassum, sea grass, coral, gorgonian, sponge) and percentage cover of the substrate and dominant species. These characteristics were the indicators for the habitat classification, as explained in the next paragraph.

Still “A” was used for a close-up view of the substrate and benthos in order to identify the type of substrate and benthos present in each drop as well as to improve the overall estimation of the percentage of the different categories of vegetation.

2.5.1 Habitat classification

Habitat types used (table 1) were similar to the habitat types used by Houtepen and Timmer (2013). One habitat type was added (bare rock) and the coral reef habitats were named differently (diffuse patch reef, dense patch reef and coral reef instead of loose reef, intermediate reef and dense reef). The habitat classification of this study was based on the systematic classification of marine habitats in the Caribbean by Mumby and Harborne (1999). Not only habitat types and habitat definition were determined as in the study of Houtepen and Timmer (2013), but quantitative indicators for an as objective as possible classification were added. Selected quantitative indicators were specific substrate percentage coverage and benthos percentage coverage.

Table 1
Classification based on the following indicators (substrate and benthos percentages coverage)

			Substrate cover	***Benthos cover***			
Colour	***Habitats Saba***	***Definition***		***Seagrass***	***Algae field***	***Gorgonian***	***Hard coral***
YELLOW	Bare sand	Sandy bottom (macro) benthos negligible	Bare sand ≥ 90%	No	Sparse algal cover possible (<10%)	No	No
GREY	Bare rubble	Rubble bottom (macro) benthos negligible	Bare rubble ≥ 90%	No	Sparse algal cover possible (<10%)	No	No
DARK BROWN	Bare rock	Rocky/hard bottom (macro) benthos negligible	Bare rock ≥ 90%	No	Sparse algal cover possible (<10%)	No	No
LIGHT GREEN	Macro algae field	Rubble/rock bottom (mainly) macro algae	Bare sand+rubble+rock <50% Rubble/rock underneath (not bare)	No	Algal cover dominated (>50%)	Sparse gorgonian possible (<3/m^2)	No
LIGHT BROWN	Sargassum field	Rubble bottom (mainly) sargassum	Bare sand+rubble+rock <50% Rubble/rock underneath (not bare)		Sargassum dominated (>50%)	Sparse gorgonian possible (<3/m^2)	No
DARK GREEN	Seagrass bed	Sandy bottom (mainly) seagrass	Bare sand around and sand underneath (not bare)	Seagrass cover: dense (>50%) sparse (<50%)	No	No	No

ORANGE	Diffuse patch reef	Sandy/rubble bottom with dispersed (living or dead) coral colonies, mixed with algae, gorgonians and sponges	Bare sand/rubble % > reef %	No	Macro algae present as part of mixed reef	Gorgonian present as part of mixed reef	(Living or dead) hard coral between 1-10% (may be more)
RED	Dense patch reef	Sandy/rubble bottom with aggregated (living or dead) coral colonies, mixed with algae, gorgonians and sponges	Bare sand/rubble % < reef %	No	Macro algae present as part of mixed reef	Gorgonian present as part of mixed reef	(Living or dead) hard coral between 1-10% (may be more)
PURPLE	Coral reef	Mainly hard substrate covered with (mainly) hard corals, mixed with algae, gorgonians and sponges	Reef >90%	No	Macro algae present as part of mixed reef	Gorgonian present as part of mixed reef	(Living or dead) hard coral between 1-10% (may be more)
BLUE	Gorgonian reef	Rubble/hard substrate covered with (mainly) soft corals	Rubble/rock underneath/ around (bare and not bare)	No	Algal cover possible (10-30%)	Number of gorgonian: dense (>3/m^2 usually >8/m^2) sparse (<3/m^2)	<1%

For each still percentage coverage was estimated for the three substrate types and eight benthos types and entered in a Data input sheet (Appendix III).

As part of the data analysis also the structural complexity at each site and the presence or absence of cyanobacteria and Acropora species (branching corals) were recorded. There were 6 categories for the structural complexity (Appendix IV) according to the methodology of Polunin and Roberts (1993).

The extra sampling of different types of vegetation was not performed by SCUBA diving as by the study of Houtepen and Timmer (2013), but the intention was to use the stills "A" for this. However, the quality of the GoPro was not good enough to do so.

2.5.1.1 BARE SAND

The habitat type 'Bare Sand' was defined as: Sandy bottom with negligible macro benthos, where bare sand cover is ≥ 90% (Table 1). Figure 5 shows an example of a habitat that satisfied the definition of 'bare band'.

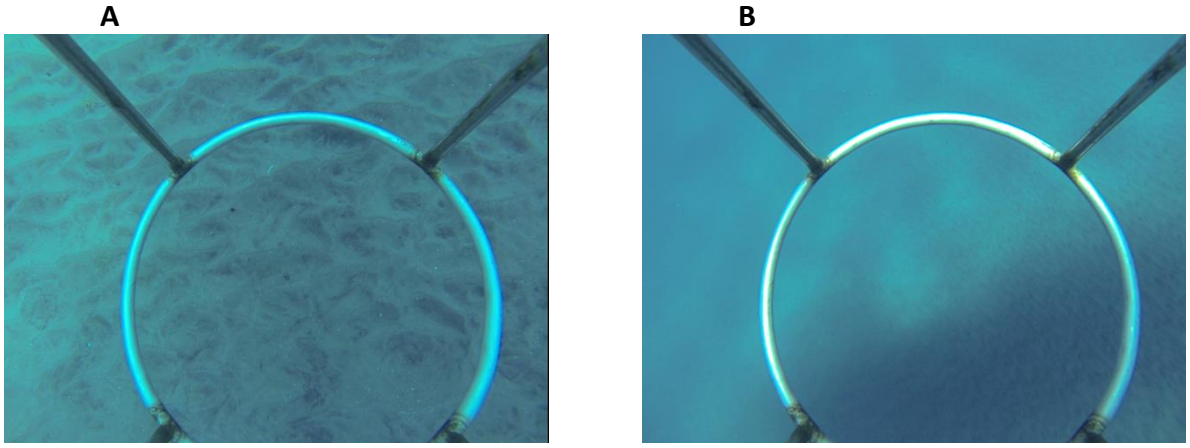


Figure 5: Still 101, classified as 'Bare Sand', consisting for 100%.

In our data analysis we deviated for some of the 'Bare Sand' habitat types from the predefined classification of ≥ 90% bare sand. The sand was in some stills less than 90% and mixed with some minor rubble (up to 15%), sparse macro algae and algal and/or cyanobacteria mats. If the sand dominated the rubble, 'Bare Sand' was chosen as habitat type (Figure 6).

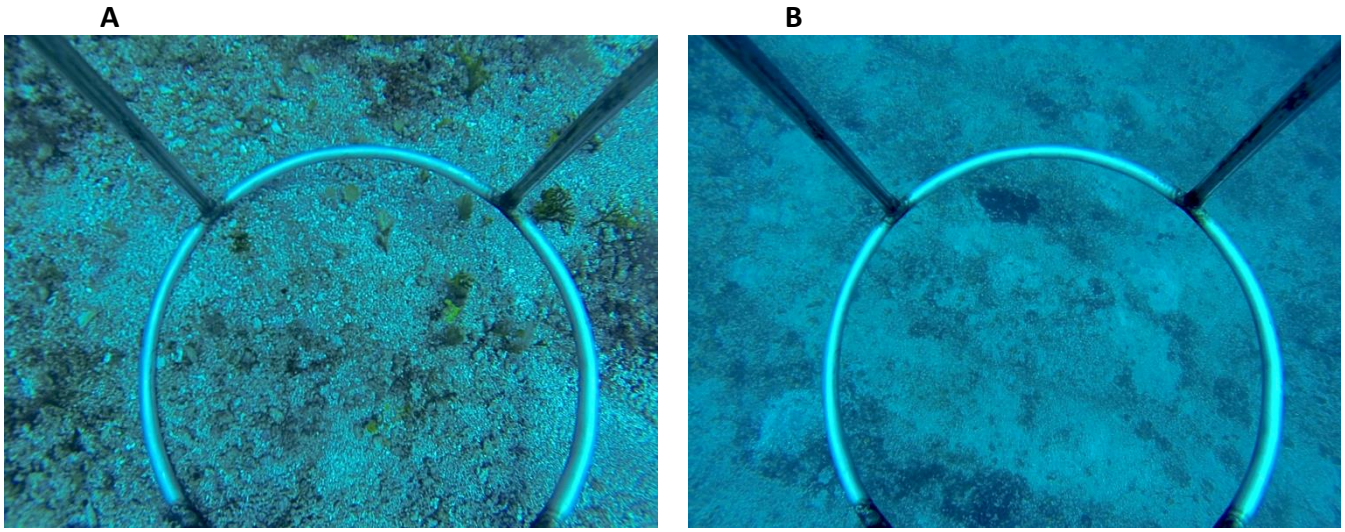


Figure 6: Still 077, consisting for 54% of Bare Sand, 35% of Bare Rubble and 11% Maco Algae.

If the sand was covered with macro algae - either dense or sparse algal fields - we classified it as 'Bare Sand' if the algal fields were covering the bottom for less than 50% (Figure 7) and we classified it as 'Macro algal field' if the algal fields covered more than 50% of the bottom (Figure 11) in paragraph 2.5.1.4).

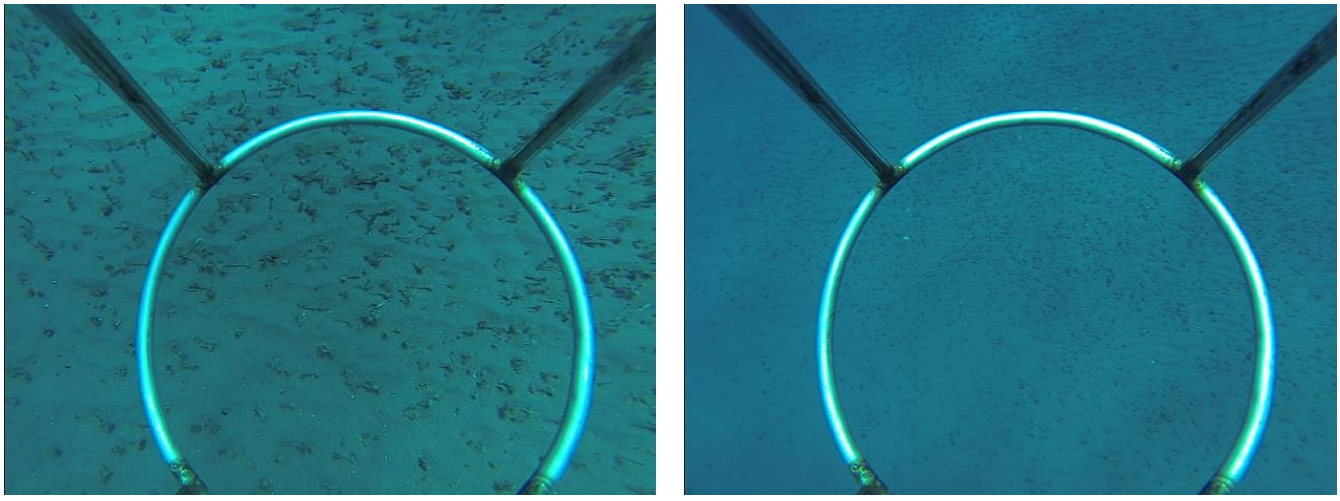


Figure 7: Still 238, consisting for 80% of Bare Sand and 20% of macro algae.

If the sand was covered with algal and/or cyanobacteria mats we also choose 'Bare Sand', because we did not include algal and/or cyanobacteria mats (Figure 8) as a separate benthic species in the percentage cover. We only registered presence or absence of potential cyanobacteria mats, which could also be algal mats.

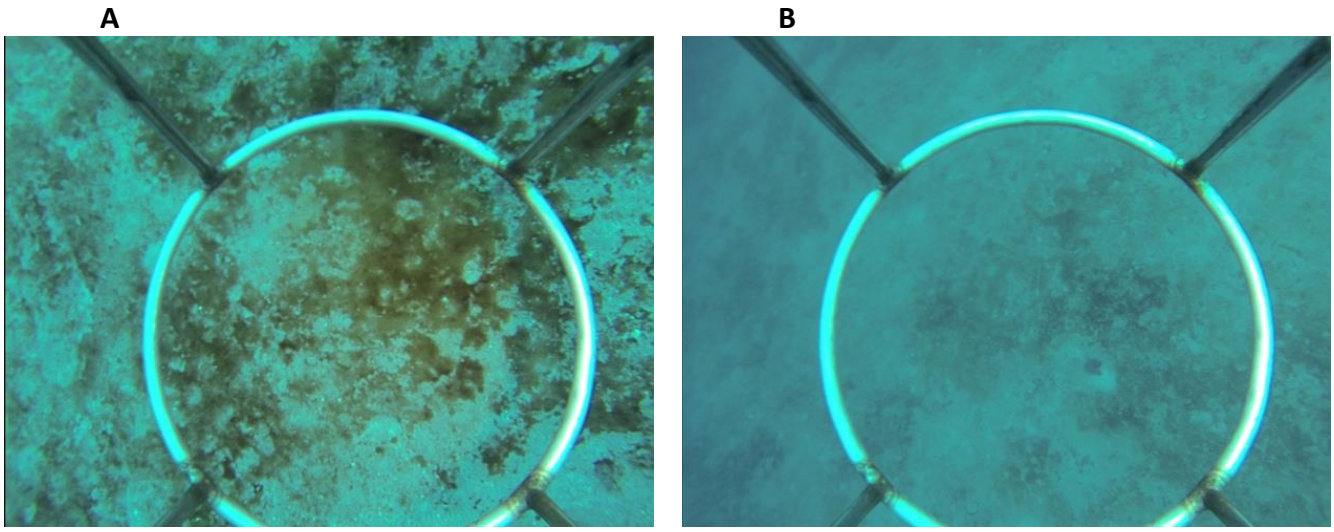


Figure 8: Still 41, classified as 'Bare sand', consisting for 100% of Bare Sand. Algal and/or cyanobacteria mats are registered as present here, but not included as a separate benthic species in the percentage cover.

Because roughly half of our habitats turned out to be sand habitats and because there were a lot of them with algal and/or cyanobacteria mats like in figure 8 we also produced a sand habitat map (paragraph 3.6) to differentiate between 'Bare Sand' and 'sand with algal and/or cyanobacteria mats'.

2.5.1.2 BARE RUBBLE

The habitat type 'Bare rubble' was defined as: "Rubble bottom with negligible macro benthos, were bare rubble cover is ≥ 90% and sparse algal cover is possible (<10%) (Table 1). During our data analysis we did not classify any "Bare Rubble" that matched the description of Bare Rubble from table 1. We did find rubble, but this was classified under other habitats due to greater percentage cover of rock, sand or reef than rubble cover. Figure 9 is an example of rather high rubble cover, which was nevertheless not classified as Bare Rubble.

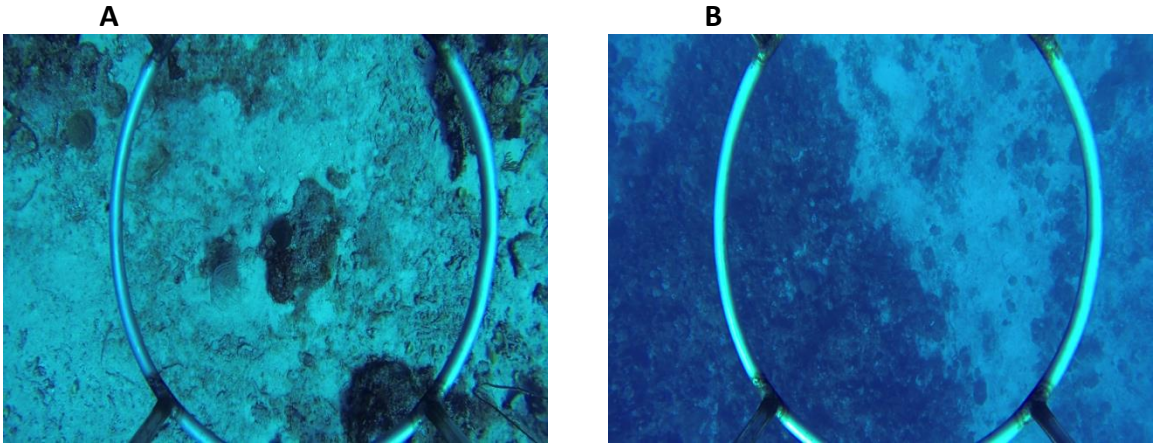


Figure 9: Still 210, consists a composition of 20% Bare Sand, 20% Bare Rock and 60% of Reef. The 60% of Reef consists of 25% Macro Algae, 20% of Sponger, 10% of Gorgonian and 5% of Hard Coral.

2.5.1.3 BARE ROCK

In our data analysis we deviated for most of the 'Bare Rock' habitat type from the predefined classification; "Rocky/hard bottom (macro) benthos negligible, bare rock ≥ 90%." More than 90% of bare rock (Figure 9) did hardly occur, however predominantly rocky substrate did. On Saba the rocky bottoms frequently have some minor benthic cover (mainly sponges, crustose coralline algae and some hard coral or fire coral) up to 15% (Figure 10), and sandy patches in between the rocks of up to 40%. Nevertheless we classified this as habitat type 'Bare Rock' as this was the dominant cover.

A B

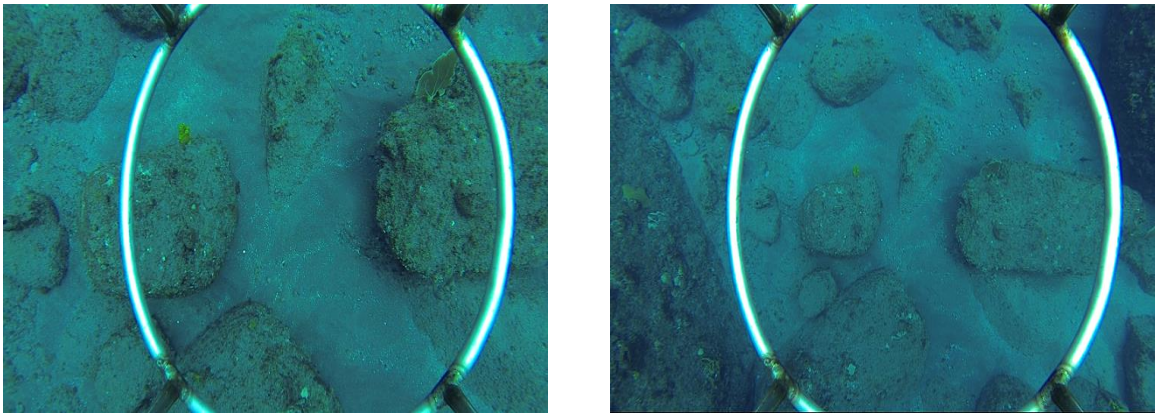


Figure 10: Still 157, consists a composition of 45% Bare Sand, 43% Bare Rock and 12% Reef. The 12% Reef consists of 5% Macro Algae, 6% Sponge and 1% of Gorgonian

A B

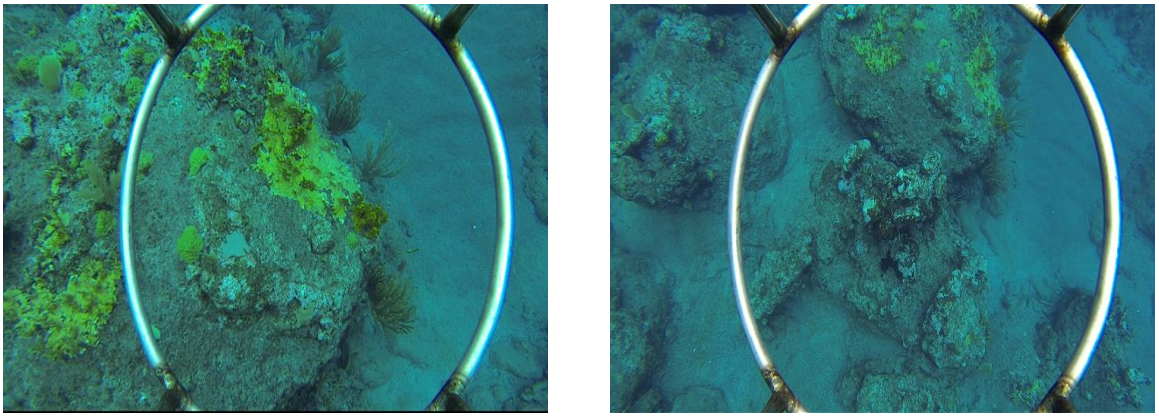
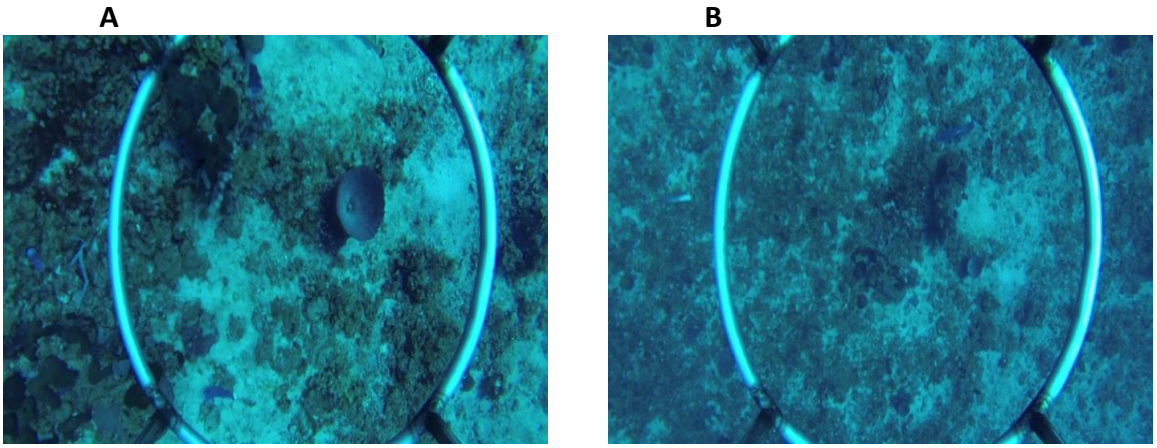


Figure 11: Still 170, consists a composition of 50% Bare Sand, 15% Bare Rock and 35% Reef. The 15% Reef consists of 8% Macro Algae, 5% Sponge, 12% Gorgonian and 10% of Hard Coral.

2.5.1.4 MACRO ALGAL FIELDS

The habitat type 'Macro algal field' was defined as: "Rubble/rock bottom (mainly) macro algae. Bare sand, including rubble and rock should be <50% Rubble/rock underneath (not bare)" from Table 1. None of the habitats found during our research satisfied that description. But we did encounter some habitats that had a high percentage of Macro Algae.



Figuur 12: Still 218, consists a composition of 30% Bare Sand and 70% of Reef. The 70% of reef consists of 50% Macro Algae and 20% of Sponge.

2.5.1.5 SARGASSUM FIELDS

Sargassum fields were not found during our study that satisfied the description of Table 1; "Rubble bottom (mainly) covered with sargassum. Bare sand including rubble and rock should be <50% with rubble/rock underneath (not bare)". But also no sargassum fields were seen during the study. Sargassum grows in the Sargasso Sea. Wind and currents are causing the movement and distribution of Sargassum through different waters, including the Caribbean Sea. According to the description of habitats where Sargassum grows, it is mainly present in shallow waters [2], which could explain why it is present on Sint Eustatius (Houtepen and Timmer, 2013) and not on Saba.

[2] MarLIN (2013), "Sargassum", http://www.marlin.ac.uk/speciesinformation.php?speciesID=4296

2.5.1.6 SEAGRASS BEDS

The Seagrass beds found in our study did not satisfy the description of Table 1; “Sandy bottom (mainly) seagrass. Bare sand around and sand underneath (not bare).” In our data set we also encountered habitat type ‘Seagrass’, however all seagrass fields were very sparsely vegetated (Figure 13) and not much of it occurred during the research drops.

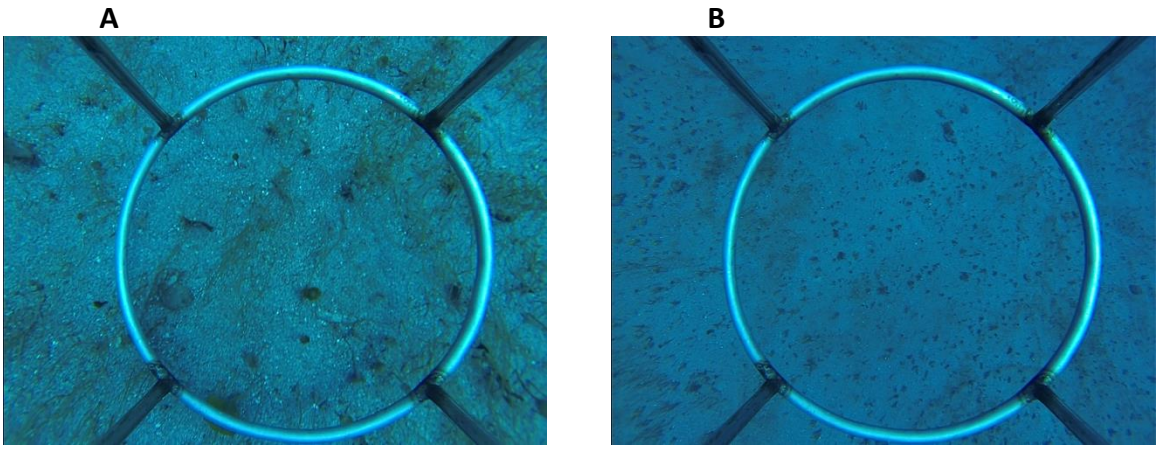


Figure 13: Still 233, consists a composition of 58% Bare sand, 25% Seagrass and 17% Macro Algae.

2.5.1.7 DIFFUSE PATCH REEF

During our data analysis we encountered habitat type “Diffuse patch reef” several times. Besides the “Bare Sand” habitat type, “Diffuse patch reef” was the second most frequently found in our research. With the definition described in Table 1: “Sandy/rubble bottom with dispersed (living or dead) coral colonies, mixed with algae, gorgonians and sponges". It was also frequently found that “Diffuse patch reef” classified drops were vegetated with gorgonians and sponges (Figure 14).

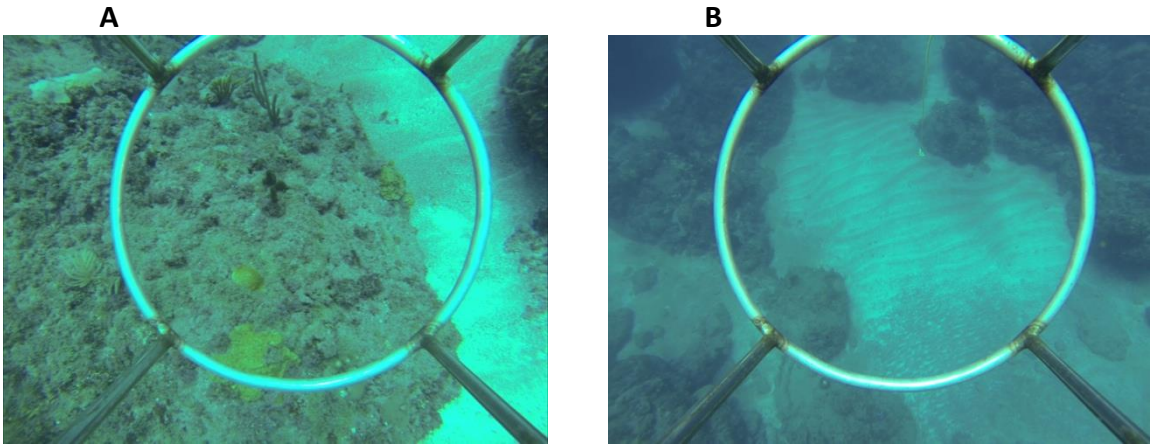


Figure 14: Still 001, consists a composition of 55% Bare Sand, 5% Bare Rock and 40% Reef. The 40% Reef consists of 30% Macro Algae, 5% Gorgonian and 5% Hard Coral.

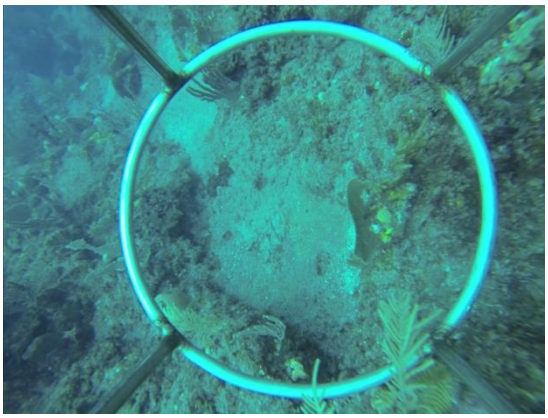
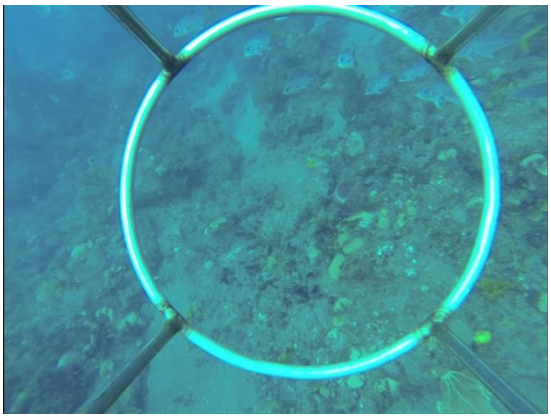
2.5.1.8 DENSE PATCH REEF

Less "Dense Patch Reefs" were found during our study. With the definition; "Sandy/rubble bottom with **aggregated** (living or dead) coral colonies, mixed with algae, gorgonians and sponges" we found dense patch reefs where most of the times we found likewise as "Diffuse patch reef" a vegetation of gorgonians and sponges (Figure 15).

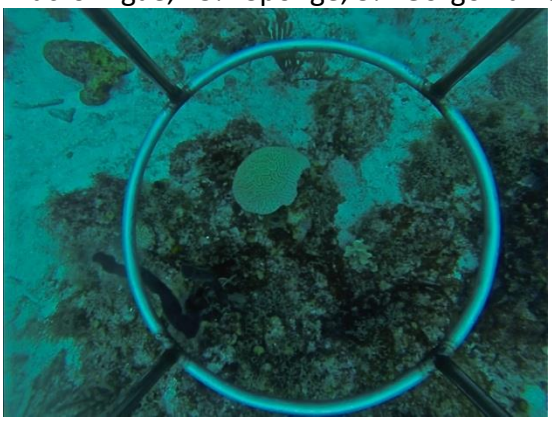
Figure 15

Still 016, consists a composition of 15% Bare Sand and 85% Reef. The 85% Reef consists a composition of 26% Macro Algae, 7% Sponge, 41% Dense Gorgonian and 11% Hard Coral.

A **B**

Still 039, consists a compostion of 25% Bare Sand, 75% Reef. The 75% of Reef consists of 40% Macro Algae, 15% Sponge, 5% Gorgonian and 15% Hard Coral.



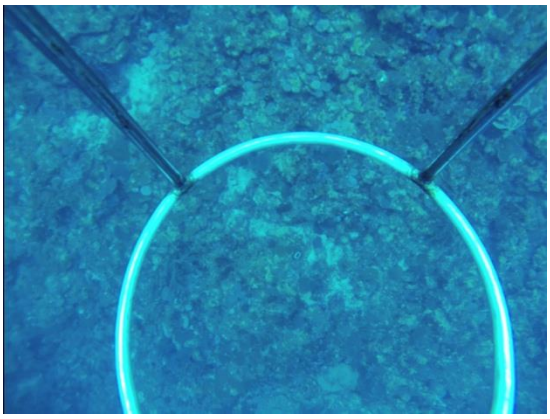

2.5.1.9 CORAL REEF

In our data analysis we found “Coral Reef” habitats. “Mainly hard substrate covered with (mainly) hard corals, mixed with algae, gorgonians and sponges. Reef >90%.” But still, most of the “Coral Reef” classified habitat contained a high coverage in gorgonians, algae and sponges in contrast with “mainly hard corals” (Figure 16).

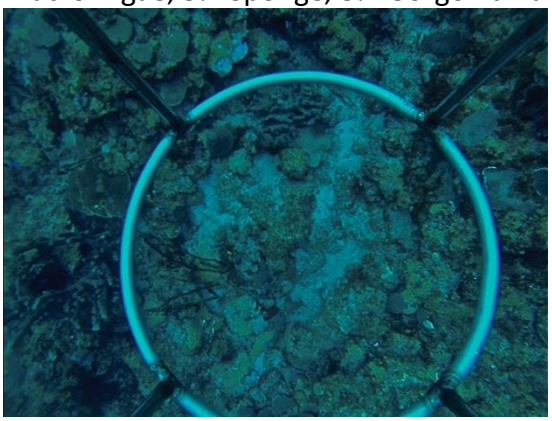
Figure 16

Still 032, consists a composition of 5% Bare Sand and 95% Reef. The 95% Reef consists a composition of 5% Sponge and 90% Hard Coral.

A **B**

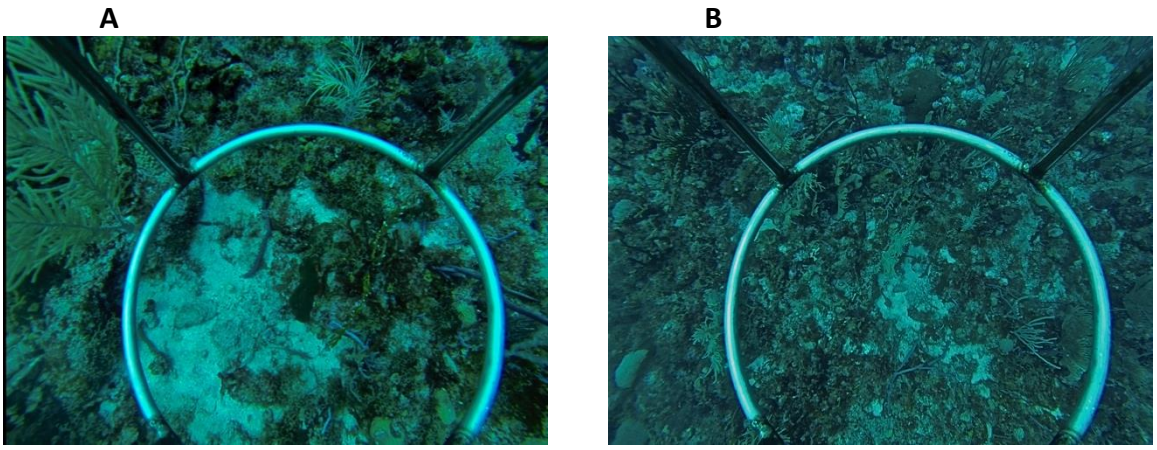



Still 038, consists a compostion of 5% Bare Sand and 95% Reef. The 95% of Reef consists of 7% Macro Algae, 5% Sponge, 3% Gorgonian and 80% Hard Coral.




2.5.1.10 GORGANIAN REEF

Surprisingly during our data analysis we did not find "Gorgonian Reef" as habitat type that fulfilled the definition of "Gorgonian Reef" as written in table 2.1: "Rubble/hard substrate covered with (mainly) soft corals. Number of gorgonian: dense (>3/m^2 usually >8/m^2) sparse (<3/m^2)". This was surprising because of the high presence of gorgonians (Figure 16) in most of the drops made during our study, but because of the requirement of "dense (>3/m^2 usually >8/m^2) sparse (<3/m^2)" we could not classify some habitat types as "Gorgonian reef."



Figuur 17: Still 033, consists a composition of 5% Bare Sand and 95% Reef. The 95% Reef consists of 8% Macro Algae, 10% Sponge, 70% Gorgonian and 7% Hard Coral.

2.6 Software

The software's were used for the making of the stills, analysing the data and recording the data were:

Google Earth

Google earth is a geographical information program that was made by Google. This program when downloaded can be used to navigate, find location and to input your own information. Google earth was used to visualize the waypoints that were made from the different sample sites. When in the process of making the data samples or drops, Google Earth was used to determine where to start to make the drops and to fill in possible gaps existent between waypoints. In the result phase Google earth was used to group the different habitat classes and were coloured coded to represent the different habitat classes, for example, bare sand. This colour coding represent almost the same as the ones that were used in Houtepen and Timmer (2013) habitats map (Houtepen and Timmer, 2013). After the waypoints were grouped and colour coded, Google earth was used to make the final habitat map.

Microsoft Office Word

Microsoft office word was used for the text processing and to read text files. In the first phase Word was used for making the proposal and sample site and to be able to read literature related to the subject. In the data collection phase Word was used to be able to read literature and to read the manual of the GPS. In the final phase the program Word was used to write the report.

Microsoft Office Excel

Microsoft office excel spreadsheet was used to (re)view, register and process data. Excel was used in the data collection phase. It was used to register the data from the boat in a spreadsheet. If the boat data was input in the spreadsheet, it could be used to find numbers of the videos and connect them with the waypoint or location. Excel was also used in the final phase of data analysis of this research. A spreadsheet was made with a similar layout of Houtepen and Timmer (2013) habitats map (Houtepen and Timmer, 2013). In this spreadsheet the final data input, analyses of the categorized videos and stills were carried out and to estimate the percentage cover and reef composition.

Paint

Paint is a graphic painting program developed by Microsoft. Paint was used on de MSI laptop to save the stills that were made from each video. First, a still was made from VLC full screen and this was copied in to Paint to save the stills.

Preview

Preview is a program to view images and PDF files for the MAC, it was developed by Mac OS X. Preview was used on the MAC laptop to save the stills that were made from each video as well. First a still was made from VLC full screen and this was copied in to Preview to save the stills and to edit the quality of the stills. Preview was used to view the still, while analysing the data to estimate the percentage cover.

Video LAN Client (VLC)

VLC is a free media player and stream program that is used to view different file formats of videos and it was developed by VideoLAN project. VLC was used to play the videos that were made by the GoPro camera. VLC is also used to make the stills.

Windows Photo Viewer

Windows Photo Viewer is a program to view images and is made by Windows. Windows photo viewer was used to view the stills while analysing them to estimate the percentage cover.

3 RESULTS

This chapter presents the benthic habitat map of Saba, and describes the results of our analysis of the habitat types per geographic location around Saba and other biological and physical characteristics per geographic location. Furthermore some habitat types were analysed in greater detail, using the underlying dataset with percentage coverage of substrate and benthos. A more detailed map of the sand habitats is presented in figure 18 and a comparison between reef habitats and the current zonation plan of the Saba Marine park is presented in figure 18.

3.1 Benthic habitat map

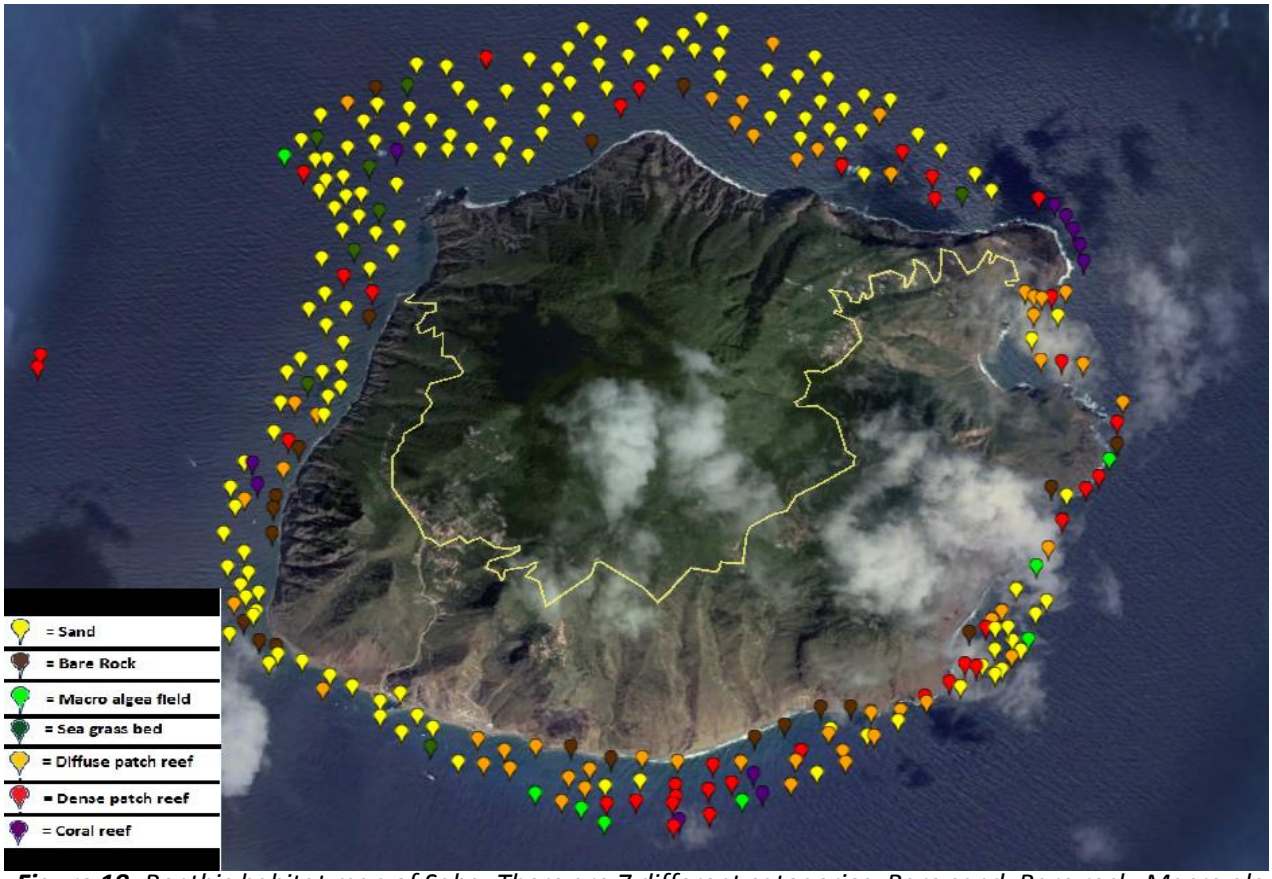


Figure 18: *Benthic habitat map of Saba. There are 7 different catogories: Bare sand, Bare rock, Macro algea field, seagrass bed, diffuse patch reef, dense patch reef and coral reef.*

The benthic habitat map in figure 17 shows the habitat types. The number and percentage occurance of the ten habitat types distinguished in this study is shown in figure 19. What stands out is that an abundance of sandy substrate occurs around Saba. During analysis it appeared to be not all bare sand as the habitat type 'Bare Sand' implies, reason why another map was made to illustrate the difference between 'truly' bare sand and sand with algal and/or cyanobacteria mats. Because of the importance of the presence of coral for the ecology and economy of the island a coral map was made to illustate

where coral is found on Saba. Another remarkable result is that three habitat types, which did occur on Sint Eustatius, were not found on Saba: sargassum fields, gorgonian reef and bare rubble.

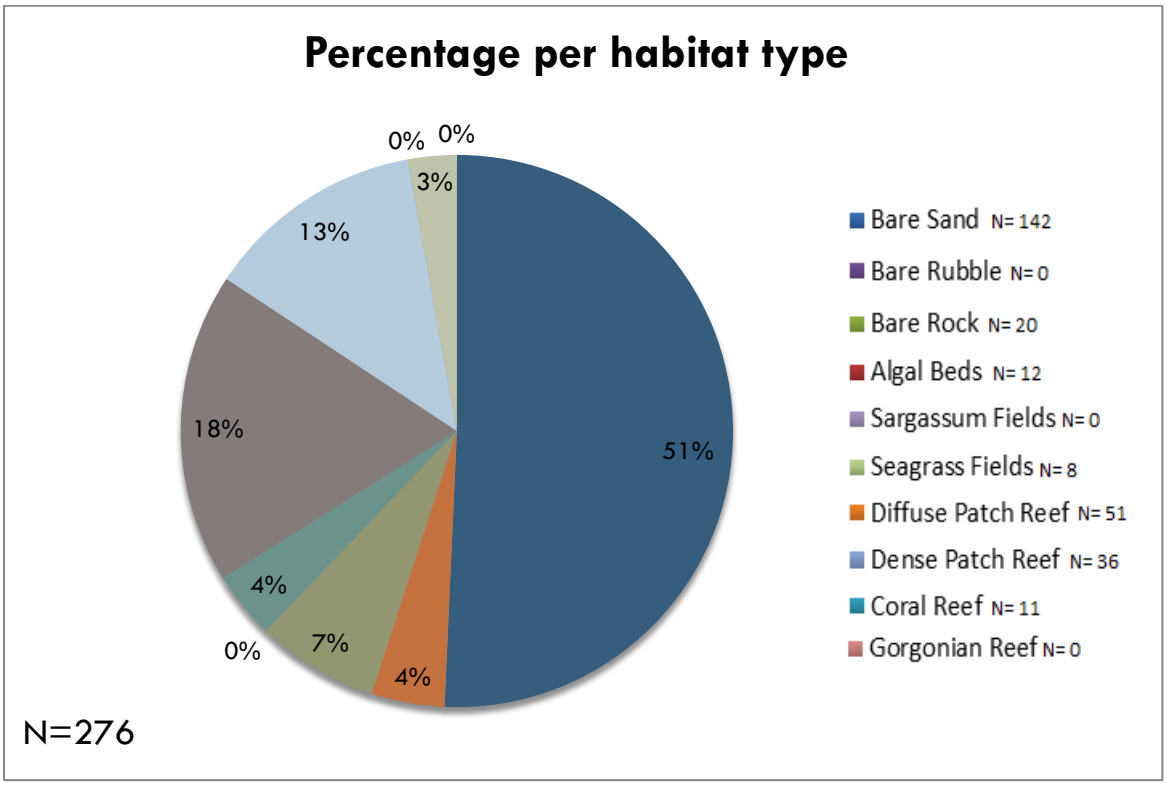


Figure 19: *This pie chart shows the percentage occurrence of each habitat type. The total sample size is N= 276. The N per habitat type is showed in the legend. Habitat types bare rubble, sargassum fields and gorgonian reef did not occur.*

3.2 Northern habitats

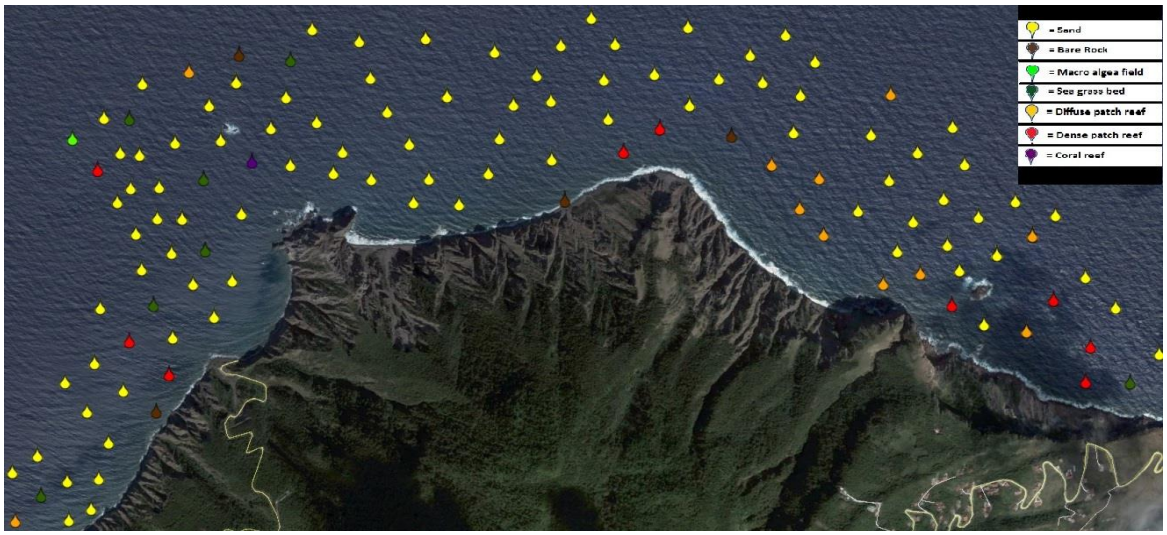


Figure 20: *The northern side of the benthic habitat map of Saba*

The rough side of Saba is mostly in the north and east side of the island, which is exposed to strong wave impacts and currents. In the north in figure 20 a lot sand and some dense and diffuse patch reefs were found, as well as one coral reef at Diamond rock, a rock formation rising from the water surface northwest of the main island. There were also a few bare rock habitats, macro algae fields and one sea grass bed west from Diamond rock.

3.3 Eastern habitats

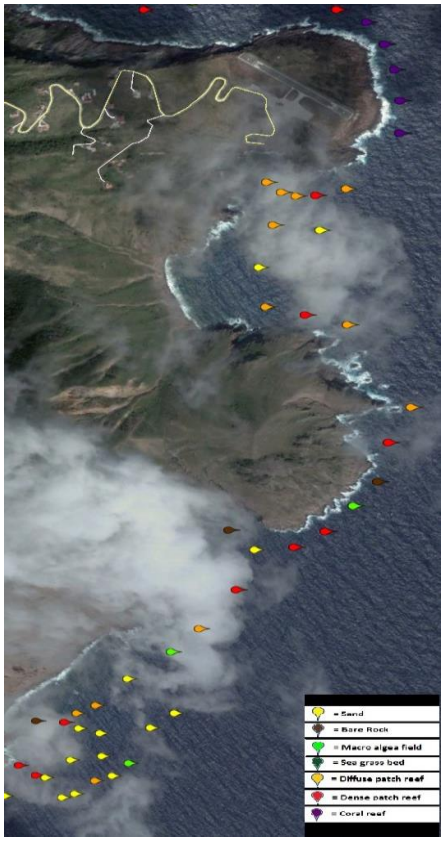


Figure 21: *The eastern side of the benthic habitat map of Saba*

As mentioned above the eastern side of Saba (figure 21) is also exposed to strong wind, waves and currents. A large coral reef was found around the airport. A nutrient poor environment could explain this, because the airport is built on a big block of concrete, which might prevent land erosion and a nutrient enrichment.

Along the whole the eastern side dense and diffuse patch reef was found. In the south-eastern part we found more sand than in the northeastern part. Also some macro algae fields and bare rock habitats were found on scattered locations in the east.

3.4 Southern habitats

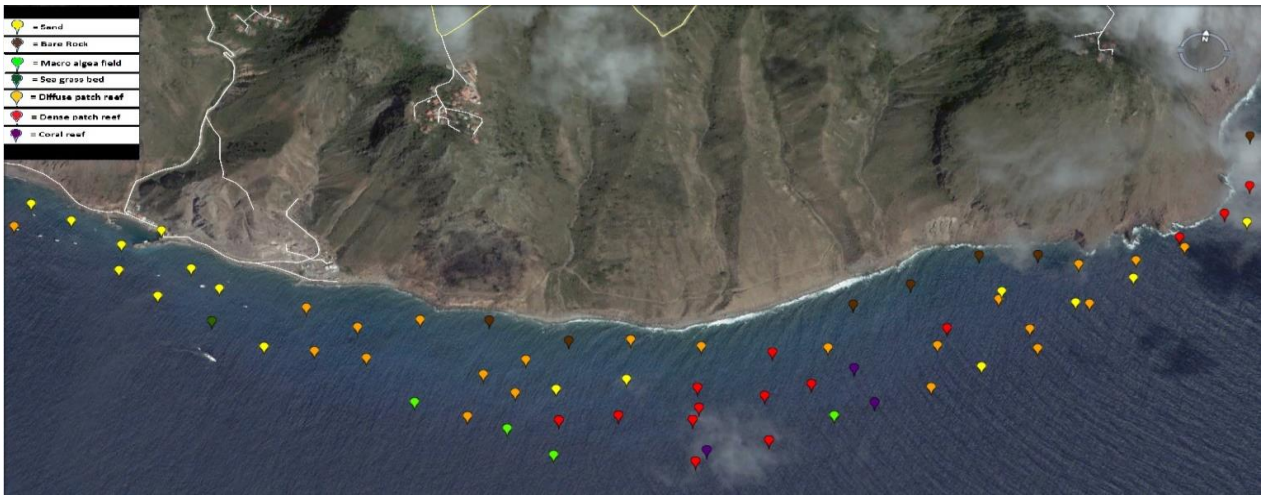


Figure 22: *The southern side of the benthic habitat map of Saba*

In the south of Saba (figure 22) a large area with coral reefs and dense patch reef was found, as well as large areas of diffused patch reef. Near the coast bare rock was found along the south-eastern side, which can be explained by strong waves and currents with so much power that anything that grows on here will get washed away. Additionally, one sea grass bed and a few macro algae fields were found. Near the harbour and mooring locations an abundance of sand was found.

3.5 Western habitats

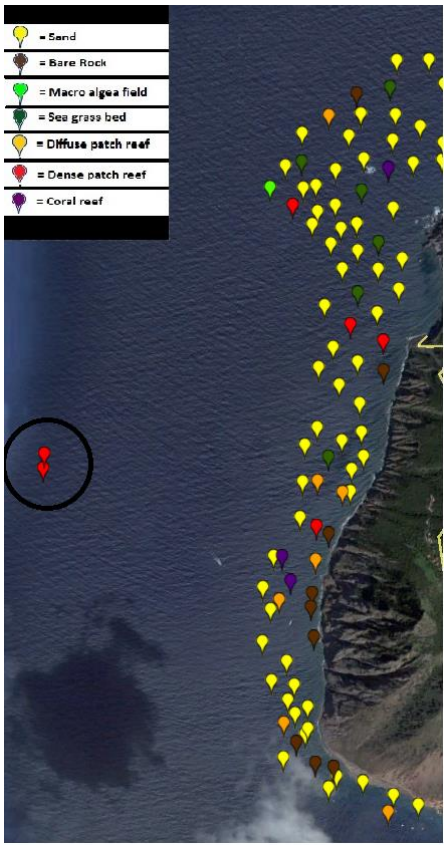


Figure 23: *The western side of the habitat map of Saba. The pinnacles are at the far western side and encircled in the map.*

On the western side of the island (figure 23) an abundance of sand was found as well. A sandy beach will appear on this side of the island at Wells Bay, which is located where the yellow road on the map ends. This phenomenon of the beach appearing and disappearing is being researched by J. Rahn. The coral reef found on this side of the island corresponds with the dive location known as tent reef. The other reef found on the western side near diamond rock is another popular diving location. Some dense and diffuse patch reefs were found in the Ladder Bay area. This area lies between the ladder and diamond rock and occupies most of the west part of Saba. These patch reefs are likely to correspond with other diving locations in this area. Some bare rock habitats were found in the southern part of this area and one sea grass bed.

A pinnacle is a peek or pointy rock formation. On Saba the Pinnacles are submerged volcanic rock formations, with the top of the pinnacle at approx. 30 meter depth. The pinnacles are shown at the far western end of the map (Figure 23). The habitats identified on the pinnacles were both dense patch reef. Because the pinnacles have a volcanic rock substrate in a nutrient poor environment it is a suitable habitat for coral. Because only two samples were collected there was insufficient data to make a definite conclusion.

3.6 Sand habitat map

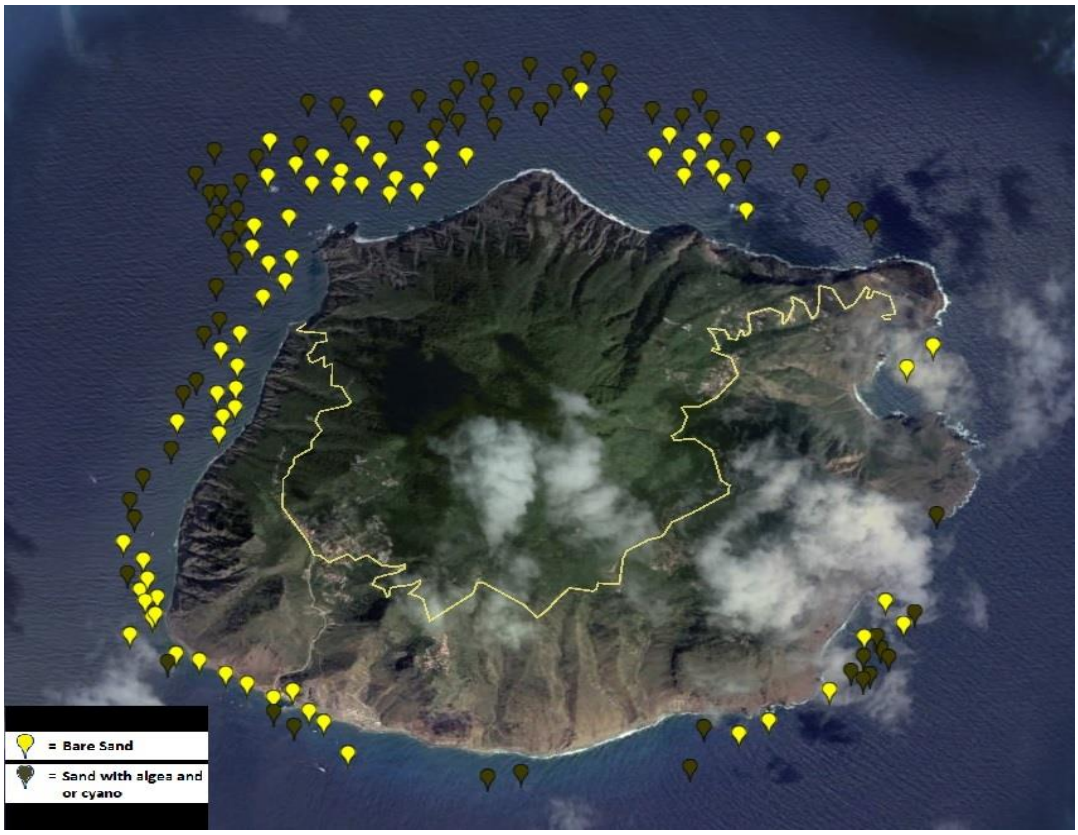


Figure 24: *The sand habitat map in which there are two categories: bare sand and sand with algal and/or cyanobacteria mats.*

Because half of the drops were identified as sandy substrate, these sand habitats were further analysed and divided in two categories to look for patterns and possible explanations for this frequent occurrence. Sand habitats were divided in (1) 'truly' bare sand, with none or almost no algal and/or cyanobacteria growth on it; and (2) sand with considerable algal and/or cyanobacteria mats growing on it. The map in figure 24 shows the algal and/or cyanobacteria mats are mainly further away from the shore. Bare sand locations were found near shore and in shallower parts, while the algal and/or cyanobacteria mats are mostly found in deeper water at depths ranging from 15 to 50 meter with the majority at 30-50 meter depth.

In a research expedition with a submarine to explore the deeper reefs of Bonaire a layer of cyanobacteria mats was found in deep waters ranging from 48 to 90 meter. (Becking, L.E. and Meesters, E. H.W.G.). The mats found around Saba cannot be identify with certainty as cyanobacteria or algal mats based on our video images, but there may be a link between the occurance of these mats around Saba and Bonaire.

3.7 Coral habitat map

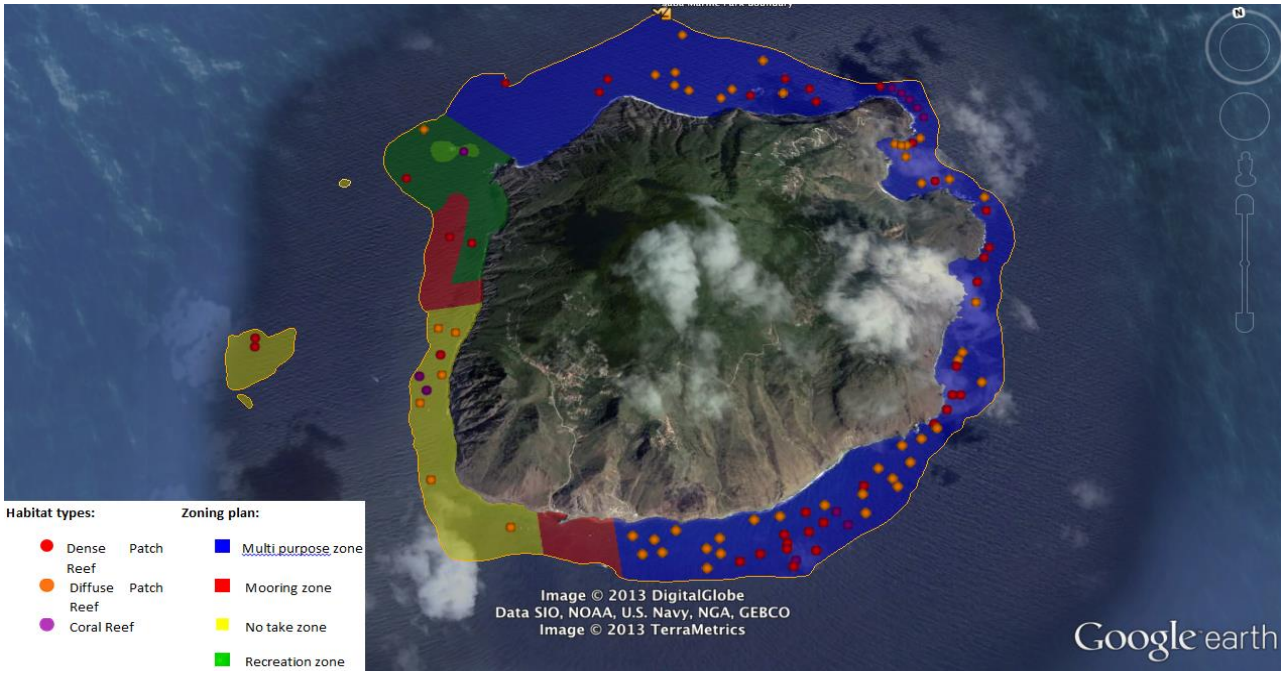


Figure 25: *The coral habitat map showing the Saba Marine Park zonation in multipurpose zone, mooring zones, no take zones and recreation zone and the three reef habitats: Coral reef, dens and diffuse patch reef.*

The coral habitat map (Figure 25) was made to compare the coral reefs around Saba with the zoning plan of the Saba Marine Park. The zoning plan was based on a study of the benthic habitats carried out in 1992, with the purpose to protect the coral reefs. If the current zoning plan of Saba is placed over the categorized habitats in Google Earth, most of the 'Coral reef', 'Diffuse patch reef' and 'Dense patch reef', are to be found in the multiple purpose zone of the marine park. Considering the current climate change and global warming scenarios it is suggested that the zones where most of these types of habitats occur, should be made no take zone as well. . Less coral and patch reef habitats occur in the Tent Reef area (west) and Ladder Bay area (Mooring zone in the west), as well as around Diamond Rock (Recreation zone).

4 DISCUSSION

4.1 Methodological flaws

GoPro images were of good quality for the identification of substrate (sand, rubble, rock) and benthic species groups (coral, algae, seagrass, gorgonian and sponge), but could not be used for identification at species level. In the study of Houtepen and Timmer (2013) species composition was accomplished by SCUBA diving at 19 locations with a quadrant made of PVC tubes. Their quadrant had a grid of 10 cm x 10 cm and within this quadrant they determined multiple times all the benthic species and the substrate composition. To create a transect line, after analysing the quadrant was flipped over. The benthic habitat is a three dimensional environment. As it was hard to judge the coverage percentage of a three-dimensional world, only 20cm of the water column above the quadrant was taken into account. When possible a picture of unknown species was taken to be determined later. For every station, GPS coordinates, depth, bottom temperature, vertical Secchi disk depth and rugosity were noted. This was measured by means of an iron chain that was attached on the quadrant. Every tenth shackle was marked to make the measuring easy (Houtepen and Timmer, 2013).

The study on Saba intentionally did not make use of SCUBA for species composition, but used High Definition video images instead to identify species within a square transect (video image at 0.5-1 meter above the seafloor). Advantages of this method were: (1) avoid time consuming SCUBA diving, as with two dives a day it would be impossible to sample all - approximately 300 – sites; (2) avoid working with inexperienced SCUBA diving students; and (3) determine species composition for all sample sites, as extrapolation of species composition of only a limited number of sample sites is statistically not possible. However, the High Definition video images were not accurate enough to identify benthos at species level. It was used instead to improve the identification of substrate and benthic species groups, as more detailed images near the seafloor were helpful for the analysis of habitat types 5 meter above the seafloor.

Another methodological flaw was the use of video lamps on the frame, as it did not improve the quality of the video images. Because the water around Saba was really clear, the GoPro did not need any extra light to perform. The video lamps often had a counterproductive effect, the light would reflex on small particles in the water, making the video images turbid with these otherwise invisible particles in the water. In addition, the specific video lamp used in this research has a fixation system, which appeared to be unsuitable to secure the lamp safely to a remote underwater video system. The fixation system came loose from the frame at two different occasions during the drops, which could not have been avoided, making this type of video lamp unsuitable to fix on a remote underwater video system.

4.2 Comparison with other studies

The methodology for this research was based on recent research in Sint Eustatius by Houtepen and Timmer (2013). They studied habitats in the Marine Park from 5 to 30 meter depth. Nine habitat types were distinguished: sand, rubble, loose coral aggregations, intermediate coral aggregations, dense coral aggregations, gorgonian aggregations, sea grass, algae and sargassum aggregations.

On Saba the Marine Park boundaries are at 60 meter depth. Other differences between the study on Sint Eustatius and this study on Saba were the use of High Definition video for improved image quality and a more detailed habitat categorization based on quantitative indicators and a systematic classification scheme of marine habitats typical for the Caribbean (Mumby and Harborne 1999). The improved quality of the High Definition images did only appear to be useful for identification of benthic groups, but not for identification at species level as described in the previous paragraph.

The habitat typesincluded one additional habitat compared to Sint Eustatius: 'Bare Rock'. This appeared to be important on Saba due to its volcanic origin with steep, rocky cliffs and granite boulders, pinnacles and lava formations that extend seaward from the island (Klomp, K. D. K., Kooistra D.J. 2003), instead of biogenic coral reefs consisting of limestone structures. The improved habitat categorization was especially useful to better distinguish between the three types of reefs: 'Diffuse patch Reef', 'Dense Patch Reef' and 'Coral Reef'. According to expert judgement this is better understood than the habitats 'loose, intermediate and dense coral aggregations' used on Sint Eustatius. The quantitative indicators to classify habitats were based on percentage coverage of substrate and benthos (table 1 in Chapter 2). This method made the classification as objective as possible, because the researchers first established substrate and benthic percentage coverage and only than determined habitat types based on the indicators as described in tabel 1.

Two remarkable outcomes of this research compared to two other IMARES habitat studies were the absence of Sargassum fields, Gorgonian reefs and bare rubble on Saba compared to Sint Eustatius (Houtepen and Timmer, 2013) and the presence of cyanobacteria mats on the sand habitats further ashore and at deeper depths, which shows some similarity with the cyanobacteria mats found during a submarine expedition of the deeper reefs of Bonaire (Becking and Meesters, 2014).

fOn Sint Eutatius sargussum fields were found on the east coast, which is the windward side of the island. Sargassum grows in the Sargasso Sea and is distributed by wind and currents to the Caribbean Sea. The reason why no Sargassum was found on Saba could be a seasonal effect, as there were no major storms during our research period. Another hypothesis is that due to the bathymetry with steeper slopes and the absence of beaches on Saba no Sargassum was found, as Sargassum is mainly present in shallow waters [2]. Gorgonian reef is also often associated with rather shallow waters and gentle slopes. The reason why gorgonian reef did not occur, was mainly because the gorgonians found were not the dominant species, but were mixed with hard coral, macro algae or sponges The reason why bare rubble did not occur was similar, as it was never the dominant substrate compared to sand, rock or reef substrate.

5 CONCLUSION AND RECOMMENDATIONS

The objective of this research was to make a benthic habitat map. We answered our research questions and identified (1) which benthic habitats are located where; and (3) what is the structural complexity in these habitats. The second research question to determine (2) what are the rough species compositions in these habitats could not be answered because the close-up stills (called “A”) were not specific enough to identify benthos at species level. However, this did not interfere with the quality of the habitat map. In fact the detailed stills A did improve the quality of the habitat map, because it provided more detail than the overview stills (called “B”).

There were some remarkable results. A lot of sand was found around Saba, more than was expected. The bare sand that was found was not always completely bare, but in approximately half of the cases contained algal and/of cyanobacteria coverage, the majority of which was found in deep water between 30 and 50 meter. There may be some similarity with the cyanobacteria mats found during a submarine expedition of the deeper reefs of Bonaire. Three habitat types, which did occur on Sint Eustatius, were not found on Saba: sargassum fields, gorgonian reef and bare rubble. Bare rock was an additional habitat type that was not included as habitat on the Sint Eustatius habitat map.

Recommendations for future research into benthic habitats and adjustment of the Saba Marine Park zonation plan are:

- Adjustment of the multi-purpose zone to a higher protection level, as by far the most patch reefs and coral reefs are found in that zone;
- Further research on the cyanobacteria and/or algal mats and algae found in the deeper reefs on Saba, to identify if this are truly cyanobacteria and if conclusions can be drawn from the presence of cyanobacteria mats on the deeper reefs of Bonaire.
- Further research on species composition of algae, sponges, corals and seagrass in the Saba Marine Park using SCUBA

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Timmer, T. and Houtepen, E. (2013). Benthic habitat mapping in the coastal waters of St. Eustatius. Internship Report nr. P462. Aquatic Ecology and Water Quality Mangement, Wageningen University

Wulf, K. (????) Saba Marine Park Zonation Map. Saba Conservation Foundation, Caribbean Netherlands

7 APPENDIX

7.1 Appendix I ''boat logbook''

Date	Waypoint	Video number	Still number A	Still number B	Latitude (decimalen)	Longitude (decimalen)	Depth (feet)	Depth (meters)	TIME IN (UTC)	Duration film (min)	Habitat (by sea viewer)
2013-09-08	385	001	001 A	001 B	17.642286	-63.220161	35	11	8:30 AM	1:17	Rock/sand
	386	002	002 A	002 B	17.642147	-63.218697	94	29	8:34 AM	2:48	Rock/sand
	388	003	003 A	003 B	17.641111	-63.218247	180	55	8:41 AM	4:04	Sand
	389	004	004 A	004 B	17.640997	-63.219561	60	18	8:46 AM	2:05	Rock/sand
	391	005	005 A	005 B	17.639592	-63.219528	50	15	8:50 AM	1:29	Sand
	392	006	006 A	006 B	17.638408	-63.218928	50	15	8:54 AM	1:22	Rock/sand
	393	007	007 A	007 B	17.638436	-63.217786	80	24	8:58 AM	1:40	Rock
	394	008	008 A	008 B	17.638425	-63.216606	160	49	9:08 AM	2:48	Rock/sand
	395	009	009 A	009 B	17.637753	-63.215292	120	37	9:15 AM	4:44	Rock
	396	010	010 A	010 B	17.631114	-63.217658	25	8	9:38 AM	1:10	Rock
	397	011	011 A	011 B	17.629292	-63.216872	70	21	9:48 AM	2:49	Rock/sand
	398	012	012 A	012 B	17.627642	-63.217467	120	37	9:55 AM	2:09	Rock/sand

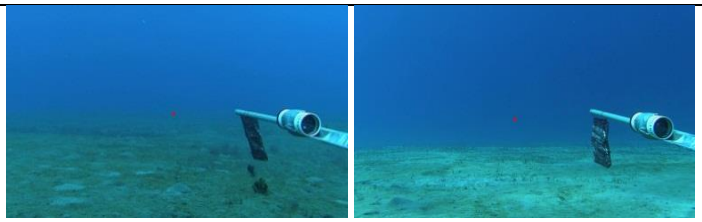
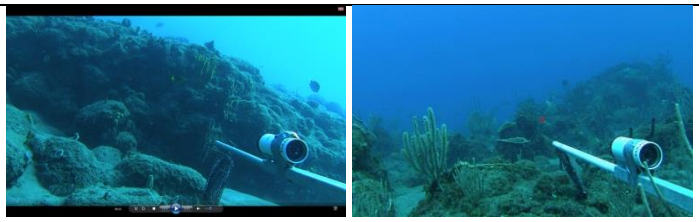
7.2 Appendix II "Data input sheet"

							Bare substrate + benthos percentage cover			Seagrass bed		Algae field			
Way point	**Movie (still)**	**Date**	**Time IN (UTC)**	**Latitude (decimals)**	**Longitude (decimals)**	**Depth (m)**	**Bare Sand**	**Bare Rubble**	**Bare Rock**	**Dense**	**Sparse**	**Sargas-sum**	**Macro algae**	**Reef**	**Total % cover**
385	1	2013-Sep-08	1:30 PM	17.642286	-63.220161	11	55		5					40	100
386	2	2013-Sep-08	1:34 PM	17.642147	-63.218697	29	30		5					65	100
388	3	2013-Sep-08	1:41 PM	17.641111	-63.218247	55	90		10						100
389	4	2013-Sep-08	1:46 PM	17.640997	-63.219561	18	80							20	100
391	5	2013-Sep-08	1:50 PM	17.639592	-63.219528	15	98							2	100
392	6	2013-Sep-08	1:54 PM	17.638408	-63.218928	15	65		15					20	100
393	7	2013-Sep-08	1:58 PM	17.638436	-63.217786	24	35		2					63	100
394	8	2013-Sep-08	2:08 PM	17.638425	-63.216606	49	60							40	100
396	10	2013-Sep-08	2:38 PM	17.631114	-63.217658	8	15		80					5	100
397	11	2013-Sep-08	2:48 PM	17.629292	-63.216872	21									0
398	12	2013-Sep-08	2:55 PM	17.627642	-63.217467	37	75		15					10	100
400	14	2013-Sep-08	3:08 PM	17.625108	-63.218964	21	95		2					3	100

Reef composition		**Gorgonian**				**Scale 1-5**	**Yes/no**	**Yes/no**	**HABITAT**
Macro algae	**Sponge**	**Dense**	**Sparse**	**Hard coral**	**Total % cover**	**Complexity**	**Acropora**	**Cyano-Bacteria**	
30			5	5	40	3	No	No	Bare Sand
20	10		5	30	65	2	No	No	Dense patch reef
					0	0	No	No	Bare Sand
	17		2	1	20	1	No	No	Bare Sand
	1		1		2	1	No	No	Bare Sand

	10		8	2	20	0	No		Bare Sand
3	15	20	5	20	63	1	No		Dense patch reef
40					40	0	No		Bare Sand
3			2		5	3	No	No	Bare Rock
					0				Patch reef
4			4	2	10	0	No		Bare Sand
			3		3	0	No		Bare Sand

Appendix III "Structural Complexity Categories of BRUV drops"

Structural Complexity Categories	Images examples
0 = bare substratum	
1 = low and sparse relief	
2 = low but widespread relief	
3 = moderate complexity	
4 = high complexity with cave systems	
5 = extreme complexity with numerous caves and overhangs