2018

Biodiversity Preliminary Study: Aruba Marine Park

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Contents

Acknowledgements

This body of work was made possible by the volunteers who provided their time, expertise and whom risked their life in obtaining data for a better future in marine resources management for Aruba.

Norman Arends and Scuba Safari Aruba are thanked for providing their boat and expertise for field data collection. Susan Hieter and JADS Dive Center are thanked for providing knowledge and training in Reef Check methodology. Carola Van Der Valk, Steven Koedijk and Anastacia Brete are thanked for their time and assistance. The Dutch Caribbean Nature Alliance and St. Eustatius Marine Park are thanked for their time.

Groups and individuals are thanked for sharing their knowledge and expertise in the history of marine resource management of Aruba and these include: Parke Nacional Arikok, Sea Mammal Foundation Aruba, Turtugaruba Foundation, Aruba Reef Care Foundation, Aruba Mermaid Dive and Rudy Davelaar.

1.0 Introduction

1.1 Background

For the past 40 years, Caribbean coral reefs have suffered a significant decline with observed reduction in coral cover and species diversity, reduction in resilience through increased instances of coral bleaching and reduced recruitment, shifts in reef fish assemblages with reduction in biomass/density of predators and herbivorous fish, reduction in key invertebrate species and increased algal cover [1–6]. With further pressure from climate change and anthropogenic activity, it is apparent that there is a need for effective management measures to secure the viability of the various ecosystem services provided by these systems for future populations.

For Aruba, the coral reefs have provided a constant source of subsistence and economy to the local population, coastal space for industrial development, resource extraction and leisurely areas for tourists and inhabitants. With the assistance of the Directorate on Nature and Environment (DNM), local non-profit organizations (NGOs) and local actors, the BEST 3.0 working document [5] was developed and provided a profile of Aruba's ecosystems and threats these areas are facing. These areas are habitat for important species including corals, migrating birds and sea turtles such as the Leatherback turtle (*Dermochelys coriacea),* Elkhorn coral (*A. palmata*) (Figure 1) and Pillar coral (*D. cylindrus*).

Aruba's coral reef system has been under constant pressure of industrial development and recreational use (Bak, 1987; Eakin, Glynn, & Feingold, 1994). There is a global consensus that governance and management frameworks must be implemented and followed to ensure the sustainable future of this important resource to the local and the international community.

Figure 1. Elkhorn coral reef at Arashi Beach Aruba May 2018.

For effective marine resource management to take place, three components are required:

1. Quantifiable objectives need to be incorporated in a management plan.
2. Standardized methods of monitoring reef health and fisheries should be used on a local and regional level.
3. Transparency in decision-making process to all stakeholders is key concerning conservation, management strategies for environment, fisheries and coastal development.

A proposal was developed for the BEST 2.0 medium grants program [7] in which three marine areas (total= 41.2km2) were chosen for conservation purposes, out of the various KBAs as a step to achieve a Marine

Park. The designated areas were previously verified in the “Ruimtelijk Ontwikkelings Plan 2009” [8] (Figure 2). Within these areas, there have not been recent studies on coral health or seagrass identification and extent. A baseline of environmental and biological data was needed to provide further justification of the KBAs chosen for environmental management with BEST Initiative [9]. This study applied component 2, in effective marine resource management (see above paragraph) for data collection.

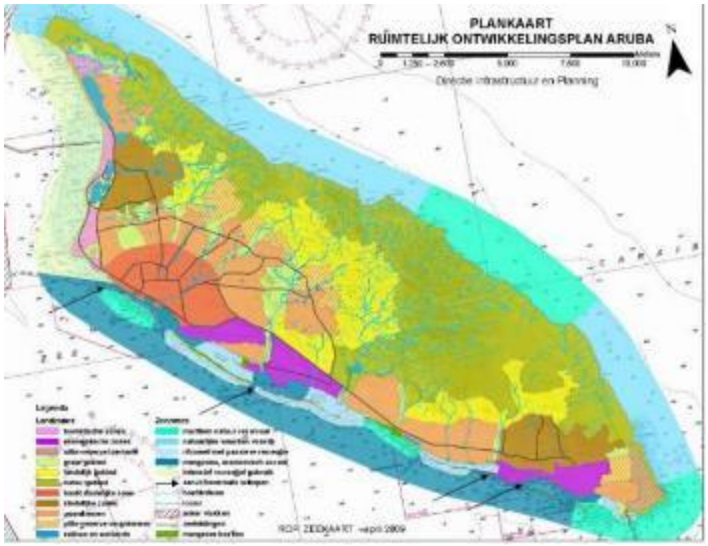


Figure 2. Spatial planning map that was accepted in 2009 by the Government of Aruba.

1.2 Reef Check

In February 2018 it was decided that Reef Check surveys would be conducted on Aruba’s coral reefs by following the Global Coral Reef Monitoring Network guidelines [10,11]. The benefits of using this method include promoting stewardship within the Aruban community and can be a cost-effective way of monitoring in the future. Reef Check provides preliminary information on the impact of anthropogenic activity on coral reef systems by monitoring possible causes of degradation. The data quantifies the type of substrate structure dominant in an area over a 100 m transect-line. Dominant substrate types could vary from silt or sand areas to rock and hard coral areas. Rock is needed to provide coral recruitment and hard coral structures provide propagules for the future. Furthermore, fish density of species of interest (grouper, snapper, tangs, grunts and butterfly fish) was determined through visual count surveys. Presence of invertebrates and coral disease indicate impacts on coral health and were determined during the surveying period. Data was collected on presence of human impact, such as run-off area, presence of anchoring, trash, and nearest population center. For site description information, refer to “Field Data Sheet” data sheet.

1.3 Seagrassnet.org and Seagrass-Watch

Another aspect of the surveying period was to establish a baseline for seagrass on Aruba. Seagrasses are understudied on the ABC islands and their role in carbon sequestration is considered significant in the face of climate change. For the baseline seagrass study, a monitoring survey [12,13] was employed in a homogenous meadow found at Santo Largo (MP3). Furthermore, the goal of the monitoring survey (SeagrassNet), it to scientifically record changes in seagrass species composition, distribution, abundance and environmental quality monitoring.

An area of interest within the proposed Marine Park is Isla di Oro. The area was surveyed using a method proposed by Seagrass-Watch [13]. Here, points were chosen to identify substrate dominant type, seagrass identification and cover, presence of invertebrates and other species of interest across visual transects.

The results of this study are meant to achieve the basis for future monitoring studies. Results reported can be used by legislators and other environmental and economic actors for implementation of management strategies for preservation of Aruba's marine resources for future generations.

2.0 Material and Method

2.1 Site description and survey period

Aruba forms part of the Leeward or ABC islands of the Caribbean and is located (12.5211, -69.9683) (Figure 3.) 24 km off the coast of Venezuela. The island's formation is characterized by folding during the Cretaceous and Early Tertiary of dioritic magma (otherwise known as volcanic rock), upliftment and denudation of the crust, resulting in batholith of intrusive igneous rock. Tectonic uplifting occurred during the Quaternary that resulted in limestone (carbonate) terraces along the coast. [14,15]

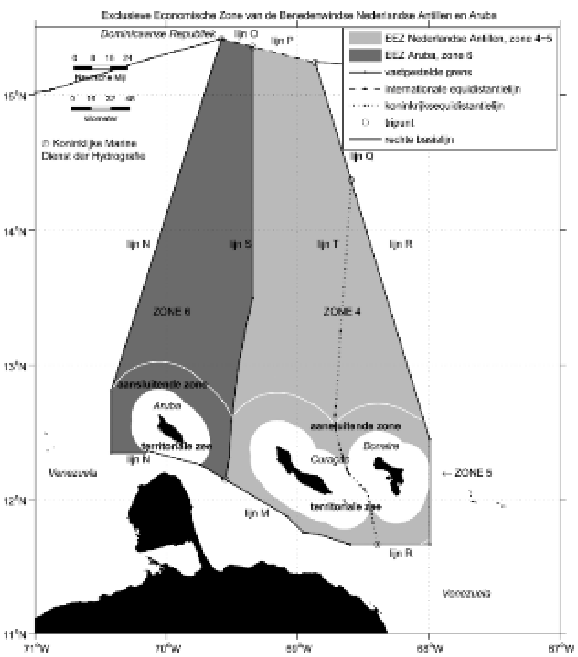


Figure 3. Location of Aruba, EEZ boundaries of Leeward islands Aruba, Bonaire, and Curacao. (STb., 2010,277)

The areas that were surveyed were priorly selected based on the National Spatial Plan (ROP)[8] and the BEST 3.0. Working Document [16].

The extension of the area covered:

- Marine Park Arikok (MP1) is 16.5km^2 and is characterized by high wave action and a rough coastline.
- Marine Park Sero Colorado (MP2) found on the southern tip of the island, is 16.4km^2. Here the islands currents move northward along the coast.
- The area of Marine Park Mangel Halto (MP3) is 8.2 km^2.

For further description of these areas, refer to the Marine Park Mangement Plan 2017 ("Plan Parke Marino Aruba Draft," n.d.).

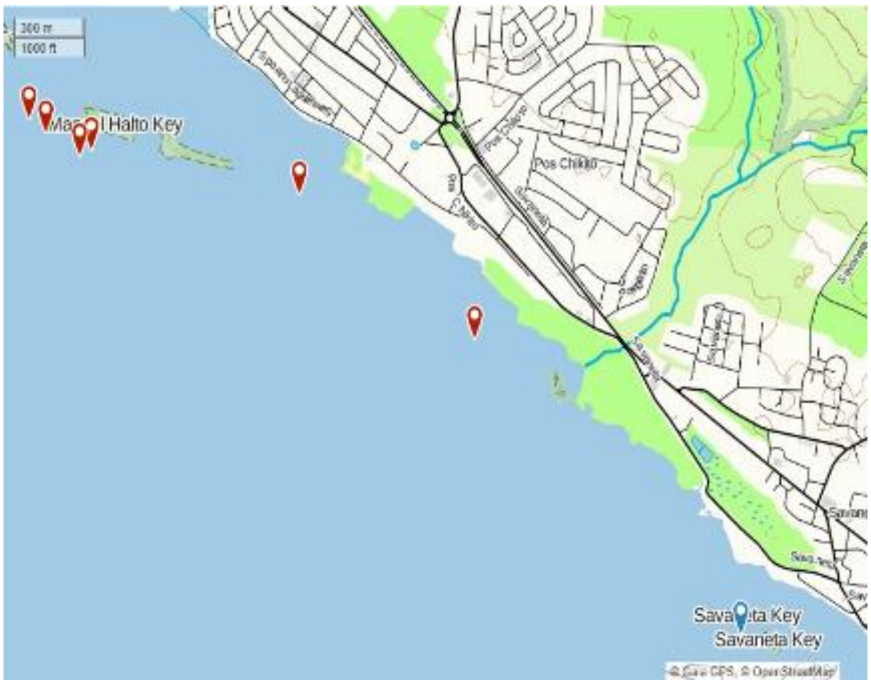
Surveys commenced on March 30th 2018 and data was collected until the 5th of May. Data collection took place through volunteer assistance by local divers and dive centers. Per dive, two or three divers were present; Reef Check recommends five divers per survey. The surveys took place in all of the three proposed areas for protection, which included an extension of Parke Nacional Arikok (MP1), Seroe Colorado (MP2), and Mangel Halto to Santo Largo (MP3). Three sites outside these areas (Outside MPs) we surveyed to provide additional preliminary information on reef health beyond the designated parks.

Sites were selected to represent the whole area for depths between 3-5 m, 5- 10 m and 11-18 m. It was intended to sample up to 20 sites per Marine Park. A total of 25 sites were visited opportunistically according to weather and logistics. MP1 (Windward North east coast), MP2 (South west coast), MP3 (Leeward Coast), and Outside MPs (Arashi Beach and Blackstone Beach, Figure 5) were surveyed 6, 7, 9 and 3 times, respectively (Figure 4). Site GPS (Global Positioning System) coordinates were taken for the majority of sites (Appendix A). A smartphone (iPhone 4S) was attached to the diver and suspended by a Surface Marker Buoy (SMB). GPS coordinates were taken with the application Gaia GPS (Gaia GPS: Hiking App & Hiking Maps, 2018.

North West

MP1- Arikok

MP2 – Seroe Colorado



MP3 – Mangel Halto

Figure 4. Reef Check survey site locations. From top to bottom: Outside MPs (Arashi sites), MP1 – Arikok incl. Black Stone Beach, MP2 – Seroe Colorado, MP3 – Mangel Halto

Figure 5. North east coast of Aruba, April 2018.

2.2 Reef Check Survey

The methodology is designed to determine the health of coral reefs by focusing on abundance of organisms that are used as indicators of the condition of the ecosystem. Specifically, studying the impacts of anthropogenic activity on reef health. The survey consists of four components:

- Site description;
- fish belt transect;
- invertebrate belt transect;
- Substrate line transect.

The Reef Check method is briefly described below. An extensive description can be found in the Reef Check Instruction Manual [10].

2.2.1 Site description

Sites visited were compared to descriptions provided by Bak, Roos, and Houtepen et al. (Bak, 1977; Bak, 1974; Houtepen, Brunel, de Graaf, Tichelaar DCM Miller, & Nagelkerke, 2015; Roos, 1971) . The survey areas are presented by zonation characteristics and are proposed as such. General site description was filled out using Site description forms provided by Reef Check.

2.2.2 Fish belt transect

In total, four 20 m by 5 m transects were surveyed on 100 m transect tape. Seven fish family species were used as indicators: *Haemulidae* (Grunts), *Serranidae* >15cm (groupers), *Muraenidae* (Moray eels), *Scaridae* (Parrotfish), *Chaetodontidae* (Butterflyfish) and *Lutjanidae* (snappers).

Fish counts were performed as the transect line was set, either by the diver with the transect reel or a diver following. Fish were observed less than 2.5 m away from the transect line on each side. At the end of the count, the diver would start the substrate line transect survey while swimming back to the start of the transect line.

2.2.3 Invertebrates belt transect

The same line transect was used to identify and count the invertebrate indicator species. These are mainly targeted for consumption or curio trade in the Wider Caribbean area. Species include: Flamingo tongue (*Cyphoma gibbosum*), Long-Spined Urchin (*Diadema antillarum*), Sea Egg (*Tripneustes ventricosus*), Trumpet Triton (*Charonia tritonis*), Banded Coral Shrimp (*Stenopus hispidus*), Pencil Urchin (*Eucidaris tribuloides*), Spiny Lobster (*Panulirus argus*) and Sea fans/whips. For Aruba, an adaptation was made to include: Conch species (*Lobatus spp)* and Caribbean Crown Conch (*Melongena melongena)* (not typically found on coral), Cone snails (*Conus mappa*, *Conastrella centurio*) sea cucumbers and sea stars.

Species were observed by one diver while swimming in a zig zag pattern. Invertebrates observed directly under the diver were identified and counted.

2.2.4 Impact and Disease

Impact was documented in severity on a scale from 0 – 3 and included:

- Boat/anchor damage
- Trash: nets/lines
- Trash: Other (e.g. tires, anchors)
- Other (e.g. fish/snail herbivory)

Diseases and bleaching were documented in total % of the population and % of the affected colony. These are not presented because of very low % bleaching. Observations of disease was very low and are presented by Figure 12

2.2.5 Substrate line transect

Along the transect line the type of substrate was categorized every 0.5 m. Categories included: hard coral (HC), nutrient indicator algae (NIA), rubble (RB), soft coral (SC), sponge (SP), sand (SD), recently killed coral (RKC), rock (RC), silt (SI) and other (other); anemones and marine debris. Impact on coral due to human activity (presence of trash, anchoring), bleaching and disease were recorded.

2.2.6 Reef Check Training

Reef Check methodology was introduced to participants by a ReefCheck coordinator. Two-half day workshops were given to volunteer divers in preparation of the surveys. A mock survey was performed using SCUBA (Self-Contained Underwater Breathing Apparatus) at 10 m depth. A team of five divers participated for the survey period. Dives were scheduled from shore and boat (for safety purposes).

2.3 Seagrass Monitoring and Mapping MP3

2.3.1 Site selection

Selection was based on guidelines provided by SeagrassNet Manual for Scientific Monitoring of Seagrass Habitat (Short et al, 2006) and Guidelines for Rapid Assessment and Mapping of Tropical Seagrass Habitats [13]. In summary, two sites (site 1 and 3) were selected for seagrass monitoring [12] that were representative of the seagrass communities found in MP3. One site (site 2) was selected for seagrass mapping. Typically, sites are to be selected in relation to environmental monitoring and should have minimum anthropogenic activity. For area specific monitoring, site selection can be adapted to the area being studied.

Selected sites in MP3 (8.6 km^2) were (Figure 6).:

- Site 1 at Santo Largo (Lat/Long: 12.45032, -69.95377). The area is relatively homogenous and can be accesed by foot. The depth range is between 0.1 and 0.5 meters. Anthropogenic activity by beach recreants was observed on the site (Figure 7). Beach recreants do not tread offshore over the meadow and. Their activity was considered of minimum impact.
- Site 2 at Isla di Oro (Lat/Long: 12.45736, -69.96059). Site 2 has been identified as a KBA. The area contains ruins of an old disco on a reef island and is difficult to access by foot (Figure 7). It was assumed that human impact was low due to lack of accesibility. Depth ranged from 0.8 – 2.0 m.
- Site 3 at Spaans Lagoen outlet (12.46198, -69.97622). A dock or “rancho” is found in the area where recreational boat fishermen are stationed. It was assumed that human impact was high due to the large catchment area of Spanish Lagoon (15.1 km) (Houtsma, 2017) that extends 5 km land inward. On the coast there is a restaurant over the water. Adjacent to the area, roads and housing can be observed. The area was selected by observation of the non-native species *Halophila stipulacea*. The area has heterogenous depth of 3-10 m between high and low tide.

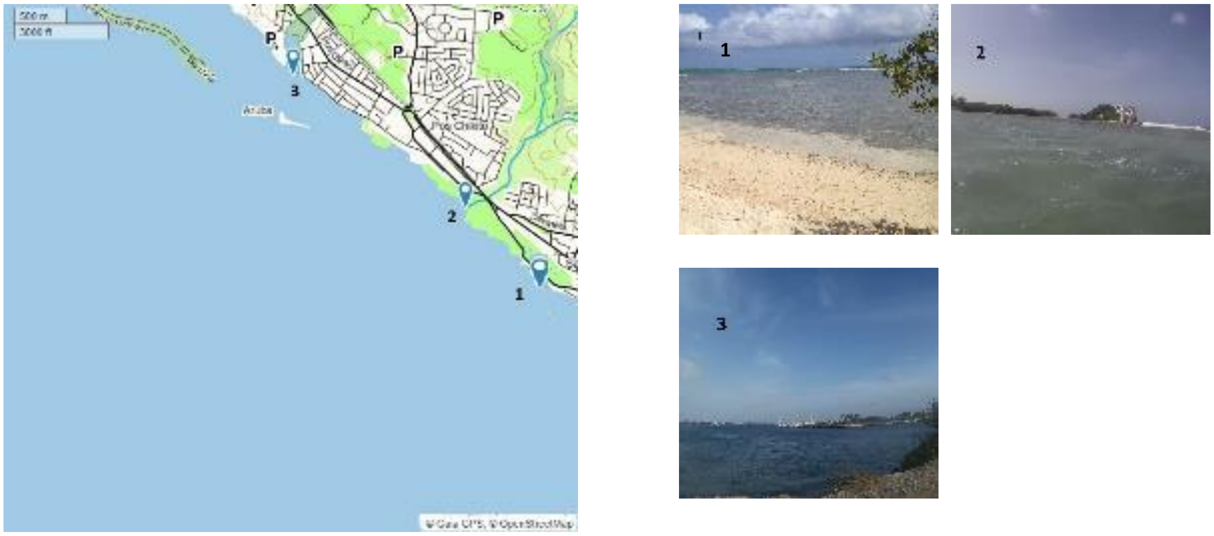


Figure 6. Map of locations for Seagrass monitoring (Site 1 and 3) and mapping (Site 2) in MP3. Photo of locations: (1) – Santo Largo (SL), (2) Isla di Oro, (3) Spaans Lagoen.

Figure 7. Left: depiction of accessibility to Site 2. Right: Beach recreant walking on seagrass meadow edge Site 1 April 2018

2.3.2 Survey Procedures

Surveying and biological sample processing took place between the 28th of April and the 14th of May 2018. Seagrass monitoring took place at Site 1 (Santo Largo). Site 3 was excluded from the survey due to limited time and dive volunteers. Seagrass mapping for site 2 could not be completed. Field procedure methods were applied and are presented. Extent of seagrass between Site 1 and Site 2 was tracked using the smartphone application, Gaia GPS. Seagrass monitoring surveys were conducted by 1 or 2 observers and would take 5-7 hours. Spring tide times were exceeded by several hours. For transect B (SL01B) and C (SL01C), this lead to incomplete (<10 cm) core samples, potentially providing an underestimation of biomass.

2.3.2.1 Transect positioning

In site 1, three 50 m cross-transects were placed parallel to the coast. Cross-transects were placed 25 m apart when possible. The first transect (A) is considered the permanent transect and was laid closest to the shore. The second station (B) was selected by moving 25 m to the left of the first station. The third station (C) was nearest to the deep meadow edge off-shore. In addition, the start of the first transect was marked as the permanent site marker (A). Station B and C were subsequently marked by using a compass and taking a heading (270 W) to ensure that the three transects were parallel to each other.

2.3.2.2. Station Measurements

Distance measures were taken at the three stations for each cross-transect: 0, 25 and 50 meters. Distance to edge of the seagrass meadow and distance to last shoot of the meadow was taken from the station using a nylon rope that was marked with distances on land or a transect tape (Appendix B).

Depth was measured nine times per site when sites were fully submerged. Time of depth measurement was registered.

Substrate was assessed per station on composition: mud, sand, fine sand, coarse sand, shell, gravel, coral rubble and rock.

Due to limited resources, a refractometer for salinity, light and temperature logger (HOBO) were not available. Air and surface water temperature daily averages were taken from www.windguru.com (https://www.windguru.cz/archive.php?id_spot=55). Tidal stages were monitored using www.tide-forecast.com.

On each cross-transect, 12 quadrats of 0.25m^2 were deployed randomly. MS Excel was used to randomize quadrat locations for each transect (RAND()-function). The first 12 numbers in the column were selected (Figure 8). Quadrats were placed on the beach side of the transect line.

0,876646	0
0,219277	0,5
0,171588	1
0,25589	1,5
0,279017	2
0,557255	2,5
0,111902	3
0,197622	3,5
0,158836	4
0,768432	4,5
0,604385	5
0,137606	5,5

➜

0,281369	0
0,555098	19,5
0,267624	17
0,122998	28,5
0,07983	13,5
0,17744	20
0,669264	16
0,881489	30
0,245382	48
0,073695	23,5
0,121633	49
0,30484	1

Figure 8. Pre-selection random quadrant distances (0-50 m) using MS Excel Rand()-function.

2.3.2.3 Seagrass Identification, Canopy Height and Grazing, Density Estimates and Biomass

Within each 0.25m^2 quadrat total percent (%) cover of all species were visually estimated by one observer. This was recorded on the slate under "all species (%)". Invertebrate and algae cover were not documented during this study. Subsequently, percent cover was estimated for individual species of seagrass that were indicated by abbreviations (e.g. *Thalassia testudinum* = Tt). Documentation of individual species cover started with the lowest percent cover working towards the dominant species percent cover. A simple linear regression was performed on species % cover to determine if there was a relationship between *H. stipulacae* % cover and *T. testudinum* % cover.

Canopy height of 5 leaves was measured with a ruler (to nearest mm) of the dominant seagrass species that was present within the quadrat. The first 5 leaves were ignored followed by measurements taken from a randomly chosen clump of leaves. Average leaf length was calculated. Presence of grazing (e.g. bite marks top of leaves) was recorded. *Thalassia* and *Halophila* species increase their expansion capacity under favorable conditions by reproducing through pollination. Counts of reproductive parts (flower and buds, seeds) was summed if observed.

Density was determined using a core sampler (PVC pipe d= 0.04 m, h= 0.30 m) for each quadrat. The samples were taken >0.5m away from the quadrat and towards the beach. Upon placing the pipe on the sediment, damaging of leaves was avoided by moving leaves around the edges of the pipe and pushing those rooted outside of the pipe away from the sampler or by cutting leaves before placing the core on the sediment. The pipe was pushed 10 cm (marked) into the sediment and a stopper was used to cap the top of the pipe for suction purposes. Samples were immediately placed in labelled plastic Ziploc bags. For density determination, samples were rinsed off with freshwater and shoots were counted per species (Figure 9). A core sample was not taken in absence of seagrass (e.g. 0% cover) or very low cover (<10%).
In cases with low cover or absence of seagrass, entry on data sheet was 0.0001 g per core, as prescribed by SeagrassNet.org.

Biomass (g m^{-2}) was determined after density counts of core samples. All plant parts (root, shoot, leaves) were separated per species and placed in labelled paper bags (113 samples). For *H. stipulacae*, cover was very low; whole plants were weighed and the whole plant biomass was used. The paper bags were placed in a household convection oven (HamiltonBeach 31100) at 60°C for 24 - 48 h^{-1}. Parts were weighed using an analytical scale (Mettler Toledo PJ400). Mean biomass (g m^{-2}) per transect was calculated. Recorded biomass will be sent to SeagrassNet.org.

Figure 9. Rinsing plant material with fresh water, separation of plant parts from left to right roots, leaves and shoot.

2.3.2.2 Photographs

For each $0.25m^2$ quadrat a photograph was taken for future reference. A labeler was used to identify the quadrant: site abbreviation, site number, transect letter, quadrant number (e.g. SL1.A.3 = Santo Largo, site 1, first station A, quadrat number 3). Photographs were taken from a vertical angle using a Yuntab Action Camera (Sport DV 1080P Mini 30-Meter). In some cases it was necessary to take the photograph from an angel or underwater to reduce light reflection that distort the image. For some quadrats videos were shot due to wind and wave effect in the water over the quadrat, significantly reducing image quality. Images will be sent to Seagrass.Net@unh.edu after completion of the study.

2.3.2.3 Herbarium

A herbarium was made by collecting two voucher specimens of all species observed in the field. One specimen is to be kept and the other is to be sent to Seagrassnet.org. These are invaluable for future reference material. Two or three complete plants (leaves, stems, rhizomes and roots) were collected. These were placed inside labelled plastic Ziploc bags with seawater. If survey time took longer than 2 hours, the bags were kept on ice in a jug to reduce decomposition rates. The specimens were washed with fresh water and all debris and algae were removed as best possible. After rinsing, samples were spread over a sheet of paper that was subsequently covered by another sheet of paper. The paper sheets were wrapped in newspaper and placed under a heavy object. Sheets were left to dry for up to two weeks. A label to be filled out on Seagrassnet.org and printed will be placed on the bottom right of the paper. Pages were labelled in pen during processing. Images of the *Herbarium* can be found in Appendix F.

2.3.2.4 Mapping Site 2 Isla di Oro

Site 2 – Isla di Oro data was collected according to the method proposed by Seagrass-Watch [13]. The survey methodology to identify seagrass for mapping in an area, focuses on the occurrence of seagrass and sediment types.

A combination of transects and spots were used for collecting mapping data. The coastline is relatively homogenous and is less than 1 km long. Walking transects were estimated to be 50 – 100 m apart by the observer, and it was not required to measure them by transect tape. Point observations were taken 30 – 50 m apart. The general field procedure was adapted for seagrass extent measure. Seagrass extent was tracked using Gaia GPS application for iPhone. At each point a quadrat of $0.25m^2$ was thrown haphazardly in a radius of 5 m with a total of 3 replicates per point observation. Field procedures took place on 19 stations (replicates= 57).

On each point substrate dominant type, seagrass identification and cover, presence of invertebrates and algae percent (%) cover were identified.

It is recommended to take a photograph of each 10^{th} mapping point at two angles. Photographs and videos were taken as often as possible of point observations using Yuntab Waterproof Action Camera (Sport DV 1080P Mini 30-Meter).

Voucher specimens were taken of species encountered for the day. Voucher specimens were processed according to ¶ 2.3.2.3.

Site description and averages obtained from replicates per station are reported.

2.3.3 Reporting

Currently, deliberations are taking place between TNO Caribbean and DNM concerning the Marine Park Management Plan (MPMP). Data from the surveys conducted on Aruba will contribute to the Reef Check, the Global Coral Reef Monitoring Network and Dutch Caribbean Nature Alliance databases. For seagrass, data will be reported to the SeagrassNet databases later in the year.

3.0 Results – Reef Check

3.1 Site Description and Zonation

Field data sheets (Site description forms) for individual sites (25) visited during the survey period are shown in Appendix C. Sites visited were compared to descriptions provided by Bak, Roos, and Houtepen et al.(Bak, 1977; Bak, 1974; Houtepen, Brunel, de Graaf, Tichelaar DCM Miller, & Nagelkerke, 2015; Roos, 1971) that were performed locally or in the region. The proposed zonation found at a depth range between 0 – 18 m are provided in the next paragraph.

3.1.1 Zonation

Shore zone (0-5 m) MP1: The starlet coral species *Sidarestrea spp.* can be found on the sandy and stony bottoms on the North eastern side. Areas with rock formations are covered in microalgae.

Shallow zone (0-4 m) MP2 and 3: Mainly consists of rubble layers and small coral and sponge settlement. Coral species present include fire coral (*Millepora complanata*), Knobby brain coral (*D. clivosa)* and gorgonians (*Gorgonidae*) are common in dispersed patches. Elkhorn coral (*A. palmata*) was observed occasionally. In the lagoon of MP3 zonation was slightly different with larger rock formation, larger *Milliporidae* structures in deeper areas and large rubble fields covered in algae in shallower parts.

Mixed reef zone (10-16 m) MP1: Reduced wave action with presence of *D. clivosa and Orbicella spp.* High instance of macroalgae. Sea fans (*Gorgonia flabellum*) and sea rods (*Plexaurella flexuosa)* were scattered amongst the hard structures.

Mixed reef zone (8-11 m) MP2: Angled sandy bottom dominated by macroalgae, large seafan and sea whip fields including: Venus seafan (*Gorgonia flabellum),* Sea plumes (*Pseudopterogorgia spp*.)

Mixed reef zone (5-11 m) MP3: In the shallow part, rubble formations are covered in small, patchy stony coral structures of the species Lobed star coral (*O. annularis),* Great star coral (*M. cavernosa*), Pillar coral (*D. cylindrus),* and Pencil coral. In deeper areas it can be characterized by dense, hard coral and rock structures, lettuce coral (*Agaricidae*), Pencil coral and gorgonian species. Lettuce coral and fire coral can also be present. High instance of coral damage by anchoring occurs in the area. Rock structures are covered in crustose corraline algae.

Drop-off zone (12-18 m) MP3: The slope starts at 12 m depth with abundance of *Orbicella spp*., *Agaricia spp*. Sea whips and sea fans are present. Other species include cactus coral *Isophyllia sinuos*, pencil corals and brain coral (Mussidae).

3.2 Fish Belt Transect

3.2.1 Fish counts and percent distribution

A total of 2749 fish were observed belonging to 8 families across 24 x 100m transects (Table 1). Fish data was lost upon entry to shore for one site at MP1 and MP3. In Figure 10, the percent total observed number of fish per Marine Park is presented. MP3 had the highest fish observations (total: 1132, N: 9) followed by MP1 (total: 716, N: 6). In MP2 (total: 457, N: 7) and outside MPs (total: 419, N: 3) similar numbers of fish were observed, despite the difference in number of sites visited (Table 1.).

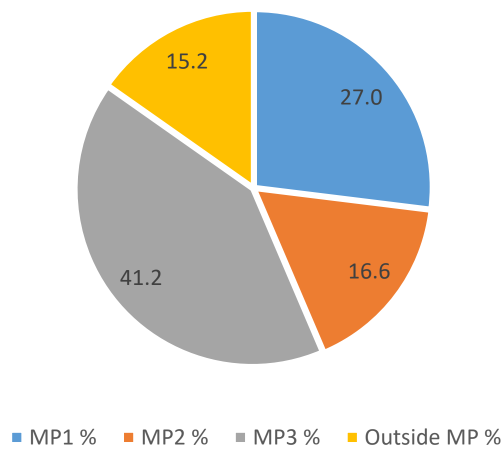


Figure 10. Percent number of fish observed per Marine Park. Highest percentage of fish found in MP3 Mangel Halto (gray) 41.2% of total fish counted, followed by MP1, 27% of total fish counted.

The highest number of fish by species was observed for Tangs (*Acanthuridae*), followed by Grunts (*Haemulidae*), Parrotfish (*Scaridae*), Butterflyfish (Chaetodontidae) with 1501, 436, 387 and 157 individuals, respectively. Species included: Blue tang (*A. coeruleus*), Doctorfish *(A. chrirurgus*), Ocean surgeonfish (*A. bahanius*), Smallmouth grunt (*H. chrysargyreum*), Bluestriped grunt (*Haemulon sciurus*), French Grunt (*H. flavolineatum*), Black Margate (*A. surinamensis*), Spotlight parrotfish (*S. viviride*), Queen Parrotfish (*S. vetula*), Banded butterflyfish (*C. striatus*), Four-eye butterflyfish (*C. capistratus*), Spotfin butterflyfish (*C. ocellatus*) and Longsnout Butterflyfish (*P. aculeatus*). Groupers larger than 50 cm were not observed during the survey. The highest number was found in sizes below 30 cm. Identification of species was not possible due to cryptic nature and lack of grouper identification experience. Snappers were found in low numbers in all parks with less than 40 individuals observed per park. Species observed included: Schoolmaster snapper (*Lutjanus apodus*) and Yellowtail snapper (*O. chrysurus*). Moray eels and rare species such as turtles, sharks and rays were least observed with 13 observation of Muraenids and 4 observations of rare animals. Moray eel species observations were made of the Green moray eel (*Gymnothorax funebris*) and Spotted moray eel (*Gymnothorax moringa*). Two Green turtles (*Chelonia mydas*) and one Nurse shark (*Ginglymostoma cirratum*) was observed during the survey period. Graphs of species totals can be found in Appendix D.

Table 1. Total fish count for 8 fish families found within the marine parks: *Chaetodontidae, Haemulidae, Serranidae, Acanthuridae, Lutjanidae, Scaridae, Muraenidae* and Rare animals included turtles, rays and sharks. One individual nurse shark was observed.

Site	**N**	**Butterflyfish**	**Grunts**	**Grouper <30cm**	**Grouper 30-40cm**	**Grouper 40-50cm**	**Grouper 50-60 cm**	**Tang**	**Snapper**	**Parrotfish**	**Moray Eel**	**Rare Animals**
Total MP1	6	20	66	40	**5**	0	0	536	29	43	2	0
Total MP2	7	46	127	36	3	2	0	135	26	79	2	1
Total MP3	9	77	108	23	5	1	0	698	35	180	5	0
Total Outside MP	3	14	135	10	3	0	0	132	34	85	4	2
Total	25	157	436	109	16	3	0	1501	124	387	13	3

Table 2. Average and standard deviation is presented with the total number of samples per area (n).

Site	**N**	**Total**	**Average**	**SD**
Total MP1	6	741	123.5	78.26411
Total MP2	7	457	65.28571	17.7091
Total MP3	9	1132	125.7778	67.15262
Total Outside MP	3	419	139.6667	84.64071
Total	25	2749	109.96	58.38057

3.3 Invertebrates Belt Transect

Soft corals in the form of sea fans and sea whips were the species most observed in the marine parks (Table 3). Average abundance of invertebrates are not highly variable between marine parks (Table 4). Highest number of invertebrates were sea fans for MP1, MP2, and MP3 with a total of 989, 1234, 1017 sea fans/whips, respectively. At times, densities were high to the point it hindered Flamingo tongue (*Cyphoma gibbosum*) count (Figure 11).

Figure 11. Sea plumes, sea rods and sea fans field at MP2 Seroe Colorado May 2018.

Invertebrates that were not observed are not reported in table 3. Banded coral shrimp (BCS, *Stenopus hispidus*), was observed rarely in MP3 and MP2. *Diadema spp* (DA) were nearly not observed in marine parks, with only 3 representatives in MP2 and MP3. Outside of MPs, 158 individuals were counted, yet these were very small. Lobster observations were made beyond the transect line and were included with Rare Animal sitings. The Three-rowed sea cucumber (*Isostichopus badionotus*) was observed in MP1, MP2 and outside (Total: 3, N: 25). Cones were nearly absent inside the parks at depths between 3-18 m. Only three sea star species were observed: the Banded sea star (*Luidia alternata*), the Common comet star (*Linckia guildingii*) and brittle stars of the *Ophiocoma spp.* were observed on the leeward coast in MP3 and outside MPs (Table 3).

Table 3. Invertebrate Belt Transect counts in three marine parks and one are outside the marine parks. BCS=Banded Coral Shrimp, DA= Diadema species, PU= Pencil Urchin, CU= Collector Urchin. Theese are presented with other species present in marine parks.

Total	BCS	DA	PU	CU	Sea cucumber	Sea fans	Flamingo tongue	Cones	Red Sea star	Brittle star
MP1	0	0	0	0	1	989	14	0	0	0
MP2	1	1	0	0	1	1234	19	0	2	0
MP3	3	2	14	0	0	1017	1	0	0	9
Outside MP	0	158	35	2	1	322	0	1	0	9

Table 4. Total invertebrates observations per Marine Park. Average and standard deviation (SD) were calculated.

Sites	**Total**	**Average**	**SD**	**N**
MP1	1004	167	153	6
MP2	1258	180	163	7
MP3	1046	116	105	9
Outside MP	528	176	135	3

3.4 Impact and Disease

Diseases and bleaching were rarely observed during the survey period. Instances were observed on small coral colonies (Figure 12.).

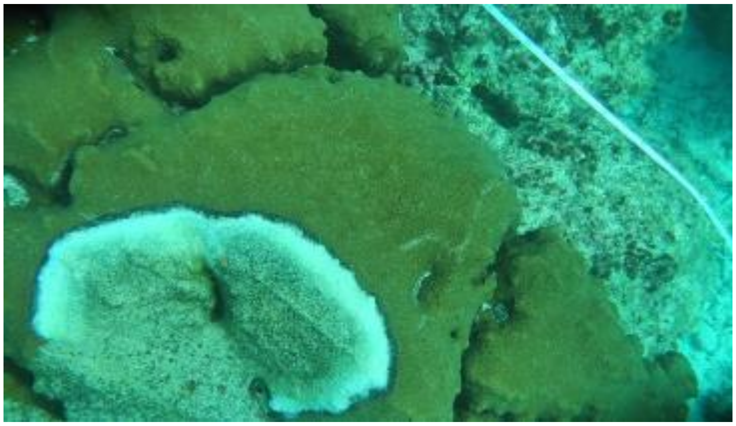


Figure 12. Black band disease on *Orbicella spp.*

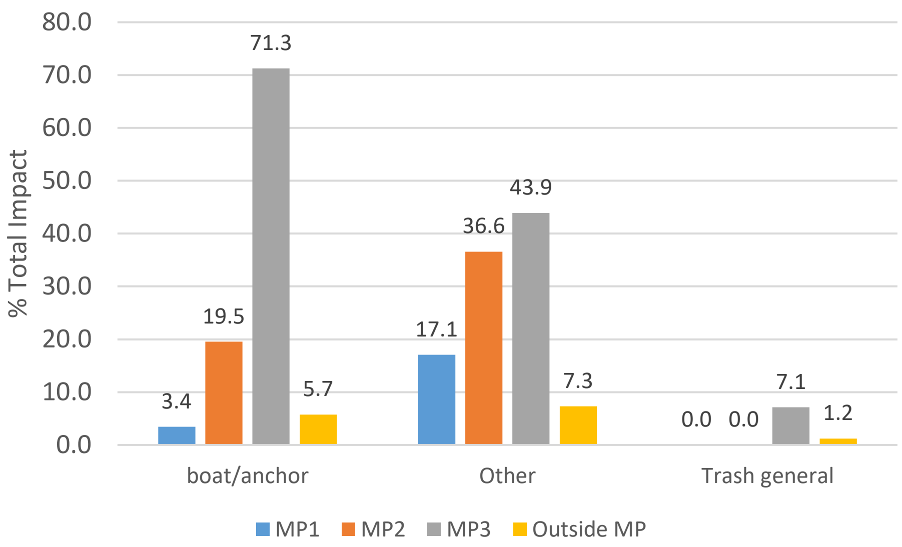


Figure 13. Impact percent (%) of total is depicted for all MPs.

Boat and anchor damage was most severe in MP2 and MP3 on the leeward side of the island (Figure 13, 14). The sites found **outside** of MP3 lagoon were affected by anchor damage. Over 70% of total anchor damage reported belonged to MP3. Abandoned anchors were the most common form of litter found, followed by plastic bottles caps and utensils. On the windward side, in MP1 high wave action and strong winds may reduce anchoring by fishermen.

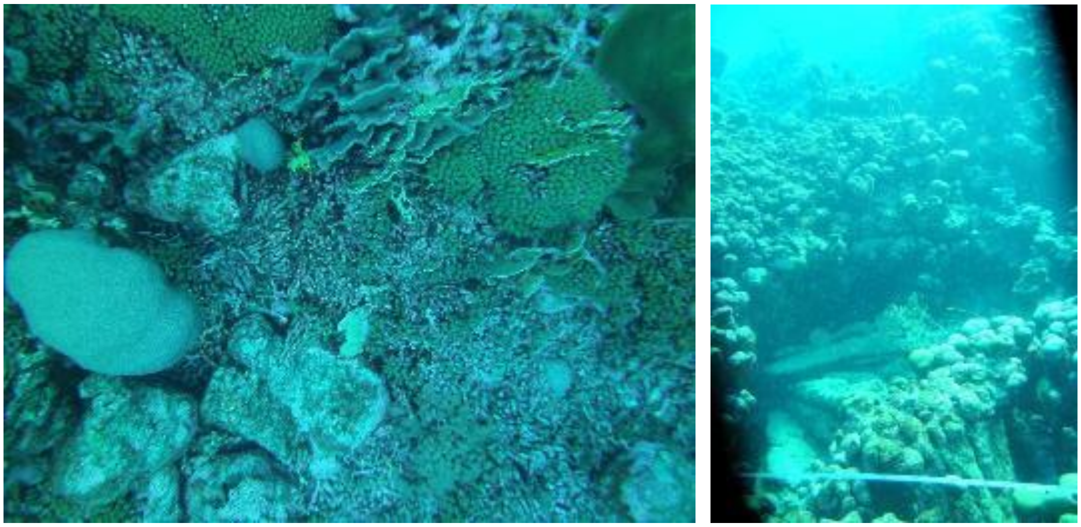


Figure 14. Boat anchor damage on mixed coral reef in MP3 (Left). Anchor damage and abandoned anchor on *Orbicella spp.* reef in MP2 (Right).

The "Other" category was mainly represented by fish and snail herbivory (Figure 15).

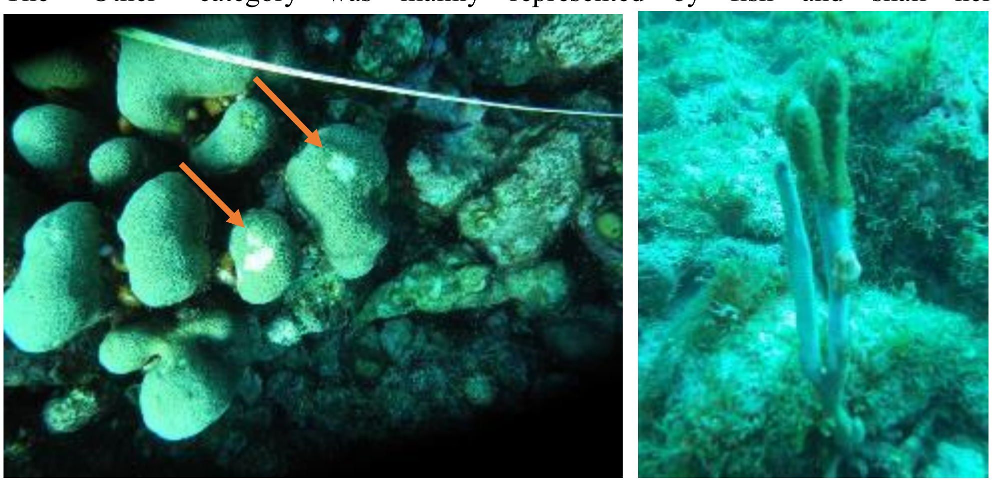


Figure 15. Fish herbivory on *Orbicella spp.* (Left). Flamingo tongue; depicting snail herbivory on soft coral.

Herbivory was most prevalent in MP3 (44%), followed by MP2 (37%) and MP1 (17%).

3.5 Substrate Line Transect

On each transect line of 100 m, 160 observations were made documenting substrate dominant category. Categories HC, SC, NIA, SP, and OT are pooled to represent Living reef and categories RKC, RC, RB, SD and SI represent Non-living reef. Data is presented as average percent (%) cover of living reef and Non-living reef found in all the marine parks (Figure 16, 17).

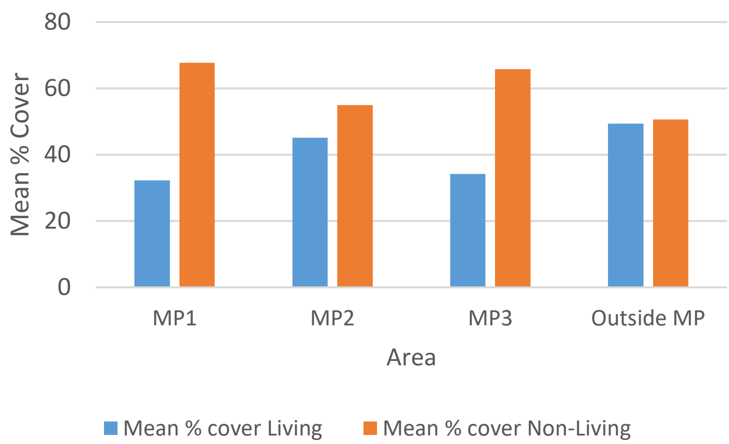


Figure 16. Mean % cover calculated per Marine Park.

Non-living coral was dominant in all areas except outside the MPs where a similar mean percent cover was observed. MP1 was observed to have a 68% mean cover of Non-living coral, followed by MP3 with 65% and MP2 with 55% mean Non-living reef (Figure 16).

The highest mean % cover of Living reef was observed in MP2 (Mean: 45%), which had a high soft coral count and hard coral count of species *Orbicella* (Table 3). MP1 and MP3 had similar values with a mean Living reef cover of 32% and 34%.

Overall Mean percent cover of Living reef and Non-living reef for all sites (MP1, MP2, and MP3) was 38.5% and 61.5%, respectively (Figure 17).

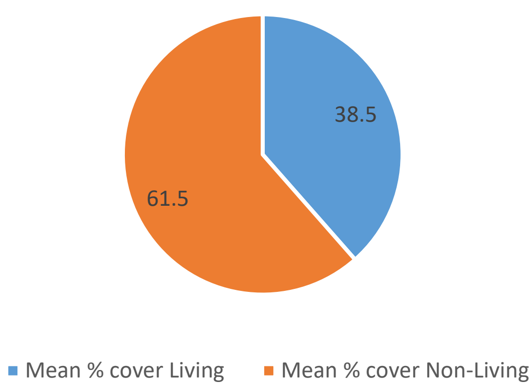


Figure 17. Total mean % cover of Living reef and Non-living reef calculated for all sites April-May 2018. Non-Living reef was dominant at survey sites during survey period (61.5%). Living reef mean cover was 38.5%.

4.0 Results - Seagrass Monitoring and Mapping

Seagrass extent was tracked between Site 1 and Site 2 (± 1.5 km) (Figure 18) at low tides during spring tide. A seagrass meadow was observed between Site 1 and 2, but could not be recorded (X) in the survey period. Grid counts within bounds (Table 5, Figure 19) yielded a total mixed seagrass extent of 8.43 ha^{-1}.

Figure 18. MP3 Site 1 (1) Santo Largo and Site 2 (2) Isla di Oro, recorded extent of seagrass meadows depicted in Gaia GPS OpenStreetMap. Line X highlights area where seagrass extent was not recorded but observed.

Figure 19. MP3 Site 1 (right) and Site 2 (left) with an overlay grid (1 square: ±0.826 ha^{-1}) in Gaia OpenStreetMap. Seagrass extent estimated visually by grid counts; within recorded tracks was ±8.43 ha^{-1}.

Table 5. Visually estimated grid counts within recorded seagrass meadow bounds. Red bound and Blue bound were found at Site 1. Blue + Purple Bound were recorded in Site 2. Estimates of area size are provided in m^{-2} and ha^{-1}.

	Site 1 Red Bound	Site 1 Blue Bound	Site 2 Blue + Purple Bound	Total
Grid Count in Bounds (± #)	4	3.4	2.8	10.2
Estimated extent (m^{-2})	33057.8512	28099.1736	23140.5	84297.52
Hectares (ha^{-1})	3.30578512	2.80991736	2.31405	8.429752

Figure 20. Station positions (3 per transect) Site 1 SeagrassNet Monitoring Survey Aruba Site 1 – Santo Largo (1) May 2018 depicted in Gaia OpenStreetView. Shallow to deep transects: SL01A, SL01B, SL01C (N=3, replicates=36). Waypoints (blue and red) mark station (right to left: 0, 25 and 50 m) locations on transect where GPS coordinates were taken and depth was measured. For SL01A and SL01C, distance to edge of meadow (m) and distance to last leaf was recorded (Appendix B).

4.1 Seagrass Monitoring

Seagrass extent at Santo Largo – MP3 was estimated at 6.1 ha^{-1}. Waypoints of the stations for seagrass monitoring were recorded and average depth per transect was determined (Figure 20, Table 6). Distance to edge of the meadow was measured for transect A and C (Appendix B). On Transect C, the second station's distance to edge could not be measured due to it exceeding the transect tape distance (>150 m). Average surface water temperature was 27^{o}C. Average wind speed was 46.5 km h^{-1}.The depth range in Site 1 was 0.175 cm on SL01A to 0.49 cm on SL01C at low tide. Sediment type at Site 1 was variable: a sandy bottom was observed at SL01A and coarse sand mixed with rocks and shells was found at SL01C.

Table 6. SeagrassNet Monitoring Site 1 and Seagrass-watch monitoring Site 2. Location, species composition, environmental information

Location	Seagrass Species	Mean Air T^{o}C	Mean Surface Water T^{o}C	Depth Range (m^{-1})	Tide (±m^{-1})	Sediment Type

Site 1 - Santo Largo	*Thalassia testudinum (Tt), Halophila stipulacae (Hs)*	28.3 -28.5	27	0.175 - 0.49	0.08 - 0.33	Sand, Coarse Sand (with shells/rock)
Site 3 - Isla di Oro	*Thalassia testudinum (Tt), Halophila stipulacae (Hs), Halodule wrightii (Hw)*		27.1	0.41 - 1.9		Mud, Sand, Coarse Sand, Rubble

Site 1 cross-transect lines (Figure 20, Appendix) were all subtidal during spring tide. At the shallow cross-transect (Figure 20: A), seagrass species present were mixed stands of *T. testudinum* and *H. stipulacae*, to pure *T. testudinum* stands at the deep cross-transect (C) (Figure 21 - 23).

Figure 21. Quadrat photos of Site 1 transect A (SL01A) April 2018 in MP3. *T. testudinum* is observed. High wind activity reduced picture quality by creating ripples over the water. Mixed seagrass species stands depicted.

Figure 22. Quadrat photos Site 1 transect B (SL01B) May 2018.

Figure 23. Quadrat photos Site 1 transect C (SL01C) May 2018. For SL01C, it was not possible to capture all the quadrats accurately (wind speed: >45 km^{-1} h^{-1}).

Table 7. Parameters measured and calculated for all transects in Site 1. Average depth, Distance to edge and last leaf from transect stations, mean seagrass cover, mean species cover (Tt and Hs), Maximum and minimum observed cover per species, Total flower and fruit count, mean density by species and dry weight (N=3, replicates =36).

Transect	**Average Depth (cm-1)**	**Mean Seagrass Cover (%) (±SD)**		**Mean Cover Tt (%) (±SD)**		**Max:min % cover Tt**		**Mean Cover Hs (%) (±SD)**		**Max:min % cover Hs**		**Total Flower/ fruit (#)**	**Mean Density Tt (# m2)**		**Mean Density Hs (# m2)**		**Dry Weight (g m2)**
SL01A	22.5	63.3	21.8	49.4	25.3	90.0	18.0	13.9	15.1	39.0	0.0	0.0	72.5	1.5	47.7	2.5	401.5
SL01B	32.0	64.4	32.7	62.2	34.3	98.0	0.0	2.2	4.2	12.0	0.0	0.0	68.4	2.5	10.4	0.9	345.2
SL01C	30.2	75.6	20.1	74.3	19.8	100	45.0	1.3	3.4	12.0	0.0	4.0	76.7	1.2	4.1	0.58	390.5

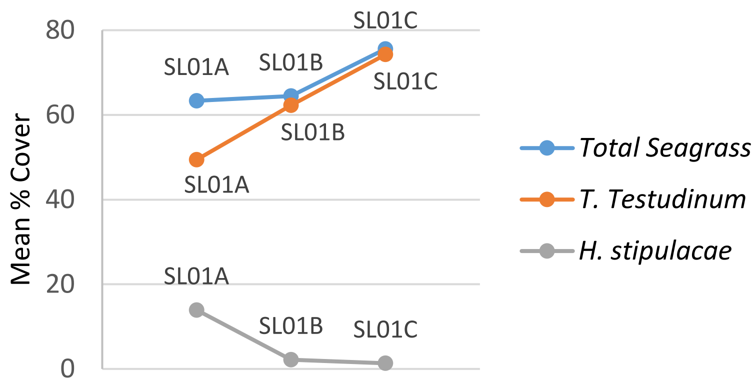


Figure 24. Mean % cover of total seagrass and observed species on transect lines at Site 1- MP3 May 2018. *T. testudinum* increased in % cover over the depth gradient of the cross-transects. In deeper water (SL01C), lower *H. stipulacae* mean % cover was observed.

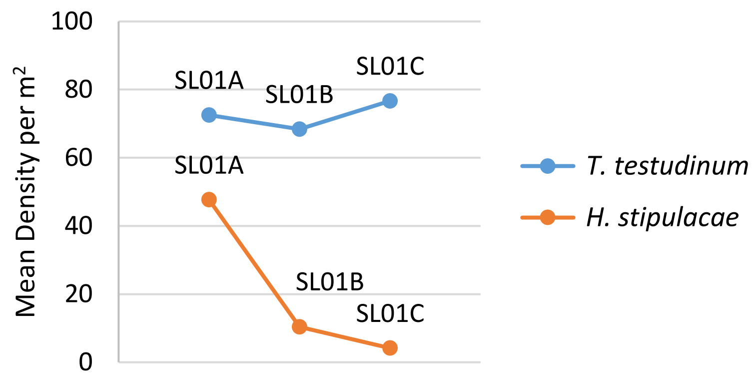


Figure 25. Mean density on Site 1 – MP3 of observed *T. testudinum* (Blue) and *H. stipulacae* (Orange) calculated per m^2 in Site 1 May 2018. Mean density per m^2 was derived from core samples (0.0402 m^2).

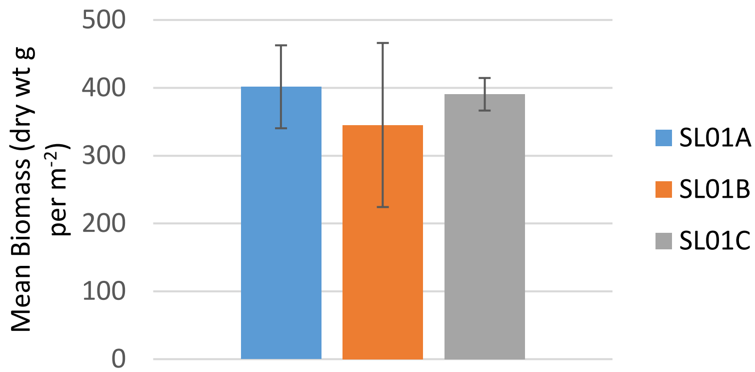


Figure 26. Mean Biomass (dry weight in grams per m^2) of seagrass (Tt and Hs). Derived from biomass core samples (N= 3, replicates= 36) (0.0402 m^2). Error bars represent standard deviations.

Mean seagrass % cover for SL01A – SL01C was 63.3% (SD: 21.8), 64.4% (SD: 32.7), 74.3% (SD: 20.1), respectively. Mean *T. testudinum* covered the cross-transects, 49.4% (SD: 25.3), 62.2% (SD: 34.3) and 74.3% (SD: 19.8) on shallow to deep transects (Figure 24). Maximum recorded *T. testudinum* cover was 100% (Figure 23: SL01C - 11 & 12) and minimum observed cover was 0% (Figure 22: SL01B – 7). For the non-native species *H. stipulacae*, mean % cover across SL01A – SL01C was 13.9% (SD: 15.1), 2.2% (SD: 4.2) and 1.3% (SD: 3.4) respectively. Highest recorded % cover for *H. stipulacae* was found on SL01A at 39% (Figure 21: SL01A - 5). Lowest cover was 0% and was observed across all transects.

Calculated overall mean shoot density (# shoots m^{-2}) for *T. testudinum* across the shallow (SL01A) to deep (SL01C) transect was 72.5 (SD: 1.5), 68.4 (SD: 2.7), 76.7 (SD: 3.1), respectively. For the non-native species H. stipulacae overall mean shoot density was 47.7 (SD: 2.5), 10.4 (SD: 0.9), and 4.1 (SD: 0.6), respectively (Figure 25, Table 7).

Estimated mean biomass (Figure 26 , Table 7) of all species found on the cross transects in MP3 (SL01 A – S01C) were 401.5 (SD: 61) g m^{-2}, 345.2 (SD: 121) g m^{-2}, and 390.5 (SD: 24) g m^{-2}, respectively.

During core sampling of cross-transect B and C (SL01B, SL01C) pushing the PVC core through the sediment proved to be difficult. In the case of SL01B, it was observed that water depth increased (±10-20 cm), in combination with sediment quality (coarse sand) and root density. For SL01C, core sampling was difficult due to sediment quality (coarse sand: rocks and whole shells) and root density.
Of the reproduction parts, 4 T. testudinum seeds were found on transect SL01C (Figure 27).

Figure 27. T. testudinum seed from Site 1 MP3 May 2018

4.2 Seagrass - Watch

The northern meadow of site 2 (Figure 22: Blue track, Site 2) was tracked and contained a dense *H. stipulacae* meadow that was mixed with *T. testudinum* and *H. wrightii* (Figure 28). Two small patches containing *T. testudinum* were recorded in the southern meadow (Figure 22: Purple track, Site 2). Total extent cover that was recorded and estimated at Site 2 was 2.3 ha^{-1}.

Figure 28. Seagrass species present at Isla di Oro, various densities can be observed. Left: *H. stipulacae*. Center: mixed stands of *H. stipulacae* and *T. testudinum*. Right: mixed stand *H. wrightii* and *T. testudinum.*

A total of 19 stations (N=19, Replicates= 57) were sampled within Site 2 for mapping. Coordinates of stations are provided in Table 8. Station 12-14 proved to be difficult to sample. Their location was on or near wave breaking point that affected accuracy of the visual transect. Station 12-14 were not followed by eachother as accurately as station 1-4, 5-7, 8-11, 15-18 due to wave action (Figure 29).

Figure 29. Waypoints indicate stations (N=19, Total replicates=57) at Site 2 Isla di Oro in MP3. Per station, 3 quadrats were haphazardly thrown for field procedures Seagrass-watch [13]. Arrows indicate walking direction. Yellow star designates wave break location on rubble reef.

H. stipulacae mean % cover was dominant at station 1-8 and ranged between 0 to 84% (Figure 30, 31, Table 8). At these stations, several macro algae species were observed but could not be identified by species. Species present were: *Udotea* spp., *Caulerpa* spp., and *Dictyota* spp. *T. testudinum* was present after station 9 and was overgrown by a dense *H. stipulacae* mat (Figure 31). *H. wrightii* was present at two stations of the surveyed area at 30% and at 4%.

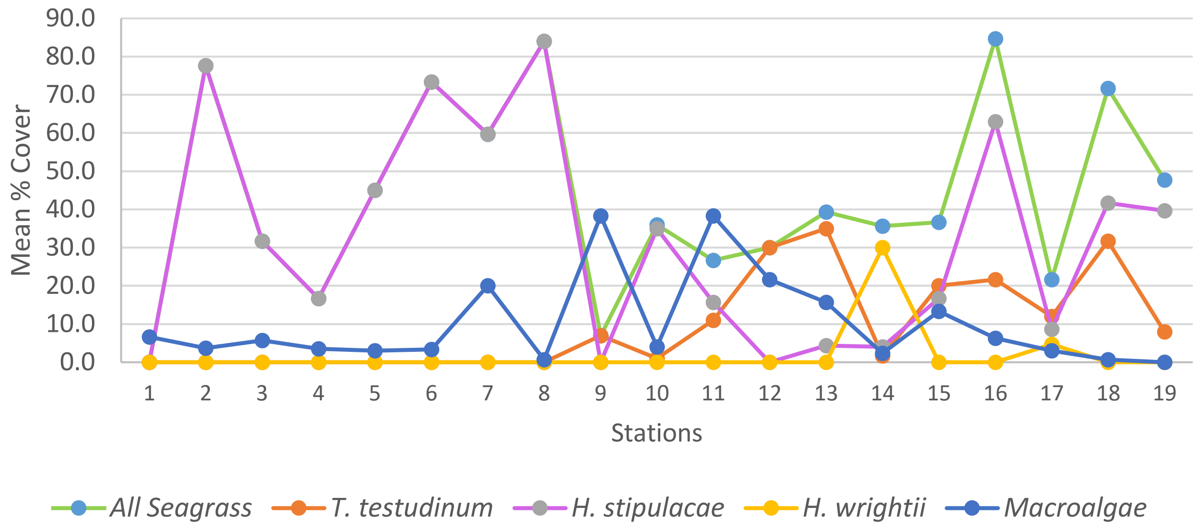


Figure 30. Mean % cover found at Site 2 – MP3 May 2018. All species % cover, *T. testudinum*, *H. stipulacae*, *H. wrightii* and macro algal % cover found in stations.

Table 8. Station mean seagrass cover (%), by species cover (Tt, Hs, Hw %) and macro algae. Latitude and longitude is provided.

Station	**Latitude**	**Longitude**	**Mean Seagrass cover (%) (±SD)**		**Mean cover Tt (%) (±SD)**		**Mean cover Hs (%) (±SD)**		**Mean cover Hw (%) (±SD)**		**Mean Macro algae cover (%) (±SD)**	
1	12.45734	-69.96053	0.0	±0.0	0.0	±0.0	0.0	±0.0	0.0	±0.0	0.0	±0.0
2	12.45712	-69.96080	77.7	±32.7	0.0	±0.0	77.7	±32.7	0.0	±0.0	10.9	±18.9
3	12.45678	-69.96105	31.7	±2.9	0.0	±0.0	31.7	±2.9	0.0	±0.0	1.0	±1.7
4	12.45662	-69.96120	16.7	±14.4	0.0	±0.0	16.7	±14.4	0.0	±0.0	4.8	±8.3
5	12.45696	-69.96138	45.0	±5.0	0.0	±0.0	45.0	±5.0	0.0	±0.0	1.7	±2.9
6	12.45710	-69.96121	73.3	±10.4	0.0	±0.0	73.3	±10.4	0.0	±0.0	3.5	±6.0
7	12.45736	-69.96084	59.7	±34.1	0.0	±0.0	59.7	±34.1	0.0	±0.0	11.4	±19.7
8	12.45766	-69.96106	84.0	±21.2	0.0	±0.0	84.0	±21.2	0.0	±0.0	7.1	±12.2
9	12.45756	-69.96110	7.0	±5.2	7.0	±5.2	0.0	±0.0	0.0	±0.0	0.0	±0.0
10	12.45731	-69.96122	36.0	±19.7	1.0	±1.7	35.0	±18.0	0.0	±0.0	6.0	±10.4
11	12.45732	-69.96152	26.7	±4.5	11.0	±1.0	15.7	±4.0	0.0	±0.0	1.3	±2.3
12	12.45730	-69.96180	30.0	±5.0	30.0	±5.0	0.0	±0.0	0.0	±0.0	0.0	±0.0
13	12.45755	-69.96177	39.3	±9.0	35.0	±5.0	4.3	±7.5	0.0	±0.0	2.5	±4.3
14	12.45750	-69.96168	35.7	±1.4	1.7	±0.3	4.0	±1.7	30.0	±0.0	10.6	±16.8
15	12.45788	-69.96172	36.7	±7.6	20.0	±5.0	16.7	±2.9	0.0	±0.0	1.0	±1.7
16	12.45795	-69.96153	84.7	±21.5	21.7	±2.9	63.0	±20.4	0.0	±0.0	6.8	±11.8
17	12.45799	-69.96138	21.7	±2.9	12.0	±5.3	8.7	±3.2	4.7	±2.5	3.5	±1.1
18	12.45820	-69.96131	71.7	±2.9	31.7	±2.9	41.7	±2.9	0.0	±0.0	1.0	±1.7
19	12.45839	-69.96154	47.7	±34.6	8.0	±6.9	39.7	±28.1	0.0	±0.0	9.4	±16.3

Figure 31. Examples of marine biodiversity present at Site 2 MP3 May 2018. Species were not identified for macroalgae. Left: unknown spp of dense macro algae patches. Center: *Caulerpa* spp and *Dictyota* spp between *T. testudinum* stands. Left: *Dictyota* spp and Branched finger coral (*P. furcata)*.

6.0 References

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7.0 Appendix

Appendix A. GPS Coordinates for Reef Check Sites Surveyed

Site	Latitude	Longitude		Site	Latitude	Longitude
Arashi_dive	12.60989	-70.05983		**MP2-8**	12.41137	-69.88560
Arashi snorkel	12.61128	-70.57280		**MP2-6**	2.41324	-69.88989
BSB.1	12.54003	-69.95067		**MP2-3**	12.41394	-69.89658
MP1-18	12.52802	-69.93056		**MP2-1**	12.41661	-69.89737
MP1-16	12.52417	-69.92752		**MP3-1**	12.46606	-69.98293
MP1-6 Boca Prins South	12.49886	-69.90397		**MP3-2**	12.46556	-69.98222
MP1-5 BocaPrinsNorth	12.50341	-69.90823		**MP3-4**	12.4648	-69.98085
MP1-dos play	12.5081	-69.91678		**MP3-3**	12.465	-69.98036
MP2-14	12.41173	-69.86958		**MP3-19**	12.46345	-69.97194
MP2-12	12.410004	-69.87412		**MP3-12**	12.45837	-69.96480
MP2-9	12.41031	-69.87999		**MP3-18**	12.44802	-69.95397

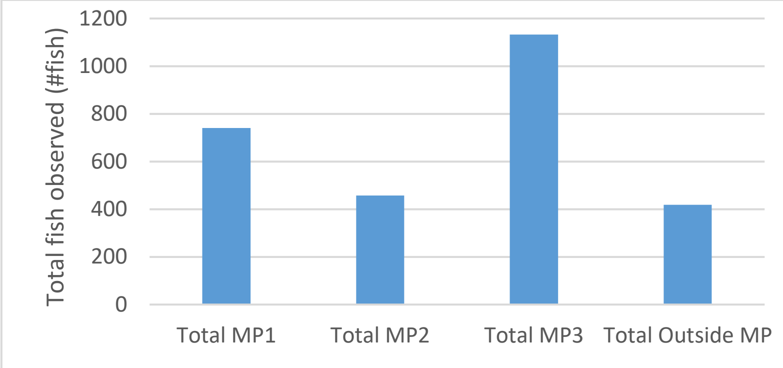
Appendix B. Seagrass Station Names, Coordinates, Distance to edge and leaf.

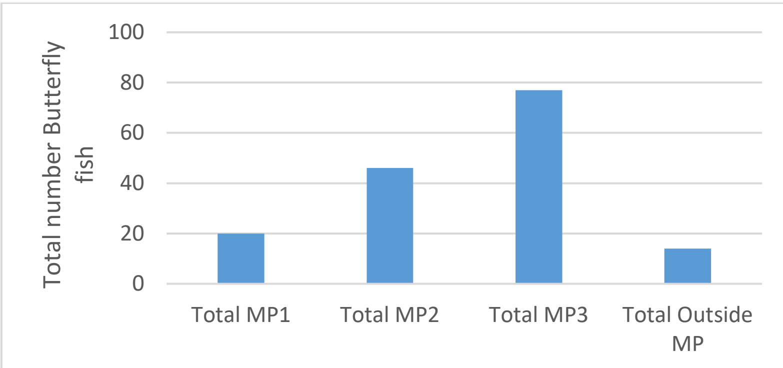
Station	Latitude	Longitude	Distance to edge (m)	Distance to last leaf (m)
SL1A-South	12.45028	-69.95358	5.5	5.5
SL1A-Center	12.45031	-69.95377	8.2	8.2
SL1A-North	12.45032	-69.95397	7.8	8.4
SL1B-South	12.45006	-69.95354	-	-
SL1B-Center	12.45007	-69.95378	-	-
SL1B-North	12.45008	-69.95399	-	-
SL1C-South	12.44938	-69.95349	69.2	78.3
SL1C-Center	12.44936	-69.95373	NA	NA
SL1C-North	12.44931	-69.95397	46.5	46

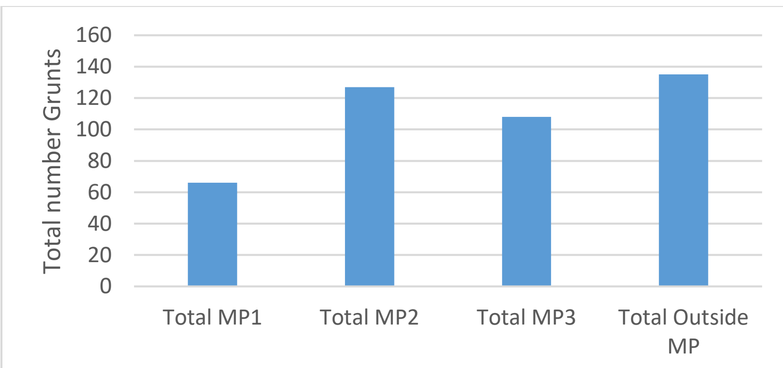
Appendix C Site description

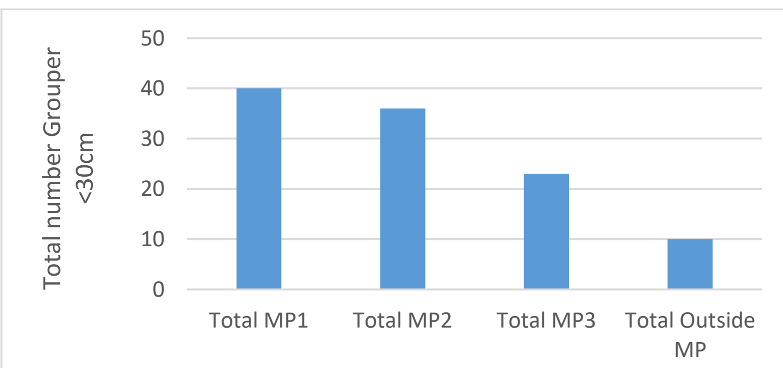
In data.

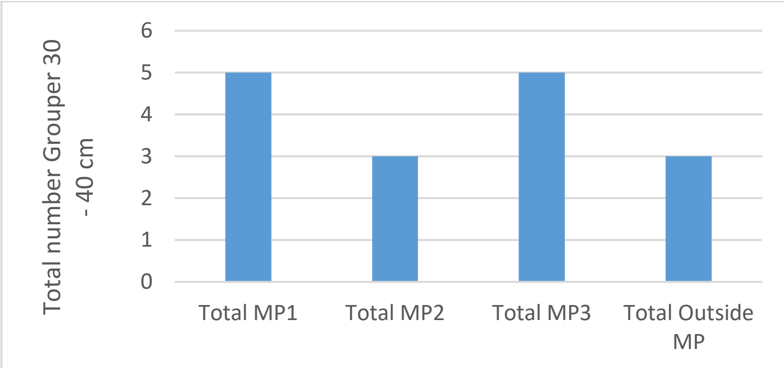
Appendix D. Total number of fish (by species) observed.

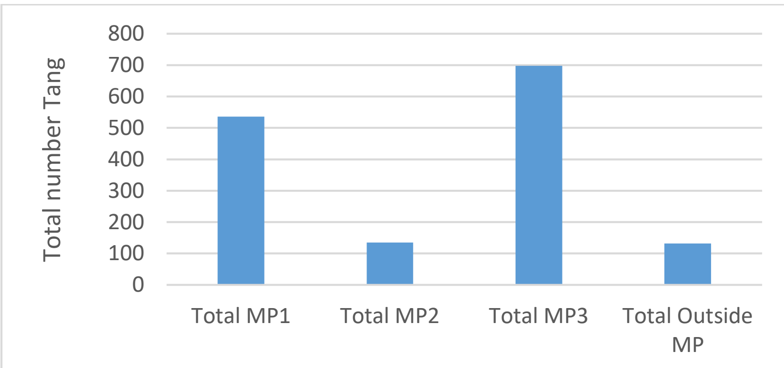


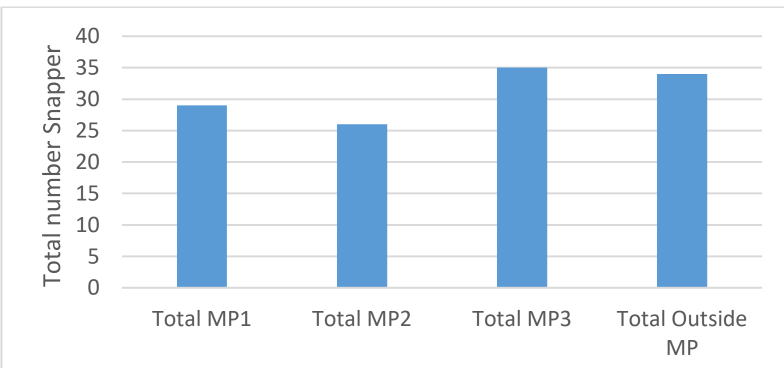


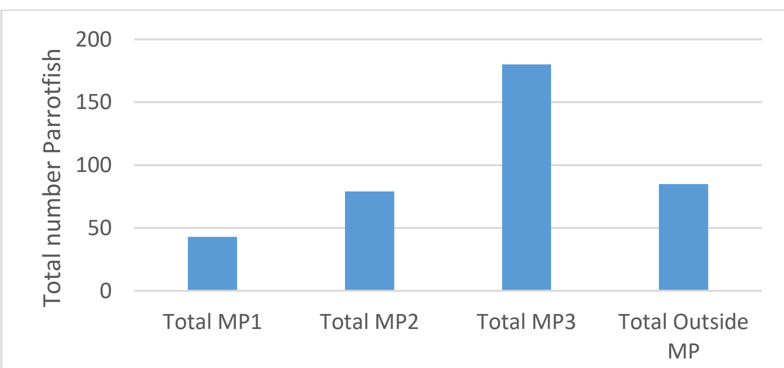





Total number Grouper 30 - 40 cm
6
5
4
3
2
1
0
Total MP1
Total MP2
Total MP3
Total Outside MP


Total number Tang
800
700
600
500
400
300
200
100
0
Total MP1
Total MP2
Total MP3
Total Outside MP


Total number Snapper
40
35
30
25
20
15
10
5
0
Total MP1
Total MP2
Total MP3
Total Outside MP


Total number Parrotfish
200
150
100
50
0
Total MP1
Total MP2
Total MP3
Total Outside MP

Appendix E. Counts for Impacts on coral reef Aruba Reef Check.

Sites	**boat/anchor**	**Other**	**Fish nets**	**Trash general**
All	87	82	0	84
MP1	3	14	0	0
MP2	17	30	0	0
MP3	62	36	0	6
Outside MP	5	6	0	1

Appendix F. Herbarium Photos