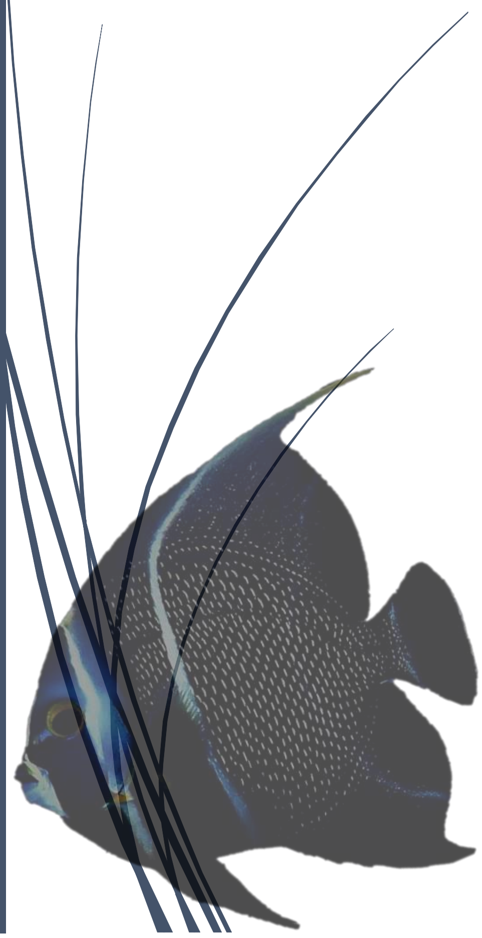
13-6-2019

Finding the preferred artificial reef type for tourist divers on St. Eustatius

A Research thesis using a Multi Criteria Analysis to look into diver preferences of reef attributes that can be linked to artificial reefs and their potential use in dive- tourism on St. Eustatius.



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Finding the preferred artificial reef type for tourist divers on St. Eustatius

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Thesis research

Coastal & marine management

AROSSTA Project

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Acknowledgement

This thesis research ‘measuring preferable reef attributes of dive tourists on St. Eustatius’ is part of the study Coastal- and Marine management at Van Hall Larenstein, University of Applied Sciences. In a 5-month period we got the opportunity to do our Thesis research under the wings of the Artificial Reefs on Saba and St. Eustatius (AROSSTA) project. In a 3-month data collection period from March until June 2019 we conducted research on the island of St. Eustatius in cooperation with CNSI, Scubaqua and Golden Rock Dive centre.

First of all, we would like to thank our supervisor Patrick Bron and supervisor/project leader Alwin Hylkema for guiding us throughout this Thesis project. The feedback was found clear and useful and even with little time there was always room for a question.

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Further we have big appreciation for the owners and staff of Golden Rock Dive Centre, who were always eager to help us out. Together with Scubaqua they gave us the opportunity to hand out questionnaires to their customers, which was highly appreciated.

For now, we wish you joy with reading this Thesis Report.

Tom van Ee & Lars ter Horst

Summary

For multiple reasons, such as; changing ocean temperatures, overfishing and unsustainable tourism coral reefs are declining worldwide. A negative feedback loop is created by the loss of three-dimensional structures that the coral reefs create. These three-dimensional structures provide shelters for grazing fish species such as; parrotfish (*Scaridae*), surgeon fish (*Acanthuridae*) and many more. The decrease in those structures cause these fish to disappear and causes algae to grow more freely and overgrow the corals. Which in turn causes loss of more three-dimensional structures. An option to battle this loss of three-dimensional structure is the use of artificial reefs. These reefs provide new structures for the fish species. Declining coral reefs not only cause ecological problems but also many local communities lose revenue with this decline. Artificial reefs placed by AROSSTA around St. Eustatius are being used to compare different reef types (Reef Balls, Layered Cakes and Pile of Rocks) on their ecological effects and possible benefits for local reefs. However, no research has been done to identify what kinds of reefs are most preferable for the dive community on St. Eustatius. To find the answer, 107 divers were interviewed and asked to rank the following eight reef attributes; 'Fish Diversity'; 'Fish abundance'; 'Coral diversity'; 'Coral abundance'; 'Benthic Diversity'; 'Benthic abundance'; 'Natural look' and 'Complex look'. Those attributes were then measured on the three different artificial reef types that are deployed by AROSSTA using standardized survey methods. The different reef types were then compared using a Multi-Criteria Analysis (MCA) with the diver preferences as the weight for the attributes. Even though the Layered Cake did not score highest on the most preferable attribute. it came out as the best option for dive tourism. This due the fact that the Layered Cakes scored overall highest on the different reef attributes. Since there is no standardized method to assign weights to the criteria, there is some room for discussion about how the weights relate to one another.

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1. Introduction

Besides being world's largest biogenic structures, coral reefs belong to the most important and diverse ecosystems on the planet providing ecosystem services for human and natural communities (Mumby & Steneck, 2008; Hoegh-Guldberg, et al., 2007). In the tropic regions many fish species rely on coral reefs as nursery habitat and for protection (Nagelkerken, et al., 2000). However, recent studies have illustrated that worldwide ~11 % of historical coral reef is lost, and that 16% of the remaining coral reefs are heavily damaged. The hard-coral cover on the reefs has already declined by 80% (Gardner, *et al*., 2003). The last 3 decades have had the strongest decline of hard coral cover, from 50 to 10 % total coral cover globally. Studies describe the changes as; reduced coral cover, reduced physical and biological diversity as a factor for the increase of macroalgae on individual reefs (Gardner, *et al*., 2003).

When coral reefs decline, the three-dimensional structure provided by the reef disappears as well. This structure provides shelter for many reef inhabiting species, furthermore this rugosity is known to increase the diversity and abundance of these species (Gratwicke & Speight, 2005). Many of these reef inhabitants like parrotfish (*Scaridae*) and sea urchins (*Echinoidea*) are grazers and forage on algae. If the algae are not reduced by grazers, they are able to out-compete corals impeding their population growth (Jompa & McCook, 2003). When the population cannot grow it may decline and the three-dimensional structures created by these coral populations will be reduced. This results in a negative feedback loop with a decline of coral and fish populations (Mumby & Steneck, 2008).

As a solution for this negative feedback loop, artificial reefs can be deployed to mimic natural reef functions. Artificial reefs are structures that are placed on the substratum deliberately to create new three-dimensional structure, therefore interrupting the negative feedback loop and giving corals the chance to settle (Baine, 2001). For many years now Reef Balls are one of the most popular artificial reef types and are deployed globally (ReefballFoundation, 2017). However, until now no research has been done on the functionality of Reef Balls compared to other available artificial reef type options.

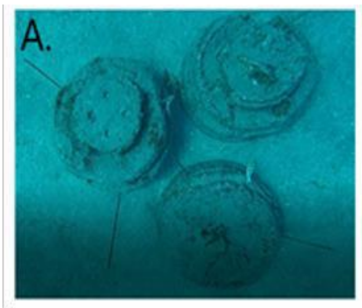


Figure 3 Layered cakes

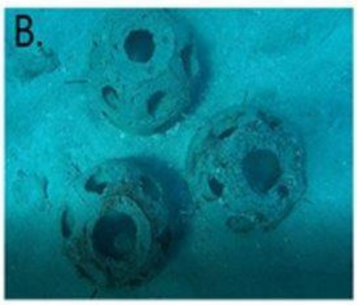


Figure 2 Reef Balls

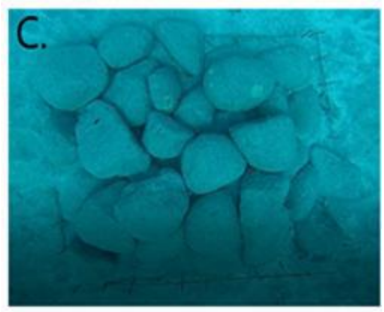


Figure 1 Pile of Rocks

Artificial reefs On Saba and St. Eustatius (AROSSTA) is using three different artificial reef types to compare the functionality of those reef types to ultimately combat coral decline and critically high biomass of macroalgae (de Graaf, *et al*., 2015).

Layered cakes (Figure 3A) are structures that are built out of four circular concrete layers with the largest on the bottom and smallest on top, creating a wedding cake-like shape. Reef Balls (Figure 2B) are dome-like structures made of concrete with holes on the sides and top. Pile of Rocks (Figure 1C) are rocks of different shapes/sizes, found on St. Eustatius, stacked on each other.

Other than potentially restoring the declining reefs, artificial reefs could be of interest for a broad range of divers (Stolk, Markwell, & Jenkins, 2007). Dive tourism is a million- dollar industry and brings a high income globally to many tropical islands like St. Eustatius. Previous efforts have described that the reef-related tourism generated a mean value of US$96,302 annually per hectare globally (Spalding, et al., 2017). On St. Eustatius the Marine environment has a total value of 1.737.190 USD, this accounts for 45% of the total ecosystem value on St Eustatius (Tiekens, et al., 2014).

Artificial reefs can also be used to reduce diving pressure on natural reefs, by providing more dive spots in the surrounding area. However, with placing an artificial reef in the marine environment the preferences of divers should be examined to make sure the dive sites will stay appealing for dive tourism (Polak & Shashar, 2012). Reefs have certain attributes that can make it attractive. Previous research showed that divers seem to prefer certain attributes in a reef over others (Williams & Polunin, 2000). The attributes that are used for this thesis are: '*Fish diversity'; 'Fish abundance'; 'Coral diversity'; 'Coral abundance'; 'Benthic diversity'; 'Benthic abundance'; 'Natural look of the artificial reef' and 'Complex look of the artificial reefs'.* If artificial reefs can represent these preferred attributes, and at the same time meet the ecological purpose of creating three- dimensional structure, they can benefit the local ecosystems and be of interest for dive tourism. This means it can generate an income as demonstrated in Monroe County where the county generated income of 32 million through different stakeholders (Jaksic, Stamenkovic, & Dordevic, 2013).

1.1 Problem Statement

AROSSTA aims to investigate the ecological effects and functionality of different artificial reef types. The artificial reefs differ in shape and complexity and therefor attract different species and their compositions. If artificial reefs are to be used to rehabilitate coral reefs it is important to know their possible contribution to dive tourism. If not assessed properly, this can work out to be counterproductive for the dive tourism. This is why the potential diver interest on these various reefs should be studied. Dive tourism is a wide sector and divers have a broad interest in different dive site attributes. It is unknown what the preferred reef attributes of divers are on St Eustatius and whether they differ on the different artificial reef types. And if so, how those attributes are present and distributed on the different artificial reef types.

1.2 Aim

The aims of this thesis is to determine which attributes ('*Fish diversity'; 'Fish abundance'; 'Coral diversity'; 'Coral abundance'; 'Benthic diversity'; 'Benthic abundance'; 'Natural look of the artificial reef' and 'Complex look of the artificial reefs'*) of coral reefs are most important to dive tourism, and to then assess whether the artificial reefs deployed by AROSSTA (Reef Balls, Layered Cakes or Pile of Rocks) provides those attributes. If so, research is done in which type reveals the highest similarities within the diver preferences.

1.3 Research Questions

Main question

"What artificial reef type deployed by AROSSTA is most preferred according to tourist diver's preferences for reef attributes* on St. Eustatius?"

Sub-questions:

1. Which of the reef attributes* used for this survey do divers on St Eustatius prefer?

2. How does reef design effect reef attributes and how do they compare between the reef types?

*Fish diversity; Fish abundance; Coral diversity; Coral abundance; Benthic diversity; Benthic abundance; Natural look of the artificial reef and Complex look of the artificial reefs.

1.4 Outline

The following sections will take you through the process of this Thesis, in the first section the stakeholders and their relationships will be described. After this the Materials and Methods will be discussed, this will take you through the site location of the research and it will describe the necessary materials and methods used in this study. In the third section the findings of the research will be shown, where after they will be described in the conclusion. In the section after this the results will be discussed and compared with other research. A recommendation will be made in the last section for stakeholders and eventual following studies.

2. Additional information

2.1 AROSSTA

AROSSTA, is a project started in collaboration with Van Hall Larenstein University of Applied Sciences, STENAPA, SCF, CNSI, IMARES and Golden Rock Dive Centre focusing on researching the effects of three different types of artificial reefs, placed on Saba and St. Eustatius, on their ecological performance (Hogeschool van Hall Larenstein, nd). As the working of artificial reefs highly depends on how they are deployed, designed and maintained, many artificial reefs do not reach their desired goals because of poor planning in one of these three steps (Abelson, 2006). AROSSTA has planned to conduct research in a 1,5-year period. In this period there will be looked into the functionality of three different artificial reef types, by looking into the settlement of fish and coral. After this project an insight will be given in which type of artificial reef is most suitable for each research location.

2.2 Tourism Sector

Tourism is among the largest industries on St. Eustatius and with ~10.000 visitors annually and generates 14 million USD per year, which makes the companies and organisations associated with tourism an important stakeholder (Steekstra, 2015). Most of the stakeholders, defined as dive school staff, marine park staff, government officials, local researchers and residents, in the tourism sector have stated that they see room for the growth of this tourism industry (Steekstra, 2015).
The tourism on St. Eustatius is highly dependent on the marine environment, as many of the tourist coming on the island are divers. Artificial reefs have the potential to create dive spots and rehabilitate the coral reefs for healthier marine environment (Stolk, Markwell, & Jenkins, 2007; Carr & Hixon, 2011). A healthier marine environment and more dive spots will contribute to higher and consistent tourist number, which is beneficial for tourism. Although, only the diving sector has a big stake in the project.

2.3 Diving Sector

Growth of the diving sector is envisioned, because it is one of the primary leisure sectors on St. Eustatius (Steekstra, 2015). Considering this, dive schools are considered an important stakeholder. Scuba diving at artificial reefs has demonstrated that it is able to generate a market impact that can help sustain local economies (Pendleton, 2004). Creating new dive sites and making the diving on St. Eustatius more attractive can create a whole new market for the diving business, and thus will be of great interest for the dive shops.
AROSSTA focusses on researching the ecological part of the artificial reefs, which in the future can potentially help with restoring the coral reefs around St. Eustatius. As the diving sector is highly dependent on healthy reefs, they have a large stake in the AROSSTA project. This Thesis project focuses more on how the artificial reefs can be of greater interesting for dive tourism. As this Thesis project depends on cooperation with the dive schools, both dive schools situated on St. Eustatius (Golden Rock Divers & Scubaqua) were contacted upon arrival. The dive shops were cooperative and interested in helping during this thesis.

2.4 STENAPA

St. Eustatius National Parks, abbreviated to STENAPA, is the organization behind the St. Eustatius national park, both terrestrial as marine. They actively manage the Marine Parks, which totals as 27.3km² of marine protected area. This marine protected area consists of the area from the high-water line to the 30m depth contour. The North and South parts of the Marine Park are reserves and are designated as no fishing and no anchoring zones (STENAPA, 2019). Together STENAPA and SCF, Saba Conservation Foundation, wanted to use artificial reefs to rehabilitate the declining reefs around St. Eustatius and Saba (Hogeschool van Hall Larenstein, nd).
STENAPA takes an interest in the AROSSTA project as AROSSTA is looking into which types of artificial reefs are the potential best solutions for this reef rehabilitation. This Thesis project can also be of interest to STENAPA in generating money for nature conservation by asking fees for dive spots where artificial reefs are placed. But furthermore, the increasing popularity of artificial reefs as a reef restoring method can make that more will be placed. This can eventually lead to a healthier coral reef around St. Eustatius, which is one of the goals STENAPA desires to reach (STENAPA, 2019).

2.5 Research Institutes

2.5.1 CNSI

When the islands of St Eustatius, Saba & Bonaire formed the Caribbean Netherlands in 2010, the Dutch ministry of Education, Culture and Science and the Island Government of St Eustatius cooperated to set up the CNSI (the Caribbean Netherlands Science Institute). This encourages the development of knowledge and capacity building on the island of St Eustatius (CNSI, nd). One of the principal tasks of CNSI is to support activities in research, education and outreach. This means that CNSI offers a way for researchers, students, island organisations, inhabitants of the island and visitors to conduct their activities. The centre serves as a workshop to accommodate for researchers, students and visitors (CNSI, nd).
For the AROSSTA project CNSI is of high importance, as well for this thesis project as CNSI provides materials and accommodation for the researchers and students working on both projects. Without some of these materials, like the CNSI boat, it would be impossible to do in- water surveys (CNSI, nd).

2.5.2 Van Hall Larenstein, University of Applied Sciences & Wageningen Marine Research

Van Hall Larenstein or "VHL", as a University of Applied Sciences provides their students a great number of opportunities to work on the AROSSTA project. VHL can use the AROSSTA project as a prime promotion for the course Coastal- and Marine management. Data sets derived from the AROSSTA project can be used for educational purposes, to offer students a look into the field work. As the AROSSTA project is of high interest for VHL a good cooperation is beneficial for as well AROSSTA and VHL.
Wageningen Marine Research is one the sponsors of the AROSSTA project, their stake is almost the same as VHL as they are both knowledge institutes.

2.6 Fisheries

The fishing industry on St. Eustatius is small-scale and operated by local fishermen (Steekstra, 2015). The island counts about 25 fishermen, which 3 of them can be considered as professional fishermen. Most fishermen also have onshore jobs and fish part-time. Still, the aggregated value of the sector is a high contribution in the island economy (White, Esteban, & Polino, 2006). Fishing is mostly conducted on the narrow shelf surrounding the island. In the North and the South of the island are Marine Park Reserves, which are no-take zones. Fishing methods used are mainly fish and lobster traps, hook and line and trawling. The largest fishery on the island is the fishing of lobster as these are found quite abundant around the island. Although one of the bottle necks found in these fisheries is the lack of lobster in tourist season (Dienst Landelijk Gebied, 2011). As artificial Reefs have revealed to increase the abundance and biomass of juvenile lobsters, deploying artificial reefs could be interesting for the lobster fisheries when there is a high demand for lobster and the lobster numbers are low (Briones-Fourzán & Lozano-Álvarez, 2001). For now, the artificial reefs deployed by AROSSTA are situated in the Marine Park Reserves. However, as these reefs have the potential to sustain a higher lobster population it is interesting to take them in account for further expansion around the waters of St. Eustatius.

It is necessary that there is good deliberation between fisheries & diving sector if there will be plans for eventual expansion of artificial reefs outside of the Marine Park Reserves. This to make sure there will be no misunderstanding about policy and regulations for the use of the reefs.

2.7 Interrelationships Between Stakeholders

Because the principal task of CNSI is to support activities in research, education and outreach they provide crucial goods and materials for the AROSSTA project. On site accommodation is provided for AROSSTA researchers, as CNSI has a building that can house 22 guests. Besides this, transport is one of the things CNSI can provide in several ways. As for the research it is important to reach the placed artificial reefs; a boat, with captain, is provided by the CNSI.

As the artificial reefs are placed in the Marine Reserves, STENAPA was involved in the planning for the placing of the artificial reefs. Because STENAPA was planning on rehabilitate the reef around St. Eustatius their interest in the AROSSTA project is high, as AROSSTA is looking into the best type of artificial reef that can be used for reef rehabilitation. This makes that AROSSTA can report their findings to STENAPA, what makes them able to use this data for conservation of the coral reefs.

As this Thesis research is going to investigate the diver preferences, there is a possibility to help STENAPA out with a search for the ideal artificial reef to place on the reefs in the Marine park if they want to incorporate dive tourism.

Another important stakeholder that has to do with STENAPA is the fisheries industry, as they need to follow the regulations in the Marine Park. Difficulties between both parties have often ended in the fishermen pointing their finger to the management of STENAPA. However, they are working to a better cooperation, were both parties will benefit from (Dilrosun, 2004).

Van Hall Larenstein and Wageningen Marine Research are both knowledge institutes that have a close relationship with the AROSSTA project. The data gathered by AROSSTA can be used for education on VHL, what offers students a better insight in the field work that is done in the Coastal- and Marine field. It also provides students with the opportunity to do minors, internships and thesis projects within the AROSSTA project(Hylkema, 2018).

Wageningen Marine Research, as one of the sponsors of the AROSSTA project, benefits from the knowledge derived from the research AROSSTA is doing. Besides this, the project leader of the AROSSTA project, Alwin Hylkema, is doing his PhD with Wageningen Marine Research.

2.8 Other Projects

The AROSSTA project mainly focuses on restoring the coral reefs by increasing three- dimensional structure on the reef, creating shelter and suitable substrate for corals, sea urchins and fish, another project running around the island of St. Eustatius is the RESCQ project (Hogeschool van Hall Larenstein, nd). Reef building corals, like staghorn (Acropora cervicornis) & elkhorn corals (Acropora palmata), have almost disappeared from the area, whilst these corals provide important three- dimensional structures for other marine organisms (RESCQ, nd). Because of this the RESCQ project focusses on the nursing of coral fragments on coral nurseries and transplant healthy grown colonies to selected restoration sites (DCNA, nd). As natural growth on the artificial reefs is not a fast process it might be interesting for the AROSSTA project to work together with RESCQ and use nursed corals to kickstart the artificial reefs. This has demonstrated to have the ability to make the reefs more attractive for marine organisms by the provided three-dimensional structure, what can moreover be interesting for divers (Kilfoyle, 2017).

Other research which focused on diver preference were Williams & Polunin (2000). In this research questionnaires were used to see which reef attributes were preferred by 195 dive tourists on Jamaica. After the questionnaires were done, they surveyed the reef regarding the aspect's abundance and variety of fishes, number of 'unusual' and number of 'large' fishes. Their research was focusing on reef attributes of different natural reefs around the western Caribbean whilst this Thesis Project will focus on artificial reefs (Williams & Polunin, 2000).

2.9 People, Planet & Profit

This Thesis project tries to take people in account by researching in what artificial reef is most preferred for dive tourism on the island of St. Eustatius. As tourism is one of the largest sectors on St. Eustatius the whole community can profit from growth of the tourism sector. The focus of AROSSTA is on the ecological differences and the functionality of various artificial reef types, but with this Thesis project Planet and People are connected as divers will be included in the research. If the artificial reefs are designed in a way that makes them attractive for recreational divers, hypothetically there will be a higher interest in deploying artificial reefs. Furthermore, Planet will profit from the deployment of these artificial reefs as there will be more substratum for sessile marine species to settle, what eventually will help in the rehabilitation of the degraded coral reefs around St. Eustatius.

2.10 Policy & Regulations

The artificial reefs AROSSTA uses are situated in the Northern- and Southern Marine Reserves around the island of St. Eustatius. These 2 reserves are being part of the St. Eustatius National Marine Park, which encircles the coastline around St. Eustatius to a 30-meter depth contour. This Park was established in 1996 and aims to protect 2750 hectares of diverse nature (DCNA, 2014). The Marine Park is actively managed by STENAPA, with one of their missions the protection and rehabilitation of coral reefs. Fishing and anchoring in the Marine Reserves is prohibited, what means that fishing mostly happens on the shelf area of the Marine Park. Before placing the artificial reefs AROSSTA consulted with STENAPA on the most ideal location for these reefs. Because fishing is prohibited in the Marine Reserves the artificial reefs are placed inside of these Marine Reserves. Diving is allowed in the Marine Reserves, but a fee must be paid prior to entering them (STENAPA, 2019).

3. Materials & Methods

3.1 Study Area

The data concerning the artificial reefs was collected around St Eustatius, which is a small island in the Caribbean. The collection period was within a timeframe of 3 months starting the 6th of March and ending the 27 of May. The artificial reefs are located on 2 different dive sites (Figure 4), around the island of St. Eustatius (Crooks castle and Twin sisters). The artificial reefs at Crooks Castle are located at (N: 17.47220, W: -062.98911), the reefs on Twin sisters at (N: 17.51715 W: -063.00337. The artificial reefs were placed between May and June in 2017. The reefs at Twin sisters are located on a depth of 18 meters, on Crooks Castle the reefs are at 16 meters depth.

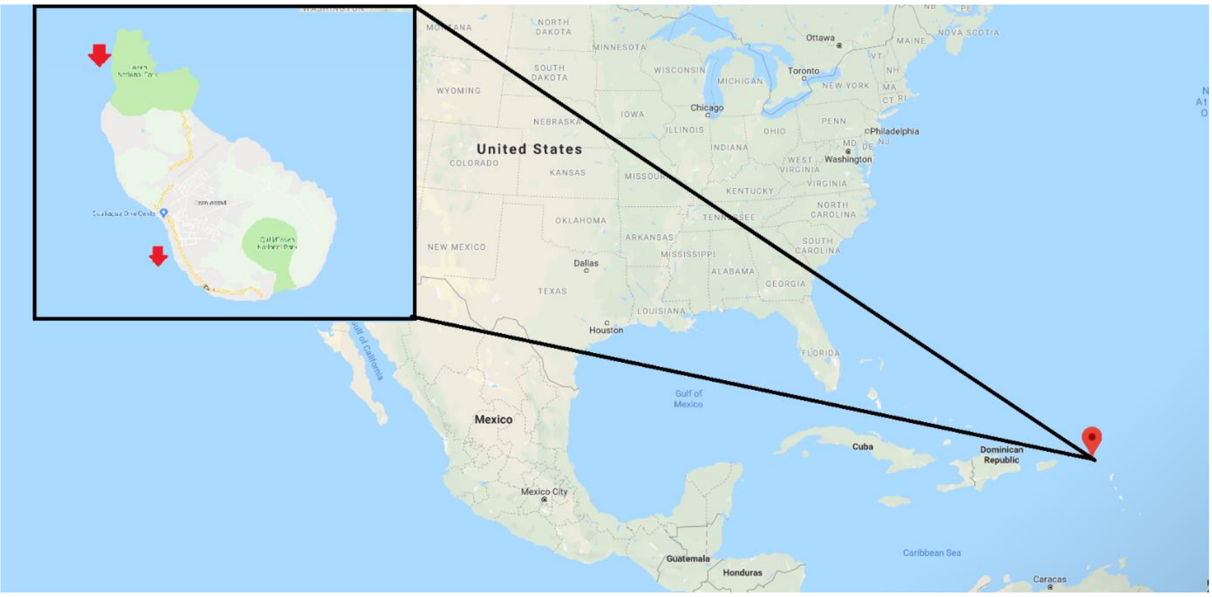


Figure 4: Location of St. Eustatius and the Artificial reefs

3.2 Data Collection

To be able to answer the main- and sub-research questions data was collected from the different reefs. The data that was collected from the reefs consisted out of;

- Fish diversity
- Fish abundance
- Coral diversity
- Coral abundance
- Benthic diversity
- Benthic abundance
- Diver preferences of the reef attributes
    - Natural look of the artificial reef
    - Complex look of the artificial reefs

3.2.1 Fish Surveys (Diversity and Abundance)

To collect the data for the fish survey 2 divers entered the water after which they wrote down their names (Observer & Filmer) and date, after which they checked for a visibility of at least 5m. After this the divers descended and reached to the bottom at least 10 meters away from the surveyed reef patches. To prevent patterns from occurring the reef patches were approached from different angels with every dive. Before approaching any of the reef patches the filming diver would film the sheet Following this, the patches were slowly approached. The filming diver stayed slightly behind the counting diver, who started to count the fleeing fish, and filmed the fleeing fish.

All the fish within a virtual cylinder (1 meter sideways of the plot and 2 meters upward from the bottom) around the experimental plot were included in the survey (Figure 5). Fish in the cylinder were identified up to species level, counted and classified in size categories; 0-5, 5-10, 10-15, 15-20, 20-25, etc. cm TL (from the tip of the snout to the tip of the longer lobe of the caudal fin).

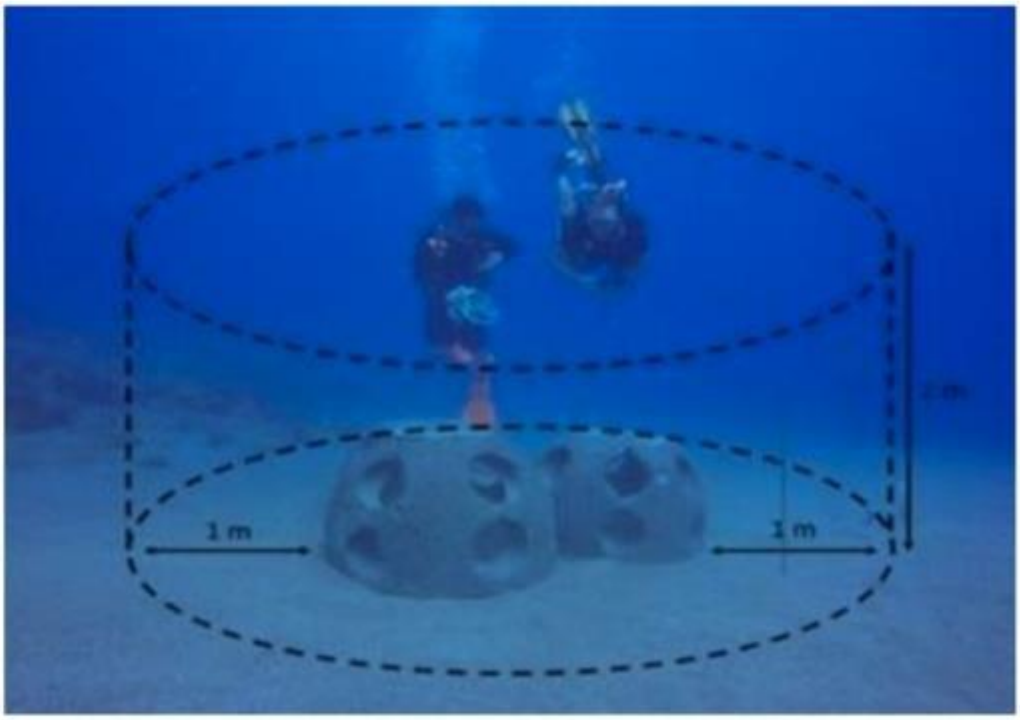


Figure 5 fish count cylinder

After 3 meters (now 2 meters away from the reef) the stationary count was started for 3 minutes and all fish in the cylinder were counted. Fish that swam in and out the cylinder multiple times were only counted once. After the 3-minute count the reef was checked thoroughly to record all hiding fish. Blennies and gobies were lump summed in 1 category, as identification tends to be difficult. Except for cleaner gobies of the genus *Elacatinus*, all fish were identified up to species level. During every dive the temperature, water current direction and water current speed were measured.

3.2.2 Benthic Surveys (Abundance and Diversity)

In order to gather benthos abundance and diversity data visual examination surveys were conducted by two divers. The survey was based on the research done by (Idjadi & Edmunds, 2008) but modified for use on artificial reefs. Instead of belt transects, as used in (Perkol-Finkel, Shashar, & Benayahu, 2006), in this Thesis research the 2 divers carefully examined the artificial reefs. The benthic macroinvertebrates that were taken in account consist out of; decapod crustaceans, molluscs, Echinoderms & Polychaetes. Torches were used in order to search for benthic organisms in between the crevices and only organisms visible without disturbing (e.g. turning rocks) were counted. Critters were determined underwater where after species and total amount were written down on a slate. Animals that were not identified under water were photographed and later identified. Due to time management and the low movability of the benthic critters there was chosen to repeat these surveys 3 times on 2 locations what did provide a total of 6 data points per reef type.

3.2.3 Coral Survey (Abundance and Diversity)

The coral abundance was measured during night dives with 2 teams of two divers. The artificial reefs were systematically searched with the use of flashing UV-lights and special goggles. The goggles gave the divers to ability to see the corals light up in the UV-light. All the hard corals were counted and written down on slates. The total count of the corals was used to determine the abundance. The corals were only surveyed once as they are sessile organisms.

For the diversity of corals intentionally Coral Point Count with Excel extension (CPCe), as described in Tabug, Manzanares, & Malawani (2016), would be used to determine different species. However, as the corals were still small none were found on the CPCe. Due to the fact that there was no more time to collect new data, there was chosen to leave the coral diversity data out of the MCA by scoring it as 0.

3.2.4 Diver Preference Survey

To be able to tell which reef attributes are most preferred by dive tourists on St Eustatius a questionnaire was used (Appendix 2). A total of 107 surveys were done, most of the surveys took place in the late afternoon when divers gathered at the dive shops after a day of diving. The surveys were done in between the beginning of March until the end of May 2019. The questionnaires were distributed to divers by the authors of this Thesis to provide information and make participants more involved. The principal question was: *'What are the attributes of a reef which you most prefer to see on a dive?'*. Respondents were shortly asked about some demographic information which after they were asked to rank each of 8 attributes: 'Fish Abundance; 'Fish diversity'; 'Coral abundance'; 'Coral diversity'; 'Benthic Critter abundance'; 'Benthic Critter Diversity'; 'Complex look' and 'Natural look' The divers were asked to rank 8 attributes from 1 to 8 (8 being the highest and 1 the lowest) all the scores could be used once to force a ranking. From all the responses an average was made for every attribute to be used as a "weight" for the final MCA. Therefore. For example, if five people gave Fish abundance an 8 and three gave it a 6 then the score would be: (5x8 + 3x6) / 8 = 7,25 which was the final score and thus the "weight" for the attribute Fish Abundance.

3.2.5 Complex -and Natural Look

To determine the "Complex look" and the "Natural look" of the reef, pictures of the reefs were shown on the backside of the questionnaires (Appendix 2) and the participants were asked to rate the natural look and the complex look of the different reef types on a Likert scale from 1 being not natural / complex looking at all to 5 very complex looking. An ANOVA test with Post-Hoc Tukey test was used to research the significance of the different answers.

3.3 Analysis

3.3.1 Diversity Attributes

All the attributes that demonstrate the diversity of species on the artificial reefs, Coral diversity, Benthic Diversity and Fish Diversity, are expressed using the Shannon-wiener index ($H=\sum[(pi)x\ In(pi))$ where pi is the proportion of individuals found in species i. For a well-sampled community, an estimation can be made for this this proportion as pi = ni/N, where ni is the number of individuals in species i and N is the total number of individuals in the community. Since the pi's will all be between zero and one, the natural log makes all of the terms of the summation negative, which is why the inverse of the sum was taken. Of the different types of artificial reefs, the Shannon Weiner Indexes were compared.

3.3.2 Fish Abundance

Firstly , For the fish abundance the normality of distribution was tested. For all the tests in this thesis an "Alpha" of 0.05 was used. The Shapiro-Wilkinson test reveals no significance for the Reef Balls (P=.736) and Layered Cakes (P= .114), which means the null hypothesis is not rejected and the data is normally distributed. What was found was that the Pile of Rocks was not normally distributed (Shapiro-Wilk- P=.005). The test of Homogeneity of Variances revealed that the data was not homogeneous (P=.046), therefore a Kruskal-Wallis test was done followed by a Post-Hoc Games-Howell test to check for significant differences between groups.

3.3.3 Benthic Abundance

This attribute was first tested on normal distribution, the Shapiro-Wilk test revealed a significance (P=.013) for the Reef Balls which meant that they are not normally distributed. The other two reefs however are normally distributed (Layered Cakes (P=.743) and Pile of Rocks (P=.299). After that they are tested for homogeneity and revealed to be homogenous (P=.241). Therefore, a Kruskal-Wallis test was done followed by a Post-Hoc Tukey test to check for significant differences between groups.

3.3.4 Coral Abundance

Coral abundance was measured as a count (total number of corals) since these are sessile organisms and because of that there can be assumed that their numbers do not change rapidly.

3.3.5 Diver Preference Survey

The diver preference surveys were tested on homogeneity using Levine's test, which revealed a significant result (P=0.003), which means the null hypothesis was rejected and the data set was not homogenous. Then they were tested on normal distribution which none of them are (P=.000 for all). Normally a Kruskal-Wallis test would be appropriate however, due to our large sample size of 107 participants it is allowed to do a one-way. ANOVA which was performed followed by a Post-Hoc equal variances not assumed Games-Howell test to find the differences within the sample.

3.3.6 Complex- and Natural Look

All the 107 participants were asked to rate the "natural" and "complex" appearance of the 3 reef types. The average answers from the survey answers where first tested on a normal distribution and homogeneity. They were both not found normally distributed (P=.000 for all) and not homogenous. (P=>0.05 for all). They were tested using a Kruskal-Wallis test followed by a Post-Hoc Games-Howell test to see the individual differences.

3.3.7 Multi Criteria Analysis (MCA)

A multicriteria analysis (MCA) is a tool that provides the option to compare the three different reef types, while taking the diver preferences in account. It is a tool that compares multiple options using a weight for certain criteria for the options (*Table 1 MCA step one*)

	Weight	Reef Ball	Layered Cake	Pile of Rocks
Reef Attribute 1				
Reef Attribute 2				
Etc…..				

Table 1 MCA step one

The scores that the reefs received for every attribute depends on the relative representation of that attribute on the different reefs. For every attribute (depending on if they were significantly different) the three different reef types received a score between 1 and 3 to bring a form of standardization. For example:
The fish abundance on the Reef Balls was found significantly higher than on the Layered Cakes and the Layered Cakes were significantly higher than the Pile of Rock the reefs were scored as following:

- Reef Balls 3
- Layered Cakes 2
- Pile of Rocks 1

If the Reef Balls scored significantly higher than the other two reefs, and those two reefs were not significantly different the scoring was as following:

- Reef Balls 3
- Layered Cakes 1,5
- Pile of Rocks 1,5

If the Reef Balls scored higher but not significantly higher than the Layered Cakes, and the Pile of Rocks were significantly lower than the other two reefs the scoring was as following:

- Reef Balls 2,5
- Layered Cakes 2,5
- Pile of Rocks 1

If there was no significant difference between the highest middle and lowest scoring reefs all reefs receive an equal 2 points.

If the highest abundance and the second highest were not found significantly different, and the second highest and the lowest were moreover not significantly different the reefs were scored the same as if they were all significantly different from each other *(Table 2 MCA + Criteria scores)*.

	Weight	Reef Ball	Layered Cake	Pile of Rocks
Reef Attribute 1		2	1	3
Reef Attribute 2		1	2,5	2,5
Etc…..		Etc.	Etc.	Etc.

Table 2 MCA + Criteria scores

The “Weight” of the Criteria was determined by the outcome of the diver preference survey where the average rank of each attribute was taken and multiplied by 2 to make the now “Adjusted Weight” more relevant since the aim of this research was to find out what divers want to see. *(Table 3 MCA with calculated weights)*

	Weight	Reef Ball	Layered Cake	Pile of Rocks
Reef Attribute 1	5,2 (x2) = 10,4	2	1	3
Reef Attribute 2	4 (x2) = 8	1	2,5	2,5
Etc…..		Etc.	Etc.	Etc.

Table 3 MCA with calculated weights

The score for every attribute on the reef types was then multiplied by the “Adjusted Weight” of that criteria. *(Table 4 MCA – Final scoring)*

	Weight	Reef Ball	Layered Cake	Pile of Rocks
Reef Attribute 1	10,4 (x)	2 (20,8)	1 (10,4)	3 (31,2)
Reef Attribute 2	8 (x)	1 (8)	2,5 (20)	2,5 (20)
Etc…..		Etc.	Etc.	Etc.

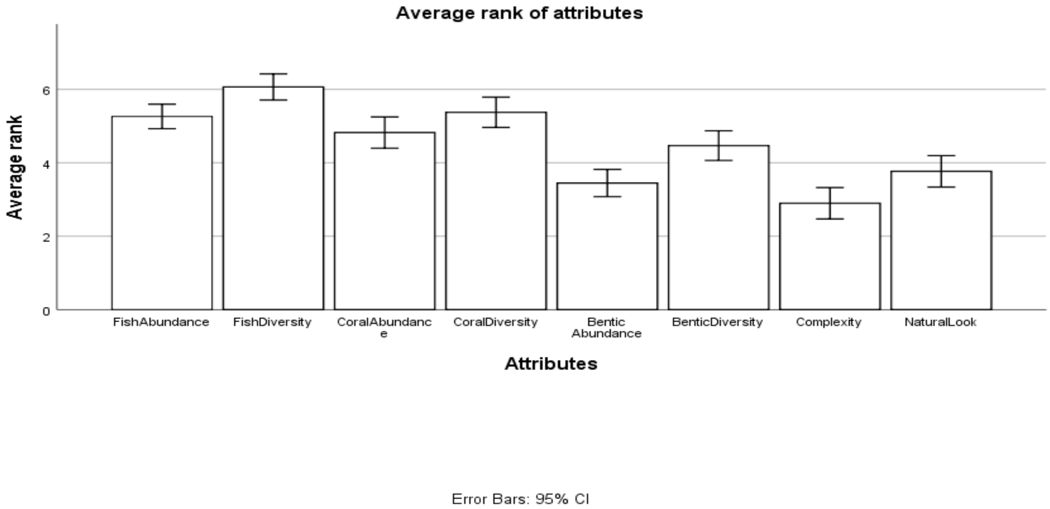
Table 4 MCA - Final scoring

The Final step was to add up all the scores from the different attributes on one reef type and the reef with the highest end score has the highest amount of the preferred attributes.

4. Results

4.1 Diver Preference Survey

A total of 107 divers participated in the survey and the received rankings for the different attributes were used to make an average score for each attribute (graph 1). The attribute that was found most important was Fish diversity, where 32,7% of the participants scored this as their most important attribute. It ended up with an average of 6,07 and was significantly higher than the other attributes except for Fish abundance and Coral Diversity (for all P values check table 5). The second highest attribute is coral diversity which ranked 5,37 on average, this is almost a shared second place with fish abundance which had an average rank of 5,26; Benthic diversity comes next with 4,47 as average rank; Natural look is ranked 5th with an average rank of 3,77; Coral abundance is after that with 3,45; Benthic abundance is ranked 7th with 3,35 and the least important attribute is the complex look of the reef with 2,87 as average rank. A more detailed description of the Divers rankings of the attributes is added in appendix 1.



Graph 1 Average rank of all Attributes

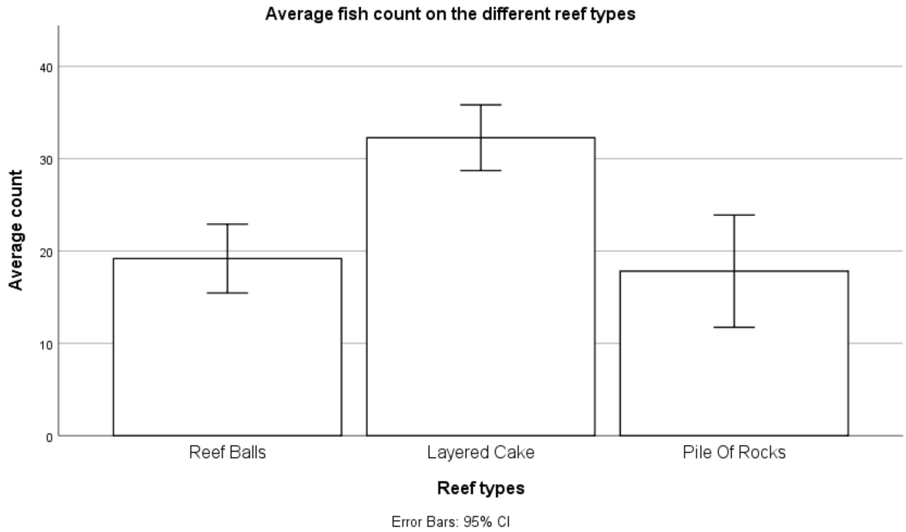
Many attributes were not found significant different from all the other attributes. The Games-Howell output in SPSS showed the significant differences for each attribute compared to all other attributes. In the table below (Table 5) is illustrated which attribute was found significantly different from another. Red indicates a not significant difference with the linked attribute green means they were found significantly different.

	Average score	Fish Diversity	Fish Abundance	Coral Diversity	Coral Abundance	Benthic Diversity	Benthic Abundance	Natural Look	Complexity
Fish Diversity	6,07	X	.086	.221	.000	.000	.000	.000	.000
Fish Abundance	5,26	.086	X	1.000	.778	.094	.000	.000	.000
Coral Diversity	5,37	.221	1.000	X	.516	0.030	.000	.000	.000
Coral Abundance	3,45	.000	.778	.516	X	.914	.000	.005	.000
Benthic Diversity	4,47	.000	.094	0.030	.914	X	.008	.206	.000
Benthic Abundance	3,35	.000	.000	.000	.000	.008	X	.952	.516
Natural Look	3,77	.000	.000	.000	.005	.206	.952	X	.045
Complex look	2,87	.000	.000	.000	.000	.000	.516	.045	X

Table 5 Significant difference between attributes averages based on the diver survey

4.2 Fish Abundance

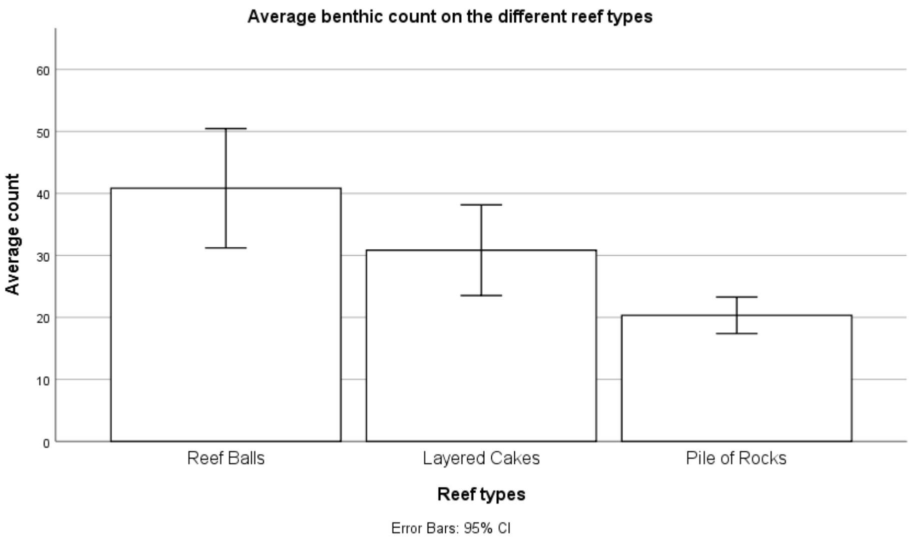
For the Fish abundance survey, there was looked at the count per survey for every reef type. The Layered Cakes revealed a significant difference ($X^2(2)$= 21,786, P=.000) from both other reefs types (P=.000) . The Reef Balls and the Pile of Rocks did not show a significant difference between one and other(P=.917) (graph 2).



Graph 2 Fish abundance on different reefs

4.3 Benthic Critter Abundance

For the benthic abundance there was looked at the count of benthic critters per survey. The Reef Balls had a mean of 40,83, the Layered Cakes a mean of 30,83 and the Pile of Rocks a mean of 20,33. The Reef Balls and Pile of Rock showed a significant difference (P=<0.05). The Layered Cakes were not found significantly different compared to any of the other reef types ($X^2(2)$=11,392, P=.003).



Graph 3 benthic critter abundance

4.4 Coral Abundance

A total of 215 individual coral colonies were found on the coral night dive. Of these colonies 142 were found on the Layered Cakes, 47 on the Reef Balls and 26 on the Pile of Rocks.

4.5 Benthic Critter Diversity

A total of 35 species of benthic critters were found on the artificial reefs, 25 on the Layered Cakes, 17 on the Reef Balls and 15 on the Rock reef. The Shannon Weiner Diversity index for Benthic critters ranged from (H')=1.88 on the Reef Balls, (H')=2.31 on the Rock Reef up to (H')=2.67 on the Layered Cakes.

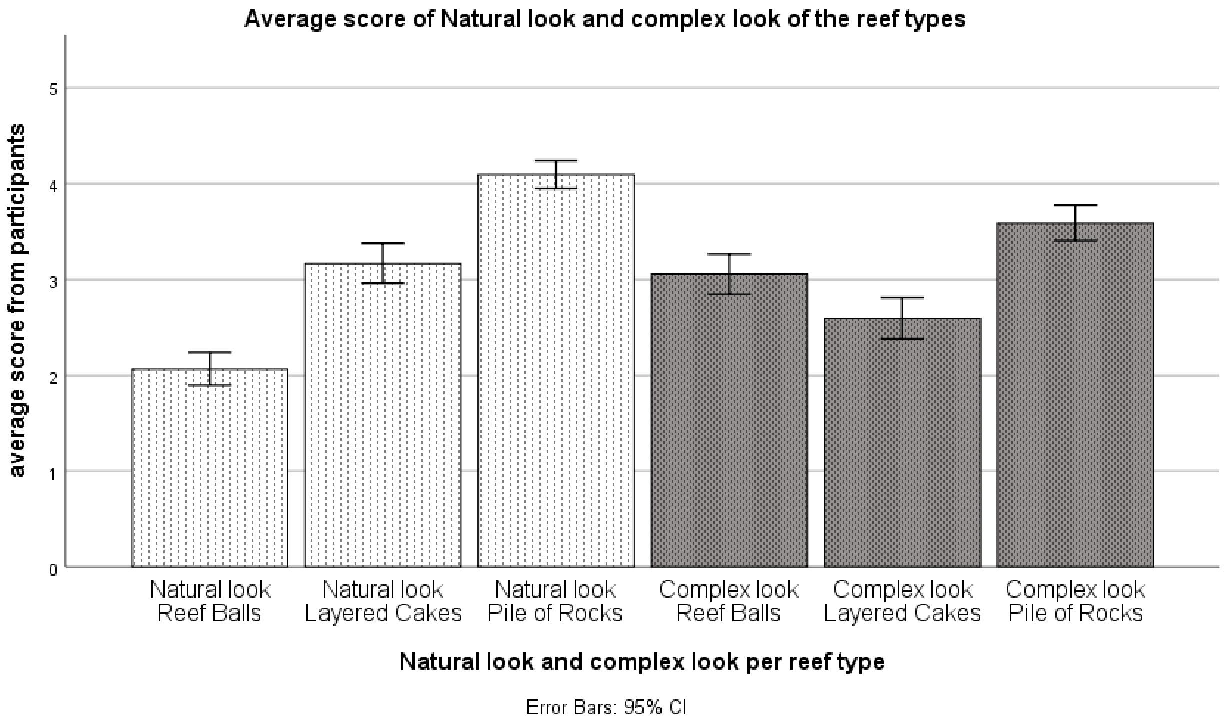
4.6 Fish Diversity

A total of 45 fish species were found on the artificial reefs, 34 on the Layered Cakes, 30 on the Reef Balls and 25 on the Rock Reef. The Shannon Weiner Diversity Index for fish ranged between from (H')=2.07 on the Pile of Rock, (H')= 2,5 on the Layered Cakes up to (H')=2.54 on the Reef Balls.

4.7 Complex- and Natural Look

All the 107 surveys were asked to rate the "natural" appearance of the 3 reef types. The Reef Balls got an average score of 2,07 out of the possible 5, the Layered Cakes ended up with 3,17 on average and the Pile of Rocks got an average score of 4,09. All these differences were found significant (P=<0.05) using a Kruskal-Wallis test with Games-Howell to see the differences between the different reefs.

The participants were also asked to rate the look of the Complexity of the reef types on the same scale as the Natural look 1 to 5, with 5 being very Complex looking and 1 being not complex looking. The average scores the reefs received for this attribute are: Reef Balls 3,06, Layered Cakes 2,59 and the Pile of Rocks scored 3,59. Which were all found significantly different from each other (P=<0.05).



Graph 4 Natural and complex looks of the different reef types

4.8 Multi Criteria Analysis (MCA)

All the gathered data was finally sorted in the MCA where the average score of the attribute, received from the diver preference survey, was used as “weight”. All Attributes were compared and a relevant score (ranging from 1-3) was given to every reef type (as explained in the Material and methods section of this thesis).

Attributes	Weight	Reef Balls	Layered Cake	Pile of Rocks
Fish Diversity	6,07	3	2	1
Fish Abundance	5,26	1,5	3	1,5
Coral Diversity	5,37	0	0	0
Coral Abundance	3,45	2	3	1
Benthic Diversity	4,47	1	3	2
Benthic Abundance	3,35	2,5	2,5	1
Natural Look	3,77	1	2	3
Complex look	2,87	2	1	3
TOTAL				

Table 6 MCA raw data

The “weight’ was then multiplied by 2 to make the “weight” differ more between each other and more relevant to the attributes. After that the score of every reef type per attribute was multiplied by the now “Adjusted Weight” to give a final score per reef type.

Attributes	Weight	Reef Balls	Layered Cake	Pile of Rocks
Fish Diversity	12,14	36,42	24,28	12,14
Fish Abundance	10,52	15,78	31,56	15,78
Coral Diversity	10,74	0	0	0
Coral Abundance	6,9	13,8	20,7	6,9
Benthic Diversity	8,94	8,94	26,82	17,88
Benthic Abundance	6,7	16,75	16,75	6,7
Natural Look	7,54	7,54	15,08	22,62
Complex look	5,74	15,08	5,74	17,22
TOTAL		114,31	140,93	99,41

Table 7 Calculated MCA with end values

5. Discussion

5.1. Diver Preference Surveys

This research showed that the attributes 'Fish Diversity, 'Fish Abundance' and 'Coral Diversity' are most preferred by divers. This confirms high importance of fish and coral condition as attributes known to affect diving experience (Uyarra, Watkinson, & Côte, 2009; Uyarra, et al., 2005). Other research has found that the similar reef attributes 'Variety of fishes', 'Fish Abundance' and 'Variety of corals' were found most important to divers around Jamaica (Williams & Polunin, 2000).

Coral abundance is known to be important for marine ecotourism (Shafer & Inglis, 2000). The divers in this research did not especially prefer the reef attribute 'Coral Abundance' over other attributes, and thus this does not support the statement made earlier in Shafer & Inglis (2000). This might be due to the fact that the hard corals around St. Eustatius are on a critical low (de Graaf, *et al*., 2015), what might influence the diver's choice to prefer the other attributes over the attribute 'Coral Abundance'. Other research has revealed that biotic factors are preferred over abiotic factors (Shafer & Inglis, 2000). This research demonstrated a similar pattern, as the reef attribute 'Complex look' is rated as the lowest preferred reef attribute.

The use of a survey where participants are forced to make a ranking is useful to find the order of preference of attributes. However, a ranking scale cannot tell if something is important or unimportant to respondents. It addresses the attributes in relation to each other rather than individually as respondents cannot give the same rating to two items, even if they are of equal importance to them. On top of that, there is no way to measure how much distance there is between levels of importance of each attribute for the divers. Which might have been interesting for this thesis because its directly related to the weight of the criteria in the MCA.

Further, ranking 8 attributes is a difficult thing to do since the participant needs to weigh every attribute against 7 others every time they want to rank a new attribute which can be difficult (Finch, 2017). Noticed was that many participants struggled to give a ranking where they were satisfied with in one go. many of them changed ranks between attributes many times because they had no clear "most important attribute". An option to solve this is to choose for a rating scale over a rank scale. However, ranking and rating scales are both options with pros and cons, the type is based on what the goal is of a survey and how the participants participate. Rating questions have as pros that they are easy understood by participants and they allow respondents to assign items the same number. The downside is that rating scales usually have a narrow distribution of ratings, which typically fall into an upper band (Verit.connect, 2013). On top of that even when there would be a differentiation among items this difference is likely to be low. Furthermore, there is the chance that respondents will not use the highest or lowest possible ranking which creates a shift in the scale of the results (Verit.connect, 2013). The last two reasons are why there was chosen for a rank style survey and not a rating. It would however be interesting to do this in a follow up study to see if there will be a difference in interest or distance in scores of the attributes.

Another possible bias is the "order effect" which means that the relative position of an item in the inventory of for example a list of reef attributes may uniquely influence the way in which a respondent reacts to the attribute. Previous research suggests that early items in an inventory may tend to act as an "anchor" up on which subsequent responses are made (Perreault, 1976). In this thesis the most desirable attributes were listed as first in the questionnaire. Mixing the order of attributes on different surveys might have been a useful option to avoid this bias in similar projects in the future.
What Williams & Polunin (2000) stated in their paper is that diver surveys in other places or at other times can reveal different preferences compared to the ones this study revealed. This is because the divers can be biased by the dives they have already done on the island, which can alter their preferences (Williams & Polunin, 2000).

5.2 Fish

There are many factors that can influence the success of fish on artificial reefs. Not only the design, but other also factors, like placement, can influence it (Ambrose & Swarbrick, 1989). The results of the fish survey revealed a higher fish abundance on the Layered Cakes, this might be because these reefs are slightly higher than the two other reefs and structures that are higher have demonstrated to attract more fish (Rilov & Benyahu, 2000; Gratwicke & Speight, 2005).

Research has revealed that substrate is one of the main factors that influence fish species diversity, especially a higher rugosity of the substratum positively influences fish diversity (Koeck, et al., 2014; Gratwicke & Speight, 2005). Highest fish diversity was found on the Reef Balls, whilst these are, although not measured, seen as least rugose (personal observations, 2019).

5.3 Coral

The coral abundance was found to be lowest on the Pile of Rocks, this might be due to the fact that these rocks were more covered in sand than the other 2 reefs. As recruited corals are prone to sedimentation, it is known to reduce the settlement rates of these recruited corals (Babcock & Smith, 2000).

One of the factors that could have impacted the number of coral recruits counted on the Reef Balls is the fact that 1 of the Reef Balls was only placed in 2018 and thus has not been exposed to recruiting corals for the same time as the other reefs.

The highest number of coral recruits was found on the Layered Cakes, this could be due the fact that the Layered Cakes are higher than the Reef Balls and Pile of Rocks, and thus, have more vertical surface. This vertical surface is known to enhance a better coral recruitment than horizontal surfaces, as these horizontal surfaces are more like to have a higher sedimentation (Babcock & Mundy, 1996).

As described in Materials & Methods initially there was chosen to use CPCe for the collection of coral abundance and diversity data. However, the coral colonies that settled on the artificial reefs were too small to be found in the CPCe. This might be because these artificial reefs were only placed 2,5 years ago and the process of settlement and growth is too slow to get sizable enough coral colonies that can be recognized by CPCe analysis. This problem could have been avoided if there was chosen for another method in the earlier phases of this Thesis research.

5.4 Benthic

The benthic (H')-values of the artificial reefs revealed a similar diversity compared to other research done in the Caribbean (Diaz-Castenada & Almeada-Jauregui, 1999). Where the (H')-values in this Thesis research had a range of (H')= 1.88 to (H')= 2.67 the values in the research done by Diaz-Castenada & Almeada-Jauregui (1999) revealed that the values only 23% of the plates used demonstrated values lower than (H')= 2.5, the rest of the values varied between (H')= 2.51 and (H')= 3.72.

To gather the data for the benthic surveys only three survey days were planned, this because many of the benthic critters in this thesis like small shrimps, tube- and fan-worms and bivalves are home bound. After the first survey a strong current influenced the last two data collecting dives as many of the benthic critters were hiding or retracted in their shelter. A fairly lower number of sessile organisms, like fan worms, was found on these last two dives. Ideally more data could have been collected to make a stronger analysis to assess the benthic critters on the reefs.

5.5 Complex- and Natural Look

To determine the values of the reef attributes 'Natural look' and 'Complex look' the divers were asked to give their opinion about the various artificial reefs. There should be noted that this is not a scientifically measured value. It is circumstantial since it is an opinion of a tourist diver. And because of that it can differ highly at specific locations and times asked (Williams & Polunin, 2000).

5.6 Multi Criteria Analysis (MCA)

Using the MCA all attributes on the reef types are taken in account, therefore, even though the most preferred attribute ‘Fish Diversity’ scores the highest on the Reef Balls and the “weight” given to the attribute is boosting that score it gets evened out by the “ecological success” of the Layered Cake. The Layered Cake simply out competes the other reefs in most of the other attributes. The Scores between 1 and 3 are given to the reefs as a standardization and create a common scale to be able to compare the different survey methods, and the different numbers that come with those surveys, with each other. These numbers might as well be in between 0 and 1 or something completely different. There are many ways to assign weights and criteria scores in an MCA. The choices of a common scale may have substantial impact on the results (different choices may lead to different rankings of the attributes). In this thesis there was chosen to use this method because there was dealt with surveys that gave numbers that differ greatly from each other between the survey methods. For example, the Shannon-wiener index is expressed in a number between 0 and usually +/- 4,5 where the benthic count is expressed anywhere between 20 to 40.

6. Conclusion

Sub question 1: "Which of the reef attributes* used for this survey do divers on St Eustatius prefer?"

The results of the diver preference survey reveal a high interest of divers in Fish and coral, with the attributes 'Fish Diversity'; 'Coral Diversity'; 'Fish Abundance' and 'Coral Abundance' scoring higher than the other reef attributes 'Benthic Critter Diversity', 'Benthic Critter Abundance', 'Complex look' and 'Natural Look'. Of the 107 divers asked, 37 agree that the attribute 'Fish Diversity' is most important when diving, only 2 divers rated it as least important.

Sub question 2: "How does reef design effect reef attributes and how do they compare between the reef types?"

The results demonstrate that the Reef Balls score highest on the attribute 'Fish Diversity' and share the highest score on 'Benthic Abundance' together with the Layered Cakes, as no significant difference was found between these reefs regarding to benthic critter abundance. A second score was obtained by the Reef Balls for the attributes 'Complex look' and 'Coral Abundance'. Further they have a shared second score on 'Fish Abundance' as there was no significant difference found regarding the score of this attribute between the Reef Balls and Pile of Rocks. The reef attributes 'Natural Look' and 'Benthic Diversity' scored significantly lowest on the Reef Balls compared to the Layered Cakes and Pile of Rocks, what means they are least represented on the Reef Balls.

Furthermore, the results demonstrate that on the reef attributes 'Fish Abundance', 'Benthic Diversity' and 'Coral Abundance' the Layered Cakes scored significantly highest compared to the two other reefs. As stated earlier the Layered Cakes share a highest score on the attribute 'Benthic Abundance' together with the Reef Balls as there is no significant difference found between the number of benthic critters found on the reef. The Layered Cakes scored a second place regarding the reef attributes 'Fish diversity' and 'Natural Look'. For 'Complex look' the Layered Cakes scored lowest. As the 'Complex look' on the other two reefs scored significantly higher.

The reef attributes 'Natural Look' and 'Complex look' were highest present on the Pile of Rocks. The Pile of Rocks scored a significant second score on the 'Benthic Diversity'. As stated earlier, the Pile of Rocks share a second place on the attribute 'Fish Abundance' as no significant difference was found between the scores on both reefs. The attributes 'Benthic Abundance', 'Coral Abundance' and 'Fish Diversity' scored significant lowest on the Pile of Rocks compared to the other two reefs.

Main question: "What artificial reef type deployed by AROSSTA is most preferred according to tourist diver's preferences for reef attributes* on St. Eustatius?"

The Layered Cakes scored high on the attributes 'Benthic Diversity', 'Fish Diversity', 'Fish Abundance' and 'Coral Abundance'. As these attributes revealed to be highly chosen by divers they were weighted high in the MCA. The MCA illustrated that the Layered Cakes scored overall highest considering tourist diver preferences.

The Reef Balls scored highest on the reef attribute 'Fish Diversity', what was ranked as most important by divers. But because the Reef Balls did not score as high on the other attributes, except for a shared high score with Layered Cakes on the attribute 'Benthic Abundance', they ended up with a second highest score as best overall artificial reef in the MCA.

As the Pile of Rocks only scored highest on the attributes 'Complex look' and 'Natural Look', which were not weighted high important by the preferences of divers, it has not revealed to be the overall best artificial reef type and obtained a third place as overall best artificial reef type in the MCA.

7. Recommendations

This research showed that the Layered Cakes has a great number of attributes that divers prefer to see on St. Eustatius. Many attributes are more present on the Layered Cakes than on the other two artificial reef types used for this thesis. Since the Layered Cakes got the highest ranking on many different ecological attributes it is recommended to look more into the ecological effects of the different reef types. This might demonstrate that they are not only useful for dive tourism but also might have a high potential for ecological purposes. If they can be used to restore degraded dive sites, they might be of economic value for the island of St. Eustatius as they are able to create a revenue for many stake holders as mentioned earlier in this thesis. If artificial reefs would be used for repairing dive sites multiple different types of artificial reefs combined would give the best representation since they all provide different amounts of different attributes. It would be beneficial to first look into the effects of combining multiple reef types before concluding that one reef type is better than the other two.

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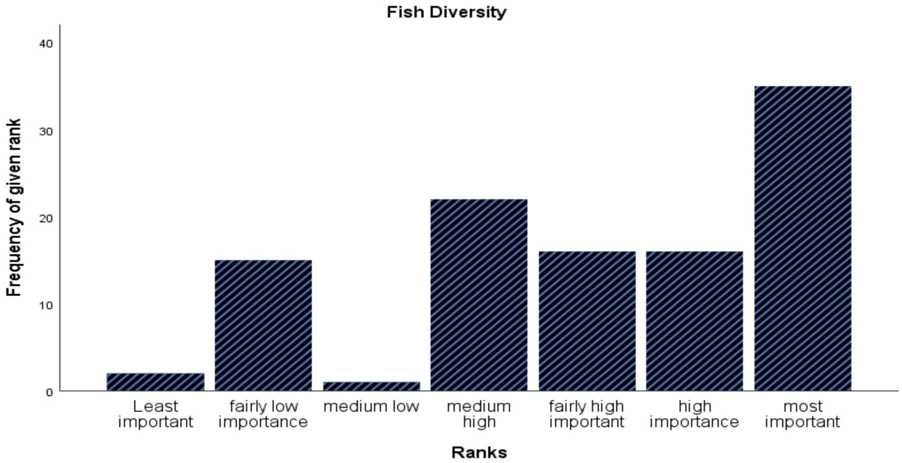
Appendix I: Detailed breakdown of diver preference survey.

Fish Diversity

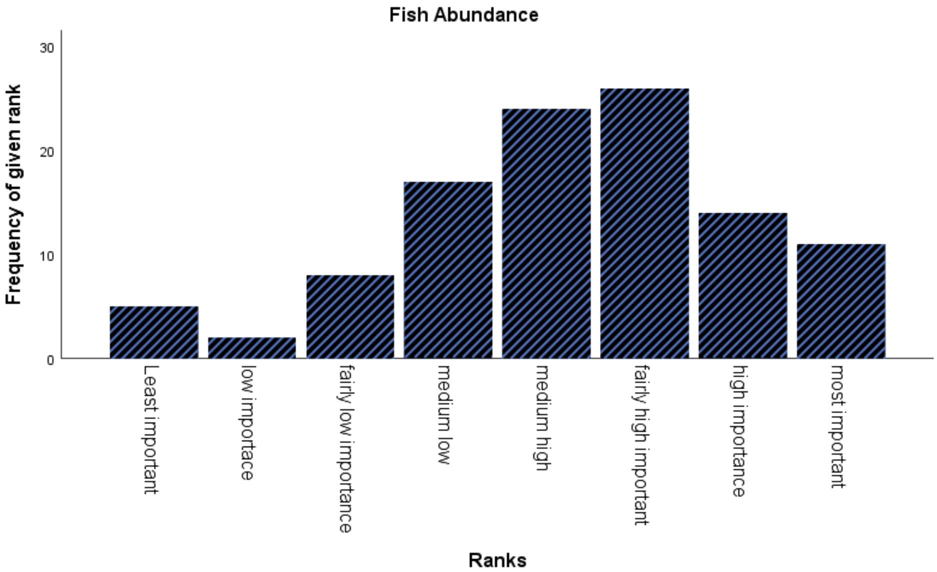
Fish diversity was found the most important attribute for divers on St. Eustatius with an average score of 6,07 it was significantly higher than 6 out of the 7 other attributes. Out of the 107 responses 37 ranked Fish diversity as Most important (8/8), 22 ranked it as medium high (5/8) 32 responses were equally divided over fairly high important (16) (6/8) and high important (16) (7/8). Only 2 respondents rated fish diversity as Least important (1/8) and 15 people rated it 3 out of the possible 8 points (graph 5).



graph 5: Diver ratings for Fish Diversity

Fish abundance

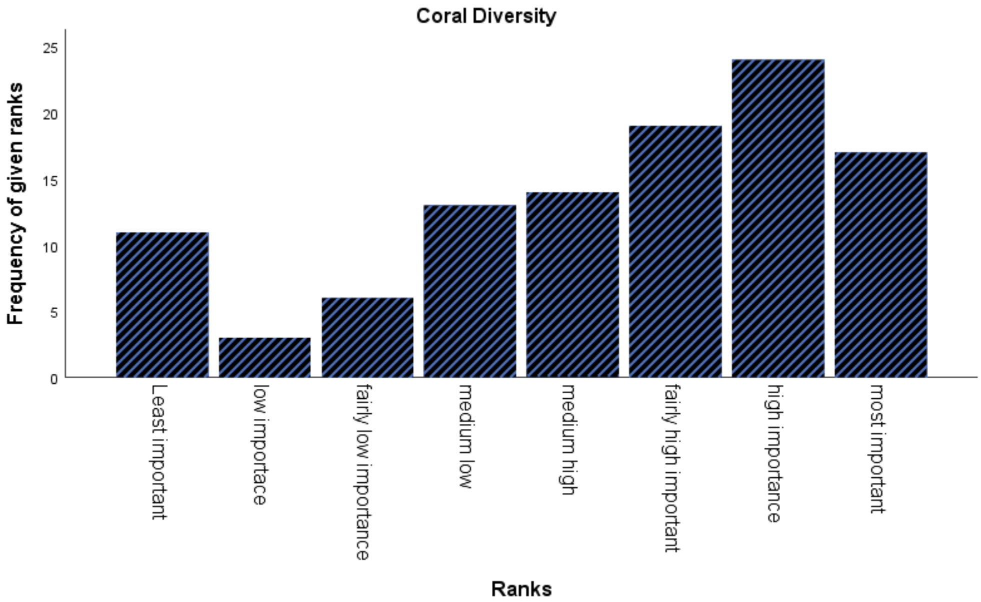
Fish abundance is technically the third attribute scoring 5,26 in the divers ranking. However, it revealed no significant difference with Coral diversity which scored 5,35. Most of the participants (26) ranked Fish abundance as Fairly high important (6/8). 24 respondents ranked Fish abundance as medium high (5/8), 17 as medium low (4/8), then 14 as high importance (7/8) and 11 as most important (8/8). 5 participants rated it as least important (1/8), 2 as Low importance (2/8) and 8 as fairly low (3/8) (graph 6).



graph 6: Diver ratings for Fish Abundance

Coral Diversity

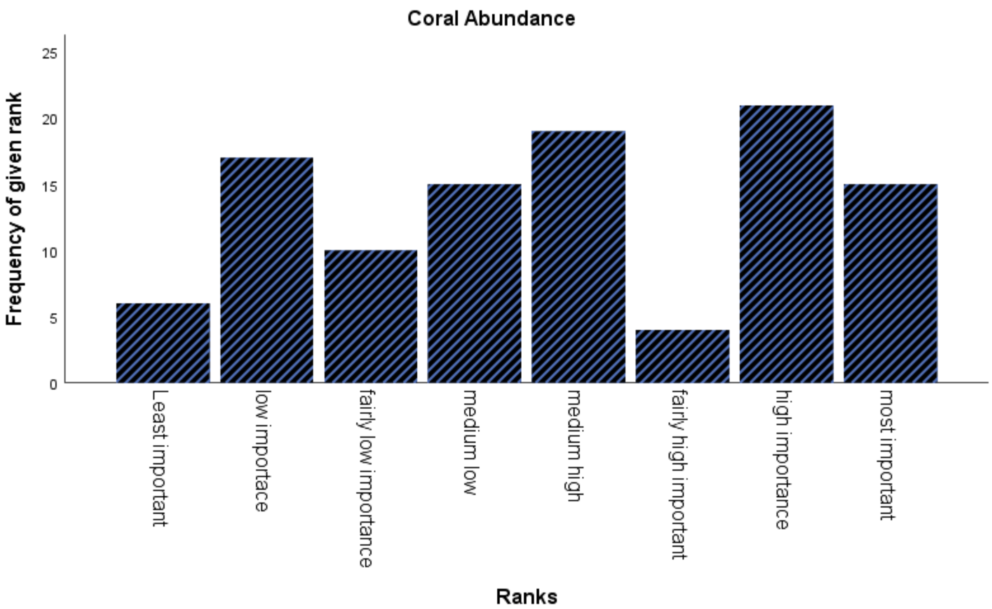
The coral diversity is the second highest ranked attribute although it is not significantly different from Fish abundance. It averaged out on 5,35. Most people (24) put this attribute as high importance (7/8), 19 participants ranked it as Fairly high important (6/8) and 17 as most important. Medium high (5/8) was the ranking 14 times Medium low (4/8) 13 times and least important 11 times. Low importance (3/8) 3 times and fairly low importance (2/8) 6 times (graph 7).



graph 7: Diver ratings for Coral Diversity

Coral Abundance

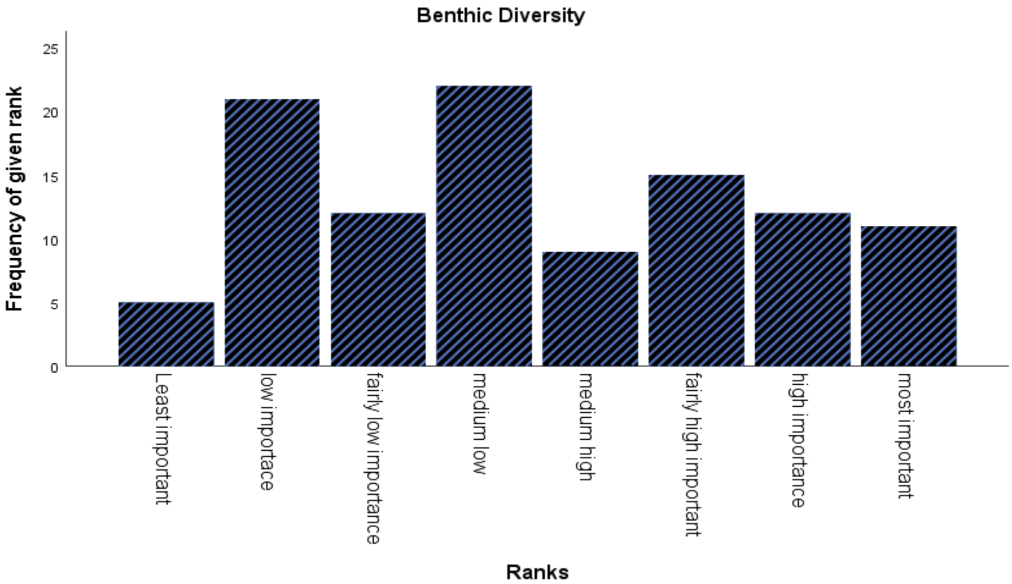
The ranks within coral abundance are more distributed and averaged out on 3,45 and comes on the fifth spot of importance. Coral abundance was not significantly different from Fish abundance, Coral diversity and Benthic diversity. Most of the participants (21) scored Coral abundance as high importance (7/8), 19 respondents scored Coral Abundance as medium high (5/8), 17 ranked it as low importance (2/8) . 15 people as medium low (4/8) and 15 as most important (8/8). Four gave it high importance (7/8) and 6 as least important (1/8) (graph 8).



graph 8: Diver ratings for Coral Abundance

BENTHIC CRITTER DIVERSITY

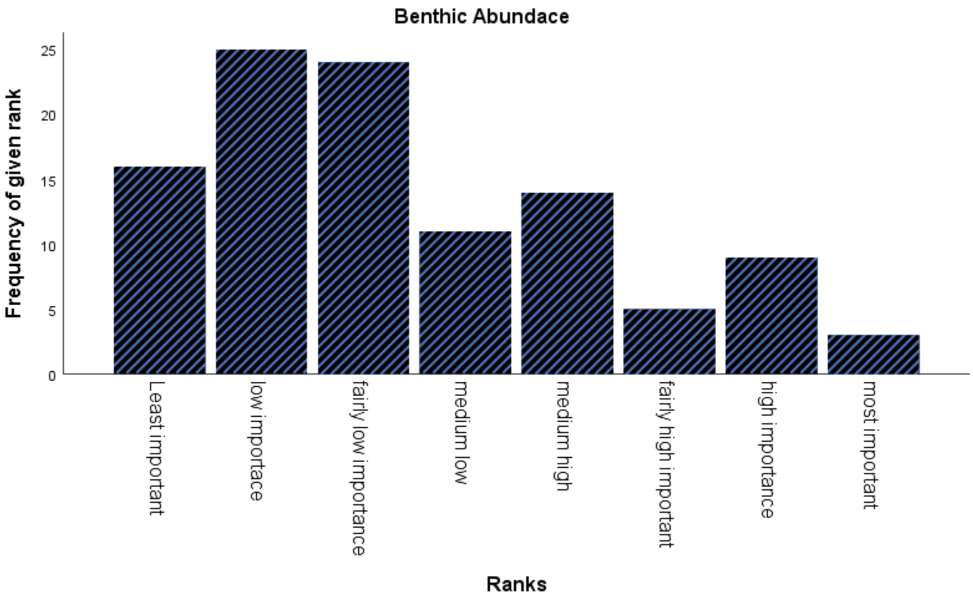
The benthic critter diversity is rated as fourth most important attribute for dive tourism with an average score of 4,47. It was fond to be not significantly different from: Fish abundance, Coral abundance, Coral diversity and natural look. 22 participants ranked this attribute as medium low (4/8) and 21 as low importance (2/8). Then 15 ranked it fairly high (6/8), 12 as high importance (7/8) and another 12 as fairly low importance (3/8). 11 ranked it highest as most important (8/8), 9 as medium high important (5/8) and only 5 ranked it as least important (1/8) (graph 9).



graph 9: Diver ratings for Benthic Diversity

BENTHIC CRITTER ABUNDANCE

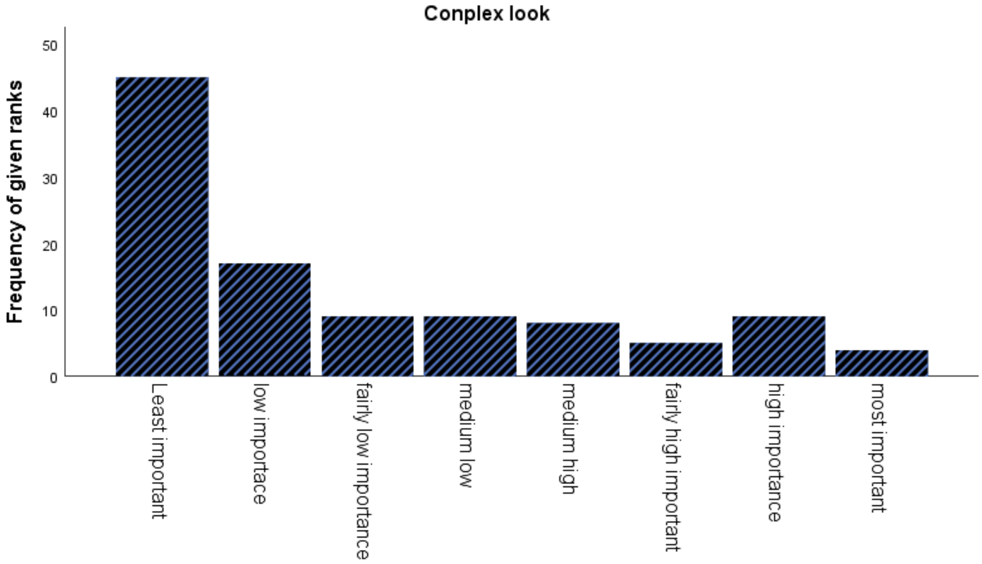
Benthic critter abundance is the attribute that is ranked on the 7th place of importance to divers on St Eustatius. This attribute is significantly different from all attributes except for complexity and natural look. Most of the participants ranked this attribute as (4/8) Low importance (25) or Fairly low importance (2/8) (24). Least important (1/8) was chosen 16 times, medium high (5/8) 14 times and medium low (4/8) 11 times. This attribute only got ranked as most important (8/8) 3 times, high importance (7/8) 9 times and fairly high (6/8) only 5 times (graph 10).



graph 10: Diver ratings for Benthic abundance

COMPLEX LOOK

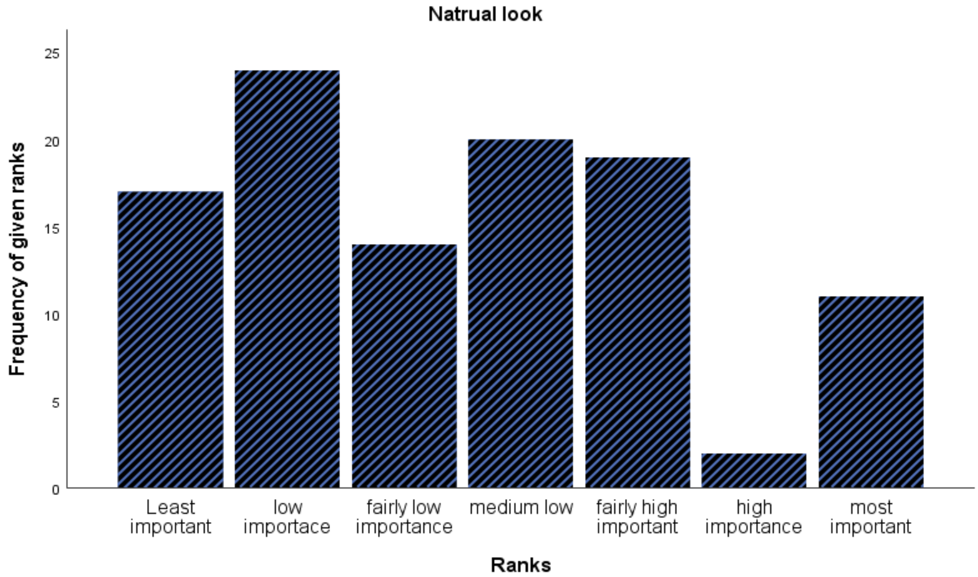
The importance of the complex look of the reef is ranked as last attribute with an average score of 2,87. It is significantly different from all other attributes except for Benthic abundance and Natural look. Out of the 107 people 45 participants ranked this attribute as least important (1/8), 17 ranked it as Low importance (2/8) this means that 58% of all participants ranked this attribute in the lowest two possible options. 9 participants ranked it fairly low (3/8) and 9 others medium low (4/8). 8 participants ranked it medium high(5/8), 5 participants ranked it as fairly high (6/8) and 9 gave it a high importance (7/8). Only 4 ranked it as their most important attribute (graph 11).



graph 11: Diver ratings for Complexity

NATURAL LOOK

The natural look is ranked as 5th out of the 8th attributes with an average score of 3,77. It is significantly different from most other attributes other than. Benthic abundance, Benthic diversity
And Complexity. This attribute is more divided but has the highest scores on the lower rankings. Most participants (24) ranked this attribute as low importance (2/8). Medium low (4/8) was the second most used rank for this attribute with 20 times. The rank fairly high (6/8) was used 19 time. Least importance (1/8) was used 17 times and fairly low importance (3/8) was used 14 times. High importance (7/8) was only used twice to rank this attribute (graph 12).



graph 12: Diver ratings for Natural Look

Appendix II: Diver Survey

DIVER SURVEY

Age:	
Country:	
Gender:	
Dives per year:	1-10 / 10-15 / 15-25 / 25+
Total dives:	0-20 / 20 – 40 / 40 – 80 / 80+
Dive certification:	
Dive Interest:	Photography / curiosity / biological / finding certain organisms / other

	Importance
Please read the attributes stated below and rank them from 1-8 in terms of how important they are to you on a dive.	(1= of no importance, =highly important)
Fish diversity	
Fish abundance	
Benthic critter diversity (Lobster, crabs, starfish, etc.)	
Benthic critter abundance (Lobster, crabs, starfish, etc.)	
Coral diversity	
Coral abundance	
Natural look	
Complexity	

Very natural/ complex looking	Not Natural/complex looking

Natural look	5	4	3	2	1
Complex look	5	4	3	2	1

Natural look	5	4	3	2	1
Complex look	5	4	3	2	1

Natural look	5	4	3	2	1
Complex look	5	4	3	2	1