Reef front heterogeneity analysis and coral genera diversity pattern in the Bunaken National Park, Indonesia

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by

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Abstract

Coral reefs are among the most diverse, complex and productive ecosystems of the world. They are an important source of income, food, pharmaceutics, leisure and protection of the shoreline against storm damage and erosion, and poses a high diversity value. Coastal development, with the increase of population, the bad fishing practices, the effects of inland pollution and erosion and the bad regulations of tourism are threatening and damaging this ecosystem. To manage and protect the coral reefs, mapping them using remote sensors is useful. Past studies proved that geomorphological classes are useful to predict coral reef diversity. The present study analysed the relation of incisions present in the reef front with the diversity of the corals and the pattern of the coral diversity. The study area consisted of an island fringing reef and a coastal fringing reef in two areas of the Bunaken National Park in North Sulawesi, Indonesia. A benthic map with 14 classes and an overall accuracy of 71.8% was produced. 44 different hard coral genera were recorded in 42 line intercept (LI) samples. The minimum amount of genera found in a single 20 m. LI was of 5 and the maximum 19. Tombariri presented a relative higher coral diversity compared to Bunaken Island. The Reef Front Heterogeneity Index (RFHI) was measured in front of each LI with 3 different scales: 50 m., 100 m., and 500 m. The result presented no correlation with the RFHI and the coral diversity in either of the scales. Despite of that, a trend could be seen. In the samples where the RFHI was high, coral diversity found was also high. Distance to the reef front presented a significant but low correlation. In Bunaken Island, 6 different sites could be identified, according to their geographic location, and a diversity pattern in these sites was found. The most remarking differences were found between the areas facing the east and west, with higher diversity to the east. The same pattern can be appreciated with the similarity index. The coral diversity didn't present variation between different management zonation levels.

KEYWORDS: Coral Reef, Genera, Coral Diversity, Reef Front Heterogeneity, Bunaken National Park, Bunaken, Tombariri.

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Table of contents

List of figures

List of tables

List of Equations

1. Introduction

1.1. Coral Reefs

Coral reefs are among the most diverse, complex and productive ecosystems of the world (Souter and Linden, 2000). Despite the fact that they cover only 1% of the total earth surface, approximately 25% of all marine species inhabit the coral reef ecosystems. The coral reefs ecosystem is an important source of income, food, pharmaceutics, leisure and protection of the shoreline against storm damage and erosion, besides of the high diversity value.

Only the indo and west pacific oceans host more than 700 species of hard corals (Birkeland, 1997). When we include in those numbers all the biota living in the coral reefs, where 32 out of the 33 phyla of the world can be found (Bryant et al., 1998), we can get a rough picture of how diverse this marine ecosystem can be.

Corals reefs are formed by the skeletons of hard corals that are produced thanks to a symbiotic relation with the Zooxanthellae, single-celled algae. The Zooxanthellae give the corals the energy from the carbon they produce, and in exchange receive protection and nutrients from the corals. The coral polyps, small spineless animals, form colonies creating the different shapes of corals.

There are four different types of coral reefs, namely the atolls, platform, fringing, and barrier reefs (figure 1). Atolls are reefs that form a sort of ring that encircles partially or completely a lagoon. The platform reefs are built in shallow areas forming round patches. The fringing reefs are the most common type of reef. They grow directly by the coast of the continent land or island. Barrier reefs are formed parallel to the coast line with a lagoon or water body in-between.

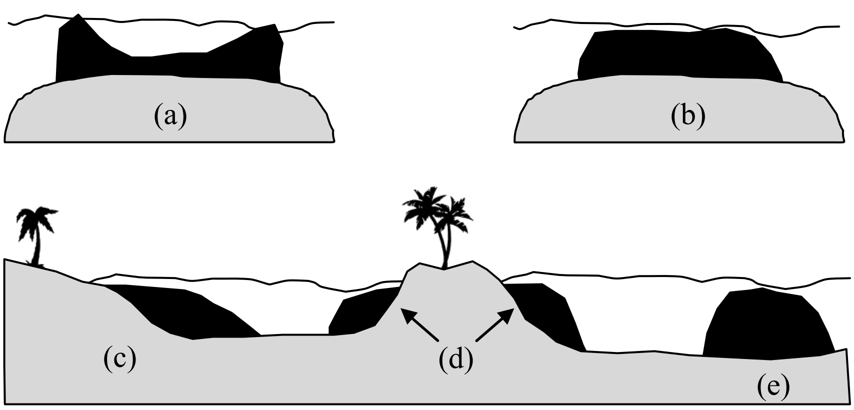


Figure 1. Different Reef Types.
(a) Atoll, (b) platform, (c) Coastal fringing, (d) Island fringing, (e) barrier.

1.2. Problem definition

The health of world's coral reefs is strongly threatened by human pressure (Bryant et al., 1998). Most of the coral reefs are located in tropical developing countries which present high rates in population increase. In Indonesia, around 85,700 km^2 (14% of the world's total) of coral reefs is found (Tomascik et al., 1997). According to some scientists this is among the richest reefs of species in the world. Coastal development, with the increase of population, the bad fishing practices, the effects of inland pollution and erosion and the bad regulations of tourism are among these threats. In the Bunaken area there is clear evidence of high rates of negative scuba-diver interactions and related damage at frequently visited diving sites (de Vantier and Turak, 2004).

In order to manage them, natural resource managers around the world are in need of different means and tools to support and improve the impact of their decisions. One basic tool that can have big impact is the mapping of coral reefs and their adjacent areas (NASA, 2009). Traditionally coral reef studies have been done by direct survey by snorkelling or by using scuba diving. This method is costly, time demanding and practically impossible to use to cover studies in large areas and for monitoring changes. Remote Sensing is therefore considered a useful tool to replace in situ surveys of coral reefs.

Satellite and airborne data are improving for its use in biodiversity science and conservation (Turner et al., 2003). The increase of both spatial and spectral resolution in remote sensors allows accurate studies to be made. Some researches like the one carried by Sterckx et al. (2005) are being made to assess which methods give better results and are more efficient to study the coral reefs diversity, using hyperspectral, multispectral and/or aerial photography.

Remote sensing data offer the potential to observe patterns of species diversity (Turner et al., 2003). This is possible by combining expert knowledge about species requirements and land cover maps derived from remote sensing. The best approach to monitor coral reef is the 'multilevel sampling' (Bryant et al., 1998), where the information is sampled locally, and then extrapolated to wider areas using remote sensors data. With the possibility to use this data in a cost-effective multi temporal manner, it facilitates to monitor changes in the coral reefs and differentiate between anthropogenic and natural pressure on coral reef (Kutser et al., 2003).

According to Andréfouët and Guzman (2005), habitat heterogeneity within geomorphological areas explains better the patterns of coral diversity. Previous studies on reef geomorphology and its relation to fish and corals, have divided the reef in 4 geomorphological habitats: lagoon, front, slope and terrace, and assessed the beta diversity between the different habitats (Arias-Gonzalez et al., 2008, Nuñez-Lara et al., 2005). Both studies results support that geomorphological classes are useful to predict coral reef diversity.

The present study analysed the relation of incisions present in the reef front with the diversity of the corals. So far no research has been carried out to study if the reef front heterogeneity can be related to its biodiversity. The presumption that there could be a correlation was based in experience of divers that have seen that apparently in these areas the coral diversity is richer.

Other variables like distance to reef edge, and site location according to its geographic position will also be studied to try to explain the diversity pattern in the study area. Also the effect of the management zonation in the National park to see if there is already differences between management levels.

To measure the diversity three characteristics were selected. In field the live coral cover percentage was measured. It gives a first insight of the richness of life of the area. The coral colonies were identified to a genera level. Meixia et al. (2008), show the increase tendency of diversity indexes from family to genera and species (1.04 < 1.42 < 1.96 for Shannon index). The result of the study despite of being lower than with a species level, still illustrate the high diversity present in the study area. To analyse the diversity richness the Shannon index was selected, being this the most commonly used index in diversity studies.

For logistics and efficiency reasons, the fieldwork data collection on diversity, and the benthic map was done together with Mochamad Arif Zainul Fuad.

1.3. Main Objective

The main objective is to study the relation between habitat heterogeneity and coral reef diversity in Bunaken Island and Tombariri, Indonesia.

1.4. Specific Objectives

- Analyze the relation between the reef front heterogeneity and coral reef diversity.
- Assess the coral reef diversity in the different habitats.

1.5. Research questions

- What is the biodiversity in the areas with different classes of reef front heterogeneity index values?
- What are the species genera richness and the similarity index values in the different habitats?

1.6. Hypothesis

- H_0. The coral reef diversity is not significant correlated with the Reef Front Heterogeneity Index.
  H_1. The coral reef diversity is significant correlated with the Reef Front Heterogeneity Index.

- H_0. The coral reef diversity is not significant correlated with the distance to the reef front.
  H_1. The coral reef diversity is significant correlated with the distance to the reef front.

- H_0. The coral reef diversity is not significant correlated with the management zones.
  H_1. The coral reef diversity is significant correlated with the management zones.

- H_0. The coral reef diversity is not different between the different geographic locations.
  H_1. The coral reef diversity is different between the different geographic locations.

2. Materials and Methods

2.1. Methodological steps

In order to fulfil the objectives the aerial photograph was gathered and prepared adequately for interpretation and analysis. The data preparation included the correct geocoding of the images. With the geocoded photograph the image interpretation was performed, producing a polygon map. Stratified representative cover estimation in the different map units was performed in order to produce the classification of the different strata and elaborate the benthic map. In the coral class of the benthic map, systematic sampling points were selected to gather the biodiversity data. This data was used to analyse the relation with the reef front heterogeneity index, the distance to reef front, the geographic site location, and the effects from the management level of the zones. In figure 2 the reader can have an overview of the methodological workflow that will be described more in detail in the following subchapters.

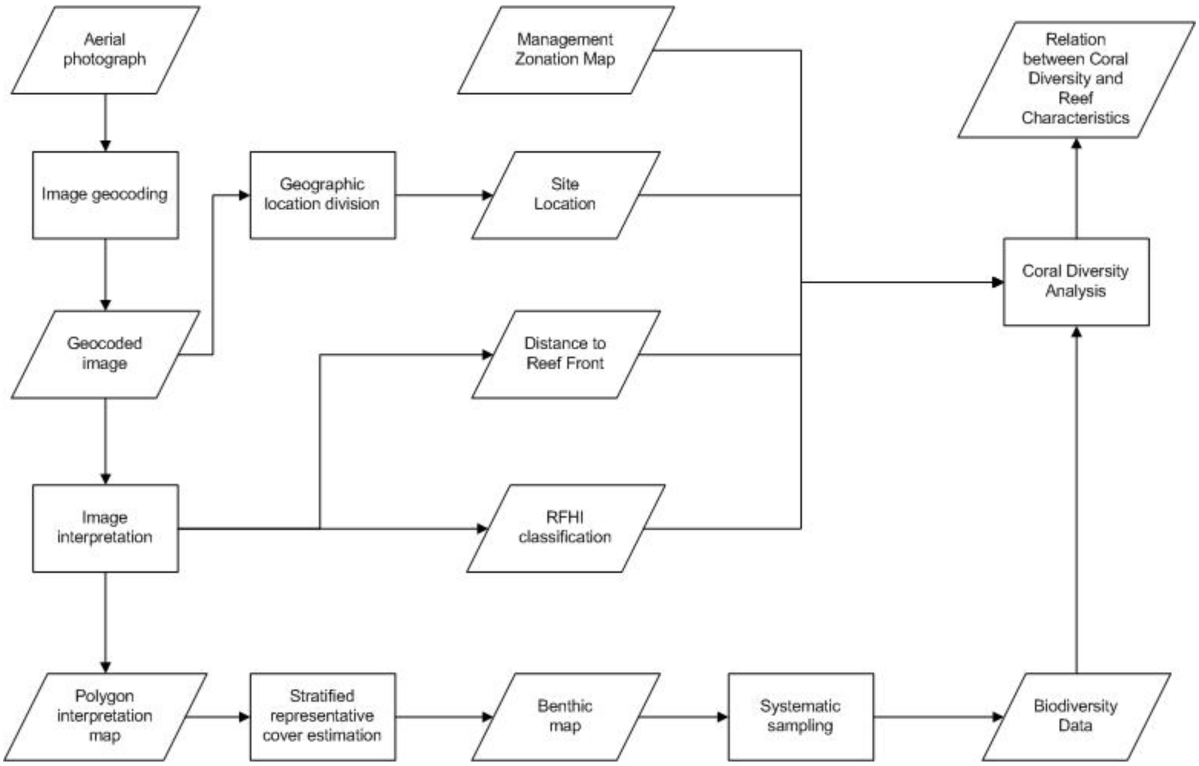


Figure 2. Methodological flowchart.

2.2. Study Area

The study area selected for this case is the fringing coral reef formation around the Bunaken Island and Tombariri district in the province of North Sulawesi, Indonesia (figure 3). Bunaken, together with other 4 islands, and Arakan-Wowontulap, a coastal section at the south-west of Manado, are part of the Bunaken Marine National Park (BNP) (Fava et al., 2009). The northern part of the park, where the islands are located, is between 1˚35'41" to 1˚32'41" North and 124˚50'50" to 124˚49'6" East. The Arakan-Wowontulap coast is located between 1˚24'0" to 1˚14'44" North and 124˚38'3" to 124˚32'22" East. Established in 1991, is among the first marine parks in an effort from Indonesia to manage and protect their marine diversity.

97% of the 89,065 ha from the reserve is covered by warm clear tropical waters, with up to 35-40 m visibility making it a perfect suitable area for corals (NTSPB, 2009). The sea-surface temperature ranges between 27˚ and 29˚C. throughout the whole year. The annual precipitation is around 3000 mm. and the average temperature is 27˚ C.

Located in the centre of the called "Coral Triangle" (CTI-Secretariat, 2008), BNP is part of an exceptional rich biodiversity area (Hoeksema, 2007). Even on land, it hosts two endemic mammals, the Crested Black Macaque, and one of the smallest primates of the world, the Tarsiers. At least 30 species of birds, 29 species of mangroves, and several other fauna and flora species are also found in the park. The marine diversity presents around 390 species, from 63 genera of hard corals (Turak and de Vantier, 2003), and more than 2000 different reef fish species (Mehta, n/a). Endangered marine mammals like the Dugong, and sea turtles inhabit also the park.

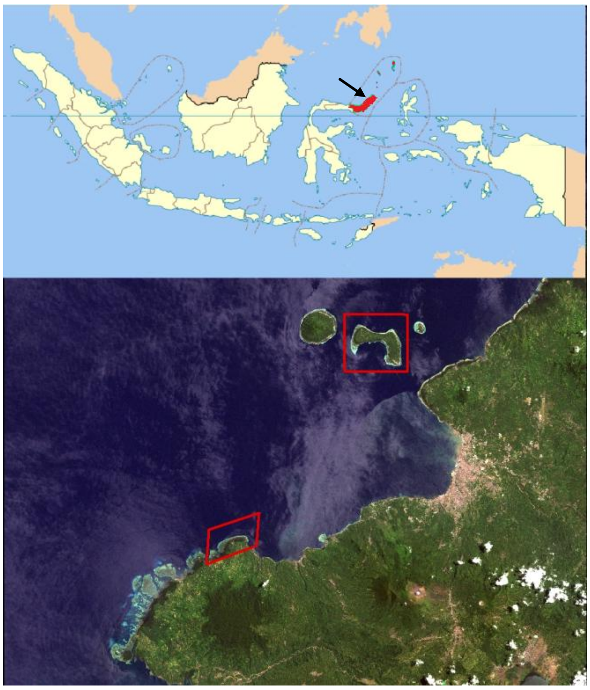


Figure 3. Study area. Bunaken Island and Tombariri region, North Sulawesi, Indonesia

The Bunaken Island is a tourism hotspot. Located in the centre of the Bunaken National Park it hosts several tourist operators and hotels. There are 15 dive spots with an estimated level of use that goes from moderate in 4 of them to heavy in the remaining 11 spots (de Vantier and Turak, 2004). The Coral Reef on the Bunaken Island consists of an island fringing reef, with a steep reef wall.

The Tombariri region is not a common tourist diving site, but has a big impact from fishing activities. Tombariri is located at the eastern part of Arakan-Wowontulap, the continental area inside the Bunaken National Park. In the area there are three villages where their main activities are farming and fishing. The coral reef in Tombariri consists of a coastal fringing reef with a wide reef flat and the reef slope that gently goes deeper.

2.3. Image Geocoding

First the Google images had to be proper geocoded. Previous field data was used to geocode the image of the Bunaken Island. For the Tombariri region there was no enough precedent field data so the first step was to collect it. Different objects across the image like trees, street crossings and mangroves were identified and then with the use of the iPaq they were sampled. The control point error achieved in Tombariri was of 2.85 m. and in Bunaken 3.05 m., meaning that it was more than enough accurate to continue with the work. The GPS error was in average 1.5 m.

2.4. Image Interpretation

The geocoded images were visually interpreted to define the different strata or map units. The map units were identified and selected according to the colour and tone, texture and location (table 1). The result was digitized and then exported to Arcpad format to be used in the iPaq during the sample process.

The benthic cover was estimated through snorkelling and examination using rowing and motor boats. 188 points of benthic cover estimation were sampled stratified throughout the whole study area (figures 7 & 8). The samples were well inside each stratum derived from the photo interpretation. At each location the percentage cover was estimated of coral, dead-coral, dead-coral covered by algae, rubble, algae, seagrass, and sand. With the data gathered, and after some analysis with the fieldwork team, a classification scheme of the benthic field samples was produced (table 3). And the classified points were used to assess the accuracy of the map.

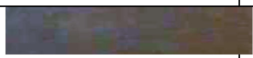
Class	Image	Location
Dense Coral		-
Open Coral		-
Dead Coral		-
Dead Coral covered by Algae		-
Rubble		-
Dense Seagrass: Thalassia		Close to land
Dense Seagrass: Enhalus acoroides		SW of Tombariri
Dense Seagrass: Thallasodendron ciliatum		Patches N of Tombariri
Open Seagrass: Thalassia		Between dense SG and coral
Open Seagrass: Halophila ovalis		E of Tombariri
Sand		-
Mangrove		-
Water		-
Land		-

Table 1. Interpretation key, showing image sample, and location description when applied.

2.5. Sampling Design

The sampling design used was systematic sampling in the coral zone. This method was chosen so that all the coral strata surrounding the Bunaken Island and the area in Tombariri could be sampled. Points were selected with a systematic evenly distribution. A couple of spots couldn't be sampled despite being revisited for the safety of the fieldwork team because of the strong currents and the limited time. A total of 45 line intercept samples were recorded. Out of the 45 LI samples, 3 weren't considered in the analysis because they were outside the coral class. Those three samples were originally recorded parallel to other LI to see the difference of coral diversity between different strata, but since no live coral was found in those samples they were discarded for latter analysis, and the team focused later only in the coral strata.

2.6. Line Intercept

The coral reef diversity was sampled using the line-intercept (LI) (Cummings and Smith, 2001).The original idea was to do a circular-line-intercept (CLI) method. Based on the LI, the CLI was intended to be used in order to be able to sample without trespassing different strata boundaries. The CLI consisted in a 20 m. perimeter circle (figure 4). The centre of the point was located with the GPS. This point was marked carefully with a stake, without disturbing the corals. The radio of the circle was measured with a stretched rope of 3.18 m. On the other extreme of this rope a second stake marked the beginning and the end of the 20 m. circumference formed by the meter roll.

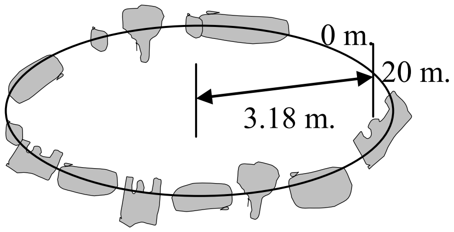


Figure 4. Circular-line-intercept (CLI)

After trying this method in the field, the team realized that due to the strong currents and the equipment we had, this method was unfeasible, being impossible to keep the circumference in its proper shape. After a short discussion we all agree to use straight LI of 20 m., parallel to the coast and sea front (figure 5). We chose then this method, since the LI is one of the most commonly used methods to assess coral diversity (Leujak and Ormond, 2007), and the materials to be used were the same.

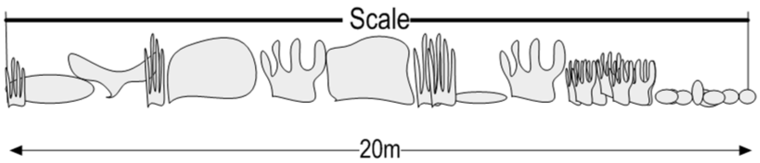


Figure 5. Line-Intercept (LI)

All objects under the metric roll were recorded marking the transition (end number of roll meter) length on the hard-slate with waterproof paper and pencil. The benthic cover was measured with a precision of one cm. The record of the covertures was based in the categories shown in table 2.

Category	Explanation	Category	Explanation
LC	Live hard coral	SG	Seagrass
DC	Dead coral	SC	Soft coral
DCA	Dead coral covered by algae	SP	Sponge
RU	Rubble	AL	Algae
SA	Sand (sandy material)	OT	Others

Table 2. Categories sampled in the LI.

The live hard corals (LC) were identified to genera level, and in the cases the identification was not possible underwater, pictures were taken with an underwater camera and identified later in screen with the help of books and some discussion. The decision to do the coral diversity study only to genera and not to a species level is mainly based on the difficulty to identify corals to a species level. The genera can already give an indication of the diversity level in an area. In cases when the time is limited, and the knowledge of the region and their species is minimal, such a study can be performed.

The seagrass (SG) was identified to a species level. Ascidians, anemones, and clams were placed in the Others (OT) category. In the rest of categories no subcategory was applied.

The data collected was transferred into excel and SPSS for analysis.

2.7. Analysis

2.7.1. Diversity

2.7.1.1. Diversity richness

The most basic diversity values used in the study were the percentage of live coral coverage in the LI, and the number of genera recorded. But further analysis was needed. Therefore to analyze the diversity richness the Shannon index was selected. This index is one of the most commonly used in diversity studies, and is recommended for studies within an ecological framework (Nagendra, 2002).

Equation 1 Shannon Index

$$SHD = 1 - \sum_{i=1}^{N} p_i \times \ln p_i$$

Where p_i is the relative abundance of each species, calculated as the proportion of cover percentage of one genus to the total cover percentage in the stratum (n_i/N).

2.7.1.2. Similarity Index

To analyse the variation or similarity of the species between the different regions surrounding the Bunaken Island and between the Island and the Tombariri coast the Sørensen's similarity index was chosen. The Sørensen's similarity index is based on presence/absence of species. If the value is close to 0 it shows lower similarity, while if the value gets closer to 1 indicates high similarity.

Equation 2 Sørensen's index

$$\beta = \frac{2c}{S_1 + S_2}$$

Where S_1 is the total number of species recorded in the first LI, S_2 is the total number of species recorded in the second LI, and c is the number of species common to both strata.

2.7.2. Reef Front Heterogeneity

To analyse the reef front heterogeneity, a Reef Front Heterogeneity Index (RFHI) was calculated. The RFHI consist in delineating and measuring the reef front complexity and a straight line through the boundary of the reef front (figure 6).

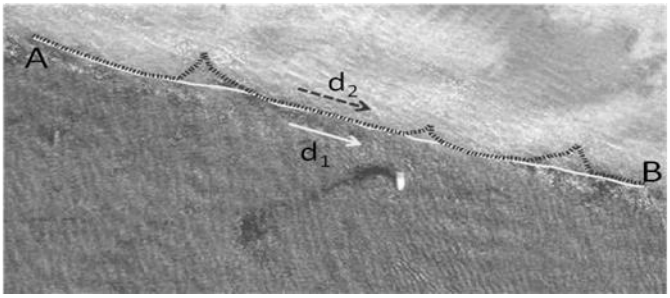


Figure 6. Reef Front Heterogeneity Index schematic representation

The reef front heterogeneity index was measured using the following equation.

Equation 3 Reef Front Heterogeneity Index

$$RFHI = 1 - \frac{d_1}{d_2}$$

Where d_1 is the distance between A and B through the reef front straight line and d_2 is the distance between A and B through the reef front and incisions line. When RFHI is closer to cero the reef front is less complex, and then it is expected lower coral reef diversity than in areas where the RFHI is higher. The RFHI was measured in front of each LI sampled. Three different scales were used to analyse the effect on which scale could be more significant. The scales used were defined by a straight line between point A and point B of 50 m, 100 m., and 500 m.

A statistical analysis was done to see the correlation between RFHI and the live coral coverage percentage, the number of genera and the Shannon index.

2.7.3. Distance to reef Front

The distance to the reef front is also expected to have influence on the diversity. It was measured using GIS, with a shortest distance between features tool. What it measured was the distance between the LI and the closest point of the reef front line. It must be highlighted, that in the Bunaken Island the reef edge is sharp and can be identified clearly, while in Tombariri the reef goes deeper gradually with a gentle slope. In Tombariri the reef front was established at the limit where the coral reef can still be seen through the water column.

3. Results

3.1. Benthic maps

The result of the photo interpretation is shown in figures 7 and 8. A benthic map of Bunaken and Tombariri with 14 classes was produced. According to the classification scheme presented in table 3, the coral coverage was divided in four classes: Dense Coral, Open Coral, Dead Coral, and Dead Coral Covered by Algae. Seagrass was divided in two groups, open and dense, and then according to the species. The classes Open and Dense Seagrass: *Thalassia* is predominated by *Thalassia hemprichii*, with other species such as *Cymodocea rotundata, C. serrulata, Enhalus acoroides*, and *Halophila ovalis* in smaller proportion. The other seagrass classes are patches where the mentioned specie (*Enhalus acoroides, Thallasodendron cilliatum* or *Halophila ovalis*) grows predominantly. The seagrass species could be identified due to the specific location of the patches.

LC	DC	SG	DCA	RU	AL	S	Classes
>=40%							Dense Coral
20<=LC<40							Open Coral
LC<20	>=50						Dead Coral
	DC<50%	>=50%					Dense Seagrass *
		20%<=SG<50%					Open Seagrass *
		SG<20%	>=50%				Dead Coral Covered by Algae
			<50%	>=50%			Rubble
					<50%	>=70%	Sand
						LC + DC > 20	Open Coral
						RU+S>60	Rubble
							Water
							Mangrove
							Land

* Species level

Table 3. Classification scheme.
LC=Live Coral, **DC**= Dead Coral, **SG**= Seagrass, **DCA**=Dead Coral Covered by algae, **RU**=Rubble, **AL**=Algae, **S**=Sand.

The maps present almost the same pattern in the distribution of the benthic strata around all of the study area, lying in bands parallel to the shoreline and the reef front. It represents a traditional fringing reef. The land is surrounded with the mangroves. After the mangroves lies a seagrass bed, that is followed by the reef flat covered by live and death corals and continues to the reef crest, and reef slope in Tombariri or steep reef wall in Bunaken, covered mostly with live coral. In the northern part of Bunaken island the pattern changes, going from the sand layer straight to the corals.

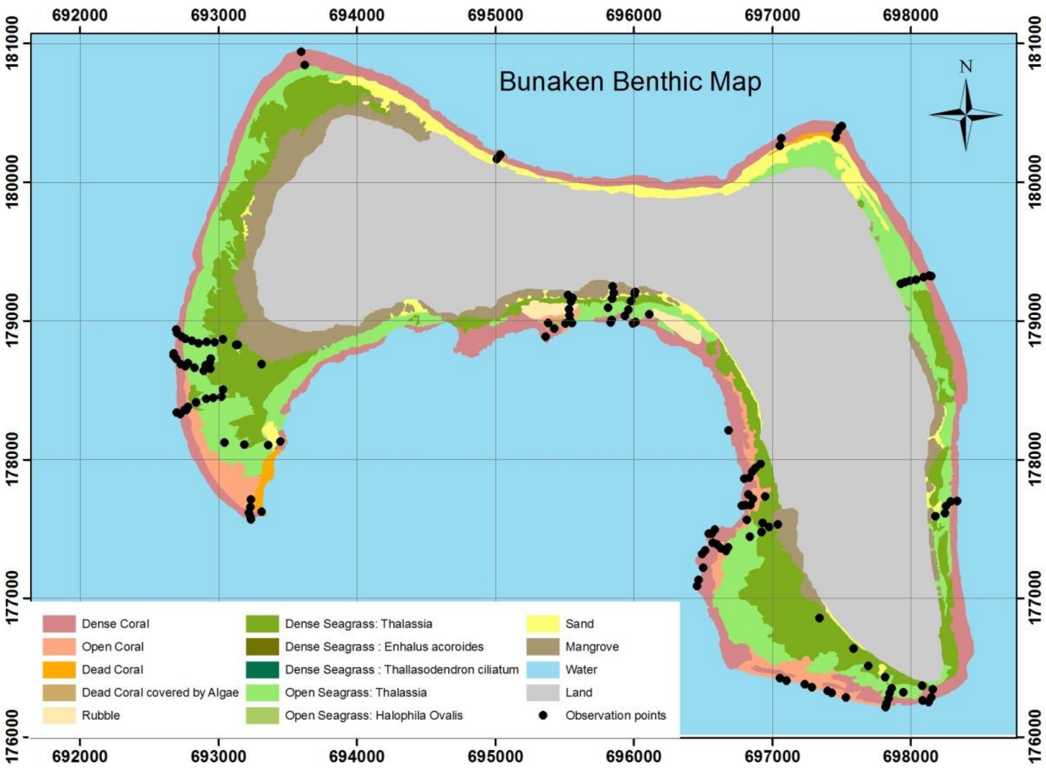


Figure 7. Bunaken Benthic Map

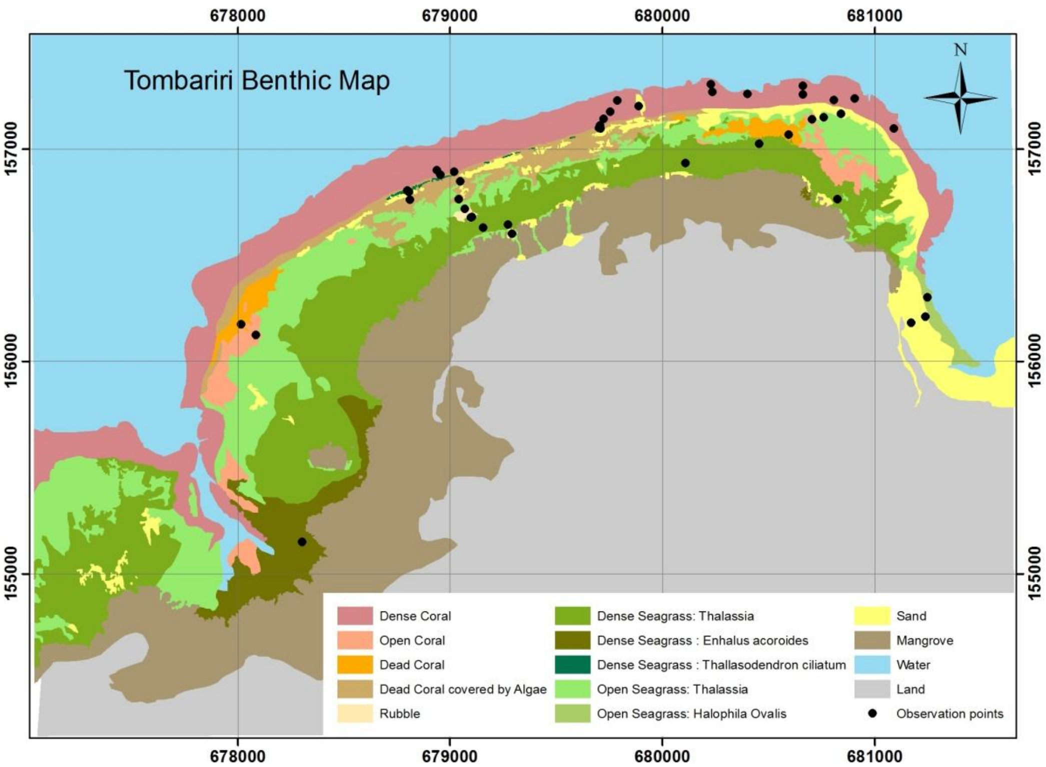


Figure 8. Tombariri Benthic Map

The classification produced an accuracy of 71.8% (table 4). From the result we can notice that most of the errors are from related classes. For instance, points classified as open or dead coral fall in the dense coral class of the benthic map; sand in Open Coral; dense seagrass in open seagrass.

Classes	Dense Coral	Open Coral	Dead Coral	Dead Coral covered by Algae	Dense Seagrass Thalassia	Dense Seagrass Enhalus Acoroides	Dense Seagrass Thallasodendron ciliatum	Open Seagrass Thalassia	Open Seagrass Halophylla ovalis	Rubble	Sand	Water	Mangrove	Grand Total	
Dense Coral	37	9	6	1						2		1		56	66%
Open Coral	1	14	3	1				1		2	5			27	52%
Dead Coral			4											4	100%
Dead Coral covered by Algae		1		6							1			8	75%
Dense Seagrass: Thalassia		1			19			2						22	86%
Dense Seagrass : Enhalus acoroides						1								1	100%
Dense Seagrass : Thallasodendron ciliatum							2							2	100%
Open Seagrass: Thalassia		3	1		6			23		1				34	68%
Open Seagrass: Halophila Ovalis									1					1	100%
Rubble	1							1		2				4	50%
Sand					1			2			10			13	77%
Water												12		12	100%
Mangrove													4	4	100%
Grand Total	39	28	14	8	26	1	2	29	1	7	16	13	4	188	83%
	95%	50%	29%	75%	73%	100%	100%	79%	100%	29%	63%	92%	100%	76%	**71.8%**

Table 4. Accuracy assessment table of the benthic maps

3.2. Coral Diversity

In the 45 LI samples, 44 different hard coral genera were recorded. The most genera encountered in one single LI was of 19, in the area known as Lekuan 2 in the southern part of Bunaken. For the analysis, only 42 of the 45 LI were considered as the other three samples fall outside a coral benthic class. In figure 9 a summary of the diversity results is presented.

		Live Coral	Nr. of Genera	Shannon Index
Bunaken (n=27)	max.	80%	19	2.34
	min.	10%	5	0.45
	average	47%	10	1.58
Tombariri (n=15)	max.	78%	18	2.40
	min.	6%	5	0.87
	average	43%	11	1.77

Table 5. Diversity analysis summary.
Where “n” is the number of samples in each area, Live Coral is represented as its percentage of the benthic cover in each LI.

It can be highlighted that Tombariri present a higher diversity value than expected compared with Bunaken, despite of being more affected by bad practices of fishing.

The complete results of the LI and the list of genera registered in the study can be found in appendices 1 and 2 respectively.

In the following subsections the diversity results are compared first with the Reef Front Heterogeneity, second with the distance to the reef front, third between different site locations in Bunaken Island, and last analysed with the different zones of management.

3.2.1. Reef Front Heterogeneity

As opposed to what was expected, the reef front heterogeneity has no correlation with the coral diversity. In table 5 the reader can look at the Pearson values (r) and the significance levels of the correlation analysis between the RFHI at the different scales and the live coral cover percentage, the number of genera and the Shannon index values.

		Live Coral		**Nr. Of Genera**		**Shannon Index**	
		Bun.	Tom.	Bun.	Tom.	Bun.	Tom.
RFHI 50 m.	r	-.069	-.264	-.062	-.319	.029	-.130
	Sig.	.366	.171	.380	.123	.443	.322
RFHI 100 m.	r	.033	-.282	.010	-.227	.020	-.057
	Sig.	.436	.154	.479	.208	.460	.420
RFHI 500 m.	r	-.091	-.194	-.015	-.149	.114	-.054
	Sig.	.325	.245	.471	.298	.285	.424

Table 6. Correlation matrix for the RFHI at different scales, in Bunaken and Tombariri.

The smallest scale chosen to analyse the reef front heterogeneity was of 50 m. The main reason of this is because since the line intercept are of 20 meters and most of the incisions are ranging from 20 to 40 meters wide, both could fit well inside the analysis. Then the scale of 100 m. was chosen to have a medium scale, and 500 m. as the largest.

Despite the low correlation, if we draw the scatter plots with the RFHIs and the Shannon diversity index, a trend can be seen both in Bunaken Island and in Tombariri. In figure 9 the plots showing the trend of the different RFHI scales and the Shannon index values in both areas are presented. It can be seen how with low RFHI values, low and high Shannon index values are present, while when as the RFHI value increases, only higher diversity values are found. Also, when we increment the RFHI scale this trend decreases, presenting lower diversity values at higher RFHI. In the scatter plots with the number of genera and live coral cover percentage no trend can be identified. For reference all the scatter plots can be seen in appendix 3.

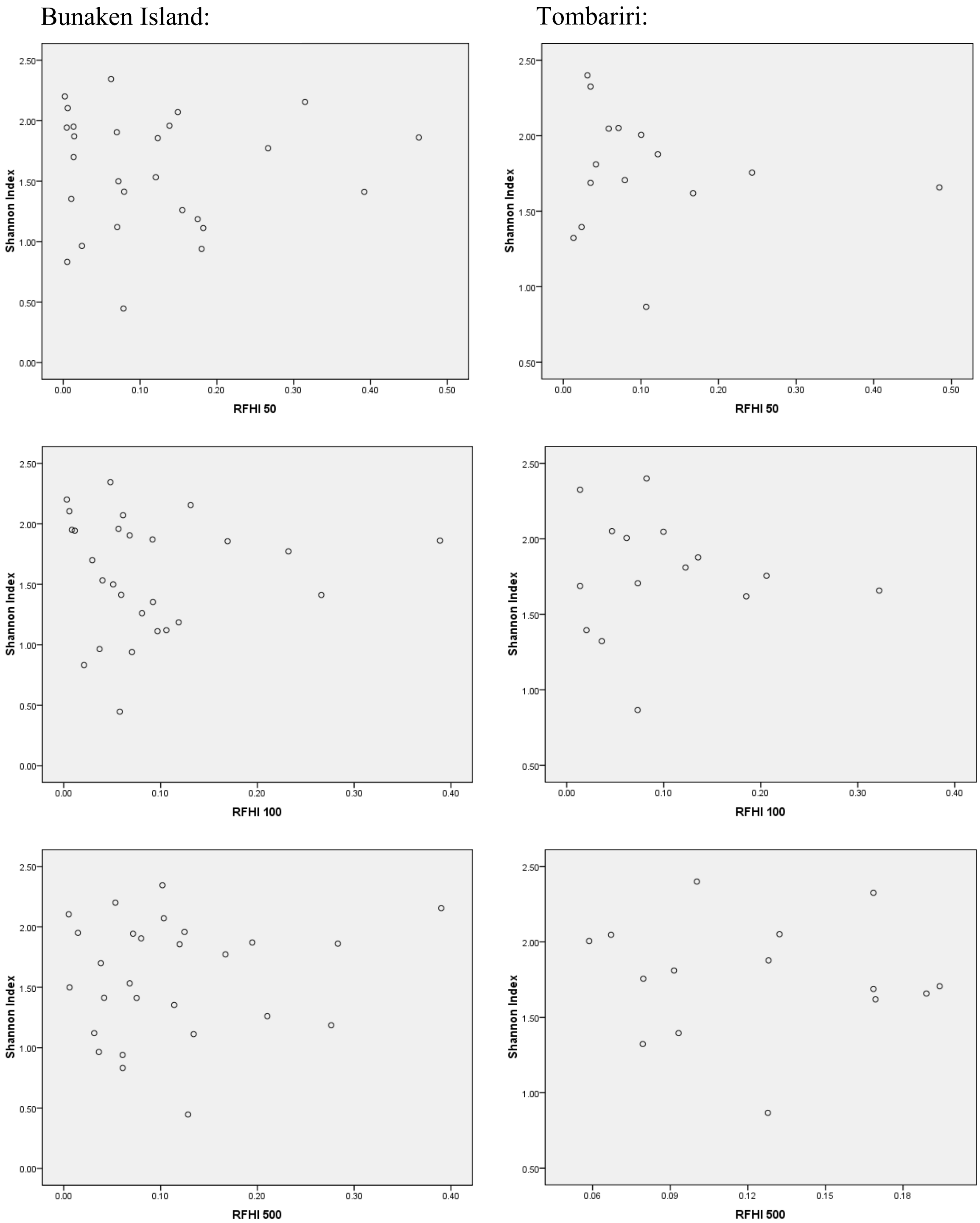


Figure 9. Relation of RFHI values with Shannon Index in Bunaken Island and Tombariri.

3.2.2. Distance to Reef Front

Since no correlations were found between Reef Front Heterogeneity Indexes and the different diversity indexes or life coral cover percentage, other variables were analysed to try to explain the diversity pattern. One of these variables that could be related is the distance from the LI to the reef front edge.

With the distance to the reef front there is a significant negative low correlation in Bunaken with the number of genera and the Shannon index, while in Tombariri the percentage of live coral coverage and the number of genera have a significant positive low correlation (table 7).

			Live Coral	Nr. Of Genera	Shannon Index
Distance to Reef front	**Bunaken**	r	-.233	-.388	-.415
		Sig.	.121	.023	.016
	Tombariri	r	.486	.507	.401
		Sig.	.033	.027	.069

Table 7. Correlation matrix for the distance to the reef front.

The reason that could explain the difference between Bunaken, having a negative correlation, and Tombariri, having a positive correlation, is that Bunaken's reef front is a vertical wall, while in Tombariri the reef slope deepens gently. This causes that the natural impacts such as waves affects differently on both study areas. On the scatter plots (figure 10) it can be distinguished the trend, but with a real low correlation.

Bunaken Island: Tombariri:

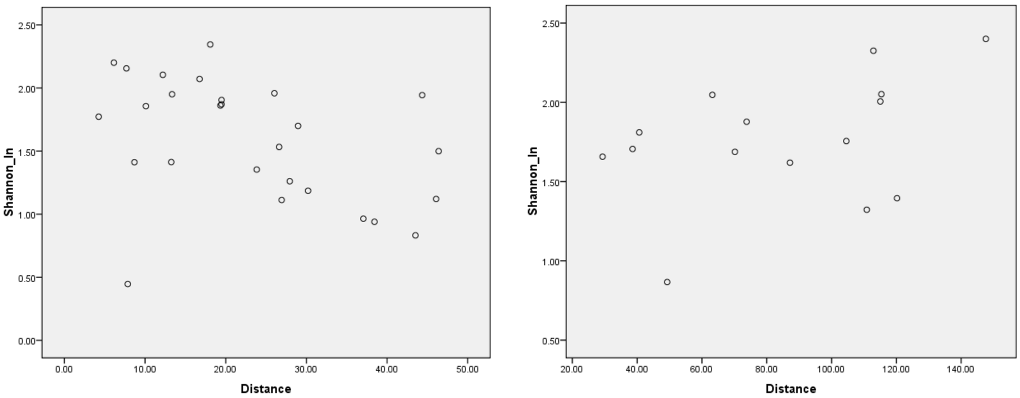


Figure 10. Relation of distance to the reef front and Shannon Index values.

3.2.3. Site Location

In the Bunaken Island, due to its characteristic shape, 6 different sites according to their location were defined (figure 11). An ANOVA was made to test if there is a difference of the different diversity values. The results of the ANOVA are shown in table 8.

The number of genera and the Shannon Index present significant differences between the different sites. It can be observed that the highest diversity values are present on the sites facing the East (East, and Alung Banua) and the lowest facing the west (West, and Liang). In the site in front of the Bunaken village, despite of having the LI with the highest diversity, the average value is medium. The live coral coverage does not differ between the different sites.

ANOVA (Live Coral)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.21538907	5	0.04307782	0.97698577	0.4546109	2.68478073
Within Groups	0.925944	21	0.04409257			
Total	1.14133307	26				

ANOVA (Number of Genera)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	269.324074	5	53.8648148	4.97395872	0.00368513	2.68478073
Within Groups	227.416667	21	10.8293651			
Total	496.740741	26				

ANOVA (Shannon Index)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.49227218	5	0.69845444	5.7028759	0.0017833	2.68478073
Within Groups	2.57195552	21	0.12247407			
Total	6.0642277	26				

Table 8. ANOVA test of diversity differences between the 6 location sites in Bunaken Island.

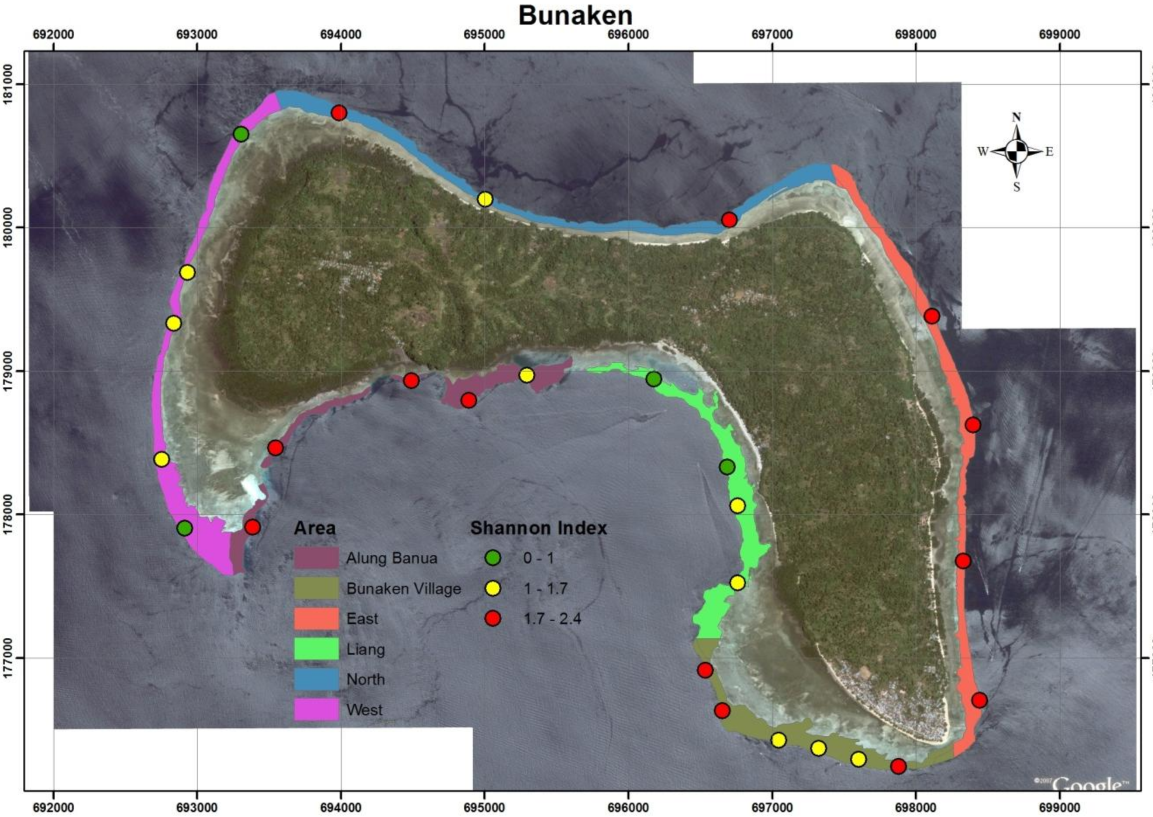
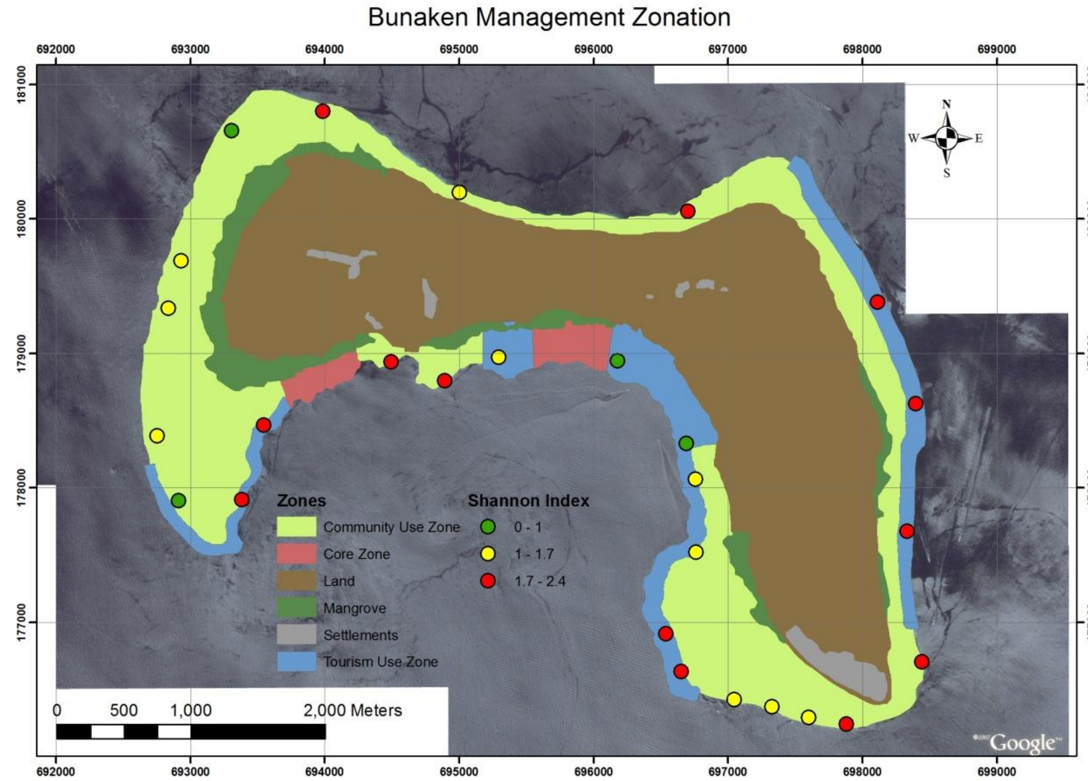


Figure 11. Bunaken sites location and LI location.

3.2.4. Management level

The management zonation map could be gathered just after the field work was done, therefore it was not considered during the sampling design, and no sample was taken from the core zone. Despite of this, in the field it was evidenced that the zonation is not being respected properly. In the area of the Liang core zone high tourism pressure was noticed. Big local tourist groups with people snorkelling, and walking directly on the reef damaging the corals were spotted. Also the difference between community use and tourism zones is not well defined, having dive spots and loads of tourists snorkelling in the community zone. Illegal coral mining activities could be evidenced in the northern coast of the Bunaken Island. As expected, there is no significant difference in the diversity between the tourism and the community zones in Bunaken Island and Tombariri. A study carried out by Christie (2005) measuring the substrate cover and fish diversity concluded that there was an improvement in the coral reef diversity in the tourism zones, while in Alung Banua core zone the reef continued degrading, manifesting the low control in that zone.



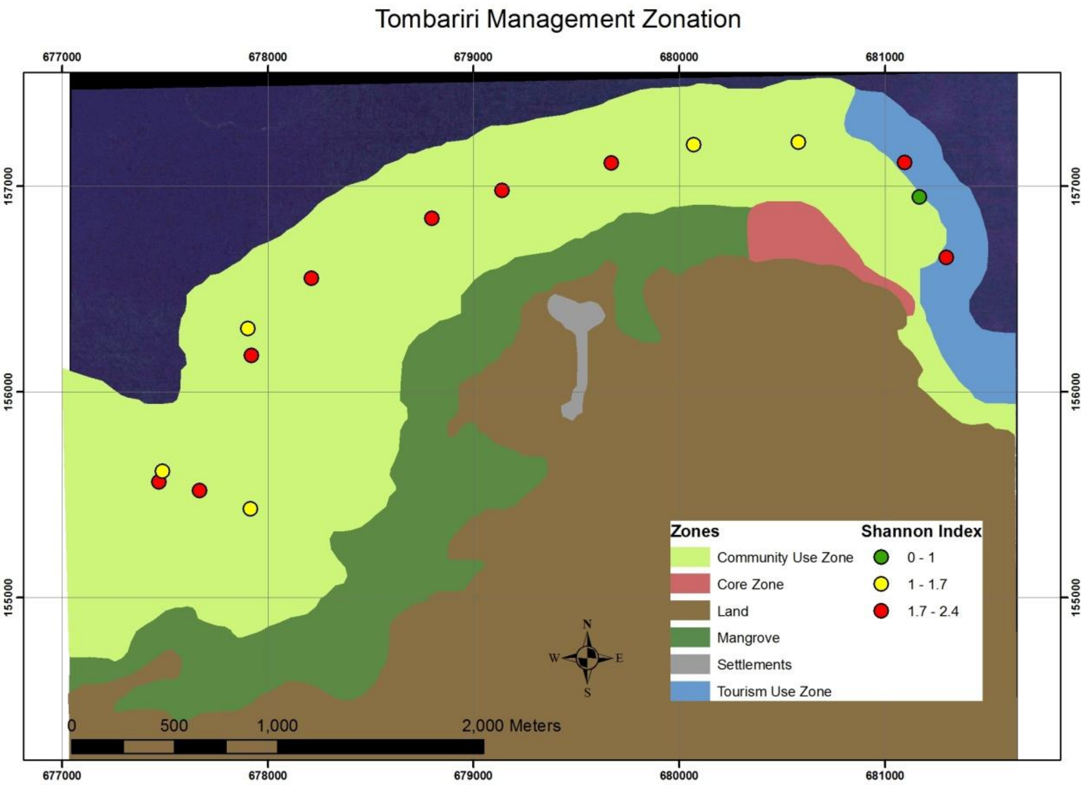


Figure 12. Zonation management map of Bunaken and Tombariri.

3.3. Similarity index

The results of the Sørensen similarity index were ordered according to the site location in the Bunaken Island and from west to east in Tombariri for an easier interpretation (Appendix 4). Most of the values are below 0.50, showing low similarity between the different samples, and explaining the high diversity of the region. In the table 9 it can be appreciated that the LI in the East and in Alung Banua are more similar than with those in the West and Liang.

		West					Liang				East				Alung Banua					
		15	25	26	27	30	14	29	34	38	16	17	36	37	28	31	32	33	39	
West	15		0.50	0.17	0.29	0.53	0.36	0.62	0.43	0.36	0.44	0.43	0.35	0.42	0.36	0.53	0.30	0.56	0.48	0 - 0.25
	25			0.50	0.43	0.53	0.18	0.62	0.57	0.55	0.33	0.35	0.43	0.42	0.55	0.53	0.40	0.56	0.38	0.25 - 0.50
	26				0.57	0.40	0.18	0.31	0.29	0.18	0.22	0.26	0.35	0.25	0.55	0.27	0.40	0.22	0.29	>0.50
	27					0.35	0.31	0.40	0.38	0.31	0.30	0.32	0.48	0.38	0.46	0.47	0.36	0.40	0.43	
	30						0.29	0.50	0.71	0.43	0.57	0.54	0.62	0.52	0.43	0.56	0.52	0.67	0.50	
Liang	14							0.17	0.31	0.20	0.47	0.36	0.27	0.26	0.40	0.43	0.42	0.47	0.30	
	29								0.40	0.33	0.32	0.42	0.42	0.48	0.33	0.56	0.52	0.67	0.45	
	34									0.62	0.50	0.56	0.40	0.54	0.46	0.59	0.55	0.70	0.35	
	38										0.35	0.45	0.27	0.26	0.40	0.43	0.42	0.47	0.20	
East	16											0.62	0.62	0.53	0.47	0.48	0.54	0.67	0.44	
	17												0.41	0.63	0.45	0.38	0.65	0.69	0.50	
	36													0.51	0.36	0.54	0.45	0.55	0.56	
	37														0.43	0.59	0.63	0.67	0.55	
Alung Banua	28															0.43	0.53	0.47	0.40	
	31																0.70	0.67	0.50	
	32																	0.69	0.48	
	33																		0.52	
	39																			

Table 9. Sørensen similarity analysis for four sites in Bunaken Island.

4. Discussion

4.1. Coral Diversity

The results confirm that Bunaken is part of the "Centre of Maximum Marine Biodiversity" (Hoeksema, 2007). If we compare the figures of the coral richness of the area with other studies we can note its importance. In the northern part of the Caribbean, in the Jaragua National Park, Dominican Republic, 56 hard coral species from 26 genera were recorded (Weil, 2006). This values are similar to the ones presented in María la Gorda-reefs and in the East coast of "Bahía de Cochinos" in Cuba, where 35 species of 19 genera with Shannon index values of 2.2 to 2.6 and 36 sp. belonging to 20 genera with Shannon index values of 2.03 to 2.53 were sampled (Caballero et al., 2004, González-Ferrer et al., 2007). It is important to highlight that those studies included deeper areas up to 40 m. below sea level. And according to Huston (1994), the coral diversity peak in the reefs occur between 15 to 30 meters below sea level, and the Shannon index was calculated at a species level. The present study focused only in the shallow reef area, less than 6 m. deep. The number of genera encountered is higher than the species in both studies of Cuba, and almost doubled the number of genera in the Jaruaga National Park.

4.1.1. Reef Front Heterogeneity

According to past experiences snorkelling and diving in different reefs, different persons shared the opinion that in incisions and their surroundings the corals appeared more diverse than in the other areas. Despite of what was thought, the reef front heterogeneity presents no statistic correlation either with the Live Coral, number of Genera, nor the Shannon index. Even though where the RFHI is high, a high diversity of corals can be expected. Probably the situation inside the incisions could differ. The samples were taken only in the reef flat and not in the slope nor in the drop-off. Other factors could be affecting the diversity on the reef flat, like the time exposed to air during low tides, and tourists or fishermen walking on top of it, destroying the corals. The relation with the reef front heterogeneity could also be different for other Phyla. Probably the fish diversity could have a higher correlation.

It is worth to mention that during the fieldwork it could be noticed that where there were incisions in the reef front, at least one boat of tourist divers was located. This was more evident near the incisions in front of the Bunaken Village, where more than 15 boats were distinguished at the same moment.

4.1.2. Coral Diversity Pattern

A clear pattern of the Coral Diversity could be identified in the study area. In the coastal fringing reef of Tombariri, the diversity richness was high in most of the area. The zones that presented lower diversity and less live coral cover percentage were in the reef entrances in the east and in the west. The reason for this can be explained with the influence of the turbidity and the fresh water that comes from two small rivers that leads to those areas. Despite of bad practices of fishing evidenced in the area, the coral diversity is still high. Although the fish population and diversity witnessed during fieldwork was much lower in this area than in the Bunaken Island. The importance of this area in the Bunaken National Park is concentrated more in the mangroves and the seagrass, where the endangered Dugong is found.

In the Bunaken Island the diversity pattern could be divided in groups. There was a constant high diversity in the East and in Alung Banua, both facing to the east. In the West and in Liang the diversity was relatively lower. In front of the Bunaken Village, and in the North of the island, the diversity presented both medium and high values. The pressure of tourism could be altering the diversity especially in front of the Bunaken Village, and in Liang. The front of the Bunaken Village is crowded with boats of divers and bottom glass boats. A lot of litter can be evidenced also in the area, and fishing activities from the local community. In the Liang area, the pressure is higher. On the beach there are a lot of tourism services, as accommodation and food. Everyday boats full of tourist come to the area. During weekends and special holidays, more than a thousand tourists can be expected. Some unconscious tourists walk on the reef flat during the low tide damaging and breaking the corals. Also some boats that want to reach the pier inside the lagoon during the low tide get stuck and force the way in or out, causing big damage to the reef.

The same pattern can be appreciated with the similarity index. The west presents the less similar coral genera compared with all the other sites, followed by Liang. This could also have an influence of the ocean currents. A map of Sulawesi with an scale of 1:40 million in the book The Ecology of Sulawesi (Whitten et al., 1987), show the sea surface currents around the island, and it can be observed that throughout the whole year the currents in this area of North Sulawesi go from west to the east. Being the West and Liang exposed directly to these currents are more disturbed, while in the sheltered areas the corals are more stable presenting higher similarity.

5. Conclusions

The genera diversity found in the study area is very high. 44 hard coral genera were sampled. 33 genera were found in Tombariri and 37 in the Bunaken Island. *Porites* is the most common genera, present in 41 LI, followed by *Goniastrea* and *Favites* with 33 and 34 LI respectively.

The diversity of the Coral genera presents no significant relation with the reef front heterogeneity, no matter what scale we use. As discussed in the previous chapter this could differ if the diversity samples are taken inside the incisions of the reef front.

The Coral reef diversity has a significant but low correlation with the distance to the reef front. This shows that the location of the LI in relation to the reef front doesn't have a mayor effect on the diversity results.

Still there is no relation on the diversity of the corals between the tourism and community management zones. The division and the regulations of the different management levels apparently are still not clear.

There is a strong relation between the coral reef diversity and its geographic location. This is confirmed with the low similarity in species according to the location of the samples.

6. Recommendations

- The use of mobile GIS for benthic mapping is a tool that facilitates the work and improves the results; therefore its use is recommended for future studies.

- Further study with scuba diving equipment to sample on the wall edge, deeper on the reef slope, and inside the incisions should be done.

- The study of coral diversity in a genera level can show a good idea on how diverse a reef is, making the research faster and easier in case the knowledge of the species in the area is low.

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8. Appendices

8.1. Appendix 1: LI samples

Sheet ID	X	Y	LC	Nr. of genera	Shannon Index
1	677921	156175	31.30%	7	1.76
2	681040	156880	1.80%	1	0.00
3	681165	156946	45.20%	5	0.87
4	680577	157214	26.05%	8	1.32
5	677478	155517	3.05%	2	0.45
6	677470	155562	71.85%	18	2.33
7	677487	155613	37.10%	8	1.69
8	677903	156307	16.30%	6	1.40
9	678798	156843	51.65%	16	2.40
10	681297	156652	5.50%	6	1.71
11	681093	157114	23.45%	11	1.81
12	681209	156652	0.15%	1	0.00
13	696534	176916	67.60%	13	1.77
14	696686	178333	62.80%	5	0.45
15	693303	180655	67.00%	6	0.83
16	698111	179384	67.10%	12	1.95
17	698328	177678	69.95%	17	2.10
18	697879	176248	51.30%	12	1.86
19	693984	180800	49.25%	15	1.94
20	695001	180199	43.15%	7	1.11
21	697598	176296	36.05%	13	1.70
22	697323	176374	19.95%	8	1.41
23	697043	176429	28.30%	7	1.41
24	696700	180056	33.65%	10	1.87
25	692930	179689	9.85%	6	1.50
26	692836	179337	30.05%	6	1.53
27	692750	178388	44.65%	8	1.12
28	695291	178974	28.40%	5	1.19
29	696757	178065	12.10%	7	1.35
30	692910	177908	66.80%	9	0.96
31	693382	177916	17.75%	9	1.96
32	693544	178469	68.00%	14	2.07
33	694490	178937	23.80%	12	2.16
34	696758	177526	44.60%	8	1.26

Sheet ID	X	Y	LC	Nr. Of Genera	Shannon Index
35	696651	176636	68.80%	19	2.34
36	698395	178628	62.25%	17	2.20
37	698441	176708	69.70%	18	1.90
38	696175	178947	32.90%	5	0.94
39	694889	178800	80.25%	15	1.86
40	677669	155520	57.35%	13	2.05
41	677915	155430	11.85%	6	1.66
42	679668	157111	78.20%	15	2.05
43	680069	157201	60.40%	13	1.62
44	679138	156978	75.40%	15	2.01
45	678212	156551	52.45%	14	1.88

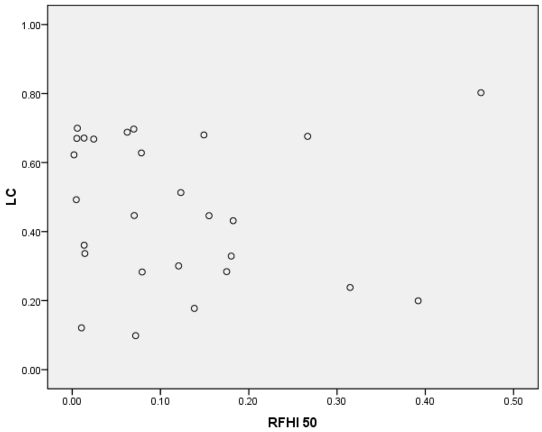
8.2. Appendix 2: List of genera

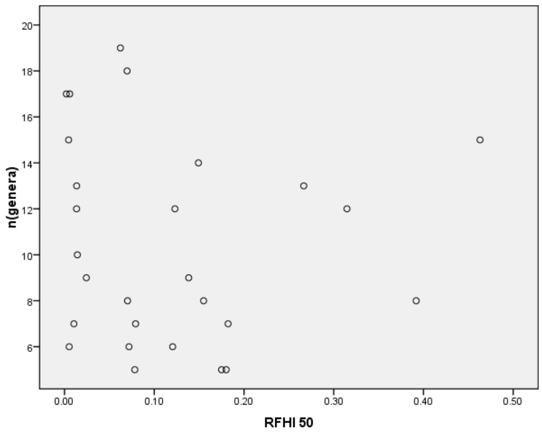
Genus	Number of samples with the genus
Acanthastrea	2
Acropora	29
Alveopora	1
Anacropora	3
Astreopora	15
Caulastrea	1
Ctenactis	3
Cycloseris	2
Cyphastrea	13
Diploastrea	7
Echinopora	4
Euphyllia	1
Favia	21
Favites	34
Fungia	8
Galaxea	22
Goniastrea	33
Goniopora	17
Hydnophora	2
Isopora	9
Leptastrea	13
Leptoria	1
Leptoseris	1
Lobophyllia	12
Merulina	1
Montastrea	20
Montipora	26
Oulophyllia	3
Oxypora	4
Pachyseris	5
Pavona	8
Pectinia	5
Platygyra	2
Pocillopora	17
Porites	41
Psammocora	2
Seriatopora	2
Siderastrea	1
Stylocoeniella	7
Stylophora	22
Symphyllia	18
Tubastrea	2
Turbinaria	4
Heliopora	4

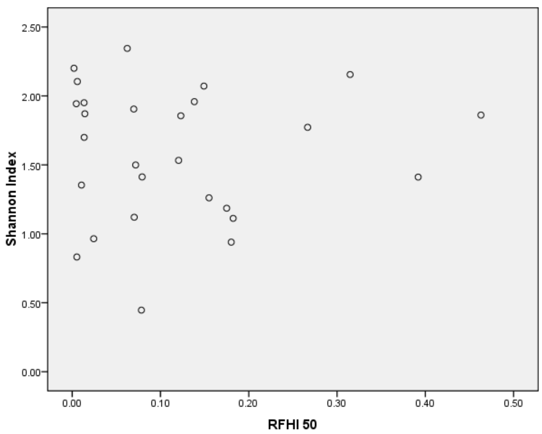
8.3. Appendix 3: RFHI Scatter plots

RFHI 50m.

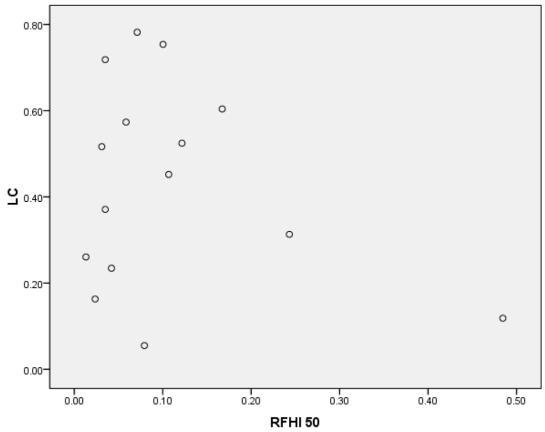
Bunaken Island:

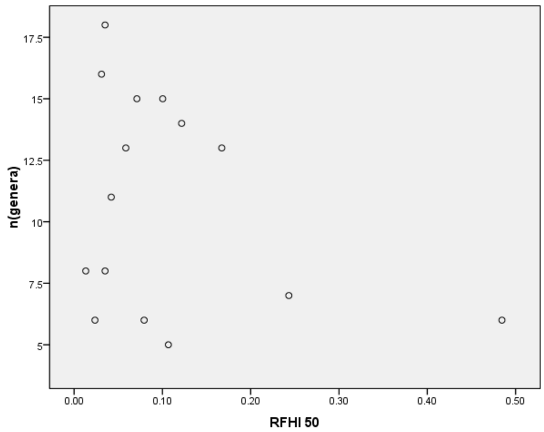


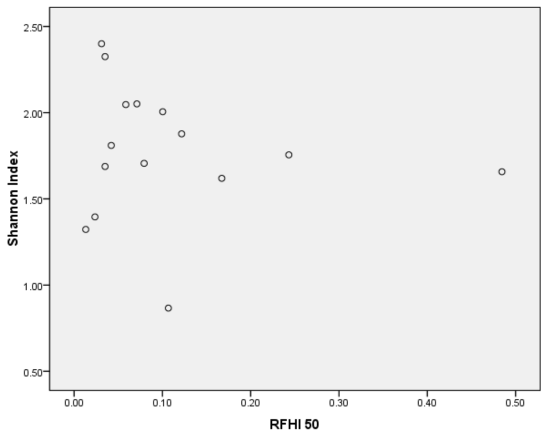




Tombariri:

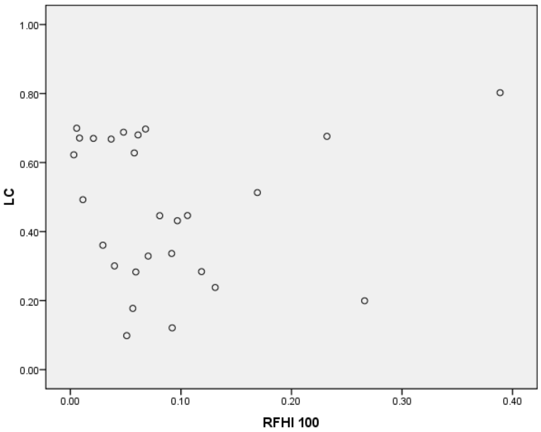


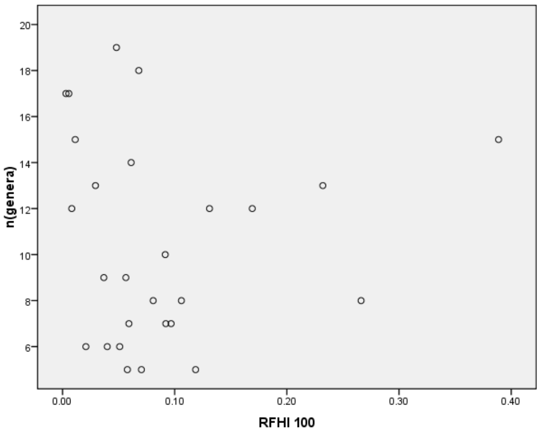


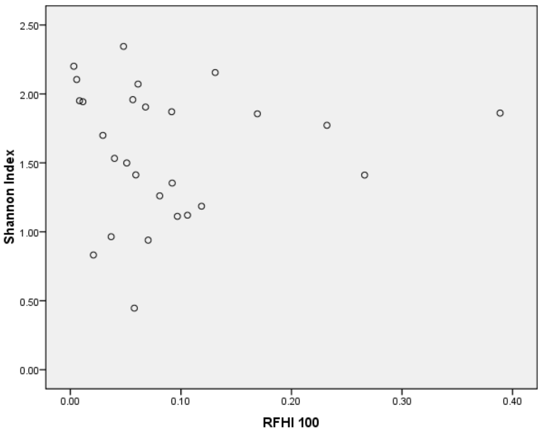


RFHI 100 m.

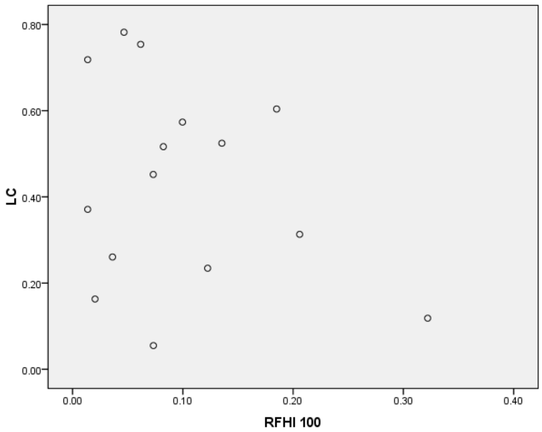
Bunaken Island:

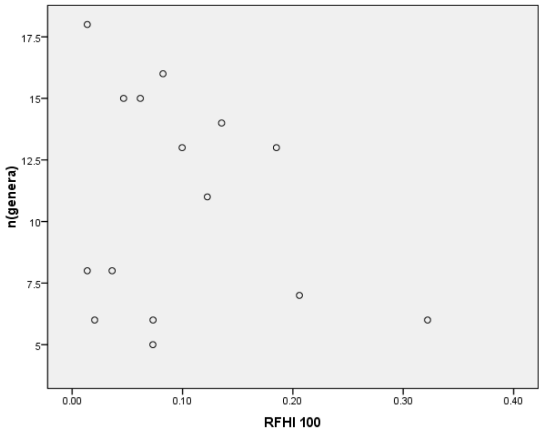


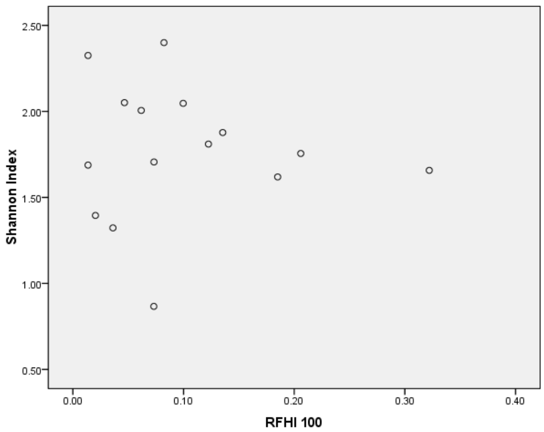




Tombariri:

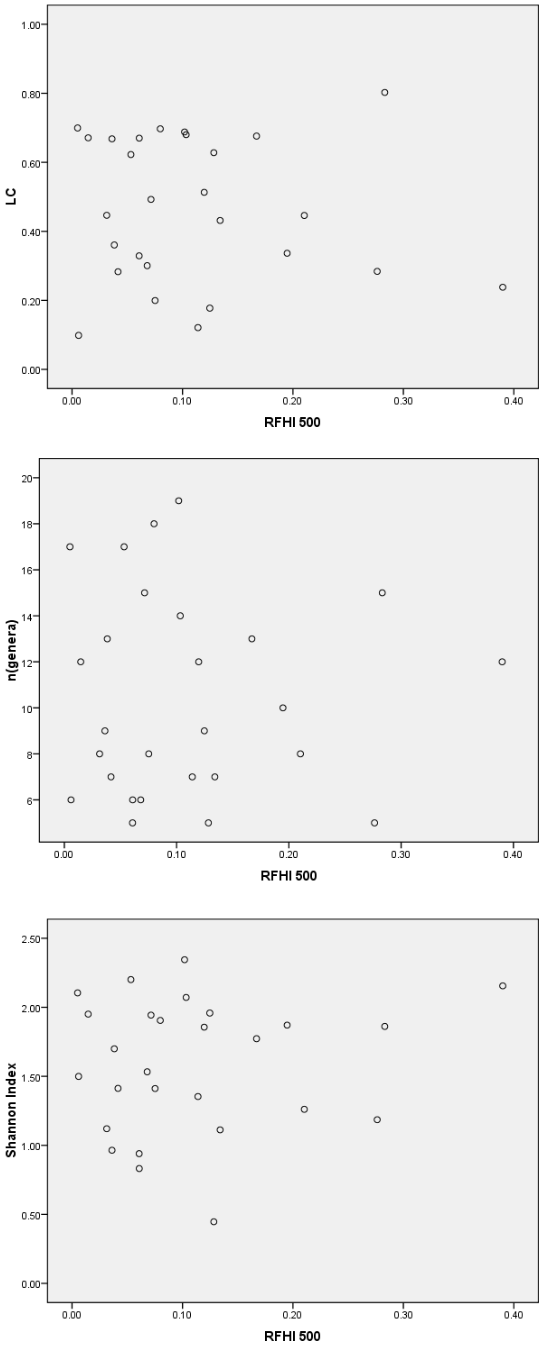






RFHI 500 m.

Bunaken Island:



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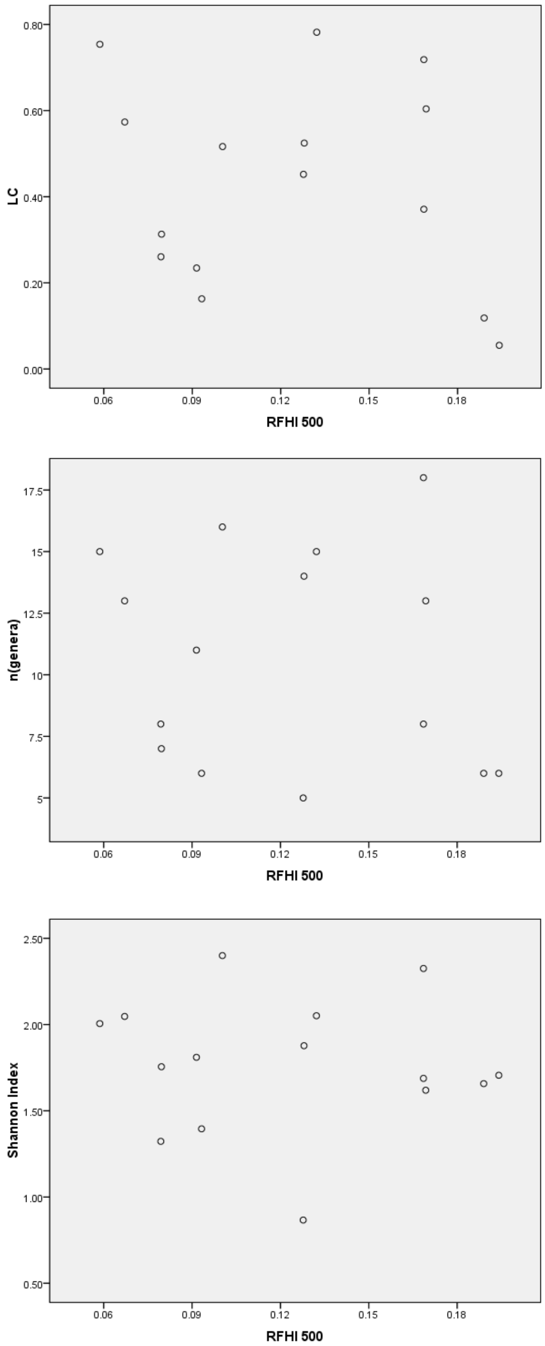

8.4. Appendix 4: Sørensen similarity index

			BUNAKEN																										
			East				North			West					Alung Banua					Liang				Bunaken Village					
			16	17	36	37	19	20	24	15	25	26	27	30	28	31	32	33	39	14	29	34	38	13	18	21	22	23	35
BUNAKEN	East	16																											
		17	0.62																										
		36	0.62	0.41																									
		37	0.53	0.63	0.51																								
	North	19	0.67	0.63	0.56	0.73																							
		20	0.32	0.33	0.25	0.32	0.27																						
		24	0.45	0.52	0.52	0.50	0.48	0.59																					
	West	15	0.44	0.43	0.35	0.42	0.38	0.31	0.63																				
		25	0.33	0.35	0.43	0.42	0.38	0.46	0.75	0.50																			
		26	0.22	0.26	0.35	0.25	0.38	0.31	0.50	0.17	0.50																		
		27	0.30	0.32	0.48	0.38	0.43	0.40	0.44	0.29	0.43	0.57																	
		30	0.57	0.54	0.62	0.52	0.58	0.38	0.74	0.53	0.53	0.40	0.35																
	Alung Banua	28	0.47	0.45	0.36	0.43	0.50	0.17	0.40	0.36	0.55	0.55	0.46	0.43															
		31	0.48	0.38	0.54	0.59	0.58	0.25	0.63	0.53	0.53	0.27	0.47	0.56	0.43														
		32	0.54	0.65	0.45	0.63	0.69	0.29	0.50	0.30	0.40	0.40	0.36	0.52	0.53	0.70													
		33	0.67	0.69	0.55	0.67	0.74	0.42	0.64	0.56	0.56	0.22	0.40	0.67	0.47	0.67	0.69												
		39	0.44	0.50	0.56	0.55	0.40	0.18	0.48	0.48	0.38	0.29	0.43	0.50	0.40	0.50	0.48	0.52											
	Liang	14	0.47	0.36	0.27	0.26	0.30	0.17	0.27	0.36	0.18	0.18	0.31	0.29	0.40	0.43	0.42	0.47	0.30										
		29	0.32	0.42	0.42	0.48	0.36	0.29	0.59	0.62	0.62	0.31	0.40	0.50	0.33	0.38	0.29	0.53	0.45	0.17									
		34	0.50	0.56	0.40	0.54	0.61	0.53	0.67	0.43	0.57	0.29	0.38	0.71	0.46	0.59	0.55	0.70	0.35	0.31	0.40								
		38	0.35	0.45	0.27	0.26	0.40	0.17	0.40	0.36	0.55	0.18	0.31	0.43	0.40	0.43	0.42	0.47	0.20	0.20	0.33	0.62							
	Bunaken Village	13	0.64	0.67	0.47	0.52	0.64	0.30	0.43	0.53	0.21	0.21	0.29	0.55	0.44	0.45	0.52	0.56	0.43	0.33	0.30	0.48	0.44						
		18	0.75	0.76	0.55	0.67	0.74	0.42	0.55	0.44	0.44	0.33	0.40	0.67	0.59	0.57	0.62	0.67	0.37	0.35	0.42	0.70	0.47	0.72					
		21	0.64	0.53	0.60	0.58	0.64	0.20	0.52	0.42	0.42	0.21	0.19	0.64	0.33	0.45	0.52	0.64	0.50	0.11	0.60	0.57	0.44	0.62	0.56				
		22	0.60	0.48	0.48	0.46	0.70	0.13	0.33	0.43	0.43	0.57	0.38	0.47	0.62	0.35	0.55	0.50	0.35	0.15	0.40	0.38	0.46	0.57	0.60	0.57			
		23	0.42	0.42	0.50	0.48	0.45	0.43	0.59	0.46	0.77	0.31	0.53	0.50	0.50	0.63	0.48	0.53	0.36	0.17	0.57	0.67	0.67	0.40	0.63	0.50	0.53		
		35	0.58	0.67	0.67	0.65	0.71	0.38	0.62	0.48	0.40	0.24	0.52	0.64	0.33	0.64	0.67	0.77	0.59	0.33	0.46	0.59	0.42	0.69	0.65	0.69	0.44	0.54	
TOMBARIRI	West to East LIT	6	0.53	0.63	0.46	0.67	0.67	0.24	0.50	0.50	0.42	0.25	0.38	0.44	0.43	0.59	0.56	0.60	0.55	0.26	0.48	0.46	0.26	0.52	0.67	0.52	0.46	0.48	0.65
		7	0.50	0.56	0.40	0.46	0.52	0.13	0.33	0.43	0.43	0.43	0.38	0.47	0.77	0.35	0.55	0.60	0.43	0.46	0.40	0.38	0.31	0.48	0.60	0.38	0.63	0.40	0.44
		40	0.56	0.60	0.53	0.58	0.57	0.20	0.35	0.42	0.42	0.21	0.38	0.45	0.44	0.55	0.67	0.72	0.71	0.33	0.40	0.38	0.33	0.54	0.48	0.62	0.57	0.50	0.69
		41	0.33	0.43	0.26	0.33	0.48	0.31	0.50	0.50	0.17	0.50	0.29	0.40	0.36	0.27	0.30	0.33	0.19	0.36	0.31	0.43	0.18	0.53	0.44	0.32	0.43	0.15	0.32
		1	0.63	0.58	0.42	0.48	0.55	0.29	0.59	0.77	0.46	0.31	0.40	0.63	0.67	0.50	0.48	0.63	0.55	0.50	0.57	0.53	0.33	0.60	0.63	0.50	0.53	0.43	0.54
		8	0.33	0.26	0.26	0.25	0.29	0.15	0.25	0.17	0.33	0.33	0.43	0.27	0.55	0.27	0.30	0.33	0.29	0.36	0.31	0.29	0.18	0.32	0.33	0.21	0.29	0.31	0.24
		45	0.62	0.58	0.65	0.63	0.76	0.29	0.50	0.50	0.40	0.40	0.45	0.52	0.53	0.52	0.57	0.69	0.62	0.21	0.48	0.45	0.32	0.74	0.62	0.74	0.73	0.48	0.73
		9	0.50	0.61	0.42	0.41	0.45	0.26	0.46	0.45	0.36	0.18	0.33	0.48	0.29	0.40	0.40	0.57	0.52	0.29	0.52	0.33	0.29	0.48	0.50	0.48	0.33	0.35	0.57
		44	0.59	0.63	0.63	0.61	0.67	0.27	0.56	0.48	0.48	0.19	0.43	0.58	0.40	0.50	0.48	0.67	0.60	0.20	0.55	0.43	0.40	0.64	0.59	0.71	0.52	0.55	0.76
		42	0.52	0.56	0.63	0.61	0.53	0.36	0.48	0.48	0.38	0.19	0.52	0.50	0.40	0.42	0.34	0.52	0.60	0.20	0.55	0.43	0.30	0.64	0.59	0.64	0.43	0.55	0.71
		43	0.56	0.60	0.60	0.65	0.64	0.40	0.52	0.53	0.42	0.32	0.48	0.55	0.56	0.55	0.52	0.64	0.64	0.22	0.50	0.57	0.33	0.77	0.72	0.69	0.57	0.60	0.75
		4	0.50	0.48	0.40	0.54	0.61	0.27	0.56	0.43	0.43	0.14	0.38	0.59	0.46	0.59	0.45	0.60	0.26	0.46	0.27	0.63	0.46	0.48	0.60	0.38	0.25	0.40	0.52
		11	0.52	0.64	0.43	0.48	0.54	0.33	0.38	0.35	0.24	0.35	0.42	0.50	0.50	0.20	0.40	0.52	0.54	0.25	0.44	0.42	0.38	0.75	0.61	0.58	0.53	0.33	0.60
		3	0.47	0.45	0.36	0.43	0.50	0.00	0.27	0.55	0.36	0.36	0.31	0.43	0.80	0.43	0.42	0.47	0.40	0.40	0.33	0.31	0.40	0.56	0.59	0.33	0.62	0.33	0.33
		10	0.33	0.43	0.17	0.33	0.38	0.46	0.38	0.17	0.17	0.33	0.14	0.40	0.36	0.13	0.40	0.44	0.10	0.36	0.15	0.43	0.00	0.32	0.44	0.21	0.29	0.15	0.32

			TOMBARIRI														
			West to East LIT														
			6	7	40	41	1	8	45	9	44	42	43	4	11	3	10
TOMBARIRI	West to East LIT	6															
		7	0.54														
		40	0.58	0.57													
		41	0.33	0.29	0.11												
		1	0.56	0.67	0.50	0.46											
		8	0.42	0.57	0.32	0.17	0.46										
		45	0.63	0.55	0.74	0.50	0.57	0.30									
		9	0.71	0.33	0.55	0.27	0.52	0.36	0.53								
		44	0.67	0.43	0.71	0.29	0.55	0.29	0.76	0.65							
		42	0.61	0.43	0.64	0.29	0.55	0.29	0.69	0.52	0.80						
		43	0.65	0.57	0.69	0.42	0.60	0.32	0.89	0.48	0.71	0.79					
		4	0.54	0.50	0.29	0.43	0.53	0.43	0.36	0.33	0.52	0.43	0.38				
		11	0.41	0.53	0.50	0.47	0.56	0.35	0.72	0.52	0.62	0.62	0.75	0.32			
		3	0.43	0.77	0.44	0.36	0.67	0.36	0.53	0.29	0.40	0.40	0.56	0.46	0.50		
		10	0.25	0.43	0.21	0.50	0.31	0.17	0.30	0.18	0.19	0.19	0.32	0.29	0.35	0.18	

0 - 0.25
0.25 - 0.50
> 0.50