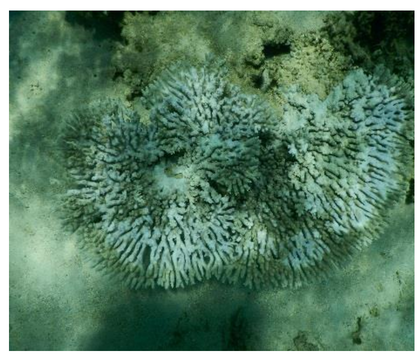
Nation-wide survey of coral bleaching due to temperature stress caused by the El Nino effect

January -December 2016





Executive Summary

Corals are marine invertebrate organisms that live in colonies and coral reefs are formed through the decay of dying corals and the development of new corals. These organisms form ecosystems considered ecological hotspots for their abundance and diversity of species. Over 4,000 species of fish are known to be found in the reefs around the world, and the 2,500 different coral species recorded, provide countless benefits to other organisms. Coral reefs are valued at about USD 375 billion, and up to 500 million people around the world are known to benefit from coral reefs from fishing, consuming fish, eco-tourism, and recreational use. However, corals are facing extreme degradation worldwide from a combination of natural and human-made pressures. Corals require specific conditions to thrive and survive, but due to the intensification of anthropogenic induced climate change variations such as temperature and pH, it is resulting in a widespread degradation and bleaching of corals. Coral bleaching is a phenomenon by which the colourful pigments are lost, and the bare pale skeleton of the coral is exposed giving it a bleached appearance, and thus the name ¨coral bleaching¨. It occurs due to the loss of Zooxanthellae algae living in symbiosis within the tissue of the coral; when the coral undergoes a stress period, the Zooxanthellae algae leave the coral.

The six sites surveyed on a monthly basis were Anse la Raie ALBC, Anse la Raie ALLC, Bain Boeuf, Balaclava, Bel Ombre Kayak, and Bel Ombre Coral Garden. The methodology for this project included substantial literature research, and the gathering and analysis of data. The data on coral bleaching was gathered by carrying out surveys and monitoring each of the six sites one time per month from February 2016 to December 2016. The methodology used for the bleaching monitoring included estimating a 2-meter radius, identifying the coral species present, coral cover, and health status based on Wildlife Conservation Spociety Methodology.

The results showed greatest bleaching during the months of March and April of 2016 for the six sites, which correlates with the 2016 mass bleaching event that took place in the Indian Ocean. Four genera of corals, *Acropora sp., Galaxea fascicularis, Montipora sp.* and *Pocillopora* sp. were the most abundant genera recorded during the study. Notably for both *Pocillopora sp.*, and Acropora sp., 50% and 40% of colony numbers respectively at all sites during the study, were recorded in the medium bleaching range of (10% - 50%).

Table of contents

List of Figures

List of Table

1.Introduction

Found beneath the ocean water in tropical regions, coral reefs provide a habitat for millions of species. Since corals are slow growing organisms, calcifying at maximum rates of 20 cm per year for some species, the complex ecosystem of corals has taken thousands of years to develop into what it is now. Nonetheless, due to natural factors and exacerbating anthropogenic pressure such as climate change: more than 20% of the worlds corals have been degraded beyond recovery and an estimated 70% of the worlds corals is expected to die by the year 2050 if no action is taken.

Corals are found mostly in tropical waters and live in specific water conditions. They are most commonly found in clear, shallow water < 50m, with relatively warm water 18-29°C and salinity of approximately 36‰. Coral reefs cover less than 1% of the planet's surface (Spalding et al., 2001) but, together with marine plants, are responsible for generating 85% of the world's oxygen.

The productivity of coral reefs is dependent on the symbiotic relationship between the coral polyp and its dinoflagellate algae, zooxanthellae, which live within the tissues of the coral. The coral acts as the host or shelter for the zooxanthellae which in exchange photosynthesise and provide the energy-rich compounds which the coral animal needs to survive. Corals can catch food using their tentacles; however, 80% of their food is provided by the zooxanthellae through photosynthesis thus the corals rely on the algae for their survival (Muscatine L, 1990).

However, when sea temperatures increase, the zooxanthellae release harmful oxygen radicals during the processing of incoming light, disrupting the coral-algal relationship. At this point the zooxanthellae, which usually provide the colour to coral tissues, are either expelled from the coral tissue as a response to the stressful conditions or they will degenerate within it. The corals thus appear bleached, as the bright white skeleton is visible through the coral's unpigmented tissue. If the bleaching is not too severe, corals have been known to recover from such events. However, they will only survive a few days without the symbiotic zooxanthellae and if the stress is prolonged they will eventually die.

The extent to which heat stress causes direct physiological damage to corals depends on both environmental and intrinsic factors. While the environmental factors influence the amount of heat stress affecting the corals, intrinsic factors such as genetics determine how much heat stress different species and individuals can tolerate before they die. In recent years, there have been increasing reports of mass bleaching events on reefs around the world. Sea temperature increases of 1-2°C above the long term average maximum are all that are needed to trigger mass bleaching (Hoegh-Guldberg, 1999; Coles and Brown, 2003).

Coral reefs in Mauritius are under threat and have already suffered mass coral bleaching events in 1998 and 2009. These events were caused by high sea water temperatures and resulted in significant loss in coral cover in our lagoons. The last bleaching event in 2009 caused the death of 50% of the corals in the lagoons, some of which have never recovered (Moothien et al 2011). The mass bleaching event of 1998 occurred on a global scale, with mass mortalities of corals in many regions leading to the loss of approximately 16% of the world's reefs (Wilkinson C, 1998). Studies suggested that the severity of mass bleaching events is likely to increase with predicted sea temperature rises and at a rate which may be faster than what the reefs can adjust to. Coral reefs can thus be expected to undergo significant and possibly irreversible changes if sea temperatures continue their upward trend. National Oceanic and Atmospheric Administration (NOAA) reported a global bleaching event and predicted that it would affect Mauritius in February 2016. As a result of the positive Indian Ocean Dipole (IOD) and the El Niño event, coral bleaching is expected to be widespread across the WIO from January to April 2016.

The project "Nation-wide survey of coral bleaching due to temperature stress caused by the El Nino effect" aims to address the upcoming bleaching event that is predicted by NOAA (National Oceanic and Atmospheric Administration) due to occur in February 2016 in Mauritius. The project aims to obtain a nation-wide view of affected areas with a more rigorous quantitative study on selected sites.

The main objectives of the project are;

- *Quantify extend of coral bleaching*
- *Monitor natural recovery of bleached areas*
- *Sensitise users to the threats of coral bleaching due to temperature stress*
  Establish a network of divers to act as opportunistic monitors on reefs used for recreational dive

The project proposes to, establish a network of boat operators and divers, sensitise and train individuals to allow them to identify bleaching as well as understand some of the causes and consequences and record suspected sightings of bleaching. Reef Conservation through this network would be alerted to where and when bleaching occurs. Thus, affected areas will be mapped around Mauritius and select target sites will be chosen where a quantitative study of the extent of bleaching can be conducted. This method implemented by WCS Kenya (Wildlife Conservation society) estimates the percentage of corals bleached within circles of 2m in diameter, three weeks after the first bleaching is observed. The areas will continue to be monitored after the bleaching event to record mortality or recovery of the affected areas.

Four locations and six survey sites in Anse la Raie, Bain Bœuf, Balaclava and Bel Ombre, have been monitored monthly for recovery using this methodology.

2. Action 1: Sensitisation on El Nino, coral bleaching, it's causes and consequences

A sensitisation and teaching presentation was prepared on coral bleaching and El Nino events for a training session scheduled for the 26th of January 2016. This event was held at the Mauritius Underwater Group and was open to the public but aimed specifically at dive centres, boat operators. Invitations were sent to Mauritius Underwater Group, Mauritius Scuba Diving Association, Mauritius Oceanographic Institute, Albion Fisheries Research Center, Mauritius Marine Conservation Society, Eco-Sud/Lagon Bleu as well as shared through social media.

The presentation focused on; what is coral bleaching, the El Nino Effect, how to identify bleached coral and how divers and snorkelers could participate in the project. The event was attended by approximately 100 persons.

During the first sensitisation event (described above), data sheets were distributed to those who were interested in participating and an e-mail list was created, with 48 people signing up. This e-mail list was used to send regular updates as well as receive information from this network. (Annex 1: Data Sheet)

3. Action 2: Create a watch network of participants including boat houses, diving centres, individuals and other NGOs interested in taking part in the project.

Through this network, bleaching was reported 12 different locations from February to April 2016 (Table1) the lagoons were the most affected with very few reports from sites beyond the reef. The most affected coral were the branching and tabular corals. Only a few massive and encrusting corals were reported as affected. The results were presented to the Mauritius Underwater Group on the 10th May 2016.

Date	Location	Site	Reef Type
4/02/2016	Balaclava	Lagoon, from public beach	Patch
5/02/2016	Bain Boeuf	Lagoon	Patch/Reef Flat
7/02/2016	Pointe Esny	Lagoon, close to the beach	Patch
14/02/2016	Mon Choisy	Behind ile aux folles	Reef Crest
17/02/2016	Bel Ombre	“site1” patch reef	Patch reef
17/02/2016	Bel Ombre	Coral Garden	Patch Reef
17/02/2016	Bel Ombre	Between “site1” and “site2”	Patch Reef
21/02/2016	Mahebourg	Between Ile de la Passe and Vacoas	Reef Crest
05/03/2016	Blue Bay	Marine Park	Lagon
12/03/2016	Pointe esny	Lagoon	Patch
13/03/2016	Pointe esny	Between Ile de la Passe and Vacoas	Patch Reef
14/03/2016	Belle mare	Lagoon	Patch
15/03/2016	Blue Bay and Pointe Esny	Lagoon	Lagoon patch reef
21/03/2016	Bain boeuf	Lagoon, from public beach	Patch
26/03/2016	Baie du tombeau	7 Patch	Patch Coral
26/03/2016	Pointe Esny	Magasin	Patch

26/03/2016	Pointe Esny	Ile au Phare	Patch
30/03/2016	Flic en Flac	Cathedral	Dive site, outside lagoon
30/03/2016	Flic en Flac	Aquarium	Dive site, outside lagoon
30/03/2016	wolmar	Public beach	Reef crest
30/0/2016	Flic en Flac	Public Beach	Reef Crest
30/03/2016	Albion	Public beach	Reef Crest
01/04/2016 01/04/2016	Albion	Public beach	Reef Slope?
01/04/2016	Albion	Outside reef	Reef Slope
02/04/2016	Black River	Bubble coral	Dive site in the pass
09/04/2016	Black River	Gorgone	Dive site outside the lagoon
09/04/2016	Black River	Grand Falaise	Dive site outside the lagoon

Table 1: location for coral bleaching - February to April 2016

Overall, professional divers were a useful source of information but would generally relay the information verbally rather than fill in and send back the data sheets. However, many persons were interested in participating in the programme and would be keen to help again in the future.

4. Action 3: Recording of extend of bleaching

4.1: Bleaching Monitoring Methodology

Methodology

The method chosen is described in the Wildlife Conservation Society (WCS) monitoring manual and Field Guide for Monitoring Coral Reef Ecosystems (McClanahan, 2008). This method has been used in 9 Western Indian Ocean countries.

The project team are working in collaboration with WCS and contributing to the regional data collection on the occurrence of bleaching. This is a rapid assessment method described in McClanahan et al 2001, and McClanahan 2004, and has been designed for estimating bleaching by evaluating the colour intensity or bleaching responses of haphazardly selected corals. Because of its simplicity and speed, it can cover large areas of reef and can be conducted with little equipment.

Extent of bleaching is recorded as follows:

- None
- Low - less than 10% - only a few corals are bleached

- Medium - 10-50%, up to half the coral seen are bleached
- High - 50-90% most of the corals are bleached but some are not
- Extreme - over 90% all the corals seen are bleached

With the bleaching data from the slates, relative density (RD) of each taxa and category (c) are calculated. This is used to calculate the Bleaching index for each genus and each site's bleaching susceptibility index.

- Unbleached (Normal colouration) = c1
- Pale (Lighter colour than usual) = c2
- 0-20% of the surface bleached = c3
- 20-50% of the surface bleached = c4
- 50-80% of the surface bleached = c5
- 80-100% of the surface bleached = c6
- Recently dead = c7

Bleaching index (BI) = $(0c1 + 1c2 + 2c3 + 3c4 + 4c5 + 5c6 + 6c7)/6$

Bleaching susceptibility index = the sum of bleaching index of each genus times the relative density of each genus.

Monitoring Methodology

To survey the coral colonies in each site the observer was required to estimate a 2- meter radius and to visually determine the percentage of coral cover present in the area. The state of each coral colony was determined based on colour categorisation using the visual guidelines described in Table 2 below.

A distance of approximately 2m was left between each survey replica and was determined by swimming away from the first survey area in a random direction without looking down at the substrate. To increase the reliability of the data, a total of 20 replicates were conducted for each site per visit.

Guideline	Picture Reference
Number of colonies **normal**	
Number of colonies **pale**	
Number of colonies bleached **0 to 20%**	
Number of colonies bleached **20 to 50%**	
Number of colonies bleached **50 to 80%**	
Number of colonies bleached **80 to 100%**	
Number of colonies **dead**	

Table 2: Coral Bleaching Guidelines Methodology

Materials

The materials used during each monitoring visit can be seen below in Table 3

Materials	Function
Waterproof Slate	To annotate observations
Pencil	To write on waterproof slate
Coral Finder Book	To identify unknown corals
Snorkelling Equipment	To swim effectively
Boat	To reach certain sites

Table 3: List of equipment

Data Gathering

Each site was visited once a month to monitor for coral bleaching. The surveys were done by the research team of Reef Conservation. The coordinates and surface area of each site where bleaching was monitored can be found in Table 4, along with the general location and water depth.

Site	Coordinates	Area	Location	Depth
Anse la Raie: ALBC	19°58'44.0"S - 57°37'52.0"E	2,500 m^2	Northern Mauritius	3 meters
Anse la Raie: ALLC	19°58'44.2"S - 57°37'57,5"E	2,800 m^2	Northern Mauritius	3 meters
Bain Boeuf	19°59'4.63"S -57°35'50.24"E	5,500 m^2	Northwestern Mauritius	3 meters
Balaclava	20°4'51.35"S - 57°30'38.27"E	4000 m^2	Western Mauritius	2 meters
Bel Ombre Kayak	19°58'42.56"S - 57°38'6.52"E	5,500 m^2	Southern Mauritius	3 meters
Bel Ombre Coral Garden	20°51'06.64"S - 57°41'21.03"E	3,400 m^2	Southern Mauritius	1 meters

Table 4: Researched sites Details

Map of survey locations

Six sites were surveyed; 2 in Anse La Raie, 2 in Bel Ombre, 1 in Balaclava and 1 in Bain Boeuf.

Data Analysis

The data was entered into an Excel file and analysed to determine the percentage of coral cover and the percentage of colonies per species bleached. The data was also used to determine the bleaching index. The Bleaching Index (BI) is a tool used to determine the overall bleaching severity of a species or a site. (Annex 3: Excel Data Sheet)

4.2: Training Session

The project team organised a training session for selected individuals from the Ministry of Ocean Economy, Mauritius Oceanography Institute, the University of Mauritius and other NGOs to demonstrate; the use of the "Coral Finder" to identify coral to genus level, the monitoring methodology used, data entry in the data base and analysis, and to further widen the network of observers in Mauritius. The training took place at Reef's Outreach Centre Nauticaz, located in Sensimar Hotel in Anse La Raie, on the 16th and 17th November from 10 am to 3pm. Below is the agenda for the workshop:

Program of training:

Wednesday the 16th November 2016 10h-15h

- 10h00- 12h00: Classroom workshop on how to use the “coral finder” manual and training on the bleaching methodology
- 12h00-13h00: Lunch
- 13h00 – 14h00: Field trip in Anse la Raie Lagoon ALLC/ALBC Site) to practice using the “coral finder”
- 14h00-15h00: Debriefing of the day

Thursday 17th November 2016 10h-15h

- 10h00- 12h00: Field trip to practice the method for recording bleaching (Bain Boeuf site)
- 12h00-13h00: Lunch
- 13h00 – 14h30: Data entry session
- 14h30 – 15h00: Debriefing of the training

6 persons took the opportunity to follow this training.

- 1 representative of Mauritius Oceanography Institute
- 1 representative Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping/ The Albion Fisheries Research Centre
- 1 student from the University of Mauritius
- 1 representative of NGO: Eco-Sud and 2 Reef Staff

An excel file including the field sheets and the data analysis sheets were sent to each participant.

Working Session in Nauticaz

Field trip session

Use the Coral Finder

All the participants

5. Action 4: Monitoring of recovery where bleaching occurs

The four locations and six sites in Anse la Raie, Bain Bœuf, Balaclava and Bel Ombre, have been monitored monthly for recovery using the same method as described above. Results were compared for 2016 and 2017.

6. Results – Action 3 Recording of extend of bleaching and Action 4 Monitoring of recovery where bleaching occurs

6.1: Bleaching Monitoring

Over the time period, February to December2016, 1206 observations were made, recording 24 genera and 463 colonies of coral with an average coral cover of 75% (with a standard deviation of 11.86%) for all the sites. Coral species diversity, for the sites was found to be an average of 0.568 with a standard deviation of 0.218, a relatively large deviation. The average site susceptibility was found to be 22.83 with a standard deviation of 4.17.

Anse La Raie Sites (In Northern Mauritius)

Bleaching and Temperature

Graphs shown below.

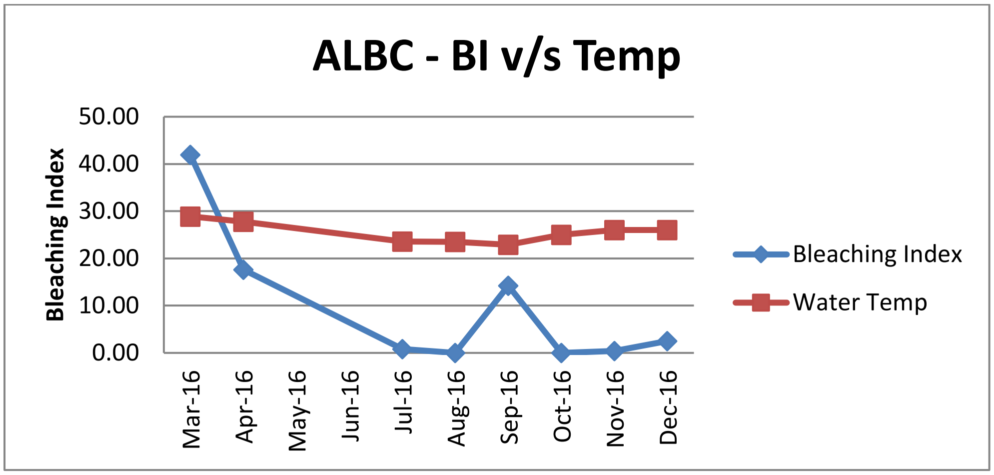


Figure 1: ALBC temperature + Bleaching analysis

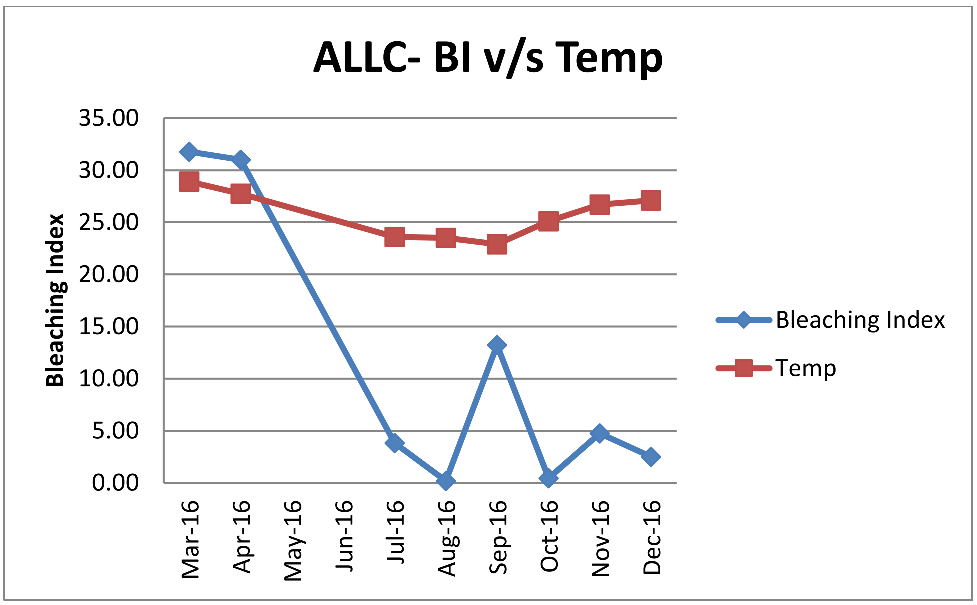


Figure 2: ALLC temperature + Bleaching analysis

As can be seen in Figure 1 and 2, the greatest bleaching incidences for both ALBC and ALLC were in March and April 2016.

In March 2016 ALBC showed BI (bleaching index) of 41.93; and ALLC showed a BI of 31.78. In April 2016 as water temperatures decreased, the BI at both sites started to decrease; ALBC decreased substantially to a BI of 17.60, while ALLC decreased slightly to a BI of 31.01. The months of March and April 2016 were at the end of the 2016 mass coral bleaching event that took place in the WIO (Western Indian Ocean).

The Bleaching Index at each site continued to decrease as sea surface temperatures decreased as expected. However, in September 2016, an unusual increase in BI was recorded for both ALBC and ALLC with indices of 13.23 and 14.21 recorded respectively. This was unusual as the water temperature was well below 25°C at each site.

Bain Boeuf Site (In North Western Mauritius)

Bleaching and Temperature:

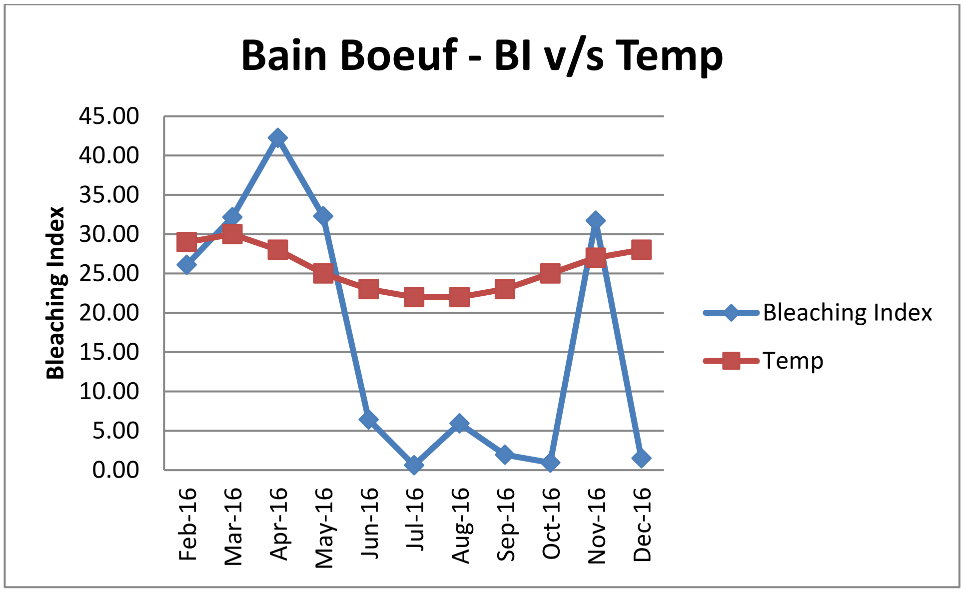


Figure 3: Bain Boeuf temperature + Bleaching analysis

Just like the sites in Anse la Raie, Bain Boeuf suffered from severe bleaching following the 2016 mass bleaching event. The BI was above 30 from March to May in 2016, with a maximum of 42.26 in April. The SST was not measured until September 2016, but as it can be seen in Figure 3 the SST logically follows the same trend as the air temperature, it has been assumed that the SST during March, April, and May 2016 was between 28° and 30° C.

The BI and temperatures dropped during the winter months, however, in November 2016 as temperatures rose to about 27°C a peak of 31.72 was recorded for BI. This coincides with the annual mass coral spawning that takes place during the months of October and November in Mauritius, this reproductive stage for corals increases their vulnerability to stress and possibly their susceptibility to bleaching as SST increase in the summer months.

Balaclava Site (in Western Mauritius)

Bleaching and Temperature

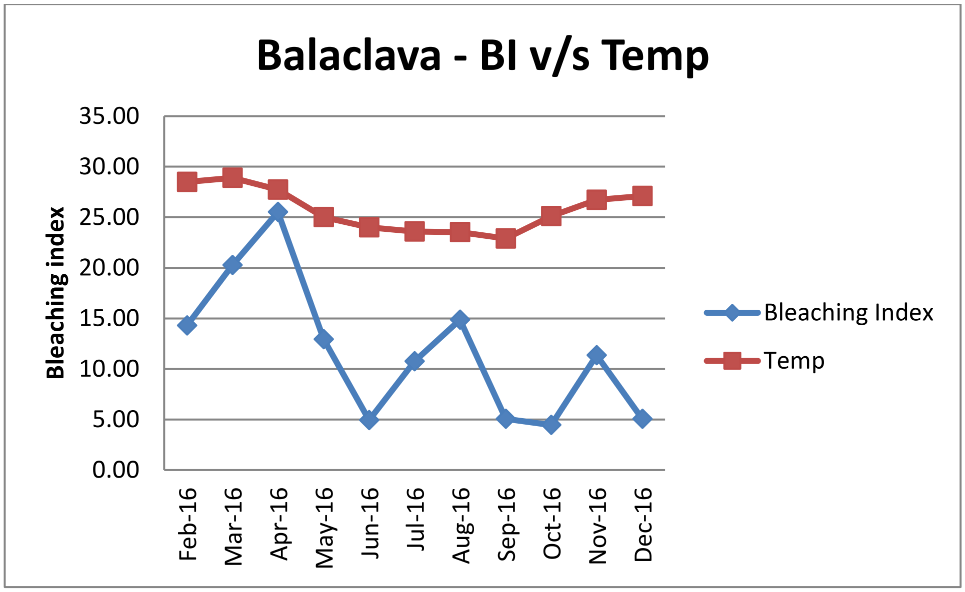


Figure 4: Balaclava temperature + Bleaching analysis

It can be noted from the results shown in Figure 4, that corals in the Balaclava site were affected to a lesser degree than those in the Anse La Raie and Bain Boeuf sites with a high BI of 20.26 in March and 25.52 in April. In comparison to Bain Boeuf, Balaclava was more resilient during the 2016 mass bleaching event with a lower BI and a faster recovery with relatively lower levels in May. The BI of 11.34 in November 2016 can be attributed to the vulnerability of corals during the coral spawning period.

Bel Ombre Site (In southern Mauritus)

Bleaching and Temperature

Two sites were investigated in Bel Ombre: Kayak and Coral Garden

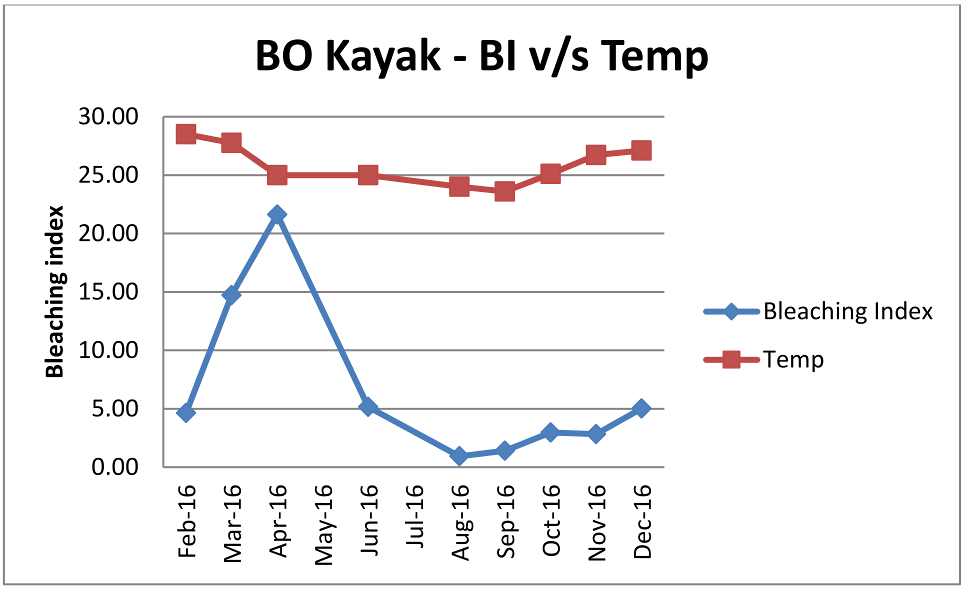


Figure 5: Bel Ombre Kayak temperature + Bleaching analysis

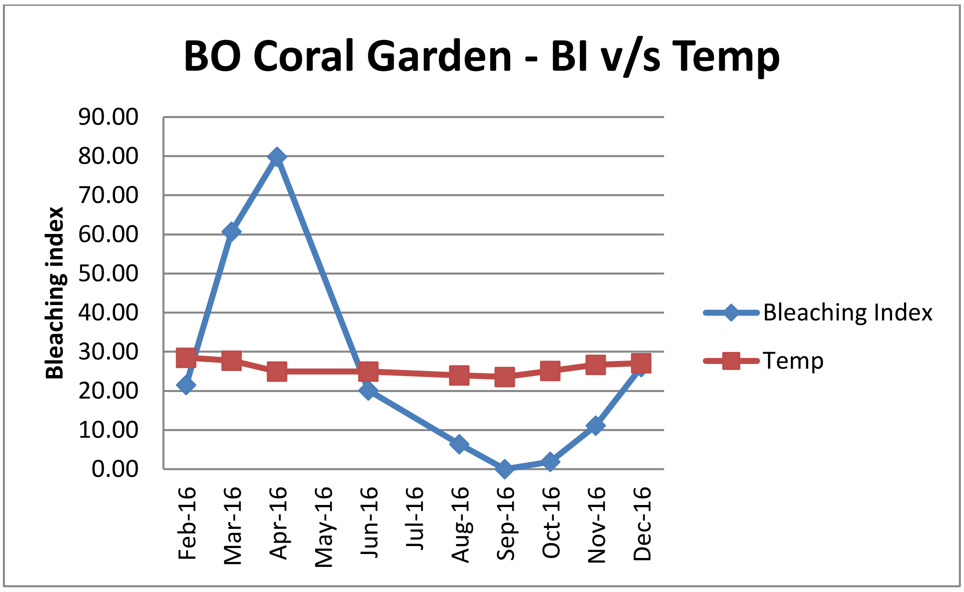


Figure 6: Bel Ombre Coral Garden temperature + Bleaching analysis

As it can be seen in Figure 5 and 6, the 2016 mass bleaching event had the biggest impact on the Coral Garden site in March, with a BI of 60.68. For the Kayak site a BI of 14.71 was recorded for the same period.

In April, a BI of 79.89 was recorded for the Coral Garden site, with 96.50% of the coral colonies in the site bleached. In comparison, the Kayak site had a BI of 21.62, even though the two sites are only about 50 meters away from each other, the results are dramatically different. The water depth at the Coral Garden site is only 1 meter, whereas at the Kayak site it is 3 meters. This difference in water depth can account for the difference in bleaching indices recorded for these sites. Additionally, the Coral Garden site has very low biodiversity and is mostly composed of *Acropora sp* which were amongst the first genera to show signs of bleaching. High biodiversity can increase the resilience of a site, while low biodiversity depending on the species present can indicate the opposite. The BI was low in the winter months of 2016, but as temperatures reached 28°C in December the BI rose to 26.07 for the Coral Garden site, indicating the susceptibility of the coral and site to future bleaching.

All Sites

Fig 1. Shows the percentage of colonies bleached for all species at all sites by bleaching class. A total of 59 observations were included in the comparison which found that most colonies of corals were recorded as showing either 1-10% or 10-50% of bleaching. Only 3% of colonies observed showed over 50% of bleaching.

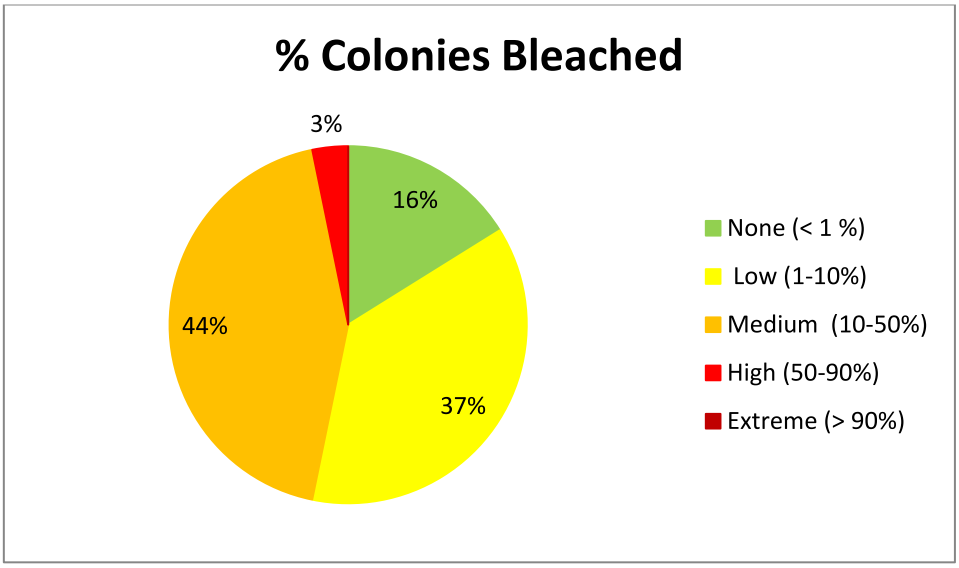


Figure 7: Percentage of colonies bleached for all species at all sites by bleaching class - February to December 2016

Below, the bleaching profile can be determined for each genus observed over all monitoring sites during the survey period of February to December 2016. In Fig 8: The Bars represent the percentage of each genus bleached and to what extent or bleaching class, during the survey period of February to December 2016.

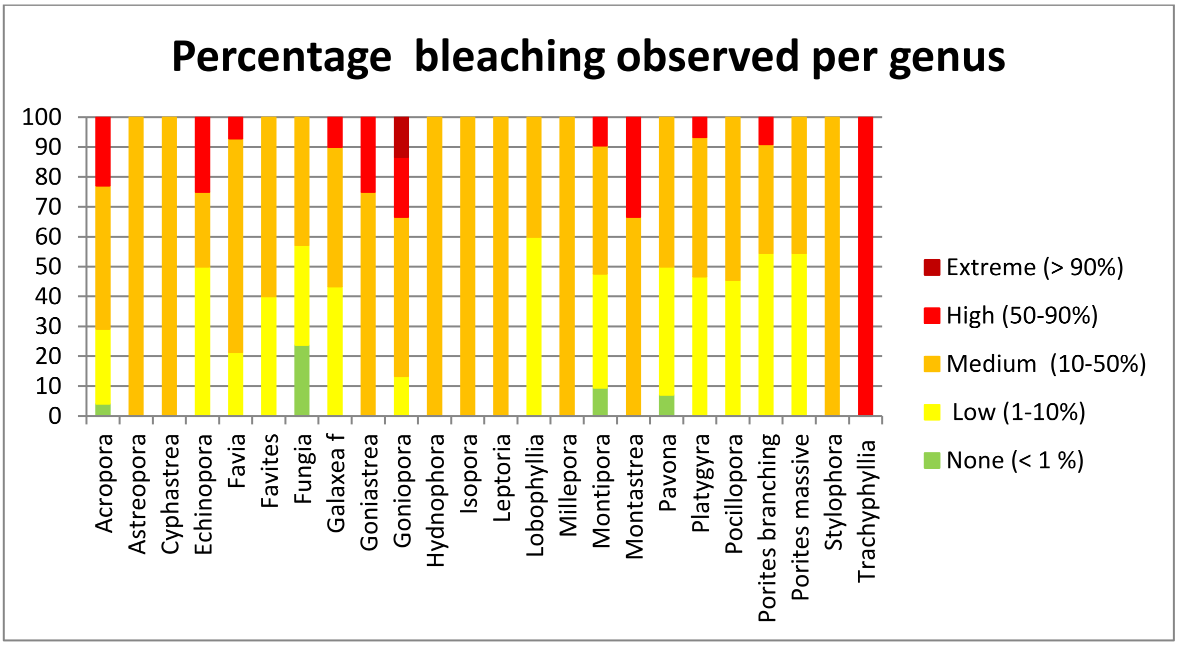


Figure 8: Percentage bleaching observed per genus – February to December 2016

Genus	Number of colonies surveyed Feb to December 2016
Acropora sp.	1396
Astreopora sp.	6
Cyphastrea sp.	1
Echinopora sp.	4
Favia sp.	67
Favites sp.	27
Galaxea sp.	461
Goniastrea sp.	13
Goniopora sp.	64
Hydnophora sp.	1
Isopora sp.	1
Leptoria sp.	9
Lobophyllia sp.	26
Millepora sp.	3
Montipora sp.	2645
Montastrea sp.	16
Pavona sp.	300
Platygyra sp.	148
Pocillopora sp.	335
Porites sp. Branching	445
Porites sp Massive	310
Stylophora sp.	1
Trachyphyllia	1

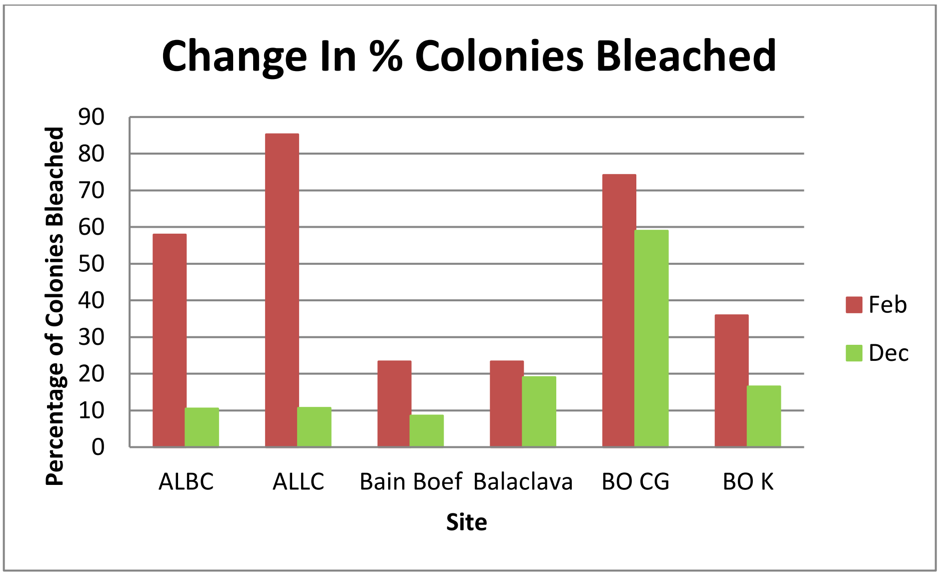


Figure 9: Change in percentage colonies bleached

Fig 9 shows the change in percentage of colonies showing bleaching at each site between February and December 2016. The most significant difference can be seen at the Anse La Raie sites, but all 6 sites showed a decrease in bleaching by December.

Figure 10: Bleaching intensity per site – February-December 2016

In Fig 10 above, the Pie charts comparing bleaching intensity levels at each site over the survey period of February to December 2016. All sites show primarily low and medium levels of bleaching, except for the Coral Garden site in Bel Ombre where high levels of bleaching were recorded.

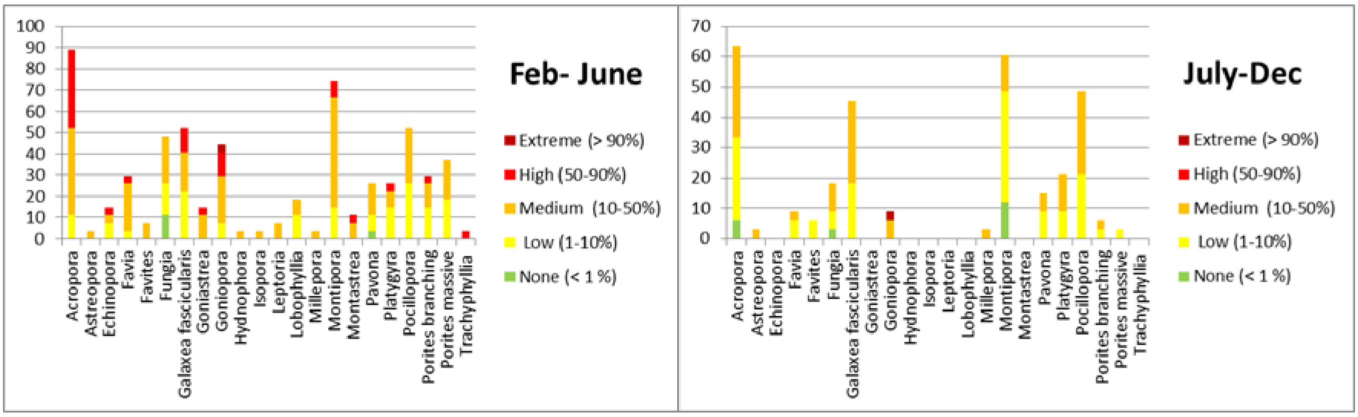


Figure 11: Changing in presence of coral genera and bleaching profiles – February to December 2016

Figure 11 shows the changes recorded for the coral genera and bleaching profiles in the first and second half of the survey period, for all sites. It is important to note that February and March are the hottest months of the year and the effects generally last until June, thus bleaching can be recorded beyond these months.

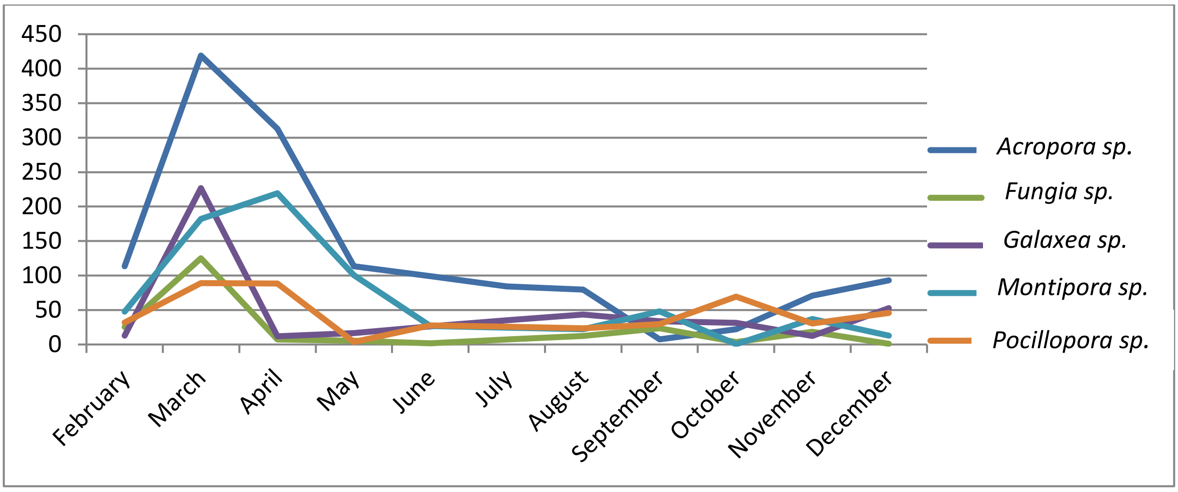


Figure 12: Bleaching index per genera – February to December 2016

Fig 12 indicates the total bleaching index recorded per genus across all sites between February and December 2016 for the 5 predominant genera observed. Bleaching is found to be worst during the hottest months, February to April 2016.

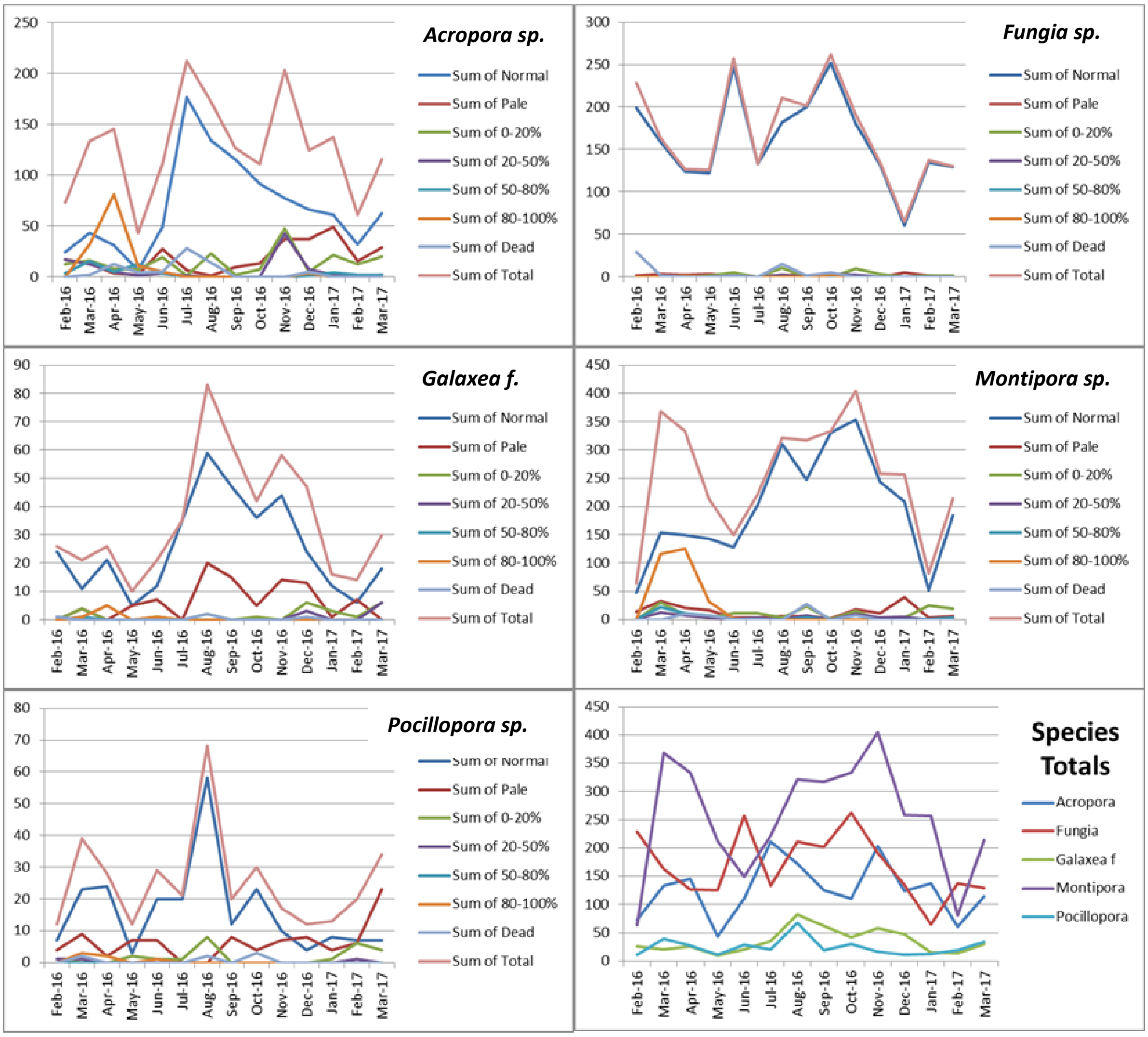


Figure 13: Bleaching index for the predominant genera – February to December

Fig 13 shows the Change in total colonies per genus for each bleaching class over the time period February 2016 to March 2017. The final graph shows a comparison of totals for all genera.

Most colonies counted were observed to have medium (10-50%) or low (1-10%) levels of bleaching. Bleaching was most severe in the Anse La Raie ALLC and Bel Ombre Coral Garden sites, where the main genera recorded were *Acropora sp.* and *Montipora sp*.

We can also deduce (Fig 12 and 13) that *Acropora sp*. is the most susceptible coral genus to bleaching, followed by *Galaxea sp*., *Montipora sp*., *Fungia sp*. and *Pocillopora sp.*

6.2: Recovery from Coral Bleaching

The highest temperatures were recorded in the months of January, February and March 2016. The effects of bleaching were still being observed and recorded till the month of June even though, there was a drop-in water temperature from the months of April and May. It was only from the month of July that corals started showing signs of recovery and appeared to return to their normal coloration.

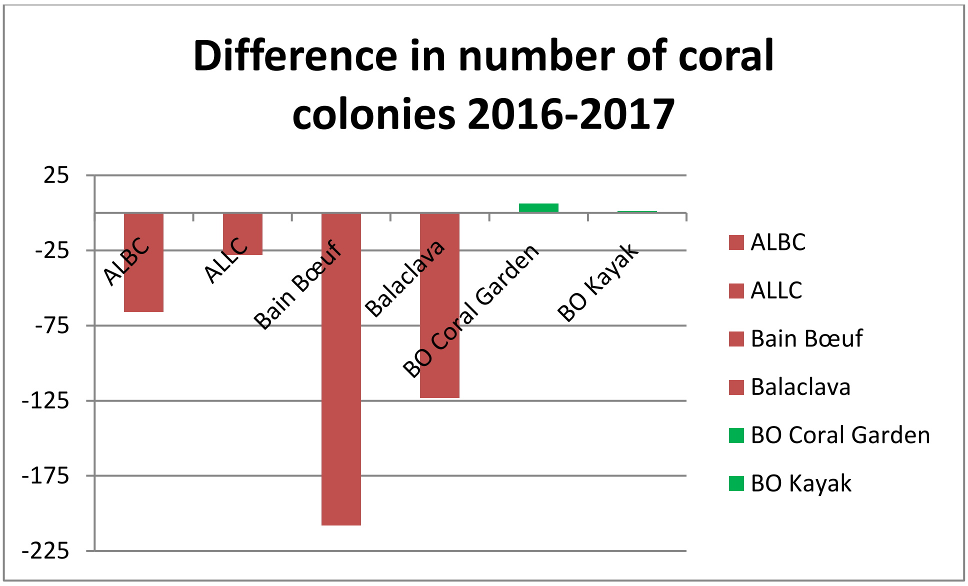


Figure 14: Difference in number of coral colonies 2016-2017

The Fig 14 show the Loss and the gain of coral colonies at each of the 6 survey sites over the period of February 2016 to March 2017 for all species. There is a generally negative trend with loss (red) observed at four sites and only a small amount of new growth (green) seen at the two Bel Ombre sites.

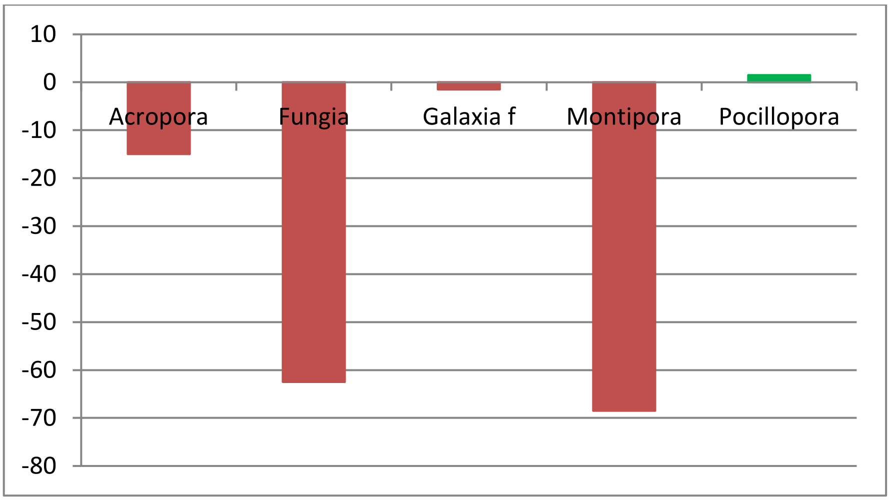


Figure 15: Difference in colonies February -March 2016 and February – March 2017

The number of colonies in Fig 15 can be compared over the space of one year to determine the recovery or the loss of colonies for each of the five genera predominantly occurring in the sites. Numbers of colonies for assessment were taken as a total over all sites. Loss is shown as red and new growth green. Both *Montipora sp* and *Fungi sp* showed least recovery whereas *Pocillopora sp* showed some recovery.

Fig 16 below shows the different levels of coral bleaching recorded for each genus from the months of July to December 2016. Extreme levels of coral bleaching were not observed.

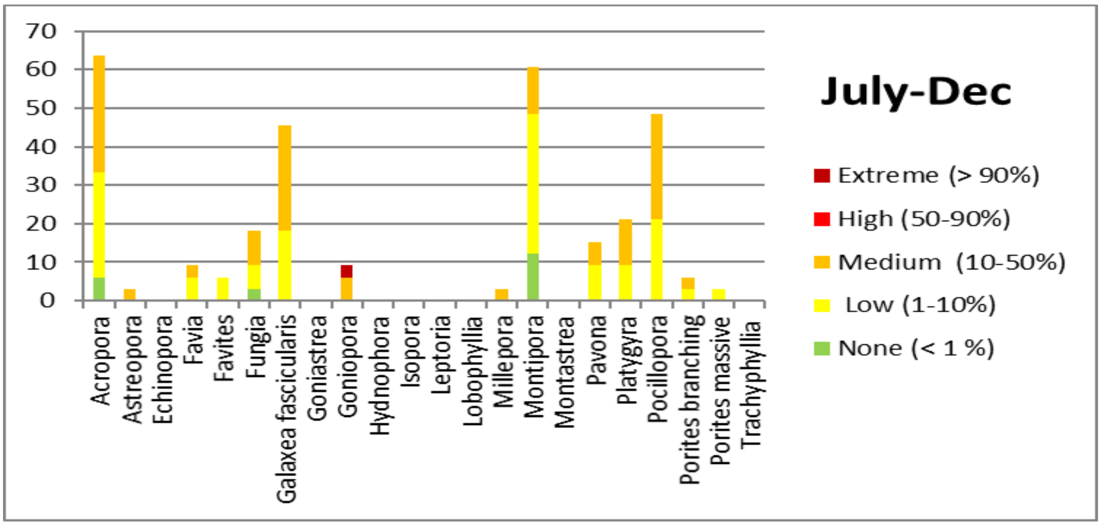


Figure 16: Coral Bleaching for each genus – July to December 2016

Fig 17 below shows the level of bleaching per genus from July 2016 to December 2016 at the different sites that were monitored. It was observed that most of the corals recovered from the major bleaching event from the summer as during the winter months the percentage of bleaching monitored barely crossed 40%.

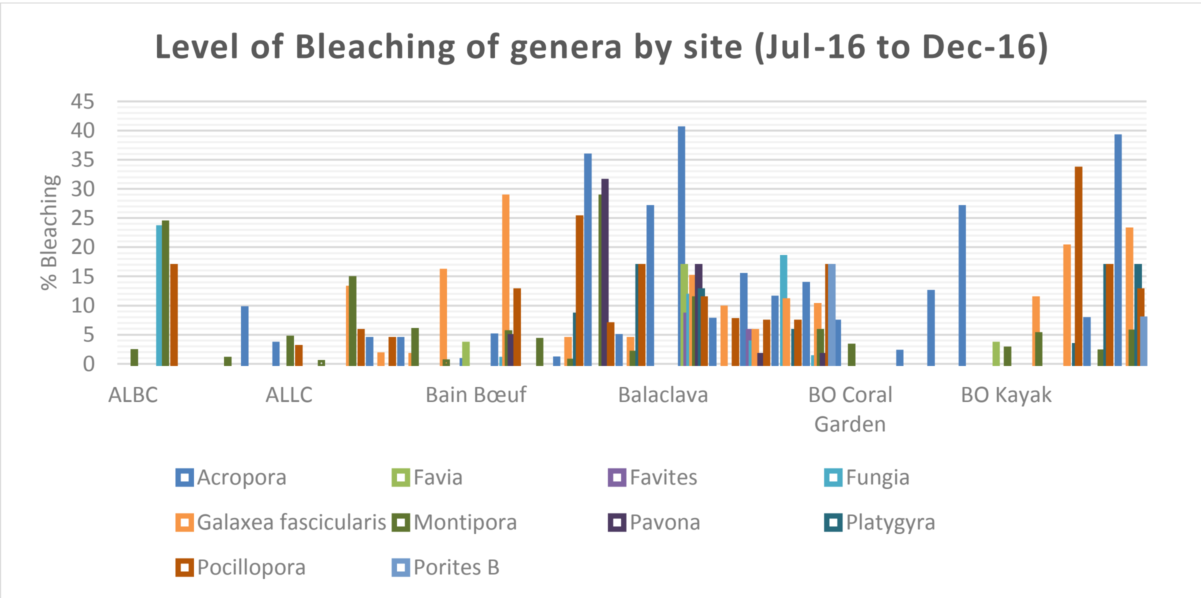


Figure 17: level of bleaching per genus – July to December 2016

In Fig 18: the bleaching index did not decline steadily as the temperatures decreased during the cooler months of July to September but was observed to be fluctuating at all sites. The trend continued during the months of October to December 2016, but it was not alarming as the BI barely exceeded 15, with one exception at the Anse La Raie ALBC site where the BI was abnormally high during the month of November 2016.

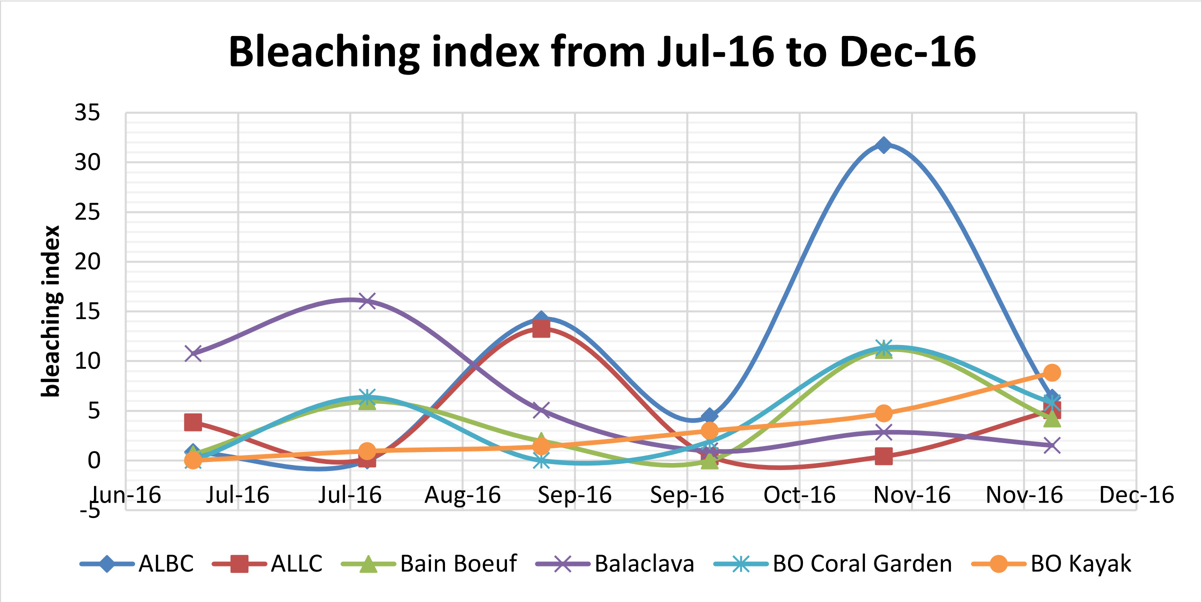


Figure 18: Bleaching index – July to December 2016

7. Discussion

7.1. Methodology

It is important to note that the methodology used to monitor for coral bleaching does not always provide fully accurate results, as the methodology allows the observer to visually determine factors such as: percentage cover, genus identification, and degree of bleaching based on visual colour categorisation. Although uniformity is an orthodox practice when monitoring, it is possible for different observers to obtain slightly different results.

New observers may also be unsure as to whether white marks observed on corals are due to bleaching, feed scars or disease and increase observation errors. Some Crown of Thorns starfish were identified at the Bel Ombre sites and as they feed on coral, they leave white scars which can contribute to difficulties in identifying bleaching. Literature indicates that similar to disease, feed scars should appear more localised and have more definite edges than bleaching. Continuous training and practice is therefore necessary for observers.

7.2: Results

Four genera of coral showed noticeable change in colony numbers amongst the sites between February to December 2016. *Acropora* sp. was found in all of the sites monitored, and a loss in colony numbers was observed at 4 of the 6 sites. *Galaxea fascicularis* was observed at 5 of the sites with losses observed at 4 of these. *Fungia sp.* was observed at 4 sites, with major losses observed at two of those, namely Bain Boeuf and Balaclava. *Montipora* sp. was observed at all of the sites and there was an increase in the number of colonies present between February to December 2016 at all but one site. However, comparing data for recovery after one year, *Montipora* sp. was found to have the largest loss of colonies overall.

Four of the above-mentioned genera *Acropora sp., Galaxea fascicularis, Montipora sp.* and *Pocillopora* sp., were the most abundant genera recorded during the study. Notably for both *Pocillopora sp.*, and

Acropora sp., 50% and 40% of colony numbers respectively at all sites during the study, were recorded in the medium bleaching range of (10% - 50%). At four of the six sites, there was a loss of over 50% of the number of colonies counted. A loss of species diversity was observed during the survey at the Balaclava site and Bain Boeuf sites with a decline in the number of genera found at both sites over time.

With regard to the more susceptible coral species, although these results recorded are mostly consistent with various published studies, they differ in the fact that Montipora sp. was recorded in this study as showing greater than expected resilience to bleaching. According to literature, *Montipora sp*. is very susceptible to coral bleaching. The opposing observations and recordings from this study may be due to the fact that the Anse La Raie ALLC site, where moderate bleaching was recorded, is dominated by 70% *Montipora sp*. cover. This high percentage cover may have skewed the susceptibility results for this genus.

Recovery of coral from bleaching was assessed by comparing data from February to March 2016 with corresponding data from 2017. After one year the bleaching index was found to have decreased at all sites analysed, and it is most likely that this corresponds to the decreases in temperature of at least 2°C at each site. In addition to bleaching recovery, an assessment of colony density recovery was conducted by comparing numbers of colonies in February to March 2016 and February to March 2017 for the 5 main genera. The most significant loss of colonies was observed in *Montipora* sp. and *Fungia sp.*, with minimal recovery only being observed in *Pocillopora sp.*

A positive trend in lower bleaching indices was seen at all sites over the time period of the study indicating that the bleaching was a temporary stress reaction to increased temperatures rather than a result of sea water pH or other factors. Bleaching as a result of temperature stress can fortunately be reversed under the right conditions and if the corals are not subjected to sustained increased temperatures. This has been observed at the survey sites by the decreased percentage of bleached colonies recorded in all of the sites during the cooler months. Even though bleached corals can survive, in many cases bleaching events have caused significant mortality of coral. While all the monitored sites showed decreased bleaching by the end of the survey, there was an average of 28.73% mortality of colonies for all sites.

8.Final Conclusions

8.1 Monitoring

This method of surveying held many advantages in an environment with limited resources. Although relatively basic, it provides adequate information on percentage of live coral cover and bleached coral colonies, dominant coral types, and the severity of the bleaching. It does require expertise or at least certain knowledge of corals to identify the corals to at least the genus level and it has the capacity to be performed in a variety of locations with limited resources. It is, however, slower than more modern surveillance techniques and requires more time spent snorkelling or diving which has associated costs.

8.2 Network – Training

To establish the network many persons and organisations were contacted, and numerous information meetings were scheduled for the Mauritius Coral Bleaching Monitoring Project. Limited data was provided by the dive centres, and it was noticed that coral bleaching was affecting more areas inside the lagoon and not outside, this is certainly due to the depth and temperature that is therefore higher in shallow areas.

An e-mail address was created but persons preferred to contact the project team via professional addresses. Persons from the private sector were not only interested in the bleaching phenomenon, but the question that came up regularly was "What can we do to stop this phenomenon?"

Although limited information was received from the network, the involvement of the private sector and concerned citizens should be encouraged and incorporated in projects where widespread observations are needed to gauge the impact of such events. Participants gain knowledge which they can pass on to others which can only have positive outcomes for conservation and management strategies in the future.

Representatives from the Ministry of Fisheries of the MOI as well as from the University of Mauritius were trained in the methodology being used but were unable to carry out monitoring on their sites due to either a lack of time or funding. For the moment in Mauritius, Reef Conservation is the only organization carrying out long term monthly monitoring for coral bleaching.

8.3 Long term monitoring programme

High temperatures, and thus increased sea temperatures, are predicted to continue to occur with increasing frequency in the coming years. The threat to coral reef systems is clear with rising concerns that mass bleaching events such as those seen in recent years will become more frequent and severe. Reef growth is a very slow process with most species only growing one to two centimetres per year, therefore, bleaching events can be catastrophic to the reef's ability to react to environmental change. The loss of coral reefs will have knock-on effects and result in a loss of biodiversity due to fish, sponges, and other organisms losing their habitats and food sources. Many species rely solely on the reef system for survival and will disappear if the current patterns of reef bleaching and degradation continue.

Reef Conservation is continuing the long-term monitoring of bleaching in Mauritius at the Bel Ombre, Bain Boeuf, Balaclava and Anse La Raie sites. We share our data with WCS (Kenya) as well as Coastal Oceans Research and Development in the Indian Ocean (CORDIO). CORDIO was initiated in 1999 as a response to the El-Niño related mass bleaching and mortality of corals in the Indian Ocean in 1998. It is a non-profit research organization, registered in Kenya, with a network of projects, collaborators and partners that extends across the Indian Ocean.

It is important that long term monitoring for coral bleaching continues in Mauritius and that more sites around the island are monitored using comparable methodologies. Understanding the susceptibility of coral species and therefore reef sites is important for long term management strategies especially for the lagoon patch reefs that are used by many different stakeholders and are found in relatively shallow waters.

References

Coles SL and Brown BE (2003). Coral bleaching—capacity for acclimatization and adaptation. Advances in Marine Biology 46:183–223.

Hughes TP, Baird AH, Bellwood DR, Card M, Connolly SR, Folke C, Grosberg R, Hoegh-Guldberg O, Jackson JBC, Kleypas J, Lough JM, Marshall P, Nystroem M, Palumbi SR, Pandolfi JM, Rosen B and Roughgarden J (2003). Climate Change, Human Impacts, and the Resilience of Coral Reefs. Science 301:929–933.

Hoegh-Guldberg O (1999). Climate change, coral bleaching and the future of the world's coral reefs. *Marine and Freshwater Research* 50:839–866.

Moothien-Pillay R., BachaGian S, Bhoyroo V. and Curpen S. (2012) Adapting Coral Culture to Climate Change: The Mauritian Experience. *Western Indian Ocean Journal of Marine Science*, 10: 155-167

Muscatine L (1990). The role of symbiotic algae in carbon and energy flux in coral reefs. *Coral Reefs* 25:75–87.

Spalding MD, Ravilious C and Green EP (2001). *World Atlas of Coral Reefs*, Prepared at the UNEP World Conservation Monitoring Centre, University of California Press, Berkeley, USA.

Wilkinson C (1998). *Status of Coral Reefs of the World: 1998*, Australian Institute of Marine Science,Townsville, Australia.

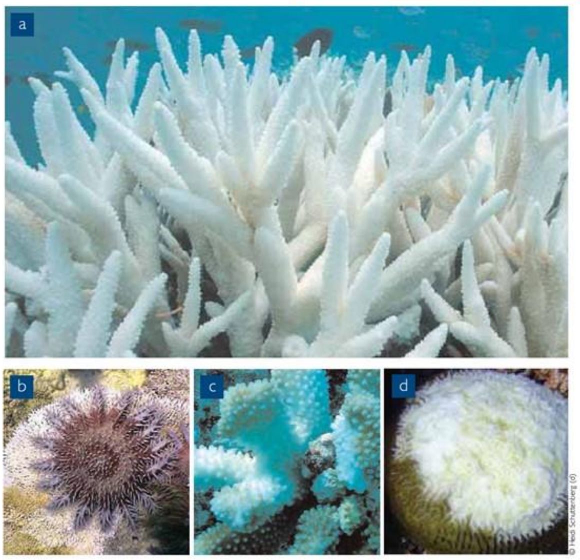
Annex 1: Data sheet to collect data on bleaching with the participants

Coral bleaching recording sheet

We recommend to look for bleaching for 5 to 6 minutes during your dive. Please fill form even if no bleaching is observed.					
Date		**Start Time**		**Weather and temperature**	
		End Time			
Location		**Dive site**		**GPS**	
Dive centre					
Bleaching (tick appropriate box)	**None**	**Low (less than 10% - only a few corals are bleached)**	**Medium (10-50%, up to half the coral seen are bleached)**	**High (50-90% most of the corals are bleached but some are not)**	**Extreme (over 90% all the corals seen are bleached)**
Photos (Yes/No)		**Name Photographer's**		**Contact of photographer**	

When bleaching is recorded please contact Reef Conservation:
Facebook: https://www.facebook.com/reefconservationmu/?fref=ts
E-mail: coralbleaching2016@gmail.com
SMS:

How to identify bleached coral?



a) Bleaching usually affects the whole colony or large sections of it in a similar way

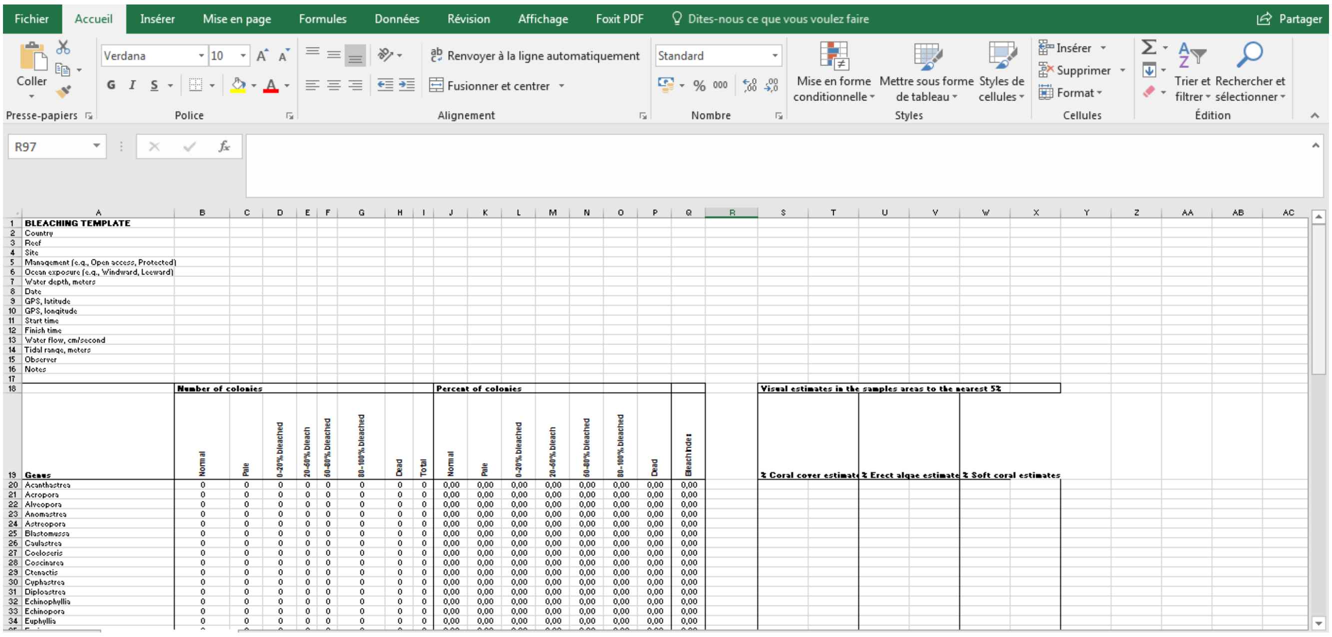
b) Crown of Thorns and c) Drupella snail predation. White sections will be next to healthy sections

d) Disease, often mistaken for bleaching. Often characterised by a strong line separating live and dead parts. Often erosion can be seen on the surface.

Source: Marshall Schuttenberg managers guide coral bleaching 2006

Annex 2:

Data Sheet for the Bleaching data analysis



1	**BLEACHING TEMPLATE**
2	Country
3	Reef
4	Site
5	Management (e.g., Open access, Protected)
6	Ocean exposure (e.g., Windward, Leeward)
7	Water depth, meters
8	Date
9	GPS, latitude
10	GPS, longitude
11	Start time
12	Finish time
13	Water flow, cm/second
14	Tidal range, meters
15	Observer
16	Notes

		Number of colonies								Percent of colonies									Visual estimates in the samples areas to the nearest 5%		
19	**Genus**	Normal	Pale	0-20% bleached	20-50% bleach	50-80% bleached	80-100% bleached	Dead	Total	Normal	Pale	0-20% bleached	20-50% bleach	50-80% bleached	80-100% bleached	Dead	Bleach index		% Coral cover estimate	% Erect algae estimate	% Soft coral estimates
20	Acanthastrea	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
21	Acropora	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
22	Alveopora	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
23	Anomastrea	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
24	Astreopora	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
25	Blastomussa	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
26	Caulastrea	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
27	Coeloseris	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
28	Coscinarea	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
29	Ctenactis	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
30	Cyphastrea	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
31	Diploastrea	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
32	Echinophyllia	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
33	Echinopora	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				
34	Euphyllia	0	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00				