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SEAGRASS MONITORING REPORT

TAKATA RESEARCH CENTER
MAHAHUAL, MEXICO

Presented to
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TABLE OF CONTENT

INTRODUCTION

Coastal ecosystems are complex and vital, greatly threatened by pollution, climate changes and other anthropic perturbations. The Yucatan peninsula has the second largest coral reef in the world, the Mesoamerican Barrier Reef System (IUCN, 2018). This ecosystem is divided in three main parts: the coral reef, the seagrass meadows and the mangrove forest. Each part of this ecosystem has a distinct and important role. The seagrass meadows are ecosystems protect the beach against erosion, stabilize the ground and enhance the production and accumulation of organic nutrients (Ondiveila et al., 2013). They also have an important capacity of oxygen and organic matters production, comparable to reefs and tropical forests (Agence Francaise pour la Protection de la Biodiversité, 2019). As a matter of fact, one square meter of seagrass can generate 10L of oxygen every day through photosynthesis (Reynolds, 2018). In addition, seagrass have an important role in the filtration of water of the reef. This filtration allows the reef to have a water with less organic nutrients, particles and damaging substances. This ecosystem also has the ability to capture carbon from the water and stock it in their leaves or in the sediment. Indeed, the world's seagrass meadows are able to stock close to 83 million metric tons of carbon a year.

The seagrass is composed of angiosperm marine plants that have the ability to exist fully submerged in salty and brackish waters. (Reynolds, 2018). These have roots and an internal transport system, so they are closer to land flowering plants than from algae. However, seagrass has a tin cuticle layer that allows gases and nutrients to diffuse into and out of the leaves, from the water to the stomata. 72 species of seagrasses have been listed in a diversity of shapes and sizes (Reynolds, 2018). Between all of those, three species can be found on the coast of Mahahual: *Thalassia testudinum, Syringodium isoetifolium* and *Halodule wrightii* (Espinoza-Avalos, 1996). For instance, the different seagrass species vary on growth rate; some grow really fast depending of their structure and the kind of habitats they live on and others grow a lot slower. This is one of the main reasons seagrass meadows fast destruction (Ondiveila et al., 2013). Furthermore, the seagrass meadows are known to be ecosystem engineers, mostly because they create unique habitats by modifying their environment (Reynolds, 2018). They create better habitats, not only for themselves, but also for many other species. Moreover, the alimentation and reproduction of a lot of reef species depends on these meadows. They create perfect nurseries and shelters for more vulnerable organisms, such as juvenile fishes, invertebrates or anemones (Reynolds, 2018). Important endangered species also retaliate on the seagrass for the main part of their alimentation, like the green turtles or manatees. The seagrass itself provides an important biomass of food for these species, but the epiphytes and bacteria growing on it are also very vital in their alimentation. Some studies have showed that the dead seagrass can even feed animals in the deep sea and some coastal decomposers (Reynolds, 2018).

Over the last years, the tourism increased considerably in Mahahual. With the construction of the Costa Maya cruise ship port, up to four boats of approximately 4000 people can dock in the city on the same day during high season. The importance of understanding the impacts of human population on the environment, more precisely on the seagrass meadows, is more important than ever. Due to this, Takata Research Center has starting a seagrass monitoring to study the impacts of different perturbators on this ecosystem and the effects on its biodiversity. This study expects to show that the sites with a lot of anthropic pressure will be more damaged and the biodiversity will be affected by these factors (boats, swimmers, waste, and *Sargassum*). This study will show the health and the location of the seagrass on the coast of Mahahual during the summer 2019. Over the next years, other monitoring of the seagrass will be done to follow the evolution and, eventually, cover a bigger area of the coast. This report specializes in the study of the seagrass and associated species living in it. It will evaluate the density and the diversity of seagrass and of associated species depending on the perturbators on different sites.

METHODOLOGY

Location of the study site

The seagrass monitoring study was performed on the coast of Mahahual, a small fishing village in the state of Quintana Roo, in Mexico. All the data were taken between 10 meters and 60 meters from the coast between the Costa Maya Port and two kilometers south from Takata Research Center. The seagrass monitoring was carried out between the 15th of May and the 18th of June of 2019. The average temperature was of 27,7 Celsius degrees (Climate data, 2018) and the climate is tropical. During this study, three plots were monitored randomly in 22 different sites.

Materials and Methods

First of all, locate the station with a GPS (see map) and determine a visual landmark to locate the site. On the map, look at the sites (squares of 200 m x 200 m) and place a GPS point on each of them. When arriving to these sites, place a square frame of 1.10 m x 1.10 m with ropes delimiting little squares of 37 cm x 37 cm on the ground, to delimit three plots that will be chosen randomly. The plots need to represent the sites, so explore the site and determine an average percentage of sand and seagrass so the number of plots with seagrass represent the quantity of seagrass on the site. Then, for ten minutes, record and observe the associated species present on the plot and in a 10 meters range around the plot. The recording will eventually be analyzed after the dive. On the plot, determine the different seagrass species. For each of the species, evaluate the percentage cover and the density. To evaluate the density, choose one of the little square (37cm x 37cm) that seems to be representative of the average density of the plot and count the number of seagrass individuals present on this square, then expand it to the whole plot. Finally, determine the percentage of leaves that are damaged on the plot. Afterwards, evaluate the percentage cover of *Sargassum* sp. On the surface and on the ground (brown mud). Also, observe and note the perturbating factors present on the plot or nearby (5 meters range) (boats, people walking on the seagrass, scuba divers, detritus, etc.). Then, evaluate and note the presence of algae by determining the percentage cover of each species (turf, brown, green, red algae and cyanobacteria). After the dive, identify the associated species by watching the recording (See Annex 1). For each species, determine if they were juvenile or adult and attribute a rank depending on the number of individuals observed (0:0 individual; 1: 1 to 5 individuals; 2: 6 to 10 individuals, 3: 11 to 15 individuals, 4: 16 and more individuals). Finally, map the different plots analyzed and sampled and determine the sensitive areas.

Data analysis

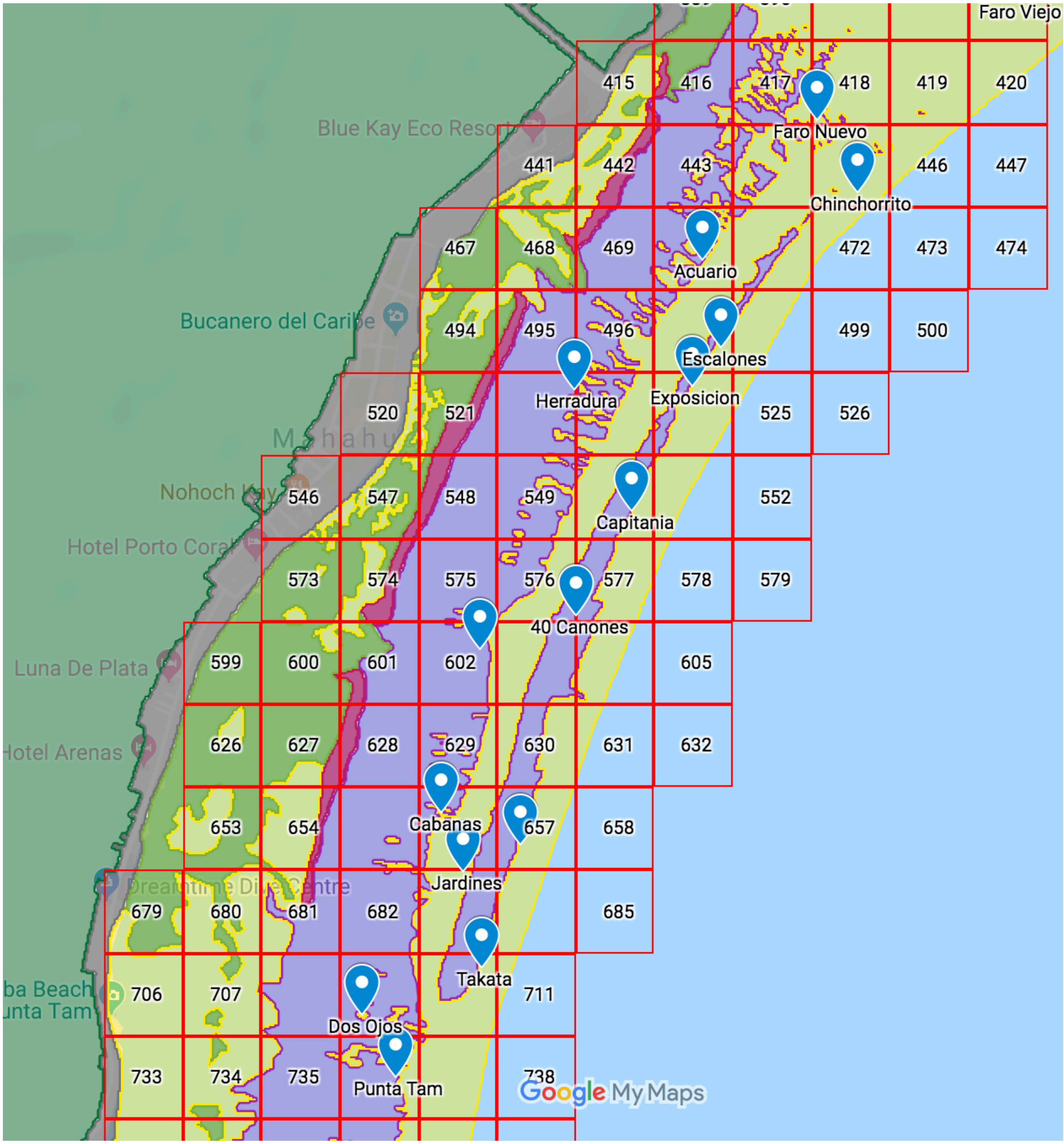
To analyse the data, tables have been made in excel to, eventually, make figures out of the tables. To show the different species that have been found during the monitoring, Annex 1 contains those species, the sites where they were found, their frequency and their abundance.

Seagrass species

The first figure represents the percentage cover of the different species of seagrass. The second figure was made to illustrate the density of seagrass species in the sites covered. The third figure represent the percentage of damaged seagrass in the different sites. The fourth graph shows the percentage cover of *Sargassum* sp. in the different sites. The fifth graphic was made to represent the percentage cover of the different types of algae.

Associated species

The sixth figure shows the Shannon Diversity Index of associated species at each site. A table also has been made to reveal the exact numbers for the index per site and maybe, eventually, use these data and do a statistic test, when the data base will be more complete. This index allows to characterize the diversity of species in a community accounting abundance and evenness of the species present on the site. The seventh figure illustrates the distribution of adult and juvenile fish in order to observe the potential of nurseries of the seagrass. The eighth figure express the distribution of the different taxonomic groups encountered during the monitoring to understand which groups are more related to seagrass. Finally, the two last figures show the repartition of those groups in the different sites monitored.



Map of the study sites. Obtain from Takata Research Center Interactive Webmap: https://takataexperience.com/research-conservation/map/)

RESULTS

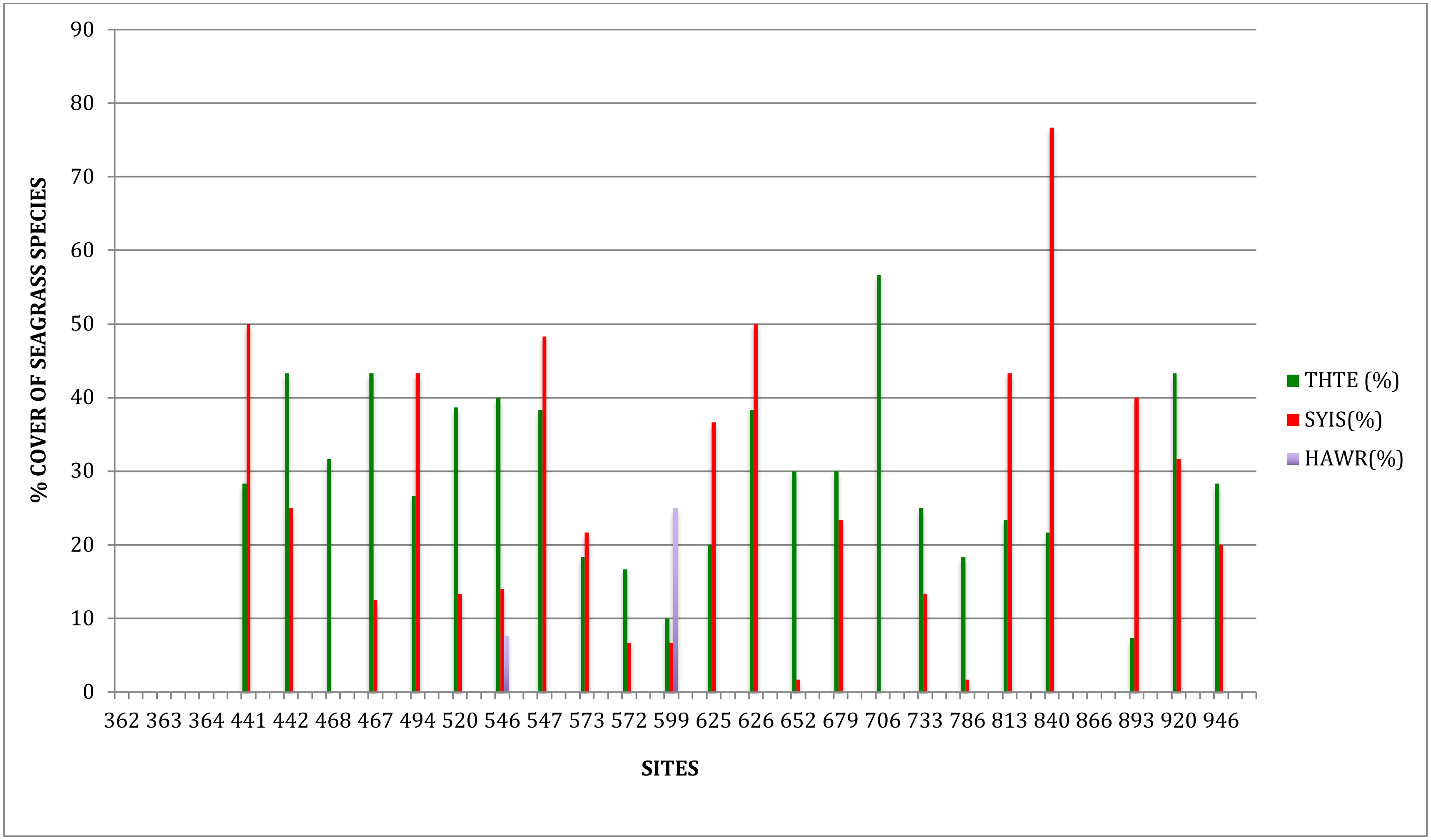


Figure 1. Percentage cover of *Thalassia testudinum*, *Syringodium isoetifolium* and *Halodule wrightii* for the sites monitored in Mahahual, summer 2019.

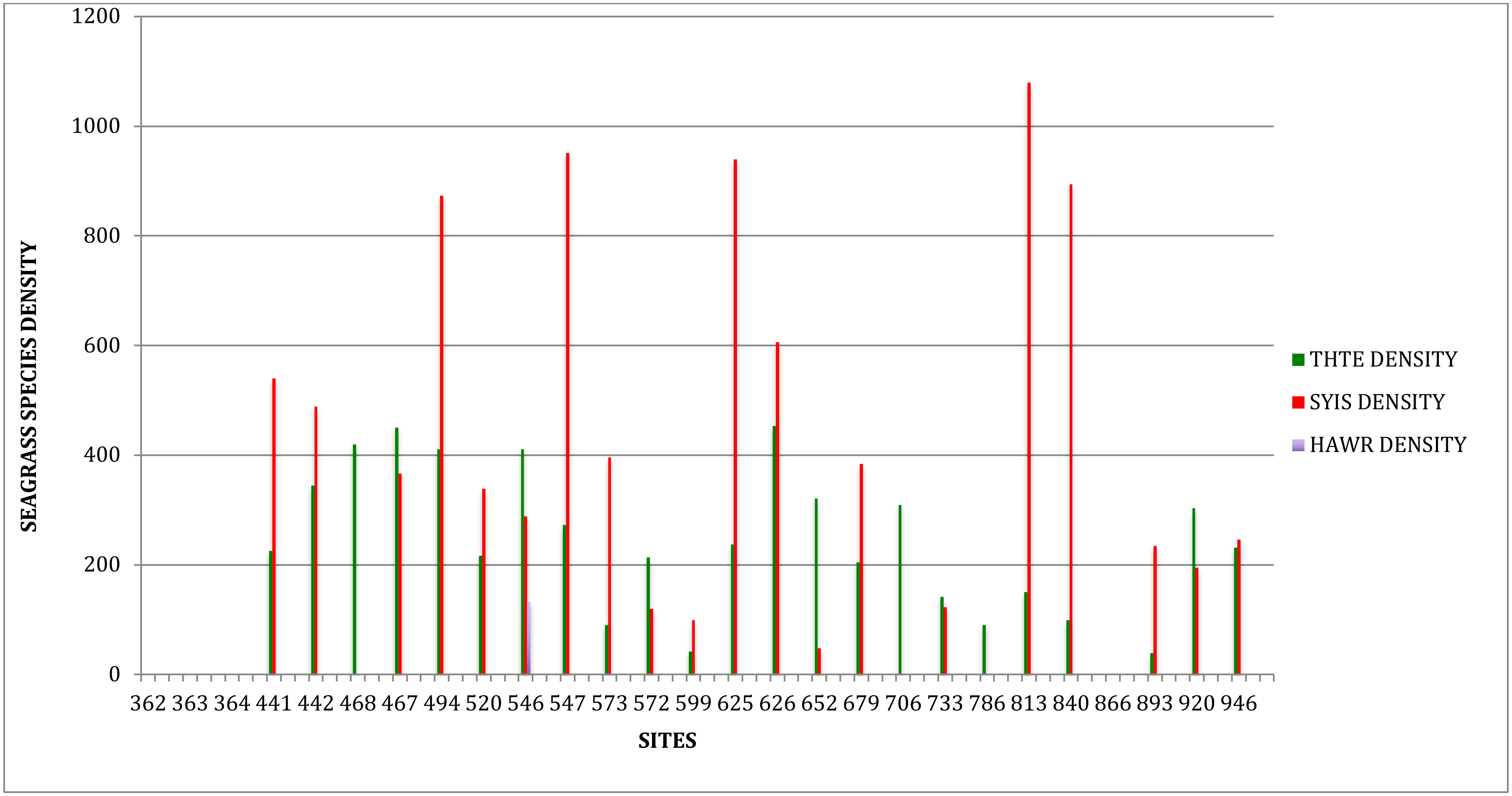


Figure 2. Density of *Thalassia testudinum*, *Syringodium isoetifolium* and *Halodule wrightii* for the sites monitored in Mahahual, summer 2019.

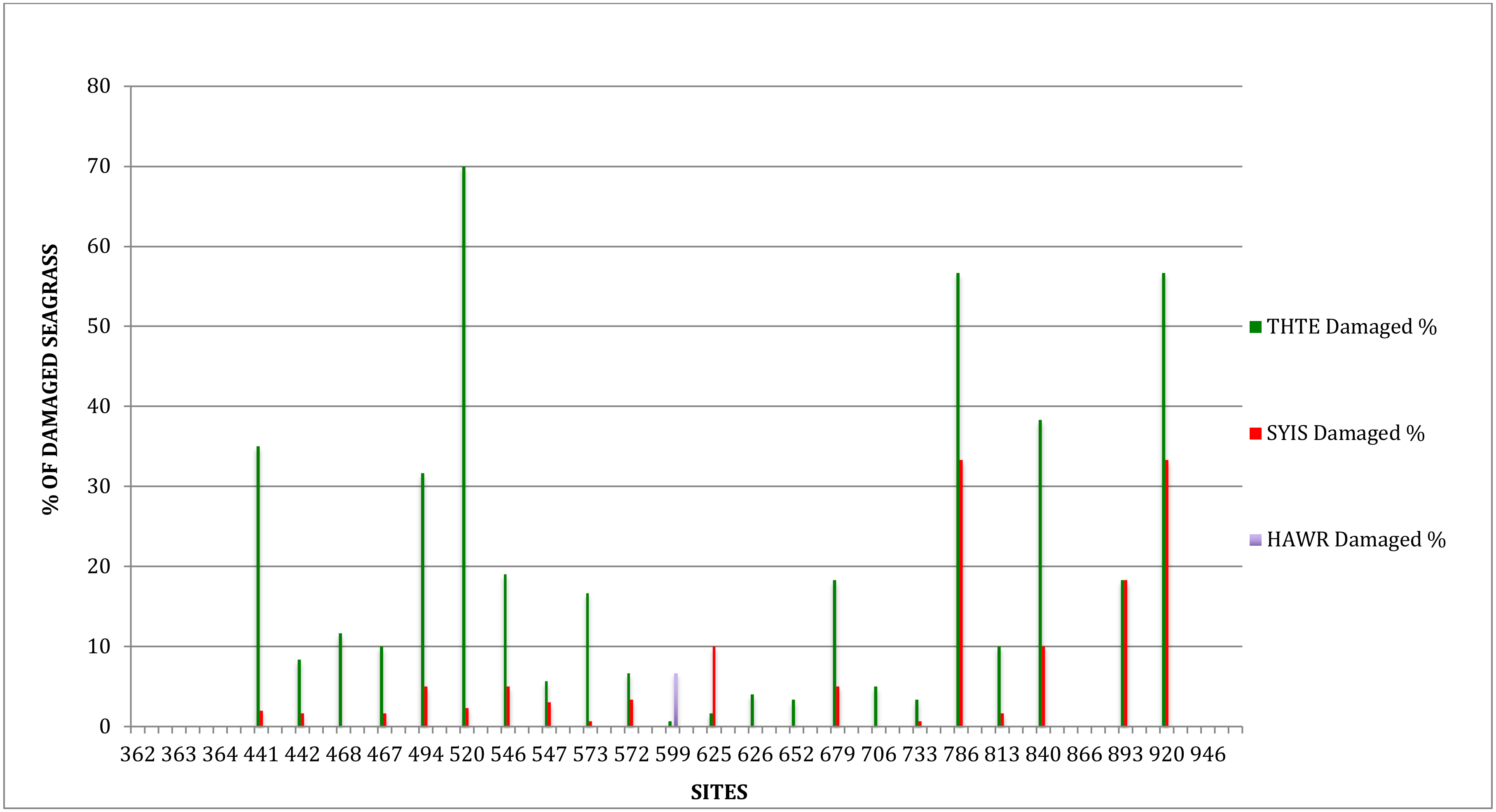


Figure 3. Percentage of damaged *Thalassia testudinum*, *Syringodium isoetifolium* and *Halodule wrightii* for the sites monitored in Mahahual, summer 2019.

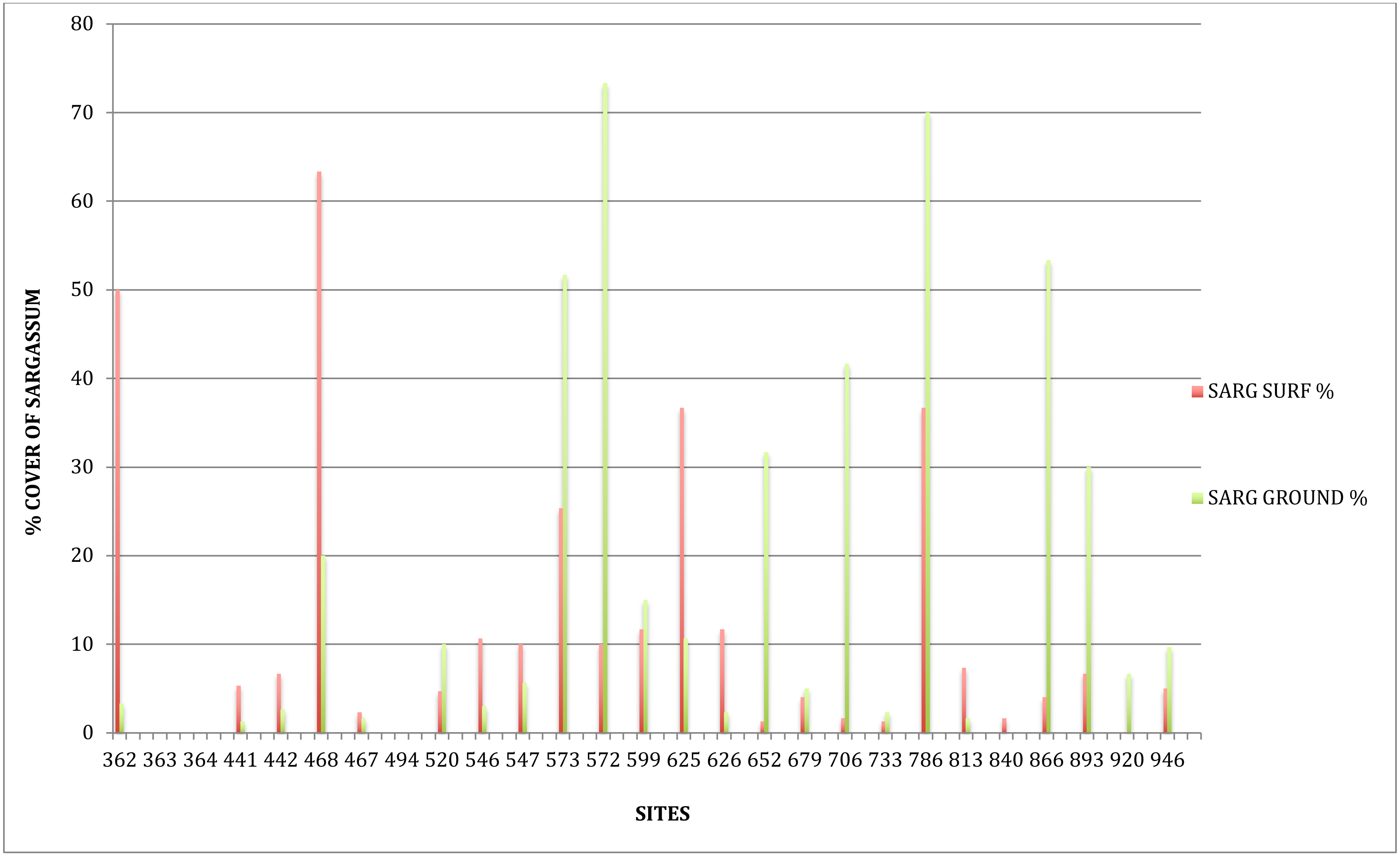


Figure 4. Percentage cover of *Sargassum sp.* at the surface and on the ground for the sites monitored in Mahahual, summer 2019.

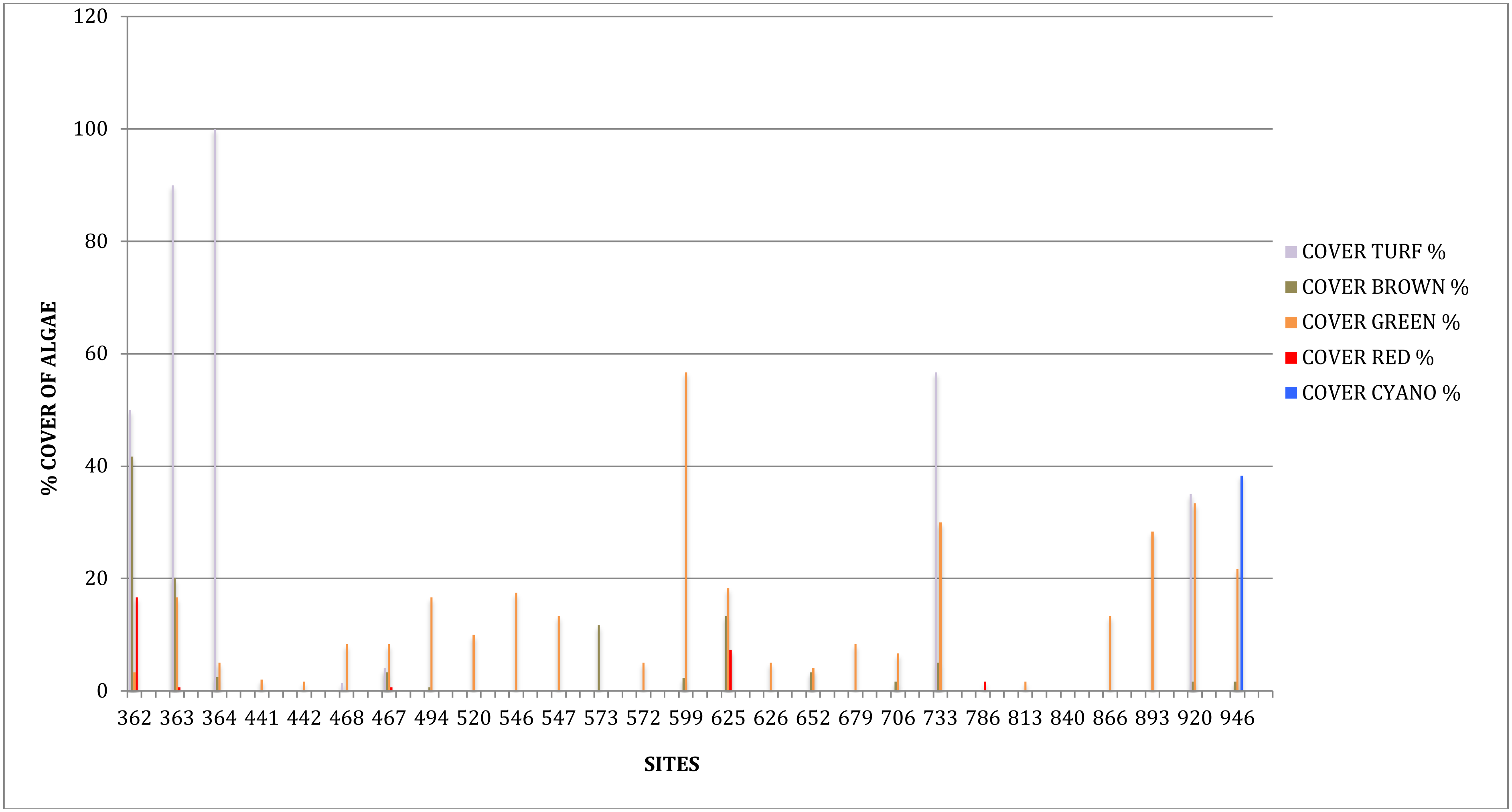


Figure 5. Percentage cover of turf algae, brown algae, green algae, red algae and cyanobacteria for the sites monitored in Mahahual, summer 2019.

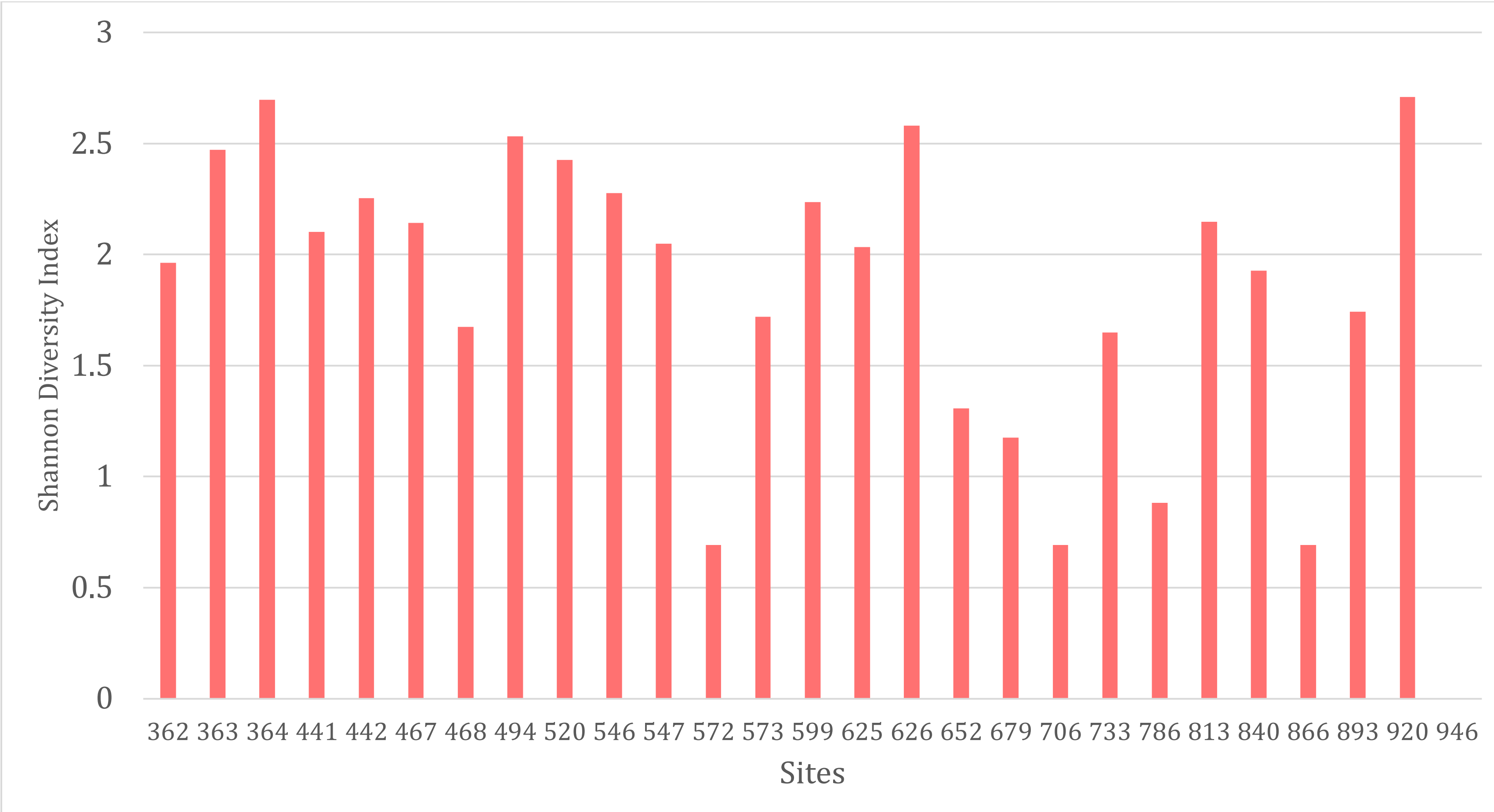


Figure 6. Shannon Diversity Index of the different sites monitored in Mahahual, summer 2019.

Table 1. Shannon Diversity Index of the different sites monitored in Mahahual, summer 2019.

Sites	362	363	364	441	442	467	468	494	520
Diversity index	1,96	2,47	2,70	2,10	2,25	2,14	1,67	2,53	2,43
Sites	**546**	**547**	**572**	**573**	**599**	**625**	**626**	**652**	**679**
Diversity index	2,28	2,05	0,69	1,72	2,24	2,03	2,58	1,31	1,18
Sites	**706**	**733**	**786**	**813**	**840**	**866**	**893**	**920**	**946**
Diversity index	0,69	1,65	0,88	2,15	1,93	0,69	1,74	2,71	0,00

Figure 6 and Table 1 demonstrate that most of the sites tend to have similar diversity index with few sites that stand out from the others. The sites with the highest Shannon Diversity Index are sites 364, 494, 626 and 920 (Figure 6). These sites have a diversity index almost four time higher than the sites 572, 706, 786 and 866 (Table 1). The last site, 946, only had one specie observed that would explain its diversity index of zero. The figure also shows that the sites at north of the reef tend to have a higher diversity index than the south sites.

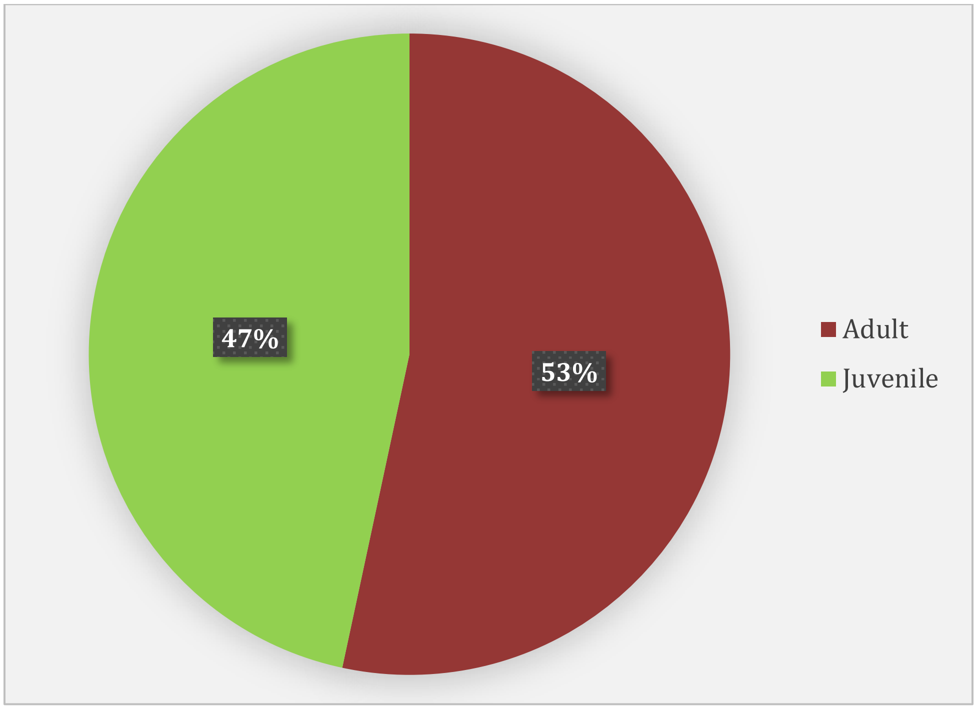


Figure 7. Distribution of adult and juvenile fishes observed in the seagrass monitoring in Mahahual, summer 2019.

This figure shows that the proportions of adults and juveniles individuals found in the different sites are almost the same (Figure 7).

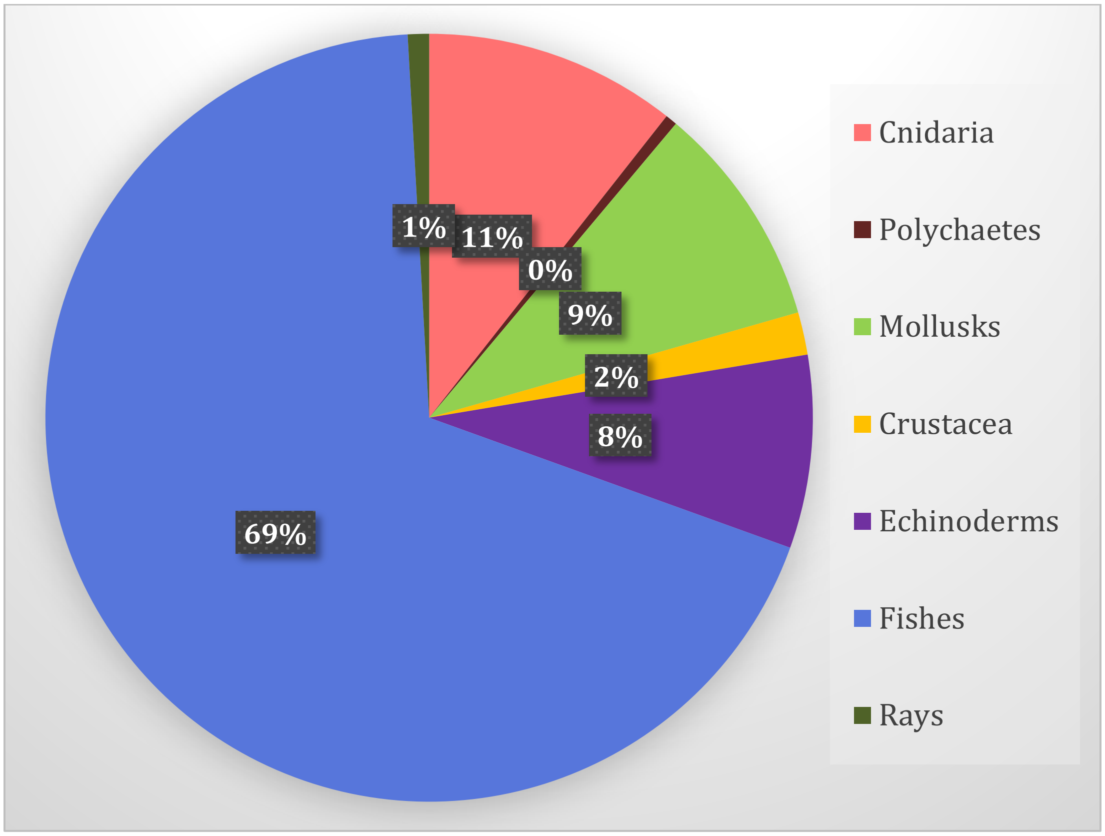


Figure 8. Distribution of the different taxonomic groups observed in the seagrass monitoring in Mahahual, summer 2019.

This figure demonstrates that the taxonomic group most encountered was the group of fishes which constitutes 69% of the individuals monitored. The second group most encountered was Cnidaria. Those individuals were still less frequent than fishes. Indeed, fishes were more than 6 times more present than Cnidaria in all the plots monitored.

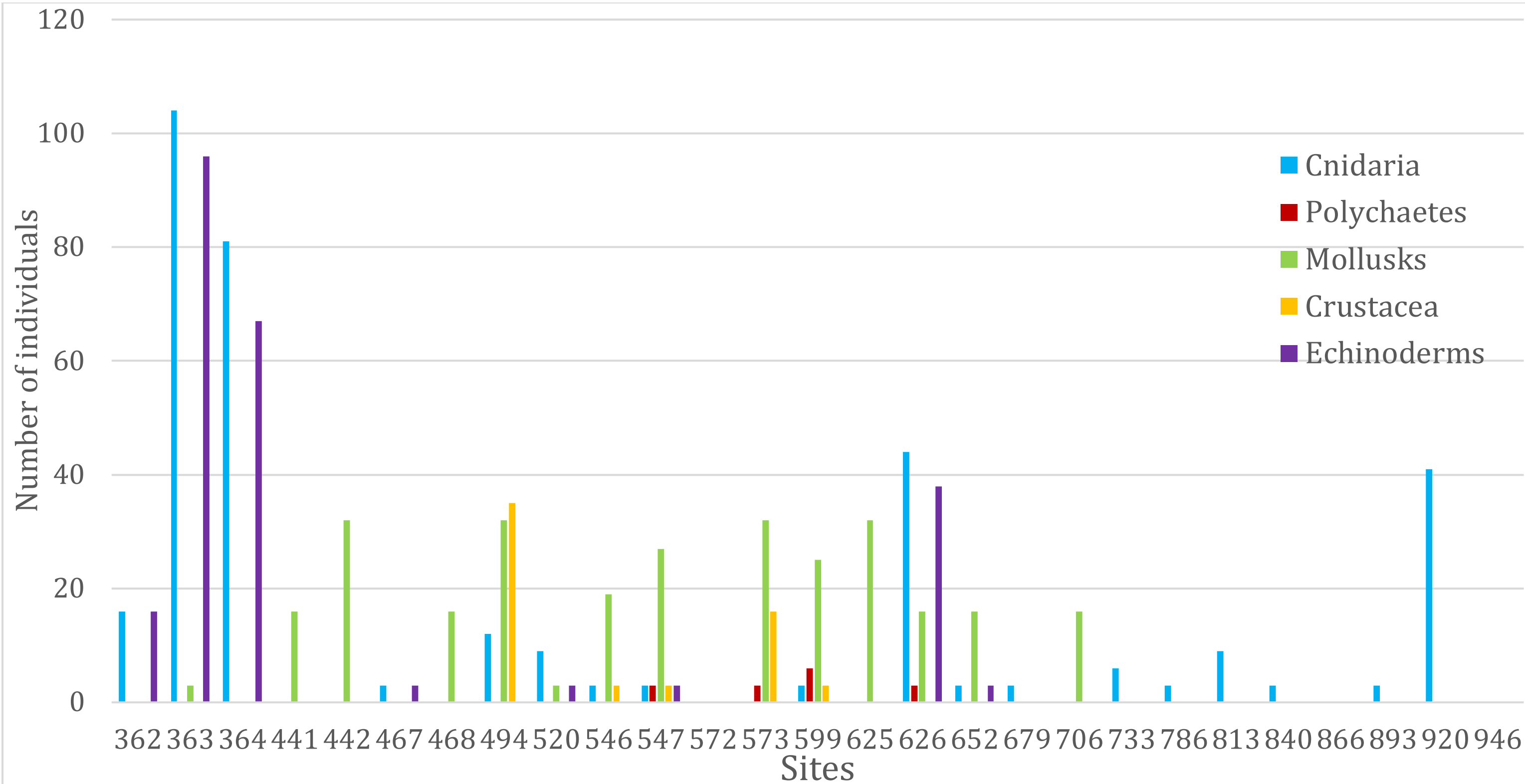


Figure 9. Distribution of invertebrates (at a taxonomic level) observed in the seagrass monitoring sites in Mahahual, summer 2019.

Figure 9 shows that the group of Cnidaria has the biggest repartition. This group was found in 67% of the sites monitored. Only few invertebrates have been found on the south sites and all of them were from the group Cnidaria. The polychaetes were only found in 15% of the sites and only few individuals were observed (3 to 6 per site). The mollusks were almost always found between 15 to 30 individuals per site and this for 52% of the sites (Figure 9).

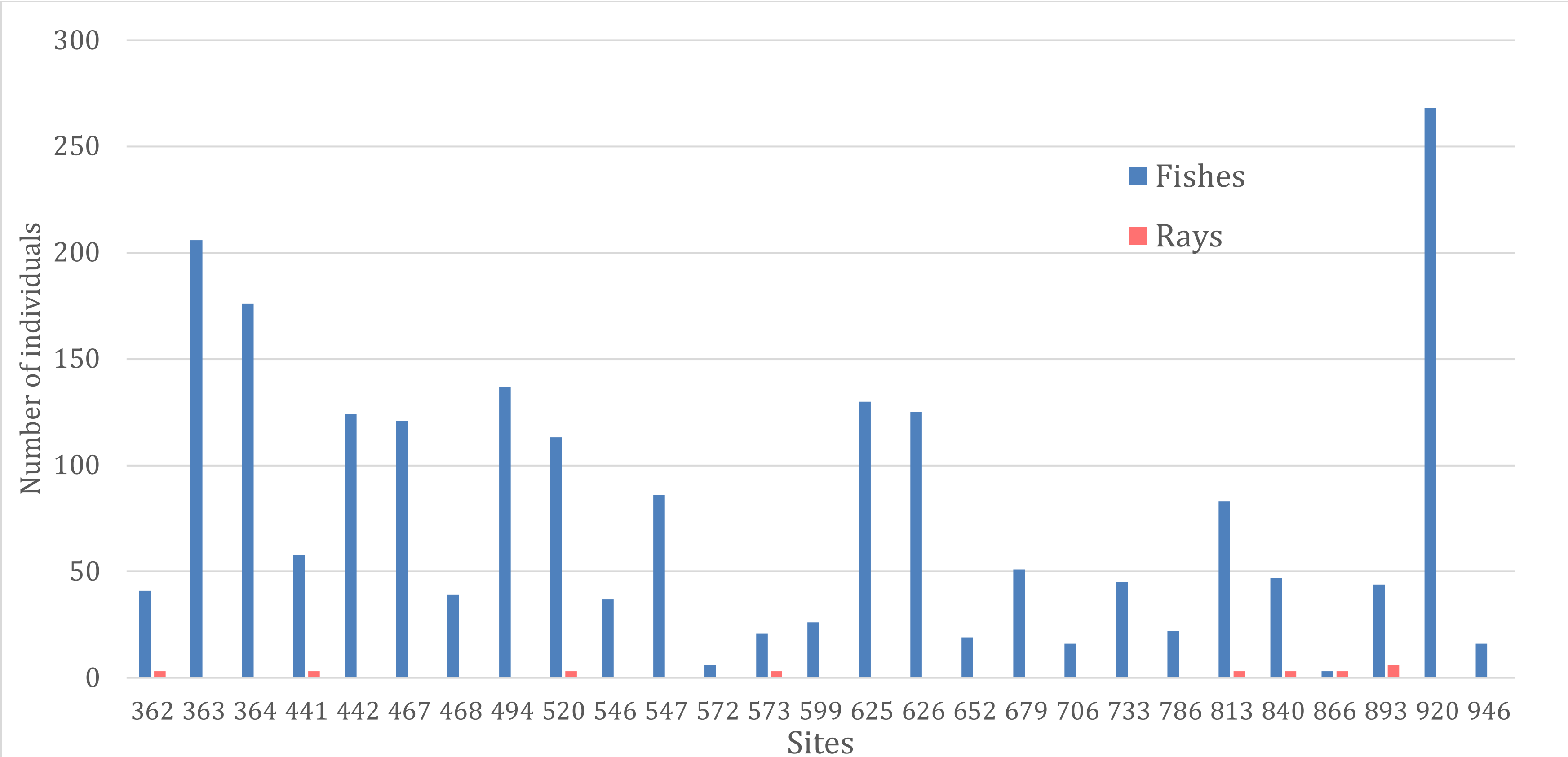


Figure 10. Distribution of vertebrates (at a taxonomic level) observed in the seagrass monitoring sites in Mahahual, summer 2019.

Figure 10 illustrates that the density of rays encountered is a lot inferior than the density of fishes. Rays were distributed in 30% of the sites monitored in small numbers of three to six per sites. For their part, the fishes were encountered in high numbers and in the entirety of the sites monitored. In the site 920, 268 fishes were observed which is 3,5 time more than the average of 76 fishes encountered per site (Figure 10).

DISCUSSION

After analyzing the different graphics, it's possible to conclude that the sites 813, 840, 625, 626 and 547 are the healthiest sites. Mainly, because they have a higher percentage cover and higher density of seagrass species. This could be explained by the fact that those sites were located in areas in which the *Sargassum* sp. percentage cover were low and where there were not many algae present. Also, these sites were located in areas where not many boat traffic was present. We observed that the sites where there was more boat traffic (Sites 520 and 547) (Figure 3), had a less seagrass density and cover, but also a high damaged seagrass percentage. It could be explained by the fact that all the boats usually use the same route and that the movement they create in the water is ripping the seagrass off or damaging it. Indeed, in the sites in which we monitored a lot of boats we also noticed a high percentage of damaged seagrass, mainly *Thalassia testudinum*, which we think might be more sensitive to damages than *Syringodium isoetifolium.* After looking at the figure 4, it's possible to conclude that *Sargassum sp*. seem to have an important impact on the presence of seagrass. In the sites where we noticed a lot of *Sargassum sp*., few healthy seagrasses were observed. This could be explained by the fact that when a lot of *Sargassum sp.* is present, it stays on the surface and therefore blocks all the light and prevent the photosynthesis needed for the seagrass. Also, the *Sargassum* sp. found on the ground, so directly on the seagrass, obstruct the growth of the seagrass. Some studies also show that *Sargassum* sp. as a high capacity of acidification of the water (Essa, 2019). This change of pH could also explain the absence of seagrass in increased presence of this algae. We also noticed that in the sites where there was an increased presence of algae, there was usually not many seagrass, as in the sites 362,363,364 and 733 (Figure 2 and 5). It could be explained by the fact that the algae take the place, the light and the nutrients available for the seagrass to grow well. However, we observed a few species of green algae that seemed to cohabitate well with *Thalassia testudinum* and *Syringodium isoetifolium*. Furthermore, we noticed that the sites that were close to the hotel and restaurant zone didn't seem to be too damaged (sites 599, 546, 547 ,573, etc.) (Figure 1 and 2). Consequently, we think that the direct impact of the tourists and swimmers is not the main reason of the degradation of the seagrass. However, we observed a lot of associated species close to the crowded beaches that live in the seagrass.

After analyzing the different graphs, it is possible to conclude that the sites 363, 364, 494, 625, 626 and 920 are the optimal sites for the associated species because they have a high Shannon Diversity Index and density of invertebrates and vertebrates. The data of the sites 363, 364 and 920 are a little bit distorted because the high values on diversity index and density are explained by the fact that those sites were constituted of corals instead of seagrass. The ground of 363 and 364 was solely composed of corals and rocks. The ground of 920 had a little bit of seagrass but mainly algae, corals and rocks. Also, the water was really shallow which constitutes a great habitat for juvenile fishes. That explains the high number of cnidaria (104 in 363, 81 in 364 and 41 in 920) in those sites compared to the average of 5 individuals of this group per sites, if those values are removed. Many studies have proven that coral is a perfect habitat for hundred of thousands of species and this clarify the diversity of species found in those sites even if they are poor in seagrass (Coral Guardian, 2010). The sites 625 and 626 have a high cover percentage and density of seagrass while the site 494 is a little bit lower. The elevated number and diversity of associated species found on those sites can be explained by the fact that they were in areas exempt of *Sargassum* sp. and not near boat passages and swimming areas. Also, some species considered as rare and only found in restricted areas such as Acanthostracion quadricornis, Lactophrys bicaudalis, Loligo pleii, etc. were found in those three sites (see Annex 1). The site 494 was not identified as one of the healthiest sites because of the high percentage of damaged seagrass. That could be explained by the fact that this site in located near the touristic and hotel area of the coast which means that the anthropic pressure is still bigger than other sites even if no boats or swimmers have been observed during the monitoring. For the site 946, the data were almost impossible to collect because the visibility was too bad with particles of sand obstructing the vision.

The sites where more boats were observed (520 and 547) have a diversity index and a density of vertebrates and invertebrates a little bit above average. This seems to indicate that the boats don’t have a direct impact on the associated species. However, the percentage of damaged seagrass was high. It would be important to watch the progression of this situation to ensure that the diversity and density of associated species do not diminish with time and the increase of damaged plants. The sites between 441 and 573 are located in the hotel area. Therefore, this area is more subject to swimmers. Nevertheless, the associated species did not seem to be influenced by this perturbation as shown in the previous figures. Another anthropic perturbator would be the wastewater rejected into the sea. It is known that near the site 441, the wastewater is thrown into the water. This could have been what influenced the low density of vertebrates and invertebrates found on this site. As a matter of fact, wastewater can contaminate fish and release a lot of nutrients in the water helping the increasing populations of algae while harming the seagrass meadows and the barrier reef (National research council, 1993).

Sargassum sp. seems to be the biggest perturbator of the associated species. Indeed, the sites 468, 572, 786 and 866 were the ones with the most cover percentage of *Sargassum* on the ground and at the surface. They also have diversity index way below the average, except for 468, and a very small density of vertebrates and invertebrates. Another site that was affected by Sargassum was 706 which did not have a lot of it at the surface, but the water was full of *Sargassum* particles in suspension. Sargassum accumulates on the shore and creates anoxia in the environment. This lack of oxygen inhibits the life of organism in those areas (UNEP, 2017). That explains why the number of animals observed in these sites were reduced. On the other side, people clean the beaches in the touristic area, explaining the higher density and diversity in the north sites.

Finally, the eighth figure demonstrates that there are equally adult and juvenile organisms. The high number of juvenile organisms is explained by the fact that seagrass is the perfect habitat for juvenile fish that are still vulnerable to eat and grow with less predators than on the reef (Reynolds, 2018). However, the number of juvenile organisms was expected to be bigger than the number of adult species. This would need to be confirmed by further studies of the associated species of seagrass meadows. The ninth figure shows that the taxonomic groups more observed in the seagrass are fishes. This could be explained by the fact that the monitoring was carried out in snorkel so the smaller individuals might not all have been seen. As an example, little mollusks can be hard to find in the seagrass meadows if you are two meters above it and you can not touch the seagrass easily to move it and see what is between the grass.

CONCLUSION

It is possible to conclude that the seagrass is not too damaged in the hotel zone, because the main threat to this ecosystem is the *Sargassum sp*. And in these areas, the *Sargassum sp.* is usually cleaned out of the beaches, not like the areas South of the hotel zone. Indeed, the areas where we observed the most damaged seagrass and the less important density and percentage cover are the areas with a lot of *Sargassum* sp. However, in the case where not a lot of these algae were monitored, but there was still not a lot of healthy seagrass or an interesting cover or density, we noticed that there was a lot of boat passages. These boat passages seam to endanger the seagrass meadows, because of the movement they create in the water. We think that it would be necessary to continue the seagrass monitoring in order to have a real idea of the well-being of this ecosystem in Mahahual.

Globally, it is possible to observe a higher diversity index and density of organism in sites away from the touristic area (625, 626), but not too far. Indeed, the sites further from the touristic area accumulates a lot of *Sargassum,* which is the perturbator with the most dramatic impacts on the seagrass meadows. Seeing the results of this study, anthropization clearly has a negative impact on the community of species living on the seagrass meadows.

RECOMMENDATIONS

In order to improve the seagrass monitoring, we think that it would be interesting to monitor the areas further away from the coast. Especially, the areas past 60-100 meters, mostly, because on the map from the navigation booklet, there seem to be a lot of seagrass and they are more interesting for the studies linked to the reef. Besides, if the goal is to create protected area for the seagrass but also for some animal species that depend on it like many turtle species, the monitoring definitely needs to cover deeper area. But in order for that to happen, the methodology would need to be revised and improved for deep water monitoring. Furthermore, we think that it would be interesting to evaluate the seagrass further north and further south from the area covered. It could be interesting to see if the cruise ships have a big impact on this ecosystem. Moreover, it would be important to see if the areas further south really are as healthy as they seem. We also had some problems with the waves and the *Sargassum sp.* during our monitoring, so some squares couldn't be completely monitored. Therefore, the squares 759,760,839,973 couldn't be used in this report but should be monitored to see the state and degradation of the seagrass in these areas.

Due to the many species of stingrays and urchins that we noticed in the seagrass close to the crowded beaches, we think that it is necessary to put signs indicating the presence of these animals. First of all, to protect the swimmers and tourists, but also to protect the seagrass and try to prompt people to be careful not to damage this important and sensitive ecosystem. Additionally, we think that education on the matter is necessary, not enough people know the importance and the value of the seagrass meadows and their role in the protection of the reef. We also recommend to the next interns to have their own equipment, mostly the GoPro which we used every day to do our data taking on the associated species.

In order to cover a bigger area and have a better vision of the seagrass meadows repartition, it would be interesting for the next students that will continue this study to monitor the sites further from the coast, past 60 meters. Moreover, all the megafauna, the turtles as an example, will be found further from the coast and the map from the navigation booklet seems to indicate great areas of seagrass in those sites. This megafauna needs to be protected and, in order to do so, studies must show the best habitats for those organisms and where they tend to be found. Those deeper sites will also be clearer than the sites closed from the coast where *Sargassum* accumulates. To do so, the protocol would need to be slightly modified so it can be done in deeper water. Indeed, the density of seagrass needs to be calculated by touching each plant and takes some time, so it is not possible to just dive underwater while snorkeling to do it. The person that would continue the study could either do it diving or make an estimation of the density. To have a better portrait of the seagrass meadows of the coast of Mahahual, it would also be interesting to monitor the areas further north and south. To do so, it might be better to have access to a boat or a kayak, to move more easily between the sites. Going north might allow the study to prove the impacts of the cruise ships on the seagrass ecosystem. Going south could help see the difference with more healthy areas. Some sites were monitored, but the visibility was too bad because of *Sargassum* particles in the water so they were removed from the report (759, 760, 839, 973). It is recommended for the next person that would continue this study to go and monitor those sites on a day with no waves and, if possible, less *Sargassum*. Three other sites (389, 415, 416) were not done either because of the necessity to access them by boat. The climate and the waves prevented the monitoring of these sites. These sites would also need to be done, eventually.

More specifically for the future people studying the associated species, it would be interesting to do statistic tests with a more complete data base to compare the sites between them. First of all, a t- test could demonstrate if there is a significant difference between the diversity index of the different sites. Another possibility would be to compare the diversity index or the density of vertebrates and invertebrates with the different perturbators to see which one has the most impact on the fauna community (a stepwise regression could do it). The person monitoring the associated species would also need to have a GoPro to film the different species observed since there are a lot of them and it is hard to learn them all before starting the monitoring.

While waiting for the study to be continued, it would be a good idea to educate the population about the importance of seagrass meadows in a coastal ecosystem. Also, some signs could be installed on the beaches, preventing people to walk on the seagrass due to organism that could hurt them (fireworms, urchins, rays, etc.) and, at the same time, protecting the meadows from being destroyed. Eventually, with more data, some protected areas could be established where swimmers and boats would not be able to pass. Those zones would protect the seagrass and the fauna that lives within it. Finally, there should be a better management of *Sargassum* so it does not accumulate and kill all the living organism around it. This management is hard because *Sargassum* is a relatively new problem evolving really fast and effective solutions have not yet been found, but it would definitely help the seagrass meadows and its associated species.

ANNEX 1: Seagrass monitoring sites on Takata´s navigation booklet.
Sites at two different scales: 200m x 200m in the bigger sites of 500m x 500m.

SITE 500mx500m	SITES	SITE 500mx500m	SITES
14G	**362**	**10D**	**625**
	363		**626**
	364		**652**
13F	**441**	**9D**	**679**
	442		**706**
	468		**733**
12E	**467**	**8D**	**786**
	494	**7C-D**	**813**
	520		**840**
11E	**546**		**866**
	547	**6C**	**893**
	573		**920**
11D	**572**	**5C**	**946**
	599		

ANNEX 2: Macrofauna species observed during the seagrass monitoring in Mahahual, summer 2019.
The table shows the sites where the megafauna species were found and the relation abundance/frequency of these species.

Relation abundance/frequency

NA/D: Not abundant, but well distributed; VA/ND: Very abundant, but not well distributed ; NA/ND: Not abundant and not well distributed; VA/R: Very abundant in restricted areas; NA/R: Not abundant in restricted areas; R/R: Rare in restricted areas

Not abundant: > or =15 < or =70; Very abundant: >70; Rare: <15; Not well distributed > or =5 < or = 10 sites; Well distributed > 10 sites; Restricted areas <5 sites

Phyllum	Family	Species	Sites	Frequency	Abundance	Relation Abundance/Frequency
Cnidaria	Gorgoniidae	*Gorgonia ventalina*	362, 363, 364, 467, 520, 599, 626, 679, 813, 893, 920	11	> 123	VA/D
		Antillogorgia bipinnata	363, 364	2	> 48	NA/R
	Merulinidae	Montastrea annularis	363, 364	2	20	NA/R
	Poritidae	Porites porites	363, 364	2	15	NA/R
	Plexauridae	sp	364, 626, 733	3	> 35	NA/R
		Plexaurella dichotoma	494, 733	2	6	R/R
		Muricea muricata	520, 920	2	6	R/R
	Mussidae	Diploria sp.	494, 920,	2	6	R/R
	Milleporidae	Millepora alcicornis	920	1	3	R/R
	Siderastreidae	Siderastrea siderea	920	1	16	NA/R

	Aiptasiidae	Bartholomea annulata	494, 520, 547, 626	4	12	R/R
	Stychodactyla	Stoichactis helianthus	363, 494	2	9	R/R
	Actiniidae	Condylactis gigantea	626, 652	2	9	R/R
		Actinostella flosculifera	813	1	3	R/R
	Hormathiidae	Calliactis tricolor	786, 840	2	6	R/R
	Cassiopeidae	Cassiopeia xamachana	546	1	3	R/R
Polychaetes	Amphinomidae	Hermodice carunculata	547, 573	2	6	R/R
	Sabellidae	Sabella melanostigma	599, 626	2	6	R/R
	Pectinariidae	Pectinaria sp.	599	1	3	R/R
Mollusks	Cerithiidae	Cerithium sp.	441, 442, 468, 494, 546, 547, 573, 599, 625, 626, 652, 706	12	>264	VA/D
	Loliginidae	Loligo pleii	494	1	3	R/R
	Octopodidae	Octopus hummelincki	363	1	3	R/R
	Strombidae	Strombus giga	520, 546, 547, 599,	4	15	NA/R
Crustacea	Xanthidae	Crab sp.	546	1	3	R/R
	Paguroidae	Hermit crab sp.	573, 494	2	>48	NA/R
	Parthenopidae	Mesorhoea belli	599	1	3	R/R
Echinoderms	Echinometridae	Echinometra lucunter	362, 363, 364	3	>96	VA/R

	Diadematidae	Diadema antillarum	363, 364, 467, 626, 652	4	>92	VA/R
	Toxopneustidae	Tripneustes ventricosus	520, 547, 626	3	>54	NA/R
	Ophiasteridae	Linckia guildingii	364	1	3	R/R
Fishes	Pomacanthidae	Pomacanthus arcuatus	364, 467	2	9 (J)	R/R
	Chaetodontidae	Chaetodon striatus	362, 363, 364, 625, 626, 920	6	18 (15 A; 3 J)	NA/ND
		Chaetodon capristatus	364, 520	2	6 (3 A; 3 J)	R/R
		Chaetodon ocellatus	364	1	3 (A)	R/R
	Acanthuridae	Acanthurus coeruleus	363, 441, 546, 626, 920,	5	15 (3 A; 12 J)	NA/ND
		Acanthurus tractus	362, 363, 364, 441, 442, 467, 468, 546,625, 733, 813, 840, 920	13	> 169 (>126 A; 43 J)	VA/D
		Acanthurus chirurgus	363, 364, 920	3	37 (A)	NA/R
	Carangidae	Caranx ruber	441, 442, 494, 546, 679, 813, 840	7	34 (26 A ; 8 J)	NA/ND
		Caranx bartholomaei	362, 467, 468, 494, 625, 626, 813, 866, 893	9	>131 (>107 A ; 24 J)	VA/ND
		Trachinotus goodei	573, 733	2	6 (A)	R/R
		Chloroscombrus chrysurus	547	1	>16 (A)	NA/R

	Belonidae	Ablennes hians	442	1	3 (A)	R/R
		Tylosurus crocodilus	442, 520	2	9 (A)	R/R
	Albulidae	Albula vulpes	494, 520, 547, 813	4	>61 (A)	VA/R
	Gerreidae	Gerres cinereus	362, 441, 442, 467, 468, 494, 520, 546, 547, 573, 599, 626, 733, 786, 813, 840	16	>140 (137 A; 3 J)	VA/D
		Eucinostomus melanopterus	442, 494, 546, 573, 599, 813, 840, 893	8	56 (A)	NA/ND
	Clupeidae	Harengula humeralis	362, 364, 467, 625, 652, 706, 786	7	>136 (>48 A ; >88 J)	VA/ND
	Kyphosidae	sp.	363	1	>16 (A)	NA/R
	Haemulidae	Haemulon flavolineatum	625	1	>16 (A)	NA/R
		Haemulon sciurus	364, 442, 625, 626, 813, 840, 920	6	>80 (>64 A ; >16 J)	VA/ND
		Haemulon plumierii	920	1	3 (A)	R/R
		Haemulon carbonarium	364, 920	1	>19 (A)	NA/R
		sp.	494, 520, 920	3	>43 (J)	NA/R
	Lutjanidae	Lutjanus analis	547, 625, 626, 813, 840, 893	6	21 (A)	NA/ND

		Lutjanus mahogoni	441, 442, 467, 494, 572, 626, 813	7	21 (J)	NA/ND
		Ocyurus chrysurus	520, 920	2	6 (3 A; 3 J)	R/R
		Lutjanus apodus	625, 733, 920	3	28 (14 A ; 14 J)	NA/R
	Pomacentridae	Stegastes leucostictus	441, 467, 494, 626, 679, 920	6	27 (12 A ; 15 J)	NA/ND
		Abudefduf saxatilis	363, 364, 441, 442, 467, 468, 625, 626, 652, 679, 733, 920	12	>401 (>123 A ; >278 J)	VA/D
		Stegastes adustus	363	1	3 (J)	R/R
	Serranidae	Serranus tabacarius	363, 920	2	6 (3 A ; 3 J)	R/R
	Scaridae	Sparisoma viride	362, 363, 364	3	28 (3 A; 25 J)	NA/R
		Sparisoma amplum	364, 920	2	12 (J)	R/R
		Cryptotomus roseus	920	1	3 (J)	R/R
		sp.	442	1	3 (A)	R/R
	Labridae	Halichoeres radiatus	467	1	3 (J)	R/R
		Thalassoma bifasciatum	363, 364, 626	3	9 (6 A ; 3 J)	R/R
		Halichoeres bivittatus	363, 441, 442, 467, 468, 494, 520, 547, 625, 626, 679, 893, 920	13	>158 (12 A ; > 146 J)	VA/D
		Halichoeres pictus	467, 572	2	6 (J)	R/R

	Holocentridae	Sargocentron vexillarium	364	1	8 (A)	R/R
	Gobiidae	Elacatinus evelynae	363, 364, 441, 599	4	39 (25 A ; 14 J)	NA/R
		sp.	494, 520, 546, 547, 573	5	18 (A)	NA/ND
	Labrisomidae	sp.	363	1	3 (A)	R/R
	Bothidae	Bothus lunatus	442, 494, 546	3	12 (6 A ; 6 J)	R/R
	Scorpaenidae	Pterois volitans	520	1	3 (J)	R/R
	Mullidae	Pseudupeneus maculatus	363, 520	1	6 (A)	R/R
	Tetraodontidae	Canthigaster jamestyleri	468, 520, 599, 920	4	26 (15 A ; 11 J)	NA/R
		Sphoeroides spengleri	494, 573, 599, 626, 920	5	18 (9 A ; 9 J)	NA/ND
	Ostraciidae	Acanthostracion quadricornis	626	1	3 (A)	R/R
		Lactophrys bicaudalis	626, 893	2	6 (A)	R/R
	Sciaenidae	Equetus punctatus	467, 626	2	6 (J)	R/R
	Ophichthidae	Myrichthys ocellatus	599, 920	2	6 (3 A ; 3 J)	R/R
	-	sp.	494, 520, 546, 547, 840, 893, 920, 946	8	>152 (J)	VA/ND
Rays	Narcinidae	Narcine bancroftii	362, 520, 893	3	9 (A)	R/R
	Urotrygonidae	Urobatis jamaicensis	441, 813, 840, 866	4	12 (A)	R/R
	Dasyatidae	Dasyatis americana	573, 893	2	6 (A)	R/R

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