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# Benthic Composition and the Dynamics of Coral-Algal Interactions in Abu Galum Protected Area, Western Coast of Aqaba Gulf

**Ahmed M. El-Sadek [1], Hussein A. El-Naggar[2]*, Abdel-Kader M. Hassan[2], Azza A. El-Ganiny[3], Hassan M. M. Khalaf-Allah[2]**

1. Nature Conservation Sector, Egyptian Environmental Affairs Agency, Cairo, Egypt.
2. Marine Biology Branch, Zoology Department, Faculty of Science, Al-Azhar University, Cairo, Egypt
3. Fisheries Division, National Institute of Oceanography and Fisheries

*** Corresponding author: hu_gar2000@azhar.edu.eg and hu_gar2000@yahoo.com**

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## ABSTRACT

Algae undoubtedly compete with the coral in space; however, coral reefs are globally degrading due to anthropogenic activities, which results in a decrease in reef-building corals and an increase in macroalgae. Therefore, it is necessary to periodically monitor the components of the bottom associated with coral reefs to check the state of the coral reef ecosystem in order to develop integrated sustainable management to preserve this strategic treasure. Thus, the recent work focused on monitoring and assessing the status of benthic components of the coral reef ecosystem and the coral-algal interactions in Abu Galum Protected Area in an attempt to provide information about coral reef status and their conditions in this region as a model in Aqaba Gulf. The present study was carried out at El-Sokhn site in Abu Galum Protected Area during the period from January to December 2018. Nine categories constituted the benthic cover in the study area; hard coral was the main dominant category, followed by turf algae, while the lowest cover was soft coral. The underwater surveys showed that hard coral cover increased at the furthest spot from the beach and vice versa for macroalgae. Turf algae and macroalgae cover increased as a result of nutrient increases during winter, while hard coral had high cover during autumn. In all reef zones, Acropora was the most abundant coral genera, resulting in the greatest number of interactions with macroalgae that was dominated by Sargassum. The current results indicate that the hard coral was strongly inversely correlated with macroalgae, where it was decreased in reef flat zone when macroalgae increased, and it was more common when macroalgae declined at reef crest and in reef slope zones. Given the rapid shifting in tropical coral reef ecosystem dynamics, future work should explore to what extent these thresholds can reach large spatial scales to improve quantitative models of the biomass of macroalgae on coral reefs. Seasonal and long-term studies are urgently required to avoid the loss of important information associated with the trajectory and resilience of coral reef ecosystems.

## INTRODUCTION

Coral reefs are tropical benthic ecosystems that span the depth range between shallow reefs in the intertidal zone and the bottom of the photic zone (~150m) **(El-Naggar, 2020)**. They are the most diverse ecosystems in the world. Because of the diversity of life found in the habitats created by corals, the reefs are often called the "rainforests of the sea". About 25% of the ocean's fish depend on healthy coral reefs. Reef-benthic communities are a key ecological component of nearly all marine ecosystems. They represent a key trophic link between organic matter production/accumulation in the benthic environment and export to other oceanic environments **(Wolkovich *et al*., 2014; El-Naggar, 2020)**. Moreover, reef-benthic communities represent the most common faunal assemblage used to assess habitat quality across the globe **(Darweesh *et al*., 2021a, b)**. In addition to the important role of benthic organisms including coral, macroalgae and coralline algae as habitat for commercially important species, benthic organisms provide a breakwater for low-lying islands, maintain biodiversity, and create aesthetically pleasing habitat **(Moberg & Folke, 1999)**.

Desirable reef conditions might be protected through legislation, but the benthos would remain vulnerable to natural perturbations. Coral reefs are dynamic ecosystems impacted by the disturbance on a variety of spatial and temporal scales **(Hughes & Connell, 1999; El-Naggar *et al*., 2022a, b)**. Physical and biological disturbances, including cyclones, crown-of-thorns starfish (COTS), and bleaching impact reefs over areas of hectares and even greater **(El-Naggar *et al*., 2017; NOAA, 2019)**.

Although the abundance and distribution of specific species can respond quickly to disturbance, changes in the marine benthic ecosystem as a result of such factors are likely to take time. Long-term data are still required to fully understand the dynamics of marine environments **(Zakaria & El-Naggar, 2019; Zakaria *et al*., 2018, 2019)**. Long-term observations of marine benthic communities are essential for a detailed understanding and predictions of the dynamics of the marine benthic ecosystem **(Mona *et al*., 2019; Piazza *et al*., 2019)**.

The species composition and assemblage structure of marine benthic organisms are strongly related to environmental conditions and can therefore be used as an effective tool to identify the impacts of various environmental factors **(Post *et al*., 2011; Abd El-Aziz *et al*., 2022)**. Tropical coral reefs worldwide are degrading due to human activities. In many cases, reef-building corals have declined, and macroalgae have become more prevalent **(McManus & Polsenberg, 2004)**. In addition, macroalgal community structure has been highlighted as a good indicator of environmental changes caused by natural or anthropogenic processes in marine coastal waters **(Pinedo *et al.*, 2007; Martins *et al*., 2012)**. Additionally, marine benthic organisms play a significant role in the flux of organic matter in the reef ecosystem. Therefore, a systematic study of marine benthic community structure will help to better understand and predict the patterns of distribution and organization of benthic communities and their vulnerability to change **(El-Naggar *et al*., 2022a)**. The combination of species interactions and abiotic conditions shape the complexity of benthic reef systems, which highlights the need to understand the relative contribution of the components to ecosystem structure and functioning **(Done, 1999)**.

The Gulf of Aqaba contain unique reef systems with different characteristics and dynamics when compared to the Indo-Pacific and the Caribbean, as a result of different historical and biogeographical factors (e.g. isolation, biogeographic barriers, reef type, geomorphological features (**Shaban *et al*., 2020 and Metwally *et al.*, 2020**). The Gulf of Aqaba has unique habitats beside coral reefs such as mangroves, coastal wetlands, seagrass and volcanic and coralline islands. All of these habitats work in harmony to create the unique biodiversity of the Gulf of Aqaba. Nevertheless, the tourism development in the gulf has adversely affected it, and thus the Gulf of Aqaba is particularly susceptible to marine pollution and ecosystem degradation **(Mona *et al*., 2019; El-Sadek *et al*., 2022)**. Therefore, it is necessary to periodically monitor the components of the bottom associated with coral reefs to always examine the state of the coral reef ecosystem to develop an integrated sustainable management to preserve this strategic treasure.

The present work aimed to monitor and determine an assessment of the status of benthic components of coral reef ecosystem and the coral and algal interactions in one of the important sites at Abu Galum Protected Area to provide the information about coral reef status and their conditions in this region as a model in the Aqaba Gulf.

## MATERIALS AND METHODS

### *1. Study area:*

The present study was carried out at El-Sokhn site in Abu Galum Protected Area along the Egyptian coast of Aqaba Gulf, northern Red Sea (Fig. 1). El-Sokhn site (latitude 28°45'31.91"N and longitude 34°37'25.46"E) is a small lagoon lying near Nuweiba City about 27km North, with a maximum depth of 6 - 15m during high tide period. The reef flat at the area composed mainly of old fossilized reef interrupted in many places by sandy depressions with vegetation of seagrass bed near the shore. This site is considered a typical coral reef habitat of the Red Sea (Fig. 1). Four stations were chosen to cover El-Sokhn site. From the shoreline to the reef slope, the study area was subdivided into three ecological zones, the shallow outer reef flat, reef crest, and reef slope (5m depth below reef crest).

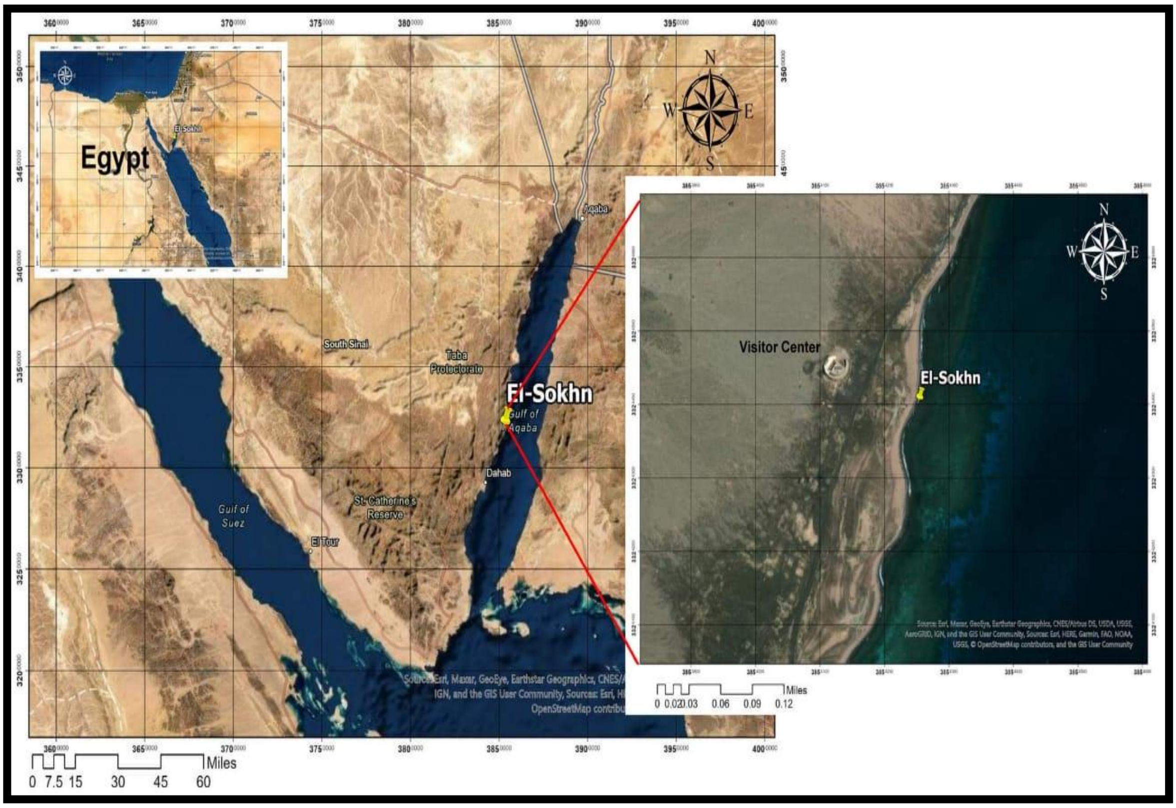


**Fig. 1.** A map of Aqaba Gulf showing the study area

***2. Benthic composition surveys:***

Marine underwater surveys were conducted in El-Sokhn area during January to December 2018. All dives were made during daylight between 09:00am and 17:00pm.

Benthic composition was determined using the point intercept transect (PIT) method **(English *et al*., 1997; Hill & Wilkinson, 2004)**. Benthos categories lying under a point of the transect line were recorded and counted every 50cm interval along the transect length and recorded giving a total of 40 points per transect (the 40 points were used to estimate proportional cover for each replicate transect). This step was repeated three times in each zone of each station.

The substrata were classified to the lowest level possible and then grouped into the following substratum categories: hard coral; soft coral; (sponges, bryozoans and ascidians) were grouped as 'other invertebrates' due to their low abundances into three functional groups of algae: crustose coralline algae (CCA), macroalgae ≥1.5 cm (MA) and epilithic algal matrix < 1.5 cm (EAM), in addition to abiotic substrate (rock, sand and rubble).

Classification of hard (Scleractinia) coral forms were done according to their morphology. Nine substrate categories covering all benthic biotic and abiotic elements were determined and expressed as live corals (HC), soft corals (SC), macro algae (MA), turf algae (TA), crustose coralline algae (CCA), epilithic algal matrix (EAM), sand (SA), Rubble (Rb) and Rock (RC).

***3. Data analysis and statistics:***

Statistical analysis and graphics of data were conducted using Microsoft Excel. Several mathematical relationships and statistics were used for data analyses. Multiple correlation analysis (Pearson correlation coefficient) was calculated to determine the relationship between the benthic cover components with a significance levels of $P \leq 0.01$ and $P \leq 0.05$. The correlation analysis was done using PAST paleontological statistics ver. 3.25 and SPSS 16.0 software program.

## RESULTS

***1. Benthic cover components:***

Nine categories constituted the benthic cover at El-Sokhn site in Abu Galume Protected area; they are hard live corals (HC), soft corals (SC), macro algae (MA), turf algae (TA), crustose coralline algae (CCA), epilithic algal matrix (EAM), sand (SA), rubble (Rb) and rock (RC). Along the study site, the hard coral was the main dominate category with a percent cover of 32.86±20.3% of the total benthic cover, followed by turf algae (25.65±8.73%), while the lowest cover was that of the soft coral (1.30±1.21%). In this context, the percent cover for macroalgae as one of the main benthic components was 11.95±16.4% of the total benthic cover (Fig. 2).

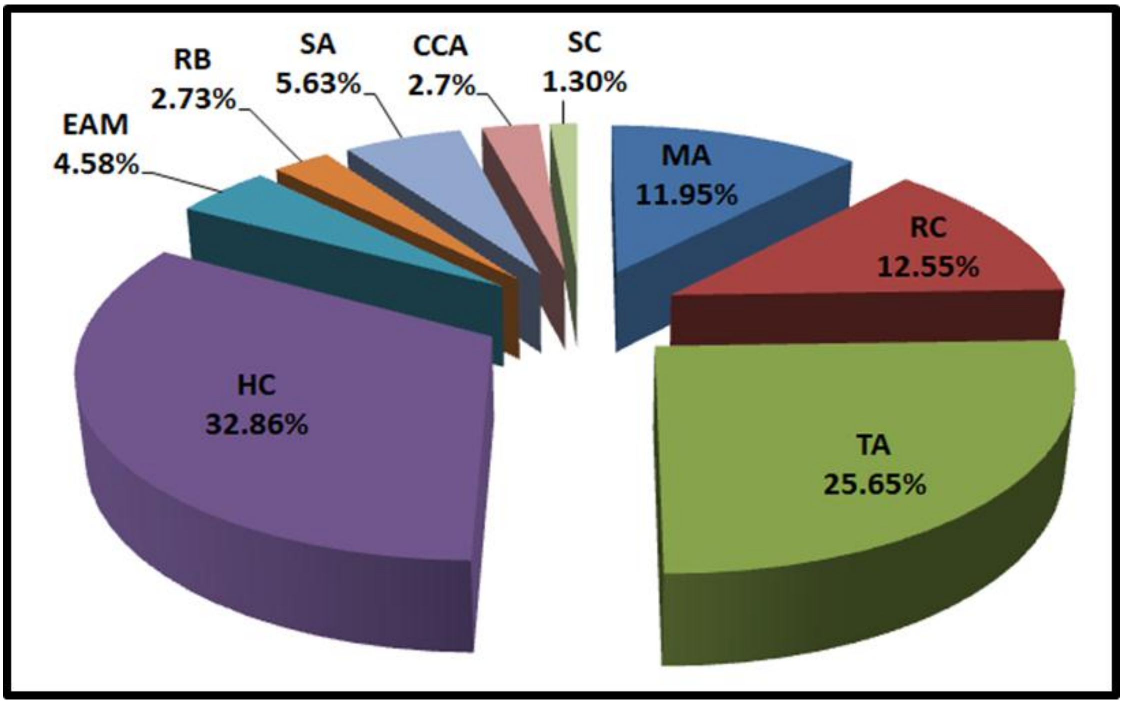


**Fig. 2.** The percentage of benthic cover components recorded at El-Sokhn Site in Gulf of Aqaba during 2018. Hard live corals (HC), soft corals (SC), macro algae (MA), turf algae (TA), crustose coralline algae (CCA), epilithic algal matrix (EAM), sand (SA), rubble (Rb) and rock (RC).

### *2. Benthic cover zonation*

The benthic categories were completely varied in their percent cover among the surveyed reef zones (Fig. 3). In the reef flat zone, macroalgae was the most dominant categories with a percent cover of 30.86±16.73% of the benthic cover, followed by turf algae (16.17±6.08%) and the lowest one was the soft coral represented by 0.08±0.03% of the benthic cover. However, hard coral was represented in the reef flat zone by 9.45±6.45% of the benthic cover.

Contrarily, hard coral was the most dominant category in reef crest zone, represented 45.55±9.19% of the benthic cover in this zone. A turf algae was the second abundant category with a percent cover of 27.42±11.03% of the benthic composation in this zone. Moreover, the percent cover of macroalgae was diminished to a very low value (3.36±5.58%). Whereas, the percent cover of the soft coral increased and reached its highest value of 2.5±2.09% of the benthic cover in this zone.

Likewise, hard coral (43.6±5.95%) was the main predominant category in reef slope zone, followed by turf algae represented by 33.36±9.46% of the benthic composation in this zone. On the other side, macroalgae decreased to its lowest value (1.64±3.53%), while the soft coral was represented by 1.33±2.09% of the benthic cover in this zone.

### *3. Spatial distribution of benthic cover*

The percent cover of any component of benthic categories didn’t record a remarkable change among the investigated stations. Regardless of the different reef zones’ compositions, the hard coral showed the highest percent cover at all stations, where it fluctuated from 30.31±18.95% at site 3 and 35.21±20.16% at site 1. In contrast, the turf algae, as a category, recorded its lowest percent cover (23.85±6.91%) at site 1 and its highest (28.65±9.43%) at site 3. Moreover, the cover of macroalgae was recorded with semi-equal percent at all stations, where it was low at site 4 with a percent cover of 9.38±12.35% and high in site 2, with a percent cover of 17.08±23.91%. In this context, the soft coral was the lowest percent cover at all stations, where its cover was varied between 0.83±1.44% at site 4 and 1.77±1.3% at site 1 (Fig. 4).

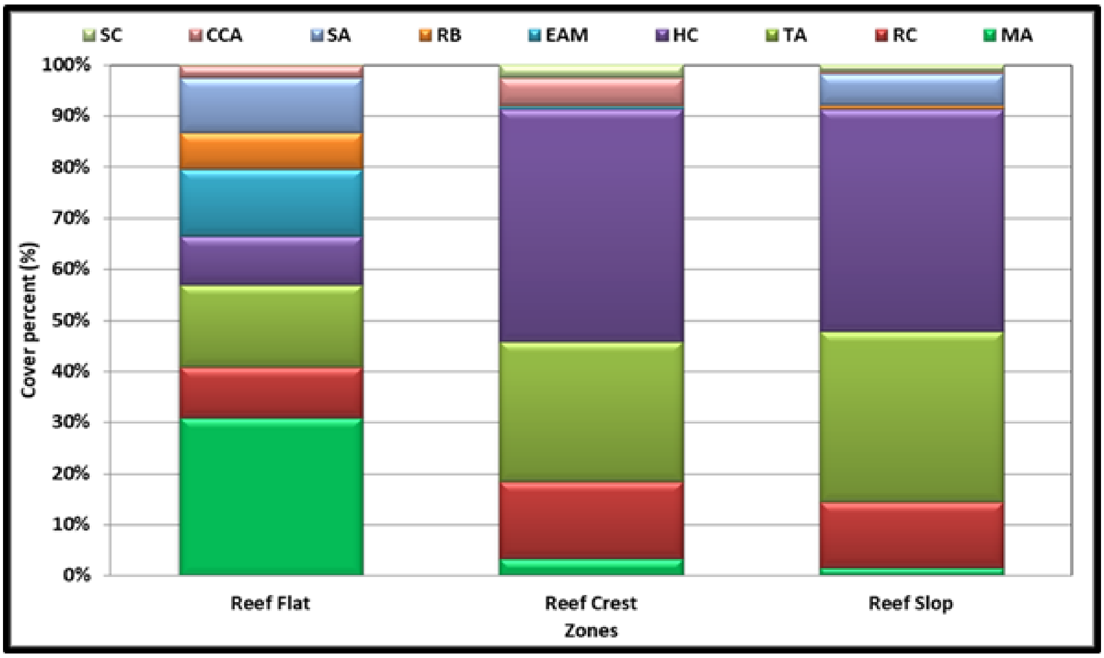


**Fig. 3.** The percent cover of benthic compensates in different surveyed reef zones recorded at El-Sokhn Site in Gulf of Aqaba during 2018. Hard live corals (HC), soft corals (SC), macro algae (MA), turf algae (TA), crustose coralline algae (CCA), epilithic algal matrix (EAM), sand (SA), Rubble (Rb) and Rock (RC).

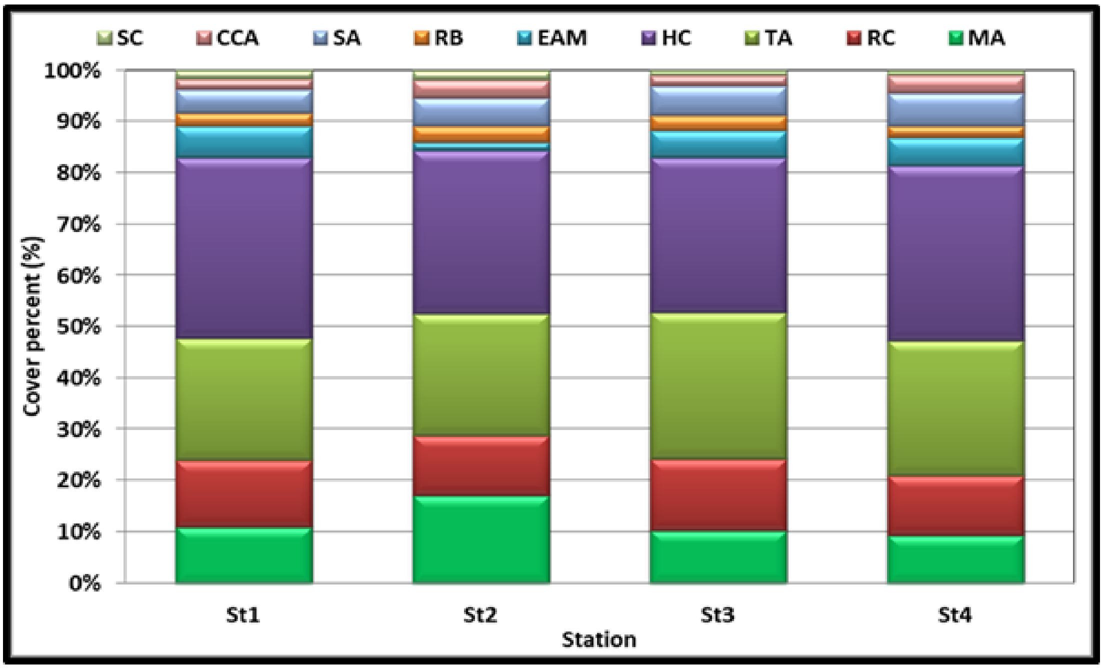


**Fig. 4.** The percent cover of benthic compensates in the surveyed stations recorded at El-Sokhn Site in Gulf of Aqaba during 2018. Hard live corals (HC), soft corals (SC), macro

algae (MA), turf algae (TA), crustose coralline algae (CCA), epilithic algal matrix (EAM), sand (SA), rubble (Rb) and rock (RC).

### *4. Temporal distribution of benthic cover*

During winter, turf algae was the main dominant category of benthic composition with a percent cover of 31.56±5.74%, followed by hard coral (27.6±7.28%) and macroalgae (16.67±3.28%), while the soft coral (1.35±1.47%) showed the lowest percent cover during winter. During spring, the percent cover of the hard coral (34.79±1.32%) was the highest, while the soft coral (1.67±0.95%) was the lowest. Accordingly, the turf algae percent cover during spring was 23.02±2.5%, and for macroalgae it was 10±5.91%. Likewise, the hard coral (29.27±1.76%) was the highest benthic cover, followed by turf algae (26.35±0.2%) and macroalgae (12.6±10.47%), but the soft coral (1.25±0.95%) was the lowest benthic cover. In addition in the fall, the percent cover of hard coral increased and reached a value of 39.79±0.26% to be ranked the first, followed by turf algae (21.67±1.91%) and macroalgae (8.54±2.52%), while the soft coral (0.94±0.81%) recorded the lowest benthic (Fig. 5).

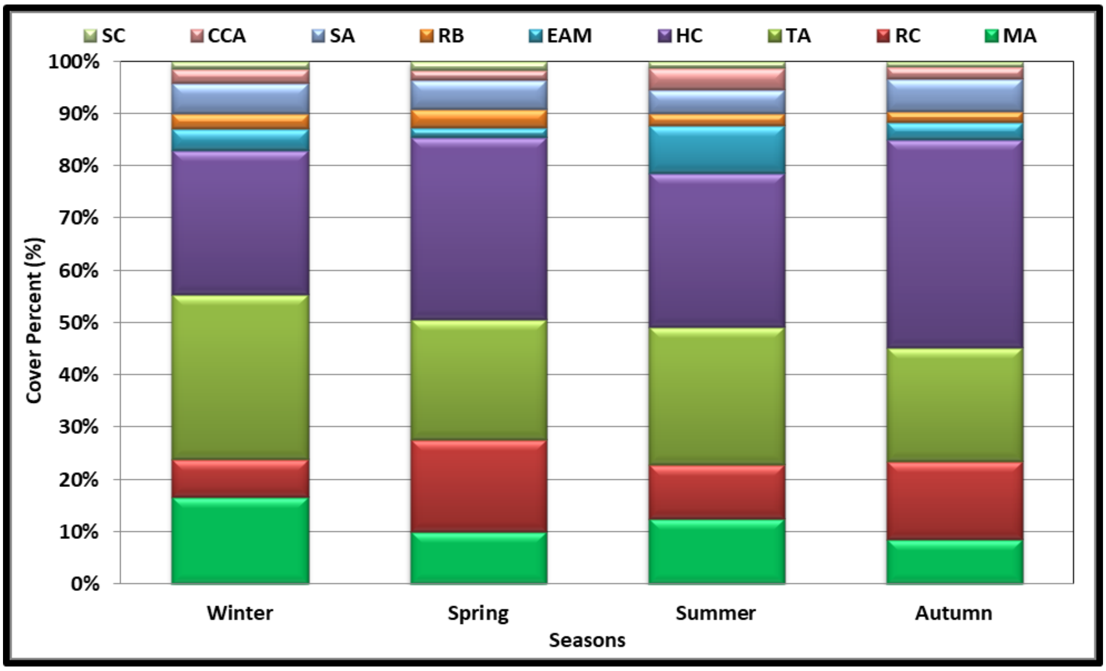


**Fig. 5.** The percent cover of benthic compensates in different seasons recorded at El-Sokhn Site in the Gulf of Aqaba during 2018. Hard live corals (HC), soft corals (SC), macro algae (MA), turf algae (TA), crustose coralline algae (CCA), epilithic algal matrix (EAM), sand (SA), rubble (Rb) and rock (RC).

### *5. Coral assemblage*

The corals (hard and soft) recorded the main benthic cover considering all zones, stations and seasons. The hard coral cover in the present study may easily be distinguished into five forms; they are branching, tabulate/or laminar, massive, foliaceous, encrusting hard corals in addition to soft corals. A total of 19 hard coral genera and 3 genera of soft coral were recorded during the present study.

The percentages of coral genera for all three zones are shown in Fig. (6). In reef flat, the most abundant genus was Acropora since it represented 38.5% of the total coral cover, followed by branching Stylophora (20.5%) and massive Cyphastrea (15.6%). Soft corals were represented in this zone by only genus Sinularia with low percent cover (0.82% of the total coral cover). Massive Porites and encrusting Montipora were represented in high percentage in this zone. In reef crest, Acropora increased in its cover to represent 45.9% of the total coral percentage, followed by branching Stylophora that decreased to represent 9.39% and Echinopora (6.63%). Branching Millepora was present in this zone with 4.7% percent cover, but it was absent in the previous zone. In this context, the soft coral Sinularia was highly raised and reached its highest percent cover (4.85 % of the total coral), while other soft coral genera were present and rare. In reef slope, *Acropora* still represents the highest percentage of coral cover but decreased with depth (46.8% of the total coral cover). Additionally with depth, the common genera were changed to encrusting *Montipora* (10.26 %) and branching *Pocillopora* (7.65 %). Moreover, the genus *Sinularia* of soft coral decreased in percent cover (2.61%) with depth, while another genera (Sarcophyton) was represented by 0.35%. Four genera (Acanthastrea, Asterop, Gardineroseris and Galaxea) of hard coral appeared for the first time in this zone.

Fig. (6) shows that the hard coral Acropora was the most common and abundant genus along study stations, where the cover percentages ranged from 44.27% to 58.04 % of the total coral cover at St2 and St4, respectively. Branching coral Stylophora was the second common genus at St3 and St4 with a percent cover of 10% and 6.55% of its total, respectively. On the other hand, Stylophora was among the main common genus and ranked the third dominant in St1 and St3 with a percent cover of 7.02% and 8.36% of its total, respectively. Encrusting Montipora was the second common genus at St1 and St2 with 7.02% and 8.36% of the total percent cover, respectively. Moreover, it appeared as a third common genus at St4 with a cover percentage of 6.25% of the total coral cover. In contrast, there are some genera with poor distribution in the studied stations, except for one station such as Seriatopora in St1, Galaxea in St3, Gardineroseris and Leptoria in St4. In this context, the genus Sinularia was the best soft coral distributed among stations, and it recorded its highest cover (5.26%) in St2 and the lowest (2.33%) in St3. Sarcophyton was recorded in St1, St2 and St3, while Cladiella was absent in St2, St3 and St4.

Concerning temporal distribution of coral genera, Acropora was the common during all seasons and recorded its highest cover during winter (56.12%) and lowest cover during spring (42%). Additionally, Stylophora and Montipora were alternately representing the second and third common genera during the whole investigated year. Pocillopora followed them in the percent cover of coral during spring and autumn, while Millepora and Echinopora were represented with high percent (6% and 5.14%, respectively) during spring. Although Sinularia was the main dominant and common soft coral genus during the year, it was highly abundant during winter (4.32) and low during fall (2.05%). Moreover, Sarcophyton was recorded during all seasons and represented with low cover percentage, while Cladiella was a rare genus and was only recorded during summer.

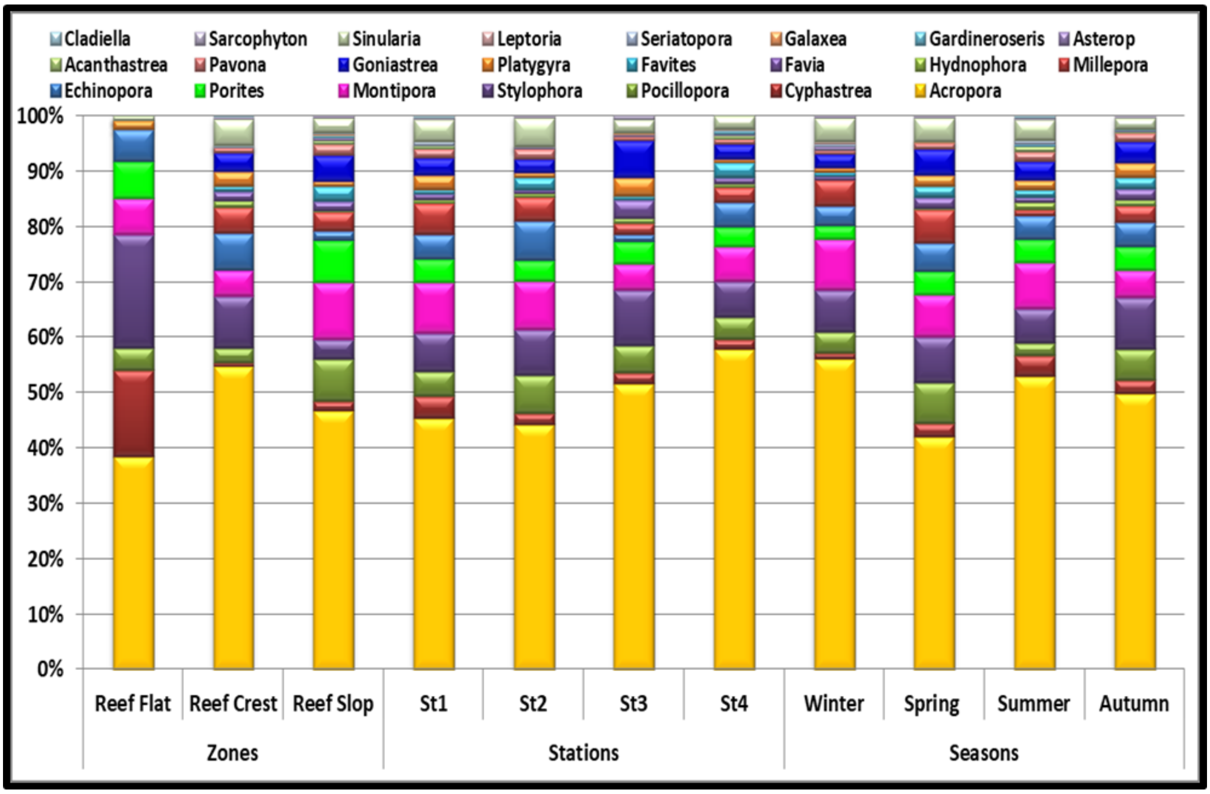


**Fig. 6.** The percent cover of hard coral forms recorded in reef zones and stations during study seasons at El-Sokhn Site in the Gulf of Aqaba during 2018

### *6. Algal cover:*

The algae population was represented in the study area with two main groups; macro and turf algae (Fig. 7). A competition was detected between the two groups, and the both were competents to the coral on space. Astoundingly, macro algae decrease with depth whereas the turf algae increase. Accordingly, the turf algae were highly distributed than macro algae at all stations during all seasons; this appears in their highly percent cover at all distributed categories in comparison to macro algae.

There are six genera representing macro algal cover, Sargassum was the most common and abundant, followed by Padina, Cystoseira, Turbo, Dictyota and Lourunica. As shown in Fig. (8), there is no symmetric distribution for macro algal genera between reef zones. Where, each genus was predominant at a specific zone, while others were absent or found with very low cover. Accordingly, the main bulk of Sargassum cover were recorded in reef flat zone (61.26% of the total macro algae cover) and very low percentage (2.33%) in reef crest and totally absent in reef slope zone. Likewise, the Turbo algae were represent with a percentage of 93.02% of the total macro algae cover in reef crest and 1.52% in reef flat and absent at reef slope zone. Ultimately, Padina represented the whole bulk of algae cover in reef slope. In this context, all macro algae genera had the same percentage on the spatial and seasonal scale distribution. The Sargassum was the main dominant genus at all stations during all seasons and had a percent cover, ranging from 39 % to 61% on the spatial scale, and it fluctuated from 45% to 59% of the total macro algal cover on the seasonal scale.

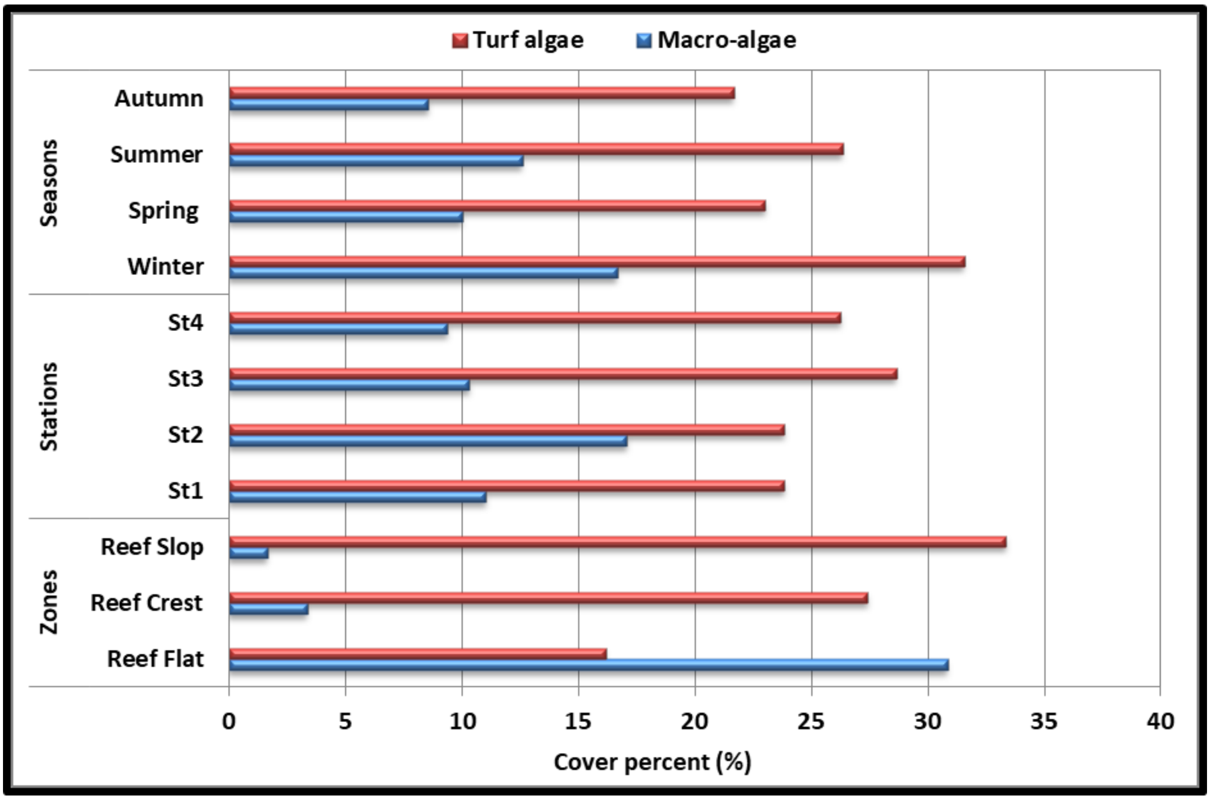


**Fig. 7.** The distribution of algae population in reef zones and stations during seasons recorded at El-Sokhn Site in Gulf of Aqaba during 2018

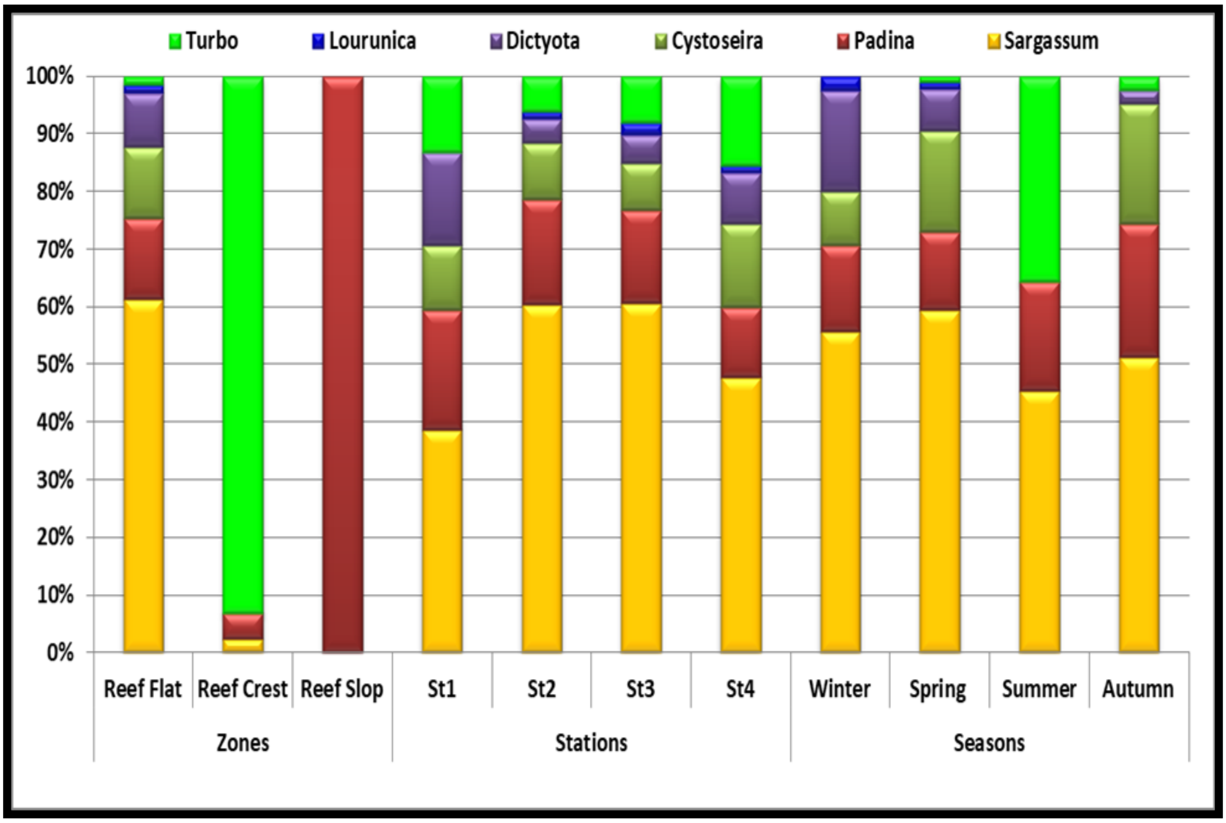


**Fig. 8.** The percent cover of macroalgae forms recorded in reef zones and stations during seasons recorded at El-Sokhn Site in Gulf of Aqaba during 2018

### *7. Corals & algae relationship:*

There is no doubt that, algae compete the coral on space. Accordingly, the hard coral was strongly and inverse correlated with macroalgae (r = -0.815, *P*<0.01), but it was weakly positive correlated with turf algae (r = 0.414, *P*<0.01) and with soft coral (r = 0.426, *P*<0.01). Regardless of the low percentage of soft coral at all study sites, but it was weakly negative correlated with macroalgae (r = -0.360, *P*<0.05), whereas there is no affect occurred between soft coral and turf algae. On the same side, macroalgae and turf algae relationship showed that there is moderate inverse correlation between them (r = -0.635, *P*<0.01). Astoundingly, there is no relation between crustose coralline algae and other live benthic cover categories either for hard coral, soft coral, macroalgae and turf algae. In this context, epilithic algal matrix has moderate negative effect on hard coral (r = -0.657, *P*<0.01) and has very weak effect on macroalgae, turf algae and soft coral. Ultimately, reef rubble was strongly correlated but negatively with macroalgae and positively with hard coral (Table 1).

**Table 1.** Correlation coefficient (r) between benthic categories recorded at El-Sokhn Site at Gulf of Aqaba, Egypt at different months during the year, 2018

| | | MA | RC | TA | HC | EAM | RB | SA | CCA | SC |
|---|---|---|---|---|---|---|---|---|---|---|
| MA | Pearson C.<br>Sig. | 1 | -0.383**<br>0.007 | -0.635**<br>0.000 | -0.815**<br>0.000 | 0.287*<br>0.048 | 0.806**<br>0.000 | 0.447**<br>0.001 | -0.050<br>0.736 | -0.360*<br>0.012 |
| RC | Pearson C.<br>Sig. | -0.383**<br>0.007 | 1 | -0.132<br>0.370 | 0.412**<br>0.004 | -0.305*<br>0.035 | -0.322*<br>0.026 | -0.306*<br>0.035 | -0.118<br>0.423 | 0.266<br>0.068 |
| TA | Pearson C.<br>Sig. | -0.635**<br>0.000 | -0.132<br>0.370 | 1 | 0.414**<br>0.003 | -0.297*<br>0.040 | -0.523<br>0.000 | -0.424<br>0.003 | -0.082<br>0.577 | 0.161<br>0.274 |
| HC | Pearson C.<br>Sig. | -0.815**<br>0.000 | 0.412**<br>0.004 | 0.414**<br>0.003 | 1 | -0.657**<br>0.000 | -0.809**<br>0.000 | -0.573**<br>0.000 | 0.032<br>0.832 | 0.426**<br>0.003 |
| EAM | Pearson C.<br>Sig. | 0.287*<br>0.048 | -0.305*<br>0.035 | -0.297*<br>0.040 | -0.657**<br>0.000 | 1 | 0.399**<br>0.005 | 0.344*<br>0.017 | 0.049<br>0.741 | -0.343*<br>0.017 |
| RB | Pearson C.<br>Sig. | 0.806**<br>0.000 | -0.322*<br>0.026 | -0.523**<br>0.000 | -0.809**<br>0.000 | 0.399**<br>0.005 | 1 | 0.521**<br>0.000 | -0.209<br>0.154 | -0.423**<br>0.003 |
| SA | Pearson C.<br>Sig. | 0.447**<br>0.001 | -0.306*<br>0.035 | -0.424**<br>0.003 | -0.573**<br>0.000 | 0.344*<br>0.017 | 0.521**<br>0.000 | 1 | -0.270<br>0.063 | -0.388**<br>0.006 |
| CCA | Pearson C.<br>Sig. | -0.050<br>0.736 | -0.118<br>0.423 | -0.082<br>0.577 | 0.032<br>0.832 | 0.049<br>0.741 | -0.209<br>0.154 | -0.270<br>0.063 | 1 | 0.062<br>0.674 |
| SC | Pearson C.<br>Sig. | -0.360*<br>0.012 | 0.266<br>0.068 | 0.161<br>0.274 | 0.426**<br>0.003 | -0.343<br>0.017 | -0.423**<br>0.003 | -0.388**<br>0.006 | 0.062<br>0.674 | 1 |

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

## DISCUSSION

Coral reefs are one of the most prolific ecosystems on the planet, providing habitat and a haven for a wide range of marine animals **(Alquezar and Boyd, 2007 and Abo Elenin *et al*., 2020)**. Coral reefs have degraded dramatically over the world in the last 50 years as a result of a multitude of stressors operating at various spatial and temporal scales. Where, as a result of anthropogenic pressures and global climate change, coral reefs are under serious threats. Coral bleaching has been induced by climate change **(Obura and Grimsdith, 2009)**, but other factors such as hurricane damage and coral disease have also been identified as dangers to coral **(Rogers and Miller, 2001)**. Human disturbances to coral reefs, such as overfishing, destructive fishing, recreational activities, and coastal development, have all contributed to coral decline **(Mona *et al*., 2019 and Shaban *et al*., 2020)**. Therefore, in order to assess whether stressors and coral declines are continuing, or if reefs are recovering, detailed baseline information about community components is required from across wide spatial and temporal scales. Unfortunately, for some regions this information is not readily available, making future reef trajectories difficult to determine.

Benthic communities are among the first to disappear under conditions of heavy stress. Benthic components play an important ecological role, thus the loss of any one of them is a liability to the ecosystem as a whole **(Farag *et al*., 2019)**. Herein, the monitor and assessment of the status of benthic components of coral reef ecosystem was done to provide the information about coral reef status and their conditions and dynamics of coral-algal interactions as a two main components of benthic cover.

The benthic community composition varied distinctly across the geomorphological zones, which was expected. Within the reef slope, regardless of depth, the benthic composition was characterized by very high hard coral cover (∼45%) and low macroalgae cover, indicating a healthy reef condition with high herbivory and low nutrients **(Littler and Littler, 2007)**. The same was in the reef crest zone. On the reef flat, community composition varied with low hard coral cover (∼9%), high macroalgal cover (∼30%) and high amounts of coral rubble.

It is clear from the results that hard coral cover was found to increases the further away from the beach, where it increase in reef crest and reef slop zones than reef flat zone. The reduction in coral cover and increase coral rubble and macroalgae observed in this study suggest that the reef flat zone is the most directly affected by different activities, in addition to it being the first recipient of coastal impacts such as dust from land as well as its shallowness. This is consistent with previously recorded results from the Red Sea **(Loya, 1972; Kotb, 1996; Kotb *et al*., 1996; Medio, 1996; De Vantier, 2000; Tilot *et al*., 2000 & 2008, Reverter *et al*., 2020 and Darawish, 2021a)**. Although the hard coral cover was varied among the studied sites, the more depth got shallower, the more the sand can accumulate between the bottom substrate structure, this leading to decreasing the chances of coral larvae to settle and grew to form a new colony **(Sheppard, 1982 and Kotb, 1996)**. **Farrag *et al*. (2019)** cited that any disturbance occurring in the natural habitats of species strongly affects their presence and stability, thus affecting biodiversity. Accordingly, **Mona *et al.* (2019)** stated that when the ecological impacts caused by habitat disturbance are coupled with general environmental degradation, such as eutrophication, toxic pollution or global climate change, the capacity of marine ecosystems to support sustainable biodiversity is reduced.

Coral reefs that supply and preserve the services for around 500 million people now impacted by natural or human disturbance such coastal expansion, newly added metropolitan areas, random fisheries, and pollution that can damage coral resilience and cause mortality **(Hughes *et al*., 2017 & 2018; Adjeroud *et al*., 2018; Lamb *et al*., 2018 and McWilliam *et al*., 2020)**. The decreases in coral coverage and increased sponge or algal coverage have a diminishing impact on the services provided **(Done 1992; Norstrom *et al*., 2009 and Bell *et al.*, 2013)**.

On the contrary to this, macroalgae was more covering in reef flat zone than reef crest and almost nonexistent in reef slope zones with very small percent. This may be due to the increase in nutrients that come from the beach, as well as the shallowness of this area to increase the process of photosynthesis, as well as the presence of some sand that supports its growth. The anthropogenic stressors (i.e., overfishing, eutrophication) are contributing to the proliferation of macroalgae and an increase in coral-algal competition **(Burkepile and Hay, 2006; Hughes *et al*., 2007; Littler and Littler, 2007 and Smith *et al*., 2010)**.

The results presented here highlight on the composition of benthic cover and the key observations of natural levels of macroalgae and coral-algal interactions. The macroalgae wasn't only varying within zones, but also within the context of well-known seasonal cycles, with macroalgal biomass peaking in winter and decreasing in the fall. The natural state of macroalgae varies in space and time due to a combination of biotic (i.e., competition and herbivory) and abiotic (i.e., wave action and temperature) processes **(Steneck and Dethier, 1994; Connell *et al*., 2004; Bruno *et al*., 2014)**. These results highlight the unique seasonality of macroalgal taxa, even within the same functional group, and demonstrate that shifts in macroalgal taxa influence the composition of coral-algal interactions. Future studies should consider the seasonality of individual macroalgal taxa when investigating coral-algal competition. Spatially, macroalgae display distinct within and between reef patterns in biomass and community composition **(Diaz-Pulido *et al*., 2007 and Wismer *et al.*, 2009)**. Macroalgae also show marked seasonal dynamics, primarily due to strong seasonal oscillations in temperature and light **(Ateweberhan *et al*., 2006 and Fulton *et al.*, 2014)**. The effects of spatio-temporal variability on tropical macroalgae, however, have mostly been inferred from the occurrence of seasonal peaks and have principally focused on large, conspicuous species (i.e., Sargassum) that bloom in the summer **(Vuki and Price, 1994; McCook, 1997 and Lefèvre & Bellwood, 2010)**.

Therefrom, it becomes clear that there is an exchange in the spatial distribution between algae and corals or there is strong competition between them on the place, and this shows the strong inverse relationship between them from the present result, which means that the increase in the cover of algae decreases the cover of the reefs and vice versa. In addition to macroalgal cover, the composition and frequency of coral-algal interactions showed distinct spatio-temporal variation. Commoner species are expected to have more interactions than rare species **(Connell *et al*., 2004)**. At all reef zones, Acropora was the most abundant coral genera, resulting in the greatest number of interactions with macroalgae. On the reef crest and reef slope zones, the most widespread interaction was between Acropora and turf algal assemblages. While these interactions were frequently observed, a very small proportion of other coral-algal interactions were encountered and the incidence of coral-algal contact was the lowest on the reef flat zone. Interactions with Sargassum were common, reflecting the significantly higher abundance of this macroalga in the reef flat zone.

There is no doubt that, algae compete the coral on space. According to the present result, the hard coral was strongly inversely correlated with macroalgae, where it was decreased in reef flat zone when macroalgar increased and it was more common when macroalgae was declined at reef crest and reef slope zones. Algae may damage corals and other species via toxicity **(Rasher and Hay, 2010)**, covering **(Box and Mumby, 2007)**, grazing **(McCook *et al.*, 2001)**. Recent research has shown that algal growths (e.g., macroalgae and benthic cyanobactroids) can disruptive coral microbioms, leading to increased coral mortality **(Haas *et al*., 2016 and Zaneveld *et al*., 2016)**. Competition for space with macroalga may further prevent coral recruitment, with dense macroalgal populations blanketing the benthos and pre-empting coral settlement **(Birrell *et al*., 2008)**. The increases of algal interference within coral reefs are considered to be the consequence of several interconnected causes, such increasing nutrient content and loss of top control because to overfishing or disease **(Rasher *et al*., 2012 and Jessen *et al*., 2013)**. Fishing can thus have a role in reducing herbivorous fish and so increasing algal coverage. The major component in macroalgal growth in studies indicating herbivory suppression **(Rasher *et al*., 2012; El-Naggar *et al*., 2019 and El-Sadek *et al*., 2022)**. Also, nutrient levels are strong factor in the macroalgae blooming. Given the important role that macroalgae and coral-algal interactions play in structuring coral reef ecosystems, these results indicate that frequent reef monitoring should be encouraged within and between zones to detect potential changes and avoid a loss of important information relating to the trajectory and resilience of coral reef ecosystems.

## CONCLUSION

Macroalgae and their interactions with corals are more relevant than ever, especially given the rapidly shifting tropical coral reef ecosystem dynamics. However, coral reef monitoring often occurs in response to ya disturbance and rarely ever considers seasonal and spatial variability. The future work should explore to what extent these thresholds are reached at large spatial scales to improve quantitative models of the biomass of macroalgae on coral reefs. The complexity of macroalgal and coral-algal dynamics across this one reef system further highlight the need for future studies to consider inter-seasonal variability across zones and illustrate the difficulty in determining the baseline condition of well-studied ecosystems. Now more than ever, seasonal and long1term studies are needed to avoid a loss of important information associated with the trajectory and resilience of coral reef ecosystems..

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