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# Quantification of coral reef communities along the Gulf of Aqaba and Ras Mohammed, Red Sea, Egypt

**Mohammed Shokry Ahmed Ammar[1,*] and Hashem Abbas Madkour[2]**

[1]National Institute of Oceanography and Fisheries, Suez & Aqaba Gulfs Branch,
[2]National Institute of Oceanography and Fisheries, Hurghada Branch, Egypt

## ABSTRACT

The present study is the first to produce a detailed species composition of corals on the species level along a transect of sites extending from Ras Mohammed at the northern Red Sea to the northern tip of the Gulf of Aqaba, Egypt. The computer software Photogrid 1.0 beta Acad was used for ecological analysis of digital photographs. The stony coral *Asteriopora myriophthalma* was indicated to be an opportunistic species while the two soft corals *Lobophytum arboretum and Rhytisma* sp. were found to be successful colonizers. Considerable recruits in deep areas of Marsa Breika and shallow areas of Katy were fostered by high number of divers. Highest percentage cover of live corals in Canyon is associated with effective management while lowest amount of live corals in South Nuweiba is associated with the considerable interlacing fishing nets and absence of effective management. Past breakage of large coral colonies in Ras Ghozlani and Temple led to increased bare rocks while past breakage of branching or small sized corals in Ras Ghozlani and Islands led to increased rubbles. Both recent and old damage initiate the alteration of the community into echinoderm and algal domination with higher amount of echinoderms in the recent damage and higher amount of algae in the old damage. Past breakage fosters the competitive ability of molluscs; water currents lead to abundant sponges; disturbance by fishing activities provides sufficient preys that foster the growth of anemones. Number of coral species in the study sites are: 123 stony corals, 2 black corals, 3 hydrocorals, 15 soft corals, 2 gorgonians, 145 total number.

**KEYWORDS:** coral reefs, Gulf of Aqaba, Red Sea

## INTRODUCTION

The Gulf of Aqaba is a small, semi-enclosed branch of the Red Sea, 180 km long and 5 to 26 km wide [1]. The same author in his review pointed out that the Gulf of Aqaba hosts an extraordinary diversity of corals and related marine life; however, approximately 210 scleractinian hard coral species and 120 species of soft coral have been recorded in the Gulf. In the early 1970's, the first SCUBA divers arrived in South Sinai, in the 1980s, the diving tourism started to boom, the 1990s witnessed a veritable explosion of the Red Sea tourism [2]. The tourism is mainly developed in Sharm El Sheikh but is progressing up the coastline to the north of Aqaba. The number of divers per site per year in most of South Sinai dive sites is increasing, resulting in the diver carrying capacity (DCC) being exceeded [3]. The number of divers per year in Ras Umm Seid, Sharm El-Sheikh (Gulf of Aqaba) was indicated to be more than 51000 which is far beyond the diver carrying capacity DCC [4]. The DCC value is an estimation of the maximum number of divers

*Corresponding author
shokry_1@yahoo.com

that a reef can tolerate per year; below this value, little damage is done and above this value, damage accumulates rapidly knowing that recreational scuba diving causes damage to reefs at exponentially increasing rates as diving intensity increases [3].

Coral reefs are important to human civilization. They provide ecosystem services which can be defined as the conditions and processes through which natural ecosystems and the species that make them up sustain and fulfil human life [5]. The ecosystem services like maintenance, production of food such as sea food and fish and coastal protection will sustain the aesthetic and cultural benefits, recreation and tourism beside improving biodiversity [5, 6]. From the review of the above mentioned literatures and others [7] different services and products of coral reefs can be summarized as follows:

1. Social and cultural services (including tourism): Support of recreation, tourism, aesthetic values and artistic inspiration, sustaining the livelihood of communities support of cultural, religious and spiritual values.

2. Physical structure services: Shoreline protection, build-up of land, promoting growth of mangroves and seagrass beds, generation of coral sand.

3. Biotic services (within ecosystem: Maintenance of habitats, biodiversity and a genetic library, regulation of ecosystem processes and functions, biological maintenance of resilience).

4. Biotic services (between ecosystems): Biological support through 'mobile links', export organic production etc. to pelagic food webs.

5. Bio-geo-chemical services: Nitrogen fixation, $CO_2$/Ca budget control, waste assimilation.

6. Information services: Monitoring and pollution record, climate control.

7. Renewable resources: Sea food products, raw materials and medicines, other raw materials (e.g. seaweed), curios and jewelry, live fish and coral collected for aquarium trade.

8. Building materials: Sand for buildings and roads.

Since other previous studies on the Gulf of Aqaba, Egypt are either localized in a certain area, or produced on the genus level or simply mentioned the species number without providing the detailed species list or species composition, also due to the above mentioned services and products of coral reefs; the present work aimed to be the first to quantify a broad area of coral reefs representing a transect of sites extending from Ras Mohammed (northern Red Sea) to the northern tip of the Gulf of Aqaba, Egypt; providing a detailed description of species composition of corals on the species level and giving insight to the human impacts and interaction with other associated fauna and flora in the study area.

## MATERIALS AND METHODS

Eight sites extending from Ras Mohammed to the northern tip of the Gulf of Aqaba were surveyed throughout the period January 2009 to June 2009. These sites are graphically represented in Fig. 1. and listed as follows:

1. Ras Ghozlani: 27° 47.527` N, 34° 15.752` E
2. Marsa Breika: 27° 47.634` N, 34° 15.453` E
3. Temple: 27° 50.827` N, 34° 18.533` E
4. Katy: 27° 50.930` N, 34° 18.001` E
5. Islands: 28° 28.634` N, 34° 30.682` E
6. Canyon: 28° 33.297` N, 34° 31.229` E
7. South Nuweiba: 28° 56.481` N, 34° 38.395` E
8. Marsa Muqabela: 29° 21.995` N, 34° 47.071` E

SCUBA diving and the camera frame (as a quadrat), were used for surveying the benthic coral reef communities. Ten frames, at one meter intervals and one meter from the object were surveyed along a transect fixed horizontally along the reef contour at the depths 1m, 5 m, 10 m, 15 m, 20 m, 30 m, 40 m and 50 m (when found) or till the end limit of coral growth at each of the studied sites [8]. A FinePix F50, 12 Mega Pixels Digital Camera, was used for taking a series of under-water photos to help identification of species and other taxa habitats. The computer software Photogrid 1.0 beta Acad was used for ecological analysis of digital photographs of corals and other taxa or habitats [9]. The previous software was used for calculating the percentage cover of live corals and other living features like sea anemones, molluscs, echinoderms, sponges, sea grasses and algae in addition to the non living features like dead corals, bare rocks, rubbles and sands/

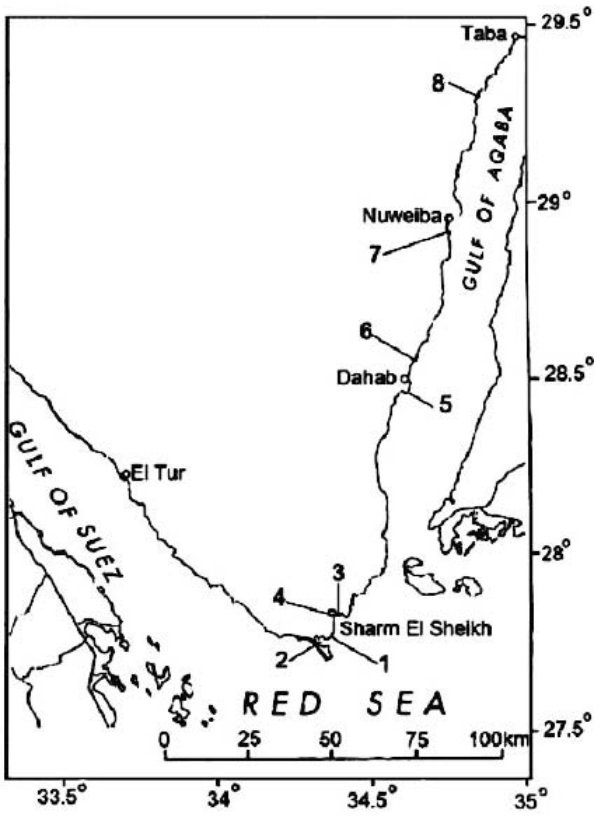


**Fig. 1.** Graphical representation of the studied sites.

sediments. Human impacts (like number of boats, number of divers, number of snorklers, interlacing fishing nets & garbage) and related management actions (like patrolling, reef access points) on these coral reef sites were assessed during the survey.

Using the computer program STATISTICA Version 5.0, the two ways joining clustering method [10] was used to compute the correlation between sites and number of different coral species, it was also used to compute the correlation between sites and percentage coverage of different coral reef taxa and habitats.

## RESULTS

### Coverage of coral species

Percentage cover of different coral species are indicated in (Tables 1-8). With respect to Ras Ghozlani (Table 1), the two stony corals *Stylophora pistillata* and *Asteriopora myriophthalma* are the only species that have been recorded in all depths; however, *Platygyra lamellina* and *Porites lutea* have the highest percentage cover among stony corals (8.1% & 5.6% respectively) while *Lobophytum arboreum* reported the highest values among soft corals. It is obvious that soft corals tend to be densely distributed at higher depths. Fish biting was reported attacking the massive stony coral *Porites* sp. (5m depth). In case of Marsa Breika (Table 2), the soft coral *Rhytisma* sp. is the only coral species reported in all depths, followed by the stony coral *Stylophora pistillata* that was reported until 40m depth. Highest reported percentage covers were given by the branching stony coral *Acropora nasuta* (29.4%, 5 m depth). New recruits were reported for 6 stony species. It is obvious that new recruits are mainly found at higher depths (20, 30 & 40 m depths). With regard to Temple, *Pocillopora verrucosa* reported the highest percentage cover for stony corals (9.4%) while *Heteroxenoa ghardaqensis* reported the highest value for soft corals (49.5%) while in case of Katy, *Echinopora fruiticulosus* recorded the highest percentage cover among stony corals while *Anthelia glauca* reported the highest value among soft corals. New recruits were reported at shallower depths for two stony corals only (*Goniastrea persi* and *Favites halicora*). For the site Islands *Porites lutea* reported the highest percentage cover for massive stony corals (12.4%, 5 m depth) while *Cladella* sp. recorded the highest percentage value for soft corals and *Millepora platyphylla* was the highest for hydrocorals. Fish biting to coral colonies was obvious for the two stony corals *Porites solida* (10 m depth) and *Porites lutea* (5 m depth). In the case of the site Canyon, the branching coral *Acropora nasuta* reported the highest percentage cover among stony corals while in South Nuweiba, the two massive corals *Goniastrea retiformis* and *Asteriopora myriophthalma* reported the highest value among stony corals. In Marsa Muqabela, the massive coral *Goniastrea retiformis* had the highest coverage among stony corals (13.38%, 1m depth) while *Heteroxenia ghardaqensis* had the highest value among soft corals. *Millepora dichotoma* had the highest coverage of hydrocorals (13.38%, 5 m depth). Number of coral species is summarized in (Table 9). Number of coral species in all sites of the study area are 123 stony corals, 2 black corals, 3 hydrocorals, 15 soft corals, 2 gorgonians; totalling 145.

**Table 1.** Percentage cover of corals at Ras Ghozlani.

| | Species and Habitats | Percentage cover Depth 1m | 5m | 10m | 15m | 20m | 30m |
|---|---|---|---|---|---|---|---|
| | **Hexacorallia** | | | | | | |
| | **Stony corals** | | | | | | |
| 1 | *Stylophora pistillata* | 1.75 | 1.25 | 0.25 | 1.375 | 0.375 | 0.5 |
| 2 | *Acropora nasuta* | 0 | 2.5 | 0.625 | 0 | 0 | 0 |
| 3 | *Acropora aculeus* | 0 | 0.25 | 0 | 0 | 0 | 0 |
| 4 | *Acropora humilis* | 1.5 | 0 | 0 | 0 | 0 | 0 |
| 5 | *Acropora hemperichi* | 5 | 0 | 0 | 0 | 0 | 0 |
| 6 | *Pocillopora verrucosa* | 0 | 0 | 0.125 | 0 | 0 | 0 |
| 7 | *Pocillopora damicornis* | 3.125 | 0 | 0 | 0 | 0 | 0 |
| 8 | *Seriatopora hystrix* | 0.125 | 0.25 | 0.25 | 0.625 | 0.875 | 0 |
| 9 | *Seriatopora caliendrum* | 0 | 0.25 | 0 | 0 | 0 | 0.25 |
| 10 | *Favites chinensis* | 0.375 | 0 | 0 | 0 | 0 | 0 |
| 11 | *Favites pentagona* | 0 | 0.125 | 1.875 | 0 | 0 | 0 |
| 12 | *Favites halicora* | 0 | 0 | 0.625 | 0.438 | 0.25 | 0 |
| 13 | *Favites abdita* | 0 | 0 | 1.25 | 0 | 0 | 5.875 |
| 14 | *Favites complanata* | 0 | 0 | 1.25 | 0 | 0 | 0 |
| 15 | *Favites vasta* | 0 | 0 | 1.875 | 0 | 0 | 0 |
| 16 | *Favia laxa* | 0 | 0 | 0.125 | 0 | 0 | 0 |
| 17 | *Favia veroni* | 0 | 0 | 0 | 0 | 0 | 0.25 |
| 18 | *Favia lacuna* | 0 | 0 | 0 | 0 | 0 | 0.375 |
| 19 | *Goniastrea retiformis* | 2.125 | 0 | 2.125 | 1.625 | 0 | 0.25 |
| 20 | *Goniastrea pectinata* | 3.25 | 0.875 | 0.625 | 0 | 0 | 0 |
| 21 | *Goniastrea cf. aspera* | 0 | 1.25 | 0 | 0 | 0 | 0 |
| 22 | *Goniastrea persi* | 0 | 0 | 0 | 0 | 0.688 | 0 |
| 23 | *Porites lutea* | 5.625 | 0 | 0 | 0.625 | 0 | 0 |
| 24 | *Porites solida* | 0 | 0.875 | 3.625 | 0 | 0.25 | 2.25 |
| 25 | *Porites* sp. | 0 | 0.5(FB) | 0 | 0 | 0 | 0 |
| 26 | *Gardineroseris planulata* | 1.5 | 0 | 0 | 0 | 0 | 0 |
| 27 | *Siderastrea savignyana* | 0 | 0.5 | 0 | 1.25 | 2 | 0.125 |
| 28 | *Platygyra lamellina* | 8.125 | 0 | 0 | 0 | 1.25 | 0.25 |
| 29 | *Platygyra acuta* | 0 | 0.125 | 0 | 0 | 0 | 0 |
| 30 | *Gyrosmilia interrupta* | 0 | | 0 | 0 | 0 | 0.125 |
| 31 | *Asteriopora myriophthalma* | 0.5 | 0.625 | 0.25 | 0.5 | 0.125 | 0.625 |
| 32 | *Psammocora hemispherica* | 0.125 | 0 | 0 | 0 | 0 | 0 |
| 33 | *Alveopora lizardi* | 0 | 0.25 | 0 | 0 | 0 | 0 |

Table 1 continued..

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 34 | *Montipora aequituberculata* | 0.625 | 0 | 0 | 0 | 0 | 0 |
| 35 | *Montipora verrucosa* | 0 | 0 | 0 | 0 | 0 | 0.1875 |
| 36 | *Pavona decussata* | 0 | 0.5 | 0 | 0 | 0 | 0 |
| 37 | *Pavona varians* | 0 | 0 | 0 | 0.125 | 0 | 0 |
| 38 | *Echinopora lamellosa* | 0 | 0 | 0.5 | 0.375 | 0 | 0.75 |
| 39 | *Echinopora gemmacea* | 0 | 0 | 0.625 | 0 | 0 | 0 |
| 40 | *Echinopora fruticulosus* | 0 | 0 | 0 | 0.125 | 0 | 0 |
| 41 | *Echinopora forskaliana* | 0 | 0 | 0 | 0 | 0 | 0.75 |
| 42 | *Echinopora trianensis* | 0 | 0 | 0 | 0 | 0 | 0.25 |
| 43 | *Turbinaria mesentrina* | 0 | 0 | 0 | 0 | 0.625 | 0 |
| 44 | *Ctenactis echinata* | 5.25 | 0 | 0 | 0 | 0 | 0 |
| | **Octocorallia** | | | | | | |
| | **Soft corals** | | | | | | |
| 1 | *Lobophytum* sp. | 6.875 | 0 | 1.25 | 0 | 0 | 0 |
| 2 | *Xenia* sp. | 4 | 0.625 | 0 | 0 | 0 | 0 |
| 3 | *Anthelia glauca* | 0 | 0 | 0.25 | 5.812 | 4 | 0 |
| 4 | *Sympodium caeruleum* | 0 | 0 | 0.125 | 0 | 0 | 0 |
| 5 | *Lithophyton* sp. | 0 | 0 | 0.23 | 0 | 0 | 0 |
| 6 | *Lithophyton arboreum* | 0 | 0 | 0 | 8.751 | 15.06 | 9.375 |
| 7 | *Rhytisma* sp. | 0 | 0 | 1 | 0.5 | 0.125 | 0 |
| 8 | *Xenia macrospiculata* | 0 | 0 | 0 | 0 | 0 | 0.25 |
| 9 | *Heteroxenia ghardaqensis* | 0 | 0 | 0 | 0 | 6.375 | 6.25 |

**Table 2.** Percentage cover of corals at Marsa Breika. R=New recruits, D=Dead.

| Species and Habitats | | Percentage cover Depths | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1m | 5m | 10m | 15m | 20m | 30m | 40m |
| | **Hexacorallia** | | | | | | | |
| | **1- Stony corals** | | | | | | | |
| 1 | *Stylophora pistillata* | 2.13 | 0.8 | 0.06 | 1.63 | 1.75 | 0 | 0.63 |
| 2 | *Stylophora mamillata* | 0.00 | 0.0 | 0.00 | 0.00 | 0 | 0 | 0.19 |
| 3 | *Syriatopora hystrix* | 0.00 | 0.1 | 1.00 | 1.00 | 0 | 0.25 | 6.38 |
| 4 | *Seriatopora caliendrum* | 0.00 | 0.0 | 0.00 | 0.25 | 0 | 0 | 0.00 |
| 5 | *Acropora maryae* | 0.00 | 0.0 | 9.38 | 0.00 | 0 | 3.125 | 0.00 |
| 6 | *Acropora nasuta* | 0.00 | 29.4 | 0.00 | 0.00 | 0 | 0 | 0.00 |
| 7 | *Acropora humilis* | 1.38 | 0.0 | 0.00 | 0.00 | 0 | 0 | 0.00 |
| 8 | *Acropora hemperichi* | 6.38 | 0.0 | 0.00 | 0.00 | 0 | 0 | 0.00 |

Table 2 continued..

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 9 | *Acropora valida* | 0.00 | 0.0 | 0.00 | 0.00 | 0.5 ® | 0.125 | 0.13 |
| 10 | *Acropora formosa* | 0.00 | 0.0 | 0.00 | 0.00 | 0 | 4.625 | 0.00 |
| 11 | *Pocillopora verrucosa* | 3.13 | 0.0 | 0.00 | 0.00 | 0 | 0 | 0.00 |
| 12 | *Pocillopora damicornis* | 0.50 | 0.0 | 0.88 | 0.75 | 0 | 0 | 0.00 |
| 13 | *Tubestrea micranthus* | 0.13 | 0.0 | 0.00 | 0.00 | 0 | 0 | 0.00 |
| 14 | *Goniastrea retiformis* | 2.88 | 0.1 | 1.00 | 0.38 | 0 | 0 | 0.00 |
| 15 | *Goniastrea persi* | 2.13 | 0.4 | 0.13 | 0.00 | 0 | 0 | 0.00 |
| 16 | *Goniastrea pectinata* | 0.00 | 0.0 | 0.00 | 0.50 | 0 | 0 | 0.00 |
| 17 | *Porites solida* | 7.38 | 1.1 | 0.50 | 0.75 | 0 | 0 | 0.00 |
| 18 | *Porites lutea* | 0.00 | 0 | 0.00 | 0.63 | 2.375 | 0 | 0.00 |
| 19 | *Porites mayeri* | 0.31 | 0 | 0.63 | 0.00 | 0 | 0 | 0.00 |
| 20 | *Porites nodifera* | 0 | 0 | 0.38 | 0.00 | 0 | 0 | 0.00 |
| 21 | *Porites rus* | 0 | 0 | 0.00 | 0.00 | 1.25 | 0 | 0.00 |
| 22 | *Siderastrea savignyana* | 0 | 0 | 0.00 | 0.00 | 0 | 0 | 0.38 |
| 23 | *Favites abdita* | 0 | 0 | 5.31 | 0.75 | 0 | 0.75 | 0.6 ® |
| 24 | *Favites halicora* | 0 | 0 | 0.00 | 0.00 | 0 | 2.85 | 0.5® |
| 25 | *Favia pallida* | 0.5 | 0 | 0.00 | 0 | 4 | 0 | 0 |
| 26 | *Favia favus* | 0 | 0 | 0.19 | 0 | 0.4® | 0 | 0 |
| 27 | *Favia lacuna* | 0 | 0 | 0.25 | 0 | 0 | 0 | 0 |
| 28 | *Favia laxa* | 0 | 0 | 2.25 | 0 | 0 | 0 | 0 |
| 29 | *Favia amicorum* | 0 | 0 | 0 | 0 | 0.2® | 1.5 | 1.125 |
| 30 | *Goniopora stokesi* | 0 | 0 | 0 | 0 | 0 | 1.375 | 0 |
| 31 | *Merulina ampliata* | 0 | 0 | 0 | 0 | 0 | 0.2® | 0 |
| 32 | *Gyrosmilia interrupta* | 0 | 0 | 0 | 0.875 | 0 | 0 | 0 |
| 33 | *Hydnophora microconus* | 0 | 0 | 0 | 0.75 | 0 | 0 | 0 |
| 34 | *Hydnophora exesa* | 0 | 0 | 0 | 1.125 | 0 | 0 | 0 |
| 35 | *Montipora tuberculosa* | 0.63 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | *Montipora verrucosa* | 0.50 | 0 | 0 | 0.25 | 1 | 1.5 | 0.25 |
| 37 | *Montipora informis* | 0.00 | 0 | 0 | 4.25 | 0 | 3.375 | 0 |
| 38 | *Montipora stilosa* | 0.00 | 0 | 0 | 2.125 | 0 | 0 | 0 |
| 39 | *Montipora cocosensis* | 0.00 | 0 | 0 | 0 | 0 | 8.875 | 1.875 |
| 40 | *Platygyra lamellina* | 6.75 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | *Cyphastrea microphthalma* | 0.13 | 0.75 | 0 | 0 | 0 | 0 | 0 |
| 42 | *Pavona decussata* | 0.00 | 0.00 | 0 | 0 | 0.3 | 0 | 0 |
| 43 | *Pavona cactus* | 0.00 | 0.00 | 0 | 0 | 0.0 | 0 | 0.25 |
| 44 | *Psammocora profundacella* | 0.00 | 0.00 | 0 | 0 | 0.0 | 0 | 0.625 |
| 45 | *Leptoseris explanata* | 0.00 | 0.00 | 0 | 0 | 0.0 | 0 | 0.68 |
| 46 | *Mycedium elephantotus* | 0.00 | 0.00 | 0 | 1.625 | 0.0 | 6.875 | 0 |

Table 2 continued..

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 47 | *Mycedium umbra* | 0.00 | 0.00 | 0 | 0 | 20.6 | 0 | 0 |
| 48 | *Asteriopora myriophthalma* | 0.00 | 0.00 | 0.63 | 0 | 0.0 | 0 | 0 |
| 49 | *Alveopora daedalea* | 0.00 | 0.00 | 0.00 | 0.125 | 0.4 | 0 | 0 |
| 50 | *Stylocoeniella guentheri* | 0.00 | 0.00 | 0.00 | 0 | 0.0 | 6 | 0 |
| | **2- Black corals** | | | | | | | |
| 1 | *Antipathes* sp. | 0.00 | 3.25 | 0.00 | 0 | 0 | 0 | 0 |
| | **Hydrocorals** | | | | | | | |
| 1 | *Millepora dichotoma* | 0.00 | 0.50 | 0.00 | 0.125 | 0.1® | 0 | 0 |
| | **Octocorals** | | | | | | | |
| | **1- Soft corals** | | | | | | | |
| 1 | *Sinularia* sp. | 8.13 | 0.00 | 0.00 | 0 | 0 | 0 | 0 |
| 2 | *Xenia macrospiculata* | 1.75 | 1.75 | 2.13 | 0 | 0 | 0 | 0 |
| 3 | *Heteroxenia ghardaqensis* | 0.00 | 7.50 | 2.75 | 0 | 1.25 | 15.5 | 0.5 |
| 4 | *Anthelia glauca* | 0.88 | 0.00 | 0.00 | 0 | 0 | 0 | 0 |
| 5 | *Sympodium caeroleum* | 0.00 | 0.00 | 0.00 | 2 | 0 | 0 | 0.25 |
| 6 | *Rhytisma* sp. | 0.13 | 1.63 | 5.13 | 1.75 | 0.625 | 0.75 | 0.13 |
| 7 | *Cladiella* sp. | 0 | 0 | 0.00 | 0 | 0 | 2.87 | 0 |
| 8 | *Lithophyton arboreum* | 0 | 0 | 5 | 4.875 | 0 | 0 | 0 |
| 9 | *Sarcophyton* sp. | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| | **2- Gorgonians** | | | | | | | |
| 1 | *Paraplexaura* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 8.38 |

**Table 3.** Percentage cover of corals at Temple.

| Species and Habitats | | Percentage cover Depths | | | | |
|---|---|---|---|---|---|---|
| | | 1m | 5m | 10m | 15m | 22m |
| | **Hexacorallia** | | | | | |
| | **Stony corals** | | | | | |
| 1 | *Stylophora pistillata* | 0 | 0.75 | 4 | 5.625 | 2 |
| 2 | *Syriatopora hystrix* | 0 | 0 | 0 | 0.25 | 0 |
| 3 | *Acropora valida* | 0 | 0 | 0 | 1.125 | 0 |
| 4 | *Acropora squarrosa* | 0 | 0 | 0 | 0.375 | 0 |
| 5 | *Acropora* sp. (new) | 0 | 0 | 0.1875 | 0 | 0 |
| 6 | *Pocillopora verrucosa* | 4.125 | 7.75 | 9.375 | 1 | 0 |
| 7 | *Montipora cocosensis* | 0 | 3.625 | 0 | 0.75 | 0 |
| 8 | *Acanthastrea echinata* | 0 | 0.75 | 0 | 0 | 0 |

Table 3 continued..

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | *Hydnophora microconus* | 0 | 0.375 | 0 | 0 | 0 |
| 10 | *Tubastrea aurea* | 0 | 0.125 | 0 | 0 | 0 |
| 11 | *Tubastrea coccinea* | 0.0625 | 0 | 0 | 0 | 0 |
| 12 | *Porites nodifera* | 0 | 0.75 | 0 | 0 | 0 |
| 13 | *Porites lichen* | 0 | 0.625 | 0 | 0 | 0 |
| 14 | *Porites solida* | 0 | 0 | 0 | 1.5 | 0 |
| 15 | *Favites halicora* | 0 | 0 | 0 | 0.625 | 0 |
| 16 | *Favia laxa* | 0 | 0 | 0 | 0.25 | 0 |
| 17 | *Favia amicorum* | 0 | 0 | 0 | 0 | 3.125 |
| 18 | *Favia pallida* | 0 | 0 | 0 | 0 | 1.375 |
| 19 | *Goniastrea retiformis* | 0 | 0 | 0 | 0 | 0.625 |
| 20 | *Goniastrea pectinata* | 0 | 0 | 0 | 1 | 0 |
| 21 | *Galaxea fascicularis* | 0 | 0 | 0 | 0.25 | 0 |
| 22 | *Coscinaraea monile* | 0 | 0 | 0 | 0 | 4.125 |
| 23 | *Turbinaria mesentrina* | 0.125 | 2.875 | 3.75 | 4 | 0 |
| 24 | *Turbinaria reniformis* | 0 | 0 | 0 | 0 | 4.375 |
| 25 | *Asteriopora myriophthalma* | 0 | 0 | 0 | 1.875 | 0.625 |
| 26 | *Leptastrea purpurea* | 0.25 | 0 | 0 | 0 | 0 |
| 27 | *Echinopora gemmacea* | 0.75 | 0 | 0 | 0 | 3.25 |
| 28 | *Echinopora fruiticulosus* | 0 | 0 | 0 | 0 | 2.25 |
| 29 | *Pavona decussata* | 0 | 0 | 0.25 | 0 | 0 |
| 30 | *Psammocora profundacella* | 0 | 0 | 0 | 1 | 0 |
| 31 | *Alveopora lizardi* | 0 | 0 | 0.875 | 0 | 0 |
| | **Octocorallia** | | | | | |
| | **1- Soft corals** | | | | | |
| 1 | *Anthelia glauca* | 0 | 0 | 0 | 2.875 | 0 |
| 2 | *Xenia macrospiculata* | 0 | 0 | 0.125 | 0 | 0 |
| 3 | *Xenia umbellata* | 0 | 0 | 0 | 4.875 | 0 |
| 4 | *Heteroxenia fuscescens* | 0 | 0 | 1.5 | 0 | 0 |
| 5 | *Heteroxenia ghardaqensis* | 0 | 0 | 0 | 2.375 | 49.5 |
| 6 | *Lithophyton arboreum* | 0 | 11.25 | 0 | 0 | 2.75 |
| 7 | *Cladiella* sp. | 0 | 2.5 | 0.875 | 0 | 0 |
| 8 | *Sympodium caeruleum* | 0 | 0 | 0 | 1.125 | 0 |
| 9 | *Rhytisma* sp. | 0 | 0 | 0 | 0.25 | 0 |
| 10 | *Sarcophyton* sp. | 0 | 0 | 0 | 0 | 1.75 |
| 11 | *Lobophytum* sp. | 0 | 0 | 0 | 0 | 0.625 |
| | **2- Gorgonian** | | | | | |
| 1 | *Anella* sp. | 0 | 0 | 9.375 | 0 | 0 |

Table 3 continued..

| | | | | | | |
|---|---|---|---|---|---|---|
| | **Hydrocorals** | | | | | |
| 1 | *Millepora dichotoma* | 5 | 0.25 | 0.0625 | 0.25 | 0 |
| | **Coral diseases/species** | | | | | |
| | White spots disease/ *Porites lichen* | 0 | 0.125 | 0 | 0 | 0 |

**Table 4.** Percentage cover of corals at Katy. R=New recruit.

| Species and Habitats | | Percentage Cover Depths | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1m | 5m | 10m | 20m | 30m | 40m | 50m |
| | **Hexacorallia** | | | | | | | |
| | **Stony corals** | | | | | | | |
| 1 | *Stylophora pistillata* | 3.67 | 4.33 | 1.67 | 0.67 | 2.67 | 0 | 0 |
| 2 | *Stylophora mamillata* | 0 | 3.67 | 1 | 3.67 | 1 | 2 | 0 |
| 3 | *Seriatopota hystrix* | 0 | 1.00 | 1 | 0 | 0 | 0 | 0 |
| 4 | *Acropora maryae* | 0 | 0.00 | 0 | 0 | 0 | 1 | 0 |
| 5 | *Pocillopora damicornis* | 0.33 | 1.00 | 0 | 0 | 0 | 0 | 0 |
| 6 | *Porites solida* | 0 | 0.00 | 0 | 0 | 1.33 | 0 | 1 |
| 7 | *Porites columnaris* | 0 | 0.00 | 0 | 0 | 2 | 0 | 0 |
| 8 | *Porites lichen* | 0 | 0.00 | 0 | 0 | 0 | 0 | 17.7 |
| 9 | *Goniastea retiformis* | 1 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 10 | *Goniastrea persi* | 0 | 1 ® | 0.16 ® | 0 | 0 | 0 | 0 |
| 11 | *Favites halicora* | 2 | 2.6 ® | 0 | 0 | 0 | 0 | 0 |
| 12 | *Favites vasta* | 0 | 0.00 | 0 | 0 | 0 | 0 | 5.33 |
| 13 | *Favia pallida* | 0 | 1.67 | 0 | 0 | 0 | 0 | 0 |
| 14 | *Favia laxa* | 0 | 0.00 | 0 | 0 | 0 | 3.5 | 0 |
| 15 | *Hydnophora exesa* | 0 | 0.00 | 0 | 0 | 0 | 16 | 0 |
| 16 | *Galaxea fascicularis* | 0 | 0.50 | 0 | 0 | 0 | 0 | 0 |
| 17 | *Montipora cocosensis* | 0 | 0.00 | 1.66 | 0 | 0 | 0 | 0 |
| 18 | *Montipora informis* | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| 19 | *Montipora tuberculosa* | 0 | 0 | 0 | 0 | 1.33 | 0 | 0 |
| 20 | *Symphillia* sp. | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 |
| 21 | *Platygyra daedalea* | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 22 | *Leptastrea purporea* | 2.33 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | *Echinopora fruticulosus* | 25.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | *Echinopora gemmacea* | 3.33 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | *Echinopora forskaliana* | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

Table 4 continued..

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 26 | *Asteriopora myriophthalma* | 1 | 0.5 | 0 | 1.33 | 1 | 0 | 0 |
| 27 | *Cyphastrea microphthalma* | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 28 | *Pachyseris rugosa* | 0 | 0 | 0 | 0 | 0 | 8.3 | 0 |
| 29 | *Pavona clavus* | 0 | 0 | 0 | 0.67 | 0 | 0 | 0 |
| 30 | *Pavona varians* | 0 | 0 | 0 | 0.33 | 0 | 0 | 0 |
| 31 | *Pavona decussata* | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 32 | *Leptoseris mycetoseroides* | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 |
| | **Octocorallia** | | | | | | | |
| | **Soft corals** | | | | | | | |
| 1 | *Anthelia glauca* | 0 | 0 | 12 | 4.67 | 7.33 | 0.2 | 8 |
| 2 | *Xenia umbellata* | 0 | 5.67 | 0 | 1.67 | 0 | 0 | 0 |
| 3 | *Xenia macrospiculata* | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 4 | *Heteroxenia ghardaqensis* | 0 | 4.67 | 4 | 1.67 | 0 | 0 | 0 |
| 5 | *Rhytisma* sp. | 0 | 0 | 1 | 0 | 2.67 | 0 | 0 |
| 6 | *Briareum hamra* | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 7 | *Lithophyton* sp. | 0 | 0 | 3.33 | 0 | 0 | 0 | 0 |

**Table 5.** Percentage cover of corals at Islands. FB=Fish biting.

| Species and Habitats | | Percentage Cover Depths | | | |
|---|---|---|---|---|---|
| | | 1m | 5m | 10m | 15m |
| | **Hexacorallia** | | | | |
| | **Stony corals** | | | | |
| 1 | *Stylophora pistillata* | 0.125 | 0 | 1.25 | 0.6 |
| 2 | *Stylophora mamillata* | 0 | 0 | 0 | 0.1 |
| 3 | *Stylophora wellsi* | 0 | 1.5 | 0 | 0.2 |
| 4 | *Acropora gemmifera* | 0.625 | 0 | 0 | 0 |
| 5 | *Acropora humilis* | 0 | 4.375 | 0 | 1.6 |
| 6 | *Acropora digitifera* | 0 | 3.5 | 0 | 0 |
| 7 | *Acropora robusta* | 0 | 1.375 | 0 | 0.6 |
| 8 | *Acropora hyacinthus* | 0 | 7.75 | 0 | 0 |
| 9 | *Acropora valida* | 0 | 2.5 | 0 | 1.9 |
| 10 | *Acropora hemperichi* | 0 | 0 | 10.125 | 9 |
| 11 | *Acropora tenuis* | 0 | 0 | 2.5 | 0 |
| 12 | *Pocillopora verrucosa* | 0 | 0.875 | 5.5 | 0.3 |
| 13 | *Montipora meandrina* | 0 | 0 | 0 | 1.6 |
| 14 | *Acanthastrea faviaformis* | 0.375 | 0 | 0 | 0 |

Table 5 continued..

| | | | | | |
|---|---|---|---|---|---|
| 15 | *Acanthastrea maxima* | 0 | 0.25 | 0 | 0 |
| 16 | *Porites solida* | 0.5 | 0 | 1.1 FB | 0 |
| 17 | *Porites lutea* | 0 | 12.3 FB | 0 | 0 |
| 18 | *Porites lobata* | 0 | 0 | 0 | 1.4 |
| 19 | *Goniastrea retiformis* | 0 | 0 | 0 | 4.7 |
| 20 | *Favites halicora* | 0 | 0 | 1.5 | 0 |
| 21 | *Favites abdita* | 0 | 0 | 2 | 0 |
| 22 | *Favites complanata* | 0 | 0 | 0 | 4 |
| 23 | *Favia* sp. (new) | 0 | 0 | 0 | 1.6 |
| 24 | *Goniopora ciliatus* | 0 | 0 | 0 | 0.7 |
| 25 | *Platygyra lamellina* | 0 | 0 | 0 | 5.2 |
| 26 | *Hydnophora exesa* | 0 | 3.75 | 0 | 0 |
| 27 | *Hydnophora microconus* | 0 | 1 | 3.75 | 0 |
| 28 | *Galaxea fascicularis* | 0 | 0 | 0.75 | 0.3 |
| 29 | *Platygyra crosslandi* | 0 | 0 | 0.75 | 0 |
| 30 | *Echinopora lamellosa* | 0 | 8.875 | 0 | 0 |
| 31 | *Echinopora gemmacea* | 0 | 0.1 | 0 | 0 |
| 32 | *Pavona varians* | 0 | 0.375 | 3.125 | 0.7 |
| 33 | *Pachyseris speciosa* | 0 | 0 | 0 | 8.2 |
| 34 | *Leptoseris incrustans* | 0 | 0 | 0 | 0.6 |
| 35 | *Ctenactis echinata* | 0 | 0 | 4.125 | 0 |
| | **Octocorallia** | | | | |
| | **Soft corals** | | | | |
| 1 | *Anthelia glauca* | 0 | 0 | 0 | 8.1 |
| 2 | *Cladiella* sp. | 6.25 | 0 | 11.25 | 0 |
| 3 | *Sinularia* sp. | 0 | 1.375 | 0 | 0 |
| 4 | *Sarcophyton* sp. | 0 | 0 | 0 | 1.8 |
| | **Hydrocorals** | | | | |
| 1 | *Millepora dichotoma* | 0 | 0 | 0 | 0.5 |
| 2 | *Millepora platyphylla* | 0.625 | 0 | 0 | 0 |

**Table 6.** Percentage cover of corals at Canyon.

| | Species and Habitats | Percentage cover Depths | | | | |
|---|---|---|---|---|---|---|
| | | 1m | 5m | 10m | 15m | 20m |
| | **Hexacorallia** | | | | | |
| | **Stony corals** | | | | | |
| 1 | *Stylophora pistillata* | 0.25 | 0 | 0 | 1.63 | 1.5 |

Table 6 continued..

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 | *Acropora humilis* | 0.88 | 0 | 2.5 | 4.13 | 0 |
| 3 | *Acropora gemmifera* | 0.25 | 0 | 0 | 0 | 0 |
| 4 | *Acropora hyacinthus* | 0.75 | 0 | 0 | 0 | 0 |
| 5 | *Acropora valida* | 0 | 1.75 | 0 | 0 | 0 |
| 6 | *Acropora digitifera* | 0 | 0.38 | 0 | 0 | 0 |
| 7 | *Acropora nasuta* | 1 | 15.5 | 0 | 0 | 0 |
| 8 | *Acropora hyacinthus* | 1 | 0 | 0 | 0 | 0 |
| 9 | *Acropora eurystoma* | 1.25 | 1.5 | 0 | 0 | 0 |
| 10 | *Acropora forskali* | 1 | 0 | 0 | 0 | 0 |
| 11 | *Acropora tenuis* | 0.63 | 0 | 1.13 | 0 | 0 |
| 12 | *Acropora hemperichi* | 0 | 3.5 | 0.5 | 0.38 | 0 |
| 13 | *Acropora pharaonis* | 0 | 0 | 0 | 8.75 | 0 |
| 14 | *Acropora nasuta* | 0 | 0 | 0 | 5 | 0 |
| 15 | *Acropora granulosa* | 0 | 0 | 0 | 0 | 11.1 |
| 16 | *Pocillopora damicornis* | 0 | 0 | 0 | 0.25 | 4.63 |
| 17 | *Trachyphyllia geoffroyi* | 0 | 0 | 0 | 0.13 | 0 |
| 18 | *Symphyllia* sp. | 0 | 0 | 0 | 0 | 2.63 |
| 19 | *Montipora verrucosa* | 0 | 0 | 0.75 | 0 | 0.25 |
| 20 | *Montipora cocosensis* | 0 | 4.5 | 0 | 0.25 | 6.88 |
| 21 | *Montipora informis* | 0 | 4.25 | 0 | 0 | 0 |
| 22 | *Montipora stilosa* | 0 | 0 | 0 | 1 | 0 |
| 23 | *Porites lutea* | 0 | 14.3 | 0.25 | 0 | 0 |
| 24 | *Porites solida* | 0 | 0 | 0 | 0.75 | 0.5 |
| 25 | *Goniastrea retiformis* | 6.63 | 3.25 | 0.38 | 0 | 0 |
| 26 | *Favites halicora* | 0.5 | 0.38 | 0 | 0 | 8 |
| 27 | *Favites pentagona* | 8.5 | 0 | 0 | 0 | 1.38 |
| 28 | *Favites chinensis* | 5.75 | 0 | 0 | 0 | 0 |
| 29 | *Favites flexusa* | 5 | 0 | 0 | 0 | 0 |
| 30 | *Favia favus* | 0.13 | 0 | 0 | 0 | 0 |
| 31 | *Favia pallida* | 0 | 0 | 0.25 | 0 | 0 |
| 32 | *Favia rotundata* | 0 | 0 | 5.63 | 0 | 0 |
| 33 | *Favia laxa* | 0 | 0 | 0 | 0 | 0.88 |
| 34 | *Favia mtthai* | 0 | 0 | 0 | 0 | 2.13 |
| 35 | *Coscinaraea monile* | 0 | 0 | 2.13 | 0 | 0 |
| 36 | *Platygyra lamellina* | 5 | 0 | 1.38 | 2 | 0 |
| 37 | *Platygyra carnosus* | 0 | 0 | 0 | 0 | 2.5 |
| 38 | *Stylocoenella guentheri* | 0 | 0 | 0 | 0 | 10.1 |
| 39 | *Astreopora myriophthalma* | 0 | 0.38 | 0 | 0 | 0 |

Table 6 continued..

| | | | | | | |
|---|---|---|---|---|---|---|
| 40 | *Echinopora gemmacea* | 0 | 0 | 0 | 0.38 | 0 |
| 41 | *Turbinaria mesentrina* | 0 | 0 | 0.75 | 0 | 0.88 |
| 42 | *Leptoseris incrustance* | 0 | 0.38 | 0 | 0 | 0 |
| 43 | *L. mycetoseroides* | 3.13 | 0 | 0 | 0 | 0 |
| 44 | *Oxypora lacera* | 0 | 0 | 0 | 0 | 0.88 |
| 45 | *Leptastrea purpurea* | 0.1 | 0 | 0 | 0 | 0 |
| 46 | *Psammocora profundacella* | 0.75 | 0 | 0 | 0 | 0 |
| | **Octocorallia** | | | | | |
| | **Soft corals** | | | | | |
| 1 | *Anthelia glauca* | 0 | 0 | 0 | 0 | 4.38 |
| 2 | *Cladiella* sp. | 0 | 0 | 0 | 1 | 0 |
| 3 | *Rhytisma* sp. | 0 | 0 | 1.25 | 0 | 0 |
| 4 | *Lobophytum* sp. | 0 | 0 | 0 | 0.25 | 0 |
| 5 | *Heteroxenia ghardaqensis* | 0 | 0 | 0 | 0.75 | 0 |
| 6 | *Lithophyton* sp. | 0 | 0 | 7.5 | 3.13 | 0 |
| 7 | *Sarcophyton* sp. | 0 | 0 | 0 | 6.75 | 0 |
| | **Hydrocorals** | | | | | |
| 1 | *Millepora platyphylla* | 0 | 0 | 0 | 0 | 0.38 |

**Table 7.** Percentage cover of corals at South Nuweiba.

| | Species and Habitats | Percentage cover Depth | | |
|---|---|---|---|---|
| | | 1m | 5m | 10m |
| | **Hexacorallia** | | | |
| | **Stony corals** | | | |
| 1 | *Stylophora pistillata* | 0.38 | 0 | 0 |
| 2 | *Stylophora wellsi* | 0 | 0 | 0.13 |
| 3 | *Acropora nasuta* | 0.5 | 1.25 | 3.75 |
| 4 | *Acropora tenuis* | 0 | 0 | 0.38 |
| 5 | *Pocillopora damicornis* | 0.25 | 0 | 0.29 |
| 6 | *Pocillopora verrucosa* | 2.6 | 0 | 0.63 |
| 7 | *Goniastrea retiformis* | 7.63 | 0.75 | 0 |
| 8 | *Porites lutea* | 2.5 | 0 | 0 |
| 9 | *Porites columnaris* | 1.13 | 0 | 0 |
| 10 | *Favites flexusa* | 0 | 0 | 1.14 |
| 11 | *Favites halicora* | 0 | 0 | 1 |
| 12 | *Favia lacuna* | 0.25 | 0 | 0 |

Table 7 continued..

| | | | | |
|---|---|---|---|---|
| 13 | *Favites vasta* | 0.75 | 0 | 0 |
| 14 | *Siderastrea savigneana* | 0.38 | 0 | 0 |
| 15 | *Galaxea fascicularis* | 0 | 0 | 0.29 |
| 16 | *Platygyra daedalea* | 1.63 | 0 | 0 |
| 17 | *Leptastrea purporea* | 0.75 | 0 | 0 |
| 18 | *Astreopora myriophthalma* | 0 | 6.25 | 0 |
| 19 | *Plesiastrea versipora* | 1.25 | 0 | 0 |
| 20 | *Cyphastrea serailea* | 0.1 | 0 | 0 |
| 21 | *Turbinaria informis* | 3.13 | 0 | 0 |
| 22 | *Turbinaria mesentrina* | 0 | 0 | 0.88 |
| 23 | *Echinopora lamellosa* | 0.25 | 0 | 0 |
| 24 | *Pavona decussata* | 0 | 0 | 2.38 |
| | **Octocorallia** | | | |
| | **Soft corals** | | | |
| 1 | *Lobophytum* sp. | 0.13 | 0 | 0 |
| | **Hydrocorals** | | | |
| 1 | *Millepora platyphylla* | 6.5 | 0 | 0 |
| 2 | *Millepora dichotoma* | 5.75 | 0 | 0 |
| 3 | *Millepora alcicorrnis* | 0 | 0 | 1.5 |

**Table 8.** Percentage cover of corals at Marsa Muqabela.

| Species and Habitats | | Percentage Cover Depth | | | |
|---|---|---|---|---|---|
| | | 1m | 5m | 10m | 15m |
| | **Hexacorallia** | | | | |
| | **Stony corals** | | | | |
| 1 | *Stylophora pistillata* | 0.375 | 1.125 | 0 | 4.125 |
| 2 | *Acropora nasuta* | 0.625 | 0 | 0 | 0.875 |
| 3 | *Acropora humilis* | 0 | 0 | 1.125 | 0 |
| 4 | *Pocillopora damicornis* | 0.375 | 0 | 0 | 0 |
| 5 | *Pocillopora verrucosa* | 2 | 0 | 0.875 | 0 |
| 6 | *Lobophyllia cf pachysepta* | 0 | 0 | 0.25 | 0 |
| 7 | *Goniastrea persi* | 0 | 0 | 0.25 | 0 |
| 8 | *Goniastrea retiformis* | 13.38 | 0 | 0.375 | 0 |
| 9 | *Porites lutea* | 10 | 0 | 0 | 0 |
| 10 | *Porites columnaris* | 1.125 | 0 | 0 | 0 |
| 11 | *Porites lobata* | 0 | 0 | 0 | 0.375 |
| 12 | *Favites vasta* | 0.75 | 0 | 0 | 0 |

Table 8 continued..

| | | | | | |
|---|---|---|---|---|---|
| 13 | *Favites abdita* | 0 | 0 | 1.125 | 0 |
| 14 | *Favites halicora* | 0 | 0 | 0.125 | 0 |
| 15 | *Favites complanata* | 0 | 0 | 11.25 | 0 |
| 16 | *Favia lacuna* | 0.125 | 0 | 0 | 0 |
| 17 | *Favia favus* | 2.375 | 0 | 2 | 0 |
| 18 | *Favia pallida* | 0 | 0 | 0.063 | 0 |
| 19 | *Favia laxa* | 0 | 0 | 0 | 2.875 |
| 20 | *Gyrosmilia interrupta* | 0 | 0 | 0.625 | 0 |
| 21 | *Siderastrea savigneana* | 0.375 | 0 | 0 | 0 |
| 22 | *Platygyra daedalea* | 3.25 | 0.188 | 0 | 0 |
| 23 | *Platygyra lamellina* | 0 | 0 | 9 | 2.25 |
| 24 | *Platygyra carnosus* | 0 | 0.25 | 0 | 0 |
| 25 | *Platygyra crosslandi* | 0 | 0.125 | 0.875 | 0 |
| 26 | *Turbinaria informis* | 4.5 | 0 | 0 | 0 |
| 27 | *Echinopora lamellosa* | 0.375 | 0 | 0 | 0 |
| 28 | *Echinopora gemmacea* | 0 | 0 | 0.188 | 0 |
| 29 | *Echinopora tiranensis* | 0 | 0 | 0 | 0.25 |
| 30 | *Leptastrea purpurea* | 0.75 | 0 | 1.625 | 0.25 |
| 31 | *Cyphastrea microphthalma* | 0 | 0 | 0.375 | 0.25 |
| 32 | *Cyphastrea serailia* | 0 | 0 | 0 | 0.25 |
| 33 | *Plesiastrea versipora* | 1.25 | 0 | 0 | 0 |
| 34 | *Psammocora profundacella* | 0 | 0 | 0.5 | 0 |
| | **Black corals** | | | | |
| 1 | *Protoptilum* sp. | 0 | 0.063 | 0 | 0 |
| | **Octocorallia** | | | | |
| | **Soft corals** | | | | |
| 1 | *Xenia umbellata* | 0 | 0 | 0 | 0.5 |
| 2 | *Xenia macrospiculata* | 0 | 0 | 0.875 | 3.5 |
| 3 | *Heteroxenia qhardaqensis* | 10.75 | 0 | 0 | 0 |
| 4 | *Lobophytum* sp. | 0.25 | 21.88 | 0 | 0 |
| 5 | *Lithophyton* sp. | 0 | 3.875 | 0 | 0 |
| 6 | *Rhytisma* sp. | 0 | 0.125 | 0 | 0 |
| 7 | *Sarcophyton* sp. | 0 | 0 | 3.375 | 0.75 |
| | **Hydrocorals** | | | | |
| 1 | *Millepora platyphylla* | 12.5 | 0 | 0 | 0 |
| 2 | *Millepora dichotoma* | 11 | 13.38 | 0 | 0 |

**Table 9.** Number of coral species in different sites of the studied area.

| Sites | Number of coral species | | | | | |
|---|---|---|---|---|---|---|
| | Stony | Black | Soft | Hydrocorals | Gorgonians | Total |
| 1-Marsa Ghozlani | 44 | 0 | 9 | 0 | 0 | 53 |
| 2-Marsa Breika | 50 | 1 | 9 | 1 | 1 | 62 |
| 3-Temple | 31 | 0 | 11 | 1 | 1 | 44 |
| 4-Katy | 32 | 0 | 7 | 0 | 0 | 39 |
| 5-Islands | 35 | 0 | 4 | 2 | 0 | 41 |
| 6-Canyon | 46 | 0 | 7 | 1 | 0 | 54 |
| 7-South Nuweiba | 24 | 0 | 1 | 3 | 0 | 28 |
| 8-Marsa Muqabela | 34 | 1 | 7 | 2 | 0 | 44 |

**Coverage of different taxa and habitats**

Percentage cover of different taxa and habitats are shown in (Table 10). Percentage cover of live corals in the studied sites is highest in Canyon (40.38%) and lowest in South Nuweiba (18.77%), while that of dead corals is highest in South Nuweiba and lowest in Temple. Coverage of bare rocks is highest in Ras Ghozlani (58.82%) and lowest in South Nuweiba (20.5%) while that of rubbles is highest Ras Ghozlani and lowest in Marsa Muqabela. Temple and Katy. Echinoderms were reported in lower values in the three sites - Islands, South Muqabela and South Nuweiba but were absent in other sites while molluscs were reported maximally in Ras Ghozlani. Similarly ascidians were reported in four sites with highest value in Katy (2.14%). Boring worms were reported in Marsa Breika and Marsa Muqabela covering 0.04% and 0.16% respectively. Algae are most dominant in Islands (17.11%) while anemones and broken corals have the highest coverage in South Nuweiba.

**Statistical analysis**

Results of two ways joining clustering method to show grouping of different coral species number in different sites are shown in Fig. 2. It is clear that stony corals have the highest linkage distance in Canyon and Marsa Breika. Black corals are grouped alone in Marsa Breika having the highest linkage distance for black corals, however each of soft corals, hydrocorals and gorgonians are grouped together in all sites having the lowest linkage distance. Total number of species are grouped together in Islands and South Nuweiba having the lowest linkage distance.

Results of two ways joining clustering method to show grouping of the percentage coverage of different coral reef taxa in different sites are shown in Fig. 3. Live corals have the highest linkage distance in Marsa Breika, Canyon, Islands and Marsa Muqabela. Dead corals have the highest linkage distance in Ras Ghozlani and Temple and lowest linkage distance in Islands and Marsa Muqabela. Bare rocks have the highest linkage distance in South Nuweiba and lowest linkage distance in Ras Ghozlani, Temple and Katy. Algae have the highest linkage distance in South Nuweiba, anemones have the highest linkage distance in Islands while broken corals have the highest linkage distance in South Nuweiba & Marsa Muqabela.

## DISCUSSION

The present study is the first to produce a detailed species composition of corals on the species level along a transect of sites extending from Ras Mohammed at the northern Red Sea to the northern tip of the Gulf of Aqaba, Egypt. Results of the number of coral species in the study sites (123 stony corals, 2 Black corals, 3 Hydrocorals, 15 Soft corals, 2 Gorgonians, 145 total) are closer to the 120 scleractinian coral species reported by [11], lower than the 210 scleractinians and 120 soft corals reviewed by [1]. However, site variations for the number of stony coral species in

**Table 10.** Percentage cover of live corals and other habitats in the studied sites.

| Sites | LC | DC | BR | RU | SA | EC | MO | AS | SP | CR | BW | AL | AN | BC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-Ras Ghozlani | 26.97 | 3.17 | 58.82 | 2.28 | 4.91 | 0.00 | 0.52 | 0.56 | 0.35 | 2.42 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2-Marsa Breika | 39.78 | 9.13 | 35.75 | 0.00 | 14.11 | 0.00 | 0.04 | 0.00 | 0.29 | 0.00 | 0.04 | 0.39 | 0.00 | 0.00 |
| 3-Temple | 36.04 | 1.35 | 55.56 | 0.00 | 2.85 | 0.00 | 0.00 | 0.00 | 0.95 | 1.50 | 0.00 | 3.25 | 0.00 | 0.00 |
| 4-Katy | 28.29 | 3.79 | 44.31 | 0.00 | 11.71 | 0.00 | 0.00 | 2.14 | 3.81 | 0.00 | 0.00 | 5.36 | 0.00 | 0.00 |
| 5-Islands | 40.06 | 0.00 | 23.42 | 1.78 | 8.07 | 1.51 | 0.03 | 0.94 | 0.16 | 0.00 | 0.00 | 17.11 | 0.00 | 0.00 |
| 6-Canyon | 42.38 | 6.00 | 36.78 | 0.73 | 12.73 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.00 |
| 7-South Nuweiba | 18.77 | 17.29 | 20.50 | 0.29 | 26.29 | 1.54 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.53 | 6.71 |
| 8-Marsa Muqabela | 42.06 | 7.28 | 23.44 | 0.09 | 21.56 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 3.91 | 0.13 | 0.03 |

LC=Live corals, DC=Dead corals, BR=Bare rocks, RU=Rubbles, SA=Sands, EC=Echinoders, CR=Crevices, SP=Sponges, AS=Ascidians, MO=Molluscs, BW=Boring worms, AL=Algae, BC=Broken corals, AN=Anemones.

**Table 11.** Human impacts at different sites.

| Sites | No. boats per | No. divers per | No. snorklers per day | Metallic buckets (%) | Clothes (%) | Fishing nets (%) | Tracks to deep water | Field guide signs | Patrolling |
|---|---|---|---|---|---|---|---|---|---|
| 1-Ras Ghozlani | 25 | 400 | 100 | 0.00 | 0.00 | 0.00 | X | X | √ |
| 2-Marsa Breika | 20 | 350 | 50 | 0.52 | 0.54 | 0.00 | X | X | √ |
| 3-Temple | 20 | 350 | 50 | 0.00 | 0.00 | 0.00 | X | X | X |
| 4-Kati | 20 | 350 | 50 | 0.00 | 0.00 | 0.00 | X | X | X |
| 5-Islands | 0 | 270 | 30 | 0.00 | 0.00 | 0.00 | √ | √ | √ |
| 6-Canyon | 0 | 270 | 30 | 0.00 | 0.00 | 0.00 | √ | √ | √ |
| 7-South Nuweiba | 0 | 0 | 0 | 0.00 | 0.00 | 7.38 | X | X | X |
| 8-Marsa | 5 | 150 | 30 | 0.00 | 0.00 | 0.00 | X | X | √ |

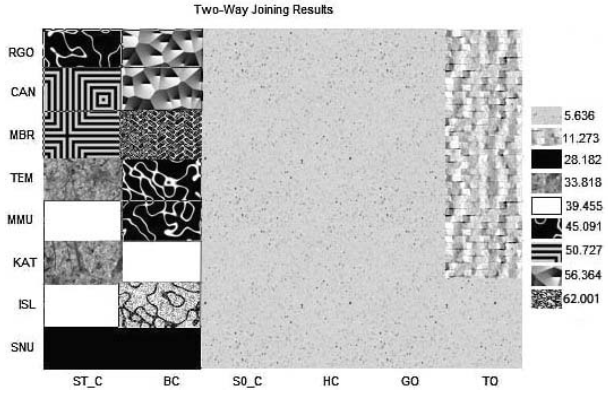


**Fig. 2.** Two-Way joining results between the number of coral species and sites. RGO = Ras Ghozlani, CAN = Canyon, MBR = Marsa Breika, TEM = Temple, MMU = Marsa Muqabela, KAT = Katy, ISL = Islands, SNU = South Nuweiba. ST_C = Stony Corals, BC = Black Corals, SO_C = Soft Corals, HC = Hydrocorals, GO = Gorgonians, TO = Total number of coral species.

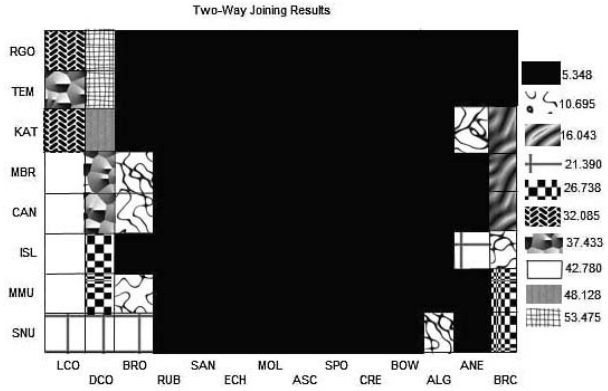


**Fig. 3.** Two-Way joining results between the percentage coverage of different coral reef taxa and sites. RGO = Ras Ghozlani, TEM = Temple, KAT = Katy, MBR = Marsa Breika, CAN = Canyon, ISL = Islands, MMU = Marsa Muqabela, SNU = South Nuweiba. LCO = Live Corals, DCO = Dead Corals, BRO = Bare Rocks, RUB = Rubbles, SAN = Sands, ECH = Echinoderms, MOL = Molluscs, ASC = Ascidians, SPO = Sponges, CRE = Crevices, BOW = Boring Worms, ALG = Algae, ANE = Anemones, BRC = Broken corals.

the present study (31-50) are similar to the 48-77 in Dahab, Gulf of Aqaba [12] and 53 at Ras Umm Seid, Gulf of Aqaba [13]. The percentage of live corals in the present study (31%) is similar to those mentioned by [14] who mentioned an average of 35% live coral cover in the Gulf of Aqaba but they both neither provided a species list nor they mentioned the source of their results. However, the present result is also similar to the 11.3% -30% in Dahab, Gulf of Aqaba, Egypt [12] and 30-47% in many sites of the Gulf of Aqaba [4].

The occurrence of the two stony corals *Stylophora pistillata* and *Asteriopora myriophthalma* in all depths at Ras Ghozlani and most depths at other sites indicates that those two species are opportunistic species. One of those two species (*Stylophora pistillata*) was suggested as an opportunistic species by [15] and confirmed by [16] in other areas of the Red Sea. The dominance of the two massive corals *Platygyra* and *Porites* in shallow areas of many sites disagree with [17] that branching corals tend to decrease with depth and are replaced by massive and flattened forms; and [18] that *Porites* sp. occurs in abundant cover in weak light. However, abundance of the branching coral *Acropora nasuta* at 5 m depth and the foliacious coral *Mycedium umbra* at 20 m depth agrees with the result of [17]. The dominance of the soft coral *Lobophytum arboreum* in the same site agrees with findings of [16] that *Lobophytum* sp. is a successful colonizer beside the soft coral *Xenia* sp. suggested by [19]; similarly the soft coral *Rhytisma* sp. is a successful colonizer in Marsa Breika. Abundance of new recruits in deep areas of Marsa Breika and shallow areas of Katy is probably due to the high number of divers promoting reproduction by fragmentation [20] that may help to mitigate some of the diver damage effects [21]; however, the mitigating effect of fragment regeneration could be maximized in case the effect of divers is stopped or divers become more eco-conscious. The dominance of the stony coral *Pocillopora verrucosa* in the clear water of Temple agrees with [22] that *Pocillopora damicornis* grow well in the clearer water and hard rocky substrate but it did not grow at all in turbid water and sandy substrate; also the dominance of *Millepora* sp. in shallow areas of most sites is similar to [23] and [24] that *Millepora* sp. prefers high illumination and has a strong skeletal density to tolerate strong waves of shallow areas.

Human impacts and level of managements are indicated in (Table 11). Highest percentage cover

of live corals in Canyon is associated with a considerably lower amount of sands or sediments [24, 25, 26], effective management like the presence of tracks to deep water, field guide signs and patrolling [1]. Lowest amount of live corals in South Nuweiba is associated with the highest amount of sands or sediments, broken corals and interlacing fishing nets of illegal fishing as well as the absence of effective management. Ammar and Mahmoud [26] indicated that a well organized fishing does not harmfully affect the corals. Highest amount of bare rocks in Ras Ghozlani and Temple indicates that those two sites are the oldest ones suffering from past breakage increasing dead corals which changed with time to bare rocks. Similarly, highest amount of rubbles in Ras Ghozlani and Islands is an indication that they have past breakage especially to branching or small sized corals which changed with time to rubbles [27]. Highest amount of echinoderms are found in South Nuweiba and Islands; the first site has the highest amount of dead and broken corals (recent damage) while the second site has considerable rubbles (old damage) and the highest amount of algae. This indicates that both recent and old damage initiate the alteration of the community into echinoderm and algal domination with higher amount of echinoderms in the recent damage and higher amount of algae in the old one. With reference to the conclusion of [28, 29, 30] that "some control of algal abundance is affected by the grazing activity of sea urchins", the previous result could generalize that conclusion to become "grazing activity of echinoderms.

Ras Ghozlani, having the maximal amount of molluscs, has also the highest amount of bare rocks, rubbles and crevices; indicating that the past breakage, which decreases the amount of corals, fosters the competitive ability of molluscs at the expense of corals. This competitive ability is also increased probably by the presence of crevices that may act as stores of nutrients [30, 31]. Highest amount of sponges in Katy is associated with the considerable water currents and lots of turbulence [32]. The highest amount of anemones in South Nuweiba is associated with the lowest amount of live corals, highest amount of dead corals, broken corals and sands, a condition that provide a sufficient space for attachment and growth of sea anemones. It could be also expected that disturbance caused by fishing activities in that site may provide sufficient preys of (e.g. small fishes, crustaceans or larvae of other marine animals) that might move in front of anemones, however that expectation should be confirmed by surveying many sites with increased fishing activities. So, it can be expected that, when live corals decrease for any reason, sponges, ascidians and anemones may increase in the coral reef community, but their increase is not as dramatic as the increase in macroalgae that alters the community structure.

## CONCLUSIONS

1. The present study is the first to produce a detailed species composition of corals on the species level along a transect of sites extending from Ras Mohammed at the northern Red Sea to the northern tip of the Gulf of Aqaba, Egypt.

2. The stony coral *Asteriopora myriophthalma* was indicated to be an opportunistic species while the two soft corals *Lobophytum arboretum and Rhytisma* sp. were found to be successful colonizers.

3. Considerable occurrence of new recruits was found in deep areas of Marsa Breika and shallow areas of Katy, this was associated with high number of divers initiating reproduction by fragmentation.

4. Highest percentage cover of live corals in Canyon is associated with effective management while lowest amount of live corals in South Nuweiba is associated with the considerable interlacing fishing nets and absence of effective management.

5. Past breakage of large coral colonies in Ras Ghozlani and Temple led to increased bare rocks while past breakage of branching or small sized corals in Ras Ghozlani and Islands led to increased rubbles.

6. Both recent and old damage initiate the alteration of the community into echinoderm and algal domination with higher amount of echinoderms in the recent damage and higher amount of algae in the old damage.

7. Past breakage fosters the competitive ability of molluscs; water currents leads to abundant sponges;

disturbance by fishing activities provides sufficient preys that foster the growth of anemones.

8. Number of coral species in the study sites are: 123 stony corals, 2 black corals, 3 hydrocorals, 15 soft corals, 2 gorgonians, 145 total number.

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