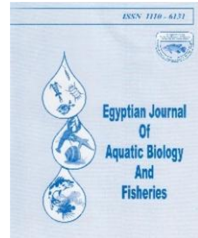
Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 25(1): 699 – 720 (2021)
www.ejabf.journals.ekb.eg



Resilience drivers in some coral reef sites in Wadi El-Gemal marine protected area, Southern Egyptian Red Sea

Abdulrahman Nassar[1], Mohamed Ismail[1], Mohamed A. Abu El-Regal[1,2]*

[1]Marine Science Department, Faculty of Science, Port Said University, Egypt

[2]Marine Biology Department, Faculty of Marine Science, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia

[*]**Corresponding Author: mabuelregal@kau.edu.sa**
M_abuelregal@yahoo.com

ARTICLE INFO

Article History:
Received: Jan. 7, 2021
Accepted: Jan. 28, 2021
Online: Feb. 17, 2021

Keywords:
coral reef resilience,
Red Sea,
Wadi El Gemal,
marine park

ABSTRACT

This study aims to evaluate the resilience status of the coral reef ecosystem in Wadi El-Gemal-Hamata National park, Southern Red Sea. Six resilience drivers (coral diversity, coral diseases, anthropogenic impacts, herbivores biomass, recruitment, and algae) have been chosen to be assessed in the different sites. Data were collected seasonally in the period from August 2015 to July 2016 using SCUBA diving from three inshore and two offshore reef sites. Offshore sites, Wadi El-Gemal and Suyul Islands recorded higher coral cover, higher fish abundance, and biomass, fewer algae, than inshore sites. Coral cover recorded 82.3% in the exposed sites compared to 63% in the sheltered sites. The average abundance of hard and soft corals was higher in the exposed sites with 91 and 5.4 colonies/125m^2, respectively. Massive corals were more abundant in the exposed sites (67) than in the sheltered sites (15). On contrary, branched corals had a higher number in sheltered sites (34 colonies/ 125m^2) than the exposed sites (23 colonies/125m^2). The average biomass of grazer, browser, and excavator fishes was higher in the exposed sites than in the sheltered sites with 9581g, 4601g, and 1029g/250m^2, respectively. Whereas the average biomass of scrapers was higher in sheltered sites (902g/250m^2) than in exposed sites (678g/250m^2). The new coral colonies of different sizes had almost the same density in both exposed and sheltered sites. The analysis of variance (ANOVA) showed that resilience factors varied significantly among sites. Based on resilience factors evaluation in this study, offshore sites are more resilient than onshore sites.

INTRODUCTION

Coral reefs and their associated seagrass beds and mangrove ecosystems sustain the world's highest marine biodiversity. Worldwide, more than 500 million people depend on them for food, storm protection, employment, and recreation. Although they occupy less than one percent of the surface of the earth, their wealth and services are valued at $375 billion annually.

Climate change is now regarded as one of the world's greatest threats to the coral reefs. While a changing climate poses many challenges to coral reefs, one of the most immediate and serious threats is bleaching from coral mass combined with exceptionally high temperatures at sea. Coral bleaching has resulted in substantial damage to coral reefs on a global scale (16% of reefs alone suffered sustained damage in 1998), with some areas losing 50-90% of their coral cover (**Wilkinson 2000**). Further loss is predicted: extreme coral bleaching events, also under optimistic climate conditions, maybe an annual phenomenon by the mid-century (**Hoegh-Guldberg 1999, Hughes *et al*. 2003**).

Two general properties determine coral communities' ability to persist in the face of rising temperatures: their sensitivity and their potential for recovery. Sensitivity is linked to the capacity of individual corals to undergo unbleached light, and how they bleach to survive. Potential for recovery relates to the capacity of the ecosystem to preserve or restore its structure and function given coral mortality. These properties are called 'resistance' and 'resilience' respectively at the coral colony and coral community level (**West and Salm 2003, Obura 2005, Grimsditch and Salm 2006**). Together they determine coral communities' resilience to temperatures rise at sea. Ecologically, resilience can be divided into resistance – when exposed to high temperatures and other mitigating factors, the capacity of individual corals to withstand bleaching, and when bleached to survive, resilience – following coral mortality, the capacity of the reef population to sustain or restore stability and work and remain in an equivalent 'process' as before coral mortality (**Obura *et al*. 2006**).

Resilience is a system's capacity to withstand (i.e., restrict effects) and recover from a disruption (**Holling 1973, Nystr¨om *et al.* 2000**). In ecology, resilience is the degree of change (resistance) or rate of return of a population or group to a specific pre-disturbance condition (recovery). The application of resilience theory to coral-reef conservation was developed and reviewed in several articles (**Bellwood et al. 2004, Hughes *et al*. 2010, Mumby and Steneck 2008, Nystr¨om *et al*. 2008, Roberts *et al*. 2017, West and Salm 2003**). In practical terms, resistance is measured as a change in ecological condition (e.g., coral cover) in an experiment or monitoring study before and immediately after a disturbance (the smaller the change, the higher the resistance), and recovery is measured as a rate or absolute time to return to the pre-disturbance state (the faster the rate, the greater the recovery).

Results of the resilience assessment may then be considered to inform management decision-making in the communication sense. Connectivity data can explicitly be used to assess where management activities are most required to maintain larvae supply and are less likely to be successful due to low larvae supplies.

The last 20 years have seen a radical progression in human activities along the Egyptian Red Sea coast, relying directly on the tourism industry, followed by rapid urbanization and subsequently high construction levels along the entire Egyptian Red Sea coastline. These activities are accompanied by many stresses on the marine environment, such as coastal landfilling, which is one of the most significant environmental problems associated with the existing human activities on the coast. It affects the physical and chemical characteristics of marine organisms, water, and sediment along the coast. The crushing coral reefs will cause physical damage to the coral reefs by boat anchors (**Dar, 2002**).

The aim of this study is to evaluate the resilience indicators in some coral reef sites in the Egyptian coast of the Red Sea and to describe a detailed and adaptable process that can guide the implementation of assessments of ecological resilience in coral reef areas and combine resilience assessments with information on connectivity.

MATERIALS AND METHODS

1.1. Study area

This study was carried out in Wadi El Gemal – Hamata Protected Area (WGHPA) in the southern Egyptian Red Sea, as an example of Marine Protected Areas (MPA). Wadi El Gemal – Hamata Protected Area (WGHPA) is situated in the Red Sea Governorate approximately 50 km south of Marsa Alam. It has a total area of 7,450 km^2 (land portion: 5,850 km^2; sea portion: 1,600 km^2, covering 305,57 km^2 in three No-Take Zones (**Baha El Din, 1998, 2003; Herman, 2003; Mansour, 2003; NCS, 2009**). Three on-shore sites, Gorgonia Beach, Shams Alam and Lahmy Azur resorts, and two off-shore sites, Suyul Island and Wadi EL Gemal Island were surveyed (Fig 1).

1.2. Data collection

The temperature variability rated was based on the field measurement records and readings from the satellites. The following data were collected seasonally in the period from August 2015 to July 2016from two depths (5m and 10m) at each site using SCUBA diving throughout a year.

1.2.1. Benthic and algal cover

Benthic cover and algal cover data have been collected using Point Intercept Transect (PIT) (**English *et al.*, 1997**). The transect was laid on selected starting points on the reef slopes along the contour of the proposed depths (5m and 10m). The tenderness benthic assemblages were recorded and numbered at each 1 m interval.

1.2.2. Coral community

Abundance of hard and soft corals was estimated at each site along a 25 m long and 5 m wide belt transect. The same transect was used to record bleached corals, broken corals, coral fragments, new coral recruitment, fragment size, and signs of recovery. For colonies larger than 10 cm, a belt transect 25 m long and 5 m wide was used to record the number of colonies of the target genera. Also, colonies whose centers are within the transect are counted.

The occurrence of threats such as eroding sea urchins, thorn crown, *Drupella*, bleaching and mortality, diseases, and other risks was examined for all colonies using the same belt transect.

1.2.3. Recruitment

At each site, Belt Line Transect (BLT) with a 25m length and 5 m width was applied at two depths 0-5 m and 5-10 m. The number of recruited colonies was counted at each BLT and defined as colonial no./ $125m^2$. Based on the size of the colony, the new colonies were divided into three class sizes: 0-2 cm, 3-5 cm, and 6-10 cm.

1.2.4. Herbivorous fish

Abundance and biomass of herbivorous fish in each site were determined. Herbivores were categorized into four functional groups: grazers, browsers, scrapers and excavators according to feeding strategy.

The fish population was assessed using 50 m length and 5 m width BLT lines at two depth 0-5 m and 5-10 m with three replicates at each depth. Species were known for all herbivorous fish and all other fish larger than 8 cm in body length, and their length was measured at the nearest cm. Using traditional weight-length relationships, the weight of each fish in grams was then calculated. The used coefficients were extracted from the Coral Reef Ecosystem Division of NOAA (**Weijerman *et al*., 2013**). Species have been listed as herbivores using IUCN classifications and were grouped as: 1) browsers, 2) grazers/detritivores, and 3) scrapers/excavators (**Green *et al*., 2009**).

Fish biomass was estimated using the length (L)—weight (M) equation: $M = aL^b$. Constants (a, b) for the most common species according to **Froese and Pauly (2003)**. The length of each species was obtained from the average length recorded at **Lieske and Myers (1994)** and Fish Base (**Froese and Pauly 2003**), and the fish biomass expressed as g/250 m^2.

Fish were identified underwater using **Randall (1986)** waterproof version. Most censuses were conducted at midday between 12:00 PM and 3:00 PM.

1.2.5. Anthropogenic impacts

Belt transect with a 25 m long and 5 m wide belt transect at each site was used to count the bleached corals, broken corals, and coral fragments to represent the impact of human.

1.2.6. Key Resilience Indicators

In this study, six resilience drivers (coral diversity, coral disease, anthropogenic impacts, herbivore biomass, recruitment, and algae) were used to assess the studied sites. To measure the resilience scores for a given reef, a 5-point Likert scale rating (0-none; 5-highest possible) was given to each of the 6 factors to quantify its degree of operation and then weighted by its evidence score for resilience (**McClanahan *et al*., 2012**).

We measured the highest value of positive factors (resistance organisms, temperature variability, coral diversity, herbivores biomass, recruitments) and gave it 5 points and the other sites evaluated according to the value of each factor at each venue. The highest value of negative factors (coral disease, anthropogenic impacts, and algae) was given 1 minus anchored score results in the final score so, the highest values are given a zero or the worst possible score for those variables.
Normalizing at all sites, and the other sites were calculated according to the value of each factor at each site. Anchored resilience scores of 0.8 to 1 represent high (relative) resilience potential, 0.6-0.79 medium, and <0.6 low.

1.3. Data analysis

The data were analyzed using Microsoft Excel and SPSS (V. 23.0.0). Analysis of variance (ANOVA) was applied to test significant differences between the coral coverage, algae, recruitments, and herbivores fish data at different sheltering condition, human impacts, and different sites. All maps were created using QGIS (V 3.0) and all graphs were illustrated using GraphPad Prism 8.

RESULTS

3.1 Temperature

The sea surface temperature (SST) showed very slight variation among different sites. Seasonally, temperature varied from the minimum in winter in Gorgonia (22.15°C) to the maximum in summer in Lahmi resort (30.01°C) (Fig.2).

3.2 Coral and benthic cover

The highest cover (88 %) of live coral had been recorded in WGI whereas, the lowest cover (52%) was recorded in LAH. On the other hand, the highest dead coral was found in LAH with 39% and lowest dead coral cover (11%) was found in in WGI. Regarding the algal cover, the highest cover of 9.5% had been recorded in LAH, whereas the lowest cover had been recorded in WGI (0.7%) (Fig 3). Conditions in the sheltered sites (GOR, SHA and LAH) were significantly different from those in the exposed sites (SUI and WGI). The percentage of coral cover recorded in the exposed sites was 82.3% compared to (63%) in the sheltered sites. On contrary, algal cover was higher in sheltered sites (6.4%) than in the exposed sites (1%). The coral cover and algal cover varied significantly among sites ($P<0.05$) but were insignificantly different at the different depth or season (Fig.3).

3.3 Coral community

The highest coral colonies number /125m^2 had been recorded in WGI where (112) colonies were found. Whereas the lowest number of coral colonies were recorded in LAH (37) colonies (Fig. 4) In additions, the highest hard coral colonies had been recorded in WGI (109 colonies/125m^2) and the lowest was found in LAH (34). Moreover, soft corals were most abundant in GOR than other sites with (7) colonies. They were less abundant in SUI where only two soft coral colonies were recorded (Fig. 4). Massive corals were more abundant in WGI (81 colonies) whereas the branched corals were found in GOR and SHA with 45 and 34 colonies respectively (Fig.4).

The average total coral cover (colonies/ 125m^2) was significantly higher (95 colonies) in the in exposed sites (SUI and WGI) than in sheltered sites (54). Furthermore, abundance of hard corals was higher in the exposed sites than the sheltered sites with 91 and 49 colonies, respectively. On contrary, soft corals were more abundant in the sheltered sites than in the exposed sites (Fig. 4).

3.4 Coral diversity

Total of 12 genera of hard corals have been chosen to study in the different sites. The most abundant genera were *Porites* and *Acropora*. *Porites* dominated the offshore sites and *Acropora* dominated the inshore sites (Fig. 5). The highest Simpson's Diversity index was found in SUI with the value of 0.35. Whereas the lowest coral diversity index (0.17) was found in LAH had been recorded.

3.5 Coral recruitments

The highest coral recruitments class size (<2 cm) and (2.5-5 cm) were found in GOR (12.87) and (21.5) colonies/125 m^2. In contrast, class size (5-10 cm) had the highest number in WGI (20.5). Suyul Island (SUI) recorded the lowest number of new coral colonies of size class of 2.5-5 cm and 5-10 cm, and Lahmi (LAH) had the lowest number of class size (<2 cm) (Fig. 7).

Sheltered sites had recorded higher number of recruitments colonies for the sizes of 2.5-5 cm and 5-10 cm, whereas exposed sites had much greater number of the smaller size colonies (<2 cm) (Fig. 7). Depths more than 10m had higher recruitment colonies of all class sizes than in shallower depths.

3.6 Herbivorous fish's assemblage

Wadi El-Gemal Island recorded the highest number of herbivorous fishes with 101 fish/250m^2. Grazers and browsers had the highest abundance in WGI with 41 and 28 fish, respectively. Grazers were represented by the members of fish families Acanthuridae (unicornfishes) and Siganidae (*Siganus rivulatus*). Browsers were represented by members of the families Acanthuridae (surgeons), Ephippidae and Kyphosidae. Examples of scrapers include parrotfishes smaller than 35cm while excavators include parrotfishes larger than 35 cm. Moreover, the highest biomass of grazers (12839g /250m^2) and browsers (6821g/250m^2) had been recorded in WGI. The highest abundance for scrapers and excavators had been recorded in SUI with 15 and 16 fish/250m^2, respectively. On the other hand, LAH had the lowest abundance of total herbivorous fishes (Fig. 9). Abundance of fishes was higher in exposed sites than in sheltered sites**.** Consequently, abundance of herbivores varied significantly among sites ($F= 6.8$ $P<0.05$) and between exposed and sheltered sites ($F=15.9$ $P<0.05$). On the other hand, there was no significant differences between depths ($F=0.3$ $P>0.05$). and seasons ($F=1.6$ $P>0.05$). All feeding groups of herbivorous fish varied significantly from site to site except scrapers ($F=2.29$ $P>0.05$).

Whereas, scrapers and excavators had the highest biomass in SUI with 935.9 and 1033g /250m^2, respectively. The lowest biomass of all herbivorous fishes had been recorded in LAH (Fig. 8). All herbivorous fishes were abundant in the exposed sites except scrapers (Fig. 9).

3.7 Anthropogenic factors:

Broken corals, bleached corals and dead corals are used as indicators of the human impacts on the health of coral reefs. study, the highest number of broken corals had been recorded in GOR (12.25 colonies /125 m^2), and the lowest number was recorded in SUI and WGI (7.0 and 7.25 colonies /125 m^2, respectively). The highest number dead corals had been recorded in LAH (22.5 and 36.7 colonies /125 m^2 for old and recent dead corals respectively). Whereas the lowest number of dead corals were recorded in WGI with 5.3 and 3.1 colonies /125 m^2 for old and recent dead corals respectively. The partially bleached corals were abundant in GOR and SUI and the totally bleached corals were more abundant in LAH (0.625 colonies /125 m^2). Signs of coral diseases were most notable in LAH compared to other sites. Sea urchins and and sea stars had the highest abundance in Shams Alam resort (SHA) with an average abundance of 2 individuals /125 m^2, while the lowest abundance was observed in (SUI) 0.37.

Lahmi Resort (LAH) recorded the highest average of totally bleached coral (0.625 colonies /125 m^2), recently dead coral (36.75), coral disease (0.75), and dead coral (22.5). Gorgonia (GOR), on the other hand, recorded the highest average number of broken corals and partially bleached corals (1.875). On contrary, the offshore site Wadi El-Gemal Island (WGI) recorded the lowest average number for bleached corals and dead corals (Fig. 11) and SUI recorded the lowest number of broken corals and coral disease.

3.8 Resilience ranks

The exposed site of Wadi El-Gemal Island (WGI)) showed the highest resilience score and resilience anchored score with 0.72 and 1:00 respectively. Consequently, this site had the highest rank of 1:00. On the other hand, the lowest resilience score and resilience anchored score had been recorded in Shams Alam resort with (SHA and LAH) with 0.26 and 0.36, respectively (Fig.12).

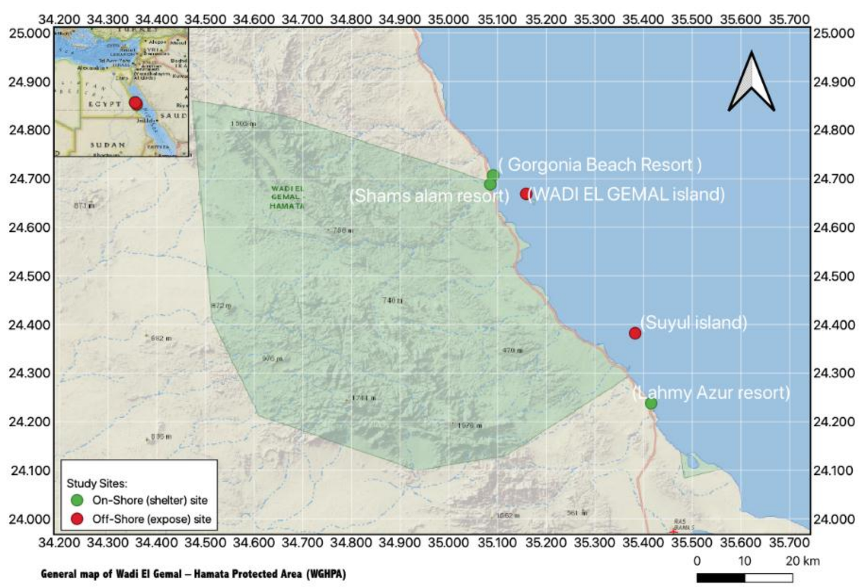


Fig (1): The Study Area - Wadi El Gemal – Hamata Protected Area (WGHPA)

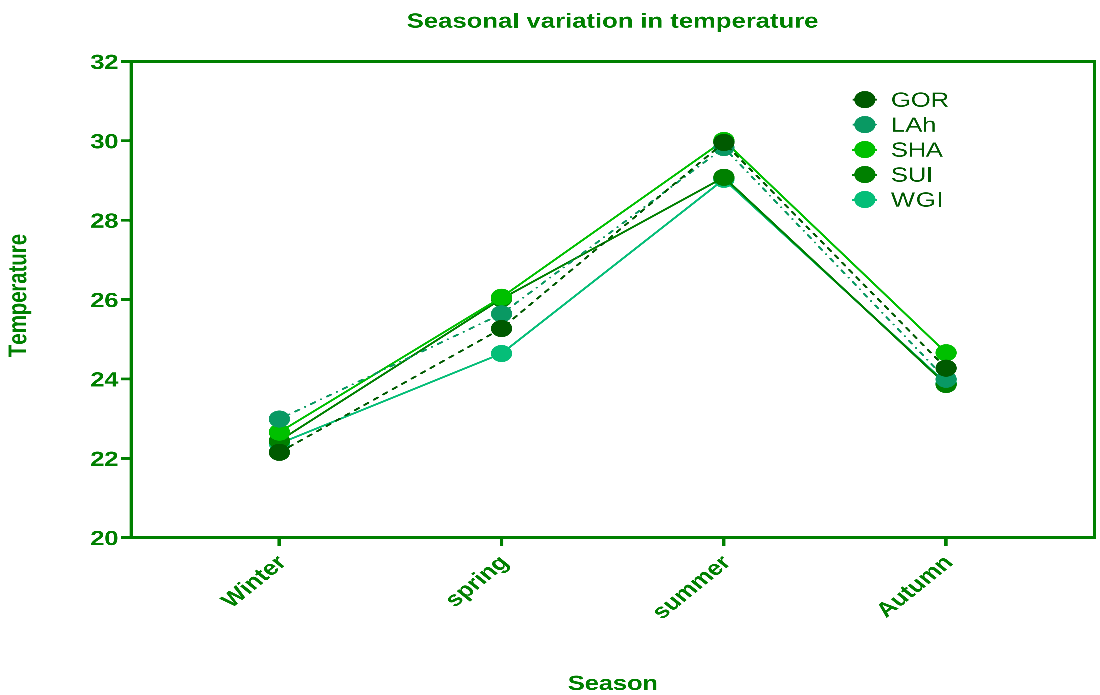


Fig.2. Seasonal variations of temperature at different sites during the period of study

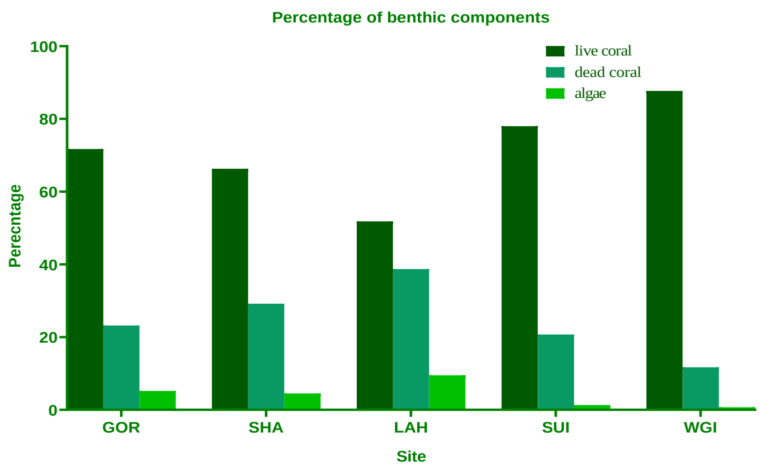


Fig. 3 Percentage contribution of different benthic components at different sites

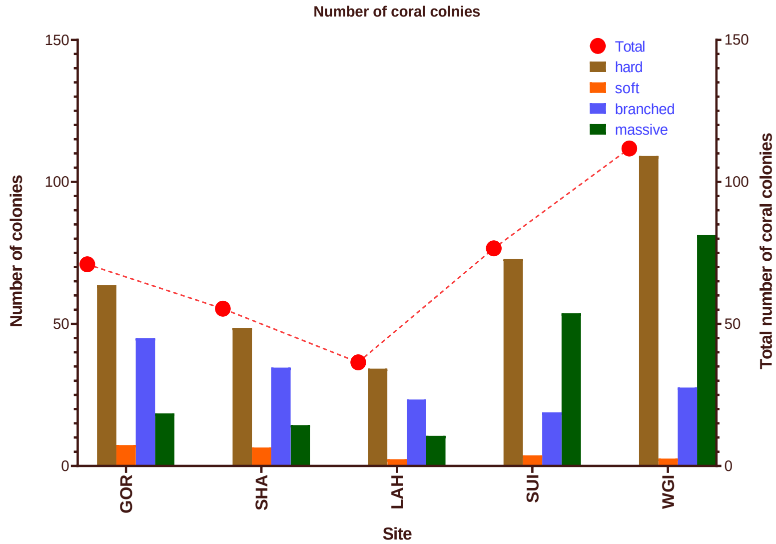


Fig. 4. The average number of coral cover and different forms

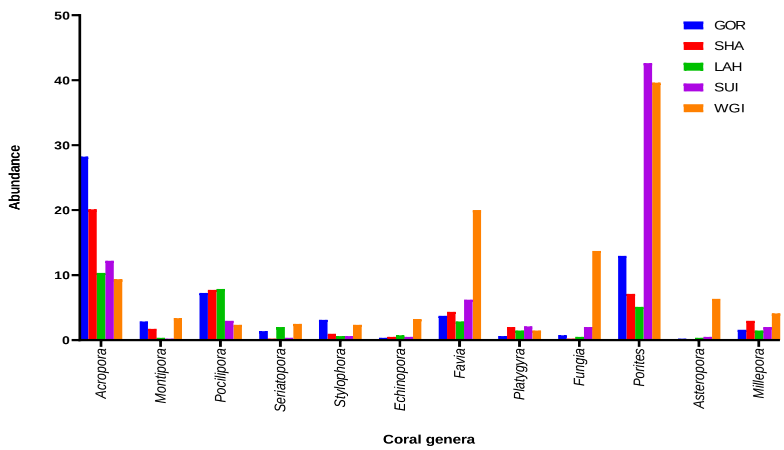


Fig.5. Abundance of the most abundant coral genera in different sites

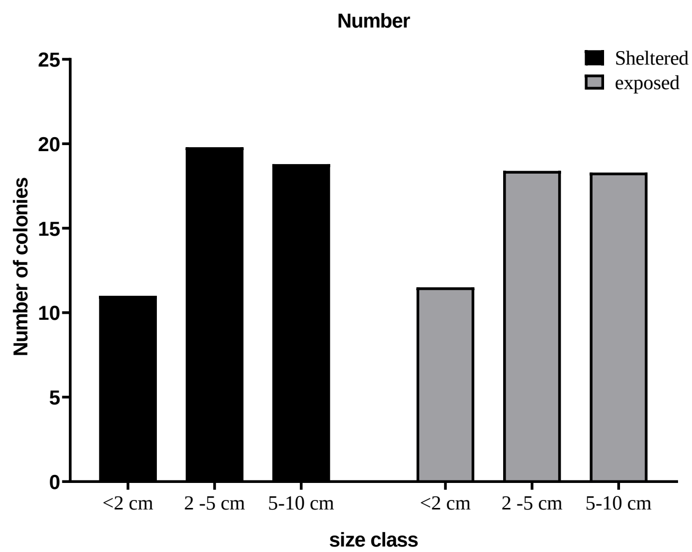


Fig. 6. The size class of the new colonies at sheltered and exposed sites

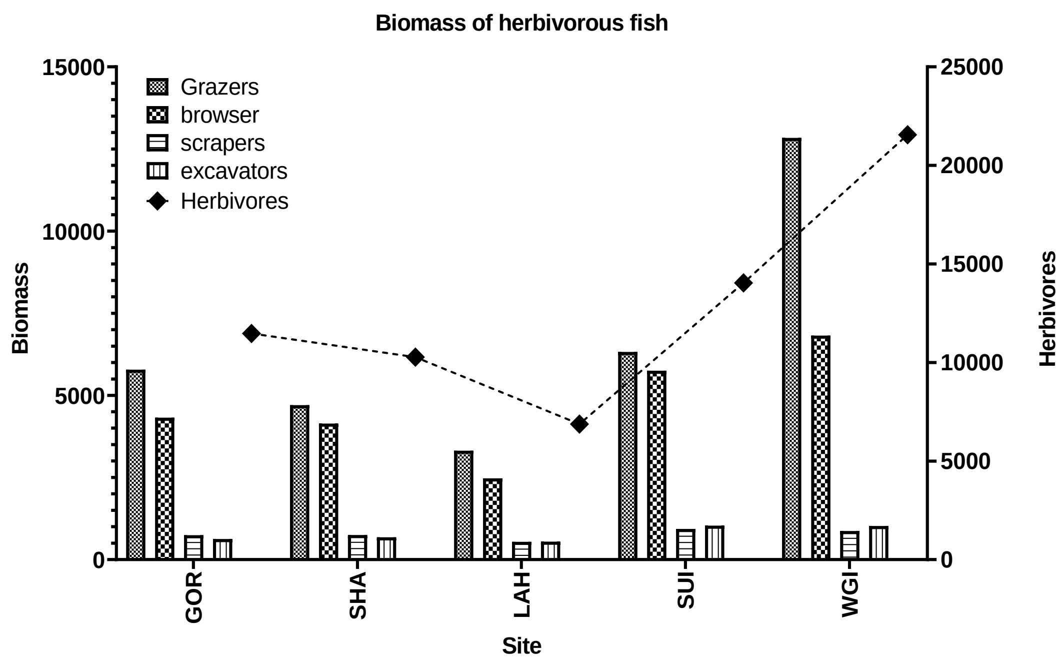


Fig. 7 Biomass of the total herbivorous and fish different categories

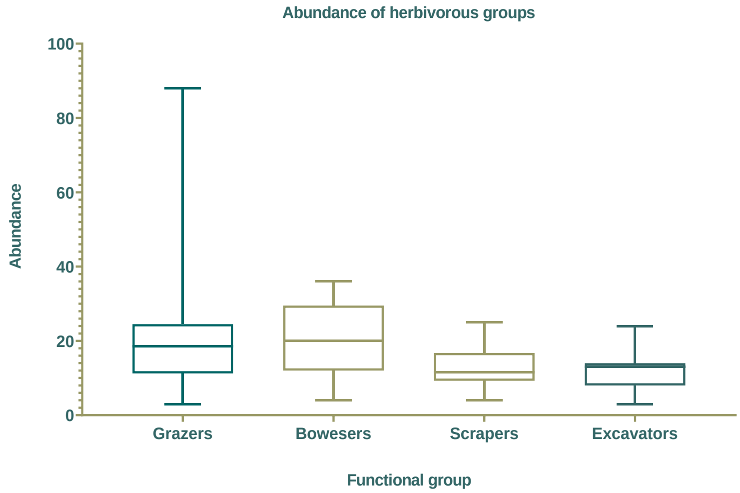


Fig. 8. Box plot showing the abundance of each feeding functional group of herbivorous fish

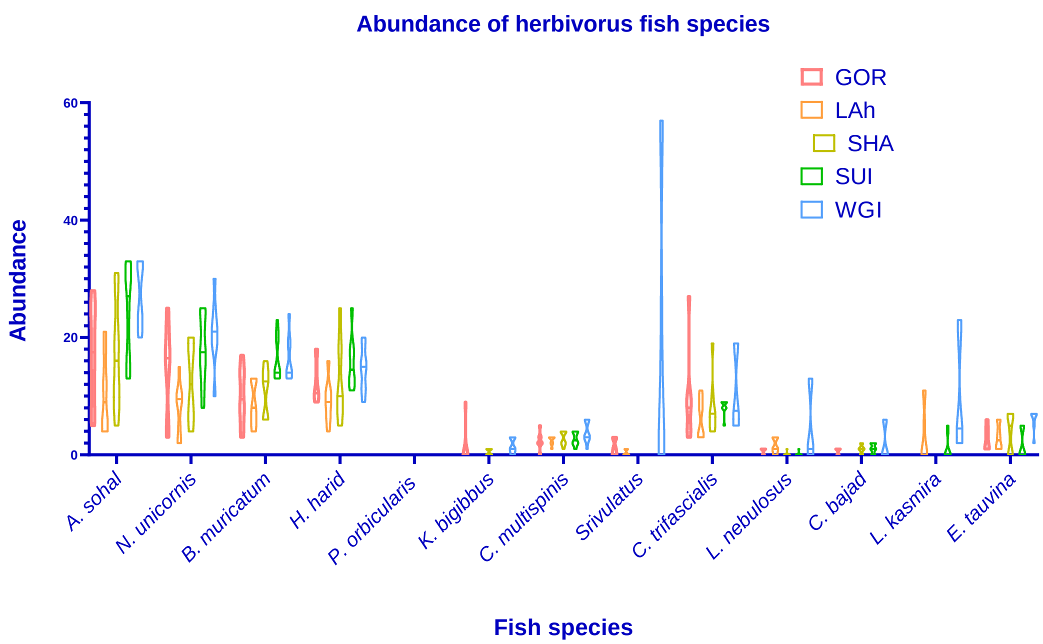


Fig. 9. Abundance of fish species in different sites

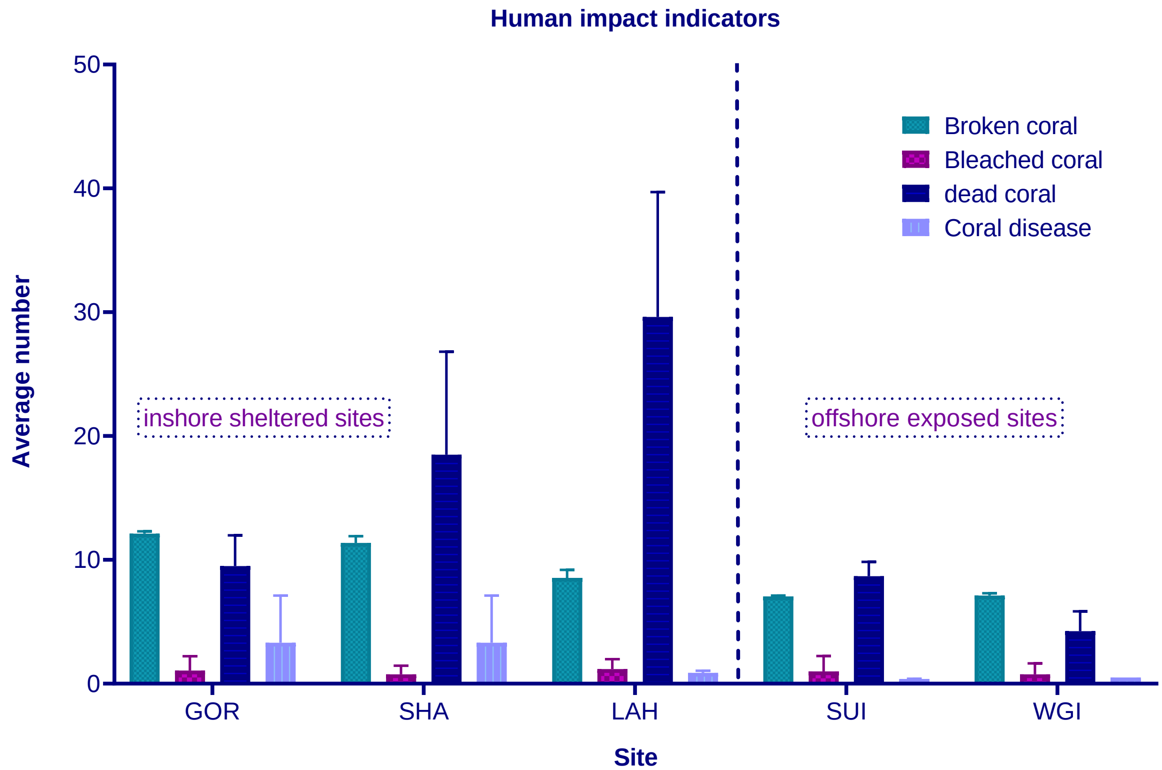


Fig. 10. The human impact factors on the reef ecosystem in different sites

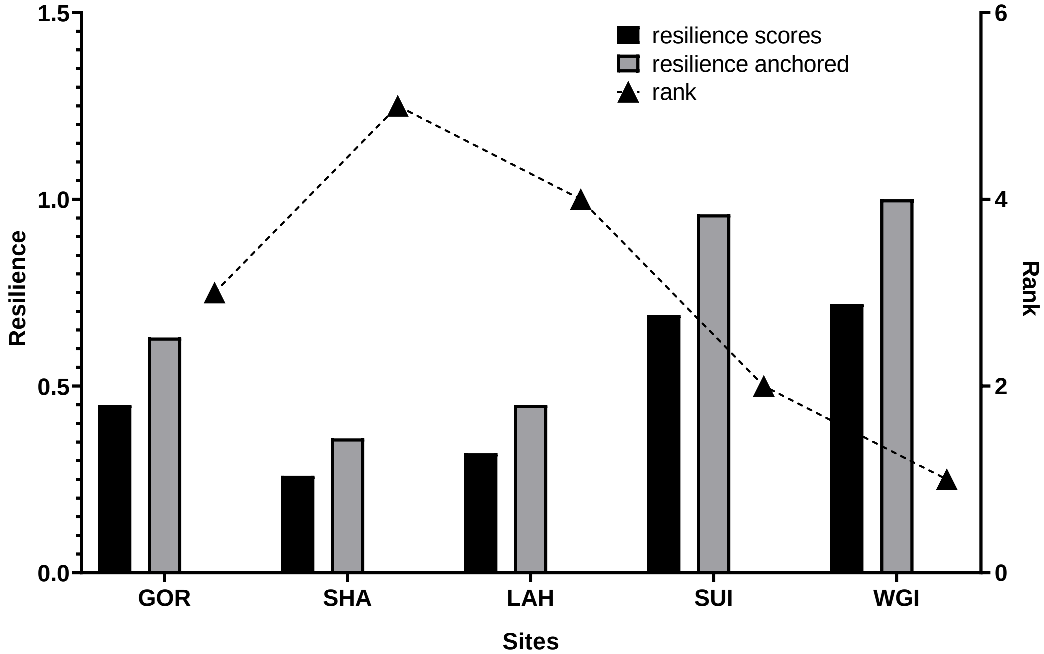


Fig.11. Resilience score, anchored resilience score and resilience rank at different sites

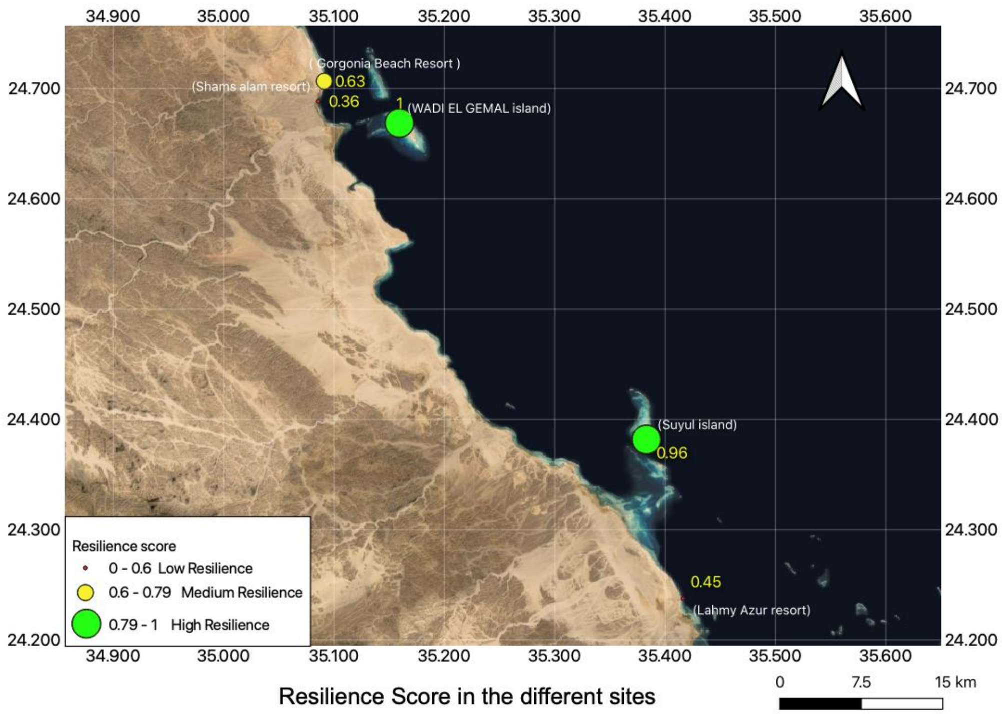


Fig. (12): Resilience scores in different sites

Table (1): Codes, coordinates, and description of different study sites

Site	Code	Coordinates	Exposure	Marina	Activities
Gorgonia	GOR	24°42'24.1"N 35°05'28.3"E	Sheltered	Yes	Snorkeling Diving swimming
Shams Alam	SHA	24°41'18.3"N 35°05'07.8"E	Sheltered	Yes	Snorkeling Diving Swimming boat dock
Lahmy Azur	LAH	24°14'15.5"N 35°24'57.9"E	Sheltered	Yes	Snorkeling Diving swimming
Suyul Island	SUI	24°22'54.6"N 35°22'59.3"E	Exposed	No	Snorkeling Diving line fishing bird watching
Wadi El-Gemal Island	WGI	24°40'07.3"N 35°09'33.6"E	Exposed	No	Snorkeling Diving line fishing bird watching

Table 2. Abundance of different herbivore functional groups at seasons and sites; Sp, Spring; Su , Summer; Au, Autumn; Wi, Winter

Fish family	Feeding habit	Georgenia				Shams alam				Lahmi				Suyul Island				Wadi El gemal Island			
		Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Acanthuridae Surgeonfish	browser	37	8	11	20	26	11	8	12	25	5	7	23	78	29	35	49	67	33	40	49
Acanthuridae Unicornfish	grazing	60	30	50	108	29	19	30	105	20	15	20	110	58	60	70	123	95	83	70	123
Scaridae (Parrotfish) >35	excavators	9	3	5	0	10	22	13	0	6	4	8	19	5	3	4	3	17	10	19	3
Scaridae (Parrotfish) <35	scrapers	33	9	15	24	26	16	20	32	28	20	25	50	39	30	40	78	35	30	25	78
Scaridae (Parrotfish) <35	browser	22	4	0	0	26	0	0	0	15	0	0	0	57	12	0	0	46	25	30	0
Ephippidae (Batfishes)	browser	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Kyphosidae (Chub)	browser	0	5	0	10	0	5	2	15	2	3	5	15	0	5	9	11	12	11	9	11
Pomacanthidae (angelfish)	Grazers	16	25	11	4	16	15	12	0	17	9	11	0	17	3	11	0	28	0	10	0
Siganidae (Rabbitfish)	Grazers	30	30	16	22	4	12	16	63	0	5	3	85	0	23	13	42	170	10	20	42

DISCUSSION

Ecological resilience can be characterized as the capacity of an ecosystem to absorb repeated disruptions or shocks and adjust to change while maintaining essentially the same role and structure (**Holling, 1973; Scheffer *el al*., 2001**). Two main components of resilience are resistance—defined as the ability of an ecological environment to withstand or survive a disturbance—and recovery— defined as the pace an environment takes to return to its original state— (**Pimm, 1984; West and Salm, 2003**). Recovery involves the replenishment of coral recruits in denuded areas (**Hughes *et al*., 2010**), the existence of suitable substrate for coral settlement and survival, (**Victor, 2008**) and low coverage of algae. High algal abundance can directly destroy corals, trap sediment and prevent coral settlement (**Smith *et al*., 2006; Mumby *et al*., 2007**).

Due to the increased anthropogenic disturbances and their interaction with natural stressors, coral reefs deteriorated in the last two decades, especially along the Egyptian Red Sea coast (**Ali *et al*., 2011**). In this study, significant differences in the live coral cover between onshore and offshore sites, as well as between the sites themselves were recorded. These differences can be attributed to the degree of anthropogenic impact on each site. The highest live cover was recorded at the offshore site (WGI) where human impacts on this large island is minimum, just few snorkeling and diving trips operating from the onshore SHA or from safari boats, besides few fishing boats for locals. In contrast, the least live cover and the highest dead corals were recorded at the onshore site of LAH (51.8%), a three stars hotel, which had been reported for many fines from WGHP authorities. In addition, there were evidences for prohibited line fishing on live coral inside the park. The fixed marina and speed boats owned by the hotel could also affect the coral community in the site. Similarly, Shams Alam, a four stars resort, has a fixed marina with almost the same conditions in onshore SHA, they have two big boats, they use it to organize snorkeling and diving trips to site 5 (WG island), signs of anchors and robs, as well as many broken corals were observed. On contrary, the onshore sites of GOR recorded the highest live cover among the entire onshore sites (71.6%). The resort is five stars and recorded the least anthropogenic impacts, it has a fixed marina to operate snorkeling and diving activities on the house reef. However, they apply restricted instructions to conserve the reef house. These results revealed that coastal sites were highly impacted by different anthropogenic activities than the exposed sites and this agree with **Ali *et al*. (2011**) and **Mohammed (2012**).

Coral diversity can increase its resistance, but this probably depends on the composition of the species, its sensitivity, and the species'disturbance tolerance (**Nyström *et al*., 2008, McClanahan *et al*., 2011**). On the other hand, there is insufficient evidence that, after disturbance, coral diversity promotes regeneration (**Cote and Darling, 2010**). Coral diversity varies from site to site and tends to increase in sheltered locations, but the rapid rise in coastal growth generally tends to decrease. In this study, we found coral diversity in some exposed sites higher than in onshore sites (sector 2) where costal growth and activity increases were more than in offshore sites. On other hand, some other onshore sites recorded higher diversity more than some offshore sites with minimum human impact.

Massive coral is considered to be the most resistant species and sometimes not affected by disturbance, and a high abundance of resistant species confers resistance (**Foster *et al*., 2011**). In addition, massive species that remain after a disturbance may continue to develop and reproduce to encourage recovery, but these are mostly slow-growing species and coral recovery may depend more on the recolonization of fast-growing branching and plating species (**Riegl and Purkis, 2009**). In this study, we found massive coral colonies in off-shore sites higher than in on-shore sites in live cover which might tend to the long term unimpacted on offshore sites or long-term impact on on-shore sites.

Algal assemblages, providing food and shelter for higher trophic levels in marine habitats, are a very significant part of many marine environments (**Bruno and Bertness, 2001**). Although potential factors are generally negative, the effect of algae on resistance is not clear. Factors may work to counteract each other. Algae can decrease growth rates, for example, and algae transmission of diseases can redirect coral resources (**West and Salm, 2003; Mumby *et al*., 2007**). Also, Algae is an important factor that restricts coral recovery after disturbance by increasing benthic substrate competition by trapping sediments that smother coral recruits (**Mumby and Steneek, 2011; Hoey and Bellwood, 2011**). In this study, we found in on-shore LAH recorded the highest algae level in this study which could connected with the low live cover to figure out how much this site impacted. This in agreement with (**Mohammed, 2006** and **Mohammed, 2012**).

In this study, there was no significant difference between sites themselves for the different sizes of recruitment colonies, but recruitment colonies < 2 cm have recorded lower number than bigger size of recruitment colonies. However, a significant difference between off-shore and on-shore sites was found, where the different sizes of recruitment colonies in on-shore sites were higher than in off-shore sites and this might be attributed to physical anthropogenic. Also, a significant effect of depth between sites for juvenile (5-10 cm in size) colonies was recorded, where this recruitment size was the highest in depth >10 m, which means that this size of recruitments had a better chance to grow up and survive at higher depths more than in shallow waters.

The distribution and abundance of herbivorous reef fish varied between and within reefs in geographic areas. Several studies have identified how herbivorous reef fish vary between reefs at various locations on the continental shelf (**Russ, 1984a, Williams, 1991**) and between reef areas (**Russ, 1984b**). Herbivores fish abundance differed between sites.

Since the study area is a national park area, fishing pressure is limited. However, other variables may effect on the herbivores fish abundance (as, anthropogenic impacts on sites). In shelter sites, fishing should be forbidden by divers and the owner of the resorts. Exposed areas, on the other hand, are used by local people for coastal fishing.

In this study, according to the feeding behaviors described in (**Green and Bellwood, 2009**), herbivores fish were divided into four functional classes according to their roles in coral reef resilience: scrapers, excavators, grazers, and browsers. **Green and Bellwood (2009)** reported that Acanthuridae, Labridae (Tribe Scarini), Siganidae, Kyphosidae, Ephippidae and Pomacanthidae were assigned to each of these functional groups based on a case study and available scientific literature and expert opinion. Grazers, browsers, and scrapers feed on algae (turfs and macro algae), accordingly, they were more abundant at shallow areas—with more algal abundance and diversity—than the exposed areas (**Bellwood and Choat, 1990; Choat, 1991; Fox and Bellwood, 2007; Hoey and Bellwood, 2008; Hoey *et al*., 2011; Alwany, 2011 & 2014**).

In this study, grazers had the most abundant group of herbivores functional groups in all study area. On the other hand, the other functional groups—browsers, scrapers, and excavators—showed low abundance comparing with the grazer fish and had the same general pattern of distribution in the studied area except, excavators which had higher abundance at exposed sites than in the sheltered ones.

In terms of biomass, grazer fish followed by browser fish recorded the highest biomass in all areas. Excavators and scrapers recorded the lowest biomass in the practical classes of herbivores.

Generally, all studied sites located in two main clusters; one includes most impacted sites (on-shore sites) and other include unimpacted sites (off-shore sites). The result thoroughly supports all our previous findings on reef coverage, recruitment, algae, herbivorous fish, and the effect of on conditions and human impacts.

ACKNOWLEDGEMENT

Thanks for EEAA Egyptian Environment affairs agency, Conservation sectors and Wadi El Gemal- Hamata National Park Team, especially my collages, Mr. Ayman Nasr, Mr. Mahmoud Saber and Mr. Ahmed Ali for helping in field work.

REFERENCES

Ali, A.; Hamed, M. and El-Azim, H. (2011). Heavy metals distribution in the coral reef ecosystems of the Northern Red Sea. Helgoland Marine Research. 65. 67-80. 10.1007/s10152-010-0202-7.

Alwany, M.A. (2011). Community structure and fish assemblage at Marsa Abu Dabab, Red Sea. Egypt J. Aquat. Biol. Fish., 15 (2): 105-124.

Alwany, M.A. (2014). Habitat diversity and fish communities on Marsa Gabal El- Rosas reefs, Red Sea. CATRINA , 9 (1): 15-23.

Baha El Din, S. M. (1997a). A pre-project study for the development of a GEF biodiversity project for coastal and wetland areas along the Egyptian Mediterranean. Tour du Valat–UNDP–EEAA. (Unpubl. report.)

Baha El Din, S. M. (1997b). Report on the vertebrate fauna of Elba Protected Area. (Unpubl. report to the Nature Conservation Sector, EEAA.)

Baha El Din, S. M. (1998). Towards establishing a network plan for protected areas in Egypt. Nature Conservation Sector, EEAA. (Unpubl. report.)

Baha El Din, S. M. (2003). Management Plan for Wadi El Gemal–Hamata. Nature Conservation Sector (NCS)

Bellwood, D. R. and Choat, J. H. (1990). A functional analysis of grazing in parrotfishes (family Scaridae) the ecological implications. Environ. Biol. Fish., 28:189–214

Bruno, J. F. and Bertness, M. D. (2001). Habitat modification and facilitation in benthic marine communities. In: Marine Community Ecology (ed. Bertness, M.D.). Sinauer Associates Inc., Sunderland, MA, pp. 201–218.

Choat, J. H. (1991). The biology of herbivorous fishes on coral reefs. In: Sale, P.F. (ed) The Ecology of Fishes on Coral Reefs. Academic Press, Sydney, Chapter 6.

Dar, M. (2002). Geological basis to study the environmental defect in the marine ecosystem as a result of touristic activities in Hurghada area and surroundings, Red sea, Egypt. PhD. Department of Geology, faculty of science, Suez Canal university.

Darling, E. S.; McClanahan T. R. and Coˆte´ I. M. (2010). Combined effects of two stressors on Kenyan coral reefs are additive or antagonistic, not synergistic. Cons Lett 3: 122–130.

English, S.; Wilkinson, C. and Baker, V. (1997). Survey manual for tropical marine resources. Australian Institute of Marine Science, Townsville. Australia., pp.34- 49.

Foster, K. A.; Foster, G.; Tourenq, C. and Shuriqi, M. K. (2011). Shifts in coral community structures following cyclone and red tide disturbances within the Gulf of Oman (United Arab Emirates). Marine Biology, pp. 1-14.

Fox, R. J., and Bellwood, D. R. (2007). Quantifying herbivory across a coral reef depth gradient. Marine Ecology Progress Series 339: 49-59.

Froese R. and Pauly, D. (2003). Fish Base. World Wide Web electronic publication, www.fishbase.org.

Green, A.L. and Bellwood, D.R. (2009). Monitoring functional groups of herbivorous reef fishes as indicators of coral reef resilience – A practical guide for coral reef managers in the Asia Pacific region. IUCN working group on Climate Change and Coral Reefs. IUCN, Gland, Switzerland. 70 pp.

Grimsditch, Gabriel D. and Salm, Rodney V. (2006). Coral Reef Resilience and Resistance to Bleaching. IUCN, Gland, Switzerland. 52pp.

Cesar, H. S. J. (2003). Economic Valuation of the Egyptian Red Sea Coral Reef. USAID-funded.

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

Hoey, A. S. and Bellwood, D. R. (2011). Suppression of herbivory by macroalgal density: a critical feedback on coral reefs? Ecol Lett, 14:267-273.

Hoey, A. S. and Bellwood, D. R. (2008). Cross-shelf variation in the role of parrotfishes on the Great Barrier Reef. Coral Reefs 27: 37-47.

Holling, C. S. (1973). Resilience and stability ofecological systems. Annu. Rev. Ecol. Syst. 4, 1–23. doi: 10.1146/annurev.es.04.110173.000245

Hughes, T. P.; Graham, N. A.; Jackson, J. B.; Mumby, P. J. and Steneck, R. S. (2010). Rising to the challenge of sustaining coral reef resilience. Trends in ecology & evolution, 25(11), 633–642. https://doi.org/10.1016/ j.tree. 2010. 07.011

Hughes, T.P.; Baird, A. H.; Bellwood, D. R.; Card, M.; Connolly, S. R;, Folke, C.; Grosberg, R.; Hoegh-Guldberg, O.; Jackson, J.B.C.; Kleypas, J.; Lough, J.M.; Marshall, P.; Nyström, M.; Palumbi, S.R.; Pandolfi, J.M.; Rosen, B. and Roughgarden, J. (2003). Climate change, human impacts, and the resilience of coral reefs. Science, 301: 929- 933.

Lieske, E. and R. Myers. (1994). Collins Pocket Guide. Coral reef fishes. Indo-Pacific & Caribbean including the Red Sea. Haper Collins Publishers, 400 p.

Mansour, A. M. (2003). Minning, Quarrying, geology and Minerals at Wadi El-Gemal – Hamata Protected Areas. MOBIS Task order No. 263-M-00-o3-00002-00, U.S. Agency for International Development

McClanahan, T. R.; Maina, J. M. and Muthiga, N. A. (2011). Associations between climate stress and coral reef diversity in the western Indian Ocean. Global Change Biology, 17: 2023-2032.

Mohammed, A. A. (2012). Coral reefs quantitatively assessment along the Egyptian Red Sea coast. Thalassas, 28(2): 17-26

Mumby, P. J. and Steneck, R. S. (2008). Coral reef management and conservation in light of rapidly evolving ecological paradigms. Trends in Ecology and Evolution 23: 555-563

Mumby P. J.; Harborne A.R.; Williams J.; Kappel C. V.; Brumbaugh D. R.; Micheli F.; Holmes K. E.; Dahlgren C. P.; Paris C. B. and Blackwell P. G. (2007b). Trophic cascade facilitates coral recruitment in a marine reserve. Proc. Natl. Acad. Sci. U. S. A. 104:8362–8367

Nyström, Magnus ; Folke, Carl and Moberg, Fredrik. (2000). Coral reef disturbance and resilience in a human-dominated environment. Trends in Ecology & Evolution. 15. 413-417. 10.1016/S0169-5347(00)01948-0.

Nyström, M.; Graham, N.A.J.; Lokrantz, J. and Norström, A.V. (2008). Capturing the cornerstones of coral reef resilience: linking theory to practice. Coral Reefs, 27: 795-809.

Obura, D. O. (2005) Resilience, coral bleaching and MPA design. Estuarine Coastal and Shelf Science 603, 353-372.

Pimm, S. L. (1984). The complexity and stability of ecosystems. Nature 307, 321–326.

Randall J. E. (1986). Red Sea reef fishes, ed. Immel, GB, 192p**.**

Riegl, B. and Purkis, S. (2009). Model of coral population response to accelerated bleaching and mass mortality in a changing climate. Ecological Modelling, 220: 192-208.

Roberts, C. M.; O'Leary, B. C.; McCauley, D. J.; Cury, P. M. and Duarte, C. M. (2017). Marine reserves can mitigate and promote adaptation to climate change. Proceedings of the National Academy of Sciences 114: 6167–6175.

Russ, G. R. (1984a). Distribution and abundance of herbivorous grazing fishes in the central Great Barrier Reef. I. Levels of variability across the entire continental shelf. Marine Ecology Progress Series 20: 23-34.

Russ, G. R. (1984b). Distribution and abundance of herbivorous grazing fishes in the central Great Barrier Reef. II. Patterns of zonation of mid-shelf and outer shelf reefs. Marine Ecology Progress Series 20: 35-44.

Scheffer, M.; Carpenter, S.; Foley, J.A.; Folke, C. and Walker, B. (2001). Catastrophic shifts in ecosystems. Nature, 413: 591–596.

Smith, J. E.; Shaw, M.; Edwards, R. A.; Obura, D.; Pantos, O.; Sala, E.; Sandin, S. A.;

Smriga, S.; Hatay, M. and Rohwer, F. L. (2006). Indirect effects of algae on coral: algae-mediated, microbe-induced coral mortality. Ecology letters, 9(7), 835–845.

Victor, S. (2008). Stability of reef framework and post settlement mortality as the structuring factor for recovery of Malakal Bay Reef, Palau, Micronesia: 25 years after a severe COTS outbreak. Estuarine, Coastal and Shelf Science 77: 175– 180**.**

Weijerman, M.; Fulton, E. A. and Parrish F. A. (2013). Comparison of Coral Reef Ecosystems along a Fishing Pressure Gradient. PLOS ONE 8(5): e63797.https://doi.org/10.1371/journal.pone.0063797

West, J. M. and Salm, R.V. (2003). Resistance and Resilience to Coral Bleaching: Implications for Coral Reef Conservation and Management. Conserv Biol., 17: 956-967.

Wilkinson, C. (2000). Status of Coral Reefs of the World: (2000). Australian Institute of Marine Science, Townsville, Australia

Williams, D. McB. (1991). Chapter 16 Patterns and processes in the distribution of coral reef fishes. In: Sale, P.F. (ed) The Ecology of Fishes on Coral Reefs. Academic Press, Sydney.

الملخص العربي

عوامل المرونه في بعض مواقع الشعاب المرجانية في محمية وادي الجمال البحرية ، جنوب البحر الأحمر المصري

عبد الرحمن نصار[1]، محمد إسماعيل[1]، محمد أبو الرجال[1،2]

[1]قسم علوم البحار، كلية العلوم، جامعة بورسعيد، بورسعيد- مصر
[2]قسم الأحياء البحرية- كلية علوم البحار- جامعة الملك عبد العزيز- جدة – المملكة العربية السعودية

تهدف هذه الدراسة إلى تقييم مرونة النظام البيئي للشعاب المرجانية في محمية وادي الجمال - حماطة جنوب البحر الأحمر. تم اختيار ستة عوامل لقياس قدرة الشعاب على الصمود (تنوع الشعاب المرجانية، وأمراض الشعاب، والتأثيرات البشرية ، والكتلة الحيوية العاشبة ، والمستعمرات الجديدة ، والطحالب) ليتم تقييمها في مواقع مختلفة. تم جمع البيانات بشكل موسمي في الفترة من أغسطس 2015 إلى يوليو 2016 باستخدام الغوص من ثلاثة مواقع على الشاطئ واثنان بعيدان عن الشاطئ. سجلت المواقع البحرية وادي الجمال وجزيرة سيال غطاءً مرجانيًا أعلى، ووفرة أسماكًا وكتلة حيوية أعلى، وعدد أقل من الطحالب، مقارنة بالمواقع الساحلية. وسجل الغطاء المرجاني 82.3٪ في المواقع البعيدة مقابل 63٪ في المواقع القريبة. كان متوسط وفرة الشعاب المرجانية الصلبة والرخوة أعلى في المواقع المكشوفة 91 و5.4 مستعمرة / 125 م 2 على التوالي. كانت الشعاب المرجانية الكثيفة أكثر وفرة في المواقع المكشوفة (67) منها في المواقع الساحلية (15). على العكس من ذلك، كان للشعاب المرجانية المتفرعة عددًا أعلى في المواقع الساحلية (34 مستعمرة / 125 م 2) من المواقع المكشوفة (23 مستعمرة / 125 م 2.(
كان متوسط الكتلة الحيوية لأسماك الراعية والمتصفح والحفار أعلى في المواقع المكشوفة عنها في المواقع الساحلية مع 9581 جم، 4601 جم، 1029 جم / 250 م 2، على التوالي. بينما كان متوسط الكتلة الحيوية للكاشطات أعلى في المواقع الساحلية (902 جم / 250 م 2) مقارنة بالمواقع المكشوفة (678 جم / 250 م 2). كانت للمستعمرات المرجانية الجديدة ذات الأحجام المختلفة نفس الكثافة تقريبًا في كل من المواقع المكشوفة والساحلية. أظهر تحليل التباين (ANOVA) أن عوامل المرونة تختلف اختلافًا كبيرًا بين المواقع..
بناءً على تقييم عوامل المرونة في هذه الدراسة، تعتبر المواقع البعيدة أكثر مرونة من المواقع الساحلية.