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ASSESSMENT OF THE CORAL REEF HABITATS, DAMAGE INDICATORS AND CORALS-REEF FISH RELATIONSHIP IN WADI EL-GEMAL NATIONAL PARK, RED SEA, EGYPT

MOHAMED ISMAIL [a] AND M. AMINUR RAHMAN [b*]

[a] Department of Marine Science, Faculty of Science, Port Said University, Port Said 42526, Egypt.
[b] Department of Fisheries and Marine Bioscience, Faculty of Biological Science and Technology, Jashore University of Science and Technology, Jashore-7408, Bangladesh.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Because of the pivotal role of the substrate composition in the ecological state of coral reef communities, the present study was attempted to investigate the substrate cover, coral reefs, and reef fishes in the marine ecosystem of the Wadi El-Gemal National Park (WGNP), Red Sea, Egypt. The surveys were conducted in the Spring and Autumn of 2015 by SCUBA diving and/or snorkeling. We applied the Point, Line, and Belt Intercept Transect (PIT, LIT and BLT) methods, to assess the state and forms of the substrate, through a quantitative assessment of the fundamental components of the benthic cover. A quantitative assessment was conducted on five main benthic categories at WGNP; hard corals, soft corals, dead corals, sand, and rocks. Six invertebrate groups; banded coral shrimp, sea urchin, sea cucumber, the crown of thorn, giant clam, and *Drupella* sp. were also investigated. The study showed that, while there was no significant difference between sites in the benthic structure and cover, sites were different in the cover of hard coral, the abundance of benthic invertebrates, and the abundance of reef fishes. We also, assessed the status of eight impact indicators of reef damage (or damage indication categories); old dead, recently dead, total bleached, partial bleached, diseased, broken, fragments, and recruitments of corals at the marine protected area as well as investigated the coral reef/reef fish community relationship. Among the eight reef impact indicators that were assessed in the current study, the old dead corals showed the highest cover of the substrate. In the same context, the cover of the diseased colonies was lower than other categories in the area of the study. The study also indicated that increasing hard coral cover in the study area had strongly affected the abundance of reef fishes. Nevertheless, the abundance of reef fishes was found to be increased with the increase of the hard coral cover ($P < 0.05$, $r = 0.8$), and this trend was attained by all reef fish families, the highest sites in coral cover and fish abundance were: Hnakourab, Wadi Lahmy and Sharm El-

**Corresponding author: Email: amin2019@just.edu.bd, aminur1963@gmail.com;*

Luli (32, 28 and 25%, and 9, 11 and 6 mean number of fish/20 m transect), respectively. Positive correlation between the hard coral cover and fish abundance was detected as well. Acanthuraidae displayed the highest mean number of individuals (53.25/20 m belt transect). The study concluded that there is a need to perform a periodic assessment of the benthic cover of the main components of coral reef communities. Also, the study emphasized the role of benthic substrate structure and cover in the reef fish ecology.

Keywords: Red Sea; Wadi El-Gemal National Park; coral reef communities; benthic cover; reef fishes; reef damage indicators.

1. INTRODUCTION

"Coral reef is considered as one of the most incredibly valuable, complex and diverse marine ecosystem among all other ecosystems. They are not only very important for nature, but also represent a very high-valued bioresource for humankind, supporting millions of people whose lives depend on these natural resources for a source of food and income. Estimates in this report show that coral reefs provide each year nearly US$ 30 billion net benefits in goods and services to the world economies, including, tourism, fisheries and coastal protection. They are considered economically valuable, providing shelter, food, and breeding sites for numerous marine organisms" [1]. "Coral reefs, which harbour 25% of the marine biodiversity and provide ecosystem services to over 500 million people, are suffering from severe degradation due to the combined effects of anthropogenic perturbations and global climate change" [2, 3]. "Anthropogenic disturbances such as overfishing, coastal development and pollution, together with increasing climate anomalies reduce coral reef resilience, which can result in changes of coral reef assemblages" [4-6]. "Decreases in coral cover and increases in alternate groups such as algae or sponges are increasingly common and have profound effects on ecosystem functioning and the ecosystem services provided" [7-9]. "Declines in the scleractinian coral cover of up to 80% in Caribbean coral reefs and 50% in the Indo-Pacific have been reported" [10-13].

"Red Sea reefs are among the most diverse in the world" [14-22]. "In total, 335 species of corals are found in the Red Sea" [15, 23]. The Red Sea harbours 94 genera and 359 species of scleractinian corals [24]. Egyptian reefs are fringing reefs alongside the coastline [16]. Wadi El-Gemal National Park (WGNP) is designated primarily as a National Park - a "protected area"- managed mainly for ecosystem protection and recreation. It falls into the IUCN's Park Area (PA) management category II [25]. "It has an area of 7,450 km² (land part: 5,850 km²; marine part: 1,600 km²" [26-29]). "The shores of the region are heterogeneous, encompassing rocky, sandy, and muddy beaches. The marine part of the protected area encompasses a strip of marine waters with an average width of 15 km along 110 km of the coast. This marine portion includes all the important coral reefs in the region, as well as marine islands, seagrass meadows, mangrove stands, intertidal pavement with algae, and intertidal sand" [26-28]. "The marine area falls under four management zones of varying protection levels: Strict natural zone, No Take Zone (NTZ), recreational zone, and multiple-use zones. All fishing forms are prohibited in the three NTZs, while recreational activities (boating, scuba diving, snorkeling, reef walking etc.) and scientific research are permitted" [27]. "Many monitoring programs are conducted by the protected area staff, including coral reefs, mangrove rehabilitation, and mooring maintenance, which are performed by Hurghada Environmental Protection and Conservation Association (HEPCA)" [29].

Ongoing problems and threats are generally due to tourism, pollution, and fishing. In areas without buoy moorings, many boat crews temporarily moor their vessels to reefs using steel, which is a potential source of coral reef damage. On the other hand, Barrania and Ibrahim [30] reported that "non– indigenous fishermen in the PA have introduced gill nets named 'sabeeb' that have a smaller mesh size than that legally permitted. They also use ring nets on corals, which can lead to physical destruction". Riegel and Luke [31] also reported that "a very small number of fishermen may still use explosives".

"Coral reefs are perhaps WGNP's most distinct and sensitive habitat, by far supporting the greatest biodiversity in the PA. The Red Sea coral assemblages considered among the most attractive, intact, well-developed, and biologically diverse ecosystem in the world" [27]. Riegel and Luke [32] described "at least 11 coral assemblage types from the Egyptian Red Sea and defined them by the dominant coral genus or genera, exposure (windward/leeward), and topography. In the PA, four assemblage types are widespread: windward *Acropora* assemblage, *Acropora* dominated patch reef assemblage, the leeward *Porites* assemblage, and *Millepora* current assemblage". Nassar et al. [33] found that massive coral colonies at WGPA in off-shore sites was higher than in on-shore sites in live cover which might tend to the long term unimpact on offshore sites or long-term impact on on-shore sites.

Fishes constitute a dominant component of the reef fauna comprising the most diverse and abundant assemblages of vertebrates within the marine ecosystem. In the Red Sea, they are as varied as the reef themselves [34]. A total of 1,078 species of fishes has been recorded in the Red Sea [35]. By recording the slender sunfish in Hurghada, this number has been increased [36]. Nearly half of these are associated with coral reefs [37]. Recently, Maaty et al. [38] recorded 93 reef fish species, representing 26 families along the area between Ras Gharib-Quseir. Farghal et al. [39] in their study on Red Sea coral reef fishes at Hurgada, recorded 47 species of coral reef fishes belonging to 8 families. In the WGNP marine area facing the main Wadi El-Gemal outlet on the Red Sea coast, a total of 94 species under 23 reef fish families were recorded [40].

The main aim of the study was to assess the state and forms of the substrate at Wadi El-Gemal MPA, through a quantitative assessment of the fundamental components of the benthic cover of six main categories. The study also aimed to assess the status of eight damage indication categories in the marine protected area as well as investigate the coral reef/reef fish community relationship.

2. MATERIALS AND METHODS

2.1 Study Sites

Six sites were selected for this study viz., 3 sheltered sites (Hankourab W.G Island and Umm Sayal), and 3 exposed sites (Ras Boghdadia; Sharm El-Luli and Wadi Lahmy), (Fig. 1 and Table 1).

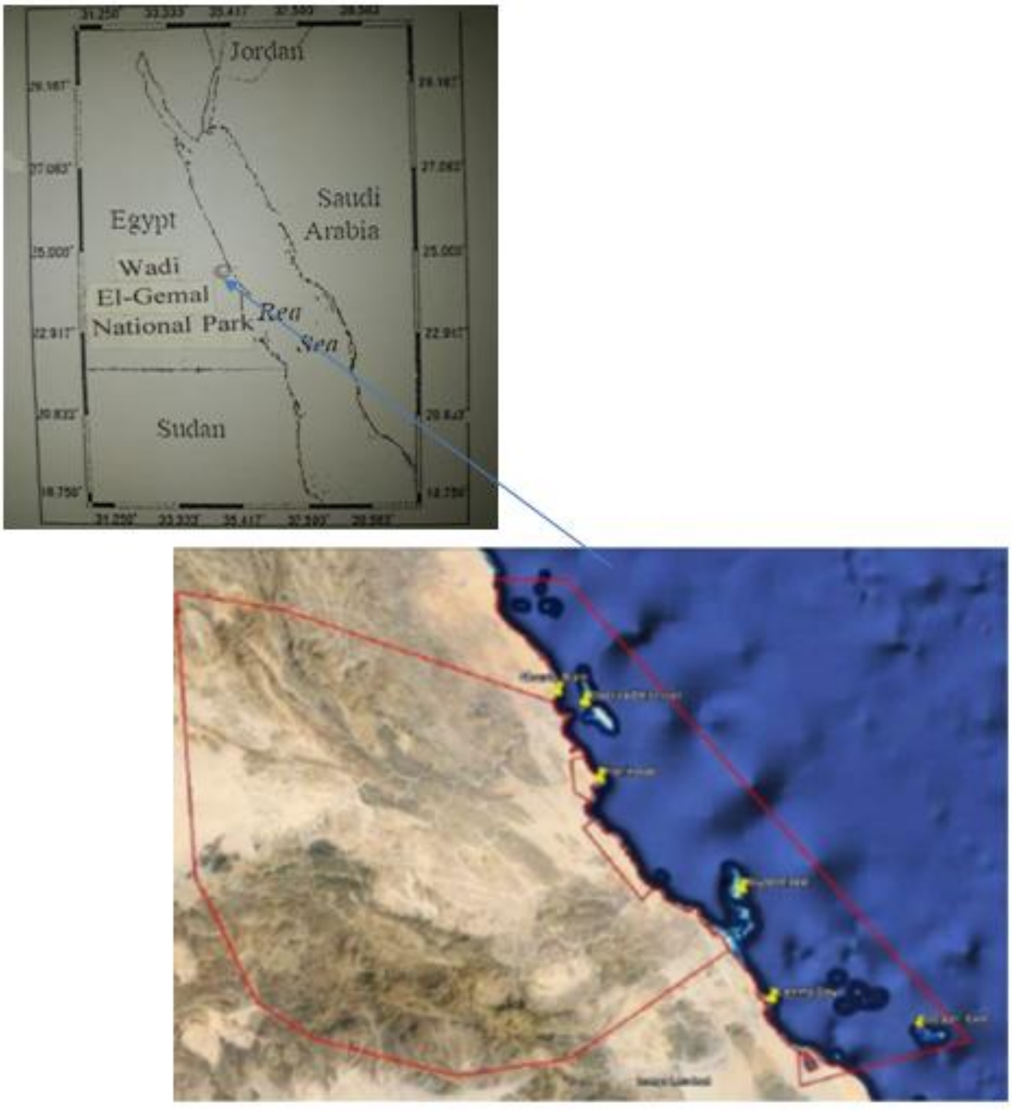

Fig. 1. Map showing location of the study sites at Wadi El-Gemal National Park (WGNP), Red Sea, Egypt

Table 1. Location and nature of the study sites at Wadi El-Gemal National Park (WGNP), Red Sea, Egypt

Site		Case				Location	
No.	**Name**	**Inshore**	**Offshore**	**Sheltered**	**Exposed**	**Longitude**	**Latitude**
1	Turfa, Ras Boghdadia		●		●	24 º 39 ′ 10.4″	35 º 6 ′ 7.6 ″
2	Gopar, Wadi El-Gemal Island	●		●		24 º 38 ′ 46.4 ″	35 º 10 ′ 35.4 ″
3	Sharm El-Luli		●		●	24 º 37′ 17.5″	35 º 06 ′ 56″
4	Hankourab		●	●		24º 33 ′ 9.3″	35 º 08 ′ 43.4″
5	Umm Sayal Island	●		●		24º 33′ 0.9″	24 33 ′ 0.9″
6	Wadi Lahmy		●		●	24 33 ′ 0.9″	24 33 0.9″

The shores of the region were heterogeneous in nature, encompassing rocky, sandy and muddy beaches [26-28]. The marine part of the protected area encompassed a strip of marine waters with an average width of 15 km along 110 km of the coast.

2.2 Data Collection

In this study, we had surveyed fringing reefs in WGNP marine area (South Red Sea, Egypt) during the Spring and Autumn of 2015 and the data were collected by SCUBA diving.

2.2.1 Reef check point intercept line transect

A quantitative assessment of the percentage cover of 5 substrate categories was made using four 20 m line transects, laid parallel to the selected depth (0.5–10 m) at each site according to PERSGA/GEF (2004). Surveys were conducted by SCUBA diving and/or snorkeling by applying the Line Intercept Transect (LIT) method of English et al. [41], to evaluate the percentage cover of the soft and hard coral communities relative to benthos of other taxa, using a 100 m long transect tape laid along the selected depth contour from a haphazardly or randomly selected starting point on the reef, with the first 20 m transect starting from the beginning of the tape. The second transect was started after an interval of 5 m from the end of the first transect (start at 25 m) and so on for the third transect (start at 50 m) and the fourth transects (start at 75 m). On each transect, a point sampling method was employed where the substrate located under the transect tape at 50 cm intervals and the measurements were recorded on a waterproof datasheet.

2.2.2 Estimation of reef fishes abundance

“Transects were laid using a 100 m fiberglass tape measure with 5 m intervals between replicate 20 m transects, ensuring that it was laid clearly along the reef by diving and then swimming back along with the tape. In sites, where the reef is not continuous (for example, reef slope areas interspersed with sand or drop-offs), 20 m measuring were used to mark out the individual 20 m sections of the transect, each separated by at least 5 m intervals from the start and end of the transect. Surveys of fish transects were started no earlier than 09:00 am. We waited for 15 minutes after transects had been deployed and checked to allow time for fish that escaped to come back to their places. The observed fishes and corals were identified according to the guide book of Lieske and Myers” [42].

2.2.3 Estimation of reef invertebrates’ abundance

The abundance of invertebrates and benthic cover data were collected using the reef check Belt Line Transects (BLT) methodology of Hodgson [43]. Replicate transects of 4 x 100 m^2 (5 m wide x 20 m long) each were centered at each depth per site on the line transects. Sea urchins, sea cucumbers, thorn crown, *Drupella*, giant clams, banded coral shrimps, as well as the bleaching and mortality, diseases, and other risks were examined for the reef colonies using the same belt transect.

2.3 Statistical Analysis

All the collected data were analyzed using SPSS (Ver. 22) and presented using Excel 2013. A one-way ANOVA was used to analyze the variance between sites, invertebrates, and fishes. The correlation between coral cover and fish abundance was tested based on Spearman correlation analysis, and multiple comparisons (Post Hoc analysis) of fish groups in the study area was done.

3. RESULTS

3.1 Substrate Structure

Along the 20 m point transect, substrate taxa showed a higher percentage cover (56.3%) of hard coral than that of other categories. The lowest category was represented by the sand cover of 2.4% (Fig. 2). The average mean points (at every 0.5 m along 20 m point transects) of hard coral were more than 20 points/transect, while the other categories showed benthic cover lower than 10 points/transect (Fig. 3).

Substrate taxa showed a high mean percentage cover of hard corals, which was more than 70% in Hankourab but it showed a low mean percentage cover (30%) in Gopar. Soft coral was found to be more than 10%, while dead coral and rocks were found to be 30% and 10 % of mean percentage cover of taxa at site 6 in absence of algae (Fig. 4). The relative benthic structure of the studied categories at each site indicated that there was no significant difference ($P > 0.05$, one-way ANOVA) between sites in the benthic structures. However, the hard coral cover was different between sites (one-way ANOVA; $P < 0.05$ (Table 2).

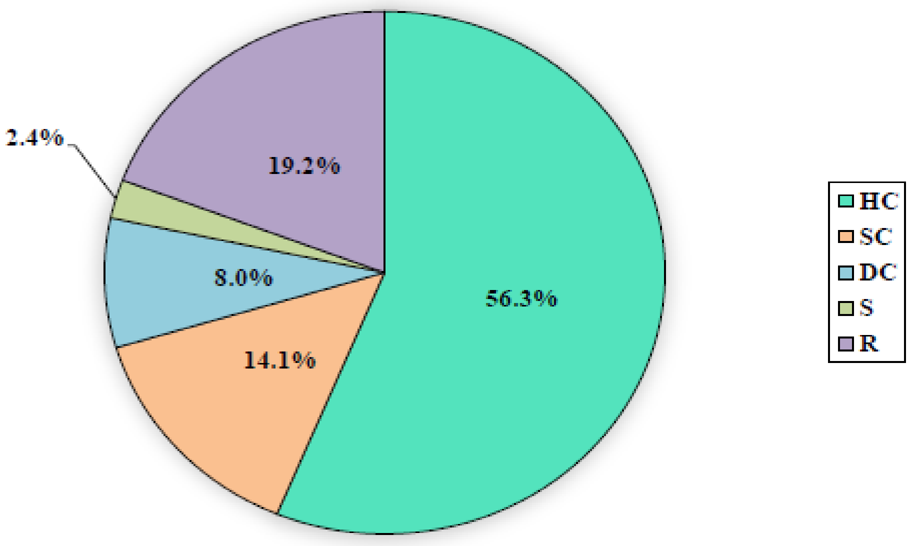

Fig. 2. Contribution of each main category in the benthic structure of substrate at Wadi El-Gemal National Park

HC = hard corals, SC = soft corals, DC = dead corals, S = sand and R = rocks

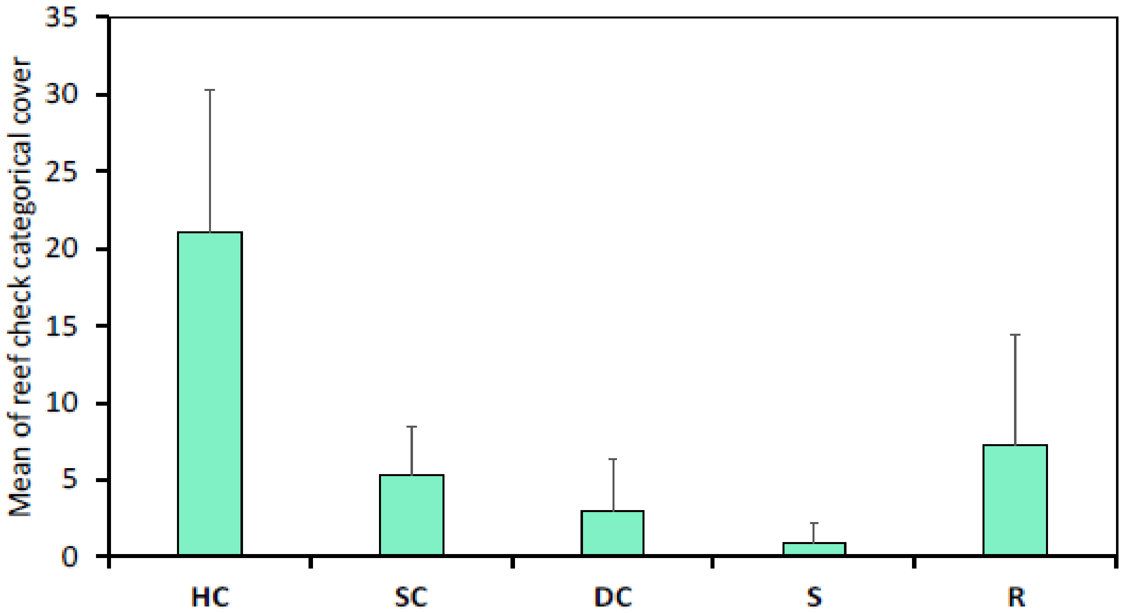

Fig. 3. Mean values of the reef check cover of the main benthic categories

HC = hard corals, SC = soft corals, DC = dead corals, S = sand and R = rocks

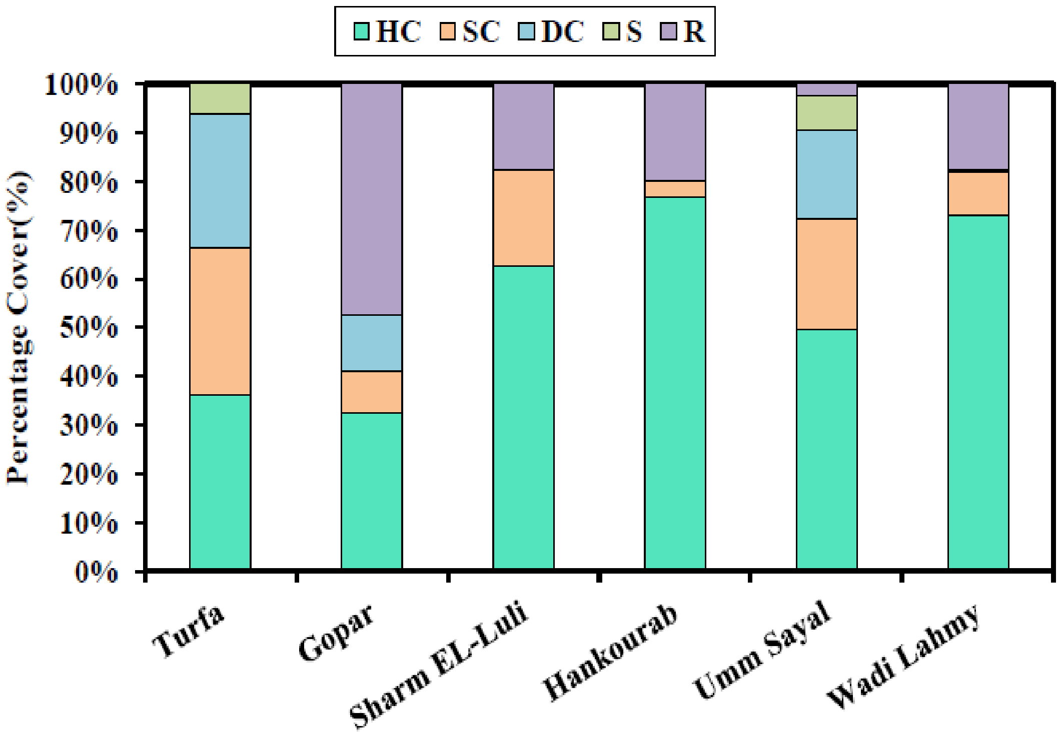

Fig. 4. Relative composition of the substrate at the study sites
HC = hard corals, SC = soft corals, DC = dead corals, S = sand and R = rocks

Table 2. Multiple comparisons (Post Hoc analysis) of the main benthic categories between the study sites

Site	Site	Mean difference	Std. error	Sig.
	Gopar	-6.75000-*	2.03750	.005
	Sharm EL-Luli	-17.75000-*	1.88635	.000
Turta	Hankourab	-23.50000-*	1.88635	.000
	Umm Sayal	-13.25000-*	2.31030	.000
	Wadi Lahmy	-22.00000-*	1.88635	.000
	Sharm EL-Luli	-11.00000-*	2.03750	.000
Bogan	Hankourab	-16.75000-"	2.03750	.000
	Umm Sayal	-6.50000-*	2.43527	.O18
	Wadi Lahmy	-15.25000-*	2.03750	.000
	Hankourab	-5.75000-*	1.88635	.008
Sharm EL-Luli	Umm Sayal	4.50000	2.31030	.070
	Wadi Lahmy	-4.25000-*	1.88635	.040
	Umm Sayal	10.25000*	2.31030	.000
Hankourab	Wadi Lahmy	1.50000	1.88635	.439
Umm Sayal	Wadi Lahmy	-8.75000-*	2.31030	.002

3.2 Benthic Invertebrates

In general, along a 20 m point transect, only 6 invertebrate groups were recorded at the study sites. Among these, banded coral shrimp, sea urchin, sea cucumber, and *Drupella* contributed to the invertebrate community with different percentages. Invertebrate taxa showed a high percentage of giant clams with 64% compared to other categories (Fig. 5). In contrast, the crown of thorn represented the lowest percentage of occurrence (4%) of the main invertebrate community.

Among the study sites, invertebrate taxa showed a high mean abundance at Hankourab. Giant clam, however, at this site displayed the highest number of individuals (29.6 individuals per 20 m belt transect). In contrast, Umm Sayal and Wadi Lahmy had the lowest biodiversity where giant clams were only recorded with an abundance of 16 and 22.25, respectively (Fig. 6). Although Turfa had the lowest abundance, there were three groups of benthic invertebrates. It is noteworthy to mention that the giant clam was the most dominant category at all study sites. On the other hand, the crown of thorn was only recorded at Sharm El-Luli with an abundance of 2 individuals along the studied transect.

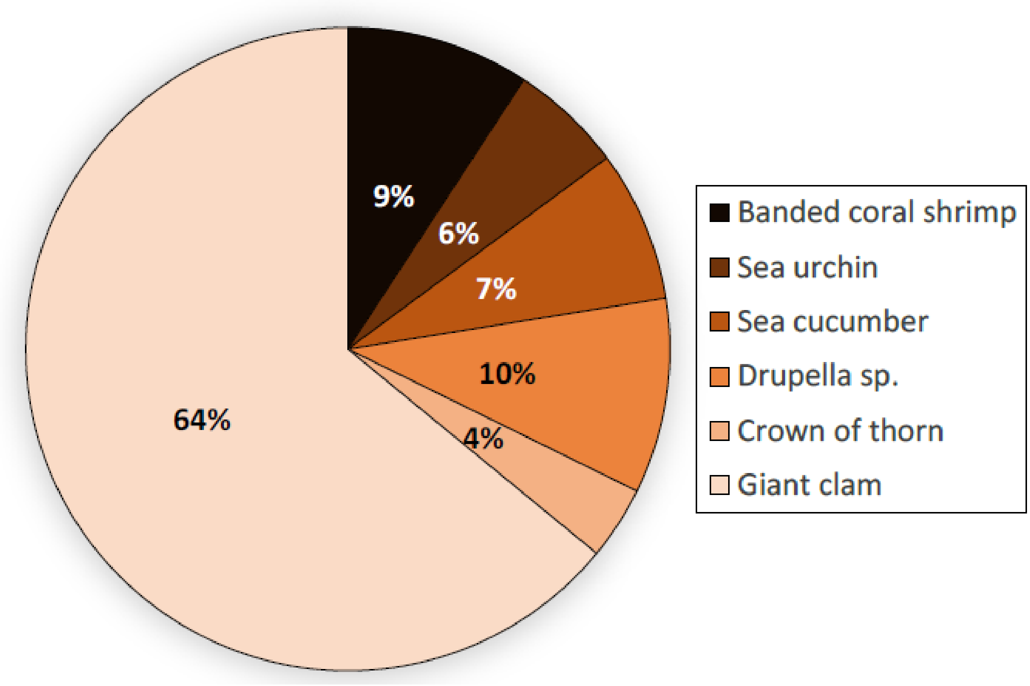

Fig. 5. Percentage of benthic invertebrates at Wadi El-Gemal National Park

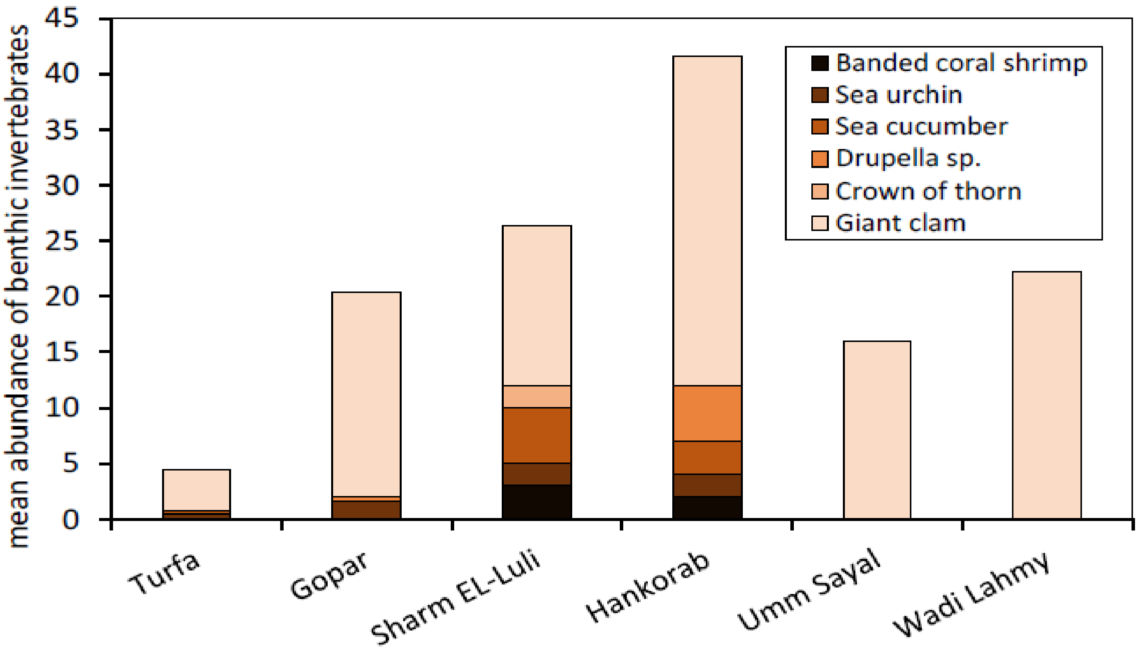

Fig. 6. Mean relative abundance of benthic invertebrates (individuals/20 m) at different study sites

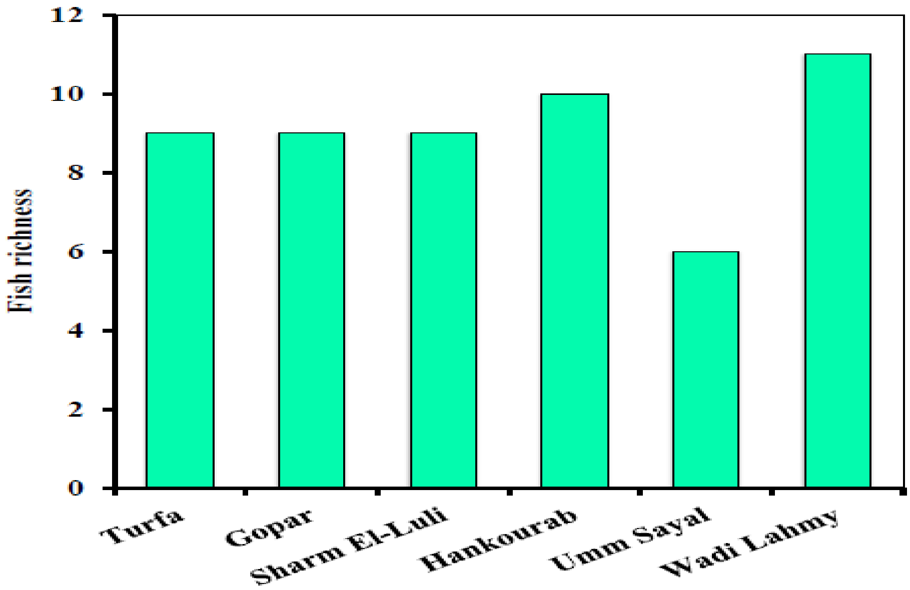

Fig. 7. Reef fish richness at the study sites

3.3 Reef Fishes

Our survey at the study sites showed that all sites have different reef fish richness (Fig. 7). At Wadi Lahmy and Umm Sayal, fish richness was represented by the maximum and a minimum number of species. Among the study sites, fish taxa showed a high abundance of reef fishes at Wadi Lahmy. Acanthuraidae (Surgeon Fish; Key herbivorous species), however, in this site displayed the highest number of individuals (53.25 individuals per 20 m belt transect). In contrast, Gopar and Turfa have the lowest biodiversity where Acanthuraidae was only recorded with an abundance of nearly 2 and 7 fish per the studied transect, respectively (Fig. 8). Although Gopar has the lowest abundance, there were nine groups of benthic fishes. It is noteworthy to mention that the Acanthuraidae was the most dominant family at the four study sites. On the other hand, Siganidae (Rabbit Fish) was only recorded at Hankourab and Wadi Lahmy with an abundance of 6 and 9.25 individuals along the studied transect. In general, along 20 m point transects, the highest abundance of reef fishes was recorded at Wadi Lahmy and Hankourab. On the other hand, the lowest abundance of reef fishes was recorded at Gopar and Turfa (Fig. 9). The average of Acanthuraidae along 20 m point transect was 19.58 individuals, which is the highest fish category, while the other benthic categories showed fish abundance lower than 10 individual/transect (Fig.10). Table 3 showed the multiple comparison of significance (Post Hoc Analysis) between different groups of fishes at the study sites.

3.4 Damage Indication Categories

Among the 8 impact indicators of reef damage (old dead, recently dead, total bleached, partial bleached, diseased, broken, fragments, and recruitments of corals), the old dead corals showed the highest cover of the substrate. This category was identified from all study sites. However, Wadi Lahmy was characterized by a high cover of old dead corals compared with the other sites (Fig. 11). The other damage indication categories (i.e., recently dead, partially bleached, broken, fragments, and recruitments) were similar in the benthic cover. These categories, however, were found with different coverage at the study sites. For example, the cover of partially bleached corals was found at Hankourab relative to other sites. On the other side, the bleached coral colonies were lower than the previously mentioned categories at the study sites. Similarly, the cover of the diseased colonies was lower than other categories in the area of the study where this category was only recorded at Wadi Lahmy and Gopar. Concerning coral recruitment, small colonies of coral were recorded at all study sites with different coverage (Fig. 12). However, Sharm El-Luli showed the highest cover of coral recruitment of different size frequencies followed by Wadi Lahmy. Also, the survey data showed that Turfa, Hankourab, and Gopar had the lowest coverage of coral recruitments. At Gopar, Turfa, and Wadi Lahmy, all the 8 damage categories were found with different percentages and represented by the same percentages, while at Wadi Lahmy, old dead corals contributed 44% of the structure of the reef substrate (Fig. 13).

The diseased corals were rare in the remaining three sites.

3.5 Coral Cover and Fish Abundance Relationship

The current study indicated that increasing the hard coral cover in the study area had strongly affected the abundance of reef fishes (Fig. 14). The abundance of reef fishes increase with the increase of the hard coral cover ($P < 0.05$, rs=0.8; Fig. 15), and this trend was attained by all reef fish families (Fig. 16).

4. DISCUSSION

Wadi El-Gemal National Park (WGNP) is among the largest marine protected areas in the Red Sea. It provides unprecedented opportunities to study the intact subtropical reef ecosystems.

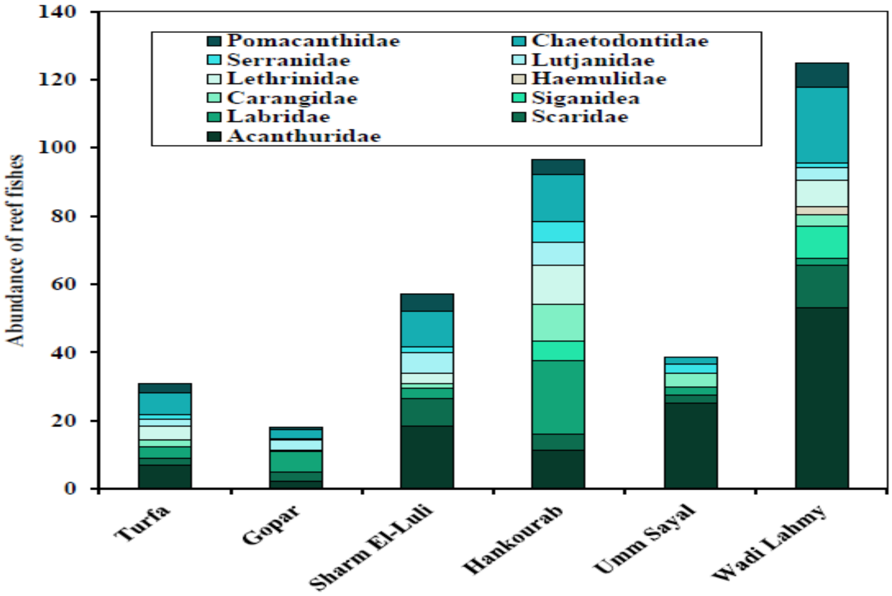

Fig. 8. Relative abundance of reef fishes (individuals/20 m) at the study sites

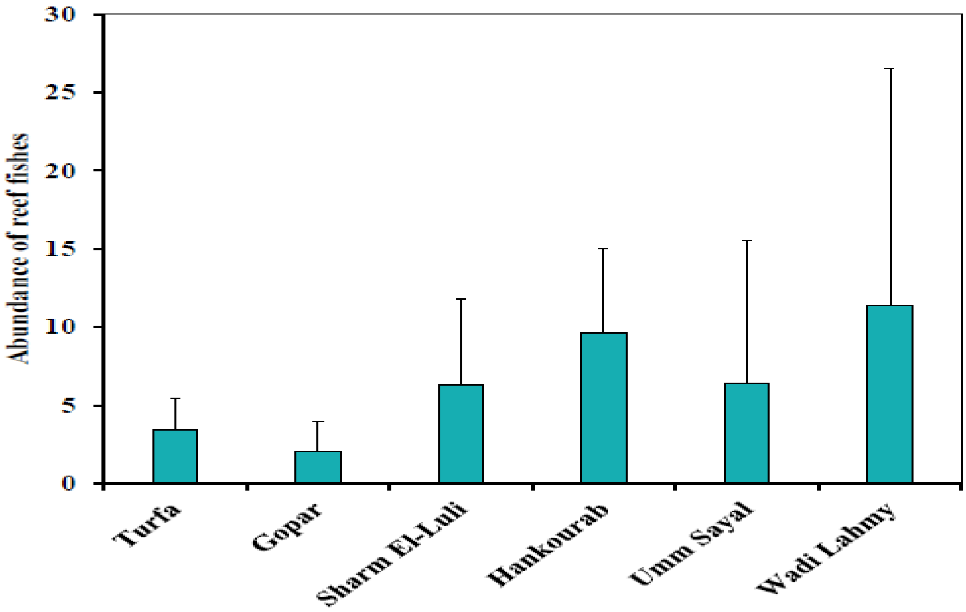

Fig. 9. Mean abundance of reef fishes (number of fishes per 20 m transect ±SE) at different study sites

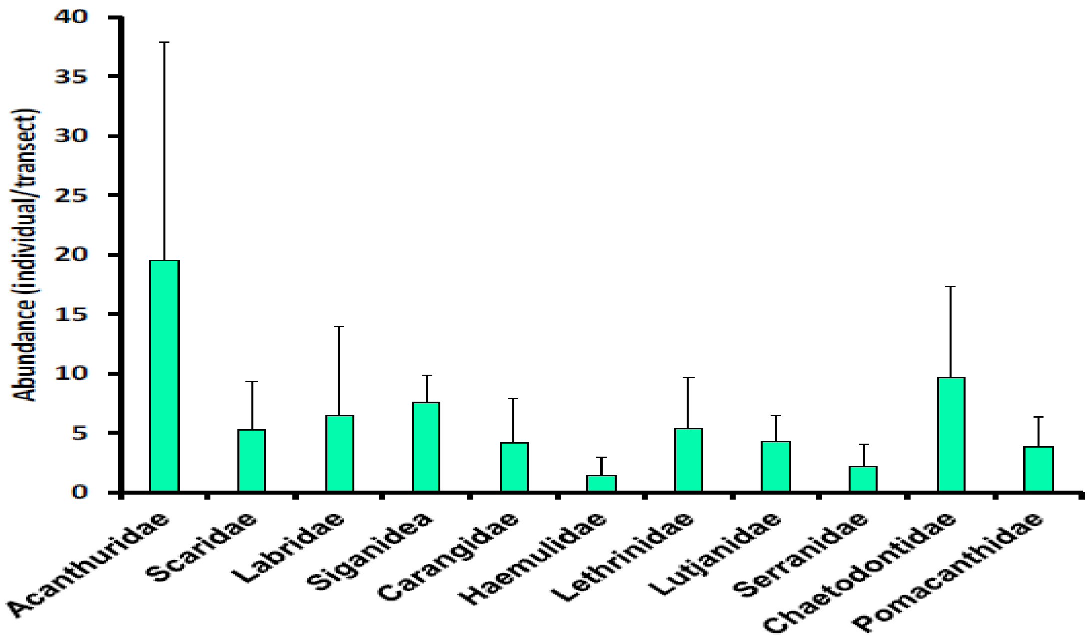

Fig. 10. Overall mean abundance (±SE) of reef fishes (number of fishes per 20m transect) at all the study sites

Table 3. Multiple comparisons (Post Hoc analysis) of fish groups at the study sites

Fish group		Mean difference	Std. error	Sig.
	Parrot	.50189*	.11147	.000
	Wrasses	.43603*	.11285	.000
	Rabbit	.40069*	.15007	.008
	Jacks	.55101*	. 12462	.000
Suxeenm fish	Sweet Lips	.72577*	.19705	.000
	Emperors	.41263	.12211	.001
	Snappers	.49326*	.11986	.000
	Groupers	.76427*	.12211	.000
	Butterfly	.16783	.11285	.139
	Angel	.48115*	.11986	.000
	Wrasses	-.06586	.11285	.560
	Rabbit	-.10120	.15007	.501
	Jacks	.04912	. 12462	.694
	Sweet Lips	.22388	.19705	.258
Parrot fish	Emperors	-.08926	.12211	.466
	Snappers	-.00863	.11986	.943
	Groupers	.26238*	.12211	.033
	Butterfly	-.33406-*	.11285	.004
	Angel	-.02074	.11986	.863
	Rabbit Fish	-.03533	.15110	.815
	Jacks	.11498	.12586	.362
	Sweet Lips	.28974	.19784	.145
	Emperors	-.02339	.12337	.850
Wrasses	Snappers	.05723	.12115	.637
	Groupers	.32824*	.12337	.009
	Butterfly	-.26820*	.11422	.020
	Angel	.04513	.12115	.710
	Jacks	.15032	. 16008	.349
	Sweet Lips	.32508	.22119	.144

Fish group		Mean difference	Std. error	Sig.
	Emperors	.01194	.15813	.940
Rabbit Fish	Snappers	.09257	.15640	.555
	Groupers	.36357*	-15313	.023
	Butterfly	-.23286	.15110	.125
	Angel	.08046	.15640	.608
	Sweet Lips	.17476	20478	.305
	Emperors	-.13838	.13422	.304
Jacks	Sues	-.05775	.13218	.663
	Groupers	.21326	.13422	.114
	Butterfly	-.38318-*	12586	.003
	Angel	-.06986	13218	.598
	Emperors	-.31314	.20326	.125
	Snappers	-.23251	20191	.251
Sweet Lips |	Groupers	.03850	20326	.850
	Butterfly	-.55794-*	19784	.005
	Angel	-.24462	20191	.228
	Snappers	08063	12981	.535
ee	Groupers	.35164	.13189	.008
	Butterfly	-.24480-*	12337	.049
	Angel	-06852	12981	.598
	Groupers	.27101*	12981	.038
Snappers	Butterfly	-.32543-*	AZS	.008
	Angel	-.01211	12770	.92525
Groupers	Butterfly	-.59644-*	.12337	.000
	Angel	-.28312-*	12981	.031
Butterfly	Angel	.31332*	.12115	.011

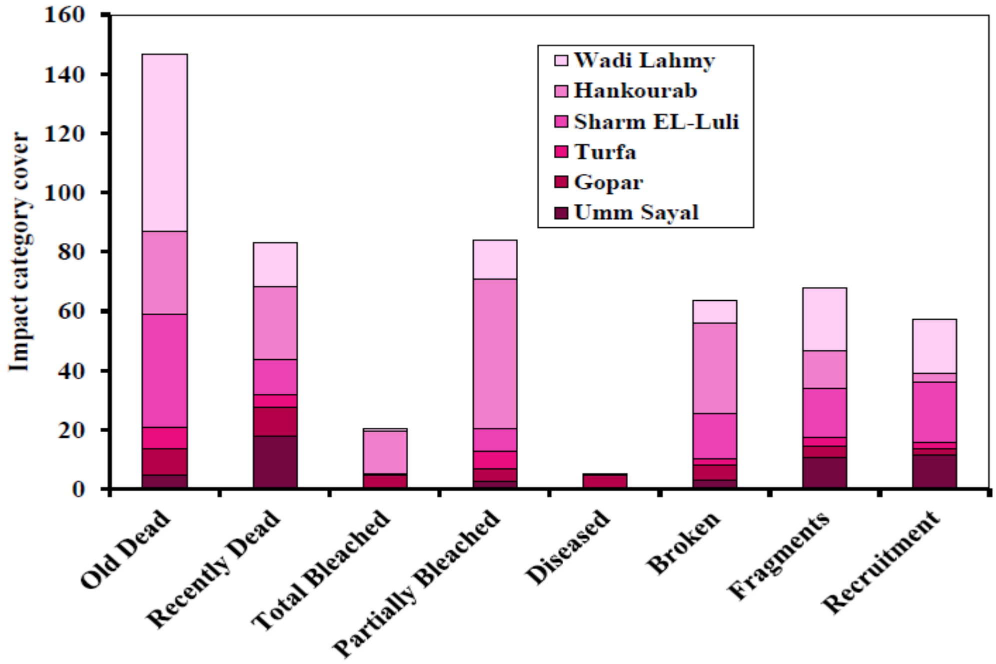

Fig. 11. Mean cover of damage indication categories per 20 m point transect

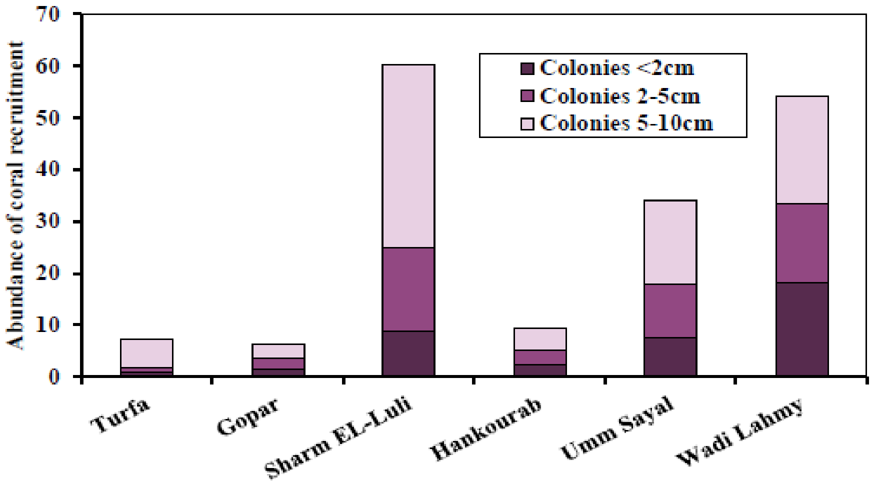

Fig. 12. Mean abundance of coral recruitments of three size categories (individuals/20 m)

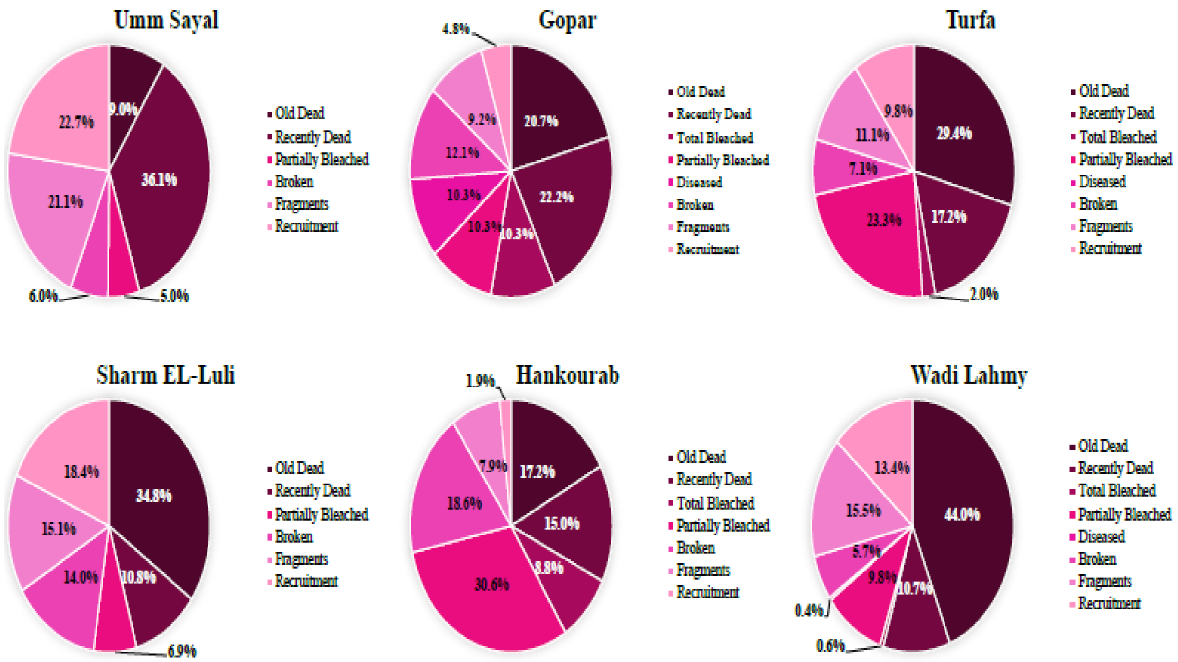

Fig. 13. Contribution of damage indication categories (%) at each study site

The percentage of hard coral cover is a representative metric to characterize available habitats on a coral reef [44]. Many studies have found a positive relationship between the community composition and structure of marine organisms and the percentage of live hard coral cover [45-47]. Hard coral cover has been shown to mediate high biodiversity on coral reefs around the world, with regional losses of live hard coral cover, resulting in sharp declines in structural complexity, hard coral diversity, and diversity of associated marine organisms [46, 48, 49].

Line-Point Intercept (LPI) method was investigated by CRED [50] for determining species-level percent coverage of benthic organisms [51], to test the degree of benthic heterogeneity that exists across the sites sampled. The results of the current study indicated that WGNP's benthic cover was dominated by live hard coral. This result is in coincidence with Ammar and Mahmoud [52]. The lower recorded amount of dead corals at Sharm El Luli though it was highly affected by fishing boats since these boats anchored on the Sharm terminal, away from the reef, and had gone to open water through the middle of the Sharm.

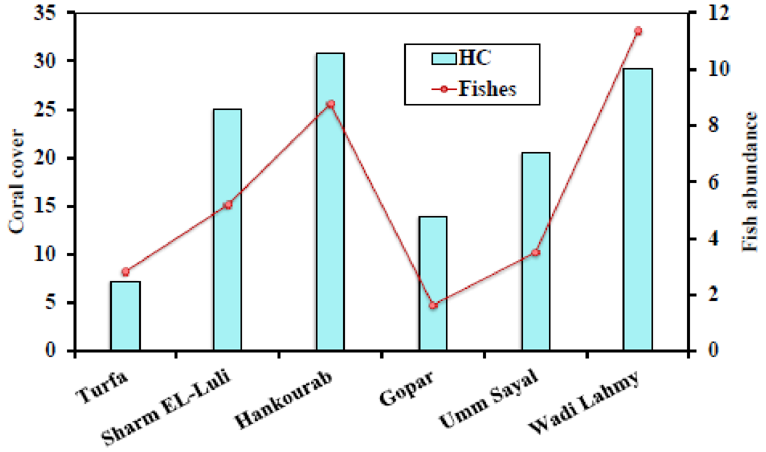

Fig. 14. General trend (mean values) of coral cover (%) and fish abundance (individuals/20 m) at Wadi El- Gemal National Park

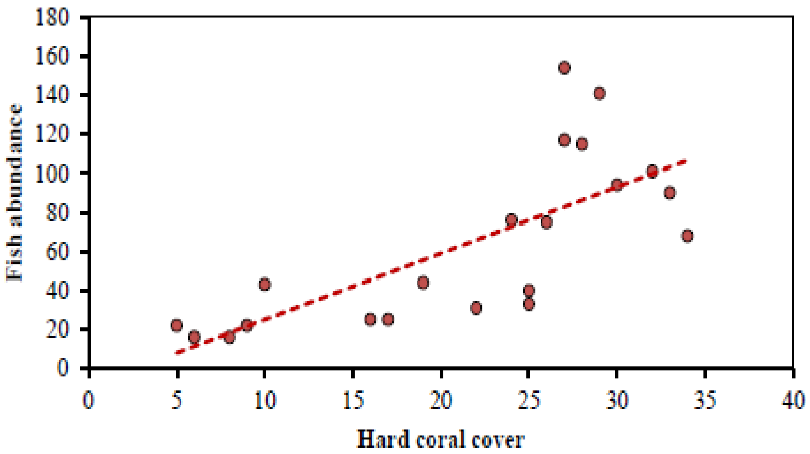

Fig. 15. Correlation of coral cover (%) and fish abundance (individuals/20 m)

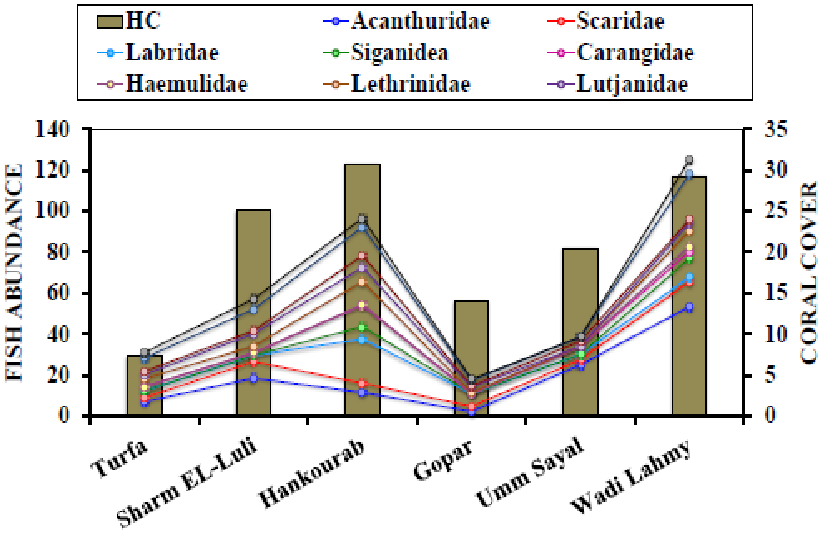

Fig. 16. Relationship between the benthic cover of hard coral (%) and reef fish families (individuals/20 m)

The current study revealed that although there was no significant difference between the study sites in the benthic cover of the main benthic categories, there was a significant difference in the hard coral cover. This may be due to the narrow geographic range that had been surveyed. However, the growth of coral reefs was related to the environmental conditions of water transparency and sedimentation rates that differed at these locations. The study also revealed that the study sites were dominated by giant clams and the natural predators of corals such as the crown of thorn are rare or absent. This observation indicated that coral reefs at WGNP had little impact by the biological threats.

The floods from the Valley of Wadi El-Gemal may not have a direct effect on the reef fish community but they affect their home and substrate; coral reefs and seagrasses. The fish community near the mouth of the valley had been greatly affected due to the damage caused to the reef as a result of the decreased salinity. The diversity of reef fishes increased significantly as they moved away from the mouth of the valley [40]. Floods in Wadi El-Gemal bring not only freshwater that decreases the salinity but also bring heavy metals that accumulate in the sediments and corals and inhibit coral growth [28, 53]. Madkour et al. [53] found that the concentrations of some metals in the sediments and coral reefs around the studied areas were higher than those caused by the anthropogenic activities at the Egyptian Red Sea coast.

5. CONCLUSIONS

The present study revealed that the status of the reef fishes (fish cover and abundance) in WGNP was related to and directly proportional to the live coral cover in the study area. Accordingly, the study addressed the role of benthic cover in the abundance of reef fishes. Concerning damage indication categories, field observations indicated that all damage categories have the same level except that of the old dead corals and the diseased colonies. The study indicated that these categories existed at different study sites with different levels. Among them, the old dead corals have the highest benthic cover and the diseased colonies were the lowest. Conclusively, the current study provided an assessment of coral reefs at WGNP. In addition, the study was the first of its kind to address the role of benthic categories, especially, hard corals in the abundance of reef fishes at the Red Sea coast of Egypt.

HUMAN AND ANIMAL RIGHTS

No humans were used in the study. All the reported experiments on animals were in accordance with the Committee for the update of the Guide for the Care and Use of Laboratory Animals.

ETHICAL APPROVAL

As per international standard, written ethical permission has been collected from the Animal Care and Used Committee of Egypt and preserved by the author(s).

COMPETING INTERESTS

The authors declared that there is no conflict of interests regarding the publication of this paper.

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