Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 25(5): 901 – 918 (2021)
www.ejabf.journals.ekb.eg

Distribution, abundance and diversity of reef fishes in waters of some cities along the northern Egyptian Red Sea coast, Egypt

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ARTICLE INFO
Article History:
Received: Nov. 25, 2021
Accepted: Nov. 30, 2021
Online: Dec. 6, 2021

Keywords:
Reef Fishes,
Red Sea,
Abundance,
Diversity,
Seasonal variation

ABSTRACT

The Egyptian Red Sea coast is characterized by the presence of a few human densities distributed over large areas, aligned with an integrated marine system, whether human or industrial. all of which have a great impact on it. The coast is also affected by the presence of ports, tourism, and commercial fishing activities. Hence, the effect of those factors on coral reef fish's distribution, abundance, and diversity were subjected to a profound study addressing some megacities along the northern Egyptian Red Sea coast (Ras Gharib, Hurgada, Safaga, and El-Qusier), where three stations in each city were surveyed. Adult fishes were counted by visual censuses. A total of 16179 individuals of reef fish species were counted, representing 93 reef fish species, belonging to 26 families. The highest fish abundance was recorded in north Hurgada (HN) with 4432 fishes. The lowest fish abundance was found in middle Hurgada (HM), where only 292 individuals were recorded. The highest diversity (54 species) was recorded in HN, while the lowest (18 species) was detected in HM. Results showed that fishes were most abundant during winter; HN had the highest number of fishes during all seasons, while HM had the lowest number of fishes during spring, summer, and autumn. In addition, HN recorded the highest diversity (53 species) during spring and north Safaga recorded the lowest diversity (only 5 species) during winter. Fishes of family Mullidae were more abundant during winter and labrid fishes were dominant during rest seasons. Labridae and Chaetodontidae were the most diverse families during all seasons of the year.

INTRODUCTION

Marine fish stocks are essential in the world food system and are particularly important for many of the poorest people in the globe **(Hilborn *et al*., 2020)**. The impact of the on the Egyptian economy is enormous, including increased income, diversification of livelihoods, supply of animal protein, and foreign exchange earnings. In marine ecosystem, fish are among the key organisms that represent high taxonomic and functional diversity. They are important components of the aquatic food web with respect to all levels of consumers, from primary consumers to top predators, as well as decomposers **(Wootton, 1998**; **Specziár & Erős, 2020)**.

In Egypt, fish are produced in the Nile River, lakes, the Mediterranean Sea and the Red Sea. A total of 1078 fish species are known to inhabit in the Red Sea **(Golani & Bogorodesky, 2010)**. This number has been increased by recording the slender sunfish last summer in Hurgada **(Abu El-Regal & Elmoselhy, 2013**; **Abu El-Regal, 2014)**. Nearly half of these species are associated with coral reefs **(Bellwood & Waineright, 2002)**.

The biotic integrity of most of the corals located in populated areas **(EEA, 2012** and **Poikane *et al*., 2017)**, is subjected to multiple anthropogenic pressures, such as degradation of littoral habitats, pollution, eutrophication and fishing including stocking **(Bíró, 1997; Istvánovics *et al*., 2007; Specziár, 2010)**.

Moreover, beside coral reef habitats, the shelf has different prevailing marine habitats, such as sheltered shallow lagoons, seagrass, open deep-water habitats and mangroves. Thus, it is distinct amongst the most appealing resorts in Egypt. The territory suffers from several human activities influenced by ecological changes **(Hilmi *et al*., 2012)**. Among the different habitats and ecosystems, an enormous number of species are associated with a single and/or multiple habitats **(Abo-Taleb *et al*., 2018)**.

The Red Sea is a unique water, hosting some of the most productive and diverse coral reefs. Human populations living along the Red Sea coasts were initially sparse due to the hot and arid climate, but this has changed due to he presence of some life facilities, including improved desalination techniques, accessible energy, and increased economic interest in coastal areas **(Fine *et al*., 2019)**. Problem management includes overcrowding of tourist boats, the effect of coastal urban, industrial and ports on coral reef communities along the mega sites of the Red Sea as it is the key element affecting a sustainable development in Egypt **(Al-Hammady & Mahmoud, 2013)**.

Coral reefs are one of the world's most diverse ecosystems, with fish as an essential component. Losing live corals can have severe impacts on the diversity and stability of this ecosystem **(Bellwood *et al*., 2006; Munday *et al*., 2008; Pratchett *et al*., 2008, 2011; Triki & Bshary, 2019)**. Subsequently, it is expected that habitat loss would lead to a decline in fish abundance **(Pratchett *et al*., 2011**; **Brandl *et al*., 2016)**.

The anthropogenic damage is mainly associated with urbanization and coastal development **(Wielgus *et al*. 2004**; **Ammar, 2011)**. As a result of natural and human activities, coral reefs have wordly witnessed degradation at disturbing rates and a decline in the calcification rate **(Spalding & Brown, 2015**; **Lizcano-Sandoval *et al*. 2018)**. These activities are requirements for the development of cities and life.

Understanding how environmental factors shape the diversity of biotic assemblages has always been a critical issue in ecology and an important prerequisite for successful biodiversity conservation **(Caley & Schluter, 1997; Gaston, 2000; Bellwood & Hugues, 2001**; **Fischer & Lindenmayer, 2006)**.

This study offers an interesting comparison between four cities, with three sites each **(Stokes *et al*., 2019)**. This work was carried out in the aim of exploring the assemblage of fish in the coastal reef on the Egyptian Red Sea coast, and addessing the different effects of human activities at different sites on fish communities along the Red Sea. Moreover, it focused on setting the possible scientific solutions to manage the fisheries in the Red Sea. A growing theory has been adopted among scientists is that marine conservation may be 10% biology and 90% management of people **(Nichols, 2003)**.

In addition, almost no assessments has been conducted on the status of fisheries **(Deines *et al*., 2017).** Relatively, few studies have been documented with regard to small-scale fisheries **(Chuenpagdee *et al*., 2011)** in coral reef, which are vital for some of the poorest people in the world. Poor or even unmanaged data have been found concerning recreational fisheries **(Arlinghaus *et al*., 2019)**. Understanding the status and the management of those fisheries should receieve a high priority concern.

To assess the biological integrity and the quality of a certain habitat,researchers can evaluate fish assemblages, diversity and abundance **(Karr, 1981**; **Ganasan & Hughes, 1998)**.

Fish assemblages respond sensitively to environmental changes, and thus, qualitative and quantitative properties of their assemblages can be effectively used as indicators of the environmental degradation **(Karr, 1981; Poikane *et al*., 2017**; **Specziár & Erős, 2020)**.

Several studies, for instance, showed that fish abundance could negatively be affected by environmental disturbances due to climate change, either directly through abiotic factors, such as temperature and ocean acidification **(Ferrari *et al*., 2011**; **Browman, 2016)**, or indirectly through habitat loss **(Munday *et al*., 2008)**. Thus, changes in fish abundance should provide reliable information on habitat quality.

The interaction between different species, combined with the limnological and physical properties of aquatic ecosystem, may influence the diversity and distribution of fish fauna **(Torres da Silva *et al*., 2013**; **Aryani *et al*., 2020)**.

The Egyptian Red Sea coast is characterized by the presence of a few human densities distributed over large areas, but at the same time, and it witnesses an integrated marine system, which is exposed to many impacts, whether human or industrial, in addition to the presence of ports, tourism and commercial fishing activities. Thus, the present work aimed to study the effect of these different human activities on coral reef fish's distribution, abundance and diversity in some mega cities along the northern Egyptian Red Sea coast.

MATERIALS AND METHODS

1. Study area

This study was conducted to estimate names and numbers of coral reef fishes in four cities; namely, Ras Ghareb, Hurgada, Safaga, and El-Ouisier in the southern Red Sea (Fig. 1). Three sites in each city (north, midtown and south) were selected to count and estimate coral reef fishes.

1.1. Ras Gharib City: Three stations were selected at Ras-Gharib City (Table 1). The first is located at General petroleum Company (Northern Ras-Gharib, **RN**). Second is at Ras-Gharib Cornash (Middle Ras-Gharib, **RM**) and the third is located at the Old Marina (Southern Ras-Gharib, **RS**).

1.2. Hurgada City: Three stations were selected at Hurgada City (Table 1). The 1st station is at the Middle reef, which is located directly in front of the National Institute of Oceanography and Fisheries (NIOF), Hurgada branch (Northern Hurgada, **HN**). It is the middle reef situated in the area that has been subjected to land filling associated with high sedimentation rate. The 2nd station is the Shipyard Harbor at Al-Mina, and this station is impacted by sewage discharge and antifouling from vessels repair (Middle Hurgada, **HM**). The 3rd station is Al-Hadaba; located southern Al-Sakala. It was affected by tourism activities (Southern Hurgada, **HS**).

1.3. Safaga City: Three stations were selected at Safaga City (Table 1). The first is located at touristic Harbor (Northern Safaga, **SN**). It suffers from navigation and touristic impacts. The second is at Abo-tartor Harbour, it is impacted by heavy load of phosphate (Middle Safaga, **SM**) and the third is at Mangrove area (Southern Safaga, **SS**).

1.4. Al-Quseir City: Three stations were selected at Al- Qusier City (Table 1). The 1st station is located at Radisson Resort forming a diving site (Northern Al- Qusier, **QN**). The 2nd station is at Al- Qusier Old Harbor (Middle Al- Qusier, **QM**) and the 3rd station is at a pristine area (Southern Al- Qusier, **QS**).

2. Counting adult fishes

Underwater visual fish census methods were used following the instructions of **Wismer *et al*. (2014)** and **Triki *et al*. (2018)**. Within each location, the observer swam three replicates of a 100 m transect line on the reef edge during the period from December 2018 to November 2020. Fish species were then categorized into functional groups based on the species' trophic level **(Butterfield & Suding, 2013**; **Brandl *et al*., 2016)**. Identification was confirmed with different guidelines **(Randall, 1983; Debelius, 1998**; **Lieske & Myers, 2001)**.

Table 1. Investigated sites, coordinate positions and type of impacts of the surveyed stations along the Red Sea coast

Site	Station	Coordinate positions		Type of Impact
		Latitude	Longitude	
Ras-Gharib	**1-North Ras Gharib (RN)**	28°22'0.26"N	33° 4'53.99"E	Oil pollution
	2- Middle Ras Gharib (RM)	28°21'44.62"N	33° 5'47.97"E	Oil pollution
	3- South Ras Gharib (RS)	28°20'55.08"N	33° 6'42.56"E	Oil pollution and fishing activities
Hurgada	**4- North Hurgada (HN)**	27°17'6.39"N	33°46'28.93"E	Only landfilling
	5- Middle Hurgada (HM)	27°13'47.13"N	33°50'38.66"E	Chemicals leaking and antifouling from vessels repairing
	6- South Hurgada (HS)	27°12'5.71"N	33°51'4.17"E	Coastal development
Safaga	**7- North Safaga (SN)**	26°46'0.31	33°46'28.93"E	Navigation and touristic impacts
	8- Middle Safaga (SM)	26°41'0.06"N	33°56'7.08"E	impacted by heavy load of phosphate
	9- South Safaga (SS)	26°37'1.44"N	34° 0'37.37"E	Pristine station
Al-Qusier	**10- North Qusier (QN)**	26°8'54.55"N"	34°15'37.02"E	Diving Site - Pristine station
	11 – Middle Qusier (QM)	26° 6'9.16"N	34°17'10.01"E	Navigation and fishing activities
	12- South Qusier (QS)	26° 4'58.24"N	34°17'54.34"E	Pristine station

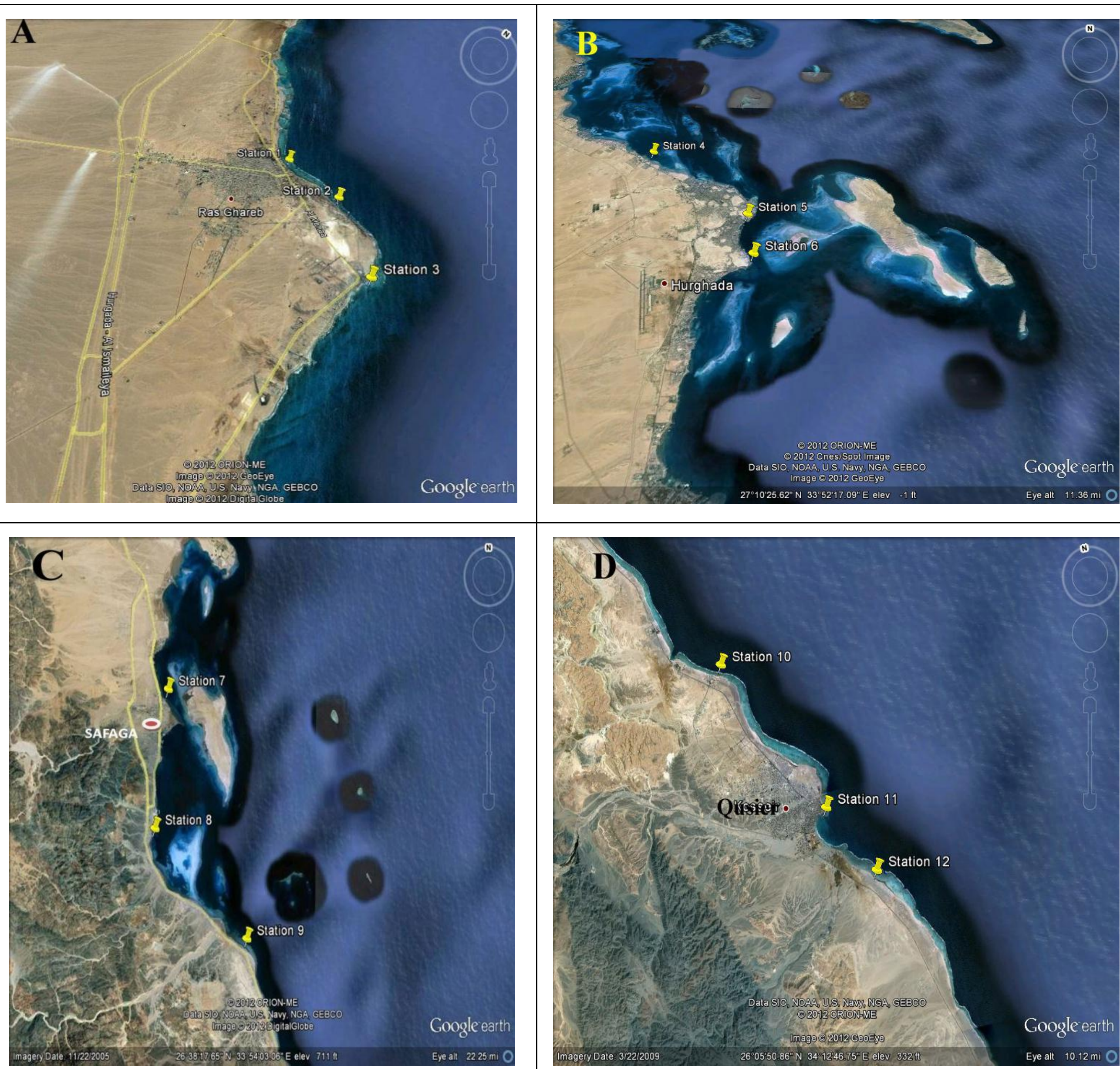

Fig. 1. Photographs of google maps for different study sites and their stations A) Ras Gharib and its stations: 1: north, 2: middle, 3: south; B) Hurgada and its stations: 4: north, 5: middle, 6: south; C) Safaga and its stations: 7: north, 8: middle, 9: south; D) Al-Qusier and its stations: 10: north, 11: middle, 12: south

4. Data Analysis

The main effects and interactions were examined using ANOVA (the corresponding multivariate tests had high power). Analysis of variance (ANOVA) applied using Holm-sidak method to refuse the null hypnosis and confirm the presence of significant variance between different levels of factors. The probabilities of Epsilon corrected F values (Greenhouse-Geisser Epsilon) were calculated to compensate for deviations from univariate assumptions. The analysis becomes available using SigmaPlot V12.5 software.

RESULTS

1. Whole abundance and diversity of Red Sea reef fishes

The visual censuses of the adult fish, in all studied stations during the period of study, recorded 16179 fish belonging to 93 reef fish species representing 26 families. From these 26 families, only 10 families were the most abundant and recorded 15238 fish individuals representing 94.18% of the total number of recorded fishes. Family Acanthuridae had the highest abundance (3387 fish) during the period of study, followed by Mullidae (2610 fish), Labridae (2587 fish), Siganidae (1559 fish), Atherinidae (1476 fish) and Pomacentridae with 1287 fish (Table 2 & Fig. 2).

The more diverse family was Labridae containing 16 species, followed by Chaetodontidae and Scaridae with 10 and 9 species, respectively, then Acanthuridae and Pomacentridae with 7 species for each, and Holocentridae, Mullidae and Serranidae were represented by 5 species for each. There were three recorded families represented by 3 species; five families represented by 2 species and ten families represented by only one species (Table 2).

Results also showed that, from the recorded 93 reef fish species, only 10 species were the mostly abundant fishes in the coral reef of the studied areas. They recorded 8992 fish individuals representing 55.6% of the recorded fishes. *Siganus revulatus* (Family: Siganidae) was the most abundant fish recording 1443 individuals; followed by *Thalassoma ruppellei* and *Acanthurus sohal*, having 1142 and 1133 fish, respectively; then *Mulloides vanicolensis* with 1032 fish (Table 3 & Fig. 3).

2. Whole regional variation in abundance and diversity of Red Sea reef fishes

During the total period of study, the highest number of fishes was recorded in north of Hurgada (HN), with 4432 individuals (belonging to 54 reef fish species representing to 19 families), followed by the north of El- Qusier (QN) with 2046 fishes (belonging to 40 species representing 14 families) and south of El- Qusier (QS) with 1515 individuals (belonging to 44 species representing 15 families). The lowest number of fishes was recorded in the middle of Hurgada (HM), where only 292 individuals were recorded; followed by both of south of Hurgada (HS) and middle of Ras Gharib with 556 individuals for each (Table 2).

The present results revealed that, Atherinidae had the highest abundance in north Hurgada (HN) with 1476 individuals; followed by Acanthuridae in both of south of El- Qusier (QS) and north of El- Qusier (QN) with 931 and 875 individuals, respectively. The highest abundant fish species were *Hypoatherina temminckii* (763 fish) and *Atherinomorus lacunosus* (713 fish) that belong to Acanthuridae. The second abundant species was *Parupeneus forsskali* (408 fish) from family Mullidae (Table 2).

Additionally, the north of Hurgada (HN) had the highest diversity (54 species of 19 families); followed by both of south Safaga (SS) and south of El- Qusier (QN) with 44 species representing 18 and 15 families, respectively. The lowest diversity was also recorded in the middle of Hurgada by 18 species of 10 families; followed by south Ras Gharib (RS), which had 24 species representing 11 families (Table 2).

With respect to different stations, south of El- Qusier (QN) recorded the highest diversity with 10 species from family Labridae; followed by the north of Ras Gharib (RN) and south Hurgada (HS) with 9 fish species from the same family. In addition, middle of El- Qusier (QN) and north Hurgada (HN) recorded 9 species (Table 2).

Table 2. Abundance of different fish species in different sites of the Egyptian Red Sea Coast during the study period

Family	Scientific name	QS	QM	QN	SS	SM	SN	HS	HM	HN	RS	RM	RN	Total
Acanthuridae	*Acanthurus nigrofuscus*	308	34	112	20	38	0	28	8	102	0	0	0	**650**
	Acanthurus sohal	248	58	370	18	35	0	76	0	170	66	39	53	**1133**
	Ctenochaetus striatus	145	72	130	7	14	0	60	18	169	50	40	23	**728**
	Naso elegans	66	46	96	0	0	0	0	0	0	0	0	0	**208**
	Naso unicornis	56	16	19	0	0	0	6	0	6	0	0	0	**103**
	Zebrasoma desjardinii	59	19	48	0	0	0	19	0	135	10	7	0	**297**
	Zebrasoma xanthurum	49	82	100	0	0	0	4	0	23	0	10	0	**268**
	Total abundance	**931**	**327**	**875**	**45**	**87**	**0**	**193**	**26**	**605**	**126**	**96**	**76**	**3387**
	Total diversity	**7**	**7**	**7**	**2**	**3**	**0**	**6**	**2**	**6**	**3**	**4**	**2**	**7**
Mullidae	*Mulloides flavolineatus*	0	41	10	0	0	0	0	0	347	0	0	0	**398**
	Mulloides vanicolensis	0	22	0	290	359	218	51	92	0	0	0	0	**1032**
	Parupeneus forsskali	46	8	10	262	115	408	5	22	61	0	13	19	**969**
	Parupeneus cyclostomus	48	0	0	37	74	0	3	0	0	0	0	0	**162**
	Parupeneus macronema	0	14	0	8	0	15	0	0	12	0	0	0	**49**
	Total abundance	**94**	**85**	**20**	**597**	**548**	**641**	**59**	**114**	**420**	**0**	**13**	**19**	**2610**
	Total diversity	**2**	**4**	**2**	**4**	**3**	**3**	**3**	**2**	**3**	**0**	**1**	**1**	**5**
Labridae	*Chelinus fasciatus*	0	11	0	17	13	19	3	0	51	10	17	0	**141**
	Chelinus lunulatus	0	6	3	0	0	0	7	0	40	0	0	6	**62**
	Cheilio inermis	0	0	2	0	0	0	0	0	0	0	0	6	**8**
	Coris aygula	11	0	0	2	4	0	16	0	0	0	7	12	**52**
	Epibulus insidiator	17	0	0	0	0	0	10	0	0	0	0	0	**27**
	Halichores marginatus	0	0	0	4	7	0	0	0	0	7	3	9	**30**
	Halichores hortulans	12	0	11	5	9	0	11	6	27	0	0	4	**85**
	Halichoeres scapularis	9	9	6	27	18	35	0	0	0	0	0	0	**104**
	Gomphosus Coeruleus	19	0	16	0	0	0	11	0	19	37	22	29	**153**
	Larabicus quadrilineatus	13	0	26	0	0	0	3	7	0	99	77	51	**276**
	Thalassoma lunare	19	0	0	0	0	0	0	0	0	57	23	13	**112**
	Thalassoma ruppellei	63	52	66	80	136	24	55	11	384	93	50	128	**1142**
	Hemigymnus fasciatus	10	36	200	17	13	19	3	0	59	0	0	0	**357**
	Anampese caeruleopunctatus	0	11	0	4	7	0	0	0	0	0	0	0	**22**
	Chelinus undulatus	1	0	0	0	0	0	0	0	0	0	0	0	**1**
	Chelinus abudjubbe	0	0	0	0	0	0	0	0	15	0	0	0	**15**
	Total abundance	**174**	**125**	**330**	**156**	**207**	**97**	**119**	**24**	**595**	**303**	**199**	**258**	**2587**
	Total diversity	**10**	**5**	**8**	**7**	**8**	**4**	**9**	**3**	**7**	**6**	**7**	**9**	**16**
Siganidae	*Siganus rivulatus*	15	131	31	226	19	427	6	0	172	114	57	245	**1443**
	S. stellatus	0	52	52	2	6	2	0	0	0	0	0	0	**114**
	S. luridus	0	0	0	0	0	0	2	0	0	0	0	0	**2**
	Total abundance	**15**	**183**	**83**	**228**	**25**	**429**	**8**	**0**	**172**	**114**	**57**	**245**	**1559**
	Total diversity	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**0**	**1**	**1**	**1**	**1**	**3**
Atherinidae	Atherinomorus lacunosus	0	0	0	0	0	0	0	0	713	0	0	0	**713**
	Hypoatherina temminckii	0	0	0	0	0	0	0	0	763	0	0	0	**763**
	Total abundance	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1476**	**0**	**0**	**0**	**1476**
	Total diversity	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**2**
Pomacanthidae	*Pomacanthus imperator*	0	0	11	0	0	0	0	0	0	0	0	0	**11**
	Pygoplites diacanthus	0	7	0	0	0	0	0	0	15	30	3	11	**66**
	Pomacanthus maculosus	7	6	7	0	0	0	4	15	0	31	18	55	**143**
	Total abundance	**7**	**13**	**18**	**0**	**0**	**0**	**4**	**15**	**15**	**61**	**21**	**66**	**220**
	Total diversity	**1**	**2**	**2**	**0**	**0**	**0**	**1**	**1**	**1**	**2**	**2**	**2**	**3**
Holocentridae	*Neoniphon sammara*	10	0	0	28	53	0	12	16	19	13	0	0	**151**
	Adjorex ruber	0	0	0	0	0	0	0	0	31	0	0	0	**31**
	A. diadeama	19	12	0	44	76	10	52	17	70	0	0	0	**300**
	A. murdjan	7	0	0	4	7	0	0	0	5	0	0	0	**23**
	Sargocentron spiniferum	0	0	0	0	0	0	0	0	17	0	0	0	**17**
	Total abundance	**36**	**12**	**0**	**76**	**136**	**10**	**64**	**33**	**142**	**13**	**0**	**0**	**522**
	Total diversity	**3**	**1**	**0**	**3**	**3**	**1**	**2**	**2**	**5**	**1**	**0**	**0**	**5**

Family	Scientific name	QS	QM	QN	SS	SM	SN	HS	HM	HN	RS	RM	RN	Total
Chaetodontidae	*Chaetodon auriga*	8	10	0	16	19	10	15	15	98	0	0	0	**191**
	Chaetodon fasciatus	14	22	9	10	19	0	16	5	14	10	7	8	**134**
	Chaetodon paucifasciatus	7	20	17	7	12	0	3	0	0	0	0	0	**66**
	Chaetodon austriacus	21	8	0	17	13	19	11	7	64	0	0	0	**160**
	Chaetodon semilarvatus	18	28	50	0	0	0	3	0	30	0	0	0	**129**
	Chaetodon lineolatus	0	4	0	1	2	0	0	0	16	13	18	12	**66**
	Gonocheatodon larvatus	0	18	4	2	4	0	0	0	0	17	28	39	**112**
	Megachaetodon trifascialis	15	7	0	2	3	0	3	4	0	0	0	0	**34**
	Heniochus intermedius	23	0	23	7	7	7	4	0	0	0	0	0	**71**
	Chaetodon melanotus	2	11	14	0	0	0	3	0	0	0	0	0	**30**
	Total abundance	**108**	**128**	**117**	**62**	**79**	**36**	**58**	**31**	**222**	**40**	**53**	**59**	**993**
	Total diversity	**8**	**9**	**6**	**8**	**8**	**3**	**8**	**4**	**5**	**3**	**3**	**3**	**10**
Scaridae	Cetoscarus bicolor	0	0	0	0	0	0	0	0	1	0	0	0	**1**
	Hipposcarus harid	0	15	51	0	0	0	0	0	88	0	0	13	**167**
	Scarus ferrugineus	0	10	0	0	0	0	6	0	5	3	29	16	**69**
	S. niger	33	45	57	0	0	0	3	7	29	6	17	27	**224**
	S. sordidus	0	17	0	0	0	0	0	0	39	10	14	24	**104**
	S. gibbus	0	0	0	0	0	0	0	0	3	0	0	0	**3**
	S. fuscopurpureus	0	0	0	0	0	0	0	0	3	0	0	0	**3**
	S. ghobban	0	0	0	0	0	0	0	0	3	0	0	0	**3**
	S. collana	0	0	0	0	0	0	0	0	3	0	0	0	**3**
	Total abundance	**33**	**87**	**108**	**0**	**0**	**0**	**9**	**7**	**174**	**19**	**60**	**80**	**577**
	Total diversity	**1**	**4**	**2**	**0**	**0**	**0**	**2**	**1**	**9**	**3**	**3**	**4**	**9**
Tetraodontidae	*Arothron diadematus*	8	0	0	4	7	0	0	0	0	0	0	0	**19**
	Arothron hispidus	0	12	14	8	6	9	15	0	14	0	3	0	**81**
	Canthigaster marigritata	6	0	0	22	29	13	7	19	37	7	0	0	**140**
	Total abundance	**14**	**12**	**14**	**34**	**42**	**22**	**22**	**19**	**51**	**7**	**3**	**0**	**240**
	Total diversity	**2**	**1**	**1**	**3**	**3**	**2**	**2**	**1**	**2**	**1**	**1**	**0**	**3**
Pomacentridae	*Pomacentrus trichorus*	0	0	0	75	120	30	0	0	32	0	0	0	**257**
	Abudefduf sordidus	0	51	368	0	0	0	0	0	0	0	0	0	**419**
	Dascyllus auranus	0	98	0	19	0	36	0	0	101	0	0	0	**254**
	Crenimugil crenilabis	0	0	0	10	0	19	0	0	0	0	0	0	**29**
	Abudefduf saxatilis	0	0	0	0	0	0	0	0	226	0	0	0	**226**
	Amphiprion bicinctus	2	4	2	0	0	0	2	0	16	0	0	0	**26**
	P.trilineatus	0	0	0	0	0	0	0	0	76	0	0	0	**76**
	Total abundance	**2**	**153**	**370**	**104**	**120**	**85**	**2**	**0**	**451**	**0**	**0**	**0**	**1287**
	Total diversity	**1**	**3**	**2**	**3**	**1**	**3**	**1**	**0**	**5**	**0**	**0**	**0**	**7**
Balistidae	*Rhinecanthus assasi*	44	17	0	8	3	13	0	0	28	0	0	0	**113**
	Sufflamen albicaudatus	3	59	10	0	0	0	0	0	0	3	3	0	**78**
	Total abundance	**47**	**76**	**10**	**8**	**3**	**13**	**0**	**0**	**28**	**3**	**3**	**0**	**191**
	Total diversity	**2**	**2**	**1**	**1**	**1**	**1**	**0**	**0**	**1**	**1**	**1**	**0**	**2**
Lethrinidae	*Lethrinus nebolosus*	0	0	0	0	0	0	0	0	7	17	38	49	**111**
	Lethrinus harak	0	0	8	4	7	0	0	0	0	0	0	0	**19**
	Total abundance	**0**	**0**	**8**	**4**	**7**	**0**	**0**	**0**	**7**	**17**	**38**	**49**	**130**
	Total diversity	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**2**
Serranidae	*Cephalopholis argus*	2	3	7	0	0	0	0	0	0	0	4	0	**16**
	Epinihpilud sumanna	0	0	0	0	0	0	0	0	10	4	4	8	**26**
	Cephalopholis miniata	12	0	18	0	0	0	0	0	0	0	0	0	**30**
	Cephalopholis rogaa	1	0	3	0	0	0	0	0	0	0	1	0	**5**
	Epinihpilus chlorostigma	0	0	0	0	0	0	0	0	0	4	4	6	**14**
	Total abundance	**15**	**3**	**28**	**0**	**0**	**0**	**0**	**0**	**10**	**8**	**13**	**14**	**91**
	Total diversity	**3**	**1**	**3**	**0**	**0**	**0**	**0**	**0**	**1**	**2**	**4**	**2**	**5**
Ostracidae	*Ostracion cubicus*	0	0	2	1	2	0	0	0	9	0	0	4	**18**
	Ostracion cyanorus	0	0	7	2	2	0	1	0	0	0	0	0	**12**
	Total abundance	**0**	**0**	**9**	**3**	**4**	**0**	**1**	**0**	**9**	**0**	**0**	**4**	**30**
	Total diversity	**0**	**0**	**2**	**2**	**2**	**0**	**1**	**0**	**1**	**0**	**0**	**1**	**2**

Family	Scientific name	QS	QM	QN	SS	SM	SN	HS	HM	HN	RS	RM	RN	Total
Muraenidae	*Gymnothorax flavimarginatus*	0	0	0	3	4	0	0	0	0	0	0	0	**7**
	Siderea grisea	0	0	0	4	0	7	0	0	0	0	0	0	**11**
	Total abundance	**0**	**0**	**0**	**7**	**4**	**7**	**0**	**0**	**0**	**0**	**0**	**0**	**18**
	Total diversity	**0**	**0**	**0**	**2**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**2**
Other families *	*Priacanthus hamrur*	28	0	56	0	0	0	0	0	0	0	0	0	**84**
	Acanthupagrus bifasciatus	0	0	0	0	0	0	6	16	19	0	0	0	**41**
	Ptrois volitans	0	0	0	6	0	10	0	7	17	0	0	0	**40**
	Plectrorynchus gatrinus	0	0	0	5	4	4	3	0	7	0	0	0	**23**
	Synodus variegatus	0	0	0	6	11	0	2	0	0	0	0	0	**19**
	Fistularia commersonii	0	0	0	4	7	0	6	0	0	0	0	0	**17**
	Lutjanus kasmira	0	0	0	0	0	0	0	0	12	0	0	0	**12**
	Carnax fulvoguttatus	4	0	0	3	0	4	0	0	0	0	0	0	**11**
	sphyraena qenie	7	0	0	0	0	0	0	0	0	0	0	0	**7**
	Himantura uarnak	0	0	0	3	0	4	0	0	0	0	0	0	**7**
	Total abundance	**39**	**0**	**56**	**27**	**22**	**22**	**17**	**23**	**55**	**0**	**0**	**0**	**261**
	Total diversity	**3**	**0**	**1**	**6**	**3**	**4**	**4**	**2**	**4**	**0**	**0**	**0**	**10**
Totals	**Abundance**	**1515**	**1204**	**2046**	**1351**	**1284**	**1362**	**556**	**292**	**4432**	**711**	**556**	**870**	**16179**
		4765			**3997**			**5280**			**2137**			
	Diversity	**44**	**41**	**40**	**44**	**39**	**24**	**41**	**18**	**54**	**24**	**28**	**26**	**93**
		65			**47**			**68**			**35**			
	Number of Families	**15**	**12**	**14**	**18**	**15**	**13**	**15**	**10**	**19**	**11**	**11**	**10**	**26**

***Other families include: Priacanthidae; Sparidae; Scorpionidae; Haemulidae; Synodontidae; Fistularidae; Lutjanidae; Carangidae; Sphyraenidae and Dasyatidae.

QS: south Qusier; QM: middle Qusier; QN: north Qusier; SS: south Safaga; SM: middle Safaga; SN: north Safaga; HS: south Hurgada; HM: middle Hurgada; HN: north Hurgada; RS: south Ras Gharib; RM: middle Ras Gharib and RN: north Ras Gharib.

Table 3. The abundance of the highest abundant reef fish species in the present study area

Family	Scientific name	QS	QM	QN	SS	SM	SN	HS	HM	HN	RS	RM	RN	Totals	
Acanthuridae	*A. nigrofuscus*	308	34	112	20	38	0	28	8	102	0	0	0	**650**	**2511**
	A. sohal	248	58	370	18	35	0	76	0	170	66	39	53	**1133**	
	C. striatus	145	72	130	7	14	0	60	18	169	50	40	23	**728**	
Mullidae	*M. vanicolensis*	0	22	0	290	359	218	51	92	0	0	0	0	**1032**	**2001**
	P. forsskali	46	8	10	262	115	408	5	22	61	0	13	19	**969**	
Labridae	*Th. ruppellei*	63	52	66	80	136	24	55	11	384	93	50	128	**1143**	**1143**
Siganidae	*S. rivulatus*	15	131	31	226	19	427	6	0	172	114	57	245	**1443**	**1442**
Atherinidae	*A.s lacunosus*	0	0	0	0	0	0	0	0	713	0	0	0	**713**	**1476**
	H. temminckii	0	0	0	0	0	0	0	0	763	0	0	0	**763**	
Pomacentridae	*A. sordidus*	0	51	368	0	0	0	0	0	0	0	0	0	**419**	**419**
Total		**825**	**428**	**1087**	**903**	**716**	**1077**	**281**	**151**	**2534**	**323**	**199**	**468**	**8992 (55.6%)**	

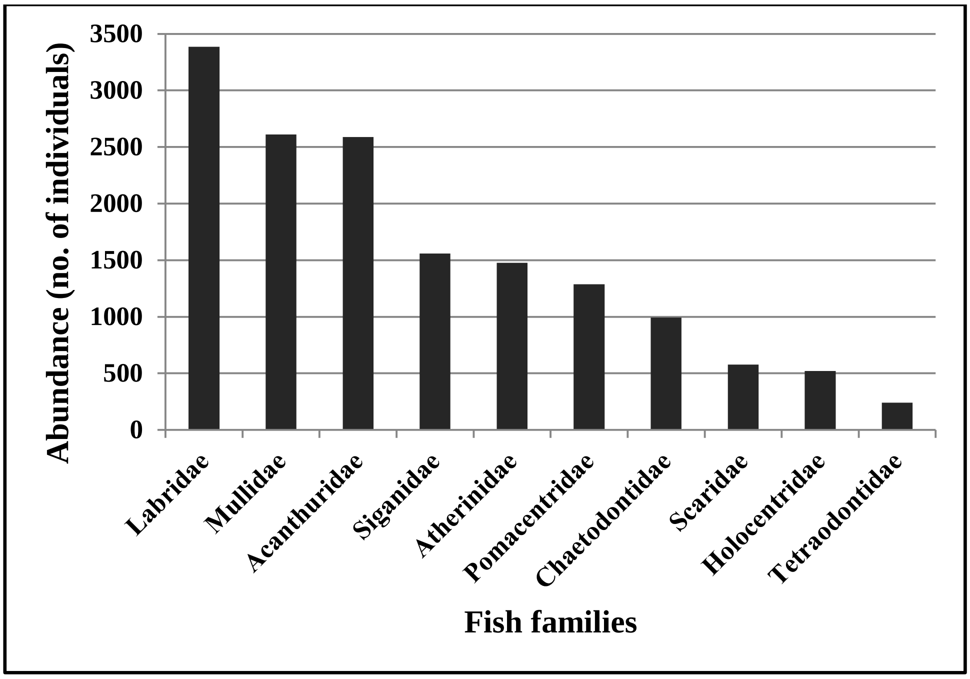

Fig. 2. Abundance of the mostly abundant reef fishes in the study area

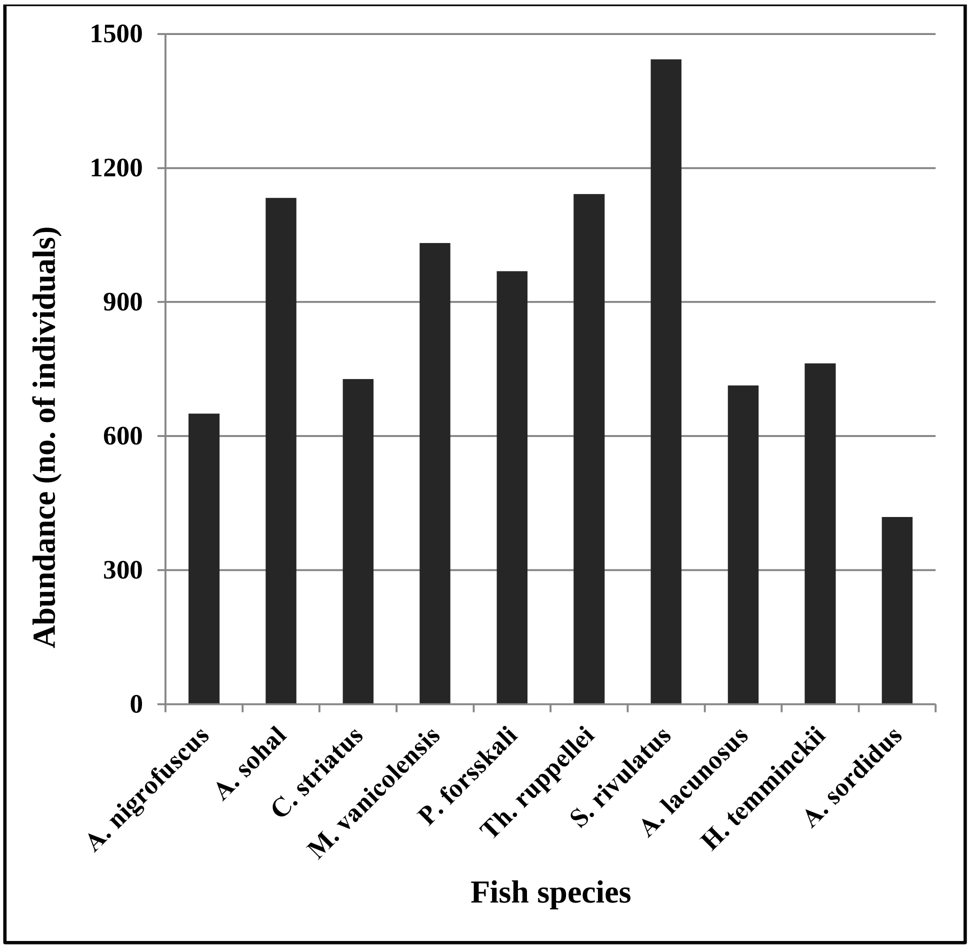

Fig. 3. Abundance of the mostly abundant reef fishes in the study area

3. Seasonal variation in abundance of Red Sea fish in different stations

During winter, the visual censuses recorded 4638 fishes (28.67% of all counted fish), representing 22 families and 75 reef fish species. The highest number of fishes was counted in the North of Hurgada (HN), with about 1108 fishes followed by the South of El- Qusier that had 717 fishes. The lowest number of fishes was found in the middle of Ras Gharib, where only 92 fishes were recorded; followed by the North of Ras Gharib, with 120 fish (Table 4).

During the season of spring, 3562 fishes (22.01% of all counted fishes) were recorded, representing 25 families and 81 reef fish species. The highest number of fishes was counted in the North of Hurgada with 1061 fishes; followed by north of El-Qusier that had 508 fishes. The lowest number of fishes was found in the middle of Hurgada where only 50 fishes were recorded; followed by the south Hurgada with 63 fishes (Table 4).

During summer, 3590 fishes (22.19% of all counted fishes) were recorded, representing 25 families and 82 reef fish species. The highest number of fishes was also recorded in the North of Hurgada with 1247 fishes; followed by the North of El-Qusier that had 578 fishes. The lowest number of fishes was also found in the middle of Hurgada, where only 33 fishes were recorded; followed by the South of Hurgada with 41 fishes (Table 4).

During autumn season, 4389 fishes (27.13% of all counted fishes) were recorded, representing all recorded families (26) and 86 reef fish species. The highest number of fishes was also recorded in the North of Hurgada with 1016 fishes; followed by the North of El-Qusier that had 618 fishes. The lowest number of fishes was also found in the middle of Hurgada where only 54 fishes were recorded; followed by the South Hurgada with 164 fishes (Table 4).

Abundance of different fish species was significantly varied ($P < 0.05$) between different studied stations and it was non-significantly varied between seasons (Tables 4, 5).

4. Seasonal variation in diversity of Red Sea fish in different stations

During winter, 75 species (80.65% of the all recorded species) were recorded. The highest number of species was recorded in the middle of El-Qusier with 42 species; followed by the North of Hurgada with 41 species. The lowest number of species was counted in the North of Safaga with only 5 species; followed by middle Hurgada with 10 species (Table 4).

During spring season, 81 species (87.09% of the all recorded species) were recorded. The highest number of species was recorded in the North of Hurgada with 53 species; followed by the South of Safaga with 38 species. The lowest number of species was counted in the South of Hurgada with only 8 species; followed by the middle Hurgada with 12 species (Table 4).

During summer season, 82 species (88.17% of the all recorded species) were recorded. The highest number of species was also recorded in the North of Hurgada with 50 species; followed also by the South of Safaga with 37 species. The lowest number of species was recorded in the South of Hurgada with only 8 species; followed by the middle Hurgada with 12 species (Table 4).

During autumn, 86 species (92.47% of the all recorded species) were recorded. The highest number of species was recorded in the North of Hurgada with 49 species; followed by the South of Safaga with 44 species. The lowest number of species was recorded in the middle of Hurgada with 17 species (Table 4).

Diversity of reef fishes species was significantly varied (P< 0.05) between different studied stations and also between different seasons (Tables 4,5).

Table 4. Seasonal variations in abundance and diversity of fish in different stations of the Egyptian Red Sea Coast during the study period

Station		Abundance (Individuals)					Diversity (Species)					Family no.
		Win.	Spr.	Sum.	Aut.	Total	Win.	Spr.	Sum.	Aut.	Total	
QS		717	215	147	436	1515	32	20	21	42	44	15
QM		359	219	263	363	1204	42	25	24	39	42	12
QN		342	508	578	618	2046	25	20	21	36	40	14
SS		431	290	299	331	1351	19	38	37	44	46	18
SM		460	247	201	376	1284	19	27	27	37	39	15
SN		397	315	382	268	1362	5	21	20	23	24	13
HS		288	63	41	164	556	38	8	9	39	40	15
HM		155	50	33	54	292	10	12	12	17	18	10
HN		1108	1061	1247	1016	4432	41	53	50	49	54	18
RS		169	204	132	206	711	11	18	17	23	24	11
RM		92	174	119	171	556	12	18	19	27	28	11
RN		120	216	148	386	870	16	14	14	26	26	10
Total	No	4638	3562	3590	4389	16179	75	81	82	86	93	26
	%	28.67	22.01	22.19	27.13	100	80.65	87.09	88.17	92.47	100	100
	Family	22	25	25	26	26	22	25	25	26	26	

Table 5. Results of statistical analysis of seasonal variations in abundance and diversity of fish between different stations of the Egyptian Red Sea Coast

Stations	QS	QM	QN	SS	SM	SN	HS	HM	HN	RS	RM	RN
QS	--	NS.	*	SS.	NS.	NS.	*	*	*	*	*	*
QM	*	--	*	*	*	*	*	*	*	NS.	*	NS.
QN	NS.	*	--	*	*	*	*	*	*	*	*	*
SS	*	NS	*	--	NS.	*	*	*	*	*	*	NS.
SM	*	NS.	*		--	*	*	*	*	NS.	*	NS.
SN	*	NS.	*	NS.	NS.	--	*	*	*	*	*	NS.
HS	*	*	*	*	*	*	--	NS.	*	*	*	*
HM	*	*	*	*	*	*	*	--	*	*	*	*
HN	*	*	*	*	*	*	*	*	--	*	*	*
RS	*	*	*	*	*	*	NS.	NS.	*	--	NS.	*
RM	*	*	*	*	*	*	NS.	NS.	*	*	--	*
RN	*	*	*	*	*	*	NS.	NS.	*	NS.	NS.	--

5. Seasonal variation in abundance and diversity of Red Sea fish families

Generally, the results revealed that, only 10 families (Labridae, Mullidae, Acanthuridae, Siganidae, Atherinidae, Pomacentridae, Chaetodontidae, Scaridae, Holocentridae and Tetraodontidae) contain about 94.18% (15237 individuals) of the total number of fish individuals during this study; whereas 16 families contain only 5.82% (942 individuals) of the total number of the recorded fishes (Table 6).

During winter, the Mullidae was the most abundant family having 1346 individuals; followed by family Labridae with 1106 individuals. The lowest number of fishes from the most abundant families was recorded in family Tetraodontidae with only 46 fishes (Table 6).

Labridae was the most abundant family during spring, summer and autumn; recording 740, 597 and 944 fishes, respectively. The less abundant families during the rest seasons (from these ten families) were Tetraodontidae and Holocentridae (Table 6).The results revealed that, the above mentioned 10 abundant families were represented by 65 species (about 69.9% of the total recorded species), whereas the rest 16 families were represented by only 26 species (30.1%). Moreover, Labridae had the highest diversity during all seasons, recording from 14 to 16 species; followed by the family Chaetodontidae during all seasons, recording from 9 to 10 species (Table 6). Abundance and diversity of reef fishes were significantly varied (P< 0.05) between different families, and they were non-significantly varied between different seasons.

Table 6. Seasonal variations in abundance and diversity of fish families in Egyptian Red Sea Coast during the study period

Family		Abundance					Diversity				
		Win.	**Spr.**	**Sum.**	**Aut.**	**Total**	**Win.**	**Spr.**	**Sum.**	**Aut.**	**Total**
1	**Labridae**	1106	740	597	944	**3387**	14	14	14	16	**16**
2	**Mullidae**	1346	255	473	536	**2610**	5	4	4	5	**5**
3	**Acanthuridae**	661	514	490	922	**2587**	7	7	7	7	**7**
4	**Siganidae**	172	536	421	430	**1559**	3	2	2	2	**3**
5	**Atherinidae**	290	290	580	316	**1476**	2	2	2	2	**2**
6	**Pomacentridae**	153	509	423	202	**1287**	6	7	7	7	**7**
7	**Chaetodontidae**	233	258	208	294	**993**	10	9	9	10	**10**
8	**Scaridae**	105	161	140	171	**577**	4	8	9	4	**9**
9	**Holocentridae**	263	88	49	122	**522**	3	5	4	5	**5**
10	**Tetraodontidae**	46	70	64	60	**240**	3	3	3	3	**3**
11	**Pomacanthidae**	63	26	16	115	**220**	3	2	2	3	**3**
12	**Balistidae**	44	32	73	42	**191**	2	2	2	2	**2**
13	**Lethrinidae**	8	15	11	96	**130**	2	2	2	2	**2**
14	**Serranidae**	38	4	3	46	**91**	3	2	2	4	**5**
15	**Priacanthidae**	60	2	1	21	**84**	1	1	1	1	**1**
16	**Sparidae**	16	9	6	10	**41**	1	1	1	1	**1**
17	**Scorpionidae**	8	17	7	8	**40**	1	1	1	1	**1**
18	**Ostraciidae**	3	7	8	12	**30**	1	1	2	2	**2**
19	**Haemulidae**	4	5	4	10	**23**	1	1	1	1	**1**
20	**Synodontidae**	4	3	2	10	**19**	1	1	1	1	**1**
21	**Muraenidae**	0	8	5	5	**18**	0	2	2	2	**2**
22	**Fistularidae**	12	0	0	5	**17**	1	0	0	1	**1**
23	**Lutjanidae**	3	4	3	2	**12**	1	1	1	1	**1**
24	**Carangidae**	0	3	2	6	**11**	0	1	1	1	**1**
25	**Sphyraenidae**	0	3	2	2	**7**	0	1	1	1	**1**
26	**Dasyatidae**	0	3	2	2	**7**	0	1	1	1	**1**
Total	**No.**	**4638**	**3562**	**3590**	**4389**	**16179**	**75**	**81**	**82**	**86**	**93**
	%	**28.67**	**22.01**	**22.19**	**27.13**	**100**	**80.65**	**87.09**	**88.17**	**92.47**	**100**
	Families	**22**	**25**	**25**	**26**	**26**	**22**	**25**	**25**	**26**	**26**

DISCUSSION

There is a total of 1120 species in 143 families and 26 orders in coastal waters of the Red Sea. They were recorded within an overall depth range of 0–200 m; among them, 165 species are exclusively endemics to the Red Sea, whilst another 51 species are restricted to the Red Sea and Gulf of Aden only, and 22 species living at depths greater than 200 m are endemic **(Bogorodsky & Randall, 2019)**.

The present study recorded 93 species of coral reef fishes belonging to 26 families in all study sites along the northern Egyptian Red Sea coast. The results revealed that only 5 families were the most diverse and recorded 49 species (52.69% of the total number of species). These families are Labridae (16), Chaetodontidae (10), Scaridae (9), Acanthuridae (7) and Pomacentridae (7).

Farghal *et al*. (2021) in their study on Red Sea coral reef fishes at Hurgada, recorded 47 species of coral reef fishes belonging to 8 families (Chaetodontidae: 10 species; Pomacentridae: 9 species; Acanthuridae: 6 species; Holocentridae: 5 species; Balistidae: 5 species; Pomacanthidae: 5 species; Serranidae: 3 species and Scaridae: 4 species). Additionally, **Randall (1992)** and **Khalf and Abdallah (2005)** recorded a total of 14 species of butterfly fishes (Chaetodontidae) in the Red Sea and the Gulf of Aden. This means that the diversity of coral reef fish families was varied in the Red Sea; this variation in diversity may be due to the distribution of these fishes in different areas of the Red Sea as described by many authors **(Bouchon-Navaro, 1980; Roberts & Ormond, 1987; Roberts *et al*., 1992)**. Coral reefs are witnessing changes because of local and global human impacts **(Pandolfi *et al*., 2003**; **Bellwood *et al*., 2004)**. **Lin *et al*. (2019)** concluded that little is known about the long-term changes in coral reef fish communities.

The present results showed that the highest abundance (4432 fishes) and diversity (54 species) of reef fish species was recorded in the North of Hurgada, which may be due to the fact that this station is greatly free of pollution and human activities compared to the other stations. Furthermore,, Al-Qusier stations recorded the second rank of abundance (a total of 4765 fishes) and diversity (a total of 65 species), where these stations were impacted with the lowest human activities (Diving and fishing). On the other hand, all stations of Ras Gharib recorded the lowest abundance and diversity of reef fishes because they were oil polluted.

Direct impacts of the coastal and marine tourism on the environment in the Red Sea were identified, including the Gulf of Aqaba and Gulf of Suez, such as local pollution, resource depletion, habitat loss and conversion, habitat and wildlife disturbances. Indirect impacts due to support infrastructure, disposal of waste, invasive species, and increase in human population were also identified **(Gladstone *et al*., 2013)**. Local residents' behavior is sometimes very harmful to the reefs. **Yu (1994)** pointed out that lampshades were made by residents near Hurgada from inflated dried pufferfish for tourist souvenirs, and the overfishing of these pufferfish leads to increased sea urchins, which damage the reefs by grazing on coral recruits and contributing to bio-erosion. **Donaldson *et al*. (2003)** concluded that overfishing may alter food-webs structure of coral reef ecosystem and may impact the fish assemblage.

The present results also showed the effect of season on population size of the studied families. The data indicated seasonal changes in the number of individuals representing the same family. These changes could be attributed to the migration of some families away from the reef during the breeding season. On the other hand some, authors tended to explain these changes as an effect of habitat structure disturbance. **Brokovich *et al.* (2006)** concluded that the coral reef fish communities at the northern tip of the Gulf of Aqaba (Red Sea) are at the extreme of their distribution range. Their results agree with the current study on the seasonal changes in population structure.

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