Impact of the valley flooding upon the abundance and diversity of the reef fishes in Wadi El-Gemal protected area, Red Sea, Egypt

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ABSTRACT

This study was conducted in Wadi El-Gemal using visual census technique in order to study the composition of the fish community in the area and to evaluate the effect of the flooding drain on the abundance and diversity of reef fishes. The area in front of the flooding drain was divided into three transects according to their proximity to the drain. Each transect was divided into three zones; reef flat, reef edge and reef slope and fishes were counted at each zone. A total of 4388 fish constituting 94 species in 23 families of coral reef fish were recorded. The highest number of species was recorded in the reef slope of transect two (85), while the lowest was present at the reef flat (11). The highest number of individuals was recorded in the reef slope, where 1002 fish were counted, while the lowest number was in the first transect (86). There were no great seasonal variations in diversity but slight differences were noted in abundance of fishes. The highest diversity was observed in the fall with 88 species and the richness was 11.9 while the lowest was in winter with 82 species and the richness was 10.7. Number of species as well as number of fish increases as the distance from the mouth of the valley increases.

Keywords: reef fish, Red Sea, Wadi El-Gemal, diversity

INTRODUCTION

Wadi El-Gemal is an Arabic name that means Valley of Camels due to the large number of camels grazing on mangrove trees in the area. Wadi El-Gemal National Park (WGNP) was declared as a protected area in January 2003. WGNP includes an area of 4,770 km² of land, and about 2,000 km² of marine waters. WGNP comprises unique terrestrial and marine components. The terrestrial component encompasses a substantial segment of the Red Sea hills and coastal desert. Wadi El-Gemal and its delta are the focal attraction of the Park, which encompasses the entire watershed of the wadi. However, the Park includes other adjacent desert and marine habitats, which complement the wadi, both ecologically and functionally (i.e. in terms of representing a meaningful management unit). Wadi El-Gemal is the third largest wadi in the Eastern Desert draining into the Red Sea, and one of the better vegetated wadis, with an estimated watershed area of some 1476.7 km² (Mansour, 2003). The marine component of the park comprises a strip of marine waters of an average width of 15 km. This component includes all the important coral reefs in the region, as well as five islands.

An extensive system of wadis (valleys) dissects the mountains in front of Wadi El-Gemal area and they flow to the Red Sea at some points including the area of study. Wadi El-Gemal has the highest value of maximum runoff, followed by Wadi Lahmi and Wadi Ghadeer.

Fishes are the heart of the coral reefs and constitute a dominant component of the reef fauna. Fishes inhabiting reefs comprise the most diverse and abundant assemblages of vertebrates found anywhere on the earth, and certainly within the marine ecosystem. Reef fish assemblages of the Red Sea region are as varied as the reef themselves (Ogden and Gladfelter, 1983). There are marked differences among areas in species richness, assemblage composition and abundance of species. The fish assemblages are helpful in illuminating much important ecological process, which help to study the contexts of the environments (Sheppard *et al*. 1992). Due to the great diversity of the fish of the Red Sea, some early investigators focused on studying the different species of the various families in the area (Forsskål, 1755; Klunzinger, 1871; Rüppell, 1828; Ormond and Edwards, 1987). The effect of floods and heavy metals on the hard corals, invertebrates and sediments has been extensively studied along the Red Sea coast (Mansour, 2003; Madkour, 2005; Madkour *et al*., (2013). However, little information about reef fishes of Wadi El-Gemal and the effect of the natural impacts on the structure of fish community is scarce.

This work aims to study the composition of the reef fish community in Wadi El-Gemal and the influence of the proximity to the mouth of the Wadi El-Gemal where floods flow on the fish community.

MATERIALS AND METHODS

Study area

Wadi El-Gemal is one of the most famous wadis in the Red Sea. It lies between 24º 39′N, 35º 05′E and 24 9º 36′N and 35º 06′ E about 50 km south to Marsa Alam city (Fig.1). Wadi El_Gemal is characterized by an arid and hot climate and rainless summer and mild winter. Most of the precipitations occur in the Wadi as heavy showers with short duration leading to flash floods from October to February (Mansour, 2003). The source rock in the area is composed of a complex of granites, diorites and green breccia. It is observed that sediments along this wadi have relatively large cuttings under the effect of the violent drive water during heavy mineral torrents. Two prominent items; palm trees and mangroves distinguish the shore area of this wadi. The rocky beach is ending abruptly with a deep bottom. In addition, Wadi El-Gemal Island lies in front of the Wadi; it is believed that it is an extension of the Wadi. The bottom between the Wadi and the island is muddy and covered by dense seagrass beds. The depth ranges from 3 to 35 m. Fringing reefs characterize the area in front of the mouth of the valley.

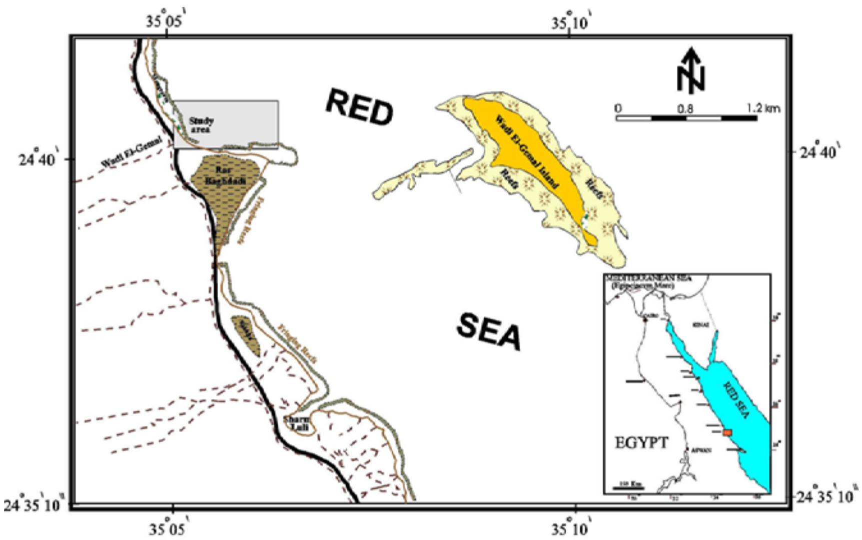

Fig. 1: Location map of the study area in Wadi El-Gemal on the Red Sea coast. (After Madkour, 2005).

Visual censuses of reef fishes

The visual census technique was used to count fishes under water using underwater identification guide. Fishes were counted by swimming slowly along 100 m long, 5 m wide and 1 m height transect with three replicates. Fishes in reef flat, reef edge and reef slope were counted. For the purpose of counting fishes and studying the effect of being close to the mouth of the valley, the area of study was divided into three transects according to the proximity to the mouth. The first transect was located in front of the mouth of the valley and extends for 100 meter north and south of the mouth of the valley. It is characterized by a rocky bottom with little number of mangroves trees and numerous pneumatophores. In the second transect, the area could be divided into reef flat, reef edge and reef slope with a depth of 6-7 m.

The area is slightly rich in corals. Reef flat is covered with many species of algae and seagrasses. The third transect is characterized by a wide reef flat and deep reef slope with a depth of about 20m.

Most of censuses were done at midday between 12:00 PM and 3:00 PM.

Fishes were identified under water using waterproof edition of Randall, 1986 (Red Sea Reef Fish Guide).

Data analysis

The univariate statistics were done in SPSS v.17.0, using ANOVA to determine differences in number of individuals and number of species between different zones of the reef. All data were tested for homogeneity of variance. Where the samples were not homogeneous, data were either transformed or the non-parametric Kruskal-Wallis test was used (Zar, 1999; Dytham, 2003). The multivariate technique cluster analysis, to determine similarities between sites and months, and diversity indices (species richness, the evenness and Shannon-Wiener), were calculated using PRIMER (Plymouth Routines in Multivariate Ecological Research) v 5.2.

RESULTS

Abundance

The visual censuses recorded 94 species belonging to 23 families of coral reef fish. The highest number of species was recorded in the reef slope of the second transect (85 species) followed by the reef slope of the third transect (83 species), while the lowest was present both in the first transect that face the mouth of the valley and the reef flat of the second transect (11 species). The highest fish density was recorded in the reef slope of the third transect where 1002 fish/100m were listed while the lowest number was in the first transect (86 fish/100) (Table 1).

The analysis of variance showed that there was a significant difference between zones regarding the number of species ($F=2633.603$, $P<0.05$). It also showed that the number of fishes varied significantly between zones ($F=3465.496$ $P<0.05$).

Table 1: Abundance and relative abundance of the common reef fish species

Species	T1	T2F	T2E	T2S	T3F	T3E	T3S	Sum	ReA
Acanthrus sohal	17	*100*	32	15	130	130	16	440	11.3
Thalassoma klunzingeri	6	*80*	42	65	32	10	10	245	6.3
Acanthurus nigrofoscus	0	*51*	20	2	15	132	5	225	5.8
Pseudoanthias squamipinnis	0	*0*	80	29	0	70	40	219	5.6
Acanthurus nigricans	5	*72*	20	2	35	45	5	184	4.7
Chromis dimidiata	0	*0*	42	33	0	45	52	172	4.4
Pseudoanthias taeniatus	0	*0*	42	20	0	65	40	167	4.3
Chromis viridis	0	*0*	35	46	0	35	46	162	4.2
Thalassoma purpureum	0	*70*	23	20	12	12	5	142	3.6
Abudefduf saxatilis	0	*0*	60	1	5	60	3	129	3.3
Chromis pembae	0	*0*	35	25	0	39	25	124	3.2
Siganus rivulatus	0	*0*	0	68	25	18	5	116	3.0
Abudefduf sexfasciatus	0	*0*	50	1	4	50	3	108	2.8
Caesio striata	0	*0*	0	50	0	0	50	100	2.6
Caesio lunaris	0	*0*	0	50	0	0	45	95	2.4
Mulloides flavolineatus	0	*0*	0	40	0	0	54	94	2.4
Caesio varilineata	0	*0*	0	50	0	0	42	92	2.4
Mulloides vanicolensis	0	*0*	0	40	0	0	46	86	2.2
Hipposcarus harid	2	*5*	0	25	18	15	15	80	2.1
Naso unicornis	0	*0*	0	26	18	25	5	74	1.9
Caesio suevica	0	*0*	0	50	0	0	15	65	1.7
Chaetodon auriga	4	*2*	14	14	4	4	10	52	1.3
Scarus ferrungineus	0	*0*	2	10	15	10	15	52	1.3
Pomacentrus sulfureus	0	*0*	21	1	0	23	5	50	1.3
Scarus frenatus	0	*0*	2	6	10	12	14	44	1.1
Abudefduf sordidus	36	*0*	0	1	0	0	0	37	1.0
Zebrasoma desjardini	0	*10*	2	0	16	7	1	36	0.9
Scarus sordidus	0	*0*	0	8	5	17	5	35	0.9
Scarus niger	0	*0*	0	6	6	8	14	34	0.9
Lethrinus nebolosus	0	*0*	0	18	0	0	14	32	0.8
Scarus fuscopurpureus	0	*0*	0	6	6	10	10	32	0.8
Gobiodon citrinus	0	*0*	10	0	10	12	0	32	0.8
Scarus gibbus	0	*0*	0	8	5	2	15	30	0.8
Monotaxis grandiculus	0	*0*	0	18	0	0	10	28	0.7
C. austriacus	0	*2*	7	5	4	6	2	26	0.7
C. fasciatus	0	*2*	4	5	4	4	5	24	0.6
Naso hexacanthurus	0	*0*	0	5	4	10	5	24	0.6
C. paucifasciatus	0	*0*	5	5	3	2	5	20	0.5
Scarus psittacus	0	*0*	0	5	8	5	2	20	0.5
Zebrasoma xanthurum	0	*0*	1	2	1	14	2	20	0.5
Gomphosus coeruleus	0	*0*	0	7	0	4	8	19	0.5
Lutjanus argentimaculatus	2	*0*	0	2	0	6	8	18	0.5
Heniochus intermedius	0	*0*	3	5	3	2	5	18	0.5
Megaprotodon trifascialis	0	*0*	10	0	5	3	0	18	0.5
Scarus genazonatus	0	*0*	0	5	5	6	2	18	0.5
Cetoscarus bicolor	0	*0*	0	2	7	7	1	17	0.4
Ctenochaetus striatus	0	*0*	0	2	5	5	2	14	0.4
Plectroglyphidodon leucogaster	0	*0*	2	1	0	2	8	13	0.3
Lutjanus ehrnbergi	5	*0*	0	2	0	5	0	12	0.3

Diversity

The reef slope of the second transect was the richest zone of coral reef fishes in the area with d= 12.37 followed by reef slope of the third transect (d = 12.28) and reef edge transect 3 (d= 9.78). The first transect and the reef flat of the second transect were the poorest zones with averages of 2.2 and 1.7 respectively (Table 2). There were no great variations in evenness values among all zones; J′ was high in reef edge and reef slope with about 0.8 indicating that the fish community in these zones was dominated by few species. In the reef flat J′ value was about 0.7 indicating that the community is dominated by one or more species that were *Acanthurus sohal* (Acanthuridae) and *Thalassoma rupellei* (Labridae).

Table 2: Diversity indices (Richness, Evenness and Diversity) for the different zones and transects

Transect	S	N	d	J'	H'
T1	11	86	2.24	0.78	1.86
T2F	11	395	1.67	0.75	1.80
T2E	51	607	7.80	0.78	3.07
T2S	87	890	12.66	0.81	3.63
T3F	36	428	5.78	0.78	2.81
T3E	70	1002	9.99	0.78	3.32
T3S	83	793	12.28	0.84	3.72

The similarity cluster analysis (Fig. 2) divided the 20 most abundant species into three main groups according to the similarity percentage. The first group included 7 species of the herbivorous fishes that are found almost in all sites but were very abundant on the reef flat. This group includes *Acanthurus sohal*, *Acanthurus nigrofuscus, Thalassoma rueppellii* and *Thalassoma purpureum siganus rivulatus and Hipposcarus harid.* The second group includes 5 schooling species that avoid the reef flat and reef edge. It includes mullid and caesionid fishes. The third group included the small schooling fishes that avoid the reef flat and are very abundant on coral heads in the reef edge and reef slope. It includes *Chromis* spp. and *Pseudoanthias* spp.

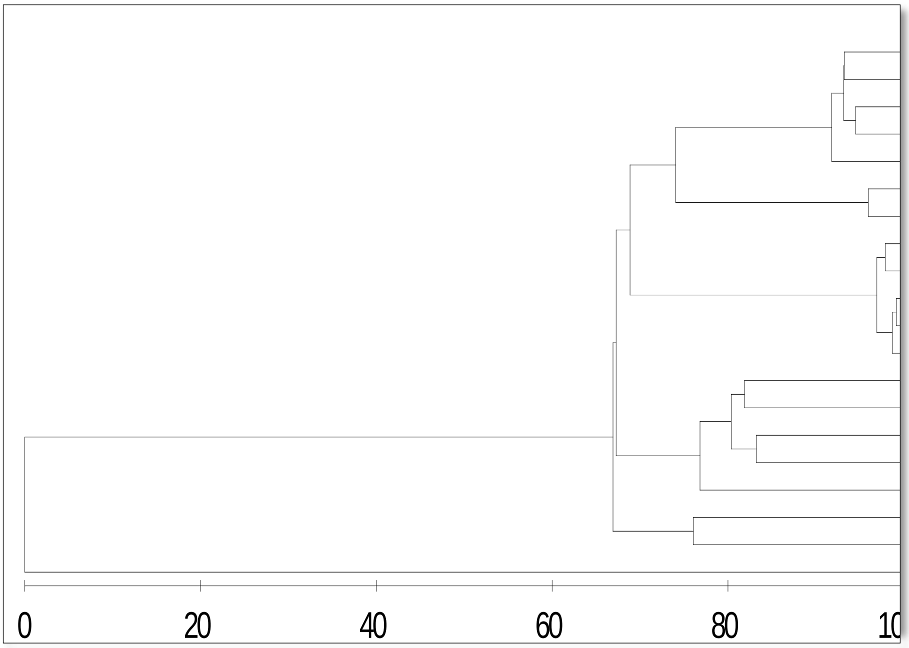

Fig. 2: Similarity between the most abundant species

Species composition and distribution of reef fishes

The ten most dominant species in the present work formed about 55% of all recoded species. The most dominant families were Pomacentridae (Damselfish), Acanthuridae (Suregeonfish), Labridae (Wrasses), Serranidae (Anthias & Groupers), Chaetodontidae (Butterflyfish) and Scaridae (Parrotfish) that form about 88% of all recorded families. Family Labridae contained the highest number of species (13 species) followed by Pomacentridae (12 species) and both Scaridae and Acanthuridae (8 species). Families Haemulidae, Balistidae, Tetraodontidae, Dascytididae, Caesionidae and Gobiidae were represented by only one species.

The Arabian surgeonfish *Acanthurus sohal* was the most abundant species of all species with 230 individuals forming about 17.35% of all species recorded. This species occurred in very large numbers on reef flats and reef edge (Fig. 3). It occurs in depths from 0.5 m to 5 m. It was seen wondering over the reefs in small to large groups. *Chaetodon auriga* was abundant on the reef edge and reef slope (Fig. 4). On the other hand, the herbivorous *Thalassoma ruppellii* (Fig. 5) and *Acanthurus nigricans* (Fig. 6) were most abundant on the reef flat.

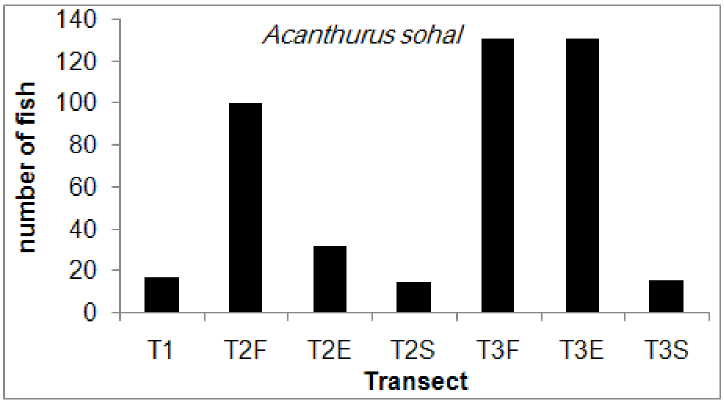

Fig. 3: Abundance of *A. sohal* at different reef zones and transects

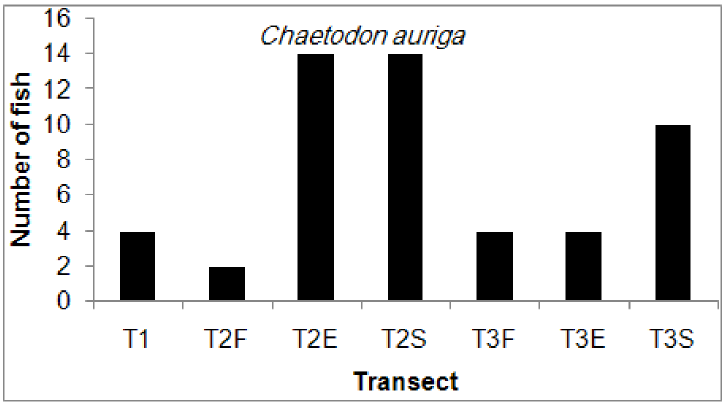

Fig. 4: Abundance of *C. auriga* at different reef zones and transects

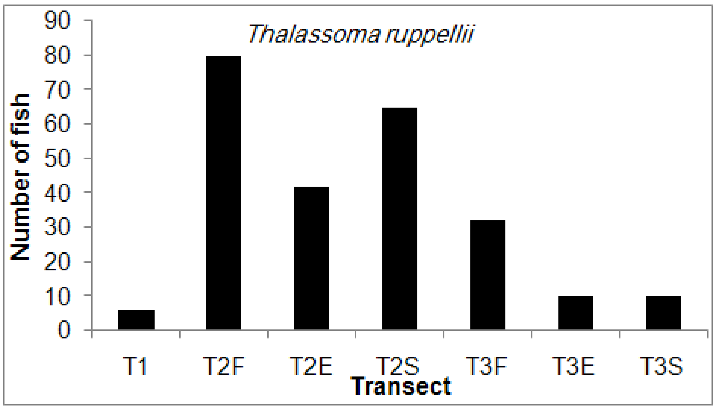

Fig. 5: Abundance of *T. ruepelleii* at different reef zones and transects

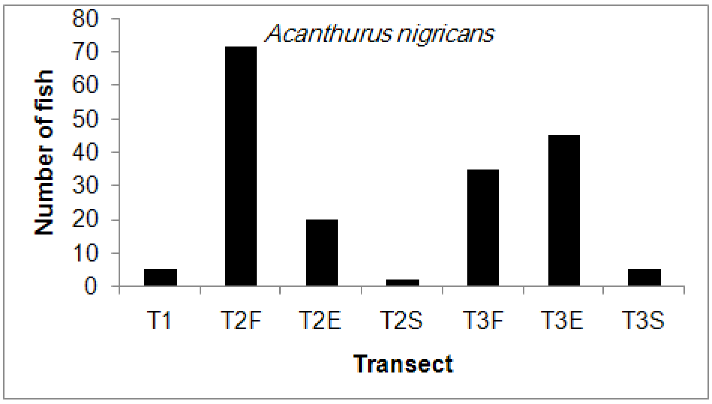

Fig. 6: Abundance of *A. nigricans* at different reef zones and transects

The second most species was the scissortail sergeant *Abudefduf saxatils* with 190 individual fish forming 14.3% of the recorded fishes. It is often occurred in the areas rich in coral especially in both reef edge and reef slope. This species along with *Abudefduf sordidus* formed the mean bulk of the damselfishes in the area. *A. sordidus* was wondering in rocky and rubble shallow and turbid areas. Other species such as *Chromis viridis*, *Chromis dimidiata* and *Pomacentrus sulfureus* occurred in low numbers. Most species were associated with reefs and sometimes occur among branches of corals especially *Acropora* sp.

Reef slope showed the highest density and diversity of coral reef fish species where 699 individual, representing 65 species forming 52% of all fish species were recorded. Nearly 92% of fishes were found on the reef slope. Fishes of *Thalassoma purpureum*, *Taeniura lymma*, *Plectroglyphidodon leucozona*, and *Rhinecanthus assasi* were absent from the reef slope. Reef edge forms about 30% with 406 individuals and 30 species (42% of all species), while reef flat achieved the lowest density and diversity with only 222 individuals and 14 species (20% of all species). Most of acanthurid fish occurred in the reef flat that was very rich in algae.

Density and diversity of fish increased as we moved apart from the mouth of the valley. Transect one which lies directly in the front of the mouth of the valley had the lowest density and diversity (86 fishes and 11 species). The number of fish increases in transects two and three.

Regarding the number of fishes, the analysis of variance (ANOVA) showed that there was a significant difference between zones according to their proximity to the mouth of the valley ($F=7.5$, $P<0.05$). Whereas, number of fish species did not change significantly from zone to another ($F=3.3$, $P>0.05$).

Species recorded at the mouth of the valley included herbivorous species; *Abudefduf sordidus* and *Siganus rivulatus* were almost restricted to this zone.

DISCUSSION

Wadi El-Gemal is one of the most active valleys along the Red Sea coasts. It receives a lot of runoff from the nearby chain of mountains. It rained on hills and wadis of Al Abyad, Holoos, Dronkate, Galy, and Abu Hamameed and on the western part of Wadi El-Gemal. Finally it accumulated a moderate strength flood along Wadi El-Gemal. It took two days of drainage in the sea. Coral reefs are almost lacking in the first transect in front of the mouth as a result of sediment accumulations due to floods. The last flood was in November 2004 after 10 of rainless years.

Roving herbivorous reef fish from families Acanthuridae (surgeonfish) and Scaridae (parrotfish) are abundant and ecologically important members of the reef community. They feed primarily on algae and detritus and generally represent the predominant reef herbivores in terms of algal biomass consumption (Horn, 1989; Hay, 1991). Since their intense feeding activity reduces spatial competition between corals and algae, are widely recognized as a critical functional group on coral reefs (Bellwood *et al*., 2004). The herbivorous fishes of Acanthuridae and Scaridae exert the primary control on coral-algal dynamics and are implicated in determining phase shifts from coral to algal dominance especially in response to other pressures such as eutrophication, mass coral mortality (Obura and Grimsditch, 2009). The fishes of these two families were abundant on the reef flat.

The patterns of association showed that increasing the distance from the mouth of the valley corresponds to the increasing number of both species and fishes. Whereas, there was no correlation between depth and diversity and density reef fish (Fig. 7).

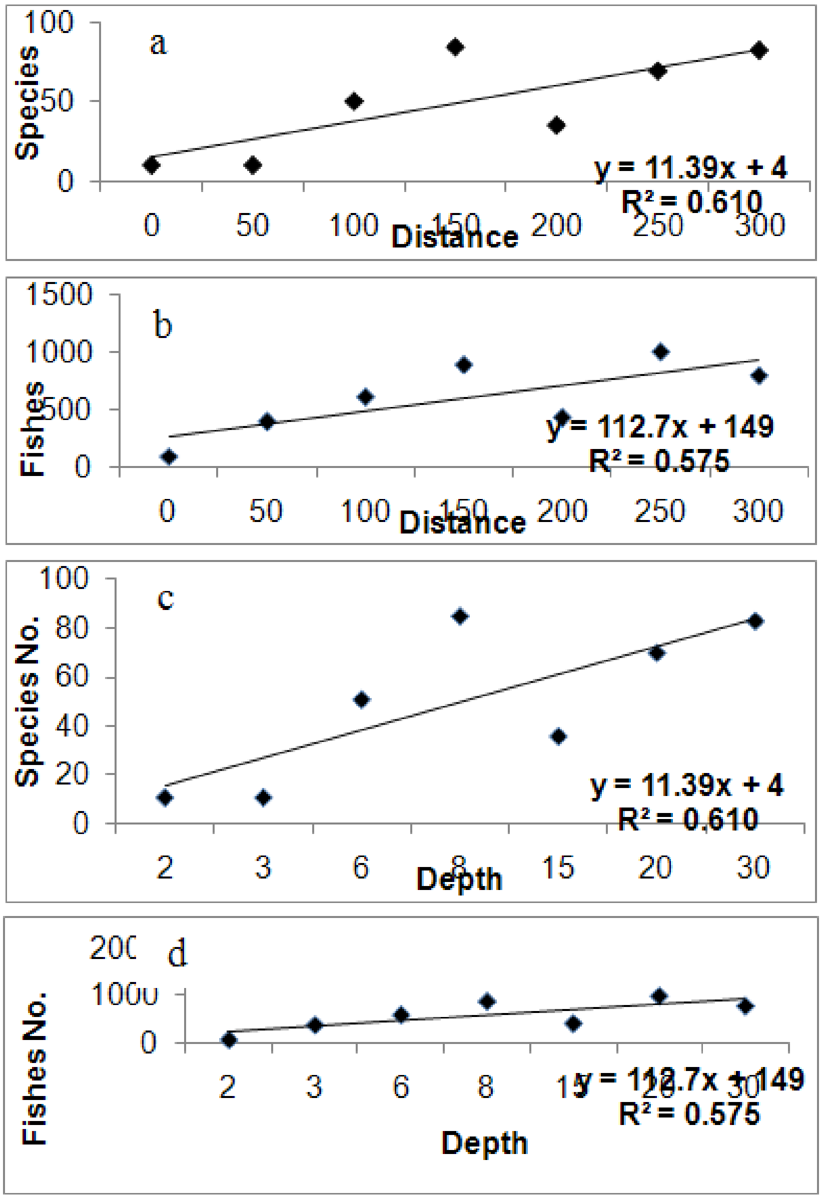

Fig. 7: Association pattern a) species with distance b) fishes with distance c) species with depth d) fishes with depth.

Climate change is expected to have serious consequences for Earth's ecological systems, resulting in an overall loss of diversity, disruptions to ecosystem processes and a reduction in the ecological goods and services provided to human societies (Thomas *et al*, 2004; Lovejoy and Hannah, 2005). Shifts in plant and animal distributions, changes to population abundances, adjustments to the timing of seasonal activities, increased prevalence of disease and the spread of invasive species have already been linked to climate change (Root *et al*., 2003; Parmesan, 2006). Cyclonic winds and floodwaters can have severe impacts on coral reef ecosystems (Thomas *et al*. 2004; Lovejoy and Hannah, 2005). Tropical cyclones often cause a temporary decline in the abundance of some fishes on impacted reefs (Halford *et al*., 2004) due to the loss of critical habitat or food for certain species (Wilson *et al*. 2006).

Floodwaters entering through the mouth of Wadi El-Gemal valley can cause stress to inshore ecosystems by reducing salinity, increasing turbidity and elevating concentrations of nutrients. Prolonged exposure can lead to death in some species, especially sessile organisms such as corals and seagrasses that provide essential habitat and food for fish, turtles and dugong. Changes to the composition and structure of coral reef habitats are expected to have further significant consequences for fish populations and communities (Pratchett *et al.* 2008).

Changes to fish populations and communities could have important feedbacks to other parts of the reef ecosystem and to human societies. Fishes have a significant presence in all major feeding groups and are important for energy transfer throughout the reef system (Depczynski *et al*. 2007). They are the dominant large predators on reefs and their presence influences the community structure and abundance of smaller species (Hixon, 1991; Almany and Webster, 2004). Some reef fishes, such as grazing herbivorous fishes have key functional roles, preventing the growth of macroalgae that might otherwise smother corals (Bellwood *et al*., 2004; Hughes *et al*. 2007). Other species facilitate the settlement of corals by removing sediment and fine algae from the substratum (Steneck, 1997). Reef fishes also have high social and economic value. They are the basis for subsistence and artisanal lifestyles of coastal communities in many tropical countries and they also support significant commercial fisheries (McClanahan *et al*., 2005; Sadovy, 2005).

A total of 1078 species of fishes has been recorded in the Red Sea (Golani and Bogorodesky, 2010). This number has been increased by recording the slender sunfish last summer in Hurghada (Abu El-Regal and Elmoselhy, 2013). Nearly half of these are associated with coral reefs (Bellwood and Waineright, 2002), yet how they will be affected by climate change has received remarkably little attention.

Floods in Wadi El-Gemal bring not only fresh water that decreases the salinity but also bring heavy metals that accumulate in the sediments and corals and inhibit coral growth (Mansour, 2003; Madkour *et al*., 2013). Madkour *et al*., (2013) found that the

concentrations of some metals in sediments and coral reefs, the studied area recorded high concentrations of some heavy metals than that of the anthropogenic activities of the Egyptian Red Sea coast. The high concentration of heavy metals in the sediments and the studied species of coral reefs can be attributed to the natural impact resulting from the high contribution of terrigenous inputs through this wadi.

This work is an attempt to examine the status of the reef fishes in one of the most active valleys along the Red Sea coast. The impacts of climate change vary among life stages, with the larval and reproductive stage expected to be most vulnerable. Most coral reef fishes have a life cycle that includes a pelagic larval stage lasting for a few weeks to months (Leis 1991). When they are sufficiently well developed, the larvae settle to the reef and become part of the reef-based population. Patterns of larval survival and dispersal play a key role in the dynamics of reef fish populations (Doherty 1991) and the ecological and genetic connectivity between populations (Sale 1991; Cowen 2002). Larval reef fishes are highly sensitive to environmental conditions (Leis and McCormick, 2002) and any effects of climate change on the number of larvae produced, or their growth, survival and dispersal patterns, could have significant consequences for adult populations.

The floods from the Valley of Wadi El-Gemal may not have a direct effect on the reef fish community but it affect their home and substrate; coral reefs and seagrasses. The fish community near the mouth of the valley has been greatly affected due to the damage caused to the reef as a result of the decreases salinity. The diversity of reef fishes increased significantly as we moved away from the mouth of the valley.

The impact of the flooding on the marine life in Wadi El-Gemal is only natural one and is slightly combined with anthropogenic impacts. Form marine management point of view, although this is an impact, it is natural, and in all cases local, because flash floods take place only at the downstream of Wadis. These Wadis are exceptional and do not exist everywhere in the Red Sea. Instead they only exist when environmental conditions are favorable (about 30 Wadis on the Egyptian Coast, of which 5-6 Wadis have proper stream into the sea).

The study area, protectorate and is well managed. Therefore, anthropogenic impacts are under control. Accordingly, there is no solution, from management view; despite that the phenomena is useful and leads to flourishing the marine environment. Although flash floods within the Red Sea is one of the development constraints, local solutions including scattered dams and road protections were constructed by the government and investors at specific sites. The Government of Egypt is producing the flash flood Atlas, to be used as the baseline to prepare a national strategy for flash flood.

Water from the flood is rarely used for agriculture because it is not consistent that is why it is only used for drinking.

This work also establishes a database about the marine life in one of the most active valleys along the Red Sea coast. The current data could be useful for any future management plans for the sustainable use area. Wadi El-Gemal area is declared as a protected area in November 2003. Wadi El-Gemal protected Area WGPA) includes not only marine but also terrestrial animals such as beer and lizards that depends mainly on well’s water for drinking and the dense vegetation for feeding.

A general conservation management plan for Wadi El Gemal National Park was adopted in March 2004, but the parks size makes it impractical to provide detailed management plans for the whole area in one document. The 770 km^2 area needs an integrated management plan that maintains the high biological diversity and the landscape features and promotes public understanding of Egypt’s natural heritage.

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ARABIC SUMMRY

تأثير السيول على كثافة و تنوع اسماك الشعاب المرجانية بمحمية وادي الجمال -البحر الاحمر- مصر

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أجريت هذه الدراسة بمنطقة وادى الجمال على الساحل الجنوبى للبحر الأحمر المصرى باستخدام العد تحت الماء لتحديد التركيب النوعى لمجتمع أسماك الشعاب المرجانية بالمنطقة ودراسة تأثير مخر السيول على كثافة وتنوع الأسماك. تقع منطقة الدراسة فى مقابلة الوادى وقد تم تقسيمها إلى ثلاث قطاعات حسب قربها من المخر كما تم تقسيم كل قطاع إلى ثلاث مناطق حسب العمق هى مسطح الشعاب وحافة الشعاب ومنحدر الشعاب. تم تسجيل أعداد وأنواع الأسماك فى كل منطقة. تم تسجيل ٤٣٨٨ سمكة تنتمى ل ٤٩ نوع و٢٣ عائلة من أسماك الشعاب المرجانية. سجل أكبر عدد من الأنواع على منحدر الشعاب بالقطاع الثانى (٨٥ نوع) بينما سجل أقل عدد من الأنواع على مسطح الشعاب (١١ نوع). لم تسجل اختلافات فى التوزيع الموسمى للأسماك. لوحظ زيادة في تنوع وكثافة الأسماك كلما ابتعدنا عن المخر.