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Distribution and Diversity of Six Common Reef Fish Families along the Egyptian Coast of the Red Sea

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Abstract: This study examines the distribution and diversity of six common families of reef fishes (Pomacentridae, Chaetodontidae, Pomacanthidae, Acanthuridae, Labridae and Scaridae) in two reef zones at 20 sites along the Egyptian coast of the Red Sea. A total of 91 fish species were recorded, representing 41 genera. The Sharm El-Sheikh region has the highest number of species (75), whereas the northern part of the Gulf of Aqaba has the lowest number (40). The highest average abundance was recorded at Ras Mohammed (2921 fish/600 m^3). Most individuals belonged to the families Pomacentridae (52.1%), followed by the Acanthuridae (19.5%), Labridae (14.7%), Chaetodontidae (7.1%), Scaridae (5.2%) and Pomacanthidae (1.3%). Average species richness ranged from 6.2 (northern Gulf of Aqaba) to 10.2 (Sharm El-Sheikh). In general, the number of species of all selected families was higher on the reef slope than on the reef flat. There was no clear zonation (restriction to reef flat versus reef slope) in the distribution of Pomacentridae, Acanthuridae, Labridae and Scaridae along the Egyptian reefs, although preferences were evident. On the other hand, certain species of Chaetodontidae and Pomacanthidae clearly preferred the reef slope. This study reveals clear geographical differences in the fish communities of the Egyptian Red Sea reefs, differences that should be taken into consideration for crucial future conservation efforts here.

Key words: Abundance, coral reef fishes, Egypt, Red Sea, species diversity

INTRODUCTION

Fishes are the most visible and important mobile component in the coral reef ecosystem (Letourneur *et al*., 2000). The high diversity of coral reef fish communities includes a large within-habitat component (Goldman and Talbot, 1976), wherein large numbers of species may co-occur in a very small space. Most coral reefs show a clear zonation and, within a reef, numbers and types of organisms may vary in the different zones.

Fishes are also influenced by this reef zonation, which is reflected in great spatial heterogeneity in terms of substrate composition and structural complexity (Done, 1982; Glynn *et al*., 1996; Rajasuriya *et al*., 1998). Accordingly, certain fish species or assemblages are characteristic for certain zones (Bell and Galzin, 1984; Harmelin-Vivien, 1989; Alwany, 1997; McClanahan and Arthur, 2001; Garpe and Öhman, 2003). They may be selective or non-selective, obligate, facultative or opportunistic in relation to their habitat (Bergman *et al*., 2000). Many reef fishes associate with particular microhabitats within the above-mentioned zones (Sale, 1991), although the importance of such associations in determining larger-scale patterns of distribution and abundance appears to vary widely among species (Munday, 2000).

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While the Red Sea fish fauna is taxonomically quite well known compared with other parts of the tropical Indo-Pacific Ocean, the structure of coastal fish communities has been less well investigated (Khalaf and Kochzius, 2002). The present study investigates community structure at local (reef flat versus slope) and at latitudinal (23-29° N) spatial scales. Information about the distribution and species diversity of reef fish communities along the Egyptian Red Sea coast is a prerequisite for future conservation and management measures.

MATERIALS AND METHODS

Study Area

Twenty reefs were studied in the summer of 1999 along the Egyptian coast of the Red Sea, spanning a distance of 1200 km (Fig. 1 and Table 1) from 23° N to 29° N. The reef type varied between coastal, barrier and island reefs along the Egyptian Red Sea coast. The study sites cover five different geographical regions (Gulf of Aqaba, Sharm El-Sheikh, Hurghada, Hamata and Shalateen) of the Egyptian coast of the Red Sea (Table 1).

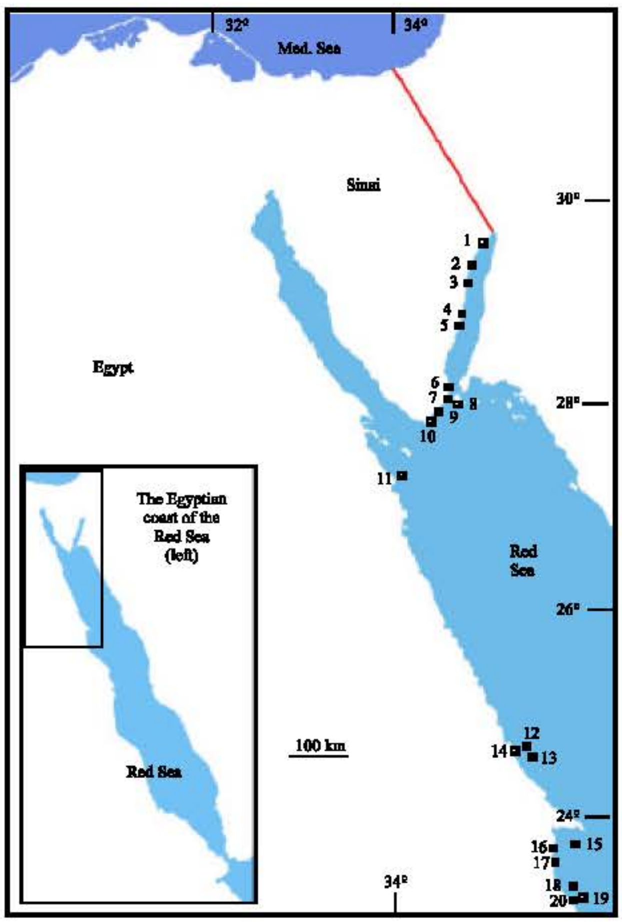

Fig. 1: The northern Red Sea showing the Egyptian coast and the study sites. For site names, compare numbers in Table 1

Table 1: List of sites and regions showing their locations, Reef Type (RT), site codes and brief description of Reef Flat (RF) and Reef Slope (RS) along the Egyptian Red Sea coast. (C = Coastal, I = Island, B = Barrier, WA = Wave Action, TW = Turbid Water, CU = Current)

Regions	Sites (code)		Location	RT	Remarks
Gulf of Aqaba					
	1	Beer Sweer	29° 08′ N	C	RF: rich in algae + TW
		(BS)	34° 41′ E		RS: scattered coral colonies + TW
	2	Maganah	29° 02′ N	C	RF: well-developed coral communities
		(MA)	34° 40′ E		RS: well-developed corals + weakly WA
	3	Newiubaa	28° 56′ N	C	RF: rich in algae and sea urchins
		(NE)	34° 39′ E		RS: rich in corals + TW + weak WA
	4	Canyon	28° 36′ N	C	RF: rich in algae and coral colonies
		(CA)	34° 30′ E		RS: well-developed corals + strong WA
	5	El-Masbat	28° 32′ N	C	RF: rich in algae and echinoderms
		(EM)	34° 29′ E		RS: well-developed coral communities + strong WA
Sharm El-Sheikh					
	6	Ras Tantur	27° 59′ N	C	RF: well-developed coral communities + strong WA
		(RT)	34° 22′ E		RS: well-developed coral communities + strong WA
	7	Ras Nassrani	27° 58′ N	C	RF: rich in algae and corals
		(RN)	34° 23′ E		RS: well-developed coral communities + strong WA
	8	Jordan reef	27° 58′ N	I	RF: rich in coral colonies and algae
		(JR)	34° 25′ E		RS: well-developed coral communities + strong CU
	9	Shoper reef	27° 58′ N	B	RF: rich in algae and echinoderms
		(SR)	34° 26′ E		RS: rich in corals and algae
	10	Ras Mohammed	27° 43′ N	C	RF: well-developed coral communities + strong WA
		(RM)	34° 15′ E		RS: well-developed coral communities + strong WA
Hurghada					
	11	Fanous reef	27° 15′ N	B	RF: rich in algae and branched corals
		(FR)	33° 53′ E		RS: well-developed corals + strong WA
Hamata					
	12	Seul Island	24° 22′ N	I	RF: poorly-developed corals + algae, sand and rocks
		(SI)	35° 23′ E		RS: rich in corals + weak WA
	13	Shawateer Island	24° 21′ N	I	RF: rich in algae and coral colonies
		(SH)	35° 23′ E		RS: rich in coral colonies + TW + weakly WA
	14	South Hamata	24° 21′ N	C	RF: rich in algae and it has mangrove trees on shore
		(HH)	35° 19′ E		RS: rich in corals and algae
Shalateen					
	15	Mirear	23° 11′ N	B	RF: well-developed coral communities
		(MI)	35° 38′ E		RS: well-developed coral communities
	16	Shalateen coast	23° 09′ N	C	RF: rich in algae and echinoderms + rocks + TW
		(SC)	35° 36′ E		RS: well-developed corals and algae
	17	Marsa Shab	22° 30′ N	C	RF: rich in algae and corals
		(MS)	36° 11′ E		RS: rich in coral colonies + algae + TW
	18	Sial Island	22° 47′ N	I	RF: rich in many groups of algae
		(SL)	36° 12′ E		RS: rich in corals + algae
	19	Dibia Patch	22° 23′ N	P	RF: rich in many groups of algae
		(DP)	36° 29′ E		RS: rich in coral colonies + TW
	20	Abu Ramad	22° 23′ N	C	RF: rich in algae and corals
		(AR)	36° 25′ E		RS: well-developed coral communities

Families Investigated

The species composition of the Egyptian Red Sea reefs is examined here based on six common families, representing a wide range of species of different sizes and trophic affiliations: damselfishes (Pomacentridae), butterflyfishes (Chaetodontidae), angelfishes (Pomacanthidae), surgeonfishes (Acanthuridae), wrasses (Labridae) and parrotfishes (Scaridae). These fishes are highly visible and represented about 88% of total fish population in the northern Red Sea (Alwany *et al*., unpublished data) on shallower reefs. The goal was not to provide a taxonomically exhaustive list: Some species were present in the study area but were absent inside our investigated transects. Fish nomenclature follows that in FishBase (www.fishbase.com).

Field Methods

Underwater visual census techniques have been used to record fish densities on reefs for fifty years (Brock, 1954) and form the basis for population ecology studies and management decisions (Harmelin-Vivien *et al*., 1985). Furthermore, they provide rapid estimates of the relative abundance and distribution of reef fishes (Samoilys and Carlos, 2000). Here, members of the six families were counted using this approach along transects ($100\times6\times1 = 600$ m^3) on the reef flat (RF, depth: 0.5-1 m) and reef slope (RS, depth: 1-8 m). On the reef flat, fishes were observed using snorkeling, on the reef slope using SCUBA during day-time from 1100 to 1400.

Data Analysis

The data were analysed statistically using the software packages PRIMER (V 5.0) and SPSS (V 11.5). The species present in the two zones were compared using the Bray-Curtis similarity index. Species richness was expressed by considering the number of species (D) and species diversity and homogeneity were determined using the Shannon-Wiener diversity index (H') and the evenness index (J') (Pielou, 1966). These parameters were calculated for each site by pooling data from the sample replicates. When necessary, abundance data were square root transformed to produce normality and homogeneity of variance.

RESULTS

General Distribution and Abundance

The species recorded at different reef types at twenty sites along the Egyptian Red Sea coast are listed in Table 2. In the six selected families, a total of 91 fish species representing 41 genera were counted. The Sharm El-Sheikh region had the highest number of species (site 10-RM, 75 species), while the northern part of Gulf of Aqaba had the lowest number (site 3-NE, 40 species). The highest average abundance was also recorded at site 10-RM (2921 fish/600 m^3), with the lowest value at sites 1-BS and 12-SI (222 fish/600 m^3). Table 2 shows that most individuals belonged to the Pomacentridae (52.1%, 29 species), follow by the Acanthuridae (19.5%, 8 species), Labridae (14.7%, 26 species), Chaetodontidae (7.1%, 11 species), Scaridae (5.2%, 12 species) and Pomacanthidae (1.3%, 5 species). In general, the number of species of all families was higher on the reef slope than reef flat. The results of one-way ANOVA, based on diversity indices and showing the effect of factors site and zone, are given in Table 3. The number of species varied highly significantly between the two zones ($p<0.001$), while the influence of sites was not significant ($p = 0.632$). The number of individuals also differed significantly between zones ($p = 0.007$), but not among sites ($p = 0.233$). Average species richness ranged from 6.2 at site 3-NE to 10.2 at site 7-RN ($p = 0.874$ among sites and $p < 0.001$ among zones). The highest evenness index (J′) was recorded at site 17-MS (0.9), while site 4-CA yielded the lowest value (0.6) ($p = 0.151$ among sites and $p = 0.446$ among zones). Average Shannon-Wiener diversity (H′) varied between 3.8 at site 15-MI and 2.4 at site 4-CA ($p = 0.188$ among sites and $p = 0.057$ among zones).

The Bray-Curtis similarity index cluster analysis of the reef flat according to fish abundance is shown in Fig. 2. This dendrogram revealed two main groups: 1. Gulf of Aqaba, Sharm El-Sheikh, Hurghada and Hamata regions (11 sites) and 2. Shalateen region (6 sites + 2 sites from the Sharm El-Sheikh region). One site (12-SI) was not assigned to either group identified above. The reef flat at this site had many rocks and was not suitable for fishes. According to this grouping, the reef flat of the Egyptian Red Sea coast is therefore divided into north (29°-24° N) and south geographical regions (24-23° N). On the other hand, the cluster analysis based on fish abundance on the reef slope revealed four main groups (Fig. 3): 1. Sharm El-Sheikh and Hurghada regions (5 sites), 2. Shalateen region (6 sites), 3. Hamata region (3 sites) and 4. Gulf of Aqaba (6 sites). This analysis clearly differentiates

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Table 2: Presence (+) and absence (-) of reef fish species, includes the number of species, number of individuals, species richness (D), evenness (J´), Shannon-Wiener (H´) and percentage of families along the Egyptian coast of the Red Sea (for abbreviations see Table 1)

	North					Sites									South					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fishes	BS	MA	NE	CA	EM	RT	RN	JR	SR	RM	FR	SI	SH	HH	MI	SC	MS	SL	DP	AR
Pomacentridae																				
Abudefduf saxatilis	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
A. sexfasciatus	-	-	-	-	+	-	+	+	+	+	+	+	-	+	+	+	+	+	+	+
A. sordidus	-	-	-	-	-	+	-	-	-	-	+	-	-	-	+	+	+	+	+	-
Amblyglyphidodon flavilatus	-	-	-	-	-	+	+	+	-	-	+	+	-	+	+	+	+	+	+	+
A. leucogaster	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Amphiprion bicinctus	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+
Chromis caerulea	-	-	-	-	-	+	+	+	-	-	-	-	+	+	-	-	-	-	-	-
C. dimidiata	+	-	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
C. ternatensis	-	-	+	-	+	+	+	+	-	+	-	-	+	-	-	-	+	+	-	-
C. trialpha	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-	-	+	-	-	-
C. weberi	-	-	-	-	-	+	+	+	-	+	-	-	+	+	+	+	+	+	-	-
Chrysiptera annulata	-	-	+	+	-	+	+	-	-	+	+	-	+	+	+	+	+	+	-	+
C. unimaculata	+	-	+	-	-	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+
Dascyllus aruanus	-	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
D. marginatus	-	-	-	-	-	+	+	+	-	+	-	+	-	+	+	+	+	+	+	+
D. trimaculatus	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	+	-	-	-	-
Neoglyphidodon melas	-	-	-	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+
Neopomacentrus miryae	-	+	-	-	-	+	+	+	-	-	+	-	-	-	+	+	-	-	-	+
N. xanthurus	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Plectroglyphidodon lacrymatus	+	-	+	+	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+
P. leucozona	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+
Pomacentrus albicaudatus	+	+	+	-	-	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+
P. aquilus	+	+	+	+	-	+	+	-	+	+	+	-	+	+	+	+	+	+	+	+
P. leptus	-	-	-	-	-	-	+	-	-	+	-	-	-	-	+	-	-	-	-	-
P. sulfureus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
P. trichourus	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+
P. trilineatus	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pristotis cyanostigma	+	-	+	+	+	+	+	+	-	+	-	-	+	+	+	+	+	+	-	+
Stegastes nigricans	+	+	+	+	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	-

Table 2: Continued

	North					Sites									South					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fishes	BS	MA	NE	CA	EM	RT	RN	JR	SR	RM	FR	SI	SH	HH	MI	SC	MS	SL	DP	AR
Chaetodontidae																				
Chaetodon auriga	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
C. austriacus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
C. fasciatus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
C. larvatus	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	+	+	+	+
C. lineolatus	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
C. melannotus	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
C. mesoleucos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
C. paucifasciatus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-
C. semilarvatus	-	-	-	-	-	+	+	-	-	+	+	+	+	-	+	+	-	+	-	-
C. trifascialis	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	-	-
Heniochus intermedius	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
Pomacanthidae																				
Centropyge multispinis	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+
Pomacanthus asfur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
P. imperator	-	-	-	+	-	-	+	+	-	+	-	-	-	-	-	-	-	-	-	+
P. maculosus	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	+	+	-	+
Pygoplites diacanthus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Acanthuridae																				
Acanthurus gahhm	-	-	-	-	-	-	+	+	-	+	-	+	+	+	+	+	+	+	+	+
A. nigrofuscus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
A. sohal	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ctenochaetus striatus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Naso lituratus	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
N. unicornis	+	+	-	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+
Zebrasoma desjardinii	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Z. xanthurum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+
Labridae																				
Anampses caeruleopunctatus	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. lineatus	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. meleagrides	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Bodianus anthioides	-	-	-	+	-	-	+	+	-	+	+	+	-	-	-	-	-	-	-	-

Table 2: Continued

Fishes	North					Sites									South					
	1 BS	2 MA	3 NE	4 CA	5 EM	6 RT	7 RN	8 JR	9 SR	10 RM	11 FR	12 SI	13 SH	14 HH	15 MI	16 SC	17 MS	18 SL	19 DP	20 AR
Cheilinus abudjubbe	-	+	-	+	-	-	+	+	-	+	-	-	+	+	-	+	-	+	-	-
C. digrammus	-	-	-	-	-	-	+	+	+	+	-	-	-	-	+	-	-	-	-	-
C. fasciatus	-	-	-	-	-	-	+	+	-	+	+	+	+	-	+	+	+	+	+	+
C. lunulatus	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
C. mentalis	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	+	+	-	+	-
C. undulatus	-	-	-	-	-	-	+	+	-	+	+	-	-	-	+	-	-	+	+	-
Coris aygula	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	-	-	-	-
C. gaimard	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Epibulus insidiator	-	-	-	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Gomphosus coeruleus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Halichoeres hortulanus	+	+	-	-	-	-	+	-	-	+	-	-	-	-	+	+	+	+	+	+
H. marginatus	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-
H. scapularis	-	-	-	-	-	-	+	-	-	+	-	-	-	-	+	+	-	+	-	+
Hemigymnus fasciatus	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+	-
Labroides dimidiatus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Larabicus quadrilineatus	-	+	+	+	+	-	-	+	+	-	-	+	+	+	+	+	+	+	+	+
Novaculichthys taeniourus	+	+	-	+	-	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+
Pseudocheilinus hexataenia	+	+	-	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+	-	-
Pseudodax moluccanus	-	-	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Stethojulis albovittata	+	+	+	+	+	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-
S. interrupta	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Thalassoma rueppellii	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Scaridae																				
Bolbometopon muricatum	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Cetoscarus bicolor	-	+	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
Chlorurus gibbus	-	-	-	+	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-
C. sordidus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Hipposcarus harid	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Scarus collana	-	-	-	-	-	+	+	+	+	+	-	+	+	-	+	+	+	+	+	+
S. ferrugineus	+	+	-	+	+	-	+	+	+	+	+	-	-	+	+	+	+	+	+	+
S. frenatus	+	+	-	+	+	+	+	+	+	+	+	-	+	+	+	+	+	-	+	+
S. fuscopurpureus	-	-	-	+	+	+	+	+	-	+	+	-	-	-	-	+	+	+	+	+

Table 2: Continued

		North					Sites									South					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fishes		BS	MA	NE	CA	EM	RT	RN	JR	SR	RM	FR	SI	SH	HH	MI	SC	MS	SL	DP	AR
S. ghobban		+	+	-	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
S. niger		-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. psittacus		-	-	-	-	-	-	+	+	+	+	+	-	-	+	+	+	+	+	+	+
No. of species		43	46	40	57	46	62	73	67	49	75	61	45	56	56	68	65	63	65	57	57
No. of individuals		222	585	561	1212	315	727	1147	976	309	2921	1020	222	386	373	906	677	881	840	786	623
Species richness (D)		7.78	7.06	6.16	7.89	7.82	9.26	10.2	9.59	8.37	9.27	8.66	8.14	9.23	9.29	9.84	9.82	9.14	9.51	8.40	8.70
Evenness (J´)		0.85	0.79	0.75	0.60	0.80	0.85	0.82	0.63	0.83	0.62	0.64	0.77	0.79	0.81	0.89	0.88	0.92	0.89	0.86	0.86
Shannon-Wiener (H´)		3.21	3.02	2.75	2.41	3.08	3.50	3.5	2.65	3.23	2.66	2.62	2.94	3.19	3.25	3.76	3.68	3.71	3.71	3.47	3.47
% Pomacentridae	(average = 52.1%)	29.3	41.7	48.7	61.1	37.5	51.4	52.4	64.5	26.9	76.0	71.4	42.8	54.7	55.5	52.1	58.5	45.9	55.4	59.9	55.4
% Chaetodontidae	(average = 7.1%)	13.7	5.8	14.3	3.9	18.2	9.6	7.4	5.5	10.8	3.3	8.7	3.9	6.3	6.6	5.9	5.1	3.2	4.3	3.0	1.5
% Pomacanthidae	(average = 1.3%)	2.9	1.1	1.8	0.6	1.9	1.1	0.7	1.0	4.4	0.5	1.5	1.1	0.8	0.4	1.1	1.2	1.1	1.0	1.4	1.1
% Acanthuridae	(average = 19.5%)	30.5	29.2	19.8	20.1	19.7	24.7	12.8	13.1	22.6	6.1	9.6	35.1	21.2	17.1	14.4	9.2	20.9	20.6	17.8	25.0
% Labridae	(average = 14.7%)	19.1	14.9	15.0	12.0	16.0	7.6	22.9	13.0	30.8	11.1	5.9	13.2	14.8	14.6	15.7	17.7	14.5	12.9	10.6	12.2
% Scaridae	(average = 5.2%)	4.7	7.2	0.3	2.3	7.0	5.5	3.8	2.9	4.5	2.9	3.0	4.2	2.3	5.6	7.8	8.2	14.5	5.8	7.3	4.8

Table 3: Results of one-way ANOVA performed on diversity indices showing the influence of sites and zones (**p<0.01, ***p<0.001)

Families	Source of variation	df	MS	F	P
Number of species	Sites	19	189.5	0.86	0.632
	Zones	1	4182.0	41.25	0.000***
Number of individuals	Sites	19	17197.9	1.40	0.233
	Zones	1	1005511.4	8.09	0.007**
Species richness (D)	Sites	19	2.2	0.59	0.874
	Zones	1	64.4	48.63	0.000***
Evenness (J´)	Sites	19	0.012	1.61	0.151
	Zones	1	0.006	0.59	0.446
Shannon-Wiener (H´)	Sites	19	0.267	1.50	0.188
	Zones	1	0.795	3.85	0.057

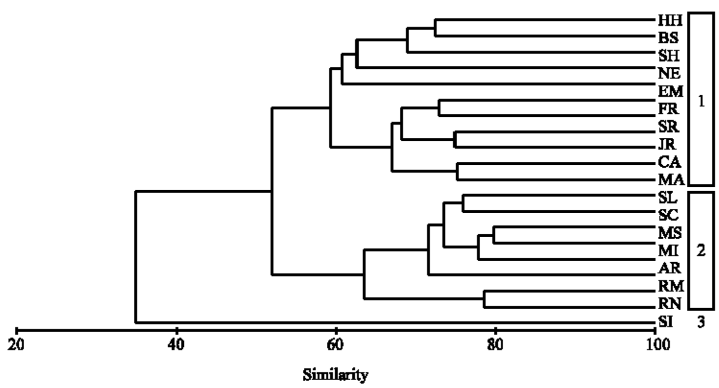

Fig. 2: Cluster analysis dendrogram (Bray-Curtis similarity, square root transformation, group average) showing associations of 20 sites on the reef flat along the Egyptian Red Sea coast

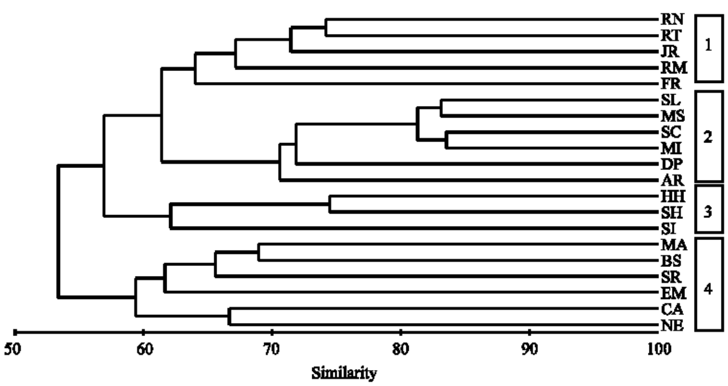

Fig. 3: Cluster analysis dendrogram (Bray-Curtis similarity, square root transformation, group average) showing associations of 20 sites on the reef slope along the Egyptian Red Sea coast

the geographical distribution of fish assemblages on the Egyptian reef slope. Accordingly, the reef slope (from reef edge to 10 m depth) of the Egyptian Red Sea coast can be divided into four geographical regions based on fish assemblages: 1. Gulf of Aqaba region (27-29° N), 2. Sharm El-Sheikh and Hurghada region (25-27° N), 3. Hamata region (24-25° N) and 4. Shalateen region (23-24° N). Thus, the reef flat and reef slope yielded very similar results, although the latter provided a somewhat more differentiated picture.

Pomacentridae (Damselfishes)

Pomacentridae had by far the highest number of species and individuals in both reef zones along the Egyptian Red Sea coast (Fig. 4). In general, *Amblyglyphidodon leucogaster* and *Pomacentrus sulfureus* were the most frequent species here (represented at all sites). The least common species were *Dascyllus trimaculatus*, *Neopomacentrus xanthurus* and *P. leptus*. This family is not restricted to a particular zone but does show preferences. Two groups were distinguished: The first preferred the reef flat (*Plectroglyphidodon leucozona* and *P. lacrymatus*), while the second preferred the reef slope (*D. aruanus*, *D. marginatus*, *Chromis dimidiata*, *C. weberi*, *C. ternatensis*, *P. sulfureus* and *A. leucogaster*). *C. dimidiata* was the most abundant damselfish species at all investigated sites (142.2 fish/600 m^3); it clearly prefers the reef slope (95.4%) over the reef flat (4.6%) due to its feeding activities (planktonic feeder). Overall, this family shows no clear geographical trend along the Egyptian reefs, although *Abudefduf sordidus*, for example, apparently preferred the southern region (Table 2). The one-way ANOVA showed an influence of species ($p<0.001$), sites ($p = 0.002$) and zones ($p<0.001$, Table 4) on the abundance.

Chaetodontidae (Butterflyfishes)

The average number of species and individuals was higher on the reef slope than on the reef flat (Fig. 4). *Chaetodon austriacus* was the most abundant butterflyfish species (11.7 fish/600 m^3), followed by *C. paucifasciatus* (7.3 fish/600 m^3). *Chaetodon auriga* and *C. fasciatus* were recorded at all sites. A zonation preference (i.e., more abundant on reef slope) was very clear for some species, such as *C. semilarvatus* and *Heniochus intermedius*, even though the latter two were hardly restricted to the reef slope at all sites. On the other hand, a preferred geographical distribution was recorded for *C. larvatus* and *C. mesoleucos*, the former being restricted to southern Egyptian reefs (Hurghada region and south from 23 to 27° N), the latter to the Shalateen region (23 to 24° N). Neither species was recorded in the Gulf of Aqaba. Furthermore, *C. semilarvatus* and *C. melannotus* were not observed at any Gulf of Aqaba sites (north) and were rare in the Shalateen region (south). One-way ANOVA indicated that the butterflyfish abundances varied highly significantly among the species, sites and zones ($p<0.001$).

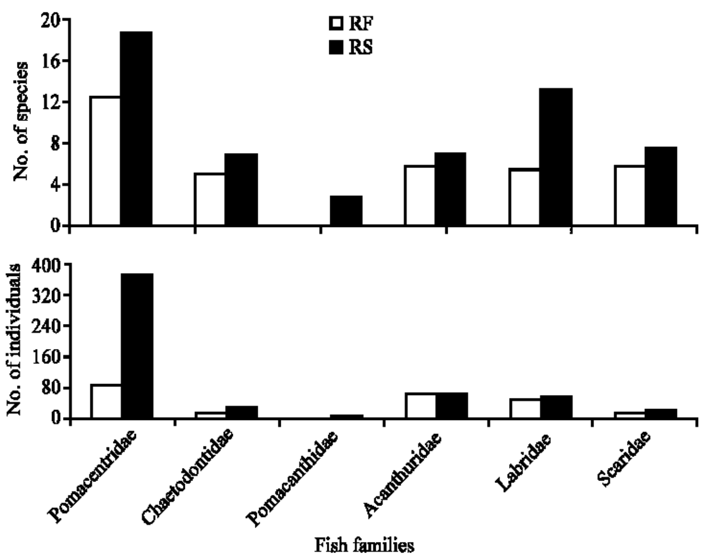

Fig. 4: Average number of species and individuals for six families along the Egyptian Red Sea coast on the Reef Flat (RF) and Reef Slope (RS)

Table 4: Results of one-way ANOVA performed on fish abundance showing the influence of fish species, sites and reef zones (*p<0.05, **p<0.01, ***p<0.001)

Families	Source of variation	DF	MS	F	P
	Species	28	6674.35	4.31	0.000***
Pomacentridae	Sites	19	3705.39	2.26	0.002**
	Zones	1	27311.81	16.54	0.000***
	Species	10	124.93	14.99	0.000***
Chaetodontidae	Sites	19	31.38	3.12	0.000***
	Zones	1	270.07	25.98	0.000***
	Species	4	24.11	10.28	0.000***
Pomacanthidae	Sites	19	1.50	0.51	0.954
	Zones	1	86.67	36.74	0.000***
	Species	7	1334.06	15.43	0.000***
Acanthuridae	Sites	19	176.53	1.61	0.053
	Zones	1	7.71	0.07	0.795
	Species	25	1559.77	29.77	0.000***
Labridae	Sites	19	102.59	1.16	0.284
	Zones	1	19.21	0.22	0.642
	Species	11	89.39	13.68	0.000***
Scaridae	Sites	19	37.74	5.22	0.000***
	Zones	1	43.97	5.26	0.022*

Pomacanthidae (Angelfishes)

This family had the lowest number of species and individuals, with values being higher on the reef slope (Fig. 4). *Centropyge multispinis* was the most abundant representative (3.8 fish/600 m^3) and was clearly restricted to the reef slope of all sites. *Pomacanthus imperator* was the rarest angelfish, present in only 5 of 20 sites. *Pygoplites diacanthus* was the most frequent representative on the Egyptian reefs (represented at all sites) and was equally present on both reef zones. Geographically, the Shalateen region (in the south) was richer in angelfishes (5 species). *P. asfur* and *P. maculosus* were found frequently at the southern sites and the former was very rare in the northern sites. One-way ANOVA shows no significant difference in angelfish abundance among sites (p = 0.954), but the difference was highly significant among species and zones.

Acanthuridae (Surgeonfishes)

The surgeonfishes were the most regularly distributed fish group along the Egyptian reefs, except in the northern part of the Gulf of Aqaba. The number of species was higher on the reef slope, but the number of individuals was nearly the same in both zones (Fig. 4). *Acanthurus nigrofuscus* was the most abundant surgeonfish (36.7 fish/600 m^3). Some acanthurids preferred the reef flat (*A. nigrofuscus*, *A. sohal* and *Ctenochaetus striatus*), while others preferred the reef slope (*A. gahhm*, *Naso lituratus*, *N. unicornis*, *Zebrasoma desjardinii* and *Z. xanthurum*). No geographical trend was observed in the distribution of acanthurids, except that *A. gahhm* was not recorded in the Gulf of Aqaba (27° to 29° N). One-way ANOVA indicated that the surgeonfish abundances varied highly significantly among species. In contrast, the effect of sites and zones was not significant (p = 0.053 and 0.795, respectively).

Labridae (Wrasses)

Wrasses had the second highest number of species on the reef slope after damselfishes. The average number of species was higher on the reef slope than on the reef flat, but individual numbers were very similar in both zones (Fig. 4). *Thalassoma rueppellii* was the most abundant species (63.7 fish/600 m^3), followed by the cleaner wrasse *Labroides dimidiatus* (12.6 fish/600 m^3). Over all sites, three species (*Gomphosus coeruleus*, *L. dimidiatus* and *T. rueppellii*) were recorded frequently and regularly. There was no clear zonation preference in the distribution of wrasses: Some species (e.g., *T. rueppellii*) preferred the reef flat, others the reef slope (e.g., *G. coeruleus* and

L. quadrilineatus). The remaining species roved frequently in all zones. No clear geographical pattern of wrasse distributions along the Egyptian reefs emerged. One-way ANOVA showed that the influence of species is highly significant ($p<0.001$), but the influence of sites and zones was not significant ($p = 0.284$ and $p = 0.642$, respectively).

Scaridae (Parrotfishes)

The average number of scarid species and individuals was somewhat higher on the reef slope than on the reef flat (Fig. 4). *Hipposcarus harid* was the most abundant parrotfish (10.2 fish/600 m^3). On the other hand, *Chlorurus sordidus* was the most frequent species (represented in all sites). No clear zonation preference was evident, except for *Cetoscarus bicolor*, which preferred the reef slope (75%) over the reef flat (25%). Most other species had very similar abundances in both zones. No clear geographical pattern of parrotfish distributions emerged. One-way ANOVA showed a highly significant difference in parrotfish abundance among species and sites ($p<0.001$) and a significant difference among zones ($p = 0.022$).

DISCUSSION

Local populations of marine reef fishes often show great spatial variation in abundance (Holbrook *et al.*, 2000). This variation results from a combination of many physical and biological factors that affect fish distribution and diversity. One example is the different distribution of fish groups, whereby herbivores are generally much more abundant in the shallow than in deeper reef zones (Bouchen-Navaro and Harmelin-Vivien, 1981). This probably reflects the richness of algae in this zone. In contrast, carnivorous fishes are usually more abundant on the reef slope.

Jennings *et al.* (1996) reported that the differences in the diversity and abundance of reef fish communities may also be attributed to spatial and temporal variations in recruitment (e.g., Doherty, 1991), habitat effects (e.g., Williams, 1991) and other factors. Habitat availability (Caley *et al*., 1996) and habitat preferences (Caley, 1995; Tolimieri, 1998b) also play a role. A variety of other factors, such as reef types or environmental conditions, can also interact with habitat associations to influence patterns of distribution and abundance (Wellington, 1992). Patterns of habitat use might also change from reef to reef depending on the intensity of interactions with other species (Werner *et al*., 1983). Finally, settlement and post-settlement processes influence abundance and distribution patterns (Gutiérrez, 1998).

General Distribution

Pomacentridae and Labridae dominated the fish fauna in terms of species richness along the Egyptian Red Sea reefs and Pomacentridae were most abundant. This result echoes the situation on the Great Barrier Reef and in New Caledonia, where Pomacentridae and Labridae are the dominant fishes (pomacentrids contribute the highest percentage of species, followed by labrids; Williams and Hatcher, 1983; Letourneur *et al*., 1997). The situation is also very similar in the Indian Ocean and central Pacific, except that the ranking of the first two groups is reversed: labrids contribute the highest percentage of species, followed by pomacentrids (Letourneur, 1996; Gladfelter *et al*., 1980). Closer to the study area, Khalaf and Kochzius (2002) demonstrated the same situation (as in the Indian Ocean) on a Jordanian reef (Gulf of Aqaba, Red Sea). In contrast, Caribbean reefs have a different composition (fewer Labridae, more Serranidae; Gladfelter *et al*., 1980; Pattengill *et al*., 1997). In the present study, pomacentrids also had the highest number of individuals. In agreement with our results, Khalaf and Kochzius (2002) demonstrated higher abundances at the reef slope versus shallow reefs (reef flat), due to schooling planktivorous fishes. On the Great Barrier Reef, Russ (1984b) demonstrated that the assemblages of herbivorous fishes (most of the species we investigated are herbivorous) on the reef flat tend to have relatively low numbers of species and individuals. Our results clearly support this relationship on the Egyptian Red Sea reefs.

Habitat Preferences

The specialization of some species on reef flat habitats and of others on reef slope habitats shows a certain degree of habitat segregation in the investigated Red Sea reefs. In principle, these species may either be occupying their preferred habitat (e.g., for feeding, nesting, sheltering, etc.) or be excluded from other habitats by competition. On the other hand, Russ (1984b) listed a few species that are almost equally abundant in all zones (e.g., *Chlorurus sordidus*, *Naso unicornis* and *C. gibbus*) on the Great Barrier Reef. He also reported certain species as being most abundant in the shallow (reef flat) zones (*Ctenochaetus striatus* and *Scarus frenatus*) or deep (reef slope) zones (*S. niger*). Our results agree with those of Russ for some species and disagree for others. Thus, in the present study, *C. sordidus* and *C. gibbus* were equally abundant in all zones in agreement with Russ, but *N. unicornis* preferred reef slope habitats (86.9%). Agreement was also achieved for *C. striatus* (reef flat), but *S. frenatus* was equally abundant in both zones. Our results for *S. niger* also agree with the findings of Russ (1984b).

Our results contrast with those of Ormond *et al.* (1996), who reported that damselfish are restricted to certain parts of the reef along the southern coast of Sinai (Egyptian Red Sea). In the present study, however, some pomacentrids did prefer certain zones, but were also recorded in other zones (although in low abundances). For instance, *Chromis dimidiata* preferred the reef slope (95.4%) over the reef flat (4.6%) due to its feeding activities (planktivorous, Masuda and Allen, 1993). Ormond *et al.* (1996) stated that many damselfishes were more abundant in some reef zones than others, some being restricted to a single zone, e.g., *Pomacentrus sulfureus*, which was only recorded on the reef edge. The present study, however, indicated that *P. sulfureus* was not restricted only to the reef edge, but also found on the reef flat (6.1 fish/600 m^3, 20.1%). On the other hand, the zonation preferences of butterflyfishes were very clear for some species. For example, *Chaetodon semilarvatus* and *Heniochus intermedius* were exclusively restricted to the reef slope of all investigated sites (100%) and were never recorded on the reef flat.

Geographical Distribution

Sheppard *et al.* (1992) examined the species richness of the families Pomacentridae, Chaetodontidae, Acanthuridae, Labridae, Scaridae and Serranidae (i.e., 5 of the 6 families investigated here) in the different regions of the northern Red Sea, Gulf of Suez and Gulf of Aqaba. They noted a decreasing number of species, from 100 at the southern coast of Egypt to 75 at the northern Gulf of Aqaba. Our results yielded virtually the same percentage between the two regions. In the present study, a total of 76 species (belonging to the studied families) were recorded in the southern region of the Egyptian Red Sea, while a total of 54 species were recorded in the northern Gulf of Aqaba (Sheppard *et al.*, 1992, 75.0%; our value: 71.1%). This small difference between the two percentages probably reflects the number of species of Serranidae (not considered in the present paper) and Pomacanthidae (not considered by Sheppard *et al.*, 1992) in the Red Sea.

The structure of both fish and coral communities differs between the northern and southern Red Sea reefs (Sheppard and Sheppard, 1991), with the northern part showing higher diversity. Rich coral communities are also present in the central part of the Red Sea (Roberts *et al.*, 1992). Our results revealed a more detailed geographical differentiation in terms of fish communities for the northern part. Based on reef flat assemblages, we can further divide this part of the Egyptian Red Sea coast into a north (24-29° N) and south regions (23-24° N). On the other hand, the reef slope yields four regions: Gulf of Aqaba (27-29° N), Sharm El-Sheikh and Hurghada (25-27° N), Hamata (24-25° N) and Shalateen (23-24° N, Fig. 3).

Shackley (1999) considers this coast to be one of the fastest growing resort areas in the world. Hawkins and Roberts (1996) predicted a 13-fold expansion of coastal tourism in Egypt and estimated that this would be associated with a rise from 19 to >26% of Egypt's reefs being affected by tourism.

In fact, the number of beds increased here from 64,500 to 145,200 between 1998 and 2002 alone and 84.5% of beds now under construction are in the Red Sea and South Sinai area (Ibrahim and Ibrahim, 2006). This trend will no doubt entail many critical environmental problems in the future for the coral habitats here. Such projected ecosystem degradation will require a huge scientific effort to provide information and support conservation and management measures, with one of the priority tasks being a better understanding of fish distribution and abundance. This study has grasped the opportunity to provide such baseline data as long as these reefs and their fish communities are still in a near-natural state.

CONCLUSIONS

The Red Sea is known for its high diversity and high degree of endemism, of coral reef fishes. At the same time, tourism along the Egyptian Red Sea coast is expanding at an unprecedented pace. Nowhere worldwide may it be more important to determine the pre-exploitation status of coral reef fish communities. This contribution meets that challenge by examining six common families of coral reef fishes-which together make up a significant percentage of the overall fish population; provide most of the indicator fish species for coral reef health- along a 1200 km stretch of this coast that will face the greatest impact. We show that the distribution of these fishes is not uniform, either geographically (north-south) or habitat-wise (reef flat versus reef slope). Such information is critical in helping to evaluate tourism expansion, to control the protected status of these reefs and to determine future management and conservation efforts.

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