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COMMUNITY STRUCTURE OF THE FAMILY LABRIDAE ALONG THE JORDANIAN COAST, GULF OF AQABA, RED SEA

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ABSTRACT

The spatial distribution and community structure of the family Labridae were studied at different depths and sites along the Jordanian coast of the Gulf of Aqaba in the seagrass and coral reef habitats. A total of 44 species of labrid fish were observed during the 187 visual census performed in seventeen sites. Out of the 44 labrid fish species encountered, 4 species including Paracheilinus octotaenia, Thalassoma rueppellii, Cirrhilabrus rubriventralis and Coris caudimaculata accounted for 64% of all individuals counted. Fishes were more abundant at 12 m depth in coral dominated sites, while a lower abundance was found in reef flat and seagrass sites. This was attributed to a higher shelter, structural complexity and food availability in the coral reef sites. The coral reef habitat had significantly higher species richness than the seagrass habitat at 6 and 12 m depths combined (p<0.0001). Within coral reef sites, the deeper transects had significantly higher species richness than those on the reef flat. It was concluded that differences among reefs and habitats were the most important components of variability in the abundance and species richness of the family Labridae along the Jordanian coast of the Gulf of Aqaba.

Keywords: Labridae, community structure, labrid fish, Gulf of Aqaba, Red Sea

INTRODUCTION

The Red Sea ichthyofauna has received a large attention compared with other parts of the tropical Indo-Pacific Ocean. Over 1248 fish species have been recorded from this almost land locked water body (Goren & Dor, 1994). Ichthyological research in the Red Sea dates back more than 200 years to collection and descriptions of fishes by Peter Forsskål (Klausewitz, 1964; Nielsen, 1993). Although the Red Sea ichthyofauna is taxonomically quite well known compared with other parts of the tropical Indo-Pacific Ocean, the community structure of shore fishes has been less well investigated.

Wrasses (Family: Labridae) are found mainly in shallow coastal waters on coral reefs, rocky substrates, sea grass beds and sandy bottoms, though some species of *Bodianus* occur in deeper waters (200 m and more). Few species are commercially used for consumption (Khalaf & Disi, 1997). Twenty six species of wrasses are used in Aquarium fish trade in the Red Sea (Khalaf & Abdallah, 2003). Goren and Dor (1994) reported the occurrence of 71 species of wrasses in the Red Sea. Along the Jordanian coast, 51 species belonging to 24 genera of labrids were recorded, (Table 1; Khalaf, in press). During their study on community structure and biogeography of shore fish community of the Jordanian coast, Khalaf & Kochzius (2002) indicated that Labridae and Pomacentridae dominated the ichthyofauna in terms of species richness. Pomacentridae was the dominant family and Labridae with 38 species formed 9.7% of the total fish abundance. Ecological studies on certain families were conducted, such as damselfish (Pomacentridae) (Fishelson *et al.*, 1974; Fricke 1977; Ormond *et al.*, 1996), butterflyfish (Chaetodontidae) *e.g.* (Bouchon-Navaro, 1980; Bouchon-Navaro & Bouchon, 1989; Roberts *et al.*, 1992) and herbivorous families (Acanthuridae, Scaridae, Siganidae) (Bouchon-Navaro & Harmelin-Vivien, 1981) but no studies have been published on the community structure of the family Labridae in the Gulf of Aqaba.

Shallow-water habitats along the Jordanian Red Sea coast are coral reefs and seagrass meadows. The coral reefs of the Jordanian coast have been studied in detail by Mergner and Schuhmacher (Mergner & Schuhmacher, 1974; 1981; Mergner, 1979; 2001).

This study investigates for the first time the labrid fish community of shallow-water habitats along the Jordanian coast. The main objectives of this study are: (1) to investigate the community structure of labrid fishes on coral reefs and seagrass meadows, (2) to reveal the ecological patterns which influence the wrasse community structure, and to describe the biodiversity of the family Labridae.

METHODS

Site description

The Gulf of Aqaba (180 km long, 20 km wide) is a semi-closed sea with many unique natural and physical features. It is geographically isolated by the narrow Strait of Tiran. While much of the Gulf is deep (>1800 m), the northern sector has a relatively shallow shelf adjacent to the major population centers. The Jordanian coast (27 km) is fringed by discontinuous belt of reefs separated by sandy bottoms that are usually covered by seagrass meadows (UNEP/IUCN, 1988). Seventeen sites distributed along the Jordanian coast (Figure 1) and presenting various types of benthic habitat were studied throughout the period between 1997 and 2003 (Table 2). The Gulf is characterized by calm and clear water with diurnal tides in the range of less than one meter. Currents specifically, and circulation generally, appear to be largely wind-driven, with additional influence from tides, density gradients, and evaporation (Manasrah *et al*., 2004; Berman *et al*., 2000).

Visual census

All fish surveys were conducted by visual census technique with SCUBA following the basic protocol outlined by English *et al*. (1994). In each site, three replicates of 50 m long marked transect lines, were deployed parallel to the sea shore at two different depths; one shallow (6 m) and one deep (12 m).

TABLE 1

Labrid Fish Inventory of the Jordanian Coast, Gulf of Aqaba, Red Sea. (Specimen, a = Collected & Deposited at the Marine Science Station, b = Photographed or Seen Under-Water during Coral Reef Fish Visual census, c = Observed in Local Fishermen Catch, d = Senckenberg Museum Frankfurt collection; ; (Literature record, 1 = Wahbeh & Ajiad, 1987, 2 = Khalaf & Disi, 1997, 3 = Khalaf & Khozius, 2002, 4 = Randall & Khalaf, 2003); (Habitat, CB = Corals & Boulders, SAA = Seagrass & Algae, SB = Sandy Bottom, DB = Deep Benthos); (Trophic Group, C = Corallivore, IF = Invertebrate Feeder, IFF = Invertebrate and Fish Feeder, O = Omnivore, Pl = Planktivore); (Remarks, E = Endemic to Red Sea & Gulf of Aden)

		Documentation		Habitat		
Scientific name	Abrev.	Specimen	References	Benthic	Trophic group	Remarks
Anampses caeruleopunctatus	*Anamcaer*	a,b,c	2;3	CB	IF	
Anampses lineatus	*Anamline*	a,b,c	2;3	CB	IF	
Anampses meleagrides	*Anammele*	a,b,c	2;3	CB	IF	
Anampses twistii	*Anamtwis*	a,b,c,d	1;2;3	CB	IF	
Bodianus anthioides	*Bodianth*	a,b,c	1;2;3	CB	IF	
Bodianus axillaris	*Bodiaxil*	a,b,c	2;3	CB	IF	
Bodianua diana	*Bodidian*	a,b,c	2;3	CB	IF	
Bodianus leucosticticus		a,b,c	2	DB	IF	
Bodianus opercularis		a,b,c	2	DB	IF	
Cheilinus fasciatus	*Cheifasc*	a,b,c,d		CB	O	
Cheilinus lunulatus	*Cheilunu*	a,b,c	2	CB	O	
Cheilinus mentalis	*Cheiment*	a,b,c,d	2;3	CB	O	
Cheilinus abudjubbe	*Cheilabud*	a,b,c,d	1;2;3	CB	O	E
Cheilinus undulatus	*Cheiundu*	a,b,c	2	CB	O	
Cheilio inermis	*Cheiiner*	a,b	2;3	SAA	O	
Choerodon robustus		a,b,c	1;2	DB	IFF	
Cirrhilabrus blatteus		a,b	2	DB	Pl	E
Cirrhilabrus rubriventralis	*Cirrrubr*	a,b,d	2;3	SAA	Pl	E
Coris aygula	*Coriaygu*	a,b,c,d	1;2;3	CB	IF	
Coris caudimacula	*Coricaud*	a,b,c,d	1;2;3	SAA	IF	
Coris gaimard	*Corigaim*	a,b,c	3	CB	IF	
Coris variegata	*Corivari*	a,b,c,d	2;3	SB	IF	
Epibulus insidiator	*Epibinsi*	b		CB	IFF	
Gomphosus caeruleus	*Gompcaer*	a,b,c,d	2;3	CB	IF	E
Halichoeres hortulanus	*Halihort*	a,b,c	2	CB	IF	
Halichoeres marginatus	*Halimarg*	a,b,c,d	2;3	CB	IF	
Halichoeres nebulosus	*Halinebu*	a,b	2	CB	IF	
Halichoeres scapularis	*Haliscap*	a,b	2;3	SAA	IF	
Hemigymnus fasciatus	*Hemifasc*	a,b,c	1;2;3	CB	IF	
Hologymnosus annulatus	*Holoannu*	a,b,c	1;2;3	CB	IFF	
Labroides dimidiatus	*Labrdimi*	a,b,d	2;3	CB	IF	
Larabicus quadrilineatus	*Laraquad*	a,b,d	2;3	CB	C	E
Macropharyngodon bipartitus bipartitus	*Macrbipa*	a,b	3	CB		
Novaculichthys macrolepidotus	*Novamacr*	a,b	12	SAA		
Oxycheilinus arenatus		a,b,c	2	CB	O	
Oxycheilinus diagrammus	*Oxycdigr*	a,b,c,d	2	CB	O	
Oxycheilinus orientalis	*Oxycorie*	a,b,c	4	SAA	O	
Paracheilinus octotaenia	*Paraocto*	a,b,d	2;3	CB	Pl	E
Pseudocheilinus evanidus	*Pseuevan*	a,b,d	2;3	CB	Pl	
Pseudocheilinus hexataenia	*Pseuhexa*	a,b,d	2;3	CB	Pl	
Pteragogus cryptus	*Ptercryp*	a,b,d	2;3	CB		
Pteragogus pelycus	*Pterpely*	a,b,c	2;3	SAA		
Stethojulis albovittata	*Stetalbo*	a,b,d	2;3	CB	IF	
Stethojulis interrupta	*Stetinte*	a,b	2;3	CB	IF	
Thalassoma rueppellii	*Thalruep*	a,b,c,d	2;3	CB	IFF	E
Thalassoma lunare	*Thalluna*	a,b,c,d	2;3	CB	IFF	
Wetmorella nigropinnata	*Wemonigr*	a,b,d		CB	IF	
Xyrichtys melanopus	*Xyrimela*	a,b,c	2	SB	IF	
Xyrichtys niger		d		SB	IF	
Xyrichtys pavo		a,b,c	2;3	SB	IF	
Xyrichtys pentadactylus	*Xyripent*	a,b,c	2	SB	IF	

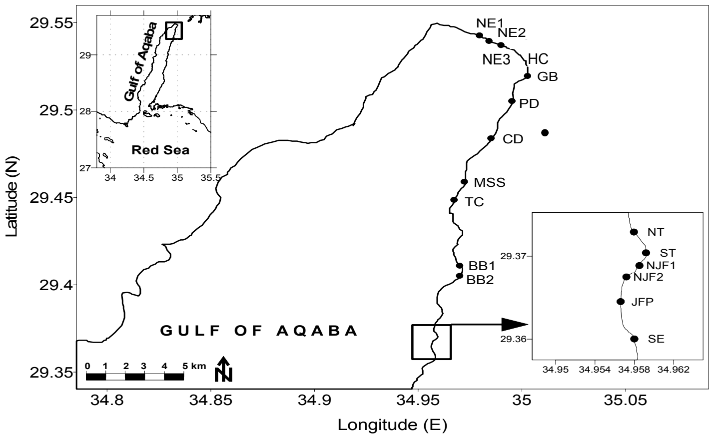

Figure 1. Map of the northern Gulf of Aqaba highlighting the 17 sampling sites as follows: NE1 = North Extension site 1, NE2 = Northern Extension site 2, NE3 = Northern Extension site 3, HC = Hotel Community, GB = Ghandoor Beach, PD = Phosphate Loading Dock, CD = Clinker-Cement Dock, MSS = Marine Science Station, TC = Tourist Camp, BB1 = Big Bay (Al-Mamlah) site 1, BB2 = Big Bay (AL-Mamlah) site 2, NT = North Thermal Power Station, ST = South Thermal Power Station, NJF1 = North Jetty site 1, NJF2 = North Jetty site 2, JFB = Jetty Port, SE = South Extension.

The replicates were laid sequentially with a 10 – 20 m distance separating them. One additional set of three fish transect lines was deployed on the reef flat (<2 m depth) in the following sites: Clinker/Cement Dock, Marine Science Station, Tourist Camp and the Southern Extension at the Jordanian-Saudi Arabia Border. In all cases, the observer waited about 10 min before counting to allow the fish to resume their normal behavior. Subsequently, the observer swam along the transect and recorded all labrid encountered within 2.5 m on each side of the line and 5 m above transect. The duration for the labrid count on each transect was approximately 15- 20 min. The surveys of benthic habitat at each visual census were conducted in most cases by line intercept method, (English *et al.*, 1994). However, at the Phosphate Loading Dock, North Thermal Power Station, South Thermal Power Station, and Southern Extension, the benthic cover surveys were conducted by the line-point intercept method (Ohlhorst *et al.*, 1988; Rogers *et al.*, 1994).

Statistical analysis

All statistical analyses used to examine the data were as described by Sokal and Rohlf (1981) and implemented via StatView computer software. Community indices of fish abundance and species richness were compared among sites and depths using the Kendalls Rank Correlation Test. Fish abundance was described by relative abundance (RA) and frequency of appearance (FA), calculated as follows:

$$\mathrm{RA} = \frac{\mathrm{Xi}}{\mathrm{Ya}} \times 100$$

where, Xi is the pooled average abundance of species i from each depth and site, and Ya is the pooled average abundance of all species from each depth and site.

TABLE 2

Listing of Study Sites and Abbreviations with Dates of Data Acquisition, GPS Coordinates and Live Substrate Cover (%)

				Coordination		Live substrate cover (%)			
SN	**Site Name**	**Abbrev.**	**Date**	**Latitude (N)**	**Longitude (E)**	**Hard Coral**	**Soft Coral**	**Hard + Soft**	**Seagrass**
1	North Extension 1	NE1	Sep 2003	29°54.27´	34°97.97´	0	0	0	86.2
2	Northern Extension 2	NE2	Sep 2003	29°53.95´	34°98.55´	0	0	0	2.7
3	Northern Extension 3	NE3	Sep 2003	29°53.66´	34° 99.00´	1	0	1	87.5
3	Hotel Community	HC	Jan 2001 Apr 2002	29°53.66´	34°98.97´	0.67	0	0.67	44.17
5	Ghandoor Beach	GB	Jan 2001	29°51.95´	35°00.29´	1.83	2.33	4.16	6.67
6	Phosphate Loading Dock	PD	Nov 2000 Nov 2001	29°50.52´	34°99.50´	5.83	0.67	6.5	35.83
7	Clinker-Cement Dock	CD	Nov 2000 Dec 2001	29°48.34´	34°98.57´	16.69	6.96	23.65	0
8	Marine Science Station	MSS	Nov 1999 Dec 2001	29°45.95´	34°97.32´	21.78	3.09	24.87	0
9	Tourist Camp	TC	Nov 1999 Nov 2001	29°44.84´	34°96.75´	23.08	6.32	29.4	0
10	Big Bay 1 (Al-Mamlah)	BB1	Apr 1997 Aug 1999	29°41.05´	34°97.07´	2.23	0.63	2.86	83.30
11	Big Bay 2 (Al-Mamlah)	BB2	Apr 1997 Aug 1999	29°40.45´	34°97.07´	3.20	3.40	6.6	70.70
12	North Thermal Power Station	NT	Aug 2000	29°43.09´	35°05.40´	20.67	4.46	25.13	0
13	South Thermal Power Station	ST	Aug 2000	29°41.84´	35°05.93´	7.27	15.47	22.74	0
14	North Jetty 1	NJF1	May 2000	29°41.09´	35°05.68´	13.20	5.23	18.43	0
15	North Jetty 2	NJF2	May 2000	29°40.45´	35°05.07´	21.68	3.91	25.6	0
16	Jetty Port	JFB	Apr 2000	29°38.98´	35°04.79´	21.69	3.92	25.61	0
17	South Extension	SE	Jan 2001 Nov 2001	29°36.88´	35°05.40´	14.5	41.0	55.5	0.67

$$FA = \frac{Ni}{Nt} \times 100$$

where Ni is the number of transects in which species i was present and Nt is the total number of all transects. Species diversity (H′) was calculated from the Shannon -Weaver Diversity Index (Ludwig and Reynolds, 1988):

$$H' = - \sum (pi \ln pi)$$

where pi is the proportion of all individuals counted that were of species i. Species richness (d) was calculated using Margslef's index (Peet, 1974) as follows:

$$d = \frac{(S-1)}{\log(N)}$$

where S is the total number of species, N is the total number of individuals.

Transect lines with no observed labrid resulted in a mathematically undefined RA and were excluded from the statistical comparisons involving RA.

RESULTS

Labrid fishes assemblages

A total of 31431 labrid fishes, representing 44 species, were observed during 187 visual census in 17 different coastal sites along the Jordanian coast of the Gulf of Aqaba.

Site distributional pattern of labrids

Out of the 44 labrid fish species encountered, 4 species (*Paracheilinus octotaenia*, *Thalassoma rueppellii*, *Cirrhilabrus rubriventralis* and *Coris caudimaculata*) accounted for about 64% of all individuals counted. Relative abundance (RA) of *P. octotaenia* (RA= 29.7%) was the highest along the entire coast of Jordan, followed by *T. rueppellii, C. rubriventralis* and *C. caudimaculata* with a mean RA of 9.6%, 9.4% and 5.1%, respectively (Table 3). *P. octotaenia* was the most abundant species in eight of the studied sites with an RA ranging between 27.3 % in the North jetty site to 63.7% in the Phosphate loading Dock, although it was missing from NB1 and JE. *T. rueppellii* was the most abundant in 3 sites with an RA ranging between 26.3% in RP to 43.1% in JE. *C. caudimaculata* was the most abundant in BB1 (RA = 30.2%) and GB (RA = 32.1%). In the NE1, *Pteragogus pelycus* was the most abundant species (RA = 50.3%) followed by *C. rubriventralis* (RA = 45.6), which was the most abundant species in NE3 (RA = 45.3%). *Oxycheilinus orientalis* was the most abundant in NE2 (RA = 26.9%) and HC (RA = 31.9).

The highest mean number of species (S) was found in SE site (Mean = 13.8) followed by MSS (Mean = 13.3) and TC (Mean = 13.1) sites, while the lowest was found in NE1 (Mean = 2.3), (Figure 2A). The highest mean fish abundance (N) was found in the MSS site (Mean = 545.8) followed by CD (Mean = 478.1) and TC (Mean = 289.9) sites, while the lowest was observed in NE2 (Mean = 6), (Figure 2B). The average species richness (d) ranged between 0.4 in NE1 to 2.7 in RP (Figure 2C). Shannon-Wiener diversity Index (H') ranged between 0.3 in NE1 to 2.0 in RP (Figure 2D).

Table 3 presents the frequency of appearance (FA) values for each species of Labridae for all sites combined. The data obtained showed that the most common labrid fishes along the Jordanian coast of the Gulf of Aqaba were *T. rueppellii* (66.8%), *C. caudimaculata* (61.0), *Anampses twisttii* (55.6), and *Pseudocheilinus hexataenia* (50.3).

TABLE 3

Relative Abundance of Fish Individuals per 250 m² Transect at Sites Along the Jordanian Coast of the Gulf of Aqaba, TRA Indicates Total Relative Abundance and TFA Indicates Total Frequency of Appearance. For Abbreviations see Tables 1 & 2

Species	NE1	NE2	NE3	HC	GB	PD	CD	MSS	TC	BB1	BB2	RP	LP	SLP	NJ	JE	SE	TRA	TFA
Anamcaer	-	-	-	-	-	-	-	0.35	0.02	0.06	-	1.09	-	-	-	-	-	0.09	4.81
Anamline	-	-	-	-	-	0.09	-	-	-	0.93	-	0.82	-	-	-	-	-	0.11	9.63
Anammele	-	-	-	-	-	-	0.15	0.09	0.26	0.71	-	0.28	-	0.68	2.12	1.90	-	0.36	13.90
Anamtwis	-	-	-	-	0.55	0.27	2.72	3.02	3.02	1.25	-	4.13	9.90	12.83	6.09	7.25	2.24	3.13	55.61
Bodianth	-	-	-	-	-	1.56	0.28	0.53	0.36	0.48	-	2.50	3.05	2.97	6.27	9.23	0.88	1.65	37.97
Bodiaxil	-	-	-	-	-	-	0.02	0.10	0.05	0.01	-	-	-	2.05	1.27	0.91	-	0.26	5.35
Bodidian	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.45	0.00	-	0.03	0.53
Cheilabud	-	-	1.11	0.16	0.55	1.28	0.14	0.22	0.24	0.79	0.41	6.64	1.65	1.87	5.33	6.35	1.02	1.63	37.97
Oxycdigr	-	-	-	-	-	-	0.41	0.90	0.26	0.98	-	-	1.02	-	-	2.55	0.12	0.37	18.72
Cheifasc	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.33	0.02	2.67
Cheilunu	-	-	-	-	-	-	-	-	0.20	0.17	0.05	0.54	-	-	0.45	-	0.09	0.09	8.02
Cheiment	-	-	-	-	1.10	1.40	1.54	1.79	1.73	1.57	0.25	6.39	5.85	2.56	1.73	6.25	3.64	2.10	45.45
Cheiundu	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	0.53
Cheiiner	-	-	-	-	-	0.09	-	-	0.05	0.81	-	-	-	-	-	-	-	0.06	12.30
Cirrrubr	45.97	-	45.26	3.08	6.59	17.51	-	-	0.46	16.56	16.20	9.81	1.28	-	2.12	-	0.09	9.70	20.86
Coriaygu	-	-	-	-	-	-	0.41	0.67	0.18	0.24	0.30	1.94	0.63	6.16	0.42	0.91	0.18	0.71	20.32
Coricaud	0.36	7.69	2.38	14.86	32.14	0.73	0.86	0.17	0.52	30.19	17.48	9.10	2.42	1.07	2.18	5.11	0.53	7.52	60.96
Corigaim	-	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	-	-	-	0.53
Corivari	-	-	-	-	-	-	1.28	0.72	0.35	1.41	1.74	1.36	1.52	1.64	1.82	0.66	0.85	0.78	29.41
Epibinsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09	0.01	0.53
Gompcaer	-	-	-	-	-	1.17	2.65	3.16	2.54	0.19	-	2.18	2.67	1.34	5.15	2.22	3.09	1.55	40.11
Halihort	-	-	-	-	-	-	0.28	-	-	-	-	-	-	-	-	-	-	0.02	1.60
Halimarg	-	-	-	-	-	-	-	0.17	-	0.07	-	1.09	-	-	-	-	0.03	0.08	8.56
Halinebu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.67
Haliscap	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	0.53
Hemifasc	-	-	-	-	-	-	-	-	0.02	0.02	-	-	-	0.53	1.27	0.91	0.12	0.17	5.88
Holoannu	-	-	-	-	-	-	-	-	0.06	0.19	0.50	1.11	-	0.27	-	0.33	0.24	0.16	10.16
Labrdimi	-	2.17	-	1.13	-	1.14	0.79	0.54	0.10	1.86	0.16	-	1.65	1.07	-	0.91	0.92	0.73	34.76
Laraquad	-	-	-	0.16	9.43	1.33	3.16	1.94	2.19	0.14	0.41	-	1.02	0.95	1.36	0.66	3.19	1.53	39.04
Macrbipa	-	-	-	-	-	-	0.16	0.11	0.07	0.02	-	-	-	-	0.42	1.82	-	0.15	7.49
Novamacr	-	-	-	-	-	-	-	-	-	0.08	-	-	-	-	-	-	-	-	1.07
Paraocto	-	10.87	5.42	18.99	29.12	63.73	62.61	45.78	50.93	27.73	50.04	8.99	11.48	33.42	27.27	-	58.35	29.69	46.52
Pseuevan	-	4.35	-	-	-	0.18	1.06	0.31	0.61	0.54	0.32	1.69	0.51	0.27	-	0.33	0.71	0.64	31.02
Pseuhexa	-	4.35	-	-	9.43	0.27	2.21	2.19	2.59	1.15	0.16	1.96	7.62	2.17	3.06	1.90	3.38	2.50	50.27
Ptercryp	-	4.35	-	-	-	-	0.55	0.01	-	0.07	-	0.28	0.26	0.95	0.91	1.57	1.92	0.64	13.90
Pterpely	50.33	12.04	32.48	15.04	-	0.57	-	-	0.10	4.43	3.13	-	-	-	-	-	-	6.95	31.55
Oxycorie	1.34	26.92	8.91	31.87	1.10	0.78	-	-	-	1.00	4.40	0.56	-	-	-	-	-	4.52	18.72
Stetalbo	-	4.35	-	5.17	-	-	0.02	0.84	0.31	0.45	0.82	1.67	2.04	-	3.00	1.90	0.30	1.23	31.55
Stetinte	-	4.35	-	0.65	8.33	-	-	-	0.89	0.35	-	1.09	0.00	-	-	-	-	0.92	8.56
Thalruep	-	4.35	-	5.81	0.55	7.14	18.13	35.72	31.74	3.45	3.01	26.25	41.59	27.18	25.09	43.06	16.63	17.04	66.84
Thalluna	-	-	-	2.74	1.10	0.74	0.57	0.68	0.11	2.10	0.61	8.55	3.83	-	2.21	3.29	1.00	1.62	43.85
Xyrimela	-	-	2.22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13	1.07
Xyripent	2.00	14.21	2.22	0.32	-	-	-	-	-	-	-	-	-	-	-	-	-	1.10	2.67
Wemonigr	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	0.53

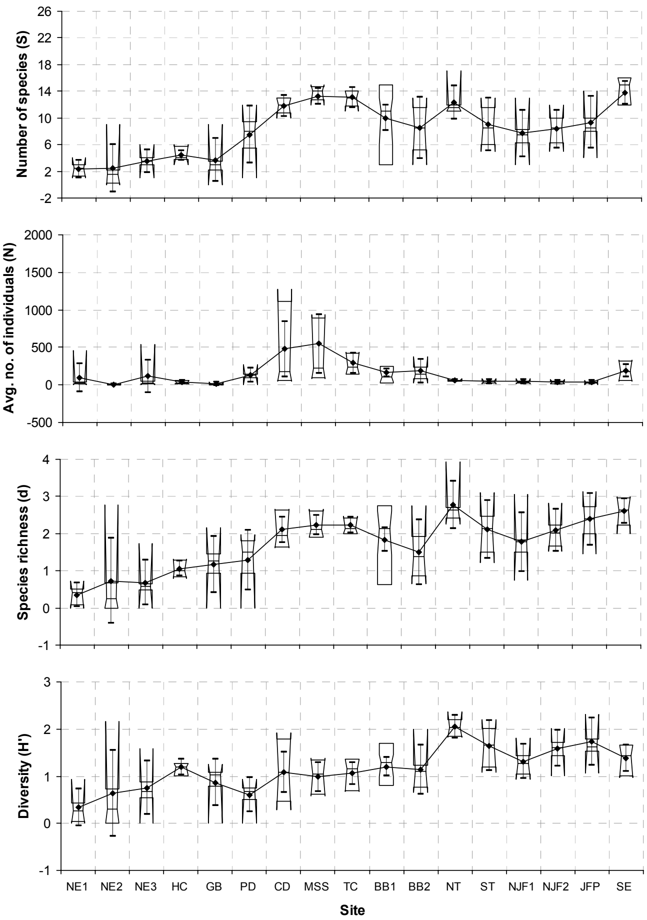

Figure 2. Box-whisker plots of (a) number of species, (b) number of individual, (c) species richness, and (d) diversity at combined depths (6 and 12 m) for different sites along the Jordanian coast of the Gulf of Aqaba. For abbreviations see Tables 1 & 2.

Distributional patterns with depth and habitat

In terms of relative abundance (RA), *T. rueppellii* was the dominant labrid fish (RA = 68.7%) in the reef flat followed by *Stethojulis albovittata* and *Halichoeres marginatus* with an RA of 11% and 7.8%, respectively (Figure 3A). The most dominant species in coral reef sites at 6m depths were *T. rueppellii* (Mean RA = 50.1%), followed by *P. octotaenia* (Mean RA = 16.4) and *A. twistii* (Mean RA = 5.3) (Figure 3B), while at the same depth in seagrass beds, the most abundant species was *C. caudimaculata* (Mean RA = 37.4) followed by *P. octotaenia* (Mean RA = 15.2%) and *C. rubriventralis* (Mean RA=12.6) (Figure 3C). In the 6m deep transects in both habitats combined, *T. rueppellii, P. octotaenia* and *C. caudimaculata* had the highest RA and constituted 32.5%, 16.4% and 15.4% of the total labrid fishes, respectively (Figure 3D). At 12m depth, the most abundant species in coral reef sites was *P. octotaenia* (RA = 86.4%) and *T. rueppellii* (RA = 3.8%) (Figure 3E), while at the same depth in seagrass habitat, *Paracheilinus octotaenia* dominated this depth (RA = 44.7%) followed by *C. rubriventralis* (RA = 28.4) and *C. caudimaculata* (RA = 8.3%) (Figure 3F). In the 12 m deep transects in habitats combined, *P. octotaenia, C. rubriventralis* and *C. caudimaculata* dominated this depth with an RA of 71.1%, 10.5% and 3.5% of the total labrid fishes, respectively (Figure 3G).

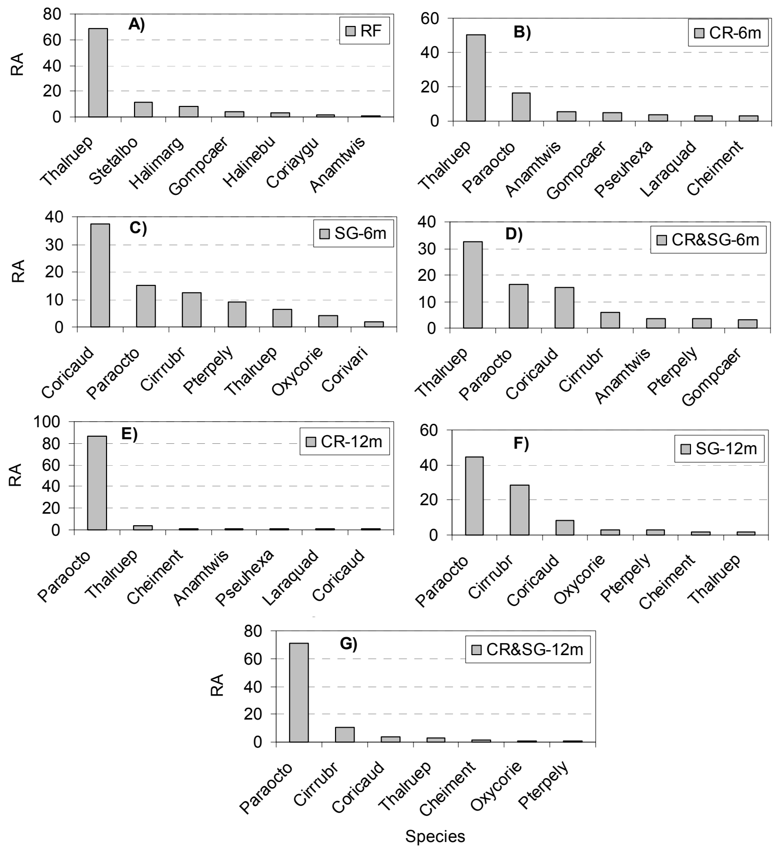

Figure 3. Relative abundance (RA) of Labrid species at different depths in coral reef and seagrass meadows along the Jordanian coast of Gulf of Aqaba, Red Sea, where A) RF = Reef Flat, B) CR-6m = 6 m depth in coral reef habitat, C) SG-6m = 6 m depth in seagrass meadows habitat, D) SG&CR-6m = 6 m depth in seagrass meadows habitat and coral reef habitat, E) CR-12m = 12 m depth in coral reef habitat F) SG-12m = 12 m depth in seagrass meadows habitat, G) SG&CR-12m = 12 m depth in seagrass meadows habitat and coral reef habitat. For species abbreviations see Table 1.

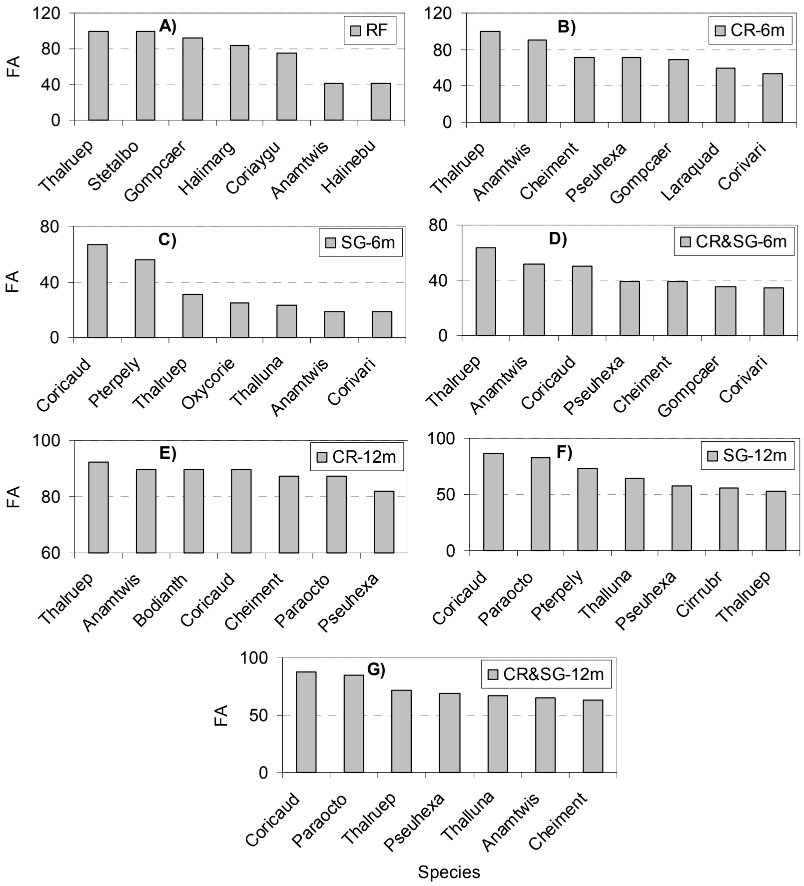

Figure 4. Frequency of appearance (FA) of labrid fish species at different depths in coral reef and seagrass meadows along the Jordanian coast of Gulf of Aqaba, Red Sea where A) RF = Reef Flat, B) CR-6m = 6 m depth in coral reef habitat, C) SG-6m = 6 m depth in seagrass meadows habitat, D) SG&CR-6m = 6 m depth in seagrass meadows habitat and coral reef habitat, E) CR-12m = 12 m depth in coral reef habitat F) SG-12m = 12 m depth in seagrass meadows habitat, G) SG&CR-12m = 12 m depth in seagrass meadows habitat and coral reef habitat. For species abbreviations see Table 1.

In terms of frequency of appearance (FA), the most common species at the reef flat were *T. rueppellii*, *S. albovittata* (100%, each), *Gomphosus caeruleus* (91.7%), *H. marginatus* (83.3%) and *Coris augyla* (75%) (Figure 4A). The most common species in coral reef sites at 6 m depth was *T. rueppellii* (100.0%) followed by *A. twistii* (89.7%), *C. mentalis* (71.8%) and *P. hexataenia* (71.8%) (Figure 4B), while for the same depth in seagrass habitat, the most common species were *C. caudimaculata* (66.7%) and *P. pelycus* (56.3%) (Figure 4C). At 6m deep transects in both habitats combined, *T. rueppellii*, *A. twistii* and *C. caudimaculata* were the most common and formed 63.2%, 51.7% and 50.6%, respectively (Figure 4D). In the coral reef habitat, there were 7 species which had FA of more than 80% at 12m deep transects (Figure 4E), while at the same depth in the sea grass habitat, only two species had FA of more than 80% (Figure 4F). In both habitats combined, *C. cauaimaculata* (FA = 88.1%), *P. octotaenia* (FA=84.5%), *T. rueppellii* (FA = 71.4%), *P. hexataenia* (FA = 69.1%), *Thalassoma lunare* (FA = 66.7%) and *A. twistii* (FA = 65.5%) were the most common at 12 m deep transects (Figure 4G).

The number of species (S) was significantly higher in the coral reef habitat (S = 10.1) than in the seagrass habitat (S = 4.5) at 6 m deep transects (p = 0.0005). Similarly, S was significantly higher at 12 m deep transects in the coral reef habitat (S = 13.0) than the seagrass habitat (S = 10.5) (p = 0.0096). In general, the coral reef habitat hosted much higher number of species than the seagrass habitat (p<0.0001) (Table 4). In terms of number of individuals (N) counted, the coral reef habitat had higher number of fishes compared with the seagrass habitat at all depths, although the difference was not statistically significant (p = 0.1215 between 6 m *vs* 6 m and p = 0.3673 between 12 m *vs* 12 m in coral reef *vs* seagrass habitat, respectively). Within the same habitat, the only significant difference found was between the 6 m and the 12 m deep transects in the seagrass habitat with the N being higher at 12 m than at 6m (p = 0.0104). In general, the 12 m deep transects in all habitats had significantly higher (p = 0.0276) number of individuals than the 6 m deep transects (Table 4).

TABLE 4

Number of Species (S) and Number of Individuals (N) of Labrids at Different Habitat along the Jordanian Coast of the Gulf of Aqaba, where RF = Reef Flat, CR-6m = 6 m Depth in Coral Reef Habitat, SG-6m = 6 m Depth in Seagrass Meadows Habitat, CR-12m = 12 m Depth in Coral Reef Habitat, SG-12m = 12 m Depth in Seagrass Meadows Habitat. For Species Abbreviations See Table 1

Labridae			
		S	N
All RF transects	**Mean**	**6.83**	**75.17**
(n=12)	Sd	2.29	56.09
All 6m transects	**Mean**	**6.98**	**56.22**
(n=88)	Sd	4.49	61.76
All 12m transects	**Mean**	**11.64**	**308.89**
(n=77)	Sd	4.89	372.99
SG6m	**Mean**	**4.51**	**41.10**
(n=49)	Sd	3.74	56.93
CR 6m	**Mean**	**10.13**	**75.64**
(n=39)	Sd	3.16	62.16
SG 12m	**Mean**	**10.45**	**210.27**
(n=44)	Sd	5.96	181.04
CR 12m	**Mean**	**12.97**	**420.15**
(n=39)	Sd	2.80	489.04
SG 6& 12m	**Mean**	**7.30**	**121.66**
(n=93)	Sd	5.76	156.41
CR 6 & 12m	**Mean**	**11.55**	**247.90**
(n=78)	Sd	3.29	387.29

DISCUSSION

A comprehensive description of the labrid fish community structure in relation to the coral reef and seagrass benthic habitats in the Jordanian coast of the Gulf of Aqaba is presented in this study. A comparison of differences between fish assemblages in relation to depth was also made. Out of 478 species of labridae present in the world (Froese & Pauly, 2000), 72 species were recorded in the Red Sea (Goren & Dor, 1994). Previous records for the number of labrid fish species in the Red Sea revealed the occurrence of 22 species in Sanganeeb, Sudan (Krupp *et al.,* 1993) and 27 species in Djibouti (Barratt & Medley, 1990). In the Gulf of Aqaba, 38 species were recorded in the Jordanian coast (Khalaf & Kochzius, 2002), 35 species in the Israeli coast (Eran, 2003) and 13 species in Nubei, Egypt (Ben-Tuvia *et al.,* 1983). A total of 44 species are presented in this study, which was conducted in 17 different sites along the Jordanian coast of the Gulf of Aqaba.

Fishes were most abundant in the coral reef dominated sites relative to the seagrass dominated sites. The number of species was significantly higher in coral reef dominated sites than in seagrass dominated sites. This could be attributed to a higher abundance of shelter and food resources present in coral reef habitats. A review of literature describing fish habitat correlation from various regions of the world presents a convincing positive relationship between structural complexity and reef fish diversity in the Caribbean (Risk, 1972; Luckhurt & Luckhurt, 1978) and in the Great Barrier Reef (McCormick, 1994). The strength of this correlation however, may vary among reef types. Reef associated fishes, due to their behavior are extremely affected by the characteristics of the reef habitat. Several studies have shown that the species diversity, abundance and biomass of the fish community are positively correlated with the structural complexity of the substrate and the live benthic cover, which influence the fish community structure via feeding interaction (Pereira, 2000). In this study, there was an evidence of the habitat characteristics effect on the number of species and species richness in the various types of habitats at different depths along the Jordanian coast of the Gulf of Aqaba. The species richness was strongly correlated with habitat complexity.

In terms of depth, the 12 m deep transects in the coral reef habitat had the highest fish abundance compared with other depths within the same habitat and in seagrass habitat. Many planktivorous fishes are abundant at this depth such as, *P. octotaenia*, which constituted more than 86% of labrid fish assemblages at 12 m depth in coral reef sites, probably in relation with a high abundance of plankton at this depth. Similar results were also obtained by Khalaf and Kochzius (2002) for the distribution of all fish species in the Gulf of Aqaba. Depth influences the composition and distribution of fish communities within tropical reefs (Goldman & Talbot, 1976; Williams, 1991). Similar result was obtained for the labrid community along the Jordanian coast during this study. *T. rueppellii* and *S. albovittata* dominated the labrid fish assemblages in the reef flat sites, *T. rueppellii* and *P. octotaenia* were more abundant at 6 m deep on coral reefs, while *C. caudimaculata* and *P. octotaenia* were the most abundant at 6 m depths in seagrass beds. At 12 m depth, the most abundant species in coral reef sites were *P. octotaenia* and *T. rueppellii*, whereas at the same depth in seagrass habitat *P. octotaenia* and *C. rubriventralis* were dominant.

Previous studies have shown that the average abundance of 10 labrid fish species studied in Jordan, Egypt, Saudi Arabia, Yemen and Djibouti differed from place to place along the Red Sea (Khalaf & Abdallah, 2003). In these studies, four distributional patterns were defined among labrid fish species: 1) species that are dominant in the northern and central Red Sea such as *A. twisttii*, *Labroides dimidiata* and *P. octotaenia*, 2) species that are dominant in the central and southern Red Sea such as *Larabicus quadrilineatus* and *T. lunare*, 3) species abundant in central Red Sea but with lower number of individuals in the northern and southern Red Sea and 4) species abundant in the northern and central Red Sea but missing from the southern Red Sea. Rilov and Benayahu (2000), in a study done in Eilat's reef found that *P. octotaenia* is the most dominant species followed by *G. caeruleus*, *L. quadrilineatus* and *Pseudocheilinus evanidus*. However, Eran (2003) found that *T. rueppellii* was the most abundant species followed by *C. rubriventralis* and *P. hexataenia* during his study in Eilat's reef on the western side of the Gulf. In this study, *P. octotaenia* was found to be most abundant in the Jordanian coast, followed by *T. rueppellii, C. rubriventralis* and *C. caudimaculata*. Based on the results of frequency of appearance it can be concluded that *T. rueppellii*, an endemic species to the Gulf of Aqaba (Khalaf & Disi, 1997), was the most common labridfish species in the Jordanian coast followed by *C. caudimaculata*, *A. twisttii* and *P. hexataenia*. This might be due to the ability of those species to live in a wide variety of habitats.

Fish species are not randomly distributed in the different habitats of a coral reef environment. On a broad spatial scale there is a clear habitat segregation, with substantially different groups of species found on seaward slopes, reef flat and lagoons (Hiatt & Strasburg, 1960). This study supports the above mentioned studies where a number of common species occupied and dominated the seagrass beds, while others dominated the coral reefs. Species varied in their abundance from reef to reef, and adjacent reef supported different groups of species. In this study, we have found that some species were restricted to certain sites or type of habitat along the Jordanian coast of the Gulf of Aqaba. For example, *G. caeruleus*, which feeds on invertebrates living in crevices and *Pteragogus cryptus*, which needs wholes and crevices for hiding, are restricted to the coral reef sites, while *Oxycheilinus orientalis*, *C. rubriventralis* and *P. pelycus*, which feed on invertebrates living in the seagrass habitat, are restricted to the sandy and seagrass habitats. *Novaculichthys macrolepidotus* is an extremely rare species and was only observed among seagrass meadows in less than 3 m depth among the seagrass *Halophila universi* in the Big Bay site, which makes it endangered species in Jordan and needs special conservation measures. Some labrid fish species, such as *P. octotaenia* and *C. rubriventralis* form schools that feed on zooplankton (Khalaf & Disi, 1997; Randall, 1983), These two species were more abundant at 12 m deep transects. Percent of live branched or massive coral, substratum diversity and complexity has been several times identified as an important predictor of the diversity of reef fish assemblages (Talbot, 1965; Talbot & Goldman, 1972; Luckhurst & Luckhurst, 1978). Loya & Slobodkin (1971) showed that the average number of colonies and percentage of live corals were highest in the fore reef, then in the moderate slope and finally the reef flat. Fish abundance in this study showed similar trends and suggest a connection between fish abundance, number of species to the number of coral colonies and percentage of live coral cover. As a general conclusion, we suggest that the differences among reefs and habitats were the most important components of variability in the number of fishes and species of the family labridae along the Jordanian coast of the Gulf of Aqaba.

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