

## Spatial and temporal distribution of larvae of coral reef fishes in northern Red Sea, Egypt

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### Abstract

The larval community of coral reef fishes in the Red Sea was studied in coastal and offshore sites to determine the effects of the exposure to waves and currents and the distance from the shore in structuring the larval fish community. Plankton sampling from inshore and offshore sites and the exposed and sheltered sides of the reefs resulted in the collection of 2048 larvae representing 49 different fish taxa belonging to 11 orders and 36 families of fish. The overall density of fish larvae at all sites was calculated as the larvae numbers in  $1000\text{m}^{-3}$  and there was a significant difference in larval density between sites and months. Most larvae were collected in the warmer months of the year from May to August. The inshore sheltered site (H3) is significantly different from all other sites in having the highest density with 2824 larvae  $1000\text{m}^{-3}$ , whereas the inshore exposed site had the lowest density of all sites (621 larvae  $1000\text{m}^{-3}$ ). Number of species varies significantly among sites. Data of the seasonal and regional occurrence of fish larvae obtained from the present work could be very valuable for fisheries management. It also gives an idea about how larval stages of reef fish are distributed in regard to the reef topography and the distance from the shore.

**Keyword:** Fish larvae, Exposure, Coral reef, Dispersal, Red Sea

## Introduction

The tropical marine ecosystem is characterized by the presence of the coral reefs, which support a large variety of fish communities, and benthic fauna that are sources of eggs and larvae of fish and benthic fauna, and the open ocean, where mesopelagic fish dominate the fish community (Nonaka *et al.*, 2000). The distribution of the pelagic stages of coral reef fishes has received more attention than any other aspect of their biology and shows that larvae of the coral reef fishes can be found from water over the reef to the open ocean many hundreds of kilometres from any reef (Victor, 1987). As such, knowledge of the natural history and ecology of fish larvae is very important for the understanding of the biology of fishes (Leis and Rennis, 1983).

Fish larval distribution is influenced by spawning behaviour of the adult fish (Leis, 1991a; Brogan, 1994; Abu El-Regal *et al.*, 2008; Abu El-Regal *et al.*, 2014), hydrographic structure at a variety of scales and the interaction with the reef topography, duration of the larval period, behaviour of the larvae and larval mortality and growth and their variation in space and time (Leis, 1991a). The degree of larval dispersal affects the connectivity between reef fish populations which in turn influences their dynamics, and small-scale studies on larval spatial distributions can give important information about possible retention mechanisms near the adults' habitats. Abu El-Regal *et al.* (2014) found that

the inshore community of fish larvae does not reflect the adult community in the area. Moreover, the study of small-scale temporal patterns of variation in the composition of assemblages can be used to determine the duration of the breeding seasons and dynamics of recruitment patterns of coastal species. Many adult reef fishes are sedentary and the pelagic stage of most species probably has a broader range than the demersal adult stage (Sale, 1980) hence the larval and juvenile stage are more likely to determine the geographical size of populations than the adult stage (Leis, 1986).

Habitat selection of reef fish larvae for settlement is one of the mechanisms proposed to explain spatial patterns in the distribution of fishes and the corresponding spatial structure of the communities (Leis, 1991a). The larval fish assemblages in nearshore waters are complex both in terms of species composition and patterns of distributions (Sponaugle *et al.*, 2002) and their spatial and temporal variations have been mainly related to the meteorological, environmental and oceanographic seasonal features (Hernández-Miranda *et al.*, 2003). Short-term coupling between physical processes and biological mechanisms can strongly modify the distribution and abundance of larval stages. Furthermore, the location and abundance of larval stages may exhibit a strong relationship with the type of habitat or spawning grounds of the adults (Cushing, 1990).

The present study aims to complement the very few studies on the larvae of the coral reef fishes in the Red Sea. Information on the composition of larval communities in the Egyptian Red Sea is limited (Abu El-Regal, 1999; Abu El-Regal, 2008, 2009; Abu El-Regal *et al.*, 2014). Although there is a highly diverse adult reef fish community in Hurghada (e.g. Al-Khloy, 1964; Ormond and Edwards, 1987; Debelius, 1998), nothing is known about the distribution of their larval stages and recruitment processes. Similarly, there are very few comprehensive studies on larval development and taxonomy in the tropical Indo-Pacific coastal fishes (Leis and Rennis, 1983; Leis and Trnski, 1989; Leis and Carson-Ewart, 2002). Nellen (1973) sampled larval fish from the southern entrance of the Red Sea and Gulf of Aden as part of a larger Indian Ocean survey but his samples were taken during a single cruise only and did not give any information about spawning seasons.

Regional and spatial distribution of larvae of coral reef fish at Sharm El-Sheikh (Abu El-Regal, 1999) and Hurghada (Abu El-Regal, 2008) was studied. The present study builds on that information by analysing the composition and distributional patterns of larval fish community on the coral reefs of the Red Sea in both inshore and offshore sites and in exposed and sheltered sides of the reef in each site. In particular, the study tests the hypothesis that larval stages of coral reef fishes from inshore and offshore

reefs of different levels of exposure have the same community structure and same pattern of spatial and temporal distribution.

## Material and methods

### *Study area*

The study area in the northern part of Hurghada, on the Egyptian coast of the Red Sea was divided into inshore and offshore sites (Fig.1). The inshore site was adjacent to the Hurghada Marine Biological Station (MBS) and the offshore sites were near the Big Giftun Island. The inshore site (stations H3, X3) lies in the northern tip of the Red Sea, 5 km away from the centre of Hurghada city. This site contains fringing reefs extending from the shore to about 500m and contains many lagoons. It extends to about 150 m seaward and ends with a lagoon of 5 m depth. The lagoon is followed by a ribbon-like reef. The offshore site, Big Giftun Island, is a very popular dive site that lies about 15 miles away from the Hurghada coast and is characterized by extensive and diverse coral cover and ichthyofauna. Two sites, Sabina 1 (X1, H1) and Sabina 2 (X2, H2), were sampled. At each site larvae were collected from both exposed and sheltered sides of the coral reef. A brief description of the different sites sampled during the study is given in Table 1.

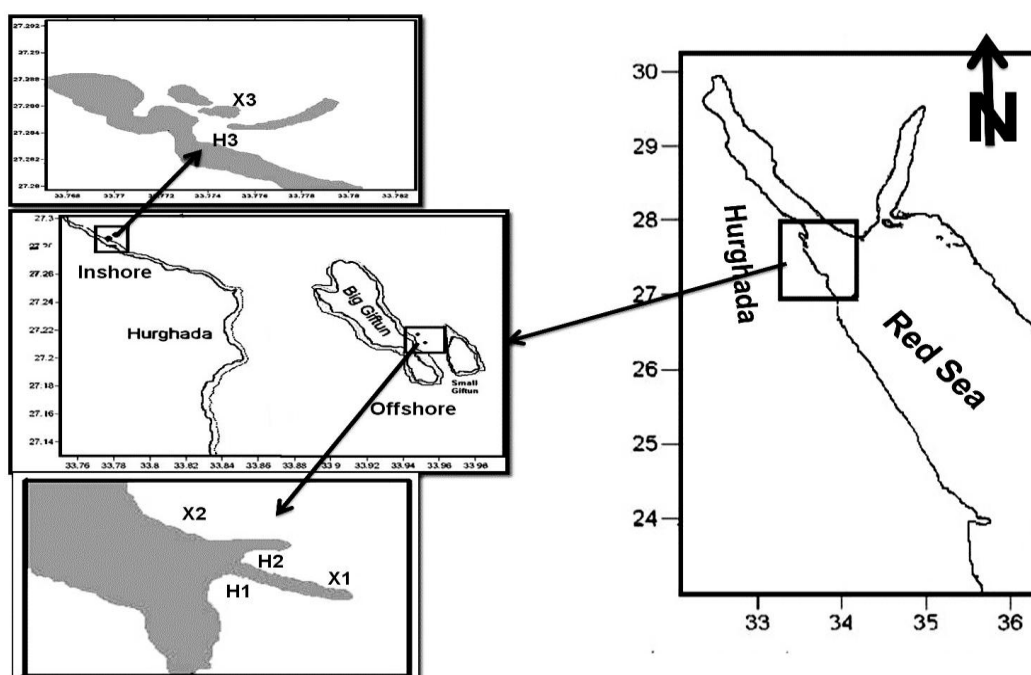


Figure 1: Map of the study area in and sampling sites at Hurghada, Red Sea.

Table 1: Location, coordinates, and description of sites.

Site	Code	Latitudes	Longitutte	Location	Exposure	Substrate type	Depth (m)
Sabina 1	H1	27° 11' 5"	33° 57' 45"	Offshore	Sheltered	Mostly sand	0.5-1.5
	X1	27° 11' 47"	33° 57' 8"	Offshore	Exposed	Mostly coral	8-12.5
Sabina 2	H2	27° 12' 44"	33° 57' 26"	Offshore	Sheltered	Mostly coral	13-20
	X2	27° 13' 6"	33° 57' 18"	Offshore	Exposed	Mostly coral	25-40
NIOF	H3	27° 17' 6"	33° 46' 22"	Inshore	Sheltered	Mostly algae and seagrass	7
	X3	27° 17' 17"	33° 46' 45"	Inshore	Exposed	Sand and rubbles	9-12.5

### Field and laboratory procedures

#### Sampling and preservation

The environmental parameters of temperature, salinity, pH, and dissolved oxygen were measured simultaneously using the Hydro-Lab on a bimonthly basis. The ichthyoplankton was collected monthly during the period from for one year using a 50 cm mouth diameter plankton net with a mesh size of 0.5 mm, early in the morning just before sunrise. Nets were towed

horizontally parallel to the reef and about 10-50 m away from the reef edge for 5-10 minutes with a towing speed of 1.5 to 2.5 knots. Samples were preserved in buffered 5% formalin solution in seawater on board for laboratory investigation. In most cases three replicates were taken although occasionally, due to sampling difficulties, only one or two replicates were obtained. The net was equipped with a flowmeter to calculate the

volume of water filtered. Densities of fish larvae were calculated as numbers of fish larvae in 1000 m<sup>3</sup> of water filtered.

#### *Laboratory procedures*

The samples were sorted and examined under an Olympus SZX7 stereomicroscope and the sorted larvae were identified to the highest possible taxonomic level. All larvae were measured to the nearest 0.1 mm before final preservation in 70% ethanol.

#### 2.3. 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 months and sites. Chi squared test was performed in order to find out the association between the degree of exposure and proximity to the shore and their influence on the structure of the larval fishes.

All data were tested for homogeneity of variance and where the samples were not homogeneous, data were either transformed or the non-parametric Kruskal-Wallis test was used (Zar, 1998; Dytham, 2003). Diversity indices

(species richness, the evenness and diversity index), were calculated using PRIMER (Plymouth Routines in Multivariate ecological Research) v 5.2.

## **Results**

### *Hydrographical conditions*

The annual mean surface water temperature was 24.89°C at Giftun and 25.16°C at MBS with the maximum during summer (July till September) and the minimum during winter (January till March) (Table 2). It fluctuated from 21.26°C in January to 27.35°C in July at the Giftun island site and from 19.54°C in January to 27.90°C in July at the inshore site. Low variability in environmental conditions was observed among sites and seasons. The seasonal and regional distribution patterns of salinity showed very slight variations where the mean annual salinity was 39.78 ppt at Giftun and 39.92 ppt inshore. The lowest value of 39.5 ppt was recorded in March at Giftun islands and the highest was 40.1ppt recorded in July at the inshore site.

**Table 2: Hydrographic parameters in Hurghada during the period of study.**

Site	Temperature (°C)					Salinity (ppt)					Transparency (cm)				
	Jan	Mar	May	Jul	Sep	Jan	Mar	May	Jul	Sep	Jan	Mar	May	Jul	Sep
H1	21.3	23.1	26.0	27.4	26.8	40.0	39.3	39.5	39.9	40.1	1.2	1.2	1.5	1.5	1.5
X1	20.8	22.8	26.1	27.0	26.5	40.0	39.8	39.8	39.9	39.8	10.1	10.6	11.0	11.0	10.9
X2	20.6	22.4	25.9	27.0	26.0	39.9	39.6	39.0	39.9	40.0	10.0	10.0	10.0	10.7	10.4
H2	21.5	23.3	26.1	27.7	27.0	40.0	40.0	39.5	39.9	39.8	8.0	8.0	8.0	8.0	8.0
X3	19.1	23.6	26.1	27.9	27.0	40.0	39.0	39.7	39.9	40.0	9.0	9.0	9.0	9.0	9.0
H3	19.5	24.0	26.9	27.9	27.5	40.0	39.5	39.6	39.9	39.9	6.0	6.5	6.0	6.5	6.0

Values of pH varied little from 8.07 to 8.23 and the water dissolved oxygen showed no pronounced variations and no indication of hypoxia; the oxygen concentration varied from 6.55 mg L<sup>-1</sup> in July to 8.05 mg L<sup>-1</sup> in January at Giftun and from 7.08 mg L<sup>-1</sup> in July to 7.57 mg L<sup>-1</sup> in January inshore. The annual mean oxygen concentrations were 7.3 mg L<sup>-1</sup> at Giftun and 7.53 mg L<sup>-1</sup> inshore.

### Density

The overall average density of fish larvae at all sites was 202 individuals 1000 m<sup>-3</sup> and there were significant differences between all sites (ANOVA  $F=4.453$ ,  $p<0.01$ ) and between all months ( $\chi^2=63.379$ ,  $p<0.01$ ) concerning the larval density. Tukey's post hoc comparison indicated that H3 was significantly different from all other sites ( $p<0.05$ ). It had the highest density with 2824 larvae 1000 m<sup>-3</sup> over the whole year while the inshore exposed

site X3 had the lowest density among all sites (621) (Fig. 2 and Table 3).

Fish larvae peaked from May to July with the highest values in May (1980 1000 m<sup>-3</sup>) and June (1475 1000 m<sup>-3</sup>) and there was another small increase in December whereas the minimum number of fish larvae was found in March (123 larvae 1000 m<sup>3</sup>). The highest number of individuals was recorded at H3 in May and June. There were no larvae present at the offshore sheltered site H1 in March, June, July and August and the offshore exposed site X1 in October and November, and at H2 in August and September and the offshore exposed site X2 in November and they were absent from the inshore exposed site X3 in January (Fig. 3). Chi squared test showed a strong association between the exposure and the proximity to the shore and a significant difference in abundance and diversity in each site.

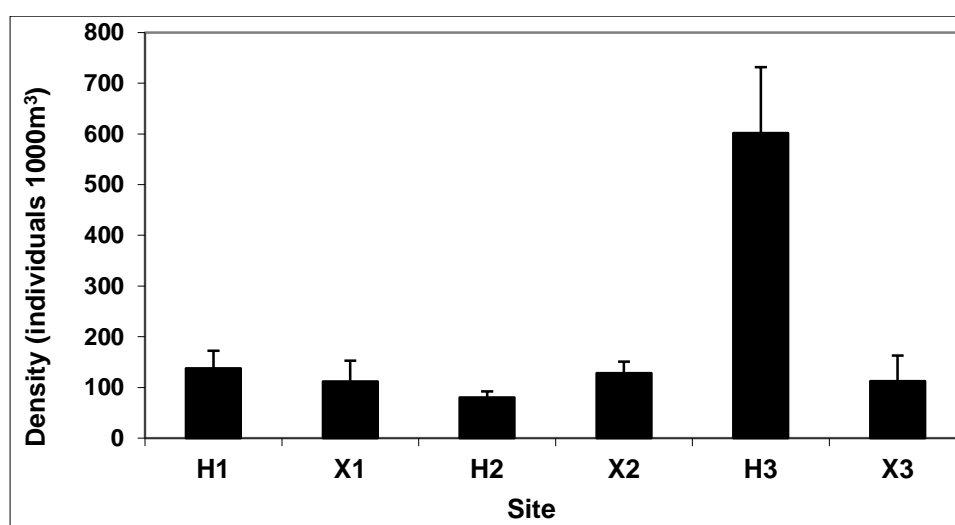


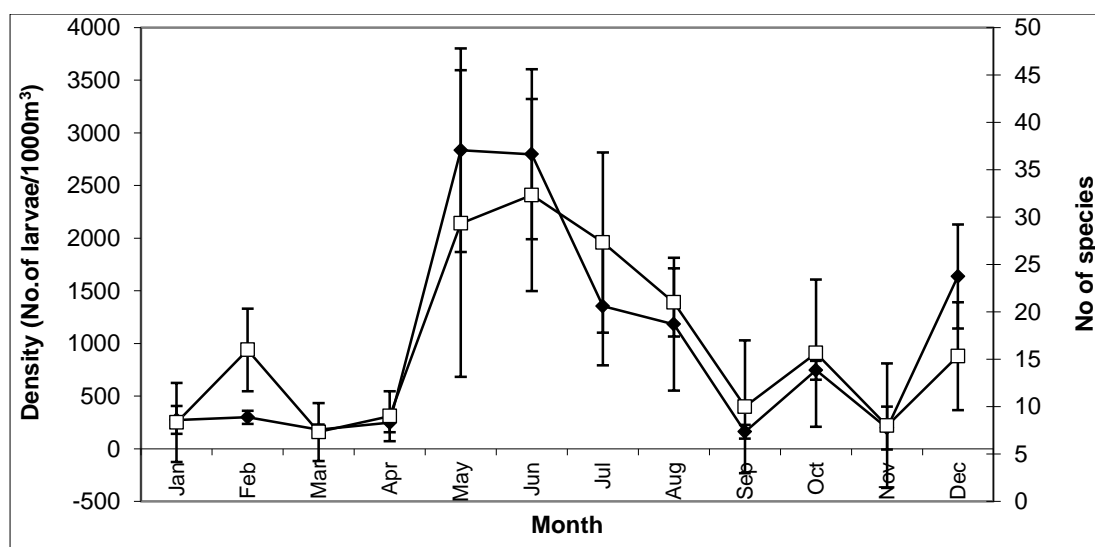
Figure 2: Density of fish larvae in different sites.

**Table 3: The mean abundance and standard deviation of fish larvae at all sites.**

Species	H1	X1	H2	X2	H3	X3
<i>Abudefduf saxatilis</i>	00	0			51±41	11±10
<i>Acanthurus sp.</i>	0	0	3.7±5.5			
<i>Apogon taeniatus</i>		0				
<i>Atherinomorus lacunosus</i>	920±218	513±220	559±104	419±149	1329±136	213±93.3
<i>Benthoosema pterotum</i>	0	43 ± 24		162±41.9		
Bythitidae	0		2±3		16±19	
<i>C. quinquineatus</i>	0				2±3	
Callionymidae	0			15.8±7.7		
<i>Centropyge multispinis</i>	0			5.9±5.1		
<i>Diodon hystix</i>	0				2±3	
Engraulidae	0			15.3±4.4		
<i>Enneapterguis sp.</i>	0	402±313		41.9±38.9	8±7	
<i>Epinephelus sp.</i>	0			2.9±5.1		
Exocoetidae	0	5±4		93.4±8.1	27±14	
<i>Fistularia commersonii</i>	0				2±3	
<i>Gerres oyena</i>	0				166±82	
Gobiidae	0			13.4±11.8	8±14	
<i>Hippocampus sp.</i>	0			16.1±1	7±8	
<i>Hypoatherina temmincki</i>	80±27	106 ±26	79±12	35.8±12	324±149	94±73.9
<i>Hyporhamphus gambrur</i>	0				118±62	6±2.8
Labridae	0					5±8.1
Lutjanidae	0			13.7±11.9		
Microdesmidae	0	8.5 ±2		10±5.8		
Mullidae	0	12.4 ±15		219±56.8	25±15	
<i>Myripristis murdjan</i>	0	15.6 ±5.2		12.2±2.3		
<i>Naso sp.</i>	0	3 ±5				
<i>Omobranchus punctatus</i>	0	5.6 ±4.9		43.4±31.3	3±5	
<i>Ostraciion sp.</i>	0				2±3	
<i>P. ancylodon</i>	0				56±26	2±2.8
<i>Paracaesio sordidus</i>	0	23.6 ±5.9	2.3±3.9	16.6±1		
<i>Pempheris sp.</i>	0				1±2	
<i>Petroscirtes mitratus</i>	4.1±7	5.4 ±9.3			186±69	87±26.2
<i>Platybelonne argalus</i>	0				16±23	
<i>Pomacentrus sp.1</i>	0				2±3	
<i>Pomacentrus sp.2</i>	0				2±3	
<i>Pomacentrus sp.3</i>	0				2±3	
<i>Priacanthus hamrur</i>	0			10.7±11.6		
<i>Pseudoanthias sp.</i>	0			21.9±27.4		

**Table 3 (continued):**

Species	H1	X1	H2	X2	H3	X3
<i>Sargocentron</i> sp.	0	6 ±4		8±9.2		
Scaridae	0			8.8±15.2		
<i>Sphyraena barracuda</i>	0				3±6	
<i>Spratelloides delicatulus</i>	95.9±67.7	32.2 ±19.4	162.8±36.1	10.4±9.1	125±64	63±54.1
Syngnathidae	0				19±8	
Synodontidae	0		1.7±2.9			
Tetraodontidae	0	6.2 ±5.4				
<i>Trachinotus</i> sp	0				3±6	
Tripterygiidae	0			7.3±12.7	18±11	3±5.4
Uidentified	0			11.1±19.2	22±38	5±8.6
<i>Vinciguerria mabahiss</i>	0	6.2 ±5.4		184.9±55.5	6±7	2±2.8

**Figure 3: Seasonal variation in numbers of fish larvae and species.**

#### Diversity

Larvae of 49 taxa belonging to 11 orders and 36 families of fish were identified. The most diverse order was the Perciformes that contained 19 families and 28 taxa. Most larvae could be identified either to the family, genus or species level although some larvae could not be identified at all. The 10 most abundant taxa, *Atherinomorus lacunosus*, *Hypoatherina temmincki*,

*Spratelloides delicatulus*, *Enneapterygius* sp., *Petroscirtes mitratus*, *Mulloides flavolineatus*, *Gerres oyena*, Exocoetidae, *Hyporhamphus gamberur* and *Abudefduf saxatilis*, formed more than 90% of all collected larvae (Fig. 4).



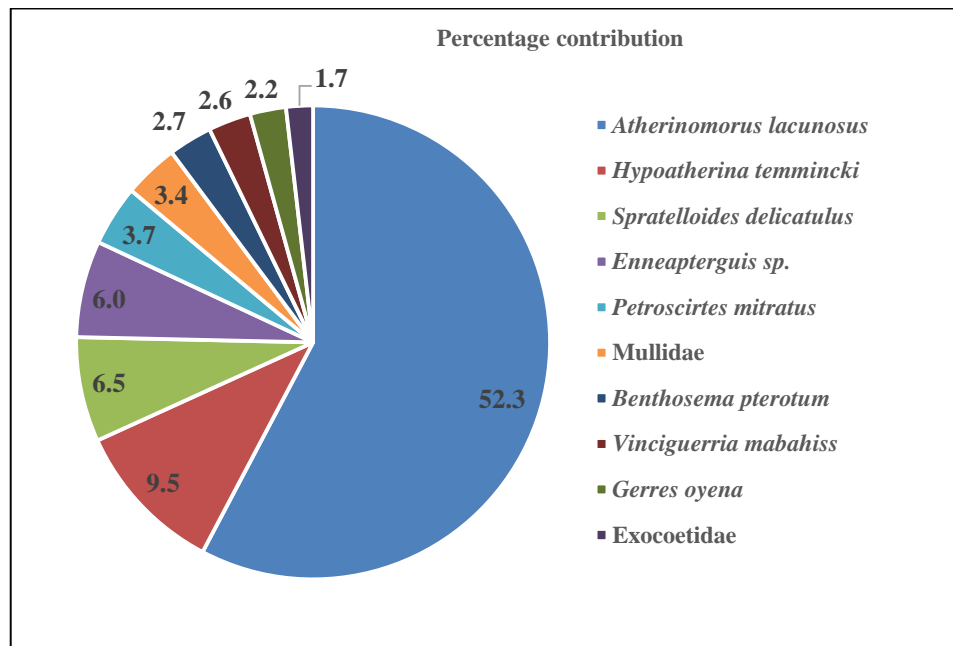


Figure 4: Percentage contribution of the dominant taxa in all sites.

The first and second most abundant the Atherinids, *Atherinomorus lacunosus* and *Hypoatherina temmincki* (family Atherinidae) that formed 52.5% and 9.5% of all larvae, respectively dominated all sites. Many species were rare in the present collection including *Pomacentrus* spp. (Pomacentridae), *Pempheris vanicolensis* (Pempheriidae) and the boxfish *Ostracion cubicus* (Ostraciidae) with only 0.02% of all larvae. Three species, *A. lacunosus*, *H. temmincki* and *S. delicatulus* were more abundant at the sheltered than the exposed sites ( $F=4.5$ ,  $p<0.05$ ) whilst the larvae of *Mulloidae flavolineatus*, *Vinciguerria mabahiss* and *Benthosema pterotum* were more abundant in the exposed than the sheltered ones ( $F=18.7$ ,  $p<0.05$ ).

The number of taxa in general showed a significant difference among

sites ( $\chi^2=47.870$ ,  $p<0.01$ ) and among months ( $F=3.497$ ,  $p<0.01$ ). The sheltered inshore site (H3) had the highest number of taxa (30) followed by X2 and X1 with 24 and 17 taxa, respectively (Fig. 5). The lowest number of taxa was recorded at H1 and H2 with only 6 and 7 taxa, respectively. The late spring and summer months, May, June, July and August had the highest number of species with a peak in July (26 taxa), whereas January and November had the lowest number of taxa with 5 taxa each (Fig. 2).

There were significant differences in the species richness in inshore and offshore sites ( $F=2.594$ ,  $p<0.05$ ) and some taxa such as Scaridae, Labridae, Acanthuridae and Priacanthidae were found to be site dependent as they were restricted to either inshore or offshore sites.

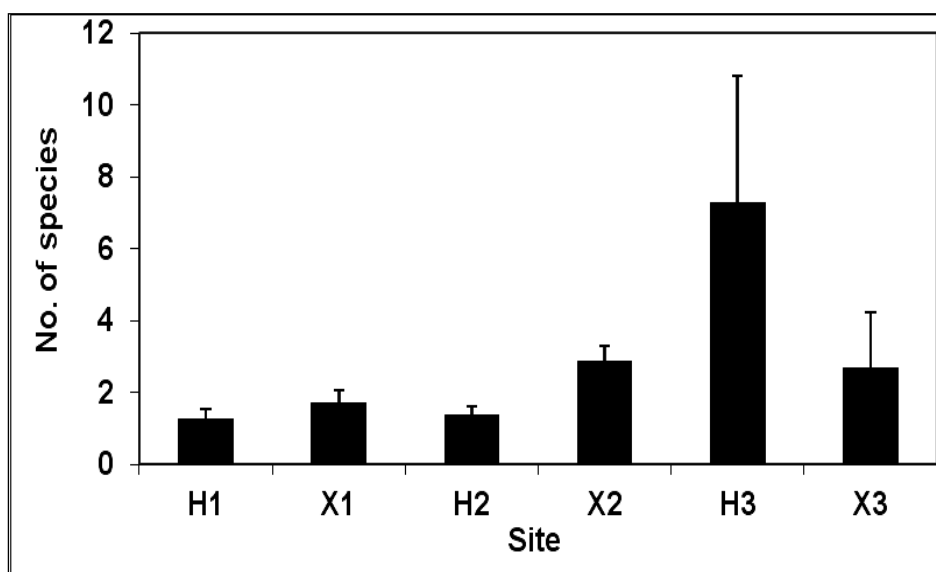


Figure 5: Number of species of fish larvae in different sites.

The larvae of 17 taxa were restricted to the offshore sites and 18 taxa were restricted to the inshore areas whereas 13 taxa were collected from both sites. These taxa were the most abundant and constituted 84% of all larvae in the inshore areas and 68% in the offshore areas.

The Margalef's index for species richness ranged from the lowest (0.4) at H1 to the highest at H3 and X3 (2.4). The highest richness values were recorded in July and June with 2.4 and 2.1, respectively (Fig. 6). The evenness was very high at H1 and X3 and was low in H3. Species in September and February had almost the same density with an evenness value of 0.9 in the two months while the fish larval populations in January and December were dominated by one or a few species as indicated by the lowest evenness values. The Shannon-Wiener diversity index was maximal in July (1.92)

followed by May, August and June and minimal in November (0.74) (Fig. 7).

Inshore larval assemblage was dominated by larger larvae than the offshore assemblage (average larval sizes of 8.3 mm and 5.2 mm, respectively). The largest larva in the collection was *Hyporhamphus gamberur* of 32 mm that was collected from H3 and the smallest larva was *Gerres oyena* of 2.3 mm. In the offshore sites, the largest larvae were *Atherinomorrus lacunosus* (25mm) and the smallest was *Acanthurus* sp. (1.8 mm). The analysis of the combined data of size range of larvae collected from inshore and offshore and from sheltered and exposed sides of the reefs indicated that most of larvae collected from the exposed sides are small and in the preflexion stages compared to their relatives in the sheltered sides.

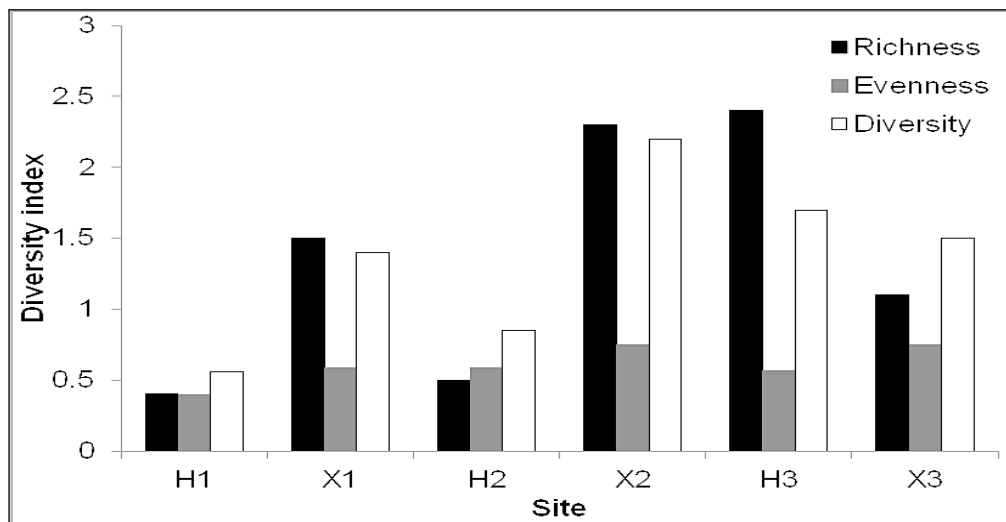


Figure 6: Variations in the diversity indices (richness, evenness and diversity) in sites.

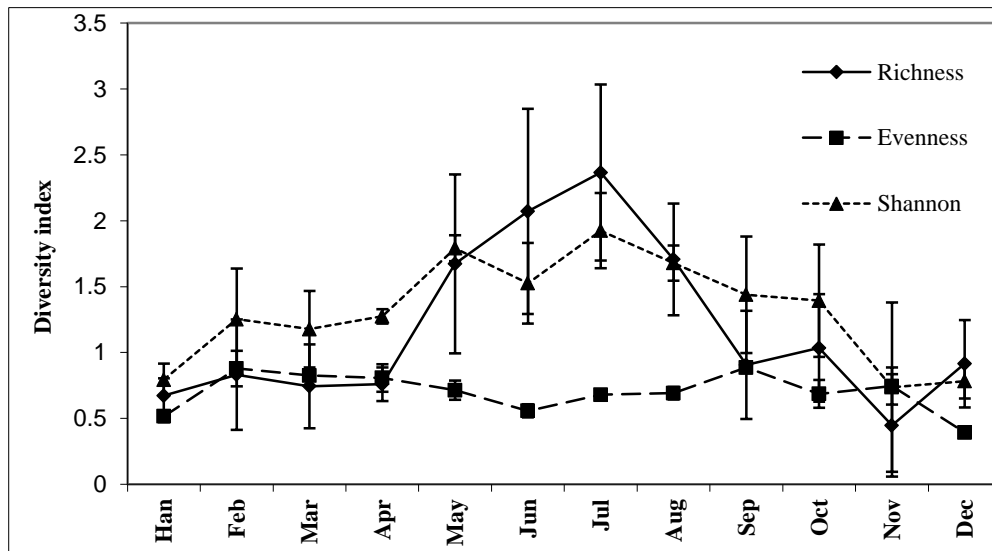


Figure 7: Seasonal variations in the diversity indices (richness, evenness and diversity).

The sheltered sides of each reef had about 62% of all larvae whereas the exposed sites had only 38% and the larvae inside the reef were larger than those outside the reef (Figs. 8 and 9).

In the offshore sites, there were regional and seasonal differences in both abundance and number of species and the exposed sides were highly significantly different from the sheltered sides ( $F=5.379$ ,  $p<0.05$ ). The

density in the offshore sites (Giftun islands) varied from the lowest in March to the highest in December. The evenness values were very low (0.37) in December. Offshore larvae were also abundant in July and August where many taxa were abundant with the evenness value of 0.92.

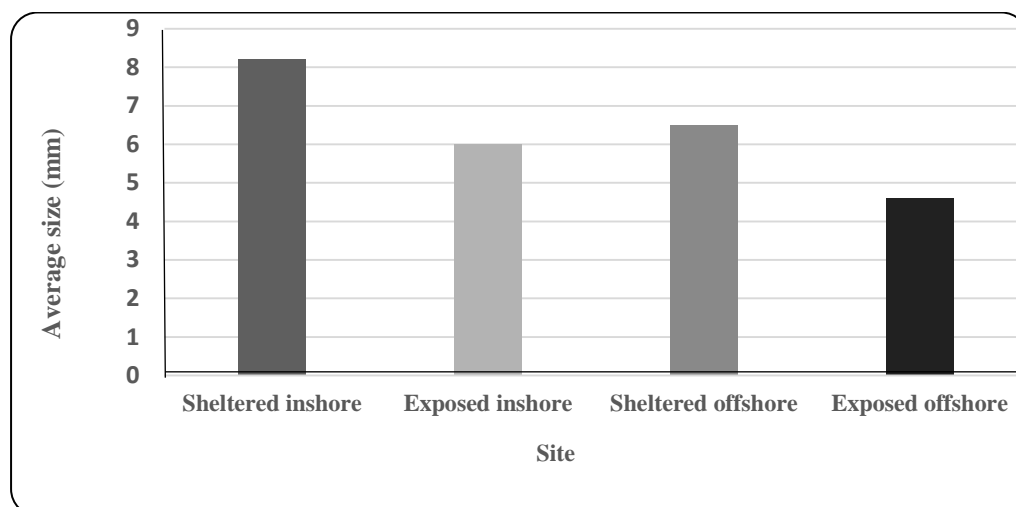


Figure 8: The average size of fish larvae in different areas.

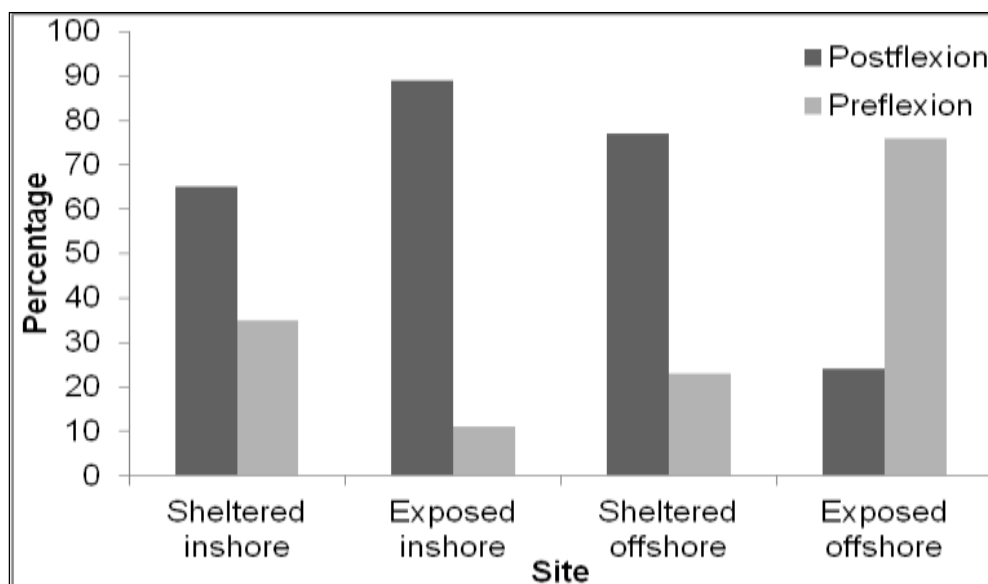


Figure 9: The percentage of preflexion and postflexion larval stages.

At the inshore site, the abundance at the sheltered side H3 is significantly different from that of the exposed site X3 ( $F=9.71$ ,  $p<0.05$ ). This site showed the highest density and diversity among all sites. Larvae of 23 families and 30 different taxa of fish were collected forming 84% of all fish larvae caught inshore. The evenness values showed

that H3 was richer than X3 with Margalef's index of 3.8 and 1.4 for H3 and X3, respectively. The overall density of fish larvae was 1161 individuals  $1000\text{ m}^{-3}$  and the highest density occurred in May followed by June. The lowest density occurred in January.

There was a significant difference between the sheltered and exposed sides at coastal sites for individuals ( $F=11.07$ ,  $p<0.001$ ) and species ( $F=7.38$ ,  $p<0.01$ ) and data for January and May were significantly different from all other months ( $F=3.132$ ,  $p<0.05$ ). The seasonal variations inshore showed that larvae of Atherinidae occurred all over the year whereas larvae of *Diodon hystrix*, *Ostracion cubicus* and *Trachintous* species were collected only in May.

### Discussion

The present study complements the very few studies on the ichthyoplankton of the coral reef fishes in the Red Sea: southern Red Sea (Nellen, 1973), Sharm El-Sheikh (Abu El-Regal, 1999), Aqaba (Faroukh, 2001) and Hurghada (Abu El-Regal, 2008). All of these studies aimed to identify the larval fishes in the studied area and to provide data on the density and seasonality of the larvae. Despite differences due to the methods of sampling, the present study confirmed the highest abundance of fish larvae was recorded from May to August. This agrees with previous reports for the northern Red Sea that larvae of coral reef fishes peaked in the warmer seasons of the year (Cuschnir, 1991; El-Sherbiny, 1997; Abu El-Regal, 1999; Faroukh, 2001; Abu El-Regal, 2008; Abu El-Regal, 2013; Abu El-Regal *et al.*, 2014a; Abu El-Regal *et al.*, 2014b; Abu El-Regal, 2015). More minor density and diversity differences between the areas may be due to the method of sampling and the gears used.

More fish families (36) were collected during the present study than those from Aqaba (25) and Sharm El-Sheikh (32). Although the lowest number of families was found in Aqaba, more taxa were identified (74) because most of species belonged to families Apogonidae and Pomacentridae that contained 23 and 17 taxa respectively. Some taxa absent from Aqaba or Sharm El-Sheikh samples were recorded in Hurghada and vice versa. Larvae of Pomacanthidae, Scaridae, Microdesmidae, Gerridae and Engraulidae were collected from Hurghada only. Of the most abundant families in Aqaba, Clupeidae, Pomacentridae, Apogonidae and Gobiidae, only clupeid larvae were abundant in the present collection. Slight differences in the species composition and density of fish larvae are found between Sharm El-Sheikh and Hurghada collections because of the similar environmental conditions. As the plankton net was of 0.5 mm mesh size, most larvae were small and preflexion compared to the larger larvae collected from Jordanian waters by light trap (Faroukh, 2001). Larger larvae of Clupeidae, Pomacentridae, Apogonidae and Gobiidae are photopositive and so more likely to swim into the trap than smaller larvae (Choat *et al.*, 1993). The plankton net used in the present work collected only two apogonid and a few pomacentrid larvae.

The offshore sites were characterized by a number of fish families that were not recorded in the inshore sites: Scaridae, Acanthuridae,

Holocentridae, Serranidae, Pomacanthidae, Lutjanidae, Microdesmidae, Synodontidae and Priacanthidae. The majority of these were coral reef fishes and were collected from the exposed sites in summer months where the average surface water temperature in Giftun Islands was 27.35°C. Larvae of Microdesmidae and at least one species of Synodontidae were recorded in winter where the temperature was 21.5°C. Most of these fishes are pelagic spawners and the larvae were generally small and most of them were in the preflexion stage. In the sheltered offshore sites, larvae of 9 families containing 10 taxa were found.

Larvae of 29 taxa belonging to 23 families were recorded at the exposed offshore sites of which 24 taxa were collected from X2. The most abundant taxa were *A. lacunosus*, *Enneapterygius* sp., *V. mabahiss*, *M. flavolineatus* and *H. temmincki*. It is clear that site X2 is more diverse than site X1 with 23 species being recorded compared to 16 species at site X1.

The majority of fish larval species present in the area are also recorded as adults. About 21% of the adult fish species recorded have their larval stages in the area while very few taxa were found only as larvae (Abu El-Regal, unpublished data). Bellwood and Wainwright (2002) stated that 281 species in 40 fish families are known to be reef fishes in the Red Sea. Larvae of 25 coral reef fish families were collected in the present study, of which,

16 families were taken inshore and 22 were taken offshore. Most notably, although taken as adults in the area, 15 families do not have larvae in the area. Young *et al.* (1986) similarly recorded 40 fish families as adults in the North West continental shelf of Australia but did not find their larvae in the area. Hence the inshore larval assemblages may not necessarily be representative of the adult fish assemblage. Larvae of many taxa of reef fishes were missing inshore (Miller, 1974, 1979; Watson and Leis, 1974) and Leis (1994) considered it possible that pelagic larval coral reef fishes disperse from their natal reef. Many of the missing reef fish larvae inshore can be found 5-12km offshore (Leis and Miller, 1976). Some species, such as that of families Chaetodontidae, Scaridae and Lutjanidae have a very short planktonic life and a rapid metamorphosis to adult, and settle to the bottom after hatching (Lowe-McConnell, 1979). Some species of Apogonidae and Pomacentridae produce demersal eggs that are attached to the substratum and the larvae never enter the pelagic life (Munro *et al.*, 1973). Visual census techniques have shown apogonid and pomacentrid larvae hidden among branches of *Acropora* corals (personal observation). This may explain the rarity of these fishes in the current samples. Pomacanthid larvae were very rare in the present collection as only two larvae were collected from Giftun Island in July. Chaetodontid larvae were missing from Hurghada (present

data), Arabian Gulf (Houde *et al.*, 1986) and Sharm El-Sheikh (Abu El-Regal, 1999).

Larvae of many commercial fishes were collected during the present study. Families such as Mullidae, Lutjanidae, Scaridae, Carangidae, Sphyraenidae, Gerridae and Serranidae are represented in the current samples by larvae indicating nearby spawning grounds. This study presents important information on the spawning seasons and spawning grounds of these fishes that form a baseline data concerning the larvae of commercial fishes as an essential part in fisheries management. However, the larvae of some fishes whose adults are important constituents of Egyptian fisheries were rare or even absent in the collection. This may be due to the behaviour of the adult or the behaviour of the larvae (Leis, 1991b; Montgomery *et al.*, 2001). Larvae of lethrinid fishes were absent in the ichthyoplankton samples during the period of study and other studies in the Red Sea (Abu El-Regal, 1999, 2008, 2009). These fishes may migrate to areas more favourable for spawning (Johannes, 1978).

The present study focuses on the effect of the proximity to the shore and the degree of exposure to wave action on the abundance, diversity and size of larval fish. There are two distinct assemblages of larval distribution in the present study. Most of the larvae collected from the inshore and offshore sites in the present study belonged to nearshore fishes. The larvae of nearshore fishes formed about 99.5%

and 92% at inshore and offshore sites, respectively.

The inshore assemblage was composed mainly of larvae that hatched from demersal spawners and that of offshore had most larvae hatched from pelagic eggs. There is evidence of reef fish being retained nearshore and that the fish larval assemblages inshore are dominated by larvae from demersal spawners (Leis 1982; Leis, 1987; Suthers and Frank, 1991; Leis and McCormic, 2002; Paris and Cowen, 2004). Leis (1982) showed that dominance by larvae of demersal spawners in inshore waters was due to a few species – primarily tripterygiid, schindleriid and gobiid larvae. In the present study, this dominance was due to the highest densities of atherinid, blennid and hemirhamphid larvae. In the offshore waters of Oahu, Clarke (1991) found that larvae from the pelagic spawners dominated the collection and that from demersal spawners were rare or completely absent. Smith *et al.* (1987) reported that inshore areas adjacent to deep waters in the Caribbean were dominated by clupeids, blennids and gobiids.

The composition and distribution of fish larvae are influenced by environmental factors such as temperature and salinity (Houde and Zastrow, 1993; Hernandez-Miranda *et al.*, 2003). There were no significant differences in salinity and temperature between the sites but there was a significant difference in temperature between seasons ( $F=90.6$   $p<0.05$ ). Hence temperature may influence the

temporal but not the spatial distribution of fish larvae in Hurghada area. The highest catch and taxon richness of fish larvae were related to high temperatures in the area and the summer months.

Indo-Pacific coral reefs, including the Red Sea, have a complex topography, hydrography and biota. The structural complexity of coral reef provides a variety of habitats most of which support fish larvae (Leis, 1991a). However, in the present study, the topography and complexity of the reef differ from site to site with highest coral cover recorded offshore in X2 (70% coral cover). Prior to the present study, little was known about the influence of exposure on the species composition and distribution of fish larvae. Miller (1979) identified windward-leeward differences in larval distribution based on surface tows and considered the differences might be related to an assumed, taxon-specific vertical distribution of larvae but thought that hydrography was the major determinant. Similarly, Leis (1991a) found strong windward-leeward differences in larval abundances and assemblages in the immediate vicinity of the reef. In the present study, the distribution between sheltered and exposed sides of the reef has two distinct patterns. In the inshore sites, larvae were more abundant and diverse on the sheltered side than on the exposed side. In contrast, the offshore sites had larger numbers of larvae and species on the exposed sides compared to the sheltered sites. Many larval fish

taxa were recorded only on the exposed side of the reef and larvae of Holocentridae, Priacanthidae, Scaridae, Pomacanthidae, Lutjanidae, Callionymidae, Microdesmidae, Serranidae and Engraulidae were never collected from the sheltered side. Most larvae collected from the offshore exposed sites hatched from pelagic spawners whereas the majority of fish larvae in the offshore sheltered sites hatched from demersal eggs. Brooders were rare in X2, abundant in H2 and H3 and totally absent from the other sites (Fig. 6). These differences in the larval community structure on both sides may be due to the topographic conditions in the different sites (Table I) and the spawning behaviour of the adults.

This study showed the distributional patterns of the larvae of coral reef fishes that help to understand the interrelationships among fish species during their larval stages and to understand the adult spawning patterns in Hurghada waters. Such information is important for fisheries management although further studies are required to understand the patterns of dispersal of fish larvae in the area, for example, on the vertical distribution of the larvae and the interaction with the physical processes in the area.

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