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Study of Diversity and Abundance of Fish Larvae in the South-western Part of the Sea of Oman in 2011-2012

Tatyana Chesalina*, Lubna Al-Kharusi, Ahmed Al-Aisry, Nader Al-Abri,
Ebtisam Al-Mukhaini, Asila Al-Maawali and Luqman Al-Hasani
Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries Wealth, Muscat, Oman
*E-mail of the corresponding author: mailto:tanleoches@mail.ru

Abstract

The study presents results on the taxonomic composition and abundance of fish larvae collected in south-western part of the Oman Sea (near Muscat and Sohar) from October 2011 to October 2012. 40 families of larval fishes were identified, which included 47 genera and 28 species. The four most common families, arranged in order of decreasing abundance, were Sparidae, Scombridae, Clupeidae and Nemipteridae. Fish larvae from 13 families occurred both in Sohar and Muscat areas (Blenniidae, Carangidae, Gerreidae, Haemulidae, Mullidae, Pomacentridae, Sphyraenidae, Teraponidae, Sparidae, Scombridae, Clupeidae, Nemipteridae and Sciaenidae). Monthly changes in abundance and diversity of fish larvae were studied. Majority of fish larvae taxa occurred in samples in February and July 2012. The higher abundance was observed in February with a density of 1534 larvae/100m^3 and in July (385 larvae/100m^3). In overall, Sohar was the richest in diversity of fish larvae and also had the highest average density (207.3 larvae/100m^3) compared to Muscat.

Keywords: fish larvae, diversity, abundance, distribution, Sea of Oman.

1. Introduction

Various aspects of early life history of fish development are an important, independent part of ichthyological investigation. Study of the species composition, abundance, spatial and temporal distribution of fish larvae provides valuable data on the locations and seasons of spawning, in particular, commercially important species. This knowledge allows to understand the life cycle, behavior and migration of fish, provides important scientific information to evaluate the reproduction success of different fish and further state of recruitment and fish stocks that can be used for rational exploitation of fish resources. Early stages of fish development (eggs and larvae) are the most vulnerable to the changes of environmental conditions; therefore study of the state of ichthyoplankton communities helps not only to estimate the reproduction success of fish populations and to predict future catches of commercially important species, but also to monitor the anthropogenic impact and climate change in marine ecosystem.

Currently, there is a small number of publications devoted to the study of ichthyoplankton in the waters of Oman. First of all, these are investigations conducted by the Marine Science and Fisheries Centre (Muscat) staff and summarized in the reports of 1987, 1989, 1991 and an article by Thangaraja & Al-Aisry (2001), which presents the results of ichthyoplankton study in the period of 1989-1990 by FAO R/V Rastrelliger in eight different areas of the Omani coast, including inshore and offshore waters. Ichthyoplankton in the adjacent waters of the Arabian Sea and the Arabian Gulf is more investigated. In 1973 Nellen published data on biodiversity and abundance of fish larvae in the Arabian Sea and the Arabian Gulf. Houde et al. (1986) studied ichthyoplankton in the western part of the Arabian Gulf, especially in the waters of Kuwait. This work became the basis for further study of ichthyoplankton and for the creation of identification guide of the early life history stages of fishes from the waters of Kuwait in the Arabian Gulf (Richards & Al-Yamani, 2008).

Taking into account that the study of ichthyoplankton in Omani waters was not conducted during last 20 years the new data about the present state of ichthyoplankton community is topical and has important scientific and practical interest. This work presents the results on the composition and abundance of fish larvae in the south-western part of the Sea of Oman in 2011-2012.

2. Materials and Methods

Monthly the zooplankton samples were collected at two stations in the south-western part of Oman Sea from October 2011 to October 2012: Station 1 (near Sohar) at 24°23'53 N, 56°46'29 E; Station 2 (near Muscat) at 23°35'42 N, 58°36'99 E (Fig. 1).

Zooplankton was sampled using a plankton net 60 cm in diameter with mesh size 200 micrometers. A flow meter was attached to the mouth of the net to determine the volume of sea water filtered during each tow. Zooplankton was towed from the sea surface layer at speed of about 2 knots for 5 minutes. Collected specimens were preserved in 10% buffered formalin. In the laboratory fish larvae were sorted out from other zooplankton and stored in separate vials in 4% buffered formalin solution. Fish larvae samples were standardized to numbers caught per 100 m^3 of sea water volume filtered.

Fish larvae were being enumerated and measured under a binocular microscope and identified to the lowest taxonomic level possible (family, genus or species) by using the ichthyoplankton guides (Fahay 1983, 2007; Leis & Carson-Ewart, 2000; Leis & Rennis, 1983; Moser et al., 1984; Nishikawa & Rimmer 1987; Neira et al. 1998, Okiyama 1988; Ozawa, 1986; Richards & Al-Yamani, 2008). Damaged and unknown larvae were placed in "unidentified" category. Fish larvae samples were standardized to numbers caught (larvae per 100 cubic meters) of sea water volume filtered.

Environmental parameters (temperature, salinity, dissolved oxygen and pH) were measured by CTD (Ocean Seven 316 plus) in each station at the same time as zooplankton was collected.

To compare the similarity of the ichthyoplankton composition and abundance in studied areas with the previous data (Thangaraja & Al-Aisry, 2001) the dominance-diversity curves were constructed using general lognormal model (Bastow, 1991), Sørensen's similarity index (Sørensen, 1948) and three biodiversity indices: richness index of Simpsons (Simpson, 1949), diversity index of Shannon-Weaver (Shannon, 1948), Margalef's diversity index (Margalef, 1958) were estimated.

3. Results

3.1 Environmental parameters

The surface water temperature ranged significantly in Sohar and Muscat during the study period with the same fluctuations: the lowest values (22.0-22.7°C) were observed in February and highest (32.1-33.1°C) were in July (Fig. 2). Salinity stratification was less pronounced, it varied from 33.86‰ (in October 2012) to 37.03‰ (in May 2012). Overall average salinity in Sohar and Muscat was slightly higher in north-east monsoon period. The dissolved oxygen concentration near the surface was also comparatively stable throughout the studied period, it increased in January-February (7.03-7.18 ml/1) in both areas and decreased in Sohar in June (to 5.28 ml/1) and near Muscat in June-July (to 6.05-6.18 ml/1). The pH values from Sohar and Muscat ranged from 6.66 to 8.28.

3.2 Sohar area

A total of 403 specimens of fish larvae were obtained from the coastal waters near Sohar. In the samples 29 families were identified, including 33 genera and 18 species (Table 1).

Five families had a density more than 100 larvae/100m^3 and accounted for 71.3 % of the total larval concentration: Sparidae, Nemipteridae, Clupeidae, Engraulidae, and Sphyraenidae. Twenty families occurred in relatively low abundance (less than 1%).

The total abundance of fish larvae was 1865.3 larvae/100m^3 and the average number per sample was 207.3 larvae/100m^3. The highest abundance was observed in February 2012 (1480.6 larvae/100m^3), higher density was also registered in October 2012 (183.9 larvae/100m^3) during other months it was on a low level and ranged from 2.1 to 51.9 larvae/100m^3.

Sixteen families were presented only from the samples collected in this station (Ambassidae, Atherinidae, Apogonidae, Callionymidae, Chaetodontidae, Engraulidae, Gobiidae, Labridae, Lutjanidae, Monocanthidae, Nomeidae, Platycephalidae, Synodontidae, Scorpaenidae, Serranidae, Sillaginidae). Sixteen families are of the commercial importance. They contributed about 84.5% of the total number of fish larvae.

Most dominant larvae in catches were represented by Sparidae (28.5%). The total abundance was 531 larvae/100m^3. The sparid larvae occurred from October 2011 to March 2012. The maximum density was in February (518 larvae/100m^3). Representatives of the two species *Acanthopagrus bifasciatus* and *Argyrops spinifer* were recognized within the Sparidae family. Both species were found in February, while single individuals of *A. spinifer* also occurred in October, December and *A. bifasciatus* in March (1.5 to 7.9 larvae/100m^3).

Nemipterid larvae were the second abundant family. Larvae were found in the late autumn, winter and mid-summer. Depending on the season, the number of larvae in the samples ranged from 1.3 larvae/100m^3 in summer to 215 larvae/100m^3 in winter.

Family Clupeidae, the third largest family, was presented by two genera (sardines and herrings) and two species *Sardinella longiceps* and *Etrumeus teres*. The percentage of *S. longiceps* (239 larvae/100m^3) was 12.82 from the total number of larvae captured and recorded in the samples. The abundance of fish larvae from December to February increased and ranged from 13.0 larvae/100m^3 to 203.5 larvae/100m^3. Herring larvae *E. teres* were also found in winter (February), the number of which composed 12 larvae/100m^3.

Anchovies were accounted for about 7.8 % of all larvae collected. Most anchovies were found in October 2012 (the density was 113 larvae/100m^3), several larvae (5-19 larvae/100m^3) were also caught in December 2011 and April 2012. All larvae were represented by one species *Encrasicholina punctifer.*

A few larvae of barracudas, *Sphyraena barracuda* were found in July, another species *Sphyraena* sp. was taken during February-March and in July and October 2012. They were the most abundant in February, the density was 98,7 larvae/100m^3.

3.3 Muscat area

A total of 255 fish larvae representing 24 families including 25 genera and 16 species were collected throughout the study (Table 2). Three families Scombridae, Pomacentridae and Clupeidae were the most dominant (71.3%) based on total concentration and frequency of occurrence from all hauls sampled. Seventeen families were the economically important group.

Larvae from eleven families were found only in this region, including Antennaridae, Bregmacerotidae, Cynoglossidae, Gempylidae, Leiognathidae, Mugilidae, Myctophidae, Ostraciidae, Pomatomidae, Trichiuridae and Tripterygiidae.

The total abundance of fish larvae was 596 larvae/100m^3. The mean density of the larvae in Muscat region was 66.2 per 100 m^3. The highest density was registered in July 2012 (374 larvae/100m^3). Higher abundance was also registered in January and February 2012 (66.1 and 53.1 larvae/100m^3 respectively). During other months their density showed a low level from 3.8 to 38.8 larvae/100m^3.

The most dominant were scombrid larvae that contributed about 40.8%. A total of 128 larvae recognized as *Rastrelliger kanagurta* were found in July 2012.

Pomacentrid larvae were on the second place of the abundance (20.3%). The density was 121 larvae/100m^3. The most common species was sergeant major *Abudefduf vaigiensis*, where the larvae were registered in July and October 2012. Another pomacentrid species (*Chromis* sp.) was recorded in October 2012.

Clupeid larvae were the third in abundance (10.2%). They occurred in October 2011, January-February and from May to July 2012. The density was 61 larvae/100m^3. The clupeid larvae were identified belonging to *S. longiceps* and *Amblygaster sirm*.

4. Discussion

Overall 40 families of fish larvae, which included 47 genera and 28 species, were identified from the plankton samples in the studied areas from October 2011 to October 2012. The most diverse family was Carangidae with six genera. Three species were recognized in families Clupeidae and Pomacentridae, two species were found in Sparidae, Teraponidae and Blenniidae, other families were represented by one genus or species.

A total of 22 commercially important families were found, including 16 from Sohar and 17 from Muscat. The larvae of commercial fishes accounted about 81% from the total number and 11 families (Carangidae, Gerreidae, Mullidae, Sphyraenidae, Teraponidae, Sparidae, Scombridae, Clupeidae, Nemipteridae, Sciaenidae, Haemulidae) were common for two investigated areas.

In the period of the study larvae of demersal fish were represented by 28 families, the larvae from the remaining families belong to pelagic fish (Bregmacerotidae, Carangidae, Clupeidae, Engraulidae, Gempylidae, Leoignatidae, Myctophidae, Nomeidae, Pomatomidae, Scombridae, Sphyraenidae, Trichiuridae).

According to the ecological classification based on the adult's habitat (Smith and Heemstra, 1986) the most common were the larvae of shallow water fishes (47.5%), they are followed by inshore-reef (22.5%) and neritic (17.5%) species (Fig. 3).

The least common were the larvae of oceanic (mesopelagic) fishes, which usually inhabit and spawn in the open waters at a great depth. Larvae of *Benthosema pterotum* (Myctophidae), *Bregmaceros nectabanus* (Bregmacerotidae), *Trichiurus lepturus* (Trichiuridae) and *Lepidocybium* sp. (Gempylidae) were found near Muscat in January 2012 and *Cubiceps* sp. (Nomeidae) was registered in the sample collected from Sohar in February 2012.

The four most dominant families, arranged in order of decreasing abundance, were Sparidae, Scombridae, Clupeidae, Nemipteridae. Their abundance ranged from 251 to 538 larvae/100m^3, composing in total 56.6% of all larvae taken. The abundance of larvae of nine families (Blenniidae, Carangidae, Engraulidae, Gerreidae, Gobiidae, Mullidae, Pomacentridae, Sphyraenidae, Teraponidae and Haemulidae) varied in 32-145 larvae/100m^3 and they comprised about 35.4%. The density of larvae from other families was less than 14 larvae/100m^3.

Sohar was the richest in ichthyoplankton diversity (29 families) and also had the highest abundance (mean 207.3 larvae/100m^3), whereas Muscat had lower diversity and density of fish larvae. Fish larvae from 13 families occurred both in Sohar and Muscat areas (Blenniidae, Carangidae, Gerreidae, Haemulidae, Mullidae, Pomacentridae, Sphyraenidae, Teraponidae, Sparidae, Scombridae, Clupeidae, Nemipteridae, Sciaenidae).

Monthly changes in abundance and diversity of fish larvae were studied. Majority of fish larvae taxa occurred in samples in February (17 families) and July 2012 (13 families) (Fig. 4, 1). The higher abundance was observed in February with a density of 1534 larvae/100m^3 and in July (385 larvae/100m^3) (Fig. 4, 2).

Larval densities were low in May (26.4 larvae/100m^3) and August 2012 (11.2 larvae/100m^3). In other months, the abundance ranged from 29 larvae/100m^3 to 183.9 larvae/100m^3. Thus, a maximum number of fish larvae was collected during February and July, indicating two major peaks of fish spawning in the Sea of Oman. Some correlation was observed between fish larval density and the environmental parameters such as surface water temperature. The primary peak of larvae abundance in February during north-east monsoon season associated with the low temperature, while the secondary in July during south-west monsoon is related to high temperature.

In addition, a comparative analysis of our data with the results of ichthyoplankton surveys carried out in 1989-1990 (Thangaraja and Al-Aisry, 2001) was made. These authors identified fish larvae from 33 families, including 34 genera and 16 species in the samples collected in offshore and inshore waters between Shinas and Muscat. A comparison of species composition of ichthyoplankton collected in 1989-1990 and 2011-2012 showed that larvae from 21 families, 17 genera and 8 species were common, but significant differences were found in dominant groups. According to our results the most abundant larvae were *A. bifasciatus* (12 %), *R. kanagurta* (10%) and *S. longiceps* (11%). In the samples of 1989-1990 larvae of Myctophidae (44.3%), Clupeidae (24.8%), Haemulidae (11.0%) and Hemiramphidae (5.9%) dominated. Family Myctophidae was represented by one species *Benthosema pterotum* and it was the most numerous in all larvae taken in 1989-1990. In 2011-2012 larvae of *B. pterotum* comprised less than 1%. This may be explained by the fact that our studies were limited to the coastal part of the Sea of Oman with shallow depth (about 30 m). Family Clupeidae is the only common family among the dominant species in two compared studies. The most common species in both studies was sardine *S. longiceps*: 23.8% in 1989-1990 and 11.6% in 2011-2012. In our study larvae of Haemulidae were accounted about 3%, and the larvae of flying fishes were not found.

To compare larval fish diversity in the studied areas the similarity coefficients and three diversity indices were estimated. The Sørensen's similarity coefficient (QS) of the fish larvae composition between Sohar and Muscat was estimated as 0.49, while this coefficient calculated between our pooled data for both areas with the data of

Thangaraja and Al-Aisry (2001) showed larger value (0.58). All estimated diversity indices were higher in Sohar than in Muscat and their values were higher in 2011-2012 in comparison with the data of 1989-1990 (Table 3).

Dominance diversity curves were constructed by ranking the log of the families density values from the highest to lowest (Fig. 5). Dominance diversity graphs in 1989-1990 and 2010-2012 showed similar trend, but decrease of the second curve was less steep which indicated that the ichthyoplankton community in 2011-2012 was in more stable condition.

The dominance diversity curves provide an easily interpretable visual representation of both species richness and abundance relationships and may be further applied to emphasize categories of ichthyoplankton that are represented in different areas. This will assist in the coastal management of this area.

The present results can be a basis for the following ichthyoplankton studies in relation to oceanographic parameters, zooplankton composition and fish distribution and further investigations are recommended.

5. Acknowledgement

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Table 1. Composition and abundance of larvae collected off Sohar from October 2011 to October 2012.

Family	Genus or species	Abundance larvae/100m^3	% in total catch	Rank
Ambassidae	*Ambassis* spp.	3	0.16	20
Apogonidae	*Apogon* spp.	14	0.75	13
Atherinidae	*Atherinomorus lacunosus*	6	0.32	18
Blenniidae	*Omobranchus* spp.	35	1.88	10
	Parablennius spp.	74	3.97	8
Callionymidae	*Callionymus* spp.	1	0.05	22
Carangidae*	*Decapterus russelli*	27	1.45	11
	Selar crumenophthalmus	2	0.11	21
	Trachurus indicus	24	1.29	12
	Carangoides spp.	1	0.05	22
	Scomberoides spp.	4	0.21	19
	Caranx spp.	1	0.05	22
Chaetodontidae	*Chaetodon* spp.	3	0.16	20
Clupeidae*	*Sardinella longiceps*	239	12.82	4
	Etrumeus teres	12	0.64	14
Engraulidae*	*Encrasicholina punctifer*	145	7.77	5
Gerreidae*	*Gerres oyena*	68	3.65	9
Haemulidae*	*Pomadasys* spp.	74	3.97	8
Gobiidae		76	4.08	7
Labridae		6	0.32	18
Lutjanidae*	*Lutjanus* spp.	2	0.11	21
Monocanthidae	*Aluterus monoceros*	6	0.32	18
Mullidae*	*Upeneus tragula*	10	0.54	16
Nemipteridae*	*Nemipterus japonicus*	283	15.17	2
Nomeidae	*Cubiceps* sp.	12	0.64	14
Platycephalidae		3	0.16	20
Pomacentridae	*Pomacentrus* spp.	2	0.11	21
Sciaenidae*		3	0.16	20
Scombridae*	*Rastrelliger kanagurta*	8	0.43	17
Scorpaenidae	*Pterois* spp.	2	0.11	21
Serranidae*	*Epinephelus* spp.	6	0.32	18
Sillaginidae*	*Sillago sihama*	3	0.16	20

Table 1 continue.

Sparidae*	*Acanthopagrus bifasciatus* *Argyrops spinifer*	290 241	15.55 12.92	1 3
Sphyraenidae*	*Sphyraena barracuda* *Sphyraena* spp.	1 119	0.05 6.39	22 6
Synodontidae*	*Trachinocephalus myops*	3	0.16	20
Teraponidae*	*Terapon jarbua*	11	0.59	15
Unidentified		45	2.41	
Total		1865		

*- commercially important family

Table 2. Composition and abundance of larvae collected off Muscat from October 2011 to October 2012.

Family	Genus or species	Abundance larvae/100m^3	% in total catch	Rank
Antennaridae	*Antennarius* sp.	2	0.34	13
Blenniidae	*Omobranchus* sp.	5	0.84	10
	Parablennius sp.	30	5.03	4
Bregmacerotidae	*Bregmaceros nectabanus*	7	1.17	9
Carangidae*	*Caranx* sp.	3	0.50	12
Clupeidae*	*Sardinella longiceps*	48	8.05	3
	Amblygaster sirm	13	2.18	7
Cynoglossidae*	*Cynoglossus* sp.	7	1.17	9
Gempylidae*	*Lepidocybium* sp.	13	2.18	7
Gerreidae*	*Gerres oyena*	4	0.67	11
Haemulidae*	*Pomadasys* spp.	2	0.34	13
Leiognathidae*	*Secutor insidiator*	7	1.17	9
Mugilidae*	*Mugil cephalus*	2	0.34	13
Mullidae*	*Upeneus tragula*	22	3.69	5
Myctophidae	*Benthosema pterotum*	13	2.18	7
Nemipteridae*	*Nemipterus japonicus*	8	1.34	8
Ostraciidae	*Ostracion meleagris*	2	0.34	13
Pomacentridae	*Abudefduf vaigiensis*	118	19.79	2
	Chromis sp.	2	0.5	12
Pomatomidae*	*Pomatomus saltatrix*	2	0.34	13
Sciaenidae*		2	0.34	13
Scombridae*	*Rastrelliger kanagurta*	243	40.77	1
Sparidae*	*Acanthopagrus bifasciatus*	7	1.17	9
Sphyraenidae*	*Sphyraena* spp.	20	3.36	6
Teraponidae*	*Terapon theraps*	4	0.67	11
Trichiuridae*	*Trichiurus lepturus*	7	1.17	9
Tripterygiidae		2	0.34	2
Total		596		

Table. 3. Biodiversity indices of the fish larvae in Sohar and Muscat in the present study and compared with previous investigation.

Biodiversity index	Sohar	Muscat	Pooled areas	Data of 1989-1990 (Thangaraja & Al-Aisry, 2001)
Simpson's	7.01	4.43	9.50	3.63
Shannon-Weaver	1.01	0.89	1.14	0.76
Margalef's	4.17	3.72	5.12	3.60

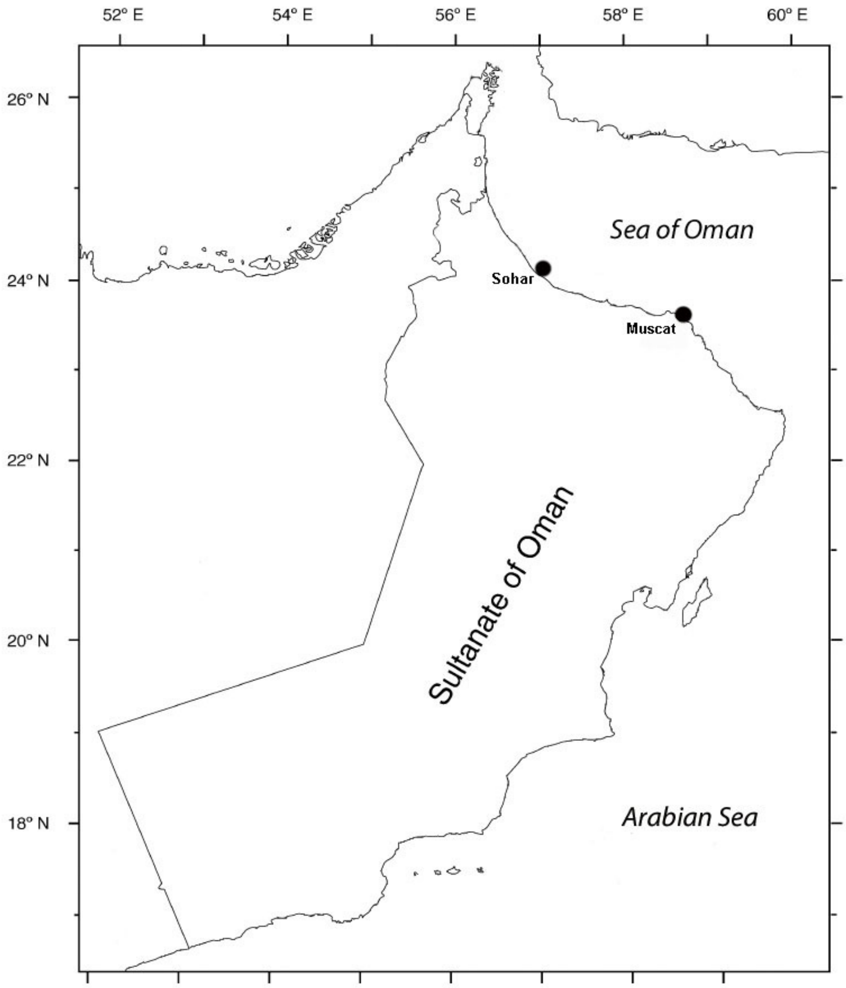

Figure 1. Map showing the location of the zooplankton sampling sites in Oman from October 2011 to October 2012.

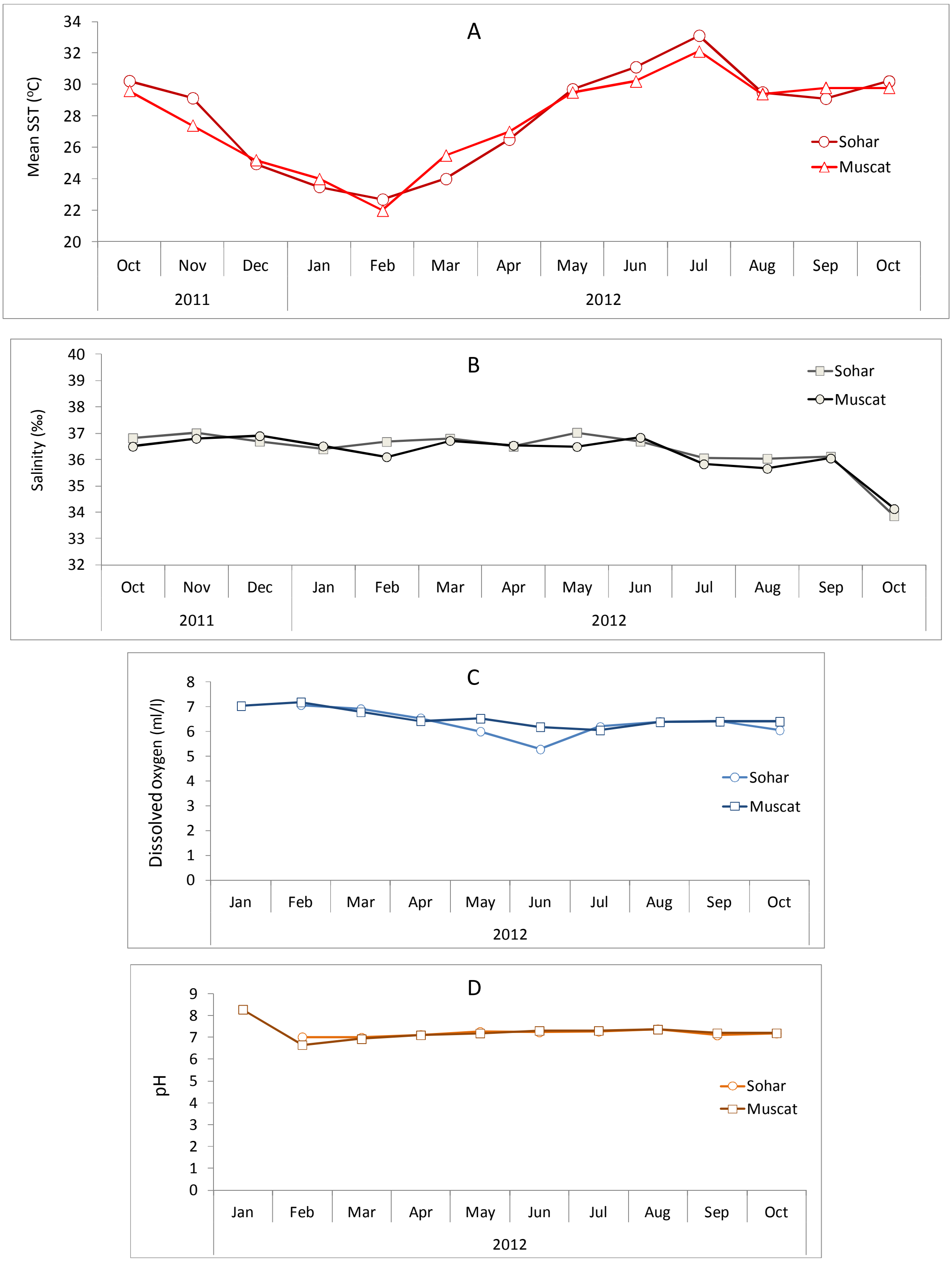

Figure 2. Monthly variation of water parameters in Sohar and Muscat areas from October 2011 to October 2012: A - surface water temperature, B - salinity, C - dissolved oxygen, D - pH.

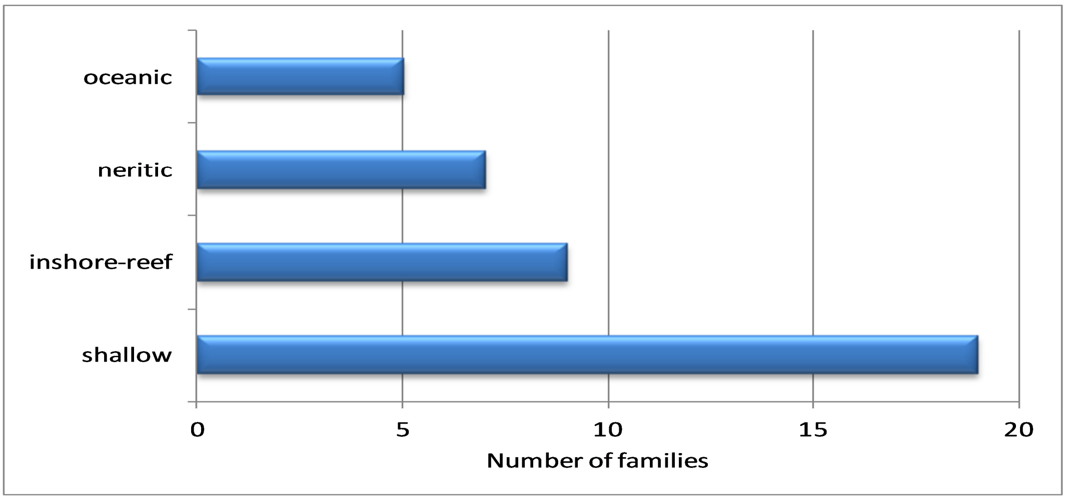

Figure 3. Fish larvae grouping based on adult habitat in the studied areas of the Sea of Oman.

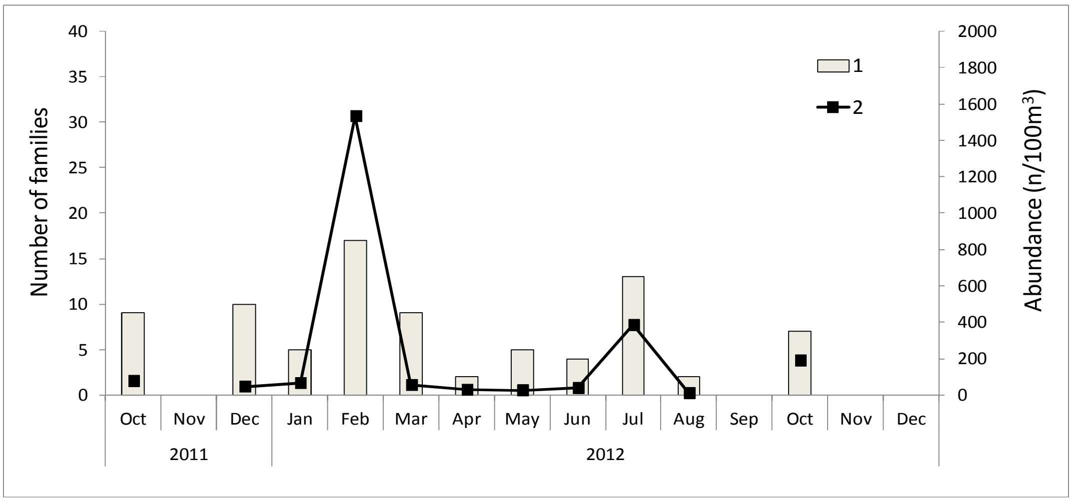

Figure 4. Monthly number of fish larvae families (1) and abundance (2) in studied areas of Oman in 2011-2012.

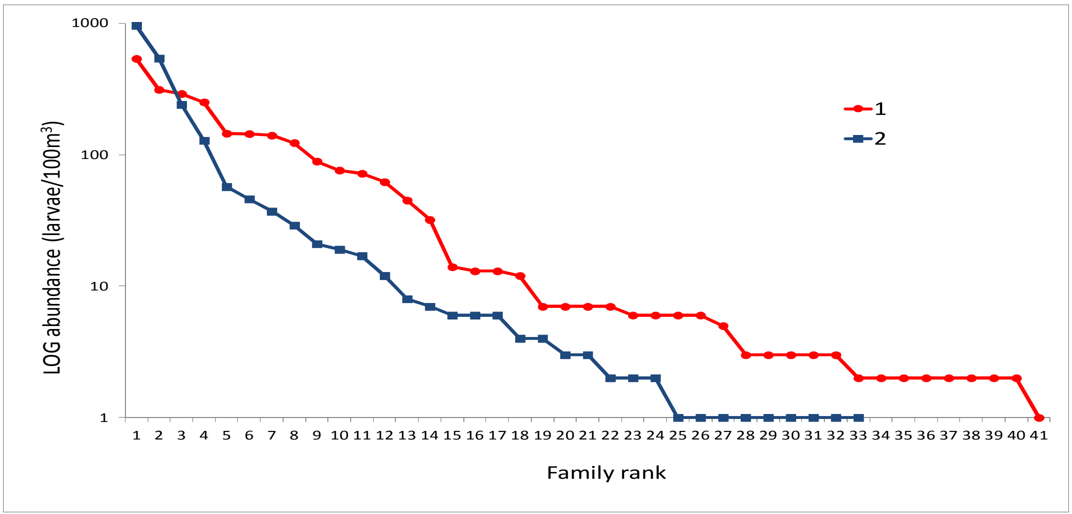

Figure 5. Dominance-diversity curves in the studied areas in 2011-2012 and in Shinas-Muscat area in 1989-1990 on data of Thangaraja & Al-Aisry (2001).