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Abundance and Diversity of Fish Larvae Assemblages in Omani Coastal Waters of Salalah Region (the Arabian Sea)

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Abstract

Due to the paucity of fish larvae research in the western Arabian Sea and the Sea of Oman, an extensive regular sampling program has been conducted in Omani coastal waters, from 2013 to 2015, over six regions (namely Khasab, Sohar, Muscat, Ashkarah, Doqum and Salalah), of which the Salalah region was analyzed in this paper. Monthly samples of fish larvae were collected from the sea surface and were accompanied by CTD casts, zooplankton sampling and modeling of regional circulation. A total of 734 fish larvae specimens including 38 families and 43 genera were collected and identified in terms of their morphology and morphometric characteristics. The bulk of ichthyoplankton catch were contributed by larvae from 5 families- Pomacentridae, Scombridae, Blenniidae, Mullidae and Clupeidae. The highest abundance of fish larvae (162 ind/100 m^3) was observed during the South-west Monsoon. The most diverse family were Carangidae and Pomacentridae, represented with five species and followed by Blenniidae, Scombridae and Terapontidae represented with three species each. The annual mean of the Shannon diversity index was 0.95±0.6. Canonical Correspondence Analysis of the major fish larvae family abundance, sea surface temperature, chlorophyll-a and zooplankton biomass showed that temperature and zooplankton were the most influential variables.

INTRODUCTION

By definition, the planktonic organisms have a limited ability to choose their favorable habitats through active swimming during their early life stages. Hence, they are exposed to external highly dynamic forces, such as winds and currents. These environmental forces regulate spatial distribution, mortality, survival and production of fish eggs, fish larvae and other zooplankton organisms (Okazaki et al., 2002; Hsieh et al., 2011). In coastal waters, the assemblages of fish larvae are considered to be a complex in terms of species composition and distribution patterns (Azeiteiro et al., 2006). Valuable information on their spatio-temporal distribution and spawning seasons could be provided through seasonal surveys of the taxonomic composition and abundance, for commercially important species.

The study of the fish larvae assemblages by the Middle East Countries was initiated about 45 years ago. In 1973, the first assessment of the biodiversity and abundance of fish larvae in the Arabian Sea and the Arabian Gulf was reported (Nellen, 1973). Later on, Houde et al. (1986) studied the ichthyoplankton, in the Kuwaiti waters. Some studies on the occurrence and abundance of fish eggs and larvae were carried out in 1980s, in Omani waters (Thangaraja, 1987, 1989, 1991 and 1998) and continued later on, by Thangaraja and Al-Aisari (2001) and Chesalina et al. (2013). Results of the latest fish larvae survey in the same region were reported by Al-Abri et al. (2017). However, the above cited surveys were not regular, so they didn't elucidate statistically reliable seasonal changes of fish larvae community structure. In this regard, an extensive three year sampling program has been conducted in Omani coastal waters by the Ministry of Agriculture and Fisheries of Oman, over six regions (namely Khasab, Sohar, Muscat, Ashkarah, Doqum and Salalah), of which the Salalah region was analyzed in this paper.

In an ecological aspect, the coastal currents propagating along the Omani coast are habitats of fish larvae communities. These currents are well developed and subjected to seasonal (wind-driven) variations. The Oman Coastal Current (which is a synonym of the East Arabian Current) is the main component of regional circulation along the Omani coast overlooking the western Arabian Sea (Cutler and Swallow, 1984; Shi et al., 2000). This current originates from the Somali Current coming from the south. The Oman Coastal Current persists during the Southwest monsoon and flows north-eastward, with a velocity of 0.5-0.8 m s^{-1}. The flow reverses its direction to the opposite one, with onset of the North-east Monsoon (NEM), during which the current is less pronounced. Two inter-monsoonal seasons are periods of the collapse of the system of coastal currents.

In the Sea of Oman, the current originating in the Arabian Gulf and propagating along the Omani coast westward (towards the Arabian Sea) is identified as the Oman East Current (Piontkovski et al., 2019). The vertical extension of both currents is about 250m. Remote sensing of sea surface heights and modeling –both implied the meandering of main flows (Piontkovski and Al-Hashmi, 2018). The meandering (induced by coastal geomorphology and baroclinic instability of currents) generates mesoscale eddies around these flows, which could impact the spatial dispersal of fish larvae.

Our study based on three years of monthly sampling was aimed at qualitative and quantitative analysis of fish larvae assemblages, with a special reference to their taxonomic composition, spawning seasons and seasonal changes of larvae abundance in the Salalah region overlooking the western Arabian Sea.

MATERIALS AND METHODS

Field surveys were carried out in the coastal waters of Salalah, 16º 56.384"N 054 º 04.704 E (Fig. 1). The sampling site was located in a region with 30 m depth, populated by different types of corals at the bottom (according to the divers' observations). Monthly hydrographic measurements and net sampling were carried out from January, 2013 to December, 2015.

A plankton net (60 cm in diameter, equipped with mesh size 400 µm) was used to collect fish larvae. Ten minutes hauls were conducted at the surface, at a speed of ~2 knots. The volume of sea water filtered during each tow was estimated by the "Hydrobios" flowmeter attached to the mouth of the net (Smith, and Richardson, 1977). Collected samples were preserved with 10% buffered formaldehyde.

In the laboratory, fish larvae were sorted out from other zooplankton and stored in small vials in 4% buffered formaldehyde. A binocular microscope (model SZ-X7) was used to identify, enumerate and measure fish larvae with a cooperation of Dr. Tanya, fish larvae expert at the marine science and fisheries center, using descriptions and illustrations from Ichthyoplankton guides (Fahay, 1983 and 2007; Leis and Rennis, 1983; Moser et al., 1984; Ozawa, 1986; Nishikawa and Rimmer, 1987; Okiyama, 1988; Neira et al., 1998; Leis and Carson-Ewart, 2000; Richards, 2008). Damaged and unknown fish larvae were included in the analysis as well.

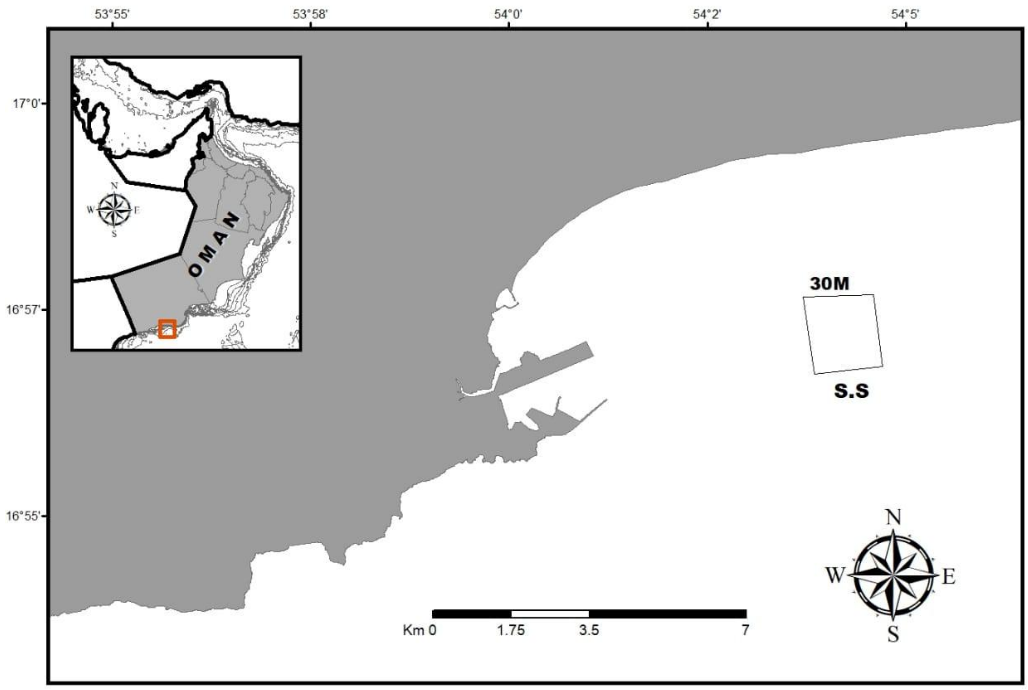

Figure 1. Map of the Sultanate of Oman and the location of the sampling station.

The larvae abundance was standardized to the number of fish larvae per 100 m^3 (Smith and Richardson, 1977). Diversity of larval fish assemblages was expressed by the Shannon-Wiener index (Shannon, 1948). Also, family richness and evenness indices were calculated, in order to compare our estimates with the previous ones (Thangaraja and Al-Aisry 2001; Chesalina et al., 2013).

Zooplankton samples were collected using a plankton net, equipped with a mesh size of 200 micrometres mounted on the 60 cm diameter ring. A digital "Hydro- Bios" flow meter was attached to the mouth of the net, to measure the volume of sea water filtered during each tow. The net was towed horizontally at the sea surface layer at a speed of about 2 knots, for 5 minutes. Collected samples were preserved with 10% buffered formaldehyde, settled in graduated cylinder and sedimentation bio-volume was recorded after 24 hours.

The Hybrid Coordinate Ocean Model (HYCOM) products were employed, to analyze spatio-temporal variations of the regional circulation,. HYCOM performs an application of eddy-resolving basin-scale ocean hindcast, nowcast and forecast systems with the 32 vertical layer discretization and the capability to apply additional coordinate surfaces to the mixed layer (Chassignet et al., 2007). This allows vertical mixing turbulence to be resembled. In being isopycnal in the open stratified ocean, the model reverts to a terrain-following coordinate in shallow coastal regions, and to z-level coordinates near the surface in the mixed layer, at the model resolution of 7 km. The snapshot archive of sea surface temperature, salinity, and surface current speed was retrieved from the GFS 3.0 image database.

Along with the HYCOM, *in situ* temperature, dissolved oxygen and salinity were measured with an "Idronaut-Ocean Seven 316" CTD probe fitted with an additional sensor for chlorophyll-a estimates. Chlorophyll-a usually refers to all photosynthetic organisms. As a result, its concentration is widely treated as an indicator of phytoplankton biomass.

In the assessment of multiple interactions, seasonally averaged sea surface temperature, salinity, chlorophyll-a, zooplankton biomass and fish larvae abundance of various families were subjected to the ANOVA (from the SPSS software). Monthly data were grouped into four categories (seasons). This approach was based on previous (historical) data on winds and temperature measurements: the North-East Monsoon (NEM), lasting from January through March, the Spring Inter-monsoon (SIM) from April to June, the South-West Monsoon (SWM), from July through September and the Fall Inter-monsoon (FIM), from October to December.

RESULTS

During SWM, warm and moist air prevails over the sampled region, which results in the development of a strong South-Western wind across the Arabian Sea, with persistently high speeds12 of ~10 m sec^{-1} (Krishnamurti, 1981). Strong winds accelerate the surface currents, drive local mixing and Open Ocean Ekman pumping (Weller et al., 2002). Also, SWM induces the Omani coastal upwelling, which supports high primary productivity and results in rich fisheries (Barber et al., 2001). Applicably to our study, we exemplified the spatial pattern of temperature, and geostrophic current speed over the western Arabian Sea by two seasonal episodes, for the year 2015 (Figure 2).

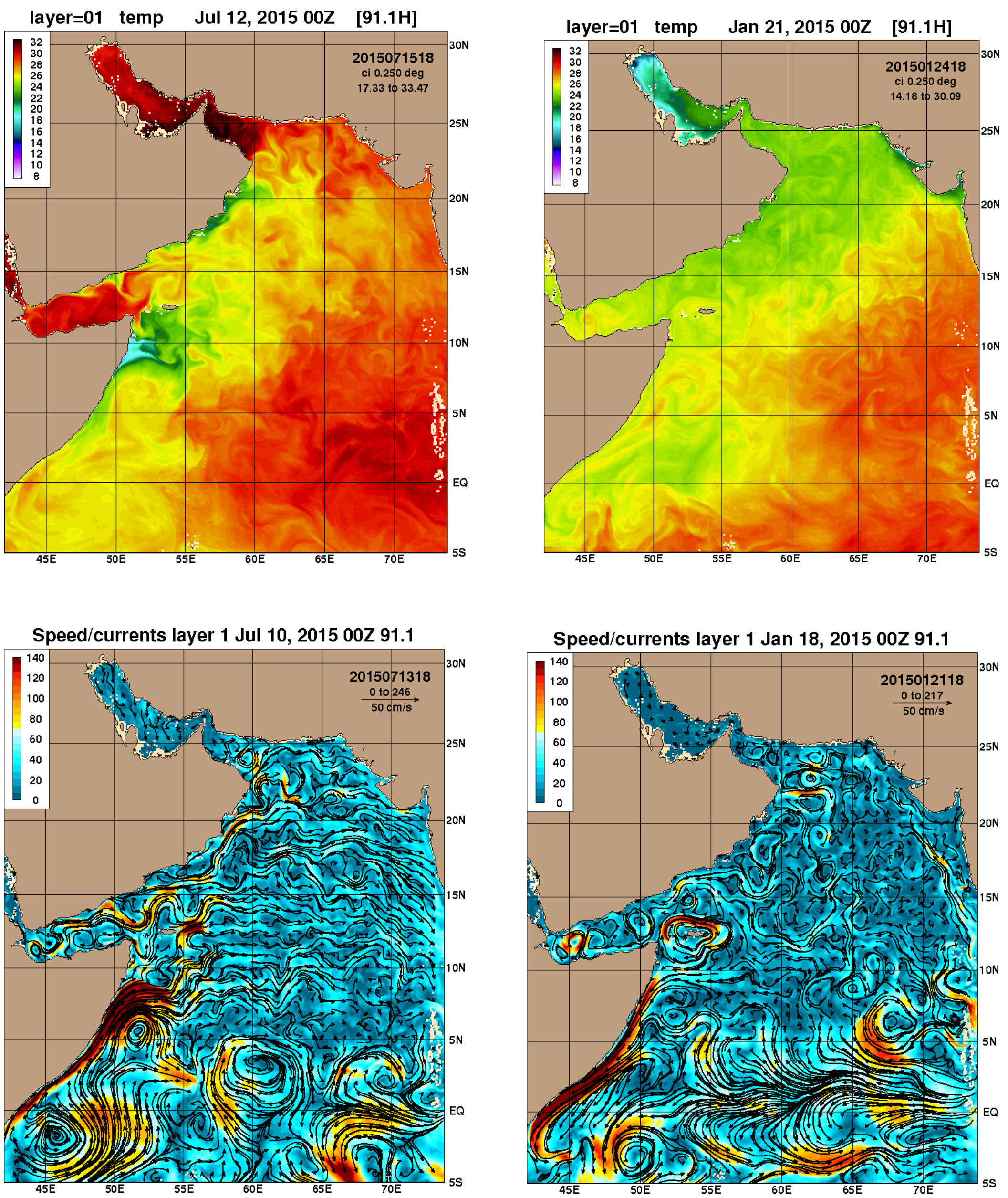

Figure 2. Spatial distribution of sea surface temperature (upper panel) and current speed (lower panel) during SWM and NEM seasons (HYCOM model; https://www7320.nrlssc.navy.mil/GLBhycomcice1-12/arabia.html).

The model products showed that in July, the temperature varied from ~32^{o}C in the Sea of Oman to ~22^{o}C in shelf waters of Salalah. The seasonal difference in temperature distribution indicates the impact of coastal upwelling on the upper layer. Obviously, the zone of minimal values observed in July was associated with the shelf area. A gradual cooling of the sea surface in January, on the scale of the whole north-western Arabian Sea, was associated with the winter overturning circulation mediated by NEM.

Spatial variations of salinity for the same episodes (not shown here) incorporated the range of values from 40ppt in the Sea of Oman to 35 ppt, in Salalah coastal waters, which is extremely broad range of variations, observed only in a few regions of the world tropical ocean. The gradient of salinity results from the excessive intensity of evaporation versus precipitation in these regions driven by the wind field.

As far as geostrophic currents are concerned, the model implied the Oman Coastal Current passing along the coast during SWM, whereas the current seemed to be less pronounced during NEM, in which a general water mass transport was reversed and directed southwestwards.

The variance of environmental characteristics has repeated on biological diversity and variability. A total of 734 fish larvae specimens were obtained and identified based on their morphology and morphometric characteristics during this study. In the samples, 38 families, 43 genera and 48 species were recorded (Table 1).

Table 1. Composition and abundance of fish larvae collected from Salalah (2013to 2015).

Family	Genus or species	Abundance	% in total catch
Apogonidae	*Apogon* spp.	21.6	2.41
Blenniidae	*Omobranchus* spp.	16	1.79
	Parablennius spp.	51.7	5.78
Carangidae	*Seriola dumerili* (Risso, 1810)	15.4	1.72
	Atule mate (Cuvier, 1833)	1.4	0.16
	Carangoides spp.	2.2	0.25
	Scomberoides commersonnianus	2.2	0.25
	Selar crumenophthalmus (Bloch,1793)	1.1	0.12
Chanidae	*Chanos chanos* (Forsskål, 1775)	4.9	0.55
Chirocentridae	*Chirocentrus dorab* (Forsskål, 1775)	22.8	2.55
Clupeidae	*Etrumeus whiteheadi* (Wongratana,1983)	6.4	0.72
	Sardinella spp.	50.8	5.68
	Sardinella longiceps (Valenciennes, 1847)	2.8	0.31
Coryphaenidae	*Coryphaena hippurus* (Linnaeus, 1758)	1.4	0.16

Family	Genus or species	Abundance	% in total catch
Creediidae		0.9	0.10
Destroyed		0.9	0.10
Fistulariidae	*Fistularia* spp	2.7	0.30
Gerreidae	*Gerres* spp.	5.3	0.59
Gobiidae	*Gobiine gobiid*	1.7	0.19
Gonostomatidae	*Cyclothone pseudopallida* (Mukhacheva, 1964)	0.6	0.07
	Cyclothone braueri	0.5	0.06
Haemulidae	*Pomadasys* spp.	5	0.56
Hemiramphidae	*Hyporhamphus* spp.	0.5	0.06
Kyphosidae	*Kyphosus* spp.	2.8	0.31
Labridae		0.9	0.10
Microdesmidae	*Gunnellichthys viridescens* (Dawson, 1968)	1.8	0.20
Monacanthidae		0.9	0.10
Mugilidae	*Mugil* spp.	1.6	0.18
Mullidae	*Upeneus* spp.	62	6.93
	Upeneus tragula (Richardson, 1846)	0.9	0.10
Muraenidae	*Gymnothorax* spp.	1.4	0.16
Nomeidae	*Cubiceps whiteleggii* (Waite, 1894)	1.6	0.18
Pempherididae	*Pempheris* spp.	34.9	3.90
Pomacentridae	*Abudefduf vaigiensis* (Quoy & Gaimard, 1825)	78.3	8.75
	Amphiprion spp.	1.6	0.18
	Chromis spp.	56.6	6.32
	Neopomacentrus spp.	1.1	0.12
	Pomacentrus spp.	178.5	19.94
Rachycentridae	*Rachycentron canadum* (Linnaeus, 1766)	1.2	0.13
Sciaenidae		2.3	0.26
Scombridae	*Rastrelliger kanagurta* (Cuvier, 1816)	7.3	0.82
	Scomber japonicus (Houttuyn,1782)	144.9	16.19
	Thunnus obesus (Lowe, 1839)	3.5	0.39
Scorpaenidae		1.6	0.18
Serranidae	*Epinephelus malabaricus* (Bloch & Schneider, 1801)	3.1	0.35
Sillaginidae	*Sillago sihama* (Forsskål, 1775)	1.9	0.21
Sparidae	*Pagellus affinis* (Boulenger, 1887)	19.8	2.21
Sphyraenidae	*Sphyraena* spp.	12.2	1.36

Family	Genus or species	Abundance	% in total catch
Syngnathidae	*Hippocampus* spp.	0.9	0.10
Synodontidae	*Saurida undosquamis* (Richardson, 1848)	2.2	0.25
Terapontidae	*Terapon puta* (Cuvier, 1829)	6.3	0.70
	Terapon jarbua (Forsskål, 1775)	3.5	0.39
	Terapon theraps (Cuvier, 1829)	3.2	0.36
Tetraodontidae		0.5	0.06
Trichiuridae	*Trichiurus lepturus* (Linnaeus, 1758)	11.6	1.30
Tripterygiidae	*Tripterygiid* spp.	0.9	0.10
Unidentified		23.4	2.61
Total		**895**	**100**

The total larvae abundance was 895 ind/100 m^3 (Table 1). The highest abundance of fish larvae was observed during SWM (162 ind/100 m^3), whereas this abundance was twice as much less during NEM, SIM and FIM (Figure 3).

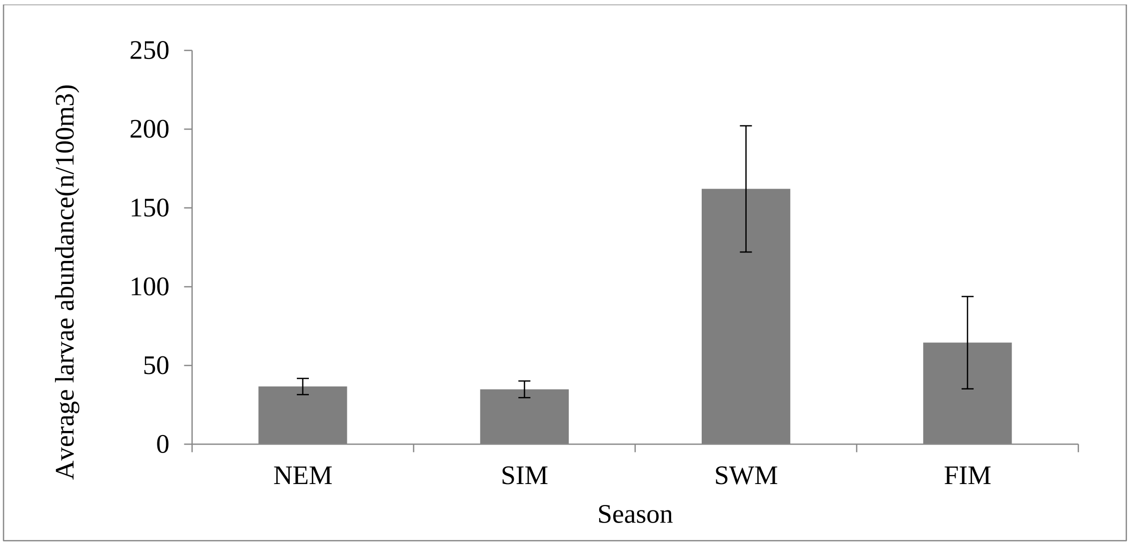

Figure 3. Seasonal changes of the fish larvae abundance in Salalah (2013-2015), with standard deviations. Acronyms stand for the North-East Monsoon (NEM), Spring Inter-monsoon (SIM), South-west Monsoon (SWM) and Fall Inter-monsoon season (FIM).

In terms of the total catch, the top five families were represented by Pomacentridae, Scombridae, Blenniidae, Mullidae and Clupeidae which accounted for 74.07 % of the total larval catch. Twenty five other families occurred in relatively low concentrations (less than 1 %).

Pomacentridae family (represented by *Abudefduf vaigiensis*, *Pomacentrus spp* and *Amphiprion* spp) was the highest dominant larvae contributing 35.33 % to the total fish larvae abundance. , which has been characterized by the total abundance. These larvae have been observed during all the seasons with the maximum density of 194 ind/100 m^3 was recorded in SWM.

The Scombridae family (represented by *Scomber japonicas*, *Thunnus obesus* and *Rastrelliger kanagurta*) was the second highest abundant family (with 17.39 %). Larvae were observed in samples during SIM and SWM, with the maximal abundance in September (132 ind/100 m^3).

Blenniidae (with two genera, namely *Parablennius* spp and *Omobranchus* spp) has accounted for 7.59 % of the total larvae catch. The larvae abundance ranged between 1 and 78 ind/ 100 m^3 .The highest abundance of larvae was observed during FIM.

Mullidae family (represented by only one genus -*Upeneus* spp) was the fourth largest family in terms of its contribution to the total larval catch. The larvae has accounted for 7% of the total catch. Also, it was noticed that these larvae were highly concentrated during NEM season and have formed the maximum of 21 ind/100 m^3, in March.

Clupeidae family (represented by two genera- *Etrumeus* pp and *Sardinella* spp) has accounted for 6% of the total catch with the abundance of 60 ind/100 m^3. The larvae of Clupeidae, were found in samples mainly during SWM. The highest concentrations were associated with the month of September (21 ind/100 m^3).

Along with the analysis of the total abundance, we distributed fish larvae according to their development stages (Pre-flexion, Flexion and Post-flexion). The observed changes were quite different, in terms of their seasonal dynamic. The pre-flexion stages showed the highest abundance during SWM, whereas the highest flexion larvae abundance was observed during SIM. The post- flexion stages have exhibited the highest abundance during FIM (Fig.4).

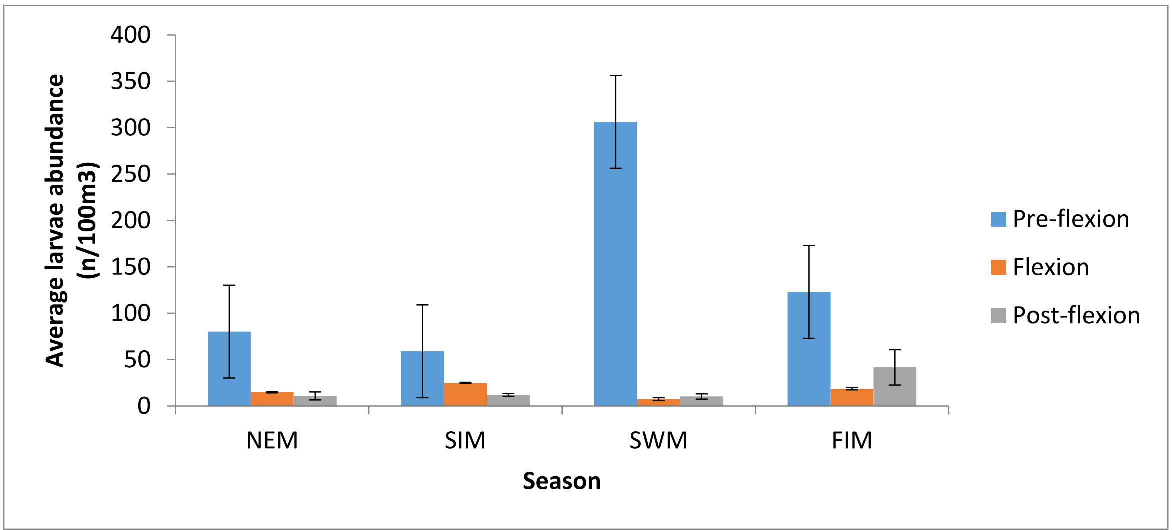

Figure 4. Seasonal changes of the development stage fish larvae abundance in Salalah (2013-2015), with standard deviations.

We compared data on seasonal changes of Scombridae family, *Rastrelliger kanagurta* (which was the second dominant group in Table 1) with the data of Gonado-Somatic Index (GSI) available from archives of the Ministry of Agriculture and Fisheries (Oman) for Salalah region. The correlation between seasonal changes of *Rastrelliger kanagurta* larvae abundance and (GSI) was statistically significant ($r = 0.67$, at $P<0.05$).

The most diverse family were Carangidae and Pomacentridae, represented with five species each followed by Blenniidae, Scombridae and Terapontidae represented with three species each. While the rest represented with one species or genus. The fish larvae diversity showed a moderate variation over the period of the study. The annual estimated mean of the Shannon diversity index (H) was 0.95±0.6. The highest value (1.76±0.08) was observed during NEM, while FIM was the highest by family richness (5.20±0.48) and evenness (0.95±0.18).

The Canonical Correspondence Analysis (CCA) was used to ordinate fish larvae abundance, taxonomic composition and environmental variables (namely sea surface temperature, chlorophyll a and zooplankton biomass). Rare families (which presented in <1% of total catch) were removed from the analysis, in order to reduce disproportionate effects of rare species (Legendre and Legendre, 1998). CCA of the major fish larvae family abundances and environmental characteristics showed that zooplankton biomass (0.89 coordination with the first axis) and temperature were the most influential variables (Figure 4). Apogonidae, Pempherididae, Blenniidae have exhibited positive correlations while Mullidae, Sphyraenidae and Clupeidae have had negative correlations with seasonal zooplankton biomass changes.

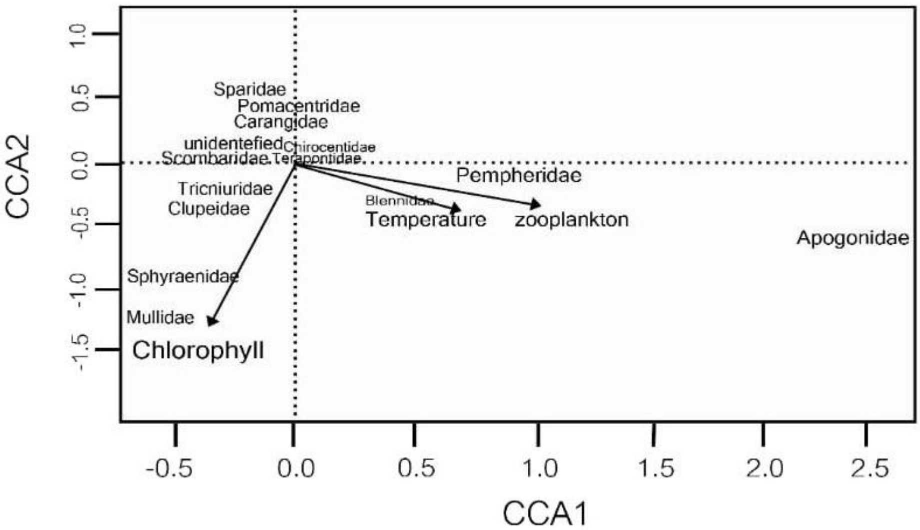

Figure 5. Statistical linkages of the fish larvae abundance with the environmental variables.

CCA was aimed at the extraction of two factors (CCA1 and CCA2), which explained the major part (77%) of the total variance in the system of selected variables, of which zooplankton and sea surface temperature appeared to be the leading ones.

DISCUSSION

Historically, 34 genera and 16 species were reported in the samples collected in 1989-1990 between Muscat and Shinas (Thangaraja and Al-Aisary, 2001). Chesalina et al. (2013) sampled the south-western part of the Sea of Oman in 2011-2012 and found 40 families of larval fishes contributed by 47 genera and 28 species. Later on, Al-Abri et al. (2017) reported 39 families, 50 genera and 55 species in the samples collected between (2013-2015) in coastal waters of Muscat. In this study, a total of 734 fish larvae (which included 38 families 43 genera and 48 species) were collected and identified. Families Carangidae and Pomacentridae were the most diverse (with 5 species), followed by Blenniidae, Scombridae and Terapontidae (with 3 species). The rest was represented by one genera, with one species.

Our assessment of the most diverse family (Carangidae) was consistent with earlier findings of Chesalina et al. (2013), who sampled the south-western part of the Sea of Oman in 2011-2012, and Al-Abri et al. (2017), who studied the fish larvae assemblages in coastal waters of Muscat (Sea of Oman), in 2013-2015. In terms of taxonomic composition, the Shannon index reported by Thangaraja and Al-Aisary (2001) was 0.76, versus the value of 0.89 reported by Chesalina et al. (2013), and the value of 1.13 reported by Al-Abri et al. (2017). Values of the 2001-202013 period seemed to be low compared to our recent averaged value which is equal to 0.95.

Coastal communities of Oman experience seasonally different impact of physical forces. This refers to the difference in modes of ocean-atmosphere interactions. The Sea of Oman is mainly affected by the North-east (winter) Monsoon, while the coastal waters of the Arabian Sea are mediated by the North-east and South-west monsoons. The later one dominates, by its ecological impact on the south-western part of the sea, including the Salalah region. The primary peak of fish larvae abundance (with 162ind/100m^3) was contributed by 9 families and was associated with SWM. (Fig. 3). In terms of ecological footprints, SWM is the most important season for the pelagic ecosystem of the south-western Arabian Sea, because the enrichment of nutrients by the coastal upwelling causes high primary productivity (Marra and Barber, 2005; Naz et al., 2013) and supports high abundance of fish larvae. Our data on the seasonality of fish larvae abundance are consistent with these observations (Fig. 3).

Seasonal patterns of fish larvae abundance revealed a different breadth of spawning periods. For instance, some species such as (*Upeneus sp* and *Parablennius sp*) have been observed throughout the year in our samples, whereas the less abundant species such as (*Chanos sp* and *Pomadasys sp*) where found only during a specific period of the year. Overall, it is believed that the duration of the pelagic larval stages is highly variable, ranging from days to months (Brothers et al., 1983; Thresher et al., 1989; Victor, 1986). Also, the other form of adaptation is the shift of spawning periods over the seasonal cycle. For instance, some larvae species can be found during winter months, while different other different larvae species could be found during summer months. Both phenomena might be interpreted as mechanisms reducing inter- and intra-specific competition for food resources in pelagic habitats, because the survival of larval fish depends on the timing as well as matching or mismatching of seasonal phytoplankton blooms (Cushing, 1990; Platt et al., 2003)

In terms of comparative analysis, the primary peak of larval fish abundance during NEM and secondary peak during SWM in the south-western part of the Sea of Oman reported in 2011-2012 (Chesalina et al., 2013) are consistent partially with our findings where the highest averaged larvae abundance were noticed during SWM. However, across the Sea of Oman, in Iranian waters, the seasonal dynamic of fish larvae abundance was completely different. The highest abundance and diversity were found during SIM and FIM (Rabbaniha et al., 2014). The above difference might be attributed to the variety of factors, like different mesh size nets used for collecting fish larvae or the sampling depths which varied over regions.

The two axis of CCA pointed to the statistically significant link between fish larvae abundance, sea surface temperature, chlorophyll-a and zooplankton biomass. Unfortunately, the zooplankton samples collected during this study have not been processed to the species level. Nonetheless, the studies carried out in a neighboring region had implied copepods to be main contributors to the total zooplankton abundance throughout the seasonal cycle. The dominance of small-sized copepods of genus such as Oithona , Temora , Oncaea , Parvocalanus , Paracalanus , Microsetella, Acartia and some others is a characteristic feature of the plankton community of the Omani shelf (Smith et al., 1998). Presumably, the nauplii stages of these (abundant) copepod species constitute the main food source for fish larvae, which used to feed on copepod nauplii stages (Morote, et al., 2008).

Overall, a statistical correlation found between zooplankton biomass and the total fish larvae abundance is consistent with previous studies (Hsieh et al., 2010; Chen et al., 2012). Also, Al-Abri, et al. (2017) have reported a significant correlation between zooplankton biomass and the abundance of *Sardinella* spp. larvae ($r=0.8$, at $p< 0.05$) in the Sea of Oman

The fish larvae abundance exhibited marked changes of seasonal cycles over development stages (Fig. 4). The pre-flexion stage was most sensible to monsoonal changes. The abundance of this stage was highest during SWM and gradually declined during FIM seasons. Perhaps, this phenomenon was associated with the availability of phytoplankton which (according to chlorophyll-a) could have had maximal concentrations during SWM, while the next two development stages showed less pronounced magnitudes of seasonal changes. According to Butler *et al.* (1988), chlorophyll-a concentration above 0.2 $mg.m^{-3}$ are sufficient to sustain a viable commercial fishery. It has been shown that regionally, fish landings could be related to phytoplankton production (Chassot *et al.*, 2007; Ware and Thomson, 2005). In the Sea of Oman, for instance, chlorophyll-a concentrations are seasonally correlated with sea surface temperature changes. Also, seasonal changes of sardine larvae abundance were consistent with artisanal sardine landings (Al-Abri et al., 2017).

The two plots featuring seasonal changes (Figures 3 and 4), implied a certain inter-annual variation reflected by standard deviation bars. In terms of inter-annual changes, the year 2015 was quite different compared to the previous years of sampling. This was the year of maximal larval abundance, which might be treated as an indicator of a potential increase of fish landings. Indeed, the fishery statistics has reported the increase of total fish landing from coastal fishery in 2016, compared to 2015 (Fisheries Statistics Book, 2016). However, the issue of inter-annual variability was out of scope of this paper.

CONCLUSION

The 3 year sampling program carried out in the coastal waters of the Salalah region has enabled a statistically validated seasonality of fish larvae abundance and species diversity to be elucidated.

A total of 734 fish larvae specimens including 38 families and 43 genera were collected and identified in terms of their morphology and morphometric characteristics. The bulk of ichthyoplankton catch were contributed by larvae from 5 families- Pomacentridae, Scombridae, Blenniidae, Mullidae and Clupeidae. The highest abundance of fish larvae (with 162 ind/100 m^3) was observed during the South-west Monsoon. The most diverse family were Carangidae and Pomacentridae, represented with five species each followed by Blenniidae, Scombridae and Terapontidae represented with three species each. Canonical Correspondence Analysis of the system consisted of major fish larvae family abundances, sea surface temperature, chlorophyll-a and zooplankton biomass showed that temperature and zooplankton were the most influential variables in seasonal changes of fish larvae abundance.

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