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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

SPATIAL AND TEMPORAL PATTERNS OF FISH LARVAE ASSEMBLAGE IN THE NORTHERN COASTAL WATERS OF PERSIAN GULF ALONG THE BUSHEHR PROVINCE SHORELINE

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Abstract: Fish larva surveys were conducted in the coastal waters of the Persian Gulf in Bushehr province during November 2001 to October 2002. The survey covered 10 stations between Farakeh estuary to Genaveh port, aiming to identify the fish larvae, their composition, abundance, and distribution patterns in relation to the measured hydrological factors. Fish larvae belonging to 20 families were identified and counted, and the total mean abundance was calculated as 8.1844 individuals per 10 m^2. Families Clupeidae, Gobiidae and Sillaginidae had more relative abundances respectively. Based on their distribution behavior fish larvae were allocated to three different ecological groups as: benthic, epibenthic and pelagic. During cold season benthic group was dominant and Gobiidae was the indicator and representative family, whereas in warm season pelagic group was dominant with Clupeidae as the indicator family. Principal Component Analysis with supplementary analyses revealed more correlation between Sillaginidae, Gerreidae, and Clupeidae with the dimdesc axes 1, while the composition and density of fish larvae were correlated with water depth and transparency. This correlation reduced in cold season. It appears that changes in the sea currents and local seasonal winds, were effective in the presence and abundance of fish larvae. Moreover, the spatial and temporal spawning patterns of broodstock fishes also played a key role in the composition and formation of the early larval assemblages.

Keywords: Fish larvae, Persian Gulf, Bushehr, Spatial and temporal patterns, Hydrological factors

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Özet:

Basra Körfezi' nin Bushehr İli Kıyı Şeridi Boyunca Kuzey Kıyı Sularındaki Balık Larvaları Biyosenözlerinin Zamansal ve Alansal Yapısı

Balık larva araştırmaları Buşehr ilinin Basra Körfezi kıyı sularında Kasım 2001ile Ekim 2002 yılları arasında yapılmıştır. Farakeh nehir ağzı ile Genaveh limanı arasında 10 istasyonu kapsayan araştırmada balık larvalarının tanımlanması, kompozisyonları, bolluk ve dağılım yapısının ölçülen hidrolojik faktörlerle ilişkisinin belirlenmesi amaçlanmıştır. 20 familyaya ait balık larvaları tanımlanmış, sayılmış ve toplam ortalama bolluk 10 m^2'ye 8.1844 birey olarak hesaplanmıştır. En fazla nispi bolluğu sırasıyla *Clupeidae, Gobiidae* ve *Sillaginidae* familyaları göstermiştir. Dağılım davranışları temel alınarak balık larvaları bentik, epibentik ve pelajik olmak üzere üç farklı ekolojik grupta incelenmiştir. Soğuk mevsimlerde bentik grup baskın olup indikatör ve temsilci familya *Gobiidae* iken sıcak mevsimlerde pelajik grup baskın olup indikatör familya *Clupeidae* 'dir. Destekleyici analizlerle birlikte temel bileşenler analizi dimdesc ekseni 1'de *Sillaginidae, Gerreidae,* ve *Clupeidae* familyaları arasında daha fazla korelasyon olduğunu gösterirken, balık larvalarının kompozisyon ve yoğunluğunun su derinliği ve görünürlüğü ile ilişkili olduğu belirlenmiştir. Bu ilişki soğuk mevsimlerde azalmıştır. Lokal mevsimsel rüzgarlar ve deniz akıntısındaki değişimler balık larvasının varlığı ve bolluğunu etkilediği görülmektedir. Ayrıca, anaç balıkların zamansal ve alansal üreme şekli, erken larval biyosenözlerin kompozisyonu ve yapısında önemli bir rol oynamıştır.

Anahtar Kelimeler: Balık larvası, Basra körfezi, Bushehr, Hidrolojik faktörler

Introduction

The larval fish assemblages in near shore coastal waters are complex both in terms of species composition and distribution patterns (Azeiteiro et al., 2006). The composition of the species assemblages, in which depending on the time of the year, it is possible to identify diverse groupings, may not necessarily represent similarities in adult habitat or direct phylogenetic relatedness (Herna´ndez-Miranda, et al., 2003). Many marine fishes, including those that are not resident species, spawn in or near productive coastal bays and estuaries (Azeiteiro et al., 2006). Despite the existence of spawning seasonality, larval fish species may also show differences in their spatial patterns of abundance (e.g. with respect to bathymetry, or distance to shore and the presence of estuary mouths/river outflow) (Herna´ndez-Miranda, et al., 2003). These patterns are particularly strong in areas very near to the coast and estuaries (Azeiteiro et al., 2006). Temporal variability in larval fish abundance has mainly been related to the meteorological, environmental (temperature, salinity and turbidity) and oceanographic seasonal features (regional oceanography and upwelling events) (Hernández-Miranda *et al*., 2003). Examining spatial and temporal patterns in distribution and abundance of ichthyoplankton in relation to hydrological conditions may provide insight into the adaptation of spawning strategies to the prevailing physical and biological processes (Somarakis et al., 2002).

Research on the identification and abundance of fish larvae in the Persian Gulf goes back to 1973, when Nellen (1973) conducted the first study on the diversity and abundance of fish larvae in the Arabian Sea and Persian Gulf. He reported the fish larvae of the Gobiidae, Clupeidae and Pomadasyidae families as dominant from the Iranian waters of the Persian Gulf. Since then many research works have been conducted by Iranian experts who were mainly focused on the identification and abundance of fish larvae (Dehghan et al., 2000; Rabbaniha, 1998; Owfi & Bakhtiary, 1999; Jokar & Saraji, 2002).

This research aims to study the fish larvae assemblages and the effects of hydrological factors on their abundance and dispersal, as well as the changes in the temporal and spatial distribution patterns of fish larvae in the study area. This area covers the northern coastal waters of the Persian Gulf along the Bushehr province (Figure 1), which is located between the latitudes 29° 08´ 05″-29° 34´ 45″and longitudes 50° 30´ 30″- 50° 41´ 15″, with a variable depth of less than 10 meters along the coastal line, between Doobeh creeck to Genaveh Port. From the ten designated sampling stations, eight were located at the junction of the creeks to the Persian Gulf, except station two which was at the estuary near the mouth of Helleh River and station ten which was situated out in more deep marine waters.

Persian Gulf is a semi-closed and continental shelf region which is connected to the Oman Sea by the Hormuz Strait. The freshwater discharge from the confluence of two large rivers (Karun from Iran and Shat-alarab from Iraq) in the north-western part of the Persian Gulf dilutes the sea-water in its vicinity, and the salinity increases gradually from north to south along with evaporation.

Throughout the year a surface water current with a velocity of more than 10 cm/s flows from the Oman Sea into the Persian Gulf through the Hormoz Strait. This current of relatively low salinity, flows north-westward along the Iranian coast, and against the prevailing north (Shamal) winds, diluting the hyper-saline water of Persian Gulf (Swift and Bower, 2003). At the longitude of about 51.5°E, it changes its course back towards the Hormuz Strait. Through its circulation and evaporation, this current becomes denser and sinks, and finally as a high salinity undercurrent, leaves the Persian Gulf through the deeper part of the Hormuz Strait (ROPME, 2004).

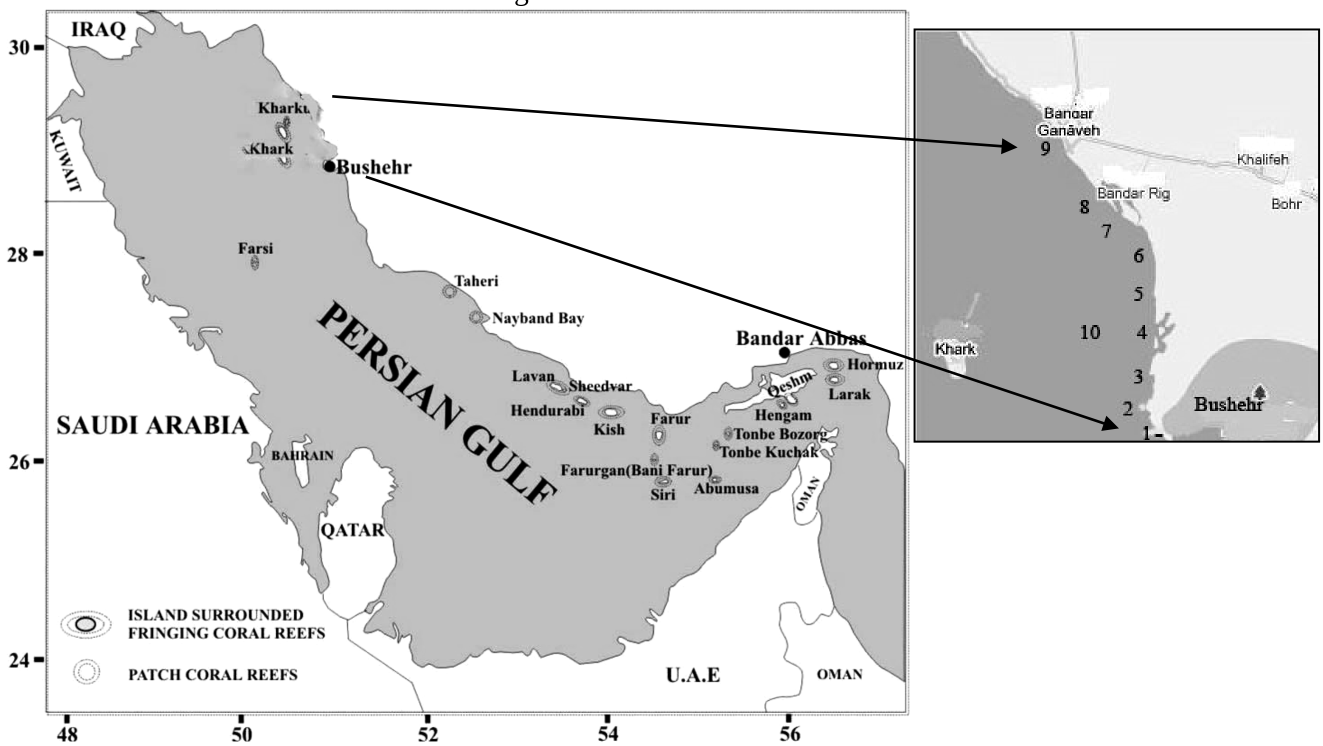

Figure 1. Sampling stations.

Materials and Methods

Monthly larval sampling was conducted in 10 sampling stations from October 2001 to September 2002 using a 60 cm diameter and 500 µm mesh size Bongo net. Adverse weather conditions prevented sampling from six stations in May and one station in June 2002. Towing was oblique and the volume of the filtered water was calculated by a calibrated flow-meter attached to the mouth of the net (Smith & Richardson, 1977). Simultaneous records of water temperature, salinity, depth, transparency and pH were also done at each station.

Hydrological Analysis

To illustrate the hydrological pattern of the study area a cumulative graph were plotted based on the standardized salinity and temperature data. Monthly variation of temperature and salinity were drawn by scatter graphs as well as the graphs for the changes in depth and transparency.

Fish Larvae Analysis

Fish Larvae abundance were standardized to the number of larvae per ten square meters (Smith & Richardson, 1977) and transformed by the formula, log(x+l), where x is the family abundance (number of larvae per 10 m^2 surface area). A data matrix was formed by these values for conducting the statistical analysis. After normalizing the data ANOVA was performed in "R" for the comparison of the fish larvae abundance in all stations and sampling months.

To find the indicator family in each hydrological condition (cold, warm), an Indicator Value was (InVal) estimated. This value is obtained by multiplying the product of two independently computed values: the specificity ($SP_{j,s}$) and fidelity ($FI_{j,s}$) of a family ,s, by 100 toward a group of samples, G_j.

$SP_{j,s}=NI_{j,s}/NI_{+j}FI_{j,s}=NS_{j,s}/NS_{j+}$

$NI_{j,s}$ is the mean abundance of family *s* across the samples G_j,NI_{+j} is the sum of the mean abundance of family *s* within the various groups, $NS_{j,s}$, is the number of samples in G_j where family *s* is present, and NS_{j+} is the total number of samples in that group. The specificity of a family for a group is therefore greatest if this species is present only in this group, whereas the fidelity of a family to a group is greatest if this species is present in all samples of the group considered (Anneville et al., 2002).

To evaluate the relationships between fish larva (Dependent continuous variables) and temperature, salinity, pH, depth and transparency (Independent variables); Principal Component Analysis (PCA) with supplementary variables was applied. For multivariate data analysis, we used R version 2.11.1 (2010), of the FactoMineR (Husson et al., 2008) of "R" statistical package (Adler, 2010).

Results and Discussion

Hydrological conditions

Hydrological conditions were mainly affected by seasonal changes in the weather temperature and rainfall. Therefore the period of this study was divided in two seasons, ie: Cold Season (November 2001 till March 2002) and Warm Season (April 2002 till October 2002). The variations in temperature and salinity are shown in Figure 2. The mean temperature in cold and warm seasons was 16.3 ºC and 25.7ºC respectively.

Taxonomic composition and abundance

Throughout the entire study a total of 3787 fish larvae belonging to 20 families were identified. The mean abundance was 8.1844 per 10 m^2 and Clupeidae, Gobiidae and Sillaginidae had more relative abundance respectively (Table 1). 57% of the larvae composition of the samples belonged to the pelagic group. This ratio was lowest at station 5 (1.46%), and showed a considerable increasing trend at stations 1, 2, 3 and 10.

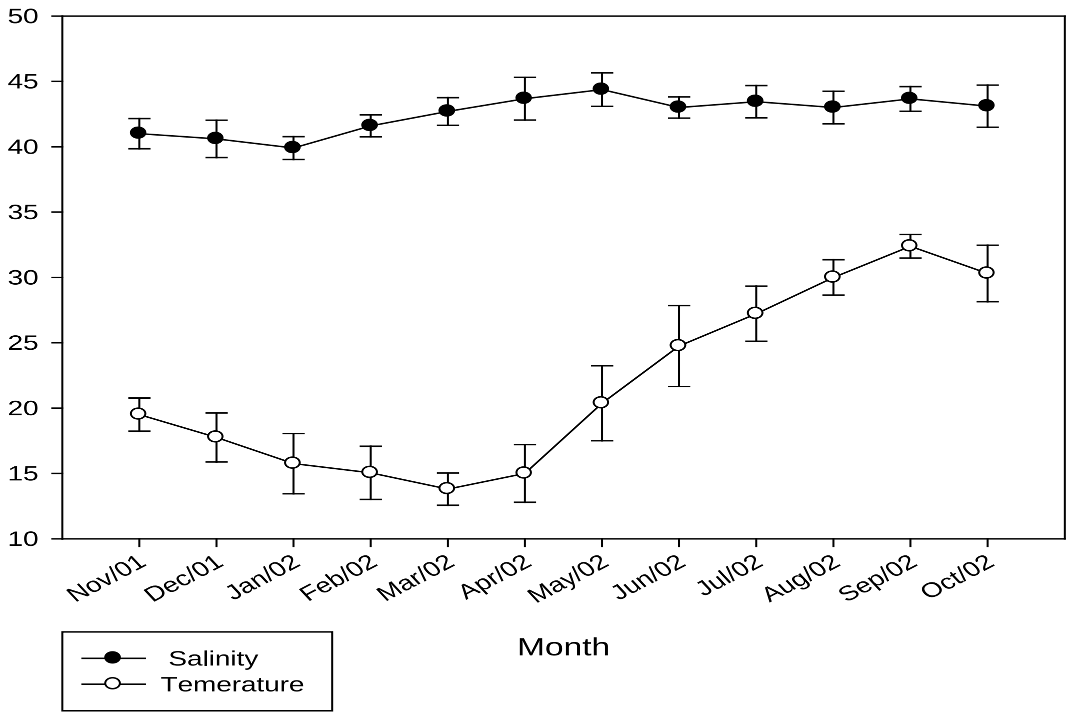

Figure 2. Monthly average and standard deviation (vertical bars), for temperature and salinity at the study area.

Table 1. List of larval fish families identified in the Bongo-net collections (November 2001, October 2002).

FAMILY	No. of specimen	Mean abundance (N/10m2)	Relative abundance
CLUPEIDAE	1814	3.9529	48.30
GOBIIDAE	1081	1.9493	23.82
SOLEIDAE	19	1.0184	12.44
SPHYRAENIDAE	1	0.4031	4.93
GERRIDAE	94	0.2456	3.00
HEMIRAMPHIDAE	12	0.2456	3.00
PLATYCEPHALIDAE	17	0.1111	1.36
ENGRAULIDIDAE	18	0.0689	0.84
SPARIDAE	238	0.0685	0.84
SCORPAENIDAE	6	0.0385	0.47
LUTJANIDAE	2	0.0317	0.39
CALLIONYMIDAE	4	0.0132	0.16
SIGANIDAE	1	0.0102	0.12
CARANGIDAE	4	0.0095	0.12
MUGILIDAE	15	0.0058	0.07
CYNOGLOSSIDAE	2	0.0048	0.06
SYNGNATIDAE	1	0.0024	0.03
BELONIDAE	1	0.0017	0.02
SILLAGINIDAE	455	0.0017	0.02
TERAPONIDAE	2	0.0015	0.02
Total	3787	8.1844	100.00

Spatial and temporal distribution of fish larvae

The variation of fish larvae abundance between the stations in base of transferred data (log(x+1)) is shown in Figure 3. There were Significant differences between stations in base of ANOVA test (P<0.05) and stations 1, 2 and 10 demonstrated the highest abundance. The result of PCA with supplementary analyses showed a positive correlation between the larvae of the families Sillaginidae (0.66), Gerreidae (0.63), Clupeidae (0.52), Engrulidae (0.51), and Soleidae (0.44), Whereas the larvae of the families Mugilidae, Sparidae and Gobiidae revealed negative correlation with dimdesc axes 1, and two axes dimdesc1 and 2, respectively explained 20.60 and 15.97 % of the variance in the fish larvae of all families in the study area. There were a weak relationship between larval abundance and environmental factors; transparency (0.47), depth (0.41), Temperature (0.37) and salinity (0.22) respectively. The monthly changes in the fish larvae abundance is shown in Figure 4 in base of transferred data (log (x+1)). The significant differences were evident between months in base of ANOVA test (P<0.05), and the highest abundance were recorded in May and June. Significant differences were evident between months in base of ANOVA test (P<0.05), and the highest abundance were recorded in May and June.

In cold season, 1127 larvae specimens belonging to 10 fish families were recorded. Six of these families comprised 89% of the total abundance, and the families Gobiidae, Clupeidae, Sparidae, Sillaginidae, Mugilidae and Soleidae, had the highest to the lowest percentage in a descending order. Gobiidae was the indicator family with an indicator value of 38%. In this period two dimdesc 1 and 2 explained 23.50 and 21.41 % of the variance in the fish larva families in the study area, and Sillaginidae (0.80), Clupeidae (0.66), Soleidae (0.41) had more correlation, while Mugilidae, Gobiidae, Sparidae showed weak or negative correlation and the result of PCA showed a weak relationship between environmental factors and larval variation; Temperature (0.35), depth (0.31), transparency (0.22), and salinity (0.05) respectively.

In the warm season, 2660 specimens belonging to 20 fish families were recorded. Seven of these families comprised 89% of the total abundance, and the families Clupeidae, Gobiidae, Sparidae, Gerreidae, Soleidae, Sillaginidae and Engraulidae, had the highest to the lowest percentage in a descending order. During this season Clupeidae, a pelagic and littoral family, was the indicator family with an indicator value of 38% followed by Engraulidae. In this period dimdesc 1 and 2 analysis explained 22.45 and 19.36 % of the variance in the fish larva family in the study area respectively. Engraulidae (0.64), Gerreidae (0.61), Soleidae (0.61), Sillaginidae (0.51), Clupeidae (0.33), Sparidae (0.11) and Gobiidae (0.07) had positive correlation with dimdesc 1. Figure 7 shows a weak relationship between larval abundance and environmental factors. The variable factor map in Figure 7 shows a positive value of (0.48) for depth and (0.43) for transparency. It also demonstrate a weak and negative correlation between salinity (-0.12), and temperature (0.022) with dimsec 1.

The fish larvae assemblages showed different distribution patterns during warm and cold seasons. Seasonal patterns of fish larvae abundance are linked to the reproductive strategies of adult populations and phases of their life cycles, which in turn are often associated with oceanographic and meteorological features (Hernández-Miranda *et al*., 2003) this study fish larvae from more families, and more abundance were recorded in warm seasons compared to the cold season. This can be attributed to the brooders which start their spawning period during spring and early summer. Two families, Clupeidae and Gobiidae were dominant in the area and represented as indicators of warm and cold seasons respectively. Clupeidae is a well known pelagic group which comprised the highest percentages of our samples in Bushehr waters, and its main spawning period coincides with early spring. Pelagic fishes such as clupeids produce pelagic eggs and their larvae are carried out to the coastal food-rich areas with sea currents, and their presence in these regions is simultaneous with peak production period of phytoplankton and zooplankton (Keenleyside, 1979). A higher abundance of this family was recorded at stations 1, 2, 3 and 10 compared to others.

The pelagic groups (Clupeidae and Engraulidae) comprised 64.72 % of relative abundance in the warm season whereas in cold season they occupy only 16.38% of the relative abundance. Gobiidae was an indicator of the inshore group of stations (1-9) with muddy intertidal flat zone. They produce benthic or demersal eggs, which are probably not affected by adjective processes until they hatch, thus reducing the chances of being transported offshore. Therefore, the distribution pattern observed might be related to both coastal spawning strategy and low dispersal due to the non-pelagic nature of their eggs. These results are similar to those published by Hernández-Miranda *et al.* (2003). Gobiid state in this region was similar to previous fish larva studies in Bushehr province, with more abundance in creek or estuary stations (4, 5, 7) than other families.

In general, the assemblage structure and distribution patterns found in this study can be compared with other studies in the region and were similar to Rabbaniha (1998), Owfi & Bakhtiary (1999), Jokar & Saraji (2002). The main habitats were coastal and creek, estuary type (except Nayband Bay with rocky-coral habitat), and Gobiidae and Clupeidae were the dominant family groups. The abundance and distribution of fish larvae depends on favorable biological conditions and fish spawning in time and places that will ensure the existence of proper and sufficient food, and minimum risk from predators and inappropriate environmental conditions (Wootton, 1990). In case of this research, the study area was a shallow coastal region with sandy and muddy bottom. In all stations except station 10 the depth was less than four meters (Figure 8), and the turbidity triggered by wave action, caused damage to the delicate gills of tiny larvae. Therefore among the hydrological factors, depth and low transparency (or turbidity) was two main factors affecting the presence of the fish larvae. The result showed more abundance of fish larvae at station 10 with a depth more than other stations. It seems that depth was the most effective determinant of the abundance and the composition of fish larvae at this site.

Figure 3 shows more abundance of fish larvae at stations 1, 2 and 3 which are located in the vicinity of Bushehr city. This can be related to the anthropogenic factor effects. The treated sewage effluents of Bushehr city are discharged to the Persian Gulf. These nutrient rich effluents cause eutrophication and plankton blooms in these areas, providing favorable grazing grounds, and subsequent more survival chances for fish larvae.

These results are consistent with other ichthyoplankton studies on continental shelves around the world (Somarakis et al., 2002, Kendall & Dunn. 1985, Espinosa-Fuentes & Flores-Coto.2003, Somarakis *et al*., 2011). However the effect of depth was reduced in cold seasons, since other factors such as marine currents which intensifies due to prevailing local winds, will affect the transportation of fish larvae specially Gobiids to offshore areas, and consequently representing more abundance in this region.

Conclusion

This study investigated the species composition and dispersal patterns of larval fish assemblages, at near shore shallow environments of northern coast of the Persian Gulf along the Bushehr province shoreline. The fish larvae composition was dominated by inshore species; benthic in cold season, and pelagic in warm season. The results showed that temporal and spatial variations in the larval fish assemblages were related to environmental conditions and biological dynamics. Our findings also suggest that abiotic factors profoundly affect the existence and occurrence of the biotic elements, and both abiotic and biotic parameters, regulated the abundance and distribution of larval fish in the near-shore shallow waters.

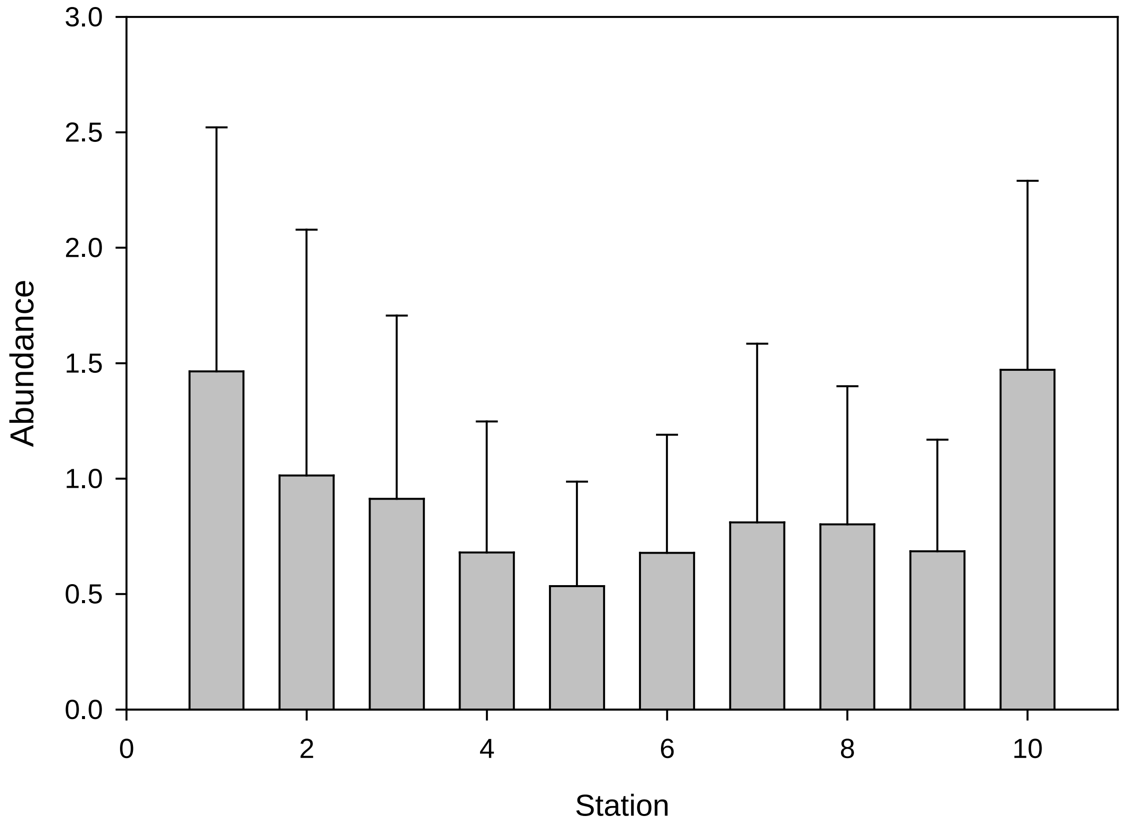

Figure 3. Abundance averages and standard deviations (SD) for fish larvae (larvae per 10 m^{2}) in the sampling stations, abundance transformed by the formula, log(x+ l).

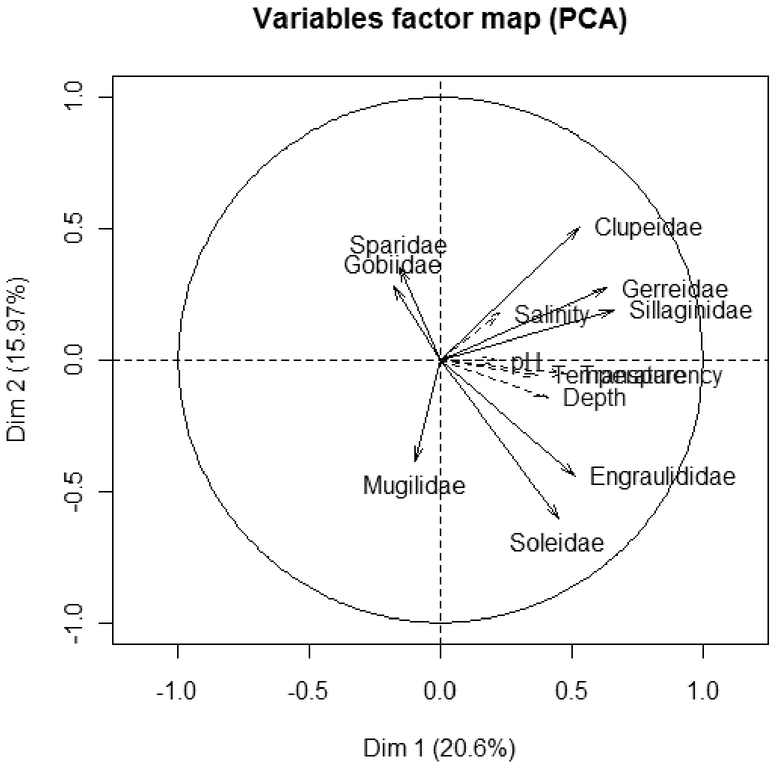

Figure 4. PCA with supplumentary variable, correlation between fish larvae abundance and some envronmental factors at the study area (November 2001, October 2002).

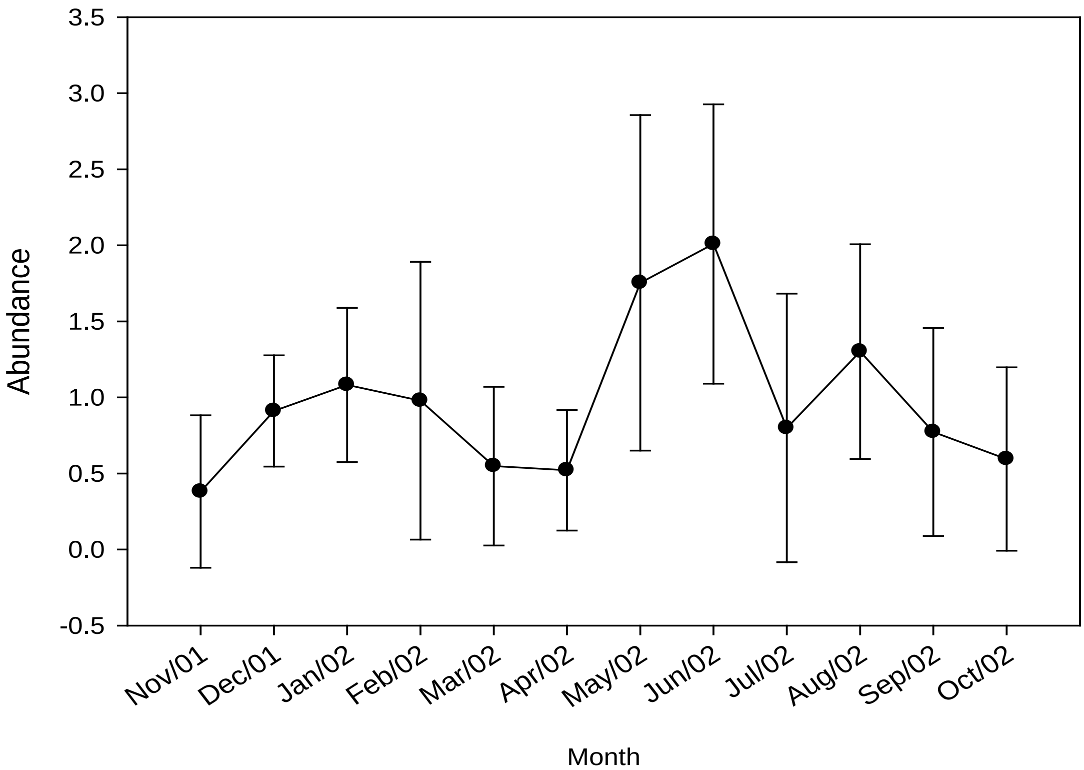

Figure 5. Monthly abundance averages and standard deviations (SD) for fish larvae (larvae per 10 $m^{2)}$ at the study area, abundance transformed by the formula, log(x+ l).

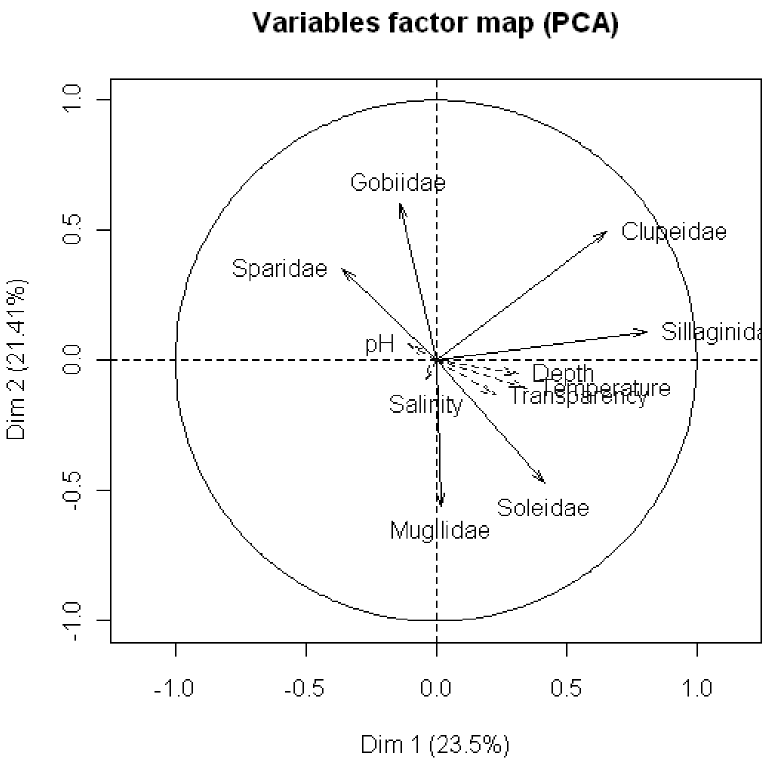

Figure 7. PCA with supplumentary variable,correlation between fish larvae abundance and some envronmental factors at the study area in cold season (November 2001, March 2002).

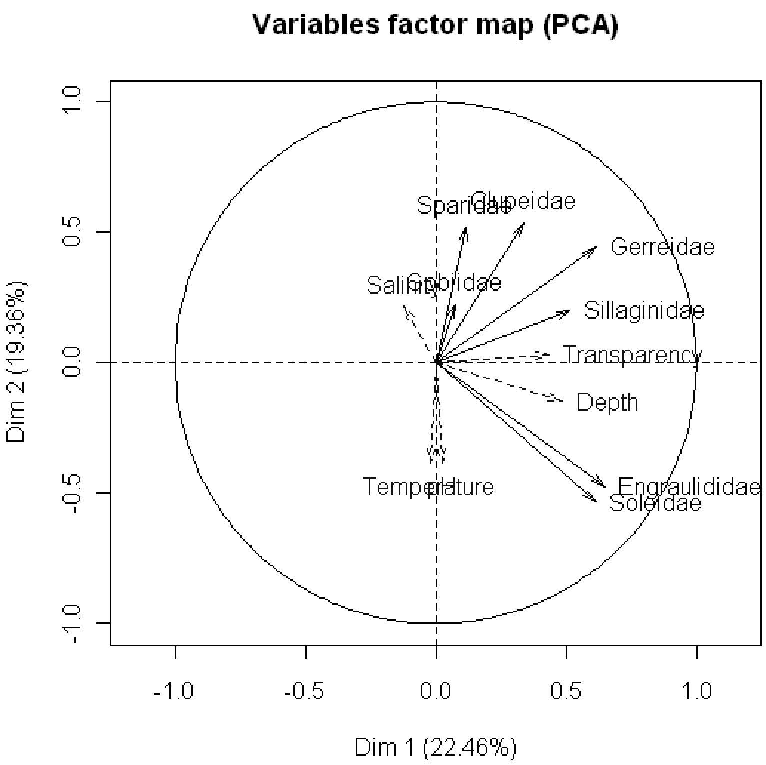

Figure 7. PCA with supplumentary variable correlation between fish larvae abundance and some envronmental factor at study area in warm season (April 2002, October 2002).

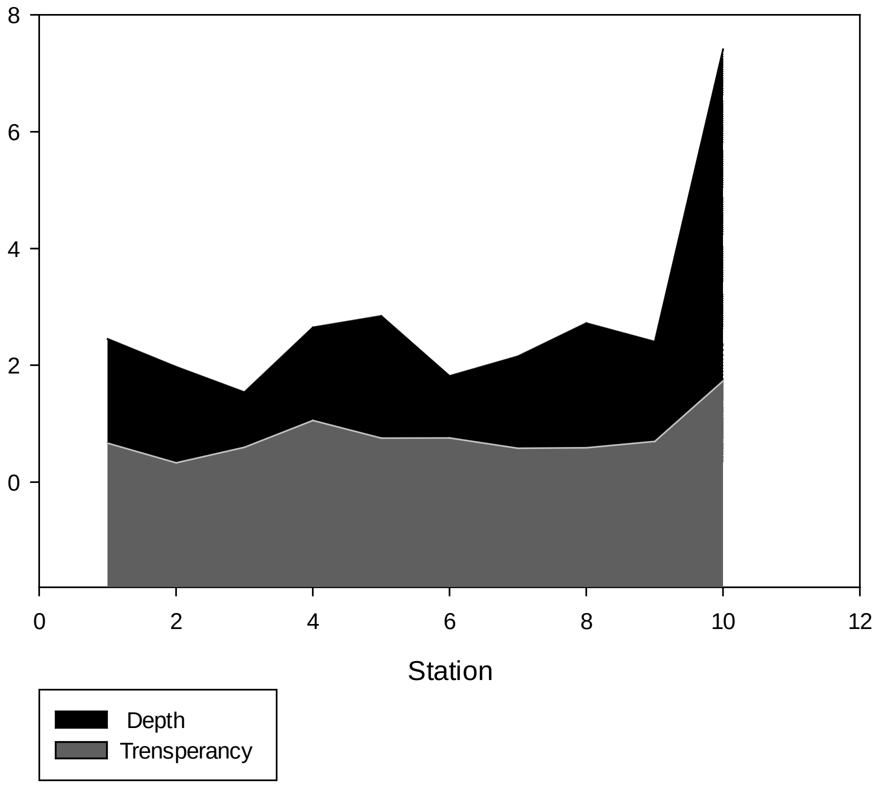

Figure 8. Depth and transparency at sampling stations

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