Preliminary Account of the Ichthyoplankton of the Marine Waters of Iraq, Northwest Arabian Gulf

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Abstract According to many previous studies about ichthyoplankton in northern parts of Arabian Gulf, the egg and larvae of Gobiidae, Engraulidae, Sciaenidae, Mugilidae, and Clupeidae dominate the ichthyoplankton comprising more than 90% of total larval account. So we can consider that the northwestern Arabian Gulf is a vital area for spawning and nursery ground for many larval fish species.

Temporal abundance of ichthyoplankton showed that peak number and types of fish larvae occurred during summer season (March to October) coincide with increasing primary and secondary productivity.

1 Introduction

Ichthyoplankton investigation provides valuable data on the location and season of fish spawning; this knowledge allow understanding the life cycle, behavior, and migration of fish and detect annual fluctuation in fish biomass (UNESCO 1975). Besides studying the state of ichthyoplankton, communities help to monitor the anthropogenic impact and climate change in marine ecosystem.

The egg and larvae of fish are considered to be a part of zooplankton—called ichthyoplankton which comprise 5% of the full mass of zooplankton. The information we obtained from studying ichthyoplankton is very important for biology and taxonomy of fish. This information is also important to understand the relationship between adult and young fish.

Embryonic development starts following fertilization till hatching, followed by larval stage which includes prolarvae with yolk sac and postlarval stage when yolk sac has been absorbed but still not get the appearance of juvenile stage.

The aims of the present study are to provide a preliminary species account for the fish larvae and to describe the composition and abundance of ichthyoplankton along the coastline of Iraqi marine waters in northwestern Arabian Gulf including Shatt

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Al-Arab estuary, Khor Abdulla, and Khor Al-Zubair and examine the effect of environmental factors and zooplankton biomass on the temporal and spatial variation of the ichthyoplankton assemblage.

2 The Marine Waters of Iraq

The Iraqi marine waters represent the estuarine part of the Arabian Gulf.

The coastline of Iraq characterized by three main features:

1-. Shatt Al-Arab estuary.
2-. Extensive mudflats.
3-. Khor Al-Zubair lagoon.

It is known that the northwestern part of Arabian Gulf is considered to be one of the most productive areas of the gulf (Bibik et al. 1970), due to the discharge of Shatt Al-Arab estuary (Abaychi et al. 1988) which is rich in nutrient. The unique topography of this area provides ideal conditions for the distribution of fish egg and larvae.

Many previous studies referred that Shatt Al-Arab estuary plays an important role as nursery and feeding ground for several coastal marine fish species as juveniles and young of the year and spawning ground for these species as adult.

The hydrology of northwestern Arabian Gulf differs from other parts of the gulf. The sediments that are carried by Shatt Al-Arab discharge are dominated. These sediments are of silty, muddy, and mixture of sand, silt, and mud (Al-Badran 1995) which is highly affected by the freshwater discharge from Shatt Al-Arab mainly salinity.

The weather in this region characterize by long hot season extended from April to October (air temperature exceeds 35 °C). The cold season confined from November to February. Water temperature ranges between 12.5 °C in winter to 34 °C in summer. Salinity is more stable in range between 32 and 38‰ and increases with increasing distant from Shatt Al-Arab estuary. However, fluctuation in salinity (4–12‰) is seen in the lower reaches of Shatt Al-Arab due to freshwater discharge.

3 Previous Studies on Ichthyoplankton in the Arabian Gulf Area

Several ichthyoplankton surveys have been carried out in Arabian Gulf (Table 1). Nellen (1973) collected fish larvae from north and eastern parts of Arabian Gulf as a part of survey include Indian Ocean. Houde et al. (1986) determined the kind and abundance of fish larvae in the southern and western parts of Arabian Gulf. The survey included determination of sites and season of spawning and identified relationship between distribution of ichthyoplankton and zooplankton density during

Table 1 The most abundant fish larvae in Arabian Gulf from previous studies

Reference	Fish larvae	Area
Nellen (1973)	Pomadasyidae, Clupeidae, Gobiidae, Apogonidae	Eastern Arabian gulf
Houde et al. (1986)	Clupeidae, Gobiidae, Sparidae, Soleidae	Western Arabian gulf
Ahmed (1990)	Gobiidae, Engraulidae, Sciaenidae	Khor Al-Zubair, northwestern Arabian gulf
Hussain and Ahmed (1995)	Gobiidae, Sciaenidae, Mugilidae, Engraulidae	Northwestern Arabian gulf
Al-Okailee (2001)	Gobiidae, Clupeidae, Sciaenidae	Shatt Al-Arab estuary, north Arabian gulf
Koochaknejad et al. (2011)	Gobiidae, Clupeidae, Sparidae, Sciaenidae	Khor Musa channel, north Arabian gulf
Rabbaniha et al. (2013)	Gobiidae, Clupeidae, Blenniidae	Chabahar port, eastern Arabian gulf
Paighambari et al. (2017)	Clupeidae, Gobiidae, Sparidae	Helleh River estuary, north Arabian gulf

a 1-year survey. Ahmed (1990) studied the abundance and diversity of fish larvae in Khor Al-Zubair, northwestern Arabian Gulf, and identified 18 larval fish families. Grabe et al. (1992) published comprehensive account on a seasonal and spatial pattern of ichthyoplankton in Kuwait Bay. Al-Okailee (2001) studied the abundance and distribution of ichthyoplankton and the relationship between ichthyoplankton abundance and zooplankton density in Shatt Al-Arab estuary, northwestern Arabian Gulf. Richards and Yamani (2008) put a first taxonomic guide book for the identification of the early life history of fishes from Arabian Gulf.

4 Importance of Estuaries

Estuaries are complex, dynamic, and biotical rich ecological systems that mark the transition between freshwater and the open coast, which are recognized among the most productive aquatic ecosystems in the world, having high level of primary and secondary production (Peterson et al. 2004). The high productivity is the reason why many fish species utilize these systems as nursery and spawning grounds (Whitfield 1999). The fish that utilize and take advantage of high food supply and shelter that estuaries provide is restricted by euryhaline species (Peterson et al. 2004).

Consequently, estuaries are generally characterized by a low ichthyofaunal diversity but high abundance of a few individual taxa (Potter et al. 1990).

Occurrence and distribution of adult and larval fish in an estuary vary according to environmental changes like precipitation regime, estuary morphology, tidal dynamic, current velocity, and availability of food resources. Temperature and salinity are important factors influencing the occurrence, density, and growth of

egg and larval fish in estuaries region. However, estuaries are distinguish by environmental fluctuation where sudden change in salinity, temperature, and turbidity is due to influx of tide and mixing of freshwater and salt water.

Most marine fish spawn offshore, and its larvae enter the estuary after hatching; thus the existence of yolk-sac larvae in a particular place give us evidence about spawning ground and time and migrating route.

The primary productivity is the base for food chain in marine habitat and correlated with the distribution and concentration of mineral nutrients. The north part of Arabian Gulf especially Shatt Al-Arab estuary is characterized by high primary productivity due to high concentration of nutrients (nitrite, nitrate, phosphorus) coming from the discharge of Shatt Al-Arab. The productive layer estimated to reach 4 meters, being the most productive part in the gulf.

Many studies refer to Shatt Al-Arab estuary and adjacent shores as spawning, nursery, nutrition, and shelter for many marine fish, which spend part of its life in this area (Hussain et al. 1997, 1999; Mohamed et al. 2001; Mohamed and Qasim 2014). Frank (1988) showed that the spawning sites of fish are characterized with high primary and secondary production and food resource.

5 Environmental Factors Affecting Ichthyoplankton Distribution in Northwestern Arabian Gulf

5.1 Temperature, Salinity, and Turbidity

The weather conditions of the region are characterized by a long hot season between April and October as air temperature exceeds 45 °C. The cold season is confined from November to February. Thus the area presents more subtropical than warm temperate conditions.

Temperature and salinity both affect the abundance and distribution of ichthyoplankton through its effect on spawning. Water temperature in the northwestern Arabian Gulf was estimated to be between 13° and 34 ° C, and higher water temperature (34 ° C) was recorded during August, while lower temperature (13 ° C) was recorded during January.

Higher percentages of fish egg (99.9%) were collected when water temperature ranged between 24.5° and 34 ° C. However, no fish egg was collected when water temperature reached 19.5 °C (Al-Okailee 2001). However, most larval families appear when water temperature ranged between 28° and 29.5 ° C, while fish larvae disappear when water temperature reached 13 ° C. The seasonal abundance of fish egg was coinciding with the seasonal fluctuation in temperature due to its influence on gonad maturation (spawning) (Ahmed 1990).

Salinity values are more stable (37–42‰) at offshore area than nearshore area (32–37‰). Lower salinity is generally recorded during April coinciding with the flood of Shatt Al-Arab River; however, salinity in the lower reaches of Shat Al-Arab

River is more fluctuated (12–34‰). It has been shown that most fish egg (99.8%) appears when salinity ranged between 32 and 42‰, while most fish larval families appear when salinity ranged between 34 and 42‰ (Al-Okailee 2001).

The high turbidity characterized Shatt Al-Arab estuary which can be considered as a good factor provide a protection for fish larvae from predation. Moreover, the detritus materials in this region attracted several marine fish families for feeding. Transparency was estimated to be ranged 15–30 cm in nearshore area (Shatt Al-Arab estuary). While transparency increase in Khor Abdulla (offshore) ranged to 100–400 cm. However higher turbidity values were recorded during April, while lower turbidity values were recorded during June coinciding with increasing amount of sediments during flood season of Shatt Al-Arab River. It has been found that higher percentage of fish egg (65%) coincide with lower turbidity (transparency of water 100–400 cm), while most larval fish families appearance coincide with high turbidity of water (transparency of water 20–25 cm) (Al-Okailee 2001).

5.2 Spawning Season

It is known that some marine fish use estuary for spawning and feeding. This is mainly due to high primary productivity and environmental condition such as high turbidity and low salinity. Shatt Al-Arab estuary is considered to be the most productive area in the Arabian Gulf (Al-Zubaidi 1998), so several marine fish species move to Shatt Al-Arab estuary during the spawning season (Hussain et al. 1999).

The main spawning activity in the northern parts of Arabian Gulf seems to take place in summer since both fish eggs and larvae are most abundant at this season with peak in abundance during April to July (Ahmed and Hussain 2001). In winter, the spawning activity seems to be less than in summer. Few larval taxa appear in winter which includes Mugilidae, Soleidae, and Sparidae (Hussain and Ahmed 1995).

5.3 Nearshore Distribution

The nearshore area represents as main spawning ground for many fish species as the eggs of Mugilidae, Soleidae, Clupeidae, and Engraulidae are distributed at this area (Ahmed and Hussain 2001).

Most larvae (80%) during April were recorded at nearshore area. During July 65% of the larvae were collected in nearshore area also. While no egg or larvae were observed in nearshore area during December (winter), however, most larvae (Gobiidae, Sciaenidae, Sparidae, Engraulidae, Clupeidae, and Polynemidae) were collected from nearshore area (Hussain and Ahmed 1995). Since the distribution and abundance of fish egg and larvae indicate productivity and spawning, it appears that

the nearshore area is not only an important nursery ground but also important as spawning ground for several species.

5.4 Offshore Distribution

High abundance of fish egg were recorded in offshore area during April. In summer (July) most spawning takes place at offshore area as 73% of eggs were collected from offshore area during July and December (Hussain and Ahmed 1995). The most abundant fish larval families in offshore area are Engraulidae, Clupeidae, Soleidae, Bregmacerotidae, Polynemidae, Callionymidae, and Blenniidae.

Ahmed and Hussain (2001) referred that Clupeidae and Chirocentridae utilize offshore area as spawning ground as their eggs were most abundant there.

6 Larval Families Account

Most fish larvae in the northwestern Arabian Gulf appear during spring till late summer (March to October) with peak in abundance was recorded during May (586 larvae/10 m), while peak in larval fish families (14 families) appear during June. During winter (November to February) few larvae appear mostly Gobiidae (Al-Okailee 2001).

The mean larval abundance in Shatt Al-Arab estuary was estimated to be 192 larvae/10m^2 (Al-Okailee 2001), while in northwestern Arabian Gulf the mean larval abundance was 179 larvae/10m^2 (Hussain and Ahmed 1995). However in Khor Al-Zubair, the mean larval abundance was 251 larvae/10m^2 (Ahmed 1990). This shows the importance of northwestern Arabian Gulf especially Shatt A-l Arab estuary as spawning and nursery ground for many fish.

Fish larval families that dominate the ichthyoplankton in the northwestern Arabian Gulf are Gobiidae, Engraulidae, Sciaenidae, Mugilidae, and Clupeidae (Table 2) which resemble many estuaries in the world, besides those families dominate as adult in northwestern Arabian Gulf.

The northwestern Arabian Gulf is characterize by low number of larval families, as Al-Okailee (2001) recorded 17 larval families in Shatt Al-Arab estuary, while Hussain and Ahmed (1995) recorded 22 larval fish families in northwestern Arabian Gulf, while Ahmed (1990) recorded 17 larval fish families in Khor Al-Zubair/ northwestern Arabian Gulf. However Houde et al. (1986) recorded 53 larval fish families in western side of the Arabian Gulf. The low number of larval families in this area could be related to environmental properties of the estuary such as fluctuation of salinity and high turbidity; thus the stenohaline marine fish do not spawn in this area.

Table 2 Larval fish families with its species, genus, and taxa that dominate the ichthyoplankton in northwestern Arabian Gulf

Larval fish family	Taxa
Blenniidae	Type A, type B
Bothidae	*Pseudorhombus arsius*
Bregmacerotidae	*Bregmaceros arabicus*
Callionymidae	*Callionymus* sp.
Carangidae	Unidentified
Centriscidae	*Centriscus scutatus*
Chirocentridae	*Chirocentrus dorab*
Clupeidae	*Dussumieria acuta*; *Ilisha megaloptera*; *Sardinella* spp.
Cynoglossidae	*Cynoglossus arel*
Engraulidae	*Stolephorus buccaneri*; *Thryssa mystax*
Gobiidae	*Boliophthalmus waltoni; Trypauchin vagina*; type A
Hemiramphidae	*Hemiramphus* sp.
Leiognathidae	*Leiognathus bindus*; type A
Mugilidae	*Liza carinata*, *Liza subviridis*; type A
Mugiloididae	*Parapercis* sp.
Platycephalidae	*Platycephalus indicus*
Polynemidae	*Polydactylus sextarius*
Pomadasyidae	*Pomadasys* sp.
Sciaenidae	*Johniopsis sina*; type A; type B
Scatophagidae	*Scatophagus argus*
Sillaginidae	*Sillago sihama*
Scorpaenidae	*Pseudosynancia melanostigma*; type A
Soleidae	*Solea elongate*; type A; type B, type C
Sparidae	Types A, B, C,D
Syngnathidae	*Hippocampus kuda*; *Halicampus zavorensis*
Sphyraenidae	*Sphyraena* spp.
Tricanthidae	*Triacanthus biaculeatus*
Trichiuridae	*Trichiurus lepturus*

The seasonal cycle of larval fish abundance during March to October coincides with food availability, as phytoplankton blooms during this time of the year followed by zooplankton which is the main food source for fish larvae.

6.1 Gobiidae

Gobies larvae are the most abundant fish larvae in northwest Arabian Gulf in both nearshore and offshore areas. Gobies larvae were common during March to November, where water temperature ranged between 16° and 32 ° C and salinity 28.5 and 32.5‰ with peak in abundance during May (302 larvae/10m^2) contributing

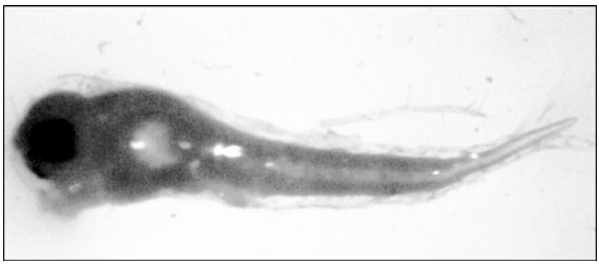

Fig. 1 Gobiidae larvae (2.5 mm NL)

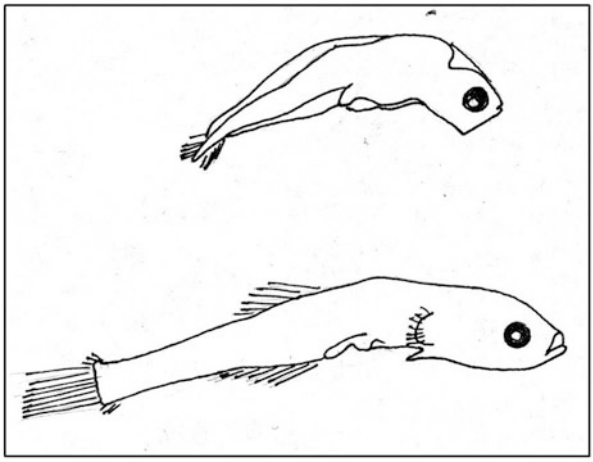

Fig. 2 *B. waltoni* larvae: 2.4 mm TL (above), 12 mm TL (below)

41% of the total larvae collected in the northwestern Arabian Gulf. The smallest larvae (<3.5 mm) are usually abundant at nearshore area (Fig. 1), indicating the spawning ground of this fish (Al-Okailee 2001).

Gobiid larvae are represented by two species (*Boliophthalmus waltoni* (Fig. 2) and *Trypauchin vagina*) and one type (type A) in Khor Al-Zubair (Ahmed 1990); however, Hussain and Naama (1989) identified five species of Gobiidae as adult from Khor Al-Zubair, while Kuronuma and Abe (1986) identified 29 species of adult Gobiidae in Arabian Gulf. However, Richards and Yamani (2008) referred to the larvae of Gobiidae as the most specious family in the Arabian Gulf and difficult to identify.

6.2 Sciaenidae

Sciaenid larvae appear during April to August mostly yolk-sac larvae, when water temperature ranged between 22° and 32 °C and salinity 29.5–31‰. Smallest larvae (<3 mm NL) are common during April in both near and offshore areas but are most

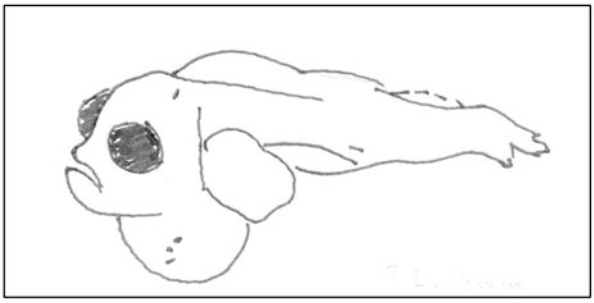

Fig. 3 Larvae of *Johniopsis sina* (3.2 mm TL)

abundant near shore. Sciaenid larvae were recorded to be one of the most abundant fish larvae in Khor Al-Zubair (Ahmed 1990).

Hussain and Ahmed (1995) identified one species (*Johniopsis sina)* (Fig. 3) and two types (A and B), while Houde et al. (1986) identified three types of sciaenid larvae from Kuwaiti waters, but did not identify any to species. However Mohamed and Qasim (2014) identified four species of sciaenid as adult from Iraqi marine waters.

6.3 Mugillidae

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Mugilidae are the characteristic of the coastal and estuarine fish (Kuronuma and Abe 1986). In Arabian Gulf they inhabit coastal waters, Khors, lagoons, estuaries, and embayment. Three species of adult mullets (*Liza subviridis*, *L. carinata*, and *Liza klunzingeri*) are common in northwestern Arabian Gulf (Mohamed et al. 2001).

Mugilidae are winter spawner fish as their egg and larvae were collected during December to April as water temperature ranged between 12.5° and 22 °C and salinity 32–38‰ indicating spawning season of this fish. The majority of Mugilidae larvae belong to *Liza* spp. and are most abundant during December in offshore area. The smallest larvae recorded (< 3mmNL) with yolk sac at offshore area indicate hatching in December. At nearshore area, Mugilidae larvae appear in February and April, whereas they disappear from offshore area indicating recruitment from offshore area.

Two species of Mugilidae larvae were identified by Ahmed and Hussain (2003) from northwestern Arabian Gulf:

1-. *Liza subviridis*: which characterized by heavy pigmentation of stellate melanophores on the gut and caudal trunk. The larvae were most abundant during April.
2-. *Liza carinata*: which characterized by fine spots of melanophores along the caudal trunk (light pigmentation) (Fig. 4). The larvae occurred from December to February.

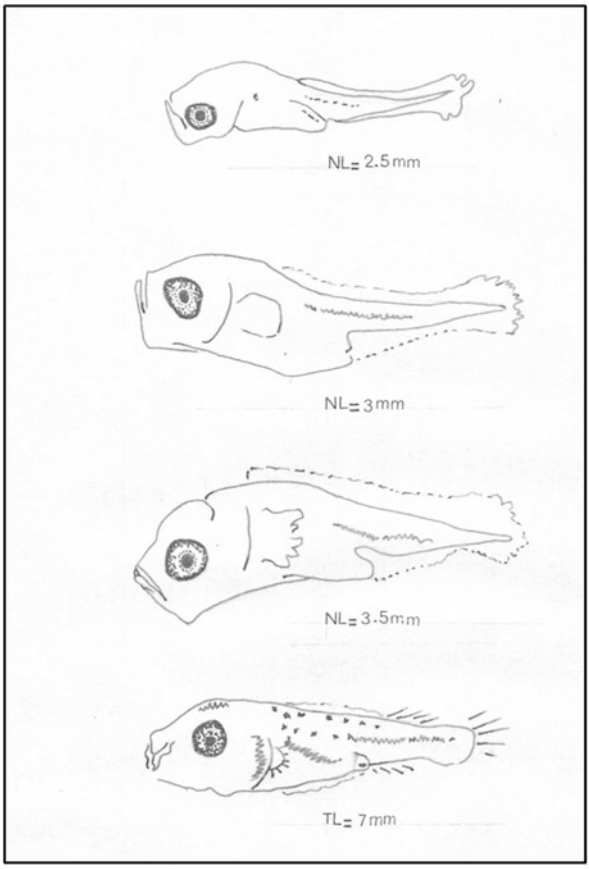

Fig. 4 *Liza carinata*, larval stage

Smallest larvae (2–4 mm) and yolk-sac larvae appear in the offshore area during December, while larger larvae (3–5 mm) appear nearshore area during April. Thus the spawning of Mugilidae occurs seaward from December to April. The pattern of nearshore movement with growth was described by Ahmed and Hussain (2003) in Shatt Al-Arab estuary.

Richards and Yamani (2008) could not identify the many larval mullet species that occur in Kuwaiti waters to species because of meristic overlap.

6.4 Engraulidae

Among the most abundant fish in Arabian Gulf (Kuronuma and Abe 1986), it is being the most abundant larval family in Kuwaiti waters (Houde et al. 1986) and Khor Al-Zubair (Ahmed 1990).

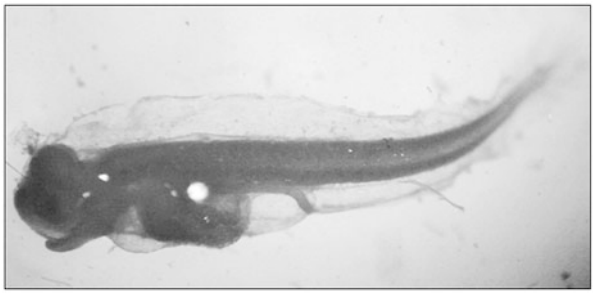

Fig. 5 Engraulidae larvae (*Thryssa mystax)*

Engraulidae larvae appear during March to October in Iraqi marine waters, with peak in abundance in April, while yolk-sac larvae (2.5–4 mm NL) were collected during July at offshore area.

Two species of Engraulidae were identified: *Thryssa mys*tax (Fig. 5) and *Stolephorus buccaneri* (Ahmed and Hussain 2003).

T. mystax larvae dominate at nearshore area, while the larvae of *S. buccaneri* dominate at offshore area; however, *T. mystax* is being more common than *S. buccaneri* in Iraqi marine waters (Hussain and Ahmed 1995).

6.5 Clupeidae

Clupeid larvae were collected at near shore and offshore in Iraqi marine waters during summer (April to July) contributing 15.7% of the total fish larvae collected from Shatt Al-Arab estuary (Al-Okailee 2001).

Most larvae were unidentified; however, three species of clupeid larvae were identified: *Ilisha megaloptera*, *Dissumeria acuta*, and *Sardinella* spp. (Ahmed and Hussain 2000a).

Clupeidae family as a pelagic fish produce pelagic egg, and their larvae reach to the estuary or coastline by current for feeding. The abundance and size of clupeid larvae at offshore and presence of yolk-sac larvae indicate the location and spawning time.

Ilisha megaloptera is the most abundant clupeid larvae in Iraqi marine waters, mostly abundant near shore during April, while it is not common in Kuwaiti waters (Houde et al. 1986).

Dussumieria acuta larvae appear during April to July in near shore and offshore with peak of abundance during June in offshore. It can be easily identified from their long compressed bodies (10–19 mm) and presence of teeth on both jaws (Fig. 6).

Sardinella spp.: these larvae appear during April only in the near shore (Fig. 7). One genus (*S. albella)* was recorded from Khor Al-Zubair as adult (Hussain and Naama 1989).

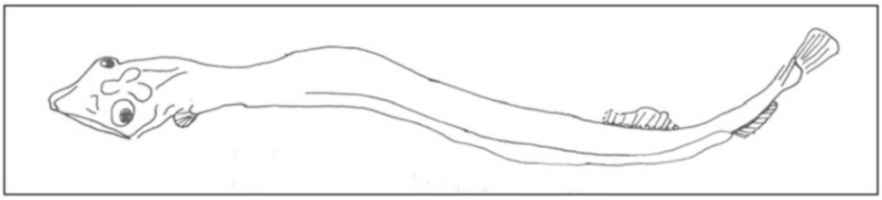

Fig. 6 *D. acuta* larvae

Fig. 7 *Sardinella* spp. (4.3 mm NL)

6.6 Soleidae

Soleid larvae appeared during December to April where water temperature ranged between 12.5° and 24 ° C and salinity 33–38‰ at near shore and offshore with a peak of abundance during December. Ahmed and Hussain (1998) identified two types (type A and type B) (Fig. 8) and one species (Solea elongate) (Fig. 9). Solid larvae which collected during December were identified as type A and type B, while those collected during February and April were identified as Solea elongate, which ranged in total length 3.5–6.3 mm. Houde et al. (1986) described five types but did not assign to any species. However, Kuronuma and Abe (1986) listed six species as adult from Arabian Gulf.

It has been found that recruitment of Solea elongate juveniles (40–100 mm TL) to Khor Abdulla/northwest Arabian Gulf occurred during August and September (Hussain et al. 1997).

6.7 Hemiramphidae

These larvae were represented by one genus *Hemiramphus* (Fig. 10), collected from Khor Al-Zubair during August where water temperature was 28 °C and salinity

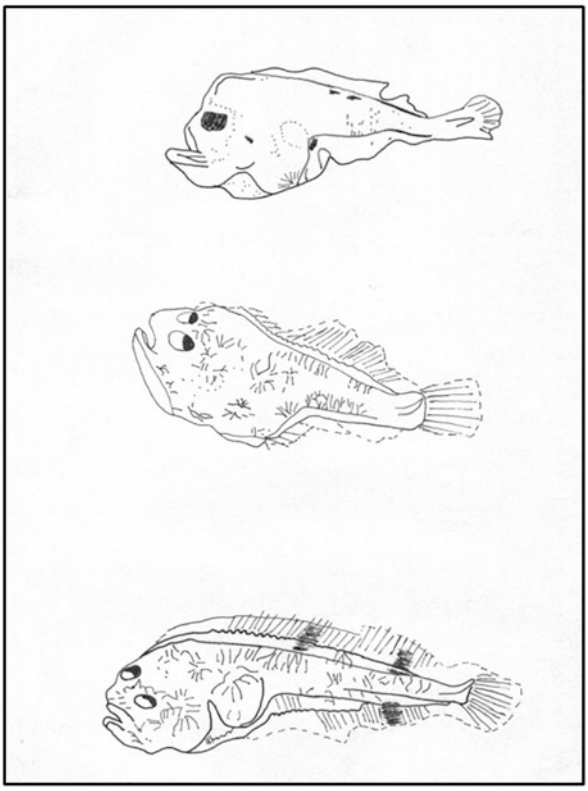

Fig. 8 Solidae type B

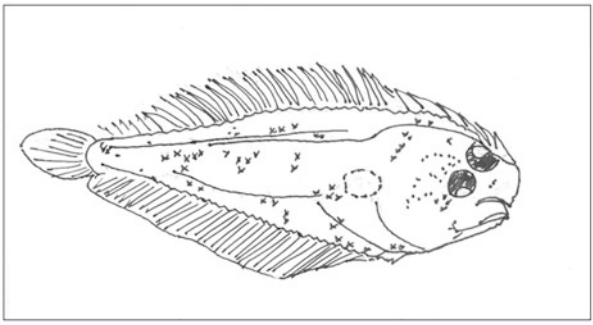

Fig. 9 *Solea elongata* larvae (9.4 mm TL)

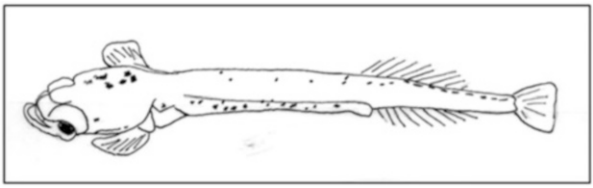

Fig. 10 *Hemiramphus* sp. Larvae (5.5 mm TL)

31‰. Hussain and Naama (1989) recorded one species *H. marginatus* as adult from Khor Al-Zubair.

6.8 Centriscidae

These small non-common larvae were represented by one species *Centriscus scutatus* (Fig. 11) with total length of 2–2.5 mm, collected during October from Khor Al-Zubair with water temperature 22 °C and salinity 30‰. They are very rare as adult.

6.9 Syngnathidae

These larvae are represented by two genus:

Hippocampus sp.: collected during May to August from Khor Al-Zubair with water temperature 26°–27 ° C and salinity 29.5–31‰. As adult one species was identified as *H. kuda* in Khor Al-Zubair (Hussain and Naama 1989).

Halicampus sp. (Fig. 12): firstly identified as adult from Iraqi marine waters as *Halicampus zavorensis* (Ziyadi et al. 2018). These larvae were collected only from Khor Al-Zubair (Ahmed 1990).

6.10 Scorpaenidae

It is collected during February to April in nearshore area, with water temperature ranged between 11 and 19 °C and salinity 30–32.5‰. One species (*Pseudosynancia melanostigma)* (Fig. 13) and one type (type A) (Fig. 14) *were* identified *(*Ahmed 1990).

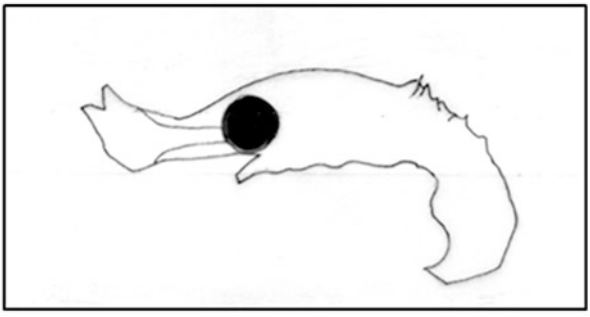

Fig. 11 *Centriscus scutatus* larvae (2 mm TL)

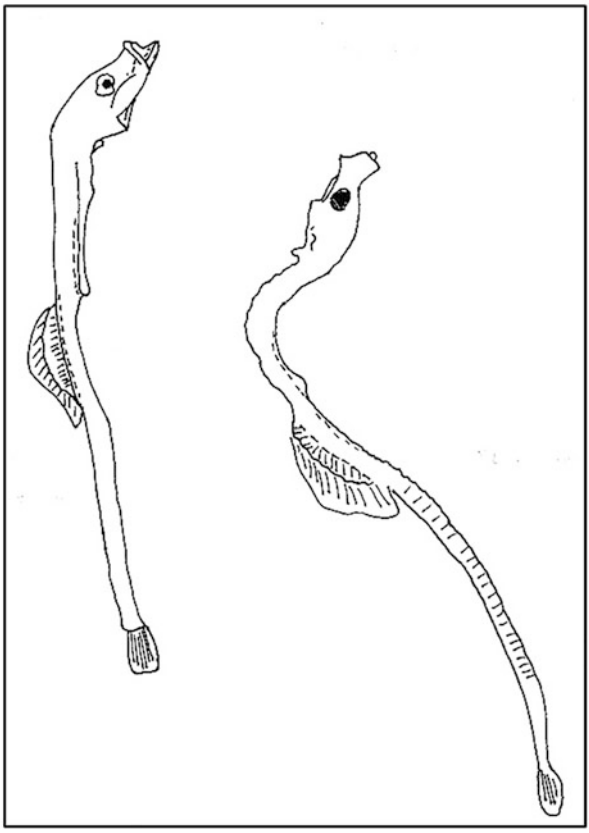

Fig. 12 Pipefish *Halicampus* sp. (6 mm TL)

Houde et al. (1986) identified 11 types of larvae of Scorpaenidae from the Arabian Gulf.

6.11 Sillaginidae

It is represented by one species *Sillago sihama* and collected during June to October where water temperature ranged between 22 and 32 °C and salinity 30.5–32‰.

6.12 Leiognathidae

It is represented by one species (*Leiognathus* spp.) (Fig. 15) and one type (type A). These larvae were collected during June to September where water temperature ranged between 27 and 32 ° C and salinity 30.5–31‰.

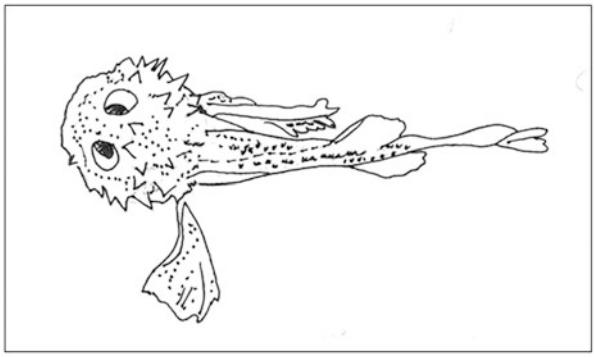

Fig. 13 *Pseudosynancia melanostigma* larvae (9.5 mm TL)

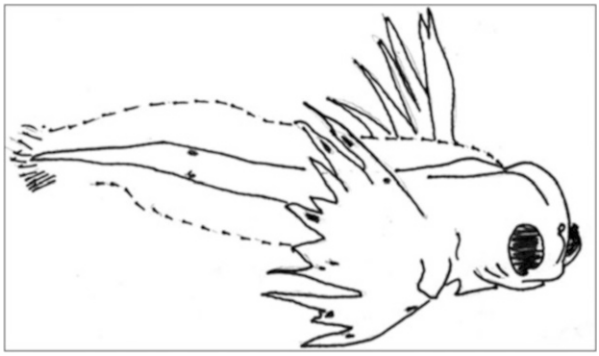

Fig. 14 Scorpaenidae larvae type A (4.2 mm TL)

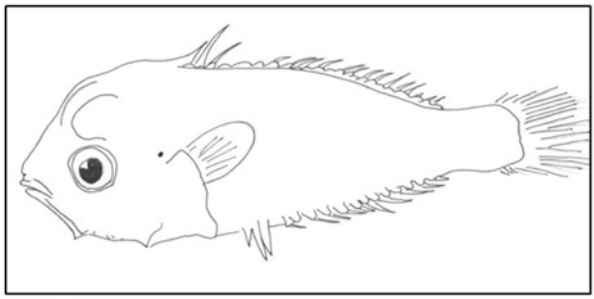

Fig. 15 *Leiognathus* spp. (8 mm TL)

Houde et al. (1986) listed eight types of leiognathid larvae from Kuwaiti waters.

6.13 Sparidae

Four types (A, B, C, D) (Fig. 16) were recognized. These larvae were collected during February to May, where water temperature ranged between 16 and 27 °C and salinity 28.5–29.5‰.

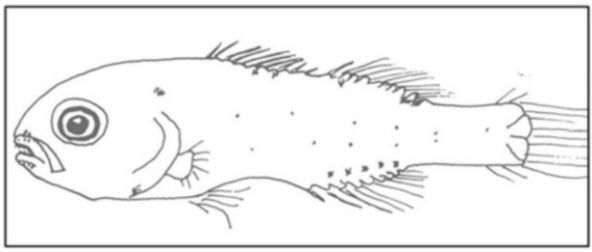

Fig. 16 Sparid larvae (type A) (12mmTL)

The sparoid fishes comprise several families' very similar appearance to larvae. Meristics are very helpful, and the following families should all be considered together when making identification: Sparidae, Nemipteridae, and Lethrinidae (Richards and Yamani 2008).

Houde et al. (1986) identified six types of Sparidae larvae in Kuwaiti waters.

6.14 Polynemidae

It is represented by one genus *Elethronema* spp. and collected during August only where water temperature was 33 °C.

Houde et al. (1986) identified *Polydactylus sextarius* larvae from Kuwaiti waters, while Kuronuma and Abe (1986) identified two species of adult Polynemidae:

Polydactylus sextarius and *Eleutheronema tetradactylum.*

6.15 Trichiuridae

One genus of these larvae was recognized as *Trichiurus* sp. (Fig. 17), with total length of 5–16 mm. It is collected during May to June with water temperature of 27 °C and salinity 29.5–30.5‰.

Trichiurus lepturus larvae were identified also by Houde et al. (1986) from Kuwaiti waters.

6.16 Cynoglossidae

Cynoglossid larvae were recorded in offshore and near shore with a peak of abundance in offshore area. Spawning activity was recognized to be during April to July where water temperature is 24–31 °C and salinity 33–38‰. The presence of small larvae in offshore area and larger one in nearshore area indicate the nearshore recruitment to Shatt Al-Arab estuary.

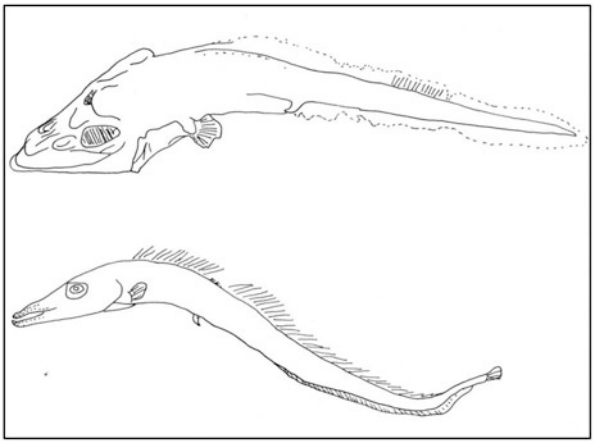

Fig. 17 *Trichiurus* sp. larvae (above: 7.5 mm TL), (below: 17 mm TL)

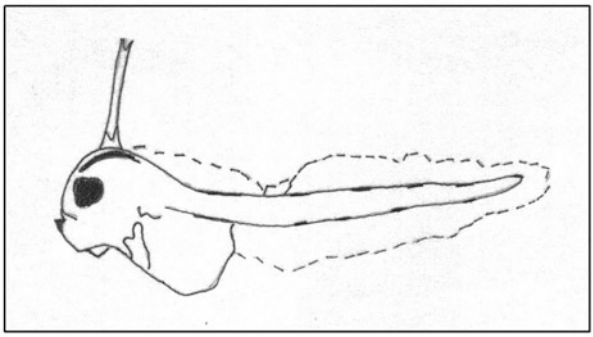

Fig. 18 *Cynoglossus arel* larvae (2.8 mm TL)

The larvae were identified as *Cynoglossus arel* (Fig. 18) (Ahmed and Hussain 1998).

Grabe et al. (1992) identified cynoglossid larvae from Kuwait Bay *as C. macrolepidotus (= C. arel)*, while Houde et al. (1986) identified cynoglossid larvae as *Cynoglossus* spp.; however, Kuronuma and Abe (1986) listed seven species as adult.

6.17 Bothidae

Bothids are not common fish as larvae in Iraqi marine waters. Bothid larvae were most abundant offshore during April where water temperature was 24 °C and salinity 37‰. However, no egg of bothid was collected.

One type of bothid larvae was recognized from Iraqi marine waters and identified as *Pseudorhombus arsius* (Fig. 19) (Ahmed and Hussain 1998). However, Mohamed et al. (2001) identified two species of adult Bothidae (*Bothus pantherinus*

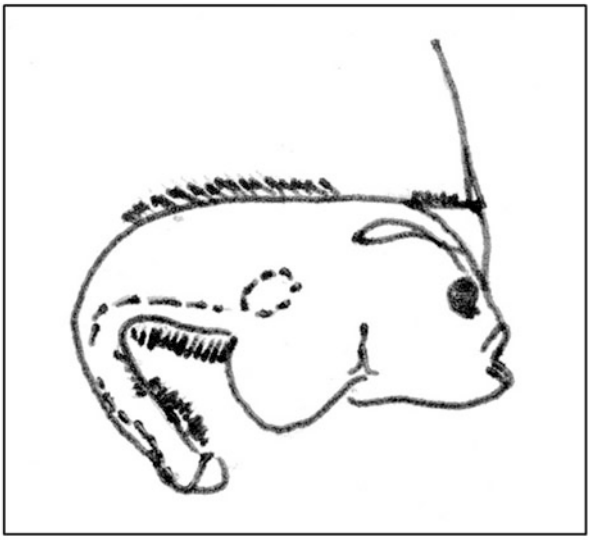

Fig. 19 *Pseudorhombus arsius* larvae (3.7 mm TL)

and *Pseudorhombus arsius*) from Iraqi marine waters. While Houde et al. (1986) identified four types of bothid larvae from Kuwaiti waters, however, Kuronuma and Abe (1986) listed six species of adult Bothidae from Arabian Gulf.

6.18 Carangidae

These larvae appear during summer (July) in offshore area and could not identify it to lower taxa.

Houde et al. (1986) identified few to species because of its complexity.

6.19 Bregmacerotidae

The codlet (Bregmacerotidae) are small fish of pelagic habits found in the neritic and oceanic waters of tropical and subtropical seas. Houde et al. (1986) identified three species of *Bregmaceros (B. nectabanas*, *B. arabicus*, *B. rarisquamous*) from Kuwaiti waters.

These larvae were found at the estuarine parts of NW Arabian Gulf during July and identified as *Bregmaceros arabicus* (Fig. 20) (Ahmed and Hussain 2000c), ranging in length 2.3–19 mm with 52 myomers, slightly pigmented larvae.

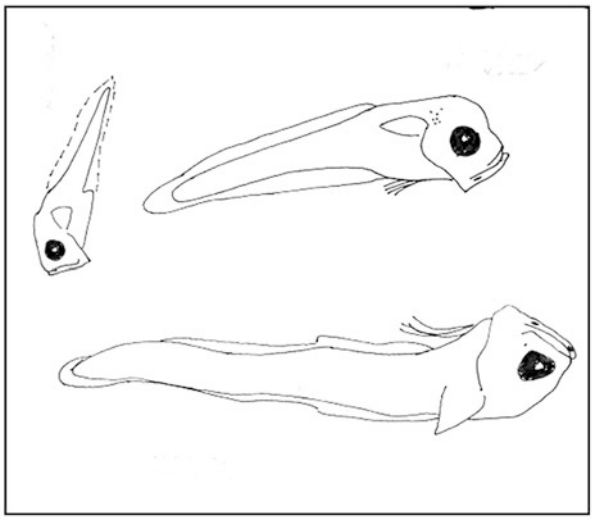

Fig. 20 Bregmaceros arabicus larvae

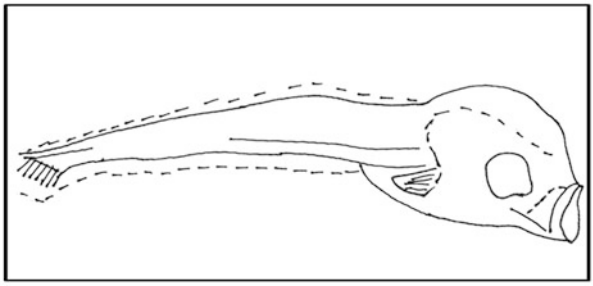

Fig. 21 Blenniidae larvae (type A) (6 mm TL)

6.20 Blenniidae

These larvae were collected during July (Hussain and Ahmed 1995) and were identified into two types (type A and type B) (Fig. 21). However, Houde et al. (1986) identified four types of Blenniidae.

6.21 Chirocentridae

Large larvae commonly present with Clupeidae larvae and are easily identified as *Chirocentrus dorab.* These larvae occurred during July mostly near shore. They are very common as adult in the estuarine parts of Arabian Gulf.

6.22 *Pomadasyidae*

They are not common as adult in the northwestern Arabian Gulf. These larvae appear during March and April with water temperature ranging between 16 and 19 °C. These larvae were identified as *Pomadasys* spp. (Fig. 22); however, two species were identified as adult from Khor al-Zubair: *P. maculatus* and *P. argenteus* (Hussain and Naama 1989).

6.23 *Fish Egg Account*

The previous studies showed that few fish egg dominated in the northern parts of Arabian Gulf; these include egg of Soleidae, Sciaenidae, Clupeidae, and Mugilidae (Houde et al. 1986; Ahmed and Hussain 2001; Al-Okailee 2015). This means that most fish egg in estuarine part of the gulf belongs to euryhaline species.

Mean fish egg abundance in Shatt Al-Arab estuary was estimated to be 1800 egg/10m^2 (Al-Okailee 2001), while Houde et al. (1986) estimated mean fish egg abundance to be 1033 egg/10m^2 in western Arabian Gulf. However, it has been shown that fish egg density increase with increasing distance from Shatt Al-Arab estuary due to increasing salinity in the offshore area and decreasing turbidity; furthermore, the increase in fish egg abundance coincides with increasing primary and secondary productivity.

Fish egg in the northwestern Arabian Gulf appear during spring to late summer (April to September). The peak in abundance is during June and July, with few egg appears during winter (November to February) (Ahmed and Hussain 2001).

In Shatt Al-Arb estuary, most fish egg belongs to six families: Mugilidae, Cynoglossidae, Soleidae, Clupeidae, Engraulidae, and Sciaenidae (Ahmed and Hussain 2001; Al-Okailee and Mutlak 2014) with soleid egg being the most

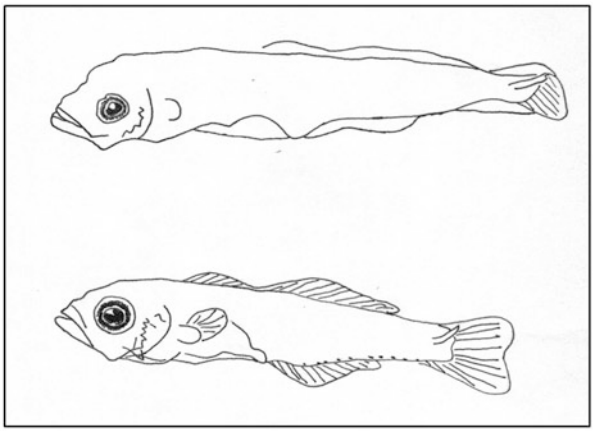

Fig. 22 *Pomadasys* spp. 4.5 mm TL (above), 10.5 mm TL (below)

Fig. 23 Unidentified fish egg

abundant fish egg (607eggs/10 m2) during winter (February) (Ahmed and Hussain 2001). These fish families dominate as adult and juveniles also in Shatt Al-Arab estuary.

The previous studies showed the importance of offshore area as spawning ground for many fish species, as 65% of fish egg were collected there (Ahmed and Hussain 2001; Al-Okailee 2001). The low abundance of fish egg in nearshore area is due to fluctuation in salinity and high turbidity.

Most fish egg in northwestern Arabian Gulf are planktonic, pelagic, spherical in shape, and transparent; some are ovoid in shape (*S. buccaneri*), and some has unusual shape (Fig. 23).

The most abundant fish eggs are related to the following families (Table 3):

1. Clupeidae: Clupeid egg was collected during March to October with mean abundance of 35 egg/10m^2, with peak in abundance during April in offshore area (Fig. 24).
2. Sciaenidae: Sciaenid egg was collected during April to October, with mean abundance of 758 egg/10m^2. The peak in abundance was reported during May in offshore area (Fig. 25).
3. Soleidae: Soleid egg was collected in both near and offshore with mean abundance of 607 eggs/10m^2 during December to February in nearshore area. This indicates winter spawning of Soleidae in northwestern Arabian Gulf. However,

Table 3 Characteristics of some fish egg from northwestern Arabian Gulf

Fish	Egg diameter mm	No. oil globules	Yolk texture	Previtaline space
Sciaenidae	0.33–0.35	7–25	Smooth	Narrow
Sardinella spp.	1.2–1.5	1	Vacuolated	Wide
Cynoglossus arel	0.65–0.70	5–10	Smooth	Narrow
Soleidae	0.70–0.74	1–8	Smooth	Narrow
Ilisha megaloptera	1.3	1	Vacuolated	Moderate
Chirocentrus dorab	1.3–1.5	1–4	Segmented	Narrow
Dussumeria acuta	1.4–1.6	1	Vacuolated	Narrow
Stolephorus buccaneri	0 val shape	1	Segmented	Narrow
Sparidae	0.71–0. 77	1	Smooth	Narrow
Mugilidae	0.65–0.69	1	Smooth	Narrow
Clupeidae	1.0–1.5	1–10	Segmented	Wide
Thryssa mystax	0.57–0.58	3–5	Segmented	Narrow

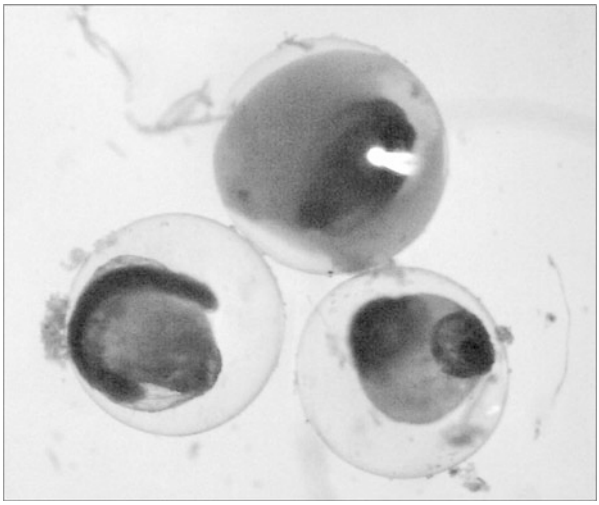

Fig. 24 Clupeid egg

Al-Okailee and Mutlak (2014) estimated sciaenid egg to compromise 51% of all fish egg collected in Shatt Al-Arab estuary.

4. Polynemidae: Appear during August only in offshore area.
5. Mugilidae: Appear during December to March, with peak in abundance (126 eggs/10m^2) during February in nearshore area and 70 eggs/10m^2 during December in offshore area.

   Two types of mugilid egg were recognized (Ahmed and Hussain 2000b):

   Type A: Egg diameter is 0.72–0.80 mm with one oil globule; its diameter is 0.05–0.1 mm. These eggs were collected from offshore during December.

   Type B: Egg diameter is 0.70–0.75 mm having two to eight oil globules. This type is collected during February from near shore.

Fig. 25 Egg of Sciaenidae

Embryo pigmentation is heavy with stellate melanophores. At hatching stellate melanophores also present on the body with fine spot along the dorsal and ventral side of caudal trunk.

6. Cynoglossidae: cynoglossid eggs were collected during July (Ahmed and Hussain 1998) in nearshore area; the mean of abundance was estimated to be 83 eggs/10m^2.
7. *Chirocentrus dorab*: easily recognized egg by its large size (1.5 mm in diameter) and large number of oil globules being common egg during July at nearshore area.
8. Engraulidae: collected during April to July. *T. mystax* egg is more common during April in nearshore area, while *S. buccaneri* egg is less common and has a unique elliptical shape which is easily recognized.

7 Discussion

Studying the community of ichthyoplankton is considered to be an important tool to understand the interaction between fish during their early life stages, as well as understanding of adult spawning sites; however, the distribution of fish larvae provides information about the factors influencing recruitment dynamic such as location and suitability of spawning habitats.

Ichthyoplankton survey can also be useful tool to estimate abundance index which used to measure the size of spawning stock. Consequently, the identification of yolk-sac larvae gives us information about the site and time of spawning and migration routes.

The spatial distribution of ichthyoplankton in northwestern Arabian Gulf appears to be a result of selection of spawning sites by the adult fish; hydrological factors predominated in the area; availability of food and biological adaptation of larvae to the high turbidity; and fluctuating temperature and moderate salinity.

The distribution and abundance of fish egg and larvae give us evidence about the productivity of the area as most larval families appear during April to October which coincides with increasing primary and secondary productivity in northwestern Arabian Gulf.

Five fish families (Gobiidae, Sciaenidae, Mugilidae, Engraulidae, and Clupeidae) dominate the ichthyoplankton of the estuarine part of the gulf, contributing 66.6% of the total number of the larvae collected. This result was also reported in other estuarine parts of Arabian Gulf:

Clupeidae, Gobiidae, Sparidae, and Engraulidae were most abundant fish larvae in Helleh River estuary in southwestern Arabian Gulf (Paighambari et al. 2017.

Dominated larval families in Bushair, eastern coast of Arabian Gulf, are Clupeidae, Gobiidae, and Solidae (Rabbaniha et al. 2013)

In Khor Musa, northern Arabian Gulf, Gobiidae, Clupeidae, Sparidae, and Sciaenidae are the most abundant fish larvae (Koochaknejad et al. 2011).

Most fish larvae were collected during spring till late summer (March to October) with peak in abundance during June and July as water temperature is ranging between 22 and 27 ° C. Taxa which show evidence of winter spawning include Mugilidae and Soleidae.

Most larvae (73%) were collected near shore, while most eggs (54%) were collected offshore. This means that actual spawning activity occurs offshore with larval transportation to nearshore area by tidal current and wind-driven current.

Fish that seem to spawn near shore include *I. megalopera* (April to July), *T. mystax* (April), Polynemidae (July), Sciaenidae (April), and *Acanthopagrus (*April).

Since the distribution and abundance of fish egg and larvae give indication of high productivity and spawning, it appears that the nearshore area is an important spawning and nursery ground for many fish species.

Offshore area seems to be important spawning site for some species such as *D. acuta, Sardinella* spp., *Stolephorus buccaneri*, and *L. subviridis.*

8 Effect of Environmental Factors on Distribution of Ichthyoplankton in Northwestern Arabian Gulf

Water temperature, salinity, and turbidity influence the spatial and temporal distribution of fish egg and larvae, as 99.9% of fish egg appeared when water temperature ranged between 24 and 34 ° C, salinity 32–42‰, and transparency of water 200–400 cm (Al-Okailee 2001).

Water temperature affects gonad maturation of adult fish beside its effect on availability of food resources, as primary and secondary productivity increase with increasing water temperature (Al-Zubaidi 1998). Hussain and Ahmed (1995) reported that water temperature has great effect on spawning of fish in northwestern Arabian Gulf.

The fluctuation of salinity especially in the nearshore area is the reason why most fish larvae are related to euryhaline species that tolerate this harsh environment. Consequently, salinity in the offshore area is more stable which reflect the increasing abundance of ichthyoplankton.

Turbidity increase near Shatt Al-Arab estuary, while it decreases with increasing distance from Shatt Al-Arab estuary. As turbidity has high effect on egg abundance and distribution, it has been shown that the abundance of fish egg increase in the offshore area as the turbidity of water is decreasing there.

Effect of turbidity on abundance and distribution is clear as larval abundance increase with increasing turbidity of water. Blaber and Blaber (1980) explained that turbidity is an important factor which affects the total number and abundance of larval species as turbidity offer shelter to fish larvae from predators.

Thus water temperature, salinity, and turbidity all affect distribution of fish egg and larvae in the northwestern Arabian Gulf.

9 Zooplankton

Zooplankton play very important role in the food web of northwestern Arabian Gulf in general and Shatt Al-Arab Delta which comprise the shallow region of Khor Abdulla and Khor Al-Zubair canal extending to the lower parts of Shatt Al-Arab River and Khor Al-Zubair canal. These areas of Iraqi marine especially coastal water of Khor Abdulla and brackish environment are considered as incubation and hatchery area for many fish and other marine and brackish water crustacean and mollusks, as a result of its richness in food supply to the food chain of the whole ecological system in this region.

Historically Shatt Al-Arab has played an important source in providing northwest Arabian Gulf high amount of nutrients with the freshwater discharge from Tigris and Euphrates rivers.

Zooplankton density increase during warm months with copepods which compromise 87% of the total mass of zooplankton in Shatt Al-Arab estuary (Al-Zubaidi 1998) and Khor Al-Zubair (Hussain And Hussain and Ahmed 1999).

In the study of Al-Okailee (2001), it has been found that the increase of copepods density coincides with increasing fish larvae abundance with significant positive correlation between ichthyoplankton abundance and zooplankton density (Al-Okailee et al. 2009). However, increasing copepods density coincide with increasing abundance of fish larvae in some months, as copepods represent a good food resources for fish larvae.

In spite of increasing abundance of fish larvae with increasing zooplankton density, it has been found that in some months, increasing density of fish larvae coincide with decreasing density of copepods; this can be explained as copepods are a main source of food for fish larvae. Ahmed (1994) find that copepod is the main food resource to Anchovy larvae (*Thryssa mystax*) in Khor Al-Zubair. Consequently Houde et al. (1986) find that peak in spawning of fish coincide with zooplankton higher density.

10 Conclusion

1-. The larvae of Gobiidae, Sciaenidae, Engraulidae, Soleidae, and Mugilidae dominate the ichthyoplankton in northwestern Arabian Gulf.
2-. The dominant species of fish larvae are related to euryhaline species which tolerate the harsh environment with fluctuation in salinity and temperature besides high turbidity.
3-. Spawning season confined to hot season from March to September coincides with increasing primary and secondary productivity in the northwestern parts of Arabian Gulf.
4-. Despite the harsh environmental condition, the northwestern parts of Arabian Gulf is considered as a suitable habitat for spawning, nursery, feeding, and shelter for many fish species.

References

Abaychi JK, Damorian SA, Douabul AAZ (1988) The Shatt Al-Arab: a nutrient salt and organic matter source to the Arabian gulf. Hydrobiologia 166:217–224

Ahmed SM (1990) Abundance and diversity of fish larvae in Khor Al-Zubair, north west Arabian gulf. University of Basrah, M.Sc. Thesis (In Arabic)

Ahmed SM (1994) Food and feeding habits of anchovy larvae (*Thryssa mystax*) in Khor Al-Zubair. Iraq Marina Mesopotamica 9(1):67–77

Ahmed SM, Hussain NA (1998) Abundance and distribution of flat fish eggs and larvae in the estuarine parts of the Arabian gulf. Marina Mesopotamica 13(2):307–315

Ahmed SM, Hussain NA (2000a) Abundance and distribution of eggs and larvae of Clupeiformes in the north western Arabian gulf. Basrah Science, B 18(1):159–164

Ahmed SM, Hussain NA (2000b) Egg and larvae of mullets (Mugilidae) in the north western Arabian gulf. Pakistan J Mar Biol 6(1):1–7

Ahmed SM, Hussain NA (2000c) *Bregmaceros arabicus* (Pisces): Bregmacerotidae from north western Arabian gulf: development and distribution. Marina Mesopotamica 15(2):389–396

Ahmed SM, Hussain NA (2001) Abundance and distribution of fish eggs in the Shatt Al-Arab estuary. Marina Mesopotamica 16(2):201–207

Ahmed SM, Hussain NA (2003) Spawning sites and migration routes of *Liza subviridis* and *Liza carinata* larvae in Iraqi marine waters. Marina Mesopotamica 18(2):105–111

Al-Badran B (1995) Lithofacies of recent sediments of Khor Abdulla and Shatt Al-Arab delta. NW Arabian Gulf Iraqi J Sc 36(4):1133–1147

Al-Okailee MT (2001) Abundance and distribution of fish eggs and larvae in Shatt Al-Arab estuary in north west Arabian gulf. University of Basrah, M.Sc. Thesis (in Arabic)

Al-Okailee MT (2015) Morphometric and taxonomic study of eggs of some fish families with a reference to their abundance in the north west of Arabian gulf. Mesopotamia J Mar Sci 30 (1):57–66

Al-Okailee MT, Mutlak FM (2014) Spatial and temporal distribution of fish egg and larvae abundance at Shatt Al-Arab estuary in the north west Arabian gulf. Marsh Bulletin 9(1):79–87

Al-Okailee MT, Younis KH, Ahmed SM (2009) Ichthyoplankton relationship with primary and secondary productivity in Shatt Al-Arab estuary. Mesop J Mar Sci 24(1):79–85

Al-Zubaidi AMH (1998) Distribution and abundance of zooplankton in the Shatt Al-Arab estuary and north west Arabian gulf. University of Basrah, Ph.D. Thesis

Bibik AVA, Lushin AE, Sparidorov BA, Assry YP, Kozhkov EB (1970) Results of the investigations of the 3rd research expedition of Azov-Black Sea fisheries institute to the Arabian gulf December 1969-march, 1970. State Fisheries Co, Iraq, p 12400

Blaber SJM, Blaber TG (1980) Factors affecting the distribution of juvenile estuarine and inshore fish. J Fish Biol 17:143–163

Frank K (1988) Independent distribution of fish larvae and their prey. Natural paradox of sampling artifact. Can J Fish Aquat Sci 45:48–59

Grabe SA, Lees DC, Allaire HP (1992) Macrozooplankton studied in Kuwait Bay (Arabian gulf). 1: distribution and composition of ichthyoplankton. Plankton Research 14:607–623

Houde ED, Almatar S, Leak JC, Dowd CD (1986) Ichthyoplankton abundance and diversity in the western Arabian gulf. Kuwait Bull Mar Sci 8:107–393

Hussain NA, Ahmed AM (1995) Seasonal composition, abundance and spatial distribution of ichthyoplankton in an estuarine sub-tropical part of the northwestern Arabian gulf. Marine Research 5(2):135–146

Hussain NA, Ahmed SM (1999) Influence of hydrographic conditions on the interaction between ichthyoplankton and macrozooplankton at Khor Al-Zubair lagoon, Iraq. Arabian Gulf Qatar Univ Sci J 18:247–259

Hussain NA, Naama AK (1989) Survey of fish fauna of Khor Al-Zubair, northwest Arabian gulf. Marina Mesopotamica 4:161–194

Hussain NA, Younis KH, Yousif UH (1997) The composition of small fish assemblages in the river Shatt Al-Arab near Basrah. Iraq Acta Hydrobiol 39:29–37

Hussain NA, Younis KH, Yousif UH (1999) Seasonal fluctuation of fish assemblage of intertidal mudflat of Shatt Al-Arab estuary, Iraq. North West Arabian Gulf Marina Mesopotamica 14 (1):33–53

Koochaknejad E, Savari A, Dehghan-Madisch S, Eskandari G, Sakhaiee N (2011) Fish larvae assemblage in the northwestern coast of the Persian Gulf Khor Mussa channel. Journal of the Persian Gulf (Marine Science) 2(3):25–29

Kuronuma K, Abe Y (1986) Fishes of the Arabian gulf. Kuwait Inst. Sci. Res.

Mohamed ARM, Hussain NA, Ali TS (2001) Estuarine component of the ichthyofauna of the Arabian gulf. Marina Mesopotamica. 16(2):209–224

Mohamed ARM, Qasim AMH (2014) Trends in the artisanal fishery in Iraqi marine waters, Arabian gulf (1965-2011). Asian Journal of Applied Sciences 2(2):209–217

Nellen W (1973) Kinds and abundance of fish larvae in the Arabian Sea and Persian gulf. In: Zeitzchel B (ed) The biology of the Indian Ocean. Springer-Verlag, New York

Paighambari SY, Pouladi M, Parsa M, Mehdipour N, Haghighatjou N, Jabaleh A, Hedayati A (2017) Seasonal relative abundance of fish larvae in Hehheh River estuary (north of Persian gulf, Iran). Biodiversitas 18(2):541–547

Peterson MS, Comyns BH, Rakocinski CF, Fulling GL (2004) Defining the fundamental physiological niche of young estuarine fishes and its relationship to understanding the distribution, vital metrics and optimal nursery condition. Environ Biol Fish 71:143–149

Potter IC, Beckly CF, Whitfield AK, Lenanton RCJ (1990) Comparisons between the roles played by estuaries in the life cycles of fishes in temperate western Australia and southern Africa. Environ Biol Fish 28:143–178

Rabbaniha M, Ghasemzadah J, Owfi F (2013) Spatial and temporal fish larval assemblage in the northern coastal waters of Persian gulf along the Bushehr Province shoreline. Journal of Fisheries Sciencescom 7(2):141–151

Richards WI, Yamani FY (2008) Identification guide of the early life history of fishes from the waters of Kuwait in the Arabian gulf, Indian Ocean. Kuwait Institute for Scientific Research

UNESCO (1975) Report of the CICAR ichthyoplankton Workshop. UNESCO Tech. Pep. In Mar. Sci. No. 20.46p

Whitfield, AK (1999) Ichthyofaunal assemblage in estuaries of South Africa case study. Rev Fish Biol Fish. 9(2): 151–186. 2018, 59: 121–126

Ziyadi MSF, Jawad L, Al-Mukhtar MA (2018) *Halicampus zavorensis* Dawson, 1984 (Syngnathidae): new record for Iraqi marine waters and for the Arabian gulf area. Cah Biol Mar 59:121–126