STUDIES ON TAXONOMY AND ECOLOGY OF SOME FISH LARVAE FROM THE GULF OF AQABA

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ABSTRACT

STUDIES ON TAXONOMY AND ECOLOGY OF SOME FISH LARVAE FROM THE GULF OF AQABA

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The taxonomy and ecology of fish larvae from the Jordanian side of the Gulf of Aqaba, was studied for a period of May 1999 to May 2000 using light trap sampling. The collected samples were drawn, photographed, and identified after taking morphometric measurements which include: Total length, standard length, preanal length, predorsal length, head length, snout length, eye diameter, and the body width. In addition, meristic measurements were undertaken which include: Dorsal fins, anal fins, pectoral fins, caudal fins, and vertebrae/myomers).

During the study period a total of 687 fish larvae belonging to 74 different taxa were described, identified, and measured. Five hundred and Fifty fish larvae were classified while 137 remained as unknown samples. This study reports three families (Gobiesocidae, Tripterygiidae, and Phosichthyidae), nine genera (*Spratelloides, Choridactylus, Plectranthias, Parapriacanthus, Plesiops, Petroscirtes, Cirripectes, Grammatorcynus, and Viniciguerria*), and five species (*Spratelloides delicatulus, Choridactylus multibarbus, Plectranthias winniensis, Parapriacanthus ransonnari,* and *Viniciguerria mabahiss*) for the first time from the Jordanian coast of the Gulf of Aqaba.

Larval abundances varied seasonally, reaching maximum during July where the minimum abundance was obtained during winter (November, December, January and February). The present study showed that the following are the sequence of most abundant and diverse families in order: Clupeidae, > Pomacentridae, > Apogonidae, > Gobiidae, > Blennidae > and Pempheridídae. Highest larval numbers were obtained when the average surface water temperature was 25.3 C^{o}. A positive correlation was obtained between fish larval and zooplankton abundance, in which both of them exhibit their highest abundance at the same season (April-August). The larval catch by the light traps varied according to the moon phases. The catch was higher when the moon was new, and lower when the moon was full, indicating the effect of the moon phases on the collected fish larvae using light traps.

A comparison between the light traps (which have been used for sampling from nearshore water) and plankton net (which have been used for sampling from the offshore water) indicated that the preflexion fish larvae are mostly abundant in the offshore water. Moreover, the postflexion fish larvae are mostly abundant in the nearshore water. The present study is the first taxonomical research on fish larvae of the Gulf of Aqaba. Such a study will certainly contribute to a better and more complete understanding of fish

ontogeny, phylogeny, and population dynamics. It comprises the basic line data for future researches on larval fish distribution and fishery management.

1-Introduction

1.1 General Introduction

Coral reefs are considered to represent one of the most diverse ecosystems on Earth (Reaka-Kudla, 1997). The center of this diversity lies in Malasia (Indo-Malayan-Archipelago and Australia), with approximately 2,500 fish species in the Philippines alone. In the Red Sea approximately 1,270 fish species have been recorded (Sheppard *et al*., 1992; Goren & Dor, 1994 and Khalaf *et al.*, 1996). Of these, 348 species were reported from the Jordanian coast in the Gulf of Aqaba (Khalaf & Disi, 1997). Most of the reported species have pelagic larval stages as an integral part of their life stages (Kendall *et al*., 1983). Little is known of where and how the pelagic larval and juveniles stages spend this period, and much is assumed or extrapolated. This is because of the difficulty in identifying the larvae of the coastal fishes (Blaxter, 1983). The larvae are often morphologically different from the adults. Also, some of them have been described as new genera or have been placed in families different from the adult ones (Lies, 1986 a). In the absence of such information it will be difficult to understand the biology of fish. From an ecological point of view the larvae and the adults are often entirely dissimilar and can be considered distinct ecospecies. They may occupy unlike niches, feed on contrary food, and have entirely discrepant behavioral patterns. Without the vital population-ecological interaction processes such as recruitment, renewal of adult populations, and the inflow of larvae from other regions cannot be understood without adequate information about the fish larvae. Therefore it became obvious that identification of fish larvae should be the first step for further investigations, concerning systematic, ecological studies, fish biology and fishery management. (Cohen, 1983)

Literature describing the adults of marine fish species from the Red Sea are extensive, and several texts are available describing the adults of most of these species (Randall, 1983; Wahbeh & Ajiad, 1987; Krupp & Paulus, 1991; Khalaf *et al.*, 1996; Khalaf & Disi, 1997). On the other hand, there are no published reports describing the fish larvae of the Red Sea.

1.2 Aims of this Study

1- To establish the main characteristic features useful in the identification of fish larvae. This will provide an overview of the fish larvae from the Gulf of Aqaba that will enable the future researchers to identify these at least to the family level.

2- To obtain information about the spawning seasons of the dominant species based on their abundance. Also, to use the gathered base line data as one of the approaches in improving fishery management.

1.3 The Gulf of Aqaba

The Gulf of Aqaba is the northeastern branch of the Red sea. It has a maximum width of 26 km at its center, and 5 km at its most northern part, with an average width of 20 km (Figure 1.1). The Jordanian coastline runs south for about 27 km. The coastline of the Gulf of Aqaba continues in the south for another 180 km to the sills of Tiran Straits. The Gulf of Aqaba has an average depth of 800 m increasing to more than 1,800 m in its deepest regions. The hydrological studies performed in the Gulf described horizontal clockwise pattern of water. Also, the current reversed its direction when it's coupled with changes in wind direction, especially with prolonged southerly winds. Water temperatures in the Gulf of Aqaba are higher in the north than in the south with a minimum temperature of 20 °C during March and a maximum temperature of 26 °C during August and September. The salinity in the Gulf of Aqaba ranges between 4.0 to 4.5 % (Hulings, 1979). And this is relatively high due to the absence of rivers or major streams flowing into the Gulf as well as the high evaporation rate.

Despite the restriction of water exchange between the Gulf of Aqaba and the Red Sea due to the Strait of Tiran, (with depth of250-300 m), which acts as a barrier for fish movement specially the deep sea fishes. Also, the fact that its fauna is strongly related to the Indo-Pacific area. There was no published work providing any data on the Ichthyoplankton components of the Gulf of Aqaba.

Figure 1.1 Gulf of Aqaba & Gulf of Suez, Red Sea. (After Geiger & Candela)

1.4 Terminology

The terminology used in the literature to name and describe different developmental stages of teleost fish varies greatly, depending on the author, due to the high diversity in the way that the fish develop.

In this study the larval stage is defined as the attainment of full external meristic characters and the loss of the temporary specializations to the pelagic life, and not just the attainment of full fin counts as many workers have suggested. This is due to two reasons (Lies & Carson-Ewart, 2000):

1- The larvae of many benthic species attain full meristic characters of the adults but they are still pelagic, transparent and without scales.

2- The presence of temporary specialization for pelagic life in many tropical reef fish.

The terminology for developmental stages utilized in this work is followed after Lies & Carson-Ewart (2000):

* **Demersal egg**: An egg which remains on the bottom of the sea either free or attached to the substratum.

* **Pelagic egg**: An egg which floats freely in the water column, often slightly positively buoyant

* **Preflexion larva**: The developmental stage which begins at hatching and ends at the start of upward flexion of the notochord.

* **Flexion larva**: development stage beginning with flexion of the notochord and ending with formation of hypural bones assuming a vertical position.

* **Postflexion larva**: developmental stage which starts from the formation of the caudal fin (hypural elements) to the attainment of full external meristic complements (fin rays and scales) and loss of temporary specialization for pelagic life.

* **Transition larva**: change from larva to juvenile stage and may take place over an extended period of time, and is especially used for pelagic taxa where there is no change in habitat at or near the end of the larval phase. Also, individuals in transitional state are considered larvae.

* **Juvenile**: developmental stage beginning with attainment of full external meristic complements and loss of temporary specializations for pelagic life to sexual maturity.

2-Literature Review

The adult ichthyofauna of the tropical Indo-Pacific is quit well known and numerous identification guides, especially for fish on coral reefs, were published (Randall, 1983; Gloerfelt-Tarp & Kailola, 1984; Allen & Steene, 1994; Lieske & Myers, 1994; Randall, 1996 a; Randall, 1996 b; Khalaf & Disi, 1997; Randall, 1999). Despite the extensive knowledge about the taxonomy of adult fish, the larval stages of these fish are poorly studied or not known at all. There are only a few comprehensive studies on larval development and taxonomy of tropical Indo-Pacific coastal fish. (Lies & Rennis, 1983; Lies & Trnski, 1989; Neira *et al*., 1998; Lies & Carson-Ewart, 2000)

2.1 Taxonomical Studies:

2.1.1 The Red Sea and Other Oceanic Water

Fishelson (1976) summarized observations on spawning and larval development in captivity of *Meiacanthus nigrolineatus* from the Red Sea. Some of the early studies of fish larvae were by Tosh (1902, 1903), who described the egg and the early larval stages of *Sillago ciliata* and figured out the egg and the early larval stages of 30 species from Moreton Bay in Australia. Dakin & Colefax (1934) described the eggs and larvae of pilchard S*ardinops neopilchardus*. Blackburn (1941) described the egg and larvae of *Engraulis australis* and the larvae of the maray (round herring) *Etrumeus teres*. In addition, Munro (1944) in his master thesis described the egg and larvae of the (sea breams) *Acanthopagrus australis* and *Acanthopagrus butcheri*. Munro (1955) described the egg and larval development of the sabre toothed Oyster blenny *Petroscirtes lupus*. Also, Helbig (1969) investigated spatial, tidal and dial variations in the distribution of fish larvae in Moreton Bay in Australia. However, the study was limited due to taxonomic problems with the most identified taxa to family level only or staying as unidentified.

In the past 25 years few comprehensive works on larval development and taxonomy of tropical Indo-Pacific coastal fishes have proliferated. Lies (1977) found that the egg and the larval stages of Porcupinefishes *Diodon hystrix* and *Diodon holocanthus* from the Indo-Pacific are similar, in which the pelagic eggs are 1.6-2.1 mm in diameter and hatch in

about 5 days at 25 °C. Also, the larvae metamorphose into spiny juveniles of 4 mm in length in about 3 weeks.

In two studies by Lies (1977), on the development of *Ranzania laevis* and the development of *Crystallodytes cokei* and *Limnichthys donaldsoni* (Lies, 1982) were described and illustrated for eggs and larvae collected from Hawaiian waters. He found that the larvae can be distinguished by shape, pigmentation and, later, by spination.

Kendall (1979) was able to identify larvae of the four genera of American Grouper on the basis of meristic data. He found that specific identification was prevented by overlaps in ranges of meristic characters among many species and by the apparent absence of any species larval characters.

Description of larvae and early juveniles of laboratory-reared Snapper *Lutjanus griseus* was investigated by Richards & Saksena (1980). The results showed different pigmentation patterns in comparison with natural larval catches. Lies & Rennis (1983) and Lies & Trnski (1989) published ‘ Larvae of Indo-Pacific Coral Reef Fishes’ and ‘ Larvae of Indo-Pacific Shore fishes’ respectively, which covered 103 famiLies in total.

An international symposium on the ontogeny and systematics of fishes was held in August 1983 based on an article prepared by 78 authors. This article was represented the state knowledge on the identification of fish egg larvae and juveniles. This work was summarized by Richards (1985) to conclude that 75% of the larvae and 36% of the eggs are known to the family level. At the generic level, 24% of the larvae and 12% of the eggs are known. Finally, at the species level, 90% of the larvae and 3.5% of the eggs are identified.

The eggs, larvae, and pelagic juveniles of *Ostracion meleagris, Lactoria fornasini*, and *Lactoria diaphana* were identified from reared and field collected specimens from Hawaii, Japan, Australia, and the Eastern Pacific by Lies (1985). They found that the eggs of these three species could not be illustrious but their larvae could be distinguished by their pigmentation patterns and the development of the carapace of ossified dermal plates.

Larval developments of the Sweepers *Pempheris xanthoptera* and *P. japonica* were described for 36 specimens, with particular attention to cartilaginous development, taken from the Japanese waters by Kohno (1986), who indicated that *P. xanthoptera* could be distinguished from *P. japonica* by the following key characters: two supracleithral spines

(one in *P. japonica*); longer pectoral fin; shorter ventral fin; and absence of melanophore on mid ventral part of lower jaw and anterolateral region of trunk, and web of ventral fin.

Victor (1987) studied the growth of planktonic labrid and pomacentrid reef fish larvae in the Eastern Pacific Ocean. He found that the growth rates of larvae younger than 70 days old were similar between the two taxa (from 0.13 to 0.19 mm day $^{-1}$). However, After 70 days the planktonic, labrid larvae grow much more slowly (0.06mm day $^{-1}$ in X*yrichtys* species). Moreover the labrid larvae had long duration of larval stage (up to 131 days in *Xyrichtys* species), while the larval lives of the pomacentrids appeared to be shorter and much less variable.

Miskiewicz (1987) gave the description of larval development for 33 taxa, and gathered data on their temporal and spatial distribution from Lake Macquarie and New South Wales coastal waters in Australia. Neira *et al.* (1998) listed 124 larval fish species from Temperate Australia, which comprise 116 marine and 8 freshwater species belonging to 53 and 4 famiLies, respectively. Seventy-Seven species of early developmental stages belonging to 60 taxa from the mangroves of the Indian Ocean Western Central Pacific were described in a manual prepared by Prince Jeyaseelan (1997). Leis & Carson-Ewart (2000) covered 124 famiLies about the larvae of coastal fishes from the Indo-Pacific to identify the larvae of tropical fishes.

This study investigates 26 different families. The following summary represent the description of these families according to: Lies & Rennies, 1983; Dor, 1984; Lies & Trnski, 1989; Goren & Dor, 1994; Neira *et al.*, 1998; and Lies & Carson-Ewart, 2000.

- **Clupeidae**

They are pelagic, schooling, silvery fishes having enormous commercial importance. Fourteen adult species belonging to seven genera have been identified from the Red Sea (Goren & Dor, 1994). Their larvae are typical of Clupeiform larvae, which are characterized by very elongate body, moderate to high number of myomeres, long straight gut, little pigmentation with some melanophores on the gut, lack of head and fin spines, short dorsal fin, and anterior migration of the dorsal fin. Larval clupeids are most likely to be confused with other clupeiform or gonorynchiform larvae. Confusion is also, possible with very elongate, lightly pigmented larvae of other orders, which include some gonostomatids and phosichthyids, synodontids, and, perhaps, ammodytids and

trichonotids. All of them lack the anterior migration of the dorsal fin. Gonostomatids and phosichthyids have considerable shorter guts than do clupeids. But some genera of the phosichthyids like *Vinciguerria* have long guts, yet they can be distinguished from clupeids because they lack ventral pigments associated with the gut. Compared to clupeids, synodontids have a very late forming dorsal fin and a gut pigment pattern without midventral series, but with large blotches dorsolaterally on the gut. Ammodytids larvae are moderately pigmented along the ventral edge of the myomeres. Trichonotids larvae can be distinguished from clupeids because their gut reaches to only the middle of body and they have a long based dorsal fin. (Lies, *et al*. 1989)

- **Antennariidae**

They are globular fishes with the first dorsal spine modified into fishing device, living in a variety of habitats, most commonly in shallow reef in warm water. Ten adult species belonging to three genera have been identified from the Red Sea (Goren & Dor, 1994). Their larvae characterized by deep body and inflated dermal sac. In pre-flexion stages antennariids are confused with other fish larvae like Tetraodontiform, lophiidae, and very early larval stages of some scorpaenid species because all of them have dermal sac. The tetraodontiforms have the gill opening anterior to the pectoral base and most lack pelvic fins. The scorpaenids have more myomeres than the antennarriids. Lophiid larvae have very elongated dorsal fin spines and pelvic rays compared with antennariids (Lies &Trnski, 1989)

- **Gobiesocidae**

They are flattened fishes usually found in shallow water where they attach to rocks or other substrates. Three different adult species have been identified from two genera from the Red Sea (Goren & Dor, 1994). Their larvae have large body shapes with long gut and heavily pigmented bodies lacking spines on the head and fins, a character, which distinguishes the gobiesocidae larvae from other larvae. Larvae of the Exocoetid are likely to be confused with gobiesocids due to similarities in body shape and pigmentation. But their early forming fins and very long rays in the pectoral and pelvic fins can distinguish them.

- **Syngnathidae**

They are slender, very elongated fishes mostly associated with sea grass and rocky sea floor. Thirty-three adult species belonging to 14 genera reported from the Red Sea (Goren & Dor, 1994). They are similar to the adult at the time of the birth by having a body composed of bony plates arranged in the form of rings with several series of longitudinal ridges extending along the entire body. Confusion is possible with fistulariidae, but it can be distinguished by its very long gut. And solenostomidae, which can be distinguished from syngnathidae by having anal fin posteriorly located and directly opposite to the dorsal fin. (Neira, *et al*, 1998)

- **Scorpaenidae**

They are benthic fish found in a variety of habitats including reef. Thirty-nine different adult species out of 16 genera have been identified from the Red Sea (Goren & Dor, 1994). Extensive head spination, pigmented and largely pectoral fins, and this characterize scorpaenid larvae, which can cause the confusion with other scorpaeniforms fishes (Platycephalids, Triglids, Dactyllopterids, Istiophorids). Platycephalids can be distinguished by their broad, dorso-ventrally flattened heads (particularly the snout), smaller parietal spines, and heavier pigmentation. Triglids can be distinguished by their broad snout and very bony heads with small parietal spines, dactyllopterids by their heavy pigment, istiophorids have large pterotic spines that resemble the parietal spines of scorpaenids, but they are heavily pigmented and have elongate snout. Some anthiine serranids with large pectoral fins may be confused with scorpaenids, but they lack parietal spines. Some malacanthid might be confused with scorpaeniids because of their eternal appearance, but they have different fin meristics (Lies & Carson-Ewart, 2000).

- **Apogonidae**

They are a very diverse group fishes found in the coastal waters and coral reefs from the tropical to temperate regions. Fifty-nine different adult species have been known from the Red Sea belonging to seven genera (Goren & Dor, 1994). Apogonidae larvae are so variable morphologically, that the only constant distinguishing characters are the typical myomeres, counts of 24, and two dorsal fins. The following famiLies represent the most similarly shaped or pigmented larvae (Acropomatidae, Ambassidae, Carangidae, Gerreidae, Kyphosidae, Lethrinidae, Opistognathidae, Pempheridídae, Plesiopidae, Serranine Serranidae), but they can be distinguished from apogonids by fin-ray counts.

Also, apogonids are most likely to be confused with small gobiids, but gobiids tend to be slightly more elongated than apogonids. Also, gobiids have longer, uncoiled gut, they lack head spination, and they have 25 to 26 myomeres. In addition, pigments dorsally located on the head are very rare in pre-flexion gobiids, which is very common in pre-flexion apogonids (Lies & Carson-Ewart, 2000).

- **Lutjanidae**

They are commercially important fishes found in a wide range of habitats including coral reefs, sandy bottoms, deep waters, and mangroves. Thirty-two different adult species from eight genera have been identified from the Red Sea (Goren & Dor, 1994). Lutjanidae larvae share the following characters: tightly coiled gut, pigment pattern, early forming head spination, and early forming spines of the pelvic fin and dorsal fin. Preopercular spines, pelvic fin, and dorsal fin spines are distinguishing characters between the lutjanids and the pomacentrids. Siganids also have early forming dorsal and pelvic fin spines, but in addition, have serrate ridges on the top of the head, which is not found in the lutjanids. Epinephelini and Anthiinae Serranids, are the larvae mostly likely to be confused with lujanids, but lutjanids have at most moderate serrations on the elongate fin spines while the serranids often have large serrations accessory spines on the fin spines, also, its possible to separate between them by fin- ray counts (Niera *et al*., 1998).

- **Serranidae**

They are a large group of marine fishes associated with coral or rocky reefs. Forty-five different adult species have been recorded from the Red Sea belonging to 15 genera (Goren & Dor, 1994). Distinguishing characters of serranid larvae are the large extremely spiny head, coiled gut that may extend beyond the mid of the body, narrow caudal peduncle, and 25-26 myomeres. Scorpaenids, lutjanids, carangids, and siganids are the most confusing famiLies with serranids. But the scorpaenids have early forming parietal spines and do not have early forming dorsal or pelvic elements. Serranids have different fin and myomere counts than the lutjanids. Some carangids have head spination with similarities to that of serranids, but they are more compressed having lateral and dorsal series of melanophores on the tail and have many more anal fin rays than the serranids. Siganids larvae have early forming spines in the dorsal and pelvic fins but have a serrate medial dorsal crest on the

head and extensive spination on the snout that is absent in the serranids larvae (Lies & Carson-Ewart, 1989).

- **Pempheridídae**

Pempheridids are gregarious, nocturnal plankton feeding fishes usually associated with reefs. Six different adult species have been known from two genera of the Red Sea (Goren & Dor, 1994). The distinguishing characters of their larvae are: short based dorsal fin, long based anal fin, long straight gut and heavy pigmentation in the pre-flexion larvae. Pempheridídae are likely to be confused with some pomacentrids, apogonids, carangids, monodactylids and stromateoids. But pomacentrids have longer dorsal fin base and have very early forming pelvic fins. Certain apogonids may also be confused with some stages of pempheridids but apogonids have two dorsal fins and short-based anal fin. Some carangids have pigments that are similar to pre-flexion pemphridids, but they have much stronger head spination. Monodactylid larvae have similar numbers of elements in dorsal and anal fins and have very different pigment pattern, but pemphridids have a very different pigment pattern than that of monodactylids. Some stromateoids have early forming pelvic fins but all of them have 30 or more myomeres and are more lightly pigmented on the dorsal surfaces (Lies & Carson-Ewart, 2000).

- **Plesiopidae**

They are cryptic reef fishes. Three different species have been reported from the Red Sea belonging to two genera (Goren & Dor, 1994). Their larvae have shared general morphology characters: near lack of external pigment, 25 myomeres, head spination, fin meristics and compact coiled gut. So they are likely to be confused with large number of nondescript perciform larvae: pomacentrids, sparids, gerreids, haemulids, nemipterids, opestognathids and serranine serranids, which have at least a series of ventral melanophores on the tail and often have melanophores on the head that are lacking in plesiopids. Pseudochromids, which have much weaker, head spination than plesiopids, 26-35 myomeres, and late coiling gut. Also, certain apogonids species lack tail pigment and have dorsal melanophres on the brain (Lies & Rennies, 1983).

- **Pseudochromidae**

They are colorful fishes that live under rocky ledges and between corals on reefs. Thirteen different species out of four genera have been recorded from the Red Sea (Goren & Dor,

1994). Their larval stages are relatively nondescript, their distinguishing characters are: Long, elongated to moderately deep body, short deep caudal peduncle, light pigmentation, long based dorsal and anal fins and the myomeres number. The confusion in their identification is possible with labrids, scarids, and plesiopids, which have similar body shape and little or no pigmentation. But pseudochromids can be separated from them by mouth size, which rarely reaches the eye in scarids and labrids. Head spination is absent in labrids and scarids, and fin counts are higher in scarids, labrids and plesiopids. Siliginids have pigmentations that are similar to that of some pseudochromids, but usually have more myomeres and similar number of rays in the dorsal and anal fins, and at least 10 spines in the dorsal fin. Pre-flexion tripterygiids may resemble pseudochromids, but the tripterygiids have shorter gut, different pigmentation, more slender caudal peduncle, and no head spination (Lies & Carson-Ewart, 2000).

- **Carangidae**

Carangids are pelagic fishes occurs in habitats ranging from estuarine-freshwater to coral reef to oceanic. Forty-seven different adult species have been known from the Red Sea belonign of 20 genera (Goren & Dor, 1994). Their larvae are extremely variable but there are a majority of characters possessed by all of them: myomeres number, head spination, preopercular spination, fin ray counts, pigment, large had and mouth, moderate to large gut, and moderately to very compressed head and body. Young chaetodontid larvae resemble carangids in body and gut shape, pigments, and certain aspects of head spination, but their gut coiled at large size than the carangids. Pomacanthidae are very similar to carangids in body and gut shape, preopercular spination and pigmentation, but they have smaller and finer preopercular spines than smaller carangids. Pre-flexion pempheridid larvae have pigmentation similar to that of some carangids, but they have posterior early forming pelvic buds located relatively high on the side of the gut. Kyphosids could be confused with heavily pigmented carangids but they have relatively small preopercular spines. Certain apogonids and anthiine serranids are less compressed laterally than similar carangids, lack lateral and dorsal series of melanophores on the tail, and have many fewer anal fin rays than carangids. Lethrinid and some sparid larvae are similar to carangids but they lack pigment series on dorsal and lateral midlines of the tail and have a much more compact gut than do carangids (Lies & Trnski, 1989).

- **Pomacentridae**

They are mostly small, colorful fishes occupy wide variety of marine niches. Forty-Five different adult species from 14 genera have been recorded from the Red Sea (Goren & Dor, 1994). The characteristic features of pomacentrid larvae include the short coiled triangular gut, myomere count, preopercular spination, pigment on the brain, gut and ventral midline of the tail, and fin counts. The most similar famiLies to them are mullids and gerreids. Mullid larvae generally have a more rounded head, more compact gut, and characteristic pigment. Gerreid larvae have an early forming ascending premaxillary process, which is much larger than that of the pomacentrids as well as very consistent, characteristic pigmentation. Flexion stage pemphridids are similar to some pomacentrids but they have early forming pelvics and many more fin rays in the anal fin than in the dorsal fin. Lutjanids, serranids, and siganids may resemble pomacentrids but they have more extensive head spination than pomacentrids. Heavily pigmented kyphosids might be confused with some pomacentrids but they have three anal-fin spines (Lies & Rennies, 1983).

- **Labridae**

These are colorful reef fishes that are extremely variying in body shape and habits. Seventy-one different adult species from 25 genera have been identified from the Red Sea (Goren & Dor, 1994). Most of their larval stages are laterally compressed having a deep caudal peduncle, a gut that is initially straight and later coils, 23-28 myomeres, 13-15 principle caudal rays, small mouth, no head spination and very little pigment. Larger larvae are distinguished by a long based dorsal fin and counts of all fins. Larvae of scarids and pseudochromids are likely to be confused with them. But the scarids and labrids have smaller mouths than the pseudochromids, and most of the labrids have little pigmentation, pseudochromids have variable pigmentation, and scarids usually have a series of melanophores on the ventral edge of the tail. Also, they can be distinguished by the counts of the dorsal and anal fins, and the caudal rays (Lies & Carson-Ewart, 2000).

- **Blenniidae**

Blennies are benthic, scaleless fishes usually associated with reefs. Forty-Six different adult species out of 20 genera have been known from the Red Sea (Goren & Dor, 1994). Their larval stages can be identified form the following characters: elongated to moderately

deep body, short to moderately long gut, 30-40 myomeres, large teeth, and very long pectoral fin. Myctophid larvae may be confused with pre-flexion blenniids because they have small teeth, rarely have head pigment and they have longer gut, but they are distinguishing by their narrow eyes, which are not found on the blenniids. Tripterygiid larvae may also resemble blenniid larvae, but they have small teeth, lightly pigmented head, gut, and small to moderate pectoral fin. Atherinid larvae have broad rounded heavily pigmented heads with short snout, short, compact gut, and about 30-50 myomeres. By these characters they are similar to some tribes of the blenniids. However, atherinids lack large teeth, large pigmented pectoral fins, and head spination. Ophidiidae has some species with round heads, more or less compact gut, and large, early forming pectoral fins, but they have more than 50 myomeres, no enlarged teeth and no head spination (Lies & Rennies, 1983).

- **Tripterygiidae**

These are small benthic, shallow water fishes associated with hard bottoms. Eleven different adult species belonging to three genera have been recorded from the Red Sea (Goren & Dor, 1994). Their larval stages are characterized by: small to moderate head without spination, elongated body, distinctive pigmentation, and 33-37 myomeres. They may be confused with sillaginds, but they have small preopercular spines, ventral pigment series on the trunk that are not found on the tripterygiids. Also, myctophid may be confused, but they have longer, more rugose gut than tripterygiid. Pseudochromid larvae can be similar to tripterygiids, but they have longer gut, different pigmantation, deeper caudal peduncle, and some head spination. Salariini blenniids may be confused with tripterygiids, but their large teeth and their preopercular spination can distinguish the blenniids (Lies &Carson-Ewart, 2000).

- **Gobiidae**

They are small fishes living in a wide variety of marine habitats; most of them are closely associated with the bottoms or living in holes or borrows. Eighty-three different adult species from 39 genera have been identified from the Red Sea (Goren & Dor, 1994). The relatively slender body, long uncoiled gut divided dorsal fin, lack of head spination, and myomere count of 24-27 will help in the separation of the gobiids from other fish larvae. The groups most likely to be confused with gobiid larvae are apogonids, scarids, cirrhitids,

silliginids and myctophids. Apogonids are generally deeper bodied and have a shorter gut. In addition many apogonids have some preopercular or other spination on the head. Preflexion scarids may resemble gobiids but they have narrow eyes. On the other hand, post flexion larvae are easily separated by fin morphology. Small cirrhitids have similar shape and gut morphology to some gobiids, but they have heavy distinctive pigment. Sillaginids have at least 32 myomeres and some head spination, which differentiate them from the gobiids. Myctophids have more than 30 myomeres than do gobiids (Lies & Rennies, 1983).

- **Chaetodontidae**

They are small, colorful, coral-reef fishes; most of their species eat coral. Twenty-one different adult species belonging to four genera have been recorded from the Red Sea (Goren & Dor, 1994). Their bony head in their larval stages is a useful character to identify them. Also, myomere counts, long uncoiled gut, and pigmentation patterns are other characters used to identify early larval stages of chaetodontids. Early larvae may be confused with carangids and pomacanthids, but the carangids are early forming, unflattened preopercular spines, and have coiled gut at a very small size. Pomacanthids have a slightly deeper body, more uniform pigmentation, and small spinules, which can be used to separate them from chaetodontids. A number of famiLies, including caproids have strong preopercular spination but none of them are similar to chaetodontids (Lies & Carson-Ewart, 2000).

- **Siganidae**

They are herbivorous fishes found in variety of habitats including coral reefs, sea grass beds, and they have commercial value as food fish. Six adult species belonging to one genus have been recorded from the Red Sea (Goren & Dor, 1994). Their early life stages are characterized by: strongly folded ovoid gut, early forming pelvic and dorsal fin spines, extensive head spination especially the serrate ridges, and the numbers of spines in anal and pelvic fins. Confusion is likely to be with lutjanids and epinepheline serranids. Siganids however, have a serrate, medial, dorsal crest on the head and extensive spination on the snout, which the other groups lack. Also the preopercular spines of the siganids are not as well developed as the other group. Lieognathids have head spination similar to that of siganids but have larger preopercular spines, are more laterally compressed, and deep

bodied, and at later levels of development they are more heavily pigmented. Some acanthurids larvae have similar head and fin spination, but they are much deeper bodied (Lies &Carson-Ewart, 2000).

- **Acanthuridae**

Most of these fishes are herbivorous, important as food fish. Seventeen adult species from five genera have been known from the Red Sea (Goren & Dor, 1994). Their larval distinguishing characters are: Coiled gut, low myomeres count, laterally compressed kite shape, long snout with small mouth, early forming head spination and early forming, elongate serrate spines in dorsal, anal and pelvic fins. Siganids and leiognathids are not kite shaped but do have serrate head crests. Also, siganids do not have moderately elongated fin spines, and both of them have larger preopercular spines than do acanthurids (Lies &Trnski, 1989).

- **Scombridae**

They are epipelagic large predatory fishes including some of the world's most important commercial fishes. Twelve adult species belonging to 10 genera have been reported from the Red Sea (Goren & Dor, 1994). Their distinguishing characters are: large head, pigmentation pattern, head spination and triangular gut. The general morphology in our collected specimens *Grammatorcynus* species is similar to that of a number of larvae with relatively large, rounded heads and a row of midventral melanophores on the tail. This includes nemipterids, sparids, microcanthids, pomacentrids, and blenniids. Nemipterids and sparids have 23-24 myomere which are fewer than *Grammatorcynus* species (31). Microcanthids and pomacentrids have 25-26 myomere. Blenniids have head spination and more myomere than *Grammatorcynus* species (Lies & Carson-Ewart, 2000).

- **Bothidae**

They are benthic carnivorous flatfishes, which occur on soft bottoms at variety of depths. Ten different adult species from four genera have been recorded from the Red Sea (Goren & Dor, 1994). Bothid larvae are distinguished by their steep and straight to concave head profile, small mouth, extremely laterally compressed body, myomeres numbers, anal fin base which turns down anteriorly to meet anus, symmetrical pelvic fins, and generally light pigmentation. Bothids are likely to be confused with other flatfish larvae only, but can be distinguished by the fin ray counts (Lies & Carson-Ewart, 2000).

- **Ostraciidae**

They are small fishes that are encased in a box-like carapace of bony plates, which are associated with coral reef. Four different species belonging to three genera haven recorded from the Red Sea (Goren & Dor, 1994). They can be distinguished from other Lophiiform and some other Tetraodontiform by body proportions, fin arrangements, pigmentation, and the location of the gill opening. Lophiiform larvae have the gill opening below to behind the pectoral base, but the gill opening of ostraciids is a small hole just anterior to the upper margin of the pectoral fin base. Their relatively more fusiform body, and pigment that tend to form bands or patches, higher pectoral fin ray counts can distinguish Tetraodontid larvae. Diodontid larvae are more dorsoventrally flattened that ostraciid larvae, having larger mouths without flaring lips. They tend to be more heavily pigmented dorsally than ventrally and have more rays in the dorsal, anal and pectoral fins. Molids have large spike-like dermal plates, but they can be distinguished by less pigmentation, particularly on the ventral surface (Lies & Carson-Ewart).

- **Diodontidae**

Four adult species from two genera have been reported from the Red Sea (Goren & Dor, 1994). Their distinguishing characters are: the wide and rotund body, and heavily dorsal pigmentation. Confusion is most likely with other tertaodontiform larvae, which have rotund body and dermal sac. In our specimen the presence of large numbers of spines on the body distinguished it from the other families (Lies &Carson-Ewart, 2000).

- **Phosichthyidae**

They are small, slender, compressed and bioluminescent fishes, which have meso- and bathypelagic habitat. Two different adult species belonging to one genus have been recorded from the Red Sea. Their larval stages characterized by elongated and slender bodies with long preanal length. Phosichthyid larvae resemble the larvae of some gonostomatids and sternoptychids. No single set of larval characters allows the separation of all species at the level of the family. However, using a combination of morphometric, meristic and pigment characters can identify all genera and most species (Watson, 1992).

2.2 Ecological and Biological Studies:

2.2.1 The Red Sea and Gulf of Aqaba

The behavior of *Meiacanthus nigrolineatus* during reproduction was described by Fishelson (1975). Wahbeh & Ajiad (1985) studied the reproductive biology and growth of the goatfish, *Parupenus barberinus* (Lacepede), in Aqaba, Jordan. The results of their study indicated that the main spawning season of *Parupenus barberinus* in Aqaba extends from May to June. Gharaibeh & Hulings (1990) studied the aspects of reproduction of three sympatric and endemic chaetodontids, *Chaetodon austriacus, C. fasciatus* and *C. paucifasciatus* from the Jordanian side of the Gulf of Aqaba. They found that the spawning period of *C. austriacus* was from July through October, that of *C. paucifasciatus* from august through October and that of *C. fasciatus* from September through December. Cuschnir in his doctoral research (1991) summarized four years of field and laboratory work (November 1985 through August 1989) the first ecological research on Ichthyoplankton performed in the Gulf of Aqaba, the results showed that spatial and temporal occurrence of fish larvae in the Gulf is clearly influenced by several environmental factors such as: temperature, zooplankton concentrations, hydrological patterns, time of day and moon phases. Also, he found high differences at the species level and the highest larval number were obtained when water temperatures ranged between 20.8-23.7 °C from March to July. Another study conducted by Wahbeh (1992) but on two species of the goatfish (Mullidae) from Aqaba, Jordan. The results indicated a distinctive short spawning season during June-August.

2.2.2 Other Oceanic Waters

Johannes (1978) suggested that in the offshore tropical surface, where waters are relatively unproductive and provide less food for pelagic egg larvae. The threat of predation is greatly reduced because these waters contain fewer planktonic and pelagic predators than inshore waters. Also, predation is a more relative factor than the availability of food in influencing when, where, and how many fish spawn and where their eggs and larvae are distributed.

Lies (1981) evaluated the role of mid waters for the life history of coral reef fish larvae at all seasons around Lizard Island, in the Great Barrier Reef. He found that only 24 of the 50 most abundant larvae completed their pelagic development near Lizard Island, which gave the indication that it is not necessary for any reef fish that spawns pelagic eggs, near Lizard Island to complete its life cycle there. Moreover the length of larval life in some coral reef fishes was estimated from the number of growth increments in the otoliths of newly settled fishes collected from the Lagoon of the Great Barrier Reef (Brothers *et al.*, 1983).

Sweatman (1985 a) investigated the time of settlement and habitats selection of *Dascyllus aruanus* larvae south west of Lizard Island research station. He found that *D. aruanus* settled in darkness, which gave the indication that vision unlikely to be an important factor in their selection of habitat. Also Sweatman (1985 b) studied the influence of adults of some Coral Reef fishes on larval recruitment. He indicated that an increase in the settlement of three species in sites where there were resident.

Lies (1986 a & b) studied the ecological requirements of the Indo-Pacific larval fishes and found that their ecological requirements are often different from those of the adults. Even if the species disperse to a new location and the adult finds new ecological conditions suitable. This is because the species will not persist if its larvae do not find suitable ecological conditions.

Smith *et al*. (1987) postulated that tropical marine fish larvae tend to be specialized either for long distance transport or for avoiding being swept downstream by offshore currents. This indicates that there are two groups of larval fishes: “far field assemblage” of larvae that are morphologically modified or behaviorally specialized for long distance transport by ocean currents and “near field assemblage” of unspecialized larvae that avoid currents, and spend their entire lives in the vicinity of the reefs.

Wellington & Victor (1989) estimated the plankton larval duration for 100 species of the Pacific and Atlantic damselfishes. They found that the plankton larval duration is shorter and less variable compared to other groups of reef fishes. Lies (1994) found, in the lagoons of two Western Coral Sea atolls (Osprey and Holmes Reefs), that the concentrations of oceanic fish larvae in the lagoons to be 13-14% of the concentrations of those in the ocean. Whereas oceanic taxa constituted less than 1% of the larvae captured in the lagoons.

The relationship between two demersally spawning fishes were selected by Cowen & Castro (1994), to examine the adult spawning strategies and the early life histories of larvae and juveniles from the Caribbean Sea. His observations demonstrated that two confamilial demersal spawners may have larvae with contrasting life history traits. This can influence patterns of juvenile recruitment.

The sustained swimming abilities of the late pelagic stages of coral reef fishes were measured by Stobutzki & Bellwood (1997) and demonstrated that the pelagic stages of reef fishes are competent swimmers and capable of actively modifying their dispersal, which directs implications on the replenishment of reef fish populations, especially with respect to mechanisms for self seeding and maintenance of regional and biogeographical patterns.

Kingsford & Finn (1997) argued that a knowledge of production mechanisms of fish (spawning /hatching), length of presettlement phases, swimming abilities and behavior, as well as biological and physical phenomena influencing survival. Also, all are required to explain variation in the replenishment of reefs.

Kucharczyk *et al*., (1997) studied the influence of water temperature on embryonic and larval development of bream (*Abramis brama)*. Its found that hatching reaches its peak at 21.1C^{o}. Moreover the developmental rate increased with increasing temperature. The individual growth of fish and biomass production rate are the highest at 27.9 °C. This degree of temperature is considered the optimal when food availability and photoperiod are not acting as limiting factors.

Hierarchical clustering by Bray-Curtis similarity of samples was used by Kochzius, (1997) to investigate the interrelation of seagrass meadow and coral reef ichthyofauna in Malatapay, Negros Oriental, Philippines. Cluster analysis separated the beach seine samples into four clusters. Day and night cluster are divided into sub-cluster depending on distance to the coral reef.

In situ, swimming and settlement behavior of *Plectropomus leopardus* (Pisces: Serranidae) of an Indo-Pacific coral-reef fish were investigated by Lies & Carson Ewart (1999). The swimming speed of these larvae in open waters or when swimming away from reefs was significantly greater than the speed of the larvae swimming towards or over reefs. The larvae did not appear to be selective about settlement substrate, but settled most frequently on live and dead hard coral. Late stage larvae of coral trout are capable swimmers with

considerable control over speed, depth and direction. Habitat selection, avoidance of predators, and settlement seem to rely on vision.

The seasonal variations and community structure of the mesozooplankton in the Gulf of Aqaba have been studied by Al-Najjar (2000). He reported that the high abundance of the total zooplankton in spring season with a peak in June.

2.3 Review of the Methods Utilized in the Identification of Fish Larvae

Hureau (1982) published methods for studying early life history stages of Antarctic fishes. The methods of collection, preservation at the sea, and treatment in the laboratory were investigated for the early life history of Antarctic fishes. Also, Microscopic techniques for studies and description of early ontogeny in fishes have been listed by Balon & Balon (1985). In this elaborate work he included the followings: (1) the collection of gametes, incubation, and feeding of larvae. (2) Equipments, procedures, and sequences of recording of ontogenetic stages such as (a) sampling, drawing and photography of live individuals, (b) processing of preserved cleavage eggs, staining and clearing of embryos and larvae, and (c) supplementary processing for special purposes, including different techniques for staining live individuals, and electron microscopy.

Doherty (1987) reported some data from Lizard Island in Northern Great Barrier Reef demonstrating the utility and limitations of automated light traps as a tool for quantifying spatial and temporal patchiness in the assemblage of larval fishes. He found that the effectiveness of light traps may vary among different species, different ages of the same species, and in conditions of different water clarity or at different times of lunar month. In addition, he also, reported that these kinds of traps give the ability to take multiple samples at the same time over large areas, which leads to improve resolution of the spatial pattern. Furthermore, the data showed that light traps have considerable potential as an alternative and/or supplementary methods for sampling pelagic communities.

Trnski & Lies (1989) described techniques to act as a general introduction for the production of line drawings suitable for publication. These techniques included photographs, equipment, choices of specimens, and specifying what to show in the drawings.

In evaluating the performance of light traps for sampling small fish and squid from open waters in the central Great Barrier Reef lagoon were reported by Thorrold (1992).The

catch was dominated by the family Pomacentridae, and smaller numbers of Lethrinids, Clupeids, Mullids and Scombrids. Size frequencies of the fish collected indicated that the light traps sampled late stage larvae and pelagic juveniles exclusively. Also, no effect of time of night was detected on the catch rate. He found also, a positive effect of the current velocity on the total collection of fish was detected when that the light traps were allowed to drift with prevailing water currents. These results have been compared with those obtained from trawl net and gave the conclusion the light traps have considerable potential for sampling nekton that are capable of avoiding conventional towed nets. Lies (1993) prepared a revised version of an article on minimum requirements for larval fish descriptions, which were originally published in Australian Ichthyoplankton Newsletter in 1987.

Borgan (1994) compared the sampling properties of night-time collecting using light traps and daytime collecting using a small plankton nets steered by a diver from the Gulf of California during summer 1989 and 1990. The taxonomic composition of samples taken by the two methods was broadly similar. The average catch per sample was greater with the plankton net in several famiLies but the size structure of catch differed between the two methods. For most species the light trap was more effective for collecting larger larvae and the net was more effective for collecting small larvae. The combination of the two sampling methods provided a more complete view of larval assemblage over the reefs than either method would have provided alone. Choat *et al* (1997) compared the sampling of larvae and pelagic juveniles of coral reef fishes by Light traps, Seined light, Purse seine, Neuston net, Bongo net, and Tucker trawl. The following results were complied from this study: (1) The bongo net caught the most diverse famiLies, and the light trap the least diverse famiLies. (2) The dominance was least in the Tucker trawl catches and greatest in light trap catches. (3) The composition of the catches was similar for all four nets. (4) For the four abundant famiLies (Apogonidae, Gobiidae, Lutjanidae, Pomacentridae), the bongo nets gave the overall highest density estimates and the Tucker trawl provided the lowest density estimates in most cases. (5) Fishes collected by Light traps, and seined light were generally larger than those taken by net.

3-Materials and methods

3.1 Fieldwork (Collection):

3.1.1 Light Traps:

Sampling was done mainly by light traps. Fish larvae are positively phototaxic therefore light traps can be used to collect various taxonomic origins of fish larvae. This device consists of three vertically stacked chambers that are internally connected (Figure 3.1). The volume of each of the upper two chambers is 27 Liter, and is made of Makrolon. Whereas, the volume of the third is 40 Liter, and is made of Poly Vinyl Chloride (PVC). The later acts as a final reservoir for the samples. The lamps and the control mechanisms are encased within the central vertical core consisting of a cylinder made of Plexiglass. At an appropriate position within this tube, there are three fluorescent tubes (10-W). Each casts a white light into one of the three chambers. The lower part of the core contains a rechargeable lead acid battery (12-V, 7.2 A.h), and a 12-V digital timer, which controls the operation of each of the individual lights. All the three fluorescent tubes, the battery, and the timer are connected together (Figure 3.1). The timer consists of a 24-h clock that can be set to real time (day/hour/minute). The three fluorescent tubes and the battery are attached to this timer which enabled programmed ON/OFF switching of the fluorescent tubes at any time and for any period. The light traps were prepared in Germany, and then assembled at the Marine Science Station according to Doherty (1987). The design of the traps utilized in the study was similar to those used by Doherty (1987). However, number of conditions had been proposed on the design of the traps, these are:

1- The ability to attract and retain a representative sample of larval fishes from the surrounding water.

2- An ability to operate without the need from human surveillance to enable concurrent sampling.

3- High reliability under a variety of conditions and over extended periods of use.

4- The lowest possible cost per unit.

The samples were taken on a weekly basis for one year, from May 1999 to May 2000. The traps were set during the afternoon and left for overnight, and then picked up early in the morning of the following day. Table 3.1 shows the lighting schedule for the programmed timer at each of the three chambers. Fish larvae were attracted to the

lower chamber following light succession down to the final reservoir. (Arrows in figure 3.1)

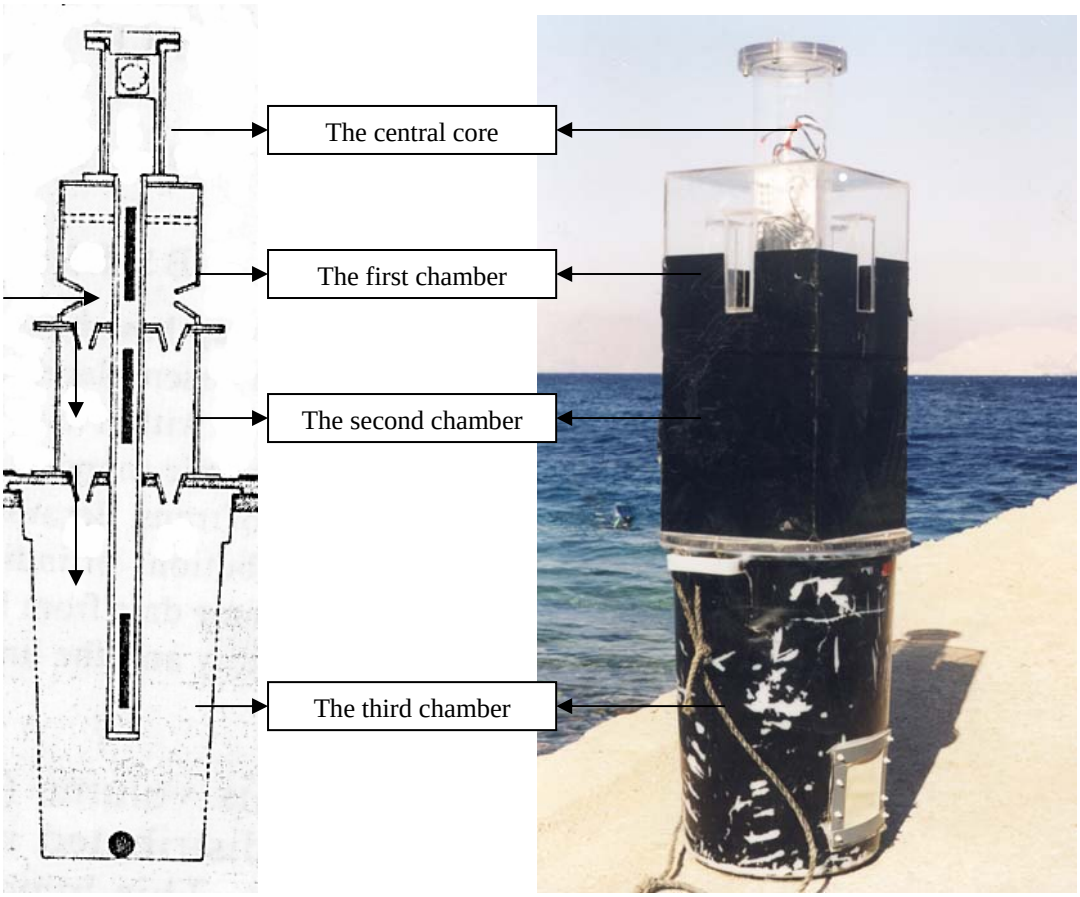


Figure 3.1 Light Trap and its components

Table 3.1 Schedule for the programmed timer.

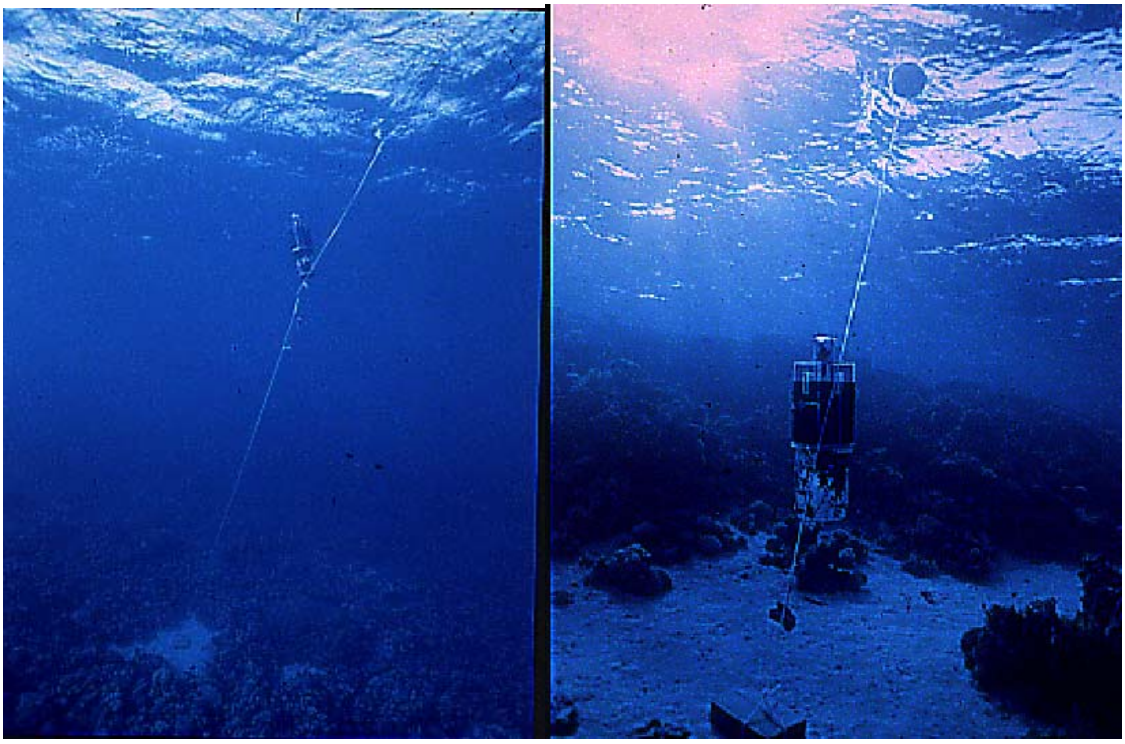
Time	Chamber		
	Upper	Middle	Lower
08:00 Pm-09:00 Pm	ON	OFF	OFF
09:00 Pm-09: 30 Pm	OFF	ON	OFF
09:30 Pm-10:00 Pm	OFF	OFF	ON
10:00 Pm-11:00 Pm	OFF	OFF	OFF
11:00 Pm-12:00 Am	ON	OFF	OFF
12:00 Am-12: 30 Am	OFF	ON	OFF
12:30 Am-01:00 Am	OFF	OFF	ON
01:00 Am-02:00 Am	OFF	OFF	OFF
02:00 Am-03:00 Am	ON	OFF	OFF
03:00 Am-03: 30 Am	OFF	ON	OFF
03:30 Am-04:00 Am	OFF	OFF	ON

The six light traps were placed in six different locations in front of Marine Science Station (Figure 3.2). Table 3.2 represents the GPS reading for each site. Three of them were placed near the coral reef at 0.5 m above the bottom of the sea (Figure 3.3 b), the others were placed at 10 m above the bottom of the sea (Figure 3.3 a). In order to ensure that the traps all were the same distance from the sea surface. Also the collection by light traps was occurred at the Big Bay area for three times during the study Period. The collected materials were isolated, and then fixed immediately in 95% ethanol until they were sorted in the Laboratory. In each trial, light traps were used for sampling after re-charging the battery, and setting the timer on.

Table3.2 GPS reading for the sites of collection

	North	**East**
Trap 1	29,27.221	34,58.329
Trap 2	29,27.200	34,58.290
Trap 3	29,27.336	34,58.443
Trap 4	29,27.370	34,58.422
Trap 5	29,27.465	34,58.549
Trap 6	29,27.440	34,58.539

Figure 3.2 Marine Science Station, Aqaba, Jordan



a- 1 cm = 130 cm b- 1 cm = 52 cm

Figure 3.3 Light traps location in two different depths

3.1.2 Plankton Net:

It is a horizontal system for sampling. The net is towed behind a boat (5 m long, with 40 Horse Power engine) by a 10 m rope. The mesh size of the net was 500 micron. A flow meter was attached to the mouth entrance of the net to calculate the amount of the filtered water.

The collection was performed in front of the Marine Science Station (2-3 km off shore) between 6 and 9 pm for four times through out the study period (May 1999 to May 2000), and for each time four trials were made. In the first trial the duration of the collection was 5 minutes, in the second trial was 10 minutes, in the third trial was 20 minutes, and in the fourth trial was 30 minutes. The collected samples were then isolated from the net, and the fixation was done on the boat using 95% ethanol. Later on, samples were sorted in the laboratory and preserved in 70% ethanol.

3.2 Laboratory Work:

3.2.1 Preservation:

The samples first were fixed in 95% ethanol and then sorted in the laboratory to isolate the larvae from the samples. The isolated fish larvae were preserved in 70% ethanol. (Steedman, 1976).

A stereomicroscope was used to isolate the larvae at magnification powers between 8X and 40X. Flexible forceps was used to handle the larvae.

3.2.2 Drawings:

Fish larvae were drawn using Camera Lucida, which was fixed on the stereomicroscope. Drawing film (polyester drafting film) was used for the final illustration which was done by rapidograph-style drafting pen with variable head thickness size.(Trnski & Lies, 1989).

3.2.3 Staining:

Clearing of the tissues and staining of cartilage and bones are indispensable in the study of the fish larvae (Figure 3.4). The larvae were stained according to the double staining technique (Potthoff, 1983).

The following steps are involved in this technique:

1. Fixation:

The larvae were fixed in 10- 15 % Formalin marble chip, for 48 hours.

2. Dehydration:

The larvae were dehydrated in graded dehydration process:

A- solution of distilled water and 95% ethanol (ratio of 1:1) for 24 hours for small size larvae (< 20 mm long) and 48 hours for the large size larvae (> 20 mm long).

B-Absolute ethanol, for 24 hours for small size larvae (< 20 mm long) and for 48 hours for large size larvae (> 20 mm long).

3- Staining cartilage:

The larvae were placed in a solution of absolute ethanol and glacial acetic acid (70% absolute ethanol, 30% glacial acetic acid) + 20 mg alcian blue / 100 ml solution, for 24 hours.

4- Neutralization:

The larvae were neutralized in a solution of saturated sodium borate, for 12 hours.

5- Bleaching:

The larvae were bleached in a solution of H_2O_2 and KOH (15% of 3% H_2O_2 + 85% of 1% KOH) for 20 minutes for small size larvae (< 20 mm long) and 40 minutes for large size larvae (> 20 mm long).

6- Trypsin digestion:

The larvae were placed in a solution of saturated sodium borate and distilled water(35 % saturated sodium borate + 65% distilled water) + few grams of Trypsin powder, until 60% of the larvae clear.

7- Staining bone:

The larvae were placed in 1% KOH solution with Alizarin red stain, for 24 hours.

8- Destaining:

The Larvae were placed in a solution of saturated sodium borate and distilled water (35 % saturated sodium borate + 65 % distilled water) + few grams of Trypsin powder for 48 hours for the small size larvae (< 20 mm long), and until the specimen is clear for the large size larvae (> 20 mm long).

9- Preservation:

the stained larvae were preserved in a graded preservation process:

A- Solution of Glycerin and 1% KOH (30 % Glycerin + 70% of 1% KOH) for 72 hours.

B- Solution of Glycerin and 1%KOH (60% Glycerin + 40% of 1% KOH) for 72 hours.

C- Solution of 100% Glycerin with Thymol as final preservation.

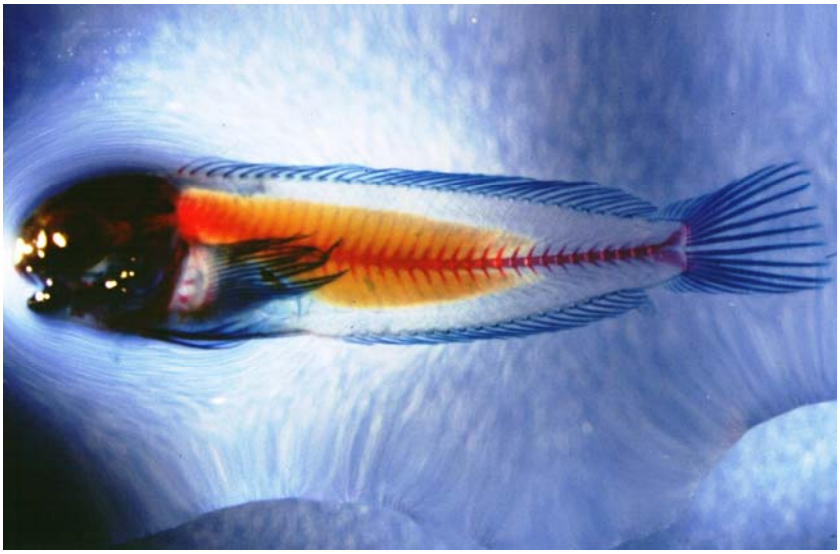


Figure 3.4 Stained Blennid Specimen, TL: 16.7mm, SL: 13.7mm

3.2.4 X-Ray:

Samples of the fish larvae were examined by X-ray to study their skeletal systems. It was done by: Faxitron Model 43805N; Kodak Type R film. Exposure data: Source to film distance, 46 cm; 45 kv; 600 mAs; exposure time was 4 minutes (Tucker & Laroche, 1983).

3.3 Characters Used In Larval Description

The Larvae were measured under the binuclear equipped with eyepiece micrometer to the nearest 0.1 mm.

3.3.1 Body shape

The following categories, which relate the body depth (BD) to the body length (BL)-which refers to the standard length in post-flexion larva, and the total length in pre-flexion larva-have been used in the descriptions (Lies & Carson-Ewart, 2000):

Very Elongated: BD <10%BL

Elongated : BD= 10-20%BL

Moderate : BD =20-40%BL

Deep : BD =40-70%BL

Very deep : BD > 70%BL

3.3.2 Head

The following categories have been used to define the head length in relation to the body length (Lies & Carson-Ewart, 2000):

Small head : HL < 20%BL

Moderate head : HL= 20-33%BL

Large head : HL >33%

3.3.3 Eye

The following categories have been used to define eye size by relating eye diameter to the head length (Lies & Carson-Ewart, 2000):

Small eye : ED < 25%HL

Moderate eye : ED = 25-33%HL

Large eye : ED > 33%HL

3.3.4 Gut

The size of the gut was classified according to the relative pre-anal length:

Short gut : PAL < 30% BL

Moderate : PAL = 30-50% BL

Long : PAL = 50- 70% BL

Very long : PAL > 70% BL

3.3.5 Head spination

Head spines are named according to the bone from which they originate, their type, size, shape, number, ornamentation, and sequence of development. Which are important characters to identify larvae to family level or beyond (Neira *et al*., 1998).

3.3.6 Pigments

The pigments description in larval fishes corresponds to melanin, the brown, and black pigment contained in specialized nucleated cells named “melanophores”, and which remains in the larvae even after preservation (Neira *et al*., 1998).

3.3.7 Morphometrics and Merisitcs measurements

Morphometrics measurements include: Total length, standard length, pre-anal length, pre-dorsal length, head length, snout length, eye diameter, and body depth. Meristics measurements include: number of dorsal spine and rays, number of anal spine and rays, number of pectoral rays, number of caudal rays, and number of vertebrae and/or myomeres. Were the spines are indicated by Romans numbers, and soft rays by Arabic

numbers. A comma (,) indicates an undivided fin, and plus (+) indicates a divided fin with the exception of the caudal fin where a plus (+) indicated the divisions between dorsal and ventral primary rays.

According to the appearance, meristic and morphometric measurements the fish larvae were classified to the family, and/or the genus/ species names of the larvae depending on literature. (Lies & Rennis, 1983; Randall, 1983; Lies & Trnski, 1989; Khalaf & Disi 1997; Neira *et al*., 1998; Lies and Carson-Ewart, 2000). (Tables.3.3)

3.4 Identification Guide

Table 3.3 represents the identification key which have been used in the identification of the samples. The following abbreviations are used in this study (Figure 3.5):

- D: Dorsal Fin, each element with a separate base (Pterygiophore) was counted
- A: Anal Fin, each element with a separate base (Pterygiophore) was counted
- P: Pectoral Fin, all elements were counted regardless to segmentations or branching
- C: Caudal Fin, rays supported by the hypural and parahypural bones were counted
- V: Vertebra
- TL: Total Length: Distance from the tip of the snout along the midline to the posterior edge of the caudal finfold.
- SL: Standard Length: Distance from the tip of the snout along the midline through to the posterior edge of the hypural plate.
- HL: Head Length: The Horizontal distance from the tip of the snout to the posterior-most part of the opercular membrane, or to the posterior margin of the cleithrum if the larva is not yet developed.
- SnL: Snout Length: The Horizontal distance from the tip of the snout to the anterior margin of the pigmented region of the eye.
- ED: Eye Diameter: The Horizontal distance across the midline of the pigmented region of the eye.
- BD: Body Depth: The vertical distance between body margins (exclusive of fins) through to the anterior margin of the pectoral fin base: This does not necessarily represent the greatest body depth.
- PDL: Pre-dorsal Length: Distance from the tip of the snout along the midline to a vertical line through the origin of the dorsal fin or dorsal fin anlage.
- PAL: Pre-anal Length: Distance from the tip of the snout along the midline to a vertical line through the posterior end of the anus.

3.5 Statistical Analysis

Analysis of variance (ANOVA) was used to ascertain whether the number of the most abundant families of fish larvae collected during the study period by using light traps differed among the sites (2-3 m depth and 10-12 m depth). The obtained results were significant at $P < 0.05$. Cluster analysis was applied with the computer software SPSS to investigate similarities between the collected families during the study period from the different six sites in front of Marine Science Station.

3.5.1 Species Composition Measurements

The abundance of each family collected from MSS by the light traps is described by two indices: Relative abundance (RA) and frequency of appearance (FA). The indices were calculated after Rilov & Benayahu, (1998) as follows:

RA = (Number of individuals of the given family from all sampling times divided by the total number of all individuals from all sampling times) X 100

FA = (Number of sampling times in which the given family was noted divided by the total numbers of sampling times) X 100.

3.5.2 Species Diversity Measurements

Two aspects can express species diversity:

1-Margalef's index (Margalef, 1968), a simple measure of species richness:

$D = (S - 1) / \ln N$

D: Species richness, S: Total number of species, ln: Natural logarithm,

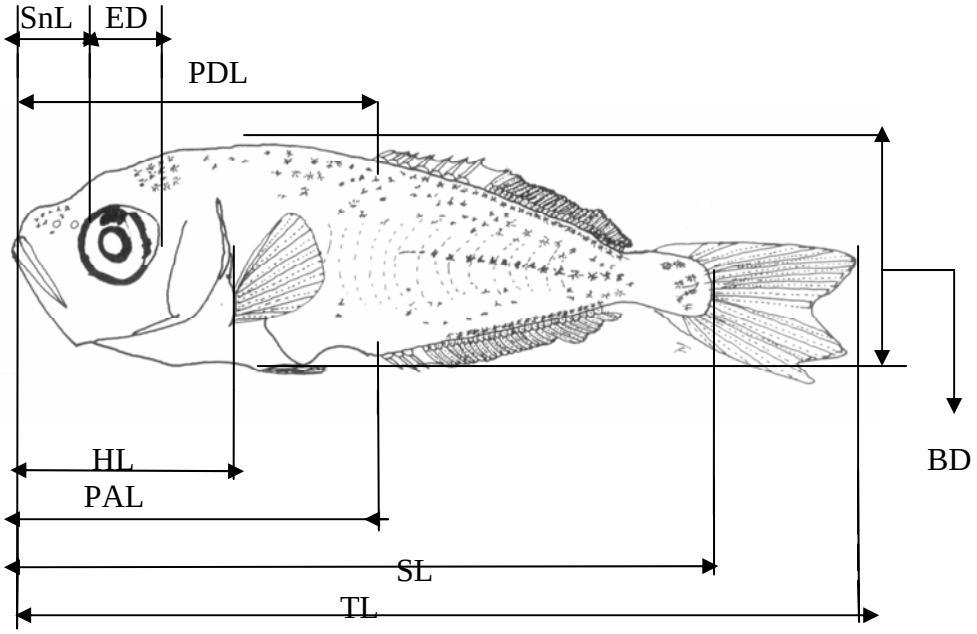
N: Total number of identified individuals

2-Heip's index (Heip, 1974) to measure evenness or equitability:

$E = (e^{H} - 1) / (S - 1)$, where $H = - \Sigma Pi \ln Pi$, where $Pi = ni / N$

E: Equitability, e: exponential number which equal 2.7, H: Heip's index, S: Total number of species, Pi: proportion of all individuals in the sample represented by the individuals of species, ln: Natural logarithm, ni: is the number of individuals for each species in the sample, N: Total number of identified individuals.

MGI PhotoSuite II SE software was used for the documentation of the drawings and the photos. Scanner Visioneer 6200, as well as 35 mm Slide scanner was used to digitize all images. Measurements of the water temperatures were taken from Al-Sokhny (2001).



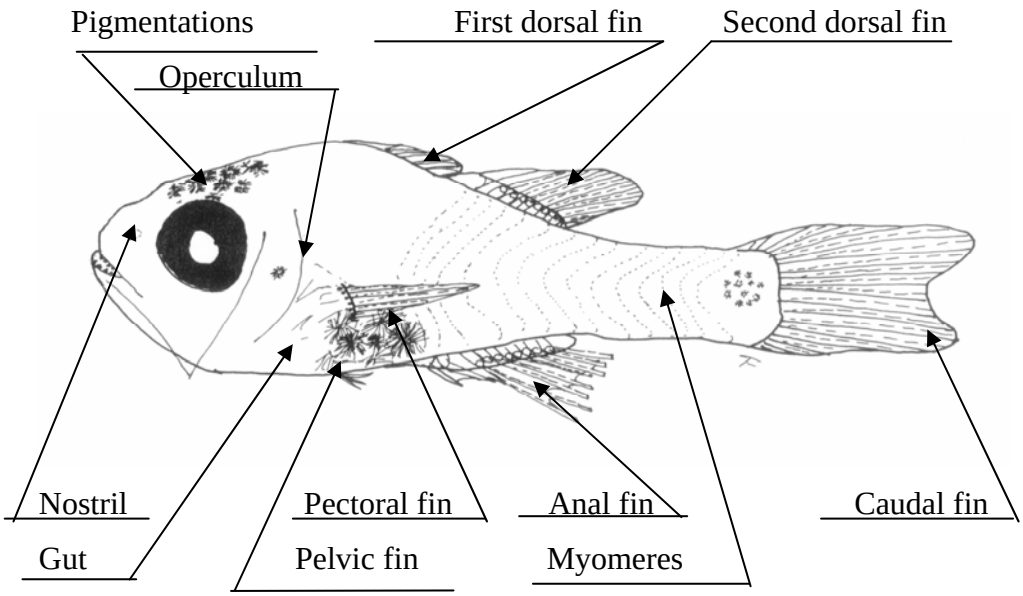


Figure 3.5 The major morphological characters and measurements of Fish Larvae used in this thesis

Table 3.3 characteristics useful in identification of fish larvae.

Order	Family	Sub-Family	Genus	Dorsal Fin	Anal Fin	Caudal Fin	Pectoral Fin	Vertebra
Gonorynchiformes	Chanidae			13-18	8-11	19	8-12	40-47
Clupeiformes	Clupeidae	Clupeinae		51-21	13-23	19	7-9	39-49
		Dussumieriinae	*Etrumeus*	18-21	9-12	19	15-16	48-55
			Spratelloides	10-14	9-14	19	8	46-47
	Engraulidae	Coilinae		5-17	26-117	19	6-10	46-76
		Engraulinae		11-18	14-25	19	7	38-47
		Thryssa		11-17	26-49	19	7	39-46
	Chirocentridae			16-19	29-37	19	6-8	69-75
Aulopiformes	Synodontidae			10-15	8-16	19	10-15	49-65
Ophidiformes	Ophidiidae			104-139	77-107	10-11	22-28	55-63
Lophiiformes	Antennariidae			III+10-16	6-10	9	6-14	18-23
Gobiesociforms	Gobiesocidae			7-15	5-15	9-18	19-31	28-37
Antheriniformes	Atherinidae			III-IV+I, 8-11	I, 7-17	17	12-20	30-47
Beloniformes	Belonidae			11-27	12-29	15	9-15	53-97
	Hemiramphidae			10-25	8-25	15	7-14	37-75
Mugiliformes	Mugilidae			IV+8-11	II-III, 7-11	16	I, 13-20	24-25
Beryciformes	Anomalopidae			II-V+I, 14-20	I-II, 10-15	19	15-19	29-30
	Holocentridae			X-XIII, 11-17	IV, 7-16	19	12-18	27-29
	Monocentridae			IV-VII, 9-13	9-12	18-19	13-15	27
Gasterosteiformes	Centriscidae			III-IV, 9-13	10-14	11	10-12	20
	Fistulariidae			13-17	14-16	12	13-17	76-87
	Pegasidae			5	5	8	9-12	19-22
	Solenostomidae			V+16-22	16-22	15-17	24-28	32-34
	Syngnathidae			7-41	0-5	0-10	0-23	
Scorpaeniformes	Aploactinidae			III-XVI, 6-16	I-IV, 4-15		9-20	24-30
	Scorpaenidae	Apistinae	*Apistus*	XIV-XVI, 8-10	III, 6-8		11-13	25-26
		Pteroinae	*Brachypterios*	XIII, 11	III, 5-7		15-16	24
			Dendrochirus	XIII, 8-11	III, 5-7	9-10	16-21	24
		Scorpaeninae	*Parascorpaena*	XII, 8-10	III, 5-7	15	14-17	24
			Scorpaena	XII, 8-10	III, 4-6	15-16	15-20	24-25
			Sebastapistes	XII, 8-12	III,5		14-20	24

Table 3.3 Continued

Order	Family	Sub-Family	Genus	Dorsal Fin	Anal Fin	Caudal Fin	Pectoral Fin	Vertebra
		Tetraroginae	*vespicula*	III+VII-XII,3-8	III, 3-6	8-10	I, 5	24-26
	Champsodontidae			IV-VI+18-23	16-21	29-33	12-16	29-33
	Dactylopteridae			I+0-I+V+I,8	6	10	28-35	22
	Triglidae			VIII-XI+13-18	13-18	13	10-11+3	30-34
Perciformes	Acropomatidae			VIII-IX+I,10	III, 7	17	15-16	25
	Apogonidae	Apogoninae	*Apogon*	VI-VIII+I, 8-9	II, 8-9	17	12-17	24
			Apogonichthys	VII-VIII+I, 9	II, 8	17	14-16	24
			Archamia	VI+I, 7-9	II, 12-18	17	13-15	24
			Cheilodipterus	VI+I, 9-10	II, 8-9	17	10-15	24
			Fowleria	VII+I, 9	II, 8	17	13-14	24
			Rhabdamia	VI-VII+I, 9-11	II, 9-13	17	12-17	24
			Siphamia	VI-VII+I, 7-10	II, 7-9	17	11-16	24
	Gerreidae			IX-X, 9-11	III, 7-10	17	15-17	24
	Haemulidae	Haemulinae	*Pomadasys*	XI-XIII, 12-18	III, 6-12	17	15-17	26
		Plectorhinchinae	*Diagramma*	IX-X, 21-26	III, 6-8	17	16-17	27
			Plectorhinchus	XI-XIV, 15-23	III, 7-9	17	16-18	27
	Lutjanidae	Asilinae	*Paracaesio*	X, 9-10	III, 8-9	17	16-18	24
		Lutjaninae	*Lutjanus*	X-XII, 12-16	III, 7-11	17	15-17	24
	Malacanthidae	Latilinae	*Branchiostegus*	VI-VII, 14-16	II, 11-13	17	17-19	24
	Mullidae		*Mulloidichthys*	VIII+9	I, 7	16	16-17	24
			Parupeneus	VIII+9	I, 7	16	14-18	24
			Upeneus	VII-VIII+I, 9	I, 7	16	13-18	24
	Serranidae	Anthiinae	*Pseudanthias*	X-XI, 15-17	III, 6-9	13-15	15-20	26
		Epinephelinae	*Cephalopholis*	IX, 13-17	III, 7-10	17	15-20	24
			Epinephelus	XI, 12-19	III, 7-10	17	15-20	24
		Diploprionini	*Aulacocephalus*	IX, 12	III, 9	17	14-16	24
		Grammistini	*Grammistes*	VII, 12-14	II-III, 8-9	17	16-18	24
			Pempheris	V-VII, 8-13	III, 30-45	17	16-19	25
	Plesiopidae	Paraplesiopinae	*Calloplesiops*	XI, 8-10	III, 9	17	17-20	25
		Plesiopinae	*Plesiops*	XI-XII, 7	III, 8	17	17-30	24-26
	Pseudochromidae	Pseudochrominae	*Pseudochromis*	III, 21-32	II-III, 11-21	17	15-20	26

Table 3.3 Continued

Order	Family	Sub-Family	Genus	Dorsal Fin	Anal Fin	Caudal Fin	Pectoral Fin	Vertebra
	Kyphosus		*Kyphosus*	X-XII, 10-16	III, 10-14	17	17-20	25-26
	Nemipteridae		*Parascolopsis*	X, 9	III, 7	17	14-17	24
	Sparidae	Denticinae	*Polysteganus*	XII-XIII, 10	III, 8	17	15-16	24
		Sparinae	*Acanthopagrus*	XI-XIII, 10-15	III. 8-12	17	14-17	24
			Argyrops	XI-XII, 8-11	III, 8-9	17	15	24
			Diplodus	X-XIII, 12-15	III, 10-14	17	15-17	24
			Rhabdosargus	XI-XII, 11-15	III, 10-13	17	13-15	24
	Carangidae	Carangini	*Alectis*	VI-VII+I, 18-19	II+I, 15-20	17	18-20	24
			Alepes	VIII+I, 23-27	II+I, 18-23	17	20-22	24
			Carangoides	VIII+I, 18-35	II+I, 16-29	17	18-24	24-25
			Caranx	VIII+I, 13-25	II+I, 14-21	17	19-23	24-25
			Decapterus	VII-VIII+I, 27-38+1	II+I, 21-31+1	17	20-24	24
			Gnathanodon	VII+I, 18-21	II+I, 15-18	17	20-23	24
			Trachurus	VIII+I, 26-36	II+I, 24-32	17	20-23	24
		Naucratini	*Elagatis*	V-V+I, 24-28+2	I+I, 15-20+2	17	19-22	24
			Naucrates	III-V+I, 25-29	II+I, 15-18	17	18-20	25
			Serioloa	VI-VIII+I, 22-39	II+I, 15-25	17	18-22	24-25
			Seriolina	VII+I, 30-37	I+I, 15-18	17	18-20	24
		Scomberoidini	*Scomberoides*	VI-VII+I, 19-21	II+I, 16-20	17	16-20	26
	Rachycentridae		*Rachycentron*	VII-VIII+I, 28-35	I-III, 22-28	17	20-22	25
	Pomacentridae	Amphiprioninae	*Amphiprion*	VIII-XI, 14-21	II, 11-15	17	15-21	26
			Chromis	XII-XV, 10-15	II, 10-14	16	15-22	26
		Pomacentrinae	*Abudefduf*	XIII, 12-16	II, 11-15	16	18-20	26
			Chrysiptra	XIII-XIV, 10-15	II, 11-16	16	14-19	26
			Neopomacentrus	XIII, 10-12	II, 10-12	16	15-18	26
			Plectroglyphiodon	XII, 14-20	II, 11-18	16	18-21	26
			Pomacentrus	XIII-XIV, 12-16	II, 12-16	16	16-19	25-26
			Teixeirichthys	XII, 12-14	II, 14-15	16	17-19	26
	Labridae	Chelinini	*Chelinius*	IX-X, 8-11	III, 8-9	13	12	23
			Cirrhilabrus	XI-XII, 8-11	III, 8-10	13	14-16	25
			Epibulus	IX, 10-11	III, 8-9	13	12	23

Table 3.3 Continued

Order	Family	Sub-Family	Genus	Dorsal Fin	Anal Fin	Caudal Fin	Pectoral Fin	Vertebra
			Paracheilinus	VIII-X, 11	III, 9	13	13-15	25
			Pseudocheilinus	IX, 10-12	III, 9	13	13-17	25
			Pteragogus	IX-XI, 9-12	III, 8-10	14	12-15	25
		Hypsigenyini	*Bodianus*	XII, 9-11	III, 11-13	14-15	15-18	28
			Choerodon	XII-XIII, 7-8	III, 9-10	14	15-19	27
		Julidini	*Anampses*	IX, 11-13	III, 10-13	14	13-14	25
			Cheilio	IX, 12-13	III, 11-12	14	12	25
			Coris	IX, 12	III, 12	14-15	13-15	25
			Gomphosus	VIII, 12-13	III, 10-12	14	14-16	25
			Halichoeres	IX-X, 11-14	III, 10-13	14	12-15	25
		Julidini	*Hemigymnus*	IX, 11	III, 11	13	14	25
			Hologymnosus	IX, 12	III, 12	14	13	25
			Stethojulis	X, 10-12	III, 10-12	14	12-15	25
			Thalassoma	VIII, 12-14	III, 10-12	14	14-17	25
		Labrichthyini	*Larabicus*	IX, 11	III, 10	14	13	25
		Novaculini	*Xyrichthys*	IX, 12	III, 12-14	14	12-13	25
	Scaridae		*Calotomus*	IX, 10	III, 9	13	13	25
			Cetoscarus	IX, 10	III, 9	13	14-15	25
			Chlorurus	IX, 10	III, 9	13	14-16	25
			Hipposcarus	IX, 10	III, 9	13	15	25
			Scarus	IX, 10	III, 9	13	13-16	25
	Uranoscopidae		*Uranoscopus*	III-VI+12-15	12-15	13	61-21	25-27
	Trichonotidae		*Trichonotus*	III-VII, 39-47	I, 34-42	13	11-15	49-56
	Tripterygiidae		*Enneapterygius*	III+IX-XVI+9-16	I, 14-21	13	13-18	30-39
	Blenniidae		*Ecsenius*	XI-XIV, 13-21	II, 13-23	13-15	12-15	29-40
			Exallias	XII, 12-13	II, 14-15	13	15	30
			Salarias	XII-XIII, 16-20	II, 18-21	13	13-15	34-37
		Nemophini	*Meiacanthus*	III-X, 20-28	II, 14-19	11-13	12-16	32-38
			Petroscirtes	X-XII, 14-21	II, 14-21	11	13-16	30-37
			Plagiotremus	VI-XII, 25-61	II, 19-58	11	11-13	38-76
	Gobiidae			0-X+0-I, 5-19	0-I, 5-19	16-17	11-25	24-55

Table 3.3 Continued

Order	Family	Sub-Family	Genus	Dorsal Fin	Anal Fin	Caudal Fin	Pectoral Fin	Vertebra
	Chaetodontidae		*Chaetodon*	XI-XVI, 15-30	III-IV, 14-27	17	13-18	24
			Heniochus	XI-XIII, 21-28	III, 17-19	17	14-18	24
	Pomacanthidae	Holacanthinae	*Apolemichthys*	XIII-XV, 16-19	III, 17-19	17	16-18	24
			Centropyge	XIII-XV, 14-20	III, 15-19	17	14-18	24
			Genicanthus	XIV-XV, 15-19	III, 14-19	17	15-17	24
			Pygoplites	XIV, 17-22	III, 17-19	17	16-17	24
		Pmacanthinae	*Pomacanthus*	XI-XIV, 16-25	III, 16-23	17	18-20	24
	Ephippidae		*Platax*	V-VII, 28-39	III, 19-29	17	16-20	24
	Siganidae		*Siganus*	XIII-XIV, 10-15	VII, 9-10	17	15-19	23
	Acanthuridae	Acanthurinae	*Acanthurus*	VI-IX, 22-33	III, 19-29	16	15-17	22
			Ctenochaetus	VIII, 24-31	III, 21-28	16	15-17	22
			Zebrasoma	IV-V, 23-33	III, 19-26	16	14-17	22
		Nasinae	*Naso*	IV-VII, 24-31	II, 23-32	16	15-19	22
	Sphyraenid		*Sphyraenta*	V+I, 8-10	II, 7-9	17	12-16	24
	Scombridea	Sardini	*Gymnosarda*	XIII-XV, 12-14, 6-7	12-13, 6	17	25-28	47-48
			Sarda	XVII-IXX, 13-18, 7	14-17, 6	17	23-27	44-46
		Scomberomorini	*Scomberomorus*	XIII-XXII, 15-25, 6-11	16-29, 5-12	17	20-26	41-56
			Scomber	IX-XIII, 12, 5	12, 5	17	18-21	31
		Thunnini	*Auxis*	X-XII, 10-12, 8	11-14, 7	17	23-25	39
			Euthynnus	X-XV, 11-13, 8-10	13-14, 6-8	17	25-29	39
			Thunnus	XI-XIV, 12-16, 7-10	11-16, 7-10	17	30-36	39
	Soleidae		*Pardachirus*	62-82	45-61	17-18	0	35-41
Tetraodontiformes	Monacanthidae		*Aluterus*	II+43-51	46-54	12	13-15	21-23
			Amanses	II+26-29	22-25	12	13	19
			Cantherhines	II+32-39	28-35	12	11-15	19
			Paramonacanthus	II+24-33	24-34	12	10-13	19
			Pervagor	II+29-39	25-36	12	10-14	19
			Thamnaconus	II+31-39	30-37	12	12-16	19
	Balistidae		*Abalistes*	III+25-27	24-25	12	14-15	18
			Balistapus	III+25-27	20-24	12	12-14	18
			Odonus	III+33-35	28-31	12	14-15	18

Table 3.3 Continued

Order	Family	Sub-Family	Genus	Dorsal Fin	Anal Fin	Caudal Fin	Pectoral Fin	Vertebra
			Pseudobalistes	III+24-27	19-24	12	14-15	18
			Rhinecanthus	III+22-27	20-24	12	12-14	18
			Sufflamen	III+26-30	23-27	12	12-14	18
	Ostraciidae		*Ostracion*	9-10	8-11	10	9-12	18
	Tetraodontidae	Canthigasterinae	*Canthigaster*	8-12	8-11	11	14-18	17
		Tetraodontinae	*Arothron*	9-13	9-13	11	14-21	17-20
			Lagocephalus	10-15	8-13	11	14-18	16-20
			Torquigener	8-11	6-11	11	13-17	17-22
	Diodontidae		*Chilomycterus*	12-14	11-14	10	19-22	22-23
			Diodon	13-18	13-18	9	19-25	20-21
Stomiformes	Phosichthyidae		*Vinciguerria*	13-16	12-17	11-15	9-11	38-45

4-Results

A total of 916 specimens were collected in front of the Marine Science Station (MSS) and the Big Bay (BB) area, at the Jordanian coast of the Gulf of Aqaba, between May 1999 to May 2000 using the light traps (LT) and the plankton net (PN). A total of 229 specimens were adult fish, 550 specimens were identified fish larvae, and 137 specimens were unidentified fish larvae. Figure 4.1 represents the percentages of the total catch.

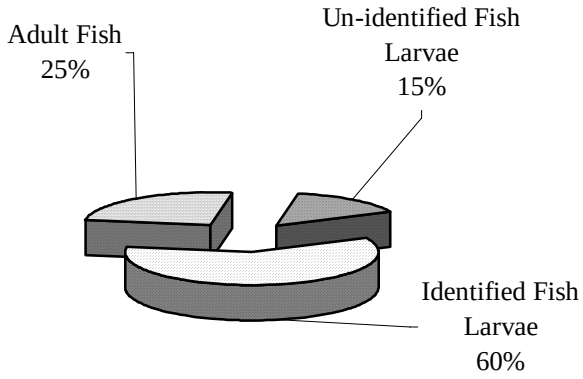


Figure 4.1 Percentages of the Total Catch from the Gulf of Aqaba

The identified fish larvae were belonging to nine orders: Clupeiformes, Lophiiformes, Gobiesociformes, Gasterosteiformes, Scorpaeniformes, Perciformes, Pleuronectiformes, Tetraodontiformes and Stomiformes. Table 4.1 represents the identified fish larvae and their numbers (the systematic arrangement used in this study according to Lies & Carson-Ewart, 2000). Seventy-four different species belonging to forty different genera from twenty-five families have been identified in this study. From the total number of the collected fish larvae, 20% remained as unidentified fish larvae, 80% have been identified to the family level, 67.8% to the generic level, and 33% to the species level (Figure 4.3).

The maximum total catch was obtained in July (Figure 4.4 a & b), when the surface water temperature was 25.3 C^{o} (Figure 4.7). There was fluctuation in the catch of fish larvae by the light traps depending on the moon phase (new moon or full moon), the results showed more catch through the new moon period (Figure 4.5). A comparison between the most abundant fish larvae using light traps from two different depths in front of MSS was obtained (Figure 4.6). Data analysis showed positive correlation between the zooplankton

concentration (g/m^3) and pomacentridae only (Figure 4.7), and no positive correlation was obtained the temperatures and any of the collected families (Figure 4.8). Table 4.2 and figure 4.2 shows the relative abundance (RA) and frequency of appearance (FA) of the collected fish larvae by the light traps from the different six sites in front of the MSS.

Table 4.1 The identified fish larvae during this study.

Order	**Family**	**Genus and/or species**	**Site**	**Method**	**Number**
Clupeiformes	Clupeidae	*Spratelloides delicatulus*	MSS	LT, PN	200
Lophiiformes	Antennariidae genus.1		MSS	PN	1
Gobiesociformes	Gobiesocidae genus.1		MSS	LT	1
Gasterosteiformes	Syngnathidae	*Corythoichthys* sp.1	MSS	LT	2
Scorpaeniformes	Scorpaenidae	*Choridactylus multibarbus*	MSS	LT	1
Perciformes	Apogonidae	*Cheilodipterus novemstriatus*	MSS	LT	1
		Archamia sp.1	MSS	LT	1
		Siphamia sp.1	MSS	LT	1
		Apogon sp.1	MSS	LT	2
		Apogon sp.2	MSS	LT	2
		Apogon sp.3	MSS	LT	11
		Apogon sp.5	MSS	LT	3
		Apogon or Cheilodipterus sp.1	MSS	LT	1
		Apogon or *Cheilodipterus* sp.2	MSS	LT	3
		Apogon or *Cheilodipterus* sp.3	MSS	LT	2
		Apogon or *Cheilodipterus* sp.4	MSS	LT	1
		Apogon or *Cheilodipterus* sp.5	MSS	LT	12
		Apogon or *Cheilodipterus* sp.6	MSS	LT	1
		Apogon or *Cheilodipterus* sp.7	MSS	LT	2
		Apogon or *Cheilodipterus* sp.8	MSS	LT	9
		Apogon or *Cheilodipterus* sp.9	MSS	LT	2
		Apogon or *Cheilodipterus* sp.10	MSS	LT	5
		Apogon or *Apogonichthys* or *Fowleria* or *Siphamia* sp.1	MSS	LT	1
		Apogon or *Apogonichthys* or *Fowleria* or *Siphamia* sp.2	MSS	LT	1

Table 4.1 Continued

Order	Family	Genus and/or species	Site	Method	Number
		Apogon or *Apogonichthys* or *Fowleria* or *Siphamia* sp.3	BB	LT	1
		Apogon or *Apogonichthys* or *Fowleria* or *Siphamia* sp.4	MSS	LT	4
		Apogon or *Apogonichthys* or *Fowleria* or *Siphamia* sp.5	MSS	LT	5
	Lutjanidae	*Lutjanus* sp.1	MSS	LT	1
	Serranidae	*Plectranthias winniensis*	BB	LT	3
		Epinephelus sp.1	MSS	PN	1
	Pempheridídae	*Parapriacanthus ransonnari*	MSS	LT	4
	Plesiopidae	*Plesiops* sp.1	MSS	LT	1
	Pseudochromidae	*Pseudochromis* sp.1	MSS	LT	2
	Carangidae	*Decapterus* sp.1	MSS	LT	1
	Pomacentridae	*Amphiprion bicinictus*	MSS	LT	8
		Dascyllus marginatus	MSS	LT	1
		Dascyllus aruanus	MSS	LT	1
		Dascyllus sp.1	MSS	LT	1
		Pomacentrus sp.1	MSS	LT	33
		Pomacentrus sp.2	MSS	LT	1
		Pomacentrus sp.3	MSS	LT	4
		Pomacentrus sp.4	MSS	LT	1
		Chromis sp.1	MSS	LT	6
		*Chromis.*sp.2	MSS	LT	4
		Neopomacentrus sp.1	MSS	LT	18
		Neopomacentrus sp.2	MSS	LT	4
		Neopomacentrus sp.3	MSS	LT	31
	Pomacentridae genus.1		MSS	LT	1
	Pomacentridae genus.2		MSS	LT	1
		Pomacentrus or *Chrysiptera* sp.1	MSS	LT	4
		Neopomacentrus or *Chromis* sp.1	MSS	LT	1
	Labridae genus.1		MSS	LT	2
	Blenniidae	*Meiacanthus nigrolineatus*	MSS	LT	1

Table 4.1 Continued

Order	Family	Genus and/or species	Site	Method	Number
		Cirripectes sp.1	MSS	LT	2
		Petroscirtes sp.1	MSS	LT	1
		Ecsenius sp.1	MSS	LT	2
		Ecsenius sp.3	MSS	LT	11
		Ecsenius sp.4	MSS	LT	3
		Ecsenius sp.5	MSS	LT	2
	Blenniidae genus.1		MSS	PN	1
	Tripterygiidae	*Enneapterygius* or *Helcogramma* sp.1	MSS	LT	6
	Gobiidae genus.1		MSS	LT	77
	Chaetodontidae	*Chaetodon* sp.1	MSS	LT	1
		Heniochus sp.1	MSS	LT	1
	Siganidae	*Siganus* sp.1	MSS	LT	1
	Acanthuridae	*Zebrasoma veliferum*	MSS	LT	1
	Scombridae	*Grammatorcynus* sp.1	BB	LT	4
Pleuronectiformes	Bothidae	*Bothus* sp.1	MSS	LT	2
Tetraodontiformes	Ostraciidae	*Ostracion cubicus*	MSS	LT	1
	Diodontidae	*Chilomycterus* sp.1	MSS	PN	1
Stomiformes	Phosichthyidae	*Viniciguerria mabahiss*	MSS	LT	5
Unidentified			MSS	LT	137

Table 4.2 Relative abundances (RA) and Frequencies of appearance (FA) of the collected fish larvae by the light traps from the six sites in the front of the MSS

Family	RA	FA	Family	RA	FA
Apogonidae	14.70%	11%	Siganidae	0.19%	0.29%
Pomacentridae	22.30%	11%	Lutjanidae	0.19%	0.29%
Blenniidae	4.70%	6%	Carangidae	0.19%	0.29%
Scorpaennidae	0.19%	0.29%	Chaetodontidae	0.37%	0.58%
Acanthuridae	0.19%	0.29%	Plesiopidae	0.19%	0.29%
Ostracidae	0.19%	0.29%	Tripterygiidae	1.10%	0.88%
Phosichthyidae	0.93%	0.58%	Labridae	0.37%	0.58%
Pempheridae	1.70%	2%	Gobiesocidae	0.19%	0.29%
Clupeidae	37.20%	6%	Gobiidae	14.37%	10%
Pseudochromidae	0.37%	0.58%	Syngnathidae	0.37%	0.58%

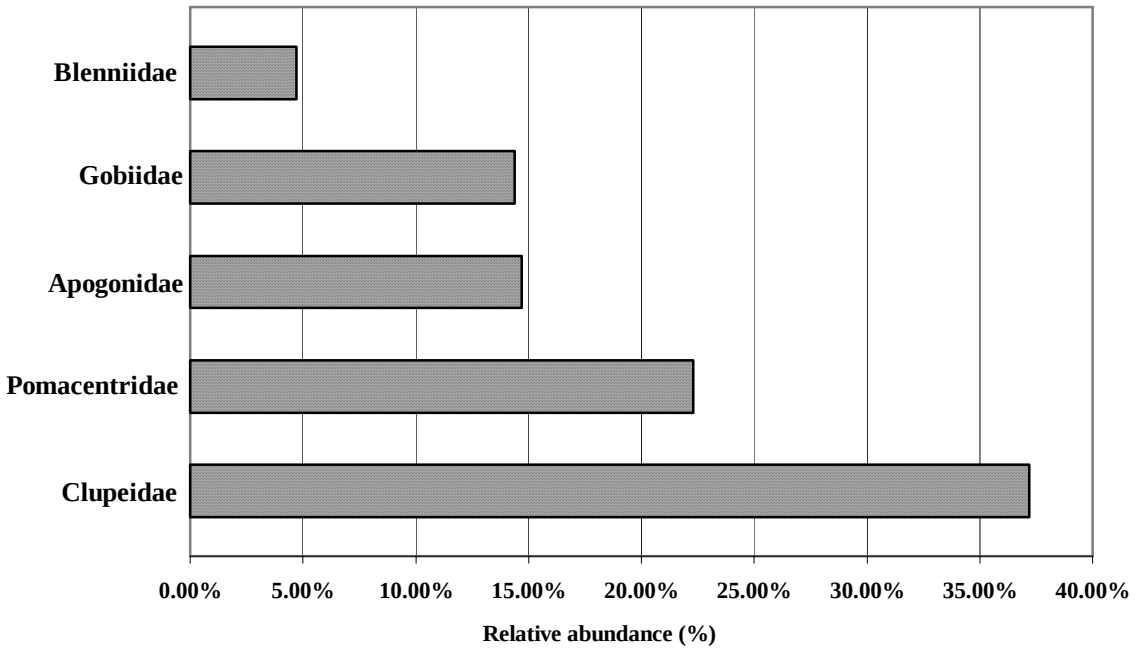


Figure 4.2 Spatial variations in the relative abundance of the most abundant families collected using light traps in front of MSS

Using Margalef's index, species richness was the highest in July. Equitability was the highest in September (Table 4.3). Figure 4.4 shows average water temperatures in the Gulf of Aqaba during June 1999 to May 2000. Similarities between the collected families using light tarps were investigated by the dendogram (Figure 4.9).

Table 4.3 Sspecies richness and equitability of the total fish larvae from the Gulf of Aqaba during May, 1999 to April, 2000.

	May	June	July	August	September	October	November	December	January	February	March	April
Species Richness	3.36	3.82	5.53	2.17	1.86	1.85	0	0	------	0	-----	1.36
Equitability	0.548	0.449	0.233	0.799	0.929	0.594	0	0	------	0	-----	0.27

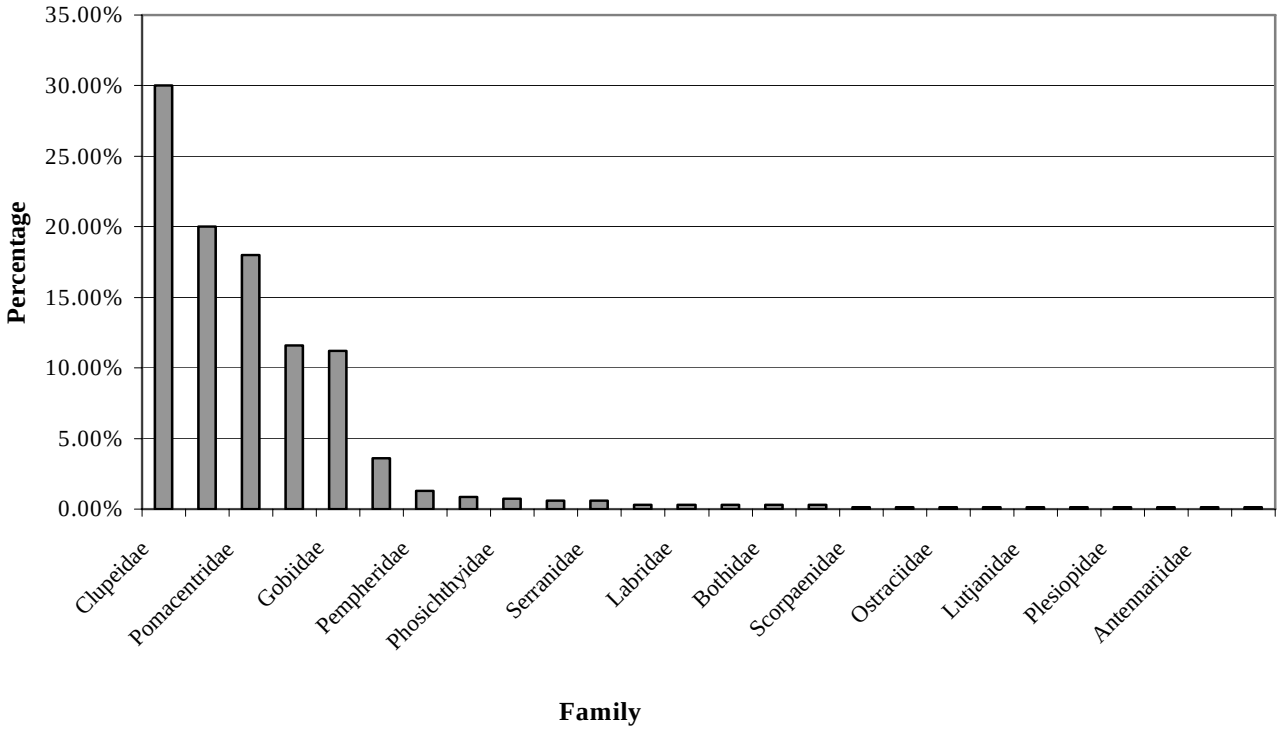
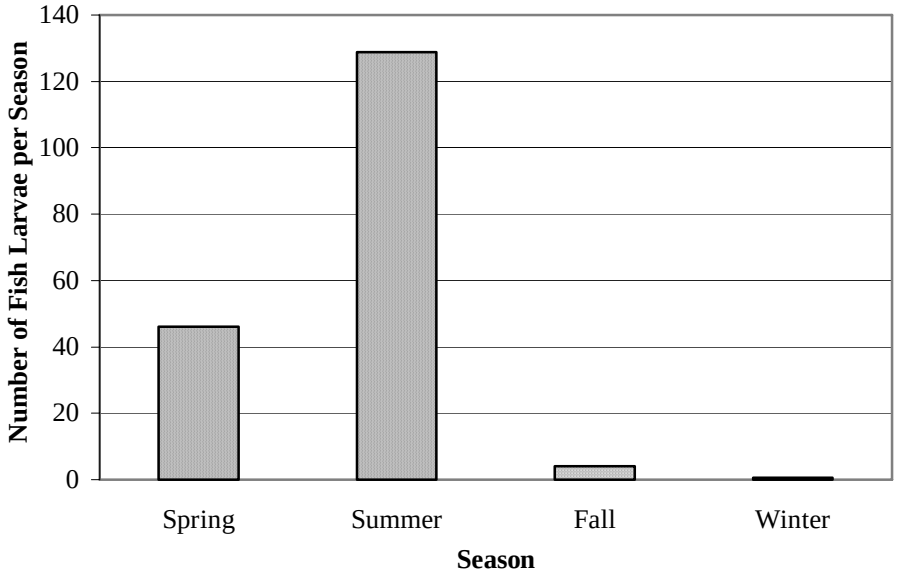
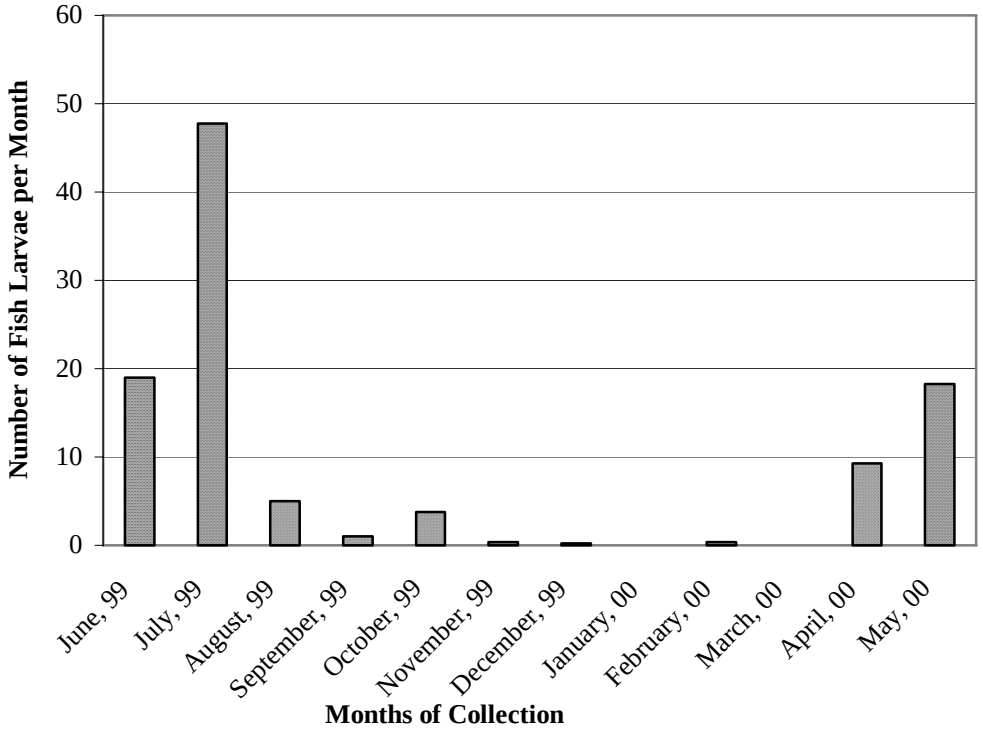


Figure 4.3 Families percentages of the collected fish larvae



A-Per Season



B-Per Month

Figure 4.4 Temporal distributions (A-Per month, B-Per Season) of the collected fish larvae from May 1999 to May 2000

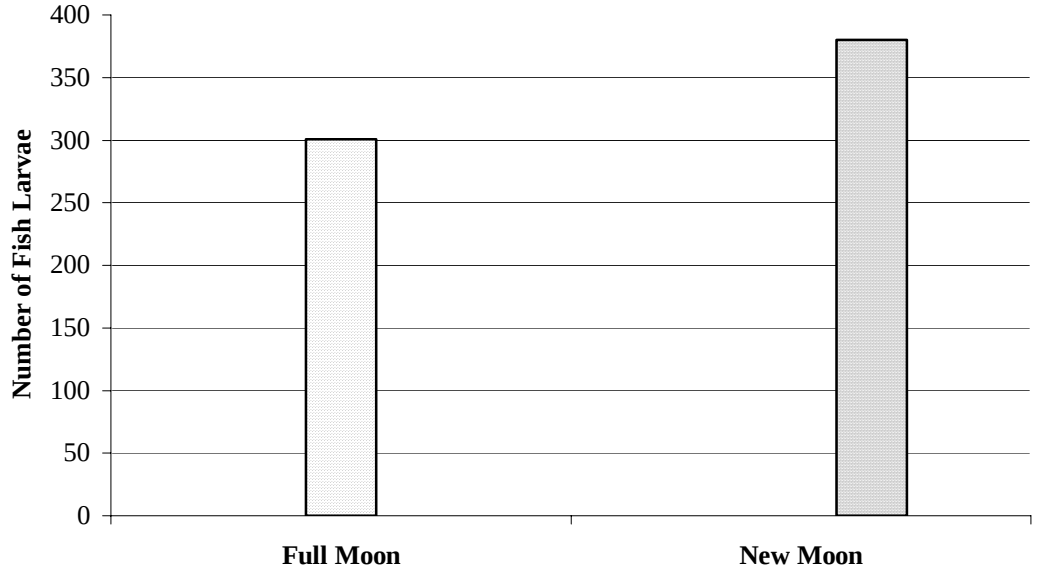


Figure 4.5 Comparison of the collected fish larvae during full moon and new moon

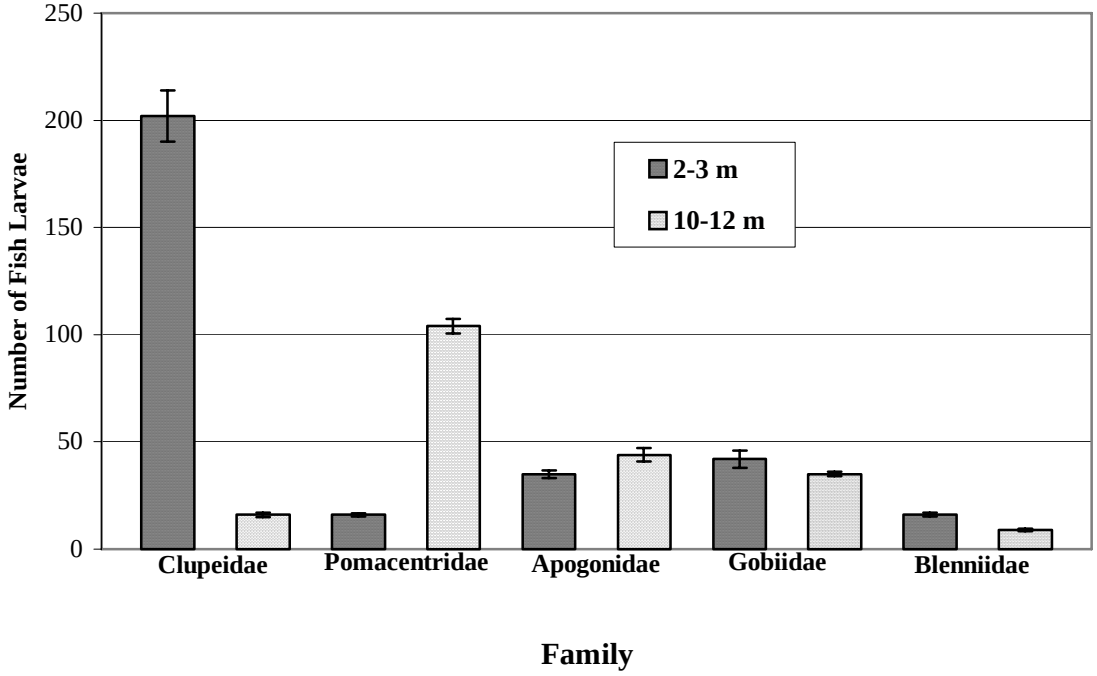


Figure 4.6 Comparisons between the most abundant fish larvae using light traps from two different depths in front of MSS. Significance tested with ANOVA at P = 0.05

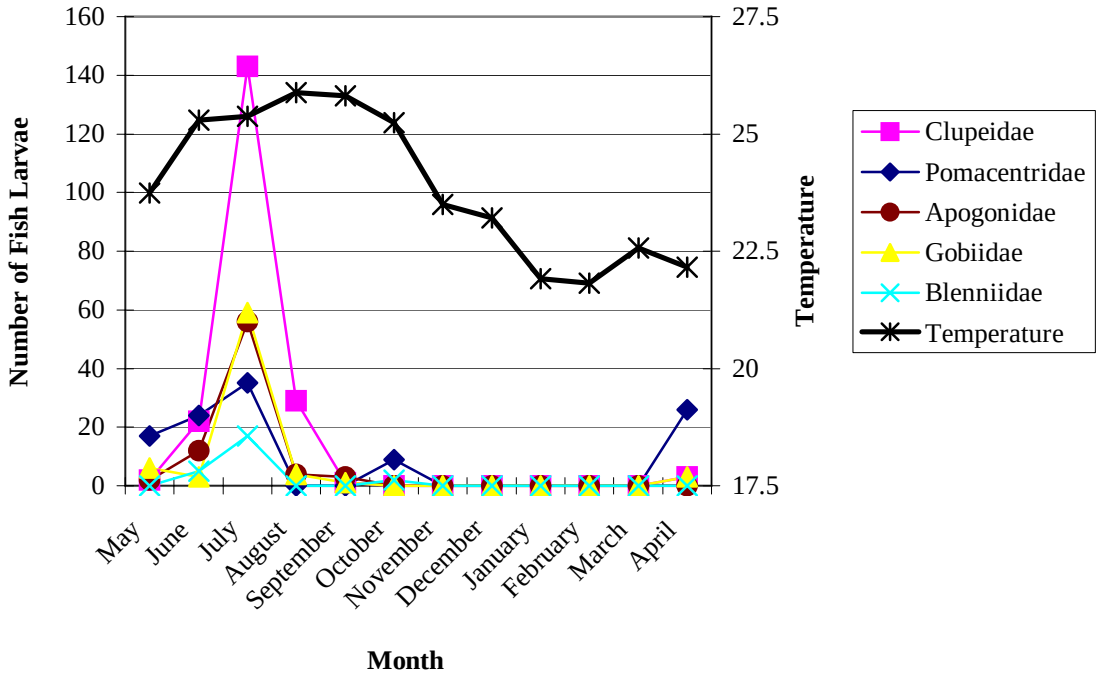


Figure 4.7 Correlation between the seasons of the most collected families of fish larvae with the average surface water temperature

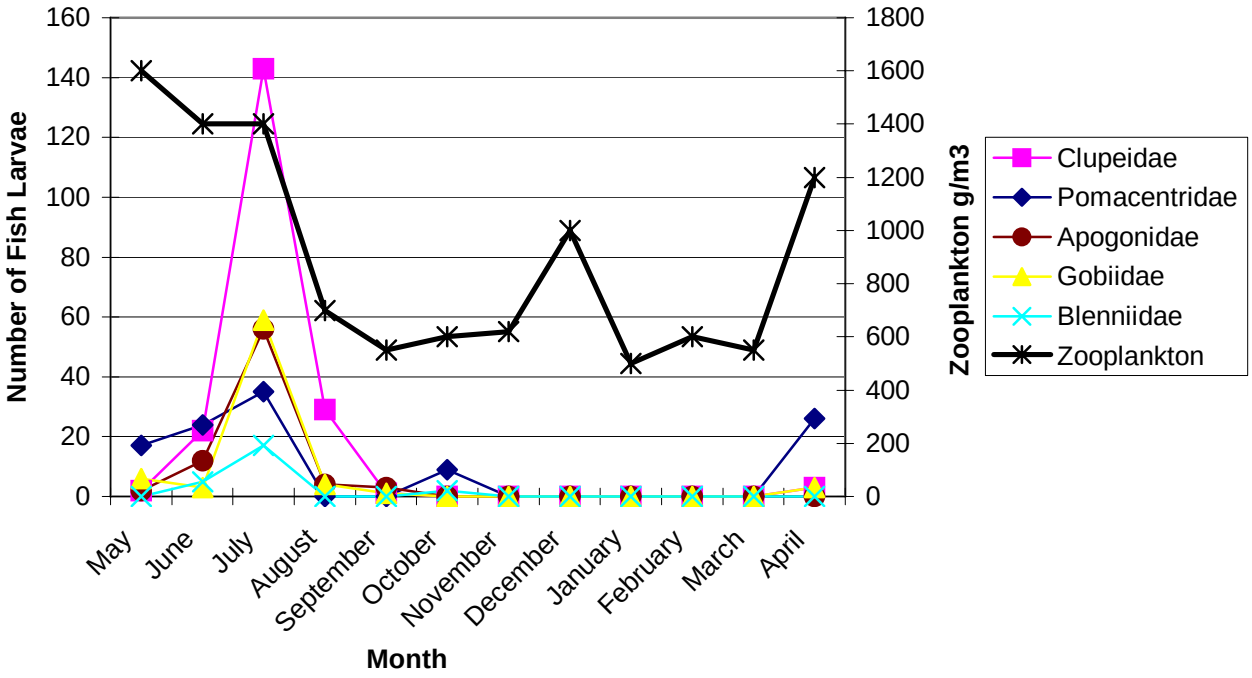


Figure 4.8 Correlation between the seasons of the most abundant families of fish larvae with the season of the zooplankton

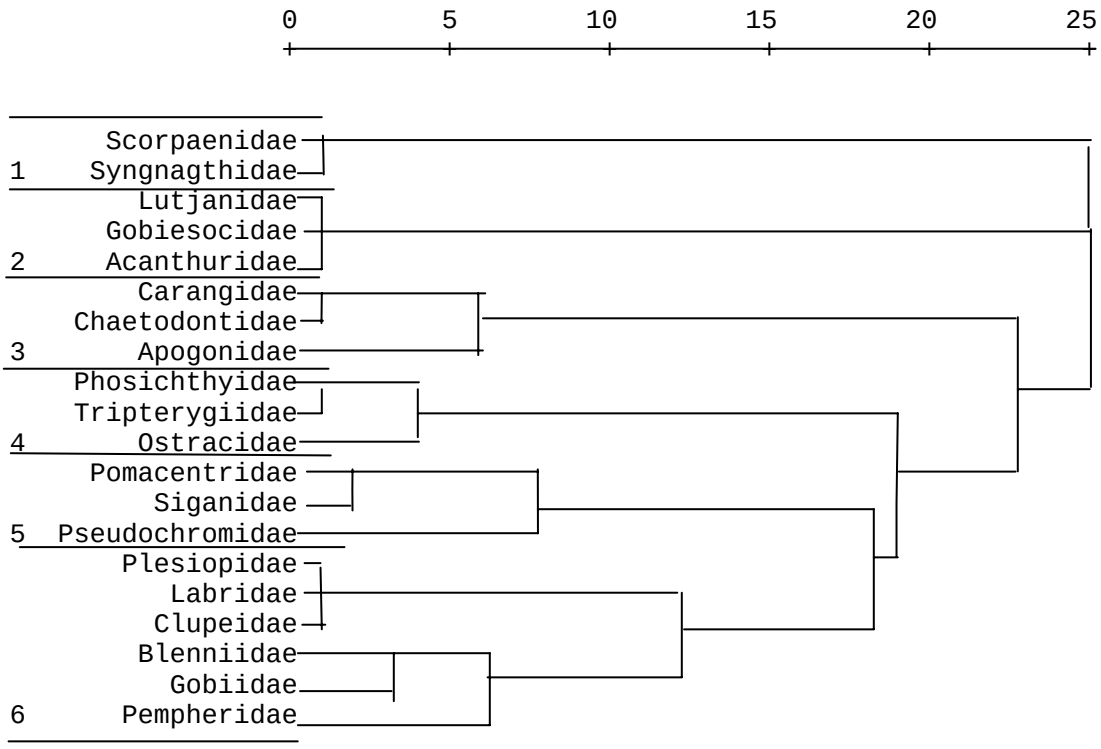


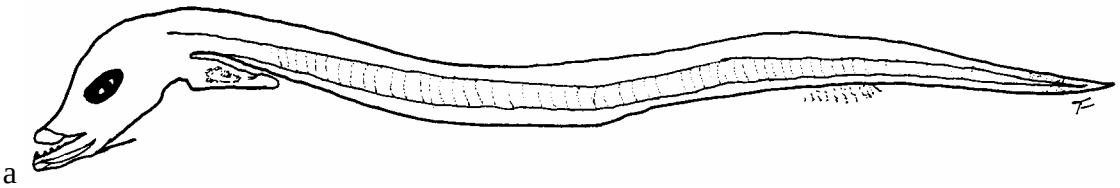
Figure 4.9 Hierarchical clustering: Families similarity dendogram of the collected samples using light traps from six sites in front of MSS (n = 20).

4.1 Clupeiformes

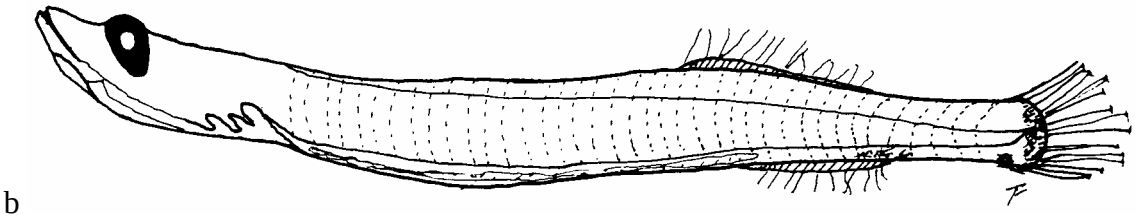
4.1.1 Clupeidae (Herrings, Sardines, Sardinellas, Scads, Sprats)

This family is represented by *Spratelloides delicatulus*, recorded for the first time from the Jordanian coast of the Gulf of Aqaba (Figure 4.10 & Plate 1) Their pre-flexion larval stages have elongated to very elongate cylindrical bodies and are ovoidal in cross section. The gut is very long and straight with only very weak striations present on the hindgut. The head is small to moderate without spination having moderate eye. The snout is pointed and initially dorso-ventrally flattened. Pigmentation characteristics of postflexion samples include a row of melanophores, which are visible along the midventral side of the hindgut, and a single melanophore is found on the upper end of the cleithrum.

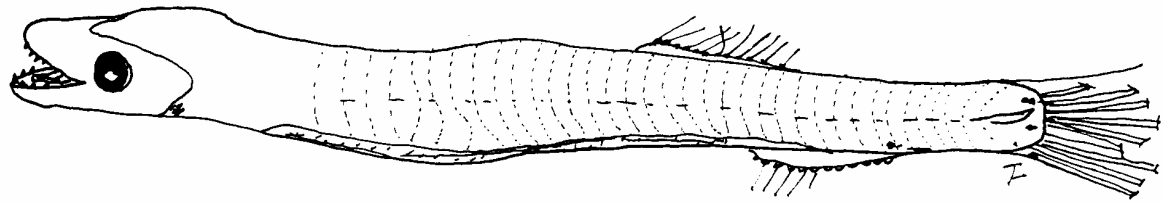
Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentages	71 - 82 %	48 – 65 %	15 – 24 %	5 – 8 %	25 – 29 %	4 – 14 %



a



b



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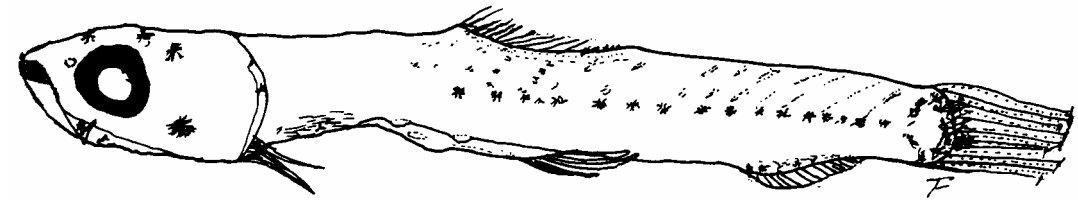
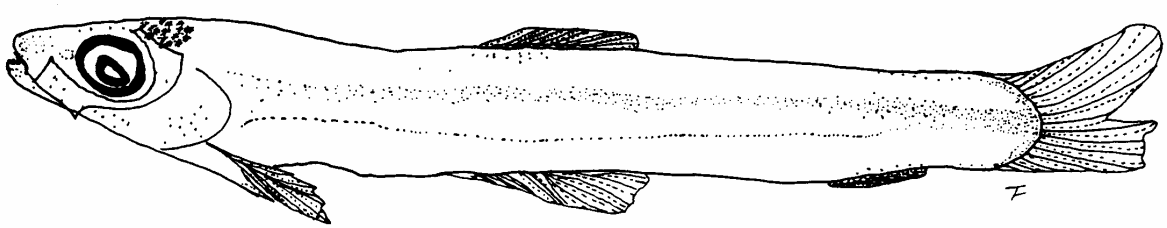


d



e

Figure 4.10 MSSAFL58, 200 sample of *Spratelloides delicatulus*, Standard length in mm: a = 9.2, b = 9.5, c = 13.3, d = 15.2, e = 28.0.D = 10, A = 10, C = 19, P = 8, V = 44. Morphometric measurements in ranges for the 200 sample are given in (mm): TL: 9.4-32.3, SL: 9.2-28.0, PAL: 6.5-22.83, PDL: 6.0-13.5, HL: 1.4-6.8, SnL: 0.5-2.2, ED: 0.4-1.7, BD: 0.4-3.8. Collected in: May, June, July, August, and September

4.2 Lophiiformes

4.2.1 Antennariidae (Frogfishes)

Their pre-flexion larval stages have deep body. The tail is elongated and compressed. The notochord is straight in the anterior portion but curved into an S-shape over the posterior portion of the gut. The body is surrounded by an inflated dermal membrane. The gut is short and coiled. They have a large and deeply rounded to moderate head with large eye, blunt snout, and small mouth. Melanophores located over the gut, the head and the tail. (Figure 4.11 & Plate 2).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	18 %	9 %	11 %	2 %	45 %	43 %

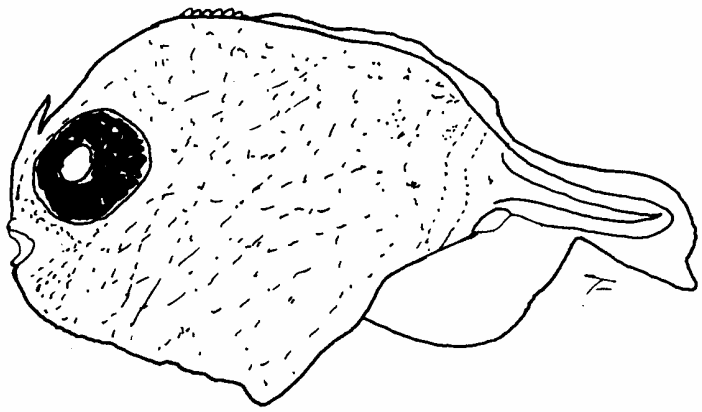


Figure 4.11 MSSAFL72. Antennariidae. One sample. Morphometric measurements are given in (mm): TL: 7.5, SL: 7.0, PAL: 1.25, PDL: 0.66, HL: 0.75, SnL: 0.14, ED: 0.34, BD: 3.0. collected in : June.

4.3 Gobiesociformes

4.3.1 Gobiesocidae (Clingfishes)

This family recorded for the first time from the Jordanian coast of the Gulf of Aqaba. The post-flexion larvae are moderate in depth, and slightly laterally compressed. They have a straight, broad very long gut that extends to beyond the midbody. Their head is round, moderate in its size and having small eye, short blunt snout and large mouth without spination. They have pigmentations over most of the body. (Figure 4.12 & Plate 3)

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	73 %	62 %	33 %	9 %	24 %	21 %

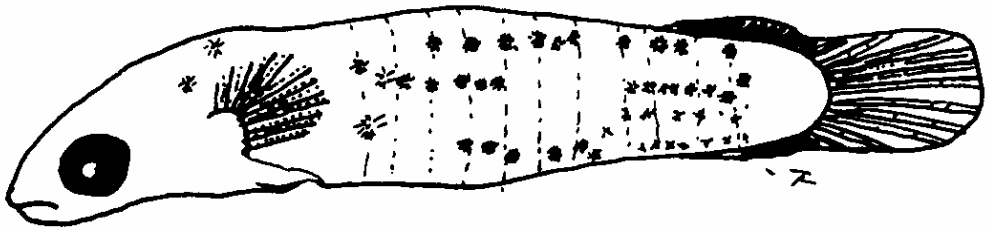


Figure 4.12 MSSAFL69.Gobiesocidae. One sample. D: 7, A: 5, C: 13, P: 22, V: 30. Morphometric measurements are given in (mm): TL: 12.5, SL: 10.5, PAL: 7.7, PDL: 6.5, HL: 3.5, SnL: 1.0, ED: 0.83, BD: 2.2. collected in: April.

4.4 Gasterosteiformes

4.4.1 Syngnathidae (Seahorses and Pipefishes)

Morphologically, the post-flexion larvae are similar to adults. They have tubular, elongated snouts tipped with tiny flap-like mouths, small heads, and small eyes. They have a short straight guts. The body is covered with plates arranged in the form of rings ranging in number from 7 to 28 for the trunk and from14 to 91 for the tail, with slight pigmentations. Pelvic fins are absent in this family (Figure 4.13 & Plate 4)

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	------	41 %	14 %	8 %	13 %	3 %

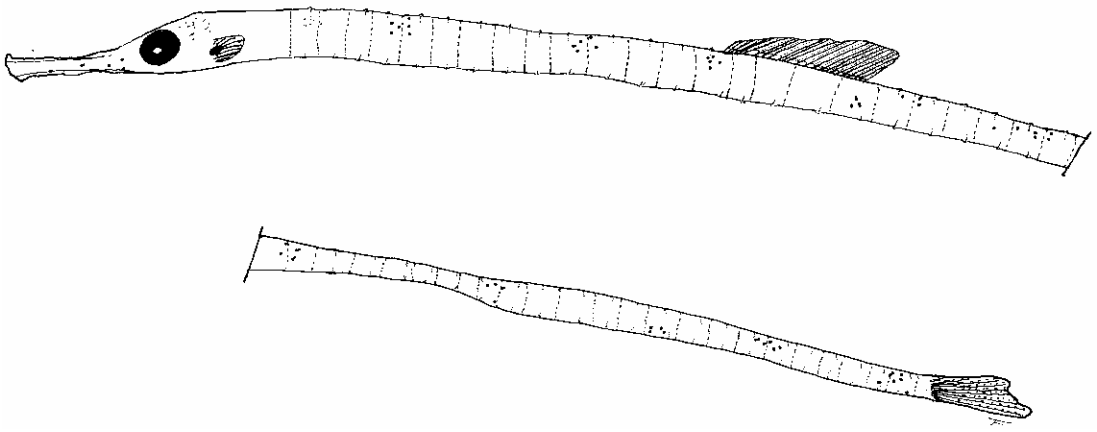


Figure 4.13 MSSAFL71. *Corythoichthys* species 1. SL: 58.8mm. Two samples. D: 25, C: 10, P: 7, Total body rings: 50. Morphometric measurements in average for the 2 samples are given in (mm): TL: 61.1, SL: 58.8, PDL: 24.0, HL: 8.5, SnL: 4.5, ED: 1.1, BD: 1.9. Collected in July.

4.5 Scorpaeniformes

4.5.1 Scorpaenidae (Scorpionfishes)

This family is represented by *Choridactylus multibarbus*, recorded for the first time from the Jordanian coast of the Gulf of Aqaba. The post-flexion larval stage has deep body with large head, large eye, and extensive head spination. The tail varies from laterally compressed to slightly ovoid in cross section. The gut is long, coiled, and compact. There is a small gap between the anus and the origin of the anal fin. The body is pigmented with

melanophores along the pectoral fin rays, and scattered over the connecting membrane (Figure 4.14 & Plate 5)

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	69 %	49 %	47 %	13 %	38 %	47 %

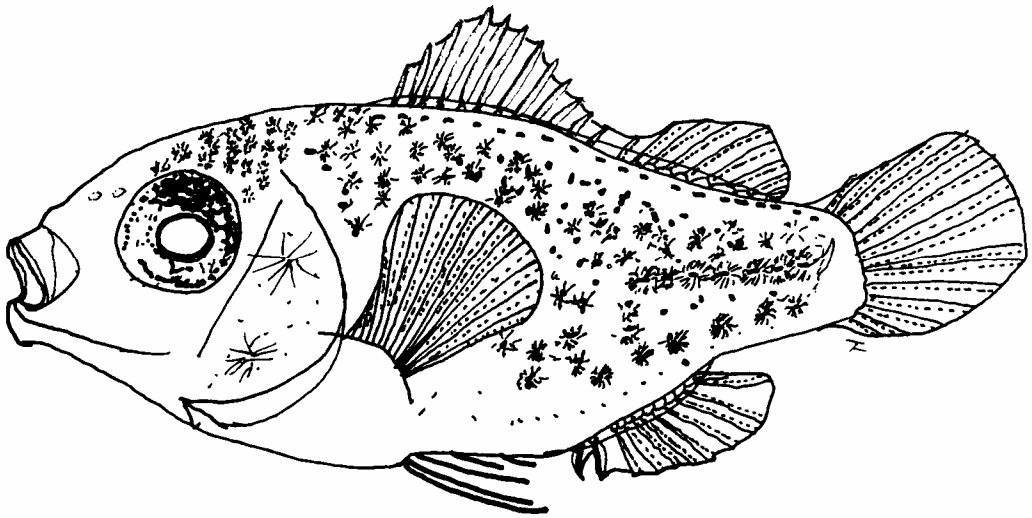


Figure 4.14 MSSAFL60.*Choridactylus multibarbus*. One sample. D: XII, 9, A: II, 9, C: 17, P: 11-12, V: 25. Morphometric measurements are given in (mm): TL: 9.0, SL: 7.5, PAL: 5.2, PDL: 3.7, HL: 3.5, SnL: 1.0, ED: 1.3, BD: 3.5. collected in: September.

4.6 Perciformes

4.6.1 Apogonidae (Cardinal fishes)

In our collection there are 23 different species belonging to six different genera. The general body shape varies from slightly laterally compressed and elongated to strongly laterally compressed and deep bodied. The gut begins to coil during the early pre-flexion stage, and by the beginning of the flexion it becomes deeply coiled and extends to approximately the middle of the body. Also, the gut varies in size from long to very long. The head shape is variable as some species have large, deep, laterally compressed heads with a short, round to truncate snout, while other species have a head of moderate size with an elongated snout. The large mouth reaches to about the middle of the eye or beyond and varies from nearly horizontal to very oblique. Small, villiform teeth are visible in both jaws

in some of the pre-flexion larvae. The round eye is large in size but may be small in some of the post-flexion larvae. The presence of head spination is variable among species; in some they are absent completely but in others they are present. But, in general, the head spination appears during pre-flexion stage and disappears or is greatly reduced prior to settlement. Also, scales are not formed until after settlement (Lies, 2000). The pigments vary from light, restricted to heavy, and distributed along the body, but they are consistently present on the dorsal surface of the gas bladder. There also, any pigmentation pattern can be found. (Figures 4.15- 4.37 & Plates 6-28)

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Proportion	51 – 95 %	31 – 65 %	27 – 43 %	8 – 9 %	37 – 39 %	16 – 59 %

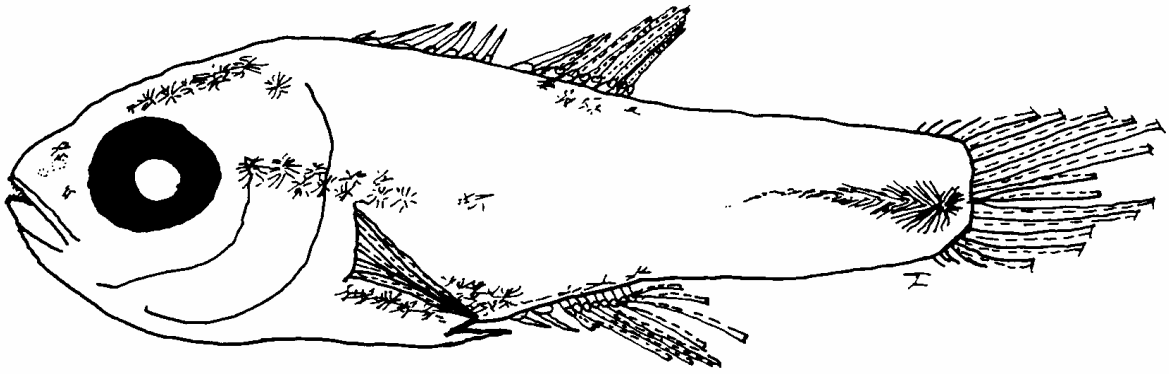


Figure 4.15 MSSAFL1. *Cheilodiptrus novemstriatus.* One sample. D: VI+I, 9, A: II, 8, C: 17, P: 13, V: 24. Morphometric measurements are given in (mm): TL: 12.7, SL: 10.5, PAL: 6.0, PDL: 4.0, HL: 3.7, SnL: 1.0, ED: 1.2, BD: 3.3. collected in: July.

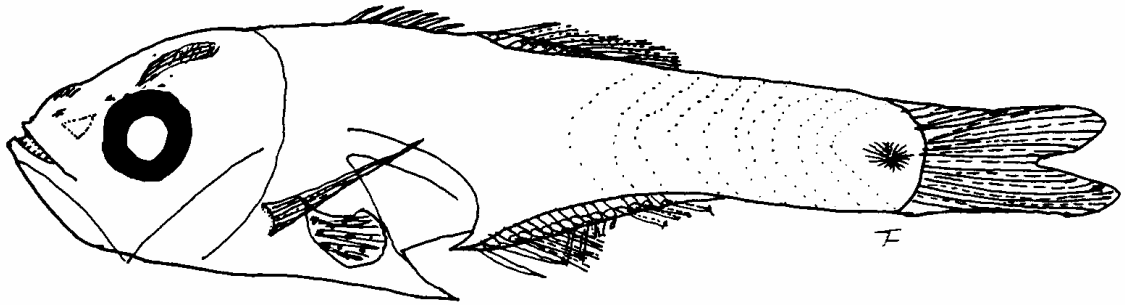


Figure 4.16 MSSAFL2.*Archaemia* species 1. One sample. D: VI+I, 9, A: II, 14. C: 17, P: 13, V: 24. Morphometic measurements are given in (mm): TL: 13.2, SL: 11.2, PAL: 5.8, PDL: 4.2, HL: 3.7, SnL: 1.0, ED: 1.2, BD: 3.0. collected in: July.

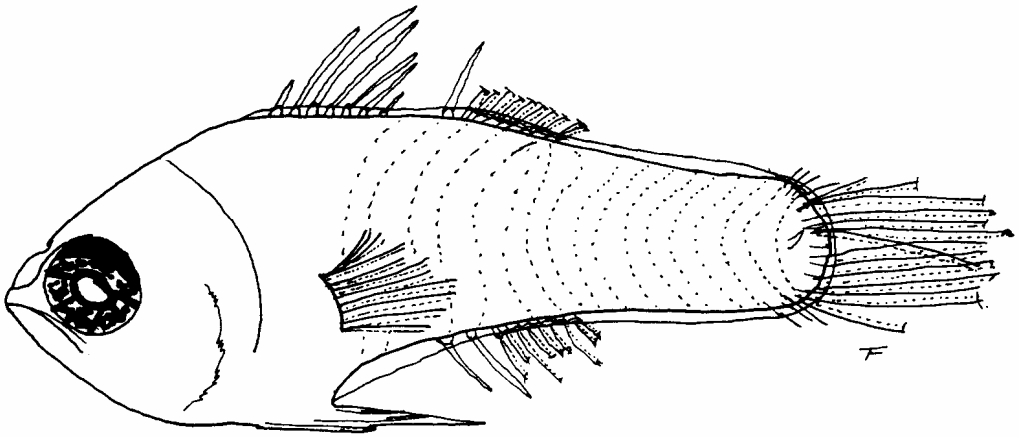


Figure 4.17 MSSAFL18.S*iphamia* species 1. One sample. D: VII+I, 9, A: II, 7, C: 17, P: 14, V: 24. Morphometric measurements are given in (mm): TL: 13.0, SL: 12.3, PAL: 6.3, PDL: 3.8, HL: 3.3, SnL: 0.86, ED: 1.1, BD: 4.1. Collected in: May.

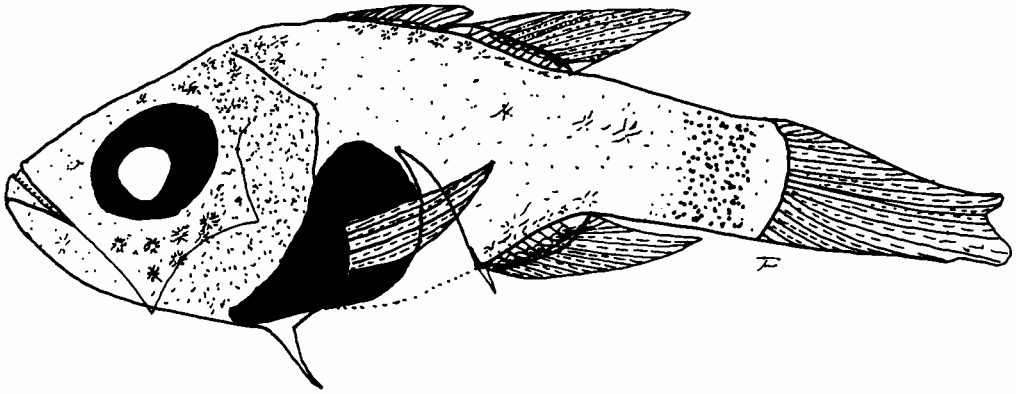


Figure 4.18 MSSAFL3. *Apogon* species 1. SL: 14.7mm. Two samples. D: VII+I, 9, A: II, 8, C: 17, P: 13, V: 24. Morphometric measurements in average for the 2 samples are given in (mm): TL: 18.5, SL: 14.7, PAL: 8.3, PDL: 5.7, HL: 5.5, SnL: 1.2, ED: 2.5, BD: 5.7. Collected in August.

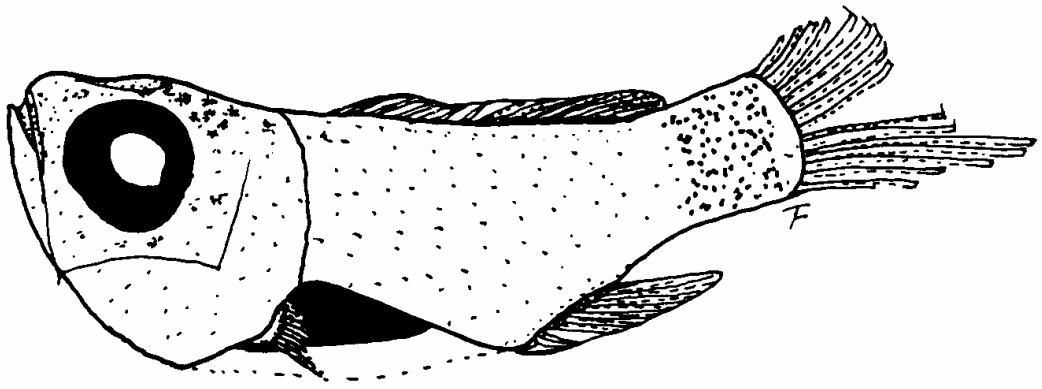


Figure 4.19 MSSAFL4, *Apogon* species 2. SL: 14.8mm. Two samples. D: VII+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements in average for the 2 samples are given in (mm): TL: 18.2, SL: 14.8, PAL: 10.3, PDL: 6.2, HL: 6.1, SnL: 1.3, ED: 2.5, BD: 4.7. Collected in July.

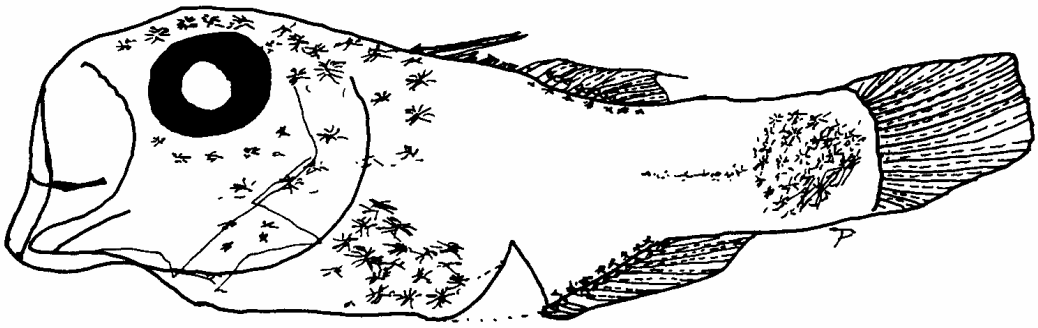


Figure 4.20 MSSAFL5. *Apogon* species 3. SL: 10.5 mm. Eleven samples. D: VI+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements in average for the 11 samples are given in (mm): TL: 12.5, SL: 10.4, PAL: 6.0, PDL: 4.7, HL: 4.5, SnL: 1.5, ED: 1.5, BD: 3.5. Collected in July.

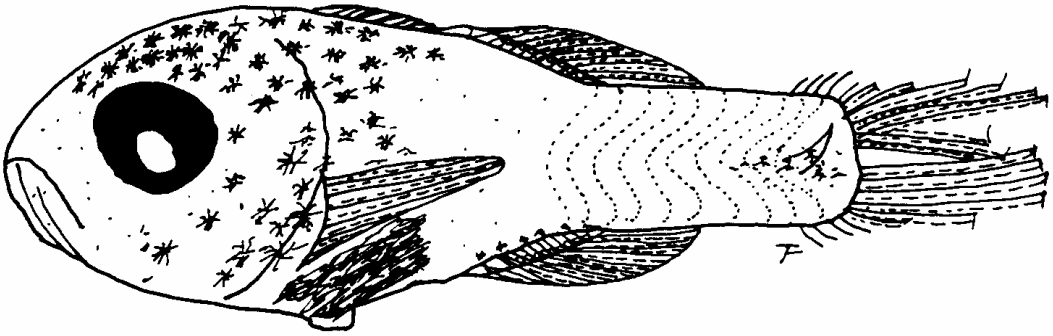


Figure 4.21 MSSAFL6. *Apogon* species 4. SL: 9.0 mm. Nine samples. D: VI+I, 9, A: II, 8, C: 17, P: 13, V: 24. Morphometric measurements in average for the 9 samples are given in (mm): TL: 11.2, SL: 9.2, PAL: 5.2, PDL: 3.5, HL: 3.5, SnL: 1.0, ED: 1.3, BD: 3.2. Collected in July.

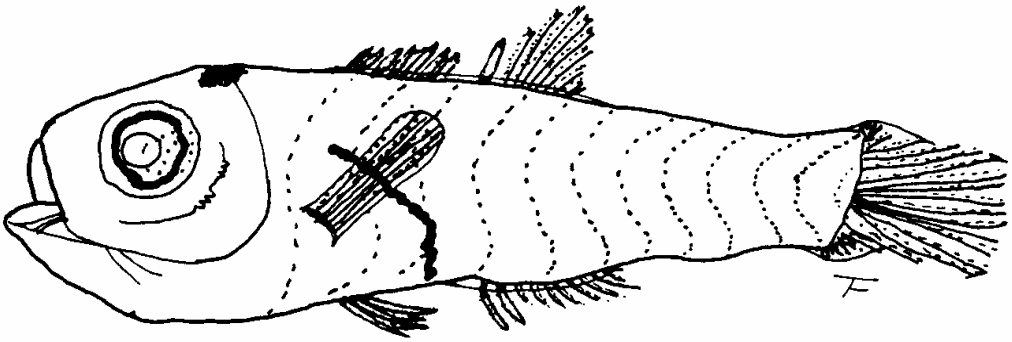


Figure 4.22 MSSAFL7. *Apogon* species 5. SL: 8.8 mm. Three samples. D: VI+I, 8, A: II, 8, C: 17, P: 13, V: 24. Morphometric measurements in average for the three samples are given in (mm): TL: 11.2, SL: 8.8, PAL: 4.8, PDL: 3.2, HL: 2.8, SnL: 0.8, ED: 1.0, BD: 2.6. Collected in June and July.

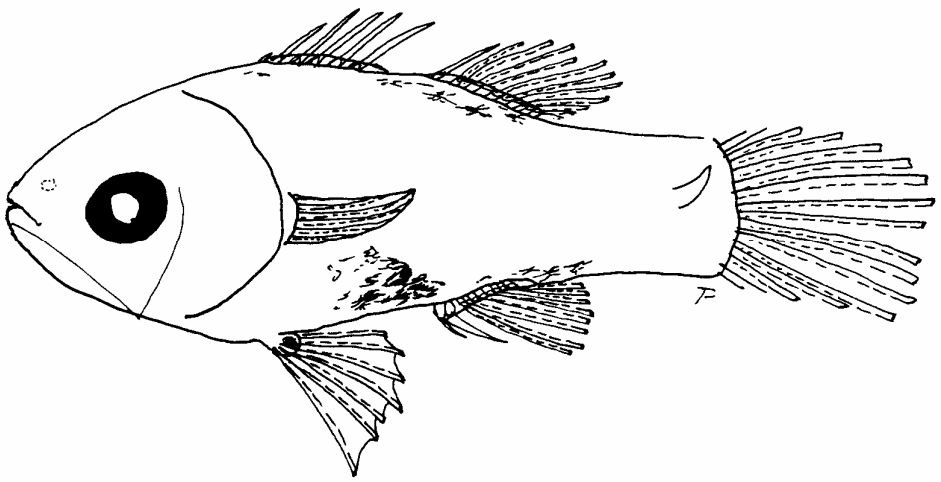


Figure 4.23 MSSAFL8. , *Apogon* or *Cheilodipterus* species 1. One sample. D: VI+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements are given in (mm): TL: 11.5, SL: 9.0, PAL: 5.5, PDL: 3.5, HL: 3.7, SnL: 1.0, ED: 1.0, BD: 3.8. Collected in June.

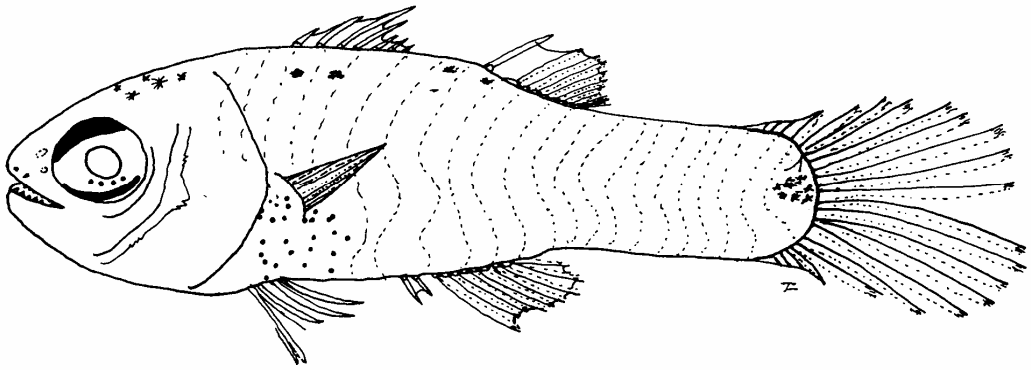


Figure 4.24 MSSAFL9. Apogon or *Cheilodipterus* species 2. SL: 15.5 mm. Three samples. D: VI+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements in average for the 3 samples are given in (mm): TL: 19.3, SL: 15.5, PAL: 8.7, PDL: 6.0, HL: 5.2, SnL: 1.3, ED: 2.0, BD: 5.2. Collected in June.

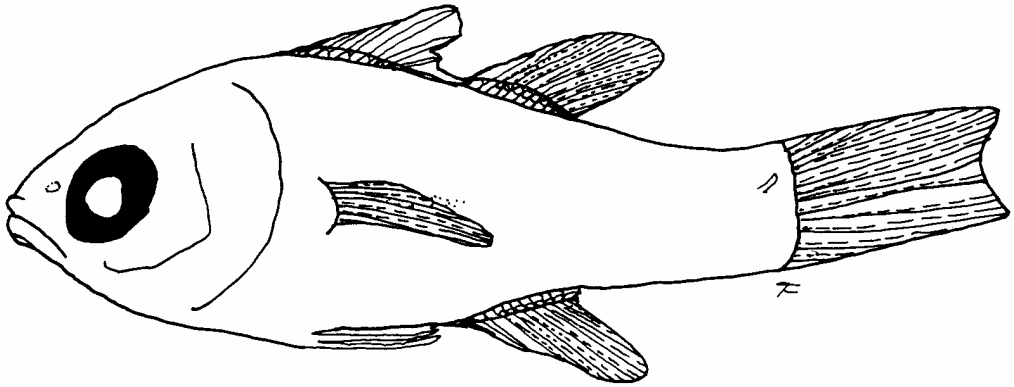


Figure 4.25 MSSAFL10. *Apogon* or *Cheilodipterus* species 3. SL: 9.5 mm, two samples. D: VII+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements in average for the two samples are given in (mm): TL: 12.0, SL: 9.5, PAL: 5.7, PDL: 3.8, HL: 3.5, SnL: 0.83, ED: 1.2, BD: 3.5. Collected in July and August.

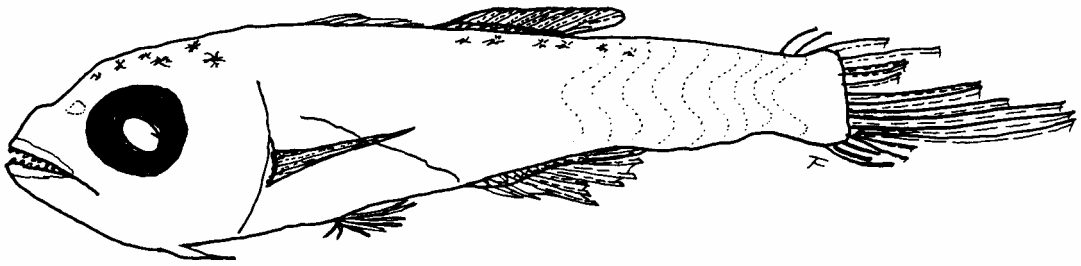


Figure 4.26 MSSAF11. *Apogon* or *Cheilodipterus* species 4. One sample. D: VI+I, 9, A: II, 8, C: 17, P: 13, V: 24. Morphometric measurements are given in (mm): TL: 12.5, SL: 10.3, PAL: 6.0, PDL: 3.8, HL: 3.2, SnL: 0.83, ED: 1.5, BD: 1.6. Collected in June.

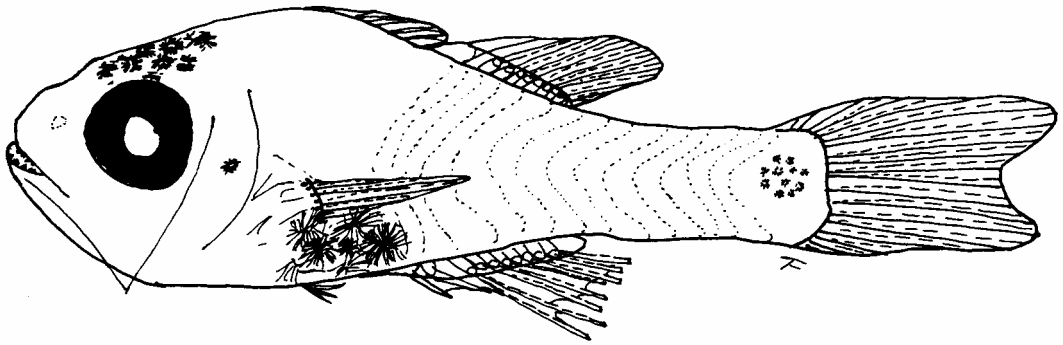


Figure 4.27 MSSAFL12. *Apogon* or *Cheilodipterus* species 5. SL: 10.0 mm, twelve samples. D: VI+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements in average for the 12 samples are given in (mm): TL: 12.7, SL: 10.2, PAL: 5.5, PDL: 4.0, HL: 3.3, SnL: 0.83, ED: 1.3, BD: 3.3. Collected in July.

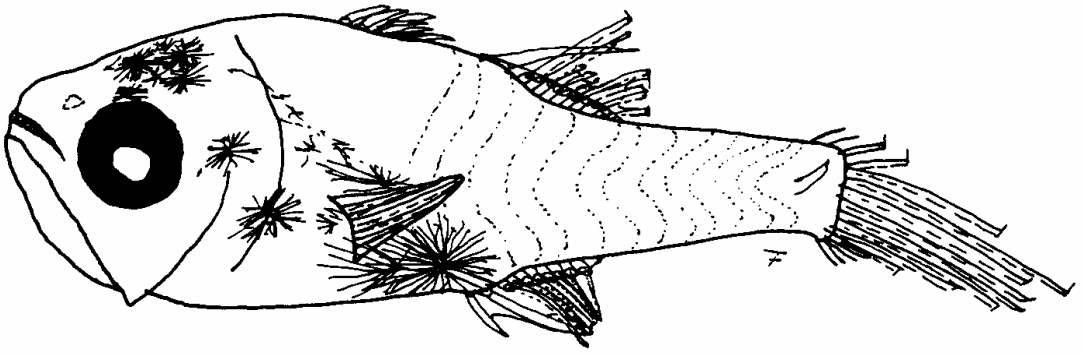


Figure 4.28 MSSAFL13. *Apogon* or *Cheilodipterus* species 6. One sample. D: VI+I, 9, A:II, 8, C: 17, P: 14, V: 24. Morphometric measurements are given in (mm): TL: 10.8, SL: 5.1, PAL: 4.8, PDL: 3.3, HL: 2.8, SnL: 0.83, ED: 1.2, BD: 3.0. Collected in July.

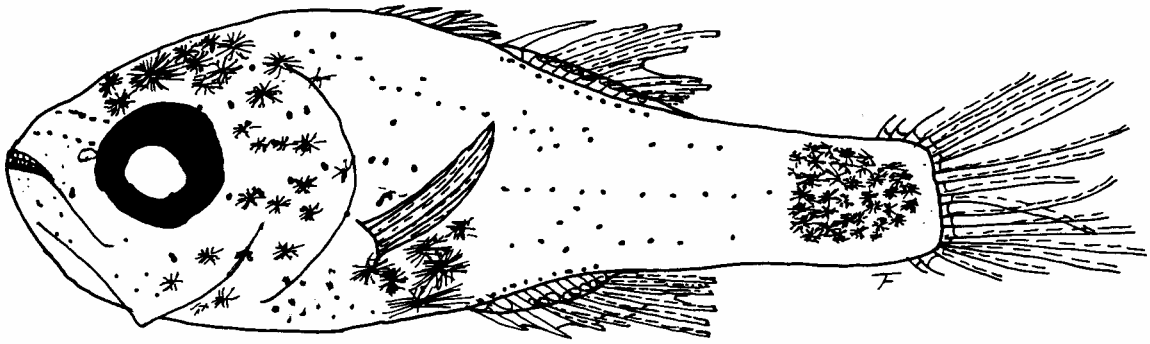


Figure 4.29 MSSAFL14. *Apogon* or *Cheilodipterus* species 7. SL: 10.2 mm, two samples. D: VI+I, 9, A:II, 8, C: 17, P: 14, V: 24. Morphometric measurements in average for the 2 samples are given in (mm): TL: 12.3, SL: 10.1, PAL: 5.4, PDL: 3.8, HL: 3.5, SnL: 1.2, ED: 1.5, BD: 3.8. Collected in July.

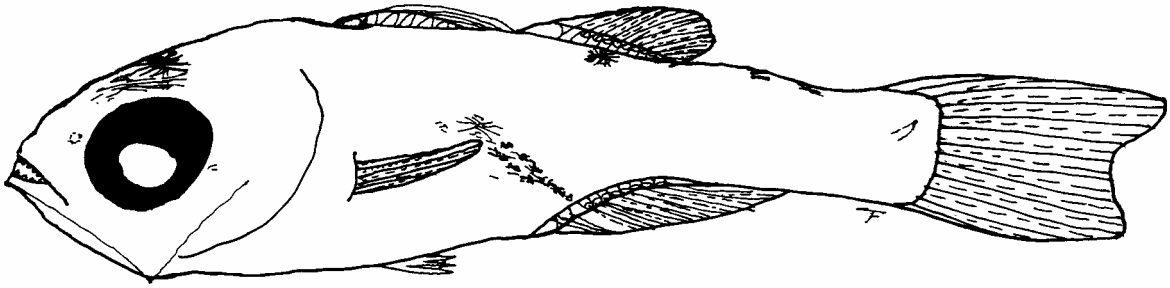


Figure 4.30 MSSAFL15. *Apogon* or *Cheilodipterus* species 8. SL: 8.2 mm, nine samples. D: VII+I, 9, A: II, 8, C: 17, P: 13, V: 24. Morphometric measurements in average for the 9 samples are given in (mm): TL: 10.5, SL: 8.1, PAL: 4.7, PDL: 2.8, HL: 3.0, SnL: 0.83, ED: 1.0, BD: 2.3. Collected in July.

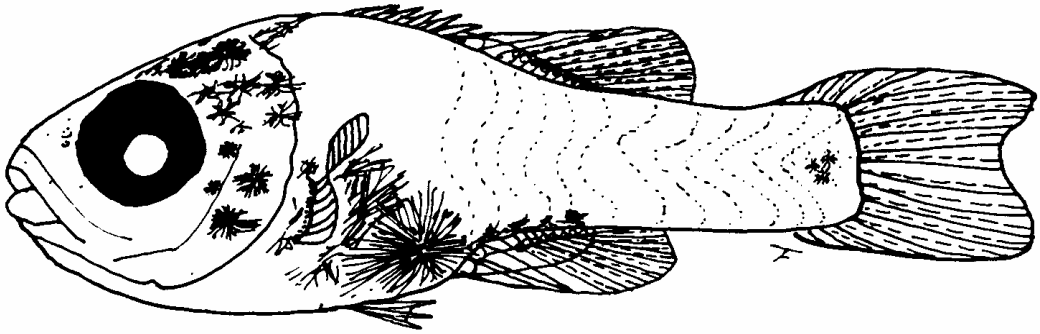


Figure 4.31 MSSAFL16. *Apogon* or *Cheilodipterus* species 9. SL: 9.0 mm, two samples. D: VI+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements in average fro the 2 samples are given in (mm): TL: 11.0, SL: 9.0, PAL: 5.2, PDL: 3.5, HL: 3.5, SnL: 0.84, ED: 1.3, BD: 1.7. Collected in July.

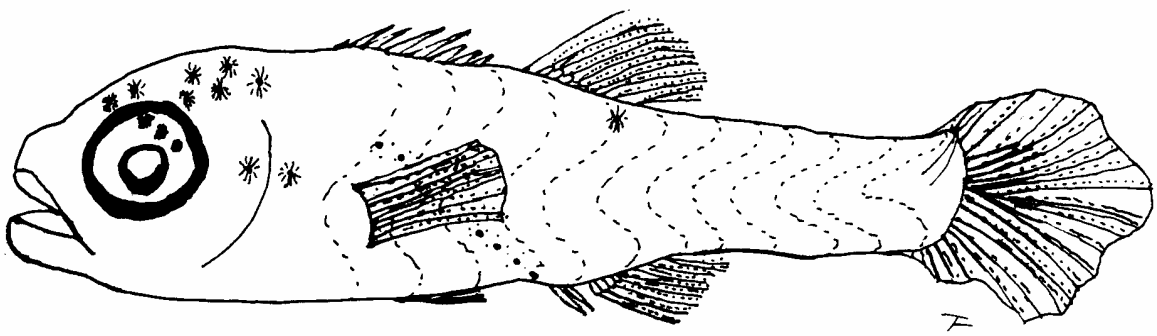


Figure 4.32 MSSAFL17. *Apogon* or *Cheilodipterus* species 10. SL: 8.8 mm. Five samples. D: VII+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements in average for the 5 samples are given in (mm): TL: 10.8, SL: 8.8, PAL: 5.1, PDL: 3.6, HL: 3.1, SnL: 0.8, ED: 1.3, BD: 2.5. Collected in June and July.

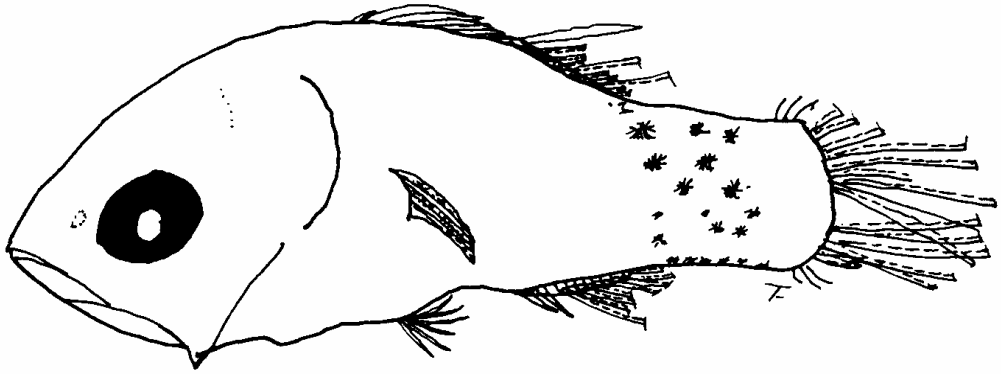


Figure 4.33 MSSAFL19. *Apogon* or *Apogonichthys* or *Fowleria* or *Siphamia* species 1. One sample. D: VII+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements are given in (mm): TL: 8.0, SL: 6.3, PAL: 4.0, PDL: 2.5, HL: 2.2, SnL: 0.67, ED: 0.83, BD: 2.3. Collected in June.

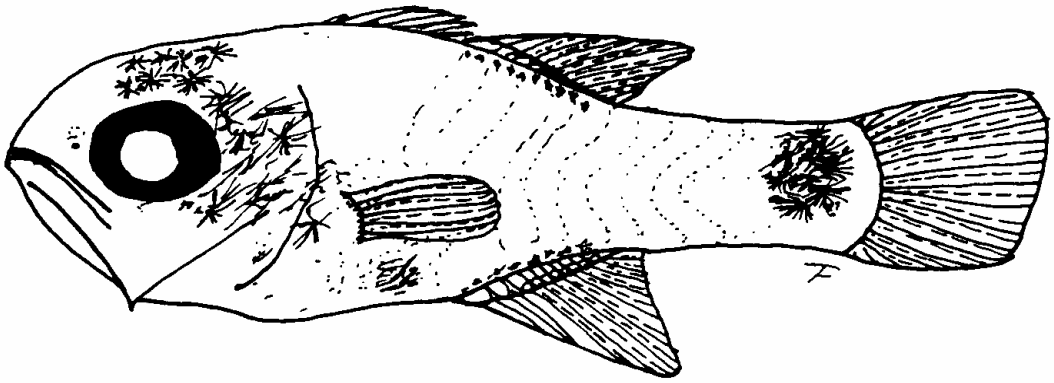


Figure 4.34 MSSAFL20. *Apogon* or *Apogonichthys* or *Fowleria* or *Siphamia* species 2. One sample. D: VII+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements are given in (mm): TL: 13.2, SL: 10.2, PAL: 5.2, PDL: 4.0, HL: 3.5, SnL: 1.0, ED: 1.5, BD: 3.5. Collected in June.

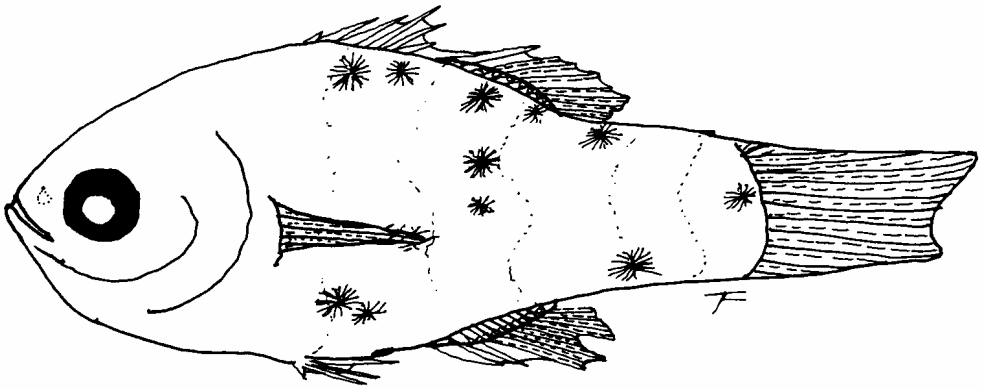


Figure 4.35 MSSAFL21. *Apogon* or *Apogonichthys* or *Fowleria* or *Siphamia* species.3. One sample. D: VII+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements are given in (mm): TL: 13.2, SL: 10.3, PAL: 6.7, PDL: 4.2, HL: 3.8, SnL: 0.83, ED: 1.3, BD: 4.2. Collected in May.

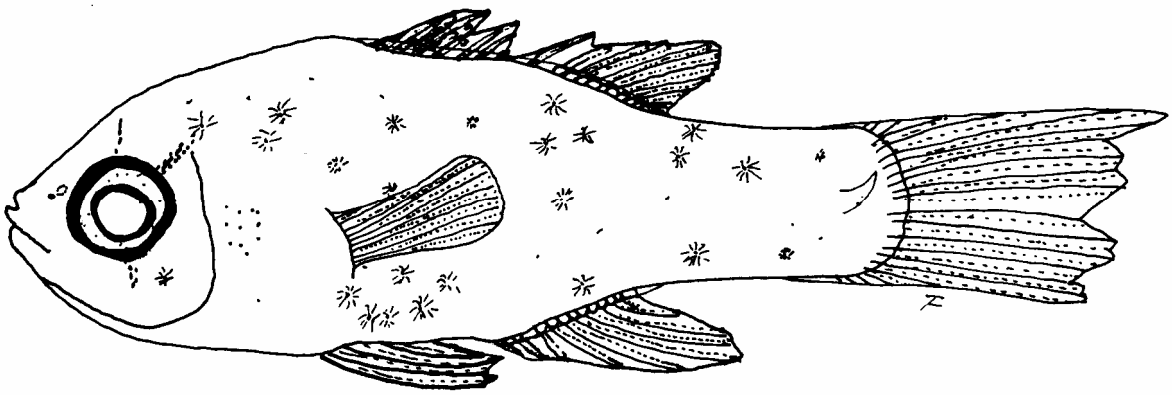


Figure 4.36 MSSAFL22. *Apogon* or *Apogonichthys* or *Fowleria* or *Siphamia* species 4. Four samples. D: VII+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements in average for the 4 samples are given in (mm): TL: 14.8, SL: 11.3, PAL: 7.5, PDL: 5.0. HL: 4.8, SnL: 1.2, ED: 0.94, BD: 4.3. Collected in May and October.

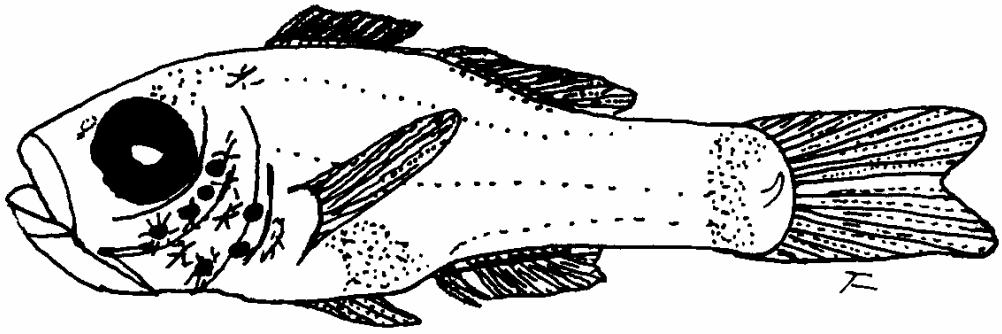


Figure 4.37 MSSAFL23. *Apogon* or *Apogonichthys* or *Fowleria* or *Siphamia* species 5. Five samples. D: VII+I, 9, A: II, 8, C: 17, P: 14, V: 24. Morphometric measurements in average for the 5 samples are given in (mm): TL: 13.2, SL: 10.2, PAL: 5.8, PDL: 3.8, HL: 3.8, SnL: 1.2, ED: 1.5, BD: 3.5.Collected in July and August.

4.6.2 Lutjanidae (Snappers)

They are represented in this thesis by *Lutjanus* species. Their morphological character includes: laterally compressed with moderate body in their post-flexion stage and coiled long gut. The head was large and moderately compressed with large eye and elongated snout. Head spination is well developed in the *Lutjanus* species. Melanophores were present on the dorsal surface of the gut. Some pigments found on the brain as well. (Figure 4.38 & Plate 29)

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentages	62 %	37 %	36 %	7 %	38 %	33 %

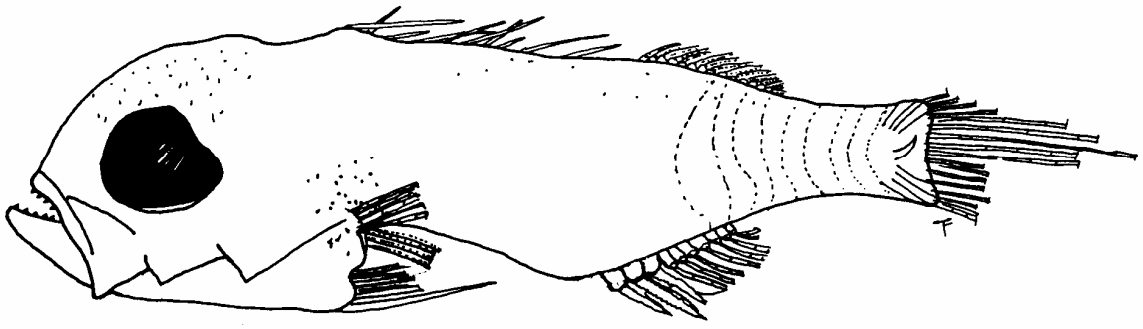


Figure 4.38 MSSAFL61. *Lutjanus* species. One sample. D: X, 14, A: III, 7, C: 17, P: 17, V: 24. Morphometric measurements are given in (mm): TL: 16.3, SL: 13.5, PAL: 8.3, PDL: 5.0, HL: 4.8, SnL: 1.0, ED: 1.8, BD: 4.5. Collected in April.

4.6.3 Serranidae (Groupers, Seabas, Rockcods, Hinds and Lyretails)

Two different genera have been collected through this study: *Plectranthias winniensis*, which is recorded for the first time from the Jordanian coast of the Gulf of Aqaba, and *Epinephelus* species. The body shape of the *Plectranthias* species is deep with a narrow caudal peduncle and coiled long gut. Their head is moderate in size with extensive spination with moderate to large eye. The snout is short, round and moderately sloped. The mouth is large reaching beyond the middle of the eye. *Plectranthias* species are not heavily pigmented except for the brain where the pigments series have few melanophores. On the

other hand, the *Epinephelus* species have moderate to compressed body depth, tightly coiled gut, large head with short and blunt snout, and some spinations on the head. *Epinephelus* pre-flexion larvae have melanophore over the gut. Small larval teeth are exerted on the premaxilla in pre-flexion *Epinephelus* larvae (Figure 4.39-4.40 & Plates 30-31).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	64 %	32 %	3 – 4 %	6 – 7 %	31 – 34 %	35 – 41 %

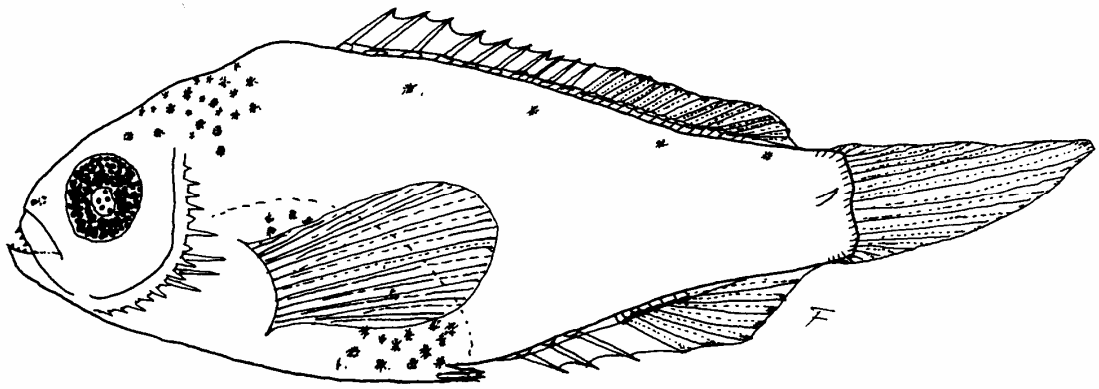


Figure 4.39 MSSAFL53. *Plectranthias winniensis*. SL: 16.0. Three samples. D: X, 17, A: III, 7, C: 17, P: 15, V: 24. Morphometric measurements for the 3 samples are given in (mm): TL: 19.0, SL: 16.0, PAL: 10.2, PDL: 5.2, HL: 4.8, SnL: 1.0, ED: 1.7, BD: 6.5. Collected in April.

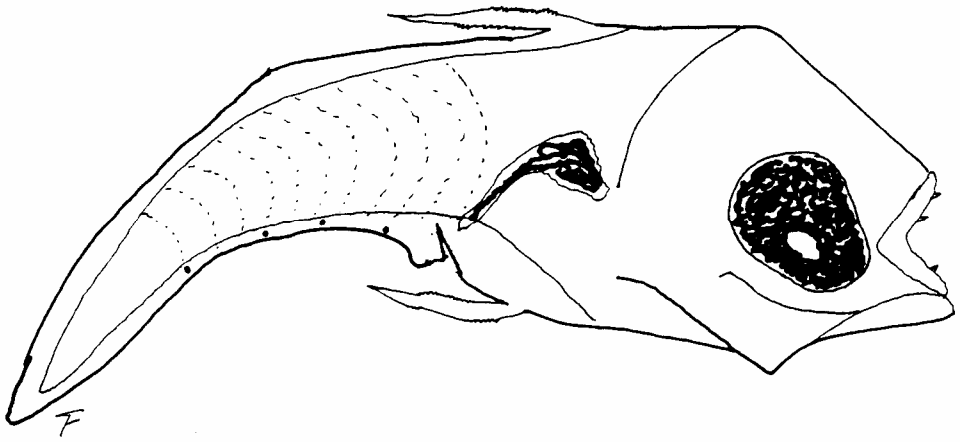


Figure 4.40 MSSAFL67. *Epinephelus* species. One sample. Morphometric measurements are given in (mm): TL: 3.9, SL: 3.5, HL: 1.4, SnL: 0.24, ED: 0.44, BD: 1.2. Collected in June.

4.6.4 Pempheridiidae (Sweepers)

Parapriacanthus ransonnari, which is recorded for the first time from the Jordanian coast of the Gulf of Aqaba, and *Pempheris* species are two different genera, which have been collected. They have moderate bodies as the long gut coils. The head is of large size having large eye and small rounded snout. The head spinations are limited. Pigments are found in the pre-flexion larval stage along the dorsal surface, the ventral surface, the gut, and the pelvic fin buds of the body (Figure 4.41 and 4.42 & Plates 32-33).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	51 – 56 %	43 %	33 – 37 %	7 – 11 %	39 – 42 %	34 – 39 %

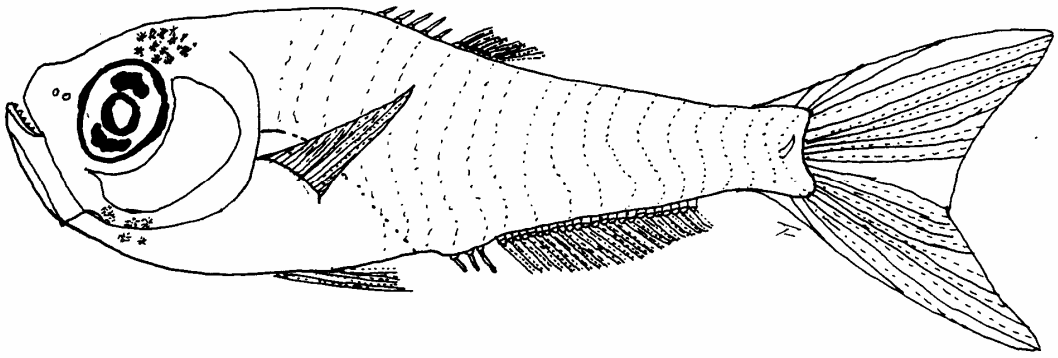


Figure 4.41 MSSAFL55. *Parapriacanthus ransonnari.* SL: 15.2 mm. Four samples. D: V, 7-8, A: III, 24, C: 17, P: 14, V: 25. Morphometric measurements in average for the 4 samples are given in (mm): TL: 18.8, SL: 15.2, PAL: 8.7, PDL: 6.7, HL: 5.2, SnL: 1.2, ED: 2.0, BD: 5.3. Collected in May.

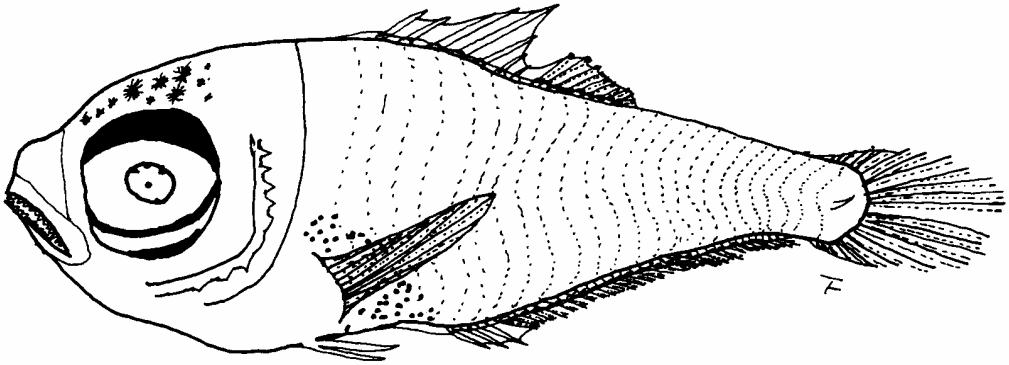


Figure 4.42 MSSAFL56. *Pempheris* species. SL: 8.3 mm. Five samples. D: VI, 9, A: III, 38, C: 17, P: 14, V: 25. Morphometric measurements in average for the five samples are in (mm): TL: 9.8, SL: 8.3, PAL: 4.2, PDL: 3.6, HL: 3.1, SnL: 0.9, ED: 1.3, BD: 3.3. Collected in May and June.

4.6.5 Plesiopidae (Longfins)

They are represented here by *Plesiops* species that is recorded for the first time from the Jordanian coast of the Gulf of Aqaba. which has moderate body depth. The gut is long and coiled. The head is large in size with moderate eye, short to moderate snout and large mouth. Their first pelvic ray is elongated. This species is lightly pigmented. Melanophores can be found on the dorsal surface of the posterior portion of the gut, another melanophore appears on the hindbrain (Figure 4.43& Plate 34)

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	56 %	34 %	36 %	9 %	29 %	29 %

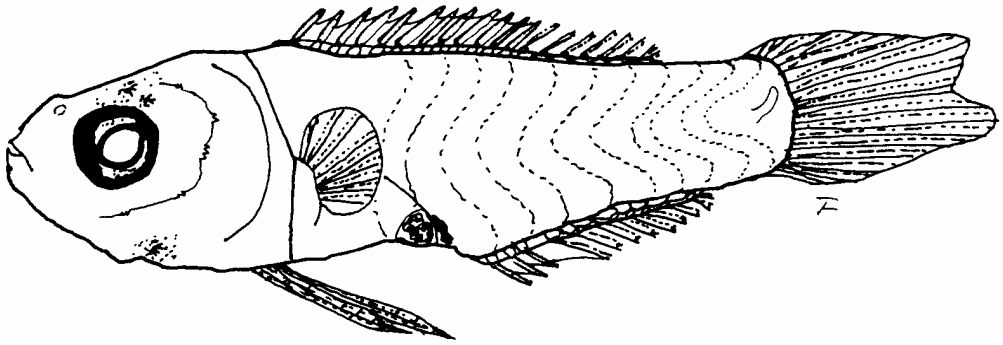


Figure 4.43 MSSAFL64. *Plesiops* species. One sample. D: XII, 7, A: III, 8, C: 17, P: 18, V: 25. Morphometric measurements are given in (mm): TL: 12.0, SL: 10.2, PAL: 5.7, PDL: 3.4, HL: 3.7, SnL: 1.0, ED: 1.1, BD: 3.0. Collected in July.

4.6.6 Pseudochromidae (Dottybacks)

Pseudochromis species are moderate in their body depth and laterally compressed after the flexion with little pigmentation. The gut at this stage of development is long and coiled extending to the middle of the body. They have moderate heads with moderate eye and short to moderate, and pointed snout.

(Figure 4.44 & Plate 35).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	56 %	32 %	28 %	8 %	32 %	27 %

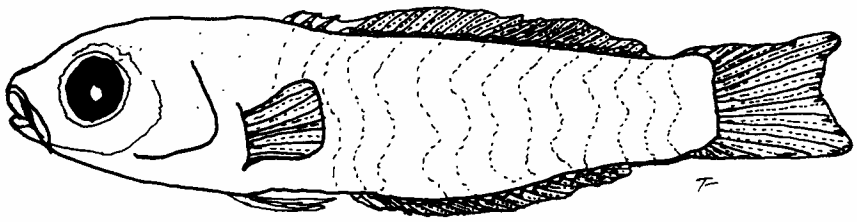


Figure 4.44 MSSAFL59. *Pseudochromis* species. SL: 13.0 mm. 2 samples. D: III, 26, A: III, 15, C: 17, P: 16, V: 26. Morphometric measurements in average for the 2 samples are given in (mm): TL: 15.2, SL: 13.0, PAL: 7.3, PDL: 4.2, HL: 3.7, SnL: 1.0, ED: 1.2, BD: 3.5. Collected in July.

4.6.7 Carangidae (Jacks, Trevallies and Queenfishes)

The collected genus from this family was *Decapterus* species, which is characterized by strongly compressed and moderate bodies. The gut is long and coiled. The head is large in the post-flexion larvae, which is usually roundly triangular having large eye. The snout is shortly to moderately convex by the post-flexion stage. Their mouth is oblique. This genus has melanophore series on the dorsal and ventral midline. Pigmentations usually occurs on the snout and brain and over the tip of the notochord (Figure 4.45 &Plate 36)

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	53 %	41 %	36 %	11 %	35 %	36 %

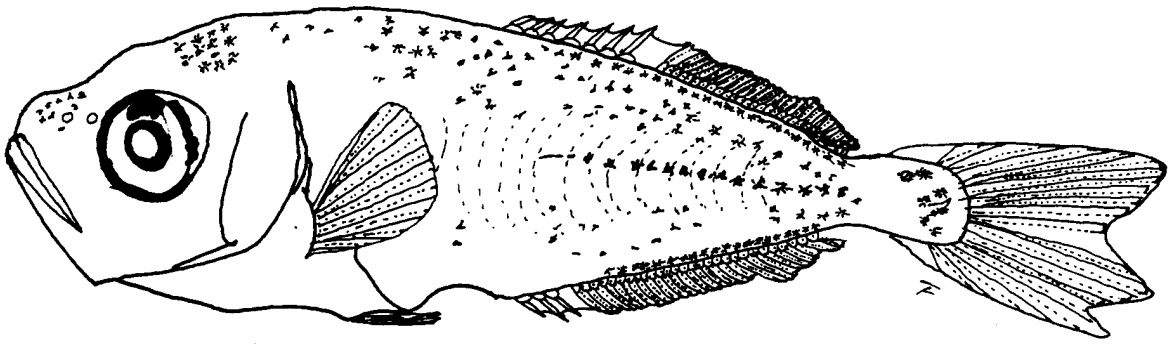


Figure 4.45 MSSAFL62. *Decapterus* species. 1 sample. D: VII, 26-28, A: III, 27-29, C: 19, P: 22,V: 24. Morphometric measurements are given in (mm): TL: 14.0, SL: 12.2, PAL: 6.5, PDL: 5.0, HL: 4.3, SnL: 1.3, ED: 1.5, BD: 4.3. Collected in April.

4.6.8 Pomacentridae (Damselfishes)

Pomacentrid larvae are slender, moderate to deep bodies, laterally compressed and usually have hunchback appearance by flexion. They have triangular gut which is tightly coiled and compacted varying from long to very long, but may extend beyond the mid of the body. Flexion and Post-flexion larvae have a moderate to large deep bodies. The head is large and laterally compressed with moderate to large eye and slightly elongated snout. They have also, moderate mouth reaching the anterior edge of the eye. Head spination is usually weak and consists of several small spines on the opercle region. Many specie are heavily pigmented during flexion, in which they may be found in all over the areas of the body with exception of the caudal fin rays (Figures 4.46- 4.63 &Plates 37-53)

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	51 – 73 %	33 – 46 %	25 – 59 %	8 – 12 %	25 – 53 %	33 – 61 %

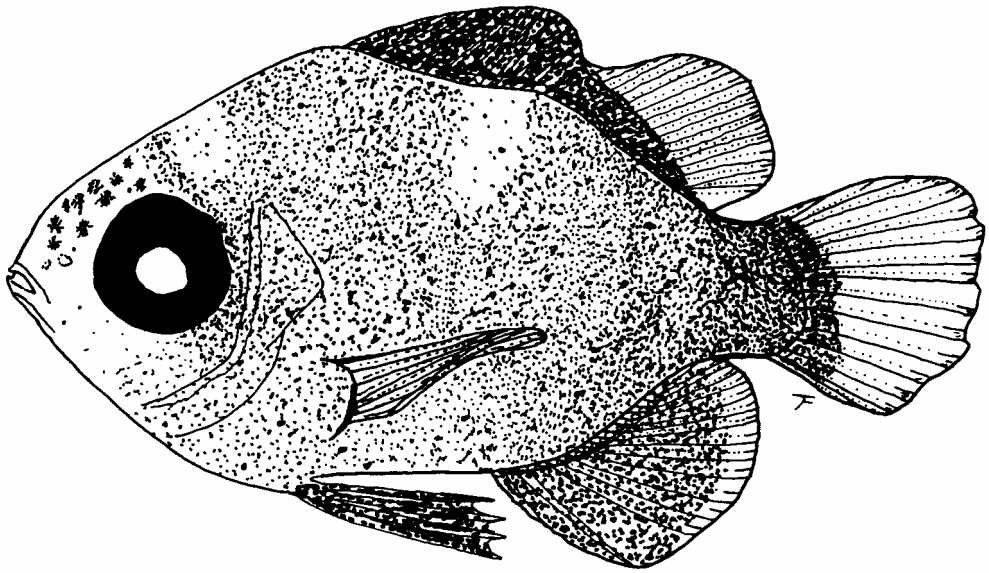


Figure 4.46 MSSAFL24. *Amphiprion bicinctus.* SL: 10.8 mm. Eight samples. D: XI, 15, A: II, 14, C: 17, P: 18, V: 26. Morphometric measurements for the 8 samples are given in (mm): TL: 13.0, SL: 10.8, PAL: 6.8, PDL: 4.3, HL: 4.7, SnL: 1.0, ED: 2.0, BD: 6.2. Collected in October.

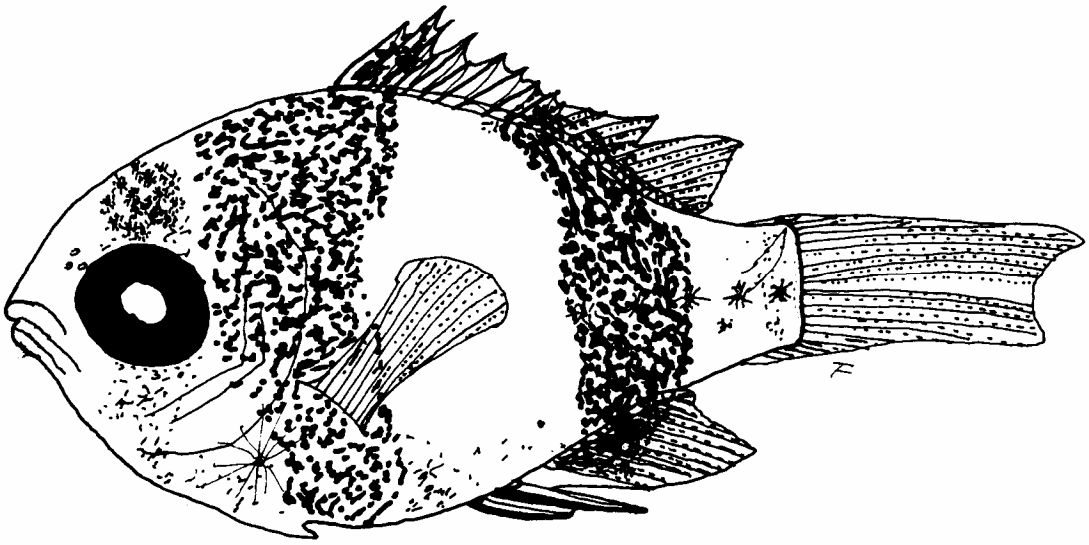


Figure 4.47 MSSAFL26. *Dascyllus aruanus*. One sample. D: XI, 13, A: II, 11, C: 16, P: 17, V: 26. Morphometric measurements are given in (mm): TL: 9.8, SL: 7.3, PAL: 4.5, PDL: 3.2, HL: 3.3, SnL: 0.75, ED: 1.3, BD: 4.3. Collected in October.

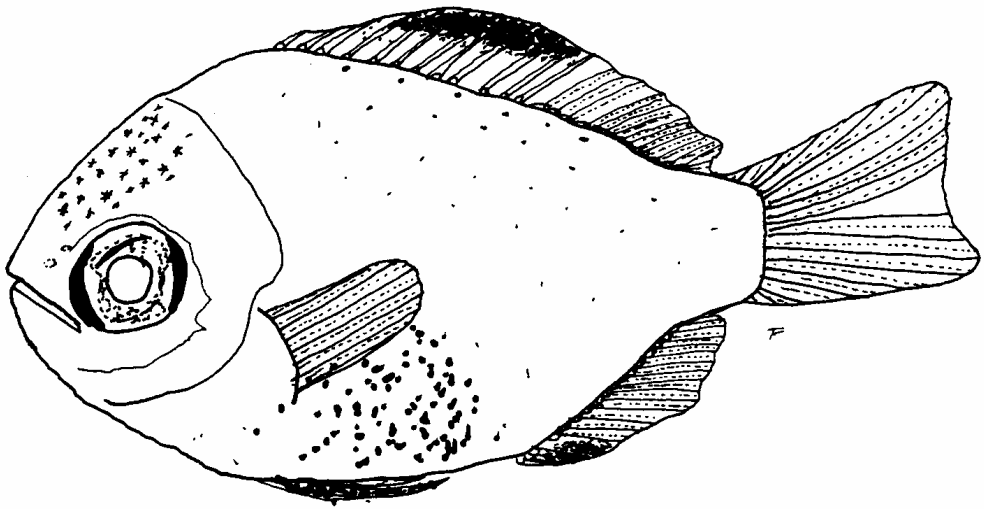


Figure 4.48 MSSAFL25. *Dascyllus marginatus*. One sample. D: XII, 14, A: II, 13, C: 17, P: 17, V: 26. Morphometric measurements are given in (mm): TL: 11.0, SL: 9.0, PAL: 5.5, PDL: 3.7, HL: 3.7, SnL: 0.83, ED: 1.5, BD: 5.3. Collected in July

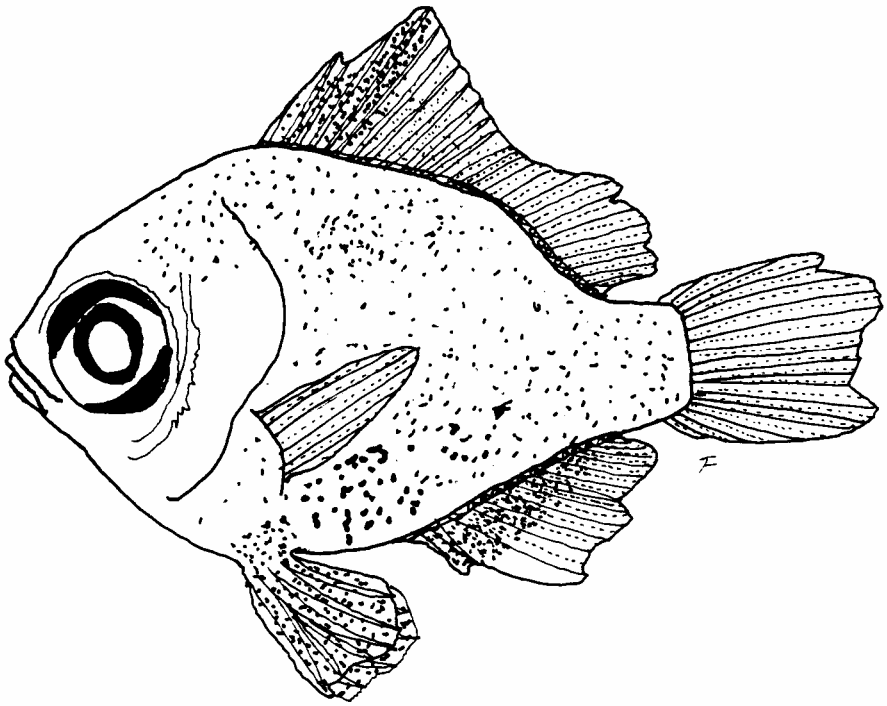


Figure 4.49 MSSAFL27. *Dascyllus* species. One sample. D: XII, 14, A: II, 14, C: 17, P: 18, V: 26. Morphometric measurements are given in (mm): TL: 13.0, SL: 9.5, PAL: 6.0, PDL: 4.2, HL: 3.8, SnL: 0.83, ED: 1.5, BD: 5.8. Collected in June.

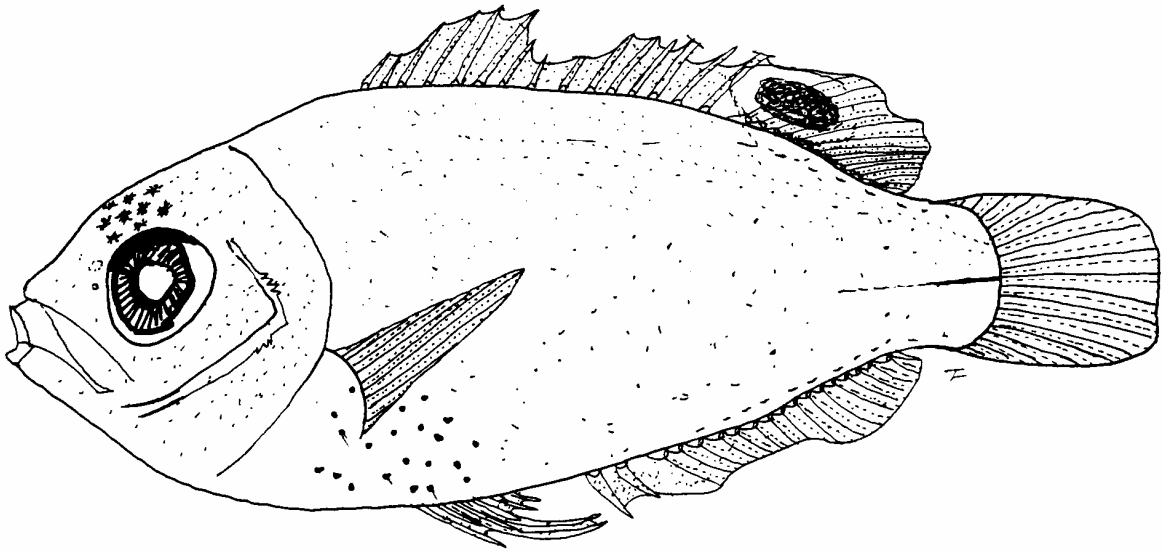


Figure 4.50 MSSAFL28. *Pomacentrus* species 1. Thirty-Three samples. SL: 12.0 mm. D: XIV, 14, A: II, 16, C: 17, P: 18, V: 26. Morphometric measurements in average for the 33 samples are given in (mm): TL: 14.0, SL: 12.1, PAL: 7.0, PDL: 4.3, SnL: 1.2, ED: 1.5, BD: 5.3. Collected in June and July.

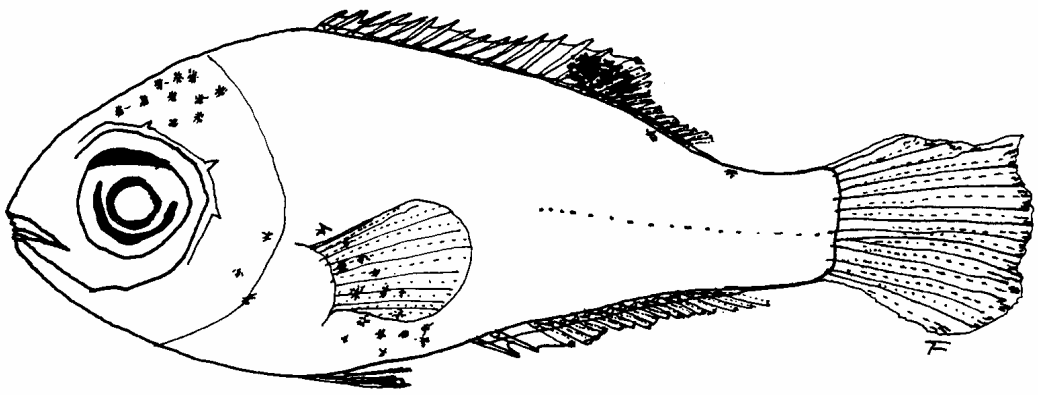


Figure 4.51 MSSAFL29. *Pomacentrus* species 2. One sample. D: XIV, 15, A: II, 16, C: 17, P: 18, V: 26. Morphometric measurements are given in (mm): TL: 14.8, SL: 12.8, PAL: 5.6, PDL: 4.2, HL: 4.2, SnL: 1.2, ED: 1.5, BD: 5.3. Collected in May.

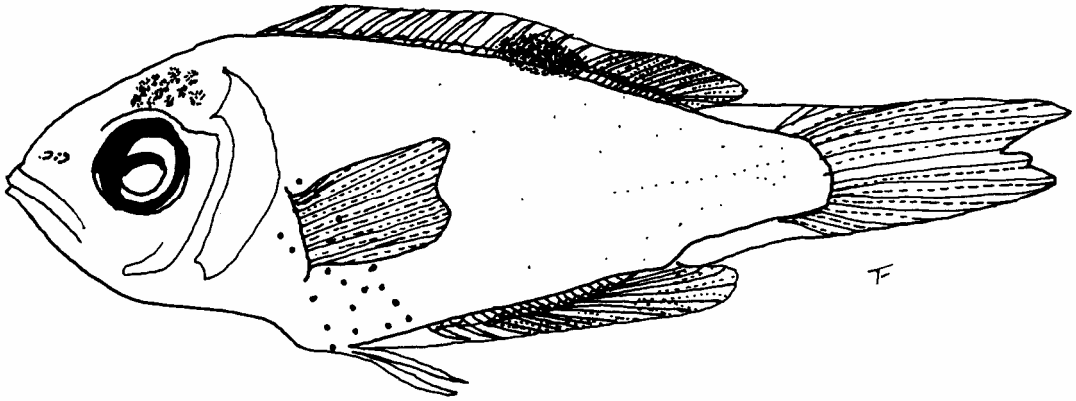


Figure 4.52 MSSAFL30. *Pomacentrus* species 3. SL: 10.8 mm. Four samples. D: XIV, 13, A: II, 15, C:17, P: 17, V: 26. Morphometric measurements for the 4 samples are given in (mm): TL: 14.2, SL: 10.8, PAL: 6.2, PDL: 3.7, HL: 4.0, SnL: 1.0, ED: 1.3, BD: 4.5. Collected in July.

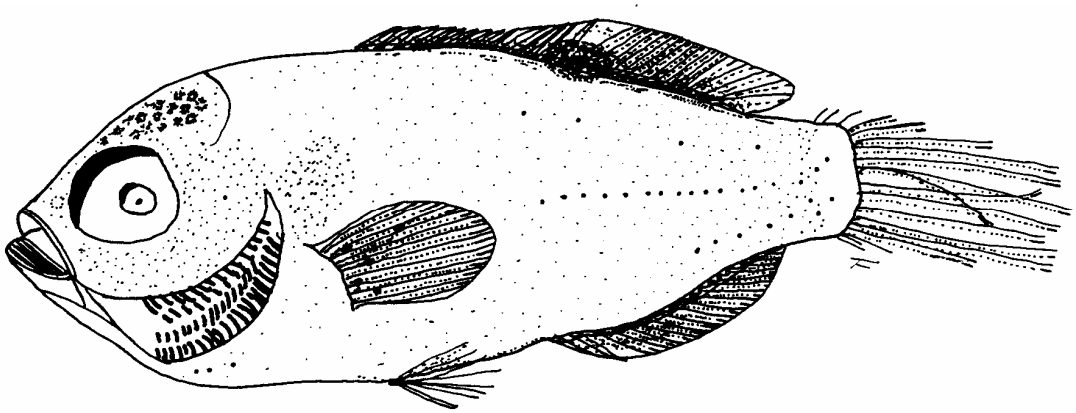


Figure 4.53 MSSAFL31. *Pomacentrus* species 4. One sample. D: XIV, 15, A: II, 16, C: 17, P: 17, V: 26. Morphometric measurements are given in (mm): TL: 15.5, SL: 12.2, PAL: 6.8, PDL: 4.7, HL: 4.3, SnL: 1.0, ED: 1.7, BD: 5.0. Collected in May.

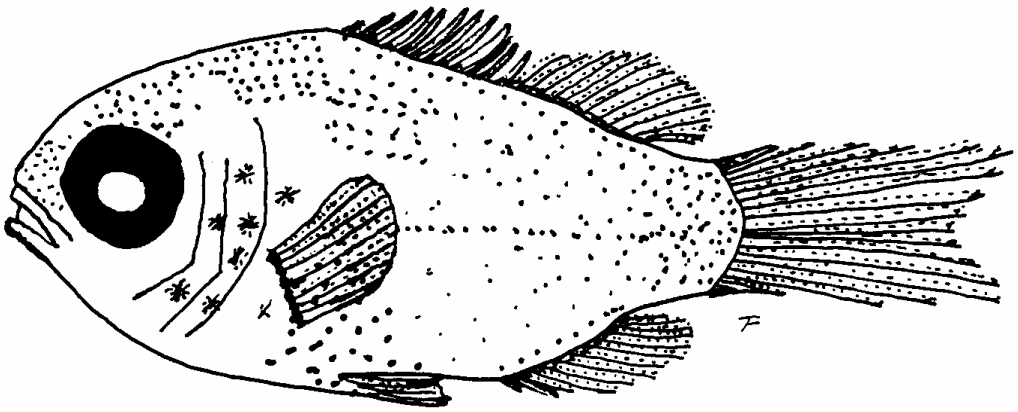


Figure 4.54 MSSAFL32. *Chromis* species 1. SL: 8.1mm. Six samples. D: XII, 10, A: II, 10, C: 17, P: 17, V: 26. Morphometric measurements in average for the 6 samples are given in (mm): TL: 9.6, SL: 8.1, PAL: 4.9, PDL: 3.6, SnL: 0.75, ED: 1.4, BD: 3.5. Collected in July.

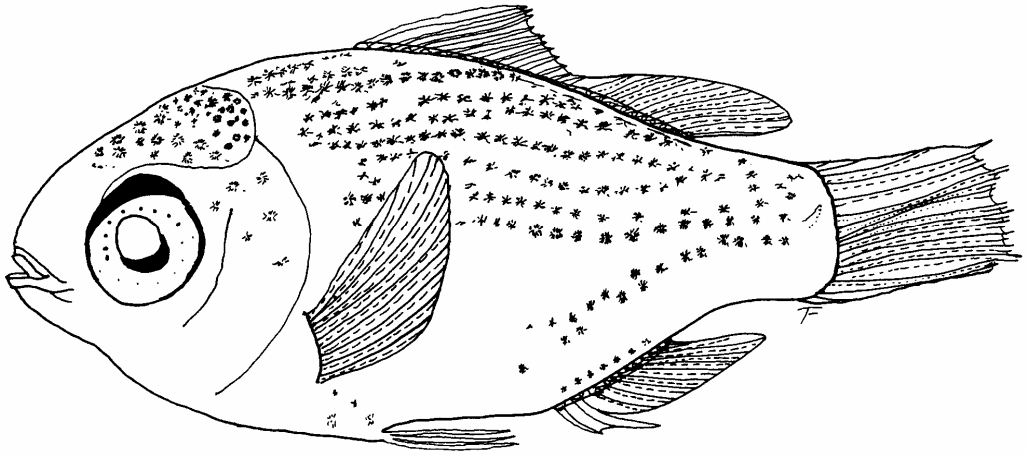


Figure 4.55 MSSAFL33. *Chromis* species 2. SL: 8.8mm. Four samples. D: XII, 13, A: II, 9, C: 17, P: 17, V: 26. Morphometric measurements in average for the 4 samples are given in (mm): TL: 11.7, SL: 8.8, PAL: 6.2, PDL: 4.0, HL: 5.2, SnL: 1.0, ED: 1.3, BD: 4.3. Collected in July and October.

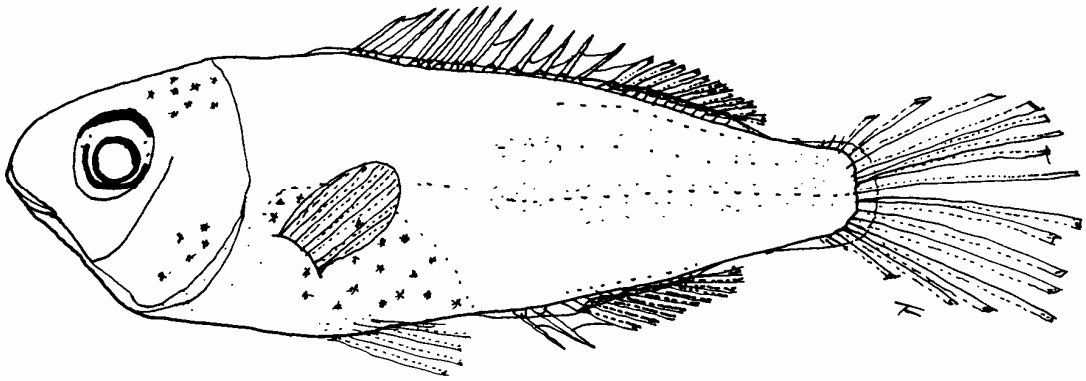


Figure 4.56 MSSAFL 34. *Neopomacentrus* species 1. SL: 13.5mm. Eighteen samples. D: XIII, 12. A: II, 11, C: 17, P: 18, V: 26. Morphometric measurements in average for the 18 samples are given in (mm): TL: 15.7, SL 13.5, PAL: 9.7, PDL 6.0, HL: 5.4, SnL: 1.5, ED: 1.7, BD: 5.6. Collected in May.

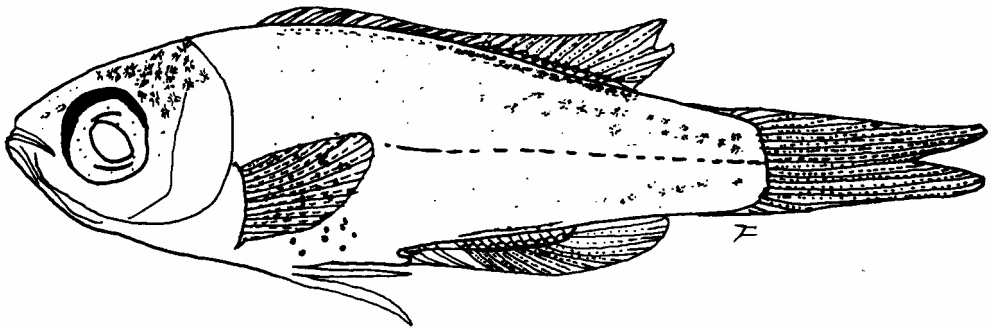


Figure 4.57 MSSAFL35. *Neopomacentrus* species 2. SL: 13.5mm. Four samples. D: XIII, 12, A: II, 11, C: 17, P: 17, V: 26. Morphometric measurements in average for the 4 samples are given in (mm): TL: 17.3, SL: 13.5, PAL: 8.3, PDL: 4.8, HL: 4.5, SnL: 1.2, ED: 1.7, BD: 4.5. Collected in June.

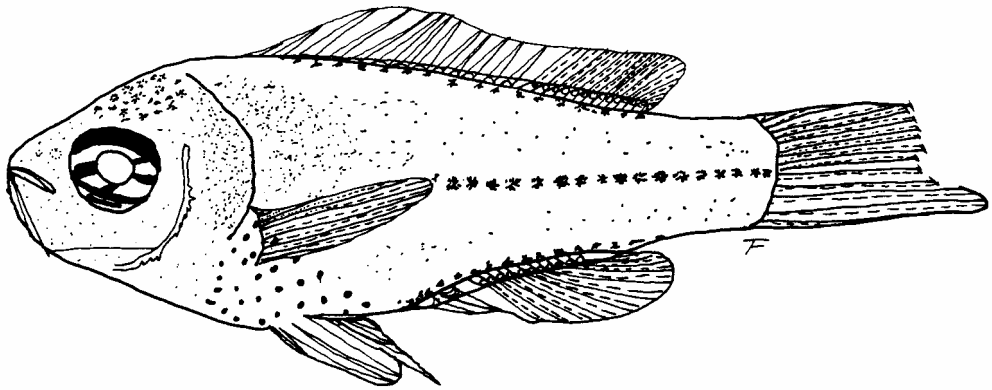


Figure 4.58 MSSAFL36. *Neopomacentrus* species 3. SL: 14.0. Thirty-One samples. D: XII, 12, A: II, 11, C: 17, P: 17, V: 26. Morphometric measurements in average for the 31 samples are given in (mm): TL: 18.0, SL: 14.0, PAL: 8.3, PDL: 4.8, HL: 3.7, SnL: 1.3, ED: 1.7, BD: 5.2. collected in April and May.

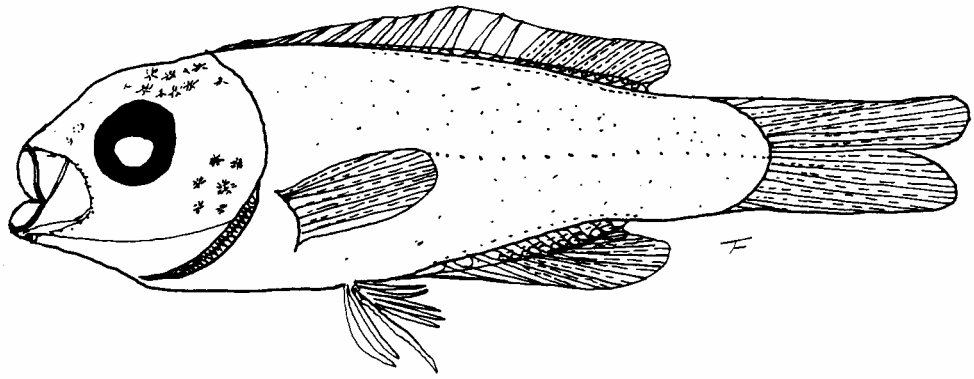


Figure 4.59 MSSAFL37. Pomacentridae genus 1. One sample. D: XIII, 12, A: II, 11, C: 17, P: 18, V: 26. Morphometric measurements are given in (mm): TL: 17.2, SL: 13.8, PAL: 8.5, PDL: 5.7, HL: 5.2, SnL: 1.7, ED: 1.7, BD: 4.5. Collected in June.

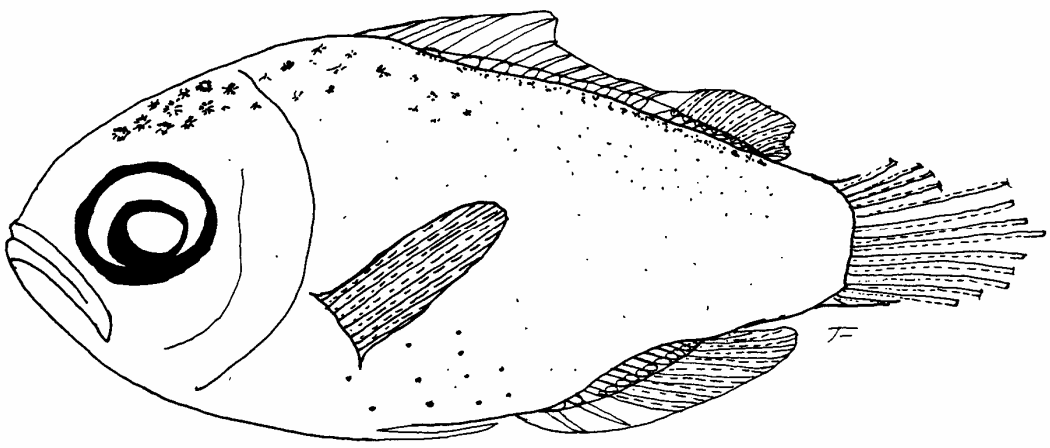


Figure 4.60 MSSAFL38. Pomacentridae genus 2. One sample. D: XI, 11, A: II, 10, C: 17, P: 18, V: 26. Morphometric measurements are given in (mm): TL: 10.2, SL: 8.2, PAL: 5.3, PDL: 3.7, HL: 3.2, SnL: 0.83, ED: 1.3, BD: 4.0. Colleted in July.

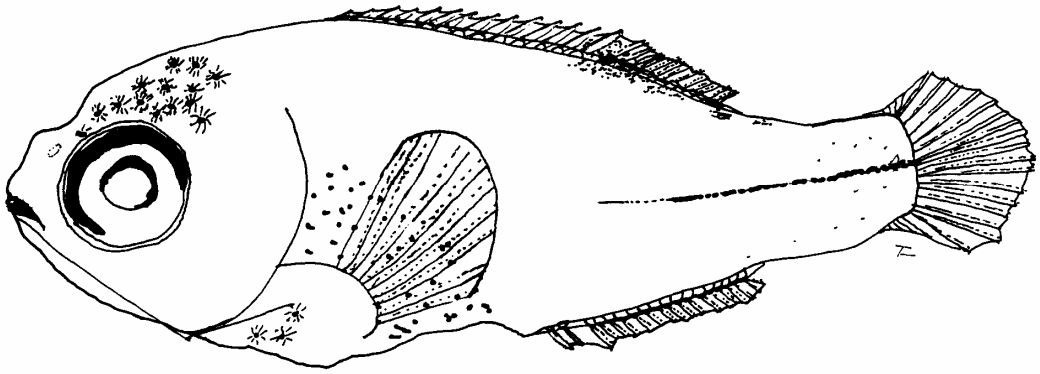


Figure 4.61 MSSAFL39. *Pomacentrus* or *Chrysiptera* species. Four samples SL: 9.5mm, 4 samples. D: XIV, 13, A: II, 15. C: 17, P: 18, V: 26. Morphometric measurements in average for the 4 samples are given in (mm): TL: 11.3, SL: 9.5, PAL: 6.5, PDL: 4.3, HL: 2.7, SnL: 1.1, ED: 1.4, BD: 3.7. Collected in July.

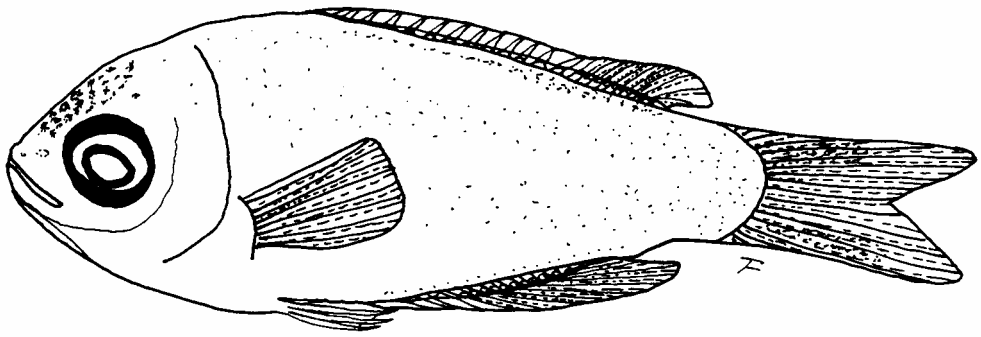


Figure 4.62 MSSAFL40. *Neopomacentrus* or *Chromis* species. One sample. D: XIII, 10, A: II, 11, C: 17, P: 18, V: 26. Morphometric measurements are given in (mm): TL: 17.7, SL: 13.8, PAL: 9.5, PDL: 5.5, HL: 4.8, SnL: 1.2, ED: 1.7, BD: 5.5. Collected in July.

4.6.9 Labridae (Wrasses)

The larvae are moderate in depth and laterally compressed. In our specimen the gut is long and coiled in the post-flexion stage. The head is laterally compressed, triangular and moderate in size with large eye and blunt snout. The mouth is small in its size. No pigmentations in our specimen have been noticed as well in the most of the other species of the labrid. (Figure 4.63 & Plate 54)

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	64 %	41 %	3 – 32 %	11 %	35 – 37 %	38 %

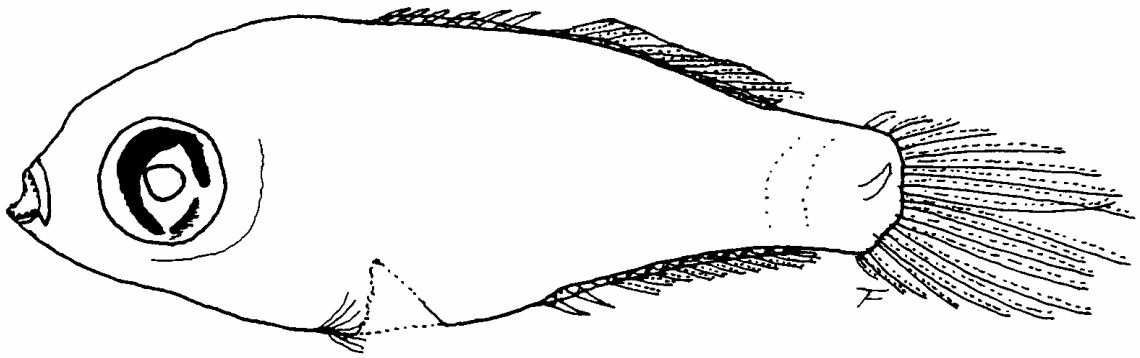


Figure 4.63 MSSAFL68. Labridae genus. SL: 6.6. Two samples. D: VI, 11, A: II, 11, C: 13. Morphometric measurements in average are given in (mm): TL: 8.0, SL: 6.6, PAL: 4.2, PDL: 2.7, ED: 0.73, BD: 2.5. Collected in May.

4.6.10 Blenniidae (Blennies)

The larvae of *Meiacanthus nigrolineatus* and *Cirripectes* species (recorded for the first time from the Jordanian coast of the Gulf of Aqaba) are of moderate depth with relatively coiled wide ranging from short, moderate to long gut. The head is rounded with short and rounded snout and large eye. The mouth is large in its size reaching the mid of the eye. Pigmentation of them are ranging from light to moderate. Tail pigmentations are typically located on the ventral midline. In these post-flexion samples the pigments varies from single broad posterior band to complete pigmentation on the dorsal and lateral sides of the larvae. Fin pigments are not common except on the tail (Figure 4.64-4.65 & Plates 55-56).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	29 – 53 %	5 – 31 %	1 – 36 %	6 – 52 %	38 – 39 %	29 – 36 %

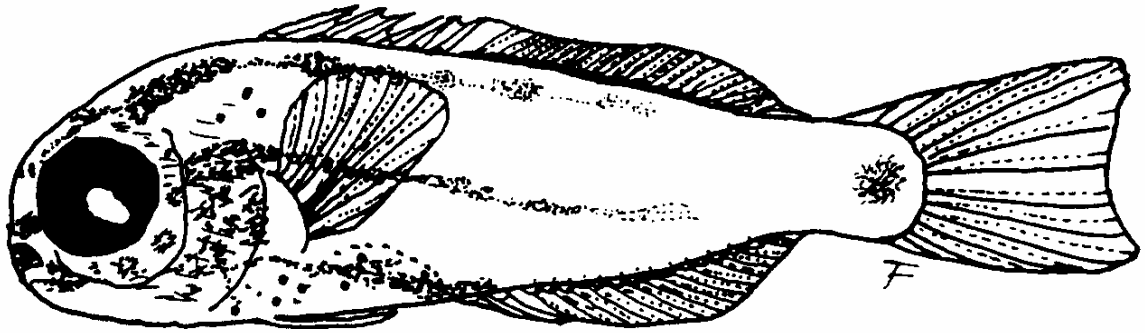


Figure 4.64 MSSAFL41. *Meiacanthus nigrolineatus*. One sample. D: IV, 23, A: II, 14, C: 14, P: 14. Morphometric measurements are given in (mm): TL: 12.8, SL: 10.4, PAL: 5.5, PDL: 3.2, HL: 3.8, SnL: 0.63, ED: 1.5, BD: 3.3. Collected in July.

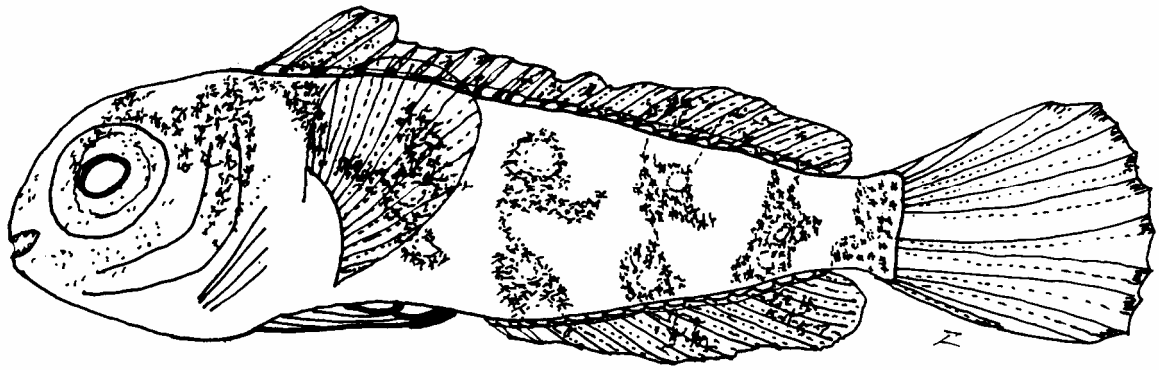


Figure 4.65 MSSAFL43. *Petroscirtes* species. One sample. D: XI, 15, A: II, 14, C: 11, P: 14. Morphometric measurements are given in (mm): TL: 14.0, SL: 11.0, PAL: 6.3, PDL: 3.0, HL: 4.1, SnL: 0.73, ED: 1.6, BD: 3.3. Collected in October.

Larvae of the *Cirripectes* species (recorded for the first time from the Jordanian coast of the Gulf of Aqaba) and *Ecsenius* species have moderate body size, which is laterally compressed in the post-flexion larvae with coiled long gut. Their head is round with moderate and slightly to very pointed snout in the post-flexion stage. The size of the eye is ranging from moderate to large. Hooked teeth are found on the flexion larval stage in the front of corners of the lower jaw and may found on the center of the upper jaw. In the *Cirripectes* species the lower teeth are curved forward and upward which are very large in the post-flexion larvae. They are lightly pigmented (Figures 4.66-4.72 & Plates 57-63)

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	49 – 54 %	21 – 27 %	28 – 41 %	4 – 8 %	29 – 38 %	23 – 37 %

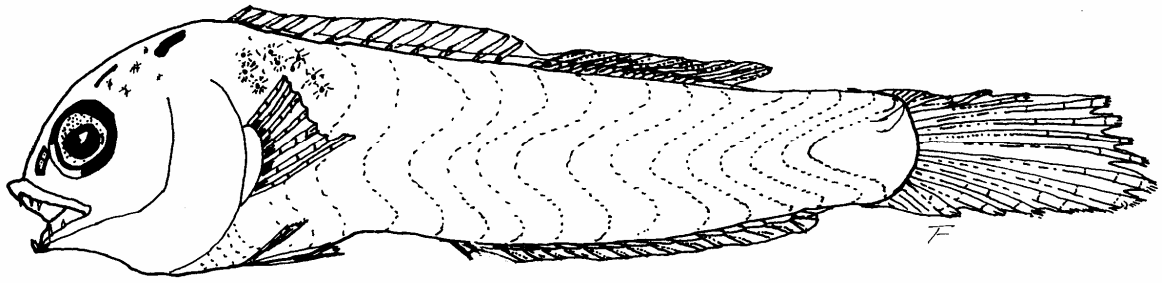


Figure 4.66 MSSAFL42. *Cirripectes* species. SL: 19.3mm. Two samples. D: XII, 14, A: II, 14, C: 13, P: 14, V: 30. Morphometric measurements in average for the 2 samples are given in (mm): TL: 24.5, SL: 19.3,PAL: 10.0, PDL: 4.3, HL: 5.5, SnL: 1.1, ED: 1.9, BD: 5.7. Collected in July.

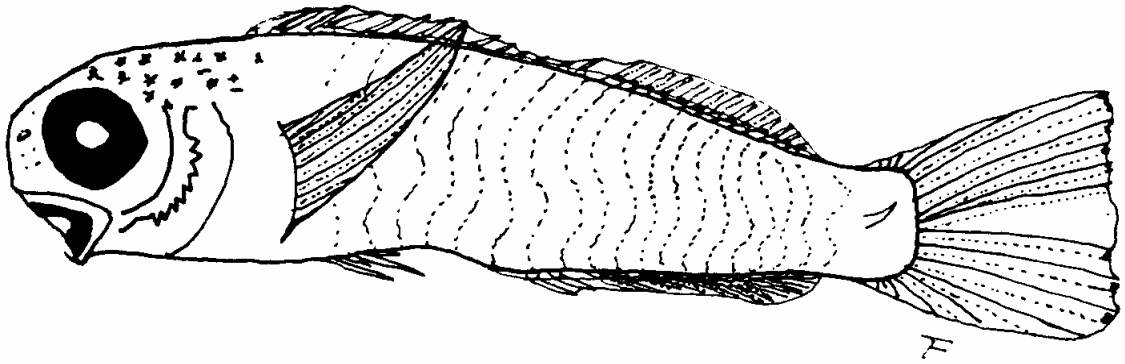


Figure 4.67 MSSAFL44. *Ecsenius* species 1. SL: 14.0mm. Two samples. D: XII, 13, A: II, 14, C: 13, P: 14, V: 30. Morphometric measurements in average for the 2 samples are given in (mm): TL: 17.2, SL: 14.0, PAL: 7.0, PDL: 3.7, HL: 5.7, SnL: 1.0, ED: 1.7, BD: 4.5. Collected in June

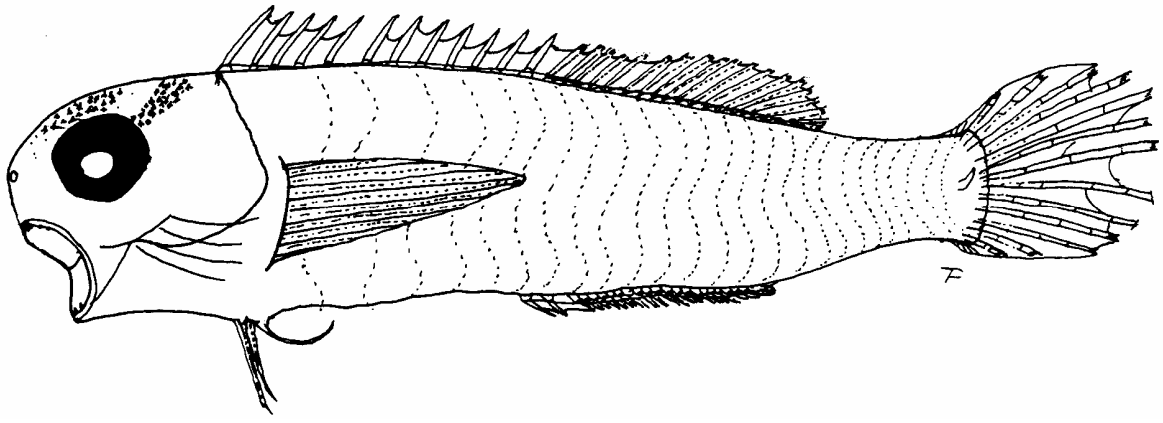


Figure 4.68 MSSAFL45. *Ecsenius* species 2. Two samples. SL: 15.8mm.D: XII, 13, A: II, 14, C: 13, P: 14, V: 35. Morphometric measurements in average for the 2 samples are given in (mm): TL: 18.3, SL: 15.8, PAL: 7.8, PDL: 3.5, HL: 6.0, SnL: 1.2, ED: 2.2, BD: 5.8. Collected in June.

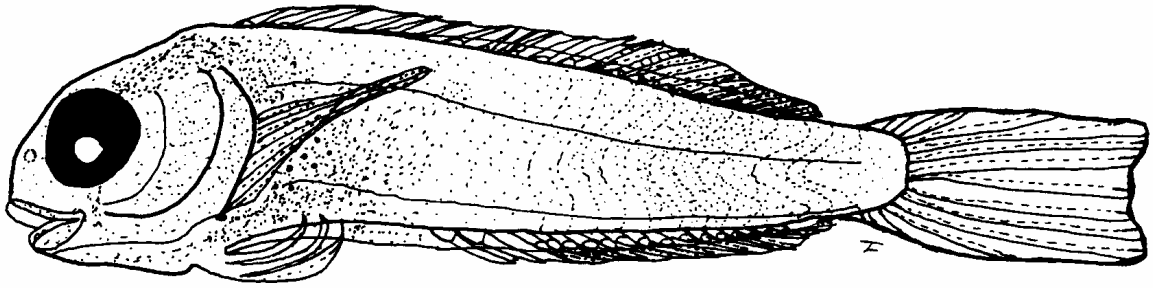


Figure 4.69 MSSAFL46. *Ecsenius* species 3. Eleven samples. SL: 20.5 mm. D: IV, 23, A: II, 14, C: 13, P: 14, V: 35. Morphometric measurements in average for the11 samples are given in (mm): TL: 25.5, SL: 20.5, PAL: 10.0, PDL: 4.7, HL: 6.3, SnL: 1.2, ED: 2.2, BD: 5.5. Collected in June, July and October.

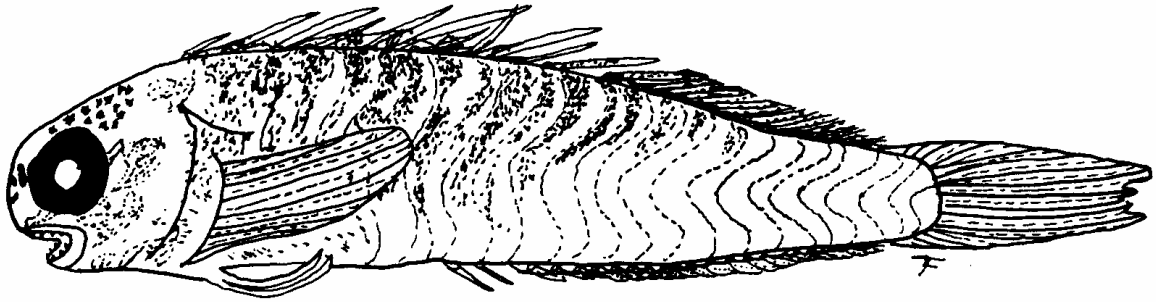


Figure 4.70 MSSAFL47. *Ecsenius* species 4. Three samples. SL: 20.2mm. D: XI, 20, A: II, 8, C: 13, P: 14, V: 34. Morphometric measurements for the 3 samples in average are given in (mm): TL: 24.2, SL: 20.2, PAL: 11.0, PDL: 4.2, HL: 5.7, SnL: 0.83, ED: 1.83, BD: 4.7. Collected in July.

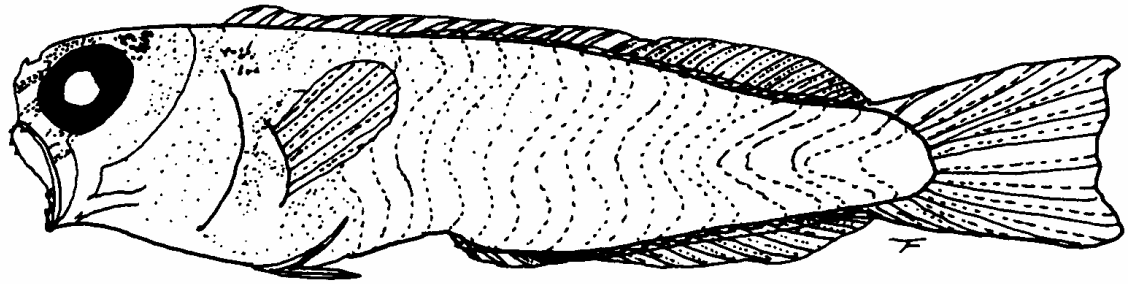


Figure 4.71 MSSAFL48. *Ecsenius* species 5. Two samples. SL: 18.5mm. D: XIV, 18, A: II, 19, C: 13, P: 14, V: 34. Morphometric measurements in average for the 2 samples are given in (mm): TL: 22.5, SL: 18.5, PAL: 9.3, PDL: 4.2, HL: 5.3, SnL: 0.83, ED: 1.8, BD: 5.0. Collected in July.

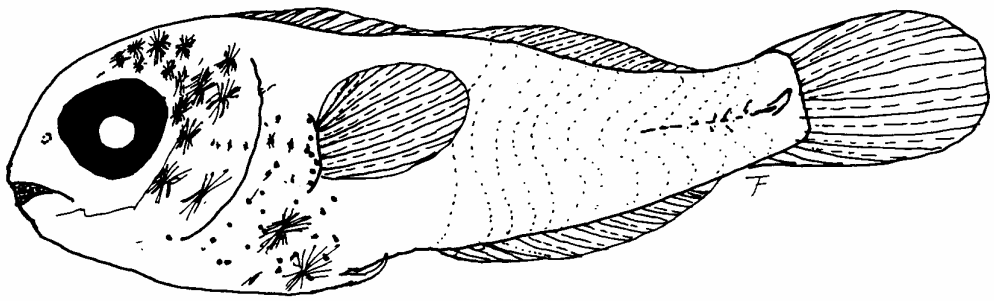


Figure 4.72 MSSAFL49. Blenniidae. One Sample. Morphometric measurements are given in (mm): TL: 9.2, SL: 8.2, PAL: 4.0, PDL: 2.2, HL: 2.7, SnL: 0.7, ED: 1.0, BD: 2.5. Collected in June.

4.6.11 Tripterygiidae (Threefin Blennies, Triplefins)

This family is recorded for the first time from the Jordanian coast of the Gulf of Aqaba. The species of this family are characterized by three dorsal fins, large pectoral fin and triangular head. They are abundant in shallow reef habitat. Their larvae have moderate and slightly laterally compressed body with coiled and long gut in the post-flexion stage. They have moderate head (without spination) with short and round snout and moderate eye. The mouth is moderate in its size reaching beyond the anterior edge of the eye. Tripterygiid larvae are lightly pigmented with some pigments on the hindgut and the head (Figure 4.73 & Plate 64).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	49 %	26 %	31 %	8 %	32 %	23 %

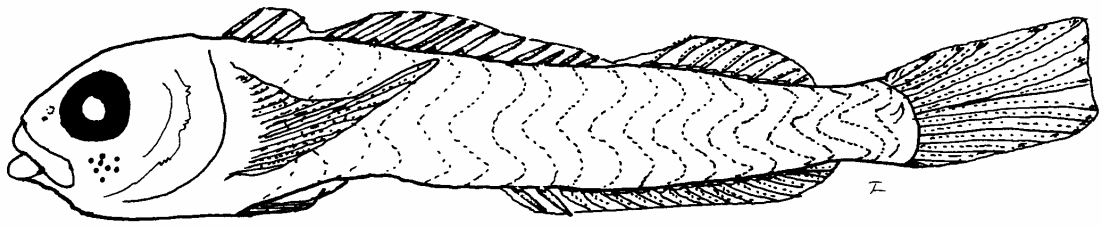


Figure 4.73 MSSAFL66. *Enneapterygius* or *Helcogramma* species. Six samples. SL: 9.1mm. D: III+XII, 9, A: I, 16, C: 13, P: 15, V: 34. Morphometric measurements in average for the 6 samples are given in (mm): TL: 10.9, SL: 9.1, PAL: 4.5, PDL: 2.4, HL: 2.8, SnL: 0.7, ED: 0.9, BD: 2.1. Collected in April and July.

4.6.12 Gobiidae (Gobies)

Their larvae are elongate to moderate in the body depth with little change of the depth from the head to the tail. The gut is long. Their head is moderate to large in size after flexion without spination having moderate eye. All the fin spines are short, smooth, weak, and

flexible. They are lightly pigmented, but some pigments have been seen over the hindgut (Figure 4.74 &Plate 65).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	54 – 55 %	38 – 42 %	33 – 35 %	8 – 9 %	3 %	12 – 26 %

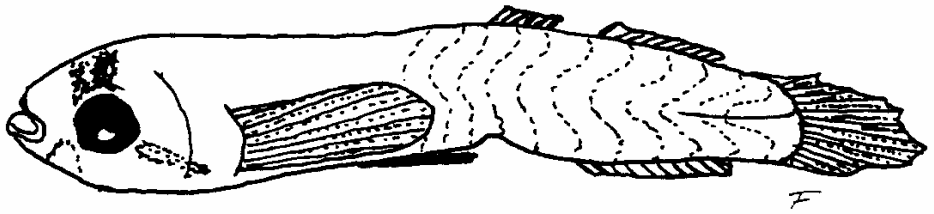


Figure 4.74 MSSAFL70. Gobiidae. Seventy-Seven samples. D: VI+I, 9, A: I, 8, C: 15, P: 17, V: 25. Morphometric measurements are given in (mm): TL: 9.9, SL: 8.2, PAL: 4.5, PDL: 3.1, HL: 2.7, SnL: 0.7, ED: 0.8, BD: 1.9. Collected in April, May, June, July, August, and September.

4.6.13 Chaetodontidae (Butterfly fishes)

The body of their larvae is deep and laterally compressed. The gut is coiled and deepens ranging from long to very long in the post-flexion stage. Their head is large varies in its shape from round to triangular having snout which is also, varies in shape from short and round to long and pointed. The size of the eye is large. The mouth is small and terminal and usually not reach the anterior edge of the eye. The larvae are moderately to heavily pigment on the brain, dorsal surface of the trunk, tail and gut and on the ventral edge of the tail. Two different genera have caught during this study *Chaetodon* species 1 and *Heniochus* species 1 (Figure 4.75-5.76 & Plates 66-67).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	41 – 72 %	46 –77 %	41 – 46 %	11 – 16 %	33 – 41 %	58 – 62 %

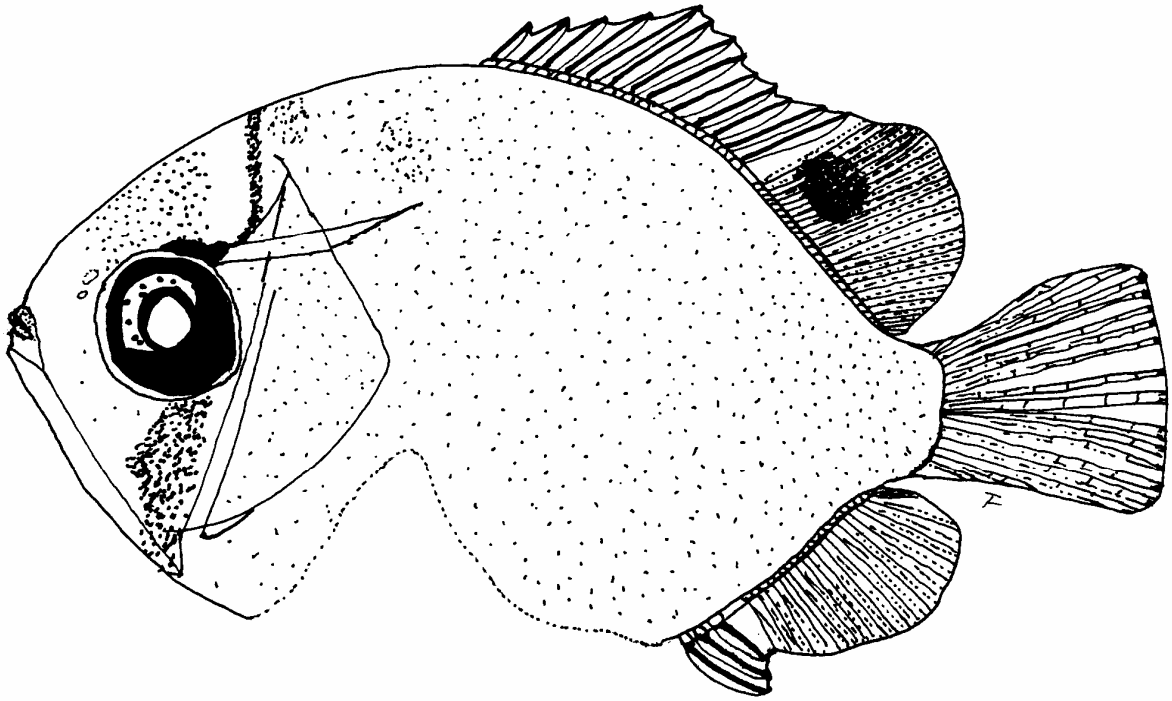


Figure 4.75 MSSAFL63. *Chaetodon* species. One sample. D: XIII, 24, A: III, 21, C: 17, P: 14, V: 24. Morphometric measurements are given in (mm): TL: 20.7, SL: 16.7, PAL: 12.8, PDL: 6.8, HL: 6.8, SnL: 1.8, ED: 2.8, BD: 10.3. Collected in August.

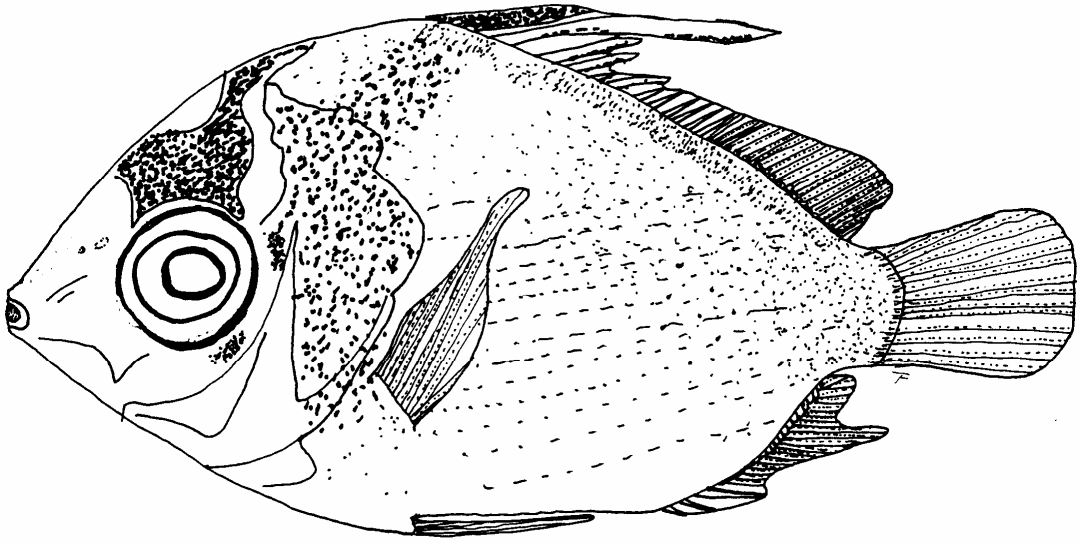


Figure 4.76 MSSAFL65. *Heniochus* species. One sample. D: XII, 24, A: III, 18, C: 17, P: 15, V: 24. Morphometric measurements are given in (mm): TL: 27.5, SL: 21.7, PAL: 15.7, PDL: 10.0, HL: 10.0, SnL: 3.5, ED: 3.3, BD: 12.7. Collected in November.

4.6.14 Siganidae (Rabbitfishes)

Their larvae are moderately in depth and laterally compressed. The gut is very long and ovoid in shape extending to about the mid of the body. The head is small in size with round and elongate snout and large eye. The larvae have pigment on the dorsal surface of the gut and along the ventral midline of the tail. Some pigments are found above the brain and on the dorsal midline of the tail. The represented sample in this study is the *Siganus* species 1 (Figure 4.77 & Plate 68).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	76 %	33 %	11 %	14 %	38 %	39 %

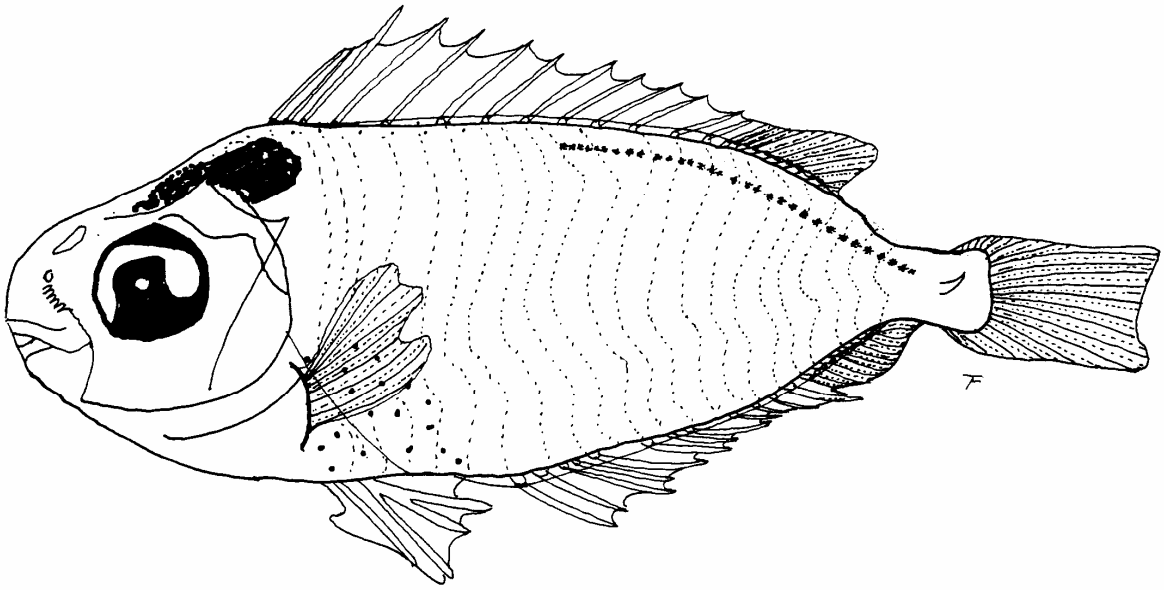


Figure 5.77 MSSAFL60. *Siganus* species. One sample. D: XIII, 10, A: VII, 9, C: 17, P: 16., V: 23. Morphometric measurements are given in (mm): TL: 25.8, SL: 20.5, PAL: 15.7, PDL: 6.8, SnL: 2.3, HL: 7.3, ED: 2.8, BD: 8.0. Collected in May.

4.6.15 Acanthuridae (Surgeonfishes)

Zebrasoma veliferum larva collected through this study is characterized by deep body and head, strongly laterally compressed. The body has kite shape after flexion with moderate gut growing downward. The large head is laterally compressed with large eye size. The

snout is long resulting in triangular head. The mouth is small and terminal with small conical teeth that found in both jaws. They have localized areas of heavy pigment especially on the brain. Strong band of pigment found around the tail (Figure 4.78 & Plate 69).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	39 %	44 %	39 %	17 %	41 %	79 %

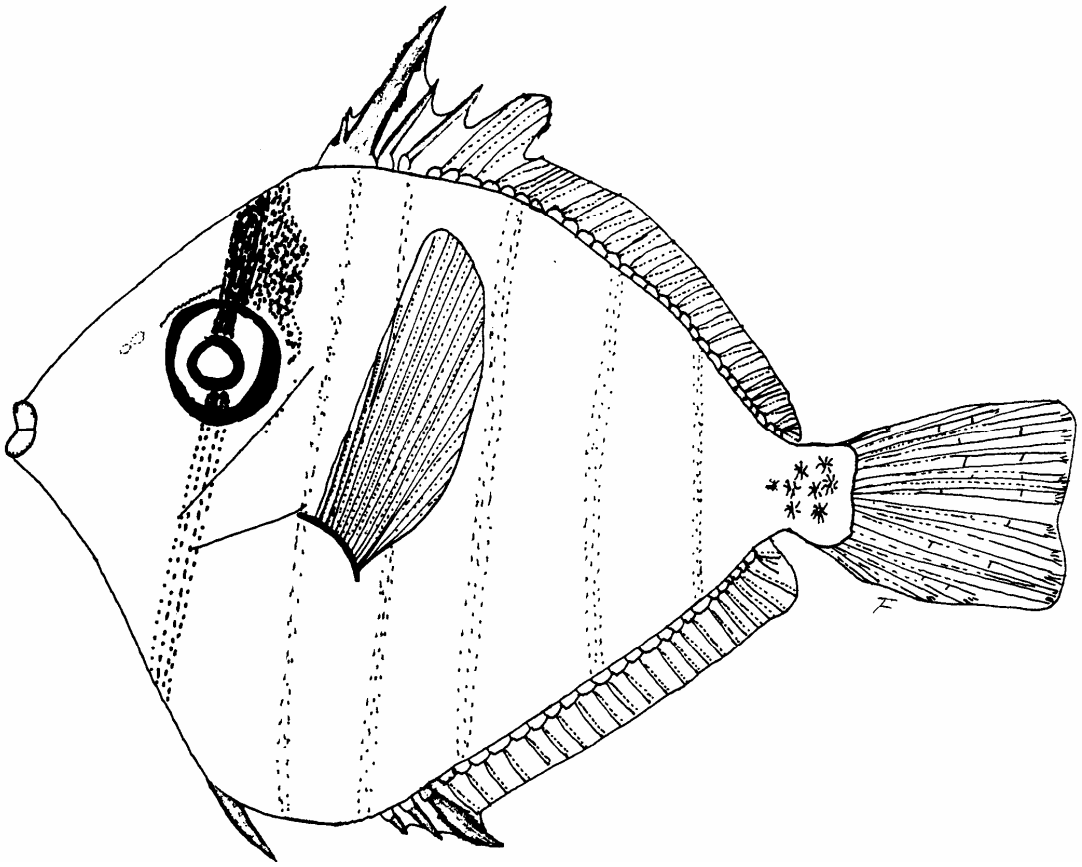


Figure 4.78 MSSAFL51. *Zebrasoma veliferum*. One sample. D: IV, 29, A: III, 23, C: 16, P: 15, V: 22. Morphometric measurements are given in (mm): TL: 20.3, SL: 16.7, HL: 6.5, SnL: 2.8, ED: 2.7, PAL: 6.5, PDL: 7.3, BD: 13.2. Collected in September.

4.6.16 Scombridae (Tunas, Mackerels, Bonitos)

Their larval stage characterized by elongate to moderate and laterally compressed body. The gut is very long, compact, coiled, and triangular in shape. The scombrid are represented in this study by *Grammatorcynus* species, which are recorded for the first time from the Jordanian coast of the Gulf of Aqaba. They have large and rounded head without

spination. The size of the eye ranged from moderate to large. The mouth is moderate reaching the anterior edge of the eye (Figure 4.79)

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	68 – 81 %	37 – 43 %	32 – 37 %	9 – 12 %	25 – 33 %	21 – 27 %

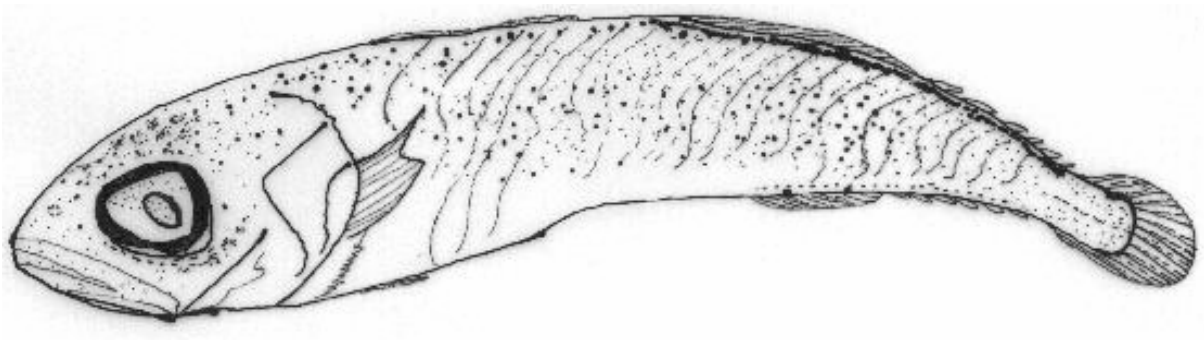


Figure 4.79 MSSAFL73. *Grammatorcynus* species. Four samples SL: 2.64mm. D: XIII+I, 11+6 finlets, A: I, 11+6 finlets, C: 17, P: 20, V: 30. Morphometric measurements are given in average for the 4 samples in (mm): TL: 4.0, SL: 3.3, PAL: 2.4, PDL: 1.3, HL: 1.1, SnL: 0.36, ED: 0.34, BD: 0.76. Collected in April.

4.7 Pleuronectiformes

4.7.1Bothidae (Left-eye flounders)

The larvae of *Bothus* species are extremely laterally compressed with deep and round bilaterally symmetrical body. The gut is short, single, coil tube elongate vertically. The head is moderate on its size having large eye. The mouth is small, oblique not reaching the margin of the eye. In the collected sample the right eye has been migrated over the dorsal midline of the head and under the dorsal fin base. Fine melanophores along the ventral margins of the head and dorsally over the gut (Figure 4.80 & Plate 70).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	28 %	5 %	26 %	5 %	33 %	45 %

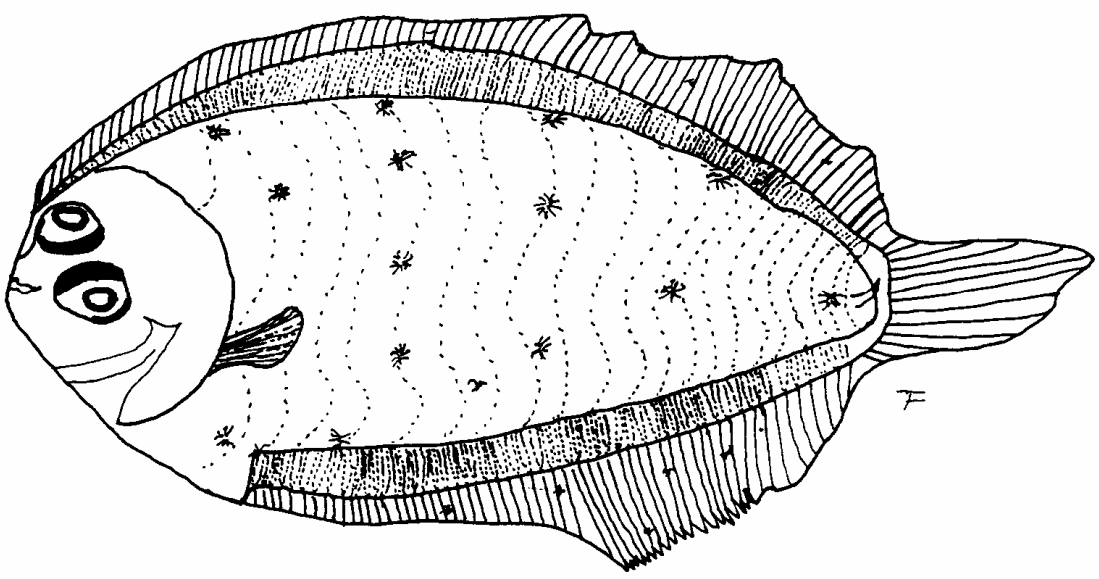


Figure 4.80 MSSAFL57. *Bothus* species. Two samples. D: 79, A: 59, C: 17, P: 8, V: 38. Morphometric measurements in average for the 2 samples are given in (mm): TL: 18.0, SL: 15.5, PAL: 4.3, PDL: 0.7, HL: 4.0, SnL: 0.7, ED: 1.3, BD: 7. Collected in April and May.

4.8 Tetraodontiformes

4.8.1 Ostraciidae (Trunkfishes)

The collected sample is *Ostracion cubicus*, which characterized by very deep body; the sac obscures the very long gut. The head is rounding, deep, and broad, and large in the size without spination. The eyes are large in size. The mouth is small with flared lips. Pigmentation is heavy with more or less uniformly scattered melanophores on the dermal sac (Figure 4.81& Plate 71).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	91 %	95 %	51 %	21 %	44 %	81 %

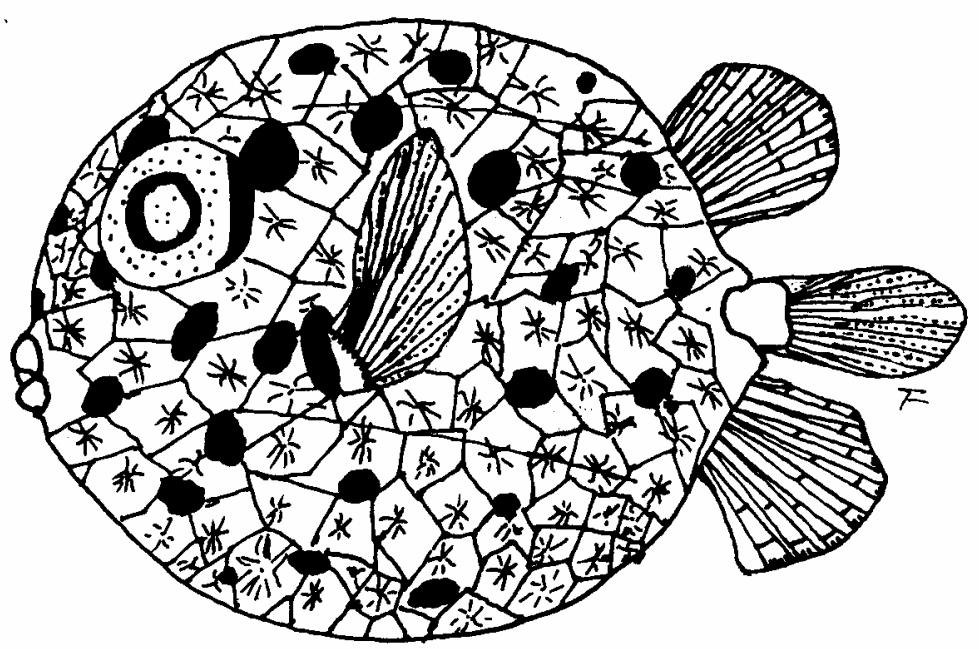


Figure 4.81 MSSAFL52. *Ostracion cubicus*. One sample. D: 9, A: 9, C: 10, P: 11. Morphometric measurements are given in (mm): TL: 11.3, SL: 8.8, PAL: 8.0, PDL: 8.3, HL: 4.5, SnL: 1.8, ED: 2.0, BD: 7.2. Collected in August.

4.8.2 Diodontidae (Porcupinefishes, burrfishes)

They are rotund fishes characterized by massive body spines (modified scales), inflatable body, and absence of pelvic fins. Their larvae are rotund and deep to very deep, but the body is wider than deep. The gut is coiled. The head is large and round with short snout and moderate eye size. (Figure 4.82).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	-------	-------	61 %	15 %	3 %	9 %

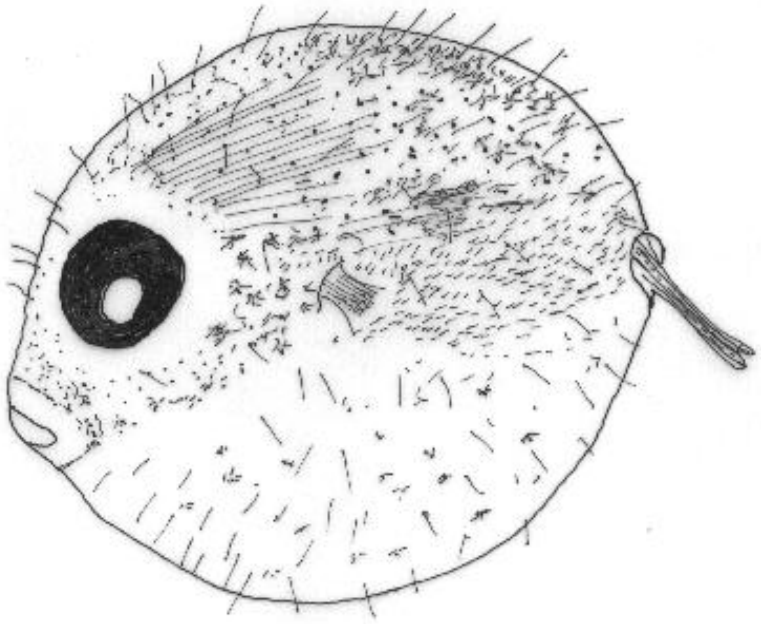


Figure 4.82 MSSAFL74. *Chilomycterus* species. 1 sample. Morphometric measurements are given in (mm): TL: 8.0, SL: 7.1, HL: 4.3, SnL: 1.1, ED: 1.3, BD: 6.4. Collected in March.

4.9 Stomiformes

4.9.1 Phosichthyidae (Light fishes)

In this study this family is represented by *Viniciguerria mabahiss*, recorded for the first time from the Jordanian coast of the Gulf of Aqaba. Its larval stage characterized by elongated and slender body, moderate on its size with long gut. The large head is triangular in shape with long snout and large eye size. The pigments are moderate occurring on the lower part of the body (Figure 4.83 & Plate 72).

Morphometric	PAL/BL	PDL/BL	HL/BL	SnL/BL	ED/HL	BD/BL
Percentage	99 %	89 %	47 – 48 %	14 %	35 %	35 %

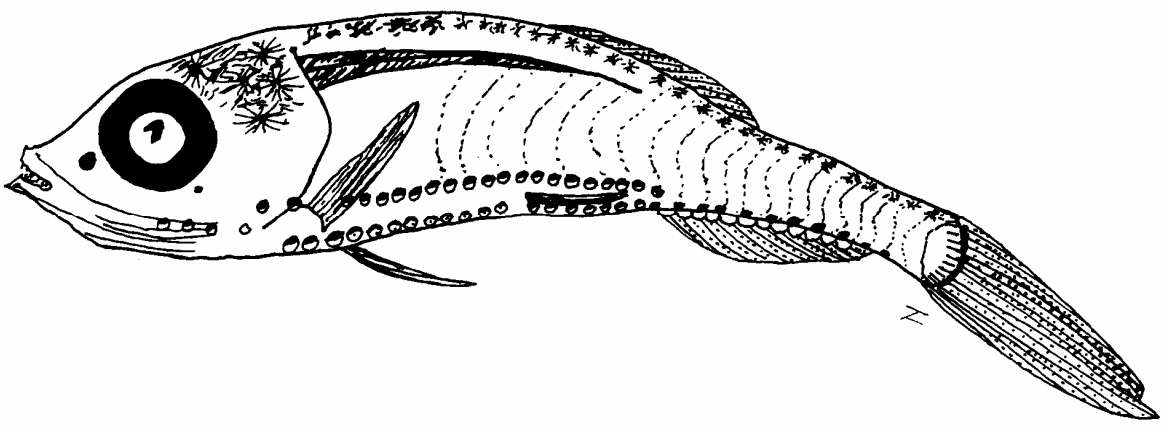


Figure 4.83 MSSAFL54. *Viniciguerria mabahiss*. Three samples. SL: 13.0mm. D: 13, A: 13, C: 13, P: 10, V: 35. Morphometric measurements in average for the three samples are given in (mm): TL: 14.0, SL: 13.0, PAL: 12.8, PDL: 11.7, HL: 6.2, SnL: 1.8, ED: 2.2, BD: 4.5. Collected in May and December.

5-DISCUSSION

This study provides the first taxonomical study on fish larvae from the Gulf of Aqaba and represents base line data for further related studies.

5.1 Ecological Data

In viewing the overall knowledge of identification, 80% of the collected fish larvae have been identified at the family level, 67.8% at the generic level, 33% at the species level. However, 20% are still unidentified, and need further investigation. The obtained results have shown that Clupeidae comprises the most abundant family through out this study (37.2%), followed by Pomacentridae (22.3%), Apogonidae (13.7%), Gobiidae (14.37%) and Blenniidae (4.7%) (Figure 4.2 & 4.3; Table 4.1). All of the identified taxa in this study have been recorded to the fish fauna in the Red Sea, but not from the Gulf of Aqaba. (Goren & Dor, 1994). This study reports three families (Gobiesocidae, Tripterygiidae, and Phosichthyidae), nine genera (*Spratelloides, Choridactylus, Plectranthias, Parapriacanthus, Plesiops, Petroscirtes, Cirripectes, Grammatorcynus, and Viniciguerria*), and five species (*Spratelloides delicatulus, Choridactylus multibarbus, Plectranthias winniensis, Parapriacanthus ransonnari,* and *Viniciguerria mabahiss*) for the first time from the Jordanian coast of the Gulf of Aqaba in this study (Wahbeh & Ajiad 1987; Khalaf & Disi 1997).

The results showed that the maximum catch of fish larvae was in April, May, June, July, and August with a peak in July (Figure 4.4 A&B). These results were in agreement with the findings of Wahbeh & Ajiad (1985) and Wahbeh (1992). They reported that the spawning season of *Parupeneus barberinus* extends from May to June, as well as the other species of the Mullidae which extend from June to August. Moreover, Cuschnir (1991) reported that the highest abundance of the fish larvae in the Gulf of Aqaba is between March and July. The collected specimen of *Chaetodon* species was in August which coincides with Gharaibeh & Hulings (1990), who reported that the spawning period of some *Chaetodon* species varies from July to December. The seasonality and recruitment of coral reef fishes inhabiting the lagoon at One Tree Island have been studied by

Russell *et al.*, (1977). They reported that most of the fishes have fairly long breeding seasons and reproduction occurs mainly during the summer months from about September to May, reaching the peak in January-February. And these are in coincides with the reproduction season of the fishes from the Gulf of Aqaba, in which both of them have their reproduction season in the summer.

A positive correlation between the abundance of pomacentridae and the availability of zooplankton in the Gulf of Aqaba was obtained. Al-Najjar (2000) indicated that the highest abundance of the total zooplankton was recorded in spring season with a peak in June due to the high population densities of Copepoda (Figure 4.8). He also, reported that the lowest densities of the zooplankton were recorded in autumn. Species richness of fish larvae recorded in this study has a peak in July (1999-2000). And these are in parallel to the species richness of the zooplankton (1998-1999) (Al-Najjar, 2000). Equitability of fish larvae was highest in September (1999-2000) while equitability of the zooplankton was highest in July (1998-1999).

The maximum surface water temperature in the Gulf of Aqaba is between June, 1999 to May, 2000 was in September (25.9 C ^{o}) and the lowest was in May (21.2 C ^{o}). The highest collection of the fish larvae in this study was in July, where the average surface water temperature was 25.3 C ^{o} (Figure 4.7). This contradicts with Cuschnir (1991) findings who reported that the highest larval number was when the water temperatures ranged between 20.8-23.7 °C. Also, it contradicts with Russell *et al.*, (1977). They reported that the recruitment of juveniles of coral reef fishes, which inhabit the lagoon at One Tree Island, Great Barrier Reef, reaches the peak when the water temperatures was the highest (28 C^{o}). In addition, Kucharczyk, *et al*., (1997) studied the effect of water temperature on embryonic and larval development of bream (*Abramis brama*) from the Kortowskie (Olsztyn, Poland). They found that 27.9 C ^{o} was an optimal temperature for the growth of fish and fish biomass production, while food availability and photoperiod were not limiting factors.

The only Significant difference was obtained for the pomacentridae from the two different depths in front of Marine Science Station, and no significant difference was obtained for the other collected families (Figure 4.6). This could be related to the correlation that was obtained only between the Pomacentridae and the zooplankton (g/m^{3}). Since there were no

correlation between any of the other collected families, in front of the Marine Science Station, with the zooplankton concentration (g/m^3)

The collected postflexion fish larvae by the light traps were higher when the moon was new in comparison with the size of collection when the moon was full (Figure 4.5). This can be attributed to attraction of the fish larvae to the light brightness of the moon (when its full), which emphasized the hypothesis of attraction of fish larvae to the light. Similar results were obtained by Doherty (1987), who obtained the data from Lizard Island, northern Great Barrier Reef. Moreover, the influence of the phase of the moon on the input of pre-settlement fishes to coral reefs at the One tree Island, Great Barrier Reef, Australia have been investigated by Kingsford & Finn (1997). They found that the high catches of many pre-settlement fishes were found just after new and full moon. The collected fish larvae by the light traps were mainly postflexion larvae, concluding that the post flexion larvae are more attracted to the light than the preflexion larvae. These results are in full agreement with Borgan findings (1994).

Cluster analysis was applied in order to show the habitat requirements for the collected families in this study. six groups appeared depending on the site of collection (Figure 4.9 & Table 3.2). Group number one (Scorpaenidae & Syngnathidae) was collected only from site number four, while group number two (Lutjanidae, Gobiesocidae & Acanthuridae) was collected only from site number one. However, group number four (Phosichthyidae, Tripterygiidae & Ostracidae) was collected from both sites number two and five. Moreover, the higher collection of group number three (Carangidae, Chaetodontidae & Apogonidae), group number five (Pomacentridae, Siganidae & Pseudochromidae) and group number six (Plesiopidae, Labridae, Clupeidae, Blenniidae, Gobiidae & Pempheridae) were from three sites six, four and three respectively. The obtained differences may be resulted from the low number of the collected specimens for certain families, or from the differences in the developmental stages of the collected larvae. Barletta-Bergan, (1999) investigated the assemblage and the recruitment processes of fish larvae and juveniles by utility of cluster analysis (Bray-Curtis similarity of samples) in potential nursery habits of the Caeté Estuary in northern Brazil. The composition, temporal and spatial abundance patterns, and developmental stages of fish larvae were examined along with salinity, environmental variables, tidal, lunar, stratum and dial effect. He

summarized the species similarity matrix for 25 taxa into six groups depending on the salinity, abundance, and frequency data of the collected taxa.

Despite the collection of fish larvae using the plankton net was limited for four times only during this study, but most of the collected fish larvae were in the preflexion stage. Most of these larvae remained as unclassified fish larvae. Also, this study has shown that the early stags of the fish larvae (dominantly the preflexion larvae) are mostly abundant in the pelagic water (more than 2 km far away from the reef). In comparison between the collected fish larvae using the light traps (nearshore) and the plankton net (offshore), the catch of the light traps was mainly postflexion larvae. On the other hand, the catch of the plankton net was mainly preflexion larvae. This means that the fish larvae disperse from the pelagic habitat to the coral reef habitat to settle and complete their life cycle. This coincides with Thorrold (1992), Choat *et al*. (1993), and Brogan (1994) findings.

Three different species belonging to three families (Scombridae, Serranidae, Apogonidae) have been collected from the sea grass bed (BB) through this study. Scombridae and Serranidae constitute two main commercial families at the Gulf of Aqaba (Odat, 2001). It is known that the scombrids are migratory fishes, and it was thought that they migrate to the Gulf of Aqaba for feeding purposes only (Odat, 2001). But the presence of the their larval stages in present collections indicated that they may migrate to the Gulf of Aqaba as a site for reproduction as well as for feeding purposes. The catch of their larvae indicated that their spawning season is in April, which forms a base line data concerning the larvae of commercially important species. This is an essential part in fishery management. The present investigation also, reported on the availability of other commercial fish larvae which include: Clupeidae, Lutjanidae, Serranidae, Carangidae, Siganidae, Acanthuridae and Scombridae. Also, the Aquarium (ornamental) groups which is evident from the collection of Antennariidae, Syngnathidae, Pseudochromidae, Chaetodontidae and Ostraciidae.

5.2 Light Traps and Plankton Net

Light traps were mainly used to collect fish larvae and have proved to be the most reliable method used to collect multiple samples at the same time and covering a large area. This is in agreement with Brogan (1994), Choat (1997) and Faber (1981) findings.

The lights were relatively bright and the trap entrances were large due to the behavior of the fish larvae around the trap. Automation was to sample large number of fish larvae simultaneously. Sampling has to be during the night, in which Goldman *et al*., (1983) reported that the density of reef fish larvae is significantly greater over the reef at night than during the day. Moreover, sampling had to be confined to narrow time windows and synchronized to real time, which was the reason to resolve spatial pattern from fixed location, mainly the shallow collection sites where the collection was higher (66%) and the deep collection sites where the collection was lower (34%) (Figure 3.3). There are variations in the effectiveness of the light traps among different species, and different stages of development (preflexion and postflexion) of the same species. Also, conditions of different water clarity, and different times of the lunar moon contributed to the variation of fish larvae capturing using the light traps. However, there may be other factors, which need further investigations, contributing to the attraction of fish larvae to the light.

5.3 Conclusion and Recommendations

This study on the taxonomy of fish larvae from the Jordanian side of the Gulf of Aqaba comprised a one-year collection of fish larvae mainly by light traps from May 1999 to May 2000. It's resulted in the description of 74 different taxa and provided the basis for future larval fish studies in the Gulf of Aqaba. Larval abundance varied seasonally with peaks in May, June, and July followed by minimum abundance in winter. Most of the collected specimens were in the postflexion stage. The dominant collected larval species was *Spratelloides delicatulus*.

This study forms a basic based line data intended to facilitate the identification of fish larvae from the Gulf of Aqaba. And increased our knowledge about fish fauna along the Gulf of Aqaba by adding new record's. Also, this study highlighted the importance of the sea grass bed in the AL-Mamlah as a spawning and nursery grounds for the commercial fishes. Also, it's provided us with a vivid picture regarding the spawning seasons of some commercial fishes such as scombrids.

As a result of this study a number of areas of future research have been identified and that will be useful to prepare Identification guide of the fish larvae from the Gulf of Aqaba:

1- Comparative surveys should be undertaken along the coastline of the Gulf of Aqaba to determine the latitudinal variations in larval occurrence. An advisable comparison should be made spatially and temporally between the sea grass bed and the coral reef area.
2- Information on the horizontal and vertical distribution of fish larvae in the Gulf of Aqaba, combined with measurements on the prevailing currents, will aid in our understanding of the mechanisms by which larvae maintain themselves (the patterns of distribution of fish larvae).
3- Collection of the fish eggs and the preflexion fish larvae, mainly by the plankton net from the offshore waters, will enrich our knowledge about the fish larvae from the Gulf of Aqaba.
4- The seasonal variations of the fish larvae should be one of the bases for the decision makers of the future fishery management.
5- The survey of the fish larvae should be added as a consideration in monitoring programs.
6- Identification of fish larvae using molecular markers which will match them to their adult stages.

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ملخص

دراسات تصنيفية و بيئية لبعض يرقات أسماك خليج العقبة

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لقد تم في هذا البحث دراسة تصنيف و بيئة يرقات أسماك الساحل الأردني لخليج العقبة لمدة سنة كاملة من شهر أيار 1999 إلى شهر أيار 2000 بإستعمال المصائد الضوئية. و لقد تم رسم و تصوير و تعريف العينات المجموعة و ذلك بعد أخذ القياسات المترية والتي شملت: الطول الكلي والطول القياسي و طول ما قبل الزعنفة الشرجية و طول ما قبل الزعنفة الظهرية و طول الرأس و طول الأنف و قطر العين و عرض الجسم. كما تم عد ما يلي: الزعانف الظهرية و الزعانف الشرجية و الزعانف الصدرية و الزعانف الذيلية و الفقرات أو القطع العضلية.

و في فترة الدراسة تم وصف و قياس ما مجموعه 687 يرقة سمك تابعة ل 74 وحدة تصنيفية مختلفة. صنف منها 550 يرقة سمك و بقي 137 يرقة سمك كعينات غير معرفة. و قد تم تسجيل العائلات التالية لأول مرة من الشاطئ الأردني لخليج العقبة و هي: (Gobiesocidae, Tripterygiidae, Phosichthyidae), و كذلك تم تسجيل الأجناس التسع التالية في الشاطئ المذكور في خليج العقبة و هي: (*Plectranthias,* Spratelloides, Choridactylus, *Parapriacanthus, Plesiops, Petroscirtes, Cirripectes, Grammatorynus, Vincigurria*) و كذلك الأنواع الخمسة التالية: (*Spratelloides delicatulus, Chrodactylus multibarbus, Plectranthias winniensis, Parapriacanthus ransonari, Vinicigurria mabahiss*). إن هذه الدراسة تشير بأن يرقات الأسماك تتغير وفرتها موسميا, حيث تصل أعلى نسبة في شهر تموز و أقلها في الشتاء (تشرين ثان, كانون أول,

كانون ثان و شباط). كما بينت هذه الدراسة أن العائلات التالية هي الأكثر وفرة و الموزعة بشكل أكثر من غيرها من العائلات, حسب الترتيب التالي:

(Clupeidae, Pomacentridae, Apogonidae, Gobiidae, Blenniidae, Pempheridiidae)

تبين أن أعلى نسبة ليرقات الأسماك تم الحصول عليها عندما كانت درجة حرارة سطح البحر 25.3 م° كما لوحظ وجود علاقة إيجابية بين يرقات الأسماك و العوالق الحيوانية البحرية, حيث إن مدى وفرة كلاهما كانت في نفس الموسم (نيسان-آب). لقد كان معدل صيد يرقات الأسماك بإستخدام المصائد الضوئية متغيرا حسب حالات القمر حيث كان الصيد أعلى عندما كان القمر هلالا و أقل عندما كان القمر بدرا.

و تبين في مقارنة ما بين طريقتين لجمع اليرقات: المصائد الضوئية (حيث استخدمت للجمع من المناطق القريبة من الشاطئ) و شبكة الهوائم (العوالق) (حيث استخدمت للجمع من المنطقة البعيدة عن الشاطئ) و بأن يرقات الأسماك في مرحلة ما قبل الإالتواء متوافرة بشكل أكثر ما يمكن في المناطق البعيدة عن الشاطئ, و يرقات الأسماك في مرحلة ما بعد الإالتواء متوافرة أكثر ما يمكن في المنطقة البعيدة من الشاطئ.

إن هذه الدراسة تعتبر أول دراسة تصنيفية ليرقات أسماك خليج العقبة. و يؤمن أن تسهم هذه الدراسة و مثيلاتها بفهم أكثر و أفضل في تطور الأسماك الفردي و النوعي, و أن تشكل معلومات أساسية للأبحاث المستقبلية على توزيع يرقات الأسماك و تنظيم عملية الصيد.