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EARLY LIFE HISTORY STAGES OF THE FAMILY CARANGIDAE IN THE EASTERN ADRIATIC

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ABSTRACT

Use of early life history stages in systematic and ecological studies of fish has increased in recent years. It is now recognized that eggs and larvae present a wide array of characters that are largely independent of adult characters and, as such, suitable for a taxonomic analysis. On the other hand, fisheries recruitment studies focus on the survival of eggs and larvae as the most important factor influencing variations in population abundance. A requisite to these studies is detailed information on the appearance of fish eggs and larvae in order to identify them in plankton samples. Family Carangidae *is of great interest to the Croatian fishery. This paper presents all available information and results on the early developmental stages of the family* Carangidae *found in the eastern Adriatic.*

Key words: early developmental stages, Carangidae, eastern Adriatic

INTRODUCTION

The importance of early-life-history studies to fisheries investigations and phylogenetic research has increased dramatically during the last decade. Early-life-history stages are now routinely used in fisheries studies to investigate the interannual variation in recruitment (Wooster, 1983), and in the studies of the phylogeny of fishes (Moser *et al.*, 1984). The study of fish eggs and larvae is a key component in research into the biology, systematics and even population dynamics of fishes, in that it provides information on spawning areas and periods of many species. By combining the location of the eggs, larvae and adults of a species with information on the surrounding environment, possible environmental effects on spawning (egg and larval transport, *etc.)* can be inferred. Studies of this type contribute to our understanding of the early stages of development of fishes, which for certain species are still completely unknown. Consideration of the factors that affect egg and larval survival is fundamental, since it is the early stages of development that will eventually determine the existence of good or bad year classes. This is one of the main thrusts of ichthyoplankton studies in those areas, in which the requisite basic information is available (egg and larval surveys in spawning areas during the spawning season, *etc.)* for the species of interest.

Family Carangidae is of great interest to the Croatian fishery. It is not possible to get new data on catch for every species now, but Grubišić (1982) reported that it is around 650 tons per year for Atlantic horse mackerel *(Trachurus trachurus* - more than 50%) and Mediterranean horse mackerel *(Trachurus mediterraneus* - less than 50%), 3 tons for pompano *(Trachinotus ovatus),* and around 30 tons for yellow tail *(Seriola dumerili).*

The aim of this paper is (1) to compile and present all the available information and results on both the early development stages of the eggs and larvae of the family Carangidae found in the eastern Adriatic and (2) to identify possible spawning areas and seasons of some species from the family.

MATERIAL AND METHODS

The present paper sets out descriptions of the eggs, yolk-sac larvae and larvae of the family Carangidae likely to be collected in plankton samples in the eastern Adriatic, together with information on the possible spawning areas and seasons for some species. The egg and larval descriptions have mostly been taken from the existing literature. In some cases the descriptions were done by the author himself based on material collected during surveys; in other instances the descriptions were

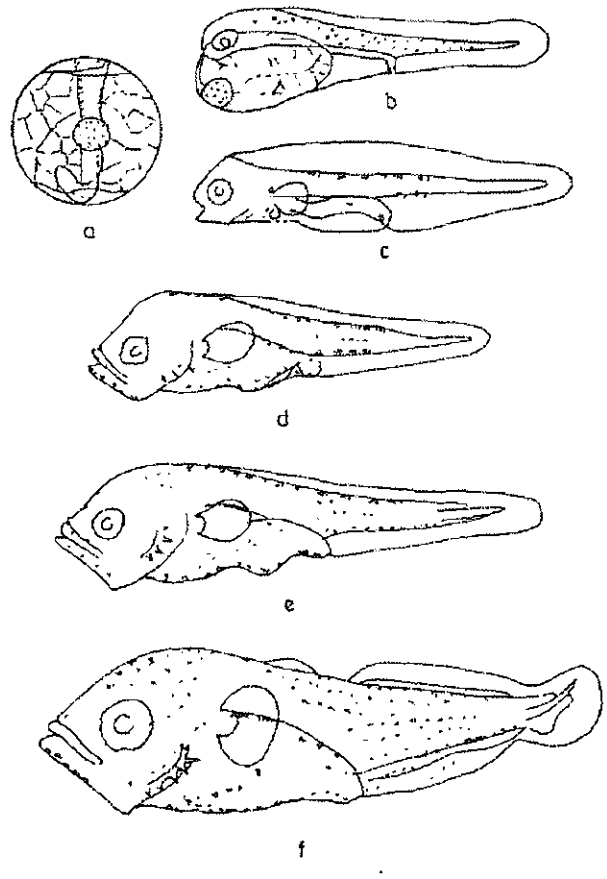

Fig. 1: *Trachurus trachurus* ***(L.). (a) egg; (b) yolk-sac larva, 2.6 mm; (c) yolk-sac larva, 3.2 mm; (d) larva, 4.9 mm; (e) larva, 5.2 mm; (f) larva, 6.7 mm (after Heincke and Ehrenbaum, 1900).***
Sl. 1: Navadni šnjur *Trachurus trachurus* ***(L.). (a) ikra: (b) larva z rumenjakovo vrečko, 2,6 mm; (c) larva z rumenjakovo vrečko, 3,2 mm; (d) larva, 4,9 mm; (e) larva, 5,2 mm; (f) larva, 6,7 mm (po Heinckeju in Ehrenbaumu, 1900).***

published by other researchers, either for eggs and larvae actually collected in the eastern Adriatic itself or for egg and larval material collected in other areas but for species that also inhabit the waters of the eastern Adriatic. Notochord (NL) length was measured for preflexion, standard length (SL) and total length (TL) for flexion larvae.

RESULTS AND DISCUSSION

Trachurus trachurus (L.)

Eggs

Pelagic, spherical, 0.81-1.04 mm in diameter, segmented yolk, oil globule 0.19-0.28 mm in diameter for the North Sea (Heincke & Ehrenbaum, 1900). Holt (1893) obtained ovarian eggs from *Trachurus trachurus* brought in by mackerel boats on 16 June at Penzance. He thus established that the egg was pelagic and had an oil globule. Later (Holt, 1894) he obtained ripe unfertilized eggs from the North Sea on 19 May and described the segmented yolk. He also recorded that in some eggs there were two or three small oil globules which later coalesced into a single large one. When the embryo is half round the yolk brownish-yellow and black pigment appears along the body contours and especially round the oil globule. Ehrenbaum (1905-09) states that the black pigment appears first, and that the other colour is more brownish-yellow by reflected light but appears more yellow by transmitted light. Holt (1897) recorded differences in sizes of eggs from the North Sea and from Plymouth as follows: Grimsby - diameter of egg - 1.03-1.09 mm and diameter of oil globule - 0.26-0.27 mm; Plymouth - diameter of egg 0.81-0.93 mm and diameter of oil globule - 0.22-0.23 mm. Polonskii and Tormosova (1969) made artificial fertilizations of eggs from parents 27-30 cm long. Twenty-four hours after fertilization the diameters of the eggs were 0.9-1.05 mm (mean 1.0 mm) and of the oil globules 0.25-0.275 mm (mean 0.269 mm). Kiliachencova (1970) reported next measures of eggs: diameter 0.90-1.10 mm and oil globule diameter 0.15-0.20 for the waters of Northwest Africa. Demir (1961) presented measure for Atlantic horse mackerel eggs from Sea of Marmara and the Black Sea: diameter is between 0.79 and 0.95 mm. An unsculptured elastic eggshell protects a completely segmented yolk with usually one oil globule at its upper surface. The eggshell and yolk are transparent and colourless. The oil globule is a light copper colour in living material. There are melanophores on the oil globule and body of the em-

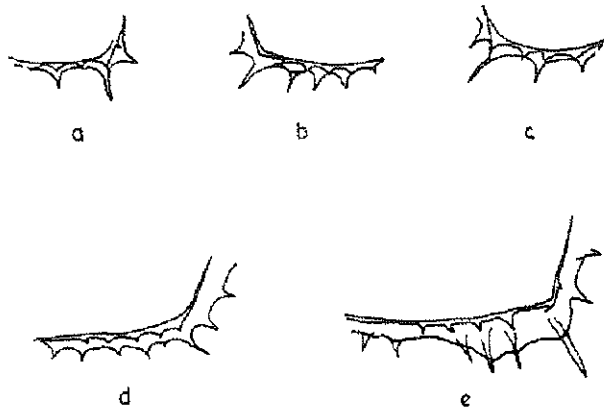

Fig. 2: *Trachurus trachurus* ***(L.). Opercular spines of larvae: (a) and (b) 3.5 mm, (c) 5.0 mm, (d) and (e) 6.5 mm (after Schnakenbeck, 1931).***
Sl. 2: Navadni šnjur *Trachurus trachurus* ***(L.). Škržni trni larv: (a) in (b) 3,5 mm, (c) 5,0 mm, (d) in (e) 6,5 mm (po Schnakenbecku, 1931).***

bryo after blastopore closure. The perivitellin space is narrow (Demir, 1961). Dulčić *(unpublished data)* found in May at Stončica station (43°00'N 16°20'E - 4Nm SE from island Vis in the middle Adriatic) horse mackerel eggs with the following measures: diameter 0.93-1.08 mm and oil globule diameter 0.17-0.22 mm (Fig. 1a).

Yolk-sac larvae

Dulčić (1992) found Atlantic horse mackerel yolk-sac larvae at Stončica station in February, March, and April with a frequency 0.40%.

The newly hatched yolk-sac larvae is about 2.5 mm long (Heincke & Ehrenbaum, 1900) (Fig. 1b). The most characteristic feature is the anterior position of the oil globule in the segmented yolk and the extension of the anterior end of the yolk sac beyond the anterior margin of the head. The anus is situated behind the posterior end of the yolk-sac; as the larvae grow it reaches about the mid-point of the body. When newly hatched the pigmentation consist of melanophores and brownish-yellow chromatophores. The melanophores are at first irregularly distributed over the body, but as development proceeds the pattern gradually changes. At first the tail region becomes free of melanophores and a few melanophores appear on the dorsal and ventral primordial fin on the level of the rectum, together with brownish chromatophores to form a distinct ventral bar. One or two marginal melanophores also appear on the anterior half of the dorsal fin and together with the brownish chromatophores tend to form a bar at the posterior end of the yolk-sac. The posterior half of the oil globule is well pigmented. By the time the yolk is nearly fully absorbed and the eyes are pigmented (length of 3.24 mm), the pigmentation is reduced to dorsal and ventral body contour rows of melanophores, and a fringe of brownish pigment along the margins of the dorsal and ventral fin (Fig. 1c).

Larvae

J. Karlovac (1967) found five Atlantic horse mackerel larvae at the Split channel station. O. Karlovac & J. Karlovac (1971) reported about 620 yolk-sac larvae and larvae found (length from 2.37 to 19.14 mm) mainly at the stations in the south and middle Adriatic during the expedition "Hvar" (1948-1949) from February to July. Regner (1980, 1982) observed larvae at the station in Kaštela Bay (43°31'N 16°19'E) in February, April, and October with frequency 0.24%, and at the Stončica station from February to August with frequency 1.44%.

In the earliest stages (3.5-4 mm) the pigmentation pattern consists of dorsal and ventral body contour rows of melanophores, with the beginnings of a mediolateral row. The dorsal row ends about mid-way between the anus and the caudal end and consists of about 10 large

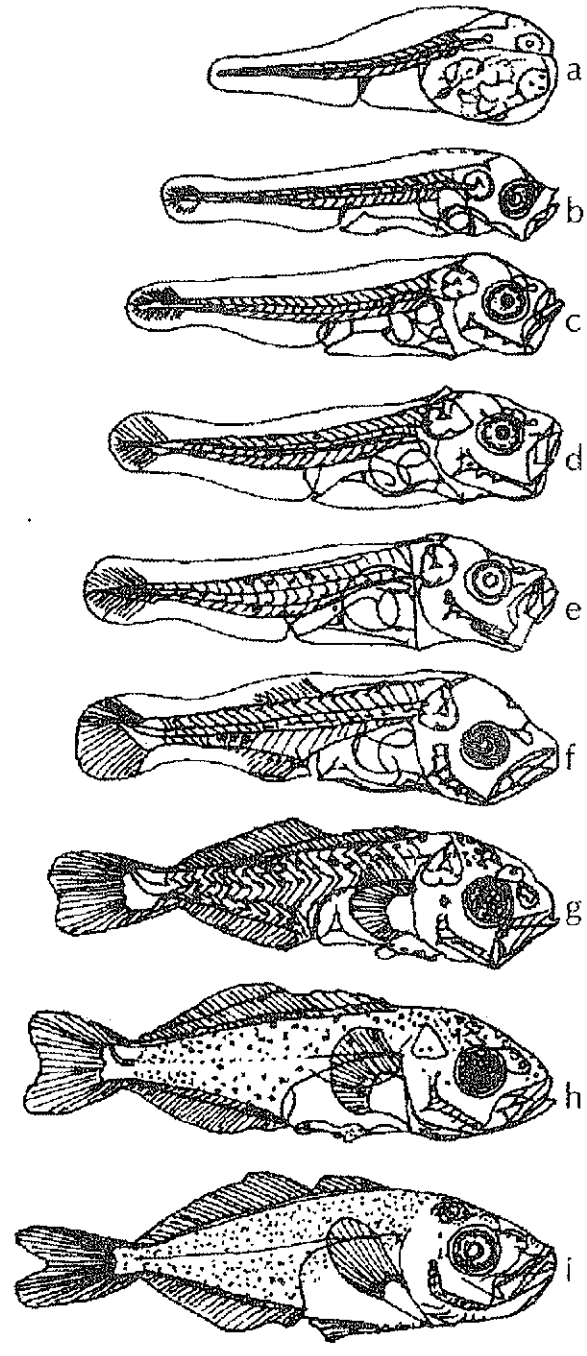

Fig. 3: *Trachurus mediterraneus* ***(Steindachner, 1868). (a) yolk-sac larva, 2.1 mm, (b) yolk-sac larva, 2.6 mm, (c) larva, 3.2 mm, (d) larva, 4.55 mm, (e) larva, 5.1 mm, (f) larva, 7 mm, (g) larva, 10 mm, (h) larva, 14 mm, (i) larva, 20.2 mm (after Demir, 1961).***
Sl. 3: ***Sredozemski šnjur*** *Trachurus mediterraneus* ***(Steindachner, 1868). (a) larva z rumenjakovo vrečko, 2,1 mm, (b) larva z rumenjakovo vrečko, 2,6 mm, (c) larva, 3,2 mm, (d) larva, 4,55 mm, (e) larva, 5,1 mm, (f) larva, 7 mm, (g) larva, 10 mm, (h) larva, 14 mm, (i) larva, 20,2 mm (po Demirju, 1961).***

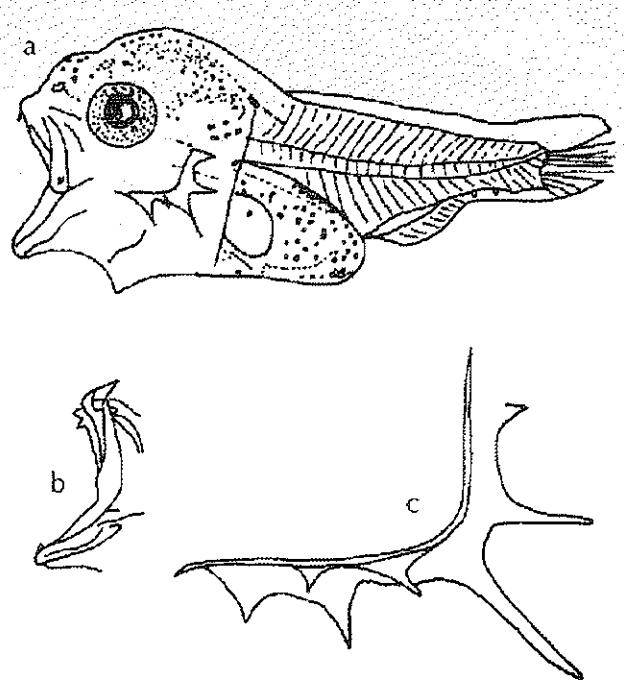

Fig. 4: *Pseudocaranx dentex* ***(Bloch & Schneider, 1801). (a) larva, 6.0 mm (after Schnakenbeck, 1931), (b) jaws, (c) opercular spines.***
Sl. 4: Vrsta *Pseudocaranx dentex* ***(Bloch & Schneider, 1801). (a) larva, 6,0 mm (po Schnakenbecku, 1931), (b) čeljusti, (c) škržni trni.***

stellate melanophores opposite those of the dorsal row followed by a number of small melanophores extending nearly to the end of the urostyle. There are also numerous melanophores on the lower jaw, along the abdomen and the upper surface of the stomach, and on the head. As the larvae grow, the number of melanophores increases to cover gradually the sides of the body, leaving the caudal end free, except for the ventral row. The mediolateral row persists and the lateral body pigment extends forward. At a length of 6 mm a row of melanophores appears along the anal fin midway between the anus and the tail, situated along the outer margin of the interspinous area. The swimbladder is already apparent when the larvae is about 4 mm long. The urostyle begins to turn up at about 6 mm length. The interspinous areas of the dorsal and anal fins begins to develop at a length of about 5 mm, the dorsal about midway between the anus and the tail, and the anal at first anteriorly near the anus (Figs. 1d and 1e). The fin rays of D_1, D_2 and A have developed by the time the larvae are 6-7 mm long and the fish is beginning to assume its carangid appearance. The pelvic fin is becoming evident at lengths of 7-8 mm (Fig. 1f). A noticable feature of the larvae is the height of the anterior half of the body and of the head. The upper jaw has small denticles along its margin and there are opercular spines (Fig. 2); the latter are not noticable unless specially looked for. Details of their development have been described by Schnakenbeck (1931). In individuals of the same size there is some slight variation in form and size of the spines and in their numbers (Fig. 2). The basic arrangement is a row of longer stronger spines on the posterior margin of the preoperculum, with an inner row of smaller spines on the crista. The spine at the angle of the preoperculum is the longest. In larvae 5 mm long there are about 4-5 spines on the outer row, and 5 on the inner row. In general the larger larvae have the greatest number of spines. The spines are already apparent in larvae 4 mm in length.

Trachurus mediterraneus (Steindachner, 1868)

Eggs

Pelagic, spherical, 0.71-0.90 mm in diameter, segmented yolk with usually one oil globule at its upper surface, perivitelline space narrow (Demir, 1961). No eggs attributable to this species have been collected so far during the surveys carried out in the eastern Adriatic.

Yolk-sac larvae

Yolk-sac larva has segmented and oval yolk-sac. The anterior edge of the yolk-sac slightly passes beyond the anterior point of the head. The oil globule is located at the anterior part of the yolk-sac. The anus is well behind the yolk-sac, and the part of the body anterior to the anus is longer than the part of body posterior to the anus (Fig. 3a). Demir (1961) supposed that the size of the yolk-sac of *Trachurus trachurus* should be larger than that of *Trachurus mediterraneus*. The most reliable characteristic which differentiates yolk-sac larvae of those two species is the melanophore which develops on the primary dorsal fin in the yolk-sac larvae of *Tr. trachurus*, while none develop in yolk-sac larvae of *Tr. mediterraneus*. The larval size at the end of the yolk-sac stage of *Tr. mediterraneus* is smaller than that of *Tr. trachurus* (Demir, 1961). No yolk-sac larvae attributable to this species have been collected so far in the eastern Adriatic.

Larvae

All subsequent larval developmental stages (*e.g.* the first appeareances of jugal spines, fins, the upward inclination of the posterior part of urostyle *etc.*) are reached earlier by the larvae of *Tr. mediterraneus* than by the larvae of *Tr. trachurus*. Besides, the melanophores on the larvae of *Tr. mediterraneus* are lesser in number but larger in size than the melanophores on the larvae of *Tr. trachurus* (Fig. 3b to Fig. 3i). However, the distinguishing characteristic of the larvae of both species are the

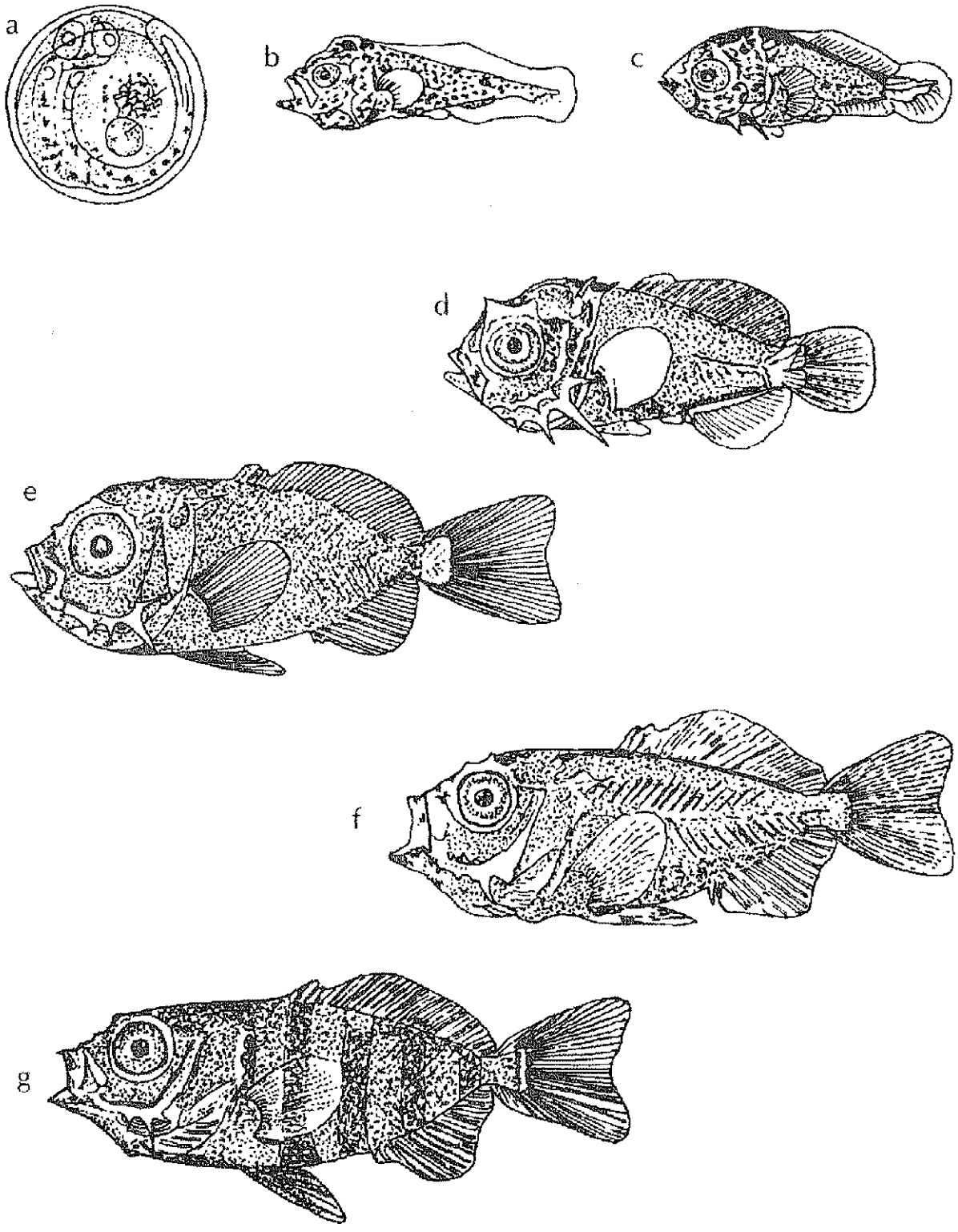

Fig. 5: Naucrates ductor **(Linnaeus, 1758). (a) egg; (b) larva, 5.4 mm; (c) larva, 6.3 mm, (d) larva, 6.9 mm, (e) larva, 11.7 mm, (f) larva, 16.0 mm, (g) larva, 20.8 mm (after Sanzo, 1931).**
Sl. 5: Pilot *Naucrates ductor* **(Linnaeus, 1758). (a) ikra; (b) larva, 5,4 mm; (c) larva, 6,3 mm, (d) larva, 6,9 mm, (e) larva, 11,7 mm, (f) larva, 16,0 mm, (g) larva, 20,8 mm (po Sanzu, 1931).**

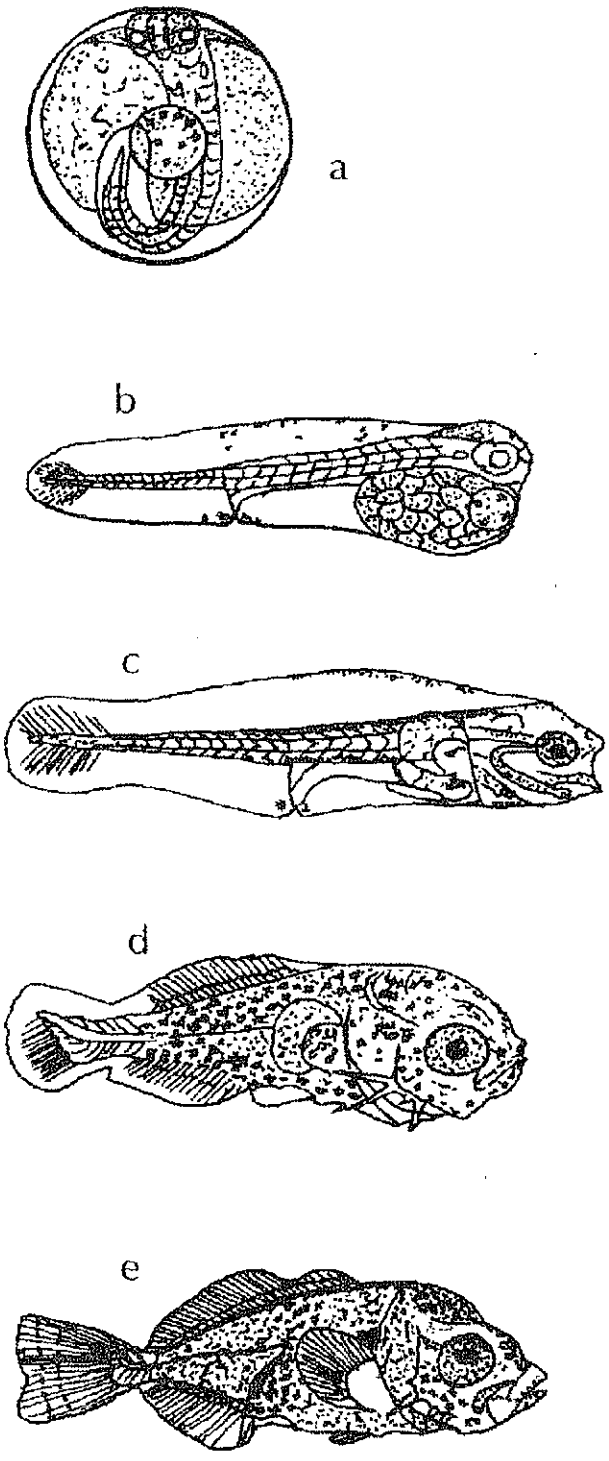

Fig. 6: *Seriola dumerili* ***(Risso, 1810). (a) egg, (b) yolk-sac larva, 3.60 mm, (c) yolk-sac larva, 4.40 mm, (d) larva, 4.80 mm, (e) larva, 9.72 mm (after Sanzo, 1933).***
Sl. 6: Gof *Seriola dumerili* ***(Risso, 1810). (a) ikra, (b) larva z rumenjakovo vrečko, 3,6 mm, (c) larva z rumenjakovo vrečko, 4,4 mm, (d) larva, 4,8 mm, (e) larva, 9,72 mm (po Sanzu, 1933).***

melanophores which develop on the preanal ventral primary fin, on the ventral side of the belly posterior to ventral fin, and on the jaws in the larvae of *Tr. trachurus*. Corresponding chromatophores are either never found or are unimportant in number and size in the larvae of *Tr. mediterraneus* (Demir, 1961). Larvae of this species were found in the southern Adriatic by Karlovac *(unpublished data)*, and at Stončica station (June; n=2, 5.1 and 5.2 mm SL) by Dulčić *(unpublished data)*.

***Pseudocaranx dentex* (Bloch & Schneider, 1801)**

Eggs

No information available.

Larvae

Regner (1982) found guelly jack *Pseudocaranx dentex* larva at Stončica station in August with frequency 0.02%.

Very little information exists concerning the larval development of this species; only descriptions of two larvae measuring 5 and 6 mm, respectively, by Schnakenbeck (1931) and Padoa (1956) are at hand. The teeth develop early. No supraoccipital crest is present. The preopercular spines are distinct from those of horse mackerel larvae; this is most apparent on the upper anterior margin of the preopercule which, unlike that on horse mackerel larvae, is devoid of spines. The most outstanding feature of the pigmentation pattern is the nearly complete lack of melanophores along the body (Fig. 4).

***Naucrates ductor* (Linnaeus, 1758)**

Eggs

The eggs are spherical, 1.32 mm in diameter, with an oil globule 0.28 mm in diameter. The yolk is segmented and the perivitelline space is very narrow (Fig 5a). The chorion is smooth (Sanzo, 1931). No eggs attributable to this species has been collected in the eastern Adriatic.

Yolk-sac larvae

No information available.

Larvae

Dulčić *(unpublished data)* found pilotfish larvae at Stončica station in August (n=2, 5.6 and 7.0 mm SL, respectively).

The head is very prominent, representing 32% of NL in very young larvae and 37% in 7 mm larvae. The

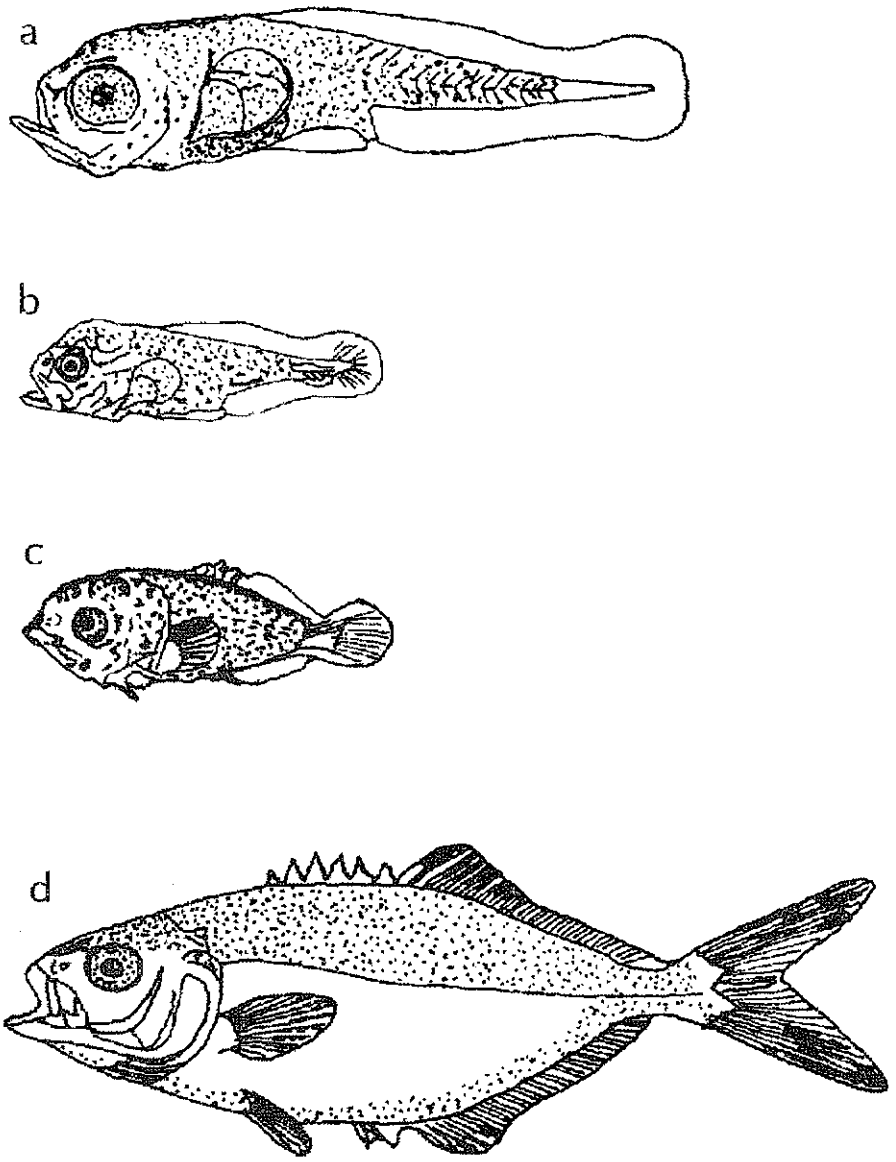

Fig. 7: *Trachinotus ovatus* ***(Linnaeus, 1758). (a) larva, 2.52 mm, (b) larva, 5.36 mm, (c) larva, 5.56 mm (after De Gaetani, 1940), (d) juvenile, 73.8 mm (after Dulčić et al., 1997).***
Sl. 7: Vrsta *Trachinotus ovatus* ***(Linnaeus, 1758). (a) larva, 2,52 mm, (b) larva, 5,36 mm, (c) larva, 5,56 mm (po De Gaetaniju, 1940), (d) mladostni primerek (po Dulčiču et al., 1997).***

shape of the body subsequently changes, with the relative head depth decreasing as body depth increases, the two approaching each other. The mouth is very small. Long preopercular spines, supraorbital crest, and two postemporal spines are present on the head from early stages of development. The body is heavily pigmented from the earliest stages of development, except on the caudal peduncle. The pigmentation pattern begins to change at a length of 7 mm (Fig. 5d); at the beginning the black pigmentation extends onto the fins; later the pigmentation of the body becomes uneven, giving rise to a certain number of very dark, transverse stripes alternating with lighter areas. Notochordal flexion takes place at between 5.5 and 6.5 mm SL (Figs. 5b and c). The upper rays of the pectoral fins are discernible in even the smallest larvae. These fins grows larger in later stages, reaching the level of the vent in 7 mm SL larvae. Ventral fin buds are also visible in very small larvae and are located at the level of the base of the pectoral fin. The final number of dorsal and anal fin rays is attained at a larval length of more than 7 mm SL (Figs. 5e, f and g) (Sanzo, 1931).

***Seriola dumerili* (Risso, 1810)**

Eggs

Pelagic, spherical, transparent, with a large colourless oil globule and slightly streaked capsule, segmented yolk, 1.04-1.12 mm in diameter, oil globule 0.28 mm in diameter (Fig. 6a) (Sanzo, 1933). Thirty hours after fertilization the embryo encloses 2/3 of the meridian and contains about 20 segments. Black and yellow pigmentation is present on the cephalic region and on the entire trunk. Stellate melanophores are obviously present on the yolk-sac (Sanzo, 1933). No eggs attributable to this species have been collected during any of the survey carried out in the eastern Adriatic.

Yolk-sac larvae

The newly hatched yolk-sac larvae is about 3.5 mm long (Fig. 6b) (Sanzo, 1933). The most characteristic feature is, as in horse mackerel larvae, the anterior position of the oil globule in the segmented yolk, which ends a notable distance from the anal opening. The mouth is not yet open. The anal opening is slightly behind the middle of the body. Melanophores are irregularly distributed on the body and some of them are on the oil globule (Fig. 6b) (Sanzo, 1933). No yolk-sac larvae attributable to this species have been collected during the surveys so far carried out in the eastern Adriatic.

Larvae

On the third day after hatching the length increases to 4.40 mm, the mouth is open and the eyes depigmented. Some melanophores are along the dorsal fin, on the ventral side of the body, and around the middle of the caudal region (Fig. 6c). When larva reaches 4.70 mm TL, the body is rather rough with a large head, the length of which is, in respect to the body, equal to 1/3 of the total length (Fig. 6d). Four short spines are in front of the preoperculum and three very long ones at the margin behind the preoperculum (Fig. 6e). Stellate melanophores are abundant all over the body except on the last part of the caudal fin, which is slightly more transparent. In larva about 9.72 mm TL, the body has suffered a notable lateral compression and the preoperculum with spines has been reduced. The abdominal trunk and caudal are uniformly intensively pigmented except the peduncle caudal. In the cephalic region the pigment is thicker on the dorsal side (Fig. 6e) (Sanzo, 1933). Regner (1982) found *S. dumerili* larvae at Stončica station in July with frequency 0.02%.

***Trachinotus ovatus* (Linnaeus, 1758)**

Eggs

No information available.

Yolk-sac larvae

No information available.

Larvae

De Gaetani (1940) described the larvae in the stage of 2.52 mm in total length; body is slender and head well developed. Eyes are slightly oval and large in proportion to the head. An intensive pigmentation is present on the entire abdominal region and on the dorsal on the head, and on the ventral and lateral region (Fig. 7a). At the stage 4.80 mm, orbital crest is notable on the cephalic region. The pigmentation was not modified, but the melanophores on the preoperculum and along the mandibular margin have become more numerous. In larvae about 5.36 mm (Fig. 7b) the pigmentation has modified slightly and the preoperculum is scarcely more developed. In respect to the previous stage the orbital crest, on the contrary, is much more evident with 3-4 spines (Fig. 7c). There is a large chromatophore in the space between the third and fourth dorsal rays.

Juvenile

Juvenile specimen of pompano *T. ovatus* was caught near sandy beach "Zlatni rat" in the vicinity of a small island settlement Bol (island Brač) in December 1994 (Dulčić *et al.*, 1997). This specimen has small teeth in both jaws, consisting of a narrow band anteriorly, tapering posteriorly (Fig. 7d). Bases of soft dorsal and anal fins are approximately equal in length; pecioral fins are longer than pelvic fins. Spinous dorsal fin has 6 spines. There are no caudal peduncle grooves. Lateral line is slightly arched above pectoral fins and straight thereafter. There are no scutes. The colour of the specimen is dark green on the top, silvery below. There are 4 dark vertically elongated blotches on the sides; distal half of dorsal and anal fin lobes and tips of caudal fin are black.

ZGODNJI RAZVOJNI STADIJI RIB IZ DRUŽINE CARANGIDAE V VZHODNEM JADRANU

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POVZETEK

Pomen zgodnjih razvojnih stadijev v sistematičnem in ekološkem raziskovanju rib postaja v zadnjih letih vse večji. Tako je danes že splošno uveljavljeno prepričanje, da ikre in larve pomenijo širok spekter bitij, ki so v veliki meri neodvisna od odraslih bitij in kot taka primerna za taksonomske analize. Po drugi strani pa se študije o prirastku ribjih populacij osredotočajo na preživetje iker in larv kot najpomembnejšega dejavnika, ki vpliva na spremembe v številnosti ribjih populacij. Prvi pogoj za te študije so podrobne informacije o videzu iker in larv, da jih lahko identificiramo v planktonskih vzorcih. Najpomembnejša za hrvaško ribištvo je družina Carangidae. *V tem članku so zajeti vsi razpoložljivi podatki in rezultati o zgodnjih razvojnih stadijih rib iz družine* Carangidae *v vzhodnem Jadranu.*

Ključne besede: zgodnji razvojni stadiji rib, Carangidae, vzhodni Jadran

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