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Article

Early life history of three Patagonian zoarcids

Desarrollo de los estadios tempranos de tres zoarcidos Patagónicos

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Resumen.- Los zoárcidos están bien representados en la zona intermareal de la costa Patagónica. Se conoce que son ovíparos con cuidado parental, pero hay poca información del desarrollo ontogenético. El objetivo de este trabajo fue describir los estadios de desarrollo temprano de 3 especies de zoárcidos patagónicos: *Iluocoetes elongatus*, *Phucocoetes latitans* y *Dadyanos insignis*. Se muestrearon masas de huevos de estas 3 especies, en la zona intermareal de la Ría Deseado (Santa Cruz, Argentina). Los huevos fueron depositados en acuarios y condiciones controladas para obtener las postlarvas y los estadios siguientes. Los huevos más grandes obtenidos fueron de *I. elongatus* con 4,94 mm de diámetro, 4,93 mm en *D. insignis* y 4,20 mm en *P. latitans*. Las postlarvas eclosionaron con un alto grado de desarrollo (tamaño de eclosión 17,5 mm de longitud estándar (LS) en *I. elongatus*, 18 mm LS en *P. latitans* y 22 mm LS en *D. insignis*), difiriendo de los juveniles por la presencia del saco vitelino. El patrón de pigmentación corresponde al de los adultos y durante el desarrollo se intensifica. La porción cefálica de la línea lateral está totalmente desarrollada al momento de la eclosión.

Palabras clave: *Iluocoetes elongatus*, *Phucocoetes latitans*, *Dadyanos insignis*, pigmentación, línea lateral

Abstract.- Zoarcids are well represented in the intertidal zone of the Patagonian coast. They are typically oviparous with parental care, but so far there is little information on their ontogenetic development. The aim of this study was to describe the early developmental stages of 3 zoarcid species: *Iluocoetes elongatus*, *Phucocoetes latitans* and *Dadyanos insignis*. Egg masses were sampled from these 3 species in the intertidal zone of the Ría Deseado estuary (Santa Cruz, Argentina), and placed in suitable aquaria to obtain postlarvae and subsequent stages. Results showed that *I. elongatus* has the largest eggs of the 3 species with 4.94 mm in diameter, 4.93 mm in *D. insignis* and 4.20 mm in *P. latitans*. The postlarvae hatch with a high degree of development (with hatching size of 17.5 mm of standard length (SL) of *I. elongatus*, 18 mm SL of *P. latitans* and 22 mm SL of *D. insignis*), differing from juveniles by the presence of a large yolk sac. The pigmentation pattern fully corresponds to that of adults and during development it becomes increasingly intense. The cephalic portion of the lateral line is also totally developed at hatching time.

Key words: *Iluocoetes elongatus*, *Phucocoetes latitans*, *Dadyanos insignis*, pigmentation, lateral line

Introduction

The eelpout family, Zoarcidae, is a widely distributed fish group in the seas around the world, with representatives occupying very diverse depth ranges, from the intertidal zone to great depths, including the abyssal zone. In the Argentine Sea, and especially off the coast of Patagonia, the Zoarcidae are very well represented, being one of the most species-rich families, with 17 genera and 25 species, living from the intertidal zone to deeper waters of the continental slope.

Most zoarcids are oviparous, with the exception of the species of the genus *Zoarces*, which are viviparous. There is a great variability in the egg size of zoarcids, ranging from 2.1-2.4 mm in *Derepodichthys alepidotus* Gilbert, 1896 (which lives in the north-eastern Pacific) to 9.2-9.8 mm in *Austrolycus depressiceps* Regan, 1913 and *Austrolycus laticinctus* (Berg, 1895) (which live off the coast of Tierra del Fuego and Patagonia, respectively) (Gosztonyi 1977, Matallanas *et al*. 1990). The latter represent one of the largest egg sizes among all teleost fishes.

Little information is available on the early development stages of Patagonian zoarcids. Gosztonyi (1977) stated that recently hatched *Phucocoetes latitans (*Jenyns, 1842) are about 20 mm long and reach 35 mm long in the following 2 months, and Matallanas *et al*. (1990) reported that recently hatched *Austrolycus depressiceps* are 22-25 mm long. In all cases, the postlarvae hatch with a relatively large yolk sac and attain an advanced state of development

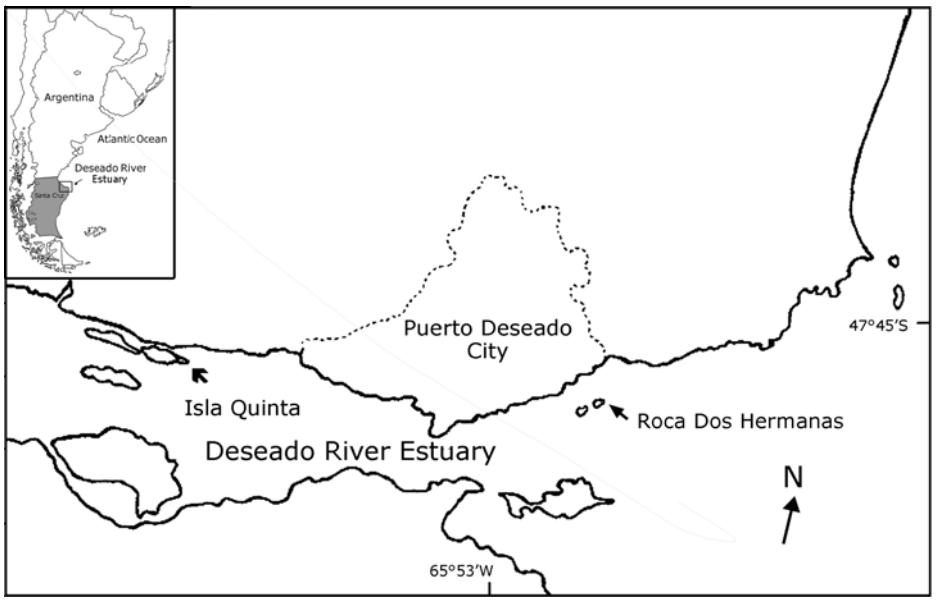

Figure 1. Sampling site. Deseado river estuary in Santa Cruz province. Patagonia Argentina / Sitio de muestreo. Estuario de la ría Deseado en la provincia de Santa Cruz, Patagonia Argentina

(Gosztonyi, pers. observ.; Anderson 1984). Gosztonyi (1984) also studied the tooth replacement in South American zoarcidae, including their ontogenetic stages, while also referring to the development of the intercalar bone in *A. depressiceps*, *Iluocoetes elogantus* (Smitt, 1898), *Dadyanos insingis* (Steindachner, 1898) and *P. latitans* (Gosztonyi 1988).

The aim of the present work was to describe the early developmental stages of 3 Patagonian zoarcids: *Iluocoetes elongatus*, *Phucocoetes latitans* and *Dadyanos insignis*.

Materials and methods

Egg masses of *Iluocoetes elongatus*, *Dadyanos insignis* and *Phucocoetes latitans* were studied as well as their parents, which were taken to the laboratory and placed in filtered and aerated sea water in aquaria under controlled temperature (10ºC). The samples were collected by hand in the Deseado River Estuary (Ría Deseado) at Isla Quinta (47°45'5.47''S; 65°56' 7.78''W, Fig. 1) at low tide, in May 2004 and April 2005.

After hatching, the postlarvae (50 specimens of *I. elongatus*, 50 of *P. latitans* and 44 of *D. insignis*) were fed 2 times a day with *Artemia persimilis* to satiety. Samples were taken every 3 days, fixed in 5% formaldehyde and stored in 70% ethanol. The above material was complemented with eggs, postlarvae and juveniles, obtained between 1970 and 1973 from the same locality.

Special emphasis was put on the description of body pigmentation, body proportions and the cephalic portion of the lateral line system (Fig. 2). The latter system, of high taxonomic value, was studied following the patterns described in Gosztonyi (1977). Due to the difficulty in applying the classical criteria of the developmental stages in fishes (Kendall *et al*. 1984, Lagler *et al*. 1984, Helfman *et al*. 1997, Cousseau *et al*. 2010) to zoarcids, we choose the following stages for the Patagonian eelpouts: Egg: before hatching; Postlarvae: from hatching to the end of yolk sac resorption. This stage was considered separately

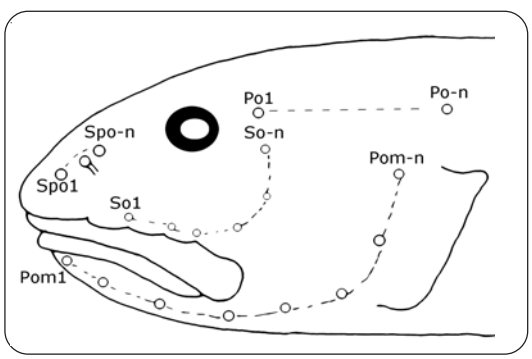

Figure 2. Cephalic channels of the lateral line from a hypothetical zoarcid. Po1-n: postorbital channel. Pom1-n: preopercular-mandibular channel. So1-n: suborbital channel. Spo1-n: supraorbital channel (taken and modified from Gosztonyi 1977) / Canales cefálicos de la línea lateral de un zoárcido hipotético. Po1-n: canal postorbital. Pom1-n: canal preopérculo-mandibular. So1-n: canal suborbital. Spo1-n: canal supraorbital (tomado y modificado de Gosztonyi 1977)

since the specimens have fins with the complete number of rays and the squamation completed, but still with the yolk sac; Juvenile: immediately after the resorption of the yolk sac. At this stage, the specimens are very similar to the adults, although much smaller in size.

For length measurements, the standard length (SL) was taken from the anterior point of the upper jaw to end of the urostyle. The egg diameter and the standard length were measured with a stereomicroscope fitted with an eyepiece micrometer. All drawings were made with a stereomicroscope fitted with a camera lucida.

Results

Iluocoetes elongatus

Iluocoetes elongatus eggs (Fig. 3A) have a mean diameter of 4.94 mm (sd = 0.37, X_{min} = 4.15, X_{max} = 6.25, n = 191) are of an intense orange colour and show a rather large oil drop. They are laid in compact masses consisting of up to 126 eggs, strongly adhered to one another.

Postlarvae (Fig. 3B, C), with lengths between 17.5 and 20 mm SL, hatch with a full complement of paired and unpaired fins and bear a large intense orange coloured yolk sac. The postlarval development takes from 15 to 20 days; with each individual reaching a SL of about 24 mm as the yolk sac is absorbed, although with the oil drop still visible. The cephalic portion of the lateral line is completely developed during the earlier stages of postlarval development. There are 2 pores in the supraorbital channel, one in the postorbital channel, 5 in the suborbital channel and 8 in the preoperculo-mandibular channel (Fig. 4A, B). The body pigmentation is faint, with 8 to 10 brown vertical bands contrasting with a lighter bottom colour.

The juvenile phase (Fig. 3D) begins between 15 and 20 days. Juveniles differ from postlarvae by the lack of a yolk sac and by more intense pigmentation, due to the

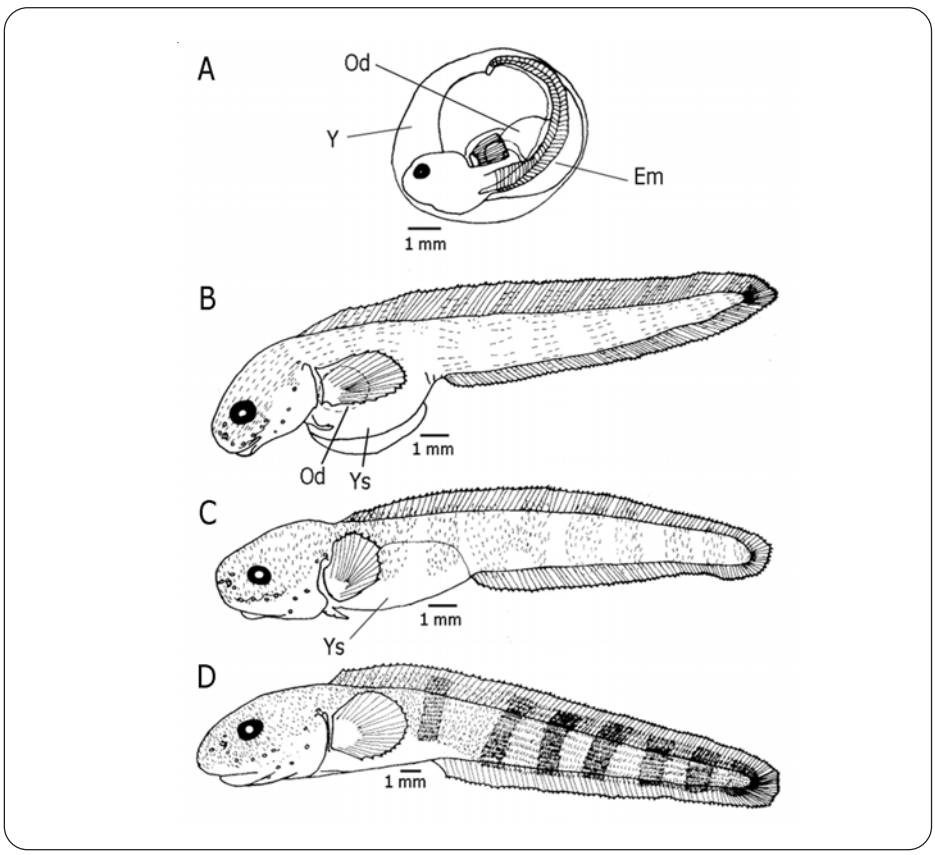

Figure 3. Development stages of *Iluocoetes elongatus*. A: egg, B: postlarva immediately after hatching, C: 10-day-old postlarvae, D: juvenile. Em: embryo, Od: oil drop, Ys: yolk sac; Y: yolk / Estadios de desarrollo de *Iluocoetes elongatus*. A: huevo, B: postlarva inmediatamente después de la eclosión, C: postlarva de 10 días de vida, D: juvenil. Em: embrión, Od: gota de aceite, Ys: saco vitelino, Y: vitelo

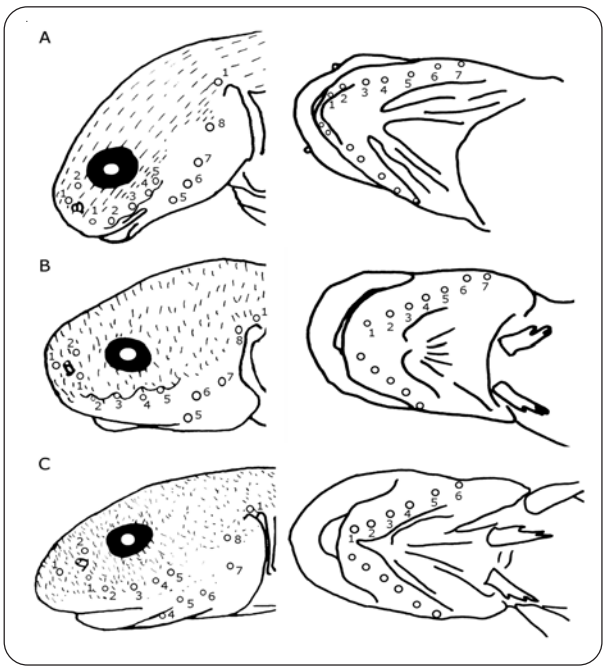

Figure 4. Cephalic portion of the lateral line in *Iluocoetes elongatus*. A: postlarva recently hatched, B: 10-day-old postlarvae, C: juvenile / Porción cefálica de la línea lateral en *Iluocoetes elongatus*. A: postlarva recién eclosionada, B: postlarva de 10 días de vida, C: juvenil

multiplication of melanocytes, making the banded pattern more evident, with the same number of bands which do not reach the abdominal portion. The number of pores in the cephalic portion of the lateral line is constant (Fig. 4C).

PHUCOCOETES LATITANS

The eggs of *Phucocoetes latitans* (Fig. 5A) are slightly smaller than those of *Iluocoetes elongatus*, with a diameter of 4.20 mm (sd, X_{min} and X_{max} N/A). Eggs are orange coloured and bear a large oil drop. They are laid in a compact mass with a smaller number of eggs (25 eggs, according to that found in Gosztonyi 1977).

Postlarvae (Fig. 5B, C) hatch at 18-20 mm SL. They have all fins totally developed and bear a large and intense orange coloured yolk sac. The latter is resorbed including the oil drop at between 10 and 15 days when the postlarvae are about 25 mm SL. During this stage, all the specimens showed 2 pores in the supraorbital channel, 2 in the postorbital channel, 6 in the suborbital channel and 8 in the preopercular-mandibular channel (Fig. 6A and B). After hatching, the dorsal portion of the body from the snout to the caudal end shows a uniform

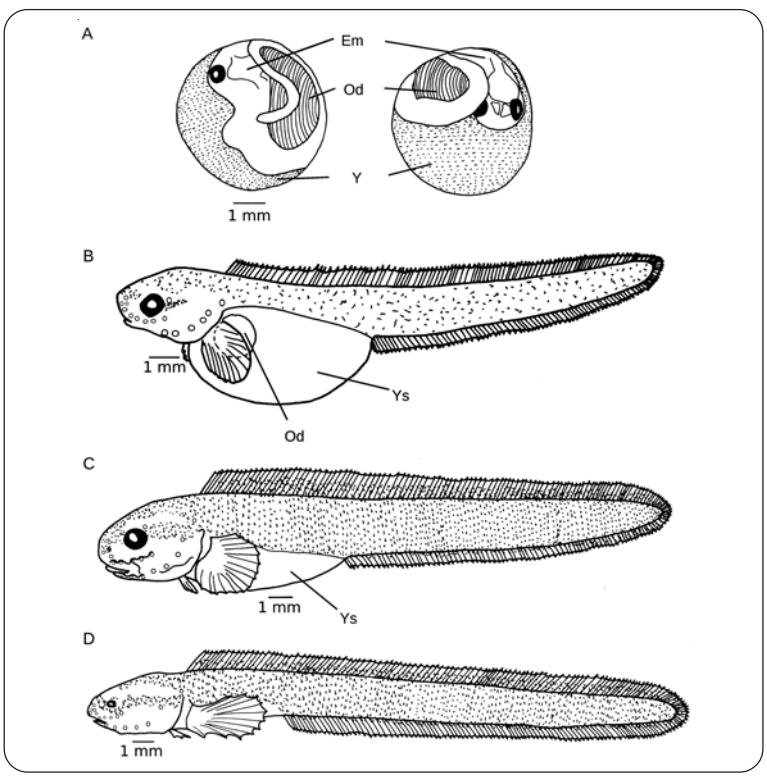

Figure 5. Development stages of *Phucocoetes latitans*. A: egg, B: postlarvae recently hatched, C: 14-day-old postlarvae, D: juvenile. Em: embryo, Od: oil drop, Ys: yolk sac, Y: yolk / Estadios de desarrollo de *Phucocoetes latitans*. A: huevo, B: postlarva recién eclosionada, C: postlarva de 14 días de vida, D: juvenil. Em: embrión, Od: gota de aceite, Ys: saco vitelino, Y: vitelo

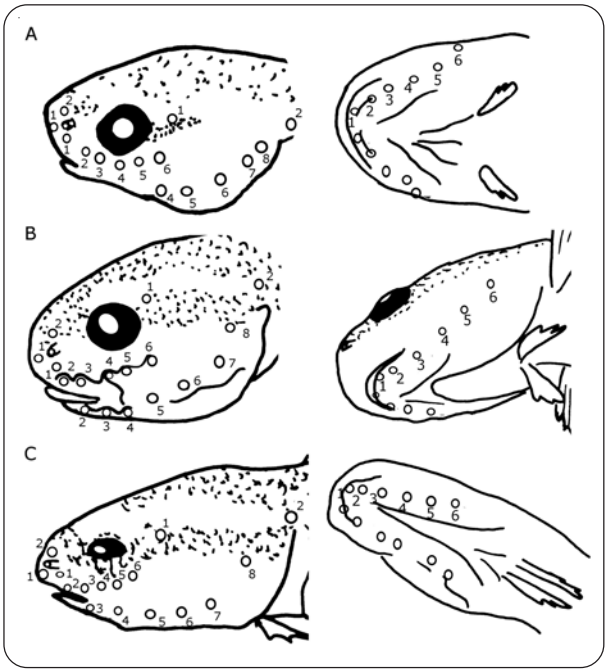

Figure 6. Cephalic portion of the lateral line in *Phucocoetes latitans*. A: postlarvae recently hatched, B: 14-day-old postlarvae, C: juvenile / Porción cefálica de la línea lateral de *Phucocoetes latitans*. A: postlarva recién eclosionada, B: postlarva de 14 días de vida, C: juvenil

pigmentation due to dispersed brown melanocytes over a lighter bottom colour. Also, there is a very characteristic streak on the side of the head from the eye to the mid-point of the opercle. The abdominal portion of the body is the only part devoid of pigmentation. The overall pigmentation pattern is similar to that of the adults.

The juvenile phase (Fig. 5D) begins between 10 to 15 days, when the resorption of the yolk sac is completed. It is characterized by a strong pigmentation in which the animals become increasingly dark due to the multiplication of melanocytes. The number and distribution of pores in the cephalic portion of the lateral line remain constant (Fig. 6C) and correspond to those observed in the adults (Gosztonyi 1977).

Dadyanos insignis

Dadyanos insignis lays eggs (Fig. 7A) with a mean diameter of 4.93 mm (sd = 0.28, X_{min} = 4.39, X_{max} = 5.5, n = 15), in concordance with that found in Gosztonyi (1977), where an average diameter of 5 mm was observed. These eggs are smaller than those of *Iluocoetes elongatus* but larger than those of *Phucocoetes latitans.* Following the family pattern, they are orange coloured and bear a large

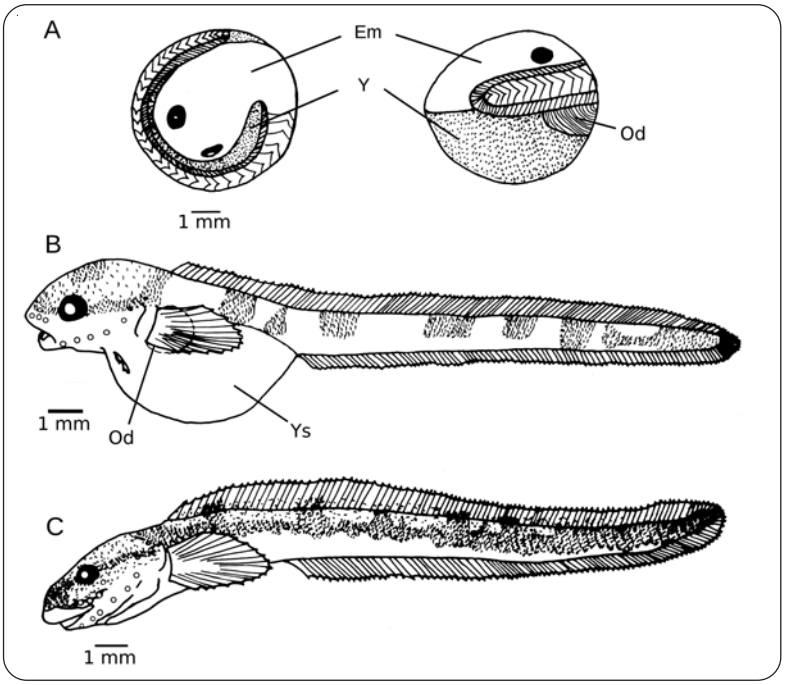

Figure 7. Development stages of *Dadyanos insignis*. A: egg, B: postlarvae recently hatched, C: juvenile. Em: embryo, Od: oil drop, Ys: yolk sac, Y: yolk / Estadios de desarrollo de *Dadyanos insignis*. A: huevo, B: postlarva recién eclosionada, C: juvenil. Em: embrión, Od: gota de aceite, Ys: saco vitelino, Y: vitelo

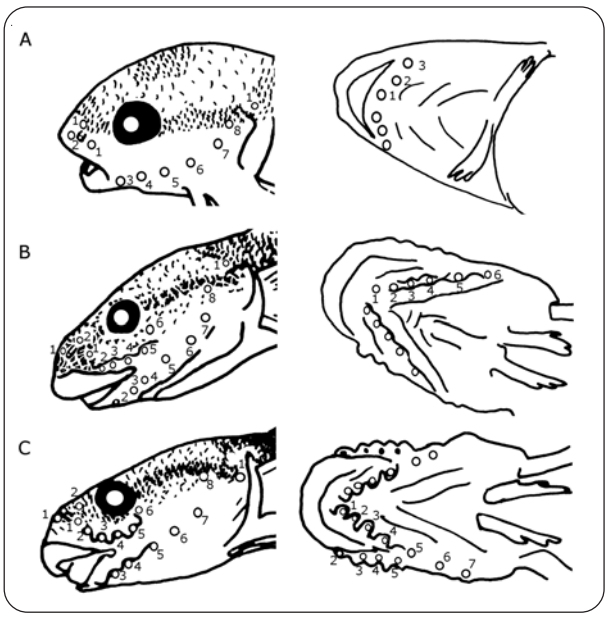

Figure 8. Cephalic portion of the lateral line in *Dadyanos insignis.* A: post larvae recently hatched, B: 14-day-old postlarvae, C: juvenile / Porción cefálica de la línea lateral en *Dadyanos insignis*. A: postlarva recién eclosionada, B: postlarva de 14 días de vida, C: juveniles

oil drop. The compact egg masses have a larger number of eggs than those of the other 2 species. Gosztonyi (1977) observed about 160 eggs in each cluster.

At hatching, the postlarvae (Fig. 7 B), 22 to 23 mm in SL, are the largest of the 3 species studied. As in the other 2 species, postlarval *Dadyanos insignis* hatch with completely developed fins and with a large yolk sac which is reabsorbed during the postlarval stage. The latter stage takes place 15 to 20 days after hatching, with the animals reaching 30 mm SL. This length makes *D. insignis* the largest of the 3 species considered in this study during their development. The cephalic portion of the lateral line (Fig. 8A, B) of most specimens has the complete number of pores as observed in the adults (Gosztonyi 1977): 2 in the supraorbital channel, one in the postorbital channel, 6 in the suborbital channel and 8 in the preopercular-mandibular channel. Only the suborbital channel of newborn individuals has one pore below the nostril. In this phase, the dermal papillae, so characteristic of the adults appears on the snout. At hatching, the specimens are lightly pigmented, with 7 to 8 dark-brown vertical bands. The first band takes the form of a ring around the head. During growth, the bands extend over the dorsal fin and ventrally join their homologue on the other side. In all cases, only the abdomen, the paired fins and the anal fin remain un-pigmented.

The juvenile phase (Fig. 7C) of *Dadyanos insignis*, as in the other 2 species, begins with the loss of the yolk sac, 15 to 20 days after hatching, with the specimens attaining more than 30 mm SL. The pigmentation pattern does not change but attains a stronger colouration due to the multiplication of melanocytes. The cephalic pore distribution (Fig. 8C) does not differ from that of the larval stage.

Discussion

There is an extensive bibliography defining most zoarcids as being oviparous. The only known exceptions are those of the genus *Zoarces*, like *Z. americanus* (Bloch & Schneider, 1801), *Z. viviparus* (Linnaeus, 1758) (Anderson 1984), and *Z. fedorovi* (Chereshnev *et al.*, 2007, Chegodaeva & Voskoboinikova 2010). It is also known that all benthic species normally make nests and exhibit parental care (Anderson 1984). This fact has been observed in *Dadyanos insignis*, *Iluocoetes elongatus*, *Phucocoetes latitans* and *Austrolycus laticinctus* in Central Patagonian shores (Gosztonyi 1977), in *Austrolycus depressiceps* in the Beagle Channel, Tierra del Fuego (Matallanas *et al*. 1990), and in *Zoarces americanus* (Olsen & Merriman 1946, Anderson 1984). The large size of the eggs is an important characteristic of the family as is the incubation time. The latter has been determined in a few species, and extends between 2.5 to 3.5 months (Gosztonyi 1977, Anderson 1984). In *D. insignis*, *I. elongatus* and *P. latitans*, these patterns are very clearly observed, but no description of the development has been documented.

As a result of the present study, we conclude that, among the 3 zoarcids studied, *Iluocoetes elongatus* has the largest eggs (4.94 mm), followed by *Dadyanos insignis* (4.93 mm), and *Phucocoetes latitans* with the smallest (4.20 mm). These results concur with those of Gosztonyi (1977), although still smaller than the largest eggs of *Austrolycus laticinctus*, *Pachycara brachycephalum*, and *Austrolycus depressiceps*, (7.5 to 8.4 mm, up to 9 mm and 9.2 to 9.8 mm in diameter, respectively), which are the largest eggs in the family (Gosztonyi 1977, Matallanas *et al.* 1990, Brodte *et al.* 2006).

The eggs of the 3 species have an intense orange colour and bear a large oil drop, in concordance with other observations within the family (Gosztonyi 1977, Anderson 1984, Matallanas *et al.* 1990).

The postlarvae strongly resemble the adults but with a large yolk sac. The latter is reabsorbed between 15 to 20 days after hatching in *Iluocoetes elongatus* (*ca.*, 24 mm

SL) and *Dadyanos insignis* (*ca.*, 30 mm SL) and after 10 to 15 days in *Phucocoetes latitans* (*ca.*, 25 mm SL).

Although recently hatched specimens of *D. insignis*, *I. elongatus* and *P. latitans* are large in size, they are not the largest within the family. *Austrolycus depressiceps*, with postlarvae 22 to 23 mm in SL (Matallanas *et al*. 1990), *Zoarces americanus* with postlarvae 28 to 31 mm total length (TL) (Anderson 1984), *Z. viviparous* with postlarvae 32 to 40 mm TL (Soin 1968, Altukhov 1979 *fide* Anderson 1984) and *Z. fedorovi* with postlarvae 32 to 33 mm TL (Chegodaeva & Voskoboinikova 2010) are some of the zoarcids whose postlarvae are larger than those of the species studied. In oviparous species, extended parental care might account for the advanced larval development. However, by means of viviparity, the species Zoarces reach the maximum limits, having the largest postlarvae of the whole family.

In the 3 species studied, the cephalic portion of the lateral line is completely developed at hatching time, showing the same distribution as that of the adults. This has also been reported in *Bothrocara hollandi* (Okiyama 1982 *fide* Anderson 1984) but not in *Zoarces americanus* (Anderson 1984) or *Gymnelus* spp. (Anderson 1982 *fide* Anderson 1984), in which post-larvae do not show the adult pore pattern.

According to Anderson (1984), there is no particular larval pigmentation pattern in zoarcids. This was corroborated here in *D. insignis*, *I. elongatus* and *P. latitans*, in which the pigmentation pattern after hatching was found to be similar to that of adults. This has been previously reported for *Gymnelus viridis*, *Bothrocara hollandi* and *Zoarces americanus* (White 1939, Rass 1949, Okiyama 1982 *fide* Anderson 1984; Anderson 1984) and *Zoarces fedorovi* (Chegodaeva & Voskoboinikova 2010).

Finally, the juveniles of the 3 species studied resemble small adults and differ from the post-larvae only by the absence of the yolk sac.

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