Larval development of laboratory-reared carpenter, *Argyrozona argyrozona* (Pisces: Sparidae)

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The larval development of the sparid *Argyrozona argyrozona* is described and illustrated from 16 individuals, representative of a batch reared in the laboratory from artificially spawned eggs. A general account of development is given as well as detailed descriptions of pigmentation, fin development, head spination, myomere counts and morphometrics. The general developmental pattern is similar to other sparids but is unique in regard to preopercular spination, premaxillary and medio-lateral pigmentation and morphometrics.

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The carpenter *Argyrozona argyrozona* (Valenciennes, 1830), is endemic to South Africa, occurring from Saldanha Bay to Port St Johns (van der Elst 1988). This carnivorous, schooling sparid spawns during the summer months between September and March (Nepgen 1977; Buxton unpublished data), and is of considerable importance to inshore fisheries in the region (Smith & Heemstra 1986; Hecht & Tilney 1989). Previous descriptions of early life history have been limited to short accounts of the yolk sac and early preflexion stages (Gilchrist 1904, 1916; Nepgen 1977). In this paper the early life history stages of *A. argyrozona* are described and illustrated from a batch spawned and reared in captivity.

Materials and methods

Adult carpenter were caught on hand-line at the peak of the natural spawning season in the Tsitsikamma National Park situated on the southern Cape coast between Nature's Valley (34°59'S, 23°34'E) and Oubos Strand (34°59'S, 24°12'E) in February 1994. After being transported to shore in 80 l plastic bins the fish were placed in a 5000 l circular holding tank and given a 0,1 ml/kg body weight injection of pituitary homogenate. After approximately 24 h the fish were stripped and the eggs fertilized by mixing in a bowl with sperm and a small amount of seawater, following the methods of Battaglene & Talbot (1992) for snapper (*Pagrus auratus*). Eggs were transported 300 km within 12 h of fertilization to a closed circuit seawater rearing facility at the Department of Ichthyology and Fisheries Science (DIFS), Rhodes University, Grahamstown, where they were reared through metamorphosis. At irregular intervals samples were removed from the rearing tanks, anaesthetized using 2-phenoxyethanol (0,1 ml/100 ml) and preserved in 4% buffered formalin (Markle 1984). Preserved specimens were drawn using a *camera lucida* attachment on a binocular microscope. Drawing techniques followed those recommended by Faber & Gadd (1983) and Leis & Trnski (1989). Unless internal melanophores were obvious in uncleared specimens, they were not illustrated. Specimens were cleared and stained for cartilage and bone following the methods of Taylor & Van Dyke (1985). Xanthophores were not illustrated.

Sixteen specimens ranging in size from 2,48–34,00 mm were examined. Morphometric features were measured using a micrometer eyepiece for specimens under 30 mm body length (BL) and larger specimens were measured with calipers. Terminology used in the written description follows that used by Leis & Trnski (1989). Body length (BL) corresponds to notochord length in preflexion and to standard length in post-flexion larvae and juveniles. All specimens have been lodged in the JLB Smith Institute fish collection in Grahamstown, South Africa (reference numbers 48839–48853).

Results

Egg and hatching

The egg was spherical, buoyant, and transparent. The egg envelope was unsculptured and the yolk unsegmented. Average egg diameter was 0,82 mm (± 0,015). The average diameter of the single oil globule was 2,2% of the egg diameter. Eggs hatched in 26–30 h at 19°C, which was similar to other sparid species (Griswold & McKennedy 1984; Fukuhara 1987). Hatched larvae measured approximately 2,4 mm BL and hung head downwards in the water column. Yolk was resorbed by two Days After Hatch (DAH), although the oil globule persisted until first feeding. Opening of the mouth and anus with concurrent first feeding on rotifers (*Brachionus plicatilis*) occurred at ± 2,5 mm BL or 3–4 DAH.

Pigmentation

Pigmentation is described in the order in which the melanophores appeared on the fish. First pigmentation of the embryo was evident at 20 h in the form of two rows of light brown melanophores running dorsally along the length of the body. Slight pigmentation of the oil droplet was also evident under strongly transmitted light (Figure 1A).

A row of melanophores developed along the ventral midline of the tail region in larvae larger than 2,5 mm BL, one being located at the base of each postanal myoseptum. Myomeres 8–16 possessed an additional melanophore in the middle of the myomere's ventral edge in pre-flexion larvae. This pigmentation became more diffuse as the fish developed but remained until metamorphosis, eventually becoming part of juvenile coloration.

The melanophore on the fin fold immediately anterior to the anus first appeared two DAH (2,5 mm BL), increasing in size as the fish grew. It persisted as a remnant in fish of about 5,0 mm BL, finally disappearing along with the fin fold.

A melanophore on the ventral surface of the gut and just posterior to the cleithral symphysis appeared at 3,2 mm BL

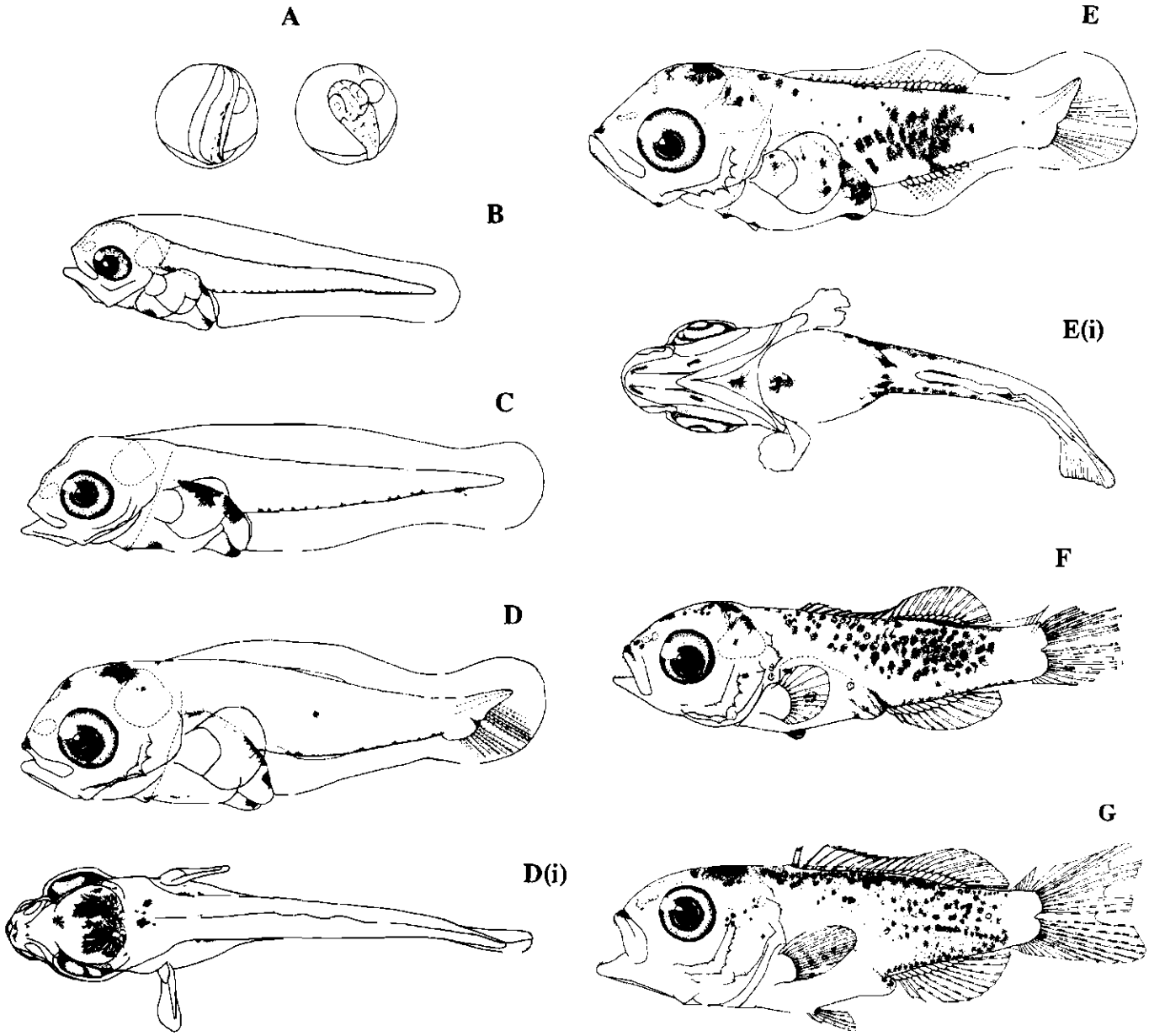

Figure 1 Larval development of *Argyrozona argyrozona*. A = 0,82 mm diameter; B = 3,17 mm BL; C = 3,72 mm BL; D = 4,75 mm BL; E = 5,05 mm BL; F = 7,58 mm BL; G = 8,6 mm BL.

(Figure 1B). This melanophore persisted through notochord flexion [Figures 1C and 1D(i)] and was still well established in fish of 5 mm BL [Figure 1E(i)]. Eventually this pigmentation started disappearing in post-flexion fish of 7,5mm BL and over.

An isolated melanophore appeared on the dorsal surface of the hindgut in fishes larger than 3 mm BL. This pigmentation expanded anteriorly and became pronounced in fishes of about 3,5 mm BL (Figure 1B, C and D). Gut pigmentation started to become obscured by body musculature in late flexion larvae (> 5 mm BL). The pigment was partially obscured in fish undergoing metamorphosis and was finally visible only as a subtle band of subsurface pigmentation in early juveniles. A melanophore dorsal to the swim bladder was visible in larvae larger than 3 mm BL. This pigmentation remained visible until being obscured by body musculature in fish larger than 5 mm BL.

An isolated melanophore ventral to the notochord tip appeared just prior to the emergence of the caudal anlage (3,7 mm BL) and persisted through flexion. It disappeared by the commencement of post-flexion.

The edge of the hypural plates in post-flexion fish was unpigmented.

Pre-flexion larvae lacked cranial pigmentation. A bilateral pair of melanophores appeared over the hindbrain and three smaller dorso-lateral melanophores were visible on the hind, mid- and forebrain of flexion animals [Figure 1D(i)]. They were supplemented by several smaller melanophores as the fish developed [Figure 1D(i)]. The cranium of juvenile fish was darkly pigmented dorsally.

Pigmentation of the snout first appeared on fish of 4 mm BL. The pigmentation spread and darkened as the fish developed and was prominent in juveniles (Figures 1D–1G).

Pigmentation of the lateral body surfaces was first visible

on the tail as a single melanophore, positioned midway between the dorsal and anal anlagen, in fish larger than 4,5 mm BL (Figure 1D). Pigmentation spread in a patch around the original melanophore, remaining in an area bound anteriorly by the gut and posteriorly by the caudal peduncle. Dorsolateral pigmentation spread anteriorly to the nape region (Figures 1D–1E). The lateral body surface remained heavily pigmented throughout development. Distinctive in the pattern of lateral pigmentation was its exclusion from the caudal peduncle until after metamorphosis.

Pigmentation of the dorsal fin was associated with the distal margin of the fin membrane. Melanophores started to develop between the spinous fin elements at approximately 8,6 mm BL (Figure 1F). This pigmentation was conspicuous in fish larger than this and appeared as a dark band, fringing the distal edge of the dorsal fin in juveniles. In larger juveniles (> 33 mm BL) dorsal fin pigmentation spread to the fin rays where it ran along the length of the rays.

Morphology

General

Nares differentiated from the olfactory pit at 5 mm BL. Fine teeth were visible on both jaws at about 7,6 mm BL. Scales first appeared at 7,6 mm BL and were fully developed by 8,6 mm BL. Large canines developed by 12 mm BL. The lower jaw (dentary) projected anteriorly beyond the upper jaw (premaxilla) in larvae measuring 3 mm BL and above. The protrusion of the lower jaw became a prominent feature in juveniles over 30 mm BL.

Myomere counts

The myomere count for all larvae 2 days and older was 25. In one-day-old larvae, either the most posterior myomere was still undeveloped or was too small to be detected. As the gut lengthened, the ratio of preanal to postanal myomeres increased from 7+18 in early preflexion larvae to 9+16 in larvae just prior to flexion. Flexion larvae had myomere counts of 10+15 while early juveniles possessed 12+13 myomeres.

Fin development

Fin development is described in the order in which the fins developed in the fish. Fin counts are summarized in Table 1. Pectoral fin buds were present in newly hatched larvae. Fin rays started differentiating in fish larger than 5 mm BL. A final count of 16 occurred in fish over 32 mm BL.

The caudal fin anlage appeared posterio-ventrally on the tail just prior to commencement of flexion in fish larger than 4,0 mm BL. Fin elements increased in number through flexion and the caudal fin was fully differentiated in 8,6 mm BL fish.

Dorsal fin anlage appeared in fish of 4,7 mm BL (Figure 1D). The adult complement of fin bases was present by 5 mm BL. The first incipient rays appeared on the middle elements in fish of this size (Figure 1E). The eleventh and twelfth (most posterior) spines formed first as rays. The twelfth was changed in fish of 8,6 mm BL (Figure 1G) and the eleventh in fish over 33,0 mm BL. Dorsal spines ossified before the rays.

Anal fin anlage appeared in fish of 4,7 mm BL (Figure 1D). The adult complement of fin-ray bases was present by 5 mm BL. The first incipient rays appeared on the middle elements in fish of this size (Figure 1D). The third (most posterior) spine formed first as a ray and the change is complete by 32,0 mm BL. Anal spines ossified before the rays. Anal fin elements ossified prior to dorsal.

Pelvic fin buds were visible at 5 mm BL and the fin elements were fully formed, (the first being a hard spine and the rest soft rays) in fish larger than 7,00 mm BL.

Table 1 Morphometrics and meristics of *A. argyrozona* larvae and juveniles reared in captivity. Measurements are in mm and are absolute. BL = Body Length; HL = Head Length; SnL = Snout Length; ED = Eye Diameter; PAL=Preanal Length; BD = Body Depth; C = Caudal; D = Dorsal; A = Anal; P1 = pectoral; P2 = pelvic

			Morphometrics						Fin counts				
Age	Stage	Fig.	BL	HL	SnL	ED	PAL	BD	C	D	A	P1	P2
1 DAH	Preflexion	–	2,48	0,23	0,050	0.17	1,033	0,17	–	–	–	–	–
2 DAH		–	2,73	0,23	0,067	0,18	1,067	0,17	–	–	–	–	–
3 DAH		–	2,96	0,65	0,24	0,23	1,08	0,20	–	–	–	–	–
5 DAH		–	3,17	0,68	0,22	0,22	1,17	0,18	–	–	–	–	–
7 DAH		1B	3,17	0,67	0,17	0,23	1,20	0,27	–	–	–	–	–
16 DAH		1C	3,72	0,97	0,33	0,36	1,73	0,46	–	–	–	–	–
20 DAH	Flexion	1D	4,75	1,58	0,35	0,51	2,40	0,80	0+7+8+0	–	–	–	–
22 DAH		1E	5,05	1,95	0,50	0,70	3,20	1,00	0+8+8+0	0,7	0,3	–	–
24 DAH	Postflexion	1F	7,58	2,95	0,92	1,00	4,90	2,00	3+9+8+4	X,12	II,9	I3	I,5
29 DAH	Juvenile	1G	8,60	3,20	1,06	0,90	5,10	1,85	9+9+9+7	XI,11	II,9	15	I,5
36 DAH		–	10,60	4,42	0,83	1,09	6,21	2,88	9+9+9+7	XI,11	III,8	15	I,5
38 DAH		–	11,97	4,39	1,74	1,36	7,88	3,94	9+9+9+8	XI,II	III,8	16	I,5
48 DAH		–	16,20	6,82	1,36	2,35	10,30	3,86	9+9+9+9	XI,11	III,8	16	I,5
64 DAH		–	32,00	11,50	3,00	4,50	21,50	9,00	10+9+9+9	XI,II	III,8	16	I,5
71 DAH		–	33,00	12,00	2,50	4,00	20,00	9,02	10+9+9+9	XII,10	III,8	16	I,5
95 DAH		–	34,00	13,51	3,00	4,00	20,50	10,00	10+9+9+9	XII,10	III,8	16	I,5

Full ossification of the fin elements was complete at 33,0 mm BL. The smallest juvenile to posses full adult fin counts (D XII,10; A III,8) was 33,0 mm BL.

Head spination

Head spination is described in the order of development. Spination of the outer preopercle first appeared in fish larger than 3,5 mm BL as two short, blunt spines (Figure 1C). These spines increased in number to a total of eleven in juvenile fish (Figure 1D). The spines reached their greatest relative length in larvae of 5 mm BL. The longest of these spines was at the preopercular angle and reached the posterior edge of the branchiostegal rays (Figure 1D). The relative size of the spines decreased with age until the spines were reduced to a serrated edge on the outer preoperculum of juvenile fish.

Spination of the inner preopercle first appeared in fish of 4,75 mm BL (Figure 1D) as two short spines. The longest at the inner preopercular angle extended past the edge of the outer preopercular plate. The relative size of the spines decreased with larval development. Juvenile fish developed a third small spine anterior to the original two (Figure 1G). These spines were reduced in larger juveniles.

Spination of the opercle developed in post-flexion fish. It consisted of one interopercular, one subopercular and one opercular spine. Juvenile fish lost the interopercular and developed a second subopercular spine (Figure 1G). The opercular spine was conspicuous in juvenile fish.

Three small supracleithral spines were visible in cleared and stained specimens from 7 mm BL. These spines were reduced in juvenile fish, disappearing in fish larger than 9 mm BL.

Spination of the posttemporal was visible as a single small spine in cleared and stained specimens from 7 mm BL. A second posttemporal spine was visible in cleared and stained juveniles of 8,6 mm BL (Figure 1G). These spines were invisible in larger juveniles.

Discussion

The larvae and juveniles of *A. argyrozona* exhibited typical sparid developmental patterns, as described by Leis & Trnski (1989), including general body shape, myomere count, sequence and nature of fin development, head spination and general pattern of pigmentation. A comparison between the larvae of *A. argyrozona* and those sympatric sparid larvae which have been described revealed some important differences.

Diplodus cervinus (Brownell 1979)

The preflexion larvae had heavy pigmentation of the otic capsule, nape, base of the brain, along the entire length of the symphysis and the ventral and lateral surfaces of the gut. Post flexion larvae had no pigmentation on the snout and displayed heavy pigmentation of the rest of the head, nape and gut. The pelvic fin was pigmented as was the edge of the hypural plates. Pigmentation of the tail was restricted to the posterior ventral edge. There were four inner and six outer preopercular spines and no interopercular spine.

Diplodus sargus (Brownell 1979; Divanach, Kentouri & Paris 1982)

Preflexion larvae lacked pigmentation on the finfold anterior to the anus and possessed conspicuous pigmentation along the dorsal midline of the tail. Flexion larvae lacked pigment on the tail and the outer preopercular spines did not reach the opercular margin. Postflexion larvae lacked posttemporal spines, possessed only a single subopercular and six preopercular spines. Pigmentation of the tail was restricted to the ventral surface. Juveniles had pigmentation on the edge of the hypural plates and caudal peduncle, and tail pigmentation was restricted to a band along the midline. There were no inner preopercular and six outer preopercular spines. The dorsal fin possessed 26 elements and the anal 16.

Lithognathus mormyrus (Brownell 1979)

Preflexion larvae under 4 mm BL were virtually indistinguishable, however, larvae over 4 mm BL had a minimum of 18 melanophores on the ventral midline, more than five on the ventral gut surface and lacked pigment on the cleithral symphysis. The lateral tail pigmentation of post flexion larvae was restricted to a thin line and the ventral hypural plates were pigmented. The inner preopercle was smooth and the outer possessed two blunt spines. There were no supracleithral, posttemporal or opercular spines. Juveniles had widespread pigmentation on the opercular region and pigment of the spinous region of the dorsal fin extended down the membrane. Tail pigment extended into the caudal peduncle. The fin count at this stage was D XI,12; A III,11.

Pachymetapon blochi (Brownell 1979)

Preflexion larvae showed pigmentation of the postero-ventral surface of the otic capsule and hindbrain. Groups of ventral midline melanophores were widely separated in post yolk-sac larvae. Postflexion larvae had pigment on the tail which was restricted to the ventral surface. They seemed to lack a supracleithral spine, had three inner opercular, eight outer opercular and a single subopercular spine.

Cheimerius nufar (Connell & Garrett in press)

Preflexion larvae had pigmentation of the otic capsule, snout operculum, hindbrain and lateral gut surface. Postflexion larvae lacked tail pigmentation but possessed a melanophore on the angle of the lower jaw. There were three preopercular, nine outer preopercular and two supracleithral spines. Both the opercular and posttemporal were smooth. The juveniles lacked lateral and dorsal pigmentation and the pigmentation on the ventral surface of the tail extended onto the caudal peduncle. Both the lower jaw and base of the pectoral fin were pigmented. There were nine preopercular, four supracleithral, two subopercular and a single posttemporal spine at this stage. The first soft ray of the pelvic fin was elongate and the dorsal fin was unpigmented.

Spondyliosoma emarginatum (Beckley 1989)

Preflexion larvae possessed three outer preopercular spines, but were otherwise indistinguishable. Flexion larvae lacked pigment on the snout, cleithral symphysis and otic capsule. There were three inner and five outer preopercular spines, of

which the longest was dorsal to the preopercular angle. Postflexion larvae lacked pigmentation of the snout or otic capsule. There were five tiny spines on the outer preoperculum and no opercular, supracleithral or posttemporal spines. Juveniles had a fin count of D X,13: A III,10. Pigmentation of the dorsal was restricted to the base of the fin elements.

Species '5' (Brownell 1979)

Preflexion larvae had melanophores on the nape, dorsal edge of the tail and pigmentation spread over the entire ventral gut surface. Descriptions of subsequent stages were not available. Brownell (1979) could have been wrong in describing species '5' as *A. argyrozona*. However his description was limited to two specimens in the preflexion stage and the possibility exists that the preflexion stage of *A. argyrozona* may be subject to some intraspecific variation.

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