

Observations on development and anomalies in the appendicular skeleton of sea bass, *Dicentrarchus labrax* L. 1758, larvae and juveniles

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Abstract. The development of the fin skeleton has been studied in both the wild and hatchery sea bass, *Dicentrarchus labrax* L., larvae, in order to identify and define morphofunctional criteria for larval quality assessments. The cartilaginous and bony skeletal elements of the larvae were studied and standard length and notochord flexure recorded. Fin anomalies were present in reared larvae, whereas they were rare or absent in specimens from the wild. These anomalies were recognizable from the very beginning of skeletal development, indicating that environmental, genetic and broodstock management factors influence even the very early stages of larval development.

Introduction

In Mediterranean aquaculture the standardization of controlled reproduction and larval rearing techniques has allowed a much increased production of finfish larvae, especially those of sea bass, *Dicentrarchus labrax* L., and gilthead sea bream, *Sparus aurata* (L.). The progeny show, however, some morphofunctional anomalies which cannot entirely be eliminated by larval selection. Reared sea bass have been reported to have an extremely high incidence of abnormalities (Barahona-Fernandes 1982). The present study aimed to describe the development of osteological fin characters in sea bass larvae and juveniles both from the wild and from the hatchery, in order to identify specific anatomical features which might be used for assessments of the quality of the larvae.

Materials and methods

Sea bass larvae ($n = 97$) were randomly sampled from a commercial hatchery. Wild sea bass fry ($n = 22$) were collected in the Tyrrhenian Sea (Focene, Roma) by means of a small purse seine. All samples were fixed in buffered formaldehyde (5%), cartilage and bone stained with Alcian blue and Alizarin Red S (Dingerkus & Uhler 1977).

Standard length (SL) (from anterior tip of snout to posterior end of notochord, before and

during notochord flexion, and to the posterior end of hypuralia, after notochord flexion, according to Kohno, Shimizu & Nose 1984), was measured on the cleared and stained specimens. Although the SL of these specimens tended to increase after the treatment, no corrected values were used in this study. Measurements were made to the nearest 0.05 mm under a binocular microscope with an ocular micrometer for the specimens under 12 mm, whereas a dial-reading caliper was used for those longer than 12 mm. Drawings were made by means of a camera lucida. The flexion angle of the end of the notochord was calculated by: $\tan X = H/L$, where L is the length from the flexure point of notochord and H is the perpendicular from the tip of the notochord to the intersection with the notochord axis (Kohno, Taki, Ogasawara, Shirojo, Taketomi & Inoue 1983). Pterygophore complement is given by the formula of Birdsong, Murdy & Pezold (1988), where the initial figure indicates the interneural space into which the first pterygophore of the fin in question is inserted. The figures following the dash each represent an interneural space, starting from the one into which the first pterygophore inserts, and the figure itself indicates the number of pterygophores inserted at that position.

Results

Normal development

At hatching, which occurred at a length of about 3.5 mm, the larvae showed a continuous finfold, extending dorsally from the otic capsul and ventrally from the posteroventral portion of the yolk sac. This was separated into anal, caudal and dorsal fins when the larvae reached 9.80 mm SL. The first acquisition of fin-ray and pterygophore counts is given in Tables 1 and 2 for reared specimens and in Tables 3 and 4 for wild ones.

The elements of the pectoral girdle were the first fin components to develop: 3.85 mm SL larva showed the coraco-scapular bud and an ossified cleithrum. Pectoral girdle and fin cartilage and bone development is illustrated in Fig. 1. Caudal fin hypuralia (1, 2 and 3) were the second fin elements to appear (6.30 mm SL) and caudal complex development is illustrated in Fig. 2. At 8.45 mm SL no component of the anal fin was discernible. The first pterygophores observed were seven anal fin cartilaginous buds, between the 14th and 16th interneural space, at 8.55 mm SL (see Table 1). They corresponded to the medial (4th–10th pterygophore) region of the anal fin. Developmental sequences of anteriormost and posteriormost anal pterygophores are shown in Fig. 3. The pterygophores of the dorsal fins first observed (11.50 mm SL) were eight cartilaginous anlagen, between the 12th and 15th interneural space (see Table 1). They corresponded to the posterior region (5th–12th pterygophore) of the second dorsal fin. Developing pterygophores were added cephalad. First dorsal separated from second dorsal fin during development (at about 14.00 mm SL). Ossification went on in caudal direction starting from I dorsal pterygophore (14.40 mm). I and II dorsal fin rays began to ossify in the same direction respectively at 16.10 mm and 17.80 mm SL. The shape of the most anterior and posterior pterygophores of the dorsal fins did not differ from those of the anal fin. Some differences were, however, identified in the development of anteriormost dorsal pterygophore, which originated from two pieces of cartilage, whereas the anal one formed from a single piece (see Fig. 4). The components of the pelvic fin were the last ones to appear. The basipterygium was only observed in larvae of 11.30 mm SL. Despite the late appearance of fin supports, the development of pelvic fin rays proceeded very fast and the final ray count was achieved at 14.00 mm SL.

Table 1. Acquisition of pterygophore and caudal fin support counts in 37 reared larvae and juveniles of *D. labrax*. SL: standard length, stained state. D: dorsal. DCC: distal caudal cartilage. HYP: hypural. EP: epural. C: cartilaginous. O: ossified (Birdsong *et al.* 1988)

SL	Pterygophores										DCC	HYP	EP
	First dorsal		Birdsong's formula	Second dorsal		Birdsong's formula	Anal		Birdsong's formula				
	C	O		C	O		C	O					
5-55	0	0		0	0		0	0			0	0	0
6-60	0	0		0	0		0	0			0	2	0
7-10	0	0		0	0		0	0			0	2	0
7-30	0	0		0	0		0	0			0	3	0
7-55	0	0		0	0		0	0			0	4	0
7-80	0	0		0	0		0	0			0	3	0
8-10	0	0		0	0		0	0			0	4	0
8-45	0	0		0	0		0	0			0	4	1
8-55	0	0		0	0		7	0	14-331		0	5	3
8-75	0	0		0	0		9	0	13-1323		0	4	3
9-00	0	0		8	0	12-2222	10	0	13-2332		0	5	4
9-45	0	0		9	0	12-3321	10	0	13-2332		1	4	3
9-80	0	0		9	0	12-12331	11	0	13-2233		0	5	3
10-10	0	0		13	0	10-122222	11	0	13-131222		1	5	3
10-40	4	0	5-1111	12	0	9-1212222	11	0	12-13232		2	5	2
11-10	5	0	5-11111	13	0	9-11131231	11	0	13-13421		2	5	3
11-50	5	0	4-1211	14	0	8-110232221	12	0	13-22332		2	5	3
11-65	7	0	4-211111	13	0	9-111223321	12	0	12-122331		2	5	3
11-95	8	0	3-2121011	14	0	10-2222222	12	0	12-114321		2	5	3
12-30	7	0	3-22111	12	0	8-111122221	13	0	12-123321		3	5	3
12-90	6	0	3-111111	13	0	8-101222221	11	0	12-12332		2	5	3
13-10	7	0	3-121111	13	0	8-11112223	11	0	12-122231		3	5	3
13-40	6	0	3-21111	13	0	8-111112222	13	0	12-123232		2	5	3
14-00	7	0	3-31111	12	0	8-10122222	12	0	13-23322		0	0	0
14-40	6	0	3-21111	13	0	9-1112231	13	0	12-12332		5	5	3
14-90	7	0	2-12111	12	0	7-111112222	12	0	12-123231		6	5	3
15-40	7	0	3-22111	13	0	8-111122221	12	0	12-123231		5	5	3
15-60	7	0	2-112111	13	0	8-110222221	12	0	12-123321		7	5	3
16-00	7	0	2-121111	10	3	8-110222221	12	0	12-123321		6	5	3
16-70	5	3	3-221111	10	3	9-2022221	10	0	12-113311		9	4	3
16-80	5	2	2-121111	12	0	8-11112222	9	2	12-122321		7	5	3
17-10	4	3	2-121111	12	0	8-11022222	11	1	12-123321		7	5	3
17-80	0	7	2-121111	13	0	8-110222221	11	1	12-12333		7	5	3
17-90	2	6	3-302111	14	0	9-11222222	7	4	12-113231		7	5	3
18-50	3	4	2-121111	12	0	8-111122213	9	2	12-12332		6	5	3
18-90	3	3	3-21111	13	0	8-10122223	10	2	12-13323		6	5	3
19-50	0	7	3-31111	0	13	8-110221321	9	2	12-12323		6	5	3
20-00	0	7	3-22111	9	5	8-111042221	8	4	12-122421		5	5	3

Flexion of notochord end

Flexion of the notochord was detectable at 6.30 mm SL (Fig. 5). The flexion was attained completely at about 8.55 mm and the final flexure angle ranged between 45° and 50°.

Table 2. Acquisition of fin-ray counts in 37 reared larvae and juveniles of *D. labrax*. SL: standard length, stained state. C: cartilaginous. O: ossified

SL	Rays										
	First dorsal		Second dorsal		Anal		Caudal			Pectoral	Pelvic
	C	O	C	O	C	O	Secondary	Upper Principal	Lower Secondary		
5.55	0	0	0	0	0	0	0	0 + 0	0	0	0
6.60	0	0	0	0	0	0	0	0 + 0	0	0	0
7.10	0	0	0	0	0	0	0	0 + 0	0	0	0
7.30	0	0	0	0	0	0	0	3 + 2	0	0	0
7.55	0	0	0	0	0	0	0	3 + 2	0	0	0
7.80	0	0	0	0	0	0	0	4 + 3	0	0	0
8.10	0	0	0	0	0	0	0	6 + 6	0	0	0
8.45	0	0	0	0	0	0	0	7 + 7	0	0	0
8.55	0	0	0	0	0	0	0	9 + 8	1	0	0
8.75	0	0	0	0	0	0	0	9 + 8	1	0	0
9.00	0	0	0	0	5	0	0	9 + 8	1	0	0
9.45	0	0	0	0	0	0	0	9 + 8	1	0	0
9.80	0	0	0	0	6	0	0	9 + 8	1	0	0
10.10	0	0	8	0	7	0	0	9 + 8	1	0	0
10.40	0	0	11	0	11	0	0	9 + 8	1	0	0
11.10	0	0	12	0	12	0	0	9 + 8	3	0	0
11.50	0	0	13	0	13	0	2	9 + 8	3	8	0
11.65	0	0	13	0	13	0	2	9 + 8	3	7	0
11.95	1	0	14	0	14	0	3	9 + 8	4	7	0
12.30	1	0	13	0	14	0	4	9 + 8	4	6	0
12.90	0	0	13	0	12	0	4	9 + 8	4	9	0
13.10	8	0	13	0	13	0	6	9 + 8	5	13	5
13.40	6	0	13	0	14	0	4	9 + 8	4	10	0
14.00	8	0	12	0	14	0	10	9 + 8	9	15	6
14.40	8	0	12	0	12	1	10	9 + 8	10	16	6
14.90	9	0	12	0	14	0	11	9 + 8	11	15	6
15.40	9	0	13	0	12	2	11	9 + 8	11	15	6
15.60	9	0	13	0	12	2	12	9 + 8	12	15	6
16.00	9	0	13	0	12	2	12	9 + 8	12	15	6
16.70	9	0	12	0	11	2	12	9 + 8	12	15	6
16.80	9	0	12	0	10	3	12	9 + 8	12	15	6
17.10	7	2	12	0	11	3	13	9 + 8	12	15	6
17.80	7	2	7	6	11	3	14	9 + 8	12	15	6
17.90	6	4	9	5	7	7	14	9 + 8	14	15	6
18.50	3	6	5	7	4	9	14	9 + 8	14	17	6
18.90	3	6	8	6	9	5	15	9 + 8	14	16	6
19.50	2	7	6	7	6	7	14	9 + 8	14	15	6
20.00	0	9	0	12	0	14	16	9 + 8	15	17	6

Table 3. Acquisition of pterygophore and caudal fin support counts in 14 wild fry of *D. labrax*. SL: standard length, stained state. D: Dorsal. DCC: distal caudal cartilage. HYP: hypural. EP: epural. C: cartilaginous. O: ossified. (Birdsong 1988)

SL	Pterygophores										DCC	HYP	EP
	First dorsal		Birdsong's formula	Second dorsal		Birdsong's formula	Anal		Birdsong's formula				
	C	O		C	O		C	O					
15-00	7	0	2-112111	13	0	8-11112223	12	0	11-112323	3	5	3	
15-80	7	0	2-121111	13	0	8-111122221	12	0	12-132321	4	5	3	
16-50	7	0	2-121111	13	0	8-11112223	12	0	12-12333	3	5	3	
17-00	7	0	2-121111	13	0	8-111122221	12	0	12-123321	5	5	3	
17-10	7	0	2-121111	13	0	8-111122221	12	0	12-123321	3	5	3	
17-30	7	0	2-121111	14	0	8-11112222	12	0	12-213321	6	5	3	
17-70	7	0	2-112111	14	0	8-111122222	12	0	12-123321	4	5	3	
18-00	7	0	2-112111	13	0	8-111122221	12	0	12-123321	6	5	3	
19-20	7	0	2-121111	14	0	8-111122222	12	0	12-123321	6	5	3	
20-00	7	0	2-121111	14	0	8-111122222	12	0	12-123321	6	5	3	
21-70	7	0	2-121111	12	0	8-111122231	12	0	12-123321	6	5	3	
22-80	0	7	2-121111	0	13	8-111122221	0	12	12-123321	2	5	3	
23-20	0	7	2-121111	0	13	8-111122221	0	12	12-123321	6	5	3	
26-20	0	7	2-121111	0	14	8-111122222	0	12	12-123321	6	5	3	

Table 4. Acquisition of fin ray counts in 14 wild fry of *D. labrax*. SL: standard length, stained state. C.: cartilaginous. O.: ossified

SL	Rays										
	First dorsal		Second dorsal		Anal		Caudal			Pectoral	Pelvic
	C	O	C	O	C	O	Upper Secondary	Lower Principal	Lower Secondary		
15-00	8	0	13	0	14	0	6	9+8	6	12	?
15-80	8	0	13	0	14	0	8	9+8	7	14	6
16-50	8	0	13	0	14	0	8	9+8	7	14	6
17-00	9	0	13	0	12	2	9	9+8	8	15	6
17-10	8	0	13	0	14	0	9	9+8	8	16	6
17-30	9	0	14	0	14	0	9	9+8	8	16	6
17-70	9	0	14	0	14	0	10	9+8	9	16	6
18-00	9	0	13	0	14	0	10	9+8	10	15	6
19-20	9	0	7	7	12	2	12	9+8	10	16	6
20-00	9	0	9	5	12	2	13	9+8	12	17	6
21-70	9	0	9	4	12	2	12	9+8	12	16	6
22-80	0	9	0	13	0	14	13	9+8	13	16	6
23-20	0	9	0	14	0	14	13	9+8	13	16	6
26-20	0	9	0	13	0	14	15	9+8	14	16	6

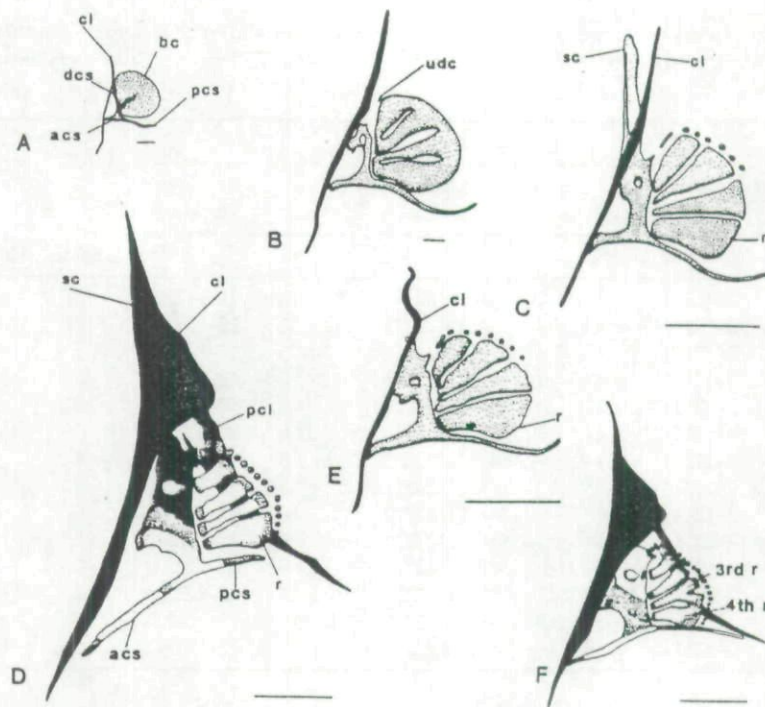


Figure 1. Pectoral girdle development. (A) 5.70 mm SL: a blade-like cartilage (bc) and a thin cleithrum (cl) were observed. The coraco-scapular cartilage has developed a posterior (pcs), dorsal (dcs) and anterior (acs) processes. (B) 11.30 mm SL: the blade-like cartilage is dividing to form the radials. The first (uppermost) distal cartilage (udc) is present. (C) 13.10 mm SL: the four cartilaginous radials (r) are now separated and the seven distal cartilages are evident. (D) 14.00 mm SL: ossification is discernible in cleithrum, supracleithrum (sc), and in postcleithrum (pcl). The adult distal cartilages and rays number is achieved. Radials, pcs and acs will be ossified at 17.9 mm SL. (E) Malformed cleithrum (compare with Fig. 1C). (F) Bifurcation of the 3rd radial (3rd r) and fusion between 3rd and 4th radials (4th r) (compare with Fig. 1D).

Postcleithra were removed in C and E. Rays and posttemporals were removed in C, D, E, F. Cartilaginous region: stippled area. Ossifying region: white area. Ossified region: black area. A, B: bar = 0.1 mm; C, D, E, F: bar = 0.5 mm.

Wild specimens

The smallest wild specimen observed was 15.00 mm SL and final fin support counts were already established. At this body length, the final ray number had already been reached in the I and II dorsal fin, while the anal fin rays were not discernible until 17.00 mm SL (Tables 3 and 4). The ossification process in I and II dorsal and anal fin supports was simultaneously attained at 22.80 mm SL. Wild specimens showed regular pterygophore formulae, with some exceptions in the II dorsal fin. None of the fin anomalies detected in hatchery specimens were observed in wild ones.

Fin anomalies

Anomalies, which started early in development, were recorded in all of the fins. In the anal

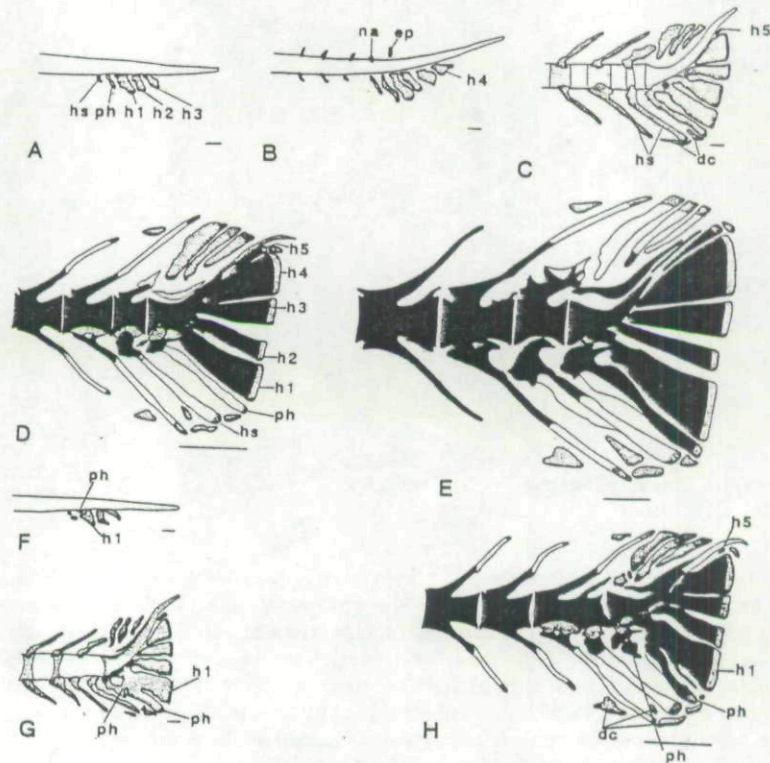


Figure 2. Development of caudal complex in *D. labrax* larvae. (A) 7.15 mm SL larva: cartilaginous buds of the haemal spine of future preural centrum 2 (hs), parhypural (ph), hypuralia 1, 2 and 3 (h1, h2, h3). (B) 8.45 mm SL larva: 4th hypural (h4), epural (ep), specialized neural arch (na) of future preural centrum 2. (C) 10.65 mm SL larva: 5th hypural (h5). In 10.40 mm specimen, fusion (*) of the parhypural with I and II hypuralia at their bases and two distal caudal radials (dc) were first observed. (D) 14.90 mm SL larva. A cartilaginous mass is present caudad to the hypural 5. The cartilaginous bar underlying urostyle is reduced to small cartilaginous portions (arrows) between parhypural and I hypural and I and II hypuralia. (E) 18.40 mm SL juvenile. Hypuralia and parhypural are completely free from each other. (F-H) Developmental sequences of the most frequent caudal fin anomaly. (F) Proximal region of parahypural develops from basiventral, while the middle and distal portions develop from hypural 1 (compare with A). (G) The final arrangement consists of a reduced parhypural, separated from the middle and distal portions, which are fused for the middle region, to an abnormal hypural 1 (compare with C). (H) More advanced stage of development of the same anomaly. Furthermore, note the extraneurary distal cartilages and the reduction of hypural 5 (compare with D).

D, E, H: bar = 0.5 mm; others: bar = 0.1 mm.

and I and II dorsal fin, anomalies affected rays (five types), pterygophores (nine) and distal radials (four). Pterygophore abnormalities were recognized as the most frequent anomalies and were identified as bifurcations, fusions and abnormal sizes (Fig. 3O,P and Fig. 4N,O). Anal, I and II dorsal fin anomalies were recorded respectively in 10.3, 11.3 and 21.6% of the observed hatchery specimens. These anomalies were already clearly recognizable during early larval development, when the fin components were developing, i.e. in a cartilaginous condition. The most precocious fin anomalies appeared at 10.70, 12.60 and 13.50 mm SL in the II dorsal, I dorsal and anal fins respectively.

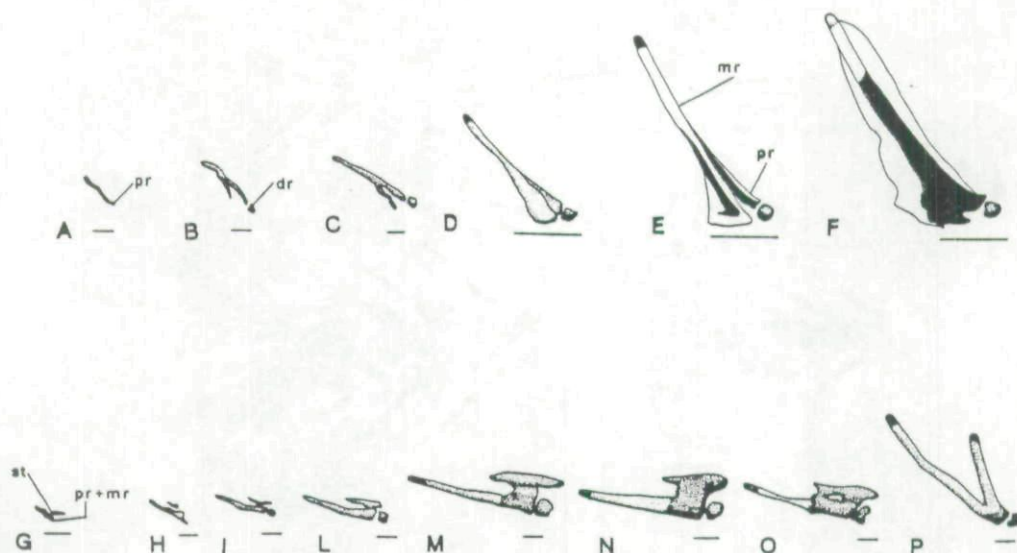


Figure 3. First (anteriormost) and last (posteriormost) anal pterygophore development. (A) 10·65 mm SL: proximal radial (pr) of anteriormost anal pterygophore. (B) 11·30 mm SL: distal radial (dr). The anteriormost pterygophore had its first ray at a SL over 10·70 mm. (C) 11·50 mm SL. (D) 14·00 mm SL: 11·95 mm SL larva first shows three hard rays. (E) 16·10 mm SL: anteriormost pterygophore is extending, from the proximal radial to the tip of medial radial (mr), for two interneural spaces (12th–13th) in caudal–cephalic direction. (F) 20·40 mm SL: final developmental stage of anteriormost pterygophore which was visible for the first time at a SL of 19·20 mm. (G) 9·50 mm SL: the posteriormost anal pterygophore first appeared as a cylindrical cartilage, the future medial and proximal radial. At this SL, a small cartilaginous bar (st), (future 'stay', Weitzman 1962) is placed caudal to it. (H) 11·00 mm SL. (I) 12·30 mm SL: a small cartilage radial is discernible. (L) 13·10 mm SL: the fusion between cartilaginous proximal and middle radials and stay has started. (M) 15·20 mm SL: the fusion is not yet completed. (N) 18·90 mm SL: the definitive structure is achieved. (O) Posteriormost anal pterygophore anomaly (compare with N). (P) Anal fin anomaly: pterygophore bifurcation.

D, E, F, bar = 0·5 mm; others, bar = 0·1 mm.

The caudal fin presented the highest incidence of anomalies (34%). Eleven different types of anomalies were identified as affecting hypuralia, epuralia, parhypural and distal caudal cartilages. In detail, the most frequent caudal fin anomaly (66% relative frequency) is shown in Fig. 2 F, G, H. Another frequent anomaly was linked to the lack of separation, normally occurring at 14·90 mm SL, between the proximal edges of parhypural and hypural 1 (see Fig. 2D). Fusion of hypuralia 1–2 and hypuralia 3–4 occurred in 15% and 6% respectively of observed specimens, resulting in a 2+2 final arrangement. Caudal fin anomalies were already detectable at 9·40 mm SL.

Lastly, pectoral fin anomalies were recorded only in the cleithrum (Fig. 1E), in the posterior process of coraco-scapular cartilage and in the radials in 13·4% of observed specimens. Pectoral fin malformations occurred early, when pectoral fin supports were still developing (6·40 mm SL in cleithrum and posterior process of coraco scapula). Radial fusions and bifurcations (Fig. 1F) were detectable at 12·50 mm SL but anomalies in the separation process of the blade-like cartilage to form the radials were clearly recognizable at 9·30 mm SL.

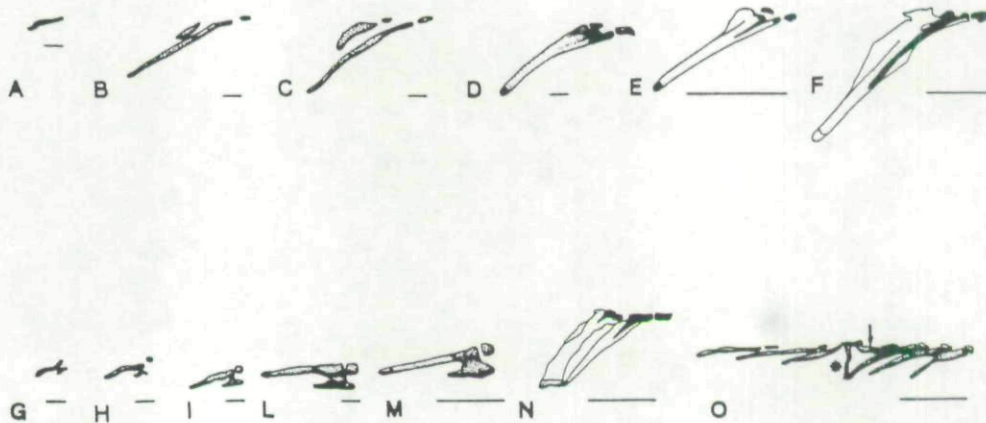


Figure 4. Anteriormost and posteriormost dorsal pterygophore development. (A) 11·00 mm SL: proximal radial of anteriormost dorsal pterygophore. (B) 12·70 mm SL: a small cartilaginous bar has appeared dorsal and cephalic to medial portion of pterygophore. A small distal radial is evident. (C) 13·10 mm SL: another distal radial (not present in anteriormost anal pterygophore, compare with Fig. 3C) is present. (D) 15·40 mm SL: the two cartilaginous rods have fused. (E) 18·50 mm SL: the proximal radial is ossifying, in the fusion area. (F) 19·20 mm SL: the second to appear distal cartilage is fused to anterior region of proximal radial. The definitive shape of anteriormost dorsal pterygophore is achieved. (G) 10·40 mm SL: proximal and middle cartilages of posteriormost dorsal pterygophore. For developmental sequences see posteriormost anal pterygophore. (H) 11·50 mm SL. (I) 12·30 mm SL. (L) 14·10 mm SL. (M) 16·10 mm SL: the definitive shape of posteriormost dorsal pterygophore is achieved. (N) Deformed anteriormost dorsal pterygophore (compare with F). (O) A common malformation involving transition region between I and II dorsal fins. The first pterygophore of the II dorsal fin (arrow) appears divided in the middle by an extranumerary and malformed (*) pterygophore of the I dorsal fin.

E, F, M, N, O bar = 0·5 mm; others bar = 0·1 mm.

Discussion

To our knowledge, no data are available on the morphological details of skeletal development in sea bass: only Fritzsche & Johnson (1980) report on the early osteological development in striped bass, *Morone saxatilis* (Walbaum).

Both the appearance and the final arrangement of fin rays were usually preceded by the completion of fin pterygophores. The final development of vertical fins, up till the cartilaginous condition, preceded that of paired fins. Among the vertical fins, caudal fin supports and rays were the first to reach the adult arrangement (8·55 mm SL). The flexion of the notochord tip started at 6·30 mm SL and was completed at about 8·55 mm SL. At the same body length, caudal fin rays shifted their direction from an oblique to a horizontal arrangement. These simultaneous and rapid changes in caudal complex development increase the propulsive force of larvae. Therefore, in the early larval life, the ability to swim seems to be dependent on the correct completion of development of caudal fin supports and rays. The same is reported for chub mackerel, *Scomber japonicus* (Houttuyn), in which the acquisition of swimming functions in early development seems to be strictly related to caudal fin development (Kohno *et al.* 1983).

Fin development did not occur in a continuous and regular way, but through alternate pauses and rapid changes. In fact fin pterygophores development was so rapid that it was not possible to detect any first pterygophore appearance in larvae which differed in length for

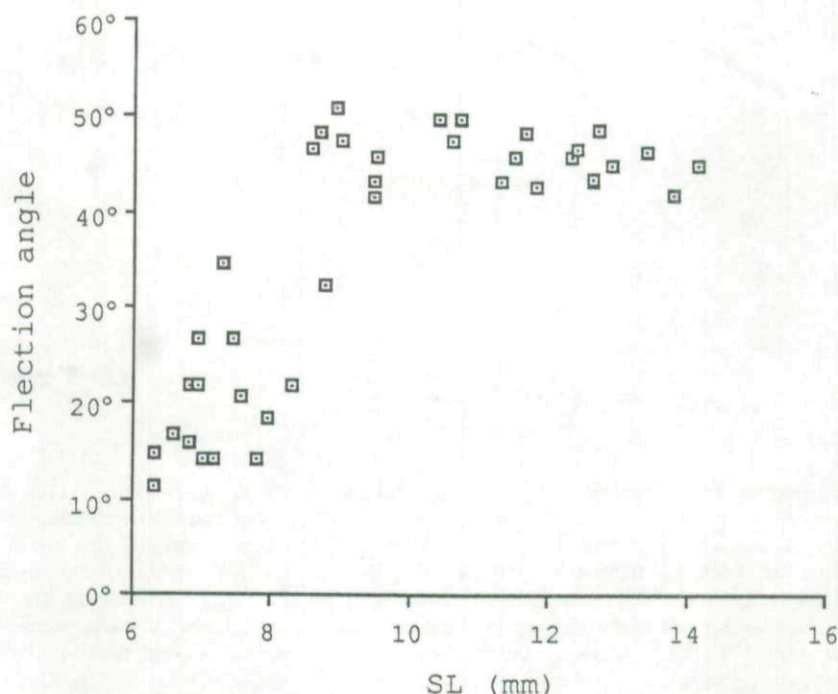


Figure 5. Relationship between the angle of flexure of notochord end and the standard length of sea bass larvae.

0.1 mm SL. Furthermore, wild specimens began simultaneously to ossify fin supports over the range of 21.70–22.80 mm SL. These observations may indicate that, although larval development is a continuous phenomenon (Kohno *et al.* 1983), some changes which define functional thresholds may be identified, during which structural and functional adaptations may occur (Balon 1971).

Anal, I and II dorsal, pectoral and caudal complexes are affected by anomalies (only one pelvic basipterygium anomaly was present). Overall 87 single and associated anomalies were observed in the hatchery larvae. Fin anomalies were clearly detectable at earliest stages of larval development, when the fin components had just begun development.

Environmental influences such as unfavourable temperature, oxygen depletion, radiation and nutritional deficiencies have been reported to induce skeletal anomalies (Brooke 1975; Wiegand, Hataley, Kitchen & Buchanan 1989). Our data suggest that factors affecting larval development have to be sought during the earliest period of tank rearing.

The caudal fin exhibits the highest incidence of anomalies (34%) which were detectable at 9.4 mm SL. Moreover hypural and parhypural fusions (66% relative frequency) affected the anatomo-functional condition of the caudal complex. Consequently, the flexibility of the caudal fin and the role of these elements in the forward propulsive thrust of larvae may be affected.

None of the aforesaid fin anomalies was detected in wild specimens. Morphological anomalies are more frequent in reared larvae and juveniles than in wild ones (Bauman & Hamilton 1984) and severe selection pressure against malformed fish in wild environment has been proposed (Vladimirov 1975). In our observations wild sea bass larvae showed

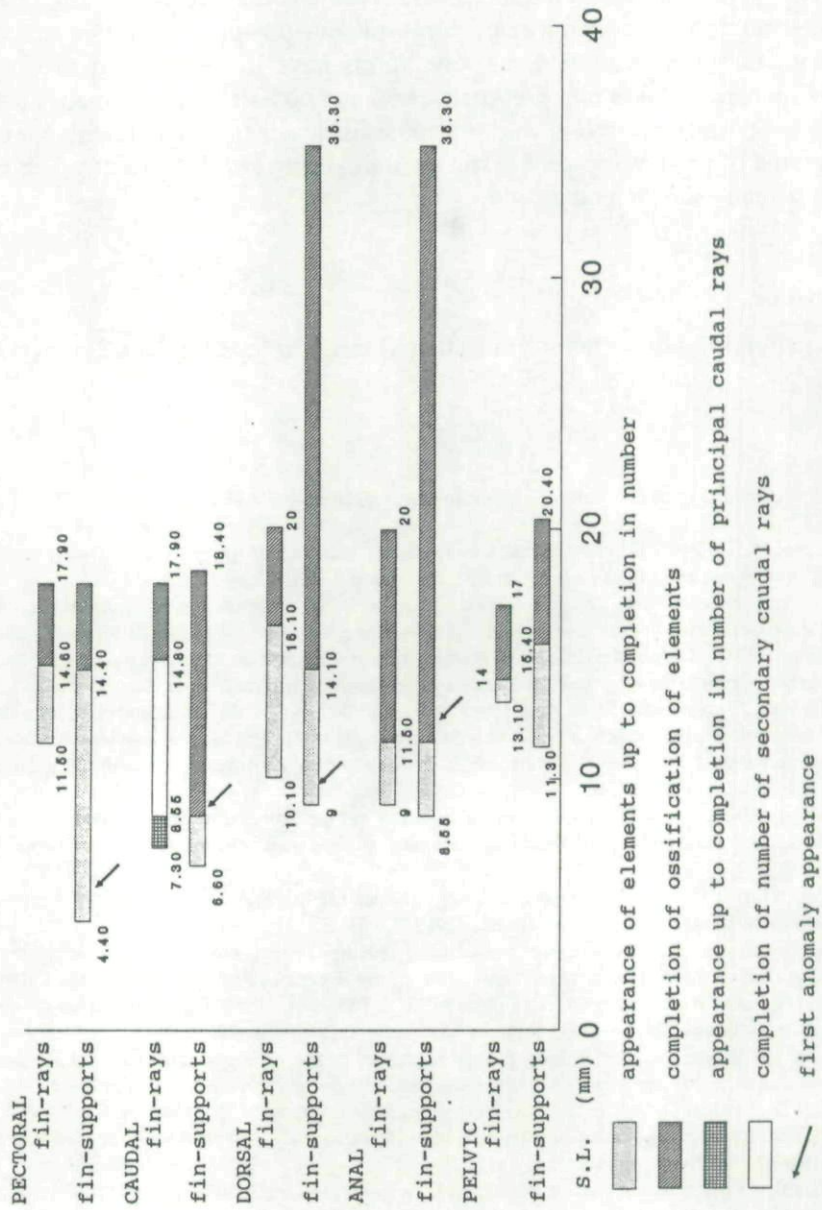


Figure 6. Schematic representation of fin development and anomalies in sea bass larvae.

pterygophore counts and formulae which were more regular than in hatchery specimens. Moreover, meristic characters have been reported as more variable in reared specimens than in wild ones (Boglione, Marino, Bertolini, Rossi, Ferreri & Cataudella 1993). Differences in pterygophore formulae have been considered as taxonomically relevant and species-specific (Birdsong *et al.* 1988). The observed differences may reflect the effects of rearing conditions during the determination of meristic characters and development of early fin supports. On the other hand, different developmental conditions have to be invoked to explain the different developmental stages observed between wild and hatchery specimens at the same body size: the ossification process in wild specimens is slower than in hatchery ones and the cartilaginous stage of fin development is still present at standard lengths at which hatchery specimens are already showing ossification.

Acknowledgment

This study was supported by a grant from Italian Ministry of the Merchant Navy, law 41/82.

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