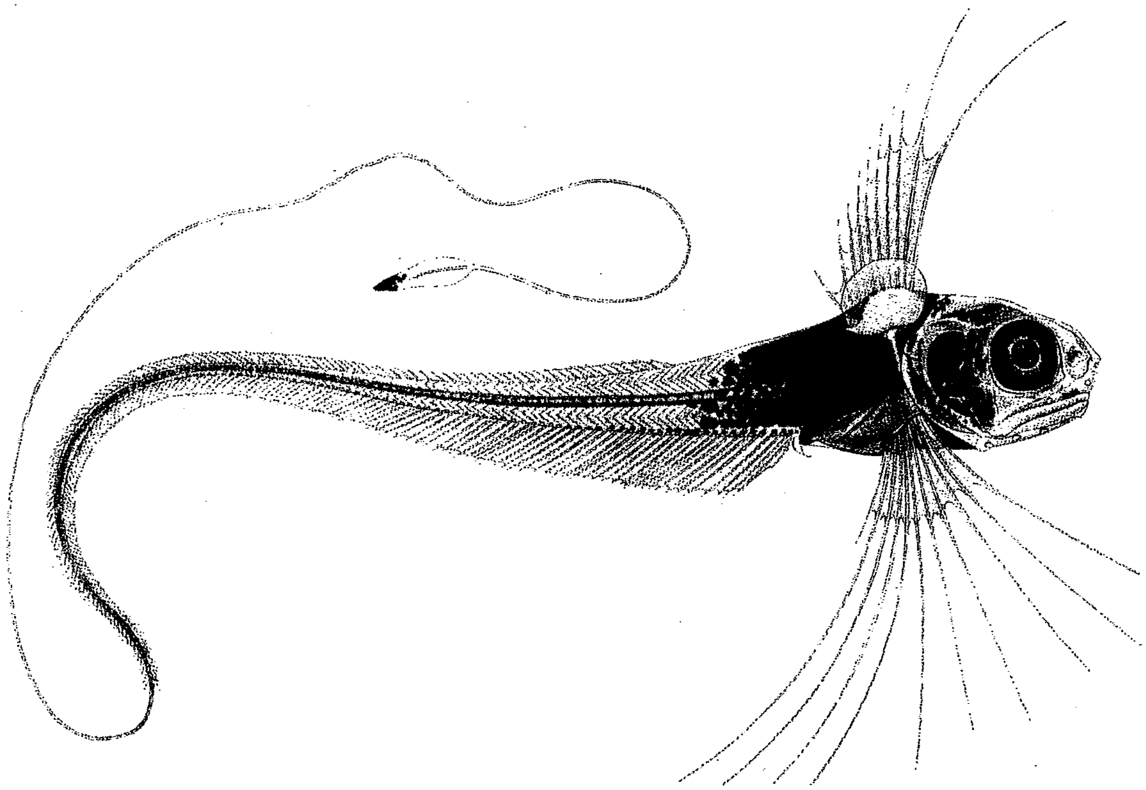
NOAA Technical Memorandum NMFS-SEFSC-498

PRELIMINARY GUIDE TO THE IDENTIFICATION OF THE EARLY LIFE HISTORY STAGES OF BATHYGADID & MACROURID FISHES OF THE WESTERN CENTRAL NORTH ATLANTIC

BY
N. R. Merrett



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, Florida 33149
May 2003

NOAA Technical Memorandum NMFS-SEFSC-498

PRELIMINARY GUIDE TO THE IDENTIFICATION OF THE EARLY LIFE HISTORY STAGES OF BATHYGADID & MACROURID FISHES OF THE WESTERN CENTRAL NORTH ATLANTIC

BY

N. R. Merrett

U.S. DEPARTMENT OF COMMERCE
Donald L. Evans, Secretary

National Oceanic and Atmospheric Administration
Conrad C. Lautenbacher, Jr., Under Secretary for Oceans and Atmosphere

National Marine Fisheries Service
William T. Hogarth, Assistant Administrator for Fisheries

May 2003

NOTICE

This report should be cited as follows:
Merrett, N. R. 2003. Preliminary guide to the identification of the early life history stages of bathygadid & macrourid fishes of the western central North Atlantic. NOAA Technical Memorandum NMFS-SEFSC-498, 32 p.

W. J. Richards, Editor. NOAA Fisheries, 75 Virginia Beach Drive, Miami, FL

This report will be posted on the Bethune Cookman College NOAA Cooperative web site later in 2003 at URL: http://www4.cookman.edu/NOAA/ and will also appear on the SEFSC web site at URL: http://www.sefsc.noaa.gov/
It will be a chapter entitled Bathygadidae & Macrouridae in the "Guide to the early life history stages of fishes of the western central North Atlantic".

Author's address:
Muttlebury's Mead, Chard Street
Thorncombe, Chard TA20 4NB
United Kingdom
E-mail: < nigel@macrourid.freeserve.co.uk >

Copies may be obtained by writing:
The author c/o Fish Group, Zoology Dept.
The Natural History Museum
Cromwell Road, London
SW7 5BD, U. K.
or
National Technical Information Center
5825 Port Royal Road
Springfield, VA 22161
(800) 553-6847 or (703) 605-6000
http://www.ntis.gov/numbers.htm

Some 48 species representing 18 genera of grenadiers (Bathygadidae and Macrouridae) occur, or potentially occur, in the western Central Atlantic (Table Bathygadidae & Macrouridae1). This is around 15% of the species known to occur in the world ocean, where these families are important constituents of the deep-sea demersal ichthyofauna (particularly on the mid and lower slope - Merrett & Haedrich 1997: 60-62). Adults of most species are distributed benthopelagically, a few only meso- to bathypelagically, within discrete sounding (depth) limits from the shelf/slope break to abyssal (>4000 m) depths. The young, termed alevins (Merrett 1986), are rare in collections, but are occasionally caught in plankton nets fished in the upper part of the oceanic water column (but see below). To date very few macrourid alevins are known from western central North Atlantic waters. Only nine (possibly ten) have been identified from plankton samples from the area, although alevins of nine other of these species have been described from elsewhere and figured here (Tables Bathygadidae & Macrouridae 1 & 2).

Adult grenadiers are medium to large sized fishes, ranging in total length from ca 30 -150 cm. They have an elongate body form, with a generally large head and short trunk tapering into a prolonged, finely pointed tail without a caudal fin. The macrouridine Macrouridae possess a single, long-based dorsal fin while the Bathygadidae and macrourine Macrouridae possess two, with the anterior one being short-based. The second dorsal and anal rays are confluent in all, but the relative length of dorsal and anal fin rays differ between the Bathygadidae (dorsal>anal) and the macrourine Macrouridae (dorsal<anal).

There is a more distinct gap between the anterior, first dorsal and second dorsal fins in the macrourine macrourids than in the bathygadids. In both families the anterior dorsal fin is comprised of a short first and an elongate second spinous ray, followed by 6-13 (14) segmented rays in species in the region. The pelvic fins are thoracic in adults, but are sometimes jugular in position in alevins. The snout is pointed (in the majority of species) to broadly rounded (e.g. *Squalogadus, Macrouroides, Cetonurus*). The mouth is terminal, subterminal (usually) or inferior, with a wide variation in jaw structure and tooth pattern. The jaws are markedly protrusible in most macrourids, which contrasts with the situation found in the Bathygadidae. The scales are cycloid, with the exposed surface covered in sharp spinules, arranged sometimes in ridge-like rows. A stout terminal scute-like scale tips the snout in some species and rows of coarse, ridge-like scales occur on the heads of some species also. The branchiostegal ray number in both families is six or seven, while gill raker numbers on the first arch is higher in the Bathygadidae (22-37, lath-like) and the macrouroidine macrourids (25-30, lath-like) than is usual in the macrourine macrourids (5-28, tubercular). The first gill slit is restricted in macrourine Macrouridae. The range in abdominal vertebrae is relatively narrower (10-15). A mental barbel is present in most macrourines (excepting *Mesobius* and some *Hymenocephalus* spp. in the region) and *Gadomus* in the Bathygadidae, but absent in the macrouroidine macrourids and absent in three out of the four species of *Bathygadus* (in *B. macrops* it may be rudimentary or absent).

Ventral abdominal light organs occur in roughly half the species likely to be encountered in the region (Table Bathygadidae & Macrouridae 2). They are absent in the macrouroids, the bathygadids, *Caelorinchus occa* and *C. caudani* (Koehler 1896) (not known from the area) and the genera *Coryphaenoides* and *Echinomacrurus*. Otherwise they are present and expressed as tubes or bulbs with a glandular lining with a single opening just before the anus. Bulbous light organs are present in the genera *Odontomacrurus, Mesobius, Nezumia, Sphagemacrurus, Ventrifossa, Malacocephalus, Trachonurus* and *Cetonurus*. In the first three genera there is a dermal window, but *Malacocephalus laevis* has two, each associated with a lens. Each species of *Hymenocephalus* has a long tubular light organ, with two lenses at the anterior end, before the pelvic fins, and another just before the anus. In *Caelorinchus* the light organ varies in form from tubular to bulbous. It is tubular in all luminous species in the area. *Hymenocephalus* have striated, presumably luminous skin on the isthmus, shoulder girdle and chest.

The anus and its surround (periproct) is variable in position, ranging from placement adjacent to the anal fin origin in the Bathygadidae, *Caelorinchus, Coryphaenoides, Mesobius, Echinomacrurus, Hymenocephalus, Cetonurus, Trachonurus, Sphagemacrurus* and the Macrouroidinae to a more anterior location close to the pelvic fin bases in *Kuronezumia, Kumba, Nezumia, Malacocephalus* and *Ventrifossa* (Table Bathygadidae & Macrouridae 2). Internally, the swimbladder is functional and well developed in all genera represented other than *Odontomacrurus, Echinomacrurus, Mesobius* and the macrouroidine genera. In *Echinomacrurus* the swimbladder is fat filled, while in adults of *Odontomacrurus, Mesobius, Squalogadus* and *Macrouroides* it is regressed. The number of gas glands in the swimbladder varies between 2 and 6 (Table Bathygadidae & Macrouridae 2) and the length of the retia mirabilia is related to species' living depth (Marshall 1972).

Despite the species richness and overall abundance of grenadiers in the deep sea, little is known about their reproduction or early life history, indicated by the paucity of such data in Table Bathygadidae & Macrouridae 1. Iteroparity seems to be the norm, although semelparity has been suggested in some continental rise and abyssal species (e.g. *Coryphaenoides (Nematonurus) armatus* - Stein 1985). Observed fecundity ranges from around 3-5 x 10^2 in the batch-spawning *Echinomacrurus mollis* to 2-6 x 10^6 in *C. (N.) armatus* (Merrett 1994)(Table Bathygadidae & Macrouridae 1). For the few species observed, the egg envelopes are variously ornamented from smooth (4 spp.), through partial ornamentation (3) to raised, hexagonal honeycomb structures (13), with *Coryphaenoides (Coryphaenoides) rupestris* seemingly producing either smooth or fully ornamented eggs (Merrett & Barnes 1996). Overall reported egg diameters are between 0.5-4.0mm (most <2 mm - Fahay & Markle 1984) and each contains an oil globule (Table Bathygadidae & Macrouridae 1). The relatively very few reports of macrourid progeny captured in the embryonic (egg and free embryo) or alevin periods [i.e. pre-juvenile life *sensu* Merrett's (1989) preliminary model of saltatory development in macrourid life history] have resulted in speculation and discussion of spawning and subsequent recruitment of young to the adult living areas (for discussion and references see Merrett & Barnes 1996). There is general agreement that spawning takes place at depth and that the eggs are buoyant, inclining them to rise in the water column. Work on the orange roughy, *Hoplostethus atlanticus* Cuvier 1829, the only deep demersal species whose post-spawning development in the water column has been followed, has indicated that pre-hatching density changes in the egg reduce and overcome early buoyancy and ascent so that hatching eventually, after some 10 days, occurred down close to the spawning depth (Zeldis et al. 1995). Merrett & Barnes (1996) argue that this may well be the pattern followed by benthopelagic macrourids, further to bear out Merrett's (1989) view that near-bottom plankton sampling, within the adult living space, would yield a far greater frequency of macrourid alevins than has hitherto been found in the much more commonly sampled near-surface layers.

Macrourids, among other benthopelagic deep-sea fishes, are evidently not equipped with conspicuous and persistent larval characteristics common among pelagic oceanic fishes with a distributive early life-history phase [e.g. myctophids – see Merrett's (1989) evaluation of macrourid early life-history characteristics in enhancing intrafamilial systematic understanding among the Gadiformes]. Permanent organs develop directly at small size, in the absence of all but a few temporary larval features, to produce an essentially adult form (alevin) by the onset of exogenous feeding. The few temporary larval features (e.g. stalked discoid pectorals and undeveloped snout) transform at metamorphosis to the juvenile period (Table Bathygadidae & Macrouridae 1). With development of the adult pectoral fin and snout (and concomitant realignment of the jaw from near vertical to sub-terminal), together with the initiation of squamation, identification of juveniles is possible from adult characters alone. Thus it is the free embryo and alevin stages that are the concern of this study. Free embryos are known from only *Caelorinchus coelorinchus*, from embryos hatched by Sanzo (1933), otherwise our information here is limited solely to alevins. Macrourid alevins are characterized by their tadpole-like appearance in all but the earliest stages. The depth of the head and abdomen is considerable relative to the tapering tail, and a stomach gorged with copepods often exaggerates this. The tail may be moderate to very elongate and lacks a differentated caudal. The pectoral fins are, as has been stated above, typically pedunculate.

Within the macrourine macrourids there is a considerable suite of adult diagnostic features differentiated in the alevin phase (e.g. Ambrose 1996, Stein 1980, Merrett 1986, 1989) (Table Bathygadidae & Macrouridae 2). Some indication of the developmental sequence of these is given by Merrett (1989), in addition to those given for gadiform fishes in general by Fahay & Markle (1984) and others (see Cohen et al. 1990). Externally, the more important are:

1. Relative tail length.

2. Position of the anus relative to the pelvic bases and the insertion of the anal fin.

3. Relative position of the origin of the second dorsal fin (D_2).

4. Number of rays in the pelvic (P_2) and first dorsal (D_1) fins, both differentiated in available species by 3 mm HL (Merrett 1989).

5. Spination of the second ray in the D_1 is important, but may be undifferentiated at very small size, or broken. Nevertheless, possession of this character is helpful diagnostically.

6. Possession of a mental barbel, but differentiated over a relatively wide size range [3.5-7 mm HL (Merrett 1989)].

7. Number of branchiostegal rays - fundamentally important among macrourines.

8. Number of gill rakers on gill arches but, again, differentiation appears to continue in many species throughout the alevin period (Merrett 1989).

9. Pigmentation - often a valuable character. The broad groupings found in alevins of the region and used here (Table Bathygadidae & Macrouridae 2) are modified from Merrett (1989) and are:

I – Conspicuous arrangement of pigment bars and patches, often blending into saddle marks, on an unpigmented ground ("pantherinus" pigmentation). Peritoneum pigmented or unpigmented. II – Overall pigmentation of scattered, often minute, melanophores which tend to fade out towards the tip of the tail. III – Most of head, abdomen and anterior part of tail darkly pigmented and often with large melanophores, terminating more or less abruptly to leave the tail tip colorless, forming an abdominal hoop markedly darker in appearance than the anterior part of the head and the greater proportion of the tail. Tail with or without obvious spots of external or internal pigmentation.

10. Possession of a light organ, recognized by a dermal window.

There are also internal features of considerable value in the diagnosis bathygadid and macrourid alevins and these, together with light organ differentiation, evidently are completed by 2-4 mm HL (Merrett 1989):

1. Possession of a functional swimbladder.

2. Number of gas glands and retia mirabilia in the swimbladder.

3. Number of abdominal vertebrae.

The above features are listed where possible for the macrouroid species of the area in Table Bathygadidae & Macrouridae 2. To this mix of species have been added *Coryphaenoides (Chalinura) profundicolus*, *Echinomacrurus mollis* and *Macrouroides inflaticeps.* Both the former are known to occur at abyssal depths in the eastern central part of the ocean and, because of their bathymetric remoteness, might be present but not yet captured in this western region. *Macrouroides inflaticeps,* on the other hand, is bathy- to benthopelagic, and is infrequently caught, but has been taken in the South Atlantic. A further addition is *Mesobius berryi*. During the course of this study, the juvenile specimen figured in Backus et al., (1965: Fig. 3), (caught mesopelagically in 09^0 25'N, 27^0 42'W) and tentatively identified therein as *Sphagemacrurus*? by N. B. Marshall (The Natural History Museum, London), was re-examined and confirmed to be *Mesobius* in line with Marshall's later conclusion (Hubbs & Iwamoto 1977: 236). While its first dorsal fin ray count was 2+8 (vs 2+10-12 in Indo-Pacific *M. berryi*), counts of the pelvic fin rays (8) and inner rakers on the second gill arch (11) indicated it to be *M. berryi* (Fig. Bathygadidae & Macrouridae 10 E). Further justification for including *M. berryi* here comes from Iwamoto (in litt. 22 April, 2003) who writes of having identified specimens of what he believes to be this species both from the equatorial and the western South Atlantic.

In the absence of developmental series these features will guide alevin identification, but confirmation will only be assured once such a series for each species becomes available. The degree of certainty of identification of the alevins illustrated here will naturally be similarly affected. Nevertheless, Tables Bathygadidae & Macrouridae 1 and 2 are given here as hopefully the most functional guide from the information now available, in association with illustrations of those alevins identified hitherto in Figures Bathygadidae & Macrouridae 1-19.

Table Bathygadidae & Macrouridae 1. Species of Bathygadidae and Macrouridae known and likely to be represented in the western central Atlantic area, indicating regional distributions, known life-history parameters, alevin-juvenile transformation sizes, together with relevant references. [Generic names (where specific diagnosis is unsure) and specific epithets in bold denote alevin stages recognised from this region; # = not recorded from the area, but may be present.]

Genus / Species	Range (Western Atlantic Only)		Life History				ELH References
	Area	Depth (M) & Habitat	Fecundity	Eggs Diameter (mm)	Shell	Alevins Transform. Size (mm HL)	
Fam. BATHYGADIDAE							
Gadomus arcuatus (Goode & Bean, 1886)	G.of Mexico, Caribbean & NE coast of S. America	600-1400 Benthopelagic				?> 7	Fahay & Markle 1984
G.dispar (Vaillant, 1888)	Caribbean, off Nicaragua	550-650 Benthopelagic				?>7	
G. longifilis (Goode & Bean, 1885)	E Florida, Florida Straits, G. of Mexico & Caribbean	600-2200 Benthopelagic	550	1.0		<13.0	Merrett 1989, 1994
Bathygadus favosus Goode & Bean, 1886	Florida Straits, Gulf of Mexico & Caribbean	750- 1700 (2745) Benthopelagic					
B. macrops Goode & Bean, 1885	Ca 37^{0}N south into G. of Mexico, Caribbean & NE S. America	350-800 Benthopelagic					
B. melanobranchus Vaillant, 1888	Gulf of Mexico, Caribbean & NE S. America	(400) 800-1400 (1700) Benthopelagic				<8.5	Merrett 1989
Fam. MACROURIDAE							
Sub-fam. Macrourinae							
Odontomacrurus murrayi Norman, 1939	First two records:- 11^0 00'N, 41^0 31'W and 12^0 38' N, 74^0 11'W	Meso- / bathypelagic				<7 >6	Marshall 1964; Merrett 1989
Caelorinchus caribbaeus (Goode & Bean, 1885)	W. tropical Atlantic from Cape Hatteras to northern Brazil	(200) 300-400 (700) Benthopelagic					
C. coelorinchus (Risso, 1810) sub-sp. *carminatus*	Grand Banks south to Brazil – generally missing in Bahamas, scarce in Antillean region	90-850 Benthopelagic		1.1 - 1.2	3	>5.0	Sanzo 1933; Merrett 1989; Merrett & Barnes 1996

Table Bathygadidae & Macrouridae 1(Continued).

C. occa (Goode & Bean, 1885)	Florida Straits to NE South America (one off Bermuda)	400-2200 Benthopelagic					
C. ventrilux Marshall & Iwamoto, 1973	West Indies area, apparently on steep island slopes	300-500 Benthopelagic				>6	
Coryphaenoides (Chalinura) brevibarbis (Goode & Bean, 1896)	Nova Scotia to Caribbean	1500-3200 Benthopelagic					
C. (C.) leptolepis Günther, 1877	US slope & abyss from $41^{0} - 31^{0}$N	(610) 1800-4900 Benthopelagic				>6 <15	Stein 1980; Merrett 1989
C. (C.) mediterraneus (Giglioli, 1893)	Gulf of Mexico	1200-2300 Benthopelagic	100 - 900K	0.6	2	<12.5	Merrett 1986, 1989, 1994; Merrett & Barnes 1996
C. (C.) profundicolus # (Nybelin, 1957)	Abyssal North Atlantic	3900-5400+ Benthopelagic					
C. (Coryphaenoides) alateralis Marshall & Iwamoto, 1973	Gulf of Mexico	1116 Benthopelagic					
C. (C.) mexicanus (Parr, 1946)	Gulf of Mexico & ? Caribbean	700-1600 Benthopelagic					
C. (C.) rudis Günther, 1878	Gulf of Mexico & Caribbean	600-2400 Benthopelagic					
C. (C.) rupestris Gunnerus, 1765	Davis Strait (66^{0}N) south to New England (about 37^{0}N)	400-2000 Benthopelagic	33 - 36K	1.5	1, 2	>7 <16	Grigorev & Serebryakov 1981; Merrett 1978, 1989, 1994; Merrett & Barnes 1996
C. (C.) zaniophorus (Vaillant, 1888)	Chesapeake Bay, G. of Mexico & Caribbean	400-2200 Benthopelagic					
C. (Lionurus) carapinus (Goode & Bean, 1883)	Nova Scotia to Cape Hatteras	L. slope to abyss Benthopelagic	50 - 220K	0.5 - 0.64		>8 <15.3	Haedrich & Polloni 1976; Merrett 1978, 1986, 1989, 1994; Fahay & Markle 1984
C. (Nematonurus) armatus (Hector, 1875)	World Ocean beneath mainly temperate surface waters	1700-5500 Benthopelagic	2.5 - 6.2M			>5.5	Fahay & Markle 1986; Stein 1985

Table Bathygadidae & Macrouridae 1(Continued).

Echinomacrurus mollis # Roule, 1916	Eastern N. Atlantic	4000-5400 Benthopelagic	360-950	2.1	2		Merrett 1994, Merrett & Barnes 1996
Mesobius berryi # Hubbs & Iwamoto, 1977	Eastern central Atlantic	*ca.* 650-1000 Bathypelagic				< 6.3	Backus et al. 1965; Hubbs & Iwamoto 1977; Ambrose 1996i
Hymenocephalus aterrimus Gilbert, 1905	Tropical western N. Atlantic	460-915 Benthopelagic					
H. billsamorum Marshall & Iwamoto, 1973	Florida Straits, Gulf of Mexico, Caribbean	400-900 Benthopelagic					
H. gracilis Gilbert & Hubbs, 1920	Tropical western N. Atlantic	275-640 Benthopelagic				>5.0	Merrett 1989 (Not figured.)
H. italicus Giglioli, 1884	Florida Straits, Gulf of Mexico and Caribbean to N. Brazil	100-500 (800) Benthopelagic		1.0 - 1.1	3	>7 <9.5	Sanzo 1933; Merrett, 1989; Merrett & Barnes 1996
Cetonurus globiceps Vaillant, 1888	Gulf of Mexico, E. Caribbean	1100-1900 Benthopelagic	10.3K	*ca* 1.0			Mead et al. 1964
Trachonurus sulcatus (Goode & Bean, 1885)	Cape Hatteras south to G. of Mexico & Caribbean	700-1500 Benthopelagic					
Sphagemacrurus grenadae (Parr, 1946)	Gulf of Mexico & Caribbean (Hudson Canyon –1 specimen)	850-1250 Benthopelagic		*ca* 1.5		>4.5 <8.8	Marshall 1973
Kuronezumia bubonis Iwamoto, 1974	Tropical western N. Atlantic	732-1062 Benthopelagic					
Kumba sp.A (of Iwamoto & Sazonov, 1994)	Western Gulf of Mexico	1280 Benthopelagic					
K. calvifrons Iwamoto & Sazonov, 1994	Equatorial Mid-Atlantic Ridge	930-960 Benthopelagic					
Nezumia aequalis (Günther, 1878)	Davis Strait to northern Brazil	200-1000 Benthopelagic	2.6K	1.6 – 1.9	1	>8.5	Farran 1924; Merrett 1989, 1994; Merrett & Barnes 1996
N. atlantica (Parr, 1946)	Gulf of Mexico, Caribbean & NE S. America	350-1100 Benthopelagic					
N. bairdii (Goode & Bean, 1877)	Grand Banks to Florida Straits	(20)90-183(2285) Benthopelagic				>8.0	

Table Bathygadidae & Macrouridae 1(Continued).

N. cyrano Marshall & Iwamoto, 1973	Gulf of Mexico, Caribbean and off Surinam	600-1400 Benthopelagic			>6.8 <9.0	Fahay & Markle 1984
N. longibarbata (Roule & Angel, 1933)	Gulf of Mexico	1460 Benthopelagic				
N. sclerorhynchus (Valenciennes, 1838)	Nova Scotia to Florida Straits (also Windward Islands)	(130) 450-750 (1100) Benthopelagic	1.6	?3		Sanzo 1933; Merrett & Barnes 1996
N. suilla Marshall & Iwamoto, 1973	N. coast Cuba, G. of Mexico, Caribbean, off Surinam	900-1500 Benthopelagic				
Malacocephalus laevis (Lowe, 1843)	Gulf of Mexico, Caribbean & NE S. America	(200) 300-700 (1000) Benthopelagic		3		Merrett & Barnes 1996
M. occidentalis Goode & Bean, 1885	Throughout area, Newfoundland south to Argentina	150-600 Benthopelagic				
M. okamurai Iwamoto & Arai, 1987	N.E. coast of S. America – off French Guiana and Brazil	229-411 Benthopelagic				
Ventrifossa macropogon Marshall, 1973	Ca 30^{0}N to G. of Mexico, Caribbean & NE S. America	(450) 500-600 (1000) Benthopelagic				
V. mucocephalus Marshall, 1973	NE Florida, Florida Straits off Cuba & W Caribbean	450-750 Benthopelagic				
Sub-fam. Macrouroidinae						
Squalogadus modificatus Gilbert & Hubbs, 1916	Gulf of Mexico	*ca* 900-1350 Benthopelagic				
Macrouroides inflaticeps # Smith & Radcliffe, 1912	South Atlantic	Bathypelagic to benthopelagic				

Table Bathygadidae & Macrouridae 2. Table of characters present in bathygadid and macrourid alevins useful in the diagnosis of species in the western central Atlantic. (Generic names (where specific diagnosis is unsure) and specific epithets in bold denote alevin stages recognised and figured from this or other regions; 1 = anus at anal fin origin; 2 = anus between pelvic and anal fins; [ ] = swimbladder regressed in adults; + = present; - = absent; { } = slight expression of character; ^ = usual Atlantic count; # = not recorded from the area, but may be present. See text for pigment pattern notation.)

Genus	Species	BrR	Barbel	Tot. g.r. (1st arch)	Abdom. verts	Gas glands	Pelvic rays (P_2)	Anterior dorsal (D_I) No.	Anterior dorsal (D_I) Sp. ray	Exaggerated fin dev.	Light organ	Posn anus	Rel. tail l. HL : TL	Pigment pattern	Text figure number
Bathygadidae															
Gadomus	*arcuatus*	7	+	22-27	11-13	4	8	2+8-11	Smooth		-	1	?1 : 5--6		(1)
	dispar	7	+	24-26	11-13	4	8	2+10-11	Smooth		-	1	?1 : 5--6		
	longifilis	7	+	33-37	11-13	4	8	2+7-9	Smooth	-	-	1	1 : 5--6	(II)	
Bathygadus	*favosus*	7	-	24-29	11-13	2	9(10)	2+7-9	Smooth		-	1			
	macrops	7	-/+	25-27	11-13	2	8	2+8-11	Smooth		-	1			
	melanobranchus	7	-	27-31	11-13	2	8(7)	2+9-11	Smooth	-	-	1	1 : 4+	(II)	
Macrouridae															
Macrourinae															
Odontomacrurus	***murrayi***	6	-	5-7	?	[2]	7-8	2+6-8	Smooth	-	Fossa	2	1 : 11--15	I	2
Caelorinchus	*caribbaeus*	6	+	9-11	11-12	4	7	2+9-10	Smooth		+	1			
	coelorhynchus	6	+	7-12	11-12	4	7	2+8-9	Smooth	D_I,P_2	+	1	1 : 4+	?III	3
	occa	6	+	7-8(9)	11-12	4	7	2+7-9	Smooth		-	1	1 : 4--6	III	
	ventrilux	6	+	7-9	11-12	4	7	2+9-10	Smooth	-	+	1	1 : 4+		4
Coryphaenoides	*(Ch.) brevibarbis*	6	+	7-8	12-13	6	8-9	2+7-8	Serrate		-	1			
	(Ch.) leptolepis	6	+	9-11	12-13	6	9	2+8	Serrate	-	-	1	1 : 5--6	III	5
	(Ch.) mediterraneus	6	+	10-11	12-13	6	12-14	2+8-10	Serrate	D_I,P_2	-	1	1 : 4--6		6
	(Ch.) profundicolus #	6	+	12-13	12-13	6	8-9	2+8-9	Serrate		-	1			
	(Co.) alateralis	6	+	10	11-12(13)	4	8	2+11	Serrate		-	1			
	(Co.) mexicanus	6	+	9	11-12(13)	4	(9)-10	2+9-11	Serrate		-	1	?1 : 5		
	(Co.) rudis	6	+	10	11-12(13)	4	9-11	2+9-11	Serrate		-	1			
	(Co.) rupestris	6	+	18-20	11-12(13)	4	7-8	2+8-11	Serrate	-	-	1	1 : 4--6	II	7
	(Co.) zaniophorus	6	+	11-12	11-12(13)	4	(9)10	2+9-11	Serrate		-	1			
	(L) carapinus	6	+	8-11	12-13	6	9-11	2+8-9	Serrate	-	-	1	1 : 5--6	(III)	8
	(N) armatus	6	+	11-14	13-15	5-6	10^	2+8-10	Serrate		-	1			9

Table Bathygadidae & Macrouridae 2(Continued).

Echinomacrurus	*mollis* #	7	+	8-9(10)		-	9-10	2+9-10	Smooth		-	1			
Mesobius	***berryi* #**	7	-	11		[2]	8	2+8	Serrate	-	+	1	1 : 12	I	10
Hymenocephalus	*aterrimus*	7	-	20-25	10-11	2	13-14	2+8-11	Smooth		+	1			
	billsamorum	7	-/+	23-28	10-11	2	(12)13-14	2+8-11	Smooth		+	1	1 : 6		
	gracilis	7	+	16-18	10-11	2	(7)8(9)	2+9-11	Serrate	D_I,P_2 & tail	+	1	1 : 6	III	
	italicus	7	+	21-25	10-11	2	(10)11(12)	2+9-12	Smooth	-	+	1	1 : 6	III	11
Cetonurus	*globiceps*	7	+	11-14	10	2	8-10	2+7-10	Serrate		+	1			
Trachonurus	*sulcatus*	7	+	5-6	12-13	2	(6)7	2+7-9	Smooth		+	2			
Sphagemacrurus	***grenadae***	7	+	9-10	11-12	2	11-12	2+10-11	Serrate	P_2	+	2	1 : 7--8	III	12
Kuronezumia	*bubonis*	7	+	8-11	13	2	(9)11-12(13)	2+10-12	Serrate		+	2			
Kumba	sp. A (I & S, '94)	7	+	12	12	2	8	2+11	{Serrate}		+	2			
	calvifrons	7	+	14	12	2	8	2+11	{Serrate}		+	2			
Nezumia	***aequalis***	7	+	8-12	13-14	2	(7)8-9	2+9-13	Serrate	P_2	+	2	1 : 7+	II	(13), 14
	atlantica	7	+	10-11	12	2	9-10	2+10-13	Serrate		+	2			
	bairdii	7	+	8-10	13-14	2	(6)7	2+9-11	Serrate	-	+	2	1 : 6		
	cyrano	7	+	6-10	13-14	2	8-10	2+9-11	Serrate	-	+	2	1 : 6--10		15
	longibarbata	7	+	9-10	13-14	2	13	2+9-10	Serrate		+	2			
	sclerorhynchus	7	+	9-11	13-14	2	(7-8)9(10)	2+9-11	Serrate		+	2			16
	suilla	7	+	7-9	13-14	2	7	2+11-13	Serrate		+	2			17
Malacocephalus	***laevis***	7	+	11-14	14	2	(8)9(10)	2+9-13	Smooth	D_I,P_2	+	2	1 : 6+ --13	I	18, (19)
	occidentalis	7	+	11-13	14	2	8	2+11-13	Serrate		+	2	?1 : 8	?I	
	okamurai	7	+	9-14	14	2	8	2+10-13	Serrate		+	2	?1 : 8	?I	
Ventrifossa	*macropogon*	7	+	13-15	(10)11-12(14)	2	9-10	2+(11)12-13(14)	Serrate		+	2			
	mucocephalus	7	+	12-14	(10)11-12(14)	2	8(9)	2+10-12	Serrate		+	2			
Macrouroidinae															
Squalogadus	*modificatus*	7	-	26-30	12-13	[3]	5	-	-		-	1			
Macrouroides	*inflaticeps*	7	-	25-29	12-13	[3]	0	-	-		-	1			

Figure Bathygadidae & Macrouridae 1. *Gadomus* sp., MCZ 58621 - 7.0 mm HL; 39.0 mm TL; 7 BrR; barbel present; 5+1+18 Gr (1st arch) – lath-like; 8 P_2; II+11 D_1; Anus - 1 (see caption to Table Bathygadidae & Macrouridae 1 for key); light organ absent; pigmentation II (see text for pattern notation). From Fahay & Markle (1984, Fig. 140B).

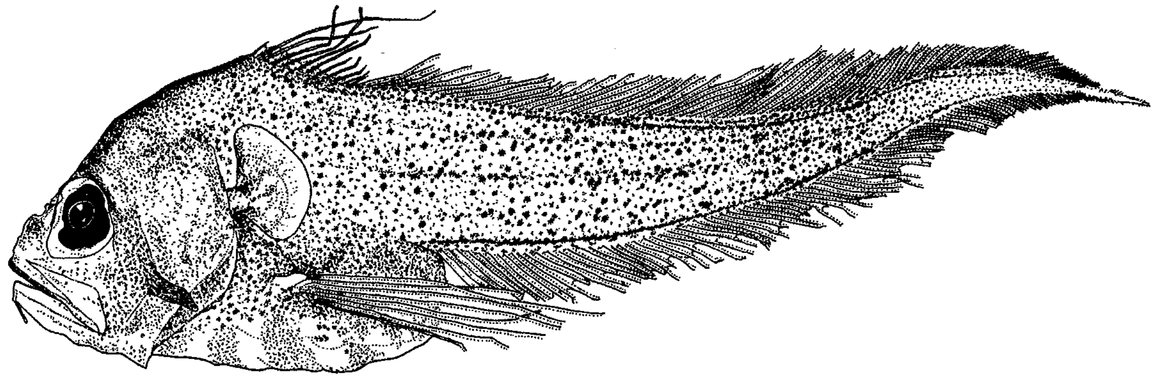
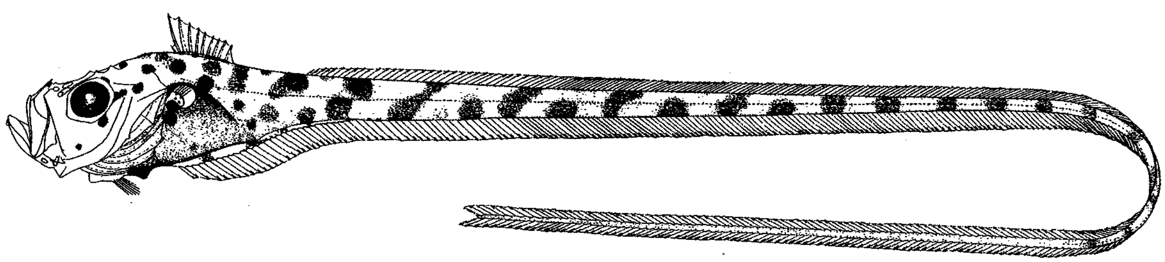
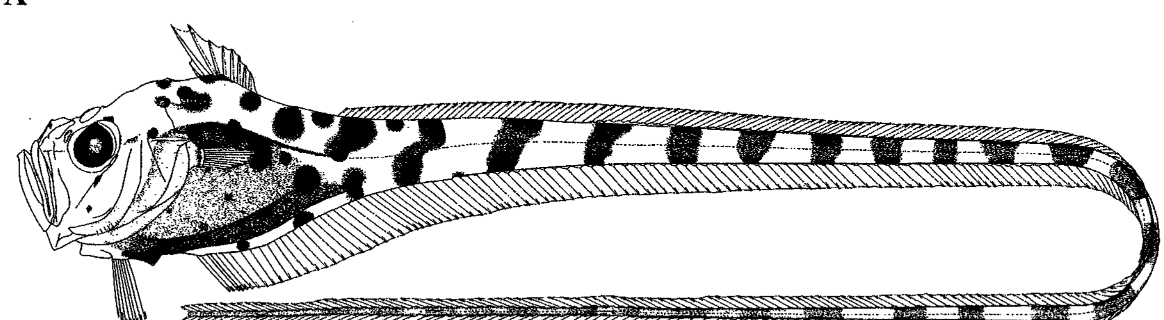


Figure Bathygadidae & Macrouridae 2. *Odontomacrurus murrayi,* A) MCZ 58620 – 6.0 mm HL; 81.0 mm TL; barbel absent; 6 BrR; 7 Gr (1st arch); 7 P_2; II+8 D_1 (2nd spinous ray smooth); anus - 2; light organ naked fossa; pigmentation – I. B) MCZ 63074 – 8.0 mm HL; 93.0 mm TL; barbel absent; 7 Gr (1st arch); 7 P_2; II+7 D_1 (2nd spinous ray smooth); anus – 2; light organ naked fossa; pigmentation – I.



A



B

Figure Bathygadidae & Macrouridae 3. *Caelorinchus coelorinchus,* A) Egg (1.2 mm diameter); B) same on 4th day of incubation; C) between 6th and 7th day; D) at the end of 1 week; E) newly hatched free embryo (4.21 mm TL); F) 8 days post-hatching (3.88 mm TL); G) 15 days post-hatching (4.64 mm TL); H) alevin 5.0 mm HL. Redrawn from Sanzo (1933) and Merrett (1986, Fig. 1).

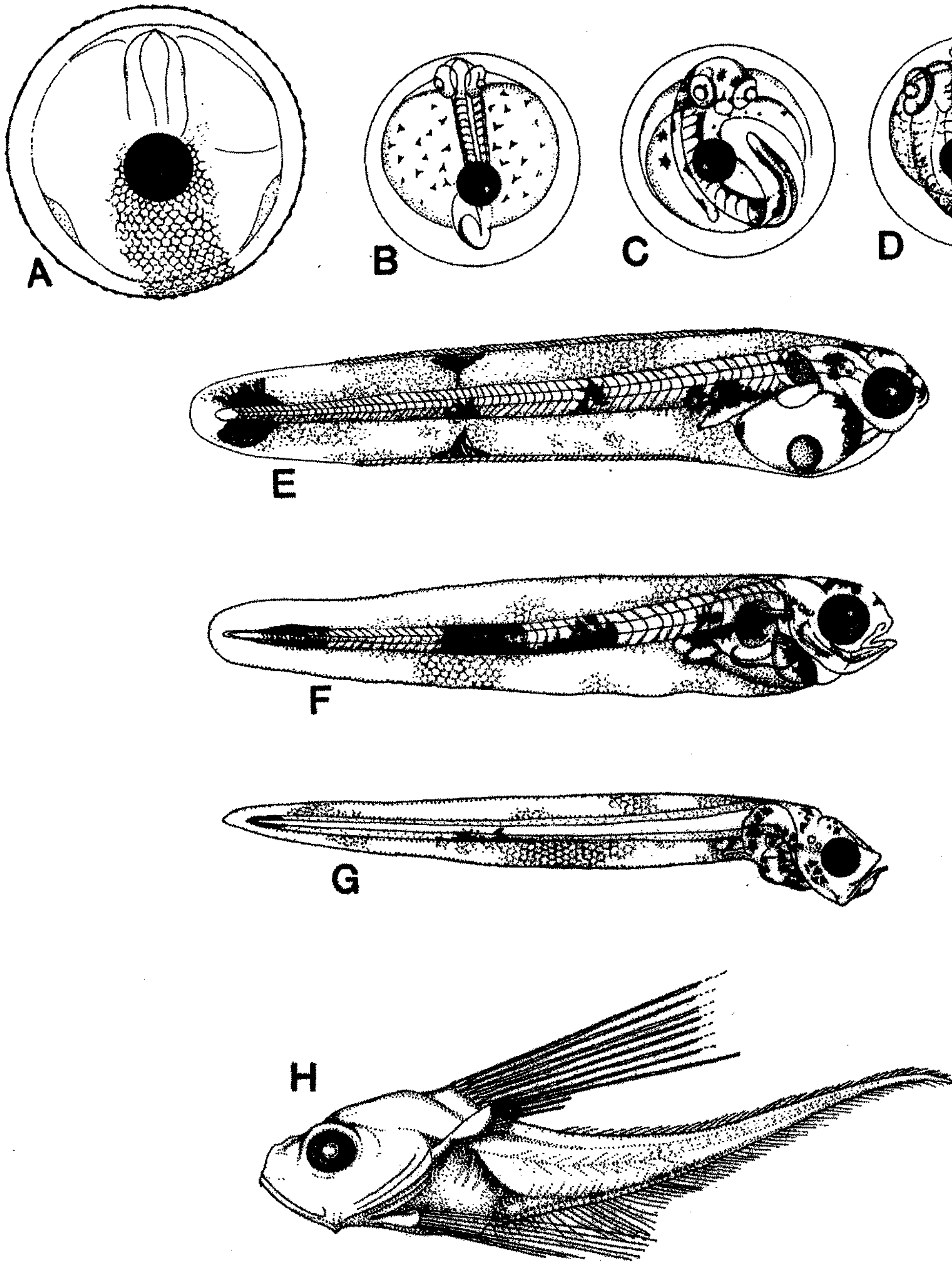


Figure Bathygadidae & Macrouridae 4. *Caelorinchus ?ventrilux*, MCZ 86058 – 6.0 mm HL; 25(+) mm TL; barbel present; 6 BrR; 6 Gr (1st arch);7 P_2; II+10 D_1 (2nd spinous ray smooth); anus - 1; light organ elongate, from anus to anterior P_2 bases; pigmentation - III.

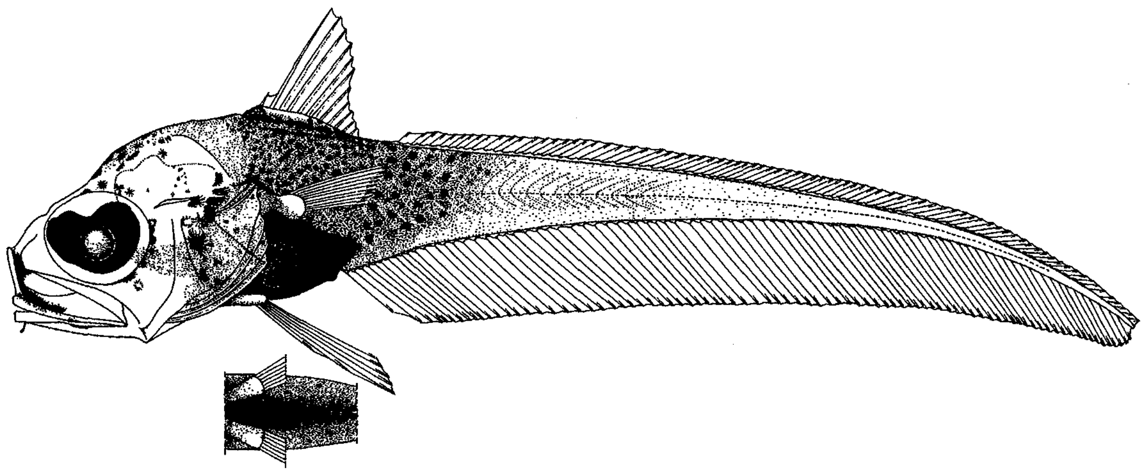
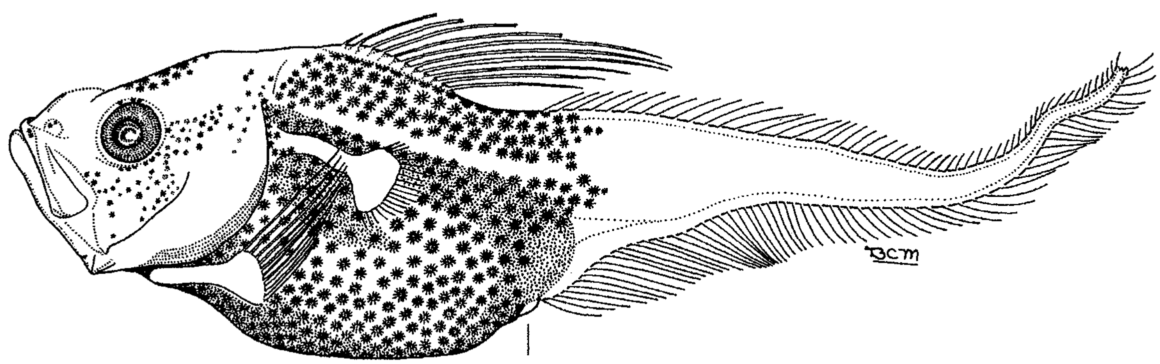
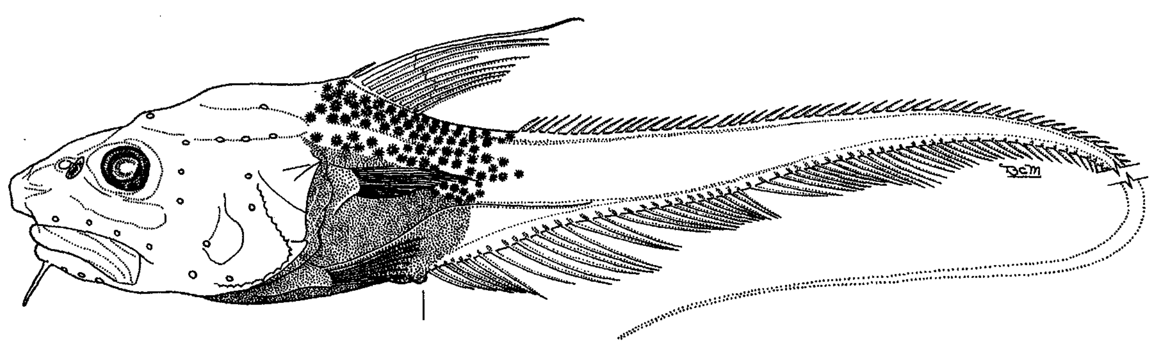


Figure Bathygadidae & Macrouridae 5. *Coryphaenoides (Chalinura) leptolepis* A) 6.2 mm HL, B) 15.2 mm HL. From Stein (1980, Fig. 2 D & E).



A



B

Figure Bathygadidae & Macrouridae 6. *Coryphaenoides (Coryphaenoides) mediterraneus*, 6.0 mm HL. From Merrett (1986, Fig. 5D).

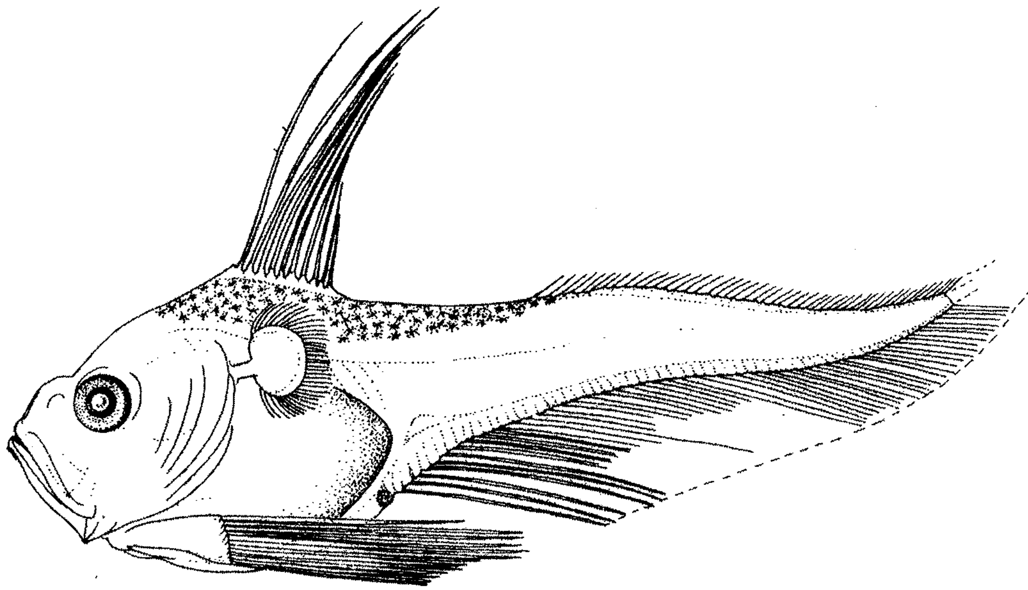


Figure Bathygadidae & Macrouridae 7. *Coryphaenoides (Coryphaenoides) rupestris*, A) 1.6; B) 2.5; C) 3.1; D) 3.3; E) 4.0; F) 5.0; G) 5.1; H) 6.9 mm HL. From Merrett (1978, Fig. 2).

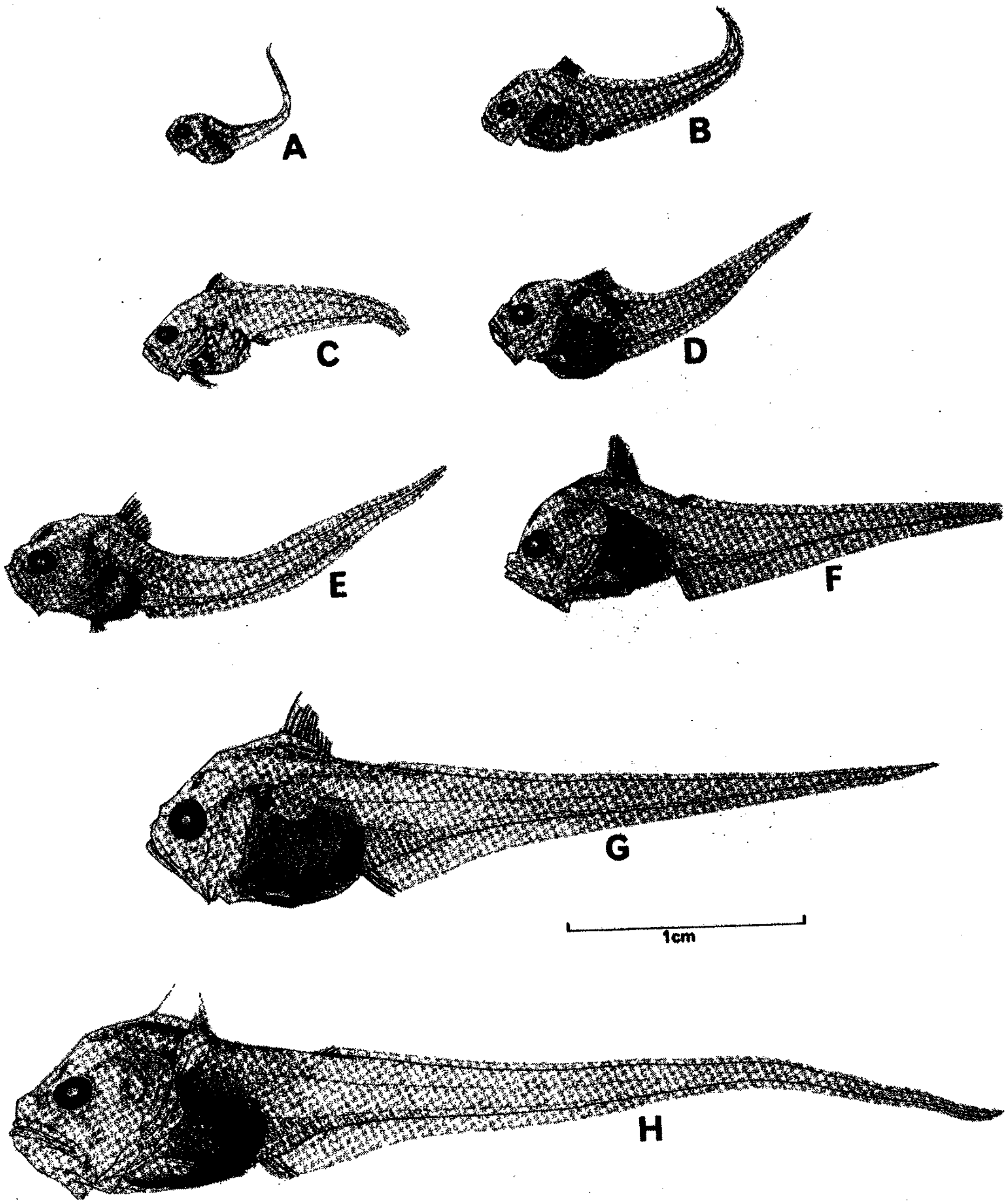
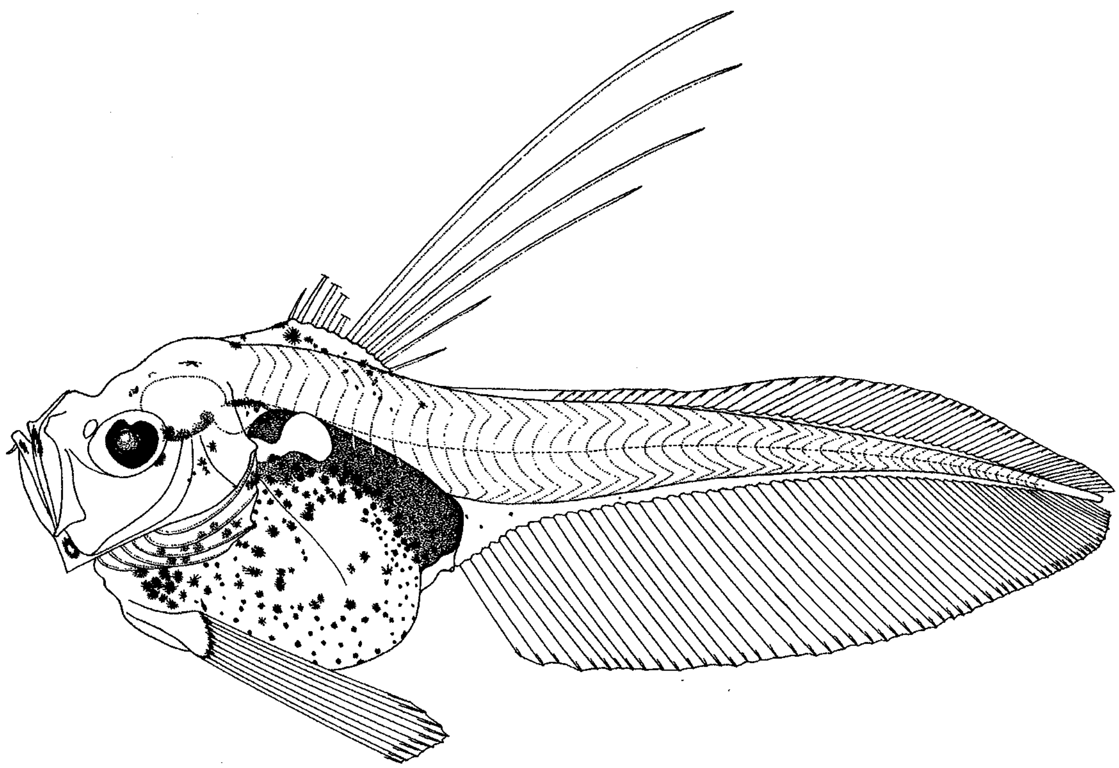
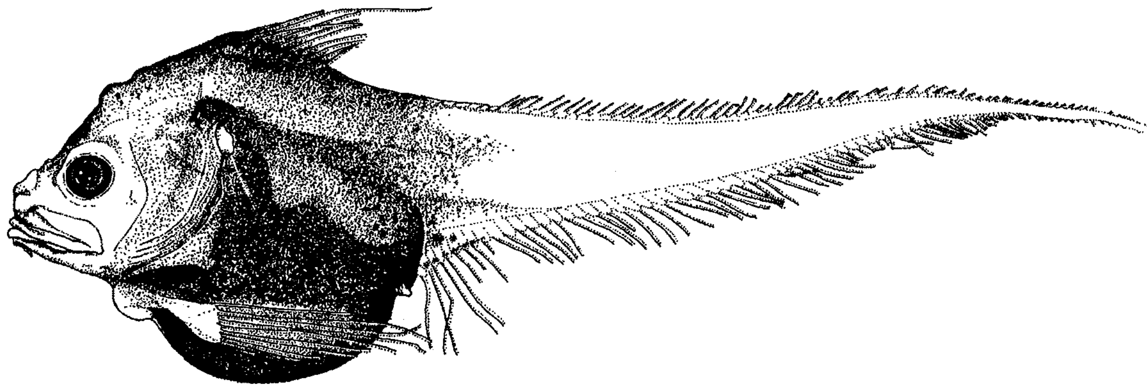


Figure Bathygadidae & Macrouridae 8. *Coryphaenoides (Lionurus) carapinus*, A) MCZ 85685 – 4.0 mm HL; 16.0 mm TL; barbel bud developing; 6 BrR; 6 (developing) Gr (1st arch); 10 P_2; II+9 D_1 (2nd spinous ray broken); anus - 1; no light organ; 6 gas glands in swimbladder; pigmentation III; B) MCZ 58622 – 7.5 mm HL; 41.0 mm TL; barbel present; 6 BrR; 8 Gr (1st arch); 10/11 P_2; II+8 or 9 D_1 (2nd spinous ray smooth(?)); anus - 1; no light organ; 6 gas glands in swimbladder; pigmentation III, From Fahay & Markle (1984; Fig. 140 (C); C) MCZ 101078 – 8.0 mm HL; 42.0 mm TL; barbel present; 6 BrR; 9 Gr (1st arch); 10 P_2; II+8 D_1 (2nd spinous ray broken); anus -1; no light organ; 6 gas glands in swimbladder; pigmentation III. [But *cf.* description and discussion of *Lionurus* alevins in Merrett (1978)].

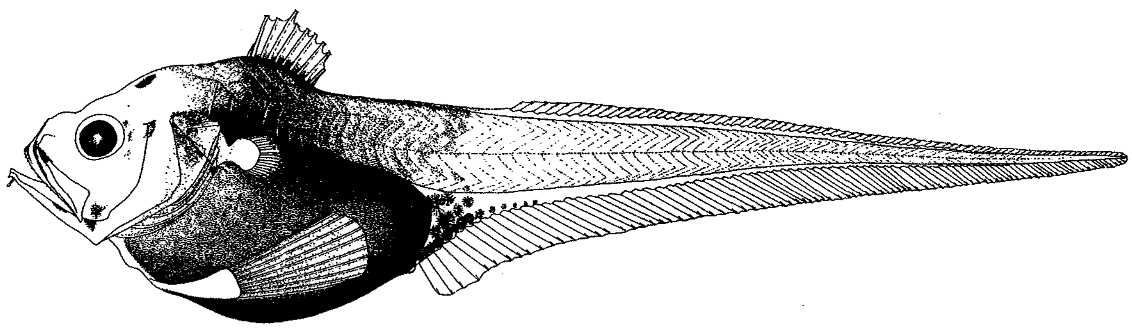


A

Figure Bathygadidae & Macrouridae 8 (Continued).



B



C

Figure Bathygadidae & Macrouridae 9. *Coryphaenoides (Nematonurus) armatus*, MCZ 58623 – 5.5 mm HL; 29(+) mm TL; barbel present; 6 BrR; 9 Gr (1st arch); 11 P_2; II+8 D_1 (2nd spinous ray broken - ?serrate); anus - 1; no light organ; 5 gas glands in swimbladder; pigmentation III. From Fahay & Markle (1984, Fig. 140D).

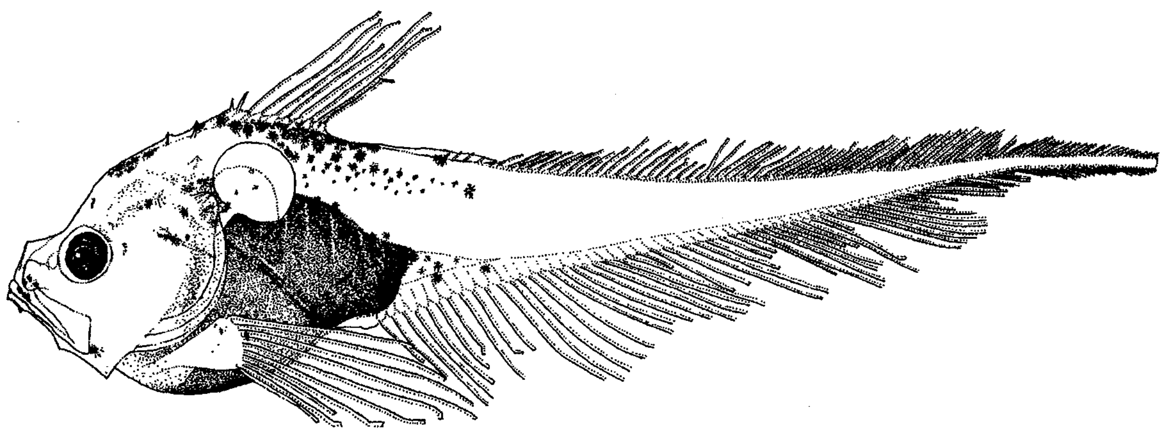
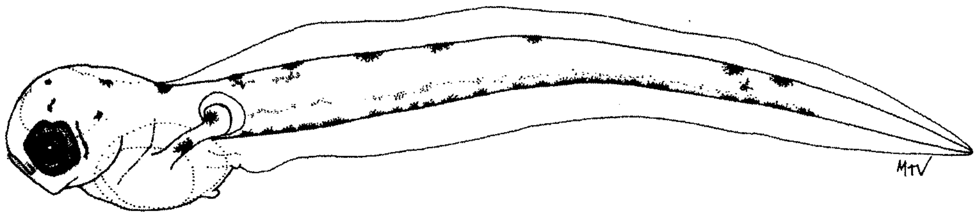
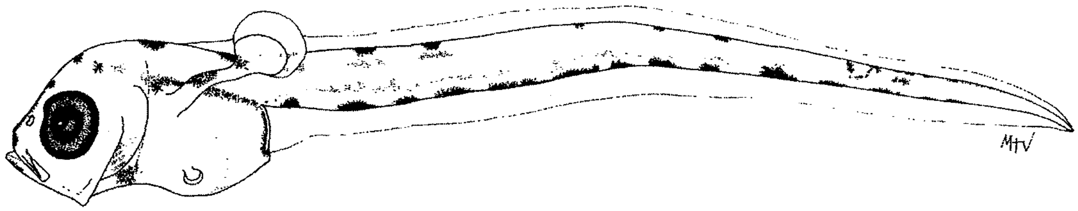


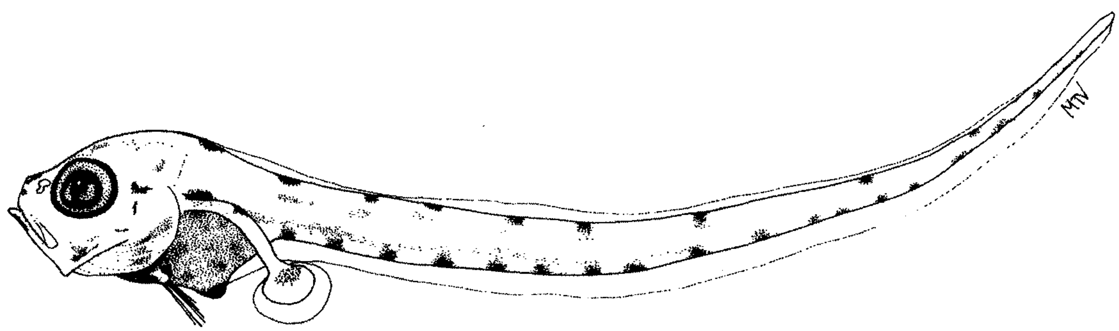
Figure Bathygadidae & Macrouridae 10. *Mesobius berryi*, A) free embryo, 5.4 mm TL; and alevins B) 6.7, C) 11.2 & D) 23.4. From Ambrose (1996i, Fig.6). E) 153 mm TL juvenile from Backus et al (1965).



A

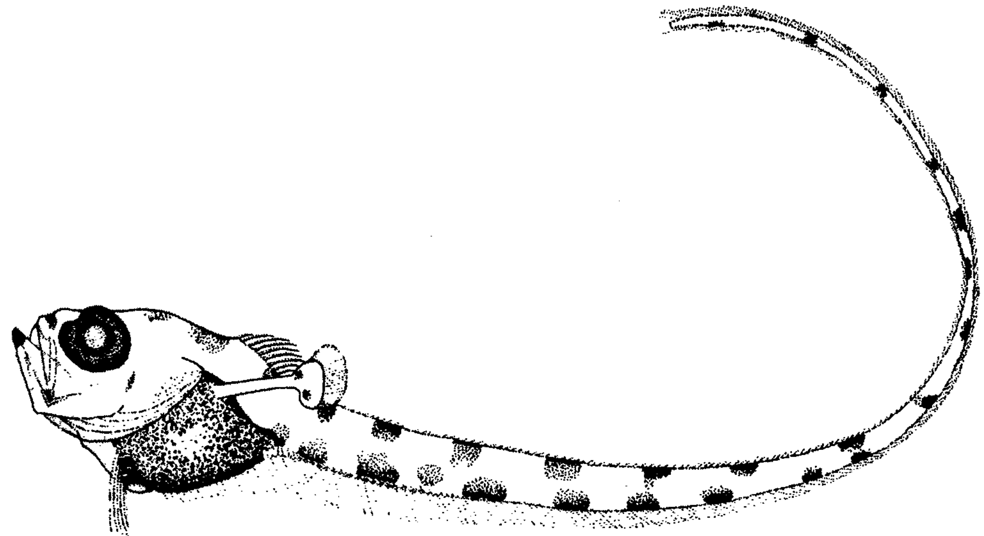


B

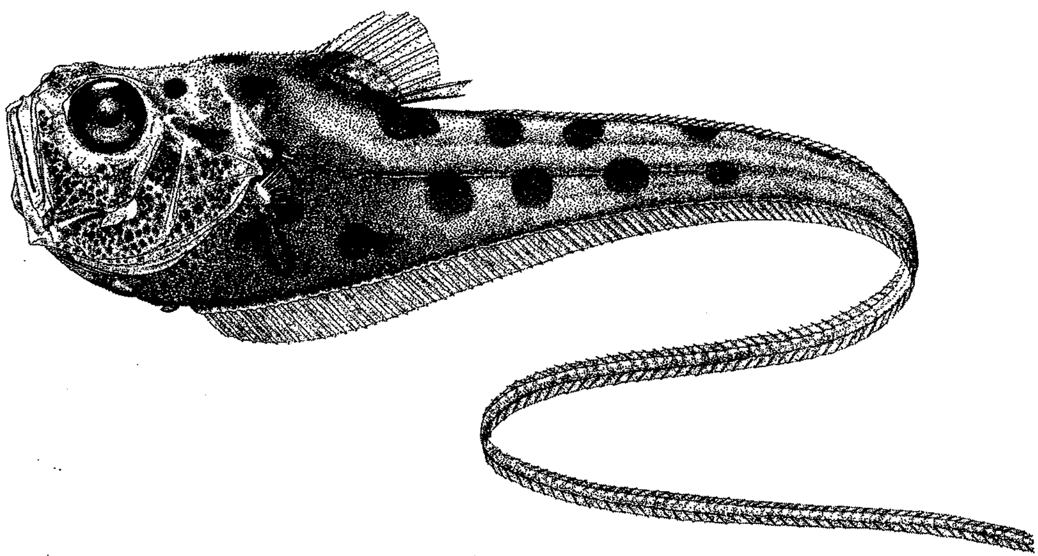


C

Figure Bathygadidae & Macrouridae 10
(Continued).



D



E

Figure Bathygadidae & Macrouridae 11. *Hymenocephalus italicus*, 10.2 mm TL. From Sanzo (1933).

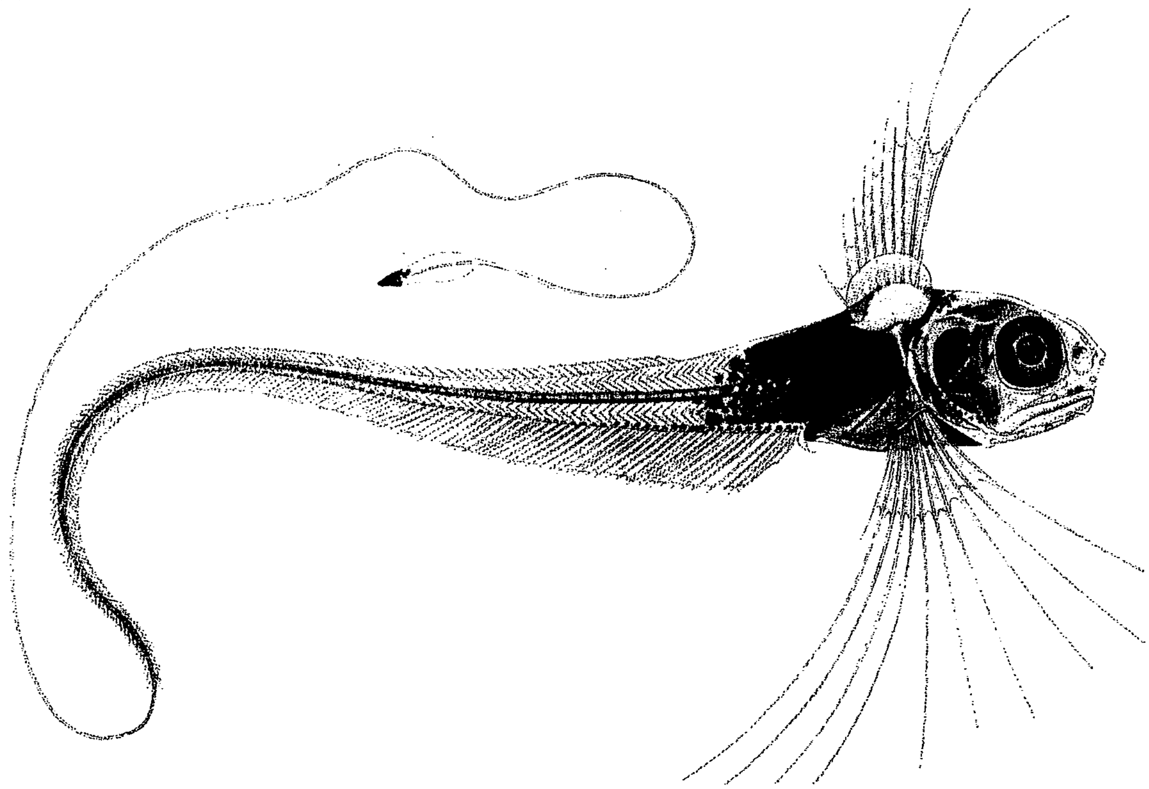
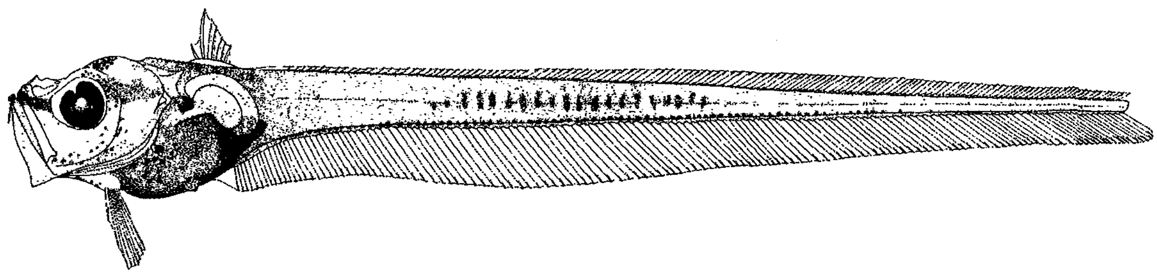
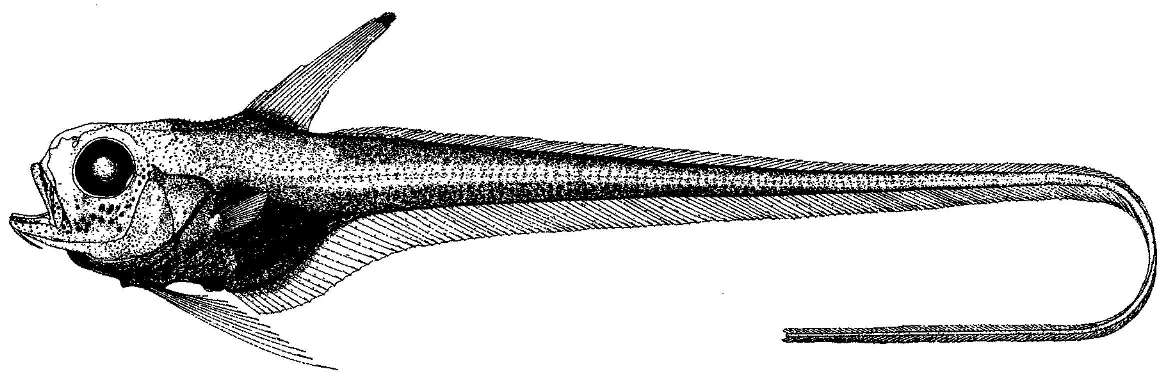


Figure Bathygadidae & Macrouridae 12. *Sphagemacrurus grenadae*, A) MCZ 86053 - 4.5 mm HL; 31.0 mm TL; barbel present; 7 BrR; 7 developing Gr (1st arch); ca. 9 P_2 (jugular); II+5 developing D_1 (2nd spinous ray ?serrate); anus – 2 (one third distance from anal origin to P_2 bases); light organ - ?periproct; pigmentation II. B) Juvenile - USNM 290724 – 8.8 mm HL; 71 mm TL; barbel present; 7 BrR; 9 Gr (1st arch); ca.11 or 12 P_2 (well anterior to pectoral base); II+11 D_1 (2nd spinous ray broken - ?serrate); anus - 2 (one third distance from anal origin to P_2 bases); light organ - periproct; pigmentation II.



A



B

Figure Bathygadidae & Macrouridae 13. ?*Nezumia* sp., MCZ 58624 - 3.0 mm HL; 27 mm TL; barbel present; 7 BrR; 6 Gr (1st arch); 8 P_2; II+9 or 10 D_1 (2^{nd} spinous ray smooth); anus – 2 (two thirds of way from P_2 base to anal origin); light organ – not differentiated; pigmentation – III. From Fahay & Markle (1984, Fig. 141 B).

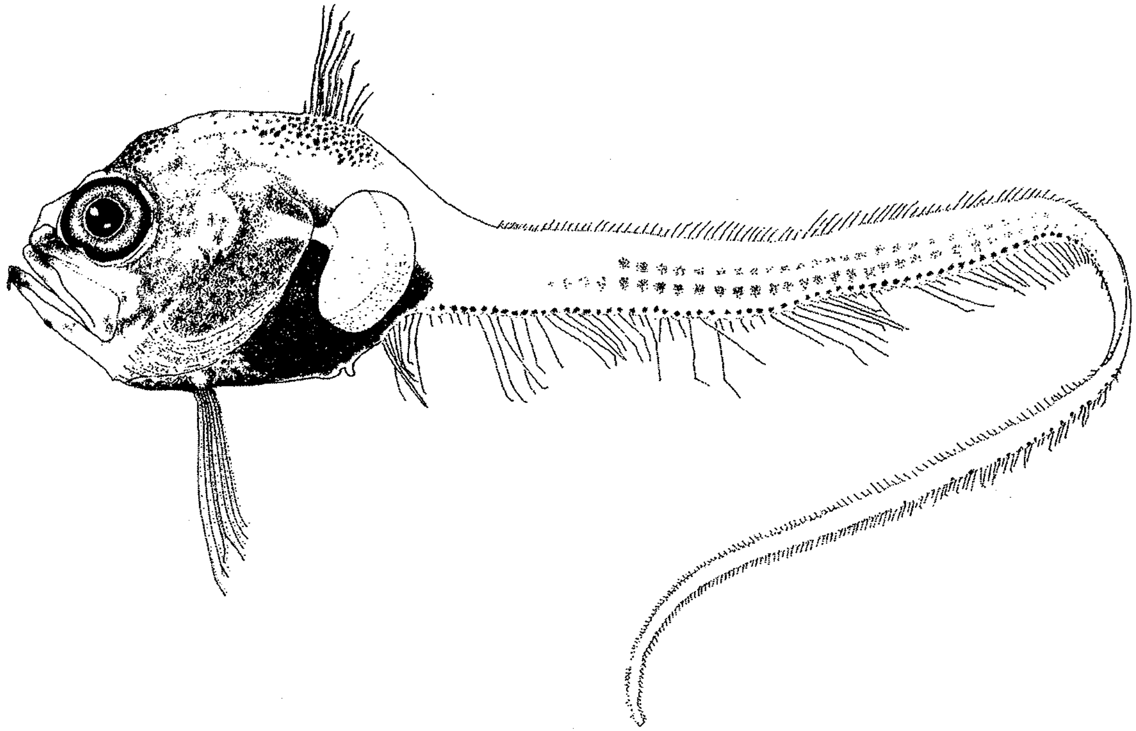


Figure Bathygadidae & Macrouridae 14. *Nezumia aequalis* (?), 8.5 mm HL. From Merrett (1989, Fig.3).

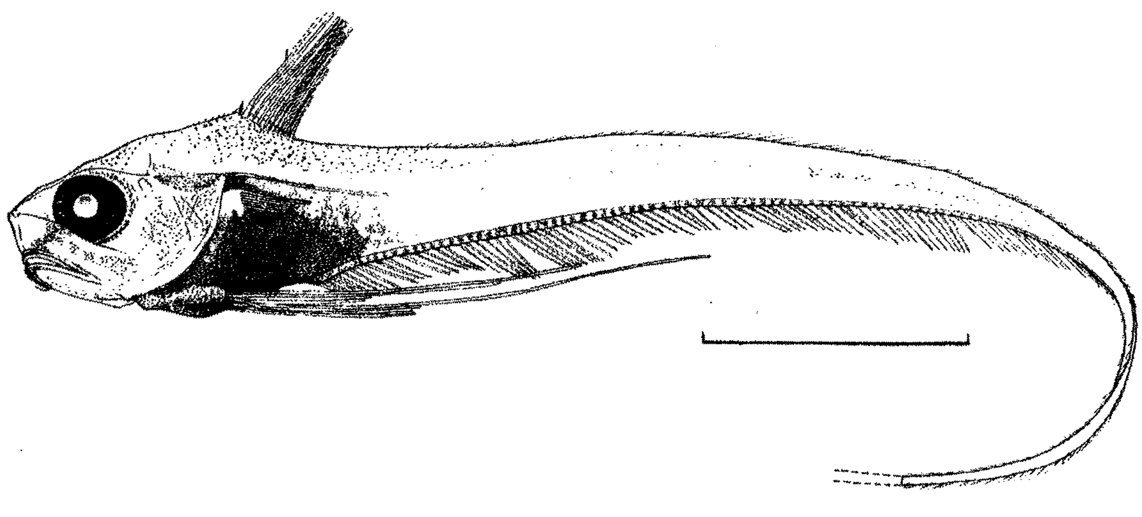
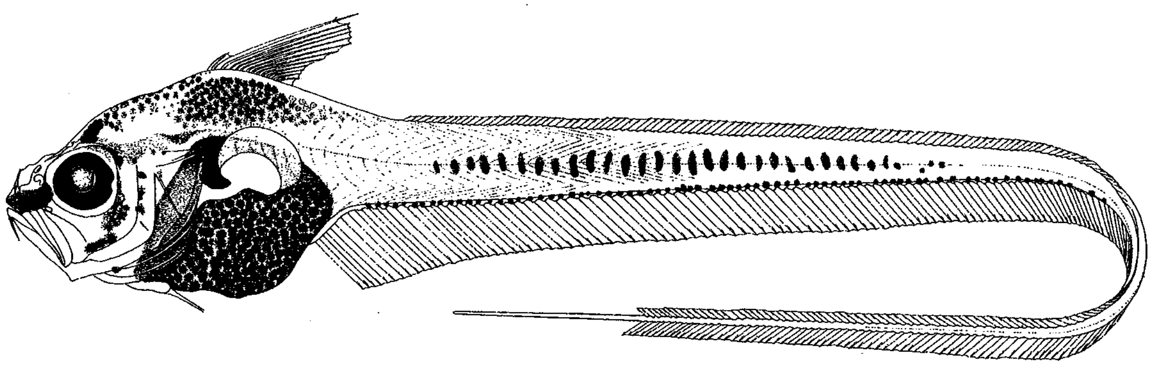
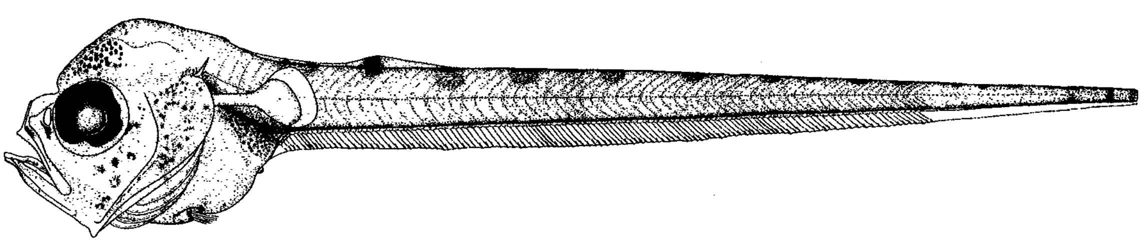


Figure Bathygadidae & Macrouridae 15. *Nezumia ?cyrano*, A) Albatross IV 8902-012 – 6.8 mm HL; 67.0 mm TL; barbel present; 7 BrR; 7 Gr (1st arch); 8 P_2; II+11 D_1 (2nd spinous ray with 1 serration at tip); anus - 2; light organ – periproct (pale); 2 gas glands; pigmentation – III. B) Possible specimen. MCZ 85682 – 1.7 mm HL; ca. 10 mm TL; barbel undeveloped; 7 BrR; no developed GR (1st arch); 5 P_2 rays developed; no D_1 rays countable; anus – 2; light organ not developed; pigmentation ?III.



A



B

Figure Bathygadidae & Macrouridae 16. *Nezumia sclerorhynchus* from Sanzo (1933) A) wild caught egg 1.60 mm diameter; B) wild caught egg 4 days later; C) free embryo 4.28 mm.

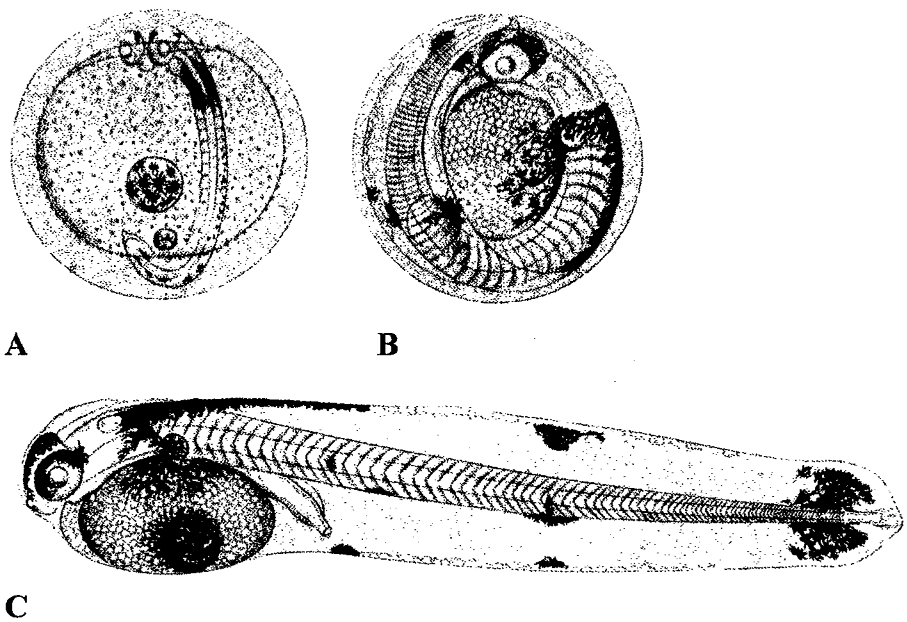
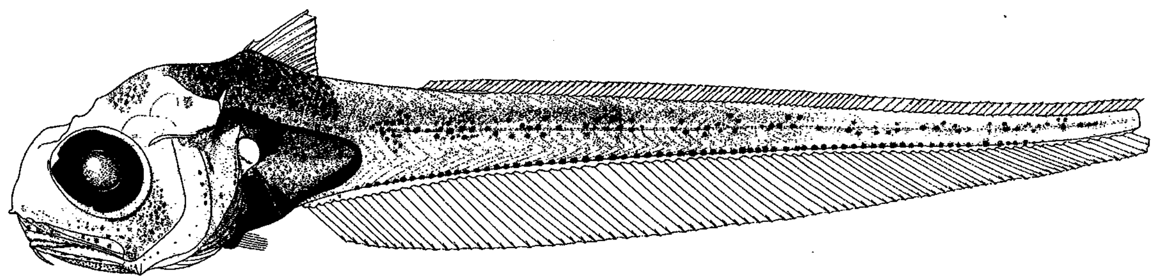
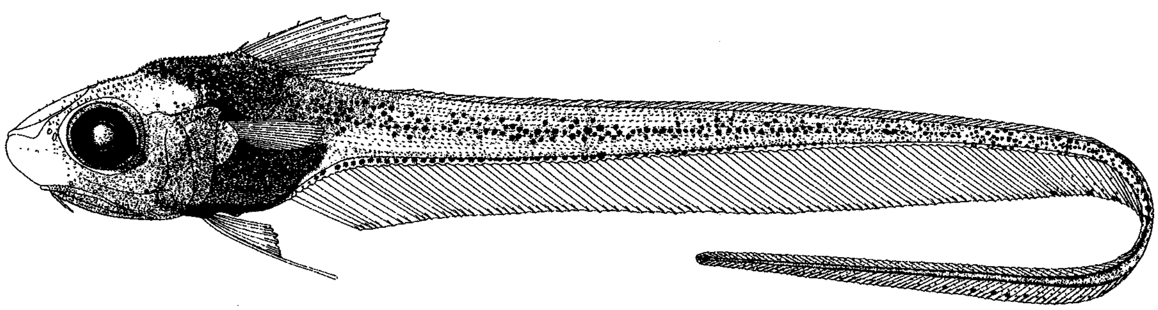


Figure Bathygadidae & Macrouridae 17. *Nezumia ?suilla*, A) MCZ 85705 – 8.0 mm HL; 73(+) mm TL; barbel present; 7 BrR; 7 Gr (1st arch); *ca.*6 or 7 P_2; II+10 or 11 D_1 (spinous ray broken - ?serrate); anus- 2; light organ – periproct; pigmentation - III; B) USNM 289478 – Juvenile, 9.0 mm HL; 72?+ mm TL; barbel present; 7 BrR; 7 Gr (1st arch); 7 P_2; II+11 D_1 (2nd spinous ray serrate); anus - 2; light organ – periproct; pigmentation - III.

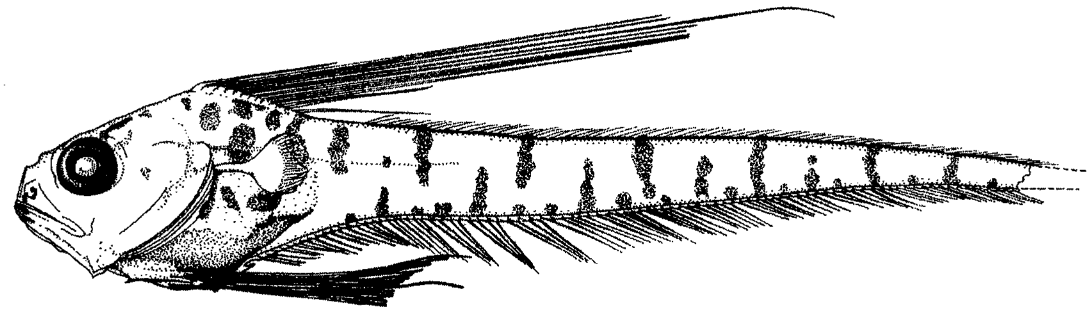


A

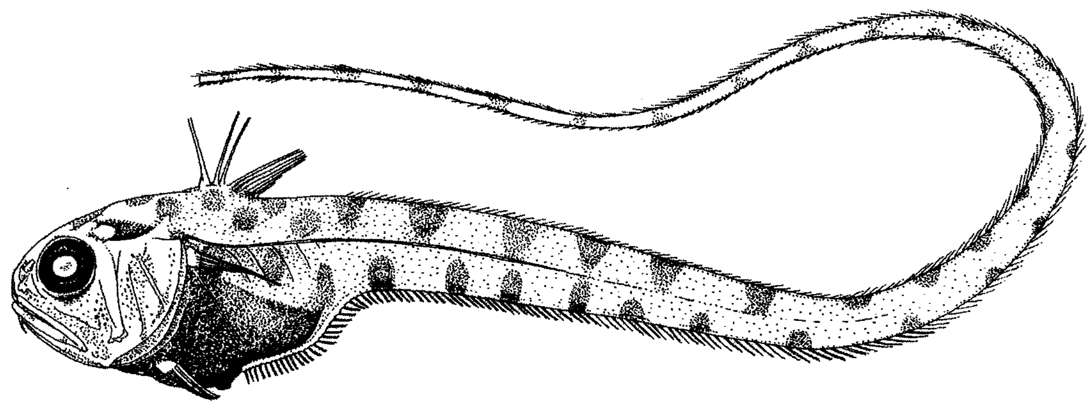


B

Figure Bathygadidae & Macrouridae 18. *Malacocephalus laevis*, A) 8.0 mm HL, B) juvenile, 10 mm HL. From Merrett (1989, Fig. 1 A & B).

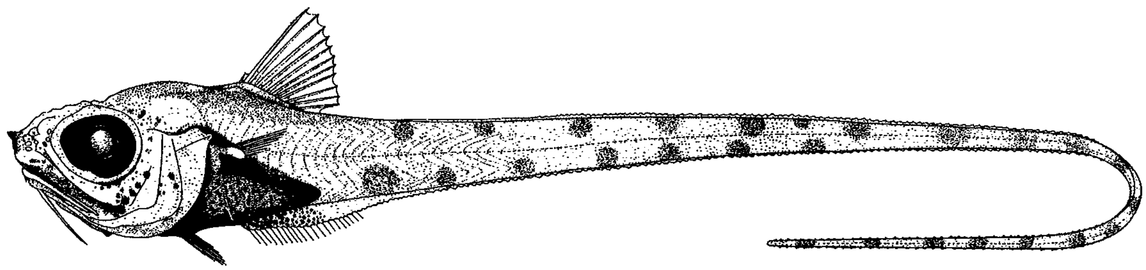


A



B

Figure Bathygadidae & Macrouridae 19. *Malacocephalus ?occidentalis/okamurai*, MCZ 65171 – Juvenile, 14.0 mm HL; 107.0 mm TL; barbel present - long, slender; 7 BrR; 9 Gr (1st arch); 7 or 8 P_2; II+10 D_1 (2^{nd} spinous ray smooth); anus - 2 (slightly closer to P_2 bases than to anal origin); 2 light organs – posterior one just anterior to periproct, separated by 4 or so scale rows from anterior one; pigmentation – I (deep-seated).



Literature Cited

Ambrose, D. A. 1996i. Macrouridae: Grenadiers. Pages 483-499 *in* The Early Stages of Fishes in the California Current Region. H. G. Moser (ed.). Calif. Coop. Ocean. Fish. Investig. Atlas (33): 1509 p.

Backus, R. H., G. W. Mead, R. L. Haedrich, & A.W. Ebeling, 1965. The mesopelagic fishes collected during cruise 17 of the R/V CHAIN, with a method for analyzing faunal transects. Bull. Mus. Comp. Zool. 134 (5): 139-158.

Cohen, D. M., T. Inada, T. Iwamoto, & N. Scialabba. 1990. FAO species catalogue. Vol. 10. Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. FAO Fish. Synop. (125) 10: 442 p.

Fahay M. P. & D .F Markle. 1984. Gadiformes: Development and Relationships. Pages 265-283 *in* Ontogeny and systematics of fishes. H. G. Moser et al. (eds.), American Society of Ichthyology and Herpetology, Special Publication (1): 760.

Farran, G. P. 1924. Seventh report of the fishes of the Irish Atlantic slope. The macrurid fishes (Coryphaenoididae). Proc. Royal Irish Acad. 36: 91-143.

Grigor'ev, G. V. & V. P. Serebryakov. 1981. Eggs of roundnose grenadier, *Coryphaenoides rupestris* Gunnerus 1765. J. Northwest Atl. Fish. Sci. 2: 73-74.

Haedrich, R. L. & P. T. Polloni. 1976. A contribution to the life history of a small rattail fish, *Coryphaenoides carapinus*. Bull. So. Calif. Acad. Sci. 75: 203-211.

Hubbs, C. L. & T. Iwamoto. 1977. A new genus (*Mesobius*), and three new bathypelagic species of Macrouridae (Pisces: Gadiformes) from the Pacific Ocean. Proc. Calif. Sci. ser. 4, 41(7): 233-251.

Marshall, N. B. 1964. Bathypelagic macrourid fishes. Copeia, 1964: 86-93.

Marshall, N. B. 1972. Swimbladder organization and depth ranges of deep-sea fishes. Pages 261-272 *in* The Effects of Pressure on Organisms. Sleigh, M. A. & A. G. MacDonald, (eds.). Symp. Soc. Exp. Biol. (26).

Marshall, N. B. 1973. Genus *Sphagemacrurus*. Pages 621-623 *in* Marshall, N.B. & T. Iwamoto. Family Macrouridae. Fishes of the western North Atlantic (Cohen, D.M., ed.), Mem. Sears Fndn. Mar. Res. 1, pt. 6.

Mead, G. W., E. Bertelsen & D. M. Cohen. 1964. Reproduction among deep-sea fishes. Deep-Sea Res. 11: 569-596.

Merrett, N. R. 1978. On the identity and pelagic occurrence of larval and juvenile stages of rattail fishes (Family Macrouridae) from 60°N, 20`W and 53°N, 20`W. Deep-Sea Res. 25: 147-160.

Merrett, N. R. 1986. Macrouridae of the eastern North Atlantic. Fiches d'Identification du Plancton, ICES, No.173/174/175, 14p.

Merrett, N. R. 1989. The elusive macrourid alevin and its seeming lack of potential in contributing to intrafamilial systematics. Pages 175-185 *in* Papers on the systematics of gadiform fishes. D.M. Cohen (ed.). Los Ang. County Nat. Hist. Mus. Sci. Ser. (32), 262 p.

Merrett, N. R. 1994. Reproduction in the North Atlantic oceanic ichthyofauna and the relationship between fecundity and species' sizes. Environ. Biol. Fishes, 41: 207-245.

Merrett, N. R. & S. H. Barnes. 1996. Preliminary survey of egg envelope morphology in the Macrouridae and the possible implications of its ornamentation. J. Fish Biol. 48: 101-119.

Merrett, N. R & R. L. Haedrich. 1997. Deep-sea Demersal Fish and Fisheries. Chapman & Hall, London. 282 p.

Sanzo, L. 1933. Macruridae. Uova, larve e stadi giovanili di Teleostei. Pages 255-265, Pl. 16 *in* Fauna e Flora del Golfo di Napoli. Stazione Zoologica di Napoli Monogr. 38(2): 177-384, Pls. 12-30. [In Italian; English translation, 1969, Jerusalem: Israel Program for Scientific Translations, 378 p.].

Stein, D. L. 1980. Description and occurrence of macrourid larvae and juveniles in the northeast Pacific Ocean off Oregon, U.S.A. Deep-Sea Res. 27A: 889-900.

Stein, D. L. 1985. Towing large nets by single warp at abyssal depths: methods and biological results. Deep-Sea Res. 32: 183-200.