PELAGIC STROMATEOID FISHES (PISCES, PERCIFORMES) OF THE EASTERN PACIFIC: KINDS, DISTRIBUTIONS, AND EARLY LIFE HISTORIES AND OBSERVATIONS ON FIVE OF THESE FROM THE NORTHWEST ATLANTIC

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CONTENTS

ABSTRACT

This contribution has a dual purpose: first, to establish the kinds of pelagic stromateoid fishes present in the eastern Pacific, including their distribution and relative abundances and second, to describe their early life histories. Complete life history series are available for 11 species: *Amarsipus carlsbergi* (Amarsipidae); *Icichthys lockingtoni* (Centrolophidae); *Tetragonurus atlanticus* and *T. cuvieri* (Tetragonuridae); and *Cubiceps caeruleus, C. pauciradiatus, Psenes arafurensis, P. cyanophrys, P. maculatus, P. pellucidus,* and *P. sio* (Nomeidae). Fragmentary series, sometimes restricted to a few specimens, are available for eight species: *Schedophilus huttoni, S. labyrinthicus, S. maculatus* (Centrolophidae); *Tetragonurus pacificus* (Tetragonuridae); and *Cubiceps capensis, Cubiceps* sp. A, *Cubiceps* sp. B, and *Nomeus gronovii* (Nomeidae). Fishes in the families Amarsipidae and Nomeidae and two species of the Tetragonuridae are primarily distributed in tropical-subtropical waters; those in the family Centrolophidae and *T. cuvieri* are largely temperate water forms.

In treating life history series, the dynamic approach of tracing developmental characters is used. For each species the following items are discussed: literature, material, distribution, distinguishing characters of juveniles and of larvae, meristics, morphometrics, ossification, and pigmentation. The importance of skeletal characters such as the number of vertebrae, possession of both a haemal spine and ribs on one to several vertebrae, the number and positioning of predorsal bones in relation to neural spines and of pterygiophores in relation to neural and haemal spines is discussed for all species. The pelagically developing eggs are known for six species, *Icichthys lockingtoni*, *Tetragonurus cuvieri*, *T. atlanticus*, *Cubiceps pauciradiatus*, *C. caeruleus*, and *Psenes sio*, and are tentatively identified for two others, *Psenes pellucidus* and *P. arafurensis*. *Cubiceps carinatus* Nichols and Murphy from the eastern Pacific is considered a synonym of *C. pauciradiatus* Günther which has a worldwide tropical-subtropical distribution.

In a critical review of stromateoid fishes, Haedrich (1967) recognized five families and 14 genera. Subsequently, Haedrich (1969) added another family, Amarsipidae, and genus *Amarsipus*. Fishes in three of the six stromateoid families are exclusively oceanic as follows: Family Amarsipidae (monotypic—*Amarsipus carlsbergi*), family Tetragonuridae (one genus *Tetragonurus*, three species), and family Nomeidae (three genera—*Nomeus* [one species], *Cubiceps* [ca. seven species], *Psenes* [ca. six species]). Fishes in the family Ariommidae (one genus *Ariomma*) are oceanic and coastal. Fishes in the family Centrolophidae with six genera, have two genera (*Centrolophus* and *Icichthys*) exclusively oceanic, one genus (*Schedophilus*) a mixture of oceanic and coastal species, and three genera (*Hyperoglyphe*, *Seriolella*, and *Psenopsis*) exclusively coastal. Fishes of the family Stromateidae (three genera, *Stromateus*, *Peprilus*, and *Pampus*) are coastal. Hence, of the 15 genera of stromateoid fishes, seven are exclusively oceanic, two are mixed oceanic and coastal, and six are exclusively coastal.

Citations for previous records of occurrences of pelagic stromateoid fishes from the eastern Pacific Ocean will be given in the accounts of the families, genera, and species. The taxonomy of the nomeid fishes has been inadequately known, although recent contributions of Haedrich, particularly Haedrich (1967, 1972) have aided in clarifying the species composition. Haedrich showed

that most species of nomeids are widely distributed in the three major oceans, and that the majority of nominal species described previously have to be relegated to the synonymy of about 14 species. Two species described from the eastern Pacific, *Psenes pacificus* Meek and Hildebrand and *Cubiceps carinatus* Nichols and Murphy have to be placed in the synonymy of *P. cyanophrys* Cuvier and Valenciennes and *C. pauciradiatus* Günther, respectively. Despite several eastern Pacific records for *Cubiceps gracilis* (Berry and Perkins, 1966; Fitch and Lavenberg, 1968; Lavenberg and Fitch, 1966), it is quite doubtful that this species occurs in the North Pacific, and Haedrich (1972) referred Japanese specimens reported by Abe (1955b) as *C. gracilis* to *C. caeruleus*.

The early life history stages are inadequately known for most oceanic stromateoid fishes. They have been best worked out for the three species of *Tetragonurus* (Grey, 1955), for one centrolophid, *Centrolophus niger* (Sanzo, 1932) and for two nomeids, *Cubiceps gracilis* (Sparta, 1946), and *Psenes cyanophrys* (Legaspi, 1956).

This paper has a dual purpose: (1) to establish the kinds of pelagic stromateoid fishes in the eastern Pacific together with their distribution and relative abundance, and (2) to describe the early life history stages of most of these. Observations on Atlantic material are included for larvae and early juveniles of the following species of

nomeids: *Nomeus gronovii, Cubiceps pauciradiatus, Psenes maculatus, P. cyanophrys,* and *P. pellucidus.*

The families and species to be dealt with are as follows (see Table 1 for their meristics):

Family Amarsipidae
    Amarsipus carlsbergi Haedrich, 1969
Family Centrolophidae
    Icichthys lockingtoni Jordan and Gilbert, 1880
    Schedophilus huttoni (Waite, 1910)
    Schedophilus labyrinthicus McAllister and Randall, 1975
    Schedophilus maculatus Günther, 1860
Family Tetragonuridae
    Tetragonurus atlanticus Lowe, 1839
    Tetragonurus cuvieri Risso, 1810
    Tetragonurus pacificus Abe, 1953
Family Nomeidae
    Cubiceps caeruleus Regan, 1914
    Cubiceps capensis (Smith, A., 1849)
    Cubiceps pauciradiatus Günther, 1872
    Cubiceps sp. A (tropical)
    Cubiceps sp. B (central water mass)
    Nomeus gronovii (Gmelin, 1788)
    Psenes arafurensis Günther, 1889
    Psenes cyanophrys Cuvier and Valenciennes, 1833
    Psenes maculatus Lütken, 1880
    Psenes pellucidus Lütken, 1880
    Psenes sio Haedrich, 1970

MATERIALS AND METHODS

Our primary source of life history series has been the collections of fish eggs and larvae sorted from plankton hauls taken on cruises of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) including extended offshore coverage on CalCOFI cruises 7205 and 7210 and cruises made into the Gulf of California; collections taken on EASTROPAC and subsequent cruises in the tropical eastern Pacific; collections made on expeditions conducted by Scripps Institution of Oceanography (SIO) including SHELLBACK (S.B.), NORPAC, CATO II, ARIES 9, STEP 1, and CLIMAX II; collections made off Hawaii on TOWNSEND CROMWELL (T.C.) cruise 32 and at the station off Hawaii sampled repeatedly by Thomas Clarke (Clarke, 1973). These have been supplemented by specimens from the western North Atlantic.

The primary sources of juveniles and adult specimens have been from midwater trawl hauls made on cruises of the National Marine Fisheries Service (NMFS) in the eastern tropical Pacific, particularly TOWNSEND CROMWELL (T.C.) cruise 51 and DAVID STARR JORDAN (JORD.) cruises 57, 60, 65, and 77, from trawl hauls made on extended CalCOFI cruises 7205 and 7210, from collections made off Hawaii as given above, and from the extensive collection at SIO obtained on their numerous expeditions.

Location and date of capture are given in the tables dealing with meristics of juveniles and adults, but not in the tables dealing with morphometrics and meristics of early life history stages. These data are omitted because their inclusion would make these tables unwieldy. However, information on locality and date of sampling for these collections has been included in the Appendix.

Complete series of life history stages were established for most of the species described in this paper by the serial method of working backwards from juveniles and adults to early stage larvae before notochord flexion (i.e., preflexion stage larvae), and in some instances, to yolk-sac larvae and eggs. The dynamic approach of tracing developmental characters sequentially was used; these characters are treated in later sections.

Three developmental series of larvae and early juveniles were selected for each species as their condition and amount of material allowed. The first series, representative of the size range of specimens available for each species, was measured with an ocular microscope for morphometrics; these measurements are presented in a separate table for each species. The specimens in the second developmental series were cleared and stained following the techniques of Hollister (1934) utilizing KOH as the clearing agent for small specimens up to approximately 15 mm SL, and the techniques of Taylor (1967) using trypsin for the clearing of larger specimens for obtaining meristic data and the sequences of ossification. Either technique can be used for small speci-

Table 1. Meristics of the stromateoid fishes in the eastern Pacific

Family/Species	Vertebrae	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pectoral fins	Pelvic fins	Caudal fin rays Sec. + princip. + Sec.	Branchio-stegals
Amarsipidae								
Amarsipus carlsbergi	16-18+29-31=46-48	X-XII	23-27	29-32	17-20	I,5	11-15 + 17 + 11-14	6
Centrolophidae								
Icichthys lockingtoni	23-25+34-37=58-61	41-46		27-32	18-20	I,5	11-13 + 17 + 10-13	7
Schedophilus huttoni	12+19-20=31-32	60-63		33-38	19-20	I,5	10-12 + 17 + 9-11	7
Schedophilus labyrinthicus	10+15=25	VII-VIII	26-27	III,18-19	22	I,5	11 + 17 + 10	7
Schedophilus maculatus	11+18=29	VIII-IX	27-28	III,23	21	I,5	10-11 + 17 + 10	7
Tetragonuridae								
Tetragonurus atlanticus	23-21+20-22=44-46	XIV-XV	10-12	I,9-11	17	I,5	9-10 + 17 + 9-10	6
Tetragonurus cuvieri	26-27+25-28=51-54	XV-XVIII	11-13	I-II,10-12	14-17	I,5	9-13 + 17 + 9-12	5-6
Tetragonurus pacificus	18+21-22=39-40	XI-XII	10-11	I,10-11	18	I,5	11 + 17 + 11	6
Nomeidae								
Cubiceps caeruleus	12+19=31	X-XII	I,20-23	III,20-22	20-23	I,5	7-10 + 17 + 7-10	6
Cubiceps capensis	12+19=31	X-XI	I,25	II,22 or 23	ca.21	I,5	8-9 + 17 + 8-9	6
Cubiceps pauciradiatus	13+18=31	X-XII	I,15 to 17	II,14-16	18-19	I,5	8-10 + 17 + 8-10	6
Cubiceps sp.A (tropical)	12+19=31	XI	I,22 or 23	III,21 or 22	20 or 21	I,5	12 + 17 + 12	6
Cubiceps sp.B (central water mass)	12+19=31	XI	I,19 or 20	III,20	ca.22	I,5	11-12 + 17 + 12	6
Nomeus gronovii	14+27=41	XI-XII	25-27	II,24-26	19-20	I,5	8-9 + 17 + 8-9	6
Psenes arafurensis	12+19=31	X-XI	I,20-23	III,21-23	20-21	I,5	7-10 + 17 + 7-10	6
Psenes cyanophrys	12+19=31	IX-X	I,23-26	III,23-27	19-20	I,5	7-9 + 17 + 7-9	6
Psenes maculatus	12+23=35	X-XI	I,22-23	III,21-22	19-22	I,5	8 + 17 + 8-9	6
Psenes pellucidus	13-14+27-29=40-42	XI-XII	I,26-30	III,27-30	18-20	I,5	8-10 + 17 + 8-10	6
Psenes sio	12-13+24-26=36-38	XI-XII	I,22-26	II,23-26	16-18	I,5	7-10 + 17 + 8-10	6

mens, but the KOH method has the advantage of being more rapid. This second series was less extensive inasmuch as fewer specimens could be spared for clearing and staining; the data obtained are shown in separate tables. In some cases, counts made from untreated specimens and from radiographs were included with data from cleared and stained material or used exclusively; these are noted on the pertinent tables. The third series of larvae was composed of a few select specimens to illustrate the early developmental stages of each species. The number of illustrations were limited to show the major developmental and pigmentation changes that occurred. Wherever possible, at least one specimen was illustrated of each of the three larval stages—preflexion, flexion, and postflexion, and usually several specimens of the latter stage. Also, one or more illustrations were included of early juveniles.

We separate the larval period into three stages which are associated with the development of the caudal fin and its supporting elements, and which are related directly to the morphometrics for each specimen. The three stages are termed preflexion-, flexion-, and postflexion-stage larvae, which are stages before, during, and after the upward flexing of the tip of the notochord. Before the initial development of the caudal fin in preflexion-stage larvae, and the formation of the fin in flexion-stage larvae, body length is measured as the distance from the tip of the snout to the tip of the notochord, designated as NL = notochord length. In postflexion larvae, when the caudal fin is fully formed and the notochord is completely flexed, the standard length (SL) measurement is used, i.e., the length from the tip of the snout to the posterior margin of the hypural bones. The tables of morphometrics and meristics are divided by dashed lines into three sections corresponding to each stage discussed above. We strongly support the standard use of preflexion, flexion, and postflexion stages in the measurement and description of larvae to allow for the meaningful comparisons of data.

Other measurements are defined as follows: snout to anus length is the distance from the tip of the snout along the midline to a vertical line through the posterior edge of the anus; head length (HL) is the horizontal distance from the tip of the snout to the posterior margin of the cleithrum; eye diameter is the distance across the midline of the pigmented area of the eye; snout length is the horizontal distance from the tip of the snout to the anterior margin of the pigmented region of the eye; body depth at the pectoral base is the vertical distance through the anterior margin of the pectoral base; the snout to origins of dorsal (Sn-D), anal (Sn-A), and pelvic or ventral (Sn-V) fins are distances from the tip of the snout along the midline to the vertical line through the origin of the respective fins. The body parts included in the snout to anus distance are the head and trunk. The post-anal portion of the body is simply referred to as the "tail." We try to be consistent in the use of these terms throughout the paper.

The separation of the larval period from that of juveniles and adults is not a sharp one in the stromateoid fishes as no abrupt metamorphic changes occur. However, we have used two criteria in distinguishing a larva at a transition size from a juvenile. These are: (1) the complete formation of rays in all fins, and (2) the initial development of scales. The occurrence of one or both of the above conditions was used to justify denoting a specimen as an early juvenile. Typically, the secondary caudal rays are the last fin rays to complete formation; also scale formation is seldom encountered on specimens that lack the complete complement of fin rays.

It should be mentioned that some latitude was allowed in distinguishing among larval stages. For example, we placed those specimens forming ossified caudal rays in the flexion stage, irrespective of whether the notochord had yet begun to flex or not. The size range over which transition from the postflexion larval stage to the juvenile stage occurred could seldom be precisely determined. Sometimes we lacked the critical specimens to determine the exact size at which this transition occurred; also the initiation of scale formation did not occur precisely at the same length at which fin formation was completed. Because of these uncertainties, we sometimes use postflexion in a broad sense to include early juveniles as well as postflexion-stage larvae.

Until now, the kinds of pelagic stromateoid fishes occurring in the eastern Pacific and particularly, their distribution and relative abundances, were inadequately known. To remedy this, we are including a series of tables giving information on meristics and localities of capture of juveniles and adults, and a series of distribution charts which incorporate occurrences for larvae, juveniles, and adults. In the tables mentioned above, information is included for 25 specimens of the more common species and for all available material of less common species. For the more common species, specimens included were selected to both bracket their distributions and to present a representative sampling within these ranges. Meristics were taken from X-ray radiographs, supplemented by fin counts made on the specimens. Counts included are those readily read from X-ray radiographs, i.e., vertebral counts and median fin counts. For vertebrae, the division into abdominal (precaudal) and caudal vertebrae is given as well as total counts. The last or ural centrum is included in the vertebral count. Our counts for precaudal vertebrae will not agree with many of the counts given in the literature. The difficulties resolved in discriminating between precaudal and caudal vertebrae are discussed later. Hence, we consider our information on precaudal and caudal counts of vertebrae as a significant contribution. As will become evident in our treatment of *Cubiceps*, so also is the information on the number of secondary caudal rays.

Distribution charts are presented for all species except *Cubiceps capensis*, *Schedophilus maculatus*, *S. labyrinthicus*, and *S.*

huttoni, the four species taken to the south of 20°S. The majority of our occurrence records are from the area covered on EASTROPAC cruises, i.e., between 20°N to 20°S and offshore to 126°W. Consequently, 8 of our 13 distribution charts are based on collections from this area. Of the remaining charts, two summarize occurrences of stromateoid larvae on NORPAC and extended CalCOFI cruises; one is a cumulative record of occurrences of larvae of *Icichthys lockingtoni* in the regularly occupied CalCOFI grid; and two charts show records of the nomeids that occur in the Gulf of California.

CHARACTERS OF STROMATEOID FISHES

Stromateoid fishes have a characteristic appearance. According to Haedrich (1967, p. 44) "there is no mistaking the 'stromateoid look' . . . it is a fat-nosed, wide-eyed, stuffed-up look, smug and at the same time apprehensive." Even larvae of stromateoid fishes, and especially those of nomeids, have the unmistakable stromateoid look; however, the "look" is best developed in early juveniles.

Another character common to all stromateoid fishes, except *Amarsipus*, is the presence of toothed saccular outgrowths in the pharynx immediately behind the inner gill arches. The pharyngeal sac can be seen developing on late postflexion larvae and is well formed on early juveniles of nomeids between 15 to 20 mm SL. These observations were made on cleared and stained specimens.

A third character, observed by Horn (1975) in 14 of the 15 genera of stromateoid fishes is the possession of a relatively small, euphysoclistous swim bladder which forms in preflexion larvae (3 to 5 mm) and regresses in all genera except possibly *Nomeus* before maturity. The organ is characteristic of the larval and juvenile stages which occupy surface layers in coastal and oceanic waters; according to Horn (1975), its loss accompanies changes in behavior and

mode of life and is part of the transition from the juvenile to the adult stage.

In tracing early life history series it is essential to utilize characters that give an unquestionable tie between the juvenile and adult stages of a species and its postflexion larval stage. Among pelagic stromateoid fishes a number of characters can be used including meristics, sequence of fin formation, morphometrics, pigmentation, and skeletal characters. In this section we will deal primarily with meristic and skeletal characters that are of importance in distinguishing among stromateoid fishes at both the larval level and the juvenile-adult levels.

Fin Meristics

Two fins of perciform fishes tend to have stabilized counts: that for the pelvic fins is I, 5 and that for the principal caudal rays is 17 (15 branched). These counts are applicable to all the species dealt with in this paper. The number of secondary caudal rays is variable even within a species, but more so between species. The range in number of dorsal secondary caudal rays is from 7 to 15 among the species we are dealing with, and the range in number of ventral secondary caudal rays is 7 to 14. For any given species, the range in secondary caudal ray counts is 2 to 4 rays per side. The count of secondary caudal rays can be an important taxonomic character among species within a genus, e.g., *Cubiceps*.

The dorsal fin in stromateoid fishes may be divided into two fins, or it may be continuous. If divided, the first dorsal fin has 9 to 18 spines and the second dorsal fin has 0, 1, or 2 spines and 10 to 30 rays, e.g., nomeids, tetragonurids, and *Amarsipus*. In *Amarsipus* and *Tetragonurus* the spines in the first dorsal fin are much shorter than the rays in the second dorsal fin. In nomeids, the longest spines in the first dorsal fin usually are in the middle of the fin, with the spines progressively shorter both anteriad and posteriad, the posterior-most spine usually being the shortest. The spine associated with the second dorsal fin usually is

longer than the terminal spine in the first dorsal fin. The continuous dorsal fin is found in the centrolophids included in this study. No attempt was made to distinguish between spines and rays in the dorsal fin in *Icichthys*. In *Schedophilus* it is sometimes difficult to distinguish between spines and rays in the continuous dorsal fin. The highest dorsal fin count among stromateoids is found in *Schedophilus huttoni* (56 to 63), a species that has been taken in the eastern South Pacific.

In stromateoid fishes the anal fin usually has about the same number of rays as the second dorsal fin, although there are some exceptions of which the most striking are found in the centrolophids. *Schedophilus labyrinthicus* has 7 or 8 more soft rays in the dorsal than in the anal fin and *S. maculatus* has 4 or 5 more rays. In *Icichthys*, where no distinction is made between spines and rays in the dorsal and anal fins, the dorsal averages 13 more elements than the anal fin. In *Amarsipus* the anal fin averages 5.5 more rays than the second dorsal. In *Tetragonurus*, the rays in the second dorsal fin average less than one more than in the anal fin. Among the 11 nomeids, the differences between dorsal and anal fin ray counts are slight, and can be higher in either fin as is shown in the following summary:

The pectoral fins in the species studied have ray counts of 14 to 23. Pectoral ray counts usually have a range of 2 to 4 rays between the highest and lowest counts for a species. The pectoral counts are too similar for most species to be used to distinguish among them.

There are two different sequences in which fins form in oceanic stromateoid fishes, depending primarily on whether the pelvic fins form early before the other fins, or whether they form late.

The pelvic fins are the first to form in *Psenes, Amarsipus*, and probably also in *Nomeus*. Among *Psenes* larvae, pelvics are present on specimens as small as 2.8 mm. When pelvics are precocious in formation in stromateoid fishes, they soon obtain their complete complement of one spine and five rays and become fairly large. In most fishes other than stromateoids that have early development of pelvic fins, there is a corresponding early development of the spines (or rays) in the anterior part of the dorsal fin. The early forming dorsal elements can become quite large and even elaborate, as for example in epinepheline serranids, gempylids, trachipterids, many bothid flatfishes and some carangids. In the stromateoids with pelvics developing first, the first dorsal is the next fin to develop, but the early forming

Cubiceps caeruleus	Second dorsal averages 0.5 ray more than anal fin
C. capensis	Second dorsal averages 2.5 ray more than anal fin
C. pauciradiatus	Second dorsal averages 1.25 ray more than anal fin
C. sp. A	Second dorsal averages 0.7 ray more than anal fin
C. sp. B	Second dorsal averages 0.3 ray less than anal fin
Nomeus gronovii	Second dorsal averages 0.5 ray more than anal ray
Psenes arafurensis	Second dorsal averages 1.2 ray less than anal fin
P. cyanophrys	Second dorsal and anal about equal
P. maculatus	Second dorsal averages 0.8 ray more than anal fin
P. pellucidus	Second dorsal averages 0.2 ray less than anal fin
P. sio	Second dorsal averages 0.5 ray more than anal fin

The complement of anal fin rays is preceded by 0, 1, 2, or 3 anal spines: 0 in *Amarsipus* and *Icichthys*, 1 in *Tetragonurus*, 2 in *Cubiceps pauciradiatus, C. capensis, Psenes sio*, and *Nomeus gronovii*, and 3 in the remaining species under consideration.

spines are only of moderate size, never enlarged or elaborated. The other fins then form in about their regular sequence. Among stromateoids, the initiation of ray development in the caudal and pectoral fins usually slightly precedes the development of the

second dorsal and anal fins. The last rays to form are usually the anterior procurrent rays of the caudal fin.

In at least three genera of stromateoid fishes from as many families, *Cubiceps*, *Tetragonurus*, and *Icichthys*, the pelvic fins are the last to initiate development. In *Cubiceps* and *Tetragonurus* the caudal fin is the first to initiate ray formation, followed by the almost simultaneous development of pectorals, second dorsal and anal fins, and somewhat later by the first dorsal and finally the pelvics. In *Icichthys* the initiation of ray formation in the pectorals precedes that of the caudal, followed by the dorsal and anal fins simultaneously, and soon thereafter, the pelvics.

Morphometrics and Pigmentation

Two of the primary characters for distinguishing among genera and species of stromateoid fishes are morphometrics and pigmentation. Morphometric tables covering the larval and early juvenile stages have been prepared for all species dealt with in this manuscript, and are treated in detail in later sections. Pigmentation patterns are best shown in illustrations, of which we include 80 of larvae and early juveniles. In addition, pigment patterns are discussed for the several species of each genus, and trenchant differences are emphasized.

Skeletal Characters

Among skeletal characters of particular relevance are (1) total number of vertebrae, (2) co-occurrence of a pair of pleural ribs and a haemal spine on each of one or more caudal vertebrae, (3) separation of vertebrae into precaudal and caudal groups, (4) position of anal fin pterygiophores in relation to haemal spines, (5) position of dorsal fin pterygiophores and predorsal bones in relation to neural spines, and (6) the supporting bones of the caudal fin.

The Vertebral Column

Number of Vertebrae.—Many centrolophids have a total count of 25 vertebrae includ-

ing *Schelophilus labyrinthicus*. However, *S. maculatus* has 29 vertebrae and *S. huttoni*, 31 or 32. *Icichthys lockingtoni* has the highest vertebral count among stromateoid fishes, 58 to 61. *Amarsipus carlsbergi* has a relatively high vertebral count, 45 to 48.

The three species of *Tetragonurus* can be separated on the basis of vertebral counts alone. Our specimens of *T. pacificus* have 39 or 40 vertebrae, *T. atlanticus*, 44 to 46 and *T. cuvieri*, 51 to 54.

The most frequent, regular vertebral count among nomeids is 31; 7 of the 11 species of nomeids have this count, including all 5 species of *Cubiceps* and *Psenes arafurensis* and *P. cyanophrys*. Other total vertebral counts obtained for nomeids include 35 for *Psenes maculatus*, 36 to 38 for *P. sio*, and 40 to 42 for *P. pellucidus* and *Nomeus gronovii*.

Vertebrae usually begin to ossify during the late preflexion stage or during early flexion and all vertebrae are ossifying by early postflexion. Ossification begins at the anterior end of the axial skeleton, with neural spines ossifying before their centra— and with ossification proceeding progressively posteriad.

Ribs on Caudal Vertebrae.—In most fishes it is not difficult to separate the precaudal group of vertebrae from the caudal group, in that ribs are found only on precaudal vertebrae and haemal spines only on caudal vertebrae. This is not the case for nomeids, inasmuch as one to five caudal vertebrae (depending upon the species) bear both a haemal spine and a pair of pleural ribs.

In Table 2 the arrangement on vertebrae 12 to 19 of pairs of ribs alone, pairs of ribs and haemal spines together, and haemal spines alone is given for eight species. For *Cubiceps caeruleus*, only one vertebra, the 13th, usually bears both ribs and a haemal spine. On *Cubiceps pauciradiatus*, two vertebrae usually have both ribs and haemal spines, the 14th and 15th, although occasionally the 14th has only ribs and occasion-

Table 2. Arrangement of pairs of ribs and/or haemal spine on vertebrae 12 to 19 in nomeids (R = Ribs, H = Haemal spine)

Species	Vertebra number							
	12	13	14	15	16	17	18	19
Cubiceps caeruleus	R	R+H	H+R	H	H	H	H	H
Cubiceps pauciradiatus	R	R	R+H	R+H	H+R	H	H	H
Nomeus gronovii	R	R	R	R+H	R+H	R+H	H	H
Psenes arafurensis	R	R+H	R+H	H	H	H	H	H
Psenes cyanophrys	R	R+H	R+H	H	H	H	H	H
Psenes pellucidus	R	R	R+H	R+H	R+H	R+H	R+H	H
Psenes sio	R	R+H	R+H	R+H	R+H	H+R	H	H
Psenes maculatus	R	R+H	H	H	H	H	H	H

ally the 16th carries small ribs as well as a haemal spine. Pleural ribs are only gradually developed in a posterior direction on juveniles, as is shown for *Cubiceps pauciradiatus* (Fig. 1). The first pair of ribs associated with a haemal spine on vertebra 14 forms relatively early, but the second pair, on vertebra 15, was only beginning to form on a 55-mm specimen, but was fully developed on a 108-mm specimen. For *Nomeus gronovii*, the 16th and 17th vertebrae carry ribs and haemal spines, and occasionally the 15th also.

The problem is somewhat more complicated in *Psenes*. Both *P. arafurensis* and *P. cyanophrys* have pairs of ribs and haemal spines on the 13th and 14th vertebrae, but *P. sio* usually has four or five vertebrae bearing ribs and haemal spines (13th to 16th or 17th) and *P. pellucidus* has five (14th to 18th).

Separation of Vertebrae into Precaudal and Caudal Groups.—If the presence of both ribs and haemal spines on one to five vertebrae were the only complicating feature, it should not be too difficult to separate the precaudal from the caudal group of vertebrae. However, there is a second complicating and obfuscating factor. This results from the backward protrusion of the organs of the abdominal cavity into the space ordinarily occupied by the first several haemal spines. The resultant backward bending and crowding together of the haemal spines and ribs on these vertebrae make them difficult to
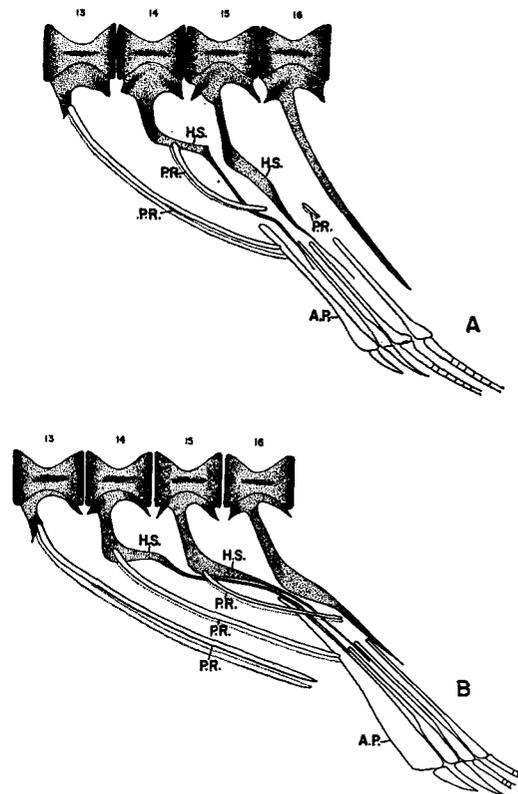
Figure 1. Lateral view of haemal spines and ribs of vertebrae 13 to 16 and interdigitation of haemal spines with the first four anal pterygiophores in *Cubiceps pauciradiatus*. A—55 mm SL; B—108 mm SL. H.S., haemal spine. P.R., pleural rib. A.P., anal pterygiophore.

interpret on radiographs. The anterior pterygiophores supporting the anal fin are also bent posteriad. The anterior-most pterygiophore is usually a large fused bone, which may bend backwards over a half dozen adjacent pterygiophores.

We have found that the haemal spines never precede the anal fin pterygiophores, rather they interdigitate between the pterygiophores until the fin terminates. Most commonly the anterior-most haemal spine interdigitates between the first and second or second and third anal fin pterygiophores, although in *P. cyanophrys* the anterior-most haemal spine interdigitates between the

fourth and fifth or fifth and sixth ptery-giophores.

In specimens in which the abdominal cavity intrudes into the anal fin area, bending haemal spines, ribs and pterygiophores posteriad, and particularly in those in which the heavy anterior pterygiophore bends back over five or six adjacent pterygiophores, the interdigitation of haemal spines between anal fin pterygiophores is obviously interfered with. As a result, we find it difficult to interpret radiographs of larger specimens of nomeids, particularly specimens over 100 mm SL.

For any given species the problem of precaudal vs. caudal vertebrae can be solved if early life history stages are available. When following the sequence of ossification in a nomeid, it can be seen that the haemal spines ossify earlier than either the ribs or the pterygiophores. Because of this, separation of caudal and precaudal vertebrae can be precisely determined on cleared and stained specimens or good radiographs of postflexion larvae or early juveniles. For example, our early juveniles of *Cubiceps capensis* have the unquestioned presence of the first haemal spine on vertebra 13, hence have $12 + 19 = 31$ vertebrae; however, in trying to decipher radiographs of larger juveniles, it is very difficult to tell whether the separation between precaudal vs. caudal vertebrae comes at the 13th, 14th, or 15th vertebra.

Pterygiophores

In discussing the association of fin elements, spines or rays, with their supporting pterygiophores, the element, whether a spine or ray, is, for convenience, termed a ray. Our terminology has been adopted from Eaton (1945) and Potthoff (1975). Except as noted for the anterior-most one or two rays in the dorsal and anal fins, each ray of these fins is in a serial arrangement with a pterygiophore. In addition, each fin ray secondarily articulates in a non-serial arrangement with the pterygiophore imme-

diately posterior to it. In the majority of stromateoid fishes, the anterior-most pterygiophore of both the dorsal and anal fins supports two rays in a non-serial secondary association and is serially associated with the third ray. All succeeding rays have the dual association with pterygiophores as noted above, except that the terminal ray which serially articulates with the terminal pterygiophore, has no secondary association with a "following" pterygiophore. In larger specimens of *Cubiceps caeruleus* and *C. pauciradiatus*, a bony "stay" is associated with the last ray in a secondary association.

When the anterior-most pterygiophore of the dorsal or anal fin carries only one ray in secondary association, this pterygiophore is serially associated with the second ray of the fin, which in turn has a non-serial articulation with the second pterygiophore. All nomeids with two anal spines have only a single spinous ray in a secondary non-serial association with the first pterygiophore, which is a relatively narrow bone without evidence of fusion. In contrast, all nomeids with three anal spines carry two spinous rays in secondary association on the first broad-based pterygiophore which apparently results from the fusion of two pterygiophores during early development. The total number of pterygiophores is identical to the number of pterygiophores in serial association with rays. Thus when the anterior-most pterygiophore carries two rays in secondary association and is serially associated with the third, the number of pterygiophores is two less than the total number of rays. If the anterior-most pterygiophore carries only one ray in secondary association and is serially associated with the second ray, the number of pterygiophores is one less than the total number of rays.

Arrangement of Anal Fin Pterygiophores

Family Nomeidae (Table 3).—The sequential arrangement of anal fin pterygiophores in relation to haemal spines in nomeids is given for 13 species in Table 3. We are

Table 3. Sequential arrangement of anal fin pterygiophores in relation to haemal spines in nomeids (the pterygiophore listed immediately precedes the relevant haemal spine)

Species	Ocean	Size SL (mm)	Number of vertebrae	Anal fin	No. spines on 1st pteryg.*	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	Method of counts
Cubiceps pauciradiatus	P	52.0	13+18=31	II,15	1	–	1	3	4	6	7	9	10	12	14	16	frag	–											C+S†
	P	78.0	13+18=31	II,15	1	–	1	3	4	6	7	9	10	12	14	16	frag	–											C+S
	P	85.0	13+18=31	II,15	1	–	1	2	4	6	7	8	10	11	13	15	16	stay											C+S
(Type C. carinatus)	P	103.0	13+18=31	II,15	1	–	1	2	4	5	7	8	10	12	14	16	frag	–											X-ray†
Cubiceps squamiceps	I	136.0	13+18=31	III,19	2	–	?	5	6	8	9	11	12	14	15	17	18	20	–									X-ray
	I	115.0	13+18=31	III,19	2	–	?	?	7	8	9	10	12	13	15	16	18	20	–									X-ray
	I	135.0	13+18=31	III,19	2	–	?	?	7	8	9	11	13	14	16	17	19	20										X-ray
Cubiceps sp. B	P	17.9	12+19=31	III,20	2	1	3	5	7	9	10	12	14	15	17	19	21	1										X-ray
	P	18.7	12+19=31	III,20	2	1	3	5	7	9	10	12	14	?	?	?	?											X-ray
Cubiceps caeruleus	P	133.0	12+19=31	III,20	2	1	3	5	7	8	10	11	13	14	16	18	19	21	stay									X-ray
	P	46.0	12+19=31	III,20	2	1	3	5	7	8	10	11	13	14	16	18	19	21	stay									C+S
	P	46.0	12+19=31	III,21	2	1	3	5	7	8	10	11	13	15	16	18	20	22	stay									C+S
Cubiceps sp. A	P	14.0	12+19=31	III,22	2	2	4	6	8	10	11	13	14	16	18	20	?	?	–									X-ray
	P	19.5	12+19=31	III,22	2	2	4	6	8	10	12	13	15	17	18	20	22	23	–									X-ray
	I	43.0	12+19=31	III,21	2	2	4	6	8	10	12	13	15	17	18	20	22	–	–									X-ray
Cubiceps capensis	I	210.0	31	II,22	1	?	?	3	5	7	9	11	13	15	17	19	21	23	–									X-ray
	I	141.0	31	II,22	1	?	?	3	5	7	9	10	12	14	16	19	21	23	–									X-ray
	P	15.7	12+19=31	II,23	1	1	2	3	5	7	8	10	12	?	?	?	?	?										X-ray
Psenes arafurensis	P	28.0	12+19=31	III,22	2	1	4	6	8	9	11	12	14	16	17	19	20	23	–									X-ray
	P	117.0	12+19=31	III,23	2	2	4	6	7	9	11	13	14	16	18	19	21	23	24	–								X-ray
	P	23.2	12+19=31	III,24	2	2	4	6	8	10	12	13	15	17	19	20	22	24	25	–								C+S
Psenes cyanophrys	P	48.0	12+19=31	III,25	2	4	6	8	10	12	14	15	17	19	20	22	24	25	26	–								C+S
	P	54.0	12+19=31	III,26	2	5	6	8	10	12	13	15	17	19	20	22	24	26	27	–								C+S
	P	53.0	13+18=31	III,26	2	–	6	8	10	12	14	15	17	18	20	22	24	25	27	–								C+S
Cubiceps gracilis	A	163.0	34	III,20	2	–	?	?	5	6	8	9	11	12	14	15	17	19	20	21	–							X-ray
	A	144.0	33	III,21	2	–	?	?	5	6	8	9	11	12	14	16	17	19	21	22	–							X-ray
	A	131.0	33	III,22	2	–	?	?	5	7	8	10	11	13	15	17	18	20	22	23	–							X-ray
Psenes maculatus	A	20.4	12+23=35	III,21	2	1	3	5	6	8	9	10	12	13	14	15	17	18	19	21	22	–						X-ray
	A	22.8	12+23=35	III,22	2	1	2	5	6	8	9	10	12	13	14	15	17	18	19	21	23	–						C+S
	A	31.2	13+22=35	III,22	2	–	2	4	6	7	9	10	11	13	14	15	17	18	19	21	22	23	–					X-ray
Psenes sio	P	48.0	12+25=37	II,23	1	1	3	4	6	7	9	10	12	13	14	16	17	18	20	21	22	24	–					C+S
	P	22.5	13+25=38	II,23	1	–	1	3	5	6	8	9	10	12	13	14	16	17	19	20	21	23	24	–				C+S
	P	54.5	12+26=38	II,26	2	1	2	3	5	6	8	9	11	12	14	15	16	18	19	20	21	23	25	26	–			X-ray
Nomeus gronovii	A	45.0	15+26=41	II,26	1	–	–	–	3	5	6	8	9	11	12	13	15	16	17	19	21	22	24	26	27	–		C+S
	P	73.0	14+27=41	II,26	1	–	–	2	3	5	6	8	9	10	12	13	15	16	18	19	21	23	24	26	27	–		X-ray
	P	117.0	14+27=41	II,27	1	–	–	2	3	4	6	8	9	10	12	13	14	15	17	18	20	21	23	25	27	28	–	X-ray
Psenes pellucidus	P	35.0	13+28=41	III,29	2	–	1	3	5	7	8	10	11	13	14	15	17	18	20	21	22	23	25	26	28	30	–	X-ray
	P	35.0	13+29=42	III,30	2	–	1	3	5	7	8	10	12	13	14	15	17	18	19	21	22	23	25	26	27	29	31	X-ray
	P	40.0	13+29=42	III,30	2	–	1	3	5	6	8	10	11	13	14	15	17	18	19	21	22	24	25	26	28	29	31	C+S

* Anal fin spines on 1st pterygiophore are in a secondary association

+ C+S, cleared and stained specimen; X-ray, radiograph of specimen

including information on two species that have not been taken in the eastern Pacific: Cubiceps squamiceps and C. gracilis and include Atlantic material for several of the other species. Inasmuch as species of nomeids with higher vertebral counts usually have "longer" anal fins, the species are listed in the table from low to high with regard to counts of vertebrae and for those with equal numbers of vertebrae from low to high with regard to anal fin counts.

No two species have exactly the same arrangement of anal fin pterygiophores in relation to haemal spines, although admittedly some are rather similar, particularly among Cubiceps. Psenes cyanophrys has

Table 4. Sequential arrangement of anal fin pterygiophores in relation to haemal spines in species of the Centrolophid genus *Schedophilus* (the pterygiophore listed immediately precedes the relevant haemal spine)

	Ocean	Size-SL (mm)	Number of vertebrae	Anal fin	No.spines on 1st pteryg.*	Haemal spine on vertebra number														
						11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
S. haedrichi	P	186.0	10+15=25	III,15	2	1	4	6	8	10	12	15	16	stay	-	-				
S. pemarco	A	185.0	10+15=25	III,17	2	1	4	6	9	11	13	15	18	-	-	-				
	A	188.0	10+15=25	II,17	1	1	4	6	9	11	13	15	17	18	-	-				
	A	225.0	10+15=25	III,17	2	1	4	6	9	11	13	16	18	-	-	-				
S. labyrinthicus	P	34.1	10+15=25	III,18	2	1	5	7	9	11	13	15	18	19	-					
	P	75.0	10+15=25	III,18	2	1	4	7	9	11	13	15	17	19	-					
	P	560.0	10+15=25	III,19	2	2	4	7	9	11	13	16	18	20	-					
S. ovalis	A	175.0	10+15=25	III,21	2	1	6	8	11	13	16	18	21	22	-					
	A	191.0	10+15=25	III,22	2	1	5	8	10	12	15	17	20	23	-					
S. medusophagus	A	74.0	10+15=25	II,26	2	1	4	6	9	12	15	18	20	23	26	-				
S. griseolineatus	A	195.0	10+16=26	III,22	2	1	4	6	8	10	12	14	17	19	22	23	-			
	A	200.0	10+16=26	III,21	2	1	3	6	8	10	12	14	17	19	22	-	-			
S. maculatus	P	23.0	11+18=29	III,23	2		1	4	6	8	10	12	13	15	18	20	22	24	-	-
	P	28.0	11+18=29	III,23	2		1	3	6	8	10	12	14	15	17	19	21	23	24	-
	Aust.	85.0	11+18=29	III,23	2		?	4	6	8	10	12	14	16	18	20	21	24	-	-
S. huttoni	P	24.8	12+19=31	II,31	2	-	-	1	3	6	9	11	14	16	18	21	23	26	28	31

* Anal fin spines on 1st pterygiophore are in a secondary association

the most distinctively different pattern; but all species of *Psenes* can be positively identified simply by combining axial skeletal characters with pterygiophore patterns and anal fin counts.

For most species included in this table, the precise positioning of pterygiophores and haemal spines anteriorly was determined by following the ossification of these structures in cleared and stained series of late larvae and early juveniles. For the two species for which only radiographs of larger specimens were available, *C. gracilis* and *C. squamiceps*, it was impossible to determine the precise arrangement of pterygiophores and haemal spines anterior to vertebra 16.

The anal fin pterygiophores begin to ossify on late postflexion larvae. The anterior pterygiophores ossify first, and then ossification proceeds progressively posteriad. In Table 3 a specimen is included for each of three species, *C. capensis*, *C.* sp. A, and *C.* sp. B, on which the posterior pterygiophores were not yet ossified, but the anterior pterygiophores were well formed. The *C. capensis* specimen in particular is an important one inasmuch as it shows the precise arrangement of haemal spines and pterygiophores anteriorly, an arrangement that is obscured in radiographs of the older specimens.

Genus Schedophilus (Family Centrolophidae) (Table 4).—Using the same characters for species of *Schedophilus*, equally interesting results are obtained (Table 4). We have been fortunate in seeing specimens or radiographs of eight species of *Schedophilus*, that currently are recognized as distinct species. This has made it possible for us to identify our several specimens of this genus to species. It also has convinced us of the importance of the vertebral column and associated bones (pterygiophores and predorsal bones) in the taxonomy of this group. As pointed out in the following section, the number and arrangement of predorsal bones is an important taxonomic character in the centrolophid genus *Schedophilus*.

It should be pointed out that there are two pairs of closely related species of *Schedophilus*: *S. haedrichi* (Chirichigno, 1973)

recently described from the Pacific off Chile, is closely related to *S. pemarco*; similarly, *S. labyrinthicus* (McAllister and Randall, 1975), described from the central South Pacific, is closely related to *S. ovalis*. *S. haedrichi* has a lower anal count than *S. pemarco*, but a similar basic arrangement of anal fin pterygiophores in relation to haemal spines. *S. labyrinthicus* also has a lower anal count than *S. ovalis*, but a similar basic arrangement of anal fin pterygiophores vs. haemal spines. The arrangements for *S. maculatus*, *S. huttoni*, *S. medusophagus*, and *S. griseolineatus* are quite different from each other and from the above four species.

Predorsal Bones

The predorsal bones are elongate splinter bones that precede the pterygiophores that support the spines and rays of the dorsal fin: they are assumed to have originated from pterygiophores (Smith and Bailey, 1961). The usual number is three in stromateoid fishes, but some species have only two, and *Icicthys lockingtoni* may have as many as 11 or 12. The arrangement of predorsal bones is fairly stabilized among nomeids, but is quite variable among centrolophids. In point of fact, the number and arrangement of predorsal bones is an important taxonomic character in the centrolophid genus, *Schedophilus*.

The pattern encountered in most nomeids is as follows: the first of the three pre-dorsals precedes the first neural spine, the second predorsal lies between the first and second neural spines, and the third lies between the second and third neural spines, usually accompanied by the first dorsal pterygiophore. In *Cubiceps gracilis* and *C. capensis* the first dorsal pterygiophore interdigitates between the third and fourth neural spines. The first dorsal pterygiophore is a wide (probably fused) bone that carries the anterior two spines of the first dorsal fin in a secondary association in *Cubiceps* and *Psenes*, but is slender and carries only one spine in a secondary association in *Nomeus*.

Hence, the three patterns encountered in nomeids are as follows:

Usual pattern:
  0/0/0 + 2/[1] found in all five species of *Psenes* and in *Cubiceps caeruleus, C. pauciradiatus, C. squamiceps, C.* sp. A and *C.* sp. B.
Variant:
  0/0/0/2/ found in *Cubiceps gracilis* and *C. capensis.*
Variant:
  0/0/0 + 1/ found in *Nomeus gronovii.*

The arrangement of predorsal bones is much more diverse in the centrolophid genus *Schedophilus*. Four patterns were encountered among species within this genus with only one pattern shared by as many as three species:

Pattern number 1:
  0/0/0 + 2/ (similar to usual pattern in nomeids). Observed in *S. pemarco* and *S. haedrichi.*
Pattern number 2:
  0/0 + 0/2 + 1/ observed in *S. maculatus* and *S. griseolineatus.*
Variant of pattern number 2:
  0/0 + 0/1 + 1 + 1/ or 0/0 + 0/1 + 1 + 1 + 1/. Observed in *S. medusophagus.*
Pattern number 3:
  0/0/2 + 1 + 1/ or 0/0/2 + 1 + 1 + 1/. Observed in *S. ovalis* and *S. labyrinthicus.*
Pattern number 4:
  0 + 0/1 + 1 + 1/ or 0 + 0/1 + 1/. Observed in *S. huttoni.*

The pattern observed in *Seriolella violacea* and *S. porosa* was the same as pattern number 1 above, i.e., 0/0/0 + 2/. This same pattern was developed in *Psenopsis anomala* and *Hyperoglyphe bythites*.

Icichthys lockingtoni has an exceptionally high predorsal count for a perciform fish, usually 7 to 11 (occasionally 12), alternatively spaced with neural spines in a one to one relationship. A predorsal precedes the first neural spine and the first pterygiophore supports one dorsal spine in a secondary association.

Among radiographs loaned to us by Dr.

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[1] In this formula, each 0 represents a predorsal, each slant a neural spine, and the numerals indicate the number of spines (or rays) borne by the first and subsequent pterygiophores in a secondary association.

Haedrich is one of *Tubbia tasmanica* in which the arrangement of predorsal bones and the anterior dorsal pterygiophore is similar to *Nomeus*, i.e., 0/0/0 + 1/. *Tubbia* almost certainly is a distinct monotypic genus in the family Centrolophidae, perhaps most closely allied to *Schedophilus*. The predorsal pattern observed in *Centrolophus niger* is 0/0/0/1 + 1/, a variant of the pattern in *Cubiceps gracilis* and *C. capensis*.

Amarsipus has only three predorsal bones, with the first spaced between the first and second neural spines. The following two arrangements have been noted in *Amarsipus*:

Usual: /0/0/0///1 + 1/ or
Occasional: /0/0//0//1 + 1/.

No predorsal bones were observed in *Tetragonurus*, although this character was carefully checked on radiographs and cleared and stained specimens of the three species. The first dorsal pterygiophore carries but a single spine in a secondary association. This pterygiophore usually follows the fifth neural spine in *T. pacificus*, the sixth neural spine in *T. atlanticus*, and seventh or eighth neural spine in *T. cuvieri*.

Caudal Fin Complex

By caudal fin complex we simply refer to the caudal fin and its supporting bones. The stromateoid caudal fin has 17 principal caudal rays and a variable number of secondary caudal rays. The principal rays are divided into two lobes, the superior with nine rays (eight branched), and the inferior with eight rays (seven branched). For the 19 species dealt with by us, the range in number of secondary rays is from seven to 15 per side, with counts of the two sides (dorsal and ventral) either the same or differing usually by only one ray. For any given species the range in secondary ray counts per side is usually three, occasionally four (Table 1 and 5). Secondary ray counts were instrumental in directing our attention to two species of *Cubiceps* (called by us *Cubiceps* sp. A and *Cubiceps* sp. B).

The stromateoid caudal fin has a single ural centrum, two to six hypural bones,[2] two or three epurals, and two pairs of uroneurals. All of these bones can be grouped under the blanket term of ural bones. The ural centrum forms from a single center of ossification; there is no recapitulation of previous fusions of ural centra, such as occurs in the myctophiform family Myctophidae (Moser and Ahlstrom, 1970).

Arrangements of ural bones are usually shared by all members of a family. Members of the family Centrolophidae retain the primitive complement of three superior and three inferior hypurals. In the family Nomeidae, adults have two superior and two inferior hypurals, but during larval development the fusion from 3 + 3 hypural bones is recapitulated. Tetragonurids also have only 2 + 2 hypurals. Although not included in Table 5, we have examined specimens of several species of *Ariomma* and all have the hypurals of each lobe fused into a single plate (1 + 1), as previously reported by Haedrich (1967). Most stromateoid fishes retain the primitive complement of three epurals; the number of epurals is reduced to two in *Tetragonurus* and *Icichthys*. Two pairs of uroneurals were present in all species studied.

The vertebra immediately adjacent to the ural centrum has the neural spine markedly reduced, a condition found in perciform fishes in general. The haemal spine on this vertebra is autogenous, as is also that on the vertebra immediately forward. The presence of two autogenous haemal spines on the two vertebrae adjacent to the ural also is widespread among perciform fishes. However, *Icichthys* normally has a third autogenous haemal spine on the third vertebra anterior to the ural, a condition that is unusual.

Teeth

Dentition is one of the important characters for distinguishing among species and

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[2] In the counts of hypurals, the parhypural is not separately discriminated, but rather it is counted as an inferior hypural.

Table 5. Counts of the stromateoid caudal fin and supporting bones

Families/Species	Principal caudal rays	Secondary caudal rays d	v	Hypurals* Sup. Inf.	Epurals	Uro-neurals	Autogenous haemal spines	Ural centra
Amarsipidae								
Amarsipus carlsbergi	9+8	11-15	11-14	3+3	3	2	2	1
Centrolophidae								
Icichthys lockingtoni	9+8	11-13	10-13	3+3	2-(3)	2	2-3	1
Schedophilus huttoni	9+8	10-12	9-11	3+3	3	2	2	1
Schedophilus labyrinthicus	9+8	11	10	3+3	3	2	2	1
Schedophilus maculatus	9+8	10-11	10	3+3	3	2	2	1
Tetragonuridae								
Tetragonurus atlanticus	9+8	9-10	9-10	2+2	2	2	2	1
Tetragonurus cuvieri	9+8	9-13	9-12	2+2	2	2	2	1
Tetragonurus pacificus	9+8	11	11	2+2	2	2	2	1
Nomeidae								
Nomeus gronovii	9+8	8-9	8-9	2+2	3	2	2	1
Cubiceps caeruleus	9+8	7-10	7-10	2+2	3	2	2	1
Cubiceps capensis	9+8	8-10	8-10	2+2	3	2	2	1
Cubiceps gracilis	9+8	8-10	8-10	2+2	3	2	2	1
Cubiceps pauciradiatus	9+8	8-10	8-10	2+2	3	2	2	1
Cubiceps squamiceps	9+8	8- 9	8- 9	2+2	3	2	2	1
Cubiceps sp. A	9+8	12-13	12	2+2	3	2	2	1
Cubiceps sp. B	9+8	11-12	12	2+2	3	2	2	1
Psenes arafurensis	9+8	7-10	7-10	2+2	3	2	2	1
Psenes cyanophrys	9+8	7- 9	7- 9	2+2	3	2	2	1
Psenes maculatus	9+8	8	8- 9	2+2	3	2	2	1
Psenes pellucidus	9+8	8-10	8-10	2+2	3	2	2	1
Psenes sio	9+8	7-10	8-10	2+2	3	2	2	1

* Parhypural counted as an hypural

genera of stromateoid fishes (Haedrich, 1972). In Table 6 we are characterizing the kinds of teeth developed on the upper and lower jaws, as well as those on the vomer, palatine, and tongue (glossohyal) for 12 of the eastern Pacific species. The characteristic teeth form during the juvenile period, sometimes over a considerable size range.

The teeth of the upper jaw (premaxillary teeth) are uniserial, conical, tapering, often moderately recurved and usually of several sizes. Although upper jaw teeth do differ somewhat among stromateoid fishes, differences are negligible when compared to the kinds of teeth on other jaw bones.

There are basically two types of teeth in the lower jaw. Many stromateoid fishes have dentary teeth that are similar to upper jaw teeth, i.e., they are conical, tapering, usually recurved and often of several sizes. However, the three species of Tetragonurus and four of the five species of Psenes have blade-like dentary teeth. These teeth are of uniform width over most of the blade, then abruptly taper to a point posteriorly. The size of specimens on which these blade-like teeth develop is discussed below for P. sio.

Teeth are developed on the vomer in all species included in Table 6 except Icichthys lockingtoni. However, for the five species of Psenes and for Amarsipus and Nomeus, teeth are limited to a patch on the head of the vomer, whereas teeth are developed on the blade of the vomer in Cubiceps and Tetragonurus. These teeth on the blade of the vomer can be used to separate Cubiceps caeruleus from the following species of Cubiceps. In C. caeruleus the teeth on the blade are conical and occur in a single, longitudinal row, whereas in C. pauciradiatus and C. capensis, the teeth are knob-like and occur in a broad patch on the blade. Tongue teeth are similar to vomerine teeth in these three species of Cubiceps, occurring

Table 6.   Dentition of juveniles and adults of pelagic stromateoid fishes

Species	Premaxillary teeth		Dentary teeth		Palatine	Vomer	Tongue (glossohyal)
Amarsipus carlsbergi	uniserial	conical	uniserial	conical	absent	small patch on head of vomer	absent
Icichthys lockingtoni	uniserial	conical	uniserial	conical	absent	absent	absent
Tetragonurus cuvieri	uniserial	conical	uniserial	blade-like larger than upper jaw teeth	single row	longitudinal row on blade	present
Nomeus gronovii	uniserial	conical	uniserial	conical	single row	short row near head of vomer	absent
Cubiceps caeruleus	uniserial fine, recurved	conical	uniserial	conical	single row	single row on blade	single row
Cubiceps capensis	uniserial	conical	uniserial	conical	single row	knobby patches on blade	knobby patch
Cubiceps pauciradiatus	uniserial	conical	uniserial	conical	single row	broad patch	oval knobby patch
Psenes arafurensis	uniserial	conical	uniserial	mostly blade-like	single row	patch on head of vomer	absent
Psenes cyanophrys	uniserial	conical	uniserial	conical	single row	same	absent
Psenes maculatus	uniserial	conical	uniserial	mostly blade-like	single row	same	absent
Psenes pellucidus	uniserial	conical	uniserial	mostly blade-like	single row	same	absent
Psenes sio	uniserial	conical	uniserial	mostly blade-like	single row	same	absent

in a single row in *C. caeruleus* and in knobby patches in the other two species. Tongue teeth are absent in *Psenes*, *Nomeus*, *Icichthys*, and *Amarsipus*. Palatine teeth are developed in a single row per side in the three genera of nomeids and in *Tetragonurus*, but are absent in *Icichthys* and *Amarsipus*.

The striking difference between the dentary teeth and those on the premaxillary of *Tetragonurus* and most *Psenes* are not to be seen in larvae, but form during the early juvenile period. The sequence of formation can be exemplified by using *Psenes sio* as an example. None of the blade-like teeth in the lower jaw are present on a 9.0-mm larva which has only four premaxillary and three dentary teeth per side, all small. A 13.4-mm specimen (an early juvenile) has eight premaxillary and seven dentary teeth per side, but only one of the latter is broad-based and knife-like. However, the difference between the size and shape of teeth in the two jaws is marked in the 22.5-mm juvenile. This specimen has 10 premaxillary teeth and 15 dentary teeth per side. The teeth in the upper jaw are rather small, narrow, pointed, recurved posteriorly, and irregularly spaced, although uniserial. The teeth in the lower jaw, also aligned uniserially, are markedly larger, especially the sixth to the 11th, and these are blade-like, much as in *Tetragonurus*. The anterior dentary teeth are less wide and more tapered, with one or two teeth per side that could be classed as canines. The posterior dentary teeth are shorter than the teeth in the middle but equally wide-based and blade-like.

Similary, the development of glossohyal teeth on the tongue was followed for *Cubiceps pauciradiatus*. In a 30-mm specimen, a single sharp tooth is present on the posterior end of the glossohyal. Teeth are added in a single series anteriorly until about 55 mm. Knob-like teeth are then added laterally so that by about 65 mm the patch is three teeth wide, and by 100 mm, the patch is 10 to 12 teeth wide and fairly large. A similar development is taking place on the blade of the vomer, where a large oval patch of knob-like teeth is developed by 100 mm.

Eggs of Pelagic Stromateoid Fishes

Our studies of early life history stages of pelagic stromateoid fishes primarily have been concerned with their larvae and juveniles, not their eggs. However, eggs are definitely known for six species and tenta-

Table 7. Localities of capture and sizes of eggs of pelagic stromateoid fishes

Species	Station	Latitude	Longitude	Date	No. eggs	Egg diameter Ave. (mm)	Egg diameter Range (mm)	Oil globule diameter Ave. (mm)	Oil globule diameter Range (mm)
Centrolophidae									
Icichthys lockingtoni	G6401-76.63	34°45.0'N	121°54.0'W	I.22.64	28	1.69	1.60-1.78	0.39	0.36-0.40
" "	G6401-76.70	34°32.0'N	122°21.0'W	I.21.64	20	1.68	1.58-1.78	0.37	0.30-0.40
" "	G6401-79.74	33°48.5'N	122°13.0'W	I.17.64	15	1.67	1.52-1.80	0.38	0.30-0.40
" "	G6401-81.67	33°46.5'N	121°30.5'W	I.14.64	24	1.67	1.56-1.76	0.40	0.34-0.44
Tetragonuridae									
Tetragonurus cuvieri	Norpac 21	42°18.0'N	135°19.0'W	VIII.18.55	10	1.17	1.10-1.24	ca.0.25	-
" "	" 41	38°39.0'N	142°59.0'W	VIII.16.55	3	1.18	1.16-1.22	ca.0.25	-
" "	" 43	38°35.0'N	149°59.0'W	VIII.25.55	4	1.19	1.12-1.26	ca.0.25	-
" "	" 67	33°04.0'N	128°45.0'W	IX.3.55	25	1.21	1.12-1.28	ca.0.25	-
" "	" 96	29°41.0'N	120°43.5'W	IX.16.55	5	1.17	1.12-1.22	ca.0.25	-
" "	" 110	28°56.0'N	117°38.0'W	IX.20.55	25	1.17	1.10-1.27	ca.0.25	-
" "	C5504-103.70	29°44.5'N	119°05.0'W	IV.21.55	18	1.15	1.12-1.18	0.28	0.25-0.30
" "	C5504-103.80	29°26.0'N	119°44.5'W	IV.20.55	10	1.19	1.12-1.26	0.28	0.25-0.30
Nomeidae									
Cubiceps pauciradiatus	ETP 12.071	05°47.5'N	104°58.0'W	II.24.67	9	0.75	0.74-0.78	0.19	0.16-0.20
" "	ETP 12.077	04°06.0'N	105°00.0'W	II.25.67	37	0.75	0.70-0.78	0.18	0.16-0.20
" "	ETP 12.079	03°31.2'N	105°02.0'W	II.25.67	38	0.75	0.70-0.80	0.19	0.16-0.20
" "	ETP 12.206	03°40.0'S	112°07.0'W	III.12.67	6	0.76	0.74-0.80	0.18	0.16-0.18
" "	ETP 45.035	14°11.2'N	119°03.8'W	VIII.10.67	10	0.74	0.72-0.76	0.17	0.16-0.18
" "	ETP 45.313	04°55.0'N	111°53.5'W	IX.4.67	8	0.75	0.72-0.78	0.17	0.16-0.18
" "	ETP 45.343	13°56.3'N	110°34.0'W	IX.8.67	33	0.73	0.70-0.76	0.16	0.14-0.18
" "	ETP 45.344	14°12.5'N	110°23.0'W	IX.8.67	6	0.74	0.72-0.76	0.18	0.16-0.20
Cubiceps caeruleus	ETP 60.068	01°29.0'N	118°43.0'W	XII.29.67	20	0.91	0.84-0.92	0.21	0.16-0.22
" "	ETP 60.090	02°35.0'S	118°45.0'W	XII.31.67	5	0.90	0.88-0.92	0.20	0.20-0.22
" "	ETP 60.092	02°58.0'S	118°46.0'W	XII.31.67	14	0.92	0.90-0.94	0.21	0.16-0.22
" "	ETP 60.095	02°20.0'S	111°48.0'W	I.2.68	4	0.93	0.88-0.96	0.21	0.20-0.22
" "	ETP 75.060	01°25.0'N	118°58.0'W	II.25.68	18	0.91	0.88-0.94	0.20	0.20-0.22
Psenes sp.	ETP 11.148	11°24.5'S	118°56.2'W	II.11.67	10	1.00	0.98-1.04	0.23	0.22-0.24
(prob. arafurensis)	ETP 11.084	02°27.0'N	119°00.5'W	II.5.67	1	1.04	-	0.26	-
" "	ETP 45.090	00°57.2'N	119°04.5'W	VIII.16.67	4	0.98	0.96-0.98	0.24	0.22-0.24
Psenes sio	ETP 13.322	11°47.0'N	95°08.0'W	III.18.67	15	1.10	1.08-1.12	0.24	0.20-0.26
" "	ETP 46.132	15°38.0'N	98°01.0'W	IX.6.67	4	1.06	1.06-1.08	0.23	0.22-0.24
" "	ETP 46.135	12°40.0'N	92°03.0'W	IX.15.67	10	1.07	1.02-1.12	0.24	0.22-0.24
" "	ETP 46.137	11°48.0'N	92°03.0'W	IX.15.67	5	1.09	1.08-1.10	0.24	0.24-0.26
" "	ETP 46.141	10°19.2'N	91°54.0'W	IX.16.67	5	1.08	1.04-1.14	0.24	0.22-0.24
Psenes sp.	ETP 47.065	01°46.0'S	81°58.0'W	VIII.6.67	21	1.21	1.14-1.26	0.25	0.24-0.26
(prob.pellucidus)	ETP 47.173	07°54.8'S	85°06.0'W	VIII.22.67	15	1.22	1.14-1.28	0.26	0.24-0.28
	ETP 60.084	01°29.0'S	118°40.0'W	XII.30.67	1	1.22	-	0.30	-

tively identified for two additional species. The former include *Icichthys lockingtoni*, *Tetragonurus cuvieri*, *T. atlanticus*, *Psenes sio*, *Cubiceps pauciradiatus*, and *C. caeruleus*; eggs tentatively identified are those of *P. arafurensis* and *P. pellucidus* (Table 7). The eggs of five species are illustrated in Figure 2.

The eggs have a number of characters in common. They are pelagic, separate and round. The size range of egg diameters of the above eight species is from 0.70 to 1.80 mm. The outer shell of all species is unsculptured, although the shell usually is colored. The yolk is unsegmented and the perivitelline space is moderate. All eight species have a single oil globule. In middle and late stage eggs, pigment forms on the embryo and on the oil globule, but usually not on the yolk. The oil globule is positioned in the posterior part of the yolk-sac in late stage embryos and yolk-sac larvae.
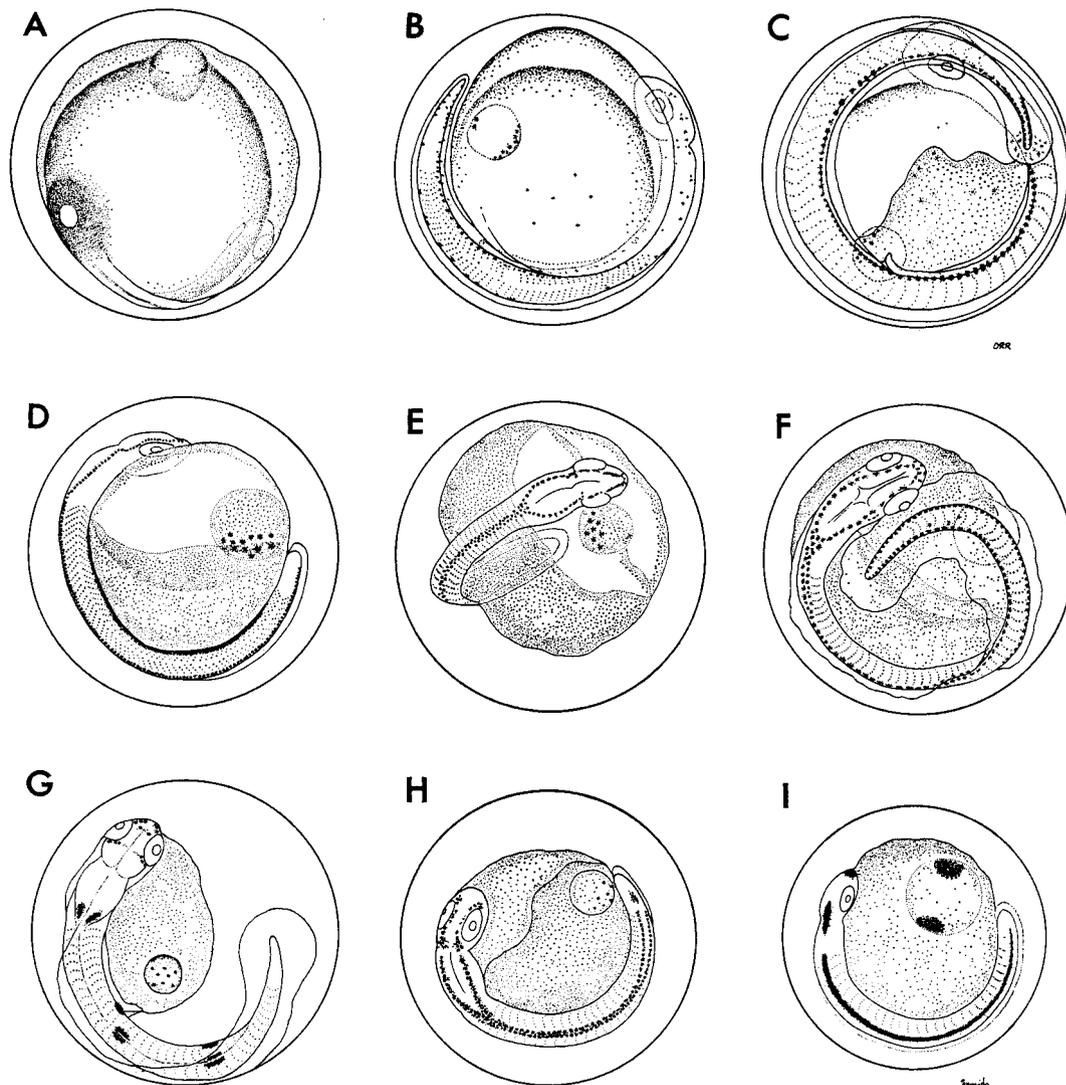
Figure 2. A-C, Eggs of *Icichthys lockingtoni*: A, early stage; B, middle stage; C, late stage. D-F, *Tetragonurus cuvieri*: D, lateral view of middle stage; E, dorsal view of middle stage; F, late stage, 1.24-mm egg diameter. G, *Psenes sio*, late stage, 1.08-mm egg diameter; H, *Psenes arafurensis*, middle stage, 0.98-mm egg diameter; I, *Cubiceps pauciradiatus*, middle stage, 0.76-mm egg diameter.

Eggs of *Icichthys lockingtoni*
Figure 2, A-C

Icichthys eggs are among the largest of pelagic stromateoid eggs in the eastern Pacific, ranging in diameter from 1.52 to 1.80 mm and in average diameter per sample between 1.67 and 1.69 mm. The oil globule also is large, ranging between 0.30 to 0.44 mm in diameter with an average diameter of 0.37 to 0.40 mm. The egg shell is not colored.

Eyes are outlined before blastopore closure. Soon after blastopore closure, anterior

somites are formed. Pigment develops soon thereafter on middle stage eggs. Dorsal pigment on the embryo is scattered, rather than arranged in a double line, as in *Tetragonurus*, and although distributed on the back from the head to near the tip of tail, it is also distributed on the sides of the embryo and out over the yolk mass. Pigment is also present on the under side of the oil globule. In late stage eggs, embryonic pigment becomes concentrated along the ventral body margin from the head to the tip of tail—distributed above the digestive tract until its terminus and then along the ventral midline of the tail; dorsal pigment is scattered and sparse, but distributed along the length of the back. Pigment on the yolk becomes inconspicuous, except the patch under the oil globule which is retained.

The late stage embryo is thin bodied with a high myomere count (58 to 61), a gut length of over 50% body length, and a wide fin fold. This stage is similar to that of *Tetragonurus cuvieri* but differs in the distribution of dorsal pigment and in its higher myomere count (58 to 61 vs. 51 to 54).

Eggs of *Tetragonurus cuvieri*
Figure 2, D-F

Based on eggs from eight samples, the range in diameters of *Tetragonurus cuvieri* eggs is from 1.10 to 1.28 mm with an average diameter per sample of 1.15 to 1.21 mm; the oil globule is between 0.25 to 0.30 mm in diameter (often amorphous and hard to measure). The egg shell is golden, with a touch of pink.

Eyes form before blastophore closure. Myomeres are evident on early middle-stage eggs and pigment forms on the developing embryo soon thereafter. Initial pigment is scattered on the head but is continuous along the length of the back in a double line. By the time the tail begins to separate from the yolk (early late-stage eggs), a continuous line of ventral pigment is evident above the digestive tract and continues along the ventral margin of the free tail (Fig. 2D). Pig-

ment on the head outlines the brain lobes and extends forward to the snout (Fig. 2E, F). During most of the late-stage period, there are continuous lines of dorsal and ventral pigment from head to tail, but before hatching most of the dorsal pigment begins to migrate ventrally except that on the very posterior part of the tail. In some late-stage embryos, there remains a concentration of pigment on the snout.

Egg of *Tetragonurus atlanticus*
(not illustrated)

A late-stage egg, unmistakably of *Tetragonurus*, was taken at EASTROPAC 11.134 located at 07°02.4'S, 118°59.0'W (February 9, 1967). The embryo has the characteristic heavy ventral pigment extending from just behind the head to the tip of the notochord, situated above the digestive tract anterior to the anus and along the ventral midline of the tail posterior to the anus. Dorsal pigment consists of a short, posterior streak ending before the terminal myomere. The only pigment remaining on the head is a patch at the snout. The egg is 1.10 mm in diameter, with a 0.24-mm diameter oil globule. Of the two tropical species of *Tetragonurus*, *T. atlanticus*, and *T. pacificus*, this egg obviously belongs to the former. It has the basic pigment pattern that is seen on small, preflexion larvae of *T. atlanticus*. The egg shell is colored like those of *T. cuvieri*.

Eggs of *Cubiceps pauciradiatus*
Figure 2, I

Eggs of *C. pauciradiatus* were observed in a number of samples. Measurements were made on eggs from eight samples. This is the smallest stromateoid egg encountered. Range in egg diameter is from 0.70 to 0.80 mm, with an average diameter of 0.75 mm; the oil globule is smaller than in other stromateoid eggs, ranging in diameter from 0.14 to 0.20 mm, with an average of 0.18 mm. The outer shell is lightly colored a pinkish tan.

The late-stage embryo is conspicuously

pigmented. The principal pigment is a wide, dark band of pigment extending along the back from behind the head to near the tip of the notochord. Initially, this is a double, separated line of pigment down the back, but pigment soon fills in between the lines. The most characteristic pigment on the late-stage embryo, however, is the patch that forms on the tip of the snout. This snout pigment is a character that simplifies recognition (identification) of these eggs. Between the snout and the nape there is a median group of pigment spots on the head. The oil globule is characteristically pigmented, having two opposing patches of pigment. In most stromateoid eggs, the dorsal pigment is rearranged on late-stage embryos, often approaching the pattern to be found on yolk-sac larvae. Such rearrangement of pigment apparently does not occur in late-stage eggs of *C. pauciradiatus*, as we observed no eggs in which any pigment had moved ventrally. A similar situation is noted for *C. caeruleus*, which retains the dorsal pattern of pigmentation without rearrangement on late-stage eggs.

Eggs of *Cubiceps caeruleus*
(not illustrated)

Eggs of *C. caeruleus* are 0.84 to 0.96 mm in diameter (average 0.91) with an oil globule 0.16 to 0.22 mm in diameter (average 0.20). The egg shell is light tan in color.

This egg is larger than that of *C. pauciradiatus* and the embryo is somewhat differently pigmented. Both have a band of pigment extending along the length of the back, but head pigment is quite differently arranged. Pigment is lacking on the center of the head in *C. caeruleus* but instead outlines the brain lobes and extends forward between the margin of the eyes to the snout. It is quite similar to head pigment on late-stage embryos of *Tetragonurus*. Even on late-stage eggs, the dorsal pigment remains as a solid band without rearrangement and no ventral pigment was observed; hence, in these characters, eggs of *Cubiceps caeruleus*

parallel the pigment pattern observed on eggs of *C. pauciradiatus*. The oil globule is pigmented on its outer margin, away from the embryo.

Eggs of *Psenes sio*
Figure 2, G

Eggs of this species were seen in a number of samples from the eastern tropical Pacific. Range in egg size, based on five samples, is 1.02 to 1.14 mm, and average diameter is 1.09 mm; oil globules range between 0.20 to 0.26 mm in diameter, averaging 0.24 mm. The egg shell has a pinkish straw color.

On an early-stage egg, just prior to blastopore closure, the embryo is outlined as a rod, without eyes, separation of somites, or pigmentation. On an early middle-stage egg eyes are outlined, about 12 somites can be counted in back of the head, and pigment is present on the head and in a double row dorsally on the body. By the end of this stage, the pigment moves ventrally but is still evident along the length of the embryo. Pigment also is present completely around the oil globule. On late-stage embryos, pigment is sparse on top of the head but outlines the brain lobes posteriorly and is heavy on the underside of the head. Body pigment becomes concentrated into three areas: first, a lateral pigment dash and a corresponding ventral patch above the gut a few somites behind the head; second, a ventral patch above the gut near its termination, and an associated dorsal patch above and slightly posterior to the anus; third, midway along the tail, there are opposing dorsal and ventral pigment patches. The pigment on late-stage embryos corresponds to that found on yolk-sac larvae.

Eggs of *Psenes pellucidus*
(Tentative Identification)
(not illustrated)

Eggs tentatively identified as *P. pellucidus* are strikingly similar to those of *P. sio*, but larger in size and with more heavily pigmented shells. Egg diameters range from

1.14 to 1.28 mm (average 1.21 mm); oil globule diameters range from 0.24 to 0.28 mm (average 0.26 mm). The outer egg shell is brownish with a tinge of rose. The pigment pattern on late-stage embryos is similar to that described above for *P. sio*, including heavy pigment on the underside of the head, on the snout, and on the back of the head, as well as its concentrations into three areas along the body. A late-stage egg, taken offshore, has added an additional pigment area on the posterior part of the tail, but otherwise, is similarly pigmented. The number of somites (ca. 40) on the embryo is too high for *P. arafurensis* or *P. cyanophrys*. These larger-sized *Psenes* eggs were taken only in the three samples listed in Table 7, in contrast to *Psenes sio* eggs which were observed in more than 50 samples. The heavy pigment under the head on late-stage embryos undoubtedly is the source of the striking pigment patch that develops under the head on only the preflexion larvae of *P. sio* and *P. pellucidus*. This head pigment was one of the prime considerations in the tentative assignment of these eggs to *P. pellucidus*.

Eggs of *Psenes arafurensis*
(Tentative Identification)
Figure 2, H

Nomeid eggs, 0.96 to 1.04 mm in diameter, with an oil globule 0.22 to 0.24 mm in diameter were taken in several offshore stations. The pigment pattern described below is based on the egg farthest along in development, taken at station ETP 11.084. On the head region of the embryo, pigment outlines the brain lobes and extends forward to the snout—the usual pattern in stromateoid eggs. On the back, a band of pigment extends along the trunk and on the forward portion of the tail; behind this on the tail the pigment is clustered into two dorsal patches with some lateral and ventral melanophores below each patch.

Just behind the head the pigment is moving laterally into the area where the anterior-

most of the patches of body pigment are present on late-stage eggs of *P. sio* and *P. pellucidus*. Ventral pigment also is present above the gut near its termination, the area of the second body pigment patch on larvae of the above two species. Hence, the pigment arrangement on late-stage eggs is intermediate between that found on eggs of *Cubiceps* in which the dorsal pigment remains intact during embryonic development prior to hatching, and in *P. sio*, in which embryonic pigment rearranges before hatching to the pattern encountered on early preflexion-stage larvae. The eggs are only lightly colored a pale straw color. The oil globule has melanophores on its outer margin. The egg illustrated is not as far advanced as the late-stage egg described above, and only the posterior-most patch is separated from the dorsal band on the body of the embryo. The eggs were obtained in an area where larvae and juveniles of *P. arafurensis* also were obtained. We are reasonably certain that the eggs are those of *P. arafurensis*.

Family AMARSIPIDAE

This is a monotypic family; *Amarsipus carlsbergi* is the only stromateoid fish that lacks toothed pharyngeal sacs. The species has a mixture of primitive and more specialized characters. The supporting bones of the caudal fin include three superior hypurals and three inferior hypurals (parahypural included) and usually three epurals; this is the primitive complement for perciform fishes and is a character shared with centrolophids, but not with other stromateoid fishes (Table 5). However, the more advanced number of only six branchiostegal rays is present, whereas centrolophids still retain seven.

Genus *Amarsipus*

The slender body of juveniles is compressed and flabby with translucent areas along the body adjacent to the dorsal and anal fins. The two dorsal fins are barely separated; the spines in the first dorsal are
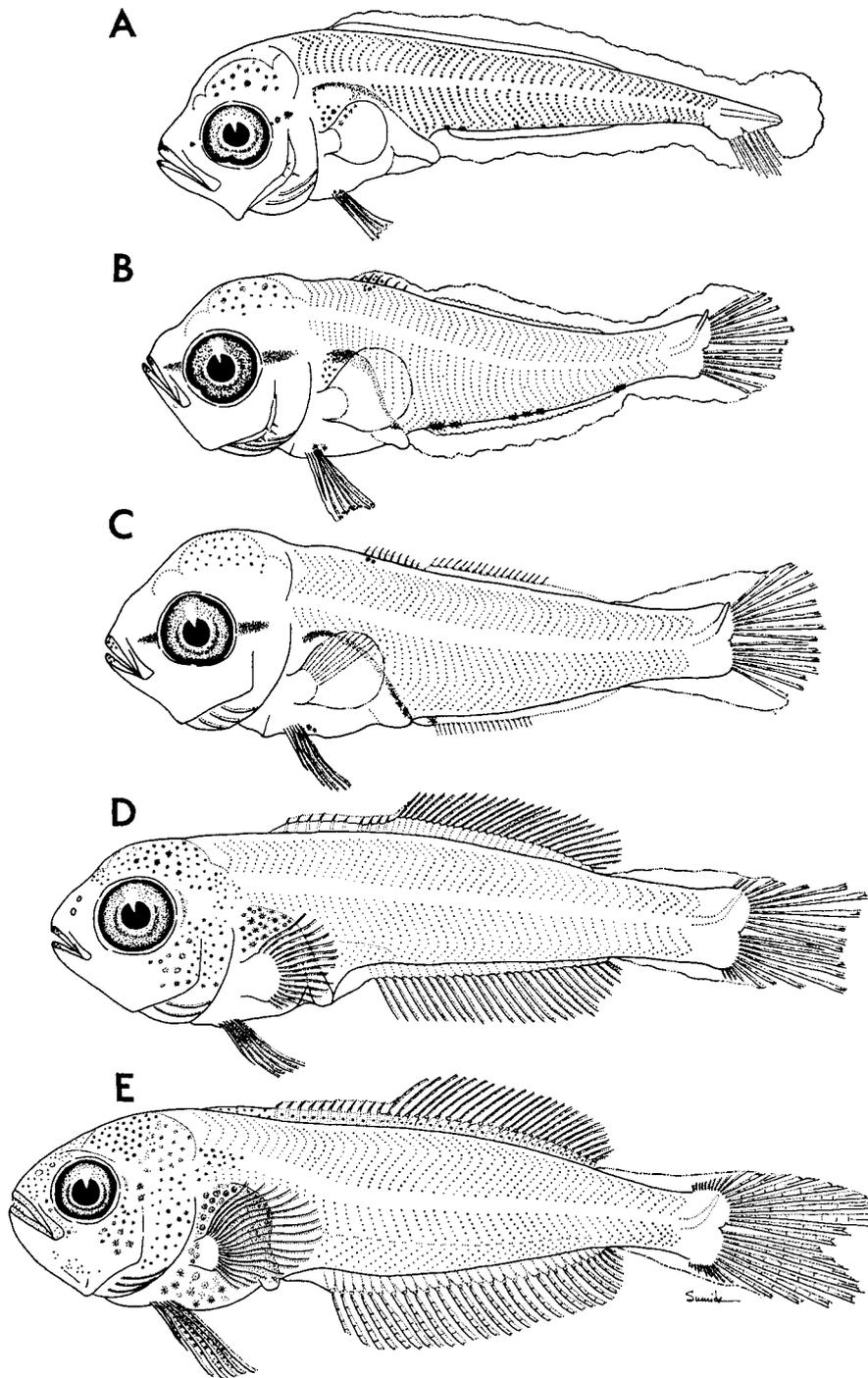
Figure 3. Developmental stages of *Amarsipus carlsbergi* (Amarsipidae). A—5.7-mm early flexion larva; B—4.6-mm late flexion larva; C—6.0-mm late flexion larva; D—11.5-mm postflexion larva; E—16.7-mm postflexion larva.
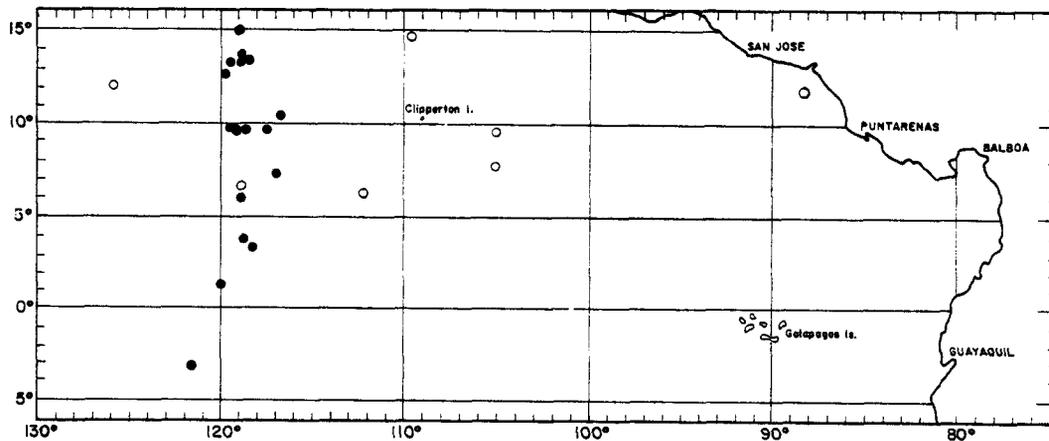
Figure 4. Occurrences of *Amarsipus carlsbergi* larvae (open circles) and juveniles (closed circles) in the eastern tropical Pacific.

quite short but the rays in the second dorsal are relatively long. The arrangement of spines and rays in this fin most closely resembles that of *Tetragonurus*. However, the number of soft rays in the second dorsal and anal fin of *Amarsipus* is at least twice the number found in *Tetragonurus*. The caudal peduncle is broad and relatively long. The pelvic fins are jugular in juveniles, but on early stage larvae they form behind the pectoral base. The vertebral count of (45) 46 to 48, is in the range of that of *Tetragonurus*, lower than for *Icichthys*, but higher than for other stromateoid fishes. The dorsal fin is farther back on the body than in most stromateoids—the origin of the fin follows the 6th neural spine. The first dorsal pterygiophore supports a single spine in a secondary association, a character shared with several centrolophids (*Centrolophus niger, Schedophilus medusophagus, S. huttoni*) and with *Nomeus gronovii*, but still is unusual, inasmuch as in other stromateoid fishes the first dorsal pterygiophore supports two spines in a secondary association. The arrangement of the three predorsal bones in relation to neural spines is unique among stromateoid fishes (refer to section titled "Predorsal Bones"). The largest known specimen, 124 mm, is probably still a juve-

nile. Hence the size attained by adults is not known.

Amarsipus carlsbergi Haedrich, 1969
Figure 3

Literature.—Haedrich (1969), in the original description of the monotypic family Amarsipidae, recorded three specimens of the new species, *Amarsipus carlsbergi* from the eastern Pacific. Ahlstrom (1972) reported catch localities of seven specimens from EASTROPAC cruises, ranging in length from 7.2 to 30.0 mm.

Material.—Sixteen collections of juveniles and eight collections of larvae were studied. The biggest specimen (124 mm) is the largest yet reported; however, it appears to us to be a juvenile.

Distribution.—*A. carlsbergi* was found mostly offshore in the eastern Pacific between 15°N and 5°S (Fig. 4). This species was also found near Hawaii but not to the north (Fig. 5). The species is rare in plankton collections but large midwater trawls towed near the surface collect juveniles frequently.

Distinguishing Characters.—JUVENILES. *A. carlsbergi* is unique among stromateoids in the combination of its vertebral count with the dorsal and anal fin meristics (Table 1).

LARVAE. The pelvic fins are precocious in development as is also characteristic of
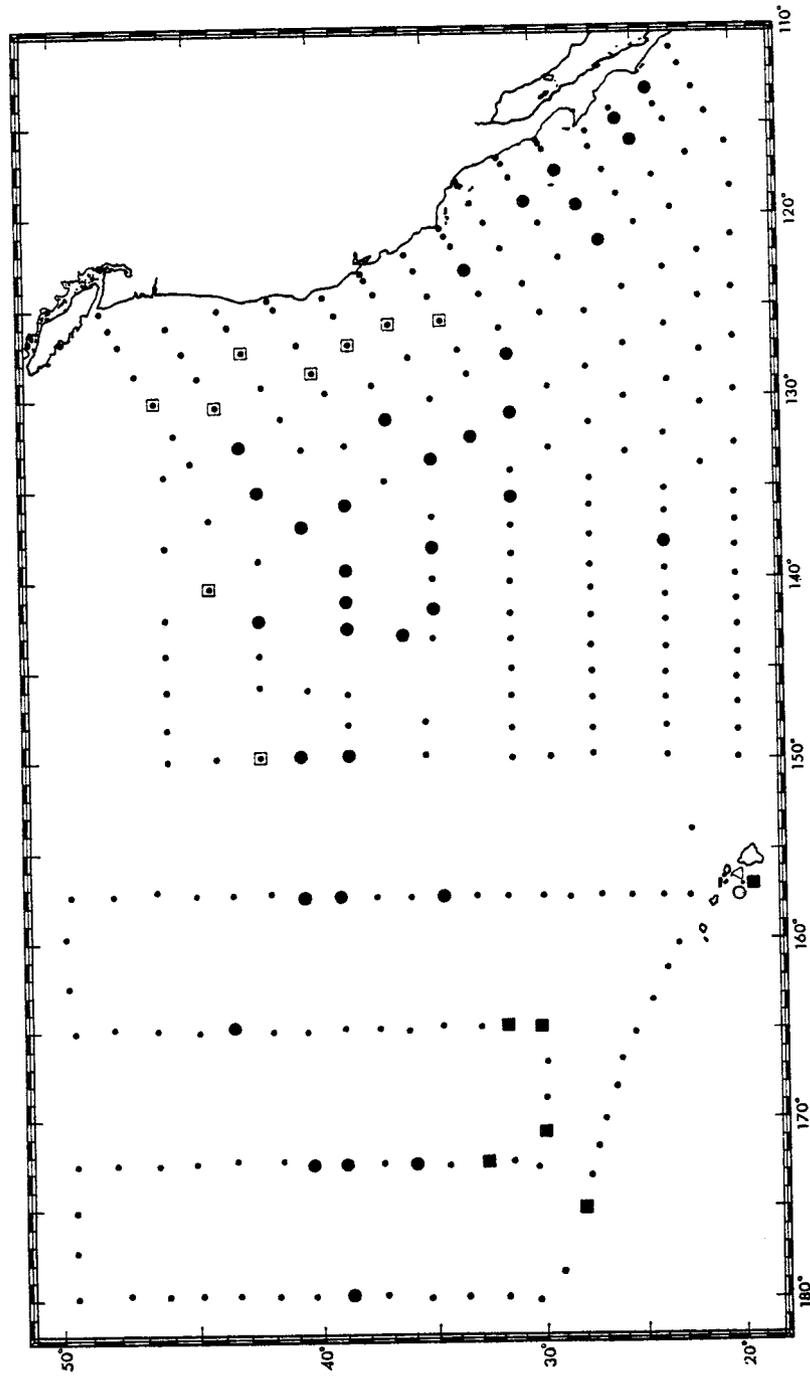
Figure 5. Location of collections of *Amarsipus carlsbergi* (open triangle), *Tetragonurus atlanticus* (closed squares), *T. cuvieri* (closed circles), and *T. pacificus* (open circle) in the NORPAC Expedition, August-September 1955. Small dots indicate occupied stations.

Psenes and probably *Nomeus*. Small larvae have a bar of pigment through the eye like that developed in *Cubiceps caeruleus*, *Tetragonurus atlanticus*, and less strikingly in *Icichthys lockingtoni* and *T. cuvieri*. Myomere counts will distinguish *A. carlsbergi* from *C. caeruleus* and *I. lockingtoni*, and the shorter gut and the longer second dorsal and anal fins will separate it from *Tetragonurus*. Pigmentation on *Amarsipus* larvae is very sparse, primarily being confined to the head and abdominal region.

Meristics.—Vertebrae 16 to 18 + 29 to 31 = 46 to 48 (average 46.6); first dorsal X to XII (average 11.0); second dorsal 23 to 27 (average 24.8); anal 29 to 32 (average 30.3); principal caudal rays 9 + 8; secondary caudal rays 11 to 15 dorsal + 11 to 14 ventral (average 12.5 + 12.4).

Meristics of 20 specimens from about 3°S to about 13°N are given in Table 8. No latitudinal variation of any count is evident.

Morphometrics.—*Amarsipus* is a relatively slender-bodied stromateoid fish, with its greatest body depth at the pectoral and tapering gradually toward the caudal peduncle. Morphometric data for a size series are presented in Table 9, and body proportions are summarized in Table 10. The head length (HL) is short relative to body length, averaging about 25% of SL (22 to 28%) on postflexion larvae and early juveniles. Eye diameter is about 40% of HL in postflexion specimens (38 to 41%). The snout, which remains bluntly pointed during larval development is 21 to 29% of HL. The body becomes more slender during development, body depth decreasing from ca. 33% of SL at flexion to ca. 23% of SL in 28- to 32-mm specimens.

The position of the pelvic fins changes markedly with growth. In the three smaller specimens, the snout to pelvic fin distance is 28% of SL, whereas, in other specimens it ranges between 19 to 21% of SL. The pelvic fins are always forward of the dorsal fin after its formation; the snout to dorsal fin origin (Sn-D) is 30 to 35% of SL as compared to 19 to 21% of SL for the pelvic fin on postflexion larvae and early juveniles. The origin of the anal fin precedes the origin of the second dorsal fin. The snout to anal fin origin (Sn-A) is 40 to 50% of SL. Despite the considerable length of the anal fin, *Amarsipus* has a well-marked caudal peduncle, intermediate in relative length between the strikingly long caudal peduncle of *Tetragonurus* and the shorter caudal peduncle on *Icichthys*.

Ossification.—Meristics from a series of eight specimens, 4.5 to 32.0 mm, are presented in Table 11. Only one specimen 21.4 mm long was cleared and stained with remaining ones kept intact for the limited collection of small-sized larvae. Although the series consists of only a few specimens, it is possible to trace the sequence of fin formation.

The pelvic fins are the first to develop rays, being formed on an early flexion specimen (Fig. 3A). *Amarsipus* shares this character of early forming pelvic fins with larvae of *Psenes* and probably *Nomeus*. Principal caudal rays are next to ossify with 7 + 6 rays present at 4.6 mm (Fig. 3B), 8 + 7 rays on 6.0-mm specimen, and the full complement of 9 + 8 principal rays on the 11.5-mm specimen. By late flexion (4.6 mm), spines are forming in the first dorsal, rays are forming in the pectoral fin, and the anlagen of the second dorsal and anal fins are present. By 6.0 mm (Fig. 3C), the first dorsal is complete and rays are ossified in the second dorsal and anal fins. No specimens are available between 6.0 and 11.5 mm; in the latter specimen (Fig. 3D), all fins are complete except for secondary caudal rays which are not fully developed until about 21.4 mm.

An account of the sequence of vertebral ossification cannot be given due to a lack of cleared and stained material. The complete set of 2 + 4 branchiostegal rays are present at 4.5 mm in addition to eight gill rakers and a few small preopercular spines. The weak, inconspicuous preopercular spines are

Table 8. Meristics of 20 juveniles of *Amarsipus carlsbergi* selected from over its distributional range in the eastern Pacific (counts made from radiographs)

Station	Location Lat.	Location Long.	Date	Size-SL (mm)	Vertebrae	1st Dorsal fin	2nd Dorsal fin	Anal fin	Caudal fin
Jord. 57.013	13°27'N	119°01'W	XI.9.70	79.8	16+31=47	X	24	31	12-17-13
"	"	"	"	51.2	16+31=47	XII	24	32	13-17-13
"	"	"	"	46.0	16+30=46	XII	26	31	13-17-12
"	"	"	"	42.5	16+30=46	XI	25	30	12-17-12
Jord. 57.012	13°16'N	119°23'W	XI.8.70	124.0	17+29=46	XI	24	29	13-17-13
"	"	"	"	43.0		XI	27	30	12-17-12
"	"	"	"	29.0	16+31=47	XII	24	31	11-17-12
Jord. 57.018	13°16'N	118°57'W	XI.9.70	23.0	17+30=47	X	26	30	12-17-11
Jord. 57.106	13°13'N	120°12'W	XI.7.70	50.8	16+30=46	XI	24	30	13-17-13
Jord. 60.160	10°57'N	116°48.5'W	IV.9.71	43.0	16+31=47	XI	25	31	12-17-11
"	"	"	"	40.5	16+31=47	XI	25	30	12-17-12
"	"	"	"	35.0	17+30=47	XI	25	30	-
Jord. 57.030	9°43.5'N	119°30'W	XI.12.70	88.2	16+30=46	XI	25	30	13-17-13
Jord. 57.042	9°12'N	118°26'W	XI.13.70	27.7	17+30=47	XI	25	31	12-17-12
Jord. 60.134	7°05'N	117°00'W	IV.5.71	65.8	17+29=46	XI	23	29	12-17-12
Jord. 57.112	7°00'N	119°20'W	XII.6.70	24.0	17+30=47	XI	24	30	12-17-11
Jord. 60.031	3°57'N	118°58'W	III.9.71	37.0	17+30=47	XI	25	31	12-17-12
Jord. 57.087	3°44'N	118°24'W	XI.23.70	20.0	16+30=46	XI	24	31	13-17-13
T.C. 51.086	1°52'N	120°05'W	XI.19.70	46.0	17+31=46	XI	25	31	14-17-14
T.C. 51.071	3°12'S	121°27'W	XI.14.70	70.5	18+30=48	XII	24	30	11-17-12

few in number and are not present on postflexion larvae.

Teeth form on the premaxillary and dentary at about 6.0 mm, increasing in number with growth. Because only one specimen was cleared and stained, the initiation of scale formation was not determined. Haedrich (1969) reported lateral line scales on a 49-mm specimen.

Pigmentation.—Early larvae have pigment along the ventral margin of the body and develop pigment before and behind the eye.

In postflexion larvae, the ventral margin pigment is lost and the head becomes uniformly pigmented.

Flexion larvae (Fig. 3A, B) have pigment on the head, over the abdomen, at the base of the pelvic fins, and along the ventral margin of the tail. In the early flexion specimen (5.7 mm) the tail pigment consists of nine unequally spaced melanophores. The head pigment consists of a scatter of melanophores over the brain, pigment at the tips of the upper and lower jaws, and a partially

Table 9. Morphometrics, in mm, of larvae and juveniles of *Amarsipus carlsbergi* (specimens above dashed line are undergoing notochord flexion)

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
ETP 50.170	4.6 NL	2.2	1.3	0.58	0.34	1.5	-	-	1.3
off Hawaii	5.7	2.4	1.3	0.56	0.34	1.4	-	-	1.6
ETP 13.105	6.0 SL	2.8	1.7	0.70	0.50	2.0	2.4	3.0	1.8
ETP 11.066	11.5	4.4	2.8	1.1	0.60	3.0	3.6	4.6	2.4
ETP 11.306	16.7	6.2	4.0	1.6	0.88	4.4	5.5	7.2	3.1
ETP 60.150	21.4 *	7.7	4.8	1.9	1.2	5.5	7.4	9.0	3.8
"	27.4 *	8.7	6.1	2.5	1.4	6.5	8.2	11.2	5.2
"	28.4 *	9.8	7.4	2.8	1.7	6.7	9.5	12.2	5.7
ETP 11.114	32.0 *	10.7	7.3	3.0	1.6	7.4	9.7	13.0	6.4

* Juvenile

Table 10. Body proportions of larvae and early juveniles of three species of *Tetragonurus*, of *Amarsipus carlsbergi*, and of *Nomeus gronovii*, expressed as percentage of standard length (SL) or head length (HL)

Species and stage	Size range (mm)	Snout to anus/SL	Head length/SL	Eye diameter/HL	Snout length/HL	Depth at P base/SL	Sn-D/SL	Sn-A/SL	Sn-V/SL
Tetragonuridae									
Tetragonurus atlanticus									
Preflexion	3.0- 5.8 NL	63-69	14-26	28-48	24-27	13-20	-	-	-
Flexion	7.3- 8.1 NL	64-69	27-30	28-31	22-29	18-23	-	66-71	33-36
Postflexion	8.5-17.2 SL*	64-71	30-35	29-34	28-29	24-28	40-42	65-71	33-37
Tetragonurus cuvieri									
Preflexion	4.2- 6.6 NL	57-64	11-23	33-50	20-28	10-18	-	-	-
Flexion	7.6-10.1 NL	56-62	24-27	29-34	25-28	18-20	-	60-64	29-33
Postflexion	11.4-17.4 SL	58-67	25-32	27-32	23-31	20-25	37-44	60-69	32-36
Tetragonurus pacificus									
Postflexion	8.9-19.5 SL	62-65	30-33	29-33	27-32	27-29	40-43	63-66	30-35
Amarsipidae									
Amarsipus carlsbergi									
Flexion	4.6- 5.7 NL	42-48	23-28	43-45	26	24-33	-	-	28
Postflexion	6.0-32.0 SL	32-38 (47)	22-28	38-41	21-29	23-33	30-35	40-50	19-21
Nomeidae									
Nomeus gronovii									
Postflexion	7.3-11.9 SL	56-59	30-34	38-44	19-25	37-41	38-40	57-61	26-34

* Postflexion specimens may include both larvae and early juveniles

developed eye bar. In the late flexion larvae (4.6 mm) the eye bar is well developed, the ventral tail pigment has become concentrated into six patches, and pigment is present between the developing spines of the first dorsal fin.

In the smallest postflexion larva (6.0 mm, Fig. 3C), the ventral tail pigment is reduced to a single spot, but the eye bar remains conspicuous. By 11.5 mm (Fig. 3D) pigment has become heavier on the head, although the eye bar has disappeared. Pigment is heavier over the abdomen, but has been lost on the body. The pigment at the base of the pelvic fin is spread over the fin. In the largest specimen illustrated (16.7 mm, Fig. 3E), pigment has become heavier over the head and abdomen; some pigment has been added behind the head on the body, and a line of melanophores has formed along the length of the dorsal fin base.

On juveniles (not illustrated) the unpaired fins are sprinkled with pigment, which is heaviest along their outer margins. The

pelvic fins are conspicuously pigmented, but the pectorals are unpigmented.

Family CENTROLOPHIDAE

A centrolophid character possessed in common with other stromateoid fishes (except Amarsipidae) is the development of toothed pharyngeal sacs just posterior to the gill arches. Centrolophids have the blunt-nosed smug appearance that characterizes most stromateoid fishes (Haedrich, 1967). This is the largest family of stromateoid fishes, with probably seven genera. The commonest vertebral count is 10 + 15 = 25, found in all species of four genera and in some *Schedophilus*. The range in numbers of vertebrae in *Schedophilus* is 25 to 32 and is markedly higher in *Icichthys*, ranging between 50 to 61; the holotype of *Tubbia* has 43 vertebrae. The spines of the dorsal fin are weakly developed and graduate to the dorsal rays on the four species we will be dealing with, but can be stout and not graduated among some centrolophids, as in *Hyperoglyphe*. Predorsal bones number

Table 11.   Meristics of larvae and juveniles of *Amarsipus carlsbergi* (specimen above dashed line is undergoing notochord flexion. Note: Only 21.4-mm specimen cleared and stained; vertebral counts of other specimens are myomere counts, or read from radiographs)

Station	Size (mm)	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchiostegal rays	Gill rakers (right)	Teeth (left) Prem.	Dent.
ETP 50.170	4.5 NL	VI	base	base	7	I,5	0-7+6-0	16+30=46	2+4	0+1+7	0	0
ETP 13.105	6.0 SL	X	15	ca.23	10	I,5	0-8+7-0	16+30=46	2+4	1+1+7	1	1
ETP 11.066	11.5	X	26	ca 29	18	I,5	3-9+8-4	16+31=47	2+4	3+1+8	11	8
ETP 11.306	16.7	X	25	30	17	I,5	10-9+8-10	16+30=46	2+4	4+1+9	12	10
Jord. 60.150	21.4*	XII	24	I,29	18	I,5	12-9+8-13	16+30=46	2+4	5+1+10	22	16
"	27.4*	X	26	30	19	I,5	14-9+8-14	16+30=46	2+4	4+1+12	20	12
"	28.4*	XII	24	I,29	17	I,5	15-9+9-14	16+31=47	2+4	5+1+12	16	9
ETP 11.114	32.0*	X	26	31	18	I,5	12-9+8-12	16+30=46	2+4	4+1+12	ca 24	ca 12

* Juvenile

three, occasionally two, in all centrolophids except *Icichthys*. Hypural bones have the primitive complement for perciform fishes of three superior and three inferior (parhypural included). There are usually three epurals (two in *Icichthys*), two or three autogenous haemal spines on vertebrae adjacent to the terminal (ural) centrum, and two pairs of uroneurals.

In addition to the four species dealt with in this paper, Haedrich and Nielsen (1966) reported a 46-mm specimen of *Centrolophus niger* Gmelin (or *C. maoricus* Ogilby) from the stomach of *Alepisaurus* taken in the Pacific at 35°55′S, 116°53′W. Chirichigno (1973) described adult specimens of *Schedophilus haedrichi* from Chile.

Young specimens of centrolophid fishes are commonly collected under jellyfish. The nine specimens of juvenile *Schedophilus* available to us from the eastern south Pacific were dipnetted under jellyfish or *Physalia*. Various specimens of *Icichthys* were also collected in association with jellyfish.

The early life history stages of only one centrolophid have been described in detail, that of *Centrolophus niger* (= *C. pompilus* C. V.) by Sanzo (1932). Sanzo's illustrations are reproduced by Padoa (1956) together with additional illustrations of early juveniles of *C. niger* and a single illustration of a 44.0-mm specimen of *Schedophilus*

ovalis. Haedrich (1966) illustrated three young specimens of centrolophids: *Icichthys lockingtoni*, ca. 17.0 mm; *Centrolophus niger*, ca. 13.0 mm; and *Schedophilus medusophagus*, ca. 18.5 mm. T. Senta in Uchida, *et al.* (1958) illustrated a 16.4-mm specimen of *Psenopsis anomala*; Shojima (1961) illustrated four specimens of *Psenopsis* sp. taken accompanying the jellyfish, *Aurelia aurita*. No information is given on meristics of the specimens. Dawson (1971) illustrated three small specimens of *Hyperoglyphe bythites*, 5.7 to 7.9 mm, and a juvenile, 54.9 mm SL.

Maul (1964) gave observations on live specimens of *Schedophilus maculatus* and *S. ovalis* collected from off Madeira and reared in aquaria. A specimen of *S. maculatus* reared for 2 months (May 1 to June 30, 1961) grew from 55 mm to 141 mm, just over 2.5 times, and increased in weight from 7 to 95 g, about 13 times. Another specimen captured in 1962 and kept for about 3 months increased in length from 75 to 280 mm SL. A specimen of *S. ovalis* captured at the same time as the smaller specimen of *S. maculatus* grew in 2 months from about 100 to 198 mm SL. These observations indicate a strikingly fast growth rate.

Icichthys lockingtoni also has a relatively rapid growth rate. A specimen, hatched at

our laboratory on June 13, 1975, from eggs collected at sea and reared by Dennis Gruber, grew to a length of 93 mm SL and weight of 15.3 g by August 30, 1975.

Genus *Icichthys*

Icichthys originally was placed in a separate family and perhaps should again be separated as it is too disparate to fit in with the other genera placed in the Centrolophidae. One of the strikingly different characters is the origin of the dorsal fin in relation to the vertebral column and to the predorsal bones. In the other centrolophids, there are two or three predorsals preceding the dorsal fin; the anterior dorsal pterygiophore interdigitates between the second and third neural spines or the third and fourth neural spines, with the most frequent arrangement of this bone with predorsals being 0/0/0 + 2/. However, there are 7 to 11 (or 12) predorsals in *Icichthys lockingtoni*, with the anterior pterygiophore usually located between neural spines 11 and 12 or 12 and 13. This posteriad placement of the dorsal fin in relation to the vertebral column also is found in *Tetragonurus* and *Amarsipus*, although the former lacks predorsal bones, and the latter has but three predorsals. In other centrolophids with high numbers of dorsal fin elements, the fins are forward on the body, particularly so in *Schedophilus huttoni*, the species with the highest dorsal fin element count. Larvae of *Icichthys* are narrower bodied and have longer digestive tracts (pre-anus lengths) than other centrolophid larvae; in point of fact, they resemble larvae of *Tetragonurus* much more closely than those of other centrolophids. Parin and Permitin (1969) created a new genus *Pseudoicichthys* for *I. australis* Haedrich 1966. They recorded 9 to 10 predorsal bones for this species. Krefft (1969) and Haedrich and Horn (1972), although mentioning the new genus, retained *australis* in *Icichthys*. As mentioned in an earlier section, we would include *Tubbia* among the recognized genera of centrolophids.

Icichthys lockingtoni
Jordan and Gilbert, 1880
Figure 6

Literature.—This species was described by Jordan and Gilbert (1880) from a 6.8 inch (ca. 170 mm) specimen brought into the San Francisco fish market. A 64-mm specimen taken at Pacific Grove under jellyfish was described by Gilbert (1904) as *Schedophilus heathi*. Hobbs (1929) described specimens obtained from the gastrovascular cavity of the medusa *Phacellophora* from Monterey Bay as *Centrolophus californicus*. Myers (1950) pointed out that Hobbs' (1929) form represented the young of *Icichthys lockingtoni*. Fitch (1949) reported on a 55-mm specimen dipnetted under the jellyfish *Pelagia* off Seal Beach, southern California. Fitch (1952), Craig and Caneday (1962), Best and Smith (1965), and Berry and Perkins (1966) reported additional specimens from off California. Cowan (1938) reported a specimen from British Columbia; Abe (1963) reported 12 specimens from Sagami Bay, Japan. Haedrich (1966 and 1967) gave descriptions and additional records; a specimen approximately 17.0 mm SL was illustrated by Haedrich (1966).

Material.—Extensive collections of eggs, larvae, and early juveniles were examined from CalCOFI and NORPAC cruises including a series of specimens reared in the laboratory from eggs collected at sea off southern California. In addition, SIO's fairly extensive collection of juveniles and adults was utilized.

Distribution.—*I. lockingtoni* is common in the transitional waters of the California Current. It is found south almost to Punta Eugenia along Baja California (Fig. 7). Further north it is found offshore to 150°W in NORPAC samples (Fig. 5) and is known to extend across the Pacific to off Japan (Haedrich, 1966).

Distinguishing Characters.—JUVENILES. The species is characterized by its limp, compressed body, bluntly rounded snout, weakly developed scales on juveniles, weak dorsal and anal spines graduating to rays, the high vertebral number, and the posteriad origin of the dorsal fin, well behind the insertion of the pectoral fins.

LARVAE. Preflexion larvae of *I. lockingtoni* resemble those of *Tetragonurus cuvieri*, but differences in myomere counts (58 to 61 vs. 51 to 54) and in dorsal body pigment
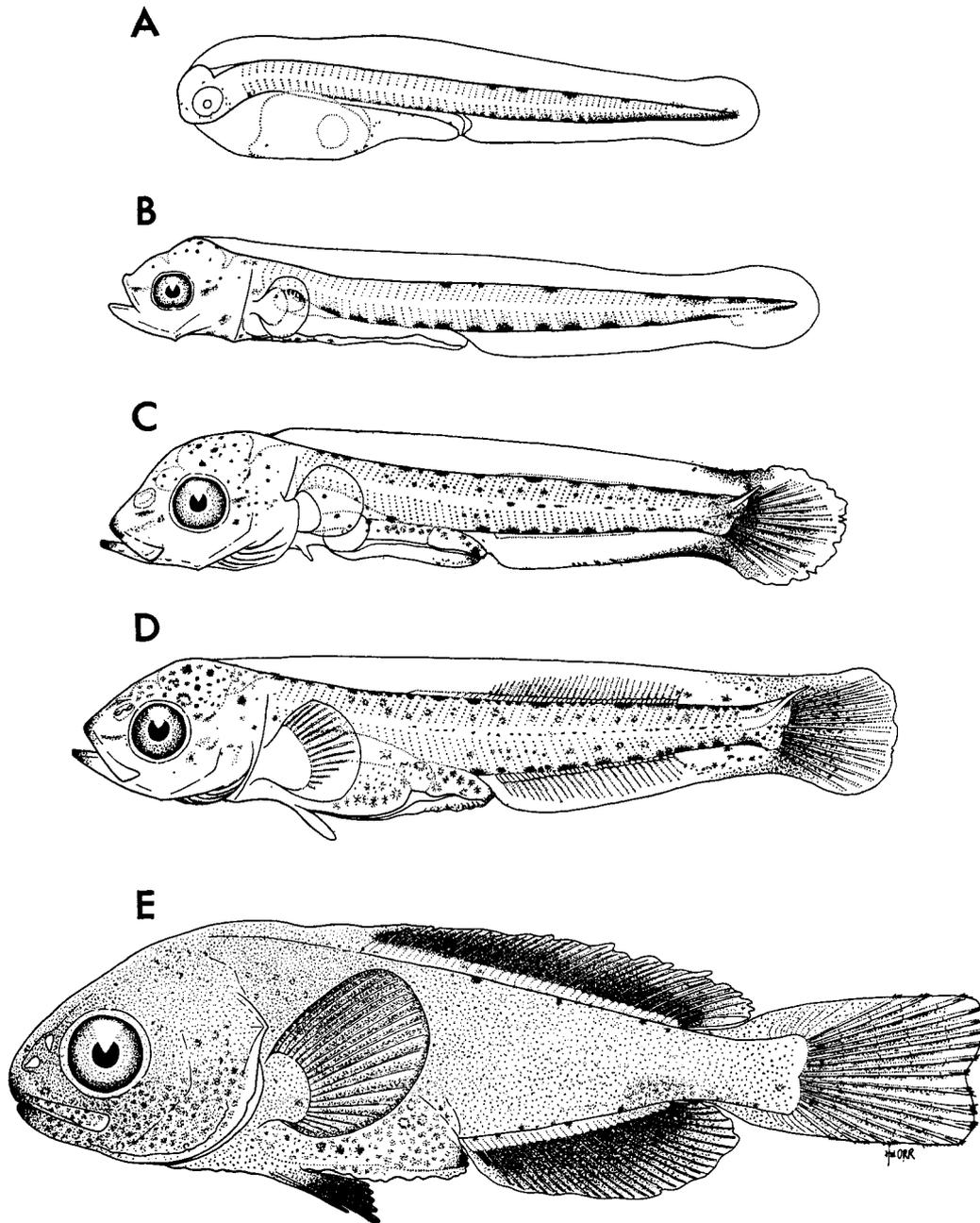
Figure 6. Developmental stages of *Icichthys lockingtoni* (Centrolophidae). A—4.3-mm preflexion larva; B—8.2-mm preflexion larva; C—10.4-mm flexion larva; D—13.5-mm postflexion larva; E—20.0-mm early juvenile.
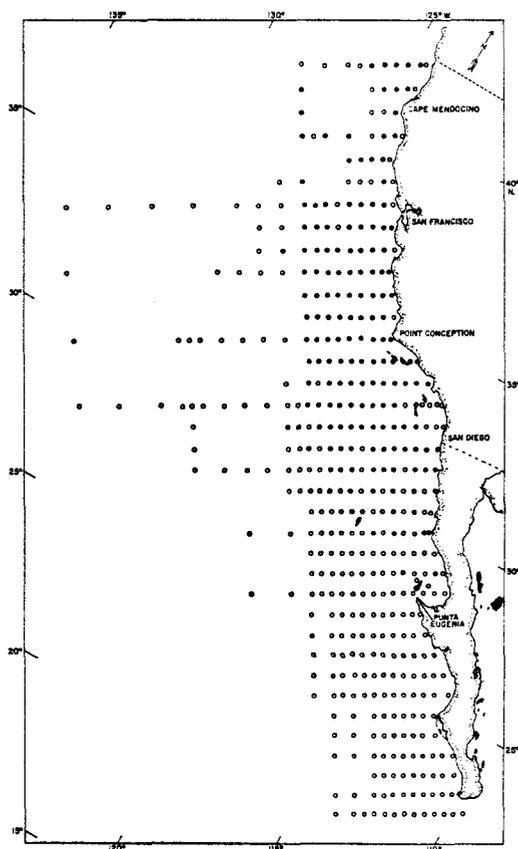
Figure 7. Distribution of *Icichthys lockingtoni* larvae in the CalCOFI region: a composite record of occurrences at CalCOFI stations during 1955-60. Closed circles are positive records, open circles are negative occurrences.

distinguish the two. *I. lockingtoni* has clusters of melanophores scattered along the posterior half of the dorsal body margin, whereas this dorsal pigment is confined to a short continuous streak on the very posterior portion of the tail in *T. cuvieri*. Once the dorsal and anal fins begin to form, there is no problem in distinguishing between the larvae of these two species (compare Fig. 6 with Fig. 13).

Meristics.—Vertebrae 23 to 25 + 34 to 37 = 58 to 61 (average 58.9); dorsal 41 to 46 (average 42.6); anal 27 to 32 (average 29.5); principal caudal rays 9 + 8; procur-

rent caudal rays 11 to 13 + 10 to 13 (average 12.1 + 11.9).

Meristics of 25 specimens from about 30°N to about 53°N and from about 112°W to about 173°E are given in Table 12. No variation of any count with latitude or longitude is indicated.

Morphometrics.—The morphometric measurements are given for a series of selected specimens in Table 13 and body proportions are summarized in Table 14. The early stage larvae of *Icichthys*, preflexion through flexion, are the slenderest among known stromateoid larvae, including *Tetragonurus*; body depth at pectoral fin ranges between 10 to 16% of SL. Body depth increases during the postflexion stage becoming about one-third of the standard length. The head increases in proportionate length from about 14% of NL at hatching to about 24% of NL at flexion, and to 32 to 35% of SL on late postflexion larvae and early juveniles. Eye diameter as a percentage of head length is moderately variable (29 to 41% of HL) but shows no consistent pattern of increase or decrease during larval development. After its full development on preflexion larvae, the snout retains about the same relative length (20 to 26% of HL) through the early juvenile stage. Gut length shows little proportionate variation during larval development (50 to 58% of NL or SL). Origin of the dorsal fin is somewhat forward of midbody (42 to 48% of SL). Origin of the anal fin is behind midbody (52 to 60% of SL). Pelvic fin bases are slightly behind the pectoral fin base (27 to 37% of SL), but considerably forward of the dorsal fin origin.

Ossification.—Sequence of fin ossification in *I. lockingtoni* can be derived from Table 15, which gives the meristics of cleared and stained specimens. The pectoral fins are the first to form rays at about 9.6 mm, with a complete complement of 18 to 20 rays being formed by 13.4 mm.

An 11.2-mm early flexion specimen has 4 + 4 principal caudal rays ossifying, and by

Table 12. Meristics of 25 juveniles and adults of *Icichthys lockingtoni* from over its distributional range in the eastern North Pacific (counts made from radiographs)

Station	Location Lat.	Location Long.	Date	Size-SL (mm)	Vertebrae	Dorsal fin	Anal fin	Caudal fin
SIO 63-640	53°10'N	166°50'W	VII.2.58	108.0	23+35=58	42	30	12-17-12
SIO 63-644	52°13'N	173°33'E	? .?.58	122.0	23+35=58	43	30	12-17-12
SIO 64-673	40°04'N	124°55'W	IX.12.50	100.0	24+36=60	43	28	13-17-13
05607-60.90	36°37'N	125°47'W	VII.23.56	45.0	24+37=61	42	30	11-17-11
SIO 67-112	36°35'N	112°18'W	VI.12.67	310.0	24+36=60	42	29	13-17-12
"	"	"	"	276.0	24+34=58	42	29	12-17-12
B5104-60.100	36°17'N	126°30'W	IV.6.51	26.0	24+36=60	46	31	11-17-11
Jord. 79 (dipnet)	36°10'N	135°00'W	VI.26.73	40.0	24+34=58	43	30	12-17-11
SIO 63-405	34°57'N	129°19'W	III.29.62	98.0	23+36=59	41	29	11-17-13
"	"	"	"	193.0	23+35=58	42	30	13-17-10
SIO 64-968	33°37'N	119°52'W	III.6.54	76.0	24+34=58	42	29	12-17-11
SIO 64-364	33°13.5'N	121°27.5'W	III.8.62	42.0	23+35=58	43	30	12-17-12
"	"	"	"	43.0	24+36=60	43	32	12-17-12
H6203-80.90	33°09'N	123°13'W	III.3.62	44.0	24+35=59	42	28	12-17-13
H6204-80.90	33°09'N	123°13'W	IV.18.62	42.0	24+35=59	43	30	12-17-12
SIO 55-096	32°52'N	117°17'W	XI.11.55	234.0	23+35=58	43	29	12-17-12
SIO 58-174	32°51'N	117°17'W	III.30.56	40.0	24+36=60	43	29	12-17-12
B6208-93.30	32°44'N	117°18'W	IX.1.62	72.0	24+35=59	42	31	13-17-12
"	"	"	"	83.0	24+36=60	45	32	12-17-12
H6105-Haul 3	32°40'N	118°55'W	V.27.61	56.0	23+35=58	43	29	12-17-12
SIO 64-955	32°39'N	119°28.5'W	II.19.51	86.0	23+35=58	42	30	12-17-12
SIO 56-114	32°28'N	117°18'W	X.30.56	76.0	23+35=58	42	30	12-17-12
SIO 64-810	31°50'N	119°34'W	II.14.57	58.0	23+35=58	41	29	13-17-13
Y5206-100.29	31°42.2'N	116°43.4'W	III.9.52	33.0	23+36=59	41	29	11-17-10
P5607-97.85	30°24'N	120°51'W	VII.9.56	28.0	24+35=59	42	27	13-17-12

12.1 mm, the complete number of 9 + 8 principal rays is formed. A total count of elements (weak spines and rays) is used for the dorsal and anal fins, and these are referred to simply as rays. The dorsal and anal fins are forming on a 12.1-mm specimen and the final complement of rays for both fins is present by 13.4 mm.

Pelvic fins do not form early as in *Amarsipus* and *Psenes*, rather they form at about the same time as the dorsal and anal fins. The pelvic fins remain rather small and complete their development by 13.4 mm.

Secondary caudal rays are the last to form; a 13.4-mm specimen has 6 + 6 rays ossifying, a 20.0-mm specimen has the minimal complete count of 11 + 11 secondary rays, and a 28.6-mm specimen has the maximal complete number of 13 + 13.

The lower complete count of 58 vertebrae (23 + 35) is ossifying in a 12.5-mm specimen. Information on vertebral ossification in smaller larvae is unavailable except for a 12.1-mm larva, as vertebrae in the other specimens did not stain.

Branchiostegal rays are first ossifying on a 9.6-mm specimen which has 2 + 4 rays, and a 12.1-mm specimen has attained the final number of 3 + 4 rays. Gill rakers of the first arch are evident by 9.6 mm with the full complement of 4 + 1 + 12 gill rakers present on a 20.0-mm specimen. Haedrich (1966) reported a range in number of gill rakers of 4 to 6 + 1 + 11 to 13.

Preopercular spines do not form during the larval period of *I. lockingtoni* as they do in *Schedophilus*, *Tetragonurus*, small *Amarsipus*, and the nomeids.

Dentary teeth first appear at 12.1 mm, and premaxillary teeth at 12.5 mm; these teeth are small and increase in number with growth (Table 15).

The first evidence of scales are those ossified above the pectoral fin base in a

Table 13. Morphometrics, in mm, of larvae and/or juveniles of *Icichthys locking-toni*, *Schedophilus huttoni*, *S. labyrinthicus*, and *S. maculatus* (specimens between dashed lines are undergoing notochord flexion)

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
Icichthys lockingtoni									
B6310-83.60	5.2 NL	2.7	0.72	0.24	0.08	.52	-	.	-
H5202-80.90	6.8	3.4	1.2	.44	.22	.90	-	-	-
L6604-73.53	7.1	4.1	1.7	.54	.42	1.1	-	-	-
H5202-80.90	8.4	4.5	1.7	.54	.40	1.0	-	-	-
B5905-70.75	9.3	5.1	2.2	.66	.54	1.5	-	-	-
B6204-113.50	9.8	5.6	2.3	.74	.52	1.5	-	base	-
B6207-87.90	11.0	6.2	2.7	.80	.72	1.8	base	"	3.2
B6107-83.80	11.7 SL	6.4	3.1	.90	.80	2.3	"	"	3.2
J6907-73.65	12.5	6.6	3.0	.96	.76	2.2	5.6	6.9	3.4
B5905-73.80	12.7	7.0	3.4	1.3	.76	2.9	5.7	7.1	3.8
H6101-77.55	13.7	7.4	3.9	1.6	.83	3.9	5.7	7.6	4.3
H6204-60.80	14.7	7.5	4.7	1.5	1.2	4.3	6.6	7.6	4.6
H5203-90.53	15.0	7.9	4.5	1.4	1.0	4.2	6.6	8.0	4.6
B6204-80.100	19.4	10.4	6.2	2.2	1.3	6.2	8.8	10.7	6.5
B6204-70.80	21.6*	12.0	7.5	2.7	1.5	7.8	10.4	12.4	7.0
"	24.7*	14.4	8.3	2.6	2.0	8.5	11.9	14.7	9.2
B5604-107.50	31.0*	16.5	10.0	3.5	2.5	10.7	13.9	16.9	10.0
Schedophilus huttoni									
SIO 65-641	18.4 SL*	9.7	5.2	1.7	1.3	6.9	5.3	10.0	5.2
"	24.0*	12.4	7.5	2.2	1.7	10.4	6.0	12.7	8.2
"	24.8*	13.5	7.5	2.3	1.8	10.2	6.2	13.8	7.8
"	25.0*	13.7	7.8	2.4	2.0	10.5	6.7	14.0	8.3
"	33.0*	17.0	10.4	3.3	2.1	14.2	8.4	17.5	10.0
Schedophilus labyrinthicus									
Climax II	34.1*	20.8	13.0	4.2	2.8	16.2	8.8	21.2	12.0
Schedophilus maculatus									
Climax II	22.1 SL*	12.8	9.2	3.4	1.8	10.5	7.5	13.7	7.8
"	28.0*	15.8	11.0	3.8	2.2	14.2	9.8	17.5	10.0
"	77.7*	38.6	24.1	6.5	4.9	35.9	19.6	41.5	20.3

* Juvenile

20.0-mm specimen. With all 11 + 11 secondary caudal rays developed, this specimen may be classed as juvenile.

Icichthys is variable in a number of skeletal characters. Several of the characters treated below were discussed by Haedrich (1966), but not their variability.

Icichthys has a predorsal bone count of 7 to 11 (occasionally 12). The first predorsal bone precedes the first neural spine and succeeding predorsals are one per interneural space. Occasionally the posterior two or three predorsal bones are reduced to fragments and occasionally two may fuse at their distal ends. The first dorsal pterygiophore occurs as a separate entity between the 11th and 12th, 12th and 13th, or, infrequently, 13th and 14th neural spines. It usually carries two weak spines in a secondary association, but sometimes only one spine. The first anal fin pterygiophore usually carries two elements in a secondary association, but specimens with only one element or as many as three elements have been observed.

The terminal portion of the axial skeleton is somewhat variable. *Icichthys* has the primitive count of three superior hypural bones and three inferior (parhypural included as an hypural). The epural bones usually number two, but occasionally three. Perciform fishes usually have two autoge-

Table 14.   Body proportions of larvae and early juveniles of four species of centrolophids, expressed as percentage of standard length (SL) and head length (HL)

Species and stage	Size range (mm)	Snout to anus/Sl	Head length/SL	Eye diameter/HL	Snout length/HL	Depth at P base/SL	Sn-D/SL	Sn-A/SL	Sn-V/SL
Centrolophidae									
Icichthys lockingtoni									
Preflexion	5.2- 8.4 NL	50-58	14-24	32-37	11-25	10-15	-	-	-
Flexion	9.3-11.0 NL	55-57	23-24	30-32	23-27	15-16	-	-	29
Postflexion	11.7-31.0 SL*	51-58	24-35	29-41	20-26	18-36	42-48	52-60	27-37
Schedophilus huttoni									
Juveniles	18.4-33.0 SL	52-55	28-32	29-33	23-26	38-43	25-29	53-63	28-34
Schedophilus labyrinthicus									
Juvenile	34.1 SL	61	38	32	22	48	35	62	35
Schedophilus maculatus									
Juveniles	22.1-77.7 SL	50-58	31-42	27-37	20	46-51	25-35	53-62	26-36

* Postflexion specimens may include both larvae and early juveniles

nous haemal spines on the vertebrae immediately preceding the ural centrum. *Icichthys* often has three autogenous haemal spines, and when only two are present there is almost invariably a doubling of the neural and/or haemal spines on one of the two vertebrae preceding the ural, usually on the second vertebra. This occurred very frequently. There are two pairs of uroneurals, one of which could be called a stegural; the other is a pair of splinter bones lying between the posterior tip of the stegural and the upper hypural bone. The stegural itself is on the posterior part of the ural centrum opposite the three superior hypurals. The neural spine of the vertebra preceding the ural is markedly reduced, as it is in most perciform fishes.

Pigmentation.—Description of pigment is based on series of reared and collected specimens. The ventral midline pigment is the dominant pigment on newly hatched larvae extending almost the length of the body from the head to the end of the notochord (Fig. 6A). Dorsal pigment consists of a series of unevenly spaced melanophores on the posterior half of the body. Lateral body pigment is lacking. Head pigment consists of small melanophores scattered around the unpigmented eyes.

Preflexion larvae maintain the earlier pigment pattern as seen in the 8.2-mm larva (Fig. 6B), except for the ventral body pigment concentrating into discrete clusters of pigment, and for heavier pigment forming over the head. There is a suggestion of an eye bar forming, but it is not conspicuous like those found in *Amarsipus*, *Tetragonurus atlanticus*, and *T. cuvieri*.

By late flexion (ca. 10.4 mm) (Fig. 6C), the dorsal margin pigment extends forward almost to the head. Dashes of lateral line pigment extend along the posterior half of the body. Between the lateral line and dorsal margin a line of dorsal-lateral spots extends for most of the body length. There is considerable pigment in the region of the developing caudal fin including over the hypurals, between principal caudal rays and on the adjacent fin fold. Head pigment has intensified; pigment is present on the tips of both jaws.

The 13.5-mm postflexion specimen (Fig. 6D) is similar to the preceding specimen, but with intensification of pigment on the head, the tail portion of the body, and over the abdomen. The weak eye bar is still present.

By 20.0 mm (Fig. 6E) pigment has spread over the entire body. Pigment is heavy on the lower part of the head. The original dorsal margin pigment is concentrated into a few conspicuous spots along the posterior

Table 15. Meristics of cleared and stained larvae and juveniles of *Icichthys locking-toni* (specimen between dashed lines is undergoing notochord flexion)

Station	Size (mm)	Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchio-stegal rays	Gill rakers (right)	Teeth (left) Prem.	Teeth (left) Dent.
L6604-73.53	7.1 NL	-	-	LP	-	-	-	-	-	-	-
"	9.6	-	-	2-R 0-L	-	-	-	2+4	0+1+5	-	-
S5805-77.50	11.2	-	-	3	-	0-4+4-0	-	2+4	0+1+5	-	-
H6107-80.60	12.1 SL	25	25	12	I,3	0-9+8-0	24+30=54 †	3+4	1+1+9	0	3
B6207-93.90	12.5	37	27	13	I,4	0-9+8-0	23+35=58	3+4	3+1+9	2	6
B6207-87.65	13.4	42	29	19	I,5	6-9+8-6	24+36=60	3+4	3+1+10	10	7
S5604-83.60	16.7	44	31	18	I,5	4-9+8-4	24+37=61	3+4	3+1+10	11	14
B6204-70.80	20.0*	43	28	20	I,5	11-9+8-11	24+35=59	3+4	4+1+12	20	13
"	28.6*	43	30	19	I,5	13-9+8-13	24+35=59	3+4	5+1+11	22	23

* Juvenile

† Vertebrae not completely developed

half of the tail and similarly the ventral pigment is concentrated into a few spots. All fins are pigmented.

Genus *Schedophilus*

Juveniles of three of the eight species of *Schedophilus* were sampled from the eastern South Pacific, all dipnetted under jellyfish. As mentioned in earlier sections, we have had the opportunity to study radiographs of eight species of *Schedophilus*, and wish again to emphasize the taxonomic value of the arrangements of predorsal bones and ptery-giophores in relation to vertebral spines.

Schedophilus huttoni
(Waite, 1910)
Figure 8

Literature.—This species has only rarely been reported in the literature. Haedrich and Nielsen (1966) reported a ca. 40-mm specimen from the stomach of *Alepisaurus* taken in the Pacific at 34° 24'S, 94°45'W. Craddock and Mead (1970) listed two specimens, 21 and 59 mm, from cruise 13 of the R/V ANTON BRUUN off Chile (32°59'–33°05'S, 74°57–59'W; 33°20'S, 73°41–42'W). Recently, Trunov (1969) reported on 24 specimens ranging in size from 420 to 720 mm from the South Atlantic. Smith (1966) described a very similar form, *Coroplopus dicologlossops*, from South Africa.

Material.—Five early juveniles, 18.4 to 33.0 mm, dipnetted off Juan Fernandez Islands, were available to us from the SIO collection.

Distribution.—Known from Australia, New Zealand, the eastern South Pacific off Chile, and the South Atlantic, this species was recorded as far north in the Atlantic as 18°S by Trunov (1969). This distribution indicates a circumglobal distribution in the southern oceans.

Distinguishing Characters.—*Schedophilus huttoni* is unique in its high number of dorsal elements (60 to 63 in our specimens —see Table 16). It is the highest total dorsal count among the stromateoid fishes, and ranges from 56 to 63 (Trunov, 1969). The vertebral counts of 12 + 19 to 20 = 31 or 32 and the total anal fin ray counts of 33 to 38 are unique among the centrolophids. The early juveniles possess strong preopercular spines as do those of *S. labyrinthicus* and *S. maculatus*. These preopercular spines are better developed in this genus than any other treated in this paper.

Meristics.—Vertebrae 12 + 19 to 20 = 31 or 32 (average 31.6); dorsal 60 to 63 (average 61.4); anal 33 to 38 (average 36.8); principal caudal rays 9 + 8; secondary caudal rays 10 to 12 dorsal + 9 to 11 ventral (average 10.7 + 9.7) (Table 16).

Morphometrics.—Morphometrics for the available specimens are presented in Table 13 and body proportions are compared with other centrolophids in Table 14. *S. huttoni*
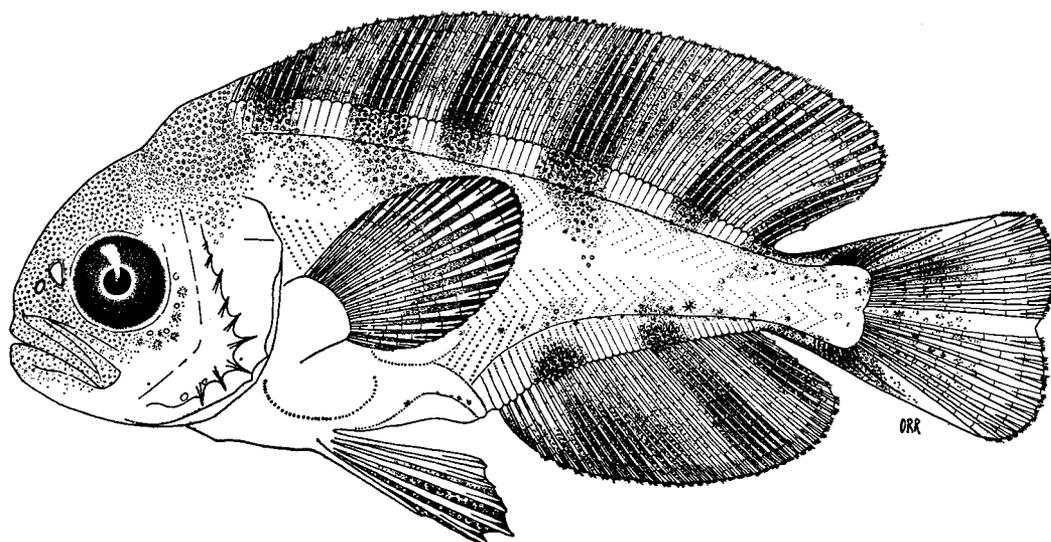
Figure 8. Early juvenile of *Schedophilus huttoni* (Centrolophidae), 25.0 mm.

is markedly more slender-bodied and has its dorsal fin originating farther forward on the body than in *S. labyrinthicus* or *S. maculatus*.

Ossification.—Data on the sequence of ossification are lacking inasmuch as only five early-juvenile specimens are available. Radiographs were made of these, and one specimen was cleared and stained. The sequential arrangement of anal fin pterygio-

phores in relation to haemal spines, based on the cleared and stained specimen, is given in Table 4.

Pigmentation.—Pigment on the early juvenile of *S. huttoni* is sparse compared to *S. maculatus* and *S. labyrinthicus* (compare Fig. 8 with Figs. 9 and 10). The head is heavily pigmented on the jaws, the snout, and over the eye, while the preopercle

Table 16. Meristics of juveniles and an adult of three species of *Schedophilus* from the eastern South Pacific (counts made from radiographs)

Station	Location		Date	Size-SL (mm)	Vertebrae	1st Dorsal fin	2nd Dorsal fin	Anal fin	Caudal fin
	Lat.	Long.							
S. huttoni									
SIO 65-641(dipnet)	33°31'S	78°49.7'W	XII.12.65	18.4	12+19=31		61*	37*	7-17-6
"	"	"	"	24.0	12+20=32		60*	38*	9-17-8
"	"	"	"	24.8	12+19=31		60*	33*	10-17-9
"	"	"	"	25.0	12+20=32		63*	38*	10-17-9
"	"	"	"	33.0	12+20=32		63*	38*	12-17-11
S. labyrinthicus									
Climax II(dipnet)	24°42'S	155°03.5'W	X.3.69	34.1	10+15=25	VII	26	III,18	11-17-10
SIO 65-650	33°34.3-35.5'S	78°54.9-55.5'W	XII.14.65	560.0	10+15=25	VIII	27	III,19	11-17-10
S. maculatus									
Climax II(dipnet)	24°42'S	155°03.5'W	X.3.69	22.1	11+18=29	IX	28	III,23	11-17-10
"	"	"	"	28.0	11+18=29	VIII	28	III,23	10-17-10
Climax II(dipnet)	24°34'S	154°50'W	X.9.69	77.7	11+18=29	IX	27	III,23	11-17-10

* Dorsal and anal counts are given for total number of elements, including weak spines
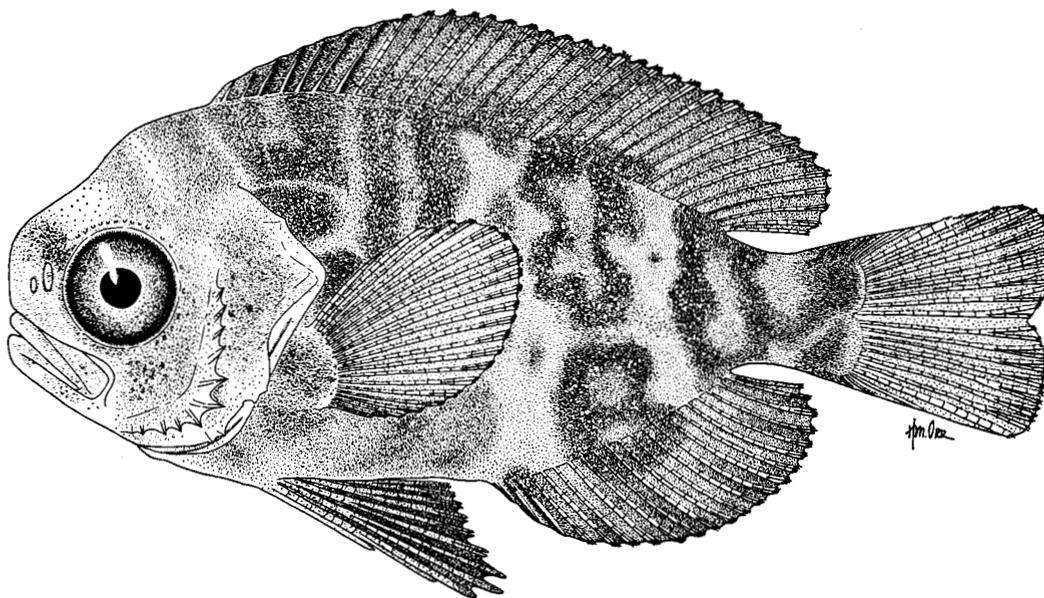
Figure 9.   Early juvenile of *Schedophilus labyrinthicus* (Centrolophidae), 34.1 mm.

and opercle are almost unpigmented. Pigment on the body is concentrated along the body margin in patches which are extensions of pigment bands on the dorsal and anal fin membranes. The pectoral and pelvic fins are rather heavily pigmented, while the caudal fin is pigmented only near its base.

Schedophilus labyrinthicus
McAllister and Randall, 1975
Figure 9

Literature.—There is a problem as to what scientific name to apply to this species. It obviously is closely related to *S. ovalis*, and may prove to be a geographical variant of that species. Stehmann and Lenz (1973) placed three nominal species from the southern oceans, i.e., *Seriolella velaini* Sauvage, 1879, *Seriolella christopherseni* Sivertsen, 1946, and *Seriolella* spec. nov. (McAllister and Randall, MS) in the synonymy of *Schedophilus ovalis*. McAllister and Randall (1975) disagreed and described their specimens as *Schedophilus labyrinthicus*, noting lower dorsal and anal fin ray counts, differences in body proportions, and disjunct distributions as the justification for separating their species from *S. ovalis*. Even if the specimens from the southern oceans are distinct from *S. ovalis*, another problem needs to be resolved—viz. whether the three described species are distinct from one an-

other. Both *S. labyrinthicus* and *S. christopherseni* possess two predorsal bones similarly arranged, a character shared in common with *S. ovalis*. This character could not be checked in *S. velaini* as the type specimen is presumably lost. *S. velaini* was collected from off St. Paul Island in the Indian Ocean, *S. christopherseni* from Tristan da Cunha in the South Atlantic. *S. labyrinthicus* is known from several localities in the South Pacific between Chile and Australia. Eventually it may be determined that all southern ocean forms belong to a single species, in which case both *S. velaini* and *S. christopherseni* would have priority over *S. labyrinthicus*. Fortunately, we do not have to make the decision whether *S. velaini* is well enough described to be definitely assigned to the southern "ovalis-like" species, or whether instead *S. christopherseni* should be used. We hope that our illustration of the southern form may stimulate a comparison with similar-sized specimens of *S. ovalis*.

Material.—A 34.1-mm juvenile dipnetted under a medusa in the south central gyre and a 560-mm adult (SIO 65-650) from Juan Fernandez Island were examined. In addition, radiographs of two specimens, one from an unknown locality and the other from off Lord Howe Island, Australia, were examined through the courtesy of Dr. R. L. Haedrich.

Distribution.—This species is now known from Juan Fernandez off Chile, Easter, and

Rapa Iti Islands, from Lord Howe Island off Australia and from the central water mass of the South Pacific. The planktonic juvenile is obviously the connecting link between widely separate populations.

Distinguishing Characters.—*Schedophilus labyrinthicus* is distinguished by osteological characters, meristics, pigmentation and morphometrics. There are only two predorsal bones and less than 20 anal fin rays. The blotched pigment pattern is different from the banded pattern of *S. maculatus* and *S. huttoni* at this stage, but a 78-mm juvenile of *S. maculatus* also has heavily mottled pigment. The body is less deep than the 44-mm specimen of *S. ovalis* illustrated by Padoa (1956). Unfortunately Padoa's specimen was bleached. The difference in body depth, also found in adults, supports the distinctness of *S. labyrinthicus* from *S. ovalis*. Whether or not *S. labyrinthicus* is distinct from *S. velaini* and *S. christopherseni* cannot be determined from our material.

Meristics.—Vertebrae 10 + 15 = 25; first dorsal VII to VIII; second dorsal 26 to 27; anal III, 18 to 19; principal caudal rays 9 + 8; secondary caudal rays 11 dorsal + 10 ventral (Table 16).

Morphometrics.—Morphometrics for the two available specimens are given in Table 13 and body proportions are presented in Table 14.

Ossification.—No ossification data are available. The sequential arrangement of anal fin pterygiophores in relation to haemal spines, based on radiographs, is given in Table 4.

Pigmentation.—Juveniles of this species are heavily pigmented over the head, body, and fins (Fig. 9). The pigment on the head is broken into areas of darker and lighter pigment, with darker patches on the snout, over the eye, and on the opercle and preopercle. The body has irregular patches of pigment that resemble the vertical barring of other species. The patches are irregular in outline

with lighter areas in the center. Pigment is heavy on the pelvic, pectoral, and caudal fins. The dorsal and anal fins are mottled like the pigment on the body.

Schedophilus maculatus
Günther, 1860
Figure 10

Literature.—This species has not been previously recorded for the eastern Pacific. The type specimen described by Günther (1860), 37 mm SL, was from the "Sea of China." *Schedophilus marmoratus* Kner and Steindachner, 1866, and *Hoplocoryphis physaliarum* Whitley, 1933, from Australia are probably synonyms (Haedrich, 1967).

Material.—Three juveniles were dipnetted under jellyfish; two of these were taken with *S. labyrinthicus*, the other separately. Radiographs of Australian material including the lectotype of *Hoplocoryphis physaliarium* were examined.

Distribution.—Our specimens were taken in the central water mass of the South Pacific. This species may prove to have a circumglobal distribution in the southern oceans.

Distinguishing Characters.—The vertebral count of 11 + 18 = 29 for *S. maculatus* is unique among centrolophids. The dorsal fin counts of VIII to IX, 27 to 28, and anal fin counts of III, 23 for this species also are unique in the genus *Schedophilus*.

Meristics.—Vertebrae 11 + 18 = 29; first dorsal VIII to IX; second dorsal 27 to 28; anal III, 23; principal caudal rays 9 + 8; secondary caudal rays 10 to 11 dorsal + 10 ventral (Table 16).

Morphometrics.—Morphometrics for the available specimens are presented in Table 13 and body proportions in Table 14. The body of *S. maculatus* is relatively deep (46 to 51% of SL) and the eyes are large (27 to 37% of HL).

Ossification.—Ossification data based on cleared and stained specimens are not available. The sequential arrangement of anal fin pterygiophores in relation to haemal spines as read from radiographs is presented in Table 4.
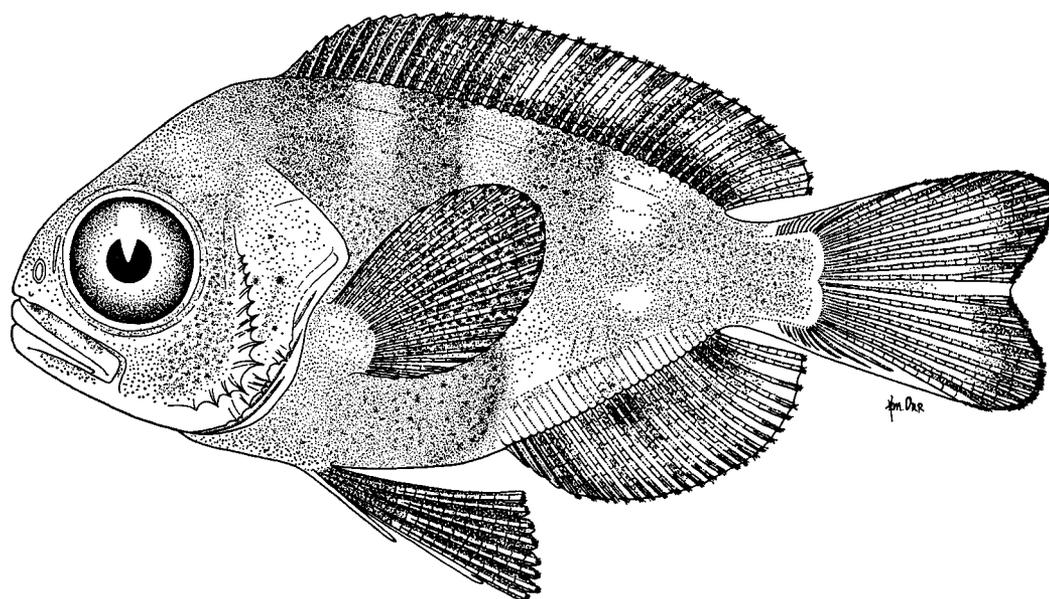
Figure 10. Early juvenile of *Schedophilus maculatus* (Centrolophidae), 22.1 mm.

Pigmentation.—Pigment on the 22.1-mm specimen is heavily developed on the head and body (Fig. 10). The head is more heavily pigmented over the eye, on the snout, and on the preopercle than on the lower jaw and the opercle. Pigment is present over the entire body but chiefly in four vertical bands; the first band at the dorsal fin origin and the last at the termination of the dorsal. The pectoral and pelvic fins are heavily pigmented as is the anterior portion of the dorsal fin. Pigment on the remainder of the dorsal fin and the anal fin is patchy. Pigment on the caudal fin is heaviest along its outer margin.

Family TETRAGONURIDAE

The tetragonurids are among the more specialized stromateoid fishes. The body is slender and elongate with a long caudal peduncle (especially so in *T. cuvieri*) supporting lateral keels on each side near its end. Scales on the body and head are keeled and strongly adherent. The two dorsal fins are not separated. Spines in the first dorsal fin are much shorter than rays in the second

dorsal. Dorsal spines number (X) XI to XVIII (XXI)[3] and dorsal rays 10 to 13 (17). The anal fin origin is slightly behind that of the second dorsal. The anal fin has I, rarely II spines and 9 to 12 (16) rays. The caudal fin has 17 principal rays (15 branched), 9 to 13 dorsal secondary rays, and 9 to 12 ventral secondary rays. The pelvic fins are short, with a complement of I, 5. The pectoral fins are rather small with 14 to 18 (21) rays.

Juveniles and adults of this family have 39 to 54 (58) vertebrae, 6 (occasionally 5) branchiostegal rays, 2 + 2 hypurals including the parhypural, 2 epurals, and no predorsal bones. The dorsal fin origin follows the neural spine of vertebrae 5 to 8. The first dorsal fin pterygiophore and first anal pterygiophore each support a single spine in a secondary association.

Genus *Tetragonurus*

The family is comprised of one genus with three species, all of which occur in the east-

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[3] Values in parentheses extending ranges are from the literature; the basic counts are from specimens examined by us.

ern Pacific. Juveniles and adults of the three species are most readily separated by meristic characters, whereas larvae are most simply separated by differences in pigmentation.

Comparative Morphometrics

The morphometrics of the three species of *Tetragonurus* are not strikingly different during larval development (Table 10). Morphometrics for only three postflexion species are available for *T. pacificus*, but fairly complete size series are available for *T. cuvieri* and *T. atlanticus*.

Head Length.—On the smallest specimens of *T. cuvieri* and *T. atlanticus* the head is smaller than on larger preflexion specimens. On a newly hatched specimen of *T. cuvieri* the head is only 11% of NL, but on a 6.6-mm specimen it has increased to 23%. On the smallest specimen of *T. atlanticus*, 3.3 mm NL, the head is only 14% of NL. The head increases rapidly in size relative to other body parts, for by 4.2 mm it is 26% of NL. Head length is 24 to 27% of NL during flexion of *T. cuvieri*, and 25 to 32% of SL in postflexion specimens. The head may be slightly larger on flexion and postflexion specimens of *T. atlanticus*, ranging 27 to 30% of NL during flexion and 30 to 35% of SL on postflexion specimens. On postflexion specimens of *T. pacificus*, HL is 30 to 33% of SL.

Eye Diameter.—The eye is round on postflexion specimens of the three species, but is off round to bluntly dumbbell-shaped on preflexion larvae. Except for the two early preflexion larvae with small heads (discussed above), eye diameter is about 30% of HL throughout larval development, ranging from 27 to 34% of HL in *T. cuvieri*, 28 to 34% of HL in *T. atlanticus* and 29 to 33% of HL in *T. pacificus*.

Snout Length.—The snout is somewhat more pointed in tetragonurids than in the nomeids, but is still moderate. The snout increases in length relative to head length in preflexion larvae of *T. cuvieri* from 20 to 22% of HL

to about 28%, and then stabilizes; in later stages it ranges between 23 to 31% of HL. The snout shows little difference in relative length among larvae of *T. atlanticus* between 4.2 to 17.2 mm: 24 to 29% of HL, with all but one value between 27 to 29%. On larvae of *T. pacificus*, snout length is 27 to 32% of HL.

Snout to Anus.—As is evident from Table 10, there is little if any change in the proportionate distance from snout to anus during larval development. In *T. cuvieri* the snout-anus length averages 60% of SL, with a range of 56 to 67%. In *T. atlanticus*, the snout-anus length averages 67% of SL, with a range of 63 to 71%. This is the most marked difference in body proportions noted for these two species. In *T. pacificus* the proportionate values are intermediate, 62 to 65% of SL.

Body Depth.—Small preflexion larvae of *T. cuvieri* and *T. atlanticus* are considerably more slender than larvae undergoing flexion or in postflexion. In *T. cuvieri* the increase in relative body depth is from 10 to 18% of NL immediately prior to flexion, remaining at 18 to 20% during flexion, and increasing only slightly thereafter, 20 to 22 (25)% of SL. In *T. atlanticus* the increase in relative body depth occurs more rapidly during the preflexion stage, from 13% to about 20% of NL; it averages 20% during flexion and about 26% of SL during postflexion (range 24 to 28%). In body depth, *T. pacificus* averages 27% of SL. Apparently, larvae of *T. cuvieri* are somewhat more slender than those of the other two species.

Snout to Fin Origins.—Measurements to the origin of fins (dorsal, anal, and pelvic) can be made on later-stage larvae only after fins are developed. Measurement of the snout to the origin of the spinous dorsal can be made only on postflexion larvae, but meaningful measurements on snout-anal fin origin or snout-pelvic fin base can be made on

some flexion larvae as well as all postflexion larvae. Only slight differences in these proportionate measurements exist among the three species (Table 10). In relation to the longer gut length noted for *T. atlanticus*, the origin of the anal fin is also somewhat farther back on the body, 68% of SL, as compared to 63% of SL in *T. cuvieri* and 65% in *T. pacificus*.

Tetragonurus atlanticus
Lowe, 1839
Figure 11

Literature.—Grey (1955) reported two specimens of *Tetragonurus atlanticus* from the eastern Pacific, a 20-mm SL specimen from Dana Station 3558 at 00°18'S, 99°07'W (September 18, 1928) and a 12.0-specimen from CalCOFI Station 5009-90.175 occupied at 28°34.5'N, 127°38'W (September 15, 1950). She illustrated a series of flexion and postflexion larvae. Abe (1955a) reported an adult taken off Japan.

Material.—Thirty-four collections of larvae from the eastern tropical Pacific and five collections from the central North Pacific were examined. Nine trawl collections from the eastern tropical Pacific contained the 16 juveniles listed in Table 17.

Distribution.—*T. atlanticus* is widely distributed in the tropical and subtropical eastern Pacific. In the EASTROPAC area it was found from 5°N to 20°S, west of the Galapagos Islands (Fig. 12). In the central Pacific, specimens were taken off Hawaii to 33°N in the central water mass (Fig. 5).

Distinguishing Characters.—JUVENILES. *T. atlanticus* is distinguished from the other two species by the number of vertebrae and the number of dorsal spines (Table 1).

LARVAE. Preflexion and postflexion larvae are characterized by the number of myomeres (44 to 46) and by their pigmentation. Pigment is lacking on the tip of the tail but present over the rest of the body. Similar stages of *T. cuvieri* are as heavily pigmented over the body, but in addition have pigment on the tip of the tail. During most of the larval period, *T. pacificus* larvae develop pigment only over the anterior portion of the body.

Meristics.—Vertebrae 23 or 24 + 20 to 22 = 44 to 46 (average 44.7); first dorsal XIV or XV (average 14.3); second dorsal 10 to 12 (average 11.3); anal I, 9 to 11 (average I, 10.2); principal caudal rays 9 + 8; secondary caudal rays 9 or 10 dorsal + 9 or 10 ventral (average 9.2 + 9.3).

Meristics of 16 specimens from about 4°S to the equator and from about 96°W to about 121°W are given in Table 17. No geographical variation of any count is indicated.

Morphometrics.—Morphometrics of a size series are presented in Table 18, and body proportions in Table 10. A discussion of the morphometrics of the three species of *Tetragonurus* is presented in an earlier section.

Ossification.—Meristics of seven cleared and stained specimens are presented in Table 19. The principal caudal rays are the earliest to develop with 8 + 7 rays formed at 7.2 mm. The complete number of 9 + 8 principal caudal rays is formed by 8.6 mm (Fig. 11D). The bases of the second dorsal and anal fins appear at 7.2 mm, and by 8.6 mm, each of these fins has developed its full complement of rays.

Rays appear in the pectoral fin at about the same size as in the second dorsal and anal fins, and the pectoral fin is complete by 13.2 mm.

At 10.5 mm, the first dorsal fin has developed its full set of 15 spines, and the pelvic fin and secondary caudal rays are partially formed. The pelvic fin is complete by 13.2 mm, and all secondary caudal rays are developed by 19.7 mm.

The fins of *T. atlanticus* differentiate earlier than in *T. cuvieri*, but not as rapidly as in *T. pacificus*. This generalization applies as well to the size at notochord flexion and the ossification of vertebrae and other structures.

Thirty-one vertebrae are ossified by 8.0 mm, and all 45 (24 + 21) vertebrae are formed by 10.5 mm. A full set of 2 + 4 branchiostegal rays are ossified by 7.2 mm.
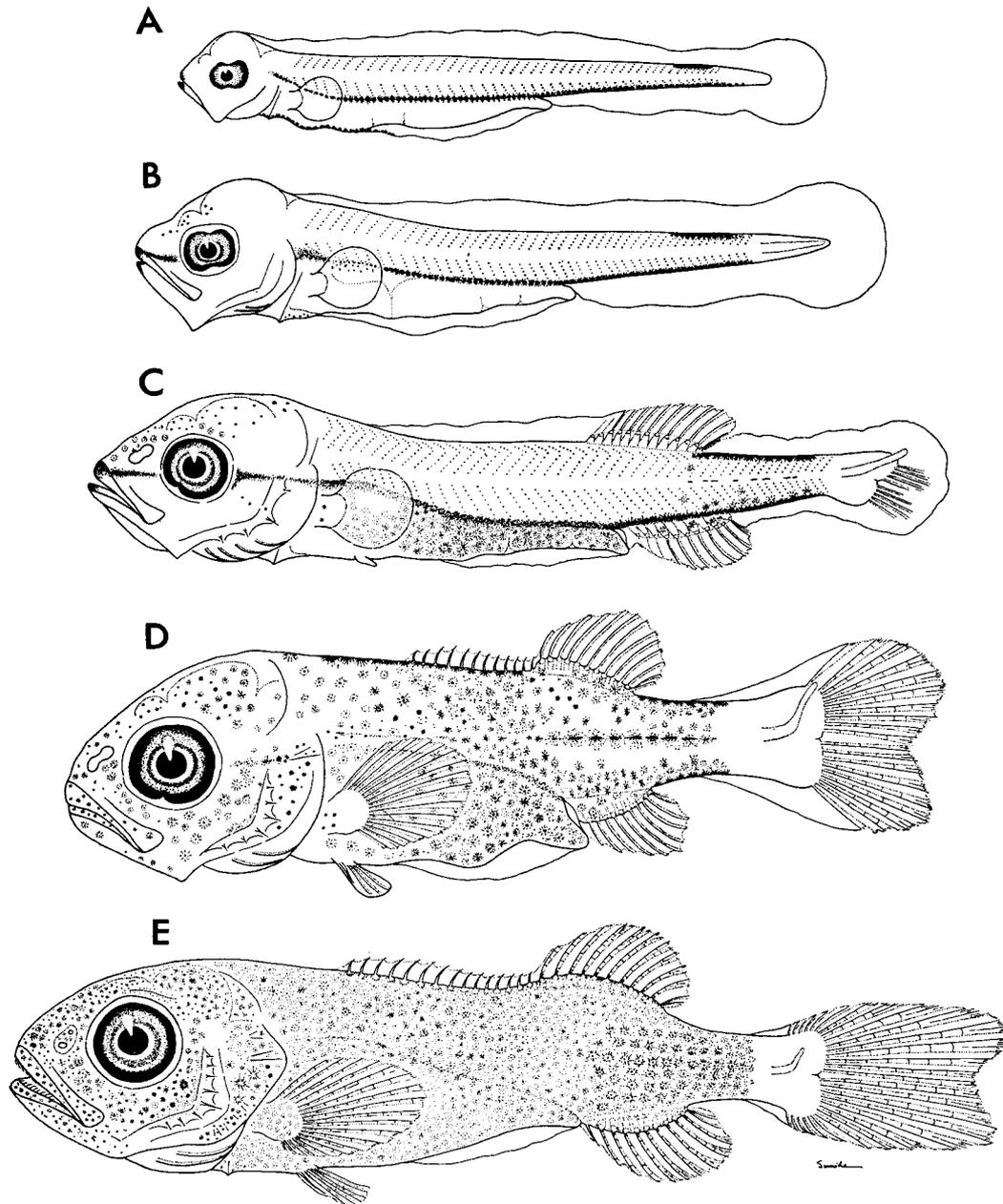
Figure 11. Developmental stages of *Tetragonurus atlanticus* (Tetragonuridae). A—3.0-mm preflexion larva; B—4.6-mm preflexion larva; C—7.6-mm early flexion larva; D—8.5-mm postflexion larva; E—17.2-mm postflexion larva.

Table 17. Meristics of 16 juveniles of *Tetragonurus atlanticus* from the eastern tropical Pacific (counts made from radiographs)

| Station | Location | | Date | Size-SL (mm) | Vertebrae | 1st Dorsal fin | 2nd Dorsal fin | Anal fin | Caudal fin |
	Lat.	Long.							
Jord. 65.164	00°30'S	96°42'W	IX.12.71	53.9	23+21=44	XIV	11	I,10	9-17-9
Jord. 65.214	00°30'S	97°13'W	IX.28.71	55.0	24+21=45	XIV	12	I,10	9-17-9
Jord. 65.160	01°29.5'S	96°42.1'W	IX.11.71	52.1	23+22=45	XV	11	11	9-17-9
T.C. 51.059	03°00'S	119°40'W	XI.10.70	21.8	24+20=44	XIV	11	I,10	10-17-10
T.C. 51.070	03°02'S	121°00'W	XI.13.70	24.0	23+21=44	XIV	12	I,11	9-17-10
"	"	"	"	25.8	23+22=45	XV	10	I,11	9-17-9
T.C. 51.066	03°10'S	120°19.5'W	XI.12.70	20.3	24+21=45	XIV	11	I,10	9-17-9
"	"	"	"	32.2	24+22=46	XIV	12	I,10	9-17-9
T.C. 51.071	03°12'S	121°27'W	XI.14.70	25.1	24+21=45	XV	12	I,11	10-17-10
"	"	"	"	55.7	23+21=44	XIV	I,11	I,11	9-17-10
T.C. 51.063	03°44'S	119°30'W	XI.12.70	18.8	23+21=44	XIV	11	10	9-17-9
"	"	"	"	19.2	24+21=45	XV	11	I,10	10-17-10
"	"	"	"	41.0	23+21=44	XV	10	I,9	9-17-9
"	"	"	"	42.0	24+21=45	XIV	11	I,9	9-17-9
T.C. 51.048	04°02'S	118°48'W	XI.8.70	13.2	24+21=45	XIV	12	I,10	9-17-9
"	"	"	"	19.7	23+21=44	XIV	12	11	9-17-9

Gill rakers of the first arch appear on the lower arch at 8.0 mm, and by 19.7 mm, 4 + 1 + 8 are formed.

A fringe- of three small spines develops along the outer margin of the preopercle at about 7.2 mm and increases to eight spines at 17.2 mm. These spines are more conspicuous in *Tetragonurus* than in the nomeids. They are later resorbed in the opercular tissue.

Premaxillary and dentary teeth first appear at 7.2 mm and increase in number with

Table 18. Morphometrics, in mm, of larvae of *Tetragonurus atlanticus* and of larvae and a juvenile of *T. pacificus* (specimens between dashed lines are undergoing notochord flexion)

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
Tetragonurus atlanticus									
ETP 20.222	3.0 NL	1.9	0.42	0.20	0.10	0.40	-	-	-
ETP 20.191	4.2	2.9	1.1	0.36	0.32	0.84	-	-	-
ETP 20.224	4.6	3.1	1.2	0.36	0.30	0.86	-	-	-
ETP 46.071	4.9	3.3	1.1	0.38	0.30	0.78	-	-	-
ETP 45.131	5.8	3.7	1.5	0.42	0.40	0.96	-	-	-
ETP 20.064	7.3	4.9	2.0	0.62	0.44	1.5	-	-	2.5
ETP 13.105	7.6	4.9	2.2	0.66	0.62	1.5	-	-	2.5
ETP 46.059	7.6	5.2	2.2	0.62	0.62	1.4	-	-	2.6
ETP 13.117	7.8	5.4	2.2	0.68	0.60	1.8	-	-	2.7
ETP 50.077	8.1	5.4	2.4	0.72	0.70	1.8	-	5.5	2.9
ETP 45.090	8.5 SL	5.9	3.0	1.0	0.80	2.4	4.1	6.0	2.8
J7210-31.139	10.5	6.7	3.2	1.1	0.88	2.5	4.2	6.9	3.8
"	12.4	7.9	4.1	1.2	1.2	3.2	4.9	8.1	4.2
ETP 20.193	17.2	12.2	5.6	1.7	1.6	4.4	7.2	12.4	6.4
Tetragonurus pacificus									
ETP 30.055	8.9 SL	5.5	2.7	0.80	0.80	2.6	3.8	5.6	3.0
"	9.4	6.1	2.8	0.80	0.90	2.5	3.8	6.2	2.8
Hawaii 70-9-2	19.5*	12.4	6.4	2.1	1.7	5.2	7.8	12.6	6.8

* Juvenile
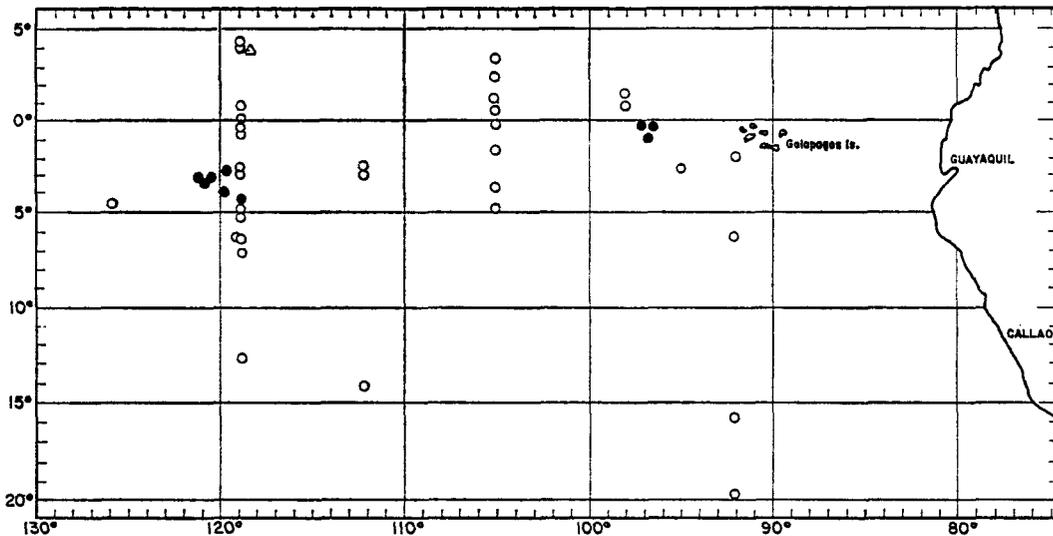
Figure 12. Occurrences of *Tetragonurus atlanticus* larvae (open circles) and juveniles (closed circles) and of a *T. pacificus* larva (open triangle) in the eastern tropical Pacific.

size. The dentary teeth are longer, broader, and more blade-like compared to the small, pointed teeth on the premaxillary. A general discussion of dentition in *Tetragonurus* and other stromateoids is given in an earlier section.

Scales are evident on a 17.2-mm specimen (Fig. 11E) and were seen on a cleared and stained specimen of 19.7 mm. The 17.2-mm specimen has only 6 + 6 secondary caudal rays, but the 19.7-mm specimen has a full complement of 9 + 9, thereby classifying it as an early juvenile.

Pigmentation.—Preflexion larvae have conspicuous pigment on the ventral margin of the body. Pigment is lacking, however, on the tip of the notochord. Postflexion larvae add pigment over the head and body except the base of the caudal fin which remains unpigmented.

Yolk-sac larvae have a continuous line of ventral pigment on either side of the body extending from the head to the tip of the notochord; forward of the anus this line of pigment is over the gut. Dorsal pigment is limited to a single median line on the last 8 to 12 myomeres extending to the tip of the notochord. There is pigment on the head around the developing mouth and scattered pigment below the yolk-sac and gut.

Simultaneous with the onset of pigmentation of the eyes, pigment is lost at and near the tip of the notochord (Fig. 11A). In contrast, pigment remains at the tip of the tail in *T. cuvieri* while it is absent in *T. atlanticus* until at least 17.2 mm.

Preflexion larvae add little pigment to what is found in the yolk-sac stage. By 4.6 mm (Fig. 11B), a line of pigment has formed on the snout from the tip of the upper jaw to the anterior margin of the eye, and scattered melanophores are present over the brain. Dorsal pigment which begins just anterior to the terminal one or two myomeres, extends forward about 10 myomeres; viewed from above, this is seen to be a double line.

Flexion larvae add pigment over the head, over the gut, and on the caudal peduncle (Fig. 11C). Pigment develops in a line posterior to the eye, forming a prominent eye bar from the snout to the edge of the opercle which connects posteriorward with

Table 19. Meristics of cleared and stained larvae and a juvenile of *Tetragonurus atlanticus* (specimens between dashed lines are undergoing notochord flexion)

Station	Size (mm)	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchiostegal rays	Gill rakers (right)	Teeth (left) Prem.	Teeth (left) Dent.
ETP 20.191	4.2 NL	-	-	-	LP	-	-	-	-	-	-	-
ETP 46.071	5.0	-	-	-	LP	-	-	-	-	-	-	-
ETP 20.064	7.2	-	base	base	LP	-	0-8+7-0	none stained	2+4	-	2	1
ETP 50.077	8.0	-	10	10	11	-	0-8+7-0	21+10=31 †	2+4	0+0+8	6	3
J7210-31.139	10.5 SL	XV	11	I,10	16	I,3	3-9+8-3	24+21=45	2+4	1+1+8	7	10
T.C. 51.048	13.2	XIV	12	I,10	17	I,5	8-9+8-8	24+21=45	2+4	3+1+8	10	16
"	19.7*	XIV	12	I,10	17	I,5	9-9+8-9	24+21=45	2+4	4+1+8	14	22

* Juvenile

† Vertebrae not completely developed

the line of pigment above the gut. Pigment forms along the lateral line and on the margins of the body on the caudal peduncle.

Postflexion larvae add pigment over the body except adjacent to the caudal fin. By 8.5 mm (Fig. 11D), pigment is heavy at the lateral line on the trunk, on the dorsal and ventral margin of the anterior half of the caudal peduncle and on the dorsal margin anterior to the second dorsal fin. The eye bar is still present behind the eye. By 17.2 mm (Fig. 11E), the head and body are uniformly pigmented except for the base of the caudal fin which remains unpigmented.

Tetragonurus cuvieri
Risso, 1810
Figure 13

Literature.—Although at one time considered a rare fish (Thompson, 1919; Fitch, 1949, 1951), *T. cuvieri* is now known to be rather common offshore (Tanonaka, 1957; Larkins, 1964). Fowler (1928), Welander and Alverson (1954), Grey (1955), Neave (1959), and Berry and Perkins (1966) gave additional records for the eastern and central North Pacific, and Craddock and Mead (1970) gave records from the South Pacific off Chile and Abe (1955) from off Japan. Sparta (1929) described and illustrated two late stage larvae and Grey (1955) illustrates a series of larvae.

Material.—Collections of larvae obtained on the NORPAC expedition and CalCOFI cruises from the North Pacific were examined, together with eight juveniles.

Distribution.—*T. cuvieri* is broadly distributed in the transition waters of the California Current and offshore in the central water mass as is shown for its distribution on NORPAC (Fig. 5). It is a temperate water form which replaces *T. atlanticus* north of about 34°N in the central Pacific and north of about 22°N in the eastern Pacific.

Distinguishing Characters.—JUVENILES. *T. cuvieri* is distinguished by its high number of vertebrae and dorsal fin spines (Table 1).

LARVAE. Preflexion and postflexion larvae are characterized by the number of myomeres (51 to 54) and by their pigmentation. Pigment is present at the tip of the notochord and at the base of the caudal fin (Fig. 13). Similar pigment is lacking in the other species of *Tetragonurus.*

Meristics.—Vertebrae 26 or 27 + 25 to 28 = 51 to 54 (average 52.1); first dorsal XV to XVIII (average 17.1); second dorsal 11 to 13 (average 12.1); anal I to II, 10 to 12 (average I, 11.3); principal caudal rays 9 + 8; secondary caudal rays 9 to 13 dorsal + 9 to 12 ventral (average 10.5 + 10.3).

Meristics of seven specimens from about 26°N to about 34°N and about 115°W to about 132°W are given in Table 20. No geographical variation of any count is indicated.
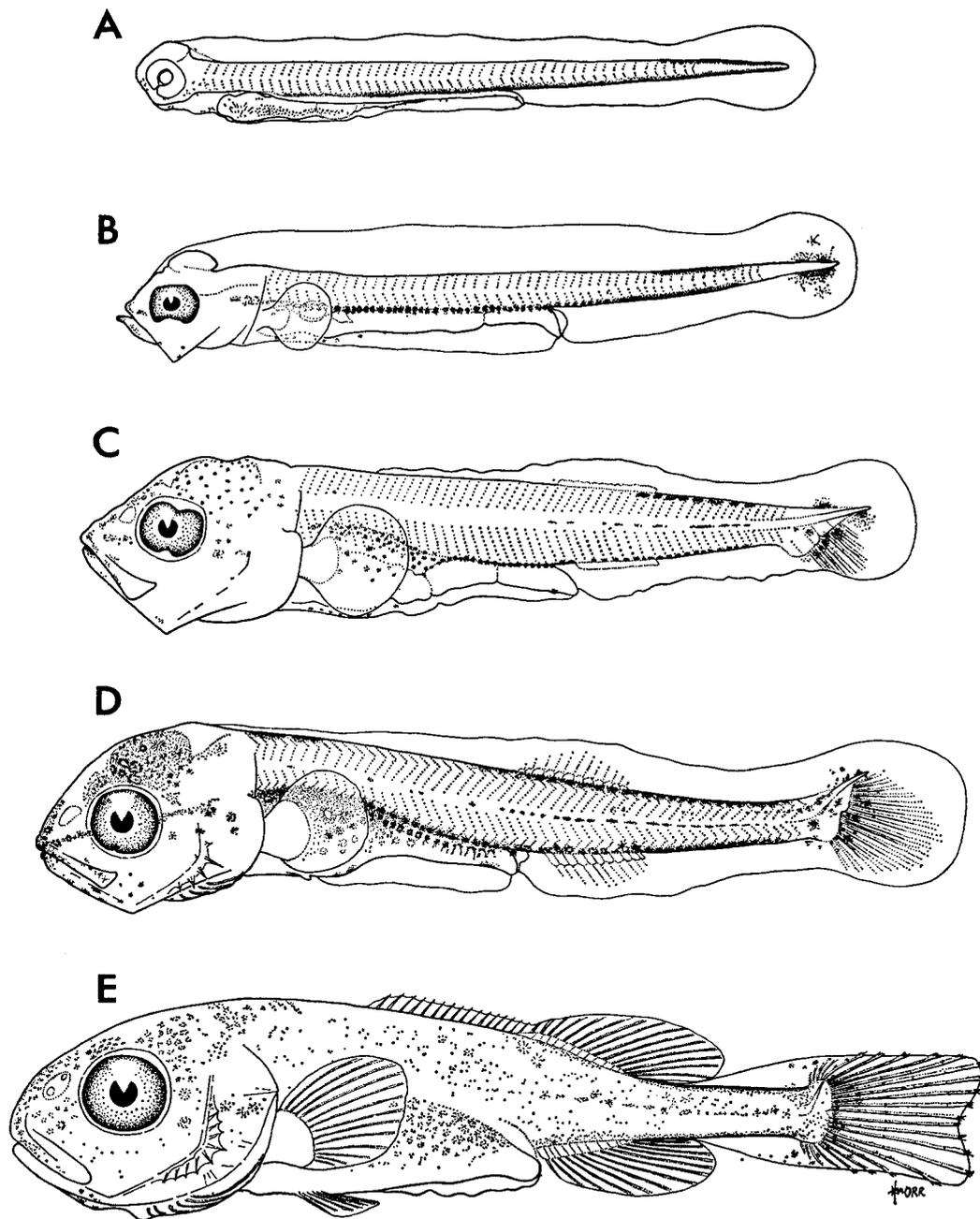
Figure 13. Developmental stages of *Tetragonurus cuvieri* (Tetragonuridae). A—4.1-mm preflexion larva; B—4.9-mm preflexion larva; C—7.6-mm early flexion larva; D—10.1-mm late flexion larva; E—17.0-mm postflexion larva.

Table 20. Meristics of seven juveniles of *Tetragonurus cuvieri* from the eastern Pacific (counts made from radiographs)

| Station | Location | | Date | Size-SL (mm) | Vertebrae | 1st Dorsal fin | 2nd Dorsal fin | Anal fin | Caudal fin |
	Lat.	Long.							
SIO 62-754	34°00'N	132° W	I.18.54	40.0	26+25=51	XVII	12	I,11	-
"	"	"	"	41.0	27+25=52	XVII	12	-	-
SIO 50-298	33°20'N	118°17.3'W	XII.8.50	54.0	27+26=53	XVIII	12	I,12	10-17-10
SIO 63-500	80 miles	off S.Diego	VIII.?.63	26.8	27+26=53	XVIII	12	I,12	9-17-9
SIO 66-006	32°31.5 - 31.6'N	117°39.4 - 30.4'W	III.13.66	47.0	27+26=53	XVI	12	I,12	10-17-11
SIO 63-368	31°06 - 04.6'N	123°12.2 - 07.5'W	III.6.63	37.0	26+25=51	XVII	11	I,11	13-17-12
SIO 58-161	26°53'N	115°00'W	VIII.24.58	62.0	26+25=51	XVIII	12	I,11	-

Morphometrics.—Morphometrics of a size series of larvae and early juveniles of *T. cuvieri* are presented in Table 21. A discussion comparing morphometrics of the three species of *Tetragonurus* is given in an earlier section titled "Comparative Morphometrics."

Ossification.—Meristics of a series of cleared and stained specimens are presented in Table 22. The principal caudal rays are first to develop with 4 + 4 rays ossified in a 9.1-mm specimen. A total complement of 9 + 8 principal caudal rays is attained by 10.9 mm. The second dorsal, anal, and pectoral fins are next to develop; all 12 second dorsal rays and 11 anal rays are ossified between 9.1 and 10.9 mm. A single anal spine is formed by 13.5 mm and a second, short anal spine is developed anterior to the first in a 65.0-mm juvenile. Twelve pectoral rays are present at 10.9 mm, and the full complement of 15 rays is formed by 13.5 mm.

Secondary caudal rays first appear at 10.9 mm, and form the full complement by 21.4 mm. The full complement of 15 spines in the first dorsal fin is present at 13.5 mm. Unfortunately, no specimens between 10.9 mm, which lacked dorsal spines, and 13.5 mm were available for staining to show a transition period in the early stages of the formation of the first dorsal fin. Bases of the pelvic fins are evident at 10.1 mm (Fig. 13D) and the full complement of I, 5 is developed by 14.0 mm.

The two anterior-most precaudal vertebrae have the neural spines ossified in a 7.6-mm specimen, and the full complement of 52 (26 + 26) vertebrae are formed in a 14.0-mm specimen.

Branchiostegal rays ossify early with 0 + 2 rays formed at 5.8 mm. The full set of 2 + 4 rays is developed at 7.6 mm. The variability in the number of branchiostegal rays in larger specimens (Table 22) is unusual for stromateoid fishes.

First arch gill rakers are first evident at 7.6 mm and increase to 5 + 1 + 8 in a 65.0-mm juvenile. The rakers on the lower limb develop quite early, but those on the upper limb are not completed until the juvenile stage (Table 22).

Preopercular spines develop along the margin of the preopercle and fewer, weaker spines lie embedded in the lower edge of the opercular flap. These spines are usually evident at about 10.0 mm, although one rather precocious 7.6-mm specimen has six spines along the preopercular margin; they gradually become embedded in the scaled opercle. Preopercular spines on *Tetragonurus* are heavier and more numerous than those found in nomeids, but less heavy than those developed on *Schedophilus*.

Premaxillary and dentary teeth first appear at 7.6 mm, and gradually increase in number with size. The dentary teeth are larger than those on the premaxillary, and are blade-like in shape. Dentition in *Tetragonurus* and other stromateoids is discussed in the introductory section of this paper.

Scales are first seen at 17.7 mm over the caudal peduncle, opercle, and along the midline of the body. By 21.4 mm, most of

Table 21.   Morphometrics, in mm, of larvae of *Tetragonurus cuvieri* (specimens between dashed lines are undergoing notochord flexion)

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
S6707-93.140	4.2 NL	2.4	0.48	0.24	0.10	0.42	-	-	-
"	5.2	3.0	.30	.32	.18	.52	-	-	-
S5603-110.80	5.2	3.1	.90	.30	.20	.56	-	-	-
86207-90.80	6.6	4.2	1.5	.50	.42	1.2	-	-	-
86207-90.120	7.6	4.6	1.9	.60	.54	1.4	base	base	-
Norpac 95 reg.	7.8	4.8	2.0	.68	.50	1.5	"	5.0	-
86310-80.80	8.4	4.8	2.0	.66	.50	1.5	"	5.3	-
B5702-107.60	9.7	5.6	2.6	.76	.66	1.9	"	5.9	3.2
G6210-80.100	10.1	5.7	2.4	.80	.64	1.8	"	6.1	2.9
S5603-110.80	11.4 SL	6.6	2.8	.90	.68	2.3	"	6.9	3.6
Norpac 95 reg.	13.4	8.1	3.7	1.0	.84	2.8	5.0	8.4	4.7
Norpac 107 reg.	14.2	8.8	4.1	1.3	1.2	3.1	5.8	9.1	4.7
S6707-107.65	16.9	11.4	5.4	1.6	1.7	4.2	7.5	11.7	6.1
Norpac 95 reg.	17.4	11.0	4.5	1.4	1.3	3.7	7.2	11.4	5.9

the body is scaled except the abdominal region. By 65.0 mm, scales cover the entire body. With scales forming and the full complement of secondary caudal rays developed at 21.4 mm, the early juvenile period may be designated as beginning at about this size.

Pigmentation.—Larvae of *T. cuvieri* have pigment similar to *T. atlanticus* except that

pigment is present at the tip of the tail in all stages of the former.

Yolk-sac larvae have continuous pigment along the ventral body margin from the head to the tip of the notochord; forward of the anus this line of pigment is over the gut (Fig. 13A). Pigment is on the dorsal margin only near the end of the notochord. Yolk-

Table 22.   Meristics of cleared and stained larvae and juveniles of *Tetragonurus cuvieri* (specimen between dashed lines is undergoing notochord flexion)

Station	Size (mm)	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchio-stegal rays	Gill rakers (right)	Teeth (left) Prem.	Teeth (left) Dent.
Norpac 95 reg.	5.0 NL	-	-	-	LP	-	-	-	-	-	-	-
"	5.8	-	-	-	LP	-	-	-	0+2	-	-	-
H4903-81.127	6.1	-	-	-	LP	-	-	-	0+3	-	-	-
Norpac 95 reg.	7.6	-	-	-	LP	-	-	2+ 0= 2†	2+4	0+1+6	3	2
H4903-81.127	8.9	-	~	-	LP	-	-	-	1+4	0+1+5	-	-
Loc. lost	9.1	-	Base	Base	LP	-	0-4+4-0	6+ 0= 6†	2+4	0+1+6	-	-
05701-100.60	10.9 SL	-	12	11	12	-	0-9+8-1	26+13=39†	2+4	1+1+7	4	8
G6301-80.80	13.5	XV	12	I,11	15	Base	0-9+8-3	27+21=48†	2+4	2+1+7	6	11
B5607-120.50	14.0	XVIII	12	I,11	17	I,5	3-9+8-3	26+26=52	2+4	2+1+8	9	12
Norpac 107 reg.	14.1	XVI	11	I,11	16	I,5	3-9+8-4	26+25=51	2+4	2+1+7	6	11
86410-93.90	15.5	XVIII	12	I,12	15	I,3	3-9+8-4	26+26=52	2+4	1+1+7	7	10
S6707-90.120	16.0	XVII	13	I,11	14	I,3	4-9+8-4	26+26=52	2+4	2+1+7	11	15
Norpac 95 reg.	17.4	XV	13	I,12	15	I,3	4-9+8-4	26+26=52	2+4	2+1+8	10	13
S6707-107.65	17.7	XVI	12	I,11	15	I,5	6-9+8-6	26+26=52	2+4	1+1+8	11	18
J6607-93.80	18.7	XVIII	13	I,10	16	I,5	4-9+8-6	26+28=54	2+4	2+1+8	9	14
05611-93.55	21.4*	XVIII	12	I,12	15	I,5	10-9+8-9	26+26=52	1+4-R 1+4-L	4+1+7	13	18
C5412-107.40	65.0*	XVIII	12	II,11	15	I,5	11-9+8-11	27+26=53	2+4-R 2+3-L	5+1+8	15	24

* Juvenile
† Vertebrae not completely developed
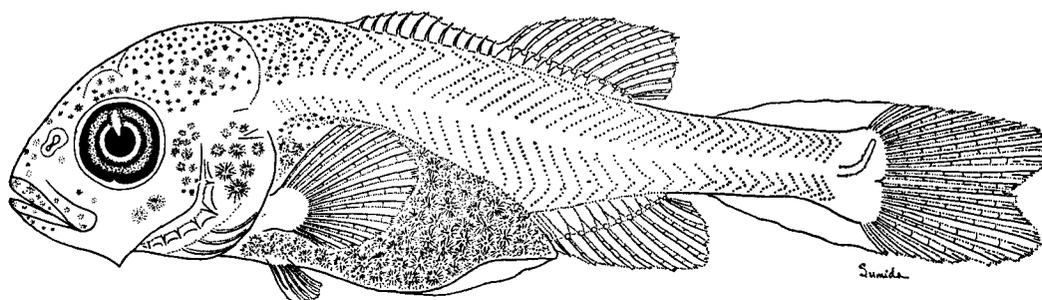
Figure 14. Postflexion larva of *Tetragonurus pacificus* (Tetragonuridae), 9.4 mm.

sac larvae can be distinguished from those of *T. atlanticus* by their larger size. *T. cuvieri* are 4.0 to 4.1 mm at hatching, whereas yolk-sac larvae of *T. atlanticus* measure 2.8 to 2.9 mm.

Preflexion larvae retain the same pigment as in the yolk-sac stage (Fig. 13B). Dorsal pigment extends forward in a double line (viewed from above) over the posteriormost 10 to 12 myomeres.

Flexion larvae add pigment on the head and along the lateral line (Fig. 13C). The eye bar forms in front of the eye at about 5.0 mm NL and behind the eye by about 6.0 mm; it persists through flexion. Pigment forms over the top of the head and spreads over the abdomen. Lateral line pigment forms from below the dorsal pigment forward to over the anus. By late flexion, 10.1 mm (Fig. 13D), the lateral line pigment is forming over the abdomen. Prominent dorsal pigment is developing behind the head and at the base of the developing second dorsal fin.

Postflexion larvae become pigmented over the entire head and body including the tail.

Tetragonurus pacificus
Abe, 1953
Figure 14

Literature.—Original descriptions of *Tetragonurus pacificus* were based on damaged specimens from the stomach of a yellowfin tuna caught west of the Solomon Islands at 6°36.5'S, 152°29'E (Abe, 1953). Grey (1955) reported a 9.5-mm specimen from Dana Station 3584 at 10°51.4'S, 168°40'W, and described a developmental series based principally on Indian Ocean material.

Material.—Three specimens were examined, one 19.5-mm juvenile from off Hawaii and two postflexion larvae from EASTROPAC station 30.055 at 3°47'N, 118°30'W.

Distribution.—Based on these two collections and the distribution given by Grey (1955), *T. pacificus* has a tropical distribution in the Pacific and Indian Ocean. It may be excluded from the oxygen minimum area of the eastern tropical Pacific as it was taken only at the western limit of the extensive EASTROPAC collections (Fig. 12).

Distinguishing Characters.—JUVENILES. *T. pacificus* is distinguished by the low number of vertebrae and of dorsal fin spines (Table 1).

LARVAE. Preflexion and postflexion larvae are distinguished by the low number of myomeres and by the pigmentation. Larvae of *T. pacificus* are the least pigmented among *Tetragonurus* and have no pigment on the body posterior to the termination of the gut until 13 mm. As Grey (1955) pointed out, larvae of *T. pacificus* develop fins and other structures at smaller sizes than either *T. atlanticus* or *T. cuvieri.*

Meristics.—Vertebrae 18 + 21 or 22 = 39 or 40; first dorsal XI or XII; second dorsal 10 or 11; anal I, 10 or 11; principal caudal rays 9 + 8; secondary caudal rays 11 dorsal + 11 ventral (Table 23).

Morphometrics.—Morphometrics of the three available specimens are presented in

Table 23. Meristics of postflexion larvae and a juvenile of *Tetragonurus pacificus* (Note: meristics of 19.5-mm specimen taken from radiograph; vertebral counts for 8.9-mm and 9.4-mm specimens are myomere counts)

Station	Size (mm)	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchiostegal rays	Gill rakers (right)	Teeth (left) Prem.	Teeth (left) Dent.
ETP 30.055	8.9 SL	XI	11	I,10	15	I,4	4-9+8-4	18+22=40	2+4	2+1+8	ca 4	ca 10
"	9.4	XI	11	I,10	16	I,4	4-9+8-4	18+22=40	2+4	3+1+8	4	11
Hawaii 70-9-2	19.5*	XII	10	I,11	18	I,5	11-9+8-11	18+21=39	2+4	5+1+10	13	ca 13

* Juvenile

Table 18 and body proportions in Table 10. A discussion of the morphometrics of the three species of *Tetragonurus* is presented in an earlier section.

Ossification.—Most of the major fins are developed on the 8.9-mm SL specimen of *T. pacificus* (Table 23), including the first dorsal (XI), second dorsal (11), anal (I, 10), pectoral (15), pelvic (I, 4), and caudal (4 + 17 + 4); only the caudal fin lacks the full complement of secondary rays and the pelvic fins are short one ray. All fins are complete between 9.4 and 19.5 mm.

Pigmentation.—One specimen of *T. pacificus*, a 9.4-mm postflexion larva, is illustrated (Fig. 14). Pigment is well developed over the head, nape, and abdomen, but the body is unpigmented behind the nape. Larvae of *T. pacificus* can be distinguished from *T. cuvieri* and *T. atlanticus* at all sizes by the lesser amount of pigment (Grey, 1955). The 19.5-mm juvenile is completely pigmented over the head and body, including the hypurals. Pigment is present on the membrane of the first dorsal fin and moderately at the bases of the second dorsal, anal, and caudal fins. The pelvic fins are lightly pigmented. The pectoral fin base is pigmented but not the rays.

Family NOMEIDAE

There are three genera in this family, *Nomeus*, *Cubiceps*, and *Psenes*, all widely distributed in the Pacific, Indian, and Atlantic oceans. Two of the fins in nomeids have the basic, unreduced counts for perciform fishes—pelvics I, 5 and caudal fin with 17 principal rays (15 branched). Secondary caudal rays range between 7 to 12 dorsal and 7 to 12 ventral. The first dorsal fin with (IX) X to XII spines is distinct from but contiguous with the second dorsal fin with I, 15 to 30 rays. The anal fin has II or III spines and 14 to 30 rays; the second dorsal and anal fins usually have about equal numbers of rays and seldom differ by more than ±2 rays. Pectoral fin counts range between 16 to 23.

The common vertebral count among species of nomeids is 31, with a range of (30) 31 to 42; the branchiostegal ray count is always 6 (2 + 4). The number of hypural bones supporting principal caudal rays in juveniles and adults is 2 + 2 (parhypural included); also present are 3 epurals and 3 predorsal bones, usually arranged 0/0/0 + 2/ (refer to introductory section dealing with predorsals). The first pterygiophore in the dorsal fin supports two spines in a secondary association for all nomeids except *Nomeus*, on which this pterygiophore secondarily supports a single spine. The anterior anal fin pterygiophore secondarily supports two spines for those species having three spines in this fin, but only a single spine is supported in a secondary association for species having two spines (i.e., *Cubiceps pauciradiatus*, *C. capensis*, *Psenes sio*, and *Nomeus gronovii*).

Upper jaw teeth on the premaxillary and lower jaw teeth on the palatine are arranged in a single row. Teeth on both jaws can be similar, i.e., needle-like, tapering, and often recurved; or the posterior dentary teeth can be blade-like, much as in *Tetragonurus*. The

latter type of teeth is found only in *Psenes* (except *P. cyanophrys*). Teeth are present on the vomer, being limited to a patch on the head of the vomer in *Psenes* and *Nomeus*, but usually developed on the blade of the vomer in *Cubiceps*, with opposing tongue teeth. Palatine teeth are developed in a single row per side in all three genera.

All pelagic stromateoid fishes studied possess an air (swim) bladder in their larval and early juvenile stages. The air bladder can be observed in preflexion larvae soon after yolk absorption, e.g., by 2.5 mm in larvae of *Cubiceps pauciradiatus* and *Psenes sio*. The air bladder can readily be seen in all larger larvae, but it becomes obscured in juveniles by overlying musculature unless these specimens are cleared and stained. Horn (1975) discussed the importance of the swim bladder in larvae and juveniles of stromateoid fishes in maintaining hydrostatic equilibrium. Juvenile fishes swim in the surface layers, frequently in association with floating objects such as jellyfishes, where hovering and high maneuverability are essential components of their locomotor behavior.

Pelvic fins are the first fins to develop on larvae of *Psenes* and *Nomeus*. They form soon after yolk absorption on *Psenes* and become relatively large. Late larvae and early juveniles of these two genera have body pigment distributed in patches and bands, whereas it becomes uniformly distributed over the body on late preflexion larvae and early juveniles of the other genus *Cubiceps*. It is interesting to note that the early stages of *Psenes* and *Nomeus* are strongly associated with medusae, siphonophores or floating drift, whereas the juveniles of *Cubiceps* have only rarely been reported with medusae (Mansueti, 1963).

Genus *Cubiceps*

There is a minimum of seven species in the genus *Cubiceps*: the five species treated in this paper, *C. caeruleus*, *C. capensis*, *C. pauciradiatus*, *C.* sp. A, *C.* sp. B, and in addition, *C. gracilis* from the western Atlantic and Mediterranean and *C. squamiceps* (Lloyd, 1909) from the Indian Ocean. The two species simply designated *C.* sp. A and *C.* sp. B have a markedly higher caudal fin secondary ray count than the other five. Both may be undescribed, or one or both could belong to inadequately described nominal species.

Of the seven species considered valid, six have 31 vertebrae and only *C. gracilis* has a higher number of 33 or 34 vertebrae. All seven species have a modal first dorsal fin count of XI spines. The main difference in meristic counts are in the number of secondary caudal rays, in number of second dorsal and anal fin rays, and in the number of anal fin spines (Table 1). With regard to the latter, *C. pauciradiatus* and *C. capensis* have only two spines, whereas the other species have three. *C. capensis* also has the highest average counts of second dorsal and anal fin rays among the species of *Cubiceps*, whereas *C. pauciradiatus* has the lowest.

C. squamiceps has a lower second dorsal and anal fin ray count than *C. caeruleus*. A distinctive character of *C. caeruleus* is its vomerine teeth. A single longitudinal row of teeth is developed on the blade of the vomer and on the tongue (glossohyal) of *C. caeruleus*, whereas in *C. pauciradiatus*, *C. capensis* and *C. gracilis* the teeth occur in a large patch on these opposing bones.

Of the five species of *Cubiceps* collected in the eastern Pacific, three are known from two or three specimens each, i.e., *C. capensis*, *C.* sp. A and *C.* sp. B. *C. caeruleus* is fairly common at the equator and in the central water mass of the North Pacific, and *C. pauciradiatus* is both common and widely distributed in the tropical eastern Pacific.

Characters that can be used to distinguish between larvae and early juveniles of *Cubiceps* and *Psenes* are discussed in the introductory section under *Psenes*.

Morphometrics of *Cubiceps* species are discussed together in one comparative section.

Table 24. Body proportions of larvae and early juveniles of five species of *Cubiceps*, expressed as percentage of standard length (SL) or head length (HL)

Species and stage	Size range (mm)	Snout to anus/SL	Head length/SL	Eye diameter/HL	Snout length/HL	Depth at P base/SL	Sn-D/SL	Sn-A/SL	Sn-V/SL
Cubiceps caeruleus									
Preflexion	3.4- 4.4 NL	32-43	18-27	41-45	24-28	21-35	-	-	-
Flexion	4.6- 4.9 NL	42-56	27-36	41-45	23-32	34-43	42	48-57	-
Postflexion	4.7-22.7 SL*	49-62	31-36	41-48	18-27	38-46	39-44	54-63	39-41
Cubiceps pauciradiatus									
Preflexion	2.1- 3.8 NL	52-59	18-29	32-46	25-38	9-32	-	-	-
Flexion	3.7- 4.3 NL	58-62	32-35	32-34	25-27	35-37	40-43	58-62	-
Postflexion	4.4-27.5 SL	59-65	31-36	32-37	19-27	28-38	35-45	60-71	37-46
Cubiceps capensis									
Postflexion	13.9-15.7 SL	59-60	31-33	35-37	27-28	30-34	40-42	61-62	39
Cubiceps sp.A (Tropical)									
Postflexion	8.7-19.5 SL	55-57	33-34	36-40	19-23	36-42	41-47	57-60	36-38
Cubiceps sp.B (Central Water Mass)									
Postflexion	12.5-18.7 SL	56	31-34	37-39	21	38-39	38-41	57-58	35-37

*Postflexion may include both larvae and early juveniles

Comparative Morphometrics

Instead of devoting an individual section under each species of *Cubiceps* to a discussion of its shape and to changes that occur therein during development, the morphometrics of all five species will be compared in this section (Table 24).

Head Length.—The head length is proportionately shortest in early preflexion specimens, ca. 18% of NL, and increases to 28 or 29% of NL in late preflexion larvae. Subsequently (flexion, postflexion and early juveniles) head length ranges between 31 to 36% of SL for all five species of *Cubiceps*. *Eye Diameter.*—The eye is proportionately larger on larvae of *C. caeruleus* (all stages) than on larvae of other kinds of *Cubiceps*. Eye diameter is 41 to 48% of HL on larvae of *C. caeruleus*. For flexion and postflexion specimens of *C. pauciradiatus*, eye diameter ranges between 32 to 37% of HL; for postflexion specimens of *C. capensis*, eye diameter is 35 to 37% of HL; for *Cubiceps* sp. A, 36 to 40% of HL; and for *Cubiceps* sp. B, 37 to 39% of HL.

Snout Length.—The snout is proportionately larger on preflexion specimens than on post-flexion specimens of *C. pauciradiatus*. The range of Sn/HL on postflexion specimens of all five species is 18 to 28% of HL, with *C. capensis* at the top of the range.

Snout to Anus.—The distance from snout to anus is proportionately longer in *C. pauciradiatus*, 59 to 65% of SL on postflexion specimens, than on any other nomeid. On larvae of *C. caeruleus*, snout to anus lengths are only 32 to 43% of NL on early preflexion specimens, increasing to 42 to 56% of NL by late preflexion and ranging between 49 to 62% of SL on postflexion specimens, with most between 55 to 60% of SL. Postflexion specimens of the other three species of *Cubiceps* (*C. capensis*, *C.* sp. A, and *C.* sp. B) also have snout to anus lengths of between 55 to 60% of SL.

Body Depth at Pectoral Fin Base.—An extensive series of preflexion specimens were available for *C. pauciradiatus* and these strikingly show the increase in body depth that occurs during this stage. Newly hatched larvae are markedly more slender (9% of NL) than late stage preflexion larvae (32% of NL). The body depth at pectoral fin base is proportionately greatest during flex-

ion, 3.7 to 4.3 mm NL, and early post-flexion, 4.4 to 7.4 mm SL; during flexion it is 35 to 37% of NL, and on early postflexion specimens it is of similar proportions (36 to 38% of SL); on specimens 8.6 to 17.5 mm, body depth at pectoral fin base ranges between 32 to 36% of SL, decreasing to 28 to 30% of SL on the two larger specimens in the series (22.2 and 27.5 mm). Preflexion specimens of *C. caeruleus* between 3.4 to 4.4 mm show an increase in body depth at pectoral fin base from 21 to 35% of NL (specimens smaller than 3.4 mm were not available); flexion specimens have a body depth at pectoral fin base of 34 to 43% of NL, and postflexion specimens of 38 to 46% of SL. Specimens of *C. caeruleus* are deeper bodied over the range of sizes studied (3.4 to 22.7 mm) than are specimens of *C. pauciradiatus* of similar sizes. The two specimens of *C. capensis* (13.9 and 15.7 mm SL) are as slender as comparable-sized specimens of *C. pauciradiatus* (30 to 34% of SL). The other two species are intermediate in this dimension between *C. pauciradiatus* and *C. caeruleus*.

In the following paragraphs the proportionate length of fin origins will be considered only for postflexion specimens of *Cubiceps*.

Snout to Dorsal Fin Origin.—As noted under the discussion of morphometric measurements for *Psenes*, the origin of the first dorsal fin is farther forward in *Psenes*, Sn/D lengths ranging between 27 to 40% of SL, while in *Cubiceps* these range between 35 to 47% of SL. Among *Cubiceps*, this proportionate measurement is not markedly different for the five species.

Snout to Anal Fin Origin.—The anal fin origin is close to the anus, seldom separated by more than 2 to 4% of SL. Consequently, the proportionate lengths from snout to anal fin origin are similar to those for snout to anus. This distance is proportionately longest in *C. pauciradiatus* (60 to 71% of SL), and shortest in *Cubiceps* sp. B (57 to 58% of SL).

Snout to Insertion of Pelvic Fins.—The insertions of the pelvic fins are either immediately under the dorsal fin origin, slightly forward of it, or slightly behind it. Only in *C. pauciradiatus* is the pelvic fin insertion consistently behind the first dorsal fin origin.

Comparative Pigmentation

Early stage larvae are available for only two species of *Cubiceps*: *C. caeruleus* and *C. pauciradiatus*; for the three other species taken in the eastern Pacific we have late postflexion larvae and/or early juveniles. Hence the discussion of pigment on preflexion and flexion stage larvae of *Cubiceps* must be limited to the former two species.

The most striking difference in the pigment patterns of early stage larvae of *C. caeruleus* and *C. pauciradiatus* is the presence of a line of pigment spots along the ventral midline of the tail on preflexion, flexion, and early postflexion larvae of *C. caeruleus* (gone by 6.2 mm), and its absence on post-yolk-sac and further developed larvae of *C. pauciradiatus*. Contrastingly, preflexion and later stage larvae of *C. pauciradiatus* have opposing dorsal, ventral and lateral line pigment patches on the tail about midway between the anus and the notochord tip. This type of tail pigment is lacking on larvae of *C. caeruleus*.

Neither of the above types of tail pigment is unique to *Cubiceps* among nomeids. Four of the five species of *Psenes* have the ventral midline series of pigment spots on preflexion larvae, persisting until the early postflexion stage (lacking on *P. cyanophrys*); all five species of *Psenes* have mid-tail lateral-line pigment extending over several myomeres with opposing ventral and usually dorsal patches, such as on *C. pauciradiatus*. On flexion and postflexion larvae, all five species of *Psenes* have a pigment patch over the hypural plates that is lacking on *Cubiceps* larvae. Preflexion larvae of *Psenes* and *Cubiceps* are most readily separable by the presence of early-forming pelvic fins on *Psenes* and their absence on *Cubiceps*. Also, pigment forms on top of the head in later

preflexion larvae of *Cubiceps*, whereas it is lacking on the head of preflexion larvae of *Psenes* beyond the yolk-sac stage, only to appear later during flexion or early post-flexion.

Sparta (1946) described the early life history stages of *Cubiceps gracilis* Lowe. The smallest specimen illustrated, a late pre-flexion specimen, lacks the series of ventral midline melanophores on the tail portion of the body that is found on *C. caeruleus*, but has a series of four or five spots along the outer margin of the anlage of the caudal fin, and has the head and abdomen more heavily pigmented than on comparable stages of *C. caeruleus* or *C. pauciradiatus*. On postflexion specimens, pigment spreads posteriad from the head on to the nape of the trunk, and also from a center of pigmentation on the tail, much as in *C. caeruleus*.

Nellen (1973) illustrated an 8.8-mm TL larva of a nomeid, as that of *Psenes whiteleggii*. The top of the head, opercle and abdomen are heavily pigmented; pigment on the body is limited to a series of ventral pigment spots and two spots over the inferior hypurals. The pigment pattern is closest to *C. caeruleus*. He sent us photographs of several additional specimens. Preflexion larvae lack precocious pelvic fins. We have no hesitation in assigning the larvae to *Cubiceps*, with the strong possibility that they belong to *C. squamiceps*.

The five species of *Cubiceps* become rather uniformly pigmented over the head and body on late postflexion larvae or early juveniles. There is no clustering of pigment into patches or bands as is the case on early juveniles of *Psenes* and *Nomeus*. As will be discussed in the species accounts, the pattern of pigment augmentation is somewhat different for each species.

On postflexion larvae of *C. caeruleus*, the pigment spreads posteriad from the head onto the trunk, while a lateral pigment patch forms simultaneously on the tail at about myomeres 18 to 22 and spreads in all directions. The pigment soon fills in from the head to the caudal peduncle, with the latter area the last to become pigmented.

The opposing dorsal, lateral line, and ventral pigment patches are a conspicuous feature on the body of *C. pauciradiatus* larvae and become a primary center for pigment augmentation on postflexion larvae. However, pigment forms along the length of the dorsal and ventral margins of the body except on the caudal peduncle before spreading over the body itself. The upper half of the body above the lateral line becomes rather uniformly pigmented except for the caudal peduncle by 8.6 mm; the latter becomes gradually pigmented in larger sizes.

Although additional material of *C. capensis* is needed to establish the sequence of pigment augmentation in this species, the 15.7-mm specimen is pigmented similarly to similar-sized specimens of *C. pauciradiatus*.

Pigment forms earlier on *C.* sp. A than on other species of *Cubiceps*, inasmuch as the 8.7-mm specimen is quite heavily pigmented over the head and body except along the bases of the dorsal, anal, and caudal fins.

Pigment augmentation appears to be closely allied in *C. caeruleus* and *C.* sp. B in that pigment first forms heavily over the head, abdomen and nape and only later over the tail portion of the body. However, tail pigment forms earlier on *C. caeruleus* than on *C.* sp. B.

It is probable that differences in pigment patterns in early juveniles of *Cubiceps* and *Psenes* may be associated with different behavioral patterns. Stromateoid fishes associated with jellyfishes or floating debris, of which *Psenes* is a prime example, usually have conspicuous patches or streaks of pigment on their bodies as early juveniles, but later become rather uniformly pigmented over their bodies when they become deeper living fish. We assume that *Cubiceps*, with its drab pigment patterns, is seldom associated with floating objects, but rather settles to deeper levels as early juveniles. Horn (1975) has emphasized the importance of coloration and maneuverability to the juvenile stromateoid that accumulates

beneath floating objects, especially coelenterates. He notes that the young fish typically have a banded, mottled, or blotched pattern whereas adults are generally uniform in color or are dark above and pale below; also, the duration of the juvenile color pattern is similar to the period when the fishes are associated with floating objects. Our observations reinforce those of Horn.

Cubiceps caeruleus
Regan, 1914
Figures 15 and 16

Literature.—*Cubiceps caeruleus* was reported from the eastern Pacific by Haedrich and Nielsen (1966) and Parin (1968). Specimens assigned to *C. gracilis* from Japan (Abe, 1955b) were reassigned to this species by Haedrich (1972) on the basis of their teeth. This species was originally described by Regan (1914) from off Three Kings Island in the Tasman Sea.

Material.—Extensive collections of larvae were examined from EASTROPAC material. Juveniles collected by STOR cruises in the same area, and larvae and juveniles collected near Hawaii were also examined.

Distribution.—*Cubiceps caeruleus* is widely distributed in the eastern tropical Pacific (Fig. 17), although more abundant offshore. It is also found over an extensive area between ca. 20° and 32°N and 123° to 180°W (Fig. 18). In this region, it would be classed as a central water mass species. It appears to avoid the oxygen minimum waters off the coasts of central America and Mexico, and does not occur in the Gulf of California. However, the offshore distribution obtained on EASTROPAC cruises is contiguous with the distribution obtained on CalCOFI cruises including NORPAC. This is the only species of stromateoid fishes for which there is such a distinct continuation in distributions as between EASTROPAC and CalCOFI cruises.

Distinguishing Characters.—Fin meristics and dentition are distinctive in *C. caeruleus* juveniles. The dorsal fin meristics of X to XII, I, 20 to 23 in combination with the anal fin meristics of III, 20 to 22 and only 7 to 10 secondary caudal rays are charac-

teristic for the species. In addition, the teeth on the blade of the vomer are in a single row, not in patches as in *C. pauciradiatus*, • *C. capensis* or *C. gracilis*.

LARVAE. The pigment pattern and lack of precocious pelvic fins will easily distinguish preflexion larvae of *C. caeruleus* from other nomeids. The pattern of pigment augmentation in flexion and postflexion larvae is strikingly different from *C. pauciradiatus* or any species of *Psenes*. Pigmentation in *C. caeruleus* is described in a subsequent section, and was also discussed above under "Comparative Pigmentation."

Meristics.—Vertebrae 12 + 19 = 31; first dorsal X or XI, rarely XII (average 10.9); second dorsal I, 20 to 23 (average I, 21.1); anal III, 20 to 22 (average III, 20.6); principal caudal rays 9 + 8; secondary caudal rays 7 to 10 dorsal + 7 to 10 ventral (average 8.5 + 8.6).

Meristics of 25 specimens from about 4°S to about 31°N and from about 96°W to about 158°W are given in Table 25. No geographical variation of any count is indicated.

Morphometrics.—Morphometrics of a size series of *C. caeruleus* are presented in Table 26 and body proportions are presented in Table 24. A discussion of the morphometrics of *C. caeruleus* in relation to other *Cubiceps* species is given in an earlier section titled "Comparative Morphometrics."

Ossification.—Fin ray development first begins in the caudal fin. A 4.8-mm specimen has 3 + 3 principal caudal rays developed, and the full complement of 9 + 8 principal caudal rays is achieved by 6.5 mm (Table 27). The anal, second dorsal, and pectoral fin rays begin to develop by 5.2 mm. The second dorsal fin is complete and the anal fin nearly complete in a 6.5-mm specimen, but the pectoral fins add rays until about 10.7 mm. The first dorsal and pelvic fins have a brief development period following notochord flexion, and rapidly achieve their full count of rays by 6.5 mm and 7.1
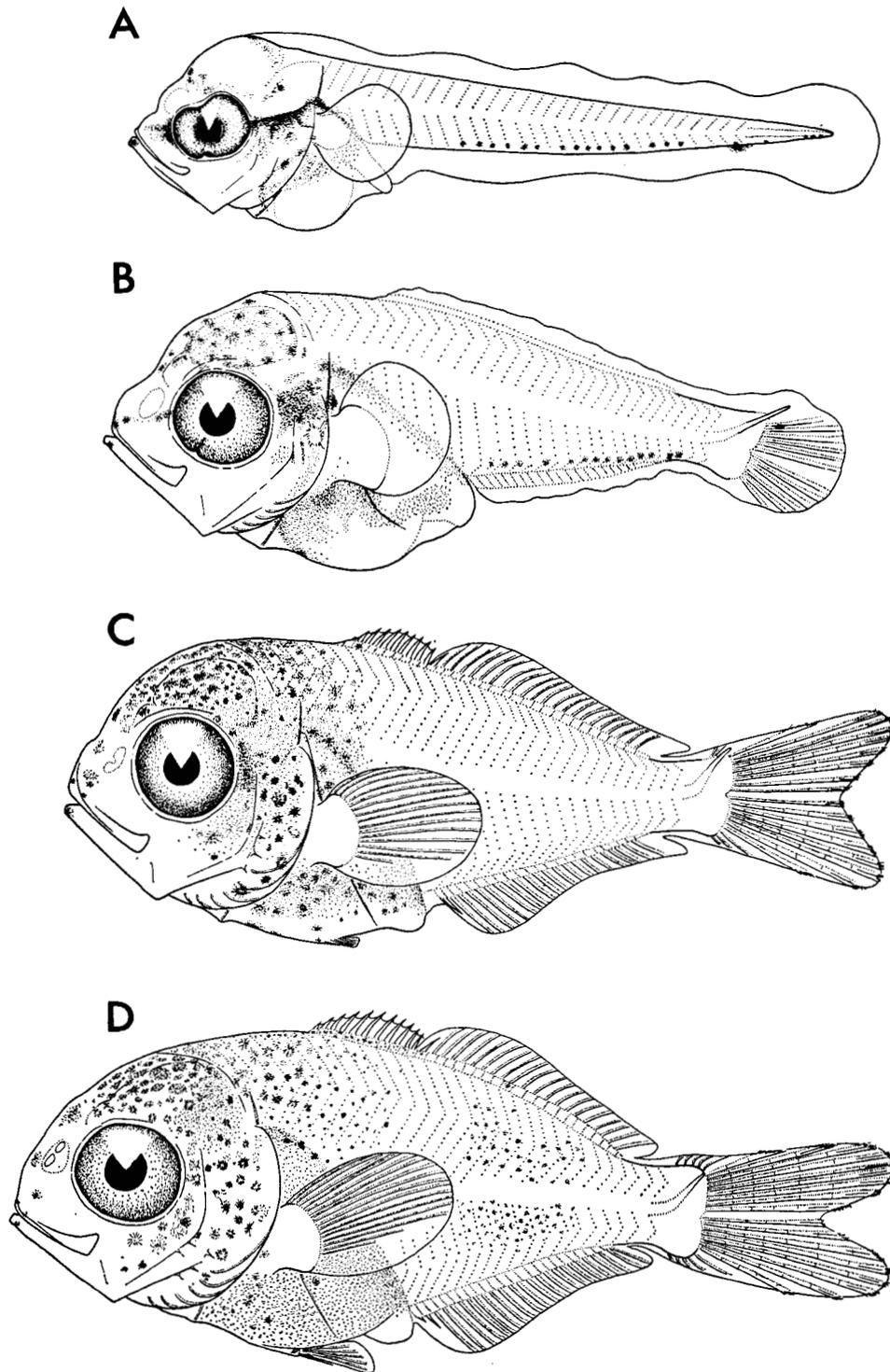
Figure 15.   Developmental stages of *Cubiceps caeruleus* (Nomeidae). A—3.7-mm preflexion larva; B—4.6-mm flexion larva; C—6.2-mm postflexion larva; D—7.1-mm postflexion larva.
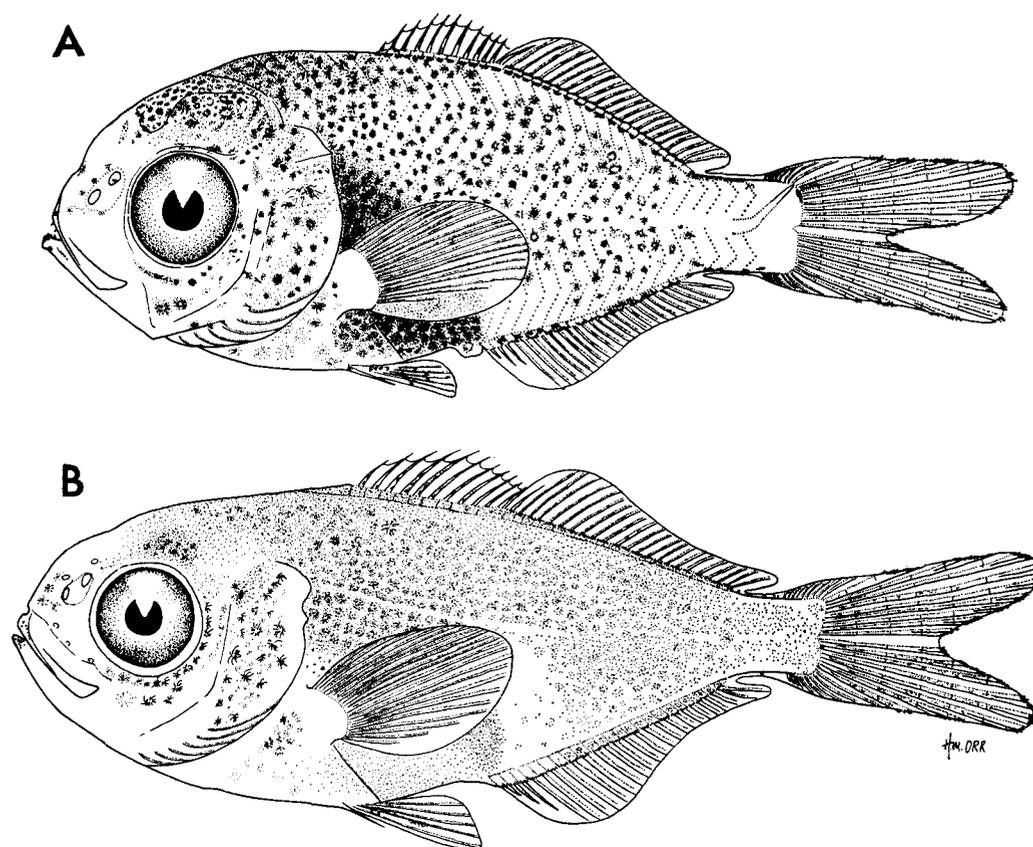
Figure 16. Developmental stages of *Cubiceps caeruleus* (Nomeidae). A—9.4-mm postflexion larva; B —17.5-mm early juvenile.

mm, respectively. Secondary caudal rays are first observed on a 6.5-mm specimen with 4 + 4 rays and may be complete on a 10.0-mm specimen, with 8 + 8 rays.

The vertebral column ossifies early with a 4.4-mm specimen having four neural spines of the most anterior precaudal vertebrae formed, but not their centra. All 31 (12 + 19) vertebrae are ossified by 6.5 mm.

Branchiostegal rays are completely formed in a 4.4-mm specimen. Gill rakers first appear at 5.2 mm, and the full count is reached in a 26.4-mm specimen.

Two or three small, inconspicuous spines form along the preopercular margin by 5.2 mm, and also along the more anterior pre-opercular ridge by 7.1 mm. These weak spines do not persist very long during the larval period and are gradually resorbed beginning in a 10.7-mm specimen, with no trace left in a 16.0-mm specimen.

A few dentary teeth appear on an 8.0-mm specimen, and premaxillary teeth as well on a 10.0-mm specimen. The teeth in both jaws are small and conical. Two palatine teeth are formed on a 17.0-mm specimen, but teeth are lacking on the vomer and glossohyal through the 26.4-mm specimen in the cleared and stained series.

Scale formation in *C. caeruleus* occurs early at a relatively small size. A 10.7-mm specimen has most of its body covered with scales which are very deciduous at this stage. This specimen also has the complete count

Table 25. Meristics of 25 juveniles of *Cubiceps caeruleus* selected from over its distributional range in the eastern Pacific, including off Hawaii (counts made from radiographs)

Station	Location Lat.	Location Long.	Date	Size-SL (mm)	Vertebrae	1st Dorsal fin	2nd Dorsal fin	Anal fin	Caudal fin
J7210-31.135	31°00'N	135°00'W	X.1.72	16.0	12+19=31	XI	I,23	III,20	8-17-8
J7210-31.145	31°00'N	145°00'W	X.4.72	12.5	12+19=31	XI	I,21	III,20	9-17-9
J7210-24.131	24°00'N	131°00'W	X.26.72	16.5	12+19=31	XI	I,21	III,21	9-17-9
J7205-24.145	24°00'N	145°00'W	V.22.72	23.0	12+19=31	XI	I,21	III,21	9-17-9
T.C. 32.010	21°22'N	158°15'W	VII.15.67	63.0	12+19=31	XI	I,22	III,20	9-17-9
T.C. 32.007	21°23'N	158°15'W	VII.14.67	68.0	12+19=31	XI	I,22	III,21	10-17-10
T.C. 32.016	21°19'N	158°13'W	VII.19.67	71.0	12+19=31	XII	I,21	III,20	8-17-10
T.C. 32.020	21°00'N	158°29'W	VII.21.67	65.0	12+19=31	XI	I,21	III,20	9-17-10
J7210-20.123	20°00'N	123°00'W	XI.6.72	15.5	12+19=31	XI	I,20	III,21	9-17-9
"	"	"	"	17.5	12+19=31	XI	I,21	III,21	9-17-9
T.C. 51.070	03°02'S	120°59'W	XI.13.70	31.0	12+19=31	XI	I,21	III,20	8-17-8
"	"	"	"	51.0	12+19=31	XI	I,22	III,21	9-17-8
T.C. 51.071	03°12'S	121°27'W	XI.14.70	35.0	12+19=31	XI	I,21	III,22	9-17-9
"	"	"	"	57.0	12+19=31	XI	I,21	III,21	8-17-8
T.C. 51.056	03°15'S	119°10'W	XI.10.70	25.0	12+19=31	XI	I,22	III,20	8-17-8
"	"	"	"	35.5	12+19=31	XI	I,21	III,20	8-17-8
T.C. 51.065	03°29'S	120°14'W	XI.12.70	24.5	12+19=31	XI	I,21	III,20	8-17-8
T.C. 51.063	03°44'S	119°30'W	XI.12.70	46.0	12+19=31	XI	I,20	III,20	8-17-8
"	"	"	"	54.0	12+19=31	XI	I,20	III,21	8-17-8
Jord. 65.144	04°00.5'S	97°02'W	IX.9.71	121.0	12+19=31	XI	I,21	III,21	8-17-8
"	"	"	"	133.0	12+19=31	XI	I,21	III,20	9-17-9
T.C. 51.048	04°02.5'S	118°48'W	XI.8.70	46.0	12+19=31	XI	I,21	III,21	9-17-8
"	"	"	"	48.0	12+19=31	XI	I,20	III,21	9-17-8
Jord. 65.138	04°05.2'S	96°31'W	IX.7.71	112.0	12+19=31	XI	I,21	III,21	7-17-7
"	"	"	"	125.0	12+19=31	X	I,21	III,21	9-17-9

of rays in all fins, hence may be considered a juvenile.

Pigmentation.—Preflexion larvae of *C. caeruleus* (2.8 to 4.3 mm) are pigmented in three major areas: the ventral tail margin, over the abdominal wall, and on the head. A 3.7-mm preflexion larva (Fig. 15A) shows this characteristic pigment pattern. The ventral tail pigment consists of a row of about 15 discrete melanophores spaced along the tail margin, usually one per myomere with a cluster near the tip of the tail. Abdominal pigment is initially heaviest on the dorsal wall of the peritoneum and gradually spreads out laterally. Head pigment is found on the tips of both jaws, over the midbrain, and in a conspicuous bar extending through the midline of the eyes.

Pigment intensifies over the head and abdomen on flexion larvae of 4.6 to 5.1 mm (Fig. 15B). However, by late flexion, the pigment bar through the eyes is faint and

the row of ventral tail melanophores are less conspicuous.

By 6.2 mm (Fig. 15C), postflexion larvae lose the ventral row of melanophores and the pigment bar through the eyes. Pigment covers the abdomen and also begins to spread over the shoulder. Beginning at about 6.6 mm, an aggregation of pigment appears on the body at about myomeres 18 to 22, which spreads to myomeres 17 to 25 by 7.1 mm (Fig. 15D). Pigment progressively fills in the area between the shoulder and posterior part of the trunk so that by 9.4 mm (Fig. 16A) the body is covered with pigment except for the caudal peduncle, a small area behind the lower abdomen and the forward part of the head. The region of the caudal peduncle remains unpigmented except along the dorsal and ventral margins until about 15 mm when the early juveniles are fairly uniformly pigmented. However, as seen in the 17.5-mm specimen (Fig. 16B), the ventral area anterior and posterior to
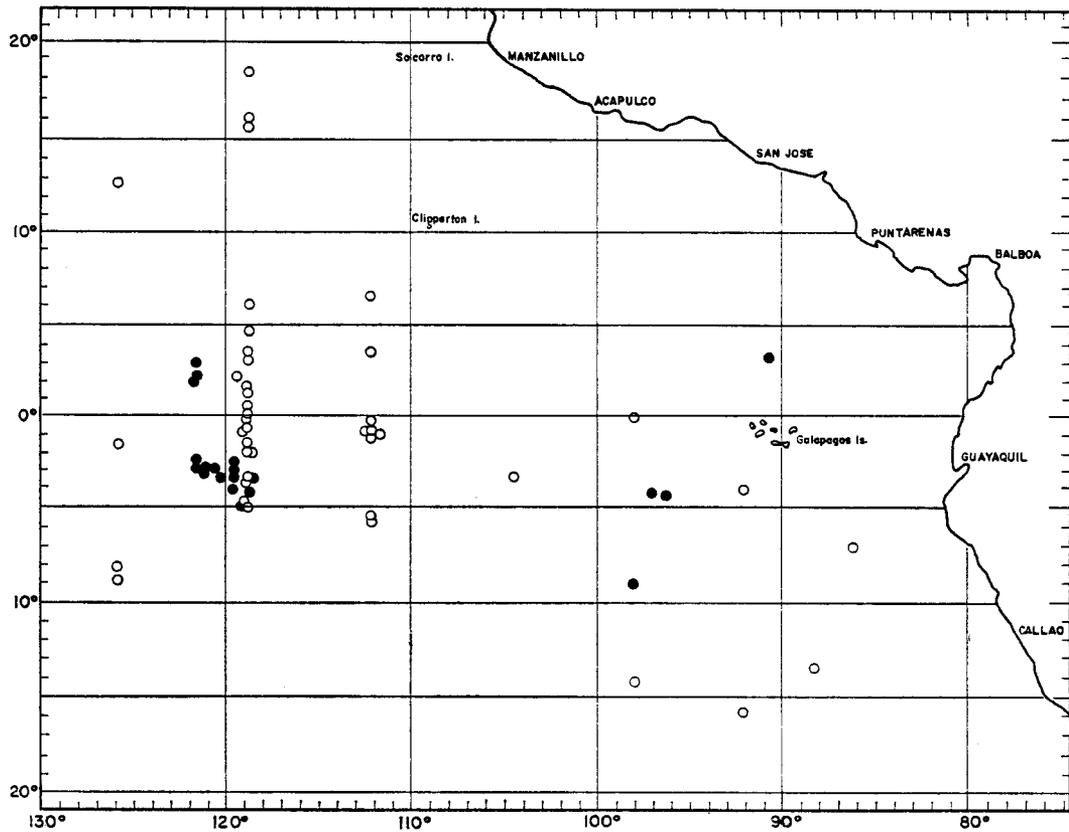
Figure 17. Occurrences of *Cubiceps caeruleus* larvae (open circles) and juveniles (closed circles) in the eastern tropical Pacific.

the abdomen and the lower portion of the head remain sparsely pigmented.

Cubiceps capensis
(Smith, 1849)

Figure 19

Literature.—Craddock and Mead (1970) reported taking a 139-mm specimen at 33°50.5′S, 82°06.14′ W.

Material.—Two late postflexion or early juvenile specimens, 13.9 mm and 15.7 mm, were studied from the eastern South Pacific. In addition, radiographs were studied from Indian Ocean and South African specimens.

Distribution.—*C. capensis* is circumglobal in distribution in the southern oceans. In the South Pacific, it is a temperate water species. Our two specimens are from widely separated localities, one from the offshore central water mass obtained on SIO cruise Cato II at 25°14.8′S, 155°07.7′W, the other taken on SIO expedition Step 1 off Chile at 18°06′S, 80°56′W. The specimen reported by Craddock and Mead (1970) also was taken off Chile.

Distinguishing Characters of Juveniles.— The second dorsal (I, 25) and anal (II, 22 or 23) fin meristics are distinctive for *C. capensis* juveniles. These are the highest counts for a species of *Cubiceps*. The arrangement of predorsal bones differs from all other *Cubiceps* except *C. gracilis* (see following section on ossification). The latter
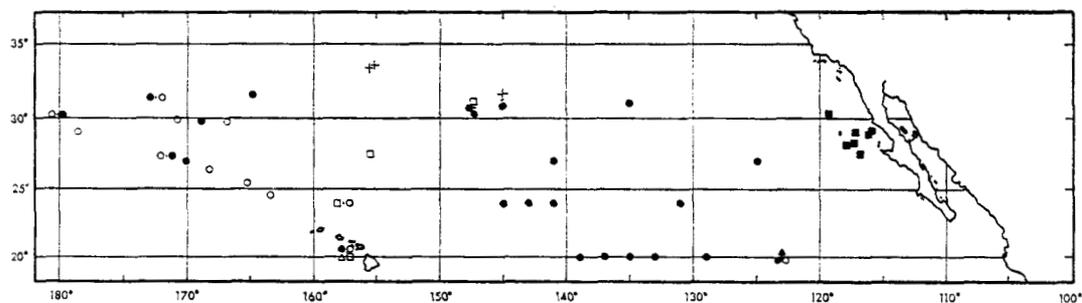
Figure 18. Occurrences of three species of *Cubiceps* and four species of *Psenes* on regular CalCOFI cruises, extended CalCOFI cruises 7205 and 7210, and NORPAC Expedition. *Cubiceps caeruleus* indicated by closed circles, *C. pauciradiatus* by open circles, *C.* sp. B by "plus" signs, *Psenes arafurensis* by open squares, *P. cyanophrys* by an open triangle, *P. maculatus* by a closed triangle, and *P. pellucidus* by solid squares. (Dots indicate station locations.)

species has 33 or 34 vertebrae, not 31, as in other *Cubiceps*.

Meristics.—Vertebrae 12 + 19 = 31; first dorsal X or XI; second dorsal I, 25; anal II, 22 or 23; principal caudal rays 9 + 8; sec-

ondary caudal rays 8 or 9 dorsal + 8 or 9 ventral (see Table 28).

Morphometrics.—The morphometrics of the two specimens of *C. capensis* are given in Table 29, and their body proportions

Table 26. Morphometrics, in mm, of larvae and juveniles of *Cubiceps caeruleus* (specimens between dashed lines are undergoing notochord flexion)

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
ETP 60.072	3.4 NL	1.1	0.62	0.27	0.15	0.70	-	-	-
ETP 60.078	3.7	1.5	0.92	0.38	0.26	0.96	-	-	-
ETP 45.125	4.4	1.9	1.2	0.54	0.30	1.6	base	2.2	-
ETP 50.071	4.8	2.2	1.3	0.58	0.42	1.7		2.4	-
ETP 50.061	4.9	2.1	1.4	0.56	0.34	1.7		2.4	-
ETP 30.083	4.6	2.5	1.6	0.68	0.36	1.9	1.9	2.5	-
ETP 45.177	4.9	2.4	1.5	0.68	0.40	2.0	2.0	2.5	2.0
ETP 75.064	4.7 SL	2.4	1.6	0.68	0.42	1.9	2.0	2.7	2.0
ETP 50.082	5.2	2.5	1.6	0.66	0.44	2.0	2.1	2.8	2.0
ETP 50.071	6.2	3.2	2.1	0.88	0.56	2.6	2.5	3.5	2.4
"	6.5	3.6	2.4	1.0	0.50	2.9	2.9	4.0	2.7
"	7.1	3.9	2.4	1.0	0.58	3.2	2.9	4.2	3.1
ETP 50.055	8.0	4.8	2.8	1.1	0.55	3.6	3.5	4.8	3.3
ETP 60.060	10.0	5.2	3.4	1.4	0.60	4.4	4.2	6.3	4.3
ETP 12.221	10.1	6.0	3.6	1.5	0.84	4.5	4.2	6.1	4.2
J7210-20.123	11.2*	6.4	3.7	1.6	0.97	4.4	4.5	6.5	4.3
"	12.4*	7.0	4.4	1.8	0.97	5.4	5.0	7.3	5.2
South Tow 13	13.2*	7.6	4.4	2.1	0.92	5.6	5.4	3.0	5.5
J7205-20.129	14.4*	8.5	4.6	2.1	0.94	5.8	5.7	9.6	5.6
"	15.0*	8.9	5.0	2.1	1.3	5.9	6.0	9.1	6.0
J7210-31.135	16.0*	9.1	5.3	2.2	1.3	6.2	6.2	9.3	6.4
ETP 45.177	17.0*	9.8	6.0	2.3	1.4	6.9	6.8	10.7	6.5
J7205-20.129	22.7*	12.5	7.2	2.7	1.5	8.5	9.2	13.2	8.0

* Juvenile
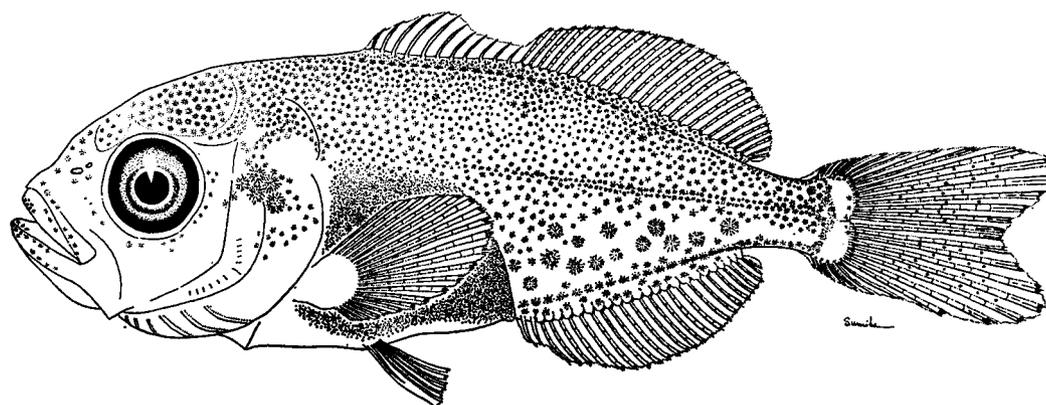
Figure 19. Early juvenile of *Cubiceps capensis* (Nomeidae), 15.7 mm.

in Table 24, and these are discussed in the previous "Comparative Morphometrics" section.

Ossification.—Although no specimen was cleared and stained, the arrangement of predorsal bones and pterygiophores in relation to the axial skeleton was determined from radiographs of these and additional specimens. The number of precaudal vertebrae could be readily determined on the two small specimens as 12. Separation of vertebrae into precaudal versus caudal groups becomes difficult on larger specimens. The dorsal fin is preceded by three predorsal bones. The first predorsal precedes the first neural

Table 27. Meristics of cleared and stained larvae and juveniles of *Cubiceps caeruleus* (specimen between dashed lines is undergoing notochord flexion)

Station	Size (mm)	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchiostegal rays	Gill rakers (right)	Teeth (left) Prem.	Teeth (left) Dent.
ETP 45.125	4.4 NL	-	-	-	LP	-	-	4+ 0= 4†	2+4	-	-	-
ETP 50.071	4.8	-	-	-	LP	-	0-3+3-0	5+ 0= 5†	2+4	-	-	-
ETP 50.082	5.2 SL	-	6	6	8	-	0-8+8-0	12+11=23†	2+4	0+1+6	-	-
ETP 50.071	6.5	X	1,21	II,22	16	1,4	4-9+8-4	12+19=31	2+4	1+1+9	-	-
ETP 75.068	7.1	X	1,21	III,20	16	1,5	4-9+8-5	12+19=31	2+4	2+1+9	-	-
ETP 50.055	8.0	XI	1,22	III,21	17	1,5	6-9+8-6	12+19=31	2+4	3+1+11	0	2
ETP 60.060	10.0	XI	1,21	III,21	19	1,5	8-9+8-8	12+19=31	2+4	4+1+12	2	4
J7210-20.123	10.7*	XI	1,20	III,20	20	1,5	8-9+8-8	12+19=31	2+4	6+1+12	1	3
"	12.4*	XI	1,21	III,22	21	1,5	9-9+8-9	12+19=31	2+4	6+1+13	6	5
Hawaii 71-6-14	13.7*	XI	1,22	III,20	20	1,5	9-9+8-10	12+19=31	2+4	6+1+14	6	6
J7205-20.129	14.4*	XI	1,22	III,20	22	1,5	10-9+8-10	12+19=31	2+4	7+1+15	6	4
T.C. 51.066	15.2*	XI	1,20	III,21	21	1,5	8-9+8-8	12+19=31	2+4	5+1+15	4	6
J7210-31.145	16.0*	XI	1,22	III,20	23	1,5	9-9+8-9	12+19=31	2+4	5+1+15	5	4
ETP 45.177	17.0*	X	1,22	III,21	22	1,5	7-9+8-8	12+19=31	2+4	6+1+14	7	6
T.C. 51.066	18.2*	X	1,22	III,21	22	1,5	9-9+8-9	12+19=31	2+4	7+1+15	8	5
T.C. 51.066	20.2*	XI	1,20	III,21	21	1,5	8-9+8-8	12+19=31	2+4	7+1+15	6	5
J7210-20.123	21.2*	XI	1,20	III,21	21	1,5	9-9+8-9	12+19=31	2+4	7+1+14	9	8
T.C. 51.066	26.4*	XI	1,21	III,20	22	1,5	8-9+8-8	12+19=31	2+4	8+1+16	10	9

* Juvenile

† Vertebrae not completely developed

Table 28. Meristics of juveniles of *Cubiceps capensis*, *Cubiceps* sp. A, and *Cubiceps* sp. B (counts made from radiographs)

Station	Location		Date	Size-SL (mm)	Vertebrae	1st Dorsal fin	2nd Dorsal fin	Anal fin	Caudal fin
	Lat.	Long.							
Cubiceps capensis									
Step 1-32	18°06'S	80°56'W	X.31.60	13.9	12+19=31	XI	1,25	II,22	9-17-9
Cato II-B3.119	25°14.8'S	155°07.7'W	VIII.1.72	15.7	12+19=31	X	1,25	II,23	8-17-8
Cubiceps sp.A									
ETP 11.066 *	06°05'N	118°51'W	II.3.67	8.7	12+19=31	XI	1,22	III,21	mangled
T.C. 51.081	02°10'N	121°37'W	XI.18.70	14.0	12+19=31	XI	1,23	III,22	12-17-12
Jord. 60.150	09°27.7'N	117°49'W	IV.7.71	19.5	12+19=31	XI	1,22	III,22	12-17-12
Cubiceps sp.B									
J7210-31.145	31°00'N	145°00'W	X.4.72	12.5	12+19=31	XI	1,20	III,20	12-17-12
Aries 9-H17	27°28.2-27.0'N	155°28.6-47.0'W	X.2.71	17.9	12+19=31	XI	1,20	III,20	11-17-12
Aries 9-A2	27°22.4-11.8'N	155°01.2-02.9'W	IX.24.71	18.7	12+19=31	XI	1,19	III,20	12-17-12

* Probably postflexion larval stage

spine, the second is spaced between the first and second neural spines, and the third predorsal is spaced between the second and third neural spines, but is not accompanied by the first dorsal fin pterygiophore as in most nomeids; rather this pterygiophore is spaced between the third and fourth neural spines, similar in arrangement to *Cubiceps gracilis*. (The first dorsal pterygiophore supports two spines in a secondary association and the first anal pterygiophore supports only one spine secondarily.) The spacing of anal fin pterygiophores in relation to haemal spines is given in Table 3.

Pigmentation.—The 13.9-mm specimen is bleached and thus of no value for observation of pigmentation. The 15.7-mm specimen (Fig. 19) has well-preserved pigment. It is uniformly pigmented over the dorsal half of the body and more sparsely pigmented on the ventral half; however, pigment is almost lacking over the hypural bones. Pigment is heavy on the upper part of the head, is present on the lips of both upper and lower jaws, but is sparse on the head ventral to the eyes. An accentuated line of pigment spots is present just below the length of the two dorsal fins and anal fin along the margins of the body. Pigment is developed along the base of the caudal fin, with a sprinkling of pigment over the caudal fin. None of the other fins is pigmented.

Cubiceps pauciradiatus
Günther, 1872
Figures 20 and 21

Literature.—Previous records for the eastern Pacific by Alverson (1963) and Haedrich and Nielsen (1966) have referred to *C. carinatus* Nichols and Murphy (1944), which was described from two specimens obtained from approximately 180 miles southwest, 5° west of Cape Mala, Panama. *Cubiceps carinatus* is here considered a junior synonym of *C. pauciradiatus* for reasons discussed below. Abe (1959) reports a specimen from off Japan.

Material.—Extensive collections of larvae were examined from EASTROPAC cruises, from collections by T. Clarke off Hawaii, and from CalCOFI cruises. Juvenile and adult material was examined from R/V DAVID STARR JORDAN and R/V TOWNSEND CROMWELL cruises in the eastern tropical Pacific and from TOWNSEND CROMWELL cruise 32 off Hawaii. Comparative larval material was examined from the Atlantic, Indian, and west Pacific oceans. Radiographs of the type and paratype of *C. carinatus* were made available by the American Museum of Natural History.

Distribution.—This species is common and widely distributed in the eastern Pacific. Only larval records for EASTROPAC I are given in Figure 22 (Ahlstrom, 1971). *C. pauciradiatus* occurs to the north into the Gulf of California (Fig. 23) where it is rather common. In the central North Pacific it was common off Hawaii and was taken to the west and north of Hawaii (Fig. 18).

Distinguishing Characters.—JUVENILES AND ADULTS. This species can be distinguished
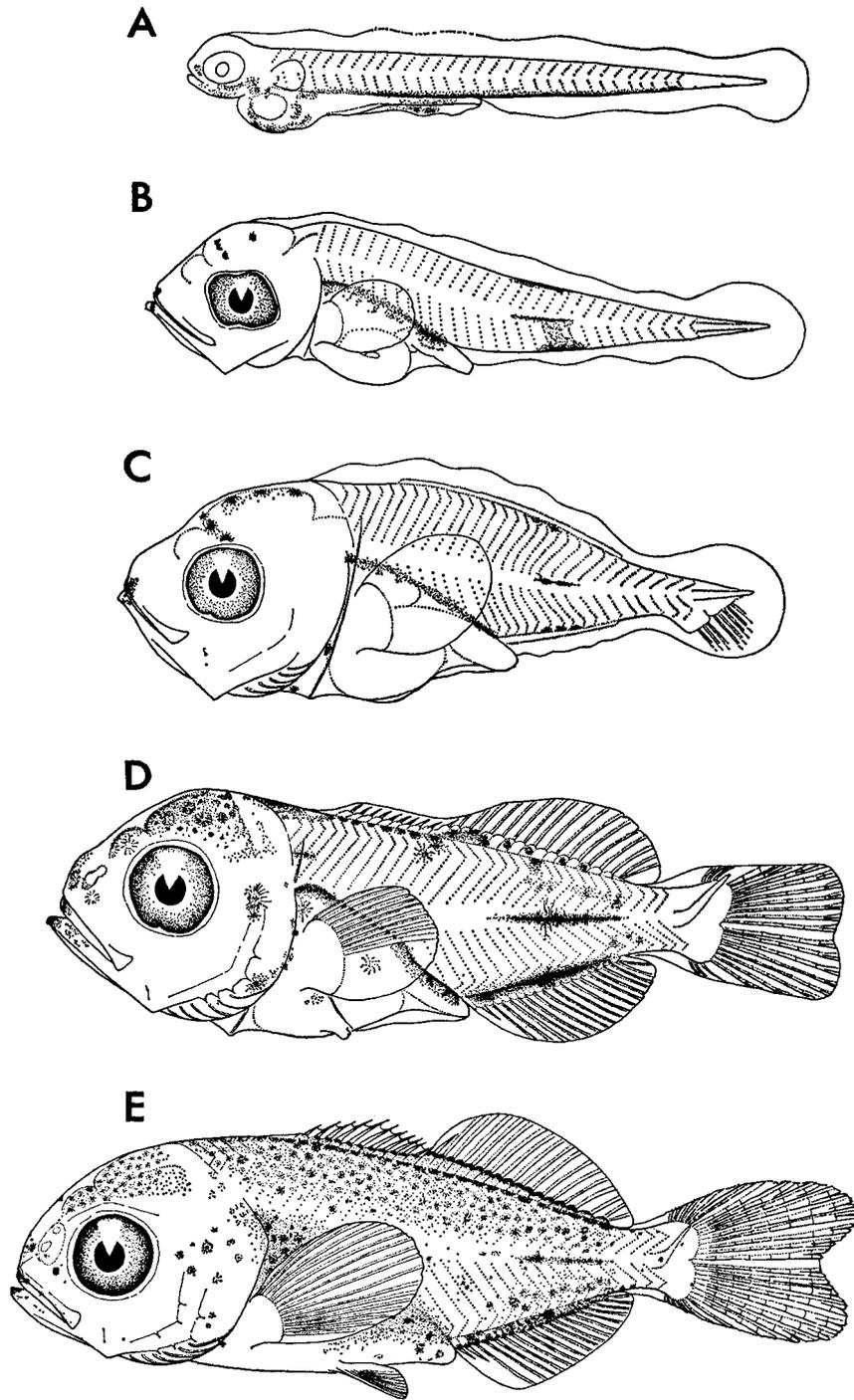
Figure 20. Developmental stages of *Cubiceps pauciradiatus* (Nomeidae). A—2.1-mm preflexion larva; B—3.1-mm preflexion larva; C—3.8-mm early flexion larva; D—5.1-mm postflexion larva; E—8.6-mm postflexion larva.
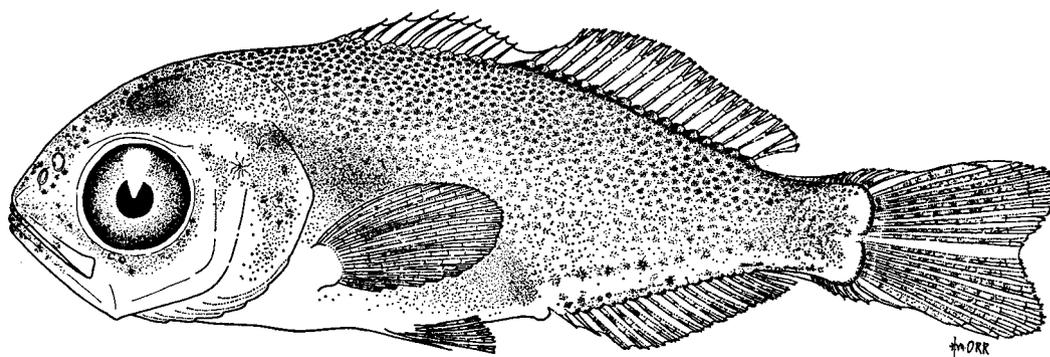
Figure 21.   Early juvenile of *Cubiceps pauciradiatus* (Nomeidae), 17.5 mm.

from all other nomeids by the low second dorsal and anal fin ray counts, the bony keel on the breast, the slender body and the broad patch of teeth on the blade of the vomer and glossohyal. Among nomeids with 31 total vertebrae, this is the only species consistently with 13 (rarely 14) precaudal vertebrae. Only *C. capensis* and this species have two anal spines rather than three among *Cubiceps*. Adults attain a length of less than 200 mm (Haedrich, 1967).

LARVAE. Preflexion larvae of *C. pauciradiatus* are most readily distinguished by the pigment pattern, which is discussed under pigmentation. This characteristic pigment consists of opposing dorsal, lateral, and

ventral streaks on about myomeres 20 to 23. On postflexion larvae, fin meristics can be used in addition to pigmentation; larvae as small as 5 mm have obtained their full complement of dorsal and anal fin rays.

Meristics.—Vertebrae $13 + 18 = 31$ (rarely $13 + 17 = 30$ or $14 + 17 = 31$). First dorsal X to XII (average 10.9); second dorsal I, 15 to 17 (average I, 16.1); anal II, 14 to 16 (average II, 15.0); principal caudal rays $9 + 8$; secondary caudal rays 8 to 10 dorsal $+$ 8 to 10 ventral (average $9.0 + 9.0$).

Meristics of 25 specimens from about 9°S to about 23°N and from about 89° to 158°

Table 29.   Morphometrics, in mm, of *Cubiceps capensis*, *Cubiceps* sp. A, and *Cubiceps* sp. B (all specimens are juveniles except 8.7-mm postflexion larva)

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
Cubiceps capensis									
Step I-32	13.9 SL	8.2	4.3	1.6	1.2	4.2	5.6	8.5	5.4
Cato II-B3119	15.7	9.4	5.2	1.8	1.4	5.4	6.6	9.7	6.2
Cubiceps sp.A									
ETP 11.068	8.7 SL	5.0	3.0	1.1	0.56	3.7	4.1	5.2	3.3
T.C. 51.081	14.0	7.7	4.8	1.9	1.1	5.6	5.8	8.0	5.2
Jord. 60.150	19.5	11.0	6.4	2.3	1.4	7.1	8.0	11.4	7.0
Cubiceps sp.B									
J7210-31.145	12.5 SL	7.0	4.3	1.6	0.9	4.7	5.1	7.1	4.6
Aries 9-H17	17.9	10.0	5.6	2.2	1.2	6.8	7.0	10.4	6.5
Aries 9-A2	18.7	10.4	6.1	2.4	1.3	7.3	7.2	10.7	6.6
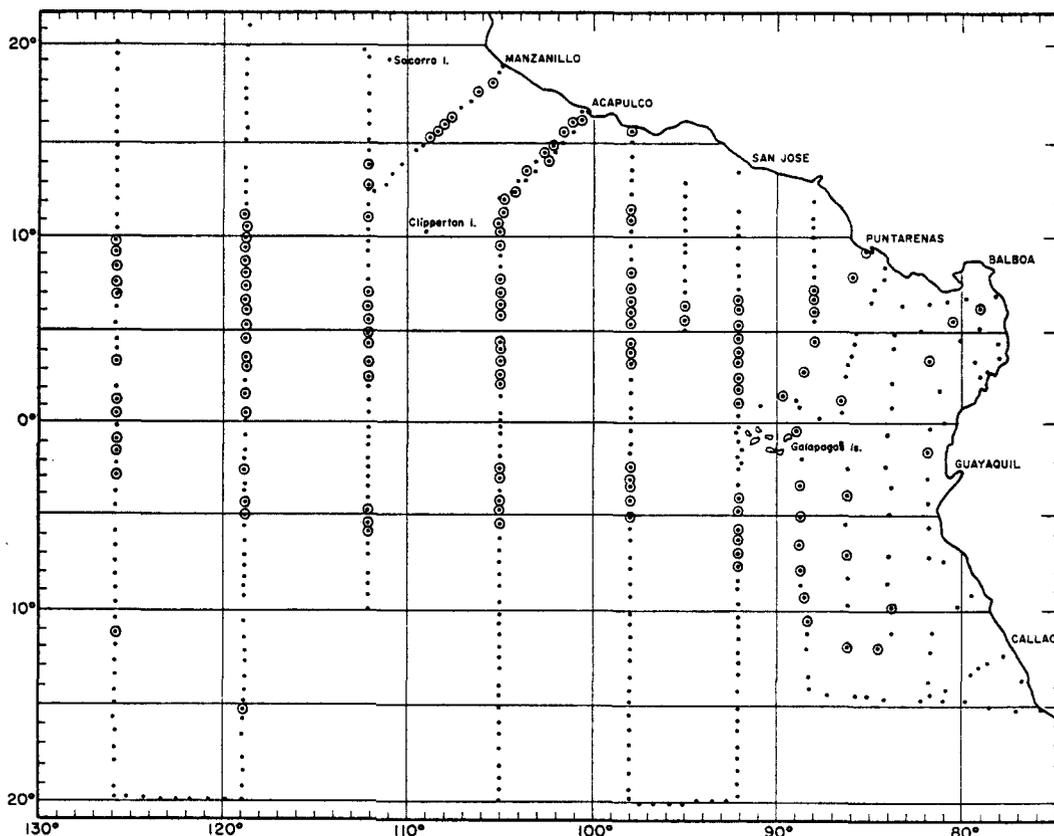
Figure 22. Occurrences of *Cubiceps pauciradiatus* larvae on EASTROPAC I. Records of larvae are indicated by open circles with dot and negative hauls by small dots.

W are given in Table 30. No geographical variation in any count is indicated.

Morphometrics.—Morphometrics of a size series of *C. pauciradiatus* are presented in Table 31. Body proportions are given along with other species of *Cubiceps* in Table 24. See the earlier comparative discussion of *Cubiceps* morphometrics.

Ossification.—The principal caudal rays are first to ossify in *C. pauciradiatus*, with 3 + 3 rays developed on a 3.7-mm specimen (Table 32). The full complement of 9 + 8 principal rays are present by 4.5 mm when secondary caudal rays begin to form. The adult number of 9 + 9 secondary rays is complete in a 12.4-mm specimen. The sec-

ond dorsal, anal, and pectoral fins begin to develop by 4.5 mm and complete their formation in that respective order by 5.0 mm, 6.2 mm, and 10.0 mm. The first dorsal fin spines begin ossifying by 5.0 mm, and a full count of XI is attained by 6.2 mm. The pelvic fins are the last fins to start development with a count of I, 4 on a 6.2-mm specimen, but they obtain the full array of one spine and five rays before 8.8 mm.

The vertebral bones begin formation early with anterior neural spines ossifying by 3.7 mm. The total number of 31 vertebrae is present by 6.2 mm.

Branchiostegal rays form very early with 0 + 4 rays ossifying on each side in a 3.1-mm specimen and the complete number (2 + 4)
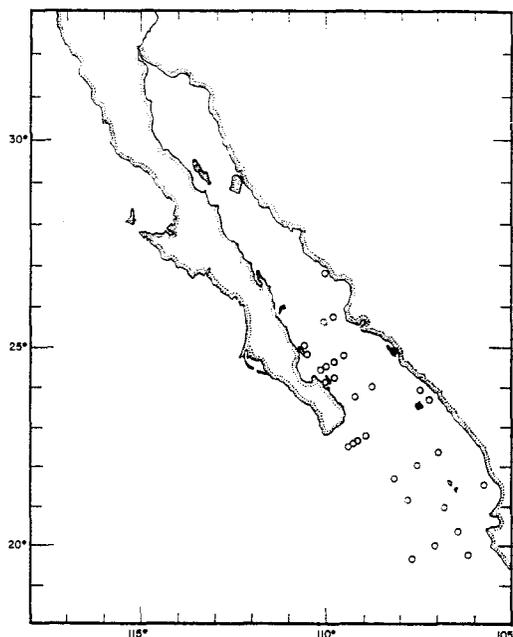
Figure 23. Occurrences of *Cubiceps pauciradiatus* larvae (open circles) and *Nomeus gronovii* (solid square) in the Gulf of California and adjacent areas.

ossifying by 3.7 mm. Gill rakers begin developing on the first arch by 3.7 mm but full counts are still not obtained in a 22.2-mm specimen.

Four to five weak spines form on the margin of the preopercle at about 5.0 mm and subsequently several appear on the pre-opercular ridge at about 8.5 mm. These preopercular spines are resorbed beginning at about 11.2 mm and are never a conspicuous feature during the larval period of development.

Teeth in larvae and early juveniles are small, uniserial, and gradual in development. Premaxillary and dentary teeth first appear by 6.2 mm and slowly increase in number (Table 32). Minute lateral teeth develop at right angles to the regular teeth on the lower jaw of early juveniles, but these are gone by 22.2 mm. The regular teeth are small, broad-based but sharply pointed, and sometimes slightly recurved. No teeth on the

palatines or blade of the vomer are evident at 22.2 mm. Development of glossohyal teeth in early juveniles is discussed in an earlier comparative section on dentition of the stromateoid fishes.

Lateral line scales are developed by 12.4 mm, then gradually spread over other parts of the body. Specimens at this size and larger can be classed as juveniles, inasmuch as all fins are complete and scale formation has begun.

Pigmentation.—In newly hatched larvae of *C. pauciradiatus*, the pigment is distributed along the back with a patch of pigment on the snout much like advanced embryos (as shown in Fig. 2). The pigment migrates ventrally, extending in a continuous line above the gut and along the ventral margin of the tail just short of the notochord tip. At this stage, there is pigment under the head and on the ventral margin of the gut, but the eyes are not yet pigmented; larvae are 1.5 to 2.2 mm long (Fig. 20A). Pigment on the tail soon concentrates into a conspicuous ventral patch beginning about three myomeres behind the anus and extending over three to seven myomeres. A series of two to five small ventral pigment spots persist on the tail just forward of the notochord tip. At this stage, the eyes are pigmented, the mouth is well formed and the body is beginning to deepen; the larvae are about 2.0 mm long. Early preflexion larvae between 2.0 and 2.5 mm develop a lateral line dash of pigment above the ventral streak, and by about 3.0 mm, form an opposing dorsal patch (Fig. 20B). Meanwhile, the pigment under the gut has coalesced into one or two spots posterior to the cleithrum, and these disappear before flexion, but a spot appears forward of the cleithrum on the ventral margin (Figs. 20C and 29K). Some pigment develops on the top of the head and on both jaws prior to flexion. Unlike *C. caeruleus*, there is no pigment streak developed through the midline of the eye on larvae of *C. pauciradiatus*.

Pigmentation during flexion does not

Table 30. Meristics of 25 juveniles and adults of *Cubiceps pauciradiatus* selected from over its distributional range in the eastern Pacific, including off Hawaii (counts made from radiographs)

Station	Location Lat.	Location Long.	Date	Size-SL (mm)	Vertebrae	1st Dorsal fin	2nd Dorsal fin	Anal fin	Caudal fin
MV 68-I-4	22°42.7'N	109°54'W	I.9.69	69.9	13+18=31	XI	I,16	II,15	9-17-9
T.C. 32.005	21°22'N	158°13'W	VII.13.67	84.0	13+18=31	XI	I,17	II,16	9-17-9
T.C. 32.023	21°00'N	158°30'W	VII.22.67	96.0	13+18=31	XI	I,17	II,16	9-17-9
Defiance 68(1)-6	19°36'N	111°07'W	VIII.19.68	115.0	13+18=31	XI	I,16	II,15	8-17-8
ETP 50.134	17°11'N	106°44'W	XI.6.67	55.3	13+18=31	XI	I,16	II,15	9-17-9
Scot Exped #81	14°47'N	94°21'W	V.29.58	55.0	13+18=31	XI	I,16	II,15	10-17-10
Jord. 57.013	13°27'N	119°01'W	XI.9.70	110.0	13+18=31	XI	I,16	II,15	9-17-10
Jord. 57.012	13°16'N	119°23'W	XI.9.70	117.0	13+18=31	XI	I,17	II,15	9-17-9
TO 59(1)-28	12°41'N	91°35'W	II.8.59	30.5	13+18=31	XI	I,16	II,15	9-17-9
Jord. 77.166	11°31'N	121°18'W	II.8.73	23.7	13+17=30	XI	I,16	II,14	8-17-8
Jord. 57.024	10°47.5'N	119°30'W	XI.11.70	93.0	13+18=31	XI	I,16	II,15	10-17-10
Jord. 57.052	10°05'N	117°42'W	XI.16.70	11.6	13+18=31	XI	I,16	II,15	8-17-8
Jord. 57.041	10°00'N	118°20'W	XI.13.70	87.0	13+18=31	XI	I,17	II,15	9-17-9
TO 58(2)-A/B	09°48.5'N	89°14.5'W	XI.22.58	28.0	13+18=31	X	I,16	II,15	9-17-9
Jord. 57.113	07°14.6'N	119°24'W	XII.7.70	25.0	13+18=31	XI	I,16	II,15	10-17-10
ETP 13.340	05°37'N	94°56'W	III.20.67	15.6	13+18=31	X	I,16	II,15	9-17-9
TO 58(1)-56	05°31.5'N	86°43'W	V.16.58	43.6	13+18=31	XI	I,16	II,14	9-17-9
Jord. 65.025	04°22'N	97°58'W	VIII.24.71	20.5	13+18=31	XI	I,17	II,15	9-17-9
T.C. 51.087	01°17'N	120°06'W	XI.20.70	122.0	13+18=31	XI	I,17	II,16	9-17-8
Jord. 65.214	00°30'S	97°13'W	IX.28.71	36.0	13+18=31	XI	I,16	II,14	9-17-9
T.C. 51.056	03°12'S	119°26'W	XI.10.70	124.0	13+18=31	XI	I,16	II,16	9-17-9
T.C. 51.071	03°12'S	121°27'W	XI.14.70	113.0	13+18=31	XI	I,15	II,15	9-17-9
T.C. 51.048	04°02'S	118°48'W	XI.8.70	107.0	13+18=31	XI	I,15	II,14	9-17-9
ETP 13.071	04°16'S	92°05'W	II.16.67	18.3	13+18=31	XI	I,16	II,14	9-17-9
Jord. 65.108	09°00'S	98°00'W	IX.3.71	107.0	14+17=31	XI	I,17	II,15	9-17-9

change significantly from that of late pre-flexion except for increased pigment on the head (Fig. 20C).

Following flexion, however, pigment formation is augmented. By 5.1 mm (Fig. 20D), the upper head region becomes densely pigmented and scattered melanophores develop on the snout and opercle. Accentuated pigment forms on the shoulder and along the bases of the dorsal and anal fins, with melanophores also appearing between the dorsal, lateral, and ventral pigment streaks.

By 8.6 mm (Fig. 20E), the upper portion of the abdomen and the dorsal half of the body, except the caudal peduncle region, become uniformly pigmented. Pigment gradually spreads over the caudal peduncle area in early juveniles, and by 17.5 mm (Fig. 21), *C. pauciradiatus* is covered with pigment although still sparse ventrally.

Discussion.—In the original description of *C. carinatus*, Nichols and Murphy (1944)

noted that the combination of long pectorals and rather short dorsal and anal fins was shared by several other species. However, they considered the keeled breast and large deciduous scales to be unique to their species, which they placed in a new subgenus, *Mandelichthys*. Haedrich (1965), in his description of *C. athenae* Haedrich, noted that the keeled breast, large deciduous scales, two anal spines, and low ray counts in the dorsal and anal fins were unifying characters for five nominal species in the subgenus *Mandelichthys*: *C. pauciradiatus*, *C. longimanus* Fowler (1934), *C. nesiotes* Fowler (1938), *C. carinatus* and *C. athenae*. Haedrich (1965, 1967) placed *C. nesiotes* Fowler as a probable synonym of *C. pauciradiatus*. Haedrich (1972) indicated that *C. longimanus* Fowler was also probably synonymous with *C. pauciradiatus* and suggested that *C. athenae* may be an Atlantic synonym of *C. pauciradiatus*.

Table 31. Morphometrics, in mm, of larvae and juveniles of *Cubiceps pauciradiatus* (specimens between dashed lines are undergoing notochord flexion)

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
ETP 60.062	2.1 NL	1.1	0.44	0.14	0.11	0.35	-	-	-
ETP 60.060	2.5	1.3	0.46	0.21	0.15	0.46	-	-	-
ETP 13.048	3.1	1.8	0.82	0.30	0.28	1.0	-	-	-
ETP 60.195	3.8	2.2	1.1	0.46	0.42	1.2	base	2.2	-
"	3.7	2.3	1.3	0.44	0.24	1.3	1.6	2.3	-
ETP 75.198	4.0	2.4	1.3	0.42	0.32	1.1	1.6	2.4	-
ETP 60.195	4.3	2.5	1.4	0.46	0.38	1.6	1.7	2.5	-
H5612-170.G.20	4.4 SL	2.8	1.5	0.54	0.40	1.5	1.9	2.8	1.8
ETP 75.198	5.0	3.2	1.8	0.59	0.48	1.8	2.3	3.4	2.3
ETP 75.048	6.3	4.0	2.2	0.76	0.55	2.3	2.6	3.9	2.6
ETP 45.028	7.4	4.8	2.6	0.97	0.71	2.8	3.3	5.3	3.2
H5612-170.G.30	8.6	5.2	2.8	0.99	0.71	3.0	3.3	5.4	3.5
ETP 12.246	9.4	5.9	3.1	1.1	0.84	3.2	3.8	6.0	4.1
H5612-170.G.20	10.0	6.2	3.4	1.2	0.80	3.3	4.0	6.3	4.2
ETP 30.248	11.2	7.2	4.0	1.3	0.83	4.0	4.5	7.3	4.8
"	12.4*	7.8	4.4	1.5	1.1	4.4	5.2	8.4	5.4
ETP 45.325	13.5*	8.4	4.6	1.7	1.0	4.5	5.5	9.0	5.5
ETP 30.248	14.2*	8.8	4.8	1.7	0.92	4.7	5.7	9.2	6.0
ETP 11.213	15.0*	9.7	5.2	1.7	1.1	5.1	6.0	10.0	6.5
ETP 20.195	16.0*	10.0	5.2	1.7	1.2	5.2	6.2	10.2	6.7
Hawaii 70-9-23	17.5*	11.0	6.0	2.0	1.3	5.7	6.5	10.9	7.0
ETP 45.028	22.2*	13.0	6.8	2.5	1.3	6.6	7.8	13.4	8.3
Hawaii 71-6-2	27.5*	17.2	8.4	3.1	2.1	7.7	10.2	17.4	11.5

* Juvenile

Haedrich (1965, 1972) distinguished *C. athenae* from *C. pauciradiatus* on the basis of a precaudal vertebral count of 13 rather than 14. We have observed that small specimens of *C. pauciradiatus* from the Pacific, Indian, and Atlantic oceans almost always have 13 + 18 = 31 vertebrae. In radiographs of larger specimens, however, the precaudal vertebrae can be read as 14 or even 15, inasmuch as the haemal spines on vertebrae 14 and 15 in larger specimens are markedly bent posteriorward and are less conspicuous than the pleural ribs that also are developed on these vertebrae (Fig. 1). Since the vertebral counts are in fact the same, *C. athenae* should be regarded as a synonym of *C. pauciradiatus*.

The dorsal and anal fin ray counts of *C. carinatus* given by Nichols and Murphy (1944) are lower than that of *C. pauciradiatus*. Radiographs of the type and paratype show higher counts. The type of *C. carinatus*, 103 mm SL, has 13 + 18 = 31 vertebrae; dorsal XI, I, 15; anal II, 15;

caudal 9-17-9. The paratype, 91 mm SL, has 13 + 18 = 31 vertebrae; dorsal XI, I, 15; anal II, 15; and caudal 7-17-7. The counts fall within the range of *C. pauciradiatus*. The arrangement of anal pterygiophores in relation to haemal spines is precisely the same as in *C. pauciradiatus*. Further, larvae from the Atlantic, Indian, and Pacific oceans do not indicate more than one species. We therefore consider *C. carinatus* a junior synonym of the cosmopolitan *C. pauciradiatus*.

Cubiceps sp. A

Figure 24

Literature.—To date, secondary caudal rays have not been given in the literature for nomeids. For that reason, we are not able to assign this species to any described for the genus *Cubiceps*.

Material.—We examined three specimens from the eastern tropical Pacific, 8.7, 14.0 and 19.5 mm (Table 28), and two specimens, 40.5 mm and 43.7 mm, from the China Sea, taken on the Scripps NAGA expedition. The latter two specimens are not
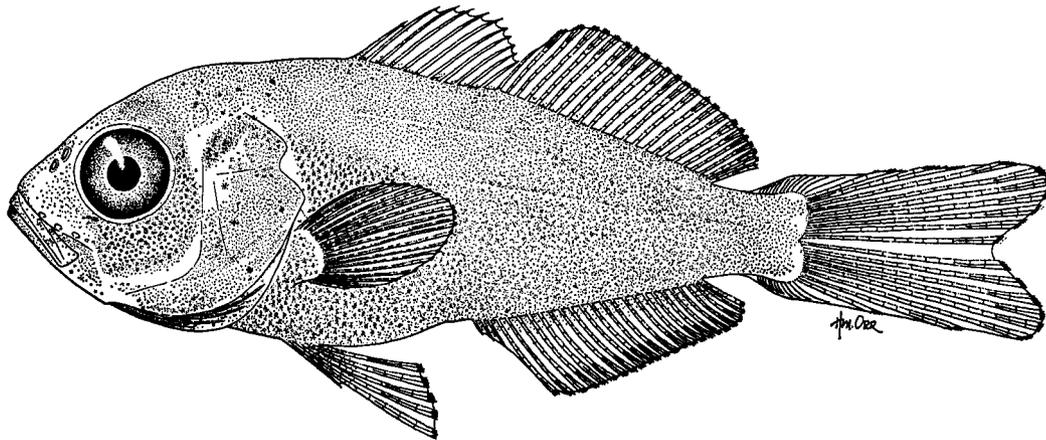
Figure 24.   Early juvenile of *Cubiceps* sp. A (Nomeidae), 19.5 mm.

included in the meristic or morphometric tables (Tables 28 and 29).

The radiograph of a 429-mm specimen in the South African Museum shows characters of *Cubiceps* sp. A. The secondary caudal ray count is somewhat lower with 11 + 10 rays. The specimen has 12 + 19 = 31 vertebrae, a dorsal count of XI, I, 22; anal fin count of III, 22, and a predorsal pterygiophore pattern of 0/0/0 + 2/. The pattern of interdigitation of anal pterygiophores with haemal spines fits the pattern given for *C.* sp. A (Table 3).

Table 32.   Meristics of cleared and stained larvae and juveniles of *Cubiceps pauciradiatus* (specimens between dashed lines are undergoing notochord flexion)

Station	Size (mm)	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchiostegal rays	Gill rakers (right)	Teeth (left) Prem.	Teeth (left) Dent.
ETP 13.048	3.1 NL	-	-	-	-	-	-	-	0+4	-	-	-
ETP 75.198	3.8	-	-	-	-	-	-	-	2+4	-	-	-
ETP 13.191	3.7	-	-	-	-	-	0-3+3-0	9+ 0= 9†	1+4	0+1+0	-	-
ETP 60.195	3.7	-	-	-	-	-	0-4+4-0	9+ 0= 9†	2+4	0+1+0	-	-
"	3.8	-	-	-	-	-	0-5+4-0	-	2+4	-	-	-
ETP 13.243	4.5 SL	-	I,13	I,11	7	-	0-9+8-1	13+10=23*	2+4	0+1+7	-	-
ETP 75.198	5.0	IX	I,15	I,16	10	-	0-9+8-1	13+14=27#	2+4	0+1+7	-	-
ETP 60.195	6.2	XI	I,16	II,15	15	I,4	4-9+8-4	13+18=31	2+4	0+1+10	1	1
ETP 75.048	6.3	XI	I,16	II,15	14	I,3	4-9+8-4	13+18=31	2+4	0+1+10	0	1
ETP 45.028	7.4	XI	I,14	II,15	16	I,4	5-9+8-5	13+18=31	2+4	0+1+10	0	2
[TP 13.048	8.8	XI	I,16	II,16	16	I,5	7-9+8-7	13+18=31	2+4	2+1+10	3	3
H5612-170.G.20	10.0	XI	I,16	II,14	17	I,5	7-9+8-7	13+18=31	2+4	4+1+11	6	3
ETP 13.048	11.2	XI	I,16	II,15	17	I,5	6-9+8-7	13+18=31	2+4	4+1+11	5	8
ETP 30.248	12.4*	XI	I,16	II,15	17	I,5	9-9+8-9	13+18=31	2+4	6+1+13	9	9
"	14.2*	XI	I,15	II,15	19	I,5	9-9+8-9	13+18=31	2+4	6+1+12	10	9
ETP 11.213	15.0*	XI	I,16	II,15	19	I,5	9-9+8-9	13+18=31	2+4	7+1+13	13	11
ETP 20.195	16.0*	XI	I,16	II,15	19	I,5	8-9+8-9	13+18=31	2+4	6+1+13	16	13
Jord. 57.030	18.4*	XI	I,17	II,16	19	I,5	9-9+8-9	13+18=31	2+4	7+1+13	10	14
ETP 45.028	22.2*	XI	I,16	II,15	19	I,5	10-9+8-9	13+18=31	2+4	7+1+13	15	12
Jord. 57.047	52.0*	XII	I,16	II,15	18	I,5	9-9+8-9	13+18=31	2+4	8+1+15	24	29

* Juvenile

" Vertebrae not completely developed
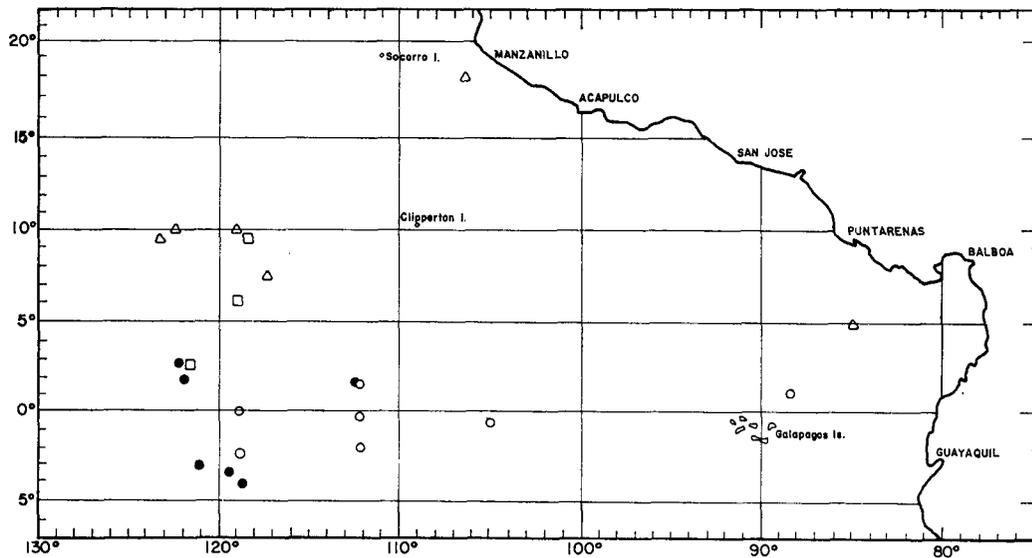
Figure 25. Occurrences of larvae and juveniles of *Cubiceps* sp. A, *Nomeus gronovii*, and *Psenes pellucidus* in the eastern tropical Pacific. Open squares indicate larvae and juveniles of *Cubiceps* sp. A and open triangles indicate larvae and juveniles of *Nomeus*. Larvae of *P. pellucidus* indicated by open circles, juveniles by closed circles.

Distribution.—This species appears to have a tropical distribution (Fig. 25).

Distinguishing Characters.—*Cubiceps* sp. A is very similar to *C. caeruleus* and *C.* sp. B. It may be separated from *C. caeruleus* by its higher number of secondary caudal rays (12 + 12 compared to 7–10 + 7–10, average 8.7 in *C. caeruleus*), its different arrangement of anal fin pterygiophores in relation to haemal spines (Table 3) and its denser pigmentation over the entire body (Fig. 24). *C.* sp. A may be separated from species B by its higher number of second dorsal and anal fin rays (Table 28) and its sparsely pigmented fins (compare Figs. 24 and 26B). As noted in the following pigmentation section, larvae of *C.* sp. A become heavily pigmented at smaller sizes than other *Cubiceps*; the contrast in this character between *C.* sp. A and *C.* sp. B is particularly marked.

Meristics.—Vertebrae 12 + 19 = 31; first dorsal XI; second dorsal I, 22 or 23; anal III, 21 or 22; principal caudal rays 9 + 8;

secondary caudal rays 12 dorsal + 12 ventral; pectoral fin rays, 20 or 21 (Tables 1 and 28).

Morphometrics.—Morphometrics for *C.* sp. A are presented in Table 29 and body proportions in Table 24. The body shape of *C.* sp. A resembles *C. caeruleus* and especially *C.* sp. B more than *C. capensis* or *C. pauciradiatus*.

Ossification.—Ossification data are not available due to the limited amount of material.

Pigmentation.—The 8.7-mm specimen of *C.* sp. A has the head and body completely covered with dense pigmentation except along the bases of the dorsal, anal, and caudal fins. Of all the fins, only the pelvics are pigmented. This species becomes heavily pigmented at a smaller size than any other *Cubiceps* species examined for the present work.

The two larger specimens, 14.0 and 19.5

mm (see Fig. 24 for 19.5-mm specimen) are similarly heavily pigmented except over the posterior margins of the hypural bones. The pelvic fins are pigmented adjacent to the body; the dorsal and anal fins have a sprinkling of pigment immediately adjacent to the body but are otherwise unpigmented; the base of the pectoral fin is pigmented but not the blade; the caudal fin is unpigmented.

Although the body is strongly pigmented on C. sp. A, the fins other than the pelvics are virtually without pigment. This contrasts with the conspicuously pigmented fins on C. sp. B.

Cubiceps
sp. B
Figure 26

Literature.—As with C. sp. A, C. sp. B cannot be assigned to any described species of *Cubiceps* since secondary caudal rays are not discussed in the literature. However, we strongly suspect that a large (586 mm) specimen of a nomeid taken off Portuguese Bend, California, and reported in the literature as C. *gracilis* (Fitch and Lavenberg, 1968) is the adult of species B. This specimen has a similarly high secondary caudal ray count of 12 + 12, 12 + 19 = 31 vertebrae, a dorsal fin count of XI, I, 21 and an anal fin count of III, 21. The specimen appears to lack teeth on the tongue and on the blade of the vomer.

Material.—Three specimens, 12.5 mm, 17.9 mm, and 18.7 mm, were available from the central water mass of the eastern North Pacific (Table 28).

Distribution.—This species appears to be a temperate water species in the North Pacific (Fig. 18).

Distinguishing Characters.—C. sp. B is closely allied to species C. sp. A and C. *caeruleus.* Species B can be distinguished from species A by its lower second dorsal and anal ray counts (Table 28) and different pigment pattern, and from C. *caeruleus* by its higher number of secondary caudal rays and its different pattern of haemal spine interdigitation with anal fin pterygiophores (Table 3).

Meristics.—Vertebrae 12 + 19 = 31; first dorsal XI; second dorsal I, 19 or 20; anal III, 20; principal caudal rays 9 + 8; sec-

ondary caudal rays 11 or 12 dorsal + 12 ventral; pectoral fin rays, 22 (Tables 1 and 28).

Morphometrics.—Morphometrics for C. sp. B are given in Table 29 and body proportions in Table 24. Species A and sp. B are strikingly similar in body shape and body proportions. The only body proportion showing any difference in the two forms was snout to origin of dorsal fin: 41 to 47% of SL in sp. A and 38 to 41% of SL in sp. B.

Ossification.—No data on the sequence of ossification are available with only three specimens in the collection, all of which have complete fins.

Pigmentation.—The smallest of the three specimens of C. sp. B in our collection, 12.5 mm, has most of its tail portion of the body unpigmented (Fig. 26A). The pigment pattern at this stage is reminiscent of that found on smaller sized (ca. 6.2 mm) C. *caeruleus*, except for the line of melanophores along the bases of the dorsal and anal fins, which is reminiscent of pigment augmentation in C. *pauciradiatus.*

The method in which pigment fills in over the tail portion of the body is not known, as the two larger specimens of 17.9 and 18.7 mm (Fig. 26B) are entirely covered with pigment with sparse pigment areas below the head and abdomen. The first dorsal, pelvic, and caudal fins are heavily pigmented but only the anterior portions of the second dorsal and anal fins and the base of the pectorals are sprinkled with pigment.

Genus Nomeus

It is now generally agreed that there is only one widely distributed species in this genus. No differences were observed between specimens from the Atlantic and Pacific oceans.

Nomeus gronovii
(Gmelin, 1788)
Figures 27 and 28

Literature.—Eigenmann (1894) reported a specimen taken in a tidepool on the Gulf of Panama, a

A

B
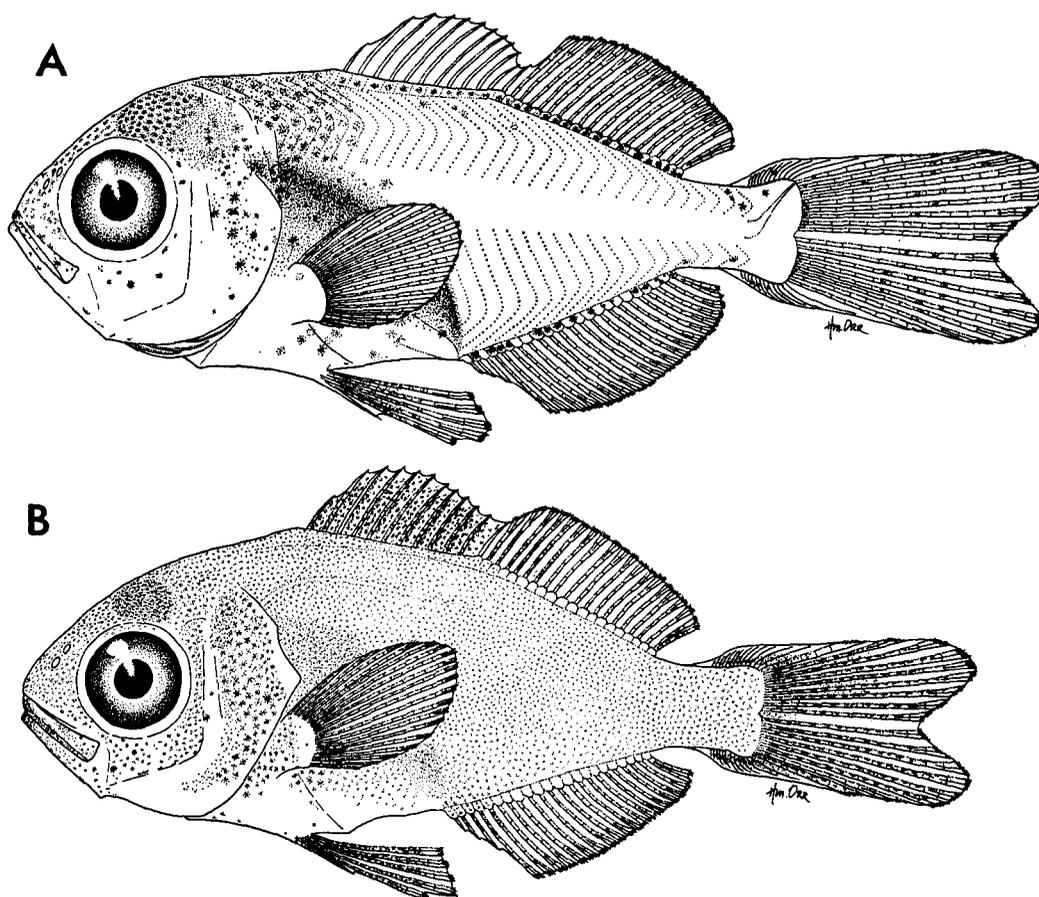
Figure 26.   Early juveniles of *Cubiceps* sp. B (Nomeidae). A—12.5 mm; B—18.7 mm.

most unusual collection locality. Fowler (1928) reported this species from the Hawaiian Islands. Fitch (1953) reported on a specimen taken under a jellyfish from Gordo Point, Baja California. Gooding and Magnuson (1967) observed a specimen at the equator south of Hawaii under a drifting raft.

Material.—Seven specimens of postflexion larvae and juveniles from the eastern tropical Pacific and a moderate number of juveniles from the western North Atlantic were studied.

Distribution.—This species was taken from widely scattered localities in the eastern Pacific. All of the collections are north of 5°N and most are well offshore (Fig. 25). One specimen was taken at the mouth of the Gulf of California (Fig. 23).

Distinguishing Characters.—JUVENILES. *Nomeus* is distinguished by the conspicuous banded pigment pattern on its body and by the large, heavily pigmented pelvic fins. Like some *Psenes pellucidus*, it has 41 vertebrae but differs in having only two anal fin spines, not three.

LARVAE. Postflexion larvae also may be distinguished by the high myomere count, dorsal and anal fin meristics, and pigmentation. Larvae of 7.0 to 8.0 mm may have pigment patches similar to comparable sized *P. cyanophrys*, but *Nomeus* is separated by its higher meristics (especially vertebrae) and more streamlined body. Preflexion larvae are lacking.
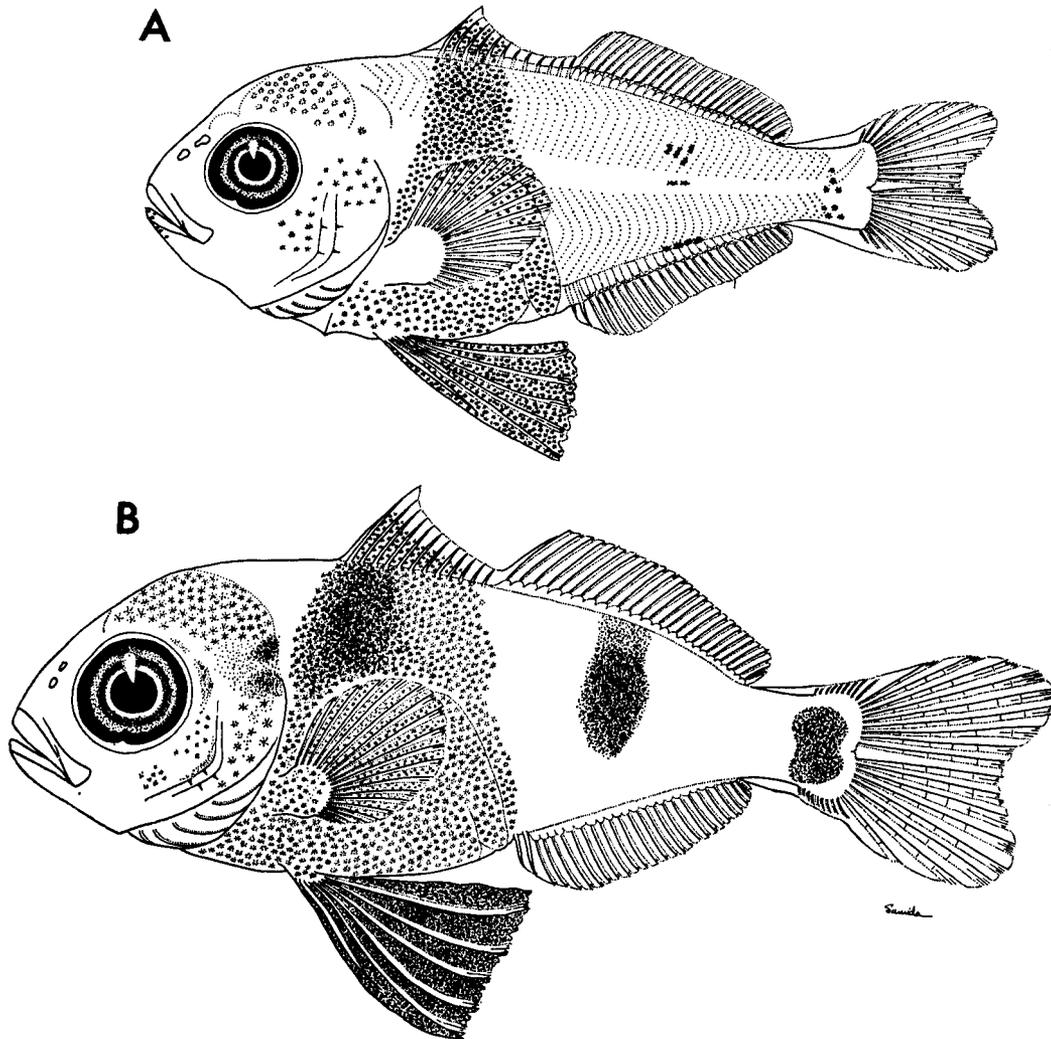
Figure 27. Developmental stages of *Nomeus gronovii* (Nomeidae). A—7.3-mm postflexion larva; B—9.2-mm early juvenile.

Meristics.—Vertebrae 14 + 27 = 41; first dorsal XI or XII (average 11.6); second dorsal 25 to 27 (average 25.9); anal II, 24 to 26 (average II, 25.1); principal caudal rays 9 + 8; secondary caudal rays 8 or 9 dorsal + 8 or 9 ventral (average 8.8 + 8.6) (Table 1).

Morphometrics.—Seven postflexion larvae and early juveniles of *N. gronovii*, 7.3 to 27.5 mm in length, were available for morphometric measurements (Table 33). In some body features, *Nomeus* is similar to *Psenes*, in others, to *Cubiceps*. The snout to anus distance of 56 to 59% of SL (Table 10) is longer than for *Psenes*, but within the range for *C. caeruleus*. The head length of 30 to 34% of SL is about average for nomeids as are the eye diameter of 38 to 44% of HL, and the snout length of 19 to
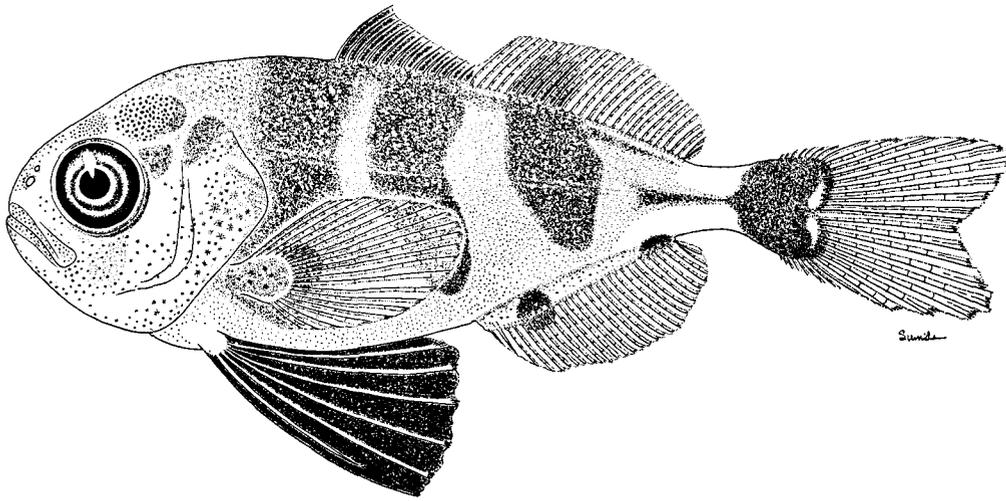
Figure 28.   Early juvenile of *Nomeus gronovii* (Nomeidae), 22.7 mm.

25% of HL. The body depth at base of pectoral fins of 37 to 41% of SL is less than for any species of *Psenes* except *P. sio*, but within the range of several species of *Cubiceps*. The distance from the snout to the anal fin origin of 57 to 61% of body length is longer than for most *Psenes*, but within the range of several species of *Cubiceps*. However, the forward position of the pelvic fin origin of 26 to 34% of SL is closer to *Psenes* than to *Cubiceps*.

Ossification.—Data on the sequence of ossification are not available since the smallest specimen examined, 7.3 mm SL, has most of its fins developed (Fig. 27A). Meristics

for the seven specimens examined are presented in Table 34.

Pigmentation.—Larval and juvenile *Nomeus* have large and heavily pigmented pelvic fins and prominent pigment bands on the body. Postflexion larvae have pigment most developed on the body above the pelvic fins. On the 7.3-mm specimen the tail pigment is very similar to *Psenes* larvae; there is opposing lateral and ventral pigment, and pigment over the hypural bones (Fig. 27A). Pigment is very heavy over the abdomen and extends dorsally in a dark band up to the anterior six spines of the first dorsal fin. However, the space between the pigmented head and

Table 33.   Morphometrics, in mm, of postflexion larvae and juveniles of *Nomeus gronovii*

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
S.B. 162	7.3 SL	4.2	2.4	0.92	0.58	2.8	2.9	4.4	2.5
ETP 45.358	7.5	4.2	2.5	1.1	.52	3.1	3.0	4.3	2.3
Jord. 57.035	8.9	5.0	2.9	1.2	.56	3.4	3.5	5.2	2.7
Jord. 77.119	9.2*	5.4	3.1	1.2	.64	3.5	3.6	5.6	2.8
Jord. 77.155	9.9*	5.6	3.3	1.4	.84	3.7	3.8	5.8	2.7
J7205-157G130	11.9*	6.8	3.6	1.6	.72	4.7	4.6	7.0	3.1
Jord. 77.144	27.5*	14.4	8.2	2.7	1.7	9.2	9.7	15.2	6.0

* Juvenile

Table 34. Meristics of postflexion larvae and early juveniles of *Nomeus gronovii* (Note: only 9.2-mm specimen cleared and stained; vertebral counts of 7.3-mm and 7.5-mm specimens are myomere counts; counts for remaining specimens taken from radiograph)

Station	Size (mm)	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchiostegal rays	Gill rakers (right)	Teeth (left) Prem.	Teeth (left) Dent.
S.B. 162	7.3 SL	XII	26	II,25	17	I,5	3-9+8-3	14+27=41	2+4	3+1+10	2	1
ETP 45.358	7.5	XI	ca 27	ca I,25	16	I,5	7-9+8-7	14+27=41	2+4	3+1+11	3	2
Jord. 57.035	8.9	XI	25	I,26	18	I,5	9-9+8-9	14+27=41	2+4	3+1+10	4	ca 2
Jord. 77.119	9.2*	XII	26	II,25	19	I,5	9-9+8-9	14+27=41	2+4	3+1+11	8	4
Jord. 77.155	9.9*	XI	27	I,26	19	I,5	9-9+8-9	14+27=41	2+4	3+1+11	7	4
J7205-157G130	11.9*	XII	26	II,25	20	I,5	8-9+8-8	14+27=41	2+4	3+1+12	ca 8	5
Jord. 77.144	27.5*	XII	25	II,24	ca 19	I,5	9-9+8-8	14+27=41	2+4	6+1+14	ca 21	ca 11

* Juvenile

the origin of the first dorsal fin remains unpigmented, even on the 9.2-mm specimen. On this specimen the lateral and ventral pigment on the tail have become a large patch under the second dorsal fin (Fig. 27B). The pigment on the hypural bones has become a prominent patch. The pigment on the head has intensified.

The 22.7-mm juvenile has four conspicuous bands of pigment on the body (Fig. 28). There are two bands of pigment under the first dorsal fin, whereas in *Psenes* there is only one band in this region. *Nomeus* has only one band of pigment under the second dorsal, whereas at this size *Psenes* has two or three bands under this fin. The hypural pigment is well developed in both genera. At this size, the pigment under the abdomen has been lost, but the nape is now pigmented. The first dorsal fin as well as the pelvic fins are heavily pigmented. The single pigment patch under the second dorsal fin extends out onto the fin. There are two small ventral pigment patches that extend onto the anal fin. The anal fin is otherwise unpigmented as is the caudal fin.

Genus *Psenes*

Five species of *Psenes* have been collected from the eastern Pacific. Four of the species also occur in the North Atlantic (Haedrich, 1972), and it has been our good fortune to be able to examine larvae and juveniles of three of these: *P. cyanophrys*, *P. maculatus*, and *P. pellucidus*. *P. arafurensis* also is known from the tropical Atlantic and Indian oceans. Only *P. sio*, the common species in the eastern tropical Pacific and Gulf of California, appears to have a distribution limited to the eastern Pacific. We have examined only larvae and juveniles of *Psenes*; adults were not available. The largest juveniles examined of the five species of *Psenes* were as follows: *P. maculatus*, 32.1 mm; *P. sio*, 65.0 mm; *P. cyanophrys*, 80.0 mm; *P. pellucidus*, 95.0 mm; and *P. arafurensis*, 117.0 mm.

Postflexion larvae and early juveniles of *Psenes* usually can be separated from those of *Cubiceps* on the basis of meristics alone; however, separation is more secure when based on a combination of meristics, pigment patterns, morphometrics, and the sequence in which fins form.

Among the five species of *Psenes* from the eastern Pacific, *P. arafurensis* and *P. cyanophrys* have 31 vertebrae, *P. maculatus* has 34 or 35, *P. sio* 36 to 38 and *P. pellucidus* 40 to 42 vertebrae. All five species of *Cubiceps*, however, have only 31 vertebrae. What meristics distinguish among the nomeids with 31 vertebrae?

Cubiceps pauciradiatus averages five less second dorsal and anal fin rays than any eastern Pacific *Psenes*. The two *Cubiceps* designated *C.* sp. A and *C.* sp. B can be separated on the basis of secondary caudal ray counts, as these average approximately four more rays than for the two species of *Psenes* with 31 vertebrae. *C. capensis*, the

species of *Cubiceps* with the highest dorsal and anal fin counts, overlaps these counts with *P. cyanophrys*. However, *C. capensis* has one more first dorsal spine (XI vs. X), one less anal spine (II vs. III), and three less anal rays (22.2 vs. 25.2) than *P. cyanophrys*. *C. caeruleus* and *P. arafurensis* have almost identical average dorsal counts, XI, I, 21.2 vs. XI, I, 21.1 but differ in average anal counts (III, 20.6 vs. III, 22.1). *P. arafurensis* is deeper-bodied than *C. caeruleus* and differently pigmented, hence readily separable on pigment and morphometric characters.

The presence of pelvic fins on preflexion larvae of *Psenes*, 3.0 mm and larger, and their absence on preflexion larvae of *Cubiceps* distinguishes between these two genera.

Differences among pigment patterns in larvae and early juveniles of *Psenes* and *Cubiceps* are summarized in a later section under comparative pigmentation. Early juveniles of *Cubiceps* become rather uniformly pigmented over the body whereas early juveniles of *Psenes* have their pigment clustered in bands and patches.

One of the characters used by Haedrich and Horn (1972) to distinguish between *Psenes* and *Cubiceps* is the origin of the first dorsal fin. The origin is before or directly over the insertion of the pectoral fins in *Psenes*, whereas it is over (in small specimens) or behind the base of the pectoral fins in *Cubiceps*. A similar relation usually is present in larvae and early juveniles of these genera.

Comparative Morphometrics

The morphometrics of *Psenes* are shown in Table 35. There are various developmental characters shared in common by all species of *Psenes*. Early preflexion larvae are smaller-headed and much more slender-bodied than late preflexion larvae and subsequent stages. All species of *Psenes* acquire pelvic fins very early, usually by 3.0 mm NL, undergo flexion at fairly small sizes, i.e., 3.8 to 5.9 mm, and complete larval development between 10 to 15 mm. There is no sharp demarcation between the larval and juvenile stages.

In the sections that follow, emphasis will be placed on postflexion larvae and early juveniles.

Head Length.—Head length ranges between 22 to 29% of NL on preflexion larvae of *Psenes*, between 29 to 36% of NL on flexion specimens, and between 27 to 39% of SL on postflexion specimens. The head is proportionately shorter on the two species with higher vertebral counts, *P. pellucidus* and *P. sio*, although the differences among species is quite moderate. Head length averages 30% of SL in *P. pellucidus*, 32% of SL in *P. sio*, and between 34 to 35% of SL in the other three species.

Eye Diameter.—Proportionate size of the eye is not significantly different among the developmental stages. Eye size averages slightly larger in *P. arafurensis*, ca. 43% of HL, and *P. cyanophrys*, 42% of HL, than in the other three species, which averages between 37 to 39% of HL.

Snout Length.—*Psenes* has a bluntly rounded snout, particularly on postflexion specimens. There is a suggestion of an inverse relationship between eye size and snout length. Snout length averages approximately 20% of HL in *P. arafurensis* and *P. cyanophrys*, 22% in *P. pellucidus*, 23% in *P. maculatus*, and 24% of HL in *P. sio*.

Snout to Anus.—Although the range in length from snout to anus is 46 to 59% of SL on postflexion larvae for the genus as a whole, the range for any given species is usually only about one-half as much. The snout-anus distance averages least on *P. pellucidus*, about 49% of SL, most on *P. maculatus* and *P. cyanophrys*, between 54 to 55% of SL, and intermediate on *P. arafurensis* and *P. sio*, between 51 and 52% of SL.

Body Depth at Pectoral Fin Base.—Postflexion larvae and juveniles of *Psenes* are relatively deep-bodied. For three species

Table 35. Body proportions of five species of *Psenes*, expressed as percentage of standard length (SL) or head length (HL)

Species and stage	Size range (mm)	Snout to anus/SL	Head length/SL	Eye diameter/HL	Snout length/HL	Depth at P base/SL	Sn-D/SL	Sn-A/SL	Sn-V/SL
Psenes arafurensis									
Preflexion	3.2 NL	43	22	47	28	26	-	-	32
Flexion	4.6- 4.9 NL	49-54	29-33	36-41	24-27	33-44	34-35	50-56	30-31
Postflexion	6.5-20.5 SL*	49-54	32-36	41-46	17-23	48-57	35-38	50-58	32-37
Psenes cyanophrys									
Preflexion	2.8- 3.3 NL	48-54	24-27	39-42	18-25	24-29	-	-	36-43
Flexion	3.9- 4.2 NL	51	33	37	23-26	39-41	38	53-54	31-34
Postflexion	4.8-19.1 SL	50-59	31-39	37-47	18-26	44-55	36-40(44)	52-61	33-38
Psenes maculatus									
Flexion	3.8 NL	47	29	36	25	32	34	-	26
Postflexion	6.7-22.8 SL	52-57	33-37	34-41	20-26	45-52	33-40	52-59	28-38
Psenes pellucidus									
Preflexion	3.8- 4.6 NL	39-45	24	37-40	22-25	20-24	-	-	33-37
Flexion	5.2- 5.9 NL	46-47	29	37-38	24-25	32-33	30-35	49-50	31-34
Postflexion	9.7-26.7 SL	46-53	27-33	35-44	18-25	43-57	27-34	48-55	29-35
Psenes sio									
Preflexion	3.2- 3.6 NL	42-50	22	38-43	22-25	20-25	-	-	31-38
Flexion	4.2- 5.5 NL	43-52	31-36	33-40	19-25	31-43	35-38	47-55	29-36
Postflexion	6.0-22.1 SL	46-53	29-35	32-42(56)	22-28	37-45	30-38	47-55	29-34

* Postflexion may include both larvae and early juveniles

(*P. arafurensis, P. cyanophrys,* and *P. pellucidus*), body depth at pectoral fin base averages 50% or more of SL, and it is only slightly less for *P. maculatus* (48% of SL). Only *P. sio* is moderately slender with body depth averaging slightly less than 41% of SL.

Snout to Dorsal Fin Origin.—This length is least for *P. pellucidus,* ca. 30% of SL, averages 34% of SL for *P. sio,* between 36 and 37% for *P. arafurensis* and *P. maculatus,* and over 38% for *P. cyanophrys.*

Snout to Anal Fin Origin.—The origin of the anal fin is close to the vent; the distance between the two seldom differ by more than about 2% of SL. This average difference for each species is approximately 2% greater than the value given under "Snout to Anus."

Snout to Insertion of Pelvic Fins.—Among the five species of *Psenes,* snout to pelvic fin insertions average between 28 to 38% of SL. For all species of *Psenes* except *P. pel-* lucidus, this value is slightly less than that for snout to dorsal fin origin.

Comparative Pigmentation

In all species of *Psenes,* the pelvic fins which form early on preflexion larvae are partially or wholly pigmented. Preflexion larvae of all species of *Psenes* dealt with (except *P. cyanophrys*) have a row of ventral midline pigment spots posterior to the vent, usually spaced one per myomere. These spots are best developed on preflexion specimens; by late preflexion and during flexion the spots become embedded and appear to move dorsad and usually persist to early postflexion. Larvae of all species of *Psenes* that were examined have a lateral line patch of pigment on the tail spaced about midway between the termination of the gut and the tip of the notochord, usually with opposing dorsal and ventral margin patches. This pigment area is developed on preflexion larvae and is retained throughout the larval period with augmentation. In addition, lar-

vae of *Psenes* have pigment on the ventral margin of the notochord near its tip on preflexion larvae, which becomes a patch over the hypural bones on flexion and postflexion larvae.
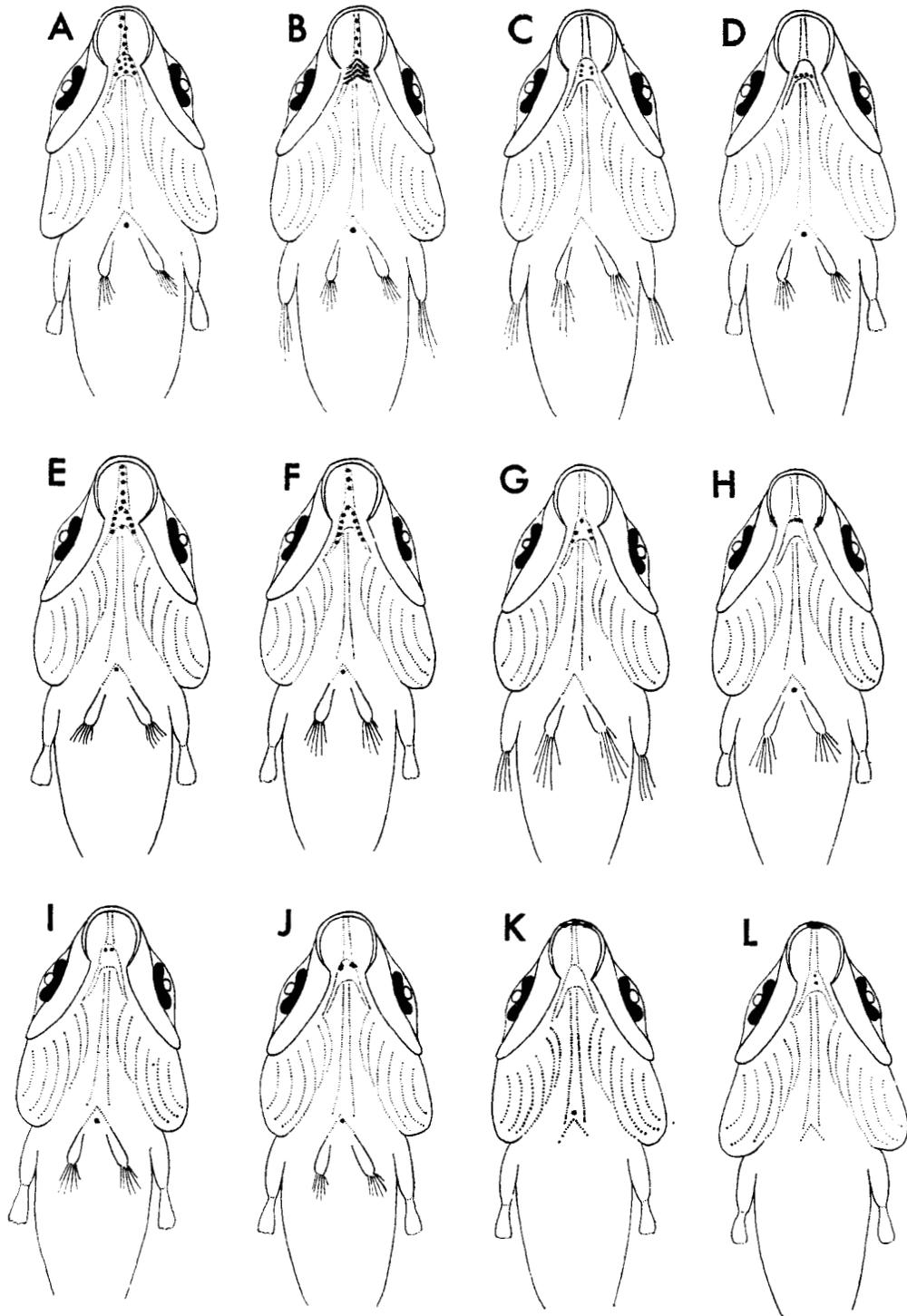
All species of *Psenes* lack pigment on top of the head on preflexion larvae. Pigment on the head begins to form above the eyes during flexion. Pigment on the upper jaw forms on late preflexion or early flexion stage larvae. The characteristic head pigment on preflexion larvae of *Psenes* is that under the lower jaw. This is shown in a series of illustrations of the ventral side of the head and trunk of five species of *Psenes* and two species of *Cubiceps* (Fig. 29). The figures are semi-diagrammatic in that the same basic body form is used for all species. However, each pigment pattern with consequent changes on the underside of the head are unique to each specimen illustrated.

Four illustrations are included of *Psenes pellucidus* (A to D). The lower jaw pigment is best developed on preflexion larvae, as is shown for a 4.2-mm specimen (A), is still heavy on the 5.7-mm early postflexion specimen (B), but is much reduced on the 9.7-mm postflexion specimen (C). Interestingly, Atlantic material of *Psenes pellucidus* lacked the forward anterior-posterior line of pigment under the jaw on a preflexion specimen (D).

Somewhat similar ventral jaw pigment is developed on larvae of *Psenes sio*, in the form of an inverted Y; it is well developed on a 3.8-mm preflexion specimen (E) and on an early postflexion specimen, 5.8 mm (F), but is much reduced on a 6.5-mm postflexion specimen (G).

In contrast to the heavy jaw pigment

developed on preflexion specimens of *P. pellucidus* and *P. sio*, only a cluster of a few spots are developed on preflexion larvae of *P. arafurensis* (H) and only two spots on preflexion larvae of *P. cyanophrys* (I) and *P. maculatus* (J).

All five species of *Psenes* have a pigment spot developed behind the cleithral symphysis on preflexion larvae, which is lost during the postflexion stage.

The ventral head pigment is sparse on preflexion larvae of *Cubiceps*. In the 3.8-mm preflexion specimen of *C. pauciradiatus* (K), the only ventral head pigment is on the tip of the lower jaw. The spot at the cleithral symphysis is anterior to it, not posterior as in *Psenes*. Preflexion larvae of *C. caeruleus* (L) lack the spot at the cleithral symphysis but have two ventral head spots forward of the isthmus and pigment on the tip of the lower jaw.

On postflexion larvae and early juveniles of *Psenes*, pigment develops in patches or streaks on the body. Most of the pigment streaks extending across the body develop from three centers of pigmentation; a dorsal, a lateral and a ventral center. Pigment is most heavily developed on late larvae and early juveniles of *P. cyanophrys*, least developed on *P. pellucidus* and intermediate on the other three species. Differences in patterns of pigmentation with increase in size are discussed under the individual species of *Psenes*. However, we were struck by the similarity in pigment patches that develop on the body of late postflexion and early juvenile specimens of *Psenes*, as is shown in Figure 30.

The pigment patches on the body are strikingly shown on a 22.2-mm specimen of

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Figure 29.   Semi-diagrammatic sketches of ventral head and cleithral pigment patterns of early stages of five species of *Psenes* and two species of *Cubiceps*. A—*Psenes pellucidus*, 4.2-mm preflexion larva; B—*P. pellucidus*, 5.7-mm postflexion larva; C—*P. pellucidus*, 9.7-mm postflexion larva; D—*P. pellucidus*, 4.2-mm preflexion larva, Atlantic specimen; E—*P. sio*, 3.8-mm preflexion larva; F—*P. sio*, 5.8-mm postflexion larva; G—*P. sio*, 6.5-mm postflexion larva; H—*P. arafurensis*, 3.3-mm preflexion larva; I—*P. cyanophrys*, 4.4-mm preflexion larva; J—*P. maculatus*, 3.8-mm preflexion larva, Atlantic specimen; K—*Cubiceps pauciradiatus*, 3.8-mm preflexion larva; L—*C. caeruleus*, 3.7-mm preflexion larva.
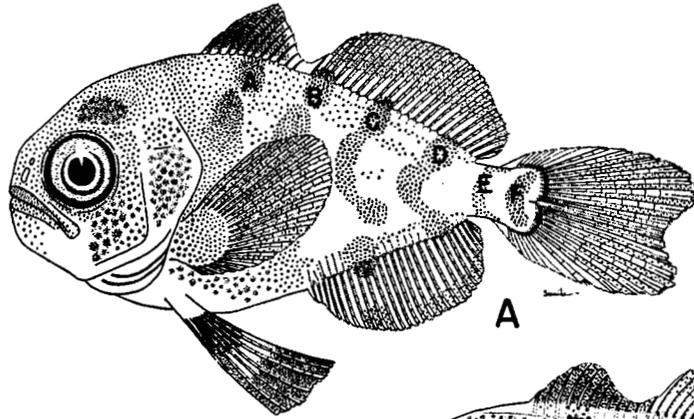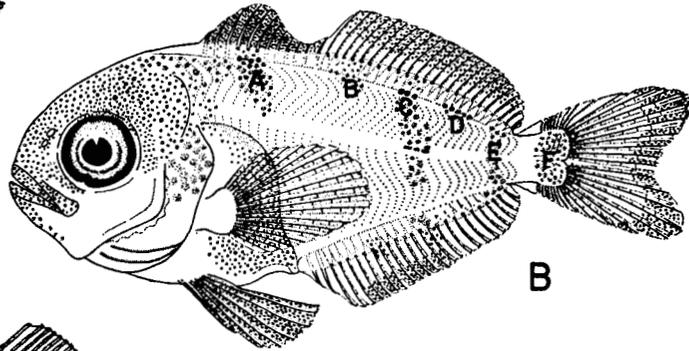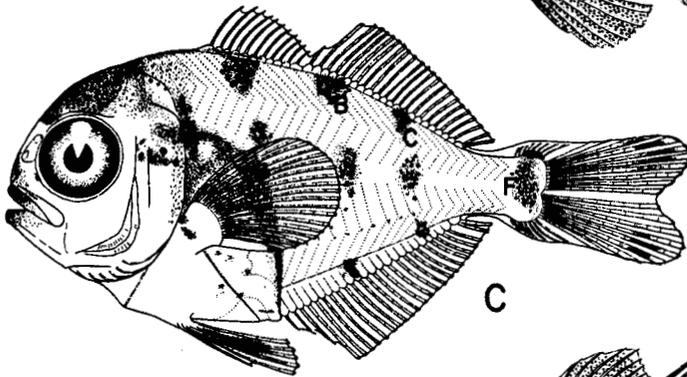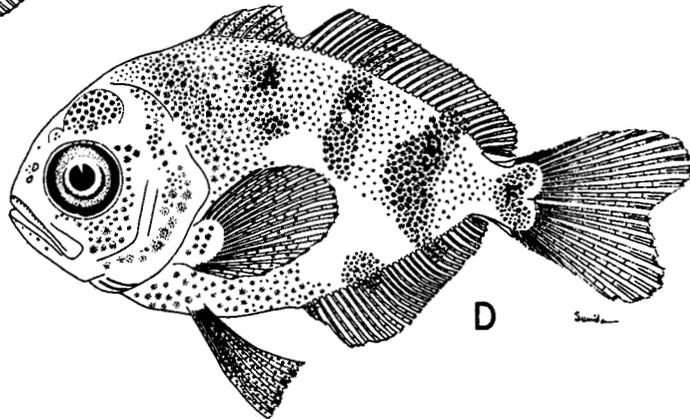
Psenes maculatus (Atlantic) (Figure 30A), which we are labelling A to F. Pigment-patch A develops under the middle of the first dorsal fin, pigment-patch B at the beginning of the second dorsal fin, pigment-patch C in the middle of the second dorsal fin, pigment-patch D near the posterior end of the second dorsal fin, pigment-patch E on the caudal peduncle and pigment-patch F over the hypural plates. The dorsal and lateral patches are still separate for A and B and the ventral patch is separate for C.

There are six dorsal patches developed on a 17.4-mm specimen of *P. sio* (Fig. 30B), that correspond almost precisely to those on *P. maculatus*. The only difference is in the more anterior placement of patch E so that it comes under the terminal rays of the second dorsal fin rather than behind it.

The two species with fewer vertebrae, *P. arafurensis* and *P. cyanophrys*, develop four patches. In an 11.0-mm specimen of *P. arafurensis* (Fig. 30C), the patches correspond to A, B, C and F on *P. maculatus* and are thus labelled. The four pigment patches on an 11.7-mm specimen of *P. cyanophrys* from the Atlantic (Fig. 30D) correspond to patches A, C, D and F of *P. maculatus*. Usually larvae of this size of *P. cyanophrys* are more heavily pigmented over the body but with the pigment patches persisting as intensified areas of pigmentation.

Body pigment develops more gradually on juveniles of *P. pellucidus*, but the six primary areas can be identified, even though additional patches fill in between them on larger specimens.

Psenes arafurensis
Günther, 1889
Figures 31 to 33

Literature.—The only previous record of *Psenes arafurensis* from the eastern Pacific was by Fowler (1928) from the Hawaiian Islands.

Material.—Larvae and early juveniles were examined from the plankton collections from EASTRO-PAC cruises, and 14 pelagic trawl collections from later cruises in the same area. In addition, larvae and early juveniles were examined from off Hawaii and from several localities to the north of Hawaii.

Distribution.—This species was widely distributed offshore between 10°N and 10°S in the eastern tropical Pacific (Fig. 34). It was quite common near Hawaii and was taken to about 32°N in the central water mass (Fig. 18).

Distinguishing Characters.—JUVENILES. This species can be distinguished from other *Psenes* by meristics, morphometrics and pigmentation. The combination of low total vertebral count (31) and low dorsal (X to XI, I, 20 to 23) and anal fin (III, 21 to 23) counts separates it from its congeners (Table 1). Early juveniles of *P. arafurensis* (Figs. 32B, C) are deeper bodied and less heavily pigmented than comparable-sized specimens of *P. cyanophrys*.

LARVAE. Preflexion larvae have a line of ventral pigment spots, a character that separates them from preflexion larvae of *P. cyanophrys*. They lack the pigment under the head found on preflexion *P. sio* and *P. pellucidus*. They resemble larvae of *P. maculatus* but preflexion stage larvae can be separated by myomere counts (31 vs. 35), and later stage larvae by differences in pigment patterns.

Meristics.—Vertebrae 12 + 19 = 31 (rarely 12 + 20 = 32); first dorsal X or XI (average 10.9); second dorsal I, 20 to 22 (23) (average I, 21.1); anal III, 21 to 23 (average III, 22.4); principal caudal rays 9 + 8; secondary caudal rays 7 to 10 dorsal + 7 to 10 ventral (average 8.1 + 8.3).

Meristics of 25 specimens from about 4°S to about 28°N and from about 96°W

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Figure 30. Composite view of four species of *Psenes*, showing similarities in patterns of body pigment patches. Pigment areas labelled A to F are explained in the text. A—*P. maculatus*, 22.2 mm (Atlantic specimen); B—*P. sio*, 17.4 mm (Pacific specimen); C—*P. arafurensis*, 11.0 mm (Pacific specimen); D—*P. cyanophrys*, 11.7 mm (Atlantic specimen).
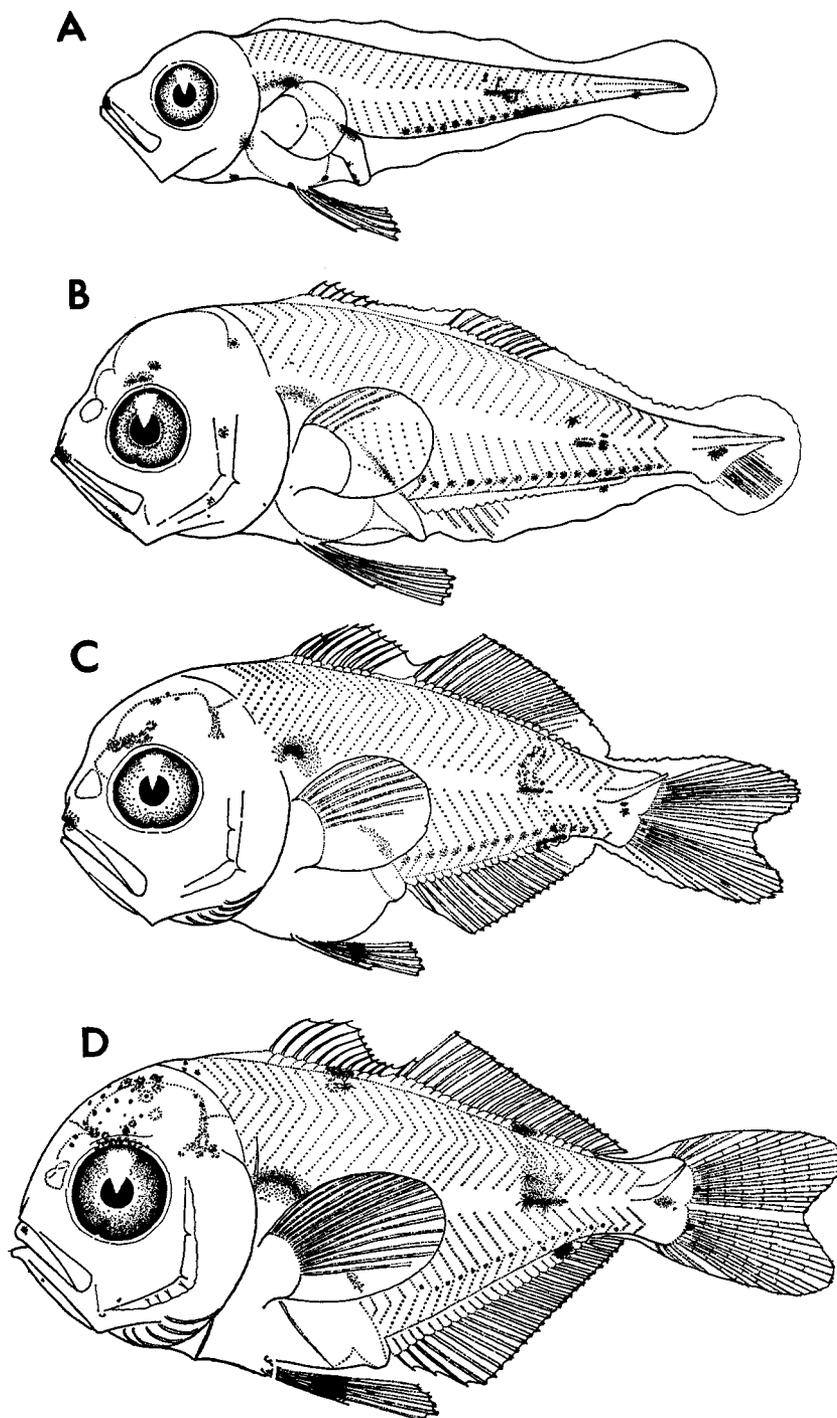
Figure 31. Developmental stages of *Psenes arafuren sis* (Nomeidae). A—3.2-mm preflexion larva; B—4.9-mm early flexion larva; C—4.6-mm late flexio n larva; D—6.5-mm postflexion larva.

Table 36. Meristics of 25 juveniles of *Psenes arafurensis* from over its distributional range in the eastern Pacific, including off Hawaii (counts made from radiographs)

Station	Location Lat.	Location Long.	Date	Size-SL (mm)	Vertebrae	1st Dorsal fin	2nd Dorsal fin	Anal fin	Caudal fin
Aries 9	27°34.6'N	155°39.7'W	X.5.71	17.4	12+19=31	X	I,22	III,23	8-17-8
T.C. 32.012	21°23'N	158°15'W	VII.16.67	36.5	12+19=31	X	I,20	III,21	8-17-8
"	"	"	"	47.3	12+19=31	XI	I,20	III,23	8-17-8
T.C. 32.055	21°23'N	158°15'W	VIII.23.67	117.0	12+19=31	XI	I,22	III,23	8-17-8
T.C. 32.002	21°22'N	158°12'W	VII.12.67	47.5	12+19=31	XI	I,20	III,22	8-17-8
"	"	"	"	62.0	12+19=31	XI	I,21	III,21	9-17-8
T.C. 32.008	21°22'N	158°16'W	VII.14.67	69.0	12+19=31	XI	I,21	III,22	9-17-9
"	"	"	"	73.5	12+19=31	XI	I,21	III,23	9-17-8
Jord. 57.053	09°51.4'N	117°32.5'W	XI.16.70	29.0	12+19=31	XI	I,22	III,23	7-17-8
T.C. 51.018	07°44'N	118°53'W	XI.3.70	12.0	12+19=31	XI	I,22	III,23	9-17-9
"	"	"	"	12.5	12+19=31	XI	I,20	III,21	8-17-8
Jord. 57.112	07°00'N	119°20'W	XII.7.70	15.0	12+19=31	XI	I,20	III,21	9-17-9
"	"	"	"	16.5	12+19=31	XI	I,21	III,22	7-17-7
ETP 11.068	06°05'N	118°51'W	II.3.67	12.5	12+20=32	XI	I,21	III,23	8-17-8
Jord. 77.101	04°21.5'N	118°14.8'W	I.28.73	12.4	12+19=31	X	I,23	III,23	9-17-10
Jord. 65.208	00°30'S	96°13'W	IX.27.71	20.0	12+19=31	XI	I,21	III,23	7-17-7
Jord. 60.046	01°43'S	118°58'W	XII.27.67	20.5	12+19=31	XI	I,21	III,22	7-17-8
T.C. 51.056	03°12'S	119°26'W	XI.10.70	18.4	12+19=31	XI	I,21	III,22	9-17-9
"	"	"	"	27.9	12+19=31	XI	I,21	III,22	7-17-8
Jord. 77.054	03°40'S	118°39'W	I.19.73	50.5	12+19=31	XI	I,21	III,23	8-17-8
T.C. 51.063	03°44'S	119°30'W	XI.12.70	44.0	12+19=31	XI	I,21	III,22	7-17-7
"	"	"	"	49.0	12+19=31	XI	I,21	III,21	7-17-7
"	"	"	"	52.0	12+19=31	XI	I,21	III,21	8-17-9
T.C. 51.048	04°02'S	118°48'W	XI.8.70	35.5	12+19=31	XI	I,21	III,23	8-17-8
"	"	"	"	40.0	12+19=31	XI	I,21	III,22	8-17-8

to about 158°W are given in Table 36. No geographical variation of any count is indicated.

Morphometrics.—Morphometrics of a developmental series are presented in Table 37. Body proportions are discussed in the "Comparative Morphometrics" section of *Psenes*.

Ossification.—The pelvic fins are first to develop after the larval pectoral fins, as is characteristic for *Psenes* larvae. The smallest available specimen, 3.0 mm, already has pelvic fins with I, 5, the full count.

Due to a limited amount of material, small larvae could not be cleared and stained, so information on early fin formation is based on careful examination of small larvae used for illustrations. A 4.9-mm specimen just prior to the beginning of notochord flexion has rays and/or spines developing in the first and second dorsal, anal, caudal, and pectoral fins (Fig. 31B). A more advanced

flexion larva of 4.6 mm (Fig. 31C) has all 9 + 8 principal caudal rays and a first dorsal fin short of only two spines. By 6.5 mm (Fig. 31D) the first dorsal, second dorsal, and anal fins are fully formed. The pectoral fins acquire all their rays (18 to 21) by 8.0 mm, and the caudal fin by 9.8 mm (Table 38).

A detailed study of vertebral ossification could not be made due to lack of small cleared and stained specimens. All 31 vertebrae (12 + 19) are ossifying by 8.0 mm, the smallest size larva that was cleared and stained (Table 38).

Branchiostegal rays form early with 0 + 4 counted on a 3.2-mm preflexion larva and the full complement of 2 + 4 present on a 4.9-mm early flexion larva. Gill rakers on the first arch are not evident on a 3.2-mm larva, but can be seen on the lower limb in a 4.9-mm larva. The adult number of gill rakers (8 + 1 + 15 to 17) is formed by 20.3 mm (Table 38).

Table 37. Morphometrics, in mm, of larvae and juveniles of *Psenes arafurensis* (specimens between dashed lines are undergoing notochord flexion)

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
ETP 11.114	3.2 NL	1.4	0.72	0.34	0.20	0.82	-	-	1.0
ETP 75.239	4.9	2.4	1.4	0.50	0.34	1.6	1.7	2.4	1.5
ETP 11.066	4.6	2.5	1.5	0.62	0.40	2.0	1.6	2.6	1.4
Hawaii 71-10-3	6.5 SL	3.4	2.2	1.0	0.48	3.1	2.4	3.6	2.4
"	6.7	3.5	2.2	0.92	0.44	3.2	2.6	3.6	2.3
"	6.9	3.4	2.3	1.0	0.44	3.6	2.6	3.6	2.2
"	7.9	4.1	2.6	1.1	0.56	3.9	2.7	4.2	2.6
"	8.0	4.2	2.6	1.1	0.52	4.2	3.0	4.2	2.7
ETP 11.068	8.0	4.1	2.9	eyes gone	0.60	4.3	2.9	4.3	2.7
Hawaii 71-10-3	8.6	4.6	3.0	1.2	0.56	4.4	3.3	4.6	2.9
"	11.0*	5.5	3.5	1.6	0.60	5.8	3.8	5.5	3.5
ETP 13.079	12.2*	6.5	4.2	1.9	0.75	6.8	4.7	6.8	4.3
Jord. 77.101	12.4*	6.7	4.2	1.8	0.83	7.0	4.3	7.2	4.2
T.C. 51.056	18.4*	9.4	6.4	2.9	1.2	10.2	6.5	9.7	5.8
T.C. 51.071	20.5*	10.4	6.7	2.8	1.4	11.7	7.7	10.7	6.8
T.C. 51.056	22.9*	16.7	10.5	4.7	2.2	15.0	10.5	17.7	11.2

* Juvenile

A few small spines develop along the margin and ridge of the preopercle on larvae between 4.5 and 9.0 mm. These weakly developed spines become embedded in a fringe-like membrane along the preopercular margin in specimens up to ca. 11.5 mm when they are completely resorbed.

Teeth are not evident in larvae until ca. 6.5 mm. An 8.0-mm larva has four premaxillary and two dentary teeth, and more are added with increasing size (Table 38).

Scales first appear below the pectoral fin base on an 8.0-mm larva, but this specimen has only 6 + 6 secondary caudal fin rays. A 9.8-mm specimen has scales extending over the ventral portion of the abdomen in addition to having 10 + 10 secondary caudal rays and ray formation in all other fins completed, thus qualifying it as an early juvenile.

Pigmentation.—The most conspicuous pigment of early larvae is a line of ventral spots on the tail (Fig. 31A to D). This pigment becomes embedded in postflexion larvae and subsequently disappears (Fig. 32). Body pigment on postflexion larvae and early juveniles forms as distinct dorsal, lateral, and ventral patches which merge into conspicuous bands (Figs. 32 and 33).

Preflexion larvae are lightly pigmented. The smallest specimen, 3.2 mm, lacks pigment on top of the head and under the lower jaw; some pigment is present on the upper

Table 38. Meristics of a cleared and stained postflexion larva and of juveniles of *Psenes arafurensis*

Station	Size (mm)	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchio-stegal rays	Gill rakers (right)	Teeth (left)	
											Prem.	Dent.
Hawaii 7-10-3	8.0 SL	XI	I,21	III,23	20	I,5	6-9+8-6	12+19=31	2+4	3+1+11	4	2
Jord. 57.113	9.8*	XI	I,20	III,23	18	I,5	10-9+8-10	12+19=31	2+4	4+1+12	6	6
T.C. 32.012	11.4*	XI	I,21	III,23	21	I,5	8-9+8-9	12+19=31	2+4	6+1+13	6	7
ETP 13.079	12.2*	XI	I,22	III,23	20	I,5	7-9+8-8	12+19=31	2+4	6+1+11	6	6
T.C. 32.010	13.4*	XI	I,21	III,23	20	I,5	8-9+8-9	12+19=31	2+4	7+1+14	8	8
T.C. 51.071	20.3*	XI	I,21	III,23	20	I,5	8-9+8-8	12+19=31	2+4	8+1+15	7	7
T.C. 32.012	23.2*	XI	I,22	III,23	21	I,5	9-9+8-10	12+19=31	2+4	8+1+17	8	11

* Juvenile
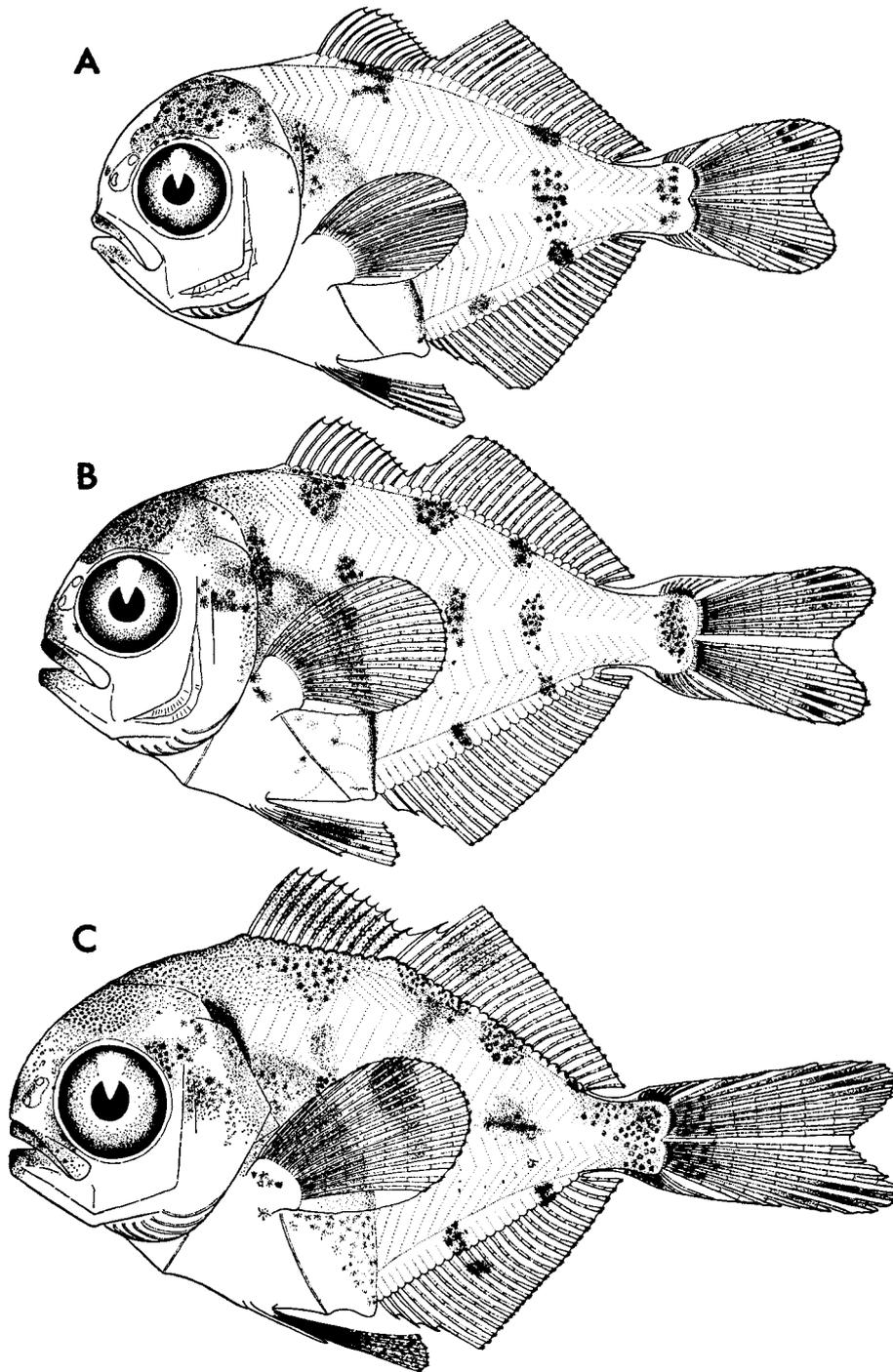
Figure 32.   Developmental stages of *Psenes arafurensis* (Nomeidae).   A—8.6-mm postflexion larva; B—
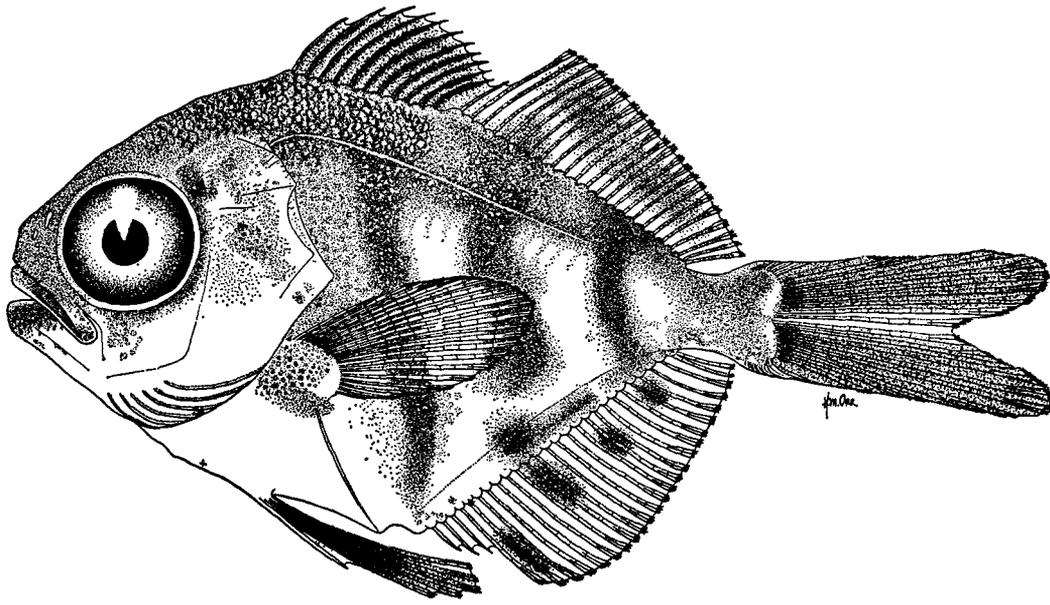11.0-mm early juvenile; C—18.4-mm early juvenile.

Figure 33. Early juvenile of *Psenes arafurensis* (Nomeidae), 30.0 mm.

jaw and embedded on the peritoneum (Fig. 31A). A melanophore is present near but posterior to the cleithral symphysis (Fig. 29H), one or two melanophores are present near the pelvic fins, and several are on the downturned gut forward of the anus. Body pigment consists of a series of about 15 melanophores spaced one per myomere along the ventral margin of the tail. Pigment ventrad of the tip of the notochord and that along the lateral line between about myomeres 21 to 25 will become prominent patches in later larvae.

Flexion larvae add pigment on the head above the eyes, over the hypurals, at the base of the developing caudal rays, and on the pelvic fins (Figs. 31B and C). The row of ventral pigment spots is still conspicuous. Pigment is lacking posterior to the cleithral symphysis and under the abdomen. Lateral line pigment at myomeres 22 to 25 spreads dorsally, an opposing ventral pigment patch forms at the base of the developing anal fin, but no opposing pigment patch has formed as yet on the dorsal margin.

Postflexion larvae and early juveniles (Figs. 31D and 32A to C) lose some of the pigment of earlier stages and develop the banded pigment pattern characteristic of the genus. Pigment intensifies on the upper jaw, on the head above the eyes, and later (11.0 mm) behind the eyes as well. Pigment forms on the lower jaw at about 8.6 mm. On the tail, the ventral line of pigment spots moves internally and disappears by 8.6 mm. The lateral line pigment gradually merges with opposing dorsal and ventral pigment to form a vertical band across the tail at about myomeres 21 to 25. A band of pigment begins developing on 6.5-mm larvae below the first dorsal fin at the base of the seventh and eighth spines. It increases in size in later stages and extends ventrally. By 11.0 mm (Fig. 32B) another dorsal patch forms under the anterior rays of the second dorsal fin midway between the two dorsal patches already characterized. Lateral and ventral pigment patches form under this middle patch, and a lateral patch also forms under the anterior dorsal patch. The pigment near
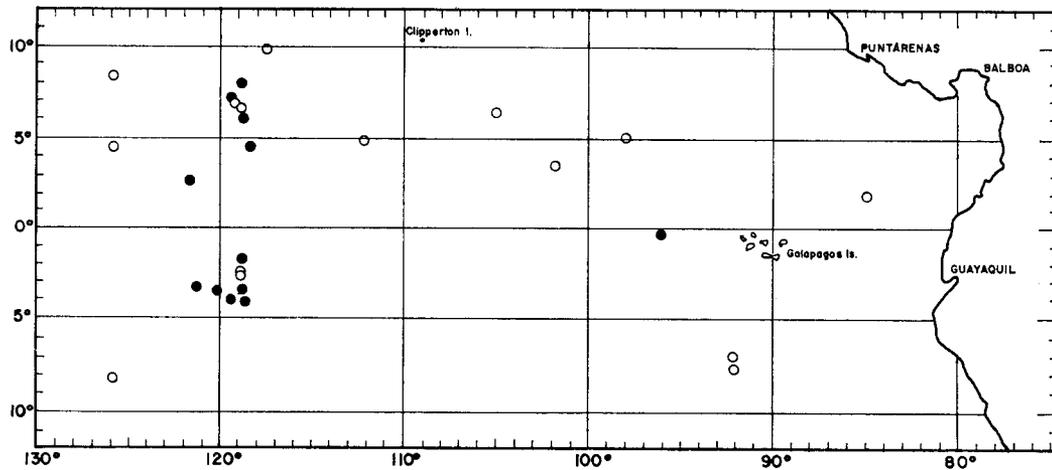
Figure 34. Occurrences of *Psenes arafurensis* larvae (open circles) and juveniles (closed circles) in the eastern tropical Pacific.

the tip of the notochord on preflexion larvae intensifies into a broad patch over the hypural bones and becomes conspicuous along the base of the caudal fin (Figs. 32A to C). A pigment patch develops near the outer margin of each of the two caudal fin lobes (by 8.6 mm, Fig. 32A). Pigment gradually forms externally over the abdominal cavity and also spreads backwards from the head to the nape (by 11.0 mm, Fig. 32B). The dorsal, anal, and pectoral fins lack pigment on this 11.0-mm specimen, which is probably an early juvenile. Body and fin pigment becomes intensified on somewhat larger juveniles (Figs. 32C and 33). On the 18.4 mm specimen, the first dorsal fin is rather heavily pigmented; the second dorsal fin is pigmented between the seven anterior rays, whereas the only pigment on the anal fin is a small patch spreading out from the anterior-most ventral patch at rays 8 to 10. The pelvic fins are now completely pigmented and the caudal fin pigment has intensified along the fin base and distally on the dorsal and ventral lobes.

On a 30.0-mm juvenile (Fig. 33) pigment is continuous along the back and in the three vertical bands on the body. All the fins are more heavily pigmented, with four distinct pigment patches on the anal fin and almost continuous pigment over much of the second dorsal fin.

Psenes cyanophrys
Cuvier and Valenciennes, 1833
Figures 35 to 37

Literature.—Three previous records from the eastern Pacific by Meek and Hildebrand (1925) and Hunter and Mitchell (1967 and 1968) referred to *P. pacificus* Meek and Hildebrand (1925) which was synonymized with *P. cyanophrys* by Haedrich (1967). It is recorded as *P. cyanophrys* by Gooding and Magnuson (1967) and Parin (1968). *Psenes kamokari*, described by Abe, Kojima and Kosakai (1963) from Kyushu in the western Pacific also is considered a synonym by Haedrich (1967).

Interestingly, it was the only nomeid recorded by Hunter and Mitchell (1967 and 1968) and ranked second in numbers of fishes captured beneath their moored rafts off Costa Rica. EASTROPAC collections, however, indicate that larvae of *P. sio* and *Cubiceps pauciradiatus* are much more common in this area than are those of *P. cyanophrys*.

In similar experiments using a floating raft with an underwater chamber, Gooding and Magnuson (1967) found that *P. cyanophrys* was the first fish to appear, attained the highest rate of accumulation and abundance in three central Pacific localities: off the leaward coast of the island of Hawaii, at the equator, and at ca. 3°S between about 148° to 159°W.

A life history series was illustrated by Legaspi
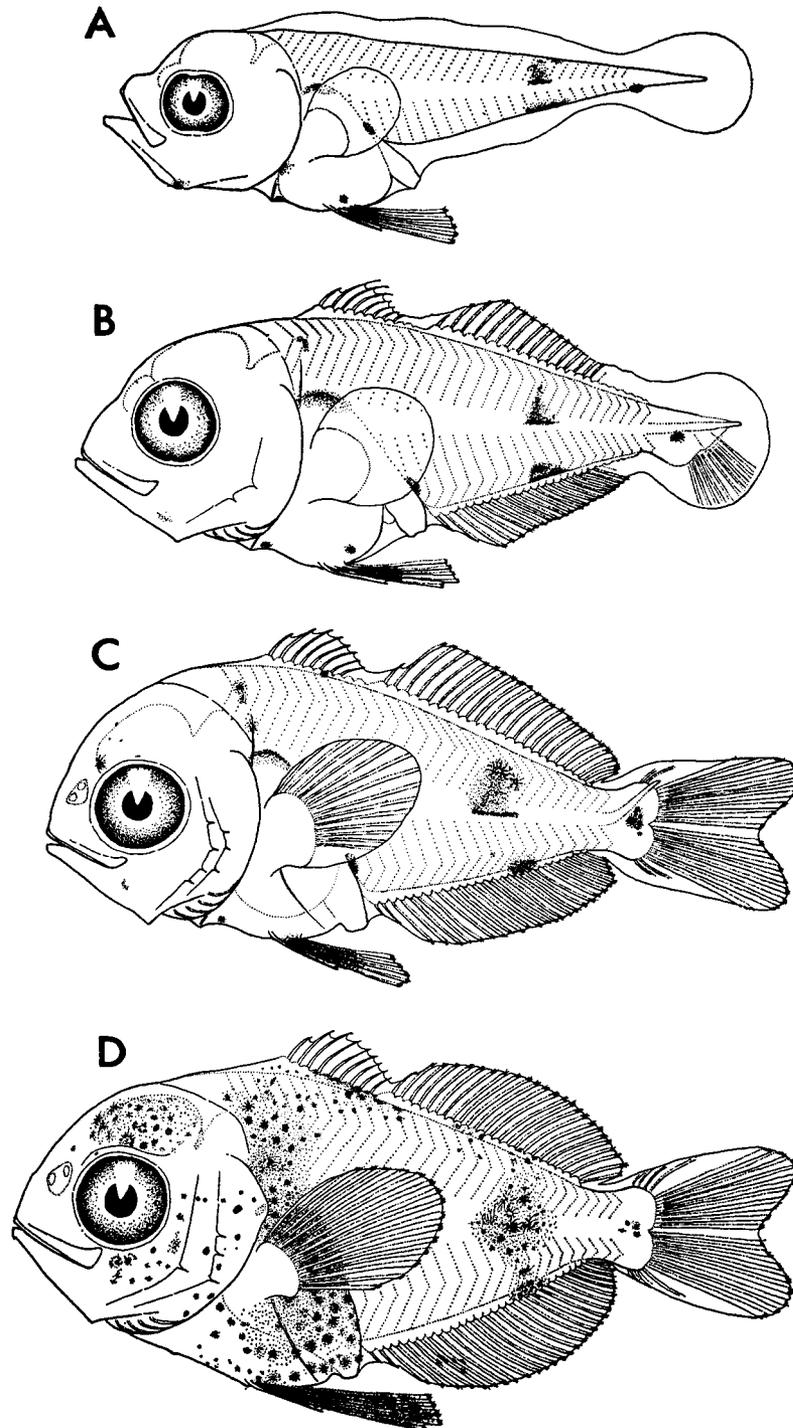
Figure 35. Developmental stages of *Psenes cyanophrys* (Nomeidae). A—3.3-mm preflexion larva; B—
4.2-mm early flexion larva; C—5.0-mm postflexion larva; D—6.8-mm postflexion larva.
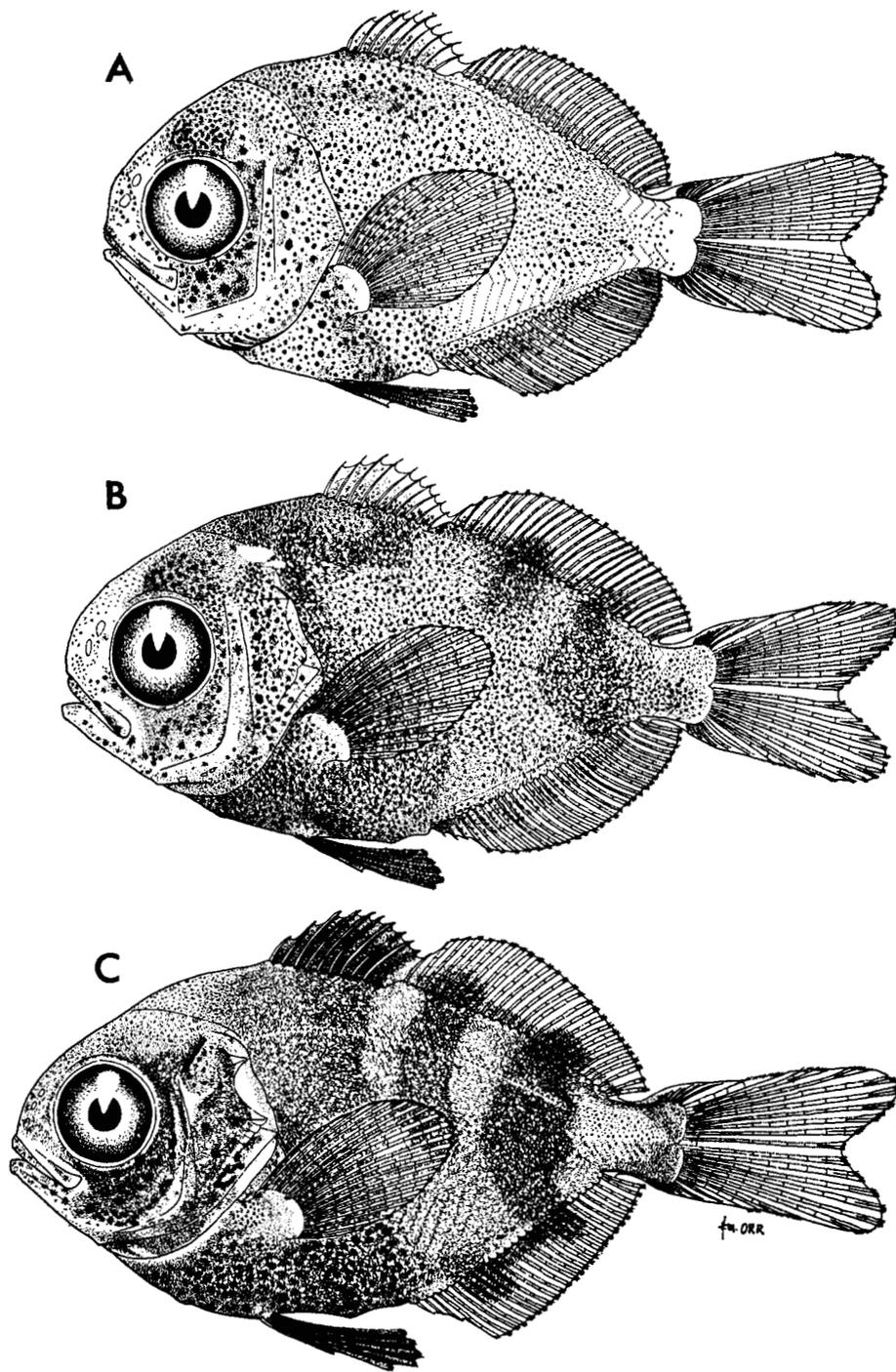
Figure 36. Developmental stages of *Psenes cyanophrys* (Nomeidae). A—10.7-mm early juvenile; B—14.5-mm early juvenile; C—19.1-mm juvenile.

Table 39.   Meristics of 25 juveniles of *Psenes cyanophrys* s lected from over its distributional range in the eastern Pacific, including off Hawaii (counts made from radiographs)

Station	Location Lat.	Location Long.	Date	Size-SL (mm)	Vertebrae	1st Dorsal fin	2nd Dorsal fin	Anal fin	Caudal fin
T.C. 32.005	21°22'N	158°13'W	VII.13.67	33.2	12+19=31	X	1,25	III,25	8-17-8
T.C. 32.008	21°22'N	158°16'W	VII.14.67	27.8	12+19=31	X	1,25	III,24	8-17-7
T.C. 32.015	21°20'N	158°12'W	VII.17.67	40.4	12+19=31	X	1,25	III,25	9-17-9
Hawaii 71-6-18	21°00'N	158°20'W	VI.16.71	13.3	12+19=31	X	1,26	III,26	9-17-9
T.C. 32.024	20°59'N	158°30'W	VII.22.67	44.0	12+19=31	X	1,26	III,25	8-17-8
T.C. 32.028A	20°59'N	158°34'W	VII.25.67	37.8	12+19=31	X	1,25	III,25	8-17-8
SIO 64-141	10°32'N	85°54'W	X.21.63	51.0	12+19=31	IX	1,26	III,26	9-17-9
SIO 63-305	10°00'N	86°00'W	IV.2.63	31.8	12+19=31	IX	1,25	III,25	8-17-8
"	"	"	"	40.0	13+18=31	X	1,26	III,24	8-17-8
SIO 63-307	10°00'N	86°00'W	IV.2.63	32.8	12+19=31	IX	1,26	III,26	9-17-9
SIO 63-313	9°49'N	85°31'W	IV.11.63	17.8	12+19=31	X	1,25	III,25	8-17-8
"	"	"	"	23.0	12+19=31	X	1,24	III,25	7-17-8
SIO 63-322	9°45'N	85°37'W	V.8.63	42.5	13+18=31	X	1,25	III,26	9-17-8
Hunter & Mitchell	9°45'N	85°39'W	IV.21.66	39.0	12+19=31	X	1,25	III,26	8-17-8
"	"	"	"	43.0	12+19=31	X	1,25	III,26	9-17-8
"	"	"	"	46.0	12+19=31	X	1,26	III,25	8-17-8
Hunter & Mitchell	9°45'N	85°43'W	IV.13.65	42.0	12+19=31	IX	1,25	III,26	8-17-8
"	"	"	"	45.0	12+19=31	X	1,25	III,25	8-17-8
"	"	"	"	47.0	12+19=31	X	1,25	III,26	8-17-8
SIO 63-319	8°32'N	83°54'W	V.4.63	70.0	12+19=31	X	1,26	III,26	8-17-8
"	"	"	"	72.0	13+18=31	X	1,25	III,25	8-17-8
"	"	"	"	80.0	12+19=31	X	1,26	III,26	8-17-8
T.C. 51.018	7°44'N	118°53'W	XI.3.70	14.2	12+19=31	IX	1,26	III,26	7-17-7
Jord. 57.113	7°14.6'N	119°24'W	XII.7.70	19.2	12+19=31	X	1,25	III,25	7-17-7
"	"	"	"	25.7	12+19=31	X	1,25	III,25	8-17-8

(1956) from the Atlantic: Of the six illustrations only the two largest, 9.4 and 17.0 mm (Figs. 3E and F) are definitely *P. cyanophrys*, and the 4.7-mm specimen (Fig. 2C) is possibly this species. The 2.5-mm and 3.2-mm specimens (Figs. 2A and B) are possibly *Ariomma*, and the 6.9-mm specimen (Fig. 3D) appears to be a carangid.

Material.—Juvenile material was examined from off Costa Rica (Hunter and Mitchell, 1967 and 1968), from trawl collections made in the eastern tropical Pacific on cruises of the DAVID STARR JORDAN and TOWNSEND CROMWELL, and from Hawaii (TOWNSEND CROMWELL cruise 32). Larvae were obtained from EASTROPAC collections. Comparative material was examined from the Atlantic and from the Gulf of Thailand.

Distribution.—A moderate number of larvae were collected on EASTROPAC cruises between 0° and 10°N (Fig. 38). Juvenile material was abundant from collections made off Costa Rica and Hawaii. There is an obvious disproportion between the abundance of juveniles observed under floating objects, and the relative scarcity of larvae in plankton hauls.

Distinguishing Characters.—JUVENILES. Juvenile *P. cyanophrys* can be distinguished by meristics, pigmentation, dentition, and skeletal characters. The combination of 31 vertebrae and 23 to 26 anal rays is unique among nomeids (Table 1). Juveniles are more heavily pigmented at all stages than other *Psenes*. It is the only *Psenes* in the eastern Pacific with small pointed teeth in the lower jaw. A trenchant skeletal character is the position of the first haemal spine (on the 13th vertebra) in relation to the anal fin pterygiophores. In *P. cyanophrys* this haemal spine interdigitates between the fourth and fifth or the fifth and sixth anal pterygiophores. In other species of *Psenes*, this haemal spine interdigitates between the first and second or the second and third pterygiophores (Table 3).

LARVAE. Larvae of *P. cyanophrys* can be distinguished in all stages from other *Psenes* by pigmentation and in postflexion larvae by meristics. Preflexion and flexion stages
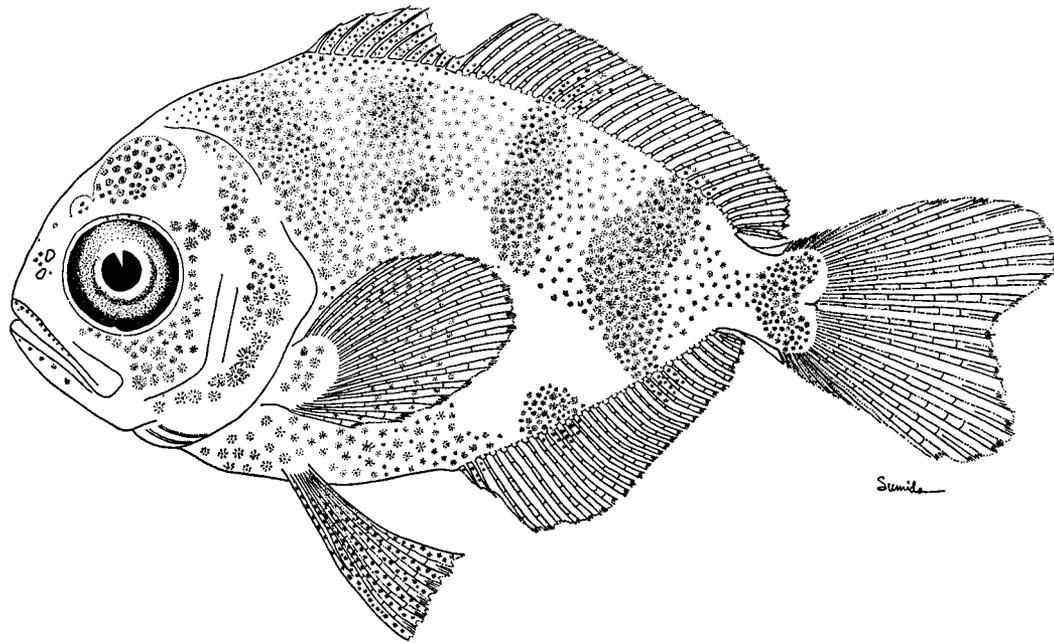
Figure 37.   Early juvenile of *Psenes cyanophrys* (Nomeidae) from the Atlantic, 11.7 mm.

of *P. cyanophrys* differ from other *Psenes* in not having a line of melanophores on the ventral margin of the body behind the anus.

Postflexion larvae develop pigment bands at small sizes. The body soon becomes completely pigmented but the banding pattern persists against the background pigment.

Meristics.—Vertebrae 12 + 19 = 31 (rarely 13 + 18 = 31); first dorsal IX or X (average 9.8); second dorsal I, 23 to 26 (average I, 25.1); anal III, 23 to 27 (average III, 25.2); principal caudal rays 9 + 8; secondary caudal rays 7 to 9 dorsal + 7 to 9 ventral (average 8.1 + 7.9).

Meristics of 25 specimens from off Hawaii and from off Central America are given in Table 39. No difference in any count is indicated between the two areas.

Morphometrics.—Morphometrics of a series of *P. cyanophrys* are presented in Table 40. Body proportions are discussed in the comparative section of *Psenes* (Table 35).

Ossification.—As is typical for *Psenes* larvae, the pelvic fins are the first to develop in *P. cyanophrys*. The pelvic fins are present on the smallest available specimen of 2.7 mm, and a 3.6-mm cleared and stained larva has the full complement of I, 5 (Table 41). The first dorsal fin is next to start development which is the usual condition when a perciform larva develops precocious pelvic fins. A 3.6-mm preflexion larva has the anterior two spines formed (Table 41). By 4.2 mm, rays and spines are ossifying in the second dorsal, anal and caudal fins. A postflexion specimen of 4.7 mm has all fins complete except for the pectoral, some secondary caudal rays, and the anterior-most anal spine. The latter is formed by 6.9 mm, and the pectoral and secondary caudal rays are complete by 9.7 mm.

The axial skeleton develops early with the two anterior-most neural spines ossifying in a 3.6-mm preflexion larva; all 31 (12 + 19) vertebrae are formed in a 4.7-mm postflexion larva.

Table 40.   Morphometrics, in mm, of larvae and juveniles of *Psenes cyanophrys* (specimens between dashed lines are undergoing notochord flexion)

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
ETP 47.244	2.8 NL	1.5	0.68	0.28	0.12	0.66	-	-	1.2
ETP 13.056	3.0	1.5	0.80	0.34	0.20	0.86	-	-	1.1
ETP 13.052	3.3	1.6	0.88	0.34	0.20	0.90	-	-	1.2
ETP 75.241	3.9	2.0	1.3	0.48	0.30	1.6	1.5	2.1	1.2
ETP 13.241	4.2	2.2	1.4	0.52	0.36	1.6	1.6	2.3	1.4
ETP 20.100	4.8 SL	2.4	1.5	0.68	0.38	2.1	1.8	2.5	1.6
ETP 45.090	5.5	2.9	2.2	0.88	0.52	2.6	2.4	3.1	1.9
ETP 75.241	6.4	3.7	2.1	0.97	0.52	3.4	2.6	3.8	2.1
Hawaii 71-9-3	7.8	4.4	2.7	1.7	0.44	3.9	2.8	4.6	2.7
ETP 14.209	9.7	5.3	3.4	1.6	0.60	4.9	3.7	5.6	3.6
Hawaii 71-9-3	10.7*	5.8	3.7	1.6	0.60	5.8	4.2	6.0	3.8
"	11.0*	6.1	3.7	1.8	0.75	5.9	4.2	6.4	3.9
"	11.7*	6.2	4.3	1.9	0.92	5.9	4.5	6.4	4.0
Hawaii 71-6-18	14.5*	7.6	5.0	2.2	0.91	7.3	5.4	7.9	4.9
Jord. 57.113	19.1*	11.0	7.2	2.7	1.4	10.5	7.7	11.7	7.0

* Juvenile

The complete set of 2 + 4 branchiostegal rays is formed by 4.7 mm at which time gill rakers, teeth and preopercular spines are evident. The largest cleared and stained specimen, 26.4 mm, still has an incomplete number of gill rakers. As with other *Psenes* larvae, the preopercular spines are small and inconspicuous. By 9.7 mm, they become embedded in a fringe of tissue and are completely resorbed after 17.0 mm.

Scales first appear on the shoulder region of a 10.0-mm specimen which has 8 + 8 secondary caudal rays developed; transformation from the larval to juvenile stage of *P. cyanophrys* is considered to occur at about this size.

Pigmentation.—Early larvae are sparsely pigmented and lack pigment spots along the ventral margin. Pigment is added rapidly after notochord flexion and soon becomes very heavy.

Preflexion larvae lack pigment on top of the head or the upper jaw (Fig. 35A). Pigment is present just behind the cleithral symphysis, on the pelvic fins, and on the gut above the pelvic fins. Internal pigment is present on the peritoneum above the air bladder and the gut. Opposing streaks of pigment are present laterally and on the ventral margin of the tail on about myomeres 20 to 23. A melanophore is present under the notochord near its tip.

Flexion larvae (Fig. 35B) add pigment near and posteriad to the cleithral symphysis and on the nape. The lateral pigment on myomeres 20 to 23 spreads dorsally and the posterior pigment spot lies over the developing hypural bones.

Postflexion larvae fairly rapidly add pigment over the entire body. Pigment develops soon over the midbrain. By 6.8 mm it has spread over the top of the head and appeared on the cheeks (Fig. 35D). Pigment on the upper and lower jaws is the last to form on the head but develops by 10.7 mm (Fig. 36A). Pigment covers the abdomen on a 5.5-mm specimen and soon spreads over the remainder of the trunk. Lateral pigment on the tail spreads dorsally and ventrally to become a vertical band by 6.8 mm (Fig. 35D). A dorsal patch develops below rays 8 to 10 of the second dorsal fin, and by 7.9 mm, a corresponding lateral patch has formed. By 10.7 mm pigment covers most of the body but is sparse ventrally above the anal fin and at the base of the caudal fin (Fig. 36A). Early juveniles develop a banded pattern against the pigmented body (Fig. 36B and C). Occasion-
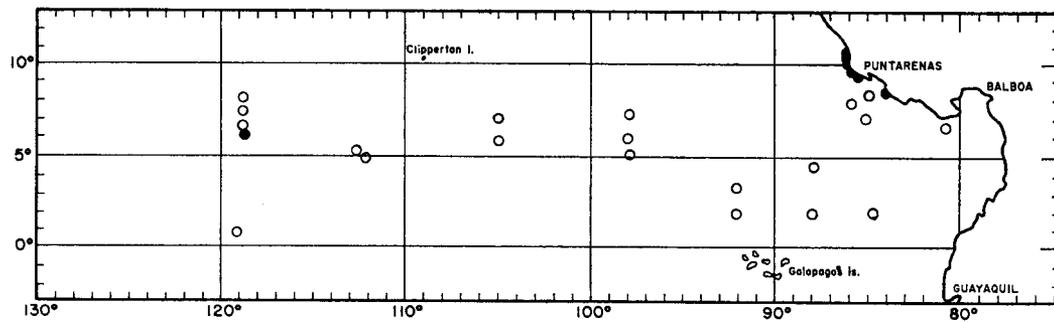
Figure 38. Occurrences of *Psenes cyanophrys* larvae (open circles) and juveniles (closed circles) in the eastern tropical Pacific.

ally, the body is less densely pigmented between the patches until a somewhat larger size, as for example on an 11.7-mm specimen from the Atlantic (Fig. 37).

Psenes maculatus
Lütken, 1880
Figures 39 and 40

Literature.—Reported here from the eastern Pacific for the first time, *P. maculatus* was recorded by Kobayashi (1961) from the western North Pacific at 43°44′N, 154°58′E. His 49.9-mm specimen had 34 vertebrae (from radiograph, Plate 1, Fig. 2). According to Kobayashi (1961), the teeth on his 49.9-mm specimen were arranged in an irregular

line on the upper jaw and were sharper and longer than those on the lower jaw. However, Haedrich and Horn (1972) include *P. maculatus* among the species of *Psenes* with "teeth in lower jaw long, knife-like, compressed, close-set, very different from those in the upper jaw;" as pointed out later, our observations reinforce those of Haedrich and Horn.

Material.—We examined one specimen from Cal-COFI station 7210-23.143, and a moderate number of collections from the western North Atlantic. The Atlantic material, labelled in Tables 42 and 43 as 0573101-N9 to 0573316-N9, was taken off Charleston, South Carolina, in replicate neuston net hauls at 32°05.0′ to 32°08.5′N and 79°13.0′ to 79°13.5′W on July 14 and 15, 1973.

Table 41. Meristics of cleared and stained larvae and juveniles of *Psenes cyanophrys* (Note: 3.6-mm specimen is a preflexion larva; no flexion larvae available for staining)

| Station	Size (mm)	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchio-stegal rays	Gill rakers (right)	Teeth (left) Prem.	Teeth (left) Dent.
ETP 47.297	3.6 NL	II	–	–	LP	I,5	–	2+ 0= 2 [†]	0+4	–	–	–
"	4.7 SL	IX	I,24	II,25	14	I,5	1-9+8-2	12+19=31	2+4	0+1+8	1	0
ETP 30.043	6.9	IX	I,25	III,25	18	I,5	6-9+8-5	12+19=31	2+4	3+1+10	2	3
ETP 14.209	9.7	IX	I,26	III,26	19	I,5	8-9+8-8	12+19=31	2+4	4+1+15	6	6
T.C. 32.023	10.0*	X	I,25	III,25	20	I,5	8-9+8-8	12+19=31	2+4	6+1+13	6	5
T.C. 32.034	12.5*	X	I,25	III,25	20	I,5	8-9+8-8	12+19=31	2+4	6+1+15	9	8
"	14.7*	X	I,25	III,26	19	I,5	8-9+8-8	12+19=31	2+4	6+1+15	9	8
"	15.0*	X	I,24	III,25	19	I,5	9-9+8-7	12+19=31	2+4	6+1+14	11	7
"	16.7*	X	I,25	III,24	19	I,5	8-9+8-7	12+19=31	2+4	6+1+16	11	10
Jord. 57.113	17.5*	IX	I,25	III,25	19	I,5	9-9+8-7	12+19=31	2+4	5+1+16	11	7
T.C. 32.034	18.0*	X	I,25	III,27	19	I,5	8-9+8-7	12+19=31	2+4	6+1+16	11	6
Hunter & Mitchell (V.14.66)	18.9*	X	I,25	III,25	20	I,5	8-9+8-8	12+19=31	2+4	6+1+16	9	8
"	20.4*	X	I,23	III,24	19	I,5	8-9+8-8	12+19=31	2+4	6+1+16	9	8
"	26.4*	X	I,23	III,23	19	I,5	8-9+8-8	12+19=31	2+4	6+1+16	10	7

* Juvenile
† Vertebrae not completely developed
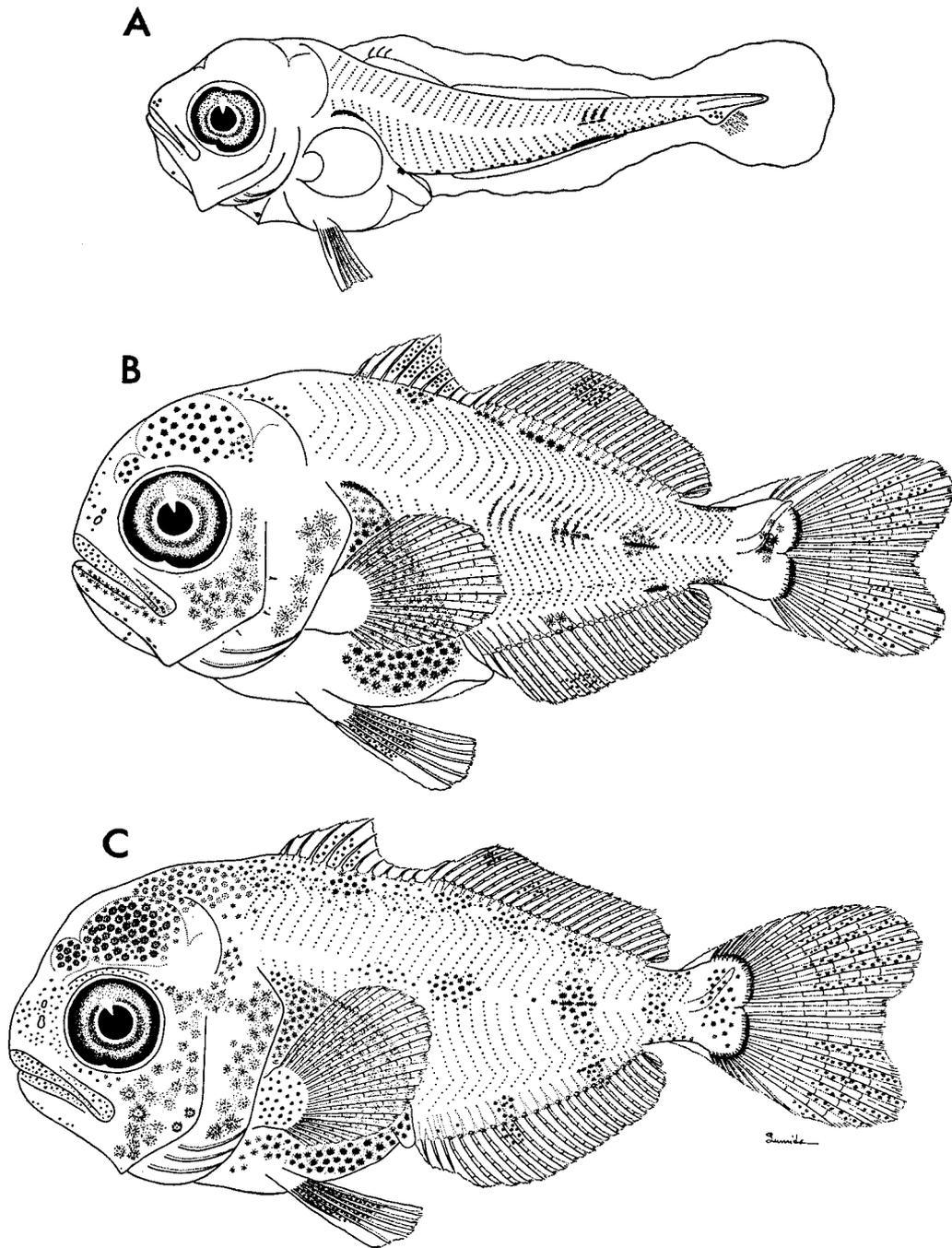
Figure 39. Developmental stages of *Psenes maculatus* (Nomeidae). A—3.8-mm early flexion larva, Atlantic specimen; B—7.6-mm postflexion larva, Atlantic specimen; C—11.6-mm early juvenile, Pacific specimen.

Table 42. Morphometrics, in mm, of larvae and juveniles of *Psenes maculatus* (Atlantic material and one Pacific specimen, 11.6 mm) (specimen above dashed line is a preflexion larva; no flexion larvae available)

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
0573236-B505	3.8 NL	1.8	1.1	0.40	0.28	1.2	1.3	-	1.0
0573310-N9	5.8 SL	3.2	2.1	.74	.48	2.7	2.2	3.3	2.2
0573316-N9	6.7	3.7	2.2	.84	.56	3.0	2.4	3.8	2.3
0573311-N9	7.6	4.2	2.6	1.0	.68	3.7	2.5	4.3	2.5
0573310-N9	7.8	4.3	2.6	1.0	.64	3.6	3.0	4.4	2.3
0573315-N9	7.9	4.3	2.8	1.0	.70	3.7	3.2	4.5	2.5
0573316-N9	8.0	4.2	2.7	1.0	.68	3.7	3.1	4.3	2.6
0573315-N9	9.0	5.0	3.2	1.1	.72	4.2	3.3	5.1	3.1
J7210-24.143	11.6*	6.0	4.0	1.4	.96	5.1	4.1	6.1	3.8
0573313-N9	12.4*	6.8	4.6	1.7	1.0	6.4	4.9	7.0	4.2
0573316-N9	12.9*	6.8	4.5	1.8	1.0	6.2	5.0	7.0	4.7
0573313-N9	14.4*	7.5	4.9	2.0	1.1	7.1	5.2	7.7	4.0
0573314-N9	16.5*	9.4	6.0	2.4	1.2	8.4	6.0	9.5	5.3
0573101-N9	22.2*	12.0	7.5	2.9	1.5	11.0	7.7	12.4	7.2
0573314-N9	22.8*	13.0	7.7	3.1	1.7	11.5	8.0	13.4	7.8

* Juvenile

Distribution.—This species is a temperate water form. In the Pacific it is known only from the North Pacific central water mass (Fig. 18).

Distinguishing Characters.—JUVENILES. Early juveniles of *P. maculatus* can be separated by meristics and pigmentation. It is the only *Psenes* with 34 to 35 vertebrae. In several characters early juveniles of *P. maculatus* are more similar to those of *P. arafurensis* than other *Psenes*, but as pointed out earlier, the pigment patterns are distinctively different.

LARVAE.—Larval *P. maculatus* are distinguished by pigmentation and number of myomeres (34 to 35). Preflexion larvae have only two melanophores under the jaw (Fig. 29J) and a line of melanophores on the ventral margin (Fig. 39A). The pigment under the jaw is similar to that on preflexion larvae of *P. cyanophrys*, but the latter lack the line of melanophores on the ventral margin of the body.

Postflexion larvae are easily separated by meristics and pigmentation. Like *P. sio*, *P. maculatus* develops six bands of pigment. Unlike *P. sio*, the fifth band is on the caudal peduncle rather than below the posterior

rays of the second dorsal fin and the banded pattern persists to larger sizes in *P. maculatus*.

Meristics.—Vertebrae 12 + 23 = 35; first dorsal X or XI (average 10.9); second dorsal I, 22 or 23 (average I, 22.1); anal III, 21 or 22 (average 21.6); principal caudal rays 9 + 8; secondary caudal rays 8 dorsal + 8 or 9 ventral (average 8.0 + 8.2).

Morphometrics.—The morphometrics of a series from 3.8 to 22.8 mm are given in Table 42. Body proportions of all *Psenes* are discussed in an earlier section (Table 35).

Ossification.—The smallest specimen available for study, a 3.8-mm larva (Fig. 39A), has the pelvic fins fully formed. The anterior three spines of the first dorsal fin and the anlagen of the caudal, second dorsal and anal fins are also developed. By 5.8 mm (Table 43), the first dorsal fin, principal caudal rays, vertebrae, and the branchiostegals are completed. By 7.8 mm, the second dorsal and anal fins have formed their full complement of spines and rays. The pectoral fin has its complete count by
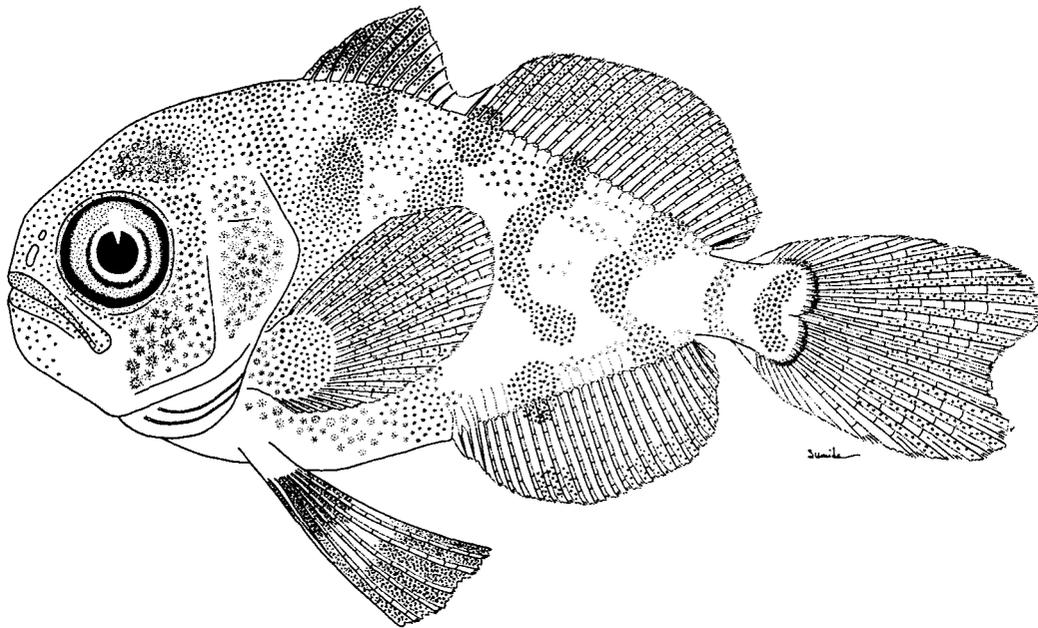
Figure 40. Early juvenile of *Psenes maculatus* (Nomeidae) from the Atlantic, 22.2 mm.

9.0 mm and all secondary caudal rays are present by 12.4 mm.

Weak preopercular spines are present in small specimens (5.0 to 9.0 mm) but become obscured in larger specimens.

Teeth on postflexion larvae are similar in appearance in both jaws. Only the 22.8-mm juvenile has the marked contrast between the teeth in the upper and the lower jaw. On this specimen, the anterior group of five dentary teeth are tapering and sharply pointed as on the premaxillary, but the

Table 43. Meristics of cleared and stained postflexion larvae and juveniles of *Psenes maculatus* (Note: all are Atlantic specimens taken off South Carolina)

Station	Size (mm)	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchiostegal rays	Gill rakers (right)	Teeth (left) Prem.	Teeth (left) Dent.
0573310-N9	5.8 SL	X	6	III,9	18	I,5	0-9+8-0	12+23=35	2+4	1+1+9	4	3
0573316-N9	6.7	VIII	-	II,5	18	I,5	2-9+8-3	12+23=35	2+4	2+1+9	6	5
0573310-N9	7.8	XI	I,23	III,22	18	I,5	5-9+8-5	12+23=35	2+4	4+1+9	6	5
0573315-N9	7.9	XI	I,22	III,21	20	I,5	5-9+8-5	12+23=35	2+4	4+1+10	9	5
0573316-N9	8.0	XI	I,22	III,19	19	I,5	4-9+8-4	12+23=35	2+4	3+1+9	7	5
0573315-N9	9.0	XI	I,22	III,22	21	I,5	6-9+8-6	12+23=35	2+4	4+1+12	5	4
0573313-N9	12.4*	X	I,22	III,21	22	I,5	8-9+8-8	12+23=35	2+4	6+1+13	9	8
0573316-N9	12.9*	XI	I,22	III,22	22	I,5	8-9+8-8	12+23=35	2+4	7+1+14	10	8
0573313-N9	14.4*	XI	I,22	III,21	21	I,5	8-9+8-9	12+23=35	2+4	8+1+14	9	6
0573314-N9	16.5*	XI	I,22	III,22	20	I,5	8-9+8-8	12+23=35	2+4	7+1+15	10	8
0573314-N9	22.8*	XI	I,22	III,22	22	I,5	8-9+8-8	12+23=35	2+4	10+1+17	10	11

* Juvenile

posterior group of six dentary teeth are wide and blade-like, similar to those in *Tetragonurus*.

Scales form on the anterior midline of the body by 12.4 mm, on the pectoral base by 14.4 mm, and over the abdomen by 16.5 mm. More than half of the body is scaled on a 22.8-mm specimen. Atlantic specimens of 12.4 mm and larger are considered juveniles because the fins have complete counts and scales are forming; the single specimen from the Pacific, 11.6 mm, has the complete fin count, and is probably a juvenile.

Pigmentation.—Early flexion larvae (3.8 mm) have a series of melanophores on the ventral margin interrupted by a pigment streak at myomeres 23 to 26 (Fig. 39A). Lateral line pigment develops at about myomeres 25 to 27 with pigment spreading dorsally along the myosepta. Pigment is present on the upper jaw, over the developing hypural bones, and on the peritoneum over the air bladder. A single melanophore is present near the cleithral symphysis, and on either side of the isthmus (Fig. 29J).

Postflexion larvae add considerable pigment and soon develop a strong banded pattern. By 7.6 mm, pigment becomes heavy over the head, jaws, operculum and abdomen (Fig. 39B), with some embedded pigment on the body and considerable myoseptal pigment. There are four dorsal pigment patches or rows of melanophores, the first under the first dorsal fin, the second at the origin of the second dorsal fin, and the third and fourth under the second dorsal fin; also two ventral patches, one above anal rays 6 to 8 and the other above rays 17 to 20. Pigment patches are conspicuous at the base of the caudal fin as well as along the lateral line at myomeres 18 to 22 and 26 to 28. By 11.6 mm the banding pattern is evident (Fig. 39C). The pigment bands at the caudal peduncle and under the posterior part of the second dorsal fin have formed. The more anterior bands are represented by patches near the dorsal margin and at the lateral line. The pigment pattern of the

22.2-mm juvenile (Fig. 40) is described in an earlier comparative section on *Psenes* pigmentation.

Psenes pellucidus
Lütken, 1880
Figures 41 to 44

Literature.—Fitch (1948) reported on a 370-mm specimen taken off Newport Beach, California. Fitch used the name *Icticus ischanus* Jordan and Thompson, 1914, which subsequently was synonymized with *Psenes pellucidus* by Haedrich (1967). Fitch and Lavenberg (1968) reported on two juveniles taken off northern Baja California. Horn and Haedrich (1973) gave measurements and counts for the Newport Beach specimen. Abe (1954) reported on a specimen from off Japan under the name *Papyrichthys ischanus*.

Material.—Study material consisted of larvae from seven CalCOFI stations, six EASTROPAC stations, one Shellback station, and of juveniles from six stations on TOWNSEND CROMWELL cruise 51. Several samples also were available from the western North Atlantic.

Distribution.—*P. pellucidus* has a disjunct distribution in the eastern Pacific. Specimens were taken in transition waters of the California Current from Catalina Island south to off Punta Eugenia, Baja California (Fig. 18). In tropical waters it was found offshore between 5°N and 5°S (Fig. 25). This distribution may be explained by a preference for cooler or more productive waters of upwelling regions or by an exclusion from oxygen minimum areas of the eastern Pacific. Although the distributions of *P. pellucidus* and *P. sio* are almost disjunct, they are more complex than was known to Horn and Haedrich (1973) who speculated that they "are closely related species which replace one another north to south in the eastern Pacific."

Distinguishing Characters.—JUVENILES. *Psenes pellucidus* is distinguished by its soft, flexible compressed body and by the high vertebral and fin ray counts (Table 1). Only *Nomeus* has as high a vertebral count, but it has somewhat lower second dorsal and anal fin ray counts and strikingly different pigment patterns.

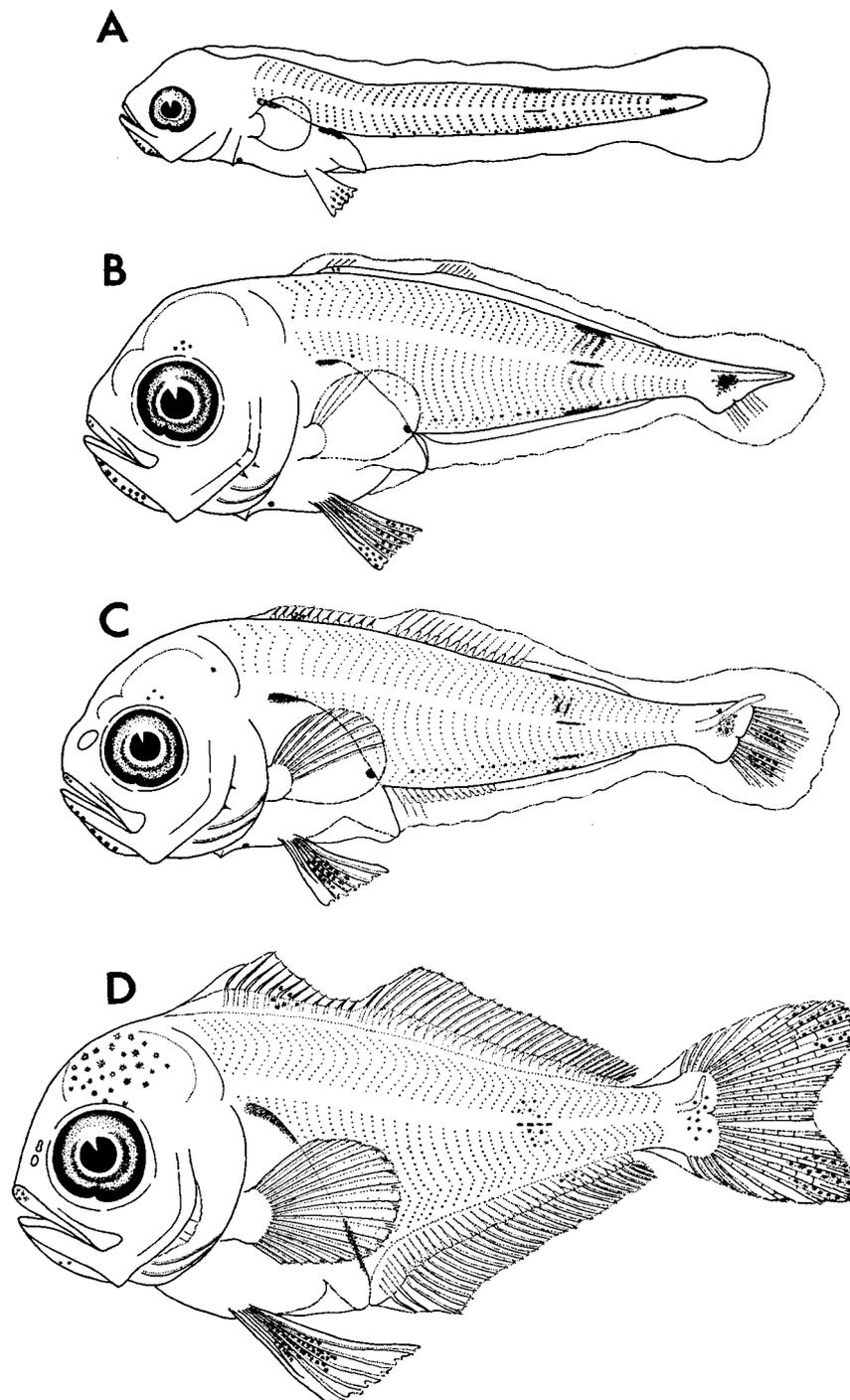LARVAE. Preflexion larvae resemble *P.*

Figure 41. Developmental stages of *Psenes pellucidus* (Nomeidae). A—3.8-mm preflexion larva; B—5.2-mm early flexion larva; C—5.9-mm flexion larva; D—9.7-mm postflexion larva.
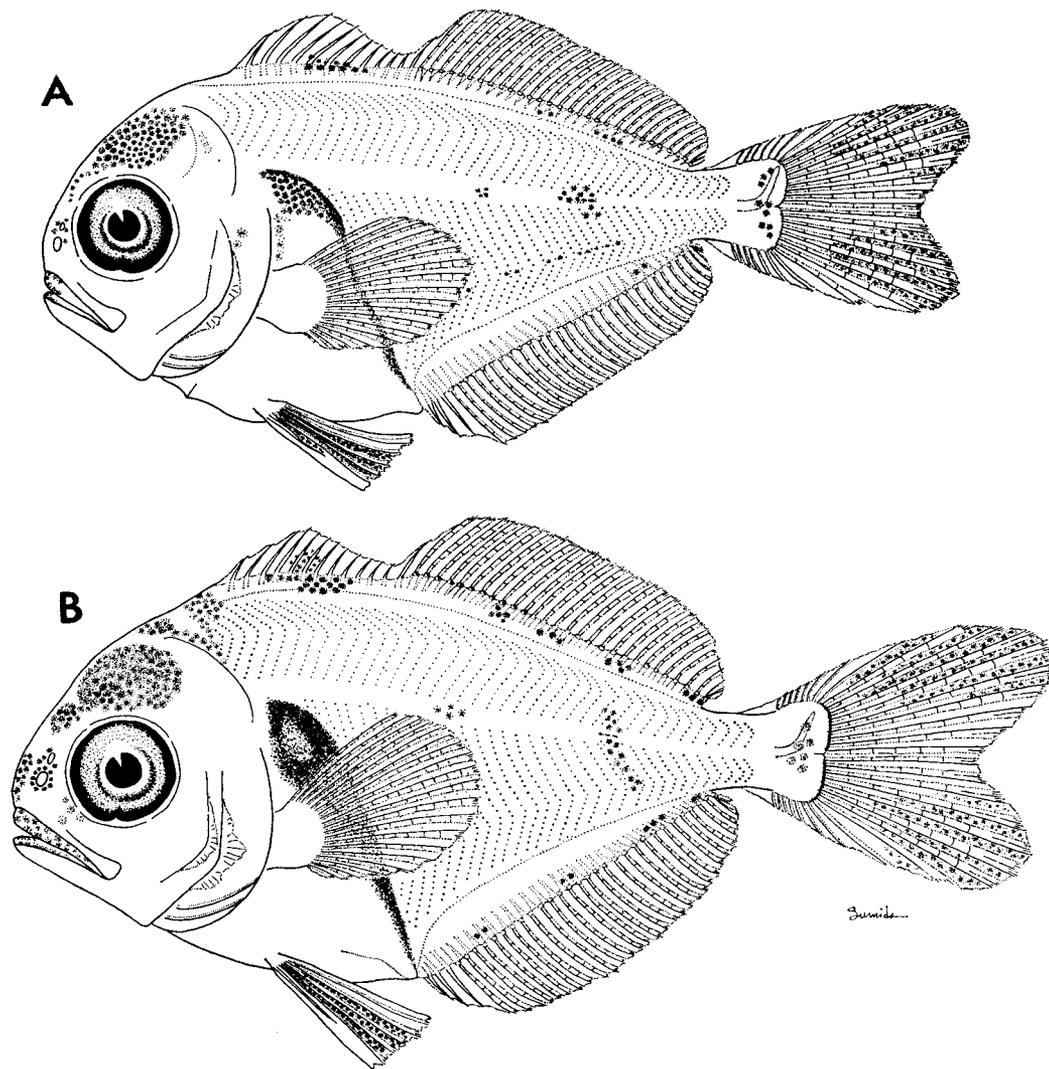
Figure 42. Developmental stages of *Psenes pellucidus* (Nomeidae). A—12.4-mm postflexion larva; B—13.4-mm early juvenile.

sio. Both have pigment under the lower jaw (Fig. 29) and ventral pigment spots on the tail portion of the body. However, *P. pellucidus* has more myomeres (40 to 42 vs. 36 to 38), lacks the dorsal pigment spot at myomeres 12 to 13, and develops lateral pigment more posteriad at myomeres 27 to 30 rather than at 22 to 25 as in *P. sio.*

Meristics.—Vertebrae 13 + 27 to 29 = 40 to 42 (average 41.1) (rarely 14 + 27 = 41); first dorsal XI or XII (average 11.9); second dorsal I (26) 28 to 30 (average I, 28.6); anal III, 27 to 30 (average III, 28.7); principal caudal rays 9 + 8; secondary caudal rays 8 to 10 dorsal + 8 to 10 ventral (average 8.9 + 8.9).

Table 44. Meristics of 21 juveniles of *Psenes pellucidus* available from the eastern Pacific (counts made from radiographs)

Station	Location Lat.	Location Long.	Date	Size-SL (mm)	Vertebrae	1st Dorsal fin	2nd Dorsal fin	Anal fin	Caudal fin
Catalina Isl.				64.5	13+28=41	XII	I,26	III,27	9-17-9
B6509-113.40	29°02'N	115°57'W	IX.15.65	16.0	13+28=41	XII	I,28	III,28	-
"	"	"	"	19.3	13+28=41	XII	I,28	III,28	9-17-9
"	"	"	"	21.0	13+28=41	XII	I,28	III,29	9-17-9
"	"	"	"	27.0	13+28=41	XII	I,28	III,27	9-17-9
T.C. 51.078	02°54'N	121°54'W	XI.17.70	60.0	14+27=41	XII	I,29	III,27	10-17-9
T.C. 51.082	01°56'N	121°41'W	XI.18.70	21.0	13+28=41	XI	I,29	III,28	8-17-9
"	"	"	"	23.0	13+29=42	XII	I,29	III,30	8-17-9
"	"	"	"	24.4	13+28=41	XII	I,29	III,28	9-17-9
"	"	"	"	25.0	13+28=41	XII	I,28	III,30	9-17-9
"	"	"	"	26.0	13+29=42	XII	I,30	III,30	9-17-9
"	"	"	"	32.0	13+28=41	XII	I,30	III,29	9-17-9
"	"	"	"	35.0	13+29=42	XII	I,29	III,30	9-17-9
"	"	"	"	95.0	13+27=40	XII	I,28	III,30	9-17-9
T.C. 51.086	01°52'N	120°05'W	XI.19.70	23.0	13+28=41	XI	I,28	III,29	8-17-8
T.C. 51.070	03°02'S	121°00'W	XI.13.70	35.0	13+28=41	XII	I,29	III,29	?-17-9
"	"	"	"	35.5	13+28=41	XII	I,28	III,29	10-17-9
T.C. 51.063	03°44'S	119°30'W	XI.12.70	39.0	13+29=42	XII	I,30	III,30	10-17-10
"	"	"	"	54.0	13+28=41	XII	I,29	-	9-17-9
T.C. 51.048	04°02'S	118°48'W	XI.8.70	21.0	13+28=41	XII	I,28	III,28	8-17-8
"	"	"	"	33.0	13+28=41	XII	I,29	III,29	8-17-8

Meristics of 21 specimens from about 4°S to about 29°N and from about 115°W to about 122°W are given in Table 44. No geographical variation in any count is indicated.

Morphometrics.—Morphometrics of a developmental series is presented in Table 45. Body proportions are discussed for all *Psenes* in an earlier section (Table 35).

Ossification.—Only five specimens were cleared and stained because of a limited amount of available material. Therefore, a detailed account of the ossification pattern in *P. pellucidus* is not presented, and fin formation is based on careful examination of remaining unstained specimens in the collection.

The pelvic fins are present on the smallest available perflexion larva of 3.8 mm (Fig. 41A). On a 5.2-mm early flexion larva, four spines are developing anteriorly in the first dorsal fin and rays are beginning to form in the second dorsal and pectoral fins; the anlagen of the caudal and anal fins are evident (Fig. 41B) and on a 5.9-mm late flexion specimen, the latter fins have rays and spines differentiated (Fig. 41C). There is a size gap between the 5.9-mm and 9.7-mm specimens available from the Pacific. In the latter specimen, the first dorsal, second dorsal, and pectoral fins have their full count of spines and/or rays; the anal fin has only two spines, whereas larger specimens all have three anal spines (Figs. 42 and 43). The caudal fin has 4 + 4 secondary rays as well as 9 + 8 principal rays. However, a 7.4-mm specimen from the Atlantic has but one anal spine (Fig. 44B), suggesting a gradual acquisition of the full complement of three anal spines. A 12.0-mm specimen has the complete number of 8 + 8 secondary caudal rays developed (Table 46).

A total of 40 vertebrae (13 + 27), which is a low but complete number for the species, is ossifying in a 12.0-mm specimen. The complete number of 2 + 4 branchiostegal rays is evident by 5.2 mm along with a few gill rakers on the first arch. The full count of gill rakers is still not achieved at 27.0 mm. Small preopercular spines are formed by 5.2 mm and become embedded by 9.7 mm.
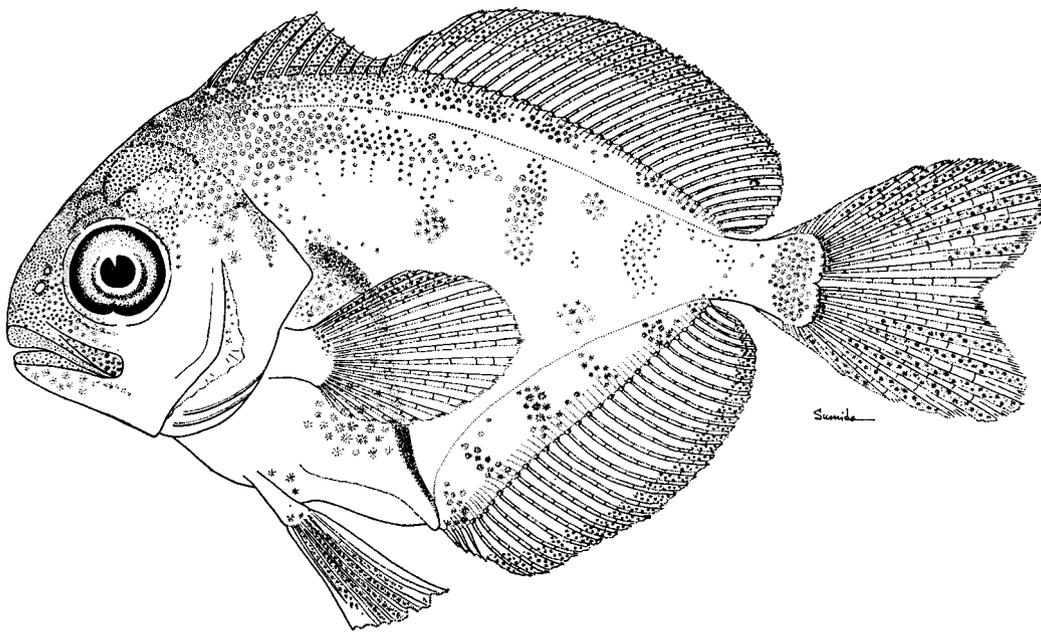
Figure 43. Early juvenile of *Psenes pellucidus* (Nomeidae), 24.4 mm.

These weak spines are finally resorbed at about 18.0 mm.

Premaxillary and dentary teeth appear from ca. 5.5 mm, and gradually increase in number with size (Table 46).

Scales are not evident on a 12.0-mm or 17.9-mm cleared and stained specimen. However, a 20.8-mm specimen is scaled in the area of the pectoral and pelvic girdle, and a 27.0-mm specimen is scaled over most of the body. The latter two specimens have the adult number of secondary caudal rays. From the above, it is difficult to pinpoint when the larval period ends and when the juvenile period begins. Fin formation appears to be complete by 13.4 mm but scale formation was first observed on a 20.8-mm specimen. We are inclined to accept the completion of fin formation as the end of the larval period.

Pigmentation.—Pigmentation on larvae of *P. pellucidus* most closely resembles the patterns on larvae of *P. sio.* Both species have pigment under the lower jaw on preflexion and flexion stage larvae (Fig. 29), a series of ventral margin spots posterior to the anus, opposing dorsal, ventral, and lateral line pigment streaks on the tail portion of the body, and pairs of dorsal and ventral spots near the tip of the notochord.

On preflexion larvae ca. 3.8 mm (Fig. 41A), pigment under the lower jaw is in the form of an inverted "Y," but melanophores are more scattered and dense compared to those in *P. sio.* A pigment spot is developed near the cleithral symphysis. Pigment is present on the precociously forming pelvic fins and internally on the peritoneum. Tail pigment consists of a series of ventral margin spots (13 on specimen illustrated), opposing dorsal, ventral, and lateral line blotches of pigment at myomeres 27 to 30, and opposing dorsal and ventral spots near the tip of the notochord.

During flexion, at 5.2 to 5.9 mm, a few pigment spots develop on the upper jaw and on the head above the eyes (Fig. 41B and C). Pigment at the tip of the notochord now
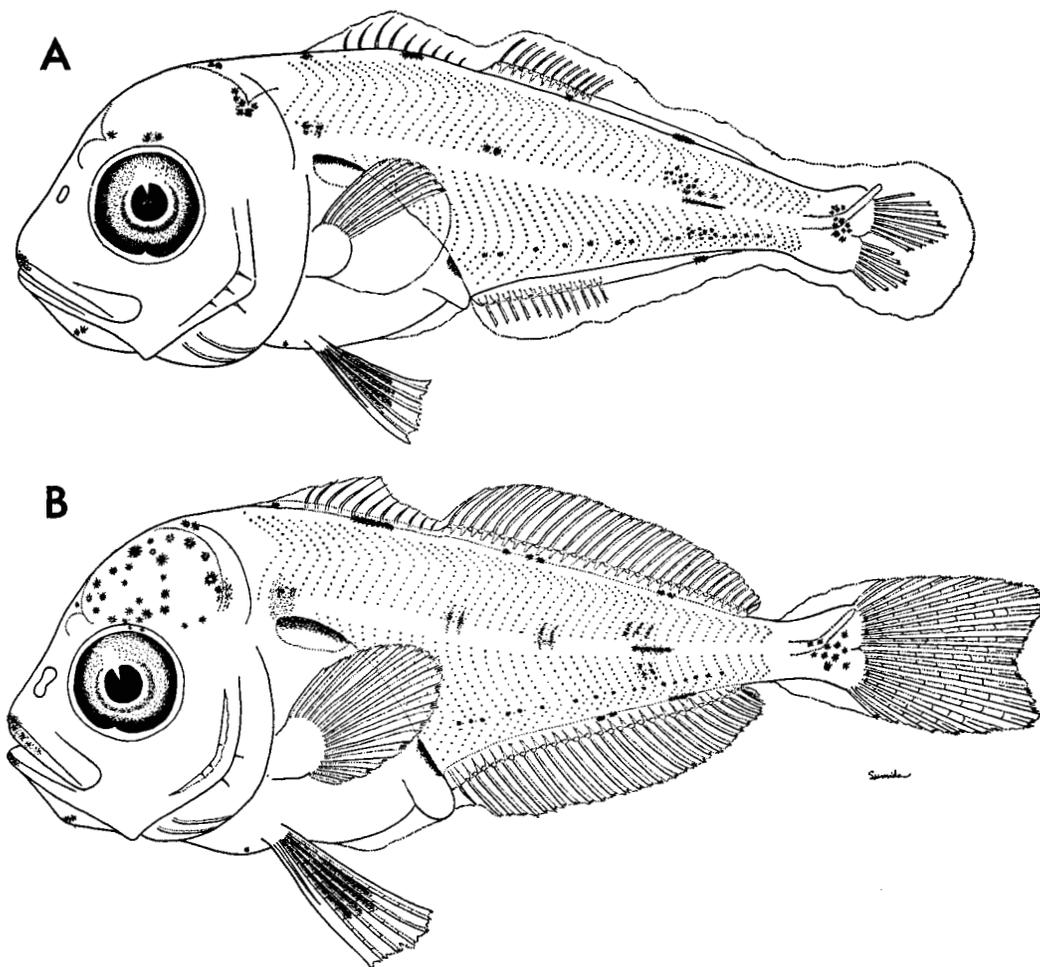
Figure 44.   Developmental stages of *Psenes pellucidus* (Nomeidae) from the Atlantic. A—5.9-mm late flexion larva; B—7.4-mm postflexion larva.

forms a patch over the hypural bones. The developing principal caudal rays also become pigmented on what will be the two lobes of the caudal fin. A few melanophores form near the anterior base of the first dorsal fin. The opposing dorsal, ventral, and lateral line tail pigment is at myomeres 28 to 31; the ventral margin spots on the tail number 17 or 18.

Pigment is added gradually in postflexion larvae. The 9.7-mm specimen (Fig. 41D) has added more pigment to the top of the head, has reduced the pigment under the lower jaw, and lost the ventral margin series on the tail. The series of ventral pigment spots are still persistent in a 12.4-mm specimen (Fig. 42A), however, although now internal and displaced dorsad. On both specimens the anterior dorsal pigment patch has spread out between the bases of the middle spines of the first dorsal fin. Pigment is added in small patches on the body adjacent to the second dorsal and anal fins; the 13.4-mm specimen (Fig. 42B) has an an-

Table 45. Morphometrics, in mm, of larvae and juveniles of *Psenes pellucidus* (specimens between dashed lines are undergoing notochord flexion)

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
B5908-113.45	3.8 NL	1.7	0.90	0.33	0.20	0.76	-	-	1.4
B5908-110.55	4.6	1.8	1.1	0.44	0.28	1.1	-	-	1.5
ETP 11.098	5.2	2.4	1.5	0.56	0.38	1.7	1.8	2.6	1.6
S.B. 178	5.9	2.8	1.7	0.64	0.40	1.9	1.8	2.9	2.0
ETP 50.090	9.7 SL	4.7	3.1	1.2	0.56	4.2	3.1	5.0	2.8
T.C. 51.063	12.4	6.1	3.5	1.4	0.72	6.2	3.6	6.2	4.1
T.C. 51.048	13.4*	6.2	3.6	1.6	0.72	6.7	3.9	6.5	4.1
ETP 12.224	17.0*	8.7	4.8	2.0	1.2	8.5	5.8	8.8	5.7
B6509-113.40	18.2*	8.4	5.3	2.1	1.2	8.8	5.3	8.8	5.2
T.C. 51.082	21.2*	11.2	6.8	2.4	1.5	10.9	6.4	11.7	7.4
"	24.4*	12.2	7.7	2.7	1.8	13.5	6.5	12.7	7.7
B6509-113.40	26.7*	13.2	8.8	3.1	2.0	15.2	7.4	13.7	8.4

* Juvenile

terior lateral line patch at myomeres 18 to 20. Early juveniles of *P. pellucidus* (Fig. 43) are only moderately pigmented compared to other species of *Psenes*. The caudal, first dorsal, and pelvic fins are rather heavily pigmented, whereas the second dorsal and anal fins are pigmented on their outer margin and the pectoral fin only between its upper rays. Pigment on the body is patchy, with several bands of pigment incompletely developed on the tail portion of the body.

Several specimens from the Atlantic develop more pigment on the body and at smaller sizes than the Pacific material (Fig. 44). Lateral pigment forms on myomeres 2 and 3, 16 and 17, 29 to 32, and over the

caudal peduncle on a 5.9-mm larva (Fig. 44A). Pigment patches along the dorsal margin of the body also form early. A 7.4-mm larva (Fig. 44B) has additional lateral pigment on myomeres 23 and 24. No specimens larger than 7.4 mm were available for study from the Atlantic.

Psenes sio
Haedrich, 1970
Figures 45 to 47

Literature.—Haedrich (1970) described *Psenes sio* from five specimens collected on STEP 1 Expedition of Scripps Institution of Oceanography between 1°24′ to 11°10′S and 80°01′ to 95°04′W. A larger specimen, 219 mm, collected at 22°N, 108° W was reported by Horn and Haedrich (1973).

Table 46. Meristics of cleared and stained larvae and juveniles of *Psenes pellucidus* (specimen above dashed line is undergoing notochord flexion; no preflexion larvae available for staining)

Station	Size (mm)	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchiostegal rays	Gill rakers (right)	Teeth (left) Prem.	Teeth (left) Dent.
ETP 60.093	5.5 NL	XI	I,19	II,17	12	I,5	1-9+8-1	13+19=32†	2+4	0+1+6	1	0
ETP 12.094	12.0 SL	XII	I,28	II,30	18	I,5	8-9+8-8	13+27=40	2+4	6+1+13	6	12
B6509-113.40	17.9*	XII	I,28	III,28	19	I,5	8-9+8-8	13+28=41	2+4	7+1+12	8	10
"	20.8*	XII	I,28	III,28	19	I,5	9-9+8-9	13+28=41	2+4	7+1+13	12	11
"	27.0*	XII	I,28	III,27	20	I,5	9-9+8-9	13+28=41	2+4	7+1+13	13	16

* Juvenile
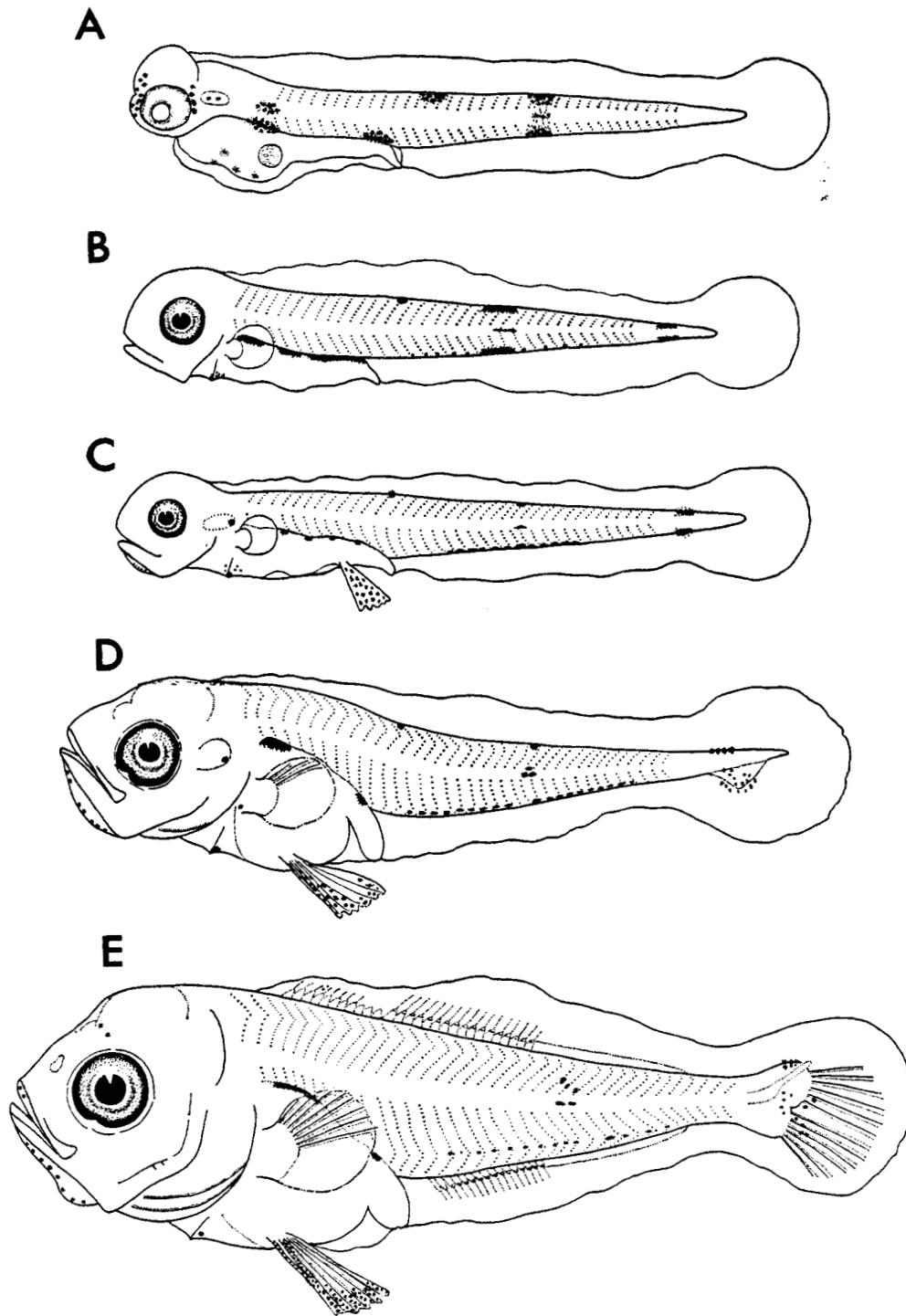
† Vertebrae not completely developed

Figure 45. Developmental stages of *Psenes sio* (Nomeidae). A—2.4-mm late yolk-sac larva; B—2.1-mm preflexion larva; C—3.5-mm preflexion larva; D—4.3-mm preflexion larva; E—5.6-mm late flexion larva.

Table 47. Meristics of 25 juveniles of *Psenes sio* selected from over its distributional range in the eastern Pacific (counts made from radiographs)

Station	Location		Date	Size-SL (mm)	Vertebrae	1st Dorsal fin	2nd Dorsal fin	Anal fin	Caudal fin
	Lat.	Long.							
Sailfish Stomach	23°40'N	109°45'W	VI.23.57	30.0	12+25=37	XI	I,23	II,23	7-17-8
J7205-157G115	23°26'N	107°45.2'W	VI.7.72	15.4	12+24=36	XI	I,23	II,23	9-17-9
Striped Marlin Stom.	23°20'N	109°21'W	VI.23.57	22.7	12+25=37	XI	I,22	II,23	8-17-8
J7205-157G100	23°17'N	107°58'W	VI.7.72	12.4	12+24=36	XI	I,22	II,23	8-17-7
ETP 50.252	14°48'N	98°10'W	XI.27.67	14.8	12+25=37	XII	I,24	II,24	9-17-9
Jord. 57.014	13°36'N	118°53'W	XI.9.70	24.6	12+25=37	XI	I,23	II,24	8-17-8
Jord. 57.013	13°27'N	119°01'W	XI.9.70	35.0	12+24=36	XI	I,23	II,23	9-17-9
"	"	"	"	65.0	12+25=37	XI	I,24	II,24	9-17-10
"	"	"	"	48.0	12+25=37	XI	I,22	II,23	8-17-9
Jord. 57.012	13°16'N	119°23'W	XI.8.70	29.5	12+24=36	XI	I,23	II,23	8-17-9
"	"	"	"	21.6	12+25=37	XI	I,24	II,25	8-17-9
Jord. 57.019	12°32'N	118°54'W	XI.10.70	18.6	12+25=37	XI	I,24	II,24	8-17-8
Jord. 57.053	09°51.4'N	117°32.5'W	XI.16.70	24.6	12+25=37	XI	I,24	II,24	9-17-8
ETP 13.328	09°42'N	95°03'W	III.18.67	16.2	12+25=37	XI	I,25	II,24	8-17-8
ETP 50.234	08°47'N	98°05'W	XI.24.67	15.0	12+24=36	XII	I,23	II,23	9-17-8
Jord. 65.037	00°12'S	98°02'W	VIII.25.71	44.0	12+25=37	XI	I,26	II,24	9-17-9
Jord. 65.208	00°30'S	96°13'W	IX.27.71	61.9	12+26=38	XII	I,24	II,25	10-17-10
Jord. 65.214	00°30'S	97°13'W	IX.28.71	27.1	12+26=38	XI	I,25	II,25	9-17-9
Jord. 65.142	03°29.4'S	96°24.3'W	IX.8.71	39.9	12+25=37	XI	I,23	II,24	8-17-8
Jord. 65.150	03°57'S	97°40'W	IX.9.71	30.0	12+26=38	XI	I,25	II,26	9-17-9
Jord. 65.144	04°00.5'S	97°02'W	IX.8.71	34.5	12+26=38	XII	I,23	II,25	8-17-8
"	"	"	"	33.5	12+26=38	XII	I,24	II,25	8-17-8
Jord. 65.138	04°05.2'S	96°31'W	IX.7.71	20.5	12+26=38	XI	I,24	II,24	8-17-8
"	"	"	"	29.5	12+24=36	XI	I,23	II,23	9-17-9
South Tow Exp.	23°24.5'S	72°20.1'W	IV.29.72	54.6	13+25=38	XII	I,24	II,25	9-17-?

Material.—Over 100 collections of larvae were examined from EASTROPAC and CalCOFI cruises. Approximately 20 collections of juveniles were examined from later cruises in the eastern tropical Pacific made during 1970 and 1971.

Distribution.—*Psenes sio* is common nearshore in the eastern Pacific (Fig. 48) and in the Gulf of California (Fig. 49). It extends offshore south of the equator to almost 100° W; north of 9°N it is found out to 120°W. This species, which is endemic to the eastern Pacific, appears to be well adapted to waters with a marked oxygen minimum layer.

Distinguishing Characters.—JUVENILES. Juveniles of *P. sio* are distinguished by meristics, pigmentation and morphometrics. The total vertebral count of 36 to 38 is unique among nomeids. It is the only *Psenes* with two anal spines. Early juveniles of *P. sio* are less deep-bodied than other *Psenes* and become uniformly pigmented at a smaller size (25 to 30 mm).

LARVAE. Larvae of *P. sio* are distinguished

by a combination of pigmentation, meristics including myomere counts, and morphometrics, especially body depth. Preflexion larvae are rather similar to those of *P. pellucidus* from the eastern Pacific. Both have heavy pigment under the lower jaw (Fig. 29), and a line of ventral pigment spots on the tail. However, preflexion larvae of *P. sio* have pigment on the dorsal body margin at myomeres 12 and 13 which is lacking in *P. pellucidus*. Also the conspicuous dorsal, lateral and ventral pigment patches on the tail develop on myomeres 22 to 25 in *P. sio* but on myomeres 27 to 29 in *P. pellucidus*. *P. sio* has several fewer myomeres (36 to 38 vs. 40 to 42) than *P. pellucidus* and is less deep-bodied.

Meristics.—Vertebrae 12 + 24 to 26 = 36 to 38 (average 37.0) (rarely 13 + 25 = 38); first dorsal XI or XII (average 11.3); second dorsal I, 22 to 26 (average 23.6); anal II, 23 to 26 (average II, 23.9); principal caudal rays 9 + 8; secondary caudal rays 7

Table 48. Morphometrics, in mm, of larvae and juveniles of *Psenes sio* (specimens between dashed lines are undergoing notochord flexion)

Station	Body length	Snout to anus	Head length	Eye diameter	Snout length	Body depth at pectoral fin base	Snout to origin dorsal fin	Snout to origin anal fin	Snout to origin pelvic fin
ETP 46.124	2.1 NL	0.98	0.42	0.17	0.10	0.42	–	–	–
S5706-153.25	3.2	1.6	0.72	0.31	0.16	0.80	–	–	1.2
S5706-157.25	3.6	1.5	0.80	0.30	0.20	0.72	–	–	1.1
S5706-153.20	4.9	2.1	1.5	0.49	0.35	1.5	1.7	2.3	1.4
ETP 13.019	4.2	2.2	1.5	0.58	0.28	1.8	1.6	2.3	1.6
"	4.7	2.4	1.5	0.56	0.37	1.8	1.8	2.4	1.6
Step 1-40	5.5	2.8	1.8	0.72	0.44	2.1	2.1	2.9	1.6
"	6.0 SL	3.0	1.8	0.70	0.48	2.2	1.9	3.1	1.8
ETP 60.189	7.2	3.7	2.5	0.86	0.54	3.1	2.7	3.9	2.4
S.B. 115	8.1	4.0	2.5	1.0	0.59	3.0	2.6	4.2	2.4
ETP 14.001	9.1	4.6	2.8	1.1	0.68	3.7	3.2	4.7	3.1
ETP 0P-044	11.0	5.8	3.4	1.4	0.82	4.4	3.3	6.0	3.2
"	12.5	6.5	3.6	1.5	0.83	4.9	3.9	6.7	3.8
ETP 47.246	13.5	6.8	4.4	1.7	1.0	6.1	4.8	7.2	4.2
Baitwell-Peru	14.4*	7.1	4.6	1.9	1.2	6.0	4.8	7.5	4.6
ETP 50.234	15.0*	7.6	4.5	1.7	1.0	6.4	4.8	7.9	4.6
ETP 47.246	15.9*	8.3	5.2	1.7	1.5	6.5	5.3	8.6	5.4
ETP 12.026	22.1*	11.2	7.1	2.3	1.6	9.4	6.7	11.9	7.5

* Juvenile

to 10 dorsal + 8 to 10 ventral (average 8.5 + 8.6).

Meristics of 25 specimens from about 23°S to about 24°N and from about 72°W to about 119°W are given in Table 47. No geographical variation of any count is indicated.

Morphometrics.—Morphometrics of a series of 18 specimens are presented in Table 48. Body proportions are discussed in an earlier section for all *Psenes* (Table 35).

Ossification.—As in all *Psenes* larvae, the pelvic fins are the first to form rays. A pre-flexion larva (3.4 mm) has the complete pelvic fin complement of one spine and five rays (Table 49). During notochord flexion rays begin to form in the caudal and pectoral fins, and spines begin to form in the first dorsal. In the caudal fin, rays first form at the junction of the two lobes; in the pectoral fins, rays ossify ventrad from the dorsal margin. In the dorsal fin, spines first develop anteriad at the origin and rapidly develop posteriad. The full complement of dorsal spines is developed before flexion is complete (4.7 mm). The second dorsal and

anal fins begin forming at the same size and are complete by the end of flexion, at 6.1 mm. Only the secondary caudal rays form gradually; 8 + 8 rays are present on a 12.4-mm specimen and 9 + 9 rays are present on a 14.4-mm specimen. The full complement is 7 to 10 + 8 to 10 rays.

The axial skeleton begins ossification at the same time that the caudal begins forming. On the 4.3-mm and 4.6-mm specimens, only the four anterior neural spines are ossifying. On a 5.4-mm specimen, all the precaudal vertebrae are formed and neural spines are ossifying on vertebrae 13 to 27, haemal spines on vertebrae 13 to 24, but centra are ossifying only on vertebrae 13 to 19. By 6.1 mm all centra, neural, and haemal spines are ossifying. The separation into precaudal and caudal vertebrae can readily be made in the 5.4- to 6.1-mm specimens, inasmuch as the haemal spines are well formed on the 13th and following vertebrae, but ribs are not yet formed on the vertebral column.

The terminal centrum, which is designated simply as a "ural" centrum, is long and markedly tapered. It is several times as long

Table 49. Meristics of cleared and stained larvae and juveniles of *Psenes sio* (specimens between dashed lines are undergoing notochord flexion)

Station	Size (mm)	1st Dorsal fin	2nd Dorsal fin	Anal fin	Pect. fin (left)	Pelvic fins	Caudal fin	Vertebrae	Branchiostegal rays	Gill rakers (right)	Teeth (left) Prem.	Teeth (left) Dent.
ETP OP-044	3.4 NL	-	-	-	-	I,5	-	-	0+4	-	-	-
S.B. 155	4.3	IV	-	-	3	I,5	0-3+3-0	4+ 0= 4+	2+4	-	-	-
S.B. 154	4.6	II	-	-	2	I,5	0-2+2-0	4+ 0= 4+	2+4	-	-	-
S.B. 155	4.7	XII	I,11	I,10	9	I,5	0-7+8-0	12+12=24†	2+4	0+1+4	-	-
S.B. 154	5.2	XI	I,15	II,13	8	I,5	0-7+8-0	12+15=27†	2+4	0+1+4	-	-
B6001-157.25	6.1 SL	XII	I,22	II,23	16	I,5	3-9+8-3	12+24=36	2+4	1+1+8	3	2
ETP 50.238	6.2	XI	I,23	I,25	16	I,5	3-9+8-3	12+25=37	2+4	0+1+8	3	1
ETP 60.189	7.8	XII	I,24	II,23	17	I,5	6-9+8-6	12+24=36	2+4	3+1+8	3	2
S.B. 150	8.3	XI	I,25	II,24	16	I,5	4-9+8-4	12+25=37	2+4	2+1+10	3	1
ETP 60.276	9.0	XI	I,24	II,23	18	I,5	6-9+8-6	12+25=37	2+4	3+1+9	5	4
ETP 47.246	12.4	XI	I,24	II,24	17	I,5	8-9+8-8	12+24=36	2+4	4+1+9	6	5
ETP 50.238	13.4	XI	I,24	II,24	16	I,5	8-9+8-8	12+25=37	2+4	3+1+11	6	7
Baitwell-Peru	14.4*	XII	I,22	II,24	17	I,5	9-9+8-9	12+26=38	2+4	5+1+11	6	7
9°27'N 89°18'W	22.5*	XII	I,24	II,23	18	I,5	10-9+8-10	13+25=38	2+4	8+1+13	10	15

* Juvenile
† Vertebrae not completely developed

as any other centrum, and on some specimens is slightly expanded at its junction with the superior hypurals. Although the ural centrum ossifies as a unit, and hence furnishes no evidence of past fusions, both its length and its appearance give the impression of a fused bone made of at least two parts, one part supporting the superior hypurals, the other the inferior hypurals. This impression is further enhanced by the fact that the stegural (anterior pair of the uroneurals) forms on the posterior half of the ural centrum, opposite the superior hypurals. The hypurals are comprised of two superior and two inferior bones (including the parhypural). At first formation, there are six centers of ossification of hypurals, but fusion soon occurs between the two inferior hypurals adjacent to the parhypural. Fusion occurs less rapidly between the inner two superior hypurals, which on many postflexion larvae are united only at their distal margins. The three epurals and the second pair of uroneurals are the last of the ural bones to ossify. The vertebra immediately anterior to the ural centrum lacks a neural spine but has a specialized neural arch and an autogenous haemal spine. The haemal

spine is also autogenous on the second vertebra anterior to the ural, but the neural spine is well-developed and spatulate. Occasionally, the haemal spine of the third vertebra anterior to the ural is autogenous (a condition frequently noted on *Icichthys* larvae and juveniles). The nomeid caudal skeleton is illustrated by Haedrich (1967).

Branchiostegal rays form quite early; all six elements (2 + 4) are present on a 4.3-mm specimen. Gill rakers are beginning to form on the first arch on a 4.7-mm specimen, but the full complement is not yet developed on a 14.4-mm specimen.

Small, weakly developed preopercular spines are formed on early flexion larvae from ca. 4.5 mm and become embedded in a fringe of tissue at about 9.0 mm. These preopercular spines are difficult to see on material that is not cleared and stained.

A discussion of the development of teeth in *P. sio* in the late larval and early juvenile period is presented in an earlier section comparing dentition of pelagic stromateoid fishes.

Scales are first evident on the body of a 14.4-mm specimen. At this size, a full complement of 9 + 9 procurrent caudal rays is
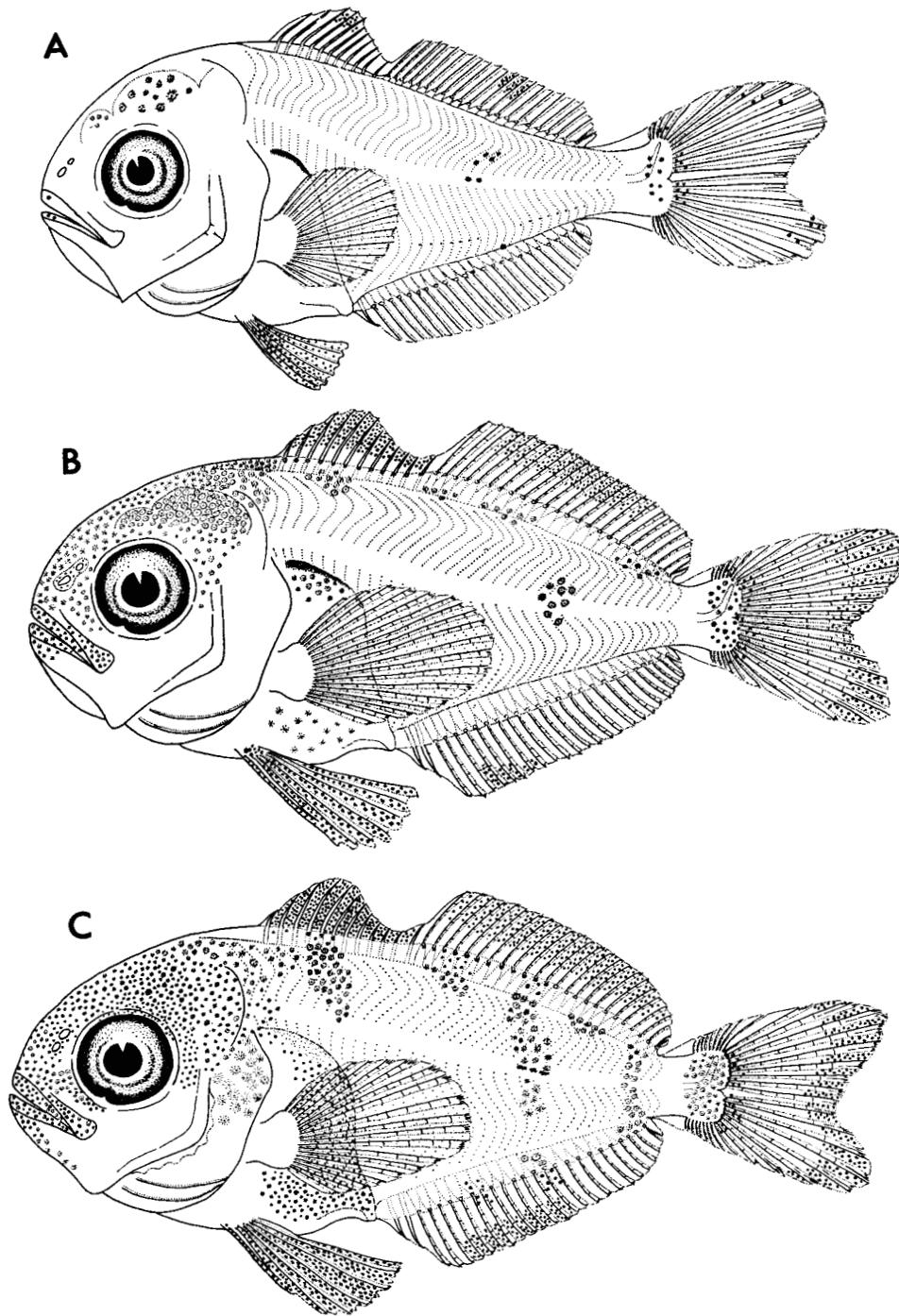
Figure 46. Developmental stages of *Psenes sio* (Nomeidae). A—7.6-mm postflexion larva; B—14.8-mm early juvenile; C—17.4-mm early juvenile.
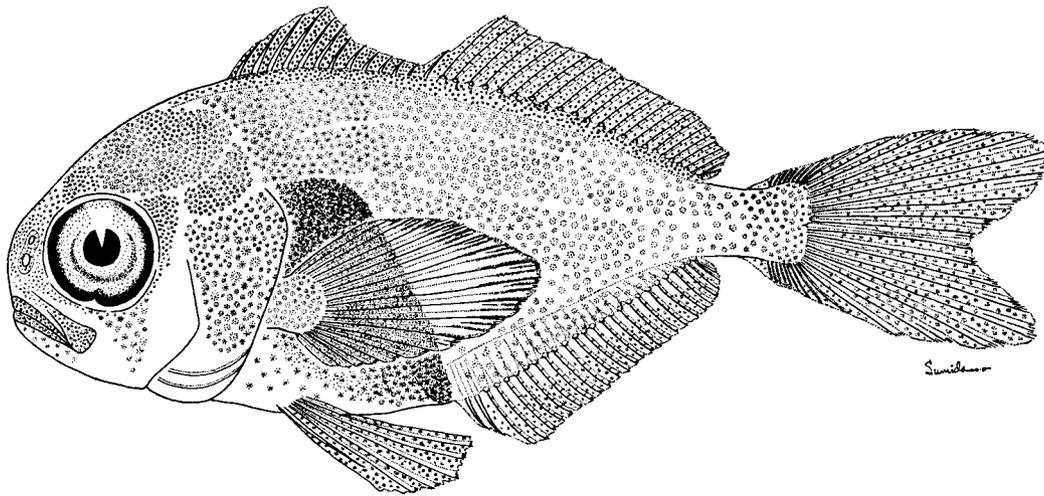
Figure 47.   Juvenile of *Psenes sio* (Nomeidae), 26.9 mm.

completed along with the other fins, characters which make specimens at this size juveniles.

Pigmentation.—Larvae of *P. sio* are pigmented similarly to other *Psenes* at small sizes but with several diagnostic differences. The banding pattern developed on early juveniles of *Psenes sio* is transitory and is soon succeeded by uniform pigmentation on juveniles as small as 27 mm.

A 2.4-mm yolk-sac larva (Fig. 45A) has pigment similar to the late embryo (Fig. 2G). Pigment is present on the head anterior and posterior to the eye, above the gut near the oil globule and anterior to the anus, and below the gut anterior to the oil globule. Pigment on the body consists of lateral pigment above the oil globule, dorsal pigment at myomeres 13 and 14 and dorsal, ventral, and lateral pigment at myomeres 22 to 24.

Preflexion larvae, 2.1 to 3.6 mm long (Figs. 45B and C), have heavy pigment under the lower jaw in the form of an inverted "Y" (Fig. 29E), pigment at the cleithral symphysis, and on the peritoneum above the gut. The tail has three dorsal pigment patches, one at myomeres 12 to 14, a second at myomeres 22 to 24, and a third

patch near the tip of the notochord. Under the second patch are lateral and ventral pigment patches, and under the third is a ventral pigment patch. There is a line of melanophores along the ventral margin of the tail. The early forming pelvic fins are pigmented.

Flexion larvae, 4.3 to 5.6 mm long (Figs. 45D and E), add little pigment to the pre-existing pattern. By late flexion some pigment develops on the upper jaw and on the head above the eyes. The dorsal, ventral, and lateral body pigment at myomeres 24 and 25 is less accentuated than on some preflexion larvae. The anterior dorsal pigment spot is lost during flexion. The 13 to 19 ventral melanophores are still conspicuous but are becoming embedded by late flexion. The dorsal and ventral pigment near the tip of the notochord spreads over the developing hypurals and bases of the caudal rays.

Postflexion larvae and early juveniles, 6.0 to 17.4 mm long, develop conspicuous pigment on the head and fins and the banded pattern of the body (Fig. 46). The ventral line of melanophores persists until 7.6 mm (Fig. 46A). Pigment begins to form on the dorsal and caudal fin membranes at this size.
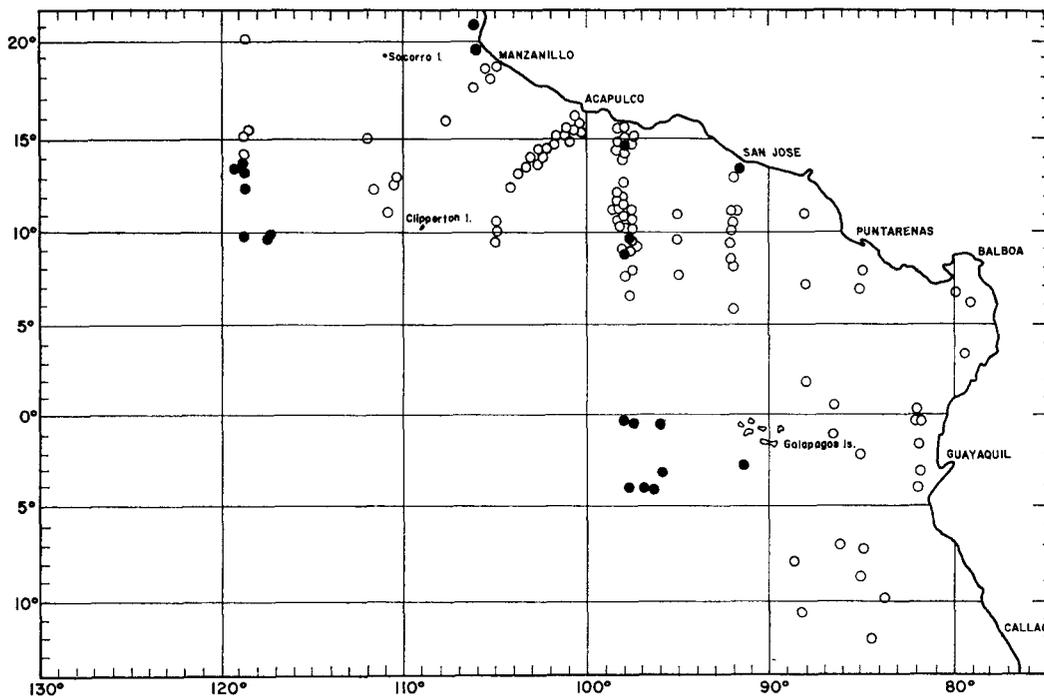
Figure 48. Occurrences of *Psenes sio* larvae (open circles) and juveniles (closed circles) in the eastern tropical Pacific.

The head becomes covered with pigment by 14.8 mm. A single pigment patch forms under the first dorsal fin. Three patches are formed under the second dorsal fin at 14.8 mm (Fig. 46B). By 17.4 mm (Fig. 46C), four patches are present under the second dorsal, about equally spaced between the origin and termination of this fin, with two of these patches spreading ventrally to form bands. In addition, the pigment over the hypural bones is heavy and spreads over to the adjacent caudal rays. On a 17.4-mm specimen, pigment is uniform on the pelvic and first dorsal fins, is present on the distal half of the second dorsal and caudal, and is patchy on the anal fin. Only the pectoral fins lack pigment.

Larger juveniles lose the banding pattern on the body formed earlier and become uniformly pigmented as illustrated for a 26.9-mm specimen (Fig. 47).

DISTRIBUTION AND RELATIVE ABUNDANCE OF PELAGIC STROMATEOID FISHES IN THE EASTERN PACIFIC

Amarsipus carlsbergi is a tropical species. It occurred in the eastern tropical Pacific between 15°N to 3°S latitude, and 105° to 125°W longitude; it was also taken off Hawaii. In abundance it would be classed between rare and rather common.

The four centrolophids from the eastern Pacific are all temperate water forms. Larvae of *Icichthys lockingtoni* are commonly taken over much of the CalCOFI pattern; their primary distribution in the eastern Pacific is in the transition waters of the California Current. The three species of *Schedophilus* (*S. maculatus*, *S. huttoni*, and *S. labyrinthicus*) were all dipnetted under jellyfish from the eastern South Pacific; none of these was taken in more than two collections; hence each is quite rare.
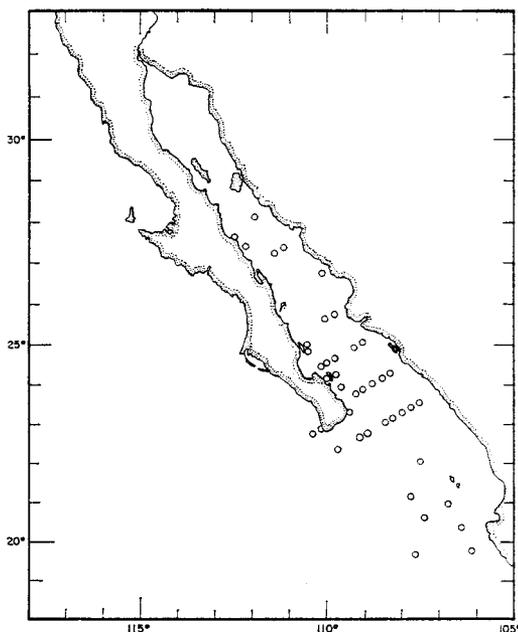
Figure 49. Occurrences of *Psenes sio* larvae in the Gulf of California and adjacent areas. Open circles indicate locality of collections.

The genus *Tetragonurus* has a wider latitudinal distribution than the other pelagic stromateoid genera. *T. cuvieri* is a temperate water form in the eastern Pacific occurring over an extensive area, including the offshore central water mass; it is moderately common. *T. atlanticus* is a tropical-subtropical species; most occurrences in the tropical eastern Pacific were in an oceanic band between 5°N and 5°S, although some specimens were obtained to 20°S. The other records for this species are from the central North Pacific, between Hawaii and the International Date Line to as far north as about 33°N. Such disjunct distributions undoubtedly result from sampling hiati rather than actual breaks in distribution. With regard to relative abundance, *T. atlanticus* would be classed between rare and rather common. We have only three specimens of *T. pacificus*, two from the tropical eastern Pacific and one from off Hawaii.

Nomeids are taken in tropical-subtropical waters, with the majority of occurrences within the tropics. Of the 11 kinds that have been collected from the eastern Pacific, four could be classed as quite rare (i.e., with one to three occurrences), one as rare (with five to 10 occurrences), three as rather comon, two as common, and only one as relatively abundant. Three of the species classed as quite rare are *Cubiceps* species: the southern occurring *C. capensis* (two occurrences), the tropical occurring *Cubiceps* sp. A (three occurrences), and the North Pacific central water mass form, *Cubiceps* sp. B (three occurrences). There is but a single occurrence of *Psenes maculatus* (20°N, 123°W). The rare form is *Nomeus gronovii* with seven occurrences. The forms classed as rather common are *Psenes pellucidus*, *P. arafurensis*, and *P. cyanophrys*; those classed as common are *Psenes sio*, which occurs in a broad coastal band in the eastern tropical Pacific extending into the Gulf of California, and the widely distributed *Cubiceps caeruleus*. The species most frequently taken was *Cubiceps pauciradiatus*, which perhaps also is the most common nomeid on a worldwide basis.

To give some quantitative assessment of the relative abundance of pelagic stromateoid larvae and juveniles, information is summarized for EASTROPAC cruises, particularly EASTROPAC I, and for collections taken off Hawaii. On EASTROPAC I, 961 specimens obtained at 178 of the 478 stations occupied were nomeid larvae, seven larvae from six stations were tetragonurids and five larvae from five stations were amarsipids. On EASTROPAC II, 1,460 specimens from 229 of 355 stations occupied were of nomeid larvae, 12 specimens from 11 stations were tetragonurid larvae and two specimens from two stations were amarsipid larvae. On both surveys, nomeid larvae contributed slightly over 1% of the total number of larvae of all kinds.

Of the nomeids taken on EASTROPAC I, 829 specimens were available for study. As mentioned in Ahlstrom (1971), eight kinds of nomeid larvae were taken on

EASTROPAC I. Of these, *Cubiceps pauci-radiatus* was by far the most common with 706 specimens taken at 135 stations. *Psenes sio* was the next most common form with 69 specimens from 32 stations, followed by *C. caeruleus* with 25 specimens from 17 stations, *P. arafurensis* with 13 specimens from nine stations, *P. cyanophrys* with nine specimens from eight stations, *P. pellucidus* with five specimens from four stations, *Cubiceps* sp. A, one specimen and *Nomeus gronovii*, one specimen. A re-examination of *Tetragonurus* material of EASTROPAC I shows that only one species was represented, *T. atlanticus*, with seven specimens from six hauls. Single specimens of the monotypic *Amarsipus carlsbergi* were taken at five stations. Collections of juveniles and adults obtained in midwater trawl hauls made on NMFS cruises in the eastern tropical Pacific (TOWNSEND CROMWELL cruise 51 and DAVID STARR JORDAN cruises 57, 60, 65, and 77) contained the above 10 kinds of pelagic stromateoid fishes in roughly the same order of relative abundance as for larvae.

Juveniles of four species of nomeids were taken in midwater trawl hauls made off Hawaii on TOMNSEND CROMWELL cruise 32. The relative abundance of the four species was as follows: *Cubiceps pauciradiatus*—798 specimens taken in 45 hauls, largest collection with 119 specimens; *Psenes cyanophrys*—139 specimens taken in 31 hauls, largest collection with 19 specimens; *P. arafurensis*—39 specimens taken in 19 hauls, largest collection with five specimens; and *C. caeruleus*—six specimens taken in five hauls.

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ADDENDUM

A paper by T. A. Pertseva-Ostroumova and T. S. Rass, 1973, Ichthyoplankton of the South-eastern Pacific Ocean, Tr. Inst. Okeanol. Akad. Nauk. SSSR 94: 7-70, has been brought to our attention. They record and illustrate three kinds of stromateoid larvae. The series referred by them to *Cubiceps caeruleus* is shown by their illustrations to be *Cubiceps pauciradiatus*. The series referred to *Nomeus albula* (Meuschen)? appears to be a mixture. The largest specimen in the series, 10.0 mm, is that of *Nomeus gronovii*, the other five illustrations, including a late-stage egg and larvae 3.2, 3.4, 4.5 and 7.5 mm, are almost certainly *Psenes sio*. A 6.5-mm specimen of *Amarsipus carlsbergi* is illustrated.

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APPENDIX 1

Station Positions of Collections of Larvae and Early Juveniles Included in Morphometric and Meristic Tables

This appendix is included to provide information on the localities of capture (station position) and date of capture of the larvae and early juveniles included in morphometric and meristic tables. In these tables, specimens were utilized from 72 EASTROPAC stations, 54 CalCOFI stations, 36 stations from 11 expeditions or special cruises as follows: JORDAN cruises 57, 60, and 77 (all in the eastern tropical Pacific); TOWNSEND CROMWELL cruise 32 (off Hawaii) and cruise 51 (eastern tropical Pacific); and Scripps Institution of Oceanography expeditions designated NORPAC, SHELLBACK (S.B.), STEP I, CLIMAX II, CATO II, ARIES 9, and SOUTH TOW. Where no Scripps expedition or cruise name was given, the Scripps collection number is listed, e.g., SIO 64-641. (This is also done in the tables of juvenile and adult meristics.) Collections listed as "Hunter and Mitchell" were made off Costa Rica (Hunter and Mitchell, 1967, 1968). In addition, the samples designated "Hawaii" followed by a series of numbers were from a station off the Hawaiian Island of Oahu which was sampled repeatedly by Thomas Clarke (Clarke, 1973).

EASTROPAC (ETP) cruises: stations numbered 11.000 to 14.000 were taken on the first multivessel EASTROPAC cruise; 11.000 series by R/V ARGO (SIO), 12.000 series by R/V DAVID STARR JORDAN (BCF); 13.000 series by R/V ROCKAWAY (U.S. Coast Guard), and 14.000 series by R/V ALAMINOS (Texas A & M). Stations numbered 20.000, 30.000, 50.000, and 60.000 were all occupied on single vessel cruises made by R/V DAVID STARR JORDAN. Stations numbered 45.000 to 47.000 were taken on the second multivessel EASTROPAC cruise; 45.000 series by R/V THOMAS WASHINGTON (SIO), 46.000 series by R/V UNDAUNTED (BCF), and 47.000 series by R/V ROCKAWAY. From the third multivessel EASTROPAC

cruises, collections are included from 75.000 series, taken by R/V THOMAS WASHINGTON. The OP series was made on a transect through the EAS-TROPAC area by R/V OCEANOGRAPHER (Environmental Science Service). Observations were numbered sequentially for each series.

The CalCOFI series were taken by no fewer than 10 research vessels. In designating CalCOFI samples the vessel is identified by a single letter that precedes the cruise and station designation. For example, station B5607-120.50 was taken from the R/V BLACK DOUGLAS (B) on cruise 5607, i.e., 56 (year) and 07 (month) for July 1956, on station 120.50, one of the permanent CalCOFI grid stations—this one located about 40 miles offshore from Cedros Island, Baja California. The designation of CalCOFI research vessels by letters in the tables are as follows: B, BLACK DOUGLAS (BCF); C, CREST (SIO); G, ALEXANDER AGASSIZ (SIO); H, HORIZON (SIO); J, DAVID STARR JORDAN (NOAA); L, ALASKA (CF&G); O, ORCA (SIO); P,

PAOLINA T. (SIO); S, STRANGER (SIO); and Y, YELLOWFIN (CF&G). The vessel is indicated before each station in the text tables, but not in the following appendix tables.

The collections from off Hawaii were obtained on TOWNSEND CROMWELL (T.C.) cruise 32 or from a series of hauls made at a station off Hawaii by Thomas Clarke. The latter are designated as Hawaii—followed by station data, as for example: Hawaii 71-9-3 identifies a haul made in 1971 (71), during September (9) which was the third of a series of hauls taken during this cruise. The Clarke series were made from R/V TERITU (University of Hawaii) in an area bounded by 21°20' to 21°35'N latitude and 158°20' to 158°35'W longitude. Cruise designated 70-9 was made on September 14-17 and 20-24, 1970; 71-6 on June 8-11 and 15-19, 1971; 71-9 on September 17-19, 1971; and 71-10 on October 4-6, 1971.

The collections taken on expeditions need no amplification.

Appendix Table 1A. Station positions of EASTROPAC (ETP) collections included in morphometric and meristic tables for larvae

Station	Latitude	Longitude	Date	Station	Latitude	Longitude	Date
11.066	06°49.8'N	118°55.5'W	II. 3.67	45.131	06°19.5'S	118°58.0'W	VIII.19.67
068	06°05.0'N	118°51.0'W	II. 3.67	177	05°21.1'S	111°59.5'W	VIII.25.67
098	00°05.8'N	119°00.0'W	II. 6.67	325	09°01.8'N	111°54.8'W	IX. 6.67
114	02°37.8'S	119°02.3'W	II. 7.67	358	17°20.5'N	106°29.8'W	IX.10.67
213	11°13.7'S	126°01.0'W	II.19.67	46.059	00°24.0'N	105°25.0'W	VIII.24.67
306	12°03.5'N	126°00.0'W	II.27.67	071	03°17.0'S	104°55.0'W	VIII.25.67
12.026	17°24.5'N	106°17.0'W	II.15.67	124	12°53.0'N	98°03.0'W	IX. 5.67
094	00°10.0'S	105°00.0'W	II.26.67	47.244	06°59.0'N	84°54.0'W	VIII.27.67
221	00°44.0'S	112°01.5'W	III.13.67	246	07°42.5'N	85°04.0'W	VIII.27.67
224	00°20.0'S	112°00.0'W	III.13.67	297	04°38.0'N	87°57.5'W	IX. 4.67
246	06°12.0'N	112°00.5'W	III.16.67	50.055	03°39.0'N	119°15.5'W	X.26.67
13.019	11°22.5'N	88°05.0'W	II. 4.67	061	02°08.5'N	119°28.0'W	X.27.67
048	04°41.0'N	91°58.0'W	II.11.67	071	01°04.4'S	119°13.0'W	X.28.67
052	03°25.0'N	91°58.0'W	II.11.67	077	02°59.0'S	112°10.0'W	X.30.67
056	01°58.0'N	92°08.5'W	II.12.67	082	01°02.5'S	112°13.2'W	X.31.67
079	06°59.0'S	92°05.0'W	II.17.67	090	02°02.4'N	112°15.0'W	XI. 1.67
105	15°45.0'S	92°07.0'W	II.20.67	170	07°29.5'N	105°10.5'W	XI.14.67
117	19°52.0'S	92°05.0'W	II.21.67	234	08°47.0'N	98°05.0'W	XI.24.67
191	02°26.0'S	97°57.0'W	III. 2.67	238	10°17.0'N	98°06.0'W	XI.25.67
241	07°19.0'N	98°03.0'W	III. 5.67	60.060	03°01.0'N	118°43.0'W	XII.28.67
243	08°05.0'N	97°59.0'W	III. 5.67	062	02°33.0'N	118°44.0'W	XII.28.67
14.001	06°52.0'N	79°44.0'W	I.31.67	072	00°51.0'N	118°39.0'W	XII.29.67
209	07°50.0'N	85°59.3'W	III.14.67	078	00°15.0'S	118°38.0'W	XII.30.67
20.064	00°02.0'S	119°17.0'W	IV.20.67	093	02°58.0'S	111°46.0'W	I. 2.68
100	05°19.0'N	112°28.0'W	IV.26.67	150	14°51.0'N	108°55.0'W	I. 7.68
191	03°27.0'N	105°22.0'W	V.13.67	189	09°13.0'N	104°46.5'W	I.16.68
193	02°46.0'N	105°29.0'W	V.13.67	195	06°58.0'N	104°46.5'W	I.17.68
195	02°13.0'N	105°23.0'W	V.13.67	276	06°54.0'N	97°44.5'W	I.26.68
222	01°11.0'N	98°05.0'W	V.18.67	75.048	03°33.0'N	118°52.0'W	II.25.68
224	02°04.0'N	98°10.0'W	V.19.67	064	00°44.0'N	118°58.0'W	II.26.68
30.043	07°51.0'N	118°24.0'W	VI.22.67	068	00°00.0'N	118°54.0'W	II.26.68
055	03°47.0'N	118°30.0'W	VI.23.67	198	03°19.0'N	98°05.0'W	III.23.68
083	01°22.0'S	111°32.0'W	VI.29.67	239	05°00.0'N	98°02.0'W	IV. 4.68
248	09°22.0'N	97°31.0'W	VII.25.67	241	06°22.0'N	98°01.0'W	IV. 5.68
45.028	16°11.3'N	119°03.3'W	VIII. 9.67	OP 044	01°57.0'S	84°58.0'W	XI.18.67
090	00°57.2'N	119°04.5'W	VIII.16.67				
125	04°45.8'S	118°53.0'W	VIII.19.67				

Appendix Table 1B. Station positions of CalCOFI collections included in morphometric and meristic tables for larvae

Station	Station position		Date	Station	Station position		Date
	Lat. N	Long. W			Lat. N	Long. W	
4903-81.127	31°47.0′	125°38.0′	III.14.49	6204-60.80	36°54.0′	125°05.0′	III.27.62
5202-80.90	33°09.0′	123°13.0′	II.21.52	6204-70.80	35°15.0′	123°49.0′	III.21.62
5203-90.53	32°37.5′	119°31.0′	III. 9.52	6204-80.100	32°57.0′	123°56.0′	III.18.62
5412-107.40	30°10.0′	116°43.0′	XII.13.54	6204-113.50	28°41.0′	116°35.0′	IV.22.62
				6207-87.65	32°50.0′	120°41.5′	VII.12.62
5603-110.80	28°16.5′	118°59.0′	III.16.56	6207-87.90	32°02.0′	122°23.0′	VII.11.62
5604-83.60	33°33.5′	120°45.0′	IV.16.56	6207-90.80	31°45.0′	121°19.5′	VIII.28.62
5604-107.50	29°53.5′	117°23.0′	IV.26.56	6207-90.120	30°24.5′	123°59.5′	VIII.27.62
5607-120.50	27°33.0′	115°52.5′	VII.13.56	6207-93.90	30°50.0′	121°34.5′	VII.16.62
5611-93.55	32°01.5′	119°16.0′	X.31.56	6210-80.100	32°54.5′	123°56.0′	X.12.62
5612-170.20	20°32.0′	107°28.5′	XII. 2.56	6301-80.80	33°27.5′	122°32.5′	I.14.63
5612-173.30	20°20.5′	106°31.0′	XII. 5.56	6310-80.80	33°28.5′	122°32.5′	X. 3.63
5701-100.60	30°39.5′	118°50.0′	I.19.57	6310-83.60	33°34.0′	120°45.0′	X. 4.63
5702-107.60	29°31.0′	118°03.0′	II.19.57	6410-93.90	30°51.0′	121°35.0′	X.11.64
5706-153.20	22°48.0′	110°22.0′	VI. 7.57				
5706-153.25	22°37.0′	110°40.0′	VI. 7.57	6509-113.40	29°02.0′	115°57.0′	IX.16.65
5706-157.25	21°55.0′	110°16.0′	VI. 8.57	6604-73.53	35°31.0′	121°28.5′	IV. 7.66
5805-77.50	34°05.0′	120°52.0′	V.11.58	6607-93.80	31°10.0′	120°54.5′	VII.27.66
5905-70.75	35°24.0′	123°27.5′	V.19.59	6707-90.120	30°23.0′	124°00.0′	VI.29.67
5905-73.80	34°33.5′	123°27.5′	V.18.59	6707-93.140	29°09.0′	124°52.5′	VI.30.67
5908-110.55	29°07.0′	117°18.0′	VIII.22.59	6707-107.65	29°18.5′	118°21.0′	VII. 9.67
5908-113.45	28°52.0′	116°18.0′	VIII.20.59	6907-73.65	35°08.0′	122°19.0′	VII.23.69
6001-157.25	22°02.5′	110°19.0′	I.27.60	7205-20.129	20°00.0′	129°00.0′	V.27.72
6101-77.55	34°56.0′	121°17.5′	I. 6.61	7205-157G130	23°33.5′	107°31.1′	VI. 7.72
6107-80.60	34°09.0′	121°09.0′	VI.30.61	7210-31.135	31°00.0′	135°00.0′	IX.30.72
6107-83.80	32°55.5′	122°05.0′	VII.13.61	7210-31.139	31°00.0′	139°00.0′	X. 2.72
				7210-31.145	31°00.0′	145°00.0′	X. 3.72
				7210-24.143	24°00.0′	142°50.0′	X.30.72
				7210-20.123	20°00.0′	123°06.0′	XI. 6.72

Appendix Table 1C. Station positions of collections obtained on special cruises or expeditions

Expedition and station	Station position		Date
	Latitude	Longitude	
SHELLBACK 115	08°16.0'S	83°42.0'W	VII. 2.52
SHELLBACK 150	07°10.5'S	84°58.0'W	VII.26.52
SHELLBACK 154	02°59.0'S	85°00.5'W	VII.27.52
SHELLBACK 155	01°56.0'S	84°59.5'W	VII.28.52
SHELLBACK 162	04°55.0'N	85°01.0'W	VII.30.52
SHELLBACK 178	01°10.0'N	89°28.0'W	VIII. 8.52
NORPAC 95	30°20.5'N	119°27.0'W	IX.16.55
NORPAC 107	29°50.0'N	115°51.0'W	IX.21.55
STEP 1 32	18°06.0'S	80°56.0'W	X.31.60
STEP 1 40	20°37.0'S	76°51.0'W	XI. 5.60
JORDAN 57.030	09°43.5'N	119°30.0'W	XI.12.70
JORDAN 57.035	10°00.0'N	119°00.0'W	XI.12.70
JORDAN 57.047	10°46.0'N	117°28.0'W	XI.15.70
JORDAN 57.113	07°14.6'N	119°24.0'W	XII. 7.70
JORDAN 60.150	09°27.7'N	117°49.0'W	IV. 7.71
JORDAN 77.101	04°21.5'N	118°14.8'W	I.28.73
JORDAN 77.119	07°30.0'N	117°20.4'W	I.31.73
JORDAN 77.144	10°00.0'N	122°19.0'W	II. 4.73
JORDAN 77.155	09°31.2'N	123°18.0'W	II. 6.73
CROMWELL 51.048	04°02.0'S	118°48.0'W	XI. 8.70
CROMWELL 51.056	03°12.0'S	119°26.0'W	XI.10.70
CROMWELL 51.063	03°44.0'S	119°30.0'W	XI.12.70
CROMWELL 51.066	03°10.0'S	120°19.5'W	XI.12.70
CROMWELL 51.071	03°12.0'S	121°27.0'W	XI.14.70
CROMWELL 51.081	02°10.0'N	121°37.0'W	XI.17.70
CROMWELL 51.082	01°56.0'N	121°41.0'W	XI.18.70
CROMWELL 32.010	21°22.0'N	158°15.0'W	VII.15.67
CROMWELL 32.012	21°23.0'N	158°15.0'W	VII.16.67
CROMWELL 32.023	21°00.0'N	158°30.0'W	VII.22.67
CROMWELL 32.034	21°01.0'N	158°32.0'W	VII.14.67
CLIMAX II (dipnet)	24°42.0'S	155°03.5'W	X. 3.69
CLIMAX II (dipnet)	24°34.0'S	154°50.0'W	X. 9.69
CATO II B3.119	25°14.8'S	155°07.7'W	VIII. 1.72
ARIES 9 H-17	27°28.2-27.0'N	155°28.6-47.0'W	X. 2.71
ARIES 9 A-2	27°22.4-11.8'N	155°01.2-02.9'W	IX.24.71
SOUTH TOW Sta. 13	28°07.0-18.3'N	155°07.8-14.9'W	II.6-7.73
Hunter & Mitchell	09°45.0'N	85°39.0'W	V.14.66