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Identification of Larval Tunas, Billfishes and other Scombroid Fishes (Suborder Scombroidei): an Illustrated Guide

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IDENTIFICATION OF LARVAL TUNAS, BILLFISHES AND OTHER SCOMBROID FISHES (SUBORDER SCOMBROIDEI): AN ILLUSTRATED GUIDE

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Abstract

Diagnostic features for recognising and separating larval fish of the families Scombrolabracidae, Gempylidae, Trichiuridae, Scombridae, Xiphiidae and Istiophoridae are listed. A key, supplemented with detailed illustrations and descriptive notes, identifies the larval tunas to species and the other larvae of family Scombridae to genera. Another illustrated and annotated key is included for separating and identifying billfish larvae (Family Istiophoridae) to species. Notes to assist in separating scombrids and billfishes from other larval fishes with morphological similarities are also included.

Contents

Introduction

Scombroid fishes which are widely distributed in the tropical and temperate seas of the world are very important as commercial food fishes. Currently, suborder Scombroidei consists of 6 families, 44 genera, and about 100 species (Collette et al., 1984). This guide deals primarily with those expected to be found in the Indian Ocean off northwestern Australia, where the CSIRO Division of Fisheries Research has recently begun to study larval southern bluefin tuna. The Fishery Agency of Japan has been conducting research on larval scombrids and billfishes in the region since 1968. The information on larval taxonomy built up during that period has largely been published in Japanese journals.These studies, along with a number of others on larval scombroids from around the world, make up a diffuse literature on the topic. It is appropriate, therefore, to consolidate the available information into a unified identification guide applicable to the larval scombroids of Australia. Because of current research interests, emphasis is placed on the larval tunas, and on the southern bluefin tuna in particular.

This guide reflects the current status of Japanese identification of tuna larvae and provides a basis for future taxonomic work; however there are inadequacies in larval tuna taxonomy that have not, as yet, been resolved. The ambiguities have been noted, but new distinguishing characteristics must be identified and described before completely unambiguous separation of the species can be made. Nevertheless, this paper should be a useful guide to field and laboratory identifications of larval scombroid fishes. It is not an exhaustive treatment of the topic and the references should be consulted for further details. The literature is extensively reviewed in Richards and Klawe (1972) and Collette et al. (1984). For information on the distribution of scombroid larvae, see Nishikawa et al. (1985).

The guide is divided into two sections: the first deals with the families Scombrolabracidae, Gempylidae, Trichiuridae and Scombridae; the second deals with the swordfish and billfish families Xiphiidae and Istiophoridae. Diagnostic features for separating and identifying larvae to family level are listed. The families Scombrolabracidae, Gempylidae and Trichiuridae are not treated beyond this level. Diagnostic keys, one for identifying the larval scombrids (family Scombridae) and one for the larval and juvenile billfishes (family Istiophoridae), are presented. Each key is based on external characters, illustrated with drawings of the larvae and supplemented with notes indicating distinctive points for identification where confusion is likely to occur. Further notes are provided to help separate the scombrids and billfishes from several other groups whose larvae have similar morphologies.

Many of the illustrations have been taken from other works and the original sources are cited in the captions. We are grateful to the various authors for permission to reproduce their figures. The figures without citations are ones prepared by the authors, specifically for this publication.

PART 1: Larval Scombroids other than Billfishes

Diagnostic Features of the Families

Family Scombrolabracidae: Tuna-like, but lower myomere count (~31whereas tunas ~39-42); relatively smaller eye; blunter snout; shorter and deeper body (body as deep as head); higher caudal peduncle; larger specimens have an elongate melanophore patch on the posterior body mid-laterally near caudal peduncle (Figure 1).See also: Potthoff et al. (1980).

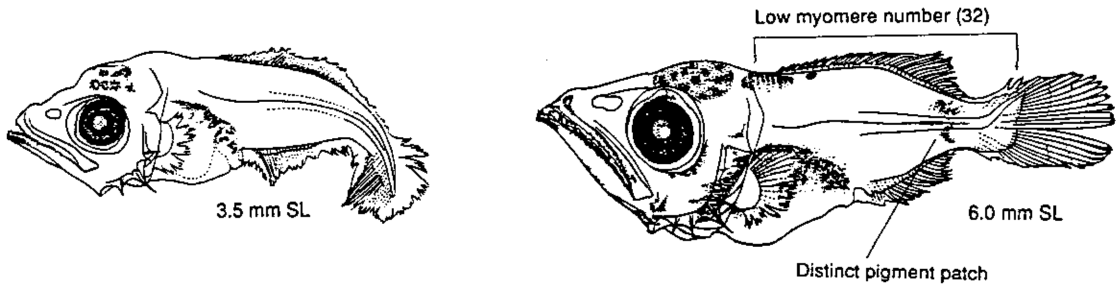

Figure 1. Larvae of *Scombrolabrax heterolepis* (from Ueyanagi, unpublished)

Family Gempylidae (snake mackerels): Well-developed, serrate pelvic spines; 1st dorsal fin develops at an early stage, and has a long, serrate 1st dorsal spine; 1st dorsal fin develops before 2nd; ~31-67 myomeres (Figure 2). See also: Nishikawa and Nakamura (1978); Nishikawa (1982; 1984a; 1984b; 1984c; 1987a; 1987b); Collette et al. (1984). Serranids may appear similar but have short 1st spine and long 2nd spine of 1st dorsal fin.

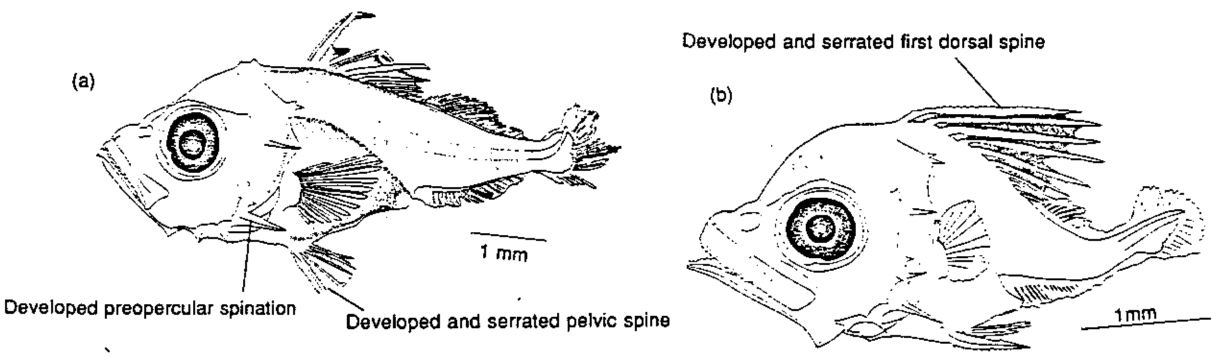

Figure 2. Larvae of: (a) *Lepidocybium flavobrunneum* and (b) *Revettus pretiosus* (both from Nishikawa, 1987a)

Family Trichiuridae (ribbon fishes or cutlass fishes): Very long, slender body (98-192 myomeres); mouth relatively small; preopercular spines relatively small; a long 1st dorsal fin, with many well developed serrate spines, develops at an early stage (not illustrated). See: Collette et al.(1984).

Family Scombridae (tunas and mackerels): The "regular" scombrids: large head; large eye; large mouth; preopercular spines present (except ***Scomber*** and ***Rastrelliger*** **spp.**); 2nd dorsal fin develops before 1st (except ***Scomber*** and ***Rastrelliger*** **spp.**); body length variable (31-64 myomeres).

This group includes Subfamily Gasterochismatinae, whose larvae are unknown. They are not included in the key, but the juvenile of *Gasterochisma melampus* is illustrated (Figure 3). See: Fraser-Brunner (1950) for more details. In the southern hemisphere the adult distribution probably overlaps that of southern bluefin tuna; however, the larvae are unlikely to co-occur, as *Gasterochisma melampus* probably spawns in higher latitudes than does southern bluefin tuna. In any event, the larvae should prove to be morphologically distinct.

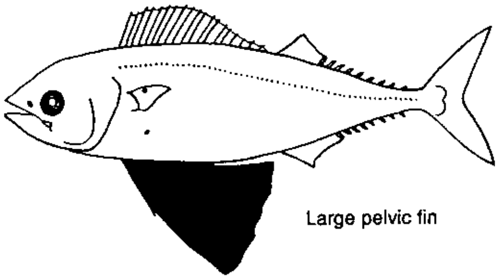

Figure 3. Juvenile of *Gasterochisma melampus* (from Fraser-Brunner, 1950)

Key to the Larvae of Family Scombridae

This diagnostic key is applicable to larvae between about 3 mm and 12 mm standard length (SL). Notes on distinguishing postlarval and juvenile stages are given separately at the end of this section. Larvae smaller than about 3 mm SL are virtually indistinguishable in external morphology. Designations of larval characteristics and measurements used in the key are shown in Figure 4.

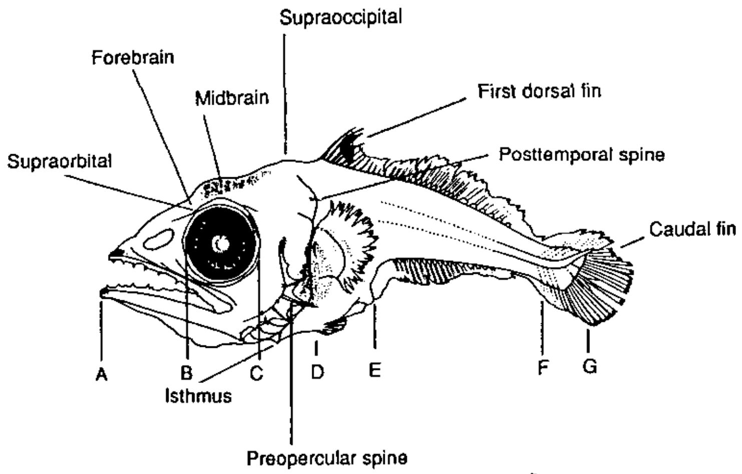

Figure 4. Designation of larval characteristics and measurements used in the key to larvae of Family Scombridae. A-B: snout length; B-C: eye diameter; A-D: head; D-E: trunk; D-G: body; E-F: tail; F-G:caudal peduncle

1a Preopercular spines absent; head and mouth relatively small; dorsal profile of head rounded; black pigment spots present along ventral edge of body; abdominal cavity somewhat elongate and ovoid; anus near midpoint of body; myomere count less than 32 . . . . ***Scomber*** and ***Rastrelligerr*** **spp.**

1b Preopercular spines present 2

2a Preopercular spines small and short (not visible in specimens <3.5 mm SL); snout rather blunt; dorsal profile of head rounded; supraorbital ridge weak; myomere count 31. Small specimens have a line of black pigment mid-laterally just anterior to the caudal peduncle. Large postlarvae and juveniles have large, saddle-shaped pigment blotches on dorsal side of body . . . . ***Grammatorcynus*** **spp.**

2b Preopercular and post-temporal spines well developed; large head, eyes and mouth; myomere count more than 32 3

3a Supraoccipital crest present 4
3b Supraoccipital crest absent (except *Euthynnus*, which appears to have a weak, rounded supraoccipital crest - see descriptive notes on the tuna larvae) 5

4a Supraoccipital crest pointed and distinct; snout long (snout length 2 x eye diameter); mouth very large; teeth strongly developed; supraorbital ridge may be serrated but without spines; black pigment spot present on isthmus, on larval fin fold just anterior to anus and on nasal area at tip of snout; large, stellate melanophores present on ventral edge of tail; myomere count 41-56 . . . . ***Scomberomorus* spp.**
4b Supraoccipital crest weakly developed and rounded; supraorbital ridge well developed and serrate, with spines present; snout moderately long (snout length 1.5 x eye diameter); strong jaws with well-developed teeth; conspicuous black pigment on isthmus and just anterior to anus; 6-10 large black pigment spots on ventral edge of tail; forebrain pigment present in larvae ≥ 3 mm SL; pelvic fins pigmented in larvae ≥ 5 mm SL; myomere count 42-46 . . . . ***Sarda orientalis***

5a Body long and slender; myomere count 62-64; mouth very large; abdominal cavity elongate and ovoid; peritoneum pigments developed; anus near or posterior to midpoint of body; line of black pigment along bases of 2nd dorsal and anal fins . . . . ***Acanthocybium solandri***
5b Body relatively short; myomere count 39-42; abdominal cavity compact and triangular 6

6a Large head with very long snout (snout length > 2 x eye diameter); well developed teeth with canines at jaw tips; black pigmentation on branchiostegal membrane, on gill filaments and on operculum; no black pigmentation on tail . . . . ***Gymnosarda unicolor***
6b Snout relatively short; body pigmentation sparse 7

7a Black pigment present on forebrain 8
7b Black pigment absent on forebrain 9

8a Black pigment absent from isthmus and just anterior to anus; distinct black pigment spot on ventral edge of tail near caudal peduncle; rarely a black pigment spot on dorsal edge of caudal peduncle; black pigment spot at tip of lower jaw; upper jaw projects farther than lower; 1st dorsal fin pigment first appears in larvae about 8 mm SL. . . . . ***Katsuwonus pelamis***
8b Black pigment spot present on isthmus and just anterior to anus; 1-3 black pigment spots on ventral edge of tail; 1st dorsal fin pigment first appears in larvae about 6 mm SL . . . . ***Euthynnus affinis***

9a Black pigment spot present on isthmus and just anterior to anus; dorsal profile of head rounded; 3 dotted lines of black pigment on tail towards caudal peduncle: one along dorsal edge, one along ventral edge and one along mid-lateral region . . . . ***Auxis* spp.**
9b Black pigment absent from isthmus and just anterior to anus; 1st dorsal fin pigment first appears in larvae about 6 mm SL 10

10a Black pigment present on tail region of body 11
10b Black pigment absent from tail region of body 12

11a Small black pigment spots on tail: 1-2 on ventral edge, none on dorsal edge; black pigment on underside of lower jaw near tip (usually a pair of distinct spots) . . . . ***Thunnus obesus***
11b Distinct black pigment spots on tail: 1-4 on dorsal edge, 1-5 on ventral edge; 1 or no black pigment spots on caudal fin . . . . ***Thunnus thynnus***
11c Black pigment spots on tail: 0-4 small faint spots on dorsal edge (usually 1; however, up to 15% of specimens may have no dorsal spots, confusing them with ***T. obesus***, see notes); 1-4 more distinct spots on ventral edge (usually 1 or 2); 1-3 black pigment spots on caudal fin (usually 2 or 3, and 1 of these may be dorsal to the notochord) . . . . ***Thunnus maccoyii***

12a Black pigment present on underside of lower jaw near tip (usually a single small spot); centre of eye in head profile situated above line of body axis . . . . ***Thunnus albacares***
12b Black pigment absent from tip of lower jaw; centre of eye in head profile situated more or less in line with body axis . . . . ***Thunnus alalunga***

Descriptive Notes on the Scombrid Larvae other than Tunas

Scomber **and *Rastrelliger* spp. (mackerels):** Preopercular spines absent; head and mouth relatively small; dorsal profile of head rounded; snout blunt; black pigment dots appear along ventral edge of tail; 31 myomeres; abdominal cavity elongate and ovoid; anus at or slightly posterior to middle of body; 2nd dorsal fin develops before 1st; juveniles have a gap between the 1st and 2nd dorsal fins (not illustrated). See: Uchida et al. (1958); Ozawa (1984).

Grammatorcynus **spp. (double-lined mackerels):** Dorsal profile of head round; snout relatively blunt; supraorbital ridge weakly developed; preopercular spines weakly developed; 31-32 myomeres; small specimens have a line of black pigment mid-laterally just anterior to the caudal peduncle; large post-larvae and juveniles have large, saddle-shaped pigment blotches on dorsal side of body (Figure 5). See also: Nishikawa (1979).

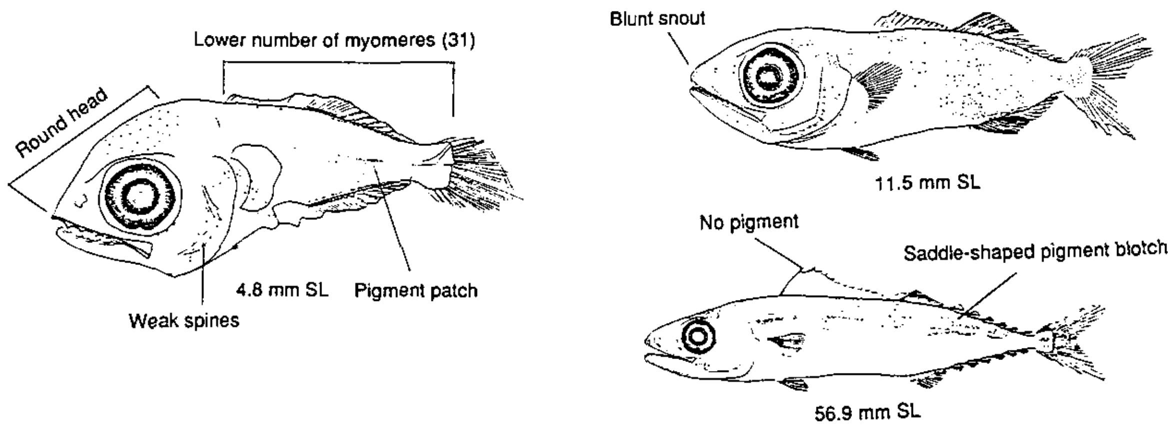

Figure 5. Larva, postlarva and juvenile of double-lined mackerel *Grammatorcynus bicarinatus* (from Nishikawa, 1979)

Scomberomorus **spp. (spanish mackerels):** Supraoccipital spine well developed and pointed; supraorbital ridge finely serrate but without spines; preopercular spines well developed; long, pointed snout (snout length 2 x eye diameter); mouth very large; well-developed teeth; 41-56 myomeres; large melanophores on larval fin fold just anterior to anus, on isthmus and on nasal area; large, stellate melanophores on ventral edge of tail (Figure 6). See also: Wollam (1970); Jenkins et al. (1984).

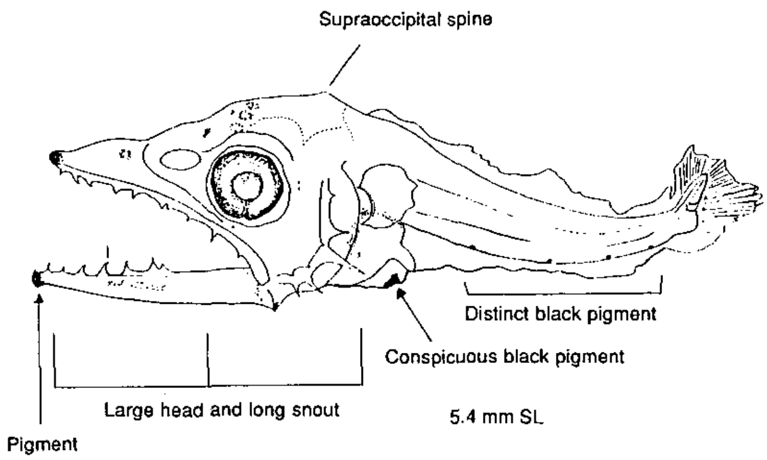

Figure 6. Larva of Spanish mackerel, *Scomberomorus* sp.

***Sarda orientalis* (striped bonito):** Supraoccipital spine weakly developed and rounded; preopercular spines weakly developed; supraorbital ridge well developed and serrate with spines present; snout moderately long (snout length 1.5 x eye diameter); large mouth; well-developed teeth; conspicuous black pigment on isthmus and just anterior to anus; usually 6-10 large melanophores embedded in skin on ventral edge of tail (may be as few as 4 in small specimens); forebrain pigment present in specimens larger than ~ 3 mm SL; pelvic fins pigmented in specimens larger than ~ 5 mm SL; 42-46 myomeres (Figure 7). See also: Harada et al. (1974); Nishikawa (in press).

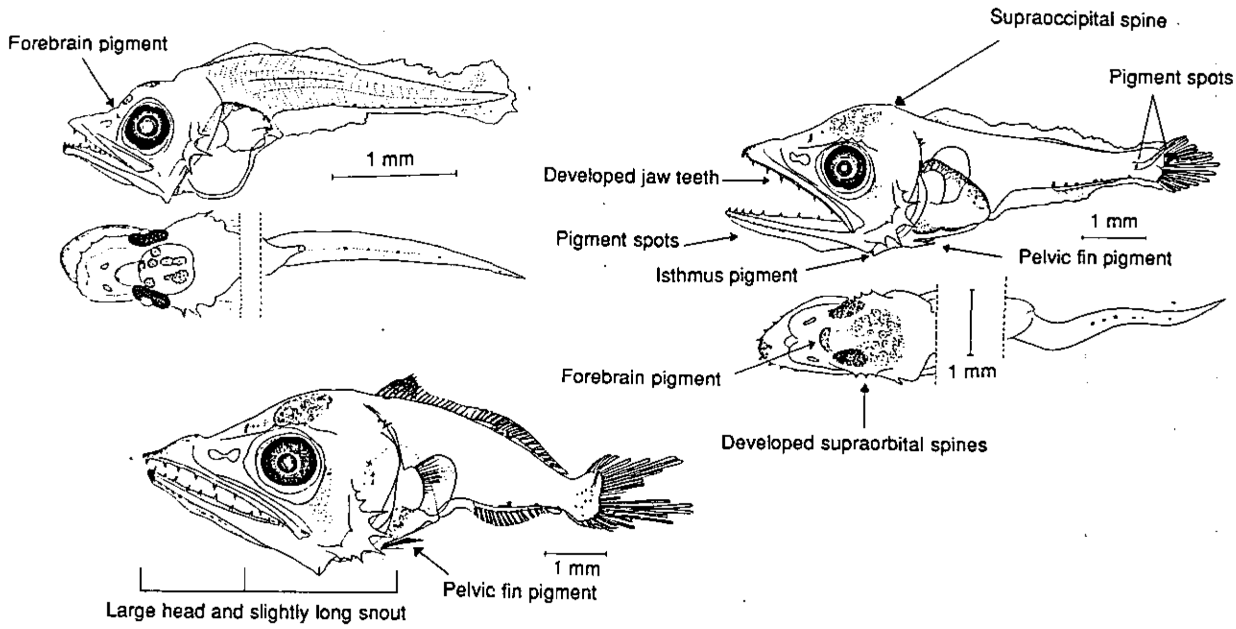

Figure 7. Larvae of striped bonito, *Sarda orientalis*

Sarda is difficult to distinguish from *Euthynnus*.. Take careful note of supraoccipital spine and spines on supraorbital ridge. *Sarda* has 4 or more pigment spots on the ventral edge of the tail, embedded in the skin; *Euthynnus* has 1 to 3 spots on the ventral edge of the tail, near the surface of the skin . *Sarda* larvae ≥ 8mm SL have pigments on the pelvic fins; in *Euthynnus* these pigments are absent. See: Nishikawa (in press).

***Acanthocybium solandri* (wahoo):** Very long slender body (62-64 myomeres); long, slender abdominal cavity; anus posterior to middle of body; preopercular spines present; very long jaws and large mouth (snout length more than 3 x eye diameter); well-developed pigment on snout; peritoneum pigments developed; 2nd dorsal and anal fin bases have strong pigment patches directly opposite one other (Figure 8). See also: Matsumoto (1967).

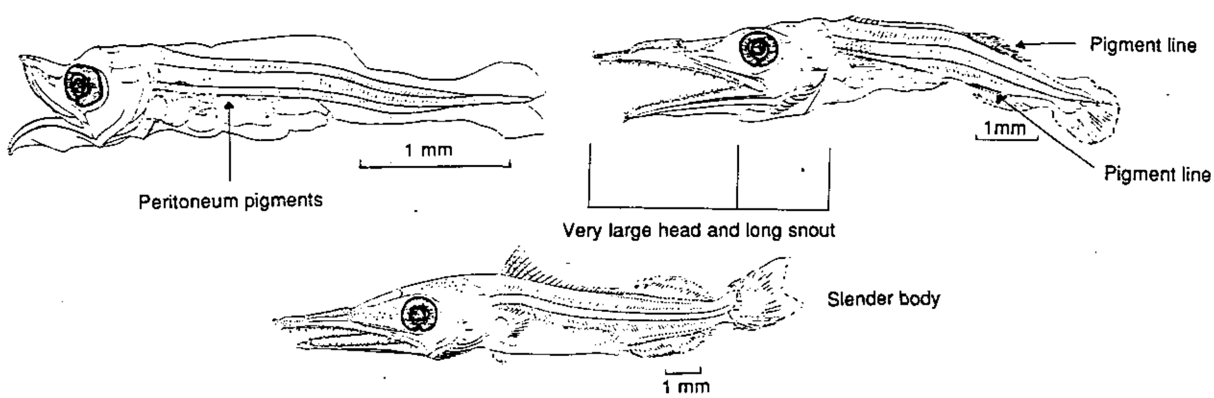

Figure 8. Larvae of wahoo, *Acanthocybium solandri* (from Matsumoto, 1967)

***Gymnosarda unicolor* (dogtooth tuna):** Large head with very long snout (snout length more than 2 x eye diameter); well-developed teeth; jaw tips bear canine teeth; well-developed preopercular spines; supraoccipital crest absent; supraorbital ridge present; body short (39 myomeres); triangular abdominal cavity; melanophores present on branchiostegal membrane, gill filaments and operculum; pigment absent from isthmus and anterior to anus; black pigment spots absent from tail (Figure 9). See also: Okiyama and Ueyanagi (1977).

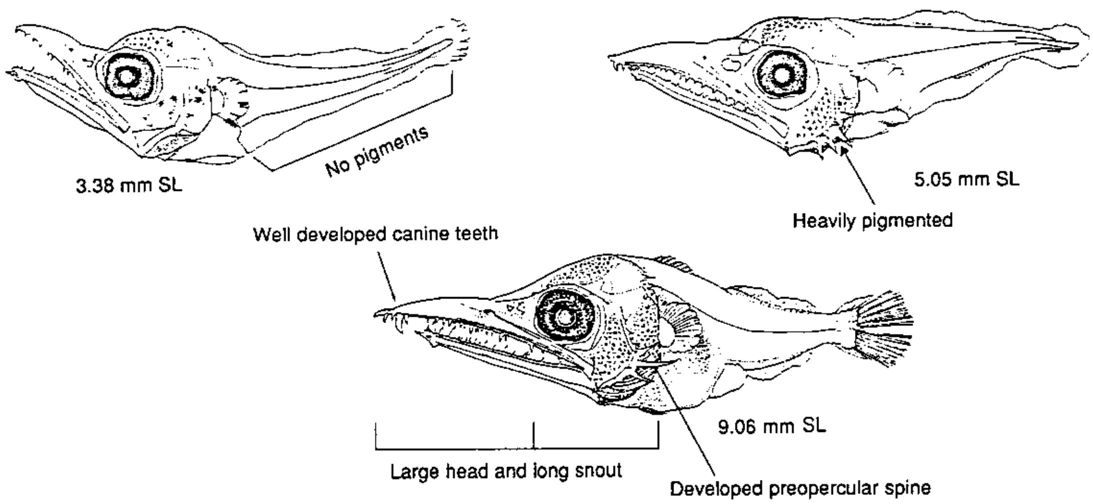

Figure 9. Larvae of dogtooth tuna, *Gymnosarda unicolor* (from Okiyama and Ueyanagi, 1977)

***Allothunnus* spp. (slender tunas):** Not included in the key . Their distribution south of 18°S largely separates them from *Thunnus* spp. larvae, which are similar in appearance, with preopercular spines, a moderately long snout, short body, triangular abdominal cavity, and weakly developed body pigments; however, *Allothunnus* specimens ≥ 6.9 mm SL differ by having a row of melanophores down the midline of the underside of the lower jaw and large black pigment spots along the base of the 2nd dorsal fin (Figure 10). See also: Watanabe et al. (1966). Red pigment-spot pattern on the tail region of small, fresh specimens is diagnostic (Figure 11).

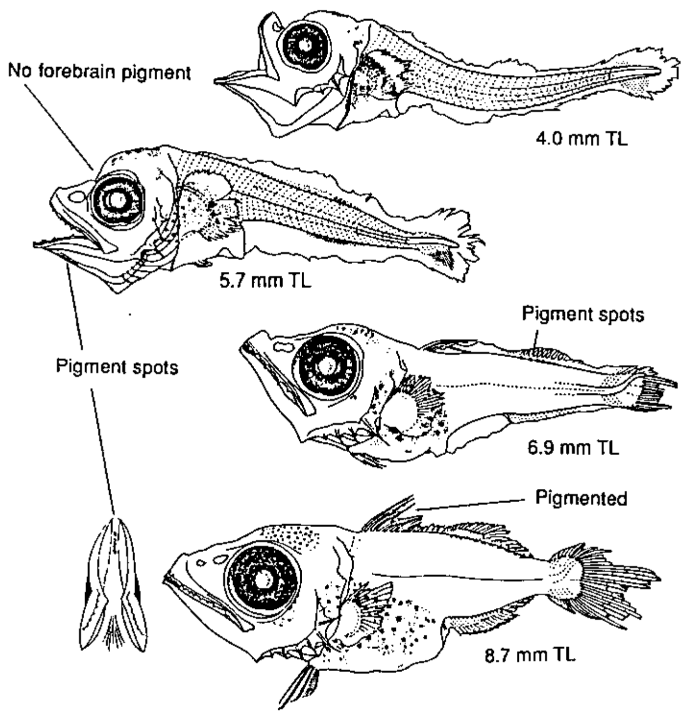

Figure 10. Larvae of slender tuna, *Allothunnus fallai* (from Watanabe et al., 1966)

Descriptive Notes on the Tuna Larvae

Tuna larvae all possess the following characteristics: relatively large head, eyes and mouth; relatively short pointed snout (snout length < 1.5 x eye diameter); relatively short body (39-42 myomeres); triangular abdominal cavity; body pigments very sparse and weakly developed; preopercular and post-temporal spines developed; supraoccipital spine absent (except *Euthynnus*, which appears to have a weak, rounded supraoccipital spine. Sometimes the *Thunnus* spp. may also have a small bump on the top of the head, which looks rather like a small supraoccipital spine).

In addition to the diagnostic characters used in the key, red pigment-spot patterns found on the tail region of small tuna larvae can be useful in identifying some species (See Figure 11). See also: Ueyanagi (1966); Matsumoto et al. (1972). Note that only small specimens of fresh larvae can be identified by red pigment-spot patterns; the red pigment spots are not found on larger specimens and the red pigment dissolves when larvae are preserved.

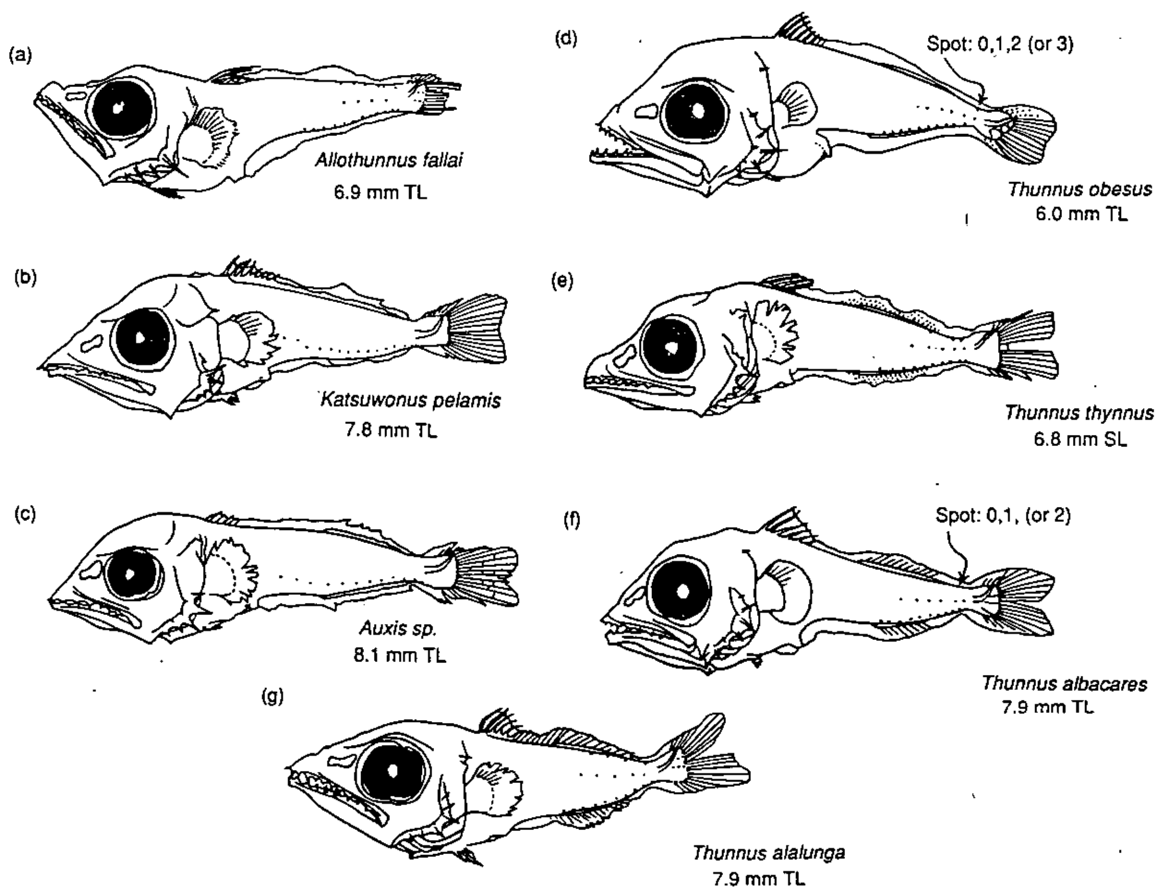

Figure 11. Red pigment-spot patterns found on small, fresh (unpreserved) specimens of larval tunas (from Ueyanagi, 1966): (a) slender tuna, *Allothunnus fallai* (b) skipjack tuna, *Katsuwonus pelamis* (c) frigate tuna, *Auxis* sp. (d) bigeye tuna, *Thunnus obesus* (e) bluefin tuna, *Thunnus thynnus* (f) yellowfin tuna, *Thunnus albacares* (g) albacore tuna, *Thunnus alalunga*

***Katsuwonus pelamis* (skipjack tuna):** Black forebrain pigment present in larvae > 4 mm SL; black pigment absent from isthmus and just anterior to anus; distinct black pigment spots on ventral edge of tail; black pigment at tip of lower jaw; rarely black pigments on dorsal edge of caudal peduncle; snout sharply pointed and projects beyond lower jaw; black pigment does not appear on 1st dorsal fin until larvae are ≥ 8 mm SL (Figure 12). See also: Yabe (1955); Matsumoto (1958). Red pigment-spot pattern on the tail region of small, fresh specimens is diagnostic (Figure 11).

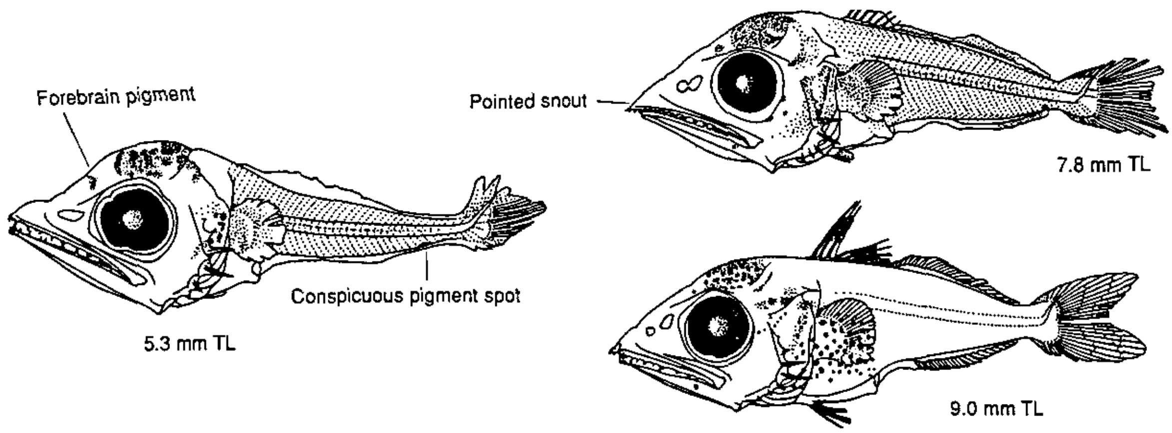

Figure 12. Larvae of skipjack tuna, *Katsuwonus pelamis* (from Yabe, 1955)

***Euthynnus affinis* (little tuna):** Black forebrain pigment present; black pigment spot present on isthmus and just anterior to anus; 1-3 black pigment spots near skin surface on ventral edge of tail (unlike *Sarda*, where pigment spots are embedded in the skin); distinct black pigment appears on 1st dorsal fin in larvae ≥ 6 mm SL; black pigment spots on underside of lower jaw (Figure 13). See also: Matsumoto (1958; 1959); Nishikawa (in press).

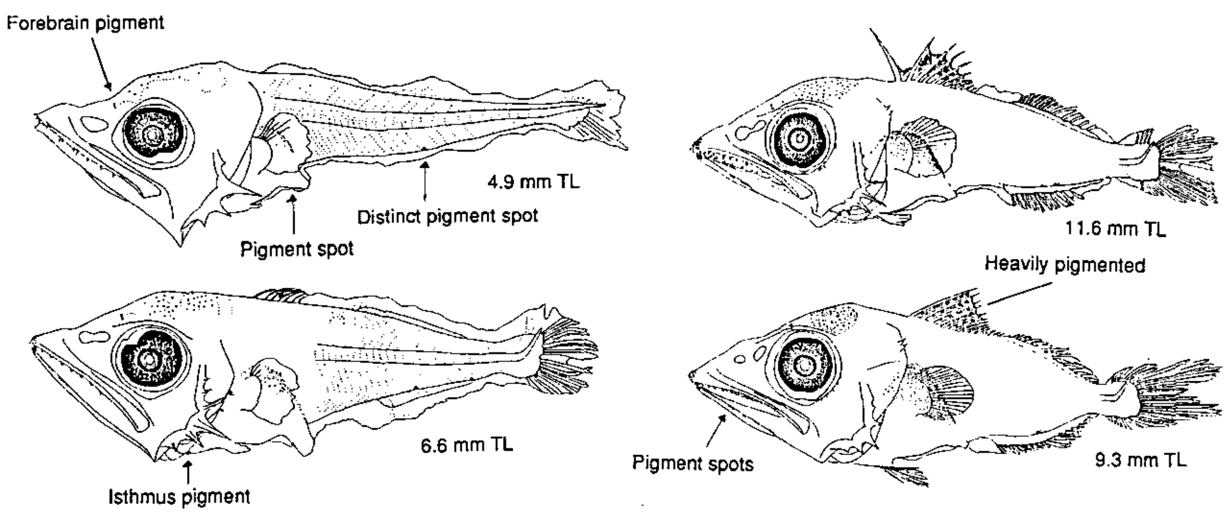

Figure 13. Larvae of little tuna, *Euthynnus affinis*

***Auxis* spp. (frigate tuna):** Dorsal head profile rounder and blunter than the other tunas; black forebrain pigment absent; black pigment spot present on isthmus and just in front of anus; 3 dotted stripes of black pigment on tail towards caudal peduncle (along dorsal edge, along mid-lateral and along ventral edge); 1st dorsal fin not pigmented; juveniles have a distinct gap between 1st and 2nd dorsal fins (Figure 14). See also: Matsumoto (1958; 1959). Red pigment-spot pattern on the tail region of small, fresh specimens is diagnostic (Figure 11).

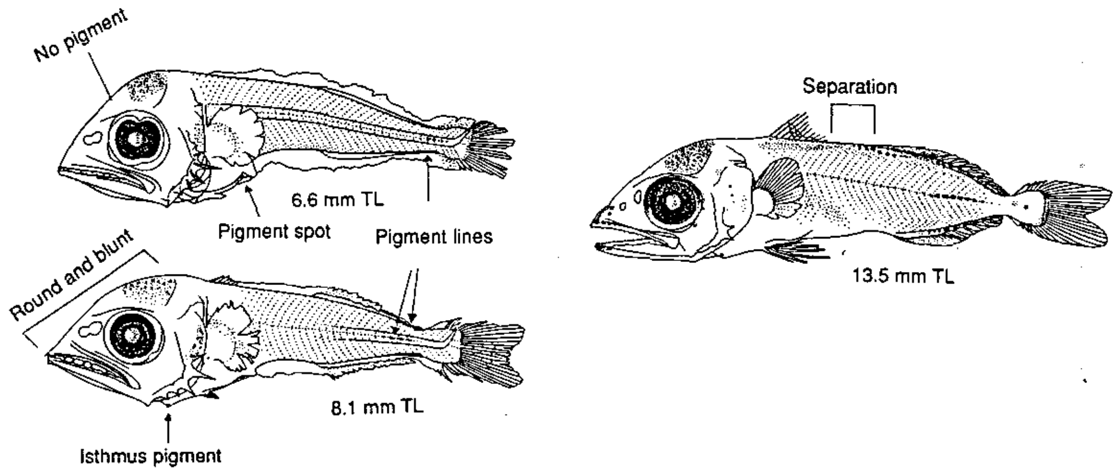

Figure 14. Larvae of frigate tuna, *Auxis* sp. (from Yabe, unpublished)

Descriptive Notes on the larvae of Genus *Thunnus*

All species of this genus share the following characteristics: forebrain pigment absent; black pigment absent on isthmus and just anterior to anus; black pigment spots on tail, if present, are small; black pigment appears on 1st dorsal fin in larvae ≥ 6 mm SL. Newly hatched specimens are difficult to recognise to genus and cannot be identified to species because the preopercular spines are not visible and pigments on the body have not yet developed. The basic clues to recognising the genus are: absence of forebrain pigment; a relatively long, deep body with 39-40 myomeres; large head, eye and mouth; compact, triangular abdominal cavity. See: Matsumoto et al. (1972).

***T. obesus* (bigeye tuna):** Black pigment spots absent on dorsal edge of tail; 1 or 2 pigment spots present on ventral edge. The ventral spots are very small and difficult to see, usually located on the ventral midline about 7 or 8 myomeres anterior to caudal fin base. The caudal fin may have 0-2 black pigment spots, usually 1 (and rarely a caudal fin pigment spot dorsal to the notochord, leading to confusion with *T. maccoyii*). (Figure 15). See also: Matsumoto (1962). Red pigment-spot pattern on the tail region of small, fresh specimens is diagnostic (Figure 11).

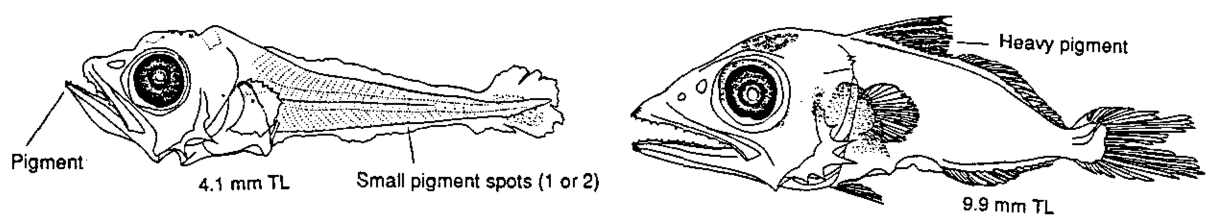

Figure 15. Larvae of bigeye tuna, *Thunnus obesus*

This species is very similar to *T. maccoyii* and *T. albacares*. It can be separated from *T. albacares* by: (1) absence of body pigment in *T. albacares*, and (2) by the pigment spots on the underside of the lower jaw tip, which are usually a pair of distinct spots in *T. obesus* and usually a single, smaller, fainter spot in *T. albacares*. See notes on *T. maccoyii* below for distinguishing from that species.

***T. thynnus* (bluefin tuna):** Distinct black pigment spots on tail: 1-4 on dorsal edge and 1-5 on ventral edge; 1 or no black pigment spots on caudal fin (Figure 16). See also: Yabe et al. (1966); Nishikawa (1985). Red pigment-spot pattern on the tail region of small, fresh specimens is diagnostic (Figure 11).

The larvae of *T. thynnus* and *T. maccoyii* are similar; however, it is unlikely they will be confused because of the broad geographic separation of the spawning areas: *T. thynnus* spawns in the western Pacific, south of Japan and *T. maccoyii* in the eastern Indian Ocean, northwest of Australia (Nishikawa et al., 1985).

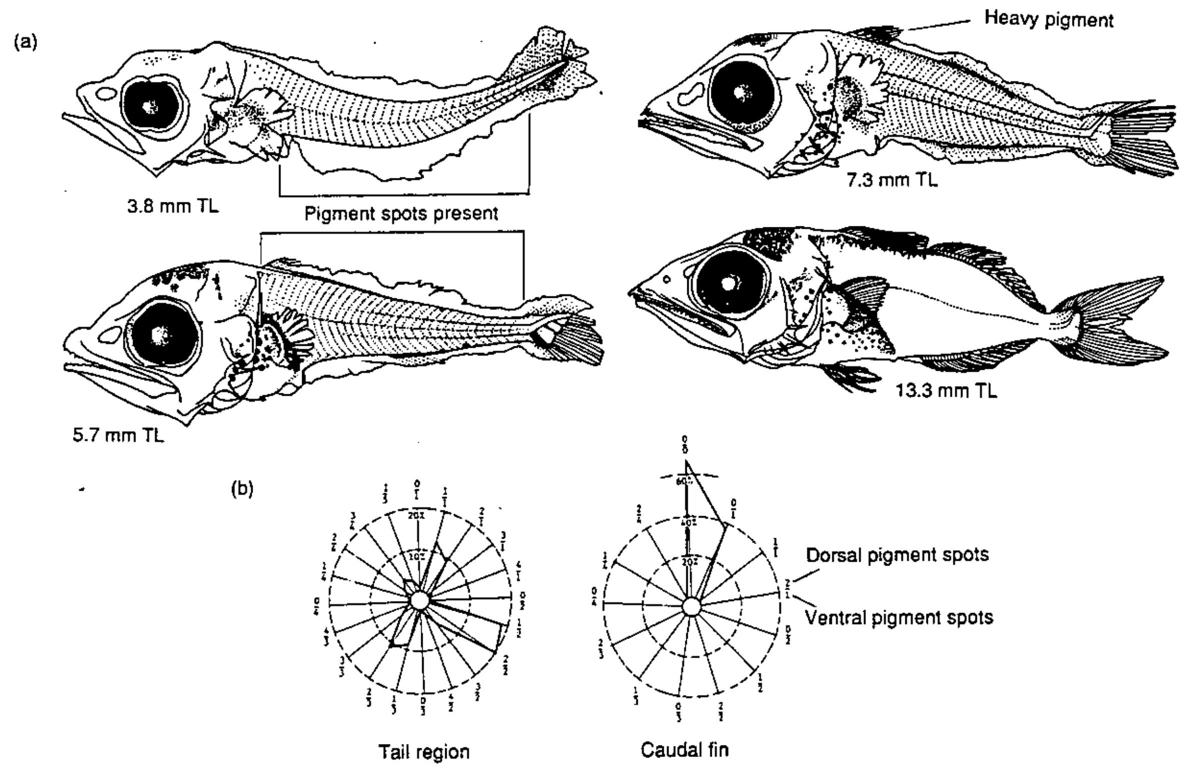

Figure 16. (a) Larvae and juvenile of bluefin tuna, *Thunnus thynnus* (from Yabe et al., 1966) (b) distribution of dorsal and ventral pigment spots on tail region and caudal fin (from Nishikawa, 1985)

***T. maccoyii* (southern bluefin tuna):** Small, faint, black pigment spots (0-4, usually 1) on dorsal edge of tail and 1-4 (usually 1 or 2) more distinct black pigment spots on ventral edge of tail; 1-4 (usually 2 or 3) black pigment spots on caudal fin, 1 (rarely 2) of which may be above the notochord (Figure 17. See also: Yabe et al. (1966); Nishikawa (1985).

The dorsal tail pigments on the body are very tiny, even in larger specimens, and especially difficult to see if the specimen has become opaque in the preservative. If they are missed, the larvae will key out as *T. obesus*. Approximately 15% of *T. maccoyii* larvae will have no dorsal body pigment spots and will key out as *T. obesus* ; however, approximately 11% have pigment mid-laterally on the body and 16% have body pigment internally, usually in the caudal peduncle region, and the presence of either of these body pigments will distinguish them from *T. obesus*. Note also that *T. obesus* has only 1 or 2 small, faint, ventral pigment spots, while *T. maccoyii* may have up to 4, and they are usually quite distinct. The caudal fin pigment in *T. maccoyii* can be diagnostic, with up to 4 black spots (0-1 in *T. thynnus* and 0-2, rarely 3, in *T. obesus*) and, except for rare occcurences in *T. obesus* , *T. maccoyii* is the only species that may have black caudal fin pigment on the dorsal side of the notochord (with the possible exception of *T. tonggol*, which is presently undescribed, but may also have dorsal caudal fin pigment. However, it is a coastal species and therefore unlikely to occur in samples with *T. maccoyii* larvae. In addition, the taxonomic affinities of *T. tonggol* suggest it probably has no body pigments, thus further distinguishing it). The only tuna besides *T. maccoyii* that may have internal (i.e. deeply embedded) melanophores is *T. thynnus* ; never *T. obesus, T. albacares* or *T. alalunga.*

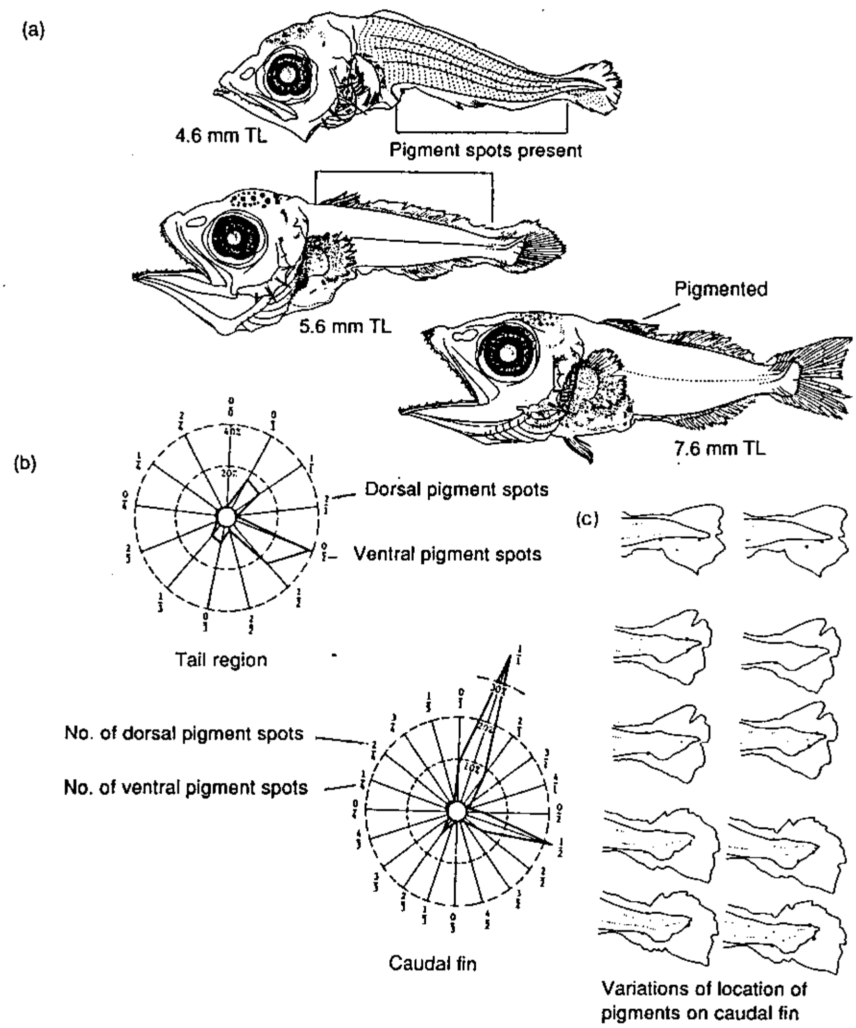

Figure 17. (a) Larvae of southern bluefin tuna, *Thunnus maccoyii* (from Yabe et al.,1966) (b) distribution of dorsal and ventral pigment spots on tail region and caudal fin (c) variation in location of caudal fin pigments (b and c from Nishikawa, 1985)

***T. albacares* (yellowfin tuna):** No black pigment spots on tail; underside of lower jaw usually has a single, small, black pigment spot (note, however, this may not develop until larvae reach 4-4.5 mm SL); centre of the eye in head profile is situated above the line of the body axis (Figure 18). See also: Matsumoto (1958); Ueyanagi (1969); Harada et al. (1971); Matsumoto et al. (1972). Red pigment-spot pattern on the tail region of small, fresh specimens is diagnostic (Figure 11).

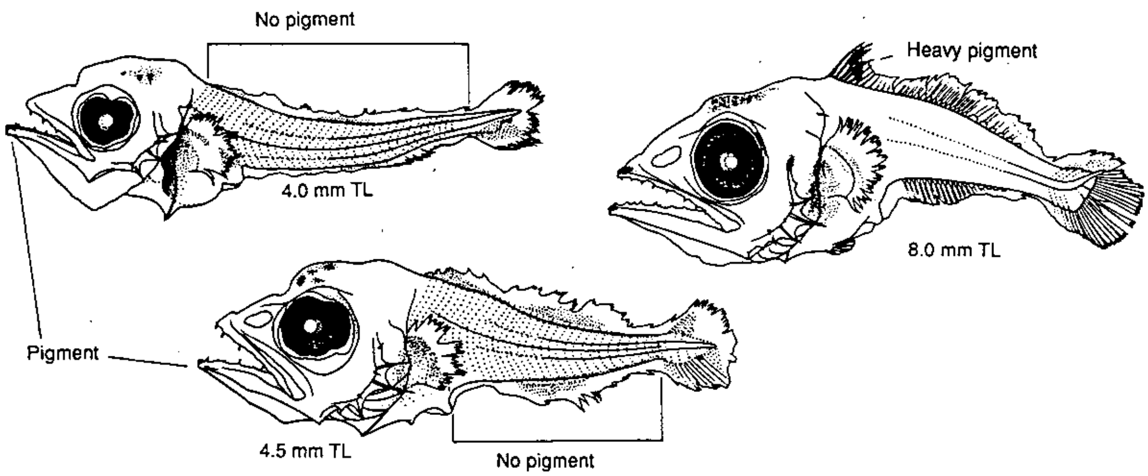

Figure 18. Larvae of yellowfin tuna, *Thunnus albacares* (from Ueyanagi, 1969)

T. obesus is similar to *T. albacares*, but has ventral body pigment (which may be difficult to see) and usually has a pair of distinct black spots on the underside of the jaw. *T. alalunga* is also similar, but its eye centre in profile is more or less in line with the body axis. It is difficult to distinguish small (< 4 mm SL) preserved specimens of *T. albacares* from *T. alalunga* because the jaw tip pigment has not yet developed and the red pigment will have disappeared in the preservative.

***T. alalunga* (albacore tuna):** No black pigment spots on tail or tip of lower jaw (inside or outside); centre of the eye in head profile is situated more or less in line with the body axis (Figure 19). See also: Ueyanagi (1969); Matsumoto et al. (1972). Red pigment-spot pattern on the tail region of small, fresh specimens is diagnostic (Figure 11).

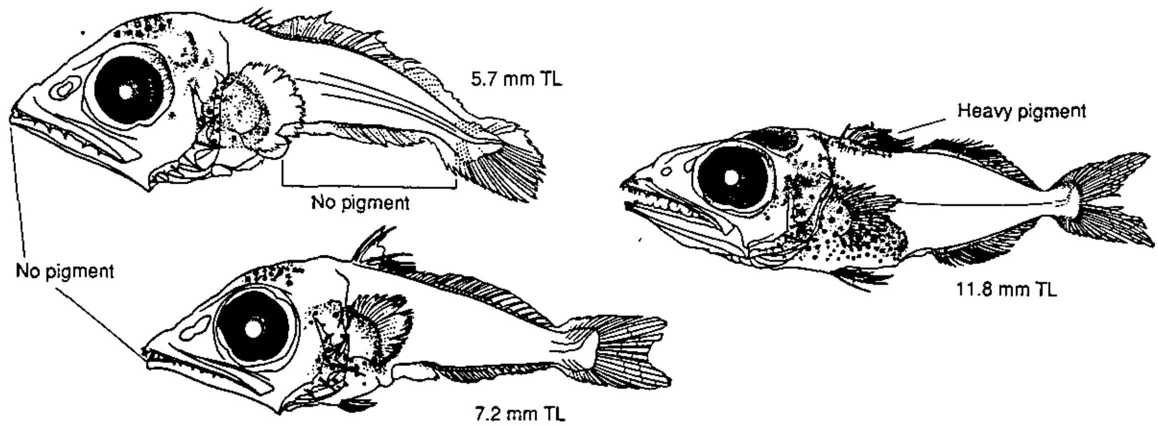

Figure 19. Larvae and juvenile of albacore tuna, *Thunnus alalunga* (from Ueyanagi, 1969)

T. albacares is similar, but the eye centre in profile is above the line of the body axis. *T. alalunga* larvae are not usually found in equatorial regions (0-10° N and S)

***T. tonggol* (longtail tuna):** Not illustrated or includced in the key. The postlarvae of this species are described by Matsumoto (1962); however, a complete developmental series has not yet been described. The early larval stages are unclear and identification is not confirmed. We feel the specimens described by Matsumoto may be a variety of bluefin tuna (*T. thynnus*), judging from the character of the body pigmentation pattern. The taxonomic affinities of *T. tonggol* with *T. albacares* and *T. atlanticus* (Iwai et al., 1965) suggest it will probably have no black pigment spots on the body and that caudal pigments may be important in separating them. This is a more coastal species than other tunas and it is thought to spawn in waters of the continental shelf in the South China Sea and probably also in the northern coastal waters of Australia, including the Northwest Shelf region.

Notes on Postlarval and Juvenile Tunas

Pigments on the forebrain area begin to appear in most tuna postlarvae by the time they reach 8-10 mm SL, which could cause confusion where forebrain pigment is used as a taxonomic character. However, the forebrain pigment used to distinguish *Katsuwonus pelamis* and *Euthynnus affinis* from *Thunnus* spp. can still be discriminated because it is internal (on the surface of the forebrain) while the other pigment on the forebrain area develops on the outer surface of the head above the forebrain. Furthermore, *Katsuwonus* and *Euthynnus* have much more pigment on the forebrain area than do *Thunnus* spp. larvae of comparable size.

Juvenile stages (15-60 mm SL) are almost impossible to identify to species because the larval characteristics become obscured by the development of general body pigmentation, and meristic counts are almost identical for all species. Juvenile stages of *Auxis, Scomber* and *Rastrelliger* have a gap between the 1st and 2nd dorsal fins, unlike the tunas which have the 1st dorsal fin continuous with the 2nd. Matsumoto et al. (1972) evaluate internal characters for separating four species of *Thunnus* juveniles.

Larger stages can be identified from the adult characteristics of gill raker counts, shape of liver and vertebral column characteristics, such as the position where the first closed neural arch occurs (Iwai et al., 1965; Collette and Nauen, 1983). *Katsuwonus pelamis* and *Euthynnus affinis* have a peculiar trellis or complex basket-work structure of the vertebral column, as well as distinct vertebral counts. *K. pelamis* has 41 vertebrae, *E. affinis* and all the *Thunnus* spp. have 39. See: Kishinouye (1923); Godsil and Byers (1944); Godsil (1954).

PART 2: Larval Billfishes

Diagnostic Features of the Families

Family Xiphidae (swordfish): Upper and lower jaws both elongated; no pterotic spines; preopercular spines present but not elongated; body slender with anus well posterior; many spiny scales make skin surface rough to touch (Figure 20). See also: Yabe et al. (1959).

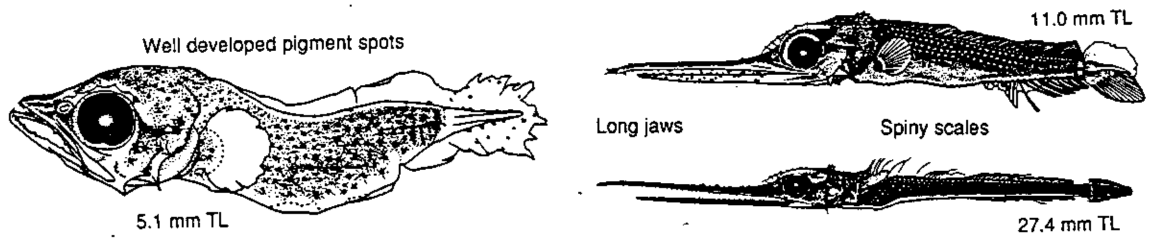

Figure 20. Larva, postlarva and juvenile of swordfish, *Xiphias gladius* (from Yabe et al., 1959)

Only one species, ***Xiphias gladius***, is described; however, there is evidence based on internal structure of the bill which suggests that more than one type is extant. It's status is currently being examined.

Family Istiophoridae (spearfish, sailfish and marlins): Well-developed, serrate preopercular spines; well-developed, serrate pterotic spines; upper jaw may be elongated, but not the lower jaw (Figures 21 to 26).

There are five species in the Indo-Pacific Region (Ueyanagi, 1963a and 1963b). The larvae are most frequently caught in the daytime, and usually in surface nets.

Key to the Larvae and Juveniles of Family Istiophoridae

This diagnostic key is applicable to larvae and juveniles between about 3 mm and 50 mm SL. Designations of larval characteristics used in the key are shown in Figure 21.

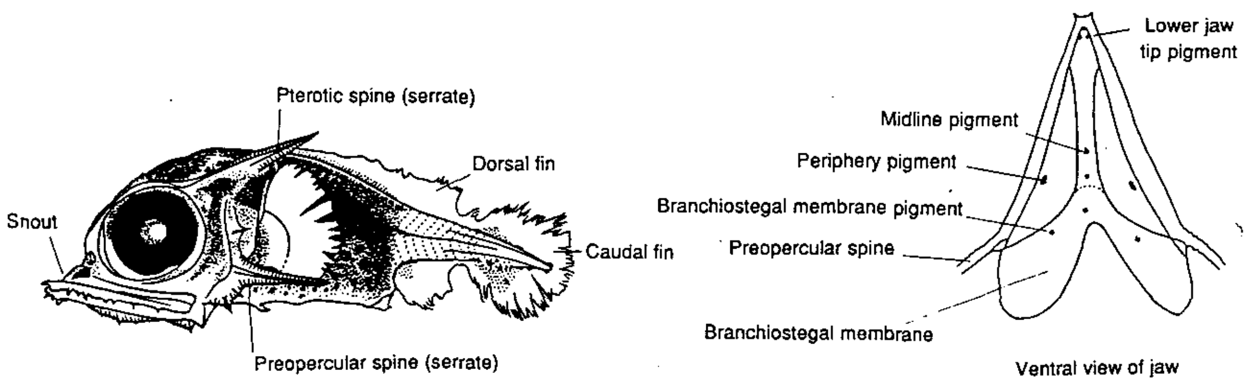

Figure 21. Designation of larval characteristics used in the key to larvae of Family Istiophoridae

1a Black pigments present on branchiostegal membrane; center of eye in head profile level with tip of snout; anterior edge of orbit does not project forward; pterotic spines rise obliquely; preopercular spines extend nearly parallel to body axis. In larvae > 14 mm SL the snout is elongated .... ***Tetrapturus angustirostris***
1b Black pigments absent from branchiostegal membrane 2

2a Black pigment spots present on periphery of lower jaw (usually 1 either side); center of eye in head profile above tip of snout; anterior edge of orbit does not project forward; pterotic spines rise obliquely; preopercular spines extend parallel to body axis. In larvae > 13 mm SL the snout is elongate. . ***Istiophorus platypterus***
2b Black pigments absent along periphery of lower jaw; center of eye in head profile level with tip of snout 3

3a Black pigments present along midline of underside of lower jaw anterior to symphysis of branchiostegal membrane; anterior edge of orbit does not project forward; pterotic spines extend nearly parallel to body axis; preopercular spines incline sharply downward. In larvae >13 mm SL the snout is long. . ***Tetrapturus audax***
3b Black pigment spots present on underside of lower jaw near tip (usually a pair); eye relatively large; anterior edge of orbit projects forward; pterotic spines rise obliquely; preopercular spines extend nearly parallel to body axis. Snout short, even in larvae >13 mm SL .... ***Makaira mazara***

Descriptive Notes on the Billfish Larvae

***Tetrapturus angustirostris* (shortbill spearfish):** Black pigments present on branchiostegal membrane; centre of eye in head profile level with tip of snout; anterior edge of orbit does not project forward; pterotic spine rises obliquely; preopercular spine extends nearly parallel to body axis; in larvae larger than ~14 mm SL, the snout is long (Figure 22). In late juveniles and adults the space between anus and anal fin origin is wide. See also: Ueyanagi (1962; 1974); Watanabe and Ueyanagi (1963).

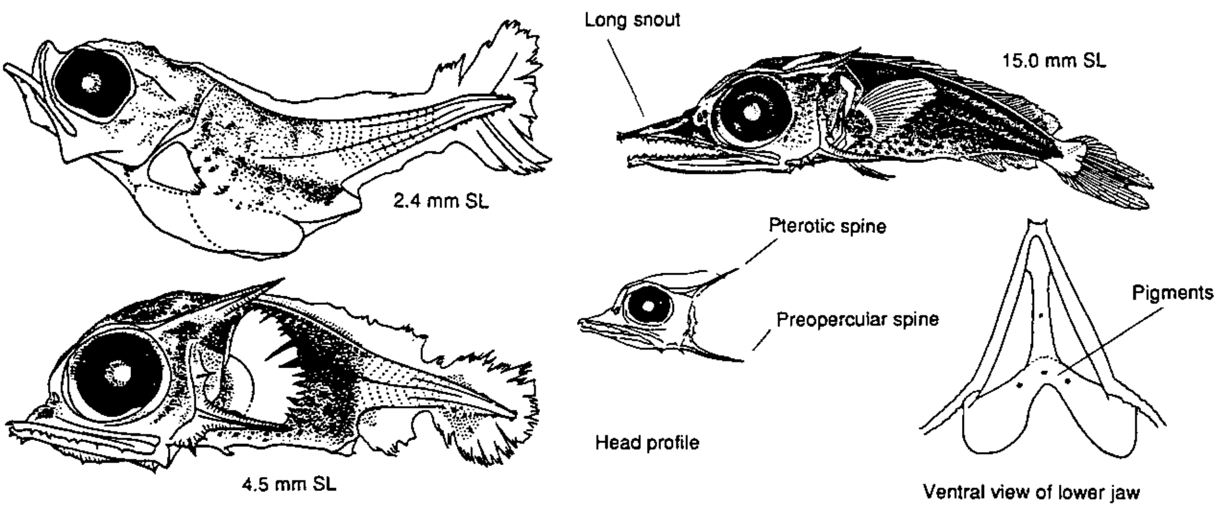

Figure 22. Larva, postlarva and juvenile of shortbill spearfish, *Tetrapturus angustirostris* (from Ueyanagi, 1962; Ueyanagi, 1974)

***Tetrapturus audax* (striped marlin):** No black pigments on branchiostegal membrane or along periphery of lower jaw; black pigment present along midline on underside of jaw anterior to symphysis of branchiostegal membrane; centre of eye in head profile level with tip of snout; pterotic spine extends nearly parallel to body axis; preopercular spine inclines sharply downwards, forming a wide angle with body axis; in larvae larger than ~13-14 mm SL, the snout is long. Larvae of this species have weaker body pigmentation than other billfish larvae (Figure 23). See also: Ueyanagi and Yabe (1959b); Ueyanagi (1974).

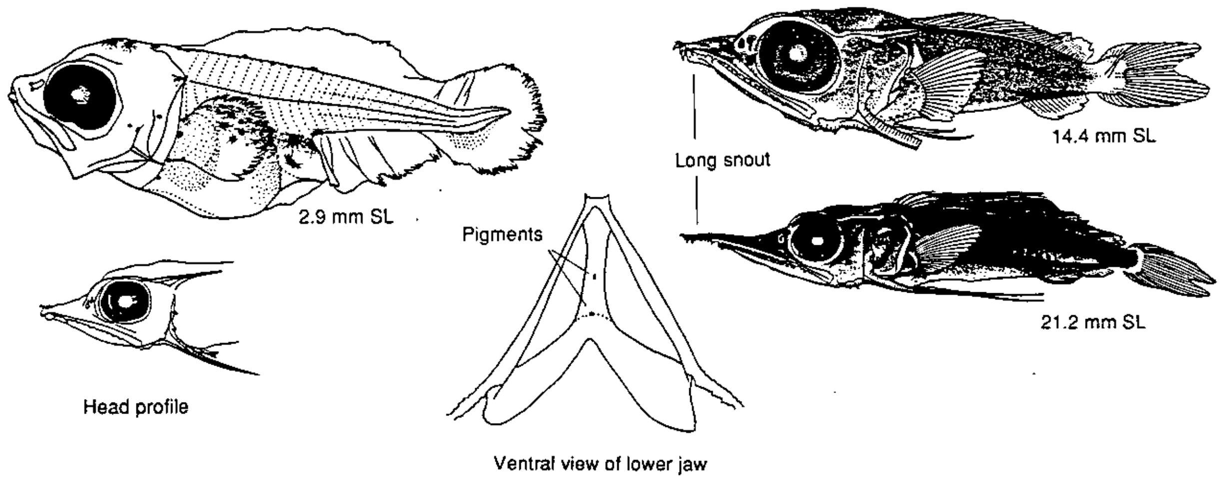

Figure 23. Larva, postlarva and juvenile of striped marlin, *Tetrapturus audax* (from Ueyanagi and Yabe, 1959b; Ueyanagi, 1974)

***Istiophorus platypterus* (sailfish):** Black pigments absent from branchiostegal membrane; black pigment spots present on periphery of lower jaw (usually 1 either side); centre of eye in head profile lower than tip of snout; anterior edge of orbit does not project forward; eye relatively small; pterotic spine rises obliquely; preopercular spine extends parallel to body axis; in larvae larger than ~13-14 mm SL, the snout is very long (Figure 24). See also: Yabe (1953); Ueyanagi (1974).

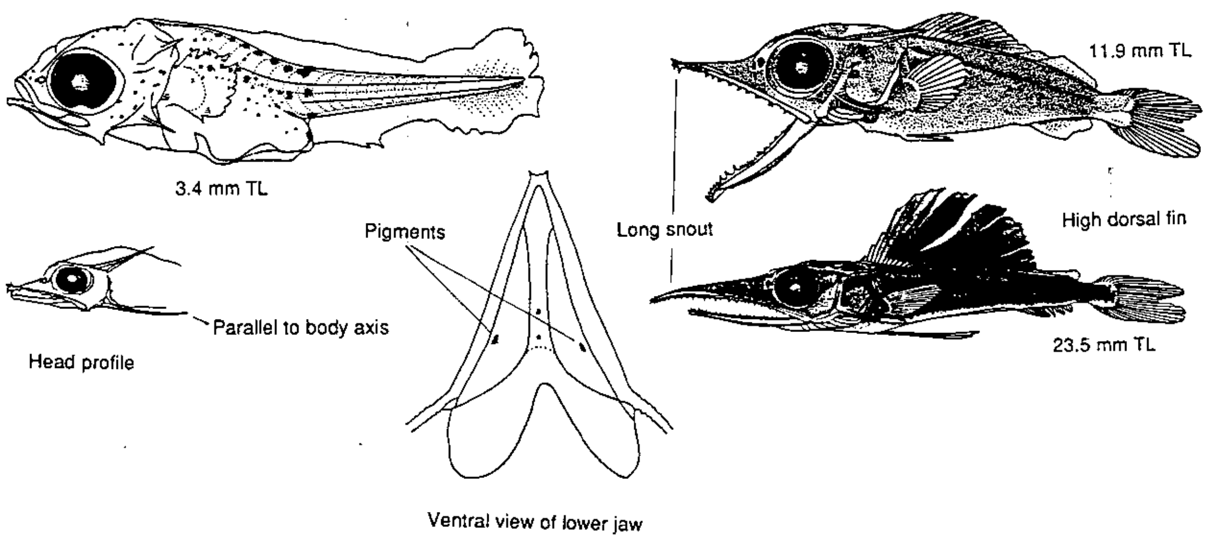

Figure 24. Larva, postlarva and juvenile of sailfish, *Istiophorus platypterus* (from Yabe, 1953; Ueyanagi, 1974)

Makaira mazara **(blue marlin):** No black pigments on branchiostegal membrane or on periphery of underside of lower jaw; black pigment spots present (usually a pair) on underside of lower jaw near tip; eye large; anterior edge of orbit projects forward; centre of eye in head profile about level with tip of snout; pterotic spine rises obliquely; preopercular spine extends nearly parallel to body axis; snout short, even in specimens larger than ~14 mm SL (Figure 25). Larvae larger than ~24 mm SL have a branched, vermiculate lateral line. All other billfishes have a straight, unbranched lateral line. See also: Ueyanagi and Yabe (1959a); Ueyanagi (1974).

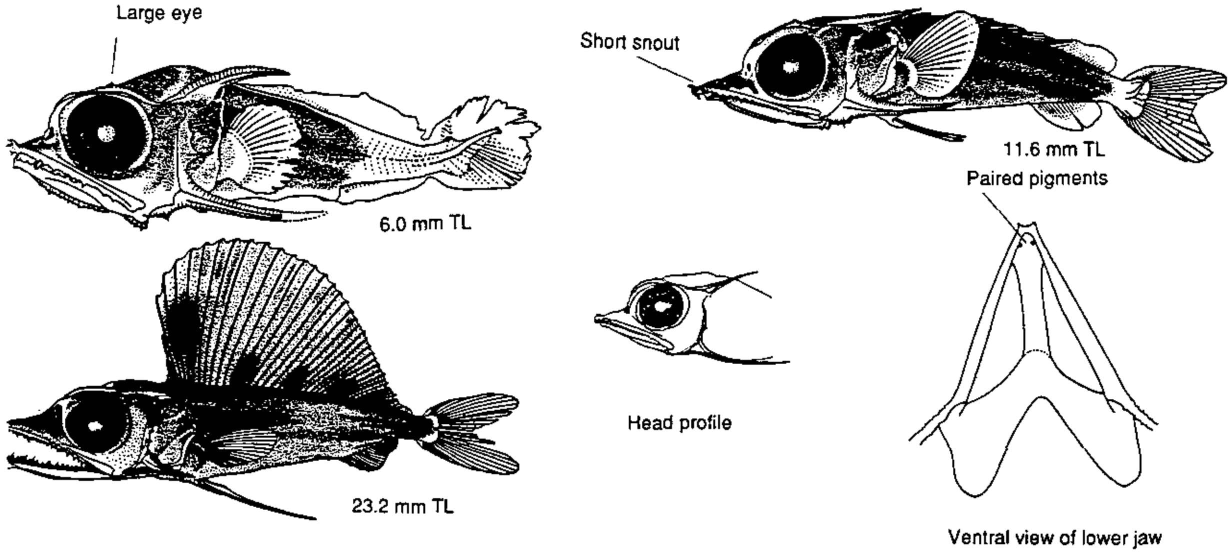

Figure 25. Larva, postlarva and juvenile of blue marlin, *Makaira mazara* (from Ueyanagi and Yabe, 1959a; Ueyanagi, 1974)

Makaira indica **(black marlin):** Not illustrated or included in the key. Some early life stages have been described by Ueyanagi (1960) and Ueyanagi and Yabe (1960). However, a complete developmental series for the young stages of this species is not available and identification of the larvae is doubtful at present. Features believed to be characteristic of this species are: rigidly extended pectoral fins; a large eye; absence of pigment on branchiostegal membrane and periphery of underside of jaw. They resemble blue marlin larvae in some respects, but differ in body shape, pectoral fin structure, height of 1st dorsal fin and head profile.

Larval Fishes with Morphological Similarities to Scombroids

Several groups of fishes have larvae that strongly resemble the larval scombroids. The task of identifying scombroid larvae will be expedited if these look-alikes are sorted out before further identification is attempted. Most confusion is likely to arise with very small specimens (larvae only a few days old).

A number of Myctophidae and Carangidae larvae (see Ozawa, 1986) are likely to be confused with larval scombroids. Myctophids and carangids will have a lower myomere count (24); usually have larger, darker pigmentation on their bodies; the shape of the abdominal cavity in most will not be triangular and compact; their anus will be more posterior (near or behind the mid-point of the body); and myctophids will lack preopercular spines. Scombroids have a relatively larger head, eye and mouth, but this may be difficult to discern in small larvae. Sometimes the head of scombroids is damaged and flattened, making their appearance more like carangids or myctophids.

Some larvae of the family Serranidae (see Kendall, 1979) may resemble those of family Gempylidae, but can be distinguished by the spines of the 1st dorsal fin: serranids have a short 1st dorsal spine and elongated 2nd spine, whereas gempylids have an elongated 1st spine. Serranids have only 24 myomeres; gempylids have 31-67.

Swordfish and billfish larvae are very distinctive in appearance; however, at first glance the larvae of *Holocentrus* or *Daicocus* could be mistaken for them (Figure 26). Note that *Holocentrus* has a small, sub-terminal mouth, a rostral spine and only a single spine on top of the head. *Daicocus* has paired opercular spines and a very blunt snout; *swordfish or billfish have a large terminal mouth and pointed snout.*

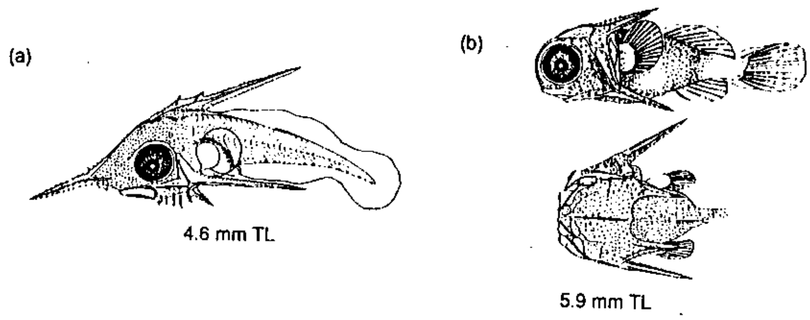

Figure 26. Larval forms with morphologies similar to billfishes (from Mito; 1966): (a) *Holocentrus* sp. (b) *Diacocus peterseni*

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