THE REGIONAL TRAINING WORKSHOP ON LARVAL FISH IDENTIFICATION AND FISH EARLY LIFE HISTORY SCIENCE

SEAFDEC/TD, SAMUT PRAKAN, THAILAND
16 – 31 MAY 2007

TRD 01: Early Life History Descriptions

From : Leis and Carson-Ewart (2000). The Larvae of Indo-Pacific Coastal Fishes : An Indentification guide to marine fish larvae. Fauna Malesiana Handbook 2

Terminology adopted

Terminology of the developmental stages of fishes has been the subject of much debate, and many attempts have been made to define a universal system. Mostly this has resulted in confusion. Because there is so much diversity in the way in which fishes develop, it is unlikely that any one system of terminology will ever be accepted by a majority of workers.

The terminology used here is based on the widely used system of Ahlstrom and co-workers (Kendall et al.,1984). We define larval stage to end with the attainment of full external meristic characters, the arrival of any mobile structure (for instance, eye of flatfishes or dorsal fin of clupeiform fishes) at its ultimate position, and the loss of temporary specializations to pelagic life (not just the attainment of full fin counts as many workers have done). This definition is adopted for two reasons. In the tropics, the larvae of many benthic species attain the full complement of fin rays but are still larvae in the sense of being 'self-supporting immature forms which differ fundamentally from the parents in structure' (Tweney&Hughes, 1961). These young stages remain pelagic, are often transparent, and they frequently lack scales. Secondly, many tropical fishes have a stages characterized by striking and often bizarre, temporary, morphological specializations for pelagic life (called the prejuvenile stage by Hubbs, 1958). These stages are often scaled and heavily pigmented but differ markedly from the adult. It is our feeling that these stages are appropriately termed larval. The larval and pelagic stages are not synonymous; the young of many benthic fishes remain pelagic for a time following transition as juveniles as, of course, do the young of pelagic fishes. However, for the majority of benthic fishes, the end of larval stage does approximately coincide with settlement. For most of these, the morphological transition from larva to juvenile is abrupt and takes place over a small size range. For most pelagic taxa transition is gradual and may take place over an extended size range, probably because there is not such a marked change in habitats, and hence selective regimes, at the end of the larval stage. Individuals in transition would generally be considered to be larval. The larval stage is further divided into three segments that are defined by formation of the caudal fin and concomitant flexion of the notochord.

Terminology for developmental stages as used here (Fig. 1)

"egg" : spawning to hatching

"**larval stage**" : hatching to attainment of complete fin ray counts and beginning of squamation (arrangement of scales on the skin)

- Yolk sac larva : Development stage beginning with hatching and ending with exhausting of yolk reserves and characterized presence of a yolk sac.
- Preflexion larva [ab] : Developmental stage beginning at hatching and ending at the start of upward flexion of the notochord.
- Flexion larva [ab] : Development stage beginning with flexion of the notochord and ending with the hypural bones assuming a vertical position.
- Postflexion larva [ab] : Development stage from formation of the caudal fin (hypural element vertical) to attainment of full external meristic complements (fin rays).
- Transition larva [b]

“juvenile [b]” : completion of fin ray counts and beginning of squamation until fish enters adult population or attain sexual maturity.

“adult [b]”

[a] Yolk sac may be present.
[b] Settlement may occur during this stage or not at all if the adults are pelagic.

This system is flexible and has the virtue of simplicity in both concept and terminology. For example, fishes that are live bearers, or never develop a caudal fin, or hatch with the caudal fin fully developed, can be accommodated by skipping the inappropriate stages. Our goal in this terminology has been to minimize the number and complexity of terms without becoming too general. To these ends we have not used terms that etymologically contradict their stated definitions (for instance, prolarva and postlarva) that have either been unclearly defined or misunderstood and used in several ways (for instance, post larva, prejuvenile) or that are exceeding complex (for instance, protopterygiolarva). A further reason for abandonment of ‘prejuvenile’ is the difficulty often present in deciding what constitutes a ‘more or less strikingly – often bizarrely – modified pelagic life history stage… not appropriately termed either postlarval or juvenile’ (Hubb,1958). Acanthurids qualify, and perhaps serranids, but do atherinids (which have a strikingly short gut) or gobiids (which have a strikingly large gas bladder)? The system used here works reasonably well for taxonomic and ecological investigations of tropical marine fish larvae of pelagic, reef, and soft-bottom demersal species and is consistent with the biological concept of the larva.

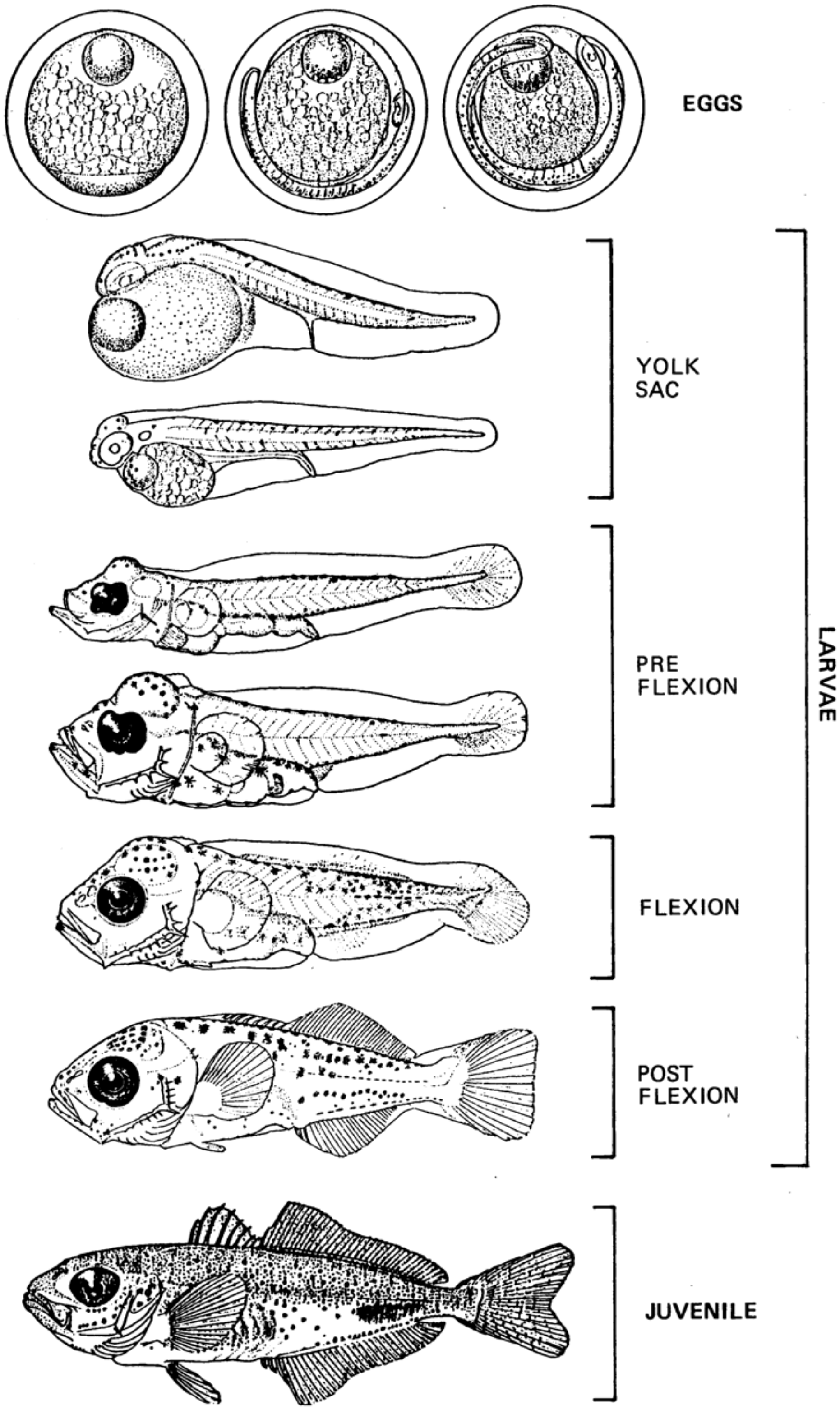


Fig. 1 Development stages (Early life history stage of Trachurua symmetricus from Ahlstrom from and Ball ,1954 cited in Kendall, Ahlstrom and Moser, 1983)

Abbreviations

These abbreviations are used throughout the text. The terms are defined in the Glossary, and illustrated in Fig. 2. A few infrequently used abbreviations are defined in the text.

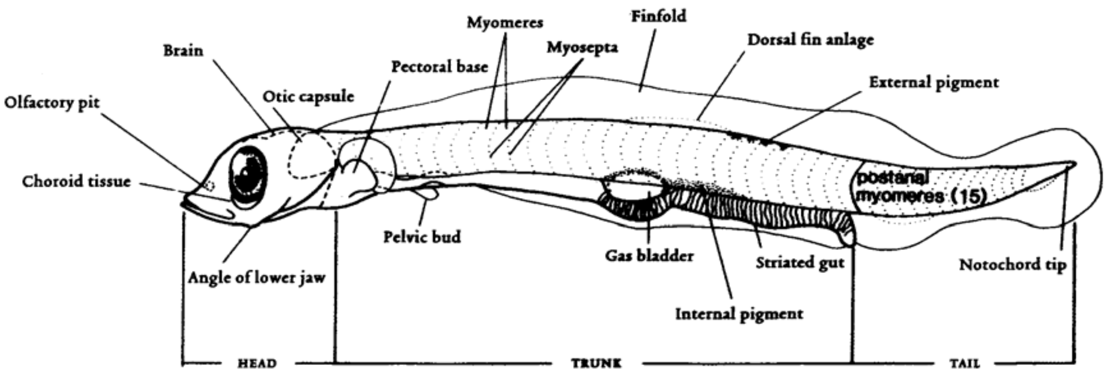
A	anal fin	P_1L	pectoral-fin length
BD*	body depth	P_2	pelvic fin
BL*	body length	P_2L	pelvic-fin length
BW	body width	PAL*	preanal length
C	caudal fin	PDL*	pre dorsal-fin length
D	dorsal fin	PGBL	pre gas-bladder length
DSL	dorsal-fin-spine length	POSL	preopercular-spine length
ED*	eye diameter	PP_2L	pre pelvic-fin length
HL*	head length	SL	standard length
HW	head width	SnL*	snout length
MW	mouth width	TL	total length
NL	notochord length	UL	unspecified length
P_1	pectoral fin	VAFL*	vent to anal-fin length

*Measurements taken routinely, see Fig.2D

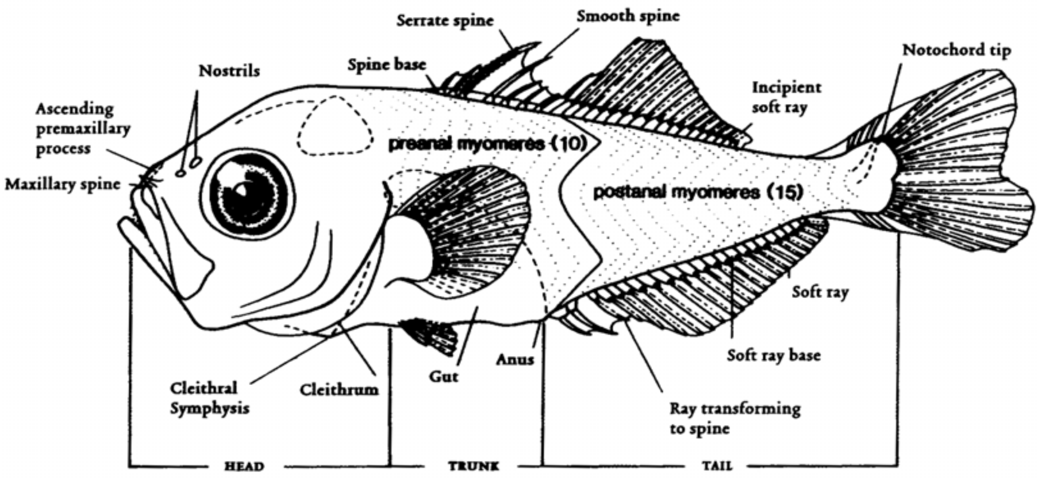
Fig 2 The major morphological characters and measurements of fish larvae used in this book. Many of the terms shown are defined in the glossary.

- **A** hypothetical preflexion larva
- **B** hypothetical postflexion larva
- **C** head of a hypothetical larva showing head and pectoral girdle spination; spines marked with '+' are unpaired medial spines
- **D** postflexion mullid larva showing the measurements taken routinely. Abbreviations are defined in the text.

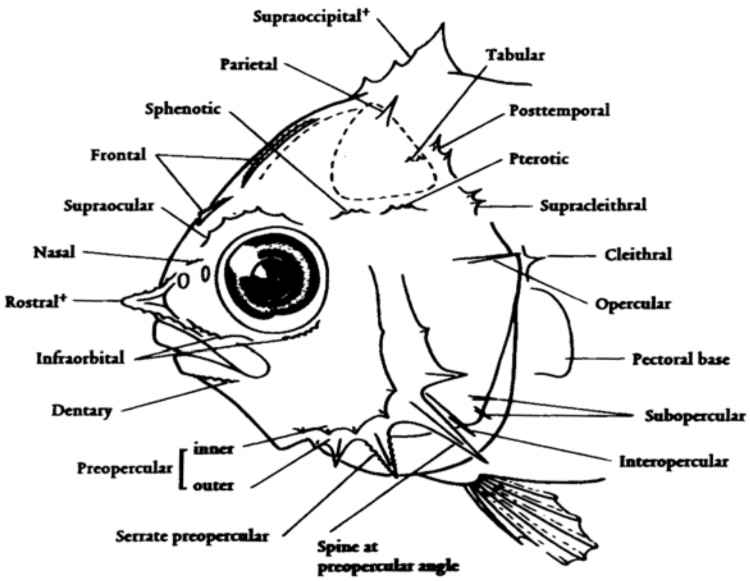
A



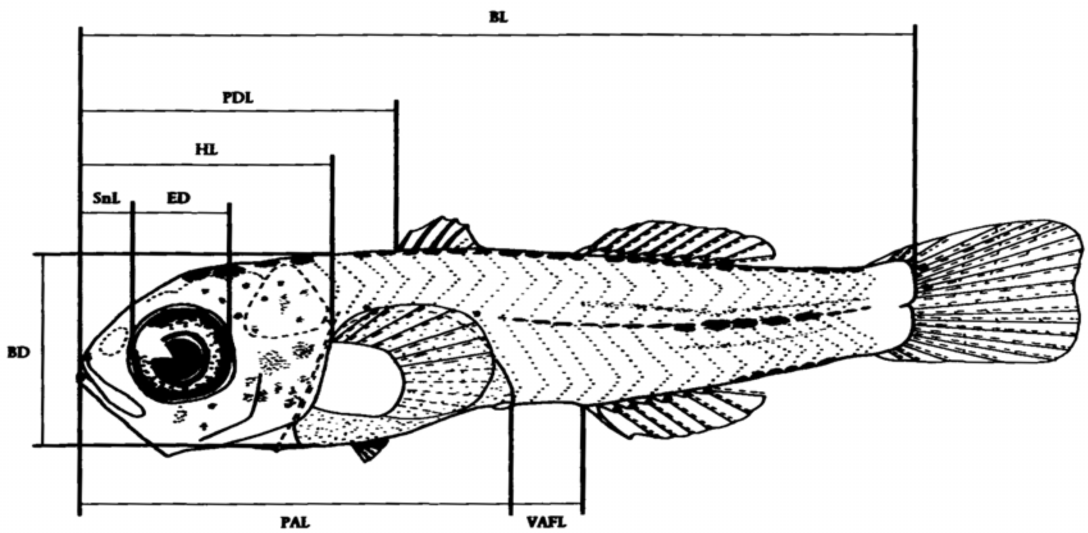
B


Serrate spine
Smooth spine
Spine base
Nostrils
Notochord tip
Ascending premaxillary process
Incipient soft ray
preanal myomeres (10)
Maxillary spine
postanal myomeres (15)
Soft ray
Soft ray base
Anus
Gut
Cleithral Symphysis
Cleithrum
Ray transforming to spine
HEAD
TRUNK
TAIL

C


Supraoccipital+
Parietal
Tabular
Sphenotic
Posttemporal
Frontal
Pterotic
Supraocular
Supracleithral
Nasal
Cleithral
Rostral+
Opercular
Infraorbital
Pectoral base
Dentary
Subopercular
Preopercular
inner
outer
Interopercular
Serrate preopercular
Spine at preopercular angle

D


BL
PDL
HL
SnL
ED
BD
PAL
VAFL

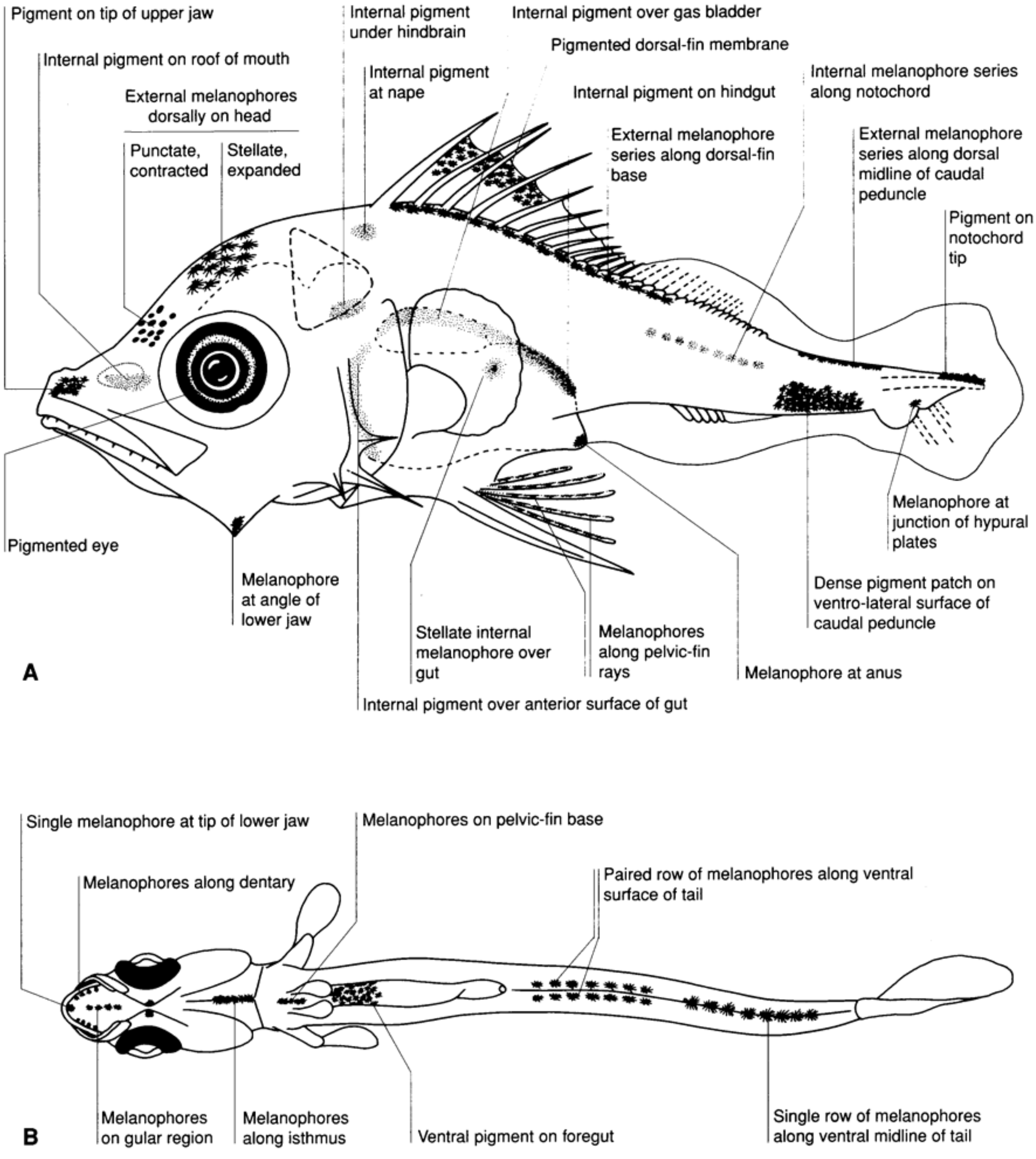


Fig. 3 Hypothetical larvae showing major pigment characters used to describe larvae in this book:

A--> Lateral view

B --> Ventral view

(From Neira et al (1998) Larvae of temperate Australian fishes: Laboratory guide for larvae fish identification)

Characters as used in descriptions of larvae

Body Shape

In our descriptions of the general shape of the body, we use the following broad categories that relate body depth (BD) to body length (BL):

Very Elongate:	BD < 10% BL
Elongate:	BD 10-20% BL
Moderate:	BD 20-40% BL
Deep:	BD 40-70% BL
Very Deep:	BD > 70% BL

Categories used to define head size relate head length (HL) to BL;

Small Head:	HL < 20% BL
Moderate Head:	HL 20-33% BL
Large Head:	HL > 33% BL

Categories used to define eye size relate eye diameter (ED) to HL;

Small Eye:	ED < 25% HL
Moderate Eye:	ED25-33% HL
Large Eye:	ED>33% HL

All references to size of body parts are to relative size. Thus, a structure that does not change in absolute size may be said to reduce, or to have become relatively smaller, because the body as a whole has grown. Similarly, if growth of a given structure is positive but does not keep pace with overall growth, it will reduce in relative size, perhaps from large to moderate. Few structures except very large fin or head spines actually become absolutely smaller during development.

Myomeres

Myomere counts include all myomeres bounded anteriorly by a myoseptum, and are divided into pre-and postanal element (per + post). This is not necessarily equivalent to the division of vertebrae between precaudal and caudal centra because the position of the anus may change ontogenetically or may be anterior to the posterior edge of the abdominal cavity. There is a near one-to-one correspondence between total number of myomeres and numbers of vertebrae. In preflexion larvae notochord segmentation posterior to the terminal myomere may be mistaken for additional myomeres.

Gut

The gut of fish larvae always starts as a straight tube. This subsequently differentiates into functionally different sections which may be visually discernible: a portion of the gut may be striated, for example. The gut usually folds or coils into loops, thereby increasing its length without increasing body length. The folding may take place before hatching, but more commonly it happens during or shortly after the yolk-sac stage and in some cases after transformation to the juvenile stage. The timing of folding and its extent are species-specific and therefore useful taxonomic characters.

Gas bladder

The buoyancy-regulating gas bladder is present in most larvae but is lost in the adults of some taxa (for instance, gobiids). In these species the gas bladder is not really a temporary specialization to pelagic larval life: it is the loss of the gas bladder in adults that is the specialization. Two factors alter the size or degree of inflation of the gas bladder. Larvae captured at depth and brought rapidly to the surface may have expanded gas bladders due to the pressure change. Secondly, many taxa have a small, inconspicuous gas bladder during the day but a strongly inflated, conspicuous gas bladder at night (for instance, clupeiformes, sillaginids). Thus, larvae collected at night may appear different from those collected during the day because of nocturnal gas bladder inflation. However, Larvae that normally have inflated gas bladders at night may have deflated bladders if collected at night around a light. Finally, in some taxa, the gas bladder migrates ontogenetically. For example, in clupeiformes, anterior migration of the gas bladder is common, whereas in many gobioid larvae, the gas bladder migrates poateriorly.

Head spination

One of the most striking larval specializations is the head spination found in many species that lack head spines as adults. The most widespread type of head spination is that on the inner and outer preopercular borders. However, spines may appear on any part of the head (Fig.2). The sequence of development, degree of elongation, placement, number, and ornamentation of the spines are important characters for identification, and we note these in the descriptions. Most of these spines are resorbed, overgrown or incorporated into sensory canals by the end of the larval stage, but some remain well into the juvenile stage, and some spines may be retained by the adults. In describring the preopercular spines, the following definitions of length apply: small – shorter than the pupil diameter; moderate – larger than pupil diameter, but do not extend over the border of the opercular series (opercle, subopercle and interopercle); large – extend past the border of the opercular series. The head spines probably have a defensive function (Moser, 1981). We include among head spines the spines of the upper pectoral girdle (supracleithrum, cleithrum, postcliethrum). Nomenclature of the borders (or edges) of the preopercle can be confusing. What some authors refer to as the posterior border or the medial border or ridge, we call the outer border because, radially, it is outside the more enclosed inner border (called anterior, or lateral border or ridge by some). Almost without exception, the spines of the outer border are larger and more numerous than those of the inner border.

Eyes

Most fish have round or nearly round eyes. A large number have eyes shaped like rounded squares or rectangles (squarish) or than are slightly elongate (longer than high). Finally, a relatively few have eyes than are much smaller laterally than they are vertically (narrow eyes, Weihs & Moser, 1981). Choroid tissue is a mass of apparently undifferentiated tissue that clings to the ventral margin of the eye of the larvae of some species. It may be involved in metamorphosis of the eye (Moser & Ahlstrom, 1970), and it is usually unpigmented although in a few species it may be nearly as dark as the eye. Choroid tissue seems to be most common in larvae with narrow eyes.

Fin formation

The fist stage in development of the medial fins is the undifferentiated finfold. The finfold is initially continuous (or nearly so) from occiput around the tail to near the cleithral symphysis, but it becomes discontinuous and eventually disappears as the fins differentiate. Thickenings, or anlagen, appear in the finfold, usually along the finfold/body interface, but at the periphery of the finfold in a few species. The anlagen soon begin to segment into discrete finbases.

The soft-ray bases are typically massive and elongate, rounded at the distal end, and have little or no space between them. The rounded end of the base articulates with the soft ray via a ball and socket joint. The incipient rays are thickenings oriented more or less perpendicular to the body axis in the finfold and extending the width of the finfold. The rays are considered to have formed (i.e. no longer incipient) when their ossification begins. One ray forms on each base, although the last ray may be divided nearly to the base. After formation the rays segment and may branch.

Spines form from triangular bases than are usually much smaller than ray bases. The spines bases are generally separated from one another, and the finfold may disappear in the interspaces while the spines are still incipient. Again, there is one spine per base. It is not unusual for the last spine of the dorsal or anal fin to form as a soft ray (complete with segments) that subsequently hardens into a spine. In this case, the base of this element is intermediate in shape and size between a spine base and ray base. Because of the differences between the types of base, it is usually possible to distinguish between spines and rays before these elements are fully formed. Even after the spines and rays are present, it may be easier to use bases rather than the spines or rays to obtain fin formulate. This is especially true in species with weak or flexible spines such as labrids.

The caudal fin has some developmental peculiarities. In most teleosts (there are exceptions among the Gadiformes and Ophidiiformes), the caudal fin forms from a ventral anlage near the tip of the notochord. The anlage breaks up into only a few segments, so there is not a 1:1 ratio of basal segments to fin rays. While the rays form, the notochord flexes upward, bringing the rays parallel to the body axis (see Ahlstrom & Moser, 1976). The basal segments become the supporting bones of the caudal complex.

The paired fins form from buds, do not form separate bases for each element, and pass through an incipient-ray stage. The pectoral bud forms very early, usually in the yolk-sac stage, but the pectoral rays may form very late. The pelvic fin often develops a spine (this is taxon-dependent), but the pectoral fin does not in any of the fish considered here.

The usual pattern of fin development is for the caudal fin to form fist. Near the end of notochord flexion, the soft rays of the dorsal and anal fins begin to ossify. The spines usually ossify after the soft rays. The pectoral rays form next, and the pelvic fin is usually last. There are many species-dependent exceptions to this generalized pattern, however, and any fin may be the first or last to form.

Certain fin spines and rays or even whole fins may become very long or become ornamented in a taxon-specific manner with various hard (for instance, serrations) or soft (for instance, fleshy bulbs) structures. These are nearly always tempolary specializations to the pelagic larval stage and probably serve in defence against predators (Moser, 1981), although it is possible some of the soft structures aid in flotation or camouflage.

Size

For each family, we give a table of size at which certain developmental events occur and size of the smallest and largest specimen examined. The ranges given reflect variation among taxa, while the size of the smallest and largest specimens examined give the size range over which our descriptions apply and how large the larvae or juveniles may become prior to settlement. Where a range of sizes is given for smallest or largest, the sizes of more than one species and included. The range given for size at flexion is the largest preflexion specimen and the smallest postflexion specimen.

Morphometrics

In the morphometrics tables measurements are expressed as a proportion of body length. Body length for preflexion and flexion larvae is notochord length. Body length for postflexion larvae is standard length. Certain measurements were made routinely on all specimens (see list of abbreviations on page 5); others were made when needed. Unless noted other otherwise in the text, all lengths are body length as specified here.

The variation in morphometrics of larval fishes is often high because of diversity in, and ontogenetic changes to, body shape, damage or distortions suffered during collection, or shrinkage. Shrinkage is probably a result of water loss from hypertonic tissues of the larva after death and is particularly severe in small larvae before the vertebral column is ossified. Changes in length of 33% following death and preservation have been reported for newly hatched, yolk-sac larvae (Miller & Sumida, 1974). Several factors can influence the degree of shrinkage including time between death and preservation, type of preservative, and method of collection (Theilacker, 1980). Because larvae usually shrink when preserved, one often encounters preserved larvae of a smaller size than that reported for newly-hatched larvae (which are often measured alive).

In the Morphometrics tables we include flexion-stage larvae with preflexion larvae. All larvae were measured under a dissection microscope equipped with an eyepiece micrometer or a digitizing pad. Magnification varied from 6 to 50 X depending on the size of the specimen, and precision of measurements ranged from 0.02 to 0.13 mm depending on magnification. Measurements in the text were usually rounded to the nearest 0.1 mm if less than 10 mm, to the nearest 0.5 mm between 10 and 20 mm, and to the nearest 1 mm if greater than 20 mm.

Pigment

We are concerned here only with melanin. Although live fish larvae may have a number of pigments, the preservatives and fixatives commonly used quickly bleach the reds, yellows, blues and silvers, leaving only the browns and blacks of melanin. The terms melanophores and pigment are thus used interchangeably, and all references are to pigment in preserved specimens. In the illustrations, pigment on the surface of the body (external pigment) is portrayed as shown in Fig.2A. Internal pigment is portrayed with stipples. We depart from this rule by using stipples to portray surface pigment that is widespread and of relatively uniform density (usually on late larvae or early juvenile specimens).

Meristics table

Nearly all meristic data were derived from the literature. Many sources were used, and we have not cited these to save space; however, reference to the papers cited in the adult section or one of the major faunal works will give a good entry to the literature on the family. In a few cases we made our own counts from specimens or radiographs. We attempted to standardize literature counts taken by different methods (see below), but in some cases the methods (for instance, if the urostyle is included in vertebral counts) were not recorded so some errors may have been introduced. Other possible sources of error were erroneous counts (often perpetuated from source to source) and artificially truncated ranges based on too few specimens or species. We attempted to include counts from all recognized species under each genus, but in most cases complete counts were not available for all species. Therefore, the Meristics Tables should be used with caution. In these tables, a '_' indicates no data.

Fin-ray and vertebral counts

Spines are indicated by Roman numerals, and soft rays by Arabic numerals. A comma indicates an undivided fin, and a '+' indicates a divided fin with the exception of the caudal fin where a '+' indicates the division between dorsal and ventral primary rays. A particular problem concerns caudal rays: the counts given are for principal (used interchangeably with primary) rays. This count is defined in the literature in at least three ways:

1. the number of branched rays plus two (Hubbs & Lagler, 1964);
2. the rays which articulate with the hypural bones (Miller & Jorgenson, 1973) however, these authors note 'our judgment, based upon our interpretation of the literature, was used to determine this count'; and
3. the rays supported by the hypurals and parahypural (Moser et al., 1977).

It was often impossible to determine in published accounts which method was used, and while definitions 1 and 3 often give identical counts, this is not always true. Definition 1 is the least useful for larvae, as fin rays branch late in ontogeny. If counts were given as branched rays rather than as principal, we have so indicated. We frequently used the book on caudal fin osteology by Fujita (1990) to obtain the required information.

Preferred counts (please note caution above):

- Caudal (C): the rays supported by the hypurals and parahypural.
- Dorsal (D), and (A): each element with a separate base was counted.
- Pectoral (P1): including all elements, usually without regard to segmentation or branching.
- Pelvic (P2): all elements
- Vertebrae: all elements including the urostyle, divided if possible into precaudal and caudal vertebrae.

Glossary

We assume the user will have a working knowledge of adult fishes, so we define only those terms of special application to fish larvae. We refer the reader without such a working knowledge to a modern ichthyology text such as Helfman et al. (1971), or to a work on fish osteology such as Rojo (1991). General terminology mostly follow that of Hubbs & Lagler (1964). For spines of the head we follow the terminology of Fig. 2C. Some infrequently occurring spines not shown in Fig. 2C are named after the bone from which they are derived.

A

Anlage – Rudimentary form of an anatomical structure; primordium; a German German word the plural of which is Anlagen.

B

body depth – The vertical distance between body margins (exclusive of fins) through the anterior margin of the pectoral-fin base: not necessarily the greatest body depth.

body length – Size of the larva; corresponds to notochord length in preflexion and flexion larvae and to standard length after flexion.

body width – The transverse distance between body margins at the pectoral-fin base.

C

choroids fissure – Line of juncture of invaginating borders of the optic cup; apparent in young fish as a trough-like area below lens.

choroids tissue – An undifferentiated mass of (usually) unpigmented tissue adhering to the ventral surface of the eye (see Moser & Ahlstrom 1970).

cleithral symphysis – The cartilaginous joint between the two cleithra where they join ventrally Often forms a prominent point along the ventral profile.

cleithrum – Prominent bone of pectoral girdle, clearly visible in many fish larvae.

D

demersal egg – An egg which remains on the bottom either free or attached to the substratum.

E

exterilium larva – A term referring to the larvae of some unidentified species of the ophidiid subfamily Neobythinae characterized by an elongate, compressed body and a very long, trailing gut ornamented with flaps and streamers (illustrations are found in Gordon et al., 1984 C); Okiyama, 1988d (p. 340).

eye diameter – The horizontal distance across the midline of the pigmented region of the eye.

F

fin elements – Fin supports; spines and soft rays.

finfold – Medial fold of integument that extends along body of developing fishes and from which media fins arise.

fin length – Length of the longest soft ray of designated fin.

flexion – Bending upward of the notochord tip as part of the process of caudal-fin formation.

flexion larva – Development stage beginning with flexion of the notochord and ending with the hypural bones assuming a vertical position.

G

gas bladder – Membranous, gas-filled organ located between the kidneys and alimentary canal in teleost fishes; air bladder or swim bladder.

H

head length – The horizontal distance from the tip of snout to posterior-most part of opercular membrane; prior to development of operculum, measured to the posterior margin of cleithrum.

head width - The transverse distance between margins at the widest area of the head. Not applicable to larvae with flared opercles.

Hypural bones – The basal bones of the caudal fin that support the caudal-fin rays.

I

incipient fin-ray – Early stage in fin-ray development; and unossified thickening in finfold articulating with the fin base.

initially – When used in the Morphology section, meaning in the smallest available specimens.

interopercle – A bone of the skull that may bear spination (see Fig. 2).

J

juvenile – Developmental stage from attainment of full external meristic complements and loss of temporary specializations for pelagic life to sexual maturity.

K

lachrymal – The anterior bone of the infraorbital series. Frequently overlaps the maxilla when the mouth is closed.

larva- Developmental stage between hatching (or birth) and attainment of full external meristic complements (fins and scales) and loss of temporary specializations for pelagic life; yolk-sac through postflexion stage inclusive.

M

melanin – A black pigment.

melanophores – Melanin-bearing cells (brown to black); frequently capable of expansions and contractions which change their size and shape.

mouth width – The gape; transverse distance between corners of the mouth.

myomeres – Serial muscle bundles of the body.

myosepta – Connective tissue partitions separating adjacent myomeres.

N

notochord - Longitudinal supporting axis of body which is eventually replaced as a support by the vertebral column in teleostean fishes.

notochord length – Straight line distance from tip of snout to posterior tip of notochord; used prior to and during flexion.

O

olfactory pit – A shallow depression on the snout from which olfactory organ develops.

opercle (operculum) – Bone of the skull that may bear spination (see Fig. 2).

ossification – Hardening of bony parts through deposition of calcium salts; usually detected by staining with alizarin

otic capsule – Sensory anlage from which the ear develops; clearly visible during early development

P

parahypural – Modified haemal spine of the penultimate vertebral centrum. Supports some caudal-fin rays.

pectoral bud – Swelling at site of future pectoral fin; anlage of pectoral fin.

pelagic – In the water column as distrinct from substrate-associated; neither necessarily planktonic nor oceanic.

pelagic egg – Egg which floats freely in the water column, often slightly positively buoyant.

pelagic juvenile – Pre-settlement juvenile of a species that is benthic or reef-associated as an adult.

pelvic bud – Swelling at site of future pelvic (ventral) fin; anlage of pelvic fin.

postanal mymeres – Myomeres posterior to the posterior margin of the anus; includes terminal myomere from which urostyle forms.

postcleithrum – Bone of the pectoral girdle that may bear a small spine just dorsal to the pectoral-fin base in a few families (for instance, Lutjanidae, see Figs 79 D-E or 80 D-E).

postflexion larva – Developmental stage from formation of the caudal fin (hypural elements vertical) to attainment of full external meristic complements (fin rays and scales) and loss of temporary specializations for pelagic life (Fig. 4 C).

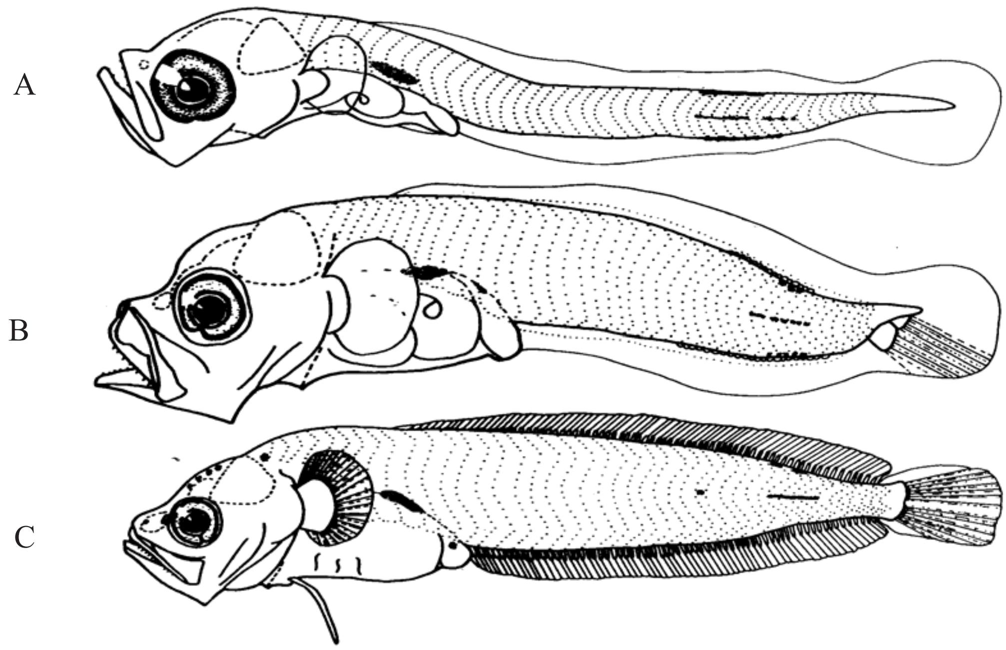


Fig. 4 Larvae of the bythitid

posttemporal – Bone of the pectoral girdle that may bear spination (see Fig. 2).

preanal length – Distance from the tip of the snout along the midline to a vertical line through the posterior edge of the anus.

pre dorsal-fin length – Distance from the tip of the snout along the midline to a vertical line through the origin of the dorsal fin or dorsal-fin anlage.

preflexion larva – Developmental stage beginning at hatching and ending at the start of upward flexion of the notochord (Fig. 4A).

pre gas-bladder length – Distance from the tip of the snout along the midline to a vertical line through the anterior edge of the gas bladder.

preopercle – Bone of the skull that may bear spination (see Fig. 2).

pre pelvic-fin length – Distance from the tip of the snout along the midline to a vertical line through the origin of the pelvic fin.

R

rays – See soft rays

S

settlement – Process by which a larva or juvenile leaves the pelagic environment and adopts a substrate-associated lifestyle; not applicable to species pelagic as adults.

settlement stage – Development stage where the pelagic larva or juvenile is morphologically and physiologically ready (competent) to adopt a substrate- associated life style. Often, but not always, associated with larva to juvenile transition. Applicable only to species that are not pelagic as adults.

snout length – Horizontal distance from the tip of the snout to the anterior margin of the pigmented region of the eye.

soft rays – Bilaterally paired, usually segmented fin supports; often referred to as rays.

spine length – Straight line distance of a fin or body spine from base to tip.

spines – 1 Unpaired, unsegmented, unbranched fin supports, usually (but not always) stiff and pungent; may initially form as bilaterally paired structures prior to ossification.

2 Bony, pointed, elongate projections on the body, usually the head, that are often temporary specializations for pelagic life.

standard length – Distance from tip of the snout along the midline to a vertical line through the posterior edge of the hypural plate.

subopercle – Bone of the skull that may bear spination (see Fig. 2)

supracleithrum – Bone of the pectoral girdle that may bear spination (see Fig. 2)

T

tail – Portion of body posterior to the anus.

teeth – Larvae of some species develop ‘larval teeth’ prior to the appearance of definitive teeth. Larval teeth are little exserted spines on the premaxilla or dentary, and they are lost during the larval phase (Baldwin, 1990). The descriptions herein do not generally distinguish between ‘larval teeth’ and definitive teeth.

temporary specializations for pelagic life – Morphological (not pigment) characters such as trailing guts, prepercular spines, or elongate fin spines that are not retained in adults but are present during the pelagic phase. Often these are lost after settlement, but if present in settled individuals, they are clearly reduced and are disappearing.

total length – Distance from the tip of the snout along the midline to the posterior edge of the caudal finfold; body length is traditionally expressed as total length in the Japanese literature.

transition – Change from the larval to the juvenile stage. May take place over an extended period of time. Especially used for pelagic taxa where there is not a change in habitat at or near the end of the larval phase. Individuals in transition are considered larval. In the text, we avoid the use of the term metamorphosis because of its implications of abrupt and extensive morphological change over a short period.

trunk – Body between head and anus.

U

unspecified length – Undefined measurement of body length derived from the literature.

urostyle – the posterior-most vertebral centrum.

V

vent to anal-fin length – Straight line distance from posterior edge of the vent (anus) to the anterior origin of the anal fin or anal-fin anlage.

Y

yolk sac – A bag-like, ventral extension of the primitive gut containing the yolk.

Yolk-sac larva – Developmental stage beginning with hatching and ending with exhaustion of yolk reserves and characterized by presence of a yolk sac.

Literature often used for identification of fish larvae

1. Fahay, M.P. 1983. Guide to the early stages of marine fishes occurring in the Western North Atlantic Ocean, Cape Hatteras to the Southern Scotian Shelf. *J. Northw. Atl*. Fish. Sci. 4 : 423 pp.

2. Fritzsche, R.A. 1978. Development of fish of the Mid-Atlantic Bight, and atlas of eggs, larval and juvenile stages. Vol. V. Chaetodontidae through Ophidiidae, U.S. Fish. Wild. Serv., Biol. Serv. Prog. FWS/OBS-78/12.

3. Leis, J.M. and B.M. Carson-Ewart. 2000. The Larvae of Indo-Pacific Coastal Fishes: An identification guide to marine fish larvae. Fauna Malesiana; Vol. 2. Leiden; Boston; Koln: Brill. 850 pp.

4. Moser, H.G., W.J. Richards, D.M. Cohen, M.P. Fahay, A.W. Kendall Jr. and S.L. Richardson. (eds.). 1984. Ontogeny and Systematic of Fishes. An International Symposium Dedicated to the Memory of E.H. Ahlstrom, Special Publication no. 1, American Society of Ichthyologists and Herpetologists. 760 pp.

5. Niera, F.J., A.G. Miskiewicz and T. Trnski. 1998. Larvae of Temperate Australian Fishes: Laboratory Guide for Larval Fish Identification. University of Western Australia Press. 474 pp.

6. Nishikawa, Y. and D.W Rimmer. 1987. Identification of larval tunas, billfishes and other scombroid fishes (suborder Scombroidei): an illustrated guide. CSIRO Marine Laboratories Report 186, 20 pp.

7. Okiyama, M. 1988. An Atlas of the Early Stage Fishes in Japan. Tokai University Press. 1157 pp. (in Japanese).

8. Ozawa, T. 1986. Studies on the oceanic ichthyoplankton in the Western North Pacific Kyushu University Press. 430 pp.