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Early Life History of the Gonostomatid Fish, *Pollichthys mauli*, in the Oceanic Region off Southern Japan

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Abstract Postlarvae of the gonostomatid fish, *Pollichthys mauli* (Poll), are described and the early life history is studied for the first time. It is shown that sequence of development is divided into two distinct forms, i. e., white-bait form changes into adult form through marked metamorphosis. White-bait larvae are slender and are devoid of pigmentation except eyes; eyes are oval and possess underlying choroid tissue; anus and anal fin are situated very posteriorly of the body. Buds of photophores appear late in the larval stage. Adult form shows the features of mesopelagic inhabitants; photophores develop prominently; forebody is elongated and/or deepened; pigments spread on the head and along the back; eyes are rounded and lost the choroid tissue; anus and anal fin are set anteriorly. Developmental stages are subdivided as follows: white-bait form, into prelarval (not included in this study), postlarval (this stage is further separated into early, middle, and late stages), and metamorphic stages; adult form, into juvenile and adult stages.

Introduction

In recent years, R/V Hakuhō maru, Ocean Research Institute, University of Tokyo, made intensive surveys on fish larvae in the sea off southern Japan (Ocean Research Institute, 1974 a, b, 1976). Preliminary studies (Tsukahara *et al.*, 1974; Matsui *et al.*, 1974; Ozawa, 1974, 1976) presented the first records of considerable number of fish larvae in the western North Pacific. The gonostomatid fish, *Pollichthys mauli* (Poll), studied in this paper is one of the such cases.

Adult of *P. mauli* was reported from the seas of Atlantic, Eastern Pacific, Philippines (Grey, 1964), and Japan (Kawaguchi, 1971). The ecology of *P. mauli* is not well known. *P. mauli* may be a member of mesopelagic fishes (Grey, 1964: 122, 123). Grey (1964) described the metamorphic larvae, and Grey (1964) and Ahlstrom (1974) suggested that the fish have the similar development with a gonostomatid genus *Vinciguerria*. The postlarval stage, however, has not been known to date. In this study, the postlarvae of *P. mauli* are described and developmental stages are defined.

Materials and methods

The postlarvae and juveniles of *F. mauli* were sampled commonly off southern Japan (Kawaguchi, 1974; Ozawa, 1974, 1976). Those used in this study are from the collections mainly by two cruises (Fig. 1): one by T/V

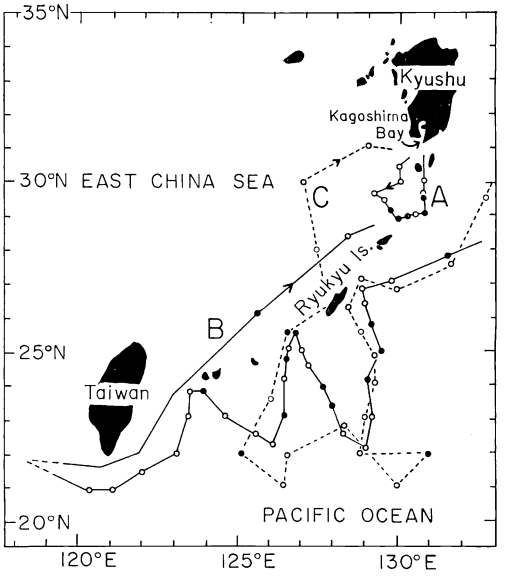

Fig. 1. Cruise tracks and sampling stations (circles) of *Pollichthys mauli* during 3 cruises. A: T/V Keiten maru (Nov. 1971). B: R/V Hakuhō maru (KH-73-2, Feb.~Mar. 1973). C: R/V Hakuhō maru (KH-73-5, Nov.~Dec. 1973). Black circles: positive stations and samples were used in this study. White circles: positive stations but samples were not studied.

Keiten maru, Kagoshima University, and the other by the Hakuhō maru. During the Keiten maru cruise (Nov. 1971), larva net with a mouth diameter of 1.6 m was used and mostly postlarvae of *P. mauli* were collected (37 specimens studied, whose standard length ranges from 3.1～18.0 mm). On the Hakuhō maru Cruise KH-73-2 (Feb.～Mar. 1973), two types of nets with a mouth diameter of 1.6 and 4.0 m were used and 60 specimens (9.2～30.8 mm SL) covering postlarvae to juveniles including metamorphic larvae of *P. mauli* were collected (for detailed explanation of the collections see Ozawa, 1973 and Ocean Research Institute, 1976). Nine specimens (11.8～48.0 mm SL) obtained by the another cruise of Hakuhō maru (KH-73-5, Nov.～Dec. 1973) were also used in this study. In addition to these, three grown-up individuals (38.4～59.0 mm SL) taken at Kagoshima Bay by bottom trawls of commercial ships in Oct. 1973 were examined. The specimens used in this study are deposited in the Laboratory of Fisheries Resources, Faculty of Fisheries, Kagoshima University.

After initial preservation in 10% formalin solution on board, the specimens were later transfered to 70% ethanol. They were measured with the ocular micrometer of a dissecting microscope. Morphometric measurements are defined as follows: Standard length, distance from tip of snout to tip of notochord or to posterior margin of hypural elements before or after the caudal fin is completed; Head length, distance from tip of snout to posterior margin of operculum or, before the posterior margin does not exceed the upper edge of operculum, to the edge; Head depth, vertical distance of head from posterior margin of lower jaw; Eye diameter, maximum length of pigmented region of eye; Body depth (maximum), vertical distance at base of pectoral fin; Snout to origin of anal fin, distance along midline of body from tip of snout to a vertical from origin of anal fin; Snout to origin of dorsal fin, distance along midline of body from tip of snout to a vertical from origin of dorsal fin.

To study the sequence of ossification of bones, the specimens were cleared with KOH and stained with Alizarin Red-S. Terms of bones follow those of Weitzman (1974). Symbols of photohpres are followed those of Grey (1964) (Fig. 2). For convenience, in the descriptive section, body lengths are given as size range of 1.0 mm. For example, "5- mm SL" refers to standard length between 5.0 and 5.9 mm.

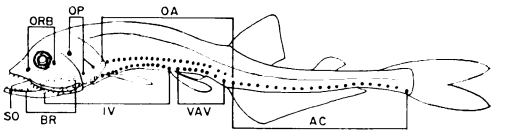

Fig. 2. Symbols of photophores in *Pollichthys mauli* used in the present paper.

Early life history

1. Development of external features

The prelarvae were absent in my samples and the smallest postlarvae collected were about 3 mm SL.

Like other gonostomatid genera such as *Vinciguerria* (Ahlstrom and Counts, 1958; Ozawa, 1973), *Diplophos* (Jespersen and Tåning, 1919), *Cyclothone* (Jespersen and Tåning, 1926; Sanzo, 1931), early postlarvae of *P. mauli* are slender and straight to the tip of notochord (Fig. 3A). Compared with the larvae of the genera mentioned above, those of *P. mauli* show the distinguishing characters: body except eye is completely devoid of pigment; anus is set very posteriorly, about 80% of SL, lying below about 34th myomere; eyes are oval, directed slightly anteriorly, having underlying choroid tissue. Head is small and slightly depressed; snout is upturned and short. Pectorals are pedunculated and fan-shaped. Median fin-folds are broard, narrowing at caudal peduncle. Myomeres are countable, about 44; 34 in abdominal, 10 in caudal part.

Between 3- and 6- mm SL, body proportions change significantly (Fig. 5). Snout to anus distance increases from 80 to 88% of SL (position of anus moves backward from 34th myomere to 39th or 40th up to 4- mm SL); head depth decreases from 62 to 42% of head length; eye diameter also decreases from 45 to 28% of head length. At 3.6 mm SL, the tip of notochord tends to be bent upward and hypurals are developing. Principal caudal rays begin to differentiate just after the completion of hypurals (6- mm SL), attaining definitive number (19) at 7- mm SL. Swimbladder is first recognized at 5- mm

SL just behind the middle of body. Dorsal fin-fold retreats posteriad. Anal and adipose fin bases appear at 6- mm SL. Snout becomes prominently pointed.

Development is progressive between 7- and 16- mm SL (Fig. 3B and C). Formation of fins is the most prominent. Following the caudal rays, dorsal fin rays are the second to differentiate at 7- mm SL and reach definitive number (10 or 11) at 13- mm SL. Anal fin base, situated very posteriorly of the body, remains narrow during postlarval stage and fin rays are going to differentiate beyond 12- mm SL; fin rays increase in number up to 17 until 16- mm SL. Ventral fins are first seen as buds at 10- mm SL below about 19th myomere and fin rays begin to differentiate at 16- mm SL. Caudal fin starts to be folked at 11- mm SL. Eyes tend to direct laterally beyond about 12- mm SL. Spleen is seen externally just above anus from 10- mm SL throughout postlarval stage.

Buds of photophores develop on the postlarvae larger than 16- mm SL (Fig. 3D). Initially the buds are small and indistinct. With growth of body, they become larger and clearer, showing the resemblance with the arrangement of adult photophores. Each of buds is formed as follows: series of BR, IV and VAV (including some anterior AC), and lower posterior OP are the first to be formed; posterior ORB and lower anterior OP are the next; anterior ORB and upper OP follow; OA series is late to develop, and eventually only anterior 4 or 5 buds are discernible in the fully developed larvae; buds of AC series, following directly VAV, are added posteriad, and interestingly, 3 or 4 buds before the last 4 ones never develop (after completion of metamorphosis this blank portion is proved to coincide with the poterior end of anal base which has moved anteriad). Insertion of ventral fin, origin of dorsal fin, and anus gradually advance during postlarval stage (Fig. 5), but their relative positions at the level of myomeres remain constant: ventral fin at 19th myomere (range 18th to 20th); origin of dorsal fin at 27th or 28th (range 26th to 29th); anus at 41st (range 39th to 43rd). Though anal base is still narrow, fin rays can be enumerated up to 24 in grown-up postlarvae. Ventral fin rays are definitive (7) at 20- mm SL. One to three pectoral rays begin to differentiate just before metamorphosis. Median fin-folds have disappeared at the beginning of metamorphic stage, but the fold between ventral fin and anus is retained throughout life. Body is completely devoid of pigmentation during postlarval stage.

Thus, the postlarvae in any stage have little resemblance with the adults (see also **Development of visceral organs**). The characters that attribute the postlarvae to the adult are buds of photophores and meristic counts such as dorsal rays (10 or 11 in the postlarvae and 10 to 12 in the adult), and number of myomeres of the postlarvae (45 to 48) corresponding to vertebral number of the adult (45 to 47).

Fully developed postlarvae suddenly change body form (Fig. 3E). In metamorphosing stage, only 4 individuals ranging from 17.2 to 18.1 mm SL were available to study. The anus and anal fin shift their position anteriad from about 87% of SL to about 55%, and the posterior end of anal base also advances, and as stated before, reaches the blank space of buds of OA photophores; this advance brings about a full complement of fin rays. Head deepens and lengthens; upper jaw lengthens; eye loses its semistalked condition and turns to be round; simultaneously choroid tissue below eye disappears; operculum entirely covers gill arches. Melanophores appear on the nape. Fin rays of pectoral, though yet pedunculate, apparently begin to differentiate from the upper side. Scales are recognizable just behind the head, and arrange like steppingstones. The sequence of scale formation could not be traced exactly because of deciduous nature.

The other prominent feature in metamorphosing stage is the pigmentation of buds of photophores. The lower 2 OP, the posterior 4 BR, the last IV and the anterior 5 VAV are pigmented at first. The pigmentation of each photophore group proceeds in the following sequence, though somewhat different according to individuals: 2 ORB are formed simultaneously; BR photophores are added anteriorly; in IV series, pigmentation occurs separately at 3 portions in the following sequence—first at the posteriormost to anteriorly, then at mid-ithmus portion and last in both directions from symphysis of cleithra—, and after these groups have been laid end to end, the remaining anteriormost ones are added anteriorly; VAV series is formed posteriad; in

AC series, pigmentation occurs separately at the intermediate portion and at the posteriormost, then proceeds to both directions at the former portion and anteriad at the latter; OA photophores are added posteriorly. The following photophores are never formed during metamorphosis: SO, 1 or 2 AC at the posterior end of anal base, and the posterior 12 to 15 OA among which 3 to 5 have already developed buds.

Thus, the postlarvae have entirely changed body form through metamorphosis, and the metamorphosed individuals basically resemble the adult form of mesopelagic inhabitants, *i. e.* juvenile stage starts (Fig. 3F). Anal fin has situated in its normal position and rays have a full complement (23 to 30). Anus, which was situated just in front of anal base during larval stage, is separated clearly from anal fin. Proportions of forebody have greatly changed, *e. g.* head length from 15 to 25% of SL, head depth from 50 to 60% of HL, and upper jaw from 53 to 75% of HL (Fig. 5). Eyes are completely

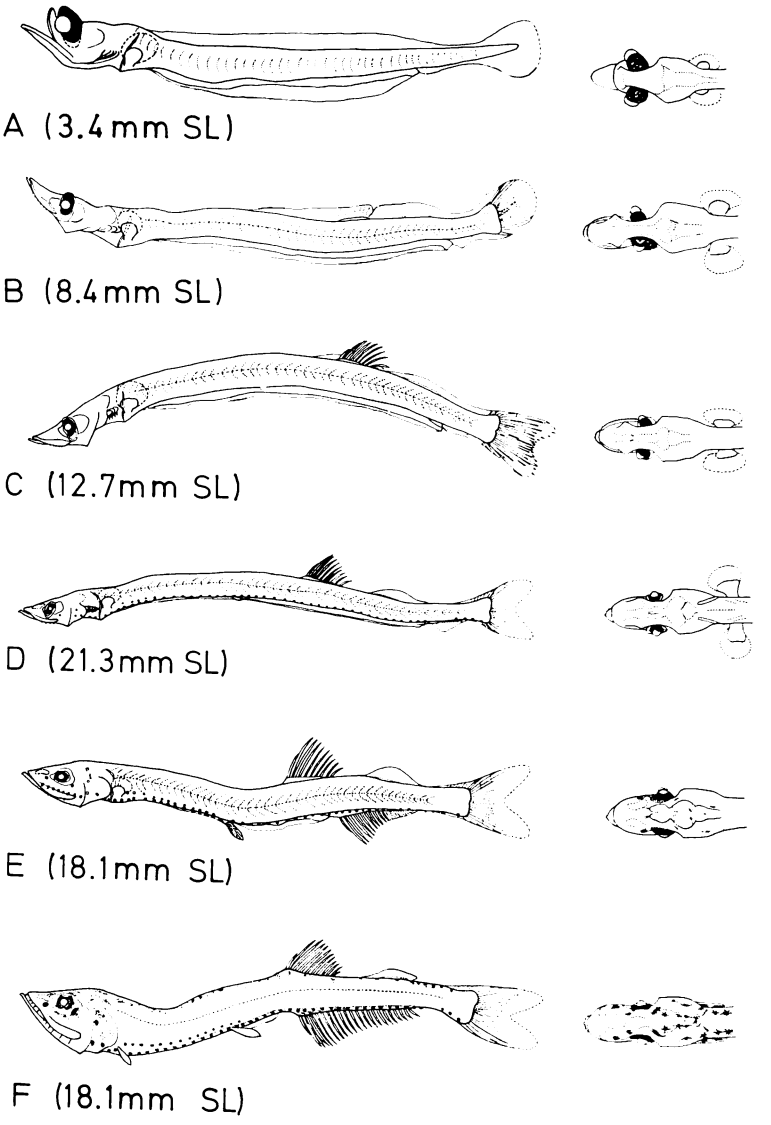

Fig. 3. Developmental stages of *Pollichthys mauli*. A: Early postlarva. B & C: Middle postlarva. D: Late postlarva. E: Metamorphic larva. F: Juvenile.

rounded. Pectoral fins have differentiated ultimately 7 or 8 rays and changed the axis to be aliform. Melanophores have been scattered on the operculum, around the orbit and the nape, along the both sides of the back posteriad to caudal fin base, and on the anterior base of anal fin. Alimentary tract has been integrated within the body. Nostril divided into two pores in the specimens larger than 18.5 mm SL. Gill rakers on the first arch, which were first observed on the larvae about 8 mm SL and increased in number with growth of body during postlarval stage, have attained the full complement (16 to 18) through metamorphosis (Fig. 4). The photophores which were not completed in metamorphosis gradually accomplish, first as buds, then as pigmented ones: SO at 19- mm SL; AC above the posterior end of anal base at 20- mm SL (AC photophores, 19 to 22 in a full complement); the posterior OA at 25- mm SL (OA photophores, 22 to 24 in a full complement).

The external features of juvenile are mostly maintained through to the adult stage; most prominently, head and body along the back become dark (see Grey, 1964, for the precise description of adult). It is the most important event that the gonads, which are discernible in early juvenile and remain quiescent, begin to mature beyond 29- mm SL.

2. Changes of body proportions (Fig. 5)

Body proportions do not change significantly before metamorphosis, though a few parts vary in the early stage between 3- and 6- mm SL: snout to anus distance increases from 80 to 88% of SL; head depth decreases from 62 to 42% of head length; eye diameter decreases from 45 to 28% of HL. In the postlarvae larger than 7- mm SL each of body parts either remains constant or changes gradually, and even the fully grown-up larvae cannot have any resemblance to the juveniles.

Metamorphosis suddenly and significantly alters the body form of postlarvae. Now, it seems worthy to note in detail the changes of body proportion before and after metamorphosis.

Distance from snout to anus: Being discernible a little advance in late larval stage, anus situates always very far back of the body; snout to anus distance occupies 85 to 90% of SL for larvae larger than 7- mm SL. During metamorphosis anus advances abruptly; snout to anus distance has decreased to about 55% of SL. (Snout to dorsal distance traces the same trend with snout to anus distance before and after metamorphosis. Snout to ventral distance, not shown in Fig. 5, also decreases during metamorphosis.)

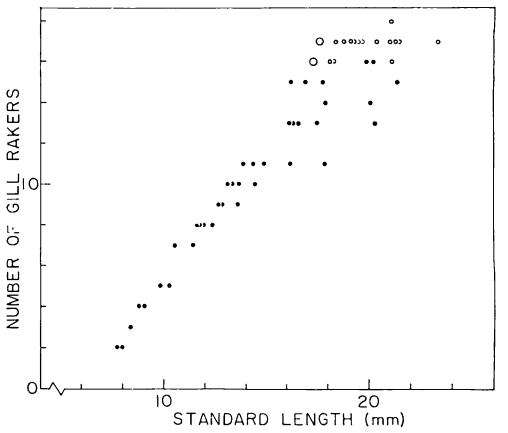

Fig. 4. Development of gill rakers on the first gill arch of *Pollichthys mauli*. Black circle: Postlarval stage. Large white circle: Metamorphic stage. Small white circle: Juvenile stage.

Length of anal fin base: Anal base, located posteriorly of the body, is very short (8% of SL) during postlarval stage and broadens prominently (28% of SL) in metamorphosis. In both postlarval and juvenile stages, slight increase of the base can be appreciated.

Head length: Head length decreases from about 20 to about 15% of SL throughout postlarval stage, then on the contrary it has increased its proportion to about 25% of SL after metamorphosis. (The change of body depth in proportion to SL is similar with that of head length. Head depth and upper jaw length in proportion to head length increase more clearly during metamorphosis.)

Diameter of eye: Eye diameter decreases gradually during larval stage and are about 20% of head length before metamorphosis. Though the proportional difference between the largest postlarvae and the smallest juvenile is very small, the inflection point can be also put at metamorphosis. Eye diameter, having a little decreased through metamorphosis, tends to increase in later stage.

The changes of body form during metamorphosis are summarized as follows: the rear parts of body move forward, while the fore parts elongate and/or deepen. Juveniles thus appeared have a close resemblance to adults who are inhabitants of mesopelagic zone, and develop uniformly.

Thus, the changes of body proportions in life history of *P. mauli* indicate that development is quite different between larval stage and juvenile stage and that this gap is bridged by marked metamorphosis. It is shown in Fig. 5 that all of the metamorphosing individuals are smaller than the largest postlarvae, therefore any increase in length does not happen during metamorphosis. However, based on these data it is difficult to give evidence on the assumption of an actual decrease (shrinking) in length.

3. Development of visceral organs

The visceral organs in 3 developmental stages are shown in Fig. 6.

During postlarval stage, the visceral organs are thin and elongate (Fig. 6A and A′), reflecting the slender body of larva. It is prominent that ovalshaped spleen, linked with pancreas by very thin tube, is situated very posteriorly to above the anus. Digestive tract is straight, slender and long. Before the mid-length of the tract, stomach has become differentiated. Just behind stomach, a pyloric caecum is recognized at 10- mm SL, two at 11- mm SL and three (definitive number) at 14- mm SL. Liver attachs to the lower part of oesophagus along its almost entire length. Pancreas straightens backwards from behind gall bladder, and continues to spleen. At the middle part of kidney, "bulbous terminal segment" (Marshall, 1960: p. 15) is conspicuous. These features are retained throughout postlarval stage.

During metamorphosis, visceral organs begin to alter in shape completely (Fig. 6B and B′). Almost all of them become thick and short. Pancreas is shrinking rapidly and draws spleen to locate behind stomach. Swimbladder is not pigmented itself but is covered by pigmented membrane which is easily separable.

Visceral organs of metamorphosed individuals are entirely different in shape from those of postlarvae (Fig. 6C and C′). Oesophagus and stomach have enlarged and are black-pigmented. Pyloric portion of intestine has turned to the right side and curved upwards. Pancreas has completely reduced around pyloric portion. Bulbous terminal segment of kidney has enlarged much conspicuously.

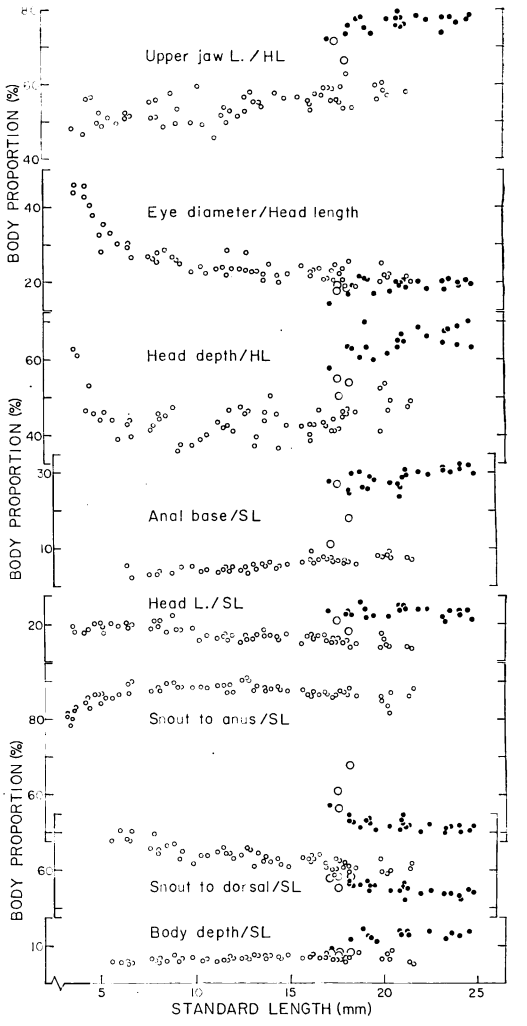

Fig. 5. Changes of body proportions through developmental stages of *Pollichthys mauli*. Small white circle: Postlarval stage. Large white circle: Metamorphic stage. Black circle: Juvenile stage. In uppermost Figure, SL Showld be read HL.

Gonads are distinguishable in early juvenile stage and begin to mature beyond 29- mm SL.

4. Sequence of ossification of bones

To study the ossification sequence of bones, specimens mostly at every 1 mm in length were cleared with KOH and stained with Alizarin

Red-S. The length of stained individuals extends from 3.1 to 24.0 mm SL. In metamorphosis only one individual (17.5 mm SL) was studied. The sequence of initial ossification of bony elements is shown in Fig. 7.

Through the life, the sequence of ossification does not proceed uniformly. In the early postlarval stage between 3- and 6- mm SL, form very few elements such as maxillary, dentary, and articular of mandibular arch. During the middle postlarval stage between 7- and 16- mm SL, ossification of many elements begins on suspensorium, opercular bones, hyoid arch, and caudal skeletons. During the late postlarval stage with buds of photophores, elements of ossification are moderate; vertebral column is the representative in this stage. Metamorphosis brings about active ossification mainly of cranial elements and, moreover exchanges larval features for adult ones (see below). At the beginning of juvenile stage, many elements of cranium and shoulder girdle form, and almost all of the bony elements complete the initial ossification.

Fig. 7 shows the start and end of ossification of the numerical bony elements. The further descriptions of these elements are given as follows: branchiostegal rays, whose definite number is 12 or 13, form in an anteriad sequence between 12- and 19- mm SL of postlarvae; in hypural bones, hypurals 1 and 2 ossify at 10- mm SL and those 3 to 7 at 12- mm SL; vertebral centra including urostyle begin to ossify at the middle portion of body and form in both direction, the anteriormost few centra being the last to ossify; in haemal spines, the last one forms early at 14- mm SL, the rest ossify suddenly during metamorphosis; in neural spines, the last one forms initially and the others follow in an anteriad sequence.

Metamorphosis brings about not only ossification of many elements mentioned above, but also exchange of larval features for adult ones. The latter happens most typically to jaw bones and their dentition (Fig. 8).

Teeth on maxillary appear early at 3.5 mm SL and, during larval stage increase in number regularly with growth of body. The most advanced larvae have 21 to 23 teeth. Premaxillary teeth form much later around 14- mm SL, and 3 to 6 are countable in the largest postlarvae. Mandibular teeth form in two rows. On the outer side of anterior part of dentary, laterally directed teeth are observed at 4- mm SL and gradually added up to 8 or 9 before metamorphosis. The inner teeth on dentary form late around 12- mm SL and increase in number up to about 6 in the largest postlarvae; they are confined to the anterior part of dentary before metamorphosis.

During metamorphosis each bony element of jaw extends posteriad and becomes rigid; especial-

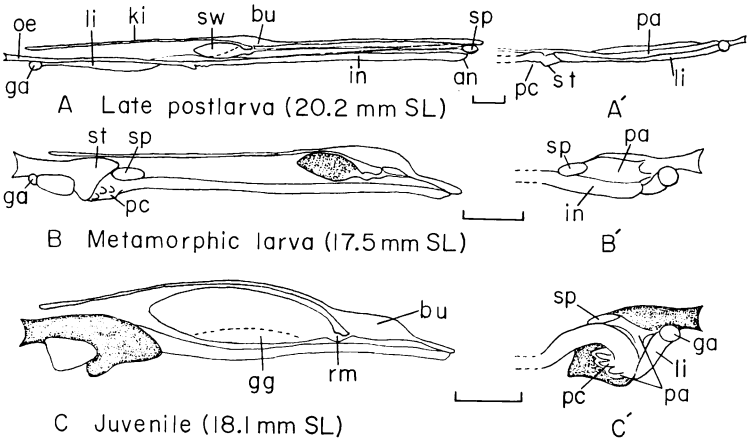

Fig. 6. Typical morphology of visceral organs in 3 developmental stages of *Pollichthys mauli*. A to C: Left side view. A′ to C′: Right side view of the anterior portion. Scales indicate 1 mm. Abbreviations: *an*, anus; *bu*, bulbous terminal segment of kidney; *ga*, gall bladder; *gg*, gas gland; *in*, intestine; *ki*, kidney; *li*, liver; *oe*, oesophagus; *pa*, pancreas; *pc*, pyloric caeca; *rm*, rete mirable; *sp*, spleen; *st*, stomach; *sw*, swimbladder.

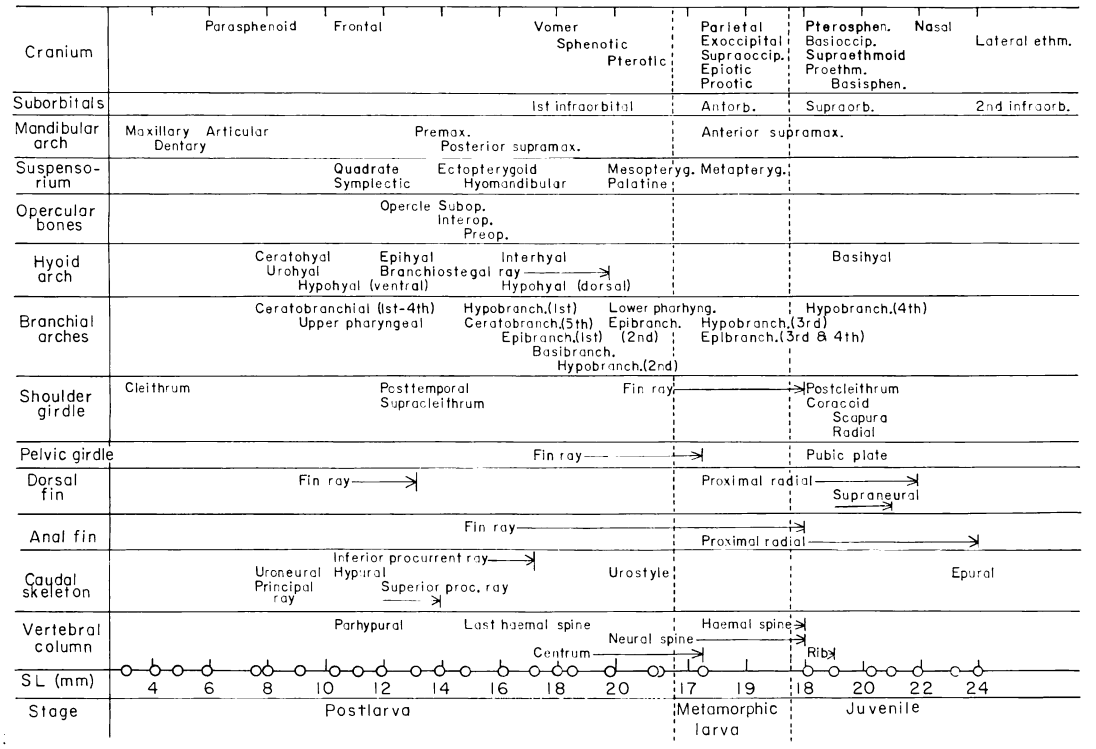

Fig. 7. Sequence of ossification of *Pollichthys mauli*. Tip of bony element indicates the length of specimen at which the initial ossification of each element was observed. Vertical lines with arrow indicate the length at which the full complements are first ossified. Circles on the horizontal line (SL) show the length of specimens examined.

ly premaxillary slides under the anterior third of maxillary. Simultaneously, dentition markedly changes. Jaw bones and their dentition of metamorphosed individuals are observed as follows. Although jaw teeth in postlarval stage arose directly from attached bones, they are articulated and movable inwards in juvenile stage. The number of jaw teeth during juvenile to adult stages could not be counted correctly, because the teeth are apt to be easily shed; therefore the number shown below may be underestimated. Teeth of premaxillary are straight, needle-like, unevenly spaced, and irregular in size. The variation of number of the teeth during metamorphosis is uncertain, *viz.* may have remained equall or increased rapidly; only 6 in the youngest juvenile (17.1 mm SL) and 14 to 16 in a little developed ones (18- mm SL). In the older stage, premaxillary teeth do not increase in number (about 16 with a range of 12 to 22). The larval maxillary teeth enumerated 21 to 23 in the most advanced larvae seem to be absorbed or shed partially or entirely during metamorphosis; only 6 in the youngest juvenile (17.1 mm SL) and about 16 ranging 8 to 24 in the juvenile of 18- and 19- mm SL. Maxillary teeth apparently increase with body growth in the later stage; the most grown-up specimen, 59.0 mm SL, has 42 teeth. Along the entire length of maxillary, small and large teeth alternate, and they are straight, needle-like and approximately, evenly spaced.

Dentary teeth of the inner row increase in number prominently during metamorphosis or at the beginning of juvenile; about 6 in the largest postlarvae, 5 in the youngest juvenile (17.1 mm SL) and about 16 ranging 11 to 20 in the juvenile of 18- and 19- mm SL. Between 18- and 26- mm SL, the number of the inner teeth increases from 16 to about 26, and in the later stage remains constant. Straight and needle-like inner teeth are unequal in size, and rather widely spaced

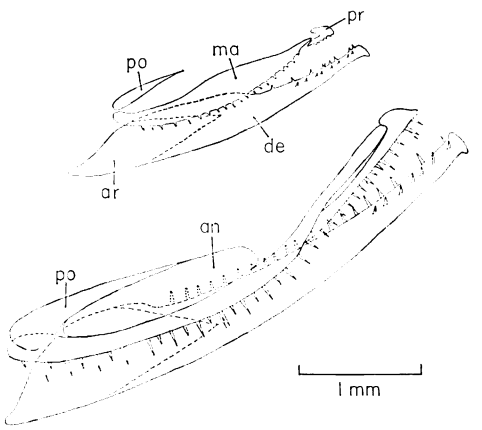

Fig. 8. Right side view of the jaws of *Pollichthys mauli*. Upper: Postlarva of 19.8 mm SL. Lower: Juvenile of 18.7 mm SL. Abbreviations: *an*, anterior supramaxillary; *ar*, articular; *de*, dentary; *ma*, maxillary; *po*, posterior supramaxillary; *pr*, premaxillary.

anteriorly and closely spaced posteriorly. The teeth of the outer row along the anterior part of dentary do not change both in number and arrangement through metamorphosis. They are sharply pointed, curved upwards, and not evenly spaced. In the later stage of juvenile, the teeth tend to be added irregularly around the old ones.

General remarks and summary

According to Ahlstrom (1974), life histories of gonostomatid have been published for 12 of the 20 genera. Genus *Pollichthys* was not included in these 12 genera. In the western North Pacific, the larvae of *P. mauli* occur rather regularly and commonly (see Ozawa, 1974, 1976). It seems therefore that the lack of metamorphic specimens has prevented the correct identification of these larvae up to date.

Ahlstrom (1974) compared the metamorphic patterns of gonostomatid genera and separated them into 3 groups. *P. mauli*, whose larval stage was not known at that time, is included into a group of genera in which most or all ventral photophores are laid down initially during a stage with buds of photophores and which have all photophores individually separated (*Vinciguerria*, *Cyclothone*, *Ichthyococcus*, etc.). This study supports well his opinion; the early life history of *P. mauli* is basically similar to those of *Vinciguerria* (Sanzo, 1931; Ahlstrom and Counts, 1958; Ozawa, 1973), *Cyclothone* (Jespersen and Tåning, 1926; Sanzo, 1931), *Ichthyococcus* (Jespersen and Tåning, 1926; Sanzo, 1931), and *Diplophos* (Jespersen and Tåning, 1919). And, most of the larval characters of *P. mauli* summarized below are shared with the above genera.

The larvae of *P. mauli* develop their own characters, seemingly having no concerns with those of adult. These characters may be (1) slender body, (2) lack of body pigmentation, (3) eyes which are oval (3-i), semistalked (3-ii), anteriorly directed (3-iii) and with underlying choroid tissue (3-iv), (4) small head, (5) backward disposition of anus and anal fin, (6) undeveloped visceral organs, particularly stomach and pyloric caeca, (7) displacement of spleen above anus, and (8) delay of initial ossification of bones. As to (8), I present in Table 1 the comparison of initial length in which some bony elements ossify during the postlarval stage; in the larvae larger than 8 mm SL, ossification retards apparently in *P. mauli* than in *V. nimbaria*. And it is known that *V. nimbaria*, in its turn, delays the ossification than a gonostomatid *Maurolicus muelleri* (Ozawa, 1973: tab. 2); the latter develops directly (Okiyama, 1971).

These larval characters develop not only in the related genera of *Pollichthys* but also fish of other widely different many taxa. Taking account of some difference in degree, most of the 8 characters of larval *P. mauli* are shared with members of the related genera, and two (3-iii and 3-iv) are exceptions; the larval character (3-iii) is seen in a gonostomatid fish *Maurolicus muelleri* (Okiyama, 1971) and (3-iv) not in gonostomatid fishes but in members of other families such as Myctophidae (Moser and Ahlstrom, 1970), Scopelosauridae (Ozawa, unpublished).

It seems that *P. mauli* develops the larval characters more typically than the related genus *Vinciguerria*, when comparing for example, the pigmentation, disposition of anus and anal fin, and initial ossification of bones (as to the larval characters of *Vinciguerria*, see Ahlstrom and Counts, 1958 and Ozawa, 1973). The development of larval characters may be concerned with the extent of metamorphosis, *i. e.* exchange of the larval characters for the adult ones. To examine this supposition, the difference of body propor-

Table 1. Standard length at initial ossification of some bones (stained with alizarin) during the postlarval stage. *Vinciguerria nimbaria* (after Ozawa, 1973: tab. 2) and *Pollichthys mauli* are compared. The length at which the full complements are first ossified is shown in parenthesis.
* Ossification retards untill the beginning of juvenile stage.

Name of bone	Length at initial ossification, mm	
	V. nimbraia	*P. mauli*
Maxillary	3.5	3.1
Cleithrum	3.5	3.1
Dentary	5.0	4.1
Caudal fin ray	5.0 (6.5)	7.6
Uroneural	6.5	7.6
Paraspenoid	6.5	5.9
Gill raker	6.5 (15.0)	10.3 (—)*
Dorsal fin ray	6.5 (14.5)	9.1 (13.1)
Anal fin ray	6.5 (10.3)	14.8 (—)
Ceratohyal	7.3	7.6
Frontal	8.7	10.3
Supracleithrum	8.7	11.8
Branchiostegal ray	9.4 (14.5)	11.8 (19.8)
Posttemporal	10.3	11.8
Premaxillary	11.4	13.0
Supramaxillary	11.4	14.0
Vertebrae	11.4 (13.5)	17.2 (21.3)
Ventral fin ray	14.4	17.2 (18.0)

Table 2. Change of body proportions (%) before and after metamorphosis in 3 species of gonostomatid fishes. Sources of data: *Vinciguerria lucetia*, from Ahlstrom and Counts (1958: tab. 5); *V. nimbaria*, from Ozawa (1973: fig. 5)

	V. lucetia			*V. nimbaria*			*P. mauli*		
	before	after	difference	before	after	difference	before	after	difference
Snout to anus/SL	67	64	−3	72	67	−5	87	55	−32
Head length/SL	21	26	+5	20	28	+8	15	25	+10
Body depth/SL	10	16	+6	10	17	+7	7	12	+ 5
Head depth/HL	—	—	—	55	60	+5	50	60	+10

tion before and after metamorphosis is compared in Table 2 among *Vinciguerria* and *Pollichthys*. Proportional differences through metamorphosis are similar between 2 species of *Vinciguerria*, on the other hand, they, except for body depth, are higher in *Pollichthys* than in *Vinciguerria*.

As mentioned above, *P. mauli* shows the close resemblance of development with *Vinciguerria* spp. in the postlarval stage. Following the definition of developmental stages in *V. nimbaria* (Ozawa, 1973), the developmental sequence in the early life history of *P. mauli* is defined and summarized as follows.

1. White-bait form stage: Larvae are slender and devoid of pigmentation except eye; eyes are oval and possess underlying choroid tissue; anus and anal fin are situated very far back of the body; and visceral organs, among which stomach and pyloric caeca are small and spleen is set above anus, are transparent. Metamorphosis alters the white-bait into adult form.

1 a. Prelarval stage: Larvae with yolk, not included in this study.

1 b. Postlarval stage (3-～21- mm SL): Larvae develop typical white-bait form. This stage can be further subdivided into three stages; **1 ba** early postlarval (3-～6- mm SL), in which eyes are directed slightly forward, some body parts rapidly change the proportions, and bony

elements to ossify are poor; **1 bb** middle postlarval (7-~15- mm SL), in which body proportions are maintained constantly, bones ossify abundantly, eyes tend to direct laterally; and **1 bc** late postlarval (16-~21- mm SL), in which buds of photophores appear typically, features of body follow those of the former stage, and elements to ossify are medium.

1 c. Metamorphic stage (17-~18- mm SL): Exchange of white-bait form for adult one occurs strikingly on the whole of body; buds of photophores begin to be pigmented; ossification as well as transformation of bony elements mainly of head part is active. There is little increase in length. Specimens collected are very rare.

2. Adult form stage: Metamorphosed individuals show the features of mesopelagic inhabitants; body, especially head part, has elongated and/or deepened; pigments have appeared on the head and along the back; anus and anal fin are set in much advanced, normal position; eyes are rounded and lost the choroid tissue; visceral organs are changed markedly, *i. e.* stomach and oesophagus are large and black-pigmented, pyloric caeca have increased in size, and pancreas has shortened. These features are conservative henceforth.

2 a. Juvenile stage (17-~28- mm SL): Stage from the end of metamorphosis to the beginning of maturation. Through metamorphosis, the full complement of fin rays has been formed. At the beginning of the stage many elements begin to ossify, and the sequence of initial ossification of almost all bones has completed. Photophores not formed during metamorphosis are added until 25- mm SL.

2 b. Adult stage (29- mm SL~): The juvenile features are conservative, but gonads begin to mature.

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日本南方外洋域におけるヨコエソ科魚類ヨウジエソの初期生活史

小沢　貴和

ヨコエソ科ヨウジエソ (*Pollichthys mauli*) の後期仔魚を初めて記載し，初期生活史を体形，内臓諸器官および化骨過程の形態面から研究した．生活史の体形はシラス形と成形魚に明瞭に2分され，それらの間に著しい変態が介在する．シラス形仔魚の特徴は，細長い体，体色素の欠除，楕円形で下方に choroid tissue を付属する眼，肛門および臀鰭の後位などである．発光器の原器が仔魚の後期に形成される．成魚形は中層性魚類の特徴を示す．即ち，発光器が顕著に発達し，体前部は相対的に長くあるいは幅広く，頭部と体背側に黒色素が出現し，眼は円形で choroid tissue を消失し，肛門および臀鰭は前位して正常な位置を占める．これら2形の発育期は，それぞれの発育期での形態発達の特徴によって次のように細分される．シラス形期は，前期仔魚期(本研究には含まれていない)，後期仔魚期(この期はさらに早期，中期および末期に区分される)および変態期に，成魚形期は稚魚期および成魚期に，細分される．

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