飼育したブリの幼期における成長と形態変化

誌名	日本水産學會誌
ISSN	00215392
著者	福原, 修 中川, 亨 福永, 辰広
巻/号	52巻12号
掲載ページ	p. 2091-2098
発行年月	1986年12月

農林水産省 農林水産技術会議事務局筑波産学連携支援センター
Tsukuba Business-Academia Cooperation Support Center, Agriculture, Forestry and Fisheries Research Council Secretariat

Bulletin of the Japanese Society of Scientific Fisheries 52(12), 2091–2098 (1986)

Larval and Juvenile Development of Yellowtail Reared in the Laboratoty

Osamu Fukuhara,*1 Tohru Nakagawa,*2 and Tatsuhiro Fukunaga*2

(Accepted May 22, 1986)

Morphological development of early life stages in laboratory-reared yellowtail was observed and reported with special reference to fin development, pigmentation and squamation. The specimens were obtained serially by experimental rearing from eggs to larvae, measuring 3.5 mm in standard length (SL) at hatching and to young (about 70 mm SL). Larval development and squamation were illustrated. The transition from post-larvae to juveniles occurred between 9.85 to 13.5 mm SL. Squamation began in larvae 22.1 mm SL and was completed when the larvae attained 40.2 mm SL. Larval growth during initial 40 days was expressed by the equation $SL=3.27e^{0.048x}$, where SL=standard length, and X=days after hatching. Some implications in morphological development of external and internal characters was discussed for better understanding the early life stages of *Seriola quinqueradiata*.

Yellowtail *Seriola quinqueradiata* has been recognized for a long time as the most important and prevalent species in Japan for intensive pen and cage aquaculture. Recently, experimentation with artificial rearing has been conducted to provide fingerlings for aquacultural purposes and restocking. Despite their common occurrence, little is known about development in early life stages. Embryonic and larval development were described by Uchida *et al.*,[1] Mitani[2] and Harada[3] for wild-caught specimens. Histological studies on initial feeding of larvae and development of digestive organs were reported by Umeda and Ochiai.[4-5]

Serial observations are needed to provide more detailed information on early life history and better utilization of raised fish. This paper deals with the descriptions of morphological characters with special reference to fin development, pigmentation and squamation to understand the developmental sequence of early life stages in yellowtail by using a series of specimens reared under laboratory conditions.

Materials and Methods

Larval Rearing

The rearing experiment was conducted at Yashima in Kagawa Prefecture beginning on April 29, 1982. Artificially fertilized eggs were transferred from Kochi Prefecture by truck, taking about 10 h. Newly hatched larvae then were maintained in a concrete tank with a water capacity of 27 m^3 and at a density of about 10,000 larvae/m^3. Larvae were fed, in succession, rotifers, *Artemia*, wild plankters and minced meat. Details of feeding were described by Mizuta.[6] *Chlorella* was added to the rearing tank at a density of 40–50 cells/m*l*. Standing water was employed during the first 40 days, then a "flow through" system was used. Dead larvae and deposits on the bottom were removed by syphoning every morning. Water temperature ranged from 19.6° to 22.1°C during the course of the experiment.

Preservation and Observation of Specimens

Specimens were collected from rearing tanks and preserved in formalin solution for further observations. Alizarin Red S was used for inspecting fin development and squamation. The methods of preserving specimens and measuring body dimensions were identical to those of Fukuhara.[7]

Results

General Morphology

The fertilized eggs were spherical, ranging from

*1 Nansei Regional Fisheries Research Laboratory, Ohno, Saeki Hiroshima 739-04, Japan (福原 修: 南西海区水産研究所).

*2 Japan Farming Fisheries Association, Higashi, Yashima, Takamatsu 761-01, Japan (中川 亨, 福永辰広: 日本栽培漁業協会屋島事業場),

1.08 to 1.18 mm in diameter (mean=1.15 mm, n=50). The diameter of eggs were slightly smaller in our trials than those of 1.19–1.27 mm with averaging 1.25 described by Uchida *et al.*[1] Newly hatched larvae had a sizable yolk sac with an anteriorly located oil globule (Fig. 1A), averaging 3.37 mm in standard length (SL, n=16). Subsequent increments of larval length are shown in Fig. 6. The mouth was open in 2 day old larvae, with a mean of 3.9 mm SL (Fig. 1C). The yolk sac was present until 3 days after hatching.

The cartilaginous hypural elements began to differentiate when the larvae attained 6.1 mm SL. No specimens had formed hypural elements by day 10. The hypural elements were evident in 20 out of 35 larvae by day 15, and in all 56 specimens by day 18.

The notochord flexion occurred in larvae as small as 6.0 mm SL. While there was no occurrence in 10 day old larvae, notochord flexion was observed in 18 out of 35 larvae by day 15 and in all larvae by day 18.

The teeth first appeared in the upper jaw of larvae measuring 4.6 mm SL, and on the both jaws after larvae reached 6.1 mm SL. The nostril was single during much of the larval stage. Separated nostrils appeared on 4 larvae of 30 specimens (7.5 to 7.75 mm SL) by day 20. The nostrils were separated in all 30-day old specimens. The preoperculum spines elongated characteristically after notochord flexion (Fig. 1 F–H).

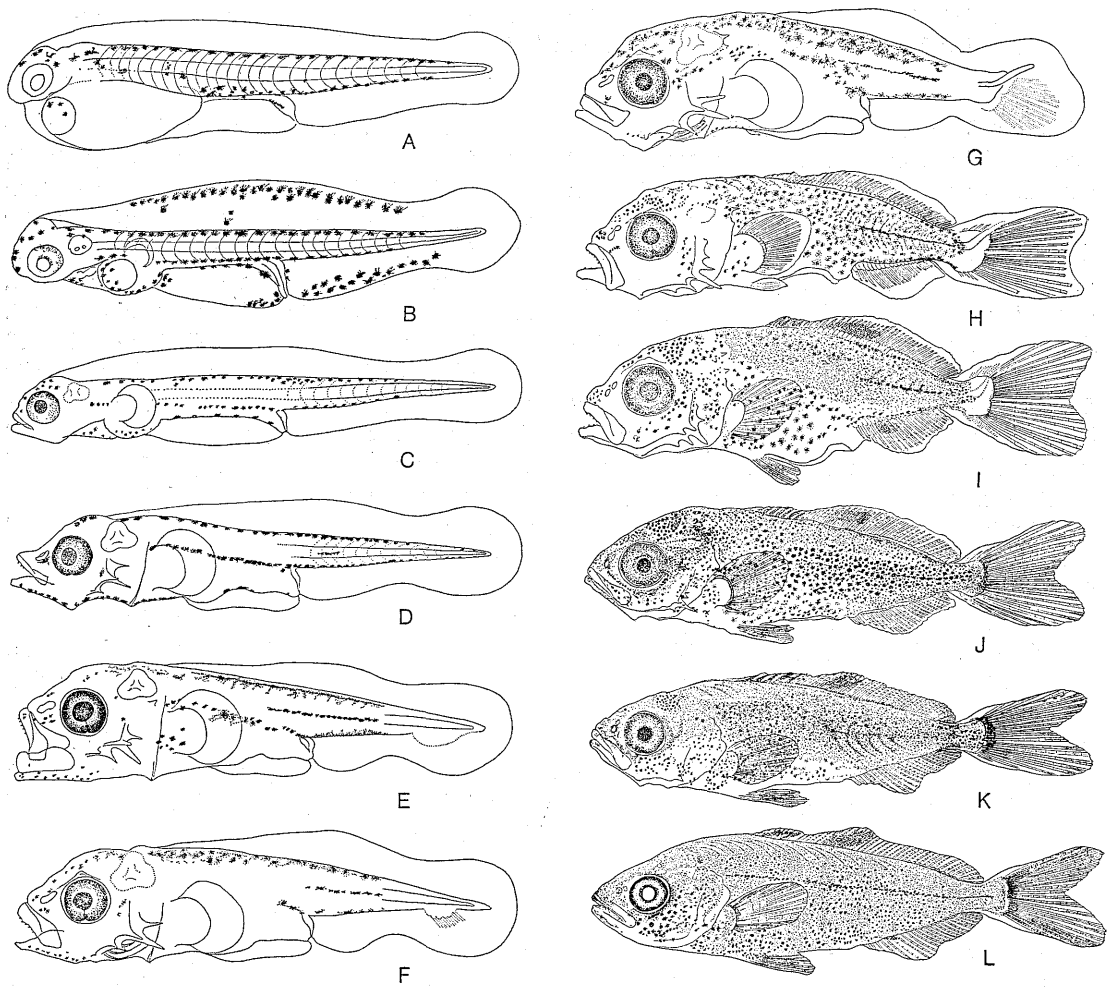

Fig. 1. Developmental stages of *Seriola quinqueradiata* reared in the laboratory. A. 3.5 mm SL, newly hatched larva; B. 3.7 mm SL, 1 day old; C. 4.1 mm SL, 2 days old; D. 4.6 mm SL, 5 days old; E. 5.9 mm SL, 10 days old; F. 6.4 mm SL, 15 days old; G. 7.0 mm SL, 18 days old; 8.9 mm SL, 25 days old; I. 12.2 mm SL, 27 days old; J. 19.3 mm SL, 30 days old; K. 21.0 mm SL, 34 days old; L. 25.8 mm SL, 40 days old.

Fin Development

Newly hatched larvae had a prominent larval fin-fold. Fan-shaped pectoral fins without rays developed 16 to 21 h after hatching at about 21°C (Fig. 1B). The primordial fin-fold formed from the occiput during larval stages (Fig. 1A–C), and gradually moved posteriorly during post-larval stages (Fig. 1D–F).

The marginal shape of the fin-fold changed markedly after notochord flexion and formation of hypural elements (Fig. 1F). The hind margin of the caudal fin also changed markedly in shape during notochord flexion: rounded until 7.6 mm SL, truncated from 6.8 mm to 7.8 mm SL and emarginated from 7.0 mm to 20.2 mm SL. Newly transformed juveniles were characterized by the emargination of the caudal fin. The ventral fin buds appeared early in 15 day old larvae as small as 5.9 mm SL. Rays first appeared in fins in the following sequence: caudal, anal, dorsal, pectoral and ventral fins. The full complement of rays in all fins as present in larvae ranging in size from 9.85 mm SL, 12.4 mm in total length (TL) to 13.5 mm SL (17.0 mm TL). Therefore, morphological transformation from larva to juvenile had been completed for laboratory-reared specimens from 9.85 to 13.5 mm SL. Segmentation of fin rays first occurred in the caudal fin at 6.25 mm SL, subsequently in the pectoral fin at 6.6 mm SL, ventral fin at 6.9 mm SL, anal fin at 7.8 mm SL and dorsal fin at 10 mm SL. The completion of segmentation in the fin was achieved at 7.8 mm SL in the caudal, 10.0 mm SL in the anal, 11.9 mm SL in the dorsal, 12.6 mm SL in the ventral and 16.7 mm SL in the pectoral.

Concerning the branching of soft-ray in each fin, the appearance was first observed at 8.3 mm SL in the caudal, 14.9 mm SL in the ventral, 17.0 mm SL in the pectoral, 20.0 mm SL in the anal and 24.1 mm SL in the dorsal fins. The full complement was observed at 17.0 mm, 16.2 mm, 36.0 mm, 36.1 mm and 46.0 mm SL, respectively (Figs. 2, 3).

Pigmentation

Newly hatched larvae had numerous melanophores in a dorso- and ventro-lateral row on each side of the body. A few melanophores could be discerned in the cephalic region, on the oil globule and around the snout (Fig. 1A). Between 12 and 24 h after larvae hatched, melanophores which quickly disappeared after preservation, were added along the dorso- and ventro-margin of the fin-fold, and near the oil globule (Fig. 1B). No marked change of pigment pattern was found until fish attained 6.4 mm SL (Fig. 1 C-F). Melanophores appeared gradually on the lateral surface of the body (Fig. 1G), and were distributed heavily on the body surface except for the cheek, thoracic and operculum (Fig. 1H). A patch of melano-

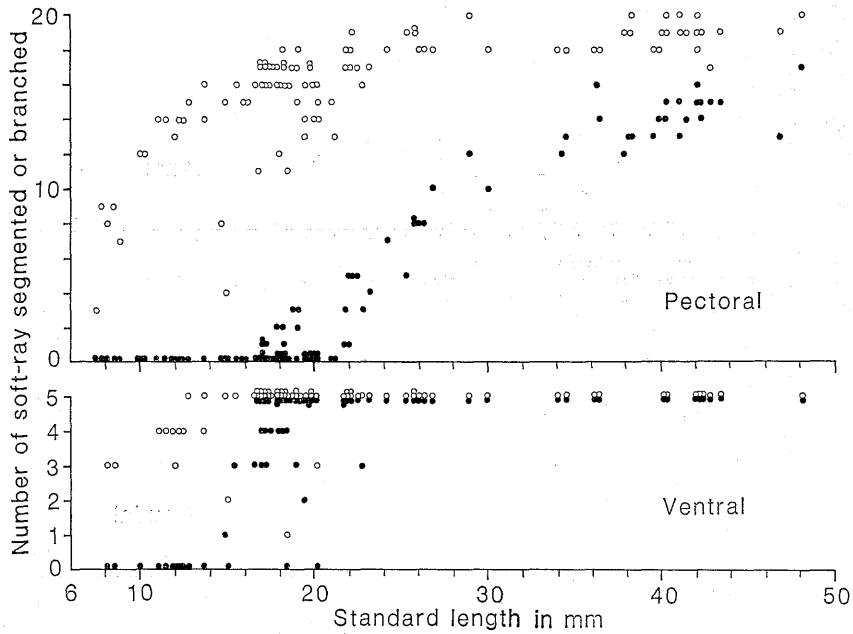

Fig. 2. The segmentation (open circles) and branching (closed circles) of soft-ray in the paired fins.

phores appeared in the fin ray portions of dorsal and anal fins (Fig. 1I, J). As development continued, melanophores intensified on the body surface, more solid on the dorsal half than ventral surface, and increased on the section of procurrent rays and base of the caudal fin (Fig. 1K, L). In the larvae of about 26 mm SL the bands of melanophores were clearly identifiable (Fig. 1L).

Scale Formation

The sequence of scale formation is given diagrammatically in Fig. 4. Developmental stages A–F were designated by the extent of scale coverage on the body surface. The developmental stages were characterized as follows:

A, few scales first appeared midlaterally on the caudal peduncle.

B, the squamated area extended anteriorly and posteriorly. Five to six scale rows at the posterior and nine to eleven at the anterior ends were discerned. A small patch of scales appeared on both sides of the caudal peduncle.

C, squamated area extended more rapidly toward the head, forming 13 to 14 scale rows in the caudal portion of the squamated area. A small patch of scales was observed at the base of anterior end of the anal fin.

D, the caudal section was fully squamated, and the anterior end reached the operculum. Only the nape and breast regions were devoid of scales.

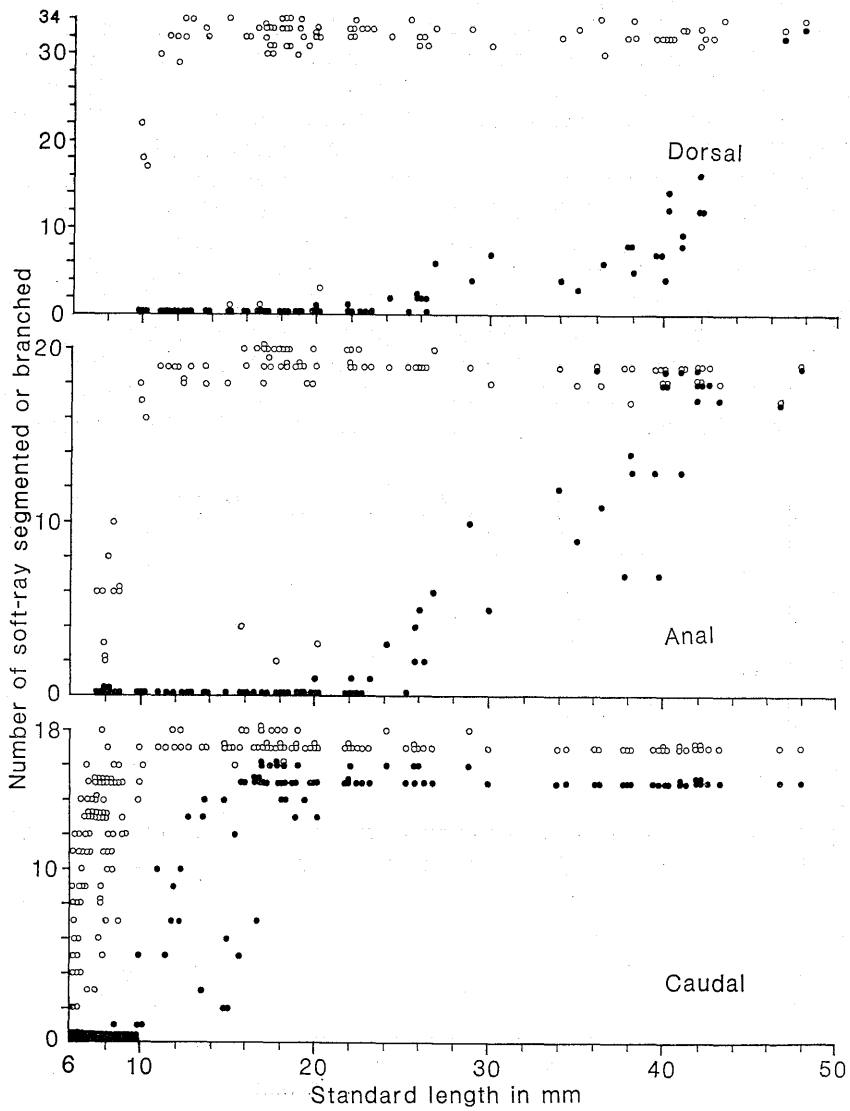

Fig. 3. The segmentation (open circles) and branching (closed circles) of soft-ray in the unpaired fins.

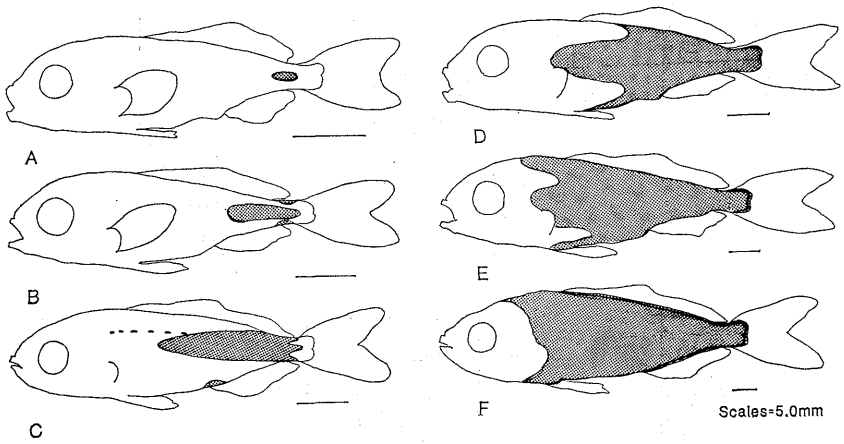

Fig. 4. Semidiagrammatic illustration of the sequence of squamation.

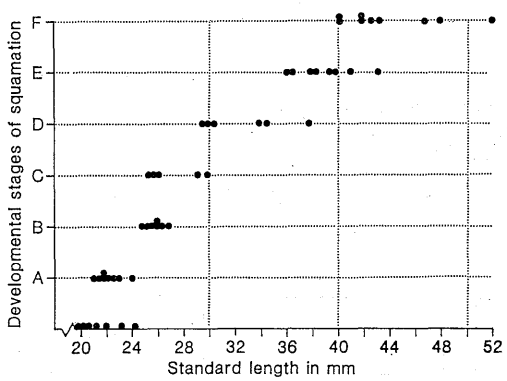

Fig. 5. Relationship between squamation and larval length for yellowtail. Refer to Fig. 4 for the developmental stages of squamation.

E, areas without scales narrowed. Only the portion around the nape and the pectoral fin base were lacking scales.
F, full squamated.

The relationship between developmental stage of squamation and larval size is depicted in Fig. 5. The largest larva without scales was 24.1 mm SL, and the smallest one with scales was 21.0 mm SL. Squamation proceeded as larvae grew. The smallest specimen fully squamated was 40.2 mm SL, and larvae more than 47.0 mm SL were assumed to have completed squamation.

Growth and Allometric Growth

Larvae reared in the laboratory grew relatively slowly throughout the larval stage, but more rapidly after transformation and during the juvenile stage. The growth curve was expressed by the equation $SL=3.27e^{0.048x}$, where SL is standard length and x represents days after hatching. In addition to the morphological change from larva to juvenile which occurred from 9.85 to 13.5mm SL, variation in fish length became larger than before (Fig. 6). With accompanying morphological changes from larvae to juveniles bigger fish frequently attacked smaller ones and this phenomenon occurred increasingly day by day. According to Mizuta,[6] the cannibalism was one of the cause in high mortalities during the course of initial rearing, and was observed when the fish attained about 18.0 mm in TL (14.1 mm SL), reaching newly transformed juveniles in this study. Size selection and segregation of survivors was necessary when the cannibalism became evident in the rearing procedure.

Standard length measurements were employed to examine the development and growth of yellowtail in comparison to other morphometric characters and further observations. The relationships between total length (TL) and both standard length and preanal length (PL) are shown in Fig. 7 for fish ranging from about 3.5 to 70 mm SL. These relationships are described with linear regressions.

Relative preanal length, from the tip of snout to the anus, ranged from about 50 to 60% of TL during the larval stage, and from about 50 to 55% TL after 11.0 mm TL (Fig. 8).

Discussion

In contrast with observations of wild-caught specimens, some characters including jaws, ventral fins, notochord flexion and hypural elements usually began to differentiate earlier. This might be attributable to the number of specimens observed; usually field investigations were restricted

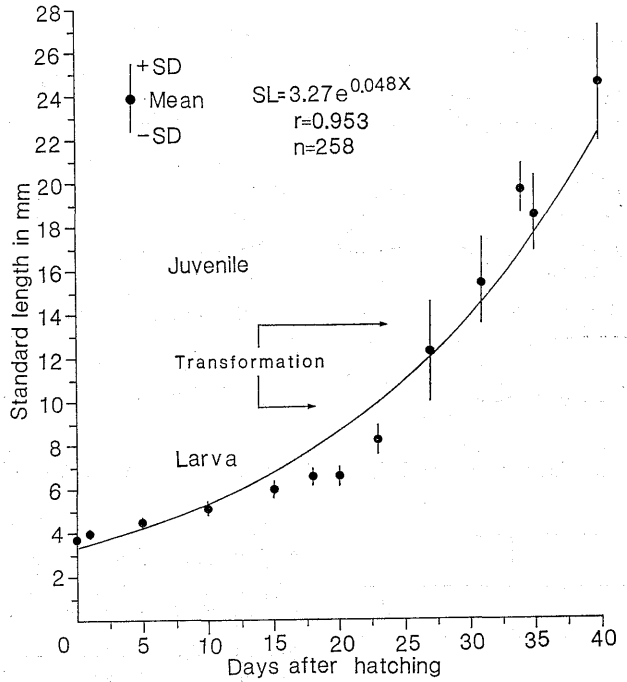

Fig. 6. Growth of larval and juvenile yellowtail reared in the laboratory at a temperature of 19.6° to 22.1°C.

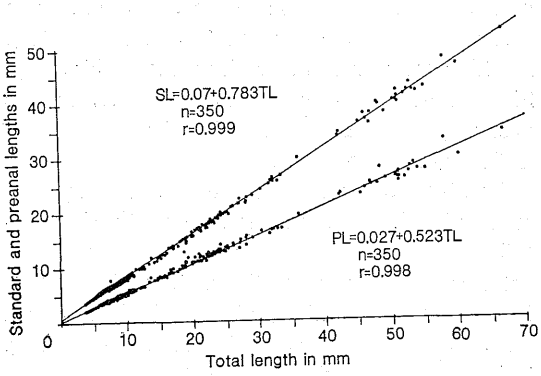

Fig. 7. Standard length and preanal length plotted against total length in larvae and juveniles of yellowtail.

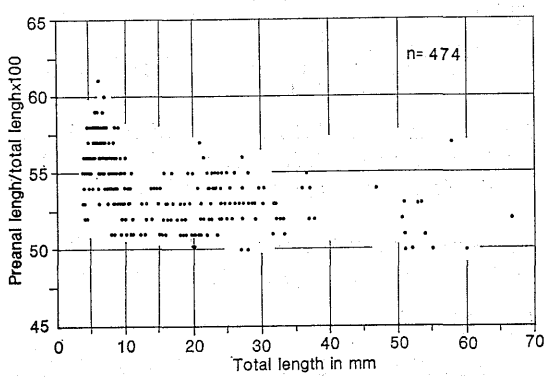

Fig. 8. Ratio of preanal length to the total length expressed as a % plotted against total length of larval and juvenile yellowtail.

respect to serial observations. On the other hand, environmental conditions particularly on food density may have varied slightly, causing different developmental rates.

In this paper the morphological transformation from post-larva to juvenile was reported to occur from 9.85 to 13.5 mm SL, which corresponds to 12.4–17.0 mm TL. In wild-caught specimens the range of larval size during which the transformation occurs is not available for comparison. However, Mito[8] reported a juvenile measuring 13.6 mm TL (11.0 mm SL, calculated from illustration enclosed) and Uchida *et al.*[1] also described a specimen of 12.0 mm TL (10.0 mm SL). Therefore, no marked difference in length appears to exist between the reared and wild specimens for newly transformed juveniles.

Fig. 9 is a schematic representation of the differentiation and development of morphological characters. Various structures differentiated during a phase between 6.0 mm and 8.0 mm SL. Namely, this phase was a time of remarkable

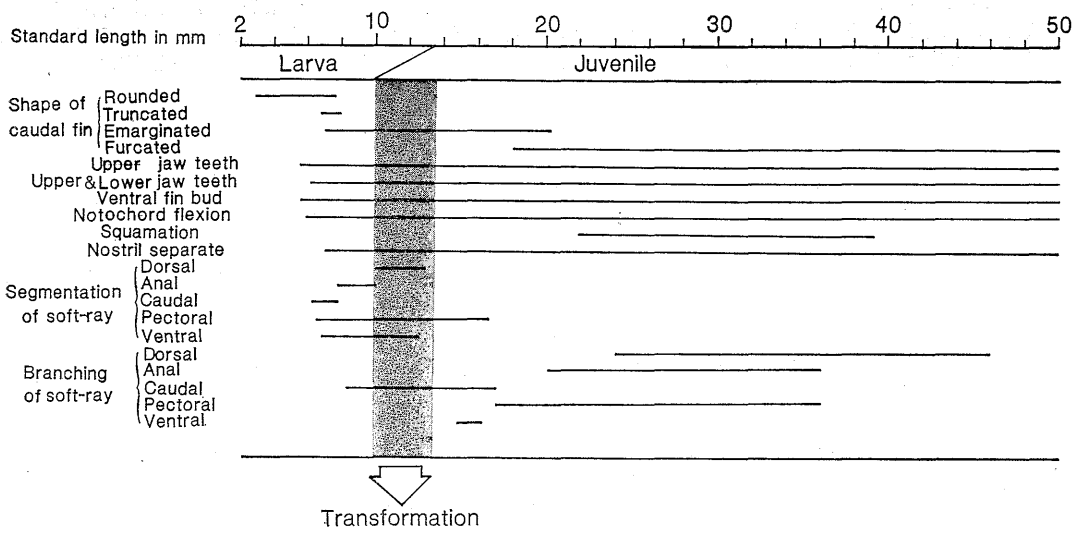

Fig. 9. The sequence of development of morphometric characters for larval and juvenile yellowtail. Each character was expressed by specimen with the shortest standard length and ranges of differentiation and formation.

organogenesis, which also included the large variation of proportional preanal length occurring between 5.0 mm and 10.0 mm in total length (Fig. 8).

Internally, the functional development of the stomach proceeded to the next developmental stage as a result of the differentiation of gastric glands from 7.5 mm TL (6.0 mm SL) long.[4] Rapid growth of juveniles after metamorphosis, represented in Fig. 6, was assumed to be associated with the changes in morphological characters and the functional development of the alimentary tract. These findings suggest that developmental phase before transformation is critical time in their early life stages. After metamorphosis, occurring from about 13.5 mm SL, proportionality of preanal length to total length became constant by 50 to 55% TL (Fig. 8). The segmentation of soft-ray, which had important role for locomotion,[9] was nearly completed in each fin. In addition, pelagic juveniles began to gather to floating seaweeds from 13.1 mm SL in wild investigation,[10] and the cannibalism was found for juveniles from 14 mm SL in the rearing tank.[6]

Consequently, morphological development in various internal and external structures occurred coincidently at a vicinity of transformation from larvae to juveniles, and considered to be linked with the changes in behaviours of cannibalism and aggregation to floating seaweed mentioned above.

Acknowledgements

The authors wish to thank Professor T. Iwai, Kyoto University, for his suggestion and advice for this study. The authors extend sincere thanks to Drs. C. Mahnken and D. Dey, Northwest and Alaska Fisheries Center, and Harald Rosenthal of Biologische Anstalt Helgoland for their critical reading of the manuscript. Thanks also due to staffs, Japan Farming Fisheries Association for their encouragement through the course of this study.

References

1) K. Uchida, Y. Dotu, S. Mito, and K. Nakahara: *Sci. Bull. Fac. Agr. Kyushu Univ.*, **16**, 329–342 (1958).
2) F. Mitani: *Mem. Fac. Agri. Kinki Univ.*, No. 1, 81–300 (1960).
3) T. Harada: *Mem. Fac. Agri. Kinki. Univ.*, No. 3, 1–291 (1965).
4) S. Umeda and A. Ochiai: *Bull. Japan. Soc. Sci. Fish.*, **39**, 923–930 (1973).
5) S. Umeda and A. Ochiai: *Japan. J. Ichthyol.*, **21**, 213–219 (1975).
6) Y. Mizuta: *Tech. Rep. Farm. Fish.*, **10**, 85–97, (1981).
7) O. Fukuhara: *Bull. Japan. Soc. Sci. Fish.*, **51**, 731–743, (1985).
8) S. Mito: Fish Eggs and Larvae, Encyclopaedia of Marine Plankton of Japan-7., Soyosha, Tokyo,

1966, pp. 48–49.
9) W. A. Gosline: Functional Morphology and Classification of Teleostean Fishes, 2nd ed., The University of Hawaii, Honolulu, 1973, pp. 22–43.
10) M. Anraku and M. Azeta: *Bull. Seikai Reg. Fish. Res. Lab.*, No. 33, 15–45 (1965).