Japanese Eel *Leptocephali* from Three Cruises in the Western North Pacific

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(Received March 28, 1991)

A total of 24 specimens of *Anguilla japonica* leptocephali were collected by three cruises in the western North Pacific: two specimens (45.9 and 50.0 mmTL) in Dec. 1961 by RV Shunyo Maru, one (41.5 mmTL) in Oct. 1971 by RV Shoyo Maru, and 21 (19.5–25.4 mmTL) in July 1990 by TV Keiten Maru. The last specimens included the smallest ones hitherto known from the field, and were collected at a station (16°29.3'N, 139°20.8'E) northwest of Guam and close to the station where the smallest leptocephalus was recorded in the past. The morphology was described separately on Shunyo Maru and Shoyo Maru specimens and Keiten Maru ones because of size difference. Discussion was made on several characters, especially the presence of caudal melanophores on two specimens, of Keiten Maru specimens different from those of larger specimens.

Japanese eel *Anguilla japonica* is one of the most important cultured fishes in and around Japan. From the view point of the culture, the prediction of elver catch and the artificial production of elvers are earnestly desired, but are unsuccessful at present. This is obviously due to the lack of information on the mysterious spawning and early life of the eel. The lack of information, in turn comes from the paucity of eel leptocephali collection from the field which amount to only 85 specimens in total so far.¹⁾

The present authors found three leptocephali (41.5–50.0 mm in total length, TL) of Japanese eel from ichthyoplankton samples collected during the cruises of RV Shunyo Maru in 1961 and RV Shoyo Maru in 1971 and deposited in the Laboratory of Fisheries Resources, Faculty of Fisheries, Kagoshima University, and collected 21 leptocephali (19.5–25.4 mm TL) inclusive of the smallest ones hitherto known from the field on July 1990 during the TV Keiten Maru cruise at nearly the same locality where the smallest leptocephali were recorded in the past.¹⁾ In this paper, the authors report the description of these specimens.

Materials and Methods

The survey of RV Shunyo Maru, Fishery

Agency of Japan was made from Nov. 29 to Dec. 17, 1961 in the area of 1°14.0'–28°15.0'N and 128°43.0'–134°50.0'E (Fig. 1).²⁾ Ichthyoplankton was collected with a conical net (mouth diameter 2.0 m, length 6.0 m, mesh aperture of anterior 2/3 1.7 mm, that of rest 1/3 0.5 mm). Horizontal 20 min tows were made simultaneously at surface and subsurface (about 20–30 m deep) layers at a ship speed of about 2.0 kt four times a day (about 03:40, 11:40, 15:40, and 19:40 JST), totalling 61 surface and 60 subsurface collections (on one collection, net was broken). After the selection of tuna larvae,³⁾ the collections were brought and deposited in the Laboratory of Fisheries Resources, Faculty of Fisheries, Kagoshima University. Two Japanese eel leptocephali (45.9 and 50.0 mm TL) were found in the subsurface collection of Stn. 13 whose data were as follows: 19:37–19:57, Dec. 2, 1961; 17°20.7'N, 128°42.8'E; surface water temperature 27.5°C.²⁾

The survey of RV Shoyo Maru, Fishery Agency of Japan was made from Sep. 25 to Oct. 25, 1971 in the area of 4°07.0'–29°04.7'N and 141°20.0'–150°33.0'E (Fig. 1).³⁾ Ichthyoplankton was collected with the same type of net and the same method with those of the above Shunyo Maru. The collections were made twice a day (08:00, 20:00) in principle, totalling 86. They were

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Fig. 1. Cruise tracks and sampling stations of RV Shunyo Maru (Nov.-Dec. 1961), Shoyo Maru (Sep.-Oct. 1971), and TV Keiten Maru (June-July 1990). Arrows indicate the stations where *Anguilla japonica* leptocephali were collected.

brought and deposited in the same laboratory with those of Shunyo Maru. One Japanese eel leptocephalus (41.5 mm TL) was found in the sub-surface sample of Stn. 40 whose data were as follows: 20:00-20:20, Oct. 23, 1971; 18° 50.5'N, 143°29.0'E; surface water temperature 28.3°C.⁸⁾

The survey of TV Keiten Maru (860 t), Faculty of Fisheries, Kagoshima University was made from June 13 to July 10, 1990 in the area of 11°42.9'-25°14.0'N and 133°17.7'-142°17.0'E (Fig. 1). Ichthyoplankton was collected with the same type of net as Ozawa *et al.*'s¹⁾ (mouth diameter 1.6 m, net length 7.35 m, mesh aperture 0.53 mm). The net was towed twice a night in the outward leg from June 13 to 17 (22:00, 02:00) and three times a night in the return leg from July 6 to 10 (about 20:00, 00:00, 04:00), totalling 20, horizontally at three depth layers (step tow) of wire length of 100, 150 and 200 m

for ten min each at a ship speed of about 2.0 kt. The depth of tow was recorded by a Depth Recorder (Yanagi Keiki, BS-10Y-A) set at the mouth of the net. The leptocephali of *Anguilliformes* were examined immediately after collection on board by binocular microscopy. Twenty one Japanese eel leptocephali (19.5-25.4 mm TL) were collected on July 7/8 (23:29-00:08) at Stn. 13 (16°29.3'N, 139°20.8'E; surface water temperature 28.8°C) with a maximum net depth of 59 m. They were preserved in 70% ethanol after fixation in 10% sea water neutral formalin for an hour.

All of the leptocephali were measured and counted following the methods adopted by Castle.⁴⁾ For comparison of morphology of the present leptocephali, all of the specimens recorded in the past^{1,5-10)} were used inclusive of the unreported data in Tabeta and Takai,⁶⁾ Tabeta and Mochioka,¹⁰⁾ and Ozawa *et al.*¹⁾

Results

The leptocephali of TV Keiten Maru are clearly different in size from those of RV Shunyo Maru and Shoyo Maru. Therefore, the description of these two lots is presented separately below.

TV Keiten Maru Specimens

Twenty one specimens, 19.5-25.4 mm TL (Cat. KUKT-90-2, No. 1-21). Among them, 13 (<24 mm TL) are smaller than the specimens hitherto known from the field.¹⁾ The description given below is mainly based on a specimen of 24.1 mm TL (Cat. KUKT-90-2, No. 8) (Fig. 2). The other specimens were utilized to show the range of characters. Measurements related to dorsal and anal origins were impossible, because all specimens were too young to develop discernible dorsal and anal origins.

Description. Measurements in mm: total length

Fig. 2. Leptocephalus of *Anguilla japonica* Temminck et Schlegel, Cat. KUKT-90-2, No. 8, 24.1 mmTL.

24.1 (19.5–25.4, mean 23.1), standard length 23.8 (19.3–25.2, 22.9), head 2.2 (1.9–2.2, 2.1), snout 0.6 (0.5–0.8, 0.7), eye 0.8 (0.6–0.8, 0.7), upper jaw 1.0 (0.9–1.1, 1.0), postorbital 0.9 (0.7–1.2, 0.8), pectoral 0.4 (0.2–0.7, 0.4), preanal 18.8 (15.1–19.5, 18.2), depth just before eye 1.2 (1.0–1.5, 1.1), at pectoral base 1.8 (1.4–1.9, 1.7), at midpoint between pectoral and vent 3.6 (2.6–3.9, 3.2), at vent 2.8 (2.2–3.1, 2.6). Branchiostegals not obvious. Total myomeres 112 (112–115, mean 113.5), preanus 72 (72–79, 76.1), 1st vertical blood vessel at 17th myomere (15th–18th or 19th, modes 16th and 18th), 2nd at 38th (34th–41st, 39th), 3rd (last) at 44th (43rd–46th, 46th), anterior margin of gall bladder at 30th (28th–37th, 35th). Hypurals in the process of formation or having just formed, and without rays. All fin rays not obvious. Teeth 1 + 1 + 2 + 4/1 + 3 + 3 (1 + 1 + 1 – 3 + 3 – 5/1 + 1 – 3 + 2 – 5, 1 + 1 + 2 + 4/1 + 2 + 3).

Body much compressed, and the greatest body depth 13.6% of TL, being lower than those of larger specimens (Fig. 5). Head short, about one-eleventh of TL; snout short, about one-fourth of head length, its dorsal profile smoothly concave at anterior nostril; anterior and posterior nostrils separated; eye little larger than snout length, oval; mouth gape oblique, extending to just behind level of anterior margin of pupil; teeth conspicuous, relatively large, very acute, 8 in the upper jaw and 7 in the lower jaw (fewer than those of larger specimens: Fig. 5), distributed as follows: first tooth of upper jaw small, directed anteriorly and placed immediately before the second much larger, grasping tooth; these two are followed by two medium-sized teeth and final series of four smaller teeth; lower teeth similar to those of upper jaw with the absence of anteriormost small tooth. Dorsal and anal fins with pterygiophores restricted to the tip of tail, their origins not obvious. Pectoral fin small, about one-sixth of head length, rounded, fleshy. Caudal fin in the state of membrane and continuous with other median fins. Intestine straight, not festooned or swollen. Gall bladder visible in front of stomach portion, oval, but not obvious in some specimens.

Color in preservative translucent with black pigment restricted to the choroid of eye and only on two specimens (Cat. KUKT-90-2, No. 9: 21.1 mm TL; No. 12: 24.7 mm TL), three small dot melanophores at the tip of tail (Fig. 3).

Fig. 3. Tail melanophores of *Anguilla japonica* leptocephalus, Cat. KUKT-90-2, No. 12, 24.7 mm TL.

RV Shunyo Maru and Shoyo Maru Specimens

Three specimens (Cat. KUSU-61, No. 1 and No. 2, and KUSO-71, No. 1). The description given below is presented in the above order of specimens.

Description. Measurements in mm: total length 45.9, 50.0, 41.5, standard length 45.1, 49.0, 40.7, head 3.8, 4.2, 3.8, snout 1.0, 1.1, 1.1, eye 1.0, 1.1, 0.9, upper jaw 1.7 for all, postorbital 1.9, 2.1, 2.8, pectoral 1.1, 1.2, 1.1, preanal 34.6, 37.4, 30.1, predorsal 30.7, 35.0, 27.3, ano-dorsal 3.9, 2.4, 2.8, depth just before eye 1.7, 1.6, 1.9, at pectoral base 3.0, 3.1, 3.0, at midpoint between pectoral and vent 6.9, 7.4, 6.8, at vent 6.2, 6.8, 5.8. Branchiostegals –, –, 8. Total myomeres 116, 115, 115, predorsal 67, 70, 70, preanal 78, 79, 78, ano-dorsal 11, 9, 8, 1st vertical blood vessel at 18th, 17th, 17th, 2nd at 38th, 39th, 41st, 3rd (last) at 45th, 46th, 46th, anterior margin of gall bladder at 30th?, 30th, 35th. Caudal fin rays 1 + 2 + 2 + 2 + 2 + 1 = 10 for all. Other fins not obvious. Teeth 0 + 1 + 2 + 11/0 + 6(?) + 3(?), 0 + 1 + 1 + 17/1 + 7(?) + 3(?), 0 + 1 + 6 + 10/1 + 6 + 5.

The present leptocephali are similar in development and size to those of Matsui *et al.*⁸⁾ (53.5 mm TL), Tabeta and Takai⁹⁾ (47.3–58.7 mm TL), and Tabeta and Mochioka¹⁰⁾ (33.9–58.7 mm TL) among the leptocephali reported so far. Referring to the descriptions on those past specimens, the present three showed differences only in the teeth arrangement. First, the anteriormost small tooth of upper jaw was missing. This is thought to be loss due to damage. The arrangement of lower jaw teeth was unclear on the two Shunyo Maru specimens because of the

gradual decrease in size rearward. Except these differences, the present specimens showed almost the same characters in body form and proportion, shape of intestine, meristics, and pigmentation with those of the above three descriptions.

Discussion

The present specimens are characterized in having an olive leaf shape, normal eye, head, and jaw suspension, simple straight gut without thickenings, loops, or arches, and absence of melanophores except eye (for the presence of three small dot melanophores at the tip of tail in two TV Keiten Maru specimens, see below). These characters fit only the *Anguillidae*.^{6,11} According to Matsui¹² (tables 1.6 and 2.1), five *Anguilla* species occur in the North Pacific, and they have the following vertebral number: *A. japonica*, 112–119; *A. marmorata*, 100–110; *A. celebensis*, 101–107; *A. bicolor pacifica*, 103–110; *A. obscura*, 101–107. The present 24 leptocephali have 112–116 total myomeres. Further, they have last vertical blood vessel usually lying at about 45th or 46th myomeres, and in three larger specimens of RV Shunyo Maru and Shoyo Maru, 8–11 ano-dorsal myomeres. These characters fit only *Anguilla japonica* Temminck et Schlegel in the North Pacific.^{1,4,6,7,10,13}

However, TV Keiten Maru specimens having a smaller size show the peculiarities in myomere number, three small dot melanophores at the tip of tail in two specimens, body proportions, and number of teeth.

Compared with the past specimens,^{1,5–10} TV Keiten Maru specimens apparently have fewer total myomeres (112–115 vs 112–118), but the other four meristics related to myomeres are nearly the same (Fig. 4). The present specimens were collected from nearly the same area with those of Ozawa *et al.*¹ having 112–117 (mean 115.3) total myomeres. Therefore, this difference does not seem to be derived from a systematic one such as local population. It is difficult to discuss this problem further.

Three small dot melanophores at the tip of tail in two Keiten Maru specimens seem the remnant of dense branched melanophores at the tip of tail and surrounding finfold observed on the hatched larvae and preleptocephali of Japanese eel raised from the artificially fertilized eggs.^{14,15} The presence of tail melanophores similar in shape and number to those of the present ones

Fig. 4. Comparison of myomere counts of *Anguilla japonica* leptocephali among TV Keiten Maru specimens with solid underlines, RV Shunyo Maru and Shoyo Maru ones with parenthesis, and those of the past descriptions^{1,5–10} with broken underlines. The numbers represent individuals having myomere counts above them. Abbreviations: TM, total myomeres; PAM, preanal myomeres; VAV 1st, 2nd, and 3rd, myomeres of first, second, and third vertical blood vessels.

is recognized on the small size leptocephali of the congeneric species from the field as follows: maximum eight melanophores present on the leptocephali of 10.5, 11.25, and 15.75 mm TL, but absent on those of 44–50 mm TL of *A. rostrata*;^{16,17} the proportion of individuals having the melanophores decreases with growth between 10 and 20 mm TL, and none over about 20 mm TL in the eastern Indian Ocean *Anguilla* leptocephali unidentified to species due to small size.¹³ Thus, the tail melanophores when present (absent in *A. anguilla*)¹⁶ disappear with development of leptocephali, and at about 20 mm TL in the case of *A. japonica*.

Among the body proportions of TV Keiten Maru specimens described above, body depth and preanal length to TL are significantly different from the past specimens (Fig. 5). Body depth/TL ranges from 14 to 22% in the past specimens, and from 12 to 16% in the present ones. Among the latter specimens, the smaller ones tend to show smaller proportions than larger

Fig. 5. Changes of three characters with growth of *Anguilla japonica* leptocephali. Black circles of smaller total length, three black ones of larger total length, and white ones represent respectively TV Keiten Maru specimens, RV Shunyo Maru and Shoyo Maru ones, and those of the past descriptions.^{1, 5-10)} Abbreviations: BD, greatest body depth; TL, total length; PAL, preanal length; No. of teeth, total number of upper jaw teeth.

specimens. Therefore, this smaller proportion can be regarded as the smaller size of present specimens. Inclusive of the present specimens, the preanal length shows gradual decrease with growth of body, indicating the lesser proportion of the present specimens being the reflection of size difference.

The number of teeth increases with growth of leptocephali until metamorphosis.¹²⁾ It is the fewest (mode 8) in the present specimens, and through gradual increase with growth, becomes constant (about 20) beyond about 50 mm TL (Fig. 5).

Acknowledgements

We wish to express our heartfelt thanks to the crew of TV Keiten Maru, Kagoshima University

for help in collection of samples, and Dr. N. Mochioka of the Faculty of Agriculture, Kyushu University for confirmation of some characters of the leptocephali.

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