Studies on Eel Pseudodactylogyrosis—I Morphology and Classification of Three Eel Dactylogyrids with a Proposal of a New Species, *Pseudodactylogyrus microrchis*

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Three species of dactylogyrids were found on the gills of the European eel, *Anguilla anguilla* which were cultured in eel farm ponds in Japan. They were all classified into the genus *Pseudodactylogyrus* GUSSEV, 1965, and were identified as *P. microrchis* n.sp., *P. anguillae* and *P. bini*. *P. microrchis* closely resembles *P. anguillae*, but definitely differs in the size of the testis and the prostatic reservoir from that of *P. anguillae*, where these organs of the former are much smaller than those of the latter. In addition, the length of anchor, the bar and the cirrus accessory of *P. microrchis* are significantly shorter than the those of *P. anguillae*.

From 1969 to 1973, elvers of the European eel, *Anguilla anguilla*, were transported in a large number from European countries to Japan every year and cultured in many eel farm ponds. What was interesting was that European eels were much more susceptible to some dactylogyrids than Japanese ones, *Anguilla japonica*. In some cases, thousands of dactylogyrids were found on the gills of a single European eel, causing the death of the host.

Although considerable attentions have been paid to these parasites from the practical point of view, we have had as yet very little informations as to their classification and biology.

The present paper is the first of a series of studies on eel Pseudodactylogyrosis and is concerned with the morphology, the classification and the description of the new species of dactylogyrid found on cultured European eels.

Materials and Methods

The materials used consisted of dactylogyrids collected from European eels cultured in ponds in Japan. They were flattened under the coverslip, fixed in SCHAUDINN's fluid, stained with HEIDENHAIN's iron haematoxylin or alum carmine and mounted in Canada balsam.

Measurements were made of the specimens thus prepared. Detailed structures were observed on fixed and stained preparations as well as on living specimens. Drawings were made with the aid of a camera lucida.

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Results

Descriptions of the eel dactylogyrids Dactylogyrids found on the gills of cultured European eels were classified into three species. They had common morphological characteristics as follows. 1) The haptor is situated ventrally unlike that of the members of the genus *Dactylogyrus*. The anchor point directs ventrally and the bar is situated ventrally to the anchors. 2) The marginal hooks are of larval type. 3) The number of the prostatic reservoir is one, while the members of the genus *Dactylogyrus* have two prostatic reservoirs.¹⁾

Since all these characteristics coincided with those of the genus *Pseudodactylogyrus* which was proposed by GUSSEV (1965),²⁾ these three species were classified into the genus *Pseudodactylogyrus*. Besides the above mentioned characteristics, GUSSEV (personal communication) stated as follows. "All (?) Dactylogyridae have additional tendon ligament ("needle") in 6th pair of hooks ("4A" after American authors³⁾). There is no such structure in *Pseudodactylogyrus* like Ancylo-discoidinae and Ancyrocephalinae." All species of dactylogyrids examined in this study, too, have no additional hook.

Pseudodactylogyrus microrchis n. sp.

Host *Anguilla anguilla*, cultured in eel farm ponds.

Locality and date Chiba and Shizuoka Prefectures, August, 1974; Aichi Pref., October, 1974.

Specimens The holotype and the paratypes are deposited in the Meguro Parasitological Museum, Tokyo, M.P.M. Coll. No. 19139.

Description The body is elongate, 374–1,259 μ long by 138–282 μ wide.

The haptor is well marked off from the body proper, triangular in form, and 91–170 μ long by 94–190 μ wide.

The anchors are slender and long and situated in the center of the haptor. The way of measuring the length of the various parts of the anchor is shown in Fig. 1. The internal process is long (54–72 μ) and reflexed ventrally in the middle. The reflexed part (35–49 μ) can be bent by the longitudinal muscle and are joined each other by the transverse muscle. The external process is short and 7–14 μ long. The anchor length, the distance between the tip of the internal process and the bottom of the curved portion (a in Fig. 1) is 100–125 μ (mean 108 μ), and the length of the anchor without the reflexed part (b in Fig. 1) is 86–102 μ (mean 93 μ). The anchor point is slender and directs ventrally, measuring 28–32 μ in length. The length of the anchor base is 60–80 μ .

The bar is 40–59 μ long, swollen at the both ends and situated ventrally to the anchors. All the seven pairs of the marginal hooks are of larval type and the same in

Fig. 1. The way of measuring the length of the various parts of the anchor. a: overall length of the anchor. b: the anchor length without the reflexed part of the internal process. c: length of the base. d: length of the external process. e: length of the internal process. f: length of the point. g: length of the reflexed part of the internal process.

Figs. 2-6. *Pseudodactylogyrus microrchis* n.sp. 2: the entire worm of the holotype, ventral view. 3: the anchors and the bar of the paratype, ventral view. 4: the anchor of the paratype with the reflexed part stretched. 5: the marginal hook of the paratype. 6: the copulatory organ of the holotype.

(C: cirrus, CG: cement gland, ES: eye spot, I: intestine, M: mouth, OT: ootype, OV: ovary, P: pharynx, RS: receptaculum seminis, T: testis, U: uterus, V: vagina)

the shape and the size, each measuring $14\text{--}17\ \mu$. No additional hook exists.

Two pairs of the eye spots are situated anterodorsally to the pharynx. Head lobes are found in two pairs and not so prominent. On each side of the head part, there are three pairs of head organs and their openings are situated at the anterior edge.

The mouth opens just anterior to the pharynx. The pharynx is ellipsoidal, $35\text{--}77\ \mu \times 34\text{--}67\ \mu$. The esophagus is short and surrounded by postpharyngeal gland cells at its anterior edge. Two intestinal caeca are simple, running on either side of the body, and united posteriorly.

Cement glands exist at the posterior end of the body proper, and open into the ventral side of the haptor.

The ovary is oval, $38\text{--}143\ \mu \times 35\text{--}86\ \mu$ and situated in the middle of the body. The oviduct starts in front of the ovary and leads into the receptaculum seminis which has a swelling at the right corner. The swelling is $10\text{--}27\ \mu \times 5\text{--}11\ \mu$ and surrounded by muscles. It expands and contracts actively by the muscles. The vagina opens on the right margin and has a chitinous tube at its opening. The vaginal duct opens into the receptaculum seminis. The ootype is partitioned by a wall from the receptaculum seminis. Mehlis glands open to the ootype. The uterus is short and leads to the genital pore on the ventral side behind the intestinal bifurcation. The vitellaria are profuse and extend along each side of the body from the level of the esophagus to the intestinal connection.

The testis ($22\text{--}84\ \mu \times 17\text{--}70\ \mu$) is oval, situated just behind the ovary and always smaller than the latter. The vas deferens starts at the upper edge of the testis and turns round the left caecum dorsally. It emerges ventrally, changes its course towards the median line of the body, and turns backwards, dilated and forms the vesicula seminalis. Prostate glands are well developed and situated between two intestinal caeca, and their secretions gather in the prostatic reservoir which is situated at the cirrus base, surrounded by muscles, globular in form and is $12\text{--}23\ \mu$ in diameter. The ducts of prostate glands are obscure in stained specimens, but visible in living specimens. The vesicula seminalis passes into the prostatic reservoir and reaches at the cirrus base. The cirrus, which is a thin long tube (about $1\ \mu$ wide) surrounded by muscles and funnel-shaped at the base, runs forwards and reaches the genital pore. The cirrus accessory is a simple rod ($28\text{--}38\ \mu$), and bears a groove from the tip to the base. The cirrus can be moved along the groove and take a free position to the cirrus accessory.

The specific epithet, *microrchis*, refers to the small size of the testis.

The entire worm and the chitinous parts are shown in Figs. 2–6, and measurements of the various body parts are given in Table 1.

Table 1. Comparison between *P. microrchis* n.sp., *P. anguillae* and *N. anguillae**¹

Species	<i>P. microrchis</i> n. sp.	<i>P. anguillae</i>	<i>N. anguillae</i> * ¹
Locality	Chiba, Shizuoka & Aichi Prefs., Japan	Aichi Pref., Japan	China
Host	<i>A. anguilla</i>	<i>A. anguilla</i>	<i>A. japonica</i>
Body length	374–1259 (649)	582–1168 (768)	482–854 (658)
width	138– 282 (294)	150– 241 (203)	167–213 (182)
Haptor l.	91– 170 (112)	112– 148 (127)	112–136 (122)
w.	94– 190 (132)	132– 174 (153)	117–131 (127)
Pharynx l.	35– 77 (51)	41– 70 (55)	mean diam.
w.	34– 67 (45)	32– 55 (43)	45–56.5 (50.2)
Cirrus accessory l.	28– 38 (34)	32– 42 (37)	35.5–36.0 (35.9)
Prostatic reservoir (diam.)	12– 23 (17)	31– 45 (37)	36– 47 (43.5)
Ovary l.	38– 143 (71)	36– 92 (53)	43.2–77.0 (59.7)
w.	35– 86 (57)	43– 70 (57)	54.5–104.4 (76.5)
Testis l.	22– 84 (44)	101– 225 (137)	90.8–154 (121.5)
w.	17– 70 (34)	68– 112 (87)	95.5–132 (109.0)
Anchor l. (a)* ²	100– 125 (108)	103– 121 (113)	104–120 (110.2)
(b)* ³	86– 102 (93)	91– 105 (99)	
Bar l.	40– 59 (50)	48– 64 (54)	50.5–58.3 (54.6)
Marginal hook l.	14– 17 (16)	14– 16 (15)	10

Dimensions in μ ; parenthesis represents mean.

*¹: Data from YIN and SPROSTON (1948)⁹.

*²: measured from the tip of the internal process to the bottom of the curved portion; a in Fig. 1.

*³: measured without the reflexed part of the internal process; b in Fig. 1.

Pseudodactylogyrus anguillae (YIN and SPROSTON, 1948)

Host *Anguilla anguilla*, cultured in eel farm ponds.

Locality and date Aichi Prefecture, October, 1974.

Specimens Deposited in the Meguro Parasitological Museum, Tokyo, M.P.M. Coll. No. 19140.

Description This species resembles *P. microrchis*. The shapes of the chitinous parts are the same as those of *P. microrchis*, but there are distinct differences in the size of the testis and the prostatic reservoir between both species; the testis of this species is well developed and always larger than the ovary, and the prostatic reservoir (31–45 μ in diameter) is twice as large as that of *P. microrchis*.

The anchor is 101–121 μ in length and the anchor without the reflexed part (b in Fig. 1) is 91–105 μ . The internal process of the anchor is 54–77 μ in length, its reflexed part is 42–48 μ , the external process 8–14 μ , the anchor point 32–34 μ , and the anchor base 67–84 μ .

The swelling of the receptaculum seminis is 14–24 μ long by 8–16 μ wide and somewhat larger than that of *P. microrchis*.

The other measurements are given in Table 1. The entire worm and the chitinous parts are shown in Figs. 7–11.

Figs. 7–11. *Pseudodactylogyrys anguillae* 7: the entire worm, ventral view. 8: the anchors and the bar, ventral view. 9: the anchor with the reflexed part stretched. 10: the marginal hook. 11: the copulatory organ.

Pseudodactylogyrys bini (KIKUCHI, 1929)

Host *Anguilla anguilla*, cultured in eel farm ponds.

Loclity and date Chiba and Shizuoka Prefectures, August, 1974.

Specimens Deposited in the Meguro Parasitological Museum, Tokyo, M.P.M. Coll. No. 19141.

Description This species also resembles *P. microrchis* morphologically.

The body is somewhat larger than the other two species, $539\text{--}1,626\ \mu \times 120\text{--}311\ \mu$.

The haptor ($65\text{--}107\ \mu \times 85\text{--}172\ \mu$) is not so well marked off from the body proper, and smaller than the other two species.

The anchors are rather stout. The internal process ($33\text{--}44\ \mu$) is reflexed in the middle, and its reflexed part is $24\text{--}26\ \mu$ long. The external process is short, $11\text{--}13\ \mu$. The anchor length is $63\text{--}76\ \mu$, and the anchor without the reflexed part (b in Fig. 1) is $53\text{--}63\ \mu$ in length. The anchor point directs ventrally, $22\text{--}26\ \mu$. The anchor base is $38\text{--}43\ \mu$ long.

The bar is situated ventrally to the anchors and smallest among three species.

Table 2. Comparison between *D. bini*, *N. bini* and *P. bini*

Species	<i>P. bini</i>	<i>D. bini</i> * ¹	<i>N. bini</i> * ²	<i>P. bini</i> * ³
Locality Host	Japan <i>A. anguilla</i>	Japan <i>A. japonica</i>	China <i>A. japonica</i>	Australia <i>A. reinhardtii</i>
Body length	539–1626 (896)	1100–1400	563–1210 (797)	1400
width	120– 311 (209)	200	135– 207 (175)	260
Haptor l.	65– 107 (85)	70–80	68– 90 (78.5)	80
w.	85– 172 (117)	140	104– 130 (114)	150
Pharynx l.	40– 91 (62)		mean diam.	diam.
w.	34– 80 (52)		50– 67 (62.8)	65–75
Cirrus accessory l.	29– 50 (41)	30–46	36– 39 (36.5)	35
Prostatic reservoir (diam.)	13– 37 (22)	30	25– 29 (26.9)	30
Ovary l.	30– 114 (64)		38.5–77.2 (61.0)	diam.
w.	32– 108 (67)		49.9–90.8 (68.0)	70–90
Testis l.	67– 265 (156)		72.6– 191 (133)	200
w.	52– 184 (114)		86.2–163.4 (121)	150
Anchor l. (a)* ⁴	63– 76 (69)		39.6–63.0 (53.8)	75–81
(b)* ⁵	53– 63 (58)	44–53		
Bar l.	35– 46 (40)	32–40	37.4–42.5 (40.1)	41–47
Marginal hook l.	15– 18 (17)	10–14	25	16–18

Dimensions in μ ; parenthesis represents mean.

*¹: Data from KIKUCHI (1929)⁴.

*²: Data from YIN and SPROSTON (1948)⁵.

*³: Data from GUSSEV (1965)³.

*⁴: a in Fig. 1.

*⁵: b in Fig. 1.

Table 3. T-test of the anchor, the bar and the cirrus accessory length between *P. microrchis* n. sp. and *P. anguillae*

	Anchor (b in Fig. 1)			Bar			Cirrus accessory		
	Group II	Group I	Group III	Group II	Group I	Group III	Group II	Group I	Group III
Nos. measured	48	10	17	43	12	24	20	12	25
Range (μ)	86–102	87–96	91–105	40–59	43–54	48–64	28–38	31–38	32–42
Mean (μ)	92.9	91.7	99.2	50.2	49.2	53.8	33.5	34.5	36.7
Probability	$P \approx 0.3$		$P < 0.01$	$P \approx 0.4$		$P < 0.01$	$P \approx 0.3$ $0.01 < P < 0.02$		

Group I: *P. microrchis* from Aichi Pref.

Group II: *P. microrchis* from Chiba and Shizuoka Prefs.

Group III: *P. anguillae* from Aichi Pref.

Seven pairs of the marginal hooks are also of larval type and each hook is 15–18 μ long. The shape and the size of the marginal hooks are similar among three species. No additional hook exists.

Cement glands are well developed and the gland zone markedly expands and occupies the whole space between the intestine and the haptor.

The testis is well developed, oval in form, and always larger than the ovary. The swelling of the receptaculum seminis is 17–49 μ long by 7–19 μ wide.

Figs. 12–16. *Pseudodactylogyrus bini*. 12: the entire worm, ventral view. 13: the anchors and the bar, ventral view. 14: the anchor with the reflexed part stretched. 15: the marginal hook. 16: the terminal genitalia, ventral view.
(C: cirrus, CA: cirrus accessory, GP: genital pore, PG: prostate gland, PR: prostatic reservoir, U: uterus, VD: vas deferens, VS: vesicula seminalis)

The other measurements are given in Table 3, and the entire worm, the chitinous parts and the terminal genitalia are shown in Figs. 12–16.

A statistical analysis of the differences in length of some chitinous structures between *P. microrchis* and *P. anguillae* A statistical analysis of the differences in length of some chitinous structures was made between the specimens of *P. microrchis* (group I) and those of *P. anguillae* (group III) which were both obtained from the same eel ponds in Aichi Pref. Further, in order to know whether or not local differences were found in length of these structures in *P. microrchis*, group I was compared with group II which were collected from Chiba and Shizuoka Prefs.

As shown in Table 3, the differences between the length of b in Fig. 1 of the anchor ($87\text{--}96\ \mu$, mean $91.7\ \mu$), the bar ($43\text{--}54\ \mu$, mean $49.2\ \mu$) and the cirrus accessory ($31\text{--}38\ \mu$, mean $34.5\ \mu$) of group I and the length of those of group III (b in Fig. 1 91--

105 μ , mean 99.2 μ ; the bar 48–64 μ , mean 53.8 μ ; the cirrus accessory 32–42 μ , mean 36.7 μ) were statistically significant. On the other hand, the values of group I were not significantly different from the respective values of group II (b in Fig. 1 86–102 μ , mean 92.9 μ ; the bar 40–59 μ , mean 50.2 μ ; the cirrus accessory 28–38 μ , mean 33.5 μ).

Discussion

KIKUCHI⁴⁾ has reported a dactylogyrid from the Japanese eel, *Anguilla japonica* for the first time. He described the morphology of the dactylogyrid in every detail, and named it *Dactylogyrus bini* as a new species. However, he made some mistakes in its description. He regarded the reflexed part of the anchor as an accessory piece, and he mentioned incorrectly that the prostatic reservoir always contained sperm. Except these points, his description of *D. bini* coincides with that of *P. bini* in this report.

YIN and SPROSTON (1948)⁵⁾ described two species of dactylogyrids from wild Japanese eels in China. On the basis of their findings that in these two species the anchors were supported by two bars, they classified them as *Neodactylogyrus bini* n. comb. and *N. anguillae* n.sp. But, in all the dactylogyrids from eels studied by us only one bar was visible in either fixed or living specimens. It seems that YIN and SPROSTON incorrectly regarded the transverse muscle joining each internal process as a dorsal bar. Besides, there are some doubts in their reports. For example, 1) they regarded incorrectly the prostatic reservoir as the vesicula seminalis interna which was always full of sperm, and 2) their descriptions on the shape and the size of the marginal hooks are obscure. The present authors think that *N. bini* and *N. anguillae* may be the same species as *P. bini* and *P. anguillae*, respectively (Table 1, 2).

GUSSEV (1965) proposed a new genus *Pseudodactylogyrus* to the eel dactylogyrids. It is regarded as a valid genus, because there are distinct differences in morphology between the two genera, *Pseudodactylogyrus* and *Dactylogyrus*, as mentioned above. He described two species, *P. bini* and *P. anguillae*. His description on *P. bini* was very elaborate, but on *P. anguillae*, he described only the chitinous parts and he was not interested in the size of the testis and the prostatic reservoir.

P. microrchis and *P. anguillae* are not different in the shape of the chitinous parts, but differ distinctly in the size of the testis and the prostatic reservoir. GUSSEV (personal communication) mentioned that the size of the testis could change with seasons and with developing stages of the parasite. Our field investigations showed that *P. microrchis* and *P. anguillae* were found on cultured eels all the year round, but no tendency was observed in either species that the size of the testis changed seasonally. *P. microrchis* and *P. anguillae* observed in this study included various stage worms from early to late in the development, as shown by the diversities on the body length (Table 1).

The fact that the size of the testis of the smallest *P. anguillae* is larger than that of the largest *P. microrchis* suggests that the difference in the size of the testis is one of the important characteristics discriminating the two species.

Besides the distinct differences in the size of the testis and the prostatic reservoir, a statistical analysis shows that the lengths of b in Fig. 1 of the anchor, the bar and the cirrus accessory of *P. microrchis* are significantly shorter than those of *P. anguillae*. On the other hand, the lengths of these chitinous structures of the specimens of *P. microrchis* obtained from Aichi Pref. and those from Chiba and Shizuoka Prefs. are not statistically different from each other. This suggests that *P. microrchis* does not differ locally in the length of chitinous structures. For the above reasons, the authors thought that *P. microrchis* can be clearly distinguished from *P. anguillae* and described the former as a new species.

KIKUCHI (1929) reported an unidentified dactylogyrid from eels which was different from *P. bini* in the size of the anchor. As his description was insufficient, it is impossible to compare it with *P. microrchis* or *P. anguillae* described here.

Our materials were all obtained from cultured European eels, but *P. bini* and *P. microrchis* are known to occur also among cultured Japanese eels. So far as the present authors are aware, *P. bini* and *P. microrchis* are very common parasites on cultured eels, but *P. anguillae* occurs only occasionally in our country.

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