

Local Differentiation within the Striated Spined Loach (the *striata* Type of *Cobitis taenia* Complex)

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Abstract Seven local races of the so-called striated spined loach (*Cobitis taenia striata*) were compared morphologically. Here they were called the large, Biwa small, Yodo small, small, Tokai small, spotted small, and middle races. Among them, the Yodo small race and Tokai small race were newly discriminated. There was a great morphological variation among the seven local races. Each race occupied its specific geographic range. Three cases of sympatric distribution of two races were found without effective hybridization. The striated spined loach is a species group which has seven local races that could be divided into three species; the large and middle races are independent species each and the five smaller races are settled into the third one. However, their scientific names cannot be given because of the uncertainty of relationship between the European population of *Cobitis taenia*, originally described by Linnaeus, and Japanese ones. While a wide extent of morphological variation within the smaller races is found, difference between the large race or middle race and their nearest smaller race is considerably smaller.

The striated spined loach (*Cobitis taenia striata*) was first described by Ikeda (1936) as a subspecies of spined loach (*C. taenia*). It is characterized by having a roundish lamina circularis at the base of the second pectoral fin ray and a striped pattern on the lateral side of the body. Its distribution area is mainly western Honshu and Shikoku Islands, Japan.

Though it has been generally regarded as one of the local populations of the widely ranged *C. taenia* inhabiting Europe and the Far East (Nakamura, 1963; Miyadi et al., 1976; Sawada, 1984), we have supposed that the striated spined loach is not a subspecies but comprises a number of species. Minamori (1955) listed five local races which were morphologically distinguishable from each other. He further claimed that, on the basis of sterility and breakdown of experimental F_1 hybrids, the striated spined loach could be divided into three biological species, and that one of them consisted of three subunits of subspecific rank (Minamori, 1960). One of us reported *Cobitis taenia* from central Honshu (Aizawa, 1981). He stated that its subspecific status was not clear and that the taxonomy of this group including the striated spined loach might be revised. Ueno et al. (1980) described two chromosomal races, one diploid and the other tetraploid. Further, Saitoh et al. (1984) showed karyological differentiation within the diploid race.

It is interesting to examine to what extent these local races of the striated spined loach are morphologically differentiated, and how they occupy their own ranges within the whole geographic range of this group. It is also significant to test whether there is a morphological grouping corresponding to the species status advanced by Minamori. In the previous paper, one of us preliminarily described morphological diversification of Minamori's five races (Saitoh, 1984). In this report, we will describe morphological features including vertebral count and geographic distribution of seven local races (Minamori's five races and two new ones) based on more detailed data obtained by further study in Honshu and Shikoku.

Materials and methods

Study areas. Collection of the striated spined loach was carried out on the following schedule: Tokai district (Pacific coast of central Honshu), October, 1981 to October, 1984. Lake Biwa, May, 1979 to May, 1984. Sanyo district (Seto Inland Sea slope of western Honshu including the Kino and Yodo Rivers), March, 1979 to November, 1984. Sanin district (westmost Honshu facing the Sea of Japan), May 1981 to May, 1984. Shikoku district, March, 1982 to October, 1983.

Materials. Specimens were generally caught

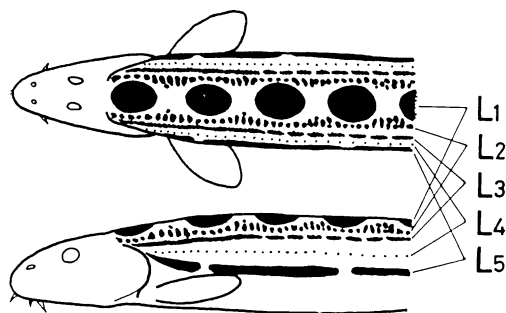


Fig. 1. Color pattern on the dorso-lateral side of the trunk of the striated spined loach (after Takeda and Fujie, 1945, revised). Five lines of dark speckles (L_1 – L_5) are shown.

with a scoop net. They were preserved in 10% formalin for morphological observations. The number of specimens used in this study is as follows: large race, 110; Biwa small race, 111; Yodo small race, 29; small race, 221; Tokai small race, 256; spotted small race, 182; middle race, 764. Most specimens were officially deposited in the Department of Fisheries, Faculty of Agriculture, Kyoto University (FAKU). Six specimens of the middle race collected from the Kurose River, Hiroshima Pref. were loaned.

Observations. Vertebral number was counted on cleared and alizarin-stained specimens or by radiographs. Discrimination between caudal and abdominal vertebrae was based on whether they had a single haemal spine or not (Hosoya, 1983). The position of the dorsal fin was indicated by vertebral count before the insertion of the posterior lobe of the anteriormost dorsal pterygiophore (Sawada and Aizawa, 1983). Specimens having deformed vertebrae, such as those with fused vertebrae, were omitted from the present measurements.

General characteristics of color pattern

Takeda and Fujie (1945) described five lines of dark speckles on the dorso-lateral side of the trunk of *Cobitis taenia* (Fig. 1). They called these lines L_1 – L_5 from the dorsal to lateral side of the trunk. L_1 and L_2 altogether are identical with zone 1 described by Gambetta (1934). The striated spined loach generally has striped L_3 and L_5 . This is the distinguishing character between *C. t. striata* and *C. t. taenia*. L_5 consists of

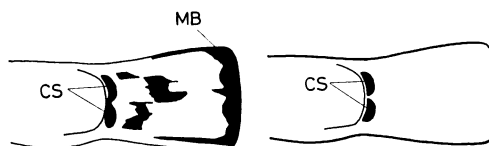


Fig. 2. Color pattern on the caudal region of the striated spined loach. Left, blotches observed on the upper pigment layer; right, those on the deeper pigment layer; CS, caudal spot; MB, marginal band.

two pigment layers, the surface and the deeper. The former is in the dermis and the latter is in the horizontal septum and its surrounding tissue. Striation of L_5 is developed from a row of spots joining each other at a young stage. Individuals having complete L_5 stripe are more frequently found among the males than among the females (Saitoh, 1984).

At the base of the caudal fin, two dark spots are present (Fig. 2). The upper one is intensively black colored while the lower is lighter. The yare formed by two pigment layers as L_5 . The surface layer is in the dermal tissue and the deeper is in the connective tissue surrounding the base of fin rays. These two pigment layers are separated by the posterior end of the lateral muscle.

There are several rows of speckles on both the dorsal and caudal fins. Sometimes a black marginal band is present at the posterior end of the caudal. Other fins do not have such a conspicuous pattern as in the dorsal and caudal.

Description of the color pattern of local races

1. **Large race** (Fig. 3A). This race is characterized by having very intensively pigmented caudal spots and completely striated L_5 .

Pigments on the surface layer of the upper caudal spot form a large oval black blotch, and those of the lower form an arcuate blotch of almost the same darkness. Pigments on the deeper layer of both upper and lower spots form large semi-circular masses, which are truncated anteriorly by the hypural plate. In most specimens the two spots are connected into a dumbbell-shape on the surface pigment layer at the center of the caudal base. The spots also come in contact or are arrayed across a very narrow gap on the deeper layer.

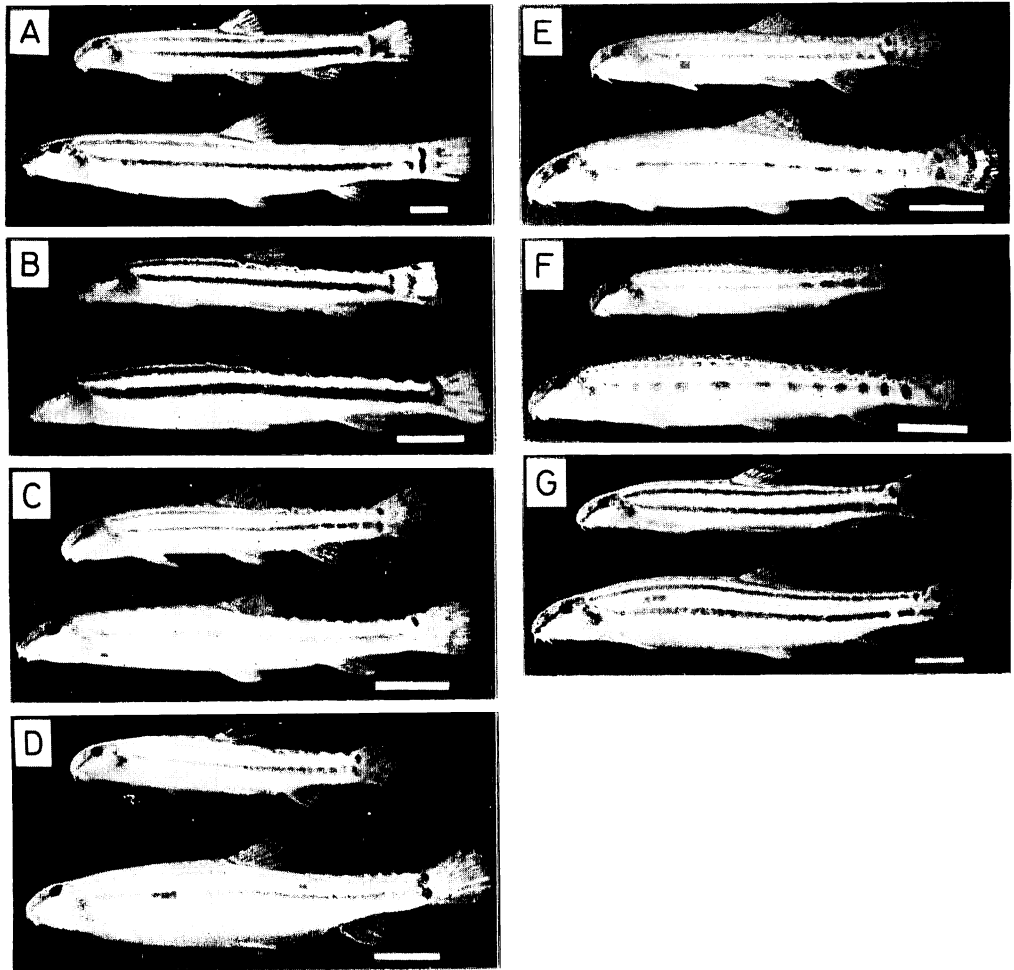


Fig. 3. Male (upper) and female (below) of the seven local races of the striated spined loach. A, large race; B, Biwa small race; C, Yodo small race; D, small race; E, Tokai small race; F, spotted small race; G, middle race. Bars indicate 1 cm.

L_3 and L_5 of this race are broad striated black lines; L_5 forms a broad and complete lateral stripe throughout the body. L_3 usually intermingles with the dorsal markings beyond the dorsal fin and cannot be traced up to the caudal peduncle. The deeper pigment layer of L_5 shows conspicuous integration of pigments. L_1 is also striated in most specimens. L_2 is usually lacking and seems to have merged into L_3 . L_4 also shows degenerated nature.

Marking on the caudal fin is also characteristic of this race. The posterior end of the caudal fin is margined by a broad pure black band. On the other region of the fin, there is a faint cloudy blotch or a mass of such blotches. A similar

pattern is also seen on the dorsal fin.

2. **Biwa small race** (Fig. 3B). One of us reported in the previous paper that the color pattern of this race and the large race were almost the same, and that it was very difficult to distinguish them by this character (Saitoh, 1984). Further observations, however, enabled us to discriminate them more easily.

The Biwa small race is distinguished from the large race by combination of the following characters: The lower caudal spot is less pigmented than the upper on the surface pigment layer, while it is almost as intensively pigmented as the upper in the large race. The striation of L_1 shows somewhat degenerated nature so that it usually consists

of a row of roundish blotches (three to six predorsally). The black marginal band at the end of the caudal fin is a little narrower, and a vertical row of speckles instead of a cloudy blotch is observed on the center of the caudal fin. The color tone of markings on the trunk and fins is reddish black.

3. **Yodo small race** (Fig. 3C). This is a newly described race which is morphologically intermediate between the Biwa small race and small race described below. Since its adult size is comparatively small (40.4–55.6 mm in the adult male and 48.2–65.8 mm in the adult female both in breeding season) and it is found only in the lower reaches of the Yodo River basin, we propose the name “Yodo small race”.

Pigments on the surface layer of the upper caudal spot constitute a small oval blotch. Those of the lower spot, sometimes merging into L_5 , are much thinner than those of the upper. The two spots do not connect as in the large and Biwa small races. Pigments on the deeper layer of both upper and lower spots are just as in the former two races.

L_3 and L_5 are narrower than in the former two races, and their striation is usually incomplete posteriorly. Pigments on the deeper layer of L_5 are conspicuous. L_1 is not striated and consists of many blotches, sometimes more than 10 before the dorsal base. The width of each blotch is inclined to be larger than its length. L_2 shows degeneration; a pair of its elements locate between L_1 blotches along the same line as L_1 , or otherwise L_2 merges into L_3 . L_4 is variable, usually more developed in the female. The color tone of these markings on the trunk is reddish brown with a slight purplish hue.

The black marginal band at the end of the caudal fin is narrow and faint. There are two or three rows of small speckles on the other region of the fin. There is a similar pattern on the dorsal fin.

4. **Small race** (Fig. 3D). Pigments on the surface layer of the upper caudal spot form a small patch, and the lower spot is indistinct and sometimes contiguous to L_5 . Pigments on the deeper layer of both the upper and lower spots are just as in the former three races.

The striation of L_3 and L_5 is less developed than in the Yodo small race. In a few extreme cases, L_5 is formed by more than 20 small blotches on the surface pigment layer. L_1 is formed by a row of small roundish or rectangular spots

(five to 10 before the dorsal base). It is usually sandwiched by many minute speckles of L_2 . L_4 is variable, generally more developed in the female. The color tone of markings on the trunk is light black with a little greenish shading because of the greenish fresh meat.

The posterior end of the caudal fin is faintly margined by a narrow band. Two to four rows of small speckles are seen on the center of the fin. A similar pattern is observed on the dorsal fin.

5. **Tokai small race** (Fig. 3E). This race is identical to the “*Cobitis taenia*” which was described by one of us (Aizawa, 1981). In the previous report, the subspecific status of this race was left unclear because of the spotted pattern on the lateral side of the body. Further study, however, revealed that the adult male of this race has a lateral stripe. So we include it within the group of the striated spined loach.

Pigments on the surface layer of the upper caudal spot form a small oval blotch and those of the lower form a small inconspicuous one sometimes merging into L_5 . Those on the deeper layer of the spots constitute two small semicircular blotches both truncated anteriorly by the hypural plate. There is a gap whose width is about the same as these blotches between them; dorsal and ventral thirds of the caudal base are occupied by pigments on the deeper layer and its central third is pale.

L_5 of this race shows sexual dimorphism. In the adult male in breeding season, striation of L_5 is usually complete, while in the female L_5 consists of a row of roundish blotches. L_5 stripe in the adult male, however, generally develops in the breeding season only. It was observed in aquaria that the lateral stripe of the male in early summer frequently broke into several spots by fall. Pigments on the deeper layer of L_5 are conspicuous and observed as a blueish band. L_3 of this race is a stripe in the adult male, or a row of small spots in the female or young. In most cases it is obscure beyond the dorsal fin. Pattern of L_1 and L_2 is just like that of the small race. L_4 is variable, usually more developed in the female. The color tone of the markings on the trunk is light black.

Marking on the caudal fin is constituted by three or four rows of thin arcuate bands. Each band is formed by many minute elements on fin ray. There is no black marginal band. There is

a similar pattern on the dorsal fin.

6. **Spotted small race** (Fig. 3F). Pigments on the surface layer of the upper caudal spot form a large oval black blotch. In larger individuals the ventral tip of this blotch sometimes bends anteriorly. Those of the lower spot form an inconspicuous blotch sometimes merging into L_5 . Pigments on the deeper layer of both the upper and lower spots are two small faint patches. There is a very wide gap between them.

L_5 and L_3 show seasonal sexual dimorphism as in the Tokai small race. In the adult male in breeding season, striation of L_5 and L_3 is usually complete. On the other hand, spotted pattern of these markings are remained in the female and young. Pigments on the deeper layer of L_5 are usually degenerated, or lacking in extreme cases. L_3 can generally be traced up to the end of the caudal peduncle. L_1 is constituted by a row of small roundish spots (five to ten predorsally) surrounded by L_2 , which consists of a crowd of minute speckles. L_4 is usually well developed and often can be traced beyond the dorsal fin. The color tone of the markings on the trunk is faint black with a slight purplish hue.

Pattern on the caudal fin is an intermediate type between the Tokai small race and the middle race described below. There are three or four arcuate bands formed by many speckles on the fin rays. Since each speckle is more pigmented than in the former race, the bands are continuous at a glance, but the center of the fin membrane is scarcely pigmented. A similar pattern is observed on the dorsal fin.

7. **Middle race** (Fig. 3G). The caudal spots of this race resembles those of the former race. However, the ventral tip of the upper spot on the surface layer bends more frequently than in the case of the former race. It always bends in the adults.

L_3 and L_5 are generally striated, though their striation is often incomplete posteriorly. Pigments on the deeper layer of L_5 are indistinct or lacking. L_3 is well developed and can be traced up to the end of the caudal peduncle. L_1 is composed of several oval or rectangular blotches. These blotches sometimes merge with each other anteriorly and form a stripe predorsally. L_2 shows degenerated nature. In many specimens a pair of its element are positioned between L_1 blotches as those of the Yodo small race. Otherwise in more vestigial case, generally in the young, L_2 is lacking. L_4 is variable. The color tone of the markings on the trunk is reddish brown.

The marking on the caudal fin is well characterizing this race. There are two or three arcuate bands on the caudal. Pigments are distributed not only in the tissue surrounding the fin rays but also on the fin membrane, so each band is wide and distinct. Posterior margin of the caudal fin is not colored except a few cases of accidental positioning of the arcuate band at the end of the fin. A similar marking is seen on the dorsal fin.

Vertebral counts and composition

Vertebral number of the seven local races varied to a considerable extent (Table 1). In terms of the mean value, the race which has the largest number of vertebral count was the large race, while the vertebral count of the Tokai small race was the smallest. Their difference scores about two points. Wide overlaps, however, were observed between any two races because of great variations within each race.

Generally speaking, the large, Biwa small, Yodo small, and middle races had large number of vertebrae, while the small and Tokai small races were with fewer vertebrae. The spotted small race was intermediate between them.

There were clear differences in vertebral compositions expressed by the abdominals and caudals between some races (Fig. 4). The large and Biwa small races, which were hardly discriminated not only by the total vertebral number but the color pattern, were rather clearly separated except for a small overlap in vertebral composition. Overlaps between the middle and Biwa small or Yodo small races were also deminished. Variation in the total vertebral count among the smaller races

Table 1. Variation in the vertebral count of the seven local races of the striated spined loach.

Race	N	Range	Mean \pm SE
Large race	103	41-44	42.87 \pm 0.08356
Biwa small race	90	40-44	42.31 \pm 0.09028
Yodo small race	28	41-45	42.82 \pm 0.1858
Small race	201	38-44	41.39 \pm 0.05768
Tokai small race	221	38-43	40.88 \pm 0.05025
Spotted small race	171	40-43	42.01 \pm 0.04976
Middle race	690	39-45	42.68 \pm 0.02813

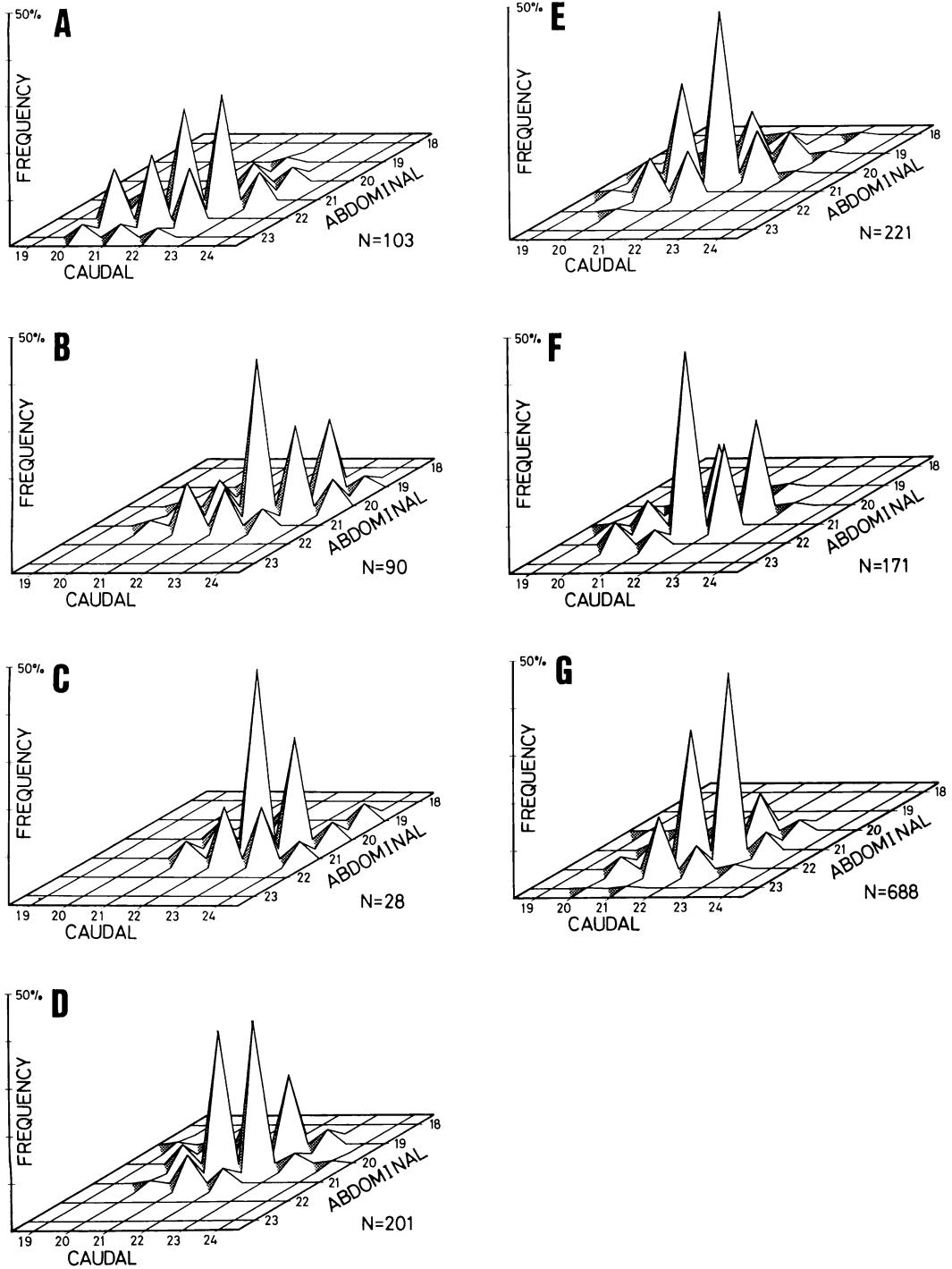


Fig. 4. Vertebral composition of the seven local races of the striated spined loach. A, large race; B, Biwa small race; C, Yodo small race; D, small race; E, Tokai small race; F, spotted small race; G, middle race.

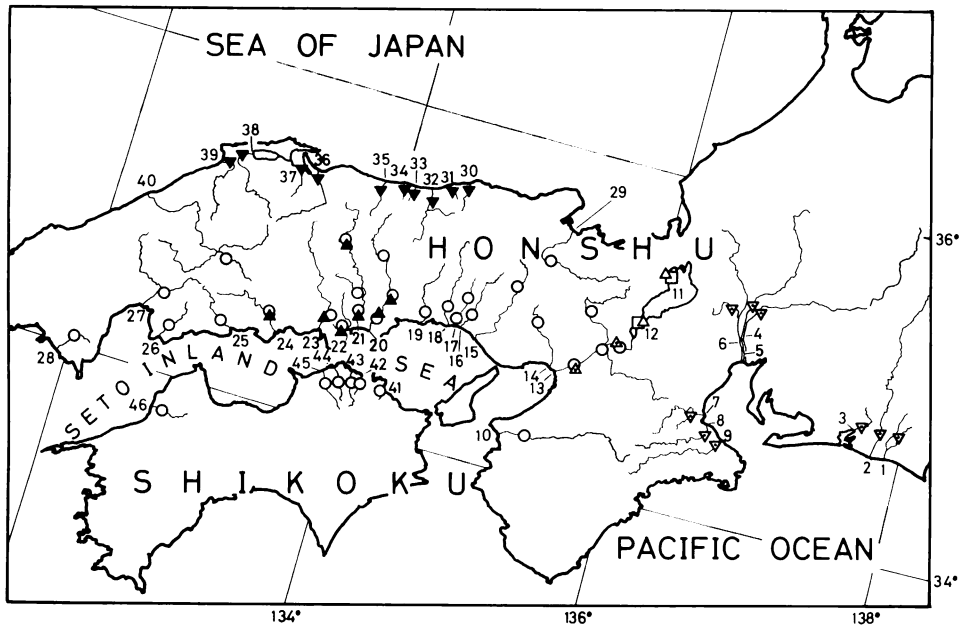


Fig. 5. Geographic distribution of the seven local races of the striated spined loach. □, large race; △, Biwa small race; ▴, Yodo small race; ▲, small race; ▽, Tokai small race; ▼, spotted small race; ○, middle race. Names of waters: 1, Ota R.; 2, Tenryu R.; 3, Miyakoda R.; 4, Kiso R.; 5, Nagara R.; 6, Ibi R.; 7, Kumozu R.; 8, Kushida R.; 9, Miya R.; 10, Kino R.; 11, northern basin of Lake Biwa; 12, southern basin of Lake Biwa, 13, Yodo R.; 14, Muko R.; 15, Kako R.; 16, Ichi R.; 17, Yumesaki R.; 18, Ibo R.; 19, Chikusa R.; 20, Yoshii R.; 21, Asahi R.; 22, Sasagase R.; 23, Takahashi R.; 24, Ashida R.; 25, Nuta R.; 26, Kurose R.; 27, Ota R.; 28, Shimata R.; 29, Yura R.; 30, Kishida R.; 31, Gamo R.; 32, Sendai R.; 33, Kouchi R.; 34, Katsube R.; 35, Tenjin R.; 36, Hino R.; 37, Hakuta R.; 38, Hii R.; 39, Kando R.; 40, Gono R.; 41, Tsuda R.; 42, Kasuga R.; 43, Kato R.; 44, Aya R.; 45, Doki R.; 46, Shigenobu R. Site 1 and 3, also collected by Aizawa (1981); 7, recorded by Aizawa (1981).

except the spotted small race is explained by increase or decrease in the number of caudal vertebrae.

Concerning the abdominal vertebrae, the seven races can be divided into two groups. The large, spotted small, and middle races have more abdominal vertebrae, while the others are with fewer abdominals.

Table 2. Variation in the position of the dorsal fin represented by the count of vertebrae before the insertion of anteriormost dorsal pterygiophore.

Race	N	Range	Mean±SE
Large race	103	14-17	15.11±0.06368
Biwa small race	90	13-16	14.13±0.07611
Yodo small race	28	14-16	14.46±0.1204
Small race	199	13-15	13.70±0.03820
Tokai small race	218	13-16	14.23±0.03984
Spotted small race	170	13-15	14.33±0.03894
Middle race	676	14-16	14.93±0.01975

Position of the dorsal fin

Position of the dorsal fin expressed by the number of vertebrae before the insertion of the anteriormost dorsal pterygiophore was employed for species identification of the genus *Cobitis* by Sawada and Aizawa (1983). This character was also useful to discriminate local races in some cases (Table 2). There was a tendency that the races whose dorsal fin were placed more posteriorly had more abdominal vertebrae, though this was not the case at the intra-racial level.

Geographic distribution

Examination of geographic distribution of the seven local races revealed that each local race occupied certain continuous area (Fig. 5). It was also revealed that there were three cases of sympatries between the large or middle race and the

smaller races, but never between any two smaller races or between the large and middle races.

The large and Biwa small races were collected only from the Lake Biwa basin. Though they were sympatrically distributed, a mild habitat segregation was found between them: Most specimens of the large race were caught by fishermen's set net ("eri" in Japanese) in the lake itself and the Biwa small race was obtained both from the lake and small streams flowing into it.

The Yodo small race was collected from the Yodo River, the outlet stream from Lake Biwa. It is interesting whether there is a distribution gap between the Biwa small and Yodo small races which resemble each other. The lowest habitat of the Biwa small race and the uppermost of the Yodo small race in the Lake Biwa-Yodo River basin are still unclear. However, there had been a rapid mountainous stream, where a large dam was constructed recently, between Lake Biwa and the Yodo River, and a certain distribution gap has therefore existed between them, because general habitats of the striated spined loach are slow flowing lowland waters or lake shores.

The small race was obtained from five river basins in Okayama and eastern end of Hiroshima where the middle race was also captured.

Although one of us reported distribution of the Tokai small race from three geographically isolated river basins like stepping stones (Aizawa, 1981), further research revealed that this race occupies a wider and rather continuous range. It was obtained from six river basins surrounding

Ise Bay and three in the western part of Shizuoka. In addition, several authors reported "*Cobitis taenia striata*" from rivers between the Miyakoda (Fig. 5: site 3) and Kiso (Fig. 5: site 4) Rivers (Kobayasi and Hara, 1958; Kobayasi et al., 1959; Ueno et al., 1980). If the fish described by them also belong to this race, its distribution area is more continuous.

Minamori (1955) reported that the spotted small race was found only in two river basins, the Sendai and Hino, in the Sanin district. Our result showed a wider and more continuous distribution. In this study the spotted small race was found in 10 river basins from the westernmost part of Hyogo to the eastern part of Shimane.

The middle race has the widest distribution range of the seven local races. It was obtained from 16 river basins in the Sanyo district, from six in the Seto Inland Sea slope of Shikoku, from two in the Sanin district, and from the Kino River in the Kii Peninsula. It coexists with some smaller races, namely with the Yodo small race in the Yodo River and with the small race in its whole range, but never with the large race.

In the three cases of sympatries, morphologically intermediate individuals which are thought to be hybrids were not obtained but for very few exceptional cases; four intermediate individuals between the small and middle races were captured from the Asahi River among more than 1500 collections of both races there (Saitoh, unpublished).

Table 3. Quantification for the nine qualitative characters of the seven local races.

Character/Score	-1	0	1	2	3
(1) L ₁	—	row of many spots	row of a few spots	stripe	—
(2) L ₂	—	well developed	degenerated	absent	—
(3) L ₃	—	degenerated	well developed	—	—
(4) L ₄	well developed	variable	absent	—	—
(5) L ₅ (surface layer)	—	male striped, female spotted	incomplete stripe	almost complete stripe	complete stripe
(6) L ₅ (deeper layer)	—	conspicuous	inconspicuous	—	—
(7) Caudal spots (surface layer)	one large, one small spots	two small spots	two large spots connecting into one	—	—
(8) Caudal spots (deeper layer)	two small spots	two medium sized spots	two large spots	—	—
(9) Caudal color pattern	a few arcuate bands	a few rows of small speckles	with a faint marginal band	with a broad marginal band	—

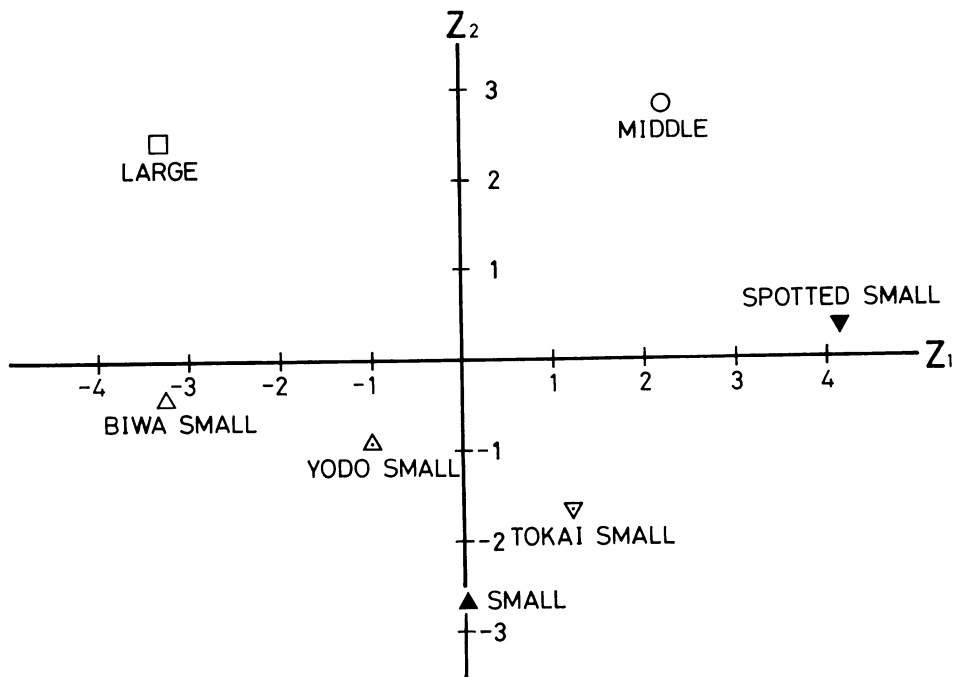


Fig. 6. Morphological diversification reflected on the plain of two major principal components (Z_1 , Z_2) in which 85% of the total variance is covered. Analysis is based upon correlation matrix of quantified 12 characters (see Tables 2, 3).

Analysis of morphological variation

To evaluate morphological variation among the seven local races, we employed principal component analysis based on the correlation matrix of 12 characters (nine on the color pattern, three on the vertebral counts and position of the dorsal fin). Qualitative characters such as color pattern were quantified by scoring for diversification from the character state of the Tokai small race or spotted small race (Tables 3, 4), both of which we suppose

to be more generalized forms as mentioned below.

Phenotypic differences of the seven local races are reflected on the plain of two major principal components (Fig. 6.; Z_1 , Z_2) which cover cumulatively 85% of the total variance. The Z_1 -axis is mainly influenced by the differences in the color pattern, and the Z_2 -axis by the variation in the vertebral counts and position of the dorsal fin. When nearest two races are connected in turn, a morphological gradient is seen as follows: Large race—Biwa small race—Yodo small race—small race—Tokai small race—spotted small race—

Table 4. Character states in 12 morphological features of the seven local races. Characters on the color pattern (1-9) are quantified in Table 3. Character No. 10, abdominal vertebrae; 11, caudal vertebrae; 12, position of the dorsal fin.

Race/Character	1	2	3	4	5	6	7	8	9	10	11	12
Large race	2	2	0	1	3	0	1	1	2	21.4	21.4	15.1
Biwa small race	1	2	0	1	3	0	1	1	2	20.0	22.3	14.1
Yodo small race	0	1	0	0	2	0	0	1	1	20.2	22.5	14.5
Small race	0	0	0	0	1	0	0	1	1	19.8	21.5	13.7
Tokai small race	0	0	0	0	0	0	0	0	0	20.1	20.8	14.2
Spotted small race	0	0	1	-1	0	1	-1	-1	-1	20.7	21.3	14.3
Middle race	1	1	1	0	2	1	-1	-1	-1	21.1	21.6	14.9

middle race.

Minamori (1960) asserted that the local races could be divided into three biological species. However, there is not such a grouping reflected on the plain in Fig. 6 to accord with his statement. Phenotypic difference between the large race and its nearest smaller race (Biwa small race) is even smaller than the variation within the smaller races. A similar situation is also seen in the middle and spotted small races.

Discussion

The striated spined loach as a species group. In this study we tentatively put the seven local races together into the so-called striated spined loach. They all have a roundish lamina circularis and a more or less striated coloration, which is the diagnostic character of this form, on the lateral side of the body.

There is, however, a great morphological variation among the seven local races. The large and Biwa small races appear to have a more typical color pattern, if we employ Ikeda's (1936) diagnosis. However, these two races are not what was originally described as stated below. On the contrary, the Tokai small and spotted small races are morphologically intermediate between *Cobitis taenia striata* and *C. taenia*. These two races are, we suppose, more generalized forms of the genus *Cobitis*, because of the following two reasons: (1) Most species in the genus as well as *C. taenia* commonly have spotted L_5 . (2) Striation of L_5 appears at a later developmental stage (Saitoh, 1984).

It is clear that the so-called striated spined loach is neither monotypic nor one of the local populations of *Cobitis taenia* because of a great differentiation in many aspects. This study revealed that there are seven local races which are more or less morphologically distinguishable from each other. Karyological differentiation among some of them was also reported (Saitoh et al., 1984; Ueno and Ojima, 1976; Ueno et al., 1980). Moreover, isolation by hybrid sterility or hybrid breakdown among local races was found (Minamori, 1956). The striated spined loach should therefore be regarded as a species group, the "*striata* type of the *Cobitis taenia* complex". We suppose that this is a subgroup of the *C. taenia* complex in which many spined loaches having a "*taenia*"-type roundish lamina circularis may be listed.

Species problem within the striated spined loach.

Minamori (1956) reported isolating mechanisms by hybrid sterility or hybrid breakdown among five local races of the striated spined loach. He found that the large race is almost completely isolated from the other four races and so is the middle race, but that the three smaller races are scarcely isolated from each other. He claimed from these results that the striated spined loach, which had been thought to be a local population of *Cobitis taenia*, could be divided into three biological species; the large and middle races are both independent species and the three smaller races are settled into the third species (Minamori, 1960). However, he did not assign any taxonomic nomenclature to them.

His conclusion on the species status of this group is supported in this study. In the three cases of sympatric distribution of two races, intermediate individuals which were regarded as hybrids were not found but for very few exceptional cases among a great deal of collections. We suppose, therefore, the large and middle races are both completely isolated from their coexistants.

In this study we described two new smaller races, the Yodo small race and the Tokai small race. We suppose that they also belong to the species of the smaller races, because the Yodo small race is intermediate between the Biwa small and small races and the Tokai small race is between the small and spotted small races in morphological aspects. More detailed studies, however, are needed to test this assumption.

Species status and morphological diagnosis. The species status of the striated spined loach asserted by Minamori (1960) based on hybridization experiments is persuasive. It is supported in the present study in terms of three cases of sympatrics without effective hybridization.

However, the species status advanced by Minamori (1960) cannot be expressed by morphological variation among the seven local races as shown in Fig. 6. The Biwa small race is strikingly different from the spotted small race in spite of their conspecificity. On the contrary the Biwa small race closely resembles the species of large race, and the spotted small race is also very similar to the species of middle race.

The above-mentioned facts suggest that the specific status in this group of fishes could hardly be shown by morphological observations employ-

ed here. This also implies a taxonomic difficulty. We suppose that this is because each local race is a certain evolutionary unit in this group; some of the races differentiated to the species level and the others did not. The fact that each local race occupies rather continuous area also suggests this supposition. Each of them might have dispersed during rather recent geological times from a small founder population. This conclusion is the case even when the Yodo small and Tokai small races, whose species status are not very clear, are omitted, because the other three smaller races contain the full extent of morphological variations.

Taxonomic problem. Now we have no reason to put the seven local races of the so-called striated spined loach together into *Cobitis taenia striata*. Obviously there should be some new species or subspecies among them.

There are, however, some difficulties for taxonomic nomenclature of the seven local races. First, it is not clear which race is the original *Cobitis taenia striata* described by Ikeda (1936). In the original description of *C. t. striata*, the depository of the type specimen(s) was not designated, but Osaka and Kagawa are only mentioned as the type localities. In Kagawa (Fig. 5: site 41–45), only the species of middle race is collected, but there are two sympatric species (the Yodo small race and the species of middle race) in Osaka (the Yodo River; Fig. 5: site 13). It is therefore unclear which is the originally described one.

Second, it is still unclear which species belongs to the same species as the European population of *Cobitis taenia*, or whether all the seven races are specifically different from it or not. It is too dangerous to employ morphological evidence to test it. In the karyological characters, there is a slight difference between the European *C. taenia* and Japanese diploid races. The European form has 32 mono-armed chromosomes (Cataudella et al., 1977), while the Japanese diploids generally 34 (Takahashi and Oka, 1976; Ueno and Ojima, 1976; Ueno et al., 1980; Saitoh et al., 1984). Increase or decrease in number of mono-armed chromosomes may be explained by pericentric inversion. However, this kind of small variation is not crucial.

At present, only the species of large race, tetraploid form, can be taxonomically named because of its unique karyotype from which reproductive isolation can easily be assumed. The description

of the new species should be done elsewhere.

Very recently, Kimizuka in Mizuno and Goto (1987: 61–70) classified the so-called striated spined loach into two groups. He put the large, Biwa small, and middle races to *Cobitis taenia striata*, and the small, Tokai small, and spotted small races to *Cobitis taenia* subsp. We completely disagree with his statement for the following reasons: 1) Kimizuka employed only the intensity of striation in the color pattern for the evidence of his grouping. We showed from 12 characters that there is no grouping which corresponds to his. 2) He put a number of species together into a single subspecies, *C. t. striata*. It is not the orthodox view to regard bisexual tetraploid and diploid as conspecific. 3) He put all local races to the same species, *C. taenia*. In contrast to him, we challenged here to divide this group of fish into the species of large race, the species of smaller races, and the species of middle race,

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スジシマドジョウ種群における地方的分化

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スジシマドジョウの7地方種族(大型・ピロ小型・淀小型・小型・東海小型・点小型・中型の各種族)の形態を比較した。7種族はそれぞれ独自の分布域を持ち、形態的に大きく分化していた。2種族が同所的にみられた3つのケースでは、雑種個体はほとんど見られなかった。したがって、従来スジシマドジョウと呼ばれてきたものは3つの種からなる種群であると考えられる。ただし、ヨーロッパの*Cobitis taenia*に対する日本産集団の分類学的位置づけが不明確なため、命名の問題は今後に残された。今回調べた種の形態的分化の程度を検討すると、種内変異の方が種間変異より大きい例がみられた。

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