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Color Pattern and Morphological Features of Dwarf Loach, *Kichulchoia brevifasciata* (Pisces: Cobitidae) from Korea

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Color patterns (including breeding colors), growth features and sexual dimorphism of the dwarf loach *Kichulchoia brevifasciata* were studied at a stream in Geumsan–myeon, Goheung–gun, Jeollanam–do, Korea. An oblique stripe from the snout tip to the eye disappeared with fish growth, concurrent with an increasing number of oval dots on the head. The opercular rim became golden–greenish during the spawning season. No significant morphological features were apparent between sexes, excepting females attained a larger body size.

Key words: color pattern, morphology, spawning season

INTRODUCTION

The freshwater fish, Family Cobitidae, distributed widely in Europe, Asia and Morocco, currently includes 177 species in 26 genera (Nelson, 2006; Kim, 2009). Cobitid fishes of Korea were classified as 16 species in 5 genera (Kim, 2009) on the structure of the lamina circularis at the base of pectoral fin in males (Vladykov, 1935), color patterns on the lateral body side and scale structure, according to external identification of the Cobitidae fishes (Mizuno, 1970; Kim, 2009).

Among Cobitidae fishes, genus *Kichulchoia* show remarkable morphological characters as caudal peduncle shorter than head, no Gambetta's zone on body sides (Gambetta, 1934), no lamina circularis, and 4 unbranched anal fin rays and 6 branched dorsal fin rays, respectively (Kim and Lee, 1995; Kim *et al*., 1997; Kim *et al*., 1999; Kim, 2009).

The dwarf loach, *Kichulchoia brevifasciata* (Kim and Lee, 1995), initially described as genus *Niwaella* (*N. brevifasciata*), was considered distinct from species in closely–related genera in lacking a dark oblique line from the snout to the eye and lamina circularis (Kim and Lee, 1995). Although the species was later placed in the new genus *Choia*, on the basis of 4 branched rays in the anal fin, by Kim *et al*. (1997), the latter name was preoccupied and subsequently replaced as *Kichulchoia* finally by Kim *et al*. (1999).

Subsequent investigations on *K. brevifasciata* have discussed its phylogenic relationships, following a molecular study (Kim *et al*., 2000; Šlechtová *et al*., 2008), distribution (Chae and Yoon, 2007) and chromosome numbers (Kim and Kim, 2008). However, there have been no detailed morphological or ecological studies following the initial description of the species.

By reason of *K. brevifasciata* is restricted to the extreme southwestern region of Korea and is under threat of extinction (Kim and Kim, 2008; Kim, 2009), the present study aimed to accumulate basic information pertinent to phylogenetic and ecological considerations, including lateral line and size–related color pattern variations, spawning colors, and morphological differences between females and males.

MATERIALS AND METHODS

A total of 50 individuals were captured for recording general color pattern variations, growth characteristics and sexual dimorphisms, using a hand net (mesh size 1 mm) in a stream in Geumsan–myeon, Goheung–gun, Jeollanam–do, Korea in August to October, 2006. The specimens were subsequently fixed in 10% formaldehyde and deposited in the Ichthyology Laboratory, Faculty of Biological Science, Chonbuk National University, Jeonju, Korea (CNUC). Fifty individuals were captured similarly between April and August 2006, so as to cover the spawning season (May to July) (Kim *et al*., unpublished data), their spawning colors recorded in the field and the fish released in the same area.

Color pattern variations were investigated following Gambetta (1934), Saitoh and Aizawa (1987) and Nalbant (1963). Following confirmation of sex by gonad dissection, morphological measurements were recorded and expressed as percentages of standard length (SL) or head length (HL) for adult males and females, using 1/20 mm dial calipers. Dorsal and ventral fin origins and pectoral fin ray shape were determined using soft X–rays (Hitex HA–80, Japan). Data for the sexual dimorphisms were compared using the two tailed Student's t–test (highly significant defined as $P<0.001$; significant as $P<0.05$).

RESULTS

Color pattern of dorsum

Dorsal color patterns were generally dark brown, being classified into major types A, B and C (Fig. 1). Type A – mid–dorsally 13 to 17 rectangular blotches distinct from dense reticulate pattern of spots on dorso–lat-

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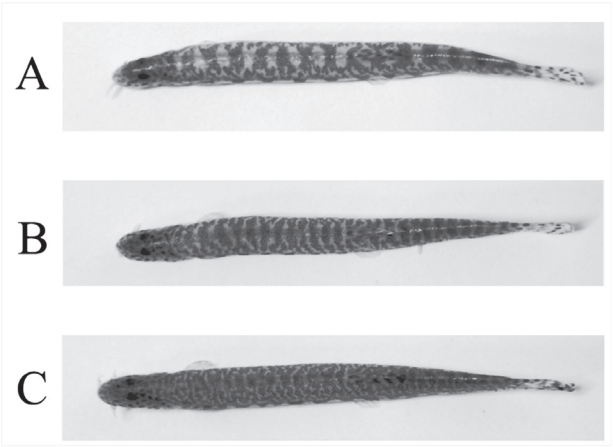

Fig. 1. Three types of dorsal color patterns in *Kichulchoia brevifasciata*.
A: Rectangular blotches with similar width interspaces; B: Many thin rectangular bands closely associated with upper body speckling; C: Bands poorly formed, having a vermiculate appearance.

eral region and separated by similar width interspaces (n = 15) (Fig. 1–A). Type B – mid–dorsally 22 to 25 dense thin rectangular bands united with speckled pattern on dorso–lateral region and separated by narrower width interspaces (n = 10) (Fig. 1–B). Type C – similar to Type B, but with bands poorly formed and having a vermiculate appearance (n = 5) (Fig. 1–C).

Color pattern on lower lateral body surface

Base color of body is light pale yellow and color of speckles on the lateral side is deep dark brown than upper part of body speckles. Generally 12 to 22 elongated spots, showing significant individual variation in shape, including oval, semicircular or bow–like, triangular, square and rectangular (Fig. 2–A, C, D) although more often an extended triangular bar (Fig. 2–B). Sometimes two or three spots coalesced into one (Fig. 2–C).

Fig. 2. Lower lateral color pattern variations in *Kichulchoia brevifasciata*.
A: Triangular, square and rectangular spots, 66.31 mm in TL; B: Vertically extended triangular spots, 53.25 mm in TL; C: Two or three coalesced spots, 52.36 mm in TL; D: Oval, semicircular or bow–like spots, 50.62 mm in TL.

Color pattern transition on the head

A dark brown line running obliquely from the barbel through the eyes to the occiput (Fig. 3) in juveniles (10 to 30 mm TL) (Fig. 3–A, B and C) becomes progressively less distinct with growth in adults (30 to 50 mm TL) (Fig. 3–D, E and F), being almost completely lost in adults greater than 50 mm TL (Table 1). Concurrently, the number of oval dots on the head gradually increased from 6 to 33 (Table 1) (Fig. 3).

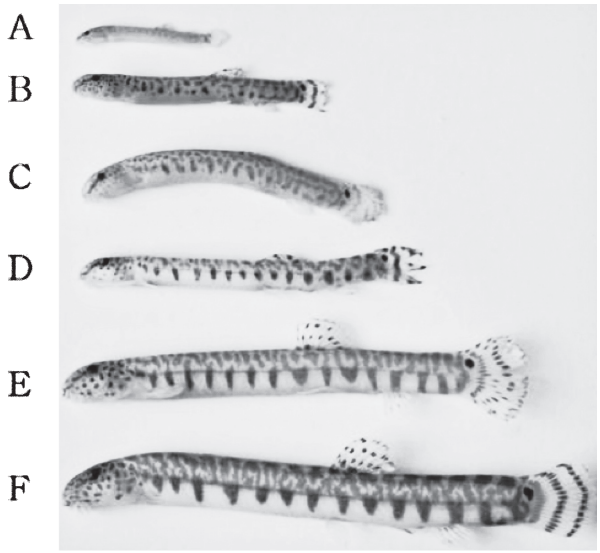

Fig. 3. Color pattern variations on the head of *Kichulchoia brevifasciata*.
A: Juvenile, 15.64 mm in TL; B: Juvenile, 26.09 mm in TL; C: Subadult, 33.25 mm in TL; D: Subadult, 34.97 mm in TL; E: Adult, 47.25 mm in TL; F: Adult, 53.62 mm in TL

Table 1. Collection data for *Kichulchoia brevifasciata*, used to investigate color pattern changes on the head

Collected date	Examined specimens	TL (mm)	No. of dots	Stripe band
			(On the head)	
August 26, 2006	5	10–20	6±2	vivid
March 24. 2007	7	20–30	17±4	vivid
September 10. 2007	9	30–40	20±2	faint
September 24. 2007	5	40–50	30±4	faint
September 24. 2007	5	50–60	33±3	lost

Color in spawning season

The opercle and rim of the opercular region became bright golden–greenish, the hue extending to the base of the pectoral fin (Fig. 4–B) than non–spawning season (Fig. 4–A). Each pectoral fin ray was characterized by a golden glitter. The sex for breeding color could not be verified because *K. brevifasciata* doesn't have distinct external sexual dimorphisms.

Comparison of morphometric data between females and males

No clear sexual dimorphism in morphometric char-

acters was apparent between 10 males and 10 females ($P>0.05$, two tailed Student's *t*–test, n = 20), although females were larger than males, 41.0 to 49.8 and 33.6 to 43.4 mm SL, respectively ($P<0.001$, two tailed Student's *t*–test, n = 20) (Table 2).

DISCUSSION

Three endemic Korean cobitid genera, *Iksookimia, Koreocobitis* and *Kichulchoia*, are separated from *Cobitis* on the basis of presence or absence of Gambett's zones on the side of the body, body color pattern, the form of the lamina circularis (in males), numbers of unbranched anal fin rays and molecular data (Nalbant, 1993; Kim *et al*., 1997; Kim *et al*., 1999; Kim, 2009). Kim and Lee (1995) noted that *K. brevifasciata* resembled *Iksookimia koreensis* and *I. longicorpa* in appearance, whereas Kim *et al*. (1997) considered it similar to *I. koreensis* and *I. pumila*. However, the present study demonstrated notable color pattern differences between *K. brevifasciata* and species in closely–related genera.

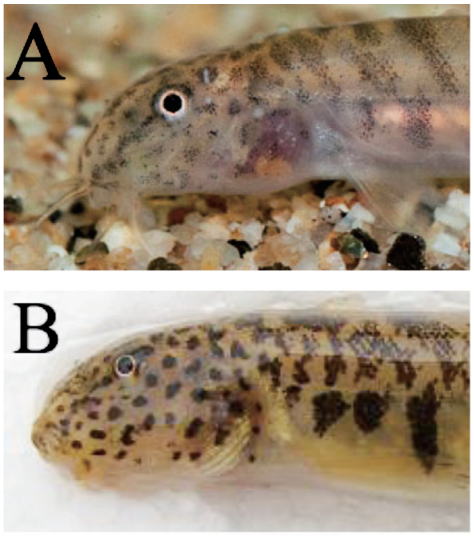

Fig. 4. *Kichulchoia brevifasciata* colors during non–spawning season (A) and spawning season (B), June, 2006.
A: 54.55 mm in TL; B: 57.31 mm in TL

Clearly *K. brevifasciata* has a greater range of color variations than previously recognized; dorsal blotches numbering 13~25 (cf. 17~21 *in* Kim and Lee, 1995) and comprising 3 types of shape variations (Fig. 1) (cf. horizonal bands in *I. koreensis in* Kim, 1975). Continuous color patterns with irregular speckles (Kim and Lee, 1995) on the upper body were represented by 2 types, including many narrow bands (Fig. 2–A), as in *I. pumila* (Kim and Lee, 1987) and *I. longicorpa* (Kim *et al*., 1976) and wide bands with distinctive cloudy speckles (Fig. 2–B, C and D) as in *I. koreensis*. In addition, *K. brevifasciata* had a greater range of markings on the side of the body (12–22 cf. 13–19 *in* Kim and Lee, 1995) with greater variations in form and length, including ventrally–directed extensions (Fig. 2), than in *Iksookimia*.

Local variations, resulting in differing color patterns, in *Niwaella delicate*, have been reported (Niwa, 1976) and Kitagawa *et al*. (2001) noted that although two morphological types of that species could be recognized (allied to distribution patterns), genetic analysis revealed intraspecific level differentiation only. The non–occur-

Table 2. Comparison of morphological proportional measurements** of female and male *Kichulchoia brevifasciata* from Geumsan–myeon, Goheung–gun, Jeollanam–do, Korea

	Females (10 specimens)			Males (10 specimens)			*P**
	Mean	Range	SD	Mean	Range	SD	
Standard length (mm)	46.5	41.0–49.8	3.2	37.5	33.6–43.4	3.1	< 0.001
In standard length (%)							
Head length	18.3	17.0–19.3	0.7	19.2	17.4–20.9	1.1	0.1
Body depth	12.7	10.9–14.0	0.9	12.0	10.8–12.8	0.7	0.1
Predorsal length	57.9	56.5–59.8	1.0	57.7	56.3–59.0	0.9	0.6
Preventral length	58.2	56.6–59.2	0.8	57.8	56.0–59.4	1.1	0.4
Preanal length	79.3	77.9–80.6	0.9	78.7	77.4–80.9	1.1	0.1
Ventral–anal length	22.9	20.5–24.2	1.1	22.2	20.1–23.9	1.4	0.3
Caudal peduncle length	15.9	14.8–17.0	0.6	15.9	14.2–17.5	1.0	0.9
Caudal peduncle depth	10.6	9.7–11.5	0.6	11.1	10.3–11.7	0.5	0.1
In head length (%)							
Snout length	44.0	41.0–47.0	2.0	43.2	40.2–45.8	2.1	0.5
Eye diameters	16.2	14.4–17.4	0.9	15.4	13.8–17.3	1.1	0.1
Interorbital width	17.9	12.5–20.7	2.4	17.3	13.9–22.6	2.7	0.7
3rd barbel length	30.2	26.1–34.2	2.4	28.3	23.2–32.3	3.2	0.2

*By two tailed Student's *t*–test
** Following Hubbs and Lagler (2004).

rence of other cobitid fishes in the present study area and consistency in morphological characters of *K. brevifasciata suggest* that the color pattern variants may be significant only at the intraspecific level or lower.

Color pattern changes on the side of the body have been reported during the spawning season in Korean *Cobitis lutheri* (Kim, 1997). Although *K. brevifasciata* showed no spawning–associated color pattern changes on the body, a bright golden–greenish hue was apparent from the opercular region to the rim of the pectoral fin, the rays of the latter having a golden glitter.

Cobitid species show sexual dimorphism as follows: females longer than males (Kim and Ko, 2005), pectoral fin with a lamina circularis and a sharp margin in males (except in *Niwaella* and *Kichulchoia*) (Kim, 1997; Kim, 2009). Although *Cobitis shikokuensis* also lacks a lamina circularis, some pectoral fin branched rays are thickened with sharp margins in males (Suzawa, 2006). The present investigation of *K. brevifasciata* found females to be 5 to 20 mm larger than males, but no other sexually dimorphic characters were apparent.

Cobitis and *Iksookimia* species generally have a distinct line on the head running obliquely from the tip of the snout to the edge of the eye (Kim, 1997; Kim, 2009) and Suzawa (2006) used existence of a similar band on the cheek to distinguish between *C. takatsuensis* and *C. shikokuensis*. Although *K. brevifasciata* and the genus *Niwaella* have been reported as not having a line from the snout tip to the eye (Kim and Lee, 1995; Kim, 1997; Kim, 2009), such a line was apparent in immature specimens examined during the present study, gradually disappearing with growth. Because developmental characters are the proximate cause of morphological traits acquired during evolution (Laubichler, 2000), seen in modifications of the second pectoral fin ray present in ancestral Cobitidae and lost in *Niwaella, Kichulchoia* and *Sabanejewia* (Šlechtová *et al*., 2008), an oblique line on the head may also be considered to be an ancestral developmental character of Cobitidae.

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