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Habitat Features of Dwarf Loach, *Kichulchoia brevifasciata* (Pisces: Cobitidae) from Korea in a Conservative Perspective

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The small cobitid fish *Kichulchoia brevifasciata*, a Korean endemic found in the extreme southwestern part of the Korea, lives in small streams of 5–65 cm in depth, with pebble bottoms with some sands and slow water currents. The habitat is shared with *Zacco koreanus*, *Rhynchocypris oxycephalus*, *Rhinogobius brunneus*, *Liobagrus mediadiposalis*, *Misgurnus anguillicaudatus*, *Gymnogobius urotaenia* and *Tridentiger brevispinis*. A mark and recapture experiment showed that the population density is 11.1/m² in the major habitat. Habitat destruction and stream modification are major threats to the continued existence of the species. Special protection status as an endangered species is urged, with special emphasis on habitat conservation and local conservation awareness.

Key words: conservation, ecology, habitat, population

INTRODUCTION

The small cobitid fish *Kichulchoia brevifasciata*, a Korean endemic, is restricted to localities in Jeollanam-do in the extreme southwestern part of Korea (Fig. 1), reported as Yamak-li, Pungyang-myeon, Goheung-gun; Okang-li, Podu-myeon, Goheung-gun; Nam-myeon, Yeosu-si; Geumsan-myeon, Goheung-gun (Kim and Lee, 1995; Kim, 1997; Kim and Kim, 2008).

Following its initial description as a new species (Kim and Lee, 1995), *K. brevifasciata* has been included in both molecular phylogenetic studies (Kim *et al.*, 2000; Šlechtová *et al.*, 2008) and karyotype analysis (Kim and Kim, 2008), in addition to confirmation of its known distribution (Chae and Yoon, 2007).

The species inhabits small shallow water streams with gravel beds and low water currents (Kim and Kim, 2008; Kim, 2009). However, specific habitat details have not been reported. It is clear that the habitat of *K. brevifasciata* is very limited in extent supporting only a very small population in southwestern Korea at the present time (Kim, 2009). Despite the serious risk of extinction arising from future habitat degradation, *K. brevifasciata* is not still designated as an endangered species (Ministry of Environment, 2008). Therefore, the purpose of the present study aimed to determine habitat features and population size of *K. brevifasciata*, thereby providing data for a conservation plan for the species.

MATERIALS AND METHODS

The habitats of *Kichulchoia brevifasciata* have

been listed as four points (Kim and Lee, 1995) (Fig. 1), as Yamak-li, Pungyang-myeon, Goheung-gun, Jeollanam-do; Okang-li, Podu-myeon, Goheung-gun, Jeollanam-do; Nam-myeon, Yeosu-si, Jeollanam-do; Geumsan-myeon, Goheung-gun, Jeollanam-do, were examined to confirm whether *K. brevifasciata* is existent or not in the present. In addition, environmental factors surrounding the habitats were investigated from four points, such as dissolved oxygen (DO), pH, conductivity (a measure of water quality) with any modification of the habitats by artificial construction for comparison with present habitat conditions in thought to be relatively stable environment of the stream from April to June 2006 monthly.

From the results in this survey of the four points, a small stream in Geumsan-myeon, Goheung-gun, Jeollanam-do currently confirmed existence of the *K. brevifasciata* was examined mainly again to acquire detailed information as the main habitat conditions. Air temperature and water temperature, were measured at the end of the month from January 2006 to May 2007 in an identified habitat of large individuals of *K. brevifasciata*. The individuals were confirmed from upstream to downstream, but mid-stream, covered with only some large rocks and water flow was sometimes disconnected about 1km flowing to under the river bed, was not included the analysis of the stream features for the benthic fish, *K. brevifasciata*. The stream characteristics between upstream and downstream were examined in May 2007 including water width and depth (measured by tapeline), water velocity (tachometer, global water instrumentation) stream shape (Kani, 1944) and stream bed type (Cummins, 1962). Upstream, mid-stream and downstream fish fauna were sampled monthly from May 2006 to May 2007 and collected individuals calculated as the percentage of the average population.

Mark and recapture experiments were attempted at a number of sites. However, most returned limited num-

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bers of fish (less than 20 captured per month) and habitat disruption due to low and intermittent water flow, sometimes disrupted for up to 1 km, became problematic. Then after certain attempts, a mark and recapture experiment was performed successfully from April 23, 2007 to May 7, 2007 at a restricted site at the upper end of the major habitat, prior to the spawning and rainy seasons.

Sampling was conducted for 2 hours at each visit on a suspected isolated population in an area of favored stream habitat (50 m×3 m). Each adult individual captured (>40 mm in TL) was marked on the initial capture by clipping the right ventral fin whilst anesthetized and subsequently released unharmed at the point of capture. Estimation of the population size followed Chapman (1951) and Seber (1970), being suitable for low sample sizes. The expected population size (determined from the first and second visits) was calculated as follows:

$$N = (M + 1)(C + 1)/(R + 1) - 1$$

where N is the estimate of total population size, M is the total number of individuals captured and marked on the first visit, C is the total number of individuals captured on the second visit, and R is the number of individuals captured on both visits.

RESULTS

Recent changes in habitat conditions to the present day

At the time of its initial description, *Kichulchoia brevifasciata* was more or less broadly distributed in southwestern Korea, including Goheung-gun and Yeosu-si, Jeollanam-do (Fig. 1) (Kim and Lee, 1995).

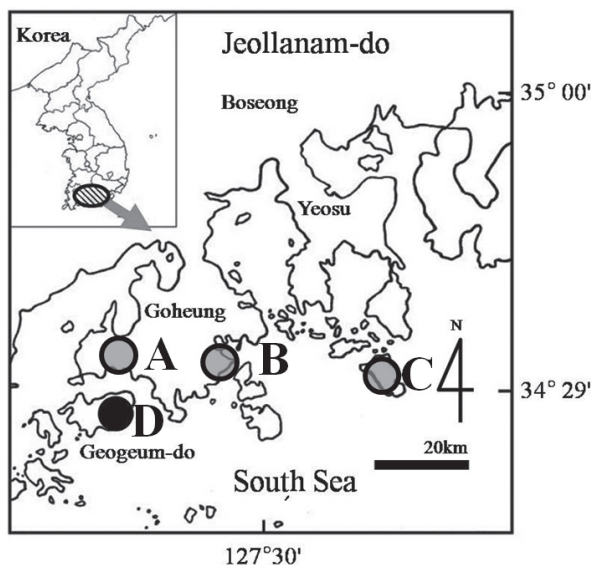


Fig. 1. Map of sites examined for populations of *Kichulchoia brevifasciata* (all in Jeollanam-do, Korea). A, Yamak-li, Pungyang-myeon, Goheung-Gun; B, Okang-li, Podu-myeon, Goheung-gun; C, Nam-myeon, Yeosu-si; D, Geumsan-myeon, Goheung-gun.

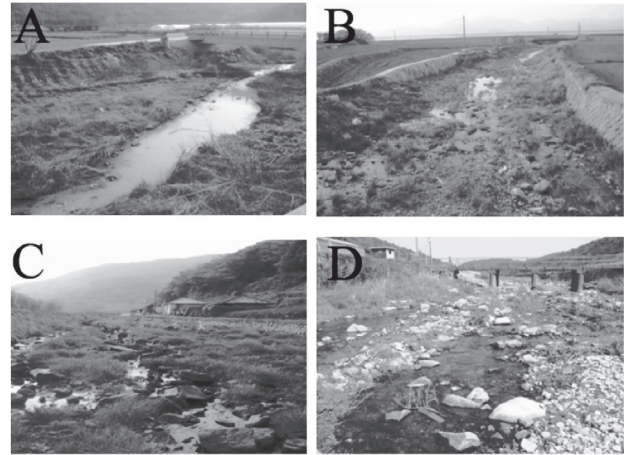


Fig. 2. Present (D) and former (A, B and C) habitats of *Kichulchoia brevifasciata* as in Fig. 1.

Table 1. Physical data from April to June 2006 for present and former habitats of *Kichulchoia brevifasciata*

Localities	DO (mg/ L)	pH (mol/ L)	Conductivity (qs/ cm)
A	8.5 ± 0.3	7.3 ± 0.2	114.3 ± 2.8
B	8.1 ± 0.3	7.1 ± 0.2	85.6 ± 3.3
C	—	—	—
D	9.4 ± 0.2	6.9 ± 0.1	81.3 ± 2.7

A: Yamak-li, Pungyang-myeon, Goheung-Gun, Jeollanam-do, Korea; B: Okang-li, Podu-myeon, Goheung-gun, Jeollanam-do, Korea; C: Nam-myeon, Yeosu-si, Jeollanam-do, Korea; D: Geumsan-myeon, Goheung-gun, Jeollanam-do, Korea

However, the present survey confirmed individuals only in one small stream at Geumsan-myeon, Goheung-gun (Fig. 1-D and Fig. 2-D). Geumsan-myeon, Goheung-gun (Fig. 2-D), where *K. brevifasciata* still maintains relatively stable populations, having better clear water quality (9.4±0.2 mg/L in DO and 81.3±2.7 qs/cm in conductivity) than the other sites (Fig 2-A and B), where *K. brevifasciata* are no longer found (Table 1).

A former *K. brevifasciata* habitat at Yamak-li, Pungyang-myeon, Goheung-Gun (Fig. 1-A and Fig. 2-A) is populated by an exotic species (American bull frog, *Rana catesbeiana*), the stream having been severely modified by cement concrete construction and a factory constructed upstream from April to June 2006.

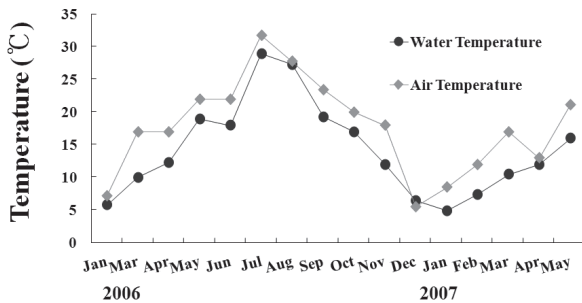
Major habitat features

The stream at Geumsan-myeon was about 4.5 km in length, the main habitat of *K. brevifasciata* being located about 3.5 km from the stream mouth. Lower stream width varied between 1.5 (winter)~16 m (summer), with a depth of 13~65 cm and water velocity of 0~6.5 cm/sec. Upper stream width varied between 0.5 and 3.5 m, depth between 5~18 cm and water velocity from 0~3.7 cm/sec (Table 2). The overall stream was classified as Aa, following Kani (1944), becoming Aa-Bb towards the stream mouth. Monthly air and water temperatures are given in Fig. 3, the highest recordings (in

Table 2. Stream characteristics in the main habitat of the *Kichulchoia brevifasciata* studied in Geumsan-myeon, Goheung-gun, Jeollanam-do, Korea in May 2007

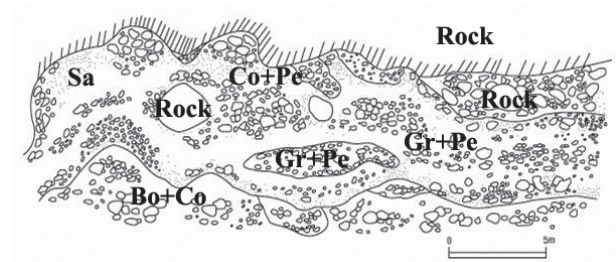
	Water width (m)	Water depth (m)	Water velocity (cm/sec)	Stream form	Bottom structure (%) [*] (B:C:P:G:S)
Upstream	0.5~3.5	0.05~0.18	0~3.7	Aa	10:20:20:20:30
Downstream	1.5~6.0	0.13~0.65	0~6.5	Aa-Bb	10:10:20:30:30

^{*} Following Cummins (1962): B (boulder, ~256 mm); C (cobble, 256~64 mm); P (pebble, 64~16 mm); G (gravel, 16~2 mm); S (sand, 2 mm)

**Fig. 3.** Monthly changes in air and water temperatures from January, 2006 to May, 2007 in Geumsan-myeon, Goheung-gun, Jeollanam-do, Korea.

July 2006) being 31.8°C and 29.1°C, respectively, and the lowest, 5.5°C (in December 2006) and 4.9°C (in January 2007), respectively. After inundation during the summer, all channels of the stream were temporarily covered by an algal bloom of the genus *Spirogyra*.

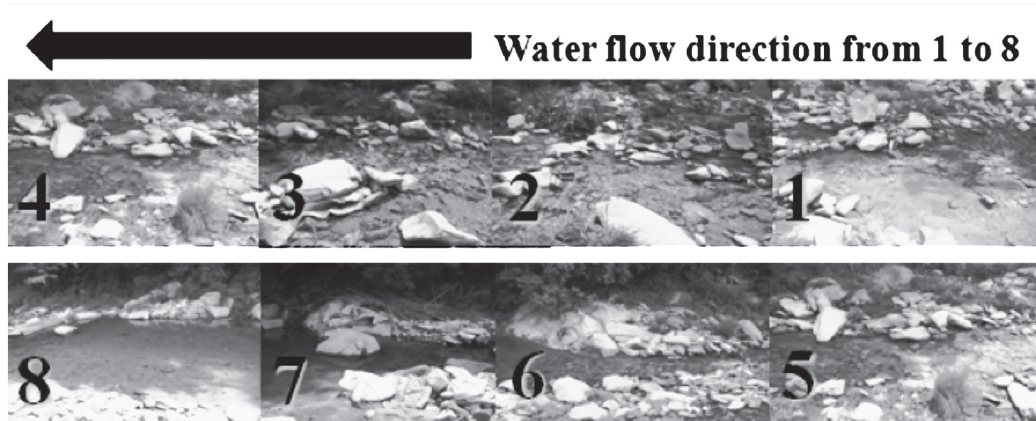
Observations of active *K. brevifasciata* were made between March and November 2006 (in air and water temperatures >10°C, adults being located under or between pebbles and gravel, but not in sand-dominated habitat (Figs. 4 and 5). The hibernation period was regarded as from December 2006 to February 2007 (in air and water temperatures <10°C). During the hibernation period, the water level in the main habitat area was lowered drastically, a very few inactive individual *K. brevifasciata* with empty stomachs being located deep in the substrate.

**Fig. 5.** Diagrammatic representation of substratum types in main habitat of *Kichulchoia brevifasciata* in Geumsan-myeon, Goheung-gun, Jeollanam-do, Korea.

Sa: sand; Gr: gravel; Pe: pebble; Co: cobble; Bo: boulder

The spawning season of *K. brevifasciata* extended from May to July 2006, in water temperatures between 19°C and 29°C. Juveniles (10~20 mm SL) were observed from August 2006 near the banks of the upper stream in low water velocity or inside the algal beds of the genus *Spirogyra*.

Other fishes present in the stream included *Zacco koreanus* (endemic) (relative abundance 31.3%), *Rhynchocypris oxycephalus* (20.5%), *Rhinogobius brunneus* (18.4%), *Liobagrus mediadiposalis* (endemic) (12%), *Misgurnus anguillicaudatus* (1.1%), *Gymnogobius urotaenia* (0.8%) and *Tridentiger brevispinis* (0.1%) (Fig. 6). The relative abundance of *K. brevifasciata* was 16.0%. *L. mediadiposalis* shared similar habitat with *K. brevifasciata* although in shallow, higher velocity waters. The former disappeared

**Fig. 4.** Overview of the main habitat of *Kichulchoia brevifasciata* in Geumsan-myeon, Goheung-gun, Jeollanam-do, Korea.

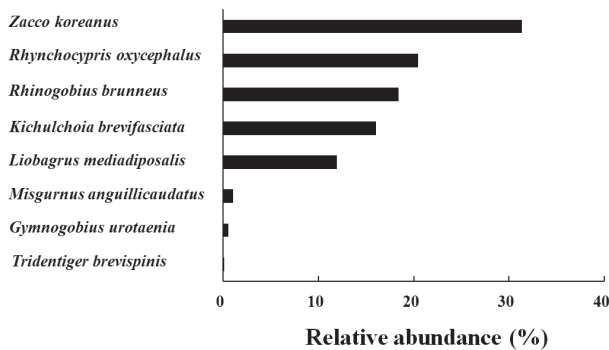


Fig. 6. Relative abundance of fishes collected from May 2006 to May 2007 (inclusive) in Geumsan-myeon, Goheung-gun, Jeollanam-do, Korea.

Table 3. Estimated population size following capture and recapture method of *Kichulchoia brevifasciata* in Geumsan-myeon, Goheung-gun, Jeollanam-do, Korea

Year, Month	Apr-May 2007
Gross area of research site (m ²)	156
Total number of 1 st captured individuals	123
Total number of 2 nd captured individuals	97
Captured on both visits	6
Sampling intervals (days)	15
Expected population size (individuals)	1735
By catch rate (%) – 1 st recapture	1%
Density (population size/ m ²)	11.1/m ²

gradually in May when *K. brevifasciata* showed enhanced activity and increased numbers. Although *Z. koreanus*, *K. brevifasciata* and *L. mediadiposalis* were observed in upper, mid- and downstream reaches, *R. oxycephalus* was restricted to upper and mid-stream sites, and *R. brunneus* and *T. brevispinis* to mid- and downstream sites.

Estimation of population size

A population size estimate (excluding juveniles) was conducted in April and May 2007 at the major upstream habitat (overall area 156 m²) (Table 3). Recaptured individuals (6) indicated a 1% recapture rate, the population at that site comprising 1735 adults at a density of 11.1 individuals per m².

DISCUSSION

During the present study, *Kichulchoia brevifasciata* was found only in a small (about 4.5 km in length) stream on Geoguem Island (Fig. 1), being absent in other previously-reported habitats (Table 4).

Although Kim *et al.* (1994) confirmed the species' existence on Geumo Island (Fig. 1-C), Chae and Yoon (2007) reported that population had become extinct. Significantly, the small streams characterizing the previously-confirmed habitats (Fig. 2-A, B and C) were

Table 4. Occurrence of *Kichulchoia brevifasciata* at examined sites

Localities	(Kim and Lee, 1995)	Present study
A	present	absent
B	present	absent
C	present	absent (Also Chae and Yoon, 2007)
D	present	present

A: Yamak-li, Pungyang-myeon, Goheung-Gun, Jeollanam-do, Korea; B: Okang-li, Podu-myeon, Goheung-gun, Jeollanam-do, Korea; C: Nam-myeon, Yeosu-si, Jeollanam-do, Korea; D: Geumsan-myeon, Goheung-gun, Jeollanam-do, Korea

extremely fragile, being narrow with limited water flow, and subject to continuing disturbance by stream development and flood control. In addition, the stream beds had been altered due to an adjacent factory construction, discharge of sewage (Fig. 2-A and D). Also, the construction of a debris barrier (about 1 km in length) at upstream of Geoguem Island (Fig. 1-D) finished in January 2007 may have also been a contributory factor in a small stream. The conflict between human needs for water resources and environmental conservation is often significant, particularly in cases of subsequently reduced stream flow and compounded problems due to water contamination (Gasith, 1992; Gasith and Resh, 1999). Therefore, it is considered that even small modifications to the fragile habitats of *K. brevifasciata* had a significant impact on those habitats.

The ichthyofauna recorded in the main habitat on Geoguem Island (Fig. 2-D) was similar to that of Geumo Island (Fig. 2-C), including *Misgurnus anguillicaudatus*, *Rhinogobius brunneus* and *Liobagrus mediadiposalis*. However, the dominant species differed, being *Zacco koreanus* and *Rhynchocypris oxycephalus* on Geoguem Island, and *R. brunneus* on Geumo Island.

Although the population size of *K. brevifasciata* in the optimal habitat area was determined as 11.1 individuals per m², it is probable that such a figure is misleading if applied to the entire stream, the actual overall population size being likely to be at much lower levels.

The preferred habit of *K. brevifasciata*, preferring gaps between flat pebbles on a gravel substrate is similar to that of *Cobitis shikokuensis*, which inhabits pebble dominant substrate with subsurface interstices under the shallow banks of clear water pools, rarely burrowing into the substrate. Accordingly, the recent extinctions of local populations of *K. brevifasciata* (Fig. 1-A,B and C) are considered to have resulted from habitat fragmentation and modification of the bed structure, similar to that reported for *C. shikokuensis* (Shizumu, 2002; Kawanish *et al.*, 2010; Kawanish *et al.*, 2011).

Despite the present habitat of *K. brevifasciata* on Geoguem Island (Fig. 1-D) still having high water quality and adequate conditions for the species, the likelihood of continuing human impact, such as stream bed

modification and construction of flood control measures, input of factory waste and pollution is ever present. In addition, high organic matter input may lower species' abundance and influence fish growth, even in otherwise unpolluted regions (Angermeier and Karr, 1994). Continuing uncontrolled habitat modification on Geogum Island by human activities may very likely result in the loss of the final known habitat of *K. brevifasciata* and the extinction of the species.

In spite of this, *K. brevifasciata* is not currently designated as an endangered species (Ministry of Environment, 2008). The impending permanent connection of Geogum Island to the Korean mainland by construction of the bridge will complete in December 2011, thereby removing the difficulty of access to the habitat of *K. brevifasciata*, is also likely to accelerate habitat destruction. Therefore, it is urgent that *K. brevifasciata* be designated as a special protected species in Korea and the habitat protected by the imposition of legal controls. Conservation activities are also essential for the re-establishment of optimum habitats and re-introductions of the species, with ongoing status assessments, in addition to the creation of conservation awareness in local residents.

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