

Distribution pattern of *Cobitis* (Telostei: Cobitidae) in northern Kyushu Island, Japan

Jun NAKAJIMA¹, Norio ONIKURA¹, Emi KITAGAWA², Tadao KITAGAWA³ and Shin OIKAWA¹

¹ Faculty of Agriculture, Kyushu University, 2506 Tsuyazaki, Fukuoka 811-3304, Japan;
e-mail: cyprin@sings.jp

² Osakana Research Institute, 3-2 Mitsugarasu, Nara 631-0061, Japan

³ Faculty of Agriculture, Kinki University, Nakamachi, Nara 631-8505, Japan

Received 27 November 2006; Accepted 21 March 2008

Abstract. The distribution patterns of seven *Cobitis* species are analysed, namely, *C. takatsuensis*, *C. biwae*, the yamato complex, the Kyushu form of *C. striata* (small race), *C. striata* (middle race), the Hakata form of *C. striata* (middle race), and the Onga form of *C. striata* (middle race) in the northern Kyushu Island, Japan. *C. takatsuensis* is distributed in the upstream areas of some rivers in the northeastern part of the island. The yamato complex is widely distributed in the northern part of the island. The other five species are distributed in five areas separated by mountains. Although the yamato complex and the four *striata* complex species are often distributed in the same river system, the former inhabit upstream areas, while the latter inhabit the downstream reaches. The results of this study reveal that habitat fragmentation by mountains and the difference in longitudinal distribution lead to this complicated distribution pattern.

Key words: Cobitinae, spined loach, geographical distribution

Introduction

The distribution patterns of freshwater fishes provide substantial geographical and biological information. Genuine freshwater fishes cannot migrate without connections of freshwater systems. Consequently, the heterogeneity in the geographic distribution pattern of genuine freshwater fishes results from changes in river systems and evolution of the fishes themselves (Watanabe 1998).

Kyushu Island is located in western Japan and occupies an area of 36,737 km². Kyushu is a mountainous island with plains covering a very small area. Although the rivers on this island are short and follow a steep course, there are approximately more than 1000 river systems. In addition, approximately 40 species of genuine freshwater fishes have been recorded in the rivers on this island (Azuma et al. 2001, Kitagawa et al. 2004, Nakajima et al. 2006b, Sakamoto & Tajima 1996). The seven *Cobitis* species—yamato complex (Y86, Y90, and Y94; *sensu* Saitoh et al. 2000), *striata* complex (the Kyushu form of the small race and the middle race), *C. biwae*, and *C. takatsuensis*—have been reported to inhabit the rivers of Kyushu Island (Saitoh et al. 2000, Saitoh 2001, Kitagawa et al. 2004). Hosoya (2000) used the scientific name *C. matsubarae* for the yamato complex. However Sawa & Aizawa (1983) had already stated that *C. matsubarae* is a junior synonym of *C. biwae*.

Recently, two additional species that genetically belong to the middle race of the *striata* complex (the Onga form and the Hakata form) were found (Kitagawa et al. 2005a, Nakajima et al. 2006a). Thus, a total of nine *Cobitis* species were found to be naturally distributed within a radius of only 150 km in the northern part of the island. In addition, all

of the *Cobitis* groups in northern Kyushu Island are only diploid or tetraploid groups. Hence, it is very important to conduct studies in this area to elucidate the mechanisms of speciation. However, to date, the distribution patterns of these nine *Cobitis* species on this island have not been studied.

In this study, the distribution pattern of *Cobitis* in the northern part of Kyushu Island was analysed, and the establishment of this distribution pattern discussed.

Materials and Methods

From 2003 to 2006, the distribution of the *Cobitis* species was surveyed in 75 river systems on northern Kyushu Island (Fig. 1). Fish specimens were caught by hand net and casting net. The cobitid specimens were classified based on the colour patterns on their body and the morphology of the lamina circularis at the base of the pectoral fins of males (Hosoya 2000, Saitoh 2001). We also compiled distribution data from the literature (Azuma et al. 2001, Kitakyushu Secondary School Gyobu 2001, Sakamoto & Tajima 1996). The three forms of the yamato complex cannot be distinguished morphologically (Saitoh et al. 2000); therefore, we analysed the distribution patterns of seven *Cobitis* groups, namely, *C. takatsuensis* (Fig. 2A), *C. biwae* (Fig. 2B), the yamato complex (Fig. 2C), the Kyushu form of *C. striata* (small race) (Fig. 2D), *C. striata* (middle race) (Fig. 2E), the Onga form of *C. striata* (middle race) (Fig. 2F), and the Hakata form of *C. striata* (middle race) (Fig. 2G). Although the three forms of the middle race are very similar, they are clearly distinguished genetically (Kitagawa et al. 2005a, Nakajima et al. 2006a). The morphological features of these *C. striata* species are currently under investigation.

Results

The distribution patterns of the seven *Cobitis* species in northern Kyushu Island are shown in Fig. 3. *C. takatsuensis* was found to be distributed in four river systems in the north-eastern part of the island. This species was collected from a mountain stream, captured from areas with a gravel-covered bottom and gentle currents. *C. biwae* was found to be distributed in two river systems in the eastern part of this island. We collected this species from the sandy bottom of the rivers. The yamato complex was widely distributed in the northern part of the island. This species was collected from the upstream and middle stream areas with sandy bottoms and gentle currents. Four *striata* complex species (the Kyushu form of the small race, the middle race, the Hakata form of the middle race, and the Onga form of the middle race) were found to be distributed in four areas separated by mountains. The environment of these habitats was very similar. These species were collected from the downstream areas of a relatively large-scale slow-flowing river system with a muddy bottom.

Discussion

The distribution pattern of *Cobitis* in the northern part of Kyushu Island was analysed. It was apparent that the *striata* complex and the yamato complex are widely distributed in this area. However, four species of the *striata* complex (the Kyushu form of the small race, the middle race, the Hakata form of the middle race, and the Onga form of the middle race) were found to be distributed in four areas separated by mountains. Geologically, the mountains of northern Kyushu Island are very old; the prototype of these mountains was formed 30 million

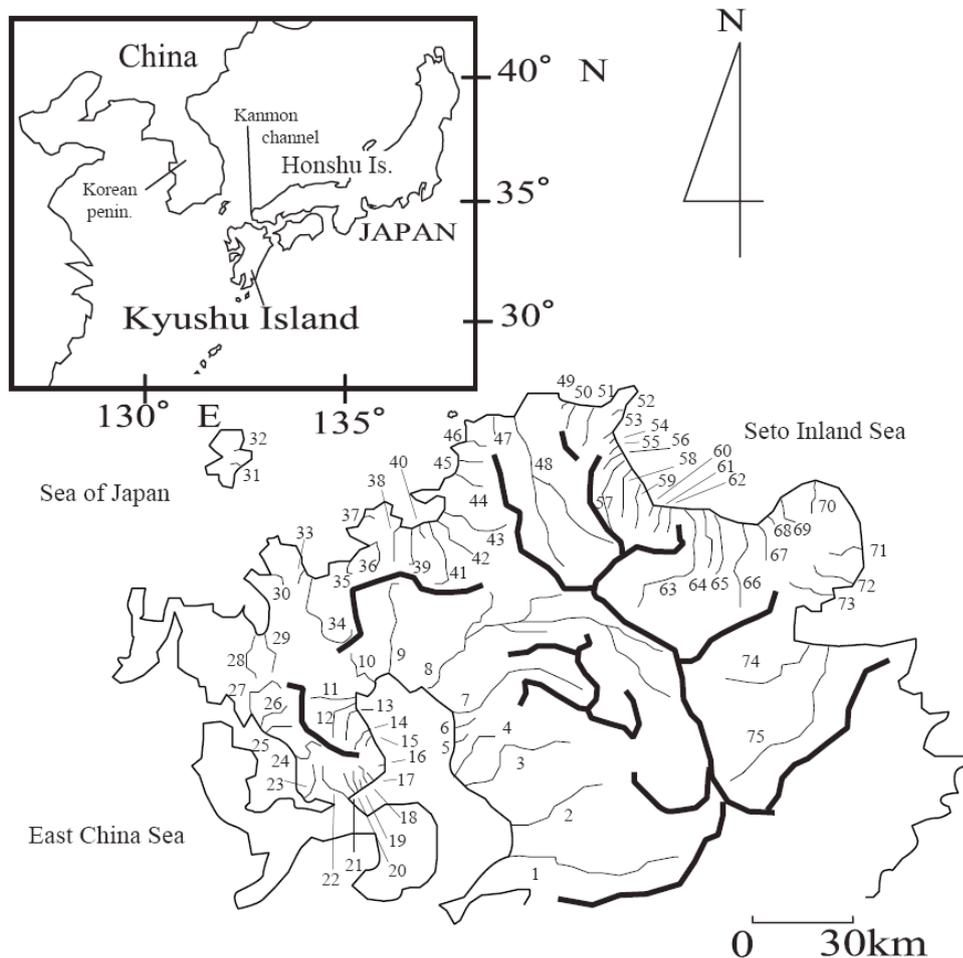


Fig. 1. Map of the study area on northern Kyushu Island. 1, Midori River; 2, Shira R.; 3, Kikuchi R.; 4, Nakiri R.; 5, Domen R.; 6, Kuma R.; 7, Yabe R.; 8, Chikugo R.; 9, Kase R.; 10, Ushizu R.; 11, Shiota R.; 12, Kashima R.; 13, Hama R.; 14, Tara R.; 15, Itoki R.; 16, Imazato R.; 17, Nagasato R.; 18, Sakai R.; 19, Yue R.; 20, Oe R.; 21, Murasaki R.; 22, Honmyo R.; 23, Suzuta R.; 24, Koori R.; 25, Chiwata R.; 26, Sonogi R.; 27, Kawatana R.; 28, Arita R.; 29, Imari R.; 30, Ariura R.; 31, Hatahoko R.; 32, Tanie R.; 33, Sashi R.; 34, Matsuura R.; 35, Kamo R.; 36, Raizan R.; 37, Sakurai R.; 38, Zuibaiji R.; 39, Muromi R.; 40, Hii R.; 41, Naka R.; 42, Mikasa R.; 43, Tataru R.; 44, Daikon R.; 45, Saigou R.; 46, Tsuru R.; 47, Shioiri R.; 48, Onga R.; 49, Enmeiji R.; 50, Itabitsu R.; 51, Murasaki R.; 52, Okuhata R.; 53, Chikuma R.; 54, Nuki R.; 55, Kusami R.; 56, Nagao R.; 57, Ima R.; 58, Harai R.; 59, Kii R.; 60, Uenokawachi R.; 61, Suda R.; 62, Naka R.; 63, Yamakuni R.; 64, Inumaru R.; 65, Iroha R.; 66, Yakkan R.; 67, Yorimo R.; 67, Hirose R.; 68, Matama R.; 69, Takeda R.; 70, Imi R.; 71, Tabuka R.; 72, Aki R.; 73, Yasaka R.; 74, Oita R.; 75, Ono R. Bold lines represent major mountains and main watersheds.

years ago, and the mountains that exist currently completed their formation half a million years ago. We hypothesize that these mountains acted as barriers that inhibited the migration of the *striata* complex species and triggered their speciation. Saito et al. (2000) reported that yamato complex included three chromosome race types (Y84, Y90, and Y94). These three chromosome race types were collected in three areas separated by mountains. Although the chromosome race types of yamato complex could not be distinguished in this study, the geographical distribution pattern may also separate by mountains ridges.

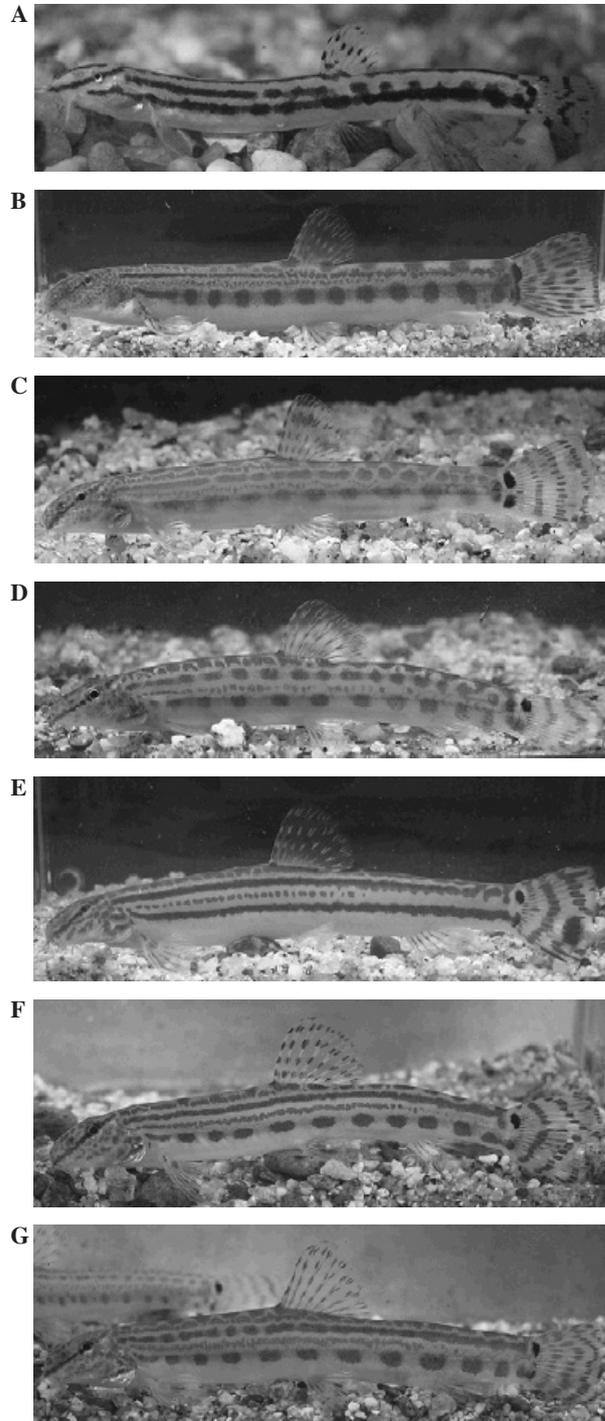


Fig. 2. The seven *Cobitis* species in northern Kyushu. A, *C. takatsuensis*; B, *C. biwae*; C, yamato complex; D, the Kyushu form of *C. striata* (small race); E, *C. striata* (middle race); F, the Onga form of *C. striata* (middle race); and G, the Hakata form of *C. striata* (middle race).

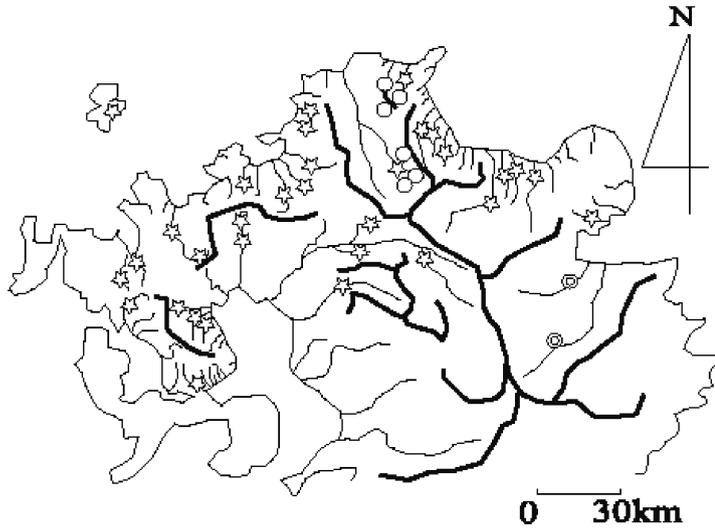


Fig. 3. Distribution patterns of each *Cobitis* species. Bold lines represent major mountains and main watersheds.

In the present study, the yamato and *striata* complex species were frequently found to be distributed in the same river system; the former inhabited the upstream areas, while the latter inhabited the downstream reaches (Fig. 3). Kyushu is a mountainous island with plains covering a very small area (M a c h i d a et al. 2001). The rivers on Kyushu Island are short and follow a steep course, and their environment varies widely. Although these two *Cobitis* complex appear to be distributed within a narrow area, the habitat suitable for each of these is different. Therefore, there is barely any overlap between the inhabitation areas of these two species, and they coexist in the same river system. Although it is unknown whether an interspecific difference exists in the longitudinal distribution of European *Cobitis* species (M r a k o v č i ć et al. 2000, V a s i l e v a 2000), it may be one of the important factors to trigger their speciation in the rivers of relatively small peninsulas or islands.

The distribution patterns of *C. takatsuensis*, *C. biwae* and *C. striata* (middle race) have been limited to the eastern part of Kyushu Island, and it is a common species in western Honshu Island. These species are known to be genetically related to the Kyushu group and the western Honshu group (K i t a g a w a et al. 2001, 2004, 2005a, S h i m i z u et al. 2004). Meanwhile, the yamato complex distributes partially on western Honshu Island, and the eastern Kyushu group of yamato complex is genetically closely related to the western Honshu group (K i t a g a w a et al. 2003). Although Kyushu Island is now separated from Honshu Island by the Kanmon channel (Fig. 1), it is believed that 20,000 years ago (during the last glacial period), the rivers in northeastern Kyushu Island were connected to other river systems in western Honshu Island (K u w a s h i r o 1959). We believe that the *Cobitis* fauna of the north-eastern part of Kyushu Island has been strongly influenced by this geological history. However, the distribution pattern of each species in this area is very complex. It may be necessary to research volcanic influences or interspecific relationships.

The results of the present study reveal that habitat fragmentation by mountains and the difference in longitudinal distribution lead to this complicated distribution pattern. Further genetic and ecological studies are required to elucidate the distribution patterns and speciation mechanisms of *Cobitis* on Kyushu Island.

Acknowledgements

We thank Daisuke Inoue (Kitakyushu Secondary School), Nobuyoshi Fuchigami (Onga River Environment Conservation Monitor), Kazuo Hoshino (Oita marine palace 'Umi-tamago'), Houkou Fujii (Asoeiho Secondary School), Kinya Fuda (Kumamoto Prefecture), Shunsuke Fujii (Saga Prefecture) and Jirou Kawahara (Environmental Museum of Water) for their useful suggestions. We also thank Yasushi Utsunomiya, Katsuhisa Eguchi, Jun Kaneto, Taketo Tanaka, and Masaya Nakatani (Fishery Research Laboratory, Kyushu University) for their assistance in sample collection.

LITERATURE

- Azuma M., Kurokawa T., Usui T. & Shibahara K. 2001: [Freshwater fish fauna of Tara mountains]. In: Nagasaki-ken Seibutsu-gakkai. (eds.), Animals of Tara Mountain. *Nagasaki: 129–152 (in Japanese)*.
- Hosoya K. 2000: Cobitidae. In: Nakabo, T. (ed.), [Fishes of Japan with pictorial keys to the species second edition]. *Tokai Univ. Press, Tokyo: 272–277 (in Japanese)*.
- Kitagawa E., Hoshino K., Okazaki T. & Kitagawa T. 2004: (*Cobitis biwae* from the Oita River system in Oita Prefecture, Japan, and its biogeographic origin). *Japan. J. Ichthyol. 51: 117–122 (in Japanese with English summary)*.
- Kitagawa T., Jeon S.R., Kitagawa E., Yoshioka M., Kashiwagi M. & Okazaki T. 2005b: Genetic relationships among the Japanese and Korean striated spined loach complex (Cobitidae: *Cobitis*) and their phylogenetic positions. *Ichthyol. Res. 52: 111–122*.
- Kitagawa E., Nakajima J., Hoshino K. & Kitagawa T. 2005a: [Distribution of the spined loaches in the north-eastern part of Kyushu Island]. *Adv. Abstr. 38th Ann. Meet. Ichthyol. Soc. Jpn. 2005: 68 (in Japanese)*.
- Kitagawa T., Watanabe M., Kobayashi T., Yoshioka M., Kashiwagi M. & Okazaki T. 2001: Two genetically divergent groups in the Japanese spined loach, *Cobitis takatsuensis*, and their phylogenetic relationships among Japanese *Cobitis* inferred from mitochondrial DNA analysis. *Zool. Sci. 18: 249–259*.
- Kitagawa T., Yoshioka M., Kashiwagi M. & Okazaki T. 2003: Genetic structure of a Japanese allotetraploid loach of the genus *Cobitis* (Osteichthyes, Cobitidae). *Folia Biol. (Kraków) 51 (Suppl.): 93–100*.
- Kitakyushu High School Gyobu 2001: [Fishes of rivers and mudflats in Kitakyushu (1)]. *Watashitachi-no-shizenshi 78: 7–10 (in Japanese)*.
- Kuwashiro I. 1958: [Bathymetric feature of Seto Inland Sea]. *Geographical review of Japan 32: 24–34 (in Japanese)*.
- Machida H., Ota Y., Kawana T., Moriwaki H. & Nagaoka N. 2001: [Regional Geomorphology of the Japanese Islands 7, Kyushu Island & Nansei Islands]. *Tokyo Univ. Press, Tokyo (in Japanese)*.
- Mrakovčić M., Schneider D., Mustafić P. & Kerovec M. 2000: Status of genus *Cobitis* and related species in Croatia. *Folia Zool. 49 (Suppl. 1): 113–116*.
- Nakajima J., Kitagawa E., Kitagawa T., Kaneto J., Tanaka T., Onikura N. & Oikawa S. 2006a: [A note of the spotted form of *Cobitis striata* (middle race) from Fukuoka city, Japan]. *Adv. Abstr. 39th Ann. Meet. Ichthyol. Soc. Jpn. 2006: 68 (in Japanese)*.
- Nakajima J., Onikura N., Matsui S. & Oikawa S. 2006b: (Geographical distribution of genuine freshwater fishes in Fukuoka Prefecture, northern Kyushu, Japan). *Japan. J. Ichthyol. 53: 117–131 (in Japanese with English summary)*.
- Saitoh K., Kobayashi T., Ueshima R. & Numachi K. 2000: Analysis of mitochondrial and satellite DNAs on spined loaches of the genus *Cobitis* from Japan have revealed relationships among populations of three diploid-tetraploid complexes. *Folia Zool. 49 (Suppl. 1): 9–16*.
- Saitoh K. 2001: Cobitis. In: Kawanabe H., Mizuno N. & Hosoya K. (eds), [Freshwater Fishes of Japan]. *Yama-Kei Publ. Tokyo: 386–391 (in Japanese)*.
- Sakamoto K. & Tajima M. 1996: [Freshwater fish fauna of Saga prefecture]. In: Saga-ken Seibutsu-bukai. (eds), [Animals of Saga Prefecture]. *Saga: 193–223 (in Japanese)*.
- Sawada Y. & Aizawa H. 1983: [*Cobitis biwae*, the valid name for the Japanese spined loach]. *Japan. J. Ichthyol. 30: 318–323 (in Japanese)*.
- Shimizu T., Suzawa Y. & Sakai H. 2004: Allozyme divergence between two groups of the Japanese spinous loach, *Cobitis takatsuensis*. *Ichthyol. Res. 51: 241–247*.
- Vasileva E.D. 2000: Sibling species in the genus *Cobitis* (Cobitidae, Pisces). *Folia Zool. 49 (Suppl. 1): 23–30*.
- Watanabe K. 1998: Parsimony analysis of the distribution pattern of Japanese primary freshwater fishes, and its application to the distribution of the bagrid catfishes. *Ichthyol. Res. 45: 259–270*.