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# The invasion of Japan by an exotic bitterling, *Aceilognathus macropterus*, and its effects

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ABSTRACT

Bitterlings (Acheilognathinae, Cyprinidae) are characteristic in using unionid freshwater mussels as hosts for their eggs. The reclamation of small ponds and construction works for improvement of rivers have lead to decline of bitterlings in recent years. Furthermore, decline of mussels, which are more sensitive to water pollution such as eutrophication than bitterlings, has accelerated the extinction of local populations of bitterlings. There are 17 species and subspecies (including 1 exotic species) of bitterlings in Japan, of which 10 species and subspecies are designated as threatened fishes of Japan. The cause of decline of bitterlings may be invasion of exotic carnivorous species such as largemouth bass as well as environmental deterioration. An invasion of exotic bitterling has made much effect on native bitterling in Japan. A first exotic bitterling, Rhodeus ocellatus ocellatus, was introduced in 1945. This subspecies can hybridize very easily with a native conspecific bitterling, Rhodeus ocellatus kurumeus. The drastic diminution of populations of pure R. o. kurumeus has been reported. A second exotic bitterling, which is larger than any of native bitterlings, was observed in Lake Kasumigaura in 2001, Ibaraki Prefecture, Japan. This report will deal with a classification of an exotic large bitterling and the effect of this bitterling on the other bitterlings in Lake Kasumigaura. The meristic character of the large bitterling is as follows: dorsal rays, □, 15-18; anal rays, □,12-13; lateral-line scales, 35-37. The coloration in nuptial males is not □igantean. The □igante is very short, being difficult to distinguish with the naked eye. From these characteristics, the large bitterling was identified as Acheilognathus macropterus, whose original distribution is East Asia. The change of composition of 5 bitterlings angled in Lake Kasumigaura in 5 years will be reported. It suggests that A. macropterus has become most dominant among 5 bitterlings.

## INTRODUCTION

Bitterlings are freshwater fish with the unique spawning habit of depositing their eggs in the gills of bivalves. Most bitterling species grow to no more than 10 cm in length. The nuptial coloration of males during the spawning season is very beautiful. With the exception of European species, bitterlings are found in Far East Russia, China, Mongolia, Taiwan, Vietnam, and Thailand. A review of the subspecies of *Acheilognathus tabira* by Arai (2007) reclassified this species into 5 subspecies instead of 3 as in the past. As a result, there are now 3 genera of bitterlings with 51 species and subspecies around the world. All 3 genera of the bitterling subfamily (Acheilognathinae) are known to exist in Japan in spite of the country being an archipelago off the eastern extreme of the Eurasian continent. Japan is an invaluable habitat for bitterlings, with 17 species and subspecies (including 1 exotic subspecies), of which 8 are endemic species.

The population of bitterlings, however, is on the decline in Japan as a result of habitat loss due to the reclamation of irrigation reservoirs and river improvement works. The susceptibility to water pollution of bivalves which are hosts to bitterling eggs has accelerated the extinction of local bitterling populations. The latest list of Threatened Fishes of Japan published on August 3, 2007 includes all but 1 of 16 native species and subspecies found in Japan. Invasions by exotic fish as well as the globalization of human activities are also contributing to the extinction of local populations. The expanding habitat of North American-native largemouth bass (*Micropterus salmoides*) adds to the critical situation of the already threatened native freshwater species. The first invasion of Japan by an exotic bitterling occurred in 1945 with the Chinese-native *Rhodeus ocellatus ocellatus*. The invading species crossed with a native subspecies, *Rhodeus ocellatus kurumeus*, resulting in the loss of identity for the native subspecies and a critical impact on its existence as a subspecies.

In 2001, another bitterling species was found in Lake Kasumigaura in eastern Japan, which is an important habitat for native bitterlings. The newly found species was much larger than the native bitterlings, and its dorsal fin extended lengthwise. Lake Kasumigaura is inhabited by 5 species of bitterlings: an endemic species *Acheilognathus melanogaster*, native species *Tanakia lanceolata* and *Acheilognathus tabira erythropterus*, *Acheilognathus rhombeus* which have been introduced from outside the basin, and an exotic species *R. ocellatus ocellatus*. The new, large species is the second bitterling species to invade Japan. This study reports the results of a taxonomic observation of the large exotic bitterling and its effects on native bitterlings as interpreted from a time-series variation of the bitterling population.

METHOD

The study site is Lake Kasumigaura, a coastal lagoon with an area of 220 km$^2$, an average depth of 4 m, and a total shore line of 249.5 km (Fig. 1). Lake Kasumigaura is in an advanced stage of eutrophication as a result of severe engineering changes made for flood control and water utilization. The lake is home to 57 species of freshwater fish, including migratory species, of which 23 species are imports from outside the basin (Hagiwara and Kumagai, 2007).

Bitterling specimens were collected from site St. 1 by stake net used by fishermen as well as by angling. This site is the place where the existence of an unfamiliar large bitterling was confirmed for the first time in 2001. The collected specimens were immediately fixed in a 10% formalin solution and morphometric and meristic attributes were measured. In addition, soft X-ray photographs were taken at a power output of 16 kV and 2 mA with an exposure between 60 and 80 seconds.

For an examination of bivalves used by the exotic bitterling for spawning, bivalves were collected using a shellfish collector in the spring of 2006. They were kept in fresh water until bitterling larvae floated out. The larvae were captured and raised to a size which would allow for identification of species. The grown bitterlings were fixed in a 10% formalin solution for identification and population counts.

Sampling sites St. 2 and St. 3 were used as the fixed points for an investigation of time-series variations in the composition of bitterling species. These two sites were selected because fixed specimens of bitterlings have been preserved from the sites since 2000, and no exotic bitterling species were captured until 2002. These facts made the sites suitable for an examination of the process of an invasion by exotic bitterling species from site St. 1. As marked in the post-2000 map (Fig. 1), these sites are located approx. 15 km from St. 1 where the exotic bitterling was first seen. The identification and population count primarily used bitterling specimens collected by angling and fixed in formalin, with supplementary measurements of specimens collected by bait traps.

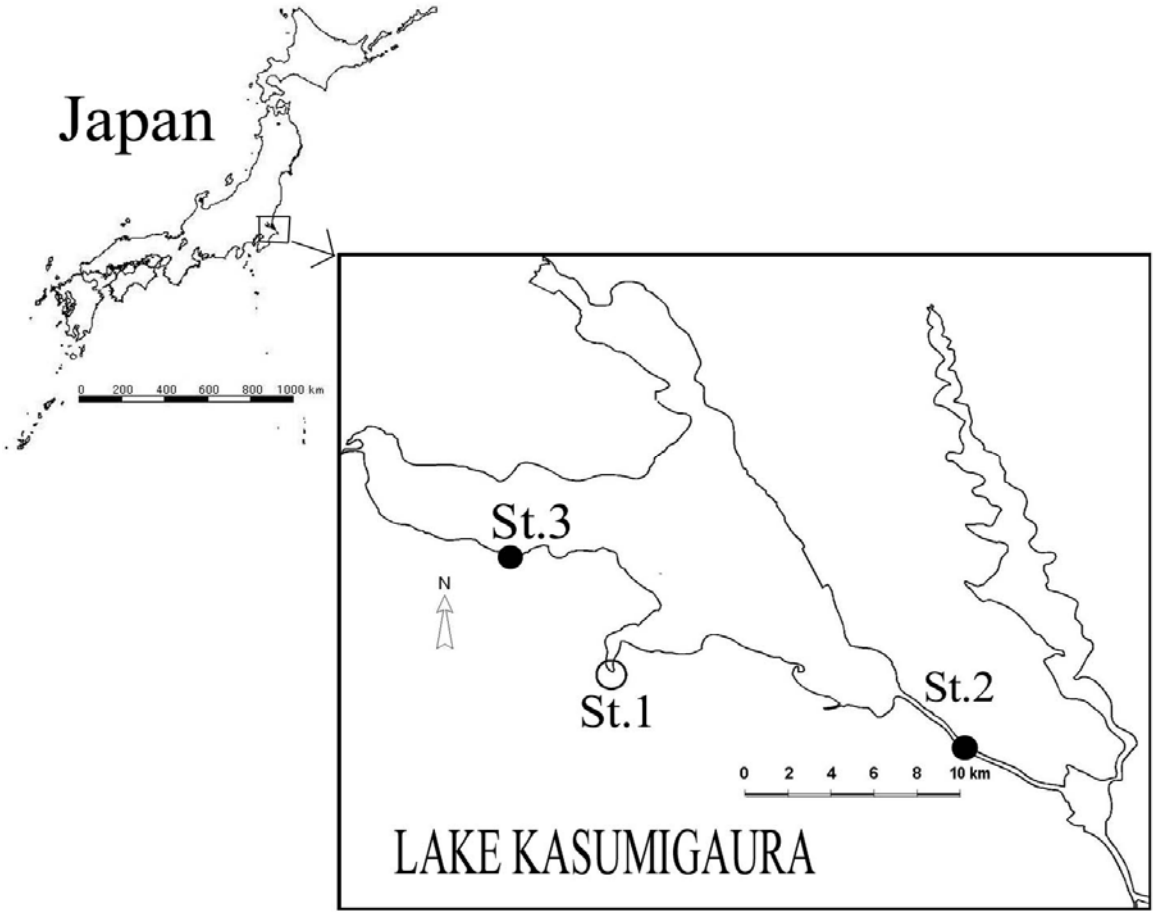


Figure 1 Map of Lake Kasumigaura and location of sampling sites
St. 1: Initial detection and collection site of the larger exotic bitterling
St. 2, St. 3: Sites for monitoring bitterling composition

RESULTS

***Observation of specimens***

Figure 2 shows a male individual with nuptial coloration. The body is in a compressiform, which becomes more noticeable as the fish matures. A distinct blue spot is visible on a scale located about 5 rows from the gill cover. During the spawning period, a male bitterling produces an additional spot on the tip of its snout. White spots on the anal fin, the first node, and the midpoint between the body and the first node become prominent and form 3 distinct white lines aligned from front to end. Little nuptial coloration develops on the body in contrast to the anal fin. The body presents a somewhat darkened color with pale pink metallic luster depending on the condition of light and the viewing angle. The abdomen also darkens (Fig. 3). The female anal fin turns yellow during the spawning period (Fig. 4). The female ovipositor is colorless at the base and somewhat darkened at the tip (Fig. 5). When extended further, the ovipositor turns colorless and the thick base protrudes outside the body, with the front edge of the pelvic fin turning white (Fig. 6). The barbels are extremely short (Fig. 7). Although the barbels can just be discerned on large individuals when they are fixed in formalin and observed from the underside of the mouth under backlit conditions (Fig. 8), on smaller individuals they are difficult to detect by the naked eye. Figure 9 presents a soft X-ray image of the individual specimen identified as No. 7 (see Table 1). This specimen has 35 vertebrae, including 1 urostyle bone, 30 connected to the neural and hemal spines, and 4 of the Weberian apparatus. The dorsal fin shows 3 spiny fin rays, including an impacted first ray, and 15 soft rays behind them. Table 1 summarizes the attributes of the 9 specimens from which soft X-ray images were taken. The dorsal fin soft rays numbered between 15 and 18, the vertebrae between 34 and 37, and the lateral line scales between 34 and 37. As these characteristics agreed well with the results of an observation in Korea by Uchida (1939), the species was identified as *Acheilognathus macropterus*.

Table 1. Meristic characteristics of specimens

| Specimen No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Sex | ND | female | BR | BR | female | female | male | female | female |
| Total length (mm) | ND | 63 | 55 | 53 | 78 | 75 | 92 | 99 | 97 |
| Standard length (mm) | ND | 49 | 43 | 41 | 61 | 58 | 71 | 76 | 77 |
| Weight (g) | ND | 2.887 | 1.844 | 1.557 | 5.502 | 4.726 | 9.684 | 13.21 | 13.94 |
| No. of soft dosal fin-rays | ND | 17 | 17 | 16 | 17 | 18 | 15 | 17 | 14 |
| No. of vertebrae | 35 | 36 | 34 | 35 | 37 | 36 | 35 | 35 | 34 |
| Lateral-line scales | ND | 36 | 35 | 35 | 37 | 36 | 37 | 35 | 35 |

ND:no data
BR:beyond recognition

Figure 2.

Figure 3

Figure 4.

Figure 5.

Figure 6.

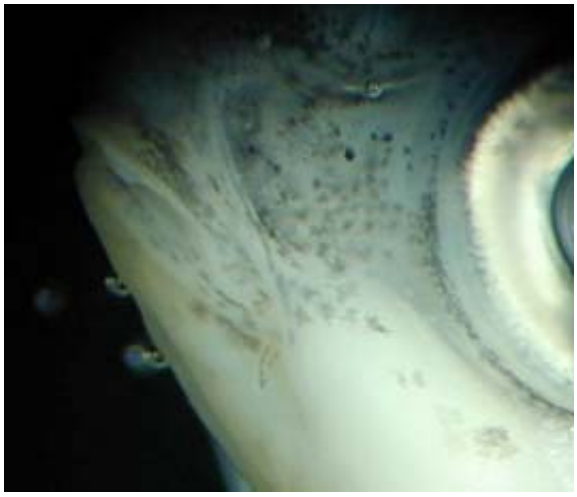

Figure 7

Figure 8

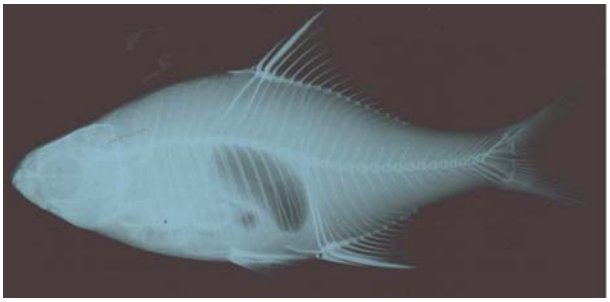

Figure 9.

***Results of an examination of bivalves used for spawning***

The results of the experiment are summarized in Table 2. All bivalves were collected from the shoreline of Lake Kasumigaura and the feeding river near the site St. 1. From 104 individuals of *Unio douglasiae*, 35 bitterling larvae floated out, and 10 individuals were identified to be *Acheilognathus macropterus*. Other individuals were *Acheilognathus rhombeus*, *Rhodeus ocellatus ocellatus,* and *Acheilognathus melanogaster*. All larvae that floated out from *Anodonta sp.* died during rearing. The results indicated that *Acheilognathus macropterus* in Lake Kasumigaura used *Unio douglasiae* as host for their eggs. This species is likely to expand its habitat over the Tonegawa river basin in the near future, corresponding to the habitat of *Unio douglasiae*. Casual removal of *Unio douglasiae* from Lake Kasumigaura by bitterling enthusiasts may also contribute to the spread of the exotic species to other waters.

Table 2. Number of postlarval bitterlings from mussels in the bitterling spawning season

| Sampling date | No. of collected unionid mussels | | No. of postlarva of bitterlings from mussels | | | | No. of dead postlarva before | Total No. o postlarva from muss |
|---|---|---|---|---|---|---|---|---|
| | *Anodonta sp.* | *Unio douglasiae* | *A. macropterus* | *A. rhombeus* | *R. ocellatus ocellatus* | *A. melanogaster* | | |
| 5/6/06 | 3 | 31 | 3 | 7 | 0 | 0 | 9 | 19 |
| 5/13/06 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5/19/06 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5/28/06 | 0 | 16 | 3 | 0 | 0 | 1 | 3 | 7 |
| 6/4/06 | 0 | 13 | 0 | 0 | 0 | 0 | 1 | 1 |
| 6/25/06 | 0 | 12 | 4 | 0 | 4 | 0 | 0 | 8 |
| Total | 3 | 104 | 10 | 7 | 4 | 1 | 13 | 35 |

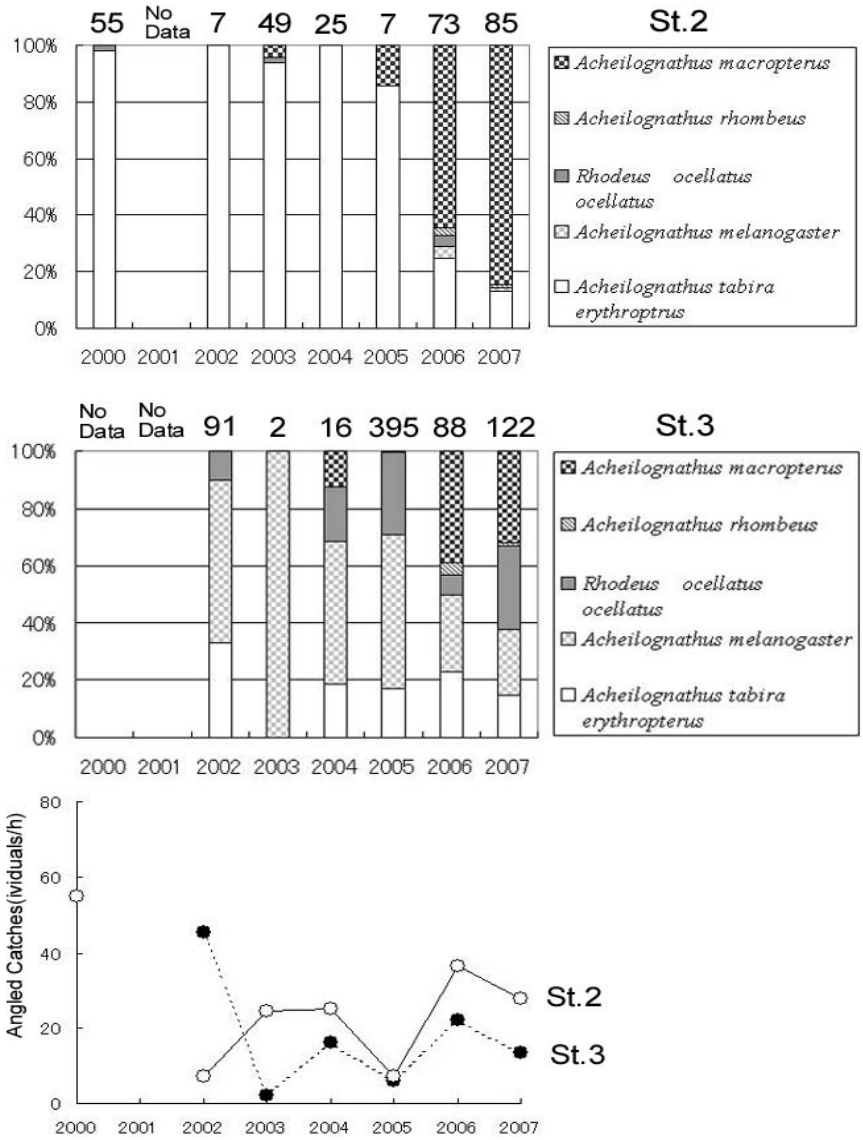


Figure 10. Upper and middle panes: The change in composition of 5 bitterling species in Lake Kasumigaura over 6 years
Number above the bar is annual total of bitterling individuals caught, including those caught by bait trap.
Lower pane: Average annual catch of bitterlings caught by angling for 1 hour.
At St. 2 and St. 3, we could not catch *Tanakia lanceolata* during this study.

***Time-series variation in bitterling composition***

The changing composition of bitterlings observed at sites St. 2 and St. 3 over the period from 2000 to 2006 is presented in Figure 10. These points are located about 15 km from St. 1 where the first exotic bitterling was detected. Site St. 2 was traditionally dominated by *A. tabira erythropterus* before the presence of *A. macropterus* became apparent in 2003. By 2007, the latter species accounted for more than 80% of the total bitterling population. Similarly at the site St. 3, where the native species such as *A. melanogaster* and *A. tabira erythropterus* accounted for 90% of the population in 2002, *A. macropterus* was first sighted in 2004 which grew to account for 30% of the total population by 2007. The native species of *T. lanceolata* could not be captured at either St. 2 or St. 3. The graph in the bottom pane of Figure 10 represents the number of bitterlings caught by angling per hour at the 2 stations. Although the catch varied from year to year, there was no discernible trend showing an increase in total bitterling population. Therefore, it can be concluded that the population of the native bitterlings is on the decline at both sites according to the increase in the number of *A. macropterus*.

SUMMARY

An unfamiliar large bitterling species with indistinct male nuptial coloration, which has been observed in Lake Kasumigaura since 2001, was identified as *Acheilognathus macropterus*.

This species was found to use *Unio douglasiae*, a native bivalve in Lake Kasumigaura, as the host for its eggs.

*A. macropterus* is gradually expanding its habitat over the entire lake area of Kasumigaura. Even though the population of the bitterling subfamily as a whole is not increasing, this species has become more dominant. Based on this observation, it is considered to be invasive and increasing its population by overwhelming other species.

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REFERENCES

Arai, R. 2007. Four New Subspecies of *Acheilognathus Bitterlings* (Cyprinidae: Acheilognathinae) from Japan. Bulletin of the National Science Museum, Tokyo, Ser. A, Supplement 1:1–28.

Hagiwara, T. and M. Kumagai (ed.) 2007. A New Illustrated Book of Fishes Fauna in Lake Kasumigaura. Kasumigaura Citizen's Association. Tsuchiura. 158 pp. (In Japanese.)

Uchida, K. 1939. The fishes of Tyosen (Korea). Part 1 Nematognathi and Eventognathi. Bulletin of the Fisheries Experiment Station of the Government-general of Tyosen, 6 (In Japanese.)