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Comparative Ecology of Young-of-the-Year between Two Amphidromous Species of *Cottus* in Hokkaido
1. Upstream Migration and Growth

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Abstract

The ecological aspects of the upstream migration at juvenile stage and growth pattern in the fluvial life after ascending the river were compared between the two closely related cohabiting species of amphidromous sculpins, *Cottus amblystomopsis* and *C. hangiongensis* in the Ryukei River in southern Hokkaido.

The upstream migration of juveniles from the sea began in late May for *C. amblystomopsis* and in early June for *C. hangiongensis*, and continued until late June and early July, respectively. The diurnal upstream migration showed a regular pattern in both species. Juveniles of both species usually ascended the river when flood tide and periods of darkness were synchronized.

The seasonal growth pattern of young-of-the-year was similar between the two species. Namely, the juveniles grew rapidly during the summer and retarded during the winter. In the fluvial life, however, the growth rate of young-of-the-year of *C. amblystomopsis* was higher than that of *C. hangiongensis*, especially during the summer. As a result of this difference of growth rate, the mean body length of *C. amblystomopsis* became larger than that of *C. hangiongensis* from mid summer, though it was apparently larger in the latter species than the former species at the time of upstream migration from the sea. Growth in body length was fairly consistent while condition factor K showed somewhat irregular seasonal pattern in both species. From summer, the K value was lower in *C. hangiongensis* than *C. amblystomopsis*, showing that the former species became slender in body shape than the latter one.

The similarity in the habits of upstream migration and the cause of differences in the growth pattern of young-of-the-year between the two species were considered on the basis of the results stated above.

Two amphidromous species of genus *Cottus*, *C. amblystomopsis* and *C. hangiongensis*, are distributed sympatrically in many rivers of the southern Hokkaido, Japan (Sato and Kobayashi, 1951, 1953; Goto *et al.*, 1978; Goto, 1980, 1981). Both species spawn in the lower course rivers during the early spring, and their larvae flow down into the sea soon after hatching. After spending about one month at sea, the juveniles ascend rivers to start a benthic life in the lower course of the river (Goto, 1975, 1981). In both species, adults are distributed within the lower course of rivers with Bb-Bc transition type or Bb type (Kani, 1944; Mizuno and Kawanabe, 1981), and utilize principally the same food resources of the environment (Goto, 1977).

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Due to similarity in the life history characteristics and overlapping in the distribution along a river between the two species, it is important to understand how they are able to coexist within the river. The sympatric occurrence of two congeneric species suggests a possible competitive coexistence, opposing Gause's contention (Gause, 1934).

In order to elucidate the interspecific relationship between the two closely related species of amphidromous sculpins, the ecology of the upstream migration in juveniles, and growth, habitat and food habits of young-of-the-year in the fluvial life stage were investigated in a river cohabited by both species. In the present paper, the ecological aspects of upstream migration and the growth of young-of-the-year were compared between the two species.

Study Area and Methods

The Ryukei River originates on Oshima Mountain of Hokkaido and drains into Hakodate Bay (Fig. 1). It is characterized by relatively high gradient and is about 6 km long. In this river, there is a notched weir approximately 2.5 km up stream from the river mouth, which completely blocks upstream immigration of amphidromous sculpins. The lower course of the river from the notched weir consists of two reach-types (Kani, 1944); Bb-Bc transition type from the river mouth to St. 3 and Bb type in the upper from St. 3. The region of Bb-Bc type is influenced by sea water at flood tide. The river mouth is about 2.5 m in width and 0.3 m in depth at the deepest point. The substratum consists of sand with some gravel intermingled. The water temperature of the river fluctuated seasonally from 2.0° to 23.2°C in 1979 to 1980 and from 3.6° to 18.4°C in 1980 to 1981 (Fig. 2).

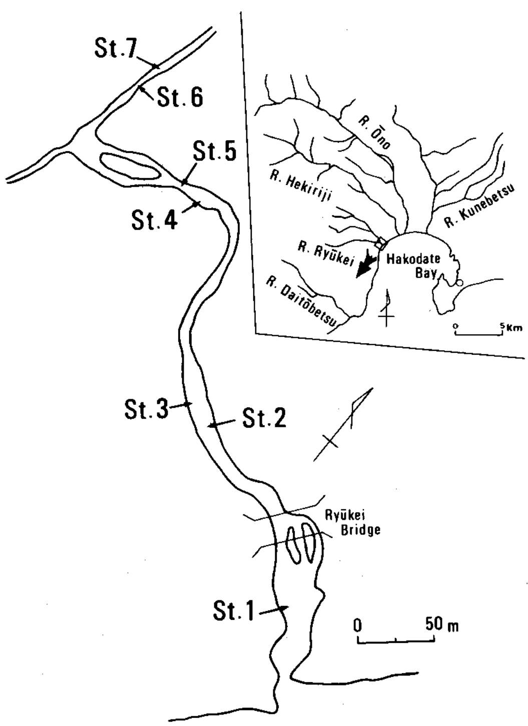

Fig. 1. Map showing the location and the study sites of the Ryukei River.

Studies of the upstream migration of juveniles were made during the period from late May to early July in 1982 and 1983, by setting up a trap net at the river mouth. The trap net, which was used to capture ascending fishes, was 2.2 m in width, 1.5 m in length and 0.4 m in height and had 2 mm mesh (Fig. 3). For the studies on diurnal upstream migration, the trap net was set up for 30 minutes every three hours for over 24 hours. The diurnal study was carried out nine times from June 10 to July 10 in 1982.

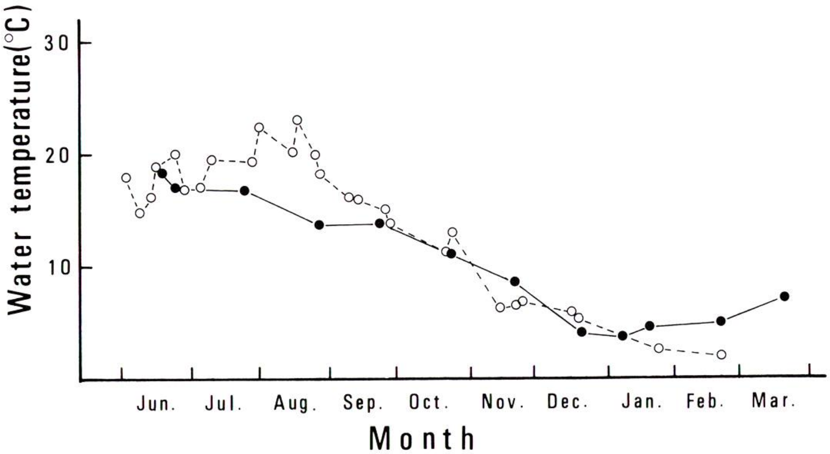

Fig. 2. Monthly changes of water temperature in the Ryukei River from June, 1979 to February, 1980 (○) and from June, 1980 to February, 1981 (●).

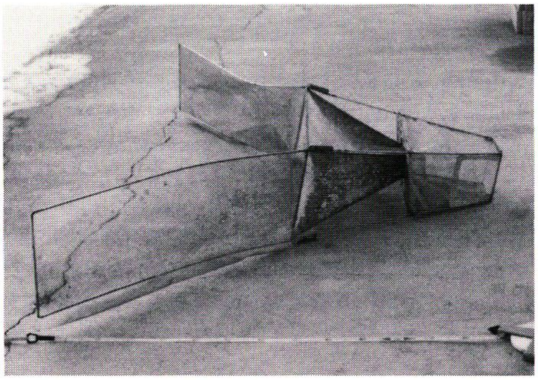

Fig. 3. Lateral view of a trap net used to capture ascending fishes.

In order to estimate the growth of juveniles after ascending the river, fish were captured with a dip net of 2 mm or 3 mm mesh in the region between St. 1 and St. 7, monthly from June to December in 1979 and from June, 1980 to February, 1981. The total number of fish collected was 1961 in *C. amblystomopsis* and 2022 in *C. hangiongensis*. Fish collected were preserved in 10% formalin. The standard length (SL) and body weight (BW) were measured with a micrometer under the dissecting microscope to the nearest 0.1 millimeter and with an electronic balance to the nearest 0.001 gram. Condition factor K was calculated by the following formula; $K = BW/SL^3 \times 1000$ (SL: mm, BW: g).

Results

Upstream migration

The upstream migration of juveniles from the sea began to take place slightly earlier in *C. amblystomopsis* than in *C. hangiongensis*; the former species began to ascend the river on May 31 and the latter one on June 10 in 1982 (Fig. 4). The immigration continued until late June in *C. amblystomopsis*, with a peak on June 16, and early July in *C. hangiongensis*, with a peak on July 3. The diurnal upstream migration showed a regular pattern in both species (Fig. 5). From June 10 to 11, for example, the ascending juveniles of both species were most abundant when the flood tide occurred shortly before sunrise (03: 00). This migration pattern was also recognized on June 12 to 13, June 16 to 17, June 28 to 29 and July 3 to 4.

The body size of ascending juveniles was apparently larger in *C. hangiongensis* than *C. amblystomopsis* (Fig. 6). The mean body length of juveniles ranged from 11.5 to 12.4 mm in *C. amblystomopsis* and from 13.7 to 14.2 mm in *C. hangiongensis*. The body length of ascending juveniles tended to increase over time in both species except for *C. hangiongensis* collected on July 3 to 4.

Growth after upstream migration

The length frequency distribution in young-of-the-year of the two species collected monthly in the lower course of the Ryukei River from early June, 1980 to late January, 1981, were shown in Fig. 7. *C. amblystomopsis* showed a mode at 11.0-12.9 mm on June 5 and June 14 respectively, and *C. hangiongensis* at 13.0-14.9 mm on June 14. The body length fell within modes 23.0-26.9 mm and 27.0-28.9 mm in *C. amblystomopsis* and 21.0-22.9 mm and 23.0-24.9 mm in *C. hangiongensis* on July 25-26 and August 27-28, respectively. On September 23-24, the mode of both species shifted to somewhat lower values than the corresponding mode values

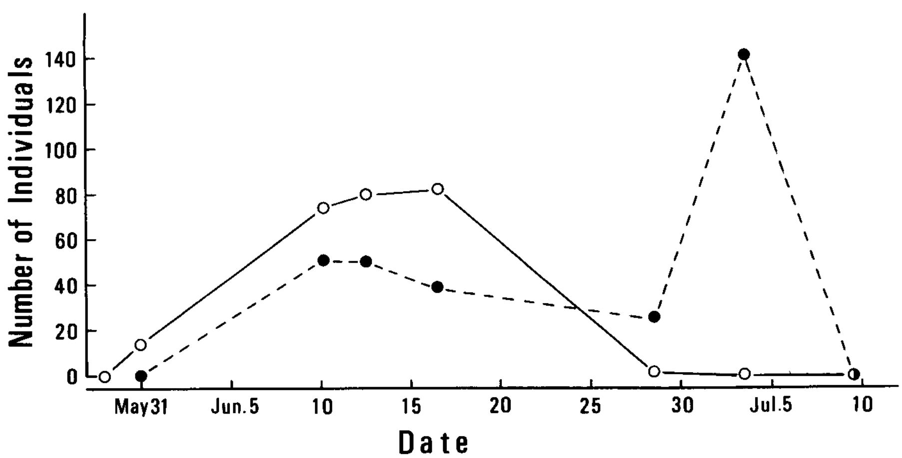

Fig. 4. Daily changes in the abundance of ascending juveniles of two amphidromous species of *Cottus* in the Ryukei River in 1982.
○, *C. amblystomopsis*; ●, *C. hangiongensis*.

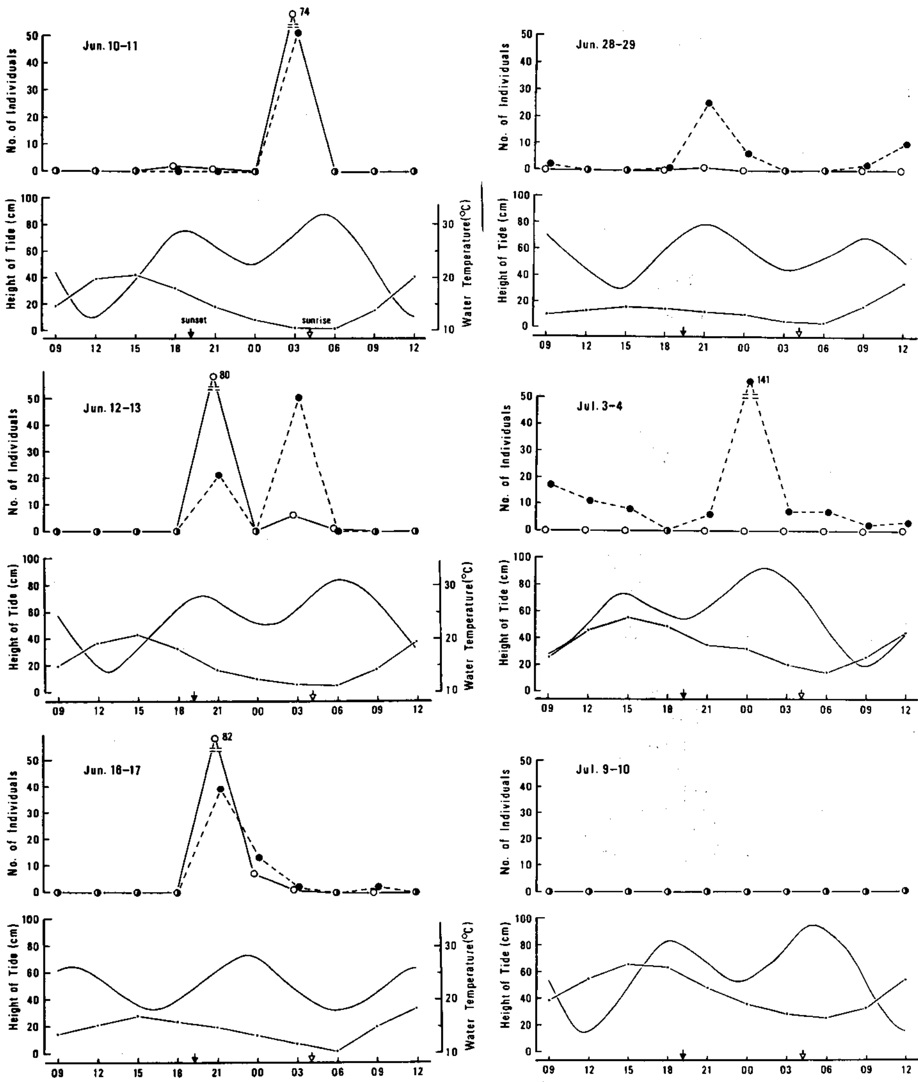

Fig. 5. Diurnal changes in the abundance of ascending juveniles, water temperature (thin line with solid squares) and height of tide (thin line).
○, *C. amblystomopsis* ; ●, *C. hangiongensis*.

on August 27-28; 25.0-26.9 mm in *C. amblystomopsis* and 21.0-22.9 mm in *C. hangiongensis*. On October 23-24, however, the body length increased in modes to 31.0-32.9 mm in *C. amblystomopsis* and 25.0-26.9 mm in *C. hangiongensis*. During the periods from late November to late February, both species showed no changes in its mode, having a mode at 31.0-32.9 or 33.0-34.9 mm in *C. amblystomopsis* and at 27.0-28.9 mm in *C. hangiongensis*.

Seasonal growth curves for body length were drawn from the mean monthly body length of each species (Fig. 8). The seasonal growth pattern was similar

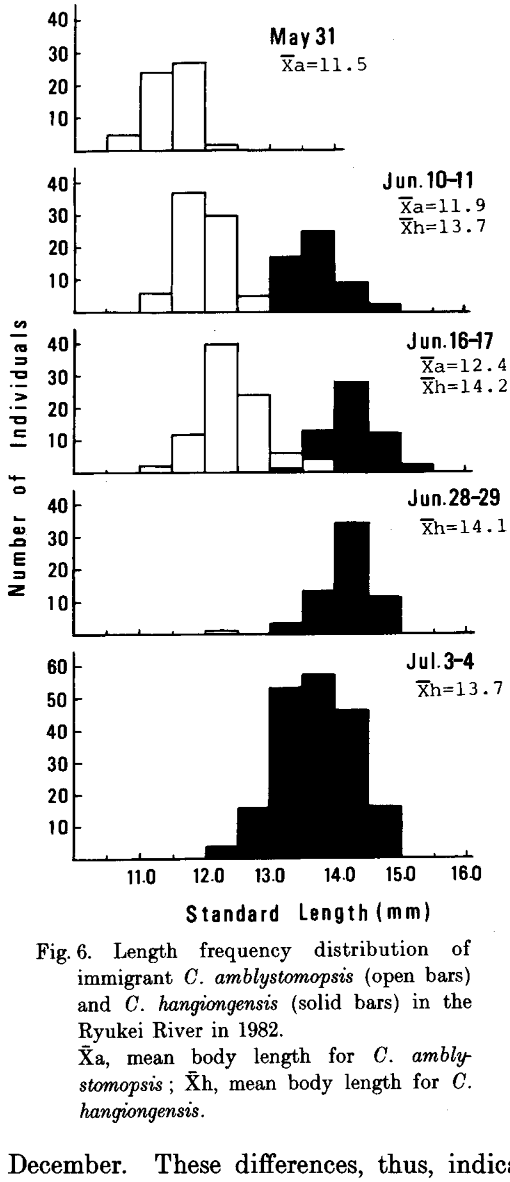

Fig. 6. Length frequency distribution of immigrant *C. amblystomopsis* (open bars) and *C. hangiongensis* (solid bars) in the Ryukei River in 1982.
X̄a, mean body length for *C. amblystomopsis*; X̄h, mean body length for *C. hangiongensis*.

between the two species; the juveniles grew rapidly in the summer from July to September, and their growth slowed in the winter from November to February. The growth rate in the summer, however, was different between the two species, with *C. amblystomopsis* having a higher growth rate than *C. hangiongensis*. Due to this difference, the mean body length of *C. amblystomopsis* was larger than that of *C. hangiongensis* after August, though the reverse was observed when they ascended the river. The growth of the 1980 year class of the both species was markedly inferior to that of 1979 year class owing mainly to the low water temperature in the summer of 1980.

Compared with the monthly growth in body length, the condition factor K showed somewhat irregular seasonal pattern in both species, in spite of similarities between the two species (Fig. 9). In both species, the mean K value increased from early July to late August and decreased rapidly through late September. Thereafter the value increased rapidly again until late October and remained constant or slightly low during the winter from November to late December. The decrease in the K value from late August to late September, however, was so striking in *C. hangiongensis* that distinct differences in the value appeared between the two species and were observed through December. These differences, thus, indicate that *C. hangiongensis* became more slender in body shape than *C. amblystomopsis* after late September.

From the mean body length (BL: cm) and the condition factor K, the average monthly body weight (BW: mg) was calculated using the formula, $BW = BL^3 \times K$. The monthly growth in average body weight showed a pattern similar to that of body length (Fig. 9). In *C. amblystomopsis*, the average body weight was 0.20 g in early July shortly after the upstream migration and increased rapidly to 0.44 g in late August. Thereafter the body weight increased gradually and reached an avrage of 0.59 g in late December. On the other hand, *C. hangiongensis* (0.16 g in the average body weight in early July) continued to grow slowly in body weight and

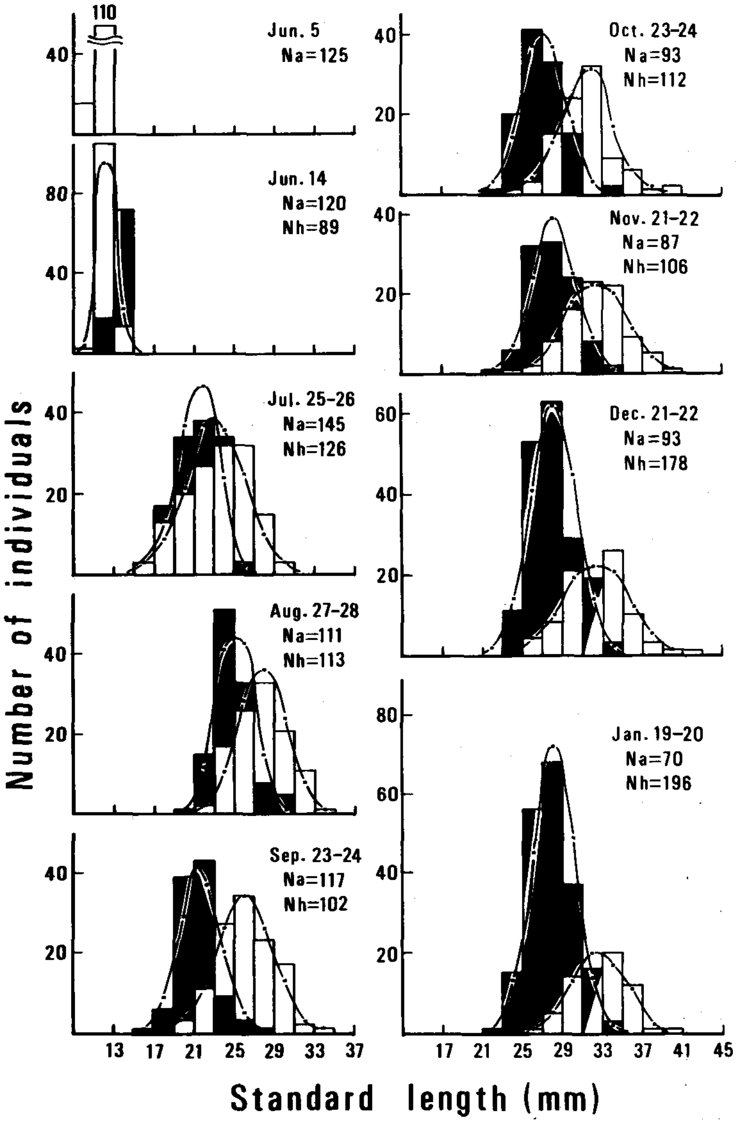

Fig. 7. Length frequency distribution of total catches of young-of-the-year of *C. amblystomopsis* (open bars) and *C. hangiongensis* (solid bars) in the Ryukei River from 1980 to 1981. Dashed and dotted lines indicate normal distribution curves. Na, the number of individuals of *C. amblystomopsis*; Nh, the number of individuals of *C. hangiongensis*.

reached an average of 0.35 g in late December.

Discussion

Many physiological and ecological studies have been done concerning the

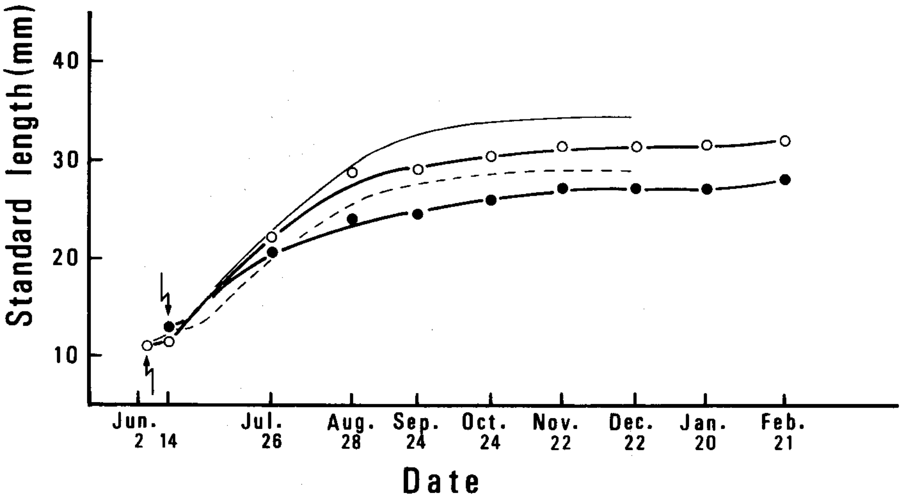

Fig. 8. Growth curves of young-of-the -year of *C. amblystomopsis* (○) and *C. hangiongensis* (●) in the Ryukei River from 1980 to 1981. The fine line indicates the growth curve of *C. amblystomopsis* and dashed line shows that of *C. hangiongensis* from 1979 to 1980, respectively. Arrows indicate the start of upstream migration.

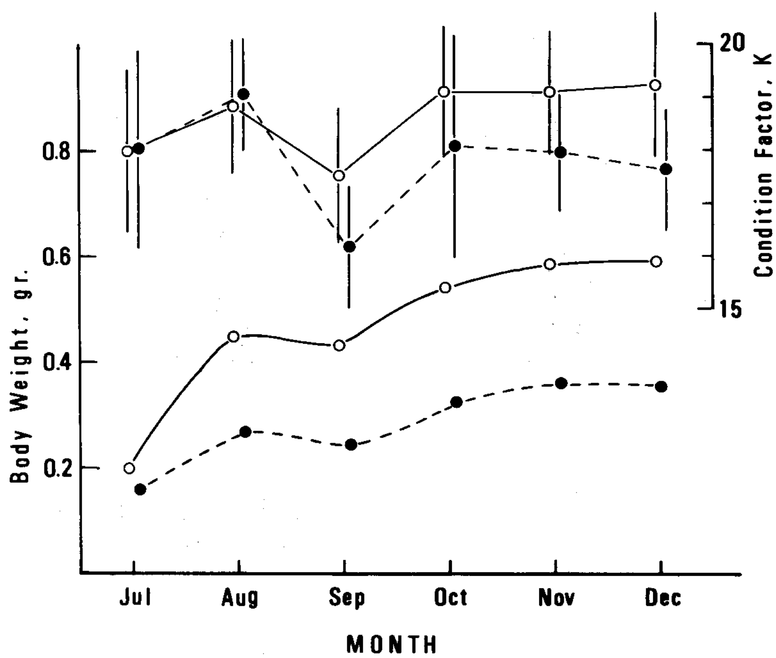

Fig. 9. Monthly changes in the condition factor K and the average body weight of young-of-the-year of *C. amblystomopsis* (○) and *C. hangiongensis* (●) in the Ryukei River in 1980. Vertical lines indicate the standard deviations.

upstream migration of fish from the sea in the anadromous fishes such as salmons and sticklebacks (Sano and Kubo, 1946, 1947; Brown, 1957; Rounsefell, 1958; Armstrong, 1965; Wootton, 1976). With the exception of the brief account on Ayu fish, *Plecoglossus altivelis* (Kawanabe *et al.*, 1957; Senta, 1967), however, there has been no detailed study on the upstream migration of amphidromous fishes which occurs at the quite different developmental stage in the ontogeny by a different biological strategy than anadromous fishes. The upstream migration at the juvenile stage in the amphidromous fishes appears to be an active behavioral trait. From circumstantial evidences it appears that free-swimming juveniles disperse in the sea and later gather along the coast near river mouths, before migrating upstream during a transition from a free-swimming to a benthic life.

In both *C. amblystomopsis* and *C. hangiongensis* the upstream migration continued for about one month. A slight difference was recognized between the migration of the two species; *C. amblystomopsis* began to ascend about two weeks earlier than *C. hangiongensis*. This difference corresponds to the difference of the spawning period; spawning occurs from early April to early May in *C. amblystomopsis* and from mid April to mid May in *C. hangiongensis* (Goto, 1975, 1981, 1983).

The results of the diurnal upstream migration show that the juveniles of both species ascend the river when flood tide and periods of darkness are synchronized. Fluctuation of water temperature appears to have no influence on the migration. Moreover, it is evident that the upstream migration in both species is not a passive transport of juveniles by the flood, because it occurs only to a limited extent during the time of flood tide in the nighttime. In the floating goby, *Chaenogobius annularis*, juveniles ascend the river to a very limited extent during the daytime. The number of immigrant fish increases rapidly a few hours before sunset and usually peaks near sunset and then drops off rapidly before midnight. Such diurnal rhythm of the upstream migration does not appear to be related to the fluctuation of water temperature or tide (Goto, unpublished data). The mechanism controlling upstream migration is different between the river sculpins ascending at the juvenile stage and the floating goby ascending at a somewhat older stage, though both fishes are classified as amphidromous fishes (Mizuno, 1963).

The habits of the upstream migration are quite similar between *C. amblystomopsis* and *C.hangiongensis*, in spite of the slight difference in timing between them. At time of upstream migration, the body size of juveniles was larger in *C. hangiongensis* than *C. amblystomopsis*. In the fluvial life, however, the growth rate of *C. amblystomopsis* was higher than that of *C. hangiongensis*, especially during the summer. As a result of such difference of growth rate, the body size of *C. amblystomopsis* was larger than that of *C. hangiongensis* after mid summer. At that time young-of-the-year of both species settle down at the stream bed and begin to segregate within the microhabitat; *C. amblystomopsis* inhabits mainly the "Hirase" rapids whereas *C. hangiongensis* lives mainly in the "Hayase" and "Asase" rapids (Goto, unpublished data). The amount of available aquatic insects for the young-of-the-year in the "Hayase" and "Asase" rapids is more than in the "Hirase" rapids. The difference of growth rate between the two species observed in both 1979 and 1980, therefore, probably reflects the interspecific difference in the activity of metabolism during the juvenile and young stages.

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