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Geographic Distribution and Variations of Two Types of *Cottus nozawae* in Hokkaido, and Morphological Characteristics of C. *amblystomopsis* from Sakhalin*

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Abstract The patterns of geographic distribution and the geographic variations of some meristic characters in two types of *Cottus nazawae* collected throughout Hokkaido were investigated with special reference to the systematics of *C. amblystomopsis* obtained in Sakhalin. In Hokkaido, the small-egg type of *C. nozawae* is distributed along the Pacific and Okhotsk Sea slopes, while the large-egg type is distributed over most of Hokkaido. Towards the north, slight increases in number of vertebrae, pectoral fin rays and second dorsal fin rays were found in the large-egg type populations of Hokkaido, as well as a slight decrease in number of gill-rakers. In the small-egg type populations, however, such "geocline" was not recognized except in the number of pectoral fin rays and gill-rakers.

Comparison of the external, particularly meristic, characters of *C. amblystomopsis* with those of the two types of *C. nozawae* suggests that the small-egg type should be identified as *C. amblystomopsis*. Accordingly, it is reasonable to apply the species name *Cottus nozawae* only to the large-egg type.

Cottus nozawae is a freshwater cottid fish first reported by Snyder in 1911 from the Ishikari River in Hokkaido, Japan. Since that time, some morphological, ecological and embryological studies have been conducted on this species (Okada, 1936; Sato and Kobayashi, 1951; Watanabe, 1958, 1960; Omi, 1962). Recently, Goto (1975a, b, 1977) found that there were two types of *C. nozawae* which differ both ecologically and morphologically. One type has an amphidromous life history and the females spawn a great number of small-sized eggs in the lower reaches of a river. The other type, in contrast, has a fluvial life history and the females spawn a small number of large-sized eggs in the middle or upper reaches. He named them, for convenience, the small-egg type and the large-egg type respectively, and presumed that the two types are independent species judging from ecological and morphological evidence, in particular the reproductive isolation of the two types despite cohabiting the same river. Berg (1965) pointed out that *C. nozawae* might be a synonym of *C. amblystomopsis*, first reported by Schmidt (1904) from the Lyutoga River in Sakhalin, USSR. However, the systematic relationship between them is not necessarily distinct, because the morphological and ecological characteristics of *C. amblystomopsis* have been studied so little that it is difficult to confirm if they are the same species or not. Moreover, if Berg's (1965) opinion is true, the following systematic problems will arise: which type of *C. nozawae* should be identified as *C. amblystomopsis*, and what species is the remaining type?

To clarify the points mentioned above, the geographic distribution and morphological variations of the two types of *C. nozawae* were studied, and the two types were compared morphologically with *C. amblystomopsis*.

Materials and methods

Field collections of *Cottus nozawae* were made from 1972 to 1979. Names of rivers and the number of specimens of *C. nozawae* examined in the present study are shown in

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Table 1 and Fig. 1. All specimens were captured with a casting net or a dip net, and preserved in 10% formalin. Four specimens (HUMZ 70555～70558, 53.4～131.3 mm SL, 3 males and 1 female from Sakhalin, USSR) of *Cottus amblystomopsis* deposited at the Laboratory of Marine Zoology, Faculty of Fisheries, Hokkaido University, were also examined.

Counts and measurements were made in accordance with the method of Matsubara (1955). The number of fin rays and vertebrae was counted under a dissecting microscope or with the use of soft X-ray.

Results

Geographic distribution of the two types of *C. nozawae* in Hokkaido. Little work has been done on the geographic distribution of the two types of *C. nozawae* (Goto, 1975b; Goto et al., 1978). Numerous locations where the two types of *C. nozawae* were captured for the present study are shown in Fig. 1.

The small-egg type, with an amphidromous life history, is restricted to the rivers of the Pacific and Okhotsk Sea slopes. On the Okhotsk Sea slope the pattern of distribution seems to be partly discontinuous, in contrast to the continuous distribution on the Pacific slope. As described by Goto (1975b), the small-egg type is generally restricted to the mouth and the lower reaches of each river. On the other hand, the large-egg type, having a fluvial life history, seems to be distributed almost throughout Hokkaido. The ecological distribution of this type is generally restricted to middle and upper reaches in all rivers, except some rivers on the Sea of Japan slope, such as the Shosanbetsu River and Marumatsu River (20 and 21 in Fig. 1) where it is widely distributed throughout the rivers.

The range of geographic distribution of the two types of *C. nozawae*, however, is not completely known, because there has been little distribution study in other areas than Hokkaido. Nakamura (1963) and Tomoda (1968) reported that *C. nozawae* was distributed in some rivers in Tohoku District of Honshu, the northern part of the main-island of Japan. The specimens of *C. nozawae* captured by these authors may have corresponded to the large-egg type of this species, for the present author also obtained some specimens of the large-egg type from the Omoto River in Iwate Prefecture of Tohoku District. This information seems to indicate that the Tohoku District is the southern limit of the geographic distribution of the large-egg type. The small-egg type has not been collected from Honshu. This fact may indicate that the southern limit of this type is the southernmost part of Hokkaido. Takayasu et al. (1954) reported

Table 1. Locality and number of specimens of two types of *C. nozawae* and *C. amblystomopsis* examined morphologically in the present study.

Locality	Number of specimens	Locality	Number of specimens
Large-egg type of *C. nozawae*		Small-egg type of *C. nozawae*	
1. Shiodomari R.	229	3. Hekirichi R.	260
2. Matsukura R.	134	4. Ryūkei R.	90
3. Hekirichi R.	231	23. Kunnui R.	56
4. Ryūkei R.	163	28. Samani R.	65
5. Assabu R.	70	30. Saruru R.	52
13. Furū R.	17	32. Rakko R.	20
16. Ishikari R.	56	37. Onbetsu R.	35
19. Teshio R.	452	38. Ichani R.	4
20. Shosanbetsu R.	15	39. Yanbetsu R.	6
32. Rakko R.	21	42. Otoshibe R.	6
33. Monbetsu R.	23	*C. amblystomopsis*	
37. Onbetsu R.	31	S. Sakhalin	4
40. Ubaranai R.	16	Total	2118
42. Otoshibe R.	62		

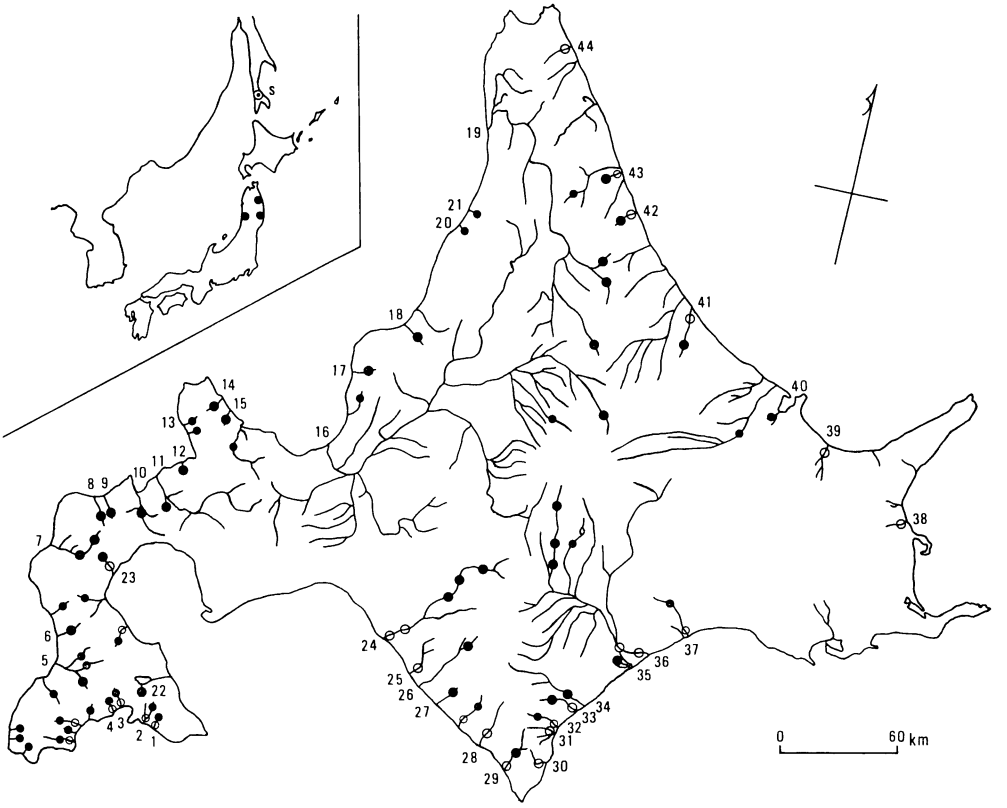

Fig. 1. Geographic distribution of two types of *C. nozawae*. ○, records of small-egg type added in this paper; ○, records of small-egg type by Goto (1975b) and Goto et al. (1978); ●, records of large-egg type added in this paper; ●, records by Nakamura (1963), Tomoda (1968), Goto (1975b) and Goto et al. (1978); ⊙, locality of *C. amblystomopsis*. 1, River Shiodomari; 2, R. Matsukura; 3, R. Hekirichi; 4, R. Ryūkei; 5, R. Assabu; 6, R. Ainumanai; 7, R. Toshibetsu; 8, R. Tomari; 9, Ohira; 10, R. Shubuto; 11, R. Shiribetsu; 12, R. Horobetsu; 13, R. Furū; 14, R. Bikuni; 15, R. Okimura; 16, R. Ishikari; 17, R. Gunbetsu; 18, R. Nobusha; 19, R. Teshio; 20, R. Shosanbetsu; 21, R. Marumatsu; 22, R. Ikusa; 23, R. Kunnui; 24, R. Saru; 25, R. Atsubetsu; 26, R. Niikappu; 27, R. Monbetsu; 28, R. Samani; 29, R. Horomitsu; 30, R. Saruru; 31, R. Hiroo; 32, R. Rakko; 33, R. Monbetsu; 34, R. Rekifuna; 35, R. Nagafushi; 36, R. Tokachi; 37, R. Onbetsu; 38, R. Ichani; 39, R. Yanbetsu; 40, R. Ubaranai; 41, R. Mobetsu; 42, R. Otoshibe; 43, R. Occharabetsu; 44, R. Kishibetsu; S, Sakhalin.

a collection of specimens of *C. nozawae* from the southern part of the Chishima Islands, but it is not known to which type these specimens belonged. Moreover, *C. amblystomopsis*, which was reported as a synonym of *C. nozawae* by Berg (1965), is distributed in the Sikhote aline and Sakhalin, USSR.

Geographic variations of some meristic characters in two types of *C. nozawae*. Number of vertebrae: The vertebral number of the two types of *C. nozawae* from each river is shown in Fig. 2. The vertebral number in the large-egg type varied from 32 to 36, the mode ranged between 34 and 36. Among populations from each river the mean number was smallest (33.95) in the population from the Ryūkei River (4 in Fig. 1) in the southernmost part of Hokkaido (range: 32～35, mode: 34). While it was largest (35.71) in the population inhabiting the Ishikari River (16 in Fig. 1) on the Sea of Japan slope (range: 34～36, mode: 36). A geocline in vertebral number with increase toward north may be observed throughout the range. In the same latitude,

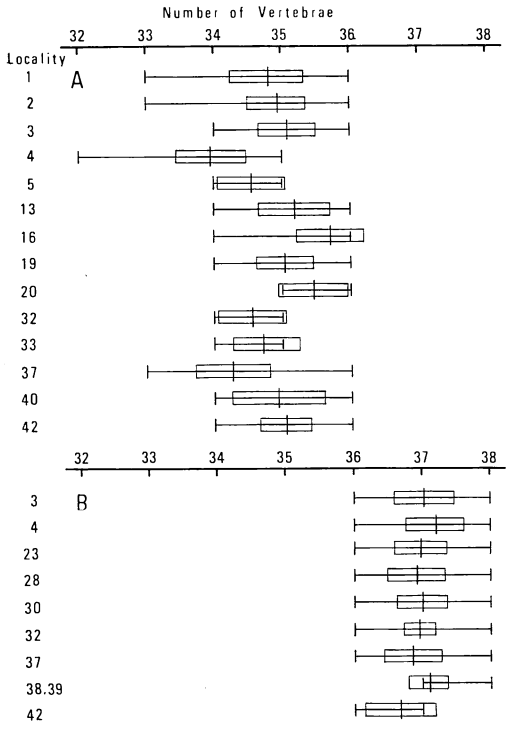

Fig. 2. Geographic variation in number of vertebrae of two types of *C. nozawae*. Locality of specimens is abbreviated by the number shown in Table 1. A: Large-egg type. B: Small-egg type.

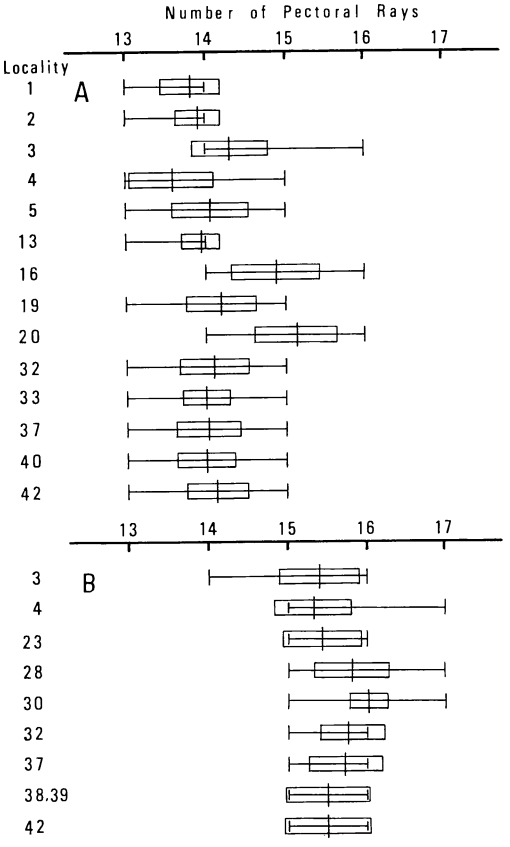

Fig. 3. Geographic variation in number of pectoral rays of two types of *C. nozawae*.

however, the number of vertebrae appeared to be larger in the populations from rivers on the Sea of Japan slope than those on the Pacific slope. Moreover, the vertebral number was larger for the Ishikari River specimens than those for the Teshio River specimens (19 in Fig. 1, range: 34～36, mode: 35, mean: 35.04), though the sampling stations on the former river are located at lower latitudes than those on the latter river (Fig. 1). The number of vertebrae of specimens from the Ryūkei River was significantly smaller than those from other rivers in the southern part of Hokkaido ($p<0.05$). On the other hand, the number of vertebrae in the populations of the small-egg type ranged from 36 to 38, with a mode of 37, and little difference was detected in the mean value among the seven rivers examined. Throughout the range of distribution, the vertebral number in the populations of the small-egg type was slightly larger than that of the large-egg type, but the variations in the former type were smaller than those in the latter type.

Number of pectoral fin rays: The number of pectoral fin rays in the large-egg type varied from 13 to 16 and the mode was 14 or 15 (Fig. 3). Toward the north, a slight increase in number was observed in populations inhabiting the rivers along the Japan Sea slope (the Assabu River, 5 in Fig. 1, 14.06 in mean value; the Fūru River, 13 in Fig. 1, 13.94; the Ishikari River, 16 in Fig. 1, 14.87; the Teshio River, 19 in Fig. 1, 14.11; the Shosanbetsu River, 20 in Fig. 1, 15.13), though the variations in this character were still smaller than those in the case of vertebral number. On the other hand, the number in the small-egg type ranged from 14 to 17

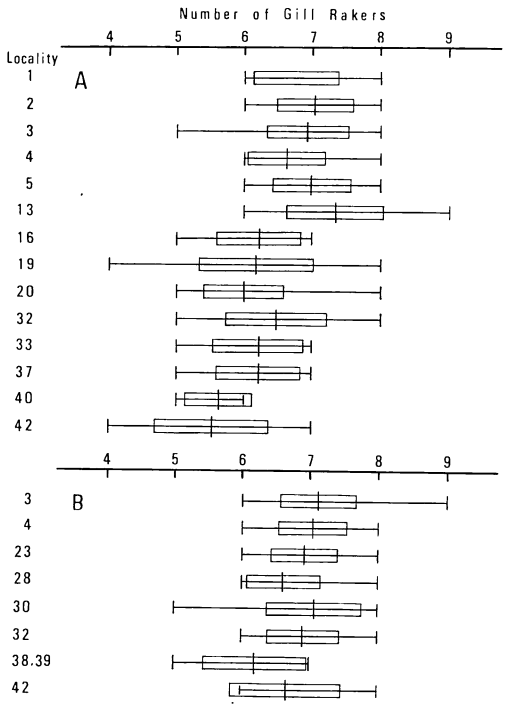

Fig. 4. Geographic variation in number of gill-rakers of two types of *C. nozawae*.

with a mode of 15 or 16, partly overlapping that for the large-egg type. However, in comparison with the populations of both types cohabiting the same river, such as the Hekirichi River or the Ryūkei River, the number in the large-egg type was so small in comparison to the number in the small-egg type, that striking differences were recognized between the two types. Also, the small-egg type seemed to show a slight increase in the number of pectoral fin rays toward the northern part of its range.

Number of second dorsal fin rays and anal fin rays: The number of rays of the second dorsal and anal fins in the large-egg type ranged from 15 to 19 (mode: 17 or 18) and 12 to 15 (mode: 13 or 14) respectively. In both fins, the range of variation overlapped among populations inhabiting different rivers. Thus no geocline was observed. In the small-egg type, the number of rays varied within the range of 17 to 20 (mode: 18) in the second dorsal fin and of 13 to 15 (mode: 14) in the anal fin. In both fin rays, little difference was detected among populations from different rivers.

Number of pyloric caeca: The number of pyloric caeca in the large-egg type ranged from 3 to 5 with a mode of 4. In the small-egg type, it varied within the range of 4 to 6 (mode: 5). In both types, little difference was observed among populations from different rivers. Throughout the range the number of pyloric caeca was slightly smaller in the large-egg type than in the small-egg type.

Number of gill-rakers: The number of gill-rakers in the large-egg type ranged from 4 to 9 (mode: 5～7) (Fig. 4). This character varied considerably among populations from different rivers and seemed to show a slight decrease in number toward the north. In the small-egg type, the number varied within the range of 5 to 9 (mode: 7), and a slight decrease toward the north was also observed.

Morphological and ecological characteristics of *C. amblystomopsis* from Sakhalin. Four specimens collected from Sakhalin were examined morphologically. These may be identified as *C. amblystomopsis*. The general morphological characteristics and meristic counts of these specimens almost correspond to those of *C. amblystomopsis*, first reported by Schmidt (1904) from specimens collected from the Lyutoga River (Table 2). Comparing the meristic counts in *C. amblystomopsis* with those in the two types of *C. nozawae* (Table 3), the vertebral number in the former (37) falls within the range of the small-egg type (36 to 38) and goes beyond that of the large-egg type (32 to 36). Other meristic counts in *C. amblystomopsis* partly overlapped the ranges of variation in both types. In other morphological characteristics, it was observed that the specimens of *C. amblystomopsis* were almost identical to those of the small-egg type, i.e., in their greatly depressed head, slightly protracted lips and low caudal peduncle (Table 3).

As far as the author knows, there has been no report on the ecological characteristics of *C. amblystomopsis*. In the present study, it was very fortunate that one of the specimens examined here (Fig. 5) was a female and had an almost fully matured ovary. The number of eggs in the ovary was counted

and compared with those in two types of *C. nozawae* (Fig. 6). Apparently, the values of egg number (841) in relation to the body size of females seems to fall within the range of variation of the small-egg type.

Table 2. Morphological comparison of the present specimens from Sakhalin with *C. amblystomopsis* recorded by Schmidt (1904) and Berg (1965).

	Present specimens	*Cottus amblystomopsis*	
		Schmidt (1904)	Berg (1965)
Total length (mm)	64～155	—	—
Standard length (mm)	53～131	208	—
Palatine teeth	absent	absent	absent
Pectoral fin	5～6 rays branched	8 rays branched	5～6 rays branched
In SL:			
Head length	3.17～ 3.38	3.3	3.3～3.4
Depth of body	4.37～ 5.68	7.7	—
Depth of caudal peduncle	12.74～14.27	17.3	—
Counts:			
Dorsal	VIII～IX, 17～18	VIII, 18	VIII～IX, 18～19
Anal	14～15	14	14
Pectoral	14～15	15	15～16
Pelvic	I, 4	I, 4	I, 4
Vertebrae	37	—	37
Preopercular spines	3	2	2～3

Table 3. Comparison of morphological characters and ecological features among two types of *C. nozawae* and *C. amblystomopsis*.

	Large-egg type of *C. nozawae*	Small-egg type of *C. nozawae*	*C. amblystomopsis*
Mouth (lips)	round	slightly round	slightly round
Palatine teeth	absent	absent	absent
Pectoral fin rays	some branched	some branched	some branched
Tuburcles on pelvic fin rays of adult male	present	present	present
In % of standard length:			
Head length	28～32	28～32	29～33
In % of head length:			
Eye diameter	18～25	17～23	15～23
Jaw width	65～95	60～70	54～81
Caudal peduncle depth	26～31	22～29	22～26
Counts:			
Dorsal rays	15～19	17～20	17～19
Anal rays	13～15	14～16	14～15
Pectoral rays	13～16	14～17	14～16
Vertebrae	32～36	36～38	37
Pyloric caeca	3～ 5	4～ 6	4～ 5
Gill-rakers	4～ 9	5～ 9	6
Preopercular spines	2～ 3	2～ 3	2～ 3
Eggs spawned	small number of large eggs	large number of small eggs	large number of small eggs
Ecological distribution	Bb to Aa	Bb-Bc to Bb	—
Forms of life cycle	fluvial	amphidromous	amphidromous (?)

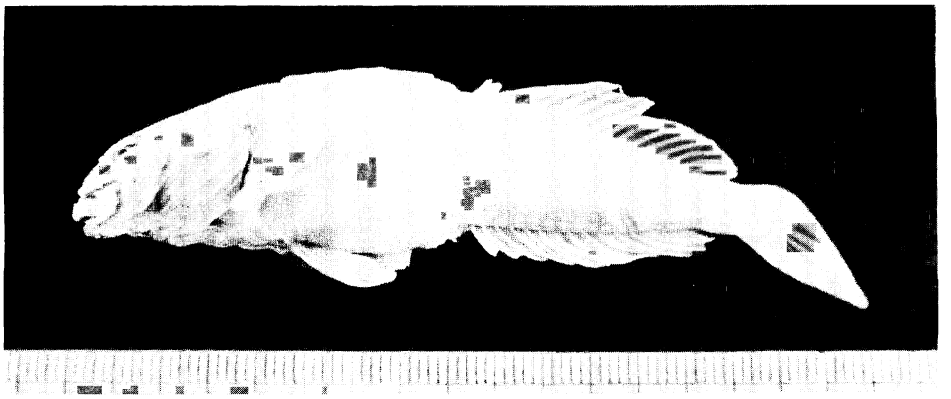

Fig. 5. *Cottus amblystomopsis*, HUMZ 70558, female, 77.0 mm SL., from Sakhalin Island, USSR.

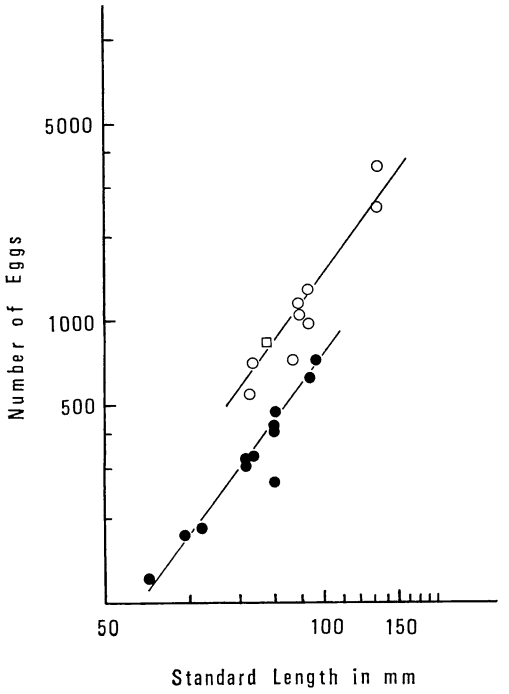

Fig. 6. Relation between number of eggs and standard length in two types of *C. nozawae* and *C. amblystomopsis*. ○, small-egg type of *C. nozawae*; ●, large-egg type of *C. nozawae*; □, *C. amblystomopsis*.

Discussion

The patterns of geographic distribution and morphological variations in the two types of *Cottus nozawae* may support the view of Goto (1975b, 1977) that both types are independent species, for they showed species-specific patterns in geographic distribution and morphological variation. As concerns distribution, the small-egg type of *C. nozawae* is distributed in rivers along the Pacific and Okhotsk Sea slopes but not in rivers facing the Sea of Japan, while the large-egg type is distributed almost throughout Hokkaido. The former type is restricted mainly to the lower reaches of rivers, the latter type, on the other hand, is widely distributed in the middle and upper reaches. In addition to the distribution mentioned above, differences in meristic counts between the two types are obvious.

It is generally recognized that there is such a geocline, meristic counts increasing toward the north, in many teleost fishes (Hubbs, 1922, 1940; Itazawa, 1957). In the case of the two types of *C. nozawae*, the large-egg type with a fluvial life history showed the same gradient as mentioned above in the number of vertebrae and pectoral fin rays, though the reverse gradient was observed in that of gill-rakers. The small-egg type with an amphidromous life history, however, showed little variation between the populations inhabiting different rivers. The differences between the two types seem to indicate that the way of appearance of geographic variation in morphological characters is different between the two types. Because of such differences the two types may be distinguished from each other, at least in the number of vertebrae and pectoral fin rays, when they are compared from the same river. This is true inspite of a partially overlapping number of every meristic character examined in the

present study when the two types are compared throughout the range of distrubution. Therefore, it is reasonable to distingush the two types as two independent species.

If the opinion that two types of *C. nozawae* are different species is accepted, the problem on the systematic relationship of them to *C. amblystomopsis* first recorded by Schmidt (1904) will arise. Berg (1965) described *C. nozawae* as a synonym of *C. amblystomopsis*. In reference to this problem, Goto (1975b) has already pointed out that the large-egg type belongs to *C. nozawae*, which was first recorded by Snyder (1911), because of the identity of its morphological characteristics. Therefore, the remaining problem is whether or not the small-egg type belongs to *C. amblystomopsis*. The general morphological characteristics and vertebral number of *C. amblystomopsis* suggest that the small-egg type belongs to *C. amblystomopsis*. Moreover, judging from the relationship between the body size and the egg number, *C. amblystomopsis* seems to have almost the same fecundity as the small-egg type. Presumably, *C. amblystomopsis* may spawn large numbers of small-sized eggs and have an amphidromous life history. Thus, the small-egg type should be identified as *C. amblystomopsis*, although it remains necessary to study ecologically the populations of Sakhalin or Sikhote aline. Hereafter, the author proposes to use "ezo-hana kajika" as the Japanese name for *C. amblystomopsis*.

In conclusion, *C. amblystomopsis* is widely distributed in Sikhote aline, Sakhalin and Hokkaido, while *C. nozawae* is restricted to Hokkaido and a part of the Tohoku District. The relationship of geographic distribution between them is considered to be contiguously allopatric.

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北海道におけるハナカジカ2型の地理的変異とサハリン産 *Cottus amblystomopsis* の形態的特徴*

後藤　晃

北海道に分布するハナカジカ *Cottus nozawae* の2型，小卵型及び大卵型，の地理的分布と形態変異を検討し，またサハリン産 *C. amblystomopsis* の形態的特徴を明らかにすることにより，これらの種間の分類学的整理を行った．

ハナカジカ小卵型は，北海道の太平洋側及びオホーツク海側に分布し，形態変異は比較的少ない．一方，ハナカジカ大卵型は，北海道のほぼ全域及び東北地方の一部の地域に分布し，形態的変異に富む．サハリン産 *C. amblystomopsis* の形態的諸特徴はハナカジカ小卵型のそれと一致し，孕卵数も極めてよく一致した．以上の結果から，ハナカジカ小卵型は分類学上 *C. amblystomopsis* に相当し，ハナカジカ大卵型は従来どおり *C. nozawae* に分類するのが妥当であるとみなした．また，*C. amblystomopsis* が日本に分布することが明らかになったことから，これに新和名エゾハナカジカを与えた．

***ハナカジカ *Cottus nozawae* の生態的・形態的分岐—III.**

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