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Reproductive Behavior of a River Sculpin, *Cottus nozawae*

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The river sculpin *Cottus nozawae* Snyder is widely distributed in Hokkaido, Japan. Recently, Goto (1975a, b; 1977; 1980) found two types in this species, and named the former type *C. amblystomopsis* and the latter type *C. nozawae*. The species name, *C. nozawae*, will be only applied to the species which possesses a small number of large-sized eggs and has a fluvial life history.

Cottus nozawae is characterized as a spring-spawning species in which the male is colored black on the back and sides of the body and the female is cryptically colored. As for the breeding habits of this species, Okada (1936), Watanabe (1960) and Goto (1975a) reported that the spawning occurs under stones and the eggs are deposited on the roof of the nest and adults seem to guard the eggs.

However, nothing has hitherto been recorded on the courtship, spawning and parental behavior of *C. nozawae* because of the difficulty in satisfying their requirements for spawning under artificial conditions, though there are some interesting works on spawning of other freshwater sculpins, such as *C. gobio* (Morris, 1954), *C. poecilopus* (Starmach, 1962) and *C. bairdi* (Savage, 1963). In the present study, the reproductive behavior of *C. nozawae* was observed under conditions almost similar to those of the natural habitat and was compared with that of the other species belonging to the genus of *Cottus* previously recorded.

Materials and methods

Mature fish of *Cottus nozawae* were captured in the Hekiriji River near Hakodate, Hokkaido, on May 5, 1979 and May 9, 1980. They were transported to the Nanae Fish Culture Experimental Station, Hokkaido University. Gravid females having fully ripe orange-colored eggs and males oozing milt when squeezed at the abdomen were selected from total catches and transferred into an aquarium ($60 \times 30 \times 35$ cm) placed on the bed of an approximately 2 m wide streamlet flowing through the Station grounds (Table 1). The aquarium, which was covered with wire netting on the front and back sides and glass on both lateral sides, was set at water-depth of approximately 30 cm. (Fig. 1A). A steel-frame fixing a reflecting mirror with the angle of inclination at 45° to the lateral glass of the aquarium was set beside it (Fig. 1B). The velocity of current was 20～30 cm/sec. One flat-bottomed stone had been placed on the gravel substratum covering the bottom of the aquarium, before the fish were transferred into it.

Observations were made every day in the morning, from 04: 00 to 07: 00 hrs., and additionally at other times of the day.

Results

Spawning behavior was observed three times in 1979 and four times in 1980 (Fig. 2). In every case, the spawning took place soon after dawn and in an almost similar behavioral pattern as is mentioned below. The water temperature on the days of spawning fluctuated approximately from 9.0° to 12.0°C at 12: 00 hrs. in both years.

A dominant male, which was usually the blackest in body color among the males, occupied the shelter under the flat-bottomed stone soon after the fish were transferred into the aquarium. When a female came into sight (Fig. 3A), the male at the entrance of the shelter dashed toward the female and immediately turned back to the shelter. The female re-

Table 1. Number and body size of the male and female of *Cottus nozawae* transferred into an aquarium in 1979 and 1980.

Date transferred	Sex	Number of individuals	Standard length (mm)
May 5, 1979	Male	3	105.1～118.8
	Female	5	82.5～ 98.0
May 9, 1980	Male	3	111.2～121.3
	Female	5	90.3～103.7

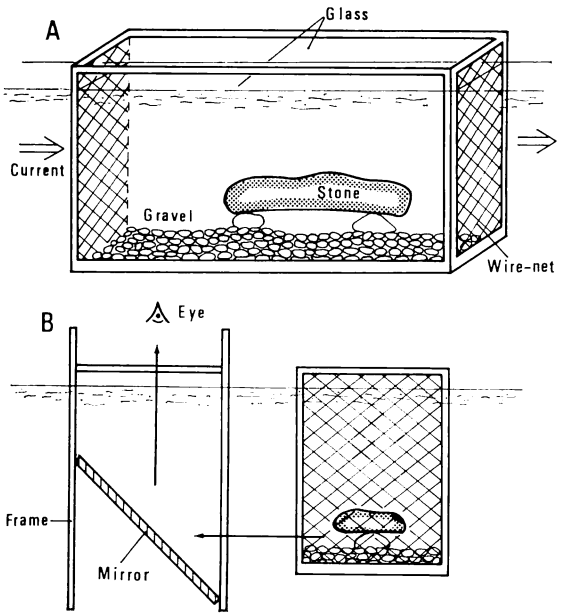

Fig. 1. Apparatus for observation on the reproductive behavior of *Cottus nozawae*. A: Lateral view of the aquarium set-up. B: Frontal view of the aquarium and a steel-frame and the adjacent reflecting mirror.

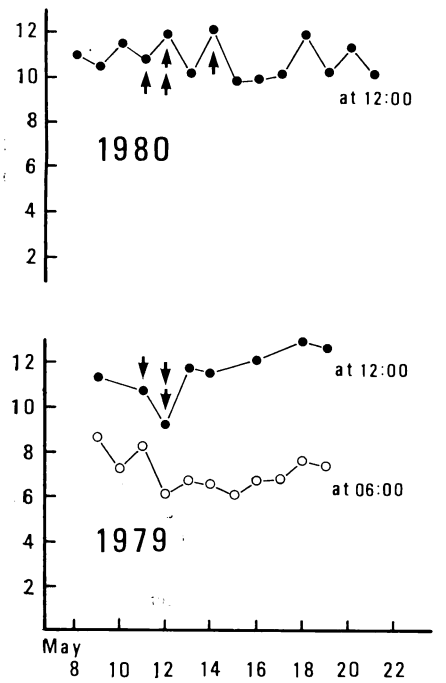

Fig. 2. Dates of spawning and changes of water temperature during the observation period of the behavior of *Cottus nozawae* in 1979 and 1980. Arrows indicate the dates of spawning.

sponded to such behavior either escaping from the male quickly or following it toward the shelter. When the female entered the shelter, the male having the first dorsal fin colored with a clear orange band around the edge became even blacker in body color and frequently nodded his head. In the shelter, both the male and female lay side by side on the floor of the nest (Fig. 3B) and turned round several times. After several minutes, the male turned upside down and crawled on the roof of the shelter (Fig. 3C), and then the female followed after the male reacting in the same manner. They were able to keep their bodies upside down on the roof with the help of their expanded dorsal, pectoral and caudal fins which were useful for props. Both the male and female lay side by side in an upside-down position. Soon, the male came to rest with his ventral surface on the dorsum of the female and with his body twisted, so that the posterior part of his body lay alongside hers. The male held the female's abdomen with the right and the left pelvic fins, and shivered for about half a minute. Their mouths were opened widely or moderately during spawning. During this behavior, the female deposited most of her eggs in a burst,

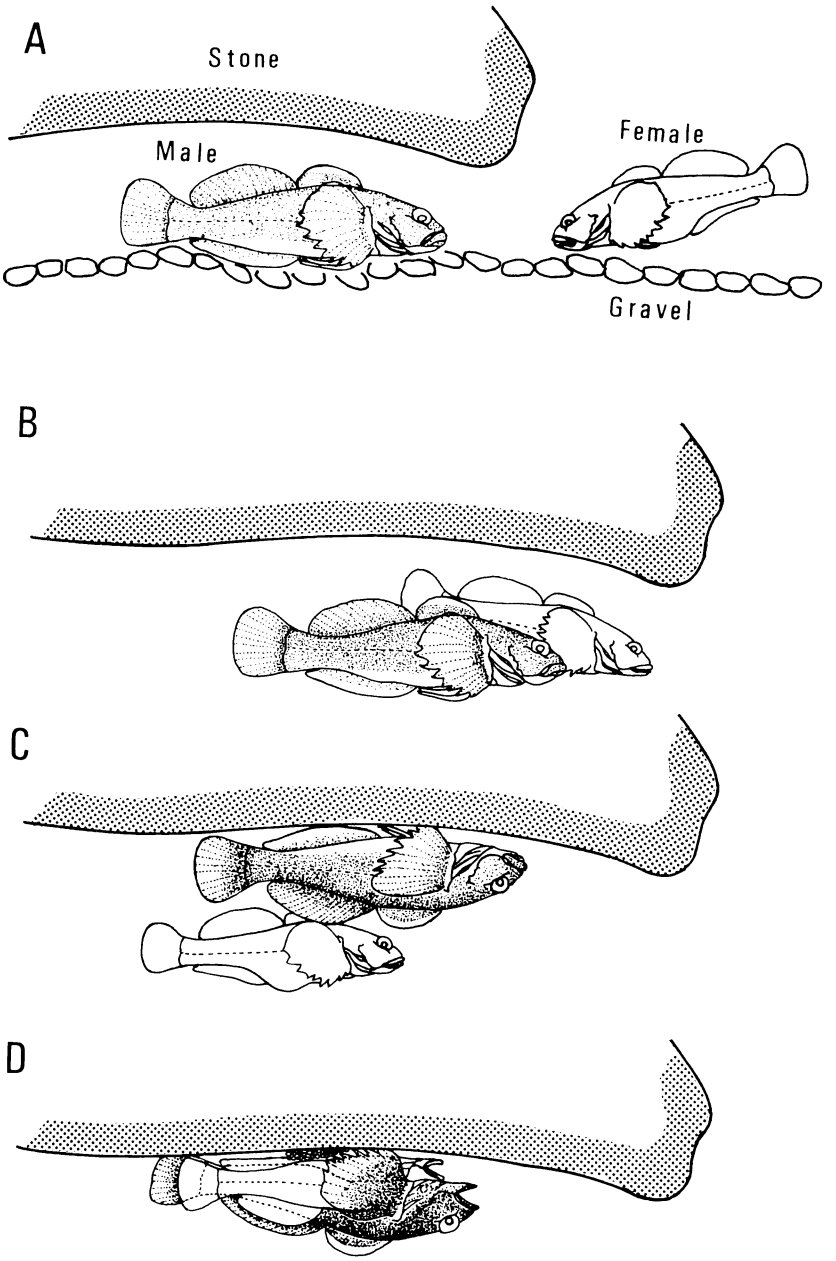

Fig. 3. Diagrammatic view of the sequence of spawning in *Cottus nozawae*. A: A male at the entrance of the shelter encounters a female when she comes into sight. B: Both the male and female lie side by side inside the shelter. C: The male turns upside-down before the female does so. D: The male lies on the inverted female and spawning occurs.

with the remaining eggs following slowly (Fig. 3D). The eggs hardened and firmly adhered to the surface of the roof within one hour after the deposition.

After spawning, the male remained for about 20 minutes with his ventral surface on the dorsum of the female in an upside-down position. Then the male turned back to a right-side up position, and remained in the nest. On the other hand, the female remained in an

Fig. 4. A male with a egg-cluster, who lies facing toward the current about 2 weeks after the spawning.

upside-down position for about 30 minutes more. The male picked or bit at the female, so that she turned to a normal position and left the nest. The male usually lay under the egg-cluster, facing toward the current (Fig. 4).

About 2 weeks after spawning, the male began to fan the eggs with the pectoral fins occasionally but this fanning behavior was weak and infrequent. The male fanned more frequently and guarded the eggs more vigrously as they continued to develop until they hatched 4 weeks after spawning.

Discussion

A Europian freshwater sculpin, *Cottus gobio*, which has been studied in terms of reproductive behavior more intensively than any other species belonging to genus *Cottus,* is capable of spawning in still water (Smith, 1922; Breder, 1932; Morris, 1954). *C. nozawae*, observed in the present study, however, spawns only in moving water, so that the egg-clusters of this species are deposited on the undersurface of stones only in the "hirase-rapids" in a river (Goto, 1975a). In spite of such a difference, the reproductive behavior of *C. nozawae* is basically similar to that of *C. gobio*, *C. poecilopus* (Starmach, 1962) and *C. bairdi* (Savage, 1963). The males of these species occupy shelters under stones and lead the females into the nest. Soon after, both fish turn upside-down, the female spawns the eggs on the roof of the nest and the male deposits his sperm over the eggs. Most eggs are deposited in a sudden burst and the remaining eggs are slowly added. After spawning, the female leaves the nest and the male fans the eggs with his pectoral fins. Therefore the fundamental pattern of the reproductive behavior is suggested to be common in most respects within the genus *Cottus*.

However, in some detailed respects, the reproductive behavior of *C. nozawae* differs from that of the species mentioned above. The male of *C. nozawae* did not show any signs of a digging behavior and used a cavity under a stone for the nest, while the males of other species such as *C. gobio* (Morris, 1954) and *C. poecilopus* (Starmach, 1962) dig a hole underneath a solid object placed on the bottom prior to pairing with the female. In addition, Morris (1954) and Savage (1963) observed that the females of *C. gobio* and *C. bairdi* turned upside-down inside the nest before the male did so. In *C. nozawae*, however, the male turned upside-down prior to such behavior of the female in almost all cases observed, as if the male induced the female to take such a position. This fact may suggest that in *C. nozawae* the male plays a more active role than in *C. gobio* and *C. bairdi* through spawning. Thus, the reproductive behavior of species falling within the genus *Cottus* seems to vary among species in some detailed respects.

Morris (1954) concluded that the male of *C. gobio* recognized gravid females because they always failed to flee after being bitten by the male. On the other hand, Savage (1963) suggested that the male of *C. bairdi* may lack the ability to discriminate between gravid and spent females. In the present study it was not clear whether or not the male of *C. nozawae*

could discriminate a gravid female from a spent or unripe one.

Such problems will be elucidated by further detailed investigations in relation to sexual recognition in these species. The reproductive behavior of *C. amblystomopsis* and *C. hangiongensis*, which are distributed sympatrically with *C. nozawae* in southern Hokkaido, remains to be investigated in the future.

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ハナカジカ *Cottus nozawae* の生殖行動

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小川に設置されたガラス水槽中で，ハナカジカ *Cottus nozawae* の求愛行動，産卵行動及び雄の保護行動が観察された．

水槽に導入された数尾の成熟雌と雄のうち，最も体色の黒い雄が石の下のシェルターを占有した．シェルター内の雄は，雌がシェルターの入口に近づいた時，この雌に向かって突進し，すぐにシェルターにもどった．この雄の動作に対して，雌は逃げ去るか，または雄に続いてシェルターに入るかのいずれかの反応を示した．そして，雌がシェルターに入った場合には一連の産卵行動が継続した．

番を形成した雄と雌は，正位の姿勢で寄り添い，シェルター内で数回輪を描くように回転した．数分後，雄は逆位になり，石の下面に沿って這うような行動をとった．まもなく，雌も逆位になり，雄は頭部を雌の頭部に重ね，胴部を雌の胴部に沿って横たえ，密着させた．雄と雌が口を開け，激しく体を震わせた時，雌は多数の卵を一度に放出し，その後ゆっくりと放卵した．

産卵後，先ず雄が正位にもどり，次に雌も正常の姿勢にもどった．まもなく，雌は雄による突きあるいは喰みつきによって，産卵巣から逃げ去った．一方，雄は産着卵とともに産卵巣に留まり，約2週間後から胸鰭によるファンニング行動を始め，孵化時まで続けた．

このような生殖行動をハナカジカ属の他種のそれと比較した結果，基本的な行動パターンは互いに類似するが，幾つかの細部の行動には違いが認められた．

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