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Spawning Behavior of Japan Sea Greenling, *Pleurogrammus azonus*, off the Bol'shoi Pelis Island, Peter the Great Bay, Russia.

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Abstract

The spawning behavior of *Pleurogrammus azonus* was observed off the Bol'shoi Pelis Island, Peter the Great Bay, Russia. Numerous males defended their territory on the spawning ground, a stony slope (4-28 m depth) off the west coast of the island. Resting mature females swam in shoals of 100-1,000 individuals near the spawning ground. When they were pregnant with mature eggs, females solitarily swam down near male territories on the bottom. Pregnant females were courted by territorial males, and selected partner during daytime. Spawning occurred at nighttime after females had stayed in a male's territory for several hours. Females deposited the eggs by pressing their abdomens to the substrate. Following sperm emission by the males, females pushed the egg mass to wedge it between stones with one side of their pectoral fins, cheek, or abdomen. These behavioral patterns were compared with past reports of other hexagrammid species.

Key words : Spawning behavior, *Pleurogrammus azonus*, Territorial male, Spawning aggregation, Night spawning.

Introduction

The family Hexagrammidae including the Japan Sea greenling, *Pleurogrammus azonus*, are known to practice paternal care (Breder and Rosen, 1966). Reproductive behaviors of some species in this family have been well studied (Gorbunova, 1970; Lariviere et al., 1981; DeMartini, 1986; Munehara and Miura, 1994; Munehara and Takenaka, 2000; Munehara et al., 2000). The spawning behavior of *P. azonus* caught near the Shakotan Peninsula, western Hokkaido, Japan, has been

observed in the laboratory by Suzuki and Hioki (1975). Gomelyuk (1988) reported the spawning behavior on spawning grounds near Dva Brata Island, Peter the Great Bay, Russia. Both reports described the agonistic behavior between territorial males, spawning behavior from pairing to sperm emission and egg care by males, with some notable differences. Suzuki and Hioki (1975) reported that night spawning was followed by females pushing the egg mass into the substrate before leaving the spawning site. Gomelyuk (1988) described the females leaving the spawning site immediately after

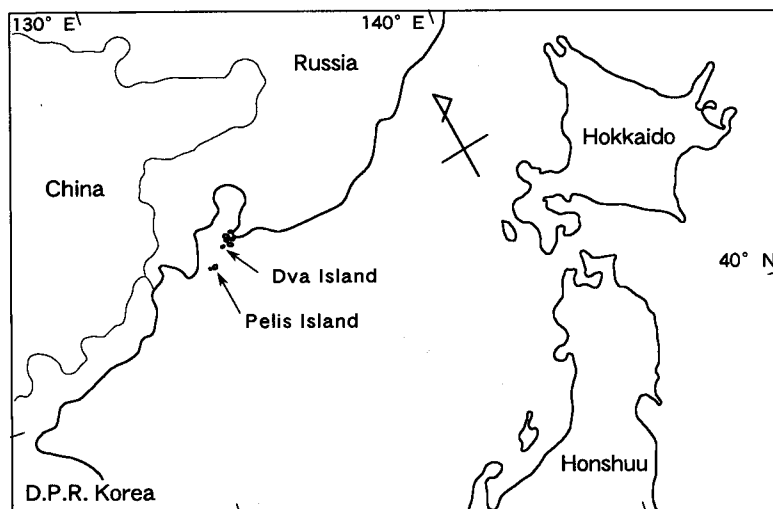


Fig. 1. Map of the research area.

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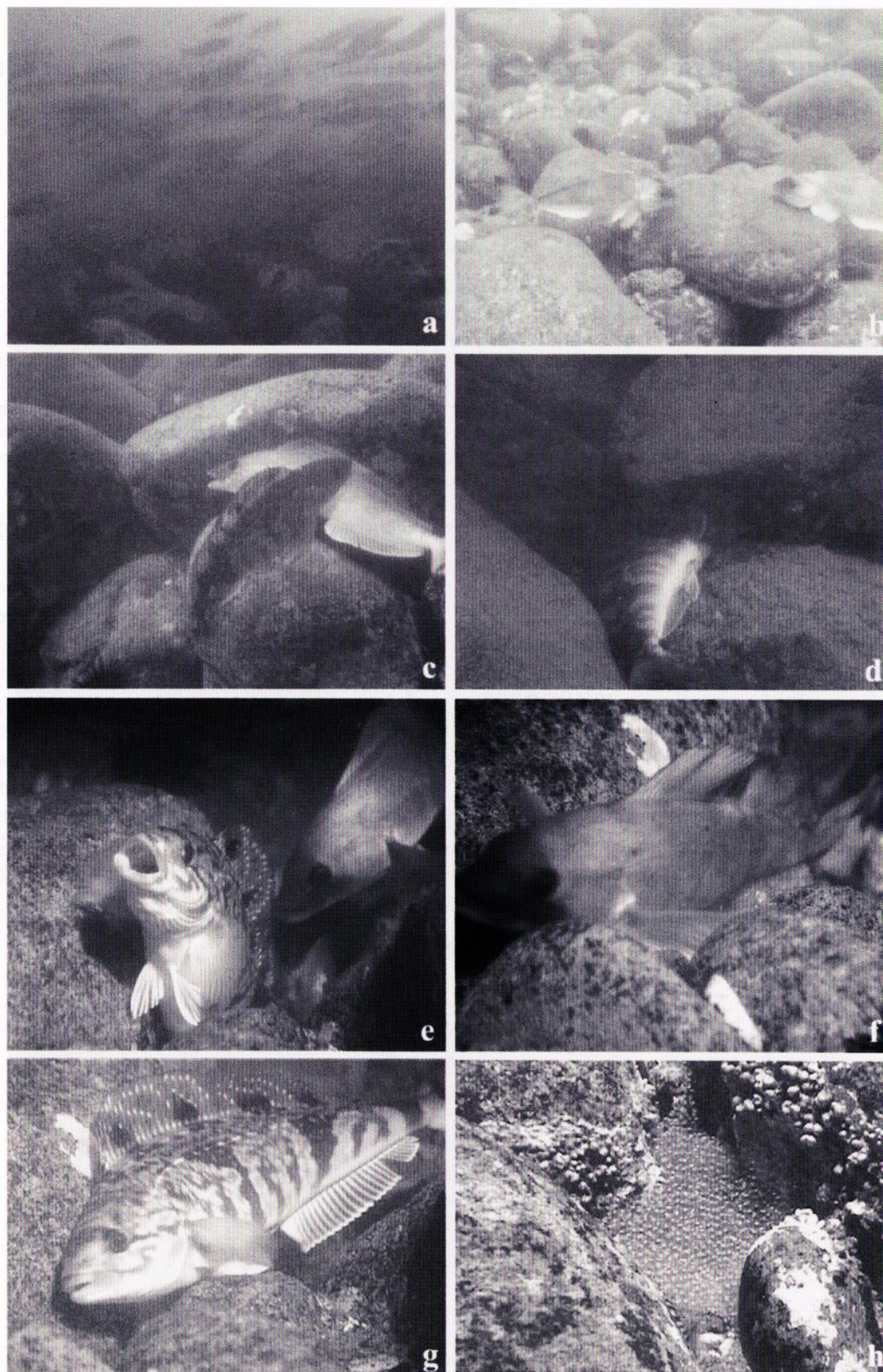
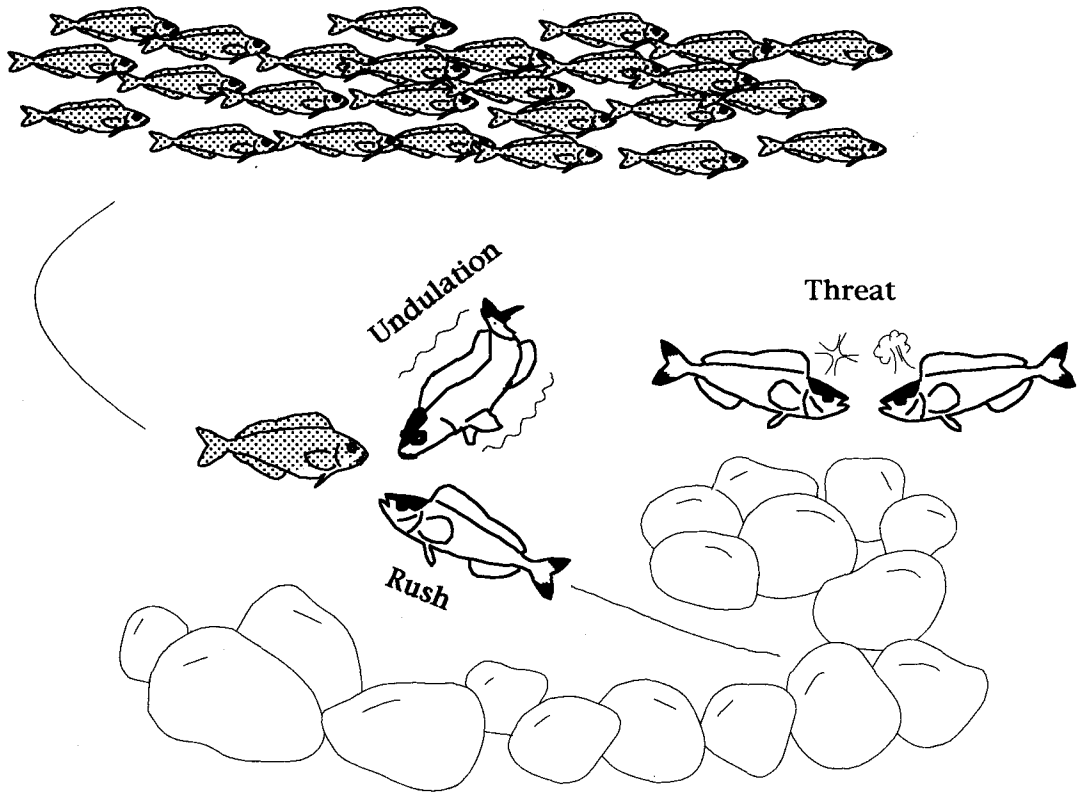
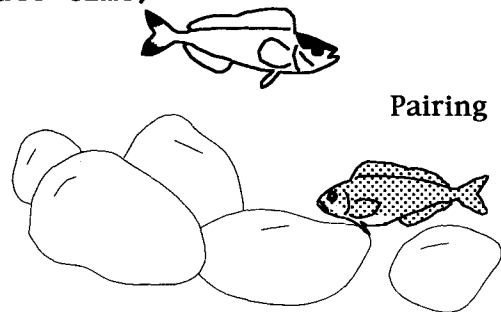


Fig. 2. Spawning behavior of *Pleurogrammus azonus*. a) a shoal of females swim near the spawning ground ; b) threat display ; c) courtship display by undulation of male (right) ; d) cleaning of spawning substrate by female ; e) spawning ; f) sperm emission ; g) the female presses the egg mass with her belly between rocks ; h) an egg mass just after spawning.

Daytime (early time)



Daytime (late time)



Night time

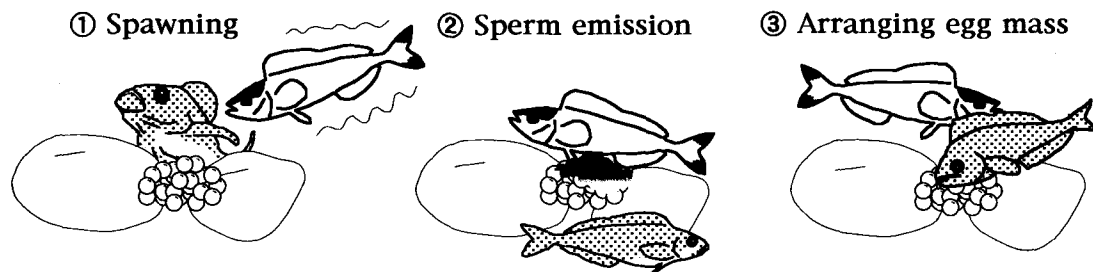


Fig. 3. Ethogram of spawning behavior in *Pleurogrammus azonus*.

day spawning. Causes of these differences were unknown.

We succeeded in observing the entire spawning behavior of *P. azonus* using an underwater video camera in the natural spawning ground off the Bol'shoi Pelis Island located in Peter the Great Bay, Russia. Markevich (1999) had reported the environmental characters of the spawning ground and some aspects of the reproductive biology of *P. azonus* in this region. In the present paper, the spawning behavior of *P. azonus* is redescribed and compared with the past literature.

Methods and Materials

Investigations were conducted in a small bay in the north of Bol'shoi Pelis Island (Fig. 1) from 26 September to 13 October 1999 with the aid of SCUBA. The observation was begun to look for territorial males courting a female. The observation was done only in daytime in the first week, and then continued for several hours after sunset because any pairs did not spawn before sunset. A halogen flashlight was used for observation in dark time. Behaviors were recorded with a hi-vision camera packed in a watertight housing by the Japan Underwater Films Company.

Results

The spawning grounds of *P. azonus* around the coastal of Bol'shoi Pelis Island, where the mature males gathered, were covered with many stones of 0.3–0.8 m in diameter on steep slope (4–28 m depth) off the west coast of the island. Markevich (1999) reported that more than 500 territorial males were found on the spawning ground >4,000 m². Fights between territorial males were frequently observed. At the beginning of our investigation, the males guarded 0–3 egg masses with the mean of 1.3 ($n=15$). The egg masses were firmly wedged between stones. The most developed embryos were estimated about 10 days after spawning based on that they had not yet attained visible eye pigmentation, suggesting that the spawning season of *P. azonus* begins in mid September. The males sometimes ventilated the egg masses by sucking and blowing.

Resting mature females swam in shoals of 100–1,000 individuals around the spawning ground (Fig. 2a, 3). Gravid females solitarily swam down near male territories on the bottom where they were courted by territorial males. The males displayed nuptial coloration of light blue with a black spot on the upper part of head and the tip of caudal fin (Fig. 2b). The males rushed to females spreading all the fins, and spasmodically undulated their body leaning obliquely. When neighbor-

ing males approached a courting male, the male promptly attacked the intruders. Two males faced each other while hovering over a female, opening mouth and displaying their opercula and branchiostegal membrane. This pose continued until one of the males swam away. These courtship and defensive displays were often found in every territory throughout the day.

A complete spawning was observed twice. Females accepting courtship stayed on a stone in the male's territory and sometime clean stones or previously deposited egg masses in the territory with her mouth. The female's genital pore gradually protruded. The males repeated the spasmodic undulation of their trunks leaning obliquely toward the female (Fig. 2c). Pairs were established by sunset. The protrusion of skin near female's genital pore was so prominent that the eggs became visible through the skin. The female frequently cleaned the future spawning site with her mouth (Fig. 2d). Shortly before spawning, the female swam through the site for 2–3 times arching her body. The male rapidly undulated his trunk while approaching the female, and sometime tapped her back with his mouth.

Spawning was done in the dark about 2 hours after sunset. The female deposited her eggs by pressing her abdomen to the substrate. While spawning, she simultaneously opened her mouth and quivered the posterior portion of her trunk (Fig. 2e). After spawning, the female stayed near the newly spawned egg mass for several minutes. The male emitted semen, when he passed over the egg mass touching them with his genital pore (Fig. 2f). A part of the deposited eggs was loosened from the mass and eaten by the male. The remaining eggs stuck to the deposition site as a mass. The female pushed the egg mass to wedge it in a gap between two stones with one side of their pectoral fins, cheeks or sometime with the belly (Fig. 2g). This action was repeated from various directions, until the egg mass was wedged firmly in the gap (Fig. 2h), and the female left the male's territory. Spawning occurred concurrently in neighboring territories. Males that failed to mate during the day slowly swam or stayed near a stone in their territories over night. Sneaking was not performed during the two successful observations in the present study. This differs from other greenlings where sneaking is common (Munehara et al., 2000; Munehara 2003).

Discussion

There were some differences in the spawning behaviors between our observation and Gomelyuk's observation of *P. azonus* off Dva Brata Island in Peter the Great Bay (Gomelyuk, 1988). The Bol'shoi Pelis Island is

Table 1 A comparison of reproductive behaviors among *Pleurogrammus azonus* and two other *Hexagrammos* species.

	<i>Pleurogrammus azonus</i>	<i>Hexagrammos otakii</i>	<i>Hexagrammos octogrammus</i>
Courtship	Spasmodic undulation with trunk bending Rushing	Spasmodic undulation with trunk bending Rush and butting	Spasmodic undulation with trunk bending Rush and butting
Spawning and subsequent behaviors	Spawning-Sperm emission -Pushing egg mass to substrate by female-Female leaving	Spawning-Female leaving -Sperm emission-Pushing egg mass to substrate by male	Spawning-Female leaving -Sperm emission
Spawning time	Nighttime	Daytime	Daytime
Male parental care	Guarding and ventilation	Guarding and ventilation	Guarding and ventilation*
References	Suzuki and Hioki (1975)	Munehara and Miura (1994) Munehara et al. (2000)	Munehara et al. (2000) *Munehara H, unpublished Data

located 40 km away from Dva Brata Island (Fig. 1). Gomelyuk (1988) reported that spawning finished in one minute under daytime, that females left the spawning site immediately after egg deposition and that ventilation of egg masses by males was absent. In contrast, we observed that spawning was done after sunset, that females stayed for several hours in the male's territory before spawning, that females repeatedly pushed the egg mass to the spawning substrate following egg deposition, and that males ventilated the egg masses by sucking and blowing. Suzuki and Hioki (1975) observed not only these behavioral patterns but also gradual increase of ventilation of the eggs with embryonic development.

The behavioral pattern of *P. azonus* observed by Suzuki and Hioki (1975) and the present study differed from those reported for other *Hexagrammos* species (Table 1). *P. azonus*'s spawning behavior began with courtship for pairing during the daytime and ended with the pushing of spawned egg masses into a gap by the female at night. Female *P. azonus* stayed in the male's territory during pairing far longer than other *Hexagrammos* species females which have been reported to spend only a few minutes in the male's territory between courtship to egg deposition. *Hexagrammos* species are daytime spawners unlike *P. azonus* (Munehara and Miura, 1994; Munehara et al., 2000). Although pushing of the egg mass to substrate after spawning is done by male in *Hexagrammos otakii*, female played the role in *P. azonus*. Gomelyuk's observation (Gomelyuk, 1988) is similar to the spawning behaviors of *H. otakii* rather than these of *P. azonus* by Suzuki and Hioki (1975) and the present study. It is possible that Gomelyuk (1988) may not have observed the spawning behaviors of *P. azonus* but rather those of *H. otakii*.

The spawning ground was large, and several hundred males had territories. Males established territories close to one another and performed frequent territorial displays. Two possible reasons for this close territorial

aggregation are the high density of courting males attract mature females (Barnett and Pankhurst, 1996) and defence of the eggs against egg predators. Previous studies have reported that the stomachs of female *P. azonus* were filled with conspecific eggs (Tanaka et al., 1986; Kaneda, 1995). The present study was carried out for a period of 18 days in the early breeding season, when the spawned eggs seemed to be well constantly guarded by the territorial males. The females joined a shoal during the interval between repetitive spawning. These shoals may raid isolated nests to eat eggs as is known in the female sticklebacks, *Gasterosteus aculeatus* (Kynard, 1978). The presence of many aggressive males may defend eggs from female raids.

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