Short Paper

Sediment Size Composition as an Important Factor in the Selection of Spawning Site by the Japanese Surf Smelt *Hypomesus japonicus*Taro Hirose[†] and Kouichi Kawaguchi

Ocean Research Institute, University of Tokyo, Minamidai, Nakano, Tokyo 164-0014, Japan

(Received February 20, 1998)

Key words: chika, sand beach, spawning site selection, egg distribution

Japanese surf smelt *Hypomesus japonicus* (Japanese name 'chika') is a small coastal fish ranging from the Korean Peninsula and northeastern Japan to the Kuril Islands.¹⁾ Hirose and Kawaguchi reported that spawning grounds were limited to the shorelines where the sand grains were coarsest and shorelines with fine sands were not used as spawning sites at Akaiso Beach in Otsuchi Bay.²⁾ This result suggested that chika select their spawning site in accordance with sand grain size composition. They also reported that eggs spawned near the shoreline were distributed just off the spawning area.²⁾ In this context, we examined the relationship between egg distribution and characteristics of the five beaches in Otsuchi Bay, i.e. sediment size composition, slope, and the material of the sediments, to elucidate factors affecting selection mechanisms for spawning sites.

Five beaches, Misagojima, Murohama, Komagasaki, Shirahama, and Koshirahama were investigated. As peak spawning of chika occurred on the spring tide around the full moon period in April,²⁾ samplings of eggs and sand were done just after the spawning peak. At each beach, four transect lines were set in the intertidal zone at equal intervals from one end to the other end of the beach with four sampling points on each transect line, i.e. on the highest (HTL), mean (MTL), and lowest (LTL) tide lines, and the 30 cm water depth point at standard tide level. Shorelines existed between MTL and LTL at all beaches during the sampling. Eggs and bottom sediment were sampled with two types of cylindrical core-samplers, one 7.2 cm in diameter and 14 cm long for egg sampling, and another 5 cm in diameter and 12 cm long for sediment sampling. Sediment sampling was not done in Koshirahama where the recent data on the median particle diameter was available from the literature.³⁾ Eggs in the sediment were preserved in 10% formalin with Rose Bengal in the field and sorted out in the laboratory. Sediment samples were washed in fresh water, dried at 60°C for 24 hours, and sorted by sieves of various mesh sizes. Sediment size composition

was expressed as percentage of weight of sand grains for each size range and median particle diameters were calculated. All to which egg were attached sand grains were sized, based on the following categories, i.e. less than 0.5 mm, 0.5 to <1 mm, 1 to <2 mm and 2 mm or more along the longest axis under a dissecting microscope.

Eggs occurred at three beaches of the five beaches surveyed (Table 1). Including data on Akaiso Beach, where eggs have been reported,²⁾ in the comparison, no remarkable differences were apparent in the sizes of the beaches, the material of sediment, or the slope angle of the intertidal zone in and of the six beaches, that might separate those beaches where spawning occurred from the other beaches. However, a difference in the median particle diameter (MPD) in the intertidal zone was noteworthy. The MPDs of the beaches where spawning occurred were >1 mm, while the MPDs of the other beaches, Shirahama and Koshirahama, were extremely small, 0.33 mm and 0.26 mm respectively (Table 1).

We examined the egg distributions in relation to sediment size composition at each beach. On the transects where eggs occurred at high densities (>1000 eggs/m²), grains of ≥2 mm (=gravel) comprised more than 40% of the total mass of grains, but <2 mm grains (=sand) also accounted for 10–60% of sediment mass, e.g. lines A and B at Misagojima and A–D at Komagasaki (Fig. 1). However, eggs were not evident along the transect lines with a high gravel component, e.g. transects C and D at Misagojima, or a high proportion of fine sands (<0.5 mm), e.g. transects A–D in Shirahama. At the spawning beaches, the percentage of gravels at the stations where eggs were absent were higher than that at stations where eggs occurred (Mann-Whitney *U*-test, *p* < 0.01). An examination of egg-bearing sand grains revealed that eggs mainly adhered to grains of 0.5 to <2 mm and grains in the ranges 0.5 to <1 mm and 1 to <2 mm comprised 31.2–46.4% and 21.8–42.6% of the total grains respectively (Table 2). The percentages were below 3.5% for the

Table 1. Characteristics of the beaches studied and egg distribution in each beach

Location	Sampling date	Length (m)	M.P.D. (mm)	Slope	M.S.* ¹	Egg distribution
Koshirahama	6 May 1993	120	0.3* ²	1:13* ²	G	–
Murohama	18 Apr. 1994	50	>2	1:11	S	+
Shirahama	18 Apr. 1994	60	0.3	1:12	G	–
Misagojima	19 Apr. 1995	60	>2	1:10	S	+
Komagasaki	19 Apr. 1995	30	>2	1:11	S	+
Akaiso* ³	26 Apr. 1994	80	1.2	1:12	G	+

+, eggs were present; –, eggs were absent.

M.P.D., median particle diameter in intertidal zone; M.S., material of sediments; G, granite; S, sedimentary rock.

*¹Yamanaka *et al.*,⁴⁾ *²Takahashi & Kawaguchi,³⁾ *³Hirose & Kawaguchi.²⁾

[†] Present address: Japan Sea National Fisheries Research Institute, Suidocho, Niigata 951-8121, Japan.

a. Misagojima

b. Murohama

c. Komagasaki

d. Shirahama

Fig. 1. Egg density and sediment size composition at the four beaches studied.

Transects were set at equal intervals from one to the other end of each beach. H.T.L., M.T.L., L.T.L., and 30 cm d. show highest, mean, and lowest tide line, and 30 cm water depth point at standard tide level, respectively. For each sampling point, left side (solid circle or x) shows egg density and right side (circle graph) indicates sediment size composition expressed as weight percent of each size fraction.

grains of the ≥ 2 mm, and 18.0–30.6% for the grains of < 0.5 mm. These results suggest that chika spawn in the intertidal zone of beaches where the bottom sediments contain both gravels and sand grains of the size suitable to the an-

Table 2. Size composition of sand grains to which Japanese surf smelt eggs attached

Beach	Size fraction (mm)			
	< 0.5	$0.5 - < 1$	$1 - < 2$	≥ 2
Komagasaki	30.6	46.4	21.8	1.2
Murohama	23.0	31.2	42.6	3.2
Misagojima	18.0	39.2	41.9	0.9

Values show the percentage of weight of each size category.

chors of eggs. These results agree with published data from Akaiso Beach where spawning is always carried out at a restricted site of grain-sand composition.²⁾

The nature of the spawning site largely determines the intensity and nature of the hazards that the eggs encounter. A lack of oxygen supply from the surrounding water and the danger of being smothered by silts are among the most important potential hazards for eggs.⁵⁾ The spawning site of chika contained little silt so siltation would not be expected to affect egg survival. On sandy or gravelly beaches, oxygen content in interstitial water is determined by grain size and the water volume flushing through the sand or gravel. As sand grain size becomes finer, more water is contained but the permeability becomes lower.^{6,7)} Eggs of chika sometimes occurred in sand about 10 cm below the surface of the sea floor.⁸⁾ If the eggs were spawned and buried at fine sand beaches, they may be exposed to a low oxygen environment. Eggs in the intertidal zone, especially near the high tide line, may suffer from desiccation during ebb tides on very gravelly beaches. The spawning sites of chika, however, contained both gravels and an amount of fine sand (Fig. 1), and these fine sediments in the interstices of the gravel matrix would play an important role in moisture retention.

It is suggested that Chika spawn at the beach affected by influx of rivers.⁹⁾ However, salinity near shoreline at Akaiso ranges from 26 to 33.5 PSU during spawning season (unpublished data). In Otsuchi Bay, inflows from the three rivers affect salinities of the surface water which washes all of the beaches studied (unpublished data), suggesting that salinity has no apparent effect on spawning site selection in this bay. It is concluded that conservation of gravelly or coarse sand beaches is essential for the propagation of chika, i.e. the loss of such beaches translates to a loss in the recruitment of this species.

References

- 1) T. Ueno: in "The Fishes of the Japanese Archipelago" (ed. by H. Masuda, K. Amaoka, C. Araga, T. Ueno and T. Yoshino), Tokai University Press, Tokyo, 1984, pp. 33.
- 2) T. Hirose and K. Kawaguchi: *Env. Biol. Fish.*, **52**, 213–223 (1998).
- 3) K. Takahashi and K. Kawaguchi: *Mar. Ecol. Prog. Ser.*, **116**, 75–84 (1995).
- 4) Y. Yamanaka, K. Kosaka, S. Tsukawaki and K. Fujioka: *Otsuchi Mar. Res. Cent. Rep.*, **16**, 27–42 (1990) (in Japanese).
- 5) R. J. Wootton: *Ecology of Teleost Fishes* 1st ed., Chapman and Hall, London, 1990, pp. 168–170.
- 6) I. Sakamoto: in "Ecology and Ecotechnology in Estuarine-Coastal Area" (ed. by Y. Kurihara), Tokai University Press, Tokyo, 1988, pp. 119–125 (in Japanese).
- 7) A. C. Brown and A. McLachlan: *Ecology of Sandy Shores*, Elsevier, Amsterdam, 1990, pp. 5–39.
- 8) T. Hirose: Ph. D. Thesis, University of Tokyo, Tokyo, 1996, p. 157. (in Japanese).
- 9) S. Maruyama: in "Fishes and Marine Invertebrates of Hokkaido: Biology and Fisheries" (ed. by K. Nagasawa and M. Torisawa), Kita-nihon Kaiyo Center, Sapporo, 1991, pp. 34–35.