仙台湾産ウバガイの底生生活初期の減耗過程

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Mortality of the Sakhalin Surf Clam in Sendai Bay in the Early Benthic Stage[*1]

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Mortality rate after settlement was estimated for 1983–1986 year classes of the young Sakhalin surf clam *Spisula sachalinensis* in Sendai Bay. A common pattern is found in their distribution, suggesting a regular, efficient mechanism to gather young clams. The pattern remains unchanged with time, showing an insignificant movement of young clams at least macroscopically.

Each year class declines exponentially and mortality rate fluctuates widely among year classes. The mean mortality rate ranges from 0.4 to 0.8 per month. Abundance of juveniles settling in the fishing ground also varies and no significant correlation is found between it and the subsequent mortality. The relative strength of each year class depends on the rate of reduction during about 6 months after it is produced, and would be controlled primarily by the fluctuation in mortality after settling rather than the heavy reduction during the pelagic life.

The Sakhalin surf clam stock, *Spisula sachalinensis*, inhabiting the sea off Isobe, Sōma, Fukushima, has fluctuated widely in year class strength, which is the primary factor that causes fluctuation in stock. Spawning of the surf clam in Isobe Ground peaks between late April and early May. Although the fecundity of an adult, 3-year-old female amounts some one hundred million,[1)] heavy reduction is assumed to occur early in the life history like other marine bivalves. It has also been pointed out that the fluctuation in year class strength may be ascribed to the heavy reduction in early stages.

The present paper aims at estimating the early reduction after settlement in Isobe Ground quantitatively.

Methods

Samples were taken from the sea bottom quantatively at 23 stations assigned in the Ground and its adjacent areas during June–October, 1983–86 (Fig. 1). Duplicate sampling was made at a station with a 1/20 m^2 Smith-McIntyre bottom-sampler.

After washing samples reserved in 10% formalin solution with a sieve of 350 μm mesh, clams in their first year were picked out and counted under a stereoscopic microscope. Young surf clams produced in the Fukushima Prefectural Fish-Farming Experimental Station were used as the standards for identification.

From horizontal isopleths of 0-Group in density, the total number of clams (N) in the fishing ground was estimated in terms of $N=\sum a_i \cdot d_i$, where a_i was the area (m^2) between i-th and $(i-1)$-th isopleths, and d_i was the mean density (number/m^2) in a_i. "Fishing Ground" is the area demarcated with lines, A and B, and isobaths of 5 and 15 m (Fig. 1). A-line is legally defined by

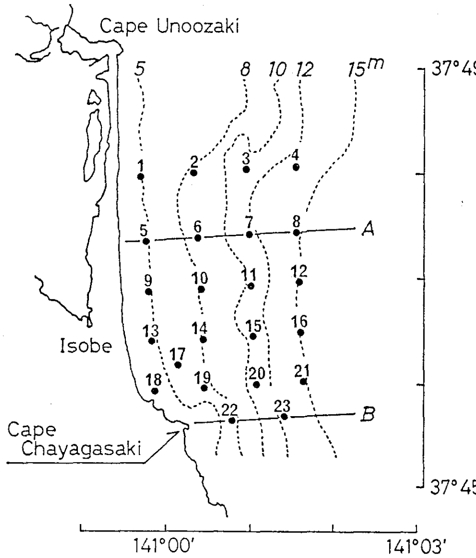

Fig. 1. Map of bottom sampling stations (solid circle). A and B-lines show the limits of area in estimating the total number of 0-Group. Numerals show station numbers.

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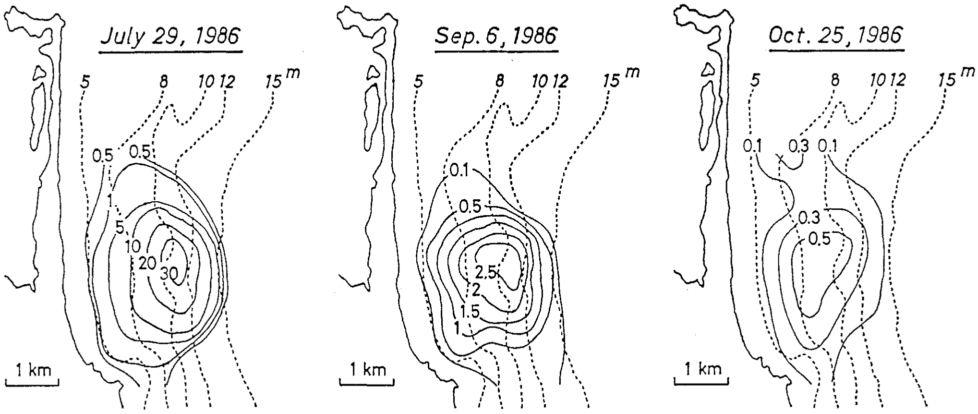

Fig. 2. Density-contours of the 1986 year class in its first year in $10^2/m^2$.

the fishery right, and B-line is the southern margin limited naturally with reefs extending offshore from Cape Chayagasaki. The area between 5 and 15 m deep is the substantial local range of the surf clam.

The mortality rate was obtained by regression analysis, regression of $\ln N_t$ on t by year classes, based on the relationship, $\ln N_t = \ln N_0 - zt$, where t was the number of days starting on June 1, N_t the abundance at t, N_0 the abundance at $t=0$, and z was the total mortality coefficient. The mortality rate per month (A) was given by $A = 1 - \exp(-30 \cdot z)$, providing a month is 30 days.

Results

Fig. 2 shows the trend in density distribution of the 1986-born clams in their first year. Observed values are in Table 1.

The distribution shows a pattern extending meridionally along the coast between 5–15 m deep with a densely populated area around the central part of fishing ground 8–10 m deep. Although their density rises to a maximum of $3000/m^2$ in late July, very few clams inhabit the areas deeper than 15 m or shallower than the breaker zone 4–5 m deep.

The total number of 0-Group is estimated to be 7.74×10^9 in July, 8.57×10^8 in September and 2.02×10^8 in October. While they become less dense with time, the substantial pattern of distribution remains unchanged.

Fig. 3 shows the distributions of 1983–1986 year classes immediately after settlement in late July. Their spatial patterns are substantially the same with interannual variations.

Table 1. Numbers of the surf clam of 0-Group caught at the stations in 1986

St.	July 29	Sep. 6	Oct. 25
1	0	0	0
2	8	0	4
3	0	0	0
4	0	0	0
5	2	0	0
6	17	4	1
7	19	1	2
8	0	0	0
9	2	2	0
10	102	24	6
11	370	30	6
12	0	0	0
13	5	0	0
14	114	17	6
15	272	24	3
16	0	1	0
17	43	9	2
18	1	0	0
19	22	3	3
20	2	4	0
21	0	1	0
22	0	0	0
23	0	0	0

They decline exponentially after settlement (Fig. 4), and the trend is formulated as follows:

Year class

1983 $N_t = 9.01 \times 10^{10} \exp(-0.0219t)$
$r = 0.987$

1984 $N_t = 1.72 \times 10^9 \exp(-0.0192t)$
$r = 0.999$

1985 $N_t = 8.65 \times 10^{10} \exp(-0.0564t)$
$r = 0.990$

1986 $N_t = 5.82 \times 10^{10} \exp(-0.0397t)$
$r = 0.969$

Data obtained on June 16, 1985, were excluded to

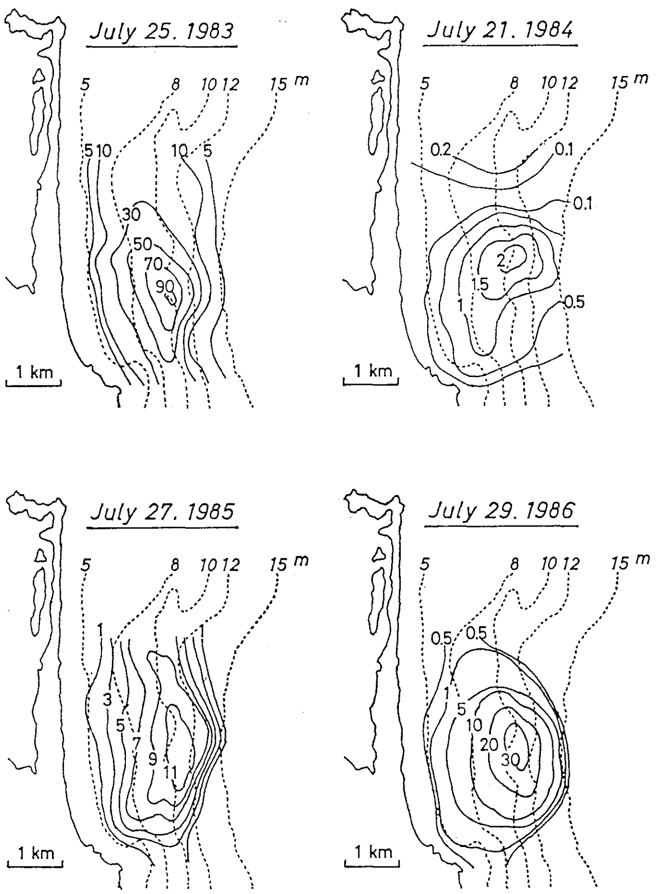

Fig. 3. Density-contours of the 1983–1986 year classes in late July in their first year in $10^2/m^2$.

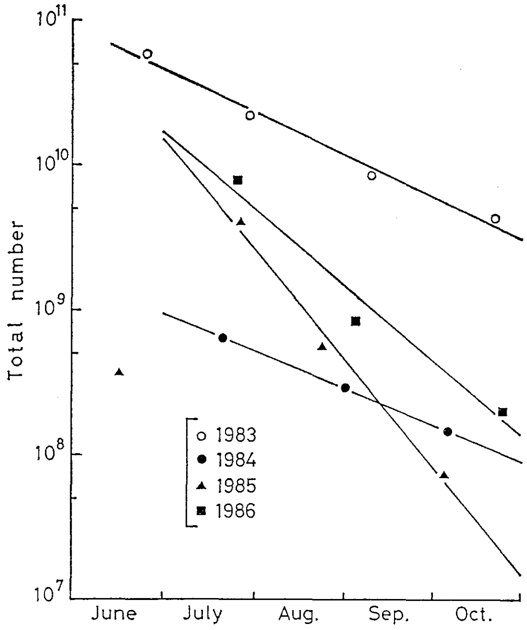

Fig. 4. Decreasing trends of the 1983–1986 year classes in the fishing ground during their first year.

Table 2. Mean mortality rate per month of 0-Group between June and October, by year classes

Year class	Mean mortality rate per month
1983	0.482
1984	0.438
1985	0.816
1986	0.696

calculate the equation, because the settlement of young clams seems to have been in progress at that time. The mortality rate after settlement varies from year to year, and its mean during a month calculated from the regression equation for each year class is shown in Table 2.

The stock size of 1985 and 1986 year classes in late June when their settlement would have completed had been above 10^{10}, which was approximately the same level as the strong 1983 one, but they decreased thereafter to some one-two hundredth and one-twentieth the 1983 year class respectively by late October from heavy mortality.

On the contrary, although the abundance of 1984

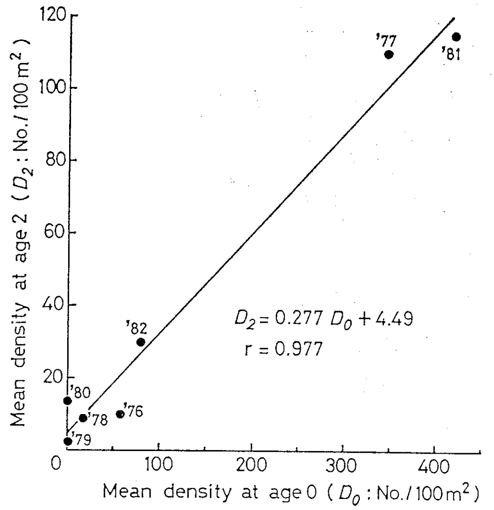

Fig. 5. Regression of the mean density of II-Group (June) on that of 0-Group (Dec.). Numerals show years of birth. (Source: Fukushima Pref. Fish. Exp. Stn.)

year class at settlement was estimated to be one-fortieth to one-fiftieth those of the other ones in early July, its biomass in late October exceeded or was nearly the same as those of the 1985 and 1986 year classes because of its low mortality.

Discussion

The overall pattern of spat distribution does not significantly differs from year class to year class, suggesting a regular, efficient mechanism to gather young clams.

However, in several places along the coast of Hokkaido juveniles having settled are carried toward the shore by the currents and waves,[2-4] unlike the situation off Isobe.

The regression of the mean density of 2-year-old clams recruited in June on that in December of their first year is indicated in Fig. 5, based on stock assessment data of the Fukushima Prefectural Fisheries Experimental Station. The correlation is significantly positive, suggesting a fairly stable survivorship. But no clear relationship is found between the spawning stock and resultant 0-Group in December.[5] These facts lead to a conclusion that the year class strength is dependent on the reduction during about 6 months since their birth.

Two factors, the abundance of settling juveniles and the mortality in early benthic stage, may influence the year class size, though the correlation between them does not seem significant. The number of larvae settling in the fishing ground was only 10^9–10^{11}, compared with the huge number of eggs produced by their mothers, over one hundred million by each.

Factors that could cause the year-to-year variation in mortality remain still unidentified. But the variation in survival after settlement would predominate over early reduction in controlling the year class strength of the surf clam, while the general notion that the stock size of marine invertebrate is regulated by the larval reduction and dispersion.

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