Short Paper

Batch Fecundity of Japanese Sardine *Sardinops melanostictus* off Southern Kyushu, Southwestern Japan in the Peak Spawning Season, 1991

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(Received November 15, 1994)

Key words: Japanese sardine, batch fecundity, reproduction, southern Kyushu

It is well known that the Japanese sardine *Sardinops melanostictus* change their reproductive characteristics such as age at first maturity and spawning area in association with long-term fluctuations in abundance. In the 1980s when population levels were high, the spawning grounds shifted southwestward and were concentrated off southern Kyushu, and age at first maturity was delayed from 2-year to 3-year.¹⁾

Nakai²⁾ and Usami³⁾ determined batch fecundity based on translucent hydrated oocytes for the Japanese sardine collected in the 1940s and 1950s, respectively. After reaching the highest level in 1936, sardine stock size decreased annually during the 1940s and hovered around a low level during the 1950s. Batch fecundity in Japanese sardine may be modifiable similarly to other reproductive characteristics. Thus, we reexamined batch fecundity of the Japanese sardine collected in the main spawning grounds off southern Kyushu in 1991, when sardine stock was at relatively high abundance though entering a period of decline.

Sardine used in this study were collected with a gill net in the end of February and early March. This period was the time of the peak spawning season in this study area.⁴⁾ Fish were preserved in 10% neutral buffered formalin. Females with hydrated eggs used to estimate batch fecundity consisted of two sample groups (Table 1). Batch fecundity was determined by counting translucent hydrated oocytes in ovaries just prior to ovulation using the gravimetric

method according to Hunter *et al.*⁵⁾ The translucent hydrated oocytes can be distinguished easily from yolked oocytes at immature stages. It was confirmed from 12 female samples that the number of hydrated eggs per gram of ovary did not differ among three positions (anterior, middle, and posterior) within right or left ovary and between right and left ovaries. Batch fecundity was calculated, based on the mean number of hydrated eggs for three tissue samples of 100–150 mg from either right or left ovary.

Batch fecundity for sample-A ranged 19,600 to 46,100 eggs with a mean of 34,900 eggs (Table 1). Relative batch fecundity, defined as the number of hydrated eggs per gram of ovary-free body weight, ranged 284 to 563 eggs/g with a mean of 434 eggs/g for sample-A. Values of batch fecundity and relative batch fecundity for samples-B were within the ranges of those for sample-A. Mean batch fecundity and mean relative batch fecundity for all samples were 33,900 eggs and 422 eggs/g, respectively.

Batch fecundity increased significantly with ovary-free body weight ($r^2=0.2577$, $p<0.05$), though it showed a wide variation within a body weight class (Fig. 1). It seems that there is only a slight increase in batch fecundity of a large-sized female. Increasing the number of female samples can give further precision. There was also a significant relationship between batch fecundity and female body length ($r^2=0.1793$, $p<0.05$). There was no change in batch fecundity ($r^2=0.0718$, $p>0.5$) and relative batch

Table 1. Batch fecundity for Japanese sardine collected in 1991 off southern Kyushu.

		Body length (cm)	Ovary-free body weight (g)	Condition factor*	Batch fecundity (eggs)	Relative batch fecun- dity** (eggs/g)
Sample-A	$n=16$					
	mean	19.8	81.0	10.4	34,900	434
	SD	1.1	15.0	0.67	7,700	81
	max	23.4	128.4	11.56	46,100	563
	min	18.7	66.8	9.29	19,600	284
Sample-B	$n=2$					
		19.2	73.5	10.4	30,000	411
		19.4	81.8	11.2	21,000	253
Total	$n=18$					
	mean	19.7	80.6	10.4	33,900	422
	SD	1.0	13.8	0.6	7,800	85

Sample-A, collected in the Kuroshio water in southern Hyuganada-sea southeast of Kyushu in early March 1991; Sample-B, from Osumi Strait south of Kyushu in the end of February and early March 1991.

* ovary-free body weight/(body length)³ $\times 10^3$

** batch fecundity/ovary-free body weight

Fig. 1. Batch fecundity of Japanese sardine plotted against ovary-free body weight. The line represents linear regression, $y = 10728 + 287x$ ($n = 18$, $r^2 = 0.2577$, $p < 0.05$).

fecundity ($r^2 = 0.0174$, $p > 0.5$) with any increase in condition factor, defined as ovary-free body weight/cube of body length $\times 10^3$.

Nakai²⁾ estimated batch fecundity of sardine to be 37,700 eggs in average ($n = 6$, $SD = 9,400$) for females with hydrated eggs collected in the 1940s. Usami³⁾ reported that mean batch fecundity of sardine was 37,100 eggs ($n = 97$, $SD = 13,200$), from an examination of females with hydrated eggs taken in the coastal areas of the Japan Sea in 1955. Our estimates did not differ significantly from these values (t -test, $p > 0.5$). Their method for batch fecundity estimate is equivalent to the current Hydrated Oocyte Method³⁾ used in this study. Additionally, the ranges of body length of females used to determine batch fecundity were similar. Unfortunately, ovary-free body weight data were not avail-

able to compare relative batch fecundity.

Relative batch fecundity is a useful measure for comparisons between different fish species.⁶⁾ According to a review of fecundity of clupeoid fishes,⁶⁾ relative batch fecundity of other *Sardinops* species ranges from 255 to 328 eggs/g. Compared with these values, the Japanese sardine has a higher relative batch fecundity. The Japanese sardine produce more eggs per body weight per batch than *Sardinops* species in other sea areas in the world. Although there is no available data for comparison on egg size and number of batches during a spawning season, a plausible interpretation would be that the Japanese sardine allocate more energy to reproduction compared to the energy to growth and survival than other *Sardinops*. For example, Le Clus⁷⁾ reported that relative batch fecundity of pilchard *Sardinops ocellatus* in the Benguela system was 270 eggs/g in average. The spawning pilchard in his study had large ovary-free body weight for its body length. Average condition factor, weight relative to length, was 13 for Le Clus' pilchard and 10 for our Japanese sardine.

Acknowledgments I thank Drs. T. Komatsu, T. Inagaki, T. Murayama, N. Azuma, M. Shiraishi and the crew of the RV 'Hakuho Maru' for their help and support.

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