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Distribution of *Fabrea salina* at Salt Pond

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Fabrea salina living at salt pond is an interesting ciliate in the research of photobiology and live food for aquaculture. This study was carried out to understand the natural habitat of *F. salina* at salt pond, which would be a basic biological knowledge for the indoor mass culture of this ciliate. In this research, the water quality as temperature, salinity, dissolved oxygen, and chlorophyll-*a* was examined with the population density of the ciliate at salt pond. The highest population density of *F. salina* occurred at 109 ppt and 31℃ with 2,390 inds./L in August, and the distribution of the ciliate was positively correlated with salinity, temperature, and chlorophyll-*a*. Even though *F. salina* is a very euryharine ciliate, it did not occur at the salinity below 47 ppt in this study. Its reason is able to be explained with the occurrence of many predators as small fish and food competitors as zooplankton living at low salinity of salt pont. While *F. salina* occurred with *Artemia* at the same habitat using the same food source, the optimum salinity for the ciliate was a little higher than that of *Artemia*, and the optimum temperature for the former was a little lower than that of the later. This should be a reason for that these two species have different ecological nich at the same habitat using the same food source.

Key words: *Fabrea salina*, ciliate, *Artemia*, salt pond, food organism

Introduction

Fabrea salina is a marine ciliate, a very active swimmer, and distributes widely at salt pond. This ciliate belongs to the Order of Heterotrichida. Its body is pear-shaped with a body length ranging from 100 to 300 μm for the long axis and from 50 to 200 μm for the short axis, and cell surface is very densely covered with cilia (Puntoni et al., 1998).

Since the study on morphological of this species by Faure-Fremiet (1911) and Ellis (1937), recently many research works focused on the photobiology or feasibility study of this species as a live food source for aquaculture.

F. salina shows two kinds of responses to light stimuli: positive phototaxis and a photophobic step-down reaction that the cells stop, turn, and start swimming again in a new direction in case of a sudden decrease in light fluence rate (Colombetti et al., 1992a, b). This interesting photobehavior has been investigated on phototaxis (Marangoni et al., 1994), rhodopsin-like molecule (Podesta et al., 1994), temperature effect on phototactic reaction (Marangoni et al., 1995), pigment (Marangoni et al., 1996a, b), and effect of Ca^{++} and K^{+} effect on photomotility (Puntoni et al., 1998).

On the other hand, several marine biologists have mentioned on the possibility of this ciliate as a live food for fry in aquaculture because of its small size and high density (Morris, 1956; Barnabe, 1974; Rene, 1974; De Winter and Persoone, 1975; De Winter et al., 1976). However, Kentouri and Divanach (1982) have reported the contrary result that Sparidae fish larvae did not eat *F. salina*. Uhlig had also mentioned that some toxic material as fabrein might exist in *F. salina*, and this would be the reason for unsuitableness of this cilate as a live food (personal communication).

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Even though *F. salina* is useful and interesting ciliate in the photophysiology and aquaculture, the research on its natural habitat was not carried out enough. Therefore, in this study, the natural habitat of this ciliate was investigated at the salt pond at the view point of distribution and population density which would be basic biological informations for mass culture of the ciliate.

Materials and Methods

F. salina was sampled at the salt pond located at Kyungki Bay, west coast of Korea, during July to October, 1987. The layout of the salt pond for the study is shown in Figure 1. Temperature, salinity, dissolved oxygen, and chlorophyll-*a* were measured at the end of each month from eight sampling stations. Those except chlorophyll-a were measured in situ with potable saline and dissolved oxygen meter, and chlorophyll-*a* was analysed by Strickland and Pasons (1968).

F. salina was sampled at the shallow water-way of each sampling station using a rectangular phytoplankton net (20×10 cm, 20 μm). The net was towed 10 meter around each station. *Artemia* was also caught with the ciliate at this sampling. The density of *F. salina* and *Artemia* were calculated into the number of individual per liter and compared each other. The size of *F. salina* in the long axis was also measured with the microscope after being fixed with Lugol's solution.

Results

1. Water quality

The monthly variations of water quality at the salt pond were shown in Table 1 and Figure 2 and 3. The water temperature varied from 14.8℃ (October, st. 1 and 5) to 35.3℃ (July, st. 8) during research periods. Monthly mean water temperature was the highest in July (32.4℃) and the lowest in October (15.4℃). Mean water temperature by the station began to increase from st. 3, and showed the highest (28.2℃) at last station 8.

The dissolved oxygen varied from 5.5 ppm (July, st. 8) to 15.4 ppm (Aug., st. 1). Mean dissolved oxygen in September (11.8 ppm) showed the highest and the lowest in July (9.7 ppm). Mean dissolved oxygen by station during July to October varied from 10.6 to 12.6 ppm at the stations from 1 through 6, and it dropped suddenly to 9.0 and 8.3 ppm at station 7 and 8, respectively.

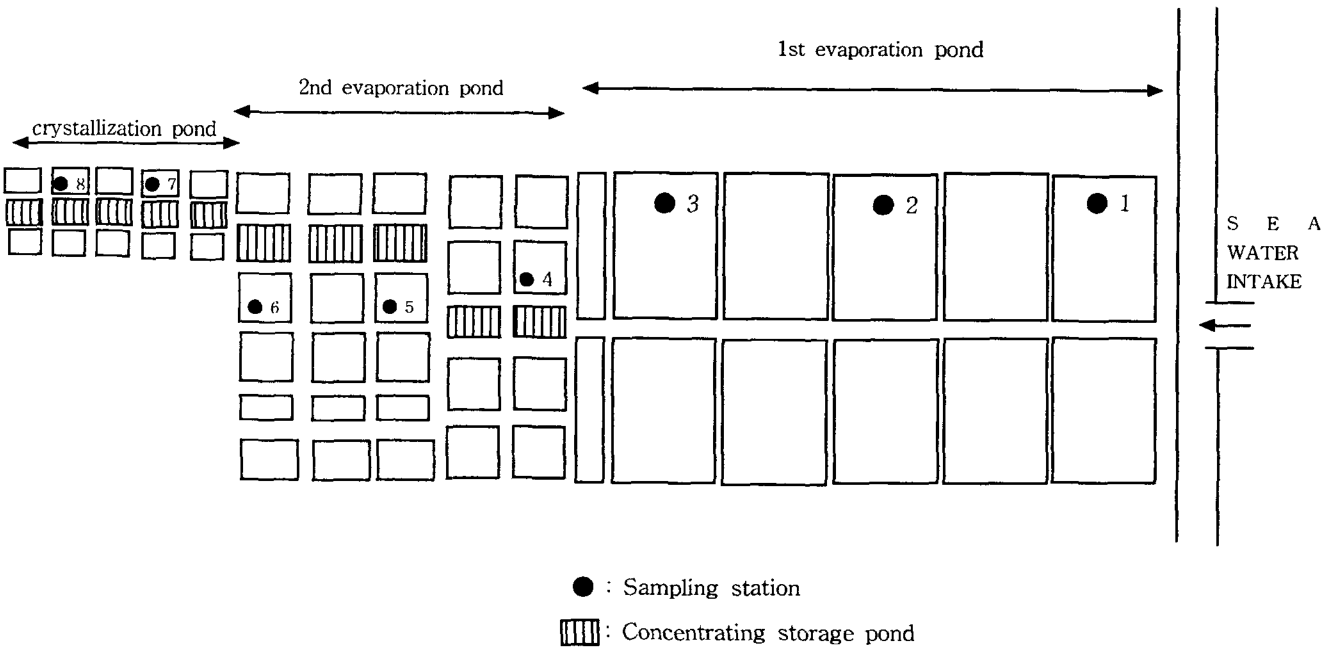

Fig. 1. Layout of the salt pond and sampling station.

Table 1. Monthly variations of water quality at the salt pond

Month	Water quality	Sampling station							
		1	2	3	4	5	6	7	8
July	Temp. (℃)	29.8	29.8	30.5	33.6	32.7	33.6	33.6	35.3
	DO (ppm)	10.9	9.6	10.7	11.2	10.3	10.8	8.2	5.5
	Salinity (‰)	29.5	42.6	53.5	44.6	57.6	84.5	105.2	173.1
	Chlorophyll-a (mg/m³)	33.7	28.8	71.0	54.0	52.2	51.0	46.8	36.5
August	Temp. (℃)	29.5	28.8	28.2	29.4	29.3	29.7	30.8	30.9
	DO (ppm)	15.4	12.7	10.3	12.2	11.9	10.8	7.9	7.4
	Salinity (‰)	30.5	40.8	31.4	48.6	50.4	94.4	109.0	145.6
	Chlorophyll-a (mg/m³)	25.2	21.5	59.2	39.3	40.1	27.9	44.1	18.7
September	Temp. (℃)	28.4	27.3	28.5	27.7	27.7	28.7	27.6	30.7
	DO (ppm)	13.6	11.7	11.1	12.8	13.3	12.6	10.2	8.9
	Salinity (‰)	29.6	46.5	69.0	77.5	105.7	131.0	170.5	260.8
	Chlorophyll-a (mg/m³)	28.0	30.0	20.2	21.3	14.3	6.6	35.3	14.2
October	Temp. (℃)	14.8	15.6	15.0	15.2	14.8	15.9	15.9	15.9
	DO (ppm)	10.6	11.5	10.4	11.5	10.7	11.8	9.8	11.2
	Salinity (‰)	35.2	29.6	32.3	40.8	54.9	85.9	108.5	145.2
	Chlorophyll-a (mg/m³)	27.6	2.0	7.3	6.1	3.9	17.1	11.8	11.3

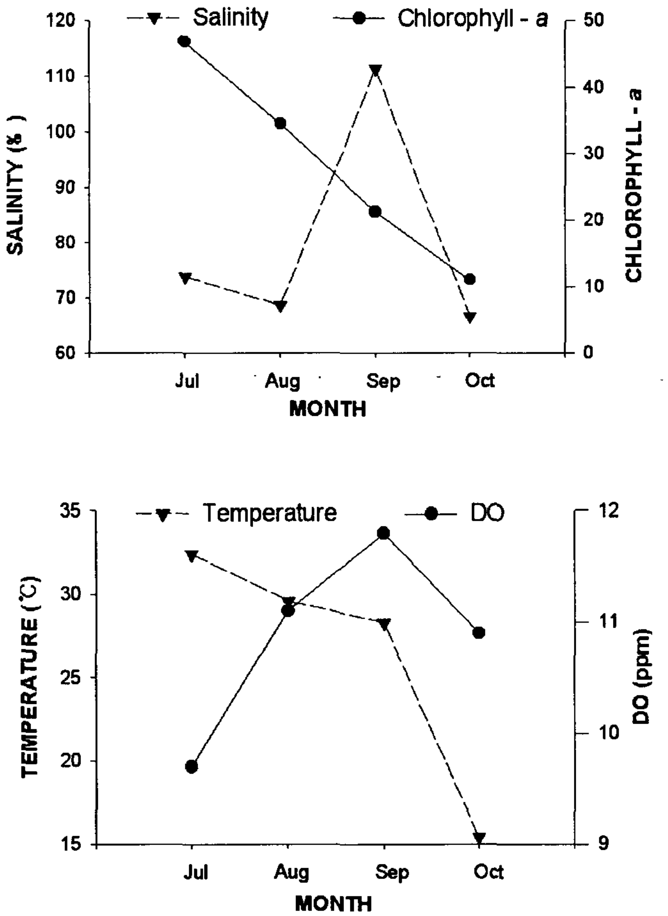

Fig. 2. Monthly Variations of water quality at the salt pond (July~Oct, 1987).

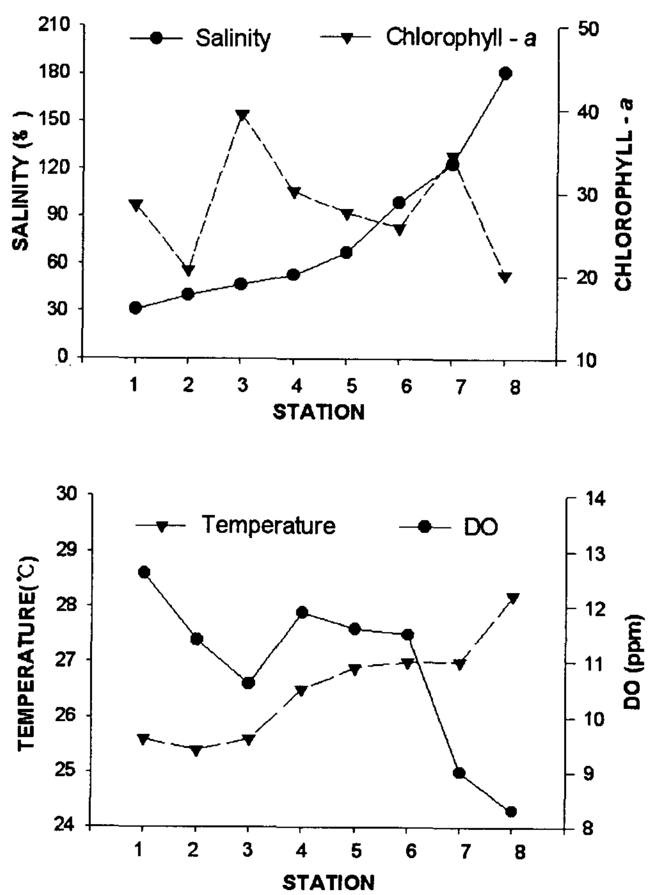

Fig. 3. Variations of water quality by stations at the salt pond (July~Oct, 1987).

The salinity varied from 29.5 ppt (July, st. 1) to 260.8 ppt (Sept., st. 8). Monthly mean salinity was the highest in September (111.3 ppt) and the lowest in October (66.6 ppt). Mean salinity by station increased with upper stations, and that at station 8 was the highest with 181.2 ppt. With regard to chlorophyll-*a*, it varied from 2.0 mg/m^3 (Oct., st. 2) to 71.0 mg/m^3 (July, st. 3). Monthly mean chlorophyll-*a* was the highest in July (46.8 mg/m^3), and then decreased continuously to 11.0 mg/m^3 in October. Mean chlorophyll-*a* by station was the highest at station 3 with 39.4 mg/m^3, and the lowest with 20.2 mg/m^3 at station 8.

2. Population density of *F. salina*

The density of *F. salina* during the study periods was shown in Table 2. The highest density occurred at station 7 in August with 2,390 inds./L. Regarding the density by station, the ciliate didn't occur at station 1 and 2, and a few ciliates less than 11 inds./L occurred at station 3, 4 and 5. It began to occur mainly from station 6 with the high salinity near 100 ppt. The water qualities at station 7 in August, where *F. salina* showed the highest density were 30.8℃, 109 ppt, 7.9 ppm in dissolved oxygen, and 44.1 mg/m^3 in chlorophyll-*a*.

On the other hand, *Artemia* was sampled at the salt pond during the study periods. Its occurrence was limited in July and August at the station from 5 through 8 with a high salinity over 50 ppt. The density was the highest at station 7 in July with 400 inds./L, and dropped suddenly at station 8. The variations of density of *F. salina*, *Artemia*, and chlorophyll-*a* by station were compared (Fig. 4). The chlorophyll-*a* showed two modes with the peak at station 3 and 7. Both of two species showed the highest density at station 7 and decreased suddenly at station 8.

Table 2. Population density (inds./L) of *Fabrea salina* and *Artemia* at the salt pond

Station	*Fabrea salina*				*Artemia*			
	July	Aug.	Sep.	Oct.	July	Aug.	Sep.	Oct.
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	11	0	0	0	0	0	0	0
4	0	0	0	7	0	0	0	0
5	0	4	0	0	56	0	0	0
6	35	226	0	1	203	21	0	0
7	58	2,390	0	22	400	124	0	0
8	9	529	33	10	0	0	0	0

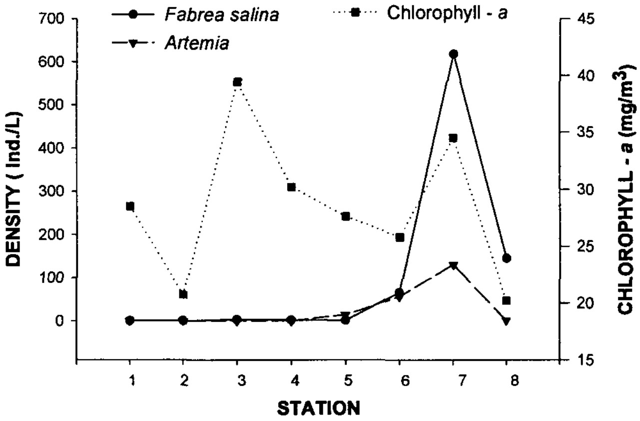

Fig. 4. Variations of the density of *Fabrea salina* and *Artemia* and the Chlorophyll-*a* by stations at the salt pond (July~Oct, 1987).

The variation of body size of *F. salina* was shown in Table 3. The mean size by station varied from 115 μm (Oct., st. 4) to 157 μm (Aug., st. 7). The mean size of *F. salina* was over 144 μm at station 7 and 8 with high salinity. It increased with higher salinity from station 3 to station 7, but it dropped slightly at station 8.

Table 3. Total length (mean±sd μm) of *Fabrea salina* collected from the sampling stations at the salt pond

Station	July	August	September	October
1	–	–	–	–
2	–	–	–	–
3	142.0±19.0	–	–	–
4	–	–	–	115.0±15.0
5	–	125.0± 5.0	–	–
6	131.8±18.7	135.1±25.0	–	124.0±18.9
7	148.8±17.3	157.3±30.3	–	150.0±16.7
8	144.5±28.6	155.1±19.3	144.0±22.4	145.9±24.2

F. salina occurred at the salinity from 53 ppt to 260 ppt in this study, but the main occurrence was at 109 ppt with 30℃. There was a tendency that the distribution of the ciliate increased with salinity up to ca. 110 ppt and decreased suddenly at higher salinity above this.

Discussion

The salt ponds are distributed along the west and south coast of Korea. Even though there are so many spacious salt ponds, there are no enough research reports on this marine habitat. The first aim of salt pond is to produce the natural salt, but it is also important and interesting habitat in terms of biological viewpoint. Recently, there are so many closed salt ponds in Korea because of high labour costs in salt production. These closed salt ponds become an extensive salt marsh that plays a role as a sea defence (King and Lester, 1995; Thompson et al., 1995).

On the other hand, the salt pond is important habitat to produce *Artemia*, and interesting habitat for the research of euryharine species such as *Fabrea salina* and *Dunaliella*. The reservoir of the salt pond is also used for shrimp farming and natural seedling collection of bivalve as clams. As mentioned above, the salt pond plays an important role in terms of environment and biological production. Even a few research had been done on the natural habitat of the salt pond in Kyungki Bay (Hur et al., 1987; Kim and Hur, 1987), these investigations were focused on only Korean *Artemia*, and the ecological research on the ciliate's natural habitat had not been considered.

In this study, the most important factor in water quality at the salt pond was the salinity. Salinity increased with the evaporation at the salt pond, its variation depended on season and weather. During the periods of this research, the salinities at the first and second evaporation pond were less than about 70 and 130 ppt, respectively. At crystallization pond, it increased rapidly and reached to about 260 ppt. The water temperature and dissolved oxygen at each station varied depending on salinity at the salt pond. The dissolved oxygen decreased with higher salinity, and the water temperature increased slightly with higher salinity. This variation influenced to the biota at the salt pond.

F. salina was known as euryhaline species (De Winter et al., 1976). However, in this study, *F. salina* did not occur at station 1 and 2 with the low salinity below 47 ppt. A few *F. salina* occurred at station 3, 4, and 5, but its main occurrence was at the station 6, 7, and 8 with high salinity over 100 ppt. In spite of the wide range of adaptation to salts concentration, the reason for that *F. salina* did not occur at low salinity in this study seemed to be due to many predators and food competitors, such as small fish and zooplankton living at low salinity area.

The variation of the mean chlorophyll-*a* by station showed two modes at station 3 and 7. The low chlorophyll-*a* at station 1 and 2 should be because of many zooplanktons at low salinity. But, with increasing the salinity from station 3, zooplankton, the predator of phytoplankton would be decreased in diversity and abundance. Hur et al. (1987) had also reported that zooplankton biomass at the salt pond was the highest at low salinity and decreased continuously with higher salinity. This should be a reason for that the chlorophyll-*a* at station 3 was the highest in this study. However, with increasing the abundance of *F. salina* and *Artemia*, the chlorophyll-*a* decreased again. The mode at station 7 seemed to be high productivity with a few phytoplankton species which were resistant to high salinity such as *Dunaliella* and *Tetraselmis*. This productivity could be used as a food source for the ciliate and *Artemia*.

With respect to density of *F. salina* at the salt pond, it varied widely with stations and months. Yufera (1985) and Rattan et al. (1994) have found that there was a seasonal pattern in abundance of this ciliate, and greater abundance in more stagnant habitats. The result of this study has shown that the population density was positively correlated with salinity, temperature, and chlorophyll-*a*. Considering the highest density, 2,390 inds./L of this ciliate at station 7 in August, the optimum salinity and temperature of *F. salina* at the natural habitat seem to be ca. 109 ppt and 31℃.

In this study, the occurrence tendency of *Artemia* was similar to that of *F. salina*. They used the same food source at brine water. However, comparing the main occurrence season and station of both species, the optimum temperature at natural habitat for *Artemia* seemed to be a little higher, and *F. salina* was less thermophilic than *Artemia* at high salinity above ca. 150 ppt. Even they use the same food source at brine water, the optimum salinity and temperature for them seemed to be slightly different. This difference would be able to allow them to have a different ecological nich.

Okada (1982) has reported the size of *F. salina* varied from 160~280 μm. Puntoni et al. (1998) have reported 100~300 μm in long axis of this ciliate. Rattan et al. (1994) have reported the body size of the ciliate varied from 100 to 780 μm. In this research, the total length of the ciliate varied 100 μm to 187 μm in long axis, and the mean total length was 140 μm. Considering this difference by the authors, the size of this ciliate seems to vary so highly with habitat environment. In this study, the size of *F. salina* showed the tendency to increase with higher salinity below ca. 100 ppt, and higher salinity above this decreased the size of the ciliate.

As the size of the ciliate at natural habitat could be affected by multi environmental factors, the variation of the size of *F. salina* should be revealed by the detail investigations in future. But, if the different size of *F. salina* would be induced by the culture environment, the ciliate will be more interesting as a food organism for aquaculture.

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