

Ecology of a Heterotrichous Ciliate *Fabrea salina* from Salterns of Bombay Coast, India

PARVEEN RATTAN¹, ZAKIR A. ANSARI² AND R.A. SREEPADA²

¹College of Fisheries, Peth Killa, Ratnagiri - 415 672, India;

²National Institute of Oceanography, Dona Paula, Goa - 403 004, India

Abstract: The abundance and population size structure of a heterotrichous ciliate, *Fabrea salina*, was studied in relation to hydrochemical and hydrobiological variables in three hypersaline ponds of Bombay, west coast of India. There was a clear seasonal pattern in abundance of *F. salina*, which appeared only during late post-monsoon and pre-monsoon and disappeared during the monsoon season. Annual average density varied from 2.6 to 13.6 ml⁻¹. Body size varied considerably from 100 to 780 µm. Maximum density was recorded in April and May coinciding with higher salinity (above 40‰). Population density was positively correlated with salinity, temperature and depth. The phytoplankton, *Dunaliella* sp., also showed a strong correlation with *F. salina*.

Résumé: L'abondance et la structure de la population d'un cilié hétérotraque, *Fabrea salina*, a été étudié en relation avec des variables hydrochimiques et hydrobiologiques dans trois étangs hypersalins de Bombay, côte ouest de l'Inde. L'abondance de *F. salina* montre une tendance saisonnière très nette, l'espèce n'apparaît que pendant les périodes d'arrière et de pré-mousson et disparaît en pleine mousson. La densité moyenne annuelle varie de 2,6 à 13,6 ml⁻¹. La taille varie beaucoup, de 100 à 780 µm. La densité maximum est atteinte en avril et mai, ce qui coïncide avec le taux de salinité le plus élevé (supérieur à 40 ‰). La densité de la population est corrélée positivement avec la salinité, la température et la profondeur. Le phytoplancton *Dunaliella* sp. montre aussi une étroite corrélation avec *F. salina*.

Resumen: Se estudió la abundancia y tamaño de la estructura poblacional de un heterotrico ciliado, *Fabrea salina*, en relación a variables hidroquímicas e hidrobiológicas en tres estanques hipersalinos de Bombay, costa oeste de la India. Hubo un claro patrón estacional en la abundancia de *F. salina*, la cual apareció solamente durante el post-monzón tardío y el pre-monzón y desapareció durante la estación de monzón. La densidad promedio anual varió de 2.6 a 13.6 ml⁻¹. El tamaño del cuerpo varió considerablemente de 100 a 780 µm. La densidad máxima se registró en Abril y Mayo coincidiendo con la salinidad más alta (arriba de 40‰). La densidad poblacional estuvo positivamente correlacionada con la salinidad, la temperatura y la profundidad. El fitoplanctónico, *Dunaliella* sp., también mostró un fuerte correlación con *F. salina*.

Resumo: A abundância e a estrutura dimensional da população do ciliado *Fabrea salina* foi estudada em relação às variáveis hidroquímicas e

hidrobiológicas de três reservatórios hipersalinos em Bombaim, na Costa Ocidental da Índia. O estudo revelou a existência de um padrão estacional claro de abundância de *Fabrea salina* que aparece no fim da pós- monção ou pré-monção e que desaparece durante a monção. A densidade média anual variou entre os 2,6 e os 13,6 ml⁻¹. As dimensões corporais variaram consideravelmente no intervalo de 100-780 µm. A densidade máxima registada foi registada em Abril e Maio coincidindo com a salinidade mais alta (acima dos 40‰). A densidade da população apresentou-se positivamente correlacionada com a salinidade, temperatura e profundidade. O fitoplactófago, *Dunaliella* sp. revelou-se igualmente fortemente correlacionado com a *F. salina*.

Key Words : *Fabrea salina*, ecology, hypersaline, tropics.

INTRODUCTION

Protists play an important role in structuring food webs because of their fast growth rate, energetic efficiency, and production. However, their ecology and biology combined with factors controlling their distribution in tropics has received very little attention (Smetacek 1991). The brine ciliate, *Fabrea salina*, is a characteristic component of the microzooplankton community, contributing between 50 and 95% of the total zooplankton. It has been reported from diverse environments such as marshes, hypersaline lakes and marine salterns with salt concentrations greater than normal seawater (Ellis 1937; Post *et al.* 1983; Yufera 1985). It is abundant in salt pans along the Indian coast (Rattan & Ansari 1982).

The salt pans vary from sub-saline to hypersaline conditions and exhibit seasonal fluctuations in hydrological features. They act as natural experimental chambers to the organisms that inhabit in these ponds. The present paper reports the nature of incidence of *F. salina*, in two salt pans and a hypersaline impoundment in relation to environmental variables.

MATERIAL AND METHODS

The salterns are low lying manmade seasonal ponds constructed mainly for the production of salt. During monsoon season (June-September) when the ponds become unsuitable for the production of salt due to inundation, they are utilized for fish culture.

Monthly field observations were carried out over the period, March 1982 - February 1983 at three sites, St. I (Bhayender salt pans), St. II (Meera Road salt pans) and St. III (Mud Island impoundment) as shown in Fig. 1. The hydrochemical characteristics (salinity, dissolved oxygen, total alkalinity and free carbon dioxide) at the study sites were analyzed following the methods described by APHA (1985). On each sampling occasion, the water temperature was recorded with a mercury thermometer and pH with a portable pH meter.

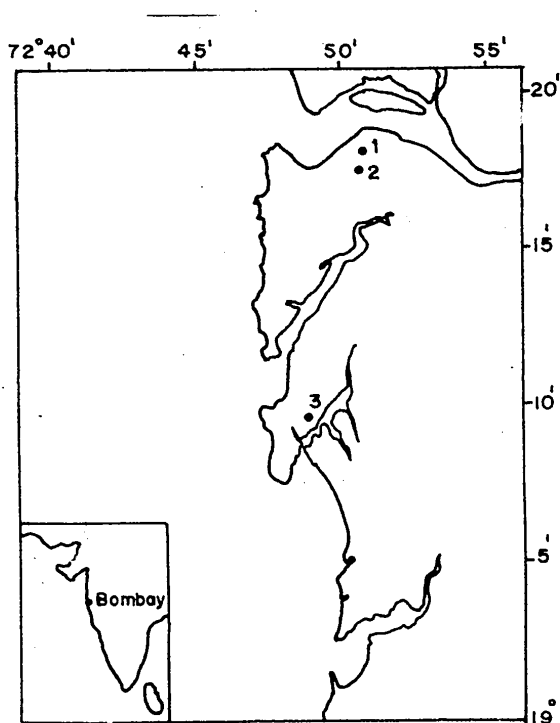


Fig. 1. Map of greater Bombay showing location of study stations at: Bhyender salt pan (1), Meera Road salt pan (2) and Mud Island impoundment (3).

Samples for phytoplankton counts were collected in 500 ml polythene bottles, fixed in Lugol's solution and brought to the laboratory. The preserved samples were concentrated to a volume of 200 ml by decanting and cell counts were made on a Sedgewick-Rafter cell counter (50 mm x 20 mm x 1 mm) of 1 ml concentrated sample under microscope. Since *F. salina* feeds extensively on unicellular algae, total phytoplankton abundance, species composition were also studied.

For estimating the abundance of *F. salina*, the water samples were collected in 1 litre glass beakers at five randomly selected points in the pond. From each sample, 1 ml aliquot was taken after thoroughly mixing the sample with the help of a pipette and counted under stereoscopic binocular microscope. Replicate aliquot were taken for counting and the average number was calculated for each month.

RESULTS

Water characteristics

The depth of the three ponds studied ranged from 8 to 48 cm, 11 to 40 cm and 10 to 74 cm at Sts. I, II and III respectively. Due to the shallowness of the ponds, high water temperatures were recorded, minimum being 28°C and the maximum 40°C (Table 1). High temperatures accompanied by the excessive evaporation rates

makes these ponds hypersaline with extremely high salinity (100‰, 135‰ and 125‰ at Sts. I, II and III respectively) particularly during summer period. The ponds were alkaline with pH above 7 while, dissolved oxygen values for most part of the year remained below saturation levels except for the monsoon season. Free CO₂ was detected only in the month of March and total alkalinity values fluctuated widely over the study period.

Phytoplankton

Total phytoplankton cell counts showed a great deal of variations between the sampling dates (Table 2). Monthly phytoplankton densities varied from 0.5×10^3 to $208 \times 10^3 \text{ ml}^{-1}$, 0.39×10^3 to $43 \times 10^3 \text{ ml}^{-1}$ and 0.006×10^3 to $13 \times 10^3 \text{ ml}^{-1}$ at sts. I, II and III respectively. Since ponds were dried in October, no samples could be collected at Sts. I and II. Mean phytoplankton density showed significant differences between the sites ($P < 0.05$). Amongst the phytoplankton, *Dunaliella* sp. was the most dominant accounting for more than 50% of the total phytoplankton except on two occasions when *Chlorella* sp. outnumbered other phytoplankton at St. I (Table 2). *Anabaena* sp, *Nitzschia* sp. and *Rhizosolenia* sp. were the other commonly observed phytoplankton. Among the less common and rarely occurring phytoplankton were *Oscillatoria* sp., *Navicula* sp., *Pleurosigma* sp. and *Syndera* sp.

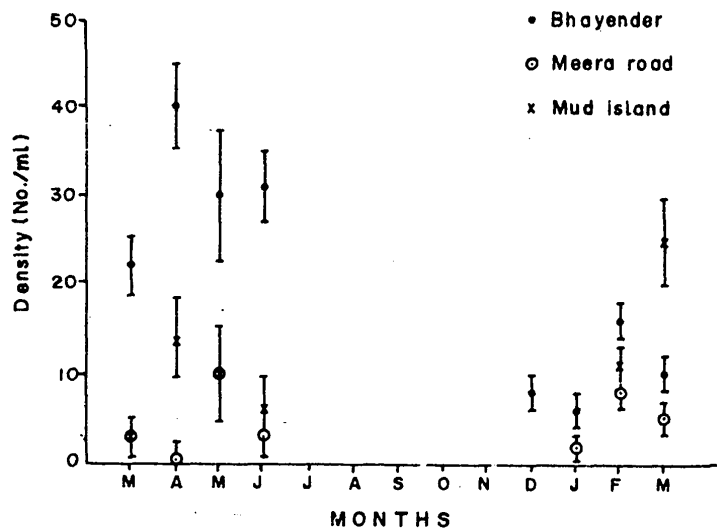


Fig. 2. Monthly variation in population density (\pm S.D.) of *F. salina* at three stations.

Fabrea salina population

Active and free swimming stages of *F. salina* occurred from March to June 1982 and December 1982 to March 1983 at St. I. Occurrence of *F. salina* at St. II and III was recorded during March-June and January-March, respectively. Free swimming forms of *F. salina* were not recorded during July to November (Fig. 2). However, during this period the dormant cysts were found attached to the surface soil and scum mats of the ponds. The presence of such dormant cysts was confirmed by sun drying the scum mat along with soil and re-soaking it in hypersaline water. Population density varied from 6 to 40 ml⁻¹ at St. I, 2 to 10 ml⁻¹ at St. II and 3 to 25 ml⁻¹ at St. III. The population density was highest at St. I during the summer period while, other stations recorded lower densities in the same period. Low population was also observed at St. II.

The size structure of *F. salina* population varied from 120 to 780 µm with a modal size group of 300 - 450 µm (Fig. 3). Modal size was 400 - 450 µm at St. I, 350 - 450 µm at St. II and 300 - 350 µm at St. III. The largest size of 780 µm were rare and could be easily seen without aid. The ciliate is positively phototactic and was found congregated in patches in the pond during morning hours day break.

The incidence of *F. salina* exhibited correlation with *Dunaliella* sp., in terms of total count and salinity as shown in Table 3, and all these factors were related directly or environmental variables did not reveal any correlation.

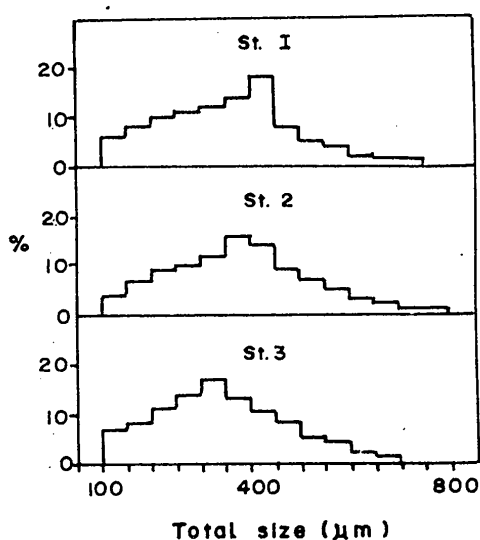


Fig. 3. Size structure of *F. salina* in three ponds during the study period.

TABLE I. Environmental characteristics of the three stations located in salterns of Bombay coast.

Variables	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
ST. I												
Water-depth (cm)	8	9	15	15	25	13.5	10	dried	48	17.4	13.7	14.4
Water temp. (°C)	34	35	38	38	32	34	32.5	-	31.5	29.5	29.5	31
Salinity (‰)	80	95	100	50	17.5	0	17	-	26.5	58	60	63
pH	8.4	9.2	8.8	9.0	9.0	9.5	8.8	-	8.9	8.9	8.1	8.5
Free CO ₂ (mg l ⁻¹)	6	-	-	-	-	-	-	-	-	-	-	-
Total alkalinity (mg l ⁻¹)	220	66	84	68	74	70	68	-	68	122	130	100
DO (mg l ⁻¹)	5.2	2.7	7.2	7.6	12.8	16.8	11.2	-	8.4	3.2	2.4	4.8
ST. II												
Water-depth (cm)	10	48	25	20	30	15.6	15	-	36	14.5	11.3	12.6
Water temp. (°C)	40	35	38	38	32	34	32.5	-	33.5	28	28.5	29.8
Salinity (‰)	95	135	110	64	20	0	13.5	-	17	47.5	44.5	58
pH	8.4	8.4	8.2	8.6	8.8	8.8	9.2	-	8.8	8.6	8.8	8.6
Free CO ₂ (mg l ⁻¹)	4	-	-	-	-	-	-	-	-	-	-	-
Total alkalinity (mg l ⁻¹)	196	168	130	68	78	90	86	-	84	50	50	100
DO (mg l ⁻¹)	3.2	2.8	4.8	5.2	4.0	9.6	14.4	-	7.6	8.1	4.4	8.8
ST. III												
Water-depth (cm)	10	38	35	32	50	60	70	73	74	17	13.4	27.5
Water temp. (°C)	35	41	41	39	32	31.5	32	35	32	32.5	29	29.5
Salinity (‰)	45	125	60	45	0	0	2.5	0	3	35.0	40.5	54
pH	8.7	8.6	8.8	8.6	8	8.6	9.2	8.8	9.2	9.2	8.6	8.6
Free CO ₂ (mg l ⁻¹)	-	-	-	-	-	-	-	-	-	-	-	-
Total alkalinity (mg l ⁻¹)	82	80	70	60	48	94	50	106	60	47	82	82
DO (mg l ⁻¹)	5.6	4.8	11.6	8.2	6.8	8.8	10	9.2	11.2	12	11.4	10.6

TABLE 2. Monthly counts (no./ml) of phytoplankton species at three stations. (values are $\times 10^3$).

Species	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Station I												
<i>Dunaliella</i> sp.	34	24	48	*	-	-	-	#	8.2	3.4	1.7	-
<i>Anabaena</i> sp.	-	**	-	**	-	-	**	#	-	-	-	**
<i>Oscillatoria</i> sp.	-	-	-	**	-	-	-	#	**	-	-	-
<i>Chlorella</i> sp.	-	60	-	-	-	-	-	#	-	-	-	-
<i>Rhizosolenia</i> sp.	-	-	-	-	-	*	**	#	-	-	-	-
<i>Navicula</i> sp.	-	-	-	-	-	*	-	#	-	**	**	-
<i>Nitzschia</i> sp.	-	-	-	-	-	-	1.2	#	-	2.4	**	*
<i>Dinophysis</i> sp.	-	-	-	-	-	-	-	#	-	-	**	**
Others	-	-	-	-	-	**	**	#	-	**	-	1.6
Total	34	84	48	1.1	-	*	1.7	#	8.4	6	2.3	2
Station II												
<i>Dunaliella</i> sp.	1	*	1.2	-	-	-	-	#	19	-	**	**
<i>Anabaena</i> sp.	-	-	-	**	**	-	11	#	-	**	-	-
<i>Nitzschia</i> sp.	-	-	-	-	5.5	-	32	#	*	-	-	-
<i>Dinophysis</i> sp.	**	**	**	-	-	-	-	#	-	-	-	-
<i>Surretilla</i> sp.	-	-	-	-	-	-	**	#	*	-	-	-
<i>Peridinium</i> sp.	-	-	-	-	-	-	-	#	**	-	*	-
Others	-	-	-	**	-	4.6	-	#	-	-	-	-
Total	1	*	1.3	**	5.6	4.6	43	#	21	**	1.3	**
Station III												
<i>Anabaena</i> sp.	1.2	-	-	3	-	-	4.3	*	2.7	**	**	**
<i>Nitzschia</i> sp.	2.2	-	-	4.5	-	-	-	**	4.5	-	3	**
<i>Navicula</i> sp.	**	-	-	-	-	-	-	4.2	-	-	-	-
<i>Oscillatoria</i> sp.	-	-	-	-	-	-	-	-	**	-	**	-
<i>Syndria</i> sp.	-	-	-	-	-	-	-	-	**	**	-	-
Others	-	-	-	-	-	**	**	-	-	-	-	-
Total	3.6	-	-	7.5	-	**	4.3	4.9	7.8	*	3.7	*

* = 0.5 - 0.99 $\times 10^3$ no/ml; ** = < 0.5 $\times 10^3$ no/ml; # = dried

TABLE 3. Correlation coefficients (r) and respective significance levels (P) between different environmental variables and the total density of *F. salina*.

Variable	Correlation coefficient	Significance level
Salinity	0.57	0.001
Temperature	0.31	0.05
Dissolved oxygen	0.39	0.01
pH	0.10	ns
Depth	0.34	0.05
Total alkalinity	0.19	ns
Phytoplankton density	0.35	0.05
<i>Dunaliella</i> counts	0.67	0.001

ns = not significant

DISCUSSION

Fabrea salina was highly seasonal in occurrence, restricting mainly to the summer period, when the salinity was high (> 40 ‰). Active forms of *F. salina* are known to occur in salt pans along the Indian coast regularly from about December to June (Rattan & Ansari 1982). The encystment takes place during July to November due to unfavourable conditions in the ponds, reduction in the salinity in particular. Within 6 months, the cysts come out as larvae and grow rapidly to form a sizeable population under favourable natural conditions. The growth of *F. salina* in the ponds is rapid and the generation time is short (25 ± 6 hours). Preliminary results based on culture experiments (unpublished) revealed that this species acclimates easily to seawater, but does not thrive well in waters of low salinity (below 17‰). De Winter & Persoone (1975) also observed that of *F. salina* does not thrive well in brackishwater. A positive correlation of population density with temperature indicates that higher temperature can act as a conducive factor in the reproduction and growth of the ciliate. Maximum excystment takes place in an alkaline medium (7-9 pH), having a salinity range of 26-52‰ and temperature range 34-38°C (Desimone & Repak 1991).

The size of *F. salina* varies from dwarf forms of 75 µm to giant size of 400 µm (Ellis 1937). In the present study a mega giant size of 780 µm was recorded, owing to increased vacuolization during starvation (Capriculo *et al.* 1991). At this stage it switches to cannibalistic feeding because of the non-availability of other food items in the ponds. Similar observations have been made in *Blepharisma* sp. (Pierce *et al.* 1978, Giffered 1985). In some salt pans which were not considered for the present study, a small size group of 75-100 µm was observed at the end of salt crystallization when the salinity attained 200-250‰.

These dwarf forms had a deformed body, covered with oral ciliature and were alive and swimming freely. Since there was no phytoplankton and perhaps very poor density of bacteria, the miniature forms may be the result of intracellular autophagy during starvation (Fenchel 1982). Thus, as the population of *F. salina* reaches its

peak, there is concomitant reduction in food and the ciliate attains giant size. Then it turns to cannibalistic feeding with progressive deterioration in the environmental and feeding conditions. This results in a reduction of population leading either to encystment and/or intracellular autophagy.

The abundance of *F. salina* showed positive correlation with the incidence of nanoplanktonic green algae, *Dunaliella* sp. Bloom of this alga was observed at sites I and II during the summer period. An examination of the food vacuoles of *F. salina* revealed the presence of a large number of *Dunaliella* cells. Porter *et al.* (1985) reported a positive correlation between ciliate biomass and the chlorophyll *a* in freshwater lakes. Furthermore, studies conducted by De Winter & Persoone (1975) have documented that *F. salina* thrives very well on *D. viridis*. However, *F. salina* was observed at St. I in the absence of *Dunaliella*, though in poor density. The preference of *Dunaliella* as food by the ciliate may either be due to its size suitability, nutritional value or predominant co-existence in the same ecosystem. In the absence of *Dunaliella* sp., *F. salina* might survive on other phytoplankton and bacteria as has been reported by Repak (1983). It is said that the ciliates lead a feast and famine existence, depending on the availability of prey (Fenchel 1987; Lynn *et al.* 1987). During brief famine periods mixotrophy may provide the energy while, encystment permit survival over longer periods in these hypersaline ponds.

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