

PLANKTON COMMUNITIES IN HYPERSALINE WATERS OF INDIAN SOLAR SALTWORKS

ABDUL A. RAHAMAN

Resource Bio-Techs Private Limited
21, Vidhya Nagar, Erode- 638 009 India.
e-mail:rahaman@eth.net

EXTENDED ABSTRACT

The plankton community of hypersaline salterns located in Tamilnadu coast, India was studied. The cyanophycean filamentous algae such as *Oscillatoria salina*, *O. formosa*, *Lyngbya majuscula*, *Xenococcus acervatus* and diatoms such as *Amphora* spp., *Navicula* sp., *Nitzschia longissima*, *Pleurosigma salinarum* and *Surirella ovalis* were found to tolerate wide range of salinity (41-150 ppt), while *Anacystis dimidiatus*, *Coccochloris elabens*, *Spirulina platensis* and *Dunaliella salina* were present only in hypersaline conditions. Altogether 33 species of microalgae were identified belonging to 22 genera 6 belonged to cyanophyceae, 5 to chlorophyceae, 21 to bacillariophyceae and 1 belonged to dinophyceae. The cyanophycean filamentous algae were found to be major primary producers in the evaporator ponds followed by chlorophyceae and bacillariophyceae.

Zooplanktons were simple in composition than phytoplankton. Protozoa and copepods formed major components. The holobiont group included *Bodo* sp and *Artemia* Halophilic group comprised of *Nassula* sp; *Rhabdonella* sp; *Diacypis* sp and harpacticoid copepod. More zooplanktons were identified under stenohaline group such as *Flavella* sp; *Brachionus* sp; medusa, polychaete and calanoid copepod and larvae of molluscs.

Based on the relative abundance of different species in relation to salinity the plankters were grouped into three categories, namely halobiont, halophilic and stenohaline. These observations present first hand knowledge about the co-existence of various species endemic to peculiar environments offered by the solar salt works. The paper evaluates their interaction among themselves in relation to the *Artemia* population and with the hydrological factors especially salinity. Field data month wise with reference to species richness, correlation matrix of gross primary productivity with hydrological factors have been discussed.

Keywords: Solar saltworks, Salinity, Microalgae and *Artemia*

INTRODUCTION

Micro algae are indeed the biological starting point for energy flow in most aquatic ecosystem and as such are the basis of food chain (Bradach *et al.*, 1972). The solar saltfield, a special case of hypersaline ecosystem provides an opportunity to examine biological dynamics and trophic interactions along a gradient of increasing salinity. Here the primary and secondary productivity in terms of quantity and quality vary widely and tends to be less productive than moderate saline ecosystems (Hammer, 1981). There are numerous reports on the planktonology of inland hypersaline lakes (Bauld, 1981; Borowitzka, 1981). Very few studies have been made on the hypersaline solar salt ecosystem (Ramamoorthy and Thangaraj, 1980). The role of microalgae and *Artemia* in the production of high quality salt have been well documented (Davis, 1980). Rahaman *et al* 1993 have given detailed account of biological management of solar salt works

through maintenance of a balanced equilibrium between microalgae and *Artemia*. The present study highlights the biological factors both qualitatively and quantitatively at Kelambakkam solar saltworks and also their relation to the hydrological factors.

STUDY AREA

The industrial saltern is located at Kelambakkam, Chennai (12° 08' N, 80° 02' E) having a series of evaporators, reservoirs and crystallizers were selected for study (Fig.1).

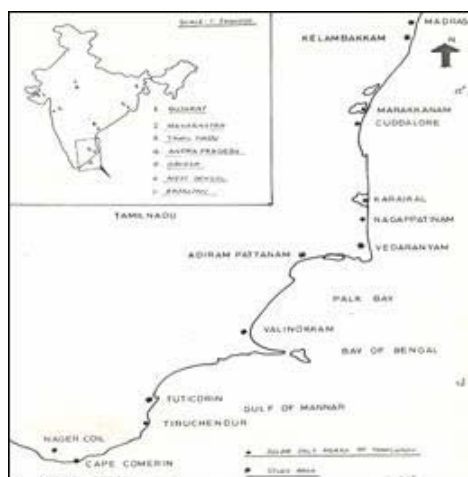


Figure 1. Showing the study area of solar salt works along the south east coast of India

The salt work is in a tropical climate region subject to high evaporation and rainfall only during a short period i.e., October – December. The source of seawater is from Bay of Bengal which enters a feeder canal by tidal action and is pumped into series of interconnected earthen ponds (evaporator) of one to two ha each. The salinity gradually increases by solar evaporation as water flows from one evaporator to another. After the brine becomes saturated, it is transferred to crystallizing pans. The layout of ponds is such that brine flows by gravity from evaporator to crystallizers (evaporator: crystallizer =1: 7 by area).The salt operation is seasonal and production period is from January to September.

MATERIALS AND METHODS

Fortnightly samples were collected from feeder canal K-I and two selected evaporation ponds denoted as K-II and K-III. The salinity of the samples were recorded by refractometer. The phytoplankton and zooplankton samples were collected from the surface waters by filtering water through a plankton net of mesh size 10 μ m and 50 μ m respectively. The samples were then subsampled and the aliquots were used for quantitative analysis. Samples were also preserved in 5% neutral formalin soon after the collection, and they were identified based on standard monographs (Hecky and Kilham, 1973; Post et al 1983 and Wongret, 1986).

Primary productivity was measured by using light and dark bottle method as outlined by (Strickland and Parsons, 1972). Species richness (SR) was estimated using Gleason's (1922) formula

$$SR = \frac{S-1}{\log_e N}$$

where S = number of species

$\log_e N$ = natural logarithm of total number of individuals of all the species in the samples.

Statistical analyses for correlation coefficient were done between gross primary productivity and various hydrological factors (Snedecar and Cochran, 1967)

RESULTS

Salinity values were fluctuated from 19.1 (October) to 168 ppt (August) in the first year and 31 (December) to 105 ppt (August) in the second year at K-I. At K-II, the values ranged between 41 (October) and 172 ppt (August), and 94 (November) and 185 ppt (July) in the first and the second year respectively. At K-III, the salinity ranged from 49.4 (October) to 183 ppt (March) in the first year and 75 (January) to 164 ppt (August) in the second year.

Salinity values showed definite seasonal variations (Fig.2). High values were recorded during the summer months,

i.e., 93.46 ± 45.65 and 92.83 ± 15.83 ppt at K-I, 156.45 ± 19.36 and 174.16 ± 8.33 ppt at K-II and 149.16 ± 17.65 and 154.5 ± 8.15 ppt at K-III In the first and the second year respectively.

The minimum values of 24.7 ± 7.29 , 7.23 ± 24.56 and 62.8 ± 13.92 ppt (at K-I, K-II and K-III respectively) in the first year and 37.33 ± 5.31 , 120 ± 26.87 and 121.66 ± 25.56 ppt at (K-I, K-II and K-III respectively) in the succeeding year a recorded during post summer.

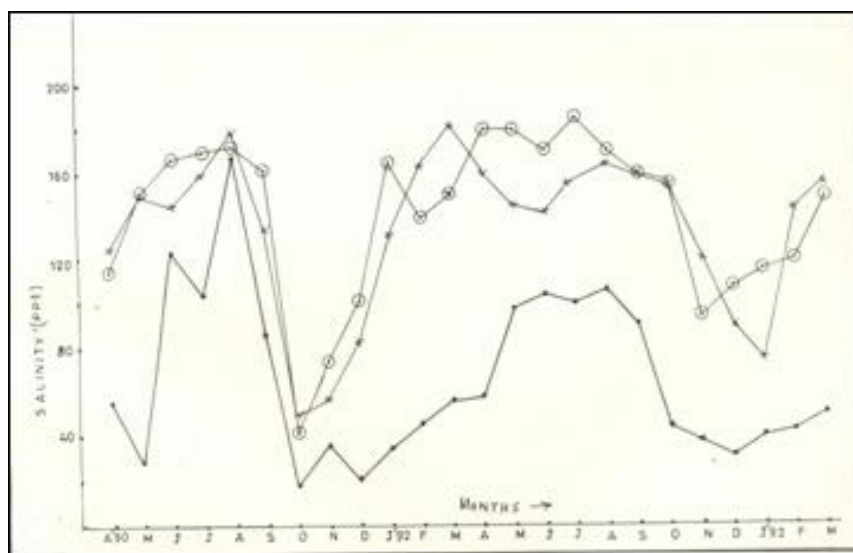


Figure 2: showing monthly variation in salinity at Kelambakkam solar salt works

PHYTOPLANKTON

A total of 26 species of phytoplanktors belonging to 19 genera were identified from Kelambakkam solar saltwork. The algae belonged to Cyanophyceae, Chlorophyceae, bacillariophyceae and dinophyceae. Out of the total of 26 species, 6 belonged to cyanophyceae, 3 to chlorophyceae and 16 to bacillariophyceae and one to dinophyceae.

A station wise consideration revealed that, 25 species belonging to 18 genera were present at K-I and 20 species belonging to 15 genera at K-II and K-III. Members of cyanophyceae were found to be the major component, followed by chlorophyceae, bacillariophyceae and dinophyceae.

Based on the salinity tolerance, the algae were broadly classified into three major groups, namely halobiont, halophilic and stenohaline. The halobiont species of high abundance in hypersaline waters (salinity range 115 to 185 ppt) were *Anacystis dimidiatus*, *Coccochloris elabens*, *Dunaliella salina* and *Spirulina platensis*. Halophilic group (species of indifferent or favoured by or which can tolerate salinity range of 41 to 150 ppt) included *Lyngbya majuscula*, *Oscillatoria salina*, *Gloeocapsa sp.*, *Synura sp.*, *Xenococcus acervatus*, *Amphora ovalis*, *Amphora sp.*, *Anaulus debilis*, *Navicula*

gracilis, *N. mutica*, *Navicula* spp., *Nitzschia* spp., *Pleurosigma distortum* *P. salinarum* and *Surirella ovalis*. Species which are totally absent in salinity above 65 ppt and abundant below 41 ppt comes under stenohaline group, eg: *Biddulphia* sp., *Chaetoceros* sp., *Gyrosigma* sp., *Amphora marina* and *Coscinodiscus* sp.

The monthly distribution and relative abundance of each species are depicted in Figure 3, 4 and 5. The total number of species recorded at K-I was almost same throughout the study period except May, October and December '90 and November and December '91. At K-II and K-III, the number of species were more during presummer and postsummer months (15-20 nos.). But during summer months, it declined to 7 to 9, when the total population was mainly composed of cyanophyceae and dinophyceae alone. The remaining other two groups were present sporadically and usually not in great numbers.

The biomass indices, i.e., total number of cells per ml varied from 1060 in August '90 to 22,300 in November '90 and 8800 in August '91 to 22,300 in March '92 at K-I during the first and second year respectively (Fig.6). At K-II, they ranged from 206 in January '91 to 15,800 in November '90 in the first year and 104 in May '91 to 11800 in December '91 in the succeeding year. The corresponding values at K-III were 120 in March '91 and 15600 in November '90 during the second year. In general, the peak values were recorded during November or December and the lowest values during March and August in all the stations studied.

The species richness varied from 0.857 (May '90) to 2.24 (September '90) and 1.004 (December '91) to 2.18 (July '91) in the first and second year respectively at K-I. At K-II, highest species richness was recorded during January (2.81) and October (2.81) in the first and second year and the lowest of 1.08 during August (first year) and 1.18 during July (second year). But at K-III, the highest was recorded during July (2.73) and August (3.09) in the first and second year respectively. The minimum species richness was encountered during August (1.18) and January (1.76) in the first and second year respectively. The water was very clear and algal mat was not observed.

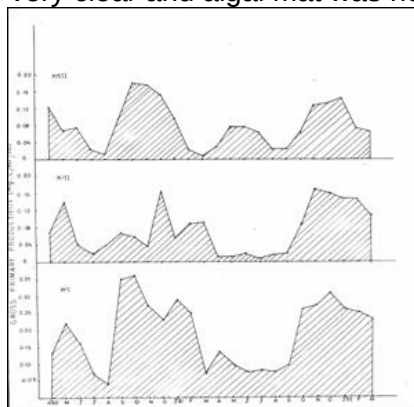


Figure 3

The gross primary productivity varied season as well as station wise. It varied from 0.04 (August) to 0.36 mgC / m² / hr (October), 0.02 (July) to 0.166 mgC / m² / hr (December) and 0.011 (March) to 0.183 mgC / m² / hr (October) in the first year at K-I, K-II and K-III respectively

In the succeeding year, it ranged from 0.075 (June) to 0.31 mgC / m² / hr (December), 0.11 (July) to 0.17 mgC / m² / hr (November) and 0.025 (September) to 0.0146 mgC / m² / hr (January) at K-I, K-II and K-III respectively comparatively high values were recorded at K-I than K-II and K-III.

Season wise, the gross primary productivity was low during pre summer and the lowest values were recorded during summer. But during post summer, the values increased to the maximum levels. The estimated during summer were 0.61 ± 0.1 and 0.094 ± 0.02 mgC / m² / hr in the first and second year respectively at K-I. post summer encountered 0.28 ± 0.05 in the first year 0.28 ± 0.02 mgC / m² / hr in the succeeding year. At K-II, the

minimum values of $0.063 \pm 0.038 \text{ mgc / m}^2 \text{ / hr}$ was recorded during summer '90. The level increased to $0.089 \pm 0.055 \text{ mgc/m}^2\text{/hr}$ during post summer '90. Afterwards it declined and next minimum was recorded during summer '91 ($0.016 \pm 0.004 \text{ mgc / m}^2 \text{ /hr}$). The productivity again increased to $0.14 \pm 0.036 \text{ mgc /m}^2 \text{ /hr}$ during post summer '91 followed by a decline during pre summer '92. At K-III also, highest level was recorded during post summer '92 (0.17 ± 0.013 and $0.108 \pm 0.031 \text{ mgc / m}^2 \text{ / hr}$ in the first and second year) and lowest level was recorded during pre summer in the first year ($0.045 \pm 0.037 \text{ mgc /m}^2 \text{ /hr}$) and summer in the succeeding year ($0.05 \pm 0.023 \text{ mgc / m}^2 \text{ / hr}$)

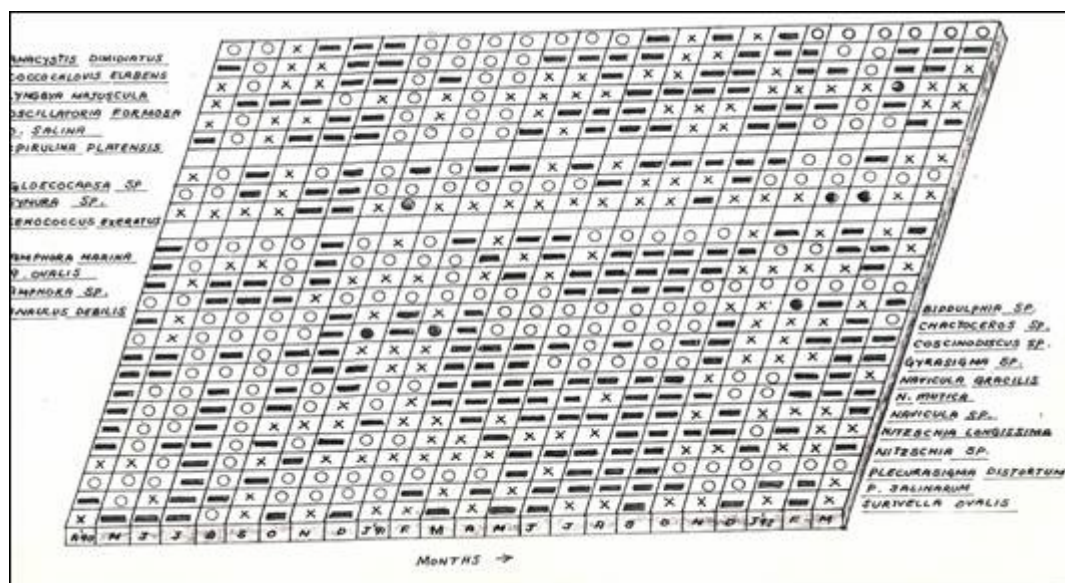


Figure 4: showing monthly distribution and relative abundance of phytoplankton at K-I

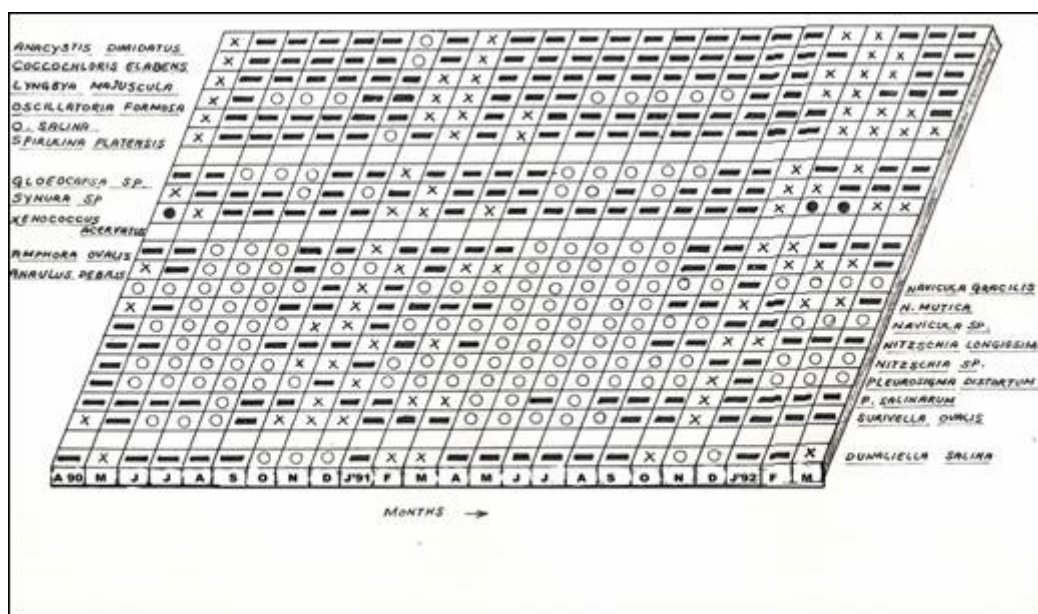


Figure 5: Showing monthly distribution and relative abundance of phytoplankton at K-II

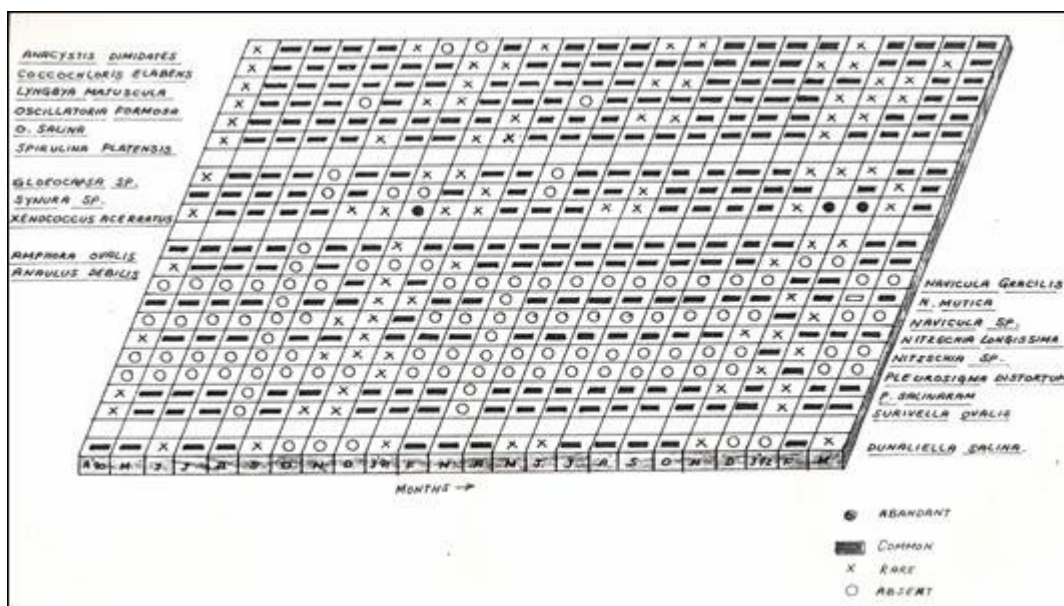


Figure 6: Showing monthly distribution and relative abundance of phytoplankton at K-I

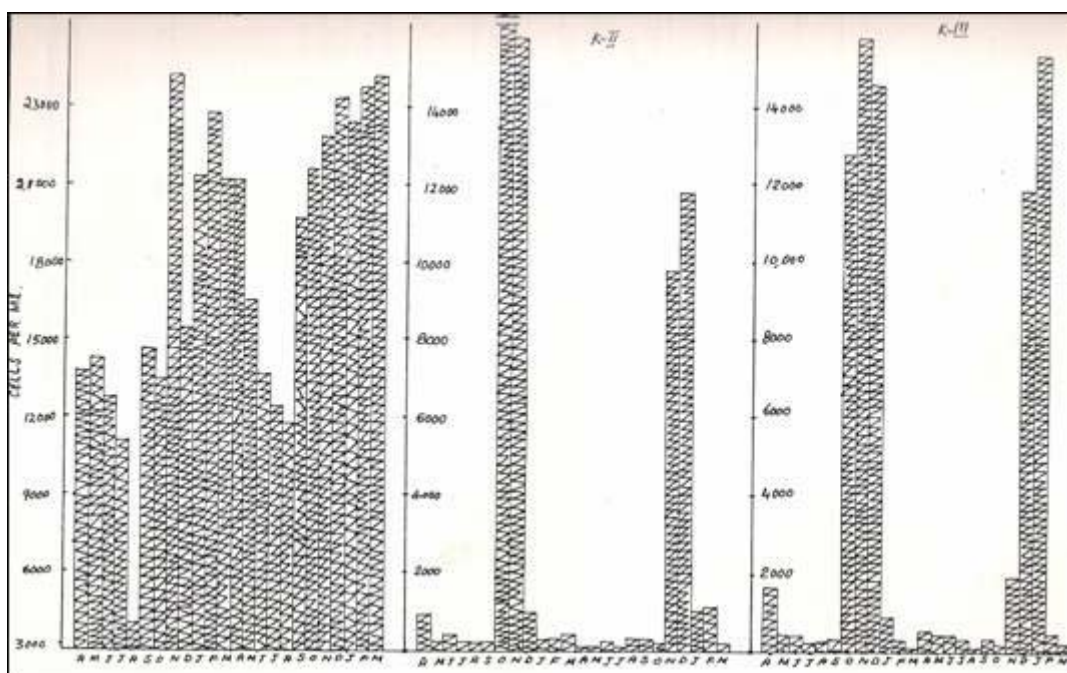


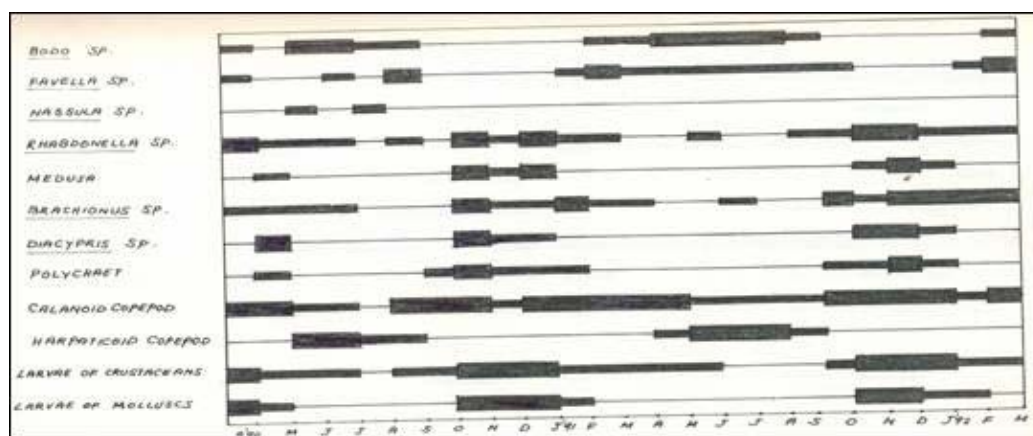
Figure 7: Showing monthly variation of phytoplankton biomass (nos/l) at Kelambakkam K-I, K-II & K-III solar salt works

STATISTICAL ANALYSIS

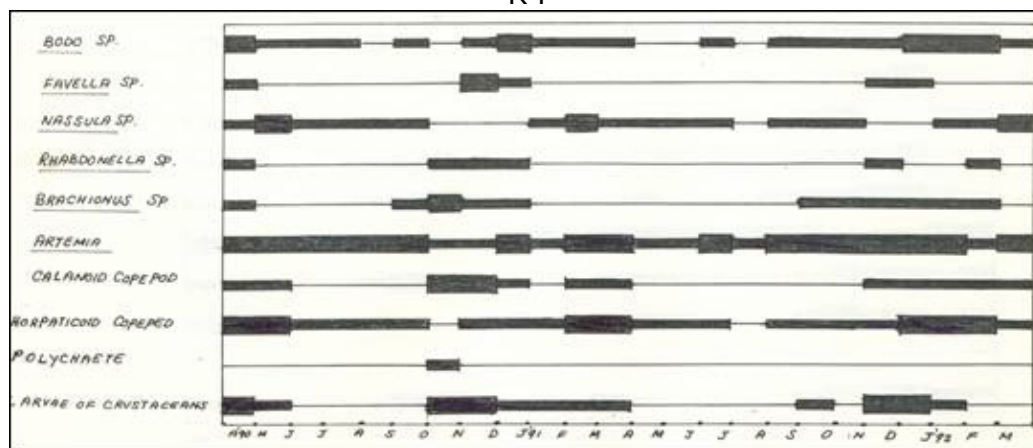
The correlation coefficient of gross primary productivity with various hydrological factors revealed that it had positive relationship with dissolved oxygen, nitrite – nitrogen, nitrate – nitrogen, and phosphate –phosphorus at 1% level of significance and silicate-silicon at non-significance level at K-I. It was negatively correlated to water temperature, calcium and conductivity at 5% of level of significance and salinity, total alkalinity, magnesium, % of total solids and total sulphides at 1% level of significance, The kind of relationship was same at K-II and K-III .

ZOOPLANKTON

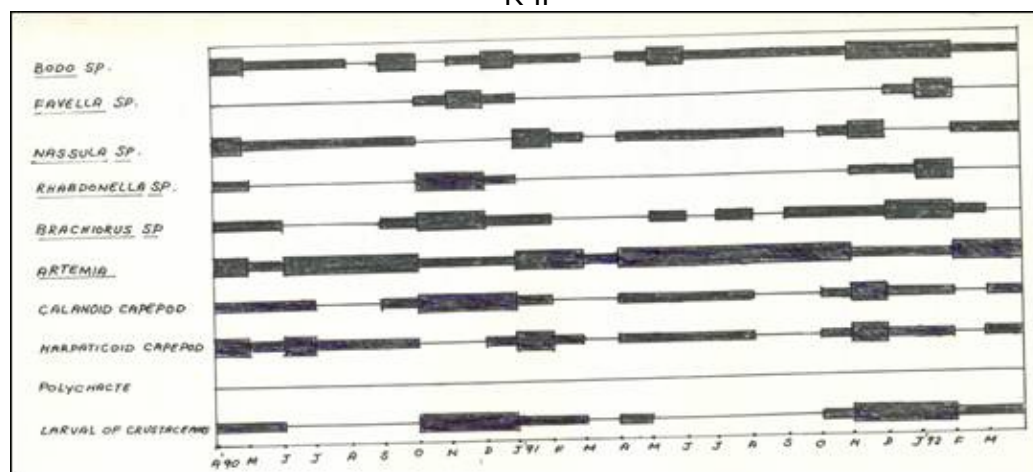
Zooplankters were simple in composition that phytoplankton. A total of 12 zooplankton groups were identified from K-I and 10 each from K-II and K-III. Protozoans and copepods formed the major components.



K-I



K-II



K-III –

Figure 7: Showing monthly distribution and relative abundance of zooplankton.

The check list of zooplankters identified and their salinity tolerance range were studied. Based on the tolerance limit of each group, they were broadly classified into three groups namely halobionts, halophilic and stenohaline as the one that was followed for the classification of phytoplankton. The halobiont group included *Bodo* sp., *Artemia*. Halophilic group comprised of *Nassula* sp., *Rhabdonella* sp., *Diacypris* sp., and

harpacticoid copepod. More zooplankters were identified under stenohaline group such as *Favella* sp., *Brachionus* sp., medusa, polychaete and calanoid copepod and larva of mollusks.

More numbers of species were identified during pre summer, early summer and post summer seasons. The number reduced to 3 during August '90 and 4 during August '91 at K-I. At K-II, the number reduced from 9 to 3 in August '90 and only one group was present during July '90. At K-III, also 3 to 5 groups of zooplankters were identified during August '90, and August & September '91. The monthly distribution and relative abundance are depicted in Fig.8.

DISCUSSION

A biological system which are able to help or harm the salt production exists in the evaporation ponds of every solar saltworks. Based on the relative abundance of different species in relation to salinity, the plankters were grouped into three categories, namely halobiont, halophilic and stenohaline. Bayly (1972) observed that for animals living in highly saline water which is apparently the upper limit of salinity tolerance may in fact be the lower limit of dissolved oxygen tolerance. William (1981) also reported that the dissolved oxygen concentrations may well be important in determining salinity tolerance in halobionts and in certain halophiles, and salinity, temperature and food supply were the major factors to which changes in zooplankton population were attributed.

During the present study also, a gradual reduction in number of species and density of plankton were observed with an increase in salinity and temperature which coincided with decrease in dissolved oxygen concentration. Slightly higher values of total algal density at the salinity range of 140-180 ppt may be due to the abundance of halobiont species like *Dunaliella salina* (Borowitzka, 1981). Britten and Johnsen (1987) found that the diatoms constituted the bulk of benthic algal biomass in low salinity, but did not occur in salinities above 130 ppt which is in agreement with the results of the present study. However, it was reported that diatom species are controlled by salinity, light penetration nitrate concentration and the planktonic diatoms can be used as indicators of time – integrated environmental pond condition in solar salt works (Campbell and Davis, 2000). The hazardous effect of phytoplankton blooming on quantity and quality of salt are well documented (Tackaert and Sorgeloos, 1992). However, the present study revealed that Kelambakkam saltworks can be grouped into a biologically managed saltworks. Here, even though the mucilaginous cyanobacterial plankters were encountered, their production (blooming) were checked by the grazing of *Artemia*, which forms the major zooplankton of the evaporation ponds.

The gross primary productivity was directly related to high nutrient supply and dissolved oxygen, and inversely proportional to various other hydrological factors like total alkalinity, calcium, magnesium, total dissolved solids and total sulphides. The low gross primary productivity during summer and comparatively high values during post and presummer may be due to the high salinity and its related hydrological factors and low dissolved oxygen and low nutrients present in summer and *vice versa*. As the salinity increased due to solar evaporation in saltwork ecosystems, the relative proportions of the ions in solution also change and organisms may exhibit sensitivity to the relative proportions of ions such as K^+ , Ca^{2+} , Na^+ , Mg^{2+} (Nixon, 1970). Bass-Becking (1931) found that cyanobacteria were sensitive to increased calcium and magnesium concentrations at higher salinities. Nissenbaum (1975) reported that the inhibitory effect of high magnesium and calcium concentrations may be the cause of very low species diversity occurring in the hypersaline Dead Sea. Another reason may be due to the feeding of *Artemia* on the microalgae. Jellison and Melack (1988) observed that algal population appears to be maintained at low levels during summer by the intense grazing of the brine shrimp. A similar pattern was observed at Great Salt lake, Utah also (Stephens and Giles, 1976).

The zooplankters other than *Artemia* also followed definite seasonal variation. The presence of larvae and juveniles of crustaceans and fishes during postsummer coincides with their peak breeding season in coastal waters and migration of juveniles along with the incoming seawater. Occurrence of larvae of insects in saltworks has also been reported by Ramamoorthy and Thangaraj (1980) at Tuticorin and Bhargava *et al.*, (1985) in Didwana Lake. The sharp decrease in salinity due to the onset of the monsoon and resulting appearance of predatory insects in the biota may affect the younger stages of *Artemia* population adversely.

These observations give a first hand knowledge about the co-existence of various phyto elements and zooplankters endemic to the peculiar environments offered by the solar saltworks at Kelambakkam and evaluate their interaction among themselves in relation to the *Artemia* population and with the hydrological factors especially the salinity.

ACKNOWLEDGEMENT

This research project was sponsored by Ministry of Environment & Forests, New Delhi, is gratefully acknowledged.

REFERENCES

- Baas, Becking, L.G.M. (1931), Historical notes on salt and salt manufactures, *Sci. monthly*, 32: 434-446
- Bayly, I.A.E. (1972), Salinity tolerance and osmotic behaviour of animals in athalassic saline and marine hypersaline waters. *Ann. Rev. Ecol. Systematics*, 3: 233- 268
- Bauld, J. (1981), Occurrence of benthic microbial mats in saline lakes. *Hydrobiol.*, 81: 87-111
- Bhargava, S.C., G.R. Jakhar, M.M. Saxena and R.K. Sinha (1985), Ecology of *Artemia* in Didwana Salt Lake (India). In : *Book of Abstract. Second International Symp. On the brine shrimp Artemia.*, Sept, 1-5, 1985, Antwerp, Belgium, 149 pp
- Borowitzka, L.J. (1981) The microflora. Adaptations to life in extremely saline lakes. *Hydrobiol.*, 81: 33-46
- Bradach, J.E., I.H. Ryther and W.O. Mc Larney (1972), Aquaculture., The farming and husbandry of fresh water and marine organisms. Wiley – Interscience, 686 pp, New York
- Britten, R.H. and R. Johnson (1987), An ecological account a Mediterranean salina: the salin de giraud, canargue (S. France) *Biological Conservation*, 42: 185 –230
- Campbell, E.E and J.S. Davis. (2000), Diatoms as indicators of pond condition in solar salt works. *8th world salt symposium*. Vol 2 ; 855-860 Edited by Rob M. Geertman, Elsevier.
- Davis, J.S. (1980), Experiences with *Artemia* at solar saltworks. In. The brine shrimp *Artemia*. Vol.3. Ecology, Culturing, use in Aquaculture G. Persoone, P. Sorgeloos, O. Roels, E. Jaspers (Eds.), Universa Press, Wetteren, Belgium, 456 pp
- Gleason, H.A. (1922), On the relation between species and area. *Ecology*, 3: 156-162
- Hammer, U.T. (1981), Primary production in saline lakes: A review. *Hydrobiol.*, 81: 47-57
- Hecky, R.E and P. Kilham (1973), Diatoms in alkaline saline lakes ecology and geochemical implications. *Limnol. Oceanogr.*, 18: 53-71
- Jellison, R and J.M. Melack (1988), Photosynthetic activity of phytoplankton and its relation to environmental factors in hypersaline Mono Lake, California. *Hydrobiol.*, 158: 69-88.
- Nissenbaum, A. (1975), The microbiology and biogeochemistry of the Dead sea. *Microbial Ecology*, 2: 139 –161.
- Nixon, S. (1970), Characteristics of some hypersaline ecosystems. Ph.D Thesis, University of North Carolina, Chapel Hill, North Carolina,
- Post F.J., L.J Borowitzka, M.A, Borowitzka, B. Mackay and T. Moulton, 1983. The protozoa of a western Australian hypersaline lagoon. *Hydrobiologia*, 105 : 95-113.
- Rahaman, A. Abdul, M. Ambikadevi and Sosamma – Easo (1993), Biological management of Indian salt works., *7th Symposium on salt* Vol 1: 633-643 Elsevier Science publishers B.V., Amsterdam.
- Ramamoorthy, K and G.S. Thangaraj (1980). *Ecology of Artemia in salt pans of Tuticorin*, South India. In: The brine Shrimp *Artemia*. Vol.3. Ecology, culturing, Use in Aquaculture. Universa Press, Belgium, 456 pp

- Snedecor, G.W. and W.G. Cochran (1967), Statistical methods, 6th Ed. The State University Press, Iowa, USA, 593 p.
- Stephens, D.W. and D.W. Giles (1976), Phytoplankton production in Great Salt lake, *Utah and a laboratory study of algal response enrichment*. Limnol. Oceanogr., 21: 74-87.
- Strickland, J.D.H. and T.R. Parsons (1972). A practical hand book of sea water analysis (2nd Edition), *Bull. Fish. Res. Board. Can.*, 167 : 310 pp
- Tackx, W and P. Sorgeloos (1992). The use of brine shrimp *Artemia* in biological management of solar saltworks., *Proc. 7th International symp. on "Salt"*, Tokyo April 6-9.
- Wongret, L. (1986), Biological analysis of *Artemia* culture from salt and saltcum *Artemia* farm. *National Artemia Reference Center, NARC/TP/No.2*. Faculty of Fisheries Kasetsart University,. Bangkok, 10903, Thailand, 38pp
- Williams, W.D.(1981), The limnology of saline lakes in Western Victoria – a review of some recent studies. *Hydrobiologia*, 82: 232 – 259.