Water is an essential requirement of all the life processes. Indeed it is a part of life itself since the protoplasm of most of the living cells contain about 80% of water, which participates either directly or indirectly in all metabolic reactions. The inland surface freshwater which is used by all the animals for various purposes, is deteriorating due to demophoric growth. The immediate result of these biotic interferences can be seen in terms of cultural eutrophication, which eventually leads to the shallowing of aquatic systems and deterioration of water quality. In addition, waste products may also reduce the productivity of fish or its quality.

Therefore, the conservation and management of the freshwater bodies is very essential for rational exploitation of these natural resources. To achieve this, the basic understanding of the structural and functional aspects of the aquatic systems is the prerequisite. Although a large amount of work on the water bodies of the temperate regions has been done, but this voluminous data is not applicable to the aquatic systems of the tropical regions where development is still begging all problems. It was with this background that a comprehensive study was undertaken.
on the phytoplankton composition and production in relation to physico-chemical properties and zooplankton production of three central Indian water bodies, which differ widely in their trophic characteristics. All these three water bodies are located in the Sagar district of Madhya Pradesh (India). Sagar lake (23°50' and 78°45'E) is situated in the heart of Sagar city at an elevation of 517 m above MSL; and the Bila (24°16'N and 79°02'E) and Chittora (23°50'N and 78°21'E) reservoirs are located about 65 km and 16 km away from the Sagar town, situated at a height of 445m and 522m above MSL respectively. The Sagar lake and Chittora reservoir are smaller in water spread and catchment area in comparison to the Bila reservoir. The lake water is mostly used for bathing washing, sewage disposal, navigation and cultivation of Trapa, Nelumbo and fish, etc. The water of the Bila reservoir is used for irrigation and fish stocking, while water of the Chittora reservoir is supplied to the cantonment area for domestic purposes. These three sites differ significantly in their trophic status as the macro-vegetation was noticed only at the Sagar lake.

The present work was performed during July 1982 to June 1983. On the basis of four months (from March 1982 to June 1982) preliminary work, two sampling stations - one each in the littoral and limnetic zones of the Sagar lake and one station each in the deep water zone of the Bila and
Chittora reservoirs were selected. The littoral zone of the Sagar lake was heavily infested with macrophytic vegetation while limnetic station was devoid of it. The analysis of the water quality of all the stations except the littoral zone of the Sagar lake was performed. In the littoral zone only phytoplankton productivity experiments were carried out. The diel depth wise studies were performed at all the stations from 0900 hr for next 24 hours with a regular interval of three hours duration. The readings of the 0900 hr have been used to understand the seasonal periodicity of all the investigated parameters except phytoplanktonic productivity which was estimated from 24 hours exposure sets for seasonal study.

Most of the physico-chemical parameters of the water like transparency, temperature, pH, free carbon dioxide, dissolved oxygen, carbonate and bicarbonate alkalinity, total carbon dioxide, chloride, calcium and total hardness and the phytoplanktonic productivity experiments were studied at the site itself, while phosphate, nitrate, phytoplankton and zooplankton were analysed in the laboratory. For the various estimations the standard methods as given in Golterman (1969) and APHA (1955, 1976) were followed. The results obtained for above mentioned attributes, the possible interrelationships and interactions among them are summarized
The variations in the water chemistry generally occur mainly due to the photosynthetic activity of autotrophs, but it may be influenced also by the meteorological conditions and morphometry of the water body. The effect of meteorological conditions and morphometry was found to be more pronounced in long term seasonal studies than the short term diel studies.

The fluctuations in water level during different seasons was found to be an important factor to regulate the seasonal periodicity of many of the chemical and biological properties of the water body. The low transparency in different seasons may be due to different reasons; it depicts high productivity, when produced by plankton populations, and low productivity when produced by organic and inorganic materials brought in the aquatic body by surface run off during rainy season. The low transparency during summer season in the Sagar lake coincided with higher planktonic population, higher phytoplanktonic productivity and low water level. The low transparency during rainy season in the Bila and Chittora reservoirs coincided with higher concentrations of eroded soil particles and low phytoplankton production.

Insolation and temperature were found to affect
directly the phytoplankton productivity and metabolism of the water bodies. Increasing sunlight and temperature always caused an increase in phytoplankton productivity and subsequently increased carbonate alkalinity, pH, chloride and dissolved oxygen, and a decrease in the free carbon dioxide and bicarbonate alkalinity. The fluctuations in bicarbonate and carbonate alkalinity, total CO₂ and pH were less in the Bila and Chittora reservoirs due to less primary productivity.

Dissolved oxygen was not found to be related with phytoplankton productivity; however, it was affected by the temperature and aeration of flowing water. It was maximum during winter season in the Sagar lake, perhaps due to high solubility of oxygen, which increases with decreasing temperature. D.O. was maximum during rainy season in the Bila and Chittora reservoirs perhaps due to increased aeration of flowing water. The trend of percent oxygen saturation was somewhat parallel to that of dissolved oxygen. Free carbon dioxide was never found in surface waters and this indicates its quick utilization by the autotrophs.

The maximum chloride content during warmer periods may be due to decreased water level and higher rate of degradation of organic wastes of animal origin. The calcium
hardness and total hardness followed similar seasonal pattern and showed their maxima in different seasons at different sites. The hardness was minimum in summer season which coincided with higher phytoplanktonic productivity. The maximum concentration of nitrate and phosphate during summer season in the Sagar lake perhaps was due to decreased water level and higher rate of decomposition. Most of the chemical attributes were maximum in concentration in the Sagar lake than the other two water bodies.

Out of all the three water bodies, the maximum number of phytoplanktonic species was recorded in the Sagar lake (47 species), while in the Bila and Chittora reservoirs the number was comparatively less (18 spp in the Bila reservoir and 16 spp. in the Chittora reservoir). The members belonging to the class Cyanophyceae were not found in the Chittora reservoir; however, this reservoir was the only one which favoured the growth of Chrysophycean (Dinobryon) and Dinophycean (Ceratium) members. The number of diatom species was more than the other algal groups in the Bila and Chittora reservoirs, while, the Chlorophycean species were in the Sagar lake.

A remarkable parallelism has been found while ranking the three water bodies on the basis of the Compound Index Value and the decreasing phytoplankton biomass or the increasing
transparency. In all the three water bodies, a more or less pronounced summer increase in the number of the phytoplankton species has been observed. All this contradicts the general belief that low productive lakes would be richer in the species composition than the highly productive lakes.

The diatoms were dominant throughout the year except during rainy and winter seasons in the Bila reservoir and during winter season in the Chittora reservoir. The members belonging to Cyanophyceae were dominant during rainy and winter seasons in the Bila reservoir and a Chrysophycean member (Dinobryon) was dominant during winter season in the Chittora reservoir. The phytoplanktonic crop was maximum in summer season except in the Chittora reservoir, where it was higher in rainy season. The fluctuations in the phytoplanktonic crop was found to be related directly with the fluctuations in the water level particularly in the Sagar lake and Bila reservoir.

The zooplankton component was mainly comprised of four major groups the protozoa, rotifera, cladocera and copepoda. The rotifers were dominant during most of the time of the year except for a short duration in rainy season when copepods were more abundant. The zooplankton composition of the water bodies under investigation did not differ greatly but the
total number of individual species varied considerably in the Sagar lake. The zooplankton crop was maximum in early summer months. Somewhat inverse relation between zooplankton and nannophytoplankton was noticed in the Sagar lake and Bila reservoir. While the phytoplankton of the Chittora reservoir which were comparatively of larger size (than the other two water bodies), did not show any relationship with zooplankton.

The phytoplankton primary productivity estimated from 24 hr incubation period was maximum in summer season and minimum during winter season. The community respiration rate showed similar seasonal periodicity as that of phytoplanktonic productivity.

Diel fluctuations in the chemical properties of water have been found to be regulated by phytoplankton productivity, which in turn is controlled by solar radiation along with temperature. Many of the physico-chemical characteristics of water showed marked diurnal variations.

Secchi transparency increased from early morning (0600 hr) till noon hours when it was maximum and afterwards it declined. This may be due to the fluctuations in light intensity and inclination of the incoming solar radiations. Air and water temperatures begin to rise from morning till
noon maxima and then decreased in the rest of the diel cycle reaching the minima in the early morning. The water temperature was found to decrease with increasing depth during day hours, while water column in night hours was more or less isothermal in nature.

The pH generally showed only little variations that too in the Sagar lake, where it was slightly higher during day hours than the night hours. It was also higher in the surface waters than that of the bottom waters. The bicarbonate alkalinity and total carbon dioxide were generally lower during day hours than that of the mid night or early morning hours. Bicarbonate alkalinity and total CO\textsubscript{2} were found to decrease with increasing depth. Carbonate alkalinity showed inverse relation with bicarbonate alkalinity. This is due to the utilization of bicarbonates during day hours in the photosynthesis by autotrophs, which resulted in the decrease of bicarbonates with subsequent increments in carbonates and pH. While, during night hours only carbon dioxide liberation occurs due to respiratory activity of the biota which brings about an increase in bicarbonate content and decrease in carbonates and pH.

Dissolved oxygen generally increased progressively from dawn till noon or afternoon maxima (1200 hr or 1500 hr). Thereafter, it decreased till midnight or early morning.
It showed somewhat direct relation with phytoplanktonic productivity. The dissolved oxygen, per cent oxygen saturation, water temperature, pH, carbonate alkalinity were higher in the surface waters than that of the bottom waters. While, total CO₂, bicarbonate alkalinity and chloride were inversely related with above factors and phytoplanktonic productivity in the vertical column.

As regards to diel vertical variation of phytoplankton population, it was seen that phytoplankton generally showed very restricted movement and always remained concentrated at the surface or near surface waters. Their stratification was generally found to be affected by turbulence caused by rains on wind actions. In the Sagar lake they were higher at 2.0m depth during winter season throughout the 24 hours cycle; while during rainy and summer seasons they remained suspended at the surface or 0.5m depth, where turbulence during rainy and summer seasons helped them to remain suspended in the upper waters.

The total zooplankton showed a clear diel vertical migration in the Chittora and Bila reservoirs. In the Sagar lake cladocerans, copepods and protozoans were observed to undergo clear diel migration in winter and summer seasons. They migrate towards bottom during day hours and towards the surface during the night hours in response to light
intensity and temperature.

The phytoplanktonic primary productivity was generally higher around noon hours and it is seems to regulated by light intensity and temperature. Community respiration rate did not show any regular diel pattern, however, generally it was higher during day hours than the night hours. The gross primary production and community respiration values as obtained by sum of 3 hrs. exposures for 24 hr were always higher than those obtained from continuous 24 hr exposures.
DIEL VERTICAL VARIATION OF *MELOSIRA GRANULATA* (EHREN) RALFS. IN A SHALLOW EUTROPHIC LAKE OF CENTRAL INDIA

A. K. Vaishya and A. D. Adoni
Limnology Laboratory, Department of Botany, Dr. Harisingh Gour Vishwavidyalaya
SAGAR, 470003 (INDIA)

Abstract

Study of diel vertical variation in the population of *Melosira granulata* was carried out for a year (from July 1982 to June 1983) in the limnetic zone of Sagar lake, a shallow eutrophic aquatic system. Depth wise samplings were made at every three hours interval for twenty-four hours, once in a month. Simultaneously, important physico-chemical properties of water were recorded. The maximum and minimum crops of *M. granulata* were recorded in rainy and winter seasons respectively. The minima coincided with low air and water temperatures, nitrates, phosphates and pH values. In rainy season their number in the surface water was more during day time than in the night due to their accumulation at the surface coupled with low number in the sub surface waters. In winter they were poorly represented at the surface in comparison to sub surface water, whereas, in summer season the reverse was noticed.

Introduction

Planktonic diatoms, particularly the members of the order Centrales, are not capable of movement due to absence of raphe in their valves. Therefore, their spatial and temporal distribution in aquatic systems, are not controlled by the organisms and are of great interest and concern. They generally have higher density than water, and hence adapt to remain in water by increasing their surface area by one or more means (e.g. spines etc.). The present study was carried out on a centric diatom *Melosira granulata* to know its seasonal, diurnal and vertical distribution, and the results are correlated with physico-chemical properties of water, as far as possible.

Material and Methods

The present investigation was carried out from July 1982 to June 1983. Water samples of various depths (surface, 0.5 m and 2 m) were collected, at every three hour interval, starting from 9 a.m. for twenty-four hour, once in a month from deep water zone of Sagar lake, by means of Ruttner water sampler. The physico-chemical properties of water were analysed according to standard methods (APHA, 1975). Water samples for phytoplankton estimation were preserved in 5% formalin and counting was made by drop count method (APHA, 1975).

Result and Discussion

The maximum and minimum crops of *M. granulata* were recorded in rainy and winter seasons, respectively. Winter minima was associated with high Secchi transparency and low pH, nitrates, phosphates, air and water temperature. This might have been caused due to dilution of water after rainy season. Highest number were noticed in September, however, a smaller peak was also observed in June. These peaks coincided with a decrease in nitrates and phosph-
ates, and increase in air and water temperature (Table 1). During-diel cycle in rainy season, maximum number for surface, 0.5 m and 2 m depth were 1220 ml⁻¹, 1155 ml⁻¹ and 970 ml⁻¹ noticed at 3 p.m., 9 p.m and 12 night, while minimum numbers 420 ml⁻¹, 680 ml⁻¹ and 500 ml⁻¹ were recorded at 6 a.m., 6 a.m. and 6 p.m. respectively (Table 2). In winter, highest frustules were noticed at 2 m depth throughout the twenty four hour cycle, except at 3 a.m. and 6 a.m. when they were higher at 0.5 metre. In this season diurnal fluctuations ranged from 40 to 120 ml⁻¹, 50 to 120 ml⁻¹ and 55 to 265 ml⁻¹ at surface, 0.5 and 2 m respectively. Maxima invariably being at 9 a.m., except for 2 m where it was observed at 3 a.m.; and the minima was at 3 p.m., 6 p.m. and 3 a.m., for surface, 0.5 m and 2 m respectively.

Table 1: Seasonal variation in physico-chemical parameters

<table>
<thead>
<tr>
<th></th>
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<tr>
<td>Sky</td>
<td>Cloidy</td>
<td>Cloidy</td>
<td>Cloidy</td>
<td>Cloidy</td>
<td>Cloidy</td>
<td>Cloidy</td>
<td>Cloidy</td>
<td>Clear</td>
<td>Clear</td>
<td>Clear</td>
<td>Clear</td>
<td>Clear</td>
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<tr>
<td>Wind</td>
<td>Fast</td>
<td>Slow</td>
<td>Slow</td>
<td>Slow</td>
<td>Slow</td>
<td>Slow</td>
<td>Slow</td>
<td>Slow</td>
<td>No</td>
<td>Slow</td>
<td>Fast</td>
<td>Strong</td>
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<tr>
<td>Depth (m)</td>
<td>2.0</td>
<td>3.5</td>
<td>5.0</td>
<td>5.5</td>
<td>4.5</td>
<td>4.25</td>
<td>4.5</td>
<td>4.25</td>
<td>3.6</td>
<td>3.5</td>
<td>3.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Secchi transparency (cm)</td>
<td>36</td>
<td>34</td>
<td>87</td>
<td>89</td>
<td>90</td>
<td>98</td>
<td>79</td>
<td>91</td>
<td>34</td>
<td>47</td>
<td>33</td>
<td>25</td>
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<tr>
<td>A.T. (°C)</td>
<td>27.5</td>
<td>24.0</td>
<td>29.5</td>
<td>30.0</td>
<td>24.0</td>
<td>24.0</td>
<td>19.0</td>
<td>20.0</td>
<td>24.75</td>
<td>33.0</td>
<td>33.0</td>
<td>31.0</td>
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<tr>
<td>W.T. (°C)</td>
<td>23.5</td>
<td>23.5</td>
<td>33.5</td>
<td>27.0</td>
<td>22.5</td>
<td>23.0</td>
<td>16.5</td>
<td>18.0</td>
<td>22.25</td>
<td>26.0</td>
<td>30.0</td>
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</tr>
<tr>
<td>pH</td>
<td>8.5</td>
<td>8.0</td>
<td>9.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>7.0</td>
<td>9.2</td>
<td>6.0</td>
<td>5.6</td>
<td>4.0</td>
<td>8.6</td>
</tr>
<tr>
<td>D.O.- (mg l⁻¹)</td>
<td>2.2</td>
<td>4.8</td>
<td>8.0</td>
<td>3.5</td>
<td>7.0</td>
<td>9.2</td>
<td>6.0</td>
<td>5.6</td>
<td>4.0</td>
<td>8.6</td>
<td>6.4</td>
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</tr>
<tr>
<td>NO₃-N (ug l⁻¹)</td>
<td>230</td>
<td>220</td>
<td>40</td>
<td>31.0</td>
<td>70</td>
<td>10</td>
<td>40</td>
<td>40</td>
<td>160</td>
<td>340</td>
<td>300</td>
<td>60</td>
</tr>
<tr>
<td>PO₄-P (ug l⁻¹)</td>
<td>119.0</td>
<td>29.90</td>
<td>13.70</td>
<td>21.81</td>
<td>54.23</td>
<td>13.7</td>
<td>13.7</td>
<td>13.7</td>
<td>33.02</td>
<td>54.23</td>
<td>38.02</td>
<td>38.02</td>
</tr>
</tbody>
</table>

Table 2: Diel vertical variation in Melosira granulata/ml (Seasonal mean values)

<table>
<thead>
<tr>
<th>Season</th>
<th>Depth (m)</th>
<th>9 a.m.</th>
<th>12 Noon</th>
<th>3 p.m.</th>
<th>6 p.m.</th>
<th>9 p.m.</th>
<th>12 Night</th>
<th>3 a.m.</th>
<th>6 a.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainy</td>
<td>0.5</td>
<td>955</td>
<td>910</td>
<td>1075</td>
<td>960</td>
<td>1155</td>
<td>860</td>
<td>870</td>
<td>680</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>740</td>
<td>870</td>
<td>785</td>
<td>500</td>
<td>780</td>
<td>970</td>
<td>950</td>
<td>950</td>
</tr>
<tr>
<td>Winter</td>
<td>0.5</td>
<td>120</td>
<td>55</td>
<td>60</td>
<td>80</td>
<td>50</td>
<td>70</td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>265</td>
<td>200</td>
<td>260</td>
<td>155</td>
<td>190</td>
<td>150</td>
<td>55</td>
<td>75</td>
</tr>
<tr>
<td>Summer</td>
<td>0.5</td>
<td>455</td>
<td>365</td>
<td>460</td>
<td>435</td>
<td>460</td>
<td>380</td>
<td>560</td>
<td>670</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>420</td>
<td>320</td>
<td>345</td>
<td>370</td>
<td>350</td>
<td>355</td>
<td>360</td>
<td>340</td>
</tr>
</tbody>
</table>
During the summer months in March and April, population was least in all the depths, which gradually increased till June. In this season highest number (670 ml$^{-1}$) was noticed at 6 a.m. in surface water and at 9 a.m. (420 ml$^{-1}$) at 0.5 metre. Throughout the twenty four hour cycle *M. granulata* was higher in surface water.

It is clearly evident from Fig. 1 and 2 that in all the months except June *Melosira* was more or less higher at 0.5 and 2 m than surface water. This might be due to settling down of *Melosira* frustules, which is in agreement with Hutchinson (1967) who suggested that most of the planktonic species of *Melosira* are rarely meroplankton and occur in the free water when it is turbulent enough to prevent their settling. The rise in the population of *Melosira* in September and June may be, partly, due to the resuspension of the filaments as these months were associated with high wind and rains. This is in harmony with Lund (1954, 1955) and Talling (1964) who also observed increase in *Melosira* after vertical mixing of the water column. Any correlation of diel vertical distribution of *M. granulata* with physico-chemical properties could not be established.

Acknowledgement

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Fig. 1: Diel vertical variations in *Melosira granulata*

Fig. 2: Diel vertical variations in *Melosira granulata*