Assessment of Changes in the Algal Diversity of Chilika Lagoon after Opening of New Mouth to Bay of Bengal

Debabrata Mohanty, Siba Prasad Adhikary
Department of Biotechnology, Institute of Science, Visva-Bharati, Santiniketan, West Bengal, India
Email: adhikarysp@visva-bharati.ac.in

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ABSTRACT

Eighty one algal taxa comprising of 24 species of Cyanophyta, 2 Rhodophyta, 19 Chlorophyta, 6 Euglenophyta and 30 Bacillariophyceae under Heterokontophyta were recorded in Chilika lagoon in different seasons of 2010-2011 in a survey after opening of new mouth to Bay of Bengal. Of these Cyanobacterium diachloros, Aphanocapsa marina, Microsystis aeruginosa, Microsystis wesenbergii, Pseudanabena limnetica, Arthospira ambiguum, Oscillatoria perornata, Oscillatoria simplicissima under Cyanophyta, Scenedesmus bijugatus, Urenema elongatum under Chlorophyta, Trachelomonas abrupt, Trachelomonas hispida under Euglenopyta and Coscinodiscus subtilis, Navicula amphirhynchus, Navicula major, Gomphonema micropus, Gomphonema olivaceu, Gomphonema sphaerophorum, Cyclotella meneghiniana, Pinnularia subsimilis, Pleurosigma javanicum, Stephanophyxis turris, Synendra tabulata, Stauroneis pusilla and Cymbella affinis under Bacillariophyceae of Heterokontophyta recorded in the survey have not been reported in the lake before opening of the mouth. Maximum number of algal species was observed in winter followed by summer and post monsoon seasons. Northern sector showed maximum algal diversity followed by Central, Southern and Outer channel sectors. The Cyanophytes followed by Chlorophytes were rich in Northern, Central and Southern sectors where as the diatoms were abundant in Outer channel sector and Northern sector. The agarophyte Gracilaria verrucosa recorded in the Outer channel sector of the lagoon for the first time showing extended distribution of the species due to increase in salinity coupled with consistent wave action in the lagoon after opening of the new mouth.

Keywords: Chilika Lagoon; Algal Diversity; New Mouth; Salinity Gradient; Seasonality

1. Introduction

Chilika lagoon in the east coast of India is the largest brackish water lake with an average depth of approximately 2 m and an area varies from 1165 to 906 km² during rainy and summer seasons respectively [1]. It was declared as Ramsar site, a wetland of international importance in 1981. The fresh water input into the lagoon is from Daya and Bhargabi rivers, several other rivulets and also salt water from Bay of Bengal. Due to confluence of fresh and salt water, a distinct salinity gradient is maintained in different seasons in the lagoon ranging from 1 - 33 ppt basing on which it is divided into four sectors i.e. Southern, Central, Northern and Outer channel sector. Prior to 2001 in Southern sector the salinity was moderate (8 - 20 ppt), in Central sector showed a seasonal variation in salinity level (5 - 30 ppt) and in the Northern sector the salinity was low varying from (0.1 - 13 ppt) due to opening of several rivers. Due to tidal impact, coupled with closure of the mouth connecting to the sea the salinity level in the Outer channel sector was nearly similar to the seawater during most times of the year except the rainy season [1]. To restore the lagoon characteristics with appropriate flux of seawater into the lake a new mouth was dredged in 2000 in the Outer channel sector near Sipakuda area. Again in March 2008, a natural mouth was opened near Gabakunda and was subsequently widened [2]. Both these new openings to the sea facilitated extensive mixing of saltwater with freshwater resulting in a wide variation in the hydrology of the lake. Several authors have reported the changes in the physico-chemical parameters of the lagoon after opening of these new mouths [2-7], however, assessment of algal diversity changes after 2001 has not been made so far.

An assemblage of marine, brackish and freshwater ecosystems in Chilika lagoon encourages occurrence of di-
verse group of phytoplankton, aquatic flora and fauna, hence is one of the biodiversity of hot spots in India. The phyco-diversity in the lagoon is a subject of interest since 1930s to estimate the trophic status of the lake and its direct relevance to fisheries. The algal flora of the lagoon was studied first by Biswas [8] and subsequently Roy [9], Ahmed [10], Patnaik [11,12], Raman [13] Adhikary & Sahu [14], Rath & Adhikary [1,15] have documented the algal flora including their seasonal variation at different salinity gradient of the lagoon.

In the present work algal forms occurring in different seasons at the four sectors of the lagoon was studied and the changes in their diversity were assessed upon comparing with the results published as a check list [15] before opening of the new mouth in 2001.

2. Materials and Methods

Algal taxa were sampled during summer (May 2011), post monsoon (September 2011) and winter (December 2011—January 2012) at seven different locations in the Chilika lagoon covering all the four sectors. These were SI (Mangaljodi, Northern sector), SII (Barakul, Central sector), SIII (Kalijai, Central sector), SIV (Pathara, Central sector), SV (Rambha, Southern sector), SVI (Ghantashila, Southern sector) and SVII (Sipakuda, Outer Channel sector) (Figure 1). Samples were stored in Tarson made specimen tubes, fixed on sport with 4% formalin and brought to the laboratory for analysis. For sampling of plankton a 45 µm pore size plankton net was used. Attached algae, e.g. epilithic, epiphytic and epipelic forms were collected using forcep, scalpel and nylon brush. Each sample was given a voucher number and deposited at the Department of Biotechnology, Visva Bharati. Microscopic observation and microphotography was done using Olympus B47 phase contrast research microscope fitted with Nikon 4500 coolpix digital camera. The organisms were identified following Kützing [16], Huberpestalozzi [17], Desikachary [18-21], Ramanathan [22], Philipose [23], Ettl & Gärtner [24], Komárek & Anagnostidis [25,26] and Wołowski & Hindák [27].

3. Results and Discussion

3.1. Algal Diversity in Chilika Lagoon in 2011-12

A total of eighty one algal species were documented from seven different collection sites of Chilika lagoon during different seasons of 2011. These belonged to Cyanophyta (24 species), Rhodophyta (2 species), Chlorophyta (19 species), Euglenophyta (6 species) and Heterokontophyta under class Bacillariophyceae (30 species). Seasonal variation in the distribution of these algal species in different collection sites is given in Table 1 and Plates 1-3. Only few cyanobacterial and algal species like Spirulina major (SI), Oscillatoria limosa (SV), Lyngbya aestuarii (SIV), Gracillaria verrucosa (SIII, SV), Spirogyra sp. (SII, SV), Chaetomorpha linum (SV), Enteromorpha compressa (SIV), Enteromorpha intestinalis (SIV), Melosira decussata (SVII), Synedra ulna (SVII) and Amphora elliptica (SVII) were exclu-
Table 1. Seasonal occurrence of algal species in different locations of Chilika lagoon during 2011. SI-(Mangalajodi in Northern sector), SII-(Barakul in Central sector), SIII-(Kalijai in Central sector), SIV-(Pathara, Central sector), SV-(Rambha in Southern sector) SVI-(Ghantashila in Southern sector), SVII-(Sipakuda in Outer channel sector), S-Summer, PM-Post monsoon, W-Winter.

| Algal taxa                        | SI  | SII | SIII | SIV | SV  | SVI | SVII |
|-----------------------------------|-----|-----|------|-----|-----|-----|------|
|                                   | S   | PM  | W    | S   | PM  | W   | S    | PM  | W   | S   |
| Cyanophyta                        |     |     |      |     |     |     |      |     |     |     |
| Cyanobacterium diachloros         |     |     |      |     |     |     |      |     |     |     |
| Komárek & Anagnostidis            | +   |     |      |     |     |     |      |     |     |     |
| Aphanocapsa marina Hansgirg       |     |     |      |     |     |     |      |     |     |     |
| Merismopedia glauca (Ehrenberg)   |     |     |      |     |     |     |      |     |     |     |
| Kützing                           | +   |     |      |     |     |     |      |     |     |     |
| Merismopedia punctata Meyer       |     |     |      |     |     |     |      |     |     |     |
| Merismopedia warmingiana Lagerheim|     |     |      |     |     |     |      |     |     |     |
| Microcystis aeruginosa Kützing     |     |     |      |     |     |     |      |     |     |     |
| Microcystis wesenbergii (Komárek) |     |     |      |     |     |     |      |     |     |     |
| Chroococcus limneticus Lemmermann | +   |     |      |     |     |     |      |     |     |     |
| Pseudanabaena limnetica Komárek    |     |     |      |     |     |     |      |     |     |     |
| Pseudanabaena minima Anagnostidis |     |     |      |     |     |     |      |     |     |     |
| Getlerinema earlei (Gardner)       |     |     |      |     |     |     |      |     |     |     |
| Anagnostidis                       | +   |     |      |     |     |     |      |     |     |     |
| Spirulina labyrinthiformis        |     |     |      |     |     |     |      |     |     |     |
| Kützing ex Gomont                 |     |     |      |     |     |     |      |     |     |     |
| Spirulina major Kützing ex Gomont | +   |     |      |     |     |     |      |     |     |     |
| Spirulina subtilissima Kützing     |     |     |      |     |     |     |      |     |     |     |
| Phormidium ambiguum Gomont        |     |     |      |     |     |     |      |     |     |     |
| Oscillatoria limosa Agardh exomont|     |     |      |     |     |     |      |     |     |     |
| Oscillatoria porornata Skuja       |     |     |      |     |     |     |      |     |     |     |
| Oscillatoria princeps Vaucher ex Gomont |     |     |      |     |     |     |      |     |     |     |
| Oscillatoria proteus Skuja         |     |     |      |     |     |     |      |     |     |     |
| Oscillatoria sancta Kützing ex Gomont |     |     |      |     |     |     |      |     |     |     |
| Oscillatoria simplicissima Gomont |     |     |      |     |     |     |      |     |     |     |
| Lyngbya aestuarii Liebman ex Gomont|     |     |      |     |     |     |      |     |     |     |
| Anabaena oscillarioides Bharadwaj |     |     |      |     |     |     |      |     |     |     |
| Anabaena variabilis Kützing ex Bornet et Flahault |     |     |      |     |     |     |      |     |     |     |
| Rhodophyta                         |     |     |      |     |     |     |      |     |     |     |
| Ceramium diaphanum Roth            |     |     |      |     |     |     |      |     |     |     |
| Gracilaria verucossa (Huds.) Papenfuss |     |     |      |     |     |     |      |     |     |     |
| Chlorophyta                        |     |     |      |     |     |     |      |     |     |     |
| Spirogyra sp.                     |     |     |      |     |     |     |      |     |     |     |
| Closterium venus Kützing           |     |     |      |     |     |     |      |     |     |     |
| Chaetomorpha linum (Mueller) Kützing|     |     |      |     |     |     |      |     |     |     |
| Cosmarium awadhense Prasad et Mehrora |     |     |      |     |     |     |      |     |     |     |
| Cosmarium decoratum G.S. West      |     |     |      |     |     |     |      |     |     |     |
| Cosmarium lunellii Delporte var. ellipticum W. et G.S. West |     |     |      |     |     |     |      |     |     |     |

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| Species                                    | Symmetry |
|-------------------------------------------|----------|
| Cosmarium miscellum Skuja                 | + + + +  |
| Cosmarium punctulatum Brébisson           | + + + + + + |
| Microspora willeana Lagerheim             | +         |
| Enteromorpha usneoides (Bonnemaison) Agardh| +         |
| Enteromorpha compressa (L.) Nees          | + + + + + + + |
| Enteromorpha intestinalis (L.) Nees        | + + + + + + |
| Euastrum dubyum Nägeli                    | + + + + + + |
| Pediasstrum tetras (Ehrenberg) Ralfs      | + + + + + |
| Chlorella protothecoides Kützing          | + + + + + |
| Scenedesmus bijugatus (Turpin) Kützing    | + + +     |
| Scenedesmus calyptratus Comas             | + + +     |
| Scenedesmus dimorphus (Turpin) Kützing    | + + +     |
| Scenedesmus protuberans Frisch et Rich    | + + +     |
| Uronema confervicolum Lagerheim           | + + +     |
| Uronema elongatum Hodgetts                | +         |
| Euglenophyta                               |           |
| Euglena acus Ehrenberg                    | + +       |
| Euglena agilis Carter                     |           |
| Euglena caudate Hüben                    | + + +     |
| Lepocinclis playfairiana Deflandre        | + +       |
| Trachelomonas abrupt Swirekno             | +         |
| Trachelomonas hispida Lemmermann          |           |
| Bacillariophyta                            |           |
| Melosira decussate (Ehrenberg) Kützing    | + + +     |
| Odontella polymorpha Kützing              | + +       |
| Coscinodiscus marginatus Ehrenberg        | + + +     |
| Chaetoceros decipiens Cleve               | +         |
| Cyclotella maxima Kützing                 | +         |
| Cyclotella meneghiniana Kützing           | + + +     |
| Fragilaria crotonensis Kitton             | +         |
| Synedra crystalline Kützing               | +         |
| Synedra radians Kützing                   | + + +     |
| Synedra tabulata Kützing                  | +         |
| Synedra ulna (Kützing) Hustedt            | + + +     |
| Tabellaria flocculosa (Roth)Kützing       | + +       |
| Cocconeis pediculus Ehrenberg             | +         |
| Fragilaria nodoso (Ehrenberg) W. Smith    | + + +     |
| Pinnularia nodosa subsimilis Gandhi       | + +       |
| Pleurosigma javanicum Grunow              | +         |
| Pleurosigma normanii Ralfs                | +         |
| Navicula amphirhythcha Ehrenberg          | +         |
| Navicula major Kützing                    | +         |
| Gomphonema micropus Kützing               | +         |
Continued

| Species                                      | Presence |     |
|----------------------------------------------|----------|-----|
| Cymbella affinis Kützing                     | +        | +   |
| Amphora elliptica Kützing                    | +        | +   |
| Nitzschia acuta Cleve                        | +        | +   |
| Hantzschia amphioxys (Ehrenberg) Grunow in Cleve & Grunow | +        | +   |
| Epithemia gibberula Grunow                   | +        | +   |

Plate 1. 1. *Cyanobacterium diachloros*; 2. *Aphanocapsa marina*; 3. *Merismopedia glauca*; 4. *Merismopedia punctata*; 5. *Merismopedia warmingiana*; 6. *Microcystis aeruginosa*; 7. *Microcystis wesenbergii*; 8. *Chroococcus limneticus*; 9. *Pseudanabaena limnetica*; 10. *Pseudanabaena minima*; 11. *Geitlerinema earlei*; 12. *Spirulina labyrinthiformis*; 13. *Spirulina major*; 14. *Spirulina subtilissima*; 15. *Phormidium ambiguum*; 16. *Oscillatoria limosa*; 17. *Oscillatoria perornata*; 18. *Oscillatoria princeps*; 19. *Oscillatoria proteus*; 20. *Oscillatoria sancta*; 21. *Oscillatoria simplicissima*; 22. *Lyngbya aestuarii*; 23. *Anabaena oscillarioides*; 24. *Anabaena variabilis*; 25. *Ceraminium diaphanum*; 26. *Spirogyra* sp.; 27. *Closterium venus*; 28. *Euastrum dubium*; 29. *Cosmarium avadhense*; 30. *Cosmarium decoratum*; 31. *Cosmarium lundellii var. ellipticum*; 32. *Cosmarium miscellum*; 33. *Cosmarium punctulatum*; 34. *Pediastrum simplex* var. simplex; 35. *Microspora willeana*; 36. *Enteromorpha usneoides* (Scale bar: Figure 26, 36 = 30 µm; Figure 6, 31 = 20 µm; Figures 1-5, 7-25, 27-30, 32-35 = 10 µm).
Plate 2. 1. Pediastrum tetras; 2. Chlorella protothecoides; 3. Scenedesmus bijugatus; 4. Scenedesmus calyptratus; 5. Scenedesmus dimorphus; 6. Scenedesmus protuberans; 7. Uronema conchicola; 8. Uronema elongatum; 9. Euglena acus var. Acus; 10. Euglena agilis; 11. Euglena caudata; 12. Lepocinclis playfairiana; 13. Trachelomonas abrupta var. Abrupta; 14. Trachelomonas hispida var. Crenulatocollins; 15. Melosira decussata; 16. Chaeotoceros decipiens; 17. Odontella polymorpha; 18. Coscinodiscus marginatus; 19. Coscinodiscus subtilis; 20. Cyclotella maxima; 21. Bacteriastrum hyalinum; 22. Cyclotella meneghiniana; 23. Fragilaria crotonensis; 24. Synedra crystallina; 25. Synedra radians; 26. Synedra tabulata; 27. Synedra ulna var. Aequalis; 28. Synedra ulna var. amphirhynchus (Scale bar: Figure 25 = 50 µm; Figure 17 = 40 µm; Figure 24 = 20 µm; Figures 1-16, 18-23, 26-28 = 10 µm).

cively occurred during this season. Maximum number of algal taxa comprised of 22 Cyanophytes, 2 Rhodophytes, 20 Chlorophytes, 6 Euglenophytes and 27 Bacillario-phyccean members occurred in the winter season. Of these, 7 species of Cyanophyta e.g. Merismopedia warmingiana, Microcystis aeruginosa, Microcystis wesenbergii, Oscillatoria perornata, Oscillatoria princeps, Oscillatoria simplicissima and Anabaena oscillarioides, 3 species of Chlorophyta e.g. Closterium venus, Cosmarium deco-
post monsoon period.

3.2. Comparison of Algal Diversity in Chilika Lagoon before and after Opening of the New Mouth to Bay of Bengal

Sector wise comparison of the algal diversity recorded in the present work with the documentation of their occurrence in different sectors of the lagoon in the immediate past 2000-2001 [1] is given in Table 2. It was observed that several algal taxa comprised of 10 Cyanophytes, 3 Chlorophytes, 2 Euglenophytes and 13 Bcillariophyce members appeared in the lagoon after opening of new mouth to the sea. These were *Cyanobacterium diachloros*, *Aphanocapsa marina*, *Microsystis aeruginosa*, *Microsystis wesenbergii*, *Pseudanabena limnetica*, *Arthospira ambiguum*, *Oscillatoria perornata*, *Oscillatoria proteus*, *Oscillatoria simplicissima*, *Scenedesmus bijugatus*, *Trachelomonas abrupt*, *Trachelomonas hispida*, *Coscinodiscus subtilis*, *Navicula amphirhynchus*, *Navicula major*, *Gomphonema micropus*, *Gomphonema olivaceum* and *Gomphonema sphaerophorum* in the Northern sector, *Cosmarium miscellum*, *Cycentodella meneghiniana* and *Pinnularia subsimilis*, in the Southern sector, *Oscillatoria princeps* and *Pleurosigma javanicum* in the Central sector and *Stephanophyxis turris*, *Synendra tabulata*, *Stauroneis pusilla* and *Cymbella affinis* in the Outer channel sector. However, the species e.g. *Lyngbya aestuarii*, *Ceramium diaphanum*, *Enteromorpha usneoides*, *Bacteriastrum hyalinum*, *Nitzschia obtusa* in the Northern sector, *Pediastrum simplex*, *Pediastrum tetras*, *Nitzschia obtusa* in the Northern sector, *Lyngbya aestuarii*, *Pediastrum simplex*, *Pediastrum tetras* in the Central sector and *Melosira borreii*, *Coscinodiscus marginatus*, *Synendra ulna*, *Nitzschia obtuse* in the Outer channel sector documented in the present work have also been recorded earlier in the lake in 2001 before the opening of new channel to Bay of Bengal [1]. The number of Bacillariophycean taxa which are principally benthic and epilithic increased in number in the lagoon in response to the change in the hydrological parameters especially increase in the saltwater influx to the lake.

Biswas in 1932 [8] reported first occurrence of 22 algal species comprising of Cyanophyta (11), Chlorophyta (5) and Rhodophyta (6) in Chilika lagoon. After almost 20 years Roy [9] reported 33 Bacillariophycean members in the entire lagoon. Subsequently Ahmed [10] reported 13 algal species comprised of 1 Cyanophyta, 5 Chlorophyta, 1 Bacillariophaecae and 6 Rhodophyta, and Patnaik [11,12] reported 57 algal species comprising 6 Cyanophyta, 8 Chlorophyta, 40 Bacillariophyceae, 7 Dinophyta, 1 Xanthophyta and 4 Rhodophyta in the lagoon. Raman [13] reported 4 species of Cyanophyta, 3 species of Chlorophyta, 10 species of Bacillariophyceae, and only 1 species of Dinophyta from the lake. Adhikary and Sahu [14] reported 9 Cyanophyta, 8 Chlorophyta, 1 Xantho-
Table 2. Comparative account of occurrence of algal species in different sectors of Chilika lagoon recorded in present work with those occurring in 2001 [1] before opening of new mouth connecting Bay of Bengal.

| Algal taxa                  | Northern sector | Central sector | Southern sector | Outer channel sector |
|-----------------------------|-----------------|---------------|-----------------|----------------------|
|                             | Earlier record  | Present record| Earlier record  | Present record        |
| Cyanophyta/Cyanoprokaryota  |                 |               |                 |                      |
| Cyanobacterium diachloros   | +               |               |                 | +                    |
| Synechocystis aquatilis     |                 | +             |                 |                      |
| Aphanocapsa marina          | +               | +             |                 |                      |
| Merismopedia elegans        |                 |               |                 | +                    |
| Merismopedia glauca         | +               |               |                 | +                    |
| Merismopedia punctata       | +               |               |                 | +                    |
| Merismopedia warmingiana    |                 | +             |                 | +                    |
| Microcystis aeruginosa      |                 |               |                 |                      |
| Microcystis wesenbergii     |                 |               |                 |                      |
| Chroococcus limneticus      |                 |               |                 |                      |
| Chroococcus turgidus        |                 |               |                 |                      |
| Pseudanabaena limnetica     |                 |               |                 |                      |
| Pseudanabaena minima        | +               | +             |                 | +                    |
| Geitlerinema earlei         |                 |               |                 | +                    |
| Spirulina labyrinthiformis |                 |               |                 |                      |
| Spirulina major             |                 |               |                 |                      |
| Spirulina subtillisima      |                 |               |                 |                      |
| Arthospira platensis        |                 | +             |                 | +                    |
| Arthospira ambigua          |                 |               |                 | +                    |
| Phormidium submembranaceum  | +               | +             | +               | +                    |
| Oscillatoria limosa         |                 |               |                 | +                    |
| Oscillatoria perornata      |                 |               |                 |                      |
| Oscillatoria princeps       |                 | +             |                 | +                    |
| Oscillatoria proteus        |                 |               |                 | +                    |
| Oscillatoria sancta         |                 | +             |                 |                      |
| Oscillatoria simplicissima  |                 |               |                 |                      |
| Lyngbya aestuarii           |                 | +             | +               | +                    |
| Anabaena torulosa           |                 | +             | +               | +                    |
| Anabaena variabilis         |                 |               |                 | +                    |
| Anabaena flos-aquae         | +               | +             |                 |                      |
| Fischerella sp.             |                 | +             |                 |                      |
| Ceranium diaphanum          |                 | +             | +               | +                    |
| Gracilaria verrucosa        |                 | +             | +               | +                    |
| Grateloupia filicina        |                 |               |                 | +                    |
| Polysiphonia subtillisima   |                 | +             |                 | +                    |
| Chlorophyta                 |                 |               |                 |                      |
| Spirogyra sp.               | +               | +             | +               | +                    |
| Chara sp.                   |                 |               |                 | +                    |
| Nhella sp.                  |                 |               |                 | +                    |
| Closterium venus            |                 | +             |                 | +                    |
| Species                        | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
|-------------------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Euastrum dubium*             |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Cosmarium awadhense*         | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Cosmarium decoratum*         | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Cosmarium impressulum*       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Cosmarium lundellii*         |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Cosmarium miscellum*         |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Cosmarium punctulatum*       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Xanthidium seximamillatum*   | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Chaetomorpha linum*          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Cladophora glomerata*        |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Ulva lactuca* Linn.          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Microspora willeana*         |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Enteromorpha compressa*      |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Enteromorpha intestinalis*   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Enteromorpha usneoides*      |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Eudorina elegans*            | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Pediastrum duplex*           | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Pediastrum simplex*          | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Pediastrum tetras*           | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Chlorella protothecoides*    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Actinastrum hantzschii*      |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Coelastrum cambricum*        |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Scenedesmus bijugatus*       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Scenedesmus acuminatus*      |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Scenedesmus calytratus*      |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Scenedesmus dimorphus*       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Scenedesmus protuberans*     |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Scenedesmus quadricauda*     |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Selenastrum gracile*         |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Tetraedron gracile*          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Tetraedron trigonum*         |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Uronema confervicolum*       | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Uronema elongatum*           |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Euglenophyta*                |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Euglena acus*                | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Euglena agilis*              | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Euglena caudata*             | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Leptocylindrus danicus*      |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Lepocinclis playfairiana*    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Trachelomonas abrupta*       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Trachelomonas hispida*       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Bacillariophyta*             |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Melosira borreii*            | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| *Melosira decussata*          | + |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

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**Continued**

| Species               |   |   |   |
|-----------------------|---|---|---|
| Odontella mobilensis  |   |   |   |
| Odontella polymorpha  | + |   |   |
| Biddulphia heteroceros|   |   | + |
| Thalassiosira subtilis|   |   |   |
| Lauderia annulata     |   |   | + |
| Skeletonema costatum  | + |   | + |
| Coscinodiscus centralis| + |   | + |
| Coscinodiscus gigas   |   |   |   |
| Coscinodiscus marginatus| + |   | + |
| Coscinodiscus subtilis| + |   |   |
| Stephanopyxis turris  |   |   | + |
| Chaetoceros affinis   |   |   | + |
| Chaetoceros decipiens |   |   | + |
| Chaetoceros diversus  | + |   | + |
| Chaetoceros eibeni    |   |   |   |
| Chaetoceros lorenzianus| + |   |   |
| Chaetoceros paradoxus |   |   |   |
| Bacteriastrium furactum|   |   |   |
| Bacteriastrium hyalinum| + |   | + |
| Rhizosolenia setigera |   |   | + |
| Cyclotella maxima     | + |   |   |
| Cyclotella meneghiniana|   |   |   |
| Fragilaria crotonensis| + |   |   |
| Grammatophora undulata| + |   |   |
| Synedra crystalline   |   |   | + |
| Synedra radians       | + |   |   |
| Synedra tabulata      |   |   | + |
| Synedra ulna          | + |   | + |
| Leptocylindrus danicus| + |   |   |
| Licmophora abbreviate | + |   | + |
| Asterionellopsis glacialis| + |   | + |
| Tabellaria fenestrata  | + |   |   |
| Tabellaria flocculosa |   | + |   |
| Bacillaria paxillifera| + |   | + |
| Cylindrotheca closterium| + |   | + |
| Thalassionema nitzschioides| + |   | + |
| Cocconeis pediculus   | + |   | + |
| Pinnularia alpine     | + |   |   |
| Pinnularia nobilis    | + |   | + |
| Pinnularia nodosa     | + |   |   |
| Pinnularia subsimilis | + |   | + |
| Pleurosigma javanicum  |   |   | + |
| Craticula normanii    | + |   | + |
| Gyrosigma acuminatum  | + |   | + |
phyta, 6 Bacillariophyta, 3 Dinophyta, and 1 Rhodophyta in the lake. Rath & Adhikary [15] studied the diversity extensively for two consecutive years in 2000 to 2001 in different seasons and reported 102 algal species comprising 12 species of Cyanophyta, 23 species of Chlorophyta, 58 species of Bacillariophyceae, 5 species of Dinophyta, and 4 species of Rhodophyta, and published a checklist of algae of the lagoon [15]. Analysis of these reports along with those species occurred in the lake after opening of the new mouth showed that of the 81 algal taxa, 20 species were recorded in the lagoon since the first report in 1932 [8] or later in 1954 [9], 1966 [10], 1973 [11], 1978 [12], 1990 [13], 1992 [14], 1999 [28] and 2001 [15], and 61 algal taxa occurred first after opening of the new mouth. Of these, 20 species belonged to Cyanophyta, 17 to Chlorophyta, 6 to Euglenophyta and 18 to Bacillariophyceae. These finding showed that salinity increase in the lagoon due to influx of seawater through the new mouth resulted in change of the algal forms in the lagoon. Further, occurrence of 6 Euglenophyta primarily in the Northern sector and part of the Central sector at SI and SII indicated the increase in eutrophication in the lagoon at these locations due to anthropogenic discharge by human habitation nearby. Two species of algae, of which one desmid, Closterium venus and one diatom, Chaetoceros diversus which were recorded earlier in 1973 [11] were not reported in subsequent times [15], however, appeared again in the lagoon due to increase of salinity.

3.3. Diversity of Seaweeds in Chilika Lagoon at Different Salinity Gradient

Occurrence of seaweeds in estuaries and lagoon is generally dependant on the salinity of the water bodies. Four species of seaweed, comprising three under Chlorophyta, Chaetomorpha linum, Enteromorpha compressa, Enteromorpha intestinalis and one under Rhodophyta, Gracilaria verrucosa were found growing luxuriantly in different sectors of Chilika lagoon. Comparative study of their qualitative and quantitative occurrence with the earlier reports [1,28] showed that Chaetomorpha linum was recorded in all the sectors of the lagoon though it did not occur earlier in the Northern sector prior to opening of the new mouth. Similarly Enteromorpha compressa pr-
sently recorded in Northern sector and Central sector at low to moderate salinity which was earlier confined to Central sector only. Enteromorpha intestinalis presently occurring all through the lake in abundance was earlier recorded in lower quantity in the Central and Southern sectors at moderate salinity levels. Growth of Gracillaria verrucosa was earlier occurring in abundance in Southern and Central sector, however, presently also appeared in Outer channel sector due to increase in salinity all through the lagoon.

Quantitative increase in the agarophyte Gracillaria verrucosa in the Southern, Central as well as in the Outer channel sector which was earlier confined only to a pocket in the Central and Southern sector of the lagoon is an important finding of the present work. Consequent upon mixing of saltwater and freshwater due to high and low tide in the Outer channel sector, and at the nearby locations in the Central sector, salinity of the lagoon increased in these area varying from 10 - 30 ppt with continuous diurnal change, hence is now suitable for maximum occurrence of the agarophyte which can be harvested for use in cottage industry.

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