A COMPARATIVE STUDY ON THE FRESHWATER ALGAL COMMUNITY FROM MAIN RIVERS IN PALAKKAD DISTRICT

Thesis Submitted to the University of Calicut
in partial fulfillment of the requirements
for the award of the degree of

DOCTOR OF PHILOSOPHY

in

BOTANY

under the faculty of Science

by

SEENA K K

under the guidance of

Dr. Ignatius Antony (Guide)
Dr. Anto P V (Co-guide)

RESEARCH AND POSTGRADUATE

DEPARTMENT OF BOTANY,

ST. THOMAS' COLLEGE (AUTONOMOUS), THRISSUR

KERALA, INDIA

DECEMBER 2021

We hereby certify that this is the revised version of the thesis entitled "**A COMPARATIVE STUDY ON THE FRESHWATER ALGAL COMMUNITY FROM MAIN RIVERS IN PALAKKAD DISTRICT**" submitted by **Ms. Seena K.K.**, under my guidance after incorporating the necessary corrections or suggestions made by the adjudicators. The content of the CD is the same as in the hard copy.

Thrissur

18. 05. 2022

Dr. Anto P.V.

Supervising Teacher

Dr. ANTO P.V., Ph.D
Assistant Professor
Department of Botany
St. Thomas College
Thrissur - 680 001

ST. THOMAS' COLLEGE (AUTONOMOUS)
THRISSUR, KERALA-680001, INDIA
Phone: 0487 2420435, 2444486
E-mail: stcthrissur@gmail.com
Visit us at stthomas.ac.in

Dr. Ignatius Antony, M.Sc., M.Phil, LL.B., Ph.D
Principal & Associate professor (Retd.)
Research and P.G Department of Botany
Ph. no. 9446230315
E-mail: ignatiusantonyk@gmail.com

CERTIFICATE

This is to certify that the thesis entitled **"A comparative study on the freshwater algal community from main rivers in Palakkad district"** is an authentic record of research work carried out by **Mrs. Seena K. K.** under my supervision in fulfilment of the requirement for the degree of Doctor of Philosophy, in Botany of University of Calicut. The results embodied in this thesis have not been included in any other thesis submitted previously for the award of any degree or diploma of any other university or institution. Also certified that the contents of the thesis have been checked using anti-plagiarism data base and no unacceptable similarity was found through the software check.

Thrissur
16 December 2021

Dr. Ignatius Antony
(Research Guide)

Dr.Ignatius Antony M.Sc., M.Phil.,Ph.D.
(Research Guide), LL.B., C.W.C.,C.C.O.F., C.C.C.
Principal & Associate Professor (Retd.)
Research Department of Botany
St.Thomas' College (Autonomous),A.Grade
Thrissur-680001,Kerala, South India
Former member: Academic Council,UG & PG Botany and
Plantation Science Board, University of Calicut

ST. THOMAS' COLLEGE (AUTONOMOUS)
THRISSUR, KERALA-680001, INDIA
Phone: 0487 2420435, 2444486
E-mail: stcthrissur@gmail.com
Visit us at stthomas.ac.in

Dr. Anto P V, B.Ed, Ph.D
Assistant professor
Research and P.G Department of Botany
Ph. no. 9446230315
E-mail: pvabotany71@gmail.com

CERTIFICATE

This is to certify that the thesis entitled **"A comparative study on the freshwater algal community from main rivers in Palakkad district"** is an authentic record of research work carried out by **Mrs. Seena K K** under my supervision in fulfilment of the requirement for the degree of Doctor of Philosophy, in Botany of University of Calicut. The results embodied in this thesis have not been included in any other thesis submitted previously for the award of any degree or diploma of any other university or institution. Also certified that the contents of the thesis have been checked using anti-plagiarism data base and no unacceptable similarity was found through the software check.

Thrissur
16 December 2021

Dr. Anto P V
(Research Co-guide)

Dr. ANTO P.V., Ph.D
Assistant Professor
Department of Botany
St. Thomas College
Thrissur - 680 001

DECLARATION

I, Seena K. K., hereby declare that the thesis entitled **"A comparative study on the freshwater algal community from main rivers in Palakkad district"** submitted to the University of Calicut, for the award of the degree of Doctor of Philosophy in Botany is a bona fide record of the original research work carried out by me under the supervision and guidance of Dr. Ignatius Antony and Co-guidance of Dr. Anto P. V., Department of Botany, St. Thomas' College (Autonomous), Thrissur and that it has not been submitted earlier either in part or full for the award of any degree/diploma to any candidate of any University.

Seena K. K.

Thrissur

16.12.2021

ACKNOWLEDGEMENT

First and foremost, I thank God Almighty for his abundant blessings, which have enriched my thoughts, deeds, and given me health, strength, and confidence to successfully complete my work.

I wish to express my sincere gratitude to my Research guide **Dr. Ignatius Antony**, Principal & Associate professor (Retd.), Department of Botany, St. Thomas' College, Thrissur, for his unceasing encouragement, excellent guidance, valuable suggestions, immense support as a result of which I could successfully complete this work.

No words to express my deep sense of gratitude to my research Co-guide **Dr. Anto P. V.,** Assistant Professor, Department of Botany, St. Thomas' College, Thrissur, for the valuable assistance, encouragement, guidance, strong support, timely suggestions, immense patience in ensuring for the successful completion of this work.

I am grateful to our Principal, Rev. **Fr. Dr. Martin K. A.** and former Principal, **Dr. K. L. Joy**, Associate professor, Department of chemistry, St. Thomas' College (autonomous), Thrissur.

I express my gratitude to former Head and Associate Professor **Dr. C. D. Varghese** and Assistant Professor **Dr. Vimala Jose**, Head of the Department of Botany, St. Thomas' College (Autonomous), Thrissur for all the facilities and help rendered for my research work.

I am grateful to **Dr. Sr. Meena K Cheruvathur**, Vice- Principal, Assistant Professor; **Dr. Regi Raphael K**, former HOD, Associate Professor; Department of Botany, St. Marys College, Thrissur for providing me lab facilities in their esteemed college during the initial stages of my research work.

I convey my sincere gratitude to Prof. **K. M. James** (Late), **Prof. Jacob Abraham Pulikal**, **Prof. C. K. John, Prof. Tony Jacob**, **Prof. N. V. Joseph,** and all my beloved teachers for their blessings and constant encouragements.

I extend my sincere gratitude to **Dr. Tessy Paul,** Associate Professor, Christ College, Irinjalakkuda for her valuable suggestions and comments time after time.

I would like to express my heartfelt gratitude to **Dr. Sr. Valsamma V.T., Dr. Sithara K Urumbil, Mrs. Sibi** and **Dr. Sreeranjini,** Little Flower College, Mammiyoor, for their blessings and constant encouragement.

I mention specials thanks to **Dr. Geethu Elizabeth**, **Dr. Thomas M.T.**, **Dr. Joby Paul**, and **Dr. Sandhya Vincent**, Assistant professors, Department of Botany, St.

Thomas' College (autonomous), Thrissur for their support and encouragement throughout my research work.

I am thankful to **CSIR**, New Delhi for providing me the fellowship to meet the financial assistance for the research.

I convey my heartfelt thanks to **Mr. Sanjo**, Librarian of St. Thomas' college (Autonomous), Thrissur.

I extend my thanks to the lab assistant **Mr. Joy, Mr. Pauly** and **Mr. Paulson** Botany Department, St. Thomas' College (autonomous), Thrissur for their co-operation and encouragement during this work.

I extend my deep sense of gratitude to **Mrs. Neenu A Santhosh, Mrs. Dhanya Jose, Mrs. Devikrishna, Dr. Geo Joseph** and **Dr. Manu Philip** and for their immense help, assistance and suggestions during the final stages of my research.

I would like to express my heartfelt gratitude to **Sr. Fides CMC** and **Fr. Saju Kollannor CMI,** for their blessings and continuous support in every step of my research carrier.

My profound sense of gratitude is extended to the research colleagues in my lab, **Mrs. Alina**, **Ms. Nimmy**, **Mrs. Keerthana**, **Mrs. Afsana**, **Mrs. Reshma**, **Mrs. Smitha**, **Mr. Jithin**, **Ms. Aiswariya**, **Mrs. Rameena**, **Mrs. Hridhya**, **Mrs. Lakshmi**, **Mrs. Sreeshma**, **Mrs. Aparna**, **Mrs. Blessy**, **Ms. Reshma Rajan** and **Mr. Shaibu** for rendering their valuable suggestions and endless support and motivation.

I also thank all teachers and research colleagues of various departments for the support and help.

I am much indebted for the encouragement and immense support of all my family members, especially my husband **Saiju Antony**, father **K. K. Kochulazar**, Mother **Elsy**, Mother-in-law **Rosily Antony**, Brothers, Brothers-in-law, Sisters-in-law, nephews and my lovely childrens **Celine rose, Christeena & Chris John** for their understanding, encouragements and goodwill, which were with me at every step in the preparation of the thesis.

Seena K. K.

PREFACE

Rivers are an important part of the earth's water cycle, they transport vast amounts of water to support life on the planet and play an important role in the earth's topography. They are taxonomically diverse and resourceful systems in which living organisms interact, modify habitat, and contribute to the preservation of aquatic ecosystems. Most of the freshwater river ecosystems get polluted due to discharge of domestic sewage, industrial effluents, agricultural runoff and dumping of solid wastes. These factors lead to a luxuriant growth of organisms especially algae. Biomonitoring the freshwater river ecosystem in terms of phycological evaluation provide useful information about the trophic status of the water body.

Algae are the most diverse group of aquatic organisms, serving as the primary food source for higher trophic levels and as biological indicators of water pollution. Algal assays are ideal for analysing a wide range of ecological issues and assessing environmental quality. Regular monthly investigations from ten permanent sampling stations were carried out to collect baseline data on the changes in algal diversity, physico chemical water quality parameters, nutrient content and pollution status from Bharathapuzha and Bhavani river ecosystem.

The present investigation is aimed to delineate the ecology and spatiotemporal variation of freshwater algal diversity with respect to physico chemical parameters in rivers of Palakkad district. Analysis and interpretation of the data on taxonomy and ecology of freshwater algae revealed that the Palakkad district's river ecosystem is moderately polluted, with high levels of organic pollution in some areas.

Dedicated to my family

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

° C	Degree Celsius
%	Percentage
µm	Micrometre
Km	Kilometre
m	Metre
mm	Millimetre
cm	Centimetre
Mg/L	Milligram per litre
µmhos/cm	Microsiemens per centimetre
fig	Figure
Lat	Latitude
Long	Longitude
pH	Potential of Hydrogen
EC	Electrical conductivity
TDS	Total dissolved solids
ANOVA	Analysis of variance
DO	Dissolved oxygen

Chapter-1

Introduction

1.1 Freshwater ecosystem

Freshwater ecosystems are taxonomically diverse and resourceful systems in which living organisms interact, modify the habitat, and also play a significant role in the preservation of aquatic ecosystems as well. On earth, life originated from water, and many organisms occupied aquatic ecosystems (Trivedi and Goel 1984). Water is a vital element for the survival of life on our planet from which the entire framework of life is built up. It covers about significant part of the earth's surface (Mishra et al. 2001). Approximately 97% of the total water exists in oceanic form. The remaining 3% is distributed in rivers, lakes, underground water, and water vapor, of which 0.62% is only freshwater available for living organisms. Conventional freshwater ecosystems as rivers, ponds, etc., are water sources and have more importance to man and other organisms. The most common and stable habitats in the biosphere are freshwater ecosystems with physical, chemical, and biological characteristics shaped by local surroundings and physiographic factors (Khan et al. 1998). Aquatic ecosystems are responsible for maintaining nutrient cycling, upholding water quality, and maintaining the continuity of food chains (Radhika et al. 2004). Rivers are an essential part of the earth's water cycle; they play an efficient and prominent role in the earth's topography by carrying vast quantities of water to support life on earth. Rivers differ through cyclic and seasonal progression and their size, length, characteristics of flow, geology of gradients, salt concentration, turbidity, etc. There is another characteristic difference in the degree to which they have suffered degradation through pollution. Limnological works in freshwater bodies in rivers, ponds, and lakes in India date back from 1890 onwards. Significant work was carried out by many workers (Turner 1892; Chacko and Ganapathi 1949; Krishnamurthy 1954; Desikachary 1959; Suxena and Venkareswarlu 1966, 1968; Kamat 1968;

Chadha and Pandey; 1977, 1978; Sarode and Kamat 1978; Iyengar and Desikachari 1981; Pandey and Pandey 1982; Hosmani and Bharati 1983; Ramesh et al. 1990; Murugesan et al. 2003).

Kerala is the land of rivers. In general, the state's topography controls the length and size of rivers. Periyar, Pamba, Bharathapuzha, and Chaliyar are considered as the significant rivers of Kerala. These rivers jointly are more than one hundred and sixty kilometers long and drain about 35% of the state's total area and carry about 45% of the entire surface water (Nair et al. 1975). Out of the 44 rivers of Kerala, three viz., Kabani, Bhavani, and the Pambar flow eastwards; all other rivers flow westwards. In India, several workers have contributed towards studies in Limnology. Chacko and Ganapati (1949) studied the hydrobiology of the Adayar River. Some significant contributions have been made by (Chakraborty et al. 2010; Hynes 1978; Sullivan 1975; Sharma 2010; Singh and Saha 1982b; Nautival and Lal 1984). The extensive ecological degradation and biodiversity loss in riverine ecosystems because of overexploitation of rivers raised broad spread concern for conservation and restoration of healthy river ecosystems throughout the world (Allan and Flecker 1993). The current river management and development policies resulted in groundwater depletion, declines in water quality and availability, saltwater intrusion into the river, and a host of other ecological, social, and economic problems. Therefore, immediate means for conservation of freshwater resources, thus assume paramount importance. The first step towards achieving these goals is to have a thorough knowledge on the ecological status of the aquatic ecosystem, composition, and distribution of the species inhabiting there, and of the factors that influence and regulate the life activities of these organisms. Biodiversity is crucial to the functioning of ecosystems. Each species has unique role in an ecosystem, and they depend on others for food, shelter, or other resources. The loss of a single species, have deep effect on the whole ecosystem. Monitoring and quantifying of the loss of biodiversity is the essential subject of ecological research and of conservation biology. Hydrological conditions of freshwater ecosystem can directly modify the physicochemical environment, in turn, have a direct impact on the biotic response.

Phytoplankton are the most beautiful and valuable components of aquatic ecosystem. They are indispensable regulators of water quality and quantity. The undisturbed and stable ecosystems have large number of species equal dominance. If the conditions changed, only some species can tolerate, while the rest will decrease due to stress. Fresh water biodiversity constitutes the study of freshwater, its inhabitants and their interaction with their environment. Algae are extensive and diverse, simple to multicellular, and phototrophic. Size of algae varies from simple unicellular to multicellular forms, solitary or colonial organisms represented by some of the shared pond scums which may or may not be motile and are entirely invisible as individuals to the naked eye, exhibit a wide range of simple cell division to complex sexual reproduction. The phytoplankton contributes more than half of total primary production at the base of the food chain worldwide (Guschina and Harwood 2009), play a vital role in maintaining the steadiness of abiotic and biotic components aquatic ecosystem. Classification of algae is based on their pigmentation, nature of food reserves, the fine structure of plastids, chemical disposition of the cell wall, and the number, position, and fine structural details of flagella in the motile stages (Krishnamurthy 2000). Freshwater algae are of various taxonomic groups such as diatoms (Bacillariophyceae), green algae (Chlorophyceae), blue green algae (Cyanophyceae), dinoflagellates (Dinophyceae), brown algae (Phaeophyceae), and red algae (Rhodophyceae) because of their characteristic adaptations to specific habitats in environments. Algae are the most diverse and are environmental assets that help to port organisms and generate oxygen into the environment utilized by organisms in all trophic levels (Bergman and Bump 2015). In freshwater ecosystems, microalgae are taxonomically diverse, very resourceful, and play an important role in worldwide ecology. Algae lodge a unique position among the primary producers. In addition to being an essential link in the food chain and food organizers, algae are also indicators of the trophic status and health of the water body. Algal assays are incredibly suitable for analyzing various ecological problems and the assessment of environmental qualities. The algal study opens the possibility of fruitful combinations of physical, chemical, and biological measurements resulting in the relevant information.

The chemical analysis provides information on the concentration of the substances present. The nature of water depends on its physical, chemical, and biological characteristics. Physical parameters include colour, odor, temperature, turbidity, etc. Chemical qualities with the presence of organic and inorganic substances in solution and these are suspended or dispersed in water. Biological characteristics include organisms present in water. The analysis of natural materials and chemical elements of water forms a valued method of water quality assessment. The term water quality is causally related to water pollution. The quality of water bodies can be determined from the analysis of Physico chemical parameters, which have an essential role in determining the distribution of aquatic organisms. In the aquatic ecosystem, water forms one of the leading media in which most chemical compounds or salts ionize readily. Some salts were naturally present in water which serve as nutrients for the growth and function of aquatic organisms. In sometimes, such nutrients enhance phytoplankton growth, while some of them are limiting factors of development. Water pollution is a critical threat faced by man today due to rapid urbanization, industrialization, agriculture, mining, and technological development. Since water can act as a universal solvent capable of dissolving or carrying a variety of toxic chemicals, several rivers and water bodies are utilized to dispose of sewage and industrial effluents. Nitrogen and phosphorus form the essential nutrients for algae growth and are known to interfere with water quality (Reddy and Kumar 2001).

The ability of algae to tolerate polluted and unpolluted water bodies has been considered valuable bioindicators in water bodies. Microalgae can have an essential role in solving environmental problems (Kurano and Miyachi 2004) have massive industrial and economic values (Rai et al. 2000), as valuable sources for pharmaceuticals, health foods, carotenoids (Lui et al. 2000), restriction endonucleases (Saravanan et al. 2003) and in the bioremediation of industrial effluent (Muthukumaran et al. 2005; Kamaleswari and Sivasubramanian 2011). Algae as biological indicators of water pollution (Palmer 1969; Prasad and Singh 1982), a source of food for larger aquatic animals. They are used to human beings being the source of food especially rich in vitamins. Many are essential sources of iodine, potassium, and other minerals (Krishnamurthy 2000). Algae also show extraordinary potential to absorb metal ions from an aqueous solution and valuable for wastewater treatment (Mehta and Gaur 2005).

The three basic requirements for living organisms on earth are air, water, and soil. In the past, these features were pure, undisturbed, uncontaminated, and most suitable for living organisms. Still, the situation is just the reverse because rapid industrialization and technology also lead to severe environmental, ecological imbalance, making it disastrous for humankind. The primary source of environmental pollution has been man's misbehavior with nature and ego that he is the master of nature. These unwanted situations are created by man and other active biotas on the earth (Mathur and Pathak 1990). Several studies prove that human interruption has caused a global increase in river input of geochemical constituents, incredibly nutrient elements leading to imposed eutrophication in many coastal areas. Raising engineering structures like dams, spillways, etc., are also accountable for alterations in river environments. The framework is being complicated further by the massive discharge of toxic contaminants from different sources. The degradation of water bodies in the earth due to domestic, industrial effluents, agricultural run-off water, and discarding solid wastes into nature (Behura 1989; Ghosh 1989). These factors lead to a luxuriant growth of organisms, mainly the algae, in the water bodies (Hynes 1978; Varshney 1991). Enrichment of organic or inorganic fertilizers either naturally or by anthropogenic activity leading to the growth of algal bloom in the freshwater ecosystem, which results from the deterioration of water quality and eutrophication. The situation is not as different in Kerala river systems, especially in the Bharathapuzha and Bhavani rivers. Discharge of pollutants from urban, agricultural and industrial sources, indiscriminate mining of construction grade materials like sand from instream and floodplain areas, damming of rivers, etc., have adversely affected the nature of these river systems. These incidences are due to human imposed stresses in these ecosystems, which perceptibly need immediate attention and corrective measures based on careful observations and studies. The present study is an effort to report certain aspects of physico chemical parameters and algal diversity of rivers Bharathapuzha and Bhavani flowing through Palakkad, Malappuram, and Thrissur districts of Kerala.

Algae play a crucial role in the freshwater ecosystem as primary producers to increase soil fertility, bioindicators, and secondary productivity. Thus, it is essential to study the algal community in fluctuating physicochemical scenario of water bodies to conserve and manage the ecosystem. Decline in biodiversity greater in freshwater ecosystem than in the terrestrial ecosystem. So, it is particularly important to study biodiversity of algal flora. The study includes a systematic analysis of algal diversity in the present study area and the water quality of these river systems. The scientific species level identity would enrich the algal diversity list in Kerala. An attempt has also been made to evaluate the pollution status of the site. The study covers the spatiotemporal variation of the above parameters and identified the most influencing parameters in months. Different groups of algae give a clear concept about the ecological parameters like pH, temperature, TDS, EC and Dissolved oxygen, etc. The differences in the use of water are also responsible for environmental variations in the algal community. 75% of the population in Palakkad district depends on surface water resources for their various needs, mainly from Bharathapuzha and its tributaries. So, the assurance of water quality should be healthy. Certain areas in the eastern part of Palakkad district showing some water quality deterioration where fluoride and mercury content is slightly high. This also leads to acute changes in the physiology of water and biodiversity. A perusal of the existing literature reveals that very few investigations related to algal biodiversity had been done on rivers in the Palakkad district. There was a lack of accurate data on the Palakkad district's freshwater algal biodiversity, especially regarding the data on the lower plant groups. Practically no evident work has been done on the taxonomy, distribution, species diversity and composition, seasonal and spatial variation of freshwater algae from rivers in Palakkad district, and hence the present work is undertaken. The species composition, distribution, and comparison of algal flora would give more information regarding the species richness of Kerala.

1.2 Objectives

1. To gather data regarding the diversity of freshwater algae in the rivers of Palakkad district up to the species level.

2. To compare the seasonal and spatial distribution of algae from the study area.

3. To compare Physicochemical aspects of water concerning algal diversity.

4. To compare the pollution status of rivers based on water quality index and algal diversity.

5. To quantify the diversity of habitat using diversity Indices.

Chapter-2

Review of literature

2.1 Riverine ecosystem

Rivers have played a vital role in inspiring minds, they are the cradles of civilizations, and every Indian is made sacred by them. They have a key role in balancing the hydrological cycle and sink of domestic, municipal and industrial waste. Distribution of phytoplankton varies according to the nature of the water bodies and climatic conditions such as temperature, pH, rainfall, humidity, nutrients and amount of suspended matter. A synchronous study of physical, chemical and biological properties of freshwater ecosystem is highly important with the aim of attaining a better understanding of the biological integrity of ecosystem. Deterioration of water quality due to the release of various types of pollutants into rivers makes them unfit for drinking, bathing, fishing and irrigation. The result of these activities converts sacred India into a land of polluted rivers. All the major rivers and their tributaries in India have become polluted due to anthropogenic activities and if this drift is continued, it may lead to serious impacts on human health in the coming years.

Research on phytoplankton composition in Indian river systems dates to the 1950s. Father of Indian limnology (Ganapati 1956; Ganapati and Alikunhi 1950), have made valuable contributions through studies conducted in rivers Cauvery and Godavari. Significant contributions on the study of Phytoplankton ecology of Indian rivers have been rendered by (Roy and Sen 1985; Singh and Sharma 1999; Srivastava et al. 2003; Gurumayum et al. 2001; Mishra and Tripathi 2003). Khan and co-workers (1998) studied variations in the distribution of phytoplankton among the different rivers in India from the river Ganges at Narora, UP. More and Nandan (2003) from the Panzara river, Maharashtra, (Yazdandoost and Kaldare 2000) from different rivers in Pune and (Biswas and Konar 2001) from the river Damodar. Unni and Naik (1997) studied the distribution, diversity and succession of phytoplankton in Indian rivers like Ganga, Yamuna, Mahanadi, Godavari, Krishna and Cauvery. Varunprasath and Daniel (2010) studied algae and water quality in river Cauvery from Bhavani to Erode. A comprehensive study of the ecology and polluted condition of Indian rivers (Trivedi et al. 1998). Assessment of the water quality of Cauvery river in bhavani region studied (Nagarajan and Sivaraja 2013). The quality of water is vital because it linked with human welfare. Several studies on water quality have been carried out in different parts of India (Sreedevi 2005; Semwal and Akolkar 2006; Thilagavathi et al. 2012).

In Kerala, (Sankaranarayanan et al. 1986) studied the hydrological features of the Periyar River. Kahar (1988) conducted studies on the quality of the Karamana river and the Poonthura backwater. Water quality of Kallada river (Abhisheka and Binoj Kumar 2018), hydro-biological features of Kallada and Neyyar rivers (Madhusoodanan and Dominic 1999). Balachandran et al. (2012) studied the water quality of the Muvattupuzha river and (Abbasi and Abbasi 2011) worked on Punnur Puzha near Kozhikode. Study on the distribution of nutrients and phytoplankton in Thalassery and Valapattanam rivers (Lakshmi 2002). Water quality studies on the Chalakkudy river (Nirmala and Shoba 2003) reported sand as the main component of sediment. Ecology and biodiversity of Nila river (Sushama 2003), diversity of zooplankton of the Shendurni River (Shamsudeen and Mathew 2010) and hydrological analysis of Karuvannur iver (Renjith and Sreekumar 2005). Chattopadhyay et al. (2005) made a case study in the Chalakkudy river basin based on the analysis of 27 water samples during four seasons. Maya (2005) studied the nature and quality of Periyar and Chalakudy rivers. Study on the biodiversity and succession of algae in Periyar river at Aluva (Zacharias and Joy 2007). Prasad et al. (2008) compared the physico chemical parameters and environmental conditions of the

Pamba and Achenkovil rivers. Nikhil Raj and Azeez (2009) examined the spatiotemporal variations in water quality and quantity of the Bharathapuzha river basin using multivariate statistical analytical tools. Nair et al. (2010) worked on the hydrology of Meenachil river, Kottayam. Joseph and Tessy (2010) studied the water quality and pollution status of Chalakkudy river at Kathikudam. Several studies were conducted to address the quality of various rivers of Kerala (Nandan 2007). Rekha et al. (2013) worked on the comparative study of water quality index between Peruvanthanam and Valiyathodu sub-watersheds of Manimala river basin, groundwater study of Karakulam Grama Panchayat (Jaya and Deepthi 2015). Binoj Kumar and Divya (2012) studied Kazhakuttam block of Thiruvananthapuram district and coast of Ernakulam district (Sreekesh et al. 2018). Jalal and Sanal Kumar (2013) analyzed the water quality assessment in environment that affects microbiological studies of the Pamba river. Maya et al. (2013) studied the changes in chemical quality of the Neyyar river basin due to natural and anthropogenic determinants. Anitha et al. (2014) analyzed the water quality of the Periyar, pampa, Neyyar and Chaliyar rivers. Drissia (2019) reviewed the spatial and temporal variation of water stress using water footprint calculated using water stress indicator in Bharathapuzha river basin.

2.2 Taxonomy of freshwater algae

Assessment of the diversity of phytoplankton is crucial in the ecological study because it reveals changes in environment affects the species composition and structure. They can exhibit seasonal alterations; some members present throughout the year, but some are found at specific periods and their abundance is limited by periods of relative water scarcity. Monitoring of phytoplankton growth generally useful for evaluation of water quality. Conservation of biodiversity will provide a successful longstanding basis for ecosystem functioning and freshwater management. These are essential for the conservation of local and global biodiversity (Moss 2000). The succession of Phytoplankton is more seasonal with a series of species throughout the year and their peak abundance may last for a week or two in each year (Sanilkumar and Thomas 2006). Dudgeon (2003) noted that due to a lack of information, knowledge about the freshwater biodiversity of tropical Asia is incomplete. Information on the algal biodiversity and related aspects in water bodies is essential for assessing water quality. Limnological studies mainly in algae have declined markedly over the last three decades, while studies covering other aquatic groups in addition to algae have intensified gradually in recent years (Irfanullah 2006). In 1754, Linnaeus gave the name algae to a group of plants and De Jussieu was the first to separate the algae well known to us today. Monographing the algal flora of India was begun in 1959. Indian algae are represented as 6500 species inhabiting both freshwater and marine environment (Rao and Gupta 1997).

2.3 Phycological research in India

Freshwater algae of India have been studied by several workers. M.O.P. Iyengar, K. Biswas, M.S. Randhawa, T.V. Desikachary and F.E. Fritsch made an outstanding contribution to the scientific community and phycology in India. The earliest work on algae in North India is that of (Royle 1970). North Indian Chlorophycean flora have been made by (Kant and Anand 1978; Habib 1995, 1996; Habib and Chaturvedi 2001; Singh and Saha 1982a; Suseela and Dwivedi 2001; Misra et al. 2005, 2009). Fritsch (1907a, 1907b) studied freshwater and terrestrial algae of Ceylon. West and West (1907) systematically described 276 species of freshwater algae belonging to 71 genera from Burma, Bengal and Madras. Biswas (1949) listed the typical fresh and brackish water algal flora of India and Burma. The pioneer works on taxonomy of freshwater algal groups are accredited to (Venkataraman 1939; Krishnamurthy 1954; Desikachary 1959; Gandhi 1959; Philipose 1967; Kamat (1968) for the first time examined the freshwater flora of some parts of South India and reported several new species. The Indian Council of Agricultural Research (ICAR) published a series of the algal flora of India (Desikachary 1959; Randhawa 1959; Venkataraman 1961; Ramanathan 1964; Philipose 1967; Gonzalves 1981; Iyengar and Desikachary 1981) and these monographs have formed the basis of algal research to all phycologists in India and the world. Seasonal changes and zonation of some intertidal algae at Visakapatanam coast (Umamaheswararao and Sreeramulu 1964). Pandhol and Grover (1976) reported the algal flora of Ludhiana and its adjacent areas. Studies of Eastern Himalayan green algal flora (Das 1961; Santra and Adhya 1973, 1976; Alfred 1978). Sarma and Khan (1980) have listed 4269 algal species from India. Rao and Gupta (1997) reported 390 genera and 4500 species coming under different freshwater algal classes. River ecology is dominated by seasonal flow, mainly due to monsoonal rains. Kant and Gupta (1998) made significant works on different algal genera than any other phycologists and reported 848 taxa from Ladakh, Jammu and Kashmir. Water pollution, salinization and over-harvesting due to anthropogenic activities are critical threats to river biodiversity (Dudgeon 2000). Alterations in the Physico-chemical properties of the aquatic ecosystem due to human interventions can have a direct impact on the biotic structure (Ramachandra et al. 2002). Das and Adhikary (2012) reported 94 species, of which ten species recorded the first time from India. Barhate and Tarar (1981) enumerated 41 algal taxa from Maharashtra. Roy and Sen (1985) from freshwater algae of Chattisgarh, Madhya Pradesh. Mahajan (1987) enumerated 32 algal forms of Madhya Pradesh. Studies on the phytoplankton diversity of Maharashtra (Kamat 1968a, 1975a; Bhosale et al. 2010a, 2010c, 2010d). Jayabhaye et al. (2007) investigated the phytoplankton diversity in parola dam, Maharashtra and noted maximum phytoplankton population during winter and minimum during the rainy season. Reports on the various studies of algal forms in Bihar (Singh and Saha 1982a; Saha and Choudhary 1984; Patralekh 1991a, 1991b, 1993a, 1994; Kargupta and Ahmad 1991). Investigation on the algal flora of Karnataka (Somashekar 1983a, 1984a; Hegde and Isaacs 1988b)). Basavarajappa et al. (2010) reported 29 algal species from Hadhinaru Lake Karnataka, Bongale and Bharati (1980a) listed 377 species of algae from the cultivated soils of Karnataka. Nafeesa and Narayana (2006) said 85 phytoplankton species from four lentic water bodies around Davangarere, Karnataka. Hegde and Isaacs (1988a, 1988b, 1989) reported freshwater algae from Uttara Kannada district of Karnataka state. The freshwater algae of Davanagere and Raichur of Karnataka state (Bongale and Bharati 1980b). Study on the freshwater algae from Karnataka (Hegde and Bharati 1983a; Hegde and Malammanavar 1988; Hegde and Somanna 1991). Bongale (1981) studied soil algae from the paddy fields of Goa and Karnataka. Assessment of phytoplankton density in relation to environmental variables in Gopalaswamy pond in Chitradurga, Karnataka (Harsha and Malammanavar 2004). Trivedy (1982) listed 62 algal forms from Jaipur, Rajasthan. Makandar and Bhatnagar (2010) from the freshwater bodies of Jodhpur, Rajasthan. Kant and Gupta (1998) reported 848 species of algae from Ladakh, Jammu and Kashmir under nine classes. Study on the algal flora of the freshwater aquatic systems of Orissa (Padhi et al. 2010). Adhikary et al. (2009) reported 307 taxa belonging to 87 genera from Orissa state. Bhakta et al. (2010) described 50 freshwater algal taxa from Sikkim, Sikkim Himalayas (Suseela and Toppo 2004), Simla (Kamat 1968b). In addition, morpho-taxonomic variation in algae was observed in the Sikkim Himalayan algal flora (Kumar and rai 2005). Bharati (1965) reported 46 species of algae from Kumta, North Kanara. Descriptive study and illustrations on the freshwater algal flora of Andaman and Nicobar Islands (Prasad and Misra 1992, 1984a, 1984b, 1984c, 1985; Prasad and Srivastava 1992). Perumal and Anand (2008a) reported 389 taxa of algae from the freshwater habitats of Tamil Nadu and listed 252 species. Thirugnanamoorthy and Selvaraju (2009) said 14 phytoplankton genera from Tamil Nadu, (Ramadosu and Sivakumar 2010) recently recorded 136 Phytoplankton from the Perumal Lake, Tamil Nadu. Reports on the algal diversity of Tamil Nadu (Suxena 1983; Kavitha and Balasingh 2007; Murugesan and Sivasubramanian 2008a). Diversity of planktonic algae of selected Temple ponds of Mahe, Puducherry (Girish et al. 2014). Meghalaya (Gupta 2002), Orissa (Dey et al. 2008), Pune (Zaware and Pingle 2003; Pingle 2006), Uttaranchal (Khare and Suseela 2004; Suseela 2005), Uttar Pradesh (Misra et al. 2004, 2005, 2008b) and West Bengal (Pal and Santra 1984; Kargupta and Keshri 2006) are also contributions to the algal flora of India. Freshwater studies of Bhagalpur (Nasar and Munshi 1976), Garhwal (Habib 2002), Goa (Shetiya and Kerkar 2004; Geeta and Kerkar 2009), Gujarat (Manohar and Patel 1985, 1988) and Jammu (Anand 1975).

Turner (1892) published a memoir of the East Indian freshwater algae incorporating 22 species of *Myxophyceae*, 542 of desmids and 60 of some green algae. Prasad (1952) identified new species in blue-green algae from the river Varanasi. Reports on the occurrence of *Glaucocystis nostochinearum* (Itzings) Rabenhorst from Alleppey in South India (Prasad and Khanna 1987). Prasad and Saxena (1980) analyzed the ecology of blue-green algae, abundance and physicochemical properties of water in the river Gomathi during the summer season. Blue-green algae from Uttar done by (Prasad and Mehrotra 1978, 1980; Pal 1975; Pandey 1982b; Pandey and Pandey 1982; Misra et al. 2010). Chaporkar and

Gangawane (1984) enumerated 33 forms of blue green algae of cultivated soils from Maharashtra. Study and description of different species of blue green algae from Maharashtra (Barhate and Tarar 1983b; Bhoge and Ragothaman 1986a; Patil and Chaugule 2009; Patil and Deore 2010a, 2010b; Ashtekar and Kamat 1980a; Kumawat and Patil 2010; Kumawat and Jawale 2001; Suryavanshi et al. 2010). Dhingra and Ahluwalia (2007) illustrated thirty-two species of *Phormidium* from various habitats of Punjab. Abdul Majeed (1935) reported diatoms from Punjab. Jha et al. (1986) reported 60 blue green algae from the rice field soils of Pusa and its adjoining areas of Bihar. The occurrence of Chroococcaceae during rice cultivation from north Bihar (Choudhary 2009; Verma et al. 1990). Jain et al. (2011) reported 25 taxa of the order Chroococcales collected from the various habitats of Alwar district, Rajasthan. Rao et al. (2008) enumerated 89 blue green algae from the rice fields of the south Telangana region, Andhra Pradesh. Distribution of Cyanophyceae from the paddy fields of West Bengal (Mukhopadhyay and Chatterjee 1981; Pal and Santra 1982, 1985; Maity and Santra 1985; Sinha and Mukherjee 1975a, 1975b, 1984). Studies on the distribution and succession of blue green algae from rice field soils of Orissa (Padhy et al. 1992; Sahu 2000) and reported the distribution of blue green algae. Misra et al. (2009) studied Chandra Lake, Himachal Pradesh, lists on the 61 species of Chlorococcales belonging to 28 genera (Jha et al. 1985) from Gobindsagar reservoir, Himachal Pradesh. Reports on the occurrence of Cyanophycean flora of southern Himanchal Pradesh (Dwivedi et al. 2008). Prasad and Srivastava (1984a, 1986) reported different taxa on Cyanophyceae from the fresh waters of Andaman and Nicobar Islands. Reports on the distribution of blue green algae from the paddy fields of Tamil Nadu (Anand and Subramanian 1994; Anand and Revathi 1987). Significant studies on the distribution of nitrogen-fixing blue green algae in the paddy fields of India were reported from West Bengal (Chatterjee and Chatterjee 1983) and Maharashtra (Kolte and Goyal 1985; Patil and Satav 1986; Sardeshpande and Goyal 1981). The freshwater blue green algae were also reported from Goa (Kerkar and Madkaiker 2003), Kanpur (Tripathi and Pandey 1991), Bihar (Saha 1984; Patralekh 1993b), Tamil Nadu (Ramakrishnan and Kannan 1992), Uttar Pradesh (Habib et al. 1992) and Sikkim (Santra 1984) are contributions to the knowledge of Indian blue green algae. The studies on the Cyanobacteria of rice fields of south India have been very much restricted, and they report on the occurrence of a few taxa from selected localities (Anand 1989). Thirty-six species belonging to six genera of Cyanophyceae are enumerated from Bhubaneswar and its adjoining regions (Mohanty (1982). Later he reported fifteen species of blue green algae from Bhubaneswar in 1984.

West & West (1897) described 45 species of desmids from Singapore. Report on desmids in 1902 from Ceylon and 1907 from Bengal and Madras. Descriptive study and illustrations on the freshwater diatoms from Uttar Pradesh (Prasad et al. 1981; Pandey 1982a; Chaturvedi 1985; Srivastava 2010. Misra et al. 2007). Shukla et al. (2008) collected 48 taxa of desmids from the foothills of Western Himalaya, Uttaranchal, Uttar Pradesh and reported 18 taxa of freshwater diatoms. Sarode and Kamat (1978, 1983a, 1983b, 1984) and Barhate and Tarar (1983a, 1985c) described freshwater diatoms from Maharashtra. Study on the distribution of freshwater diatoms in Maharashtra (Suryavanshi et al. 2009; Kumavat 2006; Dhande and Jawale 2008). Narkhede (2006a, 2006b) reported *Nitzschia, Surirella Punnularia, Amphora* and *Cymbella* from Suki dam in Maharashtra. Bacillariophyceae were reported (Singh and Saha 1982b; Saha 1986) from Bihar. Report on the diatom flora of Karnataka (Somashekar 1983b, 1984b; Bongale 1985). Prasad and Jaitly (1985) studied diatoms from Ladakh, Jammu and Kashmir. Saravanakumar et al. (2008) investigated seasonal variations of phytoplankton in the creak waters of mangroves in Kutch, Gujarat with the dominance of diatom. Das and Santra (1982) listed planktonic diatoms of Senchal Lake, Darjeeling in West Bengal. Jena et al. *(*2006b) reported diatoms from Orissa state and neighboring regions in the eastern part of India. From Andaman and Nicobar Islands (Prasad and Srivastava 1981, 1983,1984b, 1985) reported different taxa of diatoms. Abdul-Majeed (1935) had illustrated 62 freshwater diatoms from Punjab. Later Venkataraman (1939) described diatoms from Madras, Krishnamurthy (1954) reported diatoms from south India. There are reports of diatoms from Rajasthan (Gandhi 1955), Mysore (Gandhi 1957, 1958a, 1959a), Kolhapur (Gandhi 1956, 1958b, 1959b) and Ahmedabad (Gandhi 1960, 1961). Reports of diatoms from Allahabad (Pandey et al. 1983a), Hyderabad (Venkateswarlu 1983), Kashmir (Mam 1995), Tamil Nadu (Rajakumar 2005; Murugesan and Sivasubramanian 2008b), Uttar Pradesh (Suseela and Dwivedi 2002), Nainital (Kamat and Aggarwal 1975) and West Bengal (Pal and Santra 1990; Bhattacharya et al. 2011) are also contributions to the knowledge of Indian freshwater diatom flora. Study on the Cyanophyceae of Meerut (Bendre and Kumar 1975) and from Pathiala (Sarma and Kanta 1978; Sarma et al. 1979). Reddy et al. (1986) reported from northeast India, (Khare and Kumar 2010) from Nainital and from Jharkhand (Sharma 2010).

Freshwater algae belonging to the order Chlorococcales collected from Uttaranchal and Uttar Pradesh (Chadha and Pandey 1977, 1978; Pandey et al. 1983b; Habib et al. 1998; Shukla et al. 2007). Report on the freshwater planktonic Chlorococcales from Bareilly district, UP (Chaturvedi et al. 1987; Habib and Pandey 1990a; Pandey et al. 1987). Prakash et al. (2005) conducted morphotaxonomic studies of freshwater chlorophycean algae belonging to the family desmidiaceae from Sidharth Nagar, U.P. He described ten taxa of freshwater desmids belonging to six genera namely *Euastrum, Cosmarium, Staurastrum, Micrasterias, Pleurotaenium* and *Desmidium* from UP. Chlorophyceae with 36 taxa represents 18 genera (Kamat and Freitas 1976) from Nagpur, Maharashtra. Barhate and Tarar (1985a) reported 31 algal taxa of Chlorophyceae from Maharashtra. Deshmukh and Pingle (2006) studied Chlorophycean algae of Ahmednagar district, Maharashtra. Jawale et al. (2009) reported 26 taxa of freshwater unicellular Volvocales from Jalgaon district, Maharashtra, Dhande and Jawale (2009) described 23 taxa of *Cosmarium* from Hartala Lake, (Jawale et al. 2010) reported fifteen taxa of Volvocales from Jalgaon and Dhule districts, Maharashtra. Das and Purty (1990) reported 42 taxa of *Cosmarium* from Bihar. Bharati and Hegde (1982a, 1982b, 1983) worked on Desmidiaceae from Karnataka and Goa. Study on the desmids from Karnataka (Gurudeva et al. 1983; Hegde 1986b; Hegde and Isaacs 1988a, 1989; Bongale 1987). Zygospore formation in 24 desmid taxa from the North Kanara district of Karnataka was written by (Hegde and Bharati 1983b, 1986). Suxena and Venkateswarlu (1968) illustrated and described forty two taxa of desmids from Kashmir. Patel and Asokakumar (1979) reported 25 taxa of *staurastrum* from Gujarat. Patel and Daniel (1990) reported 48 taxa of *Cosmarium* and 32 taxa of *Cosmarium* from different freshwater habitats of Gujarat. Isabella and Patel (1985) described Chlorococcales from Gujarat. Study on the distribution of desmids in India (Suxena and Venkateswarlu 1966, 1970) from Pakhal Lake, Andhra Pradesh. Keshri (2009) reported eleven freshwater filamentous green algae belonging to the order Chaetophorales of West Bengal. Keshri (2010a, 2010b) studied and reported thirteen species of Ulotrichales belong to five genera: *Cylindrocapsa*, *Microspora*, *Schizomeris*, *Ulothrix, Coleochaetae, Chaetosphaeridium* and *Uronema* from West Bengal. Agarkar (1969, 1971) studied desmids from Gwalior, Agarkar et al. (1979)

conducted studies on desmids from Bhandhavgarh, M.P. and given an illustrated account of seventy one desmids from perennial stream Bhandhavgarh, one of the important national parks of the country. Toppo and Suseela (2009) described twenty eight species of *Cosmarium* from Chhattisgarh. Diversity of Chlorococcales concerning Physico chemical parameters from selected ponds in Kanyakumari district. Mohan (1987) reported the Chlorophyceae of Osman Sagar and Mir Alam, two major lakes of Hyderabad. Anand and Jitendra (2006) reported ten species of genus *Oedogonium* from Shivalik Himalayas. Tiwari and Chauhan (2004, 2007b) described species diversity and seasonal variation of desmids from the crop fields of Bichpuri, Agra. Tiwari et al. (2001) listed the Chlorococcales from Kitham Lake, Agra. Patel and Isabella (1980) reported sixteen species and one variety of Chlorococcales belonging to fifteen genera from western India. Jena and Adhikary (2007) described and illustrated fifty six taxa of Chlorococcales belonging to twenty-one genera from eastern and north-eastern states of India. They reported chlorococcales from different water bodies of Orissa, West Bengal, Assam, Meghalaya, Nagaland and Manipur. Prasad and Mehrotra (1977a, 1977b) reported desmids from the North Indian paddy fields. Reports of eighty two taxa of desmids from Nagpur (Freitas and Kamat 1979).

Diversity of Euglenineae and reported different species from Uttar Pradesh (Pandey 1985; Prasad and Chaudhary 1986; Habib and Pandey 1990b). Study on the class Euglenophyceae from different localities of Maharashtra and worked on different species like *Phacus, Trachelomonas* and *Euglena* (Ashtekar 1982; Barhate and Tarar 1985b; Bhoge and Ragothaman 1986b). 18 taxa of *Euglena* from Bihar (Gupta and Srivastava 1993) are also contributions to the algal flora of India. The studies of Euglenophyceae and illustrations from Karnataka state (Hegde and Bharati

1983a; Hosmani and Bharati 1983; Hosmani 2008)). Freshwater Euglenoides and Dinophyceae (Chaudhary and Meena 2007) from Udaipur district, Rajasthan. Srivastava and Odhwani (1990a) studied and reported 13 species of the genus *Trachelomonas* from Rajasthan. Patel and Waghodekar (1981) explained and illustrated Euglenophyceae members from other localities of Gujarat. Ratha et al. (2006) described sixty taxa of Euglenophyceae from Orissa.

2.4 Algal studies in Kerala

Kerala situated in the southern part of the Western Ghats, one of the biodiversity hotspots, is rich in flora and fauna including several endemics. The systematic study of the algal flora on Indian Algae, especially of Kerala is still far from complete (Easa 2004). According to him algae are one of the least known and less documented groups among lower plants and only 834 species were documented from Kerala. Significant contribution in area of ecology and diversity of freshwater algae in Kerala by MVN Panicker from 1988 onwards. His major works in Chlorophyceae are confined to filamentous green algae especially *Spirogyra*, *Oedogonium*, *Trentenpohlia* and *Chara*. Analysis of different stages of development in Chlorophyceae and many new species also adding to the biodiversity (Panikkar and Ambili 1988, 1992; Panikkar et al. 1997a, 1997b; Panikkar et al. 1989; Ushadevi and Panikkar 1991, 1993a, 1993b; Sindhu and Panikkar 1993, 1994a, 1994b, 1995b; Shaji and Panikkar 1995). Anand and Hopper (1987) made extensive works on blue green algae from the rice field in Kerala. Jose and Patel (1990) contributed new member of Rhodophyta belongs to the family Delesseriaceae from freshwaters of Kerala. Madhusoodanan and Dominic (1996b) reported the epiphytic cyanobacteria on mosses from Western Ghats of Kerala. He tried on the isolation and characterization of the non-symbiotic cyanobacteria of the paddy fields of Kerala and studied in biodiversity of nitrogen fixing cyanobacteria from different agroclimatic regions of the state.

Radhika and Gangadevi (2005) have investigated the phytoplankton diversity in the Vellayani lake, Thiruvananthapuram and they have observed 36 species representing Cyanophyceae, Chlorophyceae, Bacillariophyceae and Dinophyceae. Seasonal influence of the phytoplankton community in different kinds of eutrophic water bodies from Kerala in two seasons and were observed 297 algal species (Ray et al. 2020). Maya et al. (2000) listed 108 species of algae from the temple tanks of four southern districts of Kerala namely Thiruvananthapuram, Kollam, Ernakulam and Alappuzha. The systematic account of Chlorococcales of Kerala (Jose and Patel 1992) and they reported twenty taxa belonging to seven genera. In 1989 reported new species of *Actinastrum* and *Ecballocystis* from Kerala. They have collected the algae from Athirapilly water falls of Sholayar river in Kerala. Sindhu and Panikkar (1995a) described desmids from various freshwater bodies of Kerala.

Panikkar and Sreeja (2005, 2006) reported the different stages of zygospore formations of desmids collected from paddy fields, ditches and ponds from Kerala. Nasser and Sureshkumar (2012) have conducted a study on the planktonic and periphytic algal flora of Western Ghats, Kerala. Abhijna and Bijukumar (2015) studied the planktonic and periphytic flora of Kerala. Shaji and Panikkar (1994, 1996) described Cyanophyceae gathered from different parts of Kerala. Diversity of algae in Kuttanadu paddy agroecosystem soils (Smitha 2017). Analysis of algal floral characteristics concerning environmental variations in Kuttanadu paddy fields (Dhanya and Ray 2015) and revealed that specific soil and climatic factors, crop growth stages have a significant contribution to algal diversity. They reported sixty four species of blue green algae from Kuttanadu during Virippu and Puncha season.

Study on the ecology and seasonal variation of microalgal community and their effect on eutrophic nature of pond ecosystem (Joseph and Joseph 2002). Zacharias and Joy (2007) studied the seasonal variation and algal diversity in Periyar river. They noticed periphytic algae were dominant throughout the year. Roy and Joy (2007) looked at the algal genera of Periyar River at Aluva, Kerala. Vaheeda (2008) documented microalgal collection from brackish water bodies and their emergence during post-monsoon at the Kodungallur area. Jose and Francis (2007) made an exploratory work on the Algal flora of Thodupuzha thaluk, Idukki district. Joshi (2010) reported 245 species of microalgae in the form of periphytons in the Pokkali fields of Vypeen island of Ernakulam District of kerala.

Jose and Francis (2008) made a systematic study on the freshwater algal flora of the Idukki district and reported four hundred and ninety four taxa and algal diversity in different habitats from the Northern region of the Idukki district. They also reported 52 algal taxa belonging to 37 genera and five classes. Jose and Francis (2010, 2013) documented 19 new taxa belonging to the class Chlorophyceae from the Western Ghats region of the Idukki district during various seasons and thirty three taxa collected from Wetlands of Idukki district, Kerala. Jithesh (2010) identified fifty-nine taxa of Phytoplankton from Mullaperiyar region in Western Ghats. Ecology and biodiversity of Thutha river (Zeenath 2011) and reported high fish diversity and phytoplankton, abundance of all biotic parameters on post-monsoon season. Nasser and Sureshkumar (2013) analyzed the relationship between environmental variables and microalgae in Peringalkuthu Reservoir, Kerala and observed 94 species of algae. Priya et al. (2015) studied the diversity of Phytoplankton belonging to Euglenophyceae in Vellayani Lake, Thiruvananthapuram. The interaction of environmental parameters with the planktonic Chlorophycean members at

Thiruvananthapuram Museum Lake (Anila and Ajit Kumar 2015). Phytoplankton diversity and its environmental implications from Vellayani and Sasthamcottah Lake (Revathy and Krishnakumar 2018). Joseph and Prakasam (2002) identified 39 genera of Phytoplankton from the Sasthamcotta Lake of Kerala.

Chaudhary and Pillai (2010) studied the diversity of Phytoplankton at Sasthamcottah Lake. Subramoni (2007) has studied the algal diversity of Vamanapuram river of south Kerala and reported 107 species belonging to 58 genera and 24 families. Maya (2007) also studied algal diversity and water quality parameters of vamanapuram river of South Kerala and reported 107 species belongs to 58 genera. Shaji and Patel (1990) described 33 taxa of desmids from various freshwater bodies of Quilon district, Kerala. Shaji (2004) told *Pleurotaenium kayei* (Arch.) Rab. var. *major* from a paddy field in Kollam district, Kerala. Descriptive analysis and illustrations of Euglenoids collected from different habitats of the Quilon district (Shaji and Patel 1991b; Shaji et al. 1995). Sheeba and Ramanujan (2005) enumerated 135 species of Phytoplankton from the Ithikkara River, Kerala. Sahib (2004b) analyzed the Phytoplankton diversity and physicochemical characteristics of Kallada river, Kerala and total of 36 genera under the class chlorophyceae as the dominant group were identified.

Tessy and Sreekumar (2009) assessed the biodiversity and seasonal variation in freshwater algae in Trichur Kole wetlands and reported 169 taxa of Phytoplankton with their composition and abundance. The diversity and distribution of algal taxa belongs to xanthophyceae, chrysophyceae and dinophyceae from Kole lands of Thrissur (2011a). Tessy and Sreekumar (2008) listed 33 taxa under Chlorococcales from the Kole lands of Thrissur. Systematic documentation of Volvocales and described four different genera from Vembanad-Kol, Ramsar site (Tessy and

Sreekumar 2012). Tessy and Saritha (2010) enumerated thirty-six algal species belonging to Bacillariophyceae and belonging to Cyanophyceae from Poyya, Thrissur district. Tessy and Shubha (2011) reported eighty two algal taxa from the coconut husk retting area in Thalikulam, Thrissur district. Algal study from Chalakudy river (Rincy and Tessy 2009) and reported one hundred and seventeen species and (Leenamol and Tessy 2009) reported eighty three algal species.

2.5 Research in rivers of Palakkad district

The scientific studies of the rivers in Palakkad district, Kerala are still inadequate and there is a scarcity of research data except for some research papers based on water quality and floristic study of fauna. Dinesan et al. (2004) analyzed the water availability and the status of water demands in the Bharathapuzha river basin. Bijukumar and Sushama (2001) recorded 88 species of fishes from Bharathapuzha river and (Sushama et al. 2004; Bijukumar et al. 2013) studied the distribution, distribution and conservation of fishes in Nila river. Brijesh (2006) evaluated the groundwater conditions and made a groundwater model for the basin. Nikhil raj and Azeez (2009, 2012) analysed the spatio temporal variation and trend analysis of rainfall in Bharathapuzha river. Kannan and Sabu (2010) conducted the study on the groundwater quality issues in Palakkad and Chittur taluks of the basin. Raj and Azeez (2010) conducted an attempt to explore the general rainfall pattern of the Bharathapuzha river basin using monthly rainfall data for 34 years collected from 28-gauge stations. Divya and Manomani (2013) described the effects of pollutants on the physicochemical characters, nutrient load and polluted nature of Kalpathy river. Groundwater interaction of a tropical sub-basin Bharathapuzha river (Unnikrishnan and Manjula 2014). Hydrological rainfall pattern and hydrochemical characterization of Thuthapuzha sub basin of Bharathapuzha (Manjula 2015). Drissia (2019) reviewed the spatial and temporal variation of water stress using water footprint calculated using water stress indicator in Bharathapuzha river basin. Manjula and Unnikrishnan (2019) worked to determine the spatial and temporal variations in Physicochemical properties of the Thuthapuzha subbasin of Bharathapuzha and water utility for drinking and irrigation purposes. Divya et al. (2019) investigated the physicochemical and bacteriological characteristics of Kalpathy river. Lack of specific information is available on the distribution, diversity and species composition of the algal flora.

Sushama (2003) investigated the ecology and biodiversity of Nila river and reported phytoplankton and zooplankton communities and their abundance in relation with hydrological parameters. A morphometric analysis of Bharathapuzha river basin using GIS for the extraction of river basin and its drainage networks has been carried out using GIS (Magesh et al. 2013). Arulmurugan et al. (2010) studied the biodiversity of freshwater algae from temple tanks of Kerala in Palakkad, Kerala. Seena et al. (2019) studied the seasonal influence of phytoplankton community from the tributaries of Bharathapuzha. 81 species of algae with 12 pollution tolerant genus and noted the eutrophic nature of river.

Chapter-3

Materials and methods

3.1 Area of study

Kerala, a land of rivers situated in the humid tropics lies between 8º18' and 12º48' North and 74º52' and 77º22' East. Rivers originate from the Western Ghats, out of which 41 flow towards west and the other 3 rivers towards east. Bharathapuzha (Nila River), one of the major rivers of the state flows through Palakkad district. Palakkad, the largest producer of rice in Kerala also known as the granary of Kerala. Palghat gap of 32 to 40 Km in Western Ghats functions as gateway to the northeast monsoon reaches to Kerala. The district has 136257 hectares of hill area including reserve forest Silent Valley. As many as eight rivers flows through these hills especially major rivers like Bharathapuzha and Bhavani. The present investigation for detailed study of algal biodiversity was carried out on Bharathapuzha and Bhavani river in Palakkad district of Kerala.

The Bharathapuzha river is a major west flowing and second longest river in Kerala. It originates from Anamalai hills and lies approximately between 10°26' and 11°13' north latitudes and 75°53' and 77°13' east longitudes (Brijesh 2006). It has got a total area of 6186 Km^2, out of which 4400 Km^2 falls within Kerala and the rest 1786 Km^2 in Tamil Nadu. The river Bharathapuzha is the link of three districts in Kerala namely Palakkad, Malappuram and Thrissur. The Bharathapuzha river basin is well characterized by the major physiographic divisions of Kerala namely the highlands (600-1800 m), the midlands (300-600 m), lowlands (10-20 m) and coastal plains (0-l0 m). It covers the area of an elevation about 1,100 metres above mean sea level, the western Ghats are fed by four major tributaries, the Kalpathypuzha, Gayathripuzha, Thootha and Chitturpuzha, which flow through highly diverse and geomorphologic regions of Kerala. The Kalpathi river basin is the largest sub basin with an area of 1390 m^2, chased by Chittur (1315 m^2). At Parli, Kannadippuzha and Kalpathippuzha merge and flow westward as Bharathappuzha, eventually emptying into the Arabian Sea at Ponnani. Pallippuram is where the Thootha and Nila rivers meet. The smallest river basin is Thootha river, is rich in water, and after its merger, Nila becomes thicker in flow. Though Bharathappuzha has a large river basin, the water flow is relatively less compared to other long rivers in Kerala because a large portion of the river basin is in the comparatively drier regions of Tamil Nadu and Palghat Gap.

The river is the lifeline water source for a population living in four administrative divisions of Kerala, namely Malappuram, Thrissur and Palakkad districts of Kerala and part of Coimbatore and Thiruppur districts of Tamil Nadu. Rice and coconut are the dominant crops in the coastal regions of the river basin. The river basin experiences a unique climate space from the rest of the state of Kerala may be for its location beginning from the Palakkad plains in the Palghat Gap flanked by mountain ranges of the Western Ghats. Irregularities in the general rainfall and surface temperature of the region have been observed in the last couple of decades. In recent years the river basin is also reported to be facing severe scarcity of water and drought conditions.

Bhavani is an east flowing perennial river flows from the Nilgiri hills of the Western Ghats, through the Silent Valley National Park in Palakkad, and back into Tamil Nadu. The river has 217 Km long and flows through the states of Kerala and Tamil Nadu. It is a major tributary of Cauvery and second longest river in state of Tamil Nadu. It has got an area of 6200S Km^2, out of which 87% in Tamil Nadu, 9% in Kerala and 4% in Karnataka. There are many dams that have been constructed across the river, they are Bhavanisagar dam, Kodiveri dam, Kanjirapuzha dam, Mannarkkad and Siruvani dam. Kanjirapuzha dam is situated in the Palakkad district, irrigates the land of 9173 hectares in Kerala. More than 90% of river water used for irrigating the agricultural lands. The river Bhavani collects municipal sewage and industrial effluents along its river course and finally joins with the Cauvery River at Erode District. The average annual rainfall of the Bhavani river basin is 811.47 mm. The average discharge of the river at its mouth is 161 m^3/S (Vishnu et al. 2016).

To study the comparative study on the algal biodiversity of Bharathapuzha and Bhavani rivers in Palakkad district, 10 sites were selected for the collection of algae on the different tributaries of river with an approximately 15 to 20 Km distance were selected. The first 8 stations were chosen from the Bharathapuzha river, followed by stations 9 and 10 from the Bhavani river.

1) **Koodallur (Lat N10° 48' 32.4216'' and Long E76° 7' 1.686'')**

   Koodallur situated at Pattambi taluk, bordering Malappuram district. It was very beautiful and calm Kerala village on the banks of Bharathapuzha river. Range of hills and paddy fields make this village as magic place. The place got the name ‘Koodal’ by the joining of Nila river with Thuthpuzha. The area is extensively exploited for sand mining. Land filling works also undergoing on this area.

2) **Mayannur (Lat N10° 45' 50.328'' and Long E76° 22' 54.912'')**

   Situated in Kondazhi Panchayat in Palakkad district, the station is about 46 m above sea level. From this site onwards Nila river merge with Gayathripuzha and become more wider and thicker. So, this site also called Koottilmukku. Coconut plantations border the river. The river bottom has plenty of colourful rocks. As a result of sand mining there is considerable degradation of the natural habitat. The household wastes are highly discharged to this area.

3) **Chittur (Lat N10° 44' 48.9012'' and Long E76° 39' 50.1732'')**

The river flows through Thathamangalam and Chittur areas of Palakkad District. It joins the main river Bharathapuzha near Parli. This site also is known as Sokanasini river, the name was given by Thunjathu Ramanujan Ezhuthachan. The average rainfall in the river basin is 1828 mm. This site also faced the dumping of large number of public wastes and the presence of detergents from cattle washing activities.

4) **Chulliyar (Lat N10° 33' 46.631'' and Long E76° 49' 16.463'')**

Located in Muthalamada Panchayat of Chittur taluk. Chulliyar dam built across Chulliyar river, a tributary of Bharathapuzha. Illegal quarries in this area seriously affecting the nature of water bodies. This river also faced imminent death due to land use pattern. All these activities receding the water level because of decreasing water flow in the river. Surrounding drainage outlets directly open to this area.

5) **Kannadi (Lat N10°44' 48.9012'' and Long E76°39' 50.1732'')**

Located in Mathur village of Palakkad. The sampling site near to the extensive building construction. This area seriously faced human activities like dumping of household wastes from the neighbouring construction sites. Illegal sand mining is another threat towards this site. This results many pits in the riverbed which lead to the formation of green carpet of Water Hyacinth and other shrubs.

6) **Kalpathy (Lat N10°47' 47.2668'' and Long E76°38' 57.6276'')**

Along the banks of the river, a small Tamil Brahmin village located. There are many small temples near banks of the river, they are keeping their distinctive culture, temple and mode of worship intact. The river is named after the

Kalpathi Siva temple in Palakkad which is famous for its festival. Many areas of this river exploited to dumping yard of wastes from surroundings. People from the nearby used for washing and bathing. This area was highly affected by flood.

7) **Malampuzha (Lat N10°48' 16.38" and Long E76°39' 39.5028")**

Situated at 10 Km away from the Malampuzha dam. Malampuzha dam is built across the river. A printing press is located near the sampling site. The waste from the press is directly discharged into the river. This makes change in colour of water and emanates bad smell too. During summer, continuous sand mining results in extensive growth of shrubs and water hyacinth.

8) **Karimpuzha (Lat N10°55' 17.508" and Long E76°25' 14.664")**

Located at Sreekrishnapuram panchayat, Palakkad. The river that gets its waters from Kuntipuzha, Silent valley national park. The area is extensively exploited for washing.

9) **Mukkali (Lat N11°4' 16.2912" and Long E76°33' 29.092")**

A small village located in Agali panchayat of Attappadi block. The area is bounded by thick vegetation. Highly undisturbed place due to lack of developmental projects and human activities. But is affected seriously by flood and landslides.

10) **Seenkara (Lat N11°4' 37.092" and Long E76°34' 11.676")**

Situated in Attappadi block, bounded by thick vegetation. The bordered areas have banana cultivation. The area is extensively faced flood in previous years.

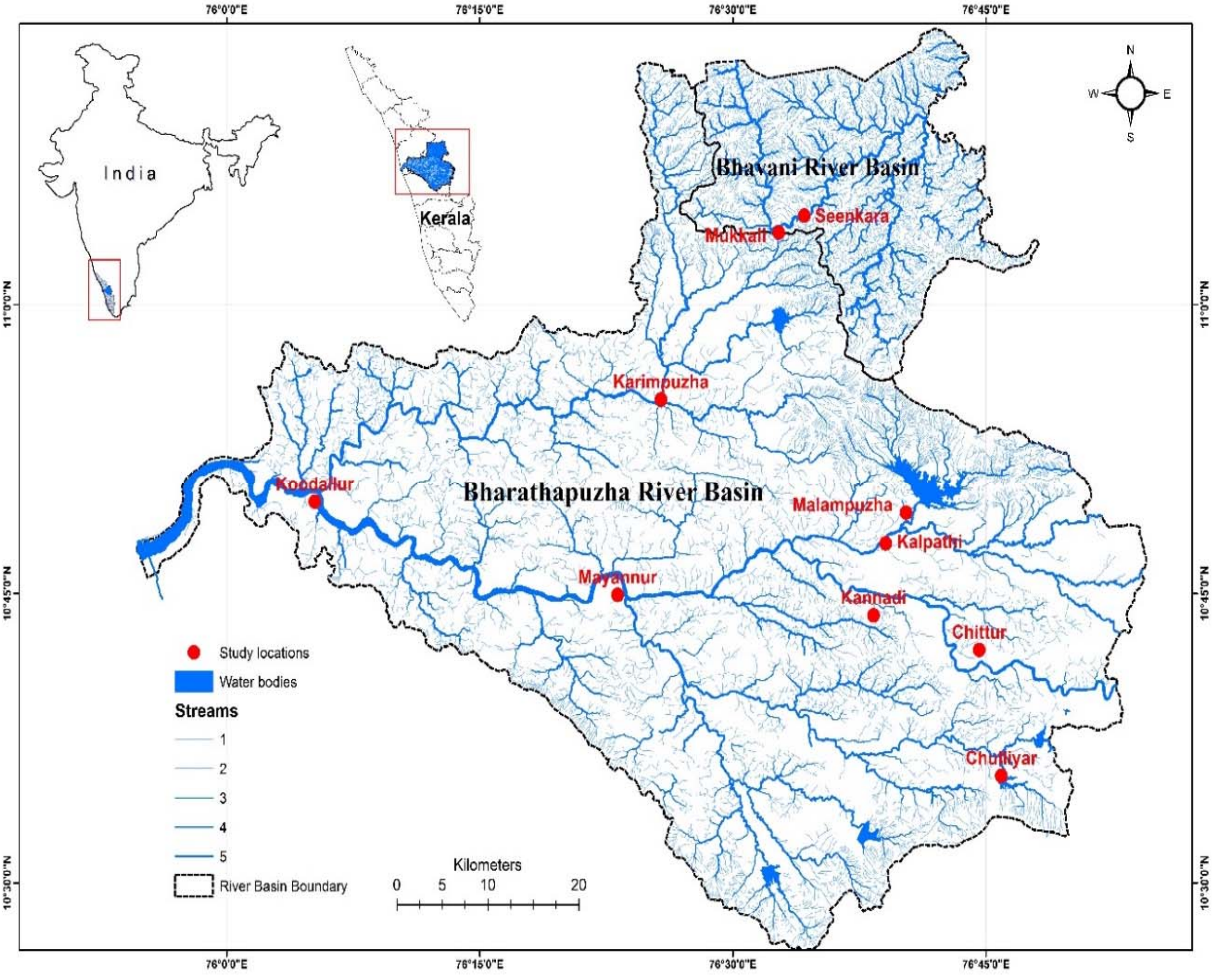


Figure 1. Map of Bharathapuzha and Bhavani river basins in Palakkad district showing sampling sites

1.Koodallur 2. Mayannur 3.Chittur

4. Chulliyar 5. Kannadi

6. Kalpathy 7. Malampuzha

8. Karimpuzha 9. Mukkali 10. Seenkara

Figure 2. Photos of sampling sites from rivers in Palakkad district

3.2 Physico chemical properties of water

Water quality can be defined in terms of physical, chemical and biological characteristics. Natural practices and anthropogenic activities influence the quality of an ecosystem. Systematic and scientific water quality monitoring are required for the analysis of quality of aquatic ecosystems. The occurrence, abundance and structure of the entire biotic community depend on the hydrographic parameters of the riverine ecosystem. Healthy aquatic systems gifted with optimal physico chemical parameters exhibit maximum productivity. A total of 8 different characteristics of water were analyzed in triplicates every month from November 2018 to October 2019. The water samples were collected from 10 study sites between 8.30 and 11.00 a.m. in 2-liter plastic containers and soon carried to the laboratory for analysis without delay. The Physico chemical parameters analyzed were Temperature, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Dissolved Oxygen (DO) were noted on the spot at the time of collection using standard instruments (digital thermometer, pH pen, EC, and TDS, DO meter). The influence of these parameters together to keeps the aquatic habitat favourable for the existence of life.

3.3 Nutrient Analysis

Study on the distribution and monthly variations of nutrients used as a tool for evaluating the biological status of an ecosystem. The excess nutrient load can be positively correlated with the increased application of fertilizers. For nutrient analysis, water samples collected in polythene bottles are rinsed three times before filling and stored in a refrigerator until nutrient analysis. Samples were analyzed for Nitrate (NO_3), Phosphate (PO_4), and Silicate (SiO_4). Samples were preserved and the methodology for the analysis of the samples as per APHA (1998) and the methodology followed for the study of the models is given in Table 1.

Table 1. Lis of instruments and analytical methods followed for water analysis

Sl. No.	Parameters	Method	Instruments
1	Temperature (^{0}c)	Thermometry	Mercury Thermometer
2	pH	Electrometry	Digital pH meter
3	EC (µmhos/cm)	Electrometry	Digital conductivity meter
4	TDS (µmhos/cm)	Electrometry	Digital TDS meter
5	Nitrate (mg/L)	Colourimetry	UV-visible spectrophotometer
6	Phosphate (mg/L)	Colourimetry	UV-visible spectrophotometer
7	Silicate (mg/L)	Colourimetry	UV-visible spectrophotometer
8	DO (mg/L)	Electrometry	Digital DO meter

The range and the mean along with standard deviation of various physico chemical characteristics of the different stations are studied. It was to test, whether any significant differences in physico chemical factors found between the stations and between months, the data tested with Two-way analysis of variance (ANOVA), using IBM SPSS 21. The values of the various physico chemical parameters were subjected to statistical analysis for the estimation of Pearson correlation coefficient, 'r' using IBM SPSS 21. The significance of correlation coefficient of different parameters was tested at 5% and 1% level.

3.4 Algal taxonomy

Relevant works of literature related to identifying the algal taxa up to the species level were carried out with the help of standard publications, authentic monographs, reference books, articles, and online sources. For the identification of various taxa (Scott and Prescott 1961; Ralfs 1962; Prescott 1982; West and West 1904, 1905, 1907, 1908, 1912; Smith 1920, 1924; Anand 1989, 1998; Prasad and Misra 1992) were used. Freshwater diatoms of Maharashtra (Sarode and Kamat 1984), Atlas of Diatoms of the Indian Oceans Six Volumes (Desikachary 1959, 1989). Freshwater algal flora of Andaman and Nicobar Islands Vol. I (Prasad and Srivastava 1986). ICAR monograph series on algae, Volvocales (Iyengar and Desikachary 1981), Chlorococcales (Philipose 1967), Cyanophyta (Desikachary 1959), Oedogoniales (Gonzalves 1981; Randhawa 1959; Ushadevi and Panikkar 1994a; Sindhu and Panikkar 1994c, 1995a, 1995b; Sinha and Naik 1997) were used for identification and classification. Taxonomic studies on Euglenophytes (Wolowski 1998; Philipose 1984, 1988) were very helpful in identifying Euglenophytes. The systematic positions of the members of cyanophyceae, chlorococcales, desmids, and bacillariophyceae were arranged according to (Desikachary 1959; Philipose 1967; Scott, and Prescott 1961; Sarode and Kamat 1984) respectively. Electronic reference *viz.* Ph.D. Thesis repositories Science Direct, Shodhganga, and Wiley, were also used. The literature retrieval system Biodiversity heritage library of New York Botanic Garden (https://www.biodiversitylibrary.org) and Digicodes (Digital image collection of desmids).

Algal samples for the systematic analysis were collected from Bharathapuzha and Bhavani river basins in Palakkad district from 10 permanent sampling stations marked in figure 1. Specimens were collected at monthly intervals from these stations of the study area for one year from November 2018 to October 2019 between 8.30 and 11 a.m. Materials are collected in tightly capped plastic bottles and labeled for algal taxonomic studies. One liter water sample from each site was collected and preserved immediately in 4% formalin solution and brought to the laboratory (APHA 1998) at the Department of Botany, St. Thomas' College (Autonomous) Thrissur, Kerala. The temporary slides were prepared from the water samples and observed under Binocular BIOMED Research Microscope using 4X, 10X, and 100X objectives. In addition, digital photomicrographs were taken for the identification of algal taxa in their original morphology. The taxa were identified with the help of authentic scientific literatures (West and West 1904, 1908; Smith 1920; Venkataraman 1961; Philipose 1967, 1984, 1988; Scott and Prescott 1961; Iyengar and Desikachary 1981; Prescott 1982; Sarode and Kamat 1984; Desikachary 1989; Prasad and Misra 1992; Prasad and Srivastava 1986; Wolowski 1998; Anand 1998; Komarek 2013 and ICAR monograph series on algae (Desikachary 1959). To the identification of the members of Bacillariophyceae, a portion of the concentrated sample was cleaned using concentrated hydrochloric acid, sulphuric acid and potassium permanganate crystals.

3.5 Quantitative analysis of phytoplankton

Phytoplankton were collected from 10 sampling sites were counted under the microscope using the Sedgewick-Rafter counting chamber (Trivedy and Goel 1984). The S-R cell with a rectangular cavity of 1 ml (1 cm^3) is used for the study. The S-R cell was covered with a cover slip without the air bubbles inside. The phytoplankton was counted after the plankton settled down under a compound microscope.

3.6 Community structure

The algal community structure was compared using species richness and evenness, as well as proportional statistics that combined both measures (Shannon-Weiner index). Correspondence analysis is the better algorithm for comparing associations containing counts of taxa across associations.

3.6.1 Diversity Indices

The ecological diversity indices such as species richness (Margalef), Pielou's evenness, Shannon-Weiner index (H) and Simpson's dominance index (1-D) of the phytoplankton were performed using PAST 3.18 (Paleontological Software Package) in different stations and months with respect to species composition and abundance (Hammer et al. 2001).

3.6.2 Multivariate similarity analysis

Multivariate analysis of ecological data by Canonical Correspondence Analysis (CCA) and Hierarchical Cluster Analysis (HCA) were conducted with the help of multivariate ecological statistical software PAST 3.18 (Hammer et al. 2001) to study on the relationship between physicochemical parameters structure of an algal community. The analysis was carried out to determine the degree of similarity between stations and months in terms of species composition and abundance. The main goal of CCA was to identify the most important physicochemical parameters influencing phytoplankton distribution.

3.7 Phytoplankton as pollution indices

Pollution indices are widely used for the monitoring of qualitative status of water bodies. In the present study, two indices are used to get the biological information based on algae for the assessment water quality-Palmer's pollution index and Boyd's diversity index. Palmer (1969) developed palmer algal genus index to identify and prepare a list of 60 genera and 80 species of algae tolerant to organic pollution. Each genera assigned a particular number based on their tolerance action. He formulates a pollution index scale by adding the number for the assessment of organic pollution. The score value above 20 indicates heavy organic pollution, 15 to 20 represents moderate organic pollution and below 15 means very light pollution.

The diversity index of (Boyd 1981) indicates the order of pollution of water bodies. Number of genera of phytoplankton in the water bodies is the main parameter for calculating the index by the following formula $H = (S-1) / \ln N$.

where H = Boyd's diversity index, S = number of genera of phytoplankton, ln is the natural logarithm and N = total number of phytoplankton. The values > 4 indicates less pollution of water, values 2–3 are characterized as moderate pollution and values < 1 are considered as heavily polluted.

Quality of an aquatic ecosystem is dependent on the physico chemical qualities of water on the biological diversity of the system. The analysis of biological parameters along with chemical factors of water forms a valid method of water quality assessment. Chemical analyses of water provide a good indication of the quality of the aquatic systems.

Chapter-4

Results

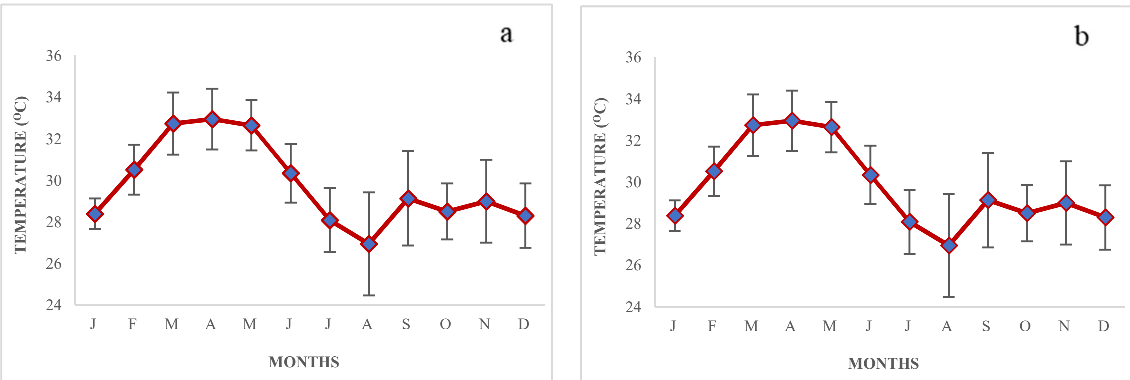
4.1 Physico chemical parameters

The monthly values of selected hydrographic parameters from the rivers of Palakkad district were collected from ten stations during November 2018 to October 2019. As a result, the data was collected and an average for various parameters was calculated.

4.1.1 Temperature

The monthly temperature variations of the surface water at the ten study stations are depicted in figures 3 a&b. The mean temperature values month wise ranged from 26.93 ±2.47 ºC (August) to 32.93 ±1.45 ºC (April). Minimum value observed in monsoon season and maximum value in pre monsoon. Water temperature fluctuated from a minimum of 27.96 ±2.98 ºC at station 10 to a maximum of 31.95 ±2.29 ºC at station 7. The ANOVA of the monthly variation of temperature showed significant difference between months (P<0.001) and sites (P<0.001). The coefficient of correlation illustrated significant negative correlation with DO and positive correlation with all other parameters.

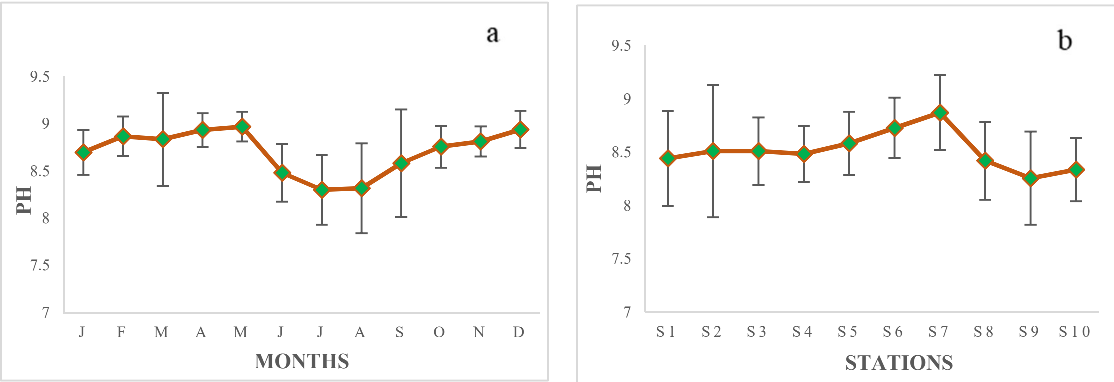
Figure 3. Graphs showing monthly and spatial variation of Temperature (a&b)



4.1.2 pH

Monthly the mean pH values ranged from 8.3 ±0.36 (July) to 8.96 ±0.15 (May) presented in figures 4 a&b. Minimum value observed in monsoon season and maximum value in pre monsoon. pH value fluctuated from a minimum of 8.2 ±0.43 at station 9 to a maximum of 8.87 ±0.35 at station 7. The ANOVA of the monthly variation of pH showed significant difference between months (P<0.001). The results showed significant negative correlation with silicate and DO positively correlation with all other parameters.

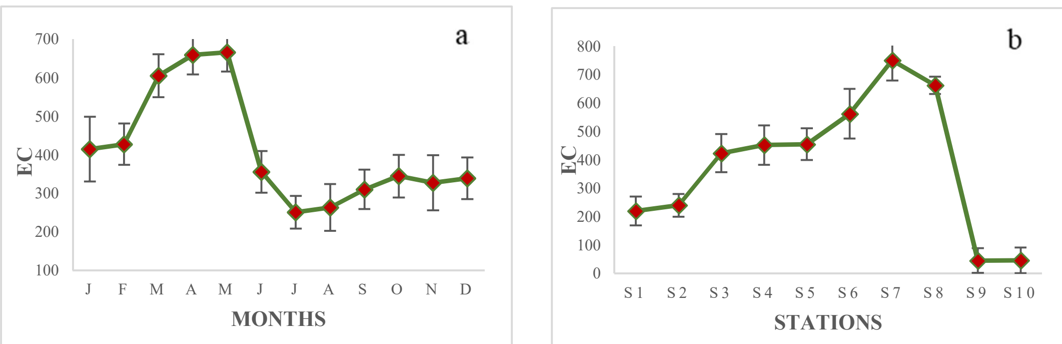
Figure 4. Graphs showing monthly and spatial variation of pH (a&b)



4.1.3 Electrical Conductivity (EC)

The mean value of the conductivity for the entire period of observation are depicted in figures 5 a&b. The highest average value recorded in the study area during the month of May (666.16 ±49.86) at station 7 (750.35 ±71.68) and the minimum conductivity was recorded from station 9 (46.03 ±43.51) during the month of July (250.53 ±42.49). The ANOVA of the monthly variation of electrical conductivity showed significant difference between months (P<0.001). The findings revealed that significant negative correlation with phosphate and nitrate.

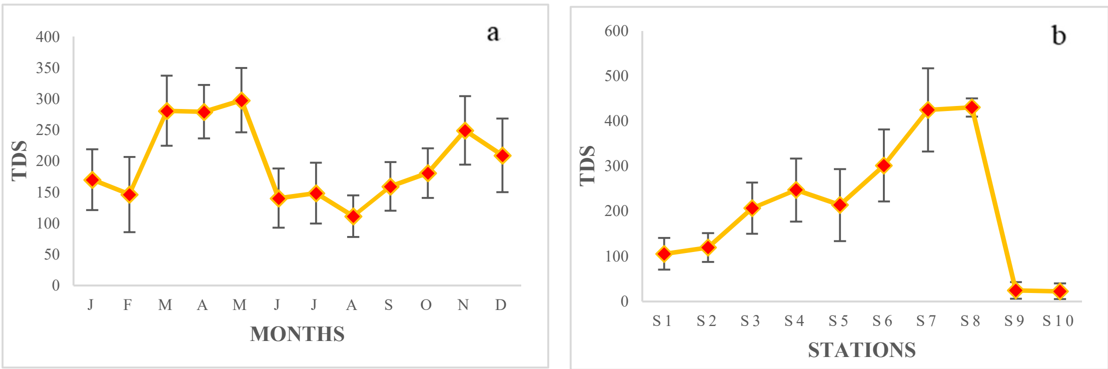
Figure 5. Graphs showing monthly and spatial variation of EC (a&b)



4.1.4 Total Dissolved Solids (TDS)

The mean value of the total dissolved solids for the entire period of study are illustrated in figures 6 a&b. In general, highest TDS was observed in May (297.96 ±51.75) at station 8 (429.93 ±20.38). The lowest value observed in the month of August (111.21 ±33.37) at station 10 (22.36 ±17.1). Analysis of variance showed no significant relation between months ($P>0.001$). The coefficient of correlation illustrated significant negative correlation with nitrate, phosphate and DO.

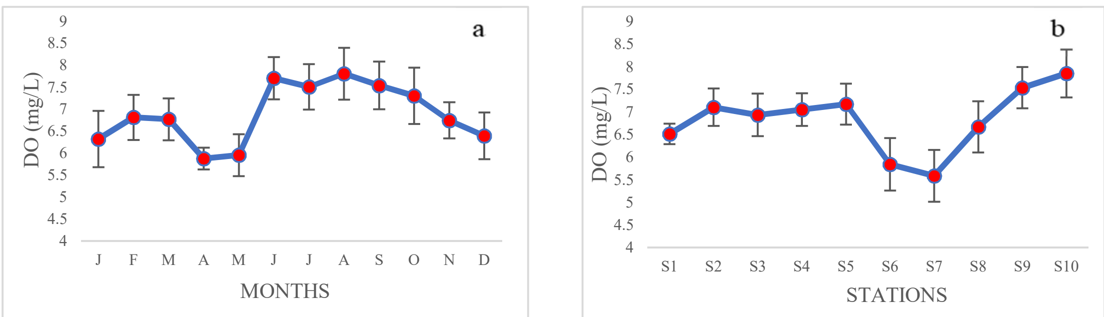
Figure 6. Graphs showing monthly and spatial variation of TDS (a&b)



4.1.5 Dissolved Oxygen (DO)

The monthly average values of DO in the study area ranged between 7.8 ±0.71 mg/L during August to 5.87 ±0.54 mg/L during April shown in figures 7 a&b. The mean value ranged between 7.85 ±0.91 mg/L at station 10 to 5.58 ±0.62 mg/L at station 7. Univariate analysis showed that sufficient variance occurs with DO in months ($P<0.001$). The correlation results revealed significant positive correlation with EC and silicate.

Figure 7. Graphs showing monthly and spatial variation of DO (a&b)



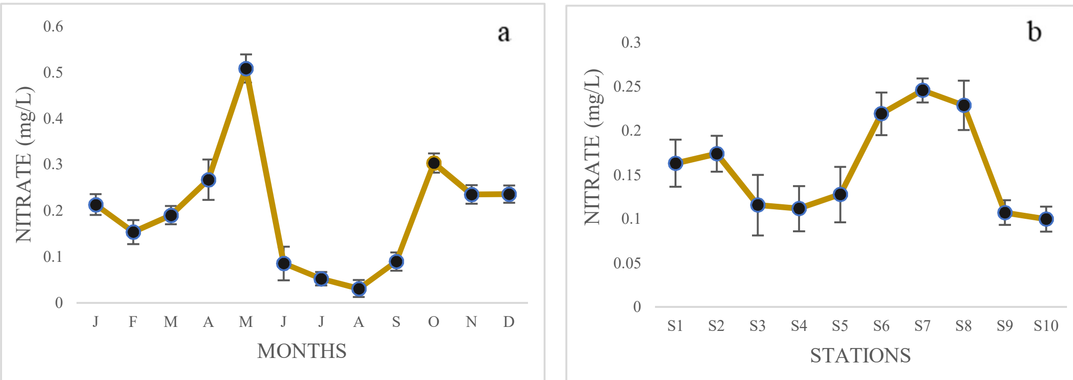
4.2 Nutrients

Nutrients like nitrate, phosphate and silicate concentration in the river ecosystem were observed during the present study. The ratio of nutrient concentration fluctuates according to the physiological and biological state of phytoplankton (Balzano et al. 2015). Growth of phytoplankton depends on the availability of nutrients.

4.2.1 Nitrate

Analysis of variance in nitrate showed that significant differences ($P<0.001$) observed with the mean temporal variation of nitrate in the study area (Figures 8 a&b) ranged from 0.03 ±0.0 mg/L in August and 0.508 ±0.03 mg/L in May. This range of difference in various stations recorded between 0.09 ±0.01 mg/L at station 10 and 0.245 ±0.013 mg/L at station 7. The correlation coefficient showed positive correlation with temperature, pH and phosphate. The variations in nitrate concentration are directly related with the growth of phytoplankton in river water because their biological processes determine the N cycling in ecosystem.

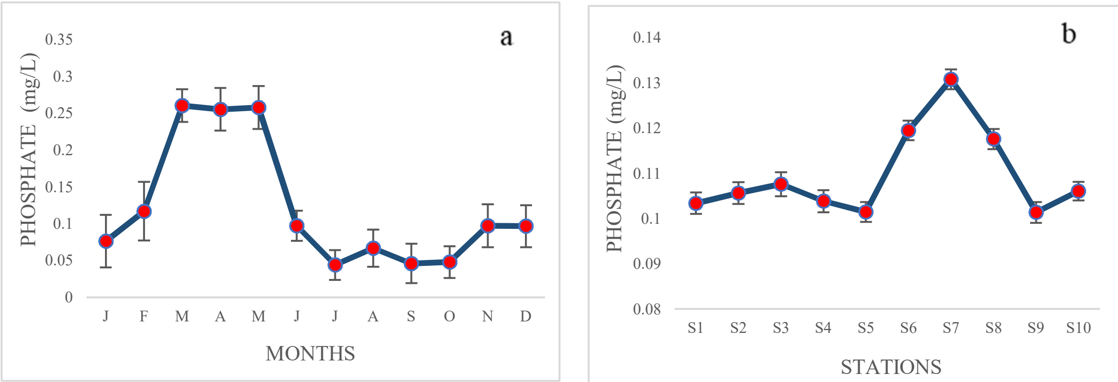
Figure 8. Graphs showing monthly and spatial variation of Nitrate (a&b)



4.2.2 Phosphate

The average values of phosphate are given in the figures 9 a&b. The monthly range of phosphate was from 0.044 ±0.02 mg/L (September) to 0.26 ±0.02 mg/L (May). The least mean values were recorded from the Stations 9 (0.10 ±0.002 mg/L) and highest mean value was from station 7 (0.131 ±0.002 mg/L). Comparatively low amount of phosphate concentration observed throughout the study period. Analysis of variance showed that significant variance between months ($P<0.001$). The coefficient of correlation illustrated significant positive correlation with temperature, nitrate and phosphate.

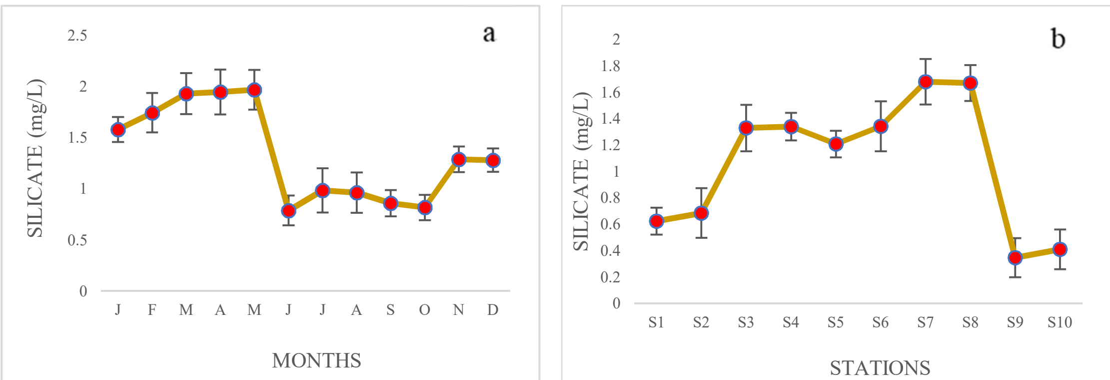
Figure 9. Graphs showing monthly and spatial variation of Phosphate (a&b)



4.2.3 Silicate

The monthly average values of silicate in the study area ranged from 0.96 ±0.56 mg/L during June to 1.97 ±0.79 mg/L during May. In the present study, the silicate concentration was found to fluctuate from 0.347 ±0.48 mg/L at station 9 to 1.67 ±0.40 mg/L at station 7 (Figures 10 a&b). The ANOVA of the monthly change of temperature showed significant difference between months ($P<0.001$). The correlation results showed significant negative relation with pH, nitrate and phosphate.

Figure 10. Graphs showing monthly and spatial variation of Silicate (a&b)



4.3 Algal taxonomy

The algal taxa recorded from the study area given in (Table 2). Phytoplankton belonging to 257 taxa under seven classes from six divisions namely Chlorophyta, Bacillariophyta, Chrysophyta, Pyrrhophyta, Euglenophyta and Cyanophyta were identified from the 10 stations studied. Out of the 257 algal taxa recorded, 88 belong to class chlorophyceae, 74 to bacillariophyceae, 69 to euglenophyceae, 24 to cyanophyceae, 1 to dinophyceae, 1 to xanthophyceae.

Algal classification mainly based on their morphological and physiological characters, pigment composition and cellular structure. According to Fritsch (1945a), algae classified into eleven classes: Chlorophyceae, Xanthophyceae, Chrysophyceae, Bacillariophyceae, Cryptophyceae, Dinophyceae, Chloromonodineae, Euglineneae, Phaeophyceae, Rhodophyceae and Cyanophyceae (Myxophyceae). In the present study, systematic positions of algae were arranged in accordance with (Prescott 1982; Desikachary 1959; Philipose 1967; Scott and Prescott 1961; Sarode and Kamat 1984) respectively. The taxa within genera were arranged in alphabetical order. The details of collections were given in appendix. The algal taxa were arranged in the following order.

Division - Chlorophyta (Class - Chlorophyceae)
Division - Chrysophyta (Class - Xanthophyceae & Chrysophyceae)
Division - Bacillariophyta (Class - Bacillariophyceae)
Division - Euglenophyta (Class - Euglenophyceae)
Division - Pyrrhophyta (Class - Dinophyceae)
Division - Cyanophyta (Class - Cyanophyceae)

Table 2. The Number of phytoplankton taxa collected from the study area

Class	Order	Family	Genus	Species	%
Chlorophyceae	2	10	26	88	34
Xanthophyceae	1	1	1	1	1
Bacillariophyceae	2	9	24	74	29
Euglenophyceae	1	1	5	69	26
Dinophyceae	1	1	1	1	1
Cyanophyceae	2	4	13	24	9
Total	**9**	**26**	**70**	**257**	**100**

Table 3. List of new reports of phytoplankton from India and Kerala

<table>
<tr><th colspan="4">New report to India</th></tr>
<tr><td>1</td><td colspan="3">Micrasterias laticeps var. acuminata</td></tr>
<tr><th colspan="4">New reports to Kerala</th></tr>
<tr><td>1</td><td>Navicula constans var. symmetrica</td><td>8</td><td>Euglena oxyuris var. minor</td></tr>
<tr><td>2</td><td>Navicula gastrum</td><td>9</td><td>Phacus viguieri</td></tr>
<tr><td>3</td><td>Navicula pusilla</td><td>10</td><td>Phacus pseudoswirenkoi</td></tr>
<tr><td>4</td><td>Cymbella signata</td><td>11</td><td>Trachelomonas planctonica f. ornata</td></tr>
<tr><td>5</td><td>Surirella tenera var. ambigua</td><td>12</td><td>Strombomonas gibberosa</td></tr>
<tr><td>6</td><td>Euglena chlamydophora</td><td>13</td><td>Peridiniopsis quadridens</td></tr>
<tr><td>7</td><td>Euglena fusca</td><td>14</td><td>Pseudoanabaena galeata</td></tr>
</table>

Table 4. The checklist of taxa recorded from the study area

Division	Class	order	Family	Species
Chlorophyta	Chlorophyceae	Volvocales	Volvocaceae	*Pandorina morum* (Mull.) Bory
				Pandorina morum (Mull.) Bory var. *major* Iyengar
			Micractiniaceae	*Golenkinia paucispina* W. & G.S.West
				Golenkiniopsis minutissima (Iyengar et Balkr.)
		Chlorococcales	Hydrodictyaceae	*Pediastrum biradiatum* Meyen
				Pediastrum boryanum (Turp.) Menegh. var. *longicorne* Reinsch
				Pediastrum simplex Meyen
				Pediastrum simplex Meyen var. *duodenarium* (Bailey) Rabenhorst
				Pediastrum tetras (Ehr.) Ralfs
				Tetraedron gracile (Reinsch) Hansgirg
				Tetraedron proteiforme (Turn.) Brunnthaler
				Tetraedron regulare Kuetzing var. *granulata* Prescott
				Tetraedron regulare Kuetzing var. *minus* (Reinsch) De Toni
				Tetraedron trigonum (Naegeli) Hansgirg
				Tetraedron trigonum (Nag.) Hansgirg fa. *crassum* (Reinsch) De Toni
				Tetraedron trigonum (Nag.) Hansgirg var. *verrucosum* Jao
			Oocystaceae	*Oocystis borgei* Snow
			Dictyosphaeriaceae	*Dictyosphaerium ehrenbergianum* Nag.
			Selenastraceae	*Ankistrodesmus convolutus* (Corda)
				Ankistrodesmus falcatus (Corda) Ralfs
				Actinastrum hantzschii Lagerheim var. *elongatum* G.M.Smith
				Micratinium pusillum Fresenius var. *elegans* G.M.Smith
				Selenastrum gracile Reinsch
			Coelastraceae	*Coelastrum microporum* Naegeli
				Coelastrum proboscideum Bohlin
				Coelastrum sphaericum Nag.
			Scenedesmaceae	*Scenedesmus acuminatus* (Lagerheim) Chodat
				Scenedesmus carinatus (Lemm.) Chodat

Division	Class	order	Family	Species
				Scenedesmus bijugatus (Turp.) Kuetz. var. *graevenitzii* (Bernard)
				Scenedesmus dimorphus (Turp.) Kuetz.
				Scenedesmus longus Meyen
				Scenedesmus perforatus Lemm.
				Scenedesmus perforatus Lemm. var. *major* (Turn.) Philipose
				Scenedesmus quadricauda (Turp.) Breb.
				Scenedesmus quadricauda (Turp.) Breb. var. *bicaudatus* Hansgirg
				Scenedesmus quadricauda (Turp.) Breb. var. *quadrispina* (Chodat) G. M. Smith
			Gonatozygaceae	*Cylindrocystis brebissonii* Menegh
			Desmidiaceae	*Closterium dianae* Ehr. var. *minus* (Wille) Schroder
				Closterium ehrenbergii Menegh
				Closterium kuetzingii Breb.
				Closterium lagoense Nordst.
				Closterium moniliferum (Bory) Ehr.
				Closterium navicula Breb.
				Closterium peracerosum Gay
				Pleurotaenium ovatum Nordst
				Pleurotaenium trabecula (Ehr.) Nag. var. *rectum* (Delp.) West et West
				Triploceras gracile Bail. var. *undulatum* Scott & Prescott
				Euastrum gayanum De Toni
				Euastrum sinuosum Lenorm.
				Euastrum spinulosum Delp.
				Micrasterias foliacea Bail.
				Micrasterias laticeps Nordstedt var. *acuminata* W.Krieger
				Micrasterias pinnatifida (Kuetz.) Ralfs
				Cosmarium auriculatum Reinsch
				Cosmarium binum Nordst.
				Cosmarium blyttii Wille
				Cosmarium depressum (Nag.) Lund.
				Cosmarium depressum (Nag.) Lund. var. *apertum* (Turn.) Hirano

Division	Class	order	Family	Species
				Cosmarium granatum Breb.
				Cosmarium granatum Breb. var. *rotundatum* Krieg.
				Cosmarium lundellii Delp.
				Cosmarium lundellii Delp. Var. *circulare* (Reinsch) Krieg.
				Cosmarium lundellii Delp. Var. *corruptum* (Turn.) West & West
				Cosmarium galeritum Nordst.
				Cosmarium maculatum Turn.
				Cosmarium margaritatum (Lund.) Roy & Biss. var. *sublatum* (Nordst.) Krieg.
				Cosmarium medioscrobiculatum West & West var. *egranulatum* Gutw.
				Cosmarium obsoletum (Hantzsch) Reinsch
				Cosmarium pseudoconnatum Nordst.
				Cosmarium punctulatum Breb. var. *subpunctulatum* (Nordst.) Borg.
				Cosmarium quadrum Lund.
				Cosmarium quadrifarium Lund.
				Cosmarium scabrum Turn.
				Cosmarium sexangulare Lund. fa. *minimum* Nordst.
				Cosmarium subspeciosum Nordst. var. *validius* Nordst.
				Cosmarium subundulatum Wille.
				Cosmarium turgidum Breb.
				Arthrodesmus curvatus Turn. var. *latus* Scott and Prescott
				Xanthidium sexmamillatum West & West var. *pulneyense* Iyengar & Bai
				Xanthidium subtrilobum West & West var. *inornatum* Skuja
				Staurastrum crenulatum (Nag.) Delp.
				Staurastrum glabrum (Ehr.) Ralfs.
				Staurastrum proboscidium (Breb) Arch.
				Staurastrum saltans Josh. var. *polycharax* Scott & Prescott
				Staurastrum sp. 1
				Onychonema laeve Nordst. var. *micracanthum* Nordst.
Chrysophyta	Xanthophyceae	Heterococcales	Centritractaceae	*Centritractus belanophorus* Lemm.
Bacillariophyta	Bacillariophyceae	Centrales	Coscinodiscaceae	*Aulacoseira granulata* (Ehr.) Simonsen
				Aulacoseira granulata (Ehr.) Simonsen var. *Angustissima* (O.Muell) Simonsen

Division	Class	order	Family	Species
				Actinocyclus normanii (Gregory) Hustedt
				Cyclotella meneghiniana Kuetz.
				Cyclotella striata (Kuetz.) Graun.
		Pennales	Fragilariaceae	*Tabellaria fenestrata* (Lyngbye) Kuetz.
				Fragilaria construens (ehr.) Grun. V. Venter grun.
				Fragilaria intermedia Grun.
				Fragilaria rumpens (Kuetz.) Carl. v. *familiaris* (Kuetz.) A.Cl.
				Synedra acus Kuetz.
				Synedra ulna (Nitz.) Ehr.
				Synedra ulna (Nitz.) Ehr. var. *subaequalis* Grun.
			Eunotiaceae	*Eunotia lunaris* (Ehr.) Gurnow
			Achnanthaceae	*Cocconeis placentula* Ehr.
				Achnanthes exigua Grun.
			Naviculaceae	*Gyrosigma distortum* (W. Smith) Cleve v. *parkeri* Harrison
				Gyrosigma kuetzingii (Grun) Cleve
				Pleurosigma salinarum Grun
				Pleurosigma elongatum W. Smith var. *karianum* (Grun.) Cleve
				Caloneis permagna (Bail.) Cleve
				Neidium productum (W. Smith) Cleve v. *bombayensis* Gonzalves
				Diploneis ovalis (Bail.) Cleve
				Stauroneis anceps Ehr.
				Stauroneis anceps Ehr. fo. *gracilis* (Ehr.) Cleve
				Stauroneis phoenicenteron Ehr. fa. *capitata* Gonzalves et Gandhi
				Stauroneis phoenicenteron Ehr. fa. *producta* Gandhi
				Navicula constans Hustedt var. *symmetrica* Hustedt
				Navicula cuspidata Kuetz.
				Navicula gsatrum Ehr.
				Navicula gracilis Ehr.
				Navicula laterostrata Hustedt
				Navicula mutica Kuetz. v. *linearis* Gonzalves et Gandhi
				Navicula pygmaea Kuetz.

Division	Class	order	Family	Species
				Navicula pupula Kuetz.
				Navicula pusilla W. Smith
				Pinnularia acrosphaeria (Breb.) W. Smith
				Pinnularia divergens W. Smith v. *elliptica* Grun.
				Pinnularia interrupta W. Smith var. *minor* Boye Pet.
				Pinnularia lundii Hustedt
				Pinnularia major (Kuetz.) Cleve var. *linearis* Cleve
				Pinnularia panhalgarhensis Gandhi
				Pinnularia stomatophoroides Mayer v. *ornata* (Ehr.) A. Cl.
				Pinnularia termis Ehr. v. *termitiana* (Ehr.) A. Cl
				Amphora ovalis Kuetz. var. *gracilis* (Ehr.) Cleve
				Cymbella bengalensis Grun.
				Cymbella hungarica (Graun.) Pant. v. *sigmata* (Pant.) A.Cl.
				Cymbella laevis Naeg.
				Cymbella tumida (Breb.) Van Heurek.
				Cymbella turgida (Greg.) Cleve
				Cymbella ventricosa Kuetz.
			Gomphonemaceae	*Gomphonema aequatoriale* Hustedt
				Gomphonema gracile Ehr. v. *intricatiforme* Mayer
				Gomphonema gracile Ehr. v. *frickei* Gandhi
				Gomphonema lacus-rankala Gandhi v. *gracilis* Gandhi
				Gomphonema montanum Schum. v. *acuminatum* mayer
				Gomphonema parvulum (Kuetz.) Grun.
				Gomphonema subapicatum Fritsch et Rich
			Epithemiaceae	*Rhopalodia gibba* (Ehr.) Muell.
			Nitzschiaceae	*Hantzschia amphioxys* (Ehr.) Gru.
				Hantzschia amphioxys (Ehr.) Gru. v. *pusilla* Dippel
				Hantzschia linearis (O.Muell.) A. Cl.
				Nitzschia apiculata (Greg.) Grun.
				Nitzschia closterium W. Smith
				Nitzschia intermedia Hantzsch

Division	Class	order	Family	Species
				Nitzschia obtusa W. Smith
				Nitzschia obtusa W. Smith v. *scalpelliformis* Grun.
				Nitzschia philippinarum Hustedt
				Nitzschia sublinearis Hustedt
			Surirellaceae	*Surirella biseriata* Breb.
				Surirella capronioides Ghandi
				Surirella robusta Ehr.
				Surirella tenera Greg. var. *ambigua* Gandhi
				Surirella tenera Greg. var. *nervosa* A. S.
Euglenophyta	Euglenophyceae	Euglenales	Euglenaceae	*Euglena acus* Ehr.
				Euglena agilis Carter
				Euglena acus Ehrenberg var. *acus* (Starmach)
				Euglena anabaena Mainx var. *anabaena* Ehr.
				Euglena archeoplastidiata Chadefaud
				Euglena chlamydophora Main
				Euglena deses fo. *deses* (Pringsheim
				Euglena deses fo. *intermedia* Klebs
				Euglena deses fo. *klebsii* (Lemmermann) Popova
				Euglena ettlii Wolowski
				Euglena fusca (Klebs) Lemm.
				Euglena gracilis Klebs
				Euglena hemichromata Skuja
				Euglena oxyuris Schmarda fo. *Oxyuris* Popova
				Euglena oxyuris Schmarda var. *charkowiensis* (Swirenko)
				Euglena oxyuris Schmarda var. *playfairii* Bourrelly
				Euglena oxyuris Schmarda var. *minor* Prescott
				Euglena polymorpha Dangeard
				Euglena proxima Dangeard
				Euglena rustica Schiller var. *rustica* (Huber-Pestalozzi)
				Euglena sanguinea Ehrenberg (Pringsheim)
				Euglena sp. 1

Division	Class	order	Family	Species
				Euglena sp. 2
				Euglena spirogyra Ehr. var. *spirogyra* Klebs
				Euglena spirogyra Ehr.
				Euglena splendens Dangeard (Pringsheim)
				Euglena tripteris (Dujardin) Klebs var. *tripteris*
				Euglena texta (Dujardin) Hubner var. *texta* (starmach)
				Euglena viridis Ehrenberg fo. *Viridis* (popova)
				Phacus anacoelus Stokes
				Phacus curvicauda Swirenko
				Phacus lefevrei Bourelly in Bourelly et Mangui
				Phacus orbicularis Huebner
				Phacus orbicularis fo. *communis* Popov
				Phacus orbicularis Hubner fo. *orbicularis*
				Phacus pseudoswirenkoi Prescott
				Phacus splendens Pochmann
				Phacus sp.1
				Phacus sp.2
				Phacus stokesii Lemmermann
				Phacus tortus (Lemm) Skvortzov
				Phacus viguieri Allorge & lefevre
				Lepocinclis fusiformis (Carter) Lemm. Emend. Conrad
				Lepocinclis ovum (Ehr.) Minikiewic var. *ovum* Starmach
				Lepocinclis playfairiana Deflandre
				Trachelomonas abrupta (Swir.) Deflandre
				Trachelomonas armata (Ehr.) Stein.
				Trachelomonas armata (Ehr.) Stein. var. *longispina* (Playf.) Defl.
				Trachelomonas caudata (Ehrenberg) stein fo. *caudata* (Starmach)
				Trachelomonas dybwoskii Drezepolski ex Deflandre
				Trachelomonas globularis (Awerincew) Lemmermann fo. *globularis*
				Trachelomonas granulosa Playfair

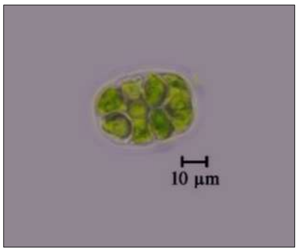
Division	Class	order	Family	Species
				Trachelomonas hispida (Perty) Stein emend. Defl.
				Trachelomonas lacustris Drezepolski
				Trachelomonas lacustris Drez. var. *klebsii* (Deflandre) Popova
				Trachelomonas planctonica fo. *ornata* Skvortzov
				Trachelomonas planctonica Swirenko fo. *planctonica*
				Trachelomonas pulcherrima Playf. var. *minor* Playf.
				Trachelomonas robusta Swirenko
				Trachelomonas sp.1
				Trachelomonas superba var. *duplex* Deflandre
				Trachelomonas superba var. *Swirenkiana* Deflandre
				Trachelomonas varians Deflandre
				Trachelomonas volvocina Ehr.
				Trachelomonas volvocinopsis Swirenko
				Strombomonas fluviatilis (Lemm.) Defl.
				Strombomonas girardiana (Playf.) Defl.
				Strombomonas gibberosa (Playf.) Defl.
				Strombomonas sp.1
Pyrrhophyta	Dinophyceae	Peridiniales	Glenodiniaceae	*Peridiniopsis quadridens* (Stein) Schiller
Cyanophyta	Cyanophyceae	Chroococcales	Chroococcaceae	*Microcystis aeruginosa* (Kuetz.) Kuetzing
				Chroococcus minimus (Keissler) Lemm.
				Chroococcus minutus (Kuetz.) Nag.
				Chroococcus turgidus (Kuetz.) Nag.
				Aphanocapsa delicatissima West & west
				Merismopedia elegans A.Braun
				Merismopedia elegans A.Braun var. *major* G.M.Smith
				Merismopedia tenuissima Lemmermann
		Oscillatoriales	Pseudanabaenaceae	*Pseudoanabaena galeata* Bocher
				Spirulina major Kutzing ex Gomont
				Spirulina nordstedtii Gomont
				Spirulina subsalsa Oersted ex Gomont
			Phormidiaceae	*Arthrospira khannae* Drouet et Strickland

Division	Class	order	Family	Species
				Phormidium articulatum Anagnostidis et Komarek
				Phormidium formosum Anagnostidis et Komarek
				Planktothrix sp. 1
				Oscillatoria limosa Agardh ex Gomont
				Oscillatoria lutea Agardh ex Gomont
				Oscillatoria meslinii Anagnostidis et Komarek
				Oscillatoria princeps Vaucher ex Gomont
				Oscillatoria sp. 2
			Nostocaceae	*Dolichospermum perturbatum* (Hill) Wacklin
				Anabaena ghosei Welsh
				Anabaena sp.1

Division: Chlorophyta
Class : Chlorophyceae
Order : Volvocales
Family : Volvocaceae

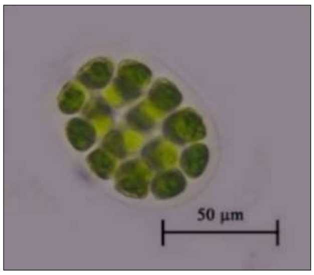
Genus: *PANDORINA* bory

1. ***Pandorina morum*** (O.F. Müller) Bory
Iyengar and Desikachary, 1981. p. 418, pl. 243, fig. 7



Dimensions:
Colony length - 45µm
Colony breadth - 26µm
Comments:
Colonies spherical, 8 celled, within a Common matrix, cells ovate and tightly packed.

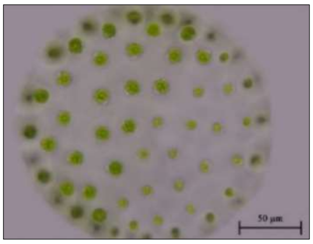
2. ***Pandorina morum*** (Mull.) Bory f. ***major*** M.O.P.Iyengar
Iyengar and Desikachary, 1981. p. 418, pl. 243, figs. 1-15



Dimensions:
Colony length - 75µm
Colony breadth - 56µm
Comments:
Colonies ellipsoidal with rounded ends, chloroplast with pyrenoids.

Genus: *PLEODORINA* Shaw

3. ***Pleodorina sphaerica*** M.O.P.Iyengar
Iyengar and Desikachary, 1981. p. 446, pl. 262, figs. 1–7

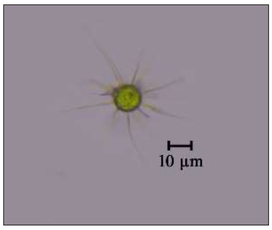


Dimensions:
Colony breadth - 182µm
Comments:
Colonies spherical, 64 celled, young colonies in posterior side and mature colonies in anterior.

Order : Chlorococcales
Family : Micractiniaceae

Genus: *GOLENKINIA* Chodat

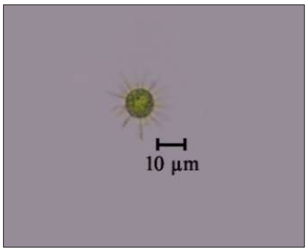
4. ***Golenkinia paucispina*** West. & G.S.West
Smith, 1920. p. 127, fig. 5



Dimensions:
Cell breadth – 12µm
Setae length – 8µm
Comments: Cells solitary, spherical with short tapering delicate setae.

Genus: *GOLENKINIOPSIS* Korshikov

5. *Golenkiniopsis minutissima* (Iyengar et Balkr.) R.Starr
Philipose, 1967. p. 103, fig. 28a

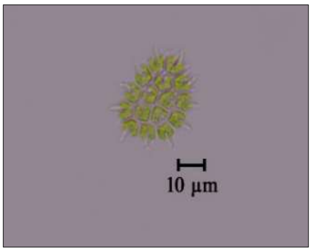


Dimensions:
Cell breadth - 9µm
Setae length - 8µm
Comments:
Cells solitary, spherical bearing several fine setae.

Family: Hydrodictyaceae

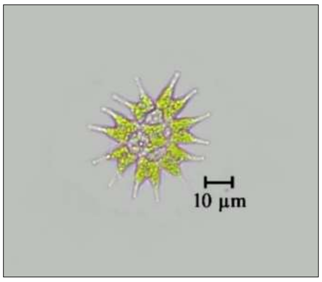
Genus: *PEDIASTRUM* Meyen

6. *Pediastrum biradiatum* (Meyen) E.Hegewald
Philipose, 1967. p. 127, fig. 44



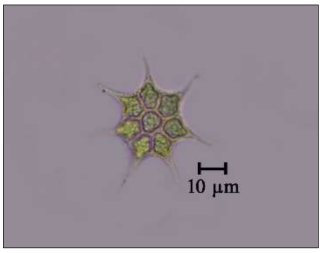
Dimensions:
Colony length - 34µm
Colony breadth - 28µm
Cell breadth - 9µm
Comments:
Colonies with 16 celled, intercellular spaces, Lobes dilated at apex and ending in horn like processes.

7. *Pediastrum boryanum* var. ***longicorne*** (Reinsch) Tsarenko
Philipose, 1967. p. 119, fig. 40b



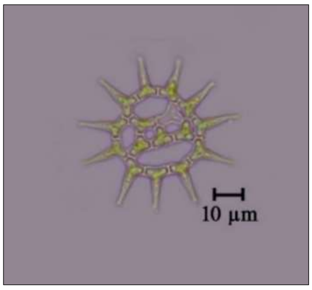
Dimensions:
Colony length - 48µm
Cell breadth - 7µm
Comments:
Colonies 8 celled, each cell with two short processes ending with short spines.

8. *Pediastrum simplex* Meyen
Philipose, 1967. p. 115, fig. 36c



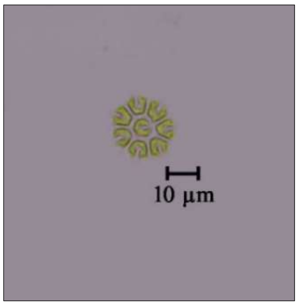
Dimensions:
Colony length - 49µm
Cell breadth - 9µm
Comments:
Colonies 8 celled, outer side produced in to tapering process, cells without intercellular spaces, cell walls granulated.

9. ***Pediastrum simplex*** var. ***duodenarium*** (Bailey) Rabenhorst
Philipose, 1967. p. 115, fig. 36 d



Dimensions:
Colony length - 52µm
Cell breadth - 9µm
Comments: Colonies with 4 celled, cells without intercellular spaces, cell wall smooth.

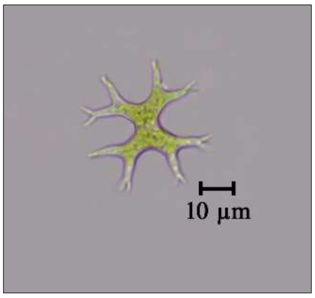
10. ***Pediastrum tetras*** (Ehr.) Ralfs
Philipose, 1967. p. 128, fig. 45 b



Dimensions:
Colony length - 17µm
Cell breadth - 5µm
Comments:
Colonies with 8 celled, cells divided into Two lobes make incision on outer side of the cell reach to middle of the cell.

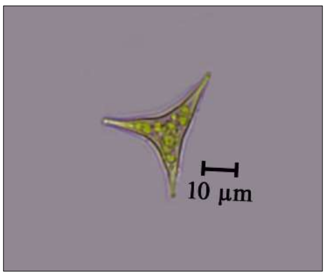
Genus: ***TETRAEDRON*** Kuetzing

11. ***Tetraedron gracile*** (Reinsch) Hansgirg
Philipose, 1967. p. 154, fig. 69a



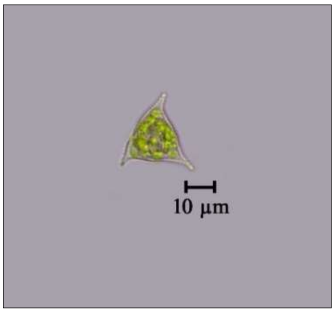
Dimensions:
Cell length - 23µm
Cell breadth -32µm
Comments:
Cells rectangular with the corners produced into narrow processes branch twice and end in spines.

12. ***Tetraedron proteiforme*** (Turn.) Brunnthaler
Philipose, 1967. p. 141, fig. 57



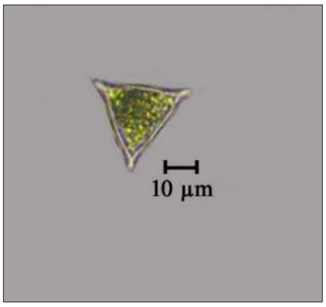
Dimensions:
Cell breadth -30µm
Comments:
Cells 3 cornered, angles drawn out and ending in long spine.

13. ***Tetraedron regulare*** var. ***granulatum*** Prescott
Philipose, 1967. p. 147, fig. 60i



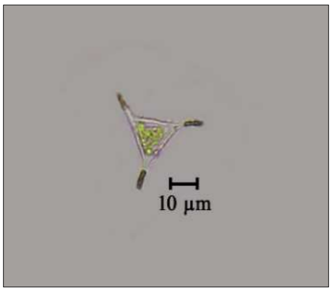
Dimensions:
Cell breadth -28µm
Comments:
Cell wall granular, angles broadly rounded with short spines.

14. ***Tetraedron regulare*** var. ***minus*** Reinsch
Philipose, 1967. p. 146, fig. 60h



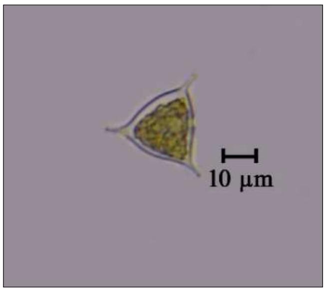
Dimensions:
Cell breadth -25µm
Comments:
Cells tetragonal with long spine on each corner.

15. ***Tetraedron trigonum*** (Naegeli) Hansgirg
Philipose, 1967. p. 142, fig. 58i



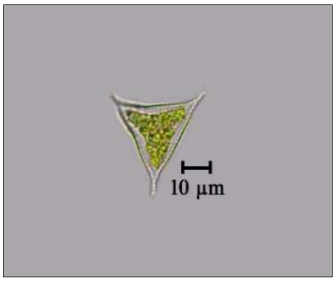
Dimensions:
Cell breadth -16µm
Spine length - 9µm
Comments:
Cells triangular, rounded corners, angles with a stout spine.

16. ***Tetraedron trigonum*** f. ***crassum*** (Reinsch) De Toni
Philipose, 1967. p. 142, fig. 58e



Dimensions:
Cell breadth - 18µm
Spine length - 6µm
Comments:
Cells triangular, rounded corners, angles with short spines.

17. ***Tetraedron trigonum*** var. ***verrucosum*** Jao
Philipose, 1967. p. 145, fig. 58n

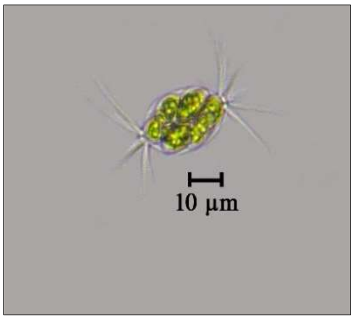


Dimensions:
Cell breadth -25µm
Spine length -7µm
Comments:
Cells triangular, angles with a short spine, cell membrane and spines irregularly granulated.

Family: Oocystaceae

Genus: *LAGERHEIMIA* Chodat

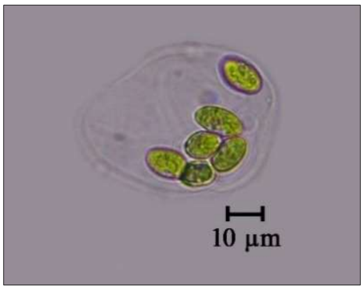
18. ***Lagerheimia ciliata*** (Lag.) Chodat
Prescott, 1982. p. 250, pl. 55, fig. 1



Dimensions:
Cell length - 23µm
Cell breadth -15µm
Setae length -15µm
Comments:
Cells oblong-ovate with setae at each pole, chloroplast with pyrenoids.

Genus: *OOCYSTIS* Naegeli

19. ***Oocystis borgei*** J.W.Snow
Prescott, 1951. p. 244, pl. 51, fig. 10

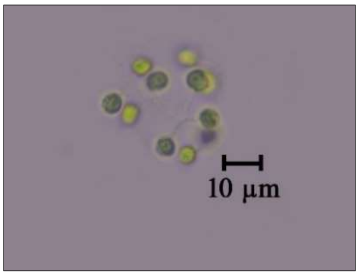


Dimensions:
Cell length - 12µm
Cell breadth -9µm
Comments:
Cells ellipsoid, ovate, enclosing envelope round.

Family: Dictyosphaeriaceae

Genus: *DICTYOSPHAERIUM* Naegeli

20. ***Dictyosphaerium ehrenbergianum*** Nageli
Philipose, 1967. p. 201, fig. 111

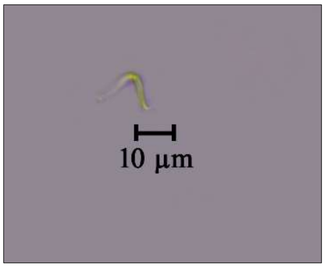


Dimensions:
Colony length - 38µm
Cell length - 4µm
Comments:
Colonies spherical, cells ovoid, chloroplast one or two in each cell.

Family: Selenastraceae

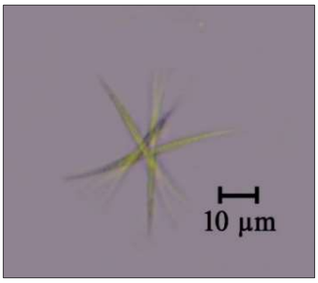
Genus: *ANKISTRODESMUS* Corda

21. *Ankistrodesmus convolutus* (Corda)
Philipose, 1967. p. 213, fig. 122 d



Dimensions:
Cell length - 3µm
Cell breadth -1.5µm
Comments:
Cells solitary, curved, ends pointed.

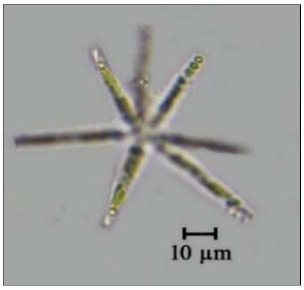
22. *Ankistrodesmus falcatus* (Corda) Ralfs
Philipose, 1967. p. 211, fig. 121 a



Dimensions:
Cell length - 50µm
Cell breadth -2µm
Comments:
Cells curved, twisted around one another, apices free, with tapering end.

Genus: *ACTINASTRUM* Lagerheim

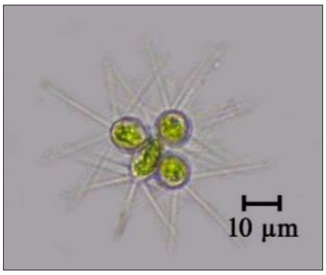
23. *Actinastrum gracillimum* var. ***elongatum*** (G.M.Smith) Fott
Philipose, 1967. p. 218, fig. 125 d



Dimensions:
Cell length - 35µm
Cell breadth -3µm
Comments:
Colonies 8 celled, cells radially arranged joined together to form colonies and apices slightly rounded.

Genus: *MICRATINIUM* Fresenius

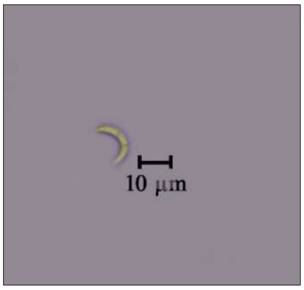
24. *Micratinium pusillum* var. ***elegans*** G.M.Smith
Prescott, 1951. p. 288, pl. 66, fig. 7



Dimensions:
Cell length - 9µm
Cell breadth -7µm
Setae - 20µm
Comments:
Colonies 4 celled, cells rounded, setae long, Associated with other cells.

Genus: *MESSASTRUM* Reinsch

25. ***Messastrum gracile*** (Reinsch) T.S Garcia
Philipose, 1967. p. 219, fig. 128

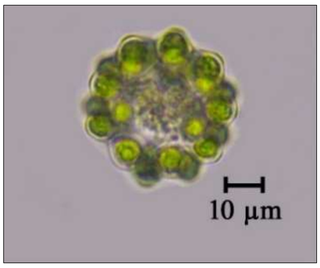


Dimensions:
Cell length - 13µm
Cell breadth -3µm
Comments:
Cells broad, sickle shaped, lunate, apices of cells acute.

Family: Coelastraceae

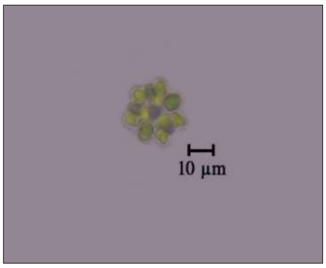
Genus: *COELASTRUM* Naegeli

26. ***Coelastrum microporum*** Nageli
Philipose, 1967. p. 228, fig. 135



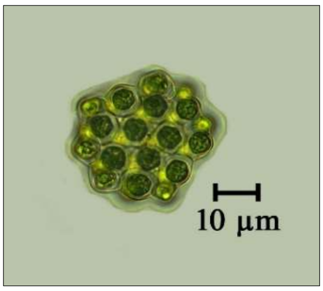
Dimensions:
Colony length - 37µm
Cell breadth -7µm
Comments:
Colonies spherical, cells spherical with small intercellular spaces.

27. ***Coelastrum proboscideum*** Bohlin
Philipose, 1967. p. 229, fig. 137



Dimensions:
Cell length - 5µm
Colony breadth -25µm
Comments:
Cells conical, truncate with intercellular spaces.

28. ***Coelastrum sphaericum*** Nageli
Philipose, 1967. p. 229, fig. 136

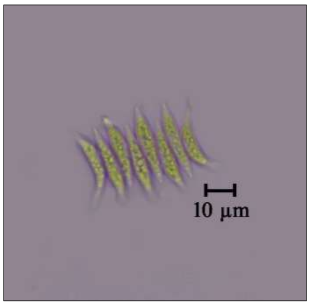


Dimensions:
Colony breadth - 31µm
Cell breadth -7µm
Comments:
Cells ovoid, narrow end directed outwards, colony spherical, cells regularly arranged.

Family: Scenedesmaceae

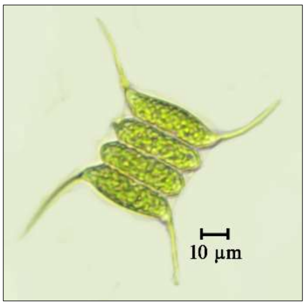
Genus: *SCENEDESMUS* Meyen

29. ***Scenedesmus acuminatus*** (Lagerheim) Chodat
Philipose, 1967. p. 251, fig. 161



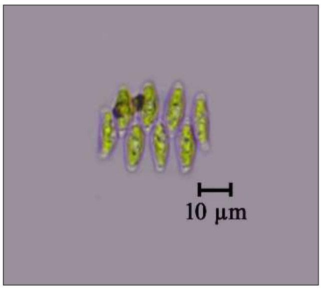
Dimensions:
Cell length - 25µm
Cell breadth - 2µm
Comments:
Colonies 8 celled, cells fusiform with sharp pointed ends, apical cell lunate shaped, cell wall smooth.

30. ***Scenedesmus carinatus*** (Lemm.) Chodat
Philipose, 1967. p. 266, fig. 172c



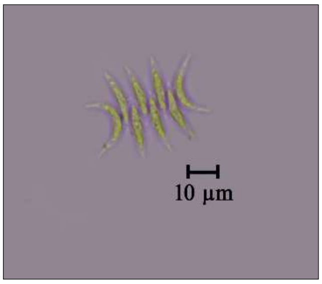
Dimensions:
Cell length - 25µm
Cell breadth - 9µm
Spine length - 17µm
Comments:
Colonies 4 celled, cells arranged in series, fusiform with pointed ends, spines of terminal cells long.

31. ***Scenedesmus bijugatus*** var. ***graevenitzii*** (Bernard) Philippose
Philipose, 1967. p. 256, figs. 164 h, j



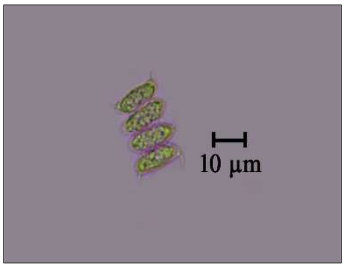
Dimensions:
Cell length - 11µm
Cell breadth - 6µm
Comments:
Colony 8 celled, cells arranged in alternating series, adjacent cells contact only through small portion of their length.

32. ***Scenedesmus dimorphus*** (Turp.) Kützing
Philipose, 1967. p. 249, fig. 160a



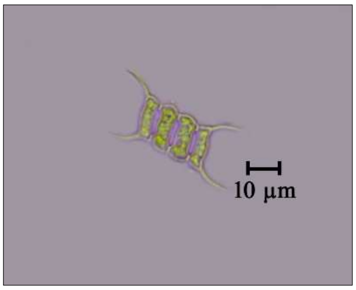
Dimensions:
Cell length - 25µm
Cell breadth -3µm
Comments:
Colonies 8 celled, apical cells lunate shaped, individual cells with tapering ends.

33. ***Scenedesmus magnus*** Meyen
Philipose, 1967. p. 273, fig. 180a



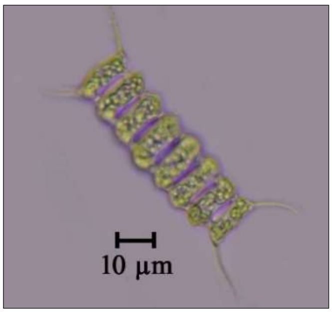
Dimensions:
Cell length - 21µm
Cell breadth - 4µm
Spine length - 1.5µm
Comments:
Colony 4 celled, cells ovoid with rounded ends, poles with spines.

34. ***Scenedesmus perforatus*** Lemm.
Philipose, 1967. p. 280, fig. 186 a



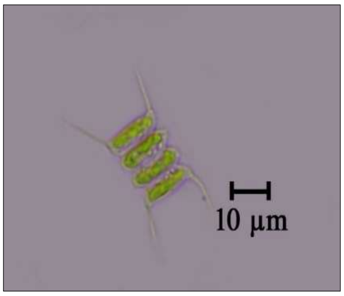
Dimensions:
Cell length - 25µm
Cell breadth - 5µm
Spine length - 10µm
Comments:
Colony 4 celled, cells with perforations And long spines.

35. ***Scenedesmus perforatus*** var. ***major*** (Turn.) Philipose
Philipose, 1967. p. 282, fig. 186 f



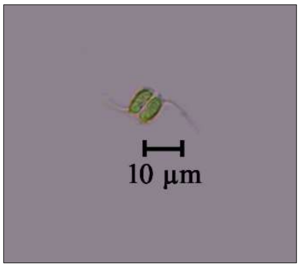
Dimensions:
Cell length - 36µm
Cell breadth - 10µm
Spine length - 22µm
Comments:
Colony 8 celled, cells with perforations 1µm broad, spines long, small perforations between adjacent cells with long spines.

36. ***Scenedesmus quadricauda*** Chodat
Philipose, 1967. p. 283, fig. 187 h



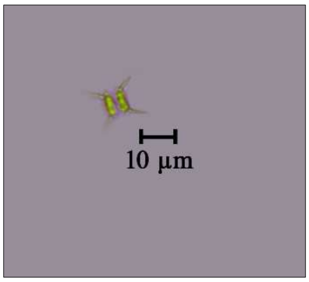
Dimensions:
Cell length - 11µm
Cell breadth - 8µm
Spine length - 9µm
Comments:
Colonies 4 celled, cells cylindrical with rounded ends, cell wall smooth with spines.

37. ***Scenedesmus quadricauda*** var. ***bicaudatus*** Hansgirg
Philipose, 1967. p. 284, fig. 187 k



Dimensions:
Cell length - 12µm
Cell breadth - 4µm
Spine length - 7µm
Comments:
Colonies 2 celled, cells with long spine from one pole only.

38. ***Scenedesmus quadricauda*** var. ***quadrispina*** (Chodat) G. M. Smith
Philipose, 1967. p. 285, fig. 187 h



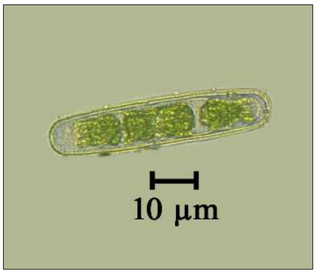
Dimensions:
Cell length - 11µm
Cell breadth - 6µm
Spine length - 3µm
Comments:
Colonies 2 celled, cells spherical, cell wall smooth, poles with short spines.

DESMIDS

Family: Gonatozygaceae

Genus: *CYLINDROCYSTIS* Meneghini

39. ***Cylindrocystis brebissonii*** (Ralfs) De Bary
Scott and Prescott, 1961. p. 8, pl. 1, fig. 3

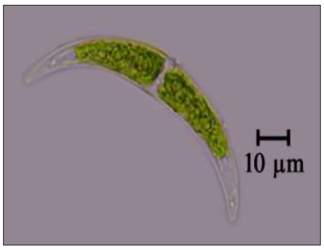


Dimensions:
Cell length - 50µm
Cell breadth - 11µm
Comments:
Cells cylindrical with large chloroplast.

Family: Desmidiaceae

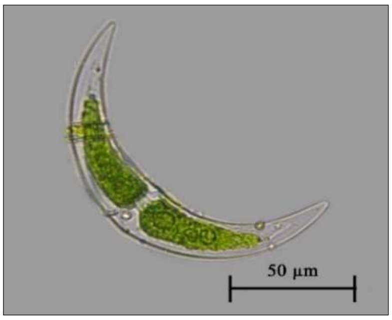
Genus: *CLOSTERIUM* Nitzsch

40. ***Closterium dianae*** var. ***minus*** Hieronyms
Scott and Prescott, 1961. p. 11, pl. 2, fig. 8.



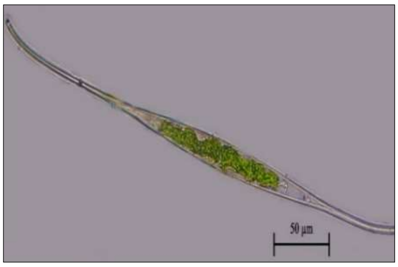
Dimensions:
Cell length - 100µm
Cell breadth - 10µm
Comments:
Cells slightly curved, attenuated at apices, apex 4µm.

41. ***Closterium ehrenbergii*** Menegh. ex Ralfs
West and West, 1904. vol. 1, p. 143, pl. 17, fig. 1



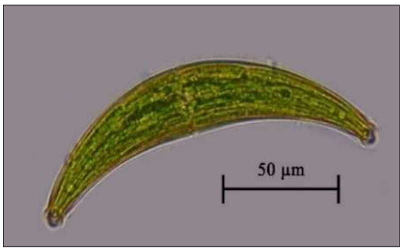
Dimensions:
Cell length - 472µm
Cell breadth - 69µm
Comments:
Cells large, curved, inner margin slightly inflated in the middle region, cell wall smooth and contain many scattered pyrenoids.

42. ***Closterium kuetzingii*** Brebisson
West and West, 1904. vol. 1, p. 186, pl. 25, figs. 6–11



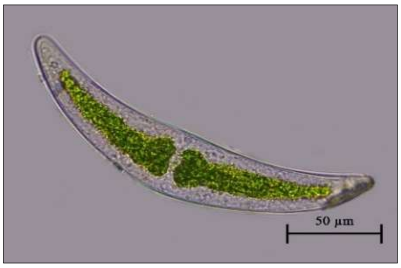
Dimensions:
Cell length - 54µm
Cell breadth - 12µm
Comments:
Cells medium size, straight, median part of the cells fusiform, lanceolate, apex 4µm.

43. ***Closterium lagoense*** Nordst.
West and West, 1904. vol. 1, p. 114, pl. 11, fig. 6



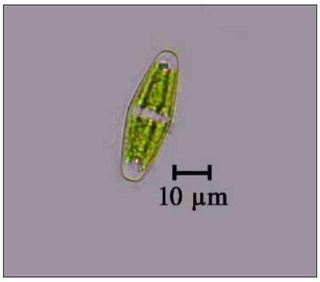
Dimensions:
Cell length - 155µm
Cell breadth - 25µm
Comments:
Cells medium size, narrowed to apices, straight, apex 6µm.

44. ***Closterium moniliferum*** Ehr. ex Ralfs
West and West, 1904. vol. 1, p. 142, pl. 16, fig. 16



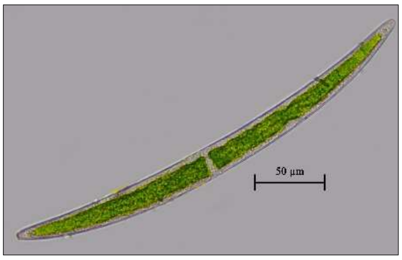
Dimensions:
Cell length – 328µm
Cell breadth - 40µm
Comments:
Cells narrowed towards the apex, cell wall smooth and colourless, poles 9µm.

45. ***Closterium navicula*** Breb. Lukemuller
West and West, 1904. vol. 1, p. 75, pl. 7, fig. 14



Dimensions:
Cell length - 35µm
Cell breadth - 12µm
Comments:
Cells small, fusiform, poles rounded, cell wall smooth and colourless.

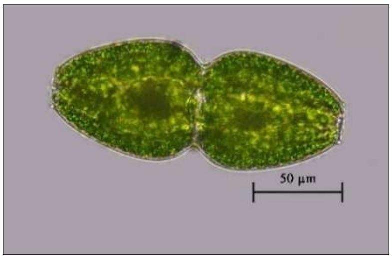
46. ***Closterium peracerosum*** F.Gay
West and West, 1904. vol. 1, p. 154, pl. XIX, figs. 9



Dimensions:
Cell length - 300µm
Cell breadth - 17µm
Comments:
Cells slightly curved, cell wall smooth, colourless, broad, chloroplasts with ridges and pyrenoids.

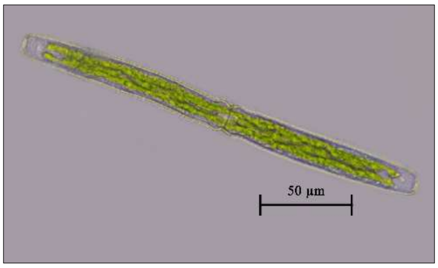
Genus: *PLEUROTAENIUM* Nageli

47. ***Pleurotaenium ovatum*** Nordst. (Nordst.)
Scott and Prescott, 1961. p. 17, pl. 6, fig. 2



Dimensions:
Cell length - 325µm
Cell breadth - 80µm
Comments:
Cells bearing a ring of tubercles, isthmus 46µm, pole 28µm,

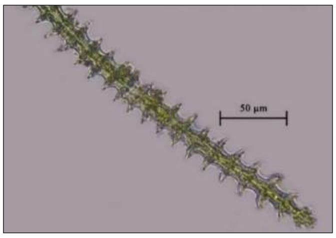
48. ***Pleurotaenium trabecula*** var. ***rectum*** (Delp.) West et West
West and West, 1904. vol. 1, p. 212, pl. 30, fig. 10



Dimensions:
Cell length - 225µm
Cell breadth - 20µm
Comments:
Cells medium size, semicells without undulations above the basal inflations, poles 14µm, isthmus 16µm.

Genus: *TRIPLOCERAS* Bailey

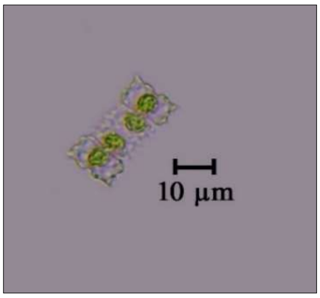
49. *Triploceras gracile* f. ***undulatum*** (Scott & Prescott)Townsend
Scott and Prescott, 1961. p. 21, pl. 6, fig. 9



Dimensions:
Cell length - 360µm
Cell breadth - 19µm
Comments:
Cells with apex 14µm.

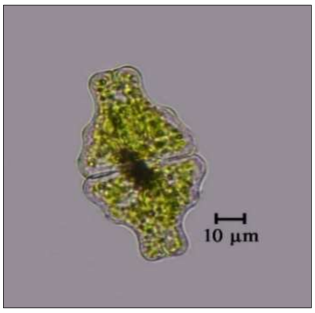
Genus: *EUASTRUM* Ehrenberg

50. *Euastrum gayanum* De Toni
Scott and Prescott, 1961. p. 27, pl. 14, fig. 3



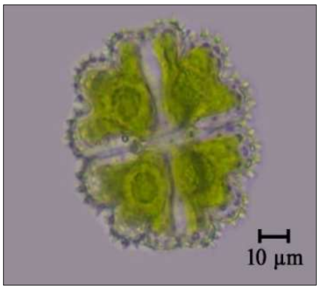
Dimensions:
Cell length – 10.5µm
Cell breadth - 3µm
Isthmus - 3.5µm
Comments:
Cells smaller type, semicells are parallel with swellings.

51. *Euastrum sinuosum* Kützing
West and West, 1905. vol. 2, p. 20, pl. 36, fig. 1



Dimensions:
Cell length - 75µm
Cell breadth - 43µm
Isthmus - 13µm
Comments:
Cells medium size, lower and upper lobes lying above one another.

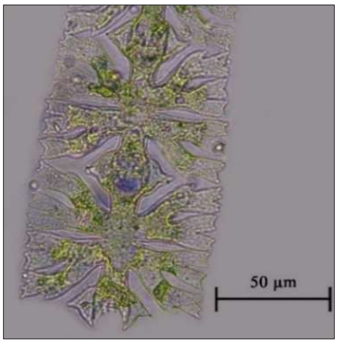
52. *Euastrum spinulosum* Delponte
Scott and Prescott, 1961. p. 40, pl. 10, fig. 3



Dimensions:
Cell length - 61µm
Cell breadth - 49µm
Isthmus - 13µm
Comments:
Cells wide and larger, widely rounded lobes, rosette shape.

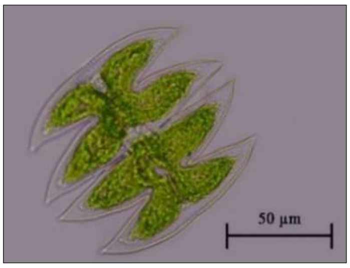
Genus: *MICRASTERIAS* Agardh

53. ***Micrasterias foliacea*** Bail. ex ralfs
Scott and Prescott, 1961. p. 48, pl. 20, fig. 4



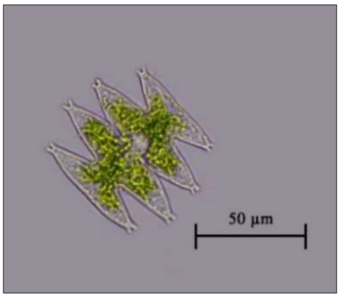
Dimensions:
Cell length - 75µm
Cell breadth - 76µm
Comments:
Cells broad and leaf like form and lobed.

54. ***Micrasterias laticeps*** var. ***acuminata*** W. Krieger
Turner, 1892. P. 95. pl. 5, fig. 2



Dimensions:
Cell length - 90µm
Cell breadth - 88µm
Comments:
Cells possess acuminate instead of 2-denticulate basal lobes.

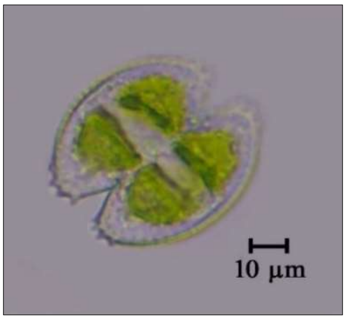
55. ***Micrasterias pinnatifida*** Ralfs
Scott and Prescott, 1961. p. 51, pl. 12, fig. 6



Dimensions:
Cell length - 60µm
Cell breadth - 64µm
Comments:
Cells with end margin straight,
lobes triangular, cells bifid projecting above the apical margin.

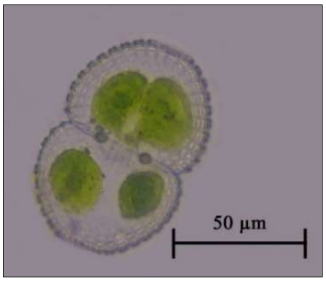
Genus: *COSMARIUM* Corda

56. ***Cosmarium auriculatum*** Reinsch
Scott and Prescott, 1961. p. 54, pl. 26, fig. 4



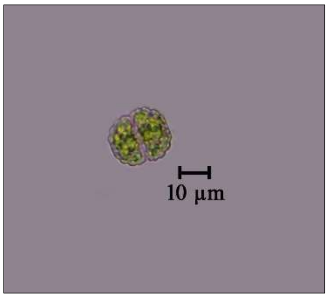
Dimensions:
Cell length - 42µm
Cell breadth - 38µm
Isthmus - 21µm
Comments:
Cells granulate and deeply constricted.

57. ***Cosmarium binum*** Nordst.
West and West, 1908. vol. 3, p. 246, pl. 88, fig. 11



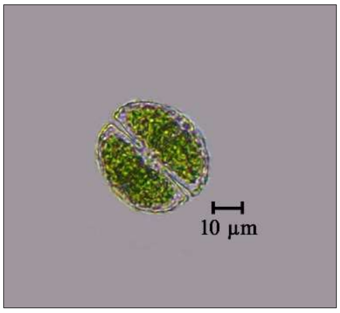
Dimensions:
Cell length - 83µm
Cell breadth - 50µm
Isthmus - 13µm
Comments:
Cell margins granulate, granules arranged in concentric rings.

58. ***Cosmarium blyttii*** Wille
Scott and Prescott, 1961. p. 55, pl. 31, fig. 15



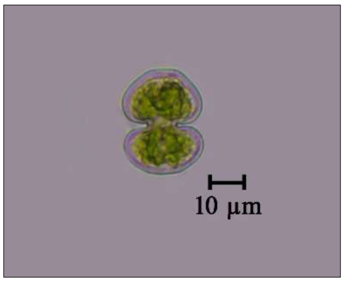
Dimensions:
Cell length - 19µm
Cell breadth - 15µm
Isthmus - 5µm
Comments:
Cells very small, crenate, wall margins wavy.

59. ***Cosmarium depressum*** (Nag.) Lund.
Scott and Prescott, 1961. p. 58, pl. 26, fig. 6



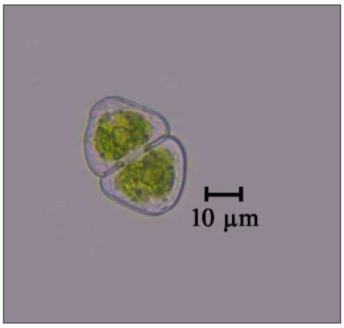
Dimensions:
Cell length - 35µm
Cell breadth - 32µm
Isthmus - 7µm
Comments:
Cells lunar shaped and margins with crenations.

60. ***Cosmarium depressum*** var. ***apertum*** (Turn.) Hirano
Scott and Prescott, 1961. p. 58, pl. 26, fig. 7



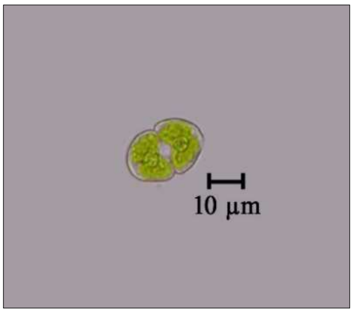
Dimensions:
Cell length - 26µm
Cell breadth - 21µm
Isthmus - 6µm
Comments:
Cell wall smooth, thick and deeply constricted.

61. ***Cosmarium granatum*** Breb. ex Ralfs
West and West, 1905. vol. 2, p. 186, pl. 63, fig. 3



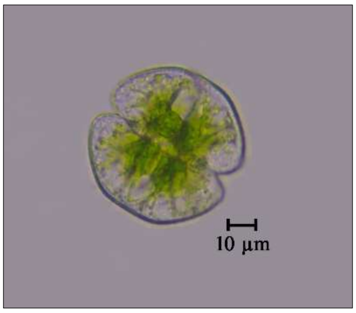
Dimensions:
Cell length - 35µm
Cell breadth - 25µm
Isthmus - 9µm
Comments:
Cells pyramidate shaped, sinus narrow and slightly dilated.

62. ***Cosmarium granatum*** var. ***rotundatum*** W. Krieg.
Scott and Prescott, 1961. p. 59, pl. 27, fig. 17



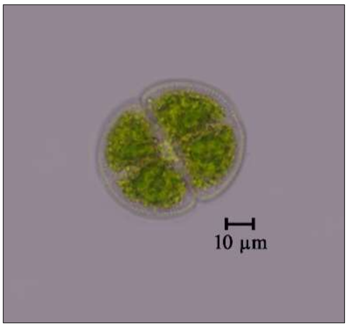
Dimensions:
Cell length - 24µm
Cell breadth - 14µm
Isthmus - 6µm
Comments:
Cells small with central dilation, semiells with single pyrenoids.

63. ***Cosmarium lundellii*** Delp.
Scott and Prescott, 1961. p. 60, pl. 25, fig. 6



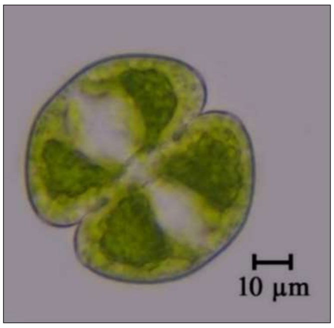
Dimensions:
Cell length - 75µm
Cell breadth - 56µm
Isthmus - 31µm
Comments:
Cells with granulations, sinus narrow and constricted, rounded at apex.

64. ***Cosmarium lundellii*** var. ***circulare*** (Reinsch) W. Krieg.
Scott and Prescott, 1961. p. 60, pl. 25, fig. 7



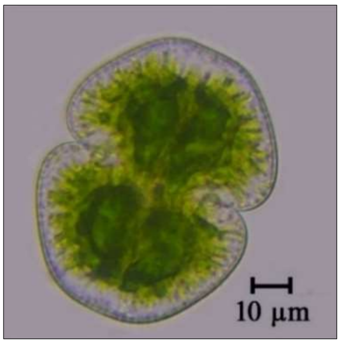
Dimensions:
Cell length - 61µm
Cell breadth - 50µm
Isthmus - 14µm
Comments:
Semicells circular in shape, cell wall smooth and simple.

65. ***Cosmarium lundellii*** var. ***corruptum*** (Turn.) West & West
Scott and Prescott, 1961. p. 61, pl. 25, fig. 9



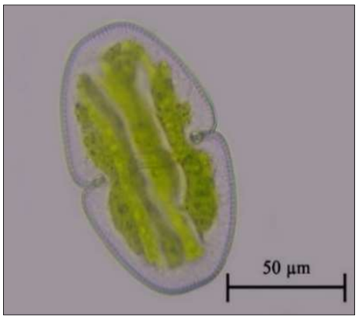
Dimensions:
Cell length - 59µm
Cell breadth - 51µm
Isthmus - 14µm
Comments:
Cells with convex apical margins, cell wall smooth, simple and closely punctate.

66. ***Cosmarium galeritum*** Nordst.
West and West, 1912. vol. 4, p. 194, pl. 63, fig. 25



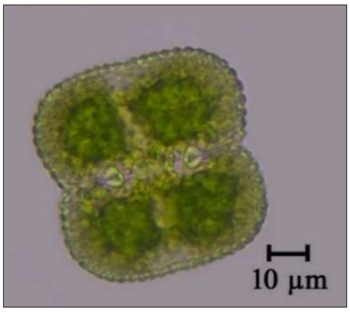
Dimensions:
Cell length - 59µm
Cell breadth - 51µm
Isthmus - 12µm
Comments:
Cells truncate-pyramidate, cell wall smooth and simple.

67. ***Cosmarium maculatum*** Turn.
Scott and Prescott, 1961. p. 61, pl. 24, fig. 2



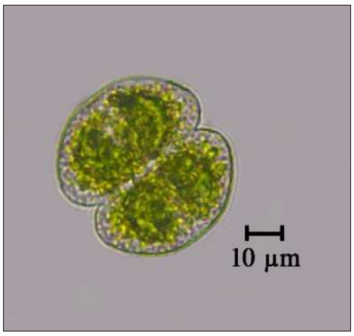
Dimensions:
Cell length - 175µm
Cell breadth - 71µm
Isthmus - 46µm
Comments:
Cells larger in size, with granulations, cell wall striated.

68. ***Cosmarium margaritatum*** var. ***sublatum*** (Nordst.) Krieg.
Scott and Prescott, 1961. p. 63, pl. 29, fig. 4



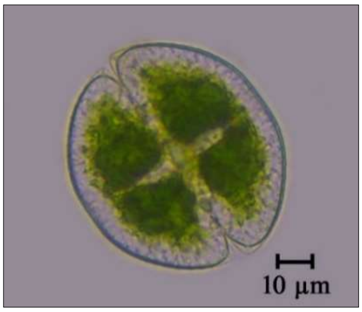
Dimensions:
Cell length - 61µm
Cell breadth - 54µm
Isthmus - 22µm
Comments:
Cells of medium size, sinus narrow and closed, cell wall granulated.

69. ***Cosmarium medioscrobiculatum*** var. ***egranulatum*** Gutw.
Scott and Prescott, 1961. p. 63, pl. 26, fig. 3



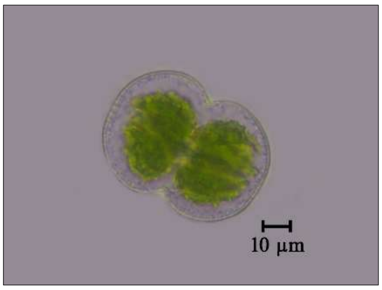
Dimensions:
Cell length - 48µm
Cell breadth - 45µm
Isthmus - 18µm
Comments:
Cells of medium size, rounded apex, sinus small.

70. ***Cosmarium obsoletum*** (Hantzsch) Reinsch
Scott and Prescott, 1961. p. 63, pl. 26, fig. 1



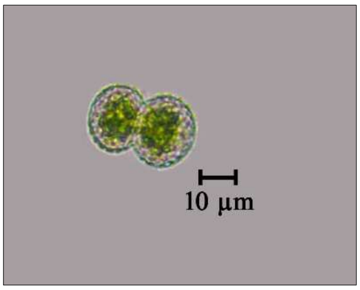
Dimensions:
Cell length - 52µm
Cell breadth - 60µm
Isthmus - 26µm
Comments:
Cells constricted with narrow sinus, granulate, apex in convex shape.

71. ***Cosmarium pseudoconnatum*** Nordst.
Scott and Prescott, 1961. p. 66, pl. 25, fig. 4



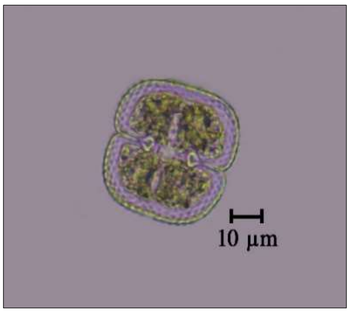
Dimensions:
Cell length - 61µm
Cell breadth - 47µm
Isthmus - 40µm
Comments:
Semicells circular, cell wall punctate, shallow sinus.

72. ***Cosmarium punctulatum*** var. ***subpunctulatum*** (Nordst.) Borg.
Scott and Prescott, 1961. p. 67, pl. 31, fig. 8



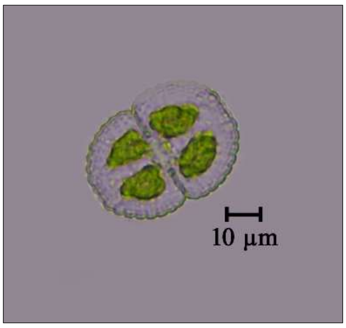
Dimensions:
Cell length - 25µm
Cell breadth - 23µm
Isthmus - 13µm
Comments:
Cells small, rounded, deeply constricted
With wavy margins.

73. *Cosmarium quadrum* P.Lundell
West and West, 1912. vol. 4, p. 20, pl. 100, fig. 4



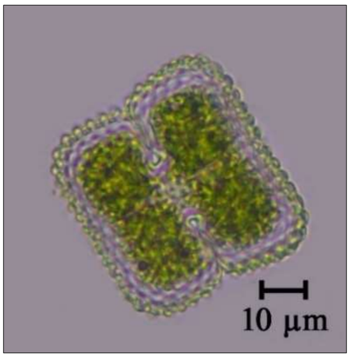
Dimensions:
Cell length - 52µm
Cell breadth - 51µm
Isthmus - 4µm
Comments:
Cells quadrate with deeply constricted, densely granulated.

74. *Cosmarium quadrifarium* P.Lundell
West and West, 1908. vol. 3, p. 141, pl. 76, figs. 15–17 & pl. 77, figs. 1–3



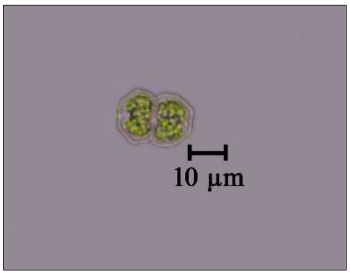
Dimensions:
Cell length - 42µm
Cell breadth - 32µm
Isthmus - 11µm
Comments:
Cells medium size, semicells semicircular and little rounded.

75. *Cosmarium scabrum* W.B.Turner
Scott and Prescott, 1961. p. 68, pl. 29, fig. 3



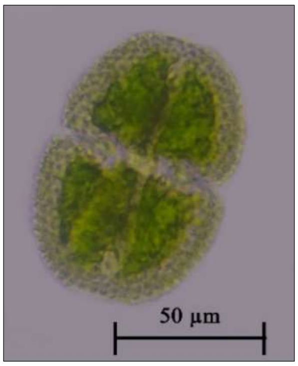
Dimensions:
Cell length - 49µm
Cell breadth - 52µm
Isthmus - 14µm
Comments:
Cells quadrate, cell wall margins granulated, sinus narrow and closed.

76. *Cosmarium sexangulare* P.Lundell
Scott and Prescott, 1961. p. 69, pl. 32, fig. 11



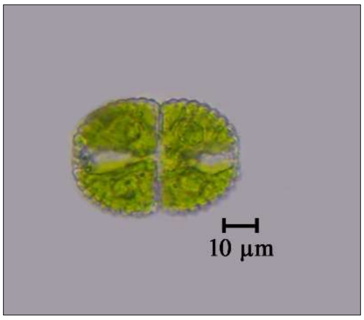
Dimensions:
Cell length - 18µm
Cell breadth - 12µm
Isthmus - 5µm
Comments:
Cells, cell wall margins smooth and wavy, sinus narrow.

77. ***Cosmarium subspeciosum*** var. ***validius*** Nordst.
West and West, 1908. vol. 3, p. 253, pl. 89, fig. 13



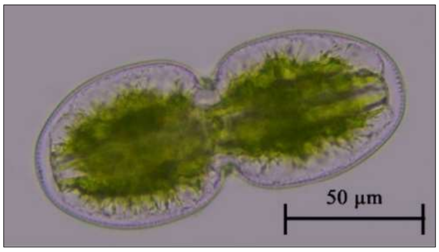
Dimensions:
Cell length - 90µm
Cell breadth - 62µm
Isthmus - 13µm
Comments:
Cells medium sized with crenations, presence of series of granules, margins also granulated.

78. ***Cosmarium subundulatum*** Wille
West and West, 1908. vol. 3, p. 151, pl. 59, fig. 14



Dimensions:
Cell length - 50µm
Cell breadth - 34µm
Isthmus - 14µm
Comments:
Cells with row of granules, cell wall margins smooth and two rows of undulations.

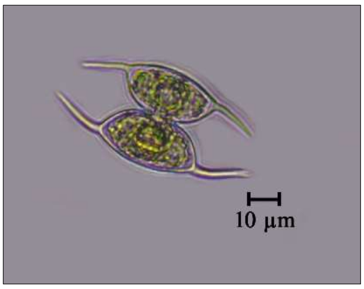
79. ***Cosmarium turgidum*** Breb. ex Ralfs
West and West, 1908. vol. 3, p. 115, pl. 75, fig. 3



Dimensions:
Cell length - 171µm
Cell breadth - 79µm
Isthmus - 38µm
Comments:
Cells large, semicells ovate with broad base, apex rounded.

Genus: *ARTHRODESMUS* Ehrenberg

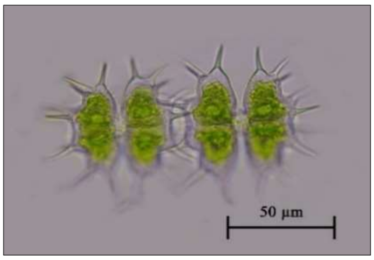
80. ***Arthrodesmus curvatus*** var. ***latus*** Scott and Prescott
Scott and Prescott, 1961. p. 76, pl. 33, fig. 7



Dimensions:
Cell length - 35µm
Cell breadth - 68µm
Isthmus - 12µm
Comments:
Cells medium size, angles acutely rounded with long spines.

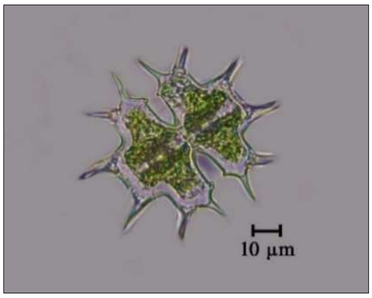
Genus: *XANTHIDIUM* Ehrenberg

81. ***Xanthidium sexmamillatum*** var. ***pulneyense*** Iyengar & Bai
Scott and Prescott, 1961. p. 84, pl. 39, fig. 2



Dimensions:
Cell length - 38µm
Cell breadth - 45µm
Isthmus - 18µm
Comments:
Cells broad with spine, spines 12µm long.

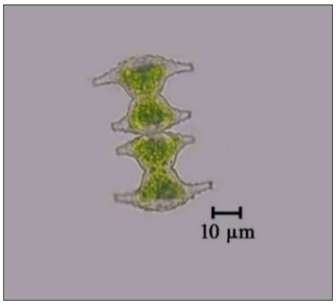
82. ***Xanthidium subtrilobum*** var. ***inornatum*** Skuja
Scott and Prescott, 1961. p. 85, pl. 38, fig. 4



Dimensions:
Cell length - 55µm
Cell breadth - 50µm
Isthmus - 38µm
Comments:
Cells medium size, longer spines, spines 13µm long.

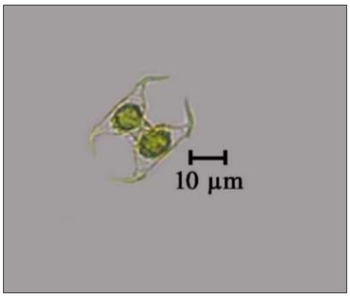
Genus: ***STAURASTRUM*** Meyen

83. ***Staurastrum crenulatum*** **(**Nag.) Delp.
Scott and Prescott, 1961. p. 88, pl. 59, fig. 10



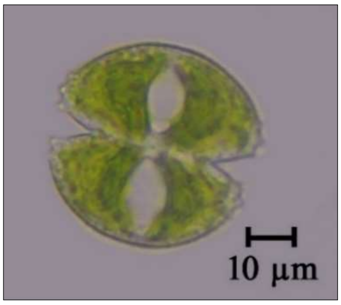
Dimensions:
Cell length - 22µm
Cell breadth - 32µm
Isthmus - 9µm
Comments:
Cells small, deeply constricted, sinus open, cell wall granulated.

84. ***Staurastrum glabrum*** Ralfs.
West and West, 1908. vol. 4, p. 129, pl. 143, fig. 15



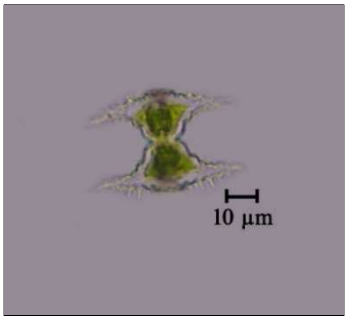
Dimensions:
Cell length - 26µm
Cell breadth - 20µm
Comments:
Cells very small and deeply constricted, sinus open.

85. ***Staurastrum proboscidium*** (Breb) Arch.
West and West, 1908. vol. 4, p. 129, pl. 143, fig. 15



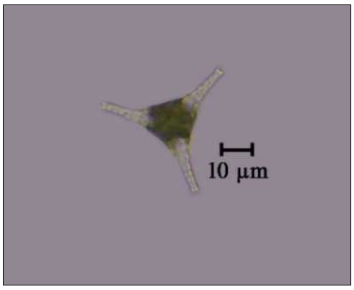
Dimensions:
Cell length - 40μm
Cell breadth - 35μm
Isthmus - 11μm
Comments:
Cells medium size, truncated apex, concentric granules, sinus acute.

86. ***Staurastrum saltans*** var. ***polycharax*** Scott & Prescott
Scott and Prescott, 1961. p. 105, pl. 51, fig. 8



Dimensions:
Cell length - 43μm
Cell breadth - 30μm
Isthmus - 9μm
Comments:
Cells with external side convex covered with short spines, sinus open.

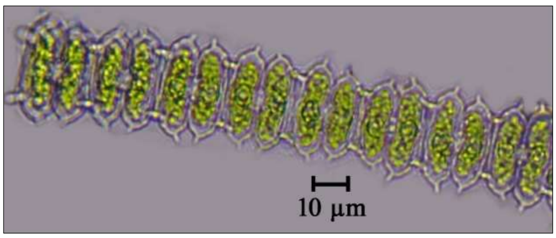
87. ***Staurastrum*** **sp. 1**



Dimensions:
Cell length - 43μm
Cell breadth - 13μm
Isthmus - 1.5μm
Comments:
Cells triangulate, angles prolonged to form Short processes.

Genus: ***ONYCHONEMA*** Wallich

88. ***Onychonema laeve*** var. ***micracanthum*** Nordst.
Scott and Prescott, 1961. p. 121, pl. 60, fig. 14

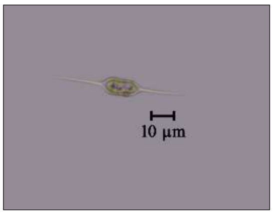


Dimensions:
Cell length - 20μm
Cell breadth - 19μm
Isthmus - 5.5μm
Comments:
Cells narrowed and rounded and at apex with short spines.

Division : **Chrysophyta**
Class : **Xanthophyceae**
Order : **Heterococcales**
Family : **Centritractaceae**

Genus: ***CENTRITRACTUS*** Lemmermann

89. ***Centritractus belanophorus*** (Schmidle) Lemm.
Prescott, 1982. p. 361, pl. 95, figs. 37 & 38

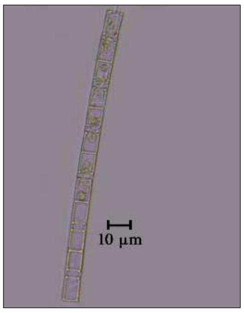


Dimensions:
Cell length - 42µm
Cell breadth - 7µm
Comments:
Cells elongate-cylindric with a long, slender spine at each pole, spines larger than the cell.

Division : **Bacillariophyta**
Class : **Bacillariophyceae**
Order : **Centrales**
Family : **Coscinodiscaceae**

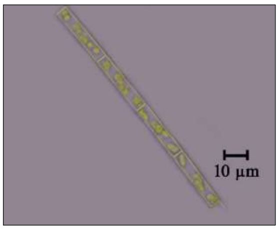
Genus: *AULACOSEIRA* Thwaites

90. ***Aulacoseira granulata*** (Ehr.) Simonsen
Sarode and Kamat, 1984. p. 18, pl. 1, fig. 1



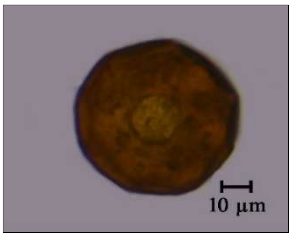
Dimensions:
Valve length - 10µm
Valve breadth - 6µm
Comments:
Frustules cylindrical and united in chains, end cells with spines, rows of aeroles.

91. ***Aulacoseira granulata*** (Ehr.) Simonsen var. ***angustissima*** (O.Muller) Simonsen
Sarode and Kamat, 1984. p. 18, pl. 1, fig. 2



Dimensions:
Valve length - 20µm
Valve breadth - 3µm
Comments:
Frustules cylindrical and united in chains, end cells with spines.

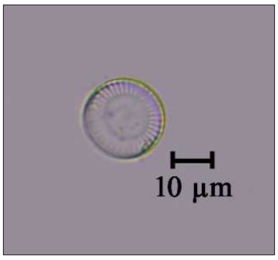
92. ***Actinocyclus normanii*** (Gregory) Hustedt
Desikachary, 1989. P.3, fig. 5



Dimensions:
Valve breadth - 3µm
Comments:
Valves circular, centric form, shallow mantle, margins striated, small refractive area at valve margin.

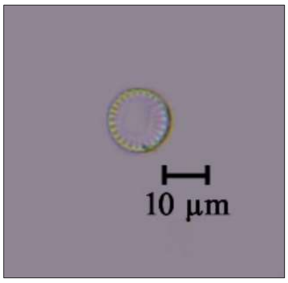
Genus: ***CYCLOTELLA*** Kuetz.

93. ***Cyclotella meneghiniana*** f. ***meneghiniana*** Kützing
Sarode and Kamat, 1984. p. 21, pl. 1, fig. 11



Dimensions:
Valve length - 42µm
Valve breadth - 7µm
Striae - 8 (10µm)
Comments:
Valves discoid, thick wavy margins, central field large and punctate,

94. ***Cyclotella striata*** (Kützing) Grunow
Sarode and Kamat, 1984. p. 23, pl. 1, fig. 16

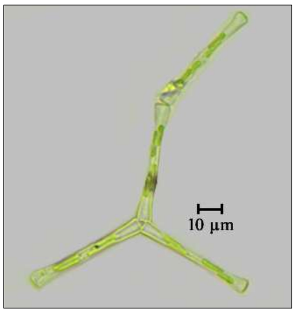


Dimensions:
Valve breadth - 16µm
Striae - 9 (10µm)
Comments:
Valves discoid, large central field.

Order : **Pennales**
Family : **Fragilariaceae**

Genus: ***TABELLARIA*** Ehrenberg

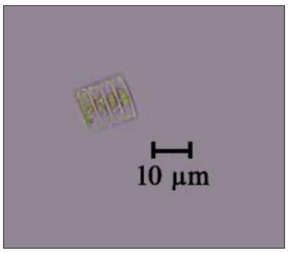
95. ***Tabellaria fenestrata*** (Lyngbye) Kützing
Venkataraman, 1939. p. 303, fig. 35



Dimensions:
Valve length - 50µm
Valve breadth - 4µm
Comments:
Valves elongated and forming zigzag chains, inflated in the middle and poles.

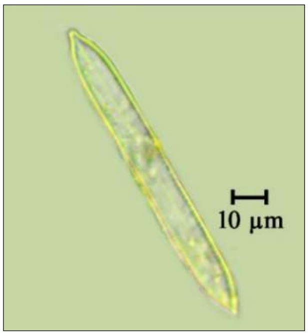
Genus: ***FRAGILARIA*** Lyngbye

96. ***Fragilaria venter*** var. ***venter*** Ehrenberg
Sarode and Kamat, 1984. p. 26, pl. 1, fig. 20



Dimensions:
Valve length - 12µm
Valve breadth - 2µm
Comments:
Valves attached together to form short chains.

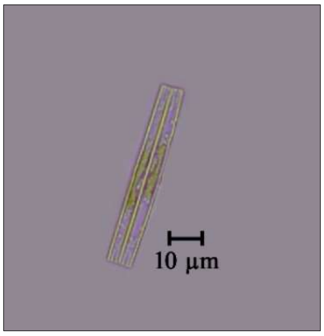
97. ***Fragilaria capucina*** var. ***vaucheriae*** (Kutz.) Lange Bertalot
Sarode and Kamat, 1984. p. 27, pl. 1, fig. 21



Dimensions:
Valve length - 94µm
Valve breadth - 8µm
Comments:
Valves linear, broad, ends tapering and rounded, axial area narrow.

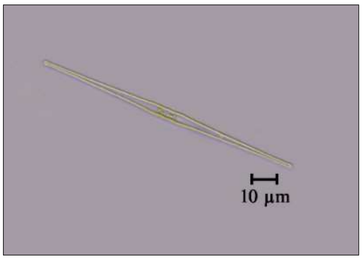
Genus: ***SYNEDRA*** Ehrenberg

98. ***Synedra familiaris*** f. ***familiaris*** Kutzing
Sarode and Kamat, 1984. p. 28, pl. 1, fig. 26



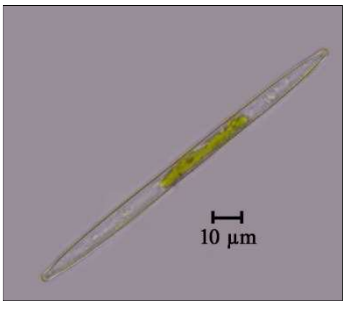
Dimensions:
Valve length - 48µm
Valve breadth - 4µm
Comments:
Valves centrally constricted.

99. ***Synedra acus*** Kuetz.
Sarode and Kamat, 1984. p. 30, pl. 2, fig. 32



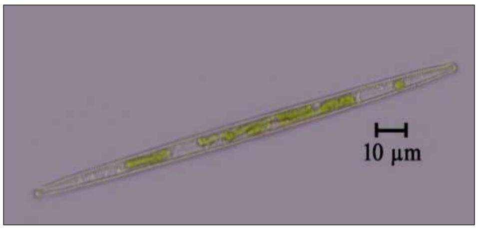
Dimensions:
Valve length - 102µm
Valve breadth - 3µm
Comments:
Valves linear, narrow needle like subcapitate ends, narrow pseudoraphe, striae indistinct, broad in the middle and tapering towards ends.

100. ***Synedra ulna*** (Nitz.) Ehr.
Sarode and Kamat, 1984. p. 31, pl. 2, fig. 37



Dimensions:
Valve length - 149µm
Valve breadth - 5µm
Raphe - 9 (10µm)
Comments:
Valves linear lanceolate, ends rounded, narrow pseudoraphe.

101. ***Synedra ulna*** var. ***subaequalis*** Grunow
Sarode and Kamat, 1984. p. 33, pl. 2, fig. 44

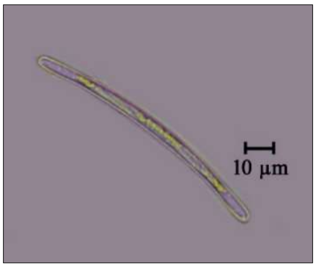


Dimensions:
Valve length - 197µm
Valve breadth – 6.5µm
Raphe - 9 (10µm)
Comments:
Valves linear lanceolate, sub-capitate ends, narrow pseudoraphe.

Family: **Eunotiaceae**

Genus: ***EUNOTIA*** Ehrenberg

102. ***Eunotia lunaris*** (Ehr.) Gurnow
Gandhi, 1957. P.49, fig. 14

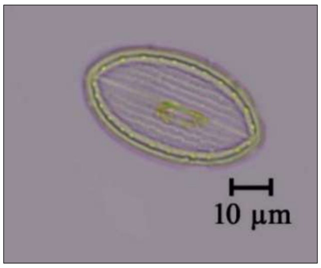


Dimensions:
Valve length - 80µm
Valve breadth - 3µm
Comments:
Valves linear, curved forming arc, small polar nodules with rounded apex.

Family: **Achnanthaceae**

Genus: ***COCCONEIS*** Ehrenberg

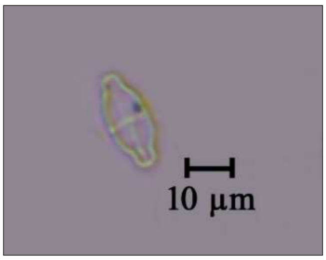
103. ***Cocconeis placentula*** Ehr.
Sarode and Kamat, 1984. p. 49, pl. 4, fig. 95



Dimensions:
Valve length - 36µm
Valve breadth - 21µm
Comments:
Valves elliptical, pseudoraphe, many longitudinal wavy hyaline bands present.

Genus: ***ACHNANTHES*** Bory

104. ***Achnanthes exigua*** Grun.
Sarode and Kamat, 1984. p. 53, pl. 5, fig. 108

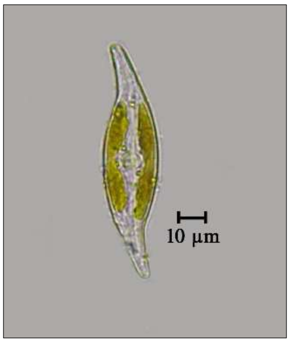


Dimensions:
Valve length - 12µm
Valve breadth - 5µm
Comments:
Valves rectangular in middle with rostrate end, raphe thin and straight.

Family: **Naviculaceae**

Genus: ***GYROSIGMA*** Hassal

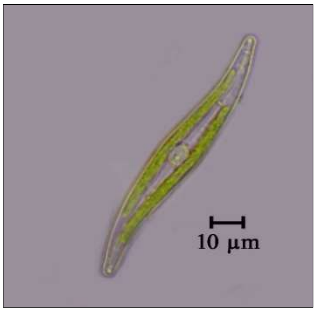
105. ***Gyrosigma distortum*** var. ***parkeri*** Harrison
Sarode and Kamat, 1984. p. 67, pl. 7, fig. 148



Dimensions:
Valve length - 78µm
Valve breadth - 17µm
Comments:
Valves slightly sigmoid, lanceolate with Protracted ends, axial area narrow.

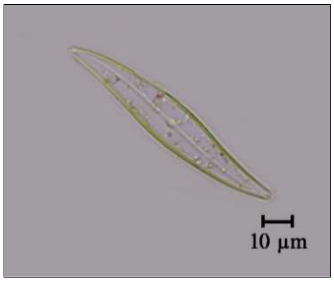
Genus: ***PLEUROSIGMA*** W. Smith

106. ***Pleurosigma kuetzingii*** f. ***kuetzingii*** Gurnow
Sarode and Kamat, 1984. p. 66, pl. 7, fig. 149



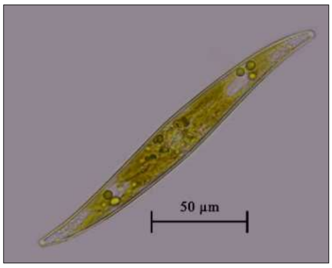
Dimensions:
Valve length - 91µm
Valve breadth - 12µm
Comments:
Valves sigmoid, lanceolate with rounded ends, raphe thick and sigmoid.

107. ***Pleurosigma salinarum*** Grun.
Sarode and Kamat, 1984. p. 70, pl. 8, fig. 157



Dimensions:
Valve length - 91µm
Valve breadth - 14µm
Comments:
Valves linear, lanceolate, sigmoid, rounded at poles.

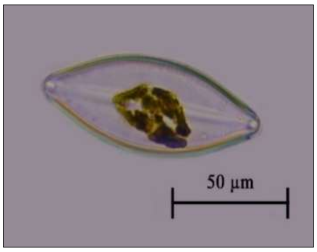
108. ***Pleurosigma elongatum*** var. ***karianum*** (Grun.) Cleve
Sarode and Kamat, 1984. p. 70, pl. 8, fig. 158



Dimensions:
Valve length - 175µm
Valve breadth - 18µm
Comments:
Valves sigmoid, attenuated and rounded ends, raphe thin, sigmoid.

Genus: ***CALONEIS*** Cleve

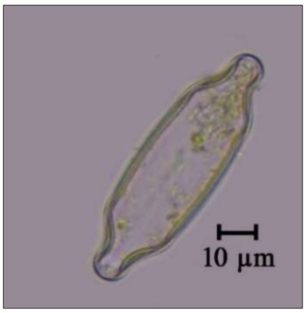
109. ***Caloneis permagna*** (Bail.) Cleve
Sarode and Kamat, 1984. p. 72, pl. 8, fig. 164



Dimensions:
Valve length - 90μm
Valve breadth - 35μm
Striae - 13 (10μm)
Comments:
Frustules large and lanceolate, rounded ends, raphe thick, terminal fissures curved.

Genus: ***NEIDIUM*** Pfitzer

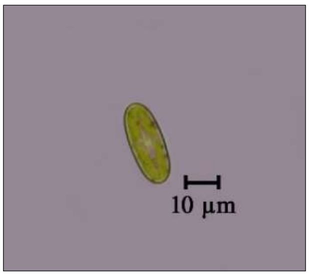
110. ***Neidium productum*** var. ***bombayensis*** Gonzalves
Sarode and Kamat, 1984. p. 85, pl. 9, fig. 199



Dimensions:
Valve length - 75μm
Valve breadth - 20μm
Comments:
Valves linear elliptic, thick margins and rounded ends, raphe thin and straight with central nodule.

Genus: ***DIPLONEIS*** Ehrenberg

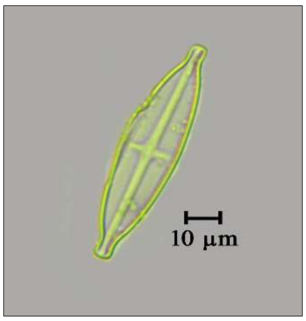
111. ***Diploneis ovalis*** (Bail.) Cleve
Sarode and Kamat, 1984. p. 86, pl. 10, fig. 203



Dimensions:
Valve length - 20μm
Valve breadth - 10μm
Comments:
Valves linear elliptic, raphe with central nodule H shaped.

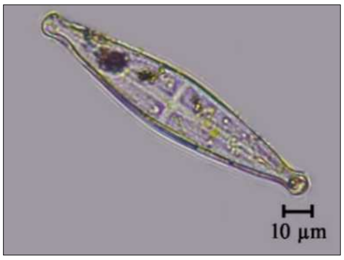
Genus: ***STAURONEIS*** Ehrenberg

112. ***Stauroneis anceps*** Ehr.
Sarode and Kamat, 1984. p. 89, pl. 10, fig. 210



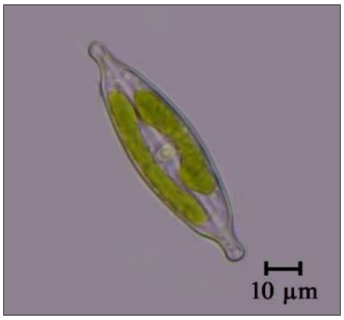
Dimensions:
Valve length - 72μm
Valve breadth - 13μm
Comments:
Valves elliptic, lanceolate, ends capitate and rounded, raphe thin, central area wide and stauroid.

113. *Stauroneis anceps* f. ***gracilis*** (Ehr.) Cleve
Sarode and Kamat, 1984. p. 89, pl. 10, fig. 211



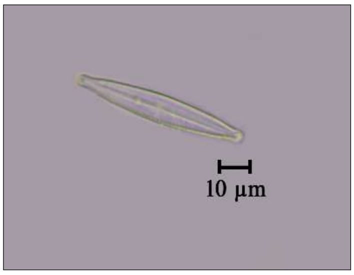
Dimensions:
Valve length - 105µm
Valve breadth - 21µm
Comments:
Valves lanceolate, ends capitate, rounded, raphe thin.

114. *Stauroneis phoenicenteron* f. ***capitata*** Gonzalves et Gandhi
Sarode and Kamat, 1984. p. 93, pl. 11, fig. 224.



Dimensions:
Valve length - 78µm
Valve breadth - 19µm
Comments:
Valves lanceolate, rounded capitate ends, thick and straight raphe with central nodules.

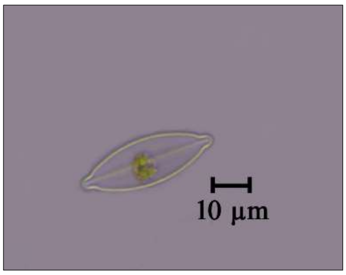
115. *Stauroneis phoenicenteron* f. ***producta*** Gandhi
Sarode and Kamat, 1984. p. 94, pl. 11, fig. 226



Dimensions:
Valve length - 52µm
Valve breadth - 9.5µm
Comments:
Valves lanceolate and capitate ends, raphe thick and straight with central nodules.

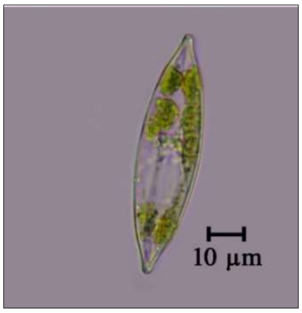
Genus: ***NAVICULA*** Bory

116. *Navicula constans* var. ***symmetrica*** Hustedt
Sarode and Kamat, 1984. p. 106, pl. 12, fig. 253



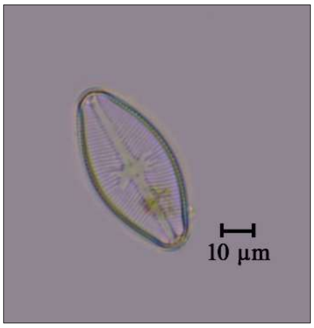
Dimensions:
Valve length - 29µm
Valve breadth - 11µm
Striae - 13 (10µm)
Comments:
Valves lanceolate with capitate ends, raphe thin with central nodules.

117. ***Navicula cuspidata*** Otto Müller
Sarode and Kamat, 1984. p. 107, pl. 12, fig. 258



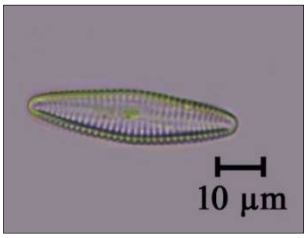
Dimensions:
Valve length - 66µm
Valve breadth - 15µm
Comments:
Valves lanceolate with rounded ends at apex.

118. ***Navicula gastrum*** Sensu Pantocsek
Sarode and Kamat, 1984. p. 111, pl. 13, fig. 272



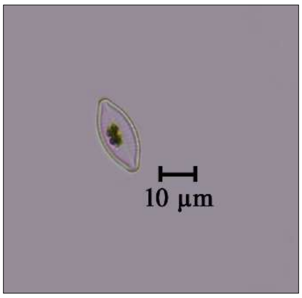
Dimensions:
Valve length - 52µm
Valve breadth - 21µm
Striae - 8 (10µm)
Comments:
Valves elliptic lanceolate, rounded ends with large central area.

119. ***Navicula gracilis*** Ehrenberg
Sarode and Kamat, 1984. p. 112, pl. 13, fig. 275



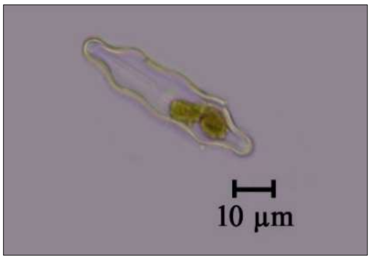
Dimensions:
Valve length - 45µm
Valve breadth - 10µm
Striae - 9 (10µm)
Comments:
Valves linear lanceolate, axial area, rounded ends, raphe thin.

120. ***Navicula laterostrata*** Hustedt
Sarode and Kamat, 1984. p. 113, pl. 13, fig. 281



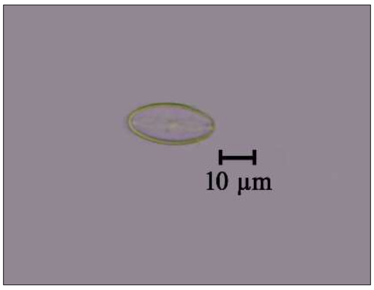
Dimensions:
Valve length - 42µm
Valve breadth - 7µm
Striae - 12 (10µm)
Comments:
Valves elliptic lanceolate with rounded ends, raphe thin and straight.

121. *Navicula mutica* var. ***linearis*** Gonzalves & Gandhi
Sarode and Kamat, 1984. p. 116, pl. 13, fig. 290



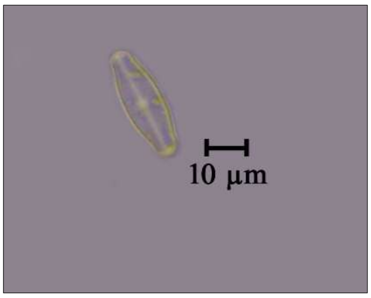
Dimensions:
Valve length - 40µm
Valve breadth - 10µm
Comments:
Valves linear lanceolate, triundulate margins, rounded and capitate ends, raphe thin and straight, axial area narrow.

122. *Navicula pygmaea* Kützing
Sarode and Kamat, 1984. p. 119, pl. 13, fig. 301



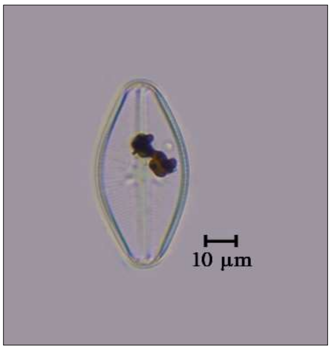
Dimensions:
Valve length - 23µm
Valve breadth - 10µm
Comments:
Valves elliptic lanceolate with rounded ends, raphe thin with central nodules.

123. *Navicula pupula* Bristol
Sarode and Kamat, 1984. p. 118, pl. 13, fig. 295



Dimensions:
Valve length - 26µm
Valve breadth - 9µm
Comments:
Valves linear lanceolate, subcapitate ends, raphe straight with central nodules.

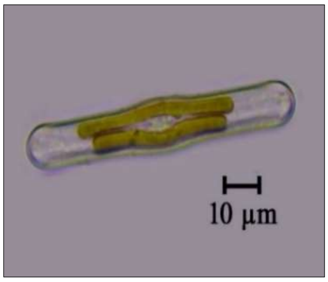
124. *Navicula pusilla* Sensu Donkin
Sarode and Kamat, 1984. p. 119, pl. 13, fig. 300



Dimensions:
Valve length - 62µm
Valve breadth - 28µm
Striae - 10 (10µm)
Comments:
Valves elliptic lanceolate with capitate ends, central area wide, raphe thick and curved with central nodules.

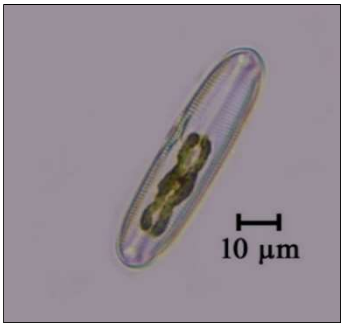
Genus: ***PINNULARIA*** Ehrenberg

125. ***Pinnularia acrosphaeria*** W. Smith
Sarode and Kamat, 1984. p. 133, pl. 15, fig. 340



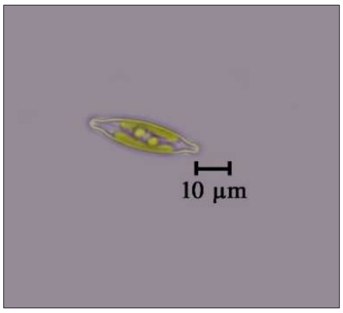
Dimensions:
Valve length - 58µm
Valve breadth – 9.2µm
Comments:
Valves axial area broad and inflated at middle with central nodules.

126. ***Pinnularia divergens*** var. ***elliptica*** Grunow
Sarode and Kamat, 1984. p. 140, pl. 16, fig. 363



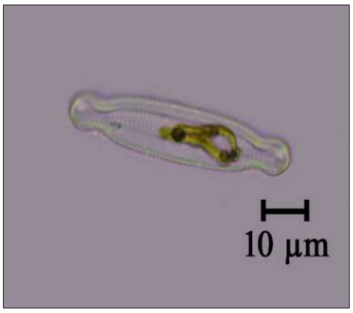
Dimensions:
Valve length - 71µm
Valve breadth - 14µm
Striae - 10 (10µm)
Comments:
Valves linear elliptical with rounded ends, terminal pores curved.

127. ***Pinnularia interrupta*** var. ***minor*** Cleve-Euler
Sarode and Kamat, 1984. p. 144, pl. 16, fig. 378



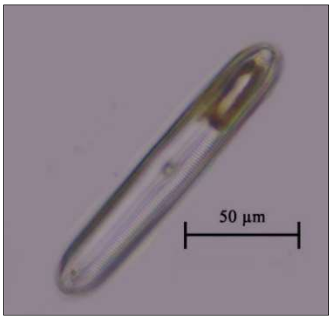
Dimensions:
Valve length - 28µm
Valve breadth - 8µm
Comments:
Valves linear lanceolate, capitate rounded ends, raphe thin.

128. ***Pinnularia lundii*** Hustedt
Sarode and Kamat, 1984. p. 146, pl. 17, fig. 386



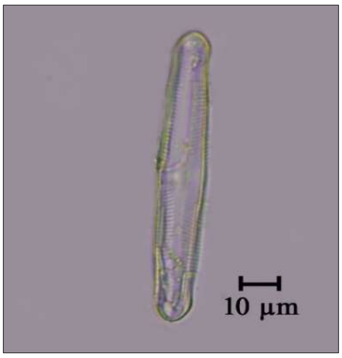
Dimensions:
Valve length - 50µm
Valve breadth - 10µm
Striae - 13 (10µm)
Comments:
Valves lanceolate, capitate rounded ends, curved terminal fissures.

129. ***Pinnularia major*** f. ***linearis*** (Cleve) Dippel
Sarode and Kamat, 1984. p. 147, pl. 17, fig. 387



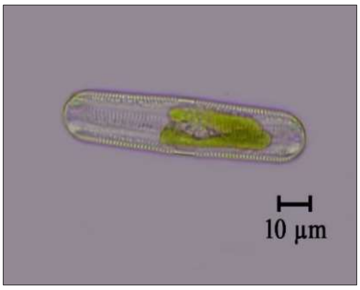
Dimensions:
Valve length - 125µm
Valve breadth - 18µm
Striae - 8 (10µm)
Comments:
Valves linear lanceolate, rounded and capitate ends, raphe thick and complex, unilaterally bend, bayonet shaped.

130. ***Pinnularia panhalgarhensis*** Gandhi
Sarode and Kamat, 1984. p. 151, pl. 18, fig. 400



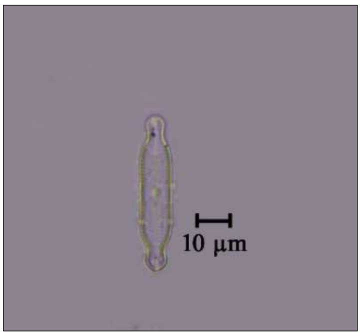
Dimensions:
Valve length - 85µm
Valve breadth - 11µm
Comments:
Valves linear, constricted ends, curved terminal fissures, raphe unilaterally bent.

131. ***Pinnularia stomatophoroides*** var. ***ornata*** (A. Cl.) Cl.-Euler
Sarode and Kamat, 1984. p. 155, pl. 18, fig. 414



Dimensions:
Valve length - 75µm
Valve breadth - 12µm
Comments:
Valves linear lanceolate, broadly rounded, capitate ends, raphe thick.

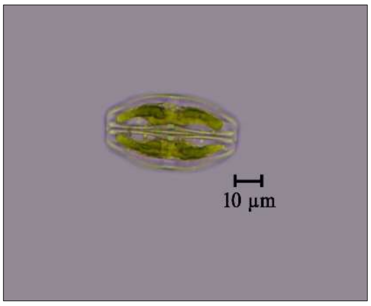
132. ***Pinnularia termis*** var. ***termitiana*** (Ehr.) A. Cl.
Sarode and Kamat, 1984. p. 157, pl. 19, fig. 420



Dimensions:
Valve length - 45µm
Valve breadth - 8µm
Striae - 12 (10µm)
Comments:
Valves lanceolate, capitate rounded ends, curved terminal fissures.

Genus: ***AMPHORA*** Ehrenberg

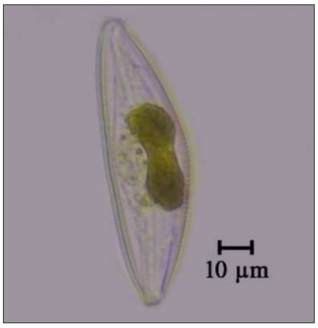
133. ***Amphora ovalis*** f. ***gracilis*** Ehrenberg
Sarode and Kamat, 1984. p. 162, pl. 19, fig. 434



Dimensions:
Valve length - 52µm
Valve breadth - 25µm
Striae - 11 (10µm)
Comments:
Valves lunate with convex dorsal side, narrow at axial side.

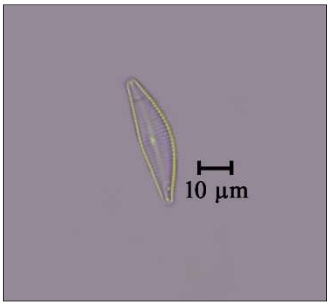
Genus: ***CYMBELLA*** Agardh

134. ***Cymbella bengalensis*** Grunow
Sarode and Kamat, 1984. p. 167, pl. 19, fig. 444



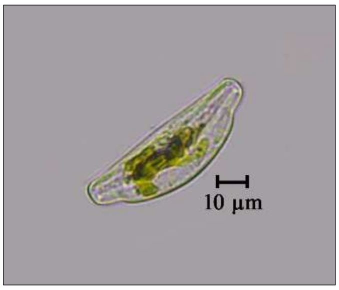
Dimensions:
Valve length - 84µm
Valve breadth - 25µm
Striae - 9 (10µm)
Comments:
Valves asymmetrical, broadly rounded ends, central area large.

135. ***Cymbella signata*** Pantocsek
Sarode and Kamat, 1984. p. 170, pl. 20, fig. 453



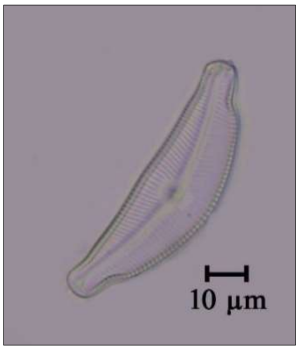
Dimensions:
Valve length - 36µm
Valve breadth - 9µm
Striae - 11 (10µm)
Comments:
Valve ends rounded, dorsal margin convex and ventral margin straight.

136. ***Cymbella laevis*** Nageli
Sarode and Kamat, 1984. p. 171, pl. 20, fig. 455



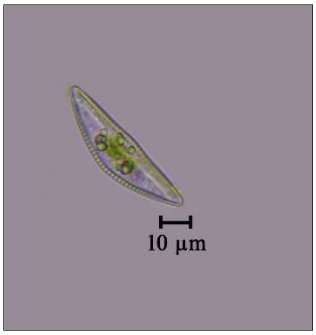
Dimensions:
Valve length - 30µm
Valve breadth - 9µm
Comments:
Valves curved, dorsal margin convex and ventral margin straight with median expansion, raphe thick.

137. ***Cymbella tumida*** (A. Schmidt) Skabichevskii
Sarode and Kamat, 1984. p. 176, pl. 20, fig. 468



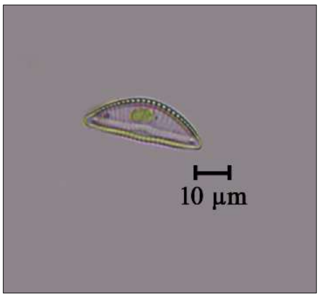
Dimensions:
Valve length - 72µm
Valve breadth - 20µm
Striae - 12 (10µm)
Comments:
Valves asymmetrical and curved, dorsal margin convex, raphe thick.

138. ***Cymbella turgida*** Pantocsek
Sarode and Kamat, 1984. p. 177, pl. 21, fig. 471



Dimensions:
Valve length - 50µm
Valve breadth - 12µm
Striae - 8 (10µm)
Comments:
Valves lunate, ends acute, rounded.

139. ***Cymbella ventricosa*** Kutzing
Sarode and Kamat, 1984. p. 178, pl. 21, fig. 473

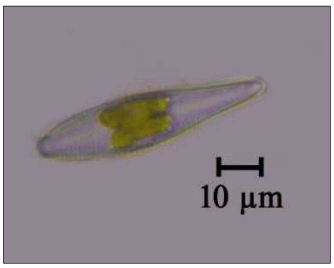


Dimensions:
Valve length - 33µm
Valve breadth - 9µm
Striae - 10 (10µm)
Comments:
Valves straight on the ventral side, ends acute, rounded.

Family: **Gomphonemaceae**

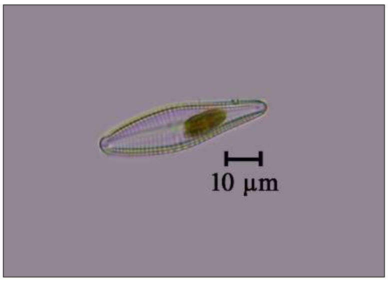
Genus: ***GOMPHONEMA*** Agardh

140. ***Gomphonema aequatoriale*** Hustedt
Sarode and Kamat, 1984. p. 182, pl. 22, fig. 500



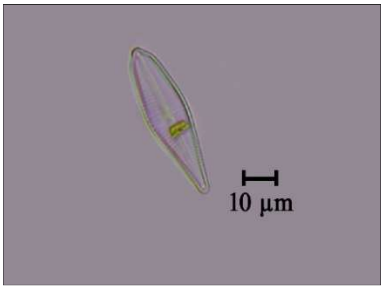
Dimensions:
Valve length - 51µm
Valve breadth - 10µm
Striae - 9 (10µm)
Comments:
Valves clavate, ends rounded at apex.

141. ***Gomphonema gracile*** var. ***intricatiformis*** Mayer
Sarode and Kamat, 1984. p. 186, pl. 21, fig. 486



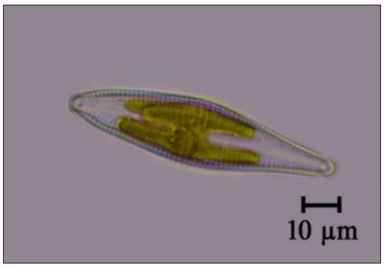
Dimensions:
Valve length - 55µm
Valve breadth - 10µm
Striae - 12 (10µm)
Comments:
Valves lanceolate, ends acutely rounded, central nodules, striae lineate.

142. ***Gomphonema gracile*** var. ***frickei*** Gandhi
Sarode and Kamat, 1984. p. 185, pl. 21, fig. 498



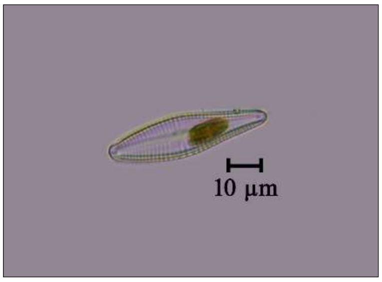
Dimensions:
Valve length - 45µm
Valve breadth - 9µm
Striae - 8 (10µm)
Comments:
Valves lanceolate, apiculate apex, distinct central nodules.

143. ***Gomphonema lacus-rankala*** var. ***gracilis*** Gandhi
Sarode and Kamat, 1984. p. 190, pl. 22, fig. 512



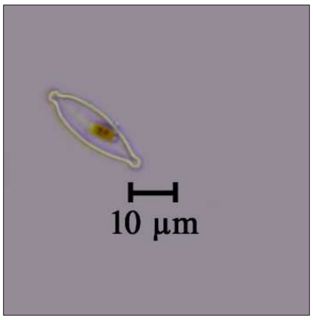
Dimensions:
Valve length - 72µm
Valve breadth - 14µm
Striae - 9 (10µm)
Comments:
Valves lanceolate, apiculate end at apex, striae shortened in the middle.

144. ***Gomphonema montanum*** var. ***acuminatum*** f. ***indicum*** Sarode & Kamat
Sarode and Kamat, 1984. p. 193, pl. 23, fig. 524



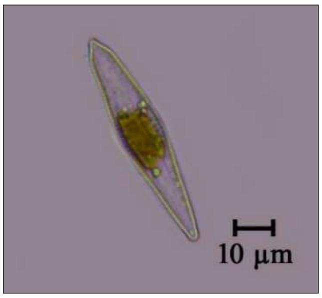
Dimensions:
Valve length - 49µm
Valve breadth - 11µm
Striae - 8 (10µm)
Comments:
Valves lanceolate, slightly constricted at apex, raphe thin and straight.

145. ***Gomphonema parvulum*** (Kuetzing) Kutzing
Sarode and Kamat, 1984. p. 196, pl. 23, fig. 534



Dimensions:
Valve length - 24µm
Valve breadth - 7µm
Comments:
Valves clavate, capitate ends at apex, raphe thin and straight.

146. ***Gomphonema subapicatum*** Fritsch & Rich
Sarode and Kamat, 1984. p. 198, pl. 23, fig. 538

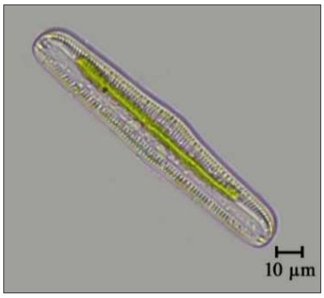


Dimensions:
Valve length - 58µm
Valve breadth - 10µm
Comments:
Valves lanceolate, clavate, subapiculate apex, raphe thin and straight, axial area narrow.

Family: **Epithemiaceae**

Genus: ***RHOPALODIA*** Muller

147. ***Rhopalodia gibba*** (Ehr.) O. Muller
Sarode and Kamat, 1984. p. 203, pl. 24, fig. 554

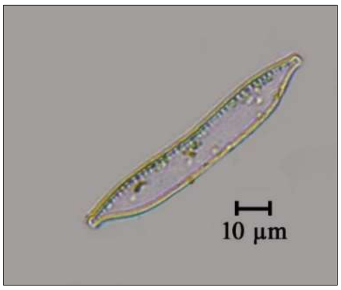


Dimensions:
Valve length - 112µm
Valve breadth - 14µm
Comments:
Valves inflations in the middle, rounded ends.

Family: **Nitzschiaceae**

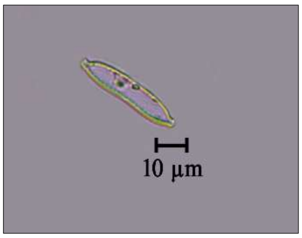
Genus: ***HANTZSCHIA*** Grunow

148. ***Hantzschia amphioxys*** (Ehr.) Grunow
Sarode and Kamat, 1984. p. 206, pl. 24, fig. 562



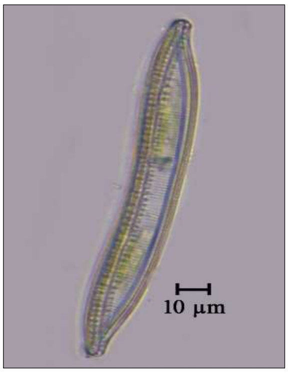
Dimensions:
Valve length - 72µm
Valve breadth - 9µm
Comments:
Valves ends constricted and capitate, keel punctae 9 in 10µm.

149. ***Hantzschia amphioxys*** var. ***pusilla*** (Gru.) Dippel
Sarode and Kamat, 1984. p. 208, pl. 24, fig. 568



Dimensions:
Valve length - 35µm
Valve breadth - 7µm
Comments:
Valves ends constricted and narrowed, small keel punctae.

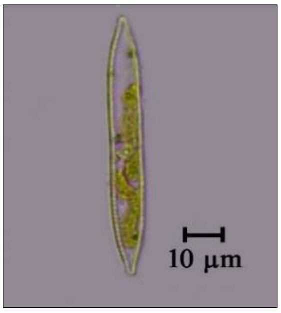
150. ***Hantzschia linearis*** (O. Mull.) Cl.- Euler
Sarode and Kamat, 1984. p. 209, pl. 25, fig. 574



Dimensions:
Valve length - 127µm
Valve breadth - 111µm
Striae - 13 (10µm)
Comments:
Valves linear, ends narrowed and subcapitate.

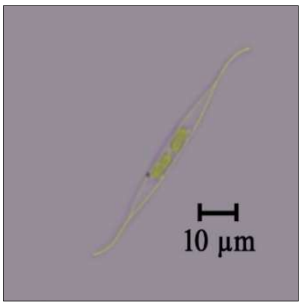
Genus: ***NITZSCHIA*** Hassal

151. ***Nitzschia apiculata*** (Greg.) Grun.
Sarode and Kamat, 1984. p. 214, pl. 25, fig. 580



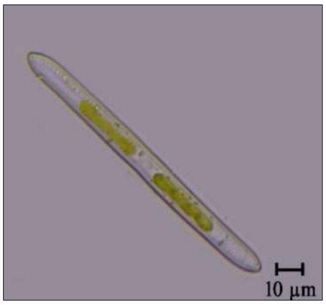
Dimensions:
Valve length - 69µm
Valve breadth - 9µm
Comments:
Valves linear with apiculate ends.

152. ***Nitzschia closterium*** Eulenstein
Sarode and Kamat, 1984. p. 215, pl. 25, fig. 584



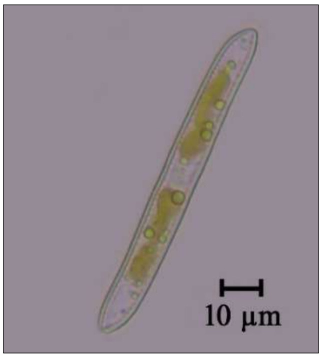
Dimensions:
Valve length - 62µm
Valve breadth - 2µm
Comments:
Valves long attenuated ends, retracted in opposite directions.

153. ***Nitzschia intermedia*** Hantzsch ex Cleve & Grunow
Sarode and Kamat, 1984. p. 218, pl. 26, fig. 598



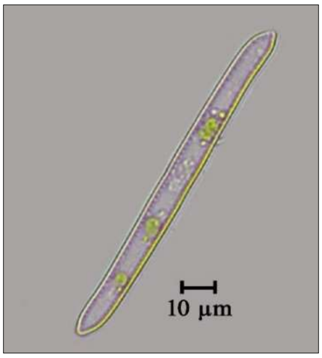
Dimensions:
Valve length - 101µm
Valve breadth - 6µm
Comments:
Valves linear, lanceolate, subcapitate ends.

154. ***Nitzschia obtusa*** W. Smith
Sarode and Kamat, 1984. p. 221, pl. 26, fig. 608



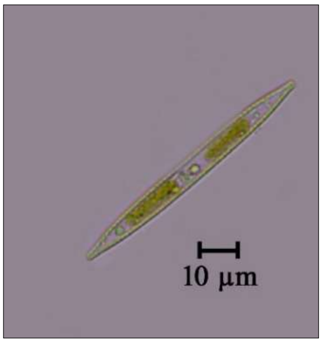
Dimensions:
Valve length - 75µm
Valve breadth - 9µm
Striae - 9 (10µm)
Comments:
Valves linear with rounded ends in opposite directions.

155. ***Nitzschia scalpelliformis*** Grunow
Sarode and Kamat, 1984. p. 222, pl. 26, fig. 609



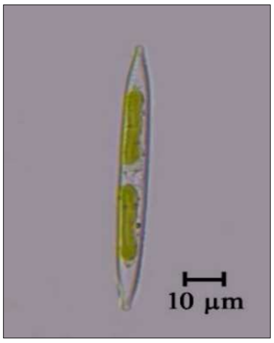
Dimensions:
Valve length - 112µm
Valve breadth – 7.5µm
Comments:
Valves linear with rounded ends in opposite directions.

156. ***Nitzschia philippinarum*** Hustedt
Sarode and Kamat, 1984. p. 223, pl. 26, fig. 615



Dimensions:
Valve length - 66µm
Valve breadth - 5µm
Comments:
Valves lanceolate, narrow capitate rounded ends.

157. ***Nitzschia sublinearis*** Hustedt
Sarode and Kamat, 1984. p. 225, pl. 26, fig. 623

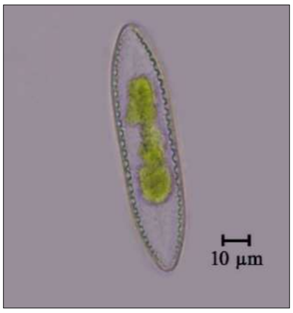


Dimensions:
Valve length - 83µm
Valve breadth - 6µm
Comments:
Valves narrow capitate ends, linear lanceolate.

Family: **Surirellaceae**

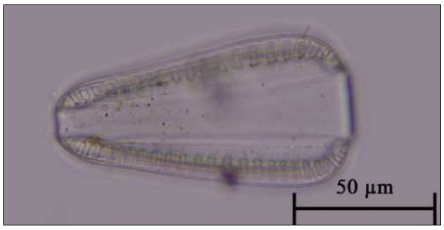
Genus: ***SURIRELLA*** Turpin

158. ***Surirella biseriata*** Brebisson
Sarode and Kamat, 1984. p. 230, pl. 27, fig. 639



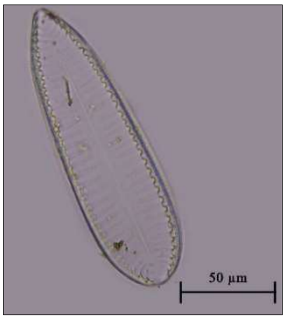
Dimensions:
Valve length - 90µm
Valve breadth - 20µm
Comments:
Valves isopolar, acutely rounded ends, linear, lanceolate.

159. ***Surirella capronioides*** Gandhi
Sarode and Kamat, 1984. p. 231, pl. 27, fig. 642



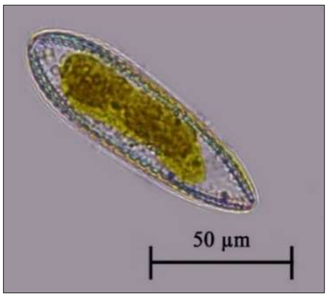
Dimensions:
Valve length - 109µm
Valve breadth - 47µm
Comments:
Valves heteropolar, ovate with rounded ends at apex, thick wavy projections from margin.

160. ***Surirella robusta*** Ehrenberg
Sarode and Kamat, 1984. p. 233, pl. 28, fig. 652



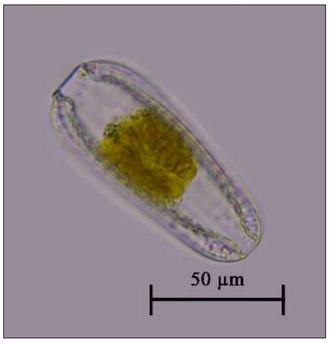
Dimensions:
Valve length - 154µm
Valve breadth - 31µm
Comments:
Valves narrowly ovate with rounded apex.

161. ***Surirella tenera*** var. ***ambigua*** Gandhi
Sarode and Kamat, 1984. p. 234, pl. 28, fig. 655



Dimensions:
Valve length - 97µm
Valve breadth - 25µm
Comments:
Valves heteropolar, striae indistinct, narrowly ovate with rounded apex.

162. ***Surirella tenera*** var. ***nervosa*** A. Schmidt
Sarode and Kamat, 1984. p. 234, pl. 28, fig. 656

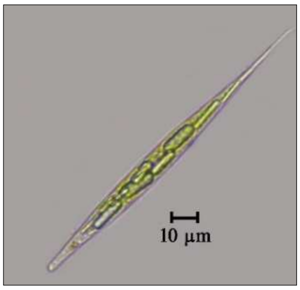


Dimensions:
Valve length - 97µm
Valve breadth - 31µm
Comments:
Valves narrowly ovate with rounded apex.

Division : **Euglenophyta**
Class : **Euglenophyceae**
Order : **Euglenales**
Family : **Euglenaceae**

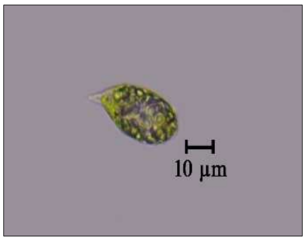
Genus: ***EUGLENA*** Ehrenberg

163. ***Euglena acus*** (O.F.Muller***)*** Ehr.
Philipose, 1984. p.564, fig. 1f



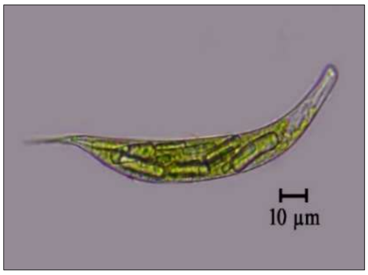
Dimensions:
Cell length - 83µm
Cell breadth - 20µm
Comments:
Cells elongate, spindle shaped, produced posteriorly into a long, fine tapering point, narrowed and truncate at the anterior end.

164. ***Euglena agilis*** Carter
Wolowski,1998. p.27, fig. 78



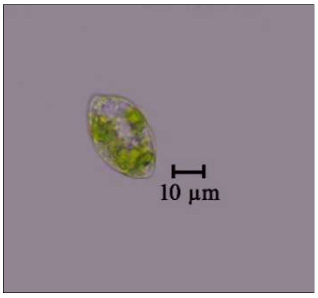
Dimensions:
Cell length - 30µm
Cell breadth - 13µm
Comments:
Cells short, fusiform, chloroplast many with pyrenoids.

165. ***Euglena acus*** var. ***acus*** Starmach
Wolowski,1998. p.13, fig. 9



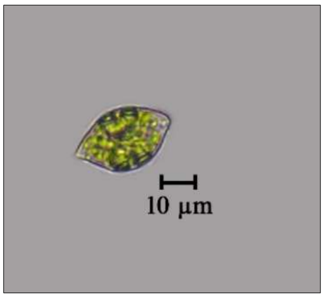
Dimensions:
Cell length - 125µm
Cell breadth - 10µm
Comments:
Cells long, fusiform, narrow at the anterior end, tapering towards posterior.

166. ***Euglena anabaena*** var. ***anabaena*** Mainx
Wolowski,1998. p.28, fig. 88



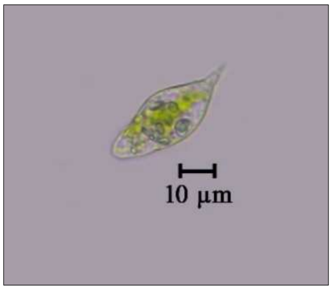
Dimensions:
Cell length - 30µm
Cell breadth - 19µm
Comments:
Cells wide, fusiform, narrowing towards the anterior end.

167. ***Euglena archeoplastidiata*** Chadefaud
Wolowski,1998. p.25, fig. 66



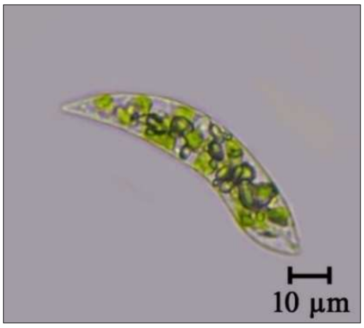
Dimensions:
Cell length - 26µm
Cell breadth - 13µm
Comments:
Cells cylindrical with several chloroplasts, rounded at posterior end.

168. ***Euglena chlamydophora*** Mainx
Wolowski,1998. p.23, fig. 53



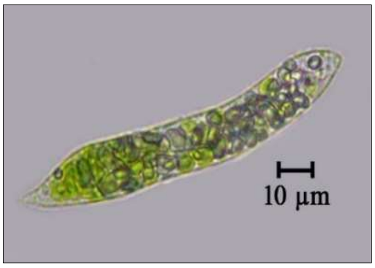
Dimensions:
Cell length - 42µm
Cell breadth - 20µm
Comments:
Cells ovate, rounded at posterior end, slightly longated anterior end.

169. *Euglena deses* fo. ***deses*** Pringsheim
Wolowski,1998. p.38, fig.125



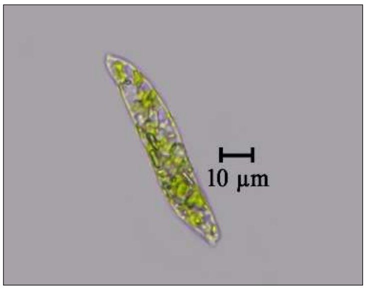
Dimensions:
Cell length - 68µm
Cell breadth - 12µm
Comments:
Cells oblong cylindrical, flattened with many chloroplasts, band shaped, narrow projection at posterior end.

170. *Euglena deses* Ehrenberg
Wolowski,1998. p.39, fig.130



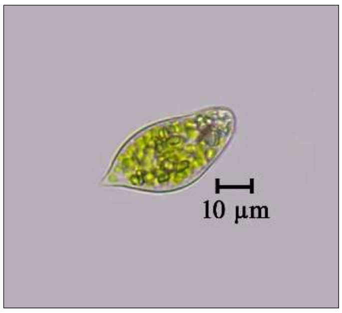
Dimensions:
Cell length - 102µm
Cell breadth - 12µm
Comments:
Cells cylindrical, truncate at the anterior end.

171. *Euglena deses* f. ***klebsii*** (Lemmermann) Popova
Wolowski,1998. p.38, fig.128



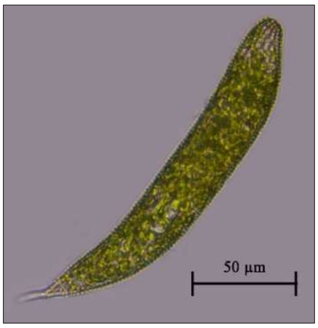
Dimensions:
Cell length - 61µm
Cell breadth - 10µm
Comments:
Cells longitudinally cylindrical, flattened with many chloroplasts.

172. *Euglena ettlii* Wolowski
Wolowski,1998. p.26, fig.72



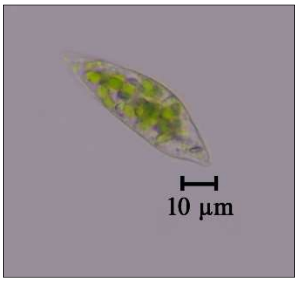
Dimensions:
Cell length - 41µm
Cell breadth - 10µm
Comments:
Cells wide fusiform, tapering towards anterior end, posterior end with short tail.

173. ***Euglena fusca*** (Klebs) Lemm.
Philipose, 1984. p.574, fig. 11a



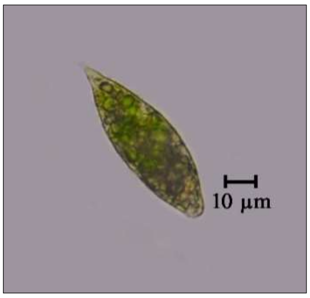
Dimensions:
Cell length - 195µm
Cell breadth - 27µm
Comments:
Cells slightly bent, posterior end tapering, paramylum present.

174. ***Euglena gracilis*** Klebs
Prescott, 1982. p. 393, pl. 85, fig. 17; Wolowski, 1998, p.31, fig.99



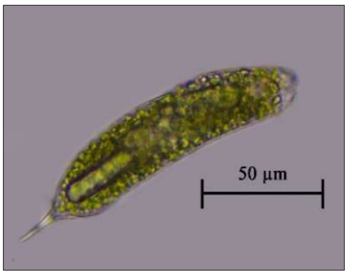
Dimensions:
Cell length - 51µm
Cell breadth - 15µm
Comments:
Cells short, fusiform to ovoid, chloroplast disc shaped and many with pyrenoids.

175. ***Euglena hemichromata*** Skuja
Wolowski,1998. p.22, fig.49



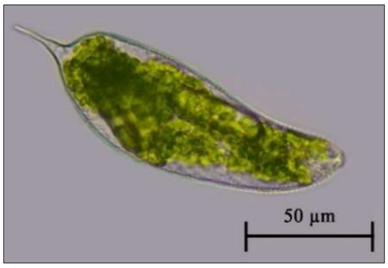
Dimensions:
Cell length - 60µm
Cell breadth - 18µm
Comments:
Cells spindle-shaped to cylindrical, anterior end rounded, posterior end tapering, presence of spherical to irregular discs.

176. ***Euglena oxyuris*** f. ***oxyuris*** Popova
Wolowski,1998. p.15, fig. 21



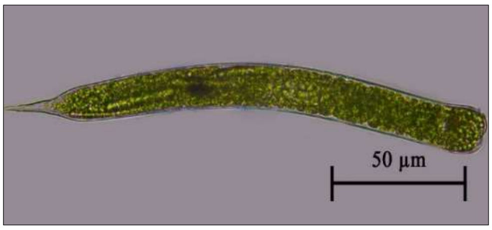
Dimensions:
Cell length - 125µm
Cell breadth - 25µm
Comments:
Cells slightly twisted, rounded at anterior end, posterior with short tail.

177. ***Euglena oxyuris*** var. ***charkowiensis*** (Swirenko) Bourrelly
Philipose, 1984. p.576, fig. 12c



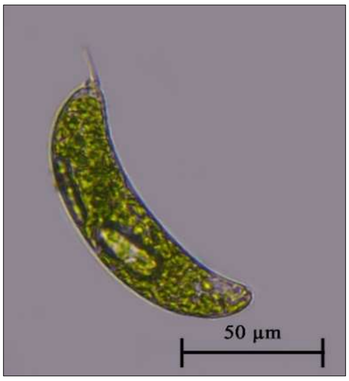
Dimensions:
Cell length - 137µm
Cell breadth - 38µm
Comments:
Cells broad, posterior with short tail have 24µm in length.

178. ***Euglena oxyuris*** var. ***playfairii*** Bourrelly
Philipose, 1984. p.575, fig. 12b



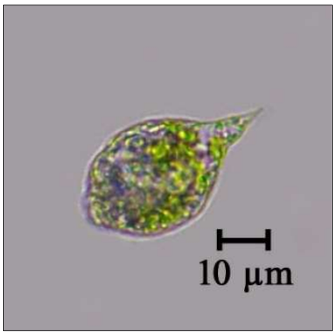
Dimensions:
Cell length - 300µm
Cell breadth - 24µm
Comments:
Cells with anterior end truncate, posterior with tail.

179. ***Euglena oxyuris*** var. ***minor*** Deflandre
Prescott, 1982. p. 393, pl. 85, fig. 18



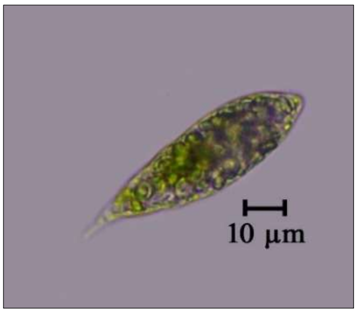
Dimensions:
Cell length - 120µm
Cell breadth - 25µm
Comments: Cells elongate, cylindrical and twisted, anterior end truncate, posterior end tapering to form short tail.

180. ***Euglena polymorpha*** Dangeard
Wolowski,1998. p.31, fig. 98



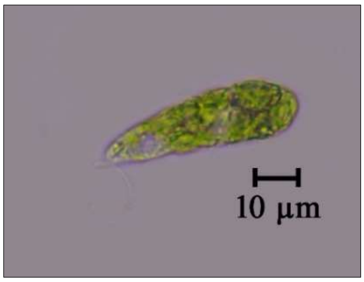
Dimensions:
Cell length - 42µm
Cell breadth - 23µm
Comments:
Cells fusiform, narrowing and rounded at anterior, short tail at posterior tip.

181. ***Euglena proxima*** Dangeard
Prescott, 1982. p. 394, pl. 85, fig. 25



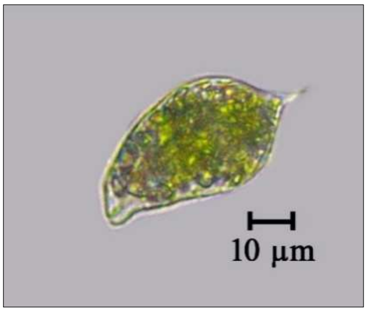
Dimensions:
Cell length - 61µm
Cell breadth - 15µm
Comments:
Cells fusiform, narrowed posteriorly to form a blunt tip, irregularly shaped chloroplasts scattered throughout the cell.

182. ***Euglena rustica*** var. ***rustica*** Huber-Pestalozi
Wolowski,1998. p.21, pl. V11, fig. 45



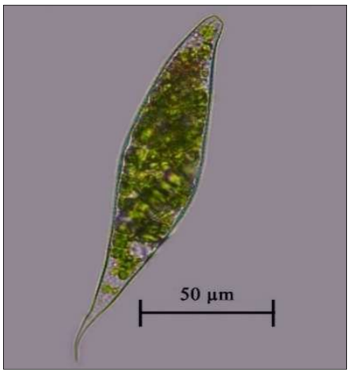
Dimensions:
Cell length - 45µm
Cell breadth - 12µm
Comments:
Cells wide, sac like, elongated at anterior end, rounded at posterior end.

183. ***Euglena sanguinea*** Ehrenberg
Wolowski,1998. p.34, fig. 113



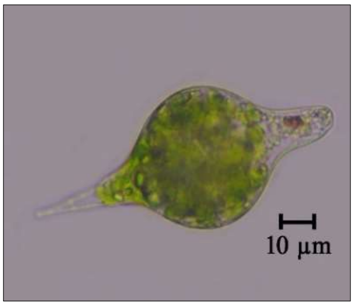
Dimensions:
Cell length - 55µm
Cell breadth - 28µm
Comments:
Cells fusiform, rounded at anterior end, tapering at posterior end.

184. ***Euglena*** **sp. 1**



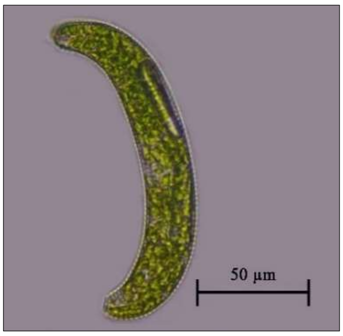
Dimensions:
Cell length - 151µm
Cell breadth - 30µm
Comments:
Cells elongated, narrowed posteriorly and form a sharp bend tail, striated with alternating rows of granules.

185. ***Euglena*** **sp. 2**



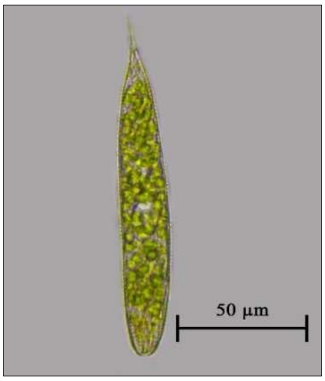
Dimensions:
Cell length - 89µm
Cell breadth - 50µm
Comments:
Cells elongated, rounded at median, narrowed posteriorly with sharp tail.

186. ***Euglena spirogyra*** var. ***spirogyra*** Klebs
Wolowski,1998. p.17, fig. 28



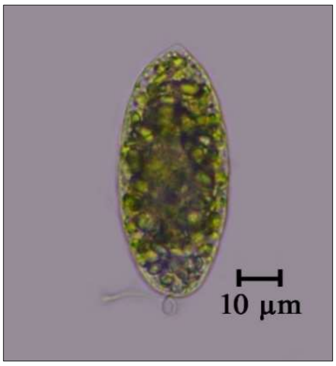
Dimensions:
Cell length - 140µm
Cell breadth - 19µm
Comments:
Cells elongated, curved, longitudinally cylindrical and narrowed posteriorly.

187. ***Euglena spirogyra*** Ehrenberg
Prescott, 1982. p. 394, pl. 86, fig. 15



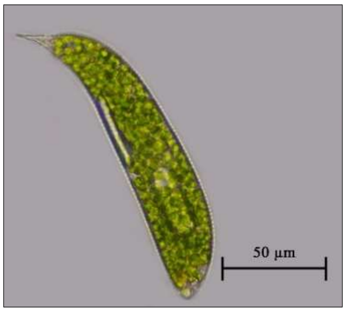
Dimensions:
Cell length - 108µm
Cell breadth - 19µm
Comments:
Cells cylindrical and twisted, narrowed posteriorly and form a sharp bend tail, spirally striated with alternating rows of granules.

188. ***Euglena splendens*** Dangeard
Wolowski,1998. p.33, pl. V11, fig. 110



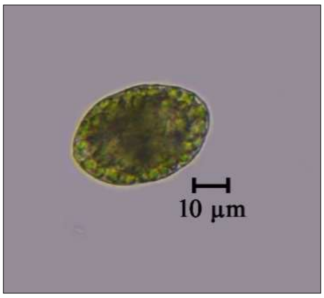
Dimensions:
Cell length - 65µm
Cell breadth - 23µm
Comments:
Cells cylindrical, rounded at anterior end, tapering towards posterior with short projection.

189. ***Euglena tripteris*** var. ***tripteris*** Klebs
Wolowski,1998. p.19, fig. 337



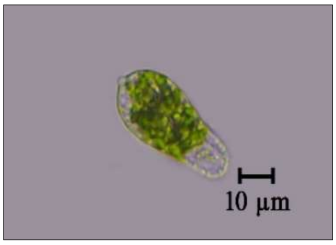
Dimensions:
Cell length - 147µm
Cell breadth - 26µm
Comments:
Cells narrowed at anterior end, slightly rounded at posterior end, tapering into a short sharp tail.

190. ***Euglena texta*** var. ***texta*** (starmach) Hubner
Wolowski,1998. p.35, pl. V11, fig. 116



Dimensions:
Cell length - 35µm
Cell breadth - 16µm
Comments:
Cells elongate-cylindric and rounded at anterior end.

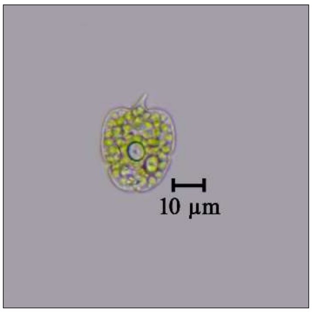
191. ***Euglena viridis*** f. ***Viridis*** (Popova) Ehrenberg
Wolowski,1998. p.35, pl. V11, fig. 116



Dimensions:
Cell length - 35µm
Cell breadth - 16µm
Comments:
Cells elongate-cylindric and rounded at anterior end.

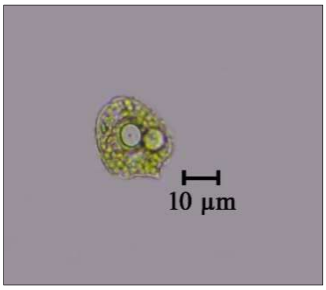
Genus: ***PHACUS*** Dujardin

192. ***Phacus anacoelus*** Stokes
Prescott, 1982. p. 397, pl. 87, fig. 7



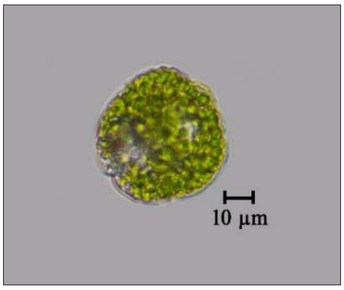
Dimensions:
Cell length - 36µm
Cell breadth - 29µm
Comments:
Cells ovoid, anterior end broadly rounded, chloroplast numerous, short caudus in posterior, paramylon bodies present.

193. ***Phacus curvicauda*** Svirenko
Prescott, 1982. p. 399, pl. 87, fig. 14



Dimensions:
Cell length - 27µm
Cell breadth - 23µm
Comments:
Cells ovoid, anterior end broadly rounded, chloroplast numerous.

194. ***Phacus lefevrei*** Bourelly
Philipose, 1984. p.520, fig. 12

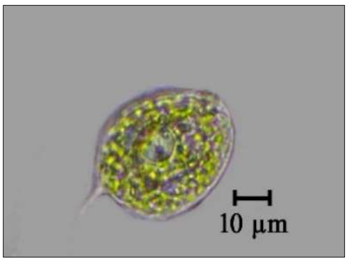


Dimensions:
Cell length - 48µm
Cell breadth - 47µm
Comments:
Cells ellipsoid with both ends rounded, broad, posterior end broader with larger swelling, numerous paramylum.

195. ***Phacus orbicularis*** Huebner
Philipose, 1984. p.529, fig. 30

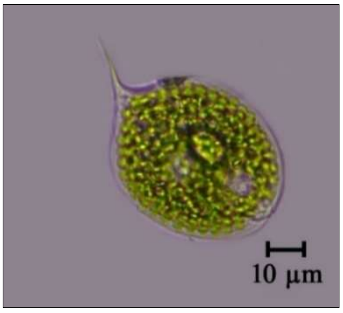
Dimensions:
Cell length - 110µm
Cell breadth - 90µm
Comments:
Cells circular, short tail, which is bent, numerous transverse striae, two paramylum, one large and in center.

196. ***Phacus orbicularis*** f. ***communis*** Popova
Wolowski,1998. p.76, fig. 260



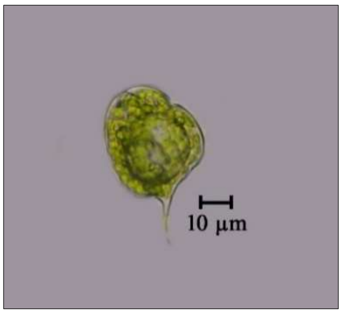
Dimensions:
Cell length - 47µm
Cell breadth - 28µm
Comments:
Cells wide, oval with posterior caudus.

197. ***Phacus orbicularis*** f. ***orbicularis*** Hubner
Wolowski,1998. p.76, fig. 260



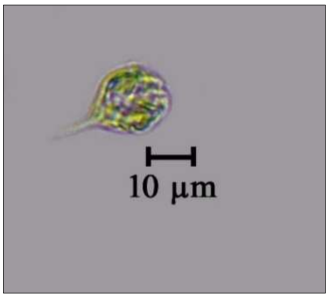
Dimensions:
Cell length - 62µm
Cell breadth - 35µm
Comments:
Cells wide, oval with long curved posterior caudus.

198. ***Phacus pseudoswirenkoi*** Prescott
Prescott, 1982. P. 402, pl. 85, fig. 26



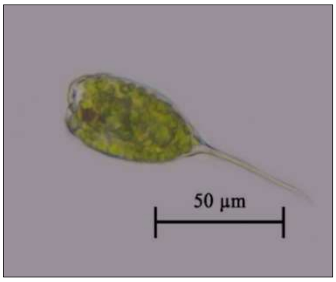
Dimensions:
Cell length - 45µm
Cell breadth - 27µm
Comments:
Cells with posterior caudus short, sharp and curved, anterior end broadly rounded with large circular disc.

199. ***Phacus splendens*** Pochmann
Wolowski,1998. p.86, fig. 303



Dimensions:
Cell length - 26µm
Cell breadth – 12.5µm
Comments:
Cells ovoid, narrowing towards posterior end with short conical cauda.

200. ***Phacus*** **sp.1**

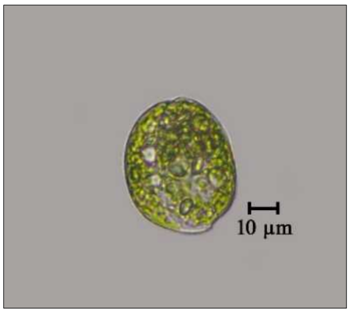


Dimensions:
Cell length - 54µm
Cell breadth - 27µm
Comments:
Cells with large eye spot, narrowing towards posterior end with long conical cauda.

201. *Phacus* sp.2

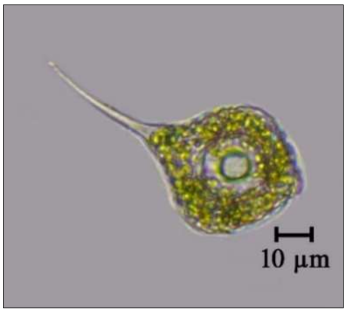
Dimensions:
Cell length - 160µm
Cell breadth - 125µm
Comments:
Cells large, circular, narrowing towards posterior end with conical cauda.

202. *Phacus stokesii* Lemmermann
Wolowski,1998. p.70, fig. 220



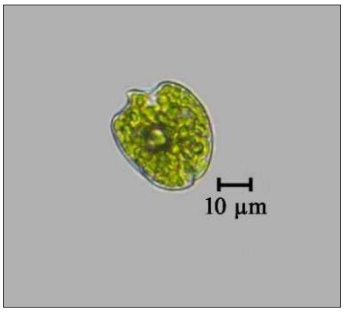
Dimensions:
Cell length - 42µm
Cell breadth - 36µm
Comments:
Cells ovoid, irregularly heart shaped and chloroplast numerous.

203. *Phacus tortus* (Lemm) Skvortzov
Philipose, 1984. p.540, fig. 40



Dimensions:
Cell length - 82µm
Cell breadth - 33µm
Comments:
Cells ovoid, anteriorly and posteriorly narrowed with long straight tail.

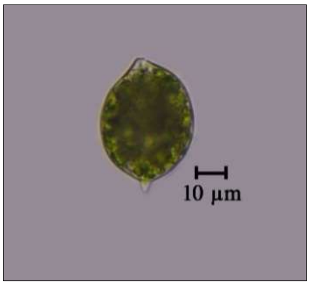
204. *Phacus viguieri* Allorge & lefevre
Wolowski,1998. p.82, fig. 285



Dimensions:
Cell length - 26µm
Cell breadth - 23µm
Comments:
Cells widely ovate, short cauda, tail alone 32µm, ovoid, anteriorly and posteriorly narrowed with long straight tail,

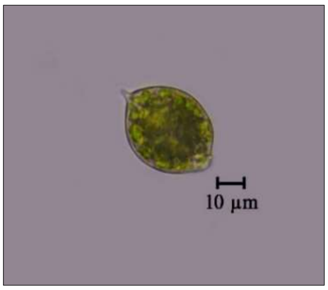
Genus: ***LEPOCINCLIS*** Perty

205. ***Lepocinclis fusiformis*** **(**Carter) Lemm.
Philipose, 1984. p.512, fig. 7a



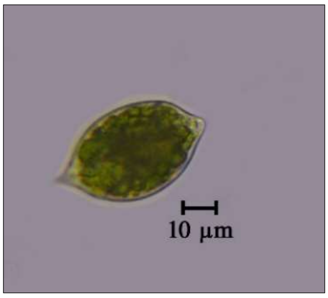
Dimensions:
Cell length - 44µm
Cell breadth - 27µm
Comments:
Cells broadly ovoid, obtuse ends, posterior end with a short caudus.

206. ***Lepocinclis ovum*** var. ***ovum*** Starmach
Wolowski,1998. p.66, fig. 210



Dimensions:
Cell length - 37µm
Cell breadth - 23µm
Comments:
Cells broadly ovoid, end broadly rounded, posterior end with caudus.

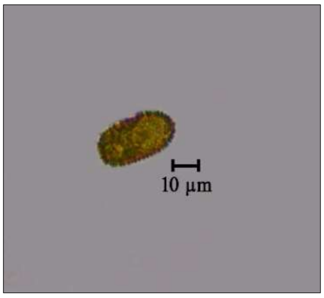
207. ***Lepocinclis playfairiana*** Deflandre
Prescott, 1982. p. 407, pl. 89, fig.16



Dimensions:
Cell length - 48µm
Cell breadth - 26µm
Comments:
Cells oval with short caudus, short rounded apex at anterior, slight invagination on lower side.

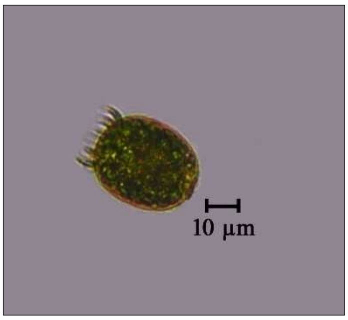
Genus: ***TRACHELOMONAS*** Ehrenberg

208. ***Trachelomonas abrupta*** Svirenko
Prescott, 1982. p. 410, pl. 83, fig. 18



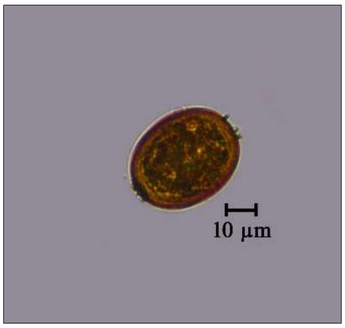
Dimensions:
Cell length - 27µm
Cell breadth - 15µm
Comments:
Cell broadly oval, wall coarsely punctate, truncate at the anterior end.

209. *Trachelomonas armata* (Ehr.) Stein.
Prescott, 1982. p. 410, pl. 83, fig. 32



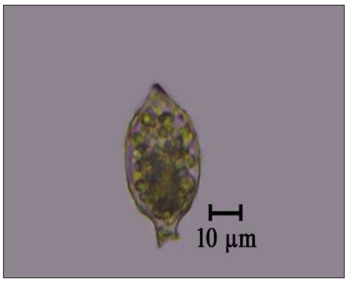
Dimensions:
Cell length - 25µm
Cell breadth - 35µm
Comments:
Cell broadly ovate and flagellum aperture in a collar.

210. *Trachelomonas armata* var. ***longispina*** Playfair
Prescott, 1982. p. 411, pl. 83, fig. 27



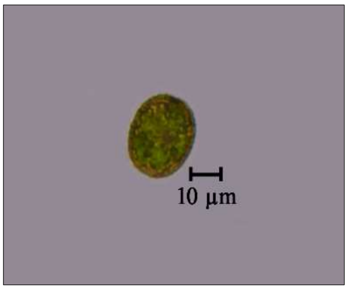
Dimensions:
Cell length - 40µm
Cell breadth - 29µm
Comments:
Cell obovate, reddish brown, with collar, posterior end short spines.

211. *Trachelomonas caudata* f. ***caudata*** Starmach
Wolowski,1998. p.64, fig. 204



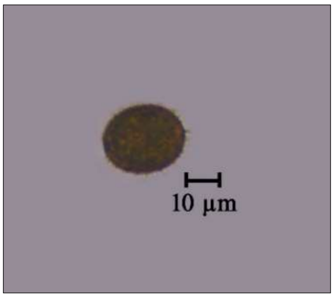
Dimensions:
Cell length - 40µm
Cell breadth - 23µm
Comments:
Cell elliptical, collar 4µm high, posterior end conical and caudate.

212. *Trachelomonas dybwoskii* Drezepolski ex Deflandre
Prescott, 1982. p. 412, pl. 83, fig.21



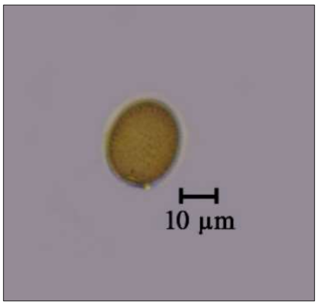
Dimensions:
Cell length - 25µm
Cell breadth - 19µm
Comments:
Cell elliptical, flagellum opening without a collar, wall smooth.

213. ***Trachelomonas globularis*** f. ***Globularis*** Lemmermann
Wolowski,1998. p.49, fig. 176



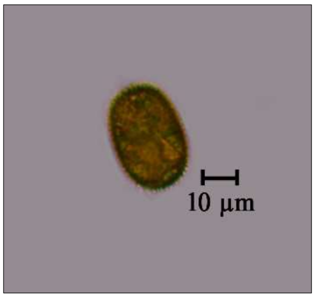
Dimensions:
Cell length - 19µm
Cell breadth - 25µm
Comments:
Cell globular, covered with short thick spines, reddish brown.

214. ***Trachelomonas granulosa*** Playfair
Philipose, 1988. p.357, fig. 31a



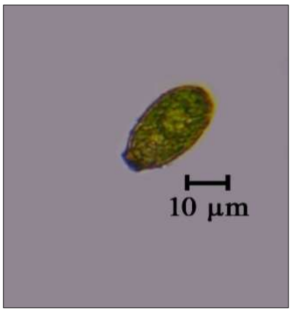
Dimensions:
Cell length - 20µm
Cell breadth - 25µm
Comments:
Cell ellipsoid with densely crowded granulations, depressed collar, reddish brown.

215. ***Trachelomonas hispida*** (Perty) Stein
Philipose, 1988. p.344, fig. 8a



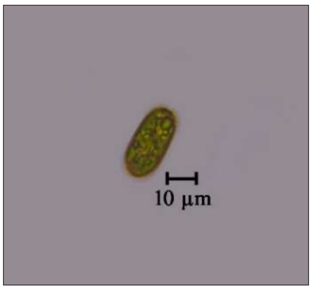
Dimensions:
Cell length - 15µm
Cell breadth - 24µm
Comments:
Cell ellipsoid, covered with short spines, very much depressed collar with few spines, reddish brown.

216. ***Trachelomonas lacustris*** Drezepolski
Prescott, 1982. p. 415, pl. 83, fig. 15



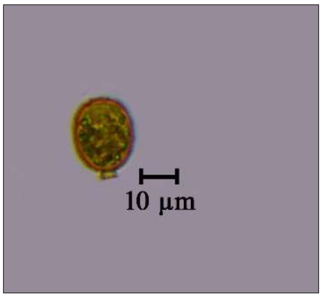
Dimensions:
Cell length - 27µm
Cell breadth - 12µm
Comments:
Cell cylindrical, flagellum aperture without collar, slightly raised rim, wall punctate, golden yellow brown.

217. ***Trachelomonas klebsii*** Deflandre
Wolowski,1998. p.54, fig. 181



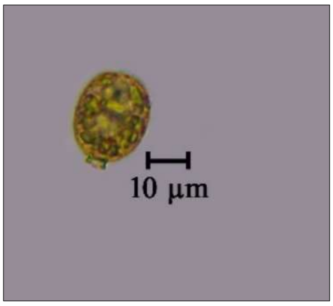
Dimensions:
Cell length - 26µm
Cell breadth - 13µm
Comments:
Cell cylindrical, covered with short spines, cylindrical, covered with short spines, without collar, yellowish brown.

218. ***Trachelomonas planctonica*** f. ***ornata*** Skvortzov
Wolowski,1998. p.62, fig. 199



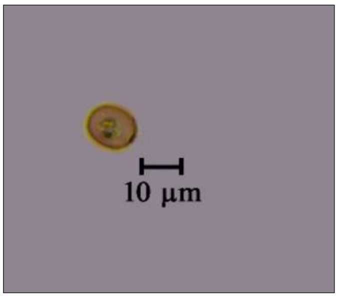
Dimensions:
Cell length - 23µm
Cell breadth - 15µm
Comments:
Cell elliptical covered with spores, collar with irregulate rim.

219. ***Trachelomonas planctonica*** f. ***Planctonica*** Swirenko
Wolowski,1998. p.62, fig. 197



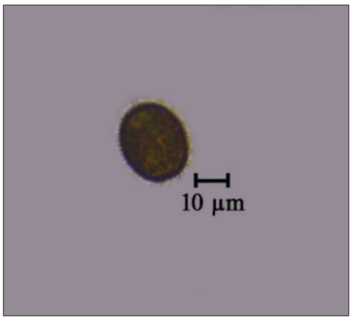
Dimensions:
Cell length - 22µm
Cell breadth - 16µm
Comments:
Cell elliptical covered with spores and granules, reddish brown in colour with dentate collar.

220. ***Trachelomonas oblonga*** var. ***minor*** (Playfair) Taskin & Alp
Prescott, 1951. p. 416, pl. 83, fig. 24



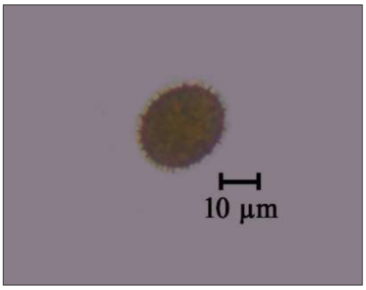
Dimensions:
Cell length - 12µm
Cell breadth - 10µm
Comments:
Cell elliptic, flagellum aperture without a collar, wall brown, smooth.

221. ***Trachelomonas robusta*** Svirenko
Prescott, 1951. p. 416, pl. 83, fig. 29



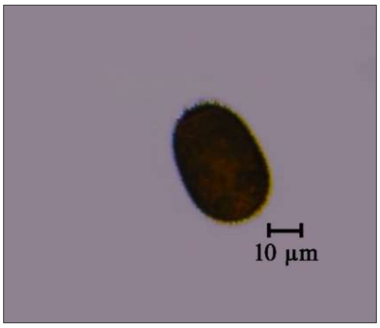
Dimensions:
Cell length - 23µm
Cell breadth - 18µm
Comments:
Cell oval without collar, sharp spines throughout the surface.

222. ***Trachelomonas*** **sp.1**



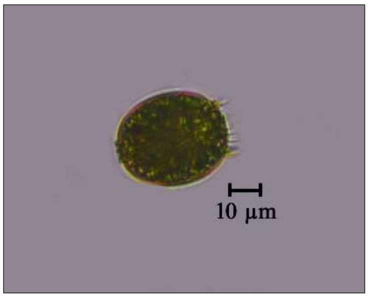
Dimensions:
Cell length - 26µm
Cell breadth - 20µm
Comments:
Cell oval with short collar, small, pointed spines interspersed throughout the surface.

223. ***Trachelomonas superba*** var. ***duplex*** Deflandre
Prescott, 1951. p. 417, pl. 84, fig. 11



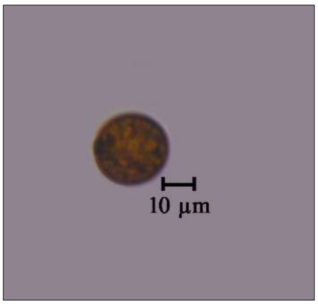
Dimensions:
Cell length - 37µm
Cell breadth - 28µm
Comments:
Cell oval with spines throughout the surface.

224. ***Trachelomonas superba*** var. ***Swirenkiana*** Deflandre
Prescott, 1951. p. 418, pl. 83, fig. 34



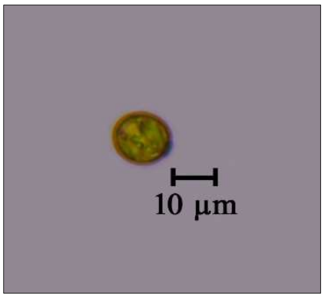
Dimensions:
Cell length - 40µm
Cell breadth - 30µm
Comments:
Cell globose, ring like collar, posterior with longer and stouter spines.

225. *Trachelomonas varians* Deflandre
Philipose, 1988. p.330, fig. 73



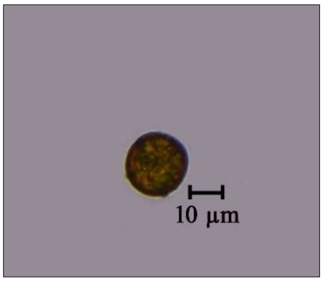
Dimensions:
Cell length - 24µm
Comments:
Cell spherical, smooth and dark reddish brown, pore 3µm.

226. *Trachelomonas volvocina* (Ehr.) Ehrenberg
Prescott, 1982. p. 419, pl. 83, fig. 1



Dimensions:
Cell length - 12µm
Comments:
Cell with depressed collar, wall smooth, yellowish brown, pore 1.5µm.

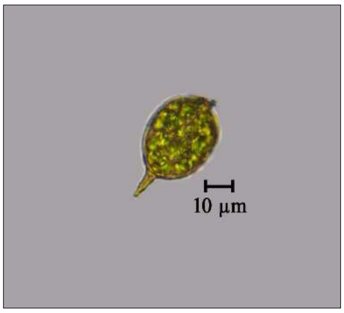
227. *Trachelomonas volvocinopsis* Svirenko
Wolowski,1998. p.48, fig. 173



Dimensions:
Cell length - 16µm
Comments:
Cell wall smooth and brown, many chromatophores.

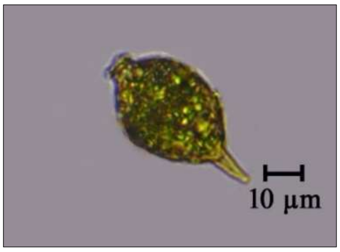
Genus: ***STROMBOMONAS*** Deflandre

228. *Strombomonas fluviatilis* (Lemm.) Defl.
Islam and Irfanullah, 2005a. pl. 3, fig. 44



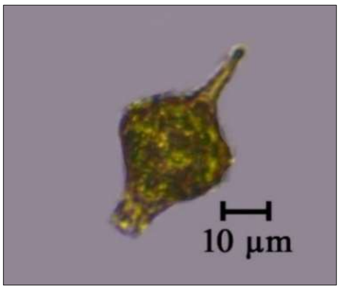
Dimensions:
Cell length - 43µm
Cell breadth - 25µm
Comments:
Cell with tail, lorica light brown colour.

229. ***Strombomonas girardiana*** (Playf.) Defl.
Philipose, 1988. p.379, fig. 53



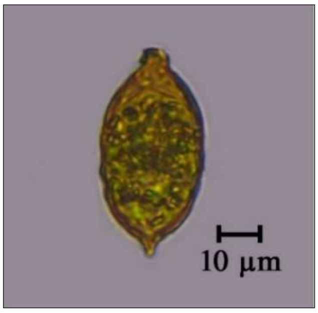
Dimensions:
Cell length - 42µm
Cell breadth - 23µm
Comments:
Cell light brown colour, tail short.

230. ***Strombomonas gibberosa*** (Playf.) Defl.
Philipose, 1988. p.385, fig. 62b



Dimensions:
Cell length - 48µm
Cell breadth - 25µm
Comments:
Cell rhomboid with median angular, lorica light brown colour.

231. ***Strombomonas*** **sp.1**

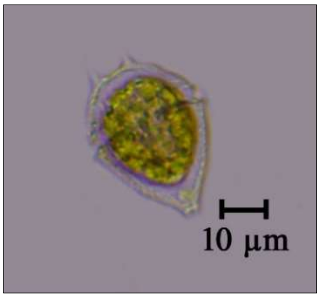


Dimensions:
Cell length - 50µm
Cell breadth - 25µm
Comments:
Cell rhomboid, posterior end with short cauda, lorica light brown colour.

Division : **Pyrrhophyta**
Class : **Dinophyceae**
Order : **Peridiniales**
Family : **Glenodiniaceae**

Genus: ***PERIDINIOPSIS*** (Ehrenberg.) Stein

232. ***Peridiniopsis quadridens*** (Stein) Bourrelly
Prescott, 1982. p. 430, pl. 90, fig. 19

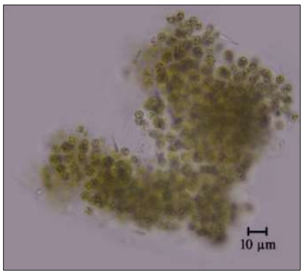


Dimensions:
Cell length - 32µm
Cell breadth - 25µm
Comments:
Cells ovate, hypocone rounded with 2 short sharp spines, transverse furrow which equally dividing the cell.

Division : **Cyanophyta**
Class : **Cyanophyceae**
Order : **Chroococcales** wettstein
Family : **Chroococcaceae** naegeli

Genus: ***MICROCYSTIS*** Kuetzing

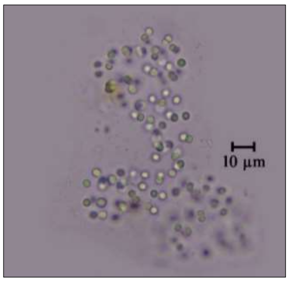
233. ***Microcystis aeruginosa*** (Kützing) Kützing
Komarek, 2013. p. 232, fig. 304



Dimensions:
Cell breadth - 7µm
Comments:
Cells spherical, colonies with large number of irregularly arranged cells.

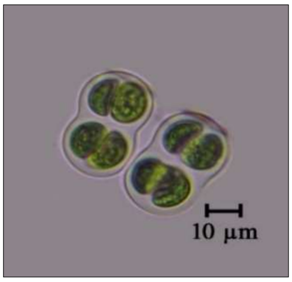
Genus: ***CHROOCOCCUS*** Nageli

234. ***Chroococcus minimus*** (Keissler) Lemm.
Komarek, 2013. p. 286, fig. 371



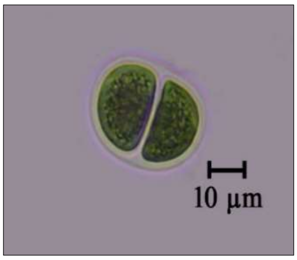
Dimensions:
Cell breadth - 2µm
Comments:
Cells spherical, pale blue green, arranged in small groups.

235. ***Chroococcus minutus*** (Kutzing) Nag.
Komarek, 2013. p. 296, fig. 391



Dimensions:
Cell breadth - 10µm
Colony length - 30µm
Comments:
Cells hemispherical, granulate content, colonies enclosed by colourless sheath.

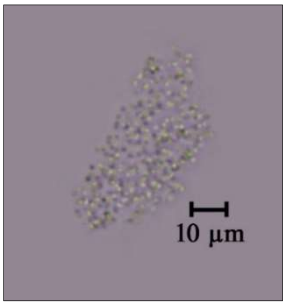
236. ***Chroococcus turgidus*** (Kuetz.) Nag.
Komarek, 2013. p. 306, fig. 407



Dimensions:
Cell length - 12µm
Colony length - 27µm
Comments:
Colony of 2 hemispherical cells enclosed by colonial sheath, bright blue green.

Genus: ***APHANOCAPSA*** Nageli

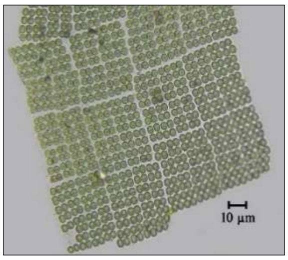
237. ***Aphanocapsa delicatissima*** West & west
Komarek, 2013. p. 151, fig. 171



Dimensions:
Cell breadth – 0.8µm
Colony length - 50µm
Comments:
Cells spherical, colonies irregular, minute, bluish colour.

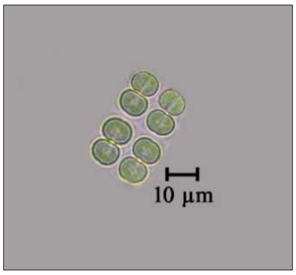
Genus: ***MERISMOPEDIA*** Meyen

238. ***Merismopedia elegans*** A.Braun ex Kützing
Komarek, 2013. p. 180, fig. 227



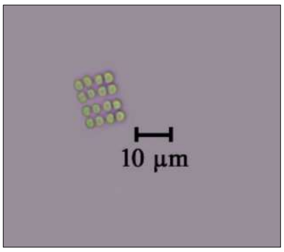
Dimensions:
Cell breadth - 5µm
Comments:
Cells spherical, densely arranged, granular content, colonies rectangular.

239. ***Merismopedia smithii*** De Toni
Prescott, 1982. p. 459, pl. 100, fig. 18



Dimensions:
Cell breadth - 9µm
Comments:
Cells spherical, large sized, mucilage distinct.

240. ***Merismopedia tenuissima*** Lemmermann
Komarek, 2013. p. 174, fig. 219

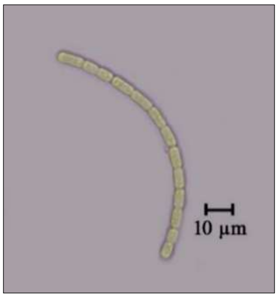


Dimensions:
Cell breadth - 2µm
Comments:
Cells hemispherical, blue green, colonies rectangular, densely packed cells.

Order : **Oscillatoriales**
Family : **Pseudanabaenaceae**

Genus: ***PSEUDANABAENA*** Lauterborn

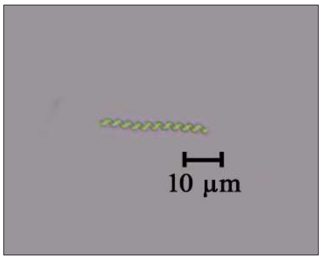
241. ***Pseudoanabaena galeata*** Bocher
Komarek, 2013. p. 88, fig. 67



Dimensions:
Cell breadth – 1.2µm
Comments:
Cells cylindrical with rounded ends, connected with cross walls, curved.

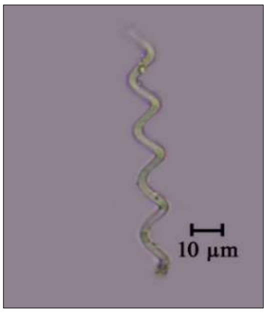
Genus: ***SPIRULINA*** Turpin ex. Gardner

242. ***Spirulina menengiana*** Zanardini ex Gomont
Komarek, 2013. p. 148, fig. 173



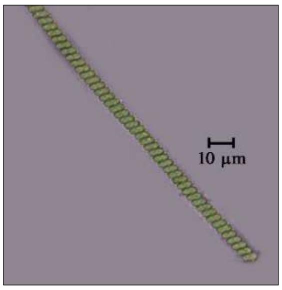
Dimensions:
Cell breadth - 1µm
Comments:
Thallus thin, blue green, not constricted at walls.

243. ***Spirulina subsalsa*** Oersted ex Gomont
Komarek, 2013. p. 148, fig. 175



Dimensions:
Cell breadth - 3µm
Comments:
Trichomes coiled, not constricted at walls, blue green.

244. ***Arthrospira fusiformis*** Komarek et Lund
Komarek, 2013. p. 150, fig. 176

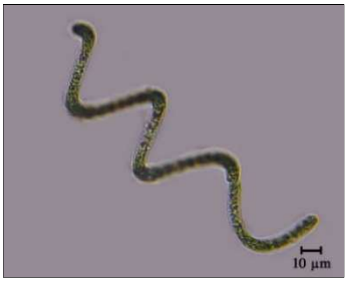


Dimensions:
Cell breadth – 1.2µm
Comments:
Thallus bright green, densely screw like coiled, not constricted at walls.

Family: **Phormidiaceae**

Genus: ***ARTHROSPIRA*** Stizenberger

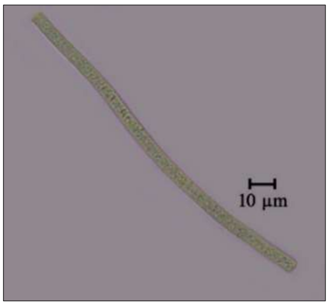
245. ***Arthrospira khannae*** Drouet et Strickland
Komarek, 2013. p. 347, fig. 482



Dimensions:
Cell breadth - 3µm
Comments:
Trichomes solitary, free floating, loosely coiled and granulated.

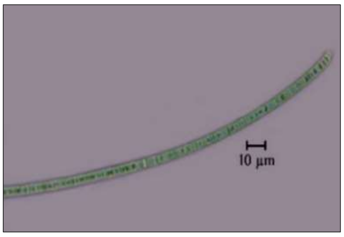
Genus: ***PLANKTOTHRIX*** Anagnostidis et Komarek

246. ***Planktothrix agardhii*** Anagnostidis et Komarek



Dimensions:
Cell breadth - 6µm
Comments:
Filaments solitary, straight, granulated cross walls.

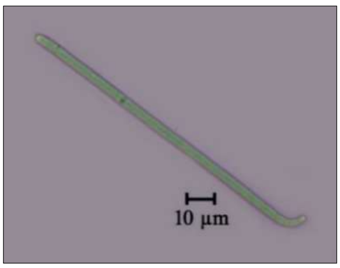
247. ***Planktothrix*** **sp.**
Komarek, 2013. p. 439, fig. 639



Dimensions:
Cell breadth - 5µm
Comments:
Filaments solitary, straight, not constricted at the granulated cross walls, attenuated ends.

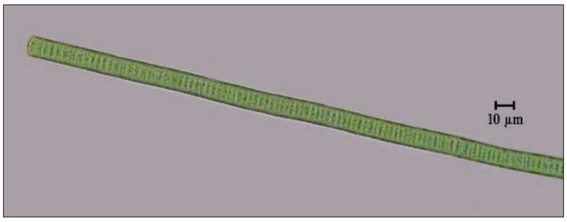
Genus: ***PHORMIDIUM*** Kuetzing

248. ***Phormidium irriggum*** Angnostidis et komarek
Komarek, 2013. p. 421, fig. 602



Dimensions:
Cell breadth – 4.5µm
Comments:
Filaments solitary, straight, granulated cross walls, attenuated ends.

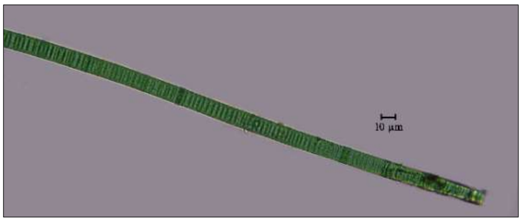
249. ***Phormidium* sp.**
Komarek, 2013. p. 593, fig. 886



Dimensions:
Cell breadth - 10μm
Comments:
Thallus blue green, straight, granulated, not attenuated at ends.

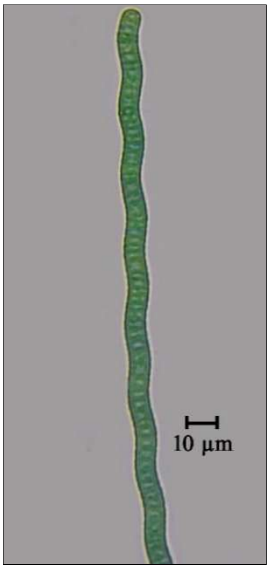
Genus: ***OSCILLATORIA*** Vaucher

250. ***Oscillatoria jenesis*** Schmid
Komarek, 2013. p. 593, fig. 884



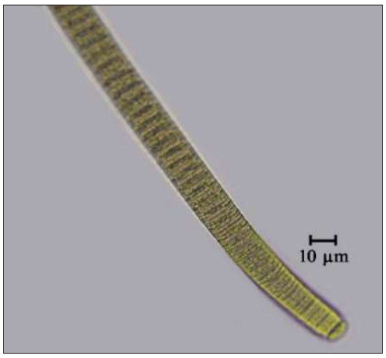
Dimensions:
Cell breadth - 8μm
Comments:
Thallus solitary, not constricted, flattened-rounded apical cells.

251. ***Oscillatoria limosa*** Agardh ex Gomont
Komarek, 2013. p. 599, fig. 902



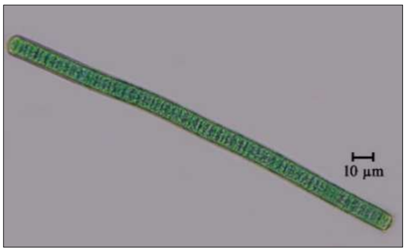
Dimensions:
Cell breadth - 7μm
Comments:
Thallus blue green, loosely spirally coiled, not attenuated and capitate at ends.

252. ***Oscillatoria princeps*** Vaucher ex Gomont
Komarek, 2013. p. 590, fig. 883



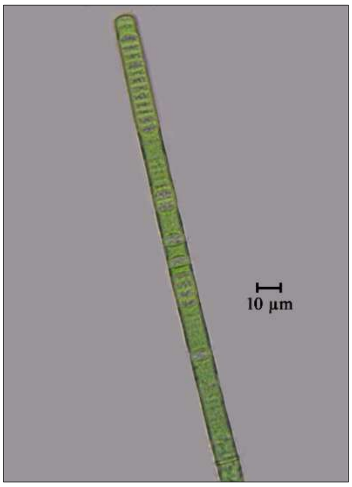
Dimensions:
Cell breadth - 21µm
Comments:
Thallus straight, long, attenuated at ends, granulated cross walls.

253. ***Oscillatoria lutea*** Agardh ex Gomont
Komarek, 2013. p. 599, fig. 802



Dimensions:
Cell breadth - 8µm
Comments:
Filaments solitary, dark blue green, straight, granulated cross walls, not attenuated at the ends

254. ***Oscillatoria subbrevis*** Schmidle
Komarek, 2013. p. 599, fig. 914

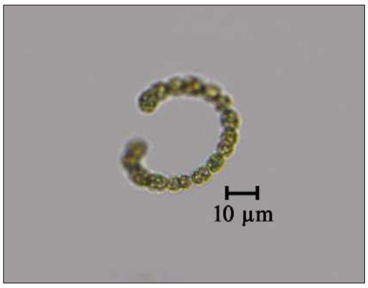


Dimensions:
Cell breadth - 10µm
Comments:
Thallus straight, granulated cross walls, rounded apical cells.

Family: **Nostocaceae**

Genus: ***DOLICHOSPERMUM*** Hoffmann et Komarek

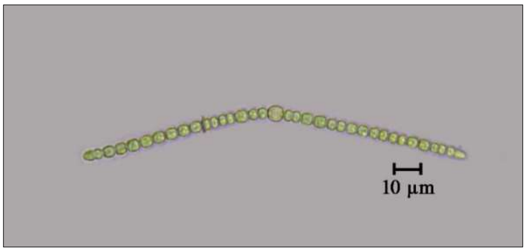
255. ***Dolichospermum perturbatum*** (Hill) Wacklin
Komarek, 2013. p. 704, fig. 868



Dimensions:
Cell breadth - 5µm
Comments:
Trichomes circular with spirals, granulated, not attenuated at ends.

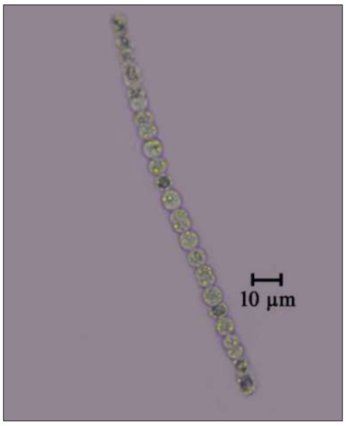
Genus: ***ANABAENA*** Bory

256. ***Anabaena ghosei*** Welsh
Komarek, 2013. p. 835, fig. 1061



Dimensions:
Cell breadth – 3.5µm
Comments:
Filaments short, constricted at walls, cells barrel shaped, apical cells conical.

257. ***Anabaena*** **sp.**



Dimensions:
Cell breadth – 7µm
Comments:
Filaments straight, constricted at walls, granulated and barrel shaped.

4.4 Quantitative analysis of phytoplankton

Station wise and month wise distribution of taxa during the study period was given in tables 5 & 6. Highest number of taxa were recorded from station 7 (353120 cells/L) and lowest at station 10 (31020 cells/L). Month wise highest taxa was recorded in May (217260 cells/L) and lowest in June (25330 cells/L).

Table 5. Monthly distribution of average number of algal taxa from the rivers in Palakkad district

Sl. No.	Taxa	Months											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
1	*Achnanthes exigua*	2210	0	0	0	40	0	2160	650	0	0	70	120
2	*Actinastrum hantzschii* var. *elongatum*	0	1140	0	0	0	210	0	50	0	110	50	0
3	*Actinocyclus normanii*	80	0	0	320	540	430	4320	70	0	0	80	50
4	*Amphora ovalis* var. *gracilis*	440	0	60	0	50	0	0	80	110	0	0	80
5	*Anabaena ghosei*	40	0	0	0	0	0	80	0	70	90	0	0
6	*Anabaena* sp.1	0	0	0	0	0	0	0	140	0	0	0	0
7	*Ankistrodesmus convolutus*	0	0	260	0	0	1100	610	0	0	0	80	40
8	*Ankistrodesmus falcatus*	150	680	0	0	1310	50	870	0	0	340	70	150
9	*Aphanocapsa delicatissima*	80	0	0	110	0	0	0	0	540	0	0	670
10	*Arthrodesmus curvatus* var. *latus*	0	40	0	720	560	40	0	0	40	40	0	0
11	*Arthrospira fusiformis*	0	0	60	0	0	0	780	0	0	0	1210	0
12	*Arthrospira khannae*	0	90	0	0	530	0	0	3420	0	0	0	0
13	*Aulacoseira granulata*	1120	980	740	60	890	9840	800	7600	70	690	60	560
14	*Aulacoseira granulata* var. *Angustissima*	0	100	0	0	540	780	2450	650	420	70	0	80
15	*Caloneis permagna*	670	80	0	230	870	0	540	0	230	0	160	0
16	*Centritractus belanophorus*	0	90	870	110	0	210	160	100	0	0	40	0
17	*Chroococcus minimus*	40	0	70	0	0	230	0	0	0	0	0	0
18	*Chroococcus minutus*	0	0	0	430	0	0	160	0	0	760	0	0
19	*Chroococcus turgidus*	0	0	450	0	0	0	0	6530	0	780	920	0

Sl. No	Taxa	Months											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
20	*Closterium dianae*. var. *minus*	650	200	0	1230	520	0	640	80	0	170	50	90
21	*Closterium ehrenbergii*	560	0	120	790	0	0	0	400	0	40	190	0
22	*Closterium kuetzingii*	400	0	0	1370	0	370	0	0	40	60	120	160
23	*Closterium lagoense*	0	0	450	0	310	0	0	60	310	0	0	80
24	*Closterium moniliferum*	450	670	0	320	0	600	170	0	120	80	100	0
25	*Closterium navicula*	40	0	120	0	0	0	0	0	0	0	0	0
26	*Closterium peracerosum*	0	0	70	0	310	140	0	90	240	300	0	0
27	*Cocconeis placentula*	0	0	620	120	360	750	680	0	310	80	0	280
28	*Coelastrum microporum*	0	40	80	110	0	0	110	80	40	0	340	40
29	*Coelastrum proboscideum*	60	0	0	130	620	0	0	80	0	0	70	290
30	*Coelastrum sphaericum*	610	50	0	0	780	0	540	0	540	120	0	50
31	*Cosmarium auriculatum*	0	640	0	50	40	420	0	110	310	0	260	180
32	*Cosmarium binum*	120	230	80	190	430	240	100	0	380	50	120	80
33	*Cosmarium blyttii*	430	100	650	0	210	0	860	120	0	160	40	0
34	*Cosmarium depressum*	120	0	400	310	0	0	80	320	240	0	0	110
35	*Cosmarium depressum* var. *apertum*	200	0	0	0	80	100	0	0	0	70	0	0
36	*Cosmarium galeritum*	0	310	0	100	0	40	0	450	0	0	410	0
37	*Cosmarium granatum*	220	80	0	340	220	0	310	0	0	0	60	160
38	*Cosmarium granatum*. var. *rotundatum*	0	0	120	60	0	0	40	440	230	0	210	0
39	*Cosmarium lundellii*	40	0	310	0	0	160	0	870	0	90	0	80
40	*Cosmarium lundellii* var. *circulare*	70	220	100	0	130	0	0	220	320	0	0	0
41	*Cosmarium lundellii* var. *corruptum*	0	0	280	0	0	0	760	40	0	80	0	0
42	*Cosmarium maculatum*.	110	540	120	0	680	0	0	0	60	0	60	0
43	*Cosmarium margaritatum* var. *sublatum*	0	110	0	430	80	0	440	540	80	210	40	0
44	*Cosmarium medioscrobiculatum* var. *egranulatum*	0	0	310	0	0	640	0	210	90	0	0	40
45	*Cosmarium obsoletum*	0	340	0	610	430	340	0	0	0	220	0	60
46	*Cosmarium pseudoconnatum*.	430	550	0	100	0	430	50	0	50	40	0	60
47	*Cosmarium punctulatum* var. *subpunctulatum*	0	0	230	170	330	60	0	0	0	100	60	210
48	*Cosmarium quadrifarium*	70	4	0	100	0	100	590	820	110	0	40	0
49	*Cosmarium quadrum*	240	0	310	0	50	80	0	0	0	60	0	40
50	*Cosmarium scabrum*	100	530	0	0	130	40	640	560	220	0	100	0
51	*Cosmarium sexangulare* fa. *minimum*	0	80	90	60	0	0	0	370	0	0	60	120

Sl. No.	Taxa	Months											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
52	*Cosmarium subspeciosum* var. *validius*	60	0	520	0	250	410	610	140	0	230	310	0
53	*Cosmarium subundulatum*	0	500	0	70	0	90	0	0	160	0	880	0
54	*Cosmarium turgidum*	0	0	210	60	0	0	50	0	120	40	0	0
55	*Cyclotella meneghiniana*	430	130	0	60	40	420	640	0	730	0	180	60
56	*Cyclotella striata*	210	180	600	80	4900	460	620	5240	80	100	70	420
57	*Cylindrocystis brebissonii*	0	0	240	0	0	0	0	0	0	70	0	110
58	*Cymbella bengalensis*	0	460	0	910	0	780	70	0	230	240	820	0
59	*Cymbella hungarica* var. *sigmata*	0	800	0	80	100	40	480	2100	0	0	540	870
60	*Cymbella laevis*	240	60	800	0	0	650	100	0	0	80	110	0
61	*Cymbella tumida*	120	620	410	600	80	80	910	90	240	60	40	110
62	*Cymbella turgida*	580	0	790	160	0	2450	60	3210	0	0	430	650
63	*Cymbella ventricosa*	0	0	520	0	0	0	0	0	640	0	0	0
64	*Dictyosphaerium ehrenbergianum*	90	0	0	0	0	0	180	0	0	640	0	0
65	*Diploneis ovalis*	0	40	0	0	140	0	320	680	0	0	60	0
66	*Dolichospermum perturbatum*	0	8400	60	0	0	780	1660	0	70	680	0	0
67	*Euastrum gayanum*	0	180	0	0	0	0	0	0	460	0	0	80
68	*Euastrum sinuosum*	0	0	640	0	120	0	0	0	0	70	0	110
69	*Euastrum spinulosum*	40	60	0	0	0	0	100	0	0	80	110	0
70	*Euglena acus*	120	620	410	0	80	0	110	0	240	0	0	0
71	*Euglena acus* var. *acus*	0	0	240	80	0	0	0	740	0	0	250	790
72	*Euglena agilis*	0	0	580	0	0	0	330	0	0	0	0	0
73	*Euglena anabaena* var. *anabaena*	0	0	0	510	0	0	0	0	0	60	360	0
74	*Euglena archeoplastidiata*	0	190	0	0	0	0	0	0	0	420	0	0
75	*Euglena chlamydophora*	60	0	0	0	0	480	80	0	80	0	0	0
76	*Euglena deses* fo. *deses*	0	0	70	60	0	0	210	0	60	00	0	90
77	*Euglena deses* fo. *intermedia*	510	480	0	40	90	60	0	0	0	0	0	80
78	*Euglena deses* fo. *klebsii*	0	0	0	0	0	0	0	430	0	0	0	80
79	*Euglena ettlii*	0	250	0	70	0	0	0	0	0	0	70	0
80	*Euglena fusca*	0	0	190	0	80	330	540	980	510	60	0	0
81	*Euglena gracilis*	480	0	0	310	0	0	0	280	80	0	60	0
82	*Euglena hemichromata*	0	0	60	100	0	0	740	580	0	0	250	0
83	*Euglena oxyuris* Schmarda fo. *oxyuris*	60	190	0	0	0	330	0	0	80	0	60	0

Sl. No.	Taxa	Months											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
84	*Euglena oxyuris* var. *charkowiensis*	0	0	0	480	70	0	120	280	0	60	0	70
85	*Euglena oxyuris* var. *minor*	0	460	40	0	0	0	870	740	0	0	50	0
86	*Euglena oxyuris* var. *playfairii*	0	0	280	0	0	780	330	0	120	0	60	0
87	*Euglena polymorpha*	0	200	0	110	0	60	0	570	0	60	0	0
88	*Euglena proxima*	50	590	120	0	0	0	650	0	30	120	0	0
89	*Euglena rustica* var. *rustica*	60	70	0	0	0	80	80	0	580	0	70	0
90	*Euglena sanguinea*	100	0	90	40	0	40	610	0	60	0	0	90
91	*Euglena* sp. 1	0	0	0	0	0	60	0	80	0	0	0	0
92	*Euglena* sp. 2	0	0	0	0	0	0	0	30	0	0	0	0
93	*Euglena spirogyra*	0	250	0	70	0	0	0	0	0	0	70	0
94	*Euglena spirogyra* var. *spirogyra*	0	0	190	0	80	330	80	980	510	60	0	0
95	*Euglena splendens*	310	0	70	0	0	0	0	880	80	0	60	0
96	*Euglena texta* var. *texta*	110	0	40	280	0	0	0	940	0	0	250	90
97	*Euglena tripteris* var. *tripteris*	0	60	680	0	0	0	830	0	0	0	0	0
98	*Euglena viridis* fo. *viridis*	0	0	0	220	0	0	970	0	0	60	760	0
99	*Eunotia lunaris*	860	0	0	540	0	1360	80	890	0	980	0	210
100	*Fragilari rumpens* var. *familiaris*	4560	0	790	0	650	430	0	8240	0	0	320	680
101	*Fragilaria construens* var. *venter*	2300	480	0	5430	0	690	0	9760	250	0	1460	70
102	*Fragilaria intermedia*	5790	70	180	430	890	6780	1350	8750	0	0	670	890
103	*Peridiniopsis quadridens*	0	0	0	0	0	0	160	0	80	0	0	0
104	*Golenkinia paucispina*	0	250	0	0	0	70	0	40	0	0	0	180
105	*Golenkiniopsis minutissima*	40	0	0	70	70	0	0	120	70	50	70	0
106	*Gomphonema aequatoriale*	0	8680	0	0	80	0	0	480	0	70	90	0
107	*Gomphonema gracile* var. *frickei*	0	0	0	50	0	60	240	0	430	0	0	890
108	*Gomphonema gracile* var. *intricatiforme*	110	0	0	570	0	0	4310	1840	0	70	480	0
109	*Gomphonema lacus-rankala* var. *gracilis*	70	180	0	0	60	340	0	7650	330	0	0	0
110	*Gomphonema montanum* var. *acuminatum*	0	0	670	190	0	890	0	1480	0	0	0	0
111	*Gomphonema parvulum*	110	70	0	280	40	340	650	0	70	0	0	0
112	*Gomphonema subapicatum*	820	90	0	70	0	560	0	7690	80	0	0	90
113	*Gyrosigma distortum* var. *parkeri*	0	0	0	80	0	0	120	80	0	0	80	0
114	*Gyrosigma kuetzingii*	260	0	50	0	50	4800	0	890	0	80	0	70
115	*Hantzschia amphioxys*	0	410	60	0	230	70	2190	90	0	210	0	0

Sl. No.	Taxa	Months											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
116	*Hantzschia amphioxys* var. *pusilla*	580	0	0	0	70	230	400	0	0	80	0	0
117	*Hantzschia linearis*	0	120	0	0	0	0	0	0	630	0	0	60
118	*Lagerheimia ciliata*	40	0	90	0	0	0	80	0	0	0	0	0
119	*Lepocinclis fusiformis*	0	0	110	60	0	0	280	760	0	80	90	0
120	*Lepocinclis ovum* var. *ovum*	80	120	0	0	60	230	0	7900	0	0	0	0
121	*Lepocinclis playfairiana*	0	0	8110	60	0	0	80	60	0	0	50	0
122	*Oscillatoria meslinii*	0	0	0	0	0	240	0	0	0	0	0	0
123	*Merismopedia elegans*	210	0	0	530	0	430	0	870	0	0	80	0
124	*Merismopedia elegans var. major*	0	0	0	0	0	0	0	0	0	540	0	0
125	*Merismopedia tenuissima*	0	0	0	0	80	80	70	0	520	0	0	80
126	*Micrasterias foliacea*	0	0	540	0	0	0	0	0	0	0	320	0
127	*Micrasterias laticeps* var. *acuminata*	60	310	0	0	70	0	100	90	0	0	0	70
128	*Micrasterias pinnatifida* (Kuetz.) Ralfs	0	0	70	110	0	60	0	0	0	210	0	670
129	*Micratinium pusillum* var. *elegans*	60	0	0	0	80	0	0	40	0	0	0	0
130	*Microcystis aeruginosa*	0	0	710	0	0	0	460	890	0	0	0	0
131	*Navicula constans* var. *symmetrica*	0	0	0	800	0	0	60	1630	0	0	320	0
132	*Navicula cuspidata*	60	570	89	0	110	790	0	4500	640	80	0	470
133	*Navicula gracilis*	80	0	0	0	0	60	0	240	0	0	80	120
134	*Navicula gastrum*	0	0	40	0	50	0	960	0	0	830	90	0
135	*Navicula lateostrata*	0	0	0	0	0	70	0	360	0	120	0	0
136	*Navicula mutica* var. *linearis*	50	430	80	50	0	80	0	760	70	0	220	0
137	*Navicula pupula*	0	0	0	420	130	0	400	640	60	0	0	670
138	*Navicula pusilla*	0	60	0	260	0	190	0	0	0	880	0	0
139	*Navicula pygmaea*	100	0	60	0	70	80	0	0	120	0	0	420
140	*Neidium productum* var. *bombayensis*	0	0	0	0	0	210	0	0	70	0	0	0
141	*Nitzschia apiculata*	0	0	210	0	0	0	240	0	0	180	0	340
142	*Nitzschia closterium*	240	0	230	0	160	690	0	1320	0	140	790	80
143	*Nitzschia intermedia*	0	250	0	640	80	0	0	7490	980	0	180	1320
144	*Nitzschia obtusa*	260	780	0	0	3500	0	140	8640	900	0	0	80
145	*Nitzschia obtusa* var. *scalpelliformis*	0	0	80	0	0	120	60	0	0	530	610	80
146	*Nitzschia philippinarum*	0	0	100	0	0	60	0	0	0	0	0	60
147	*Nitzschia sublinearis*	70	0	650	140	120	90	360	650	60	0	50	130

Sl. No.	Taxa	Months											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
148	*Onychonema laeve* var. *micracanthum*	0	620	90	0	0	0	0	490	0	110	0	0
149	*Oocystis borgei*	0	0	0	130	0	650	410	0	120	0	90	0
150	*Oscillatoria limosa*	0	450	680	0	0	80	230	0	0	0	0	690
151	*Oscillatoria lutea*	740	0	0	2100	0	70	0	580	0	0	0	0
152	*Oscillatoria princeps*	0	330	0	0	0	0	0	0	0	0	0	0
153	*Oscillatoria* sp.1	110	0	230	80	900	0	910	0	0	0	0	800
154	*Pandorina morum*	80	210	0	0	50	0	230	2100	40	210	0	790
155	*Pandorina morum* var. *major*	0	0	0	70	60	0	320	70	0	0	310	50
156	*Pediastrum biradiatum*	520	0	250	0	0	330	0	80	0	80	60	0
157	*Pediastrum boryanum* var. *longicorne*	0	60	120	0	0	0	540	540	90	60	0	0
158	*Pediastrum simplex*	0	0	0	70	50	0	0	0	0	0	80	210
159	*Pediastrum simplex* var. *duodenarium*	0	140	0	0	0	170	0	280	0	0	80	140
160	*Pediastrum tetras*	160	80	0	120	0	580	260	0	0	290	0	870
161	*Phacus anacoelus*	220	0	0	60	90	430	0	310	210	0	0	80
162	*Phacus curvicauda*	0	0	120	0	70	220	230	0	0	0	0	100
163	*Phacus lefevrei*	160	60	0	0	0	0	0	230	350	80	50	0
164	*Phacus orbicularis*	60	0	0	120	0	0	0	70	0	0	0	60
165	*Phacus orbicularis* fo. *communis*	0	0	40	0	0	0	190	0	0	0	0	0
166	*Phacus orbicularis* fo. *orbicularis*	120	70	0	0	0	140	0	920	0	100	0	230
167	*Phacus pseudoswirenkoi*	0	0	0	60	0	260	0	170	420	0	40	0
168	*Phacus* sp.1	0	0	120	0	0	310	0	0	0	0	0	0
169	*Phacus* sp.2	0	0	0	2300	0	0	0	0	0	0	0	0
170	*Phacus splendens*	80	120	0	60	130	0	220	430	0	100	0	0
171	*Phacus stokesii*	160	0	0	0	0	0	0	230	80	0	0	210
172	*Phacus tortus*	0	40	0	0	0	0	0	190	0	0	60	0
173	*Phacus viguieri*	0	0	0	0	920	0	0	0	0	40	0	230
174	*Phormidium articulatum*	0	0	0	0	0	420	0	80	0	0	0	0
175	*Phormidium formosum*	0	0	590	0	0	0	0	0	0	0	0	0
176	*Pinnularia acrosphaeria*	0	0	250	560	0	110	0	2270	50	140	190	0
177	*Pinnularia divergens* var. *elliptica*	160	0	0	0	170	0	320	0	0	0	0	0
178	*Pinnularia interrupta* var. *minor*	0	260	0	0	0	0	0	0	0	110	0	0
179	*Pinnularia lundii*	0	0	760	0	0	690	0	0	0	0	0	430

Sl. No.	Taxa	Months											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
180	*Pinnularia major* var. *linearis*	890	0	0	310	0	0	0	1240	0	0	640	0
181	*Pinnularia panhalgarhensis*	1450	370	0	0	550	0	2620	0	460	610	0	0
182	*Pinnularia stomatophoroides* var. *ornata*	140	0	0	0	0	0	0	0	50	0	0	60
183	*Pinnularia termis* var. *termitiana*	0	120	0	0	0	860	0	780	0	0	40	0
184	*Planktothrix agardhii*	0	0	0	0	690	0	0	2310	0	0	0	0
185	*Planktothrix* sp. 1	0	0	0	0	0	0	560	0	710	0	0	0
186	*Pleodorina sphaerica*	0	0	540	0	0	0	0	70	0	320	0	180
187	*Pleurosigma elongatum* var. *karianum*	0	0	0	280	0	860	410	0	0	0	230	460
188	*Pleurosigma salinarum*	790	530	0	0	0	870	0	680	0	90	0	0
189	*Pleurotaenium ovatum*	0	0	140	0	0	0	0	0	80	0	0	0
190	*Pleurotaenium trabecula*. var. *rectum*	0	0	840	0	0	0	0	0	0	0	0	0
191	*Pseudoanabaena galeata*	0	0	0	0	0	730	0	0	0	0	0	0
192	*Rhopalodia gibba*	0	430	0	1480	0	2350	0	7680	60	470	0	150
193	*Scenedesmus acuminatus*	0	0	0	100	210	0	420	0	140	0	340	70
194	*Scenedesmus bijugatus* var. *graevenitzii*	120	60	270	0	0	0	00	0	0	0	0	70
195	*Scenedesmus carinatus*	0	40	0	0	0	0	420	0	0	0	80	0
196	*Scenedesmus dimorphus*	260	0	0	0	0	0	1360	40	0	50	0	90
197	*Scenedesmus longus*	0	450	210	40	160	0	0	110	230	190	0	80
198	*Scenedesmus perforatus*	40	80	0	0	90	420	0	300	140	0	90	290
199	*Scenedesmus perforatus* var. *major*	0	420	0	0	0	0	0	0	0	0	0	270
200	*Scenedesmus quadricauda*	0	670	210	60	80	0	180	810	70	100	0	60
201	*Scenedesmus quadricauda* var. *bicaudatus*	0	210	0	0	70	0	0	380	0	0	40	0
202	*Scenedesmus quadricauda* var. *quadrispina*	180	0	50	0	0	170	0	190	80	0	70	40
203	*Selenastrum gracile*	0	80	0	0	60	0	0	0	0	0	0	100
204	*Spirulina major*	0	0	0	0	0	0	0	0	0	0	450	0
205	*Spirulina nordstedtii*	0	0	0	0	0	0	0	0	760	0	0	0
206	*Staurastrum crenulatum*	0	0	40	0	0	0	0	0	80	0	0	0
207	*Staurastrum glabrum*	60	0	0	80	0	0	120	80	0	70	40	0
208	*Staurastrum proboscidium*	120	0	0	0	0	70	110	0	70	0	40	0
209	*Staurastrum saltans* var. *polycharax*	0	0	0	80	0	0	60	0	0	0	0	120
210	*Staurastrum* sp. 1	280	0	0	0	70	0	0	40	0	0	240	0
211	*Stauroneis anceps*	90	260	920	0	790	2480	3360	8740	0	420	460	130

Sl. No.	Taxa	Months											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
212	*Stauroneis anceps* fo. *gracilis*	0	0	0	0	340	980	790	0	150	0	0	0
213	*Stauroneis phoenicenteron* fa. *capitata*	0	0	180	820	0	0	1360	750	0	160	0	460
214	*Stauroneis phoenicenteron* fa. *producta*	0	120	0	0	0	0	0	0	0	0	0	830
215	*Strombomonas fluviatilis*	90	0	0	08	50	0	240	410	90	0	70	540
216	*Strombomonas gibberosa*	0	0	0	0	0	0	0	0	0	0	80	160
217	*Strombomonas girardiana*	0	0	60	0	0	80	0	100	0	80	0	0
218	*Strombomonas* sp.1	0	0	0	0	0	0	80	0	0	0	0	40
219	*Surirella biseriata*	40	0	0	1290	0	0	850	2430	410	0	460	80
220	*Surirella capronioides*	0	820	0	0	0	210	1340	970	80	60	0	230
221	*Surirella robusta*	140	50	0	990	80	0	1250	830	100	90	60	0
222	*Surirella tenera* var. *ambigua*	0	120	70	0	900	780	640	910	800	760	0	930
223	*Surirella tenera* var. *nervosa*	0	0	0	530	0	0	90	0	0	0	0	0
224	*Synedra acus*	890	420	9800	80	6580	80	9610	9930	30	420	1230	40
225	*Synedra ulna*	590	70	8840	730	70	650	6740	9890	80	1750	970	650
226	*Synedra ulna* var. *subaequalis*	0	0	0	120	0	0	0	230	0	0	80	0
227	*Tabellaria fenestrata*	40	0	0	320	780	0	2130	4320	790	80	0	90
228	*Tetraedron gracile*	0	80	310	0	60	80	0	0	90	0	240	0
229	*Tetraedron proteiforme*	0	0	0	0	140	0	0	430	0	0	90	50
230	*Tetraedron regulare* var. *granulata*	0	0	0	0	0	700	0	0	0	90	0	0
231	*Tetraedron regulare* var. *minus*	0	80	0	0	0	0	150	0	0	0	0	80
232	*Tetraedron trigonum*	70	0	90	40	0	60	0	120	90	0	60	0
233	*Tetraedron trigonum* fa. *crassum*	0	0	0	0	0	0	0	40	0	0	80	0
234	*Tetraedron trigonum* var. *verrucosum*	0	180	0	80	40	0	0	0	160	70	0	80
235	*Trachelomonas abrupta*	0	60	0	130	80	0	40	980	80	840	80	640
236	*Trachelomonas armata*	60	0	960	450	90	5380	0	1130	0	0	650	980
237	*Trachelomonas armata* var. *longispina*	820	70	0	0	0	980	0	0	480	150	0	0
238	*Trachelomonas caudata* fo. *caudata*	0	340	0	640	0	540	590	0	0	0	160	60
239	*Trachelomonas dybwoskii*	0	0	50	0	40	0	630	140	0	0	0	0
240	*Trachelomonas globularis* fo. *globularis*	160	0	0	0	0	380	0	0	0	80	0	0
241	*Trachelomonas granulosa*	0	0	120	0	0	60	0	0	0	0	0	80
242	*Trachelomonas hispida*	640	70	0	0	0	0	0	6320	580	0	80	0
243	*Trachelomonas lacustris*	670	0	0	0	50	0	0	670	0	460	0	790

Sl. No.	Taxa	Months											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
244	*Trachelomonas lacustris* var. *klebsii*	0	0	0	860	0	0	0	830	0	0	0	950
245	*Trachelomonas planctonica* f. *ornata*	820	0	0	0	0	0	980	0	0	350	0	0
246	*Trachelomonas planctonica* fo. *planctonica*	0	840	0	0	0	790	0	0	650	0	0	260
247	*Trachelomonas pulcherrima* var. *minor*	0	0	0	0	0	0	40	80	0	0	0	0
248	*Trachelomonas robusta*	660	0	60	0	80	0	670	980	0	0	80	0
249	*Trachelomonas* sp.1	0	0	120	0	0	0	0	0	0	0	0	60
250	*Trachelomonas superba* var. *duplex*	670	40	0	640	80	940	8790	100	50	0	460	760
251	*Trachelomonas superba* var. *Swirenkiana*	0	0	90	70	0	0	1630	240	110	0	520	80
252	*Trachelomonas varians*	60	80	0	110	0	1380	0	0	0	780	0	200
253	*Trachelomonas volvocina*	200	70	1120	0	990	3260	0	8700	0	400	0	880
254	*Trachelomonas volvocinopsis*	140	170	0	0	0	0	100	4320	80	60	0	0
255	*Triploceras gracile* var. *undulatum*	0	0	0	0	50	0	0	0	0	460	0	90
256	*Xanthidium sexmamillatum* var. *pulneyense*	0	0	0	860	0	0	0	30	0	0	0	50
257	*Xanthidium subtrilobum* var. *inornatum*	0	0	0	0	0	0	0	0	450	0	90	0
Total cells/L		**43880**	**45394**	**56319**	**40548**	**39430**	**76810**	**96300**	**217260**	**25330**	**27110**	**26300**	**32450**

Table 6. Spatial distribution of average number of algal taxa from rivers in Palakkad district

Sl. No.	Taxa	Stations									
		1	2	3	4	5	6	7	8	9	10
1	*Achnanthes exigua*	0	0	0	0	560	90	3200	60	0	0
2	*Actinastrum hantzschii* var. *elongatum*	0	0	0	540	0	0	3280	0	0	0
3	*Actinocyclus normanii*	90	0	50	0	620	0	860	0	0	0
4	*Amphora ovalis* var. *gracilis*	0	430	780	0	70	110	0	680	80	0
5	*Anabaena ghosei*	0	0	0	0	0	100	120	0	0	0
6	*Anabaena sp.1*	0	310	0	0	0	0	0	0	0	0
7	*Ankistrodesmus convolutus*	60	0	260	0	0	0	670	80	0	0
8	*Ankistrodesmus falcatus*	0	0	620	0	0	0	0	0	0	0
9	*Aphanocapsa delicatissima*	1110	0	0	0	400	0	0	790	0	0
10	*Arthrodesmus curvatus* var. *latus*	70	0	0	40	180	40	6790	100	0	0
11	*Arthrospira fusiformis*	0	0	240	0	0	0	0	0	0	0

Sl. No.	Taxa	Stations									
		1	2	3	4	5	6	7	8	9	10
12	*Arthrospira khannae*	0	0	0	0	0	0	0	0	500	90
13	*Aulacoseira granulata*	5480	7640	5380	8750	90	7590	9870	5280	7210	90
14	*Aulacoseira granulata* var. *Angustissima*	0	430	690	5670	0	5460	6750	0	0	2370
15	*Caloneis permagna*	0	60	90	70	0	0	930	140	0	100
16	*Centritractus belanophorus*	0	0	0	110	320	0	700	0	0	0
17	*Chroococcus minimus*	0	0	600	0	0	0	0	0	0	0
18	*Chroococcus minutus*	450	800	0	0	790	900	2310	0	0	0
19	*Chroococcus turgidus*	900	80	210	0	650	0	500	760	90	0
20	*Closterium dianae*. var. *minus*	100	70	120	0	490	4360	900	700	0	0
21	*Closterium ehrenbergii*	0	70	600	790	0	0	0	320	0	60
22	*Closterium kuetzingii*	0	0	0	0	50	0	0	0	0	460
23	*Closterium lagoense*	0	0	0	650	0	0	0	0	0	100
24	*Closterium moniliferum*	70	0	80	0	0	870	650	50	0	0
25	*Closterium navicula*	0	50	0	0	0	600	0	0	0	0
26	*Closterium peracerosum*	0	0	0	820	0	0	0	0	0	0
27	*Cocconeis placentula*	70	540	0	0	540	780	6450	80	60	0
28	*Coelastrum microporum*	0	0	540	0	70	50	0	0	0	410
29	*Coelastrum proboscideum*	0	190	0	80	0	0	50	110	0	0
30	*Coelastrum sphaericum*	0	0	0	0	370	0	430	0	0	0
31	*Cosmarium auriculatum*	350	0	80	0	70	310	0	0	0	0
32	*Cosmarium binum*	0	570	0	0	0	0	0	420	0	320
33	*Cosmarium blyttii*	0	0	320	540	80	240	60	90	0	0
34	*Cosmarium depressum*	570	0	90	760	310	0	320	0	0	0
35	*Cosmarium depressum* var. *apertum*	0	4590	0	0	0	560	0	0	0	0
36	*Cosmarium galeritum*	0	0	0	5780	0	0	0	0	0	0
37	*Cosmarium granatum*	790	70	0	0	0	0	0	0	40	0
38	*Cosmarium granatum*. var. *rotundatum*	0	0	0	0	780	620	0	100	0	0
39	*Cosmarium lundellii*	120	60	2190	0	0	890	900	0	0	90
40	*Cosmarium lundellii* var. *circulare*	0	470	0	540	0	0	80	0	0	0
41	*Cosmarium lundellii* var. *corruptum*	760	0	0	0	0	600	470	70	0	0
42	*Cosmarium maculatum*	0	0	590	0	0	0	0	0	0	0
43	*Cosmarium margaritatum* var. *sublatum*	110	0	70	0	610	0	0	0	0	0

Sl. No	Taxa	Stations									
		1	2	3	4	5	6	7	8	9	10
44	*Cosmarium medioscrobiculatum* var. *egranulatum*	0	0	0	0	0	0	5420	310	0	0
45	*Cosmarium obsoletum*	0	120	0	320	0	0	0	0	0	0
46	*Cosmarium pseudoconnatum.*	90	650	0	0	790	0	2180	0	80	0
47	*Cosmarium punctulatum* var. *subpunctulatum*	0	70	0	540	0	0	0	70	0	0
48	*Cosmarium quadrifarium*	30	200	0	0	70	760	0	1250	100	0
49	*Cosmarium quadrum*	2500	0	450	0	0	90	5360	0	0	200
50	*Cosmarium scabrum*	0	60	90	0	0	0	0	360	0	0
51	*Cosmarium sexangulare* fa. *minimum*	80	0	0	0	600	650	0	280	0	0
52	*Cosmarium subspeciosum* var. *validius*	60	0	70	410	0	0	0	0	210	0
53	*Cosmarium subundulatum*	130	0	0	890	0	430	0	0	0	0
54	*Cosmarium turgidum*	0	430	0	60	0	0	6450	0	0	0
55	*Cyclotella meneghiniana*	560	580	5470	4670	7620	90	9870	870	890	70
56	*Cyclotella striata*	230	4350	80	700	80	7690	6890	6540	760	700
57	*Cylindrocystis brebissonii*	0	0	0	0	0	0	460	0	0	0
58	*Cymbella bengalensis*	3290	0	720	480	0	0	0	0	0	0
59	*Cymbella hungarica* var. *sigmata*	0	70	0	0	790	670	430	640	0	0
60	*Cymbella laevis*	570	0	870	970	0	0	70	0	750	0
61	*Cymbella tumida*	0	1680	0	0	640	7200	8640	860	170	810
62	*Cymbella turgida*	6540	870	2990	4310	0	2580	6780	0	0	90
63	*Cymbella ventricosa*	80	0	60	0	800	0	0	640	0	3140
64	*Dictyosphaerium ehrenbergianum*	0	0	0	60	0	0	750	80	0	0
65	*Diploneis ovalis*	80	1360	0	0	920	110	900	820	0	0
66	*Dolichospermum perturbatum*	0	0	600	0	0	0	0	0	0	0
67	*Euastrum gayanum*	0	0	0	0	0	60	0	0	0	0
68	*Euastrum sinuosum*	0	0	410	0	210	530	0	0	0	190
69	*Euastrum spinulosum*	0	540	0	320	0	740	590	140	0	0
70	*Euglena acus*	60	0	0	0	700	8790	6780	0	0	0
71	*Euglena acus* var. *acus*	0	0	7890	0	0	0	870	0	0	0
72	*Euglena agilis*	0	0	0	670	0	310	0	600	70	0
73	*Euglena anabaena* var. *anabaena*	0	50	0	0	80	80	0	0	0	0
74	*Euglena archeoplastidiata*	0	0	640	0	0	4390	4560	0	0	0
75	*Euglena chlamydophora*	120	0	0	8540	710	110	650	80	0	0

Sl. No.	Taxa	Stations									
		1	2	3	4	5	6	7	8	9	10
76	*Euglena deses* fo. *deses*	0	0	0	2470	0	0	0	0	0	420
77	*Euglena deses* fo. *intermedia*	0	430	0	2130	0	0	0	0	0	0
78	*Euglena deses* fo. *klebsii*	650	0	740	0	90	5390	430	0	0	0
79	*Euglena ettlii*	0	70	0	5310	0	4320	0	410	0	0
80	*Euglena fusca*	0	0	70	410	80	0	7650	0	0	0
81	*Euglena gracilis*	310	0	0	0	0	0	700	0	0	0
82	*Euglena hemichromata*	610	0	0	0	100	80	0	0	0	0
83	*Euglena oxyuris* fo. *oxyuris*	0	0	0	60	0	0	600	140	0	0
84	*Euglena oxyuris* var. *charkowiensis*	0	3480	690	4360	0	740	4260	0	0	50
85	*Euglena oxyuris* var. *minor*	810	0	0	0	540	0	0	0	0	0
86	*Euglena oxyuris* var. *playfairii*	0	0	150	530	8320	0	0	870	0	0
87	*Euglena polymorpha*	0	0	0	410	0	1170	6580	0	0	0
88	*Euglena proxima*	3210	50	230	70	2750	8310	90	50	40	170
89	*Euglena rustica* var. *rustica*	0	80	0	0	0	0	800	0	0	0
90	*Euglena sanguinea*	0	0	90	480	0	580	0	0	0	0
91	*Euglena* sp. 1	60	0	0	90	0	0	130	0	0	0
92	*Euglena* sp. 2	0	600	0	0	0	0	0	500	70	0
93	*Euglena spirogyra*	100	0	3280	790	0	0	7880	0	0	0
94	*Euglena spirogyra* var. *spirogyra*	0	610	0	0	400	460	6430	0	0	380
95	*Euglena splendens*	0	90	600	40	0	0	650	60	0	0
96	*Euglena texta* var. *texta*	90	0	0	0	310	0	0	0	0	0
97	*Euglena tripteris* var. *tripteris*	0	520	0	510	0	0	0	0	0	0
98	*Euglena viridis* fo. *viridis*	0	0	0	0	0	0	0	0	0	0
99	*Eunotia lunaris*	1100	0	0	0	700	90	3490	900	700	90
100	*Fragilari rumpens* var. *familiaris*	0	490	6540	0	7320	0	7640	0	600	780
101	*Fragilaria construens* var. *venter*	4630	4210	0	4170	0	890	0	690	0	900
102	*Fragilaria intermedia*	5380	60	980	3210	8650	1450	9760	80	460	790
103	*peridiniopsis quadridens*	0	0	80	0	650	0	0	0	90	0
104	*Golenkinia paucispina*	0	240	0	0	0	0	890	0	40	0
105	*Golenkiniopsis minutissima*	0	120	0	750	80	0	0	0	0	0
106	*Gomphonema aequatoriale*	520	0	650	640	300	0	500	490	1420	0
107	*Gomphonema gracile* var. *frickei*	0	600	0	0	0	0	70	0	00	210

Sl. No.	Taxa	Stations									
		1	2	3	4	5	6	7	8	9	10
108	*Gomphonema gracile* var. *intricatiforme*	0	0	0	60	0	790	0	0	260	0
109	*Gomphonema lacus-rankala* var. *gracilis*	690	460	0	430	720	0	2670	0	0	0
110	*Gomphonema montanum* var. *acuminatum*	80	0	0	110	0	0	800	380	0	0
111	*Gomphonema parvulum*	0	0	9870	0	100	0	0	0	0	0
112	*Gomphonema subapicatum*	0	440	0	0	0	4210	870	0	0	0
113	*Gyrosigma distortum* var. *parkeri*	810	0	0	50	520	0	690	0	460	120
114	*Gyrosigma kuetzingii*	650	0	670	0	480	890	0	360	0	0
115	*Hantzschia amphioxys*	650	70	0	0	60	0	60	0	0	70
116	*Hantzschia amphioxys* var. *pusilla*	0	0	580	0	780	2340	0	430	0	0
117	*Hantzschia linearis*	140	0	0	5210	0	0	5420	0	0	0
118	*Lagerheimia ciliata*	0	0	0	0	0	70	90	0	0	0
119	*Lepocinclis fusiformis*	0	670	0	500	160	0	150	310	0	0
120	*Lepocinclis ovum* var. *ovum*	60	0	0	0	700	0	0	0	670	0
121	*Lepocinclis playfairiana*	4210	0	0	0	0	0	0	0	0	0
122	*Oscillatoria meslinii*	0	2310	90	0	0	670	900	0	0	0
123	*Merismopedia elegans*	240	110	0	200	0	350	630	0	0	0
124	*Merismopedia elegans var. major*	0	0	0	0	310	0	0	0	0	0
125	*Merismopedia tenuissima*	40	90	280	90	0	3110	900	650	80	0
126	*Micrasterias foliacea*	320	0	0	0	0	0	90	0	0	0
127	*Micrasterias laticeps* var. *acuminata*	0	0	120	0	0	0	0	130	0	0
128	*Micrasterias pinnatifida* (Kuetz.) Ralfs	90	0	0	0	0	0	0	0	0	0
129	*Micratinium pusillum* var. *elegans*	0	0	0	0	0	0	4260	0	0	0
130	*Microcystis aeruginosa*	0	0	0	0	0	0	1000	0	0	210
131	*Navicula constans* var. *symmetrica*	0	110	0	0	4680	180	0	0	80	0
132	*Navicula cuspidata*	670	260	450	640	70	900	6750	780	220	780
133	*Navicula gracilis*	0	0	0	0	480	0	860	0	0	0
134	*Navicula gastrum*	0	6450	410	3210	0	0	0	0	60	0
135	*Navicula lateostrata*	0	0	0	650	0	340	0	0	0	70
136	*Navicula mutica* var. *linearis*	650	0	0	0	540	0	0	400	520	430
137	*Navicula pupula*	0	0	540	890	0	760	760	0	0	0
138	*Navicula pusilla*	0	0	220	0	0	0	0	0	70	0
139	*Navicula pygmaea*	0	80	0	760	650	0	0	0	0	870

Sl. No.	Taxa	Stations									
		1	2	3	4	5	6	7	8	9	10
140	*Neidium productum* var. *bombayensis*	0	0	0	0	0	0	0	650	0	0
141	*Nitzschia apiculata*	150	0	800	0	0	110	0	0	0	0
142	*Nitzschia closterium*	0	180	0	0	0	0	5480	110	750	0
143	*Nitzschia intermedia*	0	920	6590	670	580	0	0	0	0	0
144	*Nitzschia obtusa*	680	0	0	0	0	860	9650	0	0	800
145	*Nitzschia obtusa* var. *scalpelliformis*	0	0	3220	0	630	0	0	4390	0	0
146	*Nitzschia philippinarum*	0	90	0	0	0	0	950	0	520	1260
147	*Nitzschia sublinearis*	170	0	0	0	930	100	0	900	0	140
148	*Onychonema laeve* var. *micracanthum*	0	0	0	70	0	90	80	0	0	0
149	*Oocystis borgei*	0	0	0	60	0	0	610	0	0	0
150	*Oscillatoria limosa*	0	0	0	0	0	0	0	0	120	0
151	*Oscillatoria lutea*	500	890	0	3450	0	0	5260	0	0	0
152	*Oscillatoria princeps*	0	0	600	0	0	0	90	0	700	0
153	*Oscillatoria* sp.1	0	800	0	0	1670	800	6410	0	0	0
154	*Pandorina morum*	80	1460	0	0	650	0	0	450	0	100
155	*Pandorina morum* var. *major*	0	0	690	300	0	0	0	0	420	0
156	*Pediastrum biradiatum*	0	310	530	0	0	860	90	0	0	310
157	*Pediastrum boryanum* var. *longicorne*	0	0	0	430	410	460	260	0	0	0
158	*Pediastrum simplex*	580	0	600	0	430	0	0	760	610	0
159	*Pediastrum simplex* var. *duodenarium*	90	960	0	640	0	290	620	0	0	0
160	*Pediastrum tetras*	0	0	560	0	0	0	3650	560	0	0
161	*Phacus anacoelus*	670	0	0	0	680	0	590	0	150	0
162	*Phacus curvicauda*	0	0	0	80	0	470	0	0	0	0
163	*Phacus lefevrei*	460	80	0	0	600	0	0	0	0	60
164	*Phacus orbicularis*	0	0	0	90	0	60	0	0	0	0
165	*Phacus orbicularis* fo. *communis*	0	260	790	100	0	0	810	0	0	0
166	*Phacus orbicularis* fo. *orbicularis*	0	0	0	870	0	0	670	750	0	0
167	*Phacus pseudoswirenkoi*	700	0	0	0	600	0	2150	0	410	0
168	*Phacus* sp.1	0	0	0	0	0	0	0	0	0	60
179	*Phacus* sp.2	0	0	0	0	0	200	90	0	0	0
170	*Phacus splendens*	0	0	1740	0	0	8670	0	860	0	0
171	*Phacus stokesii*	0	0	0	480	0	910	90	0	0	0

Sl. No.	Taxa	Stations									
		1	2	3	4	5	6	7	8	9	10
172	*Phacus tortus*	0	60	0	0	80	0	850	0	0	0
173	*Phacus viguieri*	0	0	630	0	0	0	0	0	0	0
174	*Phormidium articulatum*	0	0	210	0	80	110	2100	0	0	0
175	*Phormidium formosum*	0	0	0	0	0	0	0	100	0	0
176	*Pinnularia acrosphaeria*	1280	0	0	780	650	0	0	570	60	0
177	*Pinnularia divergens* var. *elliptica*	0	4310	0	0	0	0	4530	0	0	650
178	*Pinnularia interrupta* var. *minor*	0	0	890	0	0	5430	0	0	0	0
179	*Pinnularia lundii*	100	0	0	4530	800	0	5740	0	340	630
180	*Pinnularia major* var. *linearis*	670	0	0	0	0	730	0	3140	420	0
181	*Pinnularia panhalgarhensis*	0	70	4320	0	0	0	0	0	0	0
182	*Pinnularia stomatophoroides* var. *ornata*	0	0	0	0	320	640	650	0	0	80
183	*Pinnularia termis* var. *termitiana*	0	0	450	0	0	0	0	0	160	0
184	*Planktothrix agardhii*	0	530	0	0	0	0	80	0	0	0
185	*Planktothrix* sp. 1	430	0	0	0	0	0	0	0	0	0
186	*Pleodorina sphaerica*	0	80	0	0	0	0	70	0	0	0
187	*Pleurosigma elongatum* var. *karianum*	0	0	0	0	590	0	2540	750	0	0
188	*Pleurosigma salinarum*	60	290	0	530	0	390	800	0	0	460
189	*Pleurotaenium ovatum*	0	0	0	0	0	160	80	0	0	0
190	*Pleurotaenium trabecula*. var. *rectum*	0	0	0	0	0	90	0	0	0	0
191	*Pseudoanabaena galeata*	0	0	0	400	0	0	0	0	0	0
192	*Rhopalodia gibba*	0	0	7520	0	6840	0	7510	0	750	0
193	*Scenedesmus acuminatus*	200	0	0	0	0	360	4680	0	0	0
194	*Scenedesmus bijugatus* var. *graevenitzii*	0	690	0	540	40	760	0	0	0	0
195	*Scenedesmus carinatus*	0	0	650	0	0	60	3260	0	0	90
196	*Scenedesmus dimorphus*	430	760	0	0	700	0	0	460	0	0
197	*Scenedesmus longus*	0	0	810	310	0	130	0	0	0	0
198	*Scenedesmus perforatus*	150	0	50	170	0	0	0	0	0	0
199	*Scenedesmus perforatus* var. *major*	0	700	0	0	460	790	4300	0	0	110
200	*Scenedesmus quadricauda*	160	0	360	690	0	0	3670	300	100	0
201	*Scenedesmus quadricauda* var. *bicaudatus*	0	0	0	90	0	400	0	0	0	0
202	*Scenedesmus quadricauda* var. *quadrispina*	0	0	430	0	0	0	540	0	0	0
203	*Selenastrum gracile*	0	40	0	60	0	540	0	0	0	630

Sl. No.	Taxa	Stations									
		1	2	3	4	5	6	7	8	9	10
204	*Spirulina major*	0	0	0	0	400	0	0	0	0	0
205	*Spirulina nordstedtii*	120	0	0	0	0	90	870	0	0	0
206	*Staurastrum crenulatum*	0	320	90	0	450	0	0	140	0	0
207	*Staurastrum glabrum*	160	0	0	0	0	0	0	0	0	0
208	*Staurastrum proboscidium*	70	0	0	0	0	520	0	0	0	0
209	*Staurastrum saltans* var. *polycharax*	90	0	80	500	0	0	80	890	0	0
210	*Staurastrum* sp. 1	0	100	0	0	80	0	90	0	0	140
211	*Stauroneis anceps*	0	0	600	540	650	0	0	650	8610	0
212	*Stauroneis anceps* fo. *gracilis*	0	580	0	0	0	680	1450	0	0	480
213	*Stauroneis phoenicenteron* fa. *capitata*	570	0	900	560	0	0	2640	0	0	0
214	*Stauroneis phoenicenteron* fa. *producta*	0	0	0	0	0	6470	0	0	0	0
215	*Strombomonas fluviatilis*	0	580	0	0	80	890	630	400	0	0
216	*Strombomonas gibberosa*	0	0	620	110	0	0	0	0	0	0
217	*Strombomonas girardiana*	0	0	0	0	0	0	70	60	420	0
218	*Strombomonas* sp.1	100	0	0	0	0	0	0	0	0	0
219	*Surirella biseriata*	670	800	0	3670	0	980	0	0	0	100
220	*Surirella capronioides*	0	0	170	0	750	0	0	0	0	0
221	*Surirella robusta*	310	890	0	0	860	0	5310	480	310	230
222	*Surirella tenera* var. *ambigua*	0	0	0	0	0	1760	870	0	0	90
223	*Surirella tenera* var. *nervosa*	170	3470	760	750	0	0	0	0	0	420
224	*Synedra acus*	1560	0	600	9670	0	900	9560	7860	0	800
225	*Synedra ulna*	670	6580	9879	80	6580	7460	9980	800	1250	5460
226	*Synedra ulna* var. *subaequalis*	0	0	0	5890	0	0	7760	80	890	0
227	*Tabellaria fenestrata*	560	90	0	900	5430	700	0	0	0	0
228	*Tetraedron gracile*	0	0	70	0	90	0	600	0	0	0
229	*Tetraedron proteiforme*	0	700	0	120	0	0	0	0	0	0
230	*Tetraedron regulare* var. *granulata*	0	0	0	610	0	140	0	0	0	0
231	*Tetraedron regulare* var. *minus*	70	0	0	80	340	0	400	60	0	0
232	*Tetraedron trigonum*	0	450	380	0	0	590	0	0	0	0
233	*Tetraedron trigonum* fa. *crassum*	0	0	0	50	0	0	0	0	50	0
234	*Tetraedron trigonum* var. *verrucosum*	0	0	470	0	0	0	70	400	0	0
235	*Trachelomonas abrupta*	0	80	600	0	70	0	540	0	90	0

Sl. No.	Taxa	Stations									
		1	2	3	4	5	6	7	8	9	10
236	*Trachelomonas armata*	360	50	80	5480	80	1250	800	4310	60	870
237	*Trachelomonas armata* var. *longispina*	0	420	0	0	0	0	0	0	0	620
238	*Trachelomonas caudata* fo. *caudata*	0	0	400	0	0	700	0	0	0	0
239	*Trachelomonas dybwoskii*	0	700	640	0	0	0	750	0	60	0
240	*Trachelomonas globularis* fo. *globularis*	570	0	0	0	0	0	0	0	0	0
241	*Trachelomonas granulosa*	0	0	0	570	4260	650	0	360	0	0
242	*Trachelomonas hispida*	0	0	0	90	800	640	5430	7000	0	800
243	*Trachelomonas lacustris*	520	0	600	780	0	0	0	0	120	0
244	*Trachelomonas lacustris* var. *klebsii*	0	140	0	0	0	0	7800	0	0	0
245	*Trachelomonas planctonica* fo. *ornata*	0	0	0	0	800	430	0	640	0	0
246	*Trachelomonas planctonica* fo. *planctonica*	70	0	1130	0	0	890	0	0	0	0
247	*Trachelomonas pulcherrima* var. *minor*	0	0	0	150	0	0	3160	0	0	0
248	*Trachelomonas robusta*	410	70	0	0	560	340	800	0	80	0
249	*Trachelomonas* sp.1	0	90	0	0	0	0	0	0	0	0
250	*Trachelomonas superba* var. *duplex*	0	0	640	1270	0	870	7900	870	0	0
251	*Trachelomonas superba* var. *Swirenkiana*	0	0	0	0	7450	0	0	0	0	0
252	*Trachelomonas varians*	0	1420	0	0	0	0	0	70	0	90
253	*Trachelomonas volvocina*	0	0	4360	0	0	8750	6740	560	540	0
254	*Trachelomonas volvocinopsis*	0	690	0	400	0	90	0	0	0	0
255	*Triploceras gracile* var. *undulatum*	110	0	0	0	0	0	0	0	0	0
256	*Xanthidium sexmamillatum* var. *pulneyense*	0	0	0	0	0	90	0	80	0	0
257	*Xanthidium subtrilobum* var. *inornatum*	70	0	0	0	100	0	320	0	0	0
Total cells/L		**67180**	**81860**	**116859**	**129500**	**109170**	**157830**	**353120**	**71460**	**34840**	**31020**

Figure 11. Graph showing average number of total phytoplankton in different stations (cells/L)

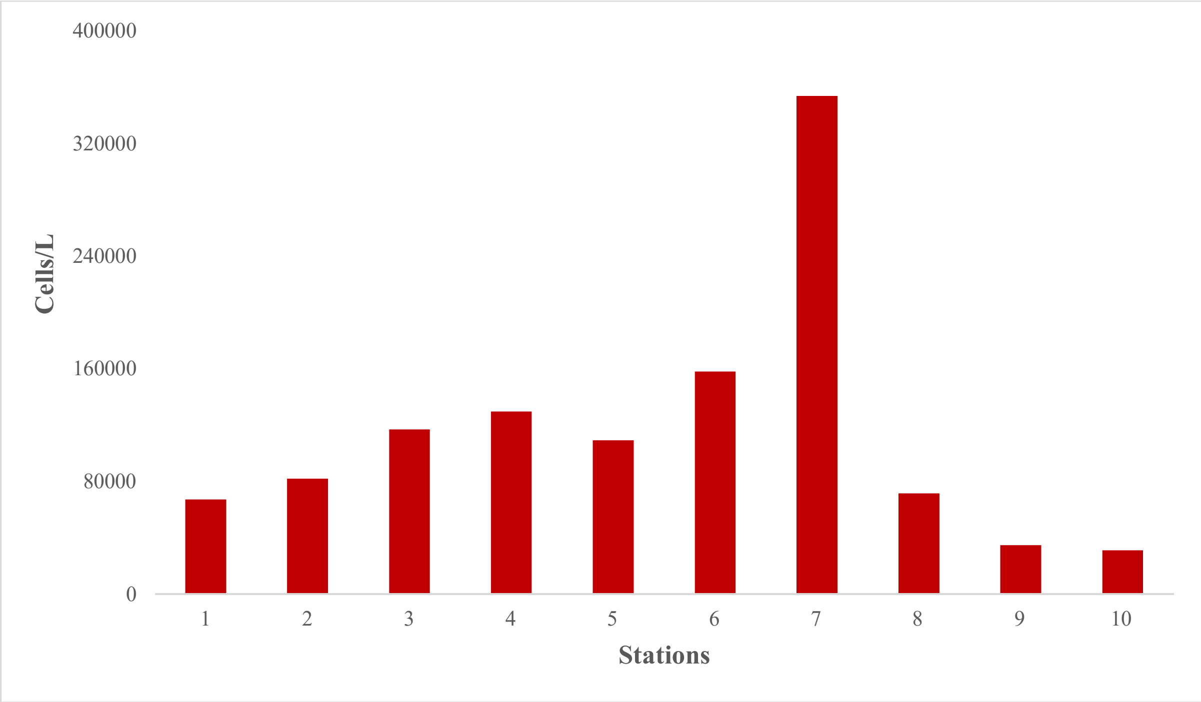


Figure 12. Graph showing average number of total phytoplankton in different months (cells/L)

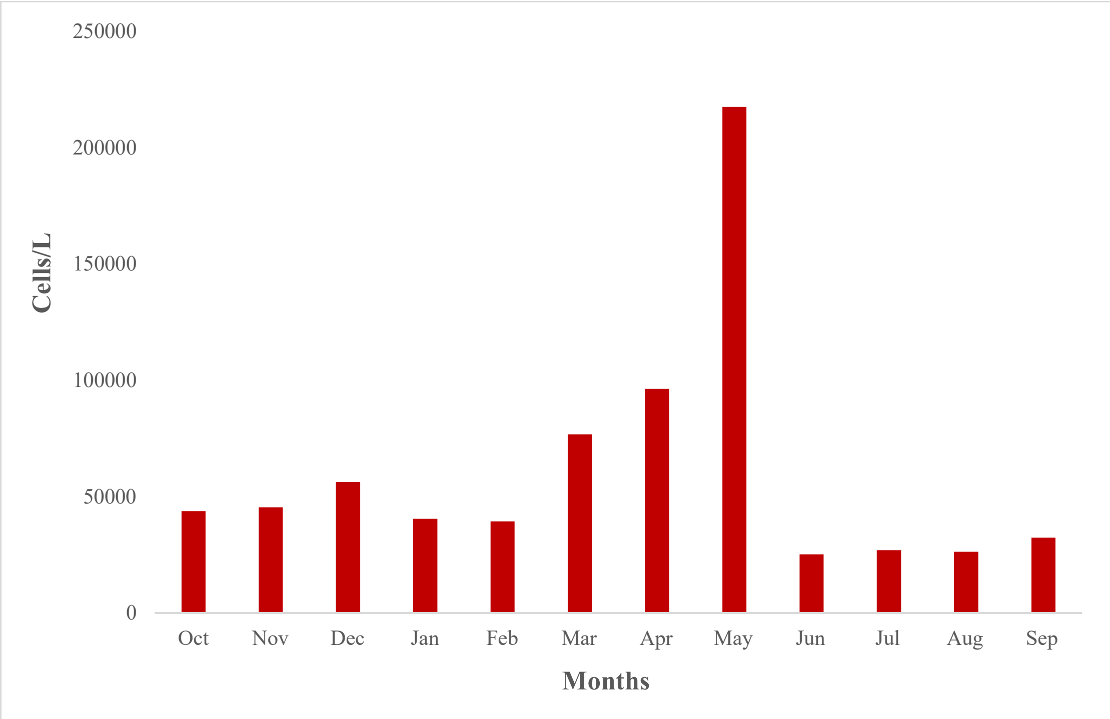


Figure 13. Graph showing spatial distribution of phytoplankton taxa from the study sites

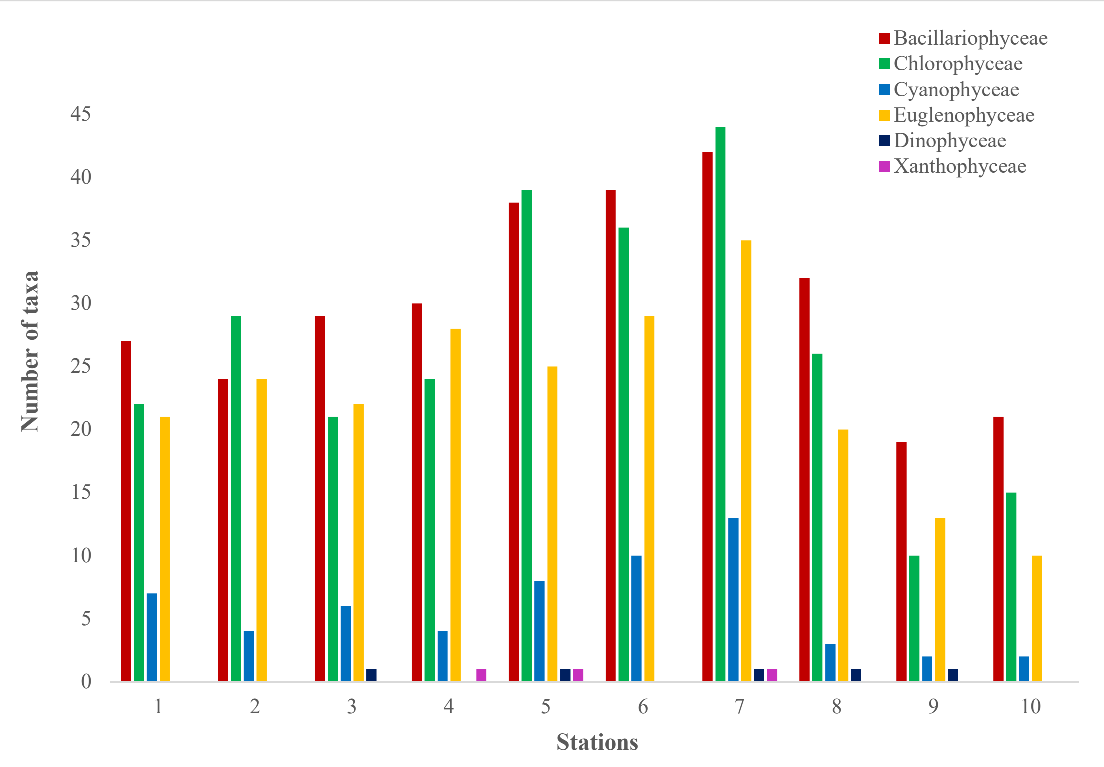


Figure 14. Graph showing spatial distribution of total phytoplankton from the study area

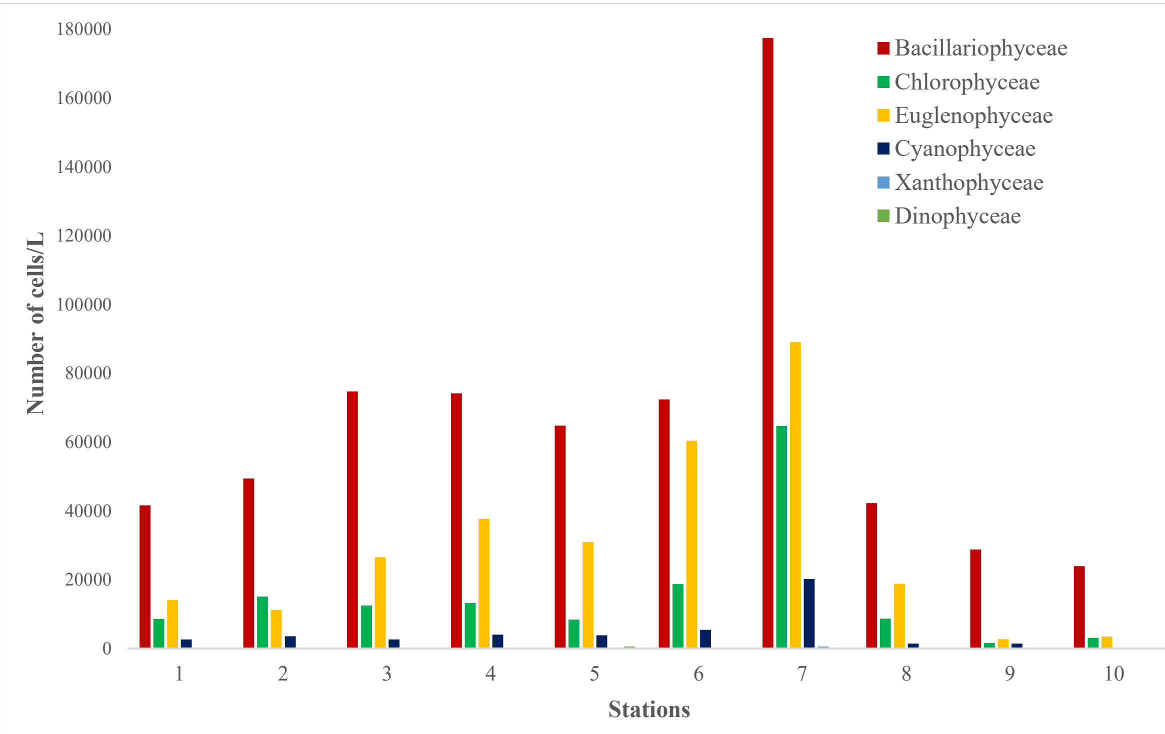


Figure 15. Graph showing monthly distribution of phytoplankton taxa from the study area

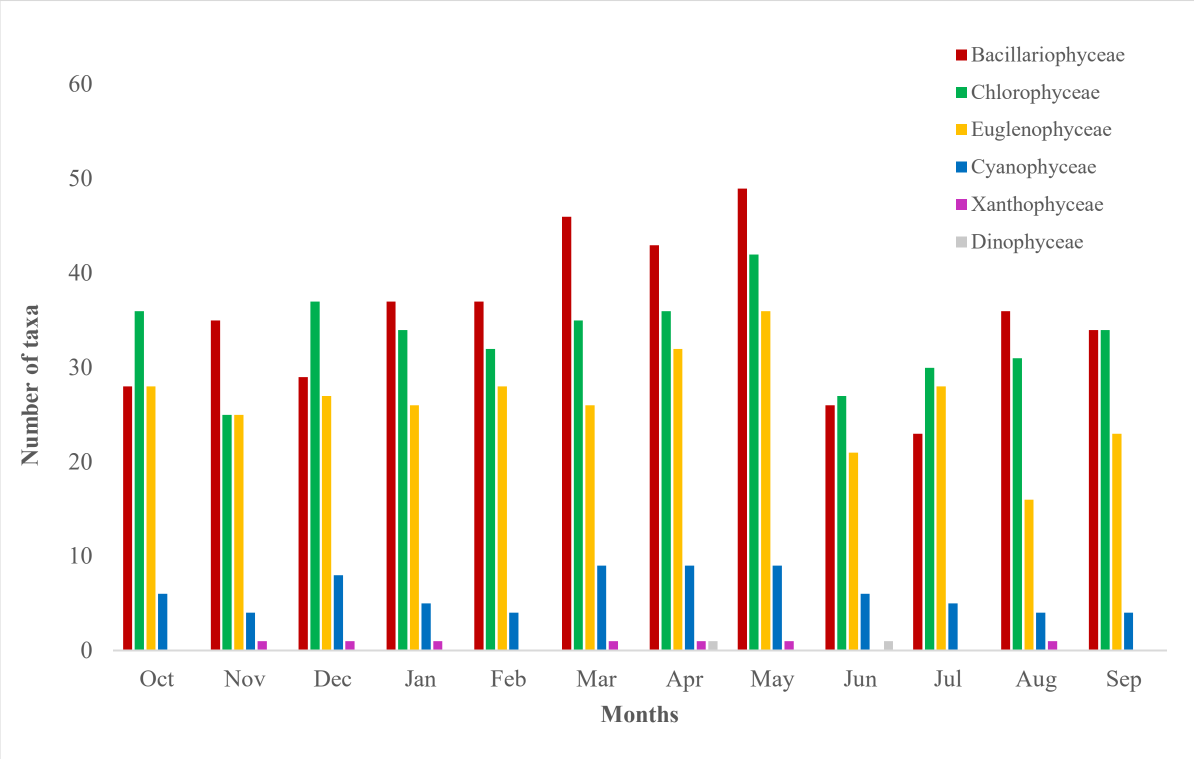


Figure 16. Graph showing monthly distribution of total phytoplankton observed from the study area

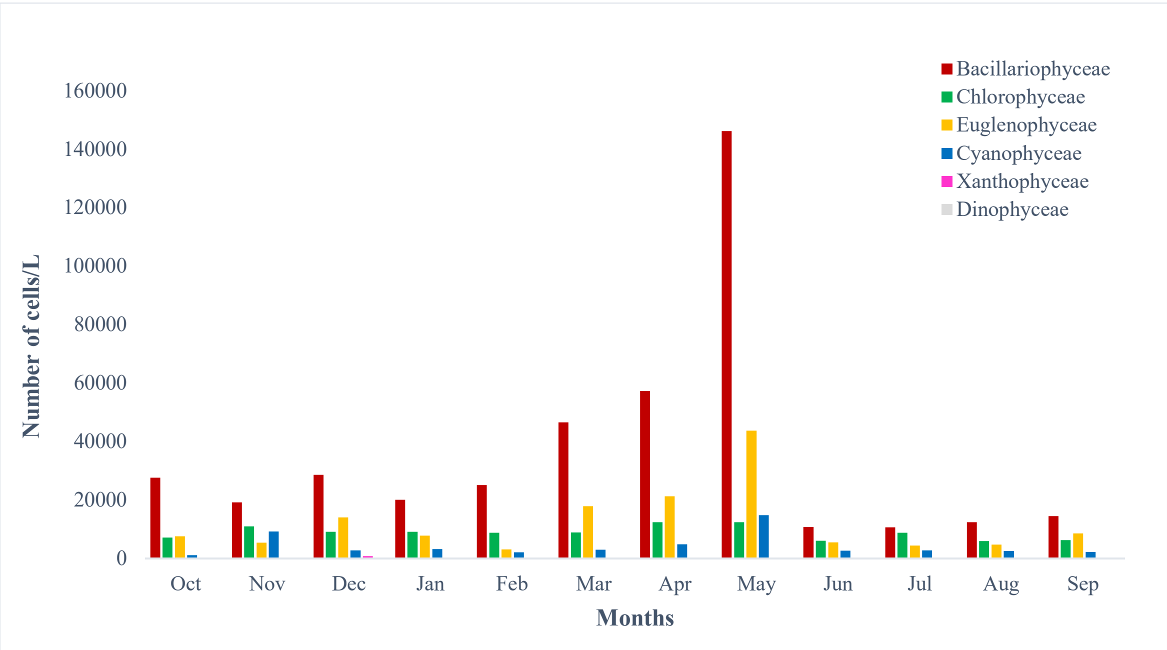


Table 7. Frequent distribution of phytoplankton recorded from the study area

Sl. No.	Name of frequent taxa	Relative frequency
1	*Synedra ulna*	7.35
2	*Aulacoseira granulata*	7.35
3	*Navicula cuspidata*	7.35
4	*Fragilaria capucina*	7.35
5	*Chroococcus turgidus*	5.14
6	*Cymbella tumida*	5.14
7	*Euglena polymorpha*	4.41
8	*Trachelomonas hispida*	4.41
9	*Euglena acus*	3.67
10	*Trachelomonas volvocina*	3.67

4.5 Community structure

A community of organisms is made up of all the interacting populations of a species that live in a specific area or habitat. Species diversity provides scientific understanding of communities and ecosystems in ecological studies. The species richness, evenness, Shannon and Simpson indices are used to measure biodiversity.

The water quality of the rivers in Palakkad district were analysed with the environmental variables as well as phytoplankton abundance and community structure. Seasonal variations in the composition and abundance of freshwater phytoplankton are influenced by interactions between physical and chemical factors, which are in turn influenced by environmental factors (Reynolds 1984). The changes in water quality are reflected by phytoplankton community structure, distribution patterns, and the proportion of sensitive species (Gharib et al. 2011; Sudeep and Hosmani 2007).

4.5.1 Diversity indices

The species diversity in various stations and months among the phytoplankton were recorded in tables 8 and 9. Number of taxa were obtained higher in May (137) and lowest obtained in July (101). The study reports that the highest taxa recorded at station 7 (135) and lowest at station 9 (57). The Shannon-wiener's diversity index value of the stations study showed comparatively highest value (4.99) during May and lowest value (2.25) in June. Station wise indices found to be high in station 7 (4.3) and low in station 9 (2.96). The highest Simpson diversity were obtained during the month of May (0.98) and least during June and July (0.92). Highest evenness index value was observed in April (0.69) and lowest value in December (0.29). The evenness value were recorded at station 7 was high (0.55) and low (0.34) at station 9 The phytoplankton richness was maximum in May (11.37) and minimum in June (9.16) and also highest richness value was obtained at station 7 (10.49) and lowest at station 9 (5.35).

Table 8. Month wise diversity indices recorded from the study area

Months	Taxa	H	1-D	Evenness	Richness
Jan	105	3.93	0.96	0.48	9.80
Feb	107	3.56	0.96	0.36	9.97
Mar	115	4.85	0.95	0.61	9.81
Apr	120	4.97	0.96	**0.69**	10.37
May	**137**	**4.99**	**0.98**	0.64	**11.37**
Jun	104	2.25	0.92	0.47	9.16
Jul	101	2.98	0.92	0.53	9.39
Aug	112	3.18	0.95	0.58	9.51
Sep	120	4.31	0.96	0.61	9.46
Oct	110	3.86	0.97	0.43	10.2
Nov	106	3.59	0.97	0.34	9.79
Dec	104	3.43	0.96	0.29	9.41

Table 9. Station wise diversity indices recorded from the study area

Stations	Taxa	H	1-D	Evenness	Richness
1	97	3.71	0.96	0.42	8.64
2	97	3.69	0.96	0.42	8.49
3	97	3.69	0.95	0.41	8.23
4	101	3.79	0.96	0.44	8.49
5	99	3.68	0.95	0.40	8.45
6	108	3.86	0.96	0.44	8.94
7	**135**	**4.3**	**0.98**	**0.55**	**10.49**
8	84	3.59	0.95	0.43	7.43
9	57	2.96	0.88	0.34	5.35
10	58	3.37	0.93	0.51	5.51

4.5.2 Multivariate similarity analysis

The average level of similarity between stations and months in terms of phytoplankton abundance and composition was determined using multivariate similarity analysis, as well as how evenly this similarity is distributed. SIMPER analysis was carried to identify the most contributed stations and months in determining algal class as temporal factor according to Bray-Curtis similarity.

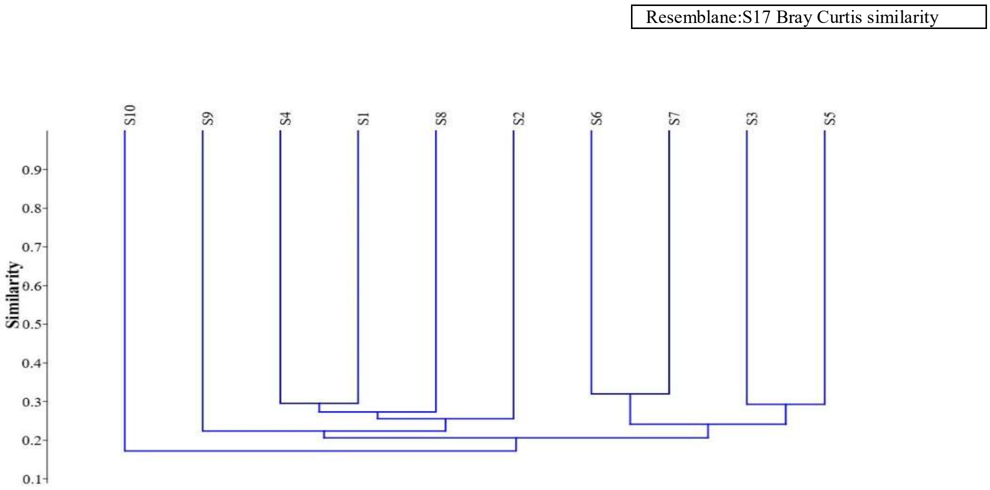
Stations 7, 3, 4, 5 and 6 were contributed more than 69% of the phytoplankton abundance in the study area (Table 10). When comparing all algal classes, the contribution percentage of station 7 was higher (22.71), followed by station 3 (12.54), station 4 (12.48), station 5 (11.3) and station 6 (10.68). Month wise similarity analysis results that high contribution percentage towards the month of May (43.19), followed by April (14.24) and March (12.2). The analysis of the data confirmed that pre monsoon season and station 7 was contributing high percentage to the significant variation in phytoplankton abundance. Analysis of similarity (ANOSYM) within stations and months can be used to determine statistical significance. The results show that phytoplankton distribution differs significantly between stations (P = 0.002, R = 0.91) and months ((P = 0.001, R = 0.82).

Table 10. data showing the contribution percentage of phytoplankton abundance in different stations and months

Variables	Av. Dissim.	Contrib.%	Cum.%
Stations			
S7	14.05	22.71	22.71
S3	7.76	12.54	35.25
S4	7.72	12.48	47.74
S5	6.99	11.3	59.03
S6	6.61	10.68	69.72
S8	4.42	7.141	76.86
S2	4.19	6.783	83.64
S1	4.11	6.64	90.28
S9	3.27	5.28	95.56
S10	2.75	4.44	100
Months			
May	25.48	43.19	43.19
Apr	8.399	14.24	57.43
Mar	7.195	12.2	69.62
Dec	3.571	6.053	75.67
Oct	3.463	5.87	81.54
Feb	3.126	5.29	86.84
Jan	2.133	3.615	90.46
Sep	1.585	2.69	93.14
Nov	1.563	2.65	95.79
Aug	1.264	2.142	97.94
Jun	0.8359	1.42	99.35
Jul	0.3822	0.65	100

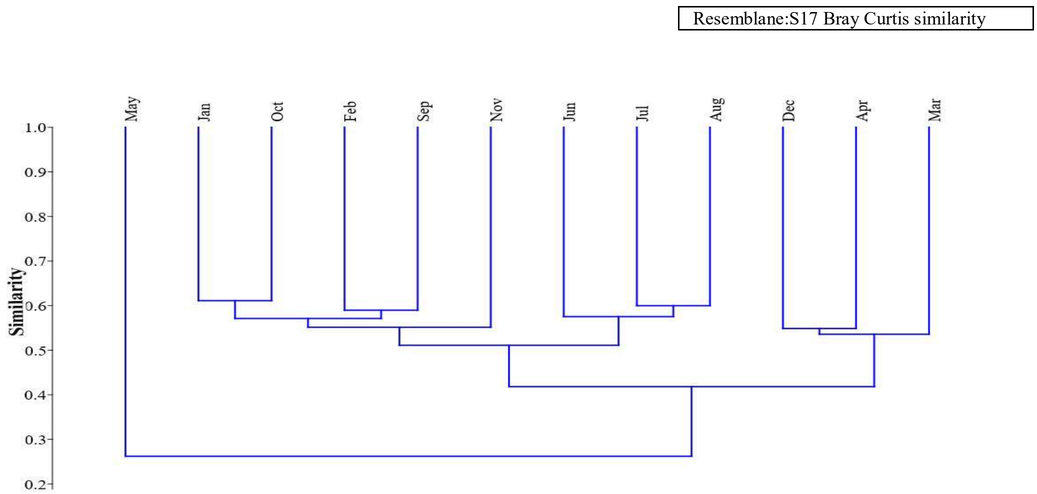
The results of the hierarchical cluster analysis, implemented on the stations and months are presented as a dendrogram that represents the grouping based on the Bray-Curtis similarity matrix values (Figures 17 and 18) formed two distinct groups at 0.223 similarity level. Station 10 forms the outgroup to other stations. The first group comprised four stations (5, 3, 7 and 6). The second group comprised four stations (2, 8, 1 and 4). Station 9 have close similarity with station 10. These two stations are located along the river Bhavani. Cluster analysis revealed that phytoplankton composition in stations 9 and 10 were distinct from that of other stations.

Figure 17. Dendrogram shows the hierarchical cluster analysis in different stations



The month wise cluster analysis based on the Bray-Curtis similarity matrix values (Figure 18) formed two distinct groups at 0.431 similarity level. The month of May represents the outgroup to other months. The first group comprised of three months which were mainly pre monsoon months and the second group comprised of monsoon and post monsoon months. Cluster analysis revealed that the phytoplankton composition in the ecosystem differed from that of the monsoon and post monsoon months.

Figure 18. Dendrogram shows the hierarchical cluster analysis in different months



Canonical Correspondence Analysis (CCA) is a multivariate tool to illuminate the relationships between phytoplankton and their environment, helps to extract environmental gradients from ecological data sets. In the present investigation, the ordination plot has revealed the statistically significant influence of physico chemical parameters on phytoplankton distribution and abundance. Seasonal variations in physico chemical parameters and quantitative assessment of phytoplankton were used as a baseline for CCA analysis. The ordination plot works out the abundance of species based on the score provided by (Chandler 1970). The number of species in a sample set larger than 100 used for the analysis which represents the 'very abundant' level. Table 11 represents the list of taxa separated for CCA analysis. The summary of CCA output in axis 1 and axis 2 given in the figures 19, 20 and 21. Environmental variables are depicted by long arrows and species are given in code words.

Figure 19. CCA plot showing the variation between environmental parameters and phytoplankton in Pre monsoon season

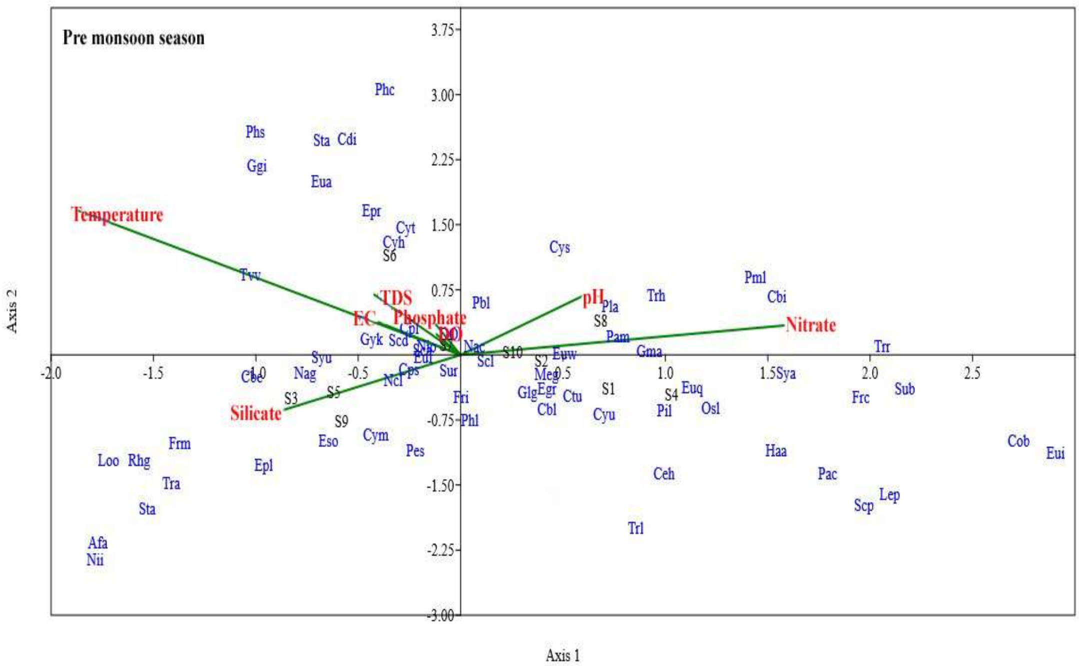


Figure 20. CCA plot showing the variation between environmental parameters and phytoplankton in monsoon season

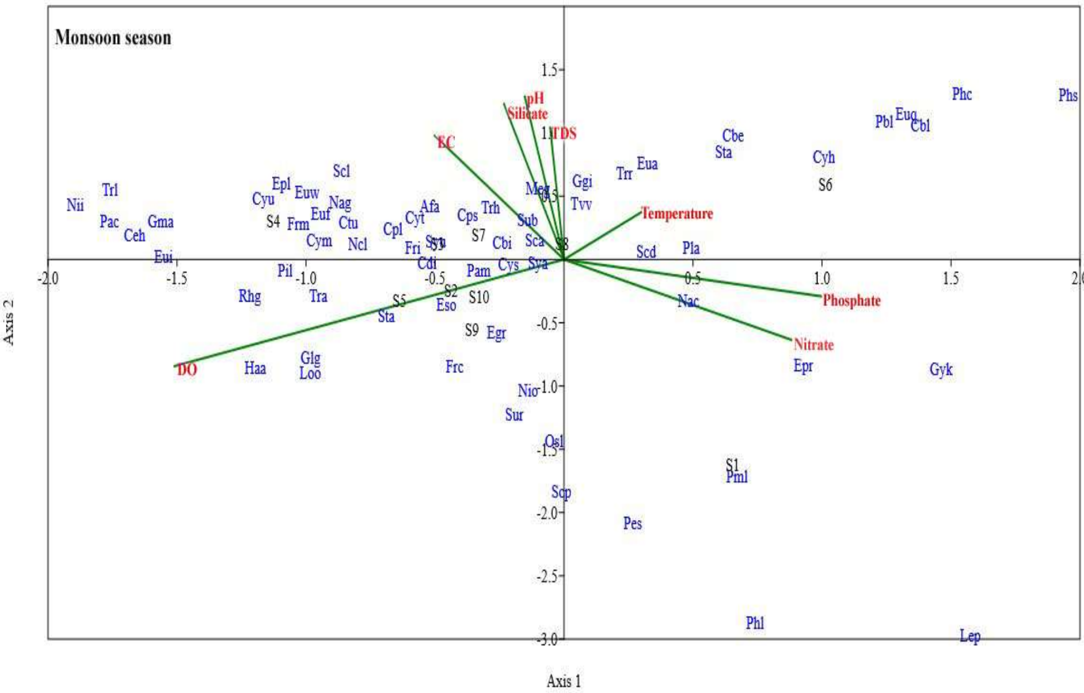


Figure 21. CCA plot showing the variation between environmental parameters and phytoplankton in Post monsoon season

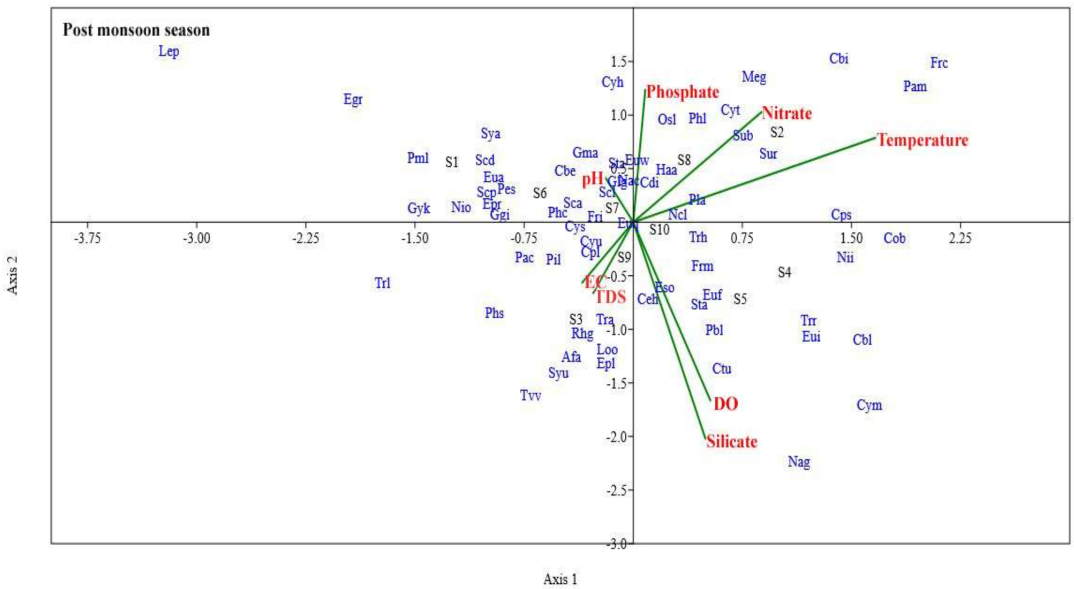


Table 11. List of phytoplankton taxa separated based on CCA axis

Taxa	Acronyms	Taxa	Acronyms
Ankistrodesmus falcatus	Afa	*Navicula cuspidata*	Nac
Aulacoseira granulata	Meg	*Navicula gracilis*	Nag
Centritractus belanophorus	Cbe	*Nitzschia closterium*	Nac
Chroococcus turgidus	Ctu	*Nitzschia intermedia*	Nii
Closterium dianae. var. *minus*	Cdi	*Nitzschia obtusa*	Nio
Closterium ehrenbergii	Ceh	*Oscillatoria limosa*	Osl
Cosmarium pseudoconnatum	Cps	*Pandorina morum*	Pam
Cyclotella meneghiniana	Cym	*Pediastrum boryanum* var. *longicorne*	Pbl
Cyclotella striata	Cys	*Pediastrum simplex*	Pes
Cymbella hungarica var. *sigmata*	Cyh	*Phacus curvicauda*	Phc
Cymbella tumida	Cyt	*Phacus lefevrei*	Phl
Cymbella turgida	Cyu	*Phacus splendens*	Phs
Euglena acus	Eua	*Pinnularia lundii*	Pil
Euglena deses fo. *intermedia*	Eui	*Pinnularia major* var. *linearis*	Pml
Euglena fusca	Euf	*Pleurosigma salinarum*	Pla
Euglena gracilis	Egr	*Rhopalodia gibba*	Rhg
Euglena oxyuris var. *charkowiensis*	Euw	*Scenedesmus acuminatus*	Sca
Euglena oxyuris var. minor	Euq	*Scenedesmus dimorphus*	Scd
Euglena proxima	Epr	*Scenedesmus longus*	Scl
Euglena spirogyra var. *spirogyra*	Eso	*Scenedesmus perforatus*	Scp
Euglena splendens	Epl	*Stauroneis anceps*	Sta
Fragilari rumpens var. *familiaris*	Frm	*Surirella biseriata*	Sub
Fragilaria construens var. *venter*	Frc	*Surirella robusta*	Sur
Fragilaria capucina var. *vaucheriae*	Fri	*Surirella tenera* var. *ambigua*	Sta
Gomphonema gracile var. *intricatiforme*	Ggi	*Synedra acus*	Sya
Gomphonema lacus-rankala var. *gracilis*	Glg	*Synedra ulna*	Syu
Gomphonema montanum var. *acuminatum*	Gma	*Trachelomonas abrupta*	Tra
Gyrosigma kuetzingii	Gyk	*Trachelomonas armata*	Trr
Hantzschia amphioxys	Haa	*Trachelomonas hispida*	Trh
Lepocinclis ovum var. *ovum*	Loo	*Trachelomonas lacustris*	Trl
Lepocinclis playfairiana	Lep	*Trachelomonas volvocina*	Tvv

4.6 Phytoplankton as pollution indicators

Environmental disturbances induce changes in structure and function of the biological system and nature of water quality. Water pollution indices are commonly used for the evaluation of water quality. Most of our water bodies, including ponds, lakes, rivers, streams, and canals, have become polluted as a result of the discharge of industrial effluents, detergents, agricultural runoff water and domestic sewage. In this study, two indices are taken into consideration of biological information based on phytoplankton Boyd's diversity index and Palmer's pollution index.

Table 12. Boyd's diversity index of phytoplankton score from the study area

Months	No. of genera (S)	Total no. of phytoplankton (N)	Score
January	31	40548	2.82
February	24	39430	2.16
March	25	76810	2.12
April	21	96300	1.65
May	20	217260	1.54
June	44	25330	4.24
July	40	27110	3.81
August	39	26300	3.73
September	41	32450	3.84
October	34	43880	2.08
November	33	45394	2.92
December	32	56319	2.83

> 4 = Less polluted, 2–3 = Moderately polluted, < 1 = Heavily polluted

Table 13. Score of Palmer pollution index of algal genera found in the study area

Phytoplankton	Score	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Euglena	5	+	–	+	+	+	+	+	–	–	–
Oscillatoria	4	–	–	–	+	+	+	+	–	–	–
Scenedesmus	4	+	–	–	+	+	+	+	–	–	–
Navicula	3	+	–	+	+	+	+	+	–	–	–
Nitzschia	3	–	+	+	+	+	+	+	–	–	–
Ankistrodesmus	2	–	–	–	+	–	–	+	+	–	–
Phacus	2	–	–	–	+	+	+	+	–	–	–
Synedra	2	+	+	+	+	+	+	+	+	+	+
Closterium	1	+	+	+	+	+	+	+	+	–	–
Cyclotella	1	+	+	+	+	+	+	+	+	+	–
Gomphonema	1	+	+	+	+	+	+	+	+	–	–
Lepocinclis	1	+	+	+	–	+	+	+	–	–	–
Aulacoseira	1	+	+	+	+	+	+	+	+	+	+
Micractinium	1	–	–	–	–	–	–	+	–	–	–
Microystis	1	–	–	–	–	–	–	–	+	–	–
Pandorina	1	–	–	–	–	+	+	+	–	–	–
Phormidium	1	–	–	+	–	+	+	+	–	–	–
Total Score		**19**	**10**	**19**	**29**	**30**	**30**	**32**	**9**	**4**	**3**

Chapter-5

Discussion

5.1 Physico chemical Parameters

In ecological studies, physico chemical variables are extremely important in analyzing the status of an ecosystem. Hydrographic properties determine the existence of phytoplankton in an aquatic ecosystem and this knowledge is important in understanding the dynamics of the ecosystem. The biodiversity of an aquatic system shaped by the qualitative and quantitative properties of water bodies. Physico chemical variables either individually or collectively influence the system structure and distribution of microalgae. The data obtained from this study has been utilized to discuss the ecology of the freshwater algae of the study area. The rainfall pattern was found to play a significant role in the fluctuations of physicochemical characteristics of water. To assess the impact of human activities on environment by comparing the seasonal changes in physicochemical properties of an ecosystem.

5.1.1 Temperature

Temperature is basically a vital factor for its effect on chemical and biological properties of water. Temperature controls the abundance of phytoplankton in aquatic ecosystems and the determination of various parameters such as pH, alkalinity and saturation level of gases in the freshwater ecosystem (Kaushik and Saksena 1994). Fluctuations in temperature may be due to wind force, the influx of freshwater, atmospheric temperature and heavy rainfall.

Maximum water temperature observed during the month of April at station 7 and least during August at station 10 (Figure 3). The highest temperature in April could be attributed to the increased solar radiation and evaporation. Station 7 is a town area with largest population and highly crowded place. All those people, their buildings and structures create more heat than rural areas. Station 10 is a part of Bhavani river which flows through Silent valley with high rural vegetation and undisturbed area results the low temperature. Higher temperature enhances the growth of organisms, solubility of gases and reaction rate of chemicals in aquatic ecosystem. Similar findings were recorded by (Eshwarlal and Angadi 2003).

5.1.2 pH

pH of aquatic ecosystem is an important environmental factor, the variation of which along with other causes is linked with the chemical changes, species composition and life processes of living communities inhabiting them (Begum et al. 1988). In natural water bodies, pH changes due to the variation in photosynthetic activity.

During the whole study period pH value was in alkaline range. Highest value observed during the month of May at station 7 and lowest during July at station 9 (Figure 4). Least value of pH during July at station 9. Alkaline water promotes high primary productivity. Alkalinity may be due to the presence of various pollutants and chemicals like carbonate, bicarbonate, or hydroxide compounds, those materials get dissolved and portable with the water. The same findings recorded by (Chandra et al 2011; Jindal and Sharma 2011b) and stated that high photosynthetic rate of phytoplankton will reduce the free carbon dioxide resulting in enhanced pH values.

5.1.3 Electrical conductivity

Electrical conductivity depends on the concentration of the ionized substances dissolved in water and the temperature at which measurement is made. It is the power of water to conduct an electrical current. Increase in electrical conductivity may be attributed to decrease in water level due to evaporation (Bhosale et al. 2010b; Barhate and Tarar 1985b).

EC show high disparity between months and stations. Maximum value observed during the month of May at station 7 and minimum at station 9 during July (Figure 5). Extreme EC value attributed due to addition of some salts through the prevailing agricultural activities. Low due to dilution of soluble salts by rainfall during monsoon season.

5.1.4 Total dissolved solids

The term applied to the material left behind after water filtered and evaporated. It includes all the suspended cations and anions, provides a qualitative measure of the number of dissolved ions.

The high TDS value during May at station 8 (Figure 6) due to the addition of agricultural runoff from the surrounding agricultural fields (Belal et al. 2016). A comparatively high value of TDS indicates highly mineralized form of water and maximum disturbance due to human activities (Sharma and Sarang 2004).

5.1.5 Dissolved oxygen

Dissolved oxygen is an especially important parameter of water quality and forms index of physical and biological processes take place in water. Low oxygen concentration is generally associated with substantial contamination by organic matter, while high values indicate extreme plant growth. Its level depends on physico chemical and biological activities of water bodies. The dominant effect of dissolved oxygen results the succession of algae in freshwater ecosystem (Begum et al. 1988).

Highest DO values in the ecosystem during the month of August at station 10 (Figure 7) might be due to high photosynthetic activity and solubility of oxygen in river flex. The lowest oxygen values in pre monsoon during the month of April at station 7 might be due to the influence of organic waste decomposition, high water temperature and nutrient inputs (Vijayakumar 1999; Simon and Travis 2011).

5.2 Nutrients

Nutrient concentrations are crucial in phytoplankton dynamics. There is a firm positive relationship between nutrient loading and phytoplankton development in freshwater. The nutrients like nitrogen and phosphorus are essential for plant growth. Increased input of nutrients due to human activities accelerates primary production, algal bloom, excessive weed growth and eutrophication. Nutrients in freshwater bodies influence the growth, reproduction, and metabolic activities of biotic components, primarily based on seasons, freshwater inflow, tidal variations, land runoff, fertilizers in the agricultural fields, nutrients consumption and regeneration of phytoplankton (Anand and Hopper 1987).

5.2.1 Nitrate

Nitrates are the most oxidized form of nitrogen and formed from the decomposition of organic matter. Increased level of nitrogen accelerates the eutrophication process and resulting algal blooms and hypoxia.

Maximum value of nitrate recorded during the month of May at station 7 and minimum value during August at station 10 (Figure 8). High levels of nitrates in freshwater mainly due to increased domestic sewage arising from anthropogenic activities and agricultural runoffs (Yazdandoost and kaldore 2000). Station 7 characterizes excess growth of plants and phytoplankton, this results the accumulation of organic matter when they die off. The nitrate concentration trends are highly correlated with the usage of fertilizers in fields. A lower nitrate concentration might be due to the high consumption of nitrate by photosynthetic organisms.

5.2.2 Phosphate

The phosphorus is identified as a key nutrient in the biological productivity of the water. Concentration of phosphate in an ecosystem forms a good index of eutrophication in water bodies and if the concentration of phosphates exceeds its normal level along with nitrogen.

Highest value observed during pre monsoon and lowest during monsoon season (Figure 9). In the present study the phosphate content was very low. The lowest values of phosphate might be due to the high utilization by phytoplankton for their development (Perumal and Anand 2008a; Sheela et al. 2011).

5.2.3 Silicate

Silicate is an essential nutrient necessary for the growth of algae, especially diatoms (Smith 1950). The higher silicate concentration was due to increased water temperature, higher evaporation rate and the release of nutrients due to decomposition. Input of biologically available silica to the aquatic ecosystem comes largely from weathering of soils and sediment.

The occurrence of low silica was found to be related with their continuous utilization by phytoplankton especially diatoms and increased population density of phytoplankton. Maximum silicate concentration during the month of May at station 7 and least during December at station 9 (Figure 10). The silicate content relatively high during pre-monsoon due to death and decomposition of diatoms (Govindasamy et al. 2000).

The hydrographic parameters of the study area and the nutrients fluctuated with months and stations. The marked variation in nutrient status of the study area concluded that it is mainly influenced by waste discharge, agricultural runoff, application of fertilizers and intense anthropogenic activities.

5.3 Algal taxonomy

The knowledge about species diversity was essential to understand life in all its totality and to preserve and manage it for future generations (Pandey 1995). Analysis of surface water samples revealed the presence of 257 taxa from rivers in Palakkad district shown in table 2. The taxa belong to 70 genera, 26 families, 9 order and 6 classes namely chlorophyceae, xanthophyceae, bacillariophyceae, euglenophyceae, cyanophyceae and dinophyceae were identified from the 10 stations. Out of the 257 taxa, 88 (chlorophyceae 34%), 1(xanthophyceae 1%), 74 (bacillariophyceae 29%), 69 (euglenophyceae 26%), 24 cyanophyceae 9% and 1(dinophyceae 1%). The most frequent taxa found in the study area listed in table 7. They are *Synedra ulna, Aulacoseira granulata, Navicula cuspidata* and *Fragilaria intermedia.* Five species of diatoms *Cymbella tumida*, *Cyclotella striata*, *Aulacoseira granulata*, *Synedra acus* and *Synedra ulna* recorded from all the months during the study. *Cyclotella meneghiniana, Cyclotella striata, Euglena proxima, Fragilaria intermedia, Aulacoseira granulata, Navicula cuspidata, Synedra ulna* and *Trachelomonas armata* were present in all the stations. *Cyclotella striata, Aulacoseira granulata* and *Synedra ulna* were present in all stations and months from the study. Out of the 257 taxa recorded from the present study, one species is new report to India and 14 species are new to Kerala are listed in table 3.

5.4 Quantitative analysis of phytoplankton

Month wise and station wise distribution on the number of taxa during the study period is given in tables 5 and 6. The highest number of phytoplankton taxa recorded at station 7 (353120 cells/L) and lowest at stations 9 (34840 cells/L) and 10 (31020 cells/L). Month wise highest amount of phytoplankton during May (217260 cells/L) and lowest in June (25330 cells/L) and July (27110 cells/L).

Spatial and temporal distribution of phytoplankton belonging to various taxonomic groups such as chlorophyceae, bacillariophyceae, xanthophyceae, euglenophyceae, cyanophyceae and dinophyceae illustrated in figures 13, 14, 15 and 16. Spatial distribution of number of taxa in bacillariophyceae highest in stations 7 (42), 6 (39) and 5 (38) respectively. All the physico chemical parameters high in station 7. Least number of taxa in stations 9 (19) and 10 (21). Total number of cells also high in station 7 and least in station 10. Monthly wise distribution of taxa and number of cells high in May (pre monsoon) followed by December (post monsoon) and lower in June (Monsoon). pH as a cofactor which influences the population of bacillariophyceae. Alkaline pH favors the abundance of diatoms stated by (Patrick 1949; Pawar et al. 2006; Gupta 2002). In the present study, pH has maximum in May and at station 7, which supported the good number of diatoms in that area. In the present investigation, temperature attain its maximum in May (pre monsoon) and least in monsoon. High temperature favors the growth of diatoms (Srinivasan 1967; Biswas 1936). Direct relationship between nitrate and bacillariophyceae observed in the study. Rao (1953) reported the similar findings. Conductivity, TDS, phosphate and silicate also high in May which favors the growth of diatoms. The dominant species are *Synedra ulna*, *S.acus*, *Fragilaria intermedia*, *Surirella robusta*, *Pinnularia lundii*, *Nitzschia obtusa*, *Navicula cuspidata*, *Cymbella tumida* and *Cyclotella striata.* The station wise abundance was ranged between 23990 cells L^{-1} at station 10 and 177400 cells L^{-1} at station 7. Monthly range of total cells abundance between 10730 cells L^{-1} in July and 146090 cells L^{-1} in May.

Chlorophyceae were recorded in high number throughout the study period, but peak proliferation seen in pre monsoon. High temperature and alkaline nature of river also favors the growth of c

hlorophyceae. Jose and Francis (2007) studied the effect of parameters on the distribution of Chlorophyceae. Maximum values of parameters in pre monsoon season which harbored the good number of chlorophyceae members. The abundance of the total cells ranged from 1650 cells L^{-1} at station 9 and 64770 cells L^{-1} at station 7. Monthly wise abundance ranged between 6160 cells L^{-1} in June and 12410 cells L^{-1} in

April and May. Most dominant species include *Cosmarium quadrum*, *C.blyttii*, *Scenedesmus quadricauda*, *S.acuminatus* and *S.perforatus*.

Next dominant group is euglenophyceae in the present study. Throughout the study they attain maximum peak value. High density of euglenophyceae were recorded during pre monsoon when all the parameters are high and dissolved oxygen low. Low DO encourages the multiplication of this group (Pawar et al. 2006). High temperature is suitable for the luxuriant growth of euglenophyceae (Gupta et al. 2018). Presence of sufficient amount of organic matter and low DO in pre monsoon most appropriate for the proliferation of euglenophyceae. The dominant species are *Euglena acus, E.proxima, E.splendens, Trachelomonas volvocina* and *T.hispida.* The abundance of cells ranged between 27800 cells L^{-1} at station 9 and 89080 cells L^{-1} at station 7. Monthly range between 4500 cells L^{-1} in July and 43710 cells L^{-1} in May.

Cyanophyceae were recorded high number in stations 6 and 7 during pre-monsoon. Alkaline pH and high temperature are luxurious for the growth of cyanophyceae (Pingale and Deshmukh 2005; Jindal and Sharma 2011a, 2011b). Influence of nutrients especially nitrate and phosphate also have role in the regulation of cyanophyceae growth (Banakar et al. 2020). The values of nutrients are low compared with other parameters. The dominant species are *Microcystis aeruginosa*, *Oscillatoria limosa* and *Chroococcus turgidus*. Abundance of cells was ranged between 300 cells L^{-1} at station 10 and 20270 cells L^{-1} at station 7. Monthly range of total cells between 1220 cells L^{-1} in October and 14820 cells L^{-1} in May. Least representation for dinophyceae and xanthophyceae from the selected stations during the period of study.

5.5 Community structure

The species diversity is an index of community diversity that include both species richness and relative abundance of species. In ecological studies species diversity gives clear and scientific knowledge about the communities and ecosystems. The species composition, diversity, distribution and abundance of phytoplankton varies with the chemical and physical properties of water. The ecological diversity generally measured by using species richness and evenness.

5.5.1 Diversity indices

Highest number of taxa in May at station 7 and lowest in June station 9. The number of individuals of a species in relation to the total number of individuals of all the species means the dominance.

Species diversity measured by Shannon index is directly related to the number of species in the sample and the homogeneity of the species distribution (Krebs 1994). The higher species diversity results the greater stability of the ecosystem. The Shannon and Wiener's diversity index of the stations study showed comparatively higher values during May and lower value in June. Station wise indices value high in 7 and low in 9. This index used as a measure of organic pollution level of an ecosystem (Trivedi and Goel 1984; Prasad and Singh 1982; Nandan and Patel 1986). The relationship between the diversity index and the pollution level of water bodies as 0-1 indicates heavy pollution, 1-2 moderate pollution, 2-3 light pollution and 3-4.5 slight pollution (Staub et al. 1970). The values obtained by using the Shannon index revealed that the present study area is highly polluted ecosystem.

The maximum Simpson's dominance index value during May and the minimum value during June. High value reported from station 7 and low in station 9 shown in tables 8 and 9. Least value of Simpson index signifies that there is the low probability that any two individuals drawn at random from a population belong to the same species. Low Simpson dominance index results in higher diversity and *vice versa* (Nandan and Sajeevan 2018). In the present study, more diversity observed during the month of June at station 9. The evenness index value ranged between during May and December. Station 7 represent high value and low in station 9. The maximum species richness index value during May and low during June. Station wise distribution high in 7 and least in 9. The diversity of species in an ecosystem is measured by the total number of species present. When comparing the total diversity profile in the study area, station 7 shows a high level of species richness in May. The increase in phytoplankton density in pre monsoon may be attributed to the rise in the temperature and concentration of available nutrients. Species richness correlated strongly with water temperature. Whereas decrease in the density during monsoon due to increased water level by rainwater and lowest temperature results in decreased photosynthetic efficiency of phytoplankton (Shinde et al. 2011).

5.5.2 Multivariate similarity Analysis

SIMPER analysis was performed to identify the most contributed stations and months in determining algal class as a temporal factor according to Bray-Curtis similarity. When comparing all algal classes, station 7 had the highest contribution percentage followed by stations 3, 5 and 6. Month wise similarity analysis reveals that the month of May has the highest contribution percentage followed by April and March (Table 10). ANOSYM similarity analysis within stations and months revealed that the distribution of phytoplankton varies significantly between stations.

According to hierarchical cluster analysis, phytoplankton composition in stations 9 and 10 differed from that of other stations and from that of the monsoon and post monsoon months. Canonical Correspondence Analysis (CCA) method was used to determine the relationship between environmental variables and phytoplankton distribution (Zhang et al. 2017). Environmental variables responsible for the phytoplankton community distribution were identified with CCA. The percentage of variance and eigenvalues in all the seasons were higher on axis 1 than axis 2. CCA plot had been drawn between 8 physico chemical parameters, 10 stations and 67 dominant species in three seasons- Pre monsoon, Monsoon and Post monsoon (Figures 19, 20 and 21).

In Pre monsoon, the eigenvalue for axis 1 (0.308) explained 21.92% correlation, and axis 2 (0.275) demonstrated 19.57% correlation between physico chemical parameters and dominant species of phytoplankton. pH and nitrate positively correlate on axis 1, exhibited maximum canonical value (0.16 and 0.45). In axis 2, all physico chemical parameters except silicate have close association of phytoplankton distribution with maximum canonical values for temperature and pH (0.474 and 0.193) respectively. CCA plot explained temperature, pH and TDS have strong relation with phytoplankton distribution in pre monsoon season than other variables indicated that their presence responsible for algae growth (Barinova et al. 2009). Among this highest value attributed to temperature and pH is the primary source for algal growth in pre monsoon. Statistically significant relationship in both axis because P-value (0.47 and 0.75) greater than 0.05. Organisms like *Euglena deses* fo. *intermedia*, *Cosmarium blyttii*, *Fragilaria construens* var. *venter*, *Lepocinclis playfairiana*, *Scenedesmus perforatus*, *Surirella biseriata*, *Synedra acus* and *Trachelomonas armata* shows positive correlation in axis 1 with maximum canonical values above 1.5. *Phacus curvicauda*, *Phacus splendens* and *Stauroneis anceps* shows positive correlation in axis 2 with maximum canonical values above 2.

In Monsoon, the eigenvalue for axis 1 (0.485) explained 23.02% correlation and axis 2 (0.449) demonstrated 21.31% correlation between physico chemical parameters and distribution of phytoplankton. Temperature, EC, TDS, nitrate and silicate have positive correlation on axis 1 with maximum canonical value for EC and silicate (0.43 and 0.36). In axis 2, temperature, nitrate and silicate have close association of phytoplankton distribution with maximum canonical values for nitrate and phosphate (0.53 and 0.37) respectively. CCA plot revealed that temperature, nitrate and silicate correlated with phytoplankton distribution in monsoon season. Statistically significant relationship in both axis because P-value (0.37 and 0.15) greater than 0.05. *Cosmarium obsoletum*, *Euglena deses* fo. *intermedia*, *Gomphonema montanum* var. *acuminatum*, *Nitzschia intermedia*, and *Trachelomonas armata* shows positive correlation in axis 1 with maximum canonical values above 2. *Gyrosigma kuetzingii*, *Lepocinclis playfairiana*, *Phacus lefevrei*, *Phacus splendens* and *Pinnularia major* var. *linearis* shows positive correlation in axis 2 with maximum canonical values above 2.

In Post monsoon, the eigenvalue for axis 1 (0.411) explained 26.05% correlation, and axis 2 (0.312) demonstrated 19.7% correlation between physico chemical parameters and phytoplankton. Temperature, nitrate, phosphate, silicate and DO positively correlate on axis 1, exhibited maximum canonical value for temperature and nitrate (0.47 and 0.25). In axis 2, temperature, pH, nitrate and phosphate have close association of phytoplankton distribution with maximum canonical values for temperature, phosphate and nitrate (0.35, 0.29 and 0.22) respectively. CCA plot explained temperature, pH, nitrate and phosphate have strong relation with phytoplankton distribution in post monsoon season. Among this highest value attributed to temperature and nitrate is the primary source for algal growth in post monsoon. Statistically significant relationship in both axis because P-value 0.98 and 0.92. *Cosmarium obsoletum*, *Cyclotella meneghiniana*, *Fragilaria construens* var. *venter* and *Pandorina morum* shows positive correlation in axis 1 with maximum canonical values above 1.5. *Cosmarium binum*, *Fragilaria construens* var. *venter* and *Lepocinclis playfairiana* shows positive correlation in axis 2 with maximum canonical values above 2.

5.6 Phytoplankton as pollution indicators

Algae forms a reliable biological indicators of water pollution. Biological indicators can serve as a useful tool for determining the degree of water pollution resulting from human settlements. The calculated value of diversity index (Boyd 1981) is shown in table 12. As per the index, values varied between 1.54 to 4.24. The values indicated that the water in the study area was moderately polluted. Less pollution occurs during June, and moderately polluted in the remaining months. This method was found to be reliable for the assessment of the pollution of water bodies (Jafari et al. 2010; Tessy and Sreekumar 2011a). On an average, the study area is moderately polluted.

Palmer (1969) developed algal genus index for the rating of organic pollution of a water body. It provides a list of 20 algal genera most tolerant to organic pollution and a number is assigned to each of them based on their relative tolerance to pollution. The number scored by each genus totalled to get the value of algal genus index. These indices are used for the detection and monitoring of water pollution (Nandan and Patel 1983, 1986; Biswas and Konar 2000; Vishnoi and Srivastava 2004; Suphan et al. 2012). Table 13 presents the index score list of genera found in the study area. The result of total score for each sampling stations from 1 to 10 are as follows- 19, 10, 19, 29, 30, 30, 32, 9, 4, 3 respectively. High organic pollution recorded in the stations 7, 6, 5 and 4 because of the presence of pollution tolerant algae like *Euglena*, *Oscillatoria, Scenedesmus, Navicula* and *Nitzschia* has been considered indicative of water bodies. The total score value of stations 1 and 3 reveals that the water quality is subjected to moderate organic pollution, while other four stations 2, 8, 9 and 10 score value indicates only light pollution. Cyanophycean members like *Oscillatoria, Microcystis* and *Phormidium* are also considered as the freshwater pollution algae (APHA 1998; Palmer 1969) are found in the study area. *Euglena*, a single species is enough than all others as a pollution-tolerant form.

Chapter-6

Summary and conclusion

The present work deals with the comparative study on the freshwater algal diversity of Bahrathapuzha river and Bhavani river. Bharathapuzha or ‘Nila’ is the second longest river in Kerala, with a prolonged outstanding contribution to the cultural, social and commercial developments of the state. It originates from Anamalai hills and flows through three districts in Kerala namely Palakkad, Malappuram and Thrissur. The Bhavani river begins in Tamil Nadu and flows through Kerala's Silent Valley before entering western Tamil Nadu after a few kilometres in Palakkad district. Silent Valley is the most ecologically diverse area on Western Ghats. A severe ongoing consequence of anthropogenic interferences are escalating in this river especially sand mining and the associated activities, which gradually reveals the current study area's ecological health. Freshwater phytoplankton are ecologically significant because they are the major resource in aquatic ecosystem with their capacity of producing organic matter. The freshwater river bodies in Palakkad district is the source of drinking water to thousands of people living on its banks. The river's ability to self-purify is being harmed by polluted river water, low or no river flow, sand mining, and deteriorating catchment area. Presence of check dams and construction activities in this river also restricted the flow of water and are projected as one of the reason for the presence of pollution.

The present study is the first attempt to elucidate the algal diversity from the river ecosystem in Palakkad district. Ten stations were surveyed for qualitative and quantitative distribution of phytoplankton for a period of one year from October 2018 to September 2019. The physico chemical parameters analyzed were temperature, pH, TDS, EC, dissolved oxygen, nitrate, phosphate and silicate. The study has brought out the spatiotemporal variation of the above parameters and identified all the parameters except DO was higher in pre monsoon compared with other seasons. Spatial variation in parameters revealed that higher values observed in stations Malampuzha, Kalpathy, and Kannadi respectively. All the parameters showed a decreasing trend with increase in altitude.

Analysis of water samples reveal the presence of total of 257 taxa belonging to 70 genera, 26 families, 9 order and 6 classes namely Chlorophyceae, Xanthophyceae, Bacillariophyceae, Euglenophyceae, Cyanophyceae and Dinophyceae were identified from the 10 stations. The chlorophyceae, bacillariophyceae and euglenophyceae were the major group in the present study. *Micrasterias laticeps* var. *acuminata* is a new species to India and 11 species are new to Kerala. Out of the 257 taxa, 88 species to chlorophyceae, 1 species to xanthophyceae, 74 species to bacillariophyceae, 69 species to euglenophyceae, 24 species to cyanophyceae and 1 species to dinophyceae. Due to similar environmental conditions such as climate, rainfall and physico chemical characteristics, the majority of the recorded taxa were common to all of the studied river sites. The most frequent taxa belong to the class bacillariophyceae are *Synedra ulna, Aulacoseira granulata, Navicula cuspidata* and *Fragilaria intermedia.* pH and temperature maximum at Malampuzha station and during the month of May, which supported the maximum growth of bacillariophyceae. Quantitative analysis of phytoplankton also showed maximum at Malampuzha during May and least occurance at stations Mukkali and Seenkara during the month of June. During the pre monsoon season, there was a greater diversity of algae, and it is thought that this is the best season for algal proliferation. The current study shows that the algal flora in freshwater river ecosystem is properly correlated to different environmental factors.

Irrespective of the monthly variation, chlorophyceae were recorded in high number throughout the study period, but highest proliferation seen in pre monsoon. Most dominant species include *Cosmarium quadrum*, *C.blyttii*, *Scenedesmus* *quadricauda*, *S.acuminatus* and *S.perforatus*. Presence of appropriate amount of organic matter and low DO in pre monsoon favours the proliferation of euglenophyceae and cyanophyceae. The dominant species are *Euglena acus, E.proxima, E.splendens, Trachelomonas volvocina* and *T.hispida.* The dominant species under cyanophyceae are *Microcystis aeruginosa*, *Oscillatoria limosa* and *Chroococcus turgidus*.

Highest Shannon index value was obtained from Malampuzha during May and least at Mukkali station during June. The same result is observed in Simpson diversity index and species richness. SIMPER analysis of the data confirmed that major station wise contributing percentage at station 7 (Malampuzha) and monthly variations maximum in May. The analysis of similarity (ANOSYM) within stations and months can be used to determine statistical significance. The multivariate similarity analysis (Bray-Curtis) based on phytoplankton abundance and composition in different stations formed, stations from Bhavani river (Mukkali and Seenakara) differed from that of the other stations during the monsoon and post monsoon months.

CCA ordination plot has unveiled statistically significant influence of physico chemical characteristics on phytoplankton abundance. The axial plot explained temperature, pH and TDS have significant influence on abundance and composition of organisms during months in pre monsoon and have effect on the abundance of only bacillariophyceae and euglenophyceae. In monsoon season, temperature, nitrate and silicate have strong effect on the algal growth. Temperature, pH, nitrate and phosphate have strong correlation on the abundance of chlorophyceae and bacillariophyceae. These findings show that temperature and pH are the most important variables in determining algae diversity, regardless of other factors. In total, the algal species diversity in the rivers of Palakkad district determined by the temperature and alkalinity level. The presence of algal species *Pandorina morum, Cosmarium obsoletum, Fragilaria construens* var. *venter, Euglena deses* fo. *intermedia, Trachelomonas armata, Phacus lefevrei*, *Phacus splendens* and *Lepocinclis playfairiana* are the regularly reported taxa in all the seasons.

Palmer’s pollution index revealed that high organic pollution recorded in the stations Malampuzha, Kalpathy, Kannai and Chulliyar because of the presence of pollution tolerant algal genus such as *Euglena*, *Oscillatoria, Scenedesmus, Navicula* and *Nitzschia* has been considered as indicative of water bodies. Only light organic pollution observed in stations Mukkali and Seenkara. These stations are located at high altitude and flow through Silent valley. Human intrusions as well as all other external activities are strictly restricted in that area. This improves the quality of water good while among the other stations.

Malampuzha is the most polluted area on the Bharathapuzha river. The urban sewage canals are directly open through that area. A paper mill is working very close to that station, wastes from there also directs the river. The Shannon and Wiener’s diversity index value revealed that present study area is highly polluted ecosystem based on the distribution of species. According to Boyd’s diversity index value, moderate level of pollution persists in that area throughout the year, except during the months in monsoon season.

The taxonomy and ecology of freshwater algae revealed that the river ecosystem of Palakkad district is moderately polluted and high organic pollution occurs in some regions such as Malampuzha, Kalpathy and Kannnadi. Hydrology of river displayed statistically significant spatiotemporal variations in physico chemical characteristics. Fertilizers, nutrients and wastes that are dumped into the river cause deterioration of the water quality to some extent. The river now faces serious threats to its existence. The river's course is expected to change due to the obstruction of tall grasses and bushes that have grown in the river. Excessive sand mining from the river has resulted in the degradation of the river bottom in certain regions. The comparative study of the algal community from undisturbed areas of the Bhavani river with that of Bharathapuzha river aids in distinguishing the human impact on the freshwater ecosystem. Proper conservation measures must be adopted to protect the river from anthropogenic interferences. Appropriate afforestation packages along the river basins, renovation of river margin vegetation, controlled mining of the sand, sustainable use of the resources of the river are crucial to conserve this freshwater body. The study of fresh water algal diversity in rivers of Palakkad district would serve as a valuable reference for the monitoring and management of freshwater river ecosystem.

References

Abbasi, T., & Abbasi, S. A. (2011). Water quality indices based on bioassessment: The biotic indices. *Journal of Water and Health*, *9*(2), 330–348.

Abdul-Majeed, M. (1935). The freshwater algae of the Punjab. Part I. Bacillariophyta (Diatomeae). *Punjab University Publications,* Lahore. 44pp.

Abhijna, U. G. & Bijukumar, A. (2015). Biomonitoring for pollution assessment: A case study in Veli-Akkulam and Vellayani lakes, Southwest Coast of Kerala**.** *Journal of Aquatic Biology & Fisheries, 3*, 80–89.

Abhisheka, V. R., & Binoj Kumar, R. B. (2018). Groundwater quality assessment for domestic and irrigational suitability in Kallada River Basin, south Kerala. *Nature Environment and Pollution Technology*. *17*(1), 153–159.

Adhikary, S. P., Jena, M., & Rath, J. (2009). Soil and freshwater algae from coastal region of Orissa state, India. *Bibliotheca Phycologica*, *115*, 1–166.

Agarkar, D. S. (1969). Contribution to the desmids of Gwalior, Madhya Pradesh, India. *Phykos*, *8*(1 and 2), 1–10.

Agarkar, D. S. (1971). Contribution to the desmids of Gwalior, Madhya Pradesh, (India) – II. *Phykos*, *10*(1 and 2), 54–69.

Agarkar, D. S., Agarker, M. S., & Dikshit, R. (1979). Desmids from Bandhavgarh, Madhya Pradesh, India. *Hydrobiologia*, *65*(3), 213–223.

Alfred, J. R. B. (1978). Algal flora of Shillong. I- Chlorophyceae. *Phykos*, *17*(1–2), 33–34.

Allan, J. D., & Flecker, A. S. (1993). Biodiversity conservation in Running waters. *BioScience*, *43*(1), 32–43.

American Public Health Association (APHA). (1998). Standard methods for the examination of water and wastewater (20th ed). American Public Health Association.

Anand, N. (1989). A handbook of blue green algae. *Bishen Singh Mahendrapal Singh publishers,* Dehradun. 79 pp.

Anand, N. (1998). Indian freshwater microalgae. *Bishen Singh Mahendrapal Singh publishers,* Dehradun. 94 pp.

Anand, N., & Hopper, R. S. S. (1987). Blue green algae from rice fields in Kerala state, India. *Hydrobiologia*, *144*, 226–240.

Anand, N., & Revathi, G. (1987). Blue green algae from rice fields of Tamil Nadu. *Phykos*, *26*, 17–21.

Anand, N., & Subramanian, T. D. (1994). Distribution of natural populations of blue green algae in a rice field. *Phykos*, *33*(1 and 2), 163–169.

Anand, V. K. (1975). A check list of planktonic algae from Mansar Lake Jammu. *Phykos*, *14*(1 & 2), 77–79.

Anand V. K., & Jitendra, P. (2006). Occurrence of genus *Oedogonium* link in aquatics of Shivalik Himalayas, India. *Journal of Aquatic Biology*, *21*(2), 1–4.

Anila, P. A., & Ajit Kumar, A. G. (2015). The Influence on Environmental Parameters on Chlorophycean Abundance: A Study from the Museum Lake in Thiruvananthapuram Kerala, India. *Phykos, 47*(2), 117-128.

Anitha, A. B., Shahul Hammed, A., & Prasad, N. B. (2014). Integrated river basin master plan for Chaliyar Proc. In: *International symposium on integrated water resources management,* 167–117pp.

Arulmurugan, P., Nagaraj, S., & Anand, N. (2010). Biodiversity of freshwater algae from Temple tanks of Kerala. *Recent Research in Science and Technology*, *2*(6), 58–71.

Ashtekar, P. V. (1982). Euglenophyceae of Aurangabad, Maharashtra. *Phykos*, *21*, 153–159.

Ashtekar, P. V., & Kamat, N. D. (1980a). Nostocales of Marathawada, Maharashtra. *Phykos*, *19*(1), 89–93.

Balachandran C., Dinakaran S., Alkananda B., Boominathan M., & Ramchandra T.V. (2012). Monitoring aquatic macroinvertebrates as indicators for assessing the health of lakes in Bangalore Karnataka. *International Journal of Advanced Life Sciences*, 5, 19-33.

Banakar, V., Alam, Q., Rajendra, S., Pandit, A., Cladious, A., & Gnanaprakash, K. (2020). Spirulina, The Boon of Nature. *International Journal of Research in Pharmaceutical Sciences, 11*, 57–62.

Barhate, V. P., & Tarar, J. L. (1981). The algal flora of Tapti River, Bhusawal, Maharashtra. *Phykos*, *20*(1 and 2), 75–78.
Barhate, V. P., & Tarar, J. L. (1983a). Additions to algal flora of Maharashtra: Diatoms from Khandesh – I. *Phykos*, *22*, 13–17.
Barhate, V. P., & Tarar, J. L. (1983b). Algae of Maharashtra: I—Additions to Cyanophyceae of Khandesh. *Phykos*, *22*, 67–72.
Barhate, V. P., & Tarar, J. L. (1985a). Additions to algal flora of Maharashtra: Chlorophyceae from Khandesh – I. *Phykos*, *24*, 180–183.
Barhate, V. P., & Tarar, J. L. (1985b). Additions to the algal flora of Maharashtra: Euglenophyceae from Khandesh – I. *Phykos*, *24*, 184–185.
Barhate, V. P., & Tarar, J. L. (1985c). Additions to the algal flora of Maharashtra: Diatoms from Khandesh – II. *Journal of the Indian Botanical Society*, *64*, 381–384.
Barinova, S. S., Bragina, T. M., & Nevo, E. (2009). Algal species diversity of arid region lakes in Kazakhstan and Israel. *Community Ecology*, *10*(1), 7–16.
Basavarajappa, S. H., Raju, N. S., Hosmani, S. P., & Niranjana, S. R. (2010). Algal diversity and physico-chemical parameters in Hadhinaru Lake, Mysore, Karnataka State, India. *BioScan*, *5*(3), 377–382pp.
Begum, Z. N. T., Mandal, R., & Paul, A. R. (1988). Succession of algal flora in deep water rice field of Sonargaon, Bangladesh. *Phykos*, *27*, 15–24.
Behura, B. K. (1989). Pollution of the wetlands. In: Agrawal, V.P., Desai, B.N. and Abidi, S.A.H. (eds.). Management of Aquatic ecosystems, *Narendra Publishing House,* Delhi, 135–139pp.
Belal, A. A. M., El-Sawy, M. A., & Dar, M. A. (2016). The effect of water quality on the distribution of macro-benthic fauna in Western Lagoon and Timsah Lake, Egypt.I. *Egyptian Journal of Aquatic Research*, *42*(4), 437–448.
Bendre, A. M., & Kumar, S. (1975). Cyanophyceae of Meerut. *Phykos*, *14*(1 and 2), 1–7.
Bergman, B. G., & Bump, J. K. (2015). Experimental evidence that the ecosystem effects of aquatic herbivory by moose and beaver may be contingent on water body type. *Freshwater Biology*, *60*(8), 1635–1646.
Bhakta, S., Das, S. K., & Adhikary, S. P. (2010). Freshwater algae of Sikkim. *Journal of Indian botanical Society*, *89*(1 & 2), 169–184.
Bharati, S. G. (1965). On some interesting algae from Kumta, N, Kanara. *Phykos*, *4*, 71–73.
Bharati, S. G., & Hegde, G. R. (1982a). Desmids of Karnataka State and Goa – Part I. *Phykos*, *21*, 143–149.
Bharati, S. G., & Hegde, G. R. (1982b). The genus *Staurastrum* Meyen and *Staurodesmus* Teil. (Desmidiaceae) in Karnataka and Goa states (India). *Hydrobiologia*, *96*(1), 31–51.
Bharati, S. G., & Hegde, G. R. (1983). Desmids of Karnataka state and Goa: Genus *Euastrum* Ehr. and *Micrasterias* Agardh. *Journal of the Indian Botanical Society, 62*, 170–175.
Bhattacharya, P., Choudhury, A. Kr., & Pal, R. (2011). Freshwater diatoms from Kolkata with special references to their taxonomy. *Indian Hydrobiology*, *13*(2): 98–112.
Bhoge, O. N., & Ragothaman, G. (1986a). Studies on the Cyanophyceae from Jalgaon region, Maharashtra. *Phykos*, *25*, 129–131.
Bhoge, O. N., & Ragothaman, G. (1986b). Studies on the Euglenophyceae from Jalgaon region, Maharashtra. *Phykos*, *25*, 132–135.
Bhosale, L. J., Dhumal, S. N., & Sabale, A. B. (2010a). Phytoplankton diversity of four lakes of Satara District, Maharashtra State, *BioScan*, *5*(3), (pp. 449–454).
Bhosale, L. J., Dhumal, S. N., & Sabale, A. B. (2010b). Seasonal variations in occurrence of phytoplankton and primary productivity of some selected lakes in Maharashtra. *BioScan* [Special Issue], *2*, 569–578.
Bhosale, L. J., Patil, S. M., Dhumal, S. N., & Sabale, A. B. (2010c). Occurrence of phytoplankton in the lakes in and around Kolhapur City (Maharashtra). *Indian Hydrobiology*, *12*(2), 133–142.
Bhosale, L. J., Patil, S. M., Dhumal, S. N., & Sathe, S. S. (2010d). Phytoplankton biodiversity in water bodies of Tahasil Kavathe Mahankal (Sangli District), during post summer period. *Indian Hydrobiology*, *12*(2), 190–194.

Bijukumar, A., & Sushama, S. (2001). The fish fauna of Bharathapuzha river, Kerala. *Journal of Natural History of India, 98*(3), 464-468.

Bijukumar, A., Philip, S., Ali, A., Sushma, S., & Raghavan, R. (2013). Fishes of river Bhatathapuzha, Kerala, India: diversity, distribution, threats and conservation. *Journal of Threatened Taxa, 5*(15), 4979-4993.

Binoj Kumar, R. B., & Divya, M. P. (2012). Spatial evaluation of groundwater quality in Kazhakuttam block, Thiruvananthapuram District, Kerala. *Journal of the Geological Society of India*, *80*(1), 48–56.

Biswas, B. K., & Konar, S. K. (2000). Impact of waste disposal on plankton abundance and diversity in the river Ganga at Hatdidah (Bihar). *Pollution Research*, *19*(4), 633–640.

Biswas, B. K., & Konar, S. K. (2001). Influence of Hazardous Industrial Wastes on Plankton in the river Damodor at Durgapur in West Bengal. *Pollution Research*, *20*(4), 583-588.

Biswas, K. (1936). Common diatoms of the Loktak lake, Manipur, Assam. *Journal of Royal Asiatic Society of Bengal*, *2*(2), 171–175.

Biswas, K. (1949). Common fresh and brackish water algal flora of India and Burma. *Records of the Botanical Survey of India*, *XV*(II). 169 pp.

Bongale, U. D. (1981). On soil algae from paddy fields of Panjim (Goa) and Chikkamanchali (Raichur dist., Karnataka), India. *Journal of the Indian Botanical Society*, *60*, 326 –329.

Bongale, U. D. (1985). Systematic account of diatoms from the cultivated soils of Karnataka State, India. *Phykos*, *24*, 18–26.

Bongale, U. D. (1987). Records of certain interesting desmid taxa from Karnataka State. *Phykos*, *26*, 53–56.

Bongale, U. D., & Bharati, S. G. (1980a). On the algal flora of cultivated soils of Karnataka State, India. *Phykos*, *19*(1), 95–109.

Bongale, U. D., & Bharati, S. G. (1980b). Freshwater algae of Davanagere and Raichur of Karnataka State, India. *Journal of the Bombay Natural History Society*, *77*(1), 6–11.

Brijesh, V. K. (2006). Hydrogeological studies and Groundwater modelling in Bharathapuzha Basin, Kerala, India. [PhD Thesis], University of Mysore.

Boyd, C. E. (1981). Water Quality in warm water fishponds. *Anburn University and Printers,* C. Alabama. 359 pp.

Chacko, P. I., & Ganapati, S. V. (1949). Some observations on the Adyar River, with special reference to its hydrobiological conditions. *Indian Geographical Journal*, *24*(3), 35–49.

Chadha, A., & Pandey, D. C. (1977). Additions to the algal flora of Allahabad, I-Genus *Scenedesmus*. *Phykos*, *16*(1 and 2), 69–75.

Chadha, A., & Pandey, D. C. (1978). Additions to the algal flora of Allahabad, II (Chlororophyta, Chlorococcales). *Phykos*, *17*(1 and 2), 73–80.

Chakraborty, T., Mukhopadhyay, A., & Pal, R. (2010). Micro-algal diversity of Kolkata, West Bengal, India. *Indian Hydrobiology*, *12*(2), 204–224.

Chandler, J. R. (1970). A biological approach to water quality management. *Water pollution control*, 69, 415-421.

Chandra, S., Singh, A., Tomar, P. K., & Kumar, A. (2011). Evaluation of physicochemical characteristics of various river water in India. *E-Journal of Chemistry*, *8*(4), 1546–1555.

Chaporkar, C. B., & Gangawane, L. V. (1984). Blue green algae of some cultivated soils of Marathwada, Maharashtra – I. *Phykos*, *23*(1 and 2), 55–58.

Chatterjee, M., & Chatterjee, S. P. (1983). Nitrogen fixing Cyanobacteria from the paddy field soils of Burdwan district. *Phykos*, *22*, 64–66.

Chattopadhyay, S., Asa Rani, L., & Sangeetha, P. V. (2005). Water quality variations as linked to land use pattern: A case study in Chalakudy river basin, Kerala. *Current Science*, *89*(12), 2163–2169.

Chaturvedi, U. K. (1985). Additions to algal flora of Rohilkhand division, U.P., India: IX Diatoms from Bareilly district. *Phykos*, *24*, 163–169.

Chaturvedi, U. K., Pandey, U. C., Habib, I., & Shukla, H. M. (1987). Desmids of Bareilly – II. *Phykos*, *26*, 95–102.

Chaudhary, B. L., & Meena, L. (2007). Notes on the freshwater euglenoides and Dinophyceae of Udaipur district, Rajasthan (India). *Journal of the Indian Botanical Society*, *86*(3 and 4), 64–67.

Choudhary, K. K. (2009). Occurrence of Chroococcaceae during rice cultivation in north Bihar, India. *Bangladesh Journal of Plant Taxonomy*, *16*(1), 57–63.

Chaudhary, R., & Pillai, R. S. (2010). Diversity of phytoplankton at Sasthamcotta Lake, Kollam, Kerala. In: Dwivedi, S.N., Tamot, P. and Yasin, A.M. (eds.). Proceedings of national seminar on "Integrated management of water resources to biodiversity and livelihood", *Academy of science, engineering and technology*, Bhopal, 163– 170pp.

Das, C. R. (1961). A new report on *Spirogyra rugulosa* Iwan off from Senchal lake, Darjeeling, India. *Bulletin of the Botanical Survey of India*, *3*(3/4), 389.

Das, P. R., & Santra, S. C. (1982). Diatoms of Senchal Lake, Darjeeling, West Bengal. *Phykos*, *21*, 99.

Das, R. N., & Purty, N. (1990). Desmids from dhunti, Ranchi. *Phykos*, *29*(1 and 2), 127–128.

Das, S. K., & Adhikary, S. P. (2012). Fresh water algae of Nagaland. *Journal of the Indian Botanical Society*, *91*(1–3), 99–123.

Deshmukh, B. S., & Pingle, S. D. (2006). Chlorophycean algae of Ahmednagar district (MS). *Indian Hydrobiology*, *9*(2), 301–305.

Desikachary, T. V. (1959). Cyanophyta-ICAR Monograph on algae. *Indian Council of Agricultural Research,* New Delhi, 686 pp.

Desikachary, T. V. (1989). Atlas of Diatoms (Marine diatoms of the Indian Ocean region), Madras Science Foundation, Madras. *Fascicle VI*, 1–27.

Dey, H. S., Bhuyan, S., Pradhan, B., & Bastia, A. K. (2008). Freshwater algal diversity of Similipal Biosphere Reserve, Orissa. *Indian Hydrobiology*, *11*(1), 167–172.

Dhande, J. S., & Jawale, A. K. (2008). On genus *Fragillaria*, *Lyngbye* and *Synedra* Ehr. from Hartala lake, Maharashtra. *Indian Hydrobiology*, *11*(2), 217–222.

Dhande, J. S., & Jawale, A. K. (2009). Genus *Cosmarium* Corda from Hartala Lake district Jalgaon Maharashtra. *Shodh Samiksha aur Mulyankan, 2 (7)*, 196–198.

Dhanya, V., & Ray, J. G. (2015). Green Algae of Unique Tropical Wetland, Kuttanadu, Kerala, India, in Relation to Soil Regions, Seasons and Paddy Growth Stages. *International Journal of Science, Environment and Technology, 4,* 770-803.

Dhingra, R., & Ahluwalia, A. S. (2007). Genus *Phormidium* Kutzing ex Gomont (Cyanoprokaryote) from diverse habitats of Punjab. *Journal of Indian botanical Society*, *86*(3 & 4), 86–94.

Dinesan, V. P., Anitha, A. B., & Gopakumar, R. (2004). Water resources scenario of Bharathapuzha River Basin. In *Proceedings of the Industrial Environmental Conference,* 36–48pp.

Divya, D. K. R., & Manomani, K. (2013). Assessment of water quality of river Kalpathypuzha, Palakkad, District Kerala. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *4*(4), 59–62.

Divya, M., Sethuraman, S., Devabharathi, N., Mondal, S. K., & Dasgupta, S. (2019). Low-temperature processing of printed field-effect transistors from sublimating-stabilizer derived oxide nanodispersions. *Advanced Electronic Materials*, *5*(7), 42-49.

Drissia, T. K. (2019). Spatial and temporal variation of water stress in Bharathapuzha River Basin, Kerala, India. *Journal of the Institution of Engineers (India): Series A*, *100*(1), 167–175.

Dudgeon, D. (2000). Riverine biodiversity in Asia: A challenge for conservation biology. *Hydrobiologia*, *418*(1), 1–13.

Dudgeon, D. (2003). The contribution of scientific information to the conservation and management of freshwater biodiversity in tropical Asia. *Hydrobiologia*, *500*(1–3), 295–314.

Dwivedi, R. K., Shukla, S. K., Shukla, C. P., Misra, P. K., & Seth, M. K. (2008). Cyanophycean flora of southern Himanchal Pradesh, India. *Ecoprint, 15*, 29–36.

Easa, P. S. (2004). Biodiversity documentation for Kerala, Part 1. Algae, *Kerala Forest Research Institute,* Peechi*,* 106 pp.

Eshwarlal, S., & Angadi, S. B. (2003). Physico-chemical parameters of two fresh water bodies of Gulbarga, India, with special reference to Phytoplankton. *Pollution Research*, *22* (3), 411-42.

Fritsch, F. E. (1945a). The structure and reproduction of the algae, I. *Cambridge University Press,* Cambridge. 791 pp.

Fritsch, F. E. (1945b). The structure and reproduction of the algae, II. *Cambridge University Press,* Cambridge. 939 pp.

Fristch, F. E. (1907a). A general consideration of the sub-aerial and freshwater algal flora of Ceylon: A contribution to the tropical algal ecology. Part I: Sub-aerial algae and algae of the inland freshwaters. *Proceedings of the Royal Society of London, Series B*, *79*(531), 197–254.

Fritsch, F. E. (1907b). The sub-aerial and freshwater algal flora of the tropics: A phytogeographical and ecological study. *Annals of Botany (London)*, *21*(2), 235–275.

Freitas, J. F., & Kamat, N. D. (1979). Desmidiaceae of Nagpur. *Phykos*, *18*(1 and 2), 97–103.

Ganapathi, S. V. (1956). Studies on the source ofthe Madras city water supply and on other waters of Madras State [PhD Thesis], University of Madras.

Ganapathi, S. V., & Alikunhi, K. H. (1950). Factory effluents from Mettur chemical and industrial Corporation Ltd., Mettur Dam and their pollutional effects on the fisheries of Cauvery. *Proceedings of the National Institute of Sciences in India*, *16*, 189–200.

Gandhi, H. P. (1955). A contribution to our knowledge of the freshwater diatoms of Partabgarh Rajasthan. *Journal of the Indian Botanical Society*, *34*, 307–338.

Gandhi, H. P. (1956). A preliminary account of the soil diatom flora of Kolhapur. *Journal of the Indian Botanical Society*, *35*(4), 402–408.

Gandhi, H. P. (1957). A contribution to our knowledge of the diatom genus *Pinnularia*. *Journal of the Bombay Natural History Society*, *54*(4), 845–852.

Gandhi, H. P. (1958a). The freshwater diatom flora of the Hirebhasgar dam area, Mysore State. *Journal of the Indian Botanical Society*, *37*(2), 249–265.

Gandhi, H. P. (1958b). Freshwater diatoms from Kolhapur and its immediate environs. *Journal of the Bombay Natural History Society*, *55*(3), 493–511.

Gandhi, H. P. (1959). Freshwater diatom flora in the Sagar of Mysore state. *Journal of the Indian Botanical Society*, *38*(3), 305–331.

Gandhi, H. P. (1959a). Freshwater diatoms from Sagar in the Mysore State. *Journal of the Indian Botanical Society*, *38*(3), 305–331.

Gandhi, H. P. (1959b). Freshwater diatom flora of the Panhalgarh Hillfort in the Kolhapur district. *Hydrobiologia*, *14*(2), 93–129.

Gandhi, H. P. (1960). On the diatom flora of some ponds around Vasna village near Ahmedabad. *Journal of the Indian Botanical Society*, *39*(4), 558–567.

Gandhi, H. P. (1961). Notes on the Diatomaceae of Ahmedabad and its environs. *Hydrobiologia*, *17*(3), 218–236.

Geeta, K., & Kerkar, V. (2009). Freshwater green algal flora from Parsem (Pernem) Goa, India. *Indian Hydrobiology*, *12*(1), 114–119.

Gharib, S. M., El-Sherif, Z. M., Abdel-Halim, A. M., & Radwan, A. A. (2011). Phytoplankton and environmental variables as a water quality indicator for the beaches at Matrouh, south-eastern Mediterranean Sea, Egypt: An assessment. *Oceanologia*, *53*(3), 819–836.

Ghosh, A. K. (1989). Wetland ecosystem in India: An overview. In Agrawal, V. P., B. N. Desai & S. A. H. Abidi (Eds.), Management of aquatic ecosystems. *Narendra Publishing House,* 141–153pp.

Girish Kumar E., Rekha C., Pradeep Kumar G., Saikala K., & Sivadasan K. K. (2014). Diversity of planktonic algae of selected temple ponds of Mahe U.T. of Puducherry, India. *International Journal of Science,* 48-52pp.

Gonzalves, E. A. (1981). Oedogoniales- ICAR Monograph on algae. *Indian Council of Agricultural Research*, New Delhi, India. 757 pp.

Govindasamy, C., Kannan, L., & Jayapaul, A. (2000). Seasonal variation in physico-chemical properties and primary production in the coastal water biotopes of Coromandel coast, India. *Journal of Environment Biology*, *21*, 1–7.

Gupta, R. K. (2002). A check list of algal flora of Shillong, Meghalaya. *Journal of Economic and Taxonomic Botany*, *26*(2), 464–468.

Gupta, R. K., & Srivastava, O. N. (1993). Studies on euglenoids of Ranchi, India – II. Additions of Bihar phycoflora. *Bulletin of the Botanical Survey of India*, *35*(1–4), 1–5.

Gupta, S., Singh, D., Rawat, M. S., & Ahmed, R. (2018). Phytoplankton community in relation to physicochemical characteristics of Renuka Lake and Parshuram Tal (H.P.), India. *International Journal of Scientific Research and Reviews*, *7*(3), 769–780.

Gurudeva, M. R., Arekal, G. D., & Somashekar, R. K. (1983). Desmid flora of Savandurga, Karnataka. *Phykos*, *22*, 48–56.

Gurumayum, S. D., Daimari, P., Goswami, B. S., Sarkar, A., & Choudhury, M. (2001). Ecology of river Subansiri in Arunachal Pradesh. *Journal of Inland Fisheries Society of India*, *33*(2), 50–54.

Guschina, I. A., & Harwood, J. L. (2009). Algal lipids and effect of the environment on their biochemistry. In M. T. Arts, M. T. Brett & M. J. Kainz (Eds.). *Lipids in aquatic ecosystems,* 1–24pp.

Habib, I. (1995). Desmids of Lakhimpur- Kheri, U.P. *Journal of Economic and Taxonomic Botany*, *19*(2), 307–311.

Habib, I. (1996). A systematic account of Chlorococcales from Najibabad (U. P.) India. *Journal of Economic and Taxonomic Botany,* (3), 681–684.

Habib, I. (2002). Some Chlorococcales from Kumaun region (U.P.) India. *Journal of Indian botanical Society, 81*, 195-198.

Habib, I., & Chaturvedi, U. K. (2001). A systematic account of Chlorococcales from Mahoba, India. *Phykos*, *40*(1&2), 107–113.

Habib, I., Ghildiyal, J. C., Negi, K. S., & Chaturvedi, U. K. (1998). A systematic account of Chlorococcales from Kotdwar, Garhwal. *Phykos, 37*(1&2), 125–129.

Habib, I., & Pandey, U. C. (1990a). On some taxa of *Cosmarium* Corda- New to Indian desmid flora. *Journal of the Indian Botanical Society*, *69*, 275–276.

Habib, I., & Pandey, U. C. (1990b). The Euglenineae from Nakatia River, Bareilly (U.P.) India. *Journal of the Indian Botanical Society*, *69*, 387–390.

Habib, I., Shukla, H. M., & Pandey, U. C. (1992). A preliminary survey of Cyanophyceae of Mala Forest, Pilibhit, (U.P.). *Journal of Economic and Taxonomic Botany*, *16*(2), 367–371.

Hammer, G. L., Hansen, J. W., Phillips, J. G., Mjelde, J. W., Hill, H., Love, A., & Potgieter, A. (2001). Advances in application of climate prediction in agriculture. *Agricultural Systems*, *70*(2–3), 515–553.

Harsha, T. S., & Malammanavar, S. G. (2004). Assessment of phytoplankton density in relation to environmental variables in Gopalaswamy pond at Chitradurga, Karnataka. *Journal of Environmental Biology*, *25*(1), 113–116.

Hegde, G. R. (1986b). New records of desmids from Karnataka State – I. *Phykos*, *25*, 117–122.

Hegde, G. R., & Bharati, S. G. (1983a). Freshwater algae of Bijapur district, Karnataka State, India. *Phykos*, *22*, 167–170.

Hegde, G. R., & Bharati, S. G. (1983b). Zygospore formation in some species of desmids – Part II. *Phykos*, *22*, 4–12.

Hegde, G. R., & Bharati, S. G. (1986). Ecological studies in ponds and lakes of Dharwad – Occurrence of euglenoid blooms. *Phykos*, *25*, 62–67.

Hegde, G. R., & Isaacs, S. W. (1988a). Certain interesting desmid taxa from Uttara Kannada district of Karnataka State. *Phykos*, *27*, 8–12.

Hegde, G. R., & Isaacs, S. W. (1988b). Freshwater algae of Karnataka State –I. *Phykos*, *27*, 96–103.

Hegde, G. R., & Issacs, S. W. (1989). New taxa of desmids from Uttara Kannada district, Karnataka State (India). *Journal of Bombay Natural History Society*, *86*(1), 88–90.

Hegde, G. R., & Malammanavar, S. G. (1988). Some noteworthy rice field algae of Dharwad, Karnataka State. *Phykos*, *27*, 4–7.

Hegde, G. R., & Somanna, K. (1991). Freshwater algae of Karnataka – II, India. *Phykos*, 30(1 & 2), 49–54.

Hosmani, S. P. (2008). Ecology of Euglenaceae from Daharwar, Karnataka. *Indian Hydrobiology*, *11*(2), 303–311.

Hosmani, S. P., & Bharati, S. G. (1983). Euglenineae of polluted and unpolluted waters. *Phykos*, *22*, 130–135.

Hynes, H. B. N. (1978). The biology of polluted waters (6th ed). *Liverpool, University Press*, Liverpool. 202 pp.

Irfanullah, H. M. (2006). Algal taxonomy in limnology: An example of the declining trend of taxonomic studies. *Hydrobiologia*, *559*(1), 1–9.

Isabella, G., & Patel, R. J. (1985). Contribution to our knowledge of Chlorococcales of Gujarat. *Journal of the Indian Botanical Society*, *64*, 139–143.

Iyengar, M. O. P., & Desikachary, T. V. (1981). Volvocales- ICAR Monograph on algae. *Indian Council of Agricultural Research,* New Delhi, India, 532 pp.

Jafari, N., Trivedy, R. K., & Pathak, R. K. (2010). Water quality and ecological assessment as indicators for freshwater ecosystem classification. *Pollution Research*, *29*(3), 523–537.

Jain, R., Jain, P. K., & Srivastava, P. (2011). A list of blue green algae of Alwar (Rajastan), India. Chroococcales – I. *Indian Hydrobiology*, *13*(2), 169–178.

Jalal, F. N., & Sanal Kumar, M. G. (2013). Water quality assessment of Pamba river of Kerala, India in relation to pilgrimage season. *International Journal for Research in the Chemical Environment*, *3*(1), 341–347.

Jawale, A. K., Kumawat, D. A., & Chaudhari, N. A. (2009). Freshwater Chlorophyceae from Jalgaon district, north Maharashtra I—Unicellular Volvocales. *Indian Hydrobiology*, *12*(1), 1–9.

Jawale, A. K., Kumawat, D. A., & Chaudhari, N. A. (2010). Additions to the Volvocales of Maharashtra. *Indian Hydrobiology*, *13*(1), 13–18.

Jaya, D. S., & Deepthi, G. P. (2015). Assessment of groundwater quality in Karakulam Grama Panchayath in Thiruvananthapuram, Kerala State, South India. *International Journal of Geological and Environmental Engineering*, *9*(10), 1209–1213.

Jayabhaye, U. M., Madlapure, V. R., & Salve, B. S. (2007). Phytoplankton diversity of Parola dam, Hingoli, Maharashtra. *Journal of Aquatic Biology*, 22(2), 27–32.

Jena, M., & Adhikary, S. P. (2007). Chlorococcales (Chlorophyceae) of eastern and north-eastern States of India. *Algae*, *22*(3), 167–183.

Jena, M., Ratha, S. K., & Adhikary, S. P. (2006b). Diatoms (Bacillariophyceae) from Orissa State and neighbouring regions, India. *Algae*, *21*(4), 377–392.

Jha, B. C., Kaushal, D. K., & Rao, Y. R. (1985). Chlorococcales of Gobindsagar reservoir-Himachal Pradesh, India. *Phykos*, *24*, 27–32.

Jha, M. N., Jha, U. N., Ahmad, N., & Malik, M. K. (1986). Cyanobacterial flora of rice field soils of Pusa and its adjoining areas. *Phykos*, *25*, 97–101.

Jindal, R., & Sharma, C. (2011a). Studies on water quality of Sutlej River around Ludhiana with reference to physico-chemical parameters. *Environmental Monitoring and Assessment*, *174*, 417–425.

Jindal, R., & Sharma, C. (2011b). Biomonitoring of pollution in river Sutlej. *International Journal of Environmental Sciences*, *2*(2), 863–872.

Jithesh, K. R. (2010). First report on the phytoplankton of Mullaperiyar – A tropical high altitude lake in the Western Ghats of Kerala. *Proceedings of 22nd Kerala Science Congress*. Kerala State Council for Science, Technology and Environment, Trivandrum, 624 – 626pp.

Jose, J., & Francis, M. S. (2007). Investigation on the algal flora of Thodupuzha thaluk, Kerala. *Indian Hydrobiology*, *10*(1), 79–86.

Jose, J., & Francis, M. S. (2008). An overview on the freshwater algal resources of Idukki district, Kerala. In P. Natarajan, K. V. Jayachandran & A. Arun (Eds.). *Proceedings of the International Conference Biodiversity Conservation and Management (BIOCAM,* *2008)*. Rajiv Gandhi Chair in Contemporary Studies, Cochin University of Science and Technology, Cochin, 28–30pp.

Jose, J., & Francis, M. S. (2010). Wetland algal resources of Western Ghats (Idukki district region), Kerala, India. *Journal of Basic and Applied Biology*, *4*(3), 34–41.

Jose, J., & Francis, M.S. (2013). New Additions to the Freshwater Algae I - Chlorophyceae. *International Journal of Pure and Applied Bioscience, 1*(6), 77-83.

Jose, L., & Patel, R. J. (1989). Contribution to the freshwater diatom flora of Kerala. *Journal of Phytological Research*, *2*(1), 45–51.

Jose, L., & Patel, R. J. (1990). *Caloglossa ogasawaraensis* (Rhodophyta, elesseriaceae), a freshwater Rhodophyceae new to India. *Cryptogamie Algologie*, *11*(3), 225–228.

Jose, L., & Patel, R. J. (1992). A systematic account of Chlorococcales new to Kerala. *Phykos*, *31*(1 and 2), 95–101.

Joseph, V., & Joseph, A. (2002). Ecology and seasonal variation of microalgal community in an oil refinery effluent holding pond: Monitoring and assessment. *Environmental monitoring and Assessment*, *80,* 175-185.

Joseph, M. L., & Prakasam, V. R. (2002). Seasonal abundance of plankton and fish in Sasthamcotta Lake, Kerala. *Proceedings of the National Seminar on Ecology and Conservation of Wetlands*, *Limnological Association of Kerala,* 59–64pp.

Joseph, R., & Tessy, P. P. (2010). Water quality and pollution status of Chalakudy River at Kathikudam, Thrissur district, Kerala, India. *Nature Environment and Pollution Technology, 9*(1), 113- 118.

Joshi, K. K. (2010). Studies on the periphytic algae in pokkali and prawn fields of N. Paravoor and Vypeen Island. PhD Thesis, M.G University.

Kahar, A. (1988). Impact of sewage on the water quality of the Karamana river and the Poonthura backwater, Kerala, India. [MPhil Dissertation], University of Kerala.

Kamaleswari, J., & Sivasubramanian, V. (2011). Role of freshwater algae in remediation of effluents and wastewater. *Indian Hydrobiology*, *13*(2), 94–97.

Kamat, N. D. (1968). Algae of Simla. *Journal of Bombay Natural History Society*, *65*(1), 271–277.

Kamat, N. D. (1968a). Algae of Alibag, Maharashtra. *Journal of Bombay Natural History Society*, *65*(1), 88–104.

Kamat, N. D. (1968b). Algae of Simla. *Journal of Bombay Natural History Society, 65*(1), 271–277.

Kamat, N. D. (1975a). Algae of Vidarbh, Maharashtra. *Journal of Bombay Natural History Society, 72*(2), 450–476.

Kamat, N. D., & Aggarwal, R. (1975). Diatoms of Nainital. *Journal of Bombay Natural History Society*, 72(1), 240–241.

Kamat, N. D., & Freitas, J. F. (1976). A check list of Euglenophyceae and Chlorophyceae of Nagpur, Maharashtra. *Phykos*, *15*(1 and 2), 121–125.

Kannan, N., & Sabu, J. (2010). Quality of groundwater in the shallow aquifers of a paddy dominated agricultural river basin, Kerala, India. *International Journal of Civil and Environmental Engineering, 2*(3), 160-178.

Kant, S., & Anand, V. K. (1978). New records of *Scenedesmus* spp. from Jammu (J. & K.). *Phykos*, *17*(1 and 2), 81–85.

Kant, S., & Gupta, P. (1998). Algal flora of Ladakh. *Journal of Economic and Taxonomic Botany Additional Series*, *15*, 1–341.

Kargupta, A. N., & Ahmad, M. R. (1991). Freshwater green algal flora of North Bihar – II. *Journal of Economic and Taxonomic Botany*, *15*(1), 203–209.

Kargupta, A. N. and Keshri, J. P. (2006). New records of the macrandrous *Oedogonium* (Oedogoniales, Chlorophyceae) taxa from West Bengal, India. *Algological Studies,* 122, 57–71.

Kaushik, S., & Saksena, D. N. (1994). The trophic status and habitat ecology of entomofauna of the water bodies at Gwalior, Madhya Pradesh. In O. P. Agarwal (Ed.), *Perspective in entomological research*, *Scientific Publishing*, 241–261pp.

Kavitha, A., & Balasingh, G. S. R. (2007). Seasonal abundance and phytoplankton diversity of a sacred grove freshwater ecosystem of Kanyakumari district, South Tamil Nadu. *Indian Hydrobiology*, *10*(2), 231–236.

Kerkar, V., & Madkaiker, S. (2003). Freshwater blue green algae from Goa. *Indian Hydrobiology*, 6(1 & 2), 45–48.

Keshri, J. P. (2009). Contribution to our knowledge of freshwater green algae (Chaetophorales) of West Bengal, India. *Algological Studies*, *131*, 43–61.

Keshri, J. P. (2010a). Contribution to our knowledge of Ulotrichales (Chlorophyta) of West Bengal, India. *Algological Studies*, *133*, 29–41.

Keshri, J. P. (2010b). Contribution to our knowledge of Coleochaetales (Chlorophyta) of West Bengal, India. *Algological Studies*, *134*, 41–54.

Khan, M. A., Panwar, R. S., Mathur, A., & Jelly, R. (1998). Studies on plankton communities and primary production in middle stretch of river Ganga in context of cultural eutrophication. *Journal of Inland Fisheries Society of India*, *30*(1), 47–68.

Khare, A., & Kumar, M. (2010). Cyanobacterial biodiversity of Ramnagar, Dist. Nainital. *Plant Archives*, *10*(2), 523–530.

Khare, R., & Suseela, M. R. (2004). Freshwater algal diversity of Nainital, Uttaranchal, India. *Phytotaxonomy*, *4*, 19–24.

Kolte, S. O., & Goyal, S. K. (1985). Distributional pattern of blue green algae in rice field soils of Vidarbha region of Maharashtra State. *Phykos*, *24*, 156–162.

Komarek, J. (2013). Cyanoprokaryota. 3. Heterocytous genera. In S. von (Ed.), Mitteleuropa/freshwater flora of Central Europe. *Springer Spektrum,* 1130 pp.

Krebs, C. J. (1994). Ecology: The experimental analysis of distribution and abundance. *Harper Collins College Publishers*, New York, 801 pp.

Krishnamurthy, V. (1954). A contribution to the diatom flora of south India. *Journal of the Indian Botanical Society*, *33*(4), 354–381.

Krishnamurthy, V. (2000). Algae of India and neighbouring countries I. Chlorophycota. *Oxford and IBH publishing co. Pvt. Ltd*. New Delhi, 210pp.

Kumar, S., & Rai, S. K. (2005). contribution to the algal flora (*Chlorophyceae*) of Namchi, Sikkim-Himalayas. *Our Nature*, *3*, 50-55.

Kumavat, D. A. (2006). Biodiversity, occurrence and succession of diatoms in Yawal and Raver tahasils of Jalgaon district, Maharashtra. *Journal of Aquatic Biology*, *21*(2), 9–12.

Kumawat, D. A., & Jawale, A. K. (2001). On *Spirulina* Turpin em Gardner from fish ponds at Anjale, Maharashtra. *Phykos, 40*(1 & 2), 115–119.

Kumawat, D. A., & Patil, J. (2010). Observations on the blue green alga *Spirulina* from the Tapi River, Jalgaon district, Maharashtra. *Journal of Indian botanical Society*, *89*(1 & 2), 127–132.

Kurano, N., & Miyachi, S. (2004). Micro-algal studies for the 21st century. *Hydrobiologia*, *512*(1–3), 27–32.

Leenamol, T. M., & Tessy, P. P. (2009). Biodiversity changes of phytoplankton in Chalakudy River due to paper mill effluents. In N. S. Bijoy, M. Salim, G. S. Pillai & V. Reeny (Eds.), A compendium on wetland biodiversity and conservation (Proceedings of the national seminar on Wetland Biodiversity). *Limnological Association of Kerala (LAK) Publishers*, Kerala, India, 104–114pp.

Lakshmi, K. (2002). Ecological studies on the mangroves of Valapattanam and Thalassery River Basins [PhD Thesis]. University of Calicut.

Lui, B. H., Zhang, D. H., & Lee, Y. K. (2000). Effects of nutrient levels on cell growth and secondary carotenoids formation in the freshwater green algae, Chlorococcum sp. *Journal of Microbiology and Biotechnology*, *10*, 201–207.

Madhusoodanan, P. V., & Dominic, T. K. (1996b). Epiphytic Cyanobacteria on mosses from Western Ghats of Kerala. *Journal of Economic and Taxonomic Botany*, *20*(2), 355–360.

Madhusoodanan, P. V., & Dominic, T. K. (1999). Cyanobacteria from extreme acidic environment. *Current Science*, *77*(8), 1021–1023.

Magesh, N. S., Jitheshlal, K. V., Chandrasekar, N., & Jini, K. V. (2013). Geographical information system-based morphometric analysis of Bharathapuzha river basin, Kerala, India. *Applied Water Science*, *3*(2), 467–477.

Mahajan, S. K. (1987). Algal flora of Pawagiri Oon, Madhya Pradesh. *Phykos*, *26*(1 & 2), 61–62.

Maity, H., & Santra, S. C. (1985). Blue green algal flora of 24-Paraganas, West Bengal (India). *Phykos*, 24, 46–51.

Makandar, M. B., & Bhatnagar, A. (2010). Biodiversity of micro-algae and Cyanobacteria from freshwater bodies of Jodhpur, Rajasthan (India). *Journal of Algal Biomass Utilization*, *1*(3), 54–69.

Mam, S. (1995). Additions to the algal flora of Kashmir – V. Bacillariophyceae. *Journal of Economic and Taxonomic Botany,* 19(2), 277–285.

Manjula, P. (2015). Hydrological and hydrochemical characterization of Thuthapuzha Sub Basin of Bharathapuzha [Thesis] submitted to Kannur University. Kannur.

Manjula, P., & Unnikrishnan Warrier, C. (2019). Evaluation of water quality of Thuthapuzha Sub-basin of Bharathapuzha, Kerala, India. *Applied Water Science*, *9*(4), 70.

Manohar, K.V., & Patel, R. J. (1985). On three colonial Volvocales – New to India. *Phykos, 24*, 80–83.

Manohar, K. V., & Patel, R. J. (1988). Study of Volvocales of Gujarat IV – The genus *Chlorogonium* Ehrenberg. *Phykos, 27*, 115–116.

Mathur, M., & Pathak, N. (1990). Chlorococcales from the rock shelters of Hoshangabad. *Phykos*, *29*(1 and 2), 111–113.

Maya, K. (2005). Studies on the nature and Chemistry of Sediments and water of Periyar and Chalakudy rivers [PhD Thesis]. Kerala. Cochin, India.

Maya, K., Remya, S. I., Baburaj, B., Baijulal, B., Lekshmi, I., Nisha, U. R., Sangeetha, J., & Padmalal, D. (2013). Natural and anthropogenic determinants of water quality changes in a small tropical river basin, SW India. *International Journal of Agricultural Sciences*, *3*(1), 363–372.

Maya, S. (2007). A study on the algal diversity of Vamanapuram River of south Kerala, in relation to certain water quality parameters. *Indian Hydrobiology*, *10*(1), 157–163.

Maya, S., Prameela, S. K., & Sarojini, M. V. (2000). A preliminary study on the algal flora of temple tanks of southern Kerala. *Phykos*, *39*(1 and 2), 77–83.

Mehta, S. K., & Gaur, J. P. (2005). Use of algae for removing heavy metal ions from wastewater: Progress and prospects. *Critical Reviews in Biotechnology*, *25*(3), 113–152.

Mishra, B. P., & Tripathi, B. S. (2003). Seasonal Variation in physico-chemical characteristics of Ganga water as influenced by sewage discharge. *Indian Journal of Ecology*, *30*, 27–32.

Mishra, S. M., Pania, S., Bajpal, A., & Bajpai, A. K. (2001). Assessment of trophic status by using Nygaard's index with special references to Bhoj wetland. *Pollution Research*, *20*(2), 147–153.

Misra, P. K., Chauhan, R. S., & Shukla, S. K. (2007). Some freshwater diatoms from Almora district, Uttaranchal State. *Journal of the Indian Botanical Society*. 86(3 & 4), 74–79.

Misra, P. K., Prakash, J., Srivastava, A. K., & Singh, P. K. (2004). Some freshwater planktonic algae from Sant Kabir Nagar, Uttar Pradesh. *Phytotaxonomy, 4*, 87–94.

Misra, P. K., Seth, M. K., Prakash, J., Shukla, M., & Dwivedi, R. K. (2009). Freshwater algae from Chandra Lake of district Lahaul and Spiti, Himachal Pradesh, India. *Indian Hydrobiology*, *12*(1), 105–113.

Misra, P. K., Shukla, M., & Prakash, J. (2008b). Some freshwater algae from eastern Uttar Pradesh. *Indian Hydrobiology*, *11*(1), 121–132.

Misra, P. K., Srivastava, A. K., Prakash, J., & Rai, S. K. (2005). Some fresh water filamentous chlorophycean algae from district Balrampur, Uttar Pradesh, India. *Ecology Environment and Conservation*, *11*(3–4), 429–431.

Misra, P. K., Tripathi, S. K., Kishore, S., Singh, S. K., & Chauhan. R.S. (2010). Cyanophyceae of western Uttar Pradesh, India. *Indian Hydrobiology*, 13(1), 36–45.

Mohan, K. S. (1987). Chlorophyceae of two lakes of Hyderabad, India. *Phykos*, 26, 8–16.

Mohanty, R. C. (1982). Blue green algae of Bhubaneswar and its adjoining regions – II. *Phykos*, *21*, 96–98.

Mohanty, R. C. (1984). Blue green algae of Bhubaneswar and its adjoining regions – III. *Phykos*, *23*(1 & 2), 90–95.

More, Y.S., & Nandan, S. N. (2003). Hydrobiological study of algae of Panzara dam (Maharashtra). *Ecology, Environment and Conservation, 9(*3), 367-369.

Moss, B. (2000). Biodiversity in fresh waters - An issue of species preservation or system functioning? *Journal of Environmental conservation*, *27*(01), 1-4.

Mukhopadhyay, A., & Chatterjee, P. (1981). A check list of blue green algae from the paddy fields of 24 Parganas and Howrah districts of West Bengal – I. *Phykos*, *20*(1 & 2), 81–84.

Murugesan, S., & Sivasubramanian, V. (2008a). Freshwater green algae from Porur Lake, Chennai. *Indian Hydrobiology*, *11*(1), 133–140.

Murugesan, S., & Sivasubramanian, V. (2008b). Freshwater diatoms from Porur Lake, Chennai. *Indian Hydrobiology*, *11*(1), 149–154.

Murugesan, V. K., Rani Palaniswamy & Manoharan, S. (2003). Productivity of reservoirs in Tamil Nadu with reference to their plankton population. *Journal of Inland Fisheries Society of India*, *35*(2), 50–56.

Muthukumaran, M., Raghavan, B. G., Subramanian, V. V. & Sivasubramanian, V., (2005). Bioremediation of industrial effluent using microalgae. *Indian Hydrobiology*, *7,* 105–122.

Nafeesa, B., & Narayana, J. (2006). Phytoplankton diversity of four lentic water bodies in and around Davangarere city, Karnataka. *Journal of Aquatic Biology*, *21*(2), 13–18.

Nagarajan, K., & Sivaraja, R. (2013). Physico-chemical investigation of river cauvery in bhavani region, Erode district, Tamil nadu, India. *Elixir pollution, 58,* 14857-14863.

Nair, I. V., Singh, K., Arumugam, M., Gangadhar, K., & Clarson, D. (2010). Trace metal quality of Meenachil river at Kottayam, Kerala (India) by principal component analysis. *World Applied Sciences Journal*, *9*(10), 1100–1107.

Nair, P. V., Joseph, K. J., Balachandran, V. K., & Pillai, V. K. (1975). A study on the primary production in the Vembanad Lake. *Bulletin Department of Marine Science University Cochin, 7*, 161–170.

Nandan, S. B. (2007). A perspective on the ecology and bioresources of the Rivers of Kerala. In *Proceedings of the DAE-BRNS National Symposium on Limnology* (NSL-07), 8-14pp.

Nandan, S. B., & Sajeevan, K. (2018). Distribution and abundance of phytoplankton in Vembanad Estuary, a Ramsar site on Southwest Coast. *International journal of Engineering and management research*, 5(3), 75–87.

Nandan, S. N., & Patel, R. J. (1983). Study of algal communities in river Vishwamitri, Baroda as indicators of organic pollution. *Indian Journal of Ecology*, *10*(1), 11–15.

Nandan, S. N., & Patel, R. J. (1986). Assessment of river quality of Vishwamitri by algal analysis. *Indian Journal of Environmental Health*, *29*, 100–161.

Narkhede, P. N. (2006a). Genus *Nitzschia* and *Surirella* from Hatnur dam, Jalgaon district, Maharashtra. *Journal of Aquatic Biology*, *21*(2), 19–22.

Narkhede, P. N. (2006b). Some diatoms of Suki dam in Jalgaon district, Maharashtra. *Journal of Aquatic Biology*, *21*(2), 23–26.

Nasar, S. A. K., & Munshi, J. D. (1976). On the algal flora of some ponds of Bhagalpur, India. *Phykos*, *15*(1 & 2), 49–52.

Nasser, M., & Sureshkumar, S. (2012). Altitude wise variation in diversity of freshwater periphytic microalgae in Anamalai area of Western Ghats. *Biodiversity documentation and taxonomy, Narenda Publishing House*, New Delhi, 127- 135pp.

Nasser, M., & Sureshkumar, S. (2013). Interaction between microalgal species richness and environmental variables in Peringalkuthu Reservoir, Western Ghats, Kerala. *Journal of Environmental Biology*, *34*(6), 1001-1005.

Nautiyal, P., & Lal, M. S. (1984). Food and feeding habits of fingerlings and juveniles of mahseer (*Tor putitora* Ham.) in Nayar River. *Journal of the Bombay Natural History Society*, *81*(3), 642–647.

Nikhil Raj, P. P., & Azeez, P. A. (2009). Spatial and temporal variation in surface water chemistry of a tropical river, the river Bharathapuzha, India. *Current Science*, *96*(2), 245–251.

Nikhil Raj, P. P., & Azeez, P. A. (2012). Trend analysis of rainfall in Bharathapuzha river basin, Kerala, India. *International Journal of Climatology*, *32*(4), 533–539.

Nirmala, V. V., & Sobha, V. (2003). An assessment of the environmental status of Chalakudy river with special reference to water quality and its inf luencing features. *Proceedings of the Natural River Conservation Management*. Environment and Forests, Govt. of India, 13–18pp.

Padhi, S. B., Das, P. K., Swain, P. K., & Behera, G. (2010). Algal flora of the freshwater aquatic systems of Mohuda, Orissa. *Indian Hydrobiology*, *12*(2), 143–148.

Padhy, J., Tripathy, S., Devi, S., & Padhi, S. B. (1992). Studies on blue green algae of rice field soils of Ganjam district of Orissa. *Phykos*, *31*(1&2), 7–12.

Pandey, A.K. (1995). Conservation of biodiversity: Present status and future strategy. In: Pandey, A.K. (ed.). Taxonomy and Biodiversity. *CBS Publishers and distributors*, New Delhi, 44–51pp.

Pandey, U.C. (1982a). Freshwater diatoms of Shahjahanpur. *Phykos, 21,* 135–136.

Pandey, U.C. (1982b). Additions to the algal flora of Rohilkhand division VI. Cyanophyceae. *Phykos, 21,* 137–140.

Pandey, U. C. (1985). Euglenineae of sewage waters – I. *Phykos*, *24*, 125–127.

Pandey, U.C., Habib, I., Gangwar, F.C. and Shukla, H.M. (1987). A contribution to our knowledge of desmids from Bareilly. *Phykos, 26,* 86–94.

Pandey, U. C., & Pandey, D. C. (1982). Additions to the algal flora of Allahabad – VIII. Cyanophyceae. *Phykos*, *21*, 76–79.

Pandey, U.C., Tiwari, G.L. and Pandey, D.C. (1983a). Diatom flora of Allahabad, India – II. *Bibliotheca Phycologia, 66*, 127-139.

Pandey, U.C., Tiwari, R.K. and Pandey, D.C. (1983b). An enumeration of Chlorococcales from Allahabad, U.P. India. *Bibliotheca Phycologia, 66*, 115–126.

Pal, S. (1975). A check list of algae from Ghaziabad. *Phykos*, *14*(1 and 2), 67–76.

Pal, T. K., & Santra, S. C. (1982). Contributions to the Cyanophyceae of Murshidabad. *Phykos*, *21*, 150–152.

Pal, T. K., & Santra, S. C. (1984). New additions to the algal flora of Murshidabad, West Bengal. *Phykos, 23*(1 & 2), 139–141.

Pal, U. C., & Santra, S. C. (1985). Algal flora of Midnapore, West Bengal (India): I Cyanophyceae. *Phykos*, *24,* 12–17.

Pal, U. C., & Santra, S.C. (1990). Algae of Midnapore, West Bengal: II Bacillariophyceae. *Phykos*, 29(1 & 2), 73–81.

Palmer, C. M. (1969). A composite rating of algae tolerating organic pollution. *Journal of Phycology*, *5*(1), 78–82.

Pandhol, R. K., & Grover, I. S. (1976). Algal flora of Ludhiana and its adjacent areas. *Phykos*, *15*(1 & 2), 81–87.

Panikkar, M. V. N., & Ampili, P. (1988). Temnogametum keralense- A new species from South India. *Journal of Economic and Taxonomic Botany*, *12*, 397–400.

Panikkar, M. V. N., & Ampili, P. (1992). Three new species of *Oedogonium* Link from the flowing waters of Kerala. *Journal of Economic and Taxonomic Botany*, *16*(1), 223–225.

Panikkar, M. V. N., Ampili, P., & Chauhan, V. D. (1989). Observation on Cephaleuros virescens Kunze from India. *Journal of Economic and Taxonomic Botany*, *15*, 473-475.

Panikkar, M. V. N., & Sreeja, K. (2005). Zygospore formation of desmids from Kollam district, Kerala (India) 1. *Closterium*. *Feddes Repertorium*, *116,* (3–4), 218–221.

Panikkar, M. V. N., & Sreeja, K. (2006). Zygospore formation of four rare desmids from Kerala, India. *Feddes Repertorium*, *117*(3–4), 277–279.

Panikkar, M. V. N., Ushadevi, K., & Ampili, P. (1997a). New species of the genus *Zygnemopsis* (Skuja) Trans. (Zygnematales, Chlorophyceae) from Kerala, India. *Journal of Economic and Taxonomic Botany*, *21*(1), 143–148.

Panikkar, M. V. N., Ushadevi, K., & Ampili, P. (1997b). A new species of *Mougeotia* (Zygnematales, Chlorophyceae) from Kerala. *Journal of Economic and Taxonomic Botany*, *21*(3), 691–693.

Patel, R. J., & Asokakumar, C. K. (1979). Desmids of Gujarat, India – 1. Genus *Closterium Nitzscia. Phykos*, *18*(1 and 2), 111–124.

Patel, R. J., & Daniel, J. K. (1990). Some Chlorococcales new to India. *Phykos*, *29*(1 & 2), 129–135.

Patel, R. J., & Isabella, G. (1980). Chlorococcales new to Western India. *Journal of the Indian Botanical Society*, *59*(1), 42–47.

Patel, R. J., & Waghodekar, V. H. (1981). The Euglenophyceae of Gujarat- India- 1 genus *Phacus* Dujardin. *Phykos*, *20*(1 and 2), 24–33.

Patil, N., & Deore, L. T. (2010a). On the genus *Dichothrix* Zanardini (Family Rivulariaceae) from Dhule, north Maharashtra. *Indian Hydrobiology*, *13*(1), 26–28.

Patil, N., & Deore, L. T. (2010b). Scytonemataceae Rabenhorst (Order Nostocales) from Khandesh region, Maharashtra. *Indian Hydrobiology*, *13*(1), 29–35.

Patil, P. L., & Satav, S. D. (1986). A study on nitrogen fixing blue green algae from rice fields of Western Maharashtra. *Phykos*, *25*, 113–116.

Patil, S. R., & Chaugule, B. B. (2009). Diversity of blue green algae in paddy fields of the western Maharashtra. *Indian Hydrobiology*, *12*(1), 89–94.

Patralekh, L. N. (1991a). Systematic enumeration of chlorophycean algal forms of a perennial pond of Bhagalpur, Bihar. *Journal of Economic and Taxonomic Botany*, *15*(1), 11–15.

Patralekh, L. N. (1991b). Euglenineae and Bacillariophyceae algae recorded from the Ganges at Bhagalpur, Bihar. *Journal of Economic and Taxonomic Botany*, *15*(1), 17–19.

Patralekh, L. N. (1993a). Systematic account of green algae collected from River Ganga at Bhagalpur, Bihar. *Journal of Economic and Taxonomic Botany*, *17*(1), 71–73.

Patralekh, L. N. (1993b). Cyanophycean flora of Rani-Talab, Bhagalpur. *Journal of Economic and Taxonomic Botany, 17*(1), 113–114.

Patralekh, L. N. (1994). Algal forms of Xanthophyceae, Bacillariophyceae, Dinophyceae and Euglenophyceae of Rani Talab, Bhagalpur, Bihar. *Journal of Economic and Taxonomic Botany, 18*(3), 581–584.

Patrick, R. (1949). A proposed biological measure of stream conditions, based on a survey of the Conestoga Basin, Lancaster County, Pennsylvania. *Proceedings of the Academy of Natural Sciences of Philadelphia*, *101*, 277–341.

Pawar, S. K., Pulle, J. S., & Shendge, K. M. (2006). The study on phytoplankton of Pethwadaj Dam, Taluka Kandhar - Nanded, Maharashtra. *Journal of Aquatic Biology*, *21*, 1-6.

Perumal, G. M., & Anand, N. (2008a). Manuel of freshwater algae of Tamil Nadu. *Bishen Singh Mahendrapal Singh Publishers*, Dehradun. 133 pp.

Philipose, M. T. (1967). Chlorococcales- ICAR Monograph on algae. *Indian Council of Agricultural Research*, 365pp.

Philipose M. T. (1984) Contributions to our knowledge of Indian algae-III. Euglenineae - Part 2. *Proceedings of Indian Academy of Sciences (Plant Science), 93*, 503-552.

Philipose M. T. (1988). Contributions to our knowledge of Indian algae-III. Euglenineae - Part 3. *Proceedings of Indian Academy of Sciences (Plant Science), 98*, 317-354.

Pingale, S. D., & Deshmukh, B. S. (2005). Some freshwater algae from Amphitheatre of Wilson Dam. *Indian Hydrobiology*, *7*, 97–100.

Pingle, S. D. (2006). Chrysophycean and Pyrrophycean algae from Pune and its neighborhood area. *Indian Hydrobiology*, *8*(1), 31–33.

Prakash, J., Kishore, S., Asthana, D. K., Misra, P. K., & Singh, S. K. (2005). Morphotaxonomy of freshwater chlorophycean algae (desmids) from Siddharth Nagar, U.P., India. *Ecoprint*, *12,* 21–25.

Prasad, B. N. (1952). Some Nostocaceae from Uttar Pradesh. *Journal of Indian Botanical Society, 31,* 358–361.

Prasad, B. N., & Jaitly, Y. C. (1985). Diatom flora of a high-altitude spring in. Ladakh. *Phykos*, *24*, 132–139.

Prasad, B.N., & Khanna, P. (1987). The Cyanophycean flora of Sikkim- I. Oscillatoriaceae. *Journal of the Indian botanical Society, 66*, 253-260.

Prasad, B. N., & Mehrotra, R. K. (1977a). Some desmids new to Indian flora. *Journal of Indian botanical Society, 56,* 343–350.

Prasad, B. N., & Mehrotra, R. K. (1977b). Desmid flora of north Indian paddy fields. *New Botanist, 4*(1–4), 47–74.

Prasad, B. N., & Mehrotra, R. K. (1978). Some new additions to Cyanophycean flora of India. *Journal of the Indian Botanical Society*, *57*, 98–101.

Prasad, B. N., & Mehrotra, R. K. (1980). Blue green algae of paddy fields of Uttar Pradesh. *Phykos*, *19*(1), 121–128.

Prasad, B. N., & Misra, P. K. (1984a). On some filamentous green algae- New to Indian flora. *Journal of the Indian Botanical Society*, *63*, 456–459.

Prasad, B. N., & Misra, P. K. (1984b). Some taxa of *Pleurotaenium* Nageli and *Staurastrum* Meyen new to Indian flora. *Current Science*, *53*(19), 1048–1050.

Prasad, B. N., & Misra, P. K. (1984c). Some taxa of Genus *Closterium* Nitzs., new to Indian flora. *Journal of the Indian Botanical Society*, *63*, 451–452.

Prasad, B. N., & Misra, P. K. (1985). Some taxa of *Cosmarium* Link- New to Indian desmid flora. *Journal of the Indian Botanical Society*, *64*, 343–347.

Prasad, B. N., & Misra, P. K. (1992). Freshwater algal flora of Andaman and Nicobar Islands, II. *Bishen Singh Mahendrapal Singh Publishers*, Dehradun. 284 pp.

Prasad, B. N., & Saxena, M. (1980). Ecological study of blue-green algae in river Gomati. *Indian Journal of Environmental Health, 22*(2), 151-168.

Prasad, B. N., Singh, Y., & Jaitly, Y. C. (1981). Some diatoms new to Indian flora. *Journal of the Indian Botanical Society*, *60*, 282–289.

Prasad, B. N., & Singh, Y. (1982). On diatoms as indicators of water pollution. *Journal of Indian Botanical Society*, *61*, 326–336.

Prasad, B. N., & Srivastava, M. N. (1981). On four new additions to taxa of genus *Eunotia* Ehr. in India. *Journal of the Indian Botanical Society*, *60*, 355–356.

Prasad, B. N., & Srivastava, M. N. (1983). On two taxa of *Synedra* Ehr-New to algal flora of India. *Phykos*, *22*, 46–47.

Prasad, B. N., & Srivastava, M. N. (1984a). Genus *Scytonema* Ag. in Andaman and Nicobar Islands. *Phykos*, *23*(1 and 2), 102–115.

Prasad, B. N., & Srivastava, M. N. (1984b). Some diatoms from Andaman and Nicobar Islands – II. *Journal of the Indian Botanical Society*, *63*, 453–455.

Prasad, B. N., & Srivastava, M. N. (1985). Some diatoms from Andaman and Nicobar Islands – I. *Journal of the Indian Botanical Society*, *64*, 348–356.

Prasad, B. N., & Srivastava, M. N. (1986). Some Cyanophyceae from Andaman and Nicobar Islands. *Phykos*, *25*, 88–96.

Prasad, B. N., & Srivastava, M. N. (1992). Freshwater algal flora of Andaman and Nicobar Islands. Vol. I. *Bishen Singh Mahendrapal Singh Publishers,* Dehradun. 369 pp.

Prasad, R. K., Mondal, N. C., & Singh, V. S. (2008). Evaluation of groundwater resource potential using GIS in Kurmapalli water of Andhra Pradesh. *Journal of the Geological Society*, *71*, 661–669.

Prasad, R. N., & Chaudhary, B. R. (1986). *Trachelomonas godwardii* and *Lepocinclis sarmii* two new euglenoid taxa from India. *Phykos*, *25*, 75–78.

Prescott, G. W. (1951). Algae of the Western Great Lakes area exclusive of desmids and diatoms. *Bulletin of the Cranbrook Institute of Science*, *31*, 1–946.

Prescott, G. W. (1982). Algae of the western great Lakes area, with an illustrated key to the genera of desmids and freshwater diatoms. *Koenigutein Otto Koeltz*, 977 pp.

Priya, H., Prasanna, R., Ramakrishnan, B., Bidyarani, N., Babu, S., & Thapa, S. (2015). Influence of cyanobacterial inoculation on the culturable microbiome and growth of rice. *Microbiological Research, 171*, 78–89.

Radhika, C. G. & Gangadevi, T. (2005). Limnological studies of a tropical freshwater lake Vellayani Lake with special reference to associated flora. [PhD Thesis]. University of Kerala, Trivandrum.

Radhika, C. G., Mini, I., & Gangadevi, T. (2004). Studies on abiotic parameters of a tropical freshwater lake- Vellayani Lake, Thiruvananthapuram district, Kerala. *Pollution Research*, *23*(1), 49–63.

Rai, L. C., Kumar, H. D., Mohn, F. H., & Soeder, C. J. (2000). Services of algae to the environment. *Journal of Microbiology and Biotechnology*, *10*, 119–136.

Raj, N., & Azeez. (2010). Land use and land cover changes in a tropical river basin: A case from Bharathapuzha River Basin, Southern India. *Journal of Geographic Information System*, *2*, 185–193

Rajakumar, N. (2005). Biodiversity of diatoms of a few lentic and lotic habitats of Coimbatore district. *Indian Hydrobiology*, *7*, 101–104.

Ralfs, J. (1962). The British Desmidieae. *Wheldon and Wesley Ltd. and Hafner publishing Cooperative,* New York. 226 pp.

Ramachandra, T. V., Kiran, R., & Ahalya, N. (2002). Status, conservation and management of wetlands. *Allied publishers (P) Ltd*. New Delhi. 228 pp.

Ramadosu, A., & Sivakumar, K. (2010). Seasonal variation of phytoplankton in relation to physico-chemical characteristics at Perumal Lake, Tamil Nadu. *Indian Hydrobiology*, *12*(2), 149–158.

Ramakrishnan, N., & Kannan, L. (1992). Blue green algal flora of Muthupet, Tamil Nadu. *Phykos*, *31*(1 and 2), 169–171.

Ramanathan, K. R. (1964). Ulotricales. ICAR Monograph on algae. *Indian Council of Agricultural Research.* New Delhi, India. 188 pp.

Ramesh, R., Subramanian, V., & Van Grieken, R. (1990). Heavy metal distribution in sediments of Krishna River basin, India. *Environmental Geology and Water Sciences*, *15*, 303–324

Randhawa, M. S. (1959). Zygnemataceae. ICAR Monograph on algae. *Indian Council of Agricultural Research,* New Delhi, India. 478 pp.

Rao, B. D., Srinivas, D., Padmaja, O., & Rani, K. (2008). Blue green algae of rice fields of south Telangana region, Andhra Pradesh. *Indian Hydrobiology*, *11*(1), 79–83.

Rao, C. B. (1953). On the distribution of algae in a group of six small ponds. *Journal of Ecology*, *41*(1), 62–71.

Rao, P. S. N., & Gupta, S. L. (1997). Fresh water algae. In V. Mudgal & P. K. Ajra (Eds.), Botanical Survey of Floristic diversity and conservation strategies in India. Vol. I. Cryptogams and Gymnosperms, Botanical Survey of India, Calcutta. *Ministry of Environment and Forests, Government of India*, 47–61pp.

Ratha, S. K., Jena, M., & Adhikary, S. P. (2006). Euglenophytes from Orissa State, east coast of India. *Algae*, *21*(1), 61–73.

Ray, J.G., Santhakumaran, P., & Kookal, S. (2020) Phytoplankton communities of eutrophic freshwater bodies (Kerala, India) in relation to the physicochemical water quality parameters. *Environment, Development and Sustainability, 22*, 3-10.

Reddy, M. V., & Kumar, A. V. (2001). Effects of Ganesh-idol immersion on some water quality parameters of Hussainsagar Lake. *Current Science*, *81*(11), 1412–1413.

Reddy, P. M., Yumnam, D. D., & Imchen, T. Y. (1986). Investigations on the blue green algae of Northeast India: Distribution and habitat preferences. *Phykos*, *25*, 148–158.

Rekha, V. B. R., George, A. V., & Rita, M. (2013). A comparative study of water quality index (WQI) of Peruvanthanam and Valiyathodu sub-watersheds of Manimala river basin, Kerala, South India. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *3*(4), 1–6.

Renjith, M. K., & Sreekumar, S. (2005). Seasonal variations of water quality in the Karuvannur river Kerala. *Research review*, 31–33.

Revathy, D., & Krishnakumar, A. (2018). Evaluation of phytoplankton diversity and environmental implications of two lacustrine wetlands, located in midland and lowland critical zones of Kerala, India. *Journal of Environmental and Social Sciences, 5*(1), 1-3.

Reynolds, C. S. (1984). The ecology of freshwater phytoplankton. *Cambridge University Press,* New York. 384 pp.

Rincy, J., & Tessy, P. P. (2009). Phytoplankton biodiversity changes in Chalakudy River due to ossein plant effluents. In N. S. Bijoy, Salim, M., G. S. Pillai & V. Reeny (Eds.), A compendium on wetland biodiversity and conservation. *Proceedings of the national seminar on Wetland Biodiversity. Limnological Association of Kerala (LAK) Publishers,* Kerala, India, 93–103pp.

Roy, M., & Sen, N. (1985). Freshwater algae of Chattisgarh. *Phykos*, *24*, 76–79.

Roy, Z., & Joy, C. M. (2007). Algal biodiversity and succession in Periyar River at Aluva, Kerala. *Indian Hydrobiology*, *10*(1), 129–133.

Royle, J. F. (1970). Illustration of the Botany and other Branches of Natural History of the Himalayan Mountains and of the Flora of Cashmere. London, 2 vols [Reprint]. *Today and Tomorrow Printers,* 1- 472pp.

Saha, L. C. (1984). Blue green algae of Bhagalpur, Bihar. *Journal of Economic and Taxonomic Botany*, *5*(4), 881–885.

Saha, L. C. (1986). Algae of Bhagalpur ponds- Bacillariophyceae. *Phykos*, *25*, 136–143.

Saha, L. C., & Choudhary, S. K. (1984). Desmids of Bhagalpur, Bihar. *Journal of Economic and Taxonomic Botany*, *5*(4), 987–988.

Sahib, S. S. (2004b). Hydrology and phytoplankton in the Kallada river, Kerala. *Journal of Economic and Taxonomic Botany, 16*(3), 185–189.

Sahu, J. K. (2000). Distribution and monthly succession of blue green algae in the rice fields of Puri district of Orissa. *Journal of Economic and Taxonomic Botany*, *24*(1), 191–196.

Sanilkumar, M. G., & Thomas, K. J. (2006). Diversity and seasonal variation of algae in Muriyad wetland (part of Vembanad- Kol wetlands- A Ramsar site). *Journal of Economic and Taxonomic Botany*, *30*(3), 656–666.

Sankaranarayanan, V. N., Udaya, V. P., Balachandran, K. K., Pylee, A. J., & Joseph, T. (1986). Estuarine characteristics of a lower reaches of the river Periyar (Cochin backwaters). *Indian Journal of Marine Sciences*, *15*, 166–170.

Santra, S. C. (1984). Algal flora of Sikkim Himalaya – 1: A contribution to our knowledge of the blue green algae of north-east Sikkim (India). *Journal of Economic and Taxonomic Botany*, *5*(5), 1209–19.

Santra, S. C., & Adhya, T. K. (1973). Zygnemataceae of Eastern Himalaya. I- Spirogyra Link. *Bulletin of the Botanical Survey of India*, *15*(3–4), 281.

Santra, S. C., & Adhya, T. K. (1976). Zygnemataceae of Eastern Himalaya. II- Spirogyra Link. *Bulletin of the Botanical Survey of India*, *30*, 47-49.

Saravanakumar, A., Rajkumar, M., Thivakaran, G. A., & Sesh Serebiah, J. (2008). Abundance and seasonal variations of phytoplankton in the creek waters of western mangrove of Kachchh-Gujarat. *Journal of Environment Biology*, *29*(2), 271–274.

Saravanan, M., Elango, K., Chandrashekaran, S., Anand, N., & Nagaraja, V. (2003). A New type II restriction endonuclease, O fo I from nonheterocystous Cyanobacterium Oscillatoria foreaui. *Current Science*, *85*(2), 188–191.

Sardeshpande, J. S., & Goyal, S. K. (1981). Distribution pattern of blue green algae in rice fields of Konkan region of Maharashtra State. *Phykos*, *20*(1 & 2), 102–106.

Sarma, T. A., & Kanta, S. (1978). Algal flora of Pathiala and its environs I. *Phykos*, *1*(2*)*, 105–111.

Sarma, T. A., Kanta, S., & Sunita. (1979). Algal flora of Pathiala and its environs – Cyanophyceae II. *Phykos*, *18*(1 & 2), 13–19.

Sarma, Y. S. R. K., & Khan, M. (1980). Algal Taxonomy in India: Botanical records and monographs – 2. *Today and tomorrow's printers and publishers,* New Delhi. 153 pp.

Sarode, P. T., & Kamat, N. D. (1978). Diatoms of Marathwada, Maharashtra – I. *Phykos*, *18*(1 and 2), 25–32.

Sarode, P. T., & Kamat, N. D. (1983a). Diatoms of Marathwada, III. *Phykos*, *22,* (26–32).

Sarode, P. T., & Kamat, N. D. (1983b). The diatom flora of Vidarbh, India – I. *Bibliotheca Phycologica*, *66*, 259–319.

Sarode, P. T., & Kamat, N. D. (1984). Freshwater diatoms of Maharashtra. *Saikripa prakashan,* Aurangabad. 338 pp.

Scott, A. M., & Prescott, G. W. (1961). Indonesian desmids. *Hydrobiologia*, *17,* 1–132.

Seena, K. K., Antony, I., & Anto, P. V. (2019). Seasonal influences on phytoplankton diversity in tributaries of river Bharathapuzha, Palakkad District, Kerala. *Indian Hydrobiology*, *18*(1 and 2), 252–264.

Semwal, N., & Akolkar, P. (2006). Water quality assessment of sacred Himalayan rivers of Uttaranchal. *Current Science*, *9*(4), 486–496.

Shaji, C. (2004). A new variety of *Pleurotaenium* from Kerala. *Journal of Economic and Taxonomic Botany, 28*(3), 602–603.

Shaji, C., & Panikkar, M. V. N. (1994). Cyanophyceae of Kerala, India. *Phykos, 33,* (1&2), 105–112.

Shaji, C., & Panikkar, M. V. N. (1995). On some little-known epiphytic algae from Kerala. *Geobios*, *14*, 51–52.

Shaji, C., & Panikkar, M. V. N. (1996). Cyanophyceae of Kerala, India – II. *Journal of Economic and Taxonomic Botany*, *20*(2), 429–433.

Shaji, C., & Patel, R. J. (1990). Desmids new to Kerala. *Feddes Repertorium*, *101,* 5–6, 277–284.

Shaji, C., & Patel, R. J. (1991b). Contributions to euglenoids of Kerala, India. *Phykos*, *30*(1 & 2), 109–114.

Shaji, C., Sindhu, P., & Panikkar, M. V. N. (1995). Contributions to Euglenoids of Kerala, India – II. *Journal of Economic and Taxonomic Botany*, *19*(2), 269–272.

Shamsudeen, R. S. M., & Mathew, G. (2010). Diversity of butterflies in Shendurny wildlife sanctuary, Kerala (India). *World Journal of Zoology*, *5*(4), 324–329.

Sharma, A. (2010). Cyanobacterial flora from freshwater habitat of Bokaro thermal power station District Bokaro, Jharkhand, India. *International Journal of Plant Sciences*, *5*(2), 679–681.

Sharma, L. L., & Sarang, N. (2004). Physico-chemical limnology and productivity of Jaisamand Lake, Udaipur (Rajasthan). *Pollution Research*, *23*(1), 87–92.

Sheeba, S., & Ramanujan, N. (2005). Phytoplankton composition and distribution in Ithikkara River, Kerala. *Indian Hydrobiology*, *8*(1), 11–17.

Sheela, A. M., Letha, J., & Joseph, S. (2011). Environmental status of a tropical lake system. *Environmental Monitoring and Assessment*, *180,* (1–4), 427–449.

Shetiya, C., & Kerkar, V. (2004). Algal flora of rice fields from Tiswadi Taluqua, Goa. *Indian Hydrobiology*, *7*(1 & 2), 73–76.

Shinde, S. E., Pathan, T. S., & Sonawane, D. L. (2011). Study of phytoplankton biodiversity and correlation coefficient in Harsool-savangi dam, District Aurangabad, India. *Middle east Journal of Scientific research, 8*(3), 544–554.

Shukla, S. K., Misra, P. K., & Shukla, C. P. (2007). Chlorococcalean algae from the foothills of Western Himalaya. *Journal of the Indian Botanical Society*, *86*(3 and 4), 80–85.

Shukla, S. K., Shukla, C. P., & Misra, P. K. (2008). Desmids (Chlorophyceae, Conjugales, Desmidiaceae) from foothills of Western Himalaya, India. *Algae*, *23*(1), 1–14.

Simon, T. N., & Travis, J. (2011). The contribution of man-made ditches to the regional stream biodiversity of the new river watershed in the Florida panhandle. *Hydrobiologia*, *661*(1), 163–177.

Sindhu, P., & Panikkar, M. V. N. (1993). Oedogoniales of Kerala – I. *Journal of Economic and Taxonomic Botany, 17*(1), 89–94.

Sindhu, P., & Panikkar, M. V. N. (1994a). Observations on the two interesting members of Chaetophorales from Kerala. *Journal of Economic and Taxonomic Botany*, *18*(3), 629–630.

Sindhu, P., & Panikkar, M. V. N. (1994b). Observations on the two species of *Coleochaete* Brebisson from Kerala. *Journal of Economic and Taxonomic Botany*, *18*(3), 738–740.

Sindhu, P., & Panikkar, M. V. N. (1994c). Occurrence of desmid flora from the paddy fields of Quilon, Kerala, 1. *Pleurotaenium* Nageli. *Journal of Economic and Taxonomic Botany*, *18*(3), 601–603.

Sindhu, P., & Panikkar, M. V. N. (1995a). Desmids new to Kerala, India – 1. *Feddes Repertorium*, *106*(3–4), 317–323

Sindhu, P., & Panikkar, M. V. N. (1995b). Desmid flora of Quilon, Kerala, *Staurastrum* Meyen. *Journal of Economic and Taxonomic Botany*, *19*(2), 331–333.

Singh, N. K., & Saha, L. C. (1982a). Chlorococcales of Bhagalpur – 1, Bihar. *Journal of Economic and Taxonomic Botany, 3,* 197–200.

Singh, N. K., & Saha, L. C. (1982b). Diatoms of Bhagalpur ponds – I. Bihar, India. *Phykos, 21*, 128.

Singh, R., & Sharma, V. K. (1999). Geoenvironmental appraisal of Mansar and Surinsar lakes, Udhampur and Jammu Districts. *Records of the Geological Survey of India*, *131*, 19–24.

Sinha, J. P., & Mukherjee, D. (1975a). Blue green algae from the paddy fields of Bankura district of West Bengal I. *Phykos*, *14*(1 and 2), 117–118.

Sinha, J. P., & Mukherjee, D. (1975b). Blue green algae from the paddy fields of Bankura district of West Bengal II. *Phykos*, *14*(1 and 2), 119–120.

Sinha, J. P., & Mukherjee, D. (1984). Blue green algae from the paddy fields of Bankura district of West Bengal III. *Phykos*, *23*(1 and 2), 142–143.

Sinha, S., & Naik, M. L. (1997). Phytoplankton and macrophytes in the ponds of Raipur city area. Pt. *Ravishankar Shukla University*, M. P. 164 pp.

Smith, G. M. (1920). Phytoplankton of the Inland lakes of Wisconsin. Part I. *Wisconsin Geological Natural History Survey Bulletin,* Madison, *57*, (12), 243pp.

Smith, G. M. (1924). Phytoplankton of the Inland lakes of Wisconsin. Part II. Desmidiaceae. *Wisconsin Geological Natural History Survey Bulletin,* Madison, *57*(1270), 227 pp.

Smith, G. M. (1950). Fresh water algae of United States (2nd ed). *McGraw - Hill Book, Company, Internet Archive,* New York. 719 pp.

Smitha, K. S. (2017). A study on filamentous algae in Kuttanadu rice agroecosystem. *International Journal of Scientific Research*, *6*, 41-43.

Somashekar, R. K. (1983a). Algal flora of river Cauvery, Karnataka, I. Cyanophyceae and Chlorophyceae. *Phykos*, *22*, 73–80.

Somashekar, R. K. (1983b). Algal flora of river Cauvery, Karnataka, II. Diatoms. *Phykos*, *22*, 81–85.

Somashekar, R. K. (1984a). Contribution to the algal flora of river Kapila, Karnataka, I. Cyanophyceae and Chlorophyceae. *Phykos*, *23*(1 and 2), 116–124.

Somashekar, R. K. (1984b). Contribution to the algal flora of river Kapila, Karnataka, II. Diatoms. *Phykos*, *23*(1 and 2), 125–129.

Sreedevi, P. D., Subrahmanyam, K., & Ahmed, S. (2005). The significance of morphometric analysis for obtaining groundwater potential zones in a structurally controlled terrain. *Environmental Geology*, *47*(3), 412–420.

Sreekesh, S., Sreerama Naik, S. R., & Rani, S. (2018). Effect of sea level changes on the groundwater quality along the coast of Ernakulam District, Kerala. *Journal of Climate Change*, *4*(2), 51–65.

Srinivasan, K. S. (1967). Conspectus of *Sargassum* species from Indian territorial waters. *Phykos*, *5*, 127–159.

Srivastava, A. K. (2010). Some freshwater Bacillariophycean algae (diatoms) from Faizabad and Balrampur districts, U.P., India. *Journal of the Indian Botanical Society*. 89(1 & 2), 63–67.

Srivastava, N. P., Das, A. K., Pandey, B. L., & Nath, D. (2003). Phytoplankton primary production and fish potential of Tawa reservoir. *Journal of Inland Fisheries Society of India*, *34*(2), 23–29.

Srivastava, P. N., & Odhwani, B. R. (1990a). Trachelomonas Ehrenberg (*Euglenophyta*) from semi-arid region of western Rajasthan. *Phykos*, *29*(1 and 2), 121–126.

Staub, R., Appling, J. W., Hofstetter, A. M., & Haas, I. J. (1970). The effects of industrial wastes of Memphis and Shelby County on primary planktonic producers. *BioScience*, *20*(16), 905–912.

Subramoni, M. (2007). A study on the diversity of Vamanapuram river of South Kerala, in relationship with certain water quality parameters. *Indian Hydrobiology, 10,* 157-163.

Sudeep, B. M., & Hosmani, S. P. (2007). Algal biodiversity and application of indices in assessing two lakes of Mysore district. *Indian Hydrobiology*, *10*(2), 269–275.

Sullivan, M. J. (1975). Diatom communities from a Delaware salt marsh. *Journal of Phycology, 11,* 384–390.

Suphan, S., Peerapornpisal, Y., & Underwood, G. J. C. (2012). Benthic diatoms of Mekong River and its tributaries in northern and north-eastern Thailand and their application to water quality monitoring. *International Journal of Science and Technology*, *6*(1), 28–46.

Suryavanshi, S. S., Pingle, S. D., & Gaikwad, V. B. (2009). Some freshwater diatoms from Ahmednagar region, (M.S.) India. *Indian Hydrobiology*, *12*(1), 53–57.

Suryavanshi, S. S., Pingle, S. D., & Gaikwad, V. B. (2010). Diversity of Cyanophyceae members in and round Ahmednagar region (M.S.). *Journal of the Indian Botanical Society*, *89*(1 and 2), 189–196.

Suseela, M. R. (2005). A preliminary survey on freshwater algal flora of Garuda Tal, near Nainital, Uttaranchal, India. *Journal of the Indian Botanical Society*, *102*(2), 176–180.

Suseela, M. R., & Dwivedi, S. (2001). A contribution to fresh water algal flora of Bundelkhand region of U.P. (Chlorophyceae and Xanthophyceae). *Phytotaxonomy*, *1*, 76–81.

Suseela, M. R., & Dwivedi, S. (2002). A contribution to freshwater algal flora (Bacillariophyceae) of Bundelkhand region of Uttar Pradesh. *Phytotaxonomy, 2,* 33–39.

Suseela, M. R., & Toppo, K. (2004). Freshwater algal flora of Changu Lake of Sikkim Himalayas, India. *Phytotaxonomy*, *4*, 100–103.

Sushama, S. (2003). Ecology and biodiversity of Nila River [PhD Thesis], University of Kerala.

Sushama, S., Tresa, R., & Bijukumar, A. (2004) Distribution of fishes in the Nila River. *Indian Journal of Fisheries, 51*(3), 385-387

Suxena, M. R. (1983). Algae from Kodaikanal Hill, South India. *Bibliotheca Phycologica*, *66*, 43–99.

Suxena, M. R., & Venkateswarlu, V. (1966). Desmids of Andhra Pradesh, I. from Pakhal Lake, Warangal. *Hydrobiologia*, *28,* 49–65.

Suxena, M. R., & Venkareswarlu, V. (1968). Desmids from Kashmir. *Phykos,* 7, 165–185.

Suxena, M.R., & Venkareswarlu, V. (1970). Desmids of Andhra Pradesh –V. Mostly from Warangal and its environs. *Phykos*, *91*, 7–28.

Tessy, P.P., & Saritha, M. K. (2010). Biodiversity of micro-algae in Poyya mangrove ecosystem, Thrissur district, Proceedings of 22nd Kerala Science Congress. *Kerala State Council for Science, Technology and Environment,* Trivandrum, 29 –30pp.

Tessy, P. P., & Shubha, S. (2011). Algal diversity of coconut husk retting area in Thalikulam backwaters, Kerala. *Indian Hydrobiology*, *13*(2), 125–129.

Tessy, P.P., & Sreekumar, R. (2008). A report on the pollution algae from the Thrissur Kol wetlands (part of Vembanad-Kol, Ramsar site), Kerala. *Nature Environment and Pollution Technology, 7*(2), 311–314.

Tessy, P. P., & Sreekumar, R. (2009). Assessment of the biodiversity and seasonal variation of freshwater algae in the Thrissur Kol wetlands (part of Vembanad-Kol, Ramsar site), Kerala. *Journal of Economic and Taxonomic Botany*, *33*(3), 721–732.

Tessy, P. P., & Sreekumar, R. (2011a). Desmid *Pleurotaenium* Nageli from the Kole lands of Thrissur (part of Vembanad-Kol, Ramsar site), Kerala, India. *International Journal of Current Research*, *3*(12), 59–63.

Tessy, P. P., & Sreekumar, R. (2012). Studies on the algal flora of Kole lands in Thrissur district, Kerala. [PhD Thesis], Mahatma Gandhi University, Kottayam

Thilagavathi, R., Chidambaram, S., Prasanna, M. V., Thivya, C., Singaraja, C., & Jainab, I. (2012). A study on groundwater geochemistry and water quality in layered aquifers system of Pondicherry region, Southeast India. *Applied water science, 2*, 253-269.

Thirugnanamoorthy, K., & Selvaraju, M. (2009). Phytoplankton diversity in relation to physico-chemical parameters of Gnanaprekasam temple pond of Chidambaram in Tamil nadu, India. *Recent Research in Science and Technology*, *1*(5), 235–238.

Tiwari, A., & Chauhan, S. V. S. (2004). An enumeration of Chlorococcales from crop fields of Bichpuri, Agra. *Indian Hydrobiology*, *7*(1 and 2), 89–93.

Tiwari, A., & Chauhan, S. V. S. (2007b). Species diversity and seasonal variation of desmids in Agra city. *Indian Hydrobiology*, *10*(2), 307–317.

Toppo, K., & Suseela, M. R. (2009). *Cosmarium* diversity of Mani Pokhar Pond of Jashpur district in Chhattisgarh State, India. *Annals of Forestry*, *17*(1), 117–124.

Tripathi, A. K., & Pandey, S. N. (1991). Studies on algae of polluted ponds of Kanpur (India) – XIII. Systematic enumeration of Cyanophyceae. *Journal of Economic and Taxonomic Botany, 15*(2), 409–421.

Trivedi, R. K., & Goel, P. K. (1984). Chemical and biological methods for water pollution studies. *Enviro media Publications,* Karad, (India). 248 pp.

Trivedi, R. K., Goel, P. K., & Trisal, C. L. (1998). Practical methods in Ecology and Environmental Science. *Enviro Media Publications,* Karad, (India). 340 pp.

Trivedy, R. K. (1982). Some observations on algal flora of Jaipur, Rajasthan. *Phykos*, *21*, 160–163.

Turner, W. B. (1892). The freshwater algae (principally Desmidieae) of East India. *Kongliga Svenska Vetenskaps- Akademiens Handlingar, 25*(5), 1–187.

Umamaheswararao, M. U., & Sreeramulu, T. (1964). An ecological study of some intertidal algae of the Visakhapatnam coast. *Journal of Ecology*, *52*(3), 595–616.

Unni, K. S., & Naik, L. (1997). Distribution and ecology of zooplankton in the headwaters of the river Narmada. *International Journal of Ecology and Environmental Sciences*, *23*, 1–16.

Unnikrishnan Warrier, C., & Manjula, P. (2014). River: Groundwater interaction of a tropical Sub Basin of Bharathapuzha, Kerala, India. *International Journal of Advanced Engineering Science and Technology*, *2*(7), 382–393.

Ushadevi, K., & Panikkar, M. V. N. (1991). A new species of *Spirogyra* Link from Kerala, south India. *Journal of Economic and Taxonomic Botany*, *15*(3), 743–745.

Ushadevi, K., & Panikkar, M. V. N. (1993a). Oedogoniales of Kerala – II. *Journal of Economic and Taxonomic Botany*, *17*(1), 61–68.

Ushadevi, K., & Panikkar, M. V. N. (1993b). Oedogoniales of Kerala—III, *Bulbochaete* Agardh. *Journal of Economic and Taxonomic Botany*, *17*(1), 147–149.

Ushadevi, K., & Panikkar, M.V.N. 1994a. Species of the genus *Spirogyra* from Kerala, India (Chlorophyceae: Zygnemataceae). *Bibliotheca Phycologica*, *97,* 1–124.

Vaheeda, K. K. (2008). Ecological studies on the brakish waters of Kodungallur area, Kerala, India. Ph.D thesis, Mahatma Gandhi University, Kottayam.

Varunprasath, K., & Daniel, N. A. (2010). Physico-chemical parameters of River Bhavani in three stations, Tamil nadu, India. *Journal of Energy and Environment*, *1*(4), 321–325.

Varshney, C. K. (1991). Water pollution and management. *Wiley eastern Limited, New Delhi.* 242 pp.

Venkataraman, G. S. (1939). A systematic account of some south Indian diatoms. *Proceedings of Indian Academy of Sciences*, *10*(6), 293–368.

Venkataraman, G. S. (1961). Vaucheriaceae. *Indian Council of Agricultural Research*, New Delhi, India. 112 pp.

Venkateswarlu, V. (1983). Taxonomy and ecology of algae in the river Moosi, Hyderabad, India – II. Bacillariophyceae. *Bibliotheca Phycologica*, *66*, 1–41.

Verma, B. N., Sinha, R., Prasad, P. K., & Das, H. N. (1990). Blue green algae from the paddy fields of north Bihar. *Phykos*, *29*(1 and 2), 55–56.

Vijayakumar, K. (1999). Freshwater ecosystem of India. *Daya Publishing House. house,* Delhi. 336 pp.

Vishnoi, S. R., & Srivastava, P. N. (2004). Algal flora of polluted water bodies around Jodhpur, Rajastan. *Indian Hydrobiology*, *7*(1 and 2), 147–150.

Vishnu M. S., John S. E., Rajimol T. R., Maya K., Sajan K., & Padmalal D. (2016). Human interventions and consequent environmental degradation of a protected freshwater lake in Kerala, SW India. *Geosciences Journal*, *20*(3), 391-402.

West, W., & West, G. S. (1897). Welwistch's African freshwater algae. *Journal of Botany*, *35*, 172-183.

West, W., & West, G. S. (1902). A contribution to the freshwater algae of Ceylon. *Trans Linnaeus Society of Botany London, 6*,123-212.

West, W., & West, G. S. (1904). A monograph of the British Desmidiaceae. Vol. 1, *The Ray Society, London*, 224pp.

West, W., & West, G. S. (1905). A monograph of the British Desmidiaceae. Vol. 2, *The Ray Society, London*, 206pp.

West, W., & West, G. S. (1907). Freshwater algae from Burma, including a few from Bengal and Madras. *Annals of the Royal Botanical Garden*, *II*. Bengal secretariat press, Calcutta, 175–260pp.

West, W., & West, G. S. (1908). A monograph of the British Desmidiaceae. Vol. 3, *The Ray Society, London*, 274pp.

West, W., & West, G. S. (1912). A monograph of the British Desmidiaceae. Vol. 4, *The Ray Society, London*, 194pp.

Wołowski, K. (1998). Taxonomic and environmental studies on euglenophytes of the Krakow–Częstochowa Upland (Southern Poland). *Fragmenta Floristica et Geobotanica, Series,* Polonica, *6*, 1–192.

Yazdandoost, M. Y., & Kaldare, M. S. (2000). Study of the population density of plankton with respect to physicochemical characteristics of water, Pune rivers. India. *Ecology Environment and Conservation, 6*(1), 127–135.

Zacharias, R., & Joy, C. M. (2007). Algal biodiversity and succession in Periyar River at Aluva. *Indian Hydrobiology*, *10*(1), 129–133.

Zaware, B. N., & Pingle, S. D. (2003). Freshwater algae from Pashan Lake. *Indian Hydrobiology*, *6*(1 & 2), 9–11.

Zeenath, M. (2011). Studies on the ecology of biodiversity of Thutha river, north Kerala, PhD thesis, University of Kannur, Kerala.

Zhang, W., Jin, X., Liu, D., Lang, C., & Shan, B. (2017). Temporal and spatial variation of nitrogen and phosphorus and eutrophication assessment for a typical arid river-Fuyang River in northern China. *Journal of Environmental Sciences*, *55*, 41–48.

Appendix

Collection Details - November 2018 to October 2019

Collections			Stations	
No.	**Bottle No.**	**Date**	**No.**	**Name**
1	Cht 11	1/11/2018	3	Chittur
2	Chl 11	1/11/2018	4	Chulliyar
3	Kap 11	1/11/2018	6	Kalpathy
4	Kan 11	1/11/2018	5	Kannadi
5	Maz 11	1/11/2018	7	Malampuzha
6	Man 11	15/11/2018	2	Mayannur
7	Kam 11	15/11/2018	8	Karimpuzha
8	Kod 11	15/11/2018	1	Koodallur
9	Muk 11	15/11/2018	9	Mukkali
10	Seek 11	15/11/2018	10	Seenkara
11	Kan 12	12/12/2018	5	Kannadi
12	Cht 12	12/12/2018	3	Chittur
13	Chl 12	12/12/2018	4	Chulliyar
14	Maz 12	12/12/2018	7	Malampuzha
15	Kap 12	12/12/2018	6	Kalpathy
16	Kam 12	19/12/2018	8	Karimpuzha
17	Kod 12	19/12/2018	1	Koodallur
18	Man 12	19/12/2018	2	Mayannur
19	Muk 12	19/12/2018	9	Mukkali
20	Seek 12	19/12/2018	10	Seenkara
21	Cht 01	22/01/2019	3	Chittur
22	Chl 01	22/01/2019	4	Chulliyar
23	Maz 01	22/01/2019	7	Malampuzha
24	Kap 01	22/01/2019	6	Kalpathy
25	Kan 01	22/01/2019	5	Kannadi
26	Man 01	28/01/2019	2	Mayannur
27	Muk 01	28/01/2019	9	Mukkali
28	Seek 01	28/01/2019	10	Seenkara
29	Kam 01	28/01/2019	8	Karimpuzha
30	Kod 01	28/01/2019	1	Koodallur
31	Kod 02	13/02/2019	1	Koodallur
32	Man 02	13/02/2019	2	Mayannur
33	Kam 02	13/02/2019	8	Karimpuzha
34	Muk 02	13/02/2019	9	Mukkali
35	Seek 02	13/02/2019	10	Seenkara
36	Maz 02	22/02/2019	7	Malampuzha
37	Kap 02	22/02/2019	6	Kalpathy
38	Kan 02	22/02/2019	5	Kannadi
39	Cht 02	22/02/2019	3	Chittur
40	Chl 02	22/02/2019	4	Chulliyar
41	Cht 03	04/03/2019	3	Chittur
42	Kap 03	04/03/2019	6	Kalpathy
43	Kan 03	04/03/2019	5	Kannadi

44	Maz 03	04/03/2019	7	Malampuzha
45	Chl 03	04/03/2019	4	Chulliyar
46	Kod 03	19/03/2019	1	Koodallur
47	Man 03	19/03/2019	2	Mayannur
48	Kam 03	19/03/2019	8	Karimpuzha
49	Muk 03	19/03/2019	9	Mukkali
50	Seek 03	19/03/2019	10	Seenkara
51	Maz 04	3/04/2019	7	Malampuzha
52	Kap 04	3/04/2019	6	Kalpathy
53	Kan 04	3/04/2019	5	Kannadi
54	Cht 04	3/04/2019	3	Chittur
55	Chl 04	3/04/2019	4	Chulliyar
56	Kod 04	16/04/2019	1	Koodallur
57	Man 04	16/04/2019	2	Mayannur
58	Kam 04	16/04/2019	8	Karimpuzha
59	Muk 04	16/04/2019	9	Mukkali
60	Seek 04	16/04/2019	10	Seenkara
61	Chl 05	18/05/2019	4	Chulliyar
62	Cht 05	18/05/2019	3	Chittur
63	Maz 05	18/05/2019	7	Malampuzha
64	Kap 05	18/05/2019	6	Kalpathy
65	Kan 05	18/05/2019	5	Kannadi
66	Muk 05	28/05/2019	9	Mukkali
67	Seek 05	28/05/2019	10	Seenkara
68	Kam 05	28/05/2019	8	Karimpuzha
69	Kod 05	28/05/2019	1	Koodallur
70	Man 05	28/05/2019	2	Mayannur
71	Cht 06	18/06/2019	3	Chittur
72	Kap 06	18/06/2019	6	Kalpathy
73	Kan 06	18/06/2019	5	Kannadi
74	Maz 06	18/06/2019	7	Malampuzha
75	Chl 06	18/06/2019	4	Chulliyar
76	Kod 06	30/06/2019	1	Koodallur
77	Man 06	30/06/2019	2	Mayannur
78	Kam 06	30/06/2019	8	Karimpuzha
79	Muk 06	30/06/2019	9	Mukkali
80	Seek 06	30/06/2019	10	Seenkara
81	Maz 07	16/07/2019	7	Malampuzha
82	Chl 07	16/07/2019	4	Chulliyar
83	Cht 07	16/07/2019	3	Chittur
84	Kap 07	16/07/2019	6	Kalpathy
85	Kan 07	16/07/2019	5	Kannadi
86	Kod 07	28/07/2019	1	Koodallur
87	Man 07	28/07/2019	2	Mayannur
88	Kam 07	28/07/2019	8	Karimpuzha
89	Muk 07	28/07/2019	9	Mukkali
90	Seek 07	28/07/2019	10	Seenkara
91	Chl 08	18/08/2019	4	Chulliyar

92	Cht 08	18/08/2019	3	Chittur
93	Maz 08	18/08/2019	7	Malampuzha
94	Kap 08	18/08/2019	6	Kalpathy
95	Kan 08	18/08/2019	5	Kannadi
96	Kam 08	25/08/2019	8	Karimpuzha
97	Muk 08	25/08/2019	9	Mukkali
98	Seek 08	25/08/2019	10	Seenkara
99	Kod 08	25/08/2019	1	Koodallur
100	Man 08	25/08/2019	2	Mayannur
101	Kod 09	18/09/2019	1	Koodallur
102	Man 09	18/09/2019	2	Mayannur
103	Kam 09	18/09/2019	8	Karimpuzha
104	Muk 09	18/09/2019	9	Mukkali
105	Seek 09	18/09/2019	10	Seenkara
106	Chl 09	22/09/2019	4	Chulliyar
107	Cht 09	22/09/2019	3	Chittur
108	Kan 09	22/09/2019	5	Kannadi
109	Kap 09	22/09/2019	6	Kalpathy
110	Maz 09	22/09/2019	7	Malampuzha
111	Cht 10	15/10/2019	3	Chittur
112	Kap 10	15/10/2019	6	Kalpathy
113	Kan 10	15/10/2019	5	Kannadi
114	Maz 10	15/10/2019	7	Malampuzha
115	Chl 10	15/10/2019	4	Chulliyar
116	Kod 10	27/10/2019	1	Koodallur
117	Man 10	27/10/2019	2	Mayannur
118	Kam 10	27/10/2019	8	Karimpuzha
119	Muk 10	27/10/2019	9	Mukkali
120	Seek 10	27/10/2019	10	Seenkara

Monthly values of physico chemical parameters

Temperature	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	25.65±0.35	31.5±0.36	29.1±0.62	30.57±0.47	31.23±0.31	29.6±0.44	29.2±0.26	28.53±0.38	25.87±0.23	26.75±0.07
Dec	28.63±0.15	30.97±0.32	26.53±0.32	28.83±0.31	28.63±0.15	28.53±0.38	27.07±0.15	30.27±0.40	27.53±0.55	25.93±0.49
Jan	29.7±1.13	28.67±0.86	27.5±0.4	28.67±0.4	27.93±0.15	27.87±0.35	28.53±0.35	29.2±0.14	28.35±0.35	27.9±0.14
Feb	29.5±0.42	28.75±0.07	30.4±0.28	29.7±0.14	31.9±0.42	32.45±0.07	31.35±0.48	30.89±0.28	29.7±1.41	30.4±0.14
Mar	30.8±0.61	31.77±0.25	33.03±0.59	32.77±0.75	30.83±0.80	32.63±0.47	33.87±0.31	34.3±0.2	35.33±0.57	31.87±0.25
Apr	31.05±0.07	31.93±0.81	33.4±0.56	32.1±0.79	34.97±0.21	34.27±0.06	34.37±0.12	33.15±0.21	30.85±0.49	31.55±0.35
May	32±0.14	32.27±0.45	34.07±0.15	30.4±0.56	32.17±0.93	34.07±0.15	32.5±0.44	34.0±0.28	32.4±0.42	32.6±0.14
Jun	30.8±0.1	31.27±0.06	30.1±0.1	29.7±0.2	31.43±0.38	31.57±0.21	32.13±0.25	30.4±0.1	27.97±0.06	27.93±0.06
Jul	28.97±0.15	29.77±0.40	28.7±0.17	28.33±0.12	29.27±0.35	28.97±0.31	29±0.53	26.83±0.35	25.57±0.38	25.4±0.36
Aug	28.7±0.14	28.4±0.42	28.3±0.14	29.65±0.21	28.25±0.49	29±0.42	29.05±0.21	25.73±0.15	23.33±0.21	23.23±0.25
Sep	29.8±0.1	28.6±0.61	29.63±0.12	29.87±0.42	32±0.36	31.13±0.25	31.6±0.2	27.6±0.46	25.23±0.57	25.77±0.45
Oct	28.43±0.15	28.63±0.12	29.03±0.67	29.27±0.15	29.87±0.83	29.87±0.57	29.13±0.25	26.9±0.2	26±0.14	26.2±0.28

pH	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	8.25±0.21	8.36±0.03	8.02±0.26	8.32±0.08	8.41±0.06	8.43±0.038	8.43±0.03	8.39±0.014	8.23±0.04	8.22±0.02
Dec	8.33±0.06	8.30±0.35	8.27±0.05	8.32±0.02	8.59±0.02	8.42±0.04	8.6±0.02	8.1±0.1	8.33±0.15	8.1±0.1
Jan	8.25±0.07	8.36±0.04	8.35±0.05	8.0 ±0.21	8.40±0.03	8.5±0.02	8.83±0.04	8.65±0.04	8.35±0.04	8.25±0.06
Feb	8.43±0.06	8.55±0.07	8.55±0.07	8.7±0.14	8.1±0.1	8.4±0.14	8.05±0.07	8.3±0.14	8.35±0.07	8.2±0.14
Mar	9.43±0.06	9.36±0.05	8.5±0.08	8.35±0.07	8.3±0.36	8.77±0.07	9.15±0.13	8.13±0.15	8.33±0.06	8.17±0.06
Apr	8.46±0.04	8.4±0.09	8.45±0.07	8.6±0.04	8.37±0.07	8.87±0.04	8.72±0.07	8.3±0.01	8.59±0.014	8.48±0.014
May	8.61±0.02	8.69±0.03	8.54±0.05	8.87±0.17	8.75±0.07	8.96±0.04	8.91±0.03	8.86±0.08	8.92±0.03	8.62±0.02
Jun	8.7±0.1	9.5±0.2	8.7±0.1	8.5±0.1	8.83±0.06	8.97±0.12	9.23±0.06	8.83±0.15	8.93±0.15	8.6±0.1
Jul	8.37±0.12	9.5±0.52	8.6±0.1	8.37±0.06	8.77±0.06	8.83±0.12	8.97±0.31	8.67±0.15	8.9±0.1	9.03±0.05
Aug	7.87±0.16	7.65±0.07	8.05±0.49	8.6±0.42	8.45±0.35	8.45±0.07	8.8±0.14	7.7±0.01	7.47±0.42	8.2±0.01
Sep	7.73±0.15	7.7±0.2	8.97±0.15	8.5±0.2	9.17±0.06	9.27±0.15	9.33±0.06	8.43±0.05	8.63±0.06	8.67±0.05
Oct	8.73±0.23	8.6±0.26	8.97±0.05	8.77±0.12	8.63±0.06	8.67 ±0.23	9.13±0.12	8.8±0.1	8.5±0.14	8.65±0.04

EC	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	286±1.41	302.67±36.3	599.33±6.52	281.33±4.16	645.33±2.5	1262.3±6.0	1374±13.4	64.67±0.58	49.33±1.15	50.5±3.54
Dec	296.67±0.58	202±47.57	548.33±6.11	678.33±11.3	505.67±2.8	734.33±7.7	1127.3±9.8	68.67±3.06	54.33±3.21	57±2
Jan	296.5±3.54	299.67±6.43	396.67±3.51	666.33±8.02	496.3±15.1	569±56.35	775.33±2.3	66±4.24	52±4.24	52±1.41
Feb	365.5±0.70	286.5±0.70	382±9.89	392±8.49	495±2.83	392.5±7.78	620±2.83	59.5±0.70	51±1.41	55.5±0.70
Mar	182.33±3.06	302.33±2.51	367.33±3.21	689±3	503±34.87	145.33±1.5	266.33±1.1	80.33±1.53	58±1	67.67±1.15
Apr	182±1.41	261.33±20.9	304.33±16.1	525.67±8.14	301±6.25	726.5±4.95	837.67±9.2	68±1.41	63±2.83	58.5±0.71
May	168.5±4.95	145.33±7.37	432.67±6.51	492.67±16.9	419±18.36	625±25.71	681.67±7.2	78.5±2.12	54.5±2.12	61±2.83
Jun	144±1.73	300.33±2.31	397.67±5.03	464.67±8.33	413±4.58	176.67±1.1	558.33±9.0	65±3.46	58±4	52.67±6.02
Jul	128±2.65	216±27.87	508±61.59	674.33±3.21	481.33±1.1	444±1	559.67±8.3	49±2.65	20±1	20.33±0.58
Aug	159.5±2.12	165.67±7.78	280.5±12.02	568±11.31	171±18.38	614±28.28	726±39.59	49.67±1.15	28.5±1	31.33±0.58
Sep	239±7.21	175.33±3.51	475.67±25.6	676.5±4.95	572±2	398.33±2.0	733.33±7.5	51±1	34.33±3.21	32±1
Oct	239.33±17.7	239.33±17.7	328.33±2.52	510.33±7.23	378±13.08	672.33±2.8	693±4.58	54±1	38.5±0.70	32±2.83

TDS	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	100±2.83	119.33±41.19	308.33±37.09	134.67±1.53	315.67±0.58	623.33±5.03	684±6.56	30.67±0.58	25.33±0.58	27±1.41
Dec	144±1	106.33±20.50	266.33±3.51	325.67±1.15	246±1.73	357±4.58	560.67±7.57	32.67±1.15	25.33±1.54	26.67±1.53
Jan	137.5±2.12	148.33±6.66	190.33±2.08	326.33±2.08	83.67±1.15	185.33±11.37	383.67±1.15	36±2.83	27.5±2.12	30.5±2.12
Feb	176.67±1.15	137±1.41	132.5±6.36	188±1.41	241.5±2.12	189±2.12	301.5±0.70	27±1.41	24.5±0.70	26.5±0.70
Mar	87±1	145.33±1.53	177±2	334.67±4.04	244±15.72	292.67±31.79	431.67±5.51	38.33±0.58	27.67±0.58	31.67±1.15
Apr	83.5±2.12	167±28	148±7	264.67±19.35	143.67±3.06	261.33±3.06	458.67±8.02	34±2.83	25±2.83	24.5±4.95
May	80.5±2.12	81.67±8.74	219.67±30.44	234.67±9.07	227±37.40	356±47.16	483.67±10.79	37±1.41	23.5±2.12	28.5±0.71
Jun	68.33±0.58	145.33±1.15	174.67±2.08	264.33±3.21	191.67±1.53	199.33±0.58	291±3	31.33±0.58	18.33±0.58	18.67±0.58
Jul	60.67±1.15	108.67±10.02	243±26.85	232±6.24	107.67±10.59	313±2.65	375.33±4.73	23.33±1.53	9.33±0.58	9.33±0.58
Aug	79.5±6.36	80.5±0.71	156.5±12.02	88±9.89	131±9.89	292±7.07	327.5±40.31	23.33±0.58	43.67±1.53	15.67±1.15
Sep	115.33±3.51	91.67±9.29	263.33±43.88	236.67±8.33	278±1	193.67±2.08	356±4.58	24.67±1.15	16.33±1.53	23.9±2.89
Oct	115±7.81	90.33±12.66	158.33±1.53	259.33±9.07	332±8.72	309.67±2.52	367±33.05	25.67±0.58	22.5±2.12	20.5±2.12

Nitrate	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	0.004±0.0007	0.06±0.002	0.015±0.005	0.014±0.002	0.039±0.009	0.02±0.002	0.018±0.0038	0.0317±0.01	0.056±0.039	0.044±0.01
Dec	0.004±0.0001	0.008±0.007	0.052±0.004	0.021±0.0025	0.045±0.006	0.04±0.013	0.04±0.003	0.023±0.002	0.002±0.001	0.002±0.001
Jan	0.003±0.0035	0.05±0.003	0.034±0.0076	0.054±0.012	0.069±0.0035	0.03±0.004	0.029±0.005	0.022±0.001	0.005±0.001	0.02±0.007
Feb	0.003±0.0007	0.053±0.007	0.05±0.013	0.061±0.001	0.048±0.009	0.06±0.007	0.055±0.009	0.003±0.001	0.0055±0.01	0.001±0.001
Mar	0.48±0.03	0.47±0.03	0.029±0.006	0.031±0.005	0.015±0.004	0.05±0.003	0.005±0.001	0.38±0.15	0.207±0.045	0.224±0.176
Apr	0.335±0.035	0.321±0.021	0.249±0.003	0.264±0.005	0.268±0.006	0.25±0.008	0.29±0.019	0.405±0.021	0.24±0.057	0.035±0.004
May	0.47±0.014	0.548±0.05	0.456±0.015	0.43±0.069	0.53±0.033	0.495±0.02	0.616±0.023	0.52±±0.014	0.525±0.021	0.49±0.014
Jun	0.256±0.015	0.089±0.006	0.045±0.005	0.043±0.004	0.042±0.006	0.02±0.004	0.067±0.023	0.234±±0.01	0.02±0.01	0.033±0.01
Jul	0.043±0.032	0.0525±0.01	0.053±0.012	0.063±0.007	0.042±0.003	0.05±0.013	0.066±0.007	0.035±0.007	0.055±0.007	0.061±0.001
Aug	0.033±0.012	0.023±0.006	0.041±0.002	0.049±0.005	0.038±0.0014	0.05±0.001	0.064±0.0035	0.006±0.004	0.023±0.005	0.008±0.002
Sep	0.085±0.013	0.072±0.013	0.069±0.016	0.086±0.017	0.0956±0.012	0.092±0.03	0.092±0.0015	0.084±0.011	0.094±0.011	0.124±0.011
Oct	0.184±0.016	0.289±0.012	0.247±0.039	0.187±0.014	0.241±0.004	0.243±0.05	0.347±0.023	0.874±0.020	0.12±0.014	0.205±0.021

Phosphate	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	0.14±0.01	0.13±0.008	0.02±0.006	0.03±0.008	0.038±0.01	0.038±0.004	0.14±0.029	0.13±0.03	0.14±0.017	0.18±0.04
Dec	0.168±0.02	0.164±0.005	0.04±0.01	0.03±0.005	0.039±0.004	0.05±0.006	0.04±0.005	0.13±0.03	0.15±0.01	0.15±0.005
Jan	0.09±0.003	0.06±0.014	0.04±0.007	0.029±0.006	0.044±0.004	0.031±0.004	0.058±0.031	0.07±0.056	0.2±0.008	0.14±0.006
Feb	0.21±0.014	0.21±0.05	0.302±0.027	0.312±0.35	0.25±0.02	0.21±0.005	0.137±0.07	0.19±0.025	0.18±0.02	0.18±0.003
Mar	0.09±0.10	0.04±0.011	0.31±0.037	0.38±0.05	0.29±0.09	0.39±0.08	0.21±0.02	0.15±0.04	0.2±0.001	0.51±0.61
Apr	0.13±0.007	0.12±0.03	0.10±0.008	0.198±0.003	0.16±0.08	0.19±0.08	0.19±0.01	0.18±0.014	0.14±0.006	0.16±0.0007
May	0.15±0.014	0.131±0.007	0.15±0.02	0.23±0.002	0.13±0.009	0.13±0.006	0.18±0.005	0.14±0.014	0.17±0.014	0.18±0.014
Jun	0.15±0.01	0.12±0.005	0.083±0.02	0.19±0.07	0.12±0.003	0.18±0.001	0.19±0.008	0.15±0.03	0.09±0.02	0.05±0.04
Jul	0.19±0.012	0.143±0.007	0.12±0.02	0.08±0.006	0.076±0.002	0.13±0.007	0.18±0.01	0.19±0.005	0.14±0.03	0.15±0.03
Aug	0.12±0.02	0.015±0.003	0.14±0.02	0.044±0.003	0.053±0.006	0.094±0.001	0.13±0.004	0.09±0.05	0.16±0.02	0.19±0.005
Sep	0.02±0.004	0.13±0.178	0.03±0.006	0.03±0.007	0.029±0.005	0.03±0.006	0.041±0.003	0.03±0.006	0.03±0.003	0.034±0.007
Oct	0.02±0.001	0.02±0.002	0.04±0.001	0.019±0.002	0.04±0.001	0.029±0.007	0.12±0.02	0.01±0.008	0.031±0.002	0.037±0.003

Silicate	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	0.09±0.002	0.058±0.02	3.07±0.17	1.67±0.02	2.88±0.03	3.23±0.05	3.42±0.09	0.25±0.07	0.28±0.23	0.35±0.078
Dec	1.37±0.11	1.29±0.09	2.56±0.11	3.67±0.03	2.09±0.05	2.71±0.02	1.87±0.12	1.12±0.12	1.34±0.06	1.41±0.07
Jan	1.16±0.02	1.37±0.09	1.72±0.15	3.48±0.57	1.77±0.11	1.57±0.038	1.89±0.025	1.12±0.06	1.26±0.04	1.56±0.049
Feb	1.31±0.08	1.09±0.029	1.26±0.014	0.57±0.07	1.64±0.160	1.67±0.11	2.09±0.04	1.42±0.36	1.69±0.03	1.71±0.007
Mar	0.42±0.12	0.48±0.046	1.24±0.003	1.87±0.09	0.59±0.03	0.77±0.09	1.78±0.003	0.76±0.02	0.87±0.023	0.88±0.077
Apr	0.37±0.06	0.39±0.05	1.17±0.03	1.56±0.01	0.73±0.03	0.21±0.003	1.27±0.008	0.67±0.03	0.61±0.09	0.61±0.045
May	0.69±0.05	0.62±0.02	1.30±0.019	1.21±0.03	1.3±0.03	1.13±0.07	1.33±0.03	0.57±0.06	0.67±0.03	0.69±0.03
Jun	0.63±0.031	0.63±0.11	1.51±0.03	1.74±0.18	0.49±0.37	1.43±0.021	1.88±0.005	0.63±0.03	0.32±0.005	0.35±0.02
Jul	0.49±0.02	0.73±0.04	1.24±0.059	1.31±0.04	1.189±0.077	1.20±0.04	1.73±0.04	0.4±0.026	0.14±0.02	0.16±0.01
Aug	0.47±0.23	0.79±0.02	1.30±0.03	1.14±0.013	1.42±0.006	1.24±0.002	1.28±0.019	0.55±0.017	0.47±0.25	0.27±0.03
Sep	0.42±0.04	0.62±0.06	0.28±0.01	0.42±0.04	0.27±0.02	0.59±0.08	0.86±0.18	0.52±0.03	0.27±0.02	0.54±0.04
Oct	0.25±0.001	0.29±0.08	0.39±0.02	0.52±0.02	0.38±0.02	0.43±0.03	0.54±0.03	0.24±0.01	0.26±0.002	0.49±0.03

DO	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	7.15±0.07	7.5±1.27	7.55±0.07	7.9±0.14	7.35±0.21	7.55±0.07	7.85±0.07	7.47±1.23	8.53±0.37	8.45±0.07
Dec	7.93±0.49	5.27±1.01	7.13±0.15	7.93±0.66	7.9±0.1	5.93±0.42	8.03±0.25	7.43±1.05	8.6±0.69	7.77±0.51
Jan	6.85±0.07	7.47±0.15	7.77±0.5	6.6±0.75	8.53±0.25	6.2±0.56	6.73±0.31	7.1±0.14	8.5±0.14	7.7±0.14
Feb	6.05±0.21	6.9±0.14	7±0.14	7.45±0.07	6.45±0.63	7.2±0.14	6.75±0.21	6.1±0.42	7±0.28	7.2±0.42
Mar	7.07±0.12	7.2±0.3	7.17±0.15	7.76±0.55	7.13±0.12	6.93±0.15	6.67±0.49	6.83±0.12	5.8±0.26	5.1±0.1
Apr	6.4±0.14	6.9±0.1	7±0.17	7.07±0.05	6.87±0.15	7.17±0.06	6.7±0.2	6.8±0.14	6.75±0.49	6.85±0.07
May	5.8±0.1	7.15±0.21	7.45±0.07	7.45±0.21	6.9±0.14	7.2±0.14	6.7±0.28	7.1±0.14	7.05±0.21	6.7±0.14
Jun	6.1±0.28	7.1±0.14	5.8±0.14	7.2±0.14	7.25±0.07	7.2±0.14	6.15±0.28	6.97±0.14	7.35±0.07	6.6±0.98
Jul	5.7±0.28	8.05±0.35	5.75±0.21	7.1±0.28	6.6±0.42	7.35±0.35	5.75±0.21	5.9±0.42	6.6±0.42	6.25±0.49
Aug	5.75±0.64	7.5±0.3	6.97±0.12	7.05±0.07	7.15±0.07	7.27±0.31	6.37±0.12	6.33±0.85	7±0.4	6.53±0.25
Sep	7.07±0.45	6.9±0.14	6.76±0.25	6.07±0.25	6.97±0.32	6.37±0.20	5.9±0.1	5.93±0.25	6.73±0.31	6.8±0.92
Oct	5.5±0.51	7.5±0.1	6.47±0.30	5±0.28	6.5±0.45	6.47±0.58	5.87±0.55	6.07±0.15	6.65±0.21	6.9±0.28

List of papers published/Communicated

- K. K. Seena, Ignatius Antony & P. V. Anto (2019). Seasonal influences on phytoplankton diversity in tributaries of river Bharathapuzha, Palakkad District, Kerala, *Indian Hydrobiology*. 18(1 & 2), 252–264.
- Seena K. K., Ignatius Antony & Anto P.V. (2018). Review Microalgae:- A Potential Source, *International journal of Research and Analytical Reviews*. 5(3), 484-494.

Conference paper

- Seena K. K., Ignatius Antony, (2019). Phytoplankton diversity indices of Kalpathy, River, Palakkad, *Albertian Journal of Multidisciplinary Research.* 1(1), 111-115.
- Seena K. K., Ignatius Antony & Anto P.V. The seasonal oscillation of physico-chemical parameters and phytoplankton distribution from South West Coast of India (Bharathapuzha river basin), *Brazilian Journal of Botany*.
- Seena K. K., Ignatius Antony, Anto P.V. & Dhanya Jose. First new report of *Micrasterias laticeps* var. *acuminata* Willi Krieger from south Southwest Coast of India (Bharathapuzha river basin), *Limnology*.

List of paper presentations

- Fresh water algal diversity and physico-chemical parameter study from Chittur river, Kerala on national conference on Vistas in biodiversity, biology, biotechnology and nanotechnology of algae at Madras Christian College, Chennai from 20/09/2018-22/09/2018
- Micro algal diversity from Chittur river, Palakkad on national seminar "Plant-microbe Interactions" Sree Neelakanta Government Sanskrit College, Pattambi from 05/12/2018-06/12/2018
- Phytoplankton diversity indices of Kalpathy river, Palakkad on international seminar on "Albertian Knowledge Summit-an International conference on multidisciplinary research" at St.Alberts College, Eranakulam on 14/01/2019
- Ecological assessment of Chittur river using phytoplankton diversity on national seminar "Species The Passion V" Air Pollution At St.Thomas, College, Thrissur from 26/06/2019 to 27/06/2019
- Seasonal variation of phytoplankton diversity in two tributaries of river Bharathapuzha, Palakkad District" on national conference on bioprospecting of algae:- resources, conservation and utilization - Central University of Kerala from 01/08/2019-02/08/2019

Indian Hydrobiology, 18(1 & 2): 252–264, 2019

Seasonal Influences on Phytoplankton Diversity in Tributaries of River Bharathapuzha, Palakkad District, Kerala

K.K. Seena*, Ignatius Antony and P.V. Anto
Department of Botany, St.Thomas' College (Autonomous), Thrissur
*Corresponding Author - Seenakk29@gmail.com

Abstract

The present paper determines the current biological and ecological state of phytoplankton diversity in three tributaries of Bharathapuzha viz., Chittur, Kalpathy and Kannadi Rivers. The phytoplankton sampling was done during three different seasons i.e. pre-monsoon, monsoon, and post-monsoon of the year 2018–2019. Environmental characteristics, Phytoplankton diversity and seasonal fluctuations were investigated from November 2018–August 2019. Eighty-one species were observed during the present study which constituted 40 species of Bacillariophyceae, 25 species of Chlorophyceae, 8 species of Euglenophyceae, 6 species of Cyanophyceae,1 species each of Xanthophyceae and Dinophyceae. Comparing the population, the abundance of each group of phytoplankton was in the order of Bacillariophyceae > Chlorophyceae > Euglenophyceae > Cyanophyceae > Dinophyceae and Xanthophyceae. Species richness and evenness high in pre-monsoon season, while species diversity in all the stations high in post-monsoon. The present study resulted in identification of 12 pollution tolerant algal genera namely *Oscillatoria, Gomphonema, Cyclotella, Cymbella, Melosira, Navicula, Nitzschia, Synedra, Phacus, Euglena, Closterium and Scenedesmus.* Temperature and pH showed marked increase in Pre-monsoon season. BOD was also noted high along with pH and temperature. TDS and conductivity level observed high during the period of post-monsoon. Higher values of nitrate and silicate were recorded in dry season. Dissolved oxygen was observed low in pre-monsoon while the highest value in monsoon season. Pollution indices analyses indicated, the organic pollution and river and eutrophic in nature of the river.

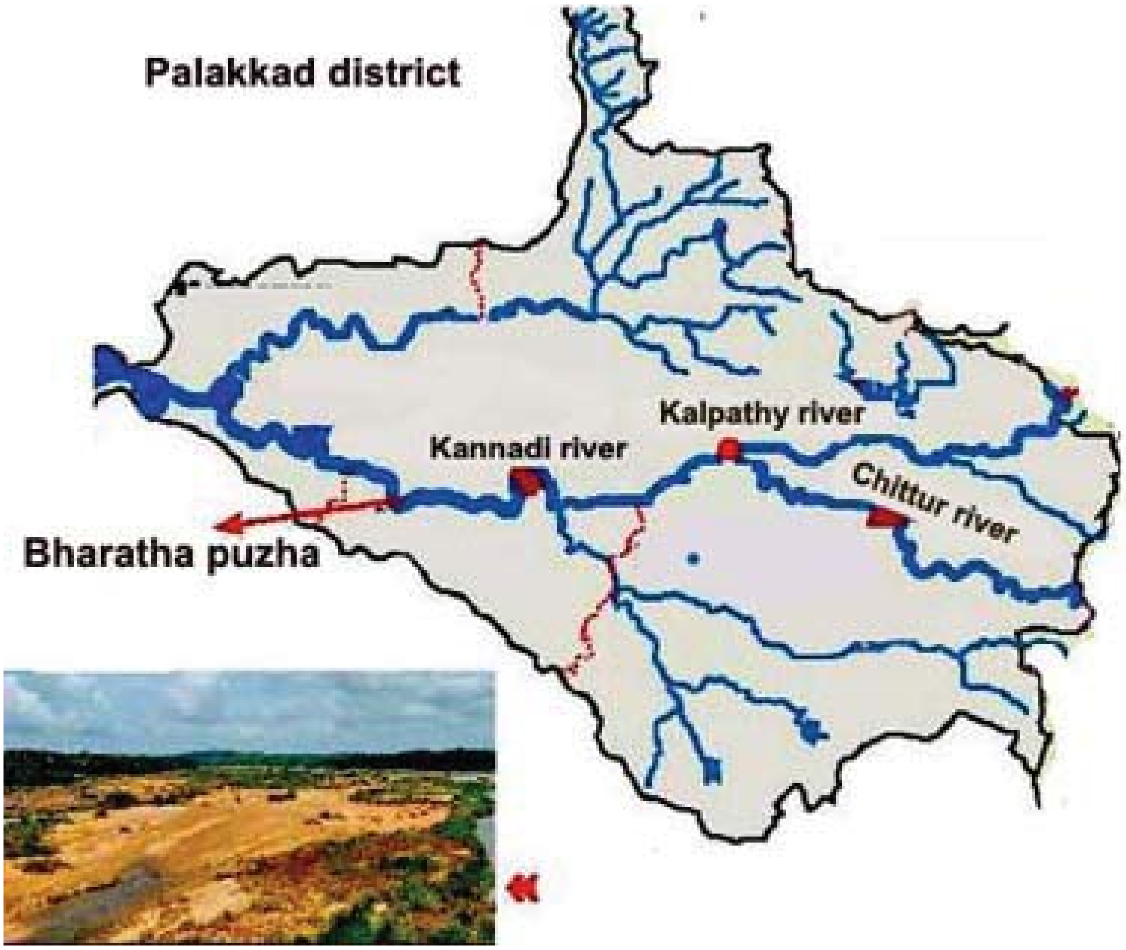
Key words: Phytoplankton, diversity index, Physico-chemical parameters, Seasonal changes.

Introduction

Phytoplanktons constitute the primary producers in both freshwater and marine ecosystems and have substantial role in calcification, silicification and nitrogen fixation (Baliarsingh *et al.*, 2012; Singh and Swarup, 1980). Facts on taxonomy of phytoplankton are vibrant to study the community dynamics in spatio-temporal scale (Gameiro *et al.*, 2007). Documentation to lively environment is a valuable thing as species composition and density of phytoplankton are sensitive to environmental changes. Varied human actions in river ecosystems can affect in alteration of water quality (leading to eutrophication), and introduction of non-native species. As a result, blooms of both non-toxic or toxic phytoplanktons arise, influencing the seasonal patterns of dominant phytoplankton community structure, thereby distressing or polluting physical, chemical and biological characteristics of water bodies. Pollution in rivers depends on the number of people living on its banks, their cultures and commercial growth. Pollution of the major rivers of India through discharge of industrial effluents and domestic sewage are the major threat in recent times (Singh *et al.*, 2007). The physicochemical aspects of river water were reported by (Gurumayum *et al.,* 2002; Deshmukh and Ambore, 2006; Santhosh, 2007; Eknath, 2013). Several scientific papers reported the existing status of Indian rivers that are in a dangerously deteriorated situation due to pollution (Biswas and Konar, 2000; Kumari and Rani, 2008; Singh *et al.*, 2007; Yazdandoost *et al.*, 2001a,b). The river water resources in Kerala State are subjected to substantial stress due to changes in riverine ecology (Joy *et al.*, 1990; Koshy and Nayar, 2001; Sankar *et al.*, 2002; Harilal *et al.*, 2004; Joseph and Tessy, 2010; Thomas and Paul, 2015; Sreenisha and Paul, 2016). The water quality is fluctuating hastily due to human activities. This anthropogenic pollutant influx are the crucial sources of change in water quality that led the scientific community for systematic monitoring (Baliarsingh *et al.*, 2012). The phytoplankton due to its importance in ecosystem requires regular study under such fluctuating environment. We focused this study as a first attempt in this river to explore the phytoplankton composition simultaneously with seasonal changes. The outcome of this study will certainly useful for environmental monitoring and impact assessment work.

Study area

Bharathapuzha river or 'Nila' River, the second largest river in Kerala State, with a total length of about 209 km, with a large basin of 6186 sq. km. The average catchment area of the river Bharathapuzha is 1828 mm. The river originates from Aanamalai Hills at Tamil Nadu in the Western Ghats and flows through Coimbatore district of Tamil Nadu, and Palakkad, Malappuram and Thrissur districts of Kerala and finally empties into the Arabian Sea at Ponnani. The major land utilization of Bharathapuzha basin includes forest (26%), cultivated area (52%), fallow (8%) and barren and cultivable land (5%). The major portion of crop is rice followed by coconut and rubber. It is popular for its geo-physical value as well as its cultural and historical significance. The river valley is considered as the frame of civilization in Kerala and have significant role in the cultural formation of Keralites. Nearly one-eighth of the total population in the state depends on the river for various resources. The main tributaries of Bharathapuzha river are Gayathripuzha,



Map 1: Map of Palakkad district showing Bharathapuzha River with sampling sites.

Chitturpuzha, Kalpathipuzha and Thuthapuzha. From the confluence of Kalpathipuzha and Chitturpuzha at Parali, the river acquires the name Bharathapuzha. Three tributaries selected for the current study, Station 1 (Chittur river), Station 2 (Kalpathy river) and station 3 (Kannadi river) (Map 1). Kannadi river along with the kalpathy and Gayathrpuzha irrigate a major portion of the Palakkad district. Station-1 lies on latitude 10.746972°N and longitude 76.6652°E, has a lot of anthropogenic activities around it. Station-2 lies on latitude 10.7471136°N and longitude 76.3935686°E, is characterized by various cultural worships on the banks of this river. Station-3 lies on latitude 10.918532°N and longitude 76.430962°E with dominant grass vegetation and heavy construction.

Materials and methods

The present research work was carried out on fixed sampling points during three seasons such as pre-monsoon, monsoon and post-monsoon of year 2018–2019. Phytoplankton samples were collected from surface and stored in polythene bottles after preservation in 4% formalin. After concentrating the sample by sedimentation method, 1 ml of sample was taken and examined with a Sedgwick rafter counting chamber under a compound microscope with different magnifications. The average count was taken to get the relative number of organisms per ml of original water sample. For taxonomic identification, standard literature and monographs were referred. Identification of phytoplankton organisms was done by consulting published works of Prescott (1962), Sarode and Kamat (1979), Philipose (1967) and Fritsch (1935). Diversity indices were used for the ecological data analysis using Past and Sigma Plot. Simultaneously with algal sampling, Temperature, pH, Conductivity, TDS, Nitrate, Phosphate, Silicate, DO, BOD and algal abundances are assessed for each sample. This analysis was useful to obtain quantitative information on the relationship between species and environmental variables.

Results and discussion

In Bharathapuzha, algae are studied from three selected tributaries namely Chittur, Kalpathy and Kannadi. Physical, chemical and biological lines are frequently considered as basic monitoring methods, for proper water management systems (Rosenberg and Resh, 1993). The taxonomic analysis of algal diversity in tributaries of Bharathapuzha revealed 81 species belonging to 6 algal classes among which Bacillariophyceae prevailed, then Chlorophyceae and Euglenophyceae (Table 1). Among algae, *Synedra, Gomphonema*, *Navicula* and *Scenedesmus* succeeded in all stations. As on (Table 2), total of 36 genera and 81 species belongs to Chlorophyceae (11 genera, 25 species; Plate 1, figs. A–H; Plate 3, fig. H) Bacillariophyceae (13 genera, 40 species; Plate 2, figs A–H; Plate 3, figs. A–E) Cyanophyceae (6 genera, 6 species), Euglenophyceae (4 genera, 8 species; Plate 3, fig. F) Xanthophyceae (1 genus, 1 species) and Dinophyceae (1 genus, 1 species; Plate 3, fig. G). Acccording to the species sensitivity towards pH, all species in study area belongs to alkaliphiles because of their resistance in high pH. Algal indicators of organic pollution according to Wang *et al.* (2014) and Watanabe *et al.* (1986), assigned to 4 species with a prevalence of *Synedra ulna, Cyclotella meneghiniana, Trachelomonas volvocina* and *Pinnularia viridis.* By comparing the details of all three study stations, more algal species seen in Station 1 and Station 3, but least number of species and high diversity observed in station 2. Dominant group included the members of the Bacillariophyceae occur in Station 1, followed by Station 2, next domoinant group is Chlorophyceae in both stations (Fig. 1). By analysing seasonal variations, high dominance of species seen in pre-monsoon, then monsoon season (Fig. 2). Cyanophyceae, Englenophyceae, Xanthophyceae and Dinophyceae counts were low compared to the observations in Bacillariophyceae and Chlorophyceae groups.

pH in all study stations varies from 8.2–9.4, highly alkaline. Conductivity and TDS show marked increase in Post-monsoon season. At the same time, pH is observed high in pre-monsoon. Concentrations on nitrate and silicate high at pre-monsoon,

Table 1: Composition and abundance of Phytoplankton.

Sl. No.	Name of the species	*Pre-monsoon	*Monsoon	*Post-monsoon
	Chlorophyceae			
1	*Scenedesmus hystrix* Lagerheim	8	6	4
2	*Scenedesmus quadricauda* (Turnip) Bebisson	12	10	6
3	*Scenedesmus dimorphus* (Turnip) Kuetzing	4	–	–
4	*Scenedesmus bijugatus* (Turnip) Kuetzing	12	–	–
5	*Scenedesmus acuminatus* (Lagerheim) Chodat	25	–	18
6	*Pediastrum duplex* Meyen	8	13	4
7	*Pediastrum tetras* (Corda) Hansgirg	16	8	–
8	*Pediastrum integrum* Naegeli	12	10	8
9	*Cosmarium granatum* Breb.*ex* Ralfs	16	12	–
10	*Cosmarium retusiforme* (Wille) Gutw.	28		18
11	*Cosmarium blyttii* Wille	2	–	10
12	*Closterium calosporum* Wittr.	6	–	–
13	*Closterium intermedium* Ralfs	5	–	4
14	*Euastrum spinulosum* Delp.	6	4	–
15	*Cosmarium portianum* Arch.	12	8	–
16	*Pediastrum simplex* Meyen	8	6	1
17	*Staurastrum crenulatum* (Nag.) Delp.	12	8	4
18	*Golenkinia radiata* Chodat	9	–	3
19	*Pandorina morum* (Mull.) Bory	25	12	4
20	*Cosmarium medioscrobiculatum* West & West	8	–	–
21	*Micrasterias sp.*	–	–	8
22	*Cosmarium auriculatum* Reinsch	4	6	–
23	*Arthrodesmus sp.*	16	–	6
24	*Closterium validum* West & West	8	6	–
25	*Tetraedron sp.*	6	2	8
	Bacillariophyceae			
26	*Cymbella tumida* (Breb.) Van Heurek.	32	28	36
27	*Gomphonema gracile* Ehr.	24	28	32
28	*Gomphonema subapicatum* F.E.Fritsch & M.F.Rich	28	22	10
29	*Gomphonema parvulum* (Kuetz.) Grun.	29	24	8
30	*Rhopalodia gibba* (Ehr.) Muell.	24	16	18
31	*Gomphonema subventricosum* Hustedt	24	18	–
32	*Cymbella hungarica* (Grunow) Pantocsek	21	–	–
33	*Nitzschia closterium* W. Smith	32	28	16
34	*Nitzschia obtusa* W. Smith	39	26	19
35	*Synedra ulna* (Nitz.) Ehr.	52	29	38
36	*Pinnularia acrosphaeria* Rabenhorst	–	21	–

Table 1: (Continued)

Sl. No.	Name of the species	*Pre-monsoon	*Monsoon	*Post-monsoon
37	*Navicula pupula* Kuetz.	28	18	10
38	*Cymbella laevis* Nageli	19	9	16
39	*Gomphonema lanceolatum* Ehr.	25	–	–
40	*Navicula rhynchocephala* Kuetz.	29	5	8
41	*Nitzschia intermedia* Hantzsch	–	–	14
42	*Cymbella osmanabadensis* Sarode & Kamat	5	–	–
43	*Navicula cuspidata* Kuetz.	38	27	37
44	*Cyclotella glomerata* H.Bachmann	28	12	8
45	*Pinnularia braunii* (Grun.) Cleve	28	18	–
46	*Pinnularia sudetica* (Hilse) Hilse	18	22	22
47	*Gomphonema montanum* (J.Schumann) Grunow	30	21	3
48	*Pinnularia divergens* W.Smith	–	15	12
49	*Gyrosigma acuminatum* (Kuetz.) Rabh.	13	8	4
50	*Synedra acus* Ehrenberg	37	28	–
51	*Cymbella tumidula* Grunow	24	14	16
52	*Cyclotella meneghiniana* Kuetz.	15	–	–
53	*Melosira granulata* (Ehr.) Ralfs	50	23	29
54	*Navicula mutica* Grunow	8	5	–
55	*Surirella tenera* Gregory	–	17	18
56	*Gyrosigma distortum* (W.Smith) Griffith & Henfrey	23	12	–
57	*Surirella capronioides* Gandhi	18	–	9
58	*Pleurosigma salinarum* (Grunow) Grunow	14	8	8
59	*Nitzschia hungarica* Grunow	6	–	5
60	*Surirella robusta* Ehr.	26	18	5
61	*Navicula halophila* (Grun.) Cleve	16	8	–
62	*Pinnularia hartleyana* Greville	8	–	14
63	*Pinnularia viridis* (Nitz.) Ehr.	28	16	18
64	*Hantzschia sp.*	18	6	4
65	*Fragilaria intermedia* Grun.	18	–	12
	Euglenophyceae			
66	*Strombomonas fluviatilis* (Lemm.) Defl.	26	16	18
67	*Phacus longicauda* (Ehr.) Dujardin	19	16	–
68	*Euglena acus* Ehr.	26	12	16
69	*Phacus acuminatus* Stokes	–	6	–
70	*Euglena oblonga* Schmitz.	24	17	3
71	*Trachelomonas armata* (Ehr.) Stein.	14	7	5
72	*Trachelomonas dubia* (Swiremend) Defl.	36	16	18

(Continued)

Table 1: (Continued)

Sl. No.	Name of the species	*Pre-monsoon	*Monsoon	*Post-monsoon
73	*Euglena sp.*	–	25	18
	Cyanophyceae			
74	*Microcystis sp.*	21	8	16
75	*Spirulina sp.*	5	–	8
76	*Oscillatoria sp.*	18	16	24
77	*Aphanocapsa sp.*	–	6	16
78	*Chroococcus turgidus* (Kuetz.) Nag.	28	18	4
79	*Merismopedia glauca* Meyen		12	18
	Xanthophyceae			
80	*Centritractus belonophorus* (Schmidle) Lemmerm.	18	3	–
	Dinophyceae			
81	*Peridinium sp.*	36	28	26
	Total Taxa	**70**	**59**	**56**
	Total individuals	**1352**	**844**	**716**

Note: *Number of phytoplankton per ml in samples.

Table 2: Diversity of Phytoplankton in study area.

Sl. No.	Algal class	Station 1			Station 2			Station 3		
		No. of genera	No. of species	%	No. of genera	No. of species	%	No. of genera	No. of species	%
1	Chlorophyceae	6	13	24	5	8	20	9	11	25
2	Bacillariophyceae	11	31	58	9	18	46	8	21	48
3	Cyanophyceae	3	3	6	4	4	10	5	5	12
4	Euglenophyceae	3	4	8	4	8	21	3	5	11
5	Xanthophyceae	1	1	2	0	0	0	1	1	2
6	Dinophyceae	1	1	2	1	1	3	1	1	2
	Total	24	53		23	39		27	44	

it provides a proper baseline for algae development. BOD also high in pre-monsoon. Dissolved oxygen low in pre-monsoon while high value in monsoon. A persual of Table 3 shows all parameters except pH and Conductivity within permissible limit. Alkaline nature of water bodies and increased conductivity give information about the level of contamination especially due to anthropogenic activities. During post-monsoon season a high level of TDS and electrical conductivity along with rich species diversity are observed. This shows strong correlation between diversity along with chemical parameters.

Community structure analysis

Algal community can predict the status of pollution because of their quick response to the pollutants and Physicochemical properties. Hence this can be used

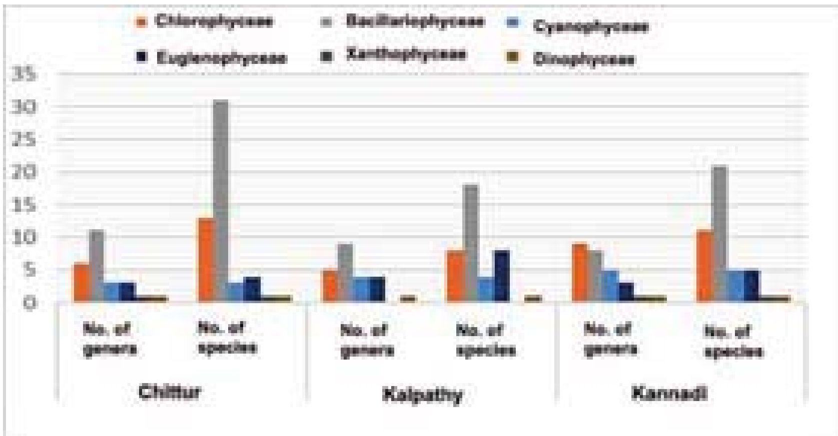


Fig. 1: **Distribution of phytoplankton in three stations.**

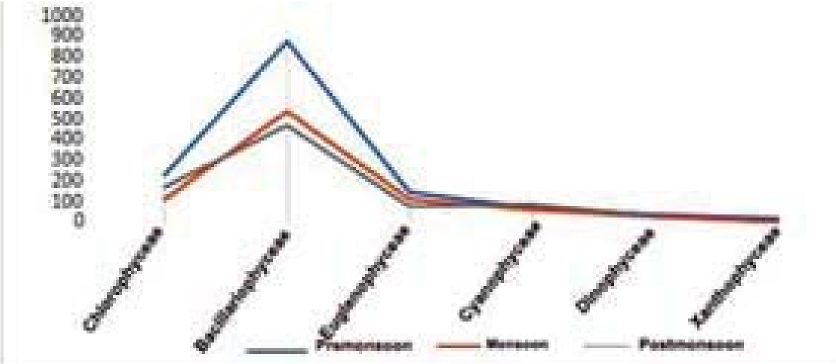


Fig. 2: **Distribution of Phytoplankton during different seasons.**

Table 3: **Results of Physicochemical parameter analysis.**

Sl. No.	Parameters	Station 1			Station 2			Station 3			Permissible limit (BIS)
		Pr-M	M	Po-M	Pr-M	M	Po-M	Pr-M	M	Po-M	
1	Temperature °C	30.2	29.1	27	34.2	31.6	28.2	33.5	31.5	28.6	–
2	pH	8.7	8.5	8.8	9.0	8.2	8.4	9.4	8.8	8.9	6.5–8.5
3	Conductivity	433	397.6	556	216	177	752	272	416	506	250
4	TDS (mg/L)	209	174.6	272	104	99	355	131	192	246	500
5	Nitrate(mg/L)	0.46	0.05	0.06	0.47	0.02	0.05	0.52	0.04	0.05	45
6	Phosphate(mg/L)	0.16	0.03	0.07	0.14	0.03	0.04	0.12	0.01	0.02	5
7	Silicate(mg/L)	2.45	1.29	1.53	2.72	0.44	1.05	2.12	1.25	0.64	
8	DO (mg/L)	5.7	7.5	6.6	6.5	7.5	6.4	7.0	7.6	7.1	–
9	BOD	0.8	0.1	0.6	1.9	0.2	0.9	0.4	0.3	0.5	–

Note: Pr-M-Pre-monsoon; M-Monsoon; Po-M-Post-monsoon.

to classify water bodies. According to Nygaard (1978), compound quotient values obtained from the study indicate the intensity of pollution. A compound quotient of value 6.5 in the present study indicates the Eutrophic nature of the entire study area. In 1965, Patrick suggested an idea to the pollution status of water bodies by evaluating algal community. Desmids, Bacillariophyceae,

Table 4: Ecological indices in different seasons.

Sl. No.	Diversity indices	Pre-monsoon	Monsoon	Post-monsoon
1	Taxa	70	59	56
2	Individuals	1352	844	71
3	Simpson	0.9815	0.9782	0.9736
4	Shannon	4.094	3.932	3.799
5	Mergalef	9.571	8.608	8.367

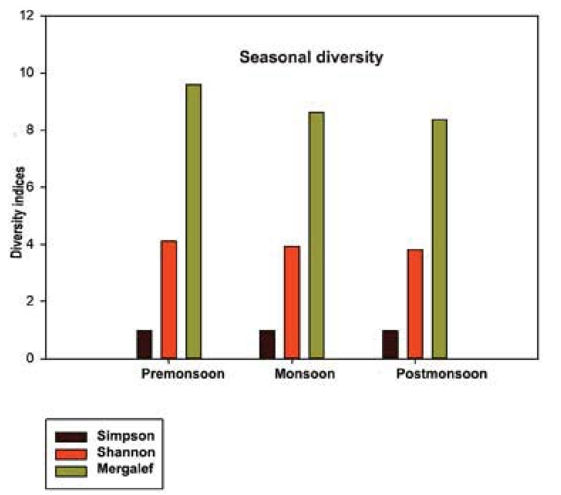


Fig. 3: Diversity profile in different seasons.

Table 5: Ecological indices in different stations.

Sl. No.	Diversity indices	Station 1	Station 2	Station 3
1	Taxa	38	17	29
2	Individuals	836	445	455
3	Simpson	0.9674	0.9272	0.9551
4	Shannon	3.496	2.712	3.218
5	Mergalef	5.499	2.624	4.575

Cyanophyceae and Euglenophyceae are used to accomplish meaningful evaluation of degree of pollution. Index value is 3.71. By analysing Palmer index (1969), with a high value that is above 20 also indicates the density of pollution may be due to enrichment of nutrients and phytoplanktons. Prasad *et al.* (1988) emphasized the importance of biological

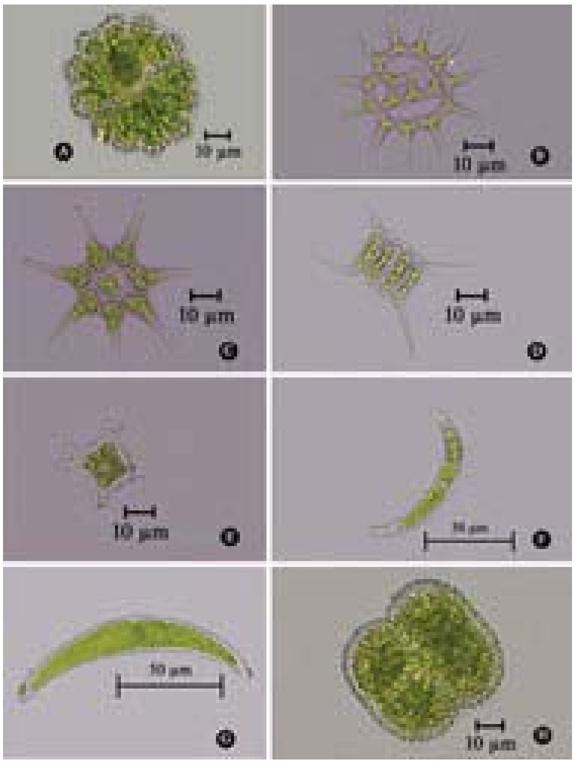


Plate 1: (A) *Euastrum spinulosum* Delp. (B) *Pediastrum simplex* Meyen (C) *Pediastrum integrum* Nageli (D) *Scenedesmus quadricauda* (Turnip) Bebisson (E) *Tetraedron* sp. (F) *Closterium calosporum* Wittr. (G) *Closterium intermedium* Ralfs (H) *Cosmarium* sp.

survey in monitoring water quality, which is dependent on qualitative and quantitative composition of aquatic population. Among the species diversity profile in all the three stations and seasons, high in post-monsoon but total taxa and species richness high in pre-monsoon season and least in post-monsoon. Shannon and Mergalef indices also high in pre-monsoon (Table 4 and Fig. 3).

The diversity index of the phytoplankton among the sample stations showed that species richness and evenness highest in station 1 followed by station 3 and least in station 2 (Table 5). Least value of Simpson index signifies

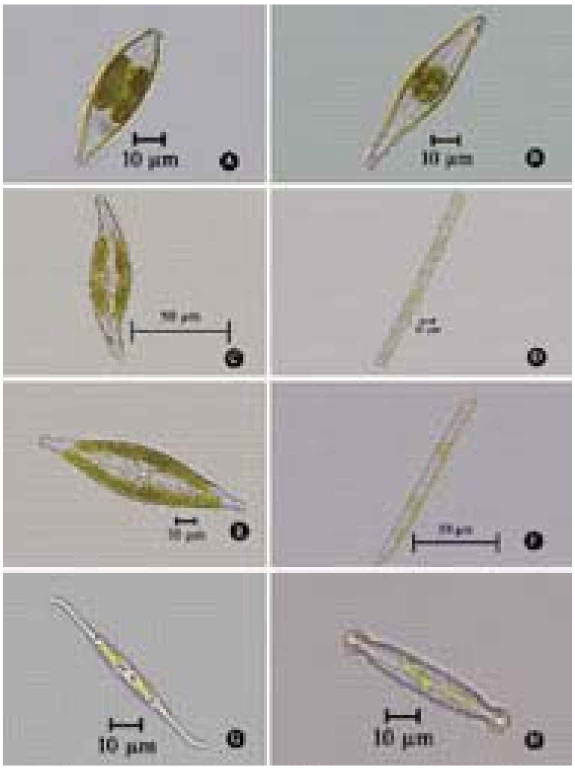


Plate 2: **(A)** ***Gomphonema montanum*** **(J. Schumann) Grunow (B)** ***Gomphonema gracile*** **Ehr. (C)** ***Gyrosigma distortum*** **(W. Smith) Griffith & Henfrey (D)** ***Melosira gramulata*** **(Ehr.) Ralfs (E)** ***Navicula cuspidata*** **Kuetz (F)** ***Nitzschia obtusa*** **W. Smith (G)** ***Nitzschia closterium*** **W. Smith (H)** ***Pinnularia braunii*** **(Grun.) Cleve.**

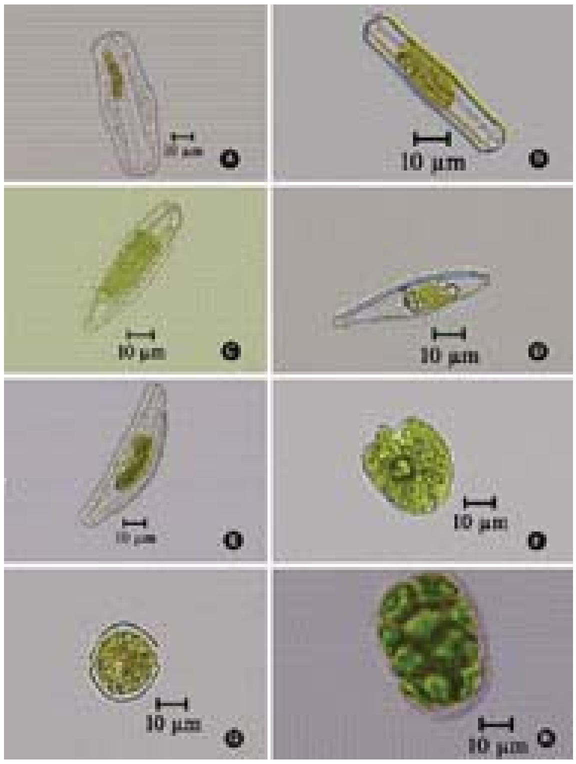


Plate 3: **(A)** ***Rhopalodia gibba*** **(Ehr.) Muell. (B)** ***Pinnularia acrosphaeria*** **Rabenhorst (C)** ***Surirella capronioides*** **Gandhi (D)** ***Gomphonema subapicatum*** **F.E. Fritsch & M.F. Rich (E)** ***Cymbella tumida*** **(Breb.) Van Heurek (F)** ***Phacus acuminatus*** **Stokes (G)** ***Peridinium*** **sp. (H)** ***Pandorina morum*** **(Mull.) Bory.**

that there is the low probability that any two individuals drawn at random from a population belong to the same species. This results in higher species diversity observed in station 2. Low Simpson dominance index results in higher diversity and *vice versa* (Ogbeibu, 2005). Like that a higher species diversity is observed in post-monsoon but species richness and evenness in pre-monsoon (Table 4). Generally low diversity observed in the study, represents a situation where most of the individuals belong to the same species. The cosmopolitan forms represent those found everywhere and most frequently encountered are *Synedra ulna*, *Melosira granulata* (Plate 2, Fig. D), *Scenedesmus quadricauda* (Plate 1, Fig. D), *Pediastrum simplex* (Plate 1, Fig. B), *Cymbella tumida* (Plate 3, Fig. E), *Navicula cuspidata* (Plate 2, Fig. E), *Euglena acus* (Plate 3, Fig. F) and *Peridinium sp.* (Plate 3, Fig. G). Other compositions that are recognized in this study are pre-monsoon and monsoon season. Dominance of Bacillariophyceae were found during pre-monsoon and Chlorophyceae during monsoon seasons. Simpson index value same in almost all the stations, facilitate to conclude that diversity was in same range. High species richness

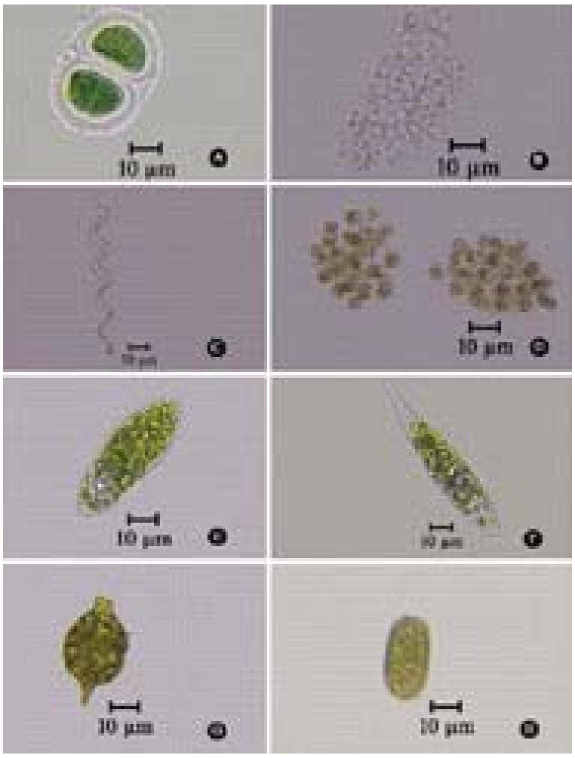


Plate 4: (A) *Chroococcus turgidus* (Kuetz.) Nag. (B) *Aphanocapsa* sp. (C) *Spirulina* sp. (D) *Microcystis* sp. (E) *Euglena* sp. (F) *Euglena acus* Ehr. (G) *Strombomonas fluviatilis* (Lemm.) Defl. (H) *Trachelomonas dubia* (Swiremend) Defl.

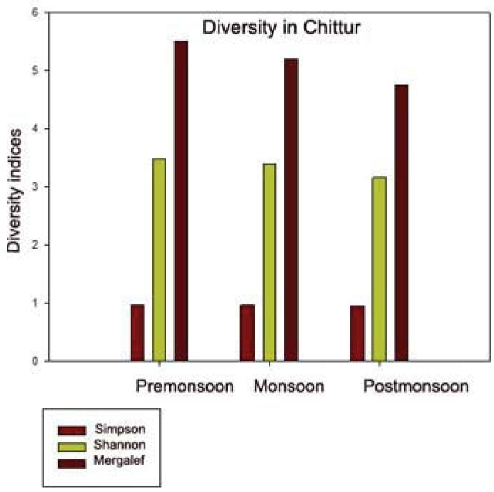


Fig. 4: Diversity profile in Chittur river.

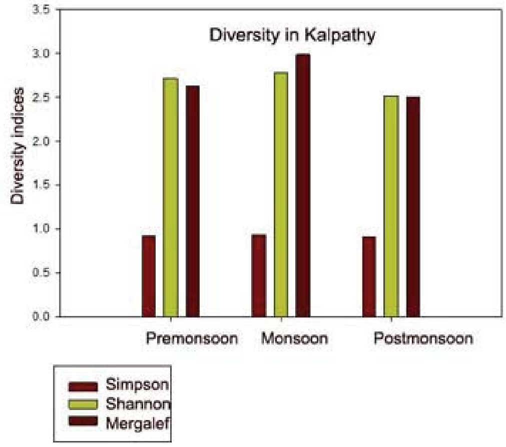


Fig. 5: Diversity profile in Kalpathy river.

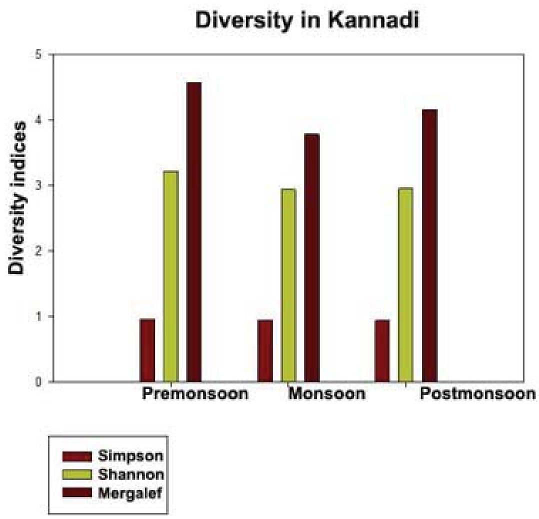


Fig. 6: Diversity profile in Kannadi river.

in pre-monsoon and station 1 (Figs. 3 and 4), then monsoon and station 2 (Figs. 3 and 6). But least value observed in post-monsoon and station 2 (Figs. 3 and 5). Comparing the total diversity profile in study area results high species richness in pre-monsoon but diversity in post-monsoon.

Conclusion

Contributions to knowledge arising from this study include the observations of

81 species of phytoplankton belonging to 6 divisions; Chlorophyceae, Bacillariophyceae, Cyanophyceae, Euglenophyceae, Xanthophyceae and Dinophyceae. Bacillariophyceae and Chlorophyceae were high compared to the observations in other algal groups. Information about the present study area is contaminated by the appearance of 12 pollution tolerant genera from the analysis of Palmer index. Marked changes in diversity and abundance of phytoplankton have been observed during post-monsoon season. TDS and Conductivity show marked increase in post-monsoon, diversity also high at post-monsoon. Studies on ecology and observation of the presence of 12 pollution tolerant algal genera from the study area reveal that the study area is organically polluted and eutrophic in nature.

Acknowledgement

The authors thank CSIR-UGC, New Delhi for the financial support and acknowledge DST FIST for their technical support throughout the study.

References

Baliarsingh, S.K., Sahu, B.K., Srichandan, S. and Sahu, K.C. 2012. Seasonal variation of phytoplankton community in navigable channel of Gopalpur Port, East Coast of India: A Taxonomic Study. *Int. J. Mod. Bot.*, **2(3)**: 40–46.

Biswas, B.K. and Konar, S.K. 2000. Impact of waste disposal on plankton abundance and diversity in the river Ganga at Hatdidah, Bihar. *Pollu. Res.*, **19(4)**: 633–640.

Deshmukh, J.U. and Ambore, N.E. 2006. Seasonal variations in physical aspects of pollution in Godavari River at Nanded, Maharashtra, India. *J. Aqua. Biol.*, **21(2)**: 93–96.

Eknath, C.N. 2013. The seasonal fluctuation of physico-chemical parameters of River MulaMutha at Pune, India and their impact on fish biodiversity. *Res. J.Animal, Veterinary and Fishery Sci.*, **1(1)**: 11–16.

Fritsch, F.E. 1935. *The structure and reproduction of the algae*, vol. 1. Cambridge University Press: London, 791 pp.

Gameiro, C., Cartaxana, P. and Brotas, V. 2007. Environmental drivers of phytoplankton distribution and composition in Tagus Estuary, Portugal. *Estuarine Coastal and Shelf Sci.*, **75**: 21–34.

Gurumayum, S.D., Daimari, P., Goswami, B.S., Sarkar, A. and Choudhury, M. 2002. Physico-chemical qualities of water and plankton of selected rivers in Meghalaya. *J. Inland Fish. Soc. India*, **34(2)**: 36–42.

Harilal, C.C., Hashim, A., Arun, P.R. and Baji, S. 2004. Hydro geochemistry of two rivers of Kerala with special reference to drinking water quality. *Ecol. Env. and Cons.*, **10(2)**: 187–192.

Joseph, R. and Tessy, P.P. 2010. Water quality and pollution status of Chalakudy River at Kathikudam, Thrissur district, Kerala, India. Nature, *Environ. Pollu. Tech.*, **9(1)**: 113–118.

Joy, C.M., Balakrishnan, K.P. and Joseph, A. 1990. Physico-chemical aspects of a tropical river receiving industrial effluents. *In*: Trivedi, R.K. (ed.). *River pollution in India.* Ashis Publishing House, New Delhi, pp. 219–236.

Koshy, M. and Nayar, V.T. 2001. Water quality of Pamba River at Pamba Triveni, Kerala. *In*: Trivedi. R.K. (ed.). *Aquatic pollu. Toxicol.* ABD Publishers Jaipur: India, pp. 167–171.

Kumari, R. and Rani, P. 2008. Ecological Investigations of Daha river of Siwan, Bihar. *Nat. Env. Poll. Tech.*, **7(2)**: 373–376.

Nygaard, G. 1978. Freshwater phytoplankton from the Narssaq area, South Greenland. *Bot. Tidsskr.*, **73**: 191–238.

Ogbeibu, A.E. 2005. *Biostatistics, A practical approach to research and data handling*. Mindex Publishing Company Ltd: Benin City, Nigeria, 264 pp.

Palmer, C.M. 1969. A composite rating of algae tolerating organic pollution. *J. Phycol.*, **5**: 78–82.

Philipose, M.T. 1967. *Chlorococcales*, I.C.A.R. Monographs on Algae, New Delhi, 365 pp.

Prasad, B.N., Srivastava, M.N. and Khanna, P. 1988. Diatoms of Kalimpong, West Bengal (India). *Geophytology*, **18(1)**: 78–86.

Prescott, G.W. 1962. *Algae of the Western Great Lakes area*. Wm. C. Brown Co., Doubuque, lowa.

Rosenberg, D.M. and Resh, V.H. 1993. *Freshwater biomonitoring and benthic macroinvertebrates*. Chapman and Hall, New York.

Sankar, P., Jayaram, P.R. and Ganga Devi, T. 2002. Studies on the hydrography of a lotic ecosystem – 'Killiar' at Thiruvananthapuram, Kerala, India. *Poll. Res.*, **21(2)**: 113–121.

Santhosh, M.A. 2007. Studies on pollution of river Nethravathi, Karnataka. *Nat. Env. Poll. Tech.*, **6(3)**: 541–542.

Sarode, P.T. and Kamat, N.D. 1979. Diatoms of Marathwada, Maharashtra-1. *Phykos*, **18(2)**: 25–32.

Singh, L.B., Pandey, P.N., Bhola Mahto and Singh, R.K. 2007. *River Pollution*. A.P.H. Publishing Corporation: New Delhi, 183 pp.

Singh, S.R. and Swarup, K. 1980. Studies on the primary production of phytoplankton in Suraha lake (Ballia, India), *Int. Rev. Hydrobiol.*, **65**: 709–717.

Sreenisha, K.S. and Paul, P.T. 2016. An Assessment of the Pollution and its Impact on the Diversity of Phytoplankton in Tirur River, Malappuram District, Kerala, India, *Int. J. Curr. Microbiol. App. Sci.*, **5(7)**: 180–190.

Thomas, M.L. and Paul, P.T. 2015. An assessment of phytoplankton and physico-chemical characteristics of Chalakudy River, Kerala. *Intl. J. Adv. Life Sci.*, **8(2)**: 197–203.

Watanabe, T., Asai, K. and Houki, A. 1986. Numerical estimation to organic pollution of flowing water by using the epilithic diatom assemblage – Diatom Assemblage Index (DAIpo). *Sci. Total Environ.*, **55**: 209–218.

Wang, X., Zheng, B., Liu, L. and Li, L. 2014. Use of Diatoms in River Health Assessment. *Annual Res. & Rev. in Bio.*, **4(24)**: 4054–4074.

Yazdandoost, M.Y. and Katdare, M.S. 2001a. The Physico-chemical studies of major rivers in Pune, India. *In*: Trivedy, R.K. (ed.). *Aquatic pollution and toxicology*. ABD Publishers, Jaipur, India, pp. 196–206.

Yazdandoost, M.Y. and Katdare, M.S. 2001b. The impact of pollution on biodiversity of phytoplankton in Pune River, India. *In*: Trivedy, R.K. (ed.). *Aquatic Pollu. Toxicol.*, ABD Publishers, Jaipur, India, pp. 227–235.

PHYTOPLANKTON DIVERSITY INDICES OF KALPATHY RIVER, PALAKKAD

Seena K. K*& Ignatius Antony

Department of Botany, St.Thomas' College (Autonomous), Thrissur

**Corresponding author:* seenakk29@gmail.com

ABSTRACT

Rivers are the most important element of physical environment and valuable resource with numerous applications. Algae are small, unicellular or multicellular organisms, some of these form colonies and reach size visible to naked eye as minute green particles and also primary producers in both fresh water and marine systems. Kalpathy river, a major headstream of Bharatapuzha, the second longest river in kerala. The present study has been carried out to know the biodiversity of fresh water algae and its effects on physical properties of river. It is a well established fact that life in water depends upon the Physico-chemical factors in the water. In this investigation water samples were collected during September –December 2018. The samples were transferred into 1000ml capacity properly labeled plastic containers and immediately preserved with 4% formalin solution. Each samples concentrated to 10ml volume in the laboratory by centrifugation and this were used for slide mount for microscopic examination. Identification of phytoplankton organisms was done by reference to standard floras, texts and monographs. A total of 28 species of phytoplanktons were identified belonging to Chlorophyceae, Bacillariophyceae, Euglenophyceae and Cyanophyceae were recorded. In terms of abundance, Chlorophyceae had the highest distribution of phytoplankton, then Euglenophyceae, Bacillariophyceae and Cyanophyceae respectively. The physico-chemical parameters studied included temperature, Nitrate, Phosphate, Silicate, pH, Electrical Conductivity and Total dissolved solids from 6 different stations. Simpson index and Mergalefs species richness index were studied. The heterogeneity and abundance of phytoplankton observed in this study shows the river to be eutrophic. This is the first documented report on the phytoplankton community structure of Kalpathy River.

Keywords:Phytoplanktons, physico-chemical parameters, species and diversity

INTRODUCTION

Phytoplanktons aresmallest and most plentiful organisms on planet earth, free-floating unicellular and colonial appearance that grow photoautotrophically in aquatic environments and play a key role in the global ecosystem (Wetzel, 1983). They are target for controlling carbon-dioxide levels in the earth's atmosphere, biological primary production and elemental cycles of the earth (Pandey, 1973).Rivers are an important part of earth's water cycle and are veins of global water with cultural, economic as well as ecological significance. Most of the world's huge cities have developed on the banks of rivers. So there is a chance of acute anthropogenic activities. Anthropogenic activities such as discharge of domestic, industrial and other activities has caused major pollution problems to these rivers. Disposal of wastes like agricultural, industrial, and domestic are reason for water contamination. This will make adverse effect on the entire life on that ecosystem. Biomonitoring of water bodies also helps to understand the composition of biota and its dynamics. Phytoplankton are important in water quality indication because of their short life cycles and ability to respond to environmental change. They are of great importance in bio-monitoring of aquatic pollution (Rishi, *et al.*, 2012), as their distribution, abundance, species diversity, species composition are used to assess the biological integrity of the water body. The aim of this study is to assess the phytoplankton community structure of Kalpathy River and to give baseline ecological information on the phytoplankton status.

Study Area

Kerala is a land blessed with diverse, luxuriant habitat types, varying topography, high rainfall and large number of water bodies.Kalpathy river originates from Anamalai hills and flows through Palakkad District.It is one of the tributary of Bharathapuzha, the second longest river in kerala. This river formed from the confluence of four tributaries, namely the Malampuzha River, Walayar River, KorayarRiver and Varattar River.MalampuzhaDam is built across this river just before it enters Palakkad town. The river is named after the Kalpathi Siva temple in Palakkad town. One of the problems faced by the Kalpathypuzha, like most other rivers in Kerala, is illegal sand mining. This has left many pits in the river bed, which leads to phytoplanktons growth. During summer the river is covered by a green carpet of Water Hyacinth and other shrubs.

MATERIALS AND METHODS

Systematic random sampling methods were adopted for collecting the water samples from rivers. Water samples collected from different stations from Kalpathy river in all the four months from September to December 2018. Keep one litre fresh samples for the phytoplankton identification and physico-chemical parameter study like Temperature, P^H, Conductivity, Total Dissolved solids, nitrate, phosphate and silicate. Samples were collected with the help of Plankton net for smaller forms and direct collection for larger ones. Collections were made from different water levels and then preserved in 4% formalin for further study. Digital images taken by Digital camera attached to microscope for further identification. Identification with the help of monographs and standard publications (Desikachary, 1959; Philipose, 1967; Prescott, 1982). Slide mounts were examined and phytoplankton organisms recorded in each mount as described by using Haemocytometer. The average count was taken to get the relative number of organisms per ml of original water sample. The following diversity indices were used for the ecological data analysis (i) Margalef species richness index (ii) Simpson's Dominance index (iii) Simpson's Reciprocal index.

RESULTS

A total number of genera 22 and species 28 belonging to Chlorophyceae (Genus-8, Species-9), Bacillariophyceae (Genus-9, Species-9), Cyanophyceae (Genus-1, Species-2), Euglenophyceae (genus-4, Species-8). Phytoplankton abundance ranged between 108 orgs/ml (station 6) and 338 orgs/ml (station 1). Due to the monthly fluctuations, Chlorophyceae Bacillariophyceae and Euglenophyceae was the dominant group of algae during the current study.

SL.NO.	PARAMETERS	AVERAGE VALUE
1	Temperature °C	27.9
2	PH	4.8
3	Conductivity mho/cm	580
4	TDS (mg/L)	260
5	Nitrate (mg/L)	0.062
6	Phosphate (mg/L)	0.0021
7	Silicate (mg/L)	1.79
9	DO (mg/L)	0.8
11	Ca (mg/L)	7.5
12	Mg (mg/L)	3.203
13	Cu (mg/L)	ND
14	Fe (mg/L)	0.864
15	Zn (mg/L)	0.008
16	Mn (mg/L)	0.011

Table 1: Results of Physico-chemical parameter analysis

ISBN: 978-93-5351-066-4

Phytoplankton	Phytoplankton Abundance (counts/ml)	Percentage Abundance (%)	No. of Species	Station	Phytoplankton Abundance (counts/ml)
Bacillariophyceae	288	24.36%	9	1	338
Chlorophyceae	432	36.54%	9	2	188
Euglenophyceae	302	25.54%	8	3	244
Cyanophyceae	160	13.54%	2	4	188
				5	116
				6	108
Total	1182		28	6	1182

Table 2: Relative Phytoplankton Abundance in Kalpathy River

No.	Name of the species	S1	S2	S3	S4	S5	S6	Total
Chlorophyceae								
1	Coelastrum sphaericum	16		32	12			60
2	Ankistrodesmus falcatus		8	4	16			28
3	Closterium gracile	48	20	4			16	88
4	Cosmarium sp.	20	16	4		8		48
5	Cosmarium quadrum		4	12	4			20
6	Pediastrum tetras		4	8	4		8	24
7	Euastrum muosum	16	32	12		4		64
8	Gonatozygon aculeatum	36			20	4		60
9	Pandorina cylindricum	4		36				40
Bacillariophyceae								

10	Achnanthes sp.			8			4	12
11	Surirella sp.	8	32			8		48
12	Melosira granulata				4			4
13	Pleurosigma angulatum	20	16		12			48
14	Stauroneis anceps		8				4	12
15	Gyrosigma acuminatum	40		36		16	12	104
16	Cymbella tumida	16	4		16		4	40
17	Pinnularia species	8						8
18	Nitzschia scalpelliformis			12				12
Cyanophyceae								
19	Chroococcus turgidus		16			32		48
20	Chroococcus tenax	32			56		24	112
Euglenophyceae								
21	Trachelomonas scabra	20			12			32
22	Phacus acuminatus	4		36	4	8		52
23	Trachelomonas superba	24		4				28
24	Strombomonas sp.				24	8	28	60
25	Phacus monilatus	18	12	4		24		58
26	Trachelomonas armata	8		20	4		8	40
27	Euglena gracilis			12				12
28	Euglena proxima		16			4		20

Table 3: Phytoplankton indices in study stations

Phyoplankton	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
Taxa	17	13	16	13	10	9

Species	338	188	244	188	116	108
Simpson's index of diversity:	0.0					
Simpson's reciprocal index:	1					
Mergalef index	3.957					

Table 4: Ecological indices of Kalpathy River

DISCUSSION

The study revealed that the water quality parameters fluctuated with sites and seasons. The growth and reproduction of phytoplankton are influenced by physico-chemical characters of water. Phytoplankton distribution in the present study results Chlorophyceae contributed the highest number of phytoplankton 36.54% followed by Euglenophyceae 25.54 % and Bacillariophyceae 24.36%. The lowest was Cyanophyceae 13.54%. Species abundance low in station 6 and high in station1. This may have resulted in the higher abundance observed in station 1. The number of green algae ranged from 8 species (Station 3) to 3 in Station 6 respectively. Bacillariophyceae ranged from 5 in station 1 to 2 in station 5. Euglenophyceae range from 5 in station 1to 2 in station 6.

CONCLUSION

Contributions to knowledge arising from this study include the observations of 28 species of phytoplankton belonging to 4 divisions; Bacillariophyta, Chlorophyta, Euglenophyta and Cyanophyta, the river is now recognized as a water body having a wide array of phytoplankton that is floristically rich and diverse.

ACKNOWLEDGEMENTS

I wish to acknowledge, Dr.Ignatius Antony, Dr.Anto P.V, Dr. C.D Varghese, and Dr.Joby Paul Department of Botany, St.Thomas' College, Thrissur for their immense contributions and super vision of this investigation.

REFERENCES

1. Arulmurugan, P., Nagaraj, S. and Anand, N. (2010) Biodiversity of freshwater algae from Temple tanks of Kerala. *Recent Research in Science andTechnology*, 2(6): 58-71.
2. Bachan, A. (2011) Riparian Flora of Chalakkudy river basin and its ecological significance. Ph.D thesis submitted to Calicut University, India.
3. Bhagyaleena ,P. and Gopalan,R. (2012) Aquatic plant diversity of ponds in Nemmara Panchayath, Palakkad district, Kerala, India. *Intern.J.of Scientific and Research publications*, 2(8):38-41.
4. Desikachary,T.V.(1959) Cyanophyta-ICAR Monograph on algae. ICAR, New Delhi, India. 666 pp.
5. Tessy, P.P. and Sreekumar, R. (2008). A report on the pollution algae from the Thrissur Kol wetlands (part of Vembanad-Kol, Ramsar site), Kerala. *Nat. Environ. Polln. Tech.,* 7(2): 311–314.

REVIEW
MICROALGAE:-A POTENTIAL SOURCE

Seena k.k., Dr.Ignatius Antony, Dr.Anto P.V.
Research Scholar, Associate Professor, Assistant Professor
Department of Botany, St.Thomas' College, Thrissur, Kerala, India

Abstract:

This review presents an overview on the potentiality of microalgae on the global demand for renewable biofuels, biological sequestration of CO2, waste water treatment, production of bioactive compounds, food additives and biotechnology. As global population and consequent energy need increase the introduction of renewable energy sources becomes a serious matter. Many research reports and articles described many advantages of microalgae especially for the production of valuable compounds or for energetic use is widely recognized due to their more efficient utilization of sunlight energy as in comparison with other available feed stocks. The prospects of microalgae in development of biodiesl is not very recent and dates back to 1978, when the US Department of Energy started a program named "Aquatic species Program –Biodiesel from Algae". Microalgae present in all existing ecosystems, can live in wide range of environmental conditions and have much higher growth rates and productivity. In the current review we will highlight on the utility of microalgae has made a more attractive alternative source for the future.

Key Words: **Microalgae; Biofuel; Biodisel; Forensic study; Lipid productivity; Waste water treatment;**

1.Introduction:

Microalgae are abundant microorganisms, which are found in freshwater and marine environments. They are critical to universe because they can produce the bulk of oxygen on Earth through photosynthesis; they produce approximately half of the atmospheric oxygen. Because they are Photoautotrophs, with minimal nutritional requirements, microalgae have more advantages compared to other cellular organisms. These microorganism-derived enzymes contain cellulases, proteases, lipases, amylases, antioxidant enzymes etc. Their growth and structural composition depends on different physical factors especially CO2, light intensity (17, 20), pH and also nutrients; mainly high lipid content (2,6,22,37). A significant positive correlation holds for chloride with PH, Mg, Na, Hardness and TDS; sodium with hardness, EC and sulphate. Negative correlation between potassium and turbidity (10, 111). Microalgal species can synthesize high value chemical products, such as carotenoids, antioxidants, fatty acids, and sterols. Green microalgae used as nutritional suppliment due to rich source of essential nutrients (63). It can use sunlight very efficiently and produce oils like plants (109). Microlagae possess high biomass productivity, oil content, growing in variety of environmental conditions, high growth rate, utilizing sunlight and other nutrients (106,68,60). They utilize huge fraction of solar energy and converted it to chemical energy (72, 34). Most recently, microalgae have become an attractive raw material of biofuel, in the form of biodiesel (28,65). They appear to be the only renewable source of biodiesel and also capable of meeting the global demand for transport fuels (119). Release of organic and inorganic substances to water; mainly from anthropogenic activities leads to organic and inorganic pollution (79,56). Microalgae have the ability to utilize inorganic nitrogen and phosphorus for their growth, so they are capable to remove heavy metals and toxic compounds (90,76) accumulate huge amount in their body and form microalgae biomass (46). Green house gases mainly from anthropogenic activities adversely affect not only global warming but also to environment and human life. Removal of CO2 from oceans mostly by algae bio-fixation, thereby reducing green house gases (83). Numerous studies have extensively reviewed about the potentialities and advantages of microalgae as biofuel, biomass cultivation, food suppliment, lipid extraction, lipid productivity and reduced cost of production(129,118). Abiotic factors can directly or indirectly influence the phytoplanktons diversity (55).

2.Viability of microalgae for biofuel:

Global climatic change and increase in atmospheric CO2 is a direct result of combustion of Petroleum for different purposes, has motivated an urgent need to develop more eco-friendly and renewable alternative to displace the present status (64,115), algae based fuels can meet this criteria (40,74). Unicellular microorganisms commonly used as biofuel production is that they are more efficient in conversion of light and nutrients into valuable products. A supportive benefit of using microalgae for biofuel production is the potential value of the spent biomass used as animal feed, also has significant contribution to the value of algal biomass (108).

In 1998, the aquatic species Program recommended a list of 50 microbial strains selected from different pools, which held the most promise as biofuel production organisms. Microalgae have the potentiality to provide the renewable fuel feed stock through utilization of non-potable water and non-arable lands, techniques for cultivation with high nutrient demands (35). Oleaginous microalgae are well known candidates for renewable energy production because of high biomass (128,31,32). In the case of diatoms, nutrient deficient conditions show maximal growth rate, this will induce tremendous amount of Triacylglycerol (TAG), it translated to biofuel which are real characteristics for biofuel production (58,33). The prime species applicable to biofuel production are Chlorophyceae family (Ulva and Caulerpa), red green growth (Gigartinales, Halymeniales, Palmariales), green growth (Fucales, Laminariales). They can be developed on sewage, waste water etc. (66). Under stressful environments, algae may switch carbon allocation from reproduction to oil production (27). Diatoms as fourth-generation biofuels. The aim of the so called fourth-generation biofuel is to co-opt basic biochemical pathways to generate photoautotrophic algal strains with high lipid yield (38,26,116). Growing diatoms as feedstock for biofuel production could displace all petroleum consumption in USA (74). Algal biofuels obtained from the solvent extraction of algal lipids through High pressure homogenization (HPH), enzymatic, microwave, ultrasound, acid pretreatment can be compared in terms of energy recovery and consumption (31,50,135). The energy input for the acid pretreatment is lower compared with other cell disruption models (31).

3.Microalgae and Boidiesel:

Microalgae are of significant because of the presence of high yields of oil, mainly triacylglycerol (TAG), that can be converted to biodiesel through esterification (33,16). Microalgae forms sustainable renewable energy source for biodiesel (9,114,71,134) like other resource which need well agricultural land and sophisticated technologies for their commercial production (122,112,51,68). It obtained from vegetable oils and animal fats through trans esterification process (30,88). General equation for transesterification reaction is shown in figure 1.

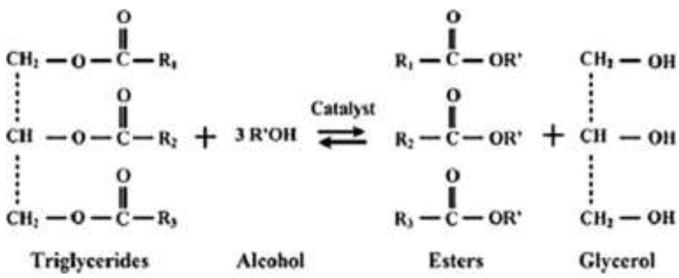


Figure 1: Shows General equation for Transesterification reaction

Yet this also can leads to food scarcity, deforestation because excess use of land, using fertilizers which harms environment (109). Biodiesel production is a well established one with soybeans, canola oil, palm oil, corn oil and waste cooking oil, most common commercial uses (11,40,118). Many research works reported that microalgae are more advantages than other available feedstocks for biodiesel production (75,117,60). Table1 shows comparison of different sources of biodiesel (126,46,7,4,109).

Biodiesel source	Oil yield (Liter oil/ha)	Land use (m2/GJ)	Energy (GJ/ha)	Water required (m3/GJ)
Soybean	446	689	15	383
Rapeseed	1190	258	39	383
Palm oil	5906	52	192	75
Sunflower	951	323	31	61
Jatropha	1896	162	62	396
Microalgae	**24355-136886**	**2-13**	**793-4457**	**<379**

Table 1. Comparison of different sources of biodiesel

4.Lipid Productivity:

Microalgae are unique photosynthetic organisms given that they accumulate lipids in substantial quantities at lower CO_2 concentrations (78) and thrive in high-salinity water. Microalgal biomass rich in lipid and nonlipid contents; lipids are potential source of biofuels and nonlipids are useful for the production of various chemicals (22, 99). Under nutrient-replete condition, accumulation of triacylglycerol (68) in cells leading to the formation of Lipid droplets (32,107). TAG accumulation also results from silicon starvation, deprivation of nutrients like nitrogen and phosphorus (24) and cell cycle arrest, that is under stress (127,2,65,120,117,33). Diatoms, as microalgae, can store lipids into oleosomes, the amount of which increases under stress conditions (32,43). This study has revealed the presence of one specific protein presenting a quinone protein-alcohol dehydrogenase. Using a fluorescent tag, the protein was found to be targeted to the endoplasmic reticulum where it could be involved in the formation of oleosomes. Transportation of oleosomes could occur by exocytosis as observed with the Chlorophyceae algae *Dunaliella salina*. (136,49). Marine microalgae are recognised as an important renewable source of bioactive lipids with a high proportion of polyunsaturated fatty acids (PUFA), which have been shown to be effective in preventing or treating several diseases. Depending on the fatty acid characteristics, oils can be utilised in the form of surfactants, biolubricants, omega-3 fattyacids, liquid fuels and gas. Microalgae based biofuel production depends on the balance between biomass growth and lipid accumulation, whereby conditions of stress, inhibit cell growth and thus lipid productivity low. So need a combinatorial framework reveals the relationship between microalgal growth and lipid accumulation which used to balance of biomass and oil productivity from algal strains ((11). Diatoms can accumulate between 25% to 45% lipids on dry weight basis, when grown in different environmental conditions.

5.Microalgae and waste water treatment:

Water pollution is one of the most critical environmental problem. To solve this various conventional methods are used in india, but that are very costly and not economical. During last 50 years, biotreatment of waste water using Microalgae have gained more importance (86,95), it is also most effective than conventional methods. Waste water treatment using commercial use of algal cultures history spans about 75 years by the production of different strains such as Chlorella and Dunaliella (90,89,104). The intensive production and harvesting of microalgae for the removal waste water was first studied by (14), further investigations by (94). They have the ability to remove nutrients (Nitrogen, Phosphorus), heavy metals, toxic substances, BOD,COD and other impurities using sunlight, CO2 and also have the ability to fix excess CO2 present in atmosphere, release O2, thereby reducing global warming (111,45,41,93,29,105). Marine diatoms studies in India were initiated by Desikachary, studies from Arabic and Indian oceans, inlcudes fossil studies. Diatoms can reconstruct productivity and silicon cycling (59), and also exporter of organic carbon to the sea (131, 4, 134). Influence of environmental and spatial gradients on freshwater diatom community and examine its acts on freshwater bodies (53). Algal culture can treat human waste (119,86,62). Livestock wastes (77) and agricultural wastes (79). Water quality assessment using diatoms has got ecological preferences, but there also lack of proper information about taxonomic identification of diatoms (48,80), this can be reduced with quality assurance (QA), as identification exercises (70,32). Phycoremediation is an eco-friendly approach and also low cost way to remove nutrients in aqutic system, its biomass utilised for the production of fuels, fertilizers, fine chemicals and feed in agriculture (91,131,25). Presence of water treatment plants (WTPs) can efficiently reduce or remove microcystins, some hepatotoxins that are produced by Cyanobacteria. Ability of microalgae to utilise organic and inorganic substances mainmly N and P in waste water for their growth leads to decrease the concentration of these substances in water bodies and also used to the generation of energy and other products through processing (38,123,53,67). Not only chemical concentrations, but also human impacts also alter the constitution of aquatic environments, so the term biomonitoring is essential one because it provides a diagnosis of aquatic ecosystems based on the characteristic of their biota (81). Accumulation of Cd by *Scenedesmus bijugus*, nitrate and phosphate consumption by *Botroyococcus braunii* (136). Cu, Pb and chlorinated hydrocarbons by Dunaliella species. One of the dominant algal community that is diatoms can significantly provides the nutrient removal and dissolved oxygen levels in water, as major carbon carrier in deep oceans to be the main contributors to Biological carbon pump (88,39,13). The combinatorial use of diatom algae- bacteria symbiosis has been proved to provide good quality of water treating by uptaking organic matters, nutrients, contaminants and pathogens (88,81). Pollutant removal efficiency also enhanced by symbiosis between algae and bacteria (8,132). To assess metrics based on diatom ecological guilds and life forms could be used to assess the impact of chemical and physical water parameter changes in the river monitoring network (69,3,28,21). Increasing nutrient and organic matter contamination can modify the relative abundances of ecological guilds and life forms (82).

6. Biological Composition of Microalgae:

Table 2. shows microalgal composition. Micoalgae contain numerous essential vitamins such as Vitamin A, B_1, B_2, B_6, B_{12}, C, E, nicotinate, biotin, folic acid and patothenic acid. Also rich source of Carotenoids, which make microalgae a great source of essential compounds for maintaining health, pharmaceutics, cosmetics, nutraceuticals and medical industries (24,116,110).

Table 2. Shows the constituents in Microalgae:

Proteins	8-71%
Carbohydrates	4-64%
Lipids	20-50%

Nucleic acids	1-6%
Vitamins	0.4 to 554 mg kg^{-1}

7.Microalgae and high value molecules:

Microalgae can be used to produce a wide range of metabolites such as proteins, lipids, carbohydrates, carotenoids or vitamins for health, food, feed additives and cosmetics. During stress conditions, microalgae synthesize considerable amount of secondary metabolites, among these Astaxanthin- xanthophyll family of carotenoids, is one of the valuable algal compound used in food, feed, cosmetics, pharmaceuticals, powerful antioxidant, used for anti-tumour therapies (15,19,71), age related muscular degeneration, Alzheimers and Parkinson diseases (97,87). Fucoidan is a sulphated polysaccharide found in some algae, commonly used as anticoagulant, anti-thrombotic, anti-cancer and anti-proliferative (42,122,62,55). Diatom-Derived Carbohydrates have significant influence on the bacterial community. Estuaries, dominated by epipelic diatoms, they exude large amount of extracellular polymeric substances (EPS) comprising polysaccharides and glycoproteins, which provides a substantial pool of organic carbon available to heterotrophs in sediments (57).

In diatom, *Nitzschia panduriformis* frustules used for protein and viral nanoparticle adsorption, so for this frustules developed into a material useful in viral nanoparticle purification systems or as a biosensor for the detection of viruses. This was one of the first approach in which cell wall (frustule) of diatoms has been attempted to be developed as an IMAC system for the purification of recombinant proteins and viral particles through chemical modification by using IPS and IDA to immobilize Cu2+ ions, the modification being confirmed by using FE-SEM, EDS and FT-IR. adsorption of VP2-441 SVPs to the Cu2+- coupled biosilica have potential to be developed into a material useful in protein and nanoparticle purification systems (84). The chemical modification of the living diatom *Thalassiosira weissflogii* using a titania precursor, titanium (IV) bis-(ammonium lactato)-dihydroxide (TiBALDH). Its incorporation of Ti into the diatom is achieved via repeated treatment of cultures with non-toxic concentrations for enhanced metabolic insertions that prolong the exponential growth phase of the culture (78,71). A first report of apoptosis induction by galactolipids using marine diatom isolated from *Phaeodactylum tricornutum,* using the patented ApopScreen cell-based screen for apoptosis-inducing, potential anticancer compounds, its structure can be determined by using NMR, mass spectrometry and chemical degradation (11).

8.Microalgae in Forensic study:

Diatoms constitutes valuable tool in forensic studies, especially in drowning cases. These are deposited in various body parts, so can predict whether a person dead or alive at the time of drowning (27,33,68,98).Same species of diatoms seen inside the body of drowned victim as that of putative drowning medium may serve as corroborative or conclusive evidence to support the diagnosis of death.

9.Microalgae and Biotechnology:

Microalgal biotechnology really began to develop in the middle of the last century. Study on the Biotechnology in algal biomass culture (18,105,124,26), it compressed to form algal biomass is the prominent product in microalgal biotechnology used for the manufacture of powders, tablets and capsules, the major source used for this purpose is chlorella and spirulina (101,102). Phototropic microalgae are used to incorporate stable isotopes from inorganic C-sources, H-sources, N-sources, it can be used for the scientific purposes like elucidation of molecular structures (101). Applications in industrial fields such as biofuel production (96,103,74), waste water treatment (95,121), fertilizers and animal feeds (85,12,9), human food (10,73), medical compounds (56).

10.Conclusion:

Global warming and the exhaustion of fossil fuels are major world-wide problems. In the present review emphasis was placed on applications of microalgae with regard to green approaches. The productivity of microalgal lipid with respect to dry weight of biomass can be 15 to 300 times greater than that derived from plants, its photosynthetic efficiency also greater than plants range from 3 to 8%. Beside its advantages, there are still many challenges in the development of algae derived fuels including algal strain selection, cultivation and processing. Microalgal biodiesel is not yet economically viable enough to replace petroleum based fuels or other conventional energy sources. Now it was totally changed, maximum efforts on algal biofuel production, maximize lipid productivity as well as energy requirements. Microalgal cultures offer an elegant solution to waste water treatment due to its ability to use inorganic nitrogen and phosphorus for their growth and also capacity to remove heavy metals as well as toxic organic compounds, that is phycoremediation is cost effective as it saves power and many chemicals and potential for CO2 sequestration-a solution for the threat of Global warming.

10.References:

[1] Agrawal, A. K. 2007. Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progress in Energy and Combustion Science, 33: 233-271.

[2] Alonso, D.L. 2000. Acyl lipid composition variation related to culture age and nitrogen concentration in continuous culture of the microalgae Phaeodactylum tricornutum. Phytochem, 54: 461–471.

[3] Almeida, S. F. P., Elias, C., Ferreira, J., Torne´s, E., Puccinelli, C., Delmas, G., Dorflinger, G., Urbanic, G., Marcheggiani, S., Rosebery, J., Mancini, L. and Sabater, S. 2014. Water quality assessment of rivers using diatom metrics across Mediterranean Europe: a methods intercalibration exercise. Science of the Total Environment, 476–477: 768–776.

[4] Anderson, O.R. 1975. The ultrastructure and cytochemistry of resting cell formation in *Amphora coffaeformis* (Bacillariophyceae). J. Phycol., 11: 272–281.

[5] Andrade, J. E. 2012. A.Perez, P.J.Sebastian, D.Eapen, A review of bio-diesel production processes. Biomass and Bioenergy, 35:1008-1020.

[6] Aninidita, K., Karmakar, S. and Mukherjee, S. 2010. Properties of various plants and animals feedstocks for biodiesel production. Bioresource Technonology, 101 (2010) 7201-7210.

[7] Atabani, A.E., Silitonga, A.S., Irfan Anjum Badruddin, Mahlia, T.M.I. and Masjuki, H.H., Mekhilef, S. 2012. A comprehensive review on biodiesel as an alternative energy resource and its characteristics. Renewable and Sustainable Energy Reviews, 16:2070-2093.

[8] Bashan, L.E., Moreno, M., Hernandez, J.P. and Bashan, Y. 2002. Removal of ammonium and phosphorus ions from synthetic wastewater by the microalgae *Chlorella vulgaris* coimmobilized in alginate beads with the microalgae growth-promoting bacterium *Azospirillum brasilense*. Water Res., 36 : 2941–2948.

[9] Becker, E.W. 1986. Nutritional properties of microalgae: Potentials and constraints, In CRC Handbook of Microalgal Mass Culture; Richmond, A., Ed.; CRC Press: Boca Raton, FL, USA. 339–419.

[10] Becker, E.W. 2007. Micro-algae as a source of protein. Biotechnol. Adv., 25 : 207–210.

[11] Bekirogullari, M. Fragkopoulos, I.S., Pittmanc, J.K. and Theodoropoulos, C. 2017. Production of lipid-based fuels and chemicals from microalgae: An integrated experimental and model-based optimization study. Algal Research, 23: 78–87.

[12] Benemann, J.R. 1992. Microalgae aquaculture feeds, J. Appl. Phycol., 4 : 233–245.

[13] Blier, R. Laliberte, G. And De la Nou e, J. 1995. Tertiary treatment of cheese factory anaerobic effluent with Phormidium bohneri and Micractinium pusillum. Bioresour. Technology, 52:151–155.

[14] Bogan, R.H., Albertson, O.E., and Pluntz, J.C. 1960. Use of algae in removing phosphorus from sewage. Proc. Am. Soc. Civil Engrs. J. Saint. Eng. Div., SA5, 86: 1–20.

[15] Borowitzka, M.A. 2013. High-value products from microalgae-their development and commercialisation. J. Appl. Phycol., 25(3): 743–756.

[16] Brennan , L. and Owende, P. 2010. Biofuels from microalgae: a review of technologies for production, processing, and extractions of biofuels and. co-products. Renew. Sust. Energ. Rev., 14(2) : 557–77.

[17] Breuer, G., Lamers, P.P., Janssen, M., Wijffels, R.H. and Martens, D.E. 2015. Opportunities to improve the areal oil productivity of microalgae. Bioresour. Technol., 186 : 294–302.

[18] Burlew, J.S. 1953. Algal culture from Laboratory to Pilot Carnegie Institution of Washington Publication 600, Washington.

[19] Cardozo, K.H.M., Guaratini, T., Barros, T.M.P., Falcao, V.R., Tonon, A.P., Lopes, N.P. and Pinto, E. 2007. Metabolites from algae with economical impact. Comp. Biochem. Physiol. C Pharmacol., 146 : 60–78.

[20] Chen, F. and Johns, M.R. 1994. Substrate inhibition of Chlamydomonas reinhardtii by acetate in heterotrophic culture. Process Biochem., 29 : 245–252.

[21] Cherry, D.S., Currie, R.J., Soucek, D.J., Latimer, H.A. and Trent, G.C. 2001. An integrative assessment of a watershed impacted by abandoned mine land discharges. Environ. Pollut., 111 : 377–388.

[22] Chisti, Y. 2007. Biodiesel from microalgae. Biotechnology Advances, 25 : 294–306.

[23] Congestri, R., Cox, E.J., Cavacini, P. and Albertano, P. 2005. Diatoms (Bacillariophyta) in phototrophic biofilms colonising an Italian wastewater treatment plant. Diatom Research, 20(2) : 241–55.

[24] Converti, A., Casazza, A.A., Ortiz, E.Y., Perego, P. and Del Borghi, M. 2009. Effect of temperature and nitrogen concentration on the growth and lipid content of Nannochloropsis oculata and Chlorella vulgaris for biodiesel production. Chem. Eng. Process. Process Intensif., 48 : 1146–1151.

[25] Craggs, R.J., Adey, W.H., Jenson, K.R., John, M.S.S., Green, F.B. and Oswald, W.J. 1996. Phosphorus removal from wastewater using an algal turf scrubber. Water Science and Technology, 33(7) : 191–198.

[26] Cresswell, R.C. Rees, T.A.V. and Shah, N. 1989. Algal and Cyanobacterial Biotechnology. Longman Scientific and Technical, New York, 12:155-159.

[27] Csavina, J.L. Stuart, B.J. Guy Riefler, R. and M.L.Vis, M.L. 2011. Growth optimization of algae for biodiesel production. Journal of Applied Microbiology, 1365-2672.

[28] Culp, J.M., Lowell, R.B. and Cash, K.J. 2000. Integrating mesocosm experimentswith field and laboratory studies to generate weight-of evidence risk assessments for large rivers. Environ. Toxicol. Chem., 19 : 1167–1173.

[29] Deng, L. Su, Y. Su, H. and Wang, X. 2006. Sorption and desorption of lead (g) from wastewater by green algae Cladophora fascicularis, J. Hazard. Mater. Dio:10.1016.

[30] Divya, B., Tyagi, V.K. 2006. Biodiesel: Source, production, consumption, properties and its benefits. Journal of Oleo Science, 55:487-502.

[31] Dong, T., Van Wychen, S., Nagle, N., Pienkos, P.T. and Laurens, L.M.L. 2016. Impact of biochemical composition on susceptibility of algal biomass to acid-catalyzed pretreatment for sugar and lipid recovery. Algal Research, 18 : 69–77.

[32] Drebler, M., Werner, P., Adler, S., Kahlert, M., Verweij, G., Schwarz, A., van der Wal, J., Kistenich, S., Hubener, T., Fazzone, A. and Galbiati, M. 2014. First German Benthic Diatom Intercalibration Exercise. 2011/2012 .

[33] Driver, T., Bajhaiya, A. and Pittman, J.K. 2014. Potential of Bioenergy Production from Microalgae. Curr. Sustainable Renewable Energy Rep., 1 : 94–103.

[34] Dwivedi, G., Jain, S. and Sharma, M.P. 2011. Impact Analysis of Biodiesel On Engine Performance- A Review. Renewable and Sustainable Energy Review, 15 : 4633-4641.

[35] Edmundson, S. Huesemanna, M. Kruka, R. Lemmonb, T., Billingb, J., Schmidtb, A. and Anderson, D. 2007. Phosphorus and nitrogen recycle following algal bio-crude production via continuous hydrothermal liquefaction. Algal Research, 26 : 415–421.

[36] Eric, H. Andrianasolo, Liti Haramaty, Vardi, A. Eileen White, Richard L., and Falkowski, P. 2008. Apoptosis-Inducing Galactolipids from a Cultured Marine Diatom, *Phaeodactylum tricornutum.* J. Nat. Prod.,71:1197–1201.

[37] Erickson, R. and Jimenez, R. 2013. Microfluidic cytometer for high-throughput measurement of photosynthetic characteristics and lipid accumulation in individual algal cells. Lab Chip, 13 : 2893–2901.

[38] Evans, L. Sebastian, J., Hennigeb, N., Willoughbyc, N., Adebayo, J., Adeloyed, Michael S., and Tony Gutierreza. 2017. Effect of organic carbon enrichment on the treatment efficiency of primary settled wastewater by Chlorella vulgaris. Algal Research, 24:368–377.

[39] Evonne, P.Y. 1997. Polar cyanobacteria versus green algae for tertiary wastewater treatment in cool climates. J. Appl. Phycol, 9: 371–381.

[40] FAO 2008. The State of Food and Agriculture, Food and Agriculture Organization, New York, NY, USA.

[41] Field, C.B., Behrenfeld, M.J. Randerson, J.T. and Falkowski, P. 1998. Primary production of the biosphere: Integrating terrestrial and oceanic components, Sci. 281: 237–240.

[42] Fletcher, H.R. Biller, P. Ross, A.B. and Adams,J.M.M. 2017. The seasonal variation of fucoidan within three species of brown macroalgae. Algal Research, 22 : 79–86.

[43] Frada, M.J. 2013. Quantum requirements for growth and fatty acid biosynthesis in the marine diatom Phaeodactylum tricornutum (Bacillariophyceae) in nitrogen replete and limited conditions. J. Phycol., 49 : 381–388.

[44] Garbisu, C., Gil, J.M., Bazin, M.J., Hall, D.O. and Serra, J.L. 1991. Removal of nitrate from water by foam-immobilized Phormidium laminosum in batch and continuous-flow bioreactors. J. Appl. Phycol., 3 : 1–14.

[45] Gordon, R. and Seckbach, J. 2012. The Science of Algal Fuels: Phycology, Geology, Biophotonics, Genomics and Nanotechnology, Springer: Dordrecht, The Netherlands.63-68.

[46] Griffiths, M.J. and Harrison, S.T.L. 2009. Lipid productivity as a key characteristic for choosing algal species for biodiesel production. J. Appl. Phycol., 21 : 493–507.

[47] Guerra, L.T. 2013. Regulatory branch points affecting protein and lipid biosynthesis in the diatom *Phaeodactylum tricornutum.* J.Biomass Bioenergy, http://dx.doi.org/10.1016/j.biombioe.2013.1010.1007.

[48] Guiry, M.D. and Guiry, G.M. 2015. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway.

[49] Guzzon, A., Bohn, A., Diociaiuti, M. P. and Albertano, P. 2008. Cultured phototrophic biofilms for phosphorus removal in wastewater treatment. Water Research, 42(16) : 4357–67.

[50] Halim, R. Harun, R. Michael K.D. and Paul, W. 2012. A Microalgal cell disruption for biofuel development. Applied Energy, 91:116-121.

[51] Halim, R., Rupasinghe, T.W.T., Tull, D.L. and Webley, P.A. 2013. Mechanical cell disruption for lipid extraction from microalgal biomass. Bioresour. Technol., 140 : 53–63.

[52] Hall, D.O., Mvnick, H.E. and Williams, R.H. 1991. Cooling the greenhouse with bioenergy, Nature. 353:11-21.

[53] Hammouda, O., Gaber, A. and Abdel-Raouf, N. 1995. Microalgae and wastewater treatment, Ecotoxicol. Environ. Saf. 31: 205–210.

[54] Handler, M.R., Canter Christina, E., Kalnes Tom N., Lupton F., Stephen, Kholiqov Oybek Shonnard, David R., Paul and Blowers, Paul. 2012. Evaluation of environmental impacts from microalgae cultivation in open-air raceway ponds: Analysis of the prior literature and investigation of wide variance in predicted impacts. Algal Research, 1:83-92.

[55] Haroun, B.M., Sharaf, A.M. and Ibraheem, I.B.M. 1995. Evaluation of natural products in some common Egyptian marine algae. J. Union, Arab. Biol., 2(B), 137–153, 2nd International Conference, 9-11.

[56] Hawkins, R.L. and Nakamura, M. 1999. Expression of human growth hormone by the eukaryotic alga, Chlorella. Curr. Microbiol. 38 : 335–341.

[57] Haynes, K. Tanja, A., Hofmann, A., Cindy, J. Smith, S.B., Andrew, S.J., Graham, C., Underwood, and Osborn, A.M. 2007. Diatom-Derived Carbohydrates as Factors Affecting Bacterial Community Composition in Estuarine Sediments. Applied and Environmental Microbiology, 73(19) : 6112–6124.

[58] Hildebrand, M., Aubrey, K.D., Sarah, R.S., Jesse C.T. and Raffaela, A. 2012. The place of diatoms in the biofuels industry. Biofuels, 3(2).

[59] Horner, R. 2002. A Taxonomic guide to some common marine phytoplankton. biopress. Bristol, England, UK. 1–195.

[60] Hu, Q., Sommerfeld, M., Jarvis, E., Maria Ghirardi, M., Posewitz, M., Seibert, M. and Al Darzins. 2008. Microalgal triacylglycerols as feedstocks for biofuel production: perspectives and advances. The Plant Journal, 54 : 621-639.

[61] Hussein, H., Ibrahim, S.F., Kandeel, K. and Moawad, K.H. 2004. Biosorption of heavy metals from wastewater using Pseudomonas sp., Electron. J. Biotechnol. 7: 3417–3458.

[62] Ibraheem,I.B.M. 1995. Phytochemical studies on some common algae of El-Sukhna and Abu-Qir Gulf, M.Sc. Thesis, Al-Azhar Univ. Fac. of Sci. Cairo, Egypt pp.197.

[63] Indira Priyadarshani and Biswajit, R.2012. Commercial and industrial applications of micro algae – A review. J. Algal Biomass Utln.,
3:89–100.

[64] IPCC Climate Change 2013: 2013. The Physical Science Basis. In Working Group I Contribution to the IPCC 5th Assessment Report (AR5). United Nations.

[65] Jiang, Y.L. 2012. Photosynthetic performance,lipid production and biomass composition in response to nitrogen limitation in marine microalgae. Plant Physio. Bioche., 54 : 70–77.

[66] Kandula, A. 2016. Biofuel generation from microalgae, Research and Reviews. Journal of Zoological Sci. RRJZS, Special Issue-S1.

[67] Kaplan, D., Christiaen, S., Arad.1988. Binding of heavy metals by algal polysaccharides. In: Stadler, T., Mollion, J., Verdus, M.C., Karamanos, Y., Morvan, H., Christiaen, D. (Eds.), Algal Biotechnology, Elsevier Applied Science, London, pp.179–187.

[68] Kaushik, N., Pal , K.S., Sharma, A. and Thakur, G. 2017. Role of Diatoms in Diagnosis of Death Due to Drowning: Case Studies. International Journal of Medical Toxicology and Forensic Medicine, 7(1) : 59-65.

[69] Kelly, M., Bennion, H., Burgess, A., Ellis, J., Juggins, S., Guthrie, R.., Jamieson, J., Adriaenssens, V. and Yallop, M. 2009. Uncertainty in ecological status assessments of lakes andrivers using diatoms. Hydrobiologia, 633 : 5–15.

[70] Kiran, M.T., Bhaskar, M.V. and Tiwari, A. 2016. Phycoremediation of Eutrophic Lakes Using Diatom Algae. Lake Sciences and Climate Change, 104-115.

[71] Koller, M., Muhr, A., Braunegg, G. 2014. Microalgae as versatile cellular factories for valued products. Algal Res., 6 : 52–63.

[72] Kumar, M., Sharma, M.P. and Gaurav, D. 2013. Algae Oil as Future Energy Source in Indian Perspective. International journal of Renewable energy research, 3(4) : 15-19.

[73] Lane, K. E.Derbyshire, E. W. Li, W. C.Brennan, C. 2014. Bioavailability and potential uses of vegetarian sources of omega-3 fatty acids: A review of the literature. Crit. Rev. Food Sci. Nutr. 54 (2014) 572–579.

[74] Levitan, O., Dinamarca, J., Hochman, G. and Falkowski, P.G. 2014. Diatoms: a fossil fuel of the future. Trends in Biotechnology, 32(3).

[75] Li, Y., Horsman, M., Wu, N., Lan, C.Q. and Dubois-Calero, N. 2008. Biofuels from microalgae. Biotechnology Progress, 24(4) : 815–20.

[76] Lim, S., Chu, W. and S. Phang. S. 2010. Use of *Chlorella vulgaris* for bioremediation of textile wastewater, J. Bioresour. Technol. 101: 7314–7322.

[77] Lincoln, E.P. and Hill, D.T. 1980. An integrated microalgae system. In: Shelef, G., Soeder, C.J. (Eds.), Algae biomass, 229–243.

[78] Lv, J.M., Cheng, L.H., Xu, X.H., Zhang, L. and Chen, H. L. 2010. Enhanced lipid production of *Chlorella vulgaris* by adjustment of cultivation conditions. Bioresour Technol., 101 : 6797–6804.

[79] Ma, A.N., Cheah, S.C. and MChow, M.C. 1990. Current status on treatment and utilization of palm oil industrial wasters in Malaysia. Special coordination meeting of the working group on environmental biotechnology, Kuala Lumpur.

[80] Mann, D.G. and Vanormelingen, P. 2013. An inordinate fondness? The number, distributions, and origins of diatom species. Journal of Eukaryotic Microbiology, 60 : 414–420.

[81] Marcel, R., B. Agnes, B. and Rimet, F. 2013. Influence of herbicide contamination on diversity and ecological guilds of river diatoms. Cryptogamie, Algol., 34 : 169–183.

[82] Marcel, R., Berthon, V., Virginie Castets, Frederic R. and Thiers, A. 2017. Modelling diatom life forms and ecological guilds for river Biomonitoring. Knowl. Manag. Aquat. Ecosyst., 418 (1).

[83] Mata, T.M., Martins, A. A., Caetano, N.S. 2010. Microalgae for biodiesel production and other applications:A review. Renew Sustain. Energy Rev., 14 : 217-232.

[84] Meng-Chuan Wu, John Jaime Perez Coca, Gary Ro-Lin Changa, Shing-Yi Suen, Chia-Feng Lind, Hong-Nong Choue, Su-Yuan Lai, Min-Ying Wanga. 2012. Chemical modification of Nitzschia panduriformis's frustules for protein and viral nanoparticle adsorption. Process Biochemistry, 47 : 2204–2210.

[85] Metting, F.B., Rayburn, W.R. and Reynaud, P.A. 1988. Algae and agriculture, In Algae and Human Affairs, C.A.Lembi, J.R.Waaland, Eds.; Cambridge University Press: Cambridge, UK, 335–370.

[86] Mohamed, N.A. 1994. Application of algal ponds for wastewater treatment and algal production. M.Sc. Thesis, Fac.of Sci. (Cairo Univ.) Bani-Sweef Branch.

[87] Monford P. A., Patel, J. and Prem Rajan, A. 2014. Algae Oil: A Sustainable Renewable Fuel of Future. Biotechnology Research International,1-8.

[88] Moreira-Santos, M., Amadeu, M.V.M., Soares, and Ribeiroa, R. 2004. An in situ bioassay for freshwater environments with the microalga Pseudokirchneriella subcapitata. Ecotoxicology and Environmental Safety, 59 : 164–173.

[89] Moreno, A. Rueda, O., Cabrera, E. and Luna-del-Castillo, J.D. 1990. Standarization in wastewater biomass growth. Ig. Mod. 94(1) :24–32.

[90] Mouchet, P. 1986. Algal reactions to mineral and organic micropollutants, ecological consequences and possibilities for industrial scale application;a review. Water Res., 20 : 399–412.

[91] Mulbry, W., Kondrad, S. and Pizarro, P. 2007. Biofertilizers from algal treatment of diary and swine manure effluents: GEMMA- Group of Environmental Engineering and Microbiology, Department of Civil and Environmental Engineering, Universitat Politecnica de Catalunya-Barcelona Tech. J. Vegetable Sci., 12 : 107-125.

[92] Mulbry, W., Kondrad, S. and Pizarro, C. 2008. Treatment of diary manure effluent using fresh water algae: algal productivity and recovery of manure nutrients using pilot- scale algal turf scrubber. Bioresour Technol., 99 : 8137-8142.

[93] Oron, G., Wildschut, L.R. and Porath, D. 1985. Wastewater recycling by Duckweed for protein production and effluent renovation, Water Sci. Technol. 17 (4&5) : 803–818.

[94] Oswald, W.J., Golueke, C.G. 1966. Eutrophication trends in the United States-a Problem, J. Wat. Poll. Cont. Fed. 38 : 964–975.

[95] Oswald, W.J. 1988. Large-scale algal culture systems (engineering aspects). Micro-algal biotechnology. Cambridge University Press, Cambridge, UK, 357–94.

[96] Panis, G., Rosales Carreon, J. 2016. Commercial astaxanthin production derived by green alga Haematococcus pluvialis: A microalgae process model and a techno-economic assessment all through production line. Algal Research, 18 : 175–190.

[97] Peabody, A.J. 1980. Diatoms and Drowning - A Review. Med. Sci. Law, 20(4) : 254-261.

[98] Pienkos, P.T. and Darzins, A. 2009. The promise and challenges of microalgal-derived biofuels, Biofuels. Bioprod. Bioref. Bioref. 3 : 431–440.

[99] Prabhakar, S.V.R.K. and Elder, M. 2009. Biofuels and resource use efficiency in developing Asia: Back to basics, Applied Energy. 86:30-36.

[100] Radmer, R.J. 1996. Algal diversity and commercial algal products. Biosci., 46 : 263–270.

[101] Raja, R., Hemaiswarya, S., Ashok Kumar, N., Sridhar, S. and Rengasamy, R. 2008. A Perspective on the Biotechnological Potential of Microalgae. Critical Reviews in Microbiology, 34 : 77–88.

[102] Ramachandra, T.V., Mahapatra, D.M., Karthick, B. and Gordon, R. 2009. Milking diatoms for sustainable energy: Biochemical engineering versus gasoline-secreting diatom solar panels. Ind. Eng. Chem. Res., 48:8769–8788.

[103] Ramachandra, T.V., Madhab, M.D., Shilpi, S. and Joshi, N.V. 2013. Algal biofuel from urban wastewater in India: Scope and challenges. Renew. Sust. Energ. Rev., 21 : 767–777.

[104] Renaud, S.M., Parry, S.M. and Thinh, D.L. 1994. Microalgae for use in tropical aquaculture. 1. Gross chemical and fatty acid composition of twelve species of microalgae from the Northern Territory, Australia. J. Appl. Phycol., 6(3):337–345.

[105] Richmond, A. 1986. Handbook of microalgal mass culture. CRC Press, Boca Raton, Florida, 528 pp.

[106] Richmond, A. 2008. Handbook of Microalgal Culture: Biotechnology and Applied Phycology,Wiley-Blackwell.

[107] Roessler, P.G. 1988. Effects of silicon deficiency on lipid composition and metabolism in the diatom *Cyclotella cryptic*. J. Phycol., 24 : 394–400.

[108] Rogers, J. N., Rosenberg, J., Bernardo, Guzman, Victor H., Oh, Luz Elena Mimbela, Abbas, G., J.Michael., Betenbaugh, A.O., George, Marc D. and Donohue. 2014. A critical analysis of paddlewheel-driven raceway ponds for algal biofuel production at commercial scales, Algal Research. 4 : 76–88.

[109] Saifullah, A.Z.A., Md. Abdul Karim, Aznijar Ahmad-Yazid. 2014. Microalgae: An Alternative Source of Renewable Energy. American Journal of Engineering Research (AJER), 03(3):330-338.

[110] Sandhage, K.H. 2005. Merging Biological Self-Assembly with Synthetic Chemical Tailoring: The Potential for 3-D Genetically Engineered Micro/Nano-Devices (3-D GEMS). Int. J. Appl. Ceram. Technol., 2 : 317–326.

[111] Satpal, A. and Khambete, K. 2016. Waste Water Treatment Using Micro-Algae - A review Paper. International Journal of Engineering Technology, Management and Applied Sciences, 5 : 4-2.

[112] Satyanarayana, K.G., Mariano, A.B. and Vargas, J.V.C. 2011. A review on microalgae, a versatile Source for sustainable energy and materials. Int J Energy Res.,35 : 291–311.

[113] Sawayama, S., Inoue, S., Dote, Y. and Yokoyama, S.Y. 1995. CO2 fixation and oil production through microalga. Energy Convers Mgmi., 36 : 729– 731.

[114] Schenk, P.M., Skye, R., Thomas-Hall, E., Stephens, U.C., Marx, H.J., Mussgnug, C., Posten and Olaf Kruse. 2008. Second Generation Biofuels: High Efficiency Microalgae for Biodiesel Production. Bioenergy Research, 1:20-43.

[115] Schuhmann, H. 2011. Perspectives on metabolic engineering for increased lipid contents in microalgae. Biofuels, 3 : 71–86.

[116] Shay, E. G. 1993. Diesel fuel from vegetables-oils-status and opportunities. Biomass Bioenergy, 4 : 227-42.

[117] Sheehan, J. 1998. A look back at the US Department of Energy’s Aquatic Species Program – biodiesel from algae. National Renewable Energy Laboratory.

[118] Sheehan, J., Dunahay, T., Benemann, and Roessler, P. 1978. A Look Back at the U.S.Department of Energy’s Aquatic Species Program: Biodiesel from Algae. National Renewable Energy Laboratory.

[119] Shelef, G. and Soeder, C.J. 1980. Algal Biomass: production and use. Elsevier/North Holland Biomedical Press, Amsterdam, 852.

[120] Shifrin, N.S. and Chisholm, S.W. 1981. Phytoplankton lipids: interspecific differences and effects of nitrate, silicate and light-dark cycles. J. Phycol., 17 : 374–384.

[121] Shilton, A.N., Powell, N. and Guieysse, B. 2012. Plant based phosphorus recovery from wastewater via algae and macrophytes. Curr. Opin. Biotechnol., 23 : 884–889.

[122] Singh, B., Guldhe, A. and Rawat Bux, F. 2011. Towards a sustainable approach for development of biodiesel from plant and microalgae, Renewable and Sustainable Energy Reviews. 29 : 216–245.

[123] Soeder, C.J., Payer, H.D., Runkel, K.H., Beine, J. and Briele, E. 1978. Sorption and concentration of toxic minerals by mass cultures of Chlorococcales. Mitt. Internat. Verein. Limnol., 21:575–584.

[124] Stadler, T., Mollion, J., Verdus, M.C., Karamanos, Y., Morvan, H. and Christiaen, D. 1988. Algal Biotechnology. Elsevier Applied Science, England, 6:156-161.

[125] Starr, T.J., Deig, E.F., Church, K.K. and Allen, M.B. 1962. Antibacterial and antiviral activities of algae extracts studies by acridine orange staining. Tex. Rep. Biol. Med., 20 : 271–278.

[126] Sushant, S., Satputaley, C., Chawane, Deshpande, N.V. 2012. A Critical Review of Biofuels from Algae for Sustainable Development, International Journal of Computer Applications, National Conference on Innovative Paradigms in Engineering & Technology.

[127] Taguchi, S. 1987.Silicate deficiency and lipid-synthesis of marine diatoms. J. Phycol., 23 : 260–267.

[128] Tao D., Eric, P.K., Ryan Davis, Lieve, Laurens, M.L., Stefanie VanWychen, and Philip, T.P. NickNagle. 2016. Combined algal processing: A novel integrated biorefinery process to produce algal biofuels and bioproducts. Algal Research, 19 : 316–323.

[129] Vandna P., Singh, R. and Pankaj G. Algal oil production: Research Paper. Res J. Chem. Environ. Sci., 3(1) : 56-57.

[130] Vandana, V., Kalina, M., Manoylov, H., Gateau, H., Blanckaert, V., Heraulter, J., Pencreach, G., Marchand, J., Richard Gordon and Schoefs, B. 2015. Diatom Milking: A Review and New Approaches. Mar. Drugs, 13 : 2629-2665.

[131] Vilchez , C., Garbayo, I. and Lobato, M.V. 1997. Microalgae mediated chemicals production and wastes removal (review). Enzyme Microb Technol., 20 : 567-572.

[132] Violeta, M., Virginija, S. and Andruleviciute, V. 2013. Biodiesel fuel from microalgae-promising alternative fuel for the future: a review. Rev. Environ. Sci. Biotechnol., 12 : 119–130.

[133] Williams, P.J., Laurens, L.M.L. 2010. Microalgae as biodiesel & biomass feedstocks: Review & analysis of the biochemistry, energetics & economics. Energy Environ. Sci., 3 : 554–590.

[134] Yang, S. Wu, R.S.S. and Kong, R.Y.C. 2002. Physiological and cytological responses of the marine diatom *Skeletonema costatum* to 2,4-dichlorophenol. Aquat. Toxicol., 60 : 33–41.

[135] Yap, B.H.J., Dumsday, G.J., Scales, P.J. and Martin, G.J.O. 2015. Energy evaluation of algal cell disruption by high pressure homogenisation, Bioresour. Technol., 184 : 280–285.

[136] Zhou, A. and Thomson, E. 2009. The Developments Of Biofuels in Asia. Applied Energy, 86 : 11-20.