BIODIVERSITY CHALLENGES

A Way Forward

Shashikanth Majagi

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Biodiversity Challenges

— *A Way Forward* —

THE EDITOR

Dr. Shashikanth H. Majagi did his M. Sc. and Ph. D. in Zoology from Gulbarga University, Kalaburagi, Karnataka. He started his carrier as Assistant professor in Government First Grade College, Chikkballapur and Government College (Autonomous) Kalaburagi. He has published 45 research papers and book articles. He has attended and presented 50 research papers in national/international conferences/symposia and 06 books to his credit. He is a reviewer/editorial board member for many journals of international acclaim. He is the life member for many academic bodies. He has given radio talks and Doordarshan programmes as well . Received prestigious Award for Research Paper (ARP) award from VGST, Government of Karnataka and IOSRD Life time award and Novel Research Academy Award of Excellence in Research. He has successfully organized two national Conference and Workshops. Successfully completed research projects funded by is UGC. Successfully Guided 02 Ph. D. students and 03 are working. He has worked as Special officer for NAAC, Department of Collegiate Education, Regional Joint Director Office, Kalaburagi. Currently he is teaching Environmental biology, Biodiversity and Limnology to Master degree Students. His research interests are on Limnology, Water quality studies and biodiversity. Currently working as Associate Professor and Chairman, Department of Zoology, Deputy Registrar (DPAR) and Nodal officer for Youth Red Cross.

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— *A Way Forward* —

– Editor –

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— *Dedicated to* —

My Beloved Sister

Late Smt. Manjula R.

Acknowledgements

I wish to express my deep sense of gratitude to all the research paper contributors who were very generous for sending their original book chapters.

I am thankful to Dr. Vijaykumar Malashetty, Professor, Department of Zoology, Vijayanagar Sri Krishnadevaraya University, Ballari for writing foreword to this book.

I Profusely thank Dr. K. Vijaykumar, Professor and Chairman, Department of Zoology, Gulbarga University, Kalaburagi and Dr. B. B. Hosetti Professor (Retd.) Kuvempu University, Shankarghatta, for reviewing the research papers.

My sincere thanks to Doddappa Sri Manikappa Majagi and Doddamma Smt. Sukumari and my parents Sri. Hanmantappa Majagi and Shakuntala Laxmibai, Wife Dr. Anita S. Majagi and daughters Miss. Sinchana and Miss. Saanidhya.

Shashikanth Majagi

Foreword

The book before you offers an overall view of this biological diversity and carries the urgent warning that we are rapidly altering and destroying the environment, its challenges and how to way forward to protect. Thus it gives me a great pleasure to contribute this foreword.

As I read the book prior to writing this Foreword, I was impressed by many unique features that I would like to share with you. Biodiversity is life! The diversity of life forms, so numerous that we have yet to identify most of them, is the greatest wonder of this planet. The biosphere is an intricate tapestry of interwoven life forms. The major threats to biodiversity that result from human activity are habitat loss, fragmentation and degradation, over exploitation of species for human use, introduction of exotic species and possibility of spread of disease. This leads to threats to the threatened species and result in the extinction of such species. Typically these threats develop so rapidly and on such a large scale that species are not able to adopt genetically to the changes or disperse to more hospitable location. The rapid and visible changes in environmental variables within few weeks of the lockdown due to COVID-19 were surprising even for experts which should create an optimistic attitude towards biodiversity conservation. The scientific community has to lead from the front, in creating solutions and in steering the socio-political will required to implement these solutions for a more long lasting process of environmental conservation. Besides there is an urgent need to create awareness among rural and urban population to highlight the importance of conserving biodiversity.

Today, the issues and challenges relating to wildlife and biodiversity conservation are embedded in understanding the human dimension with its social, cultural, political, economic and legal complexities. An interdisciplinary approach to challenges like that of human–wildlife conflict, will help scientists to arrive at better solutions that might ensure conservation of nature in the longer run.

Biodiversity Challenges – A Way Forward is a edited book, Many scientists have generously contributed in this endeavour, an updating of many of the principal issues in conservation biology and resource management. It also documents a new alliance between scientific, governmental, and commercial forces—one that can be expected to reshape the international conservation movement for decades to come. This book also accumulated enough data on deforestation, species extinction, and tropical biology to bring global problems into sharper focus and warrant broader public exposure. It also a handy resource for the local conservationist community consisting of policy makers, academicians, scientists, environmentalists, students and gross root level conservationists. It also provides an invaluable toolkit for a large and under-resourced audience of students in developing nations and addresses the key issues in conservation biology, clearly stating the challenges but also offering solutions.

Dr. Shashikanth H. Majagi is currently Associate Professor of Zoology at Vijayanagara Sri Krishnadevaraya University, Ballari and one of the leading Environmental Biologist of the country. "Dream is not what you see while sleeping. Dream is something that doesn't let you sleep" – rightly quoted by Dr. A.P.J. Abdul Kalam. His broad research interests in the field of biodiversity, strong determination and dedication made him to bought this edited book. I know that you will soon have a much larger audience for your work.

Congratulations!

Dr. Vijaykumar B. Malashetty, Ph.D

Professor,
Department of Studies in Zoology,
Vijayanagara Sri Krishnadevaraya University, Ballari

Preface

The present book provides an information about biodiversity, how its rise, about its distribution, importance and how to maintain it, representing its point of view into the literature on biological diversity. Biodiversity continues to decline, and the main drivers of biodiversity loss continue to increase. The unsustainable use of natural resources has led to an alarming rate of habitat loss. Climate change, invasive species, and pollution pose additional threats to global species richness. The present book neither complies of a technical research reports or the complete action plans and nor the detailed documentation on biodiversity importance or the issues for the loss of biodiversity. Instead, various recent research articles, here represents the relevant ideas and goals in the critical importance to sustainable development and a conservation measures on biodiversity. The biodiversity loss or crisis is one of the major global concerns and every country or community has vital role in the challenges ahead. The chapters in the book has its own impact on values, distributions and maintenance of biodiversity as of which we tried to draw out the major problems and reveal the ground reports with actual examples. This book might form a relevant source for the readers and hope to be a useful resource in exploring the main stream themes at greater levels and details.

Shashikanth Majagi

Contents

Chapter 9

Ichthyofauna Diversity in Relation to Water Quality of Lakes of Bangalore, Karnataka

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Ichthyofauna plays a vital role as consumers in the food chain and maintain the nutrient balance. The diversity and abundance of ichthyofauna depends on the nutrient levels in the aquatic ecosystem. The current study investigates ichthyofauna diversity and water quality across the lakes in Bangalore, Karnataka State, India. The order Cypriniformesis dominant in Bangalore lakes and 18 species were recorded in the current study, which is lower compared to the earlier report of 55 species in 1970. The decline in the native species and dominance of the exotic invasive species is mainly due to higher nutrient levels with the sustained inflow of untreated or partially treated wastewater to lakes. Lakes were earlier connected and now the loss of interconnectivity has also led to the disappearance of native species. Lakes of Bangalore are facing severe threat of pollution apart from the problems of encroachment of *lakes, habitat loss, invasion of exotic species and over-harvesting of wetland resources. The quality of water was monitored and the overall quality is assessed through Water quality index (WQI). Principal component analysis was performed to understand the contribution of different physico-chemical parameters and their influence on ichthyofauna species diversity. The variations in the physico-chemical parameters have altered habitat conditions, affecting the diversity and abundance of ichthyofauna biodiversity. The study highlights the need to formulate strategies to sustain native species of ichthyofauna, which support the livelihood of local people through effective regulatory measures for preventing pollutants entering the water body.*

***Keywords**: Ichthyofauna, Lakes, Water pollution, Diversity, WQI.*

Introduction

Freshwater lakes play a significant role in the socioeconomic development of a region. The addition of chemicals, nutrients and organic contents to aquatic ecosystems through anthropogenic inputs creates an ecological imbalance affecting aquatic life. The sustained inflow of untreated wastewater from domestic and industrial areas to freshwater bodies leads to water pollution, eutrophication and heavy metal contamination (Ramachandra *et al.,* 2020a). Numerous studies have pointed out the major threats to wetlands that deteriorate water quality of freshwater resources, include water pollution, climate change, urbanization, land use and land cover changes, encroachments, agricultural practices, introduction of exotic species (Ramachandra and Aithal, 2016; Bassi *et al.,* 2014; Haidary *et al.,* 2013; Huang *et al.,* 2013; Bahar *et al.,* 2008; Prasad *et al.,* 2002). In addition to anthropogenic sources, the seasonal variations in natural processes like temperature, rainfall pattern and hydrological condition also influence water quality. The growth and development of fishes is dependent on both abiotic and biotic factors such as temperature, light, pH, oxygen level, feed, plankton population *etc.* (Bhatnagar and Devi, 2013). A change in the water quality parameters may affect the growth and survival of fish. Ichthyofaunaor fish is very sensitive to changes in water quality thus, considered as an effective biological indicator in aquatic ecosystems. Various climate change-induced threats on wetland fisheries include water stress, sedimentation, proliferation of aquatic weeds and loss of inter-connectivity among wetlands (Naskar *et al.,* 2018). Fishes are the major source of polyunsaturated fatty acids (PUFA)such aseicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) which are essential for human health (Barik, 2017; Sarma *et al.,* 2013). The fisheries sector provides livelihood for several families in India, in addition to fish constitute a valuable source of protein, vitaminsand minerals. Hence, assessment ofwater quality is crucial to understand the habitat quality of ichthyofauna.

Multivariate statistical technique, such as principal component analysis (PCA), help in the interpretation of complex data sets and provides better understanding of water quality of freshwater ecosystems (Zhang *et al.,* 2011; Wang *et al.,* 2017; Ramachandra *et al.,* 2018; Mamun *et al.,* 2021). PCA helps to analyze and interpret water quality data, understand temporal/spatial variations in water quality data and identify chief pollution sources of waterbodies, enabling water resource management (Barakat *et al.,* 2016; Islam *et al.,* 2017; Zeinalzadeh and Rezaei, 2017; Diamantini *et al.,* 2018). It provides information about the most meaningful parameters in the whole dataset, while removing data redundancy and explains the correlation between parameters with minimum loss of original information (Liu *et al.,* 2021; Mishra, 2010).

The water quality index (WQI) is widely accepted now to assess the water quality and determine the suitability of water for various purposes by integrating large set of water quality data, which includes physical, chemical and biological characteristics into a single number to express the quality of freshwater ecosystems (Ramachandra *et al.,* 2020b; Sharma and Kansal, 2011). WQI has been useful in water resource management worldwide for past few decades (Chabuk *et al.,* 2020; Bora and Goswami, 2017; Wu *et al.,* 2017; Jindal and Sharma, 2011). WQI is more effective than determining the trophic state index (TSI) or trophic level index (TLI) for aquatic ecosystems (El-Serehy *et al.,* 2018).

The studies on ichthyofauna diversity of lakes in Bangalore are scanty. Hence, the present study was designed to (i) record and map the ichthyofauna diversity; (ii) assess the water quality across the lakes in Bangalore, Karnataka; (iii) identify the pollution sources and pollution levels using multivariate statistical analysis (principal component analysis, PCA)and (iv) compute water quality index (WQI).

Materials and Methods

Description of the Study Area

Greater Bangalore (city of lakes) lies between the latitude 12°49’5’’N to 13°08’32”N and longitude 77°27’29”E to 77°47’2”E, covering an area of 741 square kilometers. Bangalore landscape with undulating terrain forms three major watersheds namely Koramangala and Challaghatta Valley (K and C Valley), Vrishabhavathi Valley (V Valley) and Hebbal Valley (H Valley). Koramangala and Challaghatta Valley has the largest catchment area (255 square kilometers), followed by Hebbal Valley (207 square kilometers) and Vrishabhavathi Valley (165 square kilometers). The lakes in Bangalore are interconnected and provide goods and services to sustain livelihood of people. The interconnected lakes in K and C and H valley join Dakshina Pinakini River whereas lake systems in V valley join Arkavathi River, a tributary of Cauvery River (Ramachandra *et al.,* 2017). The current study involves field survey, water quality analysis and recording ichthyofauna diversity in 36 lakes of Greater Bangalore (Figure 9.1).

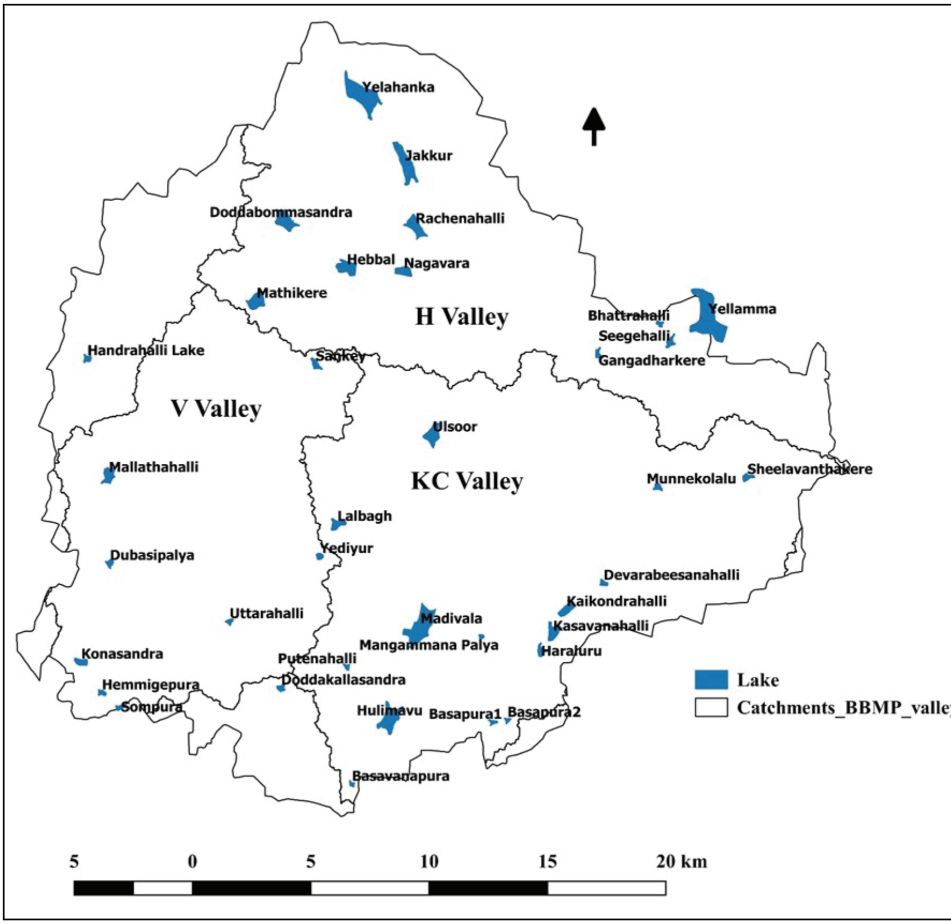

Figure 9.1: Study Area - Lakes of Greater Bangalore, Karnataka, India.

Ichthyofauna Sample Collection

Fish specimen were collected from the select lakes of Bangalore with the help of gill net or cast net by local fishermen during the study period 2018 - 2019. The photographs of ichthyofauna were taken prior to the specimen preservation. The specimens were preserved in 10 per cent formaldehyde solution and transported to the laboratory for taxonomic analysis. Collected fish specimen were identified up to the species level by using standard taxonomic keys, reference books (Jayaram, 1999; Talwar and Jhingran, 1991) and virtual database - Fish Base (http://fishbase.org). The species distribution map was generated with the help of QGIS open-source GIS software.

Water Sample Collection and Laboratory Analyses

Water samples were collected from the 36 lakes for physico-chemical analysis in the clean and sterile polypropylene bottles during the year 2018 - 2019. The monitored parameters included water temperature (WT), pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), chloride (Cl), total hardness (TH), calcium (Ca), magnesium (Mg), total alkalinity (TA), chemical oxygen demand (COD), biochemical oxygen demand (BOD), nitrate (N) and ortho-phosphate (OP). The parameters such as water temperature, pH, dissolved oxygen, total dissolved solids and electrical conductivity were measured on site using portable meter (Extech) while rest of physico-chemical parameters were estimated in laboratory. The lake water samples were analyzed using standard methods according to APHA (2005) and every experiment were carried out in triplicates. In this study, QGIS open-source GIS software was used for generating maps of various physico-chemical parameters of investigated 36 lakes in Bangalore.

Estimation of WQI of Lakes

During the present study, weighted arithmetic water quality index (WQI) was computed for the 36 lakes in Bangalore considering ten physico-chemical parameters such as pH, total dissolved solids, electrical conductivity, dissolved oxygen, total hardness, calcium, magnesium, chloride, total alkalinity and nitrate (Devi *et al.,* 2015; Sincy *et al.,* 2016).

Statistical Analysis

In the present study, multivariate analysis was carried out using PAST3 software. The principal component analysis (PCA) of the water quality data was performed to better understand water quality of the monitored lakes. Experimental data was normalized using z-scale transformation for the principal component analysis, which reduces the influence of variance of different parameters, eliminate the influence of dissimilar units of measurement of the analyzed parameters (Singh *et al.,* 2004), renders the data dimensionless (Singh *et al.,* 2020) and helps to assess the association among monitored variables (Vega *et al.,* 1998).

Results and Discussion

Ichthyofauna Diversity of Lakes

The present study records 18 species of ichthyofauna belonging to 4 orders, 7 families and 14 genera (Figure 9.2). The ichthyofauna belonging to order (Figure 9.3a) Cypriniformes were dominant in lakes (41 per cent) followed by Perciformes (33 per cent), Cyprinodontiformes (15 per cent) and Siluriformes (11 per cent).

The order Cypriniformes consists of species namely *Catla catla*, *Labeo rohita*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Cirrhinus mrigala*, *Labeo fimbriatus*, *Puntius ticto* and *Hypophthalmichthys molitrix*. Cyprinodontiformeswas represented by species such as *Gambusia affinis* and *Poecilia reticulata*. Perciformes was represented by *Oreochromis mossambicus*, *Oreochromis niloticus*, *Channa punctata*, *Channa striata* and *Parambassis ranga*. Siluriformeswas represented by *Clarias gariepinus*, *Clarias batrachus* and *Heteropneustes fossilis*. Similar results were observed in other lakes, for example, the order Cypriniformes were dominant in Mallasandralake of Tumakuru (Nayaka, 2018); Kelagerilake of Dharwad (Kamble and Ganesh, 2016) and Nagaram tank (Ramulu and Benarjee, 2013).

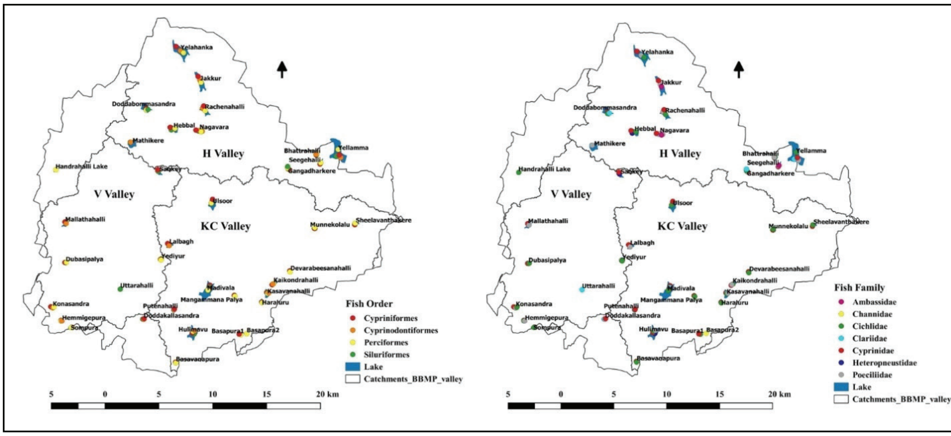

Figure 9.2: Distribution of Ichthyofauna (Order wise and family wise) in Lakes of Bangalore.

Fish species belonged to 7 families (Figure 9.3b) namely, Ambassidae, Channidae, Cichlidae, Clariidae, Cyprinidae, Heteropneustidae and Poeciliidae. Among these, Cyprinidae was dominated in 41 per cent of monitored lakes, followed by Cichlidae (28 per cent), Poeciliidae (15 per cent), Clariidae (9 per cent), Channidae (3 per cent), Ambassidae (1 per cent) and Heteropneustidae (1 per cent).

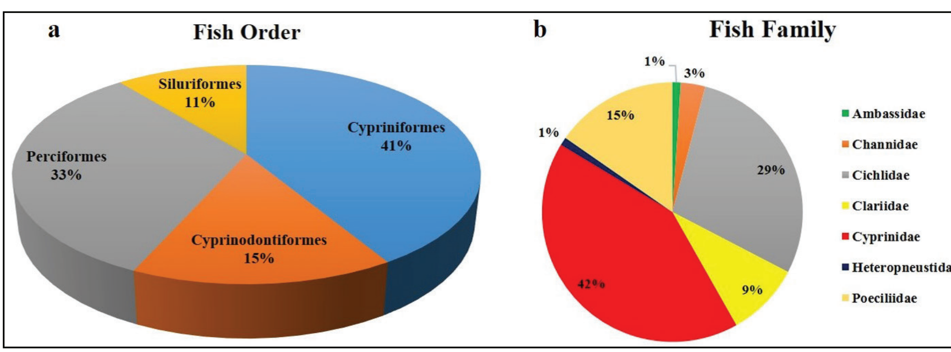

Figure 9.3: The Percentage Occurrence of Fish Orders (a) and Families (b) in Lakes of Bangalore.

Cyprinus carpio, *Ctenopharyngodon idella*, *Gambusia affinis*, *Oreochromis* sp., *Clariasgarie pinus* and *Hypophthalmichthys molitrix* are exotic fishes recorded in the current study. *Clarias gariepinus* is a hardy species and can tolerate both oxygenated as well as poorly oxygenated waterbodies (Ogundiran *et al.,* 2010).

Table 9.1: Ichthyofauna Diversity in Lakes of Bangalore, Karnataka

Sl.No.	Fish Species	Common Name	Order	Family	Genus
1	*Catla catla*	Catla	Cypriniformes	Cyprinidae	Catla
2	*Channa punctata*	Spotted Snakehead	Perciformes	Channidae	Channa
3	*Channa striata*	Striped Snakehead	Perciformes	Channidae	Channa
4	*Cirrhinus mrigala*	Mrigal	Cypriniformes	Cyprinidae	Cirrhinus
5	*Clarias batrachus*	Walking catfish/Magur	Siluriformes	Clariidae	Clarias
6	*Clarias gariepinus*	African catfish	Siluriformes	Clariidae	Clarias
7	*Ctenopharyngodon idella*	Grass carp	Cypriniformes	Cyprinidae	Ctenopharyngodon
8	*Cyprinus carpio*	Common carp	Cypriniformes	Cyprinidae	Cyprinus
9	*Gambusia affinis*	Mosquitofish	Cyprinodontiformes	Poeciliidae	Gambusia
10	*Heteropneustes fossilis*	Stinging catfish	Siluriformes	Heteropneustidae	Heteropneustes
11	*Hypophthalmichthys molitrix*	Silver carp	Cypriniformes	Cyprinidae	Hypophthalmichthys
12	*Labeo fimbriatus*	Fringed-lipped peninsula carp	Cypriniformes	Cyprinidae	Labeo
13	*Labeo rohita*	Rohu	Cypriniformes	Cyprinidae	Labeo
14	*Oreochromis mossambicus*	Mozambique tilapia	Perciformes	Cichlidae	Oreochromis
15	*Oreochromis niloticus*	Nile tilapia	Perciformes	Cichlidae	Oreochromis
16	*Parambassis ranga*	Indian glassy fish	Perciformes	Ambassidae	Parambassis
17	*Poecilia reticulata*	Guppy	Cyprinodontiformes	Poeciliidae	Poecilia
18	*Puntius ticto*	Ticto Barb	Cypriniformes	Cyprinidae	Puntius

Gambusia affinis and *Poecilia reticulata* feed on larvae and is used for mosquito control (Mahapatra *et al.,* 2014). The invasion of exotic species results in loss of native and endemic species (Singh *et al.,* 2013; Sandilyan, 2016). Exotic fish species were introduced in India for aquaculture, aquarium, sport fishing, weed control, *etc.* and the introduction of exotic species led to the decline in native species of fish and biodiversity (Kumar, 2000).

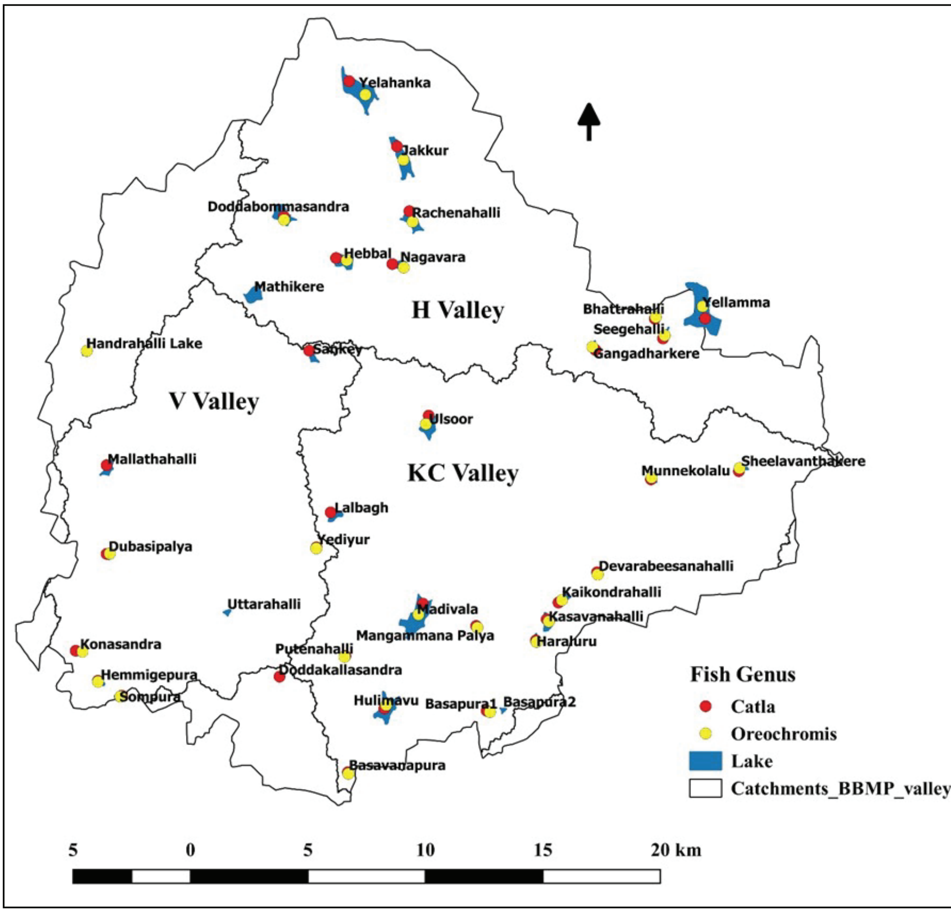

Figure 9.4: Distribution of Catla and Oreochromis in Bangalore Lakes.

Among the 14 genera, Catla was found in 32 lakes and Oreochromis was recorded in 29 lakes in the current investigation (Figures 9.4 and 9.5). Based on the diet (Table 9.2), fishes are grouped as herbivorous, omnivorous, larvivorous, planktivorous and carnivorous. For example, *Labeo rohita* (column and bottom feeder) prefers plant material and decaying vegetation. *Catla catla* (surface feeder) feed mainly on phytoplankton whereas *Cirrhinus mrigala* (bottom-feeder) feed mainly on decaying vegetation (Chattopadhyay, 2017). *Oreochromis niloticus* are opportunistic feeders and feed on detritus, phytoplankton, crustacean, aquatic insects, small fish, zooplankton and macrophytes (Mohamed and Al-Wan, 2020; Chatterjee *et al.,* 2015).Under conservation status as per IUCN (2010),one species was categorized as critically endangered, one species under near threatened, 13 under least concern and one species under vulnerable category (Table 9.2).

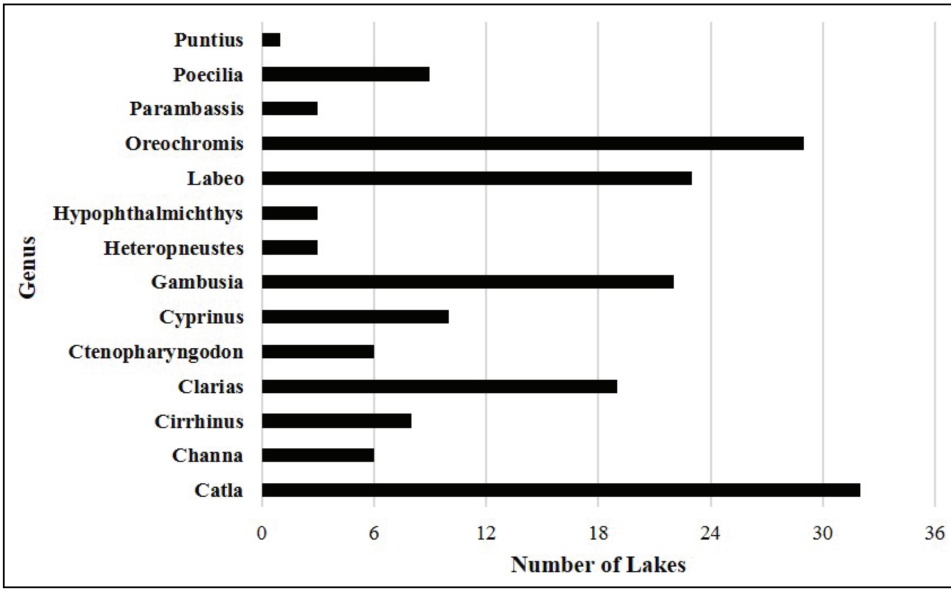

Figure 9.5: Fish Genera found in Bangalore Lakes

Table 9.2: List of Ichthyofauna, their IUCN Status, Diet Pattern and their Benefits

Sl.No.	*Fish Species*	*IUCN**	*Diet*	*Benefits*
1	*Catla catla*	LC	Omnivorous	Food fish
2	*Channa punctata*	LC	Carnivorous	Food fish
3	*Channa striata*	LC	Carnivorous	Food fish
4	*Cirrhinus mrigala*	LC	Omnivorous	Food fish
5	*Clarias batrachus*	LC	Omnivorous	Food fish
6	*Clarias gariepinus*	LC	Omnivorous	Food fish
7	*Ctenopharyngodon idella*	NE	Herbivorous	Control of weeds/ Food fish
8	*Cyprinus carpio*	CR	Omnivorous	Food fish
9	*Gambusia affinis*	LC	Larvivorous	Mosquito-control/ Ornamental
10	*Heteropneustes fossilis*	LC	Omnivorous	Food fish
11	*Hypophthalmichthys molitrix*	NT	Planktivorous	Food fish/controls pest population

Sl.No.	*Fish Species*	*IUCN**	*Diet*	*Benefits*
12	*Labeo fimbriatus*	LC	Herbivorous	Food fish
13	*Labeo rohita*	LC	Omnivore	Food fish
14	*Oreochromis mossambicus*	VU	Omnivorous	Food fish
15	*Oreochromis niloticus*	LC	Omnivorous	Food fish
16	*Parambassis ranga*	LC	Carnivorous/ Larvivorous	Ornamental fish
17	*Poecilia reticulata*	NE	Omnivorous	Ornamental fish
18	*Puntius ticto*	LC	Planktivorous	Food fish/ Ornamental fish

*LC: Least Concern; NE: Not Evaluated; CR: Critically Endangered; NT: Near Threatened; VU: Vulnerable.

Indian major carps such as *Catla catla*, *Cirrhinus mrigala* and *Labeo rohita* contribute 70 to 75 per cent of the total freshwater fish production and have high economic importance (Jayasankar, 2018). Genus such as Clarias, Channa and Heteropneustes are air breathing fishes with good market value for live fish (Thirumala *et al.,* 2011).Dishes prepared with fish flour (of *Oreochromis niloticus*) are rich in proteins, lipids, essential amino acids, ash and polyunsaturated fatty acids (PUFAs) (Alam and Aslam, 2020), which highlights the need to conserve fish fauna to sustain food and medicine to the dependent population.

Water Quality of Lakes

Health of aquatic ecosystems are assessed based on water quality considering the physical, chemical and biological characteristics of water. Evaluation of these parameters will aid in understanding the suitability of lake water for biotic consumption and health of a particular aquatic ecosystem. Fish is very sensitive to variations in water quality and hence considered as biological indicator in aquatic ecosystems. Thus, it is necessary to understand the water quality of lakes or habitat conditions of fishes. Physical, chemical and biological parameters assessed in sampled lakes are discussed next.

Water Temperature and pH

Water temperature influences both the physico-chemical variables and biological activities in the aquatic ecosystems. Temperature affects the microbial (algae and bacteria) activities in water as it influences the organic matter decomposition and nutrient cycling. Temperature also affects the solubility of gases like O_2, CO_2 and NH_3 (Siriwardana *et al.,* 2019). Water temperature in the current study varied between 23.5°C to 34.2°C (Figure 9.6). pH varied among the monitored lakes and found to range between 7.2 to 10.19, indicated an alkaline nature of lake water (Figure 9.6).

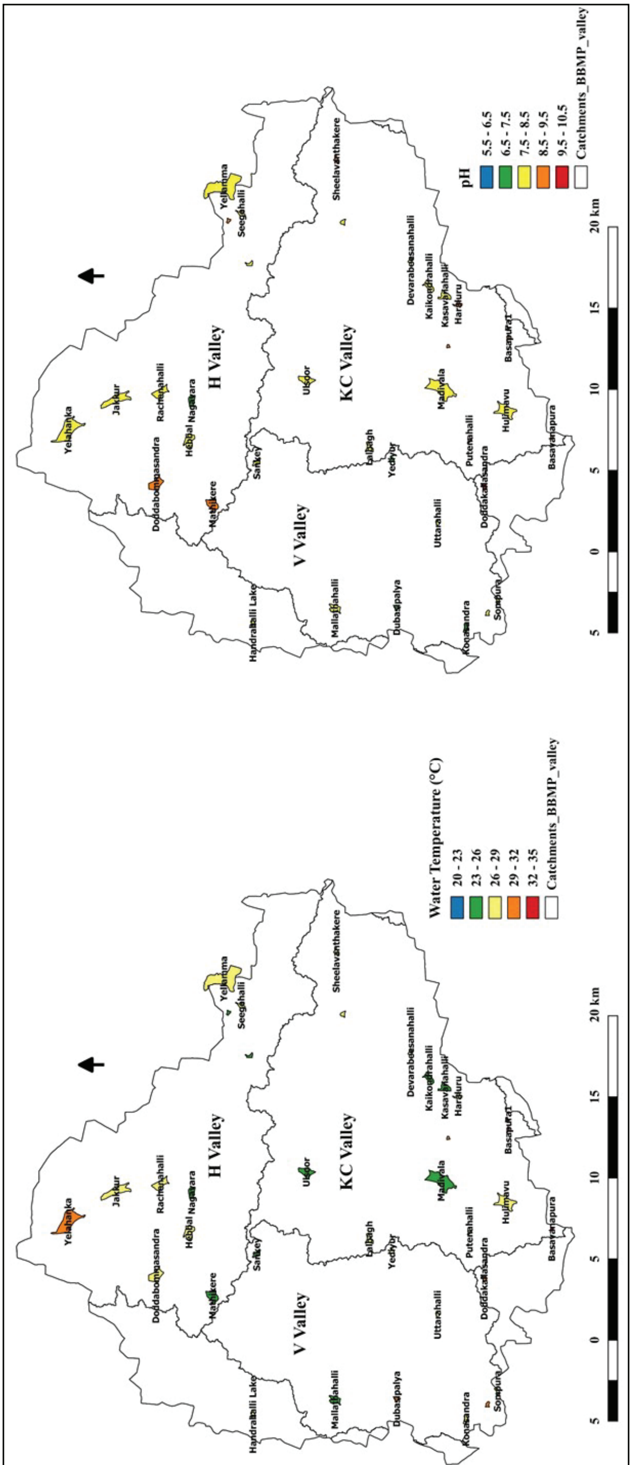

Figure 9.6: The Variation of Water Temperature and pH across Lakes of Bangalore.

pH regulates many biological processes and biochemical reactions. In case of pH, the desirable range for fish culture is 6.5 - 9.0. Doddakallasandra had high levels of pH among all the lakes due to high photosynthetic activities by phytoplankton. The photosynthesis raises the pH whereas respiration and decomposition processes lowers pH in lake water. Fish have an average blood pH of 7.4, so the acceptable range for fish culture would be 6.5 - 9.0. The pH in water ranging from 4.0 - 6.5 and 9.0 - 11.0 is stressful for fish growth and reproduction. Fish death can occur at pH level of <4 or>11 (Ekubo and Abowei, 2011).

Total Dissolved Solids (TDS) and Electrical Conductivity (EC)

Total dissolved solids in natural waters are mainly contributed by the presence of carbonates, bicarbonates, sulphates, chlorides, phosphates and nitrates of magnesium, calcium, sodium, potassium, iron *etc.* and tiny amounts of organic matter (Ramachandra *et al.,* 2014). Electrical conductivity gives the measure of the capacity of water to conduct an electric current. When the concentration of dissolved ions in water increases then, electrical conductivity also increases. The value of total dissolved solids and electrical conductivity in lakes ranged from 152.5 mg/L to 1548 mg/L and 306.67µS/cm to 2814 µS/cm, respectively (Figure 9.7). Lakes such as Basapura-1 and Basapura-2 had higher ionic contents with higher TDS and EC levels. The increased levels of dissolved and suspended solids will decrease the dissolved oxygen levels in aquatic ecosystems (Yýlmaz *et al.,* 2020). The optimum conductivity level for fish culture differs among different species as they vary in their capability to maintain osmotic pressure (Kumar *et al.,* 2017).

Turbidity and Dissolved Oxygen (DO)

Turbidity occurs due to the presence of various suspended and colloidal matter in lake water such as clay, silt, inorganic matter, organic matter, plankton and tiny micro-organisms (Ramachandra *et al.,* 2018). Turbidity in monitored lakes was found to range between10.14 NTU - 306.33 NTU (Figure 9.8) .High turbidity in lakes result in low light penetration to bottom levels, reduces photosynthetic rate and may even cause fish death due to clogging of gills (Saraswathy *et al.,* 2015). The concentration of dissolved oxygen in lake water varies with temperature, amount of organic waste, sediment quality/quantity, turbulence, photosynthetic rate and respiration/decomposition (Devi *et al.,* 2015). The solubility of dissolved oxygen decreases under low atmospheric pressure and high saline conditions (Rouse, 1979). The dissolved oxygen levels ranged between 1.52 mg/L - 11.27 mg/L in lakes with minimum value in Gangadharkere while maximum value in Jakkur lake (Figure 9.8).

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

Biochemical oxygen demand is the amount of oxygen utilized by micro-organisms in stabilizing the organic matter (Davraz *et al.,* 2019). The chemical oxygen demand is the amount of oxygen equivalent of the organic matter in lake

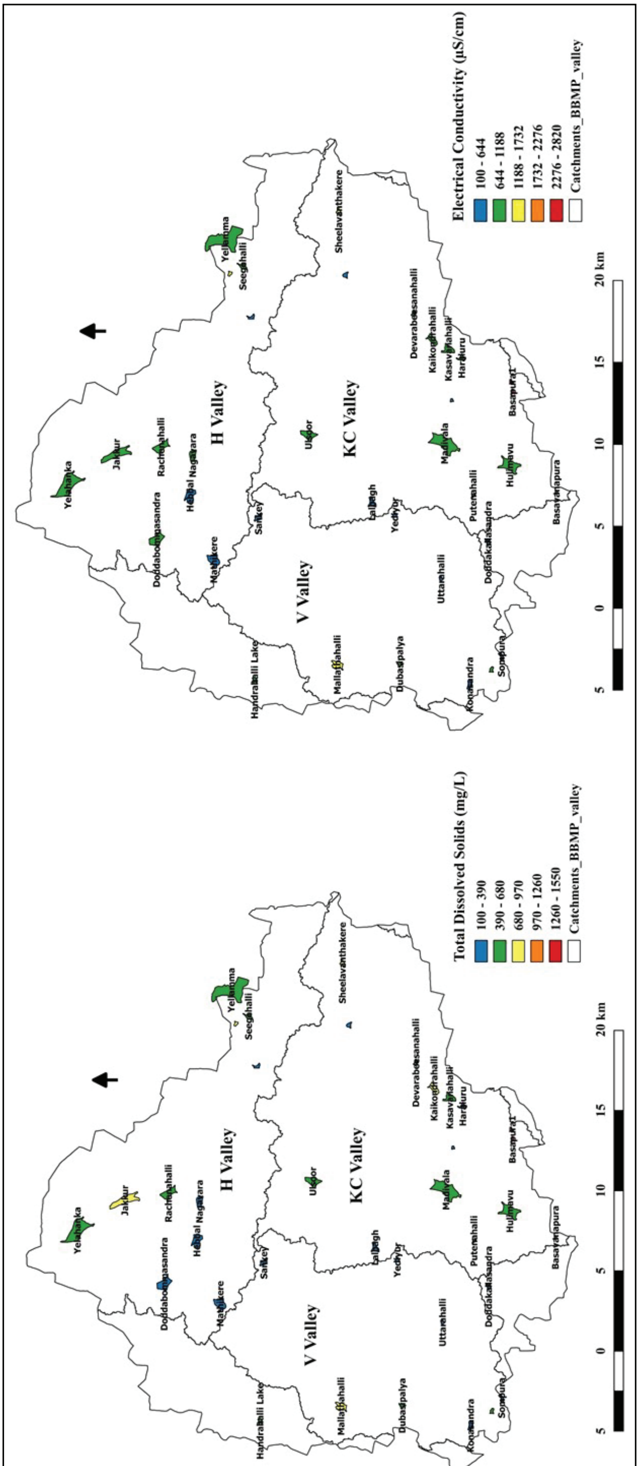

Figure 9.7: Variation of Total Dissolved Solids and Electrical Conductivity in Lakes of Bangalore.

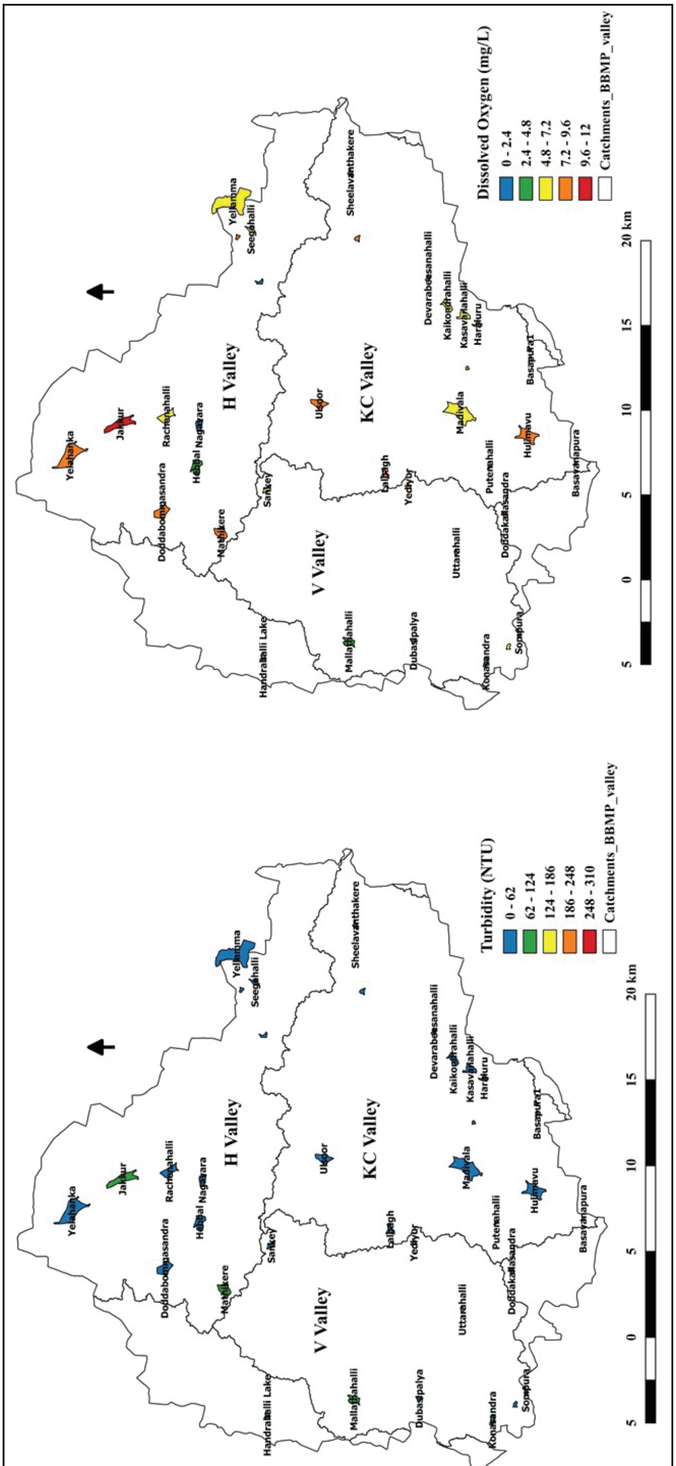

Figure 9.8: The Turbidity and Dissolved Oxygen Levels in Lakes of Bangalore.

water that is susceptible to oxidation with the help of a strong chemical oxidant. The BOD and COD of lake water samples ranged between 7.45 mg/L - 99.59 mg/L and 11.33 mg/L - 150 mg/L, respectively (Figure 9.9). Both BOD and COD of lake water increases with an increase in the organic matter content due to organic pollution from point as well as non-point sources.

Total Alkalinity and Chloride

Total alkalinity provides the measure of the ability of water to neutralize acids. Alkalinity is due to the presence of carbonates, bicarbonates and hydroxides of calcium, magnesium, potassium, sodium and salts of borates, silicates, phosphates, *etc.* (Sarkar *et al.,* 2020, Qureshimatva *et al.,* 2015). The salts of sodium (NaCl), potassium (KCl) and calcium ($CaCl_2$) contribute chlorides in lake water. The total alkalinity and chloride in sampled lakes were recorded as 81.33 mg/L - 684.33mg/L and 25.56 mg/L - 1165.82 mg/L, respectively (Figure 9.10). The desired level of alkalinity for fish culture is between 50-150 mg/L whereas the desirable level of chlorides for catfish production is > 60 mg/L (Rajbongshi *et al.,* 2016). The main source of chloride in lake water include salt deposits, untreated sewage, industrial effluents and through agricultural inputs (Sajeev *et al.,* 2020).

Total Hardness, Calcium and Magnesium

Total hardness is caused due to the presence of cations and anions such as calcium and magnesium, carbonates, bicarbonates and chloride in lake water (Kamboj and Kamboj, 2019). Calcium levels in water help in osmoregulation under stressful conditions and are important for egg and larvae development in fishes. A calcium concentration of >400 mg/L is detrimental to fish and crustaceans (Stone *et al.,* 2013). Magnesium generally occurs in lesser concentrations than calcium in lakes. The total hardness ranged between 72 mg/L – 510 mg/L in sampled lakes. Calcium and magnesium are necessary for metabolic activities like bone and scale formation in fishes (Bhatnagar and Devi, 2013). A hardness level of 150 mg/L is recommended for the optimum growth and survival of *Labeo rohita* (Rajkumar *et al.,* 2018). The calcium and magnesium varied among lakes and recorded as 14.43 mg/L - 160.32 mg/L and 3.72 mg/L - 42.41 mg/L, respectively (Figure 9.11).

Nitrate and Ortho-phosphate

Nitrate and phosphate are the limiting nutrients in aquatic ecosystem. Nitrate ranged between 0.118 mg/L - 4.283 mg/L among lakes of Bangalore (Figure 9.12).

The increased levels of nitrogen and phosphorus in water occurs due to the discharge of untreated domestic wastes, industrial effluents and agricultural runoff (Pinto *et al.,* 2020). In the present study, ortho-phosphate ranged between 0.06 mg/L - 4.41 mg/L (Figure 9.12). The increase of phosphorus levels in freshwater are due to domestic, agricultural and industrial inputs (external P loading) along with internal P loading from the bottom sediments (Calijuri *et al.,* 2002). The extensive use of detergents and sewage are the major sources of phosphates in lake

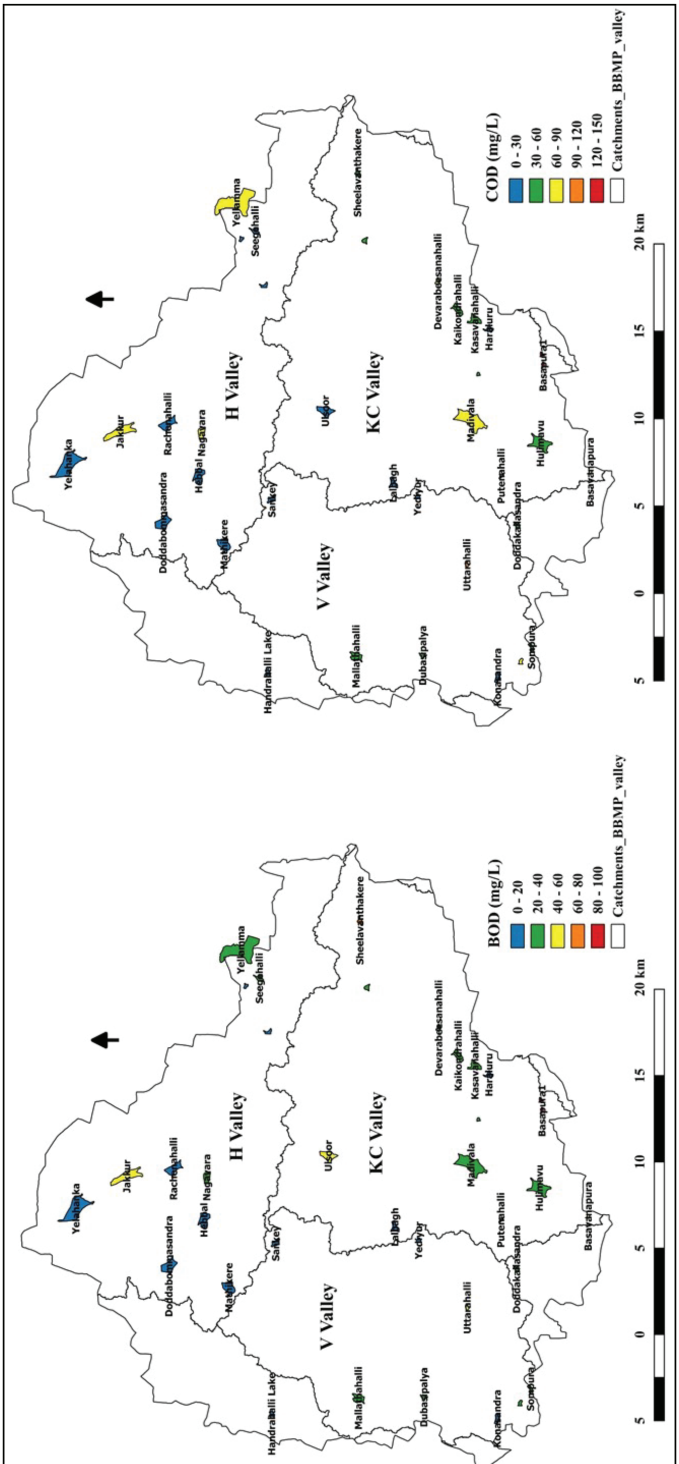

Figure 9.9: Concentration of BOD and COD in Lakes of Bangalore.

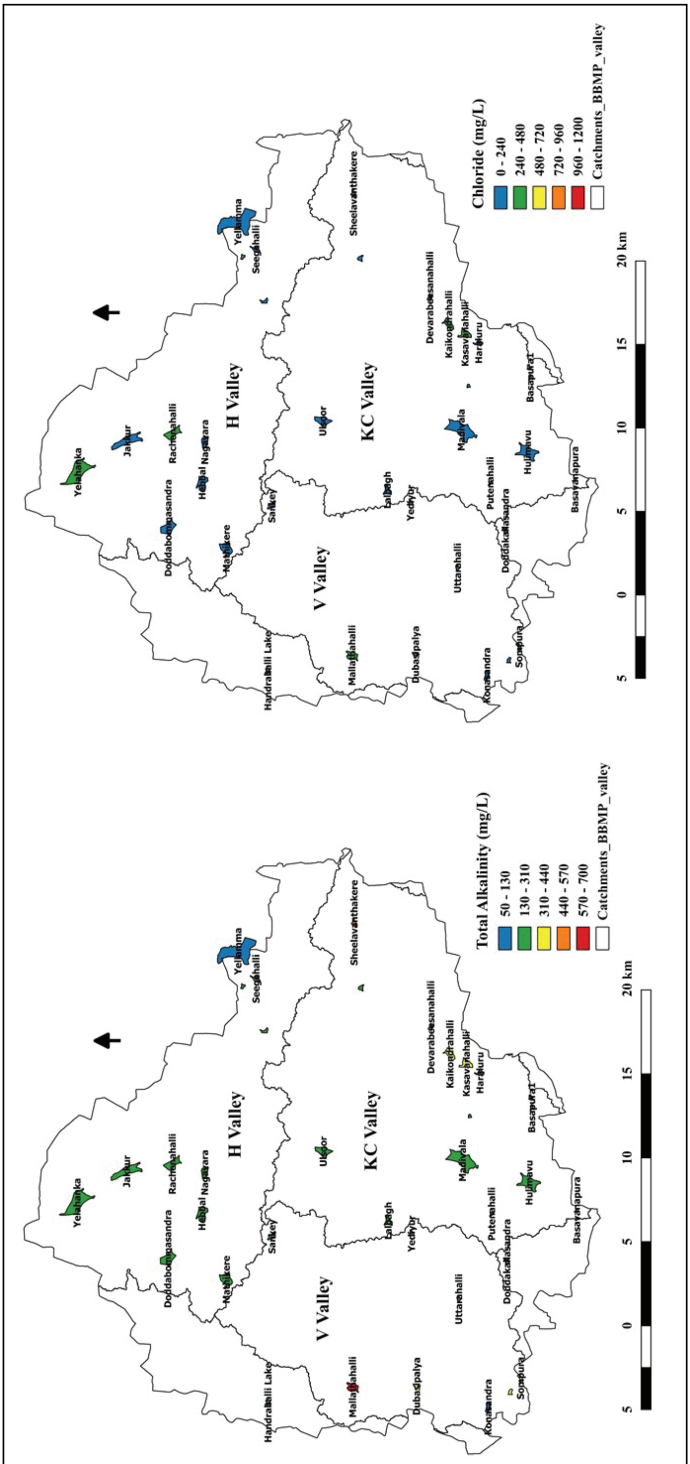

Figure 9.10: Variation of Total Alkalinity and Chloride in Lakes of Bangalore.

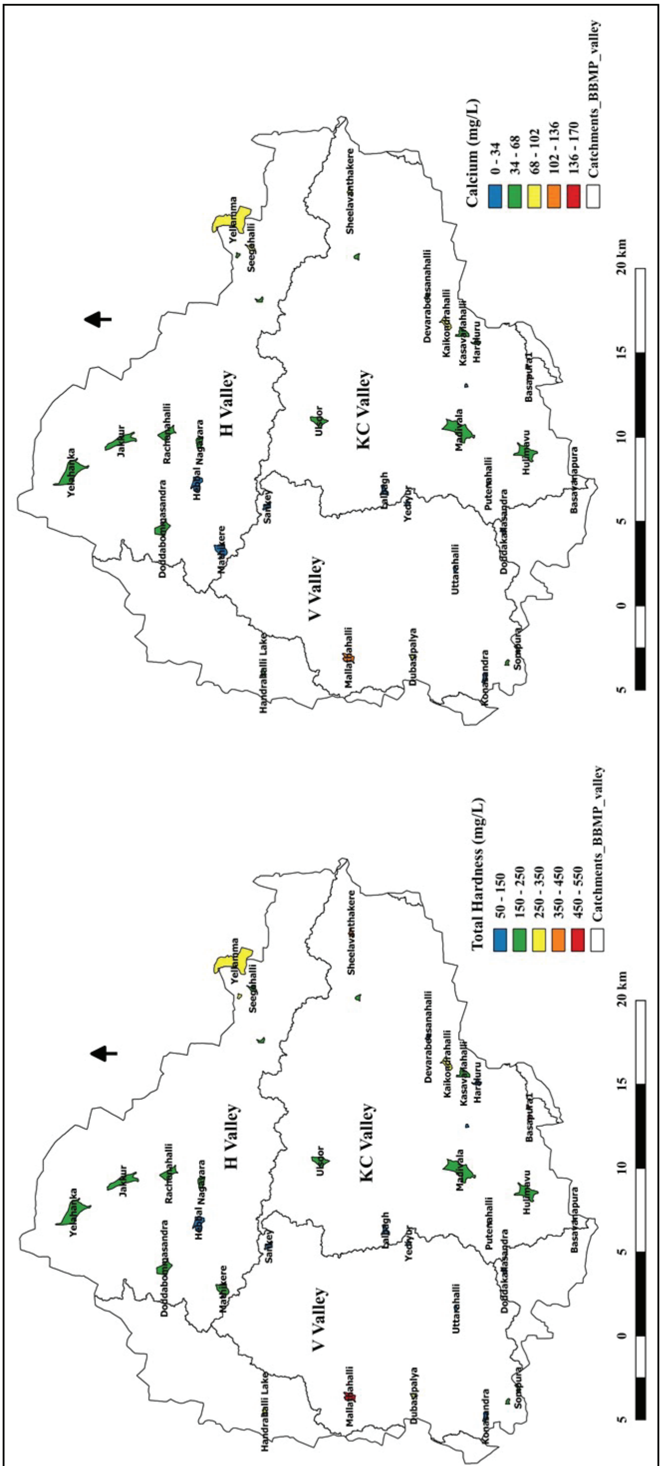

Figure 9.11: The Total Hardness and Calcium Levels in Lakes of Bangalore.

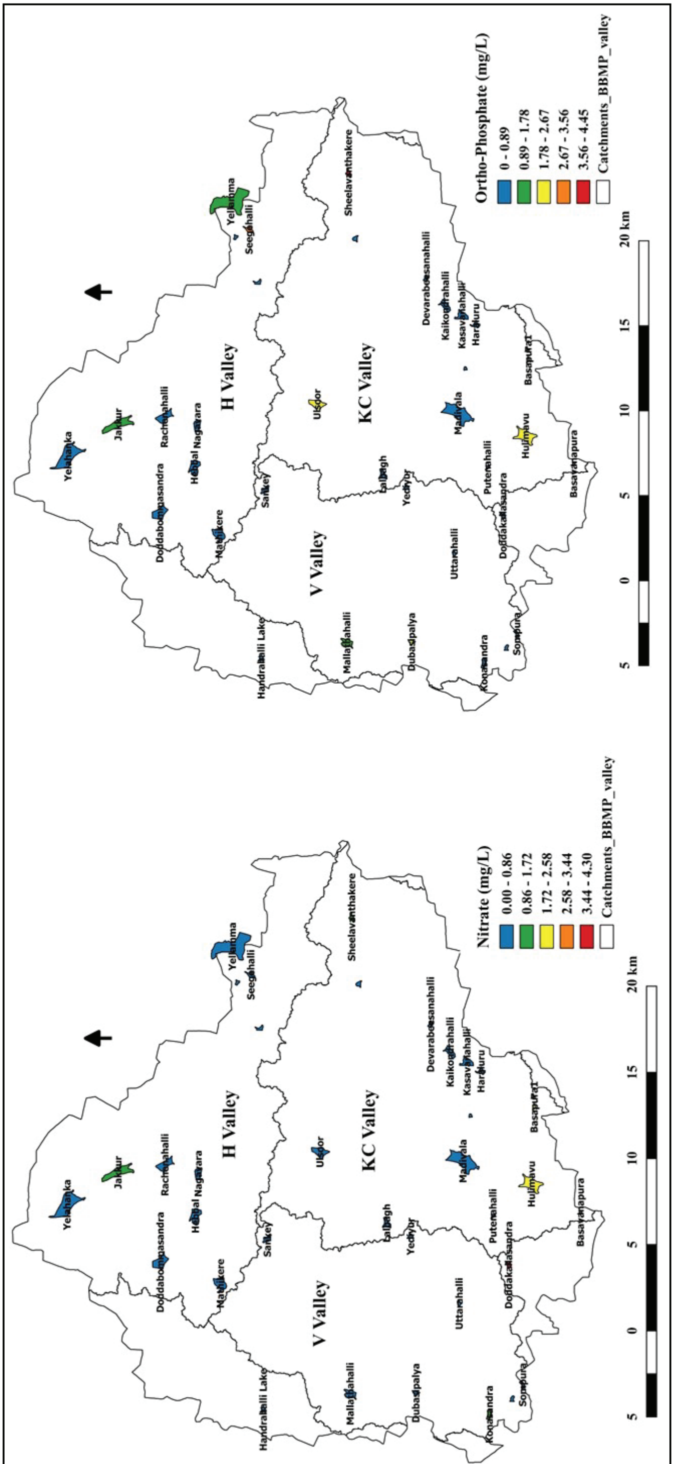

Figure 9.12: Variation of Nitrate and Ortho-phosphate in Lakes of Bangalore.

water (Abdusalam *et al.,* 2019). Water rich in phosphorus favors the growth and proliferation of algae, which results in the eutrophication in water bodies (Rocha *et al.,* 2015). Detergent effluents can induce several toxicological effects in *Clarias gariepinus* (Ogundiran *et al.,* 2010; Nkpondion *et al.,* 2016).

Factors Affecting Lake Water Quality

Principal component analysis (PCA) was applied to the normalized data sets (*i.e.*, 15 physico-chemical parameters of 36 lakes) to identify underlying factors affecting water quality of lakes. The PC loadings of > 0.75, 0.75 - 0.50 and 0.50 - 0.30 were classified as 'strong', 'moderate' and 'weak' respectively (Liu *et al.,* 2003). The principal components (PCs) with eigenvalues greater than one (>1) were considered significant to explain the whole dataset.

In the present study, four principal components were obtained with eigenvalues greater than 1, that explained 81.4 per cent of the total variance in the water quality dataset (Table 9.3). The first component, PC1 accounted for about 47.5 per cent of the total variance in the water quality data set. PC1 has positive loadings on water temperature (0.50), TDS (0.94), EC (0.97), total hardness (0.90), calcium (0.93), magnesium (0.53), chloride (0.88), turbidity (0.76), BOD (0.83) and COD (0.76). This factor is attributed to ionic and organic pollutants, which highlights of industrial and domestic discharges.

Table 9.3: Loadings of Environmental Variables on Principal Components for Water Quality Datasets

	PC 1	*PC 2*	*PC 3*	*PC 4*
Water Temperature	0.50	0.52	-0.02	-0.16
TDS	0.94	-0.10	0.08	0.19
EC	0.97	0.02	-0.04	0.15
pH	0.15	0.57	0.61	0.07
Total Hardness	0.90	-0.36	0.03	0.11
Calcium	0.93	-0.17	-0.08	0.09
Magnesium	0.53	-0.62	0.26	0.12
Chloride	0.88	0.08	-0.16	0.25
Total Alkalinity	0.41	-0.73	0.19	0.00
Turbidity	0.76	0.40	-0.29	-0.15
DO	0.06	0.51	0.18	0.73
BOD	0.83	0.23	-0.08	-0.35
COD	0.76	0.30	-0.33	-0.18
OP	0.45	-0.34	0.53	-0.36
Nitrate	0.28	0.58	0.53	-0.22
Eigenvalue	7.1	2.7	1.3	1.1
Per cent variance	47.5	18.0	8.7	7.2

PC2 accounted for about 18.0 per cent of the total variance with positive loadings of water temperature (0.52), pH (0.57), nitrate (0.58) and DO (0.51) and negative loadings of magnesium (-0.62) and alkalinity (-0.73). This factor corresponds to organic pollution and relates to the productivity of freshwater ecosystem. The PC3 explained 8.7 per cent of the total variance with positive loadings of ortho-phosphate (0.53), nitrate (0.53) and pH (0.61). This factor represents the varied sources of nutrient pollution due to domestic sources, agricultural activities (fertilizer input), industrial discharges and urbanization (urban wastewater). PC4 explained 7.2 per cent of the total variance and is related to DO (0.73) which suggests that lakes had enough amount of dissolved oxygen to sustain aquatic life. A healthy aquatic ecosystem holds DO level of 4 - 6 mg/L (Avvannavar and Shrihari, 2008). DO varies with time, season, rate of photosynthesis, decomposition and respiration activities in lake water. The untreated sewage flowing into lakes alters water chemistry by increasing the ionic, organic and nutrient contents.

WQI Status of Lakes in Bangalore

WQI is computed considering ten water quality parameters - pH, electrical conductivity, total dissolved solids, dissolved oxygen, total hardness, calcium, magnesium, chloride, total alkalinity and nitrate. The water quality condition is described on the basis of WQI value in the range of 0-25, 26-50, 51-75, 76-100 and >100 which corresponds to excellent, good, poor, very poor and unsuitable respectively. Overall, Water quality index (WQI) for the lake water samples were found in the range of 38 to 122 (Figure 9.13).

In the current study on lakes of Bangalore, about 5 per cent of lakes (Lalbagh and Yediyur) fell under good category while 31 per cent lakes fell under poor category. Majority of lakes (about 56 per cent) were classified under very poor category. Lakes namely Basavanapura, Mallathahalli and Sheelavanthakere which fell under the category of unsuitable (8 per cent), is not appropriate for fish culture. The water quality of lakes is deteriorating as evident from WQI status of lakes, mainly due to the inflow of sewage water from residential and commercial complexes, agricultural run-off, anthropogenic activities, untreated effluents from industries and factories, dumping of solid wastes into lakes and lack of proper sanitation.

In earlier studies, WQI values of Sankey tank water belonged to good water class whereas Mallathahallilake fell under poor water category (Ravikumar *et al.,* 2013). WQI values of Hebballake fell under very poor category (Sudarshan *et al.,* 2019). Earlier study has reported WQI of 3 lakes in Haryana of > 100, indicating that water is unsuitable for drinking, outdoor bathing and other uses (Kumar *et al.,* 2018). WQI status of Pariyejlake is poor and unfit for human consumption (Thakor *et al.,* 2011). Anthropogenic stress caused the deterioration of water quality of Dal lake as evident from WQI *i.e.*, polluted and unfit for human consumption (Ahmad *et al.,* 2020).

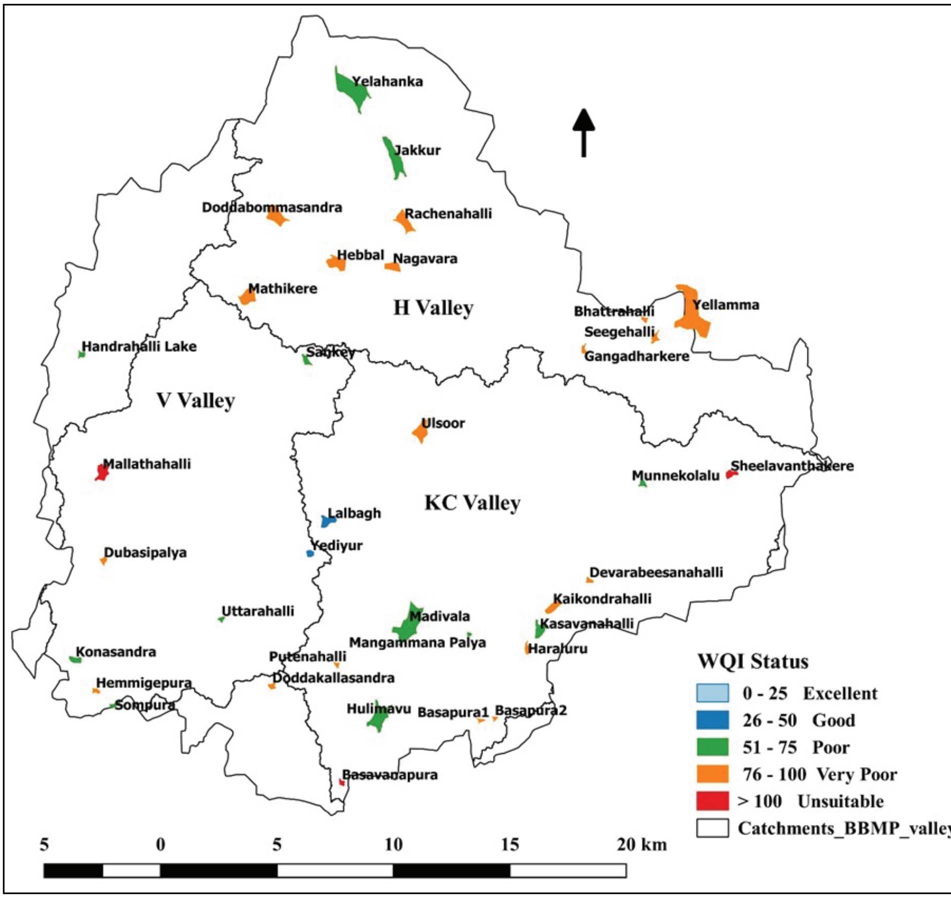

Figure 9.13: WQI Status of Lakes of Bangalore.

Water quality parameters such as temperature, suspended solids, pH, DO, ammonia, nitrite, carbon-dioxide and alkalinity play a crucial role in the growth, reproduction and survival of fish (Okoliegbe *et al.,* 2020). The diversity and distribution of ichthyofaunais governed by pH, turbidity and electrical conductivity (Shetty *et al.,* 2015). The climate change with a decline in rainfall and delayed monsoon, affects temperature of freshwater ecosystems and the breeding behavior/ ecology of fishes (Ninawe *et al.,* 2018). The growth rate of *Oreochromis niloticus* increased at higher temperature and DO whereas the growth rate declined under increased pH, conductivity and ammonia levels (Makori *et al.,* 2017). The sewage and industrial effluents let into water bodies increases the levels of total suspended solids, total dissolved solids, COD and BOD (Ramanujam *et al.,* 2014). The detergent effluents in lake water induce severe damage to gills, skin, kidney, heart, liver and brain of fish (Nkpondion *et al.,* 2016).Inorganic pollution from industries is another main threat to ichthyofauna (Rao *et al.,* 2014). The waterdepth, pressure, turbulence, temperature, light and turbidity are important for fish culture (Priyamvada *et al.,* 2013), which necessitates maintaining water quality to sustain fish production.

In 1970s, about 55 fish species were recorded in Bangalore. At present, there is a massive reduction in ichthyofauna diversity in Bangalore as the lakes are under threat due to water pollution,urbanization, encroachment of lakes, habitat loss or habitat degradation, invasion of exotic species, agricultural practices, climate change,flood, drought, over-harvesting of fish resources and loss of interconnectivity among lakes. The anthropogenic activities, water pollution, eutrophication, habitat degradation, overexploitation, hydrologic alterations, flow modification, damconstruction and climate change are the major threats to fish biodiversity (Borah and Das, 2020; Bhakta *et al.,* 2019; Gupta *et al.,* 2015; Vijaylaxmi *et al.,* 2010). Introduction of exotic species and adopting destructive fishing method such as dynamite or poisoning would cause serious threat to native ichthyofauna (Bose *et al.,* 2019). Urbanization, pollution and water abstraction for irrigation and power generation impose threat to fish diversity (Kumar Sarkar *et al.,* 2013). Hence, it is essential to regulate the sustained inflow of untreated sewage and industrial effluents into lakes to maintain the integrity of aquatic ecosystems and sustain fish diversity. The nutrient removal in lakes (bioremediation) can be achieved in a cost effective way through the integration of conventional water treatment methods with the constructed wetlands (macrophytes) and algal pond (Ramachandra *et al.,* 2018).In order to increase the ichthyofauna diversity, there is a need to avoid habitat destruction, control pollution sources, should ban the introduction of invasive species, harvesting of fish during the spawning period and the harvesting of juveniles. Environmental awareness through awareness programs would help in educating public on the impacts of water pollution on freshwater fish and also the role of healthy ecosystem in supporting people's livelihood. Regular workshops and awareness programs on wetland goods and services would also help in the conservation of aquatic biodiversity.

Conclusion

The current study recorded the ichthyofauna diversity and assessed the water quality of 36 lakes in Bangalore district, Karnataka. The order Cypriniformesis dominant in Bangalore lakes. The rapiddecline inichthyofauna diversity is noticed in Bangalore lakes due to water pollution, habitat degradation,overfishing,invasion of exotic species and climate change. A decline in the population of native species is evident due to the invasion of exotic species. The lakes of Bangalore are polluted due to the sustained inflow of raw sewage and partially treated wastewater. In the present study, PCA helped in understanding the vital physico-chemical parameters that caused changes in lake water quality. PCA of the water quality data evolved four PCs, explaining about 81.4 per cent of the total variance. The main factors affecting lake water quality are water temperature, TDS, EC, total hardness, calcium, magnesium, chloride, turbidity, BOD and COD. These factors correspond to ionic and organic pollution of lakes mainly due to the sustained discharge of untreated or partially treated domestic sewage and industrial wastewater. The water quality index (WQI) for the 36 monitored lakes, revealed that about 56 per cent of lakes fell under very poor water quality category. Lakes such as Basavanapura, Mallathahalli and Sheelavanthakere are polluted and are with poor fish diversity and yield. This necessitates rejuvenation of lakes and arresting anthropogenic pollution sources to protect the aquatic life in lakes of Bangalore. A regular monitoring of lakes and its biodiversity is necessary to raise awareness among the community and conserve the fragile productive ecosystems.

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BIODIVERSITY CHALLENGES

A Way Forward

The present book explores the new ideas, overall up-to-date overview of the biological diversity, and outcome of Biodiversity challenges and measures comprising many interesting chapters focusing on the different aspects of biodiversity. The Most chapters compile the findings of investigations and observations on biodiversity, while a few chapters relay on statistically and theoretically derived information. It is a comprehensive review across the recently emerged research endeavors in areas of biodiversity as it is highly interdisciplinary, predicated as it is on the basis that biodiversity and the health of the planet are related indistinguishably. It generates adequate knowledge on the existence, organization and classification of flora and fauna with environmental estimates from a wide variety of interesting terrestrial and aquatic habitats. With 16 engrossing and detailed chapters, Biodiversity and Conservation deals with general to specific aspects of the discipline in its own way. Conservation of the biodiversity is necessarily an umbrella term for traditional species, linkage to human health, ecosystem conservation and the need to manage the human use of the species and ecosystems in a sustainable way. The book gives detailed information, it is hoped that this book will serve the purpose of students whose curricula include biodiversity and its conversation, it forms an ideal source of scientific information to the advanced students, junior researchers, scientists related to this field. I would recommend biodiversity and conservation students to read this book because it shows how our understanding of the complexities and interaction of the natural world help us to live better life naturally.

Dr. Shashikanth H. Majagi did his M. Sc. and Ph.D. in Zoology from Gulbarga University, Kalaburagi, Karnataka. He started his carrier as Assistant Professor in Government First Grade College, Chikkballapur and Government College (Autonomous) Kalaburagi. He has published 45 research papers and book articles. He has attended and presented 50 research papers in national/international conferences/symposia and 06 books to his credit. He is a reviewer/editorial board member for many journals of international acclaim. He is the life member for many academic bodies. He has given radio talks and doordarshan programmes as well. Received prestigious Award for Research Paper (ARP) award from VGST, Government of Karnataka and IOSRD Life time award and Novel Research Academy Award of Excellence in Research. He has successfully organized two national Conference and Workshops. Successfully completed research projects funded by UGC. He has worked as Special Officer for NAAC, Department of Collegiate Education, Regional Joint Director Office, Kalaburagi. Currently he is teaching Environmental Biology, Biodiversity and Limnology to Master degree students. His research interests are on limnology, water quality studies and biodiversity. Currently working as Associate Professor and Chairman, Department of Zoology, Deputy Registrar (DPAR) and Nodal Officer for Youth Red Cross.

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