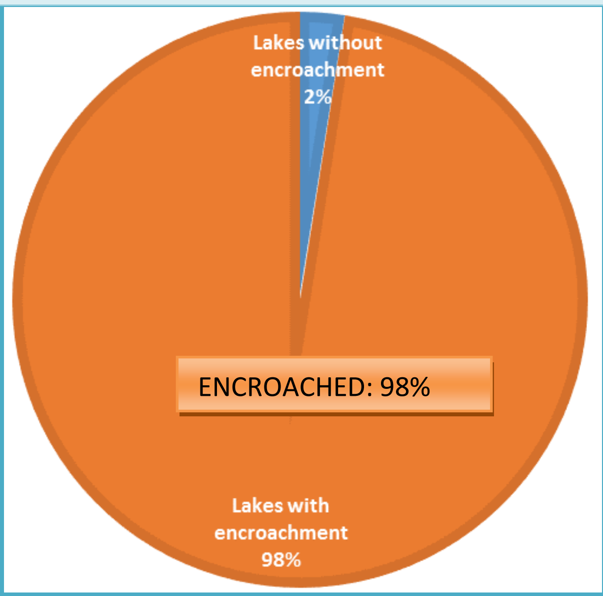
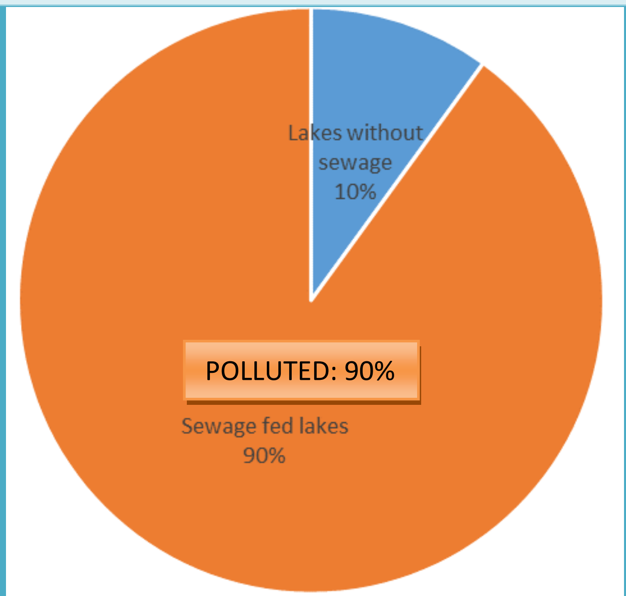
WETLANDS: TREASURE OF BANGALORE

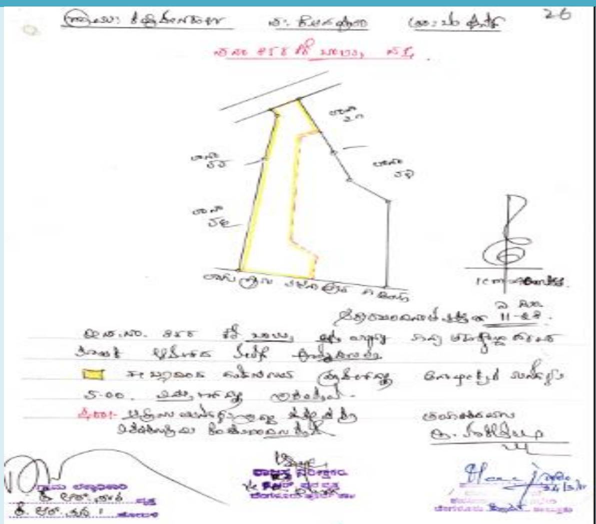
[ABUSED, POLLUTED, ENCROACHED & VANISHING]

Ramachandra T.V. Asulabha K. S. Sincy V.

Sudarshan P Bhat Bharath H. Aithal







Extent as per BBMP-11.7 acres
Encroachment- 5.00acres

VIJNANAPURA LAKE
(polygon with red represents encroachments)

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WETLANDS: TREASURE OF BANGALORE

Preface

Wetlands (and lakes) constitute the most productive ecosystems with a wide array of goods and services. These ecosystems serve as life support systems; serve as habitat for a variety of organisms including migratory birds for food and shelter. They aid in bioremediation and hence aptly known as 'kidneys of the landscape'. Major services include flood control, wastewater treatment, arresting sediment load, drinking water, protein production, and more importantly recharging of aquifers apart from aiding as sinks and climate stabilizers. The wetlands provide a low cost way to treat the community's wastewater, while simultaneously functioning as wild fauna sanctuary, with public access. These ecosystems are valuable for education and scientific endeavours due to rich biodiversity. Despite these services, wetlands – Treasure of Bangalore have been abused (with encroachments by mafia), polluted (sustained inflow of untreated sewage and industrial effluents, dumping of solid wastes and building debris) highlights the lack of (i) sense of belonging of all stakeholders, (ii) sincerity (bureaucracy and decision makers) and (iii) implementation of regulatory norms (weak governance). An exploratory field survey of 105 lakes in Bangalore was conducted during 2013. Of these, 25 lakes were fully covered with macrophytes. The physico – chemical characteristics of 80 lakes of 3 different valleys were monitored during all seasons for a period of 24 months. This report portrays the pathetic status of fragile and productive ecosystems, evident from

- **98% lakes are encroached -** Encroachment of lakebed, flood plains, etc.
- **90% lakes are sewage fed** (sustained inflow of untreated sewage) and industrial effluents

This necessitate immediate policy interventions to conserve these sensitive ecosystems. Wetlands are indispensable for the countless benefits or "ecosystem services" that they provide humanity, ranging from freshwater supply, food and building materials, and biodiversity, to flood control, groundwater recharge, and climate change mitigation. Despite good environmental legislations, loss of ecologically sensitive wetlands is due to the uncoordinated pattern of urban growth happening in Bangalore. Principal reason is lack of good governance and decentralized administration evident from lack of coordination among many Para-state agencies, which has led to unsustainable use of the land and other resources. Failure to deal with water as a finite resource is leading to the unnecessary destruction of lakes and marshes that provide us with water. This failure in turn is threatening all options for the survival and security of plants, animals, humans, etc. There is an urgent need for:

- **Restoring and conserving the actual source of water -** the water cycle and the natural ecosystems that support it - are the basis for sustainable water management
- **Reducing the environmental degradation that is preventing us from reaching goals** of good public health, food security, and better livelihoods world-wide
- **Improving the human quality of life** that can be achieved in ways while maintaining and enhancing environmental quality
- **Reducing greenhouse gases to avoid the deleterious effects of climate change** is an integral part of protecting freshwater resources and ecosystems and **Maintaining Intergeneration Equity**

A comprehensive approach to water resource management is needed to address the myriad water quality problems that exist today from non-point and point sources as well as from catchment degradation. Watershed-based planning and resource management is a strategy for more effective protection and restoration of aquatic ecosystems and for protection of human health. Decision makers need to learn from the similar historical blunder of plundering ecosystems, else Bangaloreans' will pay heavy price – evident already from severe water crisis and pollution related several health issues (higher instance of diseases related to water contamination, kidney failures, cancer, etc.).

WETLANDS: TREASURE OF BANGALORE

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WETLANDS: TREASURE OF BANGALORE

[ABUSED, POLLUTED, ENCROACHED & VANISHING]

I. Executive Summary:

Status	Wetlands: Abused, encroached and polluted
Cause	1. **98% lakes are encroached** - Encroachment of lakebed, flood plains, etc.; • Loss in lake interconnectivity - Encroachment of rajakaluves / storm water drains and loss of interconnectivity; • Lake reclamation for infrastructure activities; • Topography alterations in lake catchment; • 38% is surrounded by slums and 82% showed loss of catchment area. • unauthorised dumping of municipal solid waste and building debris; 2. **90% lakes are sewage fed** (sustained inflow of untreated sewage) and industrial effluents. • Sustained inflow of untreated or partially treated sewage and industrial effluents; • Removal of shoreline riparian vegetation; and unabated construction activities in the valley zone has threatened these urban wetlands. • Pollution due to enhanced vehicular traffic; 3. **Very poor governance** - too many para-state agencies and lack of co-ordination among them.
Solution	❖ Good governance (too many para-state agencies and lack of co-ordination). Single agency with the statutory and financial autonomy to be the custodian of natural resources (ownership, regular maintenance and action against polluters (encroachers as well as those contaminate through untreated sewage and effluents, dumping of solid wastes). Effective judicial system for speedy disposal of conflicts related to encroachment; ❖ Digitation of land records (especially common lands – lakes, open spaces, parks, etc.) and availability of this geo-referenced data with query based information system to public. ❖ Removal of encroachment of lakes / wetlands, lake beds and storm water drains (connecting feeders) after the survey based on reliable cadastral maps; ❖ Decentralised treatment of sewage and solid waste (preferably at ward levels). Letting only treated sewage into the lake (as in **Jakkur lake model**); Ensure that sewage generated in a locality /ward is treated locally. ❖ Restriction of the entry of untreated sewage into lakes; ❖ To make land grabbing cognizable non-bail offence;

	❖ Regular removal of macrophytes in the lakes; ❖ Implementation of 'polluter pays' principle as per water act 1974; ❖ Plant native species of macrophytes in open spaces of lake catchment area; ❖ Stop solid wastes dumping into lakes / in the lake bed ❖ Ensure proper fencing of lakes ❖ Restrictions on the diversion of lake for any other purposes; ❖ Complete ban on construction activities in the valley zones. ❖ Decentralised management of lakes through local lake committees involving all stakeholders
The restoration and conservation strategies has to be implemented for maintaining the ecological health of aquatic ecosystems, aquatic biodiversity in the region, inter-connectivity among lakes, preserve its physical integrity (shorelines, banks and bottom configurations) and water quality to support healthy riparian, aquatic and wetland ecosystems. The regular monitoring of water bodies and public awareness will help in developing appropriate conservation and management strategies.	

1.1 WETLANDS: ESSENTIAL FOR BANGALOREANS' SURVIVAL

Wetlands (and lakes) constitute the most productive ecosystems with a wide array of goods and services. These ecosystems serve as life support systems; serve as habitat for a variety of organisms including migratory birds for food and shelter. They aid in bioremediation and hence aptly known as 'kidneys of the landscape'. Major services include flood control, wastewater treatment, arresting sediment load, drinking water, protein production, and more importantly recharging of aquifers apart from aiding as sinks and climate stabilizers. The wetlands provide a low cost way to treat the community's wastewater, while simultaneously functioning as wild fauna sanctuary, with public access. These ecosystems are valuable for education and scientific endeavours due to rich biodiversity.

Bangalore city (Karnataka State, India) has been experiencing unprecedented urbanisation and sprawl due to concentrated developmental activities in recent times with impetus on industrialisation for the economic development of the region. This concentrated growth has resulted in the increase in population and consequent pressure on infrastructure, natural resources and ultimately giving rise to a plethora of serious challenges such as climate change, enhanced green-house gases emissions, lack of appropriate infrastructure, traffic congestion, and lack of basic amenities (electricity, water, and sanitation) in many localities, etc. Temporal data analysis reveals that that there has been a growth of 925% in urban areas of Bangalore across four decades (1973 to 2013). Sharp decline in natural resources – 78% decline in trees and 79% decline in water bodies highlight unplanned urbanisation process in the city. Urban heat island phenomenon is evident from large number of localities with higher local temperatures. The city once enjoyed salubrious climate (about 14-16 °C during peak summer – May month in early 18th century), now has been experiencing higher temperatures (34 to 37° C) with altered micro climate and frequent flooding during rainy days. The study reveals the pattern of growth in Bangalore and its implication on local climate (an increase of ~2 to 2.5 ºC during the last decade) and also on the natural resources, necessitating appropriate strategies for the sustainable management of natural resources (water bodies, tree cover, etc.). The frequent flooding (since 2000, even during normal rainfall) in Bangalore is a consequence of the increase in impervious area with the high-density urban development in the catchment and loss of wetlands and vegetation.

Urban ecosystems are the consequence of the intrinsic nature of humans as social beings to live together (Ramachandra *et al*., 2012; Ramachandra and Kumar, 2008). The process of urbanisation contributed by infrastructure initiatives, consequent population growth and migration results in the growth of villages into towns, towns into cities and cities into metros. Urbanisation and urban sprawl have posed serious challenges to the decision makers in the city planning and management process involving plethora of issues like infrastructure development, traffic congestion, and basic amenities (electricity, water, and sanitation), etc. (Kulkarni and Ramachandra, 2006). Apart from this, major implications of urbanisation are:

- **Loss of wetlands and green spaces:** Urbanisation (925% concretisation or paved surface increase) has telling influences on the natural resources such as decline in green spaces (78% decline in vegetation) including wetlands (79% decline) and / or depleting groundwater table. Quantification of number of trees in the region using remote sensing data with field census reveal 1.5 million trees and human population is 9.5 million, indicating one tree for seven persons in the city. This is insufficient even to sequester respiratory carbon (due to breathing which ranges from 540 -900 g per person per day).
- **Floods:** Conversion of wetlands to residential and commercial layouts has compounded the problem by removing the interconnectivities in an undulating terrain. Encroachment of natural drains, alteration of topography involving the construction of high-rise buildings, removal of vegetative cover, reclamation of wetlands are the prime reasons for frequent flooding even during normal rainfall post 2000.
- **Decline in groundwater table:** Studies reveal the removal of wetlands has led to the decline in water table. Water table has declined to 300 m from 28 m over a period of 20 years after the reclamation of lake with its catchment for commercial activities. In addition, groundwater table in intensely urbanized area such as Whitefield, etc. has now dropped to 400 to 500m.
- **Heat island:** Surface and atmospheric temperatures are increased by anthropogenic heat discharge due to energy consumption, increased land surface coverage by artificial materials having high heat capacities and conductivities, and the associated decreases in vegetation and water pervious surfaces, which reduce surface temperature through evapotranspiration.
- **Increased carbon footprint**: Due to the adoption of inappropriate building architecture, the consumption of electricity has increased in certain corporation wards drastically. The building design conducive to tropical climate would have reduced the dependence on electricity. Adoption of building architecture unsuitable for Bangalore climate has contributed to higher electricity consumption and hence higher GHG (Greenhouse gases). Per capita electricity consumption in the zones dominated by high rise building with glass facades require 14000-17000 units (kWh) per year

compared to the zones with eco-friendly buildings (1300-1500 units/person/year)Higher energy consumption, enhanced pollution levels due to the increase of private vehicles, traffic bottlenecks have contributed to carbon emissions significantly. Apart from these, mismanagement of solid and liquid wastes has aggravated the situation.

Unplanned urbanisation has drastically altered the drainage characteristics of natural catchments, or drainage areas, by increasing the volume and rate of surface runoff. Drainage systems are unable to cope with the increased volume of water, and are often blocked due to indiscriminate disposal of solid wastes. Encroachment of wetlands, floodplains, etc. obstructs flood-ways causing loss of natural flood storage.

1.2 WETLANDS - VITAL FOR BANGALOREANS

Wetlands are the kidneys of landscape and are vital for human survival. Wetlands are most productive environments; cradles of biological diversity that provide the water and productivity upon which countless species of plants and animals depend for survival; help in remediation - bioremediation. The wetlands perform various ecological functions such as:

1) Wetlands act as kidneys of the landscape – aids in water purification (by uptake of nutrients and heavy metals).
2) Provide wide range of ecosystem services such as food, fiber and waste assimilation.
3) Support large biological diversity.
4) Maintain stream flow, mitigate floods, and control erosion.
5) Recharge ground water.
6) Regulate microclimate.
7) Mitigate floods and loss to human life s and properties
8) Enhance the aesthetics of the landscape and support many significant recreational, social, and cultural activities, aside from being a part of our cultural heritage

Wetlands are indispensable for the countless benefits or "ecosystem services" that they provide humanity, ranging from freshwater supply, food and building materials, and biodiversity, to flood control, groundwater recharge, and climate change mitigation (http://www.ramsar.org/about/the-importance-of-wetlands).

1.3 NORMS VIOLATIONS: PERSISTENT ABUSE AND MISUSE

Bangalore Wetlands have been facing persistent threats due to (i) encroachments and unauthorised construction in the lake bed, wetlands, (ii) violation of prohibited activities in the valley zone / sensitive zone and senseless development activities (contrary to the norms of **CDP:** Comprehensive Development Plan/ **RMP:** Revised Master Plan, **2015**), (iii) violation of regulated activities in the buffer zone (30 m as per BDA), (iv) dumping of municipal solid wastes, demolished building debris, excavated earth, etc., (v) sustained inflow of partially treated or untreated sewage (by BWSSB and high-rise buildings in the lake bed), (vi) disposal of industrial effluents into the drains connecting the lake, (vii) removal of interconnectivity among lakes – by encroachment of Rajakaluve and drains connecting lakes, (viii) dumping of untreated sewage through tankers, (ix) dumping of bio-medical waste, etc.

Major violations in Bellandur-Agara wetlands are:

- LAND USE CHANGES WITH THE CONSTRUCTION ACTIVITIES IN THE PRIMARY VALLEY – SENSITIVE REGIONS (as per RMP, 2015 of BDA: The Proposed SEZ in Agara-Bellandur region is located in the primary valley of the Koramangala Challaghatta valley. Primary valleys in Bangalore **are sensitive regions** as per sensitive zone notification - Circular/35/BBMP/2008, dated: 26/11/2008) and buffer zone for primary valley is 100 m.
- The region is a wetlands as per KARNATAKA LAKE CONSERVATION AND DEVELOPMENT AUTHORITY ACT, 2014 - **KARNATAKA ACT NO. 10 OF 2015;** ***KAR. ACT 12, pg 462***; ***National Wetland Atlas, SAC Ahmedabad, 2009; Wetland rules, MoEF, Govt of India, 2010; RAMSAR Definition of wetlands.***
- Removal of wetlands affects Intergeneration Equity.
- Depriving local residents of water: Wetlands helps in recharge of groundwater in the region.
- Encroachment of Rajakalve and streams (connecting Agara lake with Bellandur Lake).
- Deprives local residents of clean, air and water (as per Article 21 of the Constitution of India).
- Dumping of building debris and excavated earth in Wetlands and also in water-spread area of Bellandur Lake.
- Affects livelihood - Forceful eviction of local farmers due to acquisition of wetlands.
- Construction of compound wall depriving local fishermen of their fundamental right.
- Further encroachment of Bellandur Lake.
- Intimidation, threats and harassment of wetland researchers and conservationists.

1.4 WETLANDS – DEFINITIONS (CONVENIENTLY IGNORED BY BUREAUCRACY)

"Lake" means an inland water-body irrespective of whether it contains water or not, mentioned in revenue records as sarkari kere, kharab kere, kunte, katte or by any other name and includes the peripheral catchment areas, Rajakaluve main feeder, inlets, bunds, weirs, sluices, draft channels, outlets and the main channels of drainages to and fro; "Landscape" includes all forms of trees, shrubs, grasses whether naturally growing or planted in water bodies to enhance aesthetic value; [KARNATAKA LAKE CONSERVATION AND DEVELOPMENT AUTHORITY ACT, 2014, **KARNATAKA ACT NO. 10 OF 2015**].

STATEMENT OF OBJECTS AND REASONS Act 10 of 2015 - **It is considered necessary,-**

1. to protect, conserve, reclaim, regenerate and restore lakes to facilitate recharge of depleting ground water by promoting integrated approach with the assistance of concerned Government departments, local and other authorities;
2. to exercise regulatory control over all the lakes within the jurisdiction of all the Municipal Corporations and Bengaluru Development Authority including prevention and removal of encroachment of lake area and its natural drainage system.
3. to prepare a plan for integrated development of lakes and to improve and also to create habitat of wetland for aquatic biodiversity, water birds and aquatic plants controlling pollution of lakes from sewage and other industrial effluents.
4. to encourage participation of communities and voluntary agencies and to launch public awareness programmes for conservation, preservation and protection of lakes.

Wetlands defined as areas of land that are either temporarily or permanently covered by water exhibit enormous diversity according to their genesis, geographical location, water regime and chemistry – ***National Wetland Atlas, SAC Ahmedabad, 2009***

Wetlands means an area or of marsh, fen, peatland or water, natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters and include all waters such as lakes, reservoirs, tanks, backwaters, lagoons, creeks, estuaries, and manmade wetland and the zone of direct influence on wetlands that is to say the drainage area or catchment region of wetlands as determined by the authority but does not include main river channels, paddy fields and the coastal wetland covered under the notification of the Government of India in the Ministry of

Environment and Forest, S.O number 114 (E) dated the 19th February, 1991 published in the Gazette of India, Extraordinary, Part II, Section 3, Subsection (ii) od dated the 20th February 1991 - ***Wetland rules, MoEF, Govt of India, 2010***

Wetland means land in which wetcrops can be grown by use of rain water or water obtained from any source which is not the property of state government – ***1964: KAR. ACT 12, pg 462***.

Ramsar Definition of a Wetland: Under the Convention on Wetlands (Ramsar, Iran, 1971) 'wetlands' are defined by Articles 1.1 and 2.1 as shown below:

Article 1.1: 'For the purpose of this Convention wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.
'

Article 2.1provides that wetlands: 'may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands'.

Wetlands means an area or of marsh, fen, peatland or water, natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters and include all waters such as lakes, reservoirs, tanks, backwaters, lagoons, creeks, estuaries, and manmade wetland and the zone of direct influence on wetlands that is to say the drainage area or catchment region of wetlands as determined by the authority but does not include main river channels, paddy fields and the coastal wetland covered under the notification of the Government of India in the Ministry of Environment and Forest, S.O number 114 (E) dated the 19th February, 1991 published in the Gazette of India, Extraordinary, Part II, Section 3, Subsection (ii) od dated the 20th February 1991 - ***Wetland rules, MoEF, Govt of India, 2010***

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Wetlands defined as areas of land that are either temporarily or permanently covered by water exhibit enormous diversity according to their genesis, geographical location, water regime and chemistry – ***National Wetland Atlas, SAC Ahmedabad, 2009***

"Lake" means an inland water-body irrespective of whether it contains water or not, mentioned in <u>revenue records</u> as sarkari kere, kharab kere, kunte, katte or by any other name and includes the peripheral catchment areas, Rajakaluve main feeder, inlets, bunds, weirs, sluices, draft channels, outlets and the main channels of drainages to and fro; "Landscape" includes all forms of trees, shrubs, grasses whether naturally growing or planted in water bodies to enhance aesthetic value; [KARNATAKA LAKE CONSERVATION AND DEVELOPMENT AUTHORITY ACT, 2014, **KARNATAKA ACT NO. 10 OF 2015**].

Ramsar Wetland Classification: The wetland types listed below are from the 'Ramsar Classification System for Wetland Type as approved by Recommendation 4.7 and amended by Resolution VI.5 of the Conference of the Contracting Parties. The categories listed herein are intended to provide only a very broad framework to aid rapid identification of the main wetland habitats represented at each site' (http://www.fao.org/docrep/003/x6611e/x6611e03d.htm; *http://www.lrm.nt.gov.au/__data/assets/pdf_file/0013/10462/appendix7.pdf*).

Human-made wetlands

1. -- Aquaculture (e.g. fish/shrimp) ponds
2. **-- Ponds;** includes farm ponds, stock ponds, small tanks; (generally below 8 ha).
3. -- **Irrigated land; includes irrigation channels and rice fields**.
4. -- **Seasonally flooded agricultural land** (including intensively managed or grazed wet meadow or pasture).
5. -- Salt exploitation sites; salt pans, salines, etc.
6. -- **Water storage areas**; reservoirs/barrages/dams/impoundments (generally over 8 ha).
7. -- Excavations; gravel/brick/clay pits; borrow pits, mining pools.
8. -- Wastewater treatment areas; sewage farms, settling ponds, oxidation basins, etc.
9. -- **Canals and drainage channels**, ditches.

Inland Wetlands

L -- Permanent inland deltas.

M -- Permanent rivers/streams/creeks; includes waterfalls.

N -- Seasonal/intermittent/irregular rivers/streams/creeks.

O -- Permanent freshwater lakes (over 8 ha); includes large oxbow lakes.

P -- Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes.

Q -- Permanent saline/brackish/alkaline lakes.

R -- Seasonal/intermittent saline/brackish/alkaline lakes and flats.

Sp -- Permanent saline/brackish/alkaline marshes/pools.

Ss -- Seasonal/intermittent saline/brackish/alkaline marshes/pools.

Tp -- Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.

Ts -- Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.

U -- Non-forested peatlands; includes shrub or open bogs, swamps, fens.

Va -- Alpine wetlands; includes alpine meadows, temporary waters from snowmelt.
Vt -- Tundra wetlands; includes tundra pools, temporary waters from snowmelt.
W -- Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.
Xf -- Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.
Xp -- Forested peatlands; peatswamp forests.
Y -- Freshwater springs; oases.
Zg -- Geothermal wetlands
Zk(b) – Karst and other subterranean hydrological systems, inland

Note: 'floodplain' is a broad term used to refer to one or more wetland types, which may include examples from the R, Ss, Ts, W, Xf, Xp, or other wetland types. Some examples of floodplain wetlands are seasonally inundated grassland (including natural wet meadows), shrublands, woodlands and forests. Floodplain wetlands are not listed as a specific wetland type herein.

1.5 Threats: Loss of Wetlands - Encroachments

The rapid development of urban sprawl has many potentially detrimental effects including the loss of valuable agricultural and eco-sensitive (e.g. wetlands, forests) lands, enhanced energy consumption and greenhouse gas emissions from increasing private vehicle use (Ramachandra and Shwetmala, 2009). Vegetation has decreased by 32% (during 1973 to 1992), 38% (1992 to 2002) and 63% (2002 to 2010).

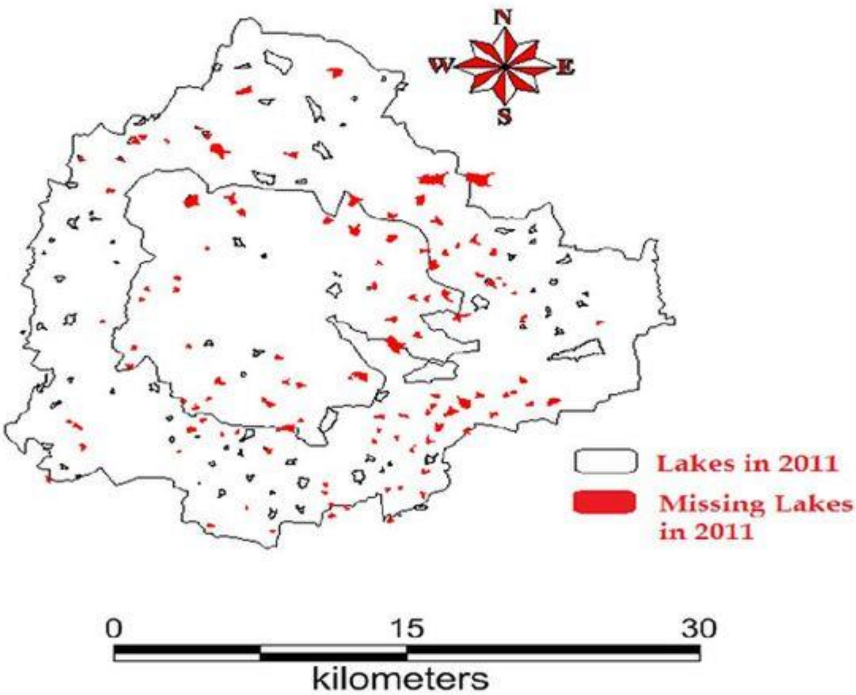

Figure 1: Lakes encroached by land mafia

Disappearance of water bodies or sharp decline in the number of water bodies in Bangalore is mainly due to intense urbanisation and urban sprawl. Latest field survey of 105 wetlands reveal that lakes (98%) have been encroached for illegal buildings (high raise apartment, commercial building, slums, etc.). Field survey of all lakes (in 2014-15) shows that nearly 90% of lakes are sewage fed, 38% surrounded by slums and 82% showed loss of catchment area. Also, lake catchments were used as dumping yards for either municipal solid waste or building debris. The surrounding of these lakes have illegal constructions of buildings and most of the times, slum dwellers occupy the adjoining areas. At many sites, water is used for washing and household activities and even fishing was observed at one of these sites. Multi-storied buildings have come up on some lake beds that have totally intervene the natural catchment flow leading to sharp decline and deteriorating quality of water bodies. This is correlated with the increase in built up area from the concentrated growth model focusing on Bangalore, adopted by the state machinery, affecting severely open spaces and in particular water bodies. Some of the lakes have been restored by the city corporation and the concerned authorities in recent times.

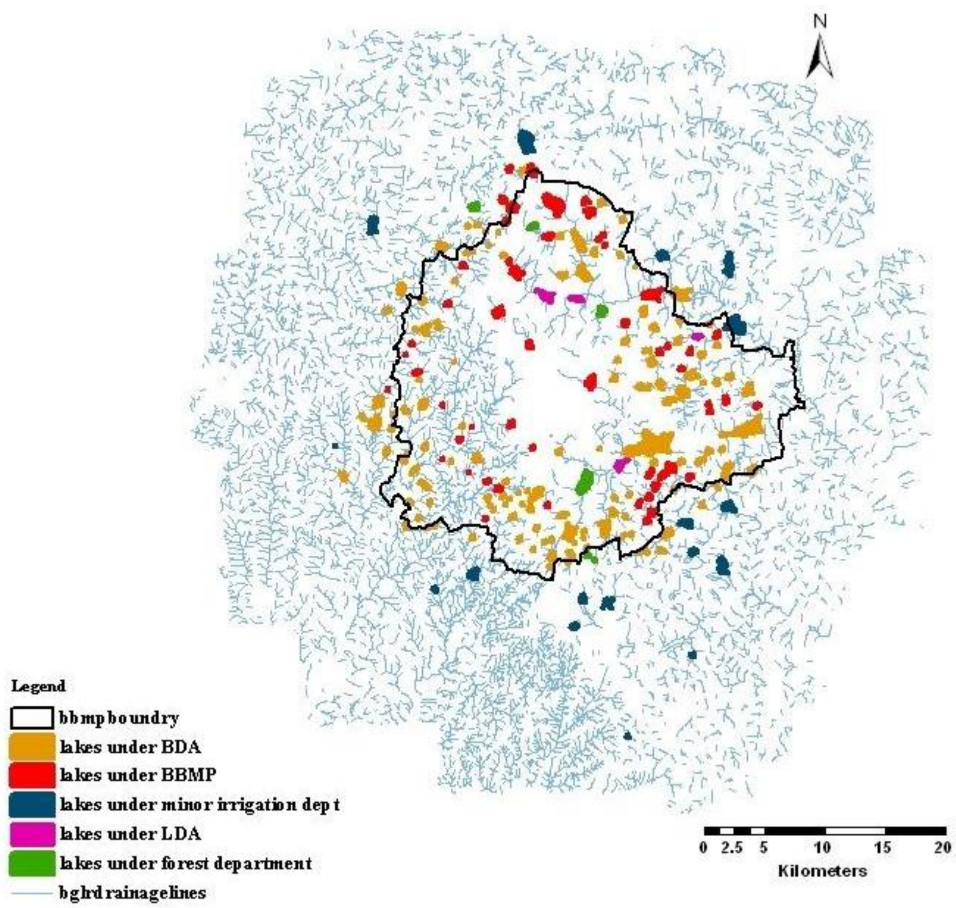

Figure 2: Spatial spread of lakes and custodians (too many – BBMP, BDA, LDA…. But too less effort to protect these lakes)

Threats faced by lakes and drainages of Bangalore:

1. Encroachment of lakebed, flood plains, and lake itself;
2. Encroachment of rajakaluves / storm water drains and loss of interconnectivity;
3. Lake reclamation for infrastructure activities;
4. Topography alterations in lake catchment;
5. Unauthorised dumping of municipal solid waste and building debris;
6. Sustained inflow of untreated or partially treated sewage and industrial effluents;
7. Removal of shoreline riparian vegetation;
8. Pollution due to enhanced vehicular traffic;
9. Too many para-state agencies and lack of co-ordination among them.
10. Different custodians for upstream and downstream lakes in the valley (Figure 2 and Table 1).

Table 1: Lakes with BBMP (A: Area in acres, G: Gunta, T: Total)

Sl.No	Name of the lake	Taluk	Hobli	Name of the village Survey No.	Extent (A-G) as per RTC
1	Agrahara Lake	B'lore North	Yelahanka	Agrahara -33	**15-34**
2	Allalasandra kere	B'lore North	Yalahanka	Allalsandra -15	**41-23**
3	Ambalipura Kelagina kere	B'lore East	Varthur	Ambalipura-40 & 41	3-0, 4-09 T-**7-09**
4	Amblipura Melinakere	B'lore East	Varthur	Ambalipura-36	**12-16**
5	Attur kere	B'lore North	Yalahanka	Attur kere-81 Ananthapura-92 Ramagondanahalli- 39 Kempanahalli-12	56-29 6-15 7-22 19-18 **T-90-04**
6	Avalahalli	B'lore North	Yalahanka	Avalahalli -10 & Singanayakanahalli 64	11-01 2-10 **T-13-11**
7	Bhimmana katte	B'lore South	Kengeri	Halagevaderahalli-138	1-23
8	Bayappanapalya Kunte (Munniyappana katte)	B'lore South	Uttarahalli	Vajarahalli -36	2-31
9	Challakere Lake	B'lore East	K.R. Puram	Challakere - 85	38-05
10	Chinnapanhalli kere	B'lore East	K.R. Puram	Chinnapanahalli 15 & 17	11-33 11-10
11	Chokkanahalli lake	B'lore North	Yelahanka	Chokkanahalli Sy-2	8-02
12	Dasarahalli kere (Chokkasandra)	B'lore North	Yeshwanthapura	Dasarahalli - 24 Chokkasandra - 5	3-29 24-04 **T-27-33**
13	Deepanjali kere	B'lore South	Kengeri	Devatige Ramanahalli-32	**7-22**
14	Devsandra kere	B'lore East	K.R. Puram	Devasandra 31	**16-08**
15	Doddabommasandra	B'lore North	Yelahanka	Dodda Bommasandra-56 Kodigehalli- 175 Thindlu - 53	39-10 49-21 35-28 **T-124-19**

16	Doddakanenahalli kere	B'lore East	Varthur	Doddakanenahalli - 109	**18-14**
17	Dore kere	B'lore South	Uttarahalli	Uttarahalli -22 Vasanthapura -06	19-11 '9-06 **T-28-17**
18	H Gollahalli Lake (Varahasandra Lake)	B'lore South	Kengeri	Kengeri Gollahalli-9 Varahasandra-9 Hemgepura-25	7-08 4-33 7-25 **T-19-26**
19	Halagevaderahalli Lake	B'lore South	Kengeri	Halagevaderahalli-1	**17-10**
20	Handrahalli	B'lore North	Yeshwanthapura	Handrahalli -8	**16-06**
21	Haraluru kere	B'lore East	Varthur	Haraluru-95	**34-70**
22	Herohalli	B'lore North	Yeshwanthapura	Herohalli-99	**34-33**
23	Harohalli lake	B'lore North	Yelahanka	Harohalli-91	**74-32**
24	Jogi kere	B'lore South	Uttarahalli	Mallasandra-30	**3-20**
25	J.P. Park (Mathikere)	B'lore North	Yeshwanthapura	Jalahalli-32 Mathikere-59 Thaniranahalli-01 Kasaba Yeshwanthpura-114	47-26 -- 20-39 -- **T-**
26	Kaikondanahalli kere	B'lore East	Varthuru	Kaikondanahalli -8 Kasavanahalli -70	18-18 30-05 **T-48-23**
27	Kalkere Agra kere	B'lore East	K.R. Puram & Bidarahalli	Kalkere-45 Kyalasanahalli-36 Beelisivale-101 & 106 Horamavu Agra-36	73-11 51-19 0-37 & 0-14 61-11 **T-187-12**
28	Kammagondanahalli	B'lore North	Yeshwanthapura	Kammagondanahalli-18 Shettyhalli-67 Myadarahalli (Medarahalli)-26	15-26 5-32 1-32 **T-23-10**
29	Kasavanhalli	B'lore East	Varthur	Kasavanahalli-50 Haralur-32	21-30 33-18 **T-56-08**
30	Kattiganahalli Kere-136	B'lore North	Jala	Kattiganahalli -136	**25-28**
31	Kattiganahalli Kere-31	B'lore North	Jala	Kattiganahalli -31	**20-10**
32	Kempambudhi Lake	B'lore North	B'lore	Kempambudhi-2	
33	Kodigehalli kere	B'lore North	Yeshwanthapura	Kodigehalli - 30	**9-25**
34	Kogilu Lake	B'lore North	Yelahanka Jala	Kogilu - 84 Kattigenahalli - 117	40-04 38-24 **T-78-28**
35	Koudenahalli kere	B'lore East	K.R. Puram	Koudenahalli -27	**55-05**
36	Kudlu Chikere	Anekal Taluk	Sarjapura	Koodlu-70	**13-05**
37	Kudlu doddakere	Anekal Talulk and B'lore South	Sarjapur & Begur	Koodlu-150 Parapanaagrahara-37	26-38 17-01 T-43-39
38	Kundalahalli Lake	B'lore East	K.R. Puram	Kundalahalli -05	30-20

39	Lingadiranahalli	B'lore North	Yeshwanthapura	Lingadiranahalli-2 & 4	5-32 4-08 **T-10-00**
40	Mahadevapura Lakde	B'lore East	K.R. Puram	Mahadevapura -7	26-23
41	Malgala kere	B'lore North	Yeshwanthapura	Malgala - 46	**6-26**
42	Munnekolalu kere	B'lore East	Varthur	Munnekolalu-25	**15-38**
43	Narasipura-20	B'lore North	Yelahanka	Narasipura-20	**15-30**
44	Narasipura-26	B'lore North	Yelahanka	Narasipura-26	**9-07**
45	Nayandanahalli kere	B'lore South	Kengeri	Nayadahalli -31	**15-18**
46	Parappana Agrahara	B'lore South	Beguru	Parappana Agrahara-23	**16-11**
47	Puttenahalli kere	B'lore South	Uttarahalli	Puttenahalli -42	**13-25**
48	Ramagondanahalli	B'lore North	Yelahanka	Ramagondanahalli-52	**36-26**
49	Sankey Tank	B'lore North	Vyalikaval	Vyalikaval - 21	35-00
50	Shilavantana kere	B'lore East	K.R. Puram	Whitefeild-41	19-32
51	Sigehalli	B'lore East	K.R Puram	Sigehalli-32	31-13
52	Singasandra Lake	B'lore South	Begur	Basapura-15 Singasandra -52	9-34 1-08 **T-11-02**
53	Sowl kere	B'lore East	Varthur	Bellandur-65 Doddakanelli-68 Kaigondanahalli-36	23-33 7-28 30-16 **T-61-37**
54	Thirumenahalli	B'lore North	Yelahanka	Thirumenahalli-63	7-10
55	Ulsoor	B'lore North	B'lore	Ulsoor	
56	Uttarahalli kere (Mogekere)	B'lore South	Uttarahalli	Uttarahalli -111	**15-16**
57	Veerasagara lake	B'lore North	Yelahanka	Veerasagara-26 Attur-25	'17-24 3-30 **T-21-14**
58	Vijanapura kere	B'lore East	K.R. Puram	Kowdenahalli -85 Krishnarajpura-97	11-28 2-07 **T-13-35**
59	Yediyur Lake	B'lore South	Utharahalli	Dasarahalli -01 Yediyur -59	No extent
60	Yelahanka kere (Kasaba Amanikere)	B'lore North	Yelahanka	Yelahanka-29 Kenchenahalli -15 Venkatala-39 Manchenahalli-19 Puttenahalli-49	53-36 30-23 199-31 7-34 18-04 **T-310-08**

Lakes with BDA

Sl. No.	**Name of the Lake**	**Taluk**	**Hobli**	**Name of the village Sy No.**	**Extent (A-G) as per RTC**
1	Abbigere kere	B'lore North	Yeshwanthpur	Abbigere-75 Singapura-95	26-06 21-7 **T-47-13**

2	Alahalli kere / Anjanapura	B'lore South	Uttarahalli	Allahalli -30 Gollahalli-3	15-35 5-30 **T-21-25**
3	Amruthalli kere	B'lore North	Yelahanka	Amruthalli-115	**24-36**
4	Annappahalli/ Yelachenahalli Lake	B'lore South	Uttarahalli	Yelachenahalli-06, Govinayakanahalli-14	4-39 1-33 **T-6-32**
5	Arakere	B'lore South	Beguru	Arakere-34	**37-21**
6	Avalahalli	B'lore North	Yelahanaka	Avalahalli-10 Shiganayakanahalli-64	11-01 2-10 **T-13-11**
7	B.Narayanapura	B'lore East	K.R. Puram	B.Narayanapura-109	15-06
8	Baiyappanahalli kere	B'lore East	K.R. Puram	Baiyappanahalli-61	8-09
9	Basapura Lake-2	B'lore South	Beguru	Basapura-66	10-29
10	Basavanapura Lake	B'lore South	Beguru	Basavanapura-14	**7-34**
11	Begur Lake	Bl'lore South	Begur	Begur-94	**137-24**
12	Bellahalli	B'lore North	Yelahanka	Bellahalli-68	**18-32**
13	Bellandur	B'lore East	Varthur	Yamaluru-62 Amanikere Bellandur Kahne-1 Ibbalur-12 Kempapura-6 Beluru-2	3-04 284-20 399-14 13-15 2-00 **T-700-13**
14	Beratena Agrahara Lake (Chowdeshwari Layout	B'lore South	Begur	Beratena Agrahara (Chowdeshwari)-18	**11-18**
15	Bhattralli kere	B'lore East	Bidarahalli	Bhattralli-2	**18-10**
16	Bheemanakuppe	B'lore South	Kengeri	Bheemanakuppe-180	75-15
17	Bhoganalli kere	B'lore East	Varthur	Bhoganalli-21	12-24
18	Byrasandra	B'lore South	Utharahalli	Byrasandra-56	15-11
19	Byrasandra kere (Chikkepet) (Melinakere)	B'lore East	K.R. Puram	Byrasandra-109	14-19
20	Chennasandra-2	B'lore East	K.R. Puram	Banasawadi-211	47-38
21	Chikka Banavara	B'lore North	Yeshwanthpur	Chikka Banavara-3, Somashettyhalli-73, Kere gullada halli-22 and Ganigarahalli-11,15	67-38 3-21 26-32 4-14 2-30 **T-105-15**
22	Chikka Bellandur kere	B'lore East	Varthur	Chikka Bellandur-9 Mullur -63	67-14 8-07 **T-75-21**
23	Chikkabasavanapura kere	B'lore East	K.R. Puram	Basavanapura-14	14-07
24	Chikkabasthi	B'lore South	Kengeri	Ramasandra-6	7-06
25	Chikkabettahalli	B'lore North	Yelahanka	Chikkabettahalli-52	1-32

26	Chick begur Lake	B'lore South	Begur	Begur-168, Singanadra-86	32-19 9-37 **T-42-16**
27	Chikkammanahalli Lake	B'lore South	Begur	Kammanahalli -22 Vamadevanahalli-	5-19
28	Chikkegowdana palya Lake	B'lore South	Kengeri	Hemmagepura-92	
29	Chunchanaghatta	B'lore South	Utharahalli	Chunchanaghatta-70, 70/2, 70/3	20-31 1-0 1-0 **T-22-31**
30	Chowdeshwari Layout Lake	B'lore South	Begur		
31	Devarakere Lake	B'lore South	Uttarahalli	Bikasipura-9	7-15
32	Doddabidarakallu	B'lore North	Yeshwanthpur	Doddabidarakallu-125 Nagasandra -06	23-21 16-36 **T-40-17**
33	Doddakallasandra	B'lore South	Uttarahalli	Doddakallasandra-27	**21-16**
34	Doddanakundi	B'lore East	K.R. Puram (village map) Varthur (In RTC-Bhoomi)	Doddanekundi -200 Kaggadasapura - 25 Vibhutipura -13	56-39 75-16 3-15 **T-135-30**
35	Dubasipalya Lake	B'lore South	Kengeri	Valagerehalli-43, 43/P1	23-35 1-0 **T-24-35**
36	Gangasetty kere (Diesel shed kere (Gangadhariahnakere) (Dyavasandrakunte kere)	B'lore East	K.R. Puram	KR Pura-58 Devasandra-46	18-32 2-35 **T-21-27**
37	Gandhinagara Lake	B'lore North			
38	Garudachar Palya Kere -1 (Achanakere)	B'lore East	K.R. Puram	Mahadevapura-31	**5-36**
39	Garudachar Palya Kere -2 (Goshala) Yekkalagatta kere	B'lore East	K.R. Puram	Mahadevapura-86	**5-14**
40	Garvebhavi Palya	B'lore South	Begur	Hongasandra -41	**18-04**
41	Gattigere palya Lake	B'lore South	Kengeri	Somapura-27/53	0-37
42	Gottigere Lake	B'lore South	Uttarahalli	Gottigere-71	**37-13**
43	Gowdana Palya Lake	B'lore South	Uttarahalli	Kadirenahalli-33	**9-30**
44	Gubbalala	B'lore South	Uttarahalli	Gubbalala-25 Vajarahalli-	**8-10**
45	Gunjur Kere (Carmelarm)	B'lore East	Varthur	Gunjur-95	**9-17**
46	Gunjur Mouji kere	B'lore East	Varthur	Gunjur-301, Kachamaranhalli-74	59-13 4-26 **T- 63-39**
47	Gunjur Palya kere	B'lore East	Varthur	Gunjur-83	**36-27**
48	Haralakunte Lake (Somasandrakere)	B'lore South	Begur	Haralakunte-51	**16-29**

49	Hoodi kere (GIDDANA KERE)	B'lore East	K.R. Puram	Hoodi-138	**28-31**
50	Hoodi kere -1	B'lore East	K.R. Puram	Hoodi-79	**15-10**
51	Horamavu Agara	B'lore East	K.R. Puram	Horamavu Agra-77	**51-34**
52	Horamavu kere	B'lore East	K.R. Puram	Horamavu-83	**37-14**
53	Hosakerehalli	B'lore South	Uttarahalli	Hosakerehalli-15	**59-26**
54	Hosakere	B'lore South			
55	Hulimavu	B'lore South	Beguru	Hulimavu-42 Kammanahalli -110	124-25 5-32 **130-17**
56	Ibbalur Lake	B'lore South	Beguru	Ibbalur-36	18-06
57	Jakkur & Sampigehalli	B'lore North	Yelahanka	Jakkur-15, 23 Yalahanka Amanikere-55 Sampigehalli-12 Agrahara-13	39-21,36-33 58-16 19-25 3-17 **T-157-32**
58	Jaraganahalli/Sarakki/Puttenahalli Lake	B'lore South	Uttarahalli	Jaraganahalli-7 Sarrakki-26 Puttenahalli - 5 Kothanuru-103 Chunchaghatta-28	38-14 38-0 6-10 11-21 13-07 **T-107-12**
59	Jimkenalli kere	B'lore East	Bidarahalli	Varanasi-47	**8-24**
60	Junnsandra kere	B'lore East	Varthur	Junnasandra-32	**24-33**
61	Kadirenapalya kere	B'lore East	KR Puram	Binnamangala-99	
62	K R Puram (BEML) Bendiganahalli kere	B'lore East	K.R. Puram	Benniganahalli-47 & 55	18-24, 27-14 **T- 45-39**
63	Kaggadasanapura	B'lore East	K.R. Puram (village map) Varthur (In RTC-Bhoomi)	Byrasandra -5 Kaggadasapura-141 Bendiganahalli - 24/3	14-24 32-16 3-26 **T-51-26**
64	Kalena Agrahara Lake	B'lore South	Begur	Kalena Agrahara-43	**7-30**
65	Kalkere Rampura kere	Anekal Taluk (B'lore East)	Jigani Bidarahalli	Kalkere-162 Rampura-22 Maragondanahalli-71 Huvineane-86	64-25 3-04 11-35 108-07 **T-187-31**
66	Kalyani / Kunte (Next to Sai Baba Temple)	B'lore South	Uttarahalli	Vasanthpura-21	**1-33**
67	Kannenahalli	B'lore North (Bng South)	Kengeri Yeshwanthpur		
68	Kelagina kere / Byrasandra	B'lore East	K.R. Puram	Byrasandra-112	**12-21**
69	Kembatha halli	B'lore South	Uttarahalli	Kembathahalli-3 Kathnuru-32/3	5-16 1-33 **T-7-20**
70	Kenchanapura	B'lore South	Kengeri	Kenchanapura-10	**17-20**

71	Kengeri Lake	B'lore South	Kengeri	Kengeri-15, Valagerehalli-85	27-03 5-13 **T-32-16**
72	Kommaghatta	B'lore South	Kengeri	Komaghatta-03 Ramasandra-46	9-04 28-01 **T-37-05**
73	Konankunte	B'lore South	Uttarahalli	Konanakunte - 2	**09-18**
74	Konasandra	Anekal Taluk	Jigani	Dyavasandra-9 Bommandahalli-18 Konasandra-17	21-13 7-39 3-20 **T-32-32**
75	Konnappana agrahara	B'lore South	Begur	Naganathpura (South)81	**5-17**
76	Kothnur	B'lore South	Utharahalli	Kothnur-54	**18-09**
77	Lakshmipura lake	B'lore North	Yeshwanthpur	Lakshmipura-25	**10-06**
78	Lingadheeranahalli	B'lore South	Kengeri	Lingadheeranahalli-13	**5-22**
79	Madavara	B'lore North	Dasanapura Yeshwanthpur	Madavara -48 Chikkabidarakallu-21 Tirumalapura-32 (from Yeshwanthpura hobli) Doddabidarakallu -98 (From Yeshwanthpura hobli	35-31 20-20 8-36 2-39 **T-68-06**
80	Mahadevapura (Bandemahadevpura kere)	B'lore East	K.R. Puram	Mahadevapura-187	**13-11**
81	Mallasandra Gudde lake	B'lore North	Dasanapura	Mallasandra-49, Mallasandra-50	11-28 5-23 **T-17-11**
82	Mallathahalli	B'lore North	Yeshwanthpur	Mallathahalli-101 Giddadakonenahalli-6	50-38 20-08 **T-71-06**
83	Manganahalli	B'lore North	Yeshwanthpur	Manganahalli - 43	**6-22**
84	Medi Agrahara	B'lore North	Yelahanka	Medi Agrahara-33	**13-15**
85	Meenakshi Kere	B'lore South	Begur	Kammanahalli (Meenakshi)-38	**18-37**
86	Mesthripalya Lake	B'lore South	Begur	Jakkasandra- 30	11-21
87	Nagarabhavi	B'lore North (Bng South)	Yeshwanthpur	Nagarabhavi-17	**17-39**
88	Nagareshwara-Nagenahalli Lake	B'lore East	K.R. Puram	Nagareshwara- Nagenahalli -10	11-08
89	Nellagaderanahalli	B'lore North	Yeshwanthpur	Nallagaderanahalli - 62	19-22

90	Nalluralli tank	B'lore East	K.R. Puram	Nalluralli-4 Pantandur Agrahara-85	20-34 27-05 **T-47-39**
91	Narasappanahalli	B'lore North	Yeshwanthpur	Karivabanahalli-40 Nelagadiranahalli - 90 Nelagadiranahalli -89 Doddabidarakallu - 24	27-13 19-05 5-26 1-20 **T-53-24**
92	Nyanappanahalli Lake	B'lore South	Begur	Begur-344	**6-07**
93	Panathur kere -38	B'lore East	Varthur	Panathur - 38	**27-17**
94	Panathur kere -48	B'lore East	Varthur	Panathur - 48	**6-30**
95	Pattandur Agrahara	B'lore East	K.R. Puram	Pattandur Agrahara-124	**16-35**
96	Pattandur Agrahara	B'lore East	K.R. Puram	Pattandur Agrahara-54	12-37
97	Pattanagere Kenchenhalli	B'lore South		Kenchenahalli-33 Pattanagere-43	3-39 0-31 **T-4-30**
98	Rachenahalli	B'lore North B'lore East	Yelahanka K.R Puram	Dasarahalli-61 (Bng East- KR Puram) Jakkur - 82 (Bng North-Yelahanka) Rachenahalli - 69 (Bng East-KR Puram)	73-23 39-07 18-16 **T-131-06**
99	Ramsandra (Hirekere)	B'lore South B'lore North	Kengeri Yeshwanthpur	Ramasandra-159 Kenchanpura-36/* Kenchenapura -36/¥ÉÊQ Kannahalli-37 (Bng north-Yeshwanthpura)	66-20 56-05 5-0 12-29 **T-140-14**
100	Sadaramangala kere	B'lore East	K.R. Puram	Sadaramangala-61, Kodigehalli-8	51-04 1-17 **T-52-21**
101	Shivanahalli	B'lore North	Yelahanka	shivanahalli-48 Allalasandra-38, 48	14-30 3-22 0-27 **T-18-39**
102	Siddapura kere	B'lore East	Varthur	Siddapura -18	**27-38**
103	Singapura Kere	B'lore North	Yelahanka	Singapura-102	**66-18**
104	Singasandra	B'lore South	Beguru	Singasandra -99, 100	10-14 0-34 **T-11-08**
105	Sitaram Palya	B'lore East	K R Puram	Sonnenahalli (Seetharmapalya)-33	**23-37**

106	Sompura	B'lore South	Kengeri	Sompura - 11	17-38
107	Srigandadakaval (near Rajivgandhi nagar)	B'lore North	Yeshwanthpur	Srigandakavalu-15	**6-33**
108	Srinivasapura Kere	B'lore North	Yelahanaka	Srinivasapura-2	**3-14**
109	Subbarayanakere	B'lore South	Uttarahalli	Gottigere-12	**5-10**
110	Subedeharanakere	B'lore South	Begur	Begur-48	**6-05**
111	Subramanyapura Lake	B'lore South	Uttarahalli	Uttarahalli-64	**18-06**
112	Sulekere (Soolikere)	B'lore South	Kengeri	Maragondanahalli Krishnasagara	
113	Swarnakunte gudda kere	B'lore South	Begur	Chandrashekarpura-1	**09-05**
114	Talaghattapura (Gowdarakere)	B'lore South	Uttarahalli	Talaghattapura -73	**19-16**
115	Ullal	B'lore North	Yeshwanthpur	Ullal-93	**24-12**
116	Vaderahalli	B'lore North	Yelahanka	Vaderahalli-32	**9-34**
117	Varahasandra Lake	B'lore South	Kengeri	Hemigepura-4, Varahasandra-24	4-11 13-09 **T-17-20**
118	Varthur	B'lore East	Varthur	Varthur-319	**445-14**
119	Vasanthapura (Janardhanakere)	B'lore South	Utharahalli	Vasanthpura-28	**7-10**
120	Venkateshpura	B'lore North	Yelahanka	Ventateshpura-12 Sampigehalli-37	6-35 11-29 **T-18-24**
121	Vibhuthipura kere	B'lore East	Varthur	Vibhuthipura-175	**45-18**
122	Vishwa nidam lake	B'lore North	Yeshwanthpur	Herohalli-50	**4-30**
123	Yellenhalli Lake (Elenahalli)	B'lore South	Begur	Yellenhalli-55	**4-39**

Lakes under Lake Development Authority (LDA)

Sl.No	Name of the Lake	Taluk	Hobli	Name of the village Sy No.	Extent (A-G) as per RTC
1	Agaram Lake	B'lore South	Kengeri	Agara-11 Venkojiraokhane-11	5-39 136-30 **T-142-29**
2	Hebbal Lake	B'lore North	Kasaba	Hebbla-38 Kodigehalli-37	92-26 99-33 **T-192-19**
3	Nagavara Lake	B'lore North	Kasaba	Nagawara-58 Vishwanatanagenahalli - 12,13	56-17 12-35 6-01 **T-75-13**
4	Vengaiahnakere	B'lore East	K.R. Puram	Krishnarajapura-9 Sannathammanahalli-46	38-12 26-23 **T-64-35**

Lakes - Karnataka Forest Department

Sl.No	Name of the Lake	Taluk	Hobli	Name of the village Sy No.	Extent (A-G) as per

					RTC
1	Hennur (K.R.Puram Range)	B'lore North	Kasaba	Hennur - 53 Nagawara - 13	58-30 14-11 **T-73-01**
2	J.B.Kaval Tank (Bangalore Range)	B'lore North	Yelahanka	Jyarakabande Kavalu-P1-36	44-21 2-04
3	Madiwala (K.R.Puram Range)	B'lore South	Begur	Madivala- 7 Kodichikkanahalli-23 Belekannahalli-64 Rupena Agrahara-11	166-39 80-09 21-35 6-10 T-275-13
4	Mylsandra (Kaggalipura Range) Gumaiahanakere (Mylasandra 1) Mylasandra 2	B'lore South	Kengeri	Mylasandra-37 Kasaba Kengeri-58 Mylasandra - 27 Kasaba Kengeri-66	6-24 6-02 **T-12-26** 10-14 5-28 **T-16-02**
5	Puttenahalli (Yelahanka Range)	B'lore North	Yelahanka	Puttenehalli - 36 Attur - 49	29-14 7-26 **T-37-00**

Lakes - Minor Irrigation Department

Sl.No	Name of the Lake	Taluk	Hobli	Name of the village Sy No.	Extent (A-G) as per RTC
1	Agara kere	Bangalore South	Kengeri	Agara - 103 Agara -102 Agara - 104	13-11 0-08 0-06 **T-13-25**
2	Alluru kere	Bangalore North	Dasanapura	Aluru-132 Vaderahalli - 8 Mathahalli - 25 Narasipura - 41	39-38 27-23 5-32 1-21 **T-75-34**
3	Bhimanakuppe kere	Bangalore South	Kengeri	Bheemanakuppe-180	75-15
4	Bidara Amanikere	Anekal			
5	Bidarahalli kere	Bangalore East	Bidrahalli	Bidarahalli-8 Byappanahalli - 21	15-10 81-16 **T-96-26**
6	Chikkanahalli	Bangalore East			
7	Doddagubbi kere	Bangalore East	Bidarahalli	Doddagubbi-38 NadagowdaGollahalli-39 Chikkagubbi-9	105-18 16-37 1-32 **T-124-07**
8	Ghattahalli Bommankere	Anekal	Sarjapura	Gattahalli-62 Rayasandra - 33	51-17 21-22 **T-72-39**

9	Hoskuru kere (Huskur Lake)	Anekal	Sarjapura	Huskur - 163 Harohalli - 51 Avalahalli - 50	91-10 23-0 --- T-114-10
10	Hulimangala Doddakere	Anekal	Jigani	Hulimangala - 22	67-07
11	Kodatikere	Bangalore East	Varthru	Kodati-8 Solikunte - 52	40-32 37-09 T-78-01
12	Margondanahalli kere	Bangalore South	Kengeri	Margondanahalli -45	5-33
13	Rampura kere	Bangalore East			
14	Sakalavara Bujangadasana kere	Anekal	Jigani	Sakalavara - 93	23-34
15	Singanayakana halli kere	Bangalore North			
16	Singena Agrahara kere	Anekal	Sarjapura	Singena Agrahara-94 Narayanaghatta - 128 Gottammanahalli - 13	95-39 19-32 8-04 **T-123-35**
17	Vaderahalli kere	Bangalore South	Kengeri	B.M.Kaval P1 -136	21-07
18	Yellemallappa Shetty kere	Bangalore East	K.R. Puram	Avalahalli -57 Avalahalli -12 Heerandahalli - 95 Heerandahalli -96 Kurudu Sonnenahalli -2 Medahalli -63 Veerenahalli -29	13-26 17-26 170-16 33-24 31-2 91-35 132-06 **T-490-15**

Source: https://www.karnataka.gov.in/ldakarnataka/documents/Listof-210Lake-BDA,BBMP,LDA, KFD, MILIst.xlsx

The anthropogenic activities particularly, indiscriminate disposal of industrial effluents and sewage wastes, dumping of building debris have altered the physical, chemical as well as biological integrity of the ecosystem. This has resulted in the ecological degradation, which is evident from the current ecosystem valuation of wetlands. Global valuation of coastal wetland ecosystem shows a total of 14,785/ha US$ annual economic value. Valuation of relatively pristine wetland in Bangalore shows the value of Rs. 10,435/ha/day while the polluted wetland shows the value of Rs.20/ha/day (Ramachandra et al., 2005). In contrast to this, Varthur, a sewage fed wetland has a value of Rs.118.9/ha/day (Ramachandra et al., 2011). The pollutants and subsequent contamination of the wetland has telling effects such as disappearance of native species, dominance of invasive exotic species (such as African catfish, water hyacinth, etc.), in addition to profuse breeding of disease vectors and pathogens. Water quality analyses revealed of high phosphates (4.22-5.76 ppm) levels in addition to the enhanced BOD (119-140 ppm) and decreased DO (0-1.06 ppm). The amplified decline of ecosystem goods and services with degradation of water quality necessitates the implementation of sustainable management strategies to recover the lost wetland benefits.

1.6 CONSERVATION AND MANAGEMENT OF WETLANDS

In recent years, there has been concern over the continuous degradation of wetlands due to unplanned developmental activities (Ramachandra, 2002)**.** Urban wetlands are seriously threatened by encroachment of drainage through landfilling, pollution (due to discharge of domestic and industrial effluents, solid wastes dumping), hydrological alterations (water withdrawal and inflow changes), and over-exploitation of their natural resources. This results in loss of biodiversity of the wetland and loss of goods and services provided by wetlands (Ramachandra, 2009). The mitigation of frequent floods and the associated loss of human life and properties entail the restoration of interconnectivity among wetlands, restoration of wetlands (removal of encroachments), conservation and sustainable management of wetlands (Ramachandra et al., 2012).

Despite good environmental legislations, loss of ecologically sensitive wetlands is due to the uncoordinated pattern of urban growth happening in Bangalore. Principal reason is lack of good governance and decentralized administration evident from lack of coordination among many Para-state agencies, which has led to unsustainable use of the land and other resources. Failure to deal with water as a finite resource is leading to the unnecessary destruction of lakes and marshes that provide us with water. This failure in turn is threatening all options for the survival and security of plants, animals, humans, etc. There is an urgent need for:

- **Restoring and conserving the actual source of water -** the water cycle and the natural ecosystems that support it - are the basis for sustainable water management
- **Reducing the environmental degradation that is preventing us from reaching goals** of good public health, food security, and better livelihoods world-wide
- **Improving the human quality of life** that can be achieved in ways while maintaining and enhancing environmental quality
- **Reducing greenhouse gases to avoid the deleterious effects of climate change** is an integral part of protecting freshwater resources and ecosystems.
- **Maintaining intergeneration Equity**

A comprehensive approach to water resource management is needed to address the myriad water quality problems that exist today from non-point and point sources as well as from catchment degradation. Watershed-based planning and resource management is a strategy for more effective protection and restoration of aquatic ecosystems and for protection of human health. The watershed approach emphasizes all aspects of water quality, including chemical water quality (e.g., toxins and conventional pollutants), physical water quality (e.g., temperature, flow, and circulation), habitat quality (e.g., stream channel morphology, substrate composition, riparian zone characteristics, catchment land cover), and biological health and biodiversity (e.g., species abundance, diversity, and range). The suggestions to implement in lakes in order to maintain its healthy ecosystem include:

- **Good governance** (too many para-state agencies and lack of co-ordination) - Single agency with the statutory and financial autonomy to be the custodian of natural resources (ownership, regular maintenance) and action against polluters (encroachers as well as those let untreated sewage and effluents, dumping of solid wastes).
- **De-congest Bangalore**: Growth in Bangalore has surpassed the threshold evident from stress on supportive capacity (insufficient water, clean air and water, electricity, traffic bottlenecks, etc.) and assimilative capacity (polluted water and sediments in water bodies, enhanced GHG – Greenhouse gases, etc.). No new projects shall be sanctioned and the emphasis would be on increasing green cover and restoration of lakes.
- **Disband BDA** – creation of Bangalore Development Agency has given impetus to inefficient governance evident from Bangalore, the garden city turning into 'dead city' during the functional life of BDA.
- **Digitation of land records** (especially common lands – lakes, open spaces, parks, etc.) and availability of this geo-referenced data with query option (Spatial Decision Support System) to public.
- **Comprehensive development plan (CDP) for the city** has to be developed through consultative process involving all stakeholders and should not be outsourced to outside agencies / consultants (from other countries).
- **Removal of encroachment** near to lakes after the survey based on reliable cadastral maps;
- Remove all encroachments (without any mercy) of wetlands, lakes, rajjakaluves (storm water drain) – encroachers have violated all humanitarian norms and deprived large section of the society of ecological services (provided by wetlands)
- Effective judicial system for speedy disposal of conflicts related to encroachment;
- Apply principles of 'polluter pays' principle to agencies responsible for contamination of Bangalore surface and ground water (Agency: BWSSB, industries);
- Action against regulatory agency (KSPCB) for dereliction of statutory duties and other responsibilities by allowing sustained contamination of water, land and air;
- Restriction of the entry of untreated sewage and industrial effluents into lakes;
- To make land grabbing cognizable non-bailable offence;
- Letting off only treated sewage into the lake through constructed wetlands and shallow algae ponds (as in Jakkur lake);
- Regular removal of macrophytes in the lakes;
- Implementation of 'polluter pays' principle as per water act 1974;
- Plant native species of macrophytes in open spaces of lake catchment area;
- Stop solid wastes (municipal and demolition debris) dumping into lakes; treatment and management of solid waste shall be as per MSW Rules 2000, GoI.
- Ensure proper fencing of lakes
- Restrictions on the diversion of lake for any other purposes - Lakes and wetlands provide ecological services (depending on the catchment integrity, duration may vary) – there are no dead lakes or wetlands
- Complete ban on construction activities in the valley zones;

- Monitoring of lakes through network of schools and colleges;
- Mandatory environment education at all levels (schools and colleges including professional courses).

Wetlands in Bangalore are to be restored considering:

Activities around lakes	**Norms to protect and conserve Wetlands**
Encroachment of lake bed and loss of interconnectivity among lakes	The Hon'ble Supreme Court in Civil appeal number 1132/2011 at SLP (C) 3109/2011 on January 28,2011 has expressed concern regarding encroachment of common property resources, more particularly lakes (and raja kaluves) and it has directed the state governments for removal of encroachments on all community lands. Eviction of encroachment: Need to be evicted as per Karnataka Public Premises (eviction of unauthorised occupants) 1974 and the Karnataka Land Revenue Act, 1964
Buildings in the buffer zone of lakes	In case of water bodies, a 30.0 m buffer of 'no development zone' is to be maintained around the lake (as per revenue records) • As per BDA, RMP 2015 (Regional Master Plan, 2015) • Section 17 of KTCP (Karnataka Town and Country Planning) Act, 1961 and sec 32 of BDA Act, 1976 • Wetlands (Conservation and Management) Rules 2010, Government of India; Wetlands Regulatory Framework, 2008. • Valley zones are sensitive and are to be with any construction activities as per RMP 2015 of BDA
Valley Zones	LAND USE CHANGES WITH THE CONSTRUCTION ACTIVITIES IN THE PRIMARY VALLIES – SENSITIVE REGIONS (as per RMP, 2015 of BDA). For example, the Proposed SEZ in Agara-Bellandur region is located in the primary valley of the Koramangala Challaghatta valley. Primary valleys in Bangalore **are sensitive regions** as per sensitive zone notification - Circular/35/BBMP/2008, dated: 26/11/2008) and buffer zone for primary valley is 100 m.
Construction activities in the valley zone (SEZ by Karnataka Industrial Areas Development Board (KIADB)) **in the valley zone**	This is contrary to sustainable development as the natural resources (lake, wetlands) get affected, eventually leading to the degradation/extinction of lakes. This reflects the ignorance of the administrative machinery on the importance of ecosystems and the need to protect valley zones considering ecological function and these regions are 'NO DEVELOPMENT ZONES' as per CDP 2005, 2015
Alterations in topography	Flooding of regions would lead to loss of property and human life and, spread of diseases.

Increase in deforestation in catchment area	Removing vegetation in the catchment area increases soil erosion and which in turn increases siltation and decreases transpiration
Documentation of biodiversity	• The biodiversity of every water body should form part of the School, College, People's Biodiversity Registers (SBR, CBR, PBR). • The local Biodiversity Management Committees (BMC) should be given necessary financial support and scientific assistance in documentation of diversity. • The presence of endemic, rare, endangered or threatened species and economically important ones should be highlighted • A locally implementable conservation plan has to be prepared for such species
Implementation of sanitation facilities	• The lakes are polluted with sewage, coliform bacteria and various other pathogens • Preserving the purity of waters and safeguarding the biodiversity and productivity, dumping of waste has to be prohibited • All the settlements alongside the water body should be provided with sanitation facilities so as not to impinge in anyway the pristine quality of water
Violation of regulatory and prohibitory activities as per Wetlands (Conservation and Management) Rules, 2010; Regulatory wetland framework, 2008	Environment Impact Assessment (EIA) Notification, 2009. **Wetlands (Conservation and Management) rules 2010, Government of India; Regulatory wetland framework, 2008** **Regulated activity** • Withdrawal of water/impoundment/diversion/interruption of sources • Harvesting (including grazing) of living/non-living resources (may be permitted to the level that the basic nature and character of the biotic community is not adversely affected) • Treated effluent discharges – industrial/ domestic/agro-chemical. • Plying of motorized boats • Dredging (need for dredging may be considered, on merit on case to case basis, only in cases of wetlands impacted by siltation) • Constructions of permanent nature within 50 m of periphery except boat jetties • Activity that interferes with the normal run-off and related ecological processes – up to 200 m

	Prohibited activity i. Conversion of wetland to non-wetland use ii. Reclamation of wetlands iii. Solid waste dumping and discharge of untreated effluents
Damage of fencing, solid waste dumping and encroachment problems in Varthur lake series	High Court of Karnataka (WP No. 817/2008) had passed an order which include: • Protecting lakes across Karnataka, • Prohibits dumping of garbage and sewage in Lakes • Lake area to be surveyed and fenced and declare a no development zone around lakes • Encroachments to be removed • Forest department to plant trees in consultation with experts in lake surroundings and in the watershed region • Member Secretary of state legal services authority to monitor implementation of the above in coordination with Revenue and Forest Departments • Also setting up district lake protection committees • Implementation of Handling, Treatment and Management of Municipal Solid Waste as per MSW Rule 2000, GoI
Polluter Pays principle	**National Environment Policy, 2006** The principal objectives of NEP includes : • Protection and conservation of critical ecological systems and resources, and invaluable natural and man-made heritage • Ensuring judicious use of environmental resources to meet the needs and aspirations of the present and future generations • It emphasizes the “Polluter Pays” principle, which states the polluter should, in principle, bear the cost of pollution, with due regard to the public interest
Prevention of pollution of lake	**National Water Policy, 2002** Water is a scarce and precious national resource and requires conservation and management. Watershed management through extensive soil conservation, catchment-area treatment, preservation of forests and increasing the forest cover and the construction of check-dams should be promoted. The water resources should be conserved by retention practices such as rain water harvesting and prevention of pollution.
Discharge of untreated sewage into lakes	**The Environment (Protection) Act, 1986** • Lays down standards for the quality of environment in its various aspects • Laying down standards for discharge of environmental pollutants from various sources and no persons shall discharge any pollutant in excess of such standards

	• Restriction of areas in which industries, operations or processes shall not be carried out or carried out subject to certain safeguards
The water pollution, prevention and its control measures were not looked upon	**Water (Prevention and Control of Pollution) Act, 1974** • It is based on the "Polluter pays" principle. The Pollution Control Boards performs the following functions : • Advice the government on any matter concerning the prevention and control of water pollution. • Encourage, conduct and participate in investigations and research relating to problems of water pollution and prevention, control or abatement of water pollution. • Inspects sewage and effluents as well as the efficiency of the sewage treatment plants. • Lay down or modifiy existing effluent standards for the sewage. • Lay down standards of treatment of effluent and sewage to be discharged into any particular stream. • Notify certain industries to stop, restrict or modify their procedures if the present procedure is deteriorating the water quality of streams.
Pathetic water scenario and insufficient drinking water in Bangalore	The depletion of ground water and drying up off lakes has affected the water availability to meet the current population. At the 4% population growth rate of Bangalore over the past 50 years, the current population of Bangalore is 8.5 million (2011). Water supply from Hesaraghatta has dried, Thippagondanahalli is drying up, the only reliable water supply to Bangalore is from Cauvery with a gross of 1,410 million liters a day (MLD). There is no way of increasing the drawal from Cauvery as the allocation by the Cauvery Water Disputes Tribunal for the entire urban and rural population in Cauvery Basin in Karnataka is only 8.75 TMC ft (one thousand million cubic – TMC ft equals 78 MLD), Bangalore city is already drawing more water-1,400 MLD equals 18 TMC—than the allocation for the entire rural and urban population in Cauvery basin

The restoration and conservation strategies has to be implemented for maintaining the ecological health of aquatic ecosystems, aquatic biodiversity in the region, inter-connectivity among lakes, preserve its physical integrity (shorelines, banks and bottom configurations) and water quality to support healthy riparian, aquatic and wetland ecosystems. The regular monitoring of waterbodies and public awareness will help in developing appropriate conservation and management strategies (Ramachandra, 2005).

Ecological and Environmental Implications:

- Land use changes: Conversion of watershed area especially valley regions of the lake to paved surfaces would alter the hydrological regime.
- Loss of Drainage Network: Removal of drain (Rajakaluve) and reducing the width of the drain would flood the surrounding residential as the interconnectivities among lakes are lost and there are no mechanisms for the excessive storm water to drain and thus the water stagnates flooding in the surroundings.
- Alteration in landscape topography: This activity alters the integrity of the region affecting the lake catchment. This would also have serious implications on the storm water flow in the catchment.
- The dumping of construction waste along the lakebed and lake has altered the natural topography thus rendering the storm water runoff to take a new course that might get into the existing residential areas. Such alteration of topography would not be geologically stable apart from causing soil erosion and lead to siltation in the lake.
- *Loss of Shoreline:* The loss of shoreline along the lakebed results in the habitat destruction for most of the shoreline birds that wade in this region. Some of the shoreline wading birds like the Stilts, Sandpipers; etc will be devoid of their habitat forcing them to move out such disturbed habitats. It was also apparent from the field investigations that with the illogical land filling and dumping taking place in the Bellandur lakebed, the shoreline are gobbled up by these activities.
- *Loss of livelihood:* Local people are dependent on the wetlands for fodder, fish etc. estimate shows that wetlands provide goods and services worth Rs 10500 per hectare per day (Ramachandra et al., 2005). Contamination of lake brings down goods and services value to Rs 20 per hectare per day.

Decision makers need to learn from the similar historical blunder of plundering ecosystems as in the case of Black Swan event (http://blackswanevents.org/?page_id=26) of evacuating half of the city in 10 years due to water scarcity, contaminated water, etc. or abandoning of Fatehpur Sikhri and fading out of AdilShahi's Bijapur (inputs from V.Balasubramanian), or ecological disaster at *Easter Island or* Vijayanagara Empire.

It is the responsibility of Bangalore citizens (to ensure intergeneration equity, sustenance of natural resources and to prevent human-made disasters such as floods, etc.) to stall the irrational conversion of land in the name of development and restrict the decision makers taking the system (ecosystem including humans) for granted as in the case of wetlands by KIADB, BDA, BBMP and many such para-state agencies.

1.7 Recommendations for Conservation and Sustainable Management of Wetlands

1. **Carrying capacity studies for all macro cities:** Unplanned concentrated urbanisation in many cities has telling impacts on local ecology and biodiversity, evident from decline of water bodies, vegetation, enhanced pollution levels (land, water and air), traffic bottlenecks, lack of appropriate infrastructure, etc. There is a

need to adopt holistic approaches in regional planning considering all components (ecology, economic, social aspects). In this regard, we recommend carrying capacity studies before implementing any major projects in rapidly urbanizing macro cities such as Greater Bangalore, etc. Focus should be on

- Good governance (too many para-state agencies and lack of co-ordination) - Single agency with the statutory and financial autonomy to be the custodian of natural resources (ownership, regular maintenance) and action against polluters (encroachers as well as those let untreated sewage and effluents, dumping of solid wastes).
- De-congest Bangalore: **Growth in Bangalore has surpassed the threshold evident from stress on supportive capacity** (insufficient water, clean air and water, electricity, traffic bottlenecks, etc.) **and assimilative capacity** (polluted water and sediments in water bodies, enhanced GHG – Greenhouse gases, etc.)
- Disband BDA – creation of Bangalore Development Agency has given impetus to inefficient governance evident from Bangalore, the garden city turning into 'dead city' during the functional life of BDA.
- Digitation of land records (especially common lands – lakes, open spaces, parks, etc.) and availability of this geo-referenced data with query option (Spatial Decision Support System) to public.

2. **Demarcation of the boundary of water bodies:**
    - The existing regulations pertaining to boundary demarcations within different states need to be reviewed according to updated norms and based on geomorphology and other scientific aspects pertaining to individual water bodies.
    - Maximum Water Level mark should form the boundary line of the water body.
    - In addition, a specified width, based on historical records/ survey records etc. may be considered for marking a buffer zone around the water body. In case such records are not available, the buffer zones may be marked afresh considering the flood plain level and also maximum water levels.
    - The width of the buffer zone should be set considering the geomorphology of the water body, the original legal boundaries, etc.
    - The buffer zone should be treated as inviolable in the long term interests of the water body and its biodiversity.
    - Declare and maintain floodplains and valley zones of lakes as no activity regions
    - Remove all encroachments – free flood plains, valley zones, storm water drains, etc. of encroachments of any kind.
    - Ban conversion of lake, lake bed for any other purposes.
    - Urban wetlands, mostly lakes to be regulated from any type of encroachments.
    - Regulate the activity which interferes with the normal run-off and related ecological processes – in the buffer zone (200 m from lake boundary / flood plains is to be considered as buffer zone)

3. **Mapping of water-bodies:** The mapping of water bodies should also include smaller wetlands, particularly streams, springs etc. The neglect of these hydrological systems could cause considerable impoverishment of water flow in the river systems as well as turn out to be threats to rare kinds of biodiversity. The waters of many of these streams are being diverted for private uses. This causes diminished water flow especially in the during the summer months. A judicious water sharing mechanism has to be worked out at the local level taking into account also the broader national interest as well as conservation of dependent biodiversity. The mapping of these smaller water-bodies, along with their catchments needs to be conducted involving also the local Biodiversity Management Committees. The jurisdictional agreements on the water usage and watershed protection need to be arrived at on a case to case basis involving all the stakeholders.
    - Spatial Extent of Water bodies,
    - Spatial extent of its catchment (watershed/basin),
    - Demarcate Flood plains,
    - Demarcate buffer zone – with a list of regulated activities,
    - Land cover in the catchment,
    - Ensure at least 33% of land cover is covered with natural vegetation (to ensure the lake perennial),
    - Identify the natural areas in the catchment,
    - Biodiversity inventory – capture entire food chain,
    - The jurisdictional agreements on the water usage and watershed protection need to be arrived at on a case to case basis involving all the stakeholders,
    - Develop a comprehensive database (spatial with attribute information) and available to public,
    - Development of Spatial Decision Support System to aid decision makers,
    - Identify and demarcate the region around the lake where all activities are to be prohibited (Flood plain)
    - The biodiversity of every water body should form part of the Biodiversity Registers (BR),
    - The local Biodiversity Management Committees (BMC) should be given necessary financial support and scientific assistance in documentation of diversity,
    - The presence of endemic, rare, endangered or threatened species and economically important ones should be highlighted,
    - A locally implementable conservation plan has to be prepared for such species.

4. **Holistic and Integrated Approaches – Conservation and Management:** Integration of the activities with the common jurisdiction boundaries of Government para-state Agencies for effective implementation of activities related to management, restoration, sustainable utilization and conservation. This necessitates:

- Common Jurisdictional boundary for all para-state agencies
- To minimise the confusion of ownership – assign the ownership of all natural resources (lakes, forests, etc.) to a single agency – **Lake Protection and Management Authority** (or Karnataka Forest Department). This agency shall be responsible for protection, development and sustainable management of water bodies).
- Custodian (single para-state agency) shall manage natural resources - let that agency have autonomous status with all regulatory powers to protect, develop and manage water bodies.
- All wetlands to be considered as common property resources and hence custodians should carefully deal with these ensuring security.
- Management and maintenance of lakes to be decentralized involving stakeholders, local bodies, institutions and community participation without any commercialization or commoditization of lakes.
- Integrated aquatic ecosystem management needs to be implemented to ensure sustainability, which requires proper study, sound understanding and effective management of water systems and their internal relations.
- The aquatic systems should be managed as part of the broader environment and in relation to socio-economic demands and potentials, acknowledging the political and cultural context.
- Wetlands lying within the protected area of National Parks and Wildlife Sanctuaries shall be regulated under the Wildlife Protection Act, 1972. Wetlands lying within the notified forest areas shall be regulated by the Indian Forest Act, 1927 and the Forest Conservation Act, 1980; and the relevant provisions of the Environment (Protection) Act, 1986. The Wetlands outside protected or notified forest areas shall be regulated by the relevant provisions of the Environment (Protection) Act, 1986.
- Immediate implementation of the regulatory framework for conservation of wetlands.
- Socio-economic studies with land use planning in and around the lakes can help in providing ecological basis for improving the quality of lakes.
- Prohibit activities such as conversion of wetlands for non-wetland purposes, dumping of solid wastes, direct discharge of untreated sewage, hunting of wild fauna, reclamation of wetlands.
- Maintain Catchment Integrity to ensure lakes are perennial and maintain at least 33% land cover should be under natural Vegetation.
- Plant native species of vegetation in each lake catchment.
- Create new water bodies considering the topography of each locality.
- Establish laboratory facility to monitor physical, chemical and biological integrity of lakes in each lake.

- Maintain physical integrity - Free storm water drains of any encroachments. Establish interconnectivity among water bodies to minimise flooding in certain pockets. The process of urbanization and neglect caused disruption of linkages between water bodies such as ancient lake systems of many cities. Wherever such disruptions have taken place alternative arrangements should be provided to establish the lost linkages.
- Encroachment of lake beds by unauthorized /authorized agencies must be immediately stopped. Evict all unauthorized occupation in the lake beds as well as valley zones.
- Restrictions on the diversion of lake for any other purposes - Lakes and wetlands provide ecological services (depending on the catchment integrity, duration may vary) – there are no dead lakes or wetlands
- Remove all encroachments (without any mercy) of wetlands, lakes, rajjakaluves (storm water drain) – encroachers have violated all humanitarian norms and deprived large section of the society of ecological services (provided by wetlands)
- Any clearances of riparian vegetation (along side lakes) and buffer zone vegetation (around lakes) have to be prohibited
- Penalise polluters dumping solid waste in the lake bed.
- Implement polluter pays principle for polluters letting liquid waste in to the lake either directly or through storm water drains.
- Lake privatized recently to be taken over and handed over to locals immediately thus restoring the traditional access to these lakes by the stakeholders.
- Restore surviving lakes in urban areas and strengthening their catchment area and allowing sloping shorelines for fulfilling their ecological functions.
- Alteration of topography in lake / river catchments should be banned.
- Appropriate cropping pattern, water harvesting, urban development, water usage, and waste generation data shall be utilized and projected for design period for arriving at preventive, curative and maintenance of aquatic ecosystem restoration action plan (AERAP).
- Desilting of lakes for removal of toxic sediment, to control nuisance macrophytes; further silting in the catchment should be checked by suitable afforestation of catchment areas and the provision of silt traps in the storm water drains.
- Maintaining the sediment regime under which the aquatic ecosystems evolve including maintenance, conservation of spatial and temporal connectivity within and between watersheds.
- Conversion of land around the lakes particularly in the valley zones and storm water drains for any kind of development must be totally banned.

- Flora in the catchment area should be preserved & additional afforestation programmes undertaken.
- Check the overgrowth of aquatic weeds like *Eichhornia, Azolla, Alternanthera* etc. through manual operations.
- Aquatic plants greatly aid in retarding the eutrophication of aquatic bodies; they are the sinks for nutrients & thereby play a significant role in absorption & release of heavy metals. They also serve as food and nesting material for many wetland birds. Therefore, knowledge of the ecological role of aquatic species is necessary for lake preservation.
- Adopt biomanipulation (Silver carp and Catla– surface phytoplankton feeders, Rohu – Column zooplankton feeder Gambusia and Guppies – larvivorous fishes for mosquito control), aeration, and shoreline restoration (with the native vegetation) in the management of lakes.
- Environmental awareness programmes can greatly help in the protection of the water bodies.

▪ Government Agencies, Academies, Institutions and NGO's must co-ordinate grass-root level implementation of policies and activities related to conservation of lakes and wetlands (both Inland and Coastal), their sustainable utilization, restoration and development including human health. There is also a need for management and conservation of aquatic biota including their health aspects. Traditional knowledge and practices have to be explored as remedial measures. Cost-intensive restoration measures should be the last resort after evaluating all the cost-effective measures of conservation and management of the wetlands.

▪ A Committee be constituted consisting of Experts, Representatives of Stakeholders (researchers, industrialists, agriculturists, fishermen, etc.) and Line Agencies, in addition to the existing Committee(s), if any, in order to evolve policies and strategies for reclamation, development, sustainable utilization and restoration of the wetlands and socio-economic development of the local people.

▪ At regional level, **Lake Protection and Management Authority (LPMA)** with autonomy, corpus funds from plan allocations of state and center and responsibility and accountability for avoiding excessive cost and time over runs. LPMA shall have stakeholders-representatives from central and state and local body authorities, NGO's and eminent people and experts shall be constituted

▪ Generous funds shall be made available for such developmental works through the Committee, as mentioned above. Local stakeholders be suggested to generate modest funds for immediate developmental needs in the aquatic systems in their localities.

▪ Provisions should be made for adoption of lakes and wetlands by the NGO's and Self-help groups for their conservation, management, sustainable utilization and restoration.

- Aquatic ecosystem restoration works taken up by any agency, Govt. or NGO's should have 10% of restoration costs (per annum) spent or set off for creating awareness , research and monitoring compulsorily in future.
- Public education and outreach should be components of aquatic ecosystem restoration. Lake associations and citizen monitoring groups have proved helpful in educating the general public. Effort should be made to ensure that such groups have accurate information about the causes of lake degradation and various restoration methods.

5. **Documentation of biodiversity:** The biodiversity of every water body should form part of the School, College, People's Biodiversity Registers (SBR, CBR, PBR). The local Biodiversity Management Committees (BMC) should be given necessary financial support and scientific assistance in documentation of diversity. The presence of endemic, rare, endangered or threatened species and economically important ones should be highlighted. A locally implementable conservation plan has to be prepared for such species.
    - All kinds of introduction of Exotic species and Quarantine measures be done in consultation with the concerned Authorities and the data bank
    - There is an urgent need for creating a `Data Bank' through inventorisation and mapping of the aquatic biota.
    - Identify water bodies of biodiversity importance and declare them as wetland conservation reserves (WCR)

6. **Pollution Prevention:**

    - Letting only treated sewage into the lake (Integration of sewage treatment plant with the constructed wetlands and shallow algal pond would help in the removal of nutrients from the sewage).
    - Complete restriction on disposal of industrial effluents into the lake directly or through drains to the lake.
    - Handling, treatment and management of municipal solid waste as per MSW RULE 2000, GoI
    - Ban on dumping building/construction debris, excavated earth in the drains as well as in the lake bed.

7. **Preparation of management plans for individual water bodies:** Most large water bodies have unique individual characteristics. Therefore it is necessary to prepare separate management plans for individual water bodies.
    - Greater role and participation of women in management and sustainable utilization of resources of aquatic ecosystems.
    - Impact of pesticide or fertilizers on wetlands in the catchment areas to be checked.
    - Regulate illegal sand and clay mining around the wetlands.

7. **Implementation of sanitation facilities:** It was noted with grave concern that the water bodies in most of India are badly polluted with sewage, coliform bacteria and various other pathogens. This involves:
    - Preserving the purity of waters and safeguarding the biodiversity and productivity, dumping of waste has to be prohibited;
    - In addition to this, all the settlements alongside the water body should be provided with sanitation facilities so as not to impinge in anyway the pristine quality of water.

8. **Management of polluted lakes:** This programme needs priority attention. This involves:
    - Implementation of bioremediation method for detoxification of polluted water bodies.
    - The highly and irremediably polluted water bodies to be restored on priority to prevent health hazards.
    - Based on the concept of **polluter pays**, a mechanism be evolved to set up efficient effluent treatment plants [ETP], individual or collective, to reduce the pollution load. Polluting industries be levied **Environmental Cess,** which can be utilised for conservation measures by the competent authorities. A `waste audit' must be made compulsory for all the industries and other agencies.

9. **Restoration of lakes:** The goals for restoration of aquatic ecosystems need to be realistic and should be based on the concept of expected conditions for individual eco-regions. Further development of project selection and evaluation technology based on eco-region definitions and description should be encouraged and supported by the national and state government agencies.
    - Ecosystem approach in aquatic ecosystem restoration endeavor considering catchment land use plan as of pre-project status and optimal land use plan shall first be prepared for short term (10 to 30 years) and long term (>30) periods keeping in view developmental pressure over time span.
    - Research and development is needed in several areas of applied limnology, and this programme should take an experimental approach which emphasizes manipulation of whole ecosystems.
    - Appropriate technologies for point and non-point sources of pollution and *in situ* measures for lake restoration shall be compatible to local ethos and site condition as well as objectives of Aquatic Ecosystem Restoration Action Plan (AERAP).
    - Traditional knowledge and practices have to be explored as remedial measures. Cost-intensive restoration measures should be the last resort after evaluating all the cost-effective measures of conservation and management of ecosystems.
    - Public needs to be better informed about the rational, goal and methods of ecosystem conservation and restoration. In addition, the need was realized for

scientist and researchers with the broad training needed for aquatic ecosystem restoration, management and conservation.

- Improved techniques for littoral zone and aquatic macrophytes management need to be developed. Research should go beyond the removal of nuisance macrophytes to address the restoration of native species that are essential for waterfowl and fish habitat.
- Basic research is necessary to improve the understanding of fundamental limnological processes in littoral zones and the interactions between littoral and pelagic zones of lakes.
- Bio manipulation (food web management) has great potential for low-cost and long-term management of lakes, and research in this emerging field must be stimulated.
- Innovative and low-cost approaches to contaminant clean up in lakes need to be developed.
- The relations between loadings of stress-causing substances and responses of lakes need to be understood more precisely. Research should be undertaken to improve predictions of trophic state and nutrient loading relationships.
- Improved assessment programmes are needed to determine the severity and extent of damage in lakes and wetlands and a change in status over time. Innovative basic research is required to improve the science of assessment and monitoring.
- There is a great need for cost effective, reliable indicators of ecosystems function, including those that would reflect long-term change and response to stress.
- Research on indicators should include traditional community and ecosystem measurements, paleoecological trend assessments and remote sensing.
- Effective assessment and monitoring programme would involve network of local schools, colleges and universities.

10. **Only treated sewage into the Lake**: Prohibition on partially treated or untreated sewage getting into the lake. Integration of constructed wetlands and shallow algal ponds with the sewage treatment plant (as in JAKKUR LAKE) helps in the removal of nutrients and other contaminants. Treatment and management of treated sewage at decentralised levels would help in the prevention of groundwater contamination and also recharge of groundwater resources.
11. **Valuation of goods and services :** Goods and services provided by the individual water bodies and the respective species to be documented, evaluated through participatory approach and be made part of the Biodiversity Registers (PBR: People’s Biodiversity Registers, SBR: School Biodiversity Registers). If in any case the traditional fishing rights of the local fishermen are adversely affected by lake conservation or by declaring it as a bird sanctuary, etc. they should be adequately compensated.

- Ecological values of lands and water within the catchment / watershed shall be internalised into economic analysis and not taken for granted. Pressure groups shall play as watchdogs in preventing industrial and toxic and persistent pollutants by agencies and polluters.

11. **Regulation of boating:** Operation of motorized boats should not be permitted within lakes of less than 50 ha. In larger lakes the number of such boats should be limited to restricted area and carrying capacity of the water body. In any case boating during the periods of breeding and congregations of birds should be banned.
12. **Protection of riparian and buffer zone vegetation:** Any clearances of riparian vegetation (along side rivers) and buffer zone vegetation (around lakes) have to be prohibited.
13. **Restoration of linkages between water bodies:** The process of urbanization and neglect caused disruption of linkages between water bodies such as ancient lake systems of many cities. Wherever such disruptions have taken place alternative arrangements should be provided to establish the lost linkages.
14. **Rainwater harvesting:** Intensive and comprehensive implementation of rain water harvesting techniques can reduce taxation of water bodies and also minimize electricity requirements. The country needs in principle a holistic rainwater harvesting policy aimed at directing water literally from “roof-tops to lakes” after catering to the domestic needs.
15. **Environment Education:** It was felt among the participants that public needs to be better informed about the rational, goal and methods of ecosystem conservation and restoration. In addition, the need was realized for scientist and researchers with the broad training needed for aquatic ecosystem restoration, management and conservation. Public education and outreach should include all components of ecosystem restoration. Lake associations and citizen monitoring groups have proved helpful in educating the general public. Effort should be made to ensure that such groups have accurate information about the causes of lake degradation and various restoration methods. Funding is needed for both undergraduate and graduate programmes in ecosystem conservation and restorations. Training programmes should cross traditional disciplinary boundaries such as those between basic and applied ecology: water quality management and fisheries or wildlife management: among lakes, streams, rivers, coastal and wetland ecology. In this regard the brainstorming session proposes:
    - Environmental education program should be more proactive, field oriented and experiential (with real time examples) for effective learning.
    - Environmental education should be made mandatory at all levels – schools, colleges, universities, professional courses, teachers and teacher educators at the teachers’ training institutes (C P Ed, B P Ed, B Ed, D Ed)
16. **Adopt Inter-disciplinary Approach:** Aquatic ecosystem conservation and management requires collaborated research involving natural, social, and inter-disciplinary study aimed at understanding various components, such as monitoring of water quality, socio-economic dependency, biodiversity and other activities, as an

indispensable tool for formulating long term conservation strategies. This requires multidisciplinary-trained professionals who can spread the understanding of ecosystem's importance at local schools, colleges, and research institutions by initiating educational programmes aimed at rising the levels of public awareness of aquatic ecosystems' restoration, goals and methods. Actively participating schools and colleges in the vicinity of the water bodies may value the opportunity to provide hands-on environmental education, which could entail setting up of laboratory facilities at the site. Regular monitoring of water bodies (with permanent laboratory facilities) would provide vital inputs for conservation and management.

Wetland Protection Laws and Government Initiatives

The primary responsibility for the management of these ecosystems is in the hands of the Ministry of Environment and Forests. Although some wetlands are protected after the formulation of the Wildlife Protection Act, the others are in grave danger of extinction. Effective coordination between the different ministries, energy, industry, fisheries revenue, agriculture, transport and water resources, is essential for the protection of these ecosystems. Thus, wetlands were not delineated under any specific administrative jurisdiction. Recently the Ministry of Environment and Forests of the Government of India issued Notification 2010 Regulatory Framework for Wetlands Conservation (Wetland Conservation Rules). Wetlands in India are protected by an array of laws given below:

- The Indian Fisheries Act - 1857
- The Indian Forest Act - 1927
- Wildlife (Protection) Act - 1972
- Water (Prevention and Control of Pollution) Act - 1974
- Water (Prevention and Control of Pollution) Cess Act - 1977
- Forest (Conservation) Act - 1980
- The Environment (Protection) Act - 1986
- Wildlife (Protection) Amendment Act - 1991
- National Conservation Strategy and Policy Statement on Environment and Development – 1992
- Environment Impact Assessment Notification, 2009
- Wetlands Regulatory Framework, 2008
- Wetlands (Conservation and Management) Rules 2010, Government of India

In addition to the above laws, India is a signatory to the Ramsar Convention on Wetlands and the Convention of Biological Diversity. According to these formulations India is expected to conserve the ecological character of these ecosystems along with the biodiversity of the flora and fauna associated with these ecosystems. Despite these, there is no significant development towards sustaining these ecosystems due to the lack of awareness of the values of these ecosystems among the policymakers and implementation agencies. The effective management of these wetlands requires a thorough appraisal of the existing laws, institutions and practices. The involvement of various people from different sectors is essential in the sustainable management of these wetlands.

Apart from government regulation, development of better monitoring methods is needed to increase the knowledge of the physical and biological characteristics of each wetland resources, and to gain, from this knowledge, a better understanding of wetland dynamics and their controlling processes. Discussions based on accurate knowledge and increased awareness of wetland issues can then begin to develop management strategies (to protect, restore and/or mitigate) that account for the function and value of all wetland resources in the face of natural and socioeconomic factors, while continuing to satisfy critical resource needs of the human population.

The Legal framework for the conservation and management of Wetland Ecosystems is provided by the following National and International Legal instruments:

The Wildlife Protection Act, 1972: This act provides for the protection of wild animals, birds and plants. For the purpose of this act, the state government constitutes the Wildlife Advisory board, which performs the following functions: It advices the state government:

- In the selection of areas to be declared as Sanctuaries, National Parks and Closed Areas.
- In the formulation of policy of protection and conservation of wildlife and specified plants.
- In relation to the measures to be taken for harmonizing the needs of the tribals and forest dwellers with the protection and conservation of wildlife.

This Act imposes prohibition on hunting of wild animals, their young ones as well as their eggs except with prior permission of the Chief Wildlife Warden. This acts prohibits the picking, uprooting, destroying, damaging, possessing of any plant in a protected area, except with prior permission of the Chief Wildlife Warden. The State government may declare any area; which it considers to have adequate ecological, faunal, geomorphological, natural or zoological significance for the purpose of protecting, propagating or developing wildlife or its environment; to be included in a sanctuary or a National Park. No person shall, destroy, exploit or remove any wildlife from a National Park and Sanctuary or destroy or damage the habitat or deprive any wild animal or plant its habitat within such National Park and Sanctuary. The State government may also declare any area closed to hunting for a designated period of time if it feels the ecosystem of that area is disturbed by hunting.

Water (Prevention and Control of Pollution) Act, 1974: for the prevention and control of water pollution and the maintaining or restoring of wholesomeness of water. To carry out the purposes of this act, the Central and the State government constitutes the Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) respectively. The main functions of the pollution control boards include:

- Advice the government on any matter concerning the prevention and control of water pollution.
- Encourage, conduct and participate in investigations and research relating to problems of water pollution and prevention, control or abatement of water pollution.
- Lay down or modify standards on various parameters for the release of effluents into streams.
- Collect and examine effluent samples as well as examine the various treatment procedures undertaken by the industries releasing the effluent.
- Examine the quality of streams.
- Notify certain industries to stop, restrict or modify their procedures if it feels that the present procedure is deteriorating the water quality of streams.
- Establish or recognize laboratories to perform its functions including the analysis of stream water quality and trade effluents.

Forest (Conservation) Act, 1980: Without the permission of the Central government, no State government or any other authority can:

- Declare that any reserved forest shall cease to be reserved.
- Issue permit for use of forest land for non-forest purpose.
- Assign any forest land or portion thereof by way of lease or otherwise to any private person, authority, corporation, agency or any other organization, not owned, managed or controlled by government.
- Clear off natural trees from a forest land for the purpose of reafforestation.

The Biological Diversity Act, 2002: India is a signatory to the United Nations Convention on Biological Resources, 1992 and in accordance with that convention, brought into force The Biological Diversity Act, 2002. This act prohibits biodiversity related activities as well as transfer of the results of research pertaining to biodiversity to certain persons. It also necessitates the approval of National Biodiversity Authority before applying for Intellectual Property Rights on products pertaining to biological diversity. This act emphasizes the establishment of National Biodiversity Authority to carry out various functions pertaining to the Act, viz guidelines for approving collection, research and patents pertaining to biological diversity. It also notifies the central government on threatened species. The central government to develop plans, programmes and strategies for the conservation, management and sustainable use of the biodiversity. Where the Central Government has reason to believe that any area rich in biological diversity, biological resources and their habitats is being threatened by overuse, abuse or neglect, it shall issue directives to the concerned State Government to take immediate ameliorative measures.

Convention on Wetlands of International Importance, especially as Waterfowl habitats, (Ramsar) 1971: To stem the progressive destruction of the wetlands, Ramsar convention was signed. Waterfowls are birds ecologically dependent on the wetlands. The various points agreed under Ramsar convention includes:

- Each contracting party should nominate at least one wetland having significant value in terms of ecology, botany, zoology, limnology or hydrology to be included in the List of Wetlands of International Importance (Ramsar sites) and precisely describe its boundaries.
- The contracting parties will have right to add further wetland sites to the list, expand the boundaries of the existing sites and also to delete or minimize the boundaries of the existing sites.
- Each contracting party shall strive for the conservation, management and restoration of the wetlands in the list.
- Establishment of nature reserves in the area of wetlands thereby protecting it as well as the biological diversity it supports.
- Restriction of boundaries or deletion of a wetland listed as Ramsar sites should be immediately compensated by the creation of additional nature reserves for the protection of waterfowls and other species habiting that wetland.

International convention for the protection of Birds, 1950: To abate the ever dwindling number of certain bird species (particularly the migratory ones) as well as the other birds, this convention was made. This is an amendment to the "International Convention for the Protection of Birds useful to Agriculture, 1902". The objectives of this convention include:

- Protection to all birds, their young ones and their eggs especially in their breeding season.
- Prohibit hunting, killing, mass capture or captivating birds, except those causing intense damage to crops or other components of the ecosystem, such so that the above said components is in the danger of extinction.
- Adopt measures to prohibit industries and other processes causing contamination of air and water that has adverse effects on the survival of birds.
- Adopt measures to prohibit the destruction of suitable breeding grounds and the bird habitat and also encourage the creation of suitable land and water habitat for the birds.

Bonn Convention on Conservation of Migratory Species, 1979: According to the Bonn Convention on Conservation of Migratory Species, the participating parties:

- Should promote, co-operate in and support research relating to migratory species.
- Shall endeavour to provide immediate protection for migratory species which are endangered.
- Shall strive to conserve and restore those habitats of the endangered species in an effort to eliminate the chances of extinction of that species.
- Shall prohibit or minimize those activities or obstacles that seriously impede or prevent the migration of the species.

Convention on Biological Diversity, 1992: The main objectives of this convention are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of benefits arising out of the utilization of genetic resources. In accordance with this convention, each contracting party shall –

- Identify places supporting immense biological diversity.
- Monitor through sampling or other means the components of biological diversity identified and strive for the conservation of those components requiring urgent attention.
- Develop new or adapt existing strategies, plans and programmes for the conservation and sustainable use of biological diversity.
- Identify activities which have or may have significant adverse impact on the sustainability of the biodiversity in an area.
- It prescribes conservation of biological diversity by either *In situ* conservation mechanisms or *Ex situ* conservation mechanisms or both.

In situ conservation: Each contracting parties shall declare a region harbouring immense biological diversity as a protected area and develop various plans and strategies for the establishment, conservation and management of these protected areas and also strive to conserve biodiversity beyond these protected areas.

- Promote environmentally sound and sustainable development in the areas adjacent to the protected areas so as to further enhance the development and protection of these protected areas.
- Promote the protection of ecosystems, prevent the introduction of alien species likely to have an adverse effect on the existing ecosystem and also rehabilitate & restore degraded ecosystems.
- Enforce legislative measures for the protection of threatened species and population.

Ex situ conservation : Each contracting party shall establish facilities for ex situ conservation and for research on plants, animals and micro-organisms, especially the threatened species, augment their number and take steps for their reintroduction in their own natural habitat.

Relative merits and scope of the respective Indian laws with respect to the wetlands protection and conservation is given in Table 2.

Table 2: Sections applicable to Wetlands in the various environmental laws

No.	Act	Relevant Sections
1	The Wildlife (Conservation) Act, 1972	Prohibits hunting of wild animals, their young ones as well as their eggs Prohibits the picking, uprooting, destroying, damaging, possessing of any plant in a protected area Can declare any area with high ecological significance as a national park, sanctuary or a closed area.

2	The Biological Diversity Act, 2002	Prior approval needed from National Biodiversity Authority for collection of biological materials occurring in India as well as for its commercial utilization. Panchayath to document biodiversity and maintain biodiversity registers
3	Forest (Conservation) Act, 1980	Without the permission of the Central government, no State government or any other authority can : • Declare that any reserved forest shall cease to be reserved. • Issue permit for use of forest land for non-forest purpose. • Assign any forest land by way of lease or otherwise to any private person, authority, corporation, agency or any other organization, not owned, managed or controlled by government. • Clear off natural trees from a forest land for the purpose of re-afforestation.
4	Water (Control and Prevention of Pollution) Act, 1974	It is based on the "Polluter pays" principle. The Pollution Control Boards performs the following functions : • Inspects sewage and effluents as well as the efficiency of the sewage treatment plants. • Lay down or modifies existing effluent standards for the sewage. • Lay down standards of treatment of effluent and sewage to be discharged into any particular stream. • Notify certain industries to stop, restrict or modify their procedures if the present procedure is deteriorating the water quality of streams.
5	Wetlands (Conservation and Management) Rules, 2010	Prohibited Activities • Conversion of wetland to non-wetland use • Reclamation of wetlands • Solid waste dumping and discharge of untreated effluents.

		Regulated activities • Withdrawal of water, diversion or interruption of sources • Treated effluent discharges – industrial/domestic/agro-chemical. • Plying of motorized boats • Dredging • Constructions of permanent nature within 50 m • Activity which interferes with the normal run-off and related ecological processes – up to 200 m
6	National Environment Policy, 2006	The principal objectives of NEP includes : • Protection and conservation of critical ecological systems and resources, and invaluable natural and man made heritage. • Ensuring judicious use of environmental resources to meet the needs and aspirations of the present and future generations. • It emphasizes the "Polluter Pays" principle, which states the polluter should, in principle, bear the cost of pollution, with due regard to the public interest.
8	The Environment (Protection) Act, 1986	Lays down standards for the quality of environment in its various aspects. Laying down standards for discharge of environmental pollutants from various sources and no persons shall discharge any pollutant in excess of such standards. Restrictions of areas in which industries, operations or processes shall not be carried out or carried out subject to certain safeguards.
9	National Water Policy, 2002	Water is a scarce and precious national resource and requires to be conserved and management. Watershed management through extensive soil conservation, catchment-area treatment, preservation of forests and increasing the forest cover and the construction of check-dams should be promoted. The water resources should be conserved by retention practices such as rain water harvesting and prevention

		of pollution.
10	KARNATAKA LAKE CONSERVATION AND DEVELOPMENT AUTHORITY ACT, 2014, **KARNATAKA ACT NO. 10 OF 2015** **RMP 2015 (BDA)**	Conservation of lakes and wetlands Primary valleys in Bangalore **are sensitive regions** as per sensitive zone notification - Circular/35/BBMP/2008, dated: 26/11/2008) and buffer zone for primary valley is 100 m. NEEDS PROTECTION – possible only with the implementation of norms without any dilutions and violations.

WETLANDS: TREASURE OF BANGALORE

[ABUSED, POLLUTED, ENCROACHED & VANISHING]

II. INTRODUCTION

Wetlands/lakes constitute the earth's most important freshwater resource, supporting huge biological diversity and provide a wide range of ecosystem services. Wetlands are highly productive ecosystems as they function as eco-tones, transition zones between different habitats, and have characteristics of both aquatic and terrestrial ecosystems. Wetlands are also the most threatened and fragile ecosystems that are susceptible to changes owing to changes in the composition of their biotic and abiotic factors (Ramachandra, 2005). They help in maintaining the ecological balance of the region and meets the need for life on the Earth such as source of drinking water, fish production, storage of water, sediment trapping, nutrient retention and removal, ground water recharge and discharge, flood and erosion control, transport, recreation, climate stabilizers, support for food chains, habitat for indigenous and migratory birds, etc. Wetlands/lakes also play a major role in treating and detoxifying a variety of waste products (Kiran and Ramachandra, 1999; Ramachandra and Solanki, 2007). Wetlands aid in remediation and aid as kidneys of landscape.

Wetland loss and degradation are due to conversion of wetland to non-wetland areas, encroachment of drainages (raja kaluves) through land filling, pollution due to sustained discharge of untreated domestic sewage as well as industrial effluents and dumping of solid waste, hydrological alterations (water withdrawal and inflow changes), and over-exploitation of their natural resources. These anthropogenic activities results in habitat degradation, weed infestation due to nutrient enrichment, loss of biodiversity and decline in goods and services provided by wetlands (Ramachandra, 2010). Pollution of water bodies is due to:

a) pollutants entering from **point sources (i)** Nutrients from wastewater from municipal and domestic effluents **(ii)** Organic, inorganic and toxic pollution from industrial effluents **(iii)** Storm water runoff
b) pollutants from **non-point sources (i)** Nutrients through fertilizers, toxic pesticides etc., from agriculture runoff (**ii)** Organic pollution from human settlements near lakes/fresh water resources.

The entry of untreated sewage into lakes has resulted in nutrient enrichment leading to eutrophication with algal blooms and macrophytes cover with dissolved oxygen depletion and malodor generation (Mahapatra et al., 2011). Land use and land cover (LULC) changes in the wetland catchment alter the physical and chemical integrity of the system, which influences the biological community structure of the area (Ramachandra et al., 2013).

Greater Bangalore with an area of 741 square kilometers lies between the latitudes 12°39’00” to 13°13’00”N and longitude 77°22’00” to 77°52’00”E. Bangalore is located at an altitude of 920 meters above mean sea level, delineating into three watersheds namely, Hebbal, Koramangala-Challaghatta and Vrishabhavathi watersheds. The undulating terrain in the region has facilitated creation of a large number of tanks (mainly attributed to the vision of Kempe Gowda and of the Wodeyar dynasty) providing for the traditional uses of irrigation, drinking, fishing and washing (Ramachandra and Kumar, 2008; Sudhira et al., 2007). Wetlands of Bangalore occupy about 4.8% of the city's geographical area (640 sq.km) covering both urban and non-urban areas. Bangalore has many manmade wetlands but no natural wetlands (Ramachandra and Ahalya, 2001). In 1973, Greater Bangalore had 207 water bodies, which has now reduced to 93 (by 2011), many lakes (54%) were encroached for illegal buildings (Ramachandra et al., 2013). Earlier field investigations had revealed that nearly 66% of lakes are sewage fed, 14% surrounded by slums and 72% showed loss of catchment area. About 30% of the lakes were drained for residential sectors. About 22% of lakes had land filling and construction activities. Now, lake beds are being used as dumping yards for either municipal solid waste or building debris (Ramachandra, 2010). The storm water drains, lake beds, flood plains and catchment areas have been encroached and converted to layouts or for commercial purposes. In case of Bangalore, a decline of vegetation by 66% and water bodies by 74% has been noticed with 584% growth in built-up area during the last four decades (Ramachandra et al., 2012). Recent studies reveal of 925% increase in built-up area with decline of 78% vegetation and 79% water bodies.

Water demand in Bangalore is roughly about 150 liters per day (lpd) per person and the total water requirement for domestic purposes is about 1,400 million liters per day (MLD). Water available from Cauvery (Stages I to IV, Phase I) and Arkavathy (Hesarghatta and Tippagondanahalli reservoirs) rivers is about 975 MLD. The loss of water during transportation and distribution is assumed to be ~30%. These indicate that there is a high demand for water/water scarcity in Bangalore (Ramachandra, et al., 2014). Functions of wetlands are listed in Table 1. Wetlands/lakes help in preventing frequent flooding and micro–climatic changes in the city. The decline in number of water bodies due to industrialization and urbanization had brought about many undesirable effects/impacts on water quality, diversity of flora and fauna and affected the livelihood of dependent population (fisherman, dhobis, etc.). There has been a decrease in the number of migratory birds. Wetlands capture rainwater efficiently and help in ground water recharge apart from aiding in the treatment as kidneys of the landscape. There has been a rapid increase in the number of bore wells in Bangalore over the last three decades from 5,000 to around 4.08 lakh. About 40% of Bengaluru populations are dependent on 750 MLD of ground water (Ramachandra, et al., 2014). The water scarcity issues in Bangalore city can be tackled if the lakes are well/properly maintained to satisfy the needs of the people.

Table 1: Importance of Wetlands/Lakes

FUNCTIONS	
Wetlands as natural water purifiers – kidneys of the landscape	Wetlands act as natural water purifiers by removing contaminants, excessive nutrients, and suspended particles and absorbing many pollutants in surface waters. This enhances the quality of groundwater supplies and mitigates the negative effects of point and non-point sources of pollution.
Role in biogeological cycles	Wetlands play an important role in atmospheric and natural cycles (bio geological cycles).
Groundwater recharge and discharge	Wetlands act like giant sponges, storing, then slowly releasing groundwater, and floodwater. The extent of groundwater recharge depends on the type of soil and its permeability, vegetation, sediment accumulation in the lakebed, surface area to volume ratio and water table gradient.
Flood mitigation and erosion control	Wetlands downstream of urban areas perform valuable flood control services. Wetlands along rivers and streams store excess water during rainstorms. This reduces downstream flood damage and lessens the risk of flash floods. The slow release of this stored water to rivers and streams helps keep them from drying up during periods of drought.
Wetlands as carbon sinks	Wetlands contain roughly 10-14% of the carbon. Their plants and rich soil store carbon instead of releasing it into the atmosphere as carbon-dioxide, which will contribute to global climate change.
Wetland products	Wetland products include fish, timber, medicinal plants, water supply for domestic and industrial purposes, energy resource, transport, recreation, tourism, etc.
Microclimate control	Wetlands control microclimate variations. Shade providing, biodiversity friendly trees and plants minimizes evapotranspiration levels.
Provides habitat	Wetlands serve as habitats for diverse organisms - planktons, insects, fishes, birds, amphibians, reptiles and support other wild life.
Recreation activities	Lakes provide areas for walking, jogging and exercise as well as small play areas for children. Many wetlands contain a diversity of plants and animals that provide beautiful places for sightseeing, fishing, hunting, boating, bird watching and photography.
Educational purposes	Wetlands provide opportunities for environmental education, research and public awareness programs.
Reference	**Ramachandra, et al., 2001; Ramachandra and Solanki, 2007;** http://www.ecy.wa.gov/programs/sea/wetlands/functions.html; http://water.epa.gov/type/wetlands/outreach/upload/fun_val_pr.pdf

According to Bruhat Bangalore Mahanagara Palike (BBMP), Bangalore city had lost many lakes due to developmental activities such as residential layouts, playgrounds, stadiums, industries, government buildings and bus stands. Lakebeds now are dominated by private projects, apartments and houses etc. (table 2).

Table 2: Lost wetlands of Bangalore

Lakes	Conversion to non- wetlands
Agarahar Hosakere	Cheluvadipalya
Akkithimmanhalli lake	Corporation Hockey stadium
Baalayyana Kere (Kamakshipalya)	Sports ground
Banaswadi lake	Subbayapalya Extension
Challaghatta lake	Karnataka golf Association
Chenamma tank	Burial ground, Banashankari 2nd Stage
Chennasandra lake	Pulla Reddy layout
Chinnagara lake	Ejipura
Dasarahalli tank	Dr. B.R Ambedkar Stadium
Dharmambundhi lake	Kempegowda Bus Terminal
Domlur lake	BDA layout
Gangashetty lake	Minerva mills and Open ground
Gangodanhalli	Gangodanhalli
Geddalahalli lake	RMV 2nd stage, 1st block
Gokula Tank	Mathikere
Hennur lake	Nagavara (HBR layout)
Hoskere	Residential Railway Stockyard
Jakarayana Kere	Krishna Floor mills
Kadirenahalli lake	Banashankari 2nd stage
Kalasipalya lake	Kalasipalya
Karanji tank	Gandhi Bazar area
Kempambudhi	Sewerage collection tank
Ketamaranahalli lake	Rajaji Nagar (Mahalakshmipuram)
Kodihalli lake	New Tippasandra/Government buildings/Residential layout
Kodugondanahalli	Kadugondanahalli/ Ambedkar Medical College
Koramangala lake	National Dairy Research Institute
Kurubarahalli lake	Basaveshwaranagar/Residential layout
Marenahalli lake	Residential layout
Mestripalya lake	Mestripalya (open ground)
Millers lake	Guru Nanak Bhavan, Badminton Stadium
Murueshpalya lake	Murueshpalya
Nagashettihalli lake	RMV 2nd stage, 2nd block/Space department
Oddarapalya lake	Rajajinagar (Industrial area)

Parangipalya lake	HSR layout
Puttennahalli tank	J.P. Nagar 6th Phase
Ramashetty Palya kere	Milk colony (Playground)
Sampangi lake	Kanteerava Stadium/Sports Complex
Saneguruvanahalli lake	Shivanahalli (Playground KSPCB buildings)
Sarakki Agrahara lake/ Doresanipalya	JP Nagar 4th phase
Shivanahalli lake	Playground, Bus stand
Shoolay lake	Football stadium
Shule tank	Ashok Nagar Football stadium
Siddapura lake	Siddapura/ Jayanagara 1st block
Siddikatte Lake	KR Market
Sinivaigalu lake	Residential layout
Sonnenahalli lake	Austin Town (RES Colony)
Subhashnagar lake	Residential layout
Sunkal tank	KSRTC Regional Workshop
Timeyard lake	Timeyard layout
Tumkur lake	Mysore Lamps
Tyagarajanagara lake	Tyagarajanagara
Vidyaranyapura lake	Vidyaranyapura (Jalahalli East)
Vijanapura lake(Kotturu)	Rajarajeshwari layout
Vijayanagar Chord Road lake	Vijayanagar
Source:http://www.bpac.in/wp-content/uploads/2014/08/Death-of-lakes-and-the-future-of-bangalore.pdf; http://bangalore.citizenmatters.in/articles/print/5029-bwssb-hoodwinking-bengaluru-on-water-crisis-says-former-bureaucrat; http://archive.deccanherald.com/deccanherald/oct192005/city20104420051018.asp	

The Bangalore Water Supply and Sewerage Board (BWSSB) is mandated to provide drinking water and treat the sewage generated in the city. Unfortunately, BWSSB has been transporting partially or untreated sewage to lakes. Due to this irresponsible act of para-state agency, existing lakes have been reduced to cesspools with the sustained inflow of untreated sewage. Coupled to this, untreated effluents from industries and dumping of solid wastes have further compounded the agony. Unplanned urbanization, lack of co-ordination among para-state agencies and enhanced anthropogenic activities have resulted to (i) the loss of interconnectivity among wetlands (due to encroachments of storm water drains and Raja kaluves, (ii) senseless conversion of wetlands, (iii) nutrient enrichment and heavy metal contamination in wetlands, (iv) increased episodes of floods, (v) dumping of solid wastes and building demolition debris, etc.

The shortfall or lack of sewage treatment facilities is the prime causal factor for contamination of surface and ground waters. The sewage treatment plants (STPs) can remove contaminants (Carbon and solids) from sewage water. BWSSB has commissioned STPs (table 3) in recent times. But the treatment efficiency is low, so a substantial part of the sewage goes untreated which makes lake water polluted. But, the introduction of an integrated wetland system as in JAKKUR Lake (consisting of sewage treatment plant, constructed wetlands with location specific macrophytes and algal pond integrated with the lake) helps in the complete removal of nutrients in a cost effective way (Ramachandra et al., 2014).

Table 3: STPs at Bangalore

Location of STP	Designed capacity (MLD)	Technology used	Capacity utilized (2010, MLD)
Vrishabhavathi (V) Valley (secondary)	180	Secondary: trickling filter	66
Koramangala-Challaghatta (K & C) Valley	248	Secondary: activated sludge process	102
Hebbal Valley	60	Secondary: activated sludge process	35
Madivala (mini STP)	4	Secondary: UASB + oxidation ponds + constructed wetlands	4
Kempambudhi (mini STP)	1	Secondary: extended aeration	1
Yelahanka	10	Activated sludge process + filteration + chlorination (tertiary)	2
Mylasandra	75	Secondary: extended aeration	33
Nagasandra	20	Secondary: extended aeration	4
Jakkur	10	Secondary: UASB + extended aeration	4
K R Puram	20	Secondary: UASB	3
Kadabeesanahalli	50	Secondary: extended aeration	31
Raja Canal	40	Secondary: extended aeration	15
Cubbon Park	1.5	Membrane	0.9
Lalbagh	1.5	Extended aeration + plate settlers + ultra-violet disinfection	0.9
Total	**721**		**302**

(**Source:** http://cseindia.org/userfiles/bangaluru_portrait.pdf)

The aquatic conservation strategy should focus on conservation and maintenance of ecological health of aquatic ecosystems to maintain the aquatic biodiversity in the region, maintain inter-connectivity among lakes, and preserve its physical integrity (shorelines, banks and bottom configurations) and water quality to support healthy riparian, aquatic and wetland ecosystems. The regular monitoring of water bodies involving students at school, college and research institutions, and also public awareness will help in developing appropriate conservation and management strategies (Ramachandra et al., 2005).

The agencies that undertake conservation, restoration and maintenance of wetlands in BBMP area are Bangalore Water Supply and Sewerage Board (BWSSB), Bangalore Development Authority (BDA), Bangalore Metropolitan Regional Development Authority (BMRDA), Bangalore Mahanagara Palike (BBMP), Lake Development Authority (LDA), Minor Irrigation Department and Karnataka Forest Department.

The important recommendations suggested through Lakshman Rau committee report, emphasizing the preservation and restoration of existing tanks in Bangalore in 1988 are:

- The existing tanks help in ground water recharge so they should not be breached but retained as water bodies
- Efforts should be made to ensure that these tanks are not polluted by discharge of domestic and industrial wastes
- The tanks which have already been breached should not be utilized for formation of sites
- Offshore development by large scale planting of trees and also removal of encroachments to prevent silting
- Existing tanks should be deweeded and aquatic life must be developed
- The tank areas where there is no catchment should be handed over to Forest department for tree planting and formation of regional parks
- The Bangalore Development Authority / Bangalore City Corporation / Minor Irrigation Department must remove encroachments in the tank areas
- The Forest Department, Bangalore Development Authority, Bruhat Bengaluru Mahanagara Palike, Minor Irrigation Department, Bangalore Water Supply and Sewerage Board, and Town Planning Department should play an active role in the implementation of recommendations and these recommendations should be reviewed periodically
- The responsibility of maintenance of water bodies in a clean and safe condition should be with Bangalore Water Supply and Sewerage Board
- The possibility of construction of more tanks along the natural valleys which now have run-off water should be examined and implementation is to be taken up

Privatization of lakes in Bangalore: Livelihood of wetland dependent population and ecology research received major blow with the ill-conceived programme implementation under "public-private partnership" of LDA (Lake Development Agency) in 2004.

LDA began a process of "public-private participation" in 2004 where, private companies bid for the lakes to develop, beautify and maintain lakes under Develop/Operate/Transfer (DOT) or NON-DOT basis for the next 15 years. The private partners can be interested private/public participants, including Registered NGO's, Corporations/Business Houses/Resident Associations etc. These private partners can be involved in the conservation of lakes and allowed to operate recreational facilities in return for conserving and maintaining the lake. The private partner shall be responsible for desilting, dredging, landscaping, sewage diversions, foreshore and island development, building of walkways and jogging paths, creation of tree parks, rock gardens, children park area, cycling tracks, fountains, electrification for illumination etc. They can be allowed to construct boat jetty, sports fishing, bird watching, Butterfly park, boating, eco-friendly water sports, eco friendly restaurants etc to generate revenues to make the project financially viable (Thippaiah, 2009; Lake Conservation, Karnataka). Some privatized lakes in Bangalore are Hebbal lake, Nagavara lake (also called Lumbini Gardens after privatization) and K.R. Puram lake or Vengaiahna kere (also called

Fantasy Lagoon, or Hagalu Kanasina Kere, after privatization). In May 2004, LDA leased out the Hebbal lake to East India Hotels Ltd (Oberoi group) for a period of 15 under the Public-Private Partnership policy.The Nagavara lake was leased to Lumbini Developers in 2004 for a period of 15 years and Vengaiahnakere was leased to Par C Ltd. The privatization of lakes has severely impacted the natural ecosystem due to:

a) increased commercialization of public/natural assets,
b) construction of theme parks, entertainment venues and shopping malls affected natural ecosystem,
c) violation of land use regulations by the private partners during implementation of the scheme,
d) denying access to dependent populations for washing, bathing; for fodder; fishing, irrigation, recreation, etc.,
e) poor water quality (due to lack of maintenance) and impact on flora and fauna

The common threats (figure 1, table 4) faced by lakes in Bangalore include a) dumping of building debris, plastic and solid waste into lakes, b) constructing buildings illegally near or on the lakes by the developers/agencies, c) improper and damaged fencing which will increase encroachments in the area, e) inflow of untreated sewage into lakes from surrounding households, apartments, companies, industries etc. and f) filling the lake area of abandoned lakes. The mismanagement of municipal solid waste management in Bangalore has affected the local environment, which is evident from illegal dumping of solid wastes and building debris in lake beds, open drains, parks and open spaces, etc. The leaching of organic fraction of solid waste contaminates land and water (Shwetmala et al., 2012).

Figure 1: Common threats faced by lakes in Bangalore: a) Dumping of building debris, b) plastic and solid waste dumping, c) constructing building near the lakes, d) improper and damaged fencing, e) inflow of untreated sewage into lakes and f) filling the lake area of abandoned lakes.

Table 4: The common threats faced by lakes in Bangalore are:

Sl.No	Problems faced by lakes	Effects on lakes
1.	Discharge of untreated domestic sewage into lakes	▪ Degradation of water quality ▪ Nutrient accumulation ▪ Dissolved oxygen depletion ▪ Over growth of algae and aquatic macrophytes ▪ Accumulation of silt and organic matter ▪ Reduction in depth of lake ▪ Contamination of ground water ▪ Odour problems; Loss of aesthetic value
2.	Encroachment of lake and construction activities in the lake catchment	▪ Reduction of catchment area of lakes ▪ Reduction of ground water table as water recharge capacity goes down ▪ Increased discharge of domestic sewage ▪ Generation of building debris and solid wastes ▪ Soil erosion, Silt accumulation ▪ Cutting down of trees in that location ▪ Affects bird population ▪ Loss of interconnectivity among lakes
3.	Land use changes	▪ Reduction of catchment area ▪ Affects the hydrological regime ▪ Affects climatic condition
4.	Unplanned urbanization	▪ Loss of wetlands and green spaces ▪ Increased frequency of floods ▪ Decline in groundwater table ▪ Heat island ▪ Increased carbon footprint
5.	Threat to ecological balance	▪ Aquatic biodiversity is affected (fish, birds, flora and fauna that are dependent on lake system)
6.	Decline of Ecosystem goods and services	▪ Affects economic growth and livelihood of local people
7.	Removal of shoreline riparian vegetation	▪ Causes soil erosion ▪ Effects the habitat of aquatic organisms
8.	Dumping of municipal solid waste and building debris	▪ Affects human health ▪ Breeding of disease vectors and pathogens
Reference		Ramachandra et al., 2015b

The main consequences faced by lakes (figure 2) due to anthropogenic activities include a) profuse growth of algae and macrophytes due to nutrient enrichment. This leads to oxygen depletion in lakes, affecting aquatic flora and fauna (example, fish death), b) lake will eventually dry up due to accumulation of silt and organic sediments. This reduces the water holding capacity of the lakes and also contaminates ground water, c) The disposal of solid and liquid wastes to the lakes makes water black in color with stinking environment, d) Foams are formed in lakes naturally when algae and fish, die and decompose, releasing a variety of organic compounds into the waterbody. The surface-active agents in wastewater include synthetic detergents, fats, oils, greases and biosurfactants. These act as surfactants and reduce surface tension among water molecules. When air mixes with water molecules vigorously, foam formation occurs. Bellandur and Varthur lakes faced severe froth formation and also fire (Ramachandra et al., 2015b).

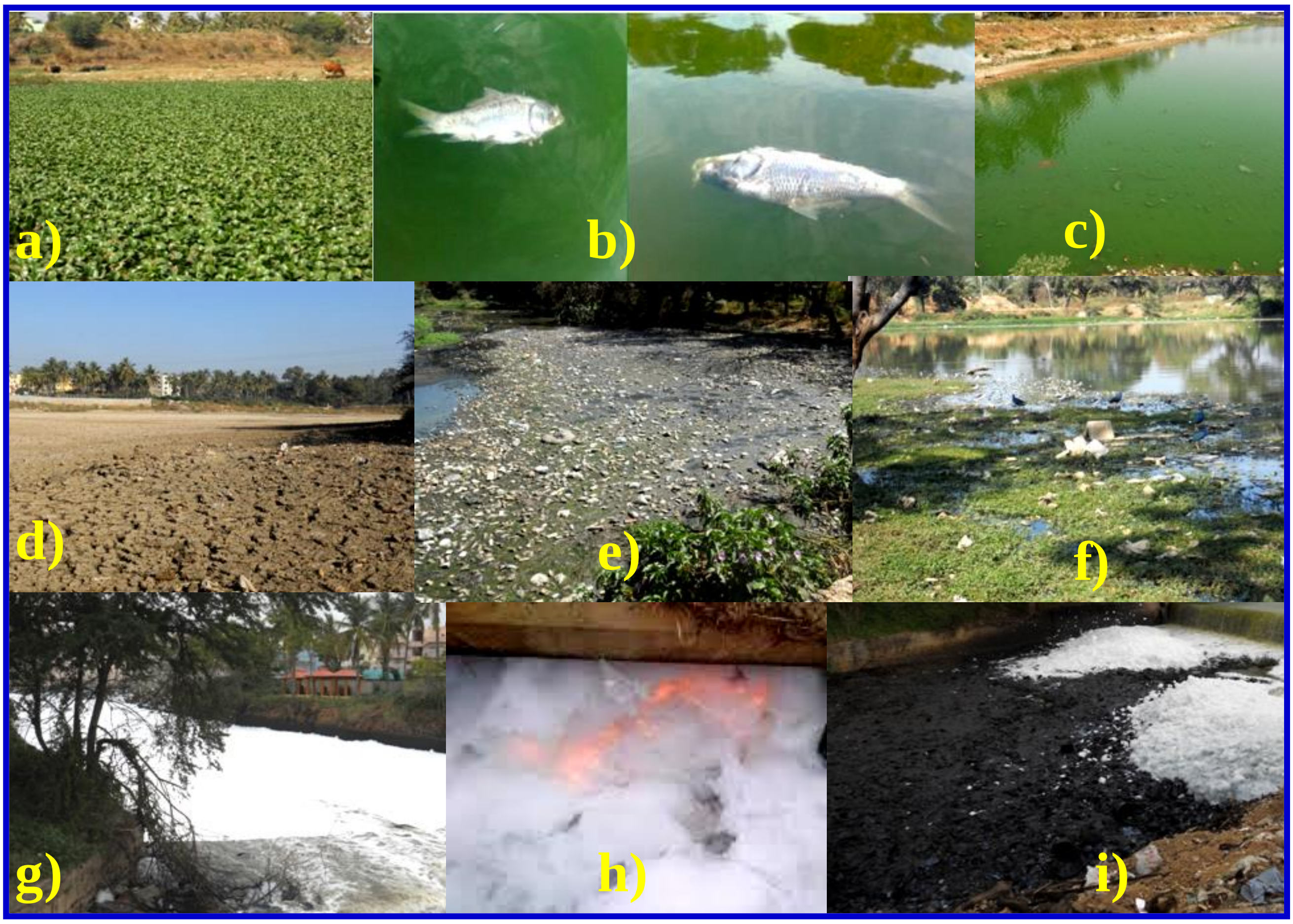

Figure 2: The consequences faced by lakes due to anthropogenic activities: a) fully covered with macrophytes, b) fish death, c) profuse growth of algae, d) dried up lake, e) lake with accumulated plastics wastes, f) black coloured stagnant water with stinking environment, g) foam formation, h) fire in lakes and i) accumulation of organic sediments.

Water pollution and health effects: The pollution of fresh water bodies and ground water are harmful for human and animal health. Polluted water may have undesirable colour, odour, taste, turbidity, high total dissolved solids (TDS), nitrates, phenols, salts, harmful chemical contents, toxic and heavy metals, pesticides, oily matters, industrial waste products, domestic sewage content, organic matter contents, bacteria, protozoa, rotifers, virus, worms, etc. These makes the fresh water unfit for drinking and irrigation purposes. Nitrate contamination in drinking water causes 'blue baby' syndrome and is linked to digestive tract cancers. Water-borne diseases like Hepatitis, cholera, dysentery, and typhoid are infectious diseases spread primarily through contaminated water. The exposure to polluted water can cause skin irritation, respiratory problems etc. Untreated water provides a habitat for the mosquito and a host of other parasites and insects that cause a large number of diseases. The proper management of water resources can tackle such water-borne epidemics and health hazards.

2.1 WATER QUALITY ASSESSMENT

Water quality assessment includes periodical monitoring of lakes to understand the present status of water bodies, identify and quantify trends in water quality, which will help in understanding the water quality problems as well as contamination status. All these information will help decision makers, resource management groups, regulatory agencies and public to solve water quality as well as water scarcity issues in the state/country and make necessary decisions (Ramachandra, 2009).

The continuous inflow of sewage into lakes results in the prolific growth of macrophytes due to increased levels of nutrient in the system. This restricts sunlight penetration and reduces algal photosynthesis hindering the aerobic environment of lake. Also, the roots of these floating macrophytes harbor bacteria. The high bacterial activity in lakes also reduces DO levels. The overgrowth, ageing, and subsequent decay of macrophytes creates anoxic conditions and depletes oxygen level in lakes which in turn, affects the food chain and the whole aquatic eco system (Mahapatra et al., 2011). The excessive growth/bloom formation of cyanobacteria persists in water bodies that contain adequate levels of essential inorganic nutrients such as nitrogen and phosphorus and increased levels of organic matter. Fish deaths in lakes occur due to water pollution and sudden change in temperature (thermal stress), high ammonia concentrations and hydrogen sulphide, oxygen depletion, diseases and parasite attacks, overcrowded fish population and excessive algae or other plant growth in lakes (Ramachandra et al., 2015). Pollution of water bodies will in turn, affect the aquatic organisms like algae, zooplankton and macrophytes, by bringing about changes in the species composition of the aquatic communities, the dominance of a particular species, decline in species diversity, mortality of some species and sensitive life stages (larvae and eggs).

Table 5: The various physico-chemical parameters with explanations

Parameters	Explanations
Water Temperature (˚C)	Temperature effects various physical, chemical and biological reactions in the aquatic organisms. It influences water chemistry i.e. DO, solubility, density, pH, alkalinity, salinity, conductivity etc. Aquatic organisms have varying tolerance to temperature. An increase in the temperature speeds up the chemical reactions, increases the rate of metabolic activities, reduces the solubility of gases like dissolved oxygen and carbon dioxide in the water.
TDS (mg/l)	Total Dissolved solids are solids that are in the dissolved state in water. TDS constitutes inorganic salts, as well as a small amount of organic matter. The chloride, carbonates, bicarbonates,

	phosphates, nitrates, sodium, potassium, iron, manganese, sulphates, etc. contribute towards TDS in lakes.
EC (µS/cm)	Electrical Conductivity (the ability of water to conduct an electric current) depends on the total concentration, mobility, valence and the temperature of the solution of ions. Chloride, carbonates, bicarbonates, phosphates, nitrates, sodium, potassium, iron, manganese, sulphates, etc. contribute towards EC in lakes.
pH	pH is the measure of acidity or alkalinity of water. pH scale ranges from 0 to 14 (i.e., very acidic to very alkaline) with pH 7 being neutral. pH is also governed by the equilibrium between carbon dioxide/bicarbonate/carbonate ions. At day time, pH increase due to the photosynthetic activity (consumption of carbondioxide) whereas pH decreases during night due to respiratory activity (release of carbondioxide).
Turbidity (NTU)	Turbidity in water is caused due to the presence of clay, silt, organic and inorganic matter, plankton and other microscopic organisms. It also makes water unfit for domestic purposes as well as other industrial uses.
DO (mg/l)	Oxygen is essential to all life forms. DO more than 5 mg/l favors good aquatic life. The two main sources of dissolved oxygen are diffusion of oxygen from the air and photosynthetic activity. The presence of high amount of organic matter, hydrogen sulphide, ferrous ions, ammonia, nitrates and other oxidizable substances in lakes imposes a very high oxygen demand, which may in turn, lead to oxygen depletion thus, affecting other aquatic life.
COD (mg/l)	Chemical oxygen demand (COD) determines the amount of oxygen required for chemical oxidation of most organic matter and oxidizable inorganic substances with the help of strong chemical oxidant. COD is also determined by the presence of various organic and inorganic materials like calcium, magnesium, potassium, sodium etc.
BOD (mg/l)	BOD is the amount of oxygen required by microorganisms for stabilizing biologically decomposable organic matter (carbonaceous) in water under aerobic conditions. Plankton/wetland plant decay and leaf fall, domestic wastes and stormwater runoff from farmland or urban areas contribute to BOD.
Alkalinity (mg/l)	Alkalinity is a measure of the buffering capacity of water. It is the good indicator of presence of dissolved inorganic carbon (bicarbonates and carbonate anions). The presence of excess of hydroxyl ions, borates, silicates, phosphate etc. in lake water causes alkalinity.
Chloride (mg/l)	Chloride is an indicator of water pollution and is an abundant anion found in the wastewaters. The sources of chloride in water are dissolution of salt deposits, discharge of effluents from industries, sewage discharges, etc. The excreta contain high quantities of chlorides and other nitrogenous compounds.

Total Hardness, Calcium Hardness and Magnesium Hardness (mg/l)	Hardness of water is mainly due to the presence of calcium, magnesium, carbonates, bicarbonates, sulphates, chloride, nitrates etc. Higher values of hardness in lakes are due to the regular addition of sewage and detergents. Hard water is unfit for domestic and industrial purposes. Calcium is an important micronutrient in aquatic environment and is especially required in large quantities by molluscs and vertebrates. Magnesium acts as a co-factor in various enzymatic reactions and constitutes the chlorophyll molecule, which is essential for photosynthesis. Sewage and industrial wastes are major contributors of calcium and magnesium in lake water.
Phosphate (mg/l)	Phosphates are essential for the growth of phytoplankton (used up as orthophosphates) and acts as a limiting nutrient that limits primary productivity of aquatic ecosystems. The major sources of phosphorus are domestic sewage, detergents, agricultural runoff and industrial wastewater.
Nitrate (mg/l)	Nitrate is the oxidized form of nitrogen and end- product of aerobic decomposition of organic nitrogenous matter. The major sources of nitrate are precipitation, surface run off, sewage, organic matter, leaf litter etc.
Sodium (mg/l)	Sodium is highly soluble in water and makes water salty and unfit for use. Sodium is present is in water treatment chemicals, in domestic water softeners, and in sewage effluents.
Potassium (mg/l)	Potassium is found in lesser concentrations naturally than calcium, magnesium and sodium ions. The natural source of potassium is weathering of rocks, but it also increases due to sewage entry to lakes.
References	Ramachandra et al., 2001; Ramachandra and Ahalya, 2001; Ramachandra et al., 2005; Ramachandra et al., 2014a; Ramachandra et al., 2014b; Ramachandra et al., 2015a; Ramachandra et al., 2015b; Ramachandra et al., 2015c; Sincy et al., 2012; Sincy et al., 2014.

The trophic structure includes various trophic levels as producers (algae, bacteria), primary consumers (zooplanktons and grazers), secondary consumers (small fish), tertiary (large fish, birds, etc.). The nutrient loading in lakes increases the phytoplankton productivity, zooplankton and fish density. Also, macrophytes grow well in nutrient rich water.

Phytoplankton/Algae (figure 3 and table 6) are unicellular, colonial or filamentous forms and mostly photosynthetic thus, forms the basis of aquatic food chain. Phytoplanktons are the producers and grazed upon by the zooplanktons and other organisms present in the same environment. The quality of water (nutrients) influence its population. Phytoplankton survey thus indicates the trophic status and the presence of organic population in the ecosystem (Asulabha et al., 2014). The high nutrients due to sewage inflow in to a water body causes algal blooms, sometimes creating offensive tastes and odours or toxic conditions in water bodies.

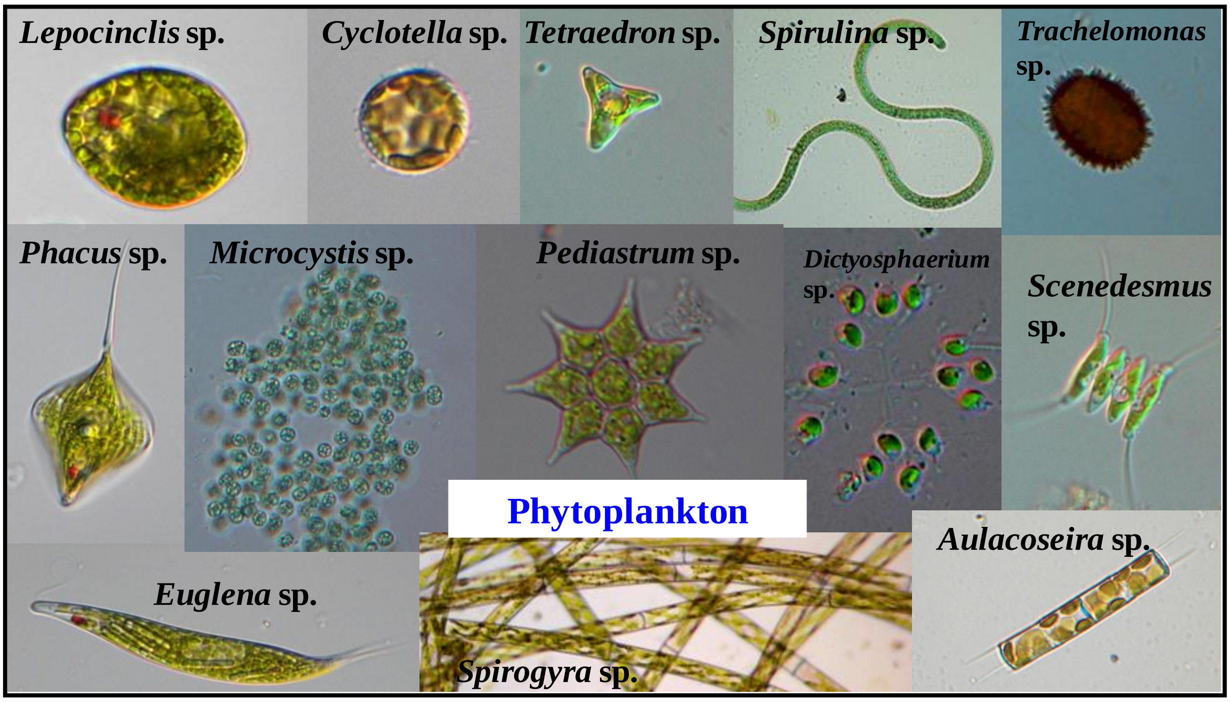

Figure 3: Phytoplanktons in lakes of Bangalore

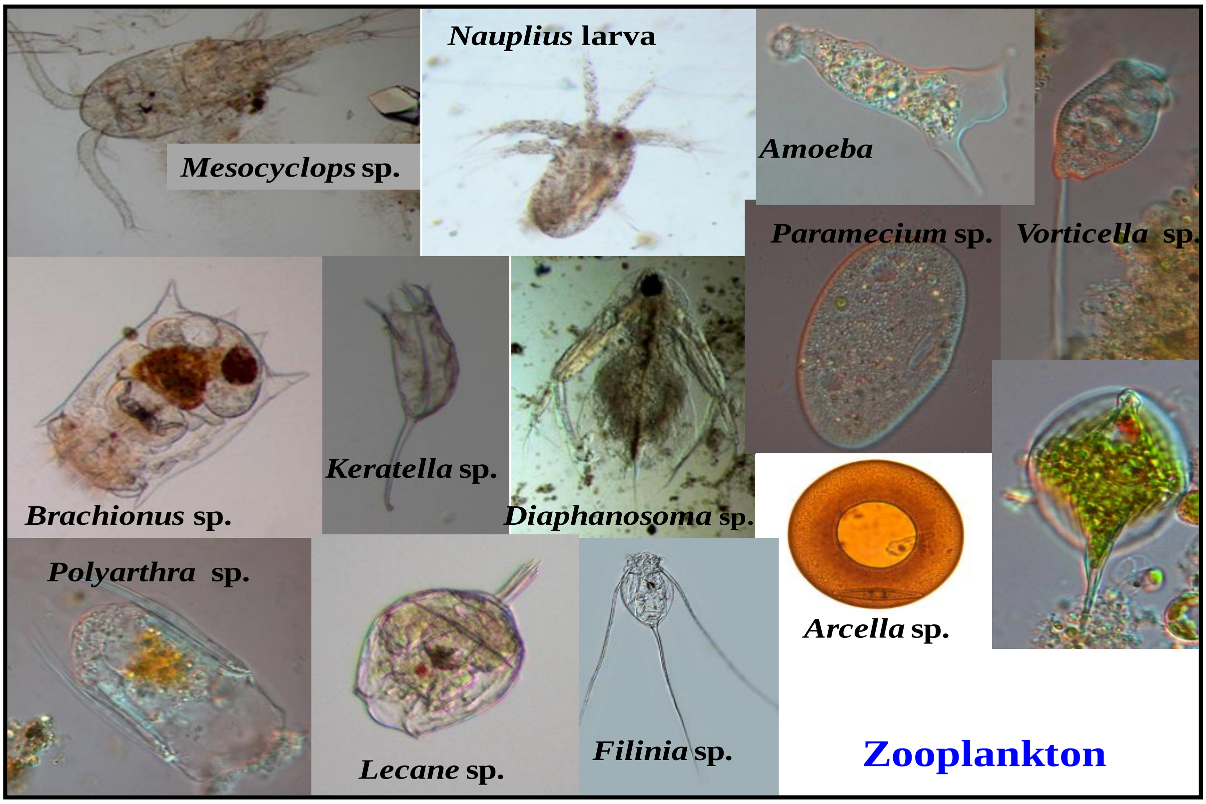

Figure 4: Zooplanktons in lakes of Bangalore

Zooplankton (figure 4 and table 6) comprises of microscopic protozoan, rotifers, cladocerons and copepods. They constitute an important link in food chain as grazers (primary and secondary consumers) and serve as food for fishes directly or indirectly. Therefore, any adverse effect to zooplankton community may affect the fish populations. Zooplanktons have short generation time (usually days to weeks). Zooplankton diversity responds rapidly to changes in the aquatic environment, so they serve as a bioindicators and thus, used for water pollution studies.

Table 6: Phytoplankton and Zooplankton as pollution indicators

Indian Standard Drinking Water - Specification (Second Revision) **ANNEX C (*Clause* 4.3.10)** **Illustrative List of Microscopic Organisms Present in Water**		
Group and Name of the Organism	**Habitat**	**Effects/significance**
Classification of Microscopic Organism: 1. Algae		
a) Chlorophyceae: 1) *Species of* Coelastrum, Gomphosphaerium, Micractinium, Oocystis, Scenedesmus, Chlorella, Actinastrum, Gonium, Eudorina, Pandorina, Pediastrum, Chlamydomonas, Spirogyra, Chroococcus, Stigeoclonium Tetraedron, Chlorogonium,	Polluted water, impounded sources	Impart colouration
2) *Species of* Pandorina, Volvox, Gomphospherium, Staurastrum, Hydrodictyon, Nitella	Polluted waters	Produce taste and odour
3) *Species of* Calothrix, Ankistrodesmus, Ulothrix, Micrasterias	Clean water	Indicate clean condition
4) *Species of* Chlorella, Closterium, Spirogyra, Palmella	Polluted waters, impounded sources	Clog filters and create impounded difficulties
b) Cyanophyceae: 1) *Species of* Anacystis and Cylindrospermopsis	Polluted waters	Cause water bloom and impart colour
2) *Species of* Anabena, Phormidium, Lyngbya, Arthrospira, Oscillatoria	Polluted waters	Impart colour
3) *Species of* Anabena, Anacystis, Aphanizomenon	Polluted waters, impounded sources	Produce taste and odour
4) *Species of* Anacystis, Anabaena, Coelospherium, Aphanizomenon	Polluted waters	Toxin producing
5) *Species of* Anacystis, Rivularia, Anabaena Oscillatoria	Polluted waters	Clog filters
c) Diatoms (Bacillariophyceae): 1) *Species of* Fragillaria, Stephanodiscus, Stauroneis	-	Cause discoloration
2) *Species of* Asterionella, Tabellaria	Hill streams high altitude, torrential and temperate waters	Taste and odour producing clog filters
3) *Species of* Synedra and Fragillaria	Polluted waters	Taste and odour producing
4) *Species of* Nitzschia, Gomphonema	Moderately	Cause

	polluted waters	discoloration
5) *Species of* Cymbella, Synedra, Melosira, Navicula, Cyclotella, Fragillaria, Diatoma	Rivers and streams impounded sources	Clog filters and cause operational difficulties
6) *Species of* Pinmularia, Surirella, Cyclotella, Meridion, Cocconeis	Clean waters	Indicators of purification
d) Xanthophyceae: *Species of* Botryococcus	Hill streams, high altitude and temperate waters	Produces coloration
Classification of Microscopic Organism: Zooplankton		
a) Protozoa: 1) Amoeba, Giardia, Lamblia, Arcella, Difflugia, Actinophrys	Polluted waters	Pollution indicators
2) Endoamoeba histolytica	Sewage and activated sludge	Parasitic and pathogenic
b) Ciliates: Paramoecium, Vorticella, Stentor, Colpidium, Coleps, Euplotes, Colopoda, Bodo	Highly polluted waters, sewage and activated sludge	Bacteria eaters
c) Crustacea: 1) Bosmina, Daphnia	Stagnant polluted waters	Indicators of pollution
2) Cyclops	Step wells in tropical climate	Carrier host of guinea worm
d) Rotifers i) Rotifers: Anurea, Rotaria, Philodina	Polluted and Algae laden waters	Feed on algae
ii) Flagellates: 1) Ceratium, Glenodinium, Peridinium, Dinobryon	Rocky strata, iron bearing and acidic water	Impart colour and fishy taste
2) Euglena, Phacus	Polluted waters	Impart colour

Macrophytes (figure 5) are aquatic plants that grow in or near water and are emergent, submergent, or floating. Macrophytes are the plants that dominate in wetlands, shallow lakes, and streams. They act as food for some fish and wildlife and produces oxygen. A decline in a macrophyte community may indicate water quality problems (high turbidity, herbicides, or salinization). If lakes have high nutrient contents, an overabundance of macrophyte occurs, which may in turn interfere with lake functioning. The nutrients so logged in the body material are released only after death, decay and subsequent mineralization thus, their role in nutrient dynamics and primary productivity of shallow systems are important (Bhat and Ramachandra, 2014). Some macrophytes are now used in “constructed wetlands” to remove nutrients and reduce concentrations of phosphorus and nitrogen from raw sewage or from the effluent sewage treatment facilities.

Figure 5: Macrophytes in lakes of Bangalore

2.2 MATERIALS AND METHODS

An exploratory field survey was conducted to understand the prevailing condition of lakes in Bangalore. The survey included 105 lakes and out of which 25 were completely covered with macrophytes (predominantly water hyacinth). The physico – chemical characteristics of 80 lakes were assessed.

Water Quality Analysis: The analysis of physico- chemical parameters like water temperature; pH; total dissolved solids; electrical conductivity; turbidity; dissolved oxygen; chemical oxygen demand; total alkalinity; chloride; total hardness; calcium hardness; magnesium hardness; nitrate; orthophosphate; sodium and potassium of lake samples collected from Bangalore district were done according to the standard procedures by APHA AWWA WEF (1998) and Trivedy Goel (1986).

Table 7: Standard methods followed for water quality analysis

Parameters	**Methods** (with Reference)
Onsite Measurements	
Water temperature (^{0}C)	Eutech: PCSTestr 35
pH	Eutech: PCSTestr 35
Total Dissolved Solids (TDS, mg/l)	Eutech: PCSTestr 35
Electrical conductivity (µS/cm)	Eutech: PCSTestr 35
Dissolved Oxygen (DO) (mg/l)	Winkler's Method (APHA, 1998: 4500-O)
Laboratory Measurements	
Hardness (mg/l)	EDTA titrimetric method (APHA, 1998: 2340-C)
Calcium hardness (mg/l)	EDTA titrimetric method (APHA, 1998: 3500-Ca B)
Magnesium hardness (mg/l)	Magnesium by calculation (APHA, 1998:3500-Mg)
Sodium (mg/l)	Flame emission photometric method (APHA, 1998:3500-Na B)
Potassium (mg/l)	Flame emission photometric method (APHA, 1998: 3500-K B)
Alkalinity (mg/l)	Titrimetric method (APHA, 1998: 2320 B)
Chloride (mg/l)	Argentometric method (APHA, 1998:4500-Cl^- B)
Biochemical Oxygen Demand(mg/l)	5-Day BOD test (APHA, 5210 B, Trivedi and Goel, 1986, pp.53-55)
Chemical Oxygen Demand (mg/l)	Closed reflux, titrimetric method (APHA, 5220 C, Trivedi&Goel, 1986, pp.55-57)
Nitrates	Phenol Disulphonic acid method (Trivedy and Goel, 1986: pp 61)
Orthophosphates (mg/l)	Stannous chloride method (APHA, 4500-P)
Turbidity(NTU)	Nephlophotometer

The water quality results are compared with reference to BIS drinking water standards and Classification of Inland Surface Water (CPCB, table 8)

Plankton collection and Identification: The plankton samples were collected by filtering 50 litres of lake water through the standard plankton net (No. 25 bolting silk cloth net of mesh size 63 mm and 30 cm diameter). The final volume of the filtered sample was made to 20 ml and then transferred to another 125 ml plastic bottle and labeled, mentioning the time, date and place of sampling. The samples collected were preserved by adding 2ml of 5% formalin. The phytoplanktons and zooplanktons were identified using microscope based on the standard keys (Ramachandra et al., 2006; Altaff, 2004; APHA, 1998; Prescott, 1954; Desikachary, 1959).

Macrophyte collection and Identification: In lakes, quadrats laid at different localities (inlet, outlet and middle) randomly and macrophyte samples are collected (all species falling in the quadrat). Then, samples were washed and identified using standard keys (APHA, 1998).

Table 8: Classification of Inland Surface Water (CPCB)

As per ISI-IS: 2296-1982	
Classification	**Type of use**
Class A	Drinking water source without conventional treatment but after disinfection
Class B	Outdoor bathing
Class C	Drinking water source with conventional treatment followed by disinfection
Class D	Fish culture and wild life propagation
Class E	Irrigation, industrial cooling or controlled waste disposal

Characteristic	A	B	C	D	E
pH	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.0 - 8.5
DO (mg/L)	6	5	4	4	-
BOD (mg/L)	2	3	3	-	-
TDS, mg/l, Max	500	-	1500	-	2100
Electrical Conductance at 25 °C, µS, Max	-	-	-	1000	2250
Total Hardness (as $CaCO_3$), mg/l, Max	300	-	-	-	-
Calcium Hardness (as $CaCO_3$), mg/l, Max	200	-	-	-	-
Magnesium Hardness (as $CaCO_3$), mg/l, Max	100	-	-	-	-
Chlorides (as Cl), mg/l, Max	250	-	600	-	600
Nitrates (as NO_2), mg/1, Max	20	-	50	-	-

III. Bangalore to Bengaluru (transition from green landscape to brown landscape)

Status	**Disappearing water-bodies and vegetation**
Cause:	**Unplanned urbanisation**
Recommendation	"**Decongest and decontaminate Bangalore**" so that at least next generation enjoys better environment in Bangalore Need to ensure the ecosystem integrity to sustain goods and services for maintaining inter-generation equity. **Carrying capacity studies for all macro cities:** Unplanned concentrated urbanisation in many cities has telling impacts on local ecology and biodiversity, evident from decline of water bodies, vegetation, enhanced pollution levels (land, water and air), traffic bottlenecks, lack of appropriate infrastructure, etc. There is a need to adopt holistic approaches in regional planning considering all components (ecology, economic, social aspects). In this regard, we recommend carrying capacity studies before implementing any major projects in rapidly urbanizing macro cities such as Greater Bangalore, etc.
Action Plan	• Good governance (too many para-state agencies and lack of co-ordination) - Single agency with the statutory and financial autonomy to be the custodian of natural resources (ownership, regular maintenance and action against polluters (encroachers as well as those let untreated sewage and effluents, dumping of solid wastes). • De-congest Bangalore: Growth in Bangalore has surpassed the threshold evident from stress on supportive capacity (insufficient water, clean air and water, electricity, traffic bottlenecks, etc.) and assimilative capacity (polluted water and sediments in water bodies, enhanced GHG – Greenhouse gases, etc.) • Disband BDA – creation of Bangalore Development Agency has given impetus to inefficient governance evident from Bangalore, the garden city turning into 'dead city' during the functional life of BDA. • Digitation of land records (especially common lands – lakes, open spaces, parks, etc.) and availability of this geo-referenced data with query option (Spatial Decision Support System) to public. • Threshold on high raise building in the region. Need to protect valley zones considering ecological function and these regions are 'NO DEVELOPMENT ZONES' as per CDP 2005, 2015 • Evict all encroachments from lake bed and raja kaluves • Reestablish interconnectivity among lakes • Restoration of lakes

3.1 Bangalore to Bengaluru (transition from green landscape to brown landscape)

Bangalore (77°37'19.54'' E and 12°59'09.76'' N), is the principal administrative, cultural, commercial, industrial, and knowledge capital of the state of Karnataka. With an area of 741 sq. km., Bangalore's city administrative jurisdiction was widened in 2006 (Greater Bangalore) by merging the existing area of Bangalore city spatial limits with 8 neighbouring Urban Local Bodies (ULBs), and 111 Villages of Bangalore Urban District (Ramachandra and Kumar, 2008; Ramachandra et al., 2012). Thus, Bangalore has grown spatially more than ten times since 1949 (69 square kilometres) and is a part of both the Bangalore urban and rural districts (figure 3.1). The mean annual total rainfall is about 880 mm with about 60 rainy days a year over the last ten years. The summer temperature ranges from 18° C – 38° C, while the winter temperature ranges from 12° C – 25° C. Bangalore is located at an altitude of 920 meters above mean sea level, delineating three watersheds, viz. Hebbal, Koramangala-Challaghatta and Vrishabhavathi watersheds (Figure 3.2). The undulating terrain in the region has facilitated creation of a large number of tanks providing for the traditional uses of irrigation, drinking, fishing, and washing. Bangalore had the distinction of having hundreds of water bodies through the centuries. Even in early second half of 20th century, in 1961, the number of lakes and tanks in the city stood at 262 (and spatial extent of Bangalore was 112 sq. km). However, number of lakes and tanks in 1985 was 81 (and spatial extent of Bangalore was 161 sq. km). This forms important drainage courses for the interconnected lake system (Figure 3.2), which carries storm water beyond the city limits. Bangalore, being a part of peninsular India, had the tradition of harvesting water through surface water bodies to meet the domestic water requirements in a decentralised way. After independence, the source of water for domestic and industrial purpose in Bangalore is mainly from the Cauvery River and ground water. Untreated sewage is let into the storm water drains, which progressively converge at the water bodies. Now, Bangalore is the fifth largest metropolis in India currently with a population of about 8.72 million as per the latest population census. Spatial extent of the city has increased from 69 (1941) to 161 (1981), 226 (2001) and 745 (2011) sq.km. Due to the changes in the spatial extent of the city, the population density varies from 5956 (1941) to 18147 (1981), 25653 (1991), 25025 (2001) and 11704 (2011) persons per sq.km.

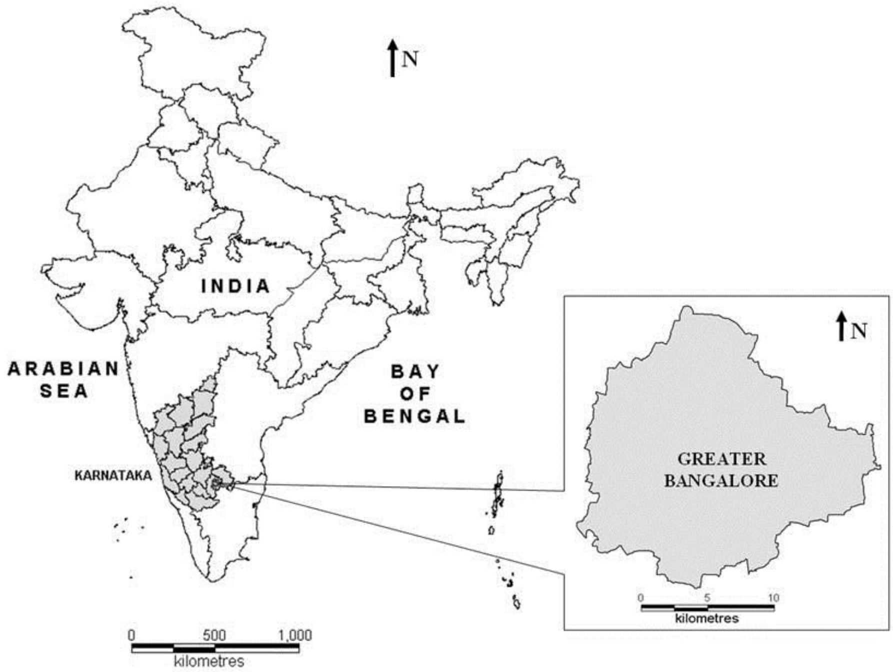

Figure 3.1: Study area –Bangalore

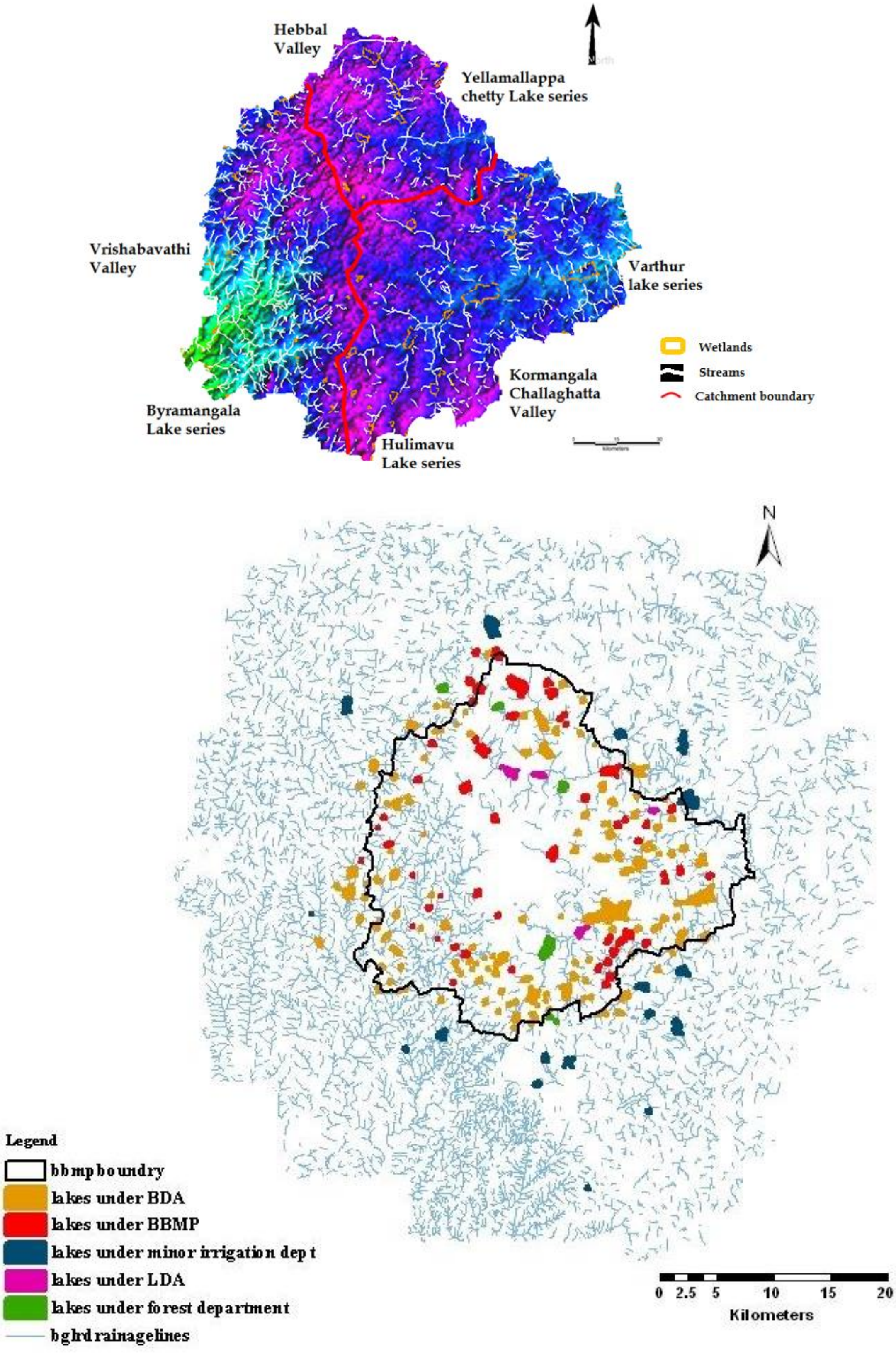

Figure 3.2: Watersheds (drainage with water bodies) of Bangalore

Land use analyses were carried out using supervised pattern classifier - Gaussian maximum likelihood classifier (GMLC) for Landsat and IRS data, and Bayesian Classifier (MODIS data). The method involved (Ramachandra *et al*., 2012): i) generation of False Colour Composite (FCC) of remote sensing data (bands – green, red and NIR). This helped in locating heterogeneous patches in the landscape ii) selection of training polygons (these correspond to heterogeneous patches in FCC) covering 15% of the study area and uniformly distributed over the entire study area, iii) loading these training polygons co-ordinates into pre-calibrated GPS, vi) collection of the corresponding attribute data (land use types) for these polygons from the field. GPS helped in locating respective training polygons in the field, iv) supplementing this information with Google Earth (latest as well as archived data), v) 60% of the training data has been used for classification, while the balance is used for validation or accuracy assessment.

Land use analysis carried out using GRASS - Geographic Resources Analysis Support System (http://wgbis.ces.iisc.ernet.in/ grass) for the period 1973 to 2013 and details are in table 3.1 and urban dynamics is illustrated in Figure 3.3. There has been a 925% increase in built up area from 1973 to 2013 leading to a sharp decline of 79% area in water bodies in Bangalore mostly attributing to intense urbanisation process. Analyses of the temporal data reveals an increase in urban built up area of 342.83% (during 1973 to 1992), 129.56% (during 1992 to 1999), 106.7% (1999 to 2002), 114.51% (2002 to 2006) and 126.19% (2006 to 2010). The rapid development of urban sprawl has many potentially detrimental effects including the loss of valuable agricultural and eco-sensitive (e.g. wetlands, forests) lands, enhanced energy consumption and greenhouse gas emissions from increasing private vehicle use (Ramachandra and Shwetmala, 2009). Vegetation has decreased by 32% (during 1973 to 1992), 38% (1992 to 2002) and 64% (2002 to 2013). Disappearance of water bodies or sharp decline in the number of water bodies in Bangalore is mainly due to intense urbanisation and urban sprawl. Many lakes (54%) were encroached for illegal buildings. Field survey of all lakes (in 2007) shows that nearly 66% of lakes are sewage fed, 14% surrounded by slums and 72% showed loss of catchment area. In addition, lake catchments were used as dumping yards for either municipal solid waste or building debris (Ramachandra, 2009a). The surrounding of these lakes have illegal constructions of buildings and most of the times, slum dwellers occupy the adjoining areas. At many sites, water is used for washing and household activities and even fishing was observed at one of these sites. Multi-storied buildings have come up on some lake beds that have totally intervene the natural catchment flow leading to sharp decline and deteriorating quality of water bodies. This is correlated with the increase in built up area from the concentrated growth model focusing on Bangalore, adopted by the state machinery, affecting severely open spaces and in particular water bodies. Some of the lakes have been restored by the city corporation and the concerned authorities in recent times.

Table 3.1: Land use changes in Bengaluru during 1973 to 2013

Class →	**Urban**		**Vegetation**		**Water**		**Others**	
Year ↓	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**
1973	5448	7.97	46639	68.27	2324	3.40	13903	20.35
1992	18650	27.30	31579	46.22	1790	2.60	16303	23.86
1999	24163	35.37	31272	45.77	1542	2.26	11346	16.61
2002	25782	37.75	26453	38.72	1263	1.84	14825	21.69
2006	29535	43.23	19696	28.83	1073	1.57	18017	26.37
2010	37266	54.42	16031	23.41	617	0.90	14565	21.27
2013	50440	73.72	10050	14.69	445.95	0.65	7485	10.94

Urbanisation in Greater Bangalore

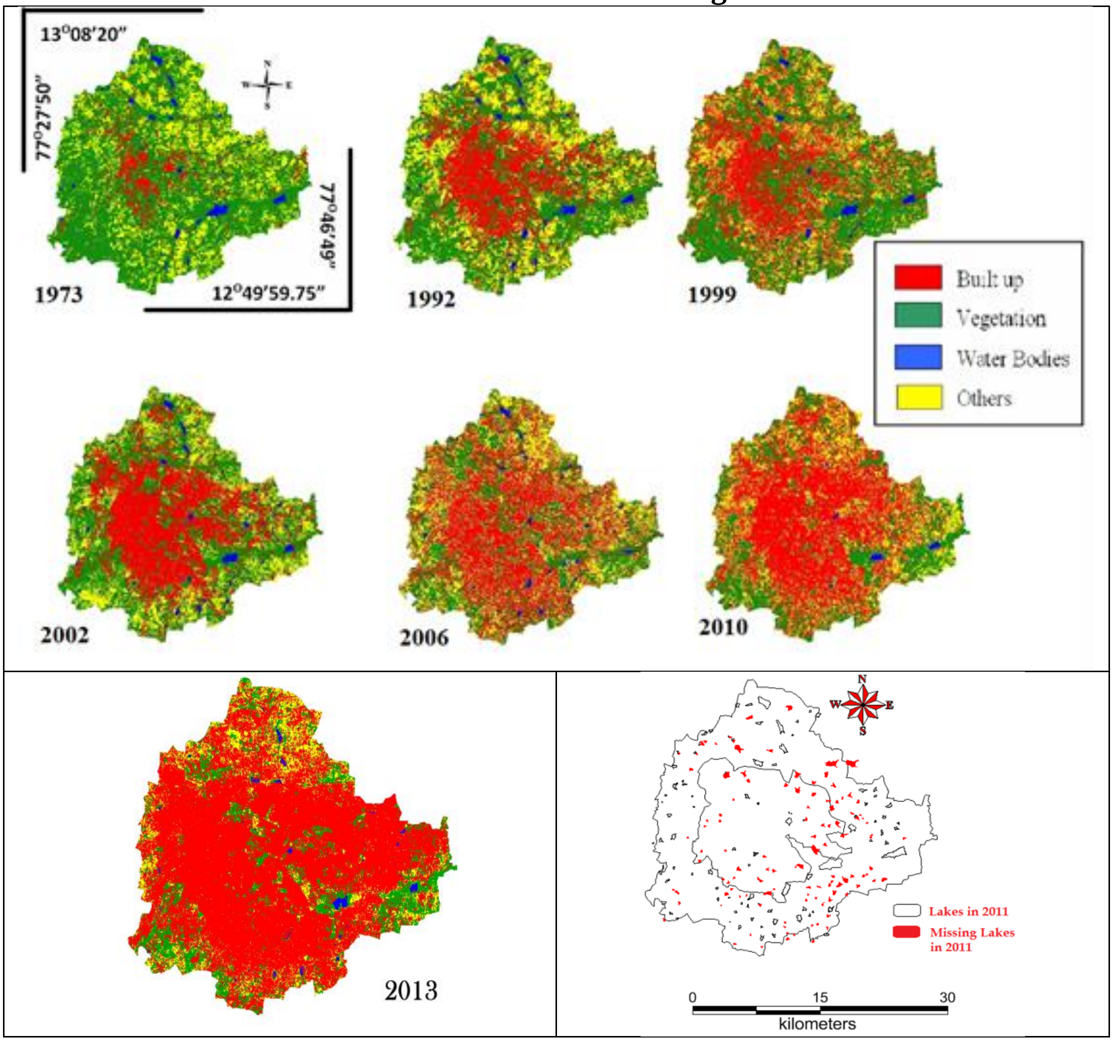

Figure 3.3: Land use dynamics since 1973

Increase in Built-up (concrete / paved surface): 925%

Loss of vegetation: 78%

Loss of water bodies: 79%

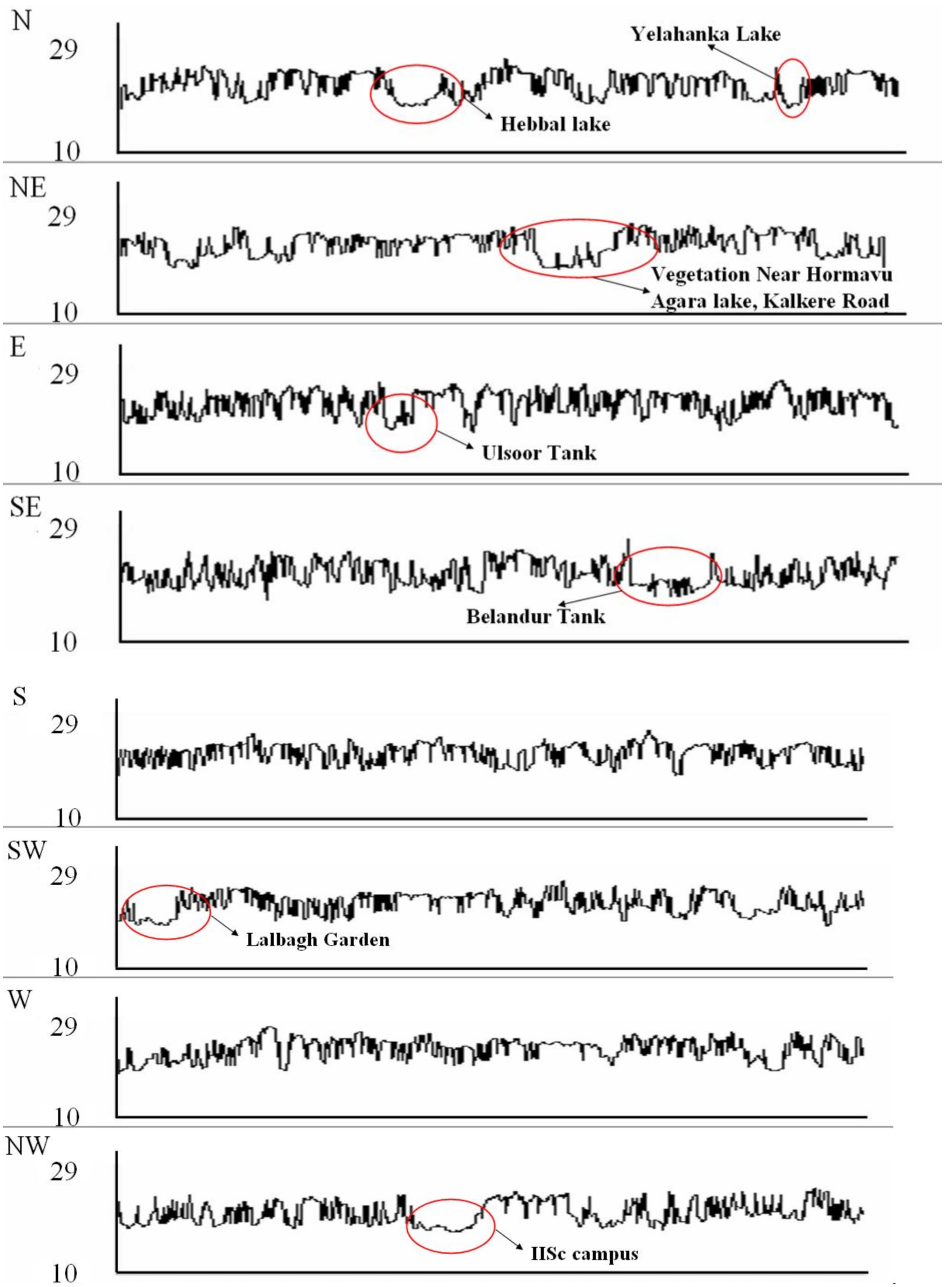

Figure 3.4: Temperature profile in various directions. X axis – Movement along the transacts from the city centre, Y-axis - Temperature (°C)

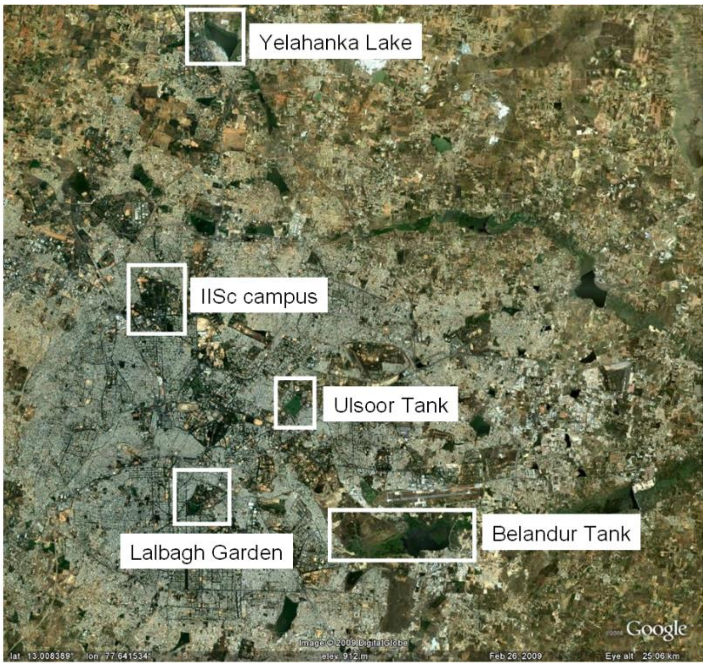

Figure 3.5: Google Earth image showing the low temperature areas [Source: http://earth.google.com/]

The temperature profile plot fell below the mean when a vegetation patch or water body was encountered on the transact beginning from the centre of the city and moving outwards eight directions along the transact as in figure 3.4 It is evident that major natural green area and water bodies act as microclimate moderators responsible for lower temperature (marked with circle in Figure 3.5). The spatial location of these green areas and water bodies are marked in figure 3.5.

Conclusion

Urbanisation and the consequent loss of lakes has led to decrease in catchment yield, water storage capacity, wetland area, number of migratory birds, flora and fauna diversity and ground water table. Temporal land use analysis reveal that there has been a 925% increase in built up area from 1973 to 2013 leading to a sharp decline of 79% area in water bodies in Bangalore mostly attributing to intense urbanisation process. The increase in urban built up area ranges from 342.83% (during 1973 to 1992), 129.56% (during 1992 to 1999), 106.7% (1999 to 2002), 114.51% (2002 to 2006) to 126.19% (2006 to 2010). The gradient analysis showed that Bangalore grew radially from 1973 to 2010 indicating that the urbanization is intensifying from the city centre and has reached the periphery of the Bangalore. The temperature profile analysis by overlaying the LST on the land use reveal of higher temperatures in urban area while vegetation and water bodies aided in moderating temperature at local levels (evident from at least 2 to 2.5 °C lower temperature compared to urban pockets).

Frequent flooding in the city is a consequence of the drastic increase in impervious area (of 925% in 4 decades) and loss of wetlands (and interconnectivity of wetlands) with the high-density urban developments. The uncoordinated pattern of urban growth is attributed to a lack of good governance and decentralized administration, which was evident from the lack of coordination among many Para-state agencies. This has led to unsustainable use of the land and other resources. The mitigation of frequent floods and the associated loss of human life and properties entail the restoration of interconnectivity among wetlands, restoration of wetlands (removal of encroachments), conservation, and sustainable management of wetlands.

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IV. STUDY AREA: Wetlands of Greater Bangalore

Greater Bangalore with an area of 741 square kilometres lies between the latitudes 12°39'00'' to 131°3'00''N and longitude 77°22'00'' to 77°52'00''E. Bangalore city administrative jurisdiction was widened in 2006 by merging the existing area of Bangalore City spatial limits with eight neighboring Urban Local Bodies (ULBs) and 111 Villages of Bangalore Urban District (Sudhira et al, 2007). Thus, Bangalore has grown spatially more than ten times since 1949 (69 square kilometres) and is a part of both the Bangalore urban and rural districts. Bangalore is located at an altitude of 920 metres above mean sea level, delineating three watersheds: Hebbal, Koramangala-Challaghatta and Vrishabhavathi watersheds. The undulating terrain in the region has facilitated creation of a large number of tanks. The mean annual total rainfall is about 880 mm with about 60 rainy days a year over the last ten years. The summer temperature ranges from 18 °C – 38 °C, while the winter temperature ranges from 12 °C – 25 °C. Bangalore, thus, enjoys a salubrious climate all year round.

An exploratory field survey of 105 lakes in Bangalore was conducted (figure 4a). The physico – chemical characteristics of 80 lakes were assessed which include lakes in the 3 different valleys (figure 4b):

- **Hebbal Valley:** Allalasandra, Bellahalli, Chelekere, Chikkabettahalli, Chikkabanavara, Chokkanahalli, Hebbal, Hesaraghatta, Jakkur, Kalkere, Kattigenahalli, Kogilu, Maragondanahalli, Mathikere, Nagavara, Narsipura 1, Narsipura 2, Palanahalli, Rachenahalli, Rampura, Sankey, Thirumenahalli 1, Thirumenahalli 2, Yelahanka and Yelemallappashetty.
- **Vrishabavathi Valley:** Anchepalya, Andrahalli, Baallehannu, Dasarahalli, Deepanjali Nagara, Doraikere, Dubasipalya, Hemmigepura, Herohalli, Kengeri, Komghatta, Konanakunte, Mallathhalli, Sompura, Ullal and Uttarahalli.
- **Koramangala-Challaghatta Valley (KC):** Agara, Ambalipura, Arekere, Bagmane, Bhattrahalli, Begur, Bellandur, Bommasndra, Chikkabegur, Chikka Togur, Chinnappanahalli, Chunchugatta, Doddanekundi, Hebbagodi, Hulimavu, Kaikondrahalli, Kammasandra 1, Kammasandra 2, Kasavanahalli, Kelagiankare, Kothanur, K R Puram, Kundalahalli, Lalbagh, Madivala, Mahadevapura, Munnekolala, Mylasandra 1, Mylasandra 2, Nallurahalli, Rayasandra, Sheelavanthakere, Singasandra, Subbrayanna, Ulsoor, Varthur, Vittasandra, Yediyur and Yeklgata.

In the exploratory survey, it was found that about 25 lakes were fully covered with macrophytes or dumped with solid and liquid wastes. Some were under restoration activities. Lake such as Lakasandra had completely turned to a barren land due to the dumping of building debris. Those 25 lakes are (figure 6a) are:

- **Hebbal Valley:** Amrutahalli, Doddabommasandra, Kammgondahalli, Puttanahalli, Horamavu, and Horamavu Agara.

- **Vrishabavathi Valley:** Avalahalli, Doddabidirakallu, Goudanakere, Herohalli, Hosakerehalli, Kempambudhi, Nalagadderanahalli, Nayandanahalli, Shivapura and Vaddarapalya.
- **Koramangala-Challaghatta Valley (KC):** Benniganahalli, Byrasandra, Chandapura, Gottigere, Garvebhavipalya, Lakasandra, Sarakki, Seetharamapalya and Veerasandra.

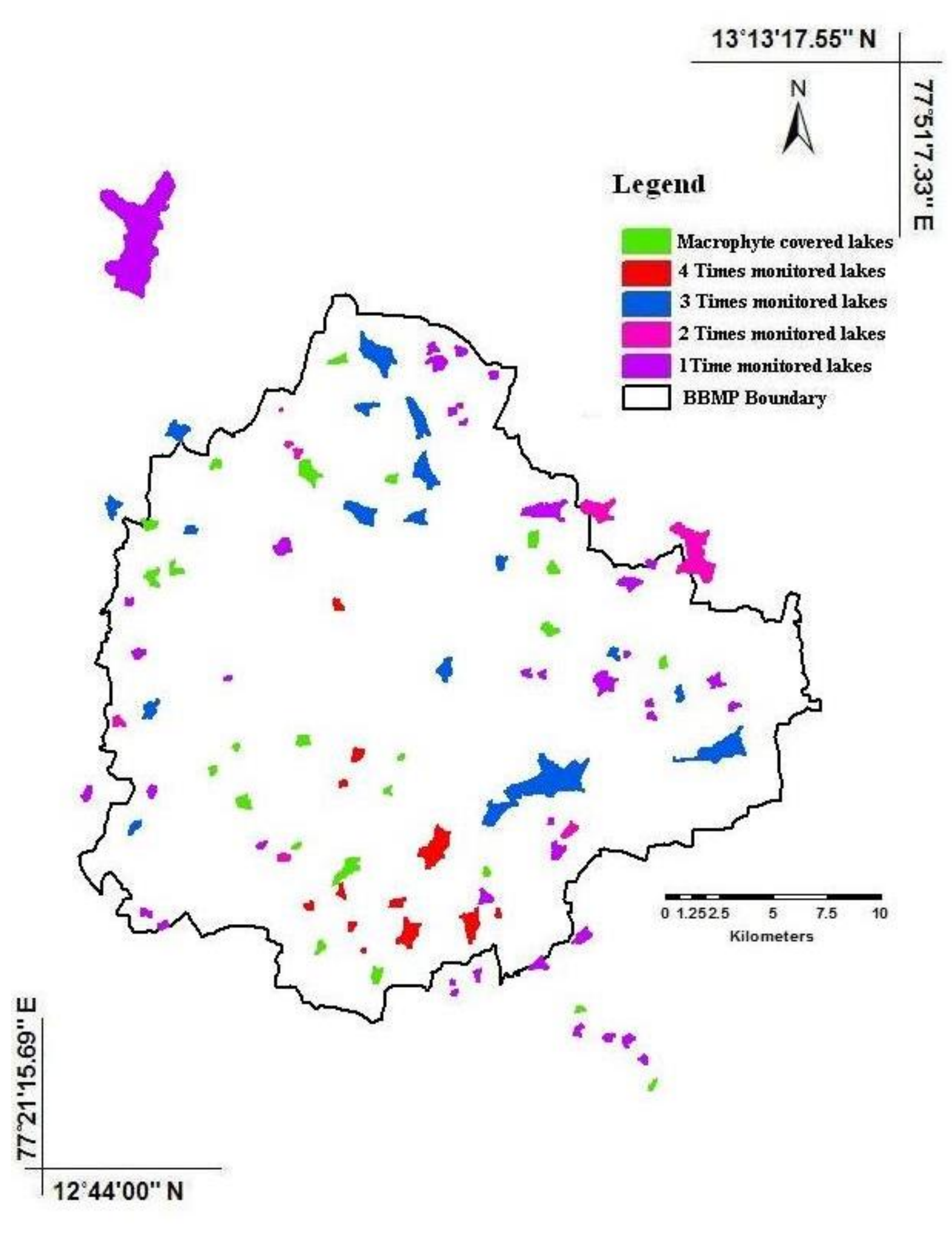


Figure 4a: Lakes monitored (105 lakes) at different time periods during the survey.

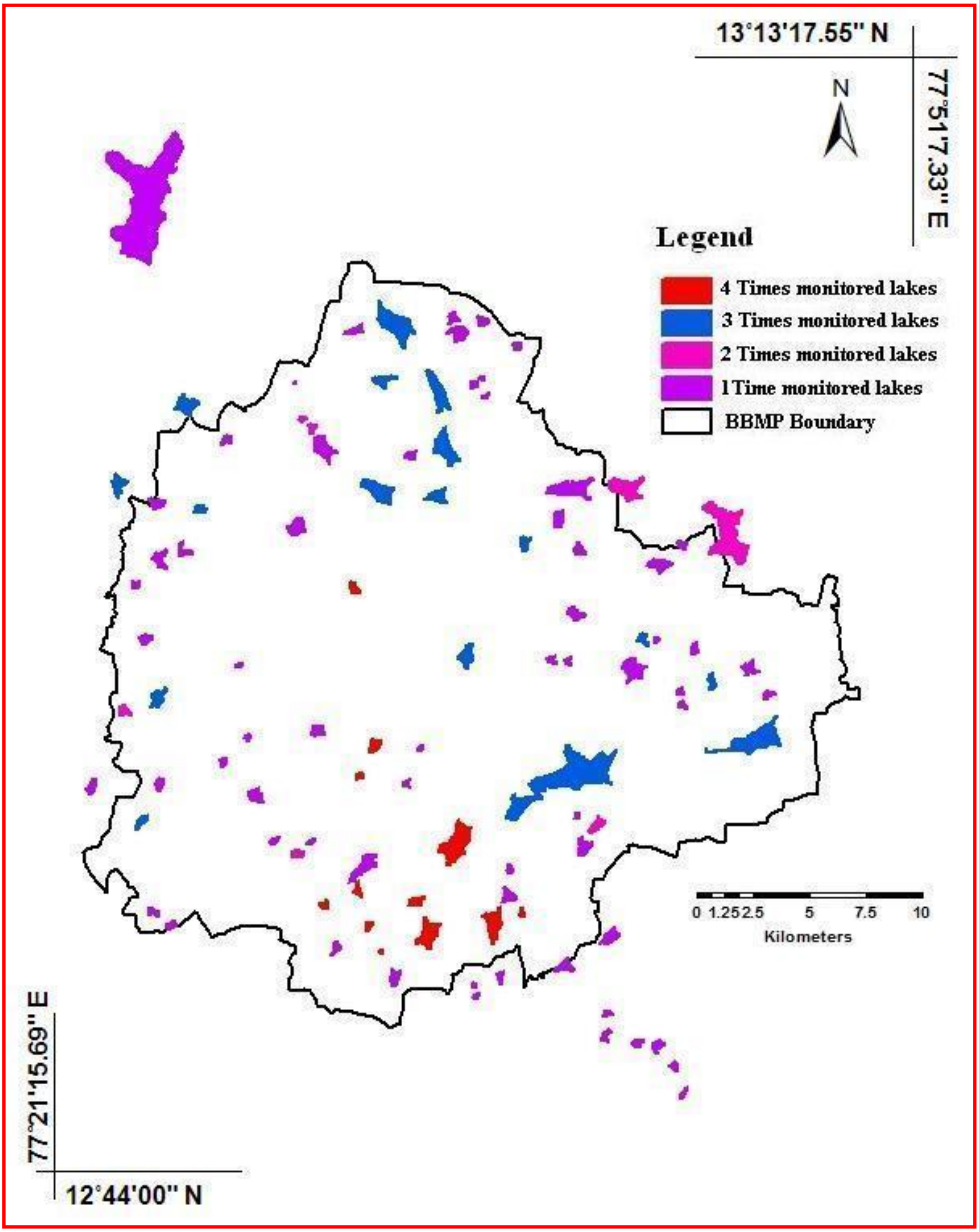


Figure 4b: Lakes (80 lakes with water quality) monitored during different time periods

1. AGARA LAKE	Koramangala-Challaghatta Valley
NAME OF THE LAKE	**AGARA LAKE**
GEOGRAPHIC DETAILS	Latitude-12°54'59.59"N to 12°55'26.64"N, 77°38'10.08"E to 77°39'04.87"E Longitude-12°54'55.00"N to 12°55'33.68"N, 77°38'19.58"E to 77°38'21.89"E
AREA AS PER RTC	142.73 Acres
CUSTODIAN	LDA
VILLAGE NAME & SURVEY NO	Agara-11, Venkojiraokhane-11
VALLEY TO WHICH LAKE BELONGS	KC Valley
STATUS	Less Polluted
RESTORATION	Restored
WATER CONDITION	Poor, Green Colour
CLASS (As per CPCB)	Class E – Water for irrigation, industrial cooling and controlled waste disposal.

Agara lake is located in Koramangala-Challaghatta Valley, in the south-east of Bangalore. The Agara lake spreads across 48.38 ha. The water from this lake drains into the adjacent Bellandur lake to the immediate north, and eventually into the Varthur lake located at the south-eastern boundary of the city. Agara lake has been providing services to the society over the centuries, including irrigation, livelihoods, groundwater replenishment, as well as supporting a number of birds and other fauna.


Agara lake


Buildings in the lake


Sewage entry to the lake


Macrophyte cover

	
Shallow water body	***Typha* sp. is the dominant macrophyte**
Problems: Inflow of untreated sewage, encroachments, spread of invasive macrophytes,	**Importance:** Fishing activity, ground water recharge, recreational activities, supports bird diversity

Water Quality Analysis of Agara Lake

Parameters	Agara	Water quality Standard IS 10500, 1991-2011	
		Desirable	Permissible
Water Temperature (˚C)	26.1	-	-
TDS (mg/l)	443	500	2000
EC (µS)	877.5	-	-
pH	7.55	6.5-8.5	No relaxation
DO (mg/l)	3.74	-	-
COD (mg/l)	18	-	-
Alkalinity (mg/l)	183.33	200	600
Chloride (mg/l)	174.9	250	1000
Total Hardness (mg/l)	154	300	600
Ca Hardness (mg/l)	32.6	75	200
Mg Hardness (mg/l)	29.5	30	100
Phosphate (mg/l)	0.047	-	-
Nitrate (mg/l)	0.352	45	100
Sodium (mg/l)	57.3	-	-
Potassium (mg/l)	29.3	-	-

Lower dissolved oxygen content is due to decay of macrophytes.
Inference: As per Classification of Inland Surface Water (CPCB), Agara lake falls under E
Class E – Irrigation, industrial cooling or controlled waste disposal

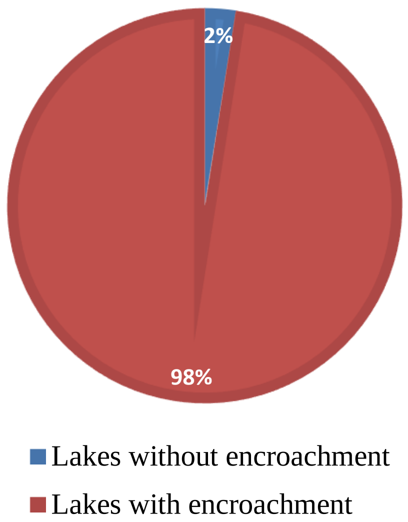
Aquatic Biodiversity

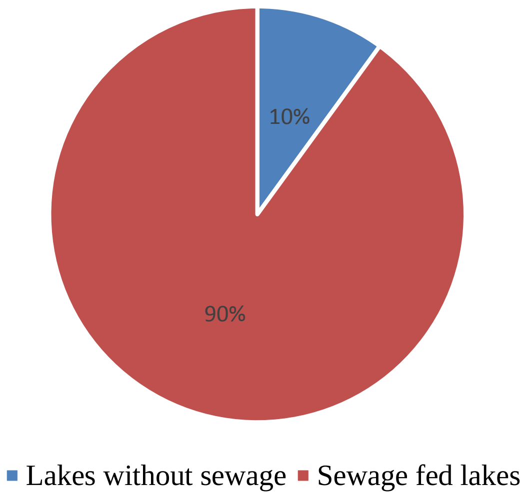
ALGAE: *Golenkinia* sp.; *Navicula* spp.; *Nitzschia* spp.; *Cocconeis* sp.; *Cyclotella* sp.; *Synedra* sp.; *Pinnularia* sp.; *Scenedesmus* spp.; *Merismopedia* sp.; *Monoraphidium* sp.; *Pediastrum* sp.; *Kirchneriella* sp.; *Tetraedron* sp.; *Euglena* spp.; *Phacus* spp. and *Trachelomonas* sp.

MACROPHYTE: *Alternanthera philoxeroides, Ipomea aquatica, Typha angustata, Cyperus rotundus, Colocasia esculanta*

RESULTS AND DISCUSSION

The current investigation focused on 105 lakes (water bodies) in Bangalore. Among these one season monitoring was done in 25 lakes as these lakes were covered with macrophytes – water hyacinth throughout the year. The study reveals that about 98% lakes have been encroached and about 90% lakes are affected due to the sustained inflow of untreated sewage and industrial effluents.





Encroachment	Sustained inflow of sewage and effluents

Physico-chemical characteristics of Bangalore lakes: The physical and chemical integrity of an ecosystem decides its biological integrity and ecosystem services. Physico-chemical characteristics of 80 lakes belonging to the 3 different valleys namely, Koramangala-Challaghatta Valley (KC), Vrishabavathi Valley (V) and Hebbal Valley (H) were monitored to understand the prevailing physic-chemical condition of lakes in Bangalore (figure 6.1). The physico-chemical parameters analysed were water temperature; pH; total dissolved solids; electrical conductivity; turbidity; dissolved oxygen; chemical oxygen demand; biochemical oxygen demand; total alkalinity; chloride; total hardness; calcium hardness; magnesium hardness; nitrate; orthophosphate; sodium and potassium.

The water quality analysis was carried out of the monthly water samples collected from lakes in Bangalore and the results are presented in figure 6.1, which revealed that lakes in Koramangala-Challaghatta Valley (KC) are the most polluted than the lakes in Vrishabavathi Valley (V) and Hebbal Valley (H). The result shows that KC valley receives lot of wastewater than the other two valleys. At inlets of KC Valley lakes, higher ionic and organic contents except phosphate were noticed. The physico-chemical parameters in inlets of different Valleys are in the order KC > V > H.

At middle part, KC valley has higher TDS, EC, pH, COD, chloride, hardness, nitrate, sodium and potassium. Alkalinity and DO are higher in Vrishabavathi Valley and support more phytoplankton growth. The physico-chemical parameters in middle part of different Valleys are in the order KC > H > V.

At outlets, KC valley has higher TDS, EC, COD, BOD, chloride, hardness and sodium. Alkalinity and DO are higher in Vrishabavathi Valley as the lakes support more algae growth. Hebbal Valley has higher pH, turbidity, orthophosphate, sodium and potassium. The physico-chemical parameters in outlet of different Valleys are in the order KC > H > V. Lakes in Hebbal valley have high phosphate content at the inlet, middle and outlet.

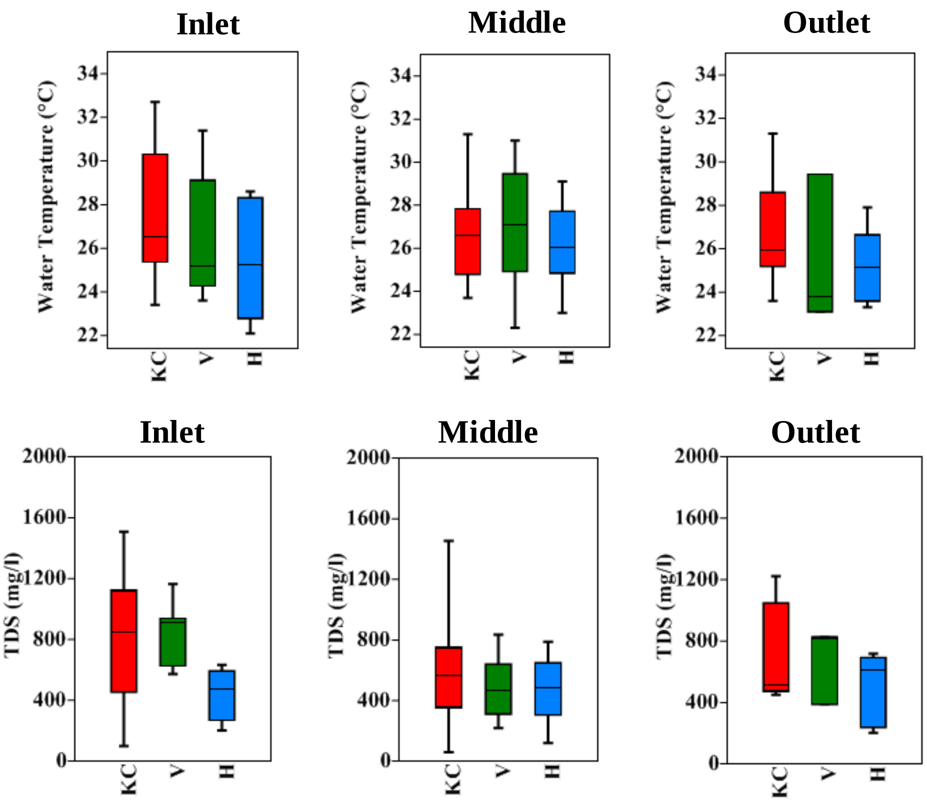
The inlet part of lakes has higher physico-chemical parameters than the middle and outlet part of lakes because of the sustained inflow of untreated sewage (Sincy et al., 2014). The continuous entry of sewage water and rainwater runoff to lakes also reduces the depth of the lake and ground water recharge capacity apart from contaminating ground water sources (Ramachandra et al., 2015b).

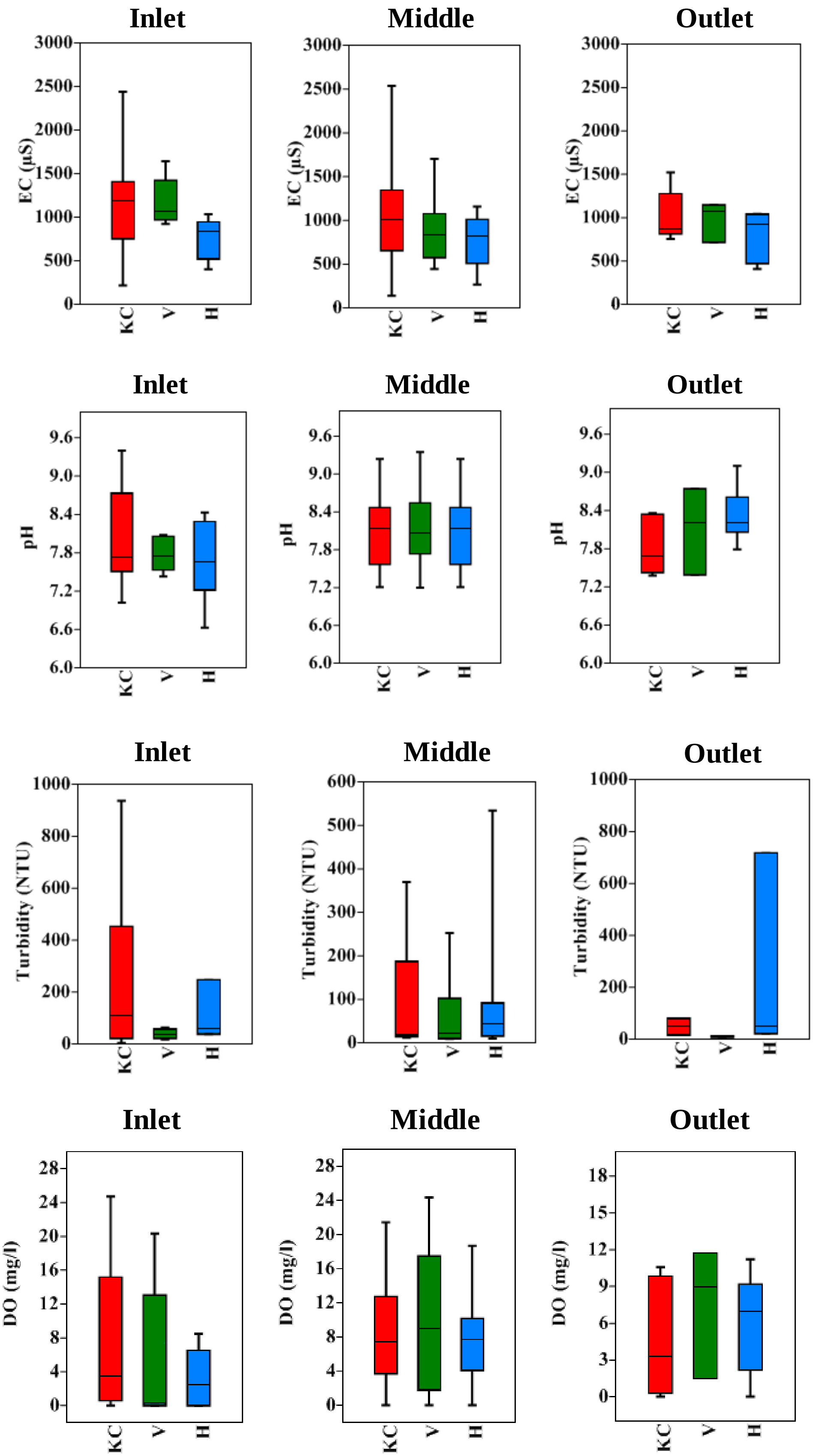
All parameters showed seasonal variations and the variations in water temperature are influenced by factors like air temperature, humidity, wind and solar energy (Sincy et al., 2012). The variation in TDS and EC is related to the concentration of calcium, magnesium, sodium, and potassium cations and carbonate, bicarbonate, chloride, sulfate, and nitrate anions in lake water (Ramachandra et al., 2015a, 2003). The increase in conductivity is due to the sustained inflow of untreated effluents (through both domestic and industrial sources) into lakes/wetlands (Alakananda et al., 2013). Higher pH values are attributed to higher photosynthetic rates of algae, using more dissolved CO_2 from the waters and thereby, causing high bicarbonate and carbonate concentrations (alkalinity). High carbonates cause calcium and magnesium ions to form insoluble minerals leaving sodium as the dominant ion in solution (Mahapatra et al., 2013). Higher turbidity values in lakes are mainly due to silt, organic matter, sewage (domestic) and other effluents (Kiran and Ramachandra, 1999).

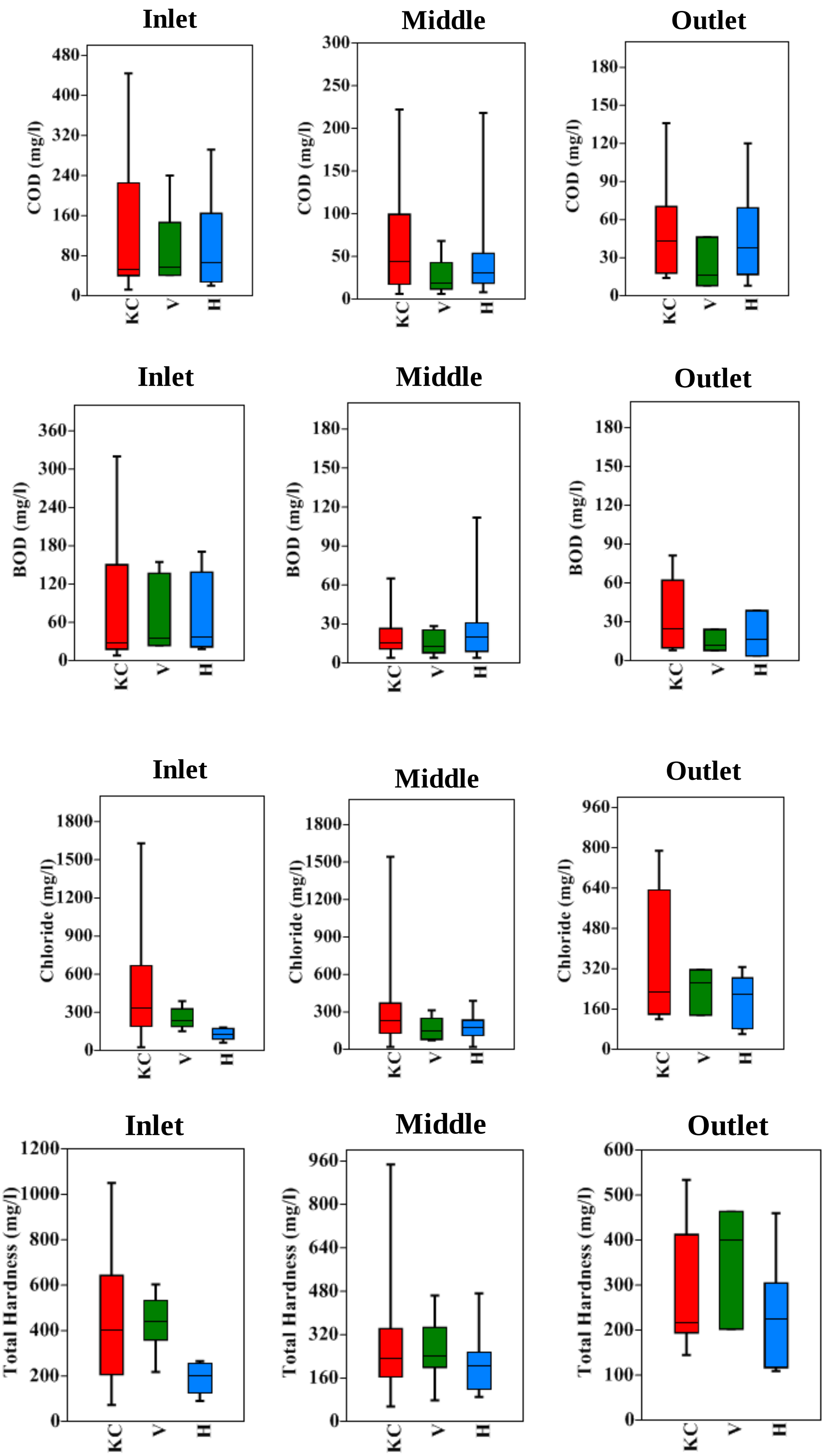
Hypoxic and even anoxic condition due to low dissolved oxygen content can be attributed to the sustained inflow of organic load, water hyacinth cover and decomposition of organic matter (Ramachandra et al., 2013). The roots of the floating macrophytes provide a good substratum for the attachment of bacteria, which drastically reduces the DO levels, resulting in hypoxia and anoxia (Mahapatra et al., 2011a). Fish death in lakes due to asphyxiation occurs due to the sudden fall in DO levels with sewage influx into lakes (Benjamin et al., 1996). Higher levels of BOD in the urban lakes can be attributed to sewage inflow through storm water drains and reduced circulation in water bodies. These also indicate higher levels of biodegradable organic matter, higher rate of oxygen consumption by heterotrophic organisms and a high rate of organic matter mineralization (Mahapatra et al., 2010). Higher values of COD indicate pollution due to oxidisable organic matter (Sincy et al., 2014). Lakes having continuous sewage inflow, low water levels and highly stressed by anthropogenic activities have high levels of COD.

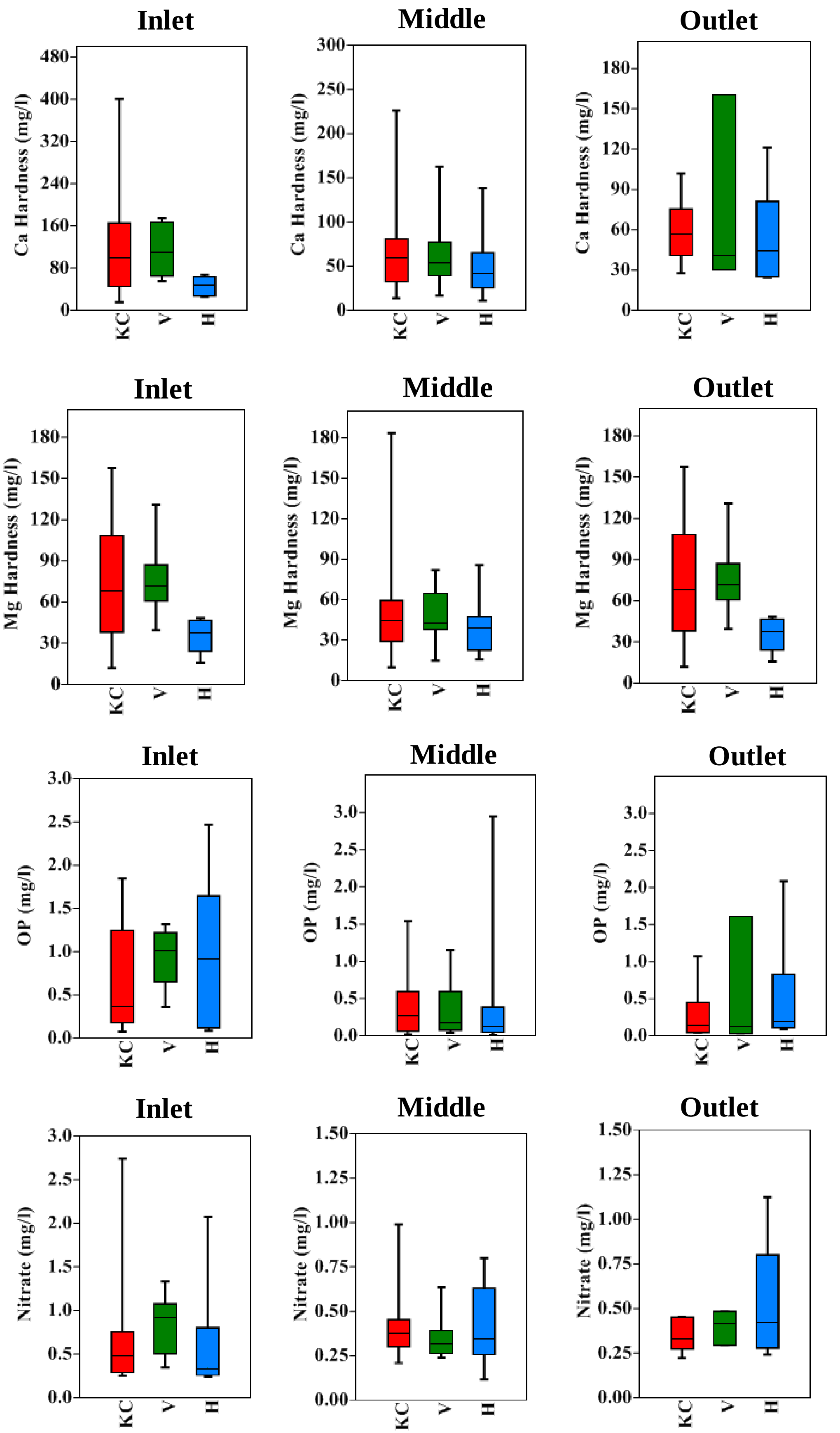
Lakes with continuous inflow of sewage have high concentrations of total hardness, alkalinity and chlorides (Ramachandra et al., 2013). Elevated chloride values could be due to many factors, including sewage, industrial effluents, and agricultural runoff. Potassium is also an essential element for plant growth. Its elevated levels indicate potential contamination from industrial effluents or fertilizer (Ramachandra, 2008). The main cause of hardness in natural water is due to calcium and magnesium salts combined with carbonates and bicarbonates. The main source of hardness is domestic and industrial washing flowing into the lake (Ramachandra et al., 2001)

Phosphate occurs in water in various forms like orthophosphates, condensed phosphates and naturally found phosphate. The increased phosphate in lake water is due to detergents, fertilizers and due to biological processes. Inorganic phosphorus is a limiting nutrient and plays an important role in aquatic ecosystems. Inorganic phosphorus in excess amounts along with nitrates and potassium causes algal bloom (Balachandran et al., 2012). When lakes receive nutrients, a substantial part is taken up by biota, leading to algal and macrophytes bloom. Macrophytes ultimately die, decompose and settles as sludge sediment in the lake bottom and with high turbulence and overflow of water during monsoon they are likely to be transported to downstream. Thus, sludge/sediments act as a major sink for C, N and P (Mahapatra et al., 2011c). Nutrients trapped in sediments gets released during monsoon with high intensity of rainfall with upwelling of sediments and churning of lake water. Phosphates leads to frothing, which are observed at the outlets of large water bodies. Nitrate at higher concentrations primarily contribute to the eutrophication of water bodies. Anoxic conditions do not favour ammonia (NH_4) to be nitrified to a large extent. Low DO (0 mg/l) favours denitrification process (Mahapatra et al., 2011b).




Inlet
Middle
Outlet
EC (µS)
pH
Turbidity (NTU)
DO (mg/l)
KC
V
H


Inlet
Middle
Outlet
COD (mg/l)
BOD (mg/l)
Chloride (mg/l)
Total Hardness (mg/l)
KC
V
H


Inlet
Middle
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Ca Hardness (mg/l)
KC
V
H
Inlet
Middle
Outlet
Mg Hardness (mg/l)
KC
V
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OP (mg/l)
KC
V
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Inlet
Middle
Outlet
Nitrate (mg/l)
KC
V
H

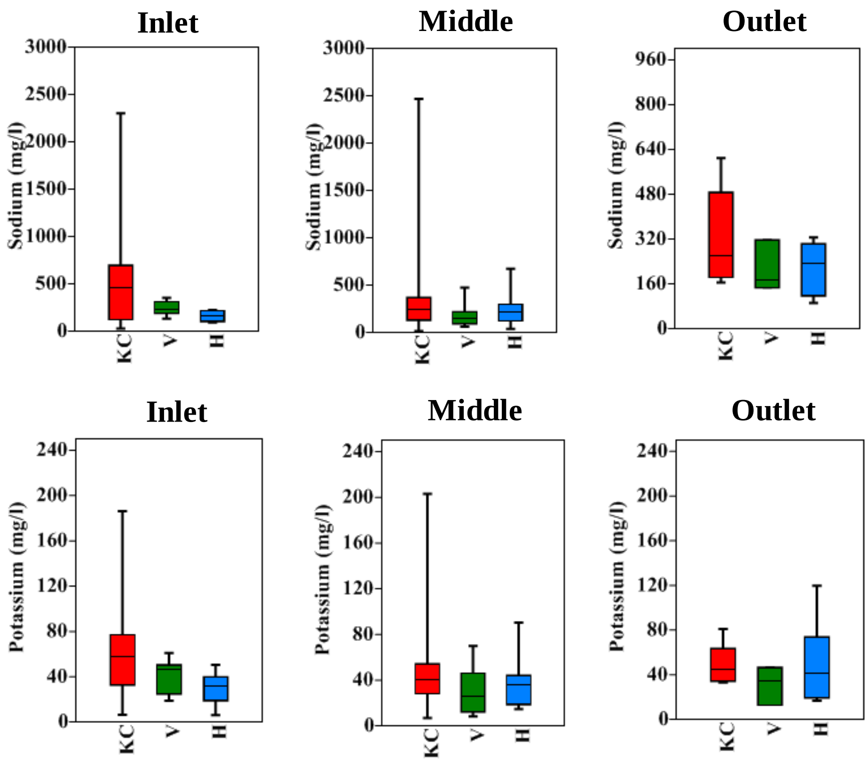

Figure 6.1: Variation of physico-chemical parameters in lakes belonging to Koramangala-Challaghatta Valley (KC), Vrishabavathi Valley (V) and Hebbal Valley (H) in Bangalore

Cluster Analysis: The Cluster Analysis of physical and chemical variables in the water of 80 lakes in Bangalore revealed the existence of three groups (figure 6.2 and 6.3).

- Group-**a**, 24 lakes, which are less polluted lakes that have low ionic as well as nutrient contents: Sompura, Bellahalli, Doraikere, Mylasandra 1, Hesaraghatta, Vittasandra, Mylasandra 2, Munnekolala, Palanahalli, Narsipura 1, Ulsoor, Uttarahalli, Rachenahalli, Agara, Rayasandra, Narasipura 2, Yelahanka, Deepanjali Nagara kere, Bagmane, Kengeri, Hebbal, Nagavara, Kogilu and Mathikere..
- Group-**b**, 22 lakes, which are moderately polluted lakes that have low ionic as well as nutrient contents compared to Group c but supports algal and macrophyte growth: Chikkabanavara, Yeklgata, Hemmigepura, Komghatta, Baallehannu, Andrahalli, Chikka Togur, Subbarayanna, Kelagiankare, Thirumenahalli 2, Jakkur, Kaikondrahalli, Kasavanahalli, Madivala, Kothanur, Yediyur, Lalbagh, Sankey, Kattigenahalli, Dasarahalli, Chokkanahalli and Thirumenahalli 1.
- Group-**c,** 34 lakes, which includes highly polluted lakes that have high ionic contents, rich in nutrients and have high oxygen demand due to high organic contents. These lakes are highly stressed due to anthropogenic activities - Kammasandra1, Hebbagodi, Bommasndra, Kammasandra 2, Ambalipura, Singasandra, Bhattrahalli, Begur, Konanakunte, Doddanekundi, Nallurahalli, Chinnappanahalli, KR Puram, Ullal, Anchepalya, Sheelavanthakere, Chunchugatta, Hulimavu, Herohalli, Kundalahalli, Chikka Begur, Dubasipalya, Chikkabettahalli, Allalasandra, Yelemallappashetty, Bellandur, Varthur, Maragondanahalli, Arekere, Mahadevapura, Chelekere, Mallathhalli, Kalkere and Rampura.

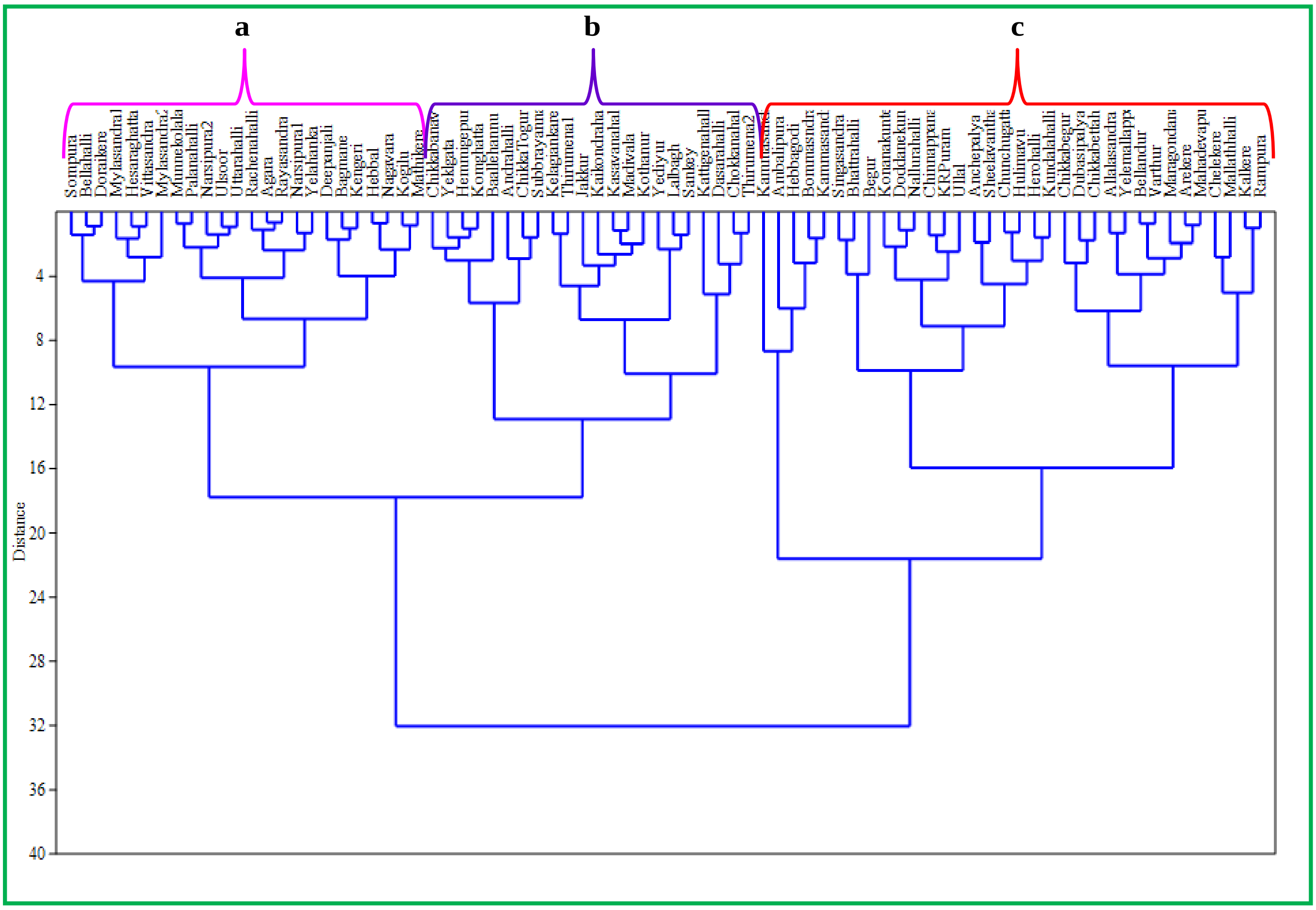

Figure 6.2: Hierarchical clustering analysis (Wards method) of 80 lakes in Bangalore based on physico-chemical parameters (like water temperature, pH, TDS, EC, DO, COD, total alkalinity, chlorides, total hardness, calcium hardness, magnesium hardness, nitrate and ortho-phosphate).

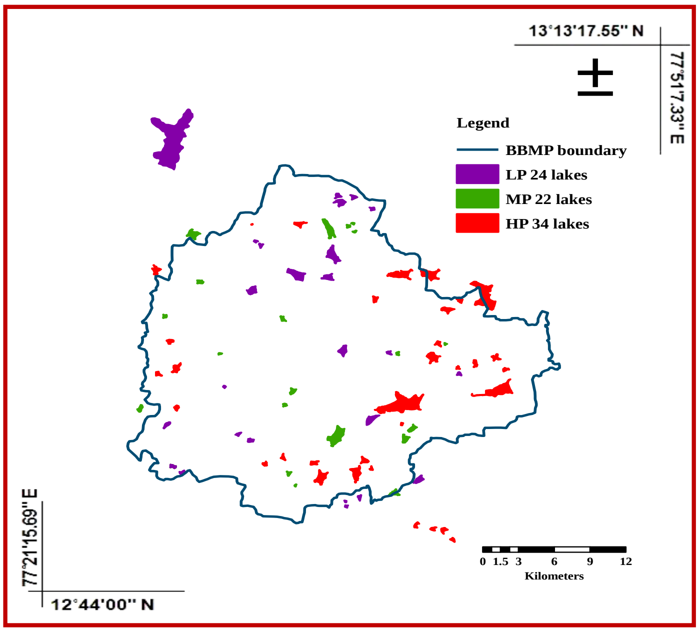

Figure 6.3: Distribution of lakes based on hierarchical clustering analysis (Wards method) - less polluted (LP), moderately polluted (MP), highly polluted (HP) lakes

Principal Component Analysis: Principal component analysis (PCA) was performed to investigate the factors that caused variations in the observed water quality variables across various lakes in Bangalore district. PCA provides information on the most meaningful parameters, which will describe the whole data set, and help in data reduction with minimum loss of original information.

Based on the eigenvalues scree plot (figure 6.3), about 13 physicochemical parameters were reduced to 10 main factors (factors 1 to 10) from the leveling off point(s) in the scree plot. The remaining 3 factors have eigenvalues of less than unity. The table 6.1 shows the corresponding eigenvalues and total variance for each factor extracted. Any factor with an eigenvalue greater than 1 is considered significant. The first factor corresponding to the largest eigenvalue (5.22) accounts for approximately 40.19% of the total variance. The second factor corresponding to the second eigenvalue (2.10) accounts for approximately 16.16% of the total variance.

Table 6.1: Eigenvalues and total variance of water quality parameters on significant principal components

PC	Eigenvalue	% variance
1	5.22	40.19
2	2.10	16.16
3	1.61	12.39
4	1.02	7.83
5	0.85	6.50
6	0.70	5.39
7	0.51	3.90
8	0.38	2.92
9	0.35	2.69
10	0.15	1.19
11	0.086	0.66
12	0.02	0.18
13	0.001	0.01

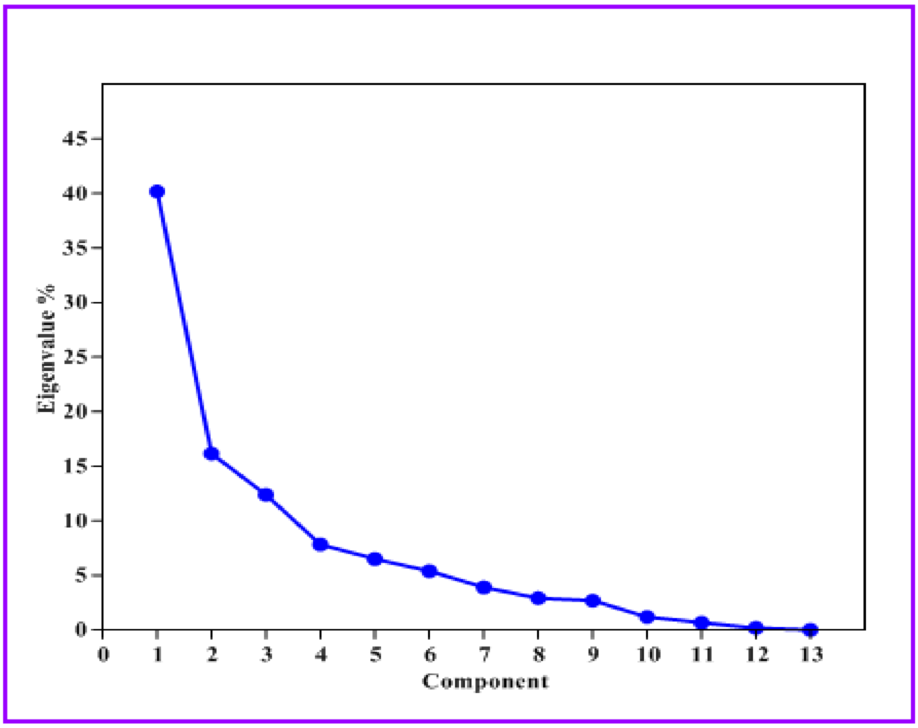

Figure 6.3: Scree plot of the eigenvalues of principal components

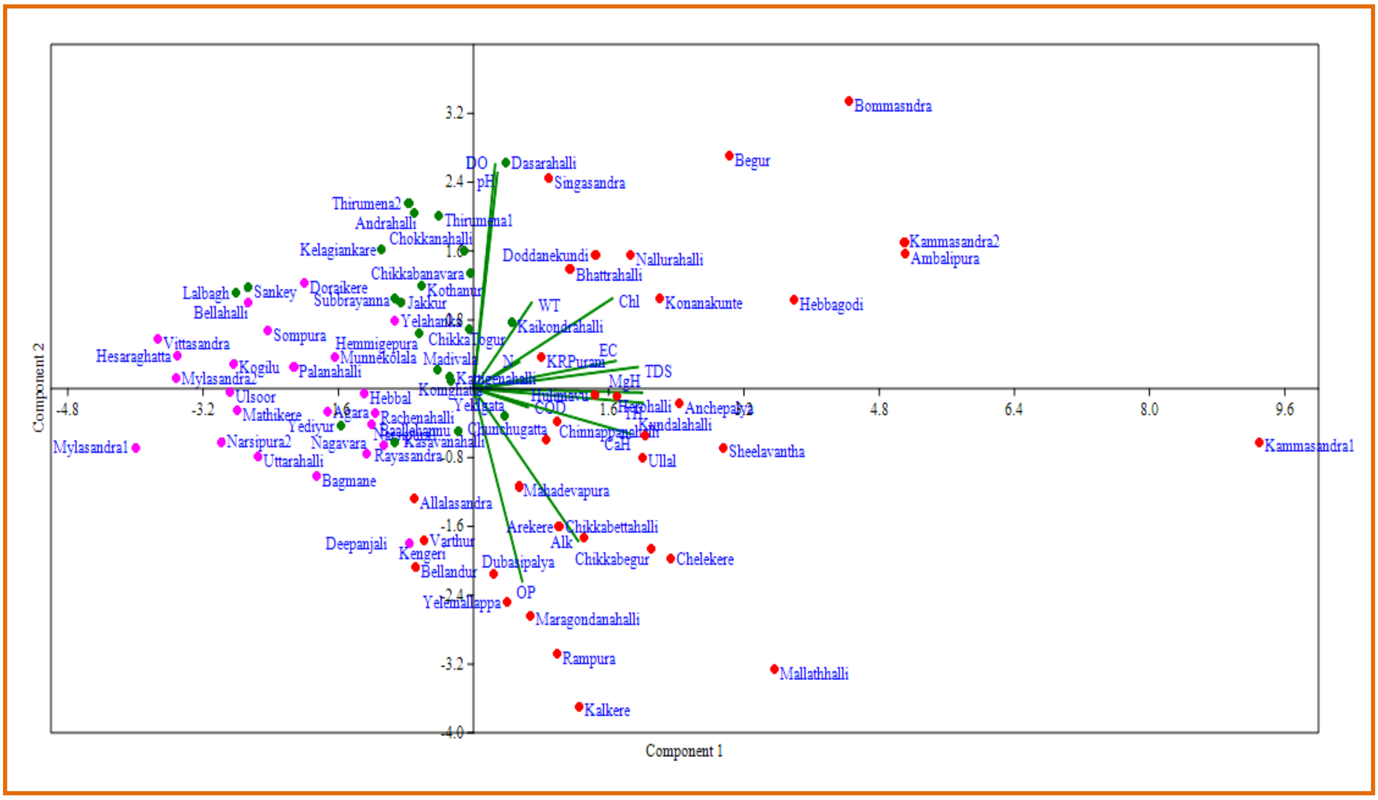

Figure 6.4: Principal component analysis for physico-chemical parameters of lakes in Bangalore

Principal component analysis for physico-chemical parameters of lakes in Bangalore (figure 6.4), revealed that

- Kammasandra 1 and Begur have higher TDS, EC, pH, COD, Total alkalinity, Total hardness, Calcium and Magnesium hardness and Nitrate.
- Yelemallappashetty, Rampura, Kalkere, Maragondanahalli, Mallathhalli, Chikka Togur, Chikka Begur, Allalasandra and Chelekere are highly influenced by orthophosphate as these lakes receive large amount of sewage water.
- Yelemallappashetty, Kammasandra 1, Ullal, Chelekere and Baallehannu are highly influenced by alkalinity. Kammasandra 1, Kattigenahalli and Chokkanahalli have higher Nitrate concentrations. Kammasandra 1, Kammasandra 2, Ambalipura, Hebbagodi, Bommasndra, Begur, Sheelavanthakere, Chikkabettahalli, Chikka Begur, Chikka Togur, Mallathhalli, Anchepalya, Herohalli and Ullal are affected by high levels of Hardness (TH, CaH and MgH).
- The lakes such as Kammasandra 1, Kammasandra 2, Begur, Hebbagodi, Ambalipura, Anchepalya and Bommasndra are highly influenced by chloride content.
- Andrahalli, Bommasndra, Singasandra, Thirumenahalli 1, Doddanekundi, Nallurahalli, Singasandra and Jakkur have high DO.
- Chikkabanavara, Dasarahalli, Chokkanahalli, Kelagiankare, Lalbagh, Sankey, Nallurahalli, Kothanur, Konanakunte, Thirumenahalli 1, Thirumenahalli 2 and Begur are highly affected by pH.
- Yelemallappashetty, Mallathhalli, Bellandur, Chikka Begur, Dubasipalya, Deepanjali Nagara kere, Kengeri, Kalkere, Arekere, Varthur, Maragondanahalli, Rampura and Bagmane are negatively correlated with DO.

The variation in water temperature had affected various parameters like pH, alkalinity, dissolved oxygen, electrical conductivity etc. and also various chemical and biological reactions such as solubility of oxygen, carbon dioxide, carbonate – bicarbonate equilibrium, and the metabolic rate.

In case of Hebbal Valley, 72% of lakes belong to class E and 28% belongs to class D and E. About 87% of lakes in Koramangala-Challaghatta Valley belongs to class E, 8% class D and E and 5% belongs to class A. In case of Vrishabavathi Valley, 69% of lakes belong to class E and 31% belongs to class D and E. When we consider all the sampled lakes in Bangalore, about 79% of lakes belongs to class E, 19% class D and E and 2% belongs to class A (figure 6.5, table 6.2).

Table 6.2: The water quality results based on Classification of Inland Surface Water (CPCB)

Sl.No	Name of the Lake	The valley to which lake belongs	Class
1	Agara Lake	Koramangala-Challaghatta Valley	E
2	Ambalipura Lake	Koramangala-Challaghatta Valley	E
3	Arekere Lake	Koramangala-Challaghatta Valley	E
4	Bagmane Lake	Koramangala-Challaghatta Valley	E

5	Bhattrahalli Lake	Koramangala-Challaghatta Valley	E
6	Begur Lake	Koramangala-Challaghatta Valley	E
7	Bellandur Lake	Koramangala-Challaghatta Valley	E
8	Bommasndra Lake	Koramangala-Challaghatta Valley	E
9	Chikkabegur Lake	Koramangala-Challaghatta Valley	E
10	Chikka Togur Lake	Koramangala-Challaghatta Valley	E
11	Chinnappanahalli Lake	Koramangala-Challaghatta Valley	E
12	Chunchugatta Lake	Koramangala-Challaghatta Valley	E
13	Doddanekundi Lake	Koramangala-Challaghatta Valley	E
14	Hebbagodi Lake	Koramangala-Challaghatta Valley	E
15	Hulimavu Lake	Koramangala-Challaghatta Valley	E
16	Kaikondrahalli Lake	Koramangala-Challaghatta Valley	D and E
17	Kammasandra Lake 1	Koramangala-Challaghatta Valley	E
18	Kammasandra Lake 2	Koramangala-Challaghatta Valley	E
19	Kasavanahalli Lake	Koramangala-Challaghatta Valley	E
20	Kelagiankare Lake	Koramangala-Challaghatta Valley	E
21	Kothanur Lake	Koramangala-Challaghatta Valley	E
22	K R Puram Lake	Koramangala-Challaghatta Valley	E
23	Kundalahalli Lake	Koramangala-Challaghatta Valley	E
24	Lalbagh Lake	Koramangala-Challaghatta Valley	D and E
25	Madivala Lake	Koramangala-Challaghatta Valley	E
26	Mahadevapura Lake	Koramangala-Challaghatta Valley	E
27	Munnekolala Lake	Koramangala-Challaghatta Valley	E
28	Mylasandra Lake 1	Koramangala-Challaghatta Valley	A
29	Mylasandra Lake 2	Koramangala-Challaghatta Valley	A
30	Nallurahalli Lake	Koramangala-Challaghatta Valley	E
31	Rayasandra Lake	Koramangala-Challaghatta Valley	E
32	Sheelavanthakere Lake	Koramangala-Challaghatta Valley	E
33	Singasandra Lake	Koramangala-Challaghatta Valley	E
34	Subbrayanna Lake	Koramangala-Challaghatta Valley	E
35	Ulsoor Lake	Koramangala-Challaghatta Valley	E
36	Varthur Lake	Koramangala-Challaghatta Valley	E
37	Vittasandra Lake	Koramangala-Challaghatta Valley	E
38	Yediyur Lake	Koramangala-Challaghatta Valley	D and E
39	Yeklgata Lake	Koramangala-Challaghatta Valley	E
40	Anchepalya Lake	Vrishabavathi Valley	E
41	Andrahalli Lake	Vrishabavathi Valley	D and E
42	Baallehannu Lake	Vrishabavathi Valley	D and E
43	Dasarahalli Lake	Vrishabavathi Valley	E
44	Deepanjali Nagara Lake	Vrishabavathi Valley	E
45	Doraikere Lake	Vrishabavathi Valley	D and E
46	Dubasipalya Lake	Vrishabavathi Valley	E
47	Hemmigepura Lake	Vrishabavathi Valley	D and E

48	Herohalli Lake	Vrishabavathi Valley	D and E
49	Kengeri Lake	Vrishabavathi Valley	E
50	Komghatta Lake	Vrishabavathi Valley	E
51	Konanakunte Lake	Vrishabavathi Valley	E
52	Mallathhalli Lake	Vrishabavathi Valley	E
53	Sompura Lake	Vrishabavathi Valley	E
54	Ullal Lake	Vrishabavathi Valley	E
55	Uttarahalli Lake	Vrishabavathi Valley	E
56	Allalasandra Lake	Hebbal Valley	E
57	Bellahalli Lake	Hebbal Valley	E
58	Chelekere Lake	Hebbal Valley	E
59	Chikkabettahalli Lake	Hebbal Valley	E
60	Chikkabanavara Lake	Hebbal Valley	E
61	Chokkanahalli Lake	Hebbal Valley	E
62	Hebbal Lake	Hebbal Valley	D and E
63	Hesaraghatta Lake	Hebbal Valley	D and E
64	Jakkur Lake	Hebbal Valley	D and E
65	Kalkere Lake	Hebbal Valley	E
66	Kattigenahalli Lake	Hebbal Valley	E
67	Kogilu Kere	Hebbal Valley	D and E
68	Maragondanahalli Lake	Hebbal Valley	E
69	Mathikere Lake	Hebbal Valley	E
70	Nagavara Lake	Hebbal Valley	D and E
71	Narsipura Lake 1	Hebbal Valley	D and E
72	Narsipura Lake 2	Hebbal Valley	E
73	Palanahalli Lake	Hebbal Valley	E
74	Rachenahalli Lake	Hebbal Valley	D and E
75	Rampura Lake	Hebbal Valley	E
76	Sankey Lake	Hebbal Valley	E
77	Thirumenahalli Lake 1	Hebbal Valley	E
78	Thirumenahalli Lake 2	Hebbal Valley	E
79	Yelahanka Lake	Hebbal Valley	E
80	Yelemallappashetty Lake	Hebbal Valley	E

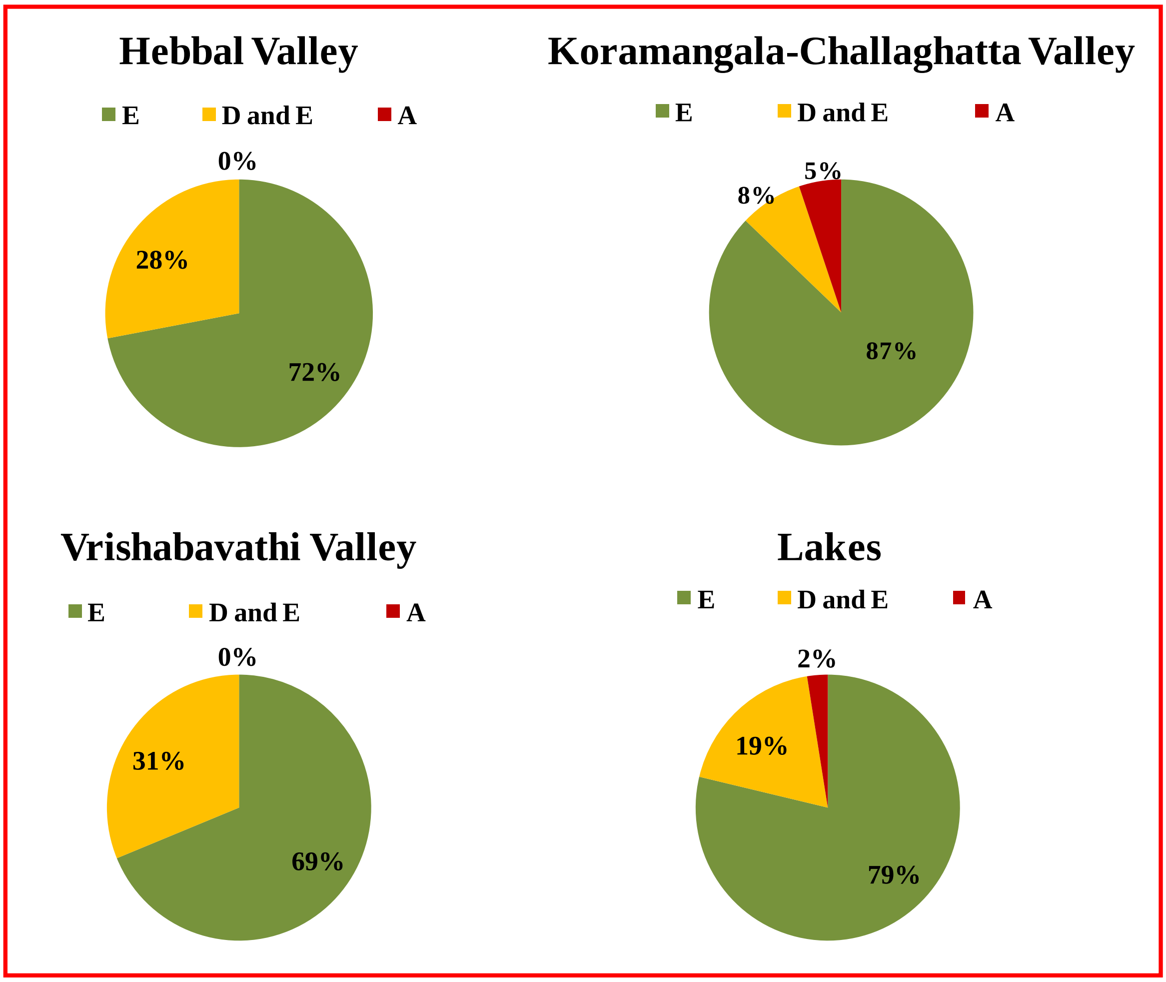

Figure 6.5: The class-wise distribution of the lakes in Bangalore belonging to 3 different valleys

CONCLUSION

An exploratory survey of 105 lakes in Bangalore revealed that about 25 lakes were found to be in a very bad state (either lakes had little/no water). The physico-chemical characteristics of 80 lakes were assessed to understand the prevailing condition of lakes in Bangalore.

- The water quality results revealed that lakes such as Andrahalli, Baallehannu, Doraikere, Hebbal, Hemmigepura, Herohalli, Hesaraghatta, Jakkur, Kaikondrahalli, Kogilu, Lalbagh, Nagavara, Narsipura 1, Rachenahalli and Yediyur falls under Class D and E, whereas all the other 63 lakes belonged to under Class E based on the Classification of Inland Surface Water (CPCB).
- Lakes in Koramangala-Challaghatta Valley (KC) are the most polluted than the lakes in Vrishabavathi Valley (V) and Hebbal Valley (H).
- About 79% of lakes monitored in Bangalore belongs to class E, 19% to class D and E and 2% belongs to class A.
- Lakes like Bellandur, Chelekere, Chikkabegur, Chunchugatta, Hebbagodi, Kalkere, Kammasandra lake 1, Kengeri, Mallathhalli, Maragondanahalli, Nallurahalli,

Rampura, Varthur and Yelemallappachetty receives enormous amount of untreated sewage water.

- Cluster Analysis of physical and chemical variables in the water of 80 lakes in Bangalore revealed the existence of three groups namely less polluted, moderately polluted and highly polluted lakes.
- All monitored parameters showed diurnal as well as seasonal variations in the present study.
- Principal component analysis for physico-chemical parameters of lakes revealed that Kammasandra 1, Kammasandra 2, Ambalipura and Begur have higher TDS, EC, pH, COD, Total alkalinity, Total hardness, Calcium and Magnesium hardness.
- An enormous amount of wastewater is generated in Bangalore daily. The treatment capacities of STPs in Bangalore are far lower than generation. Only treated sewage to be let into lakes.
- Lakes that had profuse growth of Algae i.e., Cyanophyceae (due to continuous sewage inflow and high nutrients) are Sankey, Dasarahalli, Bagmane, Ulsoor, Anchepalya, Bommasndra, Kammasandra 1and 2.
- Fish death was seen in Sankey, Lalbagh, Jakkur and Munnekolala.
- In the case of Zooplanktons, Rotifera and Protozoa were present in high numbers in polluted/nutrient rich lake.
- In the case of Macrophytes, *Eichhornia* sp., *Typh*a sp. and *Alternanthera* sp. were the most dominant species found. These macrophytes sometimes cover the entire lake surface resulting in anoxic conditions.
- Foam formation was seen in lakes such as Bellandur, Maragondanahalli, Rampura, Sarakki and Varthur.
- Recently, fire was reported in Bellandur lake.
- Lakes like Bellandur, Bommasndra, Dasarahalli, Deepanjali Nagara, Doddabidirakallu, Kammasandra, Kempambudhi, Mahadevapura, Nalagadderanahalli, Nayandanahalli, Shivapura, Varthur are near to industries.
- STPs are present in lakes like Kempambudhi, Marathahalli, Madivala, Dasarahalli, Lalbagh, Jakkur, Andrahalli, Allalsandra, Hebbal, Herohalli and Doraikere.
- About 25 lakes were found to be places for solid and liquid wastes dumping and fully macrophyte covered due to the excessive amount of nutrients present in those lakes.
- Lake such as Lakasandra had completely turned to a barren land due to the dumping of building debris.
- Immediate action should be taken for the lakes that are in worst conditions.

RECOMMENDATIONS: Immediate policy interventions are essential to protect the lakes from further deterioration, which include:

1. Maintenance of 30 m buffer around the lake (with regulated activities)
2. Mapping of lake boundary and demarcation of lake boundary (based on flood plains), buffer region and valley regions in each valley.

3. Ensure proper fencing of lakes
4. Removal of all encroachments in the lake bed after the survey based on reliable cadastral maps
5. Re-establishing interconnectivity among lakes (removal of all encroachments)
6. Threshold on high raise building in the region. Need to protect valley zones considering ecological function and these regions are 'NO DEVELOPMENT ZONES' as per CDP 2005, 2015
7. Digitization of land records (especially common lands – lakes, open spaces, parks, etc.) and availability of this geo-referenced data with query based information system to public
8. Any alteration of topography in lake catchments should be banned
9. Complete ban on construction activities in the valley zones
10. Restrictions on the diversion of lakes for any other purposes
11. Regulate illegal sand and clay mining around the wetlands
12. Restrictions on dumping solid and liquid wastes in lakes and lake bed.
13. Restrictions on letting untreated sewage into lakes
14. Allow only treated wastewater (sewage and effluents) into the lake
15. Implementation of 'polluter pays' principle as per Water Act, 1974
16. Banning of filling of a portion of lake with building debris
17. Impact of pesticide or fertiliser on wetlands need to be checked
18. Water in the lake must be cleaned or drained completely, if necessary
19. Plant native species of macrophytes in open spaces of lake catchment area
20. Regular harvesting/removal of macrophytes in the lakes like *Eichhornia* sp., *Typh*a sp., *Alternanthera* sp. etc. through manual operations
21. Treatment of wastewater through constructed wetlands and algal ponds (similar to Jakkur lake). Constructed wetlands with shallow algal ponds helps in the removal of nutrients
22. All the settlements alongside the lake should be provided with proper sanitation facilities so as to avoid open defecation
23. The shorelines of the lakes should be lined with bricks or stones to control shoreline erosion
24. Afforestation with native species in the areas around wetlands (catchment area) to control the entry of silt through runoff
25. Dredging of the sediments in the lake has to be done to improve the soil permeability, water holding capacity and ground water recharge. Wet dredging is applicable to lakes
26. Adopt techniques like biomanipulation (Silver carp, Catla, Rohu , Gambusia and Guppies for algal and mosquito control), aeration, shoreline restoration (with the native vegetation) in the management of lakes
27. Single agency with the statutory and financial autonomy to be the custodian of natural resources (ownership, regular maintenance and action against polluters (encroachers as well as those who contaminate through untreated sewage and effluents, dumping of solid wastes)
28. The MSWM (Municipal Solid Waste Management) problem has increased with rapid urbanisation. The public and agencies should follow the Municipal Solid Wastes (Management and Handling) Rules, 2000 to keep the environment clean and to safeguard the health of individuals.
29. Decentralized treatment of wastes generated in each ward, ensure proper functioning of STPs

30. Restore surviving lakes in urban areas strengthening their catchment area
31. Environmental awareness programmes can greatly help in the protection of the water bodies.

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Common threats faced by lakes due to Irresponsible activities by 21st Century Bangaloreans: a) Dumping of building debris, b) plastic and solid waste dumping, c) Encroachments and construction of buildings, d) damaged fencing, e) sustained inflow of untreated sewage into lakes and f) filling the lake area

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