FISH MORTALITY IN JAKKUR LAKE: CAUSES AND REMEDIAL MEASURES

	
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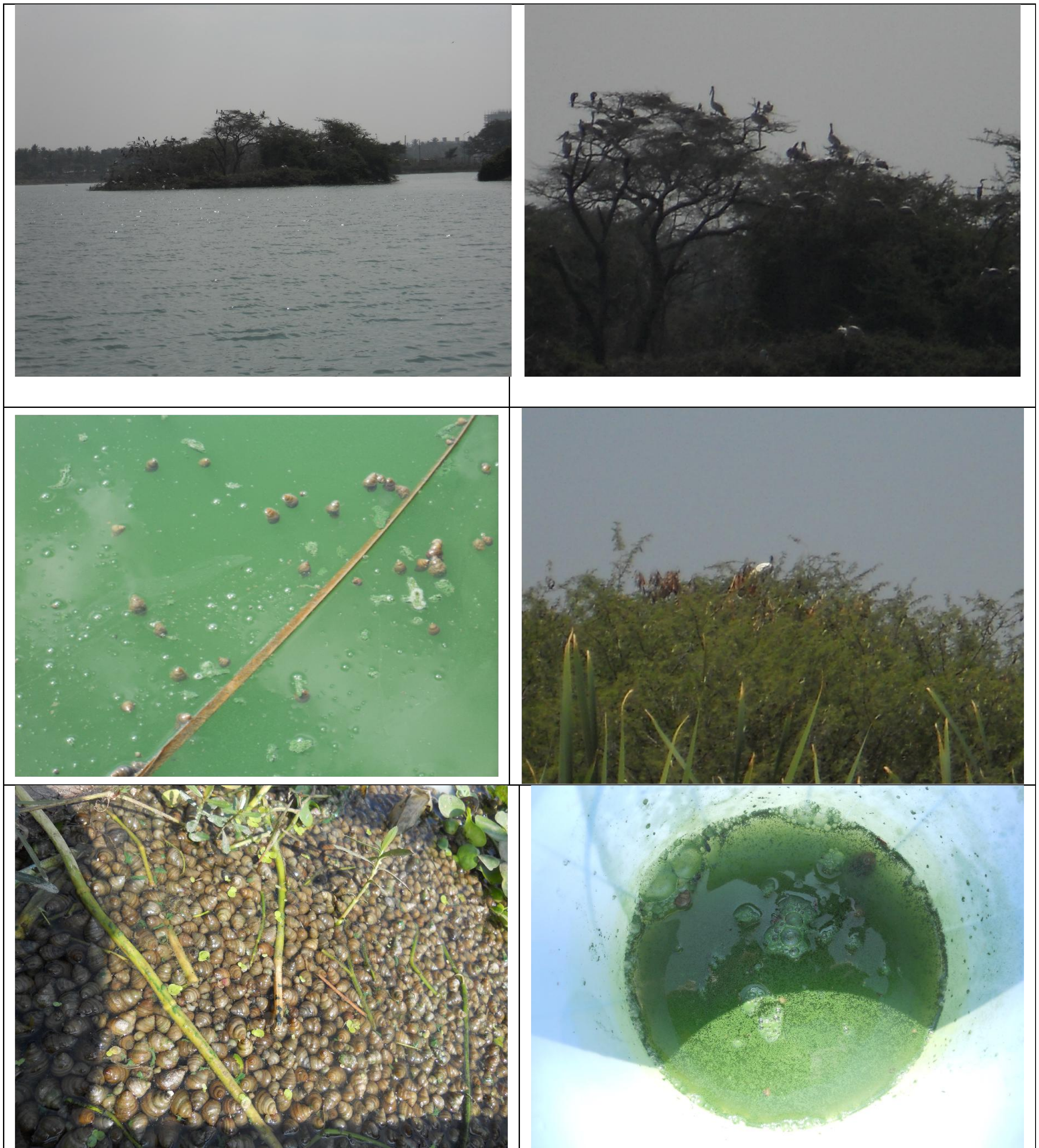

Jakkur wetlands – Birds, Algae, Molluscs

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FISH MORTALITY IN JAKKUR LAKE: CAUSES AND REMEDIAL MEASURES

EXECUTIVE SUMMARY

Wetlands constitute the ecological barometers of the health of a region. They regulate the micro climate apart from being highly productive, support exceptionally large biological diversity, and provide a wide range of ecosystem services such as food, fibre, and waste assimilation, water purification, flood mitigation, erosion control, groundwater recharge, etc. They also enhance the aesthetics of the landscape and support many significant recreational, social, and cultural activities, aside from being a part of our cultural heritage. Unplanned urbanization has telling influences on the natural resources such as decline in green spaces (vegetation) including wetlands and/or depleting groundwater table. Sustained inflow on untreated sewage to wetlands has altered the integrity of fragile wetlands disturbing the complex interactions and self purification capacity of aquatic ecosystems. Sustained inflow of untreated or partially treated sewage enriches the wetlands due to the availability of higher nutrient concentrations resulting in the prolific growth and spread of invasive exotic species such as water hyacinth (*Eichhornia crassipes*). This hinders aerobic functioning of the lake by restricting sunlight penetration and also affecting algal photosynthesis. This results in anoxic environment due to blockage of air-water interface, influencing oxygen diffusivity. Reduction in DO (0 mg/l) impacts the viability of aquatic biota and result in the disappearance of biodiversity. This is evident in the recent episodes of fish mortality in Jakkur lake with asphyxiation in some locations due to the considerable fall in dissolved oxygen (DO) levels caused by sustained inflow of large quantum of sewage let into the lake (through illegal diversions by local civil contractors). It is not due to any kind of infection because none of the fishes showed any signs of disease symptoms.

Enrichment of nutrients due to the sustained inflow of untreated sewage has led to algal blooms and profuse growth of macrophytes. Decomposition of algae or/and dense cover of macrophytes reduces dissolved oxygen leading to anaerobic conditions, which asphyxiate aquatic life including fish. The current study was carried out in response to a request from Mr.Jayaram B, DCF, Forest division, Bangalore Development Agency (BDA) subsequent to series of news reports in local dailies with large scale fish mortality in Jakkur Lake Bengaluru, Karnataka. The physico-chemical and biological composition of the lake was studied using standard protocols. Results reveal of higher nutrients due to the sustained unauthorized inflow of large quantum of untreated sewage along with partial treated water. This is confirmed with the profuse growth of invasive exotic weeds and also large scale algal blooms. The presence of dense cover of macrophytes hinders the light penetration leading o the decline of dissolved oxygen (DO) due to the prevailing anaerobic conditions with lowered algal communities. Apart from this, algal blooms also leads to anaerobic conditions during non-photosynthesis period (at night) with respiration. This lake is being monitored by us at Energy and Wetlands Research Group,

CES, IISc since 36 months. Current investigation reveals that nutrients (N and P) in the water increased by four times since unauthorized inflow of sewage from the adjacent neighbourhood. The overall water quality has deteriorated compared to previous years due to the sustained inflow of sewage from neighbourhood. The act of polluting waterbodies and consequent contamination of ground water is liable for penalty as per "Polluter pays principle", water act 1974, government of India (Water (Prevention and Control of Pollution) Act – 1974, 1977; Environmental (Protection) Act – 1986).

Significance of wetlands: Wetlands are lands transitional between terrestrial and aquatic eco-systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands constitute vital components of the regional hydrological cycle. They are highly productive, support exceptionally large biological diversity, and provide a wide range of ecosystem services such as food, fibre, waste assimilation, water purification, flood mitigation, erosion control, groundwater recharge, microclimate regulation, 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 function as kidneys of landscape due to remediation of contaminants (which include nutrients, heavy metals, etc.). These fragile ecosystems are vulnerable to even small changes in their biotic and abiotic factors. In recent years, there has been concern over the continuous degradation of wetlands due to unplanned developmental activities** (Ramachandra, 2002)**.** Most urban wetlands are seriously threatened by conversion to non-wetland purposes, encroachment of drainage through landfilling, pollution (discharge of domestic and industrial effluents, disposal of solid wastes), hydrological alterations (water withdrawal and inflow changes), and over-exploitation of their natural resources. This results in loss of biodiversity and disruption in goods and services provided by wetlands (Ramachandra, 2009).

Policy and legislative measures for Wetlands conservation in India are:

- The Indian Forest Act - 1927
- Forest (Conservation Act) - 1980
- Wildlife (Protection) Act - 1972
- Water (Prevention and Control of Pol1ution)Act - 1974
- Water (Prevention and Control of Pollution) Act - 1977
- Environmental (Protection) Act - 1986
- Wildlife (Protection) Amendment Act - 1991
- National Conservation Strategy and Policy Statement on Environment and I Development - 1992
- National Policy And Macro level Action Strategy on Biodiversity-1999
- Biological Diversity Act, 2002, areas rich in biodiversity, cultural importance, etc.
- Wetlands (Conservation and Management) rules 2010, Government of India

Current investigation reveals that nutrients (N and P) in the water increased by four times since unauthorized inflow of sewage from the adjacent neighbourhood. The overall water quality has deteriorated compared to previous years due to the sustained inflow of sewage from neighbourhood. The act of polluting waterbodies and consequent contamination of ground water is liable for penalty as per "Polluter pays principle", water act 1974, government of India (Water (Prevention and Control of Pollution) Act – 1974, 1977; Environmental (Protection) Act – 1986).

Activities	Norms
Direct sustained inflow of untreated sewage to lakes	Violation of Water (Prevention and Control of Pol1ution)Act – 1974 & 1977 • Need to penalise para-state agency BWSSB for contaminating lake (and subsequent contamination of groundwater due to the sustained inflow of untreated sewage to these lakes. Need to implement "Polluter pays" principle.
Lack of clean air, water and environment to our children	Violates the norms of 'Right to water' and right to 'healthy environment' guaranteed under Article 21of the Indian constitution. This has been protected as a fundamental human right by the Indian Supreme Court as part of the Right to Life The right to life has been expanded significantly over the last three decades to include the right to health and the right to a clean environment which can include the right to clean drinking water.
Water shortage	Bangalore is already experiencing severe water shortages as water yield in rivers (Cauvery, etc.) has come down due to large scale land cover changes. Neither Cauvery, T G Halli nor groundwater can sustain Bangalore's growing water demand. Mismanagement of wetlands and ultimate removal of these ecosystems would affect the groundwater availability in the region.

RECOMMENDATIONS:

- Penalize polluters as per "Polluter pays principle"
- Restrict the nutrient discharge into the lake;
- Allow only treated water into the lake;
- Maintain macrophytes through regular harvesting and restrict the region infested with weeds

To control the growth of algae dominated by *spirulina spp* the following fish species should be introduced into the lake

- Silver carp (*Hypophthalmichthys molitrix*) Exotic carp
- Sandkhol- (*Thinnichthys sandkhol*) Local carp
- Bighead carp (*Aristichthys nobilis*) Exotic carp

Silver Carp, Bighead carp and Sandkhol Carps are introduced to fresh water systems because of their ability to decrease phytoplankton (algae) density although zooplanktons are preferred food.

Keywords: fish mortality, Jakkur Lake, wetlands, bioremediation, "polluter pays principle"

FISH MORTALITY IN JAKKUR LAKE: CAUSES AND REMEDIAL MEASURES

INTRODUCTION

Wetlands constitute vital components of the regional hydrological cycle. They are highly productive, support exceptionally large biological diversity, and provide a wide range of ecosystem services such as food, fibre, and waste assimilation, water purification, flood mitigation, erosion control, groundwater recharge, and microclimate regulation. They also enhance the aesthetics of the landscape and support many significant recreational, social, and cultural activities, aside from being a part of our cultural heritage. It is acknowledged that most urban wetlands are seriously threatened due to unplanned rapid urbanisation with the conversion to non-wetland purposes, encroachment of drainage through landfilling, pollution (discharge of domestic and industrial effluents, disposal of solid wastes), hydrological alterations (water withdrawal and inflow changes), and overexploitation of their natural resources. This results in loss of biodiversity and disruption in goods and services provided by wetlands (Ramachandra, 2009; 2009a, b).

Wetlands ensure water security and aid as lifeline by sustaining biota. Human community depends on water for its domestic, agriculture and industrial needs. Availability of water has been a factor in the development of various civilizations near lakes and rivers (Benjamin et.al, 1996). Wetlands (Lakes, ponds and tanks) are the ecological barometers as they regulate the micro climate, which helps in maintaining the regional ecological health.

Wetlands require some nutrients to sustain biological organisms, but sustained inputs / inflow of nutrients crossing the threshold would be harmful. Sewage or agriculture runoff will have nutrients such as N and P. Sustained inflow of these nutrients beyond remediation potential of wetlands would lead to algal blooms as well as profuse growth of invasive weeds. Die-off and decomposition of large quantity of algae reduces dissolved oxygen affecting fish and other aquatic life. Invasive algae (blue-green) release toxins that are harmful to aquatic life and humans.

However the stability of ecosystem depends upon the balance between production and consumption of energy and matter at different trophic levels. The functional aspects of wetlands are tied to the tradeoff between the ecosystem function and the anthropogenic impact that makes it very sensitive and delicate. Human impacts include altering the catchment (changes in land cover), encroachment, solid waste disposal in lake beds, sustained inflow of untreated sewage from urban localities, etc. (Ramachandra, 2002, 2009a, 2010; Ramachandra et al., 2003)

The major threats to water resources are from point sources (sewage, industrial effluents, etc.) and from non-point sources (agriculture, urban, etc.). Apart from these, dumping of solid wastes, chemical spills, thermal pollution, acid precipitation, mine drainage, etc. also contribute. Pollution affects the quality of the water and then destroys the other aquatic communities, disrupting the food web in these aquatic ecosystems(Ramachandra et al., 2007).The study was done to understand the reasons for fish death and excess growth of algae and macrophytes in Jakkur lake, Bangalore.

OBJECTIVE OF THE STUDY: Objectives of the current investigations are:

a) To assess the physico-chemical and biological composition of Jakkur Lake water
b) To assess the current status with earlier studies
c) To evolve appropriate management techniques to conserve the wetlands.

MATERIAL AND METHODS

Study area: Jakkur wetlands (Figure 1) situated at 13º 04' N and 77° 36' E, North East of Bangalore. Ten MLD sewage treatment plant is functional in this locality. Partially treated water is let into Jakkur water body through wetlands (consisting of emergent macrophytes and algae). Water samples were collected (figure 1) from Inlet (without treatment and treated water from STP), inlet after wetland, middle and outlets of the lake. The treated water from the treatment plant passes through the wetlands to Jakkur Lake.

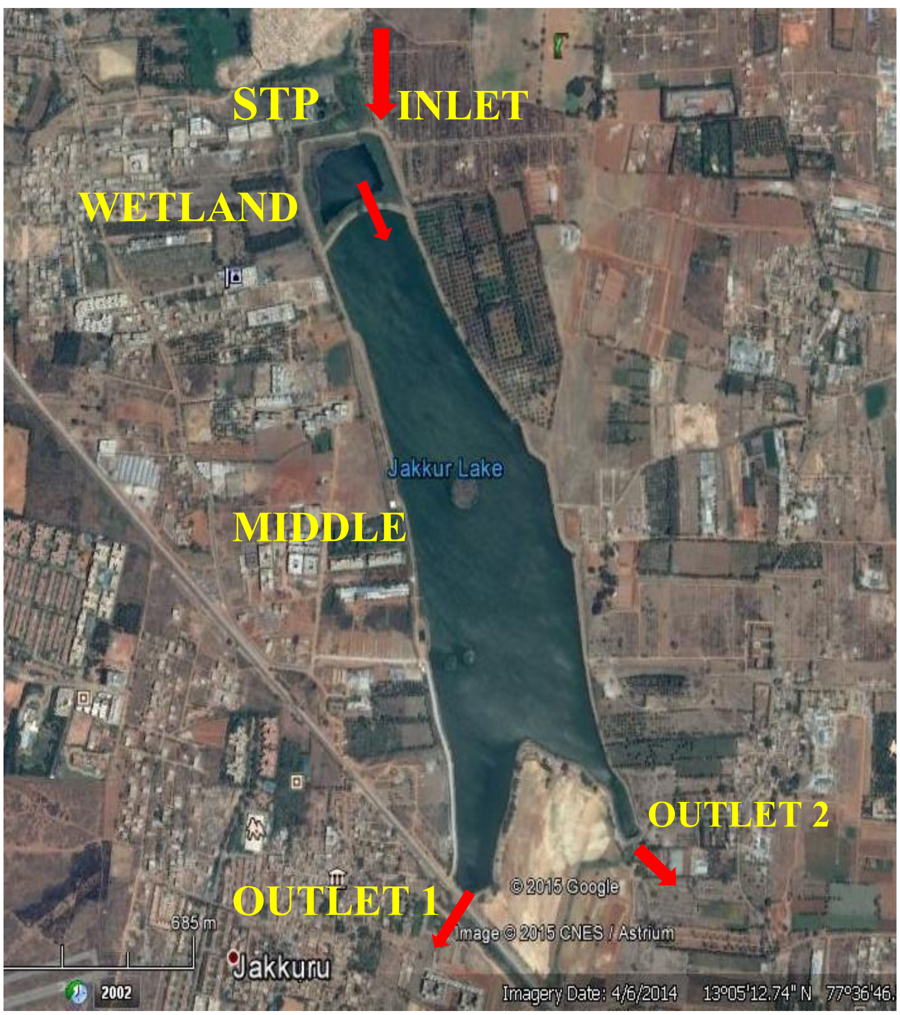


Figure 1: Jakkur Lake and sampling locations

Analysis of physico-chemical parameters: The water temperature, pH, electrical conductivity (EC) and dissolved oxygen (DO) were determined on spot at the time of sampling. Other parameters like nitrate, phosphate, total alkalinity, calcium hardness, total hardness, chlorides, COD (Chemical oxygen demand), sodium and potassium were analysed in the laboratory by using standard methods prescribed by Trivedi and Goel (1986) and APHA (1998).

Macrophyte collection and identification: Macrophyte samples were collected and washed to get rid of adhering materials. They were identified using Cook CDK (1996).

Analysis of phytoplankton: The algal species were identified based on their key morphological features, according to Prescott (1954), Desikacharya (1959).

RESULTS AND DISCUSSION

PHYSICO-CHEMICAL PARAMETERS OF LAKE

***Temperature**:* It is an important factor for aquatic life as it regulates the maximum dissolved oxygen concentration of the water, controls the rate of metabolic activities, reproductive activities and therefore, life cycles. The temperature ranges between 19.9^{0}C to 24.2^{0}C.

Dissolved Oxygen: Dissolved oxygen (DO) is the most essential feature in aquatic system that helps in aquatic respiration as well as detoxification of complex organic and inorganic mater through oxidation. The presence of organic wastes imposes a very high oxygen demand on the receiving water leading to oxygen depletion with severe impacts on the water ecosystem. The effluentsalso constitute heavy metals, organic toxins, oils, volatile organics, nutrients and solids. The DO of the analysedwater samples varied between 0 to 14.52mg/l.

Table 1: Parameters monitored at site

	WT(°C)	TDS(mg/l)	pH	EC(µS)	DO(mg/l)
Inlet without treatment	19.9	1128	10.3	1630	0.00
Inlet from STP	20.9	693	8.8	1117	4.84
Inlet from algae pond	24.2	479	9.4	816	14.52
Middle	24.1	463	9.3	793	10.48
Outlet	23.9	465	8.6	856	8.71
outlet 2	25.5	467	10	845	8.55

Profuse growth coupled with the spread of aquatic plants lead to impairment of ecosystem's functional abilities due to alterations in the food chain. Macrophytes hinder the sunlight penetration leading to anaerobic conditions with the lowered oxygen levels affecting aquatic life. Similarly algal blooms due to respiration would create lowering of oxygen. Persistence of anaerobic conditions with lower DO would create stressful conditions for fish, eventually leading to large scale mortality of aquatic life.

Table 2: Chemical Parameters of Water Analysis

	PHOSPHATE (mg/l)	NITRATE (mg/L)	COD (mg/l)	BOD (mg/l)	CHLORIDES (mg/l)	ALKALINITY(mg/l)	TH (mg/l)	Ca (mg/l)	Na (mg/l)	K (mg/l)
Inlet without treatment	1.86	0.81	84	53.23	372.51	740.00	482.67	184.37	213.6	80.4
Inlet from STP	1.52	0.81	32	19.35	210.63	682.67	325.33	88.98	258.4	49.6
Inlet from algae pond	1.41	0.71	28	24.19	207.32	468.00	323.33	79.89	290.8	55.6
middle	0.46	1.25	34	29.03	165.19	278.67	260.00	59.85	208.4	37.6
outlet	0.55	1.12	32	26.58	168.51	285.33	260.67	59.85	230.8	46.4
outlet 2	0.37	1.28	32	26.58	177.03	277.33	262.00	61.46	166	44.4

pH: pH is a numerical expression that indicates the degree to which water is acidic or alkaline, with the lower pH value tends to make water corrosive and higher pH provides taste complaint and negative impact on skin and eyes. The pH was alkaline in the entire lake ranging from 8.8 to 10.3.

Total Dissolved Solids (TDS): TDS is a measure of the amount of material dissolved in water. This material can include carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions.TDS affect the water quality in numerous ways impacting the domestic water usage for cleaning, bathing etc as well as drinking purposes. Total dissolved solids originate from organic sources such as leaves, silt, plankton, industrial waste and sewage. Other sources come from runoff from urban areas, road salts used on street, fertilizers and pesticides used on lawns and farms (APHA, 1995). Surface as well as groundwater with high dissolved solids are of inferior flavor and induce an unfavorable physiological reaction to the dependent population. A limit of 500mg/l TDS is desirable for drinking waters. The TDS values in the samples analysed, ranged from 463to 1128 mg/l across all locations.

Chlorides: Chlorides are essentially potential anionic radical that imparts chlorosity to the waters. An excess of chlorides leads to the formation of potentially carcinogenic and chloro-organic compounds like chloroform, etc. Chloride values in samples ranged from 165to 372mg/l. Chloride values were high at inlets (treated and untreated water) and relatively lower at the outlet and the middle portion of Jakkurlake. A range of 250 mg/l is desirable according to IS 10500.

Sodium: Sodium (Na) is one of the essential cations that stimulates various physiological processes and functioning of nervous system, excretory system and membrane transport in animals and humans. Increase of sodium ions has a negative impact on blood circulation, nervous coordination, thence affecting the hygiene and health of the nearby localities. According to WHO guidelines the maximum admissible limit is 200 ppm. In this study the concentration of sodium ranged from 166- 290mg/l.

Potassium: Potassium (K) is an essential element for both plant and animal nutrition, and occurs in ground waters as a result of mineral dissolution, decomposing of plant materials and also from agricultural runoff. Potassium ions in the plant root systems helps in the cation exchange capacity to transfer essential cations like Ca and Mg from the soil systems into the vascular systems in the plants in replacement with the potassium ions. Incidence of higher potassium levels in soil system affects the solute transfer (active and passive) through the vascular conducting elements to the different parts of the plants. The potassium content in the water samples ranges between 37-80mg/l.

Alkalinity: Alkalinity is a measure of the buffering capacity of water contributed by the dynamic equilibrium between carbonic acid, bicarbonates and carbonates in water. Sometimes excess of hydroxyl ions, phosphate, and organic acids in water causes alkalinity. High alkalinity imparts bitter taste. The acceptable limit of alkalinity is 200mg/l as per IS 10500. The water samples analysedhad higher alkalinities (277-740 mg/l) values.

Total hardness: Hardness is the measure of dissolved minerals that decides the utility of water for domestic purposes. Hardness is mainly due to the presence of carbonates and bicarbonates. It is also caused by variety of dissolved polyvalent metallic ions predominantly calcium and magnesium cation although, other cations like barium, iron, manganese, strontium and zinc also contribute. In the present study, the total hardness ranged between 260 to 482mg/l. According to IS 10500 and WHO guidelines the desirable limit is 300 mg/l.

Calcium: Calcium (Ca) is one amongst the major macro nutrients which are needed for the growth, development and reproduction in case of both plants and animals. The presence of Ca in water is mainly due to its passage through deposits of limestone, dolomite, gypsum and other gypsiferous materials (Manivasakam, 1989). Caconcentration in all samples analysed periodically ranged between 59 to 185mg/l.

Nutrients (nitrates and phosphates): Nutrients essentially comprise of various forms of N and P which readily dissolve in solutions that are up-taken by microbes and plant root systems in the form of inorganic mineral ions. Accumulation of N as nitrates and P as inorganic P in aquatic ecosystems causes significant water quality problems due to higher net productivity. Together with phosphorus, nitrates in excess amounts in streams and other surface waters can accelerate aquatic plant growth causing rapid oxygen depletion or eutrophication in the water. Nitrates at high concentrations (10 mg/l or higher) in surface and groundwater used for human consumption are particularly toxic to young children affecting the oxygen carrying capacity of blood cells (RBC) causing cyanosis (methemoglobinemia). In the present study, nitrate values ranged from 0.7 to 1.28mg/l and phosphate values ranged between 0.3 to 1.86 mg/l.

The process by which a body of water acquires a high concentration of nutrients, especially phosphates and nitrates is called as eutrophication. These typically promote excessive growth of algae. As the algae die and decompose, high levels of organic matter and the decomposing organisms deplete the water of available oxygen, causing the death of other organisms, such as fish.

COD and BOD: BOD and COD are important parameters that indicate the presence of organic content.

- ***Biochemical oxygen demand (BOD):*** Biochemical oxygen demand (BOD) is the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban storm water runoff.It is required to assess the pollution of surface and ground water where contamination occurred due to disposal of domestic and industrial effluents. The BOD ranged between 19 and 53 mg/l.
- ***Chemical oxygen demand (COD):*** COD is important parameter that indicates contamination with organic wastes. Chemical oxygen demand (COD) determines the oxygen required for chemical oxidation of most organic matter and oxidizable inorganic substances with the help of strong chemical oxidant. COD test is helpful in indicating toxic conditions and the presence of biologically resistant organic substances. In this study the COD values ranged from 32-84 mg/l.

COMPARISON OF PHYSICO CHEMICAL PARAMETERS WITH EARLIER STUDIES (Ramachandraet.al, 2014): The variations of physicochemical parameters of lake water are shown in figure 2-5.

Nutrients (Nitrates and Phosphates): The inlet showed an increase in the amount of nutrients with time. The nitrate values have increased almost 4 times as compared to 2013. Also, an increase in the values of phosphate were observed at the inlet. The middle portion of the lake showed 5 times increase in the values of nitrate as compared to 2013. The phosphate values increase around 5 times in the middle portion. Same trend was followed in the outlet of the lake. The 2phosphate and nitrate values increased by 4 times as compared to 2013 values (figure 2).

The results show that there is a continuous increase in the quantity of nutrient inflow into the lake over a period of time. This led to the excess growth of plants i.e., algae and macrophytes. When the plants die and decay, anaerobic conditions prevail with lower oxygen levels, which then turns green or milky white and gives off a strong rotten egg odour. The lack of oxygen is lethal for invertebrates, fish, etc.

Excess plants in a water body can create many problems. An excess in the growth of plants and algae create an unstable amount of dissolved oxygen. During the day, there will be higher levels of dissolved oxygen (in the region of algal bloom), and at night the levels of oxygen decline drastically, creating stressful conditions for fish. If the conditions persist for a long period of time, the stressed fish species will die off.

Dissolved Oxygen (DO): Figure 4 shows the variation in DO in the lake across time period. There was not much variation in the DO values in the inlet. The middle and outlet portion of the lake showed increase in DO compared to earlier studies. This is mainly because of excess of algal and macrophyte growth. An excess in the growth of plants and algae create an unstable amount of dissolved oxygen. During the day, there will be usually be high levels of dissolved oxygen, and at night the levels of oxygen can decrease dramatically. This will create stressful conditions for fish.

COD and BOD: The inlets showed higher BOD and COD values than the earlier investigations. The middle portion of the lake showed higher values than all earlier values. COD was almost 2 times higher than 2013. The outlet of the lake also showed similar trend in the BOD and COD (figure 3). This shows that there is high amount of organic load in the lake. BOD and COD directly affect the amount of dissolved oxygen in lakes, rivers and streams. The greater the BOD and COD, the more rapidly oxygen is depleted in the lake. This means less oxygen is available to higher forms of aquatic life. The consequences of high BOD and COD are the same as those for low dissolved oxygen: aquatic organisms gets stressed, suffocate, and die.

pH: pH was higher (8.8-10.3) throughout compared to previous study (figure 5). The majority of aquatic creatures prefer a pH range of 6.5-9.0. The release of carbonate converted from bicarbonate by plant life can cause pH to climb dramatically (above 9) during periods of rapid photosynthesis by dense phytoplankton (algal) blooms (Wurts and Masser. 2004). A slight change in the pH of water can increase the solubility of phosphorus and other nutrients making them more accessible for plant growth. When the pH of lake becomes highly alkaline, the effect on fish includes death, damage to gills, eyes etc. High pH also increases the toxicity of other substances and increasing the risk of absorption by aquatic life. Example ammonia is 10 times more severe at pH 8 than at pH 7.

Chlorides, Alkalinity and Hardness: The chloride values were high in the inlet compared to earlier studies. The middle and outlet portion did not show much variation (Figure 6). Alkalinity values were higher throughout the lake compared to the earlier analysis. Total hardness was also high during this study than earlier studies. Hardness mitigates metals toxicity, because Ca^{2+} and Mg^{2+} help keep fish from absorbing metals such as lead, arsenic, and cadmium into their bloodstream through their gills. The greater the hardness, the harder it is for toxic metals to be absorbed through the gills (Wurts and Robert M. Durborow, 1992).

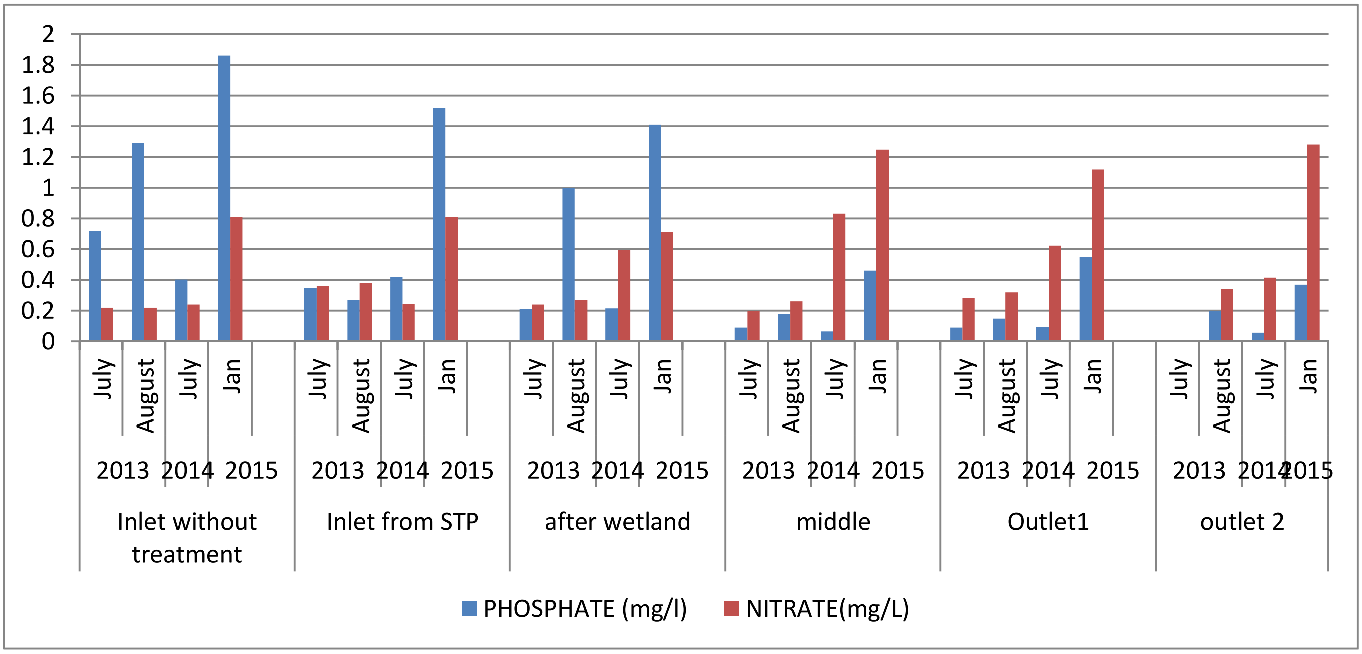


Figure 2: Comparison of Nutrients in the lake across time period

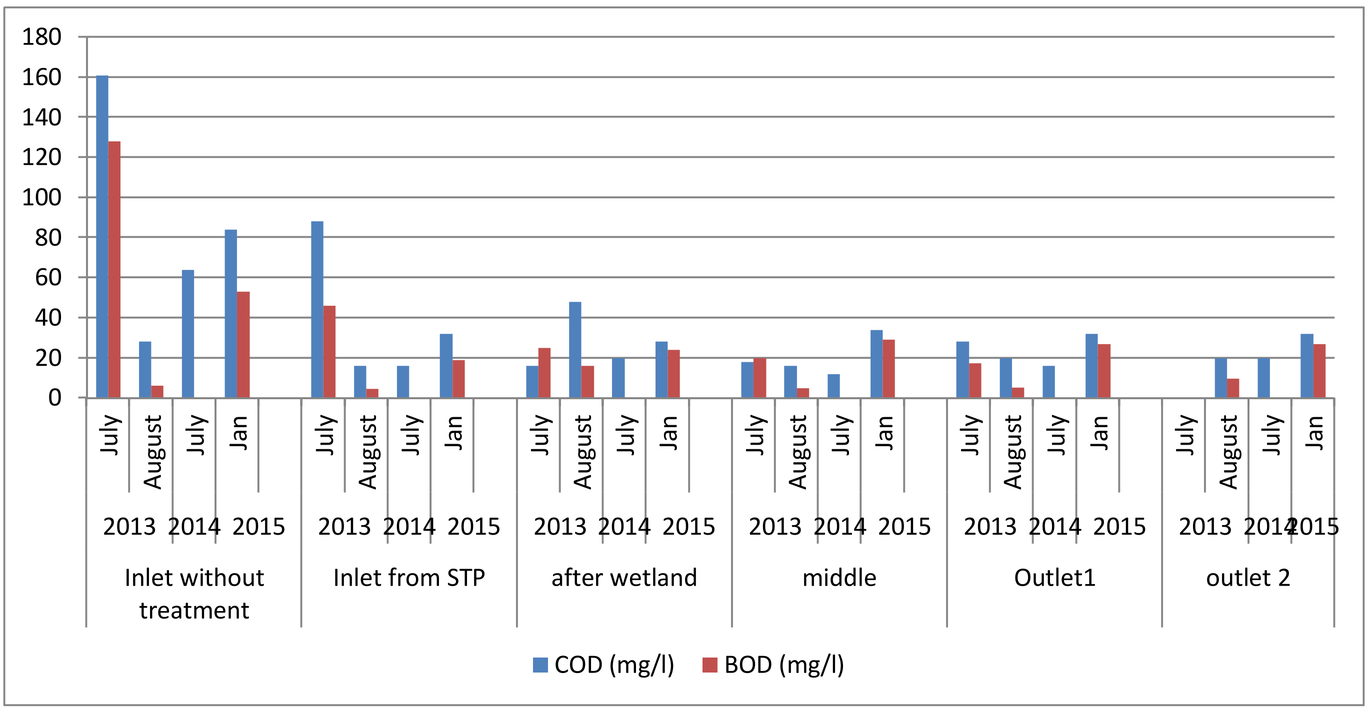


Figure 3: Comparison of COD and BOD in the lake across time period

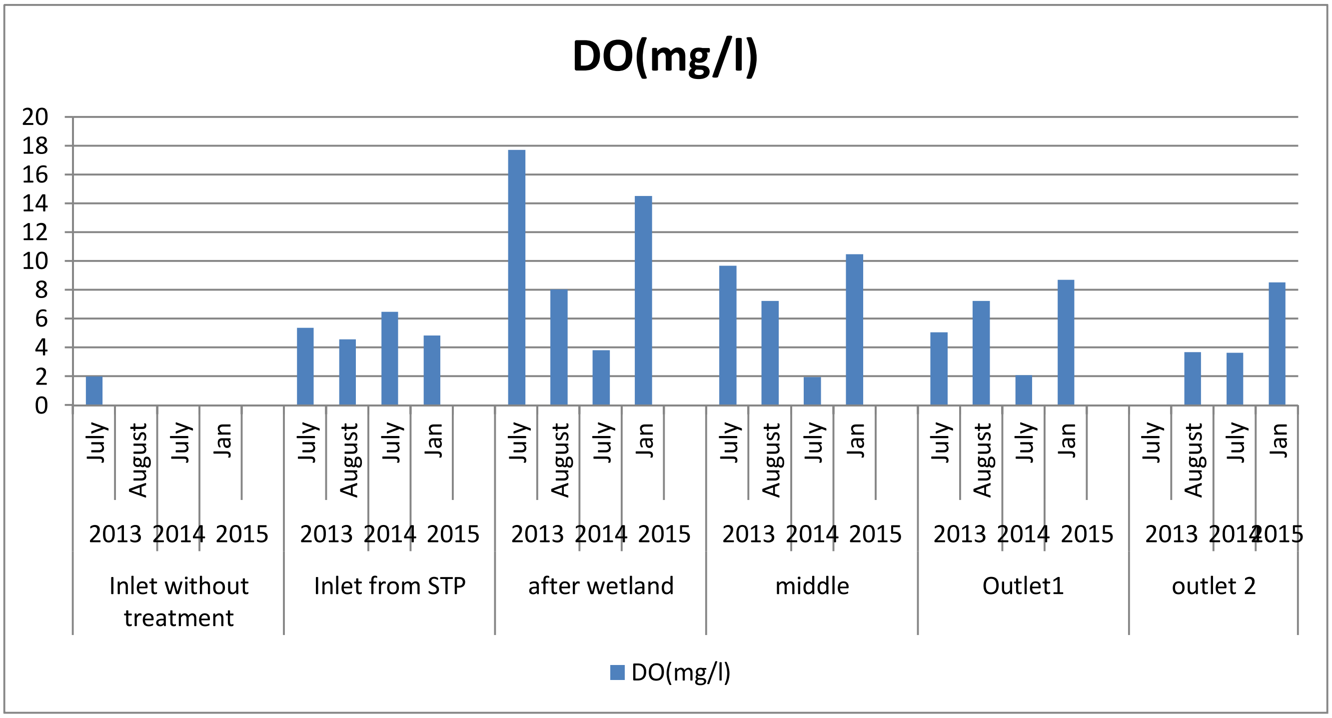


Figure 4: Comparison of DO in the lake across time period

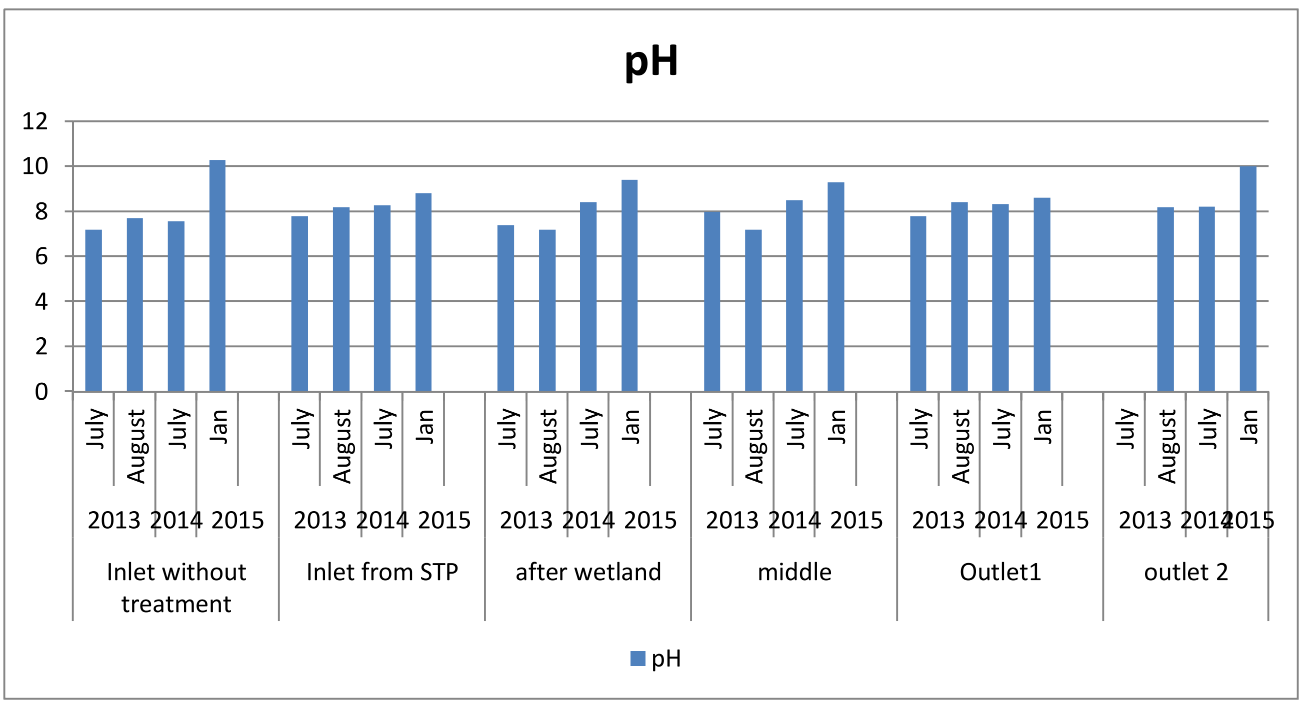


Figure 5: Comparison of pH in the lake across time period

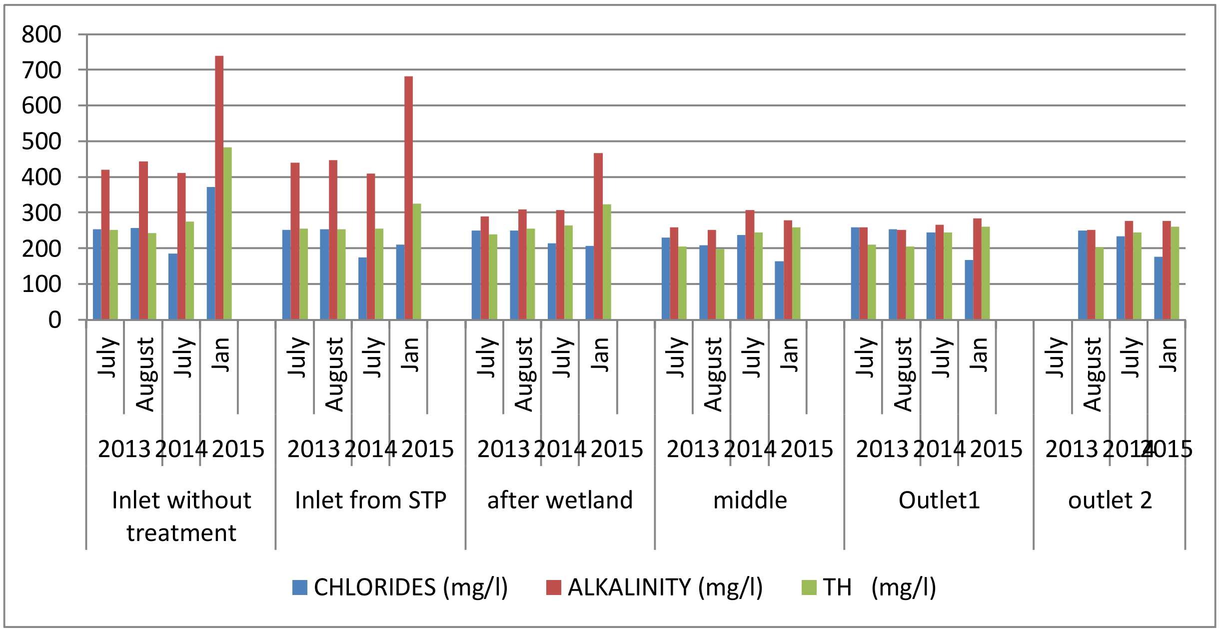


Figure 6: Comparison of chlorides, alkalinity and total hardnessin the lake across time period

MACROPHYTE DIVERSITY: Macrophytes, the aquatic macroscopic plants confine themselves to the shallow euphotic zone of the water bodies. In the littoral zone, macrophytes are the chief exploiters of plant nutrients from the sediments, which otherwise, are lost temporarily from the water. The nutrients so logged in the body material are released only after death, decay and subsequent mineralization, thus, they play a role in nutrient dynamics and primary productivity of shallow systems. Therefore, seasonal growth rate patterns and population dynamics of macrophytes are very important. Macrophytes grow profusely when there is enough room for colonization and abundant availability of nutrients,. They assimilate nutrients directly into their tissues. The inlet, middle, outlet and shoreline portion of lake is covered by macrophytes. There were mainly 7 species found in the lake. *Alternanthera philoxeroides, Ludwigia perennis, Typha angustata, Cyperus* sp*, Lemna gibba, Eichhornia crassipes (water hyacinth), Pistia stratiotes* were the main macrophyte species found in the lake (Figure 7). *Alternanthera philoxeroides s*and *Eichhornia crassipes* were the dominant macrophytes present in the lake. These indicate high amount of nutrient and other pollution load in the lake.Water hyacinth wide spread occurrence in the fresh water lakes is harmful to fishing (depleting DO) depleting water content from the water bodies and interfering in water utilization and other activities. Water hyacinth by its abundance of leaves, dense vegetation and innumerable rootlets in tertiary manner obstruct water flow and displaces many other macrophytes, and suppresses the phytoplankton growth.

Algal specie found in the lake: During our earlier studies (Ramachandraet.al, 2013) there was a good diversity of algae (64 species) found in the lake. During this study the lake was dominated by *Spirulina spp* (figure 8).

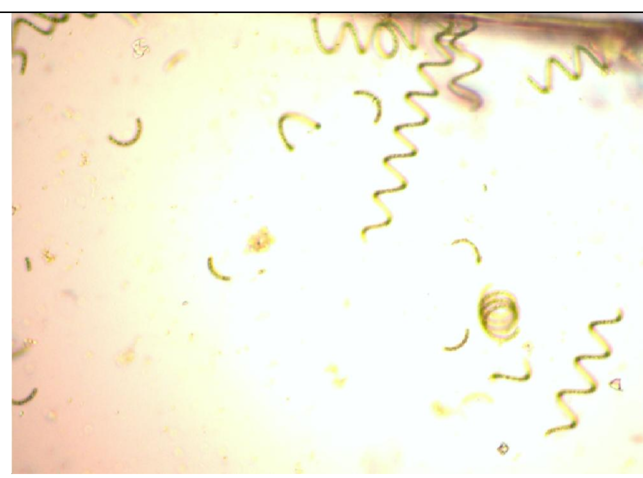
Figure 7: Macrophyte found in Jakkur lake

Alternanthera philoxeroides

Ludwigia perennis

***Typha angustata* in inlet**

Water hyacinth and Pistia in the middle

Treated (in channel) and untreated sewage water entering the lake	**Untreated sewage inlet**
	
Died and decaying macrophytes and algae in the shoreline of lake	***Cyperus sp* in the inlet of lake**
	
Thick algal growth in the middle of lake	**Macrophyte cover in the outlet of lake**
	
Figure 8: Algae (*Spirulina spp*) found in Jakkur lake	

Conservation and Management of Wetlands: The loss of ecologically sensitive wetlands is due to the uncoordinated pattern of urban growth happening in Greater Bangalore. This could be attributed to a 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 dangerous effects of climate change** is an integral part of protecting freshwater resources and ecosystems.

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). Policy interventions required in order to conserve fragile ecosystems – wetlands are:

1. **Carrying capacity studies for all macro cities:** to adopt holistic approaches in regional planning considering all components (ecology, economic, social aspects) in rapidly urbanizing macro cities such as Greater Bangalore, etc.
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. The buffer zone should be treated as inviolable in the long-term interests of the water body and its biodiversity. This requires
    - Digitisation of all land parcels (especially common lands) with clear title of ownership and availability of this information through well managed portal (with regular updating of details). This would help in curtailing unauthorised occupation of common lands.
    - 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, lakebed for any other purposes.
- Urban wetlands, mostly lakes, have 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, 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.
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). There is a need to maintain catchment integrity to ensure lakes are perennial and maintain at least 33% land cover should be under natural Vegetation.
5. **Documentation of biodiversity:** The biodiversity of every water body should form part of the School, College, People's Biodiversity Registers (SBR, CBR, and 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.
6. **Mitigation of Floods**: This entails maintenance of open spaces (vegetation, water bodies). Mitigation necessitates restoration of wetlands, removal of blockages in the drainage network, removal of encroachments (storm water drains, wetlands), prevention of indiscriminate disposal of solid waste (including building debris) in storm water drains, lake beds, catchment of wetlands and restoration of the connectivity of lakes
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.
8. **Implementation of sanitation facilities:** It was noted with concern that the water bodies in most of India are badly polluted with sewage, coliform bacteria, and various other pathogens.
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.

10. **Protection of riparian and buffer zone vegetation:** Any clearances of riparian vegetation (alongside lakes) and buffer zone vegetation (around lakes) have to be prohibited.
11. **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.
12. **Rainwater harvesting:** Intensive and comprehensive implementation of rainwater harvesting techniques can reduce taxation of water bodies and 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.
13. **Environment Education**: Lake Associations and citizen monitoring groups have proved helpful in educating the public. Effort should be made to ensure that such groups have accurate information about the causes of lake degradation and various restoration methods.

CONCLUSION

It was observed that both treated and high amount of untreated sewage water was entering into the lake. Nutrient availability in Jakkur lake water was high which was evident from the results of physico-chemical analysis, the presence of fully covered varied macrophyte species and algal species. Hence, the light penetration is obstructed and dissolved oxygen (DO) level is depleted in the lake. This led to the death of fishes in lake. Compared to the earlier studies the nutrients (N and P) in the water increased around 5 times. The overall water quality was also found to be bad than earlier.

Fish mortality in Jakkur Lake: Recent episodes of fish mortality in Jakkur lake is due to a sudden and considerable fall in dissolved oxygen (DO) levels resulting in asphyxiation in some locations caused by sustained inflow of large quantum of sewage let into the lake (through illegal diversions by local civil contractors). It is not due to any kind of infection because none of the fishes showed any signs of disease symptoms.

RECOMMENDATIONS:

- Penalize polluters as per "Polluter pays principle"
- Restrict the nutrient discharge into the lake;
- Allow only treated water into the lake;
- Maintain macrophytes through regular harvesting and restrict the region infested with weeds

To control the growth of algae dominated by *spirulina spp* the following fish species should be introduced into the lake

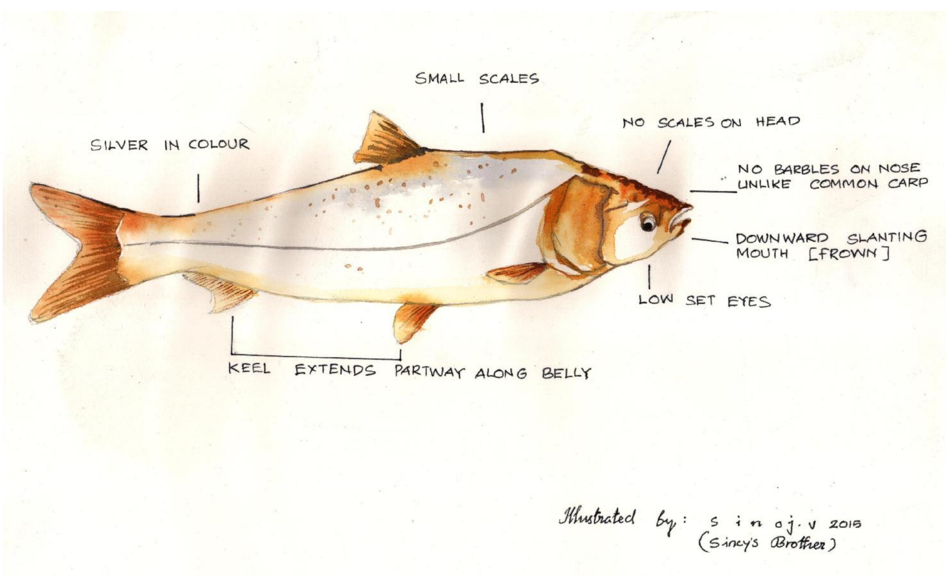
- Silver carp (*Hypophthalmichthys molitrix*) Exotic carp
- Sandkhol- (*Thinnichthys sandkhol*) Local carp
- Bighead carp (*Aristichthys nobilis*) Exotic carp

Silver Carp, Bighead carp and Sandkhol Carps are introduced to fresh water systems because of their ability to decrease phytoplankton (algae) density although zooplanktons are preferred food.

Hypophthalmic molitrix (**Common Name:** Silver Carp)

Silver carp belongs to the family Cyprinidae (the minnow and carp family). The genus name, *Hypophthalmic* is a Greek word ("hypo" means "under"; "ophthalmos" means "eye" and "ichthys" meaning "fish"). The silver carp was first named by Valenciennes in 1844.

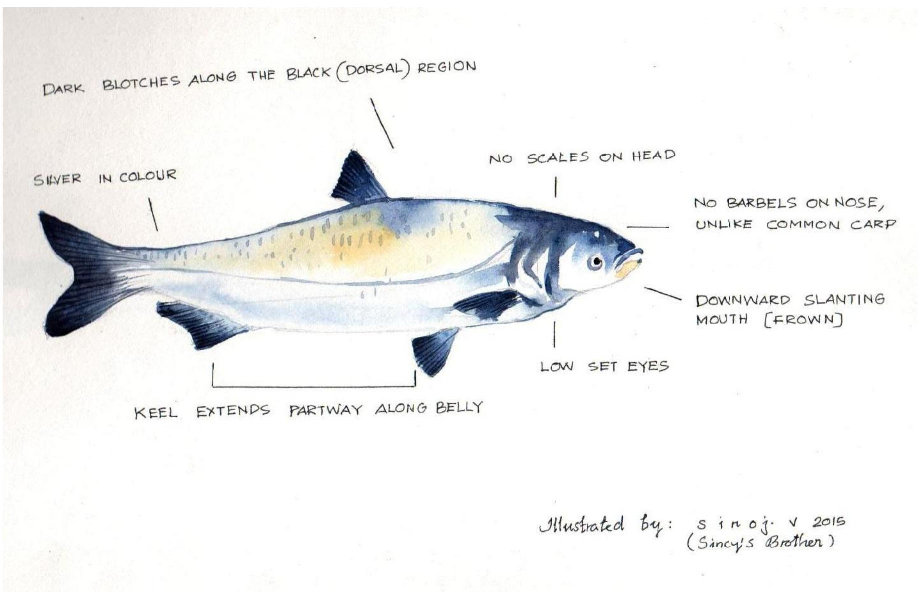
The silver carp is a deep-bodied fish, laterally compressed. They are silvery in color when young and as they become older they fade from a greenish color on the back to silver on the belly. They have very tiny scales on their body, the head and gill area are scale-less. They have a large mouth, but toothless (has pharyngeal teeth) with upturned lower jaw. Its eyes are forward that sits below the mouth and project downward. Silver carp can grow to over three feet in length and to nearly 100 pounds.



Sliver carp are filter feeders that eat phytoplankton, zooplankton, bacteria, detritus and they graze on aquatic vegetation. They live in freshwaters that are standing or slow flowing. They breed at the age of 3 years to 10 years. The spawning occurs anytime between April and September when the temperature is between 18-20 degrees Celsius.

Aristichthys nobilis (Richardson 1845) **[Common Name:** Bighead Carp, Belli-gende (India)]

Bighead Carp belongs to the family Cyprinidae. Big head carps are dark green to olive in color on their backs. They have gray to silvery sides, with a white to cream colored belly. The scales are very tiny, and the eyes are set below the midline of the body. The body of a big head carp is long and compressed. The head is very large compared to the body, so its name, the big head carp. Its head has no scales, a large mouth with no teeth, and a protruding lower jaw. The bighead carp has a smooth keel between the anal and pelvic fins that does not extend anterior of the base of the pelvic fins. They can weigh from 25-50 kg. Big head carp can be up to 1.5 meters long. The big head carp have long and comb-like gill rakers,

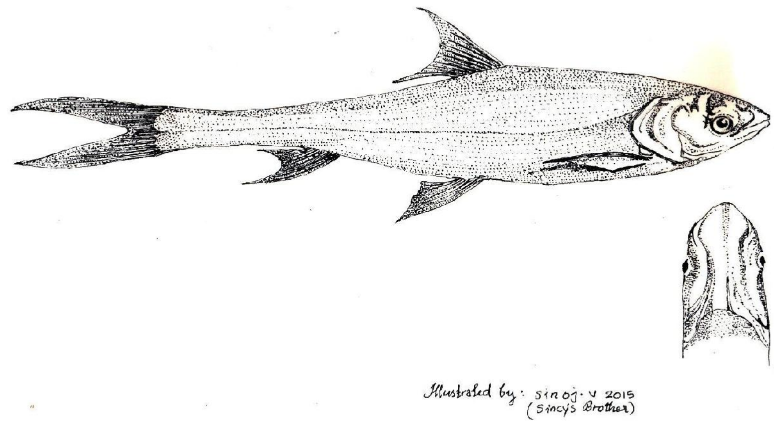


Bighead carp can tolerate salinities in the range of 6-12 parts per thousand. The preferred temperature for reproduction is about 25ºC, the maximum temperature in which bighead carp can survive is 38 ºC. Bighead carp can also survive temperatures down to nearly freezing, on the order of 1ºC. Bighead carps are found in large rivers, smaller rivers and streams, as well as lakes and ponds. Bighead carp can spawn in moving water.

The silver carp is uniform in color whereas the bighead has irregular dark blotches on its back and sides. The silver carp has a sharply keeled belly from the anal fin to the throat, whereas the bighead carp has a keeled belly from approximately its pelvic fins to the anal fin.

Thynnichthys sandkhol (Sykes, 1839) [**Common Name:** Sandkhol Carp (English), Banga (Kannada), Sandkhol (Marathi)]

Thynnichthys sandkhol is a medium carp and resembles silver carp. It is a column-cum-surface feeder and is planktophagus. They have a nearly cylindrical body, dorsal fin of 12 rays, pectoral of 14 and ventral of 10 rays, gibbous head, eyes with whitish narrow irides. The dorsal in this fish is situated a little before the centre of the back. The fish attains sexual maturity in first year at 30cm in length and 500g in weight. It is a monsoon breeder and breeds only once a year. The fecundity of the fish is about 125,000/kg body weight. The fish grows very fast and it can grow to 0.9-1.4 kg in 9-12 months.



Sandkhol Carps are found in rivers and feeds on algae, protozoans, rotifers and crustaceans. They do not breed in ponds. They are cultivated in ponds in South India.

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