

Ranjeev Benjamin (1), B.K. Chakrapani (2), Kar Devashish (3),  
A.V. Nagarathna (4), and T.V. Ramachandra (5)

(1) University of Rochester, New York, USA.

(2) Zoology Department, Bangalore University, Bangalore, India.

(3) G.C. College, Assam University, Silchar, India.

(4) Biodiversity Unit, J. N. Centre for Advanced Scientific Research, Bangalore, India.

(5) Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India.

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### **Abstract:**

Large-scale episodal mortality among the freshwater fishes of certain lakes of Bangalore City, Karnataka State, India occurred in June 1995. We conducted an intensive study of the Sankey Lake which is situated in Sadashiva Nagar of Bangalore city where fish mortality occurred on quite a large scale during June - July 1995. These studies reveal that the fish-kill in Sankey Lake was due to a sudden and considerable fall in dissolved oxygen (DO) levels in some locations caused by sewage let into the lake resulting in asphyxiation. It was not due to any kind of infection because none of the fishes appeared to show any symptom of disease.

### **Introduction**

Rivers, lakes and wells are important sources of water in a region. Water is an essential component of an eco-system. It sustains life on earth. A community depends on water for its domestic, agriculture and industrial needs. Availability of water has been a factor in the development of various civilisations near lakes and rivers. At a particular stage in development, tanks and wells are introduced to harvest rain and ground water. Wells and tanks are the sources of water in most places even today. Tanks harvest rainwater and store it, while wells tap water stored underground.

The total water spread in India is about 4.5 million hectares. Inland aquaculture resources cover about 3 million hectares. These include about 0.72 million hectares of natural lakes and 2.0 million hectares of constructed reservoirs. The state of Karnataka has about 2000 perennial and about 30,000 seasonal tanks with a total water spread area of 3,000,000 hectares. The average annual fish yield from these tanks is estimated to be about 350 kg fish per hectare per year.

In June 1995, there was a large-scale episodal mortality among the freshwater fishes of certain lakes of Bangalore city in Karnataka state, India.. We conducted an intensive study of the Sankey Lake, which is situated in Sadashiva Nagar of Bangalore city, where fish mortality occurred on quite a large scale during June-July 1995. This episode follows immediately after fish deaths in Lalbag Lake, which is located about 12 kilometers away.

### **Lakes and Bangalore City**

Lakes and tanks are known to be the ecological barometers of the health of a city. They regulate the micro climate of any urban centre. Bangalore district has about 141 lakes. The government is spending millions for development of these lakes. Rapid urbanisation has lead to the loss of wetland habitat through encroachment, bad management, pollution from sewage, and waste and litter disposal activities. These factors have seriously affected the survival of tanks and lakes and have posed serious threat to the flora and fauna supported by them.

Sankey Lake is among the few lakes in the northern part of the city with continuous drains. It is also the main source of ground water to this part of Bangalore. It harbours a rich biodiversity which includes birds, fishes, aquatic plants and microbes. The presence of a biotically diverse and beautiful botanical garden and a forest nursery adjacent to the lake increases the ecological value. The Bangalore City Corporation is also developing a park at the north western end.

The 'Sankey Lake,' situated in the heart of Bangalore City (Lat.:13° 00'24" - 13° 00'41"N; Long.:77° 33'53" - 77° 34'5"E; altitude: 921 m MSL, maximum water spread area 12 ha, maximum depth 23 ft, average depth 9 ft), is a 500 year old, perennial water body and supports a significant biotic community. Since the beginning of 1982, drainage of industrial effluent and other domestic sewage into the lake has been stopped and the lake is expected to be free from noticeable pollution. Long-term studies on hydrology and microbial ecology, conducted during the last decade, have indicated that Sankey Lake has high potentiality for development of inland fisheries practices [1]. The average annual photosynthetic profile suggests the significance of the heterotrophic food chain in sustaining the higher trophic levels. With a mean fish production of 859 metric tonnes/year, the present fish production efficiency works out to 0.43 per cent. Since the lake is still mesotrophic and is amenable to management measures, a higher target fish production appears quite feasible [1, 2].

Sankey Lake was studied for its hydrobiological characteristics by many agencies like the Central Inland Fisheries Research Institute, the Central Institute of Freshwater Aquaculture, Bangalore University, University of Agricultural Sciences and the Indian Institute of Science from time to time but a comprehensive study was not carried out by these agencies covering all aspects of ecology [1,2,3,4]. This lake forms a nucleus for research investigations and an ideal breeding ground for commercially important fishes like *Etroplus suratensis*, Murrels (*Channa marulius*), Catfishes (*Heteropneustes fossilis*), small palaemonid prawns and the commercial variety, *Macrobrachium malcolmsonii*. This lake harbours *Tilapia* along with many other smaller fishes. In the past, the lake was stocked at times with small numbers of freshwater prawns (*Macrobrachium malcolmsonii*). The results were satisfactory, thus providing evidence of its potential for freshwater prawn culture as well.

Cage culture is the growing of fish in an enclosure of fish netting material, such as nylon, to monitor growth, productivity, and survival of different species like Catla, silver carp, common carp, *Tilapia* and Mrigal. In the first ever cage culture experiment (from fry to fingerlings stages) conducted in this lake for four months, common carp fry at a stocking density of 2.13 lakh/ha, showed a survival of 97.5% and 88.0% for silver carp. Cage culture (fingerlings to table size) of common carp, Catla has shown a production range of 92 to 225 t/ha with a survival rate from 80 to 100%. Experiments of cage culture with peninsular carps like *Labeo fimbriatus*, *L. calbasu* were also undertaken in this lake. Artificial breeding of the cage reared *L. calbasu* and common carp was also tried. A viable hybrid of common carp, *calbasu*, has been produced for the first time in this country from cage reared fishes of Sankey Lake [2].

Heavy washing of clothes by dhobis and continued entry of domestic sewage in some areas are posing pollution problems. Rapid growth of human population, proliferation of buildings, roads and vehicular traffic in Bangalore have taken a heavy toll of wetlands. Further, encroachment, disfiguring by brick/tile industries, waste disposal activities and bad management have threatened the very existence of many of the valuable and productive wetland habitats in the city, thereby posing serious threat to the flora and fauna supported by them. Although there is wide public concern about wise use of wetlands, lack of knowledge of the ecological conditions of these habitats has caused many losses. The loss of environmental benefits could be very crucial in a situation which the Bangalore city faces today [3,4,5]. Sankey Lake is the only wetland which has withstood the changes in the growth of Bangalore even though it is located in the heart of the city. As a result of human activity over the years,

accumulations of silt and clay have led to changes in the pattern of sediment-water exchange. Dissolved oxygen is not a limiting factor and thus the water has promoted the growth of 21 species of phytoplankton. Although, the human activity has resulted in the enrichment of nutrients in the sediment, their level in water still remains low due to poor exchange of nutrients in the sediment [2].

Comparison of plankton species made from three different studies during 1981-84, 1982 and 1989 indicated that both the phyto and zoo plankton species richness has been increasing over the years [1,3,4]. In the 1989 survey, though *Microcystis* was observed to be dominant among the phytoplankton species, an increased number of Myxophyceae forms is considered ecologically significant. A total number of 27 phytoplankton and 28 zooplankton species have been recorded from this lake. The 1989 survey [4] covering 97 sites listed 58 plankton and 55 zooplankton species for the Bangalore area. This means that nearly half the plankton species richness of Bangalore is found in this lake which is right in the heart of urban Bangalore. From the point of view of the lake waters, the progression in plankton species richness from 1981 to 1989 probably indicates an improving situation [2].

Nevertheless, this ancient lake which reflects the cultural heritage of the city, has an annual average photosynthetic value ranging from 0.81-1.42% and has a mean fish production level of 36.57 gm<sup>-2</sup> [1]. The important role of Sankey Lake needs to be highlighted, which has been maintaining the ground water level in the surrounding areas, that includes Malleswaram, Palace Orchards, Rajamahal Vilas, Vyalikaval, Palace Gutthalli and Yeshwantpur. Careful observation of the lake morphology, hydrodynamics and sedimentation, show that the water from Sankey Lake that seeps through the soil is not lost but recharges the natural underground reservoir which in turn supplies water to wells and bore wells in all the areas mentioned [1,2,3]. This lake has great fish potential, supports human environmental needs and contributes to climatic stability. Thus the multiple contribution of the Sankey Lake to the city's economy through ground water recharge and the ecological role of the tanks needs to be recognized.

## Literature review

Water quality, habitat structure, flow regime, energy source and biotic interactions are the major environmental factors that determine water resource integrity [6]. The physical and chemical attributes of water are the critical components of a water resource. They include temperature, dissolved oxygen, pH, hardness, turbidity, concentration of soluble and insoluble organic and inorganic, alkalinity, nutrients, heavy metals, and an array of toxic substances which may have simple chemical properties or their dynamics may be complex and changing, depending upon other constituents in the geological strata, soils, and land use in the region [7]. The human effects on biological processes can result in mortality or may shift balance among species as a result of subtle effects, such as reduced reproductive rates or changing competitive ability.

Both fresh and salt water also form the habitats for innumerable organisms, such as seaweed, shellfish, crabs and other marine life that are components of human nutrition. In Europe and North America, impaired health and reproductive disorders were observed in aquatic animals and animal species that derive their sustenance from the water [8]. The causes were discovered to be contaminants in the water, such as organochlorines, e.g., DDT and other insecticides, and organic heavy metal compounds, e.g. methylmercury, which had been assimilated by the animals via their skin and respiratory systems or through food chains with associated concentration (biomagnification). Methylmercury compounds are considerably more toxic than elementary mercury and its inorganic salts. Human exposure to methylmercury comes exclusively from consumption of fish and fish products and prenatal life is more susceptible to brain damage than adults [9]. Nonetheless, these discoveries represented only the beginning; a large number of other contaminants were subsequently diagnosed and their dispersal paths identified.

In addition to restrictions in the utilization of water bodies as sources of drinking water, or other uses, contamination of fresh water and marine water can also have a multitude of indirect deleterious effects on human beings such as disruption of community and traditional activity, economic and nutritional hardships. It is therefore of overriding importance to find and improve means of monitoring and evaluating water quality and pollution levels in order to remedy and/or prevent harm to human beings and their environment.

### **Means of Detecting Water Pollution**

Theoretically it would be impossible to keep all contaminants out of all water everywhere; even without human influences contamination of bodies of water has always occurred and will continue to occur. For example, we need only think of the compounds which can be formed in lakes under certain conditions, such as hydrogen sulphide (H<sub>2</sub>S), which causes most of the organisms within the affected zone to die off, or at the very least causing oxidophilic organisms to avoid such polluted aquatic environments. If there is excessive introduction of allochthonous organic matter and/or in-situ production of organic substances, hydrogen sulfide is formed, for instance on the bottom of lakes, when the oxygen content is no longer sufficient for mineralization of organic materials by aerobic processes. Studies of the earth's history have revealed that water pollution of this kind has often happened even without human beings playing a role, such as in situ bacterial conversion of inorganic mercury species to the methylmercury form [10-13]. The industrialized nations are also still burdened with problems of this sort as is illustrated by the example of the Rhine. The quality of the water flowing in the Rhine has improved since the report of the Council of Experts for Environmental Issues in the Federal Republic of Germany, but it is still far from satisfactory [14]. Heavy metal contamination of the river even now, seems to be increasing again after an earlier controlled downward trend. However, this fact does not relieve us of the dangers of water pollution and draws our attention to the means of detecting and avoiding such pollution [14-16]. This, of course, also necessitates the provision of training and technological know-how.

### **General review of assessment procedures**

It would go beyond the scope of this paper to present here an exhaustive discussion of all possibilities which are available for the use of bioindicators and biomonitors in aquatic ecosystems. Therefore for classification of water pollution we review the following methods. To begin with, however, a brief review of the different types of evaluative procedures is in order. These are:

1. Physical and chemical water analysis
2. Biological procedures based on the use of:
  - a) Bioindicators,
  - b) Biomonitors
3. Remote sensing

### **Physical and Chemical Water Analysis**

With the aid of physical and chemical analysis techniques, it is possible to obtain information on the condition of water at the place and time at which the samples are taken. Depending on the quality of the investigatory methods used and the number of parameters studied, some useful data are yielded on the quality of the water at that point in time. How accurate and detailed the results must depend upon the purposes for which analyses are performed. In order to obtain more precise data, repeated analyses are necessary; these can even be aimed at identifying changes during the course of a single day [8]. A number of parameters are measured, including the presence of the amount of organic carbon, ammonium, nitrate, orthophosphate and oxygen, as well as the biochemical oxygen demand (BOD). By

means of additional tests, it is also possible to obtain additional information on the concentration of toxic substances. As is to be expected, continuous taking of samples and performance of analyses are associated with high technical, financial and labour inputs. The costs incurred grow with the number of samples taken and the range of substances which are tested for. Even the industrialized countries can only afford to do this within certain limits. Nevertheless, within the scope of major technical projects, it would be useful to carry out similar sample-taking and analysis programs at various locations for monitoring purposes. This would have to be specifically decided upon with respect to each individual case [6,7,8,9].

When evaluating water pollution with the aid of bioindicators, an understanding of an organism's reaction to changes in its environment is essential. These reactions can take the form of growth and/or increased population density, modified activity, reduced growth, a decline in population, or even death. Depending on their degree of complexity, size, generation time and other factors, organisms and different species react at varying rates. Most bacteria adapt very quickly to environmental changes. Protozoa and algae take longer, and insects - many of which live for a year or longer as larvae in the same aquatic environment - require longer periods to react to changes in their surroundings. As a rule, organisms with longer generation times respond more quickly to negative changes -if they exceed the limits of what is tolerable - for example by migrating to zones with satisfactory living conditions or by dying. Depending upon the time which bioindicators or indicator organisms spend in a body of water, they are subjected to the prevailing environmental conditions and any changes that occur. Thus, members of a related group of organisms or a biological community integrate and reflect environmental conditions and possible changes over an extended period of time. Consequently, critical evaluation of the species compositions of a biocoenosis can yield sufficient data on the situation of a body of water and the range of fluctuations in the environment over a lengthy period of time.

### **Remote Sensing**

Aerial photography can yield qualitative and quantitative information on changes in environmental conditions. Remote sensing can be used to provide information on the environment at a wide range of scale. At local scales it can be used to study a small area in considerable spatial detail. Spatial resolution data sets provide valuable data on the environment especially in the context of changes. The studies of this type which have been performed on the expansion of dry regions (examples: Sahara, Sahel) are well known [17-24]. Changes in the condition of large bodies of water can be detected in the same way. Studies in South India [25] have shown that satellite remote sensing techniques can provide reliable and objective data on water quality, agriculture productivity and related water management aspects.

### **Methods**

Water, fish and soil samples were collected from the Sankey Lake for six consecutive days at 12 various locations across the lake. Chemical analyses of soil, water and fish samples were carried out in various laboratories including the Zoology Department, Bangalore University, Regional Sophisticated Instrumentation Centre, North Eastern Hill University, Shillong (Meghalaya), G.C. College, Silchar (Assam) and Centre for Ecological Sciences, Indian Institute of Science, Bangalore.

### **Results and Discussion**

This study revealed that large scale mortality has occurred among fish species like *Eutroplus suratensis*, *Chanda ranga*, *Puntius sp.*, *Nandus nandus* and *Amblypharyngodon mola*. Investigations into the limnological parameters revealed not much deviation from the usual values for this region with water temperature 28°C, water transparency 31 cm, free carbon di-oxide (FCO<sub>2</sub>) generally absent, water ph 7.683 (avg: average) and 0.570 (Sd: standard deviation), water conductivity 0.397 (avg) and 0.07 (Sd)

milli mhos/cm. However, dissolved oxygen (DO) was recorded, very low at 2.6 and an average of 3.025 (Sd:0.076) mg/lit during the period of fish-kill. Estimation of nitrite and nitrate revealed 0.229 (avg) and 0.054 (Sd) and 1.374 (avg) and 0.477 (Sd) mg/lit; Phosphorous was 7.055 (avg) and 2.925 (Sd) mg/lit.

Analysis of the bottom soil revealed medium acidic pH (5.90), normal conductivity (0.07 milli mhos/cm), low available phosphorus (3.068 kg/acre) and low available potassium (17.5 kg/acre). There had not been any prolific growth of aquatic macrophytes in the lake and plankton density was also usual during the period of fish mortality. Estimation of trace elements through atomic absorption spectrophotometry revealed a low quantity of lead and cadmium in both water and soil, mercury was not detected. The results of chemical analyses shows that, in water lead quantity was 0.47 ppm and cadmium 0.04 ppm and in soil lead content was 0.55 ppm and cadmium 0.05 ppm.

These studies reveal that the fish-kill in Sankey Lake was due to sudden and considerable fall in DO levels in some locations (due to sewage let into the lake) resulting in asphyxiation and was not due to any kind of infection because none of the fishes showed any symptom of disease. Steps are to be taken for the conservation of this biotope, which not only provides a recreational spot for the tourists, but has also been serving as one of the potential sites for stocking, hybridisation and cage culture of the Indian major carps.

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### References

- [1] Ayyappan, S. 1987. Investigations on the limnology and microbial ecology of a lentic habitat. Ph.D. diss., Bangalore University.
- [2] Centre for Science and Technology. 1992. Sankey Lake: conference proceedings on Bangalore Lakes, Bangalore.
- [3] Chakrapani, B.K. 1989. Ecology and dynamics of plankton in lentic habitat. Ph.D. diss., Bangalore University.
- [4] Chakrapani, B.K. et al. 1990. Survey of irrigation tanks as wetland bird habitats in the Bangalore area, India. Report by bird watchers' field club of Bangalore.
- [5] Laxman Rao, N. 1986. Report of the expert committee constituted by the Government for submitting the proposals for preservation, restoration of the existing tanks in the Bangalore metropolitan area.
- [6] Karr, J.R. 1991. "Biological integrity: a long neglected aspect of water resource management." *Ecological Applications* 1: 66-84.
- [7] EPA. 1990. Biological criteria: national program guidelines for surface waters. EPA-440/5-90-004, Off. Water, Washington, DC.
- [8] Ellenberg, H. 1988. "Bioindicator and bioindication." *Angewandte Okologie*, Vol 1, Stuttgart: Fisher, 226-262.
- [9] Fitzgerald, W.F. and Clarkson, T.W. 1991. "Mercury and monomethyl mercury: present and future concerns." *Environmental Health Perspectives* 96: 159-166.
- [10] Gilmour, C.C. and Henry, E.A., 1991. "Mercury methylation in aquatic system affected by acid

deposition." *Environmental Pollution* 71: 131-170.

[11] Rolfhus, K.R., and Fitzgerald, W.F. 1994. "Linkages between atmospheric mercury deposition and the methylmercury content of marine fish." *Journal of Water, Air and Soil Pollution* 78: 234-237.

[12] Mason, R.P., and Fitzgerald, W.F. 1990. "Alkylmercury species in the equatorial Pacific." *Nature* 347: 457-459.

[13] Watras, C.J. et al., "Sources and fates of mercury and methylmercury in Wisconsin lakes." In *Mercury as a Global Pollutant: Towards Integration and Synthesis*, edited by C.J. Watras and J.W. Huckabee. Boca Raton, FL: Lewis Press, 1994.

[14] Ministerium Für Ernährung, Landwirtschaft und Forsten Baden-Württemberg (Ed.), 1985/86. *Gütezustand der Gewässer in Baden-Württemberg*. Stuttgart: Fricke.

[15] Geller, W., 1984. A toxicity warning monitor using the weakly electric fish *Gnathonemus petersi*. *Water Research* 18: 1285-1290.

[16] Besch, W.-K. and Scharf, B.W. "Wasseruntersuchungen mit Hilfe von Toxizitätstests." In *Limnologie für die Praxis. Grundlagen des Gewässerschutzes*, edited by W.K. Besch et al. Landsberg: Ecomed, 1985.

[17] Allan, J.A. "The role and future of remote sensing." In *Satellite Remote Sensing: Review and Preview*. Reading, UK: Remote Sensing Society, 1984.

[18] Allan, T.D., 1992. "The marine environment." *International Journal of Remote Sensing*, 13: 1271-76.

[19] NASA, 1988. *Earth system science: a closer view*, Report of the Earth System Sciences Committee, NASA Advisory Council, NASA, Washington DC

[20] Waring, R.H. et al. 1986. "Precursors of change in terrestrial ecosystems." *BioScience*, 36: 433-8.

[21] Woodcock, C.E., Strahler, A.H., 1987. "The factor of scale in remote sensing." *Remote Sensing of Environment*, 21: 311-32.

[22] Berman, H., De Wit, C.T., 1983. "Rangeland productivity and exploitation in the Sahel." *Science*, 221: 1341-7.

[23] Prince, S.D., Tucker, C.J., 1986. "Satellite remote sensing of rangelands in Botswana II: NOAA AVHRR and herbaceous vegetation." *International Journal of Remote Sensing*, 7: 1555-70.

[24] Prince, S.D., 1991. "Satellite remote sensing of primary production: comparison of results for Sahelian grasslands 1981-1988." *International Journal of Remote Sensing*, 12: 1301-11.

[25] Narayan, L.R.A., 1996, "Remote Sensing for managing water resources." *The Hindu (Weekly)*, May 26, p. 8.

*Mr. Ranjeev Benjamin <[rb0056@uhura.cc.rochester.edu](mailto:rb0056@uhura.cc.rochester.edu)>, Chemical Engineering Department, University of Rochester, New York 14627, USA.*

*Dr. Chakrapani <[energy@ces.iisc.ernet.in](mailto:energy@ces.iisc.ernet.in)> Zoology Department, Bangalore University, Jnana Bharathi Campus, Bangalore 560 056, India.*

*Dr. Devashish Kar <[dks@ces.iisc.ernet.in](mailto:dks@ces.iisc.ernet.in)> Environmental Sciences, G.C. College, Assam University, Public School Road Silchar 5, Assam, India.*

*Dr. A.V. Nagarathna <[avn@ces.iisc.ernet.in](mailto:avn@ces.iisc.ernet.in)>, <[ratna@ces.iisc.ernet.in](mailto:ratna@ces.iisc.ernet.in)> Biodiversity Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur Post Office, Jakkur, Bangalore 560 064, India.*

*Dr. T.V. Ramachandra <[cestvr@ces.iisc.ernet.in](mailto:cestvr@ces.iisc.ernet.in)>, <[cestvr@hamsadvani.serc.iisc.ernet.in](mailto:cestvr@hamsadvani.serc.iisc.ernet.in)> Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, India.*

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