AQUATIC ECOSYSTEMS

Conservation, Restoration and Management

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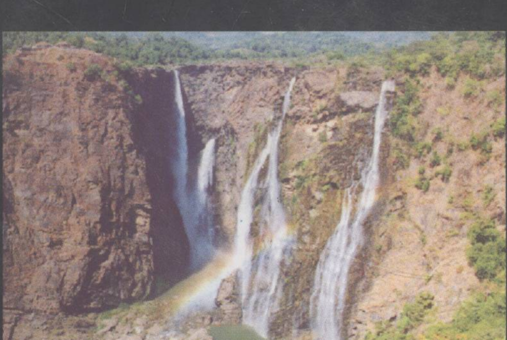

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Editors' Note

Aquatic ecosystems perform numerous valuable environmental functions. They recycle nutrients, purify water, recharge ground water, augment and maintain stream flow, and provide habitat for a wide variety of flora and fauna and recreation for people. A rapid population increase accompanied by unplanned developmental works has led to the pollution of surface waters due to residential, agricultural, commercial and industrial wastes/effluents and decline in the number of waterbodies. Increased demands for drainage of wetlands have been accommodated by channelisation, resulting in further loss of stream habitat, which has led to aquatic organisms becoming extinct or imperiled in increasing numbers and to the impairment of many beneficial uses of water, including drinking, swimming and fishing. Various anthropogenic activities have altered the physical, chemical and biological processes within aquatic ecosystems. An integrated and accelerated effort towards environmental restoration and preservation is needed to stop further degradation of these fragile ecosystems. Failure to restore these ecosystems will result in sharply increased environmental costs later, in the extinction of species or ecosystem types, and in permanent ecological damage.

Conservation, Restoration and Management is viewed in watershed context. Abatement of eutrophication, siltation and contaminant problems are more effective when inputs are controlled. Reduction of inputs enhances the long-term effectiveness of in-lake approaches. The watershed is the natural scale for restoration and would be self sustaining. Effective restoration can be achieved through collaboration among scientists, economists, managers, policy makers and local people. The *Lake 2002* symposium on conservation, restoration and management of aquatic ecosystems has enabled planners, scientists, administrators and NGO's concerned with watershed development in the region to discuss the various aspects involved in the management of wetlands. This has enabled better understanding of the hydrology, water and land resource development programmes and monitoring of their performance for sustainable development.

In this context, Lake 2002 a five-day symposium was organized to bring out the current trends in aquatic ecosystem conservation, restoration and management including the hydrological and the biophysical aspects, people's participation and the role of non-governmental, educational and the governmental organisations and future research needs for the restoration, conservation and management. This provided a forum for researchers, technologists, economists, sociologists and others to meet and discuss water related issues.

The five-day symposium (December 9-13, 2002), Lake 2002 had five plenary sessions with nine key note speakers. The key note speakers included eminent scientists from India and abroad, who touched upon various themes ranging from basics of limnology to application of remote sensing in the study of lake ecosystems.

Jack Vallentyne discusses the principles of modern limnology covering the physical, chemical and biological properties of a lake ecosystem. He describes the role of basic factors like temperature, depth, mixing, metabolism etc. occurring in the lake ecosystem. These principles are applicable to any lake ecosystem in the world.

T.V. Ramachandra discusses the restoration, conservation and management of aquatic ecosystems in detail highlighting the status of global, Indian and Karnataka aquatic ecosystems. The paper emphasises the need for watershed based approach towards aquatic resource conservation and management. The advantages of the use of GIS and remote sensing in conservation and restoration of aquatic ecosystems were outlined. Finally, the paper discusses policy options for integrated aquatic ecosystem management.

Rao and Murthy discuss the physical limnology of lakes and reservoirs that are relevant to water quality and sustainable management of small and large lakes. They stress the need for the knowledge of water movements as the circulation influences the distribution of dissolved substances, nutrients, microorganisms and plankton.

Shankar Hosmani describes how biological indicators can be used to show the degree of ecological imbalance that has occurred as against the chemical methods that measure the concentration of pollutants. The advantages of the biological indicators like Saprobic index, Nygaard's index, Palmer's algal pollution index, Biological index of pollution, Inhibition threshold for dehydrogenase activity, Colilert defined substrate test and H_2S strip test are enumerated.

Madhyastha presents reservoirs as a multipurpose ecosystem. The role of drainage basin of the reservoir plays a prime role in the ecology, economy and aging process of the water body. The paper highlights how the management of lotic waters into lentic ecosystem has become the necessity to mankind's endeavour to have better quality of life. Thus a proper understanding of the ecological characteristics and ecosystem functioning are of paramount importance before any massive resource enhancement and fishery development activities are undertaken.

Girija Jayaraman deals with the numerical simulation of seasonal circulation in the Chilika lake. The theoretical formulation in the study leads to a vertically non-linear model, which includes the effects of wind in two different seasons on the circulation of the lake. The model is capable of accurate simulation of tidal elevations throughout the lake. The physicobiological model developed in the present study can be used to study the distribution of nutrients and chlorophyll in the lake.

Devashish Kar addresses the fish genetic resources and habitat diversity of the Barak drainage, Mizoram and Tripura with an emphasis on the conservation of endangered species. The fish genetic resource survey conducted since 2000 in the river Barak, Assam and its tributaries revealed the occurrence of 103 species of fish belonging to 60 genera, 24 families and 10 orders. The author also discusses the need to conserve the fish diversity in the region.

Peeter Nõges outlines the implications of global expansion of the nuisance alga *Gonyostomum semen*. The distribution of *G. semen* in Estonian lakes along with their ecological requirements, seasonal dynamics and vertical distribution is detailed in the present paper.

Tiina Nõges enumerates the consequences of catchment processes and climatic changes on the ecological status of two large shallow temperate lakes of Estonia namely Peipsi and Võrtsjärv. The factors such as changes in riverine discharges, changes of river water chemistry, changes of nutrient loading and the consequences of changes in nutrient loading on the phytoplankton and consequences of global climate change on the water level and state of the ecosystem in the lakes of Estonia are discussed in detail.

The management of non-point organic and inorganic pollution of water bodies using bioreactors was discussed by Vinutha Devi et al.

Sanil Kumar and John Thomas discuss the macrophytes of Muriyad wetlands and their ecological role in fishing and rice cultivation. Continuing on the same lines, John Thomas et al. elaborate on the impacts of developmental activities on the ecology and fish diversity of 987 Muriyad wetlands.

G.J. Chakrapani has studied the geochemical status of lake waters in Kumaun Himalayas. According to him, the predominant concentration of calcium, magnesium and bicarbonate ions in the lake water is due to the carbonate lithology of the region.

Muralidharan et al. discuss the accumulation of heavy metals in the fishes of high altitude lakes of Nilgiris district. The study has also investigated the daily dietary intake of the metals by humans through fishes and compared with the guidelines stipulated by WHO for human safety.

K. Sampath has carried out a study on the ecological changes of the 433 irrigation tanks in Tiruvannamalai and compared it with the results obtained 10 years back. The comparative study showed reduction in the density of bird species due to various anthropogenic activities. The hydrographic characteristics, vegetation coverage, water quality and circulation patterns of Chilka lagoon during pre- and post-mouth opening conditions were studied by Mohanty et al. using remote sensing and concomitant field observations.

Vasudeva et al. have studied the breeding structure, assessed the genetic structure using isozyme and RAPD markers and evaluated the recovery of a critically endangered fresh water swamp tree species viz., *Semecarpus kathalekanensis* of western Ghats. Rakesh Kumar et al. outline the use of Phytophil technology for wetland restoration and management. Pandey and Mishra elaborate on the phytoxicity of allelochemicals on aquatic weeds with special emphasis on their use in the conservation, restoration and management of aquatic ecosystems. The potential of biotechnological application of jute geotextiles to protect the sea-shore of Andaman islands is discussed by Majumadar and Bhattacharyya. Vidyanath Jha outlines the strategies for sustainable management of biotic resources in the wetlands of north Bihar. Sahoo et al. discuss the option of sea-weed (marine algae) cultivation for sustainable management of the Chilika lake.

Thus, Lake 2002 was a platform for all stakeholders especially researchers, scientists, government agencies, teachers, students, planners and decision makers who interacted and shared experiences and knowledge on wetlands and lakes. We firmly believe recommendations by this august body will lay a strong foundation for watershed restoration efforts in the days to come. We thank all active participants for their views, suggestions, ideas, dialogues, and arguments, which contributed to the success of Lake 2002. Posters and papers presented by the participants will go a long way in establishing a better future for these fragile ecosystems and their sustainable management.

We thank the students and staff of the Energy and Wetlands Research Group, Centre for Ecological Sciences for their wholehearted support and involvement in organizing the symposium. All efforts have been taken to ensure this publication is free of any error. Editors are responsible for all errors and omissions that remain.

T.V. Ramachandra, N. Ahalya and
C. Rajasekara Murthy

Lakes of Bangalore: A Peep into History

S.V. Subramanyam

Lakebeds and riverbeds have been the preferred sites of human settlement for a long time. This has been true in the Indian peninsula also. The Indus civilization, Gangetic settlement, settlements on the Cauvery, Krishna basins are examples of the same. The historical background of Bangalore also has a similar connection. The Mysore Archeological Report of 1914-15 makes a reference to a stone tablet found in Nageswara temple, near Begur tank 10 km south of Bangalore. On this tablet is a reference to Bangalore Kale. The further history of Bangalore is closely associated with Kempegowda of 16th century who built the Kempambudhi tank as a mark of worship of his family deity, Kempamma. He also built the Dharmambudhi tank to pursue 'Dharma' and the Sampangi tank to provide drinking water. This tankbed is the present Sampangiramanagar where the Ulsoor gate is located. The Siddikatte tank too was constructed which is the present city market area and the Karanjikere to provide drinking water.

Around 1867, Bowring, the British Commissioner, built the Miller tank in the cantonment area, the Shoolay tank where the present football stadium exists, and the Ulsoor tank. The Chief Engineer of Bangalore Sankey was responsible for the Sankey tank. In 1892, Seshadri Iyer, the Dewan of Mysore realised the acute water requirements of the growing Bangalore population and built a dam for the Arkavathi River to house the Hesarghatta Lake. In 1930's Sir M.Visweswaraya Committee of the Maharaja of Mysore, Sri Krishna Devaraja Wodeyar, executed a plan to construct the Thippagondanahalli tank.

A large number of tanks existed in and around Bangalore. The names of the many extensions have been a testimony to the lakes of the earlier era. The Channammanakere Achkattu, Leggere, Abbigere, Konanakunte, Mathikere, Kargunte, Sarakki kere, Tavarekere, Agasanakere, Mavalli tank area are examples of these (kere, kunte in Kannada language means tank). The N. Lakshmana Rau Committee in its report of 1985 lists about 127 lakes

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that existed in and around Bangalore. 14 lakes more were added to this list. But we can count on our fingertips the lakes that exist today.

The lakes today are an endangered species due to many reasons: (i) encroachment of the lake area for habitation, agriculture, reclamation, litigation, (ii) injection of sewerage like domestic, industrial and dumping of wastes, (iii) mud lifting and brick making industries, (iv) grazing and (v) stoppage of water inflow.

It is needless to point out the importance of lakes. The lakes are beneficial to human habitation in many ways: (i) hydrological factors — conservation of water, (ii) drinking water supply to the population, and (iii) temperature comforts. If we consider one sq. km of land area exposed to a day of sunlight, the temperature will raise by about 8°C. A similar area of concrete surface will see an increase of temperature of 12°C. But a water surface of the same area will see an increase of only 3°C. These changes are due to the differences in the heat absorption of land, concrete and water. The formation of hot zones in many of the urban environments is due to this factor. (iv) The supply of clean air is easier on a water bed. (v) The biotic environment such as fish, birds, fertilization need a larger water surface. All this discussion points out to the positive impact of lakes on human settlements. It is therefore necessary for us to nurture and preserve the lakes in urban environments not only for our pleasure but also for our survival.

Contents

Principles of Modern Limnology

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PART I: THE PHYSICAL BACKGROUND

It is with great interest that one scans the title' of Sir Douglas Mawson's paper (1950), "Occurrence of water in Lake Eyre, South Australia". It is an important title, because if we look at it out of context, it focuses attention on the fact that a lake is completely composed of water (The title actually refers to the presence of water in a formerly dry lake basin). It stresses that water should be the first study of the limnologist. Most often, however, it is the last, for the beginning student is more attracted to the diversity of aquatic life: the whirligig beetles, bottom living insects, fish and other fantastic forms of life.

The main point to be clear on is that water is not a single molecular substance. In the first place, it is a mixture of hydrogen and deuterium (to a lesser extent also tritium) isotopes in combination with isotopes of oxygen. However, this variable isotopic combination is not peculiar to water as a chemical entity for it is characteristic of most natural organic substances. The peculiar property is that water molecules (H_2O), by virtue of their dipolar nature, interact to form quasi-stable polymers. The nature of associations between water molecules is little understood, but the evidence for association can hardly be disputed [see Dorsey (1940) for a discussion of the subject]. The nature of the linkages varies with temperature and pressure in a complex fashion. As a result it is customary to find that water shows peculiar, non-linear relationships to changing physical conditions. Although there is no conclusive agreement, it would seem that the new equilibrium states of association are assumed instantaneously with change in temperature or pressure.

Water has the highest specific heat of all substances except liquid hydrogen and lithium at high temperatures. It is this high absorption capacity for heat, which permits the local modification of climate by a water body. But the most interesting property of water to a limnologist is the parabola-like variation of density with temperature, water reaching a maximum density at 3.98°C under a pressure of one atmosphere.

If the pressure on water is increased, as it is with depth in a lake (pressure increases one atmosphere for every 10 metres depth), water is compressed to a small but measurable extent. This increased density in situ may lead to a lowering of the temperature of maximum density in the waters of deep lakes as Münster-Strom (1945) has indeed shown. The depression is small. It can only be measured in terms of a fraction of a degree even for the deepest of all lakes, Lake Baikal, Russia (1706 metres or about one mile deep).

Let us start with a lake, about 15 metres maximum depth, located in north temperate latitudes. At some time during early spring, after the ice cover has disappeared the temperature will be approximately 4°C throughout the lake. As the surface water becomes heated from above by sun's radiation, temperature stratification will develop, dividing the lake into a warm upper part and a lower cold part. Let us further assume that salinity (the content of dissolved salts) is uniform throughout the lake, and that the only factor regulating the density of water is its temperature. Figure 1 shows how the

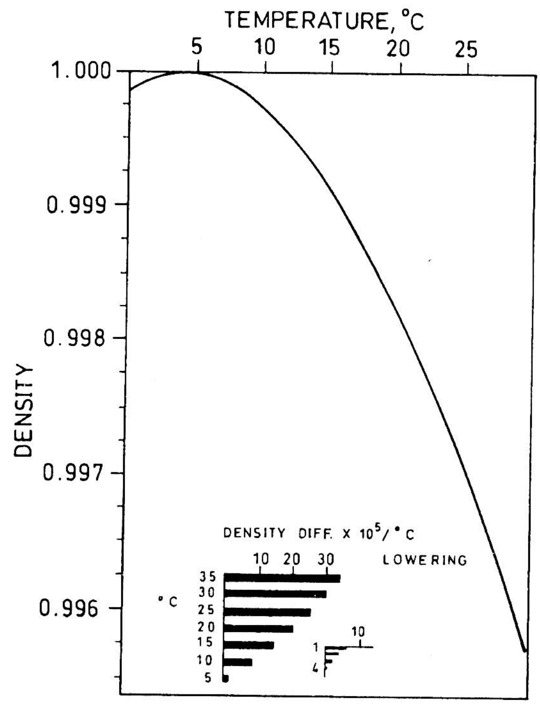

Fig. 1 Density as a function of temperature for distilled water. The density difference per °C lowering is shown in the lower part of the figure for distilled water at various temperatures.

density of distilled water varies with temperature. For our purposes it is more profitable to examine the difference in density between water at a given temperature and water at a temperature 1°C lower. We shall call this the *density difference per degree centigrade lowering*. The magnitude of this density difference for water of different temperatures is shown in the lower part of Fig. 1. One can see that the density difference per degree lowering increases as the temperature departs from 4°C, either above or below. In order to mix fluids of differing density, physical work must be performed, just as is the case when mixing cream in a bottle of milk. All other factors constant, the amount of work that must be done is proportional to the difference in density.

Thus, forty times as much work is required to mix layered water masses at 30 and 29°C as the same masses at 5 and 4°C, because the density difference is approximately forty times greater. Before pursuing the matter further, we must consider a phenomenon, which the physical chemist knows under the title Lambert's law. This law states that the light absorbed by a solution increases exponentially with the light path through the solution. For light of wavelength 0.75μ and a column of water 1 m long, only 10% passes through –90% is absorbed. If the length of the water column is increased to 2 metres, 1% passes through and 99% is absorbed. Since much of the sun's radiation is of this wavelength (0.75μ) or higher (infrared radiation), it will be clear that the uppermost two metres of the lake water absorb half of the sun's radiation. It is this absorbed radiation that is responsible for heating of the water.

Now we may examine a typical temperature-depth curve for a lake, such as the solid line shown in Fig. 2. If what we had said up to now were true, we should expect quite a different type of temperature curve, one in which the temperature decreased rapidly with depth, particularly in the uppermost metre or two. What is wrong? We have forgotten to mention one factor of prime importance; that the surface waters, which are heated by the sun, are mixed at the same time by the wind. The wind's work is important in heat transfer. We can now begin to see how this operates in the lake to produce the observed temperature curves. With regard to Fig. 2, let us divide the lake into three water masses: the epilimnion of warm isothermal water, the hypolimnion of cold isothermal water, and the intermediate thermocline where the temperature declines rapidly with depth. The temperature curve shown in Fig. 2 reflects the influence of sun in warming surface waters and the work of the wind in pushing part of the warmed surface water down to a depth of 10 metres in the lake. There appears to be some sort of barrier in the region of the thermocline, which prevents transfer of heated water to the deeper regions. What is the nature of this barrier? Before this question can be considered, we must return to a consideration of density.

As a general rule we can say that temperature is the most important factor regulating the density of lake water, though I shall mention an exception in a minute. Let us divide the temperature curve shown in Fig. 2 into ½ metre

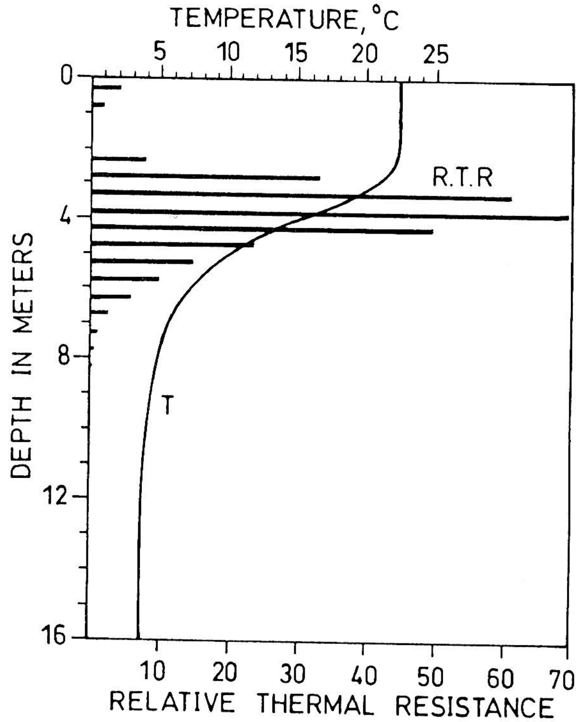

Fig. 2 A summer temperature profile (single line) and relative thermal resistance to mixing (bars) for Little Round Lake, Ontario. the relative thermal resistance (R.T.R.) to mixing is given for columns of water 0.5 metres long. One unit of R.T.R. = 8×10^{-3}, i.e. the density difference between water at 5° and at 4°C. The R.T.R. of the lake water columns is expressed as the ratio of the density difference between water at the top and bottom of each column to the density difference between water at 5° and 4°C.

intervals and calculate the densities of water at the top and bottom of each ½ metre interval (calculated from knowledge of the temperatures). What we are going to do is calculate the relative resistance to mixing offered by each ½ metre interval. A ½ metre column with a temperature gradient from 5° above to 4° below will be used as the standard. We shall define such a column as having one unit of relative thermal resistance to mixing. From knowledge of the density difference in the standard column and those in the ½ metre columns of lake water, one may calculate (following Birge, 1916) the relative thermal resistance to mixing offered by each ½ metre depth interval. The values are shown by solid bars in Fig. 2. There are two instructive points of interest. Note first of all how a barely perceptible temperature difference (0.1°C) in the warm water at the surface leads to a large increase in the resistance to mixing, and secondly how the resistance reaches a maximum which lies slightly above the inflection point of the temperature curve. One should be able to explain these observations from