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Freshwater ecosystems and biodiversity—A Case Study of Kolleru Lake, India: A Review

P.R.Reddy
Scientist –G (Retd), CSIR-NGRI, Hyderabad-500 007
E-mail: parvatarreddy@gmail.com

ABSTRACT
Freshwater Lakes, especially those that have significant importance from socio-economic point of view and sustenance of bio-diversity need to be protected from various manmade degradations. To bring in to focus the importance of organised restoration of degraded freshwater Lakes an effort is made through this write up to expose various facets of the problems encountered in Kolleru Lake and implementation of organised restoration strategies to overcome various setbacks and the future course of action, by synthesising available information.

PREAMBLE
Today, unprecedented pressures on the resources of the planet are putting our access to water at risk. Many people are already feeling this strain, and so too is nature – as rivers, lakes and other freshwater ecosystems face collapse across the planet. Traditional solutions – such as the building of dams, reservoirs and other types of infrastructure – are proving too costly and unsustainable on their own. Relying solely on these traditional water management solutions actually compromises many of the benefits that healthy lakes and rivers provide – inflicting significant costs on the people who depend on those natural systems for food, income, recreation and other services. We must find new solutions. Scientists believe that powerful alternatives exist – integrating our traditional infrastructure with solutions rooted in nature. Nature is not only the ultimate source of our water, but it also helps us keep it clean, and manage and protect it for different needs. We can fundamentally change how the world manages its water resources by researching and providing solutions that value the role nature plays in maintaining life's most fundamental resource. However, world over Man`s greed has blinded him from looking at this reality, leading to destruction of life saving elixir—WATER. To ensure restoration of degraded freshwater sources concerted efforts are to be made through a holistic approach. We believe restoration of degraded freshwater ecosystems alone can ensure positive change. Lakes and coastal wetlands are transitional areas between dry terrestrial and permanent aquatic ecosystems and are recognized as highly productive, playing a vital role in the global ecosystems. Their importance has been recognized in the maintenance of biodiversity, ecology, hydrology and recreation. However, rapid development and population growth in coastal areas as well as environmental degradation and over exploitation eroded the biodiversity and led to depleted productivity of these unique ecosystems. Forests and wetlands (hot spots for water and biodiversity) have been reduced and degraded. In addition, the indiscriminate discharge of wastes into water bodies has damaged the environment, with enormous and sometimes irreversible impact. However, managing these resources is essential if the world is to achieve sustainable development. Even though bringing out a concise presentation, covering various aspects of this important topic is difficult, we have ventured to structure this write up basically to enthuse young researchers to understand the root causes for ever increasing environmental degradation that are basically responsible for our present polluted living standards.
Freshwater ecosystems (wetlands, lakes and rivers) are critical habitats for a variety of threatened species and provide many benefits to mankind. In addition to being the source of the region's water supply, they prevent and regulate floods, prevent saline water intrusion, ameliorate erosion impacts by retaining sediments, provide nutrient retention and toxicant removal, offer micro-climate stabilization, act as a global carbon sink, serve as a means of transport and are excellent sites for tourism. Much of what freshwater ecosystems provide, including forest, wildlife, fisheries, forage, agricultural and energy resources, is available for human use. Understanding the role of

biodiversity in the hydrological cycle enables better policymaking. The term "biodiversity" refers to the variety of plants, animals, microorganisms, and the ecosystems in which they occur. Water and biodiversity are interdependent. In reality, the hydrological cycle decides how biodiversity functions. In turn, vegetation and soil drive the movement of water. Every glass of water we drink has, at least in part, passed through fish, trees, bacteria, soil and other organisms. Passing through these ecosystems, it is cleansed and made fit for consumption. The supply of water is a critical "service" (of benefit to humans) that the environment provides. There is evidence of the degradation of water and biodiversity through (a) drying rivers, wetlands and aquifers (b) bio-accumulation of agrochemicals and heavy metals in fish and other edible species (c) algal blooms from high nutrient loads (c) silting of dams and nutrient loss due to the fragmentation of rivers, and (d) the disappearance of natural forests. Much of this is caused by short-sighted development. Most countries have the legislation to protect their water resources (particularly from the point source of pollution), but the implementation of laws often lags behind because responsibilities are dispersed and costs are high. Unfortunately, non-point pollution from agriculture often constitutes a greater total pollutant load than the point-sources, and proper management options are not in place. A concerted effort has to be made by all the stakeholders to ensure sustainable development, in place of short-sighted development. This can be ensured through organised scientific management, with support from the common man. There is a need for a holistic and integrated approach to biodiversity and water management. The ecosystem approach (strategy for the integrated management of land, water, and living resources) and the integrated water resources management strategy (promotes the coordinated use of water, land and related resources, to maximise the resultant economic and social development without compromising the sustainability of aquatic ecosystems) should be benchmarks.

INTRODUCTION

Both Old World and New World cultures have been centered on freshwater habitats. Freshwater biodiversity is seriously threatened today - a telling indicator of the status of the world's freshwater ecosystems. Freshwater lakes are classical examples of habitat islands (in this case, bodies of water surrounded by expanses of land). Like islands in general, the larger, more ancient lakes tend to have high levels of endemism, and in the rift lakes of Africa or Lake Baikal of Central Asia, Chilka and Kolleru lakes of India species diversity can be spectacular. Biodiversity in freshwater systems is distributed in a fundamentally different pattern from that in marine or terrestrial systems. Organisms on land or in the sea live in media that are more or less continuous over extensive regions, and species adjust their ranges to some degree as climate or ecological conditions change. But freshwater habitats are relatively discontinuous, and many freshwater species do not disperse easily across the land barriers that separate river drainages into discrete units. This has three important consequences: a) freshwater species must survive climatic and ecological changes in place; b) freshwater biodiversity is usually highly localized, and even small lake or stream systems often harbour unique, locally evolved forms of life; and c) freshwater species diversity is high even in regions where the number of species at any given site is low, since species differ between one site and the next. Unfortunately, lakes are like islands in another way too: they suffer high rates of extinction when habitat modification begins or when exotic species are introduced. The introduction of non-native species - regrettably still often sanctioned or promoted by governments - is associated with the depletion of biodiversity and the collapse of major fisheries in such lakes as Lake Chapala of Mexico, Lake Gatun of Panama, and the Great Lakes of North America. Other factors contributing to the decline of freshwater ecosystems and their native biota are chemical and thermal pollution, over-harvesting and habitat modifications (such as dam construction). These factors have affected biodiversity to different degrees in both industrialized and developing regions. In Europe and North America, pollution, acidification, and the physical modification of streams have had the greatest impact. In much of South America and Africa, Over-harvesting and introduction of non-native species are relatively more important as agents of biodiversity loss. Programs to protect freshwater

biodiversity in industrialized countries have lagged far behind the programs for saving terrestrial biota. Unfortunately, freshwater sustainability issues do not appear to be a primary consideration in the planning and implementation of water use projects, nor in the allocation of use permits. In India, in spite of promulgating various laws to protect our water bodies and coastal wetlands, bio-degradation of these fragile ecosystems reached alarming stage necessitating focused rehabilitation of some of the famous fresh water bodies that are in one way or the other are connected with the coastal corridor and through which the adjacent offshore segments.

Study after study shows, all over the world, that the health of many of the freshwater lakes (including the 5 Great Lakes of US) is in jeopardy. While we have been working heroically to hold the line over the years to prevent their further decline, we have been entrusted with powerful new resources to rehabilitate the lakes: leadership at the highest levels demanding action, policy tools, and the promise of significant financial resources. With these, there are no more reasons for delay. After all, many of the lakes including Kolleru Lake of India have endured some 50 to 150 years of abuse. Though it will take time for the ecosystem to respond to our actions today, there is not another minute to lose in restoring these magnificent waterways for tomorrow. To the extent that actions undertaken now increase the resiliency of the ecosystem, they will also help the Lakes adapt to climate change. The well articulated Action Plans adapted by different countries, following well tested quality norms– including the funding and other policy tools that will be used to leverage its outcomes – are intended to realize our goals: that the fish are safe to eat; the water is safe to drink; the beaches and waters are safe for swimming, surfing, boating and recreating; native species and habitats are protected and thriving; no community suffers disproportionately from the impacts of pollution; and the Lakes are a healthy place for people and wildlife to live.

An effort is made here to bring into focus the alarming destruction of important water bodies of India, especially Kolleru Lake and steps initiated to cure the setbacks and prevent further degradation. Since the degradation and subsequent rehabilitation are fraught with various socio-economic ill effects, the presentation is confined to specifics of scientific importance. We, however, reproduced the excellent presentation made by Nagabhatla and Sellamuttu (2008) to educate the present generation scientific community to view at environmental issues with an open mind and take up scientific studies to focus on over all wellbeing of our environment, specially water bodies and wetlands located in the ecologically fragile coastal corridor.

Kolleru Lake

Kolleru Lake is a shallow freshwater wetland, a natural depression, the bed level being 3 ft below MSL, between the Godavari and Krishna deltaic systems in Andhra Pradesh (Figure 1). The lake is located between 81°05'E-81'20'E longitude and 16°32'N-16°51'N latitude. The total area of the lake is 95,400 ha at +10.7 feet contour and 13,500 ha at +3.0 feet contour. The water depth is 2.57 m at maximum, 0.22 m at minimum and 0.84 m on average. The high flood depth is more than 3.0 m and at this depth the lake spread is 86,000 ha. The lake serves as a natural flood-balancing reservoir for these two rivers.

Situated 35 km from the present coast, it was a coastal lagoon in the geo-logical past, believed to have been formed around 6000yearsBP, when the shoreline was far inland along the southern (seaward) margin of the lake, as evident from the presence of a series of relict sandy beach-dune ridges right up to the southern margin of the lake near Kaikalur and Akividu towns. Kolleru still maintains its connection with the Bay of Bengal through a 60 km long, intricately meandering tidal channel called Upputeru– a typical characteristic of coastal lagoons. Apparently, this lagoon has progressively fallen inland with the advancement of the Krishna and Godavari deltas on both sides of it. As a number of rivulets such as Tammileru, Budimeru and several other smaller ones draining a total catchment of about 5400 km are decanting their waters into it, the Kolleru has turned into a freshwater body, except in its south-eastern part where brackish conditions prevail, especially during dry summer months due to incursion of tidal water through Upputeru. The lake continued to exist through thousands of years after its formation, in spite of sedimentation through inland streams and reduction in the flushing capacity of Upputeru due to the over extension of its course by progressive advancement of the coastline far away into the sea. Perhaps its topographic allocation

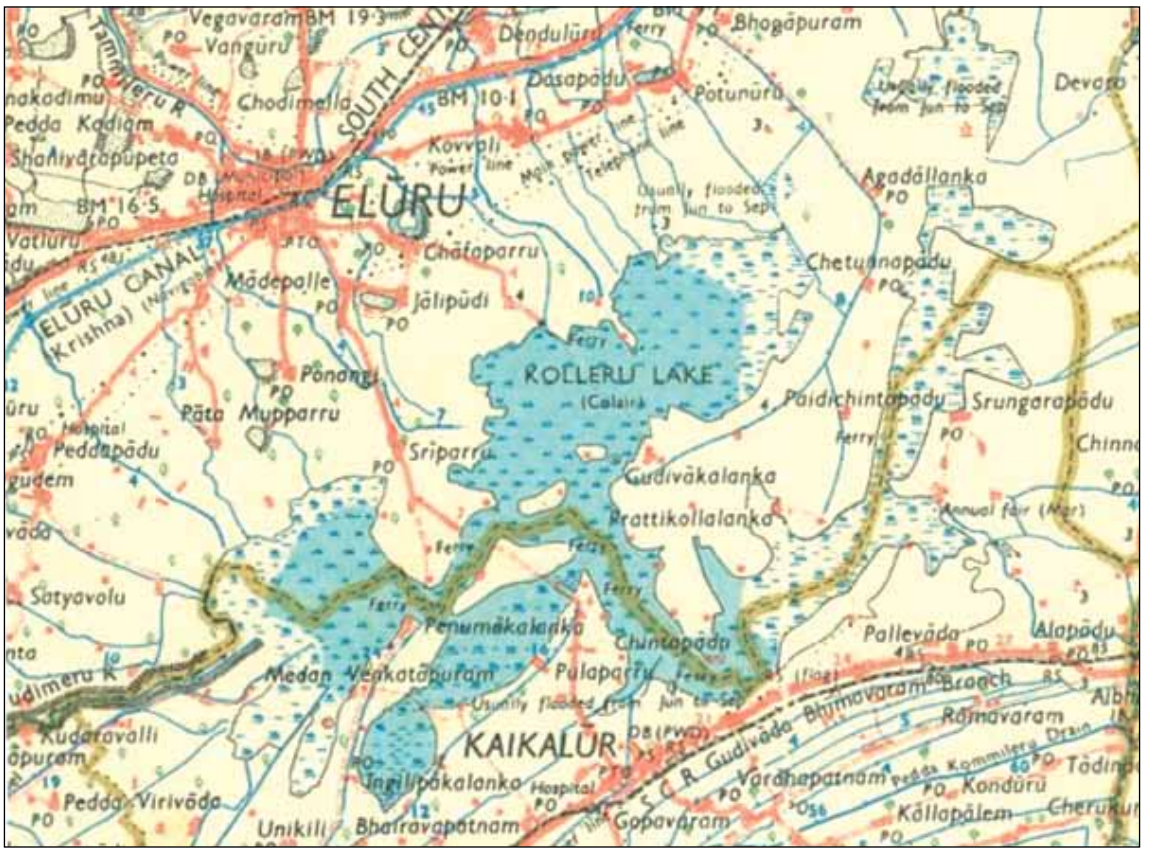

Figure 1. Kolleru Lake in Andhra Pradesh

over a deep-seated tectonic depression, which is geophysically known as Gudivada sub-basin or garben between the Bapatla and Tanuku subsurface ridges or highs, might be responsible for the persistence of the lake, although other lagoons much younger to Kolleru in the area toward the coast seem to have been emerged and dried out subsequently (Nageswara Rao et al,2004). The lake is connected to the Krishna and Godavari systems by over 68 inflowing drains and channels. It serves as a habitat for migratory birds. It supports the livelihood of fishermen and riparian population in the area. The lake was notified as a wildlife sanctuary in November 1999 under India's Wild Life (Protection) Act, 1972, and designated a wetland of international importance in November 2002 under the international Ramsar Convention.

Ecologically, the lake is divided into three zones: Zone I (the lake proper) which is purely a freshwater zone, extending from Mangaluru, Sripparu on the west to Kaikalur on the south and Pandiripalligudem on the east; Zone II, the transitional zone, extending from Pandiripalligudem on the west to Kottada on the east, receiving freshwater from the western and northern regions and tidal waters from Upputeru river from the south; and Zone III (the tidal zone) which is subject to the tidal oscillations . In the lake there are 46 island villages and 76 shoreline villages. The main occupation of people is agriculture. There are 42,000 fishermen engaged in capture fishery in the lake. About 120 species of fish and 12 species of shrimps have been recorded from the lakes, of which 35 are from the tidal zone of Upputeru canal region. Aquaculture was introduced into this predominantly agriculture and fishing based economy of the lake by the Government of Andhra Pradesh in 1977 for the Fisheries Co-operative Societies. Since then, seeing the success of the programme, the private sector has come into aquaculture in a very large way, not only in production but also packaging, long distance transportation (to Kolkata) and marketing. A large number of fish seed hatcheries have been established. It is estimated that the total water-spread area of fish ponds in the lake at 3,500 ha, the individual pond size ranging 2–16 ha. The agricultural lands in the +3 to+5 ft contours have been converted into fish ponds during the peak 1983–89 period. All farmers practise

composite carp culture. The highest production rates reported are 10–12 tonnes/ha/year. Thousands of fish tanks were dug up inside the wetland converting the lake into a mere drain. Apart from this the farmers had converted the land use pattern of the lake. This had a lot of impact in terms of pollution leading to even difficulty in getting drinking water for the local people. The total area of the lake converted to aquaculture ponds accounts for 99.73km^2 in 2004in comparison to 29.95km^2 in 1967. The area under agricultural practice in the wetland also increased from 8.40 km^2 in 1967 to 16.62km^2 in 2004. Sewage inflow from the towns of Eluru, Gudivada and even Vijayawada and industrial effluents, pesticides and fertilizers from the Krishna-Godavari delta region contaminate the lake. Eleven major industries release about 7.2 million litres of effluents into the lake every day. In 1982, the Andhra Pradesh government set up the Kolleru Lake Development Committee (KLDC), which had set up an Rs 300-crore master plan for Kolleru. It also called for the creation of a Kolleru Lake development authority to check encroachments, regulate and monitor pollution, clear the lake of weeds and use it as compost and raw material to produce biogas.

Digital processing of the IRS-1D LISS-III image revealed a highly degraded state of the Kolleru lake. Among the several techniques tried, image enhancement through automatic log residuals method clearly indicated that about 42% of the 245 km lake area was encroached for aquaculture and 8.5% more area was occupied for agriculture, while the rest of the lake is either being dried out by reclamation or is infested with weed. The study carried out in 2003 provides unambiguous visual information on the alarming levels of human-induced environmental degradation of Kolleru Lake, which is one of the important coastal wetland ecosystems in the country. The study highlights the significance of digital image processing and GIS analysis of the satellite sensor data in accurately assessing the physical environmental conditions and changes thereof in inaccessible terrains, such as in the case of the Kolleru Lake, so that appropriate preventive and/or remedial measures can be taken up to protect such fragile but important coastal wetland ecosystem (Nageswara Rao et al, 2004).

In 2006, the Central Empowered Committee (CEC), appointed by the Supreme Court directed the state to remove all sorts of encroachment including the fish tanks. This caused a huge hue and cry among the fishermen community. From then the government is undertaking many projects to restore back the glory of the lake.

Environmental constraints to carp culture in Kolleru Lake

The resources, production activities and environmental problems in Kolleru Lake were discussed at the National Workshop on "Kolleru Lake Environment Information System" organised by the Centre for Environment, School of Environment, Water Resources and Remote Sensing, Jawaharlal Nehru Technology University, at Hyderabad in October 1991. The major issues of environmental degradation considered are as follows:

1. The lake is losing out due to large-scale reclamation of land for agriculture and construction of a network of fish ponds and roads.
2. The lake is subjected to increasing pollution load by industrial effluents from sugar factories, distilleries, tanneries, agro-chemical factories, paper mills and rice mills.
3. There is dumping of sewage effluents from municipal and urban agglomerations.
4. The large duck population contributes an annual droppings of 37,000 tonnes.
5. The lake is heavily infested with macrophytes.
6. The lake is undergoing a process of eutrophication and the peripheral region has been found to be hyper-eutrophic as observed by certain abiotic factors.
7. Dominance of blue-green algae (*Oscillatoria* sp., *Spirulina* sp.), diatoms (*Diatoma* sp., *Melosira* sp.) and greenalgae (*Spirogyra* sp.) is considered as a biological indicator of pollution.
8. Thousands of tonnes of organic matter in the form of hay and paddy dust is let into the lake.
9. Residues of about 18,000 tonnes of inorganic fertilisers from paddy fields drain into the lake.
10. Mass scale decay of hydrophytes lead to severe problems.
11. The lake is threatened by accelerated sedimentation.
12. Depletion of dissolved oxygen is often

observed in the lake due to obstruction to free flow of water and occasional release of metabolite-loaded wastes from fish ponds.

13. All varieties of fish contained toxic metals (mercury, lead, cadmium, zinc and copper) although within tolerance limits.
14. The lake has been subject to more drastic changes from 1984 onwards as compared to previous periods.
15. Finally, it was urged that the Kolleru Lake Development Authority created by the Government will organise such steps as would ensure the resuscitation of the lake, habitations *etc.* preserve the ecosystem, and preserve and enrich the aquatic fauna of the lake.
16. The WWF (1992) report took note that the Kolleru Lake has lost 34,000 ha of wetland area to agriculture and stated that the noise created by irrigation pumps was considered to be one of the causes for the disappearance of large breeding colony of pelicans from the lake in the 1960s.
17. Problems would intensify in future(**P.S**: as predicted problems intensified).
18. In Kolleru Lake, the environmental changes brought about by carp and shrimp culture have been one of the reasons for loss of land, disappearance/reduced appearance of some species of migratory birds, and obstruction of waterways.

Prevention

The domestic sewage and the industrial effluents entering Kolleru Lake through various drains are to be properly treated so that no pollutants enter the coastal waters through Upputeru drain.

Restoration

Restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. For purposes of this Initiative, restoration includes ecosystem protection, enhancement, rehabilitation and remediation. A restored ecosystem is resilient; its chemical, physical, and biological functions and processes provide the requisite conditions for life. A restored ecosystem contains sustainable populations of native plant and animal species and their habitats. Potential threats or further damage have been eliminated or reduced as much as possible and the restored ecosystem is able to withstand future threats. Restoration is

Shrimp culture

Environmental issue		Cure
1.	Salinisation of land	Create adequate buffer zones.
2.	Salinisation of drinking water wells	Wells already spoiled cannot be salvaged immediately; place a buffer zone and improve water quality in course of time; undertake supply of drinking water.
3.	Obstruction of natural drainage of flood water	Provide for natural drain within the existing plan.
4.	Passage of access to sea by fishermen and public	Provide unrestricted access.
5.	Self-pollution of ponds	Improve farm management measures and quality of inputs; avoid indiscriminate use of pesticides, chemicals and drugs.
6.	Pollution of source water	Provide for treatment of effluent water; take up secondary aquaculture wherever feasible; monitor water quality parameters; improve pond management; assess carrying capacity; limit scale of intensity and expansion; laws to be enforced to monitor and regulate activity.
7.	Destruction of mangroves	Regeneration of mangroves to an extent equal to that destroyed.
8.	Land subsidence	No visible problem as yet; groundwater abstraction to be controlled; apply CRZ provision and statute.
9.	Pressure on wild seed resources and consequences thereof	Establish more hatcheries to meet demands; Regulate shrimp fry trade; educate fry collectors against destruction of by-catch.

not the attempt to change the ecosystem to past settlement conditions; however, a restored ecosystem does attempt to emulate those conditions to the extent possible under present-day chemical, physical and biological conditions. Restoration of degraded, damaged or destroyed water and lands is more costly than protection of resources before damage occurs. Therefore, this Initiative recognizes the wisdom of supporting ecological protection. Protection is defined as actions taken to prevent stress to ecosystems. Actions include the establishment of stewardship (Source: Great Lakes Restoration Initiative Action Plan-2010-2014, USA).This aptly addresses the problems encountered in Kolleru Lake.

The Rehabilitation measures

The increasing incidence of aquaculture ponds in the region in past decade was the cause of the unusual hydrological events resulting in flooding of the agricultural land in the sub-catchment. The Revenue Department in 2000, ordered the division of lake area into critical and most critical zones for the purpose of channelization in order to tackle the problem of submersion of surrounding agricultural lands. The removal of encroachments was thought as serious step by the Revenue Department for the protection of sanctuary in order to restore its function as a balancing reservoir in the event of flood, even so nothing much came into practice. In addition to the treatments of catchment area the other recommendation of the management was to increase in the carrying capacity of the existing outlet (Upputeru) into the sea to facilitate draining of flood water .However, due to various impediments it took awhile for them to be executed; finally in June 2006 the aquaculture demolition came about. Also, the lake reclamation activities took more ground; whilst the complete cancellation of the 'pattas' and the acquisition of private land inside the sanctuary were the issues of concern. With the target to free the sanctuary land from all encumbrances the Forest Department took over an active role ; the demolition of 380 fish tanks covering an extent of 21,796 acres (8820.5 hectare) was initiated to ease free flow of water in June, 2006 (as per the Forest Department records). It was seen that of official demolition records that of the 76 tanks in the encroached region in west Godavari region, 50 were breached that amounts to 191.5 hectare whilst in Krishna a total of 94.4 hectare of encroached area under aquaculture was demolished. On the contrary, the spatial analysis approach adopted in the study taken up by Nagabhatla and Sellamuttu (2008) also checked the statistical notes provided by the stakeholders, departments (post demolition), while evidently keeping a monitor on new encroachments. In addition, removal of weeds and clearing of drains was taken up to add to the process. However, the operation met resistance from fish tank owners even though all these fish tanks were illegal and most of them were actually encroachment over drains. What was needed on precedence was to assess the changes experienced by the ecological, hydrological and the social sector. As to highlight the post-demolition scene from multiple fronts, the analysis started with the quantitative characterization of the ecological spectrum of the lake using the earth observation data from 2007-Indian Satellite Series (IRS)- LISS III (with a spatial resolution of 23.5m) using a 'WINDOWS' based ERDAS IMAGINE 8.6 image processing software and refined and validated based on the information collected from the reconnaissance survey (spread from 2006-2007; pre and post classification). With an opinion that the significance of digital image processing and GIS analysis of the satellite sensor data in precisely valuing the physical landscape conditions and changes there from in inaccessible terrains, such as in the case of the Kolleru Lake, so that appropriate preventive and/or sanative framework can be designed to sustainably manage such threatened but important wetland ecosystems. It was noticed by the Forest Department officials that by 2005, more than 50 % of the lake area were cultivated for fish (as per survey statistics), while the post-demolition spatial analysis for 2007 reflects the aquaculture zone narrowing to 4 percent. On the other side the open land (lake bed region) along with marsh and the aquatic vegetation cover around 48%, hence reflecting a disposition towards restoration.

On the social front the post demolition survey (below +5 contour area) by the management authorities that centred on the socio-economic activities associated with the lake identified about 14,000 families in about 44 villages that were affected by the demolition of fish tanks .These were foreboded to be covered under the Livelihood Enhancement Action Plan that supports alternative livelihoods for the affected families covering nine mandals and two districts using live participation of the community.

Eco-tourism was seen as a potential tool to involve in the lake conservation campaign. Even though the restrictions and sanctions were sensed negatively by the people, concerted efforts by the government have helped to commence with the sanctuary restoration. The post-demolition soil analysis that both in bed and belt villages the black clay soils with a pH from 6.5-7.5 and appropriate phosphorous and potash content supports paddy as a Rabi crop (report by Forest Department); however the annual and seasonal variation in the rainfall pattern and the flood water dynamics in the wet season makes it slightly uncertain. Palpably, the drainages of the Kolleru wetland had been severely impacted (blocked) by the construction of large number of fish tanks in the past; at times also inundating the Kharif crop, such incidences were recorded in 1986, 1996 and 2005. In addition, Kolleru occasionally receives the back water flows from the sea through the Upputeru that tends to spread into the paddy field below +5 contour, thereby impacting the crop productivity and the soil salinity. The seepage from the fish tanks into the surrounding cultivated areas adds to the salinity. As of now, the backwash of the aquaculture necessitates the rehabilitation of the cultivated area to handle the salinity issues, before the farmers get back to this livelihood practice. Also the proposed set of post-demolition activities to restore the ecological and the socio-economic attributes of the lake include the raising the traditional fishing.

From the management side it was declared that after the demolition, the hydrological impacts for the agricultural zone can be explained by the dip in the surface water level from 5-7 feet (prior to tanks demolition) to 1-1.5 feet. That came as a sign of relief for the adjoining farming community. The government order [G.O.Ms.No.120] for demolition also pointed that the Kolleru Lake restoration cannot be treated in isolation of people living in that area and hence the plan of action should integrate respective departments and should put people in the Kolleru bed villages primal to the planning. However, in practice some setbacks have been noticed. It is recommended that need for a comprehensive plan of action for future that ensures community participation in the decision making process. Kolleru, the largest fresh water lake and a Ramsar site of international importance has circled around over past half century from being a fresh water balancing reservoir to agriculture land and shifting as an aquaculture treasure island and lastly ceasing to be the aquaculture centre. As nearly all stopovers of this journey was driven by policy shift that demanded economic benefit while surpassing ecological and social community growth (Nagabhatla and Sellamuttu, 2008).

The studies carried out under "Operation Kolleru"and subsequent scientific investigations carried out under the stewardship of Prof.P.Rajendra Prasad of Andhra University clearly emphasised the restoration process is incomplete, as number of ambiguities are present in the very fixation of Kolleru Lake boundary.

At present, a lot of uncertainty prevails in this regard. For instance, the Kolleru lake over an area of 901 km^2, the outer boundary of which tentatively follows the 10 foot (3 m) contour, has been declared in 2002 as a Ramsar site. Prior to that, in 1999, the AP Government declared the Kolleru area within the 5-foot (1.5 m) contour as a wildlife sanctuary. Even today, there is no agreement among the various government departments concerned over the location of the 5 foot (1.5 m) contour. The contour map prepared by the State Irrigation Department in 1966 (which was used in this study) is now being disputed by the State Revenue and Forest Departments. Adding to all this, the AP Government is now proposing to shrink the boundary of the sanctuary to the 3 feet (0.9 m) contour. In any case, once the boundary of the sanctuary is properly fixed, through rigorous survey using modern techniques like LiDAR (Light Detection And Ranging) altimetry or high-resolution satellite stereo image analysis coupled with fine resolution DGPS (Differential Global Positioning System) control points and total station surveys, the encroachments are to be cleared totally from the zone. There is a catch here. Mere breaching of the fish-tank embankments to drain off the water, as was done in many cases during the Operation Kolleru, will not restore the lake environment. Our field observations during June 2009 revealed that some of the partially demolished fish tanks have already been repaired and put to use again by locals. In other parts, the lake area appeared as dry land with decayed vegetation giving one an impression, although ironically, that fish tanks with full of water throughout the year might have been better than the lake's dried up condition (for several months). Removal of encroachments should be aimed at eliminating the embankments in the entire length and breadth of the demarcated area.

It is worthwhile to deepen certain parts of the lake and pile up the excavated earth as scattered islands where vegetation can grow, to provide resting/nesting grounds for avian tourists. Concerted efforts should be made to prevent sedimentation from the catchment; pollution from industries; pesticide residues from the surrounding cropland, and urban sewage from entering the lake through the innumerable streams and drains that now decant into the lake. It seems a long way to go, if at all, to save Kolleru Lake (Nageswara Rao, 2010).

Chronology of various Restoration Initiatives

1998: Writ petition filed by Dr. T. Patanjali Sastry, President, Environment Centre, Danavaipeta, Rajahmundry, in the High Court declaring the action of the respondents in not stopping the discharge of effluents from the industries that have come up in the vicinity of Kolleru lake and in permitting the construction of houses and roads in the catchment area of the lake and to direct the respondents to take appropriate steps to restore the lake to its pristine glory as before.

1999: Writ petitions filed by the Kolleru Fishermen and Small-Scale Farmers Association and other organizations in High Court, complaining that the Government was not taking steps to stop pollution of the lake due to discharge of effluents from industrial units and untreated drainage from municipalities. They also said that the ecological imbalance of the lake is not due to fish tanks, but it was only due to the neglect of the lake by the Government and failure to have a check on the pollution caused by several industries and the municipal corporations.

Government issued a notification constituting Kolleru Wild Life Sanctuary and defining boundaries and margins. Because of the enforcement of GO Ms No 120 through which the State government declared the lake a wildlife sanctuary, the rights of nearly two lakh people, who are basically fishermen, came at stake. By doing this, the government had made it clear that the right of the local fishermen to do fishing by traditional methods is not taken away, but aquaculture in the form of any tank is prohibited. Notice issued of demolition of all fish tanks in the area would commence from April20, 2006.

2001: High Court dismissed the writ petition of 1999 saying that wet eco system cannot be exploited to the detriment of people at large for temporary gains. The Bench dealt with the contention that the notification was ultra vires, and said that the Government had the powers to issue the notification. The Bench directed the Government to adhere to the standards laid down by the Ministry of Environment regarding the lakes and effluents. And all writ petitions were disposed of.

March 2002: The Kolleru Fishermen Cooperative Society moved to the National Human Rights Commission (NHRC) and the Amnesty International, seeking to protect the livelihood of nearly two lakh people in the Plus Five contour of Kolleru lake.

The Kolleru Fishermen Cooperative Society moved to challenge the validity of the GO Ms No 120 in Supreme Court by seeking to protect the people's right to life in the area. The ground was being prepared to file a writ petition in the Supreme Court, alleging that the Government, emboldened by the ruling by the High Court in defence of the need for wildlife sanctuary in the lake, was trying to enforce the GO Ms No 120 without having any forethought on the implications of evicting the local people at the cost of their right to life.

Sept 2005: Restoration work for the lake started. Mr. Lav Agarwal in his capacity as Collector and District Magistrate and his team sustained the pain and endurance of adamant Kolleru people.

Nov 2005: Aqua farmers and local people staged a rasta roko and threatened to commit mass suicide if their tanks were demolished. The district administrator took serious action against the agitators.

Nov 2005: A regulator will be constructed at a cost of Rs.30 crores on Upputeru at the mouth of Kolleru to provide the straight cut for the lake water to flow into the sea. The State Government will seek Rs.600 crores loan from the World Bank and other external sources for rehabilitation of the lake to its old glory with the removal of encroachments including aqua tanks up to the10ft. Contour level.

2005: Shri Pranay Waghray approached the Supreme Court for implementation of HC judgment.

2006: The Central Empowered Committee (CEC), appointed by the Supreme Court to monitor environmental issues in the country, has directed the state government to remove all the encroachments on Kolleru Lake. About 31,000 acres of fish ponds had been removed from the lake.

Feb 2006: Over 30 big leaseholders each owning fishponds of more than 100 acres gave separate written

undertakings to the Krishna District Administration that they would vacate the lake before 3rd March .

March 2006: Kolleru Fishermen Cooperative Society challenged the validity in Supreme Court by seeking to protect the people's right to life in the area. They pointed out that the government is following the Supreme Court orders without having any forethought on the implications of evicting the local people at the cost of their right to life.

June 2006: Lok Satta, a NGO said that the destruction of fish tanks in the Kolleru lake area could not bring back the past glory of the lake. It said that the massive operation to bring down these tanks would rob thousands of people of their livelihoods. It said industrial effluents and municipal sewage, and not fish tanks, were the major sources of pollution of the lake. Lok Satta has taken up the issue of Kolleru to ensure that the people receive a fair compensation and relief & rehabilitation package.

Dec 2006: The state government sanctioned Rs 15 crores for rehabilitation of the fishermen affected by the cleaning of the lake.

2007: The forest department, which started work on demarcating the area of the sanctuary, is hamstrung because of the non-cooperation of the revenue officials. The forest officials had to stop work in some pockets following opposition and threat from tank owners. The main opposition party, Telugu Desam, is backing the tank owners in some stretches and even took out a rally in Akivedu demanding a stop to demarcation work.

Feb 2008: Eco-tourism project of the Andhra Pradesh Tourism Development Corporation (APTDC) for Kolleru lake becomes a reality, with the corporation launching Rs. 1.5 Cr for the project.

June 2008: Kolleru lake to be developed at a cost of nearly Rs 860 crore over five years as the international NGO, Wetland International South Asia, has prepared proposals at the behest of the state government. Of the total cost proposed for development, Rs 500 crore has been allocated for water management works.

Sept 2008: Kolleru lake to be transformed into a bird watching with the State Government taking up a major project to develop it as an eco-tourism destination. The project as a Rs.9-crore project sanctioned by the Union Government commences in November and scheduled to be completed in 18 months.

Jan 2009: The state government is putting pressure on the forest department to finalize a proposal to reduce the sanctuary area of famous Kolleru Lake from the present plus five to three contour-levels.

April 2009: Telugu Desam Party (TDP) president N Chandrababu Naidu said that the Lake would be regularized and the surplus land from the lake will be distributed to the poor farmers. **September 2009:** The State Government has taken the decision to protect the lake up to contour-3(Courtesy: chiranjibipattanaik@gmail.co)

Common Problems

In spite of reasonable improvement in the health of Kolleru Lake, we cannot come to a conclusion that restoration carried out till now is going to sustain overall development of the Lake and restoration of pristine nature of the lake, due to lack of organised management of various restoration and rehabilitation measures**.**

Public Interest Litigation has shown up the following problems as common to all lakes, including Kolleru:

- Apathy of the executive in preventing discharge of domestic and industrial effluents in to the lakes
- Lack of proper sewage system
- Encroachments due to the nexus between the executive and the builders lobby
- Lack of access to scientific data and scientific norms for restricting building activity around the lakes
- Ineffective technology for cleaning up pollutants
- Unclear laws, too many corrupt and confused authorities (numerous govt. departments), plethora of land owning govt. agencies, political vested interests, and absence of a clear lake environment policy.

Delays in Restoration

Restoration actions taken/initiated in lakes were often delayed due to involvement of several ministries/ agencies at the Central and State level which lacked basic understanding in adopting a joint approach since lakes or wetlands are not delineated under any specific administrative jurisdiction. The delays were due to:

- Improper appreciation of the hydrological regimes at the river basin level and allocation of water, particularly for ecological purposes.

- Inadequate understanding of the sound ecological basis for interactions amongst various sectors.
- Conflict of interests among various land & water use sectors and their failure to evolve common strategy.
- Lack of involvement of Stakeholders in planning and implementation processes.
- Paucity of overall understanding of the nature and benefits of lakes in economic and ecological terms.

***Co-ordination** is a major stumbling block in effective management of water resources in the country, which inter-alia includes Lake Management. The issue is water and not bio-diversity per se. Hence, water is the fundamental problem of Lake Management. Any actions taken to address the bio-diversity issues would not revive the lakes unless the availability of better quality water is assured.

***Ineffectiveness of Legislation:** Some lakes/ wetlands have been provided protection under the Wildlife Protection Act, which is generally ineffective. This is due to lack of pragmatic regulatory regime for an integrated development and management of a drainage basin and involving joint decisions of several sectoral agencies. Effective coordination between the different ministries (energy, industry, fisheries, revenue, agriculture, transport and water resources) is essential for the protection of these ecosystems.

The way forward for better management of the lakes, reservoirs and tanks in the country could be achieved by evolving strategic integrated management action plans. The guidelines issued by MOEF in this regard are a good beginning. They need to be pursued to ensure their effective implementation (Reddy and Char, 2004).

Status as on Jan, 2014

Notwithstanding the political row over fixing of contour and removal of encroachments, the Forest Department's efforts in restoration of Kolleru lake, one of the largest fresh water eco systems of international importance, has helped in return of local and migratory birds. The budget demand pertaining to Forest department, which was tabled in the Assembly in March, 2013 had this interesting piece of information. The department says the birds that returned included endangered species like Grey Pelicans, Painted Storks and Open Bill Storks. These birds had almost shunned the place owing to rapid deterioration in the lake's eco system. The Forest Department has listed conservation of Kolleru wildlife sanctuary as one of the major tasks taken up by it. With the intervention of the Supreme Court, 1776 illegal fish tanks covering an area of about 44,700 acres in West Godavari and Krishna districts have been demolished. This was an achievement considering the fact that the lake is spread over 2,25,250 acres up to +10 ft contour. With removal of encroachments, the eco-restoration work is in progress. It is being taken up by the department in coordination with other sister departments like Revenue, Irrigation, Roads and Buildings, Fisheries, Pollution Control Board and Rural development. The objective is to see that the lake gets back its pristine glory. An Integrated Management Action Plan with an outlay of Rs. 995 crores spread over a period of five years has been prepared through consultant, Wetland International South Asia, New Delhi. This will be implemented after its approval. The locals affected by the 'Operation Kolleru" are being rehabilitated by the Revenue Department. Some employment opportunities have been created by the Forest Department. (The Hindu,29th March 2013) While this augurs well for the lake a recent study reveals a deteriorating scenario. A study by a team of geo-engineering experts of Andhra University, Visakhapatnam, revealed that salt water from the sea had made intrusion up to the northern part of the lake, which is about 40 km from the coastline. The intrusion of saline water into the lake is aided by overexploitation of ground water near Kolleru. The lake plays a key role in the ecological balance of the Krishna-Godavari deltas by serving as a natural "balancing reservoir". It stores the inflows from monsoon streams and rivulets and dozens of small agricultural channels and drains, before emptying the excess water into the sea. The AU team noted that aquaculture, agriculture, and industrial activity in and around the lake led to a change in the quality of water. Ironically, even the "paleo beach ridge" areas around the lake are dug up for exploitation of water table. Since "paleo beach ridges" are sandy in nature with high permeability, any digging activity in the vicinity leads to intrusion of salt water from the sea. Kolleru attracts thousands of migratory birds from places as far as Siberia and any change in the water quality will have a catastrophic effect on the avian population, besides the local aquatic life. "Saltwater intrusion can pose serious problems to

freshwater aquifers along coastal areas," warn the AU researchers, adding that overexploitation of ground water disturbs the natural balance between fresh water and salt water in coastal aquifers (The Times of India, 31st Jan, 2014).

It is not clear how budget allocation would be altered once the state bifurcation is completed in all respects.

CONCLUSIONS

It is clearly evident from the information gathered from presently available literature that freshwater lake management needs committed and focused integrated management strategies. Unless constant monitoring of various facets of restoration and post restoration measures is carried out on a regular basis, covering various components none can ensure sustenance of lake`s health. It is hearting to learn that significant studies are being carried out by the departments of Geo-engineering and Geophysics of Andhra university. The outcome of these studies should be made use of by the district, state and central government administrative authorities to ensure organized restoration of the fresh water Kolleru Lake and arresting salinity of the Lake waters. Details included in the present write up need to be supplemented by ongoing studies by various organisations to have a comprehensive understanding of freshwater lake ecosystem and its impact on bio-diversity.

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