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Short Communication

Hypertrophic-eutrophic alteration in Kandy Lake, following an outbreak of a *Microcystis* bloom

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Abstract

Urban water bodies especially those located in the humid tropics are vulnerable to high anthropogenic pressures although their uses are tied up with hygienic and economic conditions of the riparian communities. An aesthetic water body located in the hill capital (Kandy) in Sri Lanka was subjected to long term monitoring of chlorophyll-a and Secchi depth and other environmental variables following an outbreak of *Microcystic aeruginosa* bloom in May 1999. The episode of hypertrophic-eutrophic alteration of in Kandy Lake is discussed here in relation to monsoon-bound rainfall events and other environmental variables.

Management of urban water bodies in developing countries is neglected to a greater extent primarily due to poor awareness and financial constraints. They receive a variety of untreated effluents, particularly human and domestic wastes and galloping eutrophication leading to a hypertrophic condition is inevitable (Silva and Schiemer 2001; Silva 2003). Despite a growing pool of knowledge on water resource management in global scale, this unique problem has received very little attention and site-specific processes responsible are hardly understood. Urban water bodies loose much of their beauty and attractiveness for recreational value and gradually become nuisance ones in many instances.Shallow man-made water bodies in Sri Lanka experiencing two moisture carrying monsoons exhibit a distinct annual trophic shift from mesotrophic to eutrophic as a result of rainfall-bound filling and water release to meet the irrigation demand (Schiemer et al. 2001). However, the processes determining the ecological response due to rainfall patterns and other environmental variables in urban water bodies are different from those in irrigation and hydropower reservoirs and are not properly understood for their meaningful use. Uncertainties exist particularly in reconciling timing and amplitude of ecological responses of urban water bodies which are already eutrophic. Hypertrophic-eutrophic alteration of an urban water body is analyzed here in relation to monsoon-bound rainfall events and other environmental variables.

An aesthetic water body called Kandy Lake is situated in the heart of hill the capital, Kandy (7º 18´N; 80º 39´E at 510 m amsl) in Sri Lanka. Kandy, the second largest city in the country is also designated as a World Heritage City. The lake, which exists as a perennial water body since its construction (1810-1812) is one of the largest tourist attractions of the country because of its very location adjacent to the world famous Buddhist temple *Dalada Maligawa.* The watershed (2.64 km^2) of this water body is partially residential and urbanized but the occurrence of a dense natural forest patch in the uppermost elevation is a unique feature. Two small perennial brooks drain water into the 18 ha surface area of the lake with 0.3839 Mm^3 capacity. The mean depth is 8.5 m while the deep area extends up to 12.5 m. About 75 % of the basin is less than 4 m with the rest being more than 10 m. Public roads and concrete walls etc. skirt the lake which has no tapering littoral zone and the surrounding embankment has been planted with large trees. Water spills over the sluice gate, the only outlet, during two peak rainy seasons (April-May/October-December) but small-scale hotels, hospitals, schools and temples located around empty wastewater throughout the year which is severely contaminated with coliform bacteria (Sharaff 2003) . Nile tilapia, *Oreochormis niloticus,* which prefers blue green algae in its diet, dominates the fish population in this non-harvesting water body.

In May 1999 there was an outbreak of *Microcystis aeruginosa,* a non-nitrogen fixing Cyanobacteria in Kandy Lake. The outbreak was ascribed to sudden draw-down of water level during the preceding dry weather (Silva 2003). However, the lake was eutrophic before the outbreak and a green algae, *Pediastrum simplex* and a chain forming centric diatom (*Aulacoseira granulata*) showed an alternative oscillation under dry and wet weather (Samaradiwakara 2003). The dominance of *A. granulata* during the rainy periods was attributed to increase in dissolved silica concentration (Silva 2005) whereas *P. simplex* is a characteristic taxa in meso-eutrophic tropical water bodies (Rott et al. in press). Removal of surface scum while raising the water level with intermittent spills of water over the sluice during July-August, 1999 due to unusual rains resulted in gradual disappearance of the bloom. Nevertheless, *Microcystis* became the dominant taxa since then with some other sub-dominant cyanobacteria and a few of the other phytoplankton taxa (Silva 2005). Although *A. granulata* appeared in small numbers following rainy seasons, *P. simplex* was hardly found in the phytoplankton assemblage following the outbreak.

Despite rainfall-bound decreases in chlorophyll-a (chl-a), even up to a lower level of eutrophy specially during April-May and October-November, a progressive increase in the chl-a content with an analogous decrease in water clarity were recorded from 1999 to 2004 (Figures 1 & 2). Incident light attenuated rapidly under extreme dry weather (February-March/July-August) with instances of being prolonged when a sufficient volume of freshwater was not brought into the Lake. Sub-surface hypoxia with an accumulation of NH_4^+-N in the deep waters were common during this period (Silva 2005).

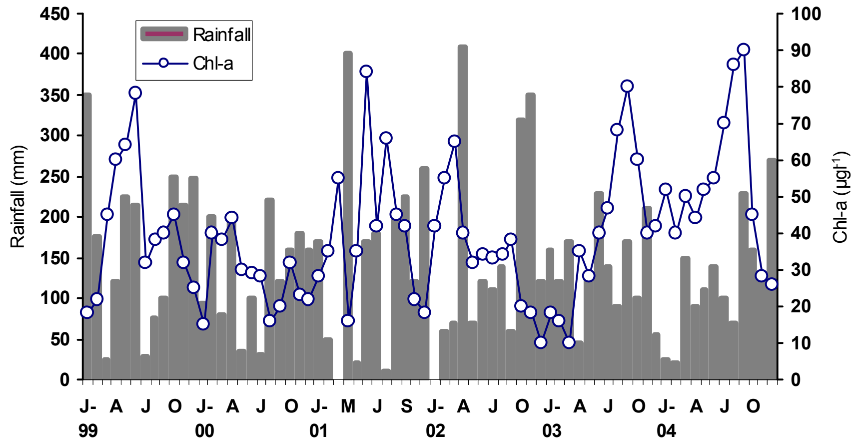

Figure 1. Monthly rainfall and chlorophyll-a (chl-a) content of Kandy Lake from 1999 to 2004

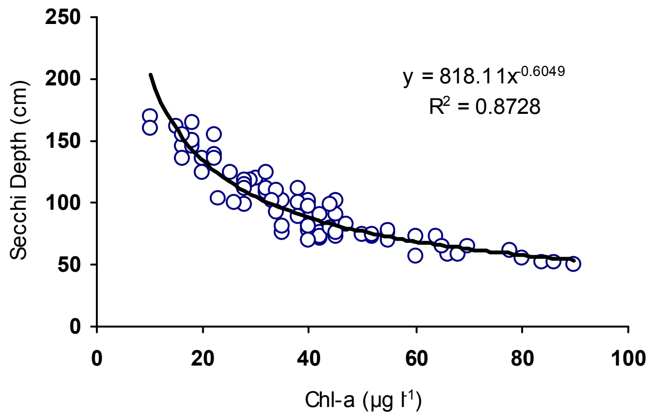

Figure 2. Chlorophyll-a versus Secchi depth in Kandy Lake

Oscillation of a diatom and a green algae may be a sign of meso-eutrophic equilibrium but progressive increase of*M. aeruginosa* exhibits a trophic shift toward hyper-eutrophication. Eutrophication, a global phenomenon usually results in the replacement of diverse phytoplankton assemblage to that of a few species with high densities (Talling and Lemoalle 1998). Although eutrophication is widespread in the humid tropics, documentation of outbreaks and aftermath are sparse. In the humid tropics as elsewhere it has been triggered by gross organic pollution. The outbreak of a cyanobacteria bloom (*M. aeruginosa*) which occurred in Kandy Lake following the dry spell in 1999, is an excellent example of trophic shift and ecosystem collapse. In non-harvesting water bodies with poor grazing efficiency, concurrent ichthyo-eutrophication is very likely to accelerate due to accumulation of fish excreta. Apparently, the sudden emergence of scum forming algal blooms in the humid tropics is necessarily not a time series phenomenon. It may appear unexpectedly when apt hydraulic balance is coupled with favourable environmental variables.

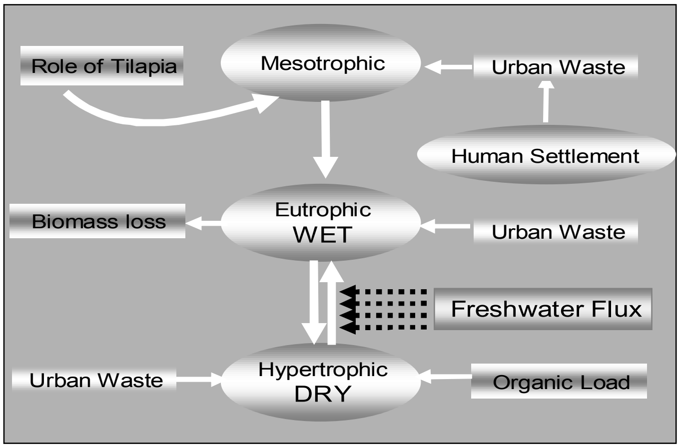

Figure 3. Schematic diagram depicting trophic evolution and eutrophic-hepertrohic alteration in Kandy Lake

Although the lake was hyper-trophic following the *Microcystis* outbreak, the lake's trophy declined dramatically reaching even the lower level of eutrophy during succeeding monsoonal and inter-monsoonal rains (Figure 1). Under this condition, species composition of phytoplankton assemblage shifted slightly with more individuals of diatom, particularly *A. ganualata.* Density of phytoplankton and in turn chl-a content also decreased while increasing water clarity in terms of Secchi depth (Figure 2). Decrease in chl-a content, and increased water clarity may be attributed primarily to dilution and biomass loss via flow-through whereas shift in phytoplankton taxa is essentially a result of the changes in hydro-chemical environment. Diatoms grow lavishly when dissolved silica concentration is high while non-nitrogen fixing cyanobacteria become more abundant under high nitrogen concentration. In the present context, several factors are accountable for existing hypertrophic-eutrophic alternation in Kandy Lake as is depicted in Figure 3. Increasing human settlements, which are not connected to a central sewerage disposal system, could make direct or indirect contributions to the nutrient pool. The droppings of resident populations of tree dwelling fruit bats, roosting cormorants, visiting birds and fall out from trees are allochthonous organic sources. Peculiar feeding and nest building behaviour of cichlid fish which stir bottom sediments may mobilize sediment-bound phosphorus from the shallow areas. Enrichment of the lake by these processes over the years has resulted in the Kandy Lake gradually becoming eutrophic. The lake became hypertrophic with the outbreak of a *Microcystis* bloom in 1999 and never reversed back to a mesotrophic condition. However, the volume of rainwater brought in with the onset of the southwest monsoon (April-May), as well as during the second inter-monsoon (October-November) may be high due to high rainfall events and this may be the primary determinant that reverses hypertrophic condition back to eutrophic level. Nevertheless regular organic loading and other environmental variables could drive it towards hyper eutrphication under dry weather of this aesthetic urban water body (Figure 3) which has not been subjected to appropriate mitigation measures yet.

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