Ecosystem modeling of the Vembanad Lake (Cochin backwaters)

K. K. Balachandran
Regional Centre, National Institute of Oceanography, Dr. Salim Ali Road, Kochi
(*email: kkbala@nio.org*)

The progressive deterioration of many of the Indian estuaries caused by anthropogenic activities is of concent because, these areas have never been considered as primary targets of conservation. The Vembanad Lake (Cochin backwaters) is an example of such disastrous management, which has lost nearly 40% area to human invasion. Considering the large human dimensions of the region (4000 persons km^{-2} and economic value Rs.300 crores yr^{-1}), there is an immediate need to protect the system, keeping pace with developmental activities.

Evidence of long-term anthropogenic impacts

The human intervention in the Vembanad Lake started as early as 1888, when the *Kol* wetlands of the southern parts were reclaimed for agriculture. Subsequent developments were (i) Harbour and Wellington Island during 1920-36 (ii) Industries in the north estuary in 1940 (iii) Intense reclamations and human settlement since 1940s (iv) Changing land use patterns since 1976 and (v) Hydraulic barriers during 1976-82. All these anthropogenic activities have lead to pollution and declining bio-resources of the estuary. The exchange volume of the estuary has also reduced from 125 Mm^3/tidal cycle during 1960 to 35 Mm^3/tidal cycle during 1985. The eutrophication imposed severe stress on grazing organisms (zooplankton) and ultimately has resulted in the disappearance of many endemic species of fishes from the estuary.

Environmental setting

The Vembanad Lake is ox-bow shaped (area 256 km^2 and volume 0.55 km^3) with six rivers flowing into it from a drainage area of 12,000 km^2. The annual rainfall over the region is 3200 mm that brings in approximately 20,000 Mm^3 of fresh water into the estuary. The monsoon-fed rivers are generally short, steep and fast–flowing.

Propagation of tides and salinity intrusion

The tides are mixed semi-diurnal (M_2 velocity 3 m s^{-1}) and their propagation is modified inside the estuary due to the complex topography, thus creating different hydrologic zones. The lake is generally ebb-dominated and tides propagate up to 60 km inside where the amplitude is about 20 cm. During pre-monsoon, the seawater reaches the head of the estuary (Alleppey), but is restricted to 25 km during monsoon. It behaves like a partially-mixed estuary during pre monsoon, but frequent rains induce strong stratification from time to time. The shallow north estuary, as it is connected to two tidal inlets, develops frequent null zones. The industrial effluents discharged through the river Periyar accumulates here, making this zone intensely polluted. The estuary is highly sensitive to meteorological events (winds and fresh water flow), which influence the stratification and flow characteristics considerably. The amplification in some of the tidal constituents towards the southern estuary indicates an asymmetry and is a cause of concern. This is because; the net movement of water has a direct bearing on the ecology of the estuary.

Water quality

The estuary receives nutrients from all tributaries apart from the industrial and domestic sewage. The nutrients exhibit tidal variation in the lower estuary, but the variations are weak in the north and south estuary. The supply of nutrients from the coastal waters is quite insignificant as compared to discharges upstream through point and non-point sources. The dominance of ammonia in the total nitrogen pool and release of phosphorus from estuarine sediments are striking. The contrasting behavior in the biogeochemistry of north and south estuaries is due to their sources and to complex hydrography. The zonal classification of the Vembanad Lake is one of the salient findings, which implies that forecasting of the Vembanad Lake requires integration of the zonal models.

Factors controlling biological productivity

The nutrients are available in surplus in the estuary, which support fairly high chlorophyll concentrations throughout the year. However, the primary productivity is not always proportional to the chlorophyll *a* concentrations, mainly because of the difference in the size and photosynthetic efficiency of phytoplankton. The zooplankton exhibits a clear seasonality with a maximum biomass during pre monsoon and minimum during other seasons. Micro-zooplankton proliferates in pre-monsoon season. It is probably this not well-studied group of organisms that provides alternate food for the carnivore meso-zooplankton. It is assumed that during other seasons when planktonic grazers are minimal, the unconsumed carbon either settles down or gets exported to the sea. This creates an important link between primary producers and their grazers involving detritus, bacteria, phytoplankton, micro and meso zooplankton and benthic production.

Status of numerical modeling

Development of an ecosystem model involves coupling of kinetics of several processes of a system including biological ones. An attempt was made to develop an ecosystem model at a test site in the Vembanad Lake. It comprises of a coupled water quality model (CWQM) where four interacting systems (DO, N, P and Phytoplankton) are represented by 8 kinetic equations. The ecosystem model was developed by including the kinetic equation for zooplankton (herbivore copepod) in the CWQM. The model considers the dynamics of nutrients, their uptake rates and preference to phytoplankton, growth-respiration-grazing-mortality of phytoplankton and assimilation by zooplankton.

The ecosystem model was found to work fairly reasonably. However, the present model needs modification to make it more comprehensive. The deviations observed in chlorophyll concentration by the model are due to several reasons. The non-linearity in the chlorophyll and primary production is due to the variable size fraction and photosynthetic efficiency of phytoplankton. The chlorophyll assimilated by different phytoplankton species and their photosynthetic efficiencies are to be included in the model. The biochemical activities of the different estuarine zones and the switch over from autotrophy to heterotrophy also must be considered separately while integrating the coupled water quality model.

The biological model for zooplankton biomass had some limitation. This is because the zooplankton is mainly represented by copepods, which constitute three groups (herbivore, omnivore and carnivore), based on their feeding behavior. The present model considered only the herbivores and therefore underestimated the zooplankton biomass. Hence, model requires modification by including kinetic terms for these groups and the rate equations of the following compartments (1) detritus (2) bacteria (3) micro zooplankton (4) copepods and (5) benthic production.

Restoration of the Vembanad Lake – a practical approach

Implementation of conservation measures of this lake using model studies requires more time during which, the system may get more polluted. Therefore, an alternative way is suggested here to revive the estuary.

- Stop further reclamation and encroachment
- Legalize 50 m wide shoreline of the lake as Govt. property
- Stop further sanction of industries around the lake
- Ensure zero effluent discharge from existing industries/agri./aquaculature
- Regulate domestic effluent discharge
- Remove all hydraulic barriers in the lake and ensure natural propagation of tides
- Ensure moderate flow through all the rivers during pre monsoon