A REVIEW ON ECOLOGICAL STATUS OF GLOBAL WETLANDS WITH A SPECIAL EMPHASIS ON WATER QUALITY AND FRESH WATER MACROPHYTES

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INTRODUCTION

Ponds, streams, rivers, reservoirs, peat bogs, grass and sedge marshes, swamps, mangroves, tidal marshes, flood plains, and paddy fields are the major types of wetlands recognized globally. Because wetlands breed mosquitoes and are sometimes barriers to the free movement of population, they have often been thought of as useless or harmful. Therefore, these wetlands have often been drained, filled, or used as dump sites. Each kind of wetland has unique qualities and serves as habitat for a variety of plants and animals. Recently, it became a big question of what to do with these natural resources which are globally available and play a vital role in the food chain and several environmental issues. These are one of the major systems which had negligible attention till recent times. Federal agencies like Environmental Protection Agency, US Fish and Wildlife, and several private agencies like Environmental Issues Forums (EIF) and Ducks Unlimited are keenly interested in preserving and managing the existing wetlands in North America specifically and globally in general. In the USA, starting from the Everglades in Florida to the southern shore of Canada, we can see a variety of wetlands. These natural resources could be thought of as transitional zones, where the characteristics of aquatic and dry land environments mix. The water levels in both saline and fresh water wetlands are subject to fluctuation and not all wetlands are natural. Most of the present day wetlands are anthropogenic in origin for human advantages. These wetlands are very good habitat for a variety of wildlife, migratory birds, specifically for waterfowl; to maintain water quality; to direct economic benefits; for education and research; to control ground water recharge; and to support a recreational and commercial activities (NAAE 1992).

The debate on wetlands is, what should we do with wetlands? The EIF answers this increasingly alarming problem and has offered some options for resolving conflict specifically dealing with wetlands of the US and Canada. According to the US Fish and Wildlife Service estimations of 1992, almost 48% (96.7% million acres) of total wetlands were lost in the lower 48 states at the time of European settlement. In 1986, USA, Canada, and Mexico signed the Ramsar Convention on Wetlands of International Importance to face the challenge on kinds of tradeoffs for conversion of wetlands. Mitigation is a strategy used in many government wetland policies. One of the main legislations of the US government is section 404 of the US Clean Water Act, which requires landowners and developers to obtain government permits for dredging and filling in wetlands. In March 1992, the Canadian government adopted the Federal Policy on Wetland Conservation. It promotes national efforts to protect wetlands and guides the management of federal lands (NAAE 1992).

The Environmental Protection Agency and Corps of Engineers define wetlands as: "Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."

Ecologically, wetlands are complex systems and represent extremely important natural resources. The goal of this paper is to compare the status of wetlands by physical and chemical parameters in two different geographic locations. Being low lying areas, most of them serve as sinks for receiving nutrients and sediments from the drainage basin and are often looked upon as wastelands. However, several wetlands are utilized as a direct resource for plant materials like reed etc., for fish or used for the cultivation of edible plants like Trapa and/or deep water rice. In some pockets of the north-eastern region of India, the wetlands are believed to play an important role in the maintenance and survival of the local people. The importance of detritus derived from marshes in the aquatic food chains is well known and needs no over emphasis.

CHEMISTRY OF WETLANDS

Water's unique temperature-density relationship results in the formation of distinct layers within nonflowing bodies of water. During the summer, a surface layer (epilimnion) is heated by solar radiation and because of its lower density, floats upon the bottom layer (hypolimnion). The epilimnion, which is exposed to light, may have a heavy growth of algae and contains relatively higher levels of dissolved oxygen and generally is aerobic. In the hypolimnion, consumption of oxygen by bacterial action on biodegradable organic material may cause the water to become anaerobic. As a consequence, chemical species in a relatively reduced form tend to predominate in the hypolimnion. Many aquatic chemical processes are influenced by the action of algae and bacteria in water. Algal photosynthesis fixes inorganic carbon from HCO_3^- ion in the form of biomass $\{CH_2O\}$ in a process that also produces carbonate ion CO_3^{-2}. Carbonate undergoes an acid-base reaction to produce OH^- ion and raise the pH; or it reacts with Ca^{+2} ion to precipitate solid $CaCO_3$. Most of the oxidation-reduction reactions that occur in water are mediated by bacteria. Bacteria convert inorganic nitrogen largely to ammonium ion NH_4^+ in the oxygen deficient lower layers of water body. Near the surface, bacteria convert inorganic nitrogen to nitrate ion (NO_3^-). Metals in water may be bound to organic chelating agents, such as pollutant nitrilotriacetic acid (NTA) or naturally occurring fulvic acid. Gases are exchanged with the atmosphere, and various solutes are exchanged between water and sediments in the water bodies. Gas solubility is another important characteristic feature of unpolluted waters since it is required to support aquatic life and maintain water quality. Oxygen is the most important dissolved gas in water. Water alkalinity is the ability of solutes in water to neutralize added strong acid. Water hardness is due to the presence of calcium and magnesium ions.

$$2HCO_3^- + h\nu \text{ ----> } \{CH_2O\} + O_2 + CO_3^{-2} \text{ (Photosynthesis)}$$

$$Ca^{+2} + CO_3^{-2} \text{ -----> } CaCO_3 \text{ (Precipitation)}$$

$$2\{CH_2O\} + SO_4^{-2} + 2H^+ \text{ ---> } H_2S + 2H_2O + 2CO_2 \text{ (Microbial action)}$$

PROBLEMS RELATED TO WETLANDS

Scientists have identified a variety of problems related to wetlands all over the globe. They also emphasized the causative agents for these problems. Some of the most serious problems that directly affect the chemistry of wetland ecosystems are: municipal pollution (depletion of dissolved oxygen, fish and other aquatic life, mortality, higher biochemical oxygen demand, higher nutrient concentrations, high turbidity and suspended solids); toxics (adverse impact on human health by metals like mercury, cadmium, iron, boron, lead etc.); pesticides (contaminate water, fish tissue, plankton, and sediments); eutrophication (stimulate the growth of algae mats and aquatic weeds, affect fish populations and recreational water uses); and conversion of wetlands for agriculture, housing, and industrial sites which causes loss of natural habitat for fish, birds, and other biota. Eutrophication is more in lakes, estuaries fed by rivers, ponds, and reservoirs, rather than in the rivers themselves, where velocities of flow reduce the adverse effects.

STATUS

A perusal of the available information on the Indian fresh water wetlands reveals that most of the investigators have laid emphasis on the study of physico-chemical factors and the biota with little stress on the functioning of the ecosystems.

A. Physico-chemical Factors

Physical factors like temperature, depth, humidity, and rain fall, and chemical factors such as pH, dissolved oxygen, total alkalinity, carbonates, bicarbonates, chlorides, and major and minor nutrients which are known to influence the biota have been studied extensively.

Detailed information is available on the temperature variation in most of the water bodies. A wide range of fluctuation has been recorded in different aquatic bodies by several scientists. Ganapathi (1955) reported that the temperature of rock pools at Mettur dam showed a diurnal fluctuation reaching the maximum 28.6^{0}C by 2 P.M. Verma (1967) reported the diurnal fluctuation in temperature is inversely proportional to the dissolved oxygen concentration. Rao (1971) observed that the mean surface water temperatures in different ponds in the same locality showed a variation ranging up to 2.3^{0}C and attributed this to the volume of water present in different situations.

Hydrogen ion concentration plays an important role in aquatic ecosystems. The pH of most of the fresh water bodies in India was found to vary between 5.0 - 10.5. Ganapathi (1940) reported a pH of 9.7 for the temple tank in Tamil Nadu. Hussainy (1967) observed that the amplitude of variation in pH was higher at the surface waters than at the bottom layers at Vihar lake, Bombay. Sreenivasan (1965) also reported a vertical variation in the range of pH of Amaravathi reservoir. George (1961) reported a correlation between pH and carbonates. Ganapathi (1940) showed that the chloride concentration in temple tanks of Tami Nadu ranged between 40.2 - 63.6 ppm during different seasons. Gonzelves and Joshi (1946) reported the chloride concentration increases in summer when the water level is low. Sreenivasan (1965) and Hussainy (1967) have reported very low concentrations of chloride in Amaravathi reservoir and Vihar lake (4 and 16 ppm respectively), while much higher concentrations (114-164 ppm) were reported by Grover et al. (1978) in fish ponds of Ludhiana and by Sreenivasan et al. (1973) in Tamaraikulam pond (88-308 ppm). Zutshi and Vass (1971) recorded a reduction in chloride concentration in Dal lake covered by Salvinia mats. Ganapathi (1940) observed that the total hardness of several temple tanks of south India varies between 4-8 ppm, while according to Hussainy, (1967) it varies from 47.0-62.5 ppm in Vihar lake. Kaul (1977) and Sharma et al. (1978) found the calcium content of the pond waters in different parts of the country varies from 8-40 ppm with lowest values during December. Information on the dissolved oxygen concentration of the various wetlands reveal a wide fluctuation in its range. George (1961) reported a fluctuation in dissolved oxygen of a fish pond at Delhi ranging between 0.1-28.2 ppm, while Verma (1967) reported a range of 4-10 ppm in Seioni fish pond. Ganapathi (1940) and Rao (1955) have observed that low concentrations of dissolved oxygen in water is associated with abundance in cyanophycean populations. Sreenivasan et al. (1973) opined that the fluctuation in the dissolved oxygen is due to the photosynthetic and tropholytic action of the phytoplankton. Rao (1977) reported an inverse relationship between dissolved oxygen and dissolved organic matter.

B. Phytoplankton

Many investigators have studied the diurnal and seasonal variations in the phytoplankton counts of several water bodies. Cyanophycean populations were found to be abundant in several ponds. However, Indira (1964) observed that the chlorophycean members are predominant in Nuggikari lake. Sitaramaiah (1966) recorded blooms of Microcystis during the winter months for a pond in Tirupathi. Zafar (1967) opined that chlorococcales are abundant in surface waters during early summer and monsoon when temperatures are high at the fish ponds in Hyderabad. He further observed that desmids are sensitive to calcium and disappear when the calcium concentration of water rose to more than 2 ppm. Krishnamoorthy and Visweswara (1965) observed the peak phytoplankton concentration in June at Gandhisagar. Vyas and Kumar (1968) who observed a luxuriant growth of cyanophycean members in Indrasagar tank attributed the same to the fluctuations of the water level, changes in pH, and visibility. He observed that the green algae are dominant during rainy and winter seasons and blue green algae during summer. Michael (1969) reported that the seasonal maxima in the periodicity of the different plankton is perhaps due to their optimal thermal requirements. Ganapathi (1940) observed that low concentrations of dissolved oxygen in waters are associated with the abundance of cyanophycean populations. Seenayya (1972) states that polluted waters harbor comparatively smaller populations of diatoms in spite of the fact that they are rich in organic matter, phosphorus, and inorganic carbon. He also opined that blue green algae showed thick growth in ponds with high nitrogen and pH (around 9.0).

The productivity of phytoplankton of the various water bodies in India ranged from zero to 97.50 g O_2 m^{-2} day^{-1}. The lowest productivity rates (0.036 g C m^{-2} day^{-1}) were observed at Ramgarh lake (Gopal et al. 1978) followed by Bhimtal and Nainital lakes in Utter Pradesh (Pande and Singh 1978). Kannan and Job (1980) observed higher production rates at the surface waters of Sathior reservoir except in the months of December and January and concluded that nutrients are not limiting for the gross primary production of Sathior. A bimodal fluctuation in the primary production was observed by Sumitra (1971) in Teppakulam tank and Nasar (1978) in sewage fed ponds in Bhagalpur. The photosynthetic efficiency of the inland water bodies was reported to vary from 0.17 % in south Indian lakes (Ganapathi 1972) to 13.80 % in a sewage pond in Ahmadabad (Jayangoudar et al. 1970).

C. Biomass of Macrophytes

The species composition of the wetlands is obviously a result of the interaction of biotic and abiotic variables, competitive relations, grazing, and changes in the physico-chemical environmental complex. Thus the species composition of various wetlands vary considerably with greater diversity of species in areas which are less polluted. The dominant macrophyte species differ markedly for the different wetlands. Eicchornia crassipes is a dominant species of Hussainsagar where a considerable amount of domestic and industrial sewage is let in. Lake Doodadri is dominated by Najas minor occupying 78% of the total lake bed (Unni 1971) and lake Kondakarla with Najas graminea and H. verticillata (Murty 1987). The earlier literature regarding macrophyte production of the Indian wetlands reveals that they received very little attention when compared to the information available from the temperate zones (Gopal et al. 1978). Gopal et al. (1978) noticed a biomass as high as 2067 g DM m^{-2} for the same species at Jaipur. Kaul et al. (1978) studied the productivity of H. verticillata and Najas spp. in the lakes of Kashmir. They also observed that in Dal and Anchor lakes Ceratophyllum spp., Myriophyllum spp., and Potamogeton lucens are the important species contributing towards the total biomass production among the submersed species, though the total production of the submersed macrophytes was found to be low compared to other life forms. Based on their findings, they inferred that mean annual net productivity was highest in Nelumbium spp. followed by Trapa natans, Nymphaea alba, N. stellata, Potamogeton natans, Hydrocharis spp., and Nymphoides peltata. They have shown that the tall growing and emergent plants are highly productive of all aquatic plant groups. The dry matter production of these plants varied between 4.25 - 19.71 g DM m^{-2} day^{-1}. They recorded highest productivity values from Typha angustata and Phragmites communis.

D. Nutrient Accumulation by Macrophytes

Information on nutrient accumulation by different macrophytes in aquatic ecosystems of India is scanty. The investigations of Gupta and Lamba (1973), Kaul et al. (1980), Trivedy and Gopal (1981), Gopal and Sharma (1981), Trivedy (1983), and Goel et al. (1985) provide valuable information to our knowledge on the nutrient uptake of the various aquatic macrophytes. Comparing the mineral removal potential of various macrophytic zones of Kashmir lakes, Kaul et al. (1980) reported that emergents are unique in removing a bulk of the nutrients. Kaul et al. (1980) reported a range of 0.95 - 3.02% for nitrogen, 0.014 - 0.262% for phosphorus, 1.06 - 2.54% for calcium, and 0.48 - 0.66% for magnesium in several macrophytes of lakes in Kashmir. They also reported the rooted floating types have lower concentrations of calcium compared to submersed forms. Goel et al. (1985) opined that the accumulation of nutrients depends mainly on the initial concentration of the nutrients in water, period of growth, and plant parts. They reported that the calcium accumulates more in rhizome, magnesium in roots, and nitrogen in leaves. Murty (1987) reported highest mean concentrations of nitrogen, calcium, sodium, and potassium in H. verticillata, phosphorus in Nymphaea nouchali (leaf), and magnesium in N. graminea at lake Kondakarla.

E. Nutrient Release

The available literature related to nutrient release and decomposition of aquatic macrophytes on Indian wetlands is very limited. Investigations of Sardana and Mehrotra (1981), Kulshreshtha and Gopal (1982 a & b), Sharma and Gopal (1982), and Sharma and Goel (1986) are valuable contributions in this direction. Kulshreshtha and Gopal (1982) consider that temperature and oxygen are the most important factors during the process of decomposition. They reported that more than 50% of sodium and potassium were lost within the first four days, and up to 90% was lost by the sixtieth day, while nitrogen and phosphorus released slowly. They also reported a rapid decomposition of above ground parts along with a rapid loss of nutrients by leaching and microbial activities in and around Jaipur. Murty (1987) studied the nutrient release in eight aquatic weeds (H. verticillata, N. graminea, N. nouchali, Nymphoides indica, Pseudoraphis spinescens, Neptunia oleracea, Ipomoea aquatica, and Ludwigea adscendens) of lake Kondakarla under in-situ and in-vivo conditions. His studies revealed that the elemental loss varied between the species during the period of decomposition under field and laboratory conditions. Among the eight macrophytes studied, either phosphorus or potassium was lost first from the decomposed tissues, while nitrogen released at a very slow rate. The elemental loss in most of the macrophytes showed the following sequence: P > K > Na > Mg > Ca > N.

TECHNOLOGY vs. WETLANDS

Until the advent of affordable Global Positioning Systems (GPS) technology, accurate positioning on lakes was limited to fixed-location control points surveyed from a known location on shore. Detailed, accurate, and cost effective surveys were difficult to conduct. The US Geological Survey, in cooperation with the NASA National Science and Technology Laboratory, is using GPS technology to solve positioning problems related to lakes (Baskin 1992). GPS enables one to enter coordinates obtained from imageries and conversion of aircraft navigation data into GPS which finally gives the specifics of the anomaly of a given wetland. Another advanced technology is multispectral videography which could be used to survey wetland not only for topographical but also for the most sensitive data to iron ion content and pH of the water bodies by analyzing the yellow-green video band. Water turbidity analysis using spectral digital data depends on the ability of multispectral bands to penetrate into a water body (Repic et al. 1991). Koeln (1992) narrated in detail about wetlands (Pearl Lake of North Dakota, Old Wives Lake of Saskatchewan based on Landsat TM images). Geographic Information Systems (GIS) takes data and compiles it geographically in layers. The information in the GIS includes land use, land ownership, hydrology, water quality, socioeconomic data, roads, streams, drainage, ecology, agriculture, elevation, property, soil type(s), and the locations of rare and endangered species and unique habitats. These data, once compiled in the computer, can be analyzed to determine a strategy for landscape restoration.

CONCLUSIONS

The available information on the ecology of fresh water wetlands reveals that primary production is one of the most commonly studied aspects. However, even most of these studies are confined to above ground biomass, with little information on the below ground accumulation and storage. Very few studies refer to the various factors that limit primary production. Though most of the wetlands serve as depositional systems, receiving drainage and sediments from various sources, very little information is available on their sediment chemistry and nutrient dynamics. The decomposer components of the Indian wetlands have not received adequate attention. Literature on the effect of various human activities either directly in the wetland ecosystem or in their catchment area is very scarce and inadequate for any meaningful conclusions. The large scale and long term application of waste waters and agricultural run-off into the wetlands is bound to result in cases of nutrient toxicity and noxious growths of aquatic weeds, causing numerous problems. However, wetlands will become attractive and important if they can be used as permanent nutrient sinks. This can only be achieved by removing nutrients from the system at the end of each growing season by harvesting the large biomass of vegetation that is capable of accumulating heavy doses of nitrogen and phosphorus. It is essential that the different macrophytes are examined in this direction to identify the promising species. The need for more detailed studies on Indian wetlands, their management, and conservation has been emphasized by several environmentalists. After reviewing the then existing situation of the wetlands at the International Wetlands Conferences in 1988 and 1992, a series of recommendations have been made for their improvement, conservation, and management. It will be beneficial to follow up these recommendations and assess the progress made in this direction.

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