WETLANDS
Ecology and Management

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INTRODUCTION

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Wetlands mean different things to different people. To some they are stretches of waterlogged wastelands that harbour pests and diseases, and should therefore be drained or filled in order to make better use of the area. To others, wetlands are beautiful serene landscapes, usually associated with open waters, and serve as important habitats for waterfowl, fish and other wildlife. Ecologically wetlands may be viewed as more important ecosystems, transitional between open water and terrestrial ecosystems, endowed with specific structural and functional attributes, and performing major ecological roles in the biosphere. The main difficulty in recognising the true value of wetlands arises from its definition. An all-inclusive definition treating wetlands as "areas of submerged or water-saturated lands, both natural and man-made, permanent or temporary, freshwater or marine," recognises peat bogs, grass and sedge marshes, swamps, mangroves, tidal marshes, flood plains, shallow ponds and littoral areas of larger water bodies, and paddy fields as wetlands. Cowardin *et al.* (1979) have proposed a definition which widens the scope further.

Until recently the wetlands received little attention beyond their recognition as important waterfowl habitats for which a wetland convention was adopted in 1971 (IUCN 1971). As early as 1957, Teal (1957) and H. T. Odum (1957) had demonstrated the importance of detritus derived from marsh plants in the aquatic food chains. While the salt marshes continued to be investigated later, freshwater wetlands, other than peat bogs, were rarely studied. During the International Biological Programme, freshwater wetlands dominated by herbaceous vegetation alone received some attention. More recently the forested freshwater wetlands have been studied in the USA. However, the wetlands in most parts of the world remain poorly known and there have been few attempts to synthesise the present day information (Good *et al.* 1978, Greeson *et al.* 1980, Kvet *et al.* 1982, Lugo *et al.* 1982. This volume resulting from an International Conference held in New Delhi, is an attempt to evaluate the present state of knowledge, identify gaps, recommend areas for further investigation, and hopefully to develop guidelines for conservation and management.

The papers included in this volume reflect fairly well the present state of knowledge, often at a quite primitive level, about wetlands of different kinds. Wetlands occur in almost all climatic regions ranging from glaciated north to the arid and semi-arid tropics. They differ widely in their biotic as well as abiotic structure. Human activities, such as earth removal, storage of water and irrigation, have resulted in creation of wetland habitats in several arid regions and elsewhere. Very little is known about the geological characteristics of the areas that result in different kinds of wetlands. In most parts of the world the natural wetlands are under increasingly greater human impact (draining, filling, dredging, hunting, etc.) for variety of socio-economic, aesthetic, and other reasons. Peat bogs and the mangroves have been studied in relatively more detail, but the tropical flood plains and marshes have hardly ever been investigated (except some ongoing work in Amazonia).

Wetlands as ecosystems are parts of wide regional landscapes and are coupled with various other kinds of systems. The water regime is the major driving force that

regulates wetland structure and processes, and therefore, hydrological studies are of greatest importance. The amount, distribution and frequency of water movement influence wetland hydrology. The frequency and duration of flooding affect seed germination and seedling growth ; physical turbulence influences sediment particle size, deposition and resuspension. Water carries pollutants, gases, nurtients, sediments and organic matter into, through, and away from wetlands, affecting wetland structure and function. Aerobic and anaerobic soil zones, wetland harvests, drinking water quality, and downstream flood potential are influenced by hydrologic regimes. Hydrology of marsh-ridden areas was the subject of a conference in 1972 (Unesco-IAHS 1975), but very little is yet known of the wetland hydrology in even temperate areas, and almost nothing in tropical and subtropical regions. Two important areas of wetland hydrology have produced conflicting results : whether the wetlands help recharge groundwater or not, and do the evapotranspirational losses increase or decrease by the presence of wetland vegetation ?

The present studies show that the wetlands are depositional systems receiving nutrients and sediments from the drainage basin. Both the deposition of sediments and organic matter, and the input of nutrients influence the plant and animal populations, their production, mineral cycling and decomposition. The chemistry of wetland sediments is among the most important factors affecting plant production. However, sediment chemistry and nutrient dynamics of wetlands are among the least understood areas.

Primary production in wetlands has been one of the most commonly investigated subject and appreciable data exist on various temperate wetlands. Such studies in tropical regions are relatively few and are confined to herbaceous wetlands. These data reveal that wetlands are among the most productive ecosystems of the world. However, these studies deal mostly with aboveground organs. Methodological problems, as in other ecosystems, have resulted in very few reliable estimates of belowground production. The available data however indicate that the belowground storage of primary production may be five or more times greater than aboveground storage, and therefore, it can be significant in controlling the ecosystem structure and functions. Studies on factors limiting primary production are also few. Among the important factors recognised to influence the rate and magnitude of primary production are : hydrological characteristics, substrate anaerobiosis, soil phytotoxins, root oxygen deficiencies, salinity, light, temperature, nutrient deficiencies (macro and micro), inter-and intra-specific interactions, herbivory, pathogens, allelopathy, and rhizosphere organisms.

Associated with the primary producers is the study of changes in their species composition which results from the interaction of the biotic and abiotic variables, competitive relations, grazing, and changes in physico-chemical environmental complex. Wetlands have generally been treated as seral communities intermediate between terrestrial and open water. This Clementsian view has long been questioned. It is shown that the species assemblage present at a particular moment may be the result of natural processes, although driving forces are often anthropogenic in origin. Recent publications have tried to explain the wetland changes utilising the Gleasonian approach which emphasises the specific life history characteristics of constituent species (van der Valk 1981) ; even wetlands have been considered as stable systems (Lugo 1980).

The studies on salt marshes had demonstrated that most of the primary production enters the detritus pathway and very little is grazed upon (Teal 1962). Most of the later wetland studies on the fate of energy fixed by primary producers emphasised

the detritus component but the consumer organisms were largely ignored. Wetland consumers would include all those animals that live or visit wetlands and are dependent on wetland habitats for food, refuge, or breeding sites. But for the waterfowl, other organisms as mammals, reptiles, fish, invertebrates have not been investigated in detail. Some of these organisms are important disease vectors and it is necessary to understand their interactions with wetlands.

The decomposer component of the wetland ecosystems is also not well understood. There are few quantitative studies of decomposer organisms and their role in nutrient cycling. The decomposition process has received some attention but mostly in salt marshes. Decomposition studies in tropics and subtropics are almost non-existent and some of the papers included in this volume are among the first reports from these regions. Decomposition refers to the breakdown of all organic materials of plant, animal and microbial origin, involving leaching, comminution, humification, and mineralisation processes. The course of decomposition differs among wetland ecosystems and individual compartments of the same system depending upon the nature of available organic substrates, the hydrological, physical and chemical characteristics of the system, and the dominant decomposer organisms. The character and quantity of the organic matter may vary among different wetland ecosystems. The organic substrates can be characterised for various systems in terms of (1) source (autochthonous, allochthonous) ; (2) genesis (animal derivatives, litter, exudates, microorganisms) ; (3) composition (chemical and physical), (4) quantity (accumulated store, input rates) ; and (5) location (above or below ground, submerged, floating, incorporated with sediments). The decomposition studies are also associated with the problems of methodology. In general, the litter bag technique used in terrestrial studies, has been employed. In most studies, changes in the nutritive value of the detritus, resulting from microbial immobilisation of nitrogen, have been reported. These observations may constitute some important considerations in wetland management, and need to be elaborated further.

One of the most neglected areas of research has been the influence of various human activities, both in the wetlands and in their upstream regions, on the structure and function of wetlands and consequent changes in the downstream open water systems associated with the wetlands. Activities like vegetation removal, channelization, filling, construction of canals, weirs, levees, etc. would affect the hydrological regime, sediment characteristics and several biotic components. Major upstream changes as overgrazing and deforestation, result in hydrological changes, increased inputs of sediments and nutrients, etc. The upstream activities may also bring pollutants (orgainc and inorganic substances, industrial wastes, pesticides, etc.) which may accumulate in the wetland sediments or vegetation and result in unpredictable effects. The studies indicate that the wetland plants accumulate large quantities of certain nutrients through luxury consumption. While the possibility of using wetlands for secondary and tertiary treatment of wastes due to these characteristics has been demonstrated in some cases, it is equally possible that these nutrients and pollutants would result in other undesirable changes in the wetland ecosystems.

The wetlands are used in different societies for different needs, ranging from drainage and clearing for putting land to other uses (roads, agriculture, settlements) to direct use of wetland resources (plant materials like reeds, cattails; fish and other animals). In many parts of the tropics, wetland areas are cultivated for production of edible plants (*Trapa*, *Euryale*, *Nelumbo*), including the widespread deepwater rice agriculture. However, the ecological values of natural wetlands are not properly realised.

Studies in the United States have shown that wetlands may have several values such as: groundwater recharge and maintenance of water quality ; dependence of agriculture and animal husbandry in drought prone areas, conservation of rare and endangered species (resident or migratory), pollution abatement (as waste treatment), flood control, biofertilisers and nitrogen fixation, etc. Besides, wetlands have other cultural and aesthetic values. Conservation and management of natural wetlands has been advocated for various wetland values in temperate regions, but so far no effort has been made in this direction in the tropics and subtropics. The main difficulty of conservation and management lies for the fact that we do not have an inventory of different kinds of wetlands and the uses to which they are being currently subjected. In fact, there is as yet no universally acceptable definition and classification system of wetlands. The most comprehensive system to date is that of Cowardin *et al.* (1979) which has not yet been tested elsewhere, and may not be applicable to tropical regions. This weakness was recognised at the first international workshop on wetlands dynamics organised by SCOPE and UNEP in USSR (July 1981). Still more important is the assessment of wetland values in different regions. Some assessment methodology is being developed in the USA, but the techniques to be employed in tropical and subtropical regions, particularly the developing countries, need to integrate the socio-cultural, ecological and economic values of wetlands. This further emphasises the total lack of knowledge about the wetland resources, their ecology and use. The first Conference organised by INTECOL, thus helped in identification of the gaps in knowledge and recommendation of a number of specific areas for further investigation. These are presented in detail in the report of the conference published separately (Turner and Gopal 1981), and some important recommendations are listed below :

(1) The wetland definition given by Cowardin *et al.* (1979) may be accepted for the present, and their classification system must be re-evaluated and tested for its applicability in other areas, particularly in the tropics and subtropics.

(2) As a first step for identifying the needs for conservation and management, and for providing practical guidelines for it, inventories of wetlands in different countries should be prepared. The inventories should include information about different uses of wetlands in various countries.

(3) Techniques should be developed for assessment of wetland values, which should include sociological and economic components in addition to biological, ecological and environmental values.

(4) Data are needed to establish threshold criteria or critical zones for the function and utility of wetlands for various values. The threshold criteria refer to size, shape and locations ; for example the minimum vegetation area to provide botanical protection, waterfowl breeding or effective flood control.

(5) Wetlands should be treated as ecosystem units in the entire catchment area as the landuse management in the whole area is relevant to long-term management of the wetland part.

(6) The wetland research should emphasise the ecosystem approach since numerous properties of systems that arise from interactions of components, cannot be predicted from the present knowledge.

(7) The studies on hydrology, sediment chemistry and nutrient dynamics should in particular emphasise : the effect of changes in hydrological regimes on wetland structure and function, geologic characteristics resulting in groundwater recharge

and discharge, effects of wetland vegetation on evapotranspiration, impact of upstream changes on hydrological regimes and sediment characteristics of wetlands, effects of wetland manipulations on downstream ecosystems, sediment budgets and input patterns, various factors and processes affecting nutrient dynamics, and the fate of pollutants in wetlands.

(8) More studies on the rates and magnitude of primary production are required in tropical and subtropical regions. Further, the global patterns of wetland primary production should be classified and mapped. There is urgent need to understand the factors limiting primary production, especially the factors related to sediment and water characteristics. Ecology of constituent species needs to be studied to understand the possible changes in vegetation with time under natural and man-caused disturbances.

(9) The role of various consumer organisms, such as the effect of herbivory on community structure, and the ecology of various consumers, should be investigated in relation to community structure and energy flow.

(10) The studies on decomposer system should focus on quantitative and qualitative measurements of organisms involved, and must be related to morphological, physical, chemical and biological properties of wetlands.

(11) Standardisation of methodology is required in all areas of wetland ecosystems, more particularly for the studies of hydrology, primary production and decomposition (incl. utilisation) of belowground parts, and wetland survey and inventorisation.

(12) In view of the widespread anthropogenic changes in wetlands, it is important to make use of studies in pristine or unmodified systems which serve as controls. Since the studies on long-term impacts of human activities are particularly lacking, it is desirable to include an experimentally oriented scientific input in the management of some wetlands. As far as possible, attempts should be made for a time series study with replicated control and experimental systems having pre-manipulation, manipulation, and post-manipulation measurements of all parameters.

(13) There is great need for international cooperation and collaboration for research, and training of personnel. Research projects in important wetland areas can benefit from multi-national collaboration where training of local scientists can be easily integrated.

(14) There is a general need to establish wetland committees at the national level along the lines of UNESCO mangrove committees.

We hope that the international organisations like UNESCO, UNEP, SCOPE, IUCN and INTECOL would contribute to joint efforts in promoting wetland research on which better management and conservation can be based.

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