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Wetland ecosystems: an appraisal

Oekosysteme der Feuchtgebiete: Eine Bewertung

by

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1. INTRODUCTION

Wetlands are ecosystems 'sitting on the fence' between the land and open water systems. They include a very wide range of habitats from the northern temperate bogs to fens, marshes, swamps and floodplains to tropical mangroves. They also include salt marshes, shallow water bodies, littoral regions of lager water bodies, and even the shallow coastal marine areas (IUCN 1971). They are often looked upon as a part of either land or open water systems with which they are associated. Terms like "reedy lakes" and "flooded forests" have been used for some wetlands. Such an approach has underestimated their specific characteristics and values. Wetlands have been called stress ecosystems and are considered as transient or seral in nature which would mean that they are not stable systems. They are considered to be among the most productive systems and their ability to upgrade wastewater effluents is currently the most important area of research (WHIGHAM 1982). They are well known for their value as habitats for waterfowl. Several other values are attached to the wetlands (LARSON 1982). During the past few years there has been increasingly greater interest in the wetland ecosystems. Only a few months ago, the IUCN and WWF jointly launched the International Year of Wetlands. Intensive national and international efforts are being made to conserve them. Undoubtedly, the wetland habitats have been in the past and are even today of crucial importance to man. But we do not understand these ecosystems sufficiently well in order to appreciate their functioning and values. Several questions concerning their productivity, diversity, energetics, nutrient dynamics, responses to perturbations and stability have found not clear answer as yet. Many areas have a great potential for contributing to the ecological theory as well. I wish to raise and briefly discuss some of these questions in the hope of stimulating discussion.

2. NATURAL VS. MAN-MADE WETLANDS

There is much concern today about the loss of wetlands by different human activities. True, the flooplains are nearly all lost. Man has regulated rivers and streams and changed the hydrological regimes by construction of dams. Human activities upstream have caused excessive silting of waterbodies downstream and changed the nature of wetlands. Many marshes are drained, others are filled in with wastes and earth to reclaim land. Peat is excavated for fuel and horticultural purposes. Bogs are reclaimed for more productive uses. But we forget the large number of new wetlands created by man. In some cases the wetlands have been modified to create a different kind of ecosystem, for example from a marsh to fishpond or rice field. The bird sanctuary at Bharatpur (India), well-known for providing overwintering grounds for the Siberian Cranes, was created out of a former floodplain. The large littoral wetland areas around reservoirs are created at the expense of modifications in the floodplains. How do these man-made wetlands differ from the natural ones in their functions and values to man? There is hardly any study on the impact of these modifications to evaluate the relative importance of modified wetlands vis-a-vis natural wetlands. In absence of proper understanding of the basic ecology of different kinds of wetlands, such an evaluation is indeed difficult.

3. WETLANDS AS STRESS ENVIRONMENTS

There is one thing common to all wetlands: their hydrological environment. The hydrological regimes are such that the soils are waterlogged for at least a part of the year (usually the growing season), and the water level fluctuates to a small or large extent. Waterlogging of the soils implies that the plant community is subject to lowered oxygen levels in their root zone. The hypoxic and often anoxic conditions result in reduction reactions leading to elimination of certain nutrients like nitrogen and sulphur or production of certain toxic substances (PONNAMPERUMA 1984). Further, the slower decomposition rates in oxygen deficient environment result in accumulation of organic matter which is often transported to open water systems.

The periodic flooding of the soils and attendant physico-chemical changes are generally considered either as a stress factor (see THOMPSON

Table 1. Primary production of major wetland pland communites
Tab. 1. Primärproduktion der Hauptpflanzengesellschaften von Nassstandorten

Plant community	Production t/ha
Sphagnum mosses	1 - 4
Calluna heath	6 - 9
Sedge marsh	5 - 20
Reeds and cattail marshes	15 - 40
Temperate conifer swamps-	
Thuja, Picea, Alnus	5 - 10
same- Taxodium	12 - 15
Waterhyacinth	30 - 80
Papyrus marsh	75 - 150
Spartina marsh	20 - 40
Intensive wetland agriculture	
(e.g., rice)	30 - 60 (grain only)

1980) or disturbance. The term stress implies some kind of limitation. Stress is defined as a factor that slows growth while disturbance causes destruction of biomass (GRIME 1977). In case of floodplains, annuals may perceive flooding as a disturbance and perennials find it a stress (MENGES and WALLER 1983). But several studies have demonstrated the dependence of wetland vegetation upon the magnitude, frequency and duration of the water level changes (HEJNY 1971). Many wetland plants are known for their high productivity (Table 1). Many organisms are not only adapted to such environment but require these conditions for their perpetuation. The species richness in wetlands is also generally high. It is difficult to explain how the wetland environment may act as a stress and yet allow optimum development of numerous organisms. I suggest that flooding and water level changes are components of a normal environment and should not be viewed as stress factor.

4. WETLAND PRODUCTVITY AND ENERGETICS

Wetlands in general have a very high primary productivity but it is certainly not true for all of them. Data on production ranges in different kinds of wetlands in different climatic zones (Tab. 2) show that the bogs are less productive than other terrestrial communities in the same climatic conditions, and towards the tropics, the wetland production increases more than in other terrestrial communities. The tropical wetlands are more productive than tropical forests or savannes. This trend in primary production further emphasizes that waterlogging and related soil changes do not act as stress factors while the temperature regime is more important.

What is still more important in terms of production is the fate of primary production. In most wetlands, herbivory plays relatively small role in the flow of energy. Most of the organic matter in the plants undergoes decomposition which is influenced primarily by temperature, pH and oxygen regimes. Thus, in bogs, decomposition is very slow, and the organic matter accumulates as peat. In other places either the decomposition is either relatively rapid or the detritus is carried away to open water systems by water. Thus, the wetlands can be grouped into two categories: accumulative and non-accumulative wetlands.

The species richness and productivity of consumers is exceptionally high in wetlands. Only in the bogs and similar accumulative wetlands the consumer populations are relatively small and productivity is low. Herbivores are very few and much of the organic matter produced by wetland plants is neither easily digestible nor very nutritious because of high amounts of structural tissues. Most of it is converted to detritus with the help of microbes (bacteria and fungi). Detritus is an important link in the energetics of the wetland ecosystem. Since the importance of detritus pathway was first pointed out by ODUM (1957) and TEAL (1957), there bave been several studies of detritus in different ecosystems (DE LA CRUZ 1979). The microbes are an integral part of the detritus and enrich it with nutrients and energy. The calorific and nutritive value of

Table 2. Annual primary production in wetland and other ecosystems (based on RODIN et al. 1975)

Tab. 2. Jährliche Primärproduktion in Feuchtgebieten und anderen Oekosystemen (nach RODIN et al. 1975)

Ecosystems	Production t/ha
Polar regions	
Tundra	2.5 - 3.0
Bogs	ca. 2.0
Boreal regions	
Tundra	4 - 5
Taiga	4 - 10
Bogs	3 - 5
Bog forests	4 - 5
Sub-boreal region	
Forests	12 - 15
Dry steppe	5 - 8
Bogs, fens, marshes	ca. - 25
Floodplains	ca. 12
Humid subtropical region	
Forests	16 - 22
Swamp forests	20 - 22
Bogs and marshes	30 - 100
Floodplains	30 - 40
Humid tropical regions	
Forests and savannas	16 - 30
Marshes, swamps and floodplains	25 - 150
Mangroves	15 - 30
Deserts	
Scrub thickets, halophytes	4 - 6
Marshes, floodplains	25 - 60

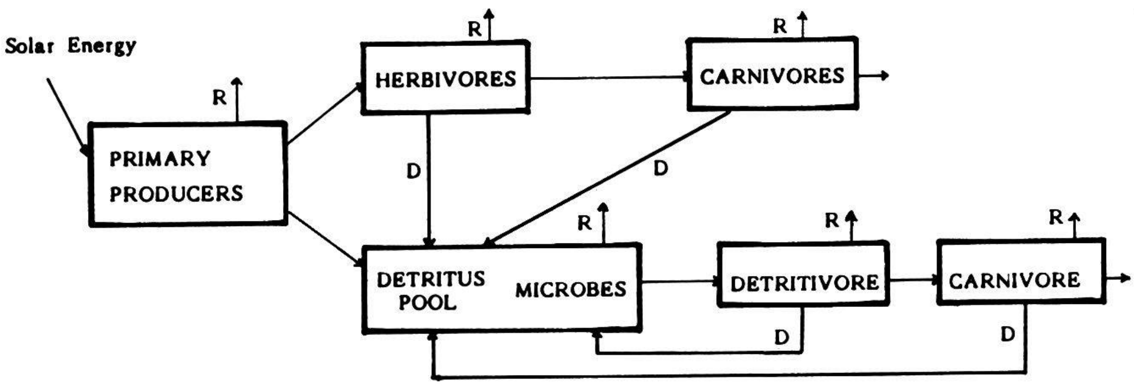

Fig. 1. Pathways of energy dynamics in a wetland ecosystem. The detritus-microbe aggregate is shown as one compartment since the two are inseparable. The importance of energy pathways marked by dark arrows has not been recognised. Their acceptance leads us to recognise energy cycling.

Abb. 1. Energieflüsse in einem Oekosystem der Feuchtgebiete. Die Beziehung Detritus-Mikroorganismus ist derart eng und untrennbar, dass sie hier in **einem** Kompartiment dargestellt wird. Dunkle Pfeile markieren die Energieflüsse, deren Wichtigkeit bisher nicht erkannt wurde und die zu einem Modell mit "Energie-Kreislauf" führt.

R = Respiration - Atmung
D = Death and excreta - tote Substanz und Ausscheidungen.

detritus is shown to increase during decomposition (DE LA CRUZ and GABRIEL 1974). The excreta and death of consumers add to the detritus pool. Thus detritus pathway should be viewed as "energy recycling pathway". The concept of energy cycling was first advanced by RIGLER (1975) but has received no attention in ecological literature so far. In the grazing pathway of energy flow, the production of detritus is relatively so small that cycling of energy is not readily appreciated. In wetlands where most of the primary production is turned into detritus, special mechanisms to conserve energy only can result in high secondary production. The production by bacteria of energy-rich food from energy-poor organic matter ensures high ecological efficiency and secondary productivity of the wetland ecosystems. This concept is diagrammatically shown in Fig. 1.

5. NUTRIENT DYNAMICS IN WETLANDS

The waterlogging of the soils in general means poorer availability of nutrients. Despite the general nutrient deficiency the wetland plants are able to draw enough nutrients from their environment. Interestingly, most wetland plants respond to the increased supply of nutrients by excessive uptake and accumulation of nutrients, as well as several toxic substances and heavy metals, in their tissues. This is referred to as "luxury consumption" (see DYKYJOVA 1978), and is partly reflected in the supposed ability of wetlands maintain high productivity in nutrient deficient environments, and what is the exact role of plants in wastewater treatment?

An important feature of most of the wetlands is their nutrient conservation strategy which involves a large magnitude of internal cycling. A large proportion of the nutrients absorbed during the growth period is translocated to the belowground storage organs during senescence and before the death and shedding of aboveground parts. Later, these nutrients are mobilised upwards for use by the young shoots in the next growing period (DAVIS and VAN DER VALK 1983, GOPAL and SHARMA 1984). In *Phragmites*, GRANELI et al. (1983) have shown that such translocations alone may account for the total phosphorus requirement during the spring growth and some P may even be lost from the system. In case of nitrogen, the reed absorbs it during early spring growth and the reserves in the belowground organs are utilized later. Translocation of nitrogen to the belowground organs and its rapid loss in leaching from the litter have other significance too. The high C:N ratio of the litter causes slow decomposition and microbial immobilization of nitrogen. Thus, nitrogen is conserved within the system and made available to consumers (in form of microbial protein) or released gradually later for uptake by new spring growth.

The nutrient removal capacity of wetlands appears to be due to denitrification process accelerated by the availability of organic carbon (cf. GERSBERG et al. 1983), and the adsorption of phosphorus onto the detritus or its coprecipitation with calcium during photosynthetic activity. It is also interesting that in nutrient poor wetlands, microbial activity to fix atmospheric nitrogen plays an important role. Symbiotic nitrogen fixation occurs in several plants like *Alnus* and *Azolla*, and is also associated with the rhizosphere of many wetland plants (PATRIQUIN and KEDDY 1978, CHAPMAN and HEMOND 1982).

6. WETLAND STABILITY

Wetlands are often treated as seral communities which would readily shift to terrestrial communities upon some kind of perturbation. However, if we recognise that hydrological component of their physical environment is the regulatory factor in creating and maintaining them as destinct ecosystems, it is clear that wetlands are also stable ecosystems. Their stability is determined by the stability of the hydrological environment. There are many studies of the influences of changes in water regimes on the species composition, and also to show the narrow ecological amplitude of various wetland plant species to hydrological factors such as the magnitude, duration and frequency of water level changes. These studies amply demonstrate that the structure of a wetland community is held in delicate balance by its hydrological environment, and any activity that directly or indirectly impinges upon the hydrology of the system, disturbs the whole system. Thus drainage, diversion of water flow, increased inflow of silt or nutrient enrichment are all responsible for a shift in the structure and function of the wetlands.

7. CONCLUSIONS

Though there is an evergrowing interest in the wetland ecosystems, our knowledge about them is far from adequate. On one hand we talk of their conservation, and on the other, despite the realisation of their unstable seral nature, recommendations are being made for their use in wastewater treatment. There is little information on the responses of wetlands to such impacts but there is every reason to believe that neither this capacity is unlimited nor the wetlands are immune from the adverse impacts of nutrient enrichment. The role of hydrology and the functioning of different kinds of wetlands is not properly understood and there is an urgent need for basic ecological research before the wetland conservation and management can be practised.

SUMMARY

Wetland ecosystems are of a high ecological value and of a crucial importance to man. Wetlands are considered as stress environments but the author suggests that flooding and water level changes are components of a normal wetland environment and should be regarded as a stress factor. Wetland productivity and energetics, nutrient dynamics as well as stability are briefly reviewed. In conculsion, the importance of basic ecological research for the wetland conservation and management is emphasized.

ZUSAMMENFASSUNG

Oekosysteme der Feuchtgebiete sind von hohem ökologischen Wert und von entscheidender Wichtigkeit für den Menschen. Feuchtgebiete werden zwar als Stress-Umwelt bezeichnet. Aber der Verfasser betrachtet Ueberschwemmung und Wasserspiegelschwankungen als normale Umwelteinflüsse in solchen Systemen. Ihre Produktion und Energieflüsse, die Nährstoff-Dynamik und auch die Stabilität werden kurz diskutiert. Daraus ergibt sich die dringende Notwendigkeit ökologischer Grundlagenforschung zur optimalen Erhaltung und Bewirtschaftung von Feuchtgebieten.

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