CHAPTER II

ENVIRONMENTAL DIMENSIONS OF WETLAND ECOSYSTEM
2.1 INTRODUCTION

Wetlands are transitional zones that occupy an intermediate position between dry land and open water. Ecosystems dominated by the influence of water, they possess characteristics of both terrestrial and aquatic ecosystems and properties that are uniquely their own. This single term encompasses a diverse and heterogeneous assemblage of habitats ranging from rivers flood plains, and rainfed lakes to mangrove swamps, estuaries, and salt marshes. A select, unifying factor characterizes the wetland ecosystem - the abundance of water for at least a part of the year.

The association of man and wetlands is ancient. Water has been the most important factor governing the distribution of man and his early homonid ancestors. It is not surprising that the first signs of civilization are traced to wetland areas. The flood plains of the Indus, the Nile delta, and the fertile crescent of the Tigris and Euphrates rivers provided man with all his basic necessities, from water for drinking to fertile soils for growing crops, and reeds and bulrushes for building homesteads. Even today wetlands support a disproportionately large fraction of the human population.

However, wetlands have not been given the importance that they deserve. Swamps, marshes, and bogs have traditionally been viewed as wastelands and been associated with disease, difficulty, and danger. These 'marginal lands' have been shunned as breeding grounds of disease-carrying insects and for providing refuge to man-eating crocodiles.

Today we are trying to reverse the notion that wetlands are wastelands. Ecologists the world over are pointing out the unseen, and previously unknown, benefits of wetlands. The amazingly high productivity of wetlands is being brought to the attention of agricultural scientists. Marshes and swamps, are being looked upon as sources of food rather than as breeding grounds of mosquitoes. The value of wetlands as wildlife habitats is also being appreciated. The majestic royal Bengal tiger of the sunderbans and the highly endangered Manipur brow-antlered deer in the swamps
around Loktak lake are prominent examples of the fauna that these ecosystems support besides mammals, a rich diversity of waterfowl is found in almost all wetland systems.

A wide range of essential functions that help sustain plants, animals and indeed, human beings themselves, is fulfilled by wetlands. These include flood control, natural sewage treatment, stabilization of shorelines against wave erosion, and the recharging of aquifers. In addition, many food chains are dependent on wetland productivity.

In recent years, wetlands have been the focus of innumerable studies. This is also the only ecosystem type to have its own international convention, namely, the convention on wetlands of International Importance especially as waterfowl Habitat, better known as the Ramsar Convention, to which India is a contracting party.

Current efforts are being made to understand and save these enigmatic ecosystems and to conserve the dwindling wetland resources. This chapter outlines the wetland ecosystem in terms of Defining wetlands, wetland habitats, wetlands values and functions and wetlands as vulnerable ecosystem.

2.2 DEFINING WETLAND

Marshes, swamps and bogs have been well known terms for centuries, but only relatively recently attempt have been made to group these landscape units under the single term "wetlands". This general term has grown out of a need to understand and describe the characteristics and values of all water logged areas to wisely and effectively manage them.

There is no single ecologically sound and universally acceptable definition of wetland ecosystem, primarily because of their diversity and for the lack of demarcation between dry and wet environments along a continuum.

However, in the nineteenth century, when the drainage of wetlands was the norm, a wetland definition was unimportant because it was considered desirable to produce upland from wetlands by draining them. Even as the value of wetlands was
being recognized in the early 1970s, there was little interest in precise definitions until it was realized that a better accounting of the remaining wetland resources of the world was needed and definitions were necessary to achieve that inventory. When national and international laws and regulations pertaining to wetland preservation began to be written in the late 1970s and afterward the need for precision became even greater as individuals recognized that definitions were having an impact on what they could or could not do with their land, the definition of a wetland, then, took on greater importance than the definition of almost any other ecosystem.

Wetland definitions and terms are many and are often confusing or even contradictory. Nevertheless, definitions are important for both the scientific understanding of these systems and for their proper management.

Formal definitions have been developed by an international treaty known as the Ramsar Convention, by several federal agencies in the United States and by wetland scientists.

The International Union for the Conservation of nature and Natural Resources (IUCN) in the Convention of wetlands of International Importance Especially as waterfowl Habitat, better known as the Ramsar Convention, adopted the following definition of wetlands as:

"Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt including areas of marine water, the depth of which at low tide does not exceed 6 meters".

The definition, which was adopted at the first meeting of the convention in Ramsar, Iran, in 1971, states that wetlands "may incorporate riparian and coastal zones adjacent to the wetlands and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands.

Navid (1989) suggests that this definition could be interpreted to include "a
wide variety of habitat types including rivers, coastal areas and even coral reefs".¹

Thus the IUCN (1971) gives a very comprehensive definition which virtually covers marshes, swamps, bogs, peats, rivers, springs, lakes, reservoirs and coastal areas.

One of the earliest definitions of the term wetlands, one that is still frequently uses today by both wetland scientists and managers, was presented by the U.S Fish and wildlife service in 1956 in a publication that is frequently referred to as circular 39.

"The term "wetlands" refers to lowlands covered with shallow and sometimes temporary on intermittent waters. They are referred to by such names as marshes, swamps, bogs, wet meadows, potholes, sloughs and river-overflow lands. Shallow lakes and ponds, usually with emergent vegetation as a conspicuous feature, are included in the definition, but permanent waters of streams, reservoirs, and deep lakes are not included. Neither are water areas that are so temporary as to have little or no effect on the development of moist soil vegetation".²

The circular 39 definition (1) emphasized wetlands that were important as waterfowl habitats and (2) included 20 types of wetlands that served as the basis for the main wetland classification used in the United States until the 1970s.

Perhaps the most comprehensive definition of wetlands was adopted by wetland scientists in the U.S. Fish and wildlife service in 1979, after several years of review. The definition was presented in a report entitled classification of wetlands and deepwater Habitats of the United states.

"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at on near the surface on the land is covered by shallow water..... wetlands must have one or more of the following three attributes: (1) at least

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periodically, the land supports predominantly hydrophytes, (2) the Substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Cowardin et al. (1979) further elaborated to delimit wetland areas as:

The term wetland includes a variety of areas that fall into one of five categories: (1) areas with hydrophytes and hydric soils, such as those commonly known as marshes, swamps and bogs; (2) areas without hydrophytes but with hydric soils for example, flats where drastic fluctuation in water level, wave action, turbidity, or high concentration of salts may prevent the growth of hydrophyte; (3) areas with hydrophytes but non hydroic soils, such as margins of impoundment's or excavations where hydrophytes have become established but hydric soils have not yet developed; (4) areas without soils but with hydrophytes such as the seaweed-covered portion of rocky shores; and (5) wetlands without soil and without hydrophytes, such as gravel beaches or rocky shores without vegetation.

The definition was further clarified by setting the boundary of wetlands with both the terrestrial and deepwater habitats. The boundary with deepwater habitats is more important in the context of IUCN definition and management of wetlands. According to Cowardin et al. (1979), the boundary between wetland and deepwater habitat in the Marine and Estuarine system coincides with the elevation of the extreme low water of spring tide; permanently flooded areas are considered deep water habitats in these systems. The boundary between wetland and deepwater habitat in the Riverine, Lacustrine and Palustrine systems lies at a depth of 2m below low water; however, if emergents, shrubs, or trees grow beyond this depth at any time, their deepwater edge is the boundary.

This definition is still one of the most widely accepted by wetland scientists in

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the United states today. Designed for the scientist as well as the manager, it is broad, flexible, and comprehensive and includes descriptions of vegetation, hydrology, and soil. This definition has been accepted as the official definition of wetlands by India and has been used in proposed wetland legislation by some states in the United states.

The U.S. Army corps of Engineers defines 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. Wetlands generally include swamps, marshes, bogs, and similar areas."

The Army Corps of Engineers definition cited above emphasizes only one indicator, vegetative cover, to determine the presence or absence of a wetland. In this legal definition it is difficult to include soil information and water conditions in a wetland definition when its main purpose is to determine jurisdiction for regulatory purposes and there is little-time to examine the site in detail.

In India, there is no single word equivalent to wetland. Of course, no language has one word to define/represent these complex ecosystems. The marshes are known as Chaurs in Bihar, and Bhils in Assam and North east. Large shallow lakes are called tals in Uttar Pradesh and Madhaya Pradesh. The terai region in the foothills of the Himalayas is also dominated by marshes and swamps. There is much confusion as to what a swamp, marshes wetland or a lake is. Should the areas which become completely dry periodically be treated as wetlands? Or is every waterbody a wetland?

The definition just described above are of no help in clearly demarcating what is or not a wetland. Wetlands have to be identified and distinguished from other ecosystems by their ecological characteristics alone for their proper management. However, the Ministry of Environment and Forests, Government of India, has adopted the IUCN definition which is used by the Ramsar convention for the purpose of its wetland conservation programme.
2.3 TYPES OF WETLANDS

Wetlands occur extensively throughout the world in all climatic zones and are estimated to cover about 6% of the earth's surface. They include a wide spectrum of habitats ranging from extensive peat bogs of northern latitudes to tropical mangrove forests, from seasonal ponds and marshes to flood plains and permanent riparian swamps, from freshwater shallow lakes and margins of large reservoirs to salt lakes, brackish lagoons, estuaries and coastal salt marshes. Extensive beds of marine algae (kelps) along sea coasts and coral reefs are also considered wetlands. Thus, wetlands exhibit very large difference in their habitat characteristics such as hydrological regimes, water quality and soils, and in the nature and diversity of their biota. Wetlands also occur in all shapes and sizes ranging from less than one hectare to hundreds of square kilometres in area.

Following are the different types of wetlands found all over the world;

2.3.1 MARSH

Marshes vary greatly, depending on their origin, geographical location, water regimes, chemistry and soil or sediment characteristics. They are dominated by herbaceous plants and sustained by water sources other than direct rainfall. They are among the most productive ecosystems in the world. A vital link between terrestrial and aquatic environments they sustain important fisheries and protect the land's edge from erosion.

There are three major groups of marsh:

- Tidal salt marshes are typical of temperate shorelines between high and low tidal extremes. They dominate large areas of the eastern coast of north America and coastal Europe, and are generally dissected by a complex of tidal creeks, important conduits for sediment, nutrients and organic matter.

- Tidal freshwater marshes are found further inland than saltmarshes, at the head of
tides. They are affected by tidal cycles but not exposed to salt water stress. They support a more diverse plant life than their salt marsh counterparts.

- Freshwater marshes are dominated by grasses and sedges but are very different in origin and appearance. They account for over 90% of the wetland area in the United States, but are prominent in all latitudes where groundwater, surface springs, streams or runoff causes frequent flooding or more or less permanent shallow water flooding.

Associated with marsh are the terms 'bogs' and 'fens'. However the distinctions between all these three are not always clear. Water flowing into mashers (which may be surface runoff, groundwater or tidal flow), and the expansion and contraction of marshes, supplies the marsh system with nutrients. This distinguishes them sharply from 'bogs', which are essentially rainfed and low in nutrients. 'Fens' are peat-forming freshwater wetlands, generally non-acidic, receiving nutrients mainly from groundwater sources and dominated by marsh-like vegetation. Where reeds dominate but the soil is not necessarily peaty, the term 'reedswamp' is commonly used.

However, marshes are commonly found in the wettest areas of floodplains and around the fringes of permanent water bodies, from the smallest ponds to the largest lake.

2.3.2 SWAMPS

Swamps develop in still water areas, around lake margins, and in parts of flood plains such as sloughs or oxbows—often described as 'back swamps'. It is a wooded wetland and has rich and diverse wildlife. Mosquitoes and poisonous snakes are quiet common making the place forbidden. The character of wooded wetlands varies according to geographic location and environment. In the northern United States, red maple, ash black spruce and larch are prominent; in the south bald cypress, water tupelo, oaks and willows dominate. In New Guinea, the swamp forests are dominated
by Melaleuca trees. Palms are a common understory.

The swamp palm forests of the caribbean have dwindled rapidly, so the swamp forests of equatorial southeast Asia, the Pacific and the Amazon represent some of the largest remaining forest reserves.

2.3.3 HERBACEOUS SWAMPS

Reed swamps are the most productive ecological systems on earth. Most reedswamps fringe wetlands of the sort once common on the edge of European lakes and river flood plains. Reeds provide excellent habitats for waterfowl, birds and aquatic animals. The area of reedswamp worldwide has fallen as shallow, open water has been drained. In Europe, reedswamp is also being lost to so-called 'reed-death', where inflowing drainage water enriched with fertiliser increases nutrient content in the lakes. The reeds grow faster but produce weaker stems.

2.3.4 MANGROVE SWAMPS

Mangrove swamps are the sub-tropical and tropical equivalents of the temperate saltmarsh. Most are limited to within 25° North and south of the Equator, but can reach higher latitudes where local conditions limit frosts to less than five consecutive-days. Mangroves cover at least 14 million hectares and are concentrated in some of the world's poorest nations.

Broadly, they are forests which tolerate salt and occupy the intertidal zone. The constitute a reservoir and refuge for many unusual plants and animals; about 60 species of mangrove tree and shrub, and over 2000 species of fish, invertebrates and epiphytic plants depend on mangroves for survival.

They are extremely varied. Giant closed forests of red mangrove and black mangrove grow 40-50 metres high in parts of Brazil, Colombia, Ecuador and Venezuela. In Asia and oceania the richer flora of the Old world forms the familiar
tangled and almost impenetrable closed forests. On more arid coasts and near the extremes of their climatic range (such as in Florida, Louisiana and the Japanese Pacific islands) stunted shrubs less than a metre high form open communities, often with discrete and widely separated clumps.

2.3.5 MAN-MADE WETLANDS

Thanks largely to the demise of 'natural' wetlands, accidentally produced and even artificial wetlands are increasingly prominent in developed countries.

Man-made wetlands include reservoirs, ponds and lagoons, extraction pits and waterways. Many are close to dense concentration of population, which increases their educational, scientific and recreational value.

Man-made wetlands have become some of the most important wildlife habitats in western Europe. Many reservoirs support nationally important populations of wintering waterfowl, but these cannot fulfil many of the other important ecological functions of the natural wetlands which might have been destroyed in their construction.

2.3.6 PEATLANDS

When plants die they begin to decompose. With the help of microbes, the plant tissue oxidise, eventually into carbon dioxide and water. Where low temperature, high aridity, low nutrient supply, waterlogging and oxygen deficiency retard decomposition, the plant matter does not oxidise, but instead accumulates and is transformed into peat.

Peat is usually called 'peat' and not 'organic soil layers'- when it is deeper than 40 cm. In mires (synonymous with peatlands), the rate of production of plant litter exceeds the rate of breakdown. Peat normally accumulates at a rate of 0.2-1.6 millimetres per year, depending on local environment, vegetation, climate and human influences, until eventually an equilibrium is reached when decay of the entire peat
mass, balances the rate of addition of fresh organic material.

Once thought to be almost entirely restricted to the high latitudes of the northern hemisphere, peatlands are now thought to cover at least 500 million hectares, and occur in all continents. Thick deposits can form in association with marsh and swamp, particularly in tropical and sub tropical lakes, floodplains and coastal regions. But peat also produces distinctive wetland landscapes of bog, moor, muskeg and fen.

'Bogs' have a high water table maintained directly by rain and snow, which also maintains waterlogging and reduces oxygen levels. The rainfall leaches out base materials, making them low in nutrients, and the slow fermentation of organic matter produces acids. Bogs are characterised by acid-loving vegetation such as cotton grass, purple moor grass, sedges and mosses.

Peat is a 'sink' for plant remains, nutrients and carbon. Active peat bogs fix carbon continually. The conversion of peat lands to agriculture changes them from carbon 'sinks' to carbon sources, and releases carbon into the atmosphere. Drained and disturbed wetlands tend to lose more stored carbon (and other elements) than can be fixed in the same amount of time. Not only does this add more gaseous carbon to the atmosphere, and other elements - including heavy metals like lead, zinc and caesium - to drainage waters, but is also reduces their storage within peat deposits.

The depth of peat in raised bogs (generally 4-12 metres) has made them prime candidates for exploitation for energy or horticulture uses. Mechanised peat cutting has made massive inroads in recent years into some of the finest examples of raised bogs in Ireland. Elsewhere, excavation, drainage and recreational pressure have dramatically reduced or altered these wetlands. The high moisture content and low bearing strength of the peat makes raised bogs and deep blanket peat extremely vulnerable to trampling.

The use of peat as a fuel is well-known; it is and has been and important fuel for domestic heating and working for centuries. Like other wetlands, peatlands absorb
excess water. It filters and purifies water, and holds nutrients and heavy metals such as caesium and lead.

2.3.7 FLOODPLAIN

Floodplain are flat lands adjacent to streams and rivers that are subjected to natural, periodic flooding. These contain a complex of diverse habitats such as swamps, marshes, and oxbow lakes, which are left behind as permanently inundated areas after the flood waters have receded. Flood plains are most extensive along the lower reaches of a river where they may terminate in an estuary or a delta.

The natural lay of the land helps to control the depth; timing and duration of flooding. Permanent or semi-permanent areas of standing water may be left after the concession of flood waters in the form of oxbows and other depressions. These waters often very shallow, but can be important dry season refuges for fish, which frequently spawn on the temporarily flooded land. They are important wildlife habitat and a key resource for many subsistence farming communities in Africa, Asia and South America. Specialised local terms reflect the special significance of flood plain areas in the lives of many people.

In the United states, periodically flooded areas produced the bottomland hardwood forests which once covered vast areas of the floodplain of the south-eastern, eastern and central United states. However, the riverside marshes and forests which once characterised the 'fringing floodplain' of rivers in Europe and North America have now largely disappeared through the deepening of river channels, the building of levels and the development of riverside land.

The Worlds remaining major seasonal floodplains are now limited to the tropics and subtropics.
2.4 CLASSIFICATION OF WETLANDS

Because wetlands occur in many different climatic zones, in many different locations and have many different soil and sediment characteristics, therefore, it is difficult to classify wetlands into different types. More than fifty schemes of classifications have been proposed for wetlands in different countries, and there is hardly any scheme that satisfies all scientific criteria and is also practically applicable in the field. Various classification schemes have employed a few to a large number of criteria. Which have been given different weightage.

The simplest classification is the one proposed by Scott (1989a) for use in Ramsar Database, and followed in the Directory of Asian wetlands (scott 1989b). It recognizes simply 22 wetland types listed in Table 1.

<table>
<thead>
<tr>
<th>Wetland types initially recognized by the Ramsar Convention</th>
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<tbody>
<tr>
<td>shallow sea bays and straits (under six meters at low tide)</td>
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<tr>
<td>estuaries, deltas</td>
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<tr>
<td>small offshore islands, islets</td>
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<tr>
<td>rocky sea coasts, sea cliffs</td>
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<tr>
<td>sea beaches (sand, pebbles)</td>
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<tr>
<td>interfedral mudflats, sand flats</td>
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<tr>
<td>mangrove swamps, mangrove forest</td>
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<tr>
<td>coastal brackish and saline lagoons and marshes</td>
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<tr>
<td>salt pans (artificial)</td>
</tr>
<tr>
<td>shrimp ponds, fish ponds</td>
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</tbody>
</table>
rivers, streams-slow flowing (lower perennial)
rivers, streams-fast flowing (upper perennial)
oxbow lakes, riverine marshes
freshwater lakes and associated marshes (lacustrine)
freshwater ponds (under 8ha), marshes, swamps (palustrine)
salt lakes, saline marshes (inland drainage system)
water storage reservoirs, dams
seasonally flooded grassland, savanna, palm savanna
rice paddies
flooded arable land, irrigated land
swamp forest, temporarily flooded forest
peat bogs.

**Source:** Scott, 1989

Most of these types are artificial and heterogeneous assemblages. For example, the category fresh water ponds, marshes and 'swamps' is different from 'shrimp ponds, fish ponds' on one hand and from the 'swamp forest, temporarily flooded forest' on the other. The 'rice paddies' are distinguished from 'flooded arable land' whereas the 'salt pans' and 'salt lakes' are recognized as different types.

This classification has been followed by the revised Directory of Indian wetlands (WWF/AWB, 1993). The most comprehensive and elaborate hierarchical system of classification has been developed by Cowardin et.al. (1979) for the United states Fish and wildlife service (Table 2).
<table>
<thead>
<tr>
<th>System</th>
<th>Subsystem</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine</td>
<td>Subtidal</td>
<td>Rock Bottom&lt;br&gt;Unconsolidated Bottom&lt;br&gt;Aquatic Bed&lt;br&gt;Reef</td>
</tr>
<tr>
<td></td>
<td>Intertidal</td>
<td>Aquatic Bed&lt;br&gt;Reef&lt;br&gt;Rocky Shore&lt;br&gt;Unconsolidated shore</td>
</tr>
<tr>
<td>Estuarine</td>
<td>Subtidal</td>
<td>Rock Bottom&lt;br&gt;Unconsolidated shore&lt;br&gt;Aquatic Bed&lt;br&gt;Reef</td>
</tr>
<tr>
<td></td>
<td>Intertidal</td>
<td>Aquatic Bed&lt;br&gt;Reef&lt;br&gt;Streambed&lt;br&gt;Rocky Shore&lt;br&gt;Unconsolidated shore&lt;br&gt;Emergent Wetland&lt;br&gt;Scrub-Shrub Wetland&lt;br&gt;Forest Wetland</td>
</tr>
<tr>
<td>Tidal</td>
<td></td>
<td>Rock Bottom&lt;br&gt;Unconsolidated Bottom&lt;br&gt;Aquatic Bed&lt;br&gt;Rocky Shore&lt;br&gt;Unconsolidated Shore&lt;br&gt;Emergent Wetland</td>
</tr>
<tr>
<td>Lower Perennial</td>
<td></td>
<td>Rock Bottom&lt;br&gt;Unconsolidated bottom&lt;br&gt;Aquatic Bed&lt;br&gt;Rocky Shore&lt;br&gt;Unconsolidated shore&lt;br&gt;Emergent Wetland</td>
</tr>
<tr>
<td>Upper Perennial</td>
<td></td>
<td>Rock Bottom&lt;br&gt;Unconsolidated Bottom&lt;br&gt;Aquatic Bed&lt;br&gt;Rocky Shore&lt;br&gt;Unconsolidated Shore</td>
</tr>
<tr>
<td>Intermittent</td>
<td></td>
<td>Streambed</td>
</tr>
<tr>
<td>Lacustrine</td>
<td>Limnetic</td>
<td>Rock Bottom&lt;br&gt;Unconsolidated Bottom&lt;br&gt;Aquatic Bed</td>
</tr>
<tr>
<td></td>
<td>Littoral</td>
<td>Rock Bottom&lt;br&gt;Unconsolidated Bottom&lt;br&gt;Aquatic Bed&lt;br&gt;Rocky Shore&lt;br&gt;Unconsolidated Shore&lt;br&gt;Emergent Wetland</td>
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<tr>
<td>Palustrine</td>
<td></td>
<td>Rock Bottom&lt;br&gt;Unconsolidated Bottom&lt;br&gt;Aquatic Bed&lt;br&gt;Unconsolidated Shore&lt;br&gt;Moss-Lichen Wetland&lt;br&gt;Emergent Wetland&lt;br&gt;Scrub-Shrub Wetland&lt;br&gt;Forest Wetland</td>
</tr>
</tbody>
</table>

Source: Cowardin et al. (1979)
It covers the deepwater habitats also, and has been extensively used in the United states for preparing wetland inventories. It recognizes five major system (Marine, Estuarine, Riverine, Lacustrine and Palustrine) which are divided into subsystems based on the nature and extent of flooding. A number of classes are recognized in each subsystem largely on the basis of the nature of the substratum. Other characteristics like water regime, water chemistry, soil types, vegetation and anthropogenic factors have been used as modifiers to further subdivided classes into lower categories.

The classification scheme suffers from certain weaknesses and requires detailed information about each wetland to be properly classified. Thus, it is not practically applicable to Indian wetlands which are yet very poorly investigated.

Dugan (1990) suggested a classification scheme which is very similar to the Cowardin system. It groups the wetlands first into salt water, fresh water and man-made wetlands. There are further subdivided into categories based on their hydrological characteristics (table 3).

### Table 3
Wetland classification

<table>
<thead>
<tr>
<th>I. SALT WATER</th>
<th>1. Subtidal</th>
<th>i) permanent unvegeted shallow water loss than 6m depth at low tide, including sea bays, straits.</th>
<th>ii) subtidal aquatic vegetation, including kelp bays, sea grasses, tropical marine meadows.</th>
<th>iii) coral reefs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1. Marine</td>
<td>1. Subtidal</td>
<td>i) Rocky marine shores, including cliffs and rocky shores.</td>
<td>ii) Shores of mobile stones and shingle.</td>
<td>iii) Intertidal mobile unvegetated mud, sand or salt flats.</td>
</tr>
<tr>
<td>2. Intertidal</td>
<td>i) Estuarine waters; permanent waters of estuaries and estuarine systems of deltas.</td>
<td></td>
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</tr>
<tr>
<td>1.2. Esturine</td>
<td>1. Subtidal</td>
<td>i) Intertidal mud, sand or salt flats, with limited vegetation.</td>
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</tbody>
</table>

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<table>
<thead>
<tr>
<th>1.3. Lagoonar</th>
<th>2. Intertidal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4. Salt Lake</td>
<td>ii) Intertidal marshes, including salt marshes, salt-meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes.</td>
</tr>
<tr>
<td></td>
<td>iii) Intertidal forested wetlands, including mangrove swamp, Nipa swamp, tidal freshwater swamp forest.</td>
</tr>
<tr>
<td></td>
<td>i) Brackish to saline lagoons with one or more relatively narrow connections with the sea.</td>
</tr>
<tr>
<td></td>
<td>i) Permanent and seasonal, brackish, saline or alkaline lakes, flats and marshes.</td>
</tr>
</tbody>
</table>

### 2. FRESHWATER

#### 2.1 Riverine

<table>
<thead>
<tr>
<th>Perennial</th>
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<tbody>
<tr>
<td>i) Permanent rivers and streams, including waterfalls.</td>
</tr>
<tr>
<td>ii) Inland deltas.</td>
</tr>
<tr>
<td>i) Seasonal and Irregular rivers and streams.</td>
</tr>
<tr>
<td>ii) Riverine floodplains, including river flats, flooded river basins, seasonally flooded grasslands.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temporary</th>
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<tbody>
<tr>
<td>i) Seaonal and Irregular rivers and streams.</td>
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<table>
<thead>
<tr>
<th>2.2 Lacustrine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent</td>
</tr>
<tr>
<td>i) Permanent freshwater lakes (&gt;8ha).</td>
</tr>
<tr>
<td>ii) Permanent freshwater ponds (&lt;8ha).</td>
</tr>
<tr>
<td>Seasonal</td>
</tr>
<tr>
<td>i) Seasonal freshwater lakes (&gt; 8ha), including floodplains lakes.</td>
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</tbody>
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<thead>
<tr>
<th>2.3 Palustrine</th>
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</thead>
<tbody>
<tr>
<td>Emergent</td>
</tr>
<tr>
<td>i) Permanent freshwater marshes and swamps on inorganic soils, with emergent vegetation whose bases lie below the water table for atleast most of the growing season.</td>
</tr>
<tr>
<td>ii) Permanent peat-forming freshwater swamps, including tropical upland valley swamps dominated by Papyrus or Typha.</td>
</tr>
<tr>
<td>iii) Seasonal freshment marshes on inorganic soil, including sloughs, potholes, seasonally flooded meadows, sedge marshes, and bamboos.</td>
</tr>
<tr>
<td>iv) Peatlands, including acidophilous, ombrogenous, or soligenous mires covered by moss, herbs or dwarf shrub vegetation, land fens of all types.</td>
</tr>
<tr>
<td>v) Alpine and polar wetlands, including seasonally flooded meadows moistened by temporary waters from snowmelt.</td>
</tr>
<tr>
<td>vi) Freshwater springs and oases with surrounding vegetation.</td>
</tr>
<tr>
<td>vii) Volcanic fumaroles continually moistened by emerging and condensing water vapour.</td>
</tr>
<tr>
<td>Forested</td>
</tr>
<tr>
<td>i) Shrub swamps, including shrub-dominated freshwater marsh, shrub carr and thickets, on inorganic soils.</td>
</tr>
<tr>
<td>ii) Freshwater swamp forest, including seasonally flooded forest, wooded swamps on inorganic soils.</td>
</tr>
<tr>
<td>iii) Forested peatlands, including peat swamp forest.</td>
</tr>
</tbody>
</table>

#### 3. MAN-MADE WETLANDS

<table>
<thead>
<tr>
<th>3. Aquaculture/Mariculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>i) Aquaculture ponds, including fish ponds and shrimp ponds.</td>
</tr>
<tr>
<td>3.2 Agriculture</td>
</tr>
<tr>
<td>i) Ponds, including farm ponds, stock ponds, small tanks.</td>
</tr>
<tr>
<td>ii) Irrigated land and irrigation channels, including rice fields, canals and ditches.</td>
</tr>
<tr>
<td>iii) Seasonally flooded arable land.</td>
</tr>
</tbody>
</table>
3.3 Salt Exploitation
3.4 Urban/Industrial
3.5 Water-storage areas

<table>
<thead>
<tr>
<th></th>
<th>i) Salt pans and salines.</th>
</tr>
</thead>
<tbody>
<tr>
<td>i)</td>
<td>Explotation</td>
</tr>
<tr>
<td>ii) Wastewater treatment areas, including sewage farms, settling ponds and oxidation basins.</td>
<td></td>
</tr>
<tr>
<td>i) Reservoirs holding water for irrigation and/or human consumption with a pattern of gradual, seasonal, draw down of water level.</td>
<td></td>
</tr>
<tr>
<td>ii) Hydro-dams with regular fluctuations in water level on a weekly or monthly basis.</td>
<td></td>
</tr>
</tbody>
</table>

Source: Dugan, 1990

This scheme is relatively simple and practical. At the same time it accords recognition to the hydrological attributes and distinguishes between natural and man-made wetlands.

Ramsar convention, at the fourth conference of the contracting parties (Montreux 1990) adopted a simple classification system of wetlands types for the description of Ramsar sites (Table 4).

Table 4
Classification System for Wetland Types

<table>
<thead>
<tr>
<th>Marine and Coastal Wetlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Marine water-permanent shallow waters less than six metres deep at low tide; includes sea bays, straits.</td>
</tr>
<tr>
<td>2. Subtidal aquatic beds; includes kelp-beds, sea-grasses, tropical marine meadows.</td>
</tr>
<tr>
<td>3. Coral reefs.</td>
</tr>
<tr>
<td>4. Rocky marine shores; includes rocky off shore islands, sea cliffs.</td>
</tr>
<tr>
<td>5. Sand, shingle or pebble beaches; includes sand bars, spits, sandy islets.</td>
</tr>
<tr>
<td>6. Estuarine waters; permanent waters of estuaries and estuarine systems of deltas.</td>
</tr>
<tr>
<td>7. Intertidal mud, sand or salt flats.</td>
</tr>
<tr>
<td>8. Intertidal marshes; includes saltmarshes, salt meadows, salting, raised saltmarshes, tidal brackish and freshwater marshes.</td>
</tr>
<tr>
<td>9. Intertidal forested wetlands; includes mangroves swamps, nipa swamps, tidal freshwater swamp forests.</td>
</tr>
<tr>
<td>10. Brackish to saline lagoons with one or more relatively narrow connections with the sea.</td>
</tr>
<tr>
<td>11. Freshwater lagoons and marshes in the coastal zone; includes delta lagoon and marsh systems.</td>
</tr>
</tbody>
</table>
Inland Wetlands

1. Permanent rivers and streams; includes waterfalls.
2. Seasonal and irregular rivers and streams.
3. Inland deltas (permanent).
4. Riverine floodplains; includes river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna.
5. Permanent freshwater lakes (over 8 ha). includes large oxbow lakes.
7. Permanent and seasonal, brackish, saline or alkaline lakes, flats and marshes.
8. Permanent freshwater ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation waterlogged for at least most of the growing season.
9. Seasonal freshwater ponds and marshes on inorganic soil; includes sloughs, portholes, seasonally flooded meadows, sedge marshes.
10. Shrub swamps; shrub dominated freshwater marsh, shrub carr, alder thickets; on inorganic soils.
11. Freshwater swamp forest; seasonally flooded forest, wooded swamps; on inorganic soils.
12. Peatlands; shrub or open bogs, fens.
13. Forested peatlands; peat swamp forest.
14. Alpine and tundra wetlands; includes alpine meadows, tundra pools, temporary waters from snowmelt.
15. Freshwater springs osases.

Man-made Wetlands

1. Water storage areas; reservoirs, barrages, hydroelectric dams, impoundments (generally over 8 ha).
2. Ponds, including farm ponds, stock, ponds, small tanks (generally below 8 ha).
3. Aquaculture ponds; fish ponds, shrimp ponds.
4. Salt exploitation; salt-pans, salines.
5. Excavations; gravel pits, borrow pits, mining pools.
6. Waste-water treatment; sewage farms, settling ponds, oxidation basins.
7. Irrigated land and irrigation channels; rice fields, canals, ditches.
8. Seasonally flooded arable land, farmland.

Wetlands associated with the shallow littoral zone of a natural lake and a reservoir may have similar biota but the fact that the reservoir may be used for irrigation (and thereby result in large man-induced water level changes), require ample consideration in management.

Source: Davis, 1994.
The system recognises 35 types grouped under three major categories: marine and coastal wetlands, inland wetlands and man-made wetlands.

In India, a classification of all wetlands has never been attempted although the forested wetlands, both freshwater and marine, were recognized as "Littoral and Swamp Forests" by Champion and Seth (1968) who subdivided them further into a number of subtypes. The herbaceous wetlands which are more widespread and are not associated with specific forest types, have never been organized into categories or types. Gopal and Sah (1995) have proposed a classification scheme which serves as a useful guide for surveying wetlands in the country.

Table 5
Classification of wetlands

<table>
<thead>
<tr>
<th>I. TIDAL WETLANDS</th>
<th>Myristica Swamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Woody vegetation</td>
<td>Submontane hill valley swamp</td>
</tr>
<tr>
<td>i. Permanently flooded (or waterlogged)</td>
<td>Creeper swamp (including cane brakes)</td>
</tr>
<tr>
<td>Mangroves</td>
<td>ii. Seasonally flooded (or waterlogged)</td>
</tr>
<tr>
<td>Mangrove scrub</td>
<td>Eastern seasonal swamp</td>
</tr>
<tr>
<td>Saltwater mixed forest (Heritiera)</td>
<td>Barringtonia swamp</td>
</tr>
<tr>
<td>Brackishwater mixed forest (Heritiera)</td>
<td>Syzygium cumini swamp low forest</td>
</tr>
<tr>
<td>Palm swamp (Nypa)</td>
<td>Seasonal swamp low forest</td>
</tr>
<tr>
<td>ii. Seasonally flooded (or waterlogged)</td>
<td>Eastern Dillenia swamp</td>
</tr>
<tr>
<td>Saline scrub</td>
<td>Riparian fringing forests</td>
</tr>
<tr>
<td>b. Herbaceous vegetation (mostly submerged)</td>
<td>Alder forests</td>
</tr>
<tr>
<td>i. Permanently flooded (or waterlogged)</td>
<td>Riverine blue pine forests</td>
</tr>
<tr>
<td>Coastal beds of kelps and seagrasses</td>
<td>Wet bamboo brakes</td>
</tr>
<tr>
<td>Lagoons</td>
<td></td>
</tr>
<tr>
<td>Estuaries and Backwaters</td>
<td></td>
</tr>
<tr>
<td>ii. Seasonally flooded (or waterlogged)</td>
<td>Cattails (mainly Typha angustata)</td>
</tr>
</tbody>
</table>
waterlogged) (may include areas flooded by very high tides.

II. INLAND WETLANDS
A. SALINE WETLANDS
a. Woody vegetation
i. Permanently flooded (or waterlogged)
   There are none.
ii. Seasonally flooded (or waterlogged)
   Saline scrub

b. Herbaceous vegetation
(submerged or other halophytes)
i. Permanently flooded (or waterlogged)
   Saline high altitude lakes
   (in most cases Littoral zones only)
ii. Seasonally flooded (or waterlogged)
   Salt lakes

B. FRESHWATER WETLANDS
a. Woody vegetation
i. Permanently flooded (or waterlogged)

<table>
<thead>
<tr>
<th>Wetland Type</th>
<th>Vegetation Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reeds</td>
<td>Tall emergents (other than reeds and cattails)</td>
</tr>
<tr>
<td>Tall sedges</td>
<td>Short sedges and grasses</td>
</tr>
<tr>
<td>Wet meadows</td>
<td></td>
</tr>
<tr>
<td>Submerged and/or floating leaved</td>
<td></td>
</tr>
<tr>
<td>Cattials (mainly Typha elephantina)</td>
<td></td>
</tr>
<tr>
<td>Reeds</td>
<td>Tall emergents (other than reeds and cattails)</td>
</tr>
<tr>
<td>Tall sedges</td>
<td>Short sedges and grasses</td>
</tr>
<tr>
<td>Wet meadows</td>
<td></td>
</tr>
<tr>
<td>Tall grasses</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Woody vegetation</th>
<th>Herbaceous vegetation (submerged or other halophytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i.</td>
<td>i. Permanently flooded (or waterlogged)</td>
</tr>
<tr>
<td></td>
<td>Saline high altitude lakes (in most cases Littoral</td>
</tr>
<tr>
<td></td>
<td>zones only)</td>
</tr>
<tr>
<td>ii.</td>
<td>ii. Seasonally flooded (or waterlogged)</td>
</tr>
<tr>
<td></td>
<td>Salt lakes</td>
</tr>
</tbody>
</table>

Source: Gopal and Sah, 1995.

In their classification scheme (table 5), wetlands are first grouped into saline and freshwater types which are then distinguished between those with herbaceous or woody vegetation. These categories are divided further on the basis of their hydrological regimes, particularly the duration of flooding. The hydrological regimes directly control the type of vegetation in a wetland, and hence, wetland types are identified by their dominant vegetation.

It is also necessary to recognize a distinction between the natural and anthropogenic (modified and created by humans) wetlands. In fact, today in India there
are more man-made aquatic habitats than natural ones. Besides large areas of paddy fields, there are numerous fish ponds (often modified from the marshes) and shallow reservoirs. Most of these anthropogenic wetlands are managed for specific economic activity whereas some are incidental to other forms of water resource utilization (e.g., irrigation). These wetlands cannot be distinguished from the natural ones by their vegetation or animals but their management has to take into account the fact that they are man-made and therefore, their hydrology is regulated by humans for various other reasons. For example, two herbaceous wetlands associated with the shallow littoral zone of a natural lake and a reservoir may have similar biota but the fact that the reservoir may be used for irrigation (and thereby result in large man-induced water level changes), require ample consideration in management.

2.5 WETLANDS AS ECOSYSTEMS

Until the middle of this Century, wetlands had no identity of their own. They were considered a part of either the terrestrial or aquatic ecosystems different kinds of wetlands were treated as permanently or regularly flooded forests or grass lands, or lakes infested with reeds or other aquatic 'weeds'. Even peat bogs dominated by mosses were considered to be one of the types of terrestrial ecosystems. It was only during the 1960's that studies under the International Biological Programme (1964-74) brought out their ecological characteristics which distinguish them from the terrestrial and aquatic ecosystems and the wetlands were recognised as distinct ecosystem. Yet, the terms wetland covers a number of habitats which differ greatly in their structure (organization of biotic community) and ecological processes. Therefore, only a few salient characteristics, common to all or most of the wetland types, are described below.

2.5.1 CLIMATE

Wetlands occur in all climatic zones - from cold Arctic and Alpine regions to
the moist and warm tropical rainforests and hot and dry subtropical deserts. Wetlands occur in areas where water level is at or near the surface of the soil, or where the soil is covered with water, for a certain minimum duration that allows the growth of specially adapted vegetation. The development of a wetland is not much dependent on the amount of annual precipitation but on the impeded drainage of water. For example, in deserts wetlands occur in low lying areas where runoff water remains standing for several months because of an impervious layer below the soil surface which prevents percolation to deeper horizons. Ground water may also move through seepage into a depression and results in the development of a wetland.

"The temperature regimes determine to a great extent whether the wetland is permanent or seasonal, and also regulate the kind of biota and the biological processes such as production and decomposition in the wetland. The year to year variations in climatic components are common in all parts of the world, and the wetlands respond to them by minor changes in their biota and other characteristics."[4]

2.5.2 HYDROLOGICAL ENVIRONMENT

Hydrology refers to all water related features such as precipitation (rain or snow) and evaporation, inflow and outflow and the resultant factors like the depth and duration of water in the wetland, frequency and time of flooding, and the amplitude of water level changes during a year. The source of water (river or tide), direction and velocity of flow, waves and tides are also important components of hydrological environment of some wetlands.

"Wherever precipitation exceeds loss in evaporation (including transpiration by vegetation), the excess water can cause waterlogging unless it runs off into streams. Similarly, the inflow of water into a wetland should exceed outflow at least for some

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period"\textsuperscript{5}. Flood plain wetlands receive their water both from the rivers overflowing their banks and as runoff from upland areas. The wetlands in the littoral zone of lakes or reservoirs receive water both as runoff and from the waterbody. Other palustrine wetlands may depend entirely on the runoff. These wetlands experience relatively large water level changes during the year according to the seasonality of rainfall and human regulation of water flow from the catchment or withdrawal of water from the lake or reservoir. The wetland many experience a single dry or low water period or the water level may fluctuate more frequently.

The hydrologic regime of the coastal and marine wetlands is governed primarily by the tides. Thus, the mangroves, lagoons, salt marshes and beds of marine algae (or seagrasses) experience a daily cycle of flooding and exposure. Besides tides, wave action also influences the hydrological environment in coastal wetlands.

The depth of water is an important factor. Majority of the submerged plants grow well in less than 2m. deep water. Almost all of the emergent plants cannot grew in deep water if the depth exceeds one meter for a long period. Similarly, waterfowl which feed on benthic organism or on below ground plant parts, cannot occur in deep water habitats.

Time of flooding is also important because water-logging or submergence is required during the growth period, and accordingly, different wetland species would occur during the summer or winter season.

2.5.3 SOILS

Wetlands are characterized by hydric soils. Hydric soils develop under the influence of excess water—either due to waterlogging or seepage of groundwater. When vertical movement of water through the soil is restricted by a hard impervious layer (a

calcareous pan) or by the obliteration of the pore space (as in heavy clayey soils), it results in waterlogging. “Waterlogging affects the soil structure as the aggregates are disrupted by reduction in cohesion and uneven swelling of soil particles. As the clay colloids shrink upon drying, soil material becomes firmer and stiffer, and vertical cracks develop in a coarse polygonal pattern. Most of the soil that are periodically submerged or waterlogged, develop higher clay content at the surface”.

An immediate consequence of waterlogging is the elimination of air from the pore spaces in the soil, and thereby creation of anaerobic condition. The oxygen in the soil is necessary not only for the respiration of roots of all plants, and other soil dwelling organisms (including micro organisms), but its elimination from the soil is followed by a series of chemical changes. In the absence of oxygen anaerobic microorganisms grow rapidly by utilizing oxygen in various ions and decomposition products of organic matter, and thereby the soil is reduced.

Wetland soils are generally divided into (a) mineral soils and (b) organic or peaty soils, depending upon their organic matter content. Peaty soils are those with more than 20% organic matter whereas those with 60% or more of organic matter are called peat. Peat develops from incomplete decomposition of organic matter. Low temperature, low PH (acidic) and anaerobic condition retard decomposition and hence, favour peat accumulation. It may accumulate in-situ, may be utilized by some organism or may be transported to open water bodies with the outflowing water. In seasonally temperature and/or nutrient availability become limiting as is true for peat bogs.

2.5.4 NUTRIENT DYNAMICS

Except the typical peat bogs, wetlands are generally eutrophic systems ie they are rich in nutrients which support their high growth rate. The nutrients are received
primarily from the surrounding catchment with the water. The nutrients in soil are also available to wetland plants whereas in deep water bodies the nutrient concentration is very low. As usual, the nutrients are absorbed by the plants for their growth, and are returned to the system after their death and decay. The nutrient availability is greatly influenced by the seasonal water level changes which may increase or decrease it.

An important feature of many wetland systems is their nutrient conservation strategy. Wetland plants like the emergent reeds and cattails store substantial quantities of nutrients in their below ground organs (rhizomes) and utilize them for growth of shoots when required in the beginning of the growing season or during the periods of deficient supply.

Many wetland plants can utilize ammonium ions as a source of nitrogen as nitrates are reduced to ammonia. Nitrogen fixation by blue green algae also plays an important role in the nitrogen supply to wetland plants. Further, the relatively low nitrogen content of dead organic matter of many wetland plants also help in microbial immobilization of nitrogen during decomposition.

Like nitrogen phosphorus is also accumulated in the below ground organs and internally recycled by the perennial plants. Accumulation of phosphorus in wetlands is further promoted by its precipitation with iron or calcium, and its adsorption on colloidal mineral (clay) and organic matter, the latter being contributed by the incomplete decay of wetland vegetation.

Similarly, heavy metals and organic toxic compounds (like pesticides) are also either absorbed by many wetland plants or are trapped in the organically rich sediments.

"All the processes involved in the dynamics of various nutrients and other toxic substances are governed directly or indirectly by the hydrological environment. The input and output of nutrients from the wetland ecosystem is directly related to the flow
characteristics of water entering or leaving the wetland at different times of the year". The uptake of nutrients by organisms and their release during decay are related to the influence of water regimes on the growth of plants, soil condition, chemical state of elements and the growth of micro-organisms and temperature. The adsorption, precipitation and accumulation in sediments is also affected by the water regime indirectly.

2.5.5 ECOLOGY OF WETLAND VEGETATION

Wetland plants and animals have many morphological, anatomical and physiological characteristics which allow them to inhabit the wetland environment. Small size, simple plant body with profuse branching and absence of lignified tissues are characteristics of many wetland plants occurring in shallow water. All wetland plants have mechanisms to provide air to their root system from the atmosphere, and therefore, are able to tolerate anaerobic condition to different extent. The submerged plants store the oxygen produced during photosynthesis in their plant body (in the extensive air space) and use it for respiration. In free floating, floating leaved and emergent plants there is an extensive system of air spaces (aerenchyma) through which air is actively transported to the roots. In mangroves, trees have specialized respiratory roots (pneumatophores) that grow upwards above the soil surface.

The kind of vegetation in a wetland is determined according to the adaptations of the species to different hydrological regimes. Very few species of trees and shrubs can tolerate permanent flooding by deep water. Among herbaceous vegetation, the submerged and floating leaved plants occur mostly in shallow water of up to 2 meter depth. Some species tolerate deep water for short periods particularly during the non-growing season. Free floating plants, on the other hand, are not affected by water depth as they keep on drifting on the water surface with the wind and wave action.

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The emergent plants like reeds, sedges, cattails require much shallower water and also periodic exposure favours their growth as regeneration occur rapidly and helps decay of dead plants. On the landward side, a larger variety of plants including most reeds and grasses require only waterlogged soils which may be flooded by a thin sheet of water for a very short period.

**2.5.6 ECOLOGY OF WETLAND ANIMALS**

Like plants, wetland animals also possess several morphological and behavioural adaptation which are related to their specific requirements for swimming, diving and feeding and other activities. Many fish truly resident of marshes and swamps are adapted for air-breathing. Several ungulates, have modified hooves (like sangai) which help them in walking over floating mats of vegetation. On the other hand, otters and beavers can swim under water. Beavers, which prefer shallow pools of water in streams, have strong teeth which help them in felling even large trees to make 'dams' across the rivers.

Most of the wetland animals are adopted to large level changes or respond to changes in water level and temperature by short and long-distance migration. Turtles, crocodiles and many fish require exposed or shallow water areas for breeding long distance migration among many estuarine fishes (eg. Salmons) and birds is well known.

**2.5.7 COMMUNITY DYNAMICS**

The community dynamics is directly related to the changing hydrologic regimes. "Dominance of species in the community changes in response to the frequency, duration, amplitude and tuning of hydrologic interaction between the two adjacent system". Thus, any natural or human disturbance in and around the wetland

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8 Patten et al., Op. Cit.
that causes a change in the water regime of the wetland would result in a change in the wetland community and its function. The inflow of silt from the catchment due to erosion results in decreased water depth, and consequently shorter duration of water. Similarly, increased supply of nutrients promotes the growth of vegetation followed by increased accumulation of organic matter in the wetland, and thus, a decrease in water depth. Diversion of flow or withdrawal of water from the wetland has similar consequences for the wetland biota.

Water level changes also affect the animal community both directly and indirectly by change in the habitat condition and availability of food. The benthic fauna as well as zooplankton may be reduced or eliminated. Many fish may die or get exposed to predation. Waterfowl populations and species composition would change according to their ability to utilize the habitat and food.

2.5.8 RESPONSE TO PERTURBATIONS

An important characteristic of ecosystems is their homeostasis, i.e. their ability to return to their normal state after small perturbations. Ecosystems are considered stable or fragile according to the magnitude of perturbation that can be withstood and the swiftness with which the system returns to its normal state. Wetlands are relatively more fragile ecosystems because the wetland biota are adapted to rather narrow hydrological regimes. Therefore, even small changes in the hydrological characteristics of the wetland bring about significant changes in the community structure and function. The time scale of changes in wetlands is related to the time scales of life cycles of individual organisms and the duration for which they can survive under unfavourable conditions. In peat bogs even small changes in water level or topography result in a shift in species composition. Drainage of peat bogs or excavation of peat is a catastrophic event leading to irreversible changes in community structure. On the other hand, in floodplains, large differences in depth, frequency and duration of flooding are required to induce significant changes. Small year to year difference in flooding may
cause only little change in the wetland system.

2.5.9 INTERACTIONS OF WETLANDS WITH ADJACENT ECOSYSTEMS

All ecosystem interact with other adjoining ecosystems in some manner. These interactions are more varied and more intense in case of wetlands. All wetlands, like other aquatic systems, are located in low lying parts of the landscape, and therefore, surrounded by upland terrestrial systems. Majority of wetlands are however, sandwiched between the terrestrial and open deep water systems. Thus, wetlands interact with these systems on both sides.

The interactions between wetlands and adjacent systems involve the exchange of mineral matter, nutrient and organic matter through the agency of water and animals. They depend on the flows of water from the land and the tidal and wave action or flooding from the water body.

As water flows from land to a water body, it carries with it silt, dissolved nutrients and organic matter together with seeds, spores, eggs and other nesting stages of various organisms. The flow of materials from water to land occurs by wave action or during flooding by tides or impeded downstream flow. The wetlands lying between the land and water act as receptacles for these materials and process them variously before they are transported further. The frequency, amplitude, duration and time of flooding determine the degree of interaction. The exchanges are periodic or regular or continuous.

The vegetation in the wetland slows down the movement of water passing through it from the uplands. "The reduction in flow velocity allows for settling of suspended silt and organic matter, and the processing of nutrients by the vegetation and other microbial and physio-chemical processes". Similarly, flood water from the rivers

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or tidal water from the seas must pass through the wetlands before reaching upland areas. Depending upon the intensity and duration of flooding, the flood water may leave behind nutrients, organic matter and biota in the wetland. At the same time, receding flood waters often carry with them significant amounts of nutrients and organic matter to the downstream waters.

The animals play a significant role in the interaction between wetlands and their adjacent system. A large proportion of animals are not permanent residents of wetlands. Most birds use the surrounding terrestrial areas for nesting and breeding. Many birds also feed partly in terrestrial areas. On the other hand, many terrestrial birds feed on other wetland animals or even plants. Amphibians and reptiles move in and out of the wetlands utilizing the resources of adjacent systems.

On the one hand, these interactions and their temporal variations ensure the high biological diversity that is observed in wetlands because the species are adapted to different hydrological, nutrient and other edaphic conditions and those with different feeding habits find a suitable niche in the wetlands. On the other hand, they greatly influence the water quality and production in open water system.

2.6 WETLAND FUNCTIONS AND VALUES

Wetlands are wastelands; that, at least, is the traditional view. Words like marsh, swamp, bog and fen imply little more than dampness, disease, difficulty and danger. Such apparent waste can only be put to good use if the wetlands are 'reclaimed' for agriculture or building.

Nothing could be further from the truth. Far from being wastelands, they are among the most fertile and productive ecosystems in the world. They are essential life support systems, play a vital role clean up our environment.

The socio-economic importance of ecological and hydrological services provided by wetlands, and of the resources dependent upon wetlands has been clearly
recognized and appreciated by the wetland scientists. Recognizing the functional importance of wetlands for the society, have motivated protection of wetlands.

Wetlands functions can be divided into four broad categories i.e.

1) physical/hydrological
2) chemical functions
3) socio-economic values

2.6.1 PHYSICAL/HYDROLOGICAL FUNCTIONS

a) Flood mitigation

Floods are the main hazard to human occupation in lowland areas and wetlands that have been assiduously reclaimed and drained often hold the key to flood mitigation.

Wetlands can mitigate flooding in several ways. They store potential flood waters at least temporarily and thereby protect downstream localities which are often former wetlands now reclaimed. They reduce flood water peaks, and their very existence can assure that flood waters from tributaries do not all reach the main river at the same time.

Thus the value of these functions in protecting lives, property and crops is increasingly important around cities, where development has lead to more and more of the land surface being packed by roads, houses etc. thus making it impervious to water.

Centuries of embanking and reclamation on the Ganges-Brahmaputra delta have reduced wetlands by many hundred of square kilometers and this is part of the cause of the severity of the downstream flooding that occurs annually.

(b) Coastal Protection

Coastal marshes absorb wave energy and reduce erosion on estuarine
shorelines, and so buffer the land from storms. "More than 50 percent of wave energy is dissipated within the first 2.5 m of the marsh, a figure which rises to 80 percent at 10m and is virtually eliminated at 30m. Similarly, erosive tidal flows can be dissipated by plant stems growing in marshes and near dunes. Coastal marshes are sinks for the suspended sediment which can accumulate at rates of between 8 and 37 mm/yr"^10.

The implications of this natural process are manifold. In the developed world the effects of storm surges, hurricanes and similar natural disasters could be lessened by marshland accretion and growth, and not through reclamation and more protection, which merely pushes the hazard further out to sea. However in the less developed world of the tropics, vast number of people are exposed on lowlands long stripped of wetland vegetation, where storm surges may be as high as 4m. Thus, there is an urgent need to encourage mangrove propagation and discourage reclamation in flood-plain delta areas, such as Bangladesh.

(c) Recharging aquifers

It is often claimed that wetlands can play important roles in charging aquifers (layers of rock or soil which hold water), but there is little scientific evidence to support any general rules, because wetland types vary so enormously. Studies in Massachusetts found that most local wetlands were helping recharge aquifers, but elsewhere wetland may in fact be sinks for water discharged from aquifers. "In Massachusetts, over 40 percent of wetlands are potential sources of drinking water, and many public wells are in the wetlands or very nearby"^11. Coastal wetlands maintain the water pressure in ground water supplies, which is vital for keeping salt water from seeping into ground water supplies and contaminating it.


(d) **Sediment trapping**

Wetlands are sinks for sediments. By slowing the velocity of water flow, and increasing the 'residence time' of water in the ecosystem, wetlands enable biological, physical and chemical changes to occur in the water.

Large sediment loads can quickly silt up rivers and reservoirs, dramatically shortening the lives of hydroelectric projects. High turbidity in estuaries can reduce the production of phytoplankton by reducing the sunlight reaching these organisms. If the suspended sediment has a high organic carbon content, then its decomposition consumes oxygen, cutting the supply for fish and other organisms. While the presence of suspended sediments is detrimental to water quality they have a strong tendency to absorb nutrients, pesticides, heavy metals and other toxins such as chlorinated and petroleum hydrocarbon. Once deposited and 'trapped' in the wetland these substances can be either removed by the wetland plants or undergo slow decomposition.

Slowed velocity not only clean the water but helps build up the land surface in subsiding coastlines, such as the Mississippi and Ganges deltas. In estuaries, the action of salt water mixing with freshwater causes the sediment to form into aggregation (clumps) and settle. Where land is subsiding, as in the Mississippi delta, sediment deposition is essential to maintain the coastal marshlands. Sediment generally builds up at 2-4 mm per year in areas with established vegetation, but on bare mudflats and areas of spreading cordgrass (spartina) build up can be as much as 37-45.5mm per year.

2.6.2 **CHEMICAL FUNCTIONS**

(a) **Pollution trapping**

Because wetlands intercept the run off from uplands before it reaches channels, they trap water and filter out pollutants, thus improving its quality. Foremost is their role in removing the nitrogen and phosphorus that comes from the use of ever-
increasing quantities of nitrogenous and superphosphate fertilisers on farmland. The over nutrient-rich water causes ripped plant and algal growth (eutrophication), and the rapid spread of undesirable aquatic plants that absorb oxygen in lakes, ponds and slow-moving waters reduces the ability of the water to support marine life and affects the quality of drinking water and recreational activities.

The removal of the pollutants is accomplished by a number of means. In the case of phosphorus, there is some uptake by the plants and it is also reduced by being absorbed and settling in anaerobic sediments, but there are finite limits to the amount of phosphorus removed. In contrast, wetlands are very efficient at removing nitrogen, again by plants but more particularly by bacterial metabolism at the water-sediment interface which promotes nitrification (transformation of nitrogen into molecular nitrogen and gaseous oxides) and denitrification (caused by anaerobic bacteria found in the wetland sediment that convert nitrate nitrogen into atmospheric nitrogen).

(b) Removal of toxic residues

Wetland plants can remove heavy metals, pesticides and herbicides and other toxins from water, fixing them at least temporarily in their own tissues, particularly by bull rush, the common reed and the water hyacinth, which is an aggressive colonizer of warm still waters. The effectiveness and efficiency of these processes varies between 20 and 100 percent depending on the pollutant and the type of wetland, and can be enhanced by deliberate planting of absorptive vegetation. It can also be removed by ion exchange and absorption in the organic and clay sediments.

(c) Waste water treatment

A very practical chemical function of wetlands is their ability to process human and animal waste material in an extremely efficient way. Their ability to do this revolves around three factor: their very high primary productivity, which means that their prolific growth takes up pollutants from the water and substrate, the absorption of
pollution by the high rate of sediment deposition and the bacterial action in the sediments.

2.6.3 SOCIO-ECONOMIC VALUES

Though most values like groundwater recharge, maintenance of water quality, checking erosion and biological production can be evaluated in economic terms, there are several direct economic benefits in the form of harvestable resources for many which traditional societies have remained dependent upon wetlands for millennia.

Wetlands provide people directly and indirectly—with range of Economic consumptive values: stable food plants, fertile grazing land, support for coastal and inland fisheries, flood control, breeding grounds for waterfowl and fuel from peat, among others.

In addition, there are many social non-consumptive benefits that usually defy quantification, but none the less are becoming increasingly important. There are the active non-consumptive benefits, such as the use of wetlands for recreation and leisure activities, and the passive non-consumptive benefits—wetlands as aesthetically satisfying and beautiful environments, as sites for scientific and archaeological research and as sites of heritage and educational value.

(a) Consumptive values: food

Wetlands are a source of economically important food plants. Rice— a wetland plant—is the major food staple of over half the world’s people. Oil palm, a tree originating in west African wetlands is one of the world’s most important sources of edible and soap-making oil.

Less well known—but no less important is sago palm. The swamp sago is an important component of the flood-plain swamps of south east Asia. Sago is the main food staple for a quarter of the population of Irian Jaya (Indonesian Island).
Wetlands are a major source of non-food plants too. Reeds are used in thatching, paper production and, in some places, bedding. High-yielding crops of willow are still grown in the Somerset Levels of southwest England to supply the raw materials for basket weaving.

Over 30 million hectares of US commercial forests (excepting Alaska and Hawaii) are in swamps or on land subject to periodic flooding. Plantations of eastern cottonwood on the Mississippi flood plain produces five times the yield of the natural bottom land hardwoods.

Bold cypress is durable, strong and lightweight timber much sought after in the US construction industry. Nearly all the original stands have long been cleared in the Southern United States, but secondary growth stands can produce 425 cubic metres per hectare. Cypress planting has been advocated recently not just to maintain wetlands but as sound forestry economics.

Mangroves yield highly durable wood ideal for poles and pilings in nearby communities. In the Sundarbans swamp forests of coastal Bangladesh, many coastal communities are sustained through harvesting firewood and producing honey and wax directly from mangroves. Mangrove bark contains 20-30% tannin-used in tanning leather and extracts are used extensively in the leather industry, in medical treatments and in the wine and beer industry. The mangrove palm variously provides fodder, fuel, alcohol, vinegar and sugar. Wild Nipa swamp, which often appears inland of the mangrove coastal fringe, can yield three tonnes per hectare of sugar.

(b) Grazing lands

The consumption of living plants is essential not only for the survival of plant-eating species - and so of the natural ecosystems of which they are part - but for the survival of human societies dependent on grazing animals. Among the many economically important wild animals which feed extensively on wetland vegetation
are: waterfowl; fur-bearing mammals such as muskrat and coypu; game species such as caribou, moose, lechwe and capybara.

Large numbers of domestic livestock are grazed on wetlands. Many African rural communities survive by moving their cattle - and their crops - as falling flood waters expose enriched bottomlands and flood plains. Because many wild species have evolved special adaptations to this environment (such as Lechwe's ability to graze in standing water) they can graze more efficiently on wetlands than domesticated herbivores. That is, they can assimilate more energy for less energy expended. This offers the possibility of properly managed wildlife providing more food without expensive environment alterations than could many farming systems which produce environmental change.

(c) Fisheries

Coastal, lake and floodplain wetlands are highly productive spawning, nursery and feeding areas for fish. Not only are they a rich food base, but they protect young fish from strong currents, sunlight and predators. About two-thirds of major US commercial fisheries depend on estuaries and salt marshes as nursery and spawning grounds. Marine species dependent on US wetlands include menhaden, bluefish, seafrout, and mullet. Shrimp, blue-craps, oysters and clams - all important economic shellfish - depend on coastal wetlands. Scientists have demonstrated a direct relationship between the existence and size of tidal wetlands estuary and the production of a marine shrimp fishery.

Mangroves support a wealth of fish, shellfish, prawns, oysters, clams and mussels.

While wetlands in developed nations produce large amounts of commercially valuable products, economic and nutritional dependence on wetlands is at its greatest among small third world communities.

As far as Inland fisheries are concerned, rivers and theirs flood plains produce
about half of the world’s inaland fish catch of 10 million tonnes. Many species may migrate short distances, but others-salmon, trout, sunfish, pickerel and some carp - may all go considerable distances; Atlantic and Pacific Salmon may migrate thousands of kilometres to spawning grounds in the aquatic vegetation beds of shallow river head waters. Thus the benefits of wetlands may be felt at some considerable distance from their location; perhaps ever in different countries. Such are the links between wetlands, rivers, lakes and the open sea that upsetting the water regime which normally maintains a wetland system and flooding cycle can have considerable knock-on effects. The increasing regulation of water flow and and development of flood plains for other land uses is increasingly devastating to natural fisheries.

Recreational fisheries are particularly important in the developed world where all freshwater recreational angling depends on wetlands. Fishing is the most popular 'sport' in the World. It provides not only the enjoyment of the sportsmen but also the financial spin-offs from recreational fishing in terms of equipment manufacturing and retail sales, licences, and income for resorts and tourism. Sport fishing is being identified by many coastal resorts in developing countries as an important potential source of foreign currency.

Wetlands with their extensive fishery resources, has also given rise to aquaculture. Thus the species which depend on wetlands are being 'farmed', an activity which requires management, breeding and selection for increased production. These efforts involve such varied species as carp, catfish, shrimp, crayfish, oysters, frogs, turtles, alligators, crocodiles and duck. Developing nations are becoming interested is aquaculture not only as a domestic economic enterprise but particularly as an earner of foreign currency. But the development of aquaculture exacts an environmental and ecological cost. Wild wetland might often prove more productive than altered, managed wetland.
(d) Non-Consumptive benefits

The non-consumptive benefits of wetlands include scenic, recreational, educational, aesthetic, archaeological, scientific, heritage and historical benefits that are difficult to both define and quantify.

These non-consumptive values have usually been considered of secondary importance compared with the direct consumptive and economic products of wetlands and the physical, chemical and biological services that they provide. Non-consumptive values are intangible and can be highly personal and subjective.

2.7 ANTHROPOGENIC IMPACT ON WETLANDS

According to some experts, the world may have lost half its wetlands since 1900.

"The United States alone has lost an estimated 54% (87 million hectares) of its original wetlands. From the 1950s to the 1970s, losses ran at 185,000 hectares per year. Agricultural development has been by far the largest single cause of loss, accounting for 87% of recent wetland losses in the contiguous United States. Urban development has taken 8% and other development another 5%" 12.

Until relatively recently, disease, flooding and waterlogged soils tended to keep large numbers of people and large development projects out of extensive wetland regions. This has been particularly true in poorer nations, where traditional economics have continued to husband the wetland ecosystem rather than alter it. However, modern technology, foreign aid programmes and demands for new agricultural land and other resources have removed the natural immunity of large wetlands to economic 'development'. The location of wetlands along rivers, on coasts and on flat land with

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inherently fertile soils, has offered many motives for people to convert them to other uses.

Direct impacts include reclamation of wetlands for different landuses, and over-exploitation of wetland resources. The indirect impacts are more varied, ranging from landuses practices in catchment (agricultural, grazing, mining etc) and direct regulation of water flows to disposal of wastes on the wetland itself or in the adjacent waterbody. Different kinds of such impacts are examined separately.

2.7.1 LAND RECLAMATION AND CONVERSION FOR LANDUSE

The most common cause of wetland loss world wide has been the reclamation of land by draining and/or filling. Reclamation is done mostly for higher economic return since the land is brought under residential, industrial and commercial use and for construction of highways. Shallow marshes and flood plains are often the preferred sites for landfills with soiled urban and construction wastes. Much of the territory of the Netherlands is a reclaimed coastal wetland which was once under sea water. Similarly, large wetland areas have been drained in other parts of Europe as well. “About half of the wetlands in the coterminous United States have been lost over the past two hundred years due to reclamation by drainage”13.

Although the loss of wetlands through their reclamation has not been estimated in India, it is well known that a very large proportion of the natural wetlands have already been filled or drained for urban and industrial use. This has happened to the floodplains of all major and medium rivers where the most important urban settlements are located today. This continues unabated even today, as far example in Delhi where plans have been made to reclaim several thousand hectares of flood-plains for recreational parts and commercial use.

Far more natural wetland area, both saline and freshwater, has been converted into fish ponds and paddy fields. "Regular cultivation in mangroves started in late 18th century, east of Calcutta in Maltah-Bidyadhari basins. Later, the forest were reclaimed also for pisciculture. These reclaimed areas are the main stay of fisheries in the Sundarbans today. In other saline wetlands brackish water fisheries and shrimp culture are being promoted." Conversion of bheels into fish ponds has been extensively discussed and advocated by fishery scientists.

2.7.2 OVER-EXPLOITATION OF WETLAND RESOURCES

A major cause of degradation of many wetland habitats is over-exploitation of their resources, particularly the biological resources for food, feed, fiber and fuel. Resource use can be based on the carrying capacity of the wetland and the growth rates of the concerned biota. Removal of plants or animals in excess of their growth rate affects their population size and also the flood-chain interactions. Excessive harvest of plant resources is bound to reduce the available riches and food of the animals. This also increases erosion through flow of water and nutrients, and consequently a change in water quality which affects and other biota. Excessive fishing in chilika lake has resulted in decreasing yields. Over-exploitation may also drive many species to near extinction for example, in pantanal flood-plains of Brazil, the caiman has become endangered by human poaching for skin.

Grazing by domestic cattle is an important activity in mangroves, floodplains and other reasonal wetlands. Large amounts of forage is also harvested, and often even the subterranean parts are scraped from these wetlands. It has been observed in many studies that overgrazing by domestic cattle in wetlands adversely impacts on biotic composition and stream bank integrity, increasing siltation and runoff with a consequent loss of vegetation and fish. Grazing and forage removal not only deplete

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the herbaceous vegetation but also impact on other biota and soil properties which may be beneficial or harmful for the wetland. For example, grazing by domestic cattle had been regarded as the most serious problem in the wetland at Bharatpur (Keoladeo Ghana National Park, Known for migratory birds) but their exclusion caused significant change in vegetation.

Mangroves have been exploited for centuries for timber and fuelwood. Many species like Sonneratia alba and Xylocarpus moluccensis yield high quality timber for furniture. The tree trunks of Heritiera tomes and Bruquiera gymnorrhiza make excellent transmission poles for telegraph and electricity lines. Excoecaria agallocha provides good pencil wood. Mangroves are an important source of fuel-wood and charcoal in all countries of South Asia. The bark of Rhizophora mangle and several other species like ceriops candolleana, Kandelia candel and Excoecaria agallocha is used for extraction of tannin for leather industry.

Wetlands are also exploited for resources other than biota. Bogs are used for peat which is mined for fuel and horticulture. In Jamaica, peat mining is an important factor in wetland degradation. Sand and silt are commonly removed from the floodplains of many rivers for use in construction.

2.7.3 REGULATION OF HYDROLOGICAL REGIMES

Equally and often more serious impacts on wetlands are made indirectly through activities which cause changes in their hydrological regimes. Most important of these are the river flow regulation projects aimed at flood control and water storage for irrigation or hydropower, and the denudation of catchment areas of the waterbodies by deforestation, excessive grazing, agriculture and similar land-based activities which increase soil erosion and the consequent inflow of silt and nutrients into the wetlands.

The floodplains are directly affected through construction of dams and barrages as the flooding regimes (frequency, duration, amplitude and timing) are altered both
upstream and downstream. Channelization of rivers and streams by dykes has the same effect on flood-plain wetlands. Permanent submergence, with minor water level fluctuation of upstream areas converts flood plains into permanent marshes and reduces both the habitat and biotic diversity. In contrast, downstream floodplains experience much less flooding of varying duration and timing; consequently, these flood-plain wetlands are degraded or lost. Modification in flooding regimes cause changes in species composition particularly of forage plants, and often less palatable and nutritionally poor species replace the important forages. Losses in the grazing value and fertility of flood-plain in turn affect the rural and tribal human populations dependent upon them. The conversion of seasonal wetlands in the floodplain of Manipur river (Loktak pat and other pats) into a permanent reservoir by the construction of Ithai barrage for hydropower generation, has greatly affected the fisheries of the area.

In the Indian part of Sunderbans, freshwater contribution through the Ganges is relatively small and is becoming still lower. In the absence of flushing, the distributaries in the deltaic region become silt laden and clogged, further reducing freshwater flow and increasing salinity of the soils. The strain and stress on mangroves has led to changes in species composition, their dominance, lower production and diminished luxuriance. For example Nypa fructicans, Heritiera tomes and phoenix paludosa have almost disappeared from the Indian part of Sunderbans, and are replaced by Excoecaria species. The increasing salinity has affected also the paddy yields on reclaimed soils. The Dampair Hodges Line (based on salinity values) which once formed the natural frontier between the agricultural lands and the mangroves, has been pushed southwards and has lost its significance.

2.7.4 ANTHROPOGENIC ACTIVITIES IN THE WATERSHED

Intense human activity, especially deforestation, on a large scale throughout the catchment of floodplains and other wetlands results in erosion of sediments which get
deposited in the wetland basins. Many shallow lakes and marshes have filled up rapidly and the characteristic wetland vegetation has disappeared together with the dependent fauna.

It also increases inflow of nutrients, leading to eutrophication. Rapid siltation and eutrophication change both plant and animal communities, impacting on wetland functions. For example explosive growth of aquatic plants follows increased nutrient inputs, and often has serious consequences for other biota.

2.7.5 POLLUTION/SEWAGE DISPOSAL

Further important impact on wetlands are made by the discharge (into the water body or wetland itself) of domestic sewage and industrial effluents, and input of pesticides and herbicides with the runoff from surrounding landscape. Even when these are directly discharged into a waterbody, associated wetlands may be affected through water level changes. Eutrophication has been demonstrated to be a major cause of decline of reed (phragmites australis) belts in Europe. The impact of sewage disposal and recreational activities in the decline of wetlands in Kashmir valley, particularly those around Srinager is well known. The shallow ox-bow lakes in Srinagar receive large amounts of domestic wastes from the surrounding watershed. The eutrophication has resulted in excessive weed growth throughout the lake resulting in encroachment of the shoreline. Ramamurthy (1984) reported large fish mortality in mangroves on the Arabian seacoast of India, due to pollution by chlorinated hydrocarbons and organochlorine resides from the surrounding agricultural lands, however, the adverse impacts of nutrient enrichment and organic and inorganic pollutants are not well understood in the tropics. Because these wetlands have received nutrients and organic wastes already for hundreds of years, their capacity to process them has been reduced to a very low level or eliminated altogether, thereby further threatening the remaining wetland area.
Oil spills from tankers and smaller transport boats as well as offshore oil exploitation are a growing pollution problem in coastal areas, estuaries and lower stretches of major rivers. "Field and laboratory studies show that petroleum products cause mortality of seedlings, damage leaves and roots, block lenticels and retard the growth of mangrove plants like *Avicennia officinalis* and *Rhizophora mucronata".\(^{15}\)

In an effort to control nuisance weeds and insect vectors within wetlands and their watersheds, herbicide and pesticides often end up in wetlands. Davies and Bowles (1983) report that use of pesticides against the tsetse fly in Okavango may eliminate the fly contributing to an increase in the grazing cattle which would adversely affect wetlands.

Other human activities like washing, bathing and recreation in water, especially when extensive, also adversely effect the water quality and wetland biota.

### 2.7.6 INTRODUCTION OF INVASIVE ALIEN SPECIES

Invasive species are an important threat to wetlands. Strangely, in the tropics these species are often neotropical natives which have been introduced in the old world tropics accidently or intentionally. Among the most important and therefore well-studied of these aquatic weeds among which the most significant are *Eichhornia crassipes* (water hyacinth), *salvinia molesta*, *Ristia stratiotes*, *Alter-nanthera philoxeroides* and *Hydrilla verticillata* water hyacinth may be singled out for the degree to which it has received global attention. "Water hyacinth has the capacity for prolific growth and completely cover the water surface with a thick mat. These mats become colonized by less desirable semi-aquatic species which replace the natural biota. Although water hyacinth is eaten by some animals, there are no native herbivores which may be used to control its growth. Water hyacinth also exhibits high

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evapotranspiration rates which coupled with organic matter accumulation can turn a wetland quickly into a dry upland"\textsuperscript{16}.

Similarly, the introduction of exotic fish like tilapia and grass carp for their ability to feed on organic wastes and herbaceous submerged vegetation, has also caused a shift in the species composition of natural fish fauna and other biota. The adverse consequences for wetland functioning have not yet been properly understood.

Mukherjee and Tiwari (1984) have listed many plants and animals which were introduced or immigrated into the Sunderban mangroves and which caused changes in the natural plant and animal populations.

2.8 CONCLUSION

Until the middle of the twentieth century, wetlands had no identity of their own. They were considered a part of either the terrestrial or aquatic ecosystem. Different kinds of wetlands were treated as permanently or regularly flooded forests or grass lands, or lakes infested with reeds or other aquatic ‘weeds’. Even peat bogs dominated by mosses were considered to be one of the types of terrestrial ecosystem. It was only during the 1960’s that studies under the International Biological Programme (1964-74) brought out their ecological characteristics which distinguished them from the terrestrial and aquatic ecosystem and the wetlands were recognized as distinct ecosystem. Yet, the term wetland covers a number of habitats which differ greatly in their structure and ecological processes. It is indeed difficult to define it in simple terms. However, wetlands have been defined variously during the past two decades. The definitions range from simple working definitions to highly technical ones.

All wetlands perform certain functions and hence, have some values. They are among the most fertile and productive ecosystems in the world. They are essential life

support systems, play a vital role in controlling water cycles, and help to clean up the environment.

The beneficial intrinsic functions of wetlands and the imputed or computed values placed on them, have been instrumental in changing attitudes towards wetlands. However, in the everyday world of wetland management there is a point where any function/value will be pitted against another, either through ignorance or entrenched attitude (e.g. draining land for food production and destroying its function of biologically enhancing water quality) or through deliberate policy in a management plan that attempts to resolve conflicts and pressures in land use, such as residential development versus coastal protection functions. Immediately, the question moves from what the uses of wetlands are in their natural state to how they should be used. Inevitably, attempts are made to quantify benefits in order to resolve conflicts.