# Guidelines for Rapid Assessment of BIODIVERSITY AND ECOSYSTEM SERVICES OF WETLANDS

Version 1.0

*Editor*: **Brij Gopal**




ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

20 YEARS Bridging Science & Policy for a Sustainable Asia-Pacific

रक्षये प्रकृति पांतु लोकाः

National Institute of Ecology

# Guidelines for Rapid Assessment of BIODIVERSITY AND ECOSYSTEM SERVICES OF WETLANDS

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*Editor*

BRIJ GOPAL
*Centre for Inland Waters in South Asia*

Prepared for

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by

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# PREFACE

Ecosystems are nature's functional units composed of an interdependent and dynamic community of plants, animals and microorganisms, interacting among themselves and with their non-living environment (energy, water, and gaseous and mineral elements). Humans are just one of millions of kinds of organisms, and therefore, depend for their existence, survival and various activities upon the Earth's ecosystems. Over millennia, humans have acquired the ability to exploit the nature's ecosystems to such extent and in such manners that they consider themselves to be independent of nature. The conceptual divide between humans and nature has led to the emergence of a view that nature provides numerous services to the humans through the functioning of its diverse ecosystems. The benefits obtained by the humans from nature are now termed as 'ecosystem services'.

Water is the most abundant substance on our Earth and yet the most critical one that sustains all living organisms — from microscopic bacteria to large mammals – and also influences all non-living components of the earth's environment. Driven by solar energy, water remains in continuous circulation, changing its form along its pathways. At many places, water is the dominant component of the environment resulting in ecosystems, such as springs, rivers, lakes and wetlands, with a distinct suite of organisms and other specific characteristics. Among these inland aquatic ecosystems, wetlands are now known for their exceptionally high biodiversity and a wide range of ecosystem services. Yet, wetlands are the most threatened ecosystems as they bear the brunt of all human activities – both in and around them. Several decades after their importance had been recognised globally, these ecosystems are still considered in most of the developing countries as 'wastelands' and their integral role in the hydrological cycle is grossly ignored. Many wetlands - even the large ones- are seasonal in nature owing the strongly monsoonal climate of South Asia. Practically all Environmental Impact Assessments are based on secondary data, very limited field surveys over a short period and for a very small area around the project site. Seasonal character of wetlands implies that most of the aquatic biota are not encountered during the dry season survey and the impacts of the projects on water bodies located farther away through the hydrological connectivity are grossly ignored.

In our view, the failure to consider and accord due importance to wetlands in various development projects, including those concerning the water resources, stems from the complexities in appreciating and assessing the biodiversity or hydrological and other ecological characteristics of wetlands (especially their interlinkages within the river basin through the hydrological cycle) and linking them to their ecosystem services. It is important that policy- and decision-makers become aware of the full value of wetlands, their biodiversity and ecosystem services for mainstreaming them into policies, particularly those related to land use and water resources projects. At the same time natural resource managers, researchers, NGOs and other stakeholders also need to understand the ecosystem services and biodiversity of different kinds of wetlands and have the capacity for their rapid assessment using appropriate methodologies.

Recognising this need, the National Institute of Ecology (NIE) decided to organise a few workshops to engage a range of stakeholders including policy makers and resource managers from the South Asian region in discussions on ecosystem services of wetlands in relation to their biodiversity and focusing on their rapid assessment. This document provides a brief introduction to the subject and a review of the current state of our understanding in regional context. It provides guidance for the rapid assessment of diversity of major groups of biota in inland wetlands and then to assess a few important ecosystem services particularly those linked with the biodiversity. Assessment of biodiversity is somewhat complex and time consuming activity as it involves collection and identification of the organisms to the species level. It requires the help of specialists for different groups of organisms. Here we introduce only basic and simple steps which can be followed by the non-specialists. Appropriate references are provided to help the younger biologists in identifying the organisms. Microbial diversity plays a very significant role in wetlands but it has not been covered here because its assessment invariably requires laboratory investigations. The document does not deal also with the genetic diversity among species. Further, specialised habitats such as springs and subterranean systems (including caves) are also not included. Our objective in preparing this document is to serve only an "appetizer" and not the full 7- or 11-course meal. Abundant references are provided to detailed studies and available methodologies for those who wish to conduct comprehensive assessments. However, we intend to revise and update the present version (1.0) of the guidelines periodically to make them more useful.

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We gratefully acknowledge the financial support from the Asia-Pacific Network for Global Change Research (APN-GCR), Kobe, Japan, for the preparation of these guidelines and for conducting the capacity building workshops. We are grateful to our partners, the Central Inland Fisheries Research Institute, Barrackpore, Kolkata (ICAR), the Kathmandu University, Nepal and Conservation Sciences-India, New Delhi, for their active collaboration and support in many ways. We thank the contributors for their help and cooperation in preparing this document. We acknowledge gratefully all individuals and institutions as well as publishers from whose works substantial material has been borrowed or adapted. As far as possible, all these sources have been identified in the text. Readers are invited to communicate their comments and suggestion for improvement and elaboration of these guidelines especially for the benefit of the water resource managers, wetland managers and policy makers.

New Delhi
8 June 2015

Brij Gopal
and Collaborators

# INTRODUCTION

Brij Gopal

## WHAT ARE WETLANDS?

Wetland is a term that was used first in 1950s for the seasonally or perennially shallow-flooded habitats of waterfowl. Until then, these diverse habitats were known by common terms such as marsh, swamp, bog, fen, mire, moor and scores of local names in different countries and languages. Gradually, since 1970s, the scope of the term 'wetland' has been expanded to bring under its umbrella a very wide range of ecosystems of which the only unifying characteristic is that their physical environment is dominated by water in and above the substratum for at least a large part of the growing season. The water may be fresh, brackish or saline, standing or flowing, and its source may be either a surface water body (a river or lake or ocean) or only the direct precipitation over the area or only the discharge from the ground. The organisms in these habitats may vary from a few to numerous kinds and in their size from microscopic to huge plants and animals. Wetlands occur in all climates, across a wide range of latitudes, and from sea level to more than 5500 m altitude (as in the Himalaya).

Bringing together such an enormous diversity of disparate habitats within a single term has made it impossible to define wetlands in a simple manner. Many definitions have been proposed and adopted in different countries for different purposes while the old, common and local terms continue to be used adding further to the confusion. Some of the definitions used more commonly are noted below.

The Ramsar Convention on Wetlands of International Importance (1971) defines wetlands as:

*Wetlands are 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 six meters.*

To ensure protection of coherent sites, the Ramsar Convention states (Article 2.1.) that wetlands *"may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands"* (Ramsar Convention Secretariat 2013).

For practically the same reason, Ramsar Convention considers lakes and rivers also as "wetlands in their entirety, regardless of their depth".

More recently, Pittock et al. (2015) use the term wetlands interchangeably with freshwater ecosystems (also called inland waters) and define them as "*places where water is the primary factor controlling plant and animal life and the wider environment, where the water table is at or near the land surface, or where water covers the land*".

Thus, wetlands have turned into waters without the role of 'land' in them. Such a broad scope of the term wetland totally ignores the role of macrophytes in determining the functions and ecosystem services. In fact, the macrophytes were a distinguishing feature in the definition of wetlands in the United States.

The United State Fish and Wildlife Service used detailed scientific criteria to define wetlands as (Cowardin et al. (1979):

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

> *predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is non-soil 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 under:

> *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 hydro-phytes 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 hydrophytes; (3) areas with hydrophytes but nonhydric soils, such as margins of impoundments 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 Ramsar definition and also the 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 2 m below low water; however, if emergents, shrubs, or trees grow beyond this depth at any time, their deepwater edge is the boundary.*

I have discussed recently the distinction between wetlands and deep open water systems (Gopal 2015). However, without discussing the merits and demerits of various definitions, it will be sufficient to spell out the scope of wetlands for these guidelines. Wetlands are usually grouped into freshwater and marine wetlands or into inland and coastal wetlands. The inland wetlands, occurring above the mean sea level, include also those which develop in saline waters (salt lakes) and experience estuarine or brackish water conditions (lagoons and backwaters). Wetlands are also considered as transitional systems because they are often located between deepwater and terrestrial habitats. Thus, the floodplains, lake littorals and coastal beaches are included among wetlands. The lagoons and backwaters usually have their bottoms below the mean sea level; they receive freshwater from the surrounding uplands and are also connected with the sea during the tides. Wetlands may develop naturally or they may have been constructed or modified by humans (e.g., fish ponds and paddy fields). It must be emphasised that all kinds of wetlands (all inland aquatic ecosystems) are integrated into different river basins where they may be physically separated but are linked together by the hydrological cycle (Figure 1). These guidelines are restricted to inland wetlands but exclude mangroves. Salt marshes are also excluded as they do not occur in South Asia. Further, the rivers, deep lakes and reservoirs are not considered here as wetlands.

## WHAT IS BIODIVERSITY?

Over the past millions of years, living organisms have evolved and diversified into innumerable forms. This diversity of life, which is a characteristic of nature, has attracted the attention of humans since times immemorial. Humans identified and named them variously. In relatively recent times systems of nomenclature were developed for plants, animals and microscopic organisms which assigned two names (genus and species) to an organism. Further, elaborate systems of classification have been proposed for inventorising the huge diversity of organisms. Further, variations occur even with the organisms of a species according to their genetic constitution and the environment in which they occur. Being distinct is a property of living systems (see Solbrig 1994, Heywood 1995). The term


Figure 1. All kinds of wetlands (inland aquatic ecosystems) are part of a river basin

biological diversity was first used by Norse and McManus (1980) for a concept that included both the number of species within a community (ecological diversity) and the genetic variation within a species (genetic diversity). The term was shortened to biodiversity for the National forum on BioDiversity organised by the National Research Council of the USA (Wilson 1988). This shortened form soon became popular among researchers and policy makers. In principle, the term includes any kind of variation at any level of biological organization from genes through populations, species and communities to ecosystems. There has been much discussion on its definition and scope to emphasise the variability at different levels of organisation (Gaston 1996, Delong 1996). but the most widely used definition is that adopted by the Convention on Biological Diversity (CBD 1992) which defines it as

'*the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this Includes diversity within species, between species and of ecosystems*'.

While it is common to segregate biodiversity into that of different groups of organisms (i.e. taxic biodiversity; e.g. algal biodiversity, microbial biodiversity, insect biodiversity, mammalian biodiversity), a true picture of biodiversity of a particular geographical area or ecosystem or habitat cannot be obtained without considering the total biodiversity of all kinds of organisms inhabiting it. The term biodiversity continues to be confused and used synonymously with 'species diversity' which refers to the number of species (i.e. species richness) occurring in an area. Whittaker (1972) distinguished species diversity into:

*Alpha Diversity*: Number of species in a local community within a specified area (e.g. one ha or a habitat patch). It is within habitat diversity.

*Beta Diversity*: Change (or turnover) in species composition between two distinct communities. It is between-habitats diversity and increases with habitat heterogeneity.

*Gamma Diversity*: Total species richness over a large geographic area (i.e. landscape scale diversity).

Biodiversity of an area varies with time (seasonal and long-term dynamics) and spatial scale. It is important to consider the beta-diversity especially in a heterogeneous habitat.

Further, the biodiversity of an area may include species which are not native to it but are alien (exotic) and had migrated by natural means or were introduced by humans. The migrants over the geological past which have naturalised in an area are referred to as 'biogeographic elements'. Some of the recent introduced aliens become invasive as they propagate rapidly and alter the composition of native communities. The biodiversity of an area/region also includes several species which are designated as Rare, Endangered or Threatened according to their conservation status and deserve special attention in any study of biodiversity (see IUCN Red list; http://www.iucnredlist.org/).

## Biodiversity of Wetlands

Wetlands are usually rich in their total biodiversity which is often much higher than that in many other ecosystems. Prolonged waterlogging of the substrates causes deficiency of oxygen (hypoxia) or its total absence (anoxia) in the soil and consequently, several chemical changes in soil characteristics. This renders the environment unsuitable for the terrestrial plants; yet a large variety of herbaceous and woody plants are well adapted to wetland environment. Hydrological variables and water quality directly or indirectly regulate a number of biological processes which in turn influence the biodiversity (Figure 2). The morphology of wetland basins together with the usually large seasonal water level changes results in relatively large niche diversification and hence, a more dynamic and diverse community of both plants and animals.

Wetland vegetation includes representatives of all taxonomic groups - from unicellular algae through bryophytes, mosses and ferns to woody angiosperms. Often a cursory look at a wetland is misleading because only one or two plant species (such as species of *Typha, Phragmites, Cyperus, Scirpus* etc.) may dominate the entire wetland. A closer examination is required to discover the total diversity of plant and animal life. Besides many submerged or free floating, rooted floating leaved and emergent plants occupying different niches, numerous species of planktonic and filamentous algae occur in different wetlands. There is also a large suite of fungi and bacteria which play a significant role in the wetland processes.

The faunal diversity includes representatives of almost all taxonomic categories, from protozoa to mammals. Wetland fauna comprises of two kinds of animals: (a) those depending entirely on wetlands for their whole life, and (b) those utilizing wetlands for a part of their life cycle or for particular needs. Gopal and Junk (2000) recognised six categories of wetland fauna: (a) residents in the wetland proper; (b) regular migrants from deepwater habitats; (c) regular migrants from terrestrial uplands; (d) regular migrants from other wetlands (e.g. waterfowl); (e) occasional visitors and (f) those indirectly dependent on wetland biota (e.g. canopy insects) Numerous species of fish, amphibia, reptiles, birds and insects depend upon habitats of different hydrological characteristics for feeding, breeding and nesting, or at different stages in their life cycle. These animals may be resident in wetlands, or may migrate periodically or seasonally into wetlands from other environments. Many animals periodically use wetlands directly (e.g. grazing) but do not reside there. They are nevertheless still dependent on other wetland biota.

Waterfowl are well known and most investigated components of wetland fauna. Their diversity is directly related to the habitat diversity that provides a variety of roosting, nesting, feeding and breeding sites, as well as a wide spectrum of food ranging from planktonic algae through seeds and insects to fish. Among the invertebrates, arthropods represented by crustacea and 11 orders of insecta, and the molluscs are the most dominant components of wetland fauna. Oligochaetes are also abundant. Among the vertebrates, amphibia, fish and birds are dominant. Many mammals like beavers, otters and rhinos occur exclusively in wetlands whereas others such as swamp deer and water buffalo use wetlands principally for grazing. Most of the insects which are terrestrial when adult, pass their larval stages in wetlands; many terrestrial birds feed on aquatic animals; and the survival of many aquatic animals such as turtles, crocodiles and many fish depends on wetlands. There are also long-distance- often across the continents - migrants among the waterfowl, turtles and fish.

For a general global overview and discussion of biodiversity in wetlands, see Gopal & Junk (2000, 2001), Gopal (2009).

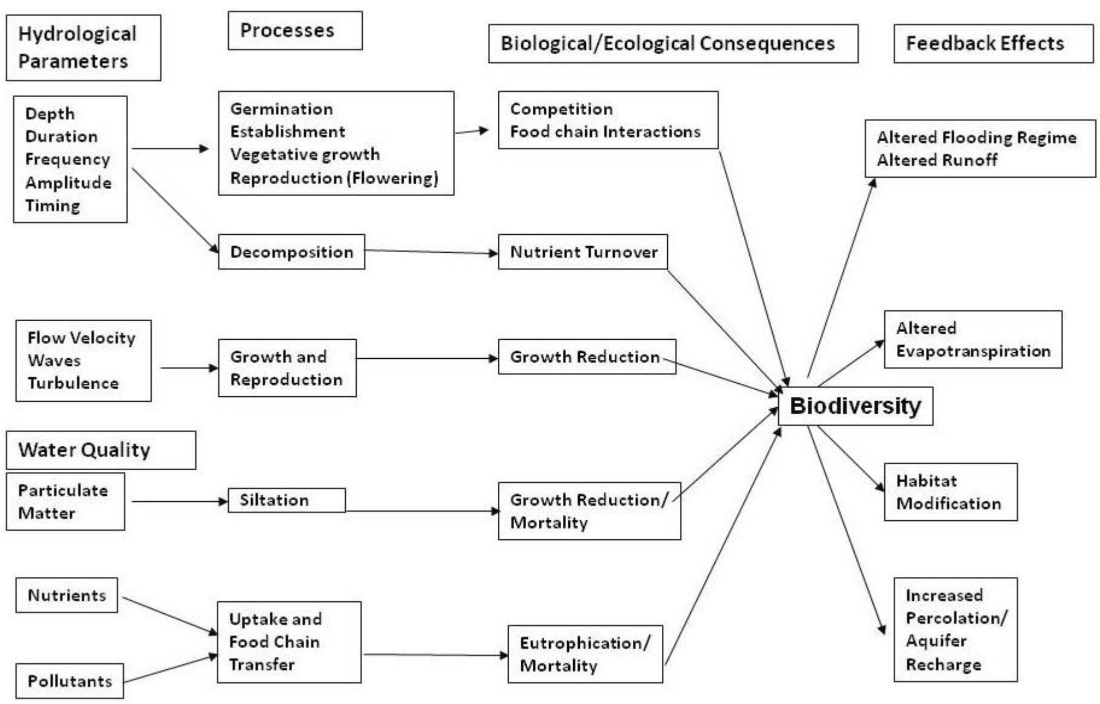


Figure 2. Hydrological variables which affect biological processes and in turn the biodiversity

## WHAT ARE ECOSYSTEM SERVICES?

Humans evolved as just another species of mammals from their Primate ancestors. The early hunter-food gatherer humans gradually learned to grow food and reduced their dependence on the vagaries of nature. They took advantage of the nature's processes and functions to get renewed soil fertility and clean water. Nature inspired and contributed to cultural and spiritual development. For many thousands of years, humans were controlled by the nature's forces until humans invented the wheel and discovered the sources of energy that led to industrial growth.

Gradually, humans learnt how to exploit, control and manipulate different nature to their advantage. The impacts of human activities and their consequences for humans themselves became apparent long before we gained insights into the organisation and interactions between different constituents and overall functioning of ecosystems at different scales. Attention was drawn to the rapid deterioration of nature (Marsh 1864), but humans did not realise the threat to themselves, as local communities did not identify themselves as part of a larger global ecosystem.

Humans were awakened to their dependence on the natural environment after environmental degradation assumed serious proportions with its global ramifications. In the 1970s, a utilitarian view of nature was put forward to increase people's interest through the notion of 'nature's services' or 'environmental services' (SCEP 1970). Ehrlich and Ehrlich (1981) introduced the term 'ecosystem services' which received wide acceptance after Daily (1997) promoted the concept by defining it as "*the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life*". The concept was elaborated by Scott et al. (1998) who explained that whereas the ecosystem (or ecological) processes are "*interactions among elements of the ecosystem*", and ecosystem functions are "*aspects of the processes that affect humans or key aspects of the ecosystem itself...*", ecosystem services are "*attributes of ecological functions that are valued by humans*". De Groot et al. (2002) defined functions as "*the capacity of natural processes and components to provide goods and services that satisfy human needs*". In other words, ecosystem processes lead to functions, which in turn lead to services. For example, the process of photosynthesis, coupled with other processes, results in production of biomass (a function of plants) that becomes available to humans as a service. For detailed discussion, see Wallace (2007).

The concept of ecosystem services was popularised by the Millennium Ecosystem Assessment (MEA 2005) which defined them simply as "the direct and indirect benefits derived by humans from the functions of the ecosystems". The Millennium Ecosystem Assessment focused specially on direct and indirect linkages between ecosystem services and human well being (including poverty alleviation) (Figure 3). The MEA examined in detail the changes in different kinds of ecosystems and their services during the past 50 years, their causes and consequences for human well-being, and the future trends of change.

The Millennium Ecosystem Assessment (2005) categorised the ecosystem services into four groups: (a) Provisioning Services (food, timber, fuel, water, and other material benefits - called also as goods), (b) Regulating Services (regulation of biogeochemical cycles including climate), (c) Supporting Services that are required to sustain the ability of the ecosystems to deliver the other three services (e.g., soil formation) and (d) Cultural Services (aesthetics, cultural, recreational and educational activities).

Regulating and Cultural services are direct and indirect, non-material benefits derived by the humans. It must be noted that all ecosystem services are interrelated and cannot be considered in isolation. The same set of biotic and abiotic processes result in many functions which are valued by humans differently.

### Provisioning Services

All kinds of food (from plants, animals, and microbes), fiber (such as wood, bamboo, grass, jute, cotton, hemp, silk and wool), fuel (wood, dung, etc.) and biochemicals and natural medicines (plant or animal origin, biocides, essential oils, food additives, etc.) used by humans are the products of terrestrial, marine or freshwater ecosystems. Human also use animal and plant products, such as skins, hair, flowers, bark, pollen, leaves, etc. for different purposes. These are all part of ecosystems' provisioning services. Further, the ecosystems provide genetic resources (e.g., genes) which are used for animal and plant breeding and biotechnology. The supply of fresh water is also a Provisioning service inasmuch as it depends upon the ecosystem processes.

## Regulating Services

Of great interest and benefit to humans is the regulation of air and water quality through several processes. Ecosystems regulate both local (microclimate) and global climate by influencing temperature and precipitation regimes and by either sequestering or emitting greenhouse gases (chiefly carbon dioxide and methane). Ecosystems regulate the water cycle by influencing runoff, flooding, and aquifer recharge. Mangrove ecosystems are known to reduce the damage caused by natural hazards such as cyclonic storms and tsunami waves. Various ecosystem processes are involved in regulating the diseases by affecting the abundance of human pathogens and disease vectors (e.g., snails, mosquitoes). Regulation of pollination by influencing the pollinator organisms is another regulating service of critical importance to humans.

## Cultural Services

The large cultural diversity across the globe is directly related to the diversity of ecosystems. Natural systems have inspired art and literature, promoted various forms of recreational and leisure activities, contributed to the development of human knowledge (based on interaction with and observation of processes and functions of nature). Humans continue to seek peace and comfort in the lap of natural ecosystems despite creating a comfortable environment of their own liking, These non-material benefits remain non-quantifiable.

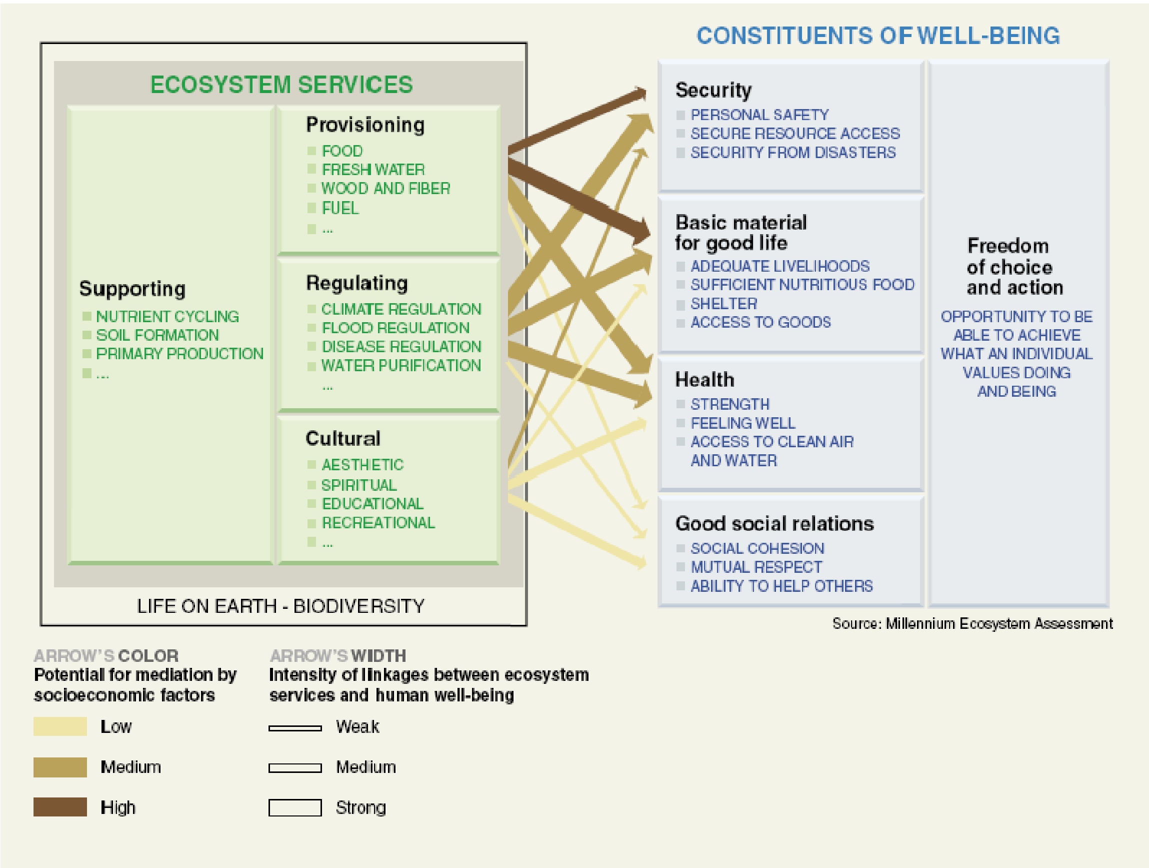


Figure 3. Relationship between ecosystem services and human well being (from MEA 2005)

## Supporting Services

The ability of ecosystems to provide the above mentioned services is supported by certain long-term processes and functions. For example, many physical, chemical and biological processes result, over centuries, in the formation of soil which is necessary for the growth of most of the vegetation.

It may be pointed out here that whereas the MEA scheme of classifying ecosystem services is very widely followed, it has its own limitations. During recent years, ecosystem services have been classified in several different ways (e.g., DeGroot et al. 2002, Wallace 2007, 2008, Fisher et al. 2009) although the main framework remains similar. Costanza (2008) has also pointed out the need for multiple classification schemes.

## LINKAGES BETWEEN BIODIVERSITY AND ECOSYSTEM SERVICES

It is obvious from the foregoing account of the ecosystem services that biodiversity is central and most critical to all of the services. The relationship between biodiversity and ecosystem functioning has been discussed by ecologists over decades (Schulze and Mooney 1993, Loreau 2000) and this is now interpreted in terms of ecosystem services (MEA 2005). Biodiversity itself is not considered as an ecosystem service but providing habitats for various organisms is a supporting service that benefits humans by enriching the diversity of biota. Biodiversity controls directly or indirectly all ecosystem services. A macrophyte may provide some goods to be used directly for by humans, will support other biota through the food chains, will sequester some carbon, oxygenate water and remove nutrients and/or pollutants, and may contribute to the aesthetics or some cultural/social benefit. A very good example of multiple ecosystem services provided by fishes is discussed by Holmlund and Hammer (1999; see Figure 4).

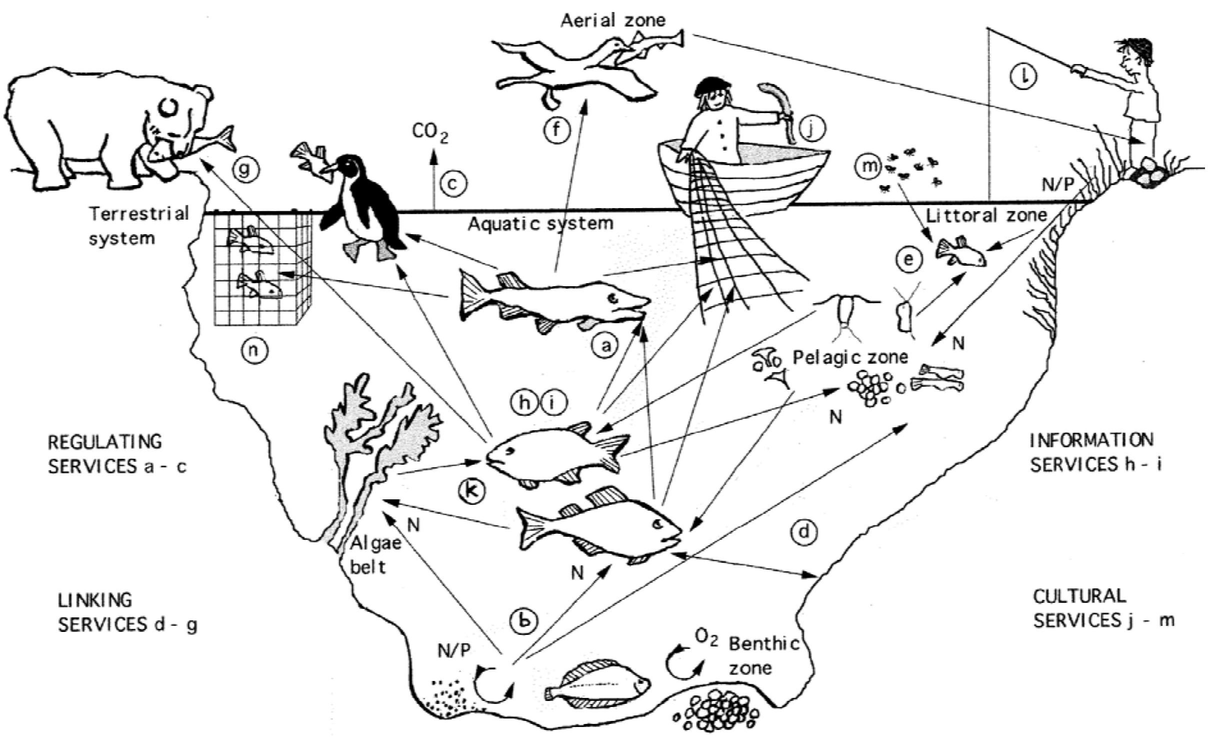


Figure 4. Diagrammatic view of ecosystem services generated by fish populations
(Reproduced from Holmlund and Hammer 1999; for details see the original publication)

Diaz et al. (2005) discussed in detail this linkage, particularly with reference to terrestrial and marine ecosystems. Their main conclusions, which are equally relevant to wetlands, are reproduced below:

- Biodiversity, including the number, abundance, and composition of genotypes, populations, species, functional types, communities, and landscape units, strongly influences the provision of ecosystem services and therefore human well-being.
- Species composition is often more important than the number of species in affecting ecosystem processes.
- Although a reduction in the number of species may initially have small effects, even minor losses may reduce the capacity of ecosystems for adjustment to changing environments.
- Productivity, nutrient retention, and resistance to invasions and diseases tend to increase with increasing species number in experimental ecosystems that have been reduced to a small number of species (10 or fewer).
- Preserving interactions among species is critical for maintaining long-term production of food and fiber on land and in the sea.
- Intended or accidental changes in the composition of ecological communities can lead to disproportionately large, irreversible, and often negative alterations of ecosystem processes, causing large monetary and cultural losses.
- Invasion by exotic species, facilitated by global trade, is a major threat to the biotic integrity of communities and the functioning of ecosystems.
- The extinction of local populations, or their reduction to the point that they become functionally extinct, can have dramatic consequences in terms of regulating and supporting ecosystem services.
- The properties of species are more important than species number in influencing climate regulation.
- The diversity of landscape units also influences ecosystem services.
- Maintenance of genetic and species diversity and of spatial heterogeneity in low-input agricultural systems reduces the risk of crop failure in a variable environment and reduces the potential impacts of pests and pathogens.
- Global change drivers that affect biodiversity indirectly also affect biodiversity-dependent ecosystem processes and services.

More recently, Harrison et al. (2014) reviewed more than 500 published studies to analyse the linkages between several biodiversity attributes and eleven ecosystem services. They observed that the ecosystem services such as water quality regulation, water flow regulation, and landscape aesthetics improved with an increase in community and habitat area. Species richness and diversity were also positively related with services such as atmospheric regulation, pest regulation and pollination. One of their network diagrams showing the linkages between biotic and abiotic attributes and ecosystem service of freshwater provision through various Ecosystem Service Providers is reproduced below (Figure 5).

## Recent Initiatives

Two international initiatives have been started in the past 4-5 years that focus on the biodiversity and ecosystem services. First, having recognised the need for scientifically credible information on the complex relationships between biodiversity, ecosystem services, and people, the need for effective methods to interpret this information for informed decision making, and that the scientific community needs to understand the needs of decision makers, the UNEP established in April 2012 an 'Intergovernmental Platform on Biodiversity and Ecosystem Services' (IPBES). IPBES provides a mechanism to synthesize, review, assess and critically evaluate relevant information and knowledge generated worldwide by governments, academia, scientific organizations, non-governmental organizations and indigenous communities.

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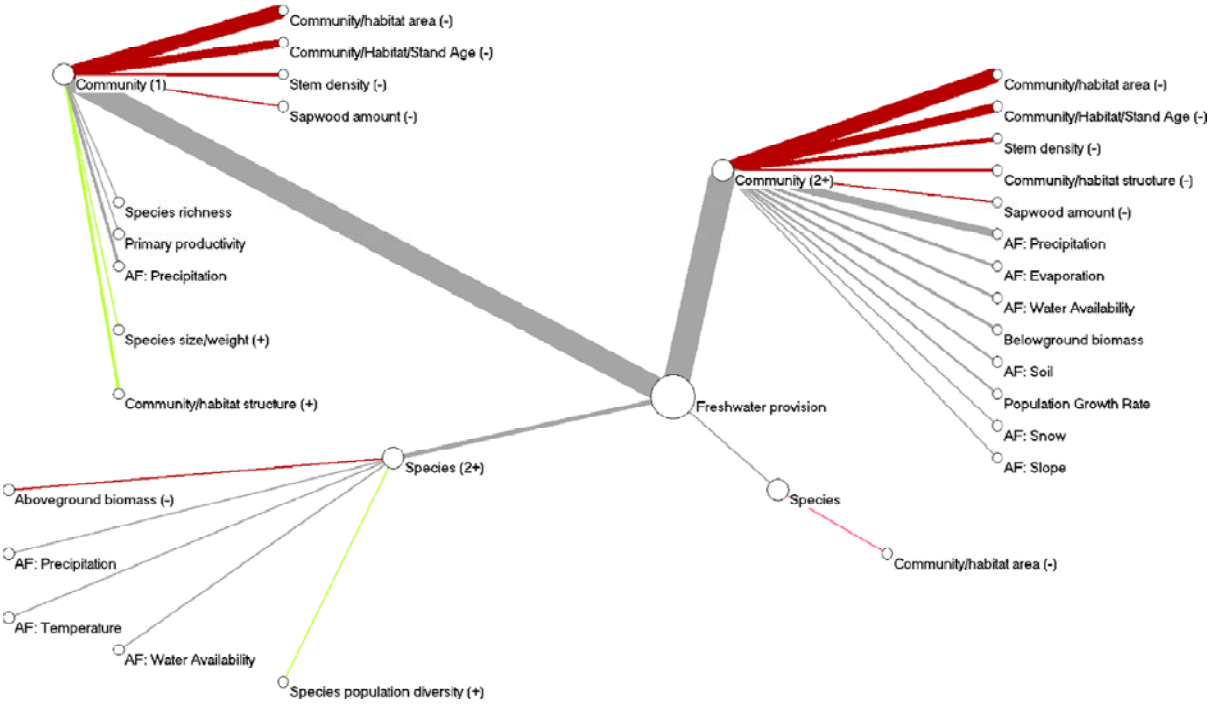


Figure 5. Network diagram showing the linkages between biotic and abiotic (AF) attributes and freshwater provision via various ESPs (reproduced from Harrison et al. 2014; see original for details)..

Second, is The Economics of Ecosystems and Biodiversity programme (TEEB 2010, 2011) which seeks to stress upon the assessments and integration of value of biodiversity and ecosystem services into national policies related to the conservation and management of natural resources. Assessments of the economic value of ecosystem services contribute to fostering better management, conservation and restoration practices.

It is important to point out that the provisioning, regulating and cultural services obtained from the biodiversity differ from region to region based on economic, socio-cultural and other factors. A plant that is considered to be of no use value in one region or by one community may be of much value in another region or to another community.

## ECOSYSTEM SERVICES OF WETLANDS

Among ecosystems, wetlands are of special significance. They harbour a large biodiversity highly disproportionate to their areal extent, and provide ecosystem services that are critical to the entire life on the Earth. These ecosystem services result from the interactions between different biodiversity components and their abiotic variables as noted earlier (see Figure 6). Wetlands provide water and water-related ecosystem services, such as food (fish, prawn, rice and many other plants), wastewater purification, hydrological regulation of floods and droughts, carbon sequestration and climate regulation, storm protection, erosion control, etc. Wetlands enhance aesthetics and support a wide range of livelihoods besides various cultural/recreational activities. Wetlands may hold important spiritual values for some cultures. Thus, wetlands contribute to human wellbeing, cultural identity and economy. The ecosystem services of different kinds of wetlands were discussed by Finlayson et al. (2005) to show major differences among them. Table 1 presents a comparison of common inland wetlands to highlight the differences in the diversity of major groups of biota and a range of ecosystem services. Some of the services are discussed later in the section on Rapid Assessment methods.

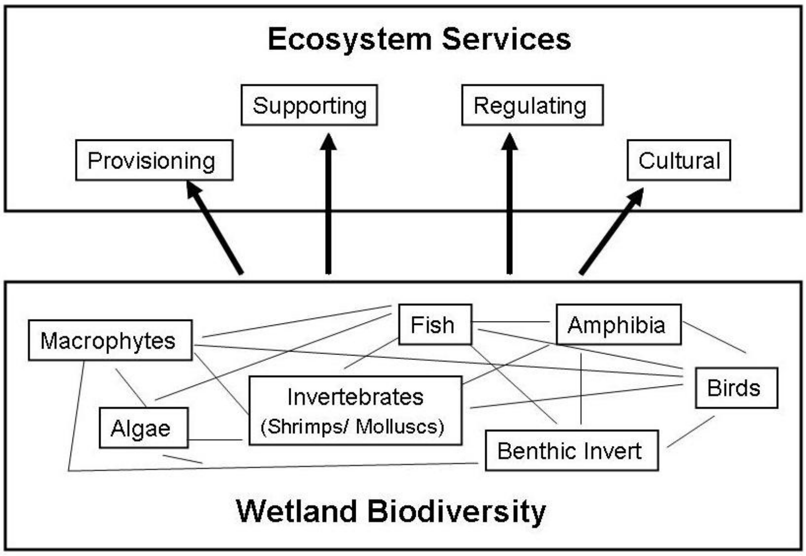

Figure 6. Linkages between Wetland biodiversity and Ecosystem Services

It is well recognised that biodiversity is governed by a number of drivers which affect processes and function and consequently the ecosystem services (Figure 7). Wetlands differ greatly in their hydrological, nutritional and salinity regimes. Further differences among wetlands occur in relation to geology, climate and anthropogenic factors. Accordingly, the drivers and wetland processes vary greatly in different kinds of wetlands and consequently, their ecosystem services (Figure 7). Not all wetlands can provide the same or similar ecosystem service(s) and also not all kinds of ecosystem services can be obtained from any particular wetland or a kind of wetland.

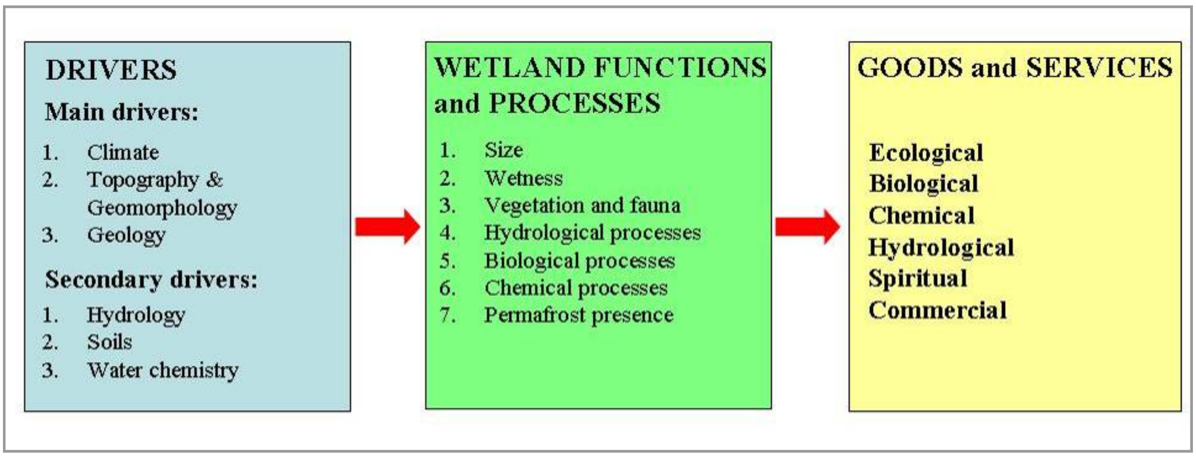

Figure 7. Drivers of wetland functions which in turn affect the ecosystem services

The relationships between various processes, ecosystem attributes (including biodiversity) and functions of wetlands that provide various goods and services are discussed by Maltby (2009) and are shown in Figure 8 below:

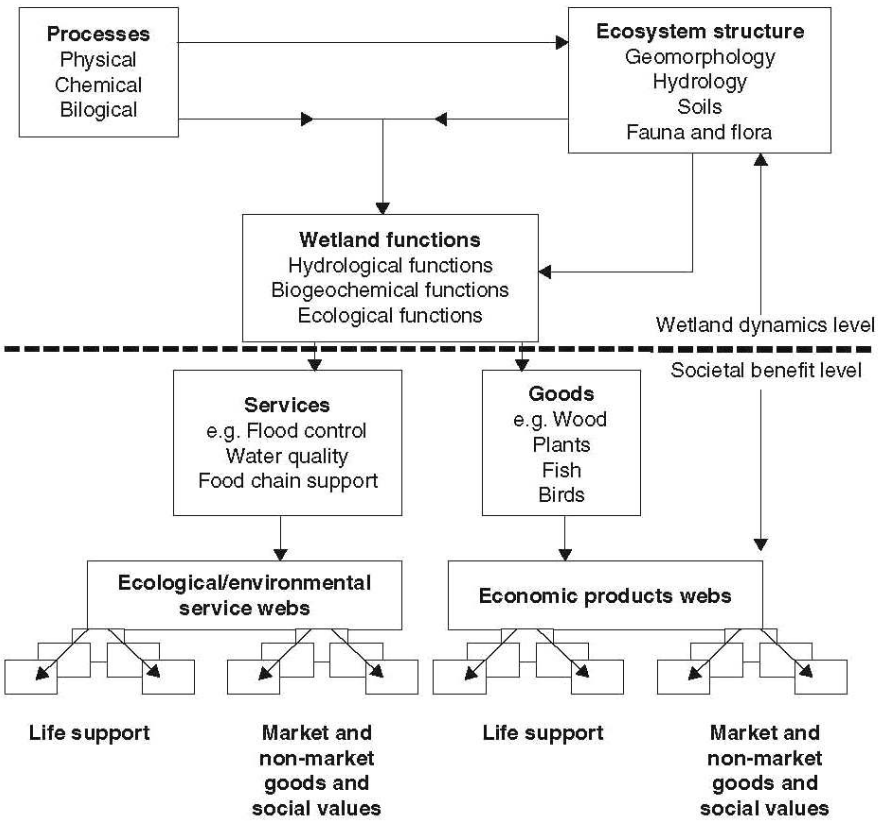


Figure 8. Wetland processes, structure, function and ecosystem services (from Maltby 2009)

## WETLAND LOSS AND DEGRADATION

Despite the human dependence upon wetlands for their major food supply (rice and fish) besides other benefits, and the fact that wetlands support biodiversity disproportionate to their areal extent, wetlands have failed to draw human interest in their conservation. In India, for example, about 38% of inland freshwater wetlands had been lost in recent decades only. Majority of the wetlands in India today are human-made, and together with natural wetlands other than rivers, cover only about 3% of the country's land surface. Urbanisation and industrial development occurs at their expense. First, urban development starts around the wetlands and then gradually, the urban expansion engulfs them. Such rapid loss of wetlands is exemplified by Delhi, Kolkata, Hyderabad, Bengaluru and Guwahati. Wetlands are used as regular land fill sites or are gradually filled up by dumping solid wastes. The recent floods in Kashmir valley and Kedarnath valley are cruel testimony to the loss of floodplain wetlands and their encroachment.

This neglect and abuse of wetlands started with the colonization of developing countries by Europeans who carried with them their own perceptions and approaches to these watery habitats. The British considered all areas as wastelands if they did not yield revenue. Marshes were considered fit for drainage especially because they harboured mosquitoes and other disease vectors. The perception remains until today as wetlands continue to be treated as wastelands.

Further, wetlands are directly impacted by large scale widespread hydrological alterations. The sources and pathways of their water supply, both as surface runoff or inflow through channels, are eliminated or blocked or their water supply is greatly altered. Many floodplain wetlands have been eliminated by embankments and in most cases, the flow storage and diversion structures upstream have greatly modified their flooding regimes. In lakes and other water bodies, water levels are regulated by withdrawal of water for different human uses.

Table 1. Relative extent of biodiversity and ecosystem services of different kinds of wetlands

RELATIVE EXTENT OF BIODIVERSITY AND ECOSYSTEM

| | Glacial Lakes | Peat bogs | Shallow lakes | Deep Lakes | Flood-plains | Marshes |
|---|---|---|---|---|---|---|
| **Biodiversity** | | | | | | |
| Microphyte | 🔵 | 🔵 | 🟠 | 🟢 | 🟠 | 🟠 |
| Macrophytes | 🔴 | 🟠 | 🟢 | 🔴 | 🟠 | 🟢 |
| Fish | 🔵 | 🔴 | 🟢 | 🟠 | 🟠 | 🟠 |
| Zooplankton | 🔵 | 🔵 | 🟢 | 🔵 | 🟠 | 🟢 |
| Benthos | 🔵 | 🔵 | 🟢 | 🔵 | 🟠 | 🟢 |
| Birds | 🔵 | 🟠 | 🟢 | 🔵 | 🟠 | 🟢 |
| Herpetofauna | 🔵 | 🔵 | 🟢 | 🔵 | 🔵 | 🟢 |
| **Benefits to Humans** | | | | | | |
| Food | ○ | ? | ⬤ | • | ● | ● |
| Fodder | ○ | • | • | ○ | ⬤ | ⬤ |
| Fuel | ○ | ● | ● | ○ | ⬤ | ● |
| Fiber | ○ | ○ | ● | ○ | ⬤ | ⬤ |
| Medicinal | ○ | • | ● | ○ | ⬤ | ⬤ |
| Biochemicals | ○ | ○ | ● | ○ | ● | ● |
| Genetic | ? | • | ● | ○ | • | ● |
| Water Storage | ⬤ | • | ● | ⬤ | ● | ● |
| Groundwater Recharge | ? | ○ | ⬤ | • | ⬤ | ⬤ |
| Sediments | ● | • | ⬤ | ● | ⬤ | ⬤ |
| Nutrients | ? | ○ | ⬤ | • | ⬤ | ⬤ |
| Heavy Metals | ○ | ● | ● | • | ⬤ | ⬤ |
| Toxics | ○ | ● | ● | • | ⬤ | ⬤ |
| C-sequestration | ○ | ● | ⬤ | • | ⬤ | ⬤ |
| GHG emission | ? | ● | ● | • | • | ● |
| Erosion control | ○ | ○ | ● | ○ | ⬤ | ⬤ |
| Disease vectors | ○ | ○ | ● | ○ | ● | ● |
| Recreation | • | ● | ⬤ | • | ⬤ | ⬤ |
| Aesthetics | • | • | ⬤ | • | ⬤ | ⬤ |
| Spiritual | • | • | ● | ○ | • | • |
| Religious | • | ○ | ● | ○ | • | • |
| Pollination | ○ | ○ | ● | ○ | ● | ● |
| Soil Formation | ○ | • | ⬤ | ○ | ⬤ | ⬤ |

Biodiversity: 🔴 usually absent; 🔵 low; 🟠 Medium; 🟢 High

## RVICES (BENEFITS) OF DIFFERENT KINDS OF WETLANDS

| Ox-bows | Lagoons | Reservoirs | Tanks | Temple Tanks | Fish ponds | Paddy fields | Village ponds |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| ● (orange) | ● (orange) | ● (green) | ● (orange) | ● (blue) | ● (green) | ● (blue) | ● (orange) |
| ● (green) | ● (green) | ● (red) | ● (orange) | ● (blue) | ● (blue) | ● (blue) | ● (blue) |
| ● (green) | ● (green) | ● (orange) | ● (orange) | ● (blue) | ● (green) | ● (blue) | ● (blue) |
| ● (green) | ● (green) | ● (blue) | ● (orange) | ● (blue) | ● (orange) | ● (blue) | ● (orange) |
| ● (green) | ● (green) | ● (blue) | ● (orange) | ● (blue) | ● (orange) | ● (orange) | ● (blue) |
| ● (green) | ● (green) | ● (blue) | ● (orange) | ● (blue) | ● (blue) | ● (blue) | ● (blue) |
| ● (green) | ● (orange) | ● (red) | ● (orange) | ● (blue) | ● (blue) | ● (blue) | ● (blue) |
| | | | | | | | |
| ● | ● | • | ○ | ○ | ⬤ | ⬤ | • |
| ● | ● | ○ | ○ | ○ | ○ | • | ○ |
| • | | ○ | ○ | ○ | ○ | ○ | ○ |
| ● | • | ○ | ○ | ○ | ○ | • | ○ |
| • | • | ○ | ○ | ○ | ○ | • | ○ |
| • | • | ○ | ○ | ○ | ○ | ● | ○ |
| ○ | ● | ○ | ○ | ○ | ○ | ○ | ○ |
| ● | ⬤ | ⬤ | ● | • | ● | ○ | ⬤ |
| ⬤ | ⬤ | • | • | • | • | • | ● |
| ⬤ | ⬤ | ● | ● | ● | • | | • |
| ● | ⬤ | • | • | • | • | • | • |
| • | ● | ○ | ○ | ○ | ○ | ○ | • |
| • | ● | ○ | ○ | ○ | ○ | ○ | • |
| • | ⬤ | • | ○ | ○ | • | • | ○ |
| • | • | ● | ○ | ○ | ○ | ● | ○ |
| • | • | ○ | ○ | ○ | ○ | ○ | ○ |
| ● | • | ○ | • | ○ | • | • | ● |
| ● | ⬤ | • | ● | • | ○ | ○ | • |
| • | ● | • | • | • | • | ○ | • |
| ○ | • | ○ | • | ● | ○ | ○ | • |
| ○ | • | ○ | • | ● | ○ | ○ | • |
| ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| ○ | • | ○ | ○ | ○ | ○ | ○ | • |

Benefits: ○ - no benefit; • - little, sometimes; ● -medium; ⬤ - large

Wetlands are further degraded by the discharge of untreated domestic and industrial wastewaters into them. It is not readily appreciated that the upstream wastewater discharges affect the wetlands downstream. Wastewaters also facilitate siltation and alter the hydrological regime besides bringing in various pollutants.

Numerous wetlands are also infested with the uncontrolled growth of exotic species, particularly water hyaci.th. In recent years, there has been little effort to remove and destroy them because of the misplaced understanding that these plants can remove pollutants and help improve water quality. It is not realised that the - the weeds to be effective have to be selectively removed - young one left and allowed to multiply. death and decay returns the nutrients and pollutants back into water while huge quantities of undecomposed organic matter accumulate, fill in the water body, eliminate dissolved oxygen and cause mass fish kills.

## Real Causes of Wetland Loss and Degradation

Thus, wetlands - both natural and human-made -are lost and degraded primarily because they do not receive attention in the development plans - whether they are concerned with land use changes or are related the development of water resources, Environmental Impact Assessments for approval of development projects are usually based on secondary data, very limited field surveys over a short period and for a very small area around the project site. Seasonal character of wetlands implies that most of the aquatic biota are not encountered during the dry season survey and the impacts of the projects on water bodies located farther away through the hydrological connectivity are grossly ignored. Wetlands are also treated as dustbins for the discharge of wastewaters and the disposal of solid wastes.

Conservation of wetlands with the objective of protecting their biodiversity, specific biophysical characteristics and obtaining optimum benefits from them requires a major shift in policies related to land and water use. Joining the Ramsar Convention is only being a part of the international community to express solidarity with its objectives. Designation of a few wetlands under the Ramsar Convention and enlisting a few other large ones as important wetlands does not ensure the conservation of all wetlands. Studies show that many small wetlands together support more biological diversity than one large wetland though some species may occur only in large wetland (Oertli et al. 2002). Just as drops make an ocean, each small wetland has a bit to contribute.

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