1 Wetland Functioning in a Changing World: Implications for Natural Resources Management

Jos T.A. Verhoeven, Boudewijn Beltman, Dennis F. Whigham, Roland Bobbink

1.1 Introduction

Wetland ecosystems are a natural resource of global significance. Historically, their high level of plant and animal (especially bird) diversity is perhaps the major reason why wetland protection has become a high priority worldwide, supported by international agreements, such as the Ramsar Convention and the International Convention of Biological Diversity (Fig. 1.1). More recently, a number of goods and services provided specifically by wetland ecosystems have been identified that may even outweigh biodiversity in terms of their importance for human welfare and sustainable natural resource management worldwide. Wetlands, as transitional zones between land and water, provide a natural protection against extreme floods and storm surges. They may also store freshwater to be used for drinking-water preparation or for irrigation. Wetlands bordering streams, rivers and lakes have a water quality enhancement function that is increasingly recognized. As natural habitats for fish, riverine wetlands, shallow lakes and coastal wetlands have the potential to produce large fish stocks, which are exploited commercially in some regions but could be enhanced by restoring wetlands in degraded areas. Because wetlands often provide spawning habitats, their importance as a source of juvenile fish for large aquatic lakes and river channels should not be underestimated. In addition to these local and regional benefits, wetlands as a global resource provide a net sink of carbon dioxide. The world's peatlands are the only type of terrestrial ecosystem with a long-term net carbon storage function. However, the large amounts of carbon that have accumulated historically in peatlands may be released as a result of drainage or excavation.

Wetlands do produce a striking variety of goods and services and it is no wonder that, more often than any other terrestrial ecosystem, they are used by

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environmental economists to illustrate ecosystem functions and their value to mankind. However, in spite of the high biodiversity and the high importance of the goods and services of wetland ecosystems, their global status is poor. Many wetlands, particularly river floodplains, deltas and estuaries, have been strongly degraded because of human impacts. Early civilizations were particularly successful in these areas, where agriculture thrived because of the natural fertility of the soils and transport was favoured by the river channels. In the industrial era, these impacts became dramatically negative as a result of floodplain reclamation, poldering, construction of flood control structures, drainage for agriculture, excavation of peat for fuel and modification and straightening of river channels in favour of navigation. Worldwide, more than 50 % of the wetland resource has been lost because of these reasons. In some densely populated regions in Europe, North America and East Asia, more than 80 % of the wetlands have been lost or severely degraded.

This volume, containing an integrated account of a number of major symposia presented at the 7th INTECOL International Wetlands Conference in Utrecht, investigates the major natural resource management issues involved in the protection of the remaining wetland resource, the enhancement of the goods and services arising from this resource and the restoration of degraded wetlands and wetland functions. In this introductory chapter, we will give an overview of recent advances in the comprehension of how both wetland biodiversity and the wetland ecosystem goods and services can be enhanced by management decisions, as treated in more detail in the other chapters of this volume. We will also identify remaining gaps in scientific knowledge and understanding that need to be addressed to optimize the decision-making process on wetland land use and management.

1.2 Clarity on Wetlands and Water Use

It is widely recognized that the limited availability of clean freshwater will increasingly become a matter of controversy between local communities in many semi-arid regions of the world. Access to healthy freshwater resources has even been identified as a fundamental human right. The relation between wetlands and the availability of freshwater recently led to confusion among natural resource managers. As Rijsberman and De Silva point out in Chapter 3, one of the services of wetland ecosystems was described as the ‘providing’ or ‘provision’ of water. This service would suggest that wetlands are sources of water and do not compete with other water-demanding sectors such as agriculture or water use for sanitation or industry. In this view, wetlands would even be potential sources of water. However, in reality, wetlands are as much dependent on water as these other sectors. Being systems with a high water table, they can only maintain their characteristic biota and functioning if

Fig. 1.1 Species-rich wet meadow with *Dactylorhiza majalis* (broad-leaved marsh orchid) bordering brackish pools on the island of Texel, The Netherlands

Fig. 1.2 *Cladium jamaicense* (sawgrass) lawns with tree islands in Shark Slough, Everglades National Park

Fig. 1.3 A stand of *Nelumbo nucifera* (water lotus) in Kakadu National Park, Australia. The water lotus is a typical wetland plant with aerenchyma

water outputs are balanced by water inputs, in a way typical for the water regime of the wetland in question. Most wetland types require inputs of surface water or groundwater in addition to the inflow through precipitation. In practice, wetlands often compete for water with agriculture or drinking-water preparation, in particular in semi-arid regions.

A first example is the use of water in many (sub)tropical countries for irrigation, which has led to the drying-out of vast wetland resources. Water resource managers often are mainly involved with the so-called 'blue' water resources, mainly to be used for urban and industrial use. The water used for irrigation, mostly present as soil moisture, also leads to a major regional water loss which is equal to the amount of water evapotranspired by the crops. This so-called 'green' water use is now increasingly being addressed in an integrated way with other water uses by water resource managers. The notion that wetlands 'provide' water has been nuanced: water conservation may be optimized by using wetlands as reservoirs where water can be temporarily stored.

A second example of a controversy on the uses of limited water resources is the situation in the Everglades, Florida. Here, a large freshwater surface resource flowing over the land surface south of Lake Okeechobee is used increasingly for urban, agricultural and industrial purposes by the metropolitan region surrounding Miami. As a result, the large wilderness area of the Everglades wetlands (see Fig. 1.2), partly protected in nature reserves (e.g. Everglades National Park), is suffering from water shortage and is threatened on the longer term. A multi-million dollar Comprehensive Everglades Restoration Plan (CERP; http://www.evergladesplan.org/index.cfm) has been designed to mitigate water shortages in the future. It remains to be seen whether this will provide a sustainable solution to the protection of the Everglades and its many biota and other values.

1.3 Wetlands and Environmental Flows

The definition and implementation of 'environmental flows' have become a major management tools in river catchments worldwide, particularly in semi-arid regions. The idea is that so much water in river systems is diverted and used for agriculture, cities or industry that rivers can no longer function naturally. River flow and flood events are increasingly limited to a narrow zone bordering the river channel, while the lateral interactions with the often extensive floodplains become diminished. This has drastic negative consequences for the biota characteristic for floodplains and for the goods and services provided by the floodplain habitat. Environmental flows (EFs) are defined as a minimum river discharge needed to meet certain targets in terms of biodiversity and/or ecosystem goods and services. Restoration of lateral connectivity by bringing floodwater only to selected parts of the original floodplain may help in restoring the intensity and temporal dynamics of typical flooding events, rather than allowing the water to create too small a flooding event in the total floodplain. This is illustrated for rivers in Australia by Coops et al. (Chapter 2) and for tropical rivers by Welcomme et al. (Chapter 7). The EF concept is in the stage of becoming widely accepted among water resource managers as a tool to maximize the quality of biodiversity restoration and associated fisheries in large river floodplains with diminished river discharge. Hopeful developments have been initiated in several large European river catchments, where river rehabilitation projects have focused on: (1) the restoration of lateral connections by removing so-called 'summer dikes', which has resulted in a higher frequency of flooding of floodplain habitats, (2) the restoration of side-channels and river dunes and (3) the enhancement of river water quality. Some of the projects described in Chapter 2 illustrate the successful restoration of floodplain habitats in the basins of the rivers Rhine, Rhone and Danube.

1.4 Wetlands and Water Quality

The role of wetlands in river and lake catchments in enhancing water quality is well established. A recent review gives a global perspective of this ecosystem service in areas of the world with high intensity of agricultural use (Verhoeven et al. 2006). Riparian wetlands bordering lower-order streams and floodplains of mid-size and larger rivers have a great potential to remove nutrients and pollutants from through-flowing water. Nitrate in surface and subsurface runoff from agricultural fields and pastures, when exposed to superficial soil layers in the riparian zone, is transferred to gaseous nitrogen species and emitted to the atmosphere, while phosphate and ammonium are retained in vegetation or bacterial biomass, adsorbed to soil particles or laid down in sediments. Long-term loading of these zones, however, enriches these riparian wetlands, which often leads to the loss of characteristic species. Critical loading rates for N and P have been established for freshwater wetlands, beyond which losses of plant and animal species are to be expected. Riparian zones have also been shown to be only effective at the catchment scale if they are sufficiently large and continuous in the landscape. Only when their total area comes near 5 % of the total catchment area can they really make a difference to water quality in the catchment. Wetlands restoration schemes in agricultural areas should take into account these limitations.

The chapter by Yin et al. (Chapter 4) deals with a rural system for water resources management which has been developed in the southern part of China. This so-called 'multipond' system, a system of many shallow ponds in the landscape connected by ditches, is the result of 2000 years of engineer-