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Opinion

Perspectives on wetland science, application and policy

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Introduction

Less than 50 years ago, the term ‘wetland’ was virtually unknown to science. Its first use can be traced back to early 1950s when the United States Fish and Wildlife Service prepared an inventory of wetlands in that country for their value as wildlife and waterfowl habitats (Martin et al., 1953; Shaw & Fredine, 1956). Eighteen years later, wetlands became the only habitat to be the focus of an international convention – now known as the Ramsar Convention, for conservation in recognition of their importance ‘especially as waterfowl habitats’ (Carp, 1972; Matthews, 1993). The term ‘wetland’ served as an umbrella to bring together a wide spectrum of habitats, known by hundreds of local names in different parts of the world, which shared between them two major characteristics: they had an abundance of water for at least some time during the year and hence, supported a large diversity of waterfowl, besides other wildlife. Marshes, swamps, bogs, fens, mangroves and shallow water bodies that had been variously used, abused and despised, became ‘liquid assets’ (IWRB, 1979) or ‘waterlogged wealth’ (Maltby, 1986). The areas sandwiched between land and water, once considered as ‘flooded forests’, ‘wet meadows’ or ‘reedy lakes’, were soon embraced by the scientific community as ecosystems enjoying the ‘best of both worlds’. Mires and moors, fens and carrs, playas and potholes, sebkhas and billabongs, chaurs and dambos have all been exiled by wetlands. Estuaries, lagoons, and even lakes may soon be forgotten before the might of wetlands.

During the past few years, there has been an unprecedented spurt of interest in wetlands at all levels – among researchers, engineers, managers, conservationists, sociologists, economists, various NGOs, and above all the Governments. This is reflected in a steep rise in the number of publications, symposia, conferences and participants, and the countries joining the Ramsar Convention. Whereas the INTECOL’s first International Conference on Wetlands (New Delhi, 1980) had only 100 participants from 13 countries, there were 905 participants from 56 countries at the fourth Conference in 1992 (Columbus, Ohio, U.S.A.)

and over 2050 participants from 72 countries at the sixth Conference and the Wetland Millennium Event (Quebec, Canada, 2000). The number of Contracting Parties to the Ramsar Convention has grown rapidly from 28 at its first Conference (COP1) in 1980 and only 54 in 1990 at COP4 to 133 in 2002 at COP8. Correspondingly, the number of Ramsar sites (and area) has grown from 212 (<9 million ha) in 1980 and 489 (30 million ha) in 1990 to 1229 (105.91 million ha) in 2002 (http://www.ramsar.org).

Though many aspects of various kinds of wetlands had been investigated for several decades and there existed a large number of publications in research journals, until the late 1970s, rarely was a book devoted wholly to wetlands, except for a couple of proceedings of national and international symposia (e.g., Chapman, 1977; Greeson et al., 1979; see also Williams, 1990). The first introductory text on wetlands was published only in 1983 (Etherington, 1983) and was soon followed by a comprehensive textbook by Mitsch & Gosselink (1986). During the 1980s and early 1990s, there appeared only about 40 books including the proceedings of international conferences (see Williams, 1990; Mitsch et al., 1994). These publications included major state-of-the-art reviews of our knowledge of all kinds of wetlands, their distribution, ecology, functions, values, management and conservation (e.g., Gopal et al., 1982; Gore, 1983a,b; Patten et al., 1990, 1994; Whigham et al., 1993; NRC, 1995). During the past ten years, there has been a spate of publications at both national and international level. Mitsch & Gosselink (2000) list more than 50 books that appeared between 1992 and 2000. An internet search at http://www.amazon.com/ in November 2002, produced a list of more than 200 books published during the same period.

In this opinion paper, triggered by the arrival of several books on wetlands within a year for review in *Hydrobiologia,* I venture to analyse the developments in our understanding of wetland ecosystems and their functions, in the application of scientific knowledge to the utilisation and enhancement of wetland resources, and in promotion of policies for their conservation and management. I reflect also on the situation in developing countries to highlight the vast gap in wetland science, application and policy between developed nations and the Third World. This analysis is based on only a few selected publications that have appeared during the past three years, and therefore, covers only a few aspects of wetland science and its application.

Wetland science

Most of wetland science emerged from numerous studies on different kinds of wetlands since the early 20th century and especially during the International Biological Programme (IBP, 1964–74) through collaboration between its sections on terrestrial (PT) and freshwater (PF) ecosystems and the production processes (PP). Though the results of these studies were published extensively, a synthesis volume appeared only recently (Westlake et al., 1999). Despite the inordinate delay in publication, and the fact that most of the information in this volume has been reviewed in different ways earlier as well, it serves as a valuable record of the contribution of the IBP in laying the foundation of wetland science.

A comprehensive up-to-date account of wetland science is presented by Mitsch & Gosselink (2000) in the third edition of their book *Wetlands*. Since its first publication in 1986, the book has served the cause of wetlands in much the same way as E.P. Odum's book, *Fundamentals of Ecology*, served ecology from the 1950s to the 1970s (Odum, 1953, 1971). Mitsch & Gosselink's organisation of the book is also comparable to that of Odum: a summary of common aspects such as hydrology, biogeochemistry, biotic adaptations and ecosystem development is followed by a fairly detailed account of specific features of major wetland types. Despite many references to wetlands in different parts of the world, the text retains its focus on the United States. This truly reflects the enormous contribution of U.S. researchers to wetland science and its application, but falls short of representing the global scenario. Many different kinds of wetlands outside North America and Europe have been investigated in some detail and the diversity of their hydrology, soils, biota, function and values, and interactions with human societies deserves to be recognised in order to appreciate their global significance.

Another book on wetlands ecology and conservation appeared on scene in the same year (Keddy, 2000). It takes a refreshingly different approach to understanding these diverse ecosystems. The book reinforces the fact that wetland ecosystems develop under, and are sustained by, particular hydrological regimes. Nutrients and other environmental factors such as disturbance, herbivory and competition interact with hydrology to create the diversity of kinds and functions of wetlands. Keddy draws examples from all parts of the world to present a relatively balanced view of wetland ecology and management. Hydrology is also the central theme of another recent book on Australian wetlands by Boulton & Brock (1999) who emphasise the role of variability and the effect of natural variation in hydrological regimes in the ecology and management of wetlands.

Several recent books are devoted to particular components of wetlands or to specific wetland types. One of the three criteria used by Cowardin et al. (1979) to define wetlands is the occurrence of hydric soils. The term 'hydric soils' was coined by the U.S. Fish and Wildlife Service and it was neither defined by them nor did it exist in the vocabulary of U.S. Soil Taxonomy of that time (USSCS, 1975). It was only later that the National Technical Committee on Hydric Soils deliberated for several years and proposed the first definition and classification. Hydric soils occur in most of the soil orders recognised by the revised Soil Taxonomy (USSCS, 1998). Interestingly, hydric soils have been only marginally discussed in most of the books. Now for the first time they form the subject of an entire volume (Richardson & Vepraskas, 2001). The volume is a tribute to the development of the concept of hydric soils over the past two decades and its application to wetland classification. Thirty one contributors discuss in great detail a diverse range of soils that occur in and around North American wetlands. First, it provides an interesting account of the background and history of the concept of hydric soils. It then examines the hydrology, chemistry and biology of wetland soils, accumulation of organic matter in organic soils, morphology of seasonally reduced soils and various approaches and methods for identifying and delineating hydric soils. Another section of the volume relates hydric soils with the hydrogeomorphic system of wetland classification and describes characteristics of soils in different kinds of wetlands such as those of the glacial terrain, vernal pools, riverine systems, tidal and fringing wetlands, coastal habitats, and peat lands. Soils of wetlands occurring in dry climates and in prairie regions also receive specific attention. Notwithstanding its focus on North American wetlands, the volume provides an excellent overview of wetland soils. It should encourage similar synthesis of information on wetlands elsewhere, particularly in the tropics, and also stimulate further research.

Wetlands were first recognised for their rich biodiversity, especially that of waterfowl and fish. Yet, the Convention on Biodiversity paid attention to inland aquatic habitats quite late. Two volumes edited by Gopal et al. (2000, 2001) now deal exclusively with a wide range of issues concerning biodiversity in a variety of wetlands from all continents. The majority of the contributions is devoted to river floodplain systems including two large wetlands, Pantanal and Okavango. Wetlands of arid and semi-arid regions are also covered. A significant contribution by Boon (2000) discusses microbial biodiversity that has remained a much neglected area of research in most wetlands. Various contributions focus on the magnitude of biodiversity and the various factors controlling it as well as its conservation and restoration. A final synthesis concludes that, whereas "the suite of hydrological, geomorphic, chemical, anthropogenic and other factors that regulate biodiversity at various spatial and temporal scales are relatively better known, the importance of biodiversity to wetland functions is poorly understood" (Gopal & Junk, 2001).

More than forty years ago, at a symposium on salt marshes held at Sapelo Island, Georgia (U.S.A.), John Teal presented his seminal studies which gave a new paradigm in ecology, stimulated lots of research and also generated some controversies. Teal (1962) hypothesised that up to half of the primary production by macrophytes in salt marshes was exported as detritus to coastal waters where it supported secondary production. Odum (1968) suggested that 'outwelling' of nutrients and organic matter from shallow water areas such as salt marshes and sea grass beds contribute to the high secondary production in coastal areas. The coastal salt marshes assumed the mantle of an engine driving marine productivity – a concept still widely promoted and often applied to mangroves as well. Since then, numerous studies in different coastal areas of the U.S.A. and in other parts of the world have produced data that both support and refute the original hypothesis. Forty years after the first conference, another meeting organised in New Jersey (U.S.A.) brought together leading salt marsh researchers from U.S.A., Canada and Europe to summarise the state of ecological research in salt marshes. The proceedings volume of this conference (Weinstein & Kreeger, 2000) provides, for the first time, an excellent synthesis of four decades of salt marsh research and also raises questions for future research. It is fortunate to have a retrospect from the two pioneers, Eugene Odum and John Teal. Various contributors discuss their studies in detail and provide insight into the processes and functions in different salt marshes. Tidal marshes differ in their contribution of organic matter and nutrients to coastal waters according to their expanse, productivity and their connection with the sea. Sources of energy and pathways to secondary production also differ as the phytobenthos, periphyton and micro-heterotrophs assume greater importance in some areas (e.g., Kreeger & Newell, 2000; Newell & Porter, 2000). In their review of studies of marsh and estuarine fluxes, Childers et al. (2000) conclude that the nature and mechanism of exchanges between different subsystems in the estuary-coastal ocean landscape, and exogenous forcing factors are important issues to be addressed while the outwelling hypothesis should be seen as a conceptual stimulus. In retrospect, Teal recognises 'obvious shortcomings' in the earlier study that considered movement of detritus as the principal export mechanism, but at the same time stresses two important functions of tidal marshes, (a) tranformation of nutrients inflowing from uplands and (b) support of large fish populations (Teal & Howes, 2000). The current state of knowledge is summarised succinctly by Odum (2000) who states that "the extent of outwelling is related to the level of productivity and extent of marsh cover within the estuary, the tidal amplitude and the geomorphology of the estuarine landscape".

Let me revert to the most fundamental aspect of wetland science: the definition and classification of wetlands which has remained an unsolved issue. Most people agree that definitions depend upon the purpose. Definitions must, however, help identify an object and help distinguish it from others. It is generally agreed that wetlands are transitional, ecotonal, intermediate between land and water. Can then water (lakes and rivers) be included within the term wetland as has been done by Boulton & Brock (1999)? It is certainly imprudent to define wetlands so broadly. Does the recognition of three major characters – hydrology, soil and vegetation – help identify wetlands better? This question is addressed admirably by Lewis (2001) who presents in the most interesting and highly readable text the evolution of wetland science within the United States in response to the federal policy of wetland protection and non-net-loss under the Clean Water Act, and consequent legal requirements and technical needs of the regulatory system. He discusses how these developments have generated some problems and controversies. There are several definitions used within the United States by different agencies for their own purposes and none of them is ideal to identify wetlands adequately. What is considered a wetland by one is not recognised so by another agency – or is at least not considered qualified for protection (see Lewis, 2001). Similarly, how many of the three criteria identified in the US-FWS system are necessary to identify a wetland: one, two or all the three? And which one is the best? It is not necessary for the hydrophytic vegetation to have hydric soils for its development, and the presence of hydric soils does not ensure the presence of hydrophytes. The occurrence of hydrophytes itself has been subjected to statistical treatment in recognising facultative and obligate hydrophytes and the frequency of their occurrence. The final answer remains elusive. In the meantime, most developing countries continue to face the dilemma or follow the Ramsar Convention definition because they cannot afford the luxury of such detailed analysis and delineation as in the United States. The absence of a clear and widely applicable definition should however not be a roadblock on the path to conservation.

Application of wetland science

Scientific understanding of ecosystem processes and factors governing them in different wetlands, particularly natural wetlands, can be applied in several ways to take optimum advantage of wetland functions and values, other than for conservation. I would consider in some detail two of these areas that are becoming increasingly important and naturally receiving great attention.

Constructed wetlands

Our understanding of the biogeochemical functions of wetlands involving the transformation of nutrients and toxic substances has been gainfully employed for water quality improvement/ wastewater treatment. This is an emerging area of research and technological development. Wetlands created specifically for the purpose, often known as constructed wetlands or treatment wetlands, are usually categorised into surface and subsurface flow systems and the latter are further grouped into vertical (upward or downward) and horizontal flow systems. Treatment systems that combine wetland cells with one or more types of flow are called hydrid systems. Extensive effort has gone into their design to improve efficiencies for the removal of nutrients and other substances, especially in Europe, U.S.A. and Australia where hundreds of these systems are now in operation. Thus, a very large bulk of published literature has accumulated over the past decade or so (see Kadlec & Knight, 1996, 2001; Mulamoottil et al., 1998; Vymazal et al., 1998; Mander & Jensen, 2002). Most of the publications in the field originate from various conferences and workshops, including the biennial international conferences under the auspices of the International Association of Water Quality (IAWQ) and appear in a variety of journals (such as *Water Science and Technology* and *Ecological Engineering*) and books (e.g., Vymazal, 1999). The publications fall in two broad categories: those presenting practical experiences and results of the functioning of different types of constructed wetlands, and those discussing the science and processes involved in these systems. The latest publication in the first category is a volume of selected papers from several sessions on the use of wetlands in improving water quality during the World Millennium event in Quebec (Pries, 2002). These papers report studies from eight countries on the potential of a variety of constructed wetlands for treating waste waters from diverse sources – domestic, industrial, dairy, piggery and storm water. Whereas almost all constructed wetlands use emergent or floating herbaceous wetland plants, woody species are also now being considered, as demonstrated by the study on *Melaleuca* in Australia (Greenway & Bolton, 2002). Another recent volume by Vymazal (2001) falls in the second category. It also forms the proceedings of a workshop held in the Czech Republic a year earlier. Twenty five of the papers presented at the workshop are included together with the discussion at the end of each presentation. It includes a detailed review of nutrient transformation processes and wastewater treatment potential of different kinds of constructed wetlands in various countries. While nitrogen and phosphorus are the focus of most studies on constructed wetland systems, other nutrients rarely receive attention. Heavy metals and organics are also important pollutants that are significantly removed by wetlands (e.g., Zakova, 2001). A detailed discussion of the role of wetlands in removing heavy metal contamination from natural systems is presented in Odum H.T. et al. (2000) who focus primarily on lead, one of the first materials used by developing civilisations and a metal used heavily in the industrial era.

It is only in the past few years that constructed wetlands have received some attention in tropical and developing countries, such as Brazil, Uganda and Malaysia. Okurut (2000, 2001) describes the Ugandan experience with treatment of domestic waste waters. In Malaysia, a very large wetland system has been constructed in the new administrative region, Putrajaya, to treat storm water. There are also reports from China (Wu et al., 2002) where natural wetlands have long been traditionally integrated with agriculture, pisciculture, poultry and pig farming to recycle organic wastes (Zhenjun et al., 1996, Zhong et al., 1997).

In spite of widespread use of these treatment systems, many issues have not yet been addressed. It is often pointed out that constructed wetlands can also support biodiversity and be aesthetically pleasing when properly designed. However, there are few comparative studies to demonstrate the differences between constructed and natural systems in their functions, and their potential/efficiency for treatment over prolonged periods. Available data suggest that the treatment efficiency declines after a few years. A major problem in the use of these systems in most developing countries is the requirement of large areas of land that is at high premium. One needs to ponder over the question, whether constructed wetlands truly replace the natural wetlands that are getting rapidly lost or degraded? Could a lesser area of natural wetland perform more functions and/or more efficiently than a larger area of constructed wetland and help conserve more biodiversity?

Several other questions remain unanswered. For example, do natural wetlands have an unlimited capacity to treat wastes (transform nutrients and other substances) without getting impacted? Can constructed wetlands insulate adjacent/downstream systems from upland influences such as diffuse pollution? Of course, one can channel the storm water to constructed wetlands and develop agricultural drainage systems and then treat the drainage water. Obviously, there is a vast scope for comparative research on natural and constructed wetlands in both the developed and developing world.

Wetland restoration

All over the world, significantly large areas of natural wetlands have been lost or are degraded to different degrees due to various anthropogenic activities, which primarily cause hydrological changes. Water extraction, diversion and flow regulation by building dams and embankments as well as drainage and landfill are among the most common activities, besides discharge of domestic and industrial waste waters. For more than a decade much emphasis has been laid on mitigating wetland losses by various means. Mitigation is defined as ‘avoiding, minimising, rectifying, reducing or compensating for resource losses’. Compensatory mitigation refers to restoration, creation, enhancement, and in exceptional cases, preservation of other wetlands as compensation for impacts to natural wetlands (NRC, 2001). There is, however, quite a bit of confusion over various terms. Restoration is generally defined as the re-establishment of pre-disturbance natural functions and related physical, chemical and biological characteristics (Cairns, 1988; Lewis, 1989). For many different reasons, it is practically difficult, if not impossible, to return to some pre-disturbance state. In this context, the return to any improved condition with some useful functions is referred to as rehabilitation. Some treat restoration and rehabilitation synonymously whereas others consider rehabilitation as an umbrella term that includes restoration (Zedler, 1999). Similarly, some consider mitigation as an all-inclusive term (NRC, 2001) whereas to others mitigation is 'simply the alleviating of any or all detrimental effects arising from a given action' (NRC, 1992).

Restoration of wetlands has been the subject of many publications which have discussed the theoretical framework as well as practical approaches in several different kinds of wetlands together with many case studies (e.g., Wheeler et al., 1995; Galatowitsch & van der Valk, 1998; FISRWG, 1998; Hey & Philippi, 1999; Streever, 1999; Middleton, 1999; Weinstein & Kreeger, 2000; Zedler, 2000). Lately, the subject of mitigation and restoration has also been discussed within the Ramsar Convention, and guidelines have been prepared for the purpose (for resolutions adopted at COP7 and COP8 and the guidelines, see http://www.ramsar.org/ strp_rest_index.htm). Wetland restoration has been discussed at many recent meetings; for example, it was the central theme of an international symposium organised by the Society of Wetland Scientists and the Chinese Academy of Sciences in Nanjing in September 2002. Beyond scientific discussions, practical efforts for the restoration of wetlands and associated aquatic ecosystems are also gaining momentum in several countries (see Streever, 1999). For example, there are several multi-million dollar projects underway to restore wetlands including the Everglades, and China has ambitious plans to restore several thousands of hectares of wetland area.

There are many questions that need to be addressed before, during and after restoration. For example, can all kinds of natural wetlands be restored to their pristine state? What should be the goals of rehabilitation? Which functions are to be maximised (or optimised) and which functions can be ignored? What factors influence restoration, what are the constraints, and how can the success of restoration be evaluated? A recent report of the United States' National Research Council's Committee on Mitigating Wetland Losses (NRC, 2001) provides some answers. The Committee reviewed various aspects of compensatory mitigation required by the federal permitting process under Section 404 of the Clean Water Act. The report examines the state of wetland restoration and creation in the United States, evaluates the performance of mitigation wetlands, and discusses several issues concerning compliance with permit conditions, and institutional aspects. It recognises that certain floristic assemblages such as those in sedge meadow wetlands are difficult to obtain and maintain without intensive management, and that shrub swamp and forested wetlands are more difficult to create and restore because of the time needed to establish mature woody plants, whereas the sea grass and salt marsh communities are relatively easy to restore or create. Among other wetland types, bogs, fens and vernal pools are almost impossible to create due to the specific combinations of their vegetation, soil and hydrological characteristics. Restoration of structure alone does not ensure the restoration of wetland functions. The factors that affect restoration goals include hydrology, wetland size, place of wetlands in the landscape, the structure and scale of the landscape, kinds of plants and animals, and time allowed for development (Simenstad et al., 2000; NRC, 2001).

Wetland restoration often requires some engineering measures to re-establish habitat features and hydrology, and in many cases, planting of vegetation if the seed bank in the area has been destroyed or depleted. All stages in the life cycle of wetland plants (and animals), from production of seeds/ propagules and their dispersal through germination to establishment, growth and maturation are generally adapted to different specific hydrological regimes (see Middleton, 2002), and therefore, restoring hydrology that mimics the natural flood pulse is essential to the success of restoration, and indeed the most difficult both socially and politically. Many recent publications have emphasised the dominant role of hydrology in restoration efforts around the globe. In the United States, several restoration projects have involved re-creating hydrological regimes (flood pulse). Various strategies and results of six such projects in the Southwest (including the Sonoran Desert communities and the Middle Rio Grande), the Upper Missouri River in Montana, the Illinois river Valley, the Southeast and the Kissimmee River region are brought together by Middleton (2002). Some others are discussed in the report of NRC (2001). A few examples of restoration of tidal marshes and mangroves are discussed in Weinstein & Kreeger (2000), Streever (1999) and Turner & Streever (2002).

It needs to be emphasised that restored wetlands may not attain functional equivalence with natural wetlands, and that they usually require management for long periods. The majority of restoration projects have been monitored for only a few years, and functional assessments are rare (though structural equivalence can be readily measured (Zedler & Lindig-Cisneros, 2000). The sustainability of restored wetlands will depend upon the continued maintenance of specific conditions. We must heed the warning issued by Lewis (2001), "The great danger in mitigation through restoration or establishment of artificial wetlands lies in the ease with which these practices could serve as a universal escape valve for pressures promoting the protection of natural, undamaged wetlands".

Finally, wetland restoration is receiving increasingly greater attention in developing countries and mangroves have been the focus of several projects in Asian countries (see Streever, 1999). Successful efforts to 'restore' the Chilika lagoon, for its shrimp fisheries, by an engineering intervention to revive its hydrological interaction with the sea were recently awarded by the Ramsar Convention at its COP8, and the site was removed from the Montreux record. However, the problems and constraints of tropical and developing countries have rarely been addressed (e.g., Crisman, 1999). It will suffice here to stress that restoration in developing countries can be successful only if the millennia-old human-wetland linkages are understood, appreciated and taken into consideration in developing and implementing various projects. Local communities that depend upon wetlands must participate in decision-making and execution of restoration projects. Economic valuation also needs to be an integral part of restoration projects as it will provide support to the formulation of appropriate policies.

Conservation and management

Conservation has very many different goals. The Ramsar Convention has been instrumental and highly successful in mobilising most nations to pledge for wetland conservation. Indeed, about 106 million ha of wetlands have been designated for conservation. But a deeper analysis reveals the other side of the story. The Ramsar Convention recognises that several types of wetlands are grossly underrepresented in their list of designated sites, and that about 50% of the wetlands designated are influenced by agriculture (including aquaculture) or are agricultural wetlands. Clearly, they cannot be truly conserved for the values for which they have been designated. The number does not represent the true story of conservation. If the U.K. has a few hundred sites whose total area is less than that of a single site in another country, what is the significance of a large number? It is more important to know what proportion of wetlands in a country has been protected (at least designated), and what steps that country takes to protect other wetlands. In most countries, the designated sites are also not well protected: as of November 2002, 58 sites have been placed under the Montreux record.

Wetlands cannot be conserved, managed or protected from human impacts without ensuring that their specific hydrologic regimes and water quality are maintained and ensured? The growing demand of water for agriculture, urban supplies and hydropower, and numerous water development projects, most of which are aimed at enhancing agriculture, are bound to impinge upon wetlands. The Ramsar Convention is conscious of these ground realities and these issues were in one way or the other reflected in the discussions and resolutions at the just concluded COP8. This leads us to the issues of policy in different countries.

Policy

Practically all countries have certain national policies related to the use of natural resources and environment protection. In most cases, these policies are highly sectoral, dealing separately with, for example, water, land use, agriculture, forests, energy, wildlife and environment. Often a number of government departments and agencies are responsible for each of these sectors but work in isolation resulting in duplication of effort and/or conflict between goals and approaches. Stimulated by the Ramsar Convention, several countries such as Canada, Australia, Uganda, and Trinidad & Tobago, have adopted specific national wetland policies. Do we really need a separate policy to protect wetlands or can the objectives be fulfilled by integrating wetland concerns with land and water use policies? It is not readily appreciated that in the United States wetland protection started with a concern for waterfowl, but is now rooted in the policy for the maintenance of water quality. It flows from the recognition of the water quality function of wetlands and their inclusion in the broad definition of 'waters of the United States'. The goal of no-net-loss of wetlands is pursued through a regulatory process under the Clean Water Act, though all is not well as wetland loss still continues (see NRC, 2001). Thus, the point I wish to make is that a national policy for wetland conservation must be integrated into a comprehensive, holistic policy on water resources that addresses the concerns of all stakeholders, combines the requirements of both quantity and quality of water, and is founded on sound scientific understanding of ecosystem processes on a river basin scale.

Development of such a policy and its implementation requires a synergy between scientists and policy makers. In the U.S.A., studies on wetlands during the 1950s – 1970s provided the basis for setting the 'no net loss' goal and subsequent requirements of the regulatory framework fuelled wetland science. Unfortunately, in most countries of the Third World, wetland science is in its infancy, and conservation is practised mostly on paper. With increasing climatic variability, water is becoming the most important global issue. It can only be hoped that the International Year of Freshwater (2003) will help focus on conserving the ecological integrity of inland aquatic ecosystems (rivers, lakes, wetlands).

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