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Abstract. *To date, wetland conservation programs and policies have focused on wetlands primarily as wildlife habitat. In spite of the extensive efforts of wildlife interest groups, wetlands continue to be lost. Successful wetland conservation in North America will require that society, as a whole, perceives broader and more significant values of freshwater wetlands than simply their role as wildlife habitat. Identifying and quantifying the functions of wetlands to the maintenance and renewal of critical freshwater resources are important steps toward expanding the base of support for wetland conservation/restoration programs throughout the continent. This paper introduces the functions and values of prairie wetlands related to the quantity and quality of fresh water. Subsequent papers in this issue evaluate the current state of our knowledge of these functions and values, identify priority information needs, and make specific recommendations for the use of this information to enhance wetland conservation restoration programs and policy.*

Human society depends on freshwater systems to provide water for drinking, hydropower, irrigation, cooling, and cleaning; products such as food, plants, wildlife, and minerals; and services such as recreation, waste purification, transportation, and aesthetics. Continentally and globally, there is abundant evidence that freshwater resources are being depleted and their quality severely degraded. At its special session in June 1997, the United Nations General Assembly acknowledged the growing crisis related to the decline in quantity and quality of freshwater resources throughout the world (Ismail 1997). Naiman et al. (1995) argued that freshwater resources in North America are being depleted and degraded and these changes represent a strategic threat to the quality of human life, the sustainability of the biosphere, and, in fact, the long-term survival of human society.

The loss and degradation of freshwater resources are a result of both the acceleration of human-caused changes and the sensitivity of freshwater

ecosystems to such change. Human societies often naively operate as if they have unlimited capacity to alter water resources and the landscape without degrading the ability of those resources to supply their needs. Moreover, the assumption exists that there is sufficient understanding and available technology to replace or compensate for lost ecological functions. In reality, there is growing uncertainty regarding the ability of freshwater ecosystems to respond to human pressures and our capability to manage water resources amid these pressures (Abramovitz 1996).

Effectively addressing problems associated with the supply and quality of fresh water requires an expanded understanding of freshwater systems and pressures on those systems in today's social and economic environment. Naiman et al. (1995) suggested that an effective approach to fill existing information needs and put all available information to work effectively will require partnerships at several levels: among natural scientists in a variety of disciplines; among natural and social scientists; and among scientists, economists, policy makers and natural resource managers. These partnerships must address the full range of interacting systems including lakes, streams, surrounding uplands (and associated land uses), and wetlands. They must not only provide high quality science, but also pertinent and timely information that can be used effectively by water resource managers and policy makers (Harwell 1997).

Wetlands are critical components of the freshwater resources in North America and one of the components most vulnerable to changes imposed by industry, agriculture, and society in general. Wetlands, large and small, are also vital components of the freshwater cycle, however their role in maintaining the abundance and quality of fresh water has attracted attention only recently (Neiman et al. 1995). The objective of this paper is to introduce the functions of prairie wetlands related to the abundance and quality of fresh water and the existing information gaps related to these functions and their associated values to society. For this discussion, functions are defined as the physical, chemical, and biological processes in wetlands related to the quality and quantity of water within and moving through these systems. Values are the public's perception of the benefits (if any) of these functions in terms of quality of life and economics.

The Challenge

To date, most wetland conservation programs and policies in North America have focused on wetlands primarily as wildlife habitat. In spite of

the extensive efforts of conservation groups, wetlands continue to be lost or degraded throughout the continent. In the continental U.S. less than 50% of the original wetland acreage remains (Bildstein et al. 1991), while in prairie Canada over 70% of the prairie potholes have been altered or lost (Young 1994). Over 85% of the wetland loss and alteration on the Canadian prairies is attributed to agricultural activities (Turner et al. 1987; Cox 1993). Unfortunately we know very little regarding the ability of the remaining wetlands and wetland complexes to function in the highly altered modern landscape. In many areas the wetland base has been completely eliminated and although wetland restoration is possible to some degree (e.g., Galatowitsch and van der Valk 1994), we have only a rudimentary understanding of the ability of managers to actually restore wetland ecosystem functions.

We face an apparent conflict between the perceived short-term gains from eliminating and altering wetlands and the poorly defined long-term costs to water quality and abundance, as well as the wildlife habitat and other human values associated with healthy wetlands. Wetland drainage and alteration have occurred largely because of the benefits perceived from eliminating wetlands for other uses. As more and more government subsidies and tax concessions are removed from the agricultural economy, farmers will be making decisions about land use based increasingly on market forces. Unless we understand the broader societal values of wetlands and the impact of land-use practices on wetland functions, it will be impossible to consider these values in decisions about alternative land uses (see Leitch and Fridgen 1998).

Successful wetland conservation in North America requires that society, as a whole, perceives broader and more significant values of freshwater wetlands than simply their role as wildlife habitat. Sound scientific information identifying and quantifying the societal values of these wetland functions is necessary before the public and governments will regard and therefore protect wetlands as a vital component of a sustainable healthy environment (see Leitch and Fridgen 1998; Scarth 1998). Close interaction among researchers, user groups (e.g., agriculture, developers), and private and public agencies with various policy or management mandates is vital to the development of progressive conservation policy and management programs. To provide effective solutions, managers and policy makers must invest immediately in research, and scientists must be cognizant of the information needs of policy/management personnel. The urgency and scale of issues affecting fresh water require that many management and policy decisions must be made now. This requires assembling our current knowledge on the function

of wetland systems, improving that understanding where necessary, and using this information to guide current and future policy and management decisions (see Scarth 1998). In addition, current programs and management projects should be viewed as management experiments with mechanisms for regular assessment and adaptive change to produce an ever-improving product. This requires that objective research becomes an integral part of ongoing policy and management programs.

Setting Geographic Priorities

Addressing information needs related to the broad array of wetland functions associated with the many wetland types throughout continental North America is a formidable task requiring considerable financial resources. A realistic approach will require prioritization of needs based on criteria relevant to continental conservation strategies. Recently the three Ducks Unlimited organizations in North America (DU Canada, DU Inc., and DU de Mexico) developed the DU Continental Conservation Plan (Ducks Unlimited 1994) to guide their wetland conservation programs through the year 2000. The approach was an analysis of waterfowl populations and their habitat status in order to formulate a priority list of geographic regions within the continent requiring wetland habitat conservation programs. The geographic area identified in this analysis as the highest priority for attention was the Prairie Pothole Region of western Canada and the north-central U.S. (Figure 1). The primary habitat concern identified by the plan in this region was continuing "drainage and degradation of wetlands."

The Prairie Pothole Region: A continental priority. Wetlands are a prominent component of the North American prairie landscape although the region has been extensively altered for agriculture. For example, across western Canada, modern agriculture has resulted in the conversion of over 95% of native grasslands to crops and pasture land and loss of half of western Canada's pre-settlement wetlands (Cox 1993). In spite of these losses, more water is required for irrigation, livestock, power generation, industry, and human consumption. Aquifers are being mined of their water with little regard towards sustainable use. For example, the huge Ogallala Aquifer, south of the Prairie Pothole Region, in the central U.S. has been pumped to the point where associated wetlands and streams in the region fed by artesian flow have dried up (Neiman et al. 1995). The health and sustainability of the prairie landscape, its people, and industries require a careful evaluation of

Figure 1. Location of the Prairie Pothole Region in central North America.

the freshwater resources and those components of the landscape that influence those resources. The importance of this region to wildlife and particularly to maintaining continental waterfowl populations has been well established (Batt et al. 1989).

Fresh Water Functions and Values of Prairie Wetlands

Freshwater wetlands are purported to serve a wide range of hydrologic functions related to the supply and quality of fresh water (Carter et al. 1978; Reimold 1994). The functions of prairie wetlands related to fresh water include:

Control and storage of surface water. Flooding, both during spring runoff and extended rain events, causes significant economic losses annually throughout the continent. By storing surface water and slowing the rate of runoff after the spring melt or major storm events, wetlands within a watershed serve to stabilize surface water flow and thereby reduce the risk of downstream flooding and associated soil erosion (Novitzki 1978; Hubbard and Linder 1986; DeLaney 1995). For example, in the Devil's Lake region of North Dakota, it is estimated that small local wetlands can store up to 72% of the annual spring runoff (Ludden et al. 1983). Based on a study of satellite imagery and long-term precipitation records, Miller and Nudds (1996) argue that increased magnitude of floods of the Mississippi River over the last several decades is due, in part, to wetland drainage in the upper reaches of the watershed. However, the various factors affecting the role of wetlands in surface water storage and flood reduction (e.g,. wetland type, position in the watershed) require further study (Hubbard 1988). The economic and societal values of these functions also require further evaluation and quantification. This information will be important to development of wetland programs and policies related to flood control management.

By storing surface water, permanent wetlands also serve as a source of fresh water for domestic, agriculture, and industrial use. Direct consumption of wetland water supplies for these uses requires a detailed understanding of wetland hydrological processes to avoid negative effects on the wetland system and its associated functions within the landscape.

Recharge of groundwater supplies. Wetlands interact with groundwater supplies in a variety of ways (Winter 1989; also see LaBaugh et al. 1998). In some regions surface water accumulated in wetland basins is slowly released to groundwater and therefore serves as potential sources of recharge for local and, in some cases, regional groundwater supplies (see van der Kamp and Hayashi 1998). The decline of groundwater tables due to water removal, primarily for irrigation, has been observed in many regions of North America. This reduction in groundwater is a serious threat to not only agriculture but to the very existence of human and economic activities in these areas. For

example, the groundwater shortage in the Ogallala region mentioned earlier is so severe that Opie (1993) states it will "bring on environmental collapse. . . . and subsequently deny human survival there." Wetlands may play an important role in avoiding these types of crises, however more detailed data on the role of wetlands in groundwater recharge are urgently required before policy makers and public agencies will move to protect and reclaim wetlands as part of an overall plan to conserve and restore groundwater supplies.

Sinks for excess nutrients. Water bodies often experience significant nutrient loading from adjacent agricultural fields, feedlots, and other agricultural and industrial operations. Wetlands serve as potential sinks for excess nutrients in agricultural and urban runoff (Neely and Baker 1989; Bingham 1994; also see Crumpton and Goldsborough 1998). Nutrients in inflow waters are incorporated into flora, fauna, and sediments within the wetland and this ability to remove nutrients from these waters has important implications for water quality down stream from the wetland (Johnson et al. 1990; Landers and Knuth 1991; DeLaney 1995). To date there is little concrete information on the role of wetlands on water quality improvement in agricultural landscapes. This information is important for the recognition and protection of wetlands as integral parts of sustainable agricultural systems.

The ability of wetlands to remove nutrients from surface water has also attracted attention with respect to their use for treating domestic and industrial sewage (Hammer 1989; Kadlec and Knight 1996). In Europe, wetlands have been used to treat domestic sewage for over 50 years, however in North America most of the activity in this regard has been fairly recent, although interest is growing at a rapid rate (Moshiri 1993). There are opportunities to develop wetlands for sewage treatment in virtually all regions of the continent, however results from projects completed to date have been highly variable (Kadlec and Knight 1996). Although much progress has been made, detailed information is required on a variety of issues (loading rates, nutrient cycling within sediments/vegetation, etc.) before consistent results can be attained for these types of projects over a range of geographic regions. In addition, assessing the effects of sewage loading on wildlife habitat and other wetland functions requires investigation before sewage treatment wetlands can be incorporated into sustainable environmental planning (Hanson et al. 1997).

Filters for sediments and a wide variety of chemicals. Wetlands serve as sediment traps thereby reducing downstream sediment loads (Boto and

Patrick 1978; Philips 1989). Shallow vegetated wetlands serve to reduce flow velocities and allow sediments to settle out. The function of wetlands as sediment filters and the impact of sedimentation on wetland systems requires careful investigation because sediment accumulation in wetlands can negatively affect other wetland functions and values (see Gleason and Euliss 1998).

Wetlands in areas of agricultural activity or receiving industrial effluents may be subjected to a variety of chemicals associated with inflow waters (Grue et al. 1989; Grover et al. 1997). In some cases, receiving wetlands can incorporate undesirable chemicals and breakdown products of these chemicals into sediments and associated vegetation (e.g., Huckins et al. 1986; Lee et al. 1995). The ability of wetlands to remove these chemicals from water, either through uptake or by breaking them down into less toxic by-products, requires research by a diverse group of specialists before reliable recommendations can be made regarding the role of wetlands as chemical filters (see Goldsborough and Crumpton 1998). The fate of chemicals and the role of wetlands in reducing and removing chemical loads has implications in sustainable agricultural, industrial, and urban development programs. An important consideration in the role of wetlands as chemical filters and processors is the direct impacts of chemicals and their breakdown products on the flora and fauna of wetland systems (Sheehan et al. 1987; Arts et al. 1996; Pastorok et al. 1996).

Other hydrologic functions. Wetlands likely play a role in regional hydrological cycling. It has been suggested that wetlands may contribute to the generation of rainfall locally and on a regional basis in drier areas of the continent (Smith 1997). Removal or alteration of wetlands in these regions may therefore affect rainfall inputs and related hydrologic functions such as groundwater recharge. The role of wetlands in regional hydrological cycles requires investigation especially as overall climate change draws increasing attention (see Robarts and Waiser 1998).

A First Step

The first step in developing a better understanding of freshwater functions and values of prairie wetlands is to assemble all existing information in order to identify specific information gaps and subsequent research needs. Steps must then be taken to ensure that this existing information is made available to the general public and policy makers. The subsequent papers in

this special issue of *Great Plains Research* will: 1) evaluate the current state of knowledge concerning the functions and values of prairie wetlands related to the abundance and quality of fresh water, 2) address our ability to restore these functions in degraded wetlands, 3) identify fundamental information gaps and priority research needs, and 4) make specific recommendations regarding the use of this information to develop wetland conservation and enhancement programs and public policy.

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