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ECOLOGICAL FUNCTIONS AND HUMAN VALUES IN WETLANDS: A FRAMEWORK FOR ASSESSING FORESTRY IMPACTS

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Abstract: The term "value" usually connotes something of use or desirable to *Homo sapiens.* Values ascribed to many wetlands include providing habitats for fishing, hunting, waterfowl, timber harvesting, wastewater assimilation, and flood control, to name a few. These perceived values arise directly from the ecological functions found within the wetlands. Ecosystem functions include hydrologic transfers and storage of water, biogeochemical transformations, primary productivity, decomposition, and community/habitat. An analysis of the relationship among wetland functions and values showed that over-utilization or intensive removal of wetland values (e.g., timber harvesting with drainage), can often result in a loss of specific wetland functions. An assessment procedure comparing changes in wetland function from both a disturbed and reference wetland was developed. This approach scales the wetland functions in a reference system to 100% and then compares the altered wetlands' functional response. Methods to analyze wetland functions in the field are outlined along with examples of the effects of forestry activities on wetland response.

Key Words: economics, forestry, landscape ecology, values, wetland

INTRODUCTION

The placement of different functions and values on the wetland ecosystem by different interest groups has resulted in major conflicts in society. For example, the value of timber productivity is of primary concern to the forest industry, and its sustained yield from the ecosystem is essential to the industry. Ecologists, on the other hand, are more concerned with any significant diminution of wetland functions, such as hydrologic flow or biogeochemical cycling and transformations of elements, on the landscape. Society places other values on these wetland systems, and many related to endangered species or recreation are considered to be of more critical concern than timber productivity. These conflicts often are the result of serious ecological, economic , and ethical differences among interests groups, scientists, and environmentalists; the spotted owl-timber resource issue being one of the most volatile examples in recent memory (Kelly and Brassch 1986, Dixon and Juelson 1987, Salwasser 1987, Simberloff 1987, Strong 1987).

Another major problem arises because there is a lack of understanding that the terms *functions* and *values* are not synonymous and that values of an ecosystem are derived directly from the existing and operating functions within the ecosystem. Confusion also exists as to which functions or values a particular ecosystem type might sustain under alterations such as forest harvesting practices. In this introductory paper, I will present a framework for distinguishing the difference between functions and values as well as give a few specific examples of how values are derived from functions and how forestry practices may affect the controlling functions in wetlands. This paper does not address a complete economic analysis of wetlands values since little specific information is available regarding the relationship of wetland "ecological functions" and "economic values." For an overview of these relationships, it is suggested that the reader consult Batie and Shabman (1982), Farber and Costanza (1987), Whitehead (1990), and Turner (1991).

In brief, we do know from these studies that meaningful prices for the developmental uses of wetlands are relatively easily established. However, ecological functions of wetlands are considered public goods, as are clean air and water, and ownership for such services is ill-defined. Because such rights are not exclusive, transferable, or enforceable, the *ecological* or non-market values of wetlands are *not* priced or traded in the market. Hence, the failure of the market to efficiently allocate wetland resources according to the laws of supply and demand has resulted in the conversion of wetlands, which in turn results in a negative benefit to society. Thus, *costs* of additional wetland development to society as a whole may be greater than the *benefits.* This has stimulated attempts to evaluate wetlands in terms of their functions and values as well as determine if any useful relationships exist between wetland functions and economic value. Gosselink et al. (1974), in an article on the value of tidal marshes, used energy as the least common denominator (life support-ecosystem approach) for an integration of ecological and economic analyses and developed a total value of $1,648/ha/year. In their critique of this approach, Shabman and Batie (1978) stated that these economic estimates are neither conceptually nor empirically correct. In his rebuttal, H. T. Odum (1978) pointed out how the embodied energy concept should be used and suggested an annual value of $1,620 to $2,025 per ha for a wetland is reasonable. However, 15 years later, we are still at an impasse between the two disciplines on how to estimate the value of wetlands. It is clear that ecologists need to do a better job of quantifying wetland functions and relate them to human values so that we at least can determine what we will lose when we alter or develop wetlands. The key ecological question that needs to be addressed under any development scenario is whether or not wetland functions have been significantly altered. For example, if water storage from a wetland was the important process on the landscape, then the question becomes: what will it "cost" to replace that function? Moreover, can the wetland function be replaced at all? Replacement costs are often far higher than the cost of selecting another area or avoiding the wetland functional loss. The billions of dollars of property and crop loss along the Mississippi and Missouri Rivers in the midwest during the record summer floods of 1993 is a case in point. States like Iowa and Missouri, which have developed nearly 90% of their wetlands, both suffered record flooding levels due to a lack of water storage capacity in natural wetlands (Bill Wilen, USFWS, unpublished report on flooding in the Mississippi, August 13, 1993), as well as uncontrolled development in the flood plains themselves.

In the following chapters of this special volume, we present current information on the effects of using one wetland value—timber harvesting—on some aspects of wetland functions. We specifically focus on the effects of forest management practices on the wetland functions of hydrology, biogeochemical cycling, productivity, wildlife, and the values of water quality and hunting. The problem of cumulative impacts and the role of wetlands on the landscape are also analyzed (see Johnston 1994).

DEFINITION OF TERMS

The **value** of a wetland is an estimate, usually subjective, of the worth, merit, quality, or importance of a particular ecosystem or portion thereof. The term imposes an anthropocentric focus, which connotes something of use or desirable to *Homo sapiens*. Values ascribed to many wetlands include providing habitats for fishing, hunting, waterfowl, timber harvesting, waste water assimilation, water quality, and flood control, to name a few. Moreover, these perceived values directly arise from the ecological **functions** found within the wetlands. For example, wetlands under anaerobic conditions process nitrate to N_2O and release the nitrogen as a gas to the atmosphere (Hemond 1983). This is an ecological **function** for wetlands. This function has **value** on the landscape in that wetlands can be successfully used to remove nitrogen from agricultural or municipal wastewater runoff (Hammer 1989). This is a value to society that is based directly on the ecological function of nitrogen cycling within the wetland ecosystem and will be lost if the wetland is drained. The functional response of the wetland to development can be negative, as in the case of wetland drainage reducing water storage capacity prior to harvesting, or it can be positive, in that selective harvesting of older trees can result in increasing primary productivity of the ecosystem if the system is not significantly impacted by drainage prior to harvest (Figure 1). The degree of alteration to wetland function is directly related to the magnitude of development, with drainage being the most serious impact that wetland functions cannot overcome. Also, an increase in one function, such as productivity, may be at the expense of another function, such as decomposition.

The ecological functions or processes ascribed to wetlands are found at the global, ecosystem, and population levels. Ecosystem functions include hydrologic transfers and storage of water, (Richardson and McCarthy 1994), biogeochemical transformations (Walbridge and Lockaby 1994), and primary productivity and decomposition (Mitsch and Gosselink 1993, Conner 1994). Wetlands are also important in the global cycling of such elements as N, S, and C (Bayley et al. 1986, Bowden 1987, Faulkner and Richardson 1989, Richardson 1989). At the population level, wetlands function as wildlife habitats, maintaining unique species and biodiversity (Wigley and Roberts 1994).

ASSIGNMENT OF FUNCTIONS AND VALUES

A general listing of the functions and values often attributed to natural wetlands is given in Table 1. The wetland functions are placed in five ecosystem-level categories with specific examples of these functions listed below. In addition, the uses to society of converted wetlands are also presented. I have placed the functions and values in separate categories to try to clarify the differences between processes that wetland systems perform and the values that society extracts from these functions. As noted earlier, wetland values are derived directly from the functions, and the specific

Table 1. Attributes generally given as functions and values of wetland ecosystems.

Wetland Functions

1. Hydrologic flux and storage
   a. Aquifer (ground water) recharge to wetland and/or discharge from the ecosystem
   b. Water storage reservoir and regulator
   c. Regional stream hydrology (discharge and recharge)
   d. Regional climate control (evapotranspiration export = large scale atmospheric losses of H_20)
2. Biological productivity
   a. Net primary productivity
   b. Carbon storage
   c. Carbon fixation
   d. Secondary productivity
3. Biogeochemical cycling and storage
   a. Nutrient source or sink on the landscape
   b. C, N, S, P, etc. transformations (oxidation/reduction reactions)
   c. Denitrification
   d. Sediment and organic matter reservoir
4. Decomposition
   a. Carbon release (global climate impacts)
   b. Detritus output for aquatic organisms (downstream energy source)
   c. Mineralization and release of N, S, C, etc.
5. Community/wildlife habitat
   a. Habitat for species (unique and endangered)
   b. Habitat for algae, bacteria, fungi, fish, shellfish, wildlife, and wetland plants
   c. Biodiversity

Wetland Values

1. Flood control (conveyance), flood storage (1, 2)*
2. Sediment control (filter for waste) (3, 2)
3. Waste water treatment system (3, 2)
4. Nutrient removal from agricultural runoff and waste water systems (3, 2)
5. Recreation (5, 1)
6. Open space (1, 2, 5)
7. Visual-cultural (1, 5)
8. Hunting (fur-bearers, beavers, muskrats) (5, 2)
9. Preservation of flora and fauna (endemic, refuge) (5)
10. Timber production (2, 1)
11. Shrub crops (cranberry and blueberry) (2, 1)
12. Medical (streptomycin) (5, 4)
13. Education and research (1–5)
14. Erosion control (1, 2, 3)
15. Food production (shrimp, fish, ducks) (2, 5)
16. Historical, cultural, and archaeological resources (2)
17. Threatened, rare, endangered species habitat (5)
18. Water quality (3, 1)
19. Water supply (1)

Table 1. Continued.

Use of *Converted* Wetlands

1. Cropland
2. Forest Plantations
3. Peat for Energy
4. Urbanization
5. Aquaculture

* Denotes wetland values which are directly related to wetland functions (1–5), or those functions which can be adversely affected by over-utilization of values. The order of the numbers suggests which primary function is most directly or first affected.

relationships are noted by the numbers following the values given in Table 1. The most important or direct relationship is listed first. It should be obvious that some of the specific functions (e.g., ground-water recharge) might be placed by some in the values column. I would argue that this is a function of the wetland and that it is seldom if ever sold for economic gain such as in the case of timber. Also, the utility of presenting these in separate categories is that it forces one to focus on which functions are potentially altered or destroyed when a certain value is obtained from the wetland. In our forestry effects case-study volume, timber production is a function of biological productivity (function 2 in Table 1) that is directly affected by any impact or harvesting technique that reduces the net primary productivity of the site. Harvesting could also seriously

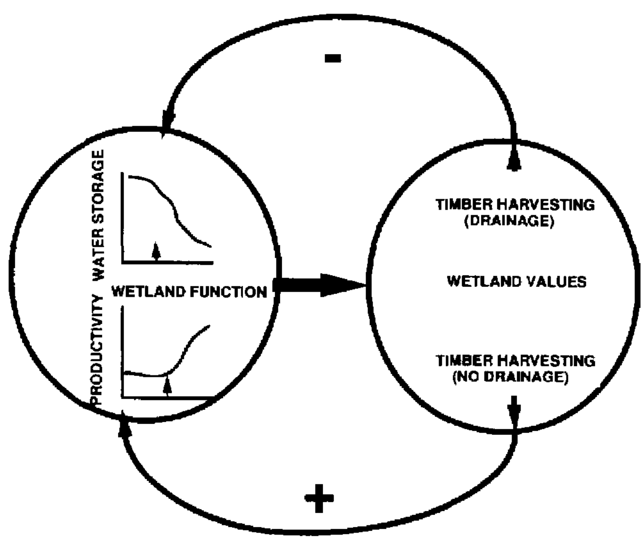

Figure 1. Relationship between wetland functions and values. Drainage of wetlands prior to vegetation removal will result in a negative (−) feedback to wetland hydrologic function, which results in a decrease in water storage capacity. Selective timber harvesting of old growth trees with no drainage may produce a positive (+) feedback resulting in an increase in ecosystem productivity. (Note: arrows on graphs depict harvesting and/or drainage disturbance).

affect biogeochemical cycling (3), decomposition (4), or other functions. The hunting value of a site is obviously primarily related to the secondary productivity and status of the community/wildlife habitat (2, 5) but also may be seriously impacted by a reduction in the biological diversity of the site. Moreover, any timber activity that significantly impacts the hydrologic cycle (1) of the wetland in question may well result in loss of the wetland itself or a loss in the ability of the wetland to perform flood control, flood storage, and sediment and erosion control as well as water quality, water supply, or even timber production values on the landscape.

Finally, the danger of listing functions and values for wetlands or any ecosystem is that it is commonly assumed by the public that every ecological function and human value is found in each and every wetland and, moreover, that each of these attributes is of great importance. However, it is clear to most that wetlands vary greatly in terms of their value for timber production, hunting, recreation, water supply, etc., and thus, it should be equally evident that the underlying supporting functions that provide these values vary greatly. This leads us to what I might call wetland principle number one (with apologies to George Orwell [1946] and the animals).

WETLAND PRINCIPLES

Principle One: All Wetlands Are Not of Equal Function or Equal Value on the Landscape.

Lesson one: It is necessary to assess the key functions and values of each wetland prior to disturbance so that any activity like logging does not significantly reduce wetland function and, in turn, value. The key operative phrase to be applied is "sustained functions from the ecosystem." In addition, the wetlands with the highest functional role on the landscape represent "critical natural capital" and should be retained in a natural or semi-natural state to the point where key functions are not degraded (Turner 1991). Unlike Turner, I would argue that unique wetlands with rare and endangered species or the only wetlands left on the local landscape, must be kept in an undisturbed state. Wetlands with important and significant function on the landscape need to be kept in as undisturbed a state as possible and, most importantly, not be allowed to have their key wetland functions degraded. This usually entails the maintenance of their hydrologic functions and connections on the landscape. Turner (1991) also suggests that, in intermediate value wetlands, it may be possible to enhance natural productivity by environmentally sensitive management, which increases one or more functions without causing significant or irreversible impacts on the others. This might be accomplished by increasing productivity by adding nutrients from wastewater, which can result in the increase of other functions such as biogeochemical cycling and storage (Craft and Richardson 1993b). One has to be careful, however, not to increase values like nutrient storage at the expense of a loss of wildlife/habitat function.

Another key question relates to who will decide which wetlands have the highest functions and values and will remain undisturbed versus which wetlands have intermediate or lower values and can be altered. The challenge for wetland scientists in the coming decade is to develop scientific criteria to help make these assignments. The conflict comes when a wetland function, like biogeochemical cycling or wildlife habitat, is deemed of lesser importance than the timber value extracted from the wetland, especially if these or other functions are greatly altered by the harvesting techniques.

Moreover, when the wetland is converted by development or altered by poor timber practices, alternatives that are often suggested are wetland restoration or construction of new wetlands. This suggests that there are easy and cheap alternatives to best management practices (BMP). This leads us to wetland principle number two.

Principle Two: A Restored or Newly Constructed Wetland May or May Not Be Equal to a Natural Wetland in Terms of Ecological Function or Value.

Lesson two: There is a need for functional replacement of wetlands on the landscape. This means that any attempt to restore an existing degraded wetland or construct a new replacement wetland must be based on an understanding and quantification of the ecological functions of that wetland prior to disturbance. If the wetland is already disturbed or highly degraded, then a similar undisturbed reference wetland can be used as a model system for scale (Figure 2a). Few data exist on the ecological functions of altered versus natural wetlands, and even fewer studies have been conducted comparing constructed versus natural wetland functions and values. In one study, comparing the chemistry of natural and created marshes, it was found that after 5 years, the created wetlands did not duplicate the hydrologic and nutrient cycling functions of the natural marsh (Craft et al. 1991). In another study, Craft et al. (1988) reported that macroorganic matter and soil nutrient reservoirs were smaller in transplanted (1 to 15 years old) marshes than in comparable natural marshes. This type of research must be completed in forested systems so that specific quantitative standards for the relationships between function and

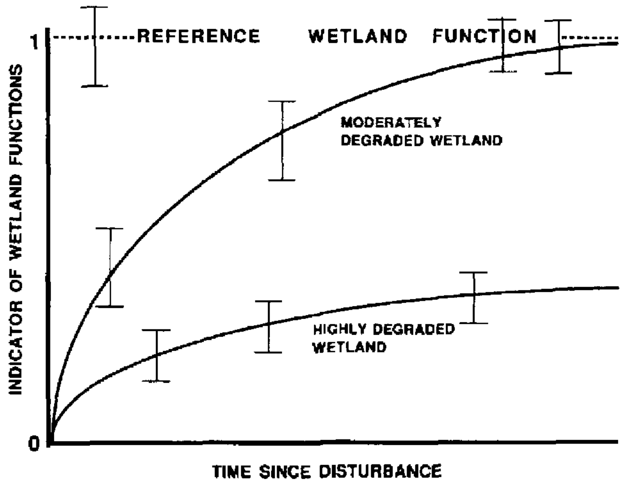

Figure 2a. A time-dependent comparison of wetland functions from highly degraded and moderately degraded systems as compared to an undisturbed reference wetland.

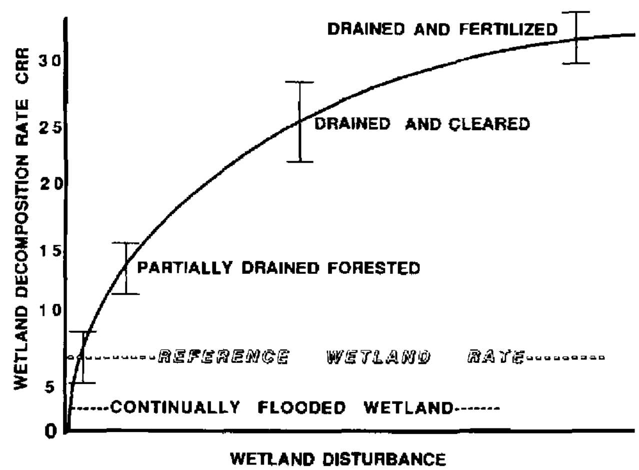

Figure 2b. A comparison of the wetland decomposition function among disturbed and a reference palustrine forested ecosystem (data from Bridgham et al. 1992 and Richardson, unpublished). (CRR refers to the cellulose rate of rotting.)

values can be assessed, as well as for harvesting effects and BMPs (see Walbridge and Lockaby 1994). The relationship between wetlands and adjacent lands, as they are affected by timber harvesting in either area, is also critical and leads to principle three.

Principle Three: Wetland Ecosystem Functions and Values are Coupled to Other Systems on the Landscape.

Lesson three: The hydrologic and biogeochemical functions of many wetlands are directly dependent on the surface and subsurface flow of water from surrounding ecosystems (e.g., fringe wetlands in lakes are affected by lake hydrology) and their position on the landscape (Verry and Timmons 1982, Winter 1989, Brinson 1993). In fact, most of these wetlands (e.g., seepage wetlands, lake edge wetlands, riverine wetlands, and even prairie potholes to a great degree) rely on adjacent landscapes for water and nutrient supplies. Thus, the development and alterations of adjacent ecosystems, especially their water flows, may result in wetland degradation or even loss. The effects of these activities are very difficult to quantify, but the ecological functions of wetlands are being altered if the normal hydrologic and biogeochemical connections between the wetland and surrounding ecosystems are severed. Also, it is often the case that once the wetland boundary is defined and approved (U.S. Army Corps of Engineers 1987), the development is allowed to proceed within centimeters of the legally mandated wetland border. This suggests that wetlands are considered to be isolated on the landscape with no connection to other ecosystems. The irony is that the connection between wetlands and other ecosystems on the landscape is critical to the survival of many wetlands since their hydrologies are often directly linked. Forestry, because of its Federal Water Pollution Control Act of 1972 (FWPCA) exemption, currently has no wetland boundary restriction and can harvest timber within the wetland.

Wetlands also provide benefits beyond their boundaries, and this is seldom recognized. These functions and values are often found on non-adjacent ecosystems and, in fact, can be found many kilometers away from the wetland.

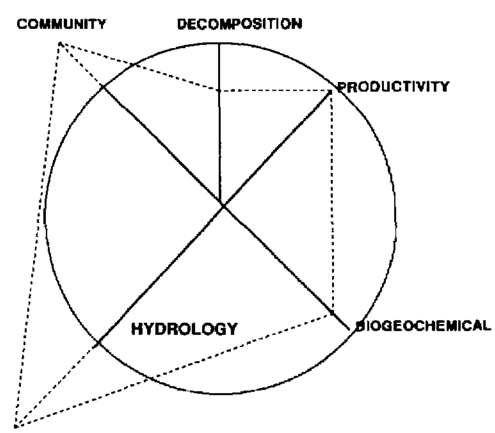

Figure 2c. Hypothetical wetland ecosystem response surface model showing the "reference wetland footprint" with a solid line (i.e., circle) and the altered wetland function response surface is shown by the dashed lines. Each functional axis line within the circle is scaled from 0 to 100%. The dashed lines show the change in functions due to a 40% increase in the hydrology controlling factor.

Principle Four: Wetlands Often Provide Functions and Values Beyond Their Boundaries and Far From Adjacent Ecosytems.

Lesson four: Wetlands can be an important source or sink of regional surface- and ground-water supplies 5–15 km from the actual wetland (Winter 1989, Johnston et al. 1990). Recent studies have shown that the relationship between the regional water table and wetlands is more complex and dynamic than once thought and that seasonal reversals of ground-water flow among wetlands and between wetlands and lakes often occur (Winter 1989). This suggests that the drainage of a wetland in one area may have serious consequences for water conditions in lakes, ground water, other wetlands, or downstream areas that are not readily evident without detailed hydrologic studies. Novitzki (1978) also demonstrated that peak stream flows are only 20% as large in basins with 40% lake and wetland areas as they are in similar basins with no lake or wetland area. Johnston (1990, 1994) further refined the relationship of wetland areas to flow peaks and suggests that when less than 10% of the watershed is in wetlands, significant peak flows occur.

Wetlands also provide a refuge for millions of migratory birds and fish (Weller 1981). The botttomland hardwood forests of the southeast are the winter home of millions of ducks that wing their way south along the meandering rivers and forested riparian wetlands. These bottomland hardwood forests provide a habitat for neotropical migrant species (Fredrickson 1978, Wigley and Roberts 1994). In addition, wetlands process NO_3, SO_4, and C and release gases (N_2O, S, H_2S, CH_4, CO_2) to the atmosphere (Faulkner and Richardson 1989, Gorham 1991, Bridgham and Richardson 1992, Walbridge 1993), thus affecting other ecosystems kilometers away. These functions are not often recognized, and thus, the functions and resulting values attributed to a particular wetland must also be assessed in a regional and global context, especially as it relates to global warming and air pollution problems (Gorham 1991).

FUNCTIONAL ASSESSMENT FRAMEWORK

One functional assessment approach is based on the concept that a selected set of variables (e.g., productivity, decomposition, community/habitat, biogeochemical, hydrologic flux) that integrates key ecosystem-level wetland processes can be used as a metric to compare impacts and quantify functional loss when compared to reference wetlands of the same hydrogeomorphological classification (Brinson 1993, Richardson 1993). For example, a wetland functional rate in a reference wetland, when compared to highly degraded wetlands at almost each point in time since disturbance indicates a 75% decrease in function but indicates only a slight decrease in function for the moderately degraded system after successional recovery (Figure 2a). Consideration of the time since disturbance is important since only later successional stages may demonstrate functions closer to undisturbed systems.

An actual assessment of the degradation and loss of the **decomposition** function (a key indicator of the ability of a wetland to maintain organic matter storage potential) due to different land use practices can be demonstrated by using data from Bridgham et al. (1991) and is shown in Figure 2b. This study shows that the decomposition process was nearly doubled by only partial drainage as compared to the reference wetland. In addition, wetland sites characterized by increased drainage showed decomposition rates that were two to five times greater than the reference sites, depending on the degree of hydrologic alteration and nutrient additions.

Productivity, another key wetland function, can be measured on a short-term (annual) basis by assessing biomass change or radial growth in forested wetlands (U.S. EPA, EMAP 1991). An integrated method proven to be effective in assessing the long-term effects of altered hydrology, nutrient additions, or toxic effects on productivity is the rate of peat or sediment accretion (Craft and Richardson 1993a, Richardson and Craft 1993). The distribution of Cs–137 or Pb–210 in the sediment or peat profile can be used to compare and quantify long-term impacts to wetland ecosystem productivity over time. For example, peat accretion rates average 1 to 2 mm per year worldwide. In the Everglades of Florida, natural rates followed the global average, but areas with blocked drainage and extended hydroperiod (days per year water is at or above the surface of the wetland) had rates of 4.0 mm/yr (Craft and Richardson 1993a). Drained wetlands averaged <0.25 mm/yr and heavily fertilized areas up to 7.0 mm/yr (Craft and Richardson 1993b). These measurements provide an excellent quantification of changes in this ecosystem function due to anthropogenic impacts. Sedimentation/accretion analysis also lends itself to quantifying the **biogeochemical** storage rates of metals, nutrients, and toxic organic materials. For example, inputs of sodium from agricultural runoff were estimated to be 1.48 gm/m^2/yr in impacted Everglades soils as compared to only 0.34 gm/m^2/yr in the undisturbed reference areas of the Everglades (Craft and Richardson 1993a).

Hydrology is the main forcing function controlling wetland processes (Mitsch and Gosselink 1993). Hydrology can be measured directly by water-level recorders and ground-water wells or indicated indirectly by such techniques as redox potential changes or the use of steel-rod oxidation (Faulkner and Richardson 1989, Bridgham et al. 1991). The hydrologic effects of land clearing and agricultural conversion on annual runoff compared to natural wetlands in North Carolina revealed a 12 to 14% increase. Forestry resulted in a 14% reduction in annual flow (Richardson and McCarthy 1994).

Habitat/community equilibrium can be estimated by determining the relationship between the number of species and the number of individuals per species—especially when plotted on a geometric interval scale (Odum 1971, Gray and Farrukh 1979). Preston, in 1948, convincingly demonstrated that a log-normal plot under slight pollution or disturbance for a community of selected invertebrates, algae, or macrophytes displays an increase in some species whereas rare species do not change in abundance compared to the undisturbed community. Under further disturbance or pollution, the numbers of individuals for all classes are reduced and the rare species disappear.

The next step in **functional assessment** is to integrate changes in wetland functions due to disturbance and scale these functions to a reference wetland (reference system = 100%), thus creating a comparative "ecosystem response surface" (Figure 2c). The reference wetland response surface is shown as a circle, and this surface is significantly different when compared to a site where the hydroperiod has been altered by increasing water level by 40% (dashed line). This functional hydrologic shift outside the reference system results in a change in key ecosystem functions. The representative functions for decomposition and community/habitat have significantly decreased and increased, respectively, due to this hydrologic impact, while productivity remains the same, and the biogeochemistry function is slightly reduced. The next phase in the development of this analysis would be to develop a threshold or surface boundary (+ or −) that would be acceptable for these functions, both singly and collectively. Finally, it must be recognized that undisturbed local or regional sites must be used as the reference sites, since distant or hydrogeomorphically different wetlands may not provide the same functional response on the landscape.

CONVERTED AND ALTERED WETLANDS

The uses of converted wetlands are usually related directly to the economic gain from the conversion of the wetland to some other use and, more importantly, to a monoculture like agriculture (Table 1). The ecological functions of the wetland are mostly lost when the site is converted to cropland, peat for energy, and urbanization. Operations such as forestry and aquaculture can result in an alteration of wetland function rather than a conversion and near total loss of wetland function. For example, aquaculture may not alter the wetland significantly, depending on the type of alterations (e.g., digging of shallow ponds for crayfish farming and maintaining natural water flow), or it may result in major ecological changes if the area is ponded and hydrologic flow is altered. The ecosystem may or may not still be characterized as a 404 jurisdictional wetland if severely drained (U.S. Army Corps of Engineers 1987).

The forestry operations and surrounding management questions addressed in this volume are far more complex. They involve everything from selective cutting, drainage, stand regeneration, and clear-cutting of bottomland stands to the complete removal of native wetland vegetation and the planting of pine or other species in plantations. There is no question that when BMPs are used, many of these activities can be accomplished without significant alterations of wetland functions. However, great controversy exists concerning what is considered a wetland and whether normal forestry practices have been greatly altering wetland functions and values (Environmental Defense Fund et al. *vs.* Tidwell et al. 1991, Dubensky et al. 1993, Floyd and MacLeod 1993, Jennings et al. 1993). In a recent analysis of the effects of foresty on wetland alteration, Cashin et al. (1992) have shown that forest plantation establishment is responsible for over 52% of the wetland *alterations* in the state of North Carolina, and agriculture conversion resulted in a 42% *loss* of wetlands in the state. The distinction here is the loss of wetland functions with agricultural conversion and the alteration of wetland functions by forestry. The degree to which wetland functions were altered by forestry practices were judged primarily on the basis of whether or not the hydrology of the wetland was significantly modified after the plantations were put into place. The absence of flash board risers (i.e., no water control) on all of the randomly selected drainage ditches of the plantations in the Cashin et al. survey was used as an indicator that wetland hydrologic function was significantly altered. Another distinction made in the Cashin et al. study is that some wetland values, but not their key functions, are protected by laws. For example, the Clean Water Act requires every state to produce a biennial 305(b) report on the status and trends of water quality. Whether the biogeochemical cycles or decomposition rates have been altered has no legal standing under current laws.

In the following chapters of this issue, we will attempt to shed light on the functions of forested wetland systems as well as analyze the positive and negative effects of forestry management practices on ecosystem functions and values. Suggestions for future research needs are also presented.

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