ECOSYSTEM FUNCTION & HUMAN ACTIVITIES

RECONCILING ECONOMICS AND ECOLOGY

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CHAPTER TEN

Ecosystem Functions and Ecosystem Values

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Introduction

Our understanding of how ecosystems function has expanded enormously since the term was first defined as a *dynamical system consisting of a biological entity, typically a regional biota (community), together with its environment* by Alfred George Tansley in 1935. In his analysis of the history of the ecosystem concept, Golley (1993) concluded that "the ecosystem, for some at least, has provided a basis for moving beyond strictly scientific questions to deeper questions of how humans should live with each other and the environment. In that sense, the ecosystem concept continues to grow and develop as it serves a larger purpose." Indeed, many societal questions related to the environment are ecosystem related (Odum 1989; Cairns et al. 1992). Here, I emphasize the ongoing national debate about wetlands, such as those that occur in the Chesapeake Bay watershed, to demonstrate the utility of the ecosystem concept. I begin with an overview of the ecosystem concept and how it is being applied when decisions have been made about the use, restoration, or conservation of natural resources. I then discuss the importance of separating ecological "functions" from societal "values" when applying the ecosystem concept. I conclude the discussion with an example of a method that is being developed to provide ecological input (i.e., information on wetland functions) to individuals who make decisions about the fate of wetlands.

The Ecosystem Concept and Society

I have chosen two examples, Chesapeake Bay and South Florida, to demonstrate the current centrality of the ecosystem concept in solving societal problems. The health of Chesapeake Bay has been of central concern for more than a decade (Horton and Eichbaum 1991; Boynton, this volume), and many of the undesirable ecological and economic changes that have occurred over the past century have been associated with human activities (Brush, this volume). Fisheries resources have declined, beds of submersed aquatic vegetation have almost disappeared, and water quality has deteriorated (Dennison et al. 1993). The causes of the negative trends in the biotic and abiotic resources of the Chesapeake Bay are numerous (e.g., wetland losses, overexploitation, disease, increased sediment, and nutrient inputs). Finding solutions to these problems individually and collectively has proven difficult, but almost everyone recognizes that management activities must focus on the entire watershed and not just the estuary. Thus, there is clear recognition that the entire ecosystem, the Chesapeake Bay and its watershed, must be managed if it is to continue to provide the goods (e.g., shellfish) and services (e.g., improvement of water quality) that have historically been associated with it. One management goal, for example, is to reduce the amount of nonpoint runoff within the watershed by 40 percent. Attaining that goal will be difficult, and it will require a range of activities including the use of Best Management Practices on farms, the restoration of riparian habitats along streams, and the creation/restoration of wetlands to intercept nutrients and sediments before they reach streams and, ultimately, the Chesapeake Bay. An analogous situation exists in South Florida.

Water flow through much of South Florida is controlled by a complex network of levees, water storage areas, channels, and large-scale pumping that has been developed over the past 90 years (Light and Dineen 1994). Most of the water control activities were designed to control flooding and manage water flow to permit regional urban/suburban and agricultural development, but consequences include a dramatic reduction in the size of the original Everglades ecosystem (Frayer and Hefner 1991; Davis and Ogden 1994); political and legal battles that primarily focused on changes in the hydrologic and phosphorus inputs into Everglades National Park (Davis 1994); and the restoration of the Kissimmee River (Dahm 1995). Similar to the Chesapeake Bay example, restoration and conservation in South Florida will require an ecosystem approach no matter whether the goal of a particular activity is the conservation of a species (e.g., Florida Panther) or the conservation of a large part (e.g., Everglades National Park) of the landscape (Gunderson et al. 1995). Davis and Ogden (1994) summarize a series of papers related to restoration of the Everglades, and each of the following recommendations involves ecosystem management:

- Their first recommendation focuses on the importance of spatial scale in ecosystems. They recommend that "the reduction in ecosystem size and compartmentalization of the remaining system are trends that must be reversed in any Everglades restoration initiative."
- The second recommendation considers disturbance and is based on the concept that when ecosystems are of sufficient spatial scale, there is adequate space to offset local disruptive effects and that disturbances contribute to the overall diversity of the system. They recommend that environmental fluctuations and extremes in hydrology and fire proceed as they would have in the natural Everglades system.
- Hydrologic parameters are key to the normal functioning of wetland ecosystems. Rainfall is the source of water for the South Florida system, and Davis and Ogden recommend that water delivery plans be developed that are based upon antecedent rainfall for all major areas of remnant Everglades marshland, including the Water Conservation Areas.
- In addition to the amount of water, the pattern of flow and distribution of water in time and space are important. They recommend to "incorporate components into rainfall-based water delivery plans that will restore flow volumes and distributions in time and space, as simulated by natural system hydrology model."
- The spatial and temporal pattern of water depth is important to food webs, reproduction, and survival of many species of flora and fauna in the Everglades. They recom-

mend to "build components into rainfall-based water delivery plans that will restore depth patterns in time and space, as simulated by the natural system hydrology model."

- Finally, prolonged hydroperiods are essential for the maintenance of the peat-based wetlands within the Everglades system. They recommend that rainfall-based water delivery plans be developed to mimic extended periods of flooding as would have occurred in the remnant Everglades marshes under predrainage conditions."

There are numerous other examples of how the ecosystem concept has become central to conservation and restoration activities. Indeed, almost all issues related to endangered species, biodiversity, and environmental conservation ultimately must focus on management of the ecosystem(s) in which the species are found (Gillis 1990; Franklin 1995; Willcox 1995). Unfortunately, the ecosystem concept has not made substantial contributions to other fields of endeavor (Peters 1991; Lovejoy 1995), and decisions that influence ecosystems are regularly made by individuals who know little about ecosystem structure and function (Franklin 1995). A good example comes from the current national debate about wetlands.

The Confusion Between Wetland Functions and Values

What is a wetland? If we did not have to draw lines on maps to show where wetlands occur, this question would not be debated at all and just about everyone would be satisfied with the science-based definition recently recommended by the Committee on Wetlands Characterization of the National Academy of Sciences (NAS 1995). The Committee defined a wetland as an

> "*ecosystem* that depends on constant or recurrent, shallow inundation or saturation at or near the surface or the substrate. The minimum essential characteristics of a wetland are recurrent, sustained inundation or saturated at or near the surface and the presence of physical, chemical, and biological features reflective of recurrent, sustained inundation or saturation. Common diagnostic features of wetlands are hydric soils and hydrophytic vegetation. These features will be present except where specific physio-

chemical, biotic or anthropogenic factors have removed them or prevented their development."

This definition is not that different from others that have been widely accepted or used in the field of wetland science (Mitsch and Gosselink 1993). The NAS definition was, however, ignored by the U.S. House of Representatives in passing H.R. 961, the 1995 reauthorization of the Clean Water Act.

H.R. 961 has several provisions and definitions that are not justified scientifically, nor are they consistent with the NAS wetland definition (Zedler 1995). For example, H.R. 961 provides for and requires the characterization of all U.S. wetlands into three categories:

- Type A wetlands would be those that have the highest *functional value* and are of critical significance to the long-term conservation of that type of wetland *ecosystem;*
- Type B wetlands would be those that provide *significant wetland functions;*
- Type C wetlands are those that provide *limited wetland function.*

There is no scientific basis for these three categories. Instead, the use of terms such as *functional value, significant wetland functions, limited wetland function* are subjective at best and defined by the dominant political view (or agenda) of the day. This subjectivity is underscored by H.R. 961 itself, which requires that no county or parish can have more than 20 percent of its area defined as Type A wetlands. Wetlands that provide important goods and services in support of human activities can and do exceed this areal extent in some regions of the country (Figure 10–1). In the Maryland counties of Dorchester and Somerset, for example, more than 35 percent of the total land area of each is wetlands, and most would be classified as Type A. The surface waters from both counties drain into Chesapeake Bay, and their economies rely heavily on resources from the Chesapeake Bay. Why should Dorchester and Somerset Counties be treated differently than the other 21 Maryland counties because their wetlands are more extensive?

I have italicized the word *ecosystem* in the NAS definition and several words (*functional value, ecosystem, significant wetland functions, limited wetland functions*) related to H.R. 961. It is significant that both characterizations of wetlands include the word

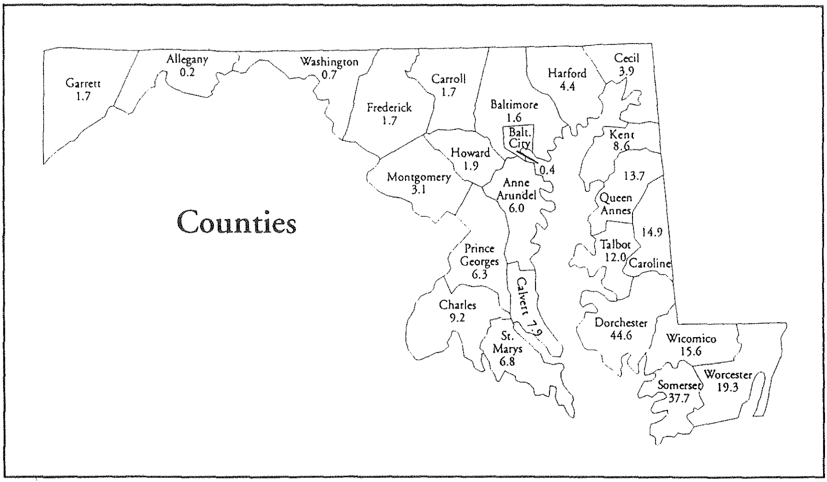

Figure 10–1. Percentage of total land area in wetlands for countries in Maryland. Source: Tiner and Burke 1995.

ecosystem because it further demonstrates that the ecosystem concept has been widely recognized in both scientific and political arenas. The words *functional value* and *functions* that appear in H.R. 961 show, however, that ecologists have not done a very good job of separating the issue of *what ecosystems do* from the reality that *human societies receive goods and services from ecosystems* that have economic value (van Wilgen et al. 1996). Another interpretation would be that ecologists often have not done a good job of promoting value(s). Ecologists can demonstrate functions but have not adequately assigned values that sway public/political opinions. What have ecologists learned from the study of ecosystems that needs to be communicated to individuals who strive to make environmental decisions that serve the public good?

Perhaps most importantly, we have learned that ecosystems are more than the sums of their parts and that they have emergent properties such as ecosystem stability and ecosystem diversity (Odum 1989; Golley 1993). Second, ecologists have learned that humans are integral components of ecosystems and that there is no place on the face of planet Earth that is not or has not been influenced in one way or another by human activities. Almost all human activities impact ecosystems and their constituent species. What we have not fully realized nor appreciated is that systems of economics are linked in a variety of ways to natural systems (Freeman, this volume; Peskin, this volume).

Van Wilgen et al. (1996) show the linkages between "ecosystem services" and economic values for fynbos (shrubland) watersheds in arid South Africa. Watersheds dominated by native fynbos species deliver cleaner water and more water than watersheds dominated by alien trees and shrubs. Economically, the unit cost for a m^3 of water is 11.9 cents for watersheds dominated by native fynbos, compared to 13.8 cents per m^3 of water for watersheds that were dominated by alien plants which require management. Howard Odum, a long-time proponent of the unity of natural systems and economic systems, has suggested that because of commonalities of systems that there are many similarities between economic systems and ecological systems (Odum 1983). Materials and energy flows in natural ecological systems (Odum 1989) and in economic systems, money flows in response to the flow of goods and services but in the opposite direction of material and energy flow. In the fynbos example described above, money that is required for management of alien flora flows to individuals who perform the work. In response to the flow of money, a return on investment is realized in the form of increased water flow and improved water quality. Odum suggests that it is possible to develop models to understand the relationships between ecosystems and economic systems using a common currency that links the flows of goods and services to the natural services (i.e. functions) of ecosystems. If Odum's suggestions are correct, why then has it been so difficult to relate economic systems to ecological systems (e.g., Bender et al. 1994)?

In part, our inability to relate economic and ecological systems has resulted from confusion over ecosystem functions and ecosystem values. Functions are the normal characteristic actions or activities of something (Smith et al. in press). In an ecological context, functions are the processes that are necessary for the self-maintenance of ecosystems. Values are the rules that determine what people consider important. Brown (1984) differentiated between held and assigned values. Held values are the precepts in which individuals or groups believe. Assigned values are the indicators of the relative importance of something to an individual or group. In an ecological context, functions exist in the absence of human activities and are a normal part of the self-sustaining properties of ecosystems. Values are the goods and services that emanate from functions (Taylor et al. 1990). The relationship between functions and values in the context of wetland ecosystems is shown in Figure 10–2. Table 10–1 (Smith et al. in press) and Richardson (1994) further show the relationships between wetland functions and values.

The dashed line in Figure 10–2 separates the physical (e.g. geomorphic) setting where wetlands occur in the landscape from societal interactions with wetlands. Items above the dashed line can continue in the absence of human activities (i.e., they are wetland functions) while those below the line show how wetland products and functions are used (i.e. wetland values). Critical processes and mechanisms such as photosynthesis and ecosystem functions such as primary production and biomass accumulation may become resources for human life support. The

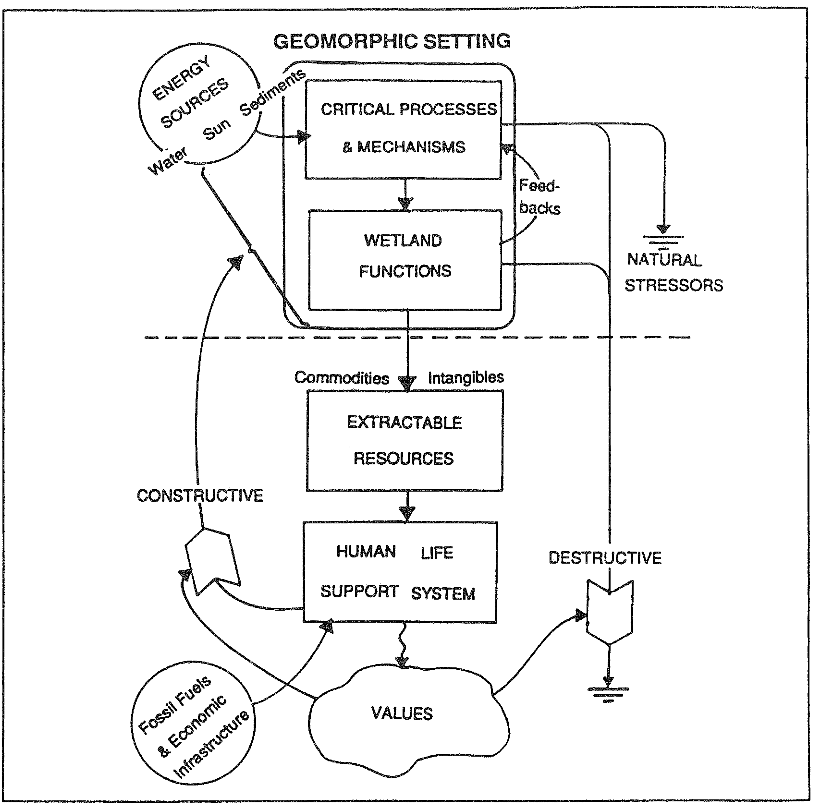

Figure 10–2. The relationship between functions and values in the context of ecosystems. Source: Brinson 1993.

Table 10–1. Wetland functions and the values (i.e., benefits, goods, and services) that they provide (Smith et al. in press).

FUNCTIONS	VALUES
Store Surface Water: The ability of a wetland to temporarily store surface water arriving as precipitation, overland or subsurface flow from adjacent upland areas, or originating from upstream or downstream (e.g. tidal) areas and arriving via overbank flooding.	Reduces flood related damage downstream
Reduce the Energy Level of Surface Water: The ability of a wetland to reduce the energy of moving surface water due to structural roughness in the wetland.	Reduce erosion from storms and floodwaters
Recharge Ground Water: The ability of a wetland to provide a conduit for the recharge of a ground water aquiter.	Maintain pumpable supplies of ground water.
Discharge Ground Water: The ability of a wetland to provide a conduit for the discharge of ground water.	Maintain stream and lake water levels
Stabilize Soils: The ability of a wetland to protect soil from the erosive action of currents and waves because of presence of litter and the binding action of roots.	Reduce erosion of shorelines and streambanks from storms and floods
Detain, Remove, and Transform Nutrients: The ability of a wetland to temporarily detain, or permanently remove nutrients from surface or ground water column through biochemical transformation, incorporation into biomass, or burial.	Maintain surface and ground water quality
Detain, Remove, and Transform Contaminants: The ability of a wetland to temporarily detain, or permanently remove contaminants from the water column through incorporation into biomass, biogeochemical transformation, or burial.	Maintain surface and ground water quality

(Continued)

Table 10–1. Wetland functions and the values (i.e., benefits, goods, and services) that they provide (Smith et al. in press). (Continued)

Detain and Remove Sediments:	
The ability of a wetland to temporarily detain, or permanently remove suspended sediments from surface water through sedimentation and burial.	Maintain surface water quality
Provide Ecosystem, Landscape, and Global Integrity	
The ability of a wetland to provide the conditions required for the biotic and abiotic processes characteristic of the wetland ecosystem, its landscape, and the world.	Maintain ecosystem, landscape, and global processes
Provide Wetland Ecosystem Structure:	
The ability of a wetland to provide the unique structural characteristics of wetland ecosystems.	Maintain populations of wetland dependent plant and animals species, preserve endangered species, maintain biodiversity, provide dispersal corridors

term extractable resources is meant to include intangibles, commodities, and all other goods and services that contribute to the human's life support system. A key to understanding the relationships between functions and values is provided in the feedback mechanisms which are called CONSTRUCTIVE and DESTRUCTIVE in Figure 10–2. Ecosystems can only continue to provide human goods and services when the feedback mechanisms allow ecosystem functions to continue at a sustainable level. When ecosystem functions cease or change due to overexploitation (i.e. destructive feedbacks), the goods and services to human societies cease to be provided. The linkages between ecosystem functions and goods and services are central to the concept of sustainability and a key concept that ecologists need to describe adequately to individuals who are involved in ecosystem management.

Wetland Assessment—Functions Versus Values

The national wetland debate has primarily focused on such lofty issues as wetland definitions, delineation, and wetland classification (NAS 1995). Local wetland issues, in contrast, often deal with the fate of a specific piece of real estate and questions such as: can a developer or homeowner fill a small section of wetland on his/her property; can the State Department of Transportation use fill to place a road across a floodplain, etc.? Decisions about the fate of wetlands have been made in a variety of ways ranging from decisions based on best professional judgment to decisions based on the application of complex functional assessment methods.

Over the last 20 years, several methods have been developed to perform functional assessment of wetlands (Larson and Mazzarese 1994; NAS 1995), the goals of which have been to develop reproducible procedures to assess the functions of wetlands. One of the most widely cited and applied assessment methods (FHWA) was developed by the Federal Highway Administration (Adamus and Stockwell 1983). FHWA was later modified into what become known as the Wetland Evaluation Technique (WET), which included an interactive computer analysis program (Adamus 1987; Adamus et al. 1991). WET, which was further developed into WET 2.0 by the U.S. Army Corps of Engineers, was the first widely used method to assess all recognized wetland functions. WET and WET 2.0, however, did not adequately separate wetland functions from wetland values; an important distinction since "the key ecological question that needs to be addressed under any development scenario is whether or not wetland functions have been significantly altered" (Richardson 1994).

Smith et al. 1995 describe the rationale behind a hydrogeomorphic (HGM) approach to a functional assessment system that is being developed for wetlands in the U.S. (Brinson 1993). The first national HGM models have been developed for riverine wetlands (Brinson et al. 1995) and specific regional models are currently being tested and evaluated. The HGM models differ from previous assessment models in three ways. First, HGM recognizes that the set of functions that need to be assessed are likely to differ between wetland types. Second, it uses functional indices that can be quantified and the quantitative scales are based on ecological data gathered from reference wetlands. Third, the developers of HGM have attempted to limit the models to wetland functions and not include wetland values.

Table 10–1 defines 10 HGM functions of riverine wetlands (Smith et al. in press) and gives examples of the values that emanate from the ecological processes. The first four functions (store surface water; reduce the energy level of surface water; recharge ground water; discharge ground water) are related to the movement of water into and through wetlands and result in widely recognized values (i.e., reduce flood damage and erosion, provide supplies of ground water). Four functions (stabilize soils; detain, remove and transform nutrients; detain, remove and transform contaminants; detain and remove sediments) are related to the cycling and retention of nutrients and contaminants which are associated with improved water quality. The last two functions (provide ecosystem, landscape, and global integrity; provide wetland ecosystem structure) are related to processes that maintain flora and fauna in the wetland and in landscapes that contain wetlands. Values that result from healthy wetlands include recreational values associated with wetlands as well as the extraction of resources (i.e., animal pelts, fish, waterfowl) from wetlands and associated water bodies.

In summary, I have attempted to document the importance of the ecosystem concept and demonstrate that ecosystems provide numerous goods and services to society which can only continue to be benefits if healthy ecosystems are maintained. I have described differences between ecological processes and ecosystem values to demonstrate that ecosystem management will have a higher probability of success when the two (i.e., functions and values) are kept separate. I believe that it is imperative to delineate clearly the functions of wetlands as a first step to making social and political decisions. Only through providing and implementing the types of formal functional assessments described above can decision makers (resource managers, state and federal agency personnel, politicians) truly characterize mechanisms and processes and give them appropriate weight in arriving at well-educated and balanced value assessments. This is essential to our sustained ability to continue to share the earth with other organisms and benefit from the goods and services that we enjoy from ecosystems.

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