Agriculture in an Ecosystems Framework

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By broadening the definition of an ecosystem to include economic activities, can we better characterize the interactions and relationships among agricultural activities and important indicators of ecological system health? This paper addresses research approaches for assessing the role of agriculture in an ecosystems context. Environmental regulation and resource management policies have heightened the interest in understanding interactions among agricultural activities and the natural resource base, including the impacts of agriculture on environmental quality and the impacts on agriculture of ecosystem restoration efforts. What are the most meaningful indicators of environmental quality? Which agricultural practices and policies should be considered, along with which nonagricultural resource uses? Finally, does the evolving thinking about ecosystems permit us to link agricultural practices and policies more directly and meaningfully to conceptions of sustainability, of both natural and socioeconomic systems? This paper presents a brief synopsis of ecosystem management, drawing from several recent governmental initiatives. It then provides an overview of the economics of ecosystem management from the perspective of the role of agriculture; discusses two specific cases, the Pacific Northwest and South Florida; and concludes with a discussion of promising economic approaches, data needs, and caveats to those engaged in policy analysis involving ecosystem restoration.

This paper focuses on research approaches for assessing the role of agriculture in an ecosystems context. Increasingly, there is interest in addressing the interactions and interfaces among agricultural activities and the natural resource base, including the impact of agriculture on environmental quality and the impacts on agriculture of ecosystem restoration efforts. The basic question of the impact of agriculture on the environment is not new. What *is* new is our evolving thinking about how best to frame this question: What is the appropriate unit of analysis with respect to economic and environmental variables? By broadening the definition of an ecosystem to include economic activities, can we better characterize the interactions and relationships among agricultural activities and important indicators of ecological system health? What are the most meaningful indicators of environmental quality? Which agricultural practices and policies should be considered, along with which nonagricultural resource uses? Finally, does the evolving thinking about ecosystems permit us to link agricultural practices and policies more directly and meaningfully to conceptions of sustainability, of both natural and socioeconomic systems?

This paper begins with a brief synopsis of ecosystem management, drawing from several recent governmental initiatives. It then provides an overview of the economics of ecosystem management from the perspective of the role of agriculture; discusses two specific cases, the Pacific Northwest and South Florida; and concludes with a discussion of promising economic approaches, data needs, and caveats to those engaged in policy analysis involving ecosystem restoration.

Background: Ecosystem Management in the Federal Context

A growing literature links sustainability to the management of high priority ecosystems. Citations from recent government agency and commission reports provide evidence of that connection. First, a broadly circulated statement from the World Commission on Environment and Development

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(Bruntland Commission) defines sustainable development in the following way:

> To meet the needs of the present without compromising the ability of future generations to meet their own needs. (World Commission on Environment and Development 1987, p. 43).

President Clinton's Council on Sustainable Development explicitly includes economic activities in the purview of sustainable development, then proceeds to include the safeguarding of "functions and viability of natural systems" in its vision statement:

> Our vision is of a life-sustaining Earth. We are committed to the achievement of a dignified, peaceful, and equitable existence. A sustainable United States will have a growing economy that provides equitable opportunities for satisfying livelihoods and a safe, healthy, high quality of life for current and future generations. Our nation will protect its environment, its natural resource base, and the functions and viability of natural systems on which all life depends. (President's Council on Sustainable Development 1996)

In a recent report on assuring a sustainable environment through ecosystem management, the Interagency Ecosystem Management Task Force stated:

> An ecosystem is an interconnected community of living things, including humans and the physical environment with which they interact. As such, ecosystems from the cornerstones of sustainable economies. The goal of the ecosystem approach is to restore and maintain the health, sustainability, and biological diversity of ecosystems while supporting sustainable economies and communities. Based on a collaboratively developed vision of desired future conditions, the ecosystem approach integrates ecological, economic, and social factors that affect a management unit defined by ecological—not political—boundaries. (Interagency Ecosystem Management Task Force 1995)

Perhaps ironically, the simple definition of sustainability adopted by the Brundtland Commission in 1987 spawned a growth industry in its wake, attempting to elucidate and operationalize relevant principles. In its vision statement, President Clinton's Council on Sustainability committed itself to the dual objectives of a growing economy and a protected environment, natural resource base, and the functions and viability of natural systems on which all life depends. Finally, the administration's National Performance Review has forged an explicit link between sustainability as a general concept and the careful management of priority ecosystems. The President's Council on Sustainability, in effect, operationalizes ecosystem management:

> The shift from managing a single resource or a single species to managing an ecosystem for a variety of resources, including the maintenance of its biodiversity makes sense. . . . Concerned about the cumulative impact of numerous local management actions, many scientists and resource managers now believe that biodiversity, water quality, and other natural resources can only be protected through cooperative efforts across large landscapes—landscapes that often cross ownership boundaries. At the same time, conflicting demands for all resources are forcing public agencies to explore new planning and policy mechanisms that would involve broader public participation to minimize conflicts. Since 1992, federal agencies, including the U.S. Forest Service, the U.S. Bureau of Land Management, the U.S. Fish and Wildlife Service, the U.S. National Park Service, and the U.S. Environmental Protection Agency, have established ecosystem management policies to guide their decisions for achieving various goals, including those set by law. (President's Council on Sustainable Development 1996, p. 18)

Finally, in a recent report, the General Accounting Office addressed some of the challenges in implementing an ecosystem management approach:

> Implementing this stage will require clarifying policy goals and taking practical steps to delineate ecosystems, understand their ecologies, and make and adapt management choices on the basis of new information. The challenge to addressing these steps is collecting new and analyzing existing data describing ecological functions and interactions with socio-economic variables. Often existing data are insufficient or noncomparable across agencies and our scientific understanding of ecosystems and human interactions is far from complete. (U.S. General Accounting Office 1994)

The U.S. Department of Agriculture has become increasingly interested in better articulating the role of agriculture in ecosystem management and identifying effective strategies for preserving sustainable ecosystems, including viable agricultural economies. Below, we develop a conceptual framework for analysis, followed by the examples of two specific cases of conflict over the use of natural resources viewed in an ecosystems context: the salmon recovery plans for the Pacific Northwest Columbia/Snake River Basin and the South Florida ecosystem recovery efforts.

The Economics of Ecosystem Management: A Conceptual Framework

The proposed conceptual framework for assessing the interactions between economic systems and ecosystems takes a dynamic, general equilibrium view of the world and draws heavily from the work of Herfindal and Kneese (1974), King, Bohlen, and Croisson (1995), and Bockstael et al. (1995). Additionally, the conceptual framework is consistent with the environmental or natural resource accounting approach popularized by Solow (1986), Hartwick (1990), and Mäler (1991), and as developed—to include the agricultural sector—by Hrubovack, LeBlanc, and Eakin (1995).

The economic world consists of stocks/endowments and economic processes/technologies that are used to produce final goods and services such as clothing, food, recreation, and savings/investment. Present economic use of capital and labor endowments increases current production of goods and services, but at the cost of future flows of goods and services. Alternatively, capital and labor investment today reduces current production but increases future capacity.

This ecological framework differs from much of the research on ecosystems in one important respect. Rather than viewing the environmental goods and services generated by an ecosystem *strictly* as externalities, it follows Solow (1992) and casts the environment as a set of natural capital assets providing flows of goods and services to the economy. In this highly stylized ecological framework, the ecosystem is divided into stocks/endowments (for example, biota, land, water quality/quantity) and ecological processes (hydrology, weather/climate, macrophyte effects, nonmacrophyte effects) that we used to produce final goods and services from which individuals derive utility (such as water to drink, birds to watch). Natural capital is subject to similar trade-offs between current and future consumption, as is man-made capital.

The focus on measuring and valuing changes in the stock of natural resources, which is consistent with growth theory, requires that the stock and flow value of each asset be assessed. Valuation of natural resource depletion or enhancement treats natural resources as capital stocks yielding a stream of productive capabilities. Natural resources are typically divided into renewable (air, biota, land, and water) and nonrenewable resources (oil and minerals). Some of these natural resources such as oil and minerals are easily defined and valued in explicit markets. Markets for other natural resource stocks—such as air, biota, land, and water—are incomplete for various reasons, resulting in valuation difficulties.

Natural capital assets can be regenerative or renewable but may be exhausted if their use rate exceeds their regenerative rate. The net rate of regeneration for land, surface-water quality, or groundwater reserves depends on the intensity of use, the natural rate of regeneration, and the effectiveness of management. For example, loss of soil productivity can be offset to some extent by the system's natural regenerative capability or by management and application of intermediate inputs such as fertilizer and capital.

By broadening the definition of an ecosystem to include economic activities, we hope to better characterize the interactions and relationships among agricultural activities and important indicators of ecological system health. The effect of agricultural production on ecosystems often results from conversion of land from one use to another or from changes in variable inputs and management practices within a given use. Although it is often possible to make qualitative statements about how changes in economic activity affect ecosystems, these effects are difficult to measure empirically, particularly marginal changes in ecosystem service flows. There is, nonetheless, a growing recognition that characterization of relationships between economic activity and ecosystem services must involve integrating or linking economic models with ecological models (see, for example, Bockstael et al. 1995). The economic models should address human decision-making both at the extensive margin (land use changes) and at the intensive margin (changes in practices). For a given land use and set of practices, ecological models must address ecosystem structures and functions and how they may be affected by practice and land use changes.

Environmental amenities are flows, or current production, of nonmarket goods. Incorporating these nonmarket goods into our economic model requires their definition, quantification, and valuation. Some of these services include consumptive goods and services—for example, timber, fish, medicine, pure water, and outdoor recreation; ecological services such as nutrient recycling and water filtration; and nonconsumptive services characterized by existence or option value (Bingham et al. 1995). In income-accounting terminology, defining the final goods and services provided by an ecosystem entails "extending the production boundaries." Once they are defined, valuation of the goods and services necessarily involves nonmarket valuation techniques.

Scientific understanding and general appreciation of ecosystem functions are incomplete, making valuation difficult. Ecosystems may provide services that are currently unknown. For example, the carbon sequestration services of ecosystems were not known a few decades ago (Bingham et al. 1995). In addition, many ecosystem functions are essential to ecosystem health but are not directly beneficial to humans, making the value of the function less evident. Finally, some ecosystem services are difficult to measure for purposes of estimating existence value.

Accounting for the role an ecosystem plays in the economy requires adjusting our economic framework in three ways. The first adjustment requires measuring and valuing stock changes in natural resources. The second adjustment requires characterizing the physical relationship between economic production and ecosystem production. For example, agricultural production affects water quality, which affects the ability of an ecosystem to provide habitat for some species of birds that people like to watch. The third adjustment requires measuring and valuing flows of nonmarketed environmental amenities generated by an ecosystem. In essence, we are concerned with both the allocation of resources across sectors of the economy (flows) and the allocation of resources over time (stock changes). While the two concepts are naturally interrelated, we attempt to treat them as separate issues to minimize confusion.

General Hypothesis and Key Research Issues

The conceptual basis discussed above suggests that the preferred analytical unit for design of environmental policy for important natural resource issues is often on an ecosystem (or landscape) basis. For example, the Endangered Species Act has been criticized for approaching species management on a species-by-species basis. As the protection of species involves managing habitat, it may therefore be preferable to consider entire ecosystems or landscapes as a basis for protecting habitat and species.

Environmentalists and developers alike have charged that current federal and state environmental protections neither adequately protect wetlands and endangered species nor guide or direct development in a rational and consistent manner (Porter and Salvesen 1995). Environmentalists, on the other hand, often claim that case-by-case land-use permitting can nibble away at ecosystems; individual development projects may have minor effects, but the eventual cumulative impact can be quite negative. Developers, on the other hand, complain about multiple layers of permitting, actual or perceived inconsistency of decisions and objectives, and the lack of coordinated efforts among levels of government. Typically, federal agencies respond to land development proposals in the order they come before the agency. Agencies often do not have the authority, funding, or will to develop comprehensive plans for entire ecosystems that reconcile resource conservation and development objectives. Traditional project-by-project approaches address development and conservation issues in a fragmented manner. Decision-making is often inefficient and inequitable, giving rise to further conflict. The recent property rights movement represents, in part, a response to apparent or real inequities arising from policy decisions.

Our working hypothesis is that conceptualizing natural resource and environmental problems within an ecosystems framework can provide a broader, more globally optimal solution. Partial, case-by-case, or species-by-species analysis fails to capture linkages and interactions between ecological functions and economic activities. The ecosystems approach attempts to exploit those linkages by specifically identifying the various functions, while recognizing that neither the necessary data for analysis and monitoring nor the analytical approaches are readily available. The approach can provide the basis for a fuller cost-benefit analysis in that both direct and indirect ecological and economic actions may be accounted. An ecosystems approach may also have potential benefits for economic agents within an ecosystem. For example, developers gain from greater predictability regarding land-use designations, restrictions, and regulations, while environmentalists gain greater assurance that sensitive lands will be preserved and that individual projects will not chip away at valuable natural areas.

An ecosystem management study should attempt to address three basic areas of inquiry:

1. What is the role of agriculture in the ecosystem and what are the associated environmental problems?
2. What is the range of policy options available?
3. What are the potential resulting economic impacts and trade-offs associated with policy options?

To address the first issue, appropriate data are essential for describing the economic system in question, that is, the relevant markets, prices of traded goods and services, amount and quality of resources and other factors that contribute to the economic function of the system. Similarly, data are essential to describe the function of the ecosystem, for example, the amount and quality of water, land, and biota. Data for both the economic and ecological systems are needed to establish a baseline from which to compare changes in system variables due to policy actions. Problems with data quickly arise with respect to such issues as availability, timing, comparable units and metrics and definition or interpretation of variables between disciplines. Finally, a good understanding of the relationships between system components is important but problematic. The relationship between farming practices and environmental outcomes—the classic problem associated with nonpoint source pollution—can be even more complicated across an ecosystem.

Policy options range from policy instruments that utilize market incentives, such as taxes and subsidies, to direct regulation, for example, setting minimum engineering standards. With regard to agriculture, sets of policy instruments may either affect the extensive margin and therefore land use patterns or affect the intensive margin and therefore practices.

Finally, assessing the potential resulting economic impacts and trade-offs associated with policy options requires integrating economic and natural systems. Modeling ecological systems in conjunction with economic systems involves developing interdisciplinary linkages. One key to understanding economic trade-offs is developing a systematic capacity for assessing the benefits that arise from market and nonmarket activities. Nonmarket evaluation is difficult, but development of some capacity in this area is essential.

Two cases are presented below, both of which represent attempts to understand the role of agriculture in an ecosystem context and to answer the three questions posed above. The first case involves a reexamination of a study of salmon recovery in the Pacific Northwest (Aillery et al. 1996). The Pacific Northwest salmon study is viewed as an important case study of ecosystem management involving critical interactions between the natural ecology, including endangered salmon runs and their habitat, and a natural resource–using industry, agricultural crop production. The interaction between the various ecological processes and functions and the human economic uses of the resources implies the need to assess the trade-offs that emerge as a result of various policy options. The second case represents the initial stages of a study to examine the South Florida ecosystem recovery effort from an agricultural perspective.

Analysis of Salmon Recovery in the Pacific Northwest

The Columbia River Basin was historically the most prolific salmon-producing region in the world. Estimates of early nineteenth century salmon spawning runs have ranged from 10 to 16 million adult fish (Northwest Power Planning Council 1992). Today, with extensive river development and associated land-use activity, the adult salmon population has fallen to an estimated 2.5 million, despite large investments in hatcheries, fish ladders, and other mitigation efforts. Declines in salmon populations, primarily due to overfishing, had already begun early in this century. Since that time, the damming of the river system for power generation and irrigation water diversion has taken its toll. Salmon populations in the Columbia Basin have declined severely as a result of fish harvesting and habitat degradation due to hydropower development, irrigation diversions, and land-use activities such as logging, mining, and grazing. Dams are a major factor contributing to salmon losses: high losses at dams are due to passage difficulties through hydroelectric turbines and high gas concentrations in spillway flows. Slack water in the reservoirs increases losses due to fish disorientation, predation, and increased travel time. The existence of dams and these activities have resulted in salmon and steelhead population declines to 20% of their peak historic levels, and wild and spawning salmon to 2% of historic levels. In 1991, just four Snake River sockeye salmon returned to their spawning grounds in Idaho's Redfish Lake; in 1992, one returned, and in 1993, eight. This significant decline in salmon populations has lead to the recovery efforts examined here.

The Columbia and Snake River watersheds encompass much of the Pacific Northwest—extending north into Canada, east into Montana and Wyoming, and south into the northern parts of Utah and Nevada. The main areas of their basins reside in the Pacific Northwest states of Idaho, Washington, and Oregon (see figure 1). The Aillery et al. study (1996) focused on alternative Snake River management strategies, including river flow augmentation and reservoir level drawdown, to assist downstream salmon migration. Flow augmentation is likely to have the greatest impact in the Upper Snake Basin, and reservoir drawdown will primarily affect the Lower Snake Basin.

Agriculture in the Upper Snake region of southern Idaho and eastern Oregon can be characterized as mixed farming, with the dominant crops being sugar beets, potatoes, alfalfa, and some small grains. A large share of the production is grown under irrigation, with surface water supplied from the Snake River system. Efforts to restore salmon populations will likely affect water withdrawals in the Upper Snake, despite the fact that the Hells Canyon Dam—located midway up the Idaho-

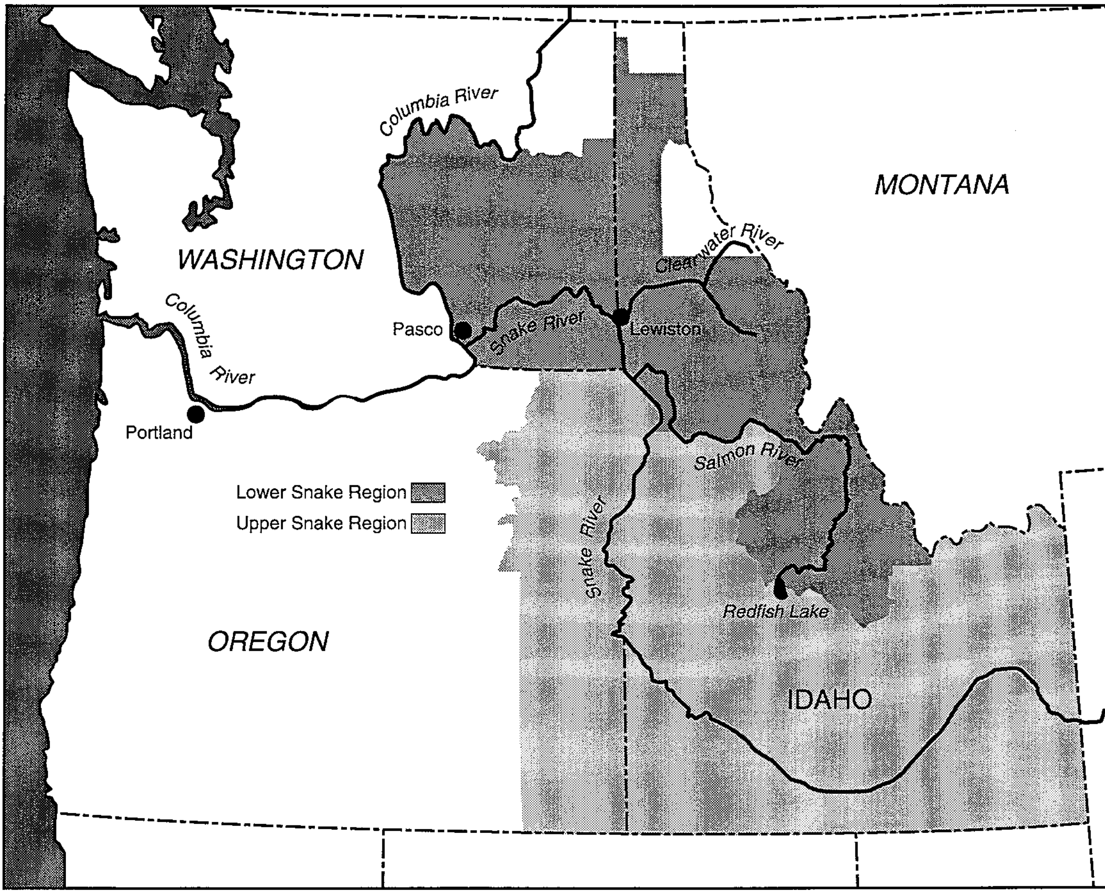

Figure 1. Pacific Northwest Region.
SOURCE: Aillery et al. 1996.

Oregon border—has blocked salmon runs upstream.

The Lower Snake region includes the Salmon River watershed in central Idaho and parts of northern Idaho and eastern Washington. The Lower Snake region was defined to include the Lower Snake from Lewiston westward and was bounded by the Columbia River above Pasco. This region of Washington and northern Idaho contains the Palouse, which includes primarily dryland agriculture, producing small grain crops such as wheat and barley. Efforts to restore salmon populations may affect reservoir levels along the Lower Snake, with implications for navigation and electric power generation.

The Columbia River Basin area north of Pasco includes the Columbia River Irrigation Project with water supplied by the Grand Coulee Dam. The dam is located on the east-west stretch of the river in the north central part of the state. The dam, the largest cement structure in the United States, holds 9 million acre feet of water, provides 6.5 million kilowatts of power, and irrigates over a half million acres of land in the Columbia Basin Irrigation Project. The Grand Coulee Dam, because of its size and resulting cost to develop ladders and other circumvention capacity, has cut access to nearly half of the watershed's historic spawning habitat, resulting in significant population declines (Reisner and Bates 1990).

The Role of Agriculture in the Pacific Northwest and Salmon Recovery

Agriculture is a key competitor with salmon for water. In many areas of the Northwest, agriculture depends largely on irrigation. In 1990, agriculture accounted for over 95% of total water consumption in the region. About 6.5 million acres of the region's crop and pasture land use irrigation, representing 55% of harvested cropland. Surface water diversion accounts for 75% of agricultural water supplies, with the balance pumped from groundwater. Approximately 13.1 million acre feet of water was consumed by irrigation in the region in 1990, with 52, 26, and 22% going to Idaho, Oregon, and Washington, respectively. In addition, many producers depend on the river system for barge transportation. The 200-mile navigable portion of the Snake and the Columbia Rivers provides a major transportation link for grains from eastern Washington, northern Idaho, Montana, and North Dakota.

Table 1 provides an overview of agricultural production in the Pacific Northwest. Total agricultural production in Idaho, Oregon, and Washington was valued at about $7 billion in 1987 and accounted for roughly 166,000 jobs or 4% of total regional employment.

Policy Options to Address Salmon Recovery

Various measures have been proposed to restore three Snake River wild salmon runs protected under the 1973 federal Endangered Species Act (ESA) and to improve the Columbia River salmon fishery as a whole. Efforts to restore Columbia River Basin salmon stocks have evolved within a complex policy environment. Two major pieces of legislation have triggered policy actions: (1) the 1980 Pacific Northwest Electric Power Planning and Conservation Act, and (2) the listing of three Snake River salmon runs as "threatened or endangered" under the ESA. The Pacific Northwest Electric Power Planning Act mandated that fish and wildlife be considered on an equal footing with traditional (recreation, fishing, and other commercial) uses of the Columbia River and that a comprehensive salmon restoration plan be developed. The ESA requires development of a plan to recover threatened species.

Table 1. Characteristics of Pacific Northwest Agriculture

Item	Regional Value	National Share
Acreage	Thousand acres	Percentage
Land in farms	46,804	5.0
Total cropland	19,339	4.4
Harvested	11,784	4.0
Irrigated	6,523	13.2
Value	Million $	
Crops sold	3,835	6.5
Animal products sold	3,200	4.2
Production		
	Million bushels	
Wheat	250	13.3
Barley	103	22.5
	Thousand tons	
Hay	8,480	6.6
Irish potatoes	8,973	48.9
Sugar beets	4,320	15.9

SOURCE: U.S. Department of Commerce, 1987 Census of Agriculture

Various measures proposed to restore the salmon runs and fishery in the Columbia River Basin restoration efforts will likely involve some combination of (1) increased river flow rates to assist juvenile migration downstream, (2) improved dam circumvention methods; and (3) modifications of land use and practices such as grazing, logging, and irrigation water management in an attempt to improve salmon habitat.

The Aillery et al. (1996) analysis focused on the effect of proposed Snake River management alternatives on agricultural production, incomes, and resources in the Pacific Northwest. Increasing flow velocity is key to salmon recovery and may be accomplished either by reducing the cross-section area of surface water (for example, by lowering reservoir levels) or by increasing water volume moving through river channels. Water volumes are increased either by releasing more water from reservoirs or by reducing irrigation water diversions in the upper Snake River Basin in Idaho and Oregon. The study examined stylized policy instruments involving (1) reservoir drawdown below barge operation levels to increase river flow velocity, and (2) reductions in irrigation water diversions in the Upper Snake to augment river flow volumes. The policy instruments are stylized in the sense that they represent a synthesis of various proposed policy options. The study assessed three potential impacts: (1) the direct agricultural income and production impacts within the region, (2) the secondary regional employment and production impacts, and (3) selected market and nonmarket benefits of salmon fishery recovery. Attempts were made in the study to address the basic areas of inquiry posed above, i.e., the role of agriculture in the ecosystem and the associated environmental problem, a set of policy options, and potential resulting economic impacts and tradeoffs. While these issues were addressed to some extent, key limitations will be considered below.

Economic Impacts and Trade-offs Associated with Policy Options

Reservoir drawdown to increase flow velocities of water through reservoirs for migrating salmon would also disrupt traditional river management practices, with important implications for hydropower generation, river navigation, irrigation, and recreation. Moreover, the effectiveness of reservoir drawdown in reducing salmon mortality is uncertain. The primary impact on the agricultural sector would be an increase in grain transportation costs in eastern Washington and northern Idaho, combined with regional increases in electric power rates. Results from the study suggest that the effect of reservoir drawdown on regional farm profits would be relatively small, ranging from \$10 to \$35 million per year, or 1 to 3%.[1] Increased power rates and grain transportation costs would have relatively minor impacts overall but could have a substantial effect on grain producers dependent on barge transportation.

Augmenting river flow velocities would be achieved by increased water releases from Upper Snake reservoir storage in Idaho, and by reduced Upper Snake irrigation diversions in Idaho and Oregon. The Bureau of Reclamation provides 60% of the surface water diversions used for irrigation in southern Idaho and 30% in eastern Oregon. The Northwest Power Planning Council (1992) recommended minimum flow augmentation rates of 0.427 million acre feet (maf) per year, with a possible 1 maf additional per year. An estimated 0.3 maf would be available from uncontracted storage, resulting in a range of net flow augmentation levels of 0.127 to 1.127 maf. Diversion amounts are increasing in augmentation rates because of irrigation system water losses and river recharge, implying that the on-farm reductions in water availability for the two augmentation levels range from 2 to 20%. Figure 2 illustrates the effect of changes in flow augmentation rates on farmer profits in the Upper Snake Basin. The effect of reduced water availability is somewhat mitigated as producers switch to crops that require less water. However, the opportunity cost to farmers of increased flow augmentation rates increases at an increasing rate because of diminished ability to substitute among inputs and outputs. The regional economy impact associated with the most severe reduction in irrigation water supply (1.127 maf) produces a reduction of total regional annual income of 0.1% and yields a net reduction in agricultural and total employment of 1.6 and 1.1%, respectively.

The Aillery et al study (1996) attempted to provide potential benefit estimates, both market and nonmarket, associated with salmon recovery efforts. The study focused on the potential positive effects of improvement in salmon populations on in-river commercial and recreational fishing, and the negative effects of reservoir drawdown on recreational activity. Nonconsumptive use values were not estimated because of lack of data. Because the effects of the suggested measures on the actual salmon population are not well understood, hypothetical increases in salmon populations were assumed, with population increases ranging from 1 to 8%. Estimates of annual commercial fishing revenue benefits associated with these population increases ranged from \$40,000 to \$350,000. Estimates of recreational benefits from sport fishing on the Columbia and Snake Rivers ranged from \$60,000 to \$490,000. Finally, the added spending by fishermen on related goods and services ranged from \$30,000 to \$270,000. Total annual commercial and recreational fishing benefits estimates ranged from \$130,000 to \$1.11 million. However, total loss in recreational benefits from reservoir drawdown ranged from \$4.4 to \$14.8 million per year. These estimates represent direct losses which may be significantly offset by substitution among recreational activities and sites, and therefore likely overestimate actual losses. If these figures are taken alone, they suggest net benefit losses of \$4.27 to \$13.7 million per year. However, the authors suggest that net benefits would be positive if nonuse values were considered and that substitute recreational activities may cancel or reduce much of the estimated loss in recreational benefits.

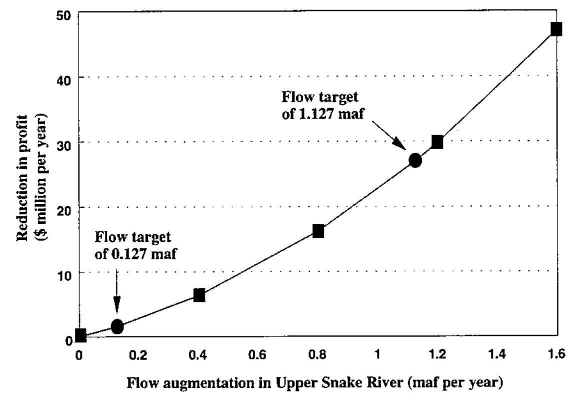

Figure 2. Reduction in Profit in Upper Snake Basin Due to Irrigation Diversion Reductions for Flow Augmentation. Flow targets of 0.127 and 1.127 million acre feet [maf] per year are based on flow augmentation objectives for salmon recovery established by the Northwest Power Planning Council.

SOURCE: Aillery et al. 1996.

Reflections on the Pacific Northwest Salmon Study

The salmon study was never intended to be an evaluation of the entire Pacific Northwest ecosys-

[1] The range of economic impacts is derived from various scenarios associated with different levels of irrigation water diversions and timing of reservoir drawdowns.

tem—such an effort would have required analyzing forest and timber management, all fish and nonfish wildlife, range and grazing, and other resources. The goal of the salmon study was to examine the impact of salmon recovery efforts in the Pacific Northwest river systems on agriculture and the regional economy, with particular emphasis on Snake River management alternatives. Within that context, the researchers focused directly on relevant aspects of the problem.

One of the chief difficulties the researchers faced was in defining a biological link between changes in river flow velocity and the rate of increase in salmon survivability and eventual population recovery. In the salmon study, the exogenous reduction in water diversions resulting from a range of possible water management options had the most significant policy impact on agriculture. An attempt was made to estimate the gains and losses in benefits associated with assumed increased salmon populations and reductions of surface water for recreation. These separate sets of costs and benefits were derived but were not used to produce an overall benefit-cost estimate associated with the policy options. The authors did not provide an overall benefit-cost estimate because the range of benefits attributable to measure evaluated is not known. Clearly, establishing a defensible linkage between the actions within a producing sector in response to policy instruments and the environmental or ecological outcome is fundamental to ecosystem-economic analysis.

While the lack of established scientific understanding may suggest an incomplete analysis, as it likely would for a strictly ecological or biological study, it points to the need to develop modeling approaches that can synthesize important interactions without reliance on highly detailed biological data. However, stylized modeling still requires a solid empirical basis and, thus, the need for data collection efforts, both primary and secondary, that establish a baseline and link ecological function with economic activity.

The Everglades Ecosystem

From different perspectives, agriculture, rural communities, environmentalists, urban residents, and the federal government share strong interests in the Everglades basin. The Everglades today is a vast area of wetlands, lowland forests, and estuaries noted for the richness of its diverse animal and plant communities. The Everglades has been recognized worldwide as a natural site of international significance. Designations as a biosphere reserve, a world heritage ecosystem, and a wetland of international importance are only a few of its accolades. The federal government owns substantial lands in the Everglades, including the Everglades National Park, the Biscayne National Park, the Loxahatchee National Wildlife Refuge, and the Big Cypress National Preserve.

The Everglades ecosystem stretches in the north from Lake Kissimmee and the Kissimmee River valley to the Florida and Biscayne Bays in the south (figure 3). The Kissimmee-Okeechobee-Everglades watershed measures over nine thousand square miles, larger than many states. The Kissimmee River was originally about hundred miles long and flowed from Orlando through the Kissimmee Valley south to Lake Okeechobee, the second largest inland lake in the nation. Averaging about twelve feet in depth, Lake Okeechobee overflowed its banks in wet periods with the surplus water historically stretching some fifty miles wide and flowing extremely slowly southeastward, gradually reaching both Florida and Biscayne Bays.

The Everglades itself is a large wetland, ostensibly a vast "river of grass," but actually encompassing a multitude of microclimates and heterogeneous eco-niches affording habitat for a diversity of flora and fauna. Part of the ecological richness of the Everglades is due to the fact that it spans features of both temperate and subtropical climates and habitats. The Everglades as a functioning ecosystem has been profoundly affected by agricultural and urban development and by water management goals that have favored their growth; the Everglades today has shrunk to less than half its original 4.5 million acres, with a more than proportional decline in species and habitat (Douglas 1988).

The evolution of South Florida land use, water management, economic development, and habitat preservation policy throughout this century has been colorful, controversial, and fraught with contradictions. The U.S. Army Corps of Engineers has been charged in three different areas with three distinctly different missions in the name of water and flood management in Florida. The first mission was swamp drainage, practiced in support of economic development throughout the first decades of the century. Wetland drainage and the creation of an extensive system of canals increased flood vulnerability, however, ushering in the second era. The era of flood control followed devastating floods in the late 1920s, 1930s, and 1940s, and led to landmark legislation in 1948 establishing the South and Central Florida Flood Management District (now, the South Florida Water Man-

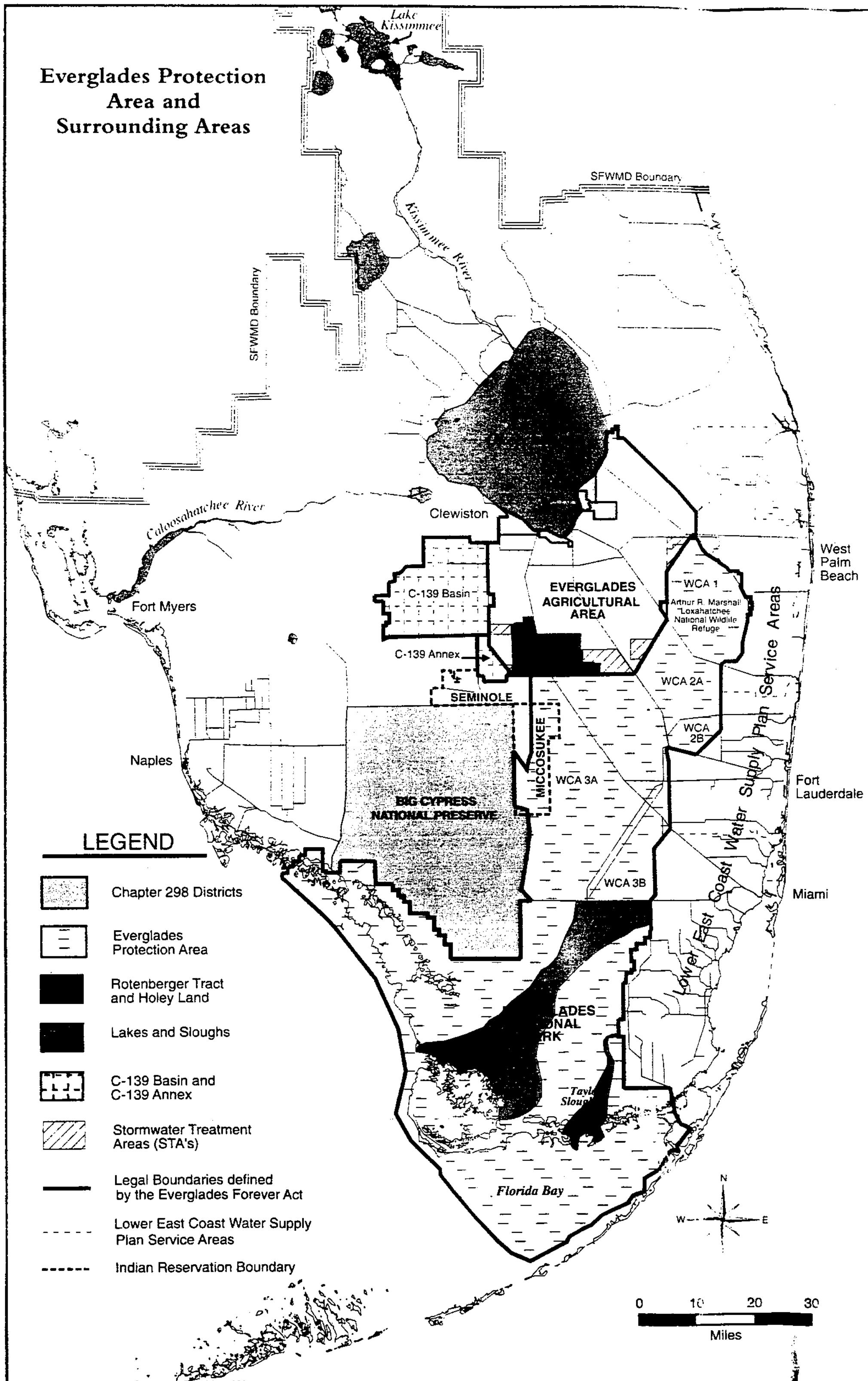

Figure 3. South Florida Ecosystem and Everglades.

SOURCE: South Florida Water Management District 1994.

agement District). Presently, the Corps is charged to restore the Everglades ecosystem. This task requires, ironically, undoing previous Corps activity: restoring the curves in the Kissimmee River, connecting up segmented waterways, and constructing synthetic wetlands to function in place of converted natural systems.

Ecological Concerns

Highlighted ecological concerns include endangered species and habitat; wetland conversion; compromised hydrology affecting water quantity, quality, connectedness, timing, and flow; soil subsidence; introduction of invasive species; and pressures of population growth. These concerns are outlined briefly.

Endangered, threatened, or diminished species. Attention has focused in recent years on the precipitous decline in many native wildlife populations, with potential losses in biodiversity, risk of extinction for numerous species, and reduced recreational benefits and commercial harvests that threaten the sustainability of local economies. Some fifty-six species are listed as endangered or threatened under the federal Endangered Species Act, with an additional twenty-nine candidate species, two of which are the Florida panther and the American crocodile. Populations of wading birds—often regarded as an indicator species for ecosystem health—are reduced by 90% over historic levels.

Wetland conversion. The implications of decreases over time in the spatial extent of the Everglades by more than 50% are a central, if plaguing issue in current discussions of restoration. Concerned about the loss of wetland functions, proponents of Everglades restoration have not yet attained a consensus as to either the optimal or the minimal necessary spatial extent required. Of the remaining wetlands, large areas are seriously degraded because of disruption in natural water flow regimes for water-supply and flood-control purposes, and impaired water quality from land-use activities.

Wetland conversion rates have varied across the region, depending on ownership and location. Public control over much of the central and southern Everglades has restricted land development but has not prevented the degradation of remaining natural wetlands. In the northern watershed, large wetland acreage within tributary basins of Lake Okeechobee was converted to pasturelands by the early 1950s. Channelization of the Kissimmee River, completed in 1971, reduced the 103-mile long, shallow, meandering river to a 56-mile long, 30-foot deep, straight channel. Approximately 30,000 acres—or two-thirds of the historic floodplain wetlands—were either drained, covered with spoil, or converted to canal.

South of Lake Okeechobee, drainage and water-control measures in the 1950s facilitated conversion of 700,000 acres of marsh, representing 27% of the historic Everglades, to the Everglades Agricultural Area (EAA) for irrigated crop production. In southeast Florida, large areas of short-hydroperiod wetlands were drained and developed for agriculture and residential development. The Central and South Florida Project (C&SFP) perimeter levee through the eastern Everglades provided flood protection to approximately 16% of the historic Everglades marsh and served as the westward limit for most development.

Impairment of hydrological functions. In the Everglades, extensive drainage and water control infrastructure has impaired natural hydrologic functions in much of south Florida. Hydrological concerns include impairment in water quantity, quality, connectedness, timing, and flow. Problems of water quantity encompass concerns about both too much water (requiring flood control) and too little water (implying the need for water storage for irrigation, municipal use, and environmental purposes). Channelization of the Everglades has reduced surface flows of water and redirected water in ways that have frequently produced unforeseen consequences: loss of fresh water to tide, and increased groundwater salinization due to saltwater incursion in coastal areas where water tables have been reduced. In Dade County, agriculturalists worry about elevations in water tables and changes in water flow. The impacts that agricultural drainage and drainage waters have on water quality in the Everglades ecosystem are a major concern. Water quality problems include eutrophication of Lake Okeechobee and excessive phosphorus and nitrogen levels in waters entering and leaving the Everglades Agricultural Area. Many human activities have contributed to water quantity and quality problems: agriculture, urbanization, fire control policies, overharvesting, off-road vehicle use, and others. Finally, the historic Everglades exhibited complex variations in water flow over time and space that supported habitat for diverse species. Much human activity has attempted to control some of the natural patterns for purposes of flood control, drainage, water storage, and irrigation, and in the process has compromised habitat.

The U.S. Army Corps of Engineers and the South Florida Water Management District recognize that to restore the integrity of the Everglades, it is necessary to reestablish more natural hydropatterns in the remaining natural system. Necessarily, more water will be directed to the Everglades, implying that increased competition is likely among agricultural and urban users.

Soil subsidence. Soils in the Everglades are a rich organic muck overlying limestone. When exposed to air, the soils oxidize, releasing phosphorus. Exposed soils are also more vulnerable to fire and compaction. Wetland drainage has exposed vast areas of the Everglades to oxidization, and the topsoil has subsided significantly, declining some five feet in areas in the Everglades Agricultural Area (at the Belle Glade Research Station, a marker illustrates this degree of subsidence). Soil subsidence reduces the productivity of cropland soils, limits the capacity of soils to store and regulate water flows, increases pumping requirements, and contributes to impaired water quality. Options being explored to reduce soil subsidence include improved irrigation and drainage practices, and the use of sugarcane cultivars and other crops more tolerant to high water tables, including water-tolerant rotation crops such as rice.

Exotic or invasive species. The changes in natural ecosystems mentioned above, along with introduction of normative species, have resulted in significant and disruptive changes to both species and habitat. Cattails, which flourish in nutrient-rich waters, along with invasive species such as melaleucca, Brazilian pepper, and water hyacinth, severely impede attempts to reestablish native ecosystems.

Population growth. Population growth is changing the face of South Florida and the lowest East Coast region (see figure 4). Population is expected to increase by some 50% from 1980 to 2010, or from under four million to over six million. Rapidly growing population stresses the natural resource base in a number of significant ways: demands for housing, water, transportation, jobs,

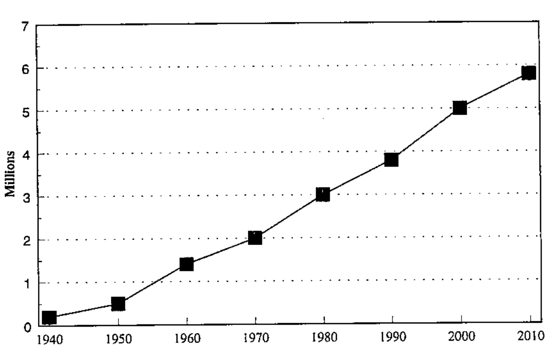

Figure 4. Population Growth in Florida's Lower East Coast Region.

SOURCE: South Florida Water Management District 1995.

recreation, and other services expand exponentially. Expanding urban centers will increase pressures on the regional water management system. Expanding urban water demands are likely to be made up, in part, by increased water storage in Lake Okeechobee, potentially threatening water-supply deliveries to the remaining Everglades marsh. Continued urban development will also increase demands for more effective flood control in the eastern Everglades, further reducing flexibility in water storage. Demand management, conservation efforts, and development of alternative water supplies (wastewater reuse, desalinization, reverse osmosis, aquifer storage and recovery) are needed to ensure adequate supplies for environmental purposes.

Agriculture and the Ecosystem

Agriculture is the second largest industry in Florida, behind tourism, and Florida is the eighth largest agricultural state in terms of revenues (Dart 1995). Agriculture has strong, though nonuniform, political and economic interests in the fate of the Everglades and Central and South Florida, and is an important economic actor and employer in the Kissimmee River valley, the Everglades Agricultural Area (Palm Beach County), and Dade County (with more minor activities in some other counties). Agriculture has come under the heaviest fire of all sectors for contributing to environmental problems in the Everglades. Effects of agricultural production on wetland systems include wetland conversion, modified water-flow regimes, water-quality effects, and soil subsidence. Phosphorous nutrient runoff from sugarcane production, dairy waste, and other agricultural chemical pollutants are considered key problems. Phosphorous discharge, especially, has resulted in lawsuits: for example, in 1988, a U.S. attorney sued the South Florida Water Management District and the Florida Department of Environmental Regulation for failing to maintain sufficient quality of water flowing into federally owned lands in the Everglades. Phosphorous discharge results from soil subsidence associated with agricultural cultivation and with water-table manipulation, as well as from actual nutrient use and runoff. In addition to wetlands loss and phosphorus discharges, pesticide residues, livestock waste, soil oxidation, and salt-water intrusion have also been attributed to agricultural activities in the region.

The agricultural economy of direct relevance to South Florida restoration efforts can be categorized by and represented by three distinct regions: the Kissimmee River valley, the Everglades Agricultural Area (EAA), and Dade County.

The Kissimmee River valley became the site of a flourishing cattle industry as early as the 1800s. In this century, dairy farmers have continued to raise cattle in the Kissimmee Valley. After the river was shortened from 100 miles in length to 50, as Canal 38—in the process reducing by some 40,000 acres the marshes previously available for water filtration—runoff from dairy operations, along with residential run-off, contributed to water quality problems in Lake Okeechobee (Snell and Boggess 1994, p. 44). In 1987 the state enacted measures to reduce nutrient loadings from livestock operations in the Lake Okeechobee watershed, including effluent regulations, herd buyouts, cost-sharing for barn-effluent control systems, and off-site drainage impoundments. A major federal/state Kissimmee River Project will restore the Kissimmee River to its original course, including 43 miles of historic river channel, and will restore 26,500 acres of converted floodplain wetlands.

The Everglades Agricultural Area was officially created in 1948 and consists of about 700,000 acres, including about 425,000 in sugarcane production, 32,500 in vegetable production, 12,000 in rice, and 25,000 in sod (Stone and Legg 1992). The total value of Everglades Agricultural Area agricultural output was estimated at $1.5 billion in 1990 (Hazen and Sawyer 1992). The EAA supported about 15,600 jobs in 1990, principally in agricultural production and also in sugarcane milling and in wholesale, retail, and service trades. Some 17,000 households (51,400 people) live in the EAA. Palm Beach County, of which the EAA is a part, leads Florida in agricultural revenues. Agricultural laborers, small rural communities, and agribusinesses depend on agriculture to an important degree. Along with these land use and water management engineering measures, important water management decisions affecting agriculture have already been implemented. In 1979, restrictions were proposed in the backpumping of agricultural runoff for flood control/storm-water runoff into Lake Okeechobee. By 1985, limitations were instituted, and backpumping is now restricted to emergency conditions.

In 1988, the U.S. attorney in Miami sued the State of Florida to prevent phosphorous runoff from the EAA from reaching the Everglades National Park, where it was destroying natural habitat. After incurring high legal costs, the state settled in 1991. The settlement agreement and the Marjory Stoneman Douglas Everglades Restoration Act require the South Florida Water Management District to purchase farmland in the EAA for conversion to filtration marshes or storm-water treatment areas (STAs). These artificial wetlands contain "phosphorous-gobbling plants" (such as cattails), which filter EAA phosphorous discharges into the northern Everglades marsh. About 35,000 acres are expected to be converted to filtration purposes, beginning with a 3,700-acre prototype. Proposed flow-ways to restore dynamic sheet-flow and provide for water storage in the EAA would reestablish 40,000 acres of "special purpose" wetlands, depending on flow-way design. Producers are also required to adopt best management practices, under regulatory restrictions.

Best management practices have been developed by the Natural Resources and Conservation Service for soil testing, nutrient use, water conservation, watertable management, subsidence control, and effluent runoff. Measures to encourage "just in time" pumping and drainage, as well as higher watertables, are being developed at Canal Point, where researchers are investigating means to maintain watertables at 12–18 inches below surface, instead of 18–24 inches, to minimize subsidence.

Previous adjustments in C&SFP operational guidelines have attempted to reverse the downward trend in wildlife populations and other environmental values. A major effort is now underway by the South Florida Water Management District (SFWMD) and the U.S. Army Corps of Engineers to restructure water storage and delivery regimes to restore, to the extent practicable, natural hydrologic functions—while achieving water-supply and flood-control objectives. Environmental provisions under evaluation include increased reserved dry-season water flows for environmental purposes, allowance for fluctuating river and lake conditions to maintain floodplain marsh habitat, reduced drainage flows and internal water storage on EAA lands, restoration of sheetflow along unobstructed flow-ways through portions of the EAA and the water conservation areas, modification of selected water-control structures and other barriers to reduce habitat fragmentation, restoration of more natural water releases based on actual precipitation patterns, establishment of wetland buffer zones along developed areas, restoration of more natural freshwater flows to coastal estuaries (including reductions in excess floodwater diversions), and management of groundwater tables and canal levels to prevent saltwater intrusion. Interim measures would be implemented with existing control structures and modified as needed to maximize effectiveness; proposed measures will in many cases involve modifications in physical infrastructure, including levees and canals, pump stations, highway culverts, et cetera.

Dade County agriculture produces a mixture of high value tropical fruits, horticultural products, and specialty vegetables. The value of agricultural output in Dade County is roughly half that of the EAA. Dade County represents a non-EAA Florida county with strong interests in developments in EAA and South Florida water management policy. Agriculturalists see agriculture playing a role as the ideal buffer between the pristine ecosystems represented by the park and reserves nearby and the urban areas literally on the doorstep to the East and North. In order to meet agricultural objectives, agriculturalists are seeking ways to make agriculture in Dade County less vulnerable to the high water tables and flooding envisioned as likely consequences of water management options being discussed for the park and the EAA. The other major threat to agriculture in Dade County involves rapid urban growth and pressures on property values.

Policy Options for South Florida Restoration

Key groups among the many players in the current policy formulation process in Florida include the Governor's Commission for a Sustainable South Florida, created by Governor Lawton Chiles in 1994 to attain broad-based consensus on coordinated Everglades restoration plans; the Federal Task Force and Working Group, comprising federal departments with programs in Florida; and the U.S. Army Corps of Engineers, working with the South Florida Water Management District.

In October 1992, Congress authorized the U.S. Army Corps of Engineers to determine feasible modifications to the original (1948) Central and South Florida Project that would improve environmental quality, protect the aquifer, and preserve the integrity of urban and agricultural water supplies. The original C&SF Project is a system of levees, canals, pump stations, and water control structures designed to provide South Florida with flood control; navigation; water supply for agricultural, urban, and environmental purposes; and recreational benefits. The project reevaluation is known as the Comprehensive Review Study or Restudy and is expected to take up to four years. Objectives for the restudy, along with significant constraints, deal with both the ecology and the hydrology of the ecosystem (table 2). Constraints include protecting threatened and endangered species, meeting water delivery schedules and needs, minimizing saltwater intrusion, and minimizing the loss of services currently provided by the C&SF Project. Finally, social and economic constraints are also recognized: disruption of communities, jobs, agriculture, tourism, commercial fishing, and other businesses.

Both the governor's commission and the Federal Task Force and Working Group have turned their attention to the restudy process, with the most important interactions among all major groups occurring in this context. Policy deliberations occur literally simultaneously on federal, state, and regional levels. The dynamism of the policy process is heightened by the fact that in parallel to the restudy process, dozens of ongoing projects relating to one or another aspect of Everglades restoration are also underway.

The menu of potential policy choices is being set jointly by the Settlement Act and the Everglades Forever Act and by the Corps's restudy process. Policies will address questions of overall hydrology (infrastructure) and water quality as well as questions of land uses and management practices. Various policy instruments are being discussed, including land acquisition, taxes on output, taxes on effluent, regulation, education, cost-sharing, markets for phosphorous discharge, and mitigation banking of wetlands.

Some of the policy decisions to be resolved relate to the appropriate level of decision making. While the governor's commission recommends redirecting growth away from the Everglades and other ecologically valuable places, effective wetland preservation will require strengthening program initiatives, including stricter local and regional land-use planning and zoning, and enforcement of drainage permits by the Corps and the Environmental Protection Agency under the Clean Water Act, Section 404. In addition, expanded funding for wetland (and upland) easements and land acquisitions by public agencies and land trusts, increased private land stewardship efforts, and improved wetland banking mechanisms and mitigation strategies that maximize the value of restored wetlands are all potential policy measures.

Currently, proponents of the South Florida restoration effort believe that the systemwide approach of the restudy differs significantly from other restoration activities typically targeted at specific problems in particular locations. While individual projects may have been worthy, the SFWMD states:

> Such an area-specific, problem solving approach frequently exacerbates ecological problems of the overall system. A problem solved in one location may reappear in another, or worse, a solution in one location can cause a new problem in another location. By taking a system-wide approach, the Restudy should avoid the difficulty of competing solutions. (South Florida Water Management District 1995b, p. 91)

Table 2. Planning Objectives and Constraints for the Comprehensive Review Study

Objectives
- Increase the total spatial extent of wetlands
- Increase habitat heterogeneity
  - -Reestablish lost historic communities in functioning condition
  - -Reestablish relative balance among historic community types
  - -Restore connections within and among community types
  - -Reduce the extent of nonnative plants and animals
- Restore hydrologic structure and function
  - -Restore sheet flow
  - -Increase dynamic storage capacity
  - -Restore hydrologic linkages
  - -Restore more natural hydropatterns
  - -Restore more natural water delivery characteristics to estuaries and bays
- Restore water quality conditions
  - -Restore more natural salinity characteristics in estuaries and bays
  - -Restore more natural quality characteristics
- Improve the availability of water
  - -Improve efficiency in water use
  - -Improve water supply
- Reduce flood damage on Seminole and Miccosukee tribal lands

Constraints
- Protect threatened and endangered species
- Deliver water that meets applicable water quality standards
- Minimize salinity intrusion into freshwater aquifers
- Minimize loss of services provided by the C&SF Project
  - -Minimize loss of water supply
  - -Minimize loss of existing flood damage protection
  - -Minimize loss of navigational opportunities
- Minimize regional and local social and ecomonic disruption
  - -Minimize disruption of communities
  - -Minimize disruption of jobs
  - -Minimize disruption of agriculture, tourism, commercial fishing, and other businesses

Challenges for the Ecosystem-Economic Analysis

It was indicated at the outset that there are three fundamental questions that need to be addressed within an ecosystem-economics context: What are the environmental problems in the ecosystem and what is the role of agriculture? What is the relevant set of policy options for analysis? What are the economic and other important impacts of these policies? Future research will involve seeking to refine the selection of relevant policy scenarios, establish meaningful spatial and temporal boundaries, and understand the relationships between agriculture, the ecosystem, and the impacts of alternative policy scenarios on the entire system. Many contrasts and comparisons may be useful in moving from the Pacific Northwest salmon study to the Everglades study. Taking a lesson from the salmon study, we need to strike a balance between relevance, tractability, and comprehensiveness. There are many parallels between the two situations. Each is characterized by a conflict over the use of natural resources, especially water and land. In each situation, degradation of the natural resource base or ecosystem exerts broad-based impacts and significant economic effects. In each case, species are endangered and natural habitat is threatened. However, significant differences also distinguish the two cases. Some of the differences, which heighten the challenges for future research, include the following:

1. *Contrast between single-species focus and ecosystem-wide focus.* In the Pacific Northwest, the policy scenarios were all driven by recovery objectives mandated by the Endangered Species Act. The Florida Everglades and South Florida recovery plans attempt to address ecosystem/landscape-wide environmental conditions. In fact, a major focus of all the policy activity now underway at several levels is to further refine and focus the relevant ecosystem considerations and the consequent policy proposals.

2. *Contrast in the complexity of the hydrology.* In the Pacific Northwest, the hydrology is relatively simple and can be characterized as a con-

tained river system, with nearly 100% of irrigation losses reentering the system as return flows. Interannual variability of water flow is of relatively minor importance to the restoration of the ecosystem in the Pacific Northwest provided minimum flows are maintained. The Everglades ecosystem, however, is extremely complex. Prior to development, the Everglades was characterized by interspatial and intertemporal irregularities, including wet prairies with short hydroperiods, sheet flow, floods, and droughts. Moreover, the linked ecosystems of the Kissimmee River, Lake Okeechobee, the former Everglades, and associated sloughs connect to coastal estuarine systems, including Florida and Biscayne Bays. Moreover, man-made water-control systems have largely disrupted natural hydropatterns. The South Florida Water Management Project epitomizes this complexity.

3. *Contrast in the nature of impacts on agriculture.* In the Pacific Northwest, impacts on agriculture are relatively small. The largest impacts are associated with reduced irrigation diversions, which could be compensated. In the Florida Everglades, policies could exert relatively major impacts on agriculture. Land buy-outs, taxes, regulation of best management practices, and changes in water distribution, flows, and costs could be significant, depending on policy formulation. In the Pacific Northwest, regional economic impacts of recovery scenarios were fairly small, on the order of less than 1%. In the agricultural sector income losses ranged from 1 to 3%. Recovery costs were broadly distributed. In South Florida, depending on restoration strategies selected, the potential impacts on the agricultural and rural sectors could be significant and unevenly distributed. For example, the Florida Forever Act and the Settlement Act established mandates to buy out significant agricultural acreage; such buy-outs could have significant effects on agriculture, depending on terms and financing mechanisms.

4. *Contrast in the dynamics of the socioeconomic system, including population growth.* In contrast to the relatively stable conditions in the Pacific Northwest, the prospective tripling of the population in South Florida within a fifty-year period implies huge changes in demands for water, land, flood protection, and other associated resource-based services.

Many problems in South Florida are attributable to past failure to consider ecosystem-like impacts of human activity. Recent efforts to restore ecosystems suggest that the case-by-case approach may not help and in fact may exacerbate problems in some instances. For example, backpumping restrictions to Lake Okeechobee, which were designed to reduce phosphorus loading into the lake, have contributed to water-quality problems in areas to the south of the Everglades Agricultural Area. Moreover, the partial view may not fully recognize potential synergistic benefits among environmental functions. For example, measures to reduce soil subsidence can provide water storage and water quality benefits downstream. The ecosystem approach provides a broader perspective, indicating the potential inconsistencies that can arise from the partial or case-by-case approach. The challenge is to identify optimal policy instruments that recognize both positive and negative interactions between environmental functions to achieve restoration goals at least social cost.

The analytical and modeling challenges implied by the above Pacific Northwest and South Florida comparisons are formidable. In addition, the policy process is extremely dynamic and will evolve along with our modest study. It is our hope that in fulfilling the dual role of analyst and providing policy counsel, the researchers can clarify relationships between the agricultural sector, the ecosystem, and efficient policy options.

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