ADAPTIVE ECOSYSTEM MANAGEMENT AND THE FLORIDA EVERGLADES: MORE THAN TRIAL-AND-ERROR?

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This is an updated version of the article "Ecosystem Management and the Florida Everglades: The Role of Social Scientists" by J. Walter Milon, Clyde F. Kiker, and Donna J. Lee that was published in the *Journal of Agricultural and Applied Economics*, Vol. 29, July 1997:99 - 107. We thank the editors of the Journal for permission to reprint parts of that article.

Within the past decade ecosystem management has become a central theme in state and federal environmental resource management and a powerful issue in environmental policy debates. A recent survey showed that more than 600 projects related to ecosystem management are underway around the U.S. (Yaffee *et al.*,). Under the Clinton Administration, a high level of federal commitment to an ecosystem management approach has developed despite many obstacles (e.g., Interagency Ecosystem Management Task Force; U.S. Environmental Protection Agency; U.S. General Accounting Office). Some have argued that the transition from traditional resource management to ecosystem management is inevitable because the scientific management principles that have dominated environmental policy and management in the U.S. " . . . lack the cross-disciplinary integration and informed speculation needed to be useful to a policy maker" (Tarlock, pp. 1133). Indeed, the appeal of ecosystem management for policymakers, resource managers, and scientists is significant, and its underlying concepts continue to evolve (Grumbine; Lackey; Swallow).

A critical component of ecosystem management is the use of an adaptive approach that openly articulates both ecological and social objectives, embraces uncertainty, and encourages monitoring, learning, and feedback to management decisions (Holling 1978; Interagency Ecosystem Management Task Force; Walters). Questions remain, however, about the ways in which adaptive ecosystem management can influence the planning process and how it would be implemented. The progress of a particular case study, the South Florida/Everglades ecosystem restoration initiative, suggests that the design and practice of adaptive ecosystem management have yet to fulfill the intellectual challenge. The Everglade's restoration initiative is a centerpiece of federal ecosystem management efforts and the success or failure of this initiative will likely influence the evolution of ecosystem management concepts in future environmental policy. In this paper we provide a brief overview of adaptive ecosystem management principles and the role of scientists and then evaluate how these principles have been applied in the South Florida/Everglades ecosystem restoration planning process.

ADAPTIVE ECOSYSTEM MANAGEMENT AND SCIENTISTS

At present there are several well-recognized principles of ecosystem management, but relatively little agreement on the details of implementation. The most cited definition by Grumbine is management that, " . . . integrates scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term" (p. 31). This definition embodies three primary themes: ecosystems - interacting biological (including human) and physical components; conservation biology - sustainable areas of biodiversity within a native habitat; and, integrated organization - coordination of social institutions to achieve desired goals. Depending upon the emphasis given to each theme, ecosystem management can be viewed as a preservation dominated approach to resource management (Sedjo) or as an organizational tool to reconcile diverse, conflicting political interests (Haeuber).

The ambiguous focus of ecosystem management is reflected in the differing perspectives expressed by various federal agencies. For example, the National Park Service's historical mandate for preservation is reflected in its description of ecosystem management as, "A philosophical approach that respects all living things and seeks to sustain natural processes and the dignity of all species and to ensure that common interests flourish" (from Haeuber, p. 25). On the other hand, the federal Interagency Ecosystem Management Task Force concluded "The goal of the ecosystem approach is to restore and sustain the health, productivity, and biological diversity of ecosystems and the overall quality of life through a natural resource management approach that is fully integrated with social and economic goals" (p. 17). This latter interpretation emphasizes the interrelationships between biological and social systems and the need for consistency between ecological and social goals.

Proponents of ecosystem management argue a fundamental advantage is that traditional resource management tends to be myopic and fails to recognize the complexity and uncertainty inherent to ecological and social systems (e.g., Agee and Johnson; Holling 1978; Ludwig, Hilborn, and Walters; Stanley). Therefore an adaptive approach that accommodates this uncertainty is a necessary element of ecosystem management (Shabman). Adaptive management is based on the premise that information about ecological and social systems is (and will always be) imperfect. Management decisions should be viewed as part of a sequential process designed to provide new information and reduce uncertainty (Walters). New information about ecological and social systems is generated from a process that views each new management decision as an experiment within a series of experiments. Each experiment is based on one or more hypotheses about the behavior of critical ecological and/or social system indicators (endpoints). Thus, adaptive management requires: (1) close integration between natural and social scientists and policymakers in the formulation of goals and hypotheses, (2) clearly defined response indicators (endpoints[1]), and (3) monitoring and evaluation to identify and assess the implications of change in the response indicators relative to goals and objectives. The Interagency Ecosystem Management Task Force believes that "Adaptive management can be effective only if monitoring and evaluation procedures are integral parts of the design *that are incorporated from inception and not simply added after implementation*" (emphasis added). Without this sequential research process, management ". . . is reduced to little more than a trial-and-error process" (Vol. II, p. 56).

Despite the integral role of research in ecosystem management, little has been written about the process of scientists working with managers in an ecosystem setting or on interactions between natural and social scientists[2]. This is surprising since a large majority of ongoing ecosystem management projects around the U.S. cite research as a primary component of the project (Yaffee *et al.*, p. 17-19). Indeed, the Interagency Ecosystem Management Task Force observes, "The need for scientific information as a foundation for resource management decisions continues to increase dramatically . . . The interface between social, economic, physical-biological, and ecological models must be improved" (Vol II, p. 65).

A conceptual framework to describe the integration of natural and social scientists in adaptive ecosystem management is presented in Figure 1. Social goals or priorities for the management of an ecosystem are expressed through various political and governmental entities. These goals reflect the desires of the public at a specific time and are often vague and ambiguous because full knowledge of the ecosystem is lacking and public desires reflect complex cultural beliefs and values that are rarely expressed with precision (Caldwell; Jasanoff). These goals can be expressed as research objectives by scientists and policymakers. The research objectives are conditioned on scientists' understanding of ecological and social relationships and policymakers' interests in achieving these goals. It goes without saying that policymakers' interests may be as complex and dynamic as the ecosystems they manage (Fortman).

Agreement between policymakers and scientists on research objectives leads to a set of ecological and social hypotheses about the performance of the ecosystem that are mutually consistent yet reflect different disciplinary perspectives. Natural scientists address an ecosystem's structure and function (biological, chemical, etc.) and the interactions of populations (including human) within the ecosystem. Social scientists consider the structural and functional features of social systems (economic, political, etc.), human behavioral interactions with non-human components of the ecosystem, and resource constraints within the social system. The hypotheses developed from the natural and social sciences form the basis for models of the natural and human systems that can be used to assess the effects of perturbations to the ecological and social systems resulting from management actions. Each disciplinary perspective may address variables that have substantially different response times and spatial scales. Nevertheless, in an ideal world the research hypotheses and related models should reflect direct interaction and exchange between natural and social scientists so that critical determinants of an ecosystem's performance and the most ecologically and socially important endpoints are simultaneously considered.

Even in this ideal world of integrated policy and research design, it is important to recognize that knowledge about many determinants will be imperfect and surprises may occur (Holling 1986). The process of developing and testing "working hypotheses" in an adaptive management framework only seeks to reduce the ambiguity inherent to natural and social systems (Caglioti). Within this scientifically informed adaptive management process, the research hypotheses form the basis for an array of possible options and actions from which policymakers select an initial preferred course of action. Following implementation, monitoring and evaluation of the physical, biological, and social systems responses must be conducted to assess the initial working hypotheses, to reduce scientific uncertainty, to inform the public and, if necessary, to develop alternative hypotheses and action plans. This is the critical "feedback" element of adaptive management that requires interdisciplinary scientific dialogue and interaction with policymakers and the public. At this stage prior investments in the development of compatible natural and social science hypotheses will be most apparent. A lack of acceptable ecological and social indicators of ecosystem performance will greatly complicate decisions about the effects of prior actions and jeopardize public trust in the management process (Lackey).

ADAPTIVE MANAGEMENT AND THE EVERGLADES/SOUTH FLORIDA ECOSYSTEM

Water management in the South Florida/Everglades region has a long history of engineering responses to societal demands for the region's resources. Initial state management efforts during the first half of the 20th century sought to control flooding and drain the wetlands during what has been described as the "cut 'n try" era (Light and Dineen). The failure of these efforts led to the creation of the Central & Southern Florida Project (C&SFP) with the Flood Control Act of 1948. Under the direction of the U.S. Army Corps of Engineers, the C&SFP established a system of dikes, canals, levees, and pump stations that controlled flooding, water supply, navigation, and land uses in the region and dramatically reconfigured the interactions between the natural and social systems (Light *et al.*; Milon *et al.*,).

While the C&SFP achieved many of the initial objectives, continuing concerns about deterioration of wetland habitats, wildlife populations, and other concerns led to a Congressional directive in the Water Resources Development Act of 1992 to evaluate modifications (P.L. 102-580, Sec. 309(1)). The Restudy (as it was named by the U.S. Army Corps of Engineers) was assisted by the South Florida Ecosystem Restoration Task Force which was created in 1993 through an interagency agreement among six federal agencies and joined by relevant state agencies and the Miccosukee and Seminole tribes. A subsequent Reconnaissance Report in 1994 noted that, "the south Florida ecosystem restoration program will most likely be successful in achieving its goals if implementation of the program is conducted by means of an adaptive management strategy" (U.S. Army Corps of Engineers, pp. 114). Later publications by the Corps observed, "The approach that is necessary to begin restoration immediately with minimum risk is adaptive management" (U.S. Army Corps of Engineers 1996, pp. 2).

Authorization to proceed with a more complete feasibility study for modifications to the C&SFP was given by Congress in the Water Resources Development Act of 1996 (P.L. 104-303, Sec. 528) along with formally establishing the Task Force. The Act directed the Corps to evaluate alternative plans to restore and preserve south Florida's ecosystem while improving water supplies and maintaining flood protection. Also, a report on a comprehensive plan must be presented to Congress by July 1, 1999. While a number of events and forces have been at work in the development of the feasibility study, these were admirable documented by Vogel and will not be repeated here. Instead, we focus on the just released "Draft Integrated Feasibility Report" (hereafter Draft

Report) and evaluate how adaptive management principles have been utilized to deal with the diverse and complex problem of the South Florida/Everglades restoration.

The 3,500 page Draft Report (available on the Internet at www.restudy.org) reflects an enormous multiagency, multidisciplinary effort to develop water management plans for the highly diverse region that encompasses more than 18,000 square miles and nearly 50 percent of Florida s 14 million residents. Various subgroups developed and evaluated models that integrated the analysis across thirteen major ecological subregions and water service areas (Draft Report, Section 7). Alternative plans were evaluated with these models to determine how each plan achieved specific ecological goals (increase the spatial extent of natural areas; improve habitat and functional quality; and improve native plant and animal species abundance and diversity) and socioeconomic goals (increase water availability for agricultural, municipal, and industrial users; reduce flood damages; provide recreational and navigation opportunities; and protect cultural and archeological resources). These goals were developed in conjunction with the Governor's Commission for a Sustainable South Florida comprised of involved citizens from South Florida (Draft Report, pp. 5-12 - 5-18).

The analytical framework for the plan evaluations was a traditional with and without analysis over a 1995 to 2050 planning horizon. The specific overall plan evaluation criteria were two ecosystem indicators: first, a summary measure of acreage across all subregion that was scored "green" (as compared to yellow or red) based on hydrological performance measures and " . . . a best professional opinion prediction of how likely each plan would achieve the long-term ecological or water supply objectives" (Draft Report, pp. 7-29). The resulting "Green Acres" measure was then multiplied by a habitat quality index for each subregion to produce a second summary measure of suitable habitat units. The quality index was based on the River of Grass Evaluation Methodology (ROGEM), a set of " . . . equations and best professional judgments" used to " . . . represent the habitat quality based on the relationship between hydrologic characteristics and habitat restoration targets" (Draft Report, pp. 7-25). The significance of this habitat suitability adjustment is apparent when one considers that, for example, one alternative plan would yield 680,000 Green Acres and 642,260 acres of suitable habitat compared to the recommended alternative which would yield 2,405,800 Green Acres but 803,000 acres of suitable habitat (Draft Report, pp. 7-55). Cost-effectiveness measures of costs per unit of output were calculated based on the Green Acres and suitable habitat indicators and the initial construction/implementation, land acquisition, monitoring, and recurring operating costs for each alternative plan (Draft Report, pp. 7-54 - 7-57).

The recommended comprehensive plan would significantly increase the water storage capacity of the current system by creating more than 200,000 acres of surface water storage and preserve areas throughout the region to store more than 1.5 million acre-feet of water, developing more than 300 aquifer storage and recovery wells to store more than 1.6 billion gallons of water per day, creating 30,000 acres of manmade wetlands to treat agricultural and urban runoff before it is discharged to natural areas, building advanced wastewater treatment plants to allow discharge to natural areas, and storing water in converted limestone quarries. Also, more than 500 hundred miles of C&SFP canals and levees would be removed to reestablish the natural sheetflow of water through the Everglades (Draft Report, pp. v-vii). The estimated implementation costs of $7.8 billion over a 20-year time frame with recurring annual costs of $175 million make this the highest single project budget recommendation made by the Corps (Overview, pp. 20).

To evaluate the recommended plan from an adaptive management perspective, three elements of the planning and implementation process are most important and will be the focus of our analysis. First, the interaction between water demand and supply used in the modeling and evaluation process. Second, the use of natural and social sciences in developing plan alternatives. And third, the expected use of monitoring and decisionmaking during implementation.

WATER DEMANDS AND SUPPLIES

For the with and without plan analysis, urban water demands (the dominant water use in the region) were estimated for the year 2050 based on both state and federal population projections using the Corps IWR-MAIN forecasting model (Draft Report, pp. E-39 - E-56). Water conservation measures were incorporated by assuming specific percentage reductions in total use based on domestic reduced flow devices. While IWR-MAIN can provide seasonal and annual projections, these were not estimated due to the characteristics of the regional-scale hydrological model (the South Florida Water Management Model (SFWMM)) used to evaluate and compare the hydrologic, water supply, and ecological (SFWMM is an integral element of ROGEM) effects of the alternative plans. The SFWMM simulates daily hydrological conditions throughout the region (including natural areas) based on 31 years of historic climatic conditions (1965-1995). But, the model equally weights each day in the period so that, " . . . it is not possible to use SFWMM to determine the likelihood of occurrence of any given hydrological event" (Draft Report, pp. E-5). Moreover, "The model does not allow for dynamic changes in south Florida s land use/land cover or for changes in the C&SF infrastructure during the simulation period" (Draft Report, pp. E-4). As a result, " . . . the rates of hydrological change and habitat recovery in response to restoration efforts could not be determined. Only existing conditions and desired end state conditions could be accurately predicted by the SFWMM analysis" (Draft Report, pp. E-5).

This comparative statics balancing of water demands and supplies is clearly inconsistent with an adaptive management approach since the analytical models (both demand and supply) provide no basis for interim hypotheses about the ecological and social responses to management actions. Yet, the Draft Report asserts that the implementation plan will proceed with " . . . incremental implementation of plan components, with each increment treated as one 'experiment' within a stair-step evolution of experiments, each planned and designed to carry the program one step closer to the ultimate goal of system restoration. Each increment can be viewed as a loosely organized experiment because the overall program objectives and performance measures were developed from a large set of water quality, ecological and hydrological hypotheses . . . . Implementation of each iteration will provide a test of how well the hypotheses predict responses by the systems" (Draft Report, pp. 10-4).

While this inconsistency between the water demand and supply modeling approach and the stated adaptive implementation strategy is troubling, perhaps more problematic is the presumption in the evaluation process that demand and supply can be balanced only through structural solutions. By assuming that future water demands are solely a function of existing demands and future growth, the combination of ecosystem restoration and water supply objectives produce what Loucks has described as " . . . a wish list of everything each stakeholder wants" (pp. 42). While Florida water law follows a 'reasonable-beneficial' standard, this does not imply service to all users regardless of cost (Saarinen and Lynne). Nonstructural approaches such as water conservation pricing strategies and retrofit incentive programs (e.g., Munasinghe) could produce real reductions in the demand side of the water planning problem and thereby create opportunities to allocate water to other uses (such as natural area restoration). Moreover, the hypothesis that pricing incentives matter can be monitored and tested in real time and used to reduce uncertainty. Similar arguments could be made for land use planning.

THE USE OF NATURAL AND SOCIAL SCIENCES

The concern that the combination of ecological and social water demands create a "wish list" of project objectives raises the issue of how the natural and social sciences were used in the Restudy process. To the Restudy s credit, the teams assembled to develop and evaluate plan alternatives utilized professionals from a broad array of disciplines (Draft Report, Section 14). The selections of alternatives and the subsequent evaluations, however, were largely driven by performance criteria based on hydrological models (Draft Report, pp. 7-9 - 7-11, Appendix D) and engineering costs. Social science dimensions of the adaptive management problem such as the effects of alternatives on community development in different regions, the effects on consumptive and nonconsumptive recreation and, perhaps most important of all, whether the alternatives were consistent with the public s perceptions of what ecosystem restoration should accomplish were not modeled or quantified in the evaluation process. Many of these issues had been raised at an earlier workshop convened for the purpose of coordinating natural and social science research for the Restudy (Gentile). Information about these elements that was included (per Federal requirements) was largely qualitative and therefore provides little basis for subsequent testing (Draft Report, pp. 7-54 - 7-64, Appendix E).

A similar neglect of social science methods occurs in the use of cost-effectiveness analysis (per Corps regulations) to evaluate the alternatives. As described above, this analysis used aggregate, system-wide output measures based on hydrological performance criteria and ROGEM even though most early reviewers of this approach had warned, "I do not believe ROGEM, in its present form, is adequate to give reliable results in a cost effectiveness analysis" (Gosselink, pp. 13). Moreover, the cost-effectiveness analysis played no role in designing the implementation plan (Draft Report, Section 10) since, "The sequencing and scheduling contained in this draft report assume an unconstrained resource scenario" (Draft Report, pp. 10-15).

Alternative versions of cost-effectiveness analysis could recognize resource constraints and different degrees of uncertainty. Following an approach suggested by Swallow, specific hydrological targets (and measures of uncertainty about these targets) for various subregions would be defined (based on hydrological or other performance criteria) and then a constrained optimization approach would be used to evaluate the shadow costs of meeting these constraints under alternative plans. This approach would clarify the ecological goals for each subregion and identify the resource costs of meeting these goals based on both structural and nonstructural alternatives. Moreover, it would allow sequencing based on least cost criteria and measures of uncertainty.

MANAGING ADAPTIVELY

Adaptive ecosystem management is intended to be more than just project selection and design and includes the project s short- and long-term environmental and social impacts. To address these monitoring and feedback functions, the Draft Report proposes the formation of a System-Wide Evaluation and Analysis Team (SWEAT) that would function throughout the planned 20 year implementation phase (Draft Report, pp. 10-11). This approach is fully consistent with adaptive management principles, but several practical issues must be addressed. First, the Draft Report explains that, "The regional monitoring program will provide measures of actual hydrological and ecological responses" (Draft Report, pp. 10-4). Yet, no specific monitoring criteria are proposed in the Draft Report nor is there any indication how the timing of ecosystem responses will coincide with the implementation schedule. Moreover, the ecological response analyses that were conducted for the project used the same with and without (1995 to 2050) comparison so there are no dynamic adjustment paths for species/communities to evaluate (Draft Report, Annex B). Can it be expected that important species will settle/colonize/utilize restored habitats within the implementation time frame? How will sequencing decisions be made in the absence of this information?

A closely related concern is how implementation and monitoring through the SWEAT will address public preferences and expectations about the ecosystem restoration. Despite an extensive public involvement and outreach program during the Restudy that included workshops, focus groups, public hearings, newsletters, and a web site to provide descriptions of the planning process and models (Draft Report, Section 11), no systematic research was conducted to provide baseline information to identify public values and priorities for the restoration. As Lackey suggests, this should go beyond simple public opinion polls and seek " . . . a credible handle on what the public considers to be the 'desired' condition of ecosystems -- the 'health' of ecosystems . . . . We all favor healthy ecosystems; we differ on what we mean by healthy" (pp. 112). This type of information is necessary for adaptive management in this setting because the Draft Report acknowledges that a restored Everglades " . . . will be different from any former version of the Everglades . . . It will be a new Everglades" (Draft Report, pp. 18 - 19). If adaptive management of restoration is dependent on both scientific and normative judgments, then some part of the monitoring, evaluation, and feedback process must include assessments of public values and expectations and *changes in these variables over time*. This type of accountability extends well beyond the usual concerns with being "on-time and on-budget" to address the fundamental rationale for ecosystem management in a democratic society (National Research Council, 1996).

CAN ADAPTIVE MANAGEMENT OF THE EVERGLADES SUCCEED?

The reader should not construe these remarks as a criticism of the recommended plan. In fact, it is remarkable that the Restudy Team was able to accomplish as much as it did given that the Corps' initial request for six years to prepare the feasibility report was reduced to three years by Congress (Vogel, pp. 90). Moreover, the Report acknowledges that, "The Comprehensive Plan has a level of detail and analysis sufficient for plan selection and cost estimating, but it is not as refined as traditional recommendations to Congress for construction authorization" (Draft Report, pp. 10-9).

These remarks and observations serve to illustrate, however, the difficulty of applying the adaptive ecosystem management paradigm to deal with uncertainty in a complex policy setting. Adaptive ecosystem management of the Everglades/South Florida restoration offers a unique opportunity for coordinated federal and state administration and for collaborative research between natural and social scientists. Clearly there is a need for more integration between natural and social scientists and planners to facilitate the adaptive management process.

Some progress has occurred, but many of the same issues raised in this article were also cited in an April 1996 workshop designed to evaluate alternative indicators of ecological and social responses to the restoration effort (Gentile, pp. viii). A committee of the Task Force has developed recommendations for future social science research (Social Science Sub-group) but there is no plan as of this date to specify *if* or *how* this research would be used in adaptive management.

The lack of substantive interaction between natural and social scientists in the Everglades/South Florida ecosystem management project is not surprising. The usual factors that hinder interactions such as differing disciplinary perspectives, limited social science staffing in natural resource management agencies, and a lack of tangible personal incentives for nonagency scientists (National Research Council, pp. 42 - 45) are all present in this setting as they have been throughout much of the history of water planning in the U.S. (Reuss). But even the Corps of Engineers, which has a unique mixture of natural and social scientists and has an important stake in the success of adaptive management (Shabman), has not defined a plan or protocol to implement an adaptive management process. And, given that the Restudy's recommended plan must receive Congressional approval and funding, it is not clear what standards Congress will accept for an adaptive management strategy for ecosystem restoration.

The enduring appeal of ecosystem management and the adaptive management process is that it provides a rational basis for scientists to help managers cope with the inherent lack of knowledge and uncertainty in natural resource management. Indeed, for the South Florida ecosystem the Corps of Engineers has recognized that, "The future Kissimmee River, Lake Okeechobee, Everglades, Big Cypress, and Florida Bay ecosystems can be, to some extent, what we want them to be, based on our value systems, and our decisions about what conditions and components constitute a restored ecosystem" (U.S. Army Corps of Engineers, 1994, Vol. 1, pp. 109). As this experiment in ecosystem restoration unfolds, the extent to which the South Florida Ecosystem Restoration Task Force articulates a clear adaptive management strategy and achieves substantive collaboration between natural and social scientists and planners will strongly influence the success of adaptive ecosystem management as a framework for environmental policy in the U.S.

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ENDNOTES

1. Endpoints are quantitative indicators of ecosystem attributes that reflect biological and social relevance, are definable and measurable, and change in response to perturbations (Suter and Barnthouse, pp. 22 - 27).

2. Notable exceptions are Harwell *et al.*, Miller, and National Research Council (1995).

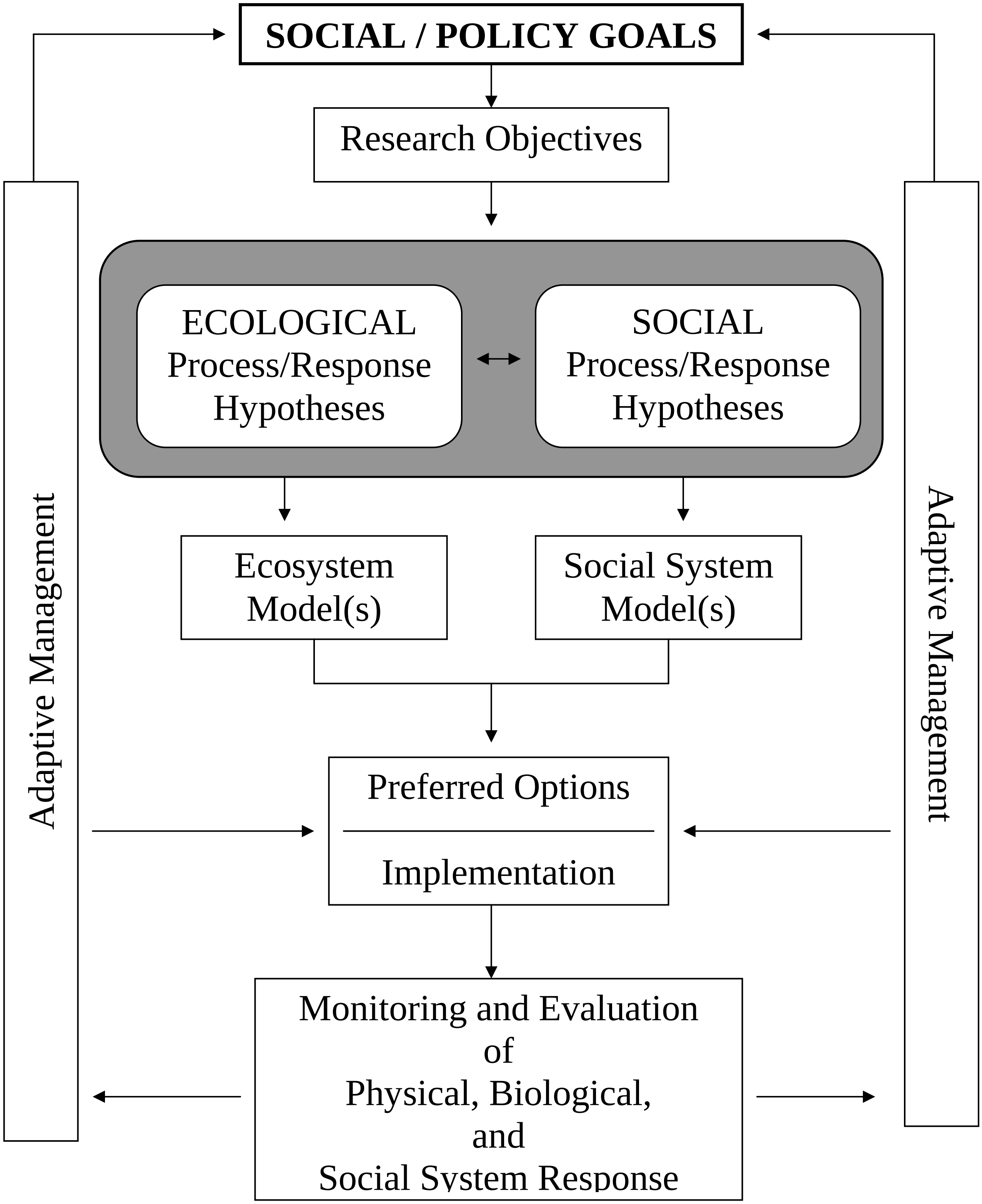

Figure 1. Natural and Social Science Research in an Adaptive Management Framework