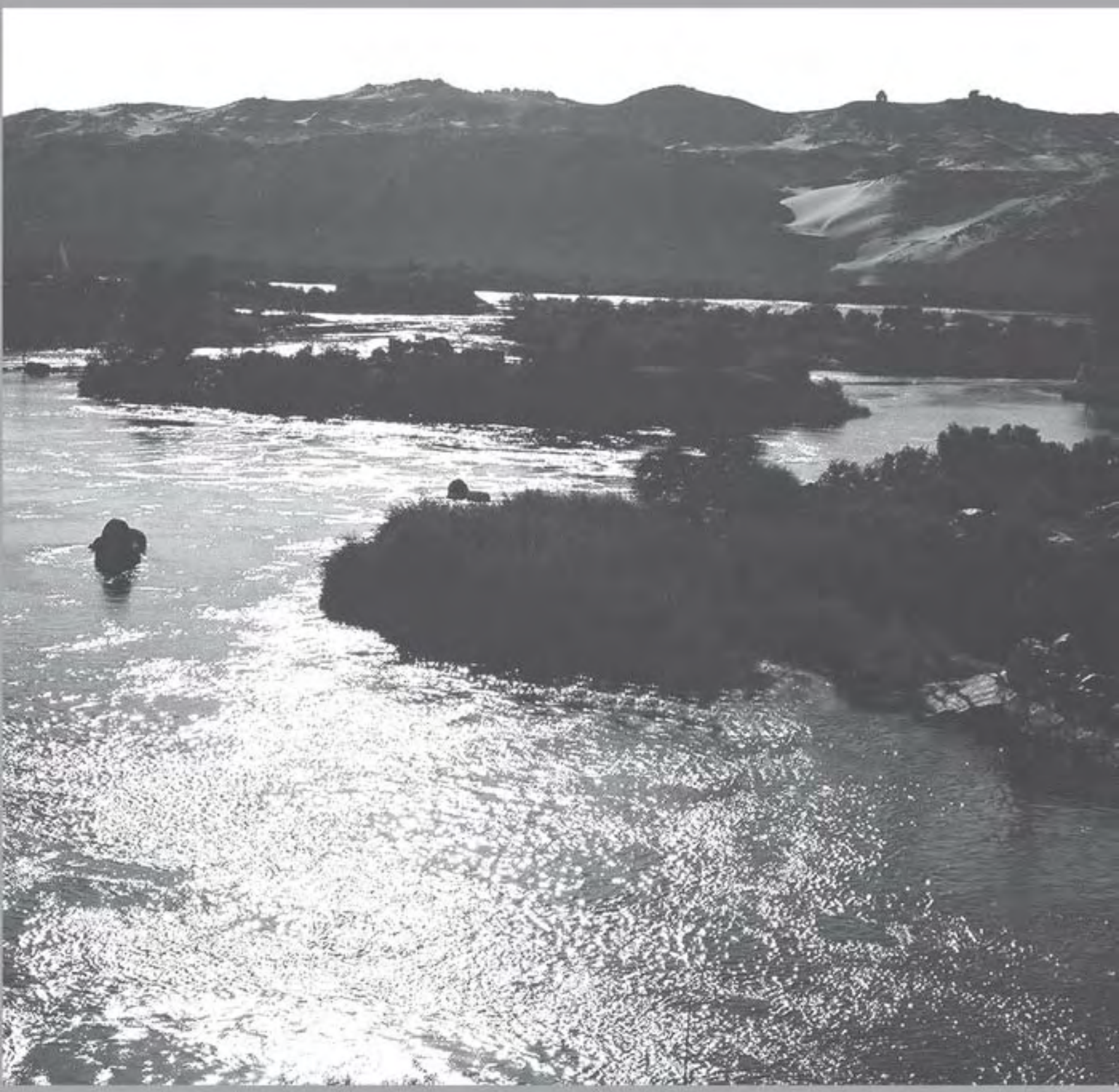
VALUING ECOSYSTEM SERVICES

TOWARD BETTER ENVIRONMENTAL DECISION-MAKING



NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

VALUING ECOSYSTEM SERVICES

TOWARD BETTER ENVIRONMENTAL DECISION-MAKING

Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems

Water Science and Technology Board

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

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COMMITTEE ON ASSESSING AND VALUING THE SERVICES OF AQUATIC AND RELATED TERRESTRIAL ECOSYSTEMS

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Preface

The development of the ecosystem services paradigm has enhanced our understanding of how the natural environment matters to human societies. We now think of the natural environment, and the ecosystems of which it consists, as natural capital—a form of capital asset that, along with physical, human, social, and intellectual capital, is one of society's important assets. As President Theodore Roosevelt presciently said in 1907,

> *The nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased and not impaired in value.*[1]

Economists normally value assets by the value of services that they provide: Can we apply this approach to ecological assets by valuing the services provided by ecosystems?

An ecosystem is generally accepted to be an interacting system of biota and its associated physical environment. Aquatic and related terrestrial ecosystems are among the most important ecosystems in the United States, and Congress through the Clean Water Act has recognized the importance of the services they provide and has shown a concern that these services be restored and maintained. Such systems intuitively include streams, rivers, ponds, lakes, estuaries, and oceans. However, most ecologists and environmental regulators include vegetated wetlands as aquatic ecosystems, and many also think of underlying groundwater aquifers as potential members of the set. Thus, the inclusion of "related terrestrial ecosystems" for consideration in this study is a reflection of the state of the science that recognizes the multitude of processes linking terrestrial and aquatic systems.

Many of the policies implemented by various federal, state, and local regulatory agencies can profoundly affect the nation's aquatic and related terrestrial ecosystems, and in consequence, these bodies have an interest in better understanding the nature of their services, how their own actions may affect them, and what value society places on their services. The need for this study was recognized in 1997 at a strategic planning session of Water Science and Technology Board (WSTB) of the National Research Council (NRC). The Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems was established by the NRC in early 2002 with support from the U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers

[1] Inscribed on the wall of the entrance hall of the American Museum of Natural History, Washington, D.C.

(USACE), and U.S. Department of Agriculture (USDA). Its members are drawn from the ranks of economists, ecologists, and philosophers who have professional expertise relating to aquatic ecosystems and the valuation of ecosystem services.

In drafting this report the committee members have sought to understand and integrate the disciplines, primarily ecology and economics, that cover the field of ecosystem service valuation. In fact, the committee quickly discovered that this is not an established field—ecologists have only recently begun to think in terms of ecosystem services and their determinants, while economists have likewise only very recently begun to incorporate the factors affecting ecosystem services into their valuations of these services. If we as a society are to understand properly the value of our natural capital, which is a prerequisite for sensible conservation decisions, then this growing field must be developed further and this report provides detailed recommendations for facilitating that development. Although the field is relatively new, a great deal is understood, and consequently the committee makes many positive conclusions and recommendations concerning the methods that can be applied in valuing the services of aquatic and related terrestrial ecosystems. Furthermore, because the principles and practices of valuing ecosystem services are rarely sensitive to whether the underlying ecosystem is aquatic or terrestrial, the report's various conclusions and recommendations are likely to be directly, or at least indirectly applicable to valuation of the goods and services provided by any ecosystem.

The study benefited greatly from the knowledge and expertise of those who made presentations at our meetings, including Richard Carson, University of California, San Diego; Harry Kitch, USACE; John McShane, EPA; Angela Nugent, EPA; Michael O'Neill, USDA; Mahesh Podar, EPA (retired); John Powers, EPA; Stephen Schneider, Stanford University; and Eugene Stakhiv, USACE Institute for Water Resources. The success of the report also depended on the support of the NRC staff working with the committee, and it is a particular pleasure to acknowledge the immense assistance of study director Mark Gibson and WSTB research associate Ellen de Guzman. Finally, of course, the committee members worked extraordinarily hard and with great dedication, expertise, and good humor in pulling together what was initially a rather disparate set of issues and methods into the coherent whole that follows.

This report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise in accordance with the procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report: Mark Brinson, East Carolina University, Greenville, North Carolina; J. Baird Callicott, University of North Texas, Denton; Nancy Grimm, Arizona State University, Tempe;

Michael Hanemann, University of California, Berkeley; Peter Kareiva, The Nature Conservancy, Seattle, Washington; Raymond Knopp, Resources for the Future, Washington, D.C.; Sandra Postel, Global Water Policy Project, Amherst, Massachusetts; and Robert Stavins, Harvard University, Cambridge.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by John Boland, Johns Hopkins University, Baltimore. Appointed by the National Research Council, he was responsible for making certain that an independent examination of the report was carefully carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the NRC.

Geoffrey M. Heal, *Chair*

Contents

Executive Summary

OVERVIEW

Ecosystems provide a wide variety of marketable goods, fish and lumber being two familiar examples. However, society is increasingly recognizing the myriad functions—the observable manifestations of ecosystem processes such as nutrient recycling, regulation of climate, and maintenance of biodiversity—that they provide, without which human civilizations could not thrive. Derived from the physical, biological, and chemical processes at work in natural ecosystems, these functions are seldom experienced directly by users of the resource. Rather, it is the services provided by ecosystems, such as flood risk reduction and water supply, together with ecosystem goods, that create value for human users and are the subject of this report.[1]

Aquatic ecosystems include freshwater, marine, and estuarine surface waterbodies. These incorporate lakes, rivers, streams, coastal waters, estuaries, and wetlands, together with their associated flora and fauna. Each of these entities is connected to a greater ecological and hydrological landscape that includes adjacent riparian areas, upland terrestrial ecosystems, and underlying groundwater aquifers. Thus, the term "aquatic ecosystems" in this report includes these related terrestrial ecosystems and underlying aquifers. Aquatic ecosystems perform numerous interrelated environmental functions and provide a wide range of important goods and services. Many aquatic ecosystems enhance the economic livelihood of local communities by supporting commercial fishing and agriculture and by serving the recreational sector. The continuance or growth of these types of economic activities is directly related to the extent and health of these natural ecosystems.

However, human activities, rapid population growth, and industrial, commercial, and residential development have all led to increased pollution, adverse modification, and destruction of remaining (especially pristine) aquatic ecosys-

[1] *Ecosystem structure* refers to both the composition of the ecosystem (i.e., its various parts) and the physical and biological organization defining how those parts are organized. A leopard frog or a marsh plant such as a cattail, for example, would be considered a component of an aquatic ecosystem and hence part of its structure. *Ecosystem function* describes a process that takes place in an ecosystem as a result of the interactions of the plants, animals, and other organisms in the ecosystem with each other or their environment. Primary production (the process of converting inorganic compounds into organic compounds by plants, algae, and chemoautotrophs) is an example of an ecosystem function. Ecosystem structure and function provide various *ecosystem goods* and *services* of value to humans such as fish for recreational or commercial use, clean water to swim in or drink, and various esthetic qualities (e.g., pristine mountain streams or wilderness areas) (see Box 3-1 for further information).

tems—despite an increase in federal, state, and local regulations intended to protect, conserve, and restore these natural resources. Increased human demand for water has simultaneously reduced the amount available to support these ecosystems. Notwithstanding the large losses and changes in these systems, aquatic ecosystems remain broadly and heterogeneously distributed across the nation. For example, there are almost 4 million miles of rivers and streams, 59,000 miles of ocean shoreline waters, and 5,500 miles of Great Lakes shoreline in the United States; there are 87,000 square miles of estuaries, while lakes, reservoirs, and ponds account for more than 40 million acres.

Despite growing recognition of the importance of ecosystem functions and services, they are often taken for granted and overlooked in environmental decision-making. Thus, choices between the conservation and restoration of some ecosystems and the continuation and expansion of human activities in others have to be made with an enhanced recognition of this potential for conflict and of the value of ecosystem services. In making these choices, the economic values of the ecosystem goods and services must be known so that they can be compared with the economic values of activities that may compromise them and so that improvements to one ecosystem can be compared to those in another.

This report was prepared by the National Research Council (NRC) Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems, overseen by the NRC's Water Science and Technology Board, and supported by the U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, and the U.S. Department of Agriculture (see Box ES-1). The committee consisted of 11 volunteer experts drawn from the fields of ecology, economics, and philosophy who have professional expertise relating to aquatic ecosystems and to the valuation of ecosystem services. This report's contents, conclusions, and recommendations are based on a review of relevant technical literature, information gathered at five committee meetings, and the collective expertise of committee members. Because of space limitations, this Executive Summary includes only the major conclusions and related recommendations of the committee in the general order of their appearance in the report. More detailed conclusions and recommendations can be found throughout the report.

Valuing ecosystem services requires the successful integration of ecology and economics and presents several challenges that are discussed throughout this report. The fundamental challenge of valuing ecosystem services lies in providing an explicit description and adequate assessment of the links between the structures and functions of natural systems, the benefits (i.e., goods and services) derived by humanity, and their subsequent values (see Figure ES-1).

Ecosystems are complex however, making the translation from ecosystem structure and function to ecosystem goods and services (i.e., the ecological production function) is even more difficult. Similarly, in many cases the lack of markets and market prices and of other direct behavioral links to underlying values makes the translation from quantities of goods and services to value (and the direct translation from ecosystem structure to value) quite difficult, though

BOX ES-1
Statement of Task

The committee will evaluate methods for assessing services and the associated economic values of aquatic and related terrestrial ecosystems. The committee's work will focus on identifying and assessing existing economic methods to quantitatively determine the intrinsic value of these ecosystems in support of improved environmental decision-making, including situations where ecosystem services can be only partially valued. The committee will also address several key questions, including:

- What is the relationship between ecosystem services and the more widely studied ecosystem functions?
- For a broad array of ecosystem types, what services can be defined, how can they be measured, and is the knowledge of these services sufficient to support an assessment of their value to society?
- What lessons can be learned from a comparative review of past attempts to value ecosystem services—particularly, are there significant differences between eastern and western U.S. perspectives on these issues?
- What kinds of research or syntheses would most rapidly advance the ability of natural resource managers and decision makers to recognize, measure, and value ecosystem services?
- Considering existing limitations, error, and bias in the understanding and measurement of ecosystem values, how can available information best be used to improve the quality of natural resource planning, management, and regulation?

both are given by an economic valuation function. Probably the greatest challenge for successful valuation of ecosystem services is to integrate studies of the ecological production function with studies of the economic valuation function. To do this, the definitions of ecosystem goods and services must match across studies. Failure to do so means that the results of ecological studies cannot be carried over into economic valuation studies. Attempts to value ecosystem services without this key link will either fail to have ecological underpinnings or fail to be relevant as valuation studies.

Where an ecosystem's services and goods can be identified and measured, it will often be possible to assign values to them by employing existing economic valuation methods. The emerging desire to measure the environmental costs of human activities, or to assess the benefits of environmental protection and restoration, has challenged the state of the art in environmental evaluation in both the ecological and the social sciences. Some ecosystem goods and services cannot be valued because they are not quantifiable or because available methods are not

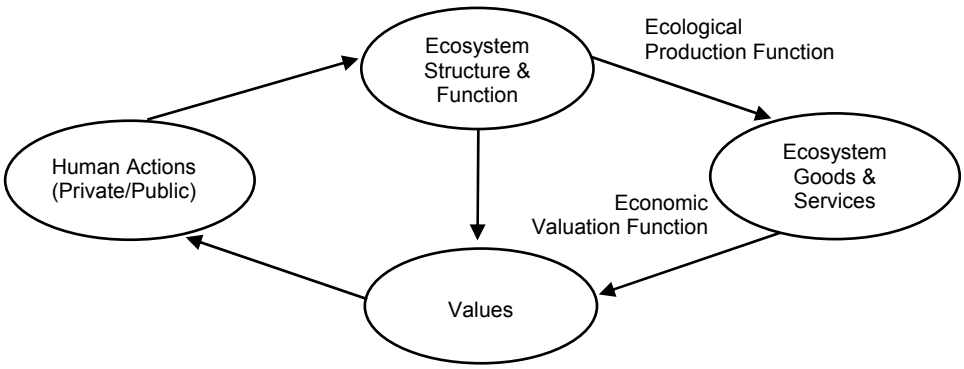

FIGURE ES-1 Components of ecosystem valuation: ecosystem structure and function, goods and services, human actions, and values. (See Figure 7-1 for an expanded version of this figure.)

appropriate or reliable. Economic valuation methods can be complex and demanding, and the results of applying these methods may be subject to judgment, uncertainty, and bias. However, based on an assessment of a very large literature on the development and application of various economic valuation methods, the committee concludes that they are mature and capable of providing useful information in support of improved environmental decision-making.

From an ecological perspective, the challenge is to interpret basic research on ecosystem functions so that service-level information can be communicated to economists. For economic and related social sciences, the challenge is to identify the values of both tangible and intangible goods and services associated with ecosystems and to address the problem of decision-making in the presence of partial valuation. The combined challenge is to develop and apply methods to assess the values of human-induced changes in ecosystem functions and services.

Finally, this report concerns valuing the goods and services that ecosystems provide to human societies, with principal focus on those provided by aquatic and related terrestrial ecosystems. However, because the principles and practices of valuing ecosystem goods and services are rarely sensitive to whether the underlying ecosystem is strictly aquatic or terrestrial, many of the report's conclusions and recommendations are likely to be directly or at least indirectly applicable to the valuation of goods and services provided by any ecosystem.

THE MEANING OF VALUE AND USE OF ECONOMIC VALUATION IN THE ENVIRONMENTAL POLICY DECISION-MAKING PROCESS

In order to develop a perspective on valuing aquatic ecosystems, it is necessary to first provide a clear discussion and statement of what it means to value something and of the role of "valuation" in environmental policymaking. In this regard, environmental issues and ecosystems have been at the core of many recent philosophical discussions regarding value (see Chapter 2). Fundamentally, these debates about the value of ecosystems derive from two points of view. The first is that the values of ecosystems and their services are nonanthropocentric and that nonhuman species have moral interests or rights unto themselves. The other, which includes the economic approach to valuation, is that all values are anthropocentric. This report focuses on the sources of value that can be captured through economic valuation.[2] However, the committee recognizes that all forms of value may ultimately contribute to decisions regarding ecosystem use, preservation, or restoration.

Although economic valuation does not capture all sources or types of value (e.g., intrinsic values on which the notion of rights is founded), it is much broader than usually presumed. It recognizes that economic value can stem from the use of an environmental resource (use values), including both commercial and noncommercial uses, or from its existence even in the absence of use (nonuse value). The broad array of values included under this approach is captured by using the total economic value (TEV) framework to identify potential sources of this value. Use of the TEV framework helps to provide a checklist of potential impacts and effects that need to be considered in valuing ecosystem services as comprehensively as possible. By its nature, economic valuation involves the quantification of values based on a common metric, normally a monetary metric. The use of a dollar metric for quantifying values is based on the assumption that individuals are willing to trade the ecological service being valued for more of other goods and services represented by the metric (more dollars). Use of a monetary metric allows measurement of the costs or benefits associated with changes in ecosystem services.

The role of economic valuation in environmental decision-making depends on the specific criteria used to choose among policy alternatives. If policy choices are based primarily on intrinsic values, there is little need for the quantification of values through economic valuation. However, if policymakers consider trade-offs and benefits and costs when making policy decisions, then quantification of the value of ecosystem services is essential. Failure to include some measure of the value of ecosystem services in benefit-cost calculations will implicitly assign them a value of zero. The committee believes that considering

[2] Unless otherwise noted, use of the terms "value," "valuing," or "valuation" refers to economic valuation, more specifically, the economic valuation of ecosystem goods and services.

the best available and most reliable information about the benefits of improvements in ecosystem services or the costs of ecosystem degradation will lead to improved environmental decision-making. The committee recognizes, however, that this information is likely to be only one of many possible considerations that influence policy choice.

The benefit and cost estimates that emerge from an economic valuation exercise will be influenced by the way in which the valuation question is framed. In particular, the estimates will depend on the delineation of changes in ecosystem goods or services to be valued, the scope of the analysis (in terms of both the geographical boundaries and the inclusion of relevant stakeholders), and the temporal scale. In addition, the valuation question can be framed in terms of two alternative measures of value, willingness to pay (WTP) and willingness to accept (compensation) (WTA). These two approaches imply different presumptions about the distribution of property rights and can differ substantially, depending on the availability of substitutes and income limitations. In many contexts, methodological limitations necessitate the use of WTP rather than WTA.

Finally, because ecosystem changes are likely to have long-term impacts, some accounting of the timing of impacts is necessary. This can be done through discounting future costs and benefits. It is essential, however, to recognize that consumption discounting is distinct from the discounting of utility, which reflects the weights put on the well-being of different generations.

Based on these conclusions, the committee makes the following recommendations (Chapter 2):

- Policymakers should use economic valuation as a means of evaluating the trade-offs involved in environmental policy choices; that is, an assessment of benefits and costs should be part of the information set available to policymakers in choosing among alternatives.
- If the benefits and costs of a policy are evaluated, the benefits and costs associated with changes in ecosystem services should be included along with other impacts to ensure that ecosystem effects are adequately considered in policy evaluation.
- Economic valuation of changes in ecosystem services should be based on the comprehensive definition embodied in the TEV framework; both use and nonuse values should be included.
- The valuation exercise should be framed properly. In particular, it should value the *changes* in ecosystem good or services attributable to a policy change.
- In the aggregation of benefits and/or costs over time, the consumption discount rate, reflecting changes in scarcity over time, should be used instead of the utility discount rate.

AQUATIC AND RELATED TERRESTRIAL ECOSYSTEMS

An ecosystem is generally accepted to be an interacting system of biota and its associated physical environment; ecologists tend to think of these systems as identifiable at many different scales with boundaries selected to highlight internal and external interactions. The phrase "aquatic and related terrestrial ecosystems" recognizes the impossibility of analyzing aquatic systems absent consideration of the linkages to adjacent terrestrial environments. For many of the ecosystem functions and derived services considered in this report, it is not possible, necessary, or appropriate to delineate clear spatial boundaries between aquatic and related terrestrial systems (see also Box 3-1). Indeed, to the extent there is an identifiable boundary, it is often dynamic in both space and time.

The conceptual challenges of valuing ecosystem services are explicit description and adequate assessment of the link between the structure and function of natural systems and the goods or services derived by humanity (see Figure ES-1). Describing structure is a relatively straightforward process, even in highly diverse ecosystems. However, ecosystem functions are often difficult to infer from observed structure in natural systems. Furthermore, the relationship between structure and function, as well as how these attributes respond to disturbance, are not often well understood. Without comprehensive understanding of the behavior of aquatic systems, it is clearly difficult to describe thoroughly all of the services these systems provide society. Although valuing ecosystem services that are not completely understood is possible (see more below), when valuation becomes an important input in environmental decision-making, there is the risk that it may be incomplete.

There have only been a few attempts to develop explicit maps of the linkage between aquatic ecosystem structure/function and value. There are, however, a multitude of efforts to separately identify ecosystem functions, goods, services, values, and/or other elements in the linkage, without developing a comprehensive argument. One consequence of this disconnect is a diverse literature that suffers somewhat from indistinct terminology, highly variable perspectives, and considerable, divergent convictions. However, the development of an interdisciplinary terminology and a universally applicable protocol for valuing aquatic ecosystems was ultimately identified by the committee as unnecessary. From an ecological perspective, the value of specific ecosystem functions/services is entirely relative. The spatial and temporal scales of analysis are critical determinants of potential value. Ecologists have described the structure and function of most types of aquatic ecosystems qualitatively, and general concepts regarding the linkages between ecosystem function and services have been developed. Although precise quantification of these relationships remains elusive, the general concepts seem to offer sufficient guidance for valuation to proceed with careful attention to the limitations of any ecosystem assessment. Further integration of economics and ecology at both intellectual and practical scales will improve ecologists' ability to provide useful information for assessing and valuing aquatic ecosystems.