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***Valuing the Protection of Ecological Systems and Services:***
***An Expanded and Integrated Approach***

# 1.INTRODUCTION

## 1.1 EPA's Mission Regarding Ecosystem Protection

The Environmental Protection Agency's (EPA's) mission is to protect human health and the environment. During its history, the EPA has focused decision making and much of its expertise on the first part of this mission, in particular the risks to human health from chemical stressors in the environment. Although protecting human health is the bedrock of the EPA's traditional expertise, the broad mission of the EPA goes beyond this. In fact, EPA's Strategic Plan explicitly identifies the need to ensure "healthy communities and ecosystems" as one of its five major goals (U.S Environmental Protection Agency 2003) and EPA's efforts in protecting ecological resources--and its authority for doing so-- have been documented in Agency publications and independent historical sources (U.S. Environmental Protection Agency 1994); U.S. Environmental Protection Agency Risk Assessment Forum 2003, (U.S. Environmental Protection Agency Science Advisory Board 2000), (Hays 1989); (Russell III 1993).

EPA's mission to protect the environment requires attention to ecological systems to ensure the wise and thoughtful use and protection of our environment. An "ecosystem" is the term used by ecologists to describe living organisms plus their physical environment working together. Trees alone make a forest, whereas trees plus soil plus streams make a forest ecosystem. Ecosystems provide basic life support for human and animal populations and are the source of spiritual, aesthetic and other human experiences that are valued by many. EPA's mission to protect the environment includes protection of ecosystems because of the services they provide and because of values held by Americans to protect the environment they have inherited.

Given the important role that ecosystems play in supporting life on earth and providing goods and services that people value, changes in the state of these systems or the flow of services they provide can have important implications. Many EPA actions (e.g., regulations, rules, programs, policy decisions) affect the condition of the

environment and the flow of ecological services from it. EPA actions can lead to improvement or deterioration of ecosystems or prevent degradation that would otherwise have occurred. These impacts can occur both at a relatively small, local scale as well as more broadly at a national scale.

Despite their importance, to date, ecological impacts have received relatively limited consideration in EPA policy analyses. EPA's ecological analysis has generally focused primarily on ecological endpoints such as those identified by tests required for pesticide regulation (e.g., effects on survival, growth, and reproduction of aquatic invertebrates, fish, birds, mammals, and both terrestrial and aquatic plants) or mortality to fish, birds, and plants and, more generally, animals, wildlife, aquatic life, as required by provisions of several laws[1] administered by the Agency (U.S. Environmental Protection Agency Risk Assessment Forum 2003). However, there is a need to go beyond this when considering the ecological impacts of EPA decisions and actions to consider the full range of possible impacts and their implications for the condition and functioning of the associated ecosystems. Failure to consider ecological impacts as fully as possible can lead to distorted policy decisions. This can occur, for example, when actions are evaluated based primarily on their impacts on human health, without adequate recognition of potentially important ecosystem impacts.

### 1.2 Scope of this Report and its Intended Audience

Despite EPA's stated mission and mandates, there is a gap between the need for protection of ecological systems and services and EPA's ability to address this need. This report is a step toward filling that gap. It describes how an integrated and expanded approach for valuation of ecological systems and services can help the Agency describe and measure the value of protecting ecological systems and services. It was prepared by the Committee on Valuing the Protection of Ecological Systems and Services (C-VPESS), which was formed by EPA's Science Advisory Board (SAB). The SAB saw a need to complement the Agency's ongoing work in ecological science, ecological risk assessment, and ecological benefit assessment by offering advice on how EPA might

better value the protection of ecological systems and services and how that information might better support decision making to protect ecological resources. Toward this end, it formed C-VPESS, an interdisciplinary group of experts from the following areas: decision science, ecology, economics, engineering, philosophy, psychology, and social sciences with emphasis on ecosystem protection.[2] C-VPESS began its work in 2003 on a project designed to strengthen the Agency's analysis for protecting ecological resources. The purpose of science advice on ecological valuation is to strengthen the Agency's knowledge and set of analytical tools to help navigate difficult trade-offs that inevitably arise when regulatory or other decisions must be made to protect ecological resources. In this project the SAB set the goals of: a) assessing Agency needs and the state of the art and science of valuing protection of ecological systems and services and b) identifying key areas for improving knowledge, methodologies, practice, and research at EPA. Senior EPA managers supported the concept of this SAB project and participated in the initial background workshop that launched the work of the C-VPESS.

This report provides an overview of the committee's initial conclusions.[3] It provides initial advice for strengthening the Agency's approaches for valuing the protection of ecological systems and services, facilitating their use by decision makers, and identifying the key research areas needed to strengthen the science base. The committee will prepare additional reports with more detailed advice at the completion of the project.[4] However, given the importance of the committee's charge, it felt that it would be useful to the Agency to issue a report that would indicate the direction that the committee's work is taking and serve as a prelude to the subsequent committee report(s). These subsequent reports will further develop the concepts in this initial advisory report and provide more detailed discussion of issues, methods, and application. In particular, they will describe in more detail how different methods could be used to understand the benefits of the protection of ecological systems and services and how results of analyses could be better integrated and communicated to decision-makers.

This initial report focuses on the need for an expanded and integrated approach for valuing EPA's efforts to protect ecological systems and services. It provides advice to

the Administrator, EPA managers, EPA scientists and analysts, and EPA staff across the Agency concerned with ecological protection. It adopts a broad view of EPA's work, which it understands to encompass national rulemaking, regional decision making, and programs in general that protect ecological systems and services. It outlines a call for EPA to expand and integrate its approach in important ways.

This report appears at a time when there is lively interest internationally, nationally, and at EPA itself in the issue of valuing the protection of ecological systems and services. Since the establishment of the SAB C-VPESS major reports have been developed focusing on how to improve the characterization of the important role of ecological resources (Millennium Ecosystem Assessment Board 2003; Silva and Pagiola 2003; National Research Council 2004; Pagiola, von Ritter et al. 2004; Millennium Ecosystem Assessment 2005). The committee's work has benefited from and will build upon those recent efforts. The C-VPESS distinguishes its work from those efforts, however, in the following ways. The C-VPESS focuses on EPA as an audience for its work. In particular, it focuses on how EPA can value its own contributions to the protection of ecological systems and services, so that the agency can make better decisions in its eco-protection programs. The C-VPESS is inter-disciplinary and does not focus solely on economic methods or values. The committee will offer advice on several approaches to characterizing or estimating values and in each case will emphasize issues relevant to EPA policy and decision-making and address how the Agency could better represent the value of ecological protection.

# 2 AN OVERVIEW OF KEY CONCEPTS

## 2.1 The Concept of Ecosystem Services

The term "ecosystem" describes a dynamic complex of plant, animal, and microorganism communities and the non-living environment, interacting as a unit. For example, ecosystems can describe organism-physical environment interactions in a woodlot, a watershed, or a larger landscape. Ecosystems encompass all organisms within the prescribed area, including humans, who are often the dominant element. Ecosystem "functions" or "processes" are the characteristic physical, chemical, and biological activities that influence the flows, storage, and transformation of materials and energy within and through ecosystems (U.S Environmental Protection Agency 2004). These include processes that link organisms with their physical environment (e.g., primary productivity and the cycling of nutrients and water) and processes that link organisms with each other, indirectly influencing flows of energy, water and nutrients (e.g., such as pollination, predation and parasitism). These processes in total describe the functioning of ecosystems.

"Ecosystem services" is an anthropocentric concept denoting the contributions that ecosystems make to people either directly or indirectly. In popular terminology these contributions are sometimes labeled the "benefits" that humans derive from ecosystems.[5] The following operational categorization of ecosystem services has recently been proposed by the Millennium Ecosystem Assessment:[6]

a) Provisioning services (products obtained from ecosystems). These include food, fuelwood, fiber, biochemicals, genetic resources and fresh water. Generally these services are traded in the open marketplace.

b) Regulating services (benefits received from regulation of ecosystem processes). This category includes a host of pathways that stem from the presence and functioning of ecosystems and influence people in positive ways, both direct and indirect.

These include flood protection, human disease regulation, water purification, air quality maintenance, pollination, pest control and climate control. These services are generally not marketed but many have clear value to society and this value will increase for many of these services as the many dimensions of global change proceed.

c) Cultural services (the nonmaterial benefits people obtain from ecosystems). Ecosystems contribute to the cultural, spiritual and aesthetic dimensions of people's well-being. They also contribute to establishing a sense of place.

d) Supporting services**.** These are the processes that maintain ecosystem functioning such as: soil formation, primary productivity, biogeochemistry, and provisioning of habitat. They all affect human well-being, but generally indirectly through their support of the provisioning, regulating and cultural service functions.

This categorization suggests a very broad definition of services, limited only by the requirement of a contribution (direct or indirect) to human well-being. This broad approach reflects the need to recognize the myriad ways in which ecosystems support human life and contribute to human well-being. However, in the context of ecological valuation, the inclusion of both direct and indirect contributions creates the potential for double-counting. For example, for an ecological change that increased pollination, it would be double-counting to value *both* the improved pollination process (as an improved ecosystem service) *and* the increased agricultural output that results from it (as a separate service). Doing so would be akin to valuing both the parts that went into production of an automobile and the final product, the automobile, itself. Thus, in identifying ecosystem services to be valued, it is important to distinguish functions or processes that are inputs into the production of another ecological service and avoid double counting of the value of both the intermediate service and the final service.

Thinking in terms of ecosystem services provides an approach to evaluating the effect of ecological changes induced by human actions in terms of the resulting effect on human well-being. The process of listing ecosystem services helps ensure consideration

of the myriad ways in which ecosystems contribute to human well-being. However, ecosystems can be valued for reasons that are independent of human well-being. As discussed below, the committee recognizes that ecosystems can be important not only because of the services they provide directly or indirectly but also for other non-anthropocentric reasons, including respect for nature based on moral, religious, or spiritual beliefs and commitments.

## 2.2 The Concept of Value

Because only people define values, all values are *anthropogenic*. However, there is disagreement about whether the ultimate goal of all values is to promote human well-being, so there is disagreement about whether all values are *anthropocentric*. When people talk about environmental values, the values of nature, or the values of ecological systems and services, they may have different things in mind. People have moral, economic, religious, aesthetic, and other interests, all of which can affect their thoughts, attitudes, and actions toward nature in general and, more specifically, toward ecosystems and the services they provide.

The most basic philosophical distinction in values is the distinction between means and ends. To value something as a mean is to value it for its usefulness in helping to realize or bring about some thing or state of affairs that is valued in its own right or as an end. Things valued for their usefulness as means in this sense are said to have instrumental value. Of course, it would not make sense to value anything instrumentally or as a means unless there was at least one thing or state that was valued for its own sake or as an end. Things valued as ends are sometimes said to have intrinsic value.[7] If intrinsic value applies to things other than human beings or human experiences, then this conception of value is non-anthropocentric. Some people defend a non-anthropocentric conception of value or goodness (Goodpaster 1978; Taylor 1986; Rolston III 1991). However, others argue that only human beings or human experiences have intrinsic value, thereby defending an anthropocentric conception of intrinsic value (Sidgwick 1901; Glover 1984; Williams 1994).

Some people also claim that the very existence of a species or ecological system has value in addition to any instrumental value derived from the usefulness of the services it provides. This claim can mean several different things. If it means that the existence of an ecological system is valuable because people derive satisfaction from its existence independent of specific uses they may make of its services, then it has what economists call "*existence value*." This concept is anthropocentric. In addition, this value can been viewed as a kind of instrumental value, since it is based on the premise that the existence of the species or ecological system is one of many things that generate human satisfaction, and that the various things that contribute to human satisfaction are potentially substitutable or commensurable. In contrast, some people claim that an ecological system may have intrinsic value of its own, and hence its existence is valuable for its own sake. If the explanation of this claim refers to reasons that are independent of the contribution that the existence of the ecological system can make to human well-being, then as noted above this is a claim that the ecosystem or one or more of its components has a non-anthropocentric intrinsic value.

This committee recognizes that there are many possible sources of value derived from ecosystems and the services they provide. To reflect this, throughout this report, the term "value" is used broadly to include values that stem from contributions to human well-being as well as values that reflect other considerations, such as social and civil norms (including rights) and moral, religious, and spiritual beliefs and commitments. As distinct from the broader concept of value, in this report we use the term "benefit" to refer more narrowly to the contribution of ecosystems and their services to human well-being. As such, benefits include only anthropocentric sources of value. In addition, throughout the report benefits are defined relative to changes in the state of an ecosystem or the flow of services it provides stemming from an actual or proposed action by EPA. Thus, the term "ecosystem benefits" refers to the positive contribution to human well-being of a change in an ecological system and/or its services. A negative contribution, for example from damages to an ecosystem, can be viewed as a "negative benefit" or cost. Similarly, the term "valuation" will refer to the process of estimating or measuring either the value of, or the value of a change in, an ecosystem, its components, or the

services it provides. Table 1 provides a summary of the usage of key terms throughout this report.

## Table 1

## Usage of Terms

For purposes of this report, the following terms are used as indicated:

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| **Ecosystem**: A dynamic complex of plant, animal, and microorganism communities and the non-living environment, interacting as a unit. |
| **Ecosystem functions or processes**: The characteristic physical, chemical, and biological activities that influence the flows, storage, and transformation of materials and energy within and through ecosystems. These include processes that link organisms with their physical environment, (e.g., primary productivity and the cycling of nutrients and water) and processes that link organisms with each other (e.g., pollination, predation, and parasitism). |
| **Ecosystem Services**: Those ecological characteristics, functions or processes that directly or indirectly contribute to the well-being of human populations or have the potential to do so in the future. |
| **Value**: This term is used broadly to include well-being; social and civil norms, including rights; and moral, religious, aesthetic, and spiritual beliefs and commitments. |
| **Valuation**: The process of estimating or measuring either the value of, or the value of a change in, an ecosystem, its components, or the services it provides. |
| **Valuation Method**: A methodology, based on theory and data, for estimating or measuring the value of, or the value of a change in, an ecosystem, its components or the services it provides. |
| **Monetary Valuation**: Valuation in which estimates are expressed in monetary units. |
| **Non-monetary Valuation**: Valuation in which estimates are expressed in non-monetary terms. |
| **Benefits**: The contribution of ecosystems and their services to human well-being and satisfaction. |
| **Economic Valuation Methods**: Methods that estimate the tradeoffs individuals are willing to make for improvements in, or to avoid degradation of, an ecosystem, its components, or the services it provides. These approaches typically focus on the amount of money an individual is willing to forgo or pay to enjoy a particular positive change (willingness-to-pay) or the amount of monetary compensation a person would accept in lieu of receiving that change (willingness to accept). This includes benefits derived from both use and non-use values. |
| **Social-Psychological Valuation Methods**: Methods that focus on individuals' judgments of the relative importance of, acceptance of or preferences for changes in ecosystems, their components, or the services they provide, typically focusing on choices or ratings among alternatives. Individuals making the judgments may respond on their own behalf or on behalf of others (society at large or specified sub-groups) and the basis for judgments may be changes in individual welfare, or civic or ethical/moral obligations relevant to ecosystems and ecosystem services. |

There are a number of methods that can be used for estimating or measuring values. In some cases, these methods lead to estimates that are expressed in monetary units ("monetary valuation"), while in other cases estimates are expressed in non-monetary terms ("non-monetary valuation"). In addition, these methods differ in their focus and, in some cases, their underlying premises. For example, economic valuation measures benefits by estimating the tradeoffs individuals are willing to make for ecological improvements or to avoid ecological degradation. These approaches typically estimate values (including existence values) in monetary units that measure the amount of money an individual is willing to pay to enjoy a particular positive change (willingness-to-pay) or the amount of monetary compensation a person would accept in lieu of receiving that change (willingness to accept). [8] Alternatively, social-psychological methods for valuation focus on individuals' judgments of the relative importance of, acceptance of, or preferences for ecological changes. These approaches typically focus on choices or ratings among sets of alternative policies, and may include comparisons with potentially competing social and economic goals. Individuals making the judgments may respond on their own behalf or on behalf of others (society at large or specified sub-groups) and the basis for judgments may be changes in individual well-being, or civic or ethical/moral obligations relevant to ecosystems and ecosystem services. Similarly, assessment methods based on voting or other group expressions of social/civic values provide information about human values revealed through these processes. The committee plans to discuss in a future report how these and other possible valuation methods might be used by analysts and decision makers at EPA to capture different kinds of ecological values.

## 2.3 The Concept of Ecological Valuation

As noted above, "valuation" is the process of estimating or measuring either the value of, or the value of a change in, an ecosystem, its components, or the services it provides. The committee is focusing on valuation in EPA contexts where there is an environmental protection decision to be made. The major components of ecological valuation are depicted in Figure 1.

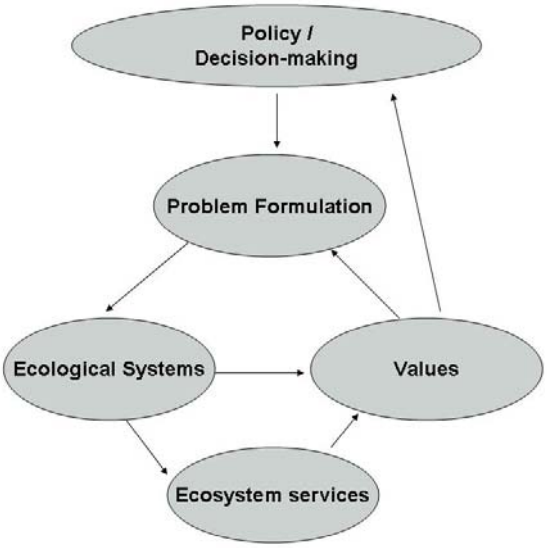


**Figure 1. Components of Ecological Valuation**

Some of the components of ecological valuation parallel components of the ecological risk framework the underlies the ecological risk guidelines developed by EPA to support decision making to protect ecological resources (U.S. Environmental Protection Agency Risk Assessment Forum 1992; U.S. Environmental Protection Agency Risk Assessment Forum 1998). The committee views ecological valuation as a complement to ecological risk assessment. Both begin with an EPA decision or policy context for which information about ecological effects is needed. This leads to a formulation of the problem and identification of the purpose and objectives of the analysis and the policy options that will be considered. In addition, both ecological risk assessment and ecological valuation involve prediction and estimation of possible ecological effects of the EPA action or decision that is under consideration. However, ecological valuation goes beyond ecological risk assessment in an important way. Risk assessments typically focus on predicting the magnitudes and likelihoods of possible adverse effects on species, populations, locations, etc., but do not provide information about the societal importance or significance of these effects. In contrast, as depicted in

Figure 1, ecological valuation takes the predicted ecological effects and seeks to characterize their importance to society by providing information on the value society places on the ecological improvements or the loss they experience from ecological degradation. As noted above, these values can reflect either changes in the flow of services provided by the ecosystem or values that are attached directly to the ecosystem itself that are independent of its contribution to human well-being. Information about these values is an important input in the evaluation of alternative decisions or policy options.

# 3 ECOLOGICAL VALUATION AT EPA

There are several different contexts in which EPA policy decisions result in ecological impacts and hence in which the need for ecological valuation will arise. In addition, EPA operates within a set of institutional, legal, organizational and practical constraints that affect this process at the Agency. Thus, EPA has specific needs in this regard that must be recognized and addressed. These needs arise in different parts of the Agency for different purposes and for different audiences. Some of the needs present structured requirements for valuing protection of ecological systems and services, while needs in other contexts are less prescriptive.

## 3.1 Policy Contexts at EPA Where Ecological Valuation Can be Important

There are at least three policy contexts in which information about the value of ecological systems and services could be very useful to EPA: a) national rule-making; b) regional decision-making; and c) program assessment and evaluation.

Benefit assessments are required for national rulemaking by two of EPA's governing statutes (the Toxic Substances Control Act and the Federal Insecticide, Fungicide and Rodenticide Act) and by Executive Order 12866 for "significant regulatory actions." The circular on "Regulatory Analysis" issued by the Office of Management and Budget (OMB) in September 2003, *OMB Circular A*-4, identified key elements of a regulatory analysis for such "economically significant rules." One of these elements is an evaluation of the benefits and costs of a proposed regulatory action and the main alternatives identified. The circular contains general guidance on how to provide monetized, quantitative, and qualitative information to characterize benefits as fully as possible, and EPA itself has developed initial guidance for ecological benefit assessment (U.S. Environmental Protection Agency 2000). In developing its 2004 draft *Ecological Benefits Assessment Strategic Plan*, EPA identified the need for improved models and methods to help implement the requirements of the circular as they relate to ecological

valuation. The Agency identified needs both to expand methods and data for economic valuation and to explore other assessment methods to provide information on ecological effects that are currently un-monetized and assigned an implicit value of $0. Managers seek approaches that are "sound, credible, and scientifically supportable" as well as flexible, affordable, and able to be implemented within the time constraints required by rulemaking (U.S. Environmental Protection Agency Science Advisory Board 2004).

EPA's regional offices, although generally not responsible for national rule-making, are responsible for several kinds of decisions and activities where the benefits of ecological protection are potentially important:

- Priority setting for regional action, such as targeting projects for wetland restoration and enhancement or identifying critical ecosystems or ecological resources for regional attention;
- Setting Supplemental Environmental Protection (SEPs) penalties for enforcement cases where those penalties involve protection of ecological systems and services;
- Choice of options for Superfund and Resource Conservation and Recovery Act (RCRA) cleanups that could take ecological benefits into account;
- Review of Environmental Impact Statements prepared by other federal agencies to comply with the National Environmental Protection Act; and
- Assisting state and local governments and other federal Agencies with protecting lands and land uses, where assessment of the value of protection options could help decision-makers make better-informed decisions.

Regions also seek low-cost methods that can be implemented quickly to inform "place-based" decisions. They seek methods that provide information on the value of ecological services; ecological diversity; conservation opportunities and threats; sustainability; and historical and cultural values associated with ecological systems or parts of ecosystems at the watershed or landscape scale. Regions experience the need to

communicate the value of ecological protection as they collaborate with other federal agencies and with government partners at the local, state, and regional levels.

The need to assess the ecological benefits of policy options arises in most of the Agency's decisions, including the assessment of ecological protection programs. EPA's need to assess the value of its ecological protection programs has two dimensions: 1) a retrospective dimension, because assessments focus on the value of EPA's current and past protection efforts and 2) a prospective dimension, because such assessments are meant to inform decisions about future EPA programs and priorities. Program assessments are mandated for EPA, as they are for all agencies of the executive branch, by the Government Performance and Results Act (GPRA) of 1993. As part of that assessment, OMB requires EPA to periodically identify its strategic goals and describe both the social costs and budget costs associated with them. EPA's Strategic Plan for 2003-2008 described the current social costs and benefits of EPA's programs and policies under each strategic goal area for the year 2002 (U.S. Environmental Protection Agency 2003). This analysis repeatedly points out that EPA lacks data and methods to quantify the ecological benefits associated with the goals in its strategic plan.

In addition, the Government Performance Results Act (GPRA) of 1993 established requirements for assessing the effectiveness of federal programs. Part of that assessment involves assessing the outcomes of programs intended to protect ecological resources. EPA must report annually on its progress in meeting program objectives linked to strategic plan goals and must engage periodically in an in-depth review [through the Program Assessment Rating Tool (PART)] of selected programs to identify their net benefits and to evaluate their effectiveness in delivering meaningful, ambitious program outcomes. Characterizing ecological benefits associated with EPA programs is a necessary part of the program assessment process.

## 3.2 Institutional and Other Issues Affecting Benefits Assessment at EPA

The committee recognizes that ecological benefits assessment at EPA must be conducted within a set of institutional, legal, organizational, and practical constraints that affect what is and can be done to incorporate ecosystem values into policy evaluations. In an effort to better understand these issues and their implications for the committee's charge, the committee conducted a series of interviews with Agency staff.[9] The interviews were focused on the process of developing benefit analyses for Regulatory Impact Assessment (RIA) for rulemaking and the relationship between EPA and the Office of Management and Budget. However, many of the questions raised are equally applicable to strategic planning, performance reviews, regional analysis, and other situations in which the Agency is called upon to assess the value of ecosystems. Below are some key observations made by the committee based on those interviews.

EPA program offices responsible for new rules initiate, finance, and administer the process for developing ecological benefit assessments. The development of a new rule – including the definition of the rule itself, options to be weighed, and the assessment of impacts arising from the rule – involves much more than scientific assessment. Political negotiations and legal analysis often dominate the process. EPA has a formal rule-development process with several stages, each of which imposes demands on the Agency, and the Agency also develops rules to meet court-imposed deadlines. Several aspects of these imposed constraints deserve emphasis. Despite the commonality of the underlying rule-development process, it is clear that there is no single way in which analysts within the Agency assess the tradeoffs that people would be willing to make to enhance ecosystems. Practices vary considerably across program offices, reflecting differences in mission, in-house expertise, etc. Program offices have different statutory and strategic missions. The organization, financing, and skills of the program offices differ enormously. The National Center for Environmental Economics (NCEE) is the Agency's centralized reviewer of economic analysis within the agency.[10] However, the primary expertise and development of the rules resides within the program offices.

Secondly, the timing of the process largely determines the kinds of analytical techniques that are employed. This is related to court-imposed deadlines on the rule process, as well as intervening requirements related to the collection and analysis of new data. The scientific community is accustomed to much longer time horizons for their analyses. Unfortunately, collecting new data poses a significant bureaucratic problem for the Agency. To collect original data, the Agency must submit an Information Collection Request, which is reviewed within the Agency and by OMB. This hurdle is required by the Paperwork Reduction Act and imposes the review responsibility on OMB. There is no discretion under the legislation in applying this review requirement (except in cases associated with the development of survey instruments). Nonetheless, the requirement can add a significant amount of time to the assessment process. With perhaps a year or two at most to conduct a study, this kind of review significantly limits the kind of analysis the Agency can conduct.

A third issue is the role of the Office of Management and Budget (OMB) in defining or directing ecosystem valuation exercises at EPA. OMB acts as an oversight body that reviews EPA's benefit analyses. EPA is required to provide sufficient justification for its claims regarding the benefits of its actions, including any ecological benefits. As noted above, EPA has been given explicit guidance by OMB in the Circular A-4, which the committee views as a reasonable document on its own because of its call for a full characterization of the impacts of different policy options, including where possible a characterization of benefits that cannot be monetized or cannot be quantified (Office of Management and Budget 2003).[11] For a benefit or cost that cannot be expressed in monetary terms, the Circular instructs Agency staff to "try to measure it in terms of its physical units," or, if this is not possible either, to "describe the benefit or cost qualitatively." Thus, although Circular A-4 does not require that all benefits be monetized, it does require at a minimum a scientific characterization of those benefits. However, little guidance is provided on how this should be done. Instead, the Circular urges regulators to "exercise professional judgment in identifying the importance of non-quantified factors and assess as best you can how they might change the ranking of alternatives based on estimated net benefits."

In conducting benefit assessments, EPA has an incentive to use methods that have been accepted by OMB in the past. The thinking at EPA seems to be "if it made it through OMB once, it will make it through again." There appears to be a pronounced tendency to use "off-the-shelf" methods to avoid problems with OMB. This creates a bias toward the *status quo* and a disincentive to explore new or innovative approaches. To this end, the committee sees the need to strike an appropriate balance between the use of established methods and the possible need to innovate in an effort to conduct more comprehensive and defensible benefit assessments for use in decision making and evaluation.

A related issue involves review of Regulatory Impact Assessments (RIAs) by external parties. The Agency does not take a standardized approach to RIA review. EPA staff and managers reported that peer review was focused only on "novel" elements of an analysis. This raises the question of how the Agency (and perhaps OMB) defines "novel." Moreover, the novelty standard actually creates a clear incentive to avoid conducting novel analyses (however defined). It is clearly cheaper and quicker to avoid review altogether. The committee advises the Agency to consider whether there is a role for a standing expert body that can bring consistency to the review of analysis, avoid duplication of review, and be sensitive to timing and resource constraints.

Finally, the committee notes the importance of the organization of assessment science within the Agency. Currently, the Agency relies upon a variety of offices to develop assessments, with varying degrees of reliance on other offices (e.g., NCEE) or outside assistance. It is not clear which approach is most effective. In addition, the organization of assessment has implications for the availability and location of data to support ecological valuation. It is important that data that are housed within individual program offices be made public and readily shared with other offices.

## 3.3 An Illustrative Example of Ecosystem Benefit Assessment at EPA

In an effort to better understand the current state of ecosystem valuation at EPA, the committee examined in detail one specific case where benefit assessment was undertaken, namely, the *Environmental and Economic Benefits Analysis* that EPA prepared in support of new regulations for Concentrated Animal Feeding Operations (CAFOs) (U.S. Environmental Protection Agency 2002).[12,13] The Agency indicated that this analysis was illustrative of other EPA regulatory analyses of ecological benefits in form and general content.

Because the proposed new CAFO rule constituted a "significant regulatory action" under Executive Order 12866, EPA was required to assess the costs and benefits of the rule.[14] EPA identified a wide variety of potential "use" and "non-use" benefits as part of its analysis.[15] Using various economic valuation methods, EPA provided monetary quantifications in its CAFO report for seven environmental benefits.[16] Approximately eighty-five percent of the monetary benefits quantified by EPA were attributed to recreational use and non-use of affected waterways. According to Agency staff, EPA's analysis was driven by what it could monetize. EPA focused on those benefits for which data were known to be available for quantification of both the baseline condition and the likely changes from the proposed rule, and for translation of those changes into monetary equivalents. EPA's final benefits assessment provides only a brief discussion of the benefits that it could not monetize. The benefits table in the Executive Summary listed a variety of non-monetized benefits[17] but designated them only as "not monetized." EPA represented the aggregate effect of these "substantial additional environmental benefits" simply by attaching a "+B" place-holder to the estimated range of total monetized benefits. Although the Executive Summary gave a brief description of these "non-monetized" benefits, the remainder of the report devotes little attention to them.

Although considerable effort was invested in the CAFO benefits assessment, the assessment illustrates a number of limitations in the current state of ecosystem valuation

at EPA. First, as noted above, in implementing the Executive Order, the CAFO analysis did not provide the full characterization of ecological benefits using quantitative and qualitative information, as required by the OMB Circular A-4. Instead, the report focused on a limited set of environmental benefits, driven primarily by the ability to monetize these benefits using generally accepted models and existing value measures (benefit transfer).[18] These benefits did not include all of the major ecological benefits that the new CAFO rule would likely generate, nor all of the benefits that generated public support for the new rule.[19] The Circular requires that a benefit assessment identify and characterize all of the important benefits of the proposed rule, not simply those that can be monetized. By focusing only on a narrow set of benefits, the CAFO analysis and report understates the benefits of the rule change and distorts the rationale supporting the final rule.[20] An unfortunate effect of this presentation is to suggest to readers that the monetized benefits constitute the principal justification for the CAFO rule.[21] Although in this case the focus on monetized benefits did not affect the outcome of the regulatory review, it is certainly possible that in a different context a benefits assessment based only on easily monetized benefits could inadvertently undermine support for a rule that would be justified based on a more inclusive characterization of benefits.

Second, the monetary values for many of the emphasized benefits were estimated through highly leveraged benefit transfers that were generally based on dated studies conducted in contexts quite different from the CAFO rule application.[22] This was undoubtedly driven to a large extent by time, data, and resource constraints, which make it very difficult for the Agency to conduct new surveys or studies and virtually force the Agency to monetize benefits using existing value estimates. However, reliance on dated studies in quite different contexts raises questions about the credibility or validity of the monetary benefit estimates. This is particularly true when values are presented as point estimates, without adequate recognition of the underlying limitations due to uncertainty and data quality.

Third, EPA apparently did not engage in a sufficiently comprehensive effort at the outset to model the rule's ecological impacts. The report presents only a simple

conceptual model that traces outputs (a list of pollutants in manure – Exhibit 2-2 in the CAFO report) through pathways (Exhibit 2-1) to environmental and human health effects.[23] This model provided useful guidance, but was not sufficiently comprehensive to assure thoughout analysis of the rule's ecological impacts. As a consequence the analysis was unduly directed by Agency presumptions (or discoveries) about the availability of relevant data and the likely opportunities to quantify effects precisely and to link and monetize associated benefits. This was undoubtedly driven in part by the time pressures of putting together the regulatory impact analysis. However, without a comprehensive modeling effort at the outset, EPA had insufficient insight into the potential benefits that needed to be analyzed and valued. Developing integrated models of relevant ecosystems at the outset of a valuation project would also help in identifying important secondary effects, which frequently may be of even greater consequence or value than the primary effects.[24]

Fourth, the CAFO analysis clearly demonstrates the challenges of conducting ecological benefit assessments at the national level.[25] National rule-makings inevitably require EPA to generalize away from geographic specifics, both in terms of ecological impacts and associated values. However, it is possible (and desirable) to make use of intensive case studies (e.g., individual watersheds, lakes, streams, estuaries) in support of the national-scale analyses. Existing and ongoing research at local and regional scales offers more detailed data and models that could be better exploited, both to fill in gaps and to validate the national-scale analyses systematically. Systematically performing and documenting comparisons to intensive study sites could indicate the extent to which the national model needs to be adjusted for local/regional conditions and could provide data for estimating the range of error and uncertainty in the projected national-scale effects.

Fifth, although EPA invited public comment on the draft CAFO analysis as required by Executive Order 12866, there is no indication in the draft CAFO report that EPA consulted with the public during its analysis to help it identify, assess, and prioritize the effects and values addressed in its analysis, nor is there discussion in the final CAFO analysis of any comments received on the draft CAFO analysis. Early public

involvement could play a valuable role in helping the Agency both a) identify all of the systems and services impacted by the proposed regulations and b) determine the regulatory effects that are likely to be of greatest value. This would ensure that the benefits assessment includes the most important impacts.

Sixth, while EPA in its analysis and report appropriately emphasized the importance of using outside peer-reviewed data, methods, and models, EPA did not seek to peer review its application of them or its integration of these components in deriving benefit values for the CAFO rule. Once again, this is undoubtedly due in part to time and resource constraints. However, peer review, especially early in the process, would help EPA staff identify relevant and available data, models, and methods to support its analysis, and provide encouragement, direction, and sanction for more vigorous and effective pursuit of ecological and human wellbeing effects associated with the proposed rule. The general idea is to have individual components of the analysis (e.g., watershed modeling, air dispersal, human health, recreation, aesthetics) each reviewed, as well as a more general review of the overall analytic scheme.

Finally, EPA's analysis and report focused nearly exclusively on meeting the requirements as described in Executive Order 12866. This may not be surprising since the Executive Order provided the proximate reason for preparing the analysis and report. However, when EPA prepares a benefit assessment specifically to comply with Executive Order 12866, the Agency need not limit itself to the goals and requirements of the Executive Order. The Executive Order does not preclude EPA from adopting broader goals. The Executive Order provides merely that EPA shall conduct an "analysis" and "assessment" of the "benefits anticipated from the regulatory action" and, "to the extent feasible, a quantification of those benefits." By adopting a narrow focus, the report failed to consider or reflect the broader purposes that a benefit assessment can serve. Environmental benefit assessments such as the CAFO study can serve a variety of important purposes, including helping to educate policy-makers and the public more generally about the benefits that stem from EPA regulations, and it is important for EPA to recognize and have an incentive to consider this broader purpose.

# 4 AN INTEGRATED AND EXPANDED APPROACH TO ECOSYSTEM VALUATION

The CAFO example discussed above highlights a number of limitations to the current state of ecosystem valuation at EPA. The committee's analysis points to the need for a comprehensive, integrated approach to valuing the ecological impacts of EPA actions, one that focuses on the impacts of most concern to people and integrates ecological analysis with valuation. This section describes a proposed framework, based on the committee's deliberations to date. A more detailed discussion of the methods that could be used to implement this framework and the issues that arise in doing so will be provided in subsequent committee reports. The goal in this report is simply to provide an organizing framework to guide the more detailed discussion regarding implementation.

The framework outlined here has three key features, which are interrelated: a) a focus on impacts of most concern to people; b) an integration of ecological analysis and valuation; and c) the use of an expanded set of valuation approaches.

The first feature reflects the committee's view that ecological valuation or benefit assessment should focus on the impacts or benefits that are likely to be most significant or of greatest concern to people, which might or might not be those that are most easily measured. This requires a systematic consideration of the many possible sources of value from ecosystem protection and an identification of the types of values that are providing the impetus for a particular policy change. Information about the ecosystem services or characteristics that are of greatest concern needs to be obtained early in the valuation process so that efforts at quantification and characterization of benefits can be focused on the related ecological changes. This requires a mapping of the effects of a given policy change on ecological assessment endpoints to the corresponding effects on ecological services. In addition, this focus will likely lead to an expansion of the types of services to be characterized, quantified, or explicitly valued. For example, even in the context of national rule-making, the inability to monetize a specific benefit should not preclude its

inclusion; if there is evidence that it is important to people, it should be included as a key component of total benefits and a detailed and careful (albeit non-monetized) characterization of that benefit should be provided.

The second key feature of the framework is the integration of ecological analysis with valuation. This integration needs to occur both at an early stage (in the identification of the impacts that matter) and at a later stage (when estimating the value of impacts). Thus, instead of having ecologists work independently initially to estimate ecological impacts and then "pass the baton" on to economists or other social scientists to value those impacts, it envisions collaborative work across disciplines to ensure that the analysis focuses on the impacts that are of greatest concern to society and that the ways in which these impacts are defined and measured are informative during the selection and, if necessary, design of the valuation techniques/methods. This requires a committed interaction among the relevant bio-physical, ecological, and social/economic scientists and analysts. The various disciplines must reach out to establish useful and credible links to each other. This interaction should commence at the beginning of the process and continue until the completion of the analysis. Ecological models need to be developed, modified, or extended to provide usable inputs for value assessments. Likewise, valuation methods and models need to be developed, modified, or extended to address important ecological/bio-physical effects that are currently underrepresented in value assessments.

Third, the framework envisions the use of a variety of methods to characterize and measure the importance of changes in ecosystems, including economic methods, social/psychological assessments, and ecological approaches. It recognizes that different approaches provide different ways of characterizing or providing information about values. Different approaches could be used at different stages of the valuation process. For example, some methods might be well-suited to providing information that would be used early in the process to guide decisions about which ecological changes are likely to be most important to people, while other methods would be well-suited to quantifying or monetizing benefits that are specific to the EPA action. In addition, the suite of methods

used could vary with the specific policy context, due to differences across contexts in: a) information needs, b) the underlying sources of value being captured; c) data availability; and d) methodological limitations. The framework should serve as a guide to EPA staff as they conduct RIAs and seek to implement the provisions of Circular A-4 (including the provisions relating to benefits that are not readily quantified or monetized), as well as in regional decision-making and program assessment.

# 5 CONSIDERATIONS FOR IMPLEMENTING AN INTEGRATED AND EXPANDED APPROACH

An overview of the process for implementing the proposed approach is depicted in Figure 2.

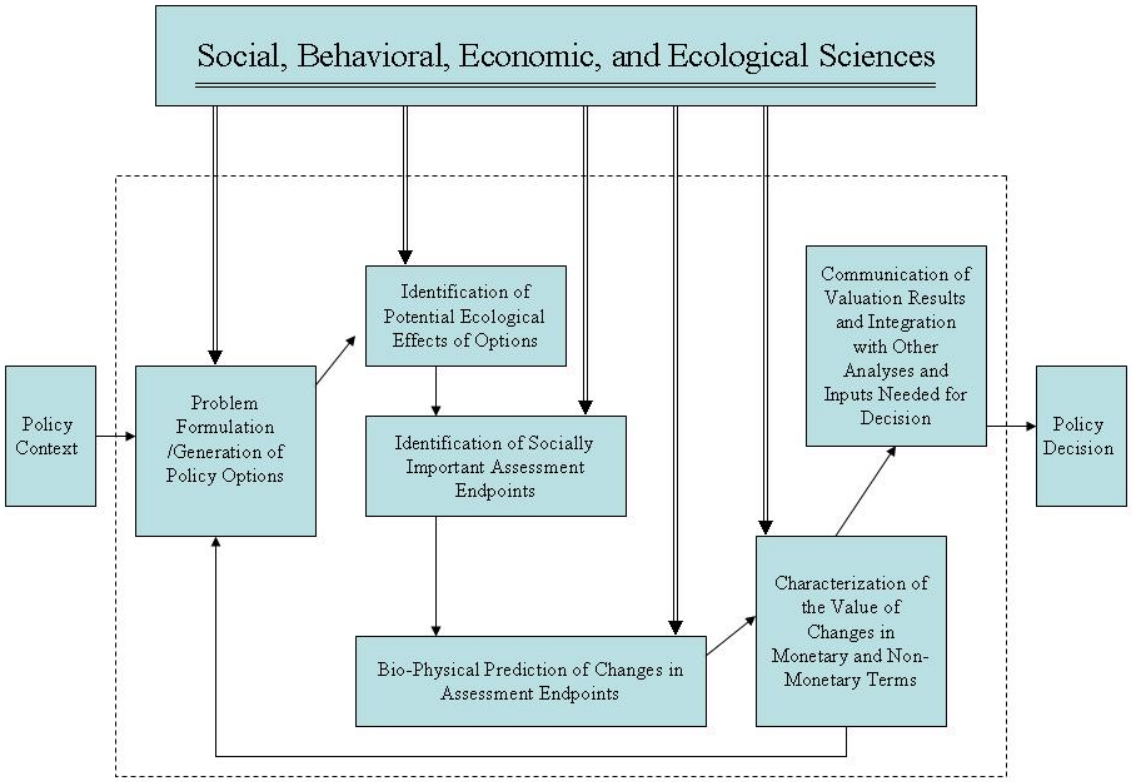


**Figure 2: Process for Implementing an Expanded and Integrated Approach to Ecological Valuation**

The process for implementing the proposed framework would involve the following steps:

- identifying the policy context;
- formulating the valuation problem and choosing policy options to be considered;
- identifying the significant ecological changes that could result under the different options;

- identifying the ecological changes that are socially important, i.e., choosing the assessment endpoints;
- predicting the changes in the assessment endpoints in biophysical terms;
- characterizing, representing, or measuring the value of changes in the assessment endpoints in monetary or non-monetary terms; and
- communicating results to policymakers.

This process parallels the Agency's Framework for Ecological Risk Assessment (U.S. Environmental Protection Agency Risk Assessment Forum 1992) and could ultimately be merged with it as part of a broader framework for ecological assessment. Note that, although Figure 2 depicts these steps as sequential, in practice it is likely that iteration will occur at some points of the process. For example, as suggested in the figure, information about the value of changes in assessment endpoints stemming from a given set of policy options might cause a reformulation of the problem or identification of alternative policy options that could be considered.

### 5.1 Policy Context and Problem Formulation

As noted above, ecological benefit assessment can play a key role in a number of different decision contexts, including national rule-making, local/regional decision-making, and program evaluation. In general, it will be governed by a set of laws, principles, mandates, and public concerns. There is a need to formulate the valuation problem within the specific EPA context. These contexts differ not only in the required scale for the analysis (e.g., national vs. local) but possibly also in the type of valuation information that is needed. For example, in a national rule-making context where benefits and costs are evaluated and compared, Circular A-4 dictates that ecological benefits be: a) measured in dollar terms when possible; b) measured using other metrics for impacts on humans (e.g., population affected) when monetary valuation is not possible; and c) fully described in qualitative terms, when quantitative information is not available. In contrast, expressing benefits in monetary terms might be of little or no importance to EPA analysts involved in program evaluation or regional assessments.

Therefore the policy context in which the assessment is cast is a key influence on the appropriateness of data, models and methods.

## 5.2 Identifying and Predicting Ecological Changes

Decisions about the changes in ecological systems or services to be included in the analysis should be based on an assessment of the changes that are likely to be most important to society, i.e., the socially important assessment endpoints. These could include both changes in the ecosystem itself that people value directly, or the resulting changes in the ecological services provided by those systems. The importance of a given change will depend on both the magnitude and bio-physical importance of the effect and the resulting importance to society.

The bio-physical impacts of a given EPA action can be identified at different temporal, spatial, and ecological levels. The latter include the individual level, the population level, the community level, the ecosystem level (union of biological populations with their surrounding physical environment), and the level of the global biosphere. Living organisms supply goods and services that differ across all levels of organization, from the individual to the ecosystem or global biosphere. For example, the service provided by an individual animal unit is different from the service provided by a given animal population. Estimating bio-physical impacts requires information about relevant ecological production functions. These functions provide a basis for estimation of the ecological *changes* that could result from a given EPA action or policy (e.g., percent reductions/avoidances of pollution in streams and lakes, reduced/avoided eutrophication of estuaries, reduced risk from the introduction of hormones and antibiotics into aquatic systems, improved/protected quality of community drinking water sources). In identifying and predicting ecological changes, it is important to consider their full range, including both primary and secondary effects, adequately accounting for uncertainty, stability of the system (including the effect of random shocks and management errors and the system's resilience), heterogeneity within a population or

ecosystem, heterogeneity across populations or ecosystems, and dynamic changes in the ecosystem over time.

Numerous mathematical models of ecological production have been developed. These models cover the spectrum of biological organization and ecological hierarchy. Some have been developed for specific contexts (species, geographic locations, etc.) while others are more general. Primers on ecological theory and modeling (e.g., Roughgarden 1998) can provide a starting point for identifying available models.

Many of these ecological models have been developed to satisfy research objectives and not EPA policy or regulatory objectives. This poses at least three key challenges when using these models to assess the ecological benefits of EPA actions. The first challenge is to link existing models with Agency actions that are intended to control chemical, physical and biological sources of stress. The valuation framework outlined above requires an estimation of the bio-physical impacts that would stem from a specific EPA action. To be used for this purpose, ecological models must be linked to information about stressors. This link is often not a key feature of ecological models developed for research purposes.

Second, the outputs from the ecological models need to be linked to types of ecological services that are obtained from ecosystems and their structural and functional components. If adapted properly, ecological models can connect material outputs to stocks and services flows, assuming that the services have been well-identified. Providing the link between material outputs and services involves several steps, including identifying “service providers,” determining the aspects of community structure that influence function, assessing the key environmental factors that influence the provision of services, and measuring the spatial and temporal scales over which services are provided (Kremen, 2005). Adaptation of existing models should consider alignment between: a) models; b) ecological services; c) ecological service providers; d) potential injuries; and e) the stressors under EPA purview.

Finally, the ecological models need to be appropriately parameterized for use in policy analysis. Numerous detailed ecological studies have been conducted at various levels, at Long-Term Ecological Research Sites, for example (Farber, Robert Costanza et al. 2006), , which could provide a starting point for parameterizing policy-driven models. A key challenge is to determine whether (or to what extent) parameters estimated from a given study site or population at a given point in time can be "transferred" for use in evaluating ecological changes in a different location or time or at a different scale. In other words, to what extent are estimated parameters adaptable to the context of interest in estimating the benefits and values associated with EPA actions? In many cases, data do not currently exist to parameterize existing models so they can be used in assessing EPA's actions. Such data may need to be developed before the Agency can use these models fully. To the extent that transferable models and parameter estimates exist, it would be extremely valuable to have a central depository that EPA could draw on for this information.

Despite the challenges described above, the many ecological models that now exist provide a rich basis for developing particular models specialized for the various rule-making and other administrative actions EPA must consider. The EPA should, as a matter or ordinary practice, plan to formulate mathematical models of the systems to which its actions pertain. It needs to acquire the expertise, both in house and through use of consultants, to carry out this part of its mission.

### 5.3 Identifying Changes that are Socially Important

For benefit assessments based on anthropocentric values, it is important to identify early in the process what people care about, i.e., which ecological changes are important to them and focus on these as assessment endpoints. For example, are individuals likely to value the re-introduction of native grasses into a marshland, or would they be just as happy with non-native grasses that perform similar ecological functions and have similar aesthetic appeal? Is animal waste disposal a concern to society primarily because of the recreational opportunities lost due to the resulting

deterioration in water quality or is society primarily concerned about other impacts? The range of ecological changes that are the focus of the valuation needs to include the changes people care most about. Previous benefit assessments have often focused on what can be measured relatively easily rather than what is most important to society. This diminishes the relevance, usefulness and impact of the assessment.

Information about what matters to people can be obtained in a variety of ways. Examples range from in-depth studies of people's mental models and how their preferences are shaped by their conceptualization of ecosystems and ecological services, to more standard survey responses from prior or purpose-specific studies. In addition, early public involvement[26] or use of focus groups or workshops comprised of representative individuals from the affected population and relevant scientific experts can help to identify relevant or potentially important ecological changes for the specific context of interest.

In eliciting information about what matters to people, it is important to bear in mind that people's preferences depend on their mental models (their understandings of causal processes and relations), and what information is at hand to influence their understanding, and how. Expressions of what is important (e.g., in surveys) can change with the amount and kind of information provided, as well as how it is provided. Collaborative interaction between analysts and public representatives can ensure that respondents have sufficient information when expressing views and preferences.

## 5.4 **Characterizing Values**

Given predicted changes in assessment endpoints, the value of these changes needs to be characterized and, when possible, measured or quantified. This requires that the output from the ecological impact assessment be in a form that can be used as an input in estimating the value of the change in ecosystems and/or ecosystem services.

To translate bio-physical impacts into human values, it is necessary to project how ecosystem changes will affect humans and the things that humans value. These impacts can be measured in non-monetary terms or in monetary terms.

The extent of the impact on humans can be measured in non-monetary terms using a variety of metrics, such as the number and characteristics of the people/communities affected, social expressions of importance, the number of people significantly affected, the likely symptoms avoided or reduced, and the duration of the impact. Estimation of impact on humans in terms of the extent of exposure, expressions of concern in survey or political venues or similar measures is crucial in three possible ways. First, in some contexts, decisions based on social expectations (e.g., protection of children's health) may look directly to these measures as indicators of the appropriate policy choice. Second, in contexts where monetary measures of value are sought, the human benefits captured by information on exposure or symptoms may help in translating benefits into their monetary equivalents. This requires an understanding of those impacts on humans before this translation can occur. Third, in some cases even where monetary values are required by regulations or executive orders, using methods that defensibly report the magnitude and human significance of such effects, rather than ignoring them, would allow the policymakers to draw their own conclusions regarding the associated potential value or benefit. Thus, in all of these cases, estimates of the impact of the ecosystem change on human populations are needed.

In contexts where monetary metrics are required or desired and the necessary data and methods exist, the impact of the ecological change on the provision of some services to human populations may be translated into a monetary equivalent of that change using standard economic valuation techniques. For some valuation contexts economic or monetary methods for valuing changes are relatively well-developed. They are designed to estimate the benefit or cost of a given ecological change using a willingness-to-pay or willingness-to-accept measure of the utility equivalent of that change. These methods have been applied to the valuation of ecosystem services in a number of studies that have produced results that are useful for policy evaluation. However, as in the CAFO study,

monetary valuation methods have generally been applied to a relatively narrow set of services. In some cases, these might not have been the services that people are most concerned about protecting. There is a need to expand the range of services to which economic valuation is applied.

As with ecological impacts, in estimating the values of impact on humans in either monetary or non-monetary terms, it is necessary to address cross-cutting issues such as uncertainty (inherent randomness and imperfect information), dynamics, scale (temporal and geographic), and heterogeneity (spatial variability and heterogeneity across people). In subsequent reports, the committee will assess the challenges of uncertainty arising out of data limitations, theory limitations, and randomness, and will recommend approaches for handling uncertainty and conveying the magnitude and nature of uncertainty to policymakers.

### 5.5 Communicating Results

Information regarding the value of ecological changes stemming from EPA actions will only be useful in improving decision-making if it is communicated effectively to policymakers and integrated with other information used in policy decisions. In addition to policymakers, information about the value of ecological changes is likely to be of interest to community members and scientists alike.

Communicating the value of protecting ecological systems and services requires conveying not only value information, but also information about the nature and state of the ecological systems and services to which they apply and the ecological processes involved. Information can be and is often conveyed using mapped ecological information, other visualizations including photographs and graphs, ecological indicators and narratives. Integrated models with a geospatial interface, such as those developed by Costanza (Costanza and Farber 1986; Costanza, Sklar et al. 1990; Costanza 1993; Bockstael, Costanza et al. 1995; Fitz, DeBellevue et al. 1996; Cowling and Costanza 1997; Higgins, Turpie et al. 1997; Costanza 2002; Binder 2003; Costanza and Voinov

2003; Costanza 2004) are another approach to depicting the state of ecological systems and services. The SAB has proposed a framework for reporting on the condition of ecological resources (EPA, 2003). The EPA's draft Report on the Environment (U.S Environmental Protection Agency 2002) and reports of the Regional Environmental Monitoring and Assessment Program (REMAP) illustrate a range of approaches that can be used.

# 6 SUMMARY AND RECOMMENDATIONS

Ecosystems play a crucial role in defining the world as we know it. They provide a wide array of services that directly or indirectly support or enhance human populations. In addition, they can be valued in their own right, for non-anthropocentric reasons stemming from ethical, religious, cultural or biocentric principles. Part of EPA's broad mission to protect human health and the environment includes the protection of ecosystems.

Many EPA actions affect the state of ecosystems and the services derived from them. However, to date ecosystem impacts have received relatively limited consideration in EPA policy analysis. It is imperative that EPA improve its ability to value ecosystems and their services to ensure that ecological impacts are adequately considered in the evaluation of EPA actions at both the national and regional levels and to provide accurate assessments of EPA programs.

To date, ecological valuation at EPA has focused primarily on a limited set of ecological benefits. This stems primarily from the difficulty of predicting the impact of EPA actions on ecological systems and the services derived from them and the difficulty of quantifying, measuring, or characterizing the resulting benefits. The perception that benefits need to be monetized in order to be carefully characterized restricts the range of ecological impacts that are typically considered in EPA analyses, particularly at the national level.

The Committee views EPA's efforts to improve its ability to value ecological systems and services as very important and timely. As EPA continues these efforts, the Committee encourages the Agency to move toward covering an expanded range of important ecological effects and human considerations using an integrated approach. Such an approach would:

- Recognize the many sources of value derived from ecosystems, including both instrumental and intrinsic values;
- Highlight the concept of ecosystem services and provide a mapping from changes in ecological systems to changes in services using the concept of an ecological production function;
- Expand the range of ecological changes that are valued, focusing on those changes in ecosystems and their services that are likely to be of greatest concern to people;
- Explore and expand the use of different methods for characterizing or measuring the value associated with these changes;
- Involve from the beginning an interdisciplinary collaboration among physical/biological and social scientists; and
- Solicit from the beginning input from the public or representatives of individuals affected by the ecological changes.

Through the use of an expanded and integrated valuation framework of this type, EPA can move toward more greater recognition and consideration of the effects that its actions have on ecosystems and the services they provide. In addition, it will allow EPA to improve environmental decision-making at the national, regional and local levels and contribute to EPA's overall mission regarding ecosystem protection.

# REFERENCES

Binder, C., R. M. Boumans, R, Costanza (2003). "Applying the Patuxent Landscape Unit Model to human dominated ecosystems: the case of agriculture." Ecological Modelling **159**.

Bockstael, N., R. Costanza, et al. (1995). "Ecological economic modeling and valuation of ecosystems." Ecological Economics **14**: 143-159.

Brink, D. O. (1989). Moral Realism and the Foundation of Ethics. Cambridge, Cambridge University Press.

Costanza, R. (2004). Value Theory and Energy. Encyclopedia of Energy.

Costanza, R., A. Voinov, R. Boumans, T. Maxwell, F. Villa, L. Wainger, H. Voinov (2002). " Integrated ecological economic modeling of the Patuxent River watershed, Maryland." Ecological Monographs **72**: 201-231.

Costanza, R. and S. Farber (1986). The Economic Value of Coastal Louisiana Wetlands. Baton Rouge, Louisiana State University.

Costanza, R., L. Wainger, C. Folke, and K-G Mäler (1993). "Modeling complex ecological economic systems: toward an evolutionary, dynamic understanding of people and nature." BioScience **43**: 545-555.

Costanza, R., F. H. Sklar, et al. (1990). "Modeling coastal landscape dynamics." BioScience **40**: 91-107.

Costanza, R. and A. Voinov, Eds. (2003). Landscape Simulation Modeling: A Spatially Explicit, Dynamic Approach. New York, Springer.

Cowling, R. and R. Costanza (1997). "Valuation and Management of Fynbos Ecosystems." Ecological Economics **22**: 103-155.

Farber, S., Robert Costanza, et al. (2006). "Linking Ecology and Economics for Ecosystem Management." BioScience: 117-129.

Fitz, H. C., E. B. DeBellevue, et al. (1996). "Development of a general ecosystem model (GEM) for a range of scales and ecosystems." Ecological Modelling **88**: 263-297.

Freeman, A. M. I. (2003). The Measurement of Environmental and Resource Values: Theory and Methods. Washington, D.C., Resources for the Future.

Glover, J. (1984). What Sort of People Should There Be? Penguin.

Goodpaster, K. (1978). "On Being Morally Considerable." Journal of Philosophy **75**: 308-25.

Hays, S. P. (1989). Beauty, Health and Permanence: Environmental Politics in the United States, 1955-1985, Cambridge.

Higgins, S. I., J. K. Turpie, et al. (1997). "An ecological economic simulation model of mountain fynbos ecosystems: dynamics, valuation, and management." Ecological Economics **22**: 155-169.

Korsgaard, C. (1996). Two Distinctions in Goodness. Creating the Kingdom of Ends. C. Korsgaard. Cambridge, Cambridge University Press. **1996:** 249-74.

Kremen, C. (2005). "Managing Ecosystem Services: What do We Need to Know about Their Ecology?" Ecology Letters 8: 468-479.

McDowell, J. (1985). Values and Secondary Qualities. Morality and Objectivity. T. Honderich, Routledge and Kegan Paul**:** 110-29.

Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Washington, D.C., Island Press.

Millennium Ecosystem Assessment Board (2003). Ecosystems and Human Well-being; A Report of the Conceptual Framework Working Group of the Millennium Ecosystem Assessment. Washington, DC, Island Press.

National Research Council (2004). Valuing Ecosystem Services; Toward Better Environmental Decision-Making. Washington, D.C., The National Academies Press.

Office of Management and Budget (2003). Regulatory Analysis, Circular A-4.

Pagiola, S., K. von Ritter, et al. (2004). Assessing the Economic Value of Ecosystem Conservation. World Bank Environment Department Papers.

Rolston III, H. (1991). Environmental Ethics: Values in and Duties to the Natural World. The Broken Circle: Ecology, Economics, and Ethics. F. H. B. a. S. Kellert. New Haven, Yale University Press.

Roughgarden, J. (1997). Primer of Ecological Theory, Prentice Hall.

Russell III, E. P. (1993). "Lost Among the Parts per Billion; Ecological Protection at the Environmental Protection Agency, 1970-1993." Environmental History **2**: 29-51.

Sayre-McCord, G. (1988). The Many Moral Realisms. Essays on Moral Realism. G. Sayre-McCord. Ithaca, Cornell University Press**:** 1-26.

Sidgwick, H. (1901). Methods of Ethics. New York, Macmillan.

Silva, P. and S. Pagiola (2003). A Review of the Valuation of Environmental Costs and Benefits in World Bank Projects. World Bank Environmental Economics Series, The World Bank.

Sturgeon, N. (1985). Moral Explanations. Morality, Reason, and Truth. D. C. a. D. Zimmerman, Rowman and Allenheld**:** 49-78.

Taylor, P. (1986). Respect for Nature: A Theory of Environmental Ethics. Princeton, Princeton University Press.

U.S Environmental Protection Agency (2004). Ecological Benefits Assessment Strategic Plan, November 3, 2004 SAB Review Draft.

U.S Environmental Protection Agency (2003). EPA Strategic Plan: Direction for the Future, EPA-190-R-03-003.

U.S. Environmental Protection Agency (2003). Appendix 1: Social Costs and Benefits. Direction for the Future: 2003-2008 EPA Strategic Plan, Appendix 1: Social Costs and Benefits.

U.S. Environmental Protection Agency Office of Policy, Economics and Innovation. (2003). Public Involvement Policy of the U.S. Environmental Protection Agency. EPA 233-B-03-002.

U.S Environmental Protection Agency (2002). Draft Report on the Environment.

U.S. Environmental Protection Agency (2000). Guidelines for Preparing Economic Analyses, EPA 240-R-00-003.

U.S. Environmental Protection Agency (1994). Managing Ecological Risks at EPA: Issues and Recommendations for Progress. EPA/600/R-94/183.

U.S. Environmental Protection Agency Risk Assessment Forum (1992). Framework For Ecological Risk Assessment, USEPA EPA/630/R-92/001.

U.S. Environmental Protection Agency Risk Assessment Forum (1992). Framework for Ecological Risk Assessment. EPA/630/R-92/001.

U.S. Environmental Protection Agency Risk Assessment Forum (1998). Guidelines for Ecological Risk Assessment, EPA/630/R095/002F.

U.S. Environmental Protection Agency Risk Assessment Forum (2003). Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment. EPA/630/P-02/004F.

U.S. Environmental Protection Agency Science Advisory Board (2000). Toward Integrated Environmental Decision-making, EPA-SAB-EC-00-011.

U.S. Environmental Protection Agency Science Advisory Board (2001). Improved Science-Based Environmental Stakeholder Processes: An EPA Science Advisory Board Commentary. EPA-SAB-EC-COM-001-006.

U.S. Environmental Protection Agency Science Advisory Board. 2001. Improved Science-Based Environmental Stakeholder Processes: An EPA Science Advisory Board Commentary. EPA-SAB-EC-COM-001-006.

U.S. Environmental Protection Agency Science Advisory Board.. 2003. Summary Minutes of the U.S. Environmental Protection Agency (EPA) Science Advisory Board (SAB) Committee on Valuing the Protection of Ecological Systems and Services Initial Background Workshop October 27, 2003, J. W. Marriott Hotel, Washington, DC.

U.S. Environmental Protection Agency Science Advisory Board. 2004. Summary Minutes of the U.S. Environmental Protection Agency (EPA) Science Advisory Board (SAB) Committee on Valuing the Protection of Ecological Systems and Services Workshop on Different Approaches and Methods for Valuing the Protection of Ecological Systems and Services April 13-14, 2004, Four Points Sheraton, 1201 K Street, NW Washington, DC, 20005.

Williams, Bernard. 1994. Must a Concern for the Environment Be Centred on Human Beings? In Reflecting on Nature, edited by L. Gruen and D. Jamieson. Oxford: Oxford University Press.

# ENDNOTES

[1]Laws include: the Clean Air Act, Clean Water Act, Comprehensive Environmental Response, Compensation, and Liability Act, Federal Insecticide, Fungicide and Rodenticide Act, Toxic Substances Control Act, and Resource Conservation and Recovery Act

[2] The SAB Staff Office published a Federal Register Notice on March 7, 2003 (68 FR 11082-11084) announcing the project and called for the public to nominate experts in the following areas: decision science; ecology; economics; engineering; psychology; and social sciences with emphasis in ecosystem protection. The SAB Staff Office published a memorandum on August 11, 2003 documenting the steps involved in forming the new committee and finalizing its membership.

[3] The committee developed the conclusions in this report after multiple public meetings and workshops: a) an Initial Background Workshop on October 27, 2003 to learn the range of EPA's needs for science-based information on valuing the protection of ecological systems and services from managers of EPA Headquarters and Regional Offices; b) a Workshop on Different Approaches and Methods for Valuing the Protection of Ecological Systems and Services, held on April 13-14, 2004; c) an advisory meeting focused on support documents for national rulemakings held on June 14-15, 2004; d) an advisory meeting focused on regional science needs, in EPA's Region 9 (San Francisco) Office on Sept. 13, 14, and 15, 2004; e) advisory meetings held on January 26-26, 2005 and April 12-13, 2005 to review EPA's draft *Ecological Benefits Assessment Strategic Plan;*and f) a Workshop on Science for Valuation of EPA's Ecological Protection Decisions and Programs, held on December 13-14, 2005 to discuss the integrated and expanded approach described in this paper. The also committee discussed a draft version of this report at public meetings on October 25 2005 and May 9, 2006.

[4] The Committee has already issued a related advisory report on the Agency's draft *Ecological Benefits Assessment Strategic Plan* (EPA SAB, EPA-SAB-ADV-05-004). This report complements that Advisory, and provides a discussion of an integrated framework alluded to in that report.

[5] It is important to acknowledge that they are many different specific definitions for the term “benefits”. When used in these technical discussions, each makes a different set of accompanying assumptions that can be important to how it is interpreted. In short, not all technical concepts for benefits are equivalent. Throughout this report, we use the term “benefits” to refer to the general concept of contributions to people. Economists generally use the term to refer more specifically to compensating or equivalent variations (see Freeman, 2003). Despite these differences, the term services and the listing of types of services here directs attention to a process of keeping track of changes in ecosystem services exclusively because of their contributions to human well being. This is an anthropocentric perspective on the benefits provided by enhancing ecosystem services.

[6] The self-discipline of explicitly listing the services derived from an ecosystem, and the enterprise involved in using the best available methods in the ecological, social, and behavioral sciences to help develop that list is very important. At a basic level, listing ecosystem services can help us "know where we stand" in relation to the ecosystem. It can help make the analysis of ecological science more transparent and accessible and can help inform decision makers of the relative merits of different options before them.

[7] There is controversy over the meaning of intrinsic value that we will not try to resolve here (Korsgaard, C. 1996). . Many people take intrinsic value to mean that the value of something is inherent in that thing. Some philosophers have argued that value or goodness is a simple non-natural property of things (see Moore 1903 for the classical statement of this position), and others have argued that value or goodness is not a simple property of things but one that supervenes on the natural properties to which we appeal to explain a thing’s goodness (this view is defended by, among others, contemporary moral realists; see McDowell, J. 1985, Sturgeon, N. 1985, Sayre-McCord, G.1988, Brink, D. O. 1989)

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[8] A large literature exists on the use of economic valuation methods to estimate the value of changes in environmental quality. For a comprehensive description of these methods, see Freeman (2003).

[9] These interviews were conducted by one committee member, Dr. James Boyd, in conjunction with the Designated Federal Officer, Dr. Angela Nugent, over the period September 22, 2004 through November 23, 2005. In seven sets of interviews, Dr. Boyd spoke with staff from the Office of Policy, Economics and Innovation, Office of Water, Office of Air and Radiation, and the Office of Solid Waste and Emergency Response.

[10] NCEE is typically brought in by the program offices to both help design and review RIAs. NCEE can be thought to provide a centralized "screening" function for rules and analysis before they go to OMB. NCEE is actively involved in discussions with OMB as rules and supporting analysis are developed and advanced.

[11] eg., see pp.27 "If monetization is impossible, explain why and present all available quantitative information" and. pp "If you are not able to quantify the effects, you should present any relevant quantitative information along with a description of the unquantified effects, such as ecological gains, improvements in quality of life, and aesthetic beauty."

[12] The Committee reviewed and critically evaluated the CAFO Environmental and Economic Benefits Analysis at its June 15, 2004 meeting. As stated in the Background Document for SAB Committee on Valuing the Protection of Ecological Systems and Services for its Session on June 15, 2004, the purpose of this exercise was "to provide a vehicle to help the Committee identify approaches, methods, and data for characterizing the full suite of ecological 'values' affected by key types of Agency actions and appropriate assumptions regarding those approaches, methods, and data for these types of decisions." The Committee based its review on EPA's final benefits report (EPA 2002) and a briefing provided by the EPA Office of Water staff. During the June meeting, members of the Committee divided into two workgroups. The workgroups each worked independently and reported their findings to the combined Committee. The leaders of the two working groups then prepared a consolidated summary of comments from the two workgroups.

[13] In December 2000, EPA proposed a new CAFO rule under the federal Clean Water Act to replace 25-year-old technology requirements and permit regulations (66FR 2959). EPA published its final rule in December 2003 (68 FR 7176). The new CAFO regulations, which cover over 15,000 large CAFO operations, reduce manure and wastewater pollutants from feedlots and land applications of manure and remove exemptions for stormwater-only discharges.

[14] Prior to publishing the draft CAFO rule in December 2000, EPA spent two years preparing an initial assessment of the costs and benefits of the major options. After releasing the draft rule, EPA spent another year collecting data, taking public comments, and preparing assessments of new options. EPA published its final assessment in 2003. An intra-agency team at EPA, including economists and environmental scientists in the Office of Water, Office of Air and Radiation, Office of Policy Economics and Innovation, and Office of Research and Development, worked on the benefit assessment. EPA also worked with the U.S. Department of Agriculture in developing the assessment. Dr. Christopher Miller of EPA's Office of Water estimated that EPA spent approximately $1 million in overall contract support to develop the benefit assessment. EPA spent approximately $250,000-$300,000 on water quality modeling as part of the assessment.

[15] The potential "use" benefits included in-stream uses (commercial fisheries, navigation, recreation, subsistence, and human health risk), near-stream uses (non-contact recreation, such as camping, and nonconsumptive, such as wildlife viewing), off-stream consumptive uses (drinking water, agricultural/irrigation uses, and industrial/commercial uses), aesthetic value (for people residing, working, or traveling near water), and the option value of future services. The potential "non-use" values included

ecological values (reduced mortality/morbidity of certain species, improved reproductive success, increased diversity, and improved habitat/sustainability), bequest values, and existence values.

[16] These benefits were recreational use and non-use of affected waterways, protection of drinking water wells, protection of animal water supplies, avoidance of public water treatment, improved shellfish harvest, improved recreational fishing in estuaries, and reduced fish kills.

[17] These include reduced eutrophication of estuaries; reduced pathogen contamination of drinking water supplies; reduced human and ecological risks from hormones, antibiotics, metals, and salts; improved soil properties from reduced over-application of manure; and "other benefits".

[18] EPA apparently conducted no new economic valuation studies (although a limited amount of new ecological research was conducted) and did not consider the possible benefits of developing new information where important benefits could not be valued in monetary terms based on existing data.

[19] For example, while the report notes the potential effects of discharging hormones and other pharmaceuticals commonly used in CAFOs into drinking water sources and aquatic ecosystems, the nature and possible ecological significance of these effects is not adequately developed or presented. Similarly, the report does not adequately address the well-known consequences of discharging Trihalomethane precursors into drinking-water sources.

[20] One of the benefits of monetary benefit estimates obviously is the ease of aggregating them by simple arithmetic. However, the Committee does not believe that reporting that a rule produced a total of "218.9 million dollars in annual benefits" is necessarily more useful, meaningful, or defensible for environmental policy than reporting, for example, the achievement of a "10% reduction in the pollution of over 129,000 miles of streams and rivers, 3.2 million acres of lakes and ponds, and 2,800 square miles of estuaries."

[21] In the case of this CAFO rule, 97% of the monetized benefits arise from recreation (boating, swimming and fishing) and from private well owners' willingness to pay for water quality, estimated using contingent valuation or travel cost methods.

[22] EPA used estimates based on a variety of public surveys in its benefit transfer efforts, including: a national survey (1983) that determined individuals' willingness to pay for changes in surface water quality relating to water-based recreational activities (Section 4 of the CAFO Report); a series of surveys (1992, 1995, 1997) of willingness to pay for reduced/avoided nitrate (or unspecified) contamination of drinking water supplies (Section 7); and several studies (1988, 1995) of recreational fishers' values (travel cost, random utility model) for improved/protected fishing success related to nitrate pollution levels in a North Carolina estuary (Section 9).

[23] Although EPA later prepared more detailed conceptual models of the CAFO rule's impact on various ecological systems and services, EPA did not prepare these models until after the Agency finished its analysis.

[24] Contamination of estuaries, for example, might negatively affect fisheries in the estuary (a primary effect) but might have an even greater impact on offshore fisheries that have their nurseries in the estuary (a secondary effect).

[25] The goal of EPA's analysis was a national level assessment of the effects of the CAFO rule. This involved the effects of approximately 15,000 individual facilities, each contributing pollutants across local watersheds into local and regional aquatic ecosystems. A few intensive case studies were mentioned in the report and used to calibrate the national scale models (e.g., NWPCAM, GLEAMS), but there was no indication that these more intensive data sets were strategically selected or used systematically for formal sensitivity tests or validations of the national-scale model results.

[26] This could include either a robust public involvement process following Administrative Procedures Act requirements (e.g., FR publication), or some other public involvement process [see EPA's public involvement policy, U.S. Environmental Protection Agency Office of Policy, Economics and Innovation 2003 and the SAB report on science and stakeholder involvement U.S. Environmental Protection Agency (Science Advisory Board 2001).