Valuing the Protection of Ecological Systems and Services: An Expanded and Integrated Approach (tentative title)

1. INTRODUCTION AND BACKGROUND

1.1. Scope of this Report and its Intended Audience

The Science Advisory Board (SAB) Committee on Valuing the Protection of Ecological Systems and Services (C-VPESS) began its work in 2003 on a project developed by the SAB to strengthen the Agency's analysis for protecting ecological resources. 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. In this project the SAB set the goals of assessing Agency needs and the state of the art and science of valuing protection of ecological systems and services and 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. The committee is an interdisciplinary group of experts from the following areas: decision science, ecology, economics, engineering, philosophy, psychology, and social sciences with emphasis in ecosystem protection.[1] The committee sees its work as a three-year initiative.

This report is intended to provide an overview of the committee's conclusions to date.[2] It is aimed at providing 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

[1] 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.

[2] 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; and 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 to discuss economic and other methods for valuing the protection of ecological systems and services. The committee discussed a draft version of this report at a public meeting on (INSERT DATE).

completion of the project.[3] However, given the importance of the committee's charge, it felt that it would be useful to the Agency to issue an initial 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 more effectively 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 focuses directly on EPA's contributions and impacts, however, and not on the general question of the value of ecosystems or ecological services in themselves. 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 ecological resources (Millennium Ecosystem Assessment 2005; Millennium Ecosystem Assessment Board 2003; National Research Council 2004; Pagiola, von Ritter, and Bishop 2004; Silva and Pagiola 2003) 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. The committee focuses specifically 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 benefits assessment approaches and in each case will emphasize issues relevant to EPA policy and decision-making and address how the Agency could better characterize the benefits of ecological protection.

1.2. The Importance of Valuing Ecosystems and their Services

1.2.1 The Concept of Ecosystem Services

[3] The Committee has already issued a related advisory report on the Agency's draft *Ecological Benefits Assessment Strategic Plan* (EPA SAB, EPA-SAB-ADV-05-00X). This report complements the *EBASP* Advisory, and provides a discussion of an integrated framework alluded to in that report.

The term "ecosystem" describes the organisms in a given area interacting with their physical environment as a functional unit. Ecosystems can describe organism-physical environment interactions in a woodlot, a watershed, or an extensive landscape. Ecosystems encompass all organisms within the prescribed area, including humans, who are often the dominant element. Processes that link organisms with their physical environment are considered ecosystem processes and include primary productivity and the cycling of nutrients and water. These processes in total describe the functioning of ecosystems. Processes that link organisms with each other, indirectly influencing flows of energy, water and nutrients, can also be considered ecosystem processes, such as pollination, predation and parasitism.

"Ecosystem services" is an anthropocentric concept denoting the benefits that humans derive from the functioning of ecosystems. An operational categorization of ecosystem services has recently been proposed by the Millennium Ecosystem Assessment:

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 benefits that humans derive from the presence and functioning of ecosystems. 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 provide cultural, spiritual and aesthetic values, and 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.

Although there are different ways in which ecosystem services can be categorized, the committee feels that the approach adopted in the Millennium Assessment is a useful approach for conveying the concept of ecosystem services and the broad array of functions and processes ecosystem services include. The ecosystem service concept is useful in many ways. First, it is a concept that is readily grasped by society, since it relates directly to human well-being. Secondly, it provides a tool for evaluating the impacts of human actions in terms of the resulting change in the benefits provided by the affected services. "Ecosystem health" can then be defined in terms of the output and sustainability of services. When defined this way, the concept of ecosystem health relates directly to the benefits provided to humans. However, life on earth can be revered

and protected independent of human benefit. As discussed below, the committee recognizes that ecosystems can be valued not only because of the human-based services they provide but also for other non-anthropocentric reasons, including respect for nature based on ethical, religious, or biocentric principles.

1.2.2 The Concept of Value

Because people define and assign values, all values are *anthropogenic*. However, as noted above, not 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 values, all of which can affect their thoughts, attitudes, and actions toward nature in general or, more specifically, ecosystems and the services they provide.

The most basic 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.[4] 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; Rolston III 1991; Taylor 1986). However, others argue that only human beings or human experiences have intrinsic value, thereby defending an anthropocentric conception of value (Glover 1984; Sidgwick 1901; Williams 1994).

Ecological systems have instrumental value to the extent that they provide useful services. Some people also claim, however, that an ecological system may have value independently of the services it provides, i.e., its very existence has value. 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, then it has what economists call "*existence value.*" This concept is anthropocentric. In addition, it is 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. Some people, however, claim that an ecological system may have intrinsic value of its own, and that we should protect it for its own sake. If the explanation of this claim refers to reasons that are independent of the contribution that the existence of an ecological

[4] There is controversy over the meaning of intrinsic value that we will not try to resolve here (Korsgaard 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 (Brink 1989; McDowell 1985; Sayre-McCord 1988; Sturgeon 1985).

system can make to human well-being, then this claim of intrinsic value should be understood in a non-anthropocentric sense.

This committee recognizes that there are many possible sources of value derived from ecosystems and the services they provide. Thus, throughout this report, the term "value" is used broadly to include values predicated on their contributions to human society (broadly defined), as well as those based on an ethical, religious, or biocentric notion of intrinsic value.

Related to the concept of value are the concepts of "benefits" and "valuation." Both of these terms are relative to a specific change. In this report, the change of interest is the change 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 increase in the value of the ecological system and/or its services. This assumes a positive change in value. Analogously, a reduction in value, 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 characterizing or measuring benefits or changes in value using various methods and techniques. For example, economic valuation measures benefits in terms of the amount people are willing to pay (WTP) to ensure an ecological improvement or the amount people are willing to accept (WTA) to forego the improvement.[5] A social/psychological assessment method might present the same ecological change and ask people to rate the importance of achieving (or preventing) that change relative to a selection of changes in a number of other (potentially competing) social goals. An ecological approach might assess the value of the targeted change in terms of the magnitude of its effect on biodiversity or some other indicator of ecological health based on the consensus that ecological health is important to human/social well-being. All of these assessments are based on an anthropocentric view of values, where ecological values are assessed in terms of their contribution to human well-being. However, they differ in terms of the means by which values are expressed, and by the extent to which the value of the targeted ecological change can then be explicitly compared (traded off) against other social values. Economic assessments claim the broadest range and most explicit method for assessing tradeoffs between, for example, ecological improvements and changes in other goods or services that also contribute to human well-being. The social/psychological methods generally settle for a relative measure of the value of the targeted ecological change and largely constrain tradeoff implications to options and circumstances that are closely related to the set of alternatives explicitly presented in the assessment. Ecological assessments might restrict tradeoff implications to the biosphere. In all cases, the ultimate purpose of the valuation process is to characterize or measure the benefits (or costs) associated with an ecological change in a way that provides useful information about these benefits to policymakers and the public at large. The committee plans to discuss these methods, what they may offer analysts and decision makers at EPA in

[5] 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 (1993).

capturing different kinds of benefits, and their limitations and related issues in a future report.

1.2.3 The Importance of Assessing Ecosystem Benefits

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. This importance has been increasingly recognized by many, both within the U.S. and internationally. The recent study by the National Research Council and the Millennium Ecosystem Assessment are indicative of this growing recognition.

Many EPA actions (e.g., regulations, rules, programs, policy decisions) affect the state of ecosystems and the flow of services derived from them. EPA actions can either lead to changes in the conditions of ecosystems (improvement or deterioration) or prevent changes 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. Yet, to date, ecosystem impacts have received relatively limited consideration in EPA policy analyses. Failure to consider these impacts as fully as possible can lead to distorted policy decisions, particularly in regulatory contexts where benefits are being compared to costs. In many cases, the result will be an under-valuation of (or failure to fully recognize) the benefits of EPA actions aimed at protecting the environment. This can occur, for example, when actions are evaluated based primarily on their impacts on human health, without a recognition of potentially important ecosystem impacts.

Valuing the changes in ecological systems and services and assessing the ecosystem benefits that result from EPA policies or programs is challenging for a number of reasons. Major challenges include: a) understanding the many sources of value that ecosystems generate, b) predicting the ecological impacts of alternative EPA actions, and expressing those predictions in the temporal and spatial scale most appropriate for decision-making, c) linking those impacts to changes in the dimensions of ecosystems or the service flows that people value, d) developing methods and techniques that can be used to characterize and/or measure the value of protecting ecological systems and services so that they may be incorporated or properly reflected in environmental decisions and policies, e) aggregating to a national level using local or regional studies from regions with different ecological and/or economic characteristics, and f) finding measures or means of representing ecological values or benefits that are commensurable with values of non-ecological changes caused by EPA actions, such as human health. Despite these challenges, it is imperative that EPA improve its ability to assess ecosystem benefits to ensure that ecological impacts are adequately considered in the evaluation of EPA actions.

2. ECOSYSTEM VALUATION AT EPA

There are several different contexts in which EPA policy decisions have ecological impacts and hence in which the need for ecosystem benefits assessment will arise. In addition, when assessing benefits, EPA must operate 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.

2.1. Policy Contexts at EPA Where Ecosystem Valuation Can be Important

The most prescriptive requirements are for national rule making. 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 provided general guidance on how to provide monetized, quantitative, and qualitative information to fully characterize benefits and EPA itself has developed initial guidance for ecological benefit assessment (U.S. Environmental Protection Agency 2000). In developing its draft *Ecological Benefits Assessment Strategic Plan* and in discussions with the committee (U.S. Environmental Protection Agency Science Advisory Board 2003), EPA identified the need for improved models and methods to help implement the requirements of the circular. The Agency identified needs both to expand methods and data for economic valuation through benefit-cost or cost-effectiveness analysis 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 come into question:

- 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
- 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 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.

EPA's need to communicate 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.

The need to assess the ecological benefits of policy options is woven into most of the Agency's decisions, including the assessment of ecological protection programs . Program assessments are mandated for EPA, as they are for all agencies of the executive branch, by the Government Performance and Results Act 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 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 meeting meaningful, ambitious program outcomes. Characterizing ecological benefits associated with EPA programs is a necessary part of the program assessment process.

2.2. 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.[6] 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 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 arguably dominate the process. EPA has a formal rule-development process with several stages, each which impose demands on the Agency and the Agency also develops rules to meet court-imposed deadlines.

Several aspects of these imposed constraints deserve emphasis. First, despite the commonality of the underlying rule-development process, it is clear that there is no single way in which ecological valuation is conducted within the Agency. 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.[7] 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 used to much longer time horizons for their analyses. They are also used to the idea that a new rule should call for the collection of new kinds

[6] 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, Office of Solid Waste and Emergency Response.

[7] 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.

of data. 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 alone can add significant drag 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. It was difficult for the committee to ascertain the EPA-OMB relationship precisely.[8] 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 and inclusion of language calling for characterization of benefits that cannot be monetized or cannot be quantified (Office of Management and Budget 2003)[9]. However, the implications of some sections of the Circular, particularly relating to the treatment of benefits that cannot be readily monetized, remain somewhat ambiguous. 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." 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."

It is clear that the Agency views the OMB as a kind of "court" that reviews its analysis. In front of this "court," methods that have been accepted in the past create incentive for the use of the same or similar methods in the future. The thinking 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 reluctance 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.

[8] OMB responded to written questions, but declined to be interviewed by Dr. Boyd. EPA staff were informed that their formal responses to all questions, including the OMB-EPA interview were to be documented as part of the Committee report and this is likely to have had a chilling effect on the discussions.

[9] 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."

A related issue involves RIA review by external parties. The Agency does not take a standardized approach to RIA review.[10] EPA staff and managers reported that peer review was focussed 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 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.[11] It is not clear which work better than others. In addition, it is not clear how different programs integrate social science and biophysical science.[12]

Do we want to advocate a "ecosystem services valuation paradigm" and/or development of a set of guidelines for doing ecosystem valuation? Relationship to risk assessment paradigm/guidelines??? See more on this in footnote below.

2.3. 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).[13,14] The Agency indicated that

[10] In some cases, review panels are appointed, in others not. In some cases, contractors are called upon to manage the review. In other cases, Program Offices themselves manage the review process.

[11] Another issue that relates to the organization of science within the Agency is the availability and location of data to support ecosystem valuation. The choice of methods is clearly related to the practical availability of data across the Agency. It is important that data that are housed within individual program offices are made public and readily shared with other offices.

[12] One anecdote is that Dr Boyd was able to speak with only one ecologist during the interviews designed (in part) to interview a set of ecologists. Economists in the agency were not able to identify ecologists to interview, for example. It also became clear that simple "counts" of professional background can be deceptive. What the agency terms an "ecologist" is not necessarily what the scientific community would call an ecologist.

[13] The Committee reviewed and critically evaluated the 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

this analysis was typical 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.[15] EPA identified a wide variety of potential "use" and "non-use" benefits as part of its analysis.[16] Using various economic valuation methods, EPA provided monetary quantifications in its CAFO report for seven environmental benefits.[17] 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 as available for quantification of both the baseline condition and the likely changes from the proposed rule, and 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

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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.

[14] 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.

[15] 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.

[16] 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.

[17] 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.

Summary listed a variety of non-monetized benefits[18] 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 much 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, 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 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.

Second, 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).[19] These benefits did not include all of the major environmental benefits that the new CAFO rule would likely generated, nor all of the benefits that generated public support for the new rule.[20] The Circular requires that a benefit

[18] These include 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".

[19] 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. The CAFO report emphasizes EPA's predisposition toward conservative benefits estimates and identifies the lack of adequate data and/or models meeting EPA standards of quality as a basis for truncating the CAFO analysis.

[20] 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,

assessment identify and characterize all 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.[21] An unfortunate effect of this presentation is to suggest to readers that the monetized benefits constitute the principal justification for the CAFO rule.[22] 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, this conservative approach to 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.

Third, 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.[23] 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.

Fourth, EPA apparently did not engage in a detailed and systematic 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

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the report does not adequately address the well-known consequences of discharging TMC precursors into drinking-water sources.

[21] 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."

[22] 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.

[23] 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).

effects.[24] This model provided useful guidance, but was not sufficiently detailed to assure an adequately comprehensive and balanced 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 detailed and 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.[25]

Fifth, the CAFO analysis clearly demonstrates the challenges of conducting ecological benefit assessments at the national level.[26] 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 systematically validate the national-scale analyses. 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.

Sixth, 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

[24] 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.

[25] 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).

[26] 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.

regulatory effects that are likely to be of greatest value. This would ensure that the benefits assessment includes the most important impacts.

Finally, 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.

3. 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 a subsequent committee report. The goal in this report is simply to provide an organizing framework to guide the more detailed discussion regarding implementation.

A key feature of the framework outlined here is that it integrates 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 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. Such a framework requires a committed dialog 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.

In addition, the framework envisions the use of a variety of methods to characterize and measure benefits or values, including economic methods, social/psychological assessments, and ecological approaches. The suite of methods to be used will vary with the specific policy or valuation 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.

The proposed framework has three main components: a) identify the context and scope of the benefit assessment, b) identify the ecological services that will be considered in the assessment, and c) characterize, represent or measure those impacts in bio-

physical, human, and/or monetary terms. This proposed framework would parallel the Agency's Framework for Ecological Risk Assessment (U.S. Environmental Protection Agency Risk Assessment Forum 1992) and ultimately be merged with it as part of a broader framework for ecological assessment.

3.1. Context and Scope

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. There is a need to formulate the benefit assessment 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, i.e., whether it requires that benefits be characterized or measured in terms of bio-physical impacts, or the resulting impacts on humans, or both.

The information needed for a given policy decision will in turn depend on the decision approach to be used in evaluating alternatives. The rule to be used could be dictated by statute, regulation, or executive order, or could be determined by the EPA staff. Possible approaches include maximization of (expected) net present value (based on cost-benefit analysis), minimization of the (expected) cost of meeting a given goal (cost-effectiveness), use of a safe minimum standard, use of the precautionary principle, or use of a moral or rights-based rule based on intrinsic value. For example, the Endangered Species Act is based on an underlying presumption that species should be preserved (either because of high existence value or high intrinsic value), and hence the value information necessary to support decisions in this context can be expressed solely in bio-physical terms. In contrast, if a strict cost-benefit rule is to be used in a rule-making context, aggregate dollar values of benefits (and costs) are needed. Under a broader interpretation (e.g., OMB Circular A-4), use of cost-benefit analysis would require 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.

3.2. Ecological Services to be Included

Decisions about the ecological services to be included in the analysis should be based on an assessment of the impacts that are likely to be most important, depending on both the magnitude and bio-physical importance of the effect and the resulting impact on humans.

3.2.1 Identifying Potentially Important Bio-Physical Impacts. The bio-physical impacts of a given EPA action can be identified at different levels. These 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. Ecological science is organized according to these scales. For the purposes of ecological benefits assessment, ecological impacts

correspond to changes in functions or services provided by the ecosystem, as described above. 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.

Many types of ecological models exist at various levels (e.g., population, community, ecosystem, biosphere) to predict impacts of perturbations on ecosystems. Some have been developed for specific contexts (species, geographic locations) while others are more general. In some cases "off-the-shelf" models may be available, while in others existing models may need to be modified or new models developed. **(what should we say about the current state of ecological modeling??? We need the committee to discuss and come to some agreement about this.)**

In identifying possible impacts, it is important to consider their full range, including both primary and secondary effects, adequately accounting for uncertainty (incomplete information), (in)stability of the system (including the effect of random shocks or 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. Ecosystems are complex, highly variable systems with many interacting parts. They are subject to both natural and anthropogenic disturbances that can propagate through the system in ways that are difficult to predict. The complexity, variability, and potential instability of the systems need to be considered when identifying impacts with the greatest ecological significance.

3.2.2 Identifying What Matters to People. For benefit assessments based on anthropocentric values, it is important to identify early in the process what people care about, i.e., which ecological services or functions are important to them. 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 aesthetic appeal? Is animal waste disposal a concern to people primarily because of the recreational opportunities lost due to the resulting deterioration in water quality, or are they primarily concerned about other impacts? The range of services that are the focus of the benefits assessment needs to include the services people care most about. Previous benefit assessments have often focused on what can be measured relatively easily rather than what is most important to people. 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 include survey information (from past surveys or surveys conducted specifically for the benefit assessment) or the results of previous valuation studies. In addition, early public involvement[27] or use of focus groups or workshops comprised of

[27] This could include either a robust public involvement process following AdministrativeProcedures 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 2003) and the SAB report on

representative individuals from the affected population and relevant scientific experts can help to identify relevant or potentially important ecological services for the specific context of interest. **(Add something about group processes here?)**

In eliciting information about what matters to people, it is important to bear in mind that what people say they care about depends on both their preferences and their information, i.e., the extent to which they are informed about an ecological system and the services it provides. Survey respondents or even members of a focus group may have preferences that are representative of the general population but may not be fully informed. Expressions of what is important (e.g., in surveys) can change with the amount of information provided. Collaborative interaction between analysts and public representatives can ensure that respondents have sufficient information when expressing preferences. **(Add something about constructed preferences here?)**

The information about those ecosystem functions and services that are important to people and potentially impacted significantly should then be integrated to select the services to include in the assessment. As noted above, this requires a collaborative effort and dialogue among analysts from a variety of disciplines early on in the valuation process.

3.3. Measuring Benefits

Given the services to be included in the assessment, the impact of the EPA action on those services needs to characterized and, when possible, measured or quantified. To measure impact on humans, the bio-physical measures of ecological impact need to be translated into their effects on the goods and services provided by those ecosystems to humans. These impacts can be measured in non-monetary terms (e.g., population affected, duration of effect, etc.) or, in contexts where benefits are to be compared directly to costs, in monetary terms if possible.

Estimating bio-physical impacts requires information about the ecological production function for the services being considered. This allows an estimation of the *change* in the level of services 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). As when selecting the services to be considered , in estimating the effect of a given action on those services, it is crucial to account for the complexity of ecosystems. In particular, predicted changes need to account for the interconnectedness of ecosystems, uncertainty about how the systems operate, possible instability of the system (including the effect of random shocks or management errors and the system's resilience), heterogeneity within a population or ecosystem, heterogeneity across

science and stakeholder involvement (U.S. Environmental Protection Agency Science Advisory Board 2001)].

populations or ecosystems, and dynamic changes in the ecosystem over time. This complexity and the associated uncertainty underscore the importance of presenting ranges rather than point estimates of values when possible.

In some contexts (e.g., endangered species) where bio-physical impacts are the primary concern, the benefit assessment can end with quantification of the impact of the EPA action on these bio-physical indicators. However, when EPA policies are to be evaluated in terms of impact on humans, the bio-physical effects must be translated into the corresponding impacts on the flow of goods and services that humans value. First and foremost, 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 ecosystem services. Again, this requires that ecologists work closely with other disciplines to ensure that the ecological assessment is designed from the start with this requirement in mind.

To translate bio-physical impacts into human benefits, it is necessary to project how ecosystem changes will affect humans through changes in the flow of the goods and services they provide. 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, the number 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 or similar measures is crucial in three possible ways. First, in some contexts, decisions based on moral or religious principles (e.g., protection of children's health) may look directly to these measures as indicators of the appropriate policy choice. Second, even in contexts where monetary measures of value are sought, the human benefits captured by information on exposure or symptoms need to be translated into their monetary equivalents. This requires an understanding of those impacts on humans before this translation can occur. Third, in some cases where monetary values are sought, it may not be possible to monetize all benefits due to data or methodological constraints. In these cases, there may be a tendency simply to "ignore" the benefits that cannot be monetized. 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 sought and the necessary data and methods exist, the impact of the ecosystem change on the provision of services to human populations can be translated into a monetary equivalent of that change using standard economic valuation techniques to determine the tradeoffs that people are willing to make. Economic or monetary methods for valuing changes are relatively well-developed. They are designed to estimate the benefit or cost of a given change in ecological services 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 (randomness, level of information), dynamics, scale (temporal, geographic), and heterogeneity (spatial variability, 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 reducing uncertainty and conveying the magnitude and nature of uncertainty to policymakers.

4. CONCLUSIONS AND RECOMMENDATIONS

[to be added]

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