UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

July 12, 2005

EPA-SAB-ADV-05-004

The Honorable Stephen L. Johnson
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Subject: Advisory Review of EPA's Draft *Ecological Benefit Assessment Strategic Plan*; An Advisory by the SAB Committee on Valuing the Protection of Ecological Systems and Services

Dear Administrator Johnson:

The SAB commends the Agency for preparing the draft *Ecological Benefit Assessment Strategic Plan* and for providing it to the SAB's multi-disciplinary Committee on Valuing the Protection of Ecological Systems and Services for review. The Board strongly supports efforts to strengthen the science and analysis supporting decisions to protect ecological resources.

The Board sees merit in many of the specific recommendations in the draft plan. The effort to array issues across EPA's national program offices and identify potential actions important to all of them shows impressive collaboration and information sharing. Indeed, many of the recommendations in the draft plan, especially in the area of ecological assessment, are innovative and creative. More important than any specific issues or actions, however, is the need for the Agency to develop an expanded interdisciplinary framework for evaluating the ecological effects of policies. Such a framework would account for the Agency's decision-making needs in different policy contexts and link evaluation of ecological effects to the characterization and measurement of benefits in terms that are relevant for evaluating these policies. It is also important to develop a strategy for implementing this framework and communicating its implications to Agency personnel and the general public.

On January 25, 2005, the Committee on Valuing the Protection of Ecological Systems and Services was informed that the goal of the draft plan was "to advance EPA's ability to identify, measure, value, and communicate the ecological benefits of its actions in order to improve EPA decision-making at the national, regional and local levels." The SAB believes that it is a priority to assess the benefits of ecological protection because life depends on the benefits ecosystems provide. The Board believes that improvements in ecological benefit assessment are

essential for the success of EPA's Strategic Plan, which includes protecting "healthy communities and ecosystems" as one of EPA's five major goals.

The SAB provides advice in the attached report to improve the draft plan and to prioritize across the many issues and actions identified. We call on the Agency to implement actions identified in a revised plan to strengthen analyses supporting upcoming decisions and to invest in research needed to fill key gaps in data and methods. The SAB's Committee on Valuing the Protection of Ecological Systems and Services is developing advice to address many of the methodological and theoretical challenges associated with valuing protection of ecological resources. The SAB anticipates providing this advice to you in future reports.

Sincerely,

/Signed/

Dr. M. Granger Morgan
Chair
Science Advisory Board

/Signed/

Dr. Domenico Grasso
Chair
SAB Committee on Valuing the Protection of Ecological Systems and Services

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1. EXECUTIVE SUMMARY

The SAB commends the Agency for preparing the draft *Ecological Benefit Assessment Strategic Plan* and for providing it to the SAB's multi-disciplinary Committee on Valuing the Protection of Ecological Systems and Services for review. The Board strongly supports efforts to strengthen the science and analysis that supports decisions about the protection of ecological resources.

The Board sees merit in many of the specific recommendations in the draft plan. The effort to array issues across EPA's national program offices and to identify potential actions important to all of them shows impressive collaboration and information sharing. More important than any specific issues or actions, however, is the need for the Agency to develop an expanded interdisciplinary framework for evaluating the ecological effects of policies. Such a framework would account for the Agency's decision-making needs in different policy contexts and link evaluation of ecological effects to the characterization and measurement of benefits in terms that are relevant for evaluating these policies. It is also important to develop a strategy for implementing this framework and communicating its implications to Agency personnel and the general public.

The SAB provides the following specific advice to strengthen the plan:

Major recommendations regarding overall structure of the plan:

- There is a need to identify more clearly the role of ecological benefits assessment in Agency decision-making, recognizing its importance in not only national rule-making but also in other decision contexts.
- There is a need to revise the plan so it serves as a "roadmap," identifying key issues first and then the specific issues/actions designed to address them.
- Once key issues have been identified, the Agency should develop criteria and a process for prioritizing the many specific issues and actions that could address these key issues.
- There is a need to adopt, communicate, and implement a more integrated framework for assessing the benefits of ecological protection. Such a framework would integrate ecological, economic and other related assessments.
- The Agency should use the plan to design parallel tracks to produce short-run results to improve analyses of ecological benefits and plan for long-run research.

Other recommendations regarding issues/actions:

- The Agency should take a more integrated approach to defining and presenting issues and actions.
- The Agency should further address the issue of uncertainty associated with ecological benefits to identify and quantify sources of uncertainty in estimating benefits under different approaches, and to link this identified need to an implementation plan.

- The Agency should build on existing data collection and method development efforts where possible.
- The plan would benefit from a strengthened discussion of how the ecological benefit assessment framework would involve and improve communication with the public.
- The plan should address institutional issues associated with improving ecological benefit assessments.
- The plan should discuss implementation mechanisms more specifically.
- The SAB emphasizes the importance of developing support for the plan and viable mechanisms for making progress on the actions identified.

2. INTRODUCTION

2.1. Background

On January 25, 2005, the SAB Committee on Valuing the Protection of Ecological Systems and Services met to receive a briefing on an EPA draft document, *Ecological Benefit Assessment Strategic Plan* (EBASP or "the plan") and to provide an advisory review of that plan. The plan was authored by a cross-Agency workgroup, under the direction of an Agency steering committee. The stated goal of the plan was "to improve EPA's ability to identify, quantify, and value the ecological benefits of its activities, in order to provide decision-makers with a better basis for choosing among environmental policy options."

The Agency requested that the SAB committee address six charge questions:

Charge Question 1: "Given the audience[1] described in Section 1.4., does the Plan adequately address the objectives described in Section 1.1.?"[2]

Charge Question 2: "Are the issues described in Section 4 the most important ones that EPA should address to improve its ability to identify, quantify, and value the ecological benefits of its activities? If not, what issues should be added?"

Charge Question 3: Are there actions in Section 4 that are the most important for EPA to undertake at this time to improve its ability to conceptualize, identify, quantify, and value the ecological benefits of its activities? Do the actions respond to the identified issues? Are there actions that are missing?

Charge Question 4: Are there other actions you would recommend?

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[1] Agency Description of Audience for Strategic Plan (Section 1.4)

- EPA managers and analysts who devote time or other resources toward basic or applied research in areas of ecology, related natural sciences and economics relevant to ecological benefit assessment.
- EPA analysts developing action plans to guide future investments in ecological benefits assessment.
- Researchers in academia, other federal agencies and members of public -- to inform about EPA's need and objectives

[2] Agency Statement of Objectives (section 1.1)

- Describe technical and institutional issues that prevent the Agency from conducting accurate and comprehensive ecological benefit assessments.
- Direction for future research, data collection and development of analytical tools.
- Propose activities to foster increased collaboration and coordination among Agency's ecologists, economists, and other analysts in ecological benefits assessment.
- Propose institutional mechanisms to facilitate adaptive implementation of plan and adjustment to reflect scientific progress.

Charge Question 5: Are there specific research approaches, or research projects, on which the Agency should focus?

Charge Question 6: Is the proposed implementation plan adequate?

2.2. Process for Developing this Advisory and the Structure of this Report

The SAB committee discussed the six charge questions at its face-to-face meeting on January 25, 2005. After the meeting a sub-committee of the full committee (a writing group) developed a draft document based on committee discussions and preliminary written comments provided by members of the committee. The writing group prepared a draft for full committee discussion at a public meeting held on April 13, 2005.

Because much of the advice provided by the committee pertained to multiple charge questions, the structure of this report does not strictly mirror the six charge questions initially presented to the committee. Instead, section 3, "Principal Recommendations" addresses charge question 1 and parts of charge questions 2 and 3 as they pertain to prioritization of issues and actions. Section 4, "Recommendations Regarding Proposed Issues and Actions," discusses charge questions 2, 3, 4 and 5 as they pertain to specific issues and actions discussed in the plan, and additional issues and actions, including research projects, that the committee advises be addressed. Section 5 addresses implementation issues raised in charge question 6. Appendix A contains specific suggestions for changes in the text to strengthen the plan.

3. PRINCIPAL RECOMMENDATIONS

3.1. Identify More Clearly the Role of Ecological Benefits Assessment in Agency Decision-Making

The committee advises the Agency to revise the plan to recognize the importance of ecological benefits assessment in a variety of EPA decision contexts, including both national regulatory analyses as well as in the review and evaluation of local and regional environmental planning. The key question that needs to be addressed here is: why is it important to assess the benefits of protecting ecological systems and services? Section 1.2 of the Agency's draft plan focuses almost exclusively on benefit-cost analysis to support national rulemaking, and Section 1.4 (Intended Audience) reflects this focus. However, the importance of ecological benefits assessment goes well beyond this, and the committee urges the Agency to think more broadly about how information about ecological benefits might be used to improve decisions in a variety of contexts. In addition, some decision contexts (e.g., regulatory analysis) require that benefits be expressed in dollar terms, while in other contexts having a single aggregate dollar value of benefits may not be appropriate or necessary. A broader recognition of the various contexts in which benefits information might be useful and the differing needs within those contexts would expand the plan's relevance and usefulness.

The plan should also reference the importance of benefits assessment in realizing the goals of the *2003-2008 EPA Strategic Plan; Direction for the Future* (EPA, 2002). It should provide the reader with a clear discussion of the need for identifying, quantifying, and valuing changes in ecosystems and their services. The committee advises the Agency to communicate through the plan the importance of ecological benefits and to convey the goal and the key elements of the plan in positive, direct terms. Rather than emphasizing historical and methodological hurdles, the message should be that the benefits of ecological protection are important to quantify, that life depends on some of the services of ecosystems, and that one of EPA's goals is to protect ecological resources. Language in the foreward, the initial paragraphs of the executive summary, and the introduction especially should be revised in this light.

In addition, the committee advises the Agency to clarify that the scope of the plan includes not just research, but also broader institutional and organizational changes needed to make progress in ecological benefit assessments. There is also a need to revise the plan to clarify that the scope was not limited to national benefit assessments and to state clearly that EPA regional needs for benefit assessments are to be addressed in the plan. It will be important to specify that regional analysts and managers are a potential audience for the plan and to involve them in future revisions and discussions about implementation.

Finally, the committee advises the Agency to clarify early in the report how the term "benefits" is used, and the types of benefits that are the focus of this effort. The recent Millennium Assessment reports (1972; Millennium Ecosystem Assessment 2005; Millennium Ecosystem Assessment Board 2003) can provide guidance to the Agency on definitions. In

addition, the committee recommends that the Agency use the recent NRC report, *Valuing Ecosystem Services* (2004), as a source and a model for acknowledging the kinds of value that are amenable to capture through economic valuation methods (the focus of much of that report) and the types of values that are not.

3.2. Revise the plan so it serves as a "roadmap" that links actions to the objectives of the plan

To be strategic, the plan needs to provide a roadmap that will allow EPA to chart progress from current practices to desired objectives. The strategic plan thus needs to address the following three questions: a) what is the current state-of-the art in ecological benefits assessment at EPA?; b) what are the most important current gaps in knowledge or institutional/procedural obstacles that limit the Agency's ability to do effective ecological benefits assessment; and c) how is the Agency planning to fill the knowledge gaps or overcome the institutional/procedural hurdles over the next five or so years? The draft report addresses these three questions to some extent. However, the committee notes that the links between these questions are not clearly identified in the plan. Section 3 is a brief introduction to the state-of-the-art in ecological and economic assessments, which ends with a call for an integrated benefits assessment process. Thus, the main "gap" identified in this review is the lack of integration between ecological and economic assessment. The committee agrees that this is a key gap. While this gap provides justification for some of the issues and actions in Section 4, many of the issues and actions in Section 4 are unrelated to it. As a result, it is not clear how the implementation of the plan will help to address the gap. In addition, the commitment to a multi-disciplinary approach in Section 3 is largely undone in Section 4, where ecological and economic assessments are once again described as if they are activities that can be undertaken separately.

Most importantly, Section 4 of the plan provides a list of issues and possible actions, not a roadmap. Some of the issues listed in the plan appear to the committee as key over-arching issues, while others are more narrowly focused. Yet, they are all given equal weight in the listings. The committee advises the Agency to revise the document to identify clearly a small number of key issues and then to relate the more specific issues and actions listed in Section 4 of the plan to these over-arching needs.

In its deliberations, the committee has identified a number of key issues or gaps that limit the evaluation of ecological benefits. The committee advises the Agency to do the same, using the following list as a starting point. The list includes: the need for a) an interdisciplinary approach to ecological benefits assessment, involving communication, coordination, and collaboration among ecologists, economists, and other social scientists; b) better measurement of the ecological impacts of alternative actions in terms that are useful for benefits assessment, with particular emphasis on adequate treatment of uncertainty; c) improved understanding of the types of ecological systems and services that are most important to people (i.e., the most relevant endpoints); and d) improved characterization and measurement of the values of the most important impacts on ecological systems and services in terms that are relevant for the specific policy contexts. The committee also advises the Agency to put high priority on the development of a set of guidelines for planning and conducting ecological benefits assessments

3.3. Develop and Implement a Process for Prioritizing Specific Issues and Actions.

Once the Agency has decided on a list of key issues, the committee advises the Agency to refine and prioritize the list of specific issues and actions in the plan and relate each specific issue and action to one or more of the key issues. Rather than providing advice on priorities, the committee advises the Agency to develop criteria and a process for prioritizing specific issues and actions under each broad need. Such a process will be essential for implementing a revised strategic plan. The committee advises the Agency to review its current practices and the current state-of-the-art in ecological benefits assessment for the purpose of explicitly identifying the primary knowledge gaps or obstacles along the lines suggested above. The Agency can then link these gaps or obstacles to specific issues and actions. This overview would allow readers to clearly see the relationship of planned actions to desired objectives and needs. It will be especially important to recognize the relationship between planned research activities and improved capacity for conducting benefit assessments. Such a roadmap will promote understanding of how components of the plan relate to its objectives and also provide the basis for measuring the Agency's progress in meeting its objectives.

The committee notes that the draft plan described a history of meetings and workshops focused on ecological benefits, where experts identified issues and recommended solutions to the problems raised. These interactions, however, do not substitute for a focused effort in the Agency to set priorities. Although such meetings and workshops are essential to solicit broad input from the various professional communities, their findings are not sufficient to establish an organization's priorities in a strategic plan. The plan, apparently deliberately, stops short of setting any priorities. The current draft identifies "considerations for prioritizing Agency actions" in Section 5 on Implementation, but states that it has not outlined a specific set of priorities. Without this, however, the plan does not offer what is claimed -- a "roadmap for an incremental and sustained effort" to improve ecological benefits assessment. If the plan is to be a roadmap and provide direction for future research or resource allocation, then considerations for prioritization should drive the discussion of specific issues and actions rather than follow it. Rather than identifying a wide range of possible actions that might be of interest (a "wish list"), it needs to identify the key issues as discussed in Section 3.2 above and prioritize among the specific issues and actions to determine those that are most crucial in advancing the Agency's ability to conduct meaningful ecological benefits assessment. This does not mean that the plan must specify priorities within program offices, but rather that it should set broad priorities that would provide guidance to specific program offices when setting program-specific priorities.

Committee members discussed a variety of possible criteria for the Agency to use in setting priorities across actions and several possible processes to use. In addition to those suggested in Text Box 3 of the draft plan (page 61), other possible criteria suggested by the Committee include the extent to which the proposed research would reduce uncertainty and whether the proposed actions would contribute substantially to the Agency's ability to assess non-use benefits. Whatever criteria and process the Agency chooses, the committee advises that the Agency describe them explicitly in a revised strategic plan, so that the reader can understand how and why the decisions were made.

3.4. Adopt, Communicate, and Implement a More Integrated Framework for Assessing the Benefits of Ecological Protection

The committee appreciates the ambitious scope of the draft plan. However, the plan would be more effective as a document for its intended audience and as a guide to implementation if it were organized more consistently around a comprehensive framework for benefits assessment. Thus, the committee advises the Agency to build on the draft by adopting, communicating, and implementing an integrated framework for assessing the benefits of protecting ecological systems as well as the identifiable services they provide. Considering ecosystem impacts in this way is expected to offer complementary strategies for assessment and to assure that interdependencies across components of ecosystems are recognized.

The draft plan does include Figure E-1, "Stylized representation of an integrated ecological benefit assessment," which is a starting point for building such a framework. The committee sees a need, however, for EPA to improve this figure. The goal should be to develop a figure or framework that can serve as a basis for a set of guidelines on conducting ecological benefits assessments and as a communication tool for the intended audiences (i.e., EPA managers and analysts engaged in planning research and analysis supporting EPA decisions and researchers in academia, other federal agencies and members of public). Although the figure displays roles for both economics and ecology in the assessment process at various stages and the title includes the word “integrated,” the descriptions in the individual boxes are confusing. They do not provide sufficient indication of the integration across multiple disciplines that is needed at the various stages of the assessment process. The boxes seem to imply that management decisions concerning both the character of endpoints to be considered in the assessment and the strategies for addressing them are made early in the process (before the benefit assessment is complete) and that activities associated with quantifying the “valuation” information enter the process at the end, after the physical impacts have been assessed.

What is needed instead is an explicit recognition that the first stages of the benefits assessment process (the selection of assessment endpoints) require ecologists, economists and other social scientists to work together to identify not only the set of impacted ecological endpoints (i.e., physical impacts) but also those that are most important to society. Valuation can play a role not only in estimating the value of changes in goods and services that would result from a given action (as depicted in Figure E-1), but also in informing the strategic decisions associated with the design of the overall benefits assessment. It can provide general information about the ecological goods and services that seem to be most important to people and hence should be the focus of detailed valuation work in the specific context of interest. In addition, it can help analysts and policy makers decide the alternatives to be valued in the overall benefits assessment.

The Committee thus calls for a framework that: a) integrates ecological, economic and other related assessments throughout a project; b) depicts the complexity and potential for interaction effects within the process of benefits assessment; and c) identifies the role of stakeholders in the ecological benefit assessment process. There are a number of existing frameworks that could provide the basis for an approach that could be adopted here (Millennium Ecosystem Assessment Board 2003; National Research Council 2004). In addition, the

committee anticipates issuing future reports that should provide useful to the Agency in this regard.

In addition, the committee notes that ecological benefits assessment faces a challenge similar to that faced by health scientists, economists, and other scientists after publication of *Risk Assessment in the Federal Government* (National Research Council 1983), the NAS study of human health risk assessment known as *The Redbook* and used at EPA. There is a need to provide a framework that is similarly compelling to provide an organizing logic to rationalize and organize the available information on ecological benefits. This framework could also be a catalyst in motivating action on addressing the components of research where information is not available.

Although the Agency's strategic plan refers to the Agency's *Guidelines for Ecological Risk Assessment* (EPA 1998) and derives much of figure E-1 from the basic paradigm in the *Guidelines*, it states that "ecological risk assessments are designed to address different questions than those posed by ecological benefits assessments" (page19). While the questions driving the assessments may be different, the need for an integrated and logical approach to assessment is the same in both contexts. The problem formulation stage provides a striking example of the need for an integrated, logic-based approach. During this stage, ecologists, economists, and other scientists need to consider jointly both the strategies that will be used for ecological assessment and the metrics for valuation. More generally, risk assessments involve characterizing the processes that give rise to different types and levels of risks and allow identification of how different policies could alter one or more constituent elements of those processes. This approach has allowed economic assessment to consider the tradeoffs people would be willing to make to realize comparable risk changes. While the strategy is far from perfect (e.g., the definitions of the events at risk and the interdependencies among them have not been structured in ways that facilitate measuring tradeoffs for interrelated sequences of activities), it has allowed greater coordination in activities associated with preparing regulatory impact assessments and in designing research that attempts to address the limiting assumptions of current methods. It provides an approach to assessment that could be applied in the context of ecological benefit assessment as well. The committee advises the Agency to exploit the parallels between risk assessment and ecological benefit assessment in developing an integrated framework within the Strategic Plan.

In calling for the Agency to develop a revised framework, the committee also notes the need for broader involvement by a variety of disciplines, whose expertise, methods, and data can inform both the problem formulation stage and the valuation stage. Figure E-1 provided in the Agency's draft plan is bi-disciplinary in orientation, focused only on ecological and economic assessment. There is a need to acknowledge that a fuller range of sciences may be necessary to assess the full range of values relevant to decision making. A framework that allows for contributions from bio-physical, natural resource, health, psychological, social, and political sciences is needed.

3.5. Design parallel tracks to produce short-run results and plan for long-run research

The committee advises the Agency to retain a dual focus in the strategic plan: 1) actions designed to make short-term progress where there is ability to integrate information on the value of ecosystem services and to have that information appear quickly in Regulatory Impact Analyses or other documents supporting Agency decisions and 2) actions that contribute to a long-term research agenda to build over time the knowledge needed for comprehensive benefit assessments. Although a dual focus is challenging, members saw benefits in selecting near-term priority actions, where success could be measured and build enthusiasm for longer-term efforts. Members note that EPA's air and water legislation impose a schedule for revisiting regulations within certain timeframes. This schedule could impose a structure for ongoing planning for integrated ecological benefits assessment at the national and regional scales that would have practical results for improving high-priority benefit analyses and advance the science in general.

3.6. Summary of responses to charge questions addressed in this section

Unless otherwise specified, section references in this part of this SAB report refer to the Agency draft plan.

Charge Question 1: Given the audiences described in Section 1.4, does the Plan adequately address the objectives described in Section 1.1.?

Response: The plan partially addresses these objectives, although there is a need: a) to identify more clearly the role of ecological benefits assessment in Agency decision-making; b) to revise the plan so it serves as a "roadmap" that links actions to the objectives of the plan; c) to develop and implement a process for prioritizing issues and actions; d) to adopt, communicate, and help implement a more integrated framework for assessing the benefits of ecological protection; and e) to design parallel tracks to ensure short-run results and plan for long-run research.

Charge Question 2: Are the issues described in Section 4 the most important ones that EPA should address to improve its ability to identify, quantify, and value the ecological benefits of its activities? If not, what issues should be added? Charge Question 3: Are there actions in Section 4 that are the most important for EPA to undertake at this time to improve its ability to conceptualize, identify, quantify, and value the ecological benefits of its activities? Do the actions respond to the identified issues? Are there actions that are missing?

Response: Section 4 identifies a number of issues that the committee views as high priority. However, it does not distinguish between key, over-arching issues and more narrowly focused issues and actions designed to address those needs. The committee urges the Agency to identify key needs (as suggested above) and then develop criteria and a process for prioritizing the many more specific issues and actions that will address these needs, either in the short run or in the long run.

4. RECOMMENDATIONS REGARDING PROPOSED ISSUES AND ACTIONS

Given the general advice summarized above, the committee limited its advice on the proposed issues and actions in the draft plan to the topics below.

4.1. Define and present issues and actions in ways that highlight an integrated scientific approach

As noted above, the committee commends the Agency for proposing an "integrated ecological benefit assessment" in the draft plan. Such an approach calls for an integrated definition and presentation of issues and actions. However, the draft report presents issues and actions primarily along disciplinary lines (ecological vs. economic issues). A more integrated approach would organize issues and actions in a way that emphasizes the need for an interdisciplinary approach. The committee notes, for example, that the need to establish baselines (section 4.5.1 of the draft plan under “Analyzing Ecological Changes”) was not unique to ecological conditions and indeed cannot even be addressed in isolation from social and economic conditions. The committee advises that it would be more consistent with an integrated approach to involve ecologists, economists, and other scientists jointly in the problem formulation stage to characterize baselines and project changes in ecological and social conditions in a coordinated way.

Similarly, the committee notes that social systems that help to define "ecological benefits" are as dynamic as the ecological systems that determine the endpoints to which benefits are linked. Immigration and aging, for example, produce shifts in demographics that affect demand for ecological services. Therefore, the committee advises the Agency to project and evaluate socio-economic factors in coordination with ecological changes. Coordinated monitoring of ecological and social outcomes would seem to be essential for: a) confirming that socio-economic effects of ecological changes (endpoints) were accurately projected by the prior benefits assessments; b) ascertaining whether wants and needs of society were changing separately or in interaction with ecological changes (potentially changing what constitutes "ecological benefits"); and c) determining whether social responses to regulations and/or changed environmental conditions were feeding back in productive or destructive ways affecting the targeted ecological concerns (a concern addressed at the end of section 4.6.1 of the plan).

The committee advises that a similarly integrated approach should be taken regarding studies to compare different methods. The committee advises the Agency to integrate its approach for comparative studies of alternative ecological indicators (section 4.5 of the plan) with assessment of other methods. It would be useful to integrate such analyses with assessments of the contributions and limits of economic assessment methods (section 4.6 of the plan) and assessments of the other methods described in the draft as "supplemental methods" (section 4.7 of the plan).

4.2. Articulate more clearly the role for "supplemental" or alternative methods as part of an integrated approach

Some sources of value cannot be captured through economic valuation and there are practical issues that can make it difficult to quantify and to monetize even those values amenable to capture through standard economic methods. In addition, in some policy contexts, the factors that can or must be considered dictate the type of benefit measures that are relevant. For example, although regulatory impact analyses are explicitly required by executive order to weigh benefits and costs (measured monetarily, if possible), such considerations are not paramount in other contexts where decisions are based primarily on other criteria. Thus the committee supports the plan's call for further investigation of what the Agency termed "supplemental" methods in the report. The committee recognizes that the nature, scope, relative utility, and possible contributions of such methods are significant and important questions. The committee is currently working to address these questions and anticipates providing guidance on the use of these methods in a future committee report.

Based on its deliberations thus far, the committee advises the Agency to call for the use of ecological, economic and other methods to support decision-making and a systematic evaluation of the usefulness and limitations of those methods in specific policy contexts. Results from each method or class of methods that measure different concepts should be identified separately to avoid confusion that might arise from the close parallels in the labels and terminologies used to describe the underlying methodologies.

4.3. Uncertainty and expert elicitation

The committee advises the Agency to strengthen section 4.2.3 in the draft plan, "Addressing Uncertainty in Ecological Benefits Assessment." The committee suggests that the section would benefit from the discussion in the NRC report (2004) on judgment and uncertainty and that several additional action items might be suggested by that report. The committee also advises the Agency to be more precise in the draft plan in discussing the limits of current data, methods, and knowledge. The draft plan currently states that data limitations constrain what can be done and that more data are needed on particular issues (page12, line 33, page 13, line 4, and *passim*). However, these statements seem to be used both to refer to situations where data are inadequate and to situations where knowledge or understanding is lacking. These situations are very different. In the case of a lack of knowledge or understanding, new research is needed to advance the science. There is no guarantee that a certain investment in research will provide the needed new understanding. This certainly is the case with regard to some of the challenges related to ecological benefit assessment. However, in other cases, there may be adequate understanding and methodologies, but the Agency does not have adequate data for the particular systems of interest. It could be relatively straightforward in these cases to collect new data. The committee advises the Agency to distinguish between these two very different situations in the discussion of limits of methods and data.

The committee also advises that the revised plan include an activity to explore what role expert elicitation might play in addressing uncertainties associated with ecological benefit assessments at EPA. The committee notes, however, than when relying on expert elicitation, it is important to identify whether experts are summarizing their technical judgments based on the

"science" -- be it ecological, economic, or other relevant science – or providing information that reflects primarily their personal preferences among alternative outcomes.

4.4. Build on existing efforts where possible

In discussing the actions identified in the draft plan, the committee emphasizes the importance of utilizing and building upon existing data collection and analysis efforts. The committee commends the Agency for the action item to increase coordination of long-term, large-scale data collection efforts within the Agency (page 32 in the plan). Members, however, identified several additional actions they believe should be included in a revised plan. The committee advises the Agency to evaluate the data provided by Environmental Monitoring and Assessment Program (EMAP) and the Agency's related Regional Vulnerability Assessment (ReVA) Tool. The plan should include an action to determine the utility and potential of these data to address the benefits of protecting ecological systems and services.

The committee also notes the need for actions to make use of data collected outside EPA. Coordination of long-term, large-scale data collection efforts is a topic that has received enormous consideration, both in the scientific literature and in the organization of research programs of other agencies, e.g., the U.S. Departments of Agriculture, Interior, and Energy and the National Science Foundation (NSF). The committee advises the Agency to inventory the information already available and include an action committing the Agency to evaluate its potential use of these data. The committee specifically advises the Agency to benefit from the 20-year and continuing NSF-sponsored Long-Term Ecological Research (LTER) program with its long-term databases and its focused work on regional data and to explore the potential for using data to be generated by the National Ecological Observatory Networks (NEON) for assessing ecological benefits.

The committee also advises that the plan include actions to build on the analytical work conducted outside the Agency. EPA could benefit from ongoing interactions with other organizations in these specific areas: development of generic ecological endpoints for benefits assessments; design of monitoring programs; assessment of existing monitoring programs; and identification of the particular ecosystem processes most relevant to assessments. The committee advises the Agency to build on the ongoing work of the Millennium Ecosystem Assessment and the H. John Heinz III Center for Science, Economics, and the Environment.

The committee notes that section 4.5 of the plan was very well written and thorough. The issues selected were the most important and the actions were appropriate, and some were quite innovative. Suggestions noted below provide some additional advice for actions to be considered for inclusion in a revised plan.

The committee notes actions in the plan calling for a catalog of population models (section 4.5.2, page 45) and a catalog of ecosystem process models (page 47). A catalog or annotated inventory of models would indeed be a reasonable beginning step. In addition, it is important to construct a decision framework for determining the applicability and limitations of existing models for specific use in ecological benefit assessment and for developing and applying new models. The committee advises the Agency to include in its revised plan an action

to identify an algorithm for deciding on proper models for different decision contexts and testing their appropriateness.

The committee notes that some of the actions identified relate to new research. The committee advises that the implementation plan specifically note research needs and needs for guidance to Agency units that will develop Requests for Proposals and Broad Agency Agreements and fund research.

4.5. Specific advice regarding issues and actions related to estimating monetary values of ecological changes

The committee advises the Agency to provide an organizing framework for its discussions in section 4.6 of the draft plan. The EPA could usefully incorporate Figure 7.1 of the NRC report (2004), which identifies connections between ecosystem structure and function, services, policies, and values, and Table 4-1 in the NRC report, which matches valuation techniques with types of valuation, with modifications suggested by recent literature eliminating the problematic distinctions between "direct" and "indirect" methods (Freeman 2003).

Committee members also suggest that the discussion of valuation studies in section 4.6 would benefit from an action calling for expanded discussion of methodologies. In addition to focus groups, there are numerous approaches to improving survey methodology that would benefit the Agency, including: individual interviewing approaches; verbal protocols (think-aloud, read-aloud protocols of individuals doing surveys); and combined individual and group interview approaches. The committee advises the Agency to consult behavioral scientists (psychologists in particular, and also judgment and decision making researchers), survey methodologists and organizational behavioral researchers (for firm-level responses to proposed actions). These consultations will aid in the development of appropriate questions to be used in the data collection instruments that provide the information used in valuation exercises designed to recover informed individual tradeoffs.

4.6. Address how the public will be involved in ecological benefit assessment and improve communication with the public

As discussed in section 3.4 of this report, the committee advises the Agency to adopt a general framework and use it to implement strategic changes in the Agency's approach to ecological benefit assessment. One of the elements important to that framework is how stakeholders relate to ecological benefit assessment. The committee notes that one of the key audiences and constituents in ecological benefit assessments is largely missing in the plan. Other than a brief section on page 36 focused on behavioral responses to different types of regulatory strategies, there is little recognition that the interested and affected public has a role to play. The committee advises the Agency to consider issues and actions related to how the public may be involved in assessing ecological benefits and how an expanded framework would improve communication with the public about the benefits of protecting ecological resources.

4.7. Address institutional issues and identify actions to improve analyses supporting decision making

Based on information provided by the Agency, the committee understands that the scope of the plan is broader than just research and is meant to encompass needed "advancements and changes to make progress in ecological benefit assessments beyond the research domain." Given that goal, the committee envisions the plan as necessarily providing "parallel tracks to produce short-run results and plan for long-run research," as discussed in section 3.5 above. To plan for short-run results, the committee advises the Agency to revise the plan to identify more clearly the chief operational hurdles faced by the Agency in conducting ecological benefit assessments. Issues associated with staffing limitations, human resource needs, the time constraints on development of ecological benefit assessments, and the legal requirements and procedural issues associated with Information Collection Requests and their review are several issues that are relevant to the development of improved benefit assessments and need to be addressed in the plan. A successful strategic plan will identify those issues and provide actions to address them.

4.8. Summary of responses to charge questions addressed in this section

Unless otherwise specified, section references in this part of this SAB report refer to the Agency draft plan.

Charge Question 2: Are the issues described in Section 4 the most important ones that EPA should address to improve its ability to identify, quantify, and value the ecological benefits of its activities? If not, what issues should be added?

Charge Question 3: Are there actions in Section 4 that are the most important for EPA to undertake at this time to improve its ability to conceptualize, identify, quantify, and value the ecological benefits of its activities? Do the actions respond to the identified issues? Are there actions that are missing?

Charge Question 4: Are there other actions you would recommend?

Charge Question 5: Are there specific research approaches, or research projects, on which the Agency should focus?

Response: Overall, the committee advises the Agency to take a more integrated approach to defining and presenting issues and actions. There is a need to explore and evaluate the role of “supplemental” or alternative methods for characterizing and measuring ecological benefits in different policy contexts. The committee also identifies the need for the Agency to address the issue of uncertainty associated with ecological benefits, to identify and quantify sources of uncertainty in estimating benefits under different approaches, and to link this identified need to an implementation plan. In addition, the Committee advises the Agency to consider how expert judgments regarding the ecological importance and stakeholder judgments of the social consequences of changes can inform ecological benefits assessments. It emphasizes the importance of building on existing data collection and method development efforts where possible. It provides some specific advice regarding issues and actions related to analyzing ecological changes and estimating the tradeoffs people would be willing to make to assure that improvements are realized (or deterioration in services is avoided). It notes that the plan would benefit from a strengthened discussion of how the ecological benefit assessment framework

would involve the lay public and communicate with it and how the Agency would address institutional issues associated with improving ecological benefit assessments.

5. IMPLEMENTATION PLAN

Charge Question 6 asked the committee to address the following question: "Is the proposed implementation plan adequate?" After discussing the detailed information provided in the plan, the committee provided the advice below as a response.

5.1. Incorporate more specific discussion of mechanisms for implementation

The committee notes that the discussion of implementation mechanisms provided in the plan was very brief and was supplemented substantially by information provided to them in a briefing by Dr. Wayne Munns on January 25, 2005. Dr. Munns noted that the Agency had envisioned that the plan would be implemented through four principal mechanisms: Program Office action plans; action plans in the Office of Policy Economics and Innovation; Office of Research and Development multi-year plans; and the extra-mural grant program, Science to Achieve Results (STAR), and other collaborations. The committee advises the Agency to include a clear discussion of these mechanisms in the revised plan, so that readers can understand how responsibilities will be assigned for different actions and the timelines associated with different actions.

The committee also asks the Agency to include a discussion in the revised plan of the incentives and motivations that will move the plan forward.

5.2. Vision, communication, and implementation are key

The committee emphasizes the importance of developing support within the Agency for the plan and viable mechanisms for making progress on the actions identified. The committee advises that each action or set of actions should have a senior manager identified as a "champion" to help insure that it does not get left behind or forgotten as the Agency undergoes changes. The committee views the plan as important and cautions that the coordination mechanisms described in the plan do not describe how decisions will be made, how conflicts will be resolved, and how priorities will be set. Establishing a forum for tracking progress on the plan will not be a sufficiently strong mechanism to achieve effective and efficient implementation without leadership support for the goals of the plan.

The committee believes that characterizing and quantifying the benefits of ecological protection is important to EPA's achieving its overall goal of protecting human health and the environment. Successful implementation of the plan depends in great part on effective communication about its goals and about the new framework for ecological benefits assessment that a revised plan should include.

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APPENDIX A: SPECIFIC SUGGESTIONS FOR CHANGES

Executive summary: The committee sees the need to revise executive summary to eliminate jargon and vague language.

Page 4, Text Box 1, first item. This should be revised to read "Ecosystem functions or processes". Ecological functions or processes include much more than is mentioned here. For instance, population dynamics, plant-animal interactions, etc. The definition provided focuses specifically on ecosystem processes.

Page 4: There is no mention of time anywhere, e.g., CBA over what time frame?

Page 12, lines 19-20: Could one not estimate changes in some cases rather than measuring them?

Page 13, lines 1-2: Should one consider the potential consequences of an action on, say, a keystone species, even if one cannot measure?

Page 19, lines 21-22: Ecological risk assessment and ecological benefits are not totally different.

Page 21, Figure 2: There is no feedback or risk communications implied here, but it is implied on page 26, lines 7-8.

Figure 4: The second and third boxes should be switched. How can one assess the effects of management actions before assessing the exposure and responses to the stressors to be managed?

Page 26, line 1: There are domains other than economics such as cultural values, etc.

Page 27, lines 17-26: Redundant.

Page 28, box 2: Redundant.

Page 32, line 43: What does "signal to noise ratio" mean here?

Page 55, lines 9-10: Should mention that a non-government panel (USEPA 1990-c) came up with totally different priorities.

Page 44. Although any definition is theoretically possible, the term "population" is usually not used to describe biomass.

Page 61. There is also a somewhat disturbing (and we believe unintended) commentary on the relative "ethics" of economists and ecologists. In text box 3 the plan suggests under the heading, "Opportunity for collaboration across disciplines," "in view of the analytical and (sometimes) ethical divide between ecologists and economists and the importance of collaboration, actions

that involve economists and ecologists working closely together on a particular aspect of the ecological benefits assessment process are highly valued." This statement appears to imply that one of the two groups is less "ethical" in some professional sense and the other will help in "policing" these lapses in ethical behavior. We don't believe this was the intention of the discussions, but it could be easily interpreted that way. We believe the intention was to note that there are there are legitimate differences in philosophical bases for valuation that sometimes lie behind disagreements between ecologists and economists on some issues. Clarification of this issue would be helpful.

APPENDIX B: BIOSKETCHES

Dr. William Ascher

Dr. William Ascher (Ph.D., Political Science, Yale University) is the Donald C. McKenna Professor of Government and Economics at Claremont McKenna College, where he also serves as Vice President and Dean of the Faculty. His research covers environmental and natural resource policymaking, evaluation and forecasting methodologies, and policymaking processes in developing countries. As the Director of the Duke University Center for International Development Research, he led workshops on the valuation of environmental services for the UN Food and Agriculture Organization and several national governments. He also undertook World Bank-funded research on the valuation of oil and mineral assets. His most recent books are Why Governments Waste Natural Resources (1999), The Caspian Sea: A Quest for Environmental Security (ed. with Natalia Mirovitskaya, 2000), and Guide to Sustainable Development and Environmental Policy (ed. with Natalia Mirovitskaya, 2001). He has also published two books on political-economic forecasting: Forecasting: An Appraisal for Policymakers and Planners (1978), and Strategic Planning and Forecasting (with William Overholt, 1983). He served on the Advisory Group on the Future of Science, U.S. House of Representatives Subcommittee on Science, Committee on Science, Space and Technology.

Dr. Gregory R. Biddinger

Dr. Gregory R. Biddinger is the Environmental Program Coordinator for ExxonMobil Biomedical Sciences, Inc. In his current position he has two primary responsibilities 1) strategic planning related to the environmental aspects of ExxonMobil's business and 2) development of methods and application of Natural Land Management strategies on ExxonMobil's current and former operating properties. He regularly represents ExxonMobil on matters of wildlife conservation and ecological restoration. Dr. Biddinger has practiced professionally as an environmental scientist for over 25 years. He received a doctoral degree from Indiana State University in Life Science (Ecology/Physiology) and post-doctoral training in Ecotoxicology at Cornell University. His experience ranges from the design and implementation of strategic environmental business planning processes for ExxonMobil, to the design and establishment of ecotoxicological testing facilities for Cornell University and the Illinois Environmental Protection Agency. He has been very active in development and review of Ecological Risk Assessment methods, and in drafting international standards related to Ecotoxicology, Risk-Based Corrective Action, Environmental Management and Greenhouse Gas Accounting. Dr. Biddinger has served on the U.S. EPA SAB Ecological Processes and Effects Committee (EPEC). In addition to his work on the U.S. EPA SAB committees, he has been active in numerous expert panels and peer reviews for U.S. EPA, Organisation for Economic Co-operation and Development and Society for Environmental Toxicology and Chemistry. His other professional activities have included chairmanships with the American Society for Testing and Materials, American Chemistry Council and International Standards Organization technical committees. Dr. Biddinger was the founding chair of the Society of Environmental Toxicology and Chemistry (SETAC) Ecological Risk Assessment Advisory Group (1992-2002). Dr. Biddinger is a founding editor of the SETAC journal Integrated Environmental Assessment and Management. His publications cover the areas of aquatic toxicology of inorganic arsenic,

phthalate esters, chemical dispersants, and the use of microcosms in estimation of tropic transfer of contaminants. Dr. Biddinger has also published and edited proceedings on ecological risk assessment and risk management, including such topics as the ecological risks of contaminated sediments, decision support systems, sustainable environmental management, integrated environmental decision-making and Landscape ecology and Wildlife Habitat Evaluation.

Dr. Ann Bostrom

Dr. Ann Bostrom (B.A., University of Washington; M.B.A., Western Washington University; Ph.D. in Public Policy Analysis, Carnegie Mellon University; Fulbright graduate studies and Lois Roth Endowment award, Stockholm University; postdoctoral studies in Engineering and Public Policy, Carnegie Mellon University; postdoctoral studies in cognitive aspects of survey methodology, American Statistical Association/National Science Foundation/Bureau of Labor Statistics award) is an Associate Professor in the School of Public Policy and Associate Dean for Research in the Ivan Allen College at the Georgia Institute of Technology. Her research focuses on mental models of hazardous processes (how people understand and make decisions about risks), and is currently funded by the National Science Foundation, and the U.S. Environmental Protection Agency in the areas of air pollution, children's environmental health, and seismic risk. She co-authored Risk Communication: A Mental Models Approach (Cambridge University Press, 2001), with M. Granger Morgan, Baruch Fischhoff, and Cynthia J. Atman. Dr. Bostrom served as program director for the Decision Risk and Management Science Program at the National Science Foundation from 1999-2001 and is on the editorial boards of Risk Analysis and the Journal of Risk Research. She is a former Councilor of the international Society for Risk Analysis, a past Chair of its Risk Communication Specialty group, and received its Chauncey Starr award for a young risk analyst in 1997. Dr. Bostrom is a past member of the executive committee of the U.S. EPA Board of Scientific Counselors, has served on National Research Council, Transportation Research Board, and Institute of Medicine committees, and has consulted for other organizations on risk communication.

Dr. James Boyd

Dr. James Boyd has been a Fellow in the Energy and Natural Resources division of Resources for the Future (RFF) since 1992. He received his Ph.D. from the Public Policy and Management Department of the Wharton Business School at the University of Pennsylvania in 1993 and has been a Visiting Professor at the Olin Business School Washington University, St. Louis. He is currently Director of RFF's Energy and Natural Resources Division. Dr. Boyd’s work is in the fields of environmental regulation and law and economics, focusing on the economic analysis of environmental liability law and environmental institutions. Work relevant to the panel includes research on the development of indicators to assess the social value of ecosystems. The work’s overarching goal is the development and evaluation of economically sound approaches to ecosystem evaluation, in order to make judgments regarding the relative value of different ecosystems.

Dr. Robert Costanza

Dr. Robert Costanza is the Gund Professor of Ecological Economics and Director of the Gund Institute for Ecological Economics at the University of Vermont. Prior to moving to Vermont in August 2002, he was director of the University of Maryland Institute for Ecological Economics, and a professor in the Center for Environmental Science, at Solomons, and in the Biology Department at College Park. Dr. Costanza received his Ph.D. from the University of Florida in 1979 in systems ecology, with a minor in economics. He also has a Masters degree in Architecture and Urban and Regional Planning from the University of Florida. Dr. Costanza is co-founder and past-president of the International Society for Ecological Economics (ISEE) and was chief editor of the society's journal: Ecological Economics from its inception until 9/02. He continues to serve as founding editor of the journal. He currently serves on the editorial board of eight other international academic journals. He is past president of the International Society for Ecosystem Health. In 1982 he was selected as a Kellogg National Fellow, in 1992 he was awarded the Society for Conservation Biology Distinguished Achievement Award and in 1993 he was selected as a Pew Scholar in Conservation and the Environment. In 1998 he was awarded the Kenneth Boulding Memorial Award for Outstanding Contributions in Ecological Economics. In 2000 he received an honorary doctorate in natural sciences from Stockholm University. He has served on the following committess and boards: the Scientific Steering Committee for the LOICZ core project of the IGBP; the U.S. EPA National Advisory Council for Environmental Policy and Technology (NACEPT); the National Research Council Board on Sustainable Development, Committee on Global Change Research; the National Research Council, Board on Global Change; the U.S. National Committee for the Man and the Biosphere Program; and the National Marine Fisheries Service Committee on Ecosystem Principles. Dr. Costanza's research has focused on the interface between ecological and economic systems, particularly at larger temporal and spatial scales. This includes landscape level spatial simulation modeling; analysis of energy and material flows through economic and ecological systems; valuation of ecosystem services, biodiversity, and natural capital; and analysis of dysfunctional incentive systems and ways to correct them. He is the author or co-author of over 300 scientific papers.

Dr. Terry C. Daniel

Dr. Terry C. Daniel is Professor of Psychology and Natural Resources at the University of Arizona. He received his B.S., M.S., and Ph.D. in Psychology at the University of New Mexico, where he was a Ford Foundation Career Scholar and a University Fellow. Professor Daniel is a Fellow in the American Psychological Association (Population and Environmental Psychology), has served as a member of the Advisory and Founding Committees for the Udal Institute for Public Policy Studies, and as an International Adjunct Professor in Behavioral Sciences at the University of Melbourne, Australia. He is a member of the editorial boards for Society and Natural Resources, Journal of Environmental Psychology, and Landscape and Urban Planning. Professor Daniel received the National Environmental Education Foundation Gifford Pinchot Award in 1993 for outstanding contributions to natural resources management education. Research has focused on the development and application of methods for quantifying relationships between bio-physical features of natural environments and human perception and judgement of environmental quality. Specific areas of research include: aesthetic and recreational impacts of forest management; effects of air pollution on perceived visual air quality in National Parks and Wilderness Areas; effects of environmental/ecological information on public perception and acceptance of environmental change; and roles for environmental data

visualization and computer simulation in evaluating public response to environmental management policies. Areas of research include: aesthetic and recreational impacts of forest management; effects of air pollution on perceived visual air quality in National Parks and Wilderness Areas; effects of environmental/ecological information on public perception and acceptance of environmental change; and roles for environmental data visualization and computer simulation in evaluating public response to environmental management policies.

Dr. A. Myrick Freeman III

Dr. A. Myrick Freeman III is Research Professor of Economics at Bowdoin College. In 2000 he retired from teaching after 35 years. Dr. Freeman received his Ph.D. and M.A. in economics from the University of Washington and his B.A. in economics from Cornell Univiversity. He has been on the faculty at Bowdoin since that time and has served as chair of the economics department and Director of the Environmental Studies Program there. He has also held appointments as Visiting College Professor at the University of Washington and Robert M. La Follette Distinguished Visiting Professor at the University of Wisconsin-Madison and as a Senior Fellow at Resources for the Future, a research organization in Washington, DC. Dr. Freeman's principal research interests are in the areas of applied welfare economics, benefit-cost analysis, and risk management as applied to environmental and resource management issues. Much of his work has been devoted to the development of models and techniques for estimating the welfare effects of environmental changes such as the benefits of controlling pollution and the damages to natural resources due to releases of chemicals into the environment. He has authored or co-authored eight books including Air and Water Pollution Control: A Benefit-Cost Assessment, and The Measurement of Environmental and Resource Values: Theory and Methods, now in its second edition. He has also published more than 70 articles and papers in academic journals and edited collections. Dr. Freeman has been a member of the Board on Toxicology and Environmental Health Hazards of the National Academy of Sciences and has served as a member of the Advisory Council on Clean Air Compliance Analysis, the Clean Air Science Advisory Committee (consultant) and the Environmental Economics Advisory Committee of the U.S. Environmental Protection Agency Science Advisory Board.

Dr. Domenico Grasso, Chair, Committee on Valuing the Protection of Ecological Systems and Services

Dr. Domenico Grasso is Dean of the College of Engineering and Mathematics at the University of Vermont, Burlington. Prior to holding this position, he was the Rosemary Bradford Hewlett Professor and Founding Director of the Picker Engineering Program at Smith College. As an environmental engineer who studies the ultimate fate of contaminants in the environment and develops new techniques to destroy or otherwise reduce the risks associated with these contaminants to human health or natural resources, he focuses on molecular scale processes that underlie the nature and behavior of contaminants in environmental systems. He holds a B.Sc. from Worcester Polytechnic Institute, an M.S. from Purdue University and a Ph.D. from The University of Michigan. He is a registered Professional Engineer in the states of Connecticut and Texas, and was Professor and Head of Department in Civil & Environmental Engineering at the University of Connecticut prior to joining Smith. He has been a Visiting Scholar at UC-Berkeley, a NATO Fellow, and an Invited Technical Expert to the United Nations Industrial Development

Organization in Vienna Austria. He is a Diplomate of the American Academy of Environmental Engineers, a Past-President of the Association of Environmental Engineering & Science Professors, and Editor-in-Chief of Environmental Engineering Science. He has authored more than 100 technical papers & reports, including four chapters and two books, and his research work is supported by Federal, state and industrial organizations.

Dr. Dennis H. Grossman

Dr. Dennis H. Grossman is the Vice President for Science at NatureServe, a non-profit conservation organization working throughout the Western Hemisphere. He holds a B.S. in ecology from the University of Wisconsin (1976), an M.S. in Plant Ecology from the University of Wisconsin (1982), and a Ph.D. in Plant Ecology from the University of Hawaii (1991). Prior to working at the Conservancy, Dr. Grossman was Chief Ecologist at The Nature Conservancy for 12 years after working as a Research Fellow at the Environment and Policy Institute of the East-West Center in Honolulu. Dr. Grossman has worked extensively with vegetation science, ecology, and conservation biology projects across the Upper Midwest, California, and Hawaii as well as in India and Indonesia. These projects include the inventory, data management and analysis, classification, mapping, conservation ranking and conservation planning for terrestrial, freshwater and coastal-marine communities. Dr. Grossman was a principal developer of the National Vegetation Classification System for the United States that is currently endorsed as an inter-agency standard by the Federal Geographic Data Committee. He has published numerous articles on ecological classification and conservation and currently manages numerous projects associated with the implementation of these methods. Dr. Grossman is a member of the Ecological Society of America and the Society for Conservation Biology, and serves Vegetation Subcommittee of the Federal Geographic Data Committee and on the executive committee of the ESA Panel for Vegetation Classification.

Dr. Geoffrey Heal

Dr. Geoffrey Heal is the Paul Garrett Professor of Public Policy and Corporate Responsibility and Professor of Economics and Finance at Columbia Business School and Professor in the School of International and Public Affairs. He is a member of the Executive Committee of the Columbia Earth Institute. Dr. Heal earned a First Class Honors Degree, Cambridge University, U.K. Major in Economics and Minor in Physics (1966). He completed his graduate studies in Economics and Mathematics at University of California, Berkeley, 1966-67. He earned his Ph.D. in Economics at Cambridge University (1968). Dr. Heal's area of expertises and research include: economic theory, general equilibrium theory, economics of insurance and reinsurance and of risk-management, economics of natural and environmental resources, and the interface between economics and the natural sciences with respect to environmental issues. He has served as Chair of the National Academy – National Research Council Committee on the Valuation of the Services of Aquatic and Related Terrestrial Ecosystems. He is also the Commissioner of the Pews Ocean Commission, Director of the Union of Concerned Scientists and the Beijer Institute of Ecology and Economics of the Royal Swedish Academy of Sciences and a member of the President's Committee on Science and Technology (PCAST) Panel on Biodiversity and Ecosystems. Dr. Heal is also a member and Ex-President, Association of Environmental and Natural Resource Economists.

Dr. Robert J. Huggett

Dr. Robert J. Huggett is an independent consultant and Professor Emeritus at the College of William and Mary in Williamsburg, VA, where he was a faculty member for 20 years. Dr. Huggett served as Vice President for Research and Graduate Studies at Michigan State University from 1997 to 2004. Before that, he was Assistant Administrator for Research and Development at the U.S. Environmental Protection Agency from 1994 to 1997. He earned an M.S. in Marine Chemistry from the Scripps Institute of Oceanography at the University of California at San Diego and a Ph.D. in Marine Science at William and Mary. As a scholar, Dr. Huggett has studied the fate and effects of hazardous chemicals in aquatic environments, publishing more than 90 articles. His work has had important effects on international environmental policy and he has been very active in research and policy organizations at the national and international level. While he was at the EPA, he served as Vice Chair of the Committee on Environment and Natural Resources and Chair of the Subcommittee on toxic substances and solid wastes, both of the White House Office of Science and Technology Policy. He also founded the EPA 100 million dollar-per-year STAR Competitive Research grants program and the 3 million dollar-per-year STAR Graduate Fellowship program. He presently serves on the Board Research Committee of the American Chemistry Council and on the Board on Environmental Studies and Toxicology of the National Research Council, National Academy of Sciences.

Dr. Douglas MacLean

Dr. Douglas MacLean is Professor of Philosophy at the University of North Carolina Chapel Hill. He is also Director of the Parr Center for Ethics and has appointments in both the Carolina Environmental Program and the Program for Peace, War, and Defense. He received his B.A. from Stanford University and his Ph.D. in philosophy from Yale University. His previous positions include senior research scholar and director of the Institute for Philosophy and Public Policy at the School of Public Affairs of the University of Maryland College Park and Professor and Chair of the Department of Philosophy at the University of Maryland Baltimore County. From 1999-2001 he was the Distinguished Visiting Professor of Ethics at the U.S. Naval Academy. His research interests are in ethics, political philosophy, decision and risk analysis, military ethics, and philosophical issues in public policy. His current research focuses primarily on philosophical issues in decisions about risk, technology, and the environment, and the philosophical implications of the psychology and culture of decision making. He has written extensively on these topics. Dr. MacLean has served as an advisor or consultant to a number of government agencies, including: the National Science Foundation, the National Endowment for the Humanities, the U.S. Environmental Protection Agency, the U.S. Congress Office of Technology Assessment, the U.S. Nuclear Regulatory Commission, and the Departments of Energy and Agriculture.

Dr. Harold A. Mooney

Dr. Harold A. Mooney holds the Paul S. Achilles Professorship in Environmental Biology at Stanford University. He received his PhD from Duke University in 1960 and was an

Associate Professor at the University of California in Los Angeles until 1968 when he came to Stanford. His research on the carbon balance of plants has provided a major theoretical framework for ecophysiological studies, and has been instrumental in the incorporation of physiological understanding to studies of ecosystem processes. This work has also led to several lines of research on the nature of interactions of plants with their biotic environment, and has provided an objective measure for evaluating many of the current theories of plant-animal interaction. He has demonstrated that convergent evolution takes place in the properties of different ecosystems that are subject to comparable climates, and has pioneered in the study of the allocation of resources in plants. He has worked in many of Earth's diverse ecosystems, including the arctic-alpine, the mediterranean-climate scrub and grasslands, tropical wet and dry forests, and the deserts of the world. He is currently engaged in research on the impacts of global change on terrestrial ecosystems, especially on productivity and biodiversity, and is also examining those factors that promote the invasions of non-indigenous plant species. In recent years he has been involved in organzing international activities through which he brought together people from many diverse disciplines to address topics that promise to contribute substantially to the advancement and integration of ecology. Most recent of these are the programs on A Global Strategy for Invasive Species and on the Ecosystem Function of Biodiversity, both sponsored by the Scientific Committee on Problems of the Environment (SCOPE). Through these efforts and his lengthy publication record of over 400 scientific books, papers, and articles, he has developed bridges between physiological ecology and other areas of ecology, and he has explored the contributions that ecologists can make toward resolving the growing problems of global habitability. Among his many honors, he was elected to the National Academy of Sciences, the American Academy of Arts and Sciences, and the American Philosophical Society.

Dr. Louis F. Pitelka

Dr. Louis Pitelka is a professor at the Appalachian Laboratory of the University of Maryland Center for Environmental Science. Research at the Appalachian Laboratory covers terrestrial and freshwater ecology with an emphasis on landscape and watershed ecology. Dr. Pitelka also currently is serving a two-year term as Science Advisor for the U.S. Department of Agriculture Competitive Grants Program. He received a B.S. in zoology from the University of California at Davis and a Ph.D. in biological sciences from Stanford University. Before moving to the University of Maryland in 1996, he held positions at Bates College, the National Science Foundation, and the Electric Power Research Institute. Dr. Pitelka’s areas of expertise include plant ecology, ecosystem ecology, and global change. His research activities have ranged from studies of the population biology of forest understory herbs to the responses of terrestrial ecosystems to climate change. Dr. Pitelka has served on numerous planning, coordinating, and review committees for both national and international organizations. He is a member of the Department of Energy's Biological and Environmental Research Advisory Committee. He served five years on the Scientific Steering Committee of the Global Change and Terrestrial Ecosystems (GCTE) core project of the International Geosphere-Biosphere Program (IGBP), and was chair of GCTE in 2003. From 1995 through 2000 Dr. Pitelka was editor-in-chief of Ecological Applications and now is on the editorial boards of Oecologia and Frontiers in Ecology and the Environment. In 2003 he served as President of the Association of Ecosystem Research Centers.

Dr. Stephen Polasky

Dr. Stephen Polasky holds the Fesler-Lampert Chair in Ecological/ Environmental Economics at the University of Minnesota. Dr. Polasky is a faculty member of the Department of Applied Economics and of the Department of Ecology, Evolution and Behavior and the interdisciplinary Conservation Biology Program. He received his Ph.D. in economics from the University of Michigan in 1986. Prior to coming to Minnesota he held faculty positions in the Department of Agricultural and Resource Economics at Oregon State University and the Department of Economics at Boston College. He was the senior staff economist for environment and resources for the President's Council of Economic Advisers 1998-1999. He served as associate editor and co-editor for the Journal of Environmental Economics and Management from 1996 to 2002. He served as a member of the National Research Council Committee on Assessing and Valuing Services of Aquatic and Related Terrestrial Ecosystems and serves as Co-Chair for Core Project 3: Developing the Science of Conservation and Sustainable Use of Biodiversity for DIVERSITAS. His research interests include biodiversity conservation and endangered species policy, integrating ecological and economic analysis, game theoretic analysis of natural resource use, common property resources, and environmental regulation.

Dr. Paul Risser

Dr. Paul Risser currently serves as Chancellor of the Oklahoma Higher Education System. Previously he served as President of Oregon State University (7 years), President of Miami University (3) years, and 6 years as Vice President for research and then Provost at the University of New Mexico. His bachelors degree in biology is from Grinnell College and his M.S. and Ph.D. in botany and soils is from the University of Wisconsin. He is a fellow of the American Association for the Advancement of Science and of the American Academy of Arts and Sciences. Dr. Risser's research has focused on ecosystem analysis, ranging from the physiological ecology of single species to mathematical models of entire ecosystems, especially as they respond to management. Dr. Risser has chaired and served on numerous committees for the National Science Foundation, National Research Council, and other state and federal agencies. He is the past president of the Ecological Society of America, American Institute of Biological Sciences, and of the Southwestern Association of Naturalists.

Dr. Holmes Rolston

Dr. Holmes Rolston is University Distinguished Professor of philosophy at Colorado State University. He has written six books, acclaimed in critical notice in both professional journals and the national press. The more recent are: Genes, Genesis and God (Cambridge University Press, 1999), Science and Religion: A Critical Survey (Random House, McGraw Hill, Harcourt Brace), Philosophy Gone Wild (Prometheus Books), Environmental Ethics (Temple University Press), and Conserving Natural Value (Columbia University Press). He has edited Biology, Ethics, and the Origins of Life (Jones and Bartlett, Wadsworth). He has written chapters in eighty other books and over one hundred articles. He is past-president of the International Society for Environmental Ethics and has served on the Board of Governors of the Society for Conservation Biology. He serves on the Advisory Board, American Association for the Advancement of Science, Program of Dialogue on Science, Ethics, and Religion. Rolston has

served as a consultant with over two dozen conservation and policy groups, including the U. S. Congress and a Presidential Commission. He is a member of the Working Group on Ethics of the World Conservation Union (IUCN). He is a founder and the associate editor of Environmental Ethics, a refereed professional journal now in its seventeenth year, and on the editorial board of Zygon: Journal of Science and Religion, Public Affairs Quarterly, Environmental Values, The South African Journal of Philosophy / Suid-Afrikaanse Tydskrif vir Wysbegeerte, Socijalna Ekologija (Zabreg, Croatia), the International Journal of Wilderness, and Conservation Biology. He serves on a half dozen other editorial boards. He has been a recipient of NEH and NSF awards. He won the Pennock Award for Distinguished Service at Colorado State University, the Dean's Award for Creativity and Excellence in the Humanities, and has been named University Distinguished Professor. He holds a B.S. from Davidson College, a Ph.D. from the University of Edinburgh in Theology and Religious Studies, an M.S. in the Philosophy of Science from the University of Pittburgh, and a Doctor of Letters from Davidson College, 2002.

Dr. Joan Roughgarden

Dr. Joan Roughgarden spent her early childhood in the Philippine Islands and Indonesia. She majored in biology and philosophy at the University of Rochester, and received a Ph.D.in theoretical ecology from Harvard University. She is Professor of Biological Sciences at Stanford University, and author, coauthor or editor of six books and over 120 papers in academic journals. Her books as sole author include: Theory of Population Genetics and Evolutionary Ecology (Macmillan), Primer of Ecological Theory (Prentice Hall), Anolis Lizards of the Caribbean (Oxford University Press) and most recently, Evolution's Rainbow: Diversity, Gender and Sexuality in Nature and People (University of California Press). She founded and directed the Earth Systems Program at Stanford, and was awarded for service to undergraduate education. She has also supervised over 30 doctoral and postdoctoral students. She has served on science advisory committees for marine protected areas in the Channel Islands National Marine Sanctuary. She has been a member of grant-review panels for the National Science Foundation and the Department of Energy, and has been an editor of the American Naturalist, Oecologia and the Journal of Theoretical Population Biology. Joan lives in San Francisco where she has also serve on citizen advisory committees for recreation, parks, and natural areas. Her current research links ecology with economic theory.

Dr. Mark Sagoff

Dr. Mark Sagoff is Senior Research Scholar in the Institute for Philosophy and Public Policy at the School of Public affairs at the University of Maryland, College Park, and has published widely in journals of law, philosophy, and the environment. He was named a Pew Scholar in Conservation and the Environment in 1991. He served from 1994-1997 as President of the International Society for Environmental Ethics. For the academic year 1998-99, Dr. Sagoff was awarded a fellowship at the Woodrow Wilson International Center for Scholars. He is a Fellow of the Hastings Center and in 2000 he was elected a Fellow of the American Association for the Advancement of Science. Dr. Sagoff has an A.B. from Harvard and a Ph.D. (Philosophy) from the University of Rochester, and he has taught at Princeton, the University of Pennsylvania, the University of Wisconsin (Madison), and Cornell before coming to the University of Maryland. Dr. Sagoff served on the Committee on Noneconomic and Economic Value of

Biodiversity, Board on Biology, Commission on Life Sciences, National Research Council, 1997-99, is Coeditor of the Journal of Policy Analysis and Management, and belongs to the editorial boards of various journals in ethics, the life sciences, and public policy.

Dr. Kathleen Segerson

Dr. Kathleen Segerson is professor and head in the Department of Economics at the University of Connecticut. Prior to coming to the University of Connecticut, Professor Segerson was an assistant professor of Natural Resource Economics at the University of Wisconsin. She is currently a co-editor of the Ashgate Studies in Environmental and Natural Resource Economics, and a member of the editorial board of the International Yearbook of Environmental and Resource Economics and Contemporary Economic Policy. She has previously served as a co-editor and an associate editor of the American Journal of Agricultural Economics and an associate editor of the Journal of Environmental Economics and Management. She has also served as Vice-President and a member of the Board of Directors of the Association of Environmental and Resource Economists (AERE), and on several other subcommittees for AERE and the American Agricultural Economics Association (AAEA). Dr. Segerson's research focuses on the incentive effects of alternative environmental policy instruments, with particular emphasis on the application of legal rules and principles to environmental problems. Specific research areas include: the impact of legal liability for environmental damages in a variety of contexts, including groundwater contamination, hazardous waste management, and workplace accidents; land use regulation and the takings clause; voluntary approaches to environmental protection; the impacts of climate change on U.S. agriculture; and incentives to control nonpoint pollution from agriculture. Dr. Segerson received a BA degree in mathematics from Dartmouth College in 1977 and a PhD in agricultural and natural resource economics from Cornell University in 1984.

Dr. Paul Slovic

Dr. Paul Slovic is president of Decision Research and a professor of psychology at the University of Oregon. He studies human judgment, decision-making, and risk analysis, and has published extensively on these topics. Dr. Slovic received a B.A. degree from Stanford University, an M.A. and Ph.D. degree from the University of Michigan, and an honorary doctorate from the Stockholm School of Economics. He is past president of the Society for Risk Analysis and in 1991 received its Distinguished Contribution Award. In 1993, Dr. Slovic received the Distinguished Scientific Contribution Award from the American Psychological Association, and in 1995 he received the Outstanding Contribution to Science Award from the Oregon Academy of Science. Dr. Slovic has served on numerous advisory committees of the National Research Council/National Academy of Sciences including the committees that wrote "Risk Assessment in the Federal Government: Managing the Process" (1983) and "Understanding Risk: Decision Making in a Democratic Society" (1996).

Dr. V. Kerry Smith

Dr. V. Kerry Smith is University Distinguished Professor and Director, Center for Environmental and Resource Economic Policy in the Department of Agricultural and Resource

Economics at North Carolina State University as well as a University Fellow in the Quality of the Environment Division of Resources for the Future. Since October 2000 he has been a member of the U.S. EPA's Advisory Council on Clean Air Compliance Analysis and in 2001 he was a member of the Arsenic Rule Benefits Review Panel of EPA's SAB. Dr. Smith received his A.B.and Ph.D. in Economics from Rutgers University. He presented the Frederick V. Waugh Lecture for the American Agricultural Economics Association (AAEA) in 1992 and at the 2002 AAEA annual meeting he was named an AAEA Fellow. In 2004 he was elected a member of the National Academy of Sciences. Dr. Smith is a member of the American Economic Association, the Southern Economic Association, the Association of Environmental and Resource Economists, and several other professional associations. He has also held editorial positions with the Journal of Environmental Economics and Management, Land Economics, Review of Economics and Statistics, and other professional journals. His research interests include non-market valuation of environmental resources, role of public information in promoting private risk mitigation, non-point source pollution and nutrient policy, and the linking of ecological and economic models.

Dr. Robert N. Stavins

Dr. Robert N. Stavins is the Albert Pratt Professor of Business and Government, Chairman of the Environment and Natural Resources Faculty Group at the John F. Kennedy School of Government, Harvard University, and Director of the Environmental Economics Program at Harvard University. He is a University Fellow of Resources for the Future, Past Chairman of the Environmental Economics Advisory Committee of the U.S. Environmental Protection Agency's (EPA) Science Advisory Board, Director of the University-wide Environmental Economics Program at Harvard University; and a Member of: the Board of Directors of Resources for the Future; EPA’s Clean Air Act Advisory Committee, the Intergovernmental Panel on Climate Change (IPCC), the Board of Directors of the Robert and Renée Belfer Center for Science and International Affairs, the Executive Committee of the Harvard University Committee on Environment (UCE), the Board of Academic Advisors of the AEI-Brookings Joint Center for Regulatory Studies. He serves on Editorial Boards of The Journal of Environmental Economics and Management, Resource and Energy Economics, Land Economics, Environmental Economics Abstracts, B.E. Journals of Economic Analysis & Policy, and Economic Issues. He is also a contributing editor of Environment, and was formerly a member of the Board of Directors of the Association of Environmental and Resource Economists. Professor Stavins' research has focused on diverse areas of environmental economics and policy, including examinations of: policy instrument choice under uncertainty; competitiveness effects of regulation; design and implementation of market-based policy instruments; diffusion of pollution-control technologies; and depletion of forested wetlands. His current research includes analyses of: technology innovation; environmental benefit valuation; political economy of policy instrument choice; and econometric estimation of carbon sequestration costs. Professor Stavins directed Project 88, a bi-partisan effort co-chaired by former Senator Timothy Wirth and the late Senator John Heinz, to develop innovative approaches to environmental and resource problems. He continues to work closely with public officials on matters of national and international environmental policy. He has been a consultant to the National Academy of Sciences, several Administrations, Members of Congress, environmental advocacy groups, the World Bank, the United Nations, the U.S. Agency for

International Development, state and national governments, and private foundations and firms. Prior to coming to Harvard, Stavins was a staff economist at the Environmental Defense Fund; and before that, he managed irrigation development in the middle east, and spent four years working in agricultural extension in West Africa as a Peace Corps volunteer.

Dr. Barton H. Thompson, Jr.

Dr. Barton H. Thompson, Jr., is Vice Dean and Robert E. Paradise Professor of Natural Resources Law at Stanford Law School, a Senior Scholar (by courtesy) at the Stanford Institute for International Studies, and a member of both the Core Faculty and Executive Committee of Stanford University's Interdisciplinary Graduate Program in Environment and Resources. He received an A.B. in Economics from Stanford University in 1972, an M.B.A. from the Stanford Graduate School of Business in 1976, and a J.D. from Stanford Law School in 1976. He has been a member of the Stanford faculty since 1986. Professor Thompson's research focuses on the interdisciplinary analysis (with an emphasis on economics, law, and cognitive psychology) of environmental and natural resource policies and the formulation of innovative tools and approaches for addressing environmental and natural resource issues. He has written several articles on the opportunities for and barriers to investments in ecosystem services and co-organized a workshop conference at Stanford University in November 2000 on Protecting Ecosystem Services: Science, Economics, and Law.