

**Summary Minutes of the
U.S. Environmental Protection Agency (EPA)
Science Advisory Board (SAB)
Ecological Processes and Effects Committee Meeting
December 17, 2007**

Panel Members: See roster of members – Appendix A

Date and Time: Monday, December 17, 2007, 11:00 a.m. – 1:00 p.m. (Eastern Time)

Location: By telephone only

Purpose: The purpose of this teleconference was to brief the Committee on upcoming meetings

Attendees:

Ecological Processes and Effects Committee Members:

Chair: Dr. Judith Meyer
Dr. Fred Benfield
Dr. Richelle Allen-King
Dr. Fred Benfield
Dr. Ingrid Burke
Dr. Allen Burton
Dr. Peter Chapman
Dr. Loveday Conquest
Dr. Wayne Landis
Dr. James Oris
Dr. James Sanders
Mr. Timothy Thompson
Dr. Ivor Van Heerden

Other SAB Committee/ Panel Members:

Dr. Gregory Biddinger
Dr. Otto Doering
Dr. Kathleen Segerson

EPA SAB Staff:

Thomas Armitage, Designated Federal Officer
Anthony Maciorowski, Associate Director for
Science

Other EPA Staff: Joseph Beaman, EPA Office of Water
Rick Linthurst, EPA Office of Research and
Development
Suzanne Marcy, EPA Office of Research and
Development

Others Present: Daniel Caldwell, Johnson and Johnson
Jane Stavely, Arcadis U.S., Inc

Meeting Summary

The discussion followed the issues and timing as presented in the meeting agenda (Appendix B).

Convene Meeting

Dr. Thomas Armitage, Designated Federal Officer (DFO) convened the teleconference at 1:00 p.m. He stated that teleconference was being held in accordance with Federal Advisory Committee Act (FACA) procedures. He stated that summary minutes of the teleconference would be prepared and certified by the Chair. He noted that time had been included on the agenda for public comments but no requests to offer comments had been received. He then identified EPEC members on the call and asked other participants to identify themselves.

Purpose of the Call and Review of the Agenda

Dr. Judith Meyer, Chair of the SAB Ecological Processes and Effects Committee welcomed participants to the teleconference and stated that the call was being held to discuss EPEC advisory activities for the coming year. Dr. Meyer reviewed the agenda for the teleconference, noting that the Committee would be briefed on topics for two upcoming meetings. She stated that the Committee would then discuss other potential advisory topics.

Introductory Remarks

Dr. Meyer provided introductory remarks. She noted some EPEC membership changes. She introduced and welcomed a new EPEC member, Dr. Ingrid Burke, to the Committee. Dr. Burke is a professor at Colorado State University in the Department of Range and Watershed Stewardship. Dr. Burke is also co-director of the graduate degree program in ecology. Dr. Meyer noted that two EPEC members, Drs. Virginia Dale and Bill Mitsch had completed their terms of service on the Committee.

Dr. Meyer also noted that several members of other SAB committees or panels had been invited to join EPEC members on the call. These invitees included Drs. Greg Biddinger,

James Boyd, Terry Daniel, Otto Doering, William Moomaw, and Kathleen Segerson. Dr. Meyer stated that because of their expertise in evaluating ecosystem services it was anticipated that these individuals would participate in the upcoming advisory on EPA's Ecological Research Plan.

Kinds of projects undertaken by EPEC

Dr. Meyer briefly reviewed the kinds of projects undertaken by EPEC. She stated that EPEC is a standing committee of the chartered EPA Science Advisory Board and through the chartered Board provides advice to the EPA Administrator on technical issues related to EPA environmental programs as well as supporting science and research to protect the health of ecosystems. Dr. Meyer noted that EPEC projects may be consultations, advisories, or reviews undertaken in response to specific requests from EPA offices. In addition, she stated that from time to time, EPEC undertakes self-initiated committee studies.

Recent EPEC work

Dr. Meyer reviewed EPEC work undertaken during the past few years. She stated that EPEC advisory activities had recently focused on models and tools for ecosystem assessment. The Committee reviewed EPA's Critical Ecosystem Assessment Model, Regional Vulnerability Assessment Program, Geographic Information System Screening Tool, and Southeastern Ecological Framework. Dr. Meyer stated that many EPEC projects were referred to the Committee by EPA's Office of Water and Office of Research and Development as well as the Agency's Regional Offices. She noted that recent EPEC work included two self-initiated projects. The Committee developed a Framework for Assessing and Reporting on Ecological Condition. This is an organizational tool to develop, assemble, and report on information about the health of ecological systems. The Committee also completed work on a report, "Advice to EPA on Advancing the Science and Application of Ecological Risk Assessment."

Dr. Meyer noted that from time to time, EPEC members also serve on other SAB panels. For example, EPEC members recently served on SAB panels that reviewed EPA's 2007 draft Report on the Environment and developed an advisory report on hypoxia in the Gulf of Mexico.

Upcoming EPEC activities

Dr. Meyer stated that EPEC had been asked to provide advice on two projects during the upcoming year. She stated that EPA scientists from the Office of Water and Office of Research and Development were on the phone to brief the Committee and answer questions on the topics to be addressed at these two upcoming meetings. She briefly described the two upcoming projects. EPA's Office of Water had requested advice on a proposed approach for deriving aquatic life water quality criteria for emerging contaminants. Dr. Meyer noted that Mr. Joseph Beaman, Acting Chief of the Ecological

Risk Assessment Branch would brief the Committee on this project.

Dr. Meyer also noted that EPA's Office of Research and Development had requested advice on the Agency's Ecological Research Strategy and Multiyear Plan. She stated that Dr. Rick Linthurst, National Program Director for Ecology in EPA's Office of Research and Development was on the phone to brief the Committee on this project.

Dr. Meyer indicated that following the two briefings, she wanted to spend time talking about a potential advisory topic for EPEC, a self-initiated project to provide advice to EPA on science priorities in light of emerging ecological problems.

Briefing on EPA's Proposed Methodology for Deriving Aquatic Life Water Quality Criteria Based on Mode of Action

Mr. Joseph Beaman of EPA's Office of Water presented a briefing on EPA's efforts to develop a methodology for deriving aquatic life water quality criteria based on mode of action. Mr. Beaman discussed the Agency's current water quality criteria derivation methodology. He reviewed issues that must be addressed for emerging contaminants such as pharmaceuticals and personal care products. He stated that EPA planned to develop a case study on ethynylestradiol to illustrate how criteria might be developed based on mode of action for endocrine disrupting chemicals. Mr. Beaman discussed efforts that had been undertaken in this area. He stated that an EPA workgroup had been formed in April 2007 to investigate criteria derivation issues for such emerging contaminants. He stated that the workgroup was developing a "white paper" on this topic to identify options for addressing issues. The white paper will be provided to EPEC for review. Mr. Beaman described the data needed to derive water quality criteria for aquatic life. He presented information on available data for selected pharmaceuticals. He also identified a number of specific issues to be addressed in deriving criteria based on mode of action. These issues include: disparity in taxa sensitivity to mechanism of action, diversity of endpoints to be addressed, roles for non-traditional endpoints, and use of non-resident species. Mr. Beaman also presented a timeline for incorporating a new methodology into the water quality guidelines revision process. Slides of Mr. Beaman's presentation are attached in Appendix C.

Mr. Beaman stated that the Office of Water (OW) was particularly interested in receiving advice on issues such as taxa to be tested, the use of species sensitivity distributions to exclude certain taxa, and how to use plant data.

Dr. Meyer asked whether OW had prepared charge questions for the panel. Mr. Beaman stated that the white paper was currently being developed and that charge questions would be provided when the paper was complete.

Dr. Meyer asked whether OW had considered using any endpoints other than the toxicity test data that are currently applied to derive water quality criteria. Mr. Beaman responded that OW had been considering several options, including the use of endpoints

typically evaluated in plant toxicity testing. A member stated that it would be useful to incorporate additional measures of uncertainty into the criteria derivation process.

Dr. Meyer thanked Mr. Beaman for his presentation and stated that she looked forward to receiving additional information from the Office of Water for the upcoming Committee meeting. She then indicated that Dr. Rick Linthurst of EPA's Office of Research and Development (ORD) was on the phone to discuss the Agency's Ecological Research Strategy and Multi-Year Plan. She asked Dr. Linthurst to present his briefing.

Briefing on EPA's Ecological Research Strategy and Multi-Year Plan

Dr. Linthurst briefed the Committee on EPA's Ecological Research Strategy and Multiyear Plan (Strategy). He stated that EPA was still developing its Strategy. He stated that the Committee had received three pieces of information for the teleconference: 1) a five page summary of the proposed Strategy, 2) a six page description of the Ecological Research Program goals and annual performance measures, and 3) Powerpoint slides for the presentation. (These documents are attached in Appendix D).

Dr. Linthurst described different Multi-Year Research Plans that have been developed at different levels by EPA's ORD. He noted that some of them were specialty plans focused on specific areas such as endocrine disruptors. He noted that there is some overlap in areas covered by different plans. He noted that ORD was working to combine some of the plans.

Dr. Linthurst outlined goals that had been developed for EPA's Ecological Research Program. He stated that the Program was moving in a new direction to focus on developing a better understanding of ecosystem services in order to inform decision making. He noted that ORD's Board of Scientific Counselors had reviewed proposed changes in the direction of the Ecological Research Program and had expressed support for the new direction. Dr. Linthurst also noted that the Ecological Research Program's focus on ecosystem services was consistent with findings in the Millennium Ecosystem Assessment and a recent report of the SAB Committee on Valuing the Protection of Ecological Systems and Services.

Dr. Linthurst noted that a challenge facing the program was changing the economic and human well-being foundation for environmental decision making. He discussed the need for interdisciplinary decision support to meet this challenge and described how the Ecological Research Program was being developed to provide such decision support. He described an approach that focused on pollutant driven ecosystem services research, ecosystem driven ecosystem services research, and place driven ecosystem services research.

Dr. Linthurst also described several proposed place-based projects that would be undertaken to demonstrate how ecosystem services could be represented and considered in decision making. These place-based projects will be located in: 1) the Tampa Bay,

Florida region, 2) the Midwestern states region, 3) the Willamette River, Oregon region, and 4) the Coastal Carolinas region.

Dr. Linthust noted that the last slide (page 21) of his briefing presented an overview of the Ecological Research Program. He stated that the slide illustrated multiple Program components including: proposed projects and long term goals, pollutant specific studies, ecosystem specific studies, community based demonstration projects, and ORD staff assigned as thematic leads.

Several Committee members commented on the proposed Ecological Research Program. A member stated that he was excited by the program but commented that, in conducting place-based research, EPA should bear in mind that ecosystems do not correspond to jurisdictional boundaries. He noted that it was important to consider cross-border issues.

A member questioned whether, in developing tools for valuing ecosystem services for land use in the Willamette River area (outlined on slide 16 of the ORD presentation), EPA was considering approaches to associate dollar values with nutrient removal. Dr. Linthurst responded that evaluation of the relative value of nutrient removal was being approached in different ways.

A member noted that evaluation of ecosystem services could be very site-specific. Another member agreed and noted that it might be helpful to begin considering how to evaluate ecosystem services in different areas by selecting those where background information indicates similarities.

A member noted that it would be helpful to include a list of references in the Ecological Research Strategy. He also commented that it would be helpful to know how ORD's planned research would interface with natural resource assessments. A member stated that EPA might specifically consider the impacts of Hurricanes Katrina and Rita when evaluating the how storm events affect ecosystem services.

A member commented that EPA does not regulate land use. He noted that this is done by land use planning boards. He noted that it could be difficult to address land use features of relatively small scale in the Ecological Research Program. He also questioned what social sciences should be included in the program. Dr. Linthurst responded that to protect and restore the environment, it was necessary to change certain kinds of behavior, and it was important to approach this from a social science perspective.

Dr. Meyer thanked Dr. Linthurst for his presentation and stated that she looked forward to receiving the draft Ecological Research Strategy for review. She then asked the DFO whether any public comments would be heard. The DFO responded that no requests to make public comments had been received. Dr. Meyer then stated that the Committee would briefly discuss other potential self-initiated advisory topics.

Discussion of Other Potential Advisory Topics

Dr. Meyer stated that for the 30th anniversary of the EPA Science Advisory Board, the Board planned to develop a report on challenges facing the Agency in the next decade. She noted that the chartered SAB had asked for input on this topic from its standing committees. EPEC had been asked to provide input on key and emerging risks to ecosystems. She stated that there would be time on the agenda of the next two EPEC meetings to further discuss this topic. She asked members for their initial thoughts.

A member stated that this topic should be considered in two parts 1) science challenges and 2) human capital challenges. He stated that it was particularly important to focus on what was needed in the area of applied ecological research and how EPA might invest in human capital. He noted that, in this regard, needs for extramural research support were important.

A member stated that climate change, associated sea level rise, severe weather, and flooding had posed key environmental problems in the City of New Orleans (e.g., arsenic in mud from Lake Pontchartrain poses a problem for New Orleans) and other areas of the country. He noted that it will be challenging for cities to deal with these problems. He stated that the Committee should broadly consider the problems that sea level rise pose for coastal communities.

A member stated that another key environmental problem is the “roll back” in air quality requirements for old power plants. In this regard, mercury, nitrogen, and sulfur pollution will pose problems. Dr. Meyer stated that it will be critical to identify science issues that must be addressed to manage the problems. A member stated that these pollutants pose toxicity problems, and science needs to better assess and manage toxics must be considered. Dr. Meyer indicated that the Committee should consider what science is needed to make policy decisions more straight forward.

A member stated that habitat change was a key problem affecting ecosystems. He stated that EPA was not doing enough to understand and address this problem. Another member concurred. Another member stated that major ecological problems included invasive species, climate change, and habitat modification. He noted that interaction between stressors must also be considered. Dr. Meyer stated that it was necessary to have information about what EPA is doing in these areas. A member stated that it would also be important to consider work that is underway in Europe in many of these areas.

A member stated that the Committee should discuss what questions needed to be answered. He stated that this would lead to identification of the key problems and challenges. Another member stated that it would be useful to examine the report that EPEC had recently completed on recommendations to improve the state of the practice of ecological risk assessment. He noted that the document discussed many of the key problems and issues.

A member stated that EPA should look at ways to link ecosystem services to economic outputs. He noted that in this regard, the U.S. was behind other countries. As an example he mentioned work that had been undertaken in other countries to manage landscapes for pulp and paper productivity.

The Chair then thanked members for their comments and stated that she wanted to continue the discussion of future problems and challenges at the next Committee meeting. She stated that the DFO would be contacting members to schedule the upcoming meetings and that review material and charge questions would be sent to members prior to the meetings. She then adjourned the teleconference.

Respectfully Submitted:

Certified as True:

/Signed/

/Signed/

Dr. Thomas Armitage
Designated Federal Officer

Dr. Judith Meyer, Chair
Ecological Processes and Effects
Committee

APPENDICES

Appendix A: Roster of SAB Ecological Processes and Effects Committee

Appendix B: Meeting Agenda

Appendix C: Briefing on Water Quality Criteria for Emerging Contaminants

Appendix D: Briefing on EPA's Ecological Research Strategy and Multi-Year Plan

Appendix A – Committee Roster

U.S. Environmental Protection Agency Science Advisory Board Ecological Processes and Effects Committee

CHAIR

Dr. Judith L. Meyer, Distinguished Research Professor Emeritus, Institute of Ecology, University of Georgia, , GA

MEMBERS

Dr. Richelle Allen-King, Associate Professor, Department of Geology, University at Buffalo, Buffalo, NY

Dr. Fred Benfield, Professor of Ecology, Department of Biological Sciences, Virginia Tech, Blacksburg, VA

Dr. Ingrid Burke, Professor, Department of Forest, Range, and Watershed Stewardship, Graduate Degree Program in Ecology, Colorado State University , Fort Collins, CO

Dr. G. Allen Burton, Professor and Chair, Department of Earth & Environmental Sciences, Wright State University, Dayton, OH

Dr. Peter Chapman, Principal and Senior Environmental Scientist, Environmental Sciences Group, Golder Associates Ltd, North Vancouver, BC, Canada

Dr. Loveday Conquest, Professor and Associate Director, School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA

Dr. Wayne Landis, Professor and Director, Institute of Environmental Toxicology , Western Washington University, Bellingham, WA, USA

Dr. James Oris, Professor, Department of Zoology, Miami University, Oxford, OH

Dr. Charles Rabeni, Leader of Missouri Cooperative Fish and Wildlife Research Unit, U.S. Geological Survey, University of Missouri, Columbia, MO

Dr. Amanda Rodewald, Associate Professor of Wildlife Ecology, School of Environment and Natural Resources, The Ohio State University, Columbus, OH

Dr. James Sanders, Director and Professor, Skidaway Institute of Oceanography, Savannah, GA

Mr. Timothy Thompson, Senior Environmental Scientist, Science, Engineering, and the Environment, LLC, Seattle, WA

Dr Ivor van Heerden, Associate Professor & Director, Department of Civil and Environment Engineering, LSU Hurricane Public Health Research Center, Louisiana State University, Baton Rouge, LA, USA

Appendix B – Teleconference Agenda

**Science Advisory Board
Ecological Processes and Effects Committee
Discussion of Upcoming Meetings
December 17, 2007, 11:00 a.m. – 1:00 p.m. (Eastern Time)**

Agenda

11:00 p.m.	Convene Meeting	Dr. Thomas Armitage, Designated Federal Officer EPA Science Advisory Board
11:05 a.m.	Introductory Remarks	Dr. Judy Meyer, Chair Ecological Processes and Effects Committee (EPEC)
11:10 a.m.	Methodology for Deriving Aquatic Life Water Quality Criteria Based on Mode of Action	Mr. Joseph Beaman, EPA Office of Water, and Committee Discussion
11:40 a.m.	Ecological Research Strategy and Multiyear Plan	Dr. Rick Linthurst, EPA Office of Research and Development, and Committee Discussion
12:10 p.m.	Other Potential Advisory Topics	Dr. Judy Meyer, Chair and Committee
12:30 p.m.	Public Comments	Dr. Thomas Armitage Designated Federal Officer
12:45 p.m.	Concluding Remarks	Dr. Judy Meyer, Chair
1:00 p.m.	Adjourn	



Water Quality Criteria for Emerging Contaminants

Water Quality Criteria Derivation Issues

Joseph Beaman,
Office of Science & Technology

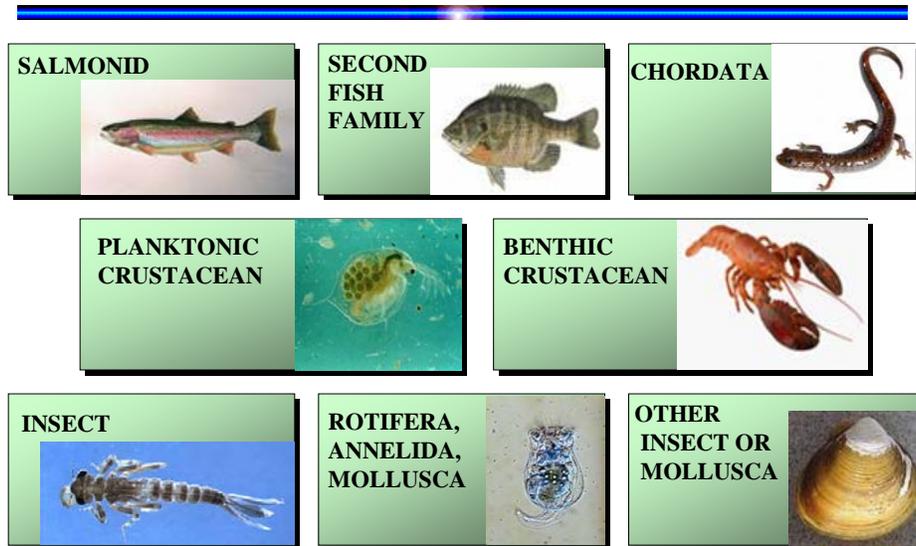
OSTI

Efforts to Date

- October 2006 Congressional Hearing on Potomac River intersex bass sparked efforts in OW.
- Workgroup formed in April 2007 to investigate criteria derivation issues for emerging contaminants.
 - Consists of ORD EDC technical experts, ORD criteria development experts, and OST scientists/policy experts
 - “Streamlined” Guidelines Revision effort due to OW priority
- Workgroup developing “white paper” to inform OST management of issues and assist in decision-making process.

1985 Guidelines Methodology Review

Minimum Dataset for Freshwater Acute Criteria Derivation – 1985 Guidelines Method



Rationale for Criteria MDR

- 1985 Guidelines assume nothing about the chemical, mechanism of action, or distribution of taxonomic sensitivity across aquatic communities
- The eight taxa in the MDRs represent the minimum sufficient taxonomic “spread”
- When ≥ 8 taxa are available, there are no specific taxonomic distribution requirements
- When MDRs are not met, no criterion can be derived
 - addresses consistency in minimum “certainty” and provides reasonable confidence that it is a good estimate

Acute Criteria Calculation (CMC)

- Step 1. Calculate Species Mean Acute Values (SMAVs)**
 - geometric mean of all acceptable acute values for species
- Step 2. Calculate Genus Mean Acute Values**
 - geometric mean of all SMAVs for genus
- Step 3. Rank Genus Mean Acute Values**
 - from most sensitive (#1) to least sensitive (n)
- Step 4. Calculate Final Acute Value Using 4 Lowest GMAVs**
- Step 5. Divide Final Acute Value by 2 to derive Continuous Maximum Concentration (CMC)**

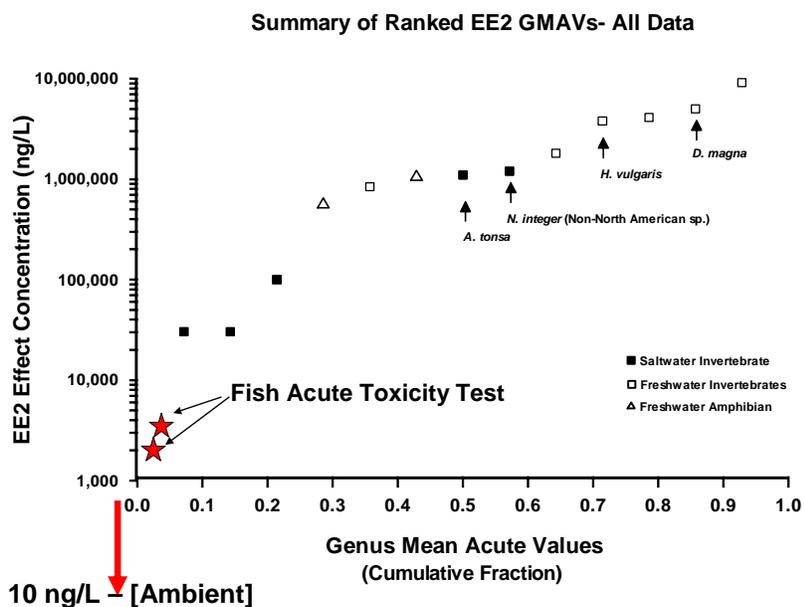
Derivation of Chronic Criteria (CCC)

- If ≥ 8 chronic tests are available (Rare):
 - Use same methodology (regression analysis) as in acute criteria derivation
- The estimated 5th percentile GMCV is the Final Chronic Value (FCV)
- If $\geq 3 < 8$ chronic tests are available
 - Calculate acute to chronic ratio for each acute-chronic test pair (by species)
 - Divide Final Acute Value (FAV) by ACR to get Final Chronic Value FCV

Environmental Concentrations: Lack of Acute Toxicity

- Many emerging contaminants of current interest are in the class of “PPCPs – pharmaceuticals and personal care products”.
- These compounds (especially most pharmaceuticals) are designed to minimize or eliminate (goal) toxicity to user.
- Compounds have highly specific modes of action, act at receptor site at very low concentrations.
- Most environmental exposure through end user – patient excretion and/or use/disposal.

EE2 Effects: Comparison of Acute Toxicity



Acute to Chronic Ratios for Selected Pharmaceuticals

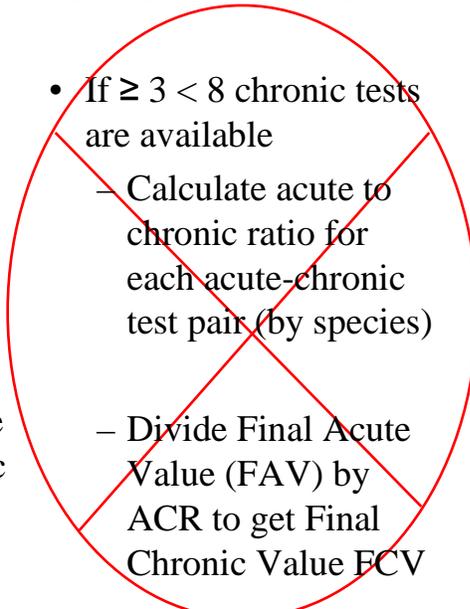
Compound	Animal	Acute LC50 ^a (µg/L)	Chronic NOEC ^a (µg/L)	Chronic LOEC ^a (µg/L)	ACR (LC50/NOEC)	Reference
Diethylstilbestrol	Copepod	>100 ^(48 h)	10 ^(21 d)	100 ^(21 d)	>10	Hutchinson et al. (1999)
	Copepod	290 ^(96 h)	3 ^(18 d)	30 ^(18 d)	97	Breitholz and Bengtsson (2001)
	Daphnid	1200 ^(48 h)	500 ^(21 d)	-----	2.4	Baldwin et al. (1995)
	Fish	1400 ^(96 h)	0.01 ^(42 d)	0.032 ^(42 d)	140 000	Hutchinson et al. (2003b)
Estradiol	Copepod	1600 ^(96 h)	160 ^(18 d)	>160 ^(18 d)	10	Breitholz and Bengtsson (2001)
	Fish	3900 ^(69 h)	0.01 ^(42 d)	0.032 ^(42 d)	390 000	Hutchinson et al. (2003b)
Ethinylestradiol	Copepod	510 ^(96 h)	50 ^(18 d)	>50 ^(18 d)	10.2	Breitholz and Bengtsson (2001)
	Daphnid	6400 ^(48 h)	387 ^(21 d)	>387 ^(21 d)	16.5	Schweinfurth et al. (1996)
	Fish	1500 ^(96 h)	0.01 ^(42 d)	0.032 ^(42 d)	150 000	Hutchinson et al. (2003b)
Ibuprofen	Mollusc	17 100 ^(96 h)	1020 ^(21 d)	2430 ^(21 d)	16.8	Pounds et al. (2004)
Propranolol	Amphipod	29 800 ^(48 h)	500 ^(27 d)	>500 ^(27 d)	59.6	Huggett et al. (2002)
	Daphnid	800 ^(48 h)	1 ^(7 d)	100 ^(7 d)	800	Huggett et al. (2002)
	Fish	24 300 ^(48 h)	<0.5 ^(28 d)	0.5 ^(28 d)	>48 600	Huggett et al. (2002)

The ACR as an Indicator (Signpost)

- Large ACRs do not make the ACR invalid, but identifies the acute criteria threshold as a moot measurement endpoint.
- It indicates that potential mechanisms of acute and chronic toxicity are different.
 - Existing examples: Se, Hg, TBT
 - Test: ACR > than 10-100 consider only chronic data?

Can we derive “Chronic-Only” WQC?

Derivation of Chronic Criteria

- If ≥ 8 chronic tests are available (Rare):
 - Use same methodology (regression analysis) as in acute criteria derivation
 - The estimated 5th percentile GMCV is the Final Chronic Value (FCV)
 - If $\geq 3 < 8$ chronic tests are available
 - Calculate acute to chronic ratio for each acute-chronic test pair (by species)
 - Divide Final Acute Value (FAV) by ACR to get Final Chronic Value FCV
- 

Options: Addressing Taxonomic Sensitivity to Mechanism of Action

- If MOA and Potency are well characterized, what level of biological organization is needed to be affected?
 - Test: what organisms can be excluded from concern because of lack of pertinent biological systems?
 - Tools: Can SSD's be used to screen for and exclude insensitive taxa, and would be protected by default? (ie invertebrates and EE2)
 - When plants are most sensitive, how do we proceed with criteria derivation?
 - Final Plant Value?
 - Regression Analysis? Approach similar to 1985 Guidelines, but limited data
 - Plant community response? (ie Atrazine CASM) –"Cadillac" Approach

Acceptable Chronic Data (Endpoints) (1985 Guidelines - pp 37-39)

1. Life Cycle Tests –

- ~48 hrs old → >24 d post F1
- Endpoint data – survival/growth of adults/young, maturation of males and females, eggs spawned per female, embryo viability (salmonids only), hatchability of F1.

2. Partial Life Cycle Tests

- immature juveniles > 2 months prior to GD → >24 d post F1
- Same endpoints as above

3. Early Life Stage Tests

- Post fertilization → early juvenile development
- Typically used as predictions of outcomes for life-cycle and partial life-cycle tests with the same species.

Endpoints not traditionally used for WQC: Overview and Possible Roles

- Organizational Events - occur during sexual differentiation/gonad development; usually not reversible
 - Phenotypic sex not aligned with genotypic sex
 - Gonadal (histological) abnormalities (intersex/ovatestis)
- Activational Events - occur later in life (adults) often during active reproduction; can be reversible
 - Morphological changes (SSC)
 - Abnormal gonadal staging (histology)
 - Biochemical alterations (e.g., vtg induction)

Roles for Non-Traditional Endpoints

- Screening: as MOA “triggers” to define appropriate tests and endpoints
 - Species sensitivity to chemical’s MOA
 - May help to define windows of sensitivity (e.g., development/reproduction)
- Possibly as a basis for quantitative assessments of risk
 - When the endpoint reflect **both** MOA *and* adverse outcome(s)
 - This requires detailed knowledge of the toxicity pathway of concern

Use of Non-Resident Species

- The 1985 Guidelines is explicit (page 22) on how data obtained with non-resident species may be used
 - Provide auxiliary information **only**.
 - Policy Decision – not based on scientific understanding
- In this context, nonresident species are not excluded if used in a contextual nature to define important exposure windows, endpoints, relative potency, etc.
- Proposal: Sound science should be used to discriminate when to use nonresident species.
 - Directly include data if
 - there is no reason to believe that native species would not show similar sensitivity
 - have the potential to substantively influence the criterion calculation

Contact Information

- Joe Beaman
– beaman.joe@epa.gov

Appendix D – Briefing on EPA’s Ecological Research Strategy and Multi-Year Plan



**Ecosystem services as a new
strategic focus for U.S. EPA’s Ecological
Research Program**

**Presentation for the SAB
December 17, 2007**

**by
Rick Linthurst, Ph.D.
National Program Director for Ecology**

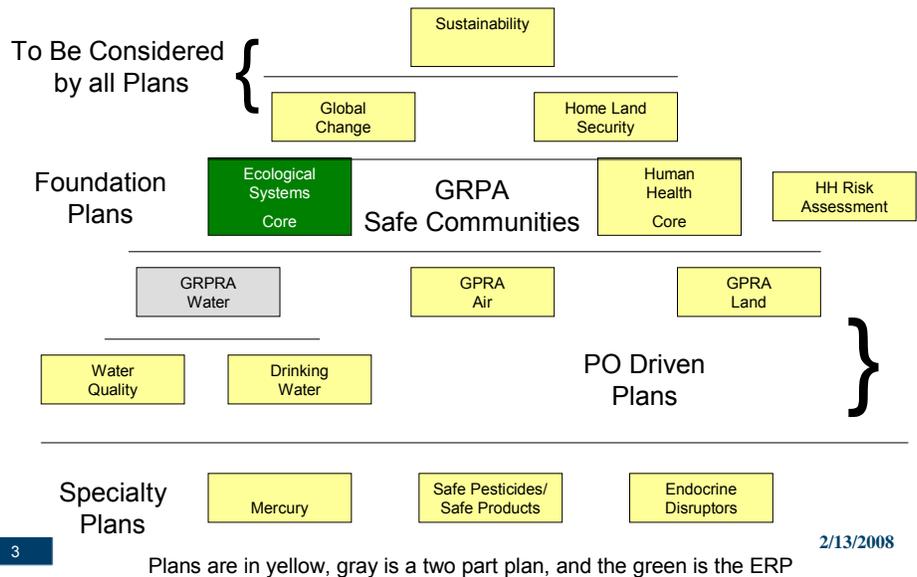
U.S. Environmental Protection Agency
Office of Research and Development



ERP in the ORD Research Context

And then there were 13 Plans?

U.S. Environmental Protection Agency
Office of Research and Development



2005 ERP Goals

- **Long-Term Goal 1: National policy makers will have the tools and technologies to develop scientifically-defensible assessments of the state of our nation's ecosystems and the effectiveness of existing national programs and policies**
- **Long-Term Goal2: States and tribes apply improved tools and methods to protect and restore their valued ecological resources**
- **Long-Term Goal 3: Decision-makers understand the importance of ecosystem services and make informed, proactive management decisions that consider a range of alternative outcomes**

SAB Valuation Committee

Several members noted that the committee report is consistent with the direction of the research program and commended Dr. Linthurst for the work done so far. One member noted the value of EPA investment in research directions advocated by the committee.

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From U.S. Environmental Protection Agency
Science Advisory Board (SAB)
Committee on Valuing the Protection of Ecological Systems and Services (C-VPESS)
Summary Meeting Minutes of a Public Teleconference Meeting
12:30 p.m. - 2:30 p.m. (Eastern Time)
June 12, 2007

2/13/2008

LIVING BEYOND OUR MEANS



NATURAL ASSETS AND HUMAN WELL-BEING

Statement from the Board

Drivers Beyond MEA

- An Executive Order that has been without ecological input (*Executive Order 12866, 9/30/93*).
 - (<http://www.epa.gov/regulations/follow.htm>)
- The other drivers include:
 - The administrators charge to advance environmental protection while maintaining our economic competitiveness,
 - The increased emphasis on environmental stewardship and information to make better decisions without regulation,
 - Sustainability of ecosystems/services as an Agency theme, and
 - Urban sprawl and rapid loss of natural areas
- Regulatory Authority
 - There is some legal authority to protect services! But a fork will never serve soup as well as a spoon... Jim Salzman, Duke University

The Challenge:

**Change the economic and human
well-being foundation for
environmental
decision-making**

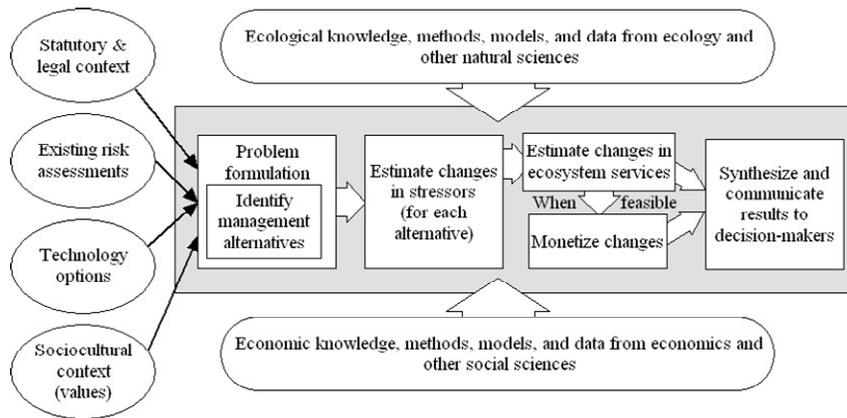
Ecological Benefits Assessments Strategic Plan

2007



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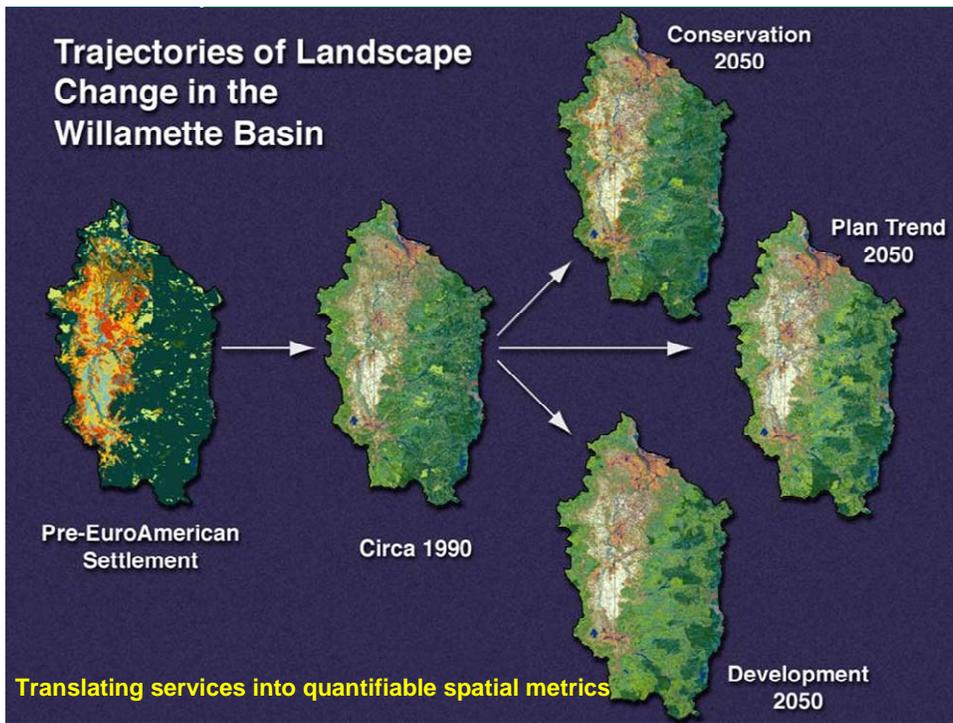
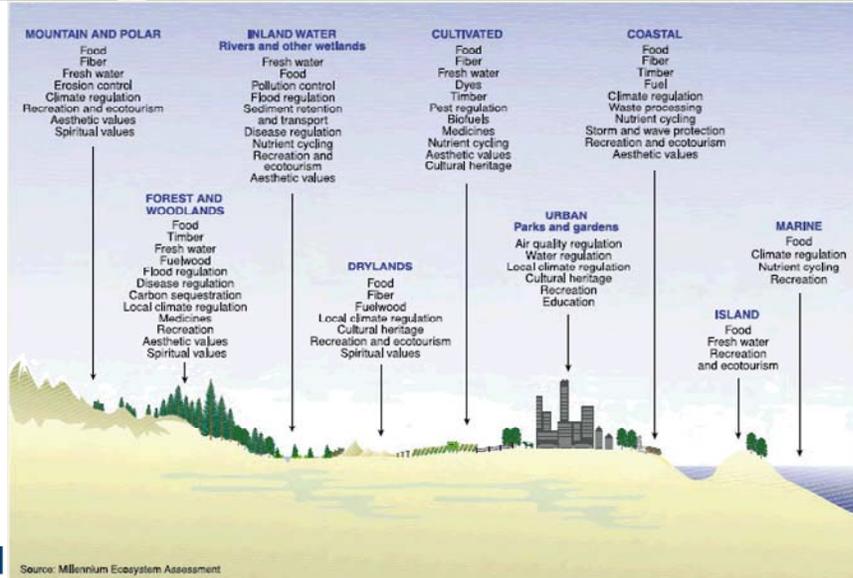
Interdisciplinary decision support



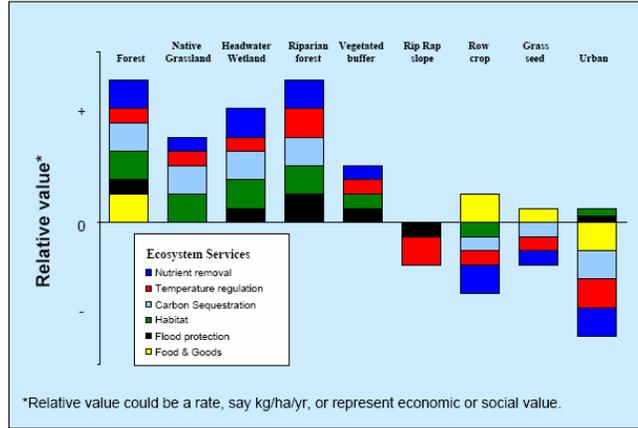
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2/13/2008

From EPA Ecological Benefits Assessment Strategy Program



**Hypothetical ecosystem service values:
Bundled by land use in the Willamette ESD**

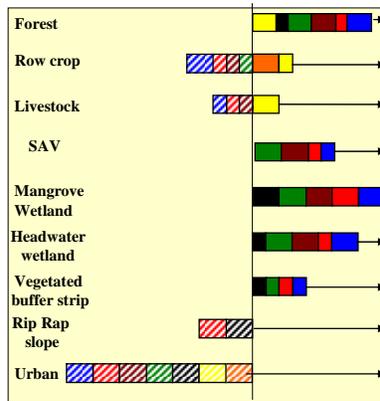


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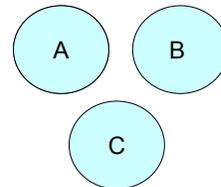
End Product

*Relative Ecosystem Services
Within an Ecosystem District*

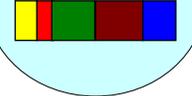


Scaling and
Aggregation
Under
Alternative
Management
Scenarios

Options



Net Value of
Services



Management
Option X

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Terms

- **Ecosystem Services**
 - *the current and future outputs of functioning, complex ecological systems that are enjoyed, consumed, or used by humans and that support their well-being, either directly or indirectly.*

- **Ecosystem Service Districts**
 - *a spatial boundary that delimits a core geographic area for the purpose of efficient, simultaneous management of multiple ecosystem services.*

Note that this boundary is not likely to coincide with watershed or municipal boundaries, but rather would be configured to address multiple services desired for an area.

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Projects and Long term Goals →		Pollutant Specific Studies: Nitrogen Regulation Services LTG 3	Eco-system Specific Studies: LTG 4		Community Based Demonstration Projects: For National, Regional, State and Local Decisions (includes Nitrogen and Wetlands services) LTG 5				Theme Leads
	Cross Program Themes and Research Objectives		Wetlands	Coral Reefs	Willamette	Tampa Bay	Mid-West	Coastal Carolinas	
Inventory, Map, and Forecast Ecosystem Services at multiple scales (National Atlas) LTG 2	Ecosystem Services and Human Health								Laura Jackson
	Landscape Characterization and Mapping								Anne Neale Megan Mehalffy
	Inventory and Monitoring of Services								Steve Jordan Mike McDonald
	Modeling for Scenarios and Forecasting for different management options								John Johnston
Integration, Decision Support and Outreach LTG 1	Valuation of Ecosystem Services								Wayne Munns
	Decision Support Platform Created to Integrate Findings from Entire Program								Ann Vega Betsy Smith
	Outreach & Education to inform decision makers of platform and findings								Suzanne Marcy
Project Area Leads	Rick Linthurst And Iris Goodman	Jonathan Garber	Mary Koutula/Virginia Engle	Bill Fisher	Dixon Landers	Marc Russell	Randy Bruins/Betsy Smith	Dorsey Worthy	Rick Linthurst Iris Goodman
Additional Coordination/Integration Required									
	Wetlands								Steve Jordan
	Nitrogen								Jonathan Garber

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**USEPA, Office of Research and Development
Ecological Research Program: Strategic Direction,
September 13, 2007**

I. Program Context: Impetus and Evolution

The Ecological Research Program (ERP) is setting a new strategic direction to meet compelling needs for better understanding the implications of human impacts on ecosystems and the resources they provide. The processes and functions of ecosystems, the foundation of our health, livelihoods and well-being, are now at risk worldwide.

Scientific and policy reports over the last decade document the need to conserve irreplaceable services provided by ecosystems (e.g., NAS, 1997¹; MEA 2005²; BOSC, 2005³; EPA Stewardship Initiative, 2006⁴; EBASP, 2006⁵; SAB C-VPES 2007⁶; Restoring Nature's Capital, 2007⁷). The United Nations Millennium Ecosystem Assessment (MEA) is one of the most comprehensive reports to date, and documented declines in 15 of 24 ecosystem services worldwide.⁸ Of particular note, the MEA concluded that:

“Even today’s technology and knowledge can reduce considerably the human impact on ecosystems. They are unlikely to be deployed fully, however, until ecosystem services cease to be perceived as free and limitless, and their full value is taken into account.” (MEA 2005)

The nation’s health, security, economic potential, and much of its culture are directly and intimately tied to ecosystem characteristics and quality. Even so, policy and management decisions have failed to take these relationships into account. The ERP will work to change this.

The ERP has been recognized as being in a unique position within the federal government for its research to establish and communicate a greater understanding of the value of ecosystem services and their interdependent relationship to human activities and well-being (BOSC 2005, 2007⁹). ERP scientists conduct core, multi-media research in support of the Agency’s Healthy Communities and Ecosystems goal and past results directly support EPA program office needs, and are now used by EPA Regions, states,

¹ "NAS 1997" = *Building a Foundation for Sound Environmental Decisions*, Chapter 4: EPA's Position in the Broader Research Enterprise, National Academy of Sciences, 1997. available at <http://www.nap.edu/openbook/0309057957/html/49.html>

² <http://MAweb.org>

³ BOSC 2005 <http://www.epa.gov/osp/bosc/pdf/eco0508rpt.pdf>

⁴ www.epa.gov/epainnov/pdf/rpt2admin.pdf

⁵ US EPA. 2006. Ecological Benefits Assessment Strategic Plan. EPA-240-R-06-001. U.S. Environmental Protection Agency, Office of the Administrator, Washington, DC.

⁶ http://www.epa.gov/sab/07minutes/c-vpess_06-12-07_minutes.pdf

⁷ Restoring Nature's Capital: An Action Agenda to Sustain Ecosystem Services, 2007" available at http://pdf.wri.org/restoring_natures_capital.pdf

⁸ We define ecosystem services as **the products of ecological functions or processes that directly or indirectly contribute to human well-being, or have the potential to do so in the future**. This definition provides a broad interpretation of ecosystem services to characterize services that may or may not be quantifiable.

⁹ BOSC 2007 <http://www.epa.gov/osp/bosc/pdf/ecomc082307.rpt.pdf>

and Tribes (e.g., Office of Water is requesting that Environmental Monitoring and Assessment Program (EMAP) procedures be used in all 50 states).

II. Strategic Directions, Science Challenges, and Research Needs

By 2009, the ERP will transition its focus to analyses of ecosystem services. We will conduct innovative, trans-disciplinary research that provides insights, information, and methods that enable decision-makers to assess the benefits of ecosystem services to human well-being. By doing so, we hope to secure the integrity and productivity of our ecological systems over time and at multiple scales. Our goal is to transform the way decision-makers understand and respond to environmental issues, making clear the ways in which their policy and management choices affect the type, quality, and magnitude of services we receive from ecosystems -- such as clean air, clean water, productive soils, and generation of food and fiber.

This new focus will be founded on ERP's extensive experience in environmental monitoring and assessment (EMAP), landscape ecology, modeling ecological stressor-response relationships, assessing vulnerability to natural and human stressors over regional scales (ReVA), and developing alternative future scenarios. It also reflects increased emphasis on ecological forecasting previously described in the ERP's 2003 Research Plan. This new focus parallels recent significant decreases in the ERP's budget and the resulting reduction in the amount of effort that can be placed on collection of regional and national scale field data.

Scientific Challenges: It is a significant scientific challenge to translate intuitive concepts about ecosystem services into operational methods for routinely incorporating quantitative information about these services into decision-making at all scales of governance. Doing so will require the development of credible, scientifically-based methods to:

- Inventory, measure and map, ecosystem services at multiple scales.
- Improve understanding of the effects of stressors on ecosystem services using stressor-response relationships and predictive models.
- Define compelling alternative management options and forecast future scenarios and outcomes.¹⁰
- Develop a decision support platform for decision-makers which enables them to explore outcomes of alternative decision options.
- Identify the "art of the possible" by making intelligent, informed use of knowledge about ecosystem dynamics, thresholds, and resilience; and cross-scale connections among social drivers and natural systems.

Drivers Prompting these Challenges: The ERP will be the first integrated US Federal program to address the difficult topic of maintaining, enhancing and restoring the services provided by the natural environment. The need is significant. In addition to national and international assessments noted above, policy drivers unique to EPA

¹⁰ Forecasting and scenario development yield plausible estimates of future outcomes, not precise predictions of short-term events. The latter is covered in the domain of calibrated modeling techniques.

(Executive Order 12866), require an examination of the environmental costs and benefits of EPA's regulatory actions (<http://www.epa.gov/regulations/follow.htm>). Since its inception in 1993, implementation of this Order has been hindered by the inability of EPA to account for the value of ecosystem services and the cost of their loss. Having tools to account for ecosystem services will benefit all Agency Program offices responsible for implementing EO 12866. ERP research will also provide a foundation for implementing EPA's Ecological Benefits Assessment Strategic Plan (2006). To meet needs for valuation and human health research, the ERP is forming partnerships with economists and social scientists within and outside the Agency to establish trans-disciplinary linkages among social and cultural values, economic and financial assessments, non-monetary valuation, and ecological outcomes. Our research will also support Administrator Johnson's charge to "advance environmental protection while maintaining our economic competitiveness." ERP will also provide methods to "conserve and restore ecosystem functions and services" as called for in EPA's Environmental Stewardship Initiative (2006). Our direction responds to needs identified in the Millennium Ecosystem Assessment (2005), the MEA Action Agenda (2007) and the BOSC 2005 and 2007 Program Review Recommendations.

Research Questions: The overarching research question for the Program is: *What are the effects of multiple stressors on ecosystem services, at multiple scales, over time?* To answer this question we need to develop quantitative, operational definitions for ecosystem services; know how these services are distributed throughout the landscape, and in what quantity and quality; project how they will respond to combinations of large and small scale stressors; and determine alternative management options that would optimize their sustainability.

III. Current Research Directions: Foundation for Future Research

In 2007, ERP is conducting research on monitoring, diagnostic and forecasting, and restoration.

Monitoring: The ERP developed the Environmental Monitoring and Assessment Program (EMAP) to establish statistically-valid, scientifically defensible monitoring frameworks to measure, assess, and report on the status and trends in ecosystem condition at regional and national scales. EMAP has successfully completed national assessments using this framework and has pioneered research to create landscape atlases that have been widely used in government and by NGOs. The ERP is transferring technical support for survey monitoring and assessment to EPA Program Offices; essential technical support for these activities will continue through the Water Quality Program. ERP will continue to analyze EMAP data and analyses as a starting point for identifying, measuring, mapping, and monitoring ecosystem services. The extensive EMAP data base will be invaluable in early testing of hypotheses focusing on landscape-related ecosystem services, such as provisioning and storage of fresh water, regulating nutrients and biogeochemical cycling, and maintaining diverse, resilient terrestrial and aquatic habitat. In collaboration with the Gund Institute at the University of Vermont and the National Geographic Society, the ERP is currently exploring the feasibility of joint

production of a report and atlas describing the “State of the Nation’s Ecosystem Services.”

Diagnostics and forecasting: The ERP is nearing completion on a variety of new methods to diagnose impairments to ecosystems. These include the Causal Analysis / Diagnosis Decision Information System (CADDIS); on-line decision tool-kits to assess regional vulnerability to natural and human stressors in the Mid-Atlantic, Southeast, and Midwest; new multi-media models to estimate the time needed for decreased air mercury emissions to result in fish safe for human consumption; and a suite of studies that are developing ways to quantify and forecast thresholds, or tipping points, in aquatic ecosystems. The ERP will build on its experience in diagnostic and forecasting methods for developing models and spatial techniques to forecast the response of ecosystem services to natural and human stressors at multiple scales and to quantify these responses in biophysical terms.

Restoration: The ERP has focused its research on restoration on aquatic systems. We are nearing completion of studies that document the effectiveness of riparian buffers on water quality; the effectiveness of small wetlands in restoring water quality in agricultural watersheds; prioritizing watersheds for restoration in the Mid-Atlantic highlands; examining the restoration potential for streams affected by mining; and restoring large floodplain rivers to obtain multiple ecosystem services, including innovative use of natural groundwater cooling to treat thermal discharges while simultaneously improving aquatic habitat, non-structural flood control, and recreational opportunities.

Future Research and Critical Path: The proposed research is designed to answer multiple questions about ecosystem services. We will develop multiple measures of services, including biophysical and monetary measures, to estimate incremental changes to ecosystem services, as well as suites of “bundled” services associated with land, air, and water systems over explicitly defined spatial and temporal scales.

Our goal is to inform a wide range of issues related to questions of social choice, with a special focus on informing trade-offs among ecosystem services provided under alternative management and policy decisions. ERP will meet high-priority EPA program office and region needs with direct relevance to EPA’s mission. We will address (a) *a national-scale pollutant – reactive nitrogen*, (b) *a priority ecosystem – wetlands*, and (c) *complex ecosystems —at community-specific locations* (Mid-west, Willamette, Tampa Bay and the Coastal Carolinas) representing a spectrum of physiographic and socioeconomic characteristics; local, regional, and national drivers of change to ecosystems; and the type and impact of decisions. In addition, cross cutting themes for *human health, landscape, inventory design, model development and valuation* will be investigated. Each research project and theme is currently being developed into a research and implementation plan that will include a critical path for work to be done.

Our Role and Partnerships: The ERP is pursuing a strategy of leadership and collaborative partnerships in order to implement its research program. The EPA mandate to “protect human health and safeguard the natural environment” places us in a unique position to lead efforts to characterize the critical link between ecosystem services and

human well-being. However to meet our research objectives we must mobilize our own expertise and engage strong partners.

We have established partnerships with EPA Regions 4, 5, 7, 8, 10 and with EPA's National Center for Environmental Economics (NCEE). We are benefiting from existing partnerships with the academic community via the extramural STAR grant program, representing about 15 universities through 2008 (currently there is no future funding for the ERP STAR program due to budget constraints). We are currently developing non-traditional partnerships with NGOs and other organizations. The ERP has established (or in process) collaborative agreements the Gund Institute for Ecological Economics, the Willamette Partnership, the Natural Capital Project, National Geographic, and NSF's National Ecological Observatory Network (NEON). Finally, the ERP is co-chairing with USDA Forest Service, an Interagency Workgroup on Ecosystem Services under the auspices of OSTP's Committee on Environment and Natural Resources (CENR) Subcommittee on Ecological Systems. Several individual collaborations are underway with NOAA related to coastal systems, and with USDA related to biofuels development.

We are also seeking ways to harness the capabilities of internet communications in order to achieve the widest possible review of our research program and to seek input and suggestions from others.

IV. Making a Difference

The ERP will collaborate with partners to create a decision support platform housing models, maps, animations, and other data-rich displays that make possible the proactive examination of a range of management options for user issues at multiple explicit spatial and temporal scales. We intend to present a new generation of decision support tools, models and visual arrays to better engage and meet the needs of policy makers and managers, and enhance ecological, social and financial knowledge and resources needed to protect and restore ecosystems and their services. The ERP is meeting with federal partners, planners and others to investigate what is needed and by whom to build the architecture for this on-line product.

Research Products: The Ecological Research Program has created four major categories of research products: (1) *Measurements and dynamic maps of ecosystem services*: spatial representations of ecosystem services for communication, outreach, planning, assessment, and resource management; (2) *Predictive models relating to the response of stressors*: forming a foundation to forecast change and proactively assess how ecosystem functions and services are likely to respond to natural and human stressors; (3) *Management Options* using prospective tools, singly and in complex arrays, to develop alternative future scenarios; and (4) *Decision Support* to allow managers and decision-makers to explore how various policies may affect the likely distribution of ecosystem services, human health and well-being outcomes, now and in the future.

Applying Research Results in the Public and Private Sector: The ERP research program is designed to act as a catalyst for innovation in policies, rules, and governance

by (1) *Setting policies and guidelines* that can achieve our mission through a variety of policy instruments that do not have the legal force of national rules; (2) *Quantifying benefits for national rule-making* in response to the Office of Management and Budget data requirements for benefit–cost assessments; (3) *Developing environmental metrics and indicators for ecosystem services* for use in periodic reports on the environment or for establishing environmental accounts within our national Gross Domestic Product accounts; and (4) *Catalyzing market innovations* that engage the private sector for environmental protection. ERP research can provide information useful for reducing transactions costs; estimates on the availability, reproducibility, permanence and/or longevity of ecosystem services over space and time; identify opportunities for maximizing multiple services per investment; recommend metrics for documenting environmental outcomes; and provide credible timelines required to achieve expected outcomes (i.e., there is often a lag between action and environmental response).

Environmental Outcomes: Measures of success for the ERP will best be found in enhanced environmental stewardship at local, regional, and national levels:

- * Ecosystem services from natural and restored ecosystems are sustained for future generations.
- * Ecosystem services are conserved or enhanced while maintaining use of ecosystem resources.

Contact

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Ecological Research Program (ERP)
GPRA Hierarchy
September 4, 2007

ERP Vision

A comprehensive theory and practice for characterizing, quantifying, and valuing ecosystem services, and their relationship to human well-being is consistently incorporated into environmental decision making.

ERP Mission:

Provide the information and methods needed by decision makers to assess the benefits of ecosystem goods and services to human well-being for inclusion in management alternatives.

ERP Overall Goal:

To transform the way decision –makers understand and respond to environmental issues by making clear the ways in which our policy and management choices affect the type, quality and magnitude of the goods and services we receive from ecosystems.¹¹

ERP Performance Goal:

An increasing number of decision-makers (5% increases per year beginning in 2009) regularly apply information and methods developed by the Program to make proactive policy and management decisions

Performance Measure:

Cumulative number of local, state, regional, national and/or other environmental decision makers confirming the use of ERP products, information and/or assistance to support decision making as measured by written, verifiable, documentation by the users.

¹¹ One of the current goals of the Ecological Research Program from which the current program is founded was: Decision-makers understand the importance of ecosystem services and make informed, proactive management decisions that consider a range of alternative outcomes.

Ecological Research Program
Long-term Goals
September 4, 2007

LTG 1: Decision Support Platform

By 2014 ORD will provide an innovative online decision support platform that offers EPA, Regions, States, local communities and resource managers the ability to integrate, visualize, and maximize use of diverse data, models and tools at multiple scales to generate alternative decision options and understand the consequences of management decisions on the sustainability of ecosystem services, their value and human well-being.¹²

LTG 2: National Mapping and Inventory

By 2013 ERP will deliver a publicly accessible, scalable, national atlas and inventory system for selected ecosystem services that can be quantified directly or indirectly across the U.S. to be used by the Agency, NGO's, and other decision makers to support prioritizing policy and management actions and their consequences.

LTG 3: Nitrogen Assessment

By 2013 ERP will provide an assessment of the positive and negative impacts on ecosystem services resulting from changes in nitrogen loadings from major source categories to support policy and management decisions in EPA's Offices of Air Resources and Water.

LGT 4: Wetlands Assessment

By 2013 ERP will provide guidance and decision support tools to target, prioritize, and evaluate policy and management actions that protect, enhance, and restore ecosystem goods and services of wetlands at multiple scales.

LTG 5: Community Based Demonstration Projects

By 2013 ERP will complete 4 site-specific demonstration projects that illustrate how regional and local managers can use alternative future scenarios to proactively conserve

¹² This long-term goal integrates the products of the other four long-term goals

and enhance ecosystem goods and services in order to benefit human well-being and to secure the integrity and productivity of ecological systems.

Ecological Research Program
New Annual Performance Goals and Annual Performance Measures
Fiscal Years 08 and 09

Decision Support Platform

09 APG: Complete Multi-Year Development Path for the On-line Decision Support Platform

08 APM: Peer reviewed valuation strategy for ERP

09 APM: Peer reviewed plan for an ecosystem services national characterization system

09 APM: Peer reviewed decision support development plan

09 APM: Guidance produced for characterizing ecosystem service production functions

National Mapping and Inventory

09 APG: Complete multi-year research and development plan for a national atlas and monitoring system.

09 APM: National ecological services inventory system design, research and development plan.

08 APM: Peer reviewed research and development plan for a national atlas of Ecosystem Services

09 APM: Production of first national ecosystem services maps in support of nitrogen and wetlands LTGs

Nitrogen Assessment

08 APG: Peer reviewed multi-year research and implementation plan for the nitrogen assessment including expectations of demonstration projects and wetlands team.

09 APG: Report on expected changes in ecosystem services as a result of decreased nitrogen inputs from multiple sources for the Eastern US

09 APM: Report for Regions 1, 2 and 3

09 APM: Report for Region 4

Wetlands Assessment

08 APG: Peer reviewed wetlands research/implementation plan including expectations of demonstration projects and nitrogen team.

09 APG: Report on the relationship between ecological function and delivery of services by wetlands by Region

APM 2009 - Report on the state of the science on linkages between wetland functions and ecosystem services at multiple scales

Community Based Demonstration Projects

08 APG: Complete research and development plans for demonstration projects

08 APM: Peer reviewed research and implementation plan for the Willamette, including special studies on nitrogen and wetlands

08 APM: Peer reviewed research and implementation plan for Tampa Bay, including special studies on nitrogen and wetlands

08 APM: Peer reviewed research and implementation plan for the Mid-west including special studies on nitrogen and wetlands

09 APM: Peer reviewed research and implementation plan for the Coastal Carolinas including special studies on nitrogen and wetlands

09 APG: Delineate and quantify the ecosystem services provided by the demonstration Projects and complete stressor scenarios.

09 APM: Map and inventory the status of key ecosystem services in the Willamette ESD to the level of current ability.

09 APM: Map and inventory the status of key ecosystem services in Tampa Bay Area to the level of current ability.

09 APM: Map and inventory the status of key ecosystem services in the Upper Mid-west to the level of current ability.

09 APM: Map and inventory the status of key ecosystem services in the Coastal Carolinas to the level of current ability.

09 APM Produce an assessment of the likely changes in environmental stressors and land use patterns and first analyses of possible changes in ES from 2005 through 2050 in Tampa Bay.

09 APM Produce an assessment of the likely changes in environmental stressors and land use patterns and first analyses of possible changes in ES from 2005 through 2050 in the Willamette

09 APM Produce an assessment of the likely changes in environmental stressors and land use patterns and first analyses of possible changes in ES from 2005 through 2050 in upper Mid-west

10 APM Produce an assessment of the likely changes in environmental stressors and land use patterns and first analyses of possible changes in ES from 2005 through 2050 in Coastal Carolinas