EPA/600/X-11/014

Report from the Workshop on Indicators of Final Ecosystem Goods and Services for Wetlands and Estuaries

Meeting Date: June 7 to 10, 2010

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ACKNOWLEDGMENTS

The quality of this report was greatly improved by workshop notes and proceedings recorded by Mary E. Kentula and comments from reviews by Matt Weber, US EPA, ORD, NRMRL and Bryan Milstead, US EPA, ORD, NHEERL, AED. The information in this document has been funded wholly or in part by the U.S. Environmental Protection Agency under cooperative agreement 83235601 to the Council of State Governments. It has been subject to review by the National Health and Environmental Effects Research Laboratory and approved for publication. Approval does not signify that the contents reflect the views of the Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

PREFACE

As ecosystems are restored, degraded, protected, or managed, the human well-being derived from them correspondingly rises and falls. Public policies seeking to protect or enhance human well-being derived from ecosystems must recognize, measure and manage the ecological wealth upon which that human well-being depends. This requires the integration of ecological and social analysis most fundamentally in terms of the units of ecosystems upon which social analysis is best constructed.

The desire to incorporate the role of ecosystems in sustaining human well-being in policy deliberations is not new[1]. It has been embodied in Executive Orders, National Academy of Sciences Reports, EPA Science Advisory reports and agency policies, and academic debates for decades. The motivation to build policies on the linkage between ecosystems and human well-being has increased and refocused especially with the development of the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005). This global assessment defines a comprehensive taxonomy of four categories of "ecosystem services": regulating (such as climate regulation), supporting (such as nutrient cycling), provisioning (such as the production of food and fiber), and cultural (such as spiritual inspiration). These goods and services, in combination with human systems, cultures, and values, benefit human well-being. While this 4 part categorization is a useful heuristic tool, it does not provide a practical operational system useful for accounting, landscape management, or valuation (Fisher et al. 2008). In order to facilitate the interaction between ecological assessment and economic valuation of changes in ecosystem goods and services, Boyd and Banzhaf (2007) advocate the need to clearly distinguish between "final

[1] Nor without question, e.g. (McCauley 2006)

ecosystem goods and services" (or endpoints) and other ecosystem goods and services more appropriately termed "intermediate goods and services". As they argue, an accounting perspective (a perspective with a set of internally consistent rules avoiding both double-counting and exclusion of substantial benefits) and an emphasis on biophysical outcome measures that facilitate economic analyses is essential. This perspective and these measures are important if we wish to aggregate or bundle benefits so that cumulative and comprehensive changes in ecosystems and the consequent changes in human well-being can be described or compared as a result of a suite of policy options.

To be clear, "final goods and services" may be the units upon which accounting systems and valuation are based. However, an understanding of "intermediate goods and services" and their relationship to final goods and services, a relationship described by ecological production functions (e.g. Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems 2004, Daily and Matson 2008), is invaluable in understanding, assessing, predicting, and managing final goods and services and the human well-being they provide. In addition, the identification of final goods and services is important for analysis of sustainability as final goods and services represent the features of ecosystems to be sustained.

The temporal, ecological, and spatial scales of intermediate and final goods and services need not be, and in fact are unlikely to be, coincident. Thus, production functions must be designed and used to link intermediate goods and services in one ecosystem at one point in time (e.g., denitrification in a set of riparian wetlands in the spring) with the production of final goods and services in another ecosystem at another point in time (e.g., the production of fish in an estuary in the summer; see slide 5 and the following slides starting on page 12 of Appendix 4). Proper construction and use of these models is crucial, as these models are essential to the delivery of policy-relevant ecological benefit analyses.

In this report we attempt to give practical meaning to the final ecosystem services concept. This takes the form of a working hypothesis on the units that need to be measured or estimated. We have made significant progress; we expect refinements with future research.

EXECUTIVE SUMMARY

This report documents a workshop whose goal was to identify metrics of final ecosystem goods and services for wetlands and estuaries. The identification of these metrics is intended to be useful in any program requiring linkages between these ecosystems and human well-being. The workshop was specifically designed to answer the following three questions: (1) What biophysical metrics directly facilitate the integration of biophysical measurement, analysis, and models with analyses of the social benefits derived from ecosystem goods and services?; (2) What principles are useful for identifying final ecosystem goods and services?; (3) What gaps exist between the metrics hypothesized to represent final goods and services and the current capacity of monitoring and modeling to report on these indicators for large regions or for the nation? The workshop provided for the extensive collaboration between natural and social scientists required when addressing these questions.

We achieved consensus on a working hypothesis of ecological

Figure 1. Metrics, Indices and Indicators

We use three inter-related terms –metric, index and indicator. Definitions for these important terms are sparse and inconsistent. We offer an example based on the development of an indicator of vertebrate biotic integrity as outlined in (Hughes and Peck 2008, Stoddard et al. 2008) to provide an operational illustration of these terms as we use them.

Consider the construction of an indicator of biotic integrity, a measurement requirement driven by the Federal Water Pollution Control Act of 1972 that establishes "biological integrity" as a goal for U.S. surface waters. First, data on vertebrate assemblages are collected by field crews (Peck et al. 2006). The data include a list of taxa, and for each taxon the number of individuals captured, their size range, and the presence of visible anomalies. Second, with knowledge of the ecological characteristics of each taxon, the assemblage is described in over 200 metrics. Metrics are calculated for each of 8 ecological categories (habitat, tolerance, trophic, reproductive, composition, richness, life history and alien species). Example metrics are: Proportion of All Species that are Native Benthic, Super Tolerant Species Richness, and Abundance of Alien Fish. Metrics are examined for their statistical properties and responsiveness to anthropogenic disturbance. A small number of these metrics (six to ten) are selected, based on their capacity to distinguish more disturbed sites from less disturbed sites. The metrics selected are then integrated into a unitless Index of Vertebrate Biotic Integrity (IBI-Vert). This index is scaled over an arbitrary range, e.g. 0 to 100. This index provides us with insight about the status of a sampled site with regard to biological integrity. Because the index provides this insight, it serves as an indicator of biological integrity.

metrics of final ecosystem goods and services for wetlands and estuaries. Translation of these metrics into implementation-ready monitoring protocols, or even understanding which metrics are of highest priority, involves significant further collaborative work. However, the meeting achieved agreement among social and natural scientists on a framework and set of practices that can direct design and implementation efforts. Importantly, the framework and practices are consistent with both ecological and economic best practices related to the analysis of ecological systems. The identification of these metrics is a major step on the way to identifying indicators of final ecosystem goods and services.

INTRODUCTION

EPA's Ecosystem Services Research Program (ESRP) is structured to create:

> "A comprehensive theory and practice for quantifying ecosystem services so that their value and their relationship to human well-being can be consistently incorporated into environmental decision-making" (Linthurst and Goodman 2009).

In response to this vision, EPA's MARA (Monitoring and Aquatic Resource Assessment) program organized a workshop to identify ecological indicators (hereafter, just "indicators") useful for characterizing the relationships between two ecosystems – wetlands and estuaries – and human well-being. Boyd and Banzhaf developed the notion of "final ecosystem goods and services" as the biophysical features, quantities, and qualities that link ecosystems to human well-being (Boyd and Banzhaf 2007, Boyd 2007). Thus, the central objective of the workshop was to develop a working hypothesis of metrics of final ecosystem goods and services for wetlands and estuaries. The identification of these metrics is intended to be useful in any program requiring linkages between these ecosystems and human well-being.

With additional analysis, these metrics can be combined to create indicators of the final ecosystem goods and services.

Metrics and indicators of final ecosystem goods and services can be used for three purposes, all of which are responsive to the needs of ESRP:

1. They provide the biophysical information necessary for cost-effectiveness analysis (i.e., analysis of socially meaningful ecological change (e.g., miles of fishable streams)) in response to policy choices;
2. They facilitate valuation studies (i.e., studies that monetize incremental changes in biophysical features over time or in response to policy choices); and
3. They help communicate the roles of ecosystems to decision-makers and the public in an effective manner.

The first two applications for indicators of final ecosystem goods and services rely on ecological production function models to relate changes in stressors (or other factors) to changes in final ecosystem goods and services. The need for these models, based on "intermediate goods and services" to predict "final goods and services", underscores the need to continue the collection of a wide range of information in addition to indicators of final goods and services. Further, indicators of final goods and services are not a substitute for existing ecological metrics. Rather, they are an important addition and complement to indicators already being monitored.

WORKSHOP ORGANIZATION

Previous workshop on streams

This workshop on wetlands and estuaries was modeled after a previous workshop on indicators of final ecosystem goods and services for streams (Ringold et al. 2009).

Participants at the streams workshop recognized that an analysis of final ecosystem goods and services required us to start by identifying a list of users of stream ecosystems. This list of users was intended to serve as a heuristic device reflecting the divergent needs of a range of users rather than as a comprehensive list. Having identified this list of users, workshop participants asked for each user, "What biophysical amounts, features, and qualities (hereafter referred to as "biophysical features") does each user want more of or less of? Is this the most concrete, tangible, and intuitive feature for this user group?" We organized these biophysical features into five broad groups of biophysical attributes, each with two or more subordinate groups of attributes (see the column headings on Table 1 of the streams workshop report, or see the column headings on Tabs 4 and 7 in Appendix 5 for examples of these attributes for estuaries and wetlands). The information on which users used each attribute was organized and represented in a "checkmark matrix" (Table 1 on page 22 of (Ringold et al. 2009)) relating attributes of ecosystems to final ecosystem goods and services directly relevant to specific users. After the streams workshop, five people[2] translated the checkmark matrix into specific metrics (http://www.epa.gov/nheerl/arm/streameco/index.html). They viewed the set of specific metrics for streams as a working hypothesis in that while the construct of the matrix as well as the specific entries were the result of thoughtful analysis, the structure and the entries should be subject to empirical evaluation.

As a matter of terminology, the specific entries are metrics. Combinations of these metrics in a manner that reflects the values of each group or segments within a group would constitute an indicator of the final ecosystem service for that user group – see Figure 1.

[2] James Boyd, Dixon Landers, Amanda Nahlik, Paul Ringold, and Matt Weber

Workshop Preparation

To facilitate the wetlands and estuaries workshop, we[3] developed a pair of checkmark matrices – one for wetlands and one for estuaries prior to the workshop. As in the streams workshop, the development of this framework not only provided a foundation for further discussion, but also enabled workshop organizers to identify the categories of expertise needed to pursue workshop goals. Participants were identified and invited to the workshop for their knowledge of wetland and estuarine attributes that the organizers believed would need to be characterized to quantify the role that these ecosystems play in human well-being. Approximately one-third of the scientists were social scientists, one-third were natural scientists with experience in wetlands, and another third were estuarine natural scientists. A pair of pre-workshop webinars and background material and presentations during the workshop ensured that workshop participants had a common understanding of workshop goals, concepts, and terms.

The list of participants, the agenda, and prepared presentations for the workshop are provided as Appendices 1, 2, and 3 (respectively).

Five Key Questions for the Wetlands and Estuaries Workshop

Workshop discussions and results focused on five key questions posed to participants:

1. What set of ecosystem boundaries should we use?

   Definition of ecosystem boundaries (Step 2 Figure 2) is important to provide clarity about the range of metrics to be considered and to ensure aggregation without duplication or gaps. For example, with streams, it was important that we defined the status of riparian ecosystems so that we knew whether to include measures of these important systems in our analysis and so that users of our analysis would know what we had included and excluded.

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[3] Paul Ringold, Dixon Landers, Matt Weber, Amanda Nahlik, plus Mary Kentula for wetlands and Ted DeWitt for estuaries

2. Does the proposed list of ecosystem attributes make sense?

   What broad attributes (Step 3 Figure 2) of an ecosystem do users in the aggregate interact with? Our advance work provided a list of these attributes (see list of ecosystem attributes on Tab 1 of Appendix 5). Did the workshop participants accept this list or wish to alter it?

3. Does the proposed list of user groups need to be modified?

   Final ecosystem services are the biophysical amounts, features, and qualities that a user wants more of or less of. Users do not have equivalent needs, thus to define these features, the group needed to posit a set of specific users. Our advance work provided a list of users (Step 4 Figure 2 and Tab 2 of Appendix 5). Did workshop participants accept this list or wish to alter it?

4. Does the proposed checkmark matrix for wetlands and estuaries need to be modified?

   What broad attributes of an ecosystem does each user interact with? This checkmark matrix documents that an ecosystem attribute represents a final service to a user. It is a prelude to defining a metric for that attribute. Our advance work provided a preliminary checkmark matrix (see Tabs 3 and 5 of Appendix 5). Did the workshop participants accept this matrix or wish to alter it?

5. What are the metrics for each checkmark?

   For each checkmark, representing an ecosystem attribute that represents a final service to a user, what are the specific metrics that represent the final ecosystem service (Step 5 Figure 2)?

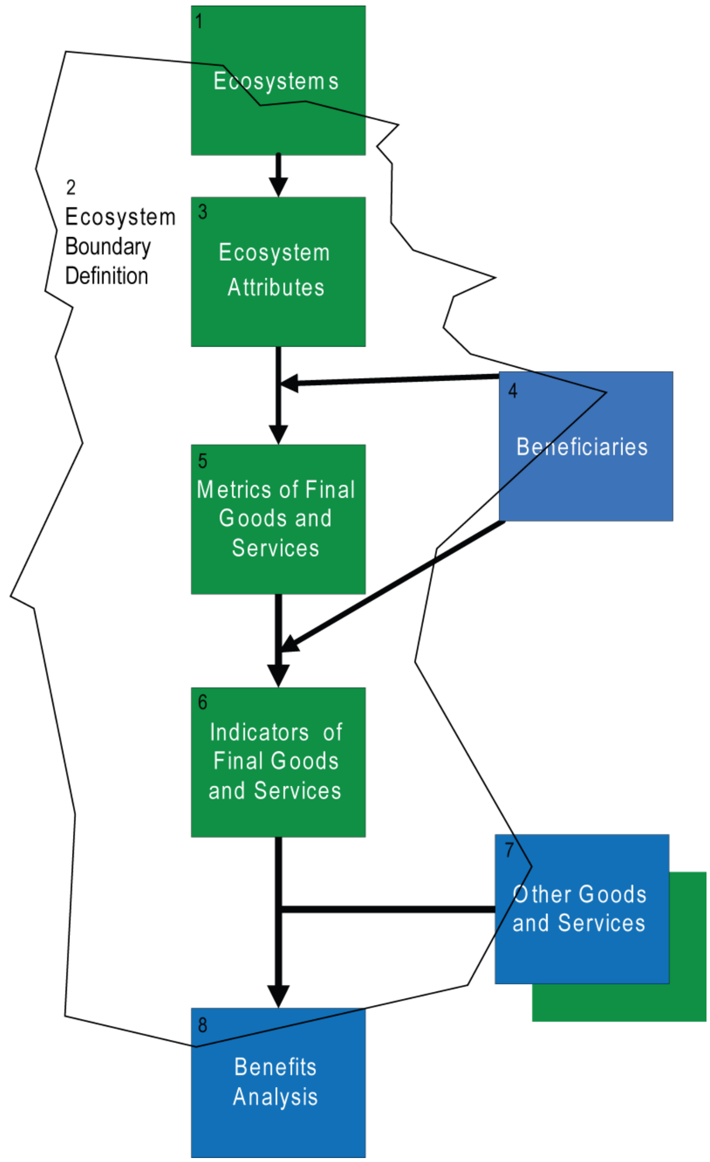

Figure 2. Relationship between ecosystems and benefits analysis. Ecosystems are viewed as having broad categories of attributes (as listed in Worksheet 1 of Appendix 5). When viewed from the perspective of beneficiaries, we can identify or propose metrics of these attributes directly contributing to the well-being of each beneficiaries. When metrics are combined in a manner that reflects beneficiary values, the combination is an indicator of the service provided by the ecosystem. When the services are available, because of the presence of other goods and services e.g. roads and other infrastructure, it is considered in analyses of benefits. Ecosystems reside within specified boundaries. Neither beneficiaries nor benefits need be within those boundaries. Efforts in the workshops focused on steps 2 through 5.

WORKSHOP RESULTS

The revised checkmark matrices and tables of metrics developed from workshop deliberations are provided as spreadsheets (see Tabs 4, 6 and 7 in Appendix 5).

Ecosystem Boundaries

Each group identified a practical boundary for its analysis working from candidate boundary definitions (see slides 5 and 6 on Page 15 of Appendix 4).

The key decision made by the estuaries group was to exclude fresh tidal ecosystems from consideration. This decision was made in part, in recognition that the matrix completed for streams would cover this ecosystem. The seaward limit provided in the candidate description was also discussed. The group agreed to accept this boundary but to revisit it if such consideration could lead to identifying different metrics of final services. The definition proposed (after NOAA 2009) and accepted was:

> Tidal habitats and adjacent tidal wetlands and waters that are at least occasionally diluted by freshwater runoff from the land resulting in salinities < 30 PSU for part or all of the year. Salinity may be periodically increased above that of the ocean by evaporation. The upper boundary extends landward and upstream to the point where ocean derived salts measure less than 0.5 parts per thousand during the period of average annual low flow while the lower boundary extends seaward to an imaginary line closing the mouth of a river, lagoon, fjord, or embayment. (Coastal And Marine Ecological Classification Standard. Version III August 2009, NOAA. Coastal Science Center)

Workshop participants within the wetland group came to the consensus that the Cowardin definition of wetlands,

> "Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year" (Cowardin et al. 1979),

describes wetlands most appropriately for the workshop. The wetlands group included farmed wetlands (wetlands converted to agricultural production prior to 1985 and still meeting the specific hydrologic criteria of a jurisdictional wetland) within this definition.

However, prior converted wetlands (wetlands converted to agricultural land prior to 1985 but no longer meeting the criteria of a jurisdictional wetland) were excluded.

In addition to these considerations of the boundaries of an ecosystem, there were also discussions over the boundaries appropriate for certain types of uses that fundamentally reflect differences in boundary issues. For example, the wetlands group was divided about whether to consider floods as a metric of a final service for wetlands on the grounds that flooding adjacent to a wetland would be outside of the wetland. In contrast, the estuaries group (and the earlier stream effort) included measures of flooding of properties adjacent to the estuary as a metric of a final service for estuaries. Metrics reflecting the flooding of adjacent properties were ultimately included in both matrices. Residential property beneficiaries raise the same issue. Is the business property within the ecosystem or in adjacent ecosystems? How are the beneficial uses of residential property separate from other beneficiary classes such as the recreational subclasses? The wetlands group used a very narrow definition; the estuary group used a broader definition.

List of Beneficiaries

"User" was questioned by the workshop participants in referring to human-use categories. Participants found the term confusing because a) non-use values, including bequest and option values, do not fit well under a "use" heading, and b) for some, "user" implies that humans are abusing ecosystems. "Human-use categories" were therefore changed to "Human beneficiaries". We spent time clarifying our understanding of each beneficiary category and revising the list that had been provided. The revised list and definitions are provided with the list of beneficiary category as Tab 2 in Appendix 5.

Human beneficiary categories warranted definitions, examples, or statements to capture the assumptions made for the sub-category (e.g., see comments in the beneficiary category column of Tab 4 in Appendix 5). For example, there was debate about whether or not beneficiaries under the "Recreational" category interacted with pathogens and parasites in attaining a final ecosystem service. We assumed that the recreational beneficiary category (including sub-categories of experience/hiking/nature appreciation/viewing, wading/swimming, hunting, fishing, and boating) had some contact with water; therefore, some metric pertaining to pathogens and parasites was important. In another example, the difference between two human beneficiary categories needed clarification: "aquaculture" was defined as an activity involving husbandry to produce a consumable. On the other hand, "food extraction" was determined to be dependent on the natural abundance of the extracted item and that this category excluded anything cultivated or underging husbandry. "Food extraction" includes salt and organic fertilizer (e.g., kelp) extraction that used in food production. These assumptions proved important for logically and consistently identifying ecosystem attributes important to beneficiary categories in providing final ecosystem goods and services.

The wetlands group suggested that carbon markets should be included as a beneficiary category. The reason for proposing to add this category is that the creation of these markets defines a category of beneficiary for sequestered carbon. However, we view environmental markets as constructed markets formed to provide a means to manage one or more final goods and services by means of altering an intermediate service. Thus, for the purpose of this analysis, we have concluded that carbon markets are not a beneficiary category (see a broader discussion on this issue below).

Identifying Final Ecosystem Goods and Services

After reviewing and modifying the list of human beneficiary categories, our intention was to consider ecosystem attributes. However, the wetland group found it difficult to evaluate which ecosystem attributes represent final ecosystem goods and services without explicitly recognizing what the final ecosystem goods and services were to each beneficiary category. Our solution was to identify potential final ecosystem goods and services for each beneficiary category (see Tab 4 in Appendix 5). Working *from* final ecosystem goods and services provided a foundation on which to evaluate the ecosystem attributes. One of the products that resulted from this exercise was a list of potential final ecosystem goods and services from wetlands. It is important to note that the final ecosystem goods and services identified are posited goods and services, as studies need to be conducted to validate our hypotheses of what goods and services contribute to well-being for each beneficiary category.

One of the principles of final ecosystem goods and services under which the groups were working concerned human inputs into ecosystems: final ecosystem goods and services are provided directly by the ecosystem itself and do not reflect anthropogenic features -- e.g., roads, buildings, stocked flora or fauna, etc.(Table **1**). One of the questions that was raised in determining final ecosystem goods and services was, "How much human input makes an ecosystem service a human feature rather than an ecosystem feature?" For example, does planting vegetation to be harvested for biofuels make the vegetation more a result of human activity than of ecosystem activity? The view of the wetlands group was that a one-time introduction of perennial seeds to a system that would then become self-perpetuating, could still allow for the perennial vegetation to be considered as providing a final ecosystem good or service. The alternative would be to consider features earlier in the overall production function, but constituting the last step in the ecological production function, e.g. soil condition, as providing the final service for a biomass harvester. This and other "gray areas" associated with this concept of human inputs warrant further discussion.

Ecosystem Attributes

We also spent time considering and clarifying our understanding and definitions of the broad ecosystem attributes providing final goods and services to beneficiary categories. Lists of these attributes and their definitions are provided as Tab 1 in Appendix 5. Two issues warrant noting:

Ecological versus Biological Integrity

Ecological and biotic integrity are ecosystem attributes of similar character and form. They differ in that biotic integrity is viewed as a narrower measure based only on the organisms observed, whereas ecological integrity reflects not only biotic composition, but also chemical and physical attributes. The hypothesized form of the metric that represents the final service is the same in either case – the difference between the observed state and the expected or reference state. "Reference state" has multiple definitions (e.g. in Stoddard et al (2006)). A key area of research should be to determine which of the definitions of "reference" if any, is the appropriate benchmark for the way people perceive nature.

Seascape or Landscape Mosaic

"Seascape or Landscape Mosaic", a habitat measure of the arrangement of multiple landcover types, is, for many purposes, an intermediate service. When the mosaic alters the capacity for a beneficiary category to use the environment, a habitat mosaic provides a final service. For example, a subsistence hunter may directly interact with the landscape mosaic while hunting for food if it provides places for the hunter to hide that also allow the target organism(s) to be seen (e.g., tall cattails at the edge of an otherwise open water wetland for a duck hunter).

Checkmark Matrices and Metrics

The key steps in workshop deliberations were discussions of the checkmark matrices and the translation of the checks into specific metrics. After reviewing and revising the checkmark matrices (provided as Tabs 3 and 6 in Appendix 5), each group attempted to identify metrics of wetland or estuarine attributes that constitute the ecological endpoints for collections of human beneficiary categories. To complete this task, each group was challenged to go through the following thought process for each beneficiary category:

1. What is (are) the final ecosystem service(s) provided to the specific category of beneficiary?
2. What ecosystem attributes does that beneficiary category directly interact with in attaining the final ecosystem service(s)?
3. What specific metrics can scientists use to indicate/measure each of those ecosystem attributes?[4]

For example, recreational angling is one category of estuarine beneficiary. The biophysical amounts, features, and qualities that this user wants more of have something to do with fish and with the aesthetics or appeal of the location (e.g., Arlinghaus 2006; see Tab 7 in Attachment 4 for the specific metrics)). Notably, in this example, benthic condition, wetland

[4] Examples of this thought exercise were provided in the presentations (see slide 11 and the following 9 slides starting on page 16 of Appendix 3).

and riparian condition in the estuary, and water chemistry and quality are all important ecosystem attributes that can change fish distribution and abundance. Within the context of the "final goods and services" concept and taxonomy that we adopted, these are examples of intermediate goods and services that are vitally important and would be candidates to be included in production function models useful for assessing or managing the final service.

Decision Rule

During discussions about which metrics represent a final service, a decision rule, proposed at the workshop by Rob Johnston, was found to be useful (Johnston and Russell 2011). Suppose one metric is constant across space. Would a reasonable user pay for different levels of a second metric? If the answer is yes, then the second metric is a metric of a final service; if the answer is no, then the second metric would be a metric of an intermediate service. For example, a recreational angler is clearly interested in fish. If fish are evenly distributed, would a reasonable angler be willing to pay for different levels of chemistry? We concluded, in this case, that the answer would generally be no, unless the chemicals would be detrimental to the anglers access to or use of the fish. Similarly, if fish are evenly distributed, would a reasonable angler pay for different levels of sensory experience? We concluded that the answer would be yes. Thus, appropriate metrics of sensory experience should be included in an indicator of the final ecosystem service for a recreational angler in an estuary.

Ecosystem provision of infrastructure

Characteristics of the ecosystem that provide structure (e.g., amount of water, substrate, water surface state, habitat mosaic, etc.), undoubtedly affect a beneficiary category's ability to attain a final ecosystem service. For example, a recreational swimmer in an estuary may not be able to swim at a particular location due to strong wave action (i.e., surface water state). Should measures of these features be counted as providing a final service? We concluded that a reasonable swimmer would pay for an ideal water surface state (i.e., calmer water), and, therefore, it should be considered as providing a final ecosystem service.

Metrics for categories of non-use beneficiaries

Determining which ecosystem attributes and metrics of those attributes were important to categories of non-user beneficiaries (including existence and option/bequest categories) proved challenging. There seemed to be consensus that the form of the metric should be "magnitude of deviation from reference conditions for the site" but with a range of opinions to which attributes a metric of this form should apply. Some members of the wetland group hypothesized that non-user categories cared about two ecosystem attributes: the amount of water in the ecosystem and the flora and fauna that are supported by the ecosystem. In contrast, members of the estuary group hypothesized that all ecosystem attributes were important to the non-use categories. In this view, the indicator of the final service would be based on a combination of metrics of all ecosystem attributes.

Sensory Experience Metrics

Sensory experience attributes include ecosystem attributes of visual appearance, odor/taste, sound, tactile, and taste. Both wetland and estuarine groups were able to hypothesize which attributes might be important to certain categories of beneficiaries, i.e., checkmarks were placed. However, no specific metrics could be provided by the wetlands group. In contrast, the estuary group, was able to posit specific metrics for each of the attributes although the metrics were of a general form.

Time and Space

In determining specific metrics that scientists can use to indicate/measure ecosystem attributes, we sought to address issues of time and space. For some ecosystem attributes, such as "conductivity/salinity" for an irrigator, we defined time clearly (e.g., "average daily conductivity of the wetland during the growing season"). However, most metrics included time as a vague condition, such as "during the time of the activity" or "at all times". Issues of space (i.e., the size of the biophysical unit valued by people) were even less clearly addressed.

DISCUSSION

Principles

In the extensive discussions that led to the identification of the metrics we used a set of general principles to determine which ecosystem attributes should be measured to quantify final ecosystem goods and services for each category of beneficiary. These principles are important not only because they define how workshop participants translated expert knowledge into a delineation of indicators of final wetland and estuarine ecosystem goods and services, but also because these principles should be readily transferrable to other ecosystems. The principles we settled on are provided as Table 1.

Terminology and Key Assumptions

When introducing the final ecosystem goods and services concept, participants raised questions over the terminology used to describe the concept. Some participants found the term “final” of concern because of its connotations with restrictive language, such as “definite”, “irrefutable”, and “irrevocable”. It was noted that whether the term used is “direct services”, “final services”, or “ecological endpoints” it is important to focus on the concept embodied by the term “final ecosystem goods and services” as described in the introduction to this report and in the presentations provided (see Appendices 3 and 4). It was further noted that the terminology should focus on both goods and services since much of what people value and what is monitored and modeled is a good (i.e., a tangible object) rather than a service (i.e., a process).

Intermediate and Final Goods and Services

We discussed the relationships between intermediate and final ecosystem goods and services. For example, lakes, floodplains, and wetlands provide flood storage, an intermediate service with the capacity to modify the magnitude and duration of flooding. Natural scientists understand that such services have value. Social scientists agree, but note that the value of these intermediate services is reflected in and accounted for in measurements of water quantity and timing in valued locations. In general, social scientists suggest that it is useful to think of these systems in the context of ecological production function models (Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems 2004, Daily and Matson 2008) which relate stressors or policy options to changes in intermediate goods and services to changes in final goods and services. Final goods and services are the entities that are valued; other ecosystem features, “intermediate ecosystem goods and services”, produce these final goods and services. Their value is embodied in the value of the final goods or services.

A further important recognition is that intermediate and final goods and services need to be linked by ecological production functions. These functions are important because they link intermediate goods or services that may be provided in one ecosystem at one point in space and time with a final good or service in another ecosystem at another point in time. For example, these functions are necessary to relate denitrification in a wetland in April to fish abundance in a downstream estuary in August. These ecological production functions can take two forms. In their qualitative form these functions illustrate linkages between different kinds of indicators and different kinds of ecosystems (see examples of qualitative production functions on slide 3 page 10 and slide 4 page 13 in Appendix 4). These illustrations are important for communicating linkages and for guiding data collection to support or evaluate quantitative production function. In quantitative form, they allow for predictions about the extent to which an incremental change in an intermediate service leads to an incremental change in a final service. Quantitative predictions are essential for linking policy options that affect ecosystems and, ultimately, human well-being. For example, an ecological production function may address the question “How would a transfer of *x* acres of floodplains to urban land in watershed *y* at time t_1 affect the abundance of fish species *z* in estuary A at time t_2?” To link to analysis of human well-being, this ecological production function would link to a social production function addressing the question, “How would the abundance of fish species *z* in estuary A at time t2 affect human well-being in specified locations over specified periods of time?”

Concern was raised in the workshop – especially in the wetland group – about how individual matrices would be interpreted without integrating this crucial concept, linking ecosystems via production functions, into the exercise. The connection to human well-being for any given ecosystem might be reflected in the final service of another ecosystem, and wetlands, positioned typically between terrestrial and aquatic systems are one of the better examples of this. The landscape position of wetlands and their unique characteristics result in many intermediate goods and services effecting final goods services downstream.

Ecosystem Markets and Final Goods and Services

Participants discussed the relationship between ecosystem markets and final goods and services. Some wondered why the market price of a good traded in an ecosystem market does not directly reflect its value to human well-being and whether an ecosystem good or service traded on an ecosystem market should qualify as a final good or service. Social scientists pointed out that ecosystem markets are constructed markets with scarcity created by regulations presumably set to provide some level of a final ecosystem service. For example, the US Congress set a limit on emissions of sulfur from specified sources (Title IV of the Clean Air Act Amendments of 1990). The law established a system of markets so that the identified emitters of sulfur could reduce their own emissions of sulfur or pay for others to reduce their emissions. While one would expect that the cost of emissions reductions should be less than the benefits (as it is, see (Chestnut and Mills 2005)), the cost of purchasing an allowance to emit a ton of sulfur is related to the scarcity of sulfur emissions created by the Clean Air Act rather than by the marginal benefits to human well-being. The final goods and services in this example are the changes in human health and ecosystems including those listed by Chestnut and Mills (2005) but also additional biophysical goods and services noted in NAPAP (National Acid Precipitation Assessment Program 1992) and not the mass of sulfur traded in the market.

Interpretation

A concern that was voiced in the workshop was over the fact that so many final ecosystem services are extractable goods (i.e., water, timber, organisms, etc.) and are associated with activities that could be construed to compromise the integrity of the ecosystem – especially if they are conducted at unsustainable rates. This potential would be addressed when tradeoffs among final ecosystem services are identified and evaluated in scenarios evaluated by production functions. For example, mineral extraction may have negative impacts on recreation. Such tradeoffs would have to be explicitly modeled so that decision-makers and categories of beneficiaries can make the wisest choices of which combinations of final ecosystem services to utilize in a location.

It is important to note that analyses where incremental differences in well-being occurring over long periods of time need to account for the timing of impacts in two ways. First, in terms of the discounting of future costs and benefits and second, the recognition that future generations may have different weights in the manner in which they link biophysical features to human well-being than the current generation (Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems 2004).

Form of the Metrics

We have metrics of three different forms –

1. General statements of the information a measurement needs to provide. Examples are:

    - Presence of chemicals in concentrations detrimental to the user in the wetland during the time of activity
    - Structure and density of vegetation in the wetland that could inhibit the activity
    - Presence of pathogens & parasites in the wetland during the growing season that are hazardous to crops or to consumers

- Water surface state that could interfere with operations for an extended period of time at all points
- Presence of dangerous substrates
- Concentration of harmful algal toxins
- Presence and abundance of fouling organism
- Quality of view including landscape attributes (e.g., shoreline naturalness, amount of open water, visual access (i.e., nothing blocking view from site))

2. Specific statements of the information a measurement needs to provide. Examples are:

   - Substrate types in the wetland that could inhibit operations

3. Specific measurements. Examples are:

   - Direct Tissue analysis of Domoic Acid or other Algal or phyto toxins with ELISA or molecular targets
   - In situ and ex situ: Maximum, minimum salinity at all points and times
   - Daily average Secchi disk depth at all times and all points

Ideally, one would want to have both a measurement (with units and temporal and spatial characteristics of the measure) and a rationale (why an attribute is of interest to a category of beneficiary) for any given cell. We suggest that linkages between specific rationales and measurements need to be considered in the further development of the final goods and services idea and in the quantitative evaluation of the working hypotheses embodied in these sets of metrics as listed in Tabs 4 and 7 of Attachment 4.

Comparison of the Lists for Wetlands and Estuaries

We did not take time during the course of the workshop to compare the rows and columns of the matrix, and we have taken little time afterwards to reconcile differences in the two matrices. Inspection suggests two reasons for the differences – 1) real differences between the ecosystems and 2) minor reconcilable differences in the perspectives of people in the two portions of the workshop. An example of the real differences is driven by the boundary assumption used by the estuaries group. Since estuaries were defined as containing only saline waters, categories of beneficiaries of fresh waters (e.g. irrigation and subsistence consumption of water) would only occur in wetlands containing freshwater. Two examples illustrate the reconcilable differences. The estuaries group added pH and nutrients as specific attributes of water quality important to some categories of estuarine beneficiaries. The wetlands group made no similar change, but inspection of the metrics listed by the wetlands group does not exclude either pH or nutrients. The wetlands group added ice skaters as a category of beneficiary of wetlands. The estuaries group did not add a similar beneficiary category.

Research Needs

The working hypothesis in its entirety, from conceptualization through the designation of the rows (i.e. the beneficiary categories) and columns (i.e. the ecosystem attributes) to the specific entries, call for common-sense[5], theoretical and empirical evaluation. Four areas though were particularly challenging for workshop participants and deserve focused attention:

1. Metrics for non-use beneficiary categories – although we have listed metrics for non-use categories as "Magnitude of deviation from reference conditions for the site" for each attribute workshop participants noted considerable uncertainty about this entry. Should it apply to all attributes or just some? What are the applicable "reference

[5] For example, the while the wetlands tables exclude grazing as a beneficiary category, grazing is a common practice in US wetlands -- http://www.fws.gov/rainwater/Management/Grazing.htm (Wyman et al. 2006)

conditions"?. Is this the right form of the metric that contributes to value for non-use categories or should it be something entirely different?

2. Sensory experience metrics – the estuaries and wetlands groups both acknowledged that metrics of sensory experience are part of what creates well-being for many categories of beneficiaries. The estuaries group listed specific metrics, but of very general form. The wetlands group did not list any metrics, but rather noted that research is needed. Given the abundance of research demonstrating the importance of the sensory experience for some categories of beneficiaries, there is a real need for original and synthetic research in this area.
3. Temporal and spatial dimensions – What are the temporal and spatial dimensions of the biophysical units that create value for people? The answer to this question is important for designing modeling, mapping and monitoring programs. However, the results of the workshop did not address this issue in a meaningful way.
4. We identified metrics of final ecosystem goods and services. A combination of these metrics in a manner that has fidelity to the way the metrics contribute to human well-being is an important research need. Since some metrics may have thresholds or may play a more or less important role in contributing to human well-being this analysis can influence the way in which we design monitoring and modeling programs. In addition, it is important to recognize that for some beneficiaries, their understanding of the way in which their well-being is affected by individual metrics in sufficient so that creating single indicators from multiple metrics may obscure ecosystem value more than it reveals it.

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TABLES

Table 1. Principles used in identifying Final Ecosystem Goods and Services

1.	Final ecosystem goods and services are biophysical features, quantities, or qualities that require little further translation to make clear their relevance to human well-being.
2.	Comprehensive identification of final ecosystem service indicators requires the identification of the full set of human beneficiary categories of ecosystem goods and services
3.	To identify final ecosystem goods and services and indicators for a particular ecosystem, the boundaries for that ecosystem must be clearly defined.
4.	Final ecosystem goods and services are provided directly by the ecosystem itself and do not reflect human features (e.g., roads, buildings, stocked flora or fauna, etc.).
5.	Regulators are not a beneficiary category. While regulations often focus on intermediate goods and services, their justification is based on the benefits associated with final ecosystem goods and services.
6.	While a list of metrics that represent a final ecosystem service must be exhaustive, it must also provide for practical parsimony by focusing on metrics that have a substantive link to human well-being.
7.	If a candidate metric of a final service is uniform in space (or time) would a beneficiary pay for (or benefit from) different levels of a second metric? If the answer is yes, then the second metric is part of the measure of the final ecosystem service.

Appendix 1: List of Workshop Attendees

Workshop on Indicators of Final Ecosystem Services for Wetlands and Estuaries
June 7 to 10, 2010

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Appendix 2: Workshop Agenda

Pre-Workshop Webinars: [See Appendix 3]

May 17 Final Services Concept and Principles -- Boyd
May 19 Application of the Principles – An Example from Streams – Ringold

Workshop on Indicators of Final Ecosystem Services for Estuaries and Wetlands
June 7 to 10, 2010

Embassy Suites Denver - Aurora Hotel
4444 N Havana Street
Denver, Colorado 80239 USA
Phone: 1-303-375-0400
Meeting Rooms are on the Main level

Workshop Goals:

1) Promote the capacity for natural and social scientists to communicate about the relationships between ecosystems and human well-being.
2) Contribute to the development of a community with an understanding of "final ecosystem services".
3) Develop an understanding of how the "final services" concept can be effectively applied in decision making.

Workshop Objectives:

1) Develop a working hypothesis of indicators of final ecosystem services for estuaries and wetlands.
2) Summarize process and principles useful for identifying final ecosystem services.
3) Identify gaps between this working hypothesis and the current capacity of monitoring and modeling to report on these indicators for the nation.

[This is the initial schedule. It will be subject to refinement and revision to meet workshop objectives as the meeting progresses.]

Monday June 7

4:30 PM Registration starts
5 PM to 6 PM – Informal Reception and Registration [Aragon/Toledo Room]

Dinner [On your own]

Tuesday June 8

Breakfast (Provided) [Hotel's regular Complimentary Cooked-to-Order Breakfast opening at 6 am Tables will be set aside for our use]
8:00 AM Welcome and Introductions: Bernard [Aragon Room]

CSG Role and Procedures – Parks
Interests in Ecosystem Monitoring and Ecosystem Services – Each Participant

8:30 AM Why are we here
Natural Science Perspective: Ringold (15 minutes) *[Appendix 4 Pages 1 to 5]*
The Social Science Version: Boyd (15 minutes) *[Appendix 3 Pages 6 to 8]*
Econ 101 – Boyd

9:30 to 10:00 AM Questions and Discussion

10:00 to 10:15 AM Break

10:15 AM Recap of Webinars
Final Services Concept and Principles – Boyd *[Appendix 4 Pages 9 to 14]*
Application of the Principles – Stream Example, Workshop Task for Wetlands and Estuaries – Nahlik/Ringold *[Appendix 4 Pages 15 to 19]*

11:00 to 12:30 Questions and Discussion

12:30 to 1:30 PM Lunch [Buffet Lunch Provided]

1:30 to 3:45 PM Split into two groups – Estuaries and Wetlands: Review the checkmark matrix prepared for each ecosystem [Aragon and Toledo Rooms]

Try examples
Should ecosystem attributes be added or deleted?
Should user categories be added or deleted?
Do the principles work?

3:45 to 4:00 PM Break

4:00 to 5:00 PM Two Group Discussions – Continue [Aragon and Toledo Rooms available]

5:00 to 6:00 PM Plenary – Identify and Address Issues Raised Facilitator -- Bernard [Aragon Room]

6:00 PM Adjourn for Dinner [On Your Own]

Wednesday, June 9

8:00 AM Breakfast Provided [Hotel's regular Complimentary Cooked-to-Order Breakfast opening at 6 am Tables will be set aside for our use]

8:30 AM Plenary [Aragon Room]

8:30 to 9:00 AM What went bump in the night -- Bernard

9:30 AM to Noon Ecosystem Breakouts continue to develop detailed matrices [Aragon and Toledo Rooms]

Noon Buffet Lunch [Provided]

1:00 – 2:00 PM Progress Reports from breakout groups on issues of principles and matrix structure. [Aragon Room]

2:00 to 3:45 PM Reconvene breakout groups [Aragon and Toledo Rooms available]

3:45 to 4:00 PM Break

4:00 to 5:30 PM Report from breakout groups [Aragon Room]

Identification of Final Service Indicators
....
5:30 PM Adjourn for Dinner [On Your Own]

Thursday, June 10

8:00 AM Continental Breakfast [Hotel's regular Complimentary Cooked-to-Order Breakfast opening at 6 am Tables will be set aside for our use]

8:30 – 11:30 AM Plenary – Bernard [Aragon Room]

Issues raised by consideration of Final Services Concepts [Note: This is a sponsor's list and short presentations can, in some instances be prepared to promote discussion. However, the facilitators and organizers may decide that it would be useful to have these discussions during the breakout sessions on Tuesday or Wednesday or during the plenary sessions on those days. In addition, we may, as a group decide it would be useful to address other similar topics. We may also decide to address these issues in breakout groups and then return to meet as a group.]

Government Employees: How could your organization use these indicators? What are the implications of your needs for the certainty, and temporal and spatial attributes of monitoring or modeling design?

If we could make a marginal investment in monitoring what principles would we use to allocate those resources so as to maximize our capacity to improve the linkage to human well-being? What principles could we use to identify the highest priority elements of the matrix. How can we bring parsimony to our results? How can we simplify these results?
Natural Science Implications

Gap Analysis

Streams – Ringold

Initial gap analysis for estuaries and wetlands

Intermediate Services - ?
Spatial and Temporal Interpolation - ??
Production Function Models--- ???

Social Science Implications

How do we falsify the working hypotheses? – xxx
How do we translate the measures associated with a user (i.e. a row of the matrix) to human well-being? – xxx
How do we aggregate information? - xxx

Joint Implications Discussion

Translatable principles?
Translatable process?
Stacking?

Case Study Tests – break into two to four groups. Select a policy question for a wetland or estuarine ecosystem. Are the final indicators useful?

Structure of the workshop report.

11:30 AM Workshop Adjourns

Final Ecosystem Services: Translating Concepts to Practice

Paul Ringold, Dixon Landers, Matt Weber, Amanda Nahlik, Ted DeWitt

US EPA, ORD

Jim Boyd

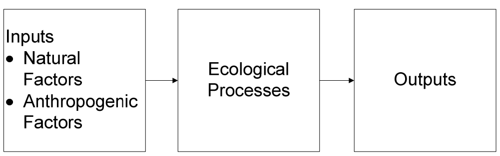
Resources for the Future

Today's Webinar

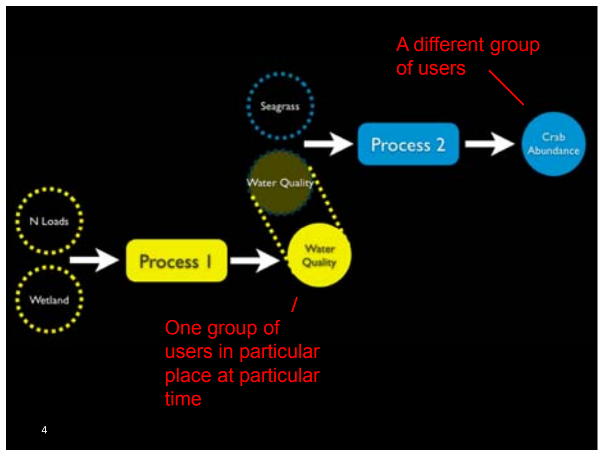
- Some repetition
- Goals
- Approach to identifying indicators of final services – the stream model
- Is this parsimonious?
- A gap analysis conclusion
- Wetlands and estuaries

2

Production Functions



3



Why Connect Ecosystems to Human Wellbeing?

- Science made more powerful
  - Link to assessments of human well being
    - Regulatory analysis, ecosystem management, bundling services, resource allocation…..
  - Additional rationale for other indicators
    - Understanding, Prediction and Management
  - Communication

Policy relevant ecology

5

" Final Services" promotes effective communication

- Language users understand in their terms
- Value things understood – outcomes not inputs or processes
  - Nutrient cycling → fish abundance
  - Rotifer productivity → polar bears
  - Hormone balance → mood
- Value
  - $
  - Willingness to take action (Jackson Kurtz and Fisher, 2000)

6

1	4
2	5
3	6

Slide Number

Why should we control acidic deposition?

- Soil buffering capacity?
- Lake Chemistry?
- Fish?

7

Why should we control acidic deposition?

- Soil buffering capacity?
- Lake Chemistry?
- Fish?

Needed for temporally explicit production functions

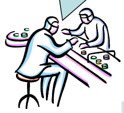
1)Needed for production functions
2) Practical predictor of final service

1) Final service
2) CAA Value of $65 million per year (Chestnut and Mills, 2005)

8

Management Relevance

We want to study soil buffering capacity



We want to predict how fish in lakes respond to changes in sulfur emissions

I have funds for new research

9

Denver Workshop Goals

1. Identify indicators of final goods & services for wetlands and estuaries
2. Compare to current capabilities
3. Establish a shared foundation/language /goals across natural and social science
4. Identify specific next steps

10

Approach to Identifying Indicators of Final Services

The Stream Model

Ecological Endpoints = Final Services Indicators

- What biophysical features, quantities and qualities require little further translation to make clear their relevance to human well-being?
- How do we identify these?
  - Complete set
  - Avoid double counting

See Boyd and Banzhaf 2007 and Boyd 2007

Three Key Steps

1. Clearly define ecosystem boundary
   – Measurements
   – Flows from one ecosystem to another
2. Identify categories of users
   – Regulators are not users
3. Identify broad attributes relevant to each user category
   – Then specific measures
   – Specify time and space

Working Hypothesis Requires Evaluation

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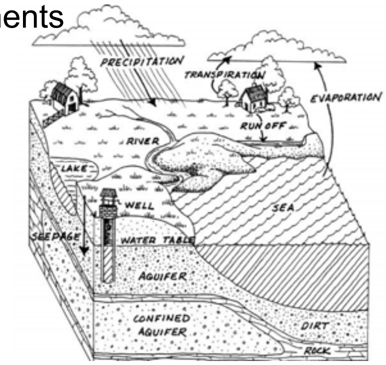
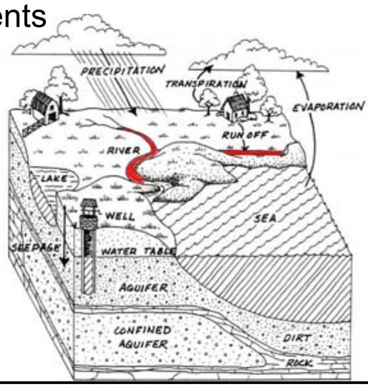
1. Ecosystem Boundaries: Measurements



1. Ecosystem Boundaries: Measurements

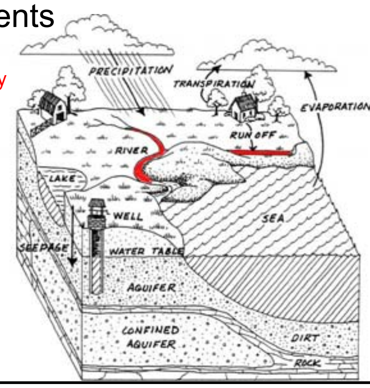
Stream Channel Only



1. Ecosystem Boundaries: Measurements

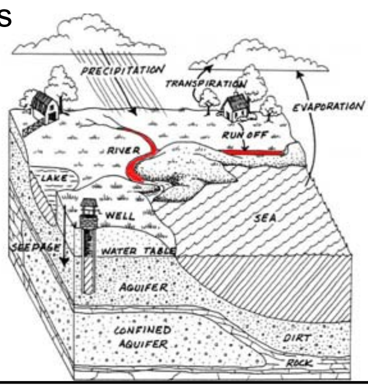
Stream Channel Only

Ensure full system of measures



1. Ecosystem Boundaries: Connections

Production function models need to connect ecosystems



2. Categories of "Users"

- Agriculture (and 5 subcategories)
- Industry (8)
- Commercial Transportation (2)
- Municipal and Residential (3)
- Recreational (4)
- Traditions (2)
- Subsistence (4)
- Non-Use (2)
- Academic (2)

Note: This categorization matches what will be proposed for wetlands and estuaries, but differs from that included in the stream workshop report.

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1	4
2	5
3	6

Slide Number

2. Regulators are not Users

- Regulations
  - Exist to manage a service valued by a user group
  - Typically focus on intermediate services
    - Dissolved oxygen
    - Toxics
    - Nutrient loads
    - Carbon
    - Temperature

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3. Attributes Relevant to Stream Users: Four Examples

Irrigator

Angler

Non-Use

WWTP

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3. Attributes relevant to Stream Users: Simple Example

	Amount of Water	Biology	Chemistry
Irrigator	X		X
Angler		X	
Non-Use		X	
WWTP	X		

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3. Attributes relevant to Stream Users: Simple Example

	Amount of Water	Biology	Ch...try
Irrigator	X		
Angler			
Non...			
WW...	X		

See Table 1 in the Stream Workshop Report
http://www.epa.gov/nheerl/arm/streameco/index.html
PDF Page 22
The "Checkmark matrix"

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3. Specific Measures: Irrigator

	Amount of Water	Chemistry
Irrigator	1) Daily average flow of water and the daily standard deviation at all points for each day during irrigation season 2) Flood during periods when it would interfere with operations at all points	Maximum and average daily conductivity at all points and times during irrigation season

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3. Specific Measures: Irrigator

	Amount of Water	Chemistry
Irrigator	1) Daily average flow of water and the daily standard deviation at all points for each day during irrigation season 2) Flood during periods when it would interfere with operations at all points	Maximum and average daily conductivity at all points and times during irrigation season

Biophysical measure

Time and space

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3. Specific Measures: Irrigator

	Amount of Water	Chemistry
Irrigator	1) Daily average flow of water and the daily standard deviation at all points for each day during irrigation season 2) Flood during periods when it would interfere with operations at all points	Maximum and average daily conductivity at all points and times during irrigation season

Flood on site, not flood protection in general

25

3. Specific measures: Non-Use

	Biology
Non-Use	1) Deviation from Expected, Desired or Undisturbed Condition in Organism Assemblages; 2) Presence of Charismatic Organisms

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3. Specific measures: Non-Use

Time and Space?

	Biology
Non-Use	1) Deviation from Expected, Desired or Undisturbed Condition in Organism Assemblages; 2) Presence of Charismatic Organisms

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3. Specific Measures: Angler

	Biology
Angler	Presence, abundance, condition, size and gender of recreationally relevant native or naturalized fish taxa at each point at all times

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3. Then Specific Measures: Angler

	Biology
Angler	Presence, abundance, condition, size and gender of recreationally relevant native or naturalized fish taxa at each point at all times

Excluding stocked fish

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3. Specific Measures: WWTP

	Amount of Water
WWTP	Flood that would interfere with operations at any time at all points

30

1	4
2	5
3	6

Slide Number

Broad List of Ecosystem Attributes

Site Characteristics
- Amount of Water
- Substrate
- Hydrologic State

Water Quality
- Temperature
- Clarity
- Dissolved Oxygen
- Conductivity
- Salinity
- Chemicals

Biology
- Pathogens and Parasites
- Invertebrates
- Fish
- Wildlife
- Vegetation
- Genetic Diversity

Sensory Experience
- Visual
- Odor
- Sound
- Tactile
- Taste

Note: These attributes derived from deliberations at the streams workshop, but continued as similar efforts were undertaken for estuaries and wetlands. Thus this list matches what will be proposed for wetlands and estuaries, but differs from that included in the stream workshop report.

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Detailed Matrix of Specific Measures

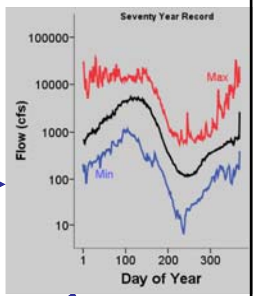
http://www.epa.gov/nheerl/arm/streameco/index.html

Look at tables under "Indicator Working Hypothesis"

Also to be handed out at workshop

32

One sampling protocol → multiple metrics



Water Quantity Metric 1
Water Quantity Metric 2
Water Quantity Metric 3
.....

33

One sampling protocol → multiple metrics

Vertebrate Metric 1
Vertebrate Metric 2
Vertebrate Metric 3
.....

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Existing Vertebrate Analysis Protocol

EMAP West -- 237 Vertebrate Metrics in 9 Categories
- Habitat
- Tolerance
- Trophic Groups
- Reproductive
- Composition
- Richness
- Life History
- Alien Species
- Abundance

EMAP W -- http://www.epa.gov/emap/west/html/docs/wstream.html or http://www.epa.gov/emap/west/html/docs/wstriv.html

35

Little Added Cost for Additional Metrics

EMAP West -- 237 Vertebrate Metrics in 9 Categories
- Habitat
- Tolerance
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- Reproductive
- Composition
- Richness
- Life History
- Alien Species
- Abundance
- Recreational Interest
- Size of Recreational Fish

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1	4
2	5
3	6

Slide Number

Gap Analysis Conclusion

- Gaps in time and space are universally significant
  - Fish in August → Fish in December?
  - Pathogen sample here → pathogen status there?
- Cannot monitor all places at all times.
- Models?

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Wetlands and Estuaries

Amanda Nahlik
Dixon Landers
Mary Kentula
Matt Weber
Paul Ringold
Steve Ferraro
Ted DeWitt
Walt Nelson

US EPA Western Ecology Division, Corvallis and Newport, OR

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Questions

- What set of ecosystem boundaries should we use?
- Does the list of user groups for streams make sense for wetlands? …for estuaries?
- Does the list of ecosystem attributes make sense for wetlands? …for estuaries
- How do the lists compare across ecosystem types?
- What does the checkmark matrix look like for wetlands? ….for estuaries?

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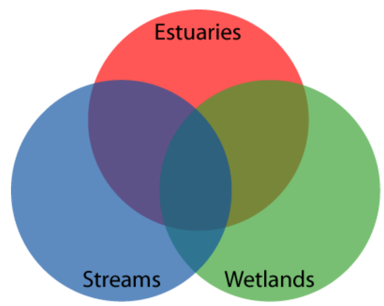
Ecosystem Boundaries



40

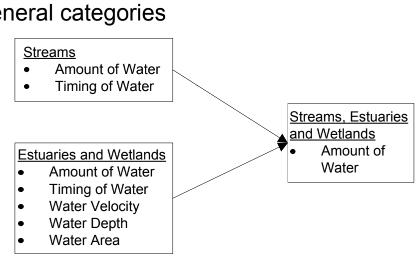
User Groups?

- Fresh thinking led to reorganization and additional categories

41

Ecosystem Attributes?

- Fresh thinking led to reorganization and more general categories



42

Conclusions from Comparing Lists

- Revised user list works for all three ecosystem categories
  - Some users not present in some ecosystems, e.g. estuaries are not a source of subsistence drinking water
- Revised attribute list works for all three

43

Checkmark Matrices for Estuaries and Wetlands

See Spreadsheets

Handout at Workshop

44

Workshop Tasks

1. Review and revise
   - Ecosystem boundaries
   - Does the list of user groups make sense for wetlands? …for estuaries?
   - Does the list of ecosystem attributes make sense for wetlands? …for estuaries
   - How do the lists compare across ecosystem types?
   - What does the checkmark matrix look like for wetlands? ….for estuaries?
2. Create working hypotheses
   - **What does the detailed matrix look like for wetlands? ….for estuaries?**

45

Denver Workshop Goals

1. Identify indicators of final goods & services for wetlands and estuaries
2. Compare to current capabilities
3. Establish a shared foundation/language /goals across natural and social science
4. Identify specific next steps

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Ecosystem Boundaries: Estuaries

tidal habitats and adjacent tidal wetlands and waters that are at least occasionally diluted by freshwater runoff from the land resulting in salinities < 30 PSU for part or all of the year. Salinity may be periodically increased above that of the ocean by evaporation. extends landward and upstream to the point where ocean derived salts measure less than 0.5 parts per thousand during the period of average annual low flow. extend seaward to an imaginary line closing the mouth of a river, lagoon, fjord, or embayment. (NOAA, 2009).

47

Ecosystem Boundary: Wetlands

The wetland ecosystem boundary is clearly defined as "all wetlands, including tidal and nontidal wetted areas, with rooted vegetation and/or shallow open water < 1m in depth and not currently in crop production. Wetland types (as classified by Cowardin) include estuarine intertidal emergent, estuarine shrub/forested, palustrine emergent, palustrine scrub/shrub, palustrine forested, palustrine unconsolidated bottom and aquatic bed, and palustrine farmed.

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Biophysical Goods and Services that Contribute Directly to Human Wellbeing

Jim Boyd
Resources for the Future
Paul Ringold, Dixon Landers, Matt Weber, EPA ORD

Motivations

- We want ecology to matter more
  - To policy and decisions
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  - Outside the science community
- We want to link ecology and economics
  - From the ground up, not after the fact
- We seek reasonable simplifications
  - Bring focus to a subject of huge complexity

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How We See This Agenda

- We are not recreating/redefining ecology
- Nothing at all wrong with "the science"
  - "...in addition to, not instead of..."
- Ecology "punches below its weight"
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Our Optimism

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  - In the literature
  - In public policy discussions
  - As a bridge between policy, ecology, and economics
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4

Congratulations!

Your paper has been cited in:

Payments for Ecosystem Services as Commodity Fetishism

Kosoy, N., Corbera, E.

Ecological Economics

volume 69, issue 6, year 2010, pp. 1228 1236

5

What Are Ecosystem Services?

- Surprising traction as a concept
- But what is the concept?
  - Nature matters to human wellbeing
  - We should be managing and protecting nature for both ecological and economic reasons
- Less traction as a practical concept

1	4
2	5
3	6

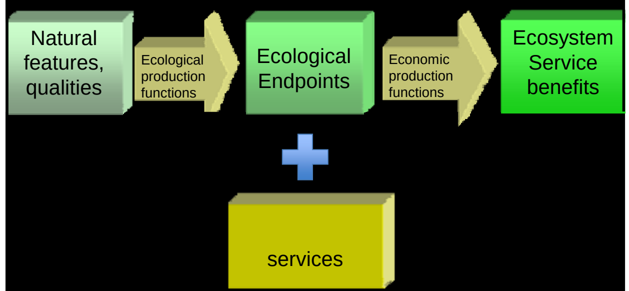
Slide Number

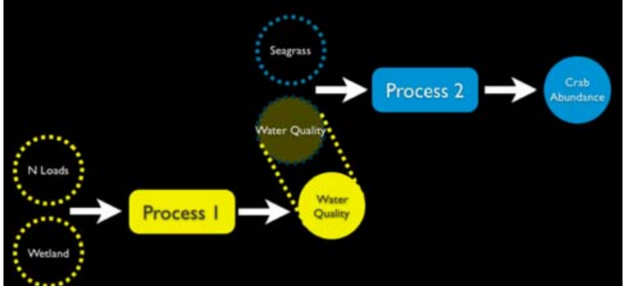
Big Picture

- Focus
  - Final ecosystem goods and services
  - What are they and why focus on them?
- But these are just one element of larger systems
  - Ecological
  - Economic
- They are the connective tissue

7

Translating Ecosystem Features into Ecosystem Service Benefits





9

Final Goods and Services

- Measurable biophysical
  - Features
  - Qualities
  - Expected changes
- The point of handoff between ecology and policy
- Reminder: "…in addition to, not instead of…"

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Why Connect Ecosystems to Human Wellbeing?

- Science made more powerful
  - Communication
  - Link to social assessment (ecosystem goods and services)

Policy-relevant ecology

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Abstract:

The U.S. Environmental Protection Agency (U.S.EPA) recently promulgated regulations to reduce air pollution from heavy-duty vehicles. This article reports the estimated health benefits of reductions in ambient particulate matter (PM) concentrations associated with those regulations based on the best available methods of benefits analysis. The results suggest that when heavy-duty vehicle emission reductions from the regulation are fully realized in 2030, they will result in substantial, broad scale reductions in ambient particulate matter. This will reduce the incidence of premature mortality by 8,300, chronic bronchitis by 5,500, and respiratory and cardiovascular hospital admissions by 7,500. In addition, over 175,000 asthma attacks and millions of respiratory symptoms will be avoided in 2030. The economic value of these health benefits is estimated at over $65 billion.

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Slide Number

Jargon Free Outcomes

"8300 fewer premature deaths"
"7500 fewer hospital admissions"
"175000 fewer asthma attacks

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Jargon Free Outcomes

"8300 fewer premature deaths"
"7500 fewer hospital admissions"
"175000 fewer asthma attacks

Calculating these effects – arising from policy choices – is the hard part

14

Our Manifesto

- The science of ecosystem services can' t be "handed off" to policy and economic experts at the 11th hour
  - Collaborative and iterative throughout (e.g. Ringold et al. 1996)
- Keep measuring what we already measure
  - Add to the suite of measures
- Economic analysis ≠ monetary valuation

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Ecological "Endpoints" = Final Good & Services Indicators

- What biophysical features, quantities and qualities require little further translation to make clear their relevance to human well being?
- How do we identify these?
  - Complete set
  - Avoid double counting

See Boyd and Banzhaf 2007 and Boyd 2007

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Ecological Endpoints or Final Ecosystem Goods & Services

- Remember the air health examples
  - Asthma attacks, hospital admissions, days lost from work, premature death
- What are the corresponding ecosystem service endpoints?
  - The next door neighbor test
    - Risk of waterborne disease
    - Probability and severity of flooding
    - Presence of charismatic fish, birds, or mammals
    - Appealing landscapes
    - Water availability
  - <u>No further scientific translation necessary</u>

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Desired Characteristics for Ecological Endpoints

- Biophysical measures, indicators that are…
  - Easy for non scientists to interpret
  - Directly or tangibly used by *users, enjoyers, caretakers*
    - Households
    - Recreators
    - Plant operators
    - Farmers

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Natural Science Indicators

- Biotic integrity measures
- Benthic disturbance
- Hydrogeomorphic wetland classification
- Habitat suitability rankings
- Tissue burdens (toxics)
- Dissolved oxygen, nitrate, phosphorus concentrations

19

Natural Science Indicators

- Biotic integrity measures
- Benthic disturbance
- Hydrogeomorphic wetland classification
- Habitat suitability rankings
- Tissue burdens (toxics)
- Dissolved oxygen, nitrate, phosphorus concentrations

Are these interpretable by non-scientists?

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Natural Science Indicators

- Biotic integrity measures
- Benthic disturbance
- Hydrogeomorphic wetland classification
- Habitat suitability rankings
- Tissue burdens (toxics)
- Dissolved oxygen, nitrate, phosphorus concentrations

Require translation into "plain English"

Science needs to do the translation

21

Thought Experiment

- How would you explain the social value of improved "surface water pH"?
  - Why does pH matter?
    - It signals water and habitat degradation
      - Why does water and habitat degradation matter?
        - » Changes in abundance of specific species

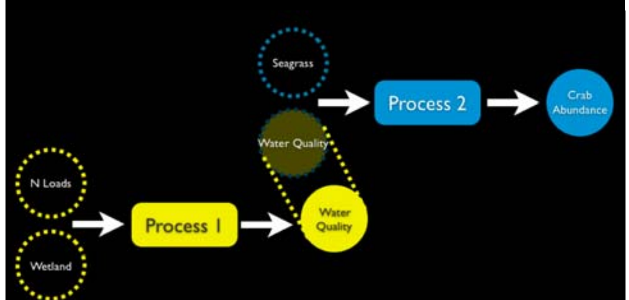
Your next door neighbor understands and cares about this

22

Production Theory

- Inputs
- Processes or functions
- Outputs
  - "Users perspective

23



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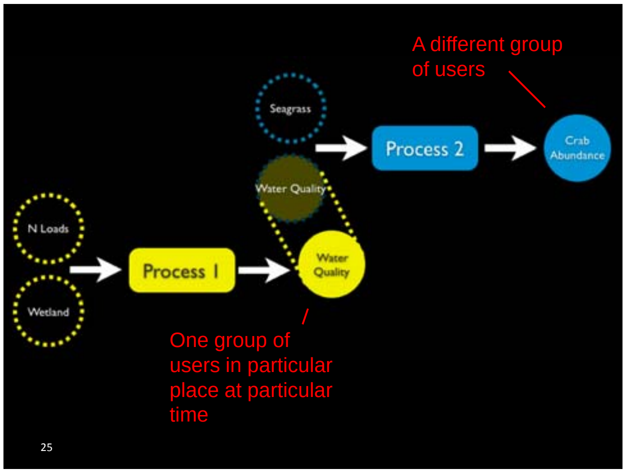

Examples

Input	Biophysical Process	Ecological Endpoint
Surface water pH	Habitat and toxicity effects	Presence of desired fish
Acres of habitat	Forage, reproduction, migration	Presence of natural bird assemblage
Wetland acres	Hydrologic processes	Probability of flooding
Urban forest acres	Shading and sequestration	Number of asthma attacks
Vegetated riparian border	Erosion processes	Presence of desired fish; Clear water

Indicators — Biophysical production functions — Endpoints

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Production Theory -- Endpoints

- Parsimony and order in natural science
  - Need to characterize final service indicators
  - Need to characterize other indicators to support characterization of these indicators
    - Understanding
    - Modeling
    - Management

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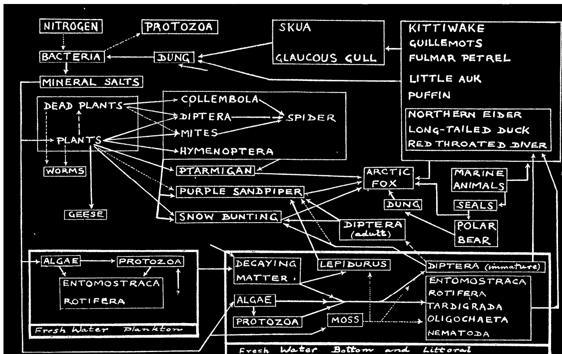

FIG. 2. Diagram of "Nitrogen Cycle" on Bear Island.
.... Probable, but no evidence from here.
----- Transformation.

Summerhayes and Elton 1923

28

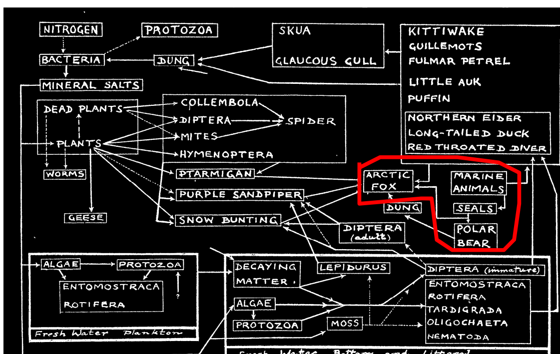

FIG. 2. Diagram of "Nitrogen Cycle" on Bear Island.
.... Probable, but no evidence from here.
----- Transformation.

Summerhayes and Elton 1923

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Are Only Final Goods Valuable?

- NO!
  - Everything in nature is valuable
  - Because everything is connected
- BUT!
  - The value of final goods embodies the value of the things it depends on

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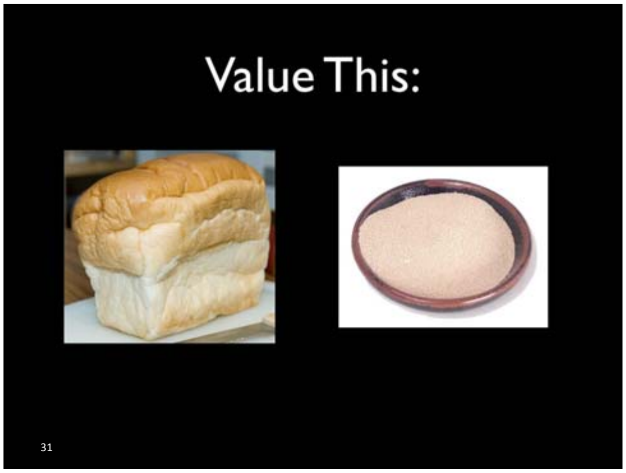
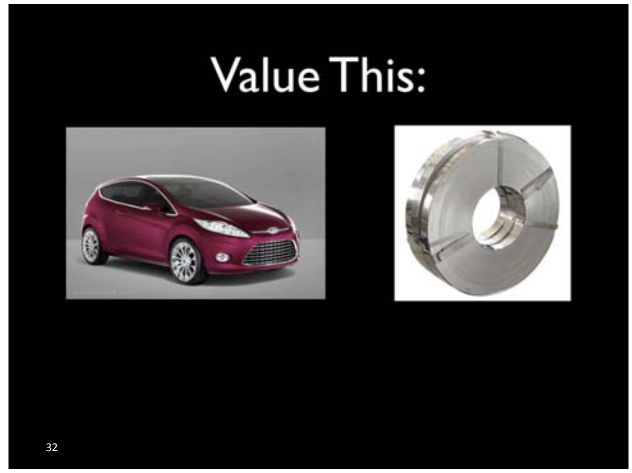

Value This:
31


Value This:
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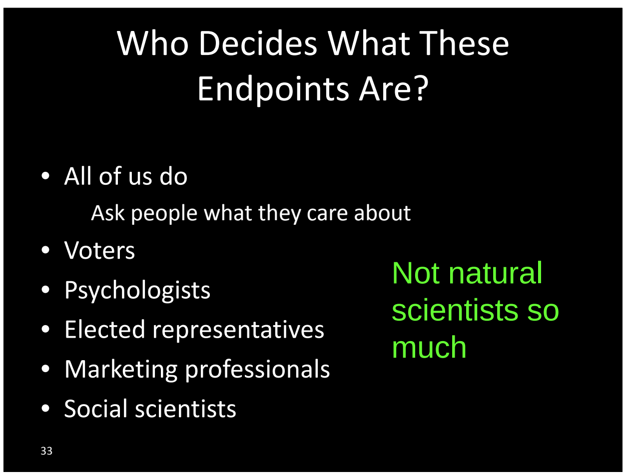

Who Decides What These Endpoints Are?
• All of us do
Ask people what they care about
• Voters
• Psychologists
• Elected representatives
• Marketing professionals
• Social scientists
Not natural scientists so much
33


Denver Workshop Goals
1. Identify indicators of final goods & services for wetlands and estuaries
Paul's Weds webinar streams
1. Compare to current capabilities
2. Establish a shared foundation/language/goals across natural and social science
3. Identify specific next steps
34

Why Are We Here?

Natural Science Perspective

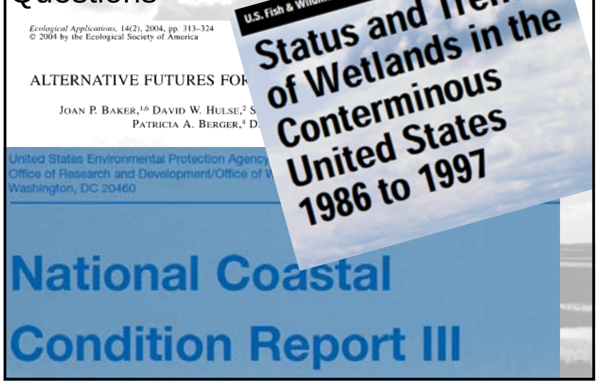
Sponsors Perspective

June, 2010
Paul L. Ringold
US EPA, ORD, NHEERL
Western Ecology Division, Corvallis, OR

Policy Questions

- What's the current status?
- Are things getting better or worse?
- What effect has our collection of policies had?
- What effect will this policy have in this place?

We Can Answer Those Questions

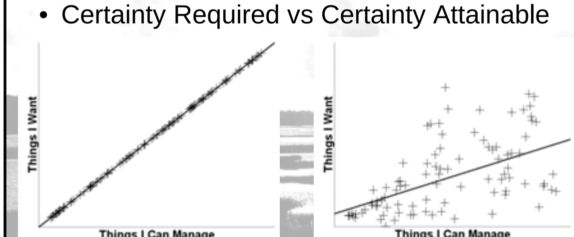


Answers Based On Measures of Ecological Status

- Water Quality Index
- Sediment Quality Index
- Benthic Index
- Habitat Index
- Fish Tissue Contaminant Index
- Landcover classes
- Wildlife abundance
- Stream habitat
- Fish IBI and richness
- Macroinvertebrate metrics
- Change in Habitat Area
- ……

Barriers to Answering Those Questions

- $$ and Time
- Reference Conditions
- Certainty Required vs Certainty Attainable



Barriers to Answering Those Questions - A Natural Science View

- $$ and Time
- Reference Conditions
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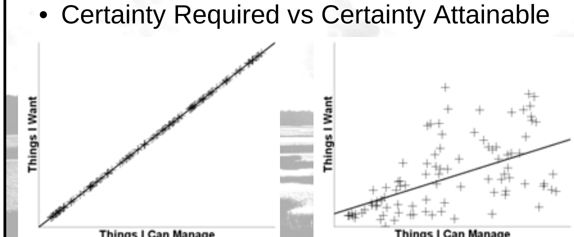

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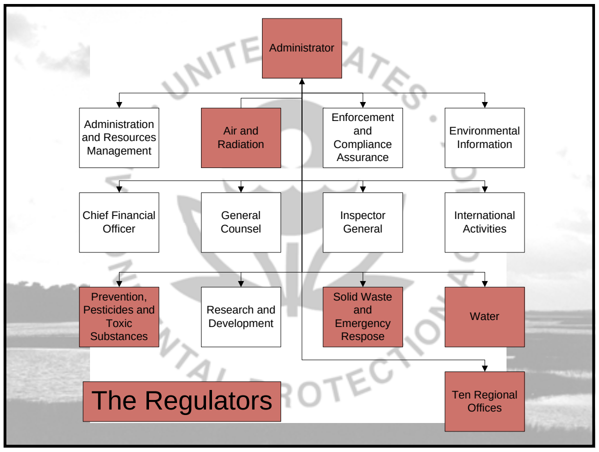
Slide Number

Why are we here?

To identify a set of indicators of wetland and estuarine ecosystems that enable reporting on the role these systems play in human well being.

Who wants to link Ecosystems to Human Well Being?

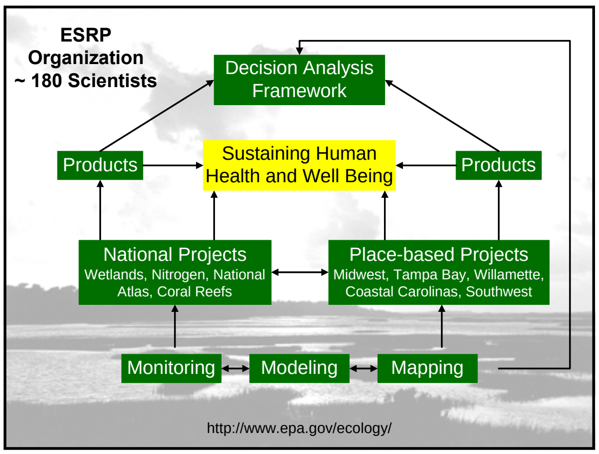
1. What effect will this policy have on human well being? → 1. Should we implement this policy?
2. What effect on human well has our collection of policies had? → 2. Do we need additional policies?
3. What effect on human well being will our policies have? → 3. Do we need additional policies?
4. Where are the biggest uncertainties and risks? → 4. How should I allocate management resources?



EPA Ecosystem Services Research Program

"A comprehensive theory and practice for quantifying ecosystem services so that their value and their relationship to human well-being, can be consistently incorporated into environmental decision making.

http://www.epa.gov/ecology/



8 ESRP Tenets

1. is human-centric and clearly shows the human use and well-being benefits of changes in ecosystem services.
2. proactively examines trade-offs or synergies for multiple services/benefits associated with any management / policy scenario / decision alternative.
3. uses a systems approach to help avoid the unintended consequences of optimizing for one ecosystem service or benefit thereby unknowingly affecting others
4. focuses on ecological production functions for final services, i.e., it considers ecosystem processes, functions, and indicators of intermediate ecosystem services (such as indices of biotic integrity, macroinvertebrate diversity, nitrogen flux rates, etc.), only to the extent that they are tied explicitly to final ecosystem services and benefits as part of ecological production functions.
5. is options-driven and informs management alternatives that are already under consideration or alternatives that emerge from ESRP scenarios developed in concert with decision makers and clients.
6. produces final results that explicitly show changes in ecosystem services associated with specific decision alternatives or scenarios.
7. provides incremental advances in research results, with the goal of producing early results that can be communicated to clients and useful for informing decisions.
8. seeks to understand how we can manage ecosystems to sustainably achieve both ecosystem protection and economic development.

1	4
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Slide Number

EPA Office of Water National Aquatic Resource Surveys

- Probability Surveys
  - Coastal, Streams, Lakes, Rivers, Wetlands

	First Cycle 2006	2007	2008	2009	2010	Second 2011 - 2015	Third 2016 - 2020
Coastal	Lab	Report	Research	Design	Field	→	→
Streams	Report	Research	Design	Field	Lab	→	→
Lakes	Design	Field	Lab	Report	Research	→	→
Rivers	Research	Design	Field	Lab	Report	→	→
Wetlands	Research	Research	Research	Research	Design	→	→

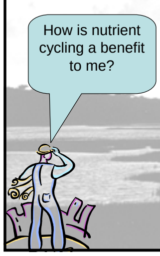
http://www.epa.gov/owow/monitoring/nationalsurveys.html

Millenium Ecosystem Assessment: Ecosystem Services

The benefits people obtain from ecosystems

Source: Millennium Ecosystem Assessment

Millenium Ecosystem Assessment

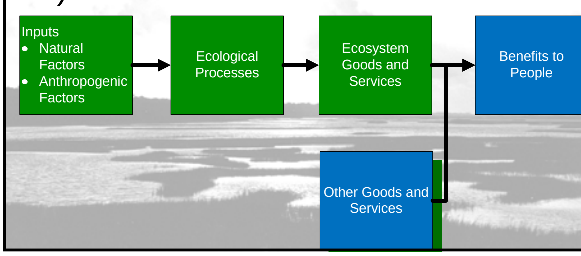


Evolution of a Definition

1) Millennium Ecosystem Assessment

"Ecosystem services are the benefits people obtain from ecosystems."

2) Another definition



What's our goal

Define a list of measurements that could be used in a national monitoring program that will support analysis of human well-being.

Or

"Tell me what to measure when I go to a site and what a site is."

Tony Olsen

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Slide Number

OR

"Tell me what to measure when I go to a site and what a site is."

Tony Olsen

AND

"The best is the enemy of the good"

Voltaire

Broader Goal

A list of indicators that could be used:

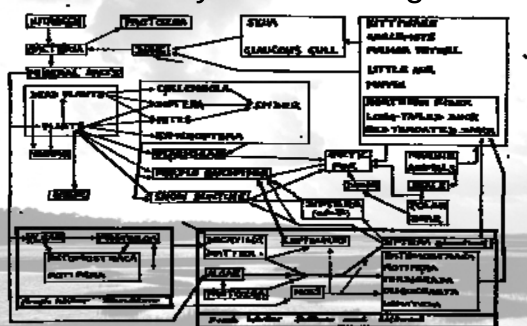
1. in national monitoring programs

Also

2. in developing local and regional monitoring programs
3. as the focus of stressor-response models
4. ….

and provide the foundation for social scientists to report on the roles wetlands and estuaries play in human well-being.

Parsimony is a challenge



Summerhayes and Elton 1923

Another Challenge

Human Well-Being

Social Sciences

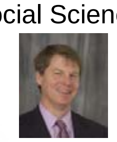
Wetland and Estuarine Ecology

Natural Sciences

Different Vocabularies, Cultures, Norms

Human Well-Being

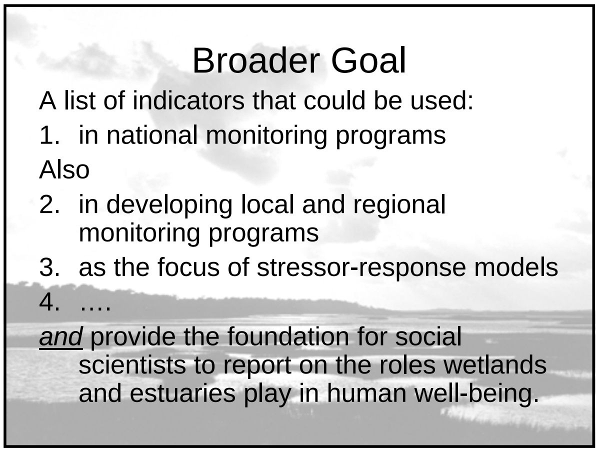
Social Sciences



Wetland and Estuarine Ecology

Natural Sciences

What ecological features do these people care about?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and provide the foundation for social scientists to report on the roles wetlands and estuaries play in human well-being.

Why Are We Here?
The Social Science Version

Jim Boyd

What We Want

- To measure changes in human wealth & wellbeing
- Arising from changes in nature

What We Want

- To measure changes in human wealth & wellbeing
- Arising from changes in nature

What We Believe

- Nature is a source of wealth
- Wealth should be managed and protected
- Choices must be made, tradeoffs faced
- Information and analysis helps

Core Questions

- What do people want from nature?
- What is the biophysical measure of what they want?
- Can we measure that in practice?

A Day In the Life

- Decision makers, policy makers ask us…
  - What is most important?
  - Which should we choose?
  - What is the monetary benefit of a new regulation?
  - What is the benefit of this wetland restoration program?

A Day In the Life

- Decision makers, policy makers ask us…
  - What is most important?
  - Which should we choose?
  - What is the monetary benefit of a new regulation?
  - What is the benefit of this wetland restoration program?
- We have ways to answer these questions
  - But all must be built on ecological foundations
  - What is nature's state and what is changing?

1	4
2	5
3	6

Slide Number

Problem

- We have a hard time connecting what we do…
- To what ecology
  - Measures
  - Thinks is important

Frustrations Being Addressed

- Problems with "inter disciplinary" work
  - Can we make progress on the linkages?
- Inconsistent biophysical measures (even within our own disciplines)
  - Can we converge on and articulate principles to guide choice of measures?

Audiences & Clients?

- Politicians, public administrators, planners (people who make policy, spend public money)
- Lawyers and judges
- Businesses that rely on natural resources
- Conservationists
- Resource managers
- Environmental accountants
- Anyone drawn to "ecosystem services"
- The good government crowd

Problem

- We have a hard time connecting what we do…
- To what ecology
  - Measures
  - Thinks is important
- It's not that we disagree or think we know better
  - We need to connect the two realms

(Again) Core Questions

- What do people want from nature?
- What is the biophysical measure of what they want?
- Can we measure that in practice?
- Can we relate natural science measures to the measure we want?

Goals of Meeting

- What do I measure at a site, and what is a site?
  - Conceptual underpinnings to link natural and social sciences
  - Hypotheses and examples of what to measure
- Want reactions to all of the above

1	4
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3	6

Slide Number

Post Meeting Proof of Concept

- Collaborations and coordination
- Convergence on language, principles, and measures
- Transfer of insights to other resource types?
- Pilots and practical deployment

Balances to Be Struck

- Complexity of problem vs.
  - Need for practical guidance
- The principles and measures we will advance to trigger discussion
  - Where we wind up

Biophysical Goods and Services that Contribute Directly to Human Wellbeing

Jim Boyd
Resources for the Future
Paul Ringold, Dixon Landers, Matt Weber, EPA ORD

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  - As a bridge between policy, ecology, and economics
- An evolving consensus that these ideas & language work
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Ecological Economics

volume 69, issue 6, year 2010, pp. 1228 1236

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What Are Ecosystem Services?

- Surprising traction as a concept
- But what is the concept?
  - Nature matters to human wellbeing
  - We should be managing and protecting nature for both ecological and economic reasons
- Less traction as a practical concept

1	4
2	5
3	6

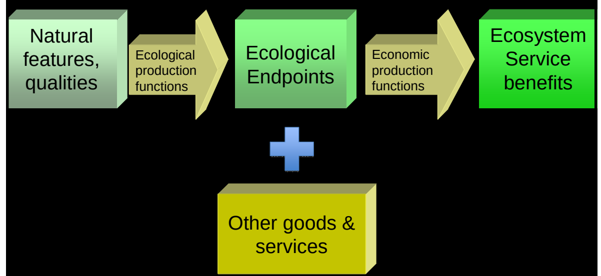
Slide Number

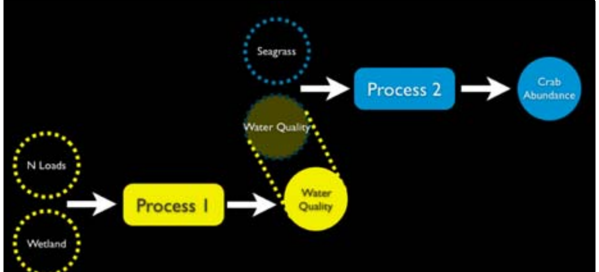
Big Picture

- Focus
  - Final ecosystem goods and services
  - What are they and why focus on them?
- But these are just one element of larger systems
  - Ecological
  - Economic
- They are the connective tissue

7

Translating Ecosystem Features into Ecosystem Service Benefits





9

Final Goods and Services

- Measurable biophysical
  - Features
  - Qualities
  - Expected changes
- The point of handoff between ecology and policy
- Reminder: "…in addition to, not instead of…"

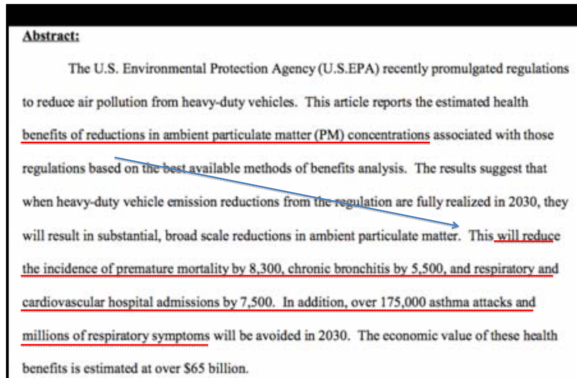
10

Why Connect Ecosystems to Human Wellbeing?

- Science made more powerful
  - Communication
  - Link to social assessment (ecosystem goods and services)

Policy-relevant ecology

11



Abstract:

The U.S. Environmental Protection Agency (U.S.EPA) recently promulgated regulations to reduce air pollution from heavy-duty vehicles. This article reports the estimated health benefits of reductions in ambient particulate matter (PM) concentrations associated with those regulations based on the best available methods of benefits analysis. The results suggest that when heavy-duty vehicle emission reductions from the regulation are fully realized in 2030, they will result in substantial, broad scale reductions in ambient particulate matter. This will reduce the incidence of premature mortality by 8,300, chronic bronchitis by 5,500, and respiratory and cardiovascular hospital admissions by 7,500. In addition, over 175,000 asthma attacks and millions of respiratory symptoms will be avoided in 2030. The economic value of these health benefits is estimated at over $65 billion.

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3	6

Slide Number

Jargon Free Outcomes

"8300 fewer premature deaths"
"7500 fewer hospital admissions"
"175000 fewer asthma attacks"

13

Jargon Free Outcomes

"8300 fewer premature deaths"
"7500 fewer hospital admissions"
"175000 fewer asthma attacks"

Calculating these effects – arising from policy choices – is the hard part

14

Our Manifesto

- The science of ecosystem services can' t be "handed off" to policy and economic experts at the 11th hour
  - Collaborative and iterative throughout (e.g. Ringold et al. 1996)
- Keep measuring what we already measure
  - Add to the suite of measures
- Economic analysis ≠ monetary valuation

15

Ecological "Endpoints" = Final Good & Services Indicators

- What biophysical features, quantities and qualities require little further translation to make clear their relevance to human well being?
- How do we identify these?
  - Complete set
  - Avoid double counting

See Boyd and Banzhaf 2007 and Boyd 2007

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Ecological Endpoints or Final Ecosystem Goods & Services

- Remember the air health examples
  - Asthma attacks, hospital admissions, days lost from work, premature death
- What are the corresponding ecosystem service endpoints?
  - The next door neighbor test
    - Risk of waterborne disease
    - Probability and severity of flooding
    - Presence of charismatic fish, birds, or mammals
    - Appealing landscapes
    - Water availability
  - No further scientific translation necessary

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Desired Characteristics for Ecological Endpoints

- Biophysical measures, indicators that are…
  - Easy for non scientists to interpret
  - Directly or tangibly used by *users, enjoyers, caretakers*
    - Households
    - Recreators
    - Plant operators
    - Farmers

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Slide Number

Natural Science Indicators

- Biotic integrity measures
- Benthic disturbance
- Hydrogeomorphic wetland classification
- Habitat suitability rankings
- Tissue burdens (toxics)
- Dissolved oxygen, nitrate, phosphorus concentrations

19

Natural Science Indicators

- Biotic integrity measures
- Benthic disturbance
- Hydrogeomorphic wetland classification
- Habitat suitability rankings
- Tissue burdens (toxics)
- Dissolved oxygen, nitrate, phosphorus concentrations

Are these interpretable by non-scientists?

20

Natural Science Indicators

- Biotic integrity measures
- Benthic disturbance
- Hydrogeomorphic wetland classification
- Habitat suitability rankings
- Tissue burdens (toxics)
- Dissolved oxygen, nitrate, phosphorus concentrations

Require translation into "plain English"

Science needs to do the translation

21

Thought Experiment

- How would you explain the social value of improved "surface water pH"?
  - Why does pH matter?
    - It signals water and habitat degradation
      - Why does water and habitat degradation matter?
        - » Changes in abundance of specific species

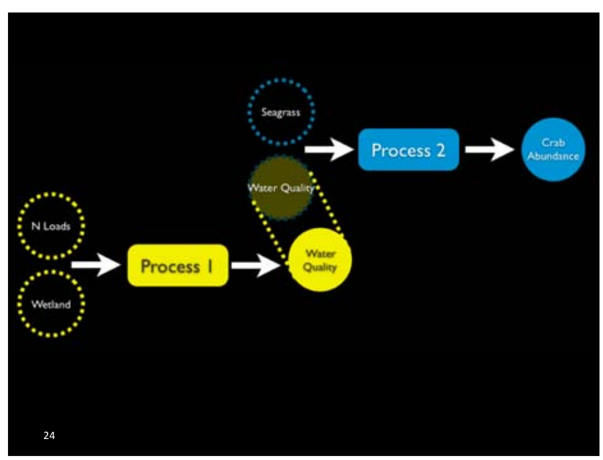
Your next door neighbor understands and cares about this

22

Production Theory

- Inputs
- Processes or functions
- Outputs
  - "Users'" perspective

23



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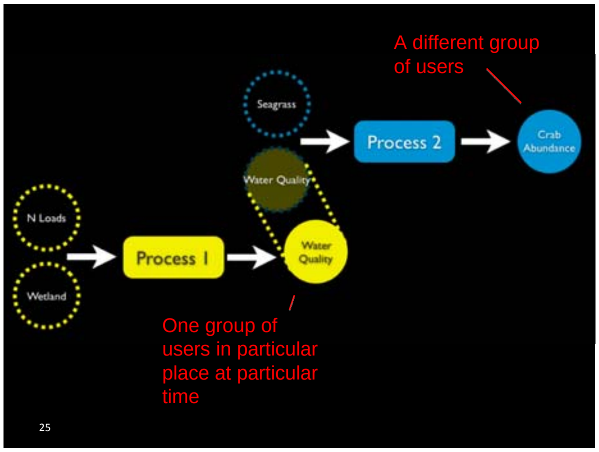

Examples

Input	Biophysical Process	Ecological Endpoint
Surface water pH	Habitat and toxicity effects	Presence of desired fish
Acres of habitat	Forage, reproduction, migration	Presence of natural bird assemblage
Wetland acres	Hydrologic processes	Probability of flooding
Urban forest acres	Shading and sequestration	Safe air quality
Vegetated riparian border	Erosion processes	Presence of desired fish; Clear water

Indicators — Biophysical production functions — Endpoints

26

Production Theory Endpoints

- Parsimony and order in natural science
  - Need to characterize final service indicators
  - Need to characterize other indicators to support characterization of these indicators
    - Understanding
    - Modeling
    - Management

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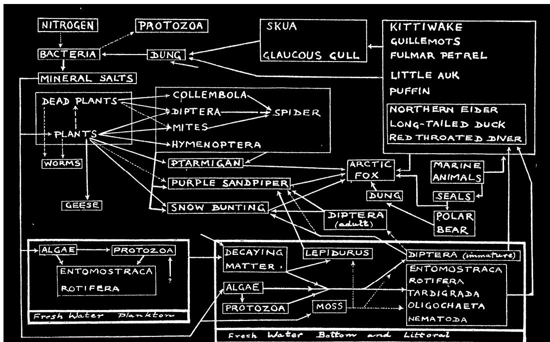

FIG. 2. Diagram of "Nitrogen Cycle" on Bear Island.
.... Probable, but no evidence from here.
------ Transformation.

28

Summerhayes and Elton 1923

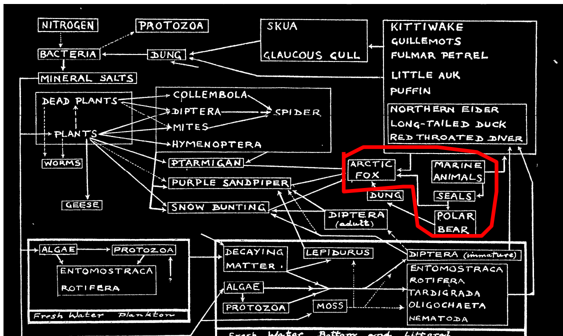

FIG. 2. Diagram of "Nitrogen Cycle" on Bear Island.
.... Probable, but no evidence from here.
------ Transformation.

29

Summerhayes and Elton 1923

Are Only Final Goods Valuable?

- NO!
  - Everything in nature is valuable
  - Because everything is connected
- BUT!
  - The value of final goods embodies the value of the things it depends on

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Slide Number

Value This:

31

Value This:

32

Who Decides What These Endpoints Are?

- All of us do
  - Ask people what they care about
- Voters
- Psychologists
- Elected representatives
- Marketing professionals
- Social scientists

Not natural scientists so much

33

Denver Workshop Goals

1. Identify indicators of final goods & services for wetlands and estuaries
   - Paul's Weds webinar – streams
2. Compare to current capabilities
3. Establish a shared foundation/language/goals across natural and social science
4. Identify specific next steps

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1	4
2	5
3	6

Slide Number

EPA Ecosystem Services Research Program

Final Ecosystem Services: Translating Concepts to Practice

A.M. Nahlik • P. Ringold • D. Landers • M. Weber • T. DeWitt • US EPA ORD
J. Boyd • Resources for the Future

1

EPA Ecosystem Services Research Program

Four Key Steps

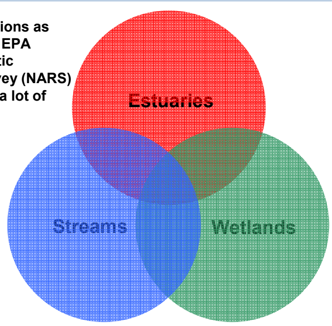
1. Clearly define the ecosystem boundary.
   - *Allows for identification of appropriate measurements.*
2. Identify categories of users.
   - *Regulators are not users.*
3. Identify broad ecosystem attributes relevant to each user category.
   - *Human-made infrastructure (e.g. roads), buildings (e.g. marinas), or other inputs (e.g. stocked fish) are not ecosystem attributes and therefore do not contribute to a Final Ecosystem Service.*
4. Identify specific measures over space and time that reflect or can be used to quantify ecosystem attributes.
   - *These are potential measures and require evaluation.*

2

EPA Ecosystem Services Research Program

Ecosystem Boundaries

Target populations as defined by the EPA National Aquatic Resource Survey (NARS) program have a lot of overlap.



3

EPA Ecosystem Services Research Program

Ecosystem Boundaries

- Stream definition:
  - *Perennial streams*
  - *Includes*
    - Wadeable streams and rivers
    - Non-wadeable streams and rivers
    - Great Rivers
  - *Boundary is set at bankfull*

4

EPA Ecosystem Services Research Program

Ecosystem Boundaries

- Wetland definition (NWCA 2010):
  - *All wetlands, including tidal and nontidal wetted areas*
  - *Rooted vegetation*
  - *Shallow open water < 1 m*
  - *Not in crop production*
  - *FWS Status & Trends classification*
    - Estuarine intertidal emergent
    - Estuarine shrub/forested
    - Palustrine emergent
    - Palustrine scrub/shrub
    - Palustrine forested
    - Palustrine unconsolidated bottom and aquatic bed

5

EPA Ecosystem Services Research Program

Ecosystem Boundaries

- Estuary definition (NOAA 2009):
  - *Tidal habitats and adjacent tidal wetlands*
  - *Diluted by freshwater runoff*
  - *Boundary determined by salinities < 30 PSU*
    - Extends landward and upstream to 0.5 ppt
    - Extends seaward to an imaginary line closing the mouth of a river, lagoon, fjord, or embayment

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1	4
2	5
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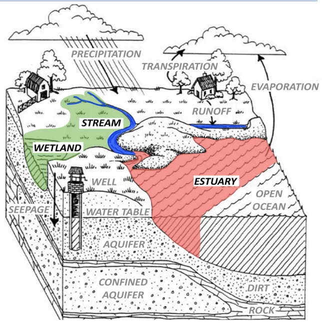
Slide Number

Ecosystem Services Research Program

Ecosystem Boundaries

- Need for defining boundaries
  - *Minimize overlap when defining measurements*
  - *Ensure full suite of measures*
- Production function models to are needed
  - *Connect ecosystems on the landscape*



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Ecosystem Services Research Program

User Categories

- Agriculture (5) ← **Number of Sub-categories**
- Industry (8)
- Commercial Transportation (2)
- Municipal & Residential (3)
- Recreational (4)
- Traditions (2)
- Subsistence (4)
- Non-Use (2)
- Academic (2)

Note: This categorization matches what will be proposed for wetlands and estuaries, but differs from that included in the stream workshop report.

8

Ecosystem Services Research Program

2. User Categories

<u>Regulators Are Not Users</u>

- Regulations exist to manage a service valued by a user group.
- Regulations are captured through users and attributes
  - *e.g. Endangered species protection is captured through recreational viewer user group x measure of presence of endangered species*

9

Ecosystem Services Research Program

Ecosystem Attributes

I. Site Characteristics
- *Amount of Water*
- *Substrate*
- *Hydrologic State*

II. Water Quality
- *Temperature*
- *Clarity*
- *Dissolved oxygen*
- *Conductivity/Salinity*
- *Chemicals*

III. Flora & Fauna
- *Pathogens & Parasites*
- *Invertebrates*
- *Fish*
- *Wildlife*
- *Vegetation*
- *Genetic Diversity*

IV. Sensory Experience
- *Visual*
- *Odor*
- *Sound*
- *Tactile*
- *Taste*

Note: This categorization matches what will be proposed for wetlands and estuaries, but differs from that included in the stream workshop report.

10

Ecosystem Services Research Program

Ecosystem Attributes & Specific Measures

Thought process for the matrix using examples from streams…

11

Ecosystem Services Research Program

Ecosystem Attributes & Specific Measures

Example: For a farmer irrigating edible crops…

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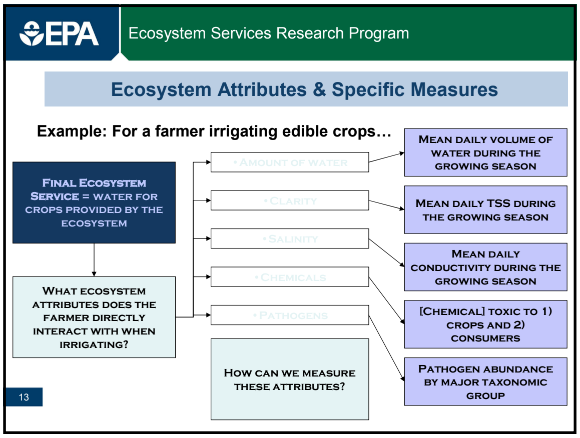
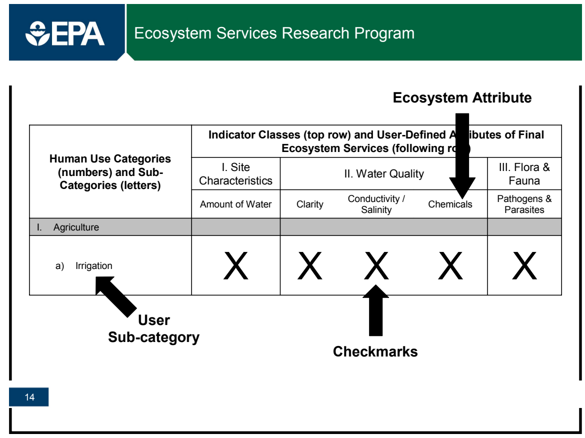
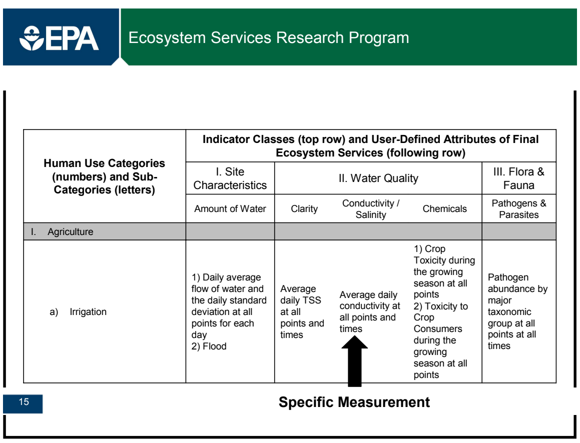
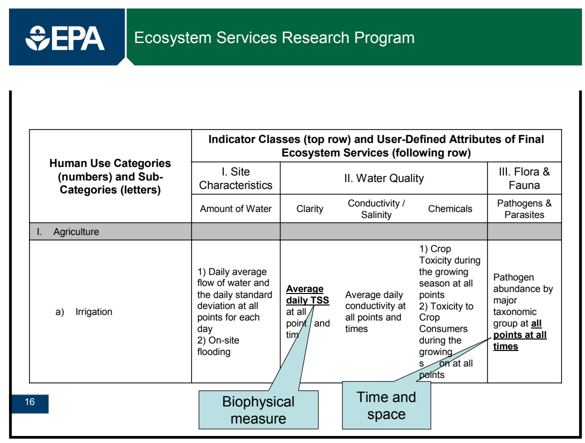
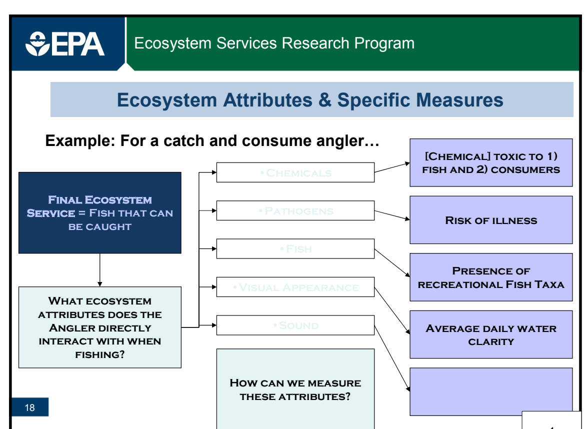
Slide Number











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Slide Number

Ecosystem Services Research Program

Human Use Categories (numbers) and Sub-Categories (letters)	II. Water Quality	III. Flora & Fauna		IV. Sensory Experience	
	Chemicals	Pathogens & Parasites	Fish	Visual Appearance	Sound
V. Recreational					
c) Fishing	1) Risk of illness at all points and times 2) Risk to equipment at all points and times	Risk of illness	Presence, abundance, condition, size and gender of recreationally relevant **native or naturalized fish** taxa at each point at all times	Average daily Color (PCU) and clarity of water; amount of visible open water, visible stream gradient at all points and times	Presence and character of sounds originating from the stream at all points and times

Excluding stocked fish

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Ecosystem Services Research Program

Human Use Categories (numbers) and Sub-Categories (letters)	II. Water Quality	III. Flora & Fauna		IV. Sensory Experience	
	Chemicals	Pathogens & Parasites	Fish	Visual Appearance	Sound
V. Recreational					
c) Fishing	1) **Risk of illness** at all points and times 2) **Risk to equipment** at all points and times	**Risk of illness**	Presence, abundance, condition, size and gender of recreationally relevant native or naturalized fish taxa at each point at all times	Average daily Color (PCU) and clarity of water; amount of visible open water, visible stream gradient at all points and times	Presence and character of sounds originating from the stream at all points and times

Not measures!!!

20

Ecosystem Services Research Program

Wetlands and Estuaries

Amanda Nahlik
Paul Ringold
Dixon Landers
Mary Kentula
Matt Weber
Steve Ferraro
Ted DeWitt
Walt Nelson

US EPA Western Ecology Division, Corvallis and Newport, OR

21

Ecosystem Services Research Program

Evolution of the Matrix

- Fresh thinking led to reorganization, additional categories, and more general categories for both user categories and ecosystem attributes.

Streams
- Amount of Water
- Timing of Water

Estuaries & Wetlands
- Amount of Water
- Timing of Water
- Water Velocity
- Water Depth
- Water Area

simplification

Streams, Estuaries, & Wetlands
- Amount of Water

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Ecosystem Services Research Program

Conclusions from Comparing Lists

- Revised user list works for all three ecosystems
  - *Some users are not present in some ecosystems*
  - *e.g. Estuaries are not a source of drinking water for subsistence users*
- Revised ecosystem attribute list works for all three ecosystems
  - *Some ecosystem attributes are not present in some ecosystems*
  - *e.g. Users do not interact with hydrologic state in wetlands*

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Ecosystem Services Research Program

Workshop Tasks

1. Review what has been done
   - *Should the ecosystem boundaries be tied to the National Aquatic Resource Surveys (NARS)?*
   - *Does the list of user groups work for …wetlands? …estuaries?*
   - *Does the list of ecosystem attributes work for …wetlands? …estuaries?*
   - *Are changes needed to the checkmark matrix for …wetlands? …estuaries?*
2. Generate potential measurements
   - *What does the detailed matrix look like for …wetlands? …estuaries?*

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Economics 101

Jim Boyd

What do We Do?

- Assume we had the biophysical information we wanted
- What would we do with it?
  - Relate it to human welfare
  - Weight things
  - Compare the costs of protection/restoration to the benefits

What is Human Welfare?

- Synonyms
  - Wellbeing
  - Utility
  - Happiness
- Not just from market consumption
  - Beauty
  - Biophilia
  - Cultural connections to place

How to Detect Changes in Welfare?

- Anthropology
- Law
- Marketing
- Psychology
- Physiology
- Economics
  - Empirical behavior
  - Choice experiments

Economic Detection

- Look for preferences, rankings, choices
- Detect "willingness to pay"
  - A particular kind of choice
  - An environmental good versus an amount of money
  - Or, versus anything whose value is known

Maybe not the best choice of words

The Goal to an Economist

- Maximize overall social welfare
- Caricature: economists care about maximizing *profits*
  - Focus on making companies richer
- Wrong
  - We want to <u>maximize *social* profits</u>
  - This includes the "profit" from species abundance, beauty, clean air and water, etc.

1	4
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3	6

Slide Number

Alternative Goals?

- What is fairest?
- What is cheapest or easiest?
- What does the majority want?
- What do scientists think is most important?
- What is legal?
- What is healthiest for the environment?
- What is most morally acceptable?

The Challenge

- Figuring out willingness to pay for nonmarket goods and services
- Easier for market goods
  - Quantities of goods and services, and prices paid, are observable

Economic Valuation In Practice

- Methods
  - Revealed preference
  - Stated preference
- Key issues
- Interpretation

Why Do Economists Like $'s

- Need a uniform measure to compare weights
- Many things already denominated in dollars, thus intuitive as a scale
- Costs come in dollars
- Seashells, arrowheads, 100 point scale, thermometer readings could also work

What Is Valuable?

- We seek to detect, reveal, uncover social values,
- We do not impose those values
- Ways of knowing:
  - Psychology
  - Marketing
  - Anthropology
  - *People's behavior*

Revealed Preference

- Our behavior can "reveal" willingness to pay
- Hedonic
  - Higher home prices near parks, beaches, rivers, lakes, open space
- Travel cost
  - Amount we "pay" to enjoy resources (entrance fees, permits, foregone wages, travel expenses)

1	4
2	5
3	6

Slide Number

Evidence on the amenity value of wetlands in a rural setting.

Bin, Okmyung; Polasky, Stephen. IN: Journal of Agricultural and Applied Economics, v.37, no.3, December 2005, pp.589-602, 2005.

LOCATION:
Journal Article

"This study uses a hedonic property price method to estimate how wetlands affect residential property values in a rural area. The study utilizes wetland inventory data coupled with extensive property sales records between January 2000 and September 2004 from Carteret Country, NC. Our results indicate that i) a higher wetland percentage within a quarter mile of a property, ii) closer proximity to the nearest wetland, and iii) larger size of the nearest wetland area associated with lower residential property values. These results contrast with previous hedonic studies that use data from urban areas, which found positive associations between wetlands and property values. The amenity value of wetlands appears to depend at least as much on the characteristics of the area being considered as it does on the characteristics of the wetlands." (p.589)

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Caveat: a very incomplete measure of a wetland's value (we know that)

Location

- Matters to us because we know it matters to you
- But also, it really matters to us for our own reasons
  - Location, location, location
  - Ecosystem services are like real estate

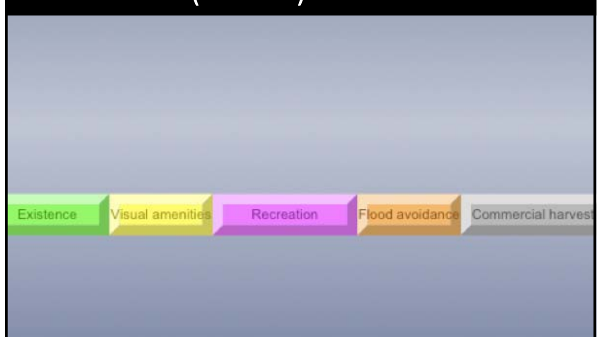
Travel Cost Detection

- If people are willing to pay $700 to travel and get access to a beach…
- A lower bound on the value of the beach experience
  - Much of that value is due to the natural resources and qualities of the beach

The Benefit Pie

- What is the value of a wetland?
  - A collection of benefits
  - Enjoyed by different groups of users
- Need a suite of detection methods
  - Each is its own sub discipline

The (Partial) Benefit Pie



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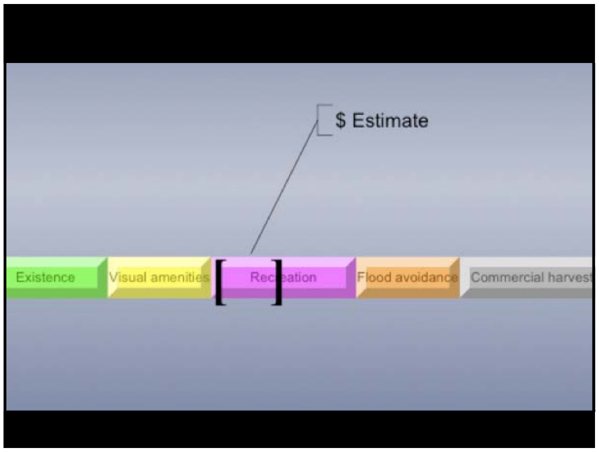

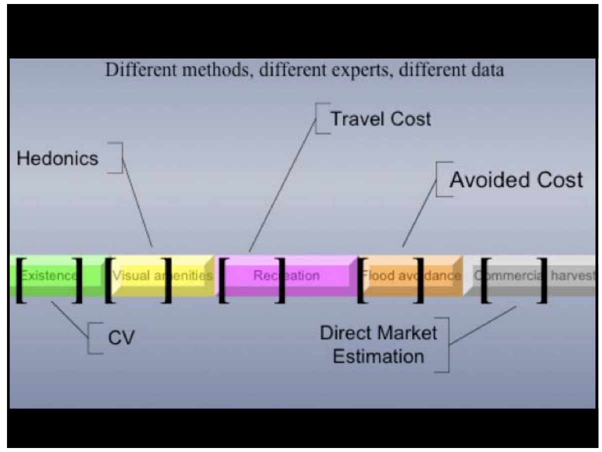

Stated Preference

- Present people with a set of hypothetical choices involving at least one good whose value is known
- The choice of environmental goods relative to that good is informative
- Advantage: you can cover a wider spectrum of benefits

Management Implications	Option 1*	Option 2	Option 3
Loss of unique ecosystems (000s of hectares)	none	70	250
Direct employment in region (currently 36,000 jobs)	Decrease by 3 percent	Increase by 1 percent	Increase by 12 percent
Hectares of Native healthy vegetation (currently 42 million)	Decrease by 8 percent	Decrease by 13 percent	Decrease by 7 percent
Annual levy on your income tax ($) (per household to fund initiative scheme)	none	25	75
Number of endangered species lost	none	20	120
Increase in regional income in 2006 ($ million / per annum)	40	30	25
Please indicate your preference (check only one option)	☐	☐	☐

(* current forest management regime)

Other Methods

- Citizen juries
- Expert elicitation
- Voting behavior
- Mediated modeling
- Quantitative, but non monetary, indicators of benefits

Example

	Wetland A	Wetland B
Hydrologic connection to aquifer used as drinking water by	100 households	10 households
Open space viewed by	10,000 commuters	2,000 commuters
Flood buffer in floodplain with	$25M worth of damageable structures	$2M worth

All Social Methods

- Benefit from ecological measures that are…
  - Directly relevant and interpretable by expert nonusers and policymakers

Scientific Paternalism

- Should we believe what natural scientists tell us is most important?
  - Yes: you are the ones who can tell us what is happening to nature
    - The experts
  - No: you have no special ability to know what is right for society
    - Just another constituency

The Value Of New Jersey?

- This is what we all want
  - Just give me the number!
- But our profession has problems with this
  - "Unsubstantiated averaging"
  - Total values of very large bundles of goods deserve skepticism
    - No real experiments can be conducted at this scale
    - And marginal changes … change with scale

Where Does Our Data Come From?

In addition to natural science data

- Market data
  - Home values
- Behavior surveys
  - Recreational surveys
- Census data
  - Demography, incomes, property
- Lab like experiments
  - Preference surveys

What If People Are Ignorant?

- A big topic in economics, we're aware of the problem
- Public ignorance as excuse for not looking at public preferences is a slippery slope
- If we describe nature in ways people can't understand, how can people learn?
- Faith in social ability to correct mistakes, overcome ignorance

Scientists: Please Give Us…

(1) Relevant, practical…

(2) Biophysical deltas" …

Changes in final goods and services

Water & air quality

Water quantities

Acres of open space

Species abundance

Flood, fire, health risks

1	4
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3	6

Slide Number

EPA Ecosystem Services Research Program

Three Questions for Working through the Matrix

1. What is the final ecosystem service(s) provided to the specific user?
2. What ecosystem attributes does that user directly interact with in attaining the final ecosystem service(s)?
3. What specific metrics can we use to indicate/measure each of those ecosystem attributes?

1

EPA Ecosystem Services Research Program

Ecosystem Attributes & Specific Measures

Example: For a farmer irrigating edible crops…

2

EPA Ecosystem Services Research Program

Ecosystem Attributes & Specific Measures

Example: For a farmer irrigating edible crops…

FINAL ECOSYSTEM SERVICE = WATER FOR CROPS PROVIDED BY THE ECOSYSTEM

WHAT ECOSYSTEM ATTRIBUTES DOES THE FARMER DIRECTLY INTERACT WITH WHEN IRRIGATING?

- AMOUNT OF WATER → MEAN DAILY VOLUME OF WATER DURING THE GROWING SEASON
- CLARITY → MEAN DAILY TSS DURING THE GROWING SEASON
- SALINITY → MEAN DAILY CONDUCTIVITY DURING THE GROWING SEASON
- CHEMICALS → [CHEMICAL] TOXIC TO 1) CROPS AND 2) CONSUMERS
- PATHOGENS → PATHOGEN ABUNDANCE BY MAJOR TAXONOMIC GROUP

HOW CAN WE MEASURE THESE ATTRIBUTES?

3

EPA Ecosystem Services Research Program

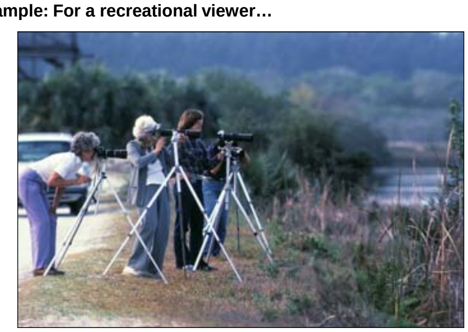
Human Use Categories (numbers) and Sub-Categories (letters)	Indicator Classes (top row) and User-Defined Attributes of Final Ecosystem Services (following row)				
	I. Site Characteristics	II. Water Quality			III. Flora & Fauna
	Amount of Water	Clarity	Conductivity / Salinity	Chemicals	Pathogens & Parasites
I. Agriculture					
a) Irrigation	1) Daily average flow of water and the daily standard deviation at all points for each day 2) Flood	Average daily TSS at all points and times	Average daily conductivity at all points and times	1) Crop Toxicity during the growing season at all points 2) Toxicity to Crop Consumers during the growing season at all points	Pathogen abundance by major taxonomic group at all points at all times

4

EPA Ecosystem Services Research Program

Ecosystem Attributes & Specific Measures

Example: For a recreational viewer…



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EPA Ecosystem Services Research Program

Ecosystem Attributes & Specific Measures

Example: For a catch and consume angler…

FINAL ECOSYSTEM SERVICE = ORGANISMS THAT CAN BE VIEWED + POSITIVE SENSORY EXPERIENCE

WHAT ECOSYSTEM ATTRIBUTES DOES THE VIEWER DIRECTLY INTERACT WITH WHEN VIEWING?

- AMOUNT OF WATER → PRESENCE OF WATER
- FLORA & FAUNA → PRESENCE OF VISIBLE NATIVE OR NATURALIZED TAXA
- VISUAL APPEARANCE → 1) DAILY COLOR (PCU) AND CLARITY OF WATER; 2) AMOUNT OF OPEN WATER
- ODOR → PRESENCE AND CHARACTER OF ODORS FROM ECOSYSTEM
- SOUND → PRESENCE AND CHARACTER OF SOUNDS FROM ECOSYSTEM

HOW CAN WE MEASURE THESE ATTRIBUTES?

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2	5
3	6

Slide Number

EPA

Ecosystem Services Research Program

Human Use Categories (numbers) and Sub-Categories (letters)	**Indicator Classes (top row) and User-Defined Attributes of Final Ecosystem Services (following row)**							
	I. Site Characteristics	III. Flora & Fauna				IV. Sensory Experience		
	Amount of Water	Invertebrates	Fish	Wildlife	Vegetation	Visual Appearance	Odor	Sound
a) Experience/Hiking	1) Daily average flow of water and the daily standard deviation at all points for each day 2) Flood	Presence of visible native or naturalized macroinvertebrate taxa at each point at any time	Presence of visible native or naturalized fish taxa at each point at any time	Presence of visible native or naturalized wildlife taxa at each point at any time	Presence and abundance visible plant taxa at all points at all times	Average daily Color (PCU) and clarity of water; amount of visible open water, visible stream gradient at all points and times	Presence and character of sounds originating from the stream at all points and times	Presence and character of sounds originating from the stream at all points and times

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EPA ECOSYSTEM SERVICES RESEARCH PROGRAM

Why Are We Here (Wayne's World)?

- Add rigor to "ecosystem services" concepts & science by focusing on practical "indicators of final ecosystem services" (primarily for monitoring, but more)
- Increase dialogue amongst the sciences
- Identify biophysical indicators of final ecosystem services for specific ecosystem types (wetlands & estuaries)
- Refine a model for all ecosystem types, and then to generate additional hypotheses
- To whit:
  - focus natural science contributions
  - describe indicators of FES for valuation for estuaries & wetlands

2

EPA ECOSYSTEM SERVICES RESEARCH PROGRAM

Services & Indicators

- **Final Ecosystem Service** – Output of ecological functions or processes that directly contributes to social welfare or has the potential to do so in the future
- **Ecological Benefit** – Contribution to social welfare of changes in ecological goods and services (specifically, attributable to policy)
- **Indicator of Final Ecosystem Service** – Biophysical feature, quantity or quality that requires little further translation to make clear its relevance to human well-being (i.e., "public-friendly" measurement)
- **Ecological Production Function** – Description of the type, quantity and interactions of natural features & processes (w/policy levers) required to generate outputs of functional indicators of final ecosystem services

3

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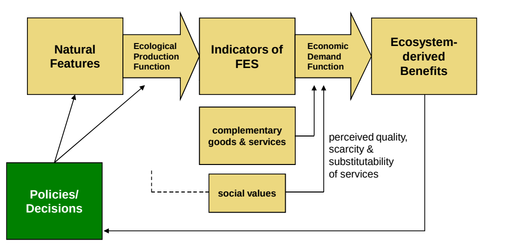

evolved from: Wainger & Boyd (2009). Valuing ecosystem services. In: Ecosystem-Based Management for the Oceans, McLeod & Leslie (eds.), Island Press.

4

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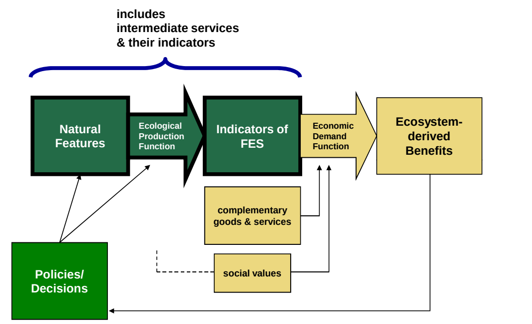

evolved from: Wainger & Boyd (2009). Valuing ecosystem services. In: Ecosystem-Based Management for the Oceans, McLeod & Leslie (eds.), Island Press.

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EPA ECOSYSTEM SERVICES RESEARCH PROGRAM

And So, I Encourage You to:

- Focus on indicators of final ecosystem services associated with wetlands & estuaries
- Keep track of key steps of ecological production functions
- Recognize that this reductionist approach is grounded in a systems view
- Get to know thy neighbor
- Give Rob a hard time

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2	5
3	6

Slide Number