Report from the Workshop on Indicators of Final Ecosystem Services for Streams

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PREFACE

As ecosystems are restored, degraded, protected or managed the social wealth derived from them correspondingly rises and falls. Public policies that seek to protect or enhance social wealth derived from ecosystems must recognize measure and manage that wealth. This requires ecological and social analysis that is integrated in terms of underlying principles and approaches to measurement.

The desire to quantitatively incorporate the role of ecosystems in sustaining human-well being in policy deliberations is not new[5]. It has been embodied in repeated 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 this ecosystem human well-being linkage has increased, and refocused, in recent years, especially by the development of the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005). This global assessment defines a comprehensive taxonomy of four categorizes 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 services, in combination with human systems, cultures and values benefit human well-being. While this categorization is seen as a useful heuristic tool it does not provide an operational definition 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

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

ecosystem goods and services, Boyd and Banzhaf (2007) advocate the need to clearly distinguish between "final ecosystem services" or endpoints and other ecosystem services more appropriately termed "intermediate services"(Daily and Matson 2008). 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 if we wish to aggregate or bundle benefits so that cumulative changes in ecosystems and the consequent changes in human well-being can be described over time or projected as a result of a suite of policy options.

To be clear, while "final services" may be the units upon which accounting systems and valuation are based, an understanding of "intermediate services" and their relationship to final services is of great importance in understanding, assessing, predicting and managing final services and the human well-being provided. This relationship between intermediate and final services is described by "ecological production functions" that relate changes in one set of biophysical features and conditions to changes in other biophysical features and conditions.(See slide 3 and the 6 following slides starting on page 20 of Attachment 3). They are essential to the delivery of policy-relevant ecological benefit analyses.

This workshop explored the concept of "final" ecosystem services – and the corollary concepts of intermediate services and production functions -- and its relevance to the design of ecological monitoring systems that can support decision-making. The focus of this exercise was on one type of ecosystem -- streams. In addition to this specific purpose, the workshop report (under the heading "Other Questions") also documents key elements of the broader discussion that needs to take place between natural sciences and social sciences if we are to succeed in making the contribution of ecosystems to human well-being a richer part of our decision making.

EXECUTIVE SUMMARY

Policy-relevant management of ecosystem services requires extensive collaboration between natural and social scientists. This report documents a workshop – featuring such collaboration – designed to answer the following 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) are these metrics already available?; (3) if not available, what steps would be required to make them available?; and (4) to what use will economic analyses of ecosystem services be put?. The workshop achieved consensus on an approach designed to identify policy- and economically-relevant ecological metrics and illustrated it via a collaborative identification of metrics applicable to the ecology of streams. Translation of these metrics into implementation ready monitoring protocols 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 a more detailed design and implementation phases. Importantly, the framework and practices are consistent with both ecological and economic best practices related to the analysis of ecological systems.

The report identifies categories of indicators that could contribute to estimates of human well-being and evaluates the current capacity to represent those indicators in a national aquatic ecosystem monitoring program. It also identifies opportunities to refine the workshop’s results,

transfer the framework and process to other ecosystems and organizations, and demonstrate the measurement approach in field efforts. As important, the document addresses key underlying issues that too often thwart effective collaboration and communications between natural and social scientists.

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)

To contribute to this vision, EPA's MARA (Monitoring and Aquatic Resource Assessment) program organized a workshop to identify ecological indicators (hereafter just "indicators") characterizing the relationships between stream ecosystems and human well-being. The central objective of the workshop was to focus on indicators of final ecosystem services as developed in (Boyd and Banzhaf 2007; Boyd 2007), relate them to other important features of natural systems (including intermediate goods and services and biophysical production functions), and using that framework identify indicators that could be included in a national stream monitoring program such as those demonstrated by EMAP efforts[6] or implemented in EPA Office of Water Programs[7] in the NARS (National Aquatic Resource Surveys) program. An additional goal was

[6] For example (Stoddard et al. 2005b; U.S. Environmental Protection Agency Office of Water 2006)
[7] http://www.epa.gov/owow/monitoring/nationalsurveys.html

to determine if indicators selected for use in national scale monitoring could be useful for monitoring programs covering smaller assessment areas (e.g. regions, watersheds, or even for short reaches of single streams) or as response variables that could be the focus of stressor-response (i.e. ecological production function) models.

Indicators of final services are not a substitute for existing ecological metrics. Rather, they are an important addition and complement to indicators already being monitored. Existing metrics are an important part of analytical systems designed to model and predict changes in final goods and services. They also have demonstrated utility in scientific, legal and planning contexts.

Indicators of final services for streams can be used for three purposes. First, they help communicate the roles of stream ecosystems to decision makers in an effective manner. Second, they provide the biophysical information necessary for cost effectiveness analysis, i.e. analysis of ecological change (e.g. miles of fishable streams) in response to policy choices, and third they facilitate valuation studies, i.e. studies that monetize incremental changes in biophysical features over time or in response to policy choices. These latter two types of analysis, linking ecological responses to policy choices rely on production function models. The need for these models, based on indicators of “intermediate services” to predict “final services”, underscores the need to continue the collection of information in addition to indicators of final services.

WORKSHOP ORGANIZATION

Workshop planning started in December 2008. The planning committee[8] developed an approach to translate the final ecosystem services concept into a framework that would allow experts to identify specific measurements. The key element of the approach was the development of a matrix with users of stream ecosystem services listed as rows, and stream attributes which might provide final services for categories of users of stream ecosystems listed as columns. This matrix was similar in form to that provided as Table 1. We provided our initial entries in this matrix by asking ourselves the question: "What biophysical amounts, features and qualities does each user want more of or less of? Is this the most concrete, tangible and intuitive feature for the user?[9] This was an initial iteration of what we intended to complete during the workshop. The development of this framework enabled the planning committee to identify the categories of expertise needed to pursue the workshop goals. Participants were then identified and invited to the workshop based on their individual and collective capacities to contribute to the goals of the workshop, and particularly for their knowledge of stream attributes that the organizers believed would need to be characterized to quantify the role that streams play in human well-being. Approximately equal number of natural and social scientists participated in the workshop.

Background material and workshop presentations ensured that workshop participants had a common understanding of workshop goals, concepts and terms. Key structural elements of the workshop were:

- A definition of final ecosystem goods and services: Biophysical features, quantities, and qualities that require little further biophysical translation to make clear their relevance to

[8] James Boyd, Dixon Landers, Paul Ringold and Matt Weber

[9] Examples of this thought exercise were provided in the presentations (See slide 4 and the following 5 slides starting on page 23 of Attachment 3).

human well-being. These goods and services tend to be directly or tangibly used, experienced or appreciated by households, firms, and communities. While we refer to "users" of ecosystem goods and services, the concept is meant to include non-consumptive beneficiaries of natural resources (e.g. Arrow et al. 1993). A final ecosystem service is also an "ecological endpoint"[10]. (See slide 2 on page 19 of attachment 3)

- The presentation of an initial matrix, developed by the planning committee as noted above, with candidate categories of users and candidate attributes of streams. The purpose of this matrix was to organize expert knowledge linking attributes of streams that are directly or tangibly used by various groups of people. (See slide 5 on page 25 of Attachment 3).

The list of participants, prepared presentations and the agenda for the workshop are provided as attachments 1, 2 and 3. In addition, participants were provided with background material to review in advance of the workshop (Boyd and Banzhaf 2007; Boyd 2007; Chee 2004; Stoddard et al. 2005b).

WORKSHOP RESULTS

Indicators

[10] Note that this definition is not identical to that used in ecological risk assessments. That definition is: "An end point is a characteristic of an ecological component (e.g., increased mortality in fish) that may be affected by exposure to a stressor ... Two types of end points are distinguished in the framework: Assessment end points are explicit expressions of the actual environmental values that are to be protected; measurement end points are measurable responses to a stressor that are related to the valued characteristics chosen as the assessment end points …."(Norton et al. 1992)

The agenda (Attachment 2) allowed ample time for discussion of the material presented. After the initial presentations and discussion the group split into six groups. Each group attempted to identify indicators of stream attributes that constitute the ecological endpoints for collections of users. In this process each group was challenged to go through the following thought exercise (the same one that we had gone through in organizing the workshop): "What biophysical amounts, features and qualities does each user want more of or less of? Is this the most concrete, tangible and intuitive feature for the user?[11] For example one category of user is a catch and release angler. 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). Exactly what these measures are and how they would be combined into a measure of well-being for a catch and release angler is an example of an issue that needs more focused attention as noted in Step 1 of the NEXT STEPS section. Notably, in this example, watershed condition, stream habitat, riparian condition, and water quantity timing and quality are all important ecosystem attributes that can change fish distribution and abundance. Within the context of the "final services" taxonomy that we adopted these are examples of intermediate services that are vitally important and would be candidates to be included in production function models useful for assessing or managing the final service.

We noted that because there are diverse users of ecosystems some ecological features are intermediate services in one context and final services in another. For example[12], for a

[11] Examples of this thought exercise were provided in the presentations (See slide 4 and the following 5 slides starting on page 23 of Attachment 3).

[12] See slides 1 and 2 on page 21 of Attachment 3.

recreational boater water clarity may be an indicator of a final service. However, for a commercial crab harvester, water clarity may be a factor in the production of crabs and thus provide an indicator of an intermediate service for this user.

This initial attempt at completing the matrix was a heuristic effort for workshop participants. By working through specific examples we intended to determine if participants felt that the general approach made sense, and if the proposed user groups or stream attributes (See slide 5 on page 24 and the following 3 slides of attachment 3) should be modified. The sentiment was that the general approach made sense. In addition the group consensus was to add one category of user, research and education, as well as one stream attribute – genetic diversity. Other categories of users and stream attributes were clarified or modified.

After this initial heuristic analysis we reviewed the revised matrix and came to consensus upon the entries that should fall in each cell of the matrix and on the usefulness of the "final services" concept. The result of this discussion, viewed as a working hypothesis, is provided as Table 1. The entries in this table are general stream attributes (such as fish); rather than specific measurements or indicators (e.g. the number of large game fish). In many instances the group discussion provided detail beyond the identification of the stream attribute that would help to define the specific indicator of the final ecosystem service or endpoint. These discussions are provided in Attachment 4. Further refinement of these entries is necessary and is noted in the Next Steps section.

The extensive discussions that led to Table 1 required us to develop and adhere to a set of general principles to determine which stream attributes should be measured to quantify final ecosystem services for each category of users (Table 3). These principles are important not only because they define how workshop participants translated expert knowledge into a delineation of indicators of final stream ecosystem services but also because these principles should be readily transferrable to other ecosystems. These principles were evaluated and revised during the course of the workshop. The first three principles were adopted directly from the background material. The fourth -- "Regulations alone could not create a final ecosystem service" --was an important additional consideration[13]. Had we chosen to assume that regulations could create final services, a number of additional stream attributes would have been identified as providing final ecosystem services. However, since regulations are not biophysical features, quantities or qualities, they cannot provide a final ecosystem service (cf. slide 3 on page 19 of Attachment 3).

We split into four groups to determine the usefulness of the indicators identified for use in a national monitoring program (as shown in Table 1) for use in monitoring programs at smaller scales and in stressor-response models. Each group was asked to identify and work through a case study of an analysis of an ecological problem at a small scale and consider what indicators of final ecosystem services they might use. The four case studies were acid rain in the

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[13] Two examples illustrate the manner in which regulations could be viewed as creating a final service.

1. A point source discharger, e.g. an industrial plant or a municipal waste water treatment plant (subcategories IIe and IIIb in Table 1), is required to discharge its effluent to meet a set of regulatory requirements. These regulatory requirements limit physical or chemical changes in the stream associated with the discharge. Thus, stream chemistry or physical attributes could be construed as providing a final service for this user category.

2. Water users, e.g. a farmer withdrawing irrigation water or a plant manager withdrawing cooling water (subcategories Ia and IIa in Table 1) can be limited in the timing or amount of their withdrawals if threatened or endangered species might be affected as a result of the withdrawal. Thus, threatened or endangered species could be construed as providing a final service for this user category.

northeastern United States, Ohio River pollutant trading, a hypothetical cold water fishery, and Root River, WI management. In all four cases, the final ecosystem services indicators identified for use in national scale monitoring were found to be useful at a smaller scale in both a monitoring and a modeling context. This provides us with some evidence that the indicators identified would be useful not only for national scale monitoring, but also for other scales and purposes.

After preparing Table 1 we evaluated the extent to which those attributes were included in existing programs that characterize the nation's waters. The results of this analysis were presented to workshop participants during a plenary session and were revised in response to comments from those participants. This comparison is provided as Table 2. Steps are specified to address the gaps identified, and were developed after the workshop. Some of the options listed in the section "NEXT STEPS" are designed to address the results of this comparison. Current data collection is likely to be sufficient for four stream attributes: fish, conductivity, clarity and streambed characteristics. However, analyses need to be conducted to express these data in terms that "require little further translation to make clear their relevance to [human] well-being". For attributes that have a high degree of temporal or temporal and spatial variability (indicators of water quantity, temperature, dissolved oxygen and pathogens), monitoring programs are likely to play a role, but it seems likely that models will need to be developed to provide national estimates of these attributes. In some cases (plants, wildlife and aesthetics), a wide range of quantitative collection protocols exist, but are not deployed in national surveys. In parallel with the definition of clear endpoints, renewed consideration can be given to including these measurements in national surveys. For the visual component of aesthetics, which may rely on reformulations of existing topographic and landcover/landuse data, this may be more achievable than for measures which require additional field efforts.

How big is a site?

Workshop participants considered the issue of the spatial scale of the units of observation (natural science terminology), or the size of the biophysical commodity directly or tangibly used (social science terminology). Consideration of this issue is a well developed question in the natural sciences for which a variety of approaches exist[14]. The three approaches are

1. Compare the relationship between sampling effort and the value of the metric of interest as compared to a true value (where the true value is estimated by much more intensive or extensive sampling)[15].

2. Capture a predictable level of natural variability[16].

3. Best professional judgment.

[14] That approaches to address these questions are well developed does not mean that they are universally applied.
[15] The development of the EMAP stream and river protocols are examples of the use of this approach. Hughes et al (2002) and Reynolds et al (2003) conclude that sampling a stream length of 40 channel widths is sufficient to characterize a vertebrate species richness for wadeable streams while a reach length of 100 channel widths is necessary for rivers (streams large enough to be sampled by raft, but excluding “Great Rivers”, e.g. the Colorado, Columbia or Mississippi)
[16] Physical and biological attributes of streams vary within stream meanders. If sampling were confined to one part of one meander, the data derived would characterize very local conditions. If another field crew were to go to the same stream reach and sample in a slightly different location their results could be very different. Monitoring designs demonstrated by EMAP and used by NARS address this issue by distributing sampling effort across multiple meanders. Since observations of many streams reveal that stream meanders are typically 7 to 10 times the channel width (Leopold et al. 1964) distributing sampling over 40 channel widths is expected to capture the range of very small scale local variability and provide data that should be repeatable and ecologically meaningful.

In contrast to the recognition of this question---how big is a sample site?—within the natural sciences, the brief discussion we had during the workshop led us to conclude that future discussions of scale, and particularly its two components: extent and grain (Forman and Godron 1986) would be productive in furthering the interaction between natural and social scientists.

Other Questions

In addition to, and in the course of, identifying indicators of final ecosystem services the scientists at the meeting identified a number of technical issues that served as barriers to communications across the disciplines.

One significant barrier was the economists' view that value can only sensibly be calculated in dollar terms when comparing differences in ecosystem states (or choice scenarios) where both of the states are comprehensible and sensible. Thus a question such as "What would be the value of water lost by a policy that reduces water produced from land in Colorado administered by the National Forest System by 10%?" is one that can be plausibly addressed. In contrast, a question such as "What is the value of all streams in the United States?" cannot be addressed in quantitative economic terms.

Furthermore, participants pointed out that often determining what these final commodities (or biophysical features, quantities or qualities) are is an important research topic. For example, in a study of consumer preferences for ecological restoration Johnston et al (2009) found that indicators must be "grounded in feasible restoration outcomes identified by ecological models, field studies or expert consultations. Choice scenarios represent each ecological attribute in relative terms with regard to upper and lower reference conditions (i.e., best and worst possible in the Pawtuxet) as defined in survey informational materials." For example people were asked about their preference for restoration that would provide 80% of fish dependent wildlife native to the study area (i.e. 28 of 36 species) being common as compared to 60% (22 of 36 species). In addition questions of similar form were asked about five other ecological attributes of the study area. Notably, the formulation of this questionnaire was based on theoretical principles and "developed and tested over 2½ years through a collaborative process involving interactions of economists and ecologists; meetings with resource managers, natural scientists, and stakeholder groups; and 12 focus groups with 105 total participants…. In addition to survey development and testing in focus groups, individual interviews were conducted with both ecological experts and non-experts." This is an example of the kind of effort that needs to be undertaken to communicate ecosystem status and its relationship to human well-being. The need to conduct research on this issue is not new; and has been thoroughly identified by natural scientists. [17]

A second issue that we addressed was the usefulness of a national monitoring program addressing broad "strategic" questions, for example, is water quality in the nation improving?[18], rather than a narrow set of questions tied to the implementation of a specific policy change based

[17]E.g. "Results of water-quality monitoring programs need to be translated into formats that enhance effective and informed responses from a wide range of stakeholders" (Covich et al. 2004); "Application of ecological knowledge will re- quire better communication between ecologists and decision-makers in all sectors of society" (Lubchenco et al. 1991); Communication must flow in both directions and become an iterative dialogue, and the scientific community must understand what pieces of information are critical…"(Christensen et al. 1996). These statements aren't all necessarily interesting in and of themselves, but the authors of these statements include 13 past presidents of the Ecological Society of America and provide evidence of the recognition on the part of natural scientists that the details of communication of natural science information is a priority.

[18] (See slide 2 on page 3 of Attachment 3)

on the application of a stressor-response or ecological production function model[19]. We termed this second set "tactical" question. After an exchange of views participants acknowledged the legitimacy of both types of questions and concluded that indicators defined with strategic questions in mind would also likely be useful for tactical questions and vice versa.

A third issue was the relationship between intermediate ecosystem services and final ecosystem services. For example lakes, floodplains and wetlands provide flood storage which has the capacity to modify the magnitude and duration of flooding. Similarly stream habitat supports biodiversity. Natural scientists believe that such assets (flood storage or stream habitat) have value. Social scientists note that such assets do have value, but that value is reflected in and accounted for in measurements of water quantity and timing in the first case, or in measurements of specific components of biodiversity which are directly and tangibly used by various categories of users in the second case. Social scientists suggest that it is useful to think of these systems in the context of ecological production function models (Daily and Matson 2008). The features in these constructs that are valued are the final services; other ecosystem features, "intermediate ecosystem services", produce these final services and have value which is captured in the final services.

NEXT STEPS

There are numerous opportunities to capitalize on the success of the workshop. A few examples are:

[19] (See slide 6 on page 21 of Attachment 3)

1. There is a great need to add operational specificity to the definitions of endpoints provided in Table 1 and in Attachment 4. Efforts related to this task would engage natural and social scientists in conducting studies, possibly including surveys of people, to add this specificity. In parallel, where we have data, e.g. with vertebrate assemblages, natural scientists could evaluate the characteristics of alternative candidate metrics under consideration by social scientists. Jackson and her colleagues (Jackson et al. 2000) provide a rich list of criteria to support this evaluation.

2. Workshop participants believe that the approach, principles and methods used in this workshop are potentially highly transferable to other ESRP activities, to other landcover categories (such as lakes, wetlands, forests, estuaries, etc.), to other research programs (e.g. climate change), and to research supported by other organizations. EPA should find opportunities to support this transfer. The October ESRP meeting would be one a good opportunity to focus on transferring this perspective.

3. The next national lake survey will take place in 2012[20]. The default design for this survey would be to replicate prior designs which did not include an explicit consideration of final ecosystem services. To address the absence of such consideration, the process implemented in this workshop could be repeated along with a lake specific analysis of the research listed in opportunity 1 above. The goal would be to provide a list of additional measurements and indicators of final services that could be deployed with the 2012 survey.

[20] http://www.epa.gov/owow/monitoring/nationalsurveys.html

4. The Electric Power Research Institute (EPRI), along with numerous public and private partners, has developed a pilot project "Ohio River Basin Trading Pilot Project"[21]. Extending this partnership to include consideration of final ecosystem services could be most beneficial in transferring these concepts outside of the research realm and outside of EPA. This is an unusually appealing opportunity because of the rich monitoring datasets developed by the Ohio EPA, Ohio River Valley Water Sanitation Commission (ORSANCO[22]) over the past three decades for this study area, and the spatial overlap between this pilot project and the ESRP Mid-West place-based study.

[21] http://my.epri.com/portal/server.pt?open=512&objID=401&&PageID=226975&mode=2
[22] http://www.orsanco.org/

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			Working Hypothesis Stream Attributes Posited to be a components of Indicators of Final Ecosystem Service to Specific User Categories and Subcategories															
			Quantity		Quality													
					Physical				Chemical			Biological					Landscapes	
		Human "Use" Categories and Subcategories	Amount	Timing	Temperature	Conductivity	Stream Bed	Clarity	Dissolved Oxygen	Chemicals	Odor	Pathogens	Ecosystem Health / Biotic Integrity	Fish	Wildlife	Plants	(Human "Experience Shed") Aesthetics	Genetic Diversity
I	Agriculture																	
	a)	Irrigated Crops	✓	✓		✓				✓		✓			✓			
	b)	Livestock (CAFO)	✓	✓		✓				✓		✓						
	c)	Aquaculture	✓	✓	✓	✓		✓	✓	✓		✓			✓			
	d)	Processing	✓	✓	✓					✓		✓						
	e)	Grazing	✓	✓		✓	✓			✓		✓			✓	✓		
II	Industry																	
	a)	Cooling Water	✓	✓	✓									✓	✓	✓		
	b)	Processing	✓	✓	✓	✓				✓				✓	✓	✓		
	c)	Hydroelectric	✓	✓			✓											
	d)	Extracting (Sand and Gravel)					✓											
	e)	Discharge	?	?														
	f)	Commercial Extraction										✓		✓	✓	✓		
	g)	Pharmaceutical Industry																✓
III	Municipal																	
	a)	Drinking Water Source	✓	✓		✓		✓		✓	✓	✓		✓	✓	✓		
	b)	WWTP Sink	?	?														
	c)	Property Owners	✓	✓			✓	✓		✓		✓		✓	✓	✓	✓	
IV	Non-Use																	
	a)	Existence/Option/Bequest	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
V	Recreational Use																	
	a)	Viewing	✓	✓			✓	✓			✓		✓	✓	✓	✓	✓	
	b)	Swimming	✓	✓	✓		✓	✓		✓	✓	✓		✓	✓	✓	✓	
	c)	Fishing												✓			✓	
	d)	Boating	✓	✓	✓		✓	✓			✓	✓		✓	✓	✓	✓	
VI	Cultural																	
	a)	Spiritual	✓	✓									✓	✓	✓	✓	✓	
	b)	Ceremonial	✓	✓									✓	✓	✓	✓	✓	
	c)	Subsistence	✓	✓									✓	✓	✓	✓	✓	
VII	Commercial Transportation																	
	a)	Goods	✓	✓														
	b)	People	✓	✓				✓			✓	✓		✓	✓	✓	✓	
VIII	Education and Research																	
	a)	Education and Research	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			✓	This attribute is posited to be of direct use to specific user categories														
				This attribute is posited to not be of direct use to specific user categories														

Table 1. Stream attributes that provide final ecosystem services for various user categories of stream users. See Attachment 4 for details on the indicators thought to be important for each cell.

Stream Attribute			Current Status	Measured in Current Programs to support national estimates of	Steps that could be taken to improve data collection or reporting in terms of endpoints
Water Quantity		Amount Timing	An extensive USGS hydrographic system provides consistent easily available data. These data do not represent the stream network as a whole	2	Existing network provides a foundation for models that could describe water quantity in terms of endpoints.
Stream Qualities	Physical	Temperature	Abundant records of stream temperature data exist housed in disparate locations, temporal resolution and extent, formats and collection protocols.	1	Estimates of national extent of temperature tied to endpoints should be provided from models rather than from measurements because of the high temporal variability of this attribute. Efforts to define the fom of the endpoint should also be pursued.
		Conductivity Stream Bed Clarity	Indicators of these measures are included in programs of national extent.	3	The scales and representation of these data that best represent endpoints needs to be evaluated.
	Chemical	Dissolved Oxygen	Abundant records of stream dissolved oxygen exist housed in disparate locations, temporal resolution and extent, formats and collection protocols.	1	Estimates of national extent of dissolved oxygen tied to endpoints should be provided from models rather than from measurements because of the high temporal variability of this attribute. Efforts to define the fom of the endpoint should also be pursued.
		Chemicals	Chemical data are included in surveys of national extent. Abundant additional records of stream chemistry exist housed in disparate locations, with different lists of chemicals, temporal resolution and extent, formats and collection protocols.	2	The scales and representation of these data that best represent endpoints needs to be evaluated. Efforts to define the fom of the endpoint should also be pursued.
		Odor	?	1	?
	Biological	Pathogens	Abundant records of stream pathogens exist housed in disparate locations, with different lists of chemicals, temporal resolution and extent, formats and collection protocols.	1	Estimates of national extent of pathogens tied to endpoints should be provided from models rather than from measurements because of the high temporal variability of this attribute. Efforts to define the fom of the endpoint should also be pursued.
		Ecosystem Health / Biotic Integrity	Diverse measures which may equate to ecosystem health are collected in programs of national extent.	2	The representation of these data or alternative data that best represent this endpoints needs to be evaluated.
		Fish	Existing protocols to collect fish consistently are included in programs of national extent.	3	The representation of these data that best represent endpoints needs to be evaluated.
		Wildlife Plants	A range of protocols of these streams attributes exist but are not included in current programs of national extent	1	The clear definition of the endpoint needs to be developed and existing protocols which could support the estimation of these endpoints would need to be evaluated adapted and deployed as appropriate
	Landscapes	(Human "Experience Shed") Aesthetics			
	Other	Genetic Diversity	Feasible measures of this attribute don't exist	1	This is a research topic.

Table 2. Steam attributes required to support national estimates of endpoints; their current status in national monitoring programs and steps that could be taken to improve our capacity to estimate these endpoints at the national scale. Status of 1 implies great discrepancy between current capacity and needs; 2 implies moderate discrepancy, and 3 implies slight discrepancy.

Table 3. Prinicples used in identifying indicators of final ecosystem services provided by streams.

1. Strictly biophysical features, quantities or qualities that require little further translation to make clear their relevance to human well-being
2. Comprehensive identification of these entities requires the identification of the full set of users (and non-users) who directly benefit from stream ecosystems.
3. While the list must be exhaustive and non-duplicative it should also provide for parsimony by keeping a focus on substantive or material services.
4. Regulations alone do not create a final ecosystem service.

Attachment 1

List of Workshop Participants

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Agenda
Workshop on Indicators of Final Ecosystem Services for Streams

Denver Renaissance Hotel
3801 Quebec Street
Denver, Colorado 80207 USA
Phone: 1-303-399-7500
All meeting rooms are on the Atrium Level

Monday July 13

4:30 PM to 6 PM – Informal Reception and Registration [Durango Room]

Tuesday July 14

8:00 AM Continental Breakfast and Registration

8:30 AM Welcome and Introductions: Weber [Vail Room]
CSG Role and Procedures – Parks
Interests in Stream Monitoring and Ecosystem Services – Each Participant

9:00 AM What's the problem we're trying to solve?
- Why Are We Here? -- Natural Science Perspective: Ringold (15 minutes)
- Why Are We Here? The Social Science Version: Boyd (15 minutes)

9:30 to 10:00 AM Questions and Discussion

10:00 to 10:15 AM Break

10:15 AM Economics 101: Boyd (20 minutes)
Surface Water Monitoring: Landers (20 minutes)
Ecological Measures for Social Analysis: Boyd (20 minutes)

Questions and Discussion

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

1:30 to 3:45 PM Plenary: Develop a Working Hypothesis

How Can We Use the Final Services Concept in Monitoring Design? (20 minutes)
Discussion

- Does this approach make sense?
- Should some stream attributes be added or deleted?
- Should user categories be added or deleted?

3:45 to 4:00 PM Break

4:00 to 5:00 PM Small Group Discussions – What are the issues raised? [Snowmass, Breckenridge, Durango and Winter Park Rooms available]

5:00 to 6:00 PM Plenary – Identify and Address Issues Raised [Vail Room]

Adopt a working hypothesis

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

Wednesday, July 15

8:00 AM Continental Breakfast

8:30 AM Plenary [Vail Room]

8:30 to 9:00 AM Introduction and Tasking -- Weber

Task 3 or 4 break out groups [Snowmass, Breckenridge, Durango and Winter Park Rooms available]

Each breakout group will address the following questions and identify the range of opinions in answering them:

1. What are user requirements for the character of information needed including it's temporal and spatial characteristics?
2. What are FES indicators for each user category as identified in the matrix?
    - Existing/Currently available, Near Term, Long-Term
3. What does an FES at a point in time and space (and flow?) represent for other times and places?
4. What is the current/probable future ability to predict FES based on the availability of extensive data (e.g. landcover, roads, census, NHD, topography….)?

Noon Buffet Lunch [Provided]

1:00 – 2:00 PM Progress Reports from breakout groups, discussion, retasking, and as necessary, restructuring.[Vail Room]

2:00 to 4:00 PM Reconvene breakout groups [Snowmass, Breckenridge, Durango and Winter Park Rooms available]

4:00 to 5:30 PM Report from breakout groups [Vail Room]
Identification of Final Service Indicators
……..

5:30 PM Adjourn for Dinner [On Your Own]

Thursday, July 16

8:00 AM Continental Breakfast

8:30 – 9:30 AM Boyd/Landers/Ringold reaction to breakout reports [Vail Room]

9:30 – 10:30 AM New breakout groups to address key issues [Snowmass, Breckenridge, Durango and Winter Park Rooms available]

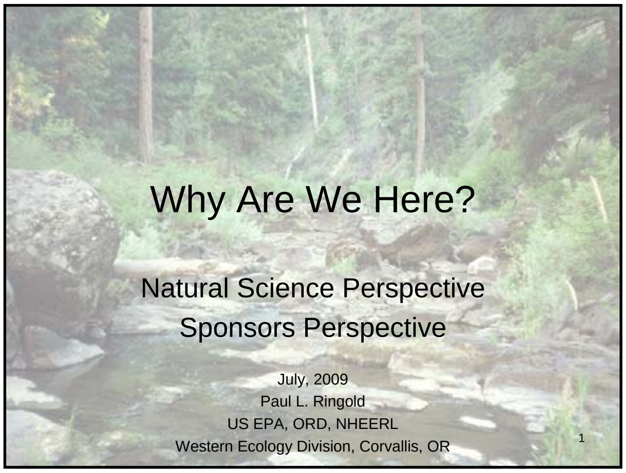
For example: 1) What practical challenges would be incurred in monitoring this set of indicators in a national program?
2) What should we do next?
3) ..

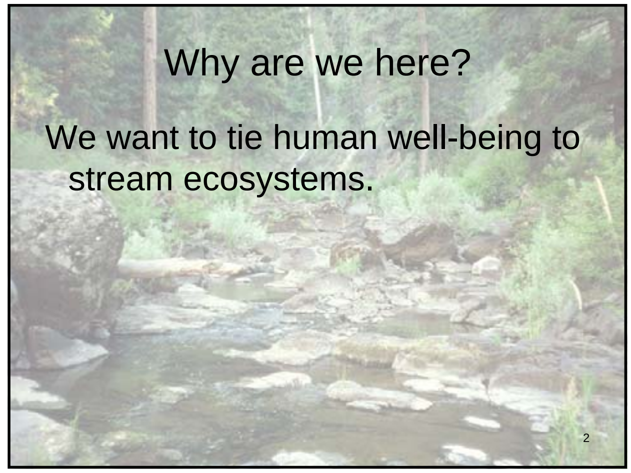
10:30 – 10:45 AM Break

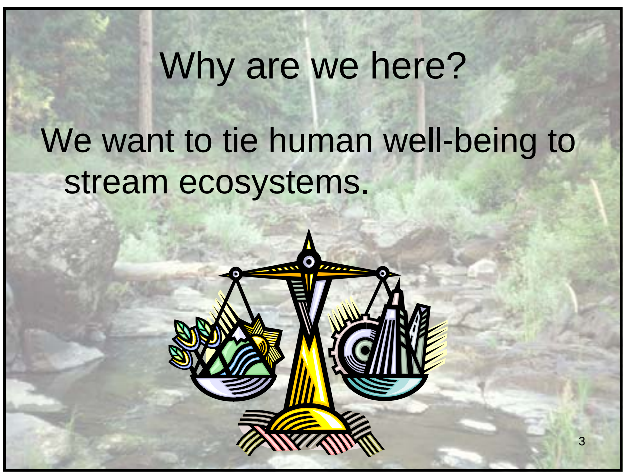
10:45 to 11:30 AM Breakout group reports [Vail Room]
Refined List of Final Service Indicators

11:30 to Noon Wrap Up Discussion [Vail Room]

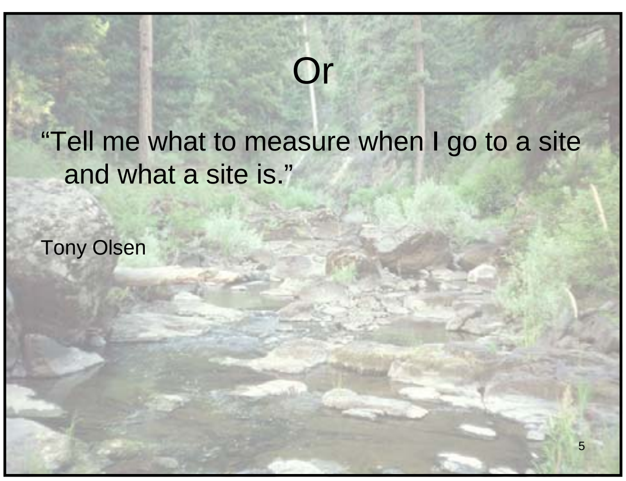
Noon Meeting Concludes for most participants

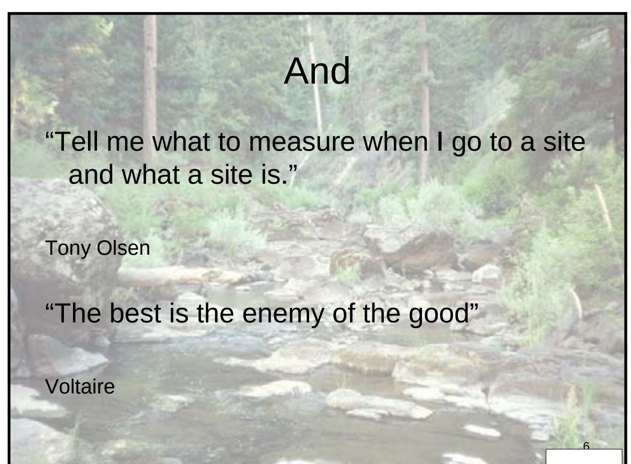

Why Are We Here?
Natural Science Perspective
Sponsors Perspective
July, 2009
Paul L. Ringold
US EPA, ORD, NHEERL
Western Ecology Division, Corvallis, OR
1

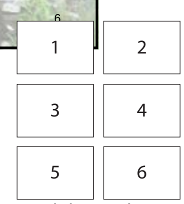

Why are we here?
We want to tie human well-being to stream ecosystems.
2


Why are we here?
We want to tie human well-being to stream ecosystems.
3


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.
4


Or
"Tell me what to measure when I go to a site and what a site is."
Tony Olsen
5


And
"Tell me what to measure when I go to a site and what a site is."
Tony Olsen
"The best is the enemy of the good"
Voltaire
6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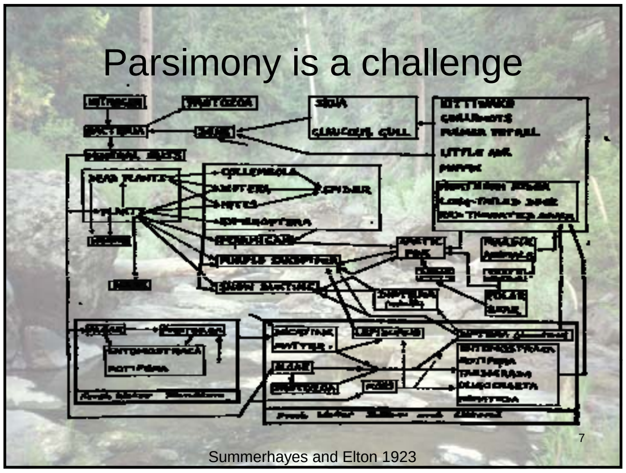

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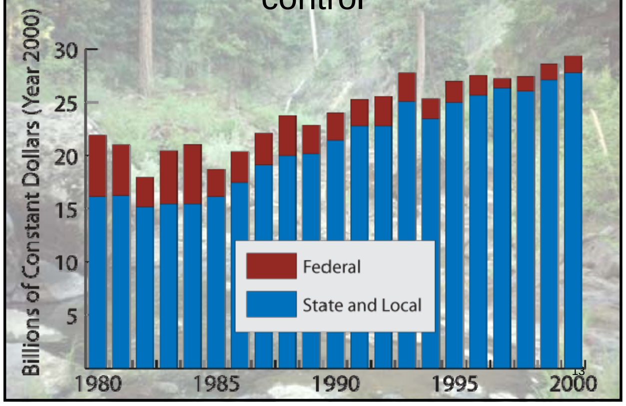
We spend a lot on water pollution control



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Can we answer simple questions?

1. What's the current status of streams?
2. Are streams improving?
3. Which places are in most need of attention?
4. Which stressors are in most need of attention?
5. What if…?
6. What are the connections between human well-being and streams?

14

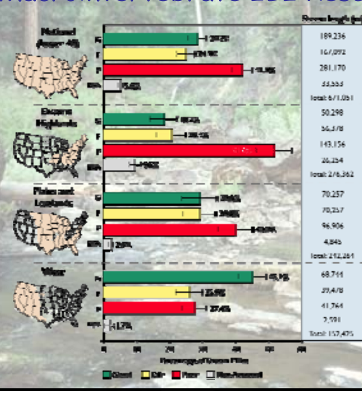
Existing Monitoring Programs Fall Short

- 1981 -- "..reports .. are not reliable" GAO
- 1984 -- "The greatest shortcoming… lack of a detailed approach that specifies why monitoring is done and what will be done with the results. Perry et al
- 1998 – "…reports do not represent an accurate picture of status for all waters and cannot be used to describe trends in the number of impaired water bodies." Paulsen et al
- 2000 -- "Key EPA and State Decisions Limited by Inconsistent and Incomplete Data" GAO
- 2002 -- "A lack of information about actual environmental conditions … has been a major obstacle to improving the effectiveness of state water quality programs" NAPA

15

Wadeable Streams Assessment

Macroinvertebrate IBI Results



16

The Clean Water Act Motivates the Reporting Goal

- Sec. 101. (a) "The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."
- Sec. 305. (b) Annual state reports on the extent to which waters "provide for the protection and propagation of a balanced population of shellfish, fish, and wildlife, and allow recreational activities in and on the water"

17

Why Biological Indicators: Ecological Understanding

- Long track record
  - 1894 Illinois State Laboratory of Natural History
    - "..objects of our Station…to prevent progressive pollution of our streams and lakes" (from Davis 1995)
- Integrates stressors over longer times and larger areas
- Diagnostic

18

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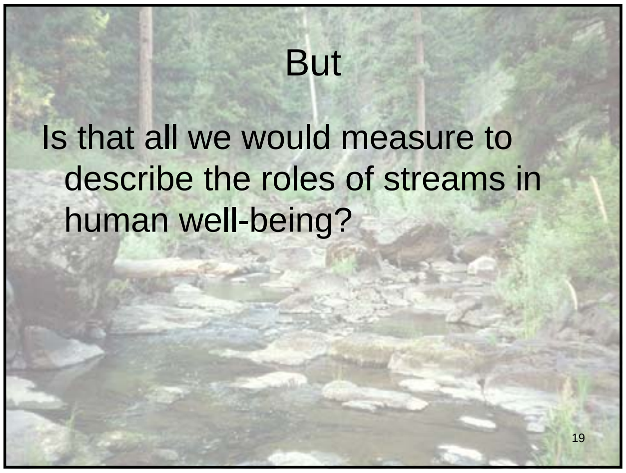

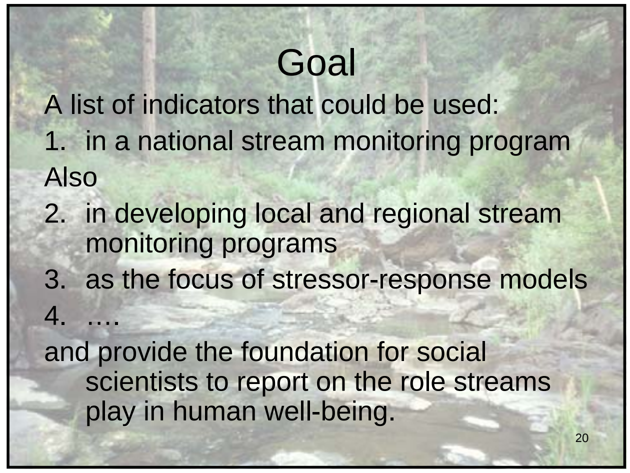

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Slide Number

Why Are We Here?
The Social Science Version

Jim Boyd

1

What We Want

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

2

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

3

Core Questions

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

4

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?

5

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 foundation
  - What is nature's state and what is changing?

1	2
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Slide Number

Problem

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

7

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

8

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?

9

(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?

10

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

11

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	2
3	4
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Slide Number

Post-Meeting Proof of Concept

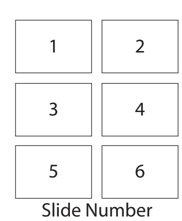
- Collaborations and coordination
- Convergence on language, principles, and measures
- Transfer of insights to other resource types?
- Pilots and practical deployment

13

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

14



Economics 101

Jim Boyd

1

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

2

What is Human Welfare?

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

3

How to Detect Changes in Welfare?

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

4

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

5

Willingness to Pay

- Consider a choice
- If you are "willing to pay" X for choice A and Y for choice B
- And if X > Y
- We infer that you prefer A to B

1	2
3	4
5	6

Slide Number

Willingness to Pay

- Consider a choice
- If you are "willing to pay" X for choice A and Y for choice B
- And if X > Y
- We infer that you prefer A to B

How do we detect willingness to pay?
In a minute, but first…

7

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.

8

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?

9

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, 100-point scale, thermometer readings could also work

10

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

11

What Is Valuable?

- We seek to detect, reveal, uncover social values,
- We do not impose those values
- Ways of knowing: Psychology, marketing, anthropologists (other social scientists)

1	2
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Slide Number

Economic Valuation In Practice

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

13

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)

14

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)

16

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

17

The Benefit Pie

- What is the value of a stream reach?
  - A <u>collection</u> of benefits
  - Enjoyed by different groups users
- Need a <u>suite</u> of detection methods
  - Each is its own sub-discipline

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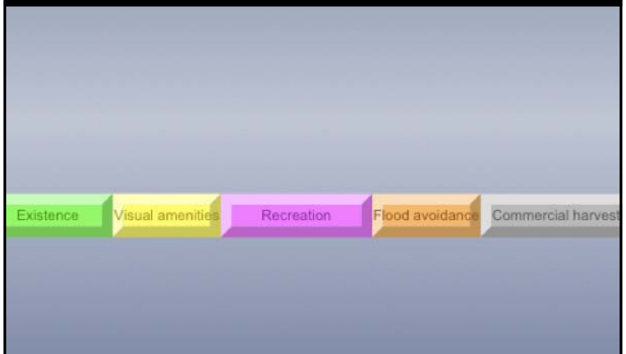
Slide Number

The (Partial) Benefit Pie



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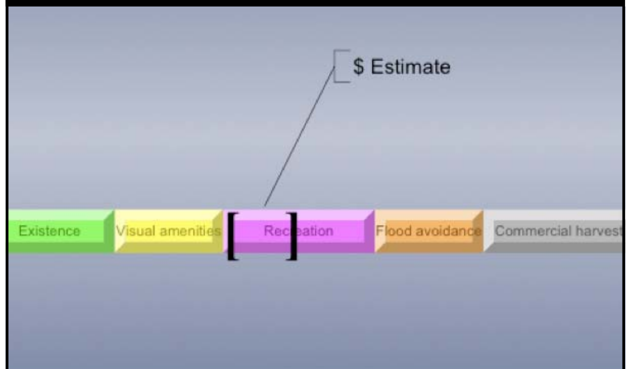

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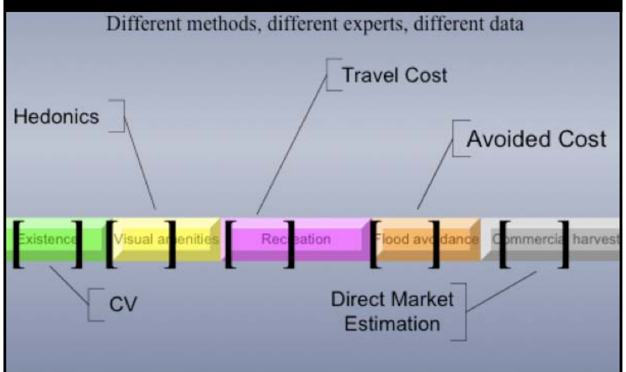

21

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

22

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)

23

Other Methods

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

1	2
3	4
5	6

Slide Number

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

25

All Social Methods

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

26

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

27

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

28

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

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Slide Number

Introduction to Stream Monitoring

Dixon H. Landers
USEPA/Western Ecology Division
Corvallis, OR

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Topics

- Stream Basics
- Monitoring Questions/Issues
  - Scales
  - Design tradeoffs
  - Indicators
  - Products

Topics

- Stream Basics
- Monitoring Questions/Issues
  - Scales
  - Design tradeoffs
  - Indicators
  - Products

A few stream basics

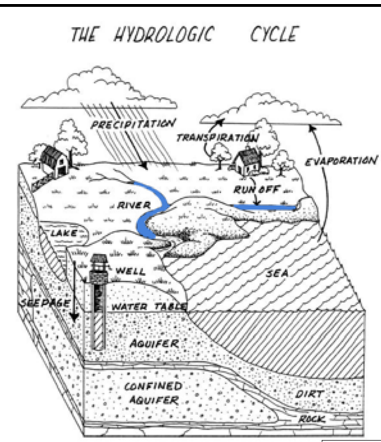
- What is a stream
- Stream perspectives
- Broad range of stream types

One Definition of a Perennial Stream

- An annually permanent, linear body of flowing surface water.
  - This would include the Mississippi River and concrete channelized drainage canals in the city of Los Angeles.
  - Identifying a *universal* population of streams can be difficult and is definition driven.

5

Streams are one component in the hydrologic cycle



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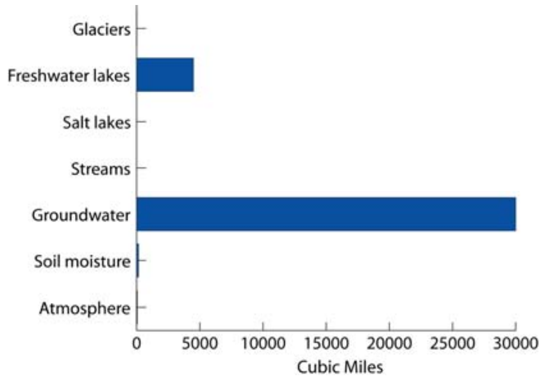
5	6

Slide Number

Streams don't hold much water



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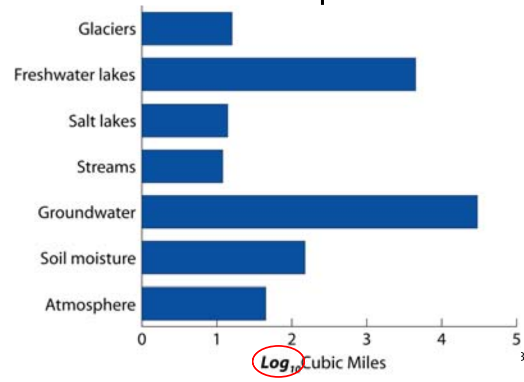
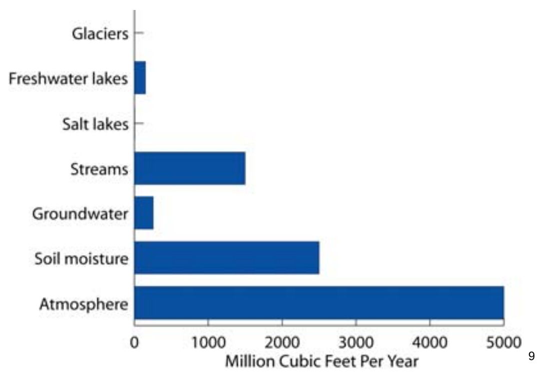
Orders of Magnitude Less Volume than other inland components



8

But, if we change the indicator…



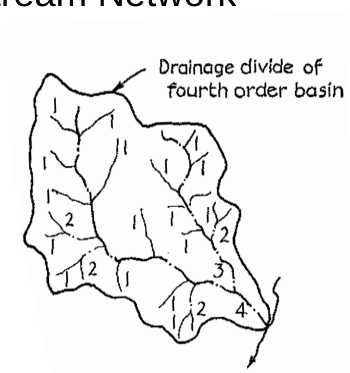
9

The Great Variability of Streams in Space and Time Has IMPORTANT Implications for

- Field Protocols
- Assessment Methods
- What do measurements at one time or place mean for other times and places?

10

Stream Network



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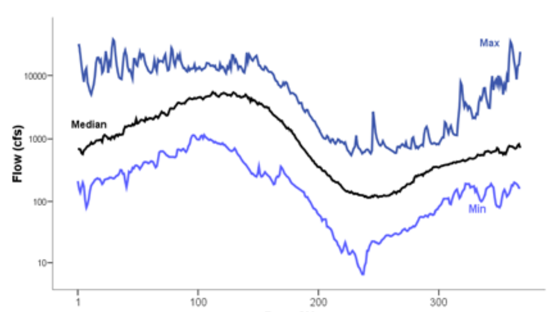
Seventy Years

John Day River, OR



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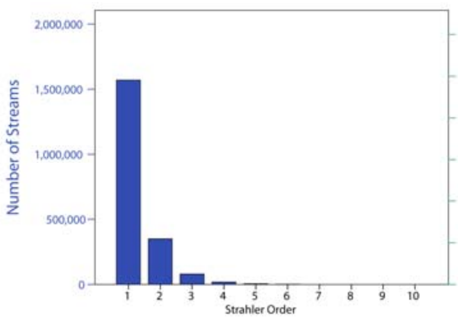
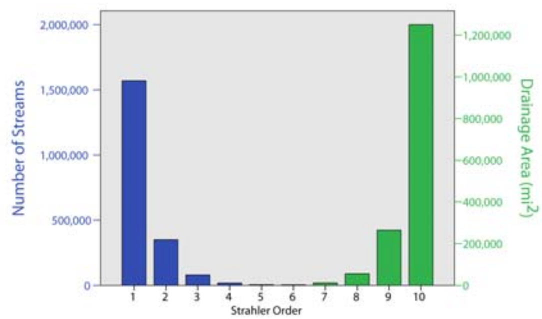
3	4
5	6

Slide Number

Most Streams are Small



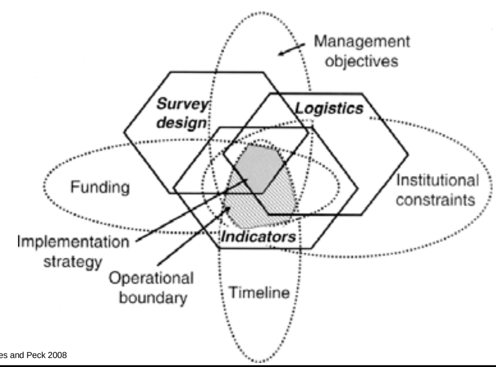
A few streams drain large areas



Topics

- Stream Basics
- Monitoring Questions/Issues
  - Scales
  - Design tradeoffs
  - Indicators
  - Products

Monitoring Program Tradeoffs



From Hughes and Peck 2008

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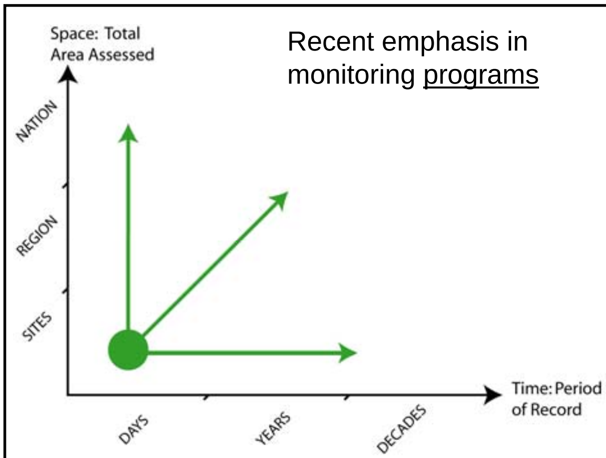
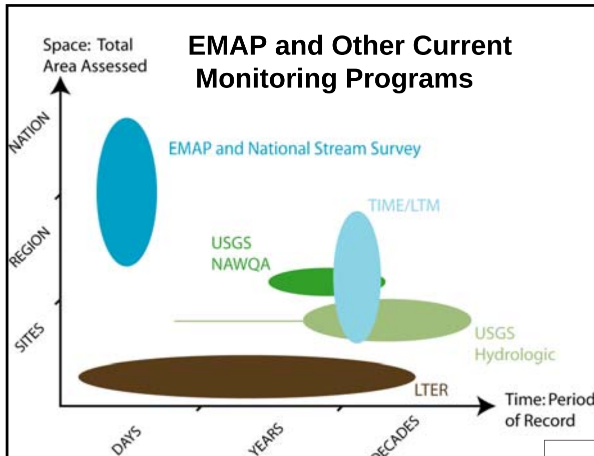
Recent emphasis in monitoring <u>programs</u>



EMAP and Other Current Monitoring Programs



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Slide Number

Goals – EMAP West

2000 – 2004   12 Western States

- Demonstration for streams in a large region
  1. assessment of ecological condition
  2. associations with stressors
- Components
  1. Reporting goals
  2. Sample design and tradeoffs
     - Site selection
     - Field methods
  3. Assessment methods

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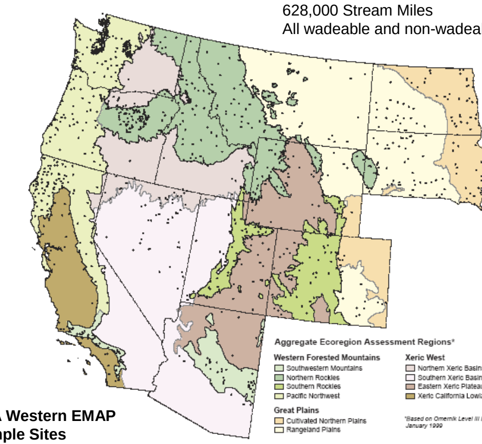
628,000 Stream Miles
All wadeable and non-wadeable streams



EPA Western EMAP Sample Sites

20

Attributes of Indicators

- Conceptual Relevance
- Feasible Implementation
- Meaningful Signal
- Understandable
  - Scientists
  - Managers
  - Public

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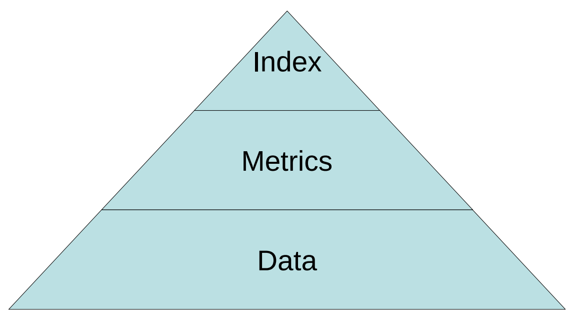
Terminology and Approach



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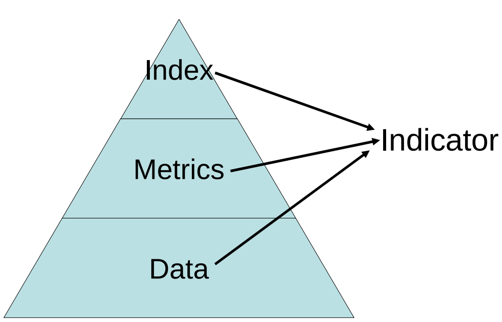
Terminology and Approach



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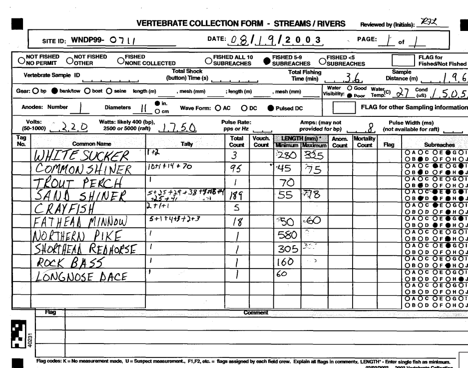
Data



VERTEBRATE COLLECTION FORM - STREAMS / RIVERS   Reviewed by (Initials): RJL

SITE ID: WNDP99- 0711   DATE: 08/19/2003   PAGE: 1 of 1

NOT FISHED NO PERMIT / NOT FISHED OTHER / FISHED NONE COLLECTED / FISHED ALL 10 SUBREACHES / FISHED 5-9 SUBREACHES / FISHED <5 SUBREACHES / FLAG for Fished/Not Fished

Vertebrate Sample ID ____ Total Shock (button) Time (s) ____ Total Fishing Time (min) 36 Sample Distance (m) 196

Gear: bp / bank/tow / boat / seine length (m) ____, mesh (mm) ____; length (m) ____, mesh (mm) ____ Water Visibility: Good / Poor Water Temp. (C) 27 Cond (uS) 1505

Anodes: Number 1 Diameters 11 in. / cm Wave Form: AC / DC / Pulsed DC FLAG for other Sampling information

Volts: (50-1000) 220 Watts: likely 400 (bp), 2500 or 5000 (raft) 1750 Pulse Rate: pps or Hz ____ Amps: (may not provided for bp) 8 Pulse Width (ms) (not available for raft) ____

Tag No.	Common Name	Tally	Total Count	Vouch. Count	LENGTH (mm)* Minimum	LENGTH (mm)* Maximum	Anom. Count	Mortality Count	Flag	Subreaches
	WHITE SUCKER	1+2	3		280	325				
	COMMON SHINER	10+1+14+70	95		45	75				
	TROUT PERCH	1	1		70					
	SAND SHINER	5+25+29+38+[illegible] +25+4[illegible]	189		55	78				
	CRAYFISH	2+1+1	5							
	FATHEAD MINNOW	5+1+4+3+2+3	18		50	60				
	NORTHERN PIKE	1	1		580					
	SHORTHEAD REDHORSE	1	1		305					
	ROCK BASS	1	1		160					
	LONGNOSE DACE	1	1		60					

Flag | Comment

40231

Flag codes: K = No measurement made, U = Suspect measurement., F1,F2, etc. = flags assigned by each field crew. Explain all flags in commentx. LENGTH* - Enter single fish as minimum.
02/03/2003 2003 Vertebrate Collection

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Slide Number

Metrics

- Number of Non-Tolerant Species Corrected for Stream Size
- Proportion of Individual Fish that are Alien

25

Index

- Vertebrate: Index of Biotic Integrity = 37.53

26

Categories of EMAP Metrics

- Benthic Macroinvertebrates
- Aquatic Vertebrates
- Water Chemistry
- Physical Habitat
- Fish Tissue Contaminants (Metals)
- Invasive Riparian Plants
- Other Non-Native Species

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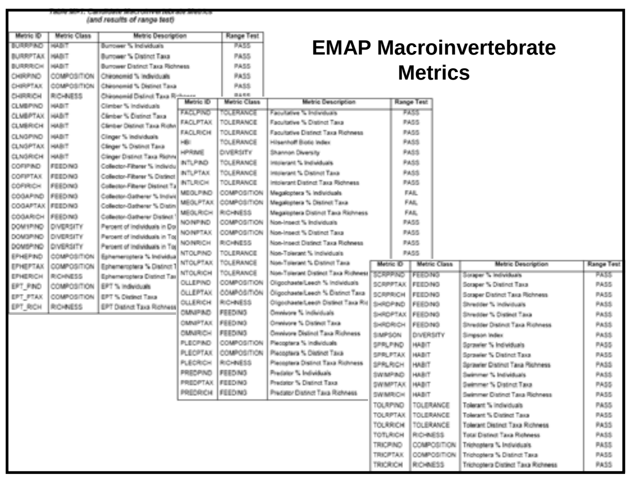
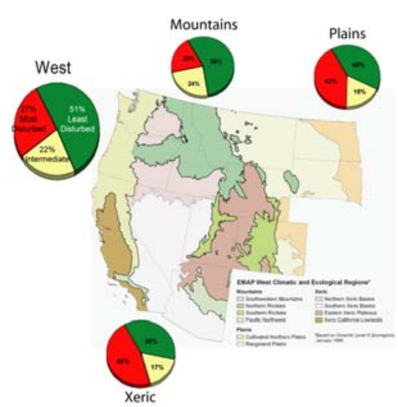
EMAP Macroinvertebrate Metrics



EMAP Physical Habitat and Fish Metal Metrics

- Habitat Volume (CDF Figures PHAB-1 to 14):
- Scaled Habitat Volume (CDF Figures PHAB-15 to 28):
- Habitat Complexity and Cover for Aquatic Biota (CDF Figures PHAB-29 to 126):
- Streambed Particle Size (CDF Figures PHAB-127 to 168):
- Scaled Bed Particle Size (CDF Figures PHAB-169 to 210):
- Relative Bed Stability (CDF Figures PHAB-211 to 224):
- Channel-Riparian and Floodplain Interaction (CDF Figures PHAB-225 to 280):
- Hydrologic Regime and Hydrologic Alteration (CDF Figures PHAB-281 to 308):
- Riparian Vegetation (CDF Figures PHAB-309 to 350):
- Riparian Vegetation Alteration (CDF Figures PHAB-351 to 364):
- Riparian Human Disturbances (CDF Figures PHAB-365 to 434):

Contaminant	Fish Class	Figure Numbers	Naming Code Used in CDFs	Comments
Mercury	Piscivores	FT Hg P-1..4	Hg_Pisc_ug.g	Sample sizes too small for reporting in 10 aggregate ecoregions
	Non-Piscivores	FT Hg NP-1..14	Hg_NonPisc_ug.g	Reported at 3 geographic scales
	Small Fish	FT Hg S-1..14	Hg_Small_ug.g	Reported at 3 geographic scales
Metals (Pb, Cd, Zn)	Piscivores	FT Mtl P-1..9	Pb_Pisc_ug.g Cd_Pisc_ug.g Zn_Pisc_ug.g	Sample sizes too small for reporting in 10 aggregate ecoregions, or for Xeric region
	Non-Piscivores	FT Mtl P-1..42	Pb_NonPisc_ug.g Cd_NonPisc_ug.g Zn_NonPisc_ug.g	Reported at 3 geographic scales
	Small Fish	FT Mtl S-1..42	Pb_Small_ug.g Cd_Small_ug.g Zn_Small_ug.g	Reported at 3 geographic scales



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Slide Number

Ecological Measures for Social Analysis

Jim Boyd

1

Desired Characteristic for Ecological Measures

- Biophysical measures, indicators that are…
- Easy for non-scientists to interpret
- Directly or tangibly used by
  - Households
  - Recreators
  - Plant operators
  - Farmers
  - Planners and politicians

2

Natural Science Indicators

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

3 3

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?

4 4

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"

Translation into what?

5 5

Examples

Input	Biophysical Process	Ecological Endpoint
Surface water pH	Habitat and toxicity effects	Fish, bird abundance
Acres of habitat	Forage, reproduction, migration	Species abundance
Wetland acres	Hydrologic processes	Flood severity
Urban forest acres	Shading and sequestration	Air quality and temperature
Vegetated riparian border	Erosion processes	Sediment accumulation in reservoirs

1	2
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5	6

Slide Number

Examples

Input	Biophysical Process	Ecological Endpoint
Surface water pH	Habitat and toxicity effects	Fish, bird abundance
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Vegetated riparian border	Erosion processes	Sediment accumulation in reservoirs

Natural science indicators — Biophysical production functions — Social science indicators

7

Definition

Two interchangeable terms
(1) Ecological Endpoints
(2) Indicators of final ecosystem goods & services

Biophysical features, quantities, qualities that require little further translation to make clear their relevance to wellbeing

8

Definition

Two interchangeable terms
(1) Ecological Endpoints
(2) Indicators of final ecosystem goods & services

Many/most natural science indicators don't meet definition

Biophysical features, quantities, qualities that require little further translation to make clear their relevance to wellbeing

9

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 species and their abundance

10

Who Decides What These Endpoints Are?

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

11

Endpoints: Market vs. Ecological Goods


Obvious


Not obvious

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1	2
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Slide Number

1. A system of production
Biophysical features that constantly interact

2. Goods we "consume"
The system's endpoints

13 13

Our Philosophy

- Keep measuring what we already measure
- But add to the suite of measures
  - Endpoints to facilitate social assessment
- Methods to link the two

14

Ecological Production Theory

- Inputs transformed into outputs via natural processes
- As a gross generalization
  - Biophysical inputs (natural science indicators)
  - Biophysical outputs (natural science indicators)
    - A subset of outputs
    - Final goods and services (ecological measures for social analysis

15

Examples

Inputs	Process	Output
Precipitation Land cover Soils	Hydrological	The hydrograph (speed, depth, timing, location of surface
Water quality Land cover	Biological and chemical	Water quality
Habitat characteristics	Forage, reproduction, predation	Species abundance

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An Inconvenient Truth: Dual Measures

- Many ecological commodities are *both* endpoint and input
  - Example
    - Water clarity (may be desirable as an end in itself)
    - But may *also* be
      - A signal of other conditions (anoxia)
      - An input to other biophysical production (seagrass)

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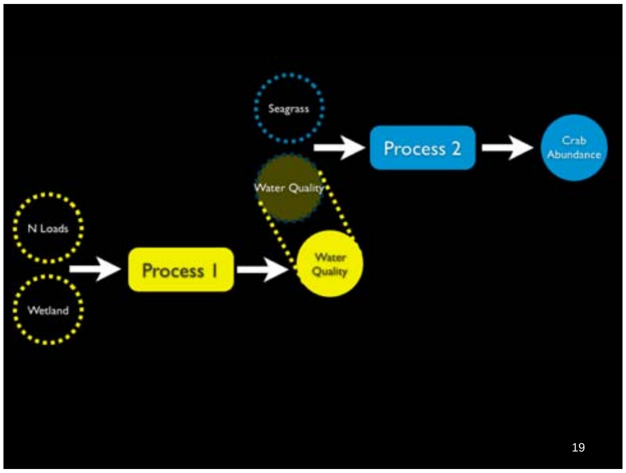
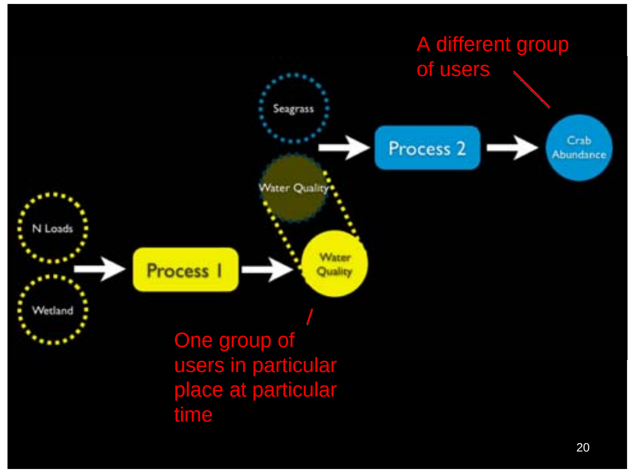
Examples

Endpoint	Biophysical Process	Different Endpoint
Trout abundance	Forage and predation relationships	Bird abundance
Forest acres	Hydrological processes	Species abundance
Wetland acres	Hydrologic processes	Flood pulse regulation

1	2
3	4
5	6

Slide Number





Think about "Users"

- The social science mindset
- A way to identify endpoints that are directly used, enjoyed
  - "final goods and services"
- Helps organize the natural system into a system of production

21

Some History & a Metaphor for Us

- Medical science in the 1960s
  - Inhaled particulate matter reduces "oxygen transfer rates in the lung"
  - Are oxygen transfer rates an endpoint/final good or service?
- What is the value of oxygen transfer rates?
  - Answer requires further biophysical translation

22

Public Health Endpoints

- Premature mortality
- Chronic bronchitis
- Hospital admissions
- Asthma attacks

No further translation necessary
Thus, amenable to social analysis

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.

1	2
3	4
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Slide Number

These Public Health Endpoints as Metaphor

- The linkage between health science and social analysis
- The way actions are justified
- Politically/socially influential

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Slide Number

How Can We Use The Final Services Concept In Monitoring Design?

July, 2009
Paul L. Ringold
US EPA, ORD, NHEERL
Western Ecology Division, Corvallis, OR

1

Key Questions

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

2

A Working Hypothesis to Defining Indicators of Final Services

- Identify significant user categories
- Identify direct or tangible uses for each user category
  – Stream Components
    - Indicators

3

An Example for One User Category

- Catch and release angler
  – Stream Component 1: Taxa and sizes of fish
  – Stream Component 2: Aesthetics of location
  – Stream Components 3…n?

One Example

- Catch and release angler
  – Stream Component 1: Taxa and sizes of fish
    - Presence, abundance, P(catch), Catch per unit effort?
  – Stream Component 2: Aesthetics of location
    - Visual features, odor, noise…
  – Stream Components 3…n?

One Example

- Catch and release angler
  – Stream Component 1: Taxa and sizes of fish
  – Stream Component 2: Aesthetics of location
  – Attributes 3…n?
- Choice, tradeoff or value
  – Measures of individual attributes, or Integrated measure

1	2
3	4
5	6

Slide Number

One Example

- Catch and release angler
  - Stream Component 1: Taxa and sizes of fish
  - Stream Component 2: Aesthetics of location
  - Attributes 3…n?
- Choice, tradeoff or value
  - Measures of individual attributes, or integrated measure

Social Science Research Question

Second Example

- Irrigation Water
  - Stream Component 1: Water Quantity and Timing
  - Stream Component 2: Chemistry
  - Stream Component 3: Biology?

Second Example

- Irrigation Water
  - Stream Component 1: Water Quantity and Timing
    - Water availability, or
    - Water use
  - Stream Component 2: Chemistry
    - Salinity, Selenium….
  - Stream Component 3: Biology?
    - Absence of pathogens
    - Absence of T&E species

Working Hypothesis Part 1: "User" Categories

7 Categories	Number of Subcategories
Agriculture	5
Industry	7
Municipal	2
Non-Use	0
Recreational Use	3
Spiritual/Cultural	0
Transportation	2
	19

10

"User" Categories and Subcategories (1/2)

- Agriculture
  - Irrigation, Livestock, Aquaculture, Processing, Grazing
- Industry
  - Cooling water, Processing, Mining, Hydro, Extracting, Receiving, Consumption
- Municipal
  - Drinking Water Source, Receiving

11

"User" Categories and Subcategories (2/2)

- Non-Use
- Recreation
  - Water contact, Viewing, Extracting
- Spiritual/Cultural
- Transportation
  - Commercial, Tourism/Recreation

1	2
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5	6

Slide Number

Working Hypothesis Part 2: Stream Components

- Quantity
- Physical Qualities
- Chemical
- Biological
- Landscapes

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Working Hypothesis Part 2: Stream Components

- Quantity
  - Amount, Timing….
- Physical Qualities
  - Temperature, Conductivity, Stream Bed, Clarity….
- Chemical
  - Chemical Water Quality Criteria, Odor….
- Biological
  - Pathogens, Ecosystem Health, Fish, Wildlife, Plants….
- Landscapes
  - Human Experience Shed….

14

Identify Direct Uses

		Stream Components			
		Quantity	Chemical	Biological	Landscape
User Categories	Agriculture				
	Industry				
	Municipal				
	Non-Use				
	Recreation				
	Spiritual / Cultural				
	Transportation				

15

Identify Direct Uses

		Stream Components			
		Quantity	Chemical	Biological	Landscape
User Categories	Agriculture	✓	✓		
	Industry	✓	✓		
	Municipal	✓	✓		
	Non-Use	✓		✓	✓
	Recreation	✓	✓	✓	✓
	Spiritual / Cultural			✓	✓
	Transportation	✓			

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Working Hypothesis

Stream Attributes Posited to be a components of Indicators of Final Ecosystem Service to Specific User Categories and Subcategories

March 18, 2009

		Quantity		Quality Physical				Chemical			Biological					Landscapes
	Human "Use" Categories and Subcategories	Amount	Timing	Temperature	Conductivity	Stream Bed	Clarity	Dissolved Oxygen	Chemical Water Quality Criteria	Odor	Pathogens	Ecosystem Health / Biotic Integrity	Fish	Wildlife	Plants	Human "Experience Shed"
I	Agriculture															
	a) Irrigation	✓	✓		✓						✓					
	b) Livestock	✓	✓													
	c) Aquaculture	✓	✓	✓				✓	✓		✓					
	d) Processing	✓	✓	✓					✓				✓	✓	✓	
	e) Grazing	✓	✓		✓						✓		✓	✓	✓	
II	Industry															
	a) Cooling Water	✓	✓	✓									✓	✓	✓	
	b) Processing	✓	✓	✓					✓				✓	✓	✓	
	c) Mining	✓	✓													
	d) Hydroelectric	✓	✓													
	e) Extracting (Sand and Gravel)	✓	✓			✓										
	f) Discharge	✓	✓	✓			✓	✓	✓	✓			✓			
	g) Extraction for Consumption												✓	✓	✓	
III	Municipal															
	a) Drinking Water Source	✓	✓						✓	✓	✓					
	b) WWTP Sink	✓	✓	✓			✓	✓	✓				✓	✓	✓	
IV	Non-Use															
	a) Existence/Option/Bequest	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
V	Recreational Use															
	a) Water Contact	✓	✓	✓			✓			✓	✓					✓
	b) Viewing						✓			✓			✓	✓	✓	✓
	c) Extracting												✓	✓	✓	✓
VI	Spiritual/Cultural	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
VII	Transportation															
	a) Commercial	✓	✓													
	b) Tourism/Recreation	✓	✓	✓			✓			✓			✓	✓	✓	✓

✓ This attribute is posited to be of direct use to specific user categories

This attribute is posited to not be of direct use to specific user categories

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Not Just Individual Indications

- Interpretation
- Aggregation
- Temporal and Spatial Scales

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Indicators and Spatial Scales

- User definition of a site?
- Ecological definition of a site
  - – Asymptote in Metric – Effort Curve
  - – Capture sufficient natural variability
  - – Best Professional Judgment

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Additional Biophysical Measures to Support Welfare Assessment?

- Substitutes
  - – Relevance, location, function
- Complements
  - – Access infrastructure
- Definitions vary by user category?

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Questions

- Useful approach?
  - ➢ No → Alternative to identifying a full set of indicators?
- Modify user categories?
  - ➢ Yes → Substantively different indicator
  - ➢ Yes → Substantial additional user category
- Modify stream attribute categories?
  - ➢ Yes → Substantively improve capacity to understand human welfare
- More Examples?

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Specific Measures of Final Ecosystem Services for Streams

I. Water Quantity

A. Amount
Flow is important for many user categories.
B. Timing
The occurrence and predictability of flows above or below certain thresholds are likely to be important for many user categories.

II. Water Quality – Physical

A. Temperature
Water temperature is a comfort issue for user categories that involve water contact; in some cases a safety issue.
B. Conductivity
Water with high conductivity can salinize agricultural land and raise water treatment costs.
C. Stream Bed
Sediment accumulation can inhibit hydroelectric generation. For swimmers (Vb) or other stream visitors aspects of the streambed are important. People don't want to contact a muddy channel. Mud can also inhibit livestock from freely transitting streams. Large rocks such as rip-rap can also make stream access difficult. For several categories (VII, and Vd) stream navigability is important. Measures for navigability include width and depth of the main channel, presence of any obstructions (i.e. downed trees), and class of any rapids.
D. Clarity
Many user categories care about water clarity. Recreationalists usually prefer higher water clarity.

III. Water Quality – Chemical

A. Dissolved Oxygen
Dissolved oxygen may not be widely understood by the public but is directly relevant for some user categories such as aquaculture (Ic).
B. Chemicals
The presence of persistent chemicals could negatively impact organic agriculture.
C. Odor
Disagreeable odors can negatively impact many user categories.

IV. Water Quality – Biological

A. Pathogens
People care about the probability of getting sick from partial or full contact with the stream. E Coli poisoning is one example.

B. Ecosystem Health / Biotic Integrity

"Naturalness" and "Ecosystem Health" are frequently stated desires especially within the non-use category.

C. Fish

For anglers (Category V.c) appropriate indicators would include abundance of desired taxa and sizes of fish and their appearance. For anglers consuming fish the presence of contaminants would also be important. Biofouling which can arise from fish, wildlife or plants is important for water intake users, but especially for IIa, IIb, and IIIa.

D. Wildlife

Typically the presence of wildlife is positive. Biofouling which can arise from fish, wildlife or plants is important for water intake users, but especially for IIa, IIb, and IIIa.

E. Plants

Different user categories may enjoy seeing riparian vegetation, and may have preferences for specific species. Biofouling which can arise from fish, wildlife or plants is important for water intake users, but especially for IIa, IIb, and IIIa. Some plants interfere with grazing.

V. Landscapes

A. Aesthetics (Human "Experience Shed")

A measure that represents all five senses is important. Studies exist that have developed aesthetic indices. The presence of garbage reduces aesthetic enjoyment. Sometimes particular groups of people care about very specific things so an exhaustive list of specific measures is difficult.

B. Genetic Diversity

Maintaining genetic diversity has been tied to nonuse values, a category which includes existence, option, and bequest values. The Education and Research user category also has a stake in genetic diversity.