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THE WEALTH OF NATURE: VALUING ECOSYSTEM SERVICES

by

A. Myrick Freeman III
William D. Shipman Professor of Economics Emeritus
Bowdoin College

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I. Introduction

In May, 2009, the U. S. Environmental Protection Agency (EPA) released a report titled "Valuing the Protection of Ecological Systems and Services" (U.S. EPA, 2009). I was a member of the EPA Science Advisory Board's Committee on Valuing the Protection of Ecological Systems and Services (C-VPESS) that produced the Report. In this paper, I will try to clarify what we mean by the terms "ecosystem services," "value," and "the wealth of nature." I will also try to see what lessons can be drawn from the C-VPESS Report and the 5 years of Committee deliberations that lie behind it and what conclusions and implications this work has for EEPSEA researchers working in the field of the economics of natural resources.[1]

II. C-VPESS:

The Committee was formed in October 2003. Its charge was to:

- assess EPA's needs for valuation to support decision making;
- assess the state of the art and science of valuing the protection of ecological systems and services; and
- identify the key areas for improving knowledge, methodologies, practice, and research at the Agency (U.S. EPA, 2009, p. 2)

I think that part of the motivation for EPA's Science Advisory Board to create the C-VPESS was to respond to the perception in some circles that EPA was unwilling to include values for impacts

[1] The views expressed in this paper are my own and do not necessarily reflect the views of the Committee as a whole.

on ecosystems in its assessments of the benefits and costs of regulatory actions.[2]

The Committee initially had 27 members, five of whom dropped out along the way for various reasons. The 22 who signed the final report included six economists, eight ecologists/biological scientists, three philosophers, two psychologists, and an attorney, among others. This diversity of disciplinary backgrounds made reaching consensus on some issues difficult but led to some very interesting discussions. The report itself runs over 100 pages; and there are another 320 pages of supplementary materials posted on the SAB web page.[3] Yet, I think that the most important conclusions and recommendations can be boiled down to a relatively few statements, as I will try to do here.

III. Concepts

A. Ecosystem Services: Ecosystem services have been defined in various ways in the literature. EPA has defined them as: "those ecological functions or processes that directly or indirectly contribute to human well-being or have the potential to do so in the future (U.S. EPA 2004, p. 4)." Ecologist Gretchen Daily defined them as:

> the conditions and processes through which natural ecosystems sustain and fulfill human life. They maintain biodiversity and the production of *ecosystem goods*, such as seafood, forage, timber . . . and their precursors . . . In addition to the production of goods, ecosystem services are the actual life-support functions, such as cleansing, recycling, and renewal, and they confer many intangible aesthetic and cultural benefits as well (Daily

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[2] I was present at one meeting of another Committee of the Agency's Science Advisory Board about 15 years ago when an ecologist said something to the effect that "You people use the value of a statistical life to measure the benefits of improving human health. Why can't you use the value of a statistical rabbit to measure the benefits of improved ecosystem health?"

[3] See, http://yosemite.epa.gov/sab/sabproduct.nsf/WebBoard/CVPESS_Web_Methods_Draft?OpenDocument

1997, 3).

She went on to list examples of ecosystem services (Daily (1997, 3–4):

purification of air and water

mitigation of floods and droughts

detoxification and decomposition of wastes

generation and renewal of soil and soil fertility

pollination of crops and natural vegetation

control of the vast majority of agricultural pests

dispersal of seeds and translocation of nutrients

maintenance of biodiversity, from which humanity has derived key elements of its

agricultural, medicinal, and industrial enterprise

protection from the sun's harmful ultraviolet rays

partial stabilization of climate

moderation of temperature extremes and the force of winds and waves

support of diverse human cultures

provision of aesthetic beauty and intellectual stimulation that lift the human spirit

Other authors (e.g., Costanza, d'Arge, et al. 1997) have added to the list such things as erosion control, habitat or refugia for species, and production of food and raw materials.

The Millennium Ecosystem Assessment (2003, p. 8) added to this conceptual framework by identifying four categories of service streams: provisioning, regulating, supporting, and cultural. Provisioning services are the flows of goods such as food, fiber, fuels, and so forth that stem from the primary and secondary productivity of ecological systems. These service streams are usually easily identified and the most apt to be governed by market interactions. Regulating services are the benefits people obtain from the regulation of ecosystem processes such as the maintenance of air quality and climate regulation. Supporting services are those that are necessary for all other ecosystem services. Supporting services provide the tools (for example, oxygen and nutrients), while regulating services do the work (atmospheric regulation). Supporting services are sometimes called “ecosystem functions.” Finally, cultural services provide benefits through recreation and other highly subjective activities like spiritual enrichment and aesthetic experience.

A careful inspection of this list and these definitions shows a strong possibility of double counting of service flows, especially between some of the supporting services and the provisioning services.[4] For example, waste decomposition is the source of the nutrients that support the bottom of the food chain and whose value eventually gets embodied in the value of the plant and animal species that are harvested for human consumption. Similarly, the value of pollination services is eventually embodied in the value of harvested plant crops. In recognition of this potential for double counting, Boyd and Banzhaf offered a more limited definition:

> Ecosystem services are components of nature, directly enjoyed, consumed, or used to yield human well-being (Boyd and Banzhaf, 2006, p. 8).

This definition makes it clear that only final products and not intermediate products and services are to be counted.

This emphasis on final vs. intermediate services also calls attention to another issue to be addressed in the identification and valuation of ecosystem services. Most of the provisioning and

[4] For examples of this type of double counting, see Costanza, d’Arge, et al. (1997).

cultural services identified by the Millennium Ecosystem Assessment are actually produced by combining ecological outputs with human labor and capital. The costs of these non-ecological inputs must be deducted from the value of the food, fiber, fuels, and recreation in determining the value of the ecosystem service itself.[5] This deduction is necessary in arriving at the value added by the ecosystem service. Thus the value of the ecosystem service is essentially the net economic rent attributable to this dimension of nature. And those economists estimating the values of fish and forest harvests have been engaged in valuing one type of ecosystem service.

So, one lesson to be taken from this view of ecosystem services is the necessity to avoid double counting of service flows. The other lesson is the importance of thinking carefully and clearly about how to identify and define the ecosystem services of interest.

B. Value: The C--VPESS spent a great deal of its time discussing just what was meant by the term "value" and which concepts of value were relevant to the consideration of ecosystem services. There was general agreement to focus on an instrumental concept of value, that is, value as the contribution of something toward some goal. The Committee attempted to develop a taxonomy of relevant concepts of value and eventually agreed to distinguish between preference-based values and biophysical values. The former " ... reflect individuals' preferences across a variety of goods and services, including (but not limited to) ecosystems and their services ... [while the latter] ... reflect contributions to explicit or implicit biophysical goals ..." such as biodiversity or the impact of an ecological change on energy or materials flows out of and into ecological systems (U.S. EPA, 2009, pp. 13-14). Biophysical values were given relatively little attention in the Report at least in part because of the skepticism about their relevance for policy

[5]Again, see Costanza, d'Arge, et al. (1997) for examples of including the values of labor and capital inputs in estimates of ecosystem service values.

making.

Preference-based values include economic values. In economics, value is a measure of the contribution of something to human welfare. Thus the economic value of an ecosystem service is its contribution to human welfare, where human welfare is measured in terms of each individual's assessment of his or her own well-being. Economic values are based on individuals' preferences or consumer sovereignty - (See Costanza and Folke, 1997, and Freeman 2003 for example). Economic values can include both use and nonuse values. Economic values are based on the assumptions that people are rational actors, that they have preferences over alternative outcomes, and that the choice of one outcome over another implies that the chosen outcome results in a higher level of well-being for the individual. Economic values are revealed by the choices that individuals make, either in real world choice situations or in responses to hypothetical questions. Economic values are normally expressed in monetary units. Economic values are based on a coherent theory of welfare economics that allows comparison of the values of ecosystem services with the values of other services produced through environmental policy changes (for example effects on human health) and with the costs of those policies.

Some Committee members expressed reservations about th e view of "nature as a factory" whose value lay in making things for people. Others were skeptical of the link between preference satisfaction and welfare or well-being, the assumption of rational and stable preference orderings, and people's ability to make consistent choices and tradeoffs, especially regarding unfamiliar goods and services. As a consequence, the Committee identified three other types of preference-based values:

- Attitude or judgment-based values which can be measured in multiple dimensions and are based on empirically derived descriptive theories of human attitudes, preferences and behavior. They are usually based on responses to survey questions and are typically expressed in non-monetary terms.

- Constructed preference based values which use some structured process such as multi-attribute utility theory as a way of assisting respondents in learning about the ecological services to be valued and constructing their preferences and values. These values can be expressed in either monetary or non-monetary terms.
- Community-based values which are based on the assumption that when placed in a position of making choices about public goods, individuals make their choices based on what they think is good for society as a whole rather than what is good for them as individuals. In other words, people base their choices on their conception of social preferences or community-based preferences rather than their individual preferences; and they could place a positive value on a change that reduced their individual well-being. See, for example, Jacobs (1997), Costanza and Folke (1997), or Sagoff (1998). The values reflected by these preferences would be revealed through some sort of structured deliberative or participatory decision making process involving open discussion. These values also can be expressed in either monetary or non-monetary terms.

The Committee noted that none of these alternative values are commensurate with measures of economic costs. Nor can they be compared with each other since they are based on different sets of assumptions and premises. The Committee recognized that values expressed by individuals engaged in a structured process or by groups engaged in a deliberative process are likely to be influenced by the process itself.

The most important lesson that I took away from this part of the Committee's work is that not all of the scientists from the academic disciplines that must be relied upon in valuing ecosystem services share the economists' commitment to the anthropocentric perspective on value. Nor do they all accept the assumptions of well-formed and stable preference orderings and rational choice that underlie our methods of economic valuation. The same thing is likely to be true of politically responsible decision makers. Economists must be sensitive to this fact and be willing to engage in broad-ranging discussions of alternative value concepts, approaches to making choices about environmental policy, and alternative valuation methods. Economists who are not sensitive to these facts run the risk of being ignored in the policy making process.

C. The Wealth of Nature: The value of that part of the natural world that contributes to human well-being or welfare through the provision of ecological goods and services can be called the wealth of nature.[6] I define the wealth of nature as the asset value that human beings derive from natural resources, whether that value emanates from converting natural resources into commodities or using them to produce services or amenities. For a recent book that makes extensive use of this concept, see Anderson, Huggins, and Power (2008).

There are two ways to think about how to measure the value of the stock of natural capital. The first is to think of the value of this stock as the discounted present value of the economic

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[6] The wealth of nature is often referred to as natural capital in the ecological economics literature (Costanza, Cumberland, et al., 1997). For a large scale collaborative effort to operationalize the concept of natural capital see The Natural Capital Project at Stanford University. Its web page states, "Our mission is to align economic forces with conservation by mainstreaming natural capital into decisions." See: http://www.naturalcapitalproject.org/home04.html

values of all of the streams of service flows from all of the ecosystems of the world. The problem is how to measure the total value of each service flow, that is, the value of moving from a zero flow to the current set of flows.

The second way to think about the value of the stock of natural capital is borrowed from the way the Bureau of Economic Analysis in the U.S. Department of Commerce develops estimates of the tangible wealth of the U. S. economy (e.g., Katz and Herman 1997). These estimates are based in principle on counts of the numbers of each type of productive asset and a set of unit values or "prices" for each asset that are assumed to be constant. The measure of wealth is the summation of the price times quantity calculations for each asset type. It has long been understood that the result of the price times quantity calculation does not represent the total value of the stock of wealth any more than gross domestic product (also a price times quantity measure) represents the value that people place on the nation's output. Both calculations use marginal values or unit prices and have no way to capture the value of inframarginal units.

In a widely cited paper in the journal *Nature*, Costanza, d'Arge, and co-authors (1997) estimated that the annual flow of ecosystem services around the globe was worth $33 trillion. They obtained this figure by estimating the annual per hectare values of 17 different ecosystem services from 16 different types of biomes (ecosystems). The authors identified a number of field studies that provided estimates of the values of each of the 17 services. Then, assuming that these unit values ($/hectare) were fixed and invariant around the globe and simply multiplying the unit values by the global areas of each type of biome, the authors pronounced the sum to be the "value of the world's natural capital."

Aside from pointing out some technical and methodological flaws in this study,[7] Bockstael et al. (2000) said that Costanza, et al. were implicitly asking one of the following two questions:

1. How much would the global population be willing to pay to prevent the loss of all of the earth's ecosystem services?
2. How much would the global population require in compensation to accept the loss of all of these services?

Since the loss of all of the world's ecosystem services would undoubtedly make the planet uninhabitable, the answer to the first question is the total income of the global population, which was much less than $33 trillion; while the answer to the second question is that there is likely no finite compensation that we would agree to accept.

The lesson to be taken from this discussion is that an estimate of the total value of the stock of natural capital is not an answer to a meaningful or policy relevant question. Economic valuation involves the comparison of two different states of the world, perhaps one with the thing being valued versus one without it, or between two different levels of provision of the thing being valued. Meaningful valuation questions involve differences between meaningful and policy-relevant states of the world, and a state of the world in which the entire stock of natural capital is gone is neither meaningful or policy relevant. The C-VPESS Report was explicit about this point, saying " ... this report focuses on valuing ecological changes, rather than on valuing entire ecosystems ...(C-VPESS, 2008, p. 15).

The lesson that I take from this discussion is that although terms such as "natural capital" and the "wealth of nature" have rhetorical value and might be useful heuristics, they are not

[7] See also Freeman (2002)

operational or policy relevant concepts since they do not answer policy relevant questions. Therefore they must be used only with care to avoid misunderstandings.

IV. Measurement

One of the principal recommendations made by the C-VPESS was that EPA should use an "expanded and integrated approach" to ecological valuation (C-VPESS, p. 100.)[8] By this, the Committee meant two things. First, the approach should be expanded to capture a much broader range of ecosystem services and not be limited to the most obvious or easy to identify service flows. And second, the approach should be integrated in the sense that it is truly interdisciplinary and involves people from a broad range of scientific and social science disciplines throughout the valuation process. Only in this way can the valuation process be built on a foundation of sound ecological and social science.

The Committee identified six steps in the expanded and integrated approach (see Section 2.4):

1. Formulate the valuation problem and choose policy options to be considered. The Committee conceived of this step as involving the development of a conceptual model of the ecosystem and of the uses people make of its services. This conceptual model was seen as the key to the development of a research strategy for understanding the necessary ecological and economic relationships.
2. Identify the significant biophysical responses that could result from the different policy options.

[8] See also Section 2.3 of the report.

3. Identify those biophysical responses and changes in ecosystem service flows that are socially important. The term "socially important" was seen as meaning more than just high economic value. The Committee suggested using any of the preference based value systems to help identify the socially important service flows.
4. Predict the responses in the ecosystem and relevant service flows that result from each policy option being considered.
5. Measure the values of the changes in ecosystem services in monetary or non-monetary terms. Measurement in monetary terms will draw on the suite of market and non-market valuation methods that have been developed by economists. But when monetary valuation is not possible, every effort should be made to quantify the ecological service flows in non-monetary terms.
6. Communicate the results to policy makers for use in policy decisions.

In my judgment, in many cases the biggest barrier to implementing the Committee's recommendation for an expanded and integrated approach lies at step 4. In order to predict the changes in service flows from the ecosystem, we need to understand the link between the structure and function of the ecosystem and the service flows that it supports. Identifying this link will not always be easy. One approach to establishing this link is to think of the relevant components of the ecosystem as being involved in a production process. Under this approach, the ecosystem is assumed to be an equilibrium system which can be subjected to comparative static analysis to determine changes in service flows in response to changes in ecosystem conditions.[9]

One complication is that ecosystems must be seen as multi-product systems in which

[9] For discussion of the production function approach, see Barbier (1994, 2000). For examples of empirical applications, see Finnoff and Tschirhart (2003a and 2003b).

jointness in production is likely to be a dominant feature. For example, a species of bird might be valued both for its pollination of a commercial fruit species and for its control of insects that damage some other commercially valuable plant. The value of the bird species is the sum of the values of all of its services. But the jointness in production must be taken into account when estimating the values of these individual service flows (Freeman, 2003, pp. 267-276). Also, some species can engage in both welfare-enhancing and welfare-decreasing activities.

Another complication is that the responses of ecosystems to perturbations might display nonlinearities, discontinuities, multiple end points, and even chaotic behavior, especially for changes in the populations of species and fluxes of energy or nutrients (Dasgupta and Maler, 2004, and Levin and Pacala, 2003). In fact, some aspects of ecosystem behavior might be fundamentally unpredictable (Huisman and Weissing 2001). For these reasons, economists might have more success in estimating the values of changes in the spatial extent of an ecosystem than changes in other characteristics of the system.

There are three important lessons to be drawn from this section. The first is that estimating ecosystem values requires cooperation and teamwork involving not only economists and other social scientists but also ecologists and other natural scientists. And this cooperation must begin at the earliest stages of the valuation process. The second is that estimating economic values requires a level of understanding of ecological systems that might not always be available. And the third is that even when estimates of monetary value can not be obtained, every effort should be made to identify non-monetary indicators of ecological impacts and that these indicators should be included in the presentation of results.

V. Uncertainty

The Report acknowledges the many sources of both ecological and economic uncertainty in the development of estimates of value for ecological services and devotes sections to the assessment and characterization of these uncertainties and how to communicate them to decision makers. The Report urges the use of probabilistic assessments such as Monte Carlo analysis whenever possible. And it urges that the presentation and discussion of the uncertainty analysis be an integral part of the report and not be relegated to an appendix. Finally, it recommends that EPA explore the use of expert elicitation methods as an alternative approach to developing information about the probability distributions of key uncertain variables.

VI. Conclusions for EEPSEA Research

A number of research projects sponsored by EEPSEA can be considered as exercises in ecosystem valuation. I have looked at those studies that have been posted on the EEPSEA web page under the category of coastal and marine resources. On the basis of my very quick reading of these papers, it appears that they are for the most part based on very simplified ecological models. In my judgment, those studies that have the objective of valuing ecological services could be strengthened by adopting the kind of expanded and integrated approach that is recommended in the C-VPESS Report. This would, among other things, mean involving ecologists in the tasks of identifying and describing a wider range of ecological goods and services for valuation. For example, biodiversity is often identified as an ecological value. But this leaves us with the questions of which of the many species that might be protected are most important and what services do they provide.

I must add that I see no reason to believe that any of the policy recommendations stemming from EEPSEA research would be changed in any major way. And so there is the question of whether the benefits of adopting a more sophisticated ecological perspective for this research would outweigh the costs of doing so. I think that this in itself is an interesting research question.

My second observation is that these papers for the most part do not convey a realistic sense of the uncertainties inherent in this kind of analysis. In my judgment, more effort should be expended in trying to achieve and convey to the reader a more realistic sense of the uncertainties inherent in this kind of research. Granted that the typical EEPSEA budget probably does not provide the resources necessary for carrying out a formal probabilistic uncertainty analysis. But I do think that greater attention to identifying and communicating the nature of these uncertainties is called for.

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