

On Measuring Economic Values for Nature[†]

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This paper describes how economists ascribe values to the things people can choose. The economic value of an ecosystem function or service relates to the contribution it makes to human welfare, where human welfare is measured in terms of each individual's own assessment of well-being. After developing how this definition is used, the paper describes problems and opportunities for advancing the state-of-the-art in measuring economic values for nature. These arguments are developed using recent studies that attempted to estimate economic values for ecosystems on a global scale. One implication of this evaluation is that there is a need for greater communication between ecologists and economists. Economic analyses must reflect the intricate web of physical interrelationships linking activities that have harmful effects in one part of an ecosystem to the potential effects on other parts. At the same time, economic values for ecosystems accept consumer sovereignty and should be interpreted as descriptions of the tradeoffs involved in evaluating well-defined changes to specific ecosystems.

Introduction

Two things have happened in environmental policy and research over the last 25 years to focus attention on the economic significance of natural systems. First, there has been increased interest in understanding the economic consequences of environmental regulation. Indeed, each of the last five U.S. presidents—two Democrats and three Republicans—issued executive orders directing federal agencies to conduct benefit–cost analyses of all major proposed regulations. This need to provide comparable and quantitative evidence of the benefits, not just the costs, of stricter environmental safeguards instigated a major new research effort within economics aimed at developing methods for valuing nonmarketed public goods such as environmental

quality. [There was an already extensive literature on the application of benefit–cost analysis for water projects dating to early contributions by Eckstein (1) and Krutilla and Eckstein (2). However, this research focused on the marketed outputs from public investment projects as the “tangibles” and enumerated, but did not attempt to estimate, the economic value for the changes in environmental amenities or quality attributed to these projects. For a history, see ref 3. Discussion of the early work on environmental valuation can be found in refs 4 and 5. For a presentation of valuation methods developed during this period, see refs 6 and 7.] Second, the focus of federal environmental protection gradually shifted during this period from an exclusive preoccupation with human health toward concerns about ecosystem integrity (see ref 8). The result has been a kind of “forced marriage” that has regulators, ecologists, and other biological scientists, as well as economists, thinking about the costs and benefits of protecting ecosystems and the services they provide.

From the perspective of many natural scientists as well as policy makers, economists have been slow at developing economic value estimates of ecological systems. A partial explanation for this is that economists have difficulty understanding the intricate web of physical interrelationships that can link harm in one part of the ecosystem to negative effects in another. Another explanation, however, is that valuing ecosystems in a way that is logically consistent with usual benefit–cost analysis is a very difficult business. In any event, application of conventional valuation methods to the problem often produces an incomplete set of disconnected values for a subset of ecosystem services, and this can lead to a dramatic underestimate of the benefits of ecosystem protection.

Given the absence of ecosystem values in the economics literature, a series of papers have emerged, authored largely by natural scientists, that attempt to fill this gap. [See Costanza et al. (9), Pimentel et al. (10), and Ehrlich and Ehrlich (11). The first paper is not exclusively authored by ecologists. The authors included two economists—R. C. d'Arge and S. Farber.] The problem that economists have with these approaches is not based on any fundamental difference in judgment about the importance of ecosystems. Rather it is about the correct application of concepts of *economic* value and about what questions provide a meaningful basis for defining economic values for purposes of benefit–cost analysis or other policy-making needs.

Two years ago, Costanza et al. (9) published a widely cited estimate of the “aggregate annual monetary value” of the services provided by a number of important ecosystems. [See also Ehrlich and Ehrlich (10), who provide an estimate of the total value of ecosystem services, and Pimentel et al. (11), who provide an estimate of the total economic and environmental value of biodiversity.] This paper has stimulated considerable debate. Pearce (12) recently reviewed its methods and concluded, “... the article by Costanza and his co-authors is deeply flawed. Yet its intention was correct: to show all of us just how valuable the natural world is.” (page 28). Pearce went on to ask an important question that is often a part of the response to any criticisms raised with the Costanza et al. approach: “Given the [desirable] purpose of that article, does it really matter if the analysis is wrong?” In what follows, we attempt to explain why it does. [Moreover, intended uses of the paper are not restricted to providing an index of importance. In interviews about his paper, Costanza has encouraged the use of these estimates for policy. Pimm's (13) commentary on the *Nature* article reaffirms this use, suggesting: “the real power of Table 2 (from Costanza et al.)

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lies in its use for local decisions.” The issue is whether and how such numbers are to be used in guiding public policy.]

As clearly as is possible in a few pages, we spell out how economists ascribe value to things—whether as pedestrian as a ball point pen or as complex as a saltwater marsh, noting the special difficulties posed by the latter. We also discuss how meaningful economic value questions are framed, and what questions do not lend themselves to this framing. To preview our argument, it makes little sense to talk about the economic value of ecosystems as if the choice were between having them as they are or not having them at all, because economic value is about tradeoffs and as such requires defining the alternatives clearly. Instead, the concept lends itself to evaluating well-defined *changes* to ecosystems. Indeed, this is the only reasonable question to ask and certainly the most relevant question for most policy analyses. Finally, we briefly describe some specific techniques that have been used to help in estimating the economic value for many of the varied services that ecosystems provide, ranging from outdoor recreation to water purification. Special attention is given to an approach that has frequently been misused—that of valuing a resource at the cost of replacing its lost services. We conclude by discussing why changes in the condition of ecosystems are so difficult to value.

The Meaning of Economic Value

In common usage, the term *value* means importance or desirability. The transfer between general usage and each discipline’s perspective on how importance or desirability should be gauged has created considerable debate among ecologists, economists, and philosophers. In economics, valuation concepts relate to human welfare. So the *economic* value of an ecosystem function or service relates only to the contribution it makes to human welfare, where human welfare is measured in terms of each individual’s own assessment of his or her well-being. Of course, this is not the only possible concept of value, nor is it always the most relevant. But for purposes of benefit–cost analysis in assessing policy options and for purposes of determining liability when natural resources have been harmed, this concept has considerable precedence as well as legal standing.

Getting environmental values to count at all in the policy and legal domain should not be taken lightly. It is the result of decades of argument that nonmarketed goods and services must be given standing on a par with marketed goods. In part, the incorporation of nonmarket (and especially environmental) values into policy and liability considerations has been possible because the economist’s concept of value has a long history of rigorous thought behind it.

For over 50 years economists have analyzed the properties of the logically consistent constructs that support answers to two types of valuation questions: First, how does one construct a measure of how much better or worse off an individual is with a (policy) change instead of without it? And second, how does one add up the gains and losses experienced by all individuals to assess the result of a given (policy) change for society as a whole? The answers to both of these questions recognize that an absolute measure of a person’s value for something is unachievable. Moreover, even if it were, aggregations of such measures over individuals would have little meaning (see refs 14–16). Economists “value” things only in comparative terms. When they say they are valuing a change, economists are really defining a tradeoff between two situations. The economic value of a policy change is defined by the amount (either positive or negative) of compensation that an individual would need in order to be as well off (by his own reckoning of well-being) as he would have been without the policy-induced change (17, 18).

Thus, an economic value estimate is an answer to a carefully defined question in which two alternatives are being compared. For example, suppose a power plant is being considered for a location that would eliminate a swimming beach. Different people can have quite different values for this change depending on whether they would use the beach, gain from the lower cost of electricity, or both. Economic value measures the amount a person would pay or be paid (in compensation) to be as well off with the power plant as without it. The compensation might be positive or negative. For a nonswimmer who benefits from lower electricity prices, the compensation will be different than for a frequent beach user. These answers do not “value the beach” per se. Instead they measure for each person the tradeoff that he is willing to make.

Answers to this question are sensitive to the circumstances of the choices. Is there a similar beach a short distance away that is not affected? Would the elimination of the specific beach cause congestion at others, resulting in inferior beach experiences? Would loss of the beach also harm an endangered species that is specific to the area? [The inclusion of protection of endangered species in the list of effects reflects the fact that preserving species has value to humans, because of the value of a diverse gene pool, for example.] These issues highlight a feature of economic values. Compensation measures cannot be defined in isolation. They are entirely dependent on the context and may change as there is a change in one or more elements of that context. This feature of economic values requires analysts to be specific about what is obtained with the change as well as the default situation that exists without it.

Because compensation is a measure of people’s tradeoffs, it can be measured in terms of any set of common units one desires. It is usually measured in money. [While the logic underlying these definitions leads to well-defined measures, this does not mean that ambiguities are entirely avoided. A recent example of the potential for effects with different choices for the numeraire is given by Brekke (19). An application that demonstrates the consequences of choosing an alternative numeraire is found in ref 20.] Given this concept of a tradeoff, two alternative compensation measures are definable: one that uses the initial well-being of the individual as the base or reference level and one that uses as the point of reference the level of well-being that would be obtained after the proposed change. The first concept answers the question: how much (negative or positive) would the individual need to receive, should the change *take place*, to make him as well off as he would be *in the absence* of the change? The other answers a parallel, but subtly different, question: how much (negative or positive) would the individual need to receive should the change *not take place*, to make him as well off as he would have been had the change *taken place*? Under some conditions, these two measures can be expected to be approximately equal. In others, they will be quite different. One measure is no more easily justified than the other for all situations.

Additional caveats are necessary. Individuals’ expressions of willingness to pay or willingness to accept compensation are conditioned by their endowments of wealth. This does not alter the meaning of the individual compensation measures, but it does suggest that care must be taken in interpreting any aggregation of these individual measures. If some groups benefit from an action while others lose, and these groups have significantly different wealth, then policy actions based on the simple aggregation of individual compensation measures can have serious distributional implications that need to be taken into account.

All of this argument assumes that individual behavior results from rational choices, an assumption that many find unsupportable. Becker’s (21) Nobel address captures the

broad generality of what is intended in this assumption. He notes that: “the analysis assumes that individuals maximize [their] welfare *as they conceive it*, whether they be selfish, altruistic, loyal, spiteful or masochistic ... Actions are constrained by income, time, imperfect memory and calculating capacities, and other limited resources, and also by the opportunities available in the economy. These opportunities are largely determined by the private and collective actions of other individuals and organizations” (page 385, term in brackets was inserted).

His position is similar to most conventional economists. It does not deny that in some circumstances people make mistakes, nor does it insist that people are always observed making seemingly rational choices. It does offer one way to express the implications of those choices—as an implied lower bound on their economic value. The usefulness of these measures depends only on the assumption that people do their best to realize the highest level of well-being given their circumstances. The other alternative strategies for defining individual values are inconsistent with such an interpretation because they replace each consumer’s judgment of what is best with some external prescription of how they *should* make choices.

Framing the Valuation Question

Measures of economic value are specific to the object of choice (i.e., what has changed between the reference and the policy induced states), the starting point or reference state, and other aspects of the context of the decision (implicit or explicit). [The importance of context in such exercises can be illustrated by considering purchases made at a young child’s lemonade stand on a hot day. Using this young entrepreneur’s experience that people pay \$1 or more for a cold drink on a hot day and concluding that modest investments will yield millions would be misleading. The circumstances of these choices influence the observed decisions. Remove the child, other dimensions of the context being unchanged, and some (if not all) of the same people would make different decisions. This is not evidence of consumer irrationality. Nobel Laureate Amartya Sen (22) in his Frisch Memorial Lecture to the Econometric Society argued that choices tell us about how “revealed” preferences can be influenced by the specific features of the act of choice, such as the identity of the chooser, the menu (or choice set), and the relation between the particular decision and social norms.] If the policy question is whether to impose national regulations on agricultural nonpoint source pollution, the status quo—as described by the current pattern of nutrient loadings—must be compared with the predicted alternative pattern of reduced loadings, which will be different and have different effects on aquatic ecosystems in different parts of the United States. To value the complete loss of a particular ecosystem function or service, one would need to compare the state of the world as it exists with a well-defined prediction of what would exist should that specific function or service be eliminated. And in doing this, we would want to include secondary effects on other ecosystem functions but hold constant those things which are unaffected.

When the stated objective is to measure *economic value*, the concepts and principles associated with performing the task are not matters of opinion. Whether one likes or agrees with the economic concept of value, the points listed above must be adequately addressed for the results to have the logically consistent properties attributable to this type of valuation. The importance of this cannot be overstated, although it has been ignored in several recent publications that purport to measure the economic value of the world’s ecosystems.

Costanza et al. (9), Ehrlich and Ehrlich (10), and Pimentel et al. (11) claim to answer the question: What is the total

value of the world’s ecosystems (or in Pimentel et al., biodiversity)? Costanza et al. (9) and Pimentel et al. (11) calculate “total values” by scaling up a variety of estimates of values taken from other studies of ecosystem services and functions. The original studies valued small changes in specific and localized components of individual ecosystems, with each study implicitly holding constant other features of the global ecosystem and the economy. It is incorrect to extrapolate the value estimates obtained in any of these studies to a much larger scale, let alone to suppose that the extrapolated estimates could then be added together and applied to the whole planet.

Environmental goods are generically different from private commodities. They are usually not divisible into discrete units, like cups of coffee or ball point pens. More important, their services are available to many people simultaneously. [This is a key element in the definition of a public good in economics; the good is not “used up” through one (or more) individuals’ consumption.] As a result, there are limits to the analogies we can draw between the economic values of nonmarket environmental goods and those associated with private goods. Nonetheless, at least one aspect of the errors of scaling up values can be easily illustrated. Whatever the private good involved in consumption choices, be it ball point pens or pairs of socks, we can expect that it will be subject to diminishing value as more of the good is purchased (and consumed) within a given (conveniently defined) period of time. In applications, this property implicitly reflects the fact that even though not all pairs of socks are the same, in most cases an individual’s willingness to pay for another pair is likely to diminish the more he already has. In this example, the individual has plenty of close substitutes for this potential new purchase. Likewise, an individual’s willingness to pay for another pen will be conditioned on how many others he already has. Take away those previously purchased socks or pens, and the willingness to pay for a new one is very different.

Thus, simple multiplication of a physical quantity by “unit value” (derived from a case study that estimated the economic value for a specific resource) is a serious error. Small changes in an ecosystem’s services do not adequately characterize, with simple multipliers, the loss of a global ecosystem. Values estimated at one scale cannot be expanded by a convenient physical index of area, such as hectares, to another scale; nor can two separate value estimates, derived under different contexts, simply be added together. When we estimate a compensation measure for one element of an ecosystem, we assume that other aspects of the world that influence human well-being are unchanged. For example, we might compute a compensation measure for the elimination of a specific wetland, holding others constant. In another analysis, a compensation measure for the elimination of a different wetland might have been estimated, holding the first at its initial level. But the two compensation measures cannot be added together to obtain the correct compensation in the event that both wetlands are eliminated. [The relationship between the sum of these two measures, on one hand, and the value of the composite change in the two ecosystems, on the other, depends both on (i) the ecological relationships between wetlands and the functions they provide and (ii) individual preferences for those functions and the size of the income effects their loss generates. The analytical features governing this relationship focus on whether the services are substitutes or complements for each other. Also, the term “income effects” refers to the effect of changes in income on the values (measured in money) that individuals assign to a specific change. For small changes, where the monetary commitments are modest, the income effects associated with doing each in isolation versus the two together may be modest, but for large changes they will not be. See Diamond (23) for an example of a case with small changes and

Hanemann (24) for a detailed treatment of all cases.] If the two wetlands are substitutes in any way, simple addition will understate their joint value.

The failure of additivity in economics has an apparent parallel in ecology. Ecosystems respond to changes through a variety of physical, biological, and chemical feedback cycles. These feedback cycles are central to the processes that link all species to each other and to their respective habitats. A linear aggregation rule treats each change as if it could be made independent of the other constituent elements. In doing so, it assumes independence within and across the ecosystems being considered, and it ignores the possible effects of feedback cycles. [One reviewer of an earlier draft of this paper suggests that some ecologists are undertaking computations of global gross production for different ecosystems by multiplying point estimates of a rate by an area for the ecosystem. Moreover it was suggested that these approaches displayed consistency with estimates from satellite imagery. We are not contending that economists and ecologists do not approximate aggregate measures. Rather, our objective is to explain the concept of economic value and highlight the features that bear in important ways on how we select among the available ways to approximate it. The approach must be consistent with the principles used to define it. When it is not, or the assumptions made in the approximations become completely implausible; there is no reason to believe the errors will decline with scale of the approximation. In fact, where interdependencies occur, scaling up by simple addition is likely to magnify the errors.]

Clearly, extrapolating from small-scale studies cannot help us to estimate the economic value for the world's ecosystems, but is there any reasonable answer to this question? We know that Costanza et al.'s estimate of an annual economic value of 33 trillion U.S. dollars is a logically inconsistent measure of what individuals would be *willing to pay* to avoid the loss, if only because this estimate exceeds their total ability to pay. Simply put, if, as Costanza et al. (9) estimate, the world's GNP is 18 trillion dollars, the world's population does not have 33 trillion dollars to spend annually. [We do not intend the argument to suggest that if all the goods and services important to people were traded on ideal private markets the GNP would then correctly measure these goods' economic values. The issue is simply that a person cannot offer to give up more than he or she has. Some might argue that income does not really define spending limits because individuals can borrow. However, this presumes the existence of someone willing to lend. There are no creditors if everyone is borrowing, and no one would lend to those with no prospect of ever paying back the loan. Thus, the offer to exchange an amount greater than one's income to obtain ecosystem protection is infeasible.] Costanza et al. (25) attempted to answer this criticism to the Pearce review cited earlier. They observed that using the GNP as an approximate measure of income is inappropriate because "ecosystems provide real income (contributions to human welfare) that is never reflected in any market". We do not deny ecosystems provide services that people do not have to pay for. But by definition, *willingness to pay* to protect the world's ecosystems from destruction reflects how much individuals *would be willing to give up in other things* to obtain this outcome. It is an explicit tradeoff that defines willingness to pay. Our criticism, as well as that of Pearce, simply suggests a person cannot give up more than he has. Costanza et al.'s estimate of world GNP is an approximation of what the world has, translated into money terms, before the proposed change; it is from this amount of money that the aggregate willingness to pay for the ecosystem must come. [It is true that GNP is not an ideal measure of total available income. There are activities that generate income that are not reflected in GNP (e.g., the so-called informal economy). It is also conceivable that

people would re-allocate their time in response to some exogenous change, giving up more leisure in exchange for work, to realize a higher level of monetary compensation. This would entail a modified definition of willingness to pay but would be generally consistent with our arguments (see Appendix D in ref 26). However, none of these adjustments to GNP would alter our basic point. The discrepancy between the Costanza et al. (9) estimates for the annual willingness to pay and any measure of income available is too great. No one would expect that these adjustments would increase the measure of aggregate income to make their estimate plausible. As a result, this dramatic overstatement remains one clear signal of their mistake in understanding the underlying concept.]

Suppose instead that one asks what compensation the people of the world *would require* in order to voluntarily give up the world's ecosystems. This *willingness-to-accept* form of the economic valuation question uses the alternative baseline and highlights the need to define clearly the alternative state that applies when the compensation is paid. This is required to measure the compensation necessary to equate each individual's well-being, given the current level of the world's ecosystems, with that in an alternative state. But what is this alternative state: a different, newly emerging set of ecosystems or a complete void?

If the answer is a different set of ecosystems, then we would need a good description of the services these ecosystems would provide before we could define exactly what is lost and, in turn, estimate the economic "value" of this loss using the compensation principle. It is possible that ecologists already know something about the ecological states that would exist were certain current states destroyed through man's mismanagement. However, it seems unlikely that anyone could reliably predict how the world would look were man to destroy simultaneously all currently existing ecosystems. The feedback effects and interactions implicit in ecological systems pose a daunting modeling task.

If the alternative state is "nothingness", then the answer to the willingness to accept question is trivial. There is *no finite compensation* that individuals would accept to agree to the loss of the world's ecosystems, and they would pay everything they had to avoid it. To an economist, this is the definition of an essential good, a good for which there is no finite compensation for its complete elimination. In this sense, ecosystems are essential. At this level of generality, there may of course be other essential inputs to the process of sustaining human well-being. For example, an institutional system that defines norms of behavior and provides some rule of law may also be deemed essential, as well as the social system, conditioning interpersonal interactions. Evaluating any one of them relative to the default of their complete absence would yield similar answers.

There is a final reason why valuing the world's ecosystems in monetary terms makes no sense. For many environmental valuation problems, monetary valuations work because they provide a common metric in which to express tradeoffs. But for the extensive changes proposed by the above authors, the economic system would change completely, generating quite different sets of prices and incomes. Since money has no meaning independent of the system in which prices and incomes are determined, it makes little sense to ask how much individuals would pay to retain the world's ecosystems. The proposed change is so great as to completely realign both the global ecosystem and the global economic system as well. Such a change transforms the units one is attempting to use to measure value. Comparing them using current prices and incomes becomes meaningless.

Methods of Revealing People's Values

Even if we knew how to frame the question—What is the economic value of the world's ecosystems?—the answer is unlikely to inform any real-world decision. While the consequences of human actions can be enormous, the actual policy choices faced are rarely if ever at the global ecosystem scale. For such profound and all-encompassing questions, conventional economic valuation is inappropriate for all the reasons given above.

When the tradeoffs we want to know about are associated with specific changes in specific resources or ecosystem services, there are a variety of valuation methods available. (For more detailed descriptions, see refs 7 or 6). Where service flows involve marketed commodities such as food and timber, information derived from demand functions for these market goods can provide a basis for estimating the values of these service flows. Information is also needed on supply conditions so that the cost of the labor, capital, and other resources devoted to the harvesting of these commodities can be deducted to determine the net value of the "surplus" due to the ecosystem contributions. As a counter example, valuing the oceans' and estuaries' food production at market prices without deducting the costs (in terms of human labor, fuel, etc.) of harvesting the fish would be incorrect.

Economic values for the nonmarket services of natural ecosystems, services that contribute to human health and to quality of life, can sometimes be derived from people's decisions to use related resources or to substitute other resources when the natural ecosystem's quality is impaired (e.g., refs 27–29). It is also possible to use stated preference choices or contingent valuation to estimate these values by proposing choices with well-defined, potential consequences or costs (e.g., refs 30 and 31).

In some specific circumstances, the cost of replacing a function of an ecological system with a human-engineered system can be used as a measure of the economic value of the function itself (e.g., ref 32). In a classic example, Gosselink et al. (33) used an estimate of the cost of a tertiary sewage treatment system as the economic value of the nutrient removal function of a wetland. However, replacement cost can be a valid measure of economic value only if three conditions are met. The conditions are the following: (i) that the human-engineered system provide functions that are equivalent in quality and magnitude to the natural function; (ii) that the human-engineered system is the least cost alternative way of performing this function; and (iii) that individuals in aggregate would in fact be willing to incur these costs if the natural function were no longer available. Full compliance with these conditions is rarely achieved, and as a result, simplistic transfers of replacement cost estimates are usually misleading.

Where the change we wish to evaluate involves the destruction or impairment of a localized ecosystem, such as the elimination of a wetland or the conversion of large portions of a watershed from forest to developed uses, economic valuation admittedly faces a more serious challenge. [For a discussion of these difficulties, see ref 34.] A change in the condition of a local ecosystem may alter its ability to provide service flows of both consumptive (e.g., fish and timber) and nonconsumptive uses (e.g., aesthetics and wildlife). [See Kahn and Kemp (35) and Strand and Bockstael (36) for attempts to trace ecosystem impairment to end products.] It may also diminish its capacity to provide functions that are indirectly valued by humans, such as climate stabilization or nutrient recycling. [Because an ecosystem provides these services over time, it is also possible to consider an ecosystem as a natural asset. Accordingly it may seem reasonable to ask whether treating ecosystems as assets would change the interpretation of their economic

values. The short answer is no. Using the concept of an asset in valuation requires that the total value of the asset reflect the value of the time profile of services it provides. Converting this time profile of values generated by allocation choices and their implied tradeoffs to a "current" value becomes important. This process leads to consideration of the role of discounting in defining an "equivalent" current value. All of these details seem more complex than the static choice between two alternatives we used to define a lower bound for an economic value. They are not. They are simply one way to account for the differential properties of some types of goods. Weitzman (37) has recently established the relevance of the simple, static choice analogy to comparing two optimal profiles. He proves it can be evaluated as if it were a static choice, paralleling what we used to define the concept of an economic value.] It may even diminish features of the ecosystem that are important to humans at a much more abstract level, features that play an important role in our heritage and culture. Because economic values depend on individuals' own assessments of their well-being, an understanding of the ways in which specific impairments of an ecosystem diminish their lives is essential.

Our ignorance does not preclude the need for these answers, nor has it prevented us from giving partial answers when complete ones were unavailable. Thirty years ago, environmental economists argued that damming a wild and pristine river in Idaho to provide electricity was a bad idea. They reached this conclusion by comparing the value, over time, of power generated to indirect measures of the economic value of the wild river as a unique recreational experience. Even without taking account of the more subtle ecosystem interactions, it was possible to recognize that the nonmarket recreational benefits provided over time by the wild river exceeded the benefits of the dam. [See the Hell's Canyon controversy discussed in Fisher et al. (38). At the time, these authors were unable to measure all the recreation benefits from the wild river. They were able to describe how the same economic factors contributing to the time profile of power benefits would be likely to affect the recreation benefits provided by the river. This description allowed them to ask a very important rhetorical question—how much do the initial preservation benefits for the river *need to be* to favor preservation? This question recognized the essence of the link between economic value and a choice. Each choice reveals a lower bound for the economic value. As a consequence, public choices for preservation need only demonstrate that the economic value of what is protected exceed that of the alternative state defining the choice.] Not all such analyses of policy change will favor the environment however. For example, in a developing country where malaria and other insect-carrying diseases are still a major threat, what little we know of the ecological damages associated with pesticide use will unlikely outweigh their human health benefits when tradeoffs use economic value methodology.

The very nature of ecosystems—their complexity in structure and function—makes understanding the consequences of ecosystem damage a daunting task even for ecologists. The larger the scale of the change, the more subtle and complex the functions impaired, and the farther removed from the end product of value to humans, the more difficult will be the task of estimating economic values. But this is not surprising since if we do not yet, as a society, fully comprehend the role different ecosystems play in our world, we cannot give meaningful values by any definition. It does not mean we should abandon the effort of measuring well-defined economic values for those consequences we do understand. They are often sufficient to answer the questions posed by policy decisions associated with ecosystems.

Discussion

No one would suggest that economic values should rule the day. Economic valuation measures are only one component of the criteria available for evaluating policy. Correctly interpreting what economic value measures mean does not require *exclusive* reliance on the results from such calculations (see ref 39).

This paper is not intended as a judgment on the appropriate definition of value. It is about furthering good science. Without cooperation, ecologists and economists cannot serve the interests of society. Moreover, cooperation is impossible without a better appreciation and respect for each others' discipline. The belief by some economists that ecological models *require* a biocentric perspective on societal objectives, with all species given equal weight in determining resource allocations, is not correct. Likewise, the belief by some ecologists that economists place values on ecological services only if they contribute to marketed commodities is equally incorrect.

Neither discipline will actually provide *the* exclusive organizing principles for how people will in fact interact with ecosystems in practice. In free societies such outcomes arise from a collection of uncoordinated (or at best loosely coordinated) activities that are constrained by the rules we collectively adopt. In this context, improving the communication between disciplines is the only hope for better informing these processes. People will ultimately make choices with or without the insights from a genuine collective effort.

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