An ecosystem is a finite resource. When we exploit an ecosystem service we invariably lose some other potential service. For example, when we turn grassland into ranch land, we gain essential food but we may lose habitat and biodiversity. This creates a trade-off between services and the constituents that might benefit from them. Exploiting an ecosystem today may increase our material well-being and alleviate poverty, but it may also prove unsustainable. Humans protect what they value most. For too long, we have failed to value and protect the services of nature — perhaps because we view them as free and limitless. But today, the limits of nature are in sight. It is time to fully value nature and its essential services to humankind.

Ecosystem services are often public goods, which means that they may be enjoyed by any number of people without affecting other peoples' enjoyment. For example, an aesthetic view is a pure public good. No matter how many people enjoy the view, others can also enjoy it.

Other services may be quasi-public goods, where at a certain level of use, others' enjoyment may be diminished. For example, a public recreation area may be open to everyone. However, crowding can decrease peoples' enjoyment of the area.

Ecosystem valuation can help resource managers by measuring their costs to society, in terms of lost economic benefits. The costs to society can then be imposed, in various ways, on those who are responsible, or can be used to determine the value of actions to reduce or eliminate environmental impacts. For example, in the case of the crowded public recreation area, benefits to the public could be increased by reducing the crowding. This might be done by expanding the area or by limiting the number of visitors. The costs of implementing different options can be compared to the increased economic benefits of reduced crowding.

Ecosystem services fall into four broad categories: provisioning; regulating; supporting; and cultural benefits.

Provisioning services. Such as food (including seafood and game), crops, wild foods, and spices; water; pharmaceuticals, biochemicals, and industrial products; and energy (hydropower, biomass fuels).

Regulating services. Such as carbon sequestration and climate regulation; waste decomposition and detoxification; purification of water and air; crop pollination; and pest and disease control.

Supporting services. Such as nutrient dispersal and cycling; and seed dispersal.

Cultural services. Such as cultural, intellectual and spiritual inspiration; recreational experiences (including ecotourism); and scientific discovery.

Humans protect what they value most.

We are living beyond our means: recent gains in quality of life have come at considerable cost to the natural systems on which we all depend. All people depend on nature and ecosystem services to provide the conditions for a decent, healthy, and secure life. By weakening nature's ability to deliver key services,

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such as clean air and water and protection from floods, disease, and other disasters, these losses come as an expense to others.

Human beings are integral parts of ecosystems; our actions shape ecosystems and our well-being is tied to them. The human condition drives change in ecosystems, and changes in ecosystems cause changes in human well-being. Human health is intimately tied to natural systems. Air and water pollution are linked to an explosion of asthma and other respiratory problems, and an increased risk of cancer and heart disease. Epidemics rage when natural systems are disrupted.

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Ecosystem values are measures of how important ecosystem services are to people – what they are worth. Economists measure the value of ecosystem services to people by estimating the amount people are willing to pay to preserve or enhance the services.

Primary Dollar-based Ecosystem Valuation Methods

> **Productivity Method.** Also referred to as the *net factor income* or *derived value method*, is used to estimate the economic value of ecosystem products or services that contribute to the production of commercially marketed goods. For example, water quality affects the productivity of irrigated agricultural crops, or the costs of purifying municipal drinking water. Thus, the economic benefits of improved water quality can be measured by the increased revenues from greater agricultural productivity, or the decreased costs of providing clean drinking water.

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To apply the productivity method, data must be collected regarding how changes in the quantity or quality of the natural resource affect: costs of production for the final good; supply and demand for the final good; and supply and demand for other factors of production.

Hedonic pricing method. This method is used to estimate economic values for an ecosystem or environmental services that directly affect market prices. It is most commonly applied to variations in housing prices that reflect the value of local environmental attributes. It can be used to estimate economic benefits or costs associated with: environmental quality, including air pollution, water pollution, or noise pollution, or environmental amenities, such as aesthetic views or proximity to recreational sites

The basic premise of the hedonic pricing method is that the price of a marketed good is related to its characteristics, or the services it provides. For example, the price of a car reflects the characteristics of that car—transportation, comfort, style, luxury, fuel economy, etc. Therefore, we can value the individual characteristics of a car or other good by looking at how the price people are willing to pay for it changes when the characteristics change.

To apply the hedonic pricing method, data must be collected on residential property sales in the region for a specific time period (usually one year) including: selling prices and locations of residential properties; property characteristics that affect selling prices, such as lot size, number and size of rooms, and number of bathrooms; neighborhood characteristics that affect selling prices, such as property taxes, crime rates, and quality of schools; and accessibility characteristics that affect prices, such as distances to work and shopping centers, and availability of public transportation.

In general, the price of a house is related to the characteristics of the house and property itself, the characteristics of the neighborhood and community, and environmental characteristics. Thus, if non-environmental factors are controlled for, then any remaining differences in price can be attributed to differences in environmental quality. For example, if all characteristics of houses and neighborhoods throughout an area were the same, except for the level of air pollution, then houses with better air quality would cost more. This higher price reflects the value of cleaner air to people who purchase houses in the area. In this case, the environmental characteristic of concern is the proximity to open space. Once the data are collected and compiled, staff can estimate the value of preserving open space by looking at how the value of the average home changes when the amount of open space nearby changes.

Contingent Valuation Method. The contingent valuation method is referred to as a *stated preference method*, because it asks people to directly state their values, rather than inferring values from actual choices. It is used to estimate economic values for all kinds of ecosystem and environmental services. It can be used to estimate both use

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and non use values, and it is the most widely used method for estimating non-use values. It is also the most controversial of the non-market valuation methods.

The contingent valuation method involves directly asking people, through a survey, how much they would be willing to pay for specific environmental services. In some cases, people are asked for the amount of compensation they would be willing to accept to give up specific environmental services. It is called "contingent" valuation, because people are asked to state their willingness to pay, contingent on a specific hypothetical scenario and description of the environmental service.

Contingent valuation is one of the only ways to assign dollar values to non-use values of the environment—values that do not involve market purchases and may not involve direct participation. These values are sometimes referred to as "passive use" values. They include everything from the basic life support functions associated with ecosystem health or biodiversity, to the enjoyment of a scenic vista or a wilderness experience, to appreciating the option to fish or bird watch in the future, or the right to bequest those options to your grandchildren. It also includes the value people place on simply knowing that giant pandas or whales exist.

It is clear that people are willing to pay for non-use, or passive use, environmental benefits. However, these benefits are likely to be implicitly treated as zero unless their dollar value is somehow estimated. So, how much are they worth? Since people do not reveal their willingness to pay for them through their purchases or by their behavior, the only option for estimating a value is by asking them questions.

However, the fact that the contingent valuation method is based on asking people questions, as opposed to observing their actual behavior, is the source of enormous controversy. The conceptual, empirical, and practical problems associated with developing dollar estimates of economic value on the basis of how people respond to hypothetical questions about hypothetical market situations are debated constantly in the economics literature.

Contingent Choice Method. The contingent choice method, also referred to as *conjoint analysis*, is similar to contingent valuation, in that it can be used to estimate economic values for virtually any ecosystem or environmental service, and can be used to estimate non-use as well as use values. Like contingent valuation, it is a hypothetical method – it asks people to make choices based on a hypothetical scenario. However, it differs from contingent valuation because it does not directly ask people to state their values in dollars. Instead, values are inferred from the hypothetical choices or tradeoffs that people make.

The contingent choice method asks the respondent to state a preference between one group of environmental services or characteristics, at a given price or cost to the individual, and another group of environmental characteristics at a different price or cost. Because it focuses on tradeoffs among scenarios with different characteristics,

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contingent choice is especially suited to policy decisions where a set of possible actions might result in different impacts on natural resources or environmental services.

This method works well where there are several possible options for preserving and/or using the site (such as allowing mining at various locations, each of which would have different impacts on the site.) Thus, several options must be weighed in terms of costs and benefits to the public. The contingent choice method provides outcomes for several policy options.

Because both contingent choice and contingent valuation are hypothetical survey-based methods, their application is very similar. The main differences are in the design of the valuation question(s), and the data analysis.

From the analysis, the researchers can estimate the average value for each of the services of the site, for an individual or household in our sample. This can be extrapolated to the relevant population in order to calculate the total benefits from the site under different policy scenarios. The average value for a specific action and its outcomes can also be estimated, or the different policy options can simply be ranked in terms of peoples' preferences.

The results of the survey might show that the economic benefits of preserving the site by not allowing mining are greater than the benefits received from allowing mining. If this were the case, the mining lease might not be issued, unless other factors override these results. Alternatively, the results might indicate that some mining scenarios are acceptable, in terms of economic costs and benefits. The results could then be used to rank different options, and to help select the most preferred option. There are a variety of formats for applying contingent choice methods, including:

Contingent Ranking—Contingent ranking surveys ask individuals to compare and rank alternate program outcomes with various characteristics, including costs. For instance, people might be asked to compare and rank several mutually exclusive environmental improvement programs under consideration for a watershed, each of which has different outcomes and different costs. Respondents are asked to rank the alternatives in order of preference.

Discrete Choice—In the discrete choice approach, respondents are simultaneously shown two or more different alternatives and their characteristics, and asked to identify the most preferred alternative in the choice.

Paired Rating—This is a variation on the discrete choice format, where respondents are asked to compare two alternate situations and are asked to rate them in terms of strength of preference. For instance, people might be asked to compare two environmental improvement programs and their outcomes, and state which is preferred, and whether it is strongly, moderately, or slightly preferred to the other program.

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Whatever format is selected, the choices that respondents make are statistically analyzed using discrete choice statistical techniques, to determine the relative values for the different characteristics or attributes. If one of the characteristics is a monetary price, then it is possible to compute the respondent's willingness to pay for the other characteristics.

Types of values

Use value is defined as the value derived from the actual use of a good or service, such as hunting, fishing, birdwatching, or hiking. Use values may also include indirect uses. For example, an Alaskan wilderness area provides direct use values to the people who visit the area. Other people might enjoy watching a television show about the area and its wildlife, thus receiving indirect use values. People may also receive indirect use values from an input that helps to produce something else that people use directly. For example, the lower organisms on the aquatic food chain provide indirect use values to recreational anglers who catch the fish that eat them.

Option value is the value that people place on having the option to enjoy something in the future, although they may not currently use it. Thus, it is a type of use value. For example, a person may hope to visit the Alaskan wilderness area sometime in the future, and thus would be willing to pay something to preserve the area in order to maintain that option.

Bequest value is the value that people place on knowing that future generations will have the option to enjoy something. Thus, bequest value is measured by peoples' willingness to pay to preserve the natural environment for future generations. For example, a person may be willing to pay to protect the Alaskan wilderness area so that future generations will have the opportunity to enjoy it.

Non-use values, also referred to as "passive use" values, are values that are not associated with actual use, or even the option to use a good or service.

Existence value is the non-use value that people place on simply knowing that something exists, even if they will never see it or use it. For example, a person might be willing to pay to protect the Alaskan wilderness area, even though he or she never expects or even wants to go there, but simply because he or she values the fact that it exists.

Ecosystem values are measures of how important ecosystem services are to people – what they are worth. Economists measure the value of ecosystem services to people by estimating the amount people are willing to pay to preserve or enhance the services.

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Case Studies

Hedonistic Valuation: Southold, Long Island

This study was conducted, using 1996 housing transactions. The study found that the following variables that are relevant for local environmental management were had significant effects on property values in Southold:

> **Open Space:** Properties adjacent to open space had, on average, 12.8% higher per-acre value than similar properties located elsewhere.
> **Farmland:** Properties located adjacent to farmland had, on average, 13.3% lower per-acre value. Property values increased very slightly with greater distance from farmland.
> **Major Roads:** Properties located within 20 meters of a major road had, on average, 16.2% lower per-acre value.
> **Zoning:** Properties located within an area with two- or three-acre zoning had, on average, 16.7% higher per-acre value.
> **Wetlands:** For every percentage point increase in the percent of a parcel classified as a wetland, the average per-acre value increased by .3%.

Based on the results of this study, managers could, for example, calculate the value of preserving a parcel of open space, by calculating the effects on property values adjacent to the parcel. For a hypothetical simple case, the value of preserving a 10 acre parcel of open space, surrounded by 15 "average" properties, was calculated as $410,907.

The hedonic pricing method is relatively straightforward and uncontroversial to apply, because it is based on actual market prices and fairly easily measured data. If data are readily available, it can be relatively inexpensive to apply.

The data are analyzed using regression analysis , which relates the price of the property to its characteristics and the environmental characteristic(s) of interest. Thus, the effects of different characteristics on price can be estimated. The regression results indicate how much property values will change for a small change in each characteristic, holding all other characteristics constant.

The analysis may be complicated by a number of factors. For example, the relationship between price and characteristics of the property may not be linear – prices may increase at an increasing or decreasing rate when characteristics change. In addition, many of the variables are likely to be correlated, so that their values change in similar ways. This can lead to understating the significance of some variables in the analysis. Thus, different functional forms and model specifications for the analysis must be considered.

Contingent Valuation: Mono Lake, California.

The State of California Water Resources Control Board was faced with a decision about how much water to allocate to Los Angeles from sources flowing into Mono Lake. The reduced water flows to the lake were affecting food supplies for nesting and migratory birds. One of the first contingent valuation studies to measure the use and non-use values that citizens have for

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public trust resources was a survey of California households regarding willingness to pay for increased water flows into Mono Lake.

The initial academic study asked California households, in a mail survey, whether they would pay more on their water bill for higher cost replacement water supplies, so that natural flows could once again go into Mono Lake. They were told that, according to biologists, the higher flows to the lake were needed to maintain food supplies for nesting and migratory birds.

The average willingness to pay per household was estimated to be $13 per month, or $156 per year. When multiplied by the number of households in California, the total benefits exceeded the $26 million cost of replacing the water supply by a factor of 50. One impact of the survey results was to change the nature of the debate over Mono Lake from "fish or people" to one that recognized that people care about fish and birds, as well as about inexpensive water supplies for Los Angeles.

The State of California determined that information about the general public's willingness to pay for increased water in Mono Lake could be an important part of the economic analysis of the water allocation decision. As part of an Environmental Impact Report, the State hired a consulting firm to perform a more detailed contingent valuation survey. This new survey involved the use of photo-simulations showing what the lake would look like at alternative water levels. It also gave detailed information about effects of changing lake levels on different bird species. The survey was conducted over the telephone, with people who had been mailed information booklets with maps and photo-simulations. Survey respondents were asked how they would vote in a hypothetical referendum regarding Mono Lake.

This study also showed that the benefits of a moderately high (but not the highest) lake level were greater than the costs. While one cannot claim the economic analysis was a deciding factor, the California Water Resources Control Board did reduce Los Angeles' water rights by half, from 100,000 acre feet to about 50,000 acre feet, to allow more flows into Mono Lake.

Contingent Valuation: Glen Canyon Dam, Arizona

One of the highest profile uses of the contingent valuation method in water resources management involved the re-regulation of Glen Canyon dam. In the early 1980's it became clear that continued operation of the dam to provide peak-load power was adversely affecting the downstream ecosystem in the Grand Canyon, and significantly reducing the quality of recreational rafting. The valuation question of concern was how much recreational rafting was worth, compared to the market value of the peak-load power supply.

The Bureau of Reclamation and National Park Service worked with a consulting firm to develop a contingent valuation survey to estimate how the value of rafting changed with different flows in the Grand Canyon. The study attempted to quantify how the value of rafting in the Grand Canyon would change with more even base flows, as compared to reduced flows during peak-power periods. The study found substantial economic values for rafting with increased water flows – $2 million per year.

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As in the Mono Lake study, the impact of the contingent valuation analysis helped change perspectives about how economic tradeoffs should be discussed. Rather than recreation versus hydropower, the challenge was now to find a release pattern that increased the economic value of all uses of the river water.

For a variety of reasons, more even flows were put into place while the final environmental impact studies were being prepared, and Congress formalized these flows when it passed the Grand Canyon Protection Act of 1992. Whatever the effects of the contingent valuation study on that decision, the study did represent one of the first federally-funded projects to estimate non-use values. It was also one of the first contingent valuation studies included as part of a federally funded economic analysis.

As it became clear that more than recreation was at stake in re-regulation of the dam, it became more obvious that citizens throughout the U.S., not just rafters, cared about how dam operations affected the natural resources of the Grand Canyon. In particular, people were concerned about threatened and endangered fish, native vegetation, and birds, which were all being adversely affected by "unnatural" water flows and a lack of high spring water flows. As a result, the Bureau of Reclamation funded a major contingent valuation study of households throughout the U.S. to estimate their willingness to pay for flow regimes that would protect the natural resources in the Grand Canyon.

The results showed strong support for a more natural flow regime. While it would be difficult to point to any one study as definitively affecting the management of the Glen Canyon dam, the public support illustrated through the contingent valuation study, and in other ways, resulted in substantial changes in the management of the dam. This included large spills during the spring of 1995 to emulate the natural high spring flows.

The contingent valuation method has great flexibility, allowing valuation of a wider variety of non-market goods and services than is possible with any other non-market valuation technique. It can be used to estimate both use and non-use values, and it is the most widely used method for estimating non-use values. It is also the most controversial of the non-market valuation methods.

Applying Ecosystem Value Estimates – Benefit-Cost Analysis

The most common use of ecosystem values for decision-making is in benefit-cost analysis. Benefit-cost analysis compares benefits and costs to society of policies, programs, or actions to protect or restore ecosystems. Benefit-cost analysis measures the net gain or loss to society from a policy or action.

The objective of benefit-cost analysis is to determine whether society, as a whole, will be better off if the policy or action is implemented. This requires enumerating and evaluating all of the measurable benefits and costs and comparing them. In this manner, a single policy or action may be evaluated to determine whether it provides net economic benefits to society. Alternatively, several policies or programs may be compared to determine which provides the greatest net economic benefits.

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Benefit-cost analysis is only one of many possible ways to make public decisions about the natural environment. Because it focuses only on economic benefits and costs, benefit-cost analysis determines the economically efficient option. This may or may not be the same as the most socially acceptable option, or the most environmentally beneficial option. Remember, economic values are based on peoples' preferences, which may not coincide with what is best, ecologically, for a particular ecosystem. However, public decisions must consider public preferences, and benefit-cost analysis based on ecosystem valuation is one way to do so. Often, when actual decisions are made, a benefit-cost analysis will be supplemented with other information, such as equity implications or overriding environmental considerations. Benefit-cost analysis is conducted in four steps:

The first step is to specify and describe the policy or action to be evaluated, including such information as its location, timing, and the people who will be affected.
The second step is to describe and quantify the effects of the policy or program that will lead to benefits and costs to society. .
The third step is to estimate the social costs and benefits. Benefits might also include non-use values for the improvements in affected ecosystems. These benefits would be quantified using one or more of the methods described in Dollar-Based Ecosystem Valuation Methods.
The final step is to compare benefits and costs of the proposed project. Because the benefits and costs usually occur over many years, this step involves calculating and comparing the present value of benefits and costs. The present value is the current value of benefits and costs that are received in the future. A discount rate is used to reduce future benefits and costs to their present time equivalent. If the net present value of a project is positive, the project is worthwhile in terms of economic efficiency.

Discounting is applied to benefits received and costs incurred in the future for two reasons. First, people generally prefer to receive benefits sooner rather than later, and to pay costs later rather than sooner. Second, money that is available now can be invested and earn a return. Thus, money available now is worth more to people than money received in the future.

For example, if $1 is invested at a 10% interest rate, it will be worth $1.10 after one year, $1.21 after two years, and so on. Discounting reverses this process, by calculating the value, in today's dollars, of a given amount received in the future. For example, if a person is promised $1.10 at the end of a year, and their discount rate is 10%, they would be equally happy with $1.00 today.

Thus, the discounted present value of a benefit received in the future is calculated as: Bt/(1+r)t, where Bt is the benefit to be received in year t, and r is the discount rate. Costs would be similarly discounted. So, a benefit of $1.21 received in two years, where the discount rate is 10%, is worth $1.21/(1.1)2 = $1.21/1.21 = $1 today. Thus, $1 is the discounted present value of $1.21 received in two years, for a 10% discount rate.

For decisions related to natural resources, the appropriate discount rate is the rate that reflects society's preferences for allocating natural resource use over time.

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A larger discount rate gives more weight to the present in relation to the future, and thus benefits to the current generation are given more weight than benefits to future generations. In many cases, the discount rate is set by federal regulations. For example, the U.S. Department of the Interior sets the discount rate for Federal water and related land resources planning, based on the average yield of interest-bearing marketable securities of the United States.

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