Only the text in the *green italics* represents the consensus views of the SAB Committee on Valuing the Protection of Ecological Systems and Services and has been approved by the chartered SAB, All other text was provided by individual committee members and is offered to extend and elaborate the very brief descriptions provided in chapter 4 of the SAB Report, *Valuing the Protection of Ecological Systems and Service* and to encourage further deliberation within EPA and the broader scientific community about how to meet the need for an integrated and expanded approach for valuing the protection of ecological systems and services.

Non-market methods - revealed preference

Excerpt from draft SAB Committee report, *Valuing the Protection of Ecological Systems and Services*: *Revealed-preference methods exploit the relationship between some forms of individual behavior (e.g., visiting a lake or buying a house) and associated environmental attributes (e.g., of the lake or the house) to estimate value. For example, travel cost methods (including applications using random utility models) use information about how much people implicitly or explicitly pay to visit locations with specific environmental attributes including, specific levels of ecosystem services, to infer how much they value changes in those attributes. Hedonic pricing uses information about how much people pay for houses or other directly-purchased items with specific environmental attributes (e.g., visibility, proximity to amenities or disamenities) to infer how much they value changes in those attributes. It also may use information about the wages people would be willing to accept for jobs with differing mortality or morbidity risk levels to infer how much they value changes in those risks. In contrast, averting-behavior methods use observations on how much people spend to avoid adverse effects, including environmental effects to infer how much they value or are willing to pay for the improvements those expenditures yield.*

Further reading

General

Bockstael, N.B., and K.E. McConnell. 2007. Environmental and resource valuation with revealed preferences: A theoretical guide to empirical models (The economics of non-market goods and resources) New York: Springer.

Travel costs

Phaneuf, D.J., and V.K. Smith. 2005. Recreation demand models. In Handbook of environmental economics, vol. 2, ed. K. Mäler and J. Vincent. Amsterdam: North-Holland.

Randall, A. 1994. A difficulty with the travel cost method. Land Economics 70: 88-96. Smith, V.K. and Y. Kaoru. 1990. Signals or noise? Explaining the variation in recreational benefit estimates. American Journal of Agricultural Economics 72: 419-433.

Walsh, R.G., D.M. Johnson, and J.R. McKean. 1992. Benefit transfer of outdoor recreation demand studies, 1968-1988. Water Resources Research 28: 707-713. 47

Hedonic pricing

Cropper, M.L, L. Deck, and K.E. McConnell. 1988. On the choice of functional forms for hedonic price functions. Review of Economics and Statistics 70: 668-75.

Mahan, B.L., S. Polasky, and R.M. Adams. 2000. Valuing urban wetlands: A property price approach. Land Economics 76: 100-113.

Palmquist, R.B. 2005. Hedonic models. In Handbook of environmental economics, vol. 2, ed. K. Mäler and J. Vincent. Amsterdam: North-Holland.

Smith, V.K., C. Poulos, and H. Kim. 2002. Treating open space as an urban amenity. Resource and Energy Economics 24: 107-129.

Averting behavior

Dickie, M. 2003. Defensive behavior and damage cost methods. In A primer on non-market valuation, ed.

P.A. Champ, K.J. Boyle, and T.C. Brown. Dordrecht: Kluwer Academic Press.

Smith, V.K. 1991. Household production functions and environmental benefit estimation. In Measuring the demand for environmental quality, ed. J.B. Braden and C.D. Kolstad. Amsterdam: North-Holland

When environmental changes affect goods and services that are not traded in markets, non-market valuation, using either revealed preference or stated preference, becomes necessary. Revealed preference methods look at people's behavior in markets that are related to ecological services to reveal underlying values. For example, someone's decision about which of two houses to purchase might reveal information about how they value air quality or a scenic view if the two houses vary with regard to that environmentally-related attribute. Because the revealed preference methods for measuring values use data on observed behavior, some theoretical framework must be developed to model this behavior and to relate the behavior to the desired monetary measures of value and welfare change. A key element in the theoretical framework is the model of the optimizing behavior of an economic agent (individual or firm) that relates the agent's choices to the relevant prices and constraints, including the level of ecological services

being provided. If a behavioral relationship between observable choice variables and the ecosystem service can be specified and estimated, this relationship can be used to calculate the economic value of changes in these service flows. For example, one well-established behavioral relationship is that between the costs to individuals of visiting a recreation site and the numbers of visits make to the site. See the discussion of the travel cost method that follows. If the numbers of visits also varies systematically with the level of an ecosystem service provided by the site, then the value of the ecological service can be inferred from these relationships.

The degree to which inferences about the value of a change in ecosystem services can be drawn from market observations, and the appropriate techniques to be used in drawing these inferences, both depend on the way in which the ecosystem service enters individual utility functions. The exploitation of possible relationships between environmental goods and private goods leads to several empirical techniques for estimating environmental and resource values. This section covers three revealed preference methods: travel cost, hedonics, and averting or mitigating behavior models.

Travel cost

Brief description of the method. The travel cost method accepts as a maintained hypothesis that people have economic demand functions for the services of environmental resources that are associated with observable choices they make to travel to a particular location. While in principle this method could be applied to travel for a variety of purposes, in practice it is applied in the context of travel associated with outdoor recreation. Lakes, rivers, forests, and beaches are examples of the types of resources involved. The essence of the method is recognition that users pay an implicit price by giving up time and money to take trips to these areas for recreation. This recognition is important because most of the public facilities for recreation in the United States do not have market determined fees for that use. The cost of a visit to a site is the out-of-pocket costs of travel including any site admission fees, opportunity cost of travel time, and the opportunity cost of time on site.[1]

[1] The last component of these costs, the cost of time on site per visit, is difficult to include because it is reasonable to assume it is jointly determined with decisions about the location to visit and the number of trips to take in a season. It is also related to measures of the amount of

The values of ecosystem services are captured by the method to the extent they can be represented as factors that influence a person's decision about where or how often to travel. For example, a measure of the availability of fish in a lake used for fishing would presumably influence (along with other factors) a person's decisions about whether or how often to visit the site for fishing.

Until about the middle 1990's, the travel cost literature estimated travel costs for the simple case of a new site or loss of site. The loss of an area (due to activities that eliminate its recreational value) is represented as "equivalent to" a price or travel cost change that is large enough to cause all existing users to no longer take trips to the site. To use the travel cost method for more sophisticated environmental policy choices, i.e., those that change the quality of recreational opportunities, analysts need to know how those quality attributes influence the demand function for recreation. In practice, most economic models for recreation now use random utility models (RUM), which describe the decision process associated with each individual selecting which recreation site among a number of alternatives to visit. A RUM framework describes these choices as the result of a constrained optimization process: selecting the site that yields the maximum level of utility (or well-being) that is possible given a person's constraints. The result can be expressed as a function of travel costs, site characteristics such as the level of ecosystem services and the facilities to support specific activities (e.g., boat ramps, ski lifts, etc.), and users' attributes.

<u>Status as method</u>. The travel cost methodology is based on well-established economic principles. There has been extensive use of this method in peer-reviewed literature, dating to 1947 when Harold Hotelling first proposed it. There is less experience with using the method to estimate trade-offs for a wide range of attributes of recreation sites. Assumptions are understood and documented. Meta analyses – Smith and Kaoru (1990), Walsh, Johnson and McKean (1992), Rosenberger and Loomis (2000), Johnston, et al. (2003) and Johnston, et al. (2005) have documented the performance of the model in different circumstances.

---

the site's services that are consumed. Most studies acknowledge these costs as an issue but don't include them in the analysis as a result of these difficulties. As a rule the time on site per trip is assumed to be held constant.

Measures of the economic value have been used in EPA's RIA analyses for regulations affecting recreation resources. A recent example is the Phase III component of the 316B rule. The rule seeks to reduce impingement and entrainment of fish and other organisms through power facilities' uptake of cooling water.

Strengths and Limitations. The primary data requirements of the travel cost methodology are as follows: data on people's usage of recreation sites; measures of individuals' values of time and time constraints; information that allows measures of the environmental attributes of the resources used for recreation to be linked to those resources; and information that describes the relationship between technical indexes of the attributes of recreation sites and measures that users can be expected to understand and know.

The analysis requires technical training in micro-economic modeling of demand and extensive experience with micro-econometrics to estimate recreation demand models. Less experience is required to use existing models to estimate economic values for changes in factors hypothesized to affect people's recreation behavior.

Uncertainties. One important source of uncertainty in the travel cost model is the value of recreationists' time as a component of the cost of a recreation trip. Randall has argued that for several reasons "travel cost is inherently unobservable" (1994, p. 88). The role of time in explaining recreation demand and in valuing recreation visits and sites raises some thorny issues for both the standard travel cost and RUM approaches of analysis. Clearly, time is an important variable in the analysis of recreation demand and value. However, numerical estimates of demand and value require either that the numerical value of the shadow price of time be known or that it be estimated from a model of the choices made regarding the uses of time. A variety of models of choice and time are available in the literature. However, as yet, different model structures yield quite different estimates of the shadow price of time, and there is no clear basis for preferring one model and its value over other models. Until these issues can be resolved, estimates of recreation values should be presented as conditional upon a specific value of the shadow price of time or a specific modeling approach regarding the role of time, and the uncertainty in the estimates that this implies should be acknowledged. For more on this issue, see Freeman (2003, Ch. 13).

Key References

Champ, P.A., K.J. Boyle and T.C. Brown, eds. 2003. *A primer on non-market valuation*. Dordrecht: Klumer Academic.

Freeman, A.M., III. 2003. *The measurement of environmental and resource values* 2nd ed. Washington, DC: Resources for the Future.

Haab, T.C. and K.E. McConnell. 2002. *Valuing environmental and natural resources*. Cheltenham, UK: Edward Elgar.

Johnston, R.J., E.Y. Besedin, and R.F. Wardwell. 2003. Modeling relationships between use and nonuse values for surface water quality: A meta-analysis. *Water Resources Research* 39: 1363-1372.

Johnston, R.J., M.H. Ranson, E.Y. Besedin, and E.C. Helm. 2005. What determines willingness to pay per fish? A meta-analysis of recreational fishing values. Under review at *Marine Resource Economics*.

Phaneuf, D.J., and V.K. Smith. 2005. Recreation demand models. In *Handbook of environmental economics*, vol. 2, ed. K. Mäler and J. Vincent. Amsterdam: North-Holland.

Randall, A. 1994. A difficulty with the travel cost method. *Land Economics* 70: 88-96.

Rosenberger, R.S., and J.B. Loomis. 2000. Using meta-analysis of economic studies: An investigation of its effects in the recreation valuation literature. *Journal of Agricultural and Applied Economics* 32: 459-470.

Smith, V.K. and Y. Kaoru. 1990. Signals or noise? Explaining the variation in recreational benefit estimates. *American Journal of Agricultural Economics* 72: 419-433.

Walsh, R.G., D.M. Johnson, and J.R. McKean. 1992. Benefit transfer of outdoor recreation demand studies, 1968-1988. *Water Resources Research* 28: 707-713.

Hedonics

Brief description of the method. Hedonic methods seek to exploit possible relationships between demands for private goods and their associated bundle of characteristics, including environmental characteristics. For example, the demand for a house depends not only on its physical attributes (e.g., total size, the number of bedrooms, etc.) but also on the surrounding environmental characteristics (e.g., air quality, proximity to beach, etc.) When people select from among the set of available goods (e.g., available houses), the hedonic model assumes that they will choose the one that is their most preferred given its price and attributes. In equilibrium, the set of prices for these differentiated goods will be structured so there is no incentive for anyone to change their choices. The hedonic price function relating prices to characteristics is a

reduced form description of this equilibrium condition. The primary applications of this logic in the field of environmental economics involve housing prices and the wage rates for jobs.

Assuming that the price of a house reflects the attributes of that house, its property, neighborhood, and facilities that are "near" it, then the hedonic price function reflects a buyer's marginal willingness to pay (WTP) for small changes in one of these attributes. This measure is a single point estimate of the marginal value. The method does not provide the basis for measuring, without additional assumptions, any economic benefits that are associated with a large change in one or more of these attributes. These attributes can include the structural features of the house, its lot, and the characteristics that are conveyed to those living in the home because of its location. For example, if a house is on the coast, residents can experience the coastal views, any beach related amenities, as well as any greater risk of damage that might arise from coastal hazards. If that feature is some aspect of an ecological service available to an individual because she lives in the house, the model allows that incremental value of a change in that service to be estimated.

If the attribute measures a characteristic that can be related to a policy, e.g., proximity to a Superfund site before and after clean up, then it is possible to describe a buyer's willingness to make trade-offs for small changes in that attribute. There are important qualifications that must be considered in evaluating the results from these models. For example, to the extent the prices for homes near wetlands or in flood zones are found to be related to (i.e., have a statistically significant association with) the measures that are used to isolate these features, then there is indirect evidence that these features are recognized by buyers and sellers. This result follows because they contribute to the observed equilibrium prices for the homes represented by the hedonic function. Relating such a recognition to a measure of the incremental value for the change in services requires assumptions describing how changes in the variable that can be measured and included in the price function relate to changes in the service of interest.

Extensive data are needed to estimate a statistical function that relates housing prices to housing characteristics that include environmental attributes so that small changes in the quality or quantity of that environmental attribute can be related to small changes in housing prices.

<u>Status as a Method</u>. The hedonic method has been widely used to evaluate site-specific amenities and disamenities. Examples of applications involve: air pollution, noise pollution,

proximity to water bodies, wetlands, coastal areas, and location of homes in hazardous areas such as earthquake or flood zones. See Palmquist (2005) for a general overview of the literature and Smith and Huang (1995) for a meta-analysis of the studies of air pollution and property values. This and other meta-analyses indicate clear support for the methods for applications where we can expect buyers and sellers to have knowledge of the amenities.

Applications involving site attributes that might be more closely aligned with services of ecosystems are much more limited. Several studies have investigated the effects of proximity to wetlands of different types as well as for distance to open space. Examples include Mahan, et al. (2000), Netusil (2005), and Smith, et al. (2002). An important difficulty in using these results arises in converting the incremental value estimated for a change in distance to a measure more directly related to changes in ecosystem service.

Strengths and Limitations. Hedonic methods are familiar to most people who have purchased or sold a house because realtors do an informal hedonic type analysis comparing homes described as "comparables" to price a proposed new listing.

The main strength of the hedonic housing method is that it is based on people's actual choices. However, all hedonic methods face significant econometric hurdles and are subject to the standard criticism of statistical relationships that they reveal correlation but fall short of revealing causation. Hedonic estimates can be sensitive to the choice of model specification (see, for example, Cropper, Deck and McConnell 1988). Moreover, relating housing prices to many ecosystem services remains elusive. Finally, hedonic methods can only capture the value of environmental changes that individual homeowners recognize. The method is best suited for local housing markets. While several studies have estimated national hedonic property value models, it is generally agreed that it is unreasonable to assume that there is a single national market for housing with an equilibrium that adequately describes the trade-offs among housing attributes in very different locations.

To implement the method for estimating the hedonic price function, it is important to have access to a real estate transaction database with sales prices, housing characteristics, and the latitude/longitude coordinates for each property. These data can then be merged to GIS files describing access to various spatially delineated environmental resources such as air quality as well as to ecosystem services.

Uncertainty. The primary sources of uncertainty with the hedonic model for policy applications arise with the measurement of attributes that are assumed to represent the environmental services available to people due to living in the house. Further research on how people learn about these aspects of a location and what they consider to be conveyed by a location would help to address this issue.

In addition, simulation analysis evaluating the performance of hedonic price functions as approximations to an equilibrium matching process would also contribute to our understanding of the sensitivity of the method to assumptions about model structure and functional form. See, for example, Cropper, Deck and McConnell (1988).

Key References

Champ, P.A., K.J. Boyle and T.C. Brown, eds. 2003. *A primer on non-market valuation*. Dordrecht: Kluwer Academic Press.

Cropper, M.L, L. Deck, and K.E. McConnell. 1988. On the choice of functional forms for hedonic price functions. *Review of Economics and Statistics* 70: 668-75.

Freeman, A.M., III. 2003. *The measurement of environmental and resource values*. 2nd ed. Washington, DC: Resources for the Future.

Haab, T.C., and K.E. McConnell. 2002. *Valuing environmental and natural resources*. Cheltenham, UK: Edward Elgar.

Mahan, B.L., S. Polasky, and R.M. Adams. 2000. Valuing urban wetlands: A property price approach. *Land Economics* 76: 100-113.

Netusil, N. 2005. The effect of environmental zoning and amenities on property values: Portland, Oregon. *Land Economics* 81: 227.

Palmquist, R.B. 2005. Hedonic models. In *Handbook of environmental economics*, vol. 2, ed. K. Mäler and J. Vincent. Amsterdam: North-Holland.

Smith, V.K., C. Poulos, and H. Kim. 2002. Treating open space as an urban amenity. *Resource and Energy Economics* 24: 107-129.

Averting behavior models

Brief Description of the Method. Averting or mitigating behavior models simulate consumer behavior and rely on the existence of an activity that substitutes for the services provided by an environmental resource. The averting behavior method infers values from defensive, mitigating, or averting expenditures, i.e., those actions taken to prevent or counteract the adverse effects of environmental degradation. For example, an individual might purchase a

water filter to avoid the health risks associated with drinking unfiltered water. By analyzing the expenditures associated with these defensive purchases, researchers impute a value that individuals place on small changes in environmental or health risks. In effect, a defensive expenditure is spending on a good that is a substitute for health protection or an environmental quality or service. Because the method is based on an estimation of the marginal rate of technical substitution between the environmental service and a market good or service with a known market price, it is capable of producing monetary estimates of the value of the environmental service. What is required is an understanding of the technical relationships underlying the ability of the environmental service and its market good substitute to enhance human well-being.

Status of the Method. There is a substantial literature on the theoretical dimensions of the method (for example, Freeman 2003, Dickie 2003, Smith 1991) but relatively few convincing studies demonstrating it will work in practice. Examples of defensive expenditures include the choice of automobile type (as it relates to fatality risk), safety helmets, fire alarms, and water filters. However, since these expenditures only capture a portion of an individual's willingness to pay (WTP) for these protections, averting behavior results are sometimes interpreted as a lower bound on willingness to pay to avoid a particular harm. The most common application of averting behavior models has been the estimation of values for morbidity (illness) risk.

Limitations. Averting behavior studies rarely provide economic values for ecosystem services. Even for those averting behavior studies for water quality, the motivation for the averting behavior is usually to protect health or life.

Key References

Dickie, M. 2003. Defensive behavior and damage cost methods. In *A primer on non-market valuation*, ed. P.A. Champ, K.J. Boyle, and T.C. Brown. Dordrecht: Kluwer Academic Press.

Freeman, A.M., III. 2003. *The measurement of environmental and resource values.* 2nd ed. Washington, DC: Resources for the Future.

Smith, V.K. 1991. Household production functions and environmental benefit estimation. In *Measuring the demand for environmental quality*, ed. J.B. Braden and C.D. Kolstad. Amsterdam: North-Holland.