

PROCEEDINGS

**1997 WORKSHOP ON VALUATION
AND ENVIRONMENTAL POLICY**

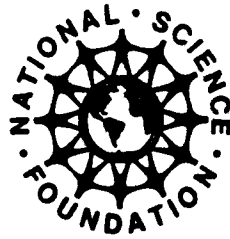
7-8 April 1997
Arlington, Virginia

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ENVIRONMENTAL PROTECTION AGENCY

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Introduction

On 8 December 1994, the National Science Foundation (NSF) and the Environmental Protection Agency (EPA) signed a 3-year Memorandum of Understanding establishing a partnership for the support and merit review of fundamental, extramural environmental research. In addition to jointly supporting research, NSF is providing assistance, consultation, and merit-review mentoring as EPA's Office of Research and Development expands its extramural grants program.

The Valuation and Environmental Policy competition was one of three competitions sponsored in FY1995 by the NSF/EPA Partnership for Environmental Research. Using panels of experts from outside the agencies, NSF and EPA staff reviewed 87 proposals and made 16 awards totaling \$2.3M. Research was encouraged on the measurement of values, with an emphasis on situations where prices or comparable standards of worth are deficient or absent. In particular, research was solicited in four related areas:

- *Fundamental Concepts.* This area of research recognizes that many critical issues in valuation, including psychological perceptions and comprehension, cultural norms, and methodological issues of social value, require contributions from a broad range of social and behavioral science disciplines.
- *Stated Preference Methods.* Stated preference methods seek to identify benefits and/or costs of environmental policy or regulation.
- *Ecosystem Valuation.* Scientific advances in ecosystem research require better understanding of the interconnectedness among social, economic, physical, and biological systems. Research in this area focuses on how comprehensive and critical ecosystem changes can be measured in terms of social welfare.
- *Valuing Environmental Resources in National Economic Accounts.* Research in this area develops valuation methods for national environmental assets, determines their consistency with accounting practices in the current national accounts, and demonstrates the practical feasibility of methods.

The April 1997 Workshop on Valuation and Environmental Policy provides a forum for investigators funded by the FY 1995 competition to interact with one another and with EPA, NSF, and other federal officials interested in valuation research. For the proceedings volume, investigators were asked to contribute statements describing the objectives and significance of their work, as well as preliminary findings from their first year of research.

The NSF/EPA Valuation and Environmental Policy competition was executed again in 1996, with an expanded focus and new title: Decision Making and Valuation for Environmental Policy. The competition reviewed 133 proposals and made 13 awards totaling \$2.6M. This year, 71 proposals have been received under the NSF/EPA Decision Making and Valuation for Environmental Policy competition. Decisions on these proposals are expected by July of 1997.

Any opinions, findings, conclusions, or recommendations expressed in this report are those of the investigators who participated in the research. For further information about this competition, please contact the Program Officers: Ms. Deborah Hanlon, EPA, 202/260-2726 or Dr. Cheryl Eavey, NSF, 703/306-1729.

Development of a Theory of Values and Their Measurement

Jonathan Baron

University of Pennsylvania, Philadelphia, PA

The ultimate purpose of this research is to design improved measures of the utility of outcomes, such as the effects of policies on the environment or on individual well-being (in the form of time or monetary expenditures or health effects). All current measures – contingent valuation, standard gambles, direct ratings, time tradeoffs, person tradeoffs, and multi-attribute judgments – have been criticized for being internally inconsistent, insensitive to relevant factors, or sensitive to irrelevant factors.

In utility measurement tasks, subjects judge the utility of objects relative to some zero value. For example, subjects may judge the disutility of losing a finger or a hand relative to the zero point of losing nothing. In some judgments, subjects produce the object rather than the relative judgment. So, they might indicate the amount of money that has half of, or all of, the utility of losing a finger (as in contingent valuation).

Judgments can be indirect in terms of hypothetical decisions such as buying or gambling. Indirect judgments are distorted by heuristics and intuitions concerned with the context of the decision rather than the values of interest: values seem protected from tradeoffs when deontological moral rules (rules prohibiting certain actions) are brought to bear; subjects confuse means with ends, and cost with value; subjects are insensitive to quantity; and subjects confuse quantity measures with each other (e.g., number of lives saved with proportion of lives saved).

Direct judgments avoid many of these problems, but they raise other problems, in particular, those concerned with the scaling of utility. For example, subjects may say that losing a finger has half the (dis)utility of losing a hand but losing a hand has ten times the (dis)utility of losing a finger. This may result from excessive attention to the subject of the comparison (finger or hand, respectively).

Our current research is directed at solutions to these problems of direct judgment, as well as continued investigation of the distorting effects of indirect methods. One type of solution involves the use of tasks designed to minimize scaling distortions, plus consistency checks and the opportunity to revise initial judgments. For example, the problem of inconsistent proportions may be avoided by using neither finger nor hand as the standard and asking for utility judgments of both simultaneously. The resulting judgments may be checked for conformity to other criteria such as transitivity (finger/arm ratio should be product of finger/hand and hand/arm). We find that most subjects can correct their judgments based on such criteria without feeling that their judgments are no longer honest representations of their views.

Preference Formation And Elicitation in Valuing Non-Market Goods

Robert Berrens, Alok Bohara, David S. Brookshire, Philip T. Ganderton, Hank Jenkins-Smith, Hillard Kaplan, Michael McKee, and Carol Silva
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The objective of this research project is to investigate the interaction between value formation and value elicitation. The project is based on the premise that an understanding of how individuals form environmental values cannot be decoupled from value statement problems and the choice of elicitation mechanism. The methods we are employing include a combination of focus groups, laboratory experiments, and telephone surveys.

The focus of the survey effort is to measure the nonmarket benefits of protecting instream flows. In February 1995, we conducted a dichotomous choice contingent valuation (CV) telephone survey using a voluntary contribution trust fund format, and replicated it in February 1996. Our analysis of the data involved sensitivity tests to detect a change in the scope of the good, and corollary tests for sensitivity to information about the collective nature of providing the good and the temporal reliability of the results. Using the pooled data, we test sensitivity to scope and the group-size reminder under alternative modeling assumptions. We use four parametric models and evaluate the results of estimates of mean and median willingness to pay (WTP) and interquartile ranges.

The evidence compiled to date supports sensitivity to scope. One policy caveat that should be noted is that estimates of mean WTP are extremely sensitive to the distributional assumption, while estimates of median WTP are much more conservative and stable. The evidence also supports insensitivity to the group-size reminder.

Of significance is the absence of evidence supporting the "contribution model." Further, our results suggest that telephone surveys may be credible as an alternative to in-person interviews for investigating particular issues in contingent valuation studies.

In the future, we will perform a side-by-side comparison of the group-size reminder for open-ended and dichotomous choice formats. We have collected all necessary data, including an additional split-sample cross treatment.

The behavioral laboratory effort for this project is focused on understanding the individual decision process in valuation. Our first investigation found that the disparity between willingness to accept (WTA) and WTP is due to uncertainty concerning the payoff from the good. This uncertainty can arise from a variety of sources. Value uncertainty is when the good is unfamiliar to the respondent. Outcome uncertainty concerns whether the agency in question will be able to provide the good with the funds generated. We found that the disparity is a function of the level of uncertainty and can be mitigated when the purchase is reversible.

A second issue that we are investigating is the role of provision mechanisms on stated WTP values. Our laboratory work will investigate WTP under different public good provision mechanisms that can be implemented in surveys. Although data collection is not yet complete, the evidence suggests that individuals give different responses for the same good depending on the mechanism. Future laboratory work will investigate the role of uncertainty concerning payoffs on public good provision and stated WTP.

Comparative Statistics of Approaches to Eliciting Economic Values

Richard T. Carson, Theodore Groves, and Mark J. Machina

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Surveys of the public are often undertaken to help ascertain the public's preferences. If successful, this information can be an important component to determining optimal public policies and making business decisions. Often, however, survey results are dismissed, particularly by some economists who question the creditability of responses to survey questions. Essentially, the argument made is that nothing is at stake for the survey respondent in answering a question. This rather automatic dismissal seems a bit odd in light of the billions of dollars spent each year by businesses and governments to collect and analyze survey data.

From a substantive perspective, this dismissal of survey responses can be seen as inappropriate if either of two conditions hold. The first occurs if survey respondents are motivated to seriously consider the questions asked and they answer truthfully. This is the basic assumption of the other social sciences disciplines, which explains to a large degree their enthusiastic embrace of the use of survey data. The second occurs if respondents believe that governments and businesses consider their survey answers in making decisions. This would appear to be not an unreasonable assumption in a world where a frequent criticism of governments is that they pay too much attention to the public's stated preferences in surveys and that business decisions are driven largely by marketing research tests. In this situation, an economist's first reaction to a survey question with real consequences might be to argue for the strong possibility of a strategic response. The pitfall economists tend to fall into here is not in considering the possibility of strategic behavior, but rather in jumping to the conclusion that if respondents behave strategically, their answers cannot provide useful information. This is obviously not true if optimal strategic behavior coincides with truth-telling or if the influence of the strategic behavior can at least be partially unraveled. We address the issue: what is the optimal strategic response to a specific survey question?

The approach that we use is to adopt the theoretical framework of mechanism design long used in economics to formally examine the role of incentives and information. The major advantage of mechanism design theory is that it provides a

consistent theoretical model for comparing a wide variety of different question formats and specific contexts in which survey questions are asked. We start by providing a formal definition of consequential and hypothetical survey questions. Economic theory provides strong predictions for optimal responses to the former but no predictions about the latter. Most, but not all, surveys generally labeled as contingent valuation or marketing surveys fall into the class of consequential surveys.

The key result of this project is that the form of the optimal strategic response is context-dependent in ways that make it difficult to make any general claims about the properties of particular response elicitation format, such as a binary discrete choice question, without further specifying the context being used. It is this context-dependence that appears to give rise to a variety of conflicting claims made in the literature. Fortunately, the properties of consequential choices, at an abstract level, depend upon only a few key features. For instance, when using a binary discrete choice response format, it is straightforward to demonstrate fairly general conditions under which the optimal strategic response is truthful preference revelation if the good is a pure public good and a coercive payment mechanism is used. In contrast, it is possible to demonstrate that truthful preference revelation can never generally be the optimal response strategy to a binary discrete choice survey question involving the provision of a new private good or a pure public good with a voluntary contribution mechanism. The key features that we consider are given in Table 1 on the next page.

We believe that our results will serve several distinct purposes. First, they provide a consistent basis upon which to make predictions about the optimal response to any particular survey question. This should assist in the interpretation of existing results and provide a basis upon which to develop new experiments to help test the model. Second, the model proposed should help researchers make informed decisions about what types of survey questions should be used in different contexts. Third, because the model predicts different (specific) behavior in different situations, it calls into question many claims in

the literature that particular results, such as differences between valuation estimates based upon two different survey question response formats, imply that respondents have inconsistent or non-existent preferences. Fourth, the model provides a clear linkage between observable behavior in political and private markets and responses to consequential surveys.

Currently, we are undertaking three activities with respect to this project. First, we are refining the basic theoretical model. Second, we are using the model to analyze specific situations of particular interest to environmental valuation. Third, we have begun to compare systematically the model's predictions to empirical tests appearing in the existing literature.

Feature	Specific Cases
Changes in choice set	Strict expansion, strict reduction, and strict alternation
Types of goods	Pure public, quasi-public, and private
Payment mechanisms	Coercive and voluntary
Uncertainty	Cost and benefit
Perceived government decision criteria	Political (plurality), efficiency (Pareto), and equity
Response elicitation formats	Binary discrete choice, double-bounded discrete choice, multiple choice, paired-comparisons, open-ended, bidding game, and payment card

Table 1. Strategic Behavior and Context-Dependence.

Valuing Environmental Damages With Stated Preference Methods: New Approaches That Yield Demonstrably Valid Values for Non-Priced Environmental Goods

*Ronald G. Cummings, Laura L. Osborne, James Pate, and Paul Brewer
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Stated preference or Contingent Valuation (CV) studies are often criticized on the grounds that responses to hypothetical willingness to pay questions may result in higher willingness to pay statements than would be observed if respondents were asked to make actual cash payments (this difference is called hypothetical bias). The objective of this project is to develop new methods for eliciting stated preferences that are demonstrably effective in eliciting unbiased responses to hypothetical questions. We developed two new designs for CV surveys, referred to as "Cheap Talk" and "Learning," and tested them for robustness. Results from over 1,500 surveys indicate that these two designs are capable of eliciting responses to hypothetical valuation questions that are indistinguishable from parallel valuation questions requiring actual payment.

Development and testing of these new survey designs drew from lessons learned in experimental economics and psychology concerning the design of valuation institutions. The Cheap Talk design introduces as part of the willingness to pay question an in-depth and candid description of the hypothetical bias encountered in CV studies. In the Learning design, respondents participate in a series of willingness to pay surveys: a hypothetical survey followed by a real survey (requiring actual cash payments) for one good, and then a final hypothetical survey for a different good. This design explores the extent to which subjects, having completed one hypothetical-then-real valuation series, will learn to anticipate a real question in responding to the hypothetical

question for the second good. We might then expect responses to the second hypothetical question to be the same as if the question involved real cash payments.

We conducted laboratory experiments with groups of individuals to obtain either real or hypothetical payments to non-profit organizations affecting non-priced environmental goods. Our experiments found evidence consistent with hypothetical bias, supporting previously published evidence using this methodology. The Cheap Talk and Learning Design for the hypothetical survey instrument were conducted in an effort to eliminate any differences found between responses to the surveys involving either real or hypothetical payments. In each case, we found both designs to be effective in eliminating hypothetical bias. Specifically, responses to the hypothetical questions (HQ) using either the Cheap Talk design (CTD) or Learning design (LD) were statistically *indistinguishable* from responses to questions involving real cash payments (RQ). These results were robust to changes in the good, changes in the survey design, and changes in the experimental design.

To the extent that these new designs can close the gap between responses to hypothetical surveys and surveys involving cash payments in a demonstrable manner, then the credibility and acceptability of environmental assessments are enhanced. The results from these experiments are expected to provide guidelines for the conduct of stated preference studies that produce valid responses to hypothetical valuation questions.

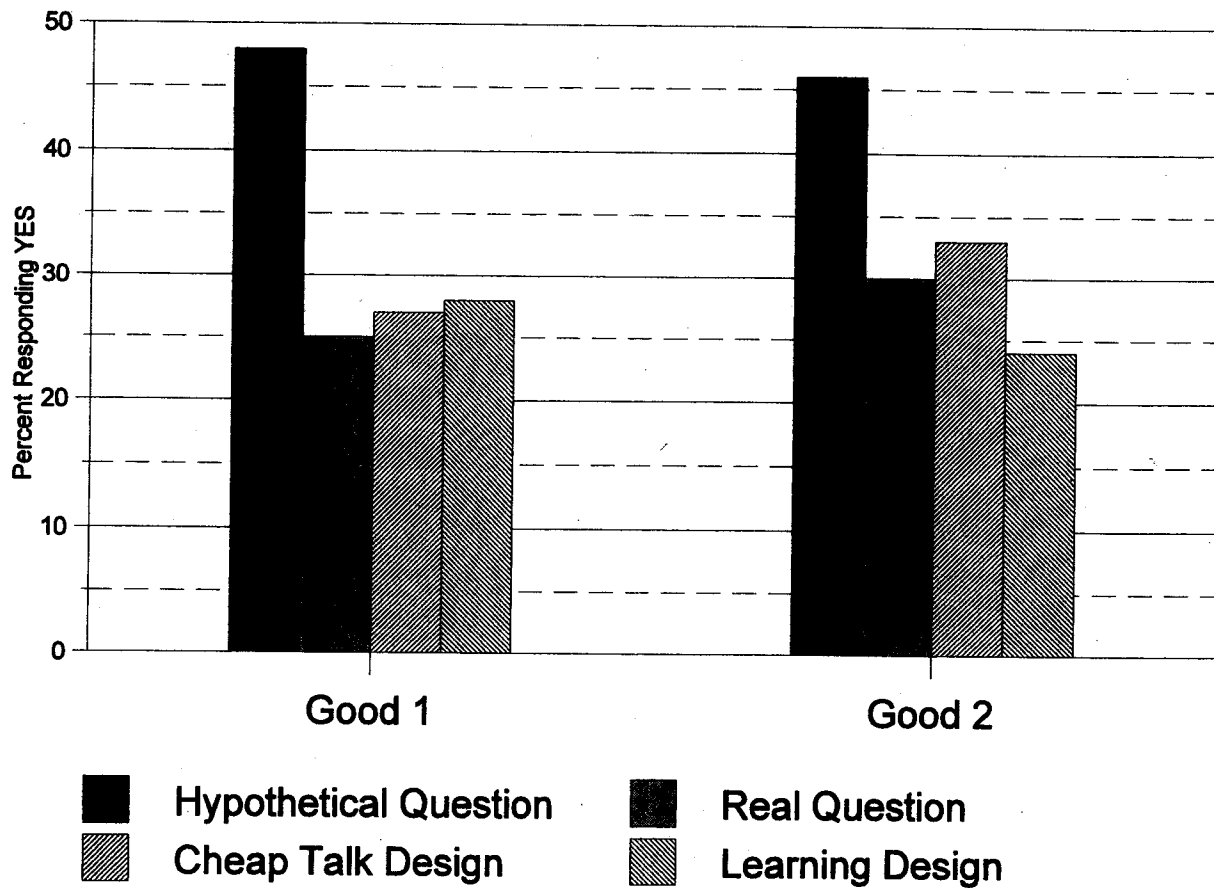


Figure 1. Responses to Referenda Questions Involving a \$10 Donation to a Public Good.

Valuing the Stock and Flow of Mineral and Renewable Assets in National Income Accounting

Graham Davis

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The purpose of this project is to advance methods of environmental asset valuation in order to accurately include additions to, and depletion of, mineral resources in national economic satellite accounts. Current income accounting does not debit the accounts for depletion of natural assets and is thus thought to misrepresent the wealth of the nation. This project focuses specifically on the valuation of mineral and energy resources, which are among the first natural resource assets to be included in the United States Department of Commerce's "Green Accounting" efforts. The broad objectives of the project are to assess and critique the existing methods of valuing the stock and depletion of commercial mineral resources, and to improve upon and supplement these methods by producing valuation methodologies that take into account price, stock, and development timing uncertainty. The goal of the project is to produce valuation methods that are not only accurate and theoretically sound, but are parsimonious and require a relatively limited amount of data such that they can be feasibly included in national income accounting exercises at a reasonable cost.

Because mineral assets do not transact on open markets, their value or "price" must be estimated via financial and economic theory. To date, valuation has been performed only on proven

reserves via various discounted cash flow methods. These methods are flawed, being based on rather simplistic formulations and yielding wide ranges of values (see Table 1 below). The approach that we take in this project is to modify these valuation formulations to correct for their weaknesses. This includes reformulating the financial theorems used to generate the valuation formulas such that they produce values that more closely match the few observed market transaction prices.

To date, we have had some success in developing improved valuation formulas for valuing the stock and depletion of proven assets where the quantity of mineral stock is known with relative certainty. These formulas remain parsimonious, requiring little more than current prices and extraction costs, yet are in close agreement with selected empirical observations of value based on market transactions. The formulas we have developed all have the basic form:

$$V = [K + \alpha(P-C)]R$$

where V is the value of the mineral reserve, R is the quantity of mineral currently in the reserve, P is the current mineral price, C is the average extraction cost, and K and α are mineral-specific

Asset	Opening Stock	Closing Stock	Net Change
Proven Mineral Assets	270.0 to 1066.9	299.4 to 950.3	-116.6 to 57.8
Oil	58.2 to 325.9	35.7 to 241.2	-84.7 to -22.5
Gas	42.7 to 259.3	49.4 to 202.2	-57.2 to 6.6
Coal	140.7 to 207.7	143.0 to 204.2	-3.4 to 2.2
Metals	< 0 to 215.3	38.5 to 244.8	29.5 to 67.2
Other Minerals	28.4 to 58.7	32.8 to 57.9	-0.8 to 4.3

Table 1. Asset Account for the United States of America, 1987, Showing Bounds on Current Estimates of Mineral Resource Stock and Depletion, Billions of Dollars
(Source: Bureau of Economic Analysis)

valuation parameters that we provide to the valuer. This looks remarkably like the net price formula $V = (P-C)R$ that is so popular in green accounting exercises, and yet through the α and K terms we incorporate many of the subtleties of mineral asset pricing left out of the net price result.

Valuing unproven reserves is more difficult, as not only do we need to estimate the unit price of the reserve, but the quantity of the mineral reserve is also uncertain. The first step has been to characterize the nature of this reserve uncertainty. Based on data for proven reserves, we find that there seems to be both a time trend in estimated reserve quantity as well as jumps, both positive and negative, as new information about the

reserve is discovered. Having characterized the stochastic nature of reserve changes, we are now proceeding to use this information in a multinomial option pricing framework, where the unproven reserve is valued as an option on proven reserves.

The new valuation methods can be applied to both proven/produced and unproven/nonproduced commercial mineral and energy resources. Time permitting, we will provide examples of these calculations. Our results will enable green accounting efforts to move forward, especially with regard to including an estimate of the stock and depletion of unproven mineral assets in satellite accounts.

Towards a Social Psychology of Stated Preferences

Thomas Dietz and Gregory A. Guagnano

George Mason University

Paul C. Stern

National Research Council

The kind of logic used in making decisions depends on the context in which the decision is made. Decisions about expensive choices, such as the purchase of a car, house, or college education, usually involve research, conversation, reflection, and comparison of alternatives. Such decisions probably are well described by rational choice theory. Routine decisions, such as the purchase of non-durable consumer goods, are repeated frequently and allow for learning over time. Thus, rational choice theory is applicable here as well. But decisions that assign value to environmental goods and services, including non-consumptive uses, may not be well described by traditional rational choice theory. Many environmental issues are novel, and the public will have limited familiarity with them. Indeed, being asked about such issues in a contingent valuation survey may be the first time many individuals have heard about such problems.

We suggest that when presented with novel phenomena, and when required to make a quick decision (as in responding to a survey), people use

cues contained in the context of the question to decide how the question links to their core values. Different cues will highlight different values and will lead to different decisions – in the case of valuation surveys, to different stated preferences. The strength of the focus effect should depend on how familiar an individual is with the objects being described in the question.

In previous studies, we have shown that payment vehicles (taxes vs. contributions to a fund) lead not only to different stated willingness to pay but also to differences in the determinants of willingness to pay. We review those results and also present preliminary analyses of a national survey with an embedded experiment in which we manipulate question wording to focus respondents on different values for some relatively familiar and some relatively unfamiliar problems. We conclude by discussing the plans for the second phase of our study in which we are experimenting with deliberative approaches to environmental valuation.

Eliciting Environmental Values: A Constructivist Approach

Baruch Fischhoff, Carnegie Mellon University

Pittsburgh, PA

There is increasing demand for thoughtful, systematic public input to environmental decision making. This demand can be found in the citizen participation components of EPA's efforts toward environmental justice and risk prioritization. It can be found in the attempts by EPA's Science Advisory Board and staff to survey public opinion for the report *Unfinished Business* and subsequent internal priority setting. And, it can be found in the need to assign dollar values to nonmarket environmental changes when setting regulatory standards. Unfortunately, the complexity and novelty of these public policy programs far outstrip the conventional uses of survey research, the research paradigm most frequently called upon to provide solutions. This project is part of an ongoing attempt to develop an alternative methodology.

The research project has three foci: how to compose complex questions, how to help respondents to produce the best answers possible, and how to characterize the definitiveness of the resulting responses (so that they can be used responsibly in public policy making). Each focus has both a methodological and a substantive thrust. To that end, we use both theoretical and empirical approaches. The former include secondary analyses of existing studies, integrative essays, and conceptual analyses of key concepts. The latter include focus group discussions, structured open-ended interviews, and experiments.

We have implemented our alternative methodology in the context of a major public policy initiative (the BTU tax proposed early in the first Clinton Administration) and a specific environmental change (a river cleanup). We have found it possible to provide a full

specification of these tasks using a framework for transactions that we proposed some years ago. We also found a willingness among citizens to participate actively in this process, as well as to probe sensibly the supplementary analyses that we made available to them. Our analyses show a mixed pattern regarding the kinds of sensitivity and insensitivity that one would want from a valid measurement technique.

One focus of our experimental and theoretical work has been identification of the sources of magnitude insensitive valuation (the tendency to provide similar valuations to different quantities of a good). We believe that our results are inconsistent with several commonly offered explanations of these measurement anomalies. A second focus is on people's conceptualization of the effects of budgetary constraints on contributions to environmental goods. Our results suggest that people have an understanding of the general issue, which they then have difficulty applying in specific cases.

We believe that we are making progress toward producing a broadly applicable methodology that grapples with the problems of the reactive measurement needed for complex, novel problems. This work brings into relief various (interesting) theoretical questions concerning how evaluation tasks (for environmental goods and others) can be formulated, understood, and completed.

We plan to continue work on each of these topics, with a particular focus on the problems of specifying the set of possible competing demands for environmental contributions and the strategies people use for conceptualizing the environment as a good.

Environmental Values and National Economic Accounts: A Theoretical Inquiry

Nicholas Flores

University of Colorado, Boulder, CO

In recent years there has been considerable discussion over the usefulness of national economic accounts such as Gross National Product, Gross Domestic Product, and Net National Product in gauging economic growth and its contribution to social welfare. The most noted shortcomings of these account measures are their failure to explicitly recognize the contribution of the environment to overall welfare. Numerous suggestions for revising or supplementing the existing set of national economic accounts are found in the literature. Our project goal is to conduct an analysis of the proposed revisions and identify potential strengths and weaknesses.

The approach we have taken is to develop a basic theoretical model using economic preference and production theory to determine the environment's contribution to overall economic welfare. The fundamental reason inefficient resource use arises is the lack of markets for most environmental goods. The lack of markets for these goods gives rise to inconsistent economic signals received by producers, whose actions may negatively affect the environment, and consumers, whose welfare is positively affected by environmental quality. Our model has two prominent dynamic features that influence the allocation of resources. First, man-made capital stock, net of depreciation, carries over into future periods and determines future production possibilities. Second, the stock of environmental goods, net of depreciation, also carries over into future periods and provides service flows that contribute to production and consumer welfare. In a departure from existing analyses, we examine the potential public goods nature of environmental goods that arises due to non-use values; technological improvement as well as shifts in preferences that may occur over time; and in some cases, changes to the environment that are irreversible.

Our preliminary findings suggest that even when the environment is properly priced in accordance with consumer preferences and producer technologies, some adjusted measures provide little insight into how welfare adjusts with time. Under certain circumstances, adjusted measures may in fact provide the wrong signal, in that the adjusted account may show an increase over time while welfare has instead declined. In cross-country comparisons, environmentally adjusted, net consumption measures will, in many cases, preserve the ordering provided by existing accounts that ignore the environment's contribution to the economy. With regard to policy implications, our preliminary results suggest that even when environmental values are correctly measured and accounts are adjusted accordingly, the measures should be interpreted with caution. If environmentally adjusted economic accounts are to become an integral part of decision makers' information sets, the potential shortcomings of these accounts need to be recognized as well.

The basis of most account adjustment recommendations is a dynamic model that correctly incorporates the environment into economic decisions. In reality, welfare evolves in an inefficient fashion due to the lack of markets for environmental goods. Our next step in the project will be to conduct numerical simulations of a simple dynamic economy as described by the theoretical model. This numerical modeling exercise should yield insight into how well various adjusted account measures reflect changes in welfare over time under the condition of missing markets.

Methods Development in Using Constructive Survey Approaches to Value Nonmarket Environmental Resources

Robin S. Gregory

Decision Research, Eugene, OR

The primary project objective is to investigate the relevance of the concept of constructed preferences, which suggests that values for complex environmental assets are not known in advance, but rather are constructed in the course of the elicitation process. This perspective argues for the adoption of environmental survey approaches that incorporate techniques for helping participants understand the attributes and implications of their own values to a much greater extent than is done at present (for example, via contingent valuation surveys). Only with this additional values tutorial, the constructed approach argues, will elicited values be accurate in the context of tradeoffs across the relevant economic, ecological, and social objectives of a proposed environmental policy.

Our project is designed to provide a theoretical structure and initial empirical results for two experimental constructive survey approaches that are intended to clarify the value of nonmarket environmental assets: decision pathway surveys and value integration surveys. The decision pathway approach asks respondents to choose among several options, thereby improving policy makers' understanding of participants' reasoning and implied tradeoffs. The value integration approach provides assistance to respondents in structuring their values, and uses this information to first create, and subsequently evaluate, a range of policy alternatives.

We have undertaken three principal tasks as part of this research effort; preliminary findings are now available for each. The first task is an examination of the rationale for using a constructed preferences approach to elicit defensible environmental values. This review is presented in a paper titled "A Constructive Approach to Environmental Valuation," written by R. Gregory and P. Slovic, that has been accepted for publication in the journal *Ecological Economics*. Application of the constructed preferences approach to valuing environmental risks is discussed by R. Gregory, T. Brown, and J. Knetsch in the paper "Valuing Risks to the Environment," *The Annals of the American Academy of Political and Social Science*, 545: 54-63. Additional findings will become available from current experiments in preference

construction that compare alternative methods for eliciting environmental policy tradeoffs.

Our second task is to develop further the decision pathways approach. A critical aspect of this experimental method is the ability to define a small number of linked (sequential) questions that effectively represent the thinking processes of participants, and we are working with small group comparisons to determine the number of pathways that typically is required. We also continue to develop case study examples of the approach. The results of a completed survey in the context of vegetation management policy alternatives are presented in "Decision Pathway Surveys: A Tool for Resource Managers," written by R. Gregory, J. Flynn, S. Johnson, S. Satterfield, and R. Wagner and accepted for publication in *Land Economics*.

Our third task is to refine the experimental value integration survey approach. An important aspect of this work is the development of techniques for combining the individual weighted value attributes that participants have stated are relevant to the environmental option in such a way that several policy alternatives can be proposed and compared. We are currently working with small groups, using techniques drawn from multi-attribute utility theory (MAUT) and decision analysis, to determine the effects of different levels of value structuring and information provision on choices. A comparison of the contingent valuation method (CVM) and value integration approaches has been completed using a forest policy case example. A second case study examines the role of value integration methods in developing alternatives for a water use plan that compares environmental, energy, flood control, management, and recreational objectives. This case study is being written for journal submission.

We believe that the preliminary findings of this research effort are of significance to the EPA and NSF in two respects. First, the findings provide insights into the nature of environmental values and the choice of appropriate elicitation techniques – ones that will be capable of capturing the multi-dimensional nature of the relevant environmental policy implications as well as the nonmonetary cognitive representation of many

key value components. Second, the results are important for the efforts of federal and state resource management agencies to develop satisfactory benefit measures for nonmarket environmental policy initiatives. Central to this contribution is the hoped-for ability of decision pathway and value integration survey methods to provide specific and high-quality information regarding the tradeoffs that identified public and expert stakeholders wish to make across the conflicting objectives of a proposed environmental policy.

The next steps of our work include further case study and empirical results from the small-group elicitation comparisons now underway. Project results were discussed at the Institute for Operations Research and the Management Sciences national meeting in Atlanta (October 1996) and the Society for Risk Analysis national meeting in New Orleans (December 1996). In addition, project results will be discussed at several conferences during 1997, linking the research effort to related ongoing projects investigating forest policy tradeoffs (directed by Clifford Russell), fishing stocks on the Columbia River (directed by Randall Peterman), and citizen participation in waste management decisions

(directed by Ortwin Renn). Meetings with members of the Advisory Committee, which includes experts in value-elicitation and survey-design methods as well as environmental policy assessments, are tentatively scheduled for late summer and early fall 1997, to review progress on the project to date and to evaluate the status of the two experimental survey approaches.

Table 1 depicts the order of key steps in a value integration survey that is designed to assist participants to construct a defensible and policy-relevant understanding of their own values. The order of the steps, and the level of detail asked of participants, is critical because the survey method introduces a way of thinking about a proposed environmental policy action. In a typical values integration survey, participants are encouraged to develop and evaluate two or three alternative programs as a step toward achieving greater reality in public input to policy decisions of this type. This assistance is in line with the notion of a values tutorial and the explicit recognition that, because value construction necessarily occurs as part of elicitation, it only makes sense to employ an explicit and careful approach.

1. Task introduction
2. Open-ended elicitation of views on proposed policy
3. Values background
4. Factual background
5. Structured values presentation: dimensions of the problem
6. Tutorial on elicitation process
7. Defining key values
8. Measuring key values (in terms of measurable attributes)
9. Rating the relative importance of specified values
10. Evaluation: valuing one dimension in terms of another
11. Connecting implied values to dimensions
12. Introduction of proposed policy alternatives A, B, C
13. Connecting expressed values to choices
14. Iterating for consistency
15. Summary evaluation of policy option (\$ willing to pay, points)
16. Selecting a preferred alternative
17. Debriefing on task and evaluation process

Table 1. Example Sequence of Value-Integration Survey Tasks.

Mortality Risk Valuation and Stated Preference Methods: An Exploratory Study

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Recent analyses of the benefits and costs of environmental regulations, such as EPA's *Retrospective Cost-Benefit Analysis of the 1970 Clean Air Act* and EPA's *Regulatory Impact Analyses for Ozone and Particulates*, pivot around the estimates of the benefits from reducing mortality risks. Each of these studies rely on a valuation literature that, being based on hedonic labor market studies of accidental workplace deaths and on contingent valuation studies of reducing accidental death risks, is not necessarily applicable to the population and type of risk reduction appropriate to the case of pollution and mortality.

Our study is designed to begin to fill some of the gaps in the mortality risk valuation literature, focusing on the effect of current age and age of life extension on willingness to pay (WTP). In this phase of the work, we are not estimating such relationships. Rather, we are using an unusually explicit contingent valuation instrument, administered in-person with visual aids and a "think aloud" protocol, to help reveal how individuals process and interpret key concepts in valuing mortality risk reductions. These concepts include: small probabilities, tradeoffs, mortality risks, the hazard rate, the rate of time preference, conditional probabilities, and framing. We are also testing a protocol for identifying individuals who demonstrate understanding of some of these concepts. The script is currently being field tested.

The introductory portion of the script opens with questions to practice thinking aloud and making choices involving tradeoffs between money and commodity characteristics. These are followed by questions involving chance that are supplemented with visual aids showing a matrix of squares with one or more squares blackened to indicate the probability of an event occurring. The final introductory questions involve the subject in a choice of living in one of two cities with different death rates for a person of their age and sex. The subject is involved in labeling the visual aid to improve (and test) their understanding of small probabilities.

The heart of the survey is four sets of WTP questions addressing: (i) a reduction in the subject's death rate from their current age to one year later, (ii) an investigation of the effect on WTP of framing the questions in terms of probability of surviving rather than dying, (iii) a series of scope tests of the magnitude of the probabilities, and (iv) a reduction in the chance of dying (surviving) between the subject's 70th and 71st birthday, conditional on survival to 70.

These questions are designed to be abstract, in the sense that the commodity, the payment vehicle, and other particulars are not specified in any detail because we want to give the subject as few cues as possible in an effort to discover how they would interpret these questions on their own. Also, particularly for the very difficult questions in set (iv), we explicitly lead the subject through the conceptual issues involved in determining WTP; i.e., discounting and the chance that the subject will not be alive at age 70. This explicitness is justified because our goal is to understand how people think about these concepts, what heuristics they use to arrive at answers, and what stumbling blocks they encounter.

The next section involves leading the subject through a short conjoint analysis exercise from Krupnick and Cropper (*Journal of Risk and Uncertainty*, Vol. 5, 1992), where subjects choose to live in one city or another based on death and "chronic bronchitis" risk characteristics of the cities. Through a series of follow-up questions, they are driven to (or closer to) a point of indifference between the cities. We plan to use these questions to determine if subjects are responding to them consistently (see the appendix of the above-referenced article), and then as a measure of whether subjects are understanding small probabilities. The concluding section contains extensive debriefing material to fill in any gaps remaining in the subject's experience with our questions.

Improving the Responses to Willingness to Accept Questions Using Alternate Forms of Compensation

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Attempts to measure the amount of compensation individuals will demand (their willingness to accept, WTA) for reductions in a public good, such as environmental quality, frequently produce unreliable data. We argue that perceptions of cash as a bribe, difficulties in mentally trading cash for public goods, and other psychological reactions to cash may be responsible for the difficulty in eliciting WTA.

We test the hypothesis that individuals will be more receptive to public goods as compensation, such as parks or schools. Each question in our survey offers respondents three options: receipt of cash as compensation for allowing a decline in environmental quality, receipt of a public good as compensation, or a choice between cash and the public good. Comparing the response rates to the three options will provide evidence about people's preferences over types of compensation.

Preliminary results, presented in Table 1 on the following page, suggest that even when the cash was worth more to the individuals than the public good in a simple choice framework, they were more likely to accept compensation in the form of a public good when faced with a "public bad" such as a landfill or noise from the local airport that would impact on their entire community. In the first row of Table 1 (column 5), a majority of the respondents choose cash savings over the public good when given the choice of houses, indicating that in a neutral market setting the cash was worth more than the public good to a majority of the respondents. However, more

respondents were willing to accept the public good as compensation for the public bad than cash (columns 2 and 3). In the other two questions concerning airport noise and a livestock farm, the number of respondents who accepted cash compensation as a fraction of the total number who accepted compensation in either compensation question (column 4) is lower than the percentage of people who choose cash in the choice question (column 5). Again this suggests that when people are asked whether they would accept compensation to allow a decline in environmental quality, they prefer public goods to cash.

Our results have implications for a number of policy issues, including the siting of noxious facilities such as landfills or solid waste incinerators. The siting process is often contentious and difficult. Surveys such as the one we are developing could improve the process by identifying the preferred type of compensation for host communities.

The next step in our project is to refine the survey before implementing the final version. If our results continue to suggest that individuals prefer public goods as compensation, then additional research will be needed to determine more specifically why this is so and whether people prefer certain types of public goods. Finally, we hope to work with policy makers to produce a survey that could be used to aid actual siting decisions.

(1) Source of problem	(2) Percentage of respondents who accept cash as compensation	(3) Percentage of respondents who accept public good as compensation	(4) Number of respondents who accept cash as compensation as percentage of total respondents who accepted either cash or the public good (2)/[(2) + (3)]	(5) Percentage of respondents who choose house with lower taxes*
Landfill	13%	18%	42%	61%
Noise from Airport	15%	23%	39%	48%
Livestock Farm	21%	29%	42%	47%

Table 1. Cash Versus Public Goods as Compensation.

*The question offered individuals the choice between two houses – one with lower property taxes and one located near a public good, such as a park. This choice provides us with information as to whether the public good is worth more or less to the individual than the cash savings.

Developing Conjoint Stated Preference Methods for Valuation of Environmental Resources Within Their Ecological Context

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The objective of this research is to further develop methods for valuing environmental resources within a complex context. The research will evaluate methods to address these challenges in two ways: 1) the usefulness of valuation methods that do not rely exclusively on money-measures of value; and 2) the potential to extend available methods of resource valuation when individuals face cognitive limits. Conjoint analysis provides a means to address these avenues of research in cases where economic analysis relies upon stated preferences of individuals. The principal objectives of the proposed project are: 1) to test and to compare alternative means of estimating relative values of natural resources using conjoint analysis; 2) to implement and to test measurement of monetary values using conjoint analysis; 3) to use conjoint analysis to develop and test models of human preferences that recognize resource values are dependent upon the ecological context; 4) to expand the neoclassical economic basis of conjoint analysis to consider concepts such as strength-of-preference indicators, fuzzy logic, effects of complexity, and ambivalence theory; and 5) to develop and test alternative survey methods for measuring values.

The complexity of natural systems presents a great challenge to federal agencies charged with managing public resources. Because ecological services are highly complex and vary widely across ecosystems, services from a particular system can be difficult to identify, measure, and communicate to the public. For example, it is not possible to value the diversity of wetland environments by measuring *the* value of wetlands. Different wetlands provide varying levels of numerous services that depend both upon the characteristics of the particular wetland and its surroundings. On the one hand, appropriate methods for valuation require that the range of services of ecological systems be appropriately represented so that values for various ecosystems reflect the services provided. On the other hand, research on valuation methods suggests that complex scenarios challenge respondents' ability to provide accurate, reliable, and valid responses. This means we need to develop methods that facilitate a two-way communication between

management agencies and the public for whom resources are managed.

Conjoint analysis offers an approach that simultaneously incorporates the multiple dimensions of a complex decision and provides a context that may facilitate choices. Rather than asking survey respondents to focus on the "dollar value" of specific resources, conjoint analysis asks the respondent to make a simple (often discrete) choice among resource packages and, in some cases, to use a simple rating scale to indicate the strength of their preferences for the alternative packages. However, monetary measures of value may still be derived from a conjoint survey if the environmental goods are described along with a cost of resource protection.

If the respondent's task is simpler or more natural, the conjoint method may encounter fewer limitations due to the cognitive abilities of potential respondents. Also, because the respondent is forced to choose between two different environmental commodities, there is less danger that responses reflect symbolic statements that "the environment is important to me."

Our project also explores the theoretical and empirical usefulness of imprecise, yet meaningful information from strength-of-preference ratings scales using concepts of fuzzy math. We explore various methodological issues regarding value elicitation, including the development of survey instruments that may facilitate respondents' cognitive assessments of valuation tasks using conjoint analysis and strength-of-preference indicators.

Preference orderings and strength-of-preference indicators are a natural application of fuzzy logic. Because fuzzy knowledge underlies human thought processes and languages, fuzzy logic provides a basis for modeling precisely the type of qualitative reasoning that humans employ in uncertain or unfamiliar situations. The set of commodities that are preferred or indifferent to some particular commodity can be viewed as a fuzzy set, where some commodities are more clearly members of the set than are others. For

strength-of-preference indicators in conjoint analysis, individuals might indicate that commodity A is "strongly preferred" to B, and B is "weakly preferred" to C. These strength-of-preference indicators can also be viewed as a measure of the degree of membership in the fuzzy set of weakly preferred commodity bundles.

Can Contingent Valuation Measure Passive-Use Values?

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Critics have raised substantial concerns about the ability of contingent valuation (CV) to produce reliable estimates of passive-use values. A serious criticism is that hypothetical survey responses may not accurately predict actual behavior (validity). The objective of our project is to address the validity issue by comparing alternative CV elicitation methods (open ended, payment card, dichotomous choice, multiple bounded discrete choice, and conjoint/stated preference) with actual participation in a Niagara Mohawk Power Corporation (NIMO) green pricing program that offered customers the opportunity to fund a landfill gas recovery project and plant 50,000 trees. The NIMO program used a provision point mechanism to address free riding.

Our research consisted of two efforts. First, we conducted laboratory experiments to explore the performance of single shot provision point mechanisms (SSPM) in large group ($n > 40$) settings. Surprisingly, these mechanisms resulted in approximately demand revealing behavior. Provision point mechanisms have a Nash equilibrium where participants' contributions sum to cost. Uncertainty in a single shot environment with many risk averse participants apparently motivates demand revelation. This is an important result both because a practical and reliable demand revealing public good mechanism is needed to calibrate CV methods, and because this mechanism can be used to facilitate actual funding of public goods by utilities, local communities, and environmental organizations.

The second part of our project consisted of a field test comparing actual and hypothetical participation levels in the NIMO Green Choice program. Two separate survey efforts were undertaken, as summarized in Table 1 on the following page. First, we conducted telephone interviews during which respondents were asked to sign up on the spot for the NIMO program (which had a \$6 monthly cost). These responses can be compared to hypothetical dichotomous

choice sign-ups for the program in a nearly identical phone interview at the single posted offer price of \$6. We also asked an open ended willingness to pay (WTP) question in another treatment. Results from the phone survey are reported in the first three columns of Table 1. Appropriate statistical tests indicate that the hypothetical dichotomous choice sign-up rate was significantly different from the actual sign-up rate. The prediction from the open ended WTP question was much closer to, and not significantly different from, the actual level of participation. These results suggest that the open ended mechanism provides a more accurate estimate of predicted participation rates than the dichotomous choice method. However, any of the methods can be calibrated based on actual participation.

The second mail survey effort utilized the entire array of standard elicitation procedures used in CV surveys. Extremely preliminary results are shown in Table 1. Mail and phone survey results are similar both for dichotomous choice and open ended WTP. Surprisingly, the payment card approach produced the lowest estimate while the conjoint/stated preference approach produced the highest estimates of value and/or participation. The multiple bounded discrete choice approach is still being analyzed.

Our findings are significant both for advancing public good mechanism design and for calibrating CV methods. This is the first field study of a public good to simultaneously use a demand revealing mechanism for the actual good and to compare actual participation with predictions for the complete range of CV methods. Replication of these findings in other settings should be a priority for future research.

	Phone Survey			Mail Surveys			
	Data for the mail survey are still being collected. Results are very preliminary since these data are incomplete and have not been verified or cleaned. At this point, only simple, trial statistical analyses have been conducted.						
	Actual \$6 Sign-Ups	Hypothetical Open-Ended	Hypothetical Dichotomous Choice at \$6	Hypothetical Open-Ended	Hypothetical Payment Card	Hypothetical Dichotomous Choice Var. \$	Hypothetical Conjoint/ Stated Preference
Response Rate (%)	71.4	74.8	71.2	63.3	68.6	65.5	65.4
Final/ Current Sample (n)	142	294	259	266	285	717	325
Actual/ Estimated Sign-Up Rate at \$6 per mo. for 12 mos. (%)	20.5	23.9	30.5	19.3	9.0	33.0	n.a.
Median WTP (Preliminary)				2.00	1.00	2.43	2.69

Table 1. Preliminary-Results From NIMO Field Research.

Deriving Biodiversity Option Value Within a Model of Biotechnology Research and Development

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The goal of this project is to develop a feasible method for computing the potential value of biodiversity in its role as a source of intellectual property. The focus is on the role of ecological and taxonomic knowledge in the process of biodiversity prospecting. We analyze a sequential-search model of biodiversity prospecting in which genetic materials are usefully differentiated by prior information. The analysis shows that, as prior information allows for the differentiation of biological habitats according to their potential as sources of new drug leads, bioprospecting values increase in some areas, while declining in others. When search procedures are optimized to take account of this information, areas of especial promise may have a high value. Information creates value both by increasing the chance of making a discovery, and by lowering the average cost of conducting searches.

Our work represents a conceptual departure from previous economic models of biodiversity prospecting (e.g., Simpson, Sedjo and Reid, 1996; Polasky and Solow, 1995) in two ways. First, we argue that the proper unit of analysis in such work is not the species, but the physical location. Relevant decisions that bear on bioprospecting – conservation, fundamental systematics, and goal-driven search projects – are generally made at the site level. Second, we argue that, once we adopt the *site* as our unit of analysis, we open the door to the possibility that searches can be guided by observable ecological and taxonomic data. The success of bioprospecting projects depends on the identification of previously unknown complex compounds. Current ecological science suggests that biochemical "creativity" – the propensity of organisms to generate the complex organic compounds that provide leads for new drugs – may be correlated with such observables (Dreyfuss and Chapela, 1994). Indeed, Sandoz Pharmaceuticals, Inc., has recently launched a Biolead Project that will attempt to identify observable factors that correlate with microbial creativity.

Consider a model in which a bioprospecting firm conducts a search for a compound that will make

possible the development of a lucrative new product. There are a large number N of sites where the compound might be found. Sites are tested sequentially, at a cost c per site. A test of the n^{th} site is treated as a Bernoulli trial with probability p_n of scoring a success (or "hit"). The hit probabilities of different sites are assumed to be independent. In order to avoid trivial cases, we assume that no site contains the desired compound with certainty ($p_n < 1$ for all n). Without loss of generality, we can assign labels to sites in order of decreasing hit probability, so that $1 > p_1 \geq \dots \geq p_N$. When a test is successful, a payoff is realized. Multiple hits are redundant.

It is shown that the pharmaceutical firm maximizes the payoff of its search program by testing the most promising sites first and, therefore, that the probability ordering (p_1, p_2, \dots, p_N) is also the order in which sites are examined (up to a permutation of equi-probable sites). Using this principle, we compute a value function that determines the expected payoff of the search at each stage, conditional on results at previous stages. Let V_n denote the *ex post* expected value of continuing the search, after $n-1$ sites have been tested unsuccessfully. This *continuation value* is characterized by the recursive relationship:

$$V_n = p_n R + (1 - p_n) V_{n+1} - c, \quad n=1, \dots, N$$

where $V_{N+1} \equiv 0$. We then derive an expression for the expected incremental contribution of the n^{th} site:

$$v_n = \alpha_n [p_n (R - V_{n+1}) - c],$$

where $\alpha_n \equiv \prod_{i=1}^{n-1} (1 - p_i)$ is the probability that the search is carried to the n^{th} stage; i.e., the probability of failure in each of the first $n-1$ tests.

Analyzing the model, we find that sites toward the front of the search queue add more to the project's expected return than do those further

back. This result is due to a combination of two factors. First, the early, high-probability sites contribute more than the others to the chance of a successful outcome. As repeated failures push investigators to pick through lower-grade ore, it becomes increasingly unlikely that a hit will ever be scored. Second, even if a hit is made eventually, the shift to low-quality sources implies an increase in the expected number of trials required to make the discovery and, therefore, an increase in the expected costs of continuing the search. Since an early success obviates the need for continued (and costly) search, sites toward the front of the queue are valuable for their capacity to reduce total search costs, in expectation. In sum, when search procedures can be optimized to incorporate useful prior information, high-probability sites command *information rents* associated with their expected contribution to the chance of success and to the avoidance of search costs.

To demonstrate the approach, we apply our formula to Myers' (1988, 1990) data on several biodiversity "hot spots," using the density of endemic species as a proxy for site quality (see Figure 1). Several insights emerge. Information values can be several orders of magnitude larger than the "scarcity value" of the material itself, and can be substantial even when scarcity values are negligible. Indeed, the values associated with the highest-quality sites (on the order of \$4,000/hectare in our simulation, for rainforest in Western Ecuador) can be large enough to motivate conservation activities. These results are robust over large ranges of parameter values.

The valuation approach advanced here could be the basis of a technique for assigning an expected bioprospecting value to a habitat or parcel. Such a technique would take advantage of available scientific knowledge, and

could be sharpened as new information emerges about relevant relationships. This includes information on the relationship between habitat, ecology, and the creativity of micro-organisms, and on how microbial communities are affected by various forms of environmental disturbance. The expected bioprospecting value of a parcel or region could be incorporated into benefit/cost studies, as an aid to policy decision making for cases in which development could disturb or imperil microbial communities. Future work in this area should include an examination of how bioprospecting values vary with changes in the institutional environment.

REFERENCES:

- DREYFUSS, M.M. and I.H. CHAPELA 1994. "Potential of Fungi in the Discovery of Novel, Low-Molecular Weight Pharmaceuticals." in Vincent P. Gullo, ed., *The Discovery of Natural Products with Therapeutic Potential*. Boston: Butterworth-Heinemann.
- MYERS, N. 1988. "Threatened Biotas: 'Hot Spots' in Tropical Forests." *The Environmentalist* 8:187-208.
- MYERS, N. 1990. "The Biodiversity Challenge: Expanded Hot-Spots Analysis." *The Environmentalist* 10:243-256.
- POLASKY, S. and A. SOLOW 1995. "On the Value of a Collection of Species." *Journal of Environmental Economics and Management* 29:298-303.
- SIMPSON, R.D., R. SEDJO, and J. REID 1996. "Valuing Biodiversity for Use in Pharmaceutical Research." *Journal of Political Economy* 104(1):163-185.

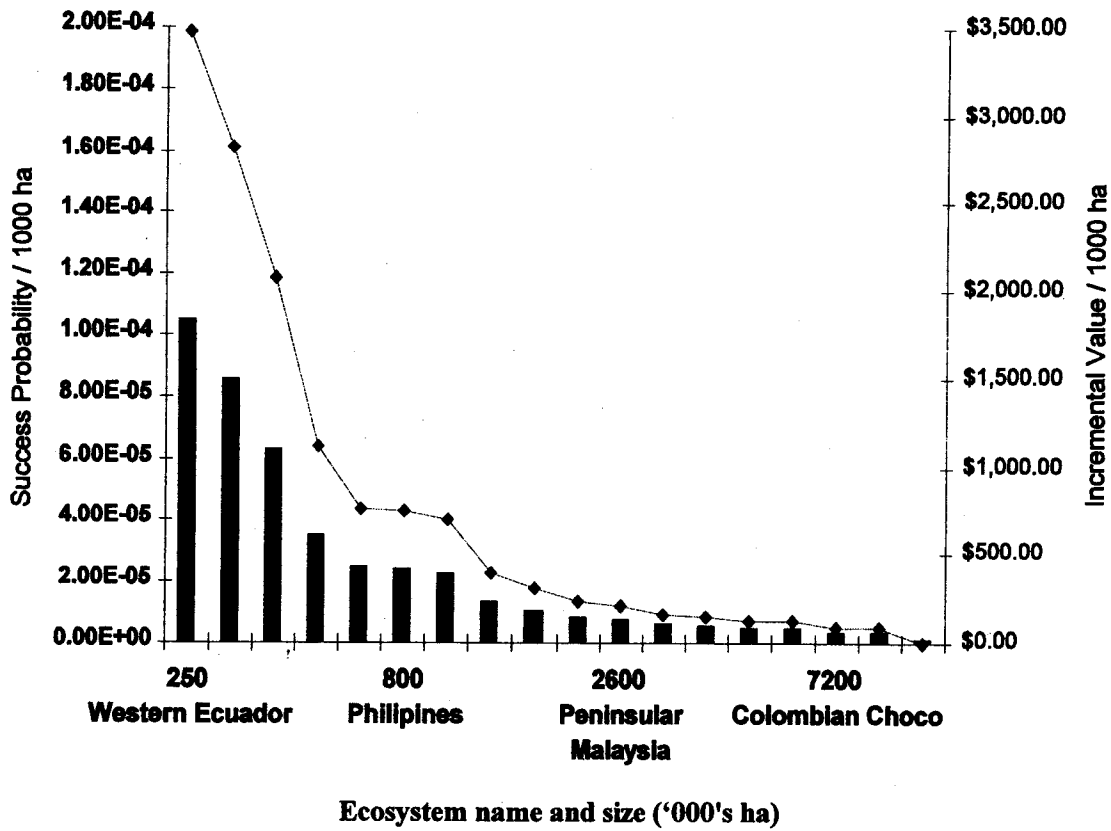


Figure 1. Bioprospecting Values in Several Ecosystems, as a Function of Success Probabilities. Assumptions: 10 search projects/year, revenues of \$450,000,000 per successful hit, cost of \$483 per 1000-ha site test, hit rates based on 1.2 E-05 hits per species, future costs and benefits discounted at 10% per year.

Using Multi-Attribute Utility Techniques in Ecosystem Valuation:

A Progress Report

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The goal of this project is to investigate the claim made in Gregory, et. al. 1993 (*Journal of Risk and Uncertainty*, Vol. 7), that multi-attribute utility (MAU) questioning techniques hold promise for direct valuation of environmental goods and services because they: (a) reduce the cognitive demands on lay respondents by simplifying the questions asked; and (b) are congruent with the multi-dimensional character of many problem settings, ecosystem valuation in particular. Specifically, using a forest valuation case study, we are examining whether and how MAU: (1) can be implemented in a manner consistent with the case; and (2) affects how lay respondents consider six-dimensional descriptions of forests.

Our approach involved the creation of an MAU valuation survey instrument that is based on a six-dimensional description of a southern appalachian forest. The dimensions are intended to be ecologically meaningful and yet relevant to respondents' judgments about the value of forests to them. (We do not prejudge the identities of the sources of these values or the suitability of any particular forest relative to any particular one of these sources.)

The six dimensions or attributes that we are using are listed in Figure 1, which is the first response work sheet from the survey. The questions on this sheet ask respondents to identify their most- and least-preferred levels of the attributes. They do this as they view visual representations and read descriptive material concerning the attributes.

The other steps in the survey are sufficiently straightforward to be within the capability of even respondents with severely limited education. These steps are: (1) to list the attributes in order of declining importance (triggered by a question asking which attribute the respondent would change first, from least to most preferred level, if they had the power); (2) to supply "swing" weights that quantify the relative importance list; and (3) to answer willingness to pay (WTP) questions concerning the most important attribute. (These questions ask about WTP to ensure that the attribute will be found at its most, rather than its least, preferred level in a forest that the respondent could easily visit.) Linearity and independence assumptions make these answers sufficient to

determine what we might call the "sub-WTP" functions for each attribute and respondent. (There is some residual uncertainty regarding parts of the functions for attributes for which a respondent has picked an interior most-preferred level in the first step.)

The last questions of the survey, and the key to the test of whether MAU makes a difference, concern three "blended" forests – forests that are described using the same six attributes in three different combinations, with the combinations presented all at once. Respondents are asked to state their preferences for forest 1 versus forest 2, for forest 2 versus forest 3, and for 1 versus 3 (the last question providing them with enough scope to display intransitivity). Respondents are also asked to supply WTP judgments for the difference between their preferred and not preferred choice in each of the first two pairings. Based on their answers to the MAU questions, we can calculate WTP numbers for each respondent and blended forest. These can then be compared with the stated preferences and WTP numbers from the last part of the survey.

Our findings should be considered very preliminary. The first data come from a "deliberative polling" exercise held in Nashville this past fall, from which we obtained about 75 completed surveys. Another, larger, event will be held in early March. This mode of administration has been necessary because we believe the instrument is far too long for a successful mail survey, and our budget will not support one-on-one interviewing.

We find that MAU does work in the sense already noted; i.e., that the tricky business of asking questions concerning a multi-dimensional ecosystem can be simplified enough that poorly educated respondents can answer. But this achievement comes at a price. Despite our many simplifications, the survey is long.

On the crucial matter of the blended forests, our first examination of the data reveals that people who have worked through all of the material do not have much trouble when asked to consider changing combinations of all six attributes. Thus, we have seen no intransitivity implied by the

preference statements, suggesting no serious confusion. Further, by and large, the stated preference orderings are the same as the orderings implied by the answers to the MAU questions. And the stated WTPs are at least in the same realm as the values implied by the sub-WTP functions derived from the MAU responses.

While we do not want to base conclusions on these early numbers, they suggest that a large investment of time and effort in familiarizing

respondents with aspects of a complex problem may be as important as the details of the questioning technique employed to seek their preferences and even their WTPs.

Our next steps will involve additional data gathering, computation of all relevant quantities for all respondents, and development of appropriate formal tests for the variety of comparisons possible within the data.

1. Tree Size

Diameter of Largest Trees 5 Ft. Above Ground

1" 6" 9" 18" 36" 54" 72"

My most-preferred level is _____. My least-preferred level is _____.

2. Forest Type

% Needle Bearing Trees

0 25 50 75 100

My most-preferred level is _____. My least-preferred level is _____.

3. Visible Plant Damage

% Loss of Vegetation

0 10 20 30 40 50 60 70 80 90 100

My most-preferred level is _____. My least-preferred level is _____.

4. Patchiness

of Forest Blocks/ 2000 Acres

15 30 45 60

My most-preferred level is _____. My least-preferred level is _____.

5. Recreation Intensity

Qualitative Class

A B C D E

My most-preferred level is _____. My least-preferred level is _____.

6. Extraction Intensity

Qualitative Class

I II III IV V

My most-preferred level is _____. My least-preferred level is _____.

Figure 1. Response Work Sheet.

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