Assigning Priority to Environmental Policy Interventions in a Heterogeneous World

Paul J. Ferraro

Abstract

Failure to consider costs as well as benefits is common in many policy initiatives and analyses, particularly in the environmental arena. Economists and other policy scientists have demonstrated that integrating both cost and benefit information explicitly into the policy process can be vital to ensuring that scarce funds go as far as they can toward achieving policy objectives. The costs of acquiring and analyzing such information, however, can be substantial. The objective of this paper is to help policy analysts and practitioners identify the conditions under which integrating cost and benefit information is likely to be vital to effective decisionmaking, and the conditions under which failing to use both cost and benefit data would result in little, if any, loss in efficiency. These points are illustrated through a conceptual discussion and an empirical analysis of a conservation initiative in the United States.

INTRODUCTION

Failure to consider both costs and benefits is common in many policy initiatives and analyses, particularly in the environmental arena. For example, in an earlier issue of this journal, Simon, Leff, and Doerksen (1995) analyzed U.S. Fish and Wildlife Service (FWS) expenditures for endangered species recovery. To allocate its limited budget, the FWS developed a priority ranking system that assigns each species a score of 1 to 18, with lower numbers indicating more benefits from immediate recovery investments. Simon, et al. (p. 416) assert that "the ability of the Fish and Wildlife Service to match species recovery priority with funding allocation will become increasingly important as more species are added to the rapidly growing list of threatened and endangered species in an increasingly austere budget climate." If the FWS uses its priority scoring system to allocate resources among species, the authors argued that they should find a strong relationship between species scores and funding levels. After failing to find such a relationship, the authors conclude (p. 424) that "priority ranking alone is not used by the Fish and Wildlife Service in a systematic way to establish priorities for funding recovery activities." Metrick and Weitzman (1996) draw similar conclusions. Assuming that the species scores are meaningful measures, these conclusions seem to imply that the FWS is allocating its resources inefficiently and in a manner inconsistent with its stated measures of policy benefits.

Manuscript received April 2002; review completed July 2002; accepted July 2002.

Journal of Policy Analysis and Management, Vol. 22, No. 1, 27–43 (2003)

Published by Wiley Periodicals, Inc. Published online in Wiley InterScience (www.interscience.wiley.com)
DOI: 10.1002/pam.10094

It can be argued, however, that the lack of a strong association between funding decisions and benefit measures is not inconsistent with efficient budget allocations. The policy context for endangered species has two important characteristics: benefits, reflected in the priority scores, and recovery costs are positively correlated; and recovery costs are more variable than priority scores among species. In such a situation, allocating funds based on priority scores alone would be quite inefficient and, as demonstrated later in this article, policy analysts examining expenditure decisions in this environment may find little or no positive relationship between benefit measures and the extent and likelihood of funding. In this policy environment, an analyst cannot conclude that an agency is allocating funds inefficiently and in a manner inconsistent with its stated measures of policy benefits without information on the costs of each policy investment.

Empirical analyses have demonstrated that incorporating cost as well as benefit information explicitly into the policy process can be vital to ensuring that scarce funds go as far as possible to achieve environmental policy objectives (Ando et al., 1998; Babcock et al., 1996; Hamilton and Viscusi, 1999; Montgomery, 1995; Polasky, Camm, and Garber-Yonts, 2001; Viscusi and Hamilton, 1999). Although these analyses convincingly demonstrate the potential gains from integrating cost and benefit data into policy analysis, they do not attempt to explain the general conditions under which such integration is absolutely critical to cost-efficient decisionmaking. Data collection and analysis can be expensive and thus policymakers and practitioners would benefit from understanding the factors that affect the magnitude of the potential gains from integrating cost and benefit data in the policy process.

The following discussion demonstrates that the correlation and the relative heterogeneity of costs and benefits across the policy landscape determine the magnitude of the potential gains from integrating cost and benefit data in policy design and analysis. Although the emphasis is on environmental policy interventions, the ideas developed in this paper are sufficiently general to be applicable to any policy intervention.

BACKGROUND

Failure to consider both costs and benefits is common in many environmental initiatives. For example, when determining priority for wildlife habitat acquisition efforts, academics and advocates often focus solely on the benefits that each parcel contributes toward the policy objective, while government agencies often focus solely on acquiring land as cheaply as possible, having only a vague notion of the benefits each acquired parcel provides.[1] In a study of assigning priority to investments for biodiversity conservation in the United States, a team of biologists (Dobson et al., 1997) found that endangered species in the United States are concentrated spatially and suggests that conservationists focus their investments on a small number of geographic areas. A team of economists (Ando et al., 1998) responded by pointing out that variability in economic factors is just as important as ecological variability in efficient species

[1] The first nine sign-ups of the U.S. Conservation Reserve Program can be characterized as seeking out the cheapest land: the program sought to maximize the contracted area using the available budget. The establishment of protected areas in Madagascar is another example of seeking out the cheapest land: reserves were overwhelmingly located in steep, marginal lands far from infrastructure (Green and Sussman, 1990). Even The Nature Conservancy (TNC), a well-known conservation group, found itself emphasizing maximum land acquisition with a given budget. When new TNC president Steve McCormick asked his staff to explain how TNC was successful (Knudson, 2001), they responded with the number of acres TNC had protected: "And I say, 'Ok, but how does that translate into the preservation of biological diversity? How does it accomplish our mission?' And they can't tell me..."

conservation. Ando and colleagues find that, given a target of conserving 453 endangered species, the approach that considers both economic and ecological variability costs less than one-sixth the cost of the approach that considers only ecological variability. A similar debate developed over ecosystem conservation investments at the global scale (Balmford, Gaston, and Rodrigues, 2000; Mittermeir et al., 1998). Polasky and colleagues (2001) also examine cost-efficient conservation strategies for species conservation in Oregon, and Babcock and colleagues (1996, 1997) examined cost-efficient contracting strategies for the U.S. Conservation Reserve Program, which annually pays about $1.8 billion for conservation contracts. These latter articles demonstrate substantial gains that could be realized if policymakers considered both costs and benefits simultaneously rather than just costs or benefits alone.

CONCEPTS

Considering costs and benefits simultaneously leads, by definition, to more cost-efficient environmental policy outcomes. But how much more efficient are such outcomes? The benefit from a given conservation investment is referred to as b_i (e.g., recovering the ith species or acquiring the ith parcel of wildlife habitat). The measure b_i is a number that captures the perceived benefit from an investment toward achieving a policy objective and is normally not measured in monetary units. The measure b_i is often an index value (e.g., U.S. FWS priority ranking score) or a measure of a key objective, such as reduction in tons of sediment into waterways from surface runoff. The cost of the ith investment is referred to as c_i, which is measured in dollars.

When assigning priority to investment initiatives, conservation scientists and practitioners often use, explicitly or implicitly, a benefit-ranking (B-rank) approach. The B-rank approach ranks initiatives from the highest environmental benefits (b_i) to the lowest and funds initiatives until the budget is exhausted. The B-rank approach can be viewed as the "crown-jewel" approach because it attempts to achieve the most valuable objective first (e.g., recover the endangered species with the highest priority score; protect the habitat with the greatest diversity or threat of conversion) while ignoring the cost of acquiring these jewels.

In contrast, the approach economists often advocate seeks to maximize environmental benefits given a budget constraint. This cost-efficient targeting approach, referred to as the E-max approach, is equivalent to ranking projects from highest to lowest benefit-cost ratio (b_i/c_i) and funding projects until the budget is exhausted.[2]

The greater the similarity in the way in which B-rank and E-max rank the relative desirability of each investment opportunity, the greater the degree to which the B-rank approach comes close to the E-max approach in terms of achieving the "biggest bang for the buck." The degree to which the two approaches rank investments in the same way will depend on how closely b_i and b_i/c_i are correlated across the policy landscape. If benefits and costs are, in general, negatively correlated (i.e., the higher the benefit from an investment, the lower the cost of that investment), then when b_i is large, b_i/c_i will also be large and the two approaches are likely to choose similar initiatives for investment. If benefits and costs are positively correlated, then when b_i is large, b_i/c_i will not necessarily be large. In this case, the two approaches could choose quite different projects for investment.

[2] The approach is mathematically equivalent to ranking projects by benefit-cost ratio because benefits and costs are not measured in common units. There are some variations in the objective function used in empirical analyses (e.g., maximum coverage problems; maximum genetic-distance problems), but the benefit-cost ratio plays an important role in determining the solution in all of these analyses.

Furthermore, the degree to which b_i and b_i/c_i are correlated will also depend on the relative variability of benefits (b_i) compared with costs (c_i) across investments. If the relative variability of b_i is much greater than that of c_i, the variability of b_i/c_i is largely determined by the value of b_i. Thus b_i and b_i/c_i will be strongly correlated. If c_i is relatively much more variable compared with b_i, then the differences in the values of b_i/c_i are largely determined by the size of c_i. In this case, ranking investments according to b_i yields decision rules that differ greatly from those derived by ranking investments according to b_i/c_i.

Thus, in a habitat-acquisition program, for example, it would be expected that the greater the positive spatial correlation between environmental benefits and acquisition costs, and the greater the spatial variability of costs compared with the variability of benefits, the greater will be the efficiency losses if conservation agents ignore costs when making decisions on where to acquire habitat (i.e., if they use the B-rank approach). Even if costs and benefits were negatively correlated, but relative cost variability was much greater than relative benefit variability, there could be large gains from integrating acquisition benefits and costs.

Parallel ideas apply when one considers an approach that ignores the differences in the benefits of each investment and instead focuses only on the costs. This approach is called the C-rank ("bargain-shopper") approach. The degree to which the C-rank and E-max approaches rank investments in the same way will depend on how closely c_i and b_i/c_i are correlated across the policy landscape, which in turn depends on the correlations between c_i and b_i and the relative heterogeneity of c_i and b_i.

CASE STUDY: LAKE SKANEATELES WATERSHED MANAGEMENT PLAN

Global concerns over the effects of private land use on the supply of environmental amenities have led to increasing reliance on conservation contracting initiatives (Ferraro, 2001). The term "conservation contracting" describes the contractual transfer of payments from one party (e.g., government) to another (e.g., landowner) in exchange for land use practices that contribute to the supply of an environmental amenity (e.g., biodiversity). Examples of conservation contracts include easements and short-term conservation leases. A key issue in the design of conservation contracting initiatives, like any conservation policy, is how to integrate information about spatially variable biophysical and economic conditions into a cost-efficient conservation plan.

The use of conservation contracts to achieve water quality objectives is becoming an increasingly popular policy tool (Johnson, Revenga, and Echeverria, 2001). For example, the New York City Watershed Management Plan will spend $250 million on conservation contracting with private landowners in the Catskill–Delaware watershed over the next 10 years to protect the city's water supply and maintain its filtration waiver from the Environmental Protection Agency (EPA) (NRC, 2000, pp. 213–239). Examples of other contracting initiatives for water quality include North Carolina's $30 million Clean Water Management Trust Fund and Costa Rica's $16 million per year effort to secure conservation contracts in, among other areas, the watersheds of municipal water supplies and hydroelectric dams.

In particular, scientists and policymakers have identified the establishment of vegetated "riparian zones that protect surface waters from inputs of nutrients, pesticides, eroded soil and pathogens" as an important policy for improving water quality (Tilman et al., 2001). One such riparian buffer acquisition initiative is currently underway in upstate New York. The city of Syracuse (population 163,860) obtains its drinking water from Lake Skaneateles, which is 20 miles away and outside the city's regulatory jurisdiction. The lake is 16 miles long, less than 1 mile wide on average, and has a 60-square-mile watershed that covers three counties, seven townships, and one village. The population of the watershed is about 5000 residents, concentrated largely in the northern half of the lake where the city's intake pipes are located. Land use is mainly a mix of forest (40 percent) and agricultural land (48 percent), on which cropping and dairy farming are most common.

The water from the lake is of exceptionally high quality and the city, using only disinfection by chlorination, meets drinking water standards without coagulation or filtration. In recent years, however, the city has come under increasing pressure to consider filtration to satisfy the provisions of EPA's Surface Water Treatment Rule. In 1994, the city signed a memorandum of agreement (MOA) with the New York State Department of Health that allows the city to avoid filtering water from the lake. The MOA requires that the city commit to a long-term watershed management program to reduce pathogen, chemical, nutrient, and sediment loading into the lake. An important part of the management program is a land acquisition program, through which the city will spend $5 million to $7 million over 7 years (2001–2008) to secure conservation easements on privately owned riparian parcels. By securing easements on riparian buffers in the watershed, the city hopes to avoid, or delay, the estimated $60 million to $70 million cost of a new filtration plant. The city wants to allocate its limited budget across the watershed in a way that will have the greatest effect on maintaining and improving water quality in the lake (Myers, Macbeth, and Nemecek, 1998).

Easements could be acquired on 202 riparian parcels in the upper watershed of Lake Skaneateles. Biophysical and economic data on these parcels were obtained from the Geographic Information Systems database of the City of Syracuse's Department of Water. The southwestern end of the lake is protected public land and is thus excluded from the analysis. Data on parcels in the southeastern end of the lake were not available at the time of analysis, but because these parcels are far from the city's intake pipes, excluding them will have only minor effects on the final results.

Four approaches (Table 1) for targeting the city's limited budget for buffer easement acquisition were analyzed: the E-max, B-rank, and C-rank approaches, and the A-max approach, which attempts to maximize acreage (a_i) acquired under a given budget and thus is equivalent to ranking land based on cost per acre. The B-rank approach is the approach the City of Syracuse adopted. The A-max approach is a common approach that the U.S. Conservation Reserve Program formerly used (Reichelderfer and Boggess, 1988), and it is equivalent to the current EPA mandate for New York City's watershed management initiative to achieve a target of 335,000 acres in its conservation contracting activities (NRC, 2000).

EMPIRICAL ANALYSIS: ASSUMPTIONS

The unit of analysis is the parcel. Each riparian parcel in the watershed is assumed to either generate net returns of c_i to the private landowner in a commercial use, or environmental benefits of b_i to the conservation agent when protected by an easement.

Table 1. Possible targeting approaches.

Approach	Method of Ranking Parcels from Most Desirable to Least Desirable
E-max ("cost-efficient" targeting)	By benefit to cost ratio of each parcel (b_i/c_i)
B-rank ("crown-jewel" targeting)	By total benefits of each parcel (b_i)
C-rank ("bargain-shopper" targeting)	By total costs of each parcel (c_i)
A-max ("cheap-land" targeting)	By acreage to cost ratio of each parcel (a_i/c_i)

Benefit Assumptions

The city wishes to reduce sediment, chemical, pathogen, and nutrient loading into its water supply. Sophisticated hydrological models, however, are not available for the Lake Skaneateles watershed. To measure the contribution of each parcel to the city's water quality objectives, the city's Department of Water convened a scientific panel to help it develop a parcel-ranking system based on known land attributes in the watershed (Myers et al., 1998). The panel developed two parcel-scoring equations: an interval-scale scoring equation and a ratio-scale scoring equation. The equations assign a score to each parcel; the higher the score, the higher the benefit from easement acquisition (see Appendix for details). Two other common parcel-scoring methods—the categorical ranking system and the parcel-pollutant-weighting equation—are also used in the empirical analysis and are described in the appendix.

All four benefit-measuring methods generate parcel scores either from weighted linear functions of the attributes or by assignment of points to each parcel based on its biophysical attributes or land uses. Such scoring methods are quite common in the academic literature (e.g., Lemunyon and Gilbert, 1993; Voogd, 1983) and in the multi-billion dollar conservation efforts of the U.S. Conservation Reserve Program (Feather, Hellerstein, and Hansen, 1998), land trusts (e.g., The Nature Conservancy; Master, 1991), international habitat protection groups (e.g., World Wildlife Fund; Olson et al., 2000), national wildlife protection initiatives (e.g., Partners in Flight; Carter et al., 1999), and farmland protection initiatives (e.g., American Farmland Trust). The purpose in presenting four parcel-scoring methods is to demonstrate how spatial correlation and heterogeneity affect the performances of the four targeting rules (Table 1), not to argue in favor of one or another scoring method.

Cost Assumptions

A regional appraising company estimated that easements around Lake Skaneateles would cost between 40 percent and 60 percent of the assessed land value of a parcel (Gardner, 2000). In this analysis, 50 percent is used. Altering the percentage will not change the qualitative results for each targeting rule. A change in the percentage will affect only the number of parcels that can be acquired for a given budget, not the order in which the parcels are acquired. Based on transaction cost information from the local Finger Lakes Land Trust, a transaction cost of $5000 per easement is also assumed.

EMPIRICAL ANALYSIS: RESULTS

The sum of parcel scores generated by the contracted land portfolios of each targeting approach was analyzed at 34 budget levels, ranging from $0 to $11.8 million. The maximum budget level was equivalent to enough money to buy riparian easements on all 202 parcels, given the assumed cost of contracting. This amount is referred to as the total watershed cost (i.e., $\sum_{i=1}^{202} c_i$). The sum of all parcel scores under a given scoring method is called the total watershed benefit (i.e., $\sum_{i=1}^{202} b_i$).

Figure 1 illustrates the results for the interval-scale scoring equation. The x-axis represents expenditures as a percentage of the total watershed cost. The y-axis represents the environmental benefits achieved as a percentage of the total watershed benefit. By definition, the optimal E-max approach achieves the maximum benefits per dollar expended, and thus its curve is on the outside. The cost-ranking approach

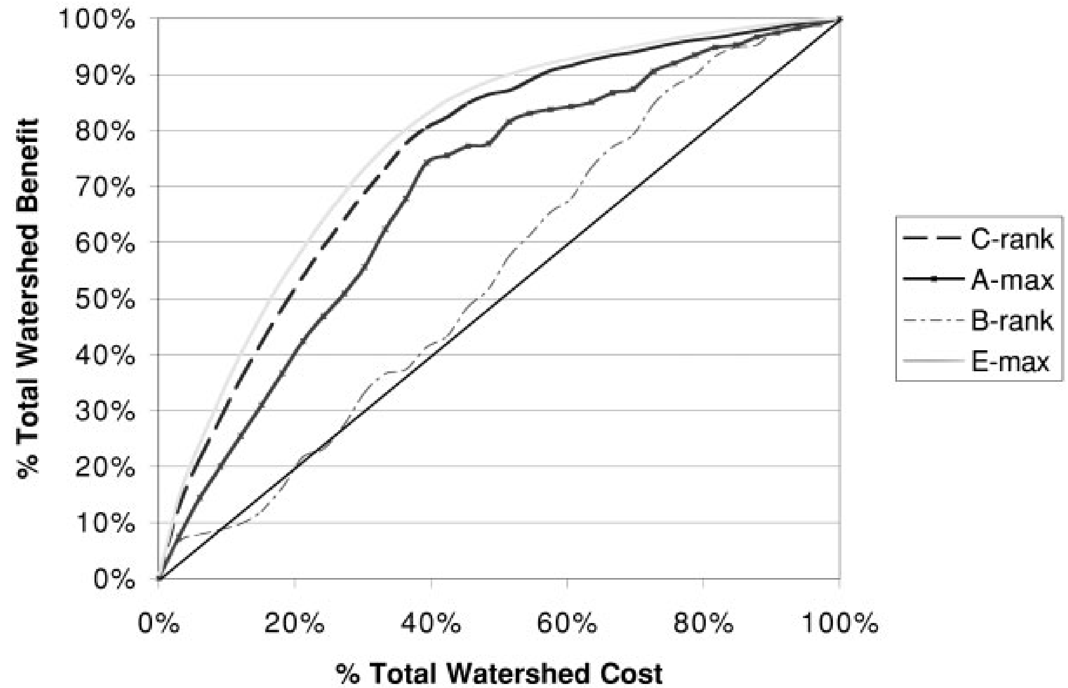

Figure 1. Efficiency outcomes for different targeting approaches (linear interval-scale scoring).

(C-rank) does a good job, and the acreage-maximization approach (A-max) a fair job, of generating environmental benefits in a cost-efficient manner. The benefit-ranking approach (B-rank), however, performs poorly under most budgets. For example, with a budget of about $5 million (about 42 percent of the total watershed cost, or approximately the amount of funds the city will allocate to easement acquisition), the E-max approach achieves 85 percent of the total benefits, the C-rank approach achieves 82 percent, the A-max approach achieves 76 percent, and the B-rank approach achieves 43 percent.[3] In general, the greater the budget available for easement acquisition, the smaller the efficiency losses associated with choosing a targeting approach other than E-max.

One can generate similar graphs for the other scoring functions. Figure 2 presents the outcomes under the parcel-pollutant-weighting scoring system. With a budget of about $5 million, the E-max approach achieves 90 percent of the total benefits, the C-rank approach achieves 78 percent, the A-max approach achieves 86 percent, and the B-rank approach achieves 79 percent, performing substantially better than it did under the interval-scale scoring equation.

As one can see from the graphs, however, picking a single point does not necessarily capture the overall efficiency of a particular targeting rule. To consider the differences in the cost-efficiency of the different targeting approaches over all budget levels, compare the areas under the curves and above the 45° line in Figures 1 and 2 and the equivalent figures for the other two scoring equations: the

[3] Recall, however, that the easements may cost more or less than our estimated costs. For this reason, one should focus on the overall curves, rather than specific points on the curves.

bigger the area, the greater the cost-efficiency of the approach (Babcock et al., 1996). An area equal to twice the size of the area under a given curve and above the 45° line[4] is estimated by using trapezoids at each of the 34 budget intervals. The greater the difference between the measured area under the E-max curve and the equivalent area under the other curves, the greater the loss in efficiency from using a targeting approach other than E-max. The areas under the curves for each scoring system are listed in Table 2. For example, the area under the E-max curve using the interval-scoring equation is 0.55, and the area under the B-rank curve is 0.09. This means that the B-rank approach is overall only 16 percent as efficient as the E-max approach in achieving the greatest amount of environmental benefits per dollar expended.

Table 2 indicates that a B-rank investment targeting approach that focuses solely on benefits can be anywhere from 16 percent to 67 percent as efficient as the E-max approach, which considers benefits and costs. A C-rank investment targeting approach that focuses solely on costs can be anywhere from 51 percent to 92 percent as efficient as the E-max approach. An A-max investment targeting approach that focuses solely on acquiring as much land as possible can be anywhere from 67 percent to 92 percent as efficient as the E-max approach. For two reasons the E-max, C-rank, and A-max approaches do relatively well, and B-rank does not: the spatial correlation between parcel costs and parcel benefits is positive; and the relative spatial variability in costs is greater than the relative spatial variability in benefits.

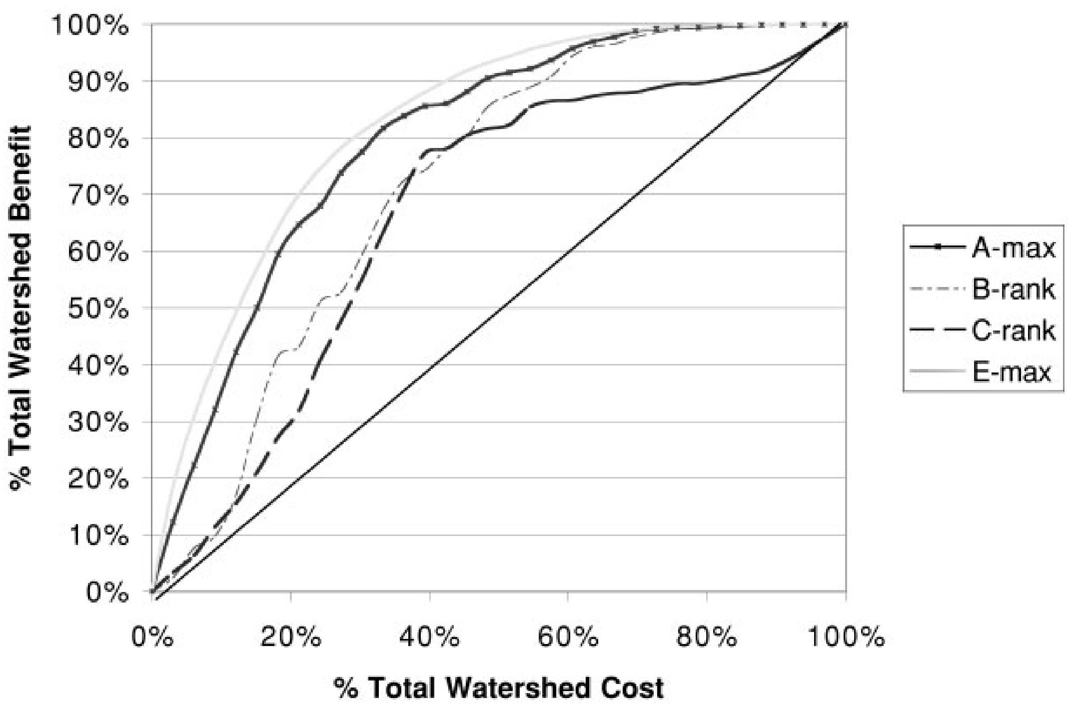

Figure 2. Efficiency outcomes for different targeting approaches (parcel-pollutant-weighting scoring).

[4] $Area = \int_0^1 F(B)dB - \frac{1}{2}$, where $F(B)$ is the fraction of the total watershed benefit achieved with the expenditure of B.

Table 2. Targeting rule performance and spatial correlations and heterogeneity.

Targeting Approach (See Table 1 for details.)	PPW	Ratio-Scale	Categorical	Interval-Scale
E-max	0.65	0.66	0.54	0.55
B-rank	0.44	0.37	0.11	0.09
B-rank Efficiency (% Emax)	67%	57%	20%	16%
C-rank	0.33	0.56	0.49	0.51
C-rank Efficiency (% Emax)	51%	85%	91%	92%
A-max	0.60	0.51	0.39	0.37
A-max Efficiency (% E-max)	92%	79%	72%	67%
Correlation (benefit/parcel-cost/parcel)	0.39	0.25	0.23	0.18
Benefit Variability (coefficient of variation)	1.42	1.03	0.49	0.46
Cost Variability*	1.44	1.52	1.44	1.44

* Cost variability changes under the ratio-scale equation because some parcels are assigned a score of zero and thus are removed from the analysis (see Appendix A.2).

No matter which scoring function is used, the correlation between parcel benefits and parcel costs is positive. For example, under the interval-scale scoring equation, the (Spearman) correlation coefficient between parcel costs and parcel benefits is $\rho = 0.18$; in other words, the high-benefit parcels tend to be the high-cost parcels. The scoring functions give higher scores to large parcels with water frontage that are near the town center of Skaneateles, where the intake is located; these parcel are also likely to be expensive. In comparison to the E-max approach, the B-rank approach is more likely to target parcels that are expensive relative to the amount of benefits they provide, and the C-rank approach is likely to target cheap parcels that produce few benefits. Holding benefit and cost heterogeneity constant, the greater the degree of positive correlation, the greater the efficiency losses associated with using the C-rank and B-rank approaches.

Correlation, however, is only part of the story. The reader may notice that despite the positive correlation between benefits and costs, the C-rank performs well under three of the four scoring equations, and, as correlation in Table 2 increases, the B-rank approach seems to perform better, not worse. This apparent paradox is resolved when one looks more closely at changes in the relative variability of benefits and costs across equations.

To assess the relative variability of costs and benefits, the coefficient of variation of parcel benefits and costs under each scoring system is used. The coefficient of variation is the standard deviation divided by the mean. The greater the coefficient of variation, the greater is the relative variability (note that the absolute variance is not important). One can see from Table 2 that the coefficient of variation of costs is greater than the coefficient of variation of benefits under each equation. If c_i is much more variable compared with b_i, then the differences in the values of b_i/c_i are largely determined by the size of c_i. With greater relative cost variability, approaches like E-max, C-rank, and A-max that seek the least expensive lands first will perform better than an approach that ignores costs.[5] The greater the cost coefficient of variation relative to the benefit coefficient of variation, the greater the losses from using the B-rank approach rather than the E-max, C-rank, or A-max approach. The greater the similarity in relative variability of costs and benefits, the greater the similarity in efficiency losses associated with the C-rank and B-rank approaches (efficiency losses of A-max depend on the correlation between scores and acreage as well). In the empirical example, the effect of decreasing benefit heterogeneity across scoring equations (left to right) swamps the effect of decreasing correlation and causes the very poor performance of the B-rank approach under the categorical and interval-scale scoring equations.

RECOGNIZING WHEN MORE DATA COULD HELP: TWO CASE STUDIES

Global Biodiversity Conservation

Two more examples will further develop the ideas in this paper. In the case of global biodiversity conservation, recent research by a group of ecologists (Balmford et al., 2002) suggests that, at the global scale, the costs of conservation are spatially negatively correlated with the spatial benefits (using bird species density as a proxy). The authors argue that these data suggest that a larger share of ecosystem protection investments should be directed toward low-income nations.[6] The authors, however, also note that the cost measures are much more variable than the benefit measures. Their data therefore also suggest a radically different public research investment portfolio.

With negative spatial correlation between benefit and cost measures and relatively higher cost variability, policymakers and practitioners interested in global biodiversity conservation are in a situation much like that portrayed in Figure 1, with the C-rank curve even closer to the E-max curve. The current biodiversity conservation research portfolio is heavily weighted toward investing in research on species systematics and ecology—i.e., the benefit side. As two prominent scholars recently wrote in the journal *Science* (Clark and May, 2002, p. 191), biologists believe "it is difficult to imagine how we can save all the parts without knowing anything about the vast majority of those parts." Investments in economic analyses of the global distribution of conservation costs, however, may be a more productive use of scarce research funds.

As Figure 1 suggests, many of the benefits that are achieved by the E-max approach with a given budget could be obtained simply by focusing on the costs of conservation and completely ignoring the benefits. Although such a conclusion might strike conservationists as impossible—how can one determine which areas of the globe should be targeted for biodiversity conservation activities without investing heavily in biological research?—Balmford et al.'s (2002) data suggest that, at the global level, we could indeed achieve substantial conservation benefits with only limited knowledge about "the parts."[7]

[5] Although the A-max approach focuses only on a single attribute (i.e., acreage), its portfolios perform fairly well because of the high relative cost variability and because acreage is positively correlated with parcel score in the different scoring equations (e.g., $\rho = 0.66$ with the interval-scoring equation).
[6] In a different paper, Balmford et al. (2000) argue that conservationists must integrate biological and economic data to generate cost-efficient investment strategies; i.e., the E-max approach should be used.
[7] Balmford et al.'s data (2002) are at the scale of nations and it may be that once the nations in which to invest have been determined, the biophysical variables will become important for determining exactly where in a nation the conservation funds should be invested.

Georgia Drought

The state of Georgia offers a second example. Georgia has experienced a severe drought since 1998. As one policy initiative to help mitigate intra-state and inter-state water conflicts, the state's Environmental Protection Division (EPD) allocated more than $5 million in 2001 to compensate farmers in southern Georgia who voluntarily agreed to stop irrigating their crops during the year. The budget was not sufficient to pay all farmers in the region and thus the EPD asked economists at Georgia State University to design an auction to allocate the state's scarce procurement budget (Laury, 2002). Given that Georgia irrigation water is not metered, and time and money for data collection were limited, a decision was made to allocate the "no-irrigation" contracts according to cost alone (i.e., a C-rank approach). Farmers bid the amount of money per acre that they were willing to accept to forego irrigation on their lands, the bids were ordered from lowest to highest and the state procured contracts until the budget was spent. The decision to focus only on cost measures was justified based on agronomic expertise that suggested water use and contract costs would be negatively correlated and thus the parcels that experienced the greatest water use were also the low-cost parcels. Although spatial correlation is important, the relative variabilities of contract costs and water use are also important in determining whether forgoing collecting and integrating data on water use would likely lead to large efficiency losses. If, for example, crop type could serve as a proxy for water use, EPD officials could use available agricultural data to obtain a better idea of the relative spatial heterogeneity of contract costs and water use and thus ascertain whether their decision to ignore water use variability was justified.[8]

A SIMULATION OF ENDANGERED SPECIES RECOVERY

Consider again the question of whether the FWS's expenditures on endangered species recovery should be highly correlated with its priority ranking scores if the service is allocating its limited budget in a manner consistent with its stated measures of policy benefits. When one examines the components of the FWS priority ranking system, one notices immediately that a species cannot receive a high priority rank (the top 33 percent of scores) if it is not under a "high" degree of threat of extinction. An emphasis on extinction threat is sensible because species threatened with imminent extinction require funding today if they are going to persist into the future. But species under a high degree of threat are also likely to be more expensive to recover because economic pressures are often a critical cause of species endangerment (Innes, Polasky, and Tschirhart, 1998). Furthermore, priority scores are higher if a species is in conflict with construction, development projects, or other economic activity. Although such conflict implies a greater need for intervention by the FWS, it also implies a higher opportunity cost of recovery. Cost estimates for endangered species recovery were not available, but given the way the FWS calculates priority scores, a positive correlation between benefits (scores) and costs in endangered species recovery could reasonably be assumed. Such correlation suggests that priority scores alone should not be used to make funding decisions.

Moreover, as Simon, et al. (1995) note, 91 percent of the species received a score between 1 and 9 (of a possible 18), with approximately equal numbers of species in

[8] Cost data from the auction and water use inferred from data on state-wide irrigated crop areas and average water use for each crop (Harrison and Tyson, 2001) indicate that water use is almost twice as relatively variable as contract costs are. More precise data broken down by county would be necessary to make a final determination.

each category, suggesting low relative variability of the priority scores. If cost variability were high relative to benefit variability, as one might expect given the geographic dispersion of endangered species, then one would have an even stronger reason to avoid using priority scores alone to make funding decisions. In a review of the economics of the Endangered Species Act, Brown and Shogren (1998, p. 14) find that the economic cost "of critical habitat designation is not evenly distributed across regions and states." One can use average recovery cost data by species category from Doerksen, Leff, and Simon (1998, p. 367), FWS data on number of listed species by category, and data on the distribution of priority scores in Simon, et al. (1995, p. 421) to obtain a rough estimate of the relative variabilities of the priority scores and recovery costs across listed species: the coefficient of variation on recovery costs was about 1.50 and the coefficient of variation on priority scores was about 0.60, indicating that costs are about 2.5 times more variable than the priority scores.

Simon, et al. (1995, p. 422) find that simple correlation coefficients between priority score and level of expenditures "indicate only a weak relationship, if any at all, of 0.04." They also find the relationship between priority score and the likelihood of a species receiving funding to be weak. If the FWS were allocating funds efficiently, would not an analyst observe substantial positive correlation between priority scores and the likelihood and extent of funding for a given species? When recovery costs and priority scores are positively correlated and costs are relatively more variable than scores, the answer to our question is "no."

To illustrate this point, a simulated data set was created of costs and benefits for 2000 possible conservation investments (e.g., 2000 endangered species). Costs and benefits are both drawn randomly from standard beta distributions, but these distributions differ in their relative variability. Costs are highly heterogeneous (beta parameters $p = q = 0.5$) and benefits are more uniformly distributed ($p = q = 50$). Using a technique developed by Johnson and Tenenbein (1981), correlation to the marginal distributions of costs and benefits was added, and a sample of correlated b_i and c_i observations drawn from the distributions. The correlation was set at $\rho = 0.30$, indicating moderate positive correlation between costs and benefits. It was then assumed that a conservation agent has enough money to invest in 57 percent of the total number of investments if it were to allocate its budget in the most efficient way possible (57 percent is approximately the percentage of endangered species that received funding in Simon, et al.'s [1995] analysis).

After allocating the available funds to achieve the largest benefits possible (i.e., E-max approach), the correlation between priority scores and expenditures is only 0.07. Furthermore, the correlation between priority scores and the decision to invest any money in a project is negative (–0.18). An analysis that focused only on the correlation between benefit measures and funding outcomes would suggest that the conservation agent was not making its decisions in a manner consistent with its stated benefit measures. Yet, by construction, this conclusion must be incorrect, and thus the danger is apparent in attempting to infer behavior through the relationship between policy benefit measures and funding decisions.[9]

The objective of the simulation is not to argue that the FWS makes its funding decisions to maximize the environmental benefit of every dollar spent. Given the various political pressures and data limitations that the FWS faces, it likely does not. The objective is merely to point out that the results in Simon et al. (1995) are

[9] The insignificant coefficient on priority ranking score that Simon et al. (1995) obtain in their Probit analysis of funding and expenditure decisions could also be a result of an inefficient and biased estimator caused by an omitted variable; i.e., costs.

not necessarily inconsistent with cost-efficient funding decisions. The absence of a strong correlation between policy benefit measures and funding decisions does not imply that scarce resources are being allocated inefficiently (nor would the presence of a strong correlation imply efficient allocation). Such a conclusion in this case could only be drawn after considering information on both benefits and costs.

CONCLUSION

Policymakers and practitioners often focus only on the benefits of policies or only on the costs, whereas considering both benefits and costs allows for more efficient use of limited budgets. This much is well known in the policy and economics literature. This article demonstrates that the magnitude of the efficiency gains from integrating cost and benefit data depends on the correlations between, and relative variabilities of, costs and benefits across the policy landscape.

A conceptual presentation and a GIS-based empirical analysis of a conservation contracting initiative in New York demonstrated that ignoring costs in policy decisions may have only minor effects (e.g., more than 90 percent of the attainable benefits can still be achieved) when budgets are large, benefits and costs are strongly negatively correlated, and the relative variability of benefits from different policy investments is much greater than the relative variability of costs. In contrast, ignoring costs in policy decisions may have substantial effects on the cost-efficient attainment of policy objectives (e.g., less than 50 percent of the attainable benefits can be achieved) when budgets are small, benefits and costs are strongly positively correlated, and the relative variability of costs is greater than that of benefits. Parallel conditions determine the efficiency losses associated with ignoring policy benefits (e.g., ignoring benefits may have an insignificant effect on cost-efficient policy design when the relative variability of costs is far greater than that of benefits). Also demonstrated is that, when benefits and costs are positively correlated and the relative variability of costs is greater than that of benefits, the absence of a strong positive correlation between benefit measures and funding decisions does not indicate that an agency is making decisions in a manner inconsistent with its stated policy objectives.

If policymakers have some sense of the correlation between costs and benefits and the relative heterogeneity of each across the policy landscape, they can deduce ex ante the importance of collecting detailed data on both costs and benefits prior to making budget allocations. Based on our analysis, we suspect that the large estimated gains from integrating cost and benefit information in many environmental policy situations (e.g., Ando et al., 1998; Balmford et al., 2000; Polasky et al., 2001) stem from positive correlations between environmental benefits and policy investment costs, and greater relative heterogeneity of costs compared to that of benefits. Although environmental policy interventions have been emphasized in the discussion and analysis, the ideas developed in this paper are sufficiently general to be applicable to any policy intervention.

The author benefited from comments by Ron Cummings, Kristin Rowles, Laura Taylor, and three anonymous reviewers. The author also thanks Lee Macbeth and the Department of Water at the City of Syracuse for access to the Lake Skaneateles data and Resources for the Future and the New York Water Institute for financial support.

PAUL J. FERRARO is an Assistant Professor of Economics at the Andrew Young School of Policy Studies, Georgia State University.

APPENDIX. PARCEL SCORING EQUATIONS

A1. Interval-Scale Scoring Equation

The interval-scale scoring equation developed by the City of Syracuse is:

Environmental Benefit Score (EBS) = 0.2 *acreage* + 0.2 *priority zone* + 0.25 (*distance to intake*)$^{-1}$ + 0.25 *acres of hydrologically sensitive land* + 0.1 *stream length*

The attribute *distance to intake* measures the planametric distance from the geometric center of the parcel to a point exactly midway between the city's two water intake pipes. The closer to the pipes, the more desirable is the parcel of land. *Priority zone* is a categorical variable, converted to a numeric scale, that captures the development potential and land use intensity of the zone in which a parcel is found. *Stream length* is the length of the stream frontage in each parcel, and *acres of hydrologically sensitive land* includes hydric soils, steeply sloped soil, frequently flooded soils, and wetlands. The higher the parcel score (EBS), the more desirable the parcel is for water quality protection. In order that parcel attributes can be meaningfully compared to each other and that the units of measurement do not affect the scores, each attribute is scaled so that the least-favorable observed value generates a score of zero and the most-favorable observed value generates a score of one. For example, the smallest parcel in the data set was 0.17 acres, and thus this parcel received a standardized score of zero for the acreage attribute. The largest parcel was 136 acres and thus received a standardized score of one for the acreage attribute. Intermediate values receive a standardized score based on the relative position between the high and low values:

$$Interval - Scale\ Score_{ij} = \frac{OBS_{ij} - MIN_i}{MAX_i - MIN_i}$$

The standardized score of attribute i for parcel j, called an Interval-Scale Score, derives from subtracting the minimum observed value for the attribute from the observed value and dividing this number by the difference between the maximum and minimum values for attribute i.

A2. Ratio-Scale Scoring Equation

The ratio-scale scoring equation uses the weights and attributes found in the interval-scale equation, but its form and normalization differs:

Environmental Benefit Score (EBS) = 0.27 *acreage* + 0.27 *priority zone* 0.27 *distance to intake* + 0.33 *acres of hydrologically sensitive land* + 0.13 *stream length*

Excluding the *Distance to Intake* weight, all the weights sum to one. Each parcel is then penalized for its distance from the intake (represented by a negative coefficient on *Distance to Intake*). All parcel scores are assumed to be greater than or equal to zero. A parcel that generates a negative score from the ratio-scale scoring function is scored as zero. Each attribute is scaled so that the most-favorable observed value generates a score of one and every other parcel is compared to that parcel; i.e., for the jth parcel and the ith attribute,

$$Ratio - Scale\ Score_{ij} = \frac{OBS_{ij}}{MAX_i}$$

A3. Categorical Scoring Equation

The categorical scoring equation is similar to what the U.S. Department of Agriculture (USDA, 1999) uses in its Conservation Reserve Program (CRP). For each parcel, the CRP scoring system assigns points to a parcel's attributes. The total amount of points achievable for each attribute is determined by relative weights (e.g., up to 10 points can be awarded for proximity to wetlands and up to 15 points can be awarded for endangered species habitat). Our categorical scoring equation uses a similar point-scoring system for each land attribute listed in the interval-scale scoring equation. We separate each attribute into three or four categories (e.g., 0 to 10 acres, 11 to 50 acres, more than 50 acres) and allow as many as 300 total points to be allocated to each parcel. The maximum amount of points possible for each attribute is determined by the same weights used in the interval-scale scoring equation.

A4. Parcel-Pollutant-Weighting Model

The parcel-pollutant-weighting model is based on the approaches used by the New York State Department of Health (1999) and Hermans (1999) and is developed and explained in Azzaino, Conrad, and Ferraro (2002). We summarize the model briefly. Each parcel is assigned a land-use classification based on GIS data collected from New York's Real Property database. Based on this classification, the biophysical attributes of the land parcel (e.g., drainage area, distance to intake) and the results of a published water quality study (New York State Department of Health, 1999), we qualitatively assessed each parcel's potential loading of phosphorus and pathogens. This qualitative assessment was then assigned an index number ranging from 10, for a qualitative assessment of "high," to 3.33, for a qualitative assessment of "low." If a parcel was acquired for the riparian buffer easement, a percentage reduction in pollutant loading was assumed, based on the current qualitative assessment and data in Hermans (1999, p. 136). Equal weights were used on reductions in pathogens and phosphorous loadings.

REFERENCES

Ando, A., Camm, J., Polasky, S., & Solow, A. (1998). Species distributions, land values, and efficient conservation. Science, 279, 2126–2128.

Azzaino, Z., Conrad, J.M., & Ferraro, P.J. (2002). Optimizing the riparian buffer: Harold Brook in the Skaneateles Lake watershed, New York. Land Economics, 78(4).

Babcock, B.A., Lakshminarayan, P.G., Wu, J., & Zilberman, D. (1996). The economics of a public fund for environmental amenities: A study of CRP contracts. American Journal of Agricultural Economics, 78, 961–971.

Babcock, B.A., Lakshminarayan, P.G., Wu, J., & Zilberman, D. (1997). Targeting tools for the purchase of environmental amenities. Land Economics, 73(3), 325–339.

Balmford, A., Gaston, K.J., & Rodrigues, A.S.L. (2000). Integrating costs of conservation into international priority setting. Conservation Biology, 14(3), 597–604.

Balmford, A., Gaston, K.J., Blyth, S., James, A., & Kapos, V. (2002). Global variation in conservation costs, conservation benefits, and unmet conservation needs. Unpublished Working Paper, Conservation Biology Group, Department of Zoology, University of Cambridge, Cambridge, UK.

Brown, G.M., & Shogren, J.F. (1998) Economics of the endangered species act. Journal of Economics Perspective, 12(3), 3–20.

Carter, M.F., Hunter, W.C., Pashley, D.N., & Rosenberg, K.V. (1999). Setting priorities for landbirds in the United States: The partners in Flight approach. Ithaca, NY: Cornell Laboratory of Ornithology.

Clark, J.A., & May, R.M. (2002). Taxonomic bias in conservation research. Science, 297(July 12), 191–192.

Dobson, A.P., Rodriguez, J.P., Roberts, W.M., & Wilcove, D.S. (1997). Geographic distribution of endangered species in the United States. Science 275(January 24), 550–555.

Doerksen, H., Leff, C.S., & Simon, B.M. (1998). Policy goals for endangered species recovery. Society and Natural Resources, 11(4), 365–373.

Feather, P., Hellerstein, D., & Hansen, L. (1998). Exploring methods of selecting cropland for conservation. Agricultural Outlook, (September), 21–24.

Ferraro, P.J. (2001). Global habitat protection: Limitations of development interventions and a role for conservation performance payments. Conservation Biology, 15(4), 990–1000.

Gardner, K.V. (2000). Skaneateles Lake Watershed Land Protection Program: Methodology and market analysis for conservation easement valuation. Ithaca, NY: North East Appraisals and Management Co.

Green, G., & Sussman, R. 1990. Deforestation history of the eastern rain forests of Madagascar from satellite images. Science, 248 (April 12), 212–215.

Hamilton, J.T., & Viscusi, K. (1999). How costly is clean? An analysis of the benefits and costs of Superfund site remediations. Journal of Policy Analysis and Management, 18(1), 2–27.

Harrison, K.A., & Tyson, A.W. (2001). Irrigation survey for Georgia. In Hatcher (Ed.), Proceedings of the 2001 Georgia Water Resources Conference (pp. 421–424). Athens: University of Georgia Institute of Ecology.

Hermans, L.M. (1999). Design of phosphorus management strategies for the Cannonsville basin. Ithaca, NY: Cornell University, New York State Water Resources Institute.

Innes, R., Polasky, S., & Tschirhart, J. (1998). Takings, compensation and endangered species protection on private lands. Journal of Economic Literature, 12(3), 35–52.

Johnson, M.E., & Tenenbein, A. (1981). A bivariate distribution family with specified marginals. Journal of the American Statistical Association, 76(373), 198–201.

Johnson, N., Revenga, C., & Echeverria, J. (2001). Managing water for people and nature. Science, 292(May 11), 1071–1072.

Knudson, T. (2001) Environment, Inc.: Leader steers Conservancy in a radical new direction. Sacramento Bee. (December 29). Available at: http://www.sacbee.com/static/archive/news/projects/environment/20011229.html. Accessed February 1, 2002.

Laury, S.K. (2002). Designing an auction mechanism to reduce irrigation during severe drought. Water Policy Working Paper Series. Atlanta: Georgia State University. Available at: http://www.gsu.edu/~ecoskl/research.htm. Accessed August 2002.

Lemunyon, J.L., & Gilbert, R.G. (1993). The concept and need for a phosphorous assessment tool. Journal of Production Agriculture, 6, 483–486.

Master, L. (1991). Assessing threats and setting priorities for conservation. Conservation Biology, 5, 559–563.

Metrick, A., & Weitzman, M.L. (1996). Patterns of behavior in endangered species preservation. Land Economics, 72, 1–16.

Mittermeir, R.A., Myers, N., Thompsen, J.B., Fonseca, G.A.B., & Olivieri, S. (1998). Global biodiversity hotspots and major tropical wilderness areas. Conservation Biology, 12, 516–520.

Montgomery, C. (1995). Economic analysis of the spatial dimensions of species preservation: The distribution of northern spotted owl habitat. Forest Science, 41, 67–83.

Myers, S., Macbeth, L., & Nemecek, R. (1998). Skaneateles Lake watershed management plan. Prepared for the U.S. Environmental Protection Agency and The New York State Department of Environmental Conservation. Syracuse, NY: City of Syracuse.

NRC [National Research Council]. (2000). Watershed management for potable water supply: Assessing New York City's approach. Washington, DC: National Academy Press.

New York State Department of Public Health. (1999). New York State Source Water Assessment Program Plan. Troy, NY: Bureau of Public Water Supply Protection.

Olson, D.M., Dinerstein, E., Abell, R., Allnutt, T., Carpenter, C., McClenachan, L., D'Amico, J., Hurley, P., Kassem, K., Strand, H., Taye, M., & Thieme, M. (2000). The Global 200: A representation approach to conserving the Earth's distinctive ecoregions. Washington, DC: World Wildlife Fund.

Polasky, S., Camm, J.D., & Garber-Yonts, B. (2001). Selecting biological reserves cost-effectively: An application to terrestrial vertebrate conservation in Oregon. Land Economics, 77(1), 68–78.

Reichelderfer, K., & Boggess, W.G. (1988). Government decision making and program performance: The case of the Conservation Reserve Program. American Journal of Agricultural Economics, 70, 1–11.

Simon, B.M., Leff, C.S., & Doerksen, H. (1995). Allocating scarce resources for endangered species recovery. Journal of Policy Analysis and Management, 14(3), 415–432.

Tilman, D., Fargione, J., Wolff, B., D'Antonio, C., Dobson, A., Howarth, W., et al. (2001). Forecasting agriculturally driven global environmental change. Science, 292(13 April), 281–284.

USDA [U.S. Department of Agriculture]. (1999). Conservation Reserve Program Sign-up 20: Environmental Benefits Index. Fact Sheet. Washington, DC: Farm Service Agency.

Viscusi, K., & Hamilton, J.T. (1999). Are risk regulators rational? Evidence from hazardous waste cleanup decisions. American Economic Review, 89(4), 1010–1027.

Voogd, H. (1983). Multicriteria evaluation for urban and regional planning. London, UK: Pion Limited.