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COST-EFFECTIVE CONSERVATION PLANNING: TWENTY LESSONS FROM ECONOMICS

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Abstract

Economists advocate that the billions of public dollars spent on conservation should be allocated to achieve the largest possible social benefit. This is what we term "cost-effective conservation"--a process that incorporates both benefits and costs that are measured with money. This controversial proposition has been poorly understood and not implemented by conservation planners. Drawing from evidence from the largest conservation programs in the United States, this paper seeks to improve the communication between economists and planners and overcome resistance to cost-effective conservation by addressing the open questions that likely drive skepticism among non-economists and by identifying best practices for project selection. We first delineate project-selection strategies and compare them to optimization. Then we synthesize the body of established research findings from economics into 20 practical lessons. Based on theory, policy considerations, and empirical evidence, these lessons illustrate the potential gains from improving practices related to cost-effective selection and also address how to overcome landowner-incentive challenges that face programs.

1. Introduction and Policy Setting

Governments should use conservation policies to enhance the benefits to society in lieu of fully functional markets for ecosystem services. These policies conserve land by requiring or incentivizing landowners to protect habitat for endangered species, control erosion, enhance riparian buffers and wetlands. They also preserve agricultural and forest land by purchasing land outright or purchasing conservation easements to preclude development. While conservation activity exists throughout the world, most of these efforts are less effective than they could be. Drawing from evidence from conservation programs in the United States this paper reviews the process by which governments and large non-governmental organizations pursue conservation and recommends best practices that will enhance conservation outcomes.

At a fundamental level, economists recommend that conservation planning should account for all of the social benefits resulting from a project, regardless of to whom they accrue, rather than focusing on environmental benefits alone. These policies should ensure that these social benefits are as large as possible given constrained conservation budgets. *Cost-effective* project selection is a process that incorporates both benefits and costs that are measured commensurately with money and seeks to maximize the conservation outcomes important to the public. This type of approach delivers the “best bang for the buck” and any other selection approach sacrifices some achievable benefits. While an *economically efficient* solution is to pursue all conservation projects for which the social benefit exceeds the social cost, unfortunately, limited budgets for conservation generally preclude such an effort. Thus, we focus on cost-effectiveness rather than efficiency and study the complexities of optimal project selection. These complexities include conflicting incentives, selection challenges, dynamic effects, interdependencies, and uncertainties.

The use of the terms *cost-effective conservation* in this review should not be confused with *cost-effectiveness analysis,* a decision science method, which is common in health economics and has been used in some literature related to conservation selection. Cost-effectiveness analysis explicitly excludes measuring benefits in monetary terms, which we show in this manuscript can often lead to suboptimal conservation outcomes.

Allocating funds to achieve the greatest possible conservation benefit—the economic concept of cost-effectiveness—remains controversial among academics and lacks widespread adoption by conservation planners, policymakers, conservation program architects, and funders (hereafter referred to collectively as "planners"). Although many papers in the conservation planning literature identify the advantages of cost-effective conservation, several recent papers have argued against this growing push because the complex interaction between humans and nature exceeds the capacity of traditional economic methods (Arponen et al. 2010; Gowdy et al. 2010). Such critiques arise close to the heart of economics and complement long-standing objections to the use of benefit-cost analysis. For instance, Odling-Smee (2005:616) points out that some see efforts to monetize nature as violating "ethical and spiritual dimensions of conservation." While acknowledging these critiques, we believe that modern economic valuation techniques can provide some measurement of these values and targets this manuscript at the practical problems of improving the effectiveness of current conservation programs.

Conservation expenditures are rapidly increasing. The U.S. Farm Bill covering 2008-2012 allocates $11.7 billion to working lands programs such as the Environmental Quality

Incentives Program (EQIP), $1 billion to agricultural land preservation, and $13 billion to land retirement programs such as the Conservation Reserve Program (CRP) (author calculation based on data reported in Claassen (2010)). U.S. federal conservation expenditures represent a $7.8 billion increase over the prior baseline (Hajkowicz et al. 2009), and yet this still understates conservation efforts because it does not include state, local, and nongovernmental conservation activity. Private U.S. land preservation by 1,667 land trusts and nongovernmental organizations had protected 37 million acres by 2005, with total preservation doubling between 2000 and 2005 (Aldrich & Wyerman 2006). Furthermore, the federal government and states spent at least $11.1 billion on endangered species recovery between 1989 and 2004 (Langpap & Kerkvilet 2010). Conservation efforts in the European Union (EU) may exceed those in the U.S.; for instance, between 2007 and 2013 the EU plans to spend €35.4 billion on agri-environmental payments alone (author calculation based on data from the EU (2009)). Governments throughout the world pursue conservation. For instance, in New South Wales, Australia, the Environmental Services Scheme provides incentives to alter private land management in an effort to improve delivery of environmental services (Oliver et al. 2005). Finally, China's Sloping Land Conversion Program, perhaps the world's largest conservation program with an estimated budget of $48 billion, seeks to convert crop and wasteland to forests (Xu et al. 2010).

Evidence suggests challenges in communication between planners, policymakers, and economists. Banzhaf (2010: 592), in part, faults economists' for their "lack of interest in making academic work accessible". Prendergast et al. (1999: 484) cites a lack of awareness and understanding as possible obstacles to using theoretically driven conservation planning, as well as limited funds and even "antipathy" toward "prescriptive" selection tools. Planners may also resist cost-effectiveness because they are not familiar with optimization mathematics and lack tools for implementation amongst numerous other reasons (Ferraro and Pattanayak 2006; Messer et al. 2011). Calls for greater dialogue and collaboration are long-standing (Prendergast et al. 1999; Armsworth et al. 2004). It is this lack of constructive communication, cooperation, and resistance to economic approaches that motivates this synthesis.

2. Methods

The scientific literature on the practice of cost-effective conservation is vast, and a book-length treatment would be required to review it all. In addition, there is an applied literature that evaluates certain programs and a call for more work in this area (Laycock et al. 2009; Ferraro and Pattanayak 2006). Existing syntheses, therefore, focus on somewhat narrow aspects. One rationale for this work is to present cost-effective conservation in a new and, hopefully, more useful package for planners. This section explains how literature was selected and organized. We briefly review existing approaches before turning to the one in this paper.

Claassen et al. (2008) offered a comprehensive review of the CRP and EQIP and found, in part, that existing rules delivered were better than some alternative selection processes, but were still not truly cost effectiveness. Wu (2004) summarized many of the challenges to cost-effective conservation and focused on impediments associated with the policy process and complexities associated with the resources targeted for protection. Newburn et al. (2005) comprehensively assesses cost-effective conservation in light of vulnerability. Sarkar et al. (2006) synthesized the concepts, techniques, and software available for optimal biodiversity conservation planning. Most similar in approach to our paper is Wilson et al. (2009), which offered lessons about setting priorities in biodiversity planning. Wilson et al. (2009) identified specific challenges to prioritizing conservation—including temporal issues, uncertainty, and spatial heterogeneity, and drew conclusions about the need for location-specific planning.

Unlike prior syntheses, we offer 20 lessons to assist planners make more cost-effective decisions with their limited resources, thereby increasing the supply of ecosystem services. Practical guidance grounded in research is needed because, as Prendergast et al. (1999) argued, the benefits of cost-effectiveness frequently fail to reach planners who make actual conservation decisions. Several lessons presented in this paper arise from recent research while others are practical guidance original to this work. In addition, this paper offers a broad, and therefore shallow, perspective to complement other syntheses offering topical depth. Finally, the paper also highlights areas where research has identified significant challenges in conservation planning. Explicit recognition of the current challenges facing cost-effective conservation hopefully will help build credibility with potential adopters and clarify future research agendas.

Economic research in conservation tends to focus on empirical analyses of and challenges to the practice of conservation because the theory of optimal selection is relatively straightforward. Therefore, the next section briefly summarizes the theory and defines cost-effective conservation. We then distill the literature into 20 best-practice lessons and organize these lessons into five sections (summarized in table 1): optimal selection, benefits, costs, budgets, and incentive problems.

3. Theory: Cost-Effective Project Selection

Planners typically pursue *conservation benefits*, such as biodiversity, habitat provision, agricultural land quality, and air quality, and use *benefit indices* to measure the benefits that would arise from investment in a project. For example, the CRP and the Wetlands Reserve Program in the United States assign relative weights, which are periodically adjusted for each type of environmental benefit targeted (Cattaneo et al. 2006). These weights substantively impact project priorities but there is little guidance on how to sum these benefits when they are incommensurate. Hajkowicz et al. (2009) conducted an assessment of programs that use benefit indices and recommended better incorporation of social preferences in the weights (measured with appropriate techniques) and development of standardized indices.

Measuring the costs of conservation, such as acquisition, transaction, monitoring, and stewardship costs, is more straightforward because existing markets often reveal these values. Nevertheless, Ando et al. (1998) notes that costs are not widely incorporated in conservation decisions. Ignoring costs may have once made sense when the goal was protection of unique natural amenities such as the national parks of Yellowstone or the Grand Canyon. However, current conservation practices extend to many settings where programs must decide where to invest their limited funds among a number of high-quality projects that are close substitutes in terms of environmental benefits but differ substantially in cost. In these settings, paying too much can significantly reduce the benefits from conservation efforts.

Selection strategies that focus on only one measure—benefit targeting or cost targeting—consistently lead to suboptimal results. Strategies that include both costs and benefits, such as benefit-cost targeting, benefit maximization targeting, and mathematical programming methods, are being adopted, albeit slowly. This section distinguishes these techniques.

Benefit targeting (BT), also termed "benefit ranking" or "rank-based model" ranks projects according to their environmental benefit and selects the highest-ranking ones until the budget is exhausted (Ferraro 2003). It is used frequently for private and public conservation programs, such as the U.S. Fish and Wildlife Service (Wu 2004), for the establishment of national parks (Babcock et al. 1997; Wu et al. 2001). BT has intuitive appeal to many conservationists, who are drawn to projects with the largest environmental benefits. However, BT ignores cost as a selection criterion, and the outcome is likely to be cost-ineffective because the budget can be exhausted by a couple of high-benefit, high-cost projects (Messer 2006).

Cost targeting (CT) ranks projects solely by acquisition cost and selects the least expensive ones until the budget is depleted—a "bargain shopper" tactic (Ferraro 2003). In practice, CT tends to maximize acreage rather than net benefit (Babcock et al. 1997). Pure CT seems to be relatively rare in practice, though examples exist. Babcock et al. (1997), for example, framed the CRP's early efforts as equivalent to CT. Another related example is the Delaware Agricultural Lands Preservation (DALP) program that uses a reverse auction—an auction with one buyer and multiple sellers—and selects projects based on the level of discount offered by owners on the appraised development increment (Messer and Allen 2010).

Benefit targeting with a cost adjustment is similar to BT but scores conservation costs as a nonmonetary benefit measure. For example, Ribaudo et al. (2001) calculated that the cost factor score used by the CRP represents 27% of total possible points, subject to soil quality, in the Environmental Benefits Index. While this strategy may have intuitive appeal because it seems to analyze costs and benefits jointly, it is not truly cost-effective (Hajkowicz et al. 2009) as it is easy to construct examples where scoring costs as a benefit leads to sub-optimal environmental results.

Benefit-cost targeting (BCT) selects projects with the highest benefit-cost ratios until the budget is exhausted. This approach ensures selection of individual projects that have the highest benefit per dollar, which will achieve no worse and typically greater cost-effectiveness than BT or CT (Babcock et al. 1996). This characteristic leads many economists to promote BCT (Ferraro 2003). In fact, U.S. federal programs, such as the CRP and EQIP, use a version of BCT that seeks to maximize environmental benefit per dollar spent (Wu et al. 2001), however, since cost is measured as a benefit index true cost-effectiveness is not achieved.

Wu et al. (2001) and Wu (2004) described how characteristics of commodity markets might create secondary impacts that prevent BCT from maximizing total net social benefits in some conservation settings. These technical distinctions led to an improved selection strategy: benefit-maximization targeting. *Benefit-maximization targeting* selects projects to minimize increases in commodity output prices and, thus, slippage (described later) and achieves the same level of environmental benefit as BCT but at a lower cost (Wu 2004). In principle, benefit-maximization targeting is fully cost-effective; however, the literature has tended to employ relatively simple problems to demonstrate this technique. Because project selection occurs in a complex world of constraints and interdependencies, true cost-effectiveness requires even more advanced techniques.

Optimization involves a set of mathematical programming algorithms, such as binary linear programming and goal programming, from operations research that seek to maximize total net benefits and achieves cost-effectiveness in more complex situations, such as a need to enroll a minimum number of acres, to maximize the number of species preserved, to select a minimum number of projects from a particular region, or to meet disparate goals (Underhill 1994; Sarkar et al. 2006; Balmford et al. 2000; Kaiser & Messer 2011; Fooks & Messer, *forthcoming*). Optimization algorithms can identify optimal selections when ecological complexities such as thresholds introduce jointness to the selection of projects, a problem investigated by Wu et al. (2000) and Wu (2004). In addition, these techniques can offer slight advantages over iterative selection techniques, such as BCT, by adjusting to account for budget remainders (Messer 2006).

4. Twenty Lessons for Cost-Effective Selection Processes

4.1 Optimal Selection

Lesson 1: Benefit targeting and cost targeting can lead to suboptimal project selection. The weakness of these approaches can be demonstrated with a numerical example provided in table 2, which gives hypothetical data for prioritization of six conservation projects using costs and monetized benefits. The second panel of table 2 compares the projects selected with a budget of $6 by several ordinal (ranking) and cardinal (quantity) prioritizations arising from BT (column I) and CT (column J) with the selections made by optimization using monetized benefit-cost ratios (column L). In this example, net benefits are maximized at $44 by selecting projects A, B, and C. BT and CT prioritizations are suboptimal at a net benefit of $40 and $43 respectively.

Empirical evidence supports the hypothetical example, and the magnitude of the cost-ineffectiveness can be substantial. In an application to endangered species protection, Ando et al. (1998) found savings of as much as 75% when costs were systematically accounted for. Messer and Allen (2010) examined the DALP program and showed that optimal selection would have preserved the same number of acres with an equal benefit score but would have saved approximately $21 million relative to DALP's CT system (more than 20% savings) and substantially more if DALP had used BT. In the case of conservation of terrestrial vertebrates in Oregon, incorporating land costs would have generated a ten-fold improvement in cost-effectiveness (Polasky et al. 2001). Recent adoption of BCT in Baltimore County, Maryland, resulted in protection of an additional 680 high-quality agricultural acres—saving $5.4 million—compared to BT in just three years (Kaiser & Messer 2011:271).

Fully optimal methods require substantial data. However, several studies suggest that policymakers might approach optimal selection even if some data are unavailable. This depends on what one knows about the distribution of unobserved costs and benefits. When benefits and costs are uncorrelated, BT performs better when benefits vary more than costs —and vice versa for CT (Babcock et al. 1997). A number of studies have examined optimal selection with observed data on variability of costs and/or benefits (Ando et al. 1998; Balmford et al. 2003; Ferraro 2003; Perhans et al. 2008) and evaluated selection performance without complete data (Babcock et al. 1997; Ferraro 2003; Perhans et al. 2008). In general, positive statistical correlation between a project's costs and benefits tends to improve the performance of BCT relative to BT or CT, while a negative correlation leads to more similar performances for the three methods (Babcock et al. 1997).

Lesson 2: Efforts to distribute conservation funds evenly across political jurisdictions will tend to be suboptimal. The political process and perceptions of fairness may introduce constraints. For example, the CRP limits program participation to 25% of cropland in any county to protect local economies (Sullivan et al. 2004), and Pennsylvania's agricultural land preservation program distributes money to all participating counties, each administering individual programs (3 P.S. § 914.1(b,h)). Such constraints reduce cost-effectiveness because they restrict the feasible set of solutions and, by definition, cannot improve the cost-effectiveness of the solution (Kaiser & Messer 2011). These constraints also can work against efforts to target conservation in settings where biological thresholds are important (Wu et al. 2000, Wu & Boggess 1999; Wu & Skelton-Groth 2002; Wu 2004). The political reality, however, is that distributing funds across jurisdictions may help secure broad legislative support for a program. Likewise, nongovernmental organizations may win political favors or improve fundraising by, at times, focusing on high-profile projects.

4.2 Benefits

Lesson 3: Measure conservation benefits that are positive externalities. Gardner (1977) provided an early summary of fundamental economic concerns about emerging land preservation policies. Because some of its points remain underappreciated while others have been misunderstood, revisiting Gardner's arguments is worthwhile.

Gardner notes that policy interventions in land markets can increase total social benefits if there is a market failure, but they reduce the productivity of scarce resources if no failure exists. Gardner found a land market failure in the under-provision of public goods—in other words, land markets provide too few ecosystem services. Termed *external benefits* or *positive externalities*, such services include wildlife habitat, water quality protection, scenic views, and carbon sequestration. Landowners rationally undersupply them because existing markets do not fully capture the social benefits of their decisions. Gardner's argument implies that external benefits should be measured and then policy should internalize them by incentivizing conservation. Gardner correctly anticipated that policymakers would incentivize easy-to-measure benefits such as soil quality and, thus, cautioned that increasing the supply of such benefits does not clearly enhance resource allocation efficiency because no obvious market failure exists for soil quality (i.e., farmers already pay more for high-quality land). Instead, Gardner argued that appropriate conservation benefit measures reflect factors that are external to markets and are associated with benefits that accrue to neighbors and the general public.

Lesson 4: Measure benefits to the public, not to experts. The logic for this potentially controversial lesson is that the public is the group that receives the services. The economic literature offers evidence that the conservation preferences of experts may or may not diverge from those of the public (Strager & Rosenberger 2006; Columbo 2009). While this lesson may not be relevant to private conservation organizations as they are driven by their donor priorities, it does apply to government agencies and perhaps also to larger conservation organizations. Some public preferences can be measured or estimated (see Kline 2006). We acknowledge that this lesson may be challenging to follow when the conservation benefits are associated with ecosystem services that the public is unlikely to fully understand, such as implications of specific pollutant loads or habitat needs for an endangered species.

Lesson 5: Monetize benefit measures. Monetized benefit measures (conservation benefits measured in dollar terms) are required for cost-effective policy because they must be balanced with the costs of conservation, which are often largely monetized—Kido & Seidl (2008) apply such techniques to develop optimal protected area entry fees. Conservation programs tend to use benefit indices derived from agri-environmental criteria such as soil quality, crop productivity, soil erosion, water quality, and carbon sequestration (Hajkowicz et al. 2009). The CRP, for example, uses the Environmental Benefits Index while some agricultural land preservation programs use the Land Evaluation and Site Assessment (LESA) system. EQIP uses a ratio of value of the benefit index (BI) to the cost to achieve statutorily mandated cost-effectiveness in securing environmental benefits (Cattaneo 2003). These indices capture well the services that landowners supply; however, they do not correspond to the value society places on the supply of such services (Smith 2006).

Note that efforts to monetize public welfare can lead to systematic biases if income and net-benefit incidence are correlated and wealth is unequally distributed. This is a well-known challenge to all benefit-cost analyses. Also, some find this assertion controversial if one does not believe that values for ecosystem services can be measured monetarily.

Fortunately, monetized benefit measurement has advanced considerably over the past three decades. For instance, many applications measure the benefits of preserved land, and these benefits increase on-parcel and off-parcel human welfare (Bastian et al. 2002). Valuation techniques include revealed preferences (such as hedonic analysis) and stated preferences (such as contingent valuation and choice modeling). Future areas of research in this area include the influence of certain amenities, such as public access, spatial relationships, and different agricultural uses (Bergstrom & Ready 2009).

Decision-makers have argued, incorrectly as will be shown, that nonmonetized benefit measures (benefit indices) equally promote cost-effectiveness, particularly if the indices use cardinal measures (the index employs units that reflect more than a ranking). Economists and other environmental researchers have employed sophisticated cardinal techniques for aggregating preferences. Techniques include the analytic hierarchy process (see Ananda & Herath 2009) and the logic scoring of preferences (Allen et al. 2011), which can be used with groups of experts or the general public.

Lesson 6: Benefit indices can lead to suboptimal project selection. Messer & Allen (2010:45–46) demonstrate how benefit indices, which are often averaged for the conservation project as a whole rather than assigned per acre, can lead to scaling problems. In effect, an averaged benefit index will be biased against large projects.

Benefit indices also can map poorly into monetized benefits. This can be demonstrated by revisiting the example in table 2. Assume that monetized benefits are shown to be a linear function of the benefit index: $B=BI+7 (column D). Even with this simple, monotonically increasing relationship of just adding 7 (one can readily imagine a more complex relationships between $B and BI), this example shows that the BI-cost ratio (column K) produces a smaller total net benefit of $40 than the optimum of $44 (column L). This result may be counterintuitive, but it occurs because systematic mismeasurement of the monetized benefit reverses the rank of the selected projects. Although the values shown in table 2 were selected to demonstrate these points, the example demonstrates that an ostensibly reasonable cardinal BI can lead to smaller net benefits even when monetized benefits are a simple transformation.

Lesson 7: Targeting conservation benefits leads to greater cost-effectiveness when thresholds are present. Conservation thresholds complicate optimal selection and exist when an environmental benefit depends on achieving some minimum level of conservation (Wu et al. 2000; Wu & Skelton-Groth 2002; Wu 2004). Examples are when a minimum amount of habitat is needed to sustain an endangered species or a critical mass of farmland must remain to sustain a region's viable agricultural industry. Wu & Boggess (1999) offered an assessment on how thresholds complicate optimal selection. Wu et al. (2000) and Wu & Skelton-Groth (2002) extended that work with empirical evidence about how targeting conservation leads to greater cost effectiveness when thresholds exist for fish habitat protection.

Lesson 8: Interrelationships (correlations and interactions) among conservation projects are often unobserved. This is especially true when readily available benefit measures such as soil quality drive the selection process. Studies have examined how targeting conservation leads to optimal selections when projects are interrelated (Wu & Boggess 1999). Interrelationships can take many forms. For instance, preserving habitat on two contiguous parcels will likely deliver greater joint benefits than two discontiguous parcels, all else equal. In other words, spatial scale matters and there can be a spatial agglomeration of benefits. An interrelationship also may exist between two different types of ecosystem services, such as riparian protection that improves the land-based and the aquatic habitat. A number of studies have examined efforts involving agglomeration bonuses to incentivize landowners to coordinate their behavior (see Parkhurst et al. (2002); Parkhurst & Shogren (2007); Drechsler et al. (2010)).

Many studies have sought to spatially model environmental benefits (see van der Horst (2007)), however, fewer studies have examined monetized benefits spatially (Bateman et al. 2003; Hynes et al. 2010; Campbell et al. 2009). van der Horst (2006, 2007) developed a method for considering multiple benefits in space and calculating effectiveness gains from spatial targeting of two benefits, which is then assessed via an analysis of the Farmland Woodland Premium Scheme in Scotland. Wu (2004) argued that lack of information, rather than a failure to recognize the interrelationships, has led to the current policy environment, which tends to focus on specific resources rather than the more complex ecosystems relationships.

Lesson 9: Optimal selection accounts for development risk. Conservation decisions typically are made with uncertainty about future benefit supply. Some projects supply benefits even in the absence of conservation, while others risk diminution or destruction. Therefore, researchers promote and many planners desire conservation targeted at the most vulnerable benefits first, though there so far is no consensus on how best to do this. For instance, Messer (2006) argues that development threat can be predicted from observable parcel characteristics (location, soil quality, proximity to highways, etc.) that can in turn give weights to various benefit measures prior to optimization. Because development risk tends to vary directly with cost, Newburn et al. (2005) offered an approach to optimal selection (benefit-loss-cost targeting) that allows risk and costs to be assessed jointly. Costello & Polasky (2004) developed an optimal dynamic selection model that accounts for development risk and found that heuristic selection performs reasonably well when a dynamic problem becomes too large. Nonmarket valuation offers an additional perspective as it directly estimates the marginal benefit of preserving lands at various levels of development risk. Johnston & Duke (2007) estimated higher benefits from preservation of parcels at the highest risk of development.

Lesson 10: The policy process impacts the conservation benefit received. Empirical evidence demonstrates that the public cares about how and by whom conservation benefits are secured, where the policy process refers to the policy used and administering entity. Many policies exist to deliver conservation services and, furthermore, these services can be delivered by governmental agencies or nongovernmental organizations. These groups preserve land with easements or fee simple ownership, and governments can use zoning/regulatory mechanisms. Water quality, for example, may be enhanced by regulations, incentive programs such as the CRP, government-sponsored relocation of nutrients, tax instruments, or nutrient trading. Johnston & Duke (2007) found, in the case of farmland, that mandatory governmental zoning was viewed by the public negatively compared to a voluntary state easement program that was viewed more favorably and therefore delivered higher monetized benefits. Of course, the costs of these efforts can be different as some studies have shown zoning, while controversial, to be relatively low cost and effective (Ozama and Tertley, 2007).

Lesson 11: Markets will tend to capitalize location-specific benefits. For example, a house will tend to increase in value if it borders a newly protected preserve or farm (Geoghegan 2002; Irwin 2002; Netusil 2005; Geoghegan et al. 2003). Property values will even increase if proximity to a conserved area allows for access to newly supplied services such as nature trails. Although potential capitalization does not invalidate conservation benefits, competitive rental markets can drive renters to indifference (Landsburg 1993:34–37), i.e., owners may increase rent to account for the enhanced environment. This obviously represents a potential equity problem: because capital owners tend to be wealthier than nonowners, thus, capitalization will tend to lead to some efficiency mismeasurement (Duke & Johnston 2011). This is an area for future research as researchers have not yet devised definitive advice on how to integrate capitalization into analyses of public good supply. Also, not all conservation benefits will be location-specific (e.g., endangered species protection) so capitalization will not complicate all selection problems.

4.3 Costs

Lesson 12: Include and fully account for all costs. Optimal selection requires data on the projects' costs, and Naidoo et al. (2006) offers a thorough accounting of why and how costs should be used in conservation planning. Although markets do supply some project cost data, such as the cost of acquiring the land or easement, economists note that optimality requires accounting for all costs—and this is directly related to a landowner's willingness to participate in programs (Miller et al. 2011). Frequently ignored factors include in-kind costs such as volunteer labor and external costs such as increased nuisance species. Likewise, costs should be estimated for future management and restoration costs. Naidoo et al. (2006:682) offers a typology of these costs, and Wilson et al. (2009:242) presents an extensive list of costs and associated research studies. Moilanen and Arponen (2011) address more complicated planning situations, such as when priorities must be set though future costs are uncertain.

Lesson 13: Costs should be monetized. Naidoo et al. (2006) describes efforts to proxy with nonmonetized costs and argues that simple averages ignore spatial heterogeneity while more advanced estimates can sufficiently capture variation. Carwardine et al. (2010) extends this work by assessing how sensitive optimal prioritization is to levels of cost uncertainty.

Lesson 14: Sequential assessment of benefits and then costs tends to be suboptimal. To understand this potential pitfall, consider again the DALP easement program that uses a LESA benefit index to score all applicant parcels and then selects a subset of parcels that exceed a minimum score for further consideration (3 Del. C. § 9-908(a)(4)). The high-scoring parcels are then sorted by the owners' offered discounts (i.e., cost targeting) (3 Del. C. § 9-914(b)(3)). While this selection method analyzes benefits and costs, the sequential approach cannot guarantee optimality. Consider a hypothetical example where high-benefit project A offers a benefit of 10 and a cost of 9, project B offers a benefit of 9 and a cost of 9, and low-benefit projects C, D, and E each offer a benefit of 7 and a cost of 3. Assume the benefits reflect all relevant conservation data. With a budget of 9, cost-effectiveness will select C, D, and E, conserving three projects for total net benefits of 12. Sequential analysis would immediately eliminate C, D, and E and focus on A and B. If A is chosen, the budget would be exhausted and the net benefit would be just one. Thus, the sequential approach may seem to control the cost of seeking high-benefit projects, but it is generally suboptimal.

4.4 Budgets

Lesson 15: Large budgets allow conservation of all projects, any selection strategy will be optimal (Babcock et al. 1997). While this lesson is straightforward, it is important to recall that the differences in selection strategy arise when budgets are limited. Furthermore, the more limited the program's budget, the greater the potential gain from optimal prioritization.

Lesson 16: Optimization improves cost-effectiveness when budget remainders are significant. Remainders are a significant problem with limited budgets. Large remainders are most likely when budgets are severely limited, especially when project costs are high relative to the budget, when agencies cannot implement projects in fractions, and when budgets cannot be carried over into new periods. Such gains are a key difference between BCT and optimization (Messer 2006). Consider that BCT might select the ten highest-ratio projects before finding that project 11 exceeds the budget remainder, at which point the algorithm looks further down the list for the next affordable project (say, project 20). Optimization, in contrast, searches for the set of projects that maximizes the net benefit (say, projects 1 through 9, 11, and 12). Optimization thus can find that projects 11 and 12 produce greater net benefits than projects 10 and 20.

Lesson 17: Intertemporal complications can limit potential cost-effectiveness. If severe enough, intertemporal issues (decision making over time) can lead to a selection of parcels that is optimal today, but viewed from a broader time horizon would be suboptimal. This can be referred to as myopic optimality. At a basic level, simply carrying budget remainders over to future periods can improve cost-effectiveness by avoiding problems with budget remainders and spending out budgets on low-priority projects. Cost-effectiveness becomes significantly more complicated when the future availability of projects is uncertain or the conservation benefit is time limited (extinction of a species or nonrenewability threshold). Costello & Polasky (2004) assessed optimal selection in an intertemporal optimization problem and found, in part, that budgets available in early periods deliver much greater benefits. Meir et al. (2004) formulated the problem of dynamic budgets when benefits and project availability are uncertain and found that a relatively simple, opportunistic selection strategy can outperform myopic solutions.

Lesson 18: Cooperation among conservation entities can help mitigate intertemporal issues. This cooperation can insure against the risk that any one entity cannot afford to secure an opportunistic project. One strategy common in the conservation community is for a nongovernmental entity to acquire opportunistic projects and then transfer them to a government agency once the governmental budget is renewed.

4.5 Incentive Problems

Conservation policy is an imperfect instrument and incentive problems may arise. Incentive problems occur when, in response to a new policy, the “wrong” landowners signup (adverse selection) or landowners alter their behavior in ways that work against the goals of the policy (unintended consequences).

Lesson 19: Adverse selection creates incentive problems that work against cost-effective conservation policy. Adverse selection arises because landowners typically have private information about the costs of delivering conservation services. For instance, a planner cannot observe how likely (or costly) it would be for a landowner to expand riparian buffers without a policy incentive to do so. Voluntary conservation policy will tend to attract landowners who are already most likely to deliver the conservation services, if planners do not distinguish landowners by their propensity to deliver services. If owners who would already be willing to supply benefits participate in a conservation program (wrong types), then some benefits are erroneously attributed to the program. As programs incur costs to secure participation, they may incur these costs without significant conservation gains on the ground. Likewise, the conservation gains can be overstated as comparisons are not made to the outcomes that would occur in the absence of the program. In these cases, the analysis that was based on observed benefits and costs is invalidated. Adverse selection will be exacerbated when programs use CT or reverse auctions to secure participation (Arnold et al. 2010). While the landowners’ costs are not observable, the landowners most likely to offer conservation services at a low price tend to be those inclined to conservation already.

Some recent conservation efforts have sought to address adverse selection with the concept of additionality. In carbon programs, for example, landowners currently pursuing sequestration (via no-tillage) are not eligible to sell carbon credits. Planners are addressing complications that come with implementation, such as costly monitoring, questions of equity (early adopters are sometimes punished), and complicated dynamic issues (a farmer could till this year so the farmer could enter a program next year).

Wu & Babcock (1996) offered an early analysis of adverse selection that evaluated information asymmetry (i.e., the government is unaware of landowners' costs) in the context of the CRP. Their mechanism sorted landowners and achieved participation by the best attainable method (this is known as second-best optimality, where the first-best outcome is unavailable because of information asymmetry). An empirical study by Kirwan et al. (2005) examined landowner behavior in CRP auctions and found evidence that 10–40% of the funds were premiums (i.e., payments above the cost of supplying the conservation service), suggesting that adverse selection may be present. Recent studies have examined ways to reduce adverse selection using theory and existing program data from the United Kingdom's Environmental Stewardship Scheme (Fraser 2009; Quillerou & Fraser 2010). Arnold et al. (2010) used game theory and lab experiments to compare the impact of adverse selection on the cost-effectiveness of various conservation policies. They found that tax instruments are more efficient than reverse auctions, mechanism designs, and an absence of policy in the presence of adverse selection.

Lesson 20: Unintended consequences of conservation policy may be impossible to fully control. In evaluating the CRP, Wu (2000) described the problem of *slippage*. Because the CRP is a voluntary program and does not regulate land uses, landowners can bring previously unfarmed land into production to compensate for land they enroll in the CRP. Wu found that 20 acres were converted for every 100 acres enrolled, thus offsetting as much as 14% of the environmental benefits. Any type of incentive-based land-retirement program will likely be vulnerable to this type of unintended consequence.

Mixed-use land markets present a related problem. For instance, some conservation efforts produce benefits that accrue in part to neighboring parcels, which will increase in value. If a neighboring parcel is undeveloped, its relative value for development increases, which in turn raises the likelihood it will be developed or at least increase the costs of future conservation. Armsworth et al. (2006) examined this phenomenon in the context of biodiversity conservation.

5. Conclusion

Although the theory of cost-effective conservation is straightforward, several decades of research show that significant complications arise in real conservation planning situations. These issues may partly explain planners' failure to use optimization methods. Lack of familiarity is surely another. Drawing from evidence from conservation programs in the United States, this paper offers a broad new synthesis of the benefits and challenges associated with cost-effective conservation. The 20 lessons presented can answer many common questions about optimal selection processes and can guide planners in government agencies and large conservation organizations to more effectively employ their budgets.

The first objective of the paper was to establish a working definition of cost-effective conservation as incorporating both benefits and costs that are measured commensurately with money. The paper distinguished the concepts of optimization from its close relatives, such as

BCT, and compared the results of optimization to those of less effective selection strategies, such as CT and BT. Twenty lessons were gleaned from this review regarding the problems of limiting optimal selection with political constraints, using a nonmonetized benefit measures or benefit indices, ignoring development risk, using incomplete cost measures, and employing cost measures sequentially or as benefit indices. The paper highlighted complications associated with interrelationships between benefits, issues of capitalization, and intertemporal planning. The manuscript also identifies challenges that need more research guidance including incentive problems and concepts of adverse selection, additionality, and slippage.

The implications of this synthesis are controversial, especially for those concerned about monetizing environmental benefits in social terms. Because these lessons are suggested to guide the selection of which conservation projects yield the most benefits and not *whether* the benefits of environmental policy outweigh cost (such as the case with traditional cost benefit analysis) hopefully this will not be as negatively viewed by environmental planners and policymakers. Ultimately, conservation planning cannot be reduced to a simple dichotomy of cost-effective versus cost-ineffective. Rather, it is a complicated process—one that is context-dependent and subject to significant information problems. That said, following these lessons can help planners do considerably better with their scarce resources and help lawmakers and policymakers design institutions that are likely to deliver greater conservation benefits from a given budget. The lessons also suggest ways for planners to determine whether the costs of acquiring improved data are less than the benefit provided by improved selection. Ideally, as policy development processes seek greater cost-effectiveness and then communicate prioritized needs for further study, researchers can target their studies to deliver the greatest return on their efforts.

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Table 1. Summary of Twenty Lessons for Cost-Effective Conservation Planning.

Optimal Selection	Benefits		Costs	Budgets	Incentive Problems
1. Benefit targeting and cost targeting can lead to suboptimal project selection 2. Efforts to distribute conservation funds evenly across political jurisdictions will tend to be suboptimal	3. Measure conservation benefits that are positive externalities. 4. Measure benefits to the public, not to experts 5. Monetize benefit measures 6. Benefits indices can lead to suboptimal project selection 7. Targeting conservation benefits leads to greater cost-effectiveness when thresholds are present	8. Interrelationships (correlations and interactions) among conservation projects are often unobserved. 9. Optimal selection accounts for development risk 10. The policy process impacts the conservation benefits received 11. Markets will tend to capitalize location-specific benefits	12. Include and fully account for all costs 13. Costs should be monetized 14. Sequential assessment of benefits and then costs will tend to be suboptimal	15. Large budgets allow conservation of all projects, any selection strategy will be optimal 16. Optimization improves cost-effectiveness when budget remainders are significant 17. Intertemporal complications can limit potential cost-effectiveness 18. Cooperation among conservation entities can help mitigate intertemporal issues	19. Adverse selection creates incentive problems that work against cost-effective conservation policy. 20. Unintended consequences of conservation policy may be impossible to fully control.

Table 2: Hypothetical Example of Ranking and Benefit-Index Suboptimality

Panel A: Hypothetical Project Costs, Benefit Index, and Monetized Benefits

A	***B***	***C***	***D***	***E***	***F***	***G***
Project ID	Costs ($C)	Benefit Index (BI)	Monetized Benefits ($B=7+BI)	Net Benefits ($NB)	BI-Cost Ratio (BI/$C)	Benefit-Cost Ratio ($B/$C)
A	$1	11	$18	$17	11.0	18.0
B	$2	8	$15	$13	4.0	7.5
C	$3	10	$17	$14	3.3	5.7
D	$5	21	$28	$23	4.2	5.6
E	$1.5	1	$8	$6.5	0.7	5.3
F	$1.5	1	$8	$6.5	0.7	5.3

Panel B: Hypothetical Project Prioritization and Selection with $6 Budget

H	***J***	***I***	***K***	***L***
Prioritization	Benefit-Targeting (Ordinal/Cardinal)	Cost-Targeting (Ordinal/Cardinal)	BI-Cost Ratio (Cardinal)	Benefit-Cost Ratio (Cardinal)
1st	D	A	A	A
2nd	A	E	D	B
3rd	C	F	B	C
4th	B	B	C	D
5th	E	C	E	E
6th	F	D	F	F
Projects selected with $6 budget	DA	AEFB	AD	ABC
Sum of Net Benefits ($NB)	40	43	40	44