An Economic Framework for Benefit-Cost Analysis in Wildlife Damage Studies

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Abstract: Benefit-cost analysis (BCA) involves comparing all of the gains and losses from a given wildlife damage management action or management technique over time in similar units, thereby providing a total picture of potential gains and losses to society. This technique is at the core of justifications for wildlife damage management efforts. BCA has been noticeably absent from the study of vertebrate pest management problems, and in the few studies where a BCA has been included, the analysis is incomplete. This paper provides an overview of the steps in a BCA, using specific wildlife damage examples to highlight and expand the technique for researchers interested in documenting these effects.

Key Words: Benefit-cost analysis, economics, decision tree analysis, sensitivity analysis, time-series data.

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INTRODUCTION

The management of vertebrate pest problems is a complex and difficult issue involving numerous factors, some of which may be contradictory. Economics is the study of the proper allocation of resources between competing wants. In the case of wildlife damage studies, economics involves the most efficient allocation of different wildlife species and management resources (i.e., money, time, equipment, personnel, etc.) toward alternative proposed wildlife damage management efforts. Benefit-cost analysis (BCA) is at the core of justifications for wildlife damage management efforts. This type of analysis measures the benefits vs. the costs of management efforts. The decision to pursue any wildlife damage management action implies a cost. BCA provides the tool necessary to evaluate the relationship between the costs and benefits that this action will bring to society. This tool can provide a comprehensive understanding of the management issue over time and can lead to the optimal use of scarce resources.

The use of BCA's in wildlife damage studies is scant (Hone 1994). In the few studies that have incorporated BCA's (Leitch et al. 1997, Smith et al. 1986), two major problems are evident. First, these studies do not fully develop the notion of economics and instead of performing a benefit-cost analysis (e.g., examination of all of the benefits and costs accruing to a project over time), these studies simply perform benefit-cost accounting (e.g., direct benefits minus direct costs), which leaves the estimates of benefits and costs incomplete. These investigations have focused almost exclusively on direct benefits (e.g., animals reduced, crop savings) and costs (e.g., salaries, chemicals, equipment) of management efforts. Few, if any, have dealt with indirect benefits (e.g., future savings from a preventative approach, proliferation of suppressed species, noise abatement) and costs (e.g., spray-drift traffic delays, losses of non-targets), and none have examined the induced benefits (e.g., job creation to collect residue samples and perform chemical analyses of exposed areas) and costs (e.g., water treatment, soil-chemical degradation).

Second, and perhaps more significant, is that most of these studies only provide a snapshot in time of the problem. Many of these studies do not look at the management issue over time; they simply judge the success (direct benefits > direct costs) or failure (direct benefits < direct costs) of a wildlife damage management problem at a single point in time. Time series analysis or an examination over time of the management issue is in most cases completely absent from BCA. Time series analysis provides a complete understanding of the problem by examining the trend in the data, the variability in the data, the interaction of the different factors involved in the issue, and allowing for forecasting of possible scenarios into the future.

Incorporating economics into a wildlife damage study should involve a measurement of the proposed efficiency of the allocation of scarce resources among competing programs. BCA is a useful tool in the evaluation of competing management programs by identifying and determining the costs and benefits that accrue to differing programs. A BCA attempts to incorporate numerous aspects of the management habitat, technique, environment, services of the environment, and individual preferences. Randall (1984) provides a general discussion of the complex relationship between all aspects of the problems that are incorporated into a BCA.

A general BCA framework can be considered from the point of view of a simple utility maximization question (Zerbe and Dively 1994). The goal of each individual is to maximize utility (happiness) given that utility is a function in part of the services provided by the environment (Nas 1996). The physical environment is valuable because it provides services valued by people. These services are determined by the environment's attributes, which are themselves determined by the characteristics of the natural system and by the activities of people. Therefore, in most cases the goal of damage management efforts is to modify the attributes, and as a result change the services the environment provides and its value.

Consider the example of an airport and a bird strike management program. The environment in this case is the airport, which has terminals, runways, and opens spaces (the attributes) that provide services (airline travel) that are valued by individuals. Wildlife damage managers enter the environment by modifying the attributes of the airport to increase the utility of individuals. The benefits that accrue to society are determined by their valuations of the services provided (in this example, safe airline travel). Policymakers can estimate the change in services as a result of a change in human-controlled inputs. From this understanding the BCA should proceed. The paper will discuss the 5-step process of BCA and provide relevant examples.

There are 5 basic steps in a BCA, and each step builds on the previous step. The first step is determining the analysis environment. Step 2 involves determining the analysis design, while Step 3 analyzes the data that were collected in the plan from Step 2. Step 4 incorporates statistical or econometric tools to determine which variables are “sensitive” to changes in other variables. Step 5 involves determining, presenting, and instituting the results. Figure 1 displays the 5 steps in the BCA process. Through this process it is possible to determine the optimal wildlife damage management program from a variety of choices, and implement that program to achieve the desired outcome. Using the above example it would be possible to estimate the benefit cost ratios for different combinations of techniques used to prevent bird strikes at airports. This information could then be used to determine which of these techniques provide the optimal amount of control.

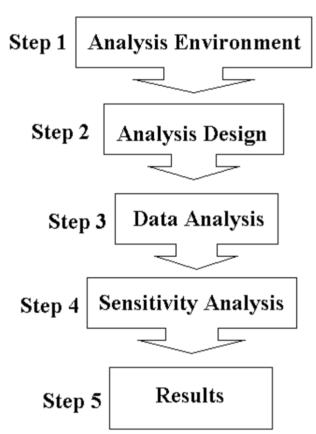

Figure 1: Benefit-cost analysis flowchart, describing the five steps involved in performing a complete BCA.

THE FIVE STEPS OF A BCA

Step 1: Analysis Environment

Understanding the analysis environment is a crucial first step in designing the appropriate benefit-cost study. In Step 1 it is important to understand the interaction between the environment, habitat, humans, and the services provided. This is necessary because this understanding will determine the client (i.e., the federal government, state and local government, the rancher, animal rights groups, etc.) and identify the goals and objectives of the analysis. The purpose of determining the client is to be sure to measure the relevant benefits and costs. For example, in the case of bird strikes, the benefits of safe airline travel accrue to all those who fly, and to the airlines that would suffer substantially from a damaged or destroyed plane, while the costs of a bird management program accrue to the airport. This issue is critical to understanding whose perspective should be taken in the BCA analysis. Indirect and induced costs and benefits will accrue to all parties involved.

The goal may be to improve safety to aircraft. Every BCA analysis will have a goal or set of goals that the analyst strives to meet during the process of the analysis. The determination of these goals helps to define the problem (Zerbe and Dively 1994). The objectives may be to reduce the number of bird strikes to aircraft, minimize the detrimental pecuniary impact of a bird strike, minimize the detrimental impact on landscape and ecology, and ensure that strategies fall within the limited resources of wildlife damage managers. Determination of the objective is crucial because it lays out how the problem is to be treated in a practical manner (Boardman et al. 1996). Defining the objective in part helps to give structural definition to the goal. The determination of the objective determines the dependent variable for the sensitivity analysis (which will be discussed in later sections). In this case the dependent variable will be a function of what the “experts” (biologists, ecologists, chemists, etc.) agree is important.

Step 2: Analysis Design

The purpose of this step is to identify the important analytical variables for which data must be collected to determine the benefits and costs of a wildlife management program. In many wildlife damage management programs several techniques may be used to manage a particular problem. It is therefore important to select a portfolio of alternative scenarios under which a program may be implemented. A reasonable number of alternatives can be chosen to provide a more complete picture of the potential benefits and costs accruing to a project.

In wildlife damage studies the alternatives usually represent the different management techniques used in the case of an ex-post (conducted at the end of a project) study, and proposed in the case of an ex-ante (conducted before the project begins) study (Boardman et al. 1996). In the bird strike example, possible alternatives may be represented by different management techniques used: bird harassment (Approach 1), habitat management (Approach 2), and fencing (Approach 3). These 3 combinations of different management techniques will represent the possible policy variables or alternatives available to decision-makers. As always, one policy alternative should involve the option of doing nothing or maintaining the status quo, which is represented by Approach 4 (no program).

Researchers may want to employ the use of a decision tree to fully outline all of the possible alternatives. A decision tree represents a flow chart of the alternative programs and can incorporate and summarize information gathered earlier, in a format that is easy to understand (Figure 2). A decision tree is a diagramming technique that illustrates the outcome of each competing policy option. The decision tree evolves out of the BCA process as the possible options for management emerge and each option is mapped out to their pecuniary conclusion.

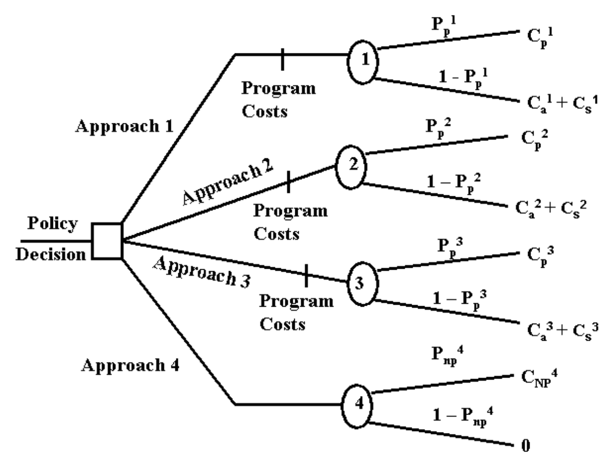

Figure 2: Example decision tree denoting four approaches available to manage bird strikes at an airport. Approach 1 denotes bird harassment, Approach 2 represents habitat management, Approach 3 represents fencing, and Approach 4 denotes no management program.

The box in Figure 2 presents the initial set of policy alternatives available to decision-makers. At the initial decision box, a choice must be made as to which policy to pursue. In this example the decision-maker is faced with 4 possible alternatives. In this example and in numerous real life situations, the benefits are recognized as the costs avoided. The objective of minimizing costs is equivalent to maximizing net benefits (Boardman et al. 1996). In Figure 2, P_p represents the probability of a bird strike and $1\text{-}P_p$ represents the probability of no bird strike.

After designing the decision tree, the next step in the analysis is the identification and valuation of the physical impacts of the alternatives. This is central to the benefit-cost analysis. A thorough BCA entails cataloguing potential physical impacts (between the habitat and humans in the environment) and selecting measurement indicators. In BCA, the only important relationship is between an impact and individual utility. If the impact does not have any value to humans, then it is not counted. This step involves identifying the branches on the above diagram. In some instances the true impact is unobservable, however, a suitable proxy can be used. The choice of specific indicators usually depends on data availability and what is easy to measure and monetize.

The second part of this step involves identifying the method that will be used to value the predicted scenarios. Most of the scenarios will involve market valuation (i.e., valuation of repairing damage to goods and services, timber, livestock, etc.). Other scenarios that involve the valuation of non-market commodities (i.e., valuation of endangered species, clean air, etc.) must employ alternative valuation methods such as contingent valuation method and travel cost method for estimating recreation demand and benefits (Loomis and Walsh 1997).

After the determination of the method of valuing the impacts, a data collection spreadsheet should be formalized. This spreadsheet is developed from the functional relationship between the dependent variables and the independent variables. Other variables will be added also that do not have a direct causal link to the dependent variable. These variables are essential to the overall BCA, although they will not be used for the sensitivity analysis since there is no causal relationship.

This spreadsheet will be used by researchers in the field making daily, weekly, monthly, or annual reports on the status of these variables. A more robust analysis is possible with more frequent observations. Aggregation of data doesn't present a problem however, disaggregating data is difficult. Numerous variables on the data sheet may be dummy variables. These variables will receive a 0 or 1 depending on the circumstance. For example, the dependent variable for bird strikes receives a 0 if no bird strike occurred and a 1 if a bird strike was reported. The characteristics of the data recorded on the dummy variable will obviously determine the method used to analyze the data.

The possible impact scenarios have been determined; therefore the next step involves attaching probabilities to those possible scenarios, represented by the P's in Figure 2. Referring to the decision tree, it would be necessary for the analyst to determine the likelihood of a bird strike in the first year given that the airport does (does not) have a bird strike program in place. In the bird strike example, this information would be obtained from historical data collected most likely at the airport. This would involve records of bird strikes detailing the extent of damage, type of bird, type of aircraft, time of day, etc. All of this information would aid in the determination of the magnitude and probability or frequency of a bird strike at a particular airport. For wildlife damage estimates, many of the studies will not have a previous (or theoretical) foundation in which to base the probabilities.

Step 3: Data Analysis

This step involves performing the actual benefit-cost analysis. The first requirement in this section is to monetize the impacts. The impacts were identified and probabilities were attached to each impact, in earlier sections. For example, the upper branch of the decision tree shows that 2 impacts were identified. The uppermost branch indicates that the probability of a bird strike is P_p^1, and that as a result of that impact cost $C^1{}_p$ was incurred. The equation below represents the formulation of these costs,

$$C^1{}_p = C_a + C_s + P_p^1\,\bar{A}_c$$

where,

C_a = the administrative costs of the bird strike program.

C_s = costs associated with the adverse effects of using lethal removal. This represents the opportunity costs of the program, which can include direct, indirect, and induced costs.

P_p^1 = a variable indicating the probability of a bird strike. If a bird strike program has been in place long enough to be effective, it would be expected that $P_p^1 < P_{np}^1$, $P_p^1 > 0$.

$\bar{A}_c$ = the average cost of a bird strike. This can include repair costs to the plane, delay costs to passengers, compensation costs to passengers, etc.

The branch below the uppermost branch indicates a different scenario. This scenario outlines the cost associated with Approach 1 when no bird strikes occur. $1 - P_p^1$ represents the probability of no bird strike occurring. These costs are simply the costs of the program, $C_a + C_s$.

Similar costs are incurred for following Approach 2 or 3. The final set of outcomes results from the policy decision not to pursue a bird strike program (Approach 4), and therefore no program costs were incurred. The probability of no bird strike occurring with no bird strike program in place is $1 - P_{np}^1$, and it would be expected that $1 - P_p^1 > 1 - P_{np}^1$, meaning that the probability of no bird strike is greater if a program is implemented.

The lower branch of the no bird strike program limb indicates the costs incurred under the scenario of a bird strike with no program, C_{np}. This follows the equation,

$$C_{np} = P_{np}^1\,\bar{A}_c + \Omega$$

where,

P_{np}^1 = a variable indicating the probability of a bird strike given that no bird strike program is in place, it would be expected that $P_p^1 < P_{np}^1$, $P_{np}^1 > P_p^1 > 0$.

$\bar{A}_c$ = the average cost of a bird strike. This can include repair costs to the plane, delay costs to passengers, compensation costs to passengers, etc. This is the average of all different degrees of bird strikes since the alternatives just listed strike or no strike. It would be possible to derive different average costs for different degrees or severity of damage.

Ω = this variable represents the costs incurred as a result of a bird strike occurring with no program in place, (i.e., a lawsuit).

Since management programs will run over multiple years, the values must be brought in to present value terms. All of the previous steps built the framework and collected the data necessary for the BCA. This step involves taking the information obtained in the earlier steps and using it to calculate the actual benefit cost numbers. There are several different methods that exist to sum the benefits (B) and costs (C) over the lifetime of the project, including net present value (NPV), and benefit-cost ratio (BCR).

If only one project is being compared, then the project should proceed if the NPV = B – C > 0. If multiple projects are being compared, then the several different methods of BCA analysis can be chosen to determine project selection. The net present value (NPV) equation below represents the present value of the benefits minus the present value of the costs. This method calculates the benefits minus the costs for each year and this difference is discounted back (using the interest rate i) to the present time period (t = 0).

$$NPV = \frac{(B_1 - C_1)}{(1+i)^1} + \frac{(B_2 - C_2)}{(1+i)^2} + \frac{(B_3 - C_3)}{(1+i)^3} + \ldots + \frac{(B_t - C_t)}{(1+i)^t}$$

The BCR equals the present value of the benefits divided by the present value of the costs. This equation uses the same information as the equation above.

$$BCR = \frac{\text{present value of benefits}}{\text{present value of costs}}$$

$$BCR = \frac{(B_1/(1+i)^1) + (B_2/(1+i)^2) + (B_3/(1+i)^3) + \ldots + (B_t/(1+i)^t)}{(C_1/(1+i)^1) + (C_2/(1+i)^2) + (C_3/(1+i)^3) + \ldots + (C_t/(1+i)^t)}$$

Step 4: Sensitivity Analysis

The role of sensitivity analysis is to measure how sensitive the result of the benefit-cost analysis or the dependent variable is to a change in one of the quantitative variables. The role of sensitivity analysis is to attempt to deal with uncertainty or different states of the world. Due to the uncertain and inexact nature of wildlife damage management issues, sensitivity analysis is a fundamental step in increasing the applicability and believability of the results of the BCA. In the bird strike example, this analysis involves determining how sensitive or responsive the number of bird strikes is to a change in one of the quantitative independent variables.

Econometrics or mathematical economics is a tool of economic measurement and is often used to perform sensitivity analysis in benefit-cost studies. Econometrics employs statistical estimation of the mathematical relationships between the dependent variable and the independent variables. In many cases econometrics is used to verify theoretical relationships between variables or to discover new relationships between variables that will form the foundation for theory. In wildlife damage management studies, econometrics is an invaluable tool to aid in the refinement of programs to manage different wildlife issues. Using econometrics to analyze time series data provides the opportunity to discover the trend in variables and explain the variance that some variables exhibit over time.

Again referring to the bird strike example, econometrics would allow for the discovery and analysis of the most significant causes of bird strikes over time. This type of analysis involves examining the variability in the data over time and using that variability to explain the movement in the dependent variable. It is in this way that the use of econometrics provides the complete picture when looking at wildlife damage management issues. Furthermore, econometrics allows for the manipulation of variables to determine the optimal use of resources devoted to a particular management approach. By changing the number of hours worked by a technician for example, the program manager could then determine the optimal number of hours worked to minimize the number of bird strikes. The use of econometrics to analyze time series data is an essential component of a complete BCA.

Step 5: Results

This step involves the presentation of the results. Throughout the BCA, data were collected, monetized and analyzed to determine which program was the "best" program, meaning which had the greatest BCR or highest NPV. BCA not only allows policy makers to determine the best program but if a program should be in place at all. After a particular program or approach is decided on, the next step in the analysis involves using sensitivity analysis to "fine tune" the program to give the optimal use of resources. The optimal choice of factor (labor and other resources) can be chosen to optimize the approach.

CONCLUSION

Benefit-cost analysis (BCA) can be an invaluable tool in wildlife damage management studies that can provide justification for damage management intervention. This type of analysis also should allow policymakers to "fine tune" a program to meet a number of issues including, budget concerns, habitat changes, changing attitudes of the public, and other issues that may be unique to their particular situation. Additionally, policymakers will be able to use BCA to provide a complete understanding of the management intervention approach over the lifetime of the project. The collection of detailed time series data is crucial for this type of analysis and provides the information necessary to hypothesize different outcomes under different scenarios of management and other variables to forecast potential future scenarios. By collecting time series data, researcher will be able to complete a comprehensive analysis of wildlife damage management issues.

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