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Economic Effects of Environmental Quality Change on Recreation Demand

by

© ALISON GAYLE COYNE

A THESIS

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The undersigned certify that they have read and recommended to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled ECONOMIC EFFECTS OF ENVIRONMENTAL QUALITY CHANGE ON RECREATION DEMAND submitted by ALISON COYNE in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in AGRICULTURAL ECONOMICS.

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Abstract

The objective of the research contained in this volume was to develop a methodology which can be used to examine the economic effects of changes in environmental quality on recreation demand. The two main areas of investigation in this study were the determination of environmental quality variables which affect recreation demand and the statistical investigation of the effects of changes in these variables on recreation demand and benefits. The particular recreation activity examined was Bighorn sheep hunting in Alberta.

A review of theoretical and empirical recreation demand models shows that discrete choice models are extremely well suited to recreation applications and have the advantage of explicitly incorporating environmental quality into the analysis. The multinomial logit discrete choice model was chosen as an appropriate method for investigating Bighorn sheep hunting site choice.

Estimation of the multinomial logit model for Bighorn sheep hunting required identification and measurement of environmental quality variables which affect demand for hunting sites. Site quality attributes identified as having an effect on Bighorn sheep hunting site choice included sheep populations, accessibility of sites and congestion at sites.

Model results were used to determine the welfare effects of changes in environmental quality variables; to calculate the value of specific Bighorn sheep hunting sites; and to predict the change in probability of site selection for a change in site quality. The welfare estimates derived from the model were comparable to values derived by other models in the literature.

Overall, this study has shown the discrete choice model to be a valuable potential tool for policymakers. There is a broad range of possible applications in the context of recreation planning and policy analysis.

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I. INTRODUCTION

A. Study Background

There has always been a strong relationship between Alberta's natural resources and outdoor recreation activities. This relationship is acknowledged in the most recent policy directives issued by government agencies responsible for the legislative and operational aspects of outdoor recreation in Alberta (Alberta Energy and Natural Resources, 1984[1]; Alberta Recreation and Parks, 1985). Recent studies conducted on recreational activities show that many of the activities most preferred by Albertans are outdoor activities where the natural environment is a principle component of the activity (Jackson, 1985). This would suggest that policies or programs which improve the quality of the natural environment may have a significant impact on the benefits derived from outdoor recreation activities[2].

Studies in the United States have indicated that a large proportion of the benefits derived from improvements in environmental quality accrue through recreational uses of the environment (Freeman, 1979). In Alberta, where many natural resources are owned by the Government of Alberta on behalf of the public, programs directed at improving environmental quality are the responsibility of the

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[1]Since 1986, Alberta Forestry, Lands and Wildlife has been responsible for developing recreation policies and programs relating to Alberta's public lands and wildlife resources.

[2]Natural phenomenon such as fires or floods also lead to changes in environmental quality and can therefore have an impact on recreation activities. This study will primarily be concerned with those changes that can be controlled by natural resource managers.

government. Measuring the recreation benefits resulting from a specific government policy requires an understanding of how the policy affects economic activities.

Freeman (1979) identifies three relationships which indicate the linkages between an environmental policy and the recreation benefits derived from implementation of the policy. A simple example concerning improvements in water quality can be used to illustrate the relationships.

1. An environmental policy designed to improve the natural environment at a specific site leads to changes in various measures of environmental quality at the site. An improvement in water quality could result from a policy to reduce effluent levels in a specific water body and the improvement can be measured by various criteria such as dissolved oxygen levels, temperature, color, and odor.

2. The improvement in environmental quality will lead to changes in the recreational opportunities available at the site. High levels of dissolved oxygen are necessary to support most game fish populations therefore an increase in dissolved oxygen levels will enhance the carrying capacity of the lake. Increased fish populations will improve recreational fishing opportunities at the site.

3. The changes in recreational opportunities lead to changes in individual welfare or recreation benefits. The enhanced recreational fishing opportunities at the site may have several effects on individual welfare. Anglers who currently use the site may do so more often; anglers who currently fish at other sites may switch to the improved site; or individuals who are not currently anglers may take up the sport. It is with this final set of relationships that

economists are primarily concerned but, knowledge of the other relationships is critical to the determination of empirical estimates of recreation benefits.

Similar scenarios can be developed for any government policy which leads to the improvement in some aspect of environmental quality. Economists can also examine losses in recreation benefits resulting from a degradation in environmental quality. The values that individuals place on actions designed to increase environmental quality or to prevent a reduction in environmental quality constitute a measure of recreation benefits. Implementing environmental projects or policies will require the expenditure of public funds. For this reason, it would be useful to have a means of selecting among various projects or policies leading to environmental change.

Benefit-cost analysis is a method of economic analysis that has been used to examine the implications of land and water resource policies including the establishment of government funded recreation areas (Freeman, 1979; McConnell, 1985)[3]. At the most fundamental level, benefit-cost analysis is simply a set of techniques for choosing among alternative policies or projects to achieve stated goals (Johansson, 1987). Benefit-cost analysis provides a set of definitions and procedures with theoretical underpinnings for measuring benefits and costs and can therefore assist in environmental decision making (Freeman, 1979). A project being considered by the government may be evaluated on the net benefits it provides to

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[3]See Howe (1971) for a detailed description of benefit-cost analysis as applied to water system planning and see Mishan (1976) for a general overview of benefit-cost analysis..

society. Therefore, projects which enhance environmental quality can be evaluated using benefit-cost analysis.

Unfortunately, assigning a dollar value to the benefits associated with recreation activities is a difficult task. Economists have well established techniques which can be used to measure the value of private goods and services traded in the marketplace. The process of purchasing goods leads individuals to reveal their preferences for these goods. However, such markets do not exist for public goods.

Economists describe most environmental assets, including those used for recreation purposes, as public goods. It is worthwhile to make a distinction between pure public goods and what some researchers have referred to as quasi-private goods (Mitchell and Carson, 1989). Pure public goods are characterized by conditions of non-rivalry/ congestion and of nonexcludibility (Just et al., 1982). For example, no one individual can be prevented from enjoying the benefits of clean air. In addition, one individual's consumption of the clean air does not affect another indivdual's consumption either in terms of quantity or quality. Pure public goods are not traded in any market and therefore neither a market price nor the quantity and quality demanded of the goods can be observed.

By contrast, quasi-private goods may be offered to individuals at a given price, although the goods are not freely traded in a competitive market. Recreation sites and the provision of recreation opportunities at the sites can be classified as quasi-private goods. For example, hunting licences have a purchase price but, this price is usually arbitrarily set at a level below potential market price. However, the fact that purchases must be made in order to allow an individual to participate in certain recreation activities has allowed researchers to observe the quantity and quality demanded of these goods. Taking advantage of this link between market purchases and consumption of public goods, economists have developed techniques which can be used to assign values to the benefits derived from the use of environmental assets for recreation purposes. In recent years, research efforts have concentrated on measuring the magnitude of recreation benefits associated with changes in the quality of the environmental resource.

Recent theoretical and empirical research in the area has concentrated on measuring the magnitude of the recreation benefits associated with changes in air and water quality (Bockstael et al., 1984). As studies in the United States have shown, a large proportion of the economic benefits associated with improvements in air and water quality result from recreational use of the environment (Bockstael et al., 1984; Freeman, 1979). Air and water quality are two very important components of a general environmental quality. However, there are other aspects of environmental quality which, if altered, could cause changes in recreation benefits.

B. Study Objectives

The preceding discussion suggests that analysis of the effect of environmental quality on recreation activities is an important element of a sound environmental policy. While several studies in Alberta have analyzed the value of recreation there are few studies that consider the qualitative aspects of the resource and its contribution to economic value. The objective of this study is to develop a methodology which can be used to examine the economic effect of changes in environmental quality on recreation demand and to apply the methodology to an Alberta case study. The methodology will focus on the use of recreation demand models and the particular application to be examined is the case of Bighorn sheep hunting in Alberta. The two main areas of investigation are determination of environmental variables which may affect hunter demand at Bighorn sheep hunting sites and statistical investigation of the effects of changes in these characteristics on hunter demand at the hunting sites. Specifically, model results will be used to determine the welfare effects of changes in particular environmental quality variables; to calculate the value of specific Bighorn sheep hunting sites; and to predict the change in probability of site selection for a given quality change.

C. Study Plan

The plan of this study is as follows. Recreation demand modeling research efforts in the last decade have led to advances in both theoretical and empirical frameworks. New evaluation techniques and improvements to established evaluation techniques have resulted from these efforts. Chapter II contains a review of the literature on these techniques and includes a discussion of empirical models. The discussion examines the development of theoretical models which incorporate environmental quality. Empirical models used for estimating the impact of environmental quality changes on recreation activities are derived from these theoretical models. The most recent developments in these models, particularly discrete choice models which can be used to incorporate environmental quality into a multiple site framework, are presented. Welfare theory which allows model results to be used in calculating recreation benefits is also presented.

Chapter III contains a discussion of environmental quality measures. A case study of Bighorn sheep hunting in Alberta is used to illustrate how quality measures can be incorporated into a discrete choice model. Issues surrounding the data to be used in estimating such a model are also discussed.

In Chapter IV, one form of a discrete choice model is estimated and several uses for the results are demonstrated. Conclusions and recommendations for additional research are contained in Chapter V.

Before proceeding with the study plan it is useful to have a general understanding of the concepts surrounding the measurement of recreation benefits. The following section is concerned with this issue.

D. Benefit Concepts and Measurement

1. Definitions

Given that individuals know the effects brought about by quality changes, they can form preferences regarding these effects. Individual preferences are the basis for determining the economic benefits from environmental changes. Freeman (1979) defines the benefit of an environmental improvement as "the sum of the monetary values assigned to these effects by all individuals directly or indirectly affected by that action". However, it is useful to define more precisely the meaning of benefits as the terms "benefits", "costs", and "damages" are often used interchangeably (Feenberg and

Mills, 1980; Freeman, 1979).

Cost can refer to the value of resources used to bring about an environmental change. In this sense, it refers to project costs such as labor and materials and these are valued at market prices. Cost can also refer to opportunity cost which may include the elimination of some recreation benefits. When used in this manner, cost can be confused with damages.

The distinction between damages and benefits depends on the choice of an initial bench mark from which environmental changes are measured. Benefits can be measured by comparing the existing state of the environment with an alternative where environmental quality has been improved. Benefits are the values individuals assign to the improved quality level. Some projects or policies may lead to changes which deteriorate the level of environmental quality. Values placed on these losses represent damages. For purposes of this study, the term benefits will be used to refer to gains associated with improvements in environmental quality and to the reduction of damages resulting from a degradation in environmental quality. The values that individuals place on achieving the above changes are a measure of recreation benefits from environmental change.

2. Benefit Classification

A detailed examination of the benefits from a change in environmental quality should include all of the benefits which could result from a change in the provision of an environmental asset. Benefits have been broadly categorized into "use" benefits and "existence" or "non-use" benefits. Mitchell and Carson (1989) have described these categories of benefits and their discussion is summarized below.

Use benefits result from the indirect and direct ways in which individuals currently use a public good. For example, improving water quality at a lake may indirectly enhance photography opportunities or duck hunting opportunities around the lake. Improving water quality will directly affect many recreation activities such as swimming, and commercial activities such as fishing. In addition, withdrawal uses of water such as agriculture or municipal water reservoirs will benefit directly from the improvement in water quality.

The existence class of benefits recognizes the fact that individuals may derive utility from an environmental asset for reasons other than their expected use of the asset. The idea that individuals do not have to be physically involved with an environmental asset to benefit from it is a central concept for the existence class of benefits. This class of benefits has been divided into two categories. The vicarious consumption category of benefits reflects the idea that individuals may gain utility from knowing that other individuals such as family, friends, or the general public can consume the resource. Stewardship benefits involve a desire to see environmental assets used in a responsible manner and conserved for future generations. Stewardship benefits are further divided into bequest values and inherent values. Bequest values exist if an individual enjoys knowing that the current provision of an amenity will make it available for others in the future. Inherent values stem from the individual's satisfaction that an environmental resource is preserved regardless of whether it is ever to be used.

Measuring the benefits associated with an environmental resource can be a complex undertaking. For this reason, most researchers have concentrated on examining only one aspect of benefits at any given time. Over time, contributions by many researchers has led to improved understanding of the overall benefit framework. The research contained in this volume focuses on the direct use class of benefits associated with the influences of environmental quality on recreation demand.

E. Summary

This chapter has provided background information on the study objectives. The analysis of the effect of environmental quality on recreation is an important element of a sound environmental policy. This study will develop a methodology which can be used in such analyses. A definition of benefits and a discussion of different classes of benefits have been presented. The next chapter presents a literature review with emphasis on the development of theories relating to recreation demand models.

II. Recreation Demand Models and Welfare Theory

A. Introduction

As the previous chapter has illustrated, there are many important instances where the effective management and planning of recreation resource use require understanding of site demand. To be appropriate for demand and benefit estimation under different scenarios, recreation demand models must be sensitive to all variables which influence demand. Examples of such variables include: site attributes which determine the suitability of a site for the recreation activity in question; travel cost and related variables that impede or enhance site accessibility; location of competing sites; and characteristics of the recreationist that influence site choice behavior. Recreation site demand can be thought of as a product of individual choices and site attributes. Analyses of site demand or recreation benefits can best be achieved in a modeling framework which incorporates human decision processes and behavior (Peterson et al.,1983).

Numerous recreation demand models have been proposed and estimated since the pioneering work by Hotelling (1949) and Clawson (1959). The form of these models has varied considerably but they do share some common characteristics. The general approach has been to explain site demand in terms of travel cost variables, attributes of the site in question, accessibility and attributes of substitute sites, and socioeconomic characteristics of the recreationists. Early models only provided demand and benefit information for a single site and quality attributes of the site were often ignored. More recently, modeling approaches have attempted to provide demand and benefit information for entire systems of sites and many of the new techniques have explicitly incorporated site quality.

The purpose of this chapter is to review and assess the various recreation demand models that can be used to elicit recreation site demand and benefit information. Each approach will be examined in terms of its ability to incorporate site quality into the modeling framework. In order to provide logical direction for the review, recreation demand models can be divided into four categories: traditional travel cost models, generalized travel cost models, hedonic travel cost models, and discrete choice models. It is important to note that several complications in the applications of recreation demand models are common to all the approaches reviewed below[4]. These issues involve separability assumptions and model specification; treatment of time; estimation concerns such as aggregation, demand heterogeneity, truncation and censoring; and treatment of uncertainty and learning. In addition, data requirements for state-of-the-art recreation demand analyses are enormous. Testing the reliability of the advanced recreation demand models and improving upon them will, to a large degree, depend on the ability of researchers to collect the appropriate data.

The ultimate objective of the research contained in this volume is to develop a recreation demand model which can be used to examine how demand and benefits change with fluctuations in site quality, site availability, or conditions of site access. As such analyses are carried out in a welfare theoretic framework, the basic concepts of

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[4]See Bockstael et al. (1984); Smith (1989); and Fletcher et al. (1990) for a discussions regarding the treatment of many of these issues.

welfare theory as it relates to the definition and measurement of welfare changes will conclude this chapter.

Before turning to the discussion in the following sections of this chapter, a digression concerning other approaches to obtaining demand or benefit information is appropriate. Recreation demand models represent only one group of methods which are currently being used to measure the benefits and demand for nonmarket goods. Using the terminology of Mitchell and Carson (1989), recreation demand models can be referred to as *observed/indirect* techniques for valuing nonmarket goods. The techniques are based on observing actual market behavior and using this information to indirectly make inferences about individual preferences. The main competition to recreation demand models in benefit estimation is contingent valuation. Contingent valuation is part of the *hypothetical/direct* category of techniques[5]. Using this class of techniques, researchers obtain estimates of benefits by directly asking individuals for their responses to questions regarding hypothetical situations. When posing the hypothetical questions to respondents, the contingent valuation approach assumes that respondents will give thoughtful answers, that respondents will not behave in any number of strategic ways, and that they will not be influenced by the nature of the survey instrument or an interview process.

As Bockstael et al. (1984) point out, the two approaches (recreation demand models and contingent valuation) applied to the

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[5]For a detailed discussion of these and alternative methods of measuring recreation demand and benefits see Mitchell and Carson (1989).

same research problem can potentially yield similar results since both approaches are based on individual preferences. While some researchers have conducted comparisons of benefit estimates from the two approaches, these comparisons have not controlled for differences in the underlying assumptions of the studies from which the benefit estimates were derived. It would be productive for researchers to view the two approaches as complementary and further research into both techniques should be encouraged. The immediate objective of the research in this volume, however, is to examine various techniques for incorporating environmental quality into recreation demand models. While contingent valuation methods can be used to examine environmental quality issues it is beyond the scope of this study to include such methods in the discussion and analysis.

B. Recreation Demand Models

1. Traditional Travel Cost Models

The oldest and most frequently used method for obtaining demand and benefit information for a recreation site is the travel cost technique proposed to the U.S. National Park Service by Hotelling (1949) and developed further by Clawson (1959) and Clawson and Knetsch (1966). The travel cost technique exploits the fact that people live in different locations and incur different travel costs to reach the [illegible] recreation site. Therefore, they can be expected to visit the [illegible] different rates. In effect, travel costs to a site can be [illegible]idered a proxy for market price since it is expected that as distance from a site increases the demand for the site will decrease. A proxy for market price is necessary since recreation sites usually have a zero or token entrance fee. An introduction to travel cost models and examples of empirical applications can be found in Walsh (1986), Rosenthal et al. (1984), Freeman (1979), and Dwyer et al. (1977). The basic travel cost models as presented below are adapted from Freeman (1979, 1985).

In formulating a simple travel cost model certain assumptions must be made. First, as mentioned above, individuals are assumed to treat changes in travel costs the same as they would changes in entrance fee charges to a site. Second, it is assumed that there is only one recreation site available to the individuals in the defined study area Third, it is assumed that the only purpose of the trip is to [illegible] the specified site; that is, only the costs associated with travelling to the recreation site should be included in the analysis. Fourth, it is assumed that all individuals spend an equal and fixed amount of time at the site. Finally, it is assumed that recreationists travel purely for the purpose of accessing the recreation site; there is no utility in the travel itself. Given these assumptions the procedure used in determining a demand curve for the site can be set out in the following manner:

1. The area surrounding the recreation site is divided into concentric circular zones and travel costs from each zone to the recreation site are determined.

2. Visitors to the recreation site are sampled to determine their zones of origin and visitation rates defined as visitor days per capita are calculated for each zone.

3. Visitation rates are regressed on travel costs and socioeconomic variables.

4. The observed total visitation for the site from all travel cost zones at the prevailing site entrance fee (which may be zero) represents one point on the demand curve.

5. Since individuals are assumed to respond to changes in entrance fees in the same way that they would to changes in travel costs, additional points on the demand curve can be found by using the estimated demand function to compute new visitation rates and total visits for all travel cost zones with the existing travel cost plus some increment. Visits are summed across zones to determine the predicted total visitation at the higher hypothetical entrance fees until the full demand curve is determined.

More formally, for each zone z the relationship

$$V_z = V\left(TC_z, S_z\right), \qquad z = 1, \ldots, Z, \tag{1}$$

is estimated, where V_z is visits per capita from zone z, TC_z is travel cost for trips from zone z, and S_z is a vector of socioeconomic characteristics describing the population of zone z. The total number of visits to the site is described by

$$V = \sum_{z=1}^{Z} Pop_z \; V_z \;, \tag{2}$$

where POP_z is the population of zone z. Incremental entrance fees, P, are added to the travel costs to identify the demand curve as given by

$$V(P) = \sum_{z=1}^{Z} V\left(TC_z + P, S_z\right). \tag{3}$$

P is increased until V(P) = 0 and the full demand curve has been identified.

The travel cost model as described above uses population zones and aggregate numbers of visits. But, it is possible to base the analysis on individual observations and currently, this is the type of model which is typically estimated. With individual observations, the dependent variable in the regression is the number of visits per individual. Models based on individual observations can only be estimated if there is sufficient variation in the number of trips taken by individuals to the recreation site (Freeman, 1979). The procedure is similar to the zonal travel cost procedure. The estimated relationship is

$$V_n = V\left(TC_n,\ S_n \right), \qquad n = 1,\ldots,N, \tag{4}$$

where V_n is the number of visits made by the nth individual to the site, TC_n is the travel cost associated with the nth individual, and S_n is a vector of socioeconomic characteristics associated with the nth individual. Spatial variation leads to different travel costs for different individuals and adding up the quantities demanded at each price provides an aggregate demand curve for the site. If the assumptions underlying weak complementarity are met, (4) can be used to determine the benefits associated with the recreation site[6].

When there is more than one recreation site within a region, following the above procedures to estimate the demand for any one site would lead to biased results since the prices (travel costs) of competing sites are excluded from the estimated demand function (Freeman, 1979; Bockstael et al., 1984; Caulkins, Bishop and Bouwes, 1986)[7]. Burt and Brewer (1971) were the first researchers to

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[6]Weak complementarity will be discussed in detail in section C of this chapter.

[7]For a thorough treatment of the issues surrounding estimation of multiple site models see Bockstael et al. (1984).

explicitly incorporate substitution possibilities in a modified travel cost model. Their model was an extension of the simple single-site travel cost model to a system of demands for sites. The model was specified as

$$V_j = V\left(TC_1,\ TC_2, \ldots, TC_J,\ S \right), \qquad j=1,\ldots,J \qquad (5)$$

where V_j is the number of trips taken to site j, TC_j is the travel cost to site j, S represents socioeconomic characteristics, including income, and J is the number of sites in the system. The model was estimated using individual observations. Sites within the study region were grouped into categories based on similarities in site characteristics. For each group of sites, the number of trips to the sites was regressed on the travel costs to the sites, travel costs to substitute sites and relevant socioeconomic variables. The result was a set of demand functions, one for each category of recreation sites, and using the same travel cost procedures described above, site demand curves could be derived.

The system of demands travel cost model has the ability to reveal substitution among different types of sites resulting from changes in prices. The main application of the model has been to value a new recreation site by examining how patterns of demand for existing sites would change with the addition of the new site. The benefits from the new site are assessed by examining the effects of a price change for the existing site most similar to the proposed site. Gains from the new site are the result of reduced travel costs for some individuals and site quality does not play any role in the model. Differences due to the quality characteristics of sites are reflected in the estimated coefficients of the demand functions for the different categories of sites. However, because the approach does not explicitly model the effect of site characteristics on site demand, it cannot be used to determine how a change in a particular quality variable at one site will affect demand at the site or at other sites in the demand system.

Including site quality variables in the site demand functions would seem to be an appropriate step towards capturing the effects of quality on site demand (Freeman, 1979). If there are several sites within a region, each with different levels of quality then the individual demand functions can be written as

$$V_{ni} = V\left(TC_{ni},\ TC_{nj},\ Q_i,\ Q_j,\ S_n \right), \qquad \begin{array}{r} n = 1,\ldots,N \\ i,j = 1,\ldots,J \\ i \neq j \end{array} \qquad (6)$$

where V_{ni} is the number of visits by individual n to site i, TC_{ni} and TC_{nj} are travel costs for individual n to sites i and j, Q_i and Q_j are vectors of site quality characteristics for site i and j, and S_n is a vector of socioeconomic characteristics for individual n. Since recreation models are usually estimated from data collected at a single point in time there will be no variation in the Q vectors. The vectors will be the same for all individuals even though site demand is expected to be a function of quality (Freeman, 1979; Bockstael et al., 1984).

2. Generalized Travel Cost Model

While site characteristics cannot be incorporated as separate variables in site demand equations, they can be introduced in other ways. The generalized travel cost model is a model which incorporates alternative sites and quality variables in the modeling process[8]. A system of demand equations, where the number of visits to a site is specified as a function of the travel costs associated with visiting the site and socioeconomic variables. This is estimated by

$$V_{nj} = \beta_{0j} + \beta_{1j}TC_{nj} + \beta_{2j}S_n + \varepsilon_{nj} \qquad \begin{array}{l} n = 1,\ldots,N \\ j = 1,\ldots,J \end{array} \qquad (1)$$

where V_{nj} is the number of visits by individual n to site j, TC_{nj} is the travel costs incurred by individual n travelling to site j, S_n is a socioeconomic variable such as income, and ε_{nj} is the error term. The parameter values for all sites are then regressed against observed quality characteristics of each site as given by

$$\beta_{0j} = \alpha_{00} + \alpha_{01}Q_{1j} + \alpha_{02}Q_{2j} + \mu_{0j}$$

$$\beta_{1j} = \alpha_{10} + \alpha_{11}Q_{1j} + \alpha_{12}Q_{2j} + \mu_{1j}$$

$$\beta_{2j} = \alpha_{20} + \alpha_{21}Q_{1j} + \alpha_{22}Q_{2j} + \mu_{2j} \qquad (2)$$

where the βs are the parameters estimated in step 1, Q_{1j} and Q_{2j} are measures of two quality attributes at each site, the α_{kl} are parameters to be estimated in step 2, and the μ_{kj} are the error terms.

While the generalized travel cost method allows multiple site characteristics to be included in the model most applications of the approach have tended to omit substitute prices in the estimation of (1). As the model is specified above, the number of trips to the jth site depends solely on the travel costs to the jth site and the characteristics of the jth site. An individual will travel to the site regardless of prices or the qualities of other sites. Also, the

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[8]For applications of this approach see Vaughan and Russell, 1982 and Smith and Desvousges, 1986.

model requires data on a large number of sites since the number of observations to be used in the second stage of the estimation procedure is equal to the number of sites (Bockstael et al., 1984).

3. Hedonic Travel Cost Model

The origins of the hedonic travel cost model can be found in the traditional travel cost model and the hedonic price model often used in property value studies[9]. The model assumes that a recreation site can be described by a vector of its attributes or quality levels. An individual at a given location faces a number of alternative sites with different characteristics. Each site is available at a different price where price includes an entrance fee and travel costs to the site. Consumers reveal their demand for site characteristics by choosing some bundle of site characteristics for a particular travel cost. As Brown and Mendelsohn (1984, page 427) state, "by observing purchases of a private good (travel) which must be made in order to gain access to the public good (recreation site), it is possible to observe a price for the public good (the site). Treating heterogeneous sites as if each was a bundle of characteristics, the site price can be decomposed into a set of implicit prices for each characteristic using the traditional hedonic method."

The hedonic travel cost method consists of two separate procedures. First, the area is divided into residence zones and

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[9]The basic references to the hedonic travel cost model are Brown and Mendelsohn (1984); Mendelsohn (1984, 1984a); and Smith and Kaoru (1987). For a discussion of hedonic price models see Brown and Rosen (1982).

recreation sites are identified. For each residence zone a relationship is estimated between the costs of travel to sites and the levels of characteristics at sites. This is expressed by

$$TC_{nij} = f_i\left(Q_j \right) \qquad \text{for all} \quad \begin{array}{l} n = 1,\ldots,N_i \\ i = 1,\ldots,I \\ j = 1,\ldots,J \end{array} \qquad (1)$$

where TC_{nij} is the travel costs associated with individual n, who lives in residence zone i, visiting site j and Q_j represents various site quality characteristics. Separate regressions are estimated for each residence zone i, using the data from individuals living within each zone. The costs of visiting any given site and the characteristics of the site are identical for all individuals living within one particular residence zone. Variation in the data comes from variation in the sites visited by the individuals from the same residence zone. The partial derivative of this travel cost function with respect to each characteristic, $\partial TC / \partial Q$, provides the hedonic or implicit price for each characteristic. One set of implicit prices is provided for each residence zone. The second step in the hedonic travel cost method is to regress the implicit prices against a measure of the quality attributes found at each site and a set of socioeconomic variables. This is expressed by

$$\partial TC / \partial Q = g\left(Q_j, S_{ni} \right) \qquad (2)$$

where S_{ni} represents selected socioeconomic characteristics of individuals. Equation (2) provides inverse demand functions for attributes.

The hedonic travel cost model is based on a different view of individuals' recreation site choice than that of other travel cost models. It has been criticized because it does not have a solid theoretical base (Bockstael et al., 1984). Hedonic price theory is used to examine housing and labor markets. In recreation demand analyses the recreation sites do not necessarily exist in a similar type of market. The hedonic travel cost model presumes that individuals can choose along a continuum of quality. That is, an array of sites exist where increasing quality can be purchased at higher travel costs and the individual can freely choose where to be along that array[10]. The approach does not estimate demands for sites but rather, focuses on estimating demands for characteristics. As such the approach does not examine recreation behavior such as site substitution or exit by some individuals from participating in a particular recreation activities. Smith and Kaoru (1987) identify a number of theoretical and practical issues in the hedonic travel cost model, including the determination of residence zones and the definition of site characteristics. One of the major problems in the hedonic travel cost model is the fact that many of the prices are negative. Bockstael et al. (1985) and Smith and Kaoru found significant numbers of negative price coefficients. These may be explained as discontinuities in the array of characteristics. Nevertheless, they cause difficulty in the determination of benefits.

4. Discrete Choice Models

During the late 1970s, it was recognized by some researchers that

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[10]As Bockstael et al. (1984) point out, in many instances this may not be a valid assumption.

the choice of recreation sites could be modeled using discrete choice techniques which had been developed in the transportation literature[11]. In choosing between different modes of transportation or different recreation sites, individuals are faced with a discrete and finite set of mutually exclusive alternatives. It seemed logical that discrete choice models would be applicable to recreation site choice problems[12]. As in the hedonic travel cost model, the discrete choice approaches model site choice as a function of the physical characteristics of sites. Instead of assuming a market for characteristics however, the discrete choice approaches assume that individuals use their knowledge of site attributes to rank recreation sites. The individual will choose the recreation site with the highest ranking or utility.

An important aspect of discrete choice models is that they are developed from utility theory and, therefore, theoretically correct benefit estimates can be derived from them. The main difference between discrete choice models and the travel cost models described above is that analysis involves working directly with utility functions rather than the derivation of demand functions. Derivation of demand functions requires the assumption that choices are selected from a set of continuous variables. This allows the use of calculus

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[11]This work is summarized in Domencich and McFadden (1975). Detailed development of discrete choice models can be found in Ben Akiva and Lerman (1985) and Hensher and Johnson (1981).

[12]Binkley and Hanemann (1978) and Hanemann (1978) were the first to use discrete choice models as a means of incorporating site quality into recreation demand analysis. Other examples of studies which have employed discrete choice models include: Feenberg and Mills (1980); Bockstael et al. (1985); Caulkins (1986); Carson et al. (1989); and Jones (1989).

to derive demand functions. However, when choices are discrete, as in the case of selecting one recreation site from many, the number of visits to some sites can be zero and the maximization problem may have a corner solution[13]. Therefore, a discrete representation of alternatives requires a different analytical approach. The formulation of a discrete choice model is presented in detail in the following sections[14].

Indirect utility, V, is defined as a function of the attributes of the alternative recreation sites, Q, and the socioeconomic characteristics of the recreationist, S, as in

$$V_{in} = V\left(Q_{in}, S_n \right) \tag{1}$$

where Q_{in} is a vector of the attribute values for site i as viewed by recreationist n and S_n is a vector of characteristics of the decision maker n. The set of recreation sites available can be denoted by C and the constraints faced by an individual recreationist n determine his or her choice set, C_n, which may include all the sites in C or only a subset of these sites.

Site i will be chosen by the recreationist only if

$$V_{in} > V_{jn}, \qquad \text{all } j \neq i,\ i,j \in C_n. \tag{2}$$

The next step in the development of a discrete choice model of recreation demand is to introduce a probabilistic component to the utility function. The probabilistic component allows the researcher to acknowledge in the modeling process, problems which are often

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[13]See Bockstael et al. (1984) for a detailed discussion.

[14]The model as presented is adapted from Ben Akiva and Lerman (1985). Additional references are cited in the text where appropriate.

encountered when modeling human behavior. The probabilistic mechanism can be used to capture the effects of unobserved variation among recreationists and unobserved attributes of alternative recreation sites. The recreationist is always assumed to select the recreation site with the highest utility. However, the utility derived by the recreationist from visiting any one recreation site is not known to the researcher with certainty. Utility must therefore be modeled as a random variable and the observed inconsistencies in choice behavior are assumed to be the result of observational deficiencies on the part of the researcher.

More specifically, the random utility of selecting any one recreation site can be expressed as the sum of observable and unobservable components of the total utilities. In other words,

$$V_{in} = v_{in} + \varepsilon_{in} \tag{3}$$

where v_{in} is the systematic or observable component of the utility of choosing site i and ε_{in} is the random component referred to as the disturbance.

The probability of recreationist n choosing recreation site i can be denoted as $\pi_n(i)$. The probability that site i will be chosen is equal to the probability that the utility of choosing site i, V_{in}, is greater than or equal to the utilities of choosing all other sites in the choice set which can be expressed as

$$\pi_n(i) = \Pr\left[v_{in} + \varepsilon_{in} \geq v_{jn} + \varepsilon_{jn} \text{ , all } j \in C_n \right] \tag{4}$$

Certain assumptions are required to derive a specific discrete choice random utility model. The observable components of utility, v_{in} and v_{jn} are functions which are assumed to be deterministic. The ε_{in} and ε_{jn} terms may also be functions but they are random from the observational perspective of the researcher. It is necessary to specify some functional form for the systematic component of the utility function. There is often a trade off between selecting a functional form with convenient computational properties and one which is based on *a priori* knowledge about how selected variables will affect utility. Most researchers have specified linear utility functions of the form

$$V_{in} = \beta_1 X_{in1} + \beta_2 X_{in2} + \beta_3 X_{in3} + \beta_K X_{inK} , \tag{5}$$

where the X_{ink} are either measures of site quality, Q_{in}, or individual characteristics, $S_{n,}$ and the βs are unknown parameters. The mean of the disturbance terms is assumed to be zero and making different assumptions about the distributions of the disturbance terms leads to the development of different discrete choice models.

The multinomial logit model arises from the assumption that the disturbances, ε_{in}, are type I extreme value distributed[15]. In this case, $\pi_n(i)$ is determined by

$$\pi_n(i) = \frac{e^{V_{in}}}{\sum_{j \in C_n} e^{V_{jn}}} \text{ for } j = 1,\ldots,J. \tag{6}$$

The assumption that the disturbances are independent and identically distributed represents an important restriction in the multinomial logit model. The assumption requires that the sources of errors contributing to the disturbances must do so in a way that the disturbances are independent. In cases where alternatives are very similar in their observable attributes it is plausible that they are

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[15]The definitive reference concerning the development and derivation of multinomial logit models is Domencich and McFadden (1975).

also similar in their unobservable attributes. If this is the case, the multinomial logit model could lead to incorrect choice predictions. This aspect of the multinomial logit model has been referred to as the independence from irrelevant alternatives property (IIA). This property requires that for a specific individual the ratio of choice probabilities of any two alternatives is unaffected by the systematic utilities of any of the other alternatives[16]. For the multinomial logit model this can be illustrated as

$$\frac{\pi_n(i)}{\pi_n(l)} = \frac{e^{V_{in}} \Big/ \sum_{j\in C_n} e^{V_{jn}}}{e^{V_{ln}} \Big/ \sum_{j\in C_n} e^{V_{jn}}} = \frac{e^{V_{in}}}{e^{V_{ln}}} \qquad (7)$$

The IIA property can be considered to be a strength of the multinomial logit model since it makes the model statistically tractable and allows alternatives to be easily added or deleted from the choice set (Stynes and Peterson, 1984). This is useful when the model is to be used to predict the effect on demand from adding a new recreation site or closing an existing site. However, the IIA property may be unreasonable in cases where the choice set is not defined adequately.

The classic example of such a case is McFadden's red bus/ blue bus transportation problem. Assume that there are two modes of transportation, autos and blue buses, and that each mode captures 50 percent of a given travel market. Then assume that a new bus service is introduced which offers exactly the same service as the blue buses except that the buses are painted red. It would seem logical that the

[16]See Hensher and Johnson (1981) or Ben Akiva and Lerman (1985) for a detailed discussion of the IIA property.

new market shares would be 50, 25, and 25 percent for the auto, blue bus, and red bus respectively; no auto users will switch to buses and bus users will split evenly between the two bus modes. However, the multinomial logit model will predict that each of the three modes will capture one-third of the market because the IIA property requires that the ratio of the auto share to the blue bus share be unaffected by the introduction of the red bus service. This example illustrates the importance of choice set definition.

A simple solution to avoid possible inconsistencies resulting from the IIA property is to define the choice alternatives so that they are perceived by individual's to be distinct. This is often a difficult task. Individuals do not always face conditions of complete certainty when choosing a recreation site (Fletcher et al., 1990). For example, they may not know what quality levels will be found at a site or they may not even realize that particular sites exist. Yet, researchers must make decisions regarding which sites will be included in an analysis and which quality attributes to measure. It is difficult to know if each site in the resulting choice set will be viewed by the recreationist as a unique site.

Another way to circumvent the difficulties caused by the IIA property is to estimate a nested multinomial logit model where the disturbances are assumed to have a generalized extreme value distribution (GEV) (Maddala, 1983). In the nested multinomial logit model, the recreationist makes some choices first and then, conditional on these choices, other decisions are made. For example, an angler might first decide which species to fish and then choose a site to fish. Such a model allows correlations between choices to be incorporated into the model and has been applied to recreation demand problems by Bockstael et al. (1987) and Carson et al. (1989). In nested models, however, the choice of the nesting structure becomes a maintained hypothesis which may place restrictions on recreation behavior. To date, little research has been conducted concerning the assumptions underlying different nesting structures or on how alternate nesting structures influence model results.

Multinomial logit models can be estimated using maximum likelihood techniques. For illustrative purposes, let N denote the sample size and define

$$y_{in} = \begin{cases} 1 & \text{if individual } n \text{ chose alternative } i, \\ 0 & \text{otherwise.} \end{cases}$$

The likelihood function for a general multinomial choice model is

$$\mathcal{L}^{*} = \prod_{n=1}^{N} \prod_{i \in C_n} \pi_n(i)^{y_{in}} , \tag{8}$$

where $\pi_n(i)$ is as defined in (6) above. Taking the log of (8) yields the log likelihood function

$$\mathcal{L} = \sum_{n=1}^{N} \sum_{i \in C_n} y_{in} \left(\beta' x_{in} - \ln \sum_{j \in C_n} e^{\beta' x_{jn}} \right). \tag{9}$$

The maximum of $\mathcal{L}$ can be found by differentiating (9) with respect to each of the βs and setting the partial derivatives equal to zero. These first order conditions can be expressed as

$$\frac{\delta \mathcal{L}}{\delta \beta_k} = \sum_{n=1}^{N} \sum_{i \in C_n} y_{in} \left(x_{ink} - \frac{\sum_{j \in C_n} e^{\beta' x_{jn}} x_{jnk}}{\sum_{j \in C_n} e^{\beta' x_{jn}}} \right) = 0, \tag{10}$$

$$\text{for } k = 1, \ldots, K.$$

Thus, to find the maximum likelihood estimate, a system of K nonlinear equations in K unknowns must be solved. If the likelihood function is globally concave then a solution to the first order conditions will be unique[17]. The maximum likelihood estimates are consistent, asymptotically efficient, and asymptotically normal. The parameter estimates can be found using a nonlinear algorithm such as the Newton-Raphson method or the Davidson-Fletcher-Powell method[18]. Programs such as GAUSS and LIMDEP have built in multinomial logit algorithms.

C. Welfare Theory and Benefit Measurement

Economists define recreation benefits in terms of the area under the demand or inverse demand curve for the recreation site. In principle, benefits are measured by the area under the appropriate Hicks-compensated demand curve for the compensating variation or equivalent variation definition of benefits. As the previous sections have shown, these demand curves exist even for nonmarketed goods such as the services provided by recreation sites. This section is concerned with the measurement of benefits from these demand models.

A basic model of individual preference and demand which incorporates environmental quality as an argument of the utility function can be outlined[19]. Assume that an individual's utility is a

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[17] A sufficient condition for global concavity of the log likelihood function is that the matrix of second derivatives is negative semidefinite for all values of β (Ben Akiva and Lerman, 1985).

[18] See Ben Akiva and Lerman (1985) or McFadden (1973) for a formal description of various nonlinear optimization algorithms.

[19] A more thorough treatment of individual preference and demand theory can be found in Varian (1978) or other advanced microeconomic textbooks.

function of purchased goods, X, and the level of environmental quality, Q. Purchased goods may include trips to recreation sites. The appearance of Q in the individual's utility function means that the individual perceives the effects of changes in environmental quality. Tastes and preferences are given and do not change. The individual faces a set of given prices, P, for the purchased goods and an exogenously determined level of environmental quality. The vector of prices, P, includes travel costs to any recreation sites visited by an individual. The individual chooses quantities of the private goods so as to maximize utility given the constraints of prices, money income, Y, and the level of quality. Using functional notation, this is expressed as

$$\max_{X} U = U\left(X;\ Q \right); \qquad X = x_1,\ldots,x_i,\ldots,x_n \quad P = p_1,\ldots,p_i,\ldots,p_n$$

subject to

$$\sum_{i=1}^{n} p_i x_i \le Y \tag{1}$$

The solution to this problem provides a set of ordinary demand functions expressed as

$$x_i = x_i\left(P,\ Q,\ Y \right). \tag{2}$$

Substituting the ordinary demand functions back into the utility function provides the indirect utility function

$$U = V\left(P,\ Q,\ Y \right) \tag{3}$$

where utility is expressed as a function of prices, environmental quality and income.

The indirect utility function, (3), can be inverted to reveal the expenditure function. The expenditure function describes the minimum money expenditure necessary to achieve a specified utility level, given the prevailing prices. The expenditure function is useful in defining measures of welfare change. The expenditure function can also be determined by considering the dual to the utility maximization problem presented above. Assume that the solution to (1) is U_0 then, the dual to the utility maximization problem concerns minimizing expenditures

$$\sum_{i=1}^{n} p_i x_i$$

subject to

$$U\left(X, Q \right) \geq U_0. \tag{4}$$

The solution to this problem gives the expenditure function

$$Y = E\left(P, Q, U_0 \right). \tag{5}$$

The derivative of the expenditure function with respect to any price gives the Hicks-compensated demand function for that good (Freeman, 1979). This can be expressed as,

$$\partial E / \partial p_i = x_i^* = x_i^*\left(P, Q, U_0 \right). \tag{6}$$

Similarly the derivative of the expenditure function with respect to Q, along with a sign change, gives the Hicks-compensated inverse demand function or marginal willingness to pay for Q (Freeman, 1979). This is expressed as

$$- \partial E / \partial Q = w_i^* = w_i^*\left(P, Q, U_0 \right). \tag{7}$$

The Hicks-compensated demand functions show the quantities and qualities consumed at various prices assuming that income is adjusted (compensated), so that utility is held constant at U_0. The ordinary demand curves and the Hicks-compensated demand curves can be used to define three alternative measures of welfare change. A measure of welfare change derived from Hicks-compensated demand curves is either a compensating variation (CV) or equivalent variation (EV) measure of welfare change depending on the level of utility at which the change is evaluated. A third measure of welfare change is the ordinary consumer's surplus. Using the utility maximization problem described in this section these measures of welfare change are discussed below taking first the case of a price change and then a change in environmental quality[20].

1. **Price Changes and Continuous Choices**

A change in the price of one good, say x_1, from p_1' to p_1'' will cause utility to change from U' to U''. The expenditure function can be used to provide an expression for the EV and CV measures of welfare change. The EV is the amount an individual's income must change, in the absence of the price change, to enable the individual to realize the same level of utility s/he would have with the change in price. In terms of the expenditure function this can be expressed as

$$EV = E\left(P',\ Q,\ U'' \right) - E\left(P'',\ Q,\ U'' \right). \tag{8}$$

There is a Hicks-compensated demand curve for the good x_1 which is

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[20]For a detailed discussion and rigorous definition of the consumer surplus, compensating variation, and equivalent variation measures of welfare change in the case of continuous goods see Just et al. (1982) or Boadway and Bruce (1984). Small and Rosen (1981), Hanemann (1982, 1984), and Hau (1983) address welfare measurement in discrete choice models.

associated with the utility level U''. The EV is measured by the area under this demand curve between the two prices. This is illustrated in Figure 1 and is expressed by

$$EV = \int_{p_1'}^{p_1''} x_1^*\left(P,\ Q,\ U'' \right) dp_1. \qquad (9)$$

The compensating variation is the offsetting change in income, in the presence of the price change, which would leave the individual at the same level of utility as before the price change. The CV is defined by

$$CV = E\left(P',\ Q,\ U' \right) - E\left(P'',\ Q,\ U' \right). \qquad (10)$$

There is a Hicks-compensated demand curve which is associated with the original utility level, U'. The CV can be calculated from the area between the two price lines bounded by the demand curve associated with U', or

$$CV = \int_{p_1'}^{p_1''} x_1^*\left(P,\ Q,\ U' \right) dp_1. \qquad (11)$$

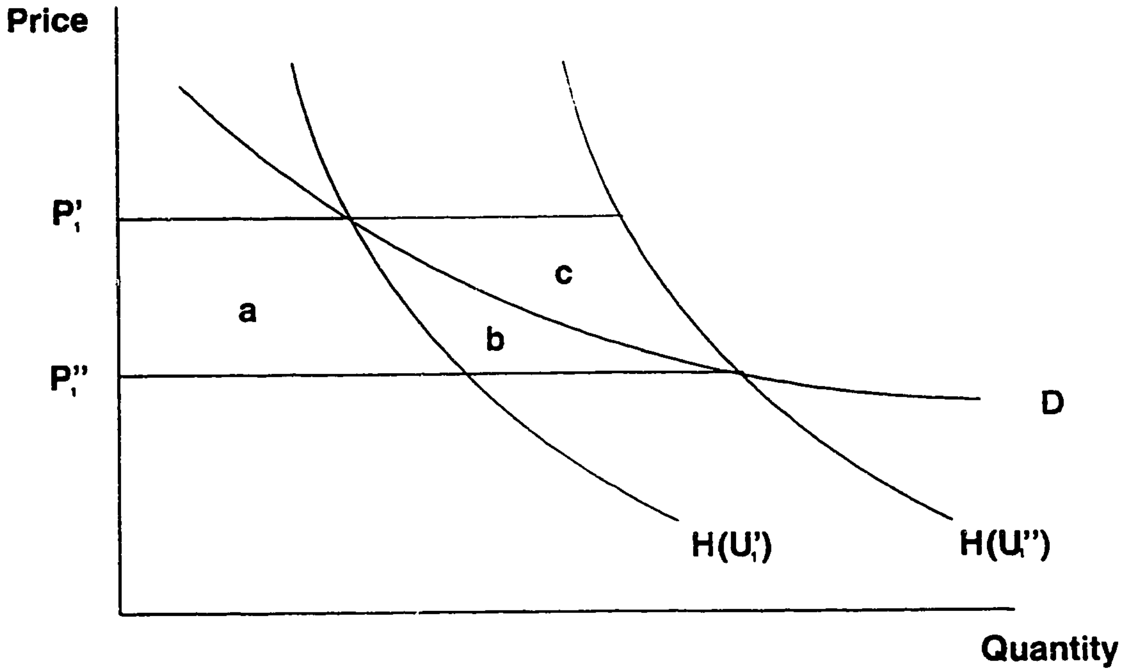
The CV for a price decrease is illustrated in Figure 1.

Ordinary consumer's surplus (CS) is defined as the area between the two price lines bounded by the ordinary (Marshallian) demand curve. This can be written as

$$CS = \int_{p_1'}^{p_1''} x_1\left(P,\ Q,\ Y \right) dp_1 \qquad (12)$$

and is also illustrated in Figure 1.

If the individual direct or indirect utility functions are known, any of the three measures of welfare change can be calculated. In most empirical applications researchers use the demand functions as a starting point. If the data allows for the derivation of the Hicks-compensated demand functions then the EV and CV of a price



D = Marshallian demand curve
H(U'1); H(U''1) = Hicks-compensated demand curves
Consumer surplus = a+b
Compensating Variation = a
Equivalent Variation = a+b+c

Figure 1 : Comparison of Alternative Welfare Measures for a Price Decrease

change can be calculated. Using the CV or EV measure of a welfare change is preferable to the CS measure because these measures are based on the individual's utility function. However, one of the main problems with using the CV or EV measure of welfare change is that the Hicks-compensated demand curves cannot usually be derived from observable market data[21]. Demand data is more often amenable to

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[21]A complete system of demand functions which satisfy integrability

calculating ordinary demand curves and the CS measure of a welfare change is the most readily attainable. In most cases the three measures of welfare change will yield different values but, Willig (1976) has shown that in many situations the CS will be a close approximation to either the CV or EV.

Using results obtained from the traditional travel cost models or the hedonic travel cost model the welfare measures presented above can be used to determine changes in individual welfare. These recreation demand models make the assumption that the consumption or use of recreation sites is of a continuous nature. In the case of discrete choices, an alternative approach is required.

2. Price Changes and Discrete Choices

In the case of discrete choices, the levels of prices, environmental quality, and income may lead to corner solutions where a recreation site is not visited at all. In this case, the derivative of the expenditure function, (5), with respect to price or quality may be undefined. Small and Rosen (1981) have provided a welfare measure which can be used in the discrete choice case. As in the continuous goods case presented above the compensating variation measure of a welfare change resulting from a change in the price of x_1 can be expressed as

$$CV = \int_{P_1'}^{P_1''} x_1^*\left(P, Q, U_0' \right) dp_1 . \tag{13}$$

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conditions must be estimated in sufficient detail to permit derivation of the compensated demand functions for specific commodities. See Freeman (1979).

If x_1 represents a recreation site which is currently being visited by the recreationist, a change in the costs of visiting the site will affect the individual by the amount $x_1^* dp$. If the site is not visited the change in welfare will be zero since $x_1^* = 0$ in this case. In the discrete choice case, the compensated individual demand function, x_1^*, can be written as

$$x_1^* = \delta_1\left(P,\ Q,\ U_0 \right)\ x_1^*\left(P,\ Q,\ U_0 \right) \tag{14}$$

where δ_1 is a discrete choice index which corresponds to 1 if recreation site x_1 is visited and 0 otherwise. The compensating variation is expressed as

$$CV = \int_{p_1'}^{p_1''} \delta_1\left(P,\ Q,\ U_0 \right)\ x_1^*\left(P,\ Q,\ U_0' \right)\ dp_1 . \tag{15}$$

Using a random utility formulation of a discrete choice model, a researcher will not know with certainty whether or not a recreationist, n, will visit the recreation site x_1. A probability, $\pi_n(1)$, that the site will be visited is all that is known and the discrete choi:e index, δ_1, is replaced with this probability as in

$$CV = \int_{p_1'}^{p_1''} \pi_n(1)\ x_1^*\left(P,\ Q,\ U_0' \right)\ dp_1 \tag{16}$$

Small and Rosen (1981) show that by specifying functional forms for the indirect utility functions, choosing a specific joint probability distribution function for the disturbance terms, and assuming no income effects the welfare change (WC) resulting from a price change can be computed by

$$WC = -\frac{1}{\mu} \int_{V_{1p'}}^{V_{1p''}} \pi_n(1)\ dV_1 , \tag{17}$$

Using recreation site choice as an example, $V_{1p'}$ and $V_{1p''}$ would be the indirect utilities derived from visiting site 1 before and after the price change, μ is the marginal utility of income or the coefficient on the travel cost parameter,[22] and $\pi_n(1)$ is the probability of individual n visiting site 1 where $\pi_n(1)$ is a function of $V_1, V_2, \ldots V_j$. For the multinomial logit model the choice probability would be given by

$$\pi_n(1) = \frac{e^{V_{1n}}}{\sum_{j \in C_n} e^{V_{jn}}} \tag{18}$$

Substituting this probability into the previous equation, the individual's welfare change for the logit model can be calculated as

$$WC = -\frac{1}{\mu}\left[\ln\left(\sum_j \exp\,(V_j)\right)\right]\Bigg|_{p_1'}^{p_1''} \tag{19}$$

3. **Environmental Quality Changes and Continuous Choices**

Freeman (1979), by assuming conditions of weak complementarity, provided a theoretical justification for measuring benefits of environmental quality changes from demand functions. The conditions of weak complementarity were first described by Mäler (1974). Applied to a recreation site choice problem, the conditions stipulate that if environmental quality at a recreation site and a market good (travel to the site) have some form of complementary relationship then when the quantity demanded of the market good is zero a change in quality at the recreation site will not affect the individual. More formally,

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[22]See Hanemann (1982) for a detailed explanation.

weak complementarity can be presented by defining a utility function, U, in terms of commodities $x_1, \ldots x_N$ and a characteristic of one good, Q, where Q is a weak complement of x_1. The weak complementarity condition can be expressed as

$$\delta U(x_1, x_2, \ldots, x_N, Q) \Big/ \delta Q \Big|_{x_1=0} = 0 \qquad \text{for all } x_n,\ n = 1, \ldots N.$$

The weak complementarity condition permits the estimation of changes in welfare resulting from a change in environmental quality using knowledge of the demand for the market good.

As in the case of a price change, the CV and EV are exact measures of welfare change resulting from a change in environmental quality. As shown above, differentiating the expenditure function (4) with respect to Q gives

$$- \partial E / \partial Q = w_1^* = w_1^* \left(P, Q, U_0 \right). \tag{20}$$

which is the compensated inverse demand function or marginal willingness to pay for Q. The EV is the area under the compensated inverse demand curve for Q associated with the new level of U and bounded by the two levels of Q. This is written as

$$EV = \int_{Q'}^{Q''} w^* \left(P, Q, U'' \right) dQ . \tag{21}$$

The CV is similarly defined with reference to the initial utility level, that is,

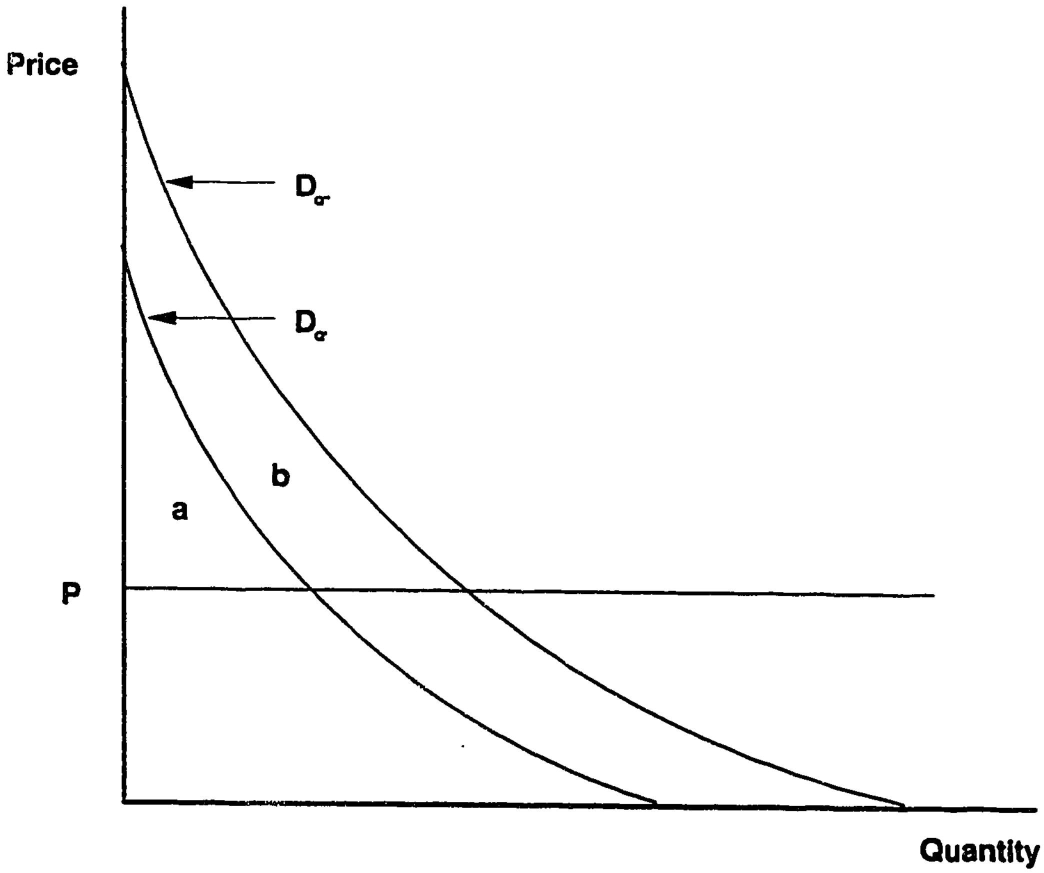
$$CV = \int_{Q'}^{Q''} w^* \left(P, Q, U' \right) dQ . \tag{22}$$

Finally, the ordinary consumer surplus measure is the area under the uncompensated inverse demand curve, or

$$CS = \int_{Q'}^{Q''} w \left(P, Q, M \right) dQ , \tag{23}$$

where w is the ordinary inverse demand curve for Q.

A simple example depicting measurement of a welfare change resulting from an environmental quality improvement is presented in Figure 2.



D_Q = demand curve with original environmental quality

$D_{Q'}$ = demand curve with improved environmental quality

Figure 2 : Welfare Measurement of an Improvement in Environmental Quality

If D_Q, and $D_{Q'}$, are Marshallian demand curves, then the consumer surplus before the quality change is measured by area a and after the quality change by area a+b. The net effect or benefit derived from the improvement in quality is measured by area **b**. If $D_{Q'}$ and $D_{Q''}$ are Hicks-compensated demand curves then area **b** is an exact measure of welfare change resulting from the change in quality.

4. Environmental Quality Changes and Discrete Choices

In addition to developing a welfare measure for price changes in a discrete choice framework, Small and Rosen (1981) also derived a welfare measure for quality changes in a discrete choice framework. As with the welfare measure developed for price changes, Small and Rosen base their analysis on the expenditure function and by making some fairly strong assumptions about the structure of consumer preferences they develop a welfare measure for quality changes. Hanemann (1982, 1984) has since extended this analysis and demonstrated how a similar welfare measure for quality changes can be developed by relaxing some of Small and Rosen's more restricting assumptions.

Hanemann (1982, 1984) bases his analyses on the unconditional indirect utility function. The unconditional indirect utility function measures the individual's utility level with given prices, quality attributes and income, therefore, it can be used to construct measures of welfare change resulting from a change in prices or quality. Assuming there is one quality attribute and it changes from Q' to Q'' an alternate way of expressing the CV of this change is

$$V\left(P',\ Q'',Y - CV \right) = V\left(P',\ Q',Y \right). \tag{24}$$

This expression can be used to define the CV of a price and/or quality change for both continuous and discrete choices. Since individual preferences in a discrete choice framework are partially unobservable, the analysis for discrete choices is based on the expectation of the individual's unconditional indirect utility function,

$$V\ (P,\ Q,\ Y) \cong E\ [V\ (P,\ Q,\ Y;\ \varepsilon)] \tag{25}$$

If the discrete goods are sufficiently unimportant that income effects from quality changes are negligible then the compensated demand function will be approximated by the ordinary demand function. If the multinomial logit form of the random utility model is chosen, the formula for the CV of the quality change is

$$CV = -\frac{1}{\mu}\left[\ \ln\left(\sum_j \exp\ (V_j)\right)\right]\Bigg|_{Q'}^{Q''} \tag{26}$$

D. **Summary**

A major emphasis in this study is to develop a methodology which can be used to accurately measure recreation benefits resulting from environmental quality changes. It is important that the methodology be theoretically acceptable and empirically tractable. This chapter has outlined the theory underlying recreation demand models and their estimation. Basic tenets of welfare theory which allow benefit estimates to be calculated from model results have also been presented. This discussion indicates that models of individual behavior which can be analyzed using welfare theory provide the preferred means for assessing benefits.

Traditional travel cost models which examine a single site cannot be used to evaluate quality changes because variation in quality at the site is not sufficient to determine individuals' responsiveness to quality changes. In addition, a single site model does not recognize that individuals often choose a recreation site from a choice set containing more than one site.

Adaptations of the traditional travel cost model to multiple site models have the potential for incorporating quality variation and site substitution in the modeling process. The system of demands approach captures site substitution but fails to address site quality. The generalized travel cost model incorporates site quality but often ignores site substitution possibilities. Also, these two models fail to incorporate one basic aspect of recreation demand. In most cases, individuals have access to a number of sites and may visit more than one during a recreation season. However, individuals will probably not visit all sites. This leads to a corner solution problem in traditional demand analysis.

The hedonic travel cost approach models individuals' demands for various site characteristics rather than specific sites. If quality at one site changes then the hedonic prices for the quality characteristics would change but, it has not been shown how the original model could be used to predict the new prices (Bockstael et al., 1984). Also, the hedonic price functions do not adequately capture individual recreation behavior. Predictions concerning how quality changes will affect an individual's site choice or desire to participate in the recreation activity have not been attempted with the hedonic travel cost approach.

The discrete choice model of recreation behavior offers a promising avenue of research for recreation demand modeling. As with the other recreation demand models, the discrete choice approach has its shortcomings. The IIA assumption may be restrictive in many practical applications. One strength of the discrete choice approach, however, is that the model is developed explicitly from utility theory. Furthermore, the discrete choice model has the potential to incorporate many different aspects of individual behavior. The model recognizes that some individuals will visit more than one recreation site but not all the sites. Additionally, it is possible to include the total number of trips taken by individuals to each site. While discrete choice models have the potential to incorporate these aspects of recreation demand, very few researchers have attempted to estimate such elaborate models. As the next chapter will illustrate, estimation of a discrete choice model for a specific recreation demand problem such as Bighorn sheep hunting in Alberta requires the appropriate data. It is often the case that data collection lags behind theoretical advancements in recreation demand modeling.

III. QUALITY MEASURES AND DATA REQUIREMENTS

A. Introduction

If recreation demand models and data used to estimate these models were exact representations of human behavior then, estimation of demand for recreation sites and calculation of recreation benefits would be greatly simplified. As the last chapter illustrated, even advanced recreation demand models such as the discrete choice model do not completely capture all aspects of recreation behavior. This problem is compounded by the fact that data requirements can not always be met. This chapter discusses issues surrounding the collection of data for use in estimating a discrete choice model and presents a description of the variables which will be used to estimate a discrete choice model of Bighorn sheep hunting in Alberta.

Data used to estimate the effects of environmental quality changes on recreation activities are frequently collected using surveys. In the past, some common procedures in data collection involved surveying users at recreation sites or sending out mail surveys to users at the end of the recreation season. Recreationists were asked to provide information on standard socioeconomic variables such as age, income and education. These early surveys were not designed for the purpose of estimating recreation benefits or changes in demand at these sites. While providing a wealth of information on participants' socioeconomic characteristics these types of surveys are often lacking information required to calculate travel distance and costs. Travel costs to sites are crucial for estimating recreation benefits or changes in site demand.

Over the past decade, numerous surveys have been administered to recreationists for the specific purpose of collecting information which could be used to estimate recreation demand models. It is now recognized that the environmental quality at the site is an important factor in determining the demand for a specific site. Without data that contain variation in site quality it is not possible to estimate models which predict how site demand will be affected by environmental quality changes. It is rare, however, that data on environmental quality have been collected in association with a participant survey[23]. Fortunately, environmental quality data have often been collected for other purposes and these data can be used with recreation participant surveys to estimate recreation demand models.

Even though environmental quality data exists, it cannot be assumed that the available measures of environmental quality will be consistent with the goal of estimating a recreation demand model. There are many difficulties involved in measuring environmental quality and in incorporating information about environmental quality into an economic model. Environmental quality is often examined using scientific techniques which are designed to measure particular quality attributes (Bockstael et al., 1984). Examples of the measured attributes might be the bacteria levels in a water body or the number of developed campsites at a recreation area. These types of quality measures can be used as separate variables in a recreation demand model or they can be combined into an overall index of environmental

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[23]Recently, several studies have been initiated which are collecting quality data in conjunction with user surveys (Bockstael et al., 1985; Carson et al., 1989).

quality at a particular site. These measures are often referred to as objective measures because by following specified guidelines they can be determined consistently at various sites.

Social scientists recognize that there might be a difference between environmental quality as indicated by the objective measures and individuals' perceptions of environmental quality. Bockstael et al. (1984, pg.199) outline the potential problem resulting from the above observation as it relates to water quality. "...Water quality policy is directed toward changing objective measures whereas benefits from the policy are argued to arise from changes in perceptions. If there is an inconsistency between objective measures and perceptions, then there is a major obstacle to valuing the benefits from "improved" water quality. It is possible that improvements in water quality by objective standards may not be perceived by individuals. Individuals not perceiving the improvement will not alter their behavior, and economists using indirect market methods to measure the benefits will not detect any change."

The statement above indicates the importance of selecting objective measures of environmental quality variables which have a high correlation with individual perceptions of environmental quality. In the case of water quality, objective measures have been used successfully in recreation demand models (Bockstael et al., 1984). They have been statistically significant factors in determining the demand for water based recreation. While much more research is needed in this area, particularly research into perceptions of environmental quality other than water quality, the successes of earlier research would tend to support the continuing use of objective measures of environmental quality in recreation demand models.

The data used in this study are from a number of sources. Data on individual hunters are from a survey conducted in Alberta during 1981 (Adamowicz, 1983). This study also utilizes environmental quality data from the 1981 survey. Other environmental quality data were solicited from the Alberta Fish and Wildlife Division, the agency responsible for wildlife management in Alberta. The remainder of this chapter provides a description of these data sources and a discussion of variables used in this study.

B. Hunter Data

The primary source of data relating information on individual hunters is a 1981 study of big game hunting in the Eastern slopes region of Alberta[24]. This study provides information on hunters' socioeconomic characteristics such as household income, age, and education. It also provides information on place of residence, hunting site choices, and number of hunting trips associated with individual hunters for the 1981 hunting season.

A subset of data containing socioeconomic and trip information for resident trophy Bighorn sheep hunters was extracted from the main data set. A total of 623 trophy Bighorn sheep licence holders responded to the 1981 survey. From this group, a usable set of observations was derived for this analysis. Respondents who took at least one trophy Bighorn sheep hunting trip during the 1981 season were selected[25].

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[24]See Adamowicz (1983) for a detailed description of the study design.

[25]While all selected respondents held trophy sheep licences not all

Observations containing missing values were eliminated. This resulted in 227 observations of resident sheep hunters who took a total of 423 sheep hunting trips to 27 different wildlife management units (WMUs).

1. Hunter Characteristics

Adamowicz (1983) provides a detailed summary and description of statistics relating to sheep hunters used in this study. Table 1 presents some of the socioeconomic characteristics of the sheep hunters.

Table 1: 1981 Trophy Sheep Hunter Characteristics

	Mean	S.D.
Age	35.02	(10.90)
Sex (percent male)	98.6	
Income (median)	31123	
Education (years)	12.70	(2.77)
Big Game Experience (years)	17.68	(11.20)

Comparison of these statistics with those from other big game hunters revealed that sheep hunters had characteristics very similar to other hunters in the 1981 study (Adamowicz, 1983). When compared to other ungulate hunters, sheep hunters had slightly higher levels of income and education and they had more years of big game hunting experience. As was the case with hunters of all other species examined in the 1981 study, nearly all of the sheep hunters were male.

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licences holders took sheep hunting trips. These respondents were eliminated from the analysis. In effect, this results in a truncated sample. Heckman (1976) has developed a procedure which can be used to correct for this problem. While the problem is acknowledged, it was beyond the scope of this study to carry out such an analysis.

2. Hunting Activity

While the socioeconomic characteristics of all big game hunters were found to be similar, hunting activity varied depending on the species sought. Sheep hunters were found to have intense hunting activity levels measured in terms of days hunted, distance travelled to hunt, and number of hunting trips taken. While not all hunting trips were limited strictly to sheep hunting, the data serve to highlight the uniqueness of sheep hunters' activities and reinforce the idea that the sheep hunting experience may be quite responsive to changes in site quality.

The sheep hunters used in this analysis took an average of 1.86 sheep hunting trips to 27 different WMUs during the 1981 season. Hunters took sheep hunting trips to almost all WMUs where sheep hunting was legal in 1981[26]. Table 2 presents the number of hunting trips to each WMU and Figure 3 indicates the location of these WMUs in Alberta's Eastern slopes region. These figures reflect a breakdown of trips to administrative units (WMUs). This breakdown does not necessarily correspond to distinct Bighorn sheep hunting sites. Hunting sites will be described in detail in the next chapter.

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[26]The WMUs not visited by the hunters used in this analysis were 328, 429, 446, 414, and 417. In the original sample of 623 respondents hunters did take sheep hunting trips to these areas but the observations were eliminated because of missing values. As these areas lie on the fringe of the Eastern slopes and sheep populations are concentrated closer to the mountains very few trips were made to the WMUs not represented in the analysis.

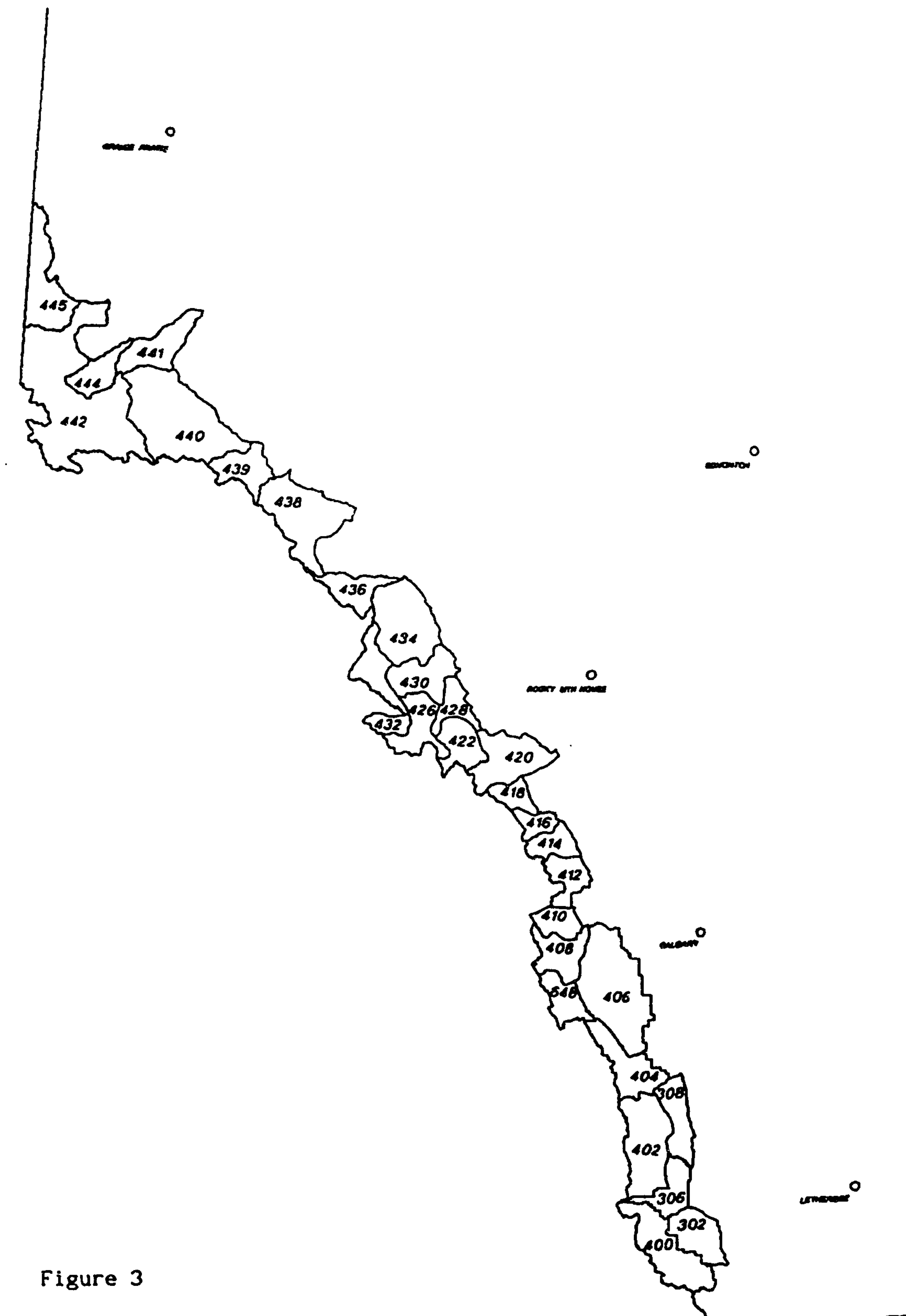

Figure 3

Wildlife Management Units

Table 2: Hunting Trips to Wildlife Management Units

WMU	No. of Trips	WMU	No. of Trips
302	9	426	4
306	1	428	1
308	2	430	7
400	85	432	6
402	85	434	6
404	32	436	3
406	33	438	11
408	43	439	1
410	21	440	9
412	7	441	1
416	11	442	11
418	7	444	1
420	13	445	4
422	9		

C. Site Quality Data

Before collecting site quality data, literature in the recreation and leisure research field was reviewed in an attempt to determine dimensions of site quality for Bighorn sheep hunting. Examination of the literature revealed that while no research has been conducted specifically on sheep hunting, some work has been done on big game hunting in general. This literature guided efforts to select appropriate site quality variables for sheep hunting.

One of the most obvious indicators of site quality for hunting is the population of the desired species in the hunting area. Animal populations are important indicators of site quality since research has shown that seeing, shooting, and bagging game are very important to big game hunters. Surveys done by researchers show that these variables are the strongest predictors of hunters' overall satisfaction with a hunting trip (Heberlein and Laybourne, 1978; Donnelly and Vaske, 1981; Vaske et al., 1982). It is important to note that the harvesting of an animal is not necessarily important but rather, hunters want to know that there is at least a chance of viewing, shooting, and possibly bagging game. Therefore, sheep populations are a very important measure of the quality of a site for sheep hunting.

While bagging an animal may not always be the most important aspect of hunting big game, it would be an error to assume that the harvesting of game is an insignificant part of the hunting experience. As mentioned above, research has shown that harvest is an important attribute of the hunting experience. Sheep hunters could be expected to return to areas where they had been successful in the past. Sheep hunters may be made aware of other's successes through conversations with fellow hunters and they may go to new hunting areas based on these discussions (Stevenson, 1989). Bighorn sheep harvest is, therefore, another variable which could be used to measure the quality of a site for sheep hunting. While wildlife management agencies may not be able to control harvest directly, they can certainly do so indirectly by changing hunting regulations.

Also related to viewing and bagging game is the issue of access to a hunting area. Game cannot be viewed or hunted if it is impossible to get to hunting areas. For most hunting experiences in Alberta this is not a large problem given the extensive network of roads cutting through agricultural and forested areas of the province. Vehicles can be driven into many areas where game can be viewed from or near the vehicle. This is the case in some sheep hunting areas while in others hunters must pack into the area with horses. Such a trip might take three or four days and only then can sheep hunting actually begin

(Stevenson, 1989).

Some researchers have examined access issues by looking at the number of miles of certain types of roads and trails in a hunting area (Langenau, 1979). In these studies, when questioned directly, hunters often state that they are against new roads and trails being put into hunting areas and that they like hunting in natural, undisturbed areas. However, when actual hunter behavior is examined, hunters seem to prefer areas with easier access over less accessible areas (Langenau,1979). This apparent contradiction might be explained in the following way. While hunting in wilderness areas likely adds enjoyment to the overall hunting experience, easier access to the area can increase chances of seeing and shooting game. Also, once an animal has been bagged, it is easier to retrieve in areas with well-developed trail and road systems. In a review of several studies on deer hunting, Langenau found that harvest was higher in areas with trails than in areas without and a large percentage of kills occurred within 600 feet of roads or trails. Access to sheep hunting areas is therefore another measure of site quality which could be related to hunter site choice.

Access to a hunting area may in part determine congestion or crowding at a particular hunting site. The easier it is to get to a site the more people will be tempted to go there. This is especially true if time available for recreation is a factor. It has long been acknowledged that congestion plays a role in site choice for many recreation activities (McConnell, 1985). For many people enjoyment from participating in an activity is diminished if too many other people are at the recreation site.

There does not seem to be a great deal of consensus in the literature on the effects of crowding on hunter behavior (Heberlein et al.,1982; Graefe et al., 1984). In part, the effects of crowding seem to depend on the main objective of the recreation activity and the nature of the activity. In the case of hunting the main objective may be to bag an animal. Depending on the species hunted this will require different tactics. As Heberlein and Laybourne (1978) noted, when deer hunting the presence of other hunters is often considered an asset because they may help move deer and increase chances of bagging game.

In comparison, Bighorn sheep are known to utilize the same winter ranges each year. In Alberta, hunting season occurs during the period when the sheep are on or near their winter ranges thus hunters will go to these known areas and scout for a legal ram. Often, even if a hunter has a good shot at one ram, s/he will pass up the chance in hopes that s/he may have a chance at the "once-in-a-lifetime" ram who is just out of gun range (Stevenson, 1989). This is the type of hunting experience where intrusion of other hunters or hikers into an area could move the game away from one hunter's carefully planned strategic location. It could be hypothesized that a high concentration of other recreationists in a sheep hunting area would not be looked upon favorably.

The foregoing discussion has provided insight into some environmental quality variables which may influence the demand for Bighorn sheep hunting at various sites in Alberta. Not all of the variables discussed can be included in the model. For example, lack of data made it difficult to determine a measure of access to hunting sites. The following sections describe the data used to measure those variables which will be included in the model.

1. Sheep Populations

Conducting inventories of wildlife populations is often a difficult task. Big game animals are spread out over large areas, many parts of which may be inaccessible to man. Many techniques have been used in an attempt to measure big game populations. In Alberta, the most common approach has been to fly aerial surveys over known big game ranges. Aerial surveys are expensive and subject to weather conditions, therefore they cannot usually be carried out in all regions each year. This means that population data for particular species are quite sporadic[27].

For this study sheep population data was required for all sheep ranges in Alberta. Examination of Alberta Fish and Wildlife records indicated that sheep population surveys had been conducted in 1971, 1973, 1975, 1978, and 1979-80. However, closer examination of this data revealed that the 1979-80 survey was the only one where the entire provincial Bighorn sheep range had been flown. In addition, the survey technique had changed throughout the earlier surveys[28]. The 1979-80 survey was the only one where the same survey technique had been used in all areas of the province. Also, as the hunter data used in this study is from the 1981 hunting season, the 1979-80 sheep

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[27]Since 1984 the Alberta Fish and Wildlife Division has been conducting harvest surveys which can be used to track wildlife populations. See Alberta Forestry, Lands and Wildlife (1985) for a discussion and example of a harvest survey.

[28]See Cook, 1987 for a discussion of survey techniques and limitations.

population data may best reflect sheep populations around that time. Table 3 presents the sheep population data as reported by WMU.

Table 3: Bighorn Sheep Population by Wildlife Management Unit (1978-79)

WMU	TOTAL SHEEP POP	TOTAL RAM POP	LEGAL RAM POP	WMU	TOTAL SHEEP POP	TOTAL RAM POP	LEGAL RAM POP
302, 400	391	65	14	426	58	15	4
				428	57	14	4
306, 308, 402	51	8	2	432	44	5	1
				434, 436	183	28	9
404	242	58	1				
406	108	34	2	438	437	148	53
408	80	26	0	439	18	5	1
410	144	27	5	440	285	56	8
412	100	35	8	441, 442	269	64	16
416	24	3	0				
418	298	67	8	444	270	49	16
420	244	66	16	445	135	27	7
422	175	41	16				

Some of the data cannot be broken down by WMU as some of the Bighorn sheep ranges extended into more than one WMU. The population survey provided data on total sheep population, total ram population and legal ram population[29]. These population figures will be combined

[29]A legal ram or trophy sheep is a bighorn sheep having at least a four-fifths horn curl. The official description used in the Big Game Regulations is "a male bighorn sheep with horns, one of which can be intercepted at both the front of the horn base and the tip of the horn by a straight line drawn along the front of the eye when viewed in profile (Alberta Forestry, Lands, and Wildlife. Summary of Big Game Regulations. 1981.).

with the hunter data to reflect specific sheep hunting sites. It is important to note that limitations of the population survey technique make it unlikely that these figures reflect exact sheep populations. However, they do provide an index of populations and allow relative comparisons between different areas of the province. For the purposes of this study this relative comparison value is extremely important[30].

2. Harvest Data

The Alberta Fish and Wildlife Division was also the source of Bighorn sheep harvest data. Since the early 1970s Trophy Bighorn sheep hunters have been required to report the location (by WMU) of any harvest of these animals. The total reported Trophy Bighorn sheep harvest between 1971 and 1980 is presented in Table 4.

Table 4: Bighorn Sheep Harvest by Wildlife Management Unit (1971-1980)

WMU	TOTAL HARVEST	WMU	TOTAL HARVEST
302	7	426	38
306	9	428	26
308	5	430	56
400	165	432	96
402	96	434	54
404	70	436	16
406	102	438	120
408	106	439	33
410	13	440	142
412	21	441	0
416	25	442	62
418	18	444	19
420	88	445	8
422	94		

[30] For wildlife management purposes the population survey would be carried out every few years and over time reliable estimates of actual sheep populations would be derived.

3. Congestion

As well as sheep hunting trips, the 1981 hunter survey provides information on the number of goat, elk and moose hunting trips taken in the Eastern slopes region during the 1981 hunting season. The trips were recorded by WMU. It is not possible to determine if these trips were taken at the same time as the sheep hunting trips, but generally speaking these hunting seasons overlap to a great extent (Alberta Fish and Wildlife Division, 1981).

The trip data for goat, sheep, elk and moose can be used to determine an index of crowding[31]. The trip data were generated from a sample of the total hunting population. Each respondent to the survey is considered to represent a portion of hunters from the total population and an estimate of the total number of hunters hunting in each WMU can be calculated[32]. The crowding index provides a means of ranking sites based on the estimated number of hunting trips made to the site. Estimates of the total number of hunting trips to each WMU are provided in Table 5.

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[31]Sheep hunting trips are included since sheep hunters, as well as hunters of other species could have an impact on the sheep hunting experience.

[32]The crowding index derived from the hunter survey data does not take into account individuals who may have been hunting species other than those identified above. Also, the index does not include information on other activities which may have been taking place in the sheep hunting areas.

Table 5: Estimate of Total Number of Hunting Trips by Wildlife Management Unit

WMU	NO. OF TRIPS	WMU	NO. OF TRIPS
302	3152	426	538
400	4831	428	16
306	1968	430	3538
308	3572	432	154
402	6940	434	290
404	1843	436	12
406	4421	438	3348
408	1766	439	23
410	2777	440	1618
412	714	441	16
418	284	442	608
420	2416	444	902
422	52	445	274

D. Summary

This chapter has examined measures of environmental quality which can be incorporated into a recreation demand model for Bighorn sheep hunting in Alberta. Included in this set of quality measures are Bighorn sheep populations, harvest and a hunter congestion index. Chapter IV will use the data described in this chapter to estimate a model of site choice for Bighorn sheep hunters.

CHAPTER IV MODEL ESTIMATION AND RESULTS

A. Introduction

The previous chapter described in detail the data to be used in estimation of the model. The estimation of a multinomial logit discrete choice model of Bighorn sheep hunting site choice is the subject of this chapter. Model estimation results will be used to determine the welfare effects of changes in environmental quality variables; to calculate the value of specific Bighorn sheep hunting sites; and to predict the change in probability of site selection for a given quality change or site closure. The purpose of estimating the model is to make operational the discrete choice model discussed in Chapter II. The data limitations discussed in Chapter III need to be addressed before the model could be used to test specific hypotheses about Bighorn sheep hunting behavior in Alberta.

Before a model of Bighorn sheep hunting demand can be estimated, an important consideration is the definition of the choice set available to hunters. In the case of Bighorn sheep hunting this involves aggregating the data presented in the last chapter into unique Bighorn sheep hunting sites. The first two sections of this chapter provide a description of the choice set and the recreation demand model. The final section of the chapter presents the results obtained from estimation of the model and from the applications of the model.

B. Hunting Site Choice Set

A choice set is made up of a set of alternatives and it is the environment of the decision makers which determines these alternatives

(Ben Akiva and Lerman, 1985). A decision maker must be aware of an alternative and find it feasible in order for the alternative to be included in the choice set. The feasibility of an alternative can be determined by such factors as physical availability, monetary resources, time constraints or informational constraints. For purposes of this study it is assumed that each alternative in the choice set described below represents a feasible alternative for all resident Bighorn sheep hunters in Alberta.

In this study the alternatives under consideration by Bighorn sheep hunters are hunting sites. All of the data collected for this study have been described in terms of WMUs. Classifying data in terms of WMUs is often useful for administrative purposes, however, WMUs do not necessarily correspond to discrete Bighorn sheep hunting sites.

After consultation with Alberta Fish and Wildlife personnel, the WMUs were aggregated into 10 Bighorn sheep hunting sites (Stevenson, 1989). The sites and corresponding WMUs are presented in Table 6. Figure 3 indicates the location of the hunting sites. Definition of the hunting sites was based on the location of known wintering ranges for Bighorn sheep as well as the need to provide alternatives which are heterogeneous in terms of their attributes. As one of the main objectives of this study is to examine the role that environmental quality plays in recreation site choice it is important to define sites that reflect a difference in quality over the attributes selected for measurement.

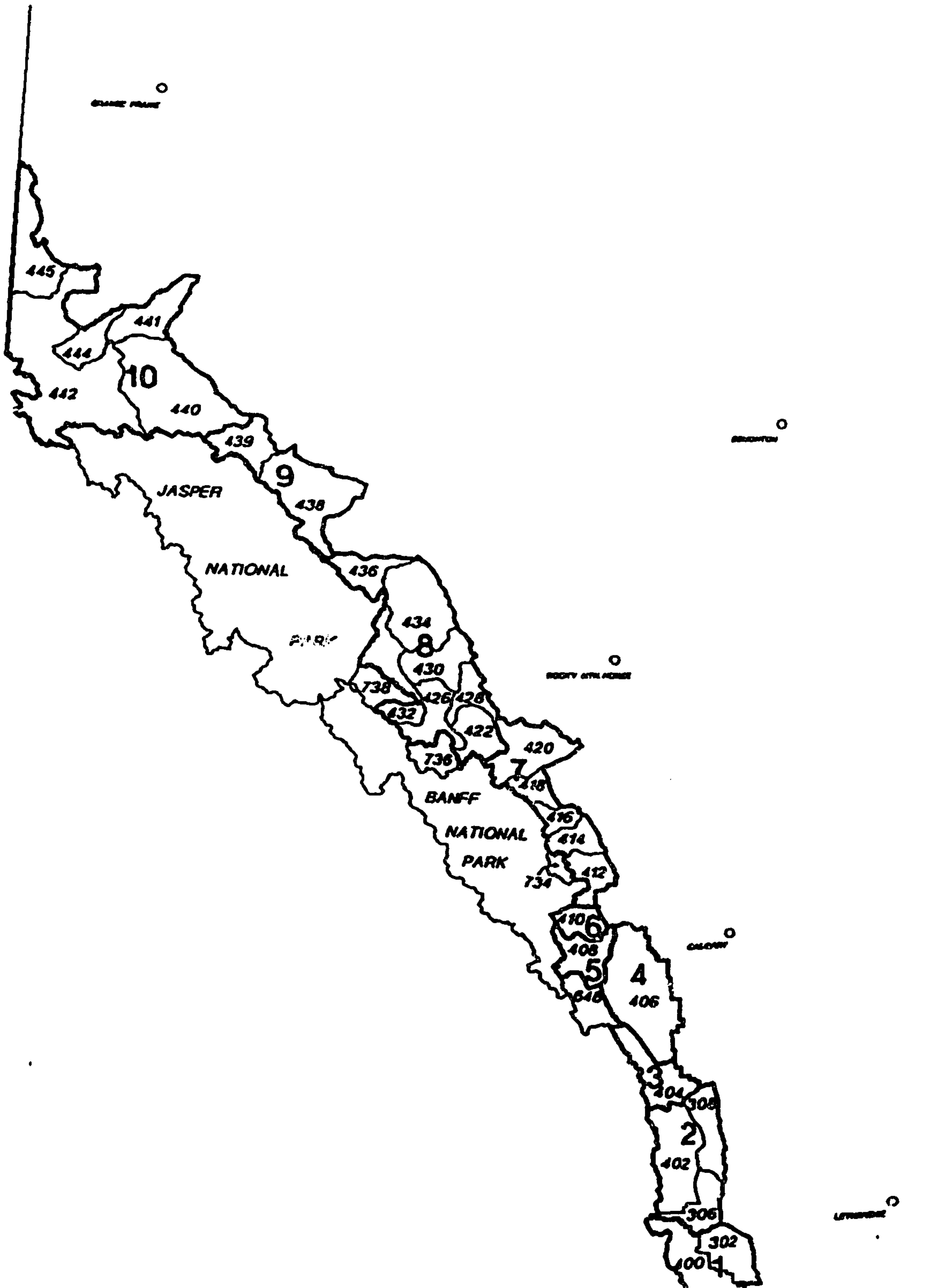

Figure 4:
Bighorn Sheep Hunting Sites

Table 6: Bighorn Sheep Hunting Sites

Site 1	WMUs	302 400
Site 2	WMUs	306 308 402
Site 3	WMU	404
Site 4	WMU	406
Site 5	WMU	408
Site 6	WMU	410
Site 7	WMUs	412 416 418 420
Site 8	WMUs	422 426 428 430 432 434 436
Site 9	WMUs	438 439
Site 10	WMUs	440 441 442 444 445

C. Specification of a Multinomial Logit Model of Bighorn Sheep Hunting

In this section, the multinomial logit model which is applicable to the discrete choice problem of choosing among Bighorn sheep hunting sites, is described. In this case study, the analytical objective is to estimate the probability of an Alberta resident Bighorn sheep hunter taking a sheep hunting trip to a particular hunting site during the season. Using the multinomial logit model outlined in chapter II and the variables described in chapter III the model used to calculate this probability can be developed.

The general model can be expressed in the following manner.

$$\pi_n(i) = \frac{e^{V_{in}}}{\sum_{j \in C_n} e^{V_{jn}}} \qquad \text{for } j = 1,\ldots,J \qquad (1)$$

where $\pi_n(i)$ is the probability that hunting site i is chosen, V_{in} is the indirect utility associated with choosing hunting site i and V_{jn} represents the indirect utility associated with choosing hunting sites j=1, ...,J.

More specifically, when the indirect utility functions are specified as linear combinations of coefficients and variables the probability that the "n"th hunter chooses the "i"th hunting site is given by

$$\pi_n(i) = \frac{e^{\beta' X_{ni}}}{\sum_{j \in C_n} e^{\beta' X_{nj}}} \qquad (2)$$

The vector of the attributes of the "i"th hunting site and the "j"th hunting site as perceived by the "n"th hunter is given by X_{ni} and X_{nj} respectively and β' represents the parameters to be estimated. A description of the variables or attributes (X_{nj}) entering individual hunter's utility functions which will be used in estimating the model defined above can now be provided.

TCST : Travel cost from each hunter's place of residence to each site j. Distances were extracted from Alberta Transportation distance charts and maps (Alberta Transportation, 1980; Alberta Transportation, 1989). When more than one route to a hunting site was feasible, the shortest distance was used in travel cost calculations. The distances for each hunter to each hunting site were multiplied by a mileage charge of 18 cents per kilometre to determine travel costs[33]. The coefficient on this variable should be negative.

TPOP : Total sheep population at each site j. Total sheep population was calculated by aggregating the WMU total sheep population data into the hunting sites as defined above. The population figures for each site were then

[33]The per kilometre charge was the private vehicle allowance used by provincial government agencies in 1981.

divided by the area of the site. The resulting population index is expressed in terms of sheep population per square kilometre. The coefficient on all population variables, including RPOP and LRPOP should be positive.

RPOP : Total ram population at each site j. Total ram population was calculated by aggregating the WMU ram population data into the defined hunting sites. The ram population figures for each site were divided by the area of the site. The resulting ram population index is expressed in terms of ram population per square kilometre.

LRPOP : Total legal ram population at each site j. This population index is expressed in terms of legal ram population per square kilometre and was calculated in the same manner as the other population indices using the WMU legal ram population data.

CNGEST: A measure of crowding conditions at each site j. This index was computed by aggregating the total number of hunting trips by WMU into the hunting sites as defined above. The trip figures for each site were then divided by the area of the site. This index of congestion is expressed in terms of the number of big game hunting trips per square kilometre. The coefficient on CNGEST is expected to be negative.

HVST : A measure of Trophy Bighorn sheep harvests at site j. This index was calculated by aggregating the WMU harvest data into the appropriate hunting site and then dividing the harvest totals for each site by the area of the site.

the harvest totals for each site by the area of the site. The harvest index is expressed in terms of total number of Bighorn sheep harvested per square kilometre. The HVST coefficient should be positive.

$CNST_j$: Alternative specific constants. For example, the variable CNST1 would be defined as 1 in the site 1 choice alternative and 0 for all other site choice alternatives. The alternative specific constants reflect the mean of $\varepsilon_{in}-\varepsilon_{jn}$, that is, the difference in the utility of alternative i from that of j when all else is equal. In the general case, as many as J - 1 constants can be included in the model.

An example of one possible specification of the systematic component of sheep hunters' utilities is provided in Table 7.

Before proceeding, it is worthwhile to note that because of the structure of the logit model, variables which do not change across alternatives cannot be included in the simple form of the multinomial logit model. These variables will cancel out during estimation since the estimated model is a function of $V_i - V_j$. Therefore, individual specific variables cannot be included in the model[34]. The model estimated below does not attempt to include socioeconomic variables.

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[34]It is possible to have the effects of socioeconomic characteristics incorporated into the model if a particular socioeconomic variable is believed to influence an alternative specific variable. The two variables could be combined into one interactive variable (Feenberg and Mills, 1980; Bockstael et al., 1984).

Table 7: Example of Multinomial Choice Model Data for One Observation

	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}	β_{12}
Site 1 utility	1	0	0	0	0	0	0	0	0	$TCST_1$	$TPOP_1$	$CNGEST_1$
Site 2 utility	0	1	0	0	0	0	0	0	0	$TCST_2$	$TPOP_2$	$CNGEST_2$
Site 3 utility	0	0	1	0	0	0	0	0	0	$TCST_3$	$TPOP_3$	$CNGEST_3$
Site 4 utility	0	0	0	1	0	0	0	0	0	$TCST_4$	$TPOP_4$	$CNGEST_4$
Site 5 utility	0	0	0	0	1	0	0	0	0	$TCST_5$	$TPOP_5$	$CNGEST_5$
Site 6 utility	0	0	0	0	0	1	0	0	0	$TCST_6$	$TPOP_6$	$CNGEST_6$
Site 7 utility	0	0	0	0	0	0	1	0	0	$TCST_7$	$TPOP_7$	$CNGEST_7$
Site 8 utility	0	0	0	0	0	0	0	1	0	$TCST_8$	$TPOP_8$	$CNGEST_8$
Site 9 utility	0	0	0	0	0	0	0	0	1	$TCST_9$	$TPOP_9$	$CNGEST_9$
Site 10 utility	0	0	0	0	0	0	0	0	0	$TCST_{10}$	$TPOP_{10}$	$CNGEST_{10}$

D. Model Estimation and Results

1. Model Estimation

The model was estimated using various combinations of the variables described above. Estimation was carried out on an IBM personal computer using the GAUSS MNLOGI2 program. Initially, attempts were made to include all alternative specific constants in the analysis. Difficulties in getting the program to converge necessitated estimating a model with selected variables[35].

[35]Most studies using multinomial logit estimation techniques have not

A number of other models using various combinations of variables were investigated. In all estimated models the TCST coefficient had the correct sign and was highly significant. Three of the variables, TPOP, RPOP, and LRPOP are related to sheep populations. A fourth variable, HVST, might also be expected to depend on sheep populations. Because of the possible correlation between these variables, only one of these variables was included in the model during each estimation[36]. Including RPOP or LRPOP in the model tended to make the sign on the CNGEST coefficient positive which was contradictory to expectations. TPOP was the population variable which performed the best. The TPOP variable was significant in almost all estimated models. In addition, the sign of the TPOP coefficient was positive as expected. The HVST variable was insignificant on all runs and altered the signs on other variables when included in the model. As noted above, the coefficient for the CNGEST variable was extremely sensitive to the inclusion of other variables.

As not all constants could be included in the model, an attempt was made to include constants for those sites which represented quality attributes which had not been incorporated into the model due to data limitations. CNST1, CNST2, and CNST3 were included in the

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included alternative specific constants. The one study which did include these constants does not mention problems getting the program to converge (Tay, 1989). However, the Tay study had a smaller choice set than that used in this study. In this study, the estimation program converged when six or fewer constants were included in the model.

[36]Subsequent tests of correlation between these variables indicated a high degree of correlation between the sheep population variables but, low or negative correlations between the HVST variable and sheep population variables (Boxall and Watson, 1990). This might indicate measurement error in the HVST variable.

model because these areas were the most accessible sites of the ten available sites. CNST10 was included because this sheep hunting area is the most inaccessible. Including these four constants represents an attempt to incorporate site accessibility in the model. CNST6 was included because this hunting area is restricted to bow hunting only for all species and the area therefore represents a unique opportunity to hunters.

2. Results and Discussion

The variables included in the final model were CNST1, CNST2, CNST3, CNST6, CNST10, TCST, TPOP, and CNGST. Table 8 presents estimated coefficients and test statistics from the final logit regression. All coefficients were significant at the 0.05 level and the signs for the TCST variable and the quality variables were as predicted. The likelihood ratio test was highly significant at the 0.01 level[37]. The likelihood ratio index is an informal goodness of fit index which measures the fraction of the initial log likelihood value explained by the model[38]. The index value for the estimated

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[37]The Likelihood Ratio test compares the log likelihood estimate with the parameters set to zero, with the log likelihood using the coefficients chosen during the maximum likelihood estimation. If $\mathcal{L}(0)$ is the zero estimate and $\mathcal{L}(\beta)$ is the maximum likelihood estimate, then $-2*(\mathcal{L}(0) - \mathcal{L}(\beta))$ is distributed chi-square with r degrees freedom (Ben Akiva and Lerman, 1985). The r degrees of freedom correspond to the number of independent variables. The null hypothesis for this test is that all the parameters are zero.

[38]The likelihood ratio index, ρ^2, is calculated using the following formula: $\rho^2 = 1 - \mathcal{L}(\beta) / \mathcal{L}(0)$ (Ben Akiva and Lerman, 1985). The statistic is sometimes compared to R^2 statistic used in regression analysis. There are many problems with this statistic and for that reason it is not wise to judge a model based on this statistic alone (Bockstael et al., 1984).

model is within the range expected when estimating models of this type (McFadden, 1973).

Table 8: Multinomial Logit Estimates of Bighorn Sheep Hunting Site Choice

Variable	Coefficient	t-Statistic
CNST1	0.7075	3.86
CNST2	2.1180	5.86
CNST3	-1.4350	-4.54
CNST6	-0.6402	-2.29
CNST10	1.2947	4.28
TCST	-65.3705	-13.97
TPOP	7.0778	4.74
CONGEST	-3.6801	-4.36

Log likelihood at convergence -701.7595
Log likelihood at zero -973.9935
Number of cases 423
Number of observations 4230
Likelihood ratio test 544.468
Likelihood ratio index 0.2795

Another method for examining the reliability of the model is to compare the distributions of actual and predicted site choices[39]. These results are presented in Table 9[40].

The estimated model predicted a trip distribution which was not significantly different from the actual distribution at the 0.20 level

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[39]The predicted distribution can be calculated by determining $\sum_{n=1}^{423} \pi_n(j)$ for sites j = 1,...,J. The predicted distribution can be compared to the actual distribution using a χ^2 test with J - 1 degrees of freedom (Ben Akiva and Lerman, 1985). Ideally, data used to test the predictive reliability of the model should be from a different source than the data used to estimate the model.

[40]The results presented in Table 9 have been prepared by Boxall and Watson (1990). Their work extended the original analysis to examine the predictive reliability of the estimated model and alternative functional forms. Results from exploring alternative functional forms will be discussed below.

Table 9: Actual and Predicted Trip Distributions

Site	Actual Trips	Predicted Trips
1	94 (17.10)*	93.95
2	88 (16.70)	87.98
3	32 (10.88)	32.04
4	33 (11.04)	38.51
5	43 (12.42)	41.30
6	21 (8.90)	20.95
7	38 (11.76)	35.16
8	36 (11.48)	24.27
9	12 (6.82)	22.79
10	26 (9.88)	26.03
* Numbers in brackets are (2xS.E.)[41]	χ^2, 9 *df* (P)	11.87 (0.220)

of significance. Ben Akiva and Lerman (1985) suggest that model specification errors may be indicated if, for any choice alternative, the predicted values deviate from observed values by more than two standard errors. Results in Table 9 suggest that this was the case for sheep hunting site 9 where the model over-estimated the number of visits to this site. This may be an indication that some characteristics of the site have not been captured in the specified model. One possible explanation of this result is that the model did not take account of nonhunting activities in the study area. Site 9 borders Jasper National Park and the town of Hinton is located within the area. Hinton and the surrounding area supports a number of logging and mining operations. As well, the area's natural amenities and close proximity to the park and major population centers make it attractive for other recreational activities such as hiking and

[41]The standard errors are approximated using the binomial distribution (Ben Akiva and Lerman, 1985).

cross-country skiing. While a congestion measure was included in the model, this measure only incorporated other hunting activity. Model specification may be improved by incorporating a more comprehensive measure of congestion.

Mendelsohn (1987) stresses the importance of exploring alternative functional forms for the utility function as the linear specification can be restrictive. Other studies of recreation demand models have shown that functional form can influence the measures of welfare change derived from the model results (Ziemer et al., 1980; Adamowicz et al., 1989). Boxall and Watson (1990) examined alternative functional forms for the model specified above and, while they did not carry out welfare calculations, their results indicated that the linear model did not differ greatly from any of the other functional forms estimated. The comparisons were carried out using the likelihood ratio tests, goodness of fit tests, and the predictive capability tests described above.

The estimated model was also examined for the IIA property. Testing for IIA involves comparisons of the model estimated with the full choice set with models estimated with subsets of alternatives. If the IIA assumption holds for the full choice set, then the model should apply to choices from a subset of alternatives. If the model is correctly specified, consistent coefficient estimates of the same subvector of parameters from a model estimated with a full choice set and from a model estimated with a restricted choice set can be obtained (Ben Akiva and Lerman, 1985). Hausman and McFadden (1984) developed a test for the null hypothesis $\beta_{FC} = \beta_{RC}$ where β_{FC} denotes the coefficients estimated from a model with a full choice set and β_{RC}

denotes the coefficients estimated from a model with a restricted choice set. The test statistic is expressed as

$$\left(\beta_{RC} - \beta_{FC}\right)'\left(\Sigma_{\beta_{RC}} - \Sigma_{\beta_{FC}}\right)^{-1}\left(\beta_{RC} - \beta_{FC}\right)$$

where $\Sigma_{\beta_{RC}}$ and $\Sigma_{\beta_{FC}}$ are the covariance matrices. This statistic is asymptotically χ^2 distributed with K degrees of freedom, where K is the dimension of β_{RC}. While this test has been referred to by other researchers in the literature (Ben Akiva and Lerman, 1985), applying it to the linear model estimated above led to negative χ^2 values. As this is not a valid result, it is possible that the test is invalid for a sample of the size used in this study[42]. However, the coefficients and standard errors from the coefficients for the estimated models can be compared. For example, coefficients from the model estimated from the full choice set can be compared to a model estimated with sites 4 and 5 removed from the choice set[43]. The coefficients and their standard errors are presented in Table 10.

Estimation of the restricted model led to sign changes on several of the coefficients. However, the standard errors on the new coefficients are quite large. It is important to note that TCST

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[42]Hausman and McFadden (1984) found some negative χ^2 values when conducting this test for IIA on models developed from small samples. They provided some suggestions for adjusting the test for small sample sizes but, these adjustments have not been attempted in this study. In the current literature, actual applications of the test are rare. Ben Akiva and Lerman (1985) provide suggestions for other means of testing for IIA. Again, most of these tests have been developed recently and have not been applied in the literature to any great extent.

[43]Similar comparisons can be made by removing other sites from the choice set. Sites 4 and 5 were chosen simply for illustrative purposes.

Table 10: Coefficient Estimates From Full and Restricted Choice Sets (Sites 4 and 5 Removed)

Variable	Full Choice Set	Restricted Choice Set
CNST1	0.707 (.183)*	-0.440 (.380)*
CNST2	2.118 (.361)	-2.974 (1.600)
CNST3	-1.435 (.316)	0.161 (.601)
CNST6	-0.640 (.279)	-0.835 (.287)
CNST10	1.295 (.302)	0.796 (.339)
TCST	-65.370 (4.681)	-64.556 (5.344)
TPOP	7.078 (1.494)	-12.328 (6.182)
CNGEST	-3.680 (.845)	2.726 (2.190

*Standard errors

proved to be very stable in terms of the sign and size of the coefficient. Similar comparisons were conducted with other restricted choice sets with similar results. These results are inconclusive although a closer examination of site definitions could be carried out if additional research into Bighorn sheep hunting site choice were undertaken.

The quality variables which performed the most consistently in the analysis were TPOP and CONGEST. It is possible that TPOP performed better than the other population variables because hunters may have a clearer sense of total sheep populations in an area. Rams are more dispersed and because of their small numbers hunters may not have knowledge of relative population levels at hunting sites. They likely use knowledge of overall sheep populations to make inferences about ram populations.

CONGEST was another significant quality variable in the model although as noted above, it proved to be sensitive to model specification. However, results indicate that crowding at sites does affect site choice. The congestion index was derived from data collected during one hunting season. It is possible that sensitivity to model specification would be reduced if the index could be recalculated using several years of hunting trip data for all wildlife species in Bighorn sheep hunting areas. At best, the CNGEST variable included in this analysis is a rough proxy for activity levels at hunting sites during sheep hunting seasons.

TCST was a highly significant variable in the model results. As noted above TCST was consistently significant and of the same sign regardless of model specification. This is important since the foundation of all recreation demand models is that travel costs can be used as a proxy for price to estimate the demand for sites.

Results from the model indicate that a hunting site would be more attractive to Bighorn sheep hunters if sheep populations were increased, if crowding was reduced and if the site was less expensive to reach. Sites restricted to bow hunting would be less attractive.

In general, sites that allow easier access to Bighorn sheep ranges would be preferred by hunters. Three sites with easy access were included in the analysis. At two of the sites, Bighorn sheep ranges are located within 10 kilometres of a primary highway and the coefficients for the variables representing these sites are positive. At the third site, while vehicle access to Bighorn sheep ranges exists, the ranges are at least 40 kilometres from the nearest highway. The coefficient for the variable representing this site is negative. These results would seem to indicate that there are many aspects to the issue of hunting site access and these will have to be examined carefully in the context of recreation demand modeling.

The coefficient on CNST10 was positive which, given the results described in the preceding paragraph, would seem to be a contradiction. CNST10 was initially included in the analysis because it represents an area where vehicle access is limited. For this reason, it might be predicted that the site would be less attractive to hunters. However, the coefficient in the model results indicates that the attributes of the site represented by CNST10 are attractive to hunters. It is possible that the CNST10 coefficient reflects site quality attributes which have not been explicitly incorporated into the model. For example, many hunters may feel that the remote, pristine wilderness of a site is an important part of the Bighorn sheep hunting experience.

3. Application of Results

The estimated model can be used to determine the welfare effects of changes in the environmental quality variables TPOP and CNGST. The value of one or all of the Bighorn sheep hunting sites can be evaluated by examining the welfare change resulting from the closure of the site in question. Also, the model can be used to predict the change in probability of site selection for a given quality change or site closure. The welfare analysis techniques described in Chapter II can be used to carry out these analyses. Examples of these calculations are provided below.

Estimates of changes in net benefits were carried out for two hypothetical changes in hunting site quality. The first scenario examined the welfare impact of increasing Bighorn sheep populations by 10 percent in all zones. Such a population increase might be brought about by disease irradication programs or restrictions on non-resident hunting. The welfare change is calculated for each individual using the formula presented in Chapter II. Evaluating this formula results in

$$WC = -\frac{1}{\mu} * \left(\ln(\sum e^{V_0}) - \ln(\sum e^{V_1}) \right)$$

v_0 represents the individual's utility given the initial situation and v_1 represents the individual's utility given the increase in sheep populations. The coefficient on the travel cost parameter represents the marginal utility of income (μ). Changes in individual welfare are summed to provide a total welfare change for the hunters included in sample.

To determine a welfare estimate for all sheep hunters in Alberta, the individual welfare impacts must be adjusted to represent the total population of sheep hunters in Alberta. During the 1980-81 sheep hunting season, 2,480 Bighorn sheep licences were sold. However, only 2306 (93 percent) of these hunters were active during the 1980-81 hunting season. Data from 227 hunters were used in this analysis, therefore, each hunter in the analysis represents roughly 10.16 active Bighorn sheep hunters. Thus, total welfare estimates from the analysis must be multiplied by 10.16 to determine the total welfare effects for all sheep hunters in Alberta.

The Bighorn sheep population change resulted in an increase of $713 in net benefits aggregated over all individual hunters included in the analysis. Adjusting this to reflect the entire population of sheep hunters, the overall welfare change is $7,244 per season.

A second scenario examined the impact of increased congestion at all hunting sites. If successful, recent efforts to attract more non-resident hunters and wildlife tourists to Alberta could increase crowding at sites. Following the same procedures that were used to determine the welfare effects of a change in sheep populations, the welfare change from an increase in congestion can be determined. A 10 percent increase in congestion at all Bighorn sheep hunting sites would reduce total benefits received by Alberta resident Bighorn sheep hunters by $8,494 each season.

The welfare impacts of a hypothetical 10 percent increase in travel costs to all hunting zones were also evaluated using the techniques described above. Such an increase in travel costs might be brought about by an increase in the price of fuel. This increase in travel costs would lead to a welfare loss of $20,413 each season.

The impacts of closing a site to Bighorn sheep hunting were also examined. This analysis can be carried out by making travel costs to a particular site sufficiently high so as to reduce visits to the site to zero. The loss in welfare associated with closing one site while all others remain open are presented in Table 11.

Table 11: Annual Welfare Losses Associated with Site Closure

Site Closed	Total Welfare Loss	Loss/Sheep Hunting Trip
1	$25,787	$6.00
2	$14,927	$3.47
3	$ 3,881	$ .90
4	$ 9,795	$2.28
5	$ 8,128	$1.89
6	$ 3,455	$ .80
7	$ 5,832	$1.36
8	$ 3,332	$ .78
9	$ 3,570	$ .83
10	$ 8,890	$2.07

Closure of site 1 would have the greatest affect on hunter welfare followed by closures of site 2, site 4 and site 10. This type of information could be important to wildlife managers in the event that site closure becomes necessary. Sites closures with the least impact on hunter welfare could be carried out first.

Finally, the model was used to predict the change in probability of site selection accompanying the changes in site quality, travel costs and site closures. The probability of any hunter, n, choosing each site is calculated by

$$\pi_n(i) = \frac{e^{V_{in}}}{\sum_{j \in C_n} e^{V_{jn}}} \qquad \text{for } j = 1, \ldots, J.$$

The mean probability of a hunter visiting a given site is determined by

$$\sum_{n=1}^{423} \pi_n(j) \Big/ 423.$$

The original site choice probabilities along with site choice probabilities for the scenarios involving changes in environmental quality variables, changes in travel costs, and closure of site 1 are presented in Table 12.

Table 12: Selected Site Choice Probabilities

Site	Original Prob.	↑TPOP 10% Prob.	↑CNGEST 10% Prob.	↑TCST 10% Prob.	Close Site 1 Prob.
1	.2222	.2317	.2206	.2260	.0000
2	.2080	.1896	.2013	.2076	.3398
3	.0756	.0822	.0803	.0739	.1048
4	.0909	.0842	.0950	.0946	.1083
5	.0976	.0951	.1002	.0990	.1148
6	.0496	.0548	.0455	.0499	.0571
7	.0833	.0916	.0766	.0828	.0933
8	.0573	.0556	.0615	.0547	.0616
9	.0539	.0555	.0548	.0538	.0561
10	.0615	.0598	.0641	.0576	.0642

The increase in sheep populations cause the probability of visiting sites 1,3,6,7,and 9 to increase while the probability of visiting all other sites decreases. This example illustrates one of the main advantages of discrete choice models. Changes in attributes at one or all sites will cause substitutions from one site to another. In spite of sheep populations of all sites being increased equally, other attributes of the sites such as congestion or travel costs, in combination with the increase in population levels, lead to some sites becoming more attractive than others. Increasing congestion at all sites appears to have the potential to shift hunters away from the most visited sites (1 and 2) and move them to sites closest to these sites or to some of the more inaccessible sites. Increasing travel costs might lead to more visits to site 1 and about the same number of visits to site 2. As well, sites farther away from major population centers are visited less while sites closer to Calgary are visited more. As expected, closure of site 1 causes the probability of visiting site 2 to increase dramatically. Site 2 is closest to site 1 and next to site 1 it is the most frequently visited site.

It would be desirable to compare the welfare estimates computed from the Bighorn sheep multinomial logit model with welfare estimates from similar studies on big game hunting. Unfortunately, most of the multinomial logit models estimated have been concerned with improvements in water quality and welfare measures have been computed for such activities as fishing, swimming or boating. It is possible, however, to compare the welfare estimates derived in this study to one other study which also used the data on Bighorn sheep hunters but, applied different modeling approaches.

Adamowicz et al. (1990) provide welfare estimates for Bighorn sheep hunters using results provided by estimation of a sequential choice recreation demand model[44]. Adamowicz et al. investigate hunting trips to WMU 400 as a function of travel costs to the site, travel distance to a substitute site, WMU 402, and harvest[45]. Three sequential choice models were estimated. A model which included the substitute site and harvest variables provided a welfare estimate of $34.89 per trip. The estimate from the model without the substitute variable was $50.73 while the welfare measure was $52.83 for the model without the harvest or substitute variable. As expected, removal of the substitute site resulted in an increase in welfare since the possibility of site substitution is removed.

Adamowicz et al.(1989) also estimate a number of traditional travel cost models for visits to WMU 400 using the Bighorn sheep hunting data. One of the models used a simple OLS procedure with a truncated sample. The other three models were estimated using information on individuals individuals who did not visit the site (a censored sample) using OLS, Tobit maximum likelihood and the Heckman two-step procedure. Estimates of consumer surplus per visit ranged from $10 to $218 depending on the estimation approach.

Comparing these results, derived for WMU 400, to the welfare estimates derived for Site 1 from the multinomial logit model

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[44]A sequential choice model is a type of discrete choice model which models a discrete number of sequentially chosen trips to a site as a function of site specific variables and variables realized on previous trips.

[45]For the purposes of comparison, WMU 400 can be considered to correspond with Site 1 as defined in this analysis.

estimated in this study, some general points can be made. Table 13 presents a comparison of results.

The results are not directly comparable since the data used in the Adamowicz et al. (1989, 1990) studies included all hunting trips made by sheep hunters whereas the data used in this study contained

Table 13: Comparison of Welfare Measures for Bighorn Sheep Hunting Trips to WMU 400 from Alternative Recreation Demand Models

Model	Welfare Measure ($/trip)
Multinomial Logit	6
Sequential Choice w/ substitute/harvest	35
Sequential Choice w/ harvest	51
Sequential Choice w/o substitute/harvest	53
Travel Cost 1 (OLS/Truncated)	89
Travel Cost 2 (OLS/Censored)	218
Travel Cost 3 (Heckman/Censored)	45
Travel Cost 4 (MaxLike/Censored)	10

information on sheep hunting trips only. As is the case, one would expect the welfare measures in the Adamowicz studies to be higher than the estimate provided by the multinomial logit model. However, this does not account for the entire difference in welfare measures. While it is difficult to generalize, the results seem to indicate that models which incorporate variables or use statistical procedures in an attempt to accurately reflect the true nature of the recreation site choice process lead to lower welfare estimates for Bighorn sheep hunting trips to WMU 400. Thus, the welfare estimate provided by the multinomial logit model is a reflection of the 9 alternative sites incorporated into the model. Given the specification of the Adamowicz models, the welfare estimate for WMU 400 derived from the multinomial logit model results does not seem out of line.

E. Summary

In this chapter a multinomial logit model of Bighorn sheep hunting site choice was specified and estimated. The model was examined for reliability using statistical tests and several practical issues surrounding estimation of discrete choice models were discussed. Model results were used to calculate welfare changes resulting from changes in environmental quality variables and the travel cost variable. Values for Bighorn sheep hunting sites were also determined. In addition, site choice probabilities were presented for

al hunting site choice problem and changes in these

ies for changes in site attributes or the site choice set

ated. As the final chapter will highlight, applications of

ice models to recreation demand problems, such as

he demand for and valuing Bighorn sheep hunting sites, can

useful tool to policymakers.

V. Conclusions

A. Review of Research Objectives

The purpose of this study was to develop a methodology which could be used to examine the economic effects of changes in environmental quality on recreation demand and to apply the methodology to an Alberta case study. Recent studies on recreation demand in Alberta have shown that Albertans prefer outdoor activities where the natural environment is a principle component of the activity. This would indicate that changes in environmental quality could affect the demand for recreation. In Alberta, it is the responsibility of the provincial government to implement programs which enhance or prevent degradation of the natural environment. Because implementing such projects or policies requires expenditure of public funds, it is important to have a means of selecting among various the policies. Benefit-cost analysis provides a method to carry out such analyses. However, the public good nature of recreation activities complicates the task of assigning dollar values to benefits associated with the activities. Fortunately, economists have developed a class of techniques referred to as recreation demand models which can be used to evaluate recreation benefits.

Very little empirical work concerning the evaluation of changes in recreation demand or benefits resulting from changes in environmental quality has been conducted in Canada. Theoretical and empirical work in the United States has concentrated on using selected recreation demand models to measure the magnitude of recreation benefits associated with air and water quality improvements. The focus of the research in this study has been to develop a recreation demand model which can be used to evaluate changes in Bighorn sheep hunting benefits resulting from changes in selected environmental quality variables. Part of the research process, therefore, involved identifying quality variables which were relevant to a Bighorn sheep hunting experience. Identified variables included sheep populations, sheep harvest, access to hunting areas, and congestion at sites. A second part of the research concerned selection of a recreation demand modeling approach which appropriately captured Bighorn sheep hunter behavior. The model selected was a specific form of a discrete choice model of recreation behavior. Finally, using the identified quality variables and selected recreation demand model, a statistical model was estimated. The results of the model were used to determine the effects of changes in particular environmental quality variables, to calculate the value of specific Bighorn sheep hunting sites, and to predict the change in probability of site selection for a given change in quality.

B. Summary of Discrete Choice Analysis

In addition to allowing some general implications to be drawn about the relationship between environmental quality variables and recreation demand or benefits, this study demonstrated the usefulness of discrete choice models for analyzing recreation behavior. Discrete choice models are developed explicitly from utility theory which means that benefit measures derived from these models will be theoretically defensible. As the calculation of benefit measures is one of the main uses of recreation demand models, this feature of discrete choice models is extremely important.

Discrete choice models provide a distinct framework for examining various aspects of recreation behavior including definition of recreation sites or alternatives, incorporation of site substitution possibilities, identification of the structure of recreation choice processes, and, as emphasized in this study, incorporation of site quality attributes. Discrete choice models have the capability of modeling each step of a recreationist's choice process and the model can be used to predict how the recreationist's decisions at all steps would change as the result of a policy which would alter environmental quality at any or all sites. This all-inclusive framework, by appropriately modeling the recreationists decision process, can better accommodate the structure of recreation behavior. Capturing individual behavior in recreation demand models is important since one of the basic tenets of all recreation demand models is that values can be revealed through behavior.

One potential drawback of some discrete choice models is the IIA property. The IIA property may be restrictive in discrete choice models such as the multinomial logit model estimated in this study. However, discrete choice models which incorporate a more elaborate choice structure into the modeling process, eliminate the problems arising from the IIA property. One possible area for expanding on the research contained in this study would be to develop a nested logit model for Bighorn sheep hunting.

C. Summary of Environmental Quality Measures and Data Requirements

In making any advanced recreation demand model operational, the difficulties of incorporating environmental quality information must be recognized. The measures of environmental quality must be consistent with the desired objective of determining welfare changes resulting from a change in quality. It is possible that changes in environmental quality, as measured by objective standards, may not be perceived by recreationists. If recreationists do not acknowledge the change in quality then they will not alter their behavior. Economists analyzing such a situation using recreation demand models, such as the one used in this study, will not detect any change in benefits. There must be a link between the quality variables used in the model and recreationists' perceptions of environmental quality. For example, the sheep harvest variable included in some of the models estimated in this study was not significant in explaining Bighorn sheep hunting site choice. The hunting literature would indicate that harvest is an important aspect of a hunting experience. It is possible that alternate forms of the harvest variable need to be explored in order to capture the role of harvest in the Bighorn sheep hunting experience.

Even if the variables, appropriate for inclusion in the model, can be identified it is often difficult to obtain the data needed to measure the variables. In this study, access to Bighorn sheep hunting sites was identified as an important quality variable. However, a measure of access could not be included in the model since a satisfactory measure of access to hunting sites could not be found. To date, many of the theoretical developments in recreation demand modeling have been tested using data which have been collected previously for other purposes. The full potential of advanced recreation demand models, such as the discrete choice models, will only be realized if data requirements can be met. The discrete choice model has the capability of modeling the complex nature of an individual's recreation choices. These highly structured models may best be developed through a comprehensive study design which includes a data collection component.

D. Limitations of the Study and Possibilities for Future Research

One of the limitations of this study concerns the identification of environmental quality variables which affect Bighorn sheep hunting site choice. Variables were selected based on a review of the hunting literature. While this review provided many useful insights into variables which affect hunting behavior and satisfaction, the model would likely be enhanced if additional quality variables could be identified and included. The need to examine, in greater detail, quality variables which affect recreation behavior is not unique to this study. Research into factors underlying recreation behavior would greatly enhance all recreation demand modeling efforts.

A second limitation of this study concerns the measurement of the quality variables. Access to hunting sites was identified as an important variable in Bighorn sheep hunting site choice yet no suitable measure of access could be determined. Site access was incorporated into the model through the site specific constants. This approach may be adequate if the model is to be used to value an entire site. However, if access is considered to be a site attribute which can be controlled by management then, it must be explicitly included in the model or the effect of changes in the level of access cannot be examined. While data was available on site congestion, the model might benefit from a more comprehensive measurement of the congestion variable. It may also be worthwhile to re-examine the measurement of the harvest variable and test the performance of alternate forms of the variable in the model.

The analysis did not incorporate any socioeconomic variables. Unless entered in a specific manner, these variables which are constant across all sites would drop out of the model and their coefficients could not be recovered. In the case of Bighorn sheep hunters, it might be hypothesized that sheep hunting is a unique activity which attracts individuals with similar socioeconomic characteristics. If the model was to be expanded to analyze all hunting activity there would be a need to incorporate socioeconomic variables.

E. Summary of Study Results and Potential Policy Applications

Bighorn sheep hunting site choice was investigated using the multinomial logit specification of a discrete choice model. The model specified a hunter's utility as a linear function of travel costs, various site quality variables, and several site specific constant representing site access. The main results of the analysis can be described as follows:

i. Bighorn sheep hunters' site choice is strongly influenced by travel costs to the hunting sites. Hunters prefer sites which are close to their place of residence and are, therefore, less costly to reach. The relationship between site choice and travel costs was stable over all estimated models. The general magnitude and sign of the travel cost coefficient did not vary. This result is extremely important since it supports the notion that travel costs can be used as a proxy for price in estimating the demand for and benefits from Bighorn sheep hunting.

2. The final model estimated provides evidence that quality variables are also important in Bighorn sheep hunting site choice. Total sheep populations affected site choice as did congestion at hunting sites. Sites with larger sheep populations are preferred to those with smaller sheep populations and less crowded sites will be chosen over sites with more hunters.

3. While access could not be specifically incorporated into the model, the inclusion of site specific constants which represented sites with easy access or sites with restricted access provided results which indicated that access to a hunting site plays an important role in site selection.

4. The model results provide an indication that hunters' perceptions of site attributes play an important role in site choice. The sheep population variable which measured the number of legal rams at each site was not as useful in determining site choice as was a sheep population variable measuring overall sheep populations. Hunters may make inferences about legal ram populations from overall population levels.

The model can be used to determine the welfare effects of changes in environmental quality variables or travel costs to the hunting sites. As well, the value of all or one of the Bighorn sheep hunting sites can be examined. The change in probability of site selection for a given change in quality or travel costs can also be calculated. The implications of changes in site attributes, travel costs and site availability were illustrated using hypothetical examples. The results from these calculations were reasonable when compared to analyses of the same dataset using other recreation demand modeling approaches.

While the examples were hypothetical they illustrate the applicability of discrete choice models to management level planning. The discrete choice modeling approach can help identify significant site quality variables that can be measured objectively and controlled by the wildlife manager. The province of Alberta is fortunate to have abundant wildlife populations for most big game species. However, the demand for big game hunting opportunities by both resident and non-resident hunters may be increasing. Hunting trophy animals is especially popular. Currently, there are many big game species which can only be hunted in certain WMUs and it is possible that restrictions will need to placed on other species. If there are alternatives as to which sites should be closed to hunting, an appropriately specified discrete choice model could be used to determine which site closure will have the least impact on hunter welfare. In addition, the wildlife managers could use the model to predict which sites hunters will substitute for the closed site. This will allow them to prepare for problems which might occur at substitute sites as the result of closure of one site.

While it has not been common practice in Alberta, some jurisdictions raise small game animals or birds for release into the wild to enhance hunting opportunities. Such programs are usually expensive undertakings. Discrete choice models can be used to determine the hunter benefits derived from such programs. Programs could be designed so as to enhance populations at sites having the greatest potential for increase in hunter benefits.

These simple examples provide a mere glimpse into the potential of discrete choice models to assist wildlife managers. Results from such discrete choice analyses could not be the sole basis for decision making but, an understanding of the benefits accruing to humans from the wildlife rescurce would improve the effectiveness of wildlife policy. It is important to note that the existence of healthy wildlife populations in Alberta provide benefits to individuals beyond those accruing to resident hunters. A complete analysis of benefits accruing to Albertans from the wildlife resource should take into account non-resident hunting and nonconsumptive uses as well.

Overall, the research contained in this study implies that discrete choice recreation demand models are extremely well suited to valuing the recreation benefits associated with changes in environmental quality. However, discrete choice models have the capability of providing information which is useful to managers in a broader range of applications. This is important since research resources are often scarce and techniques which provide information which can be used for a number of purposes should be favored.

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