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Effects of Regulatory Mechanisms on Anglers and Walleye Populations in Northern Alberta Lakes

by

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ABSTRACT

Recreational angling pressure in Northern Alberta has reduced sportfish populations to near critical levels in some locations and traditional regulatory efforts have typically been ineffective in preventing the decline of walleye populations. This research uses data from the Northern River Basins Study to produce a model of anglers' site preferences in a random utility model. These angler preference estimates are combined with a walleye biological model and further developed into an integrated economic and ecological framework.

In this modelling framework, regulation scenarios are implemented to control lake access, simulate site closure, limit angler effort to a maximum level, and add various fee programs. The best policy options appear to be the site fee and angler effort quotas, which stabilize fish populations and have less welfare loss comparatively. However, regardless of their positive impacts on walleye populations, new regulatory tools will unequivocally decrease overall angler utility.

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CHAPTER 1: INTRODUCTION

1.1 SUSTAINABILITY

Increasingly, Alberta's resource managers are faced with challenges as they attempt to effectively align economic, sociological, and environmental objectives in sustainable development. One of the resources that the environment provides is recreational fishing to sport anglers.[1] The increasing popularity of sports fishing has resulted in rapidly reduced fish populations in some regions of the province. It has been suggested that sports fisheries under current regulatory frameworks are not "sustainable"; is it possible to change regulations so that angling practices are sustainable in terms of fish populations and yet provide benefits to recreationists?

Although the definition of sustainability is not widely agreed upon, it is clear that the central issue of concern is the continued provision of environmental services for future generations, given the growing pressure on the natural environment to provide many valued services (Saha and Poole 2000). Thus, the reality of sustainability can be broken down into several categories, two of which are biological and economic sustainability and are of concern in this case. Biological sustainability relates to a method of harvesting or using a resource so that the resource is not exhausted or permanently damaged. Similarly, economic sustainability is often defined as the maintenance of the stocks of capital or assets in order to produce a non-declining set of benefits (Bateman and Willis 1999). Environmental valuation is one approach through

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[1] As an indication of the large economic value of sport-fishing, in 1995, the angling population spent $7.4 billion in Canada of which $4.9 billion was directly associated with their sport (DFO 1995).

which economic sustainability, or keeping the well-being or welfare of individuals at a non-declining level, can be examined (Field and Olewiler 2002).

The appropriate management of a resource takes into consideration both economic and biological sustainability. However, sometimes both forms of sustainability are not possible; this forces one to make substitutions between both the time frame and the forms of sustainability for which resource management is conducted. A truly sustainable society recognizes that people, the economy, and the environment are all connected and promotes integrated management of economic and biological sectors. Ultimately, sustainability requires the utility of future generations to remain uncompromised in terms of market and non-market values.

1.2 FISHERIES CHALLENGE

Recently in Alberta, there has been much concern among anglers and resource managers about the biological sustainability of walleye (*Stizostedion vitreum*) populations. In fact, declining fish populations have been so evident in the last few years that sportfish status has made headlines in the Canadian news, stating that many sportfish populations are in danger of collapsing, especially in Alberta (Thomas 2001, Struzik 2002).

The cause of the near-collapse of the walleye species in Alberta is the subject of considerable debate. Some hypothesize that the threat to walleye populations is due to poor spawning habitat caused by years of drought (Thomas 2001) while others blame it on overfishing due to high angler pressure[2] from too many people fishing lakes and rivers near large urban areas. Although the spawning habitat problem cannot feasibly be regulated, the overfishing and excessive angler effort on the lakes can be altered by policy. Additional regulation is not often a politically popular notion, but in the case of walleye populations, many commentators believe that perhaps the time has come to adopt more restrictive regulations such as lotteries or draws[3] to limit angler pressure (Struzik 2002; CFCN News 2002; CBC News 2002).

Currently, walleye fishing in Alberta is being regulated by seasonal closures, year round site closures, catch and release regulations, bag limits and size limits (Alberta Environmental Protection 2002). In effectively regulating sport fishing, several other policy options or combinations of options can be assessed. Access to a site (usually due to forestry access roads) can be limited or added. Quota systems, either area specific or lake specific, can be introduced to reduce angler pressure. Additional fees can be added to a lake to reduce the number of anglers. Bag limits and size restrictions can be made stricter. Each of these regulations will be considered in this research to compare the relative impacts on the fish populations and identify the policy with the most desirable effect to optimize economic welfare over time to generate sustained economic value.

1.3 RESEARCH PROBLEM

Before a solution can be found to such a complex problem, the current situation must be fully understood. Figure 1 is a simple illustration of policy and its effects on

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[2] Post et al. (2002) note that in Alberta, Alberta has approximately 375 licensed anglers per lake, while in other inland Canadian provinces, angler pressure is less than 3 licensed anglers per lake.
[3] See Boxall (1995) for a discussion of lotteries and draws as regulatory mechanisms in recreational hunting.

anglers and fish populations. When a policy is implemented, it can affect not only angler behaviour, but also angler preferences and walleye populations. For example, policy may influence the decision of whether or not to fish. This decision has the potential to affect fish populations. If a trip is taken, the success of the fishing trip affects the angler's perceptions of that site and these influence the angler's preferences. Preferences and perceptions determine whether the angler will or will not to return to that site.

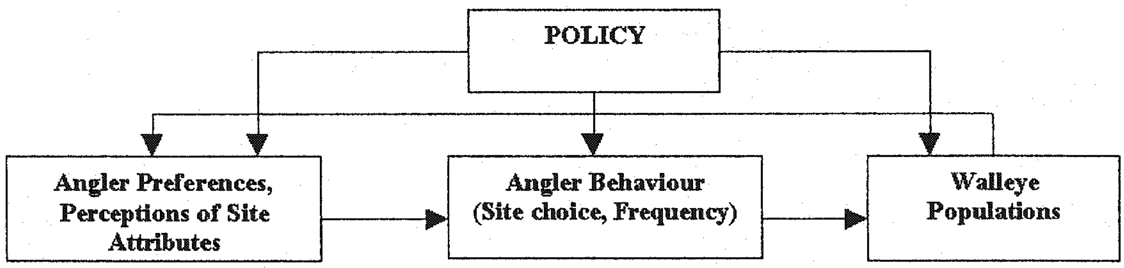

Figure 1. Current Policy Impacts on Angler Choice

Policy / regulatory mechanisms can also influence angler preferences and perceptions as well as the fish populations. When a new policy is announced, there is a direct impact on the angler as to whether or not that site is still preferable. An example of this is the recent "free fishing day" given to Alberta residents to fish within the current regulations, but without need of a fishing license. This would likely cause more Albertans to perceive fishing as more affordable and perhaps more potential anglers would be encouraged to continue with the sport. The information that governments and regulators release to the public regarding lake specific quality of fishing would alter fishing site perceptions as well. The walleye populations are also directly affected by policy. For instance, stocking of lakes causes an immediate increase in walleye populations at a lake.

Regulatory mechanisms (policy) cause various impacts on both the angler and the walleye populations. A policy may cause either an increase or decrease in walleye populations, and may also affect angler welfare negatively or positively. To evaluate each of the policies, the biological changes and human economic impacts will need to be examined over a period of time.

1.4 APPROACH

In order to aid in the recovery of walleye populations in Alberta, new management strategies should be considered in an integrated model format. Post et al. (2002, pg. 15) describe the importance of dynamic management models in fish sustainability:

> "We need to recognize, quantify, and incorporate depensatory[4] processes, where and when they exist, into dynamic management models to identify thresholds of populations abundance necessary to sustain fish populations and the social and economic value that they provide. Only then can fisheries management and society as a whole hope to respond in a timely fashion to avoid the collapses and costly mistakes that have characterized the science and management of the world's commercial fisheries."

In order to create a dynamic management model, a slightly more complicated model of angler/fish dynamics is considered in this study. The relationship between the angler and fish can be effectively modelled with the added component of regulations and economic benefits. Thus, as new policy is incorporated, sport angling regulation models can examine the feedback mechanisms between anglers, welfare measures, and fish populations (see Figure 2).

[4] Mortality is depensatory when its rate (proportion of population affected) increases as the size of the population decreases.

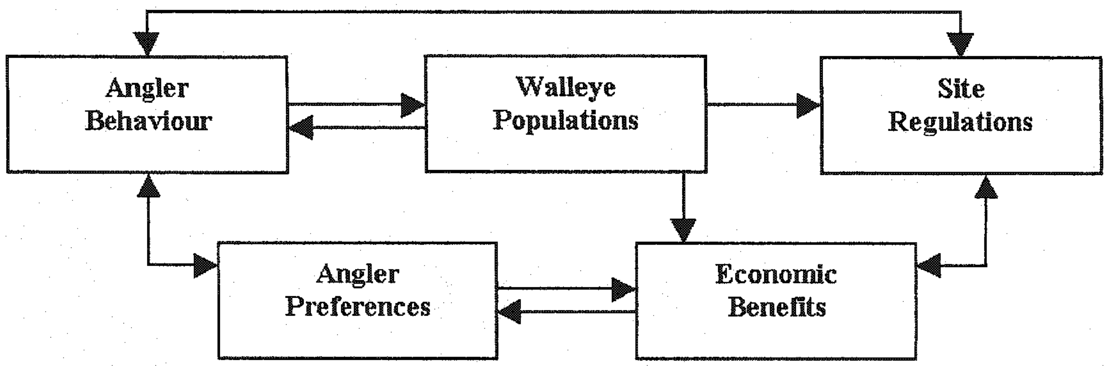

Figure 2. Interactions Between Walleye and Anglers

In Figure 2, the model includes a general behavioural component as the human sector. Angler behaviour is influenced by angler preferences, by site regulations, and by fish populations. Angler preferences are affected by angler behaviour (by the process of learning) and by the utility received from each fishing site. Site regulations are affected by the angler welfare or utility, as well as the fish population levels, which are in turn affected by the angler. Economic benefits are derived from the angler's preferences, the fish populations and the regulations that were implemented.

There are concerns regarding deteriorating fish populations in many of Alberta's lakes and rivers. However, this particular study focuses on only the Northeastern area of Alberta and includes the following 10 lakes: Amisk, Baptiste, Beaver, Calling, Lac La Biche, Long, North Buck, Pinehurst, Skeleton, and Touchwood. A brief description of each lake is provided in Table 1.

Table 1. Characteristics of Lakes in Choice Set (Mitchell and Prepas 1990)

Lake	Location	Lake Area (km^2)	Mean Depth (m)	River Basin	Other Notes
Amisk	- 175 km NE of Edmonton - 15 km E of Boyle	5.15	15.5	Beaver	-Long and narrow lake, with north and south basins
Baptiste	- 165 km NW of Edmonton - 16 km W of Athabasca	9.81	8.6	Athabasca	-Has two distinct basins joined by a long neck called the Narrows
Beaver	- 170 km NE of Edmonton - 5 km NW of Lac La Biche town	33.1	7.1	Beaver	- Popular lake for boating, fishing - No sandy beaches or designated swim areas
Calling	- 200 km N of Edmonton - 55 km N of Athabasca	138.0	Not Available	Athabasca	- Large attractive lake with sandy shoreline
Lac La Biche	- 220 km NE of Edmonton - 3 km E of Plamondon	234.0	8.4	Athabasca	- Known for its excellent beaches and well-forested park and shoreland areas
Long	- 130 km NE of Edmonton - 15 km S of Boyle	5.84	4.3	Beaver	- Set in a steep-sided, heavily wooded area. - Has year-round camping facilities
North Buck	- 180 km NE of Edmonton - 1 km N of Caslan	19.0	2.5	Beaver	- This lake became the focal point for recreational and residential development
Pinehurst	- 245 km NE of Edmonton - 60 km SE of Lac La Biche	40.7	12.2	Beaver	- Popular destination for anglers, hunters, campers, and trappers
Skeleton	- 160 km NE of Edmonton - 6.5 km NE of Boyle	7.89	6.5	Beaver	- Regional focal point for water-based recreation and is extensively developed.
Touchwood	- 265 km NE of Edmonton - 45 km E of Lac La Biche	29.0	14.8	Beaver	- Has little access and no day-use area - Holds the status of Protective Notation

As shown in Table 1, there are lakes included from both the Beaver and Athabasca River Basin Regions. Although these lakes vary substantially in area, depth, surrounding development, and scenery, they are located close to one another. Figure 3 shows a map of the choice set area. These lakes were chosen because of the low walleye populations at several of the lakes, the availability of biological and economic information and the fact that the lakes together form a plausible choice set for anglers living in northern Alberta (Sullivan 2002) .

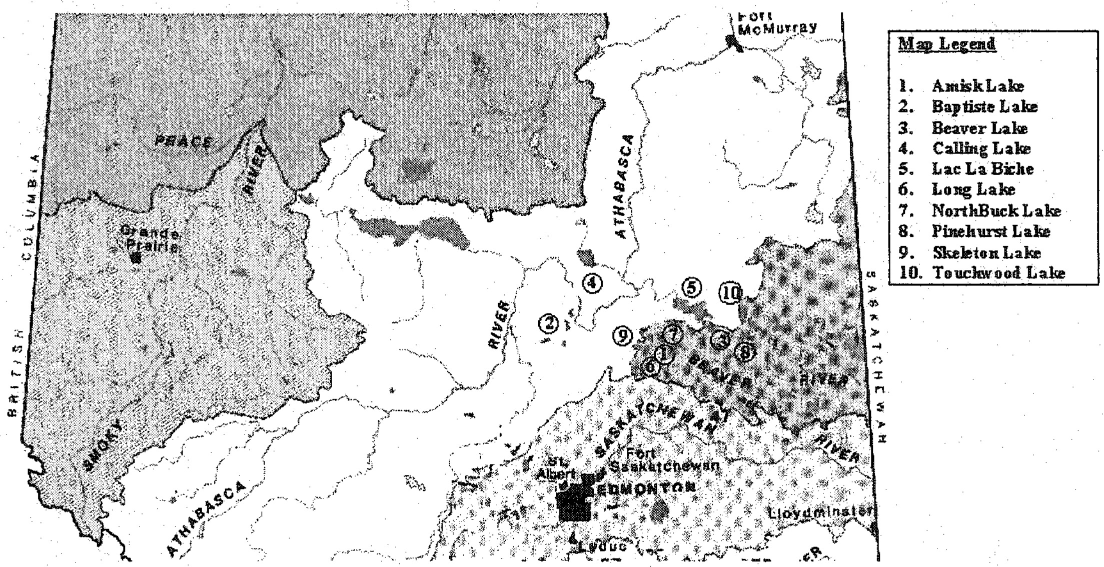

Figure 3: Map of Lake Choice Set (Mitchell and Prepas 1990)

1.5 STUDY PLAN

This thesis is organized as follows: The next chapter provides a detailed literature review of similar studies and other related research. Chapter 3 discusses the random utility model, conditional logit models, and welfare estimation. In Chapter 4, the various data sources are described and the econometric (conditional logit) results are presented. Chapter 5 examines the methods employed in creating an integrated ecological/economic model. Each of the variables and sectors within the model are outlined and various regulation techniques are explained. In Chapter 6 the integrated model results are depicted and discussed. Chapter 7 follows with a summary and a brief discussion of the study limitations and conclusions.

CHAPTER 2 LITERATURE REVIEW

2.1 PROPERTY RIGHTS

Like many natural resources, lakes are often categorized as public goods. However, a true public good is non-exclusive and non-rival in consumption. Other resource stocks such as clean air may be classified as public goods, but even though most angling sites are not privately owned in Alberta they are more correctly identified as "open access" or "regulated access" resources (Gordon 1954; Hackett 1998). Open access resources have the following characteristics that distinguish them from a public good (Hackett 1998):

-There is a difficulty in excluding individuals from appropriating from the resource stock; this is especially true when the stock is not partitioned by a well-defined and enforced property rights regime.

-There is rivalry in consumption; if one individual consumes the good, another individual cannot.

The conclusion drawn about open access resources is that such conditions lead to economic inefficiency and often to over exploitation in the biological case (Clark 1973). This concern about open access resources is not a recent realisation—there has been discussion about this phenomenon for years. Gordon (1954, pg. 135) writes:

> "…There appears, then, to be some truth in the conservative dictum that everybody's property is nobody's property. Wealth that is free for all is valued by none because he who is foolhardy enough to wait for its proper time of use will only find that it has been taken by another."

This lack of property rights gives anglers no reason to become more than mere harvesters (Brubaker 1996) and because of the undefined rights, inefficiency occurs and recreational fishing under open access regimes will inevitably result in too many anglers (McConnell and Sutinen 1979).

Discussion regarding the link between the biology and economics of the open access problem is not a new notion. In the 1970s, economists saw "too many boats chasing too few fish" as an economic problem, while ecologists saw the same problem as a biological threat (Wilen 1988). In attempting to remedy the situation, several approaches have been attempted from both economic and biological angles. However, when dealt with individually, there appears to be less progress. Scott (1979) states that the problem is that economists often make much of the government's action to remedy the wastes of the common property and other market failures. However, it is unlikely that inefficiency in resource allocation enters the motivation for intervention. Thus, it is essential to have all players-- regulators, politicians, economists, and biologists to help make policy to prolong and sustain the fishery by influencing the decisions and procedures of harvesters.

Because of the threat of exploitation of the resource, most lakes are now "regulated open access resources" rather than simply "open access resources". This means that the anglers are free to enter, but are subject to certain regulations imposed by a management agency in the form of area closures, season length restrictions, bag limits, etc. (Homans and Wilen 1997). Regulators choose the suite of instruments and their respective levels to reflect the current and future conditions of each site in an endogenous and dynamic framework.

In choosing an appropriate form of regulation the transactions costs and enforcement costs must also be accounted for. Because each regulation has costs associated with its implementation, the issue is the relative enforcement and transactions costs of the proposed regulations compared to current policy. The estimation of the transactions costs of each regulatory mechanism is beyond the scope of this project but should be a topic for further research in this area. In this project each policy option is assumed to have equivalent transactions costs.

Regardless of the management scheme chosen, anglers have three possible decisions they can make in relation to a new regulation (Opaluch and Bockstael 1984). They may:

1. change intensity of fishing
2. redistribute effort among sites
3. entry or exit from fishing altogether.

Since the cost structure of fishing for each angler is different and the choice of regulatory instruments may be site specific (depending on the parameter values of the site in question), it is difficult to choose one policy or combination of policies as "the best scheme" (Anderson 1988).

2.2 OVERVIEW OF SIMILAR APPROACHES

Similar research has been done to better understand the interactions between anglers and the biological models. These studies provide insight and are a stepping stone to building more predictive and dynamic integrated models. The source of the data used for the angler/fish studies are often just as important as the conclusions. The next section describes revealed preference data, then discusses some similar angler preference and regulation simulation models.

2.2.1 Revealed Preference Data Approach

Numerous studies have focused on recreational fishing where the data are gathered from surveys. Within the survey approach, the data can be gathered through stated preference (SP) techniques or revealed preference (RP) techniques. The data for this research are RP data, therefore this section will focus on the description and characteristics of this approach[5]. Whereas SP surveys involve hypothetical questions, RP surveys ask the respondents to describe their actual behaviour. The RP approach relies on currently available attributes to generate a behavioural representation of choice as opposed to revealing choices for hypothetical questions. Some drawbacks to an RP approach are that data can be costly or difficult to collect, the data usually includes only primary variables (because they are most often expressed in objective units), there is often high correlation among explanatory variables or insufficient variation to allow robust estimates (and therefore collinearity effects), and measurement errors might be difficult to identify with an unspecified choice set. In collecting RP data, there may also be a problem with biases; the respondent may not remember perfectly the "actual" behaviour and therefore try to approximate, resulting in recall bias. The benefits of the RP approach are that the objective component of the utility function is comprised of measures of attributes of the "real" alternatives, and decisions which are actually made, observed, and are real choices in real markets are employed in the analysis.

[5] This section was adapted from Danielis and Rotaris (1999).

2.2.2 Angler Preference Models

Many recreational fishing studies have been done to model angler and recreational angling preferences derived from various fishing attributes. There is a very comprehensive literature review with a list and summary of these studies in the Sportfishing Values Database (IEc 1998). The next section will briefly describe some integrated angler models that incorporate various aspects similar to this study.

2.2.3 Regulation Simulation Models

Preliminary research incorporating regulation and policy simulation has been done in an economic framework. In Anderson (1988) an ocean fisheries perspective is taken to regulation and is similar to models of the sport fishery. In research by Walters (1994), a computer simulation model of dynamic regulations on hypothetical lake data are used to get estimates of trade-offs and decisions over time. Models by Johnson and Carpenter (1994) integrate human interactions with fish and vice versa for Lake Mendota, Wisconsin. This was done seasonally, to examine trends in angler effort over the seasons and time series. Schuhmann and Easley (2000) use Random Utility Models (RUMs) to estimate benefits for species-specific anglers from hypothetic reallocation. This links the dynamics of angler response to fish stock dynamics and results in an ex-ante approximation of stock reaction to potential policy changes. It also permits valuation of projected changes rather than the traditional estimation of arbitrary improvements. Another approach taken by Andrews and Wilen (1988) examines effort responsiveness to success in the California salmon partyboat sport fishery. The management targets were harvest levels using closed seasons, restricted gear, and possession limits. In recent work by Wilen (1985, 1988, 1993) and Wilen and Homans (1998), regulation (such as boat restrictions, taxing fish, and taxing fishing effort) are examined for the open access fishery.

The literature contains several models that link angler behaviour with biological processes. A framework that has been used effectively is to employ a random utility model of angler site choice behaviour and link it with biological models of the fishery, and an excellent overview of recent research in RUM theory is can be found in Parsons (2002). In the next chapter a RUM for northern Alberta is presented.

CHAPTER 3: THEORY OF INDIVIDUAL ANGLER BEHAVIOUR

3.0 INTRODUCTION

An intermediate step in estimating the angler utility change from policy and regulation is to estimate a model of angler preferences. These estimates can be used to characterize the behaviour of the human sector in the integrated ecological economic model. Once the behavioural model is created, it can be linked to a dynamic biological model to predict site choice as well as calculate resulting site specific and aggregate welfare measures. This chapter describes the importance of deriving non-market values, the theory behind travel cost and random utility models, as well deriving welfare measurements.

3.1 BENEFIT MEASUREMENT IN RECREATION DEMAND MODELS

A common classification of economic benefits is the distinction between 'market' benefits and 'non-market' benefits. Market benefits arise where the item providing the benefit is bought and sold; non-market benefits have no market-determined value and are not generally bought or sold, but may possess significant value to individuals who would pay to receive these benefits if a market existed (Freeman 1993).

Monetary values are often used as a 'metric' so that both market and non-market goods can be represented on a similar basis to be used in economic analyses or in calculating welfare measures (Bateman and Willis 1999). However, non-market values such as wildlife or habitat are often given little weight compared to those that have market benefits in traditional economic analyses (Phillips, Haney, and Adamowicz 1993).

In order to best allocate resources and assess the value of a regulation change, it is necessary to examine the resulting utility derived from the resource and the environmental impact of the activity in question. This can be done by assessing the benefits of preserving and improving environmental resources compared with the uncertain opportunity costs of foregone values (Bateman and Willis 1999). Two popular methods of deriving non-market economic benefits from recreation are the traditional travel-cost method and the random utility model.

3.2 TRAVEL COST MODEL

The travel cost model was introduced by Hotelling in 1949 and has since become a widely-used and relatively simplistic method for calculating non-market values. The underlying principle in travel-cost modelling is that recreators at a site pay an implicit price for using its services through the travel and time costs associated with getting to that site. Since recreationists have various places of origin, the relation between differences in implicit price and travel behaviour can be used to analyze the site's demand (Freeman 1993). If a site gives high enjoyment value for an individual, that person will be willing to drive further to be at that site. The value for the site is derived by examining the total number of trips taken to a site by an individual, as well as the travel cost.

However, a problem with simple travel cost models is that they do not easily incorporate substitutes into the demand function; thus, the benefits from the recreation site tend to be overstated. Multiple site models do a better job of incorporating these values, but can only estimate the value of a trip as a whole, rather than for the improvement of one specific characteristic (Freeman 1993). The travel cost model is excellent in analyzing zones and zonal averages and single site demand over a period of time, but are typically based on aggregated data and not on individual preferences (Freeman 1993).

3.3 DISCRETE CHOICE / RANDOM UTILITY MODEL

In recreational demand models that examine recreation site choice, the individual is faced with a choice from a finite set of discrete bundles of attributes. The decision problem is characterized as the choice as a result of five steps: definition of the choice problem, generation of alternatives, evaluation of attributes of alternatives, choice, and implementation (Ben-Akiva and Lerman 1985).

These alternatives are both feasible and known to the decision maker during the decision making process. When choosing site alternatives, the occurrence of zero quantity demanded is possible, which in traditional consumer theory would cause the utility maximization solution to have a corner solution where first order conditions do not hold. Thus in discrete choice models, rather than deriving demand functions, researchers derive (conditional indirect) utility functions.

One method to represent recreation choice behaviour is to use the random utility model (RUM) to analyze behaviour and value recreation sites at an individual level[6]. The premise behind the RUM is a framework that assumes that the individual knows the characteristics of all possible alternatives. Within these alternatives, the individual weighs each one against the other, and makes a mutually exclusive decision for that time

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[6] For other related literature see Adamowicz (1994), Adamowicz et al. (1994), Bockstael, McConnell, and Strand (1989), Greene et al. (1997), Kling (1987).

period to the alternative that provides maximum utility. This utility is a function of the site's characteristics and the individual's preferences.

3.3.1 APPLICATION OF RANDOM UTILITY[7]

Decisions, by definition, are made from a nonempty set of alternatives, and the environment of the decision maker determines the universal set of alternatives. Any single decision considers a subset from the universal set, which is referred to as a choice set. The alternatives within the choice set are assumed to be both feasible and known to the decision maker. The assumption is that accurate information is received rapidly when in fact may take longer for anglers to learn about site attributes. Thus, this model will probably overstate the speed with which anglers respond to changes in site attributes.

In the context of recreational fishing, anglers are faced with choosing a fishing site within a set of lakes in a given area. They will choose the lake with attributes (Q) that generate the highest utility (U) within that set of alternatives. The utility that angler *i* receives from lake *j* in choice set C_{iJ} is:

$$U_{ij} = U(Q_{ij}) \qquad (1)$$

where Q_{ij} is a vector of attributes perceived by angler *i*, describing lake *j*. However, the meaning of randomness in the RUM is that the deterministic component of utility is complemented by an error term. Thus, more formally, the conditional indirect utility (U_{ij}) that angler *i* receives from lake *j* can be defined as a combination of the indirect observable utility (V_{ij}) and an error component (ε_{ij}) and can be written as:

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[7] Based on Ben-Akiva and Lerman (1985).

(2) $$U_{ij} = V_{ij} + \varepsilon_{ij}$$

The conditional indirect observable utility V_{ij} of the anglers can be further described in the linear form:

(3) $$V_{ij} = \beta_1 + \beta_2 x_{ij2} + \beta_3 x_{ij3}, \ldots, + \beta_k x_{ijk}$$

where the β's are the relevant parameters and x_{ijk} (which is an element of vector Q_{ij}) includes the attributes of the fishing sites. The error component ε_{ij} in Equation 2 captures any unexplained factors not directly considered in the model, such as observational deficiencies resulting from unobserved attributes, unobserved taste variations, and researcher error (Ben-Akiva and Lerman 1985).

Because of this random component, RUMs are probabilistic rather than deterministic in nature; therefore, it follows that the probability of choosing lake *j* from the choice set C_{iJ} is determined by the relative utilities that the angler receives from each lake alternative. Thus, the probability of choosing lake *j* is equal to the probability that the utility of the alternative *j* in U_{ij} is greater or equal to the utilities of all other lakes in the choice set C_{iJ} (Ben-Akiva and Lerman 1985). This can be expressed as:

(4) $$P(j) = \Pr(U_{ij} \geq U_{jk}); \forall\, k \in C_{iJ}$$

By substituting Equation (2) into Equation (4), the observable indirect utility and the error component are included:

(5) $$P(j) = \Pr(V_{ij} + \varepsilon_{ij} \geq V_{ik} + \varepsilon_{ik}); \forall\, j \neq k,\, k \in C_{iJ}$$

Therefore, by rearranging the error components and indirect utilities:

(6) $$P(j) = \Pr(V_{ij} - V_{ik} \geq \varepsilon_{ik} - \varepsilon_{ij}); \forall\, j \neq k,\, k \in C_{iJ}$$

A common assumption is that the error terms are independently and identically distributed (IID) with the Gumbel (Weibull) Distribution[8] (Ben-Akiva and Lerman 1985), (Judge, Griffiths, Hill, Lutkepohl, and Lee 1985) which allows the transition to be possible from preference to probability of choosing an alternative. This yields:

$$P(j) = \frac{\exp^{V_{ij}}}{\sum_{k=1}^{J} \exp^{V_{ik}}} \qquad (7)$$

as the probability of individual i choosing alternative j. The parameters in V_{ij} can be estimated using maximum likelihood techniques. This model is referred to as a conditional logit model (sometimes referred to as multinomial logit models or MNL models), where the numerator represents the conditional indirect utility for a specific lake, *j* and the denominator is the sum of the conditional indirect utilities over all the alternatives in C*ij*.

Conditional logit models are commonly used in recreational models where the number of attributes or the number of alternatives in the choice set is large. One of the most widely discussed and misinterpreted aspects of the MNL models is the assumption of Independence of Irrelevant Alternatives (Ben-Akiva and Lerman 1985). This property states that "the ratio of the probabilities of choosing one alternative over another (given that both alternatives have a non-zero probability of choice) is unaffected by the presence or absence of any additional alternatives in the choice set" (Louviere, Hensher, and Swait 2000). This condition of IIA can be seen as both a strength and a weakness to the model.

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[8] This means that the difference between any two random error variables within this distribution has a logistic distribution function, giving the multinomial logit function (Judge et al. 1985). Gumbel's Distribution is a special case of the log Weibull distribution. For a description of the properties of the Gumbel Distribution, see Ben-Akiva and Lerman (1985) pg. 104-105.

It is computationally convenient, but is inaccurate when unobserved components of utility are correlated among alternatives.

However, the satisfaction of the IIA axiom should not be of general concern for a given model because without examination, IIA cannot be determined as either desirable or undesirable. Thus, one must determine whether or not the ratio of the choice probabilities of any two alternatives is entirely unaffected by the systematic utilities of any other alternatives—and depending on the result, the IIA assumption should be accepted or rejected depending on the circumstances (Louviere et al. 2000).

3.4 MODEL ESTIMATION

The most used widely procedure for estimation of MNL models is the maximum likelihood[9] technique. This method provides an estimator of β which results in the likelihood function being a maximum. The likelihood function is concave in the unknown parameters (Judge et al. 1985) such that a unique maximum exists.

The estimation of the coefficients is accomplished by defining the log likelihood function as the product of probabilities over a sample of individuals by simply multiplying the probability[10] of each person's chosen alternative across all people in the sample:

(8) $$L = \prod_{i=1}^{I} \prod_{j \in C_{iJ}} P_i(j)^{y_{ij}}$$

[9] See Louviere et al. (2000) for detailed Maximum Likelihood description (pg. 66-71)

[10] Note that logit models can be estimated using both frequencies or proportions.

where the i subscripts are the individuals in the sample of J observations and P_j is defined in Equation 7. This can be further transformed by taking the log of the likelihood function in Equation 8 yielding:

(9)
$$\mathcal{L} = \sum_{i=1}^{I} \sum_{j \in Ci/} y_{ij} \, (\ln (P_{ij}))$$

$$= \sum_{i=1}^{I} \sum_{j \in Ci/} y_{ij} \, (\beta' x_{ij} - \ln \sum_{k \in CiJ} \exp^{\beta' x_{ik}})$$

Equation 9 can be simply defined in words as the log of the probability of the chosen alternative of each individual, summed over all sampled decision makers where the estimate of β is that which maximizes the sum.

There are several reasons why maximum likelihood techniques are commonly used in multinomial logit models. Firstly, the criterion of finding those parameter values most likely to have produced the sample observations is an intuitively pleasing one. Also, under fairly general conditions, maximum likelihood estimators have a number of desirable asymptotic properties. The maximum likelihood estimation procedure yields an estimate of β that is consistent[11], asymptotically normal[12] and asymptotically efficient[13] (Berkley 2002) relative to all other consistent uniformly asymptotically normal estimators (Judge et al. 1985). Finally, the maximum likelihood estimator of conditional logit model

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[11] Consistency means that as the sample size increases, the true parameter value is estimated more accurately.

[12] Asymptotically normal refers to large sample size, where the maximum likelihood estimate will have an approximate normal distribution centered on the true parameter value. The standard errors are "asymptotic standard errors" because they are large sample approximations to the sampling variance of the maximum likelihood estimates.

[13] Efficiency pertains to the fact that maximum likelihood estimators will have smaller (asymptotic) variance than other consistent uniformly asymptotically normal estimators.

can be shown under very general conditions to provide estimators reasonably well even with quite small samples (Zarembka 1973).

3.5 WELFARE THEORY

Welfare measures provide the foundation for analysis of costs and benefits associated with environmental change. The methods by which welfare is altered can be through changes in the qualities or quantities of non-marketed goods, or through the price of goods (Freeman 1993).

The method of measuring angler welfare change used in this study is Compensating Variation (CV). Compensating variation is calculated by solving the following expression:

$$V(P, Q^0, M) = V(P, Q^1, M + CV) \tag{10}$$

where Q^0 is the initial environmental quality and Q^1 is the environmental quality after the policy change. The expression essentially states that the indirect utility will remain constant after the quality change, given the compensation, CV. Thus, using the expression for the expected value of the maximum and assuming zero income effects, the CV expression for the conditional logit model (derived by Hanemann (1984)) becomes:

$$CV = -\frac{1}{\mu}\left[\ln \sum_{j \in C_{iJ}} e^{V_{ij0}} - \ln \sum_{j \in C_{iJ}} e^{V_{ij1}}\right] \tag{11}$$

where V_{ij0} is the utility before the change and V_{ij1} is the level of utility in the subsequent state and μ is the marginal utility of money (the adjusted coefficient of the travel cost/ price attribute) (Adamowicz, Boxall, Louviere, Swait, and Williams 1994). The logsums of the utilities provide an aggregate welfare measure for all sites in the choice set by implicitly combining the relative site quality with the proportion of anglers that choose that site.

In this study, compensating variation provides measures of the impact of changes in angler welfare in response to fishing site closures, access changes, fees, and the use of quotas to limit fishing effort. These welfare measures are not directly calculated using the coefficients derived for angler preferences in the multinomial logit model. Instead, the representation of angler behaviour is modified to link it to the ecological model. In addition, adjustments are made to the behavioural model to account for regulatory compliance. In the integrated model, the regulations cause changes in angler utility by changing site attributes and ecological conditions. Within the integrated model, the regulations may impose welfare loss due to lake restrictions, but welfare gain due to higher walleye populations. Depending on the relative magnitude of restrictions the policy imposes and the effects on fish populations, it is possible for fish stocks to increase, yet still have a net decline in angler utility. Details about the development of this integrated model are provided in Chapter 5.

CHAPTER 4: ECONOMETRIC DATA AND RESULTS

4.0 DATA SET

Data were required for the development of the angler behaviour model (conditional logit model). Revealed preference data from the Northern River Basins Study angler survey were used to construct the conditional logit parameter estimates. The biological model was taken largely from a previously existing walleye population model. This chapter will describe the key variables included in the travel cost (RUM) behavioural model. The integration of the walleye population data with the human preferences and regulation models will be discussed in Chapter 5 (Model Development).

4.1 NORTHERN RIVER BASINS STUDY[14]

The Northern River Basins Study (NRBS) was a four-and-one-half year, $12-million project established in 1991 by the governments of Canada, Alberta and Northwest Territories to provide fundamental information regarding the impact of human activities and development in the river basins. The study focused on the Peace, Slave and Athabasca River Basins in Alberta and the NWT, which are the subject of considerable development pressure from pulp and paper, oil sand, agriculture, and municipal growth. In addition, they contain two national parks and a large number of residents who depend upon a traditional subsistence lifestyle.

The study was aimed at providing a scientifically sound information base and engaging the public in its conduct. It was essentially organized into eight components: contaminants, nutrients, food chain, drinking water, aquatic uses, hydrology/sediments, traditional knowledge and synthesis/modelling. The relevant component for this study is aquatics, and focuses on the study objective: "Who are the stakeholders and what are the consumptive and non-consumptive uses of the water resources in the river basins?" (Meisner 1997).

Given that there were no existing data bases describing northern resident use of the basins for aquatic resources, a survey[15] was designed and conducted as the most effective tool to obtain this information. The survey questioned households on revealed (actual) fishing behaviour, as opposed to stating their choices for hypothetical alternatives sites. Furthermore, unique to this survey was that the sample was not based on those who held Alberta Sport-Fishing licenses, which are typically used as a sample universe for sportfishing surveys. Instead, it was localized to the residents within Athabasca, Peace and Slave River regions, and includes aboriginal users without licenses but excludes anglers residing outside the region such as anglers from Edmonton, the nearest major center.

The household survey involved contacting a random, stratified sample of a total of 2,621 households in order to find 1,400 that were willing to complete the survey. In the study 714 questionnaires had been completed. After deletion of non-response to origin/destination and compensating for low site frequency (less than 10 visits), the sample size equalled 344. The question in the NRBS survey that pertained to this research was Question 40:

> "List in order of preference, the sites on rivers and lakes that you and members of your household visit most often for recreational purposes.

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[14] This section is paraphrased and adapted from Meisner (1997).
[15] This survey was identified as Project 4121-D3.

Also, indicate the usual activity on these trips, the number of trips to each site in an average year, and the main purpose for preferring this site."

4.2 LAKE CHOICE SET

In order to simulate scenarios in the integrated ecological economic model, it was necessary to choose a choice set. This is the set of fishing sites that are considered a system of substitute sites for the population surveys in the NRBS. The lakes in the choice set are site destinations from Question 40, close enough in proximity to be correctly assigned as substitutes for one another. Also, for the purposes of this study, the sites had to have walleye data available from the same year as the survey. The list of lakes in the final choice set (as described in Figure 1, Chapter 1) is Amisk, Baptiste, Beaver, Calling, Lac La Biche, Long, North Buck, Pinehurst, Skeleton, and Touchwood.

Of the 344 households in the NRBS survey, 295 indicated that they went *fishing* in the year of the survey. From those 295 angler households, 72 angler households fished at *rivers only* and 223 households *fished at lakes* or fished at *both lakes and rivers*. Out of the 223 households that fished at lakes, 46 respondents went fishing to *at least one lake* within the choice set. Within the 46 respondents who went fishing to the choice set lakes, the *average* per household number of angler trips taken within the choice set that year is 14.11, with a *minimum* of 1 trip and a *maximum* of 104 trips and a *total* of 649 angler trips.

4.3 RELEVANT VARIABLES FROM THEORY

In the recreational fishing literature, numerous variables are included when modelling angler preferences. Many studies have used their model to help specify which variables are important in angler site choice. (Refer to the literature review in Chapter 2 for examples of these studies). In recreational fishing models, the two types of variables[16] often used are site specific attributes or angler specific demographics.

In McConnell, Strand, and Blake-Hedges (1995), past research is summarized pertaining to various angler success measures used in random utility models. Some of these previous measures used to define the angler success are: annual catch rates, expectations of catch, catch rate per species sought, average number of fish caught per trip, mean pounds of fish caught per fishing unit effort, mean catch per angler, and percent of anglers that caught at least one of target species. A disadvantage of many of these measures of success is that they are based on the angler's perceptions and prior expectations of the site, rather than an objective measure of the quality of fishing at a site. The angler success variables used for the conditional logit in this study are examined in more detail in the next part of this chapter.

4.4 VARIABLES IN THE LOGIT MODEL

In order to estimate coefficients in the random utility model, several different variables were used. Described below are the variables that were statistically significant in the model and are later used in the integrated ecological economic model. (Other

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[16] In the data set, many lake specific attributes were available, but were purposefully excluded from the final model. For example, lake quality attributes such as Secchi depth and turbidity were highly correlated with the fish quality value. Likewise, the quality of pike populations were also very highly correlated with walleye population and were therefore not included in the model. Site attributes such as campsite number, beaches, swimming, day-use facilities, and playground did not add any explanatory power to the model. The reason for this may be that because the survey respondents live near the area, they were not as concerned about having extra facilities, campsites, and other entertainment while fishing. The presence of a boat launch is also a common factor in angler site choice but was excluded from this model because all of the lakes in the choice set have a boat launch and there would not be any variation between the sites in that variable. Demographic variables are also excluded from the conditional logit model. Surprisingly, the age variable did not add any explanatory power to the model, either as a linear or as an exponential variable. The gender variable was not significant either.

ecological and demographic variables did not increase the explanatory power of the model.)

4.4.1 Site Choice

The dependent variable in any travel cost model is the frequency of site choice or the proportion of total trips to each site in the choice set. In the NRBS survey, the number of visits to a site was obtained through Question 40 (above). In the conditional logit model, the frequency of visits was used as the dependent variable. (The frequencies are nonnegative integers or zero values for the outcomes in the choice set) and the software converts the number of trips to a proportion.

4.4.2 Distance Calculations

The distance travelled to a site is clearly an important factor for basin residents in choosing angling locations. The NRBS survey obtained information on household origins (by indicating the closest city or town) and the fishing site destinations in the past year. Distances were calculated on this data by Meisner (1997) using the Rand MacNally's TripMaker program. The distances are not converted to travel cost in either the conditional logit model or the integrated ecological economic model—thus, the distance variable is used as a proxy for travel cost. This proxy is taken into consideration when calculating welfare measure using compensating variation (Equation 11). The resulting welfare measures are estimated by converting utility to dollar values by including the marginal utility of money, which is further discussed in Chapter 6.

4.4.3 Lake Access and Cottage Access

A major concern with increased forestry in remote areas is the impacts that increases in access have on angling pressure and walleye populations (Gunn and Sein 2000). The "access" variable in the logit model is a sum of the total number of paved and gravel roads leading to each lake in the choice set. The "cottage access" variable is the number of roads that lead out to the cottages surrounding the lakes. These numbers were provided for each lake by Michael G. Sullivan, a Fisheries Biologist from Alberta Fish & Wildlife Service.

4.4.4 Quality of Fishing Index

Several popular indexes have been used to measure the fishing status. The one used in this model is the Quality of Fishing Index (QFI). The values for the QFI were provided by M. Sullivan (Fisheries Biologist) and were derived from creel surveys from the past years. The QFI considers both the catch rates and walleye length. The catch rates are essentially how *many* fish the angler catches per unit of effort and the proportional *size* of the fish is calculated as a stock density. These two factors give a single value to gauge the quality of fishing at any given site. Refer to Section 5.2.3 for further details and calculations of QFI.

4.5 RESULTS

A non-nested conditional logit model was estimated. The results for this model are shown in Table 2.

Table 2. Estimation Results for the Conditional MNL Model

Variable	Coefficient	t-ratio	p-value
Distance	-0.052918	-22.400	0.0000
Ln QFI	0.11933	6.240	0.0000
Access	0.799708	5.335	0.0000
Access squared	-0.0596256	-2.855	0.0043
Cottage Access	-1.12887	-6.610	0.0000

N = 460
Rho squared adjusted = 0.37192
Likelihood value = -927.2527

Estimation was performed in LIMDEP Version 7.0 (Greene 1995). The model analysed all the anglers that chose one of the lakes in the choice set at least once in their previous year of sportfishing. The overall significance of the model was very high. A likelihood ratio test yielded a χ^2 value of 1134.25, which was substantially greater than the critical value for a 5% confidence limit (P=0.05). The values for Rho squared adjusted, the likelihood value, and the total number in the sample are shown below Table 2. In the values found in Table 2, note that estimated coefficients that are positive can be interpreted as increasing the probability of choosing a fishing site while a negative sign implies a decrease in the probability of choosing a site.

Distance, which was used as a proxy for travel cost, was found to be highly significant and negative indicating that the larger the distance (and larger the travel costs), the lower probability of site choice, as expected.

The other significant variables in the conditional logit model have intuitively correct signs as well. The variable Ln QFI is the measure of the quality of fishing and is significant and positive. This means that a site with a higher quality of fishing attracts a higher proportion of anglers than a site with a poorer quality of fishing. In terms of angler site preference for access, there is a quadratic relationship. The angler prefers sites with increasing accessibility until a certain point, at which increasing access negatively affects their choice. The access squared variable is negative indicating that too much access is not desirable. The last variable used in the conditional logit model, cottage access, is essentially as a proxy for development. This coefficient is negative, indicating that Northern River Basins' residents derive disutility from cottage visitors and the implicit development at fishing sites.

In summary, the conditional logit model used here examines revealed preference data to measure the angler preferences for site specific attributes. These resulting coefficients have implications for angler site choice and frequency, and thereby the potential effects of biological impacts as well as impacts from various regulatory instruments. The next chapter will discuss the integrated ecological economic model where these sectors are combined.

CHAPTER 5: INTEGRATED ECOLOGICAL ECONOMIC MODEL[17] DEVELOPMENT

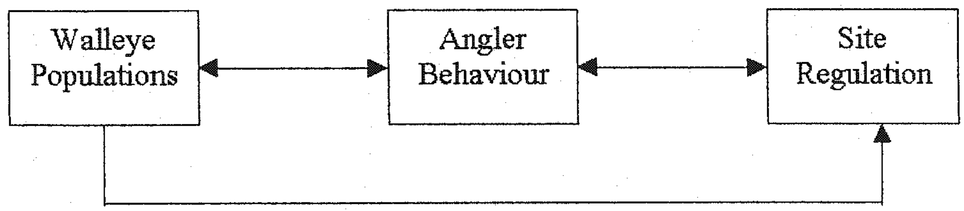
5.0 INTRODUCTION

The integrated ecological economic model is the next step in modelling the dynamic relationship between fish populations and angler utility. This chapter will focus on the development of the integrated model and the analysis of the regulatory mechanisms.

5.1 OVERVIEW OF THE MODEL

The integrated model was developed in STELLA Version 5.1.1 (HPS 1997). This modelling program allows a dynamic representation of various elements within the model. The main objective is to incorporate population dynamics and angling activity together with periodic as well as instrument adjustments into the decision process for choosing the optimal type and level of regulatory instrument. The integrated model can be broken down into three main components: fish (walleye) populations, angler behaviour, and site regulation.

[17] The model code and additional information are available from the author.



Walleye Components	Angler Components	Regulation Components
Initial Population	Compliance	Access Limits
Spawning	Habitual Behaviour	Site Closure
Egg Production	Preferences to:	Single Lake Quota
Population Dynamics	- **QFI**	Multiple Lake Quota
Catch & Harvest	- Access / Cottage Access	Site Charges
Vulnerability & Catch Rate	- Distance	Size/Bag Limits
Quality Fishing Index (QFI)	Angler Welfare Measures	

Figure 4. Interactions Between Sectors

Figure 4 shows the interactions between the 3 basic components of the model. The walleye populations affect angler's site choice because the anglers are assumed to prefer healthy walleye populations (high Quality Fishing Index or QFI); likewise, the angler's site choice (and implicit angling effort) affects the walleye populations (and therefore the QFI) because as more anglers frequent an area, the more the fish populations are reduced[18]. The angler's site choice and walleye populations also affect the site regulations because mangers must implement angling regulations to the more visited, thereby often overfished lakes. These regulations in turn affect angler site choice. (Recall that the angler response to a change in QFI is assumed to be instantaneous with perfect information, when in fact the learning rate may be slower.) In the next part of the

[18] Johnson and Carpenter (1994) indicate that there are definite strong feedbacks in both directions between anglers and fish populations.

chapter, each of the key variables identified in Figure 4 for each component will be discussed in terms of a dynamic integrated model.

5.2 WALLEYE POPULATION

The biological component in this model is vital to the integration of the walleye populations and human behaviour. The dynamic walleye model was developed by Michael Sullivan for one typical northern Alberta lake and its fish population. The walleye component includes the following sectors: spawning, egg production, population dynamics, catch and harvest, vulnerability and catch rate, and size/ bag limit effects. The population model also includes such variables as the age structure of the stock, the age at first spawning (deposition or fertilization of fish eggs), fecundity (average number of eggs each age fish can produce), growth rate of the fish, natural mortality (the rate at which fish die from natural causes), and fishing mortality (the rate at which fish die from being harvested). This version of the model assumes that walleye populations have no threshold below which they are extirpated. This provides an elastic simulation of the walleye populations and provides a very conservative estimate of walleye collapse in the model. Figure 5 provides a basic diagram of walleye population dynamics used for the integrated model.

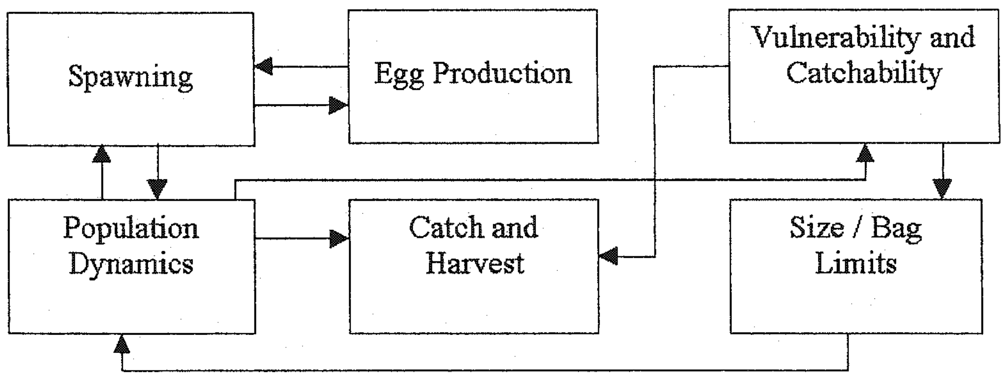


Figure 5. Walleye Population Dynamics

Each of the lakes in the choice set was assumed to have the same biological structure in terms of population dynamics, spawning rates, egg production, natural mortality, age specific vulnerability, and catchability. These lakes are all in the same region and do not have significant differences among them in these variables (Sullivan 2002). The initial walleye population for each lake in the choice set is assigned for year one of the simulation (1990) and are based on creel data from those lakes that year.

Although sport fisheries are known to be highly variable due to unpredictable recruitment and spawning randomness (Johnson and Carpenter 1994) the integrated model uses a deterministic rather than stochastic model[19]. The reason for this is to isolate the main impacts of policy options on fish population and angler utility from the stochasticity in the system. An extension of the methods developed here could be used to assess the distribution of impacts by running the simulation many times and constructing distributions of key outcome variables.

[19] Anderson and Sutinen (1984) remark that, "In several cases, optimal policy under stochastic conditions is qualitatively different from optimal policy under deterministic conditions. Such differences are not unambiguous. Two empirical studies (Lewis 1982, Smith 1980) conclude that deterministic policies are reasonably good substitutes for stochastic policies on average."

One of the main outputs of interest from the biological model is the quality of fishing index (QFI) because it is the connecting factor between walleye and humans. QFI is an indicator of the overall quality of sportfishing at a site and is comprised of two components: catch per unit effort (CUE) and proportional stock density (PSD). This is described in detail below.

5.2.1 Catch per Unit Effort

The CUE is a measure of angler success that is related to *how many* fish there are; the higher the catch is for every hour of fishing, the higher number of fish (and higher quality of fishing) the lake has. At each lake, the catch rates are assumed to be the same for each angler. This makes the assumption that every angler has the same skill level in fishing and will catch the same number of fish, given the same conditions. When biologists sample a large lake or river, they use catch rates as a population index. Catch rates are nothing more than the number of fish captured during a sampling period, in this case, expressed as catch per hour. In the model developed here the lake specific CUE is the total catch divided by lake total angler effort and lake area:

$$\text{CUE} = \frac{\text{CATCH}}{\text{hours per hectare} * \text{lake area}} \tag{12}$$

Changes in catch rates suggest increases or decreases in the population; the higher the high catch rate, the more fish in the population. Catch rates alone, however, can be misleading. For example, a lake with large numbers of small walleye could have a very high capture rate, but a poor population of large fish. To account for this, one can study a site's proportional stock density or PSD.

5.2.2 Proportional Stock Density (PSD)

PSD is the other indicator of angler success commonly used to characterize fish populations (Anderson 1976; Gabelhouse 1984). Those sites dominated by small fish have a low PSD value, while populations with large fish have a high PSD value. PSD can be defined as a ratio of the number of fish of a "quality size" in a population to "stock size" fish.

$$PSD = \frac{\#\text{ of fish} \geq \text{minimum "quality" length}}{\#\text{ of fish} \geq \text{minimum "stock" length} } *100 \quad (13)$$

In Equation 13, "quality" length is unique for each species of fish, but is usually the minimum size that most anglers will keep and tends to be within a range of 36 to 41% of the world record length" (U.S. Fish and Wildlife Service 2002; Murphy and Willis 1996). The record size for a walleye caught in Alberta[20] is 90 cm, therefore using 36-41% of the record, "quality" lengthy would be 32-37 cm. Because this range is smaller than the allowable walleye size limit, for this model the "quality" length used in the model is 50 cm. The "stock" length is also species specific and is the smallest of the standard length category, usually within a range of 20 to 26% of the world record length and at or near which a species reaches maturity (U.S. Fish and Wildlife Service 2002; Murphy and Willis 1996). In this model, the "stock" length is calculated using the standard 20 to 26% of 90 cm, thus the "stock" length ranges between 18-23 cm.

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[20] The record walleye caught in Alberta was in 2000 by J. Smith in Pembina River. The walleye measured in at 90.0 cm, with a weight of 15 lbs. 8.0 ozs. (Alberta Outdoorsmen 2002).

5.2.3 Quality of Fishing Index (QFI)

Recall that the QFI is an indicator of the overall quality of sportfishing at a site and that anglers are assumed to prefer sites with a higher QFI. Equation 14 uses the site specific CUE and PSD to form QFI:

(14) $$QFI = CUE * PSD, \qquad \text{therefore,}$$

$$Ln\ QFI = Ln\ (CUE * PSD)$$

The angler behaviour component of the model incorporates the initial 1990 walleye Ln QFI value and the coefficient derived from the conditional logit model for Ln QFI. (The natural logarithm of QFI was used in the specification as it smoothed the original highly variable data). By using a fish index that considers both size and quantity, it is possible to compare a wider variety of sites. For example, if the fish populations are low, but the average forklength of the fish caught is high, then the fishing quality could be contrasted to a lake where the catch rate was high, but the fish were small.

5.2.4 Fish Stocking

Another point to make note of in the biological part of the integrated model is the fact that there is no stocking of fish. The addition of fish to the original population by unnatural means is often not considered a biologically sound method to stabilize a suffering population and may cause a loss in wild fish stocks (Post et al. 2002). One reason for this is that new recruits may exceed natural recruits, especially in small lakes. Another reason is that by artificially increasing the CUE by stocking, the number of anglers will increase, which may exploit the reproductive potential of wild population. Additionally, there is a problem of stocked fish cannibalising the smaller naturally produced juveniles, as well as suppressing the juveniles through predation and competition, ultimately leading to a accelerated collapse of natural stocks (Post et al. 2002). While fish stocking could be incorporated in such a model it would significantly increase model complexity.

5.3 HUMAN SECTION

In the representation of a sportfishery, anglers are an essential element, often being opportunistic and responding to changes in their quarry. This provides many of the dynamics and complexities to the sport fishery (Johnson and Carpenter 1994). Many models incorporate the "predator" and prey" and the interactions between both sectors. However, angling behaviour cannot be reduced to simply "predator" status because of several important distinctions between humans and other predators (Johnson and Carpenter 1994). Firstly, a reward for the angler does not necessarily mean death of the fish. Secondly, even a catch of sub-legal size may attract new anglers. And most importantly, the number of anglers is not necessarily restricted by the number of fish.

The integrated model incorporates the values from the conditional logit model presented in Chapter 4 to attempt to model the complexities of human behaviour and interactions. The logit model was estimated using a single year of data, individual household trips, and 100% angler participation (as opposed to including those that did not fish). Because the integrated model is dynamic and aggregated, the behavioural model used here is a modification of the logit model. The modifications are discussed below.

5.3.1 Distance

The distance variable was aggregated for the integrated ecological economic model because the software[21] used to simulate trips changes does not have the capabilities for analyzing individual trips. The aggregated distance from origin to lake was calculated to be the average of distances from the origins (in the Athabasca area) to the lakes in choice set. In effect, the model uses a "representative angler" who reflects the average characteristics (including distance) of the anglers in the study region. (The calculated distances are detailed in Appendix A.) This is a limitation to the integrated model, but because 86% of the respondents live in such close proximity to one another in the Northern River Basins study area, it was indeed possible to aggregate the distances.

5.3.2 Quality of Fishing Index (QFI)

The integrated model uses the QFI as the feedback mechanism between anglers and the lake populations. As walleye populations change, both in number and relative age structure, the angler preference for that site also changes. As the characteristics of a site improve, a higher proportion of anglers will choose that site from the choice set. This logit model represents the annual share of trips to each site. The expected value of the maximum of utility, or the "logsum" is used to represent the utility to the overall sample of anglers. The proportion that choose to go to each site is represented by Equation 7 in Chapter 2. A high QFI at a site leads to a higher proportion of the total angler population choosing that site. This higher proportion negatively affects that site's QFI in the next period, resulting in a lower QFI and less angler effort. These effects feed

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[21] The models are run in STELLA, a software tool specializing in dynamic simulations (HPS 1997).

back into the walleye populations. This dynamic behaviour continues for the 30-year period for which the model simulation is conducted.

5.3.3 Habit Formation and Learning

Habit formation or the impact of previous choices on current choice are often found to play an important role in recreational demand. However, models seldom contain previous experience with the site as a characteristic and few studies have analyzed site choice that is affected by inertia, variety seeking, habit effects, or learning (Adamowicz 1994). In the modelling of recreational fishing site choice, one must be careful to not misspecify quality attributes as "habitual behaviour" in the sense that a site is visited because it is the best choice, not because it is a formed habit.

To account for experience or habit formation, angler behaviour is assumed to be affected by the QFI for the previous two years. Therefore, if the QFI was excellent or poor in the previous years, the angler will "remember" and use that information in their decision of which lake to visit in the current year. The values for the previous year's QFIs are included in the present year's utility function as proxy for habit formation. The magnitude of the effects of the habitual behaviour parameters are based on Adamowicz (1994) and the calculations are presented in Appendix B. Since these habit effects were not derived from the NRB database, the model is also simulated without these effects to determine the sensitivity of the results to these temporal relationships. It was found that the habit effects made a difference of only between 0 - 3% increase or decrease in each site's annual utility.

5.3.4 Compliance

Compliance with regulations is necessary if the benefits from management are to be realised. Therefore, we can use compliance as a measure or indicator of enforcement performance (Sutinen and Hennessey 1986). Compliance is fundamentally a choice for individuals subject to regulation. The angler's behaviour can be assumed to be a 2-stage decision making process. First, the angler must decide whether to violate or comply. Second, the angler decides the extent of the violation, if any (Sutinen 1993). It is assumed that anglers act to maximize their own welfare and act in terms of expected value of the trips with or without compliance (Sutinen and Hennessey 1986).

In terms of sportfishing, the percentage non-compliance rate is the percent of sub-legal sized fish caught and not returned. In relation to Alberta walleye anglers, the rate of non-compliance with regulations increases with declining catch rates, leading to greater per capita mortality at lower fish abundance (Post et al. 2002). This human behaviour also tends to lead to depensatory mortality. Therefore, compliance is endogenous to the model and is dependent on catch per unit effort as a negative exponential relationship; people tend to comply with size regulations when fishing quality is good but violate these regulations when fishing quality is poor (Post et al. 2002). The proportion of Alberta walleye anglers in compliance tends to vary between 0.90 and 1, depending on the quality of fishing that year (Sullivan in press).

In the model, compliance is used indirectly in the angler preference model because it affects the fish populations. The rate of compliance and non-compliance (one minus compliance), fish vulnerability, angler effort, bag limits, size limits and hooking mortality are used in combination to derive the total fish mortality for a year. The lower the compliance rate, the higher the fish mortality. High fish mortality leads to a lower QFI, which negatively affects angler site choice and low QFI also provides incentive to further violate regulations.

There are several problems with using compliance as a tool to measure policy performance. A high level of compliance does not necessarily mean that the policy is either cost effective or efficient (Sutinen and Hennessey 1986). Secondly, the extent of the overall compliance is not actually known. The available data only measure detected non-compliance and not the actual level of compliance (Sutinen and Hennessey 1986). Although a number of documented infractions is known, this is merely a subset of the total non-compliance.

5.3.5 Option to "Stay Home"

The data used in the logit model to obtain the parameters for the integrated model contained only households that actually went fishing in one of the sites within the choice set. However, in a dynamic model, it is necessary to create an option that lets anglers have the option to stop fishing or go to a new fishing area outside the choice set if the site conditions are unfavourable. To account for this possibility, an option to "stay home" was created with a constant value for utility. The "stay home" utility is calculated on the initial year of the simulation so that for that year virtually 100% of the anglers go to one of the fishing sites in the choice set. If during the simulation the angler utility drops (due to low lake specific QFI and imposed regulations), they are not "forced" to go fishing.

5.3.6 Summary of Model Utility Components

The human behavioural model derives from each site for each year the aggregate angler utility. Each of the previously described components of the model affect the utility, either directly or indirectly. The variables that directly affect utility are: Distance, QFI, Access, Access^2, Cottage Access, and Habitual Behaviour. Therefore, given the estimates from the logit model (Table 2), the site-specific utility at a lake is:

$$\textbf{UTILITY} = 0.799*access - 0.0596*access^2 - 0.0529*distance - 1.13*cottage + 0.119*LnQFI + 0.03*habit1yr + 0.015*habit2yr \quad (15)$$

5.4 REGULATIONS

The third component of the integrated model is the implementation of regulation and policy. In the simulation of various policies, one must recognize the unfortunate reality noted by Pena-Torres (1997), "Most management techniques have some advantages, but all have disadvantages; several will work well when conditions are right, but none will work well under all conditions". Therefore, it is necessary to find policy that will work within the conditions of the choice set and angler populations. The following section in this chapter outlines the various policies simulated in the integrated ecological economic model.

5.4.1 Access Limits

When access to fishing sites is created, perhaps by forestry roads, it appears that these sites are also quickly affected by angling pressure (Gunn and Sein 2000). A method to model the effects of forestry road networks on fish populations is to add access to a site previously inaccessible. In the simulation model, a hypothetical[22] new lake can be added to the choice set, called "Lake X". It is a lake that initially has a relatively large walleye population, due to no angler access. To simulate zero access, travel cost is set to a very high level resulting in zero angler effort. When site access is added, Lake X becomes an additional option just as the other lakes in the choice set are.

5.4.2 Site Closure

Rather than adding access to a lake, the other extreme is to close a lake by either restricting all fishing activity or by closing access roads. The reason for a closure rather than the traditional catch and release regulation would be to further protect the walleye populations. In fact, some believe that any lake with a conservation issue due to vulnerable populations should be closed because catch and release does not prevent hooking mortality[23] (Meredith 2000).

In the model there are several possible methods to simulate a site closure. The first method is to choose a "known vulnerable site" at the beginning of the simulation, close that site, and let the fish populations recover at that site over the duration of the simulation (diverting angler pressure to other sites). The other method is to use annual site specific fish population values as an indicator of fish population stability; if the fish population for the previous year is too low, the site becomes closed for the next year. (This can be used for one vulnerable site or for multiple sites). In both methods of site closure, the site is closed within the model by giving the closed site "zero access" so that

[22] Although hypothetical, the values for the parameters for this lake are realistic and are listed in Appendix C along with the summary of values used for the other sites.

the model recognizes travel costs as infinite and the proportion of anglers choosing that site becomes zero.

5.4.3 Quota on One Lake

An alternative to closing a site completely is to put a quota or limit on the number of angler hours allowed for a lake in one season. This would be done by a draw system similar to that used in Alberta hunting regulations. Anglers would draw an "angling weekend" at a lake and only those with permits would be allowed to fish at that site. By regulating fishing pressure (hrs/ha) at one site, the excess angler hours get transferred to the other sites (or the option not to fish) in order of preference derived from site utility[24]. Anglers can be affected in two ways by the implementation of quotas. First, they may not be able to access their favourite sites and are forced to move to a less preferred (and less overfished) lake. Second, they may experience QFI levels that differ from those without quotas because of the impacts of quotas on fish populations. These changes affect the new angler utility and resulting welfare measures.

5.4.4 Quota on All Lakes

Instead of quotas on a single lake quotas could be implemented on all lakes. If angling pressure exceeds a certain threshold it gets redistributed among the lakes according to preference. The change in angler utility after the imposition of the

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[23] Hooking mortality occurs when a fish is released and has been injured to the point that it dies. In this model, hooking mortality is set at 10% (Sullivan 2002).
[24] Because the change to the proportion of anglers at each site occurs exogenously to the model, the implementation of the policy is not captured by using a simple logsum. See Appendix D for a detailed explanation of change in utility.

regulation calculated in the same fashion as for the single site quota case. The "extra" hrs/ha from the anglers choosing the restricted sites are summed and redistributed to the lakes that have less angler pressure.

5.4.5 Site Charges

Another method for reducing angler effort at a site is to add a site-based fee or charge. A fee will implicitly reduce the preference for a site and cause anglers to go to other lakes. The addition of a fee is equivalent to increasing travel costs to a site. It is assumed that there are no transactions costs in administering the fee system.

5.4.6 Change in Bag Limit / Catch and Release

Bag limit restrictions are a common method to control the number of fish legally allowed to be taken by anglers. However, these restrictions have limitations. For instance, the bag limit has much more effect on better anglers where the probability of (catch≥limit) is high. For many anglers, the probability that (catch≥limit) will be zero, so the bag limit will have zero effect (McConnell et al. 1995). Also, the bag limit inherently restricts the number of fish kept, but not the number caught. This raises issues with hooking mortality; anglers who catch and release are still causing mortalities, even when they are not keeping their catch (Meredith 2000). However, even with the problems that arise from limiting catch numbers, it still is a somewhat effective and politically feasible tool for sportfishing.

In the model, the bag limit can be varied between two size categories: walleye <50 cm and walleye ≥50 cm. To make a site catch and release (but not closed), a zero bag limit for each size category is imposed. However, in the integrated model, the feedback between angler utility and fish populations is provided by the variable QFI. Recall from Equations 12, 13, and 14 that the QFI is a function of fish *caught* not fish *kept*. Because the QFI may inevitably increase with this policy implementation, (even with hooking mortality), this model gives the impression of a much higher utility derived from this policy than would be realistic.

5.4.7 Change in Minimum Size

Minimum size limits are also common for most species of fish in Alberta lakes. The limits are set to accomplish the goals of limiting over-fishing and improving fishing quality through increasing average size of fish caught (Homans and Ruliffson 1999). The model has the capability to make site specific size regulations on a yearly basis to the scale of 15 size categories. The option of catch and release for a particular size of fish can also be done with the size limit by restricting a size range for a lake as "protected" (and therefore zero limit for that size range). This level of detail for simulating site specific annual size restrictions is not explored in this research, but would be interesting as a further study. The next chapter will show the results from the various regulation and policy simulations.

CHAPTER 6: RESULTS AND DISCUSSION

6.0 ORGANIZATION OF RESULTS

The results from the integrated ecological economic model are presented in this chapter in the following manner. Firstly, the predictions from the integrated ecological / biological model will be compared to the "true" values for each of the 10 lakes in the model. Then, each scenario / regulatory instrument will be presented separately in the form(s) relevant for that simulation. Following the results from each scenario, the changes in welfare measures will be examined. Lastly, this chapter will provide a discussion of the results and compare them to the previous literature.

6.1 MODEL PREDICTION SUCCESS

An important aspect to mention in simulation models is the accuracy and prediction success of the model. The integrated simulation model began in 1990 and the resulting values from this simulation are used to assess the forecasting performance of the model. This simulation included angler behaviour as well as biological dynamics, incorporating 1990 initial values for 10 lakes with the following settings as the base case simulation:

Bag Limit for 0-50cm fish: 3
Bag Limit for 50+ cm fish: 3
All entry limits and fees are zero.
# of Angler trips for the area=50,000[25]

The actual walleye data for 2002 are not available for the choice set lakes, therefore QFI values from the most recent years (1996-1999) were compiled and used as best estimates in each case. In order to calculate the QFI for each of these lakes, creel data were used to find average walleye size and were multiplied by the catch per unit effort total. In the lakes where the walleye populations were so low that there was no value assigned for average catch size and catch per unit effort total, fishing derby competitions were examined to estimate angler catch rates, which had QFI values near zero. Table 4 below provides a detailed assessment of the model predictions compared to the actual data.

Table 3. Comparison of Simulation and Actual Lake QFIs

Lake *Simulation*	**Predicted* QFI for 1996, 1997, 1998, 1999**	**Quality Category**	**Lake, year** *Actual Data*	**QFI**	**Quality Category**
Beaver	6.25, 2.74, **23.54**, 33.67	High	Beaver 1998	35.87	High
Pinehurst	15.61, **11.67**, 54.84, 79.15	Medium	Pinehurst 1997	34.61	High
Calling	3.24**, 2.60, 7.65, 11.79**	Low	Calling 1996	22.90	High
Touchwood	**15.45,** 11.8, **55.53, 79.47**	Medium	Touchwood 1997	17.48	Medium
Baptiste	5.43, 2.74, 20.1, **26.25**	**High**	**Baptiste 1999**	6.34	**Low**
Long	0.00, **0.00**, 30.22, 0.30	Low	Long 1996	0.30	Low
Skeleton	1.49, 0.34, **7.68**, 8.14	Low	Skeleton 1997	≈ 0	Low
North Buck	5.61, 3.63, **23.47**, 32.14	High	North Buck 1998	≈ 0	Low
Lac LaBiche	**0.68, 0.58,** 0.65, **1.05**	Low	Lac LaBiche 1998	≈ 0	Low
Amisk	0.85, **0.23**, 2.43, 2.73	Low	Amisk 1996	≈ 0	Low

* The bold font value corresponds with the recent year for which actual lake data were available.

The first set of numbers are the QFI predictions from the integrated ecological economic model from 1996 through 1999. The second set of numbers is the actual

[25] This is approximately the number of angler trips for this choice set of lakes (Sullivan 2002).

value of QFI in the year specified. The third and sixth columns represent the relative lake qualities, where Low is a QFI less than 10, Medium is a QFI between 10 and 20, and High is a QFI greater than 20.

The performance of the model was generally very good. For most of the lakes that showed a low QFI in the simulation, the actual lake data indicated "Low" populations as well that year. Also, most of the lakes that showed a "Medium" or "High" relative fish population in the integrated model corresponded correctly to the actual data. The exceptions were Baptiste and North Buck lakes that showed high QFIs in the integrated model but in fact, were low that year. Also, Calling Lake had a high QFI in the simulation but the actual data showed that the walleye population was low that year. However, in lakes such as Pinehurst, the simulation gave a "Medium" value rather than a "High" value. Examining the Pinehurst simulation values for the next two years, the population at Pinehurst is increasing, which would make the predicted values much closer to the actual values.

Because this model of the lakes and angler behaviour has no periodic regulations imposed on the base model, some discrepancies are to be expected. Anglers and lakes have a high degree of natural and human variability. There could be new parameters and factors entering the actual data that are not part of the simulation model. Therefore, given the variability in the natural systems and the variability in the data collection, the model prediction is deemed to be acceptable and, (if need be), can be calibrated for future research.

6.2 REGULATION SIMULATION RESULTS

Each of the policies that were simulated in the integrated ecological economic model was purposefully chosen to illustrate the effects of a specific regulatory instrument. The addition of access to a previously inaccessible site is chosen because of its importance in boreal forest management, and is essentially an independent case study. By modelling access to a new site, researchers can better forecast issues for ecosystem management. The site closure policy is chosen because this is what agencies often do in Alberta, and the inclusion of the bag limit simply illustrates the impact of this popular policy approach. The quota is chosen as an alternative to maintain a more "orderly" and well defined QFI. Finally, the fee case-study is chosen to forecast both the effects of a walleye-population dependent fee and a constant fee, which are later compared to the individual site quota.

These policy simulations in the integrated model can be assessed by several indicators of regulatory change. These indicators are the QFI (to assess resulting fish populations and age structure), angler pressure (hrs/ha) at each lake, proportional changes of % of anglers to a site and % of anglers that choose to stop fishing. For each scenario, the corresponding figure contains several representative lakes from the choice set to portray general patterns rather than show each lake separately. There are also resulting changes in angler utility and welfare measures that will be examined later this chapter.

6.2.1 Opening Access to a Previously Inaccessible Site

To simulate the effects of new access to a previously inaccessible site, a new hypothetical lake[26] termed Lake X is opened to the anglers with 2 points of road access (no cottage access). Because the lake was previously not fished, the initial fish populations were very high. By adding access to this lake one can see the possible effects this change will have on both the fish populations and the anglers.

The impact on the QFI at Lake X is depicted in Figure 6, which shows the change in QFI from before the site was accessible to after the site was opened. The negative values on the graph indicate the steep drop in walleye populations upon opening the site. Initially, the walleye populations are highly variable, and then the populations continue to fluctuate but are, as expected, much lower than if the lake had not been opened. The other lakes in the simulation remained either unchanged or fluctuated only slightly, with the QFIs generally becoming higher at the other lakes.

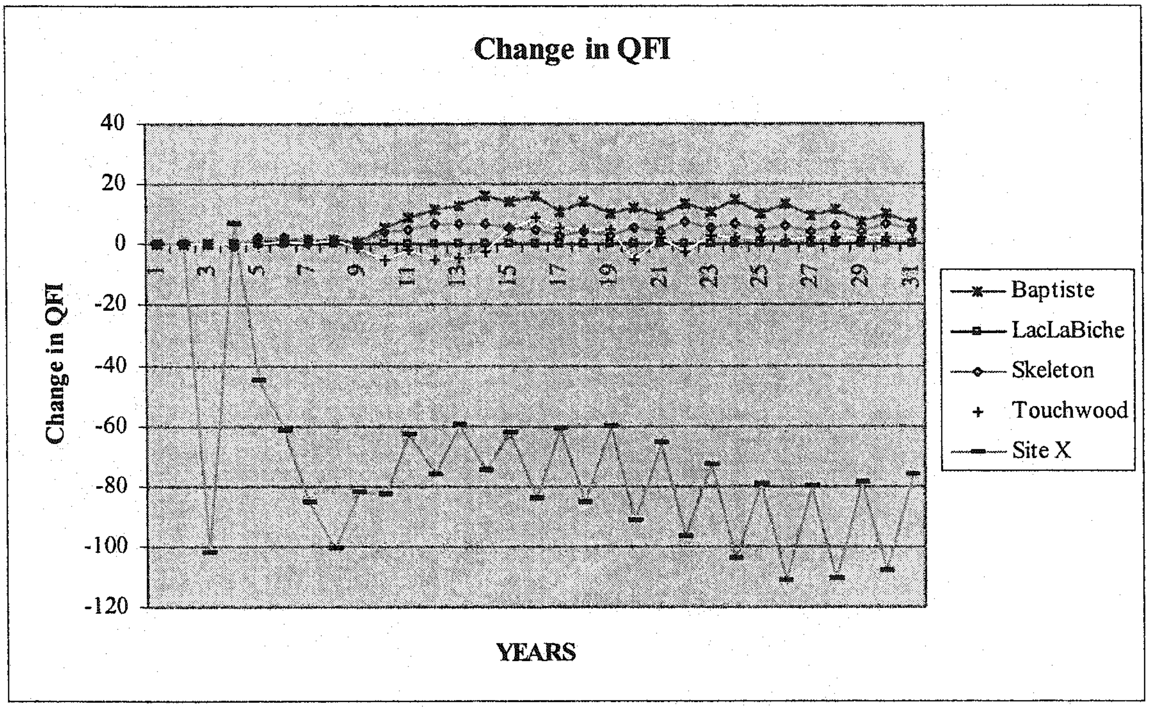

Figure 6. Change in QFI After a Opening a Previously Inaccessible Lake

In order to interpret the effect that the introduction of the new site had on anglers, both the resulting change in site angler pressure and the change in proportional site visits can be examined. In Figure 7, the change in angler effort is compared in angler hours per hectare. Lake X, which had zero angler effort when inaccessible, increases to about 5-7 angler hours per hectare. The angler effort at the other lakes largely decreases, especially at lakes such as Skeleton and Baptiste because Lake X supports some of the angling pressure. Other lakes such as Lac La Biche were not affected very much by the new lake opening.

[26] More detail about Lake X are given in Chapter 5.4.1 and the site characteristics for Lake X are in Appendix C.

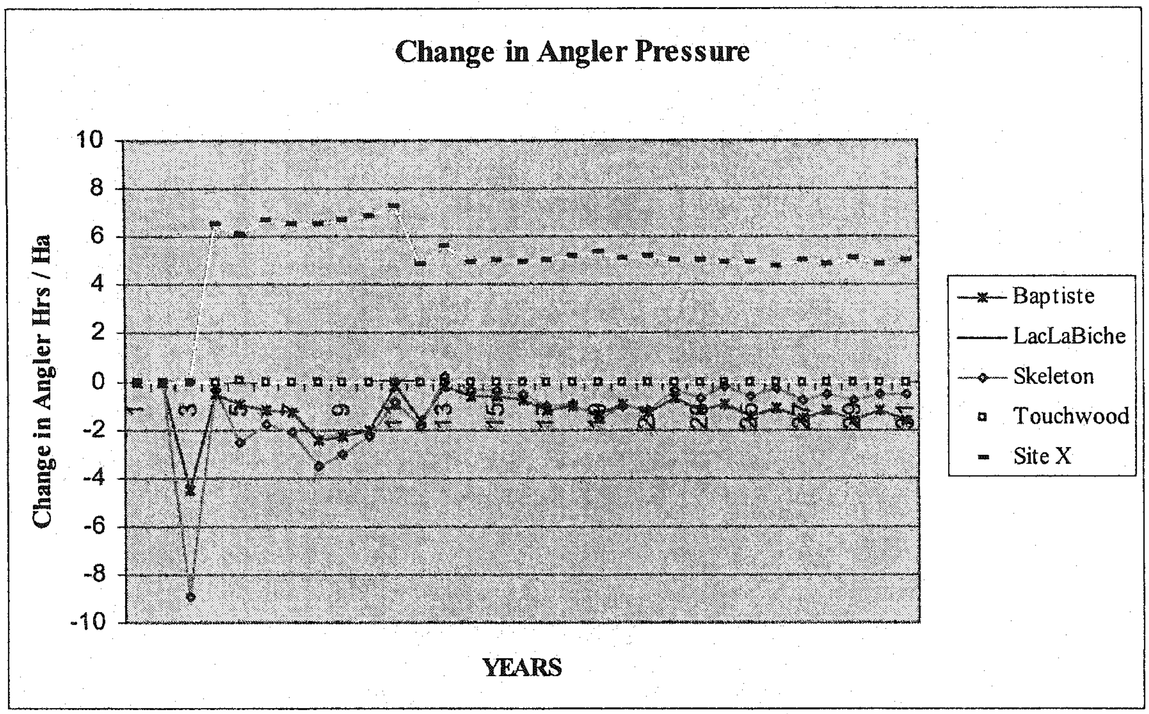

Figure 7. Change in Angler Pressure After a Opening a Previously Inaccessible Lake

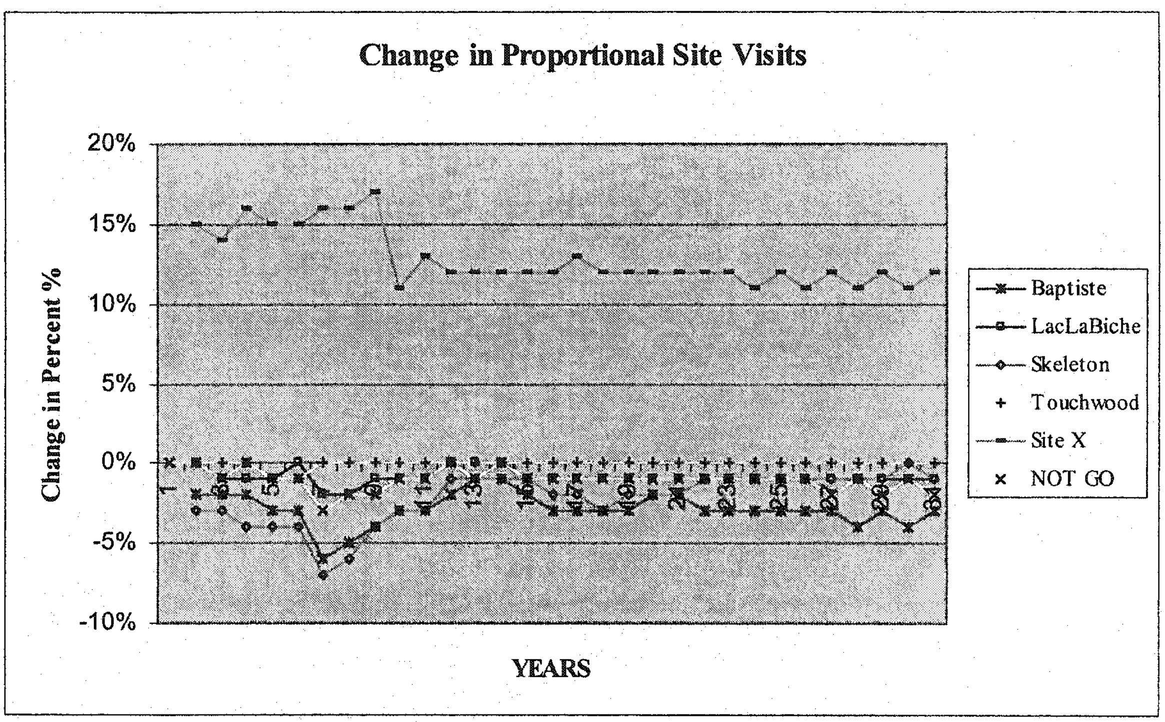

Figure 8. Change in Proportional Site Visits After a Opening a Previously Inaccessible Lake

Another way to assess the changes in angler behaviour is to examine the changes in the proportion of site visits. In Figure 8, Lake X experiences gains between 10 and 20 percent of the angler population with a larger proportion earlier in the simulation and falling slightly as the simulation continues. Because Lake X gains new site visits, the other sites thereby lose some of the proportion of the angler visits. It is also interesting to note that the change in percent of anglers not going fishing decreases, i.e. more anglers start to fish because of the better fishing conditions, although this effect is very small. The results from the site access case can be seen as a test of the model performance to give the model credibility. The results are intuitive and appear to successfully project the expected outcome as described in previous literature and therefore show that the model can be used to simulate the opening of new sites.

6.2.2 Site Closure

A common regulatory measure is the closure of a site or a moratorium on fishing when fish populations are low. The imposition of site closure on a previously fished lake causes large changes in the fish populations and in angler behaviour. The case shown in the results is closure for any site that has a low fish population the previous year. Therefore, if a site has a low number of fish in time *T-1*, the lake will be closed in time *T* and re-evaluated for opening in time *T+1*. Figure 9 shows the impacts on the QFI at several representative sites when this regulatory mechanism is used.

In many of the sites, the fish populations become highly volatile—one year the populations are high, the next year the anglers visit the site in large quantities and the fish population is depleted. This effect is termed the "whack-a mole" effect[27] because as soon as one lake appears to be recovering and is re-opened, the angler pressure becomes very high. The high level of fluctuations at each site does not lead to a higher overall stable QFI for any of the sites in the simulation. The response to the increase in QFI would be largely due to media and word-of-mouth. However, because the model assumes anglers have perfect information at all times, the speed and accuracy at which they detect the change in QFI (and switch fishing sites) is probably somewhat exaggerated in this model. However, while the speed of adjustment may be somewhat more rapid than expected, the pattern of response will probably continue to be as predicted.

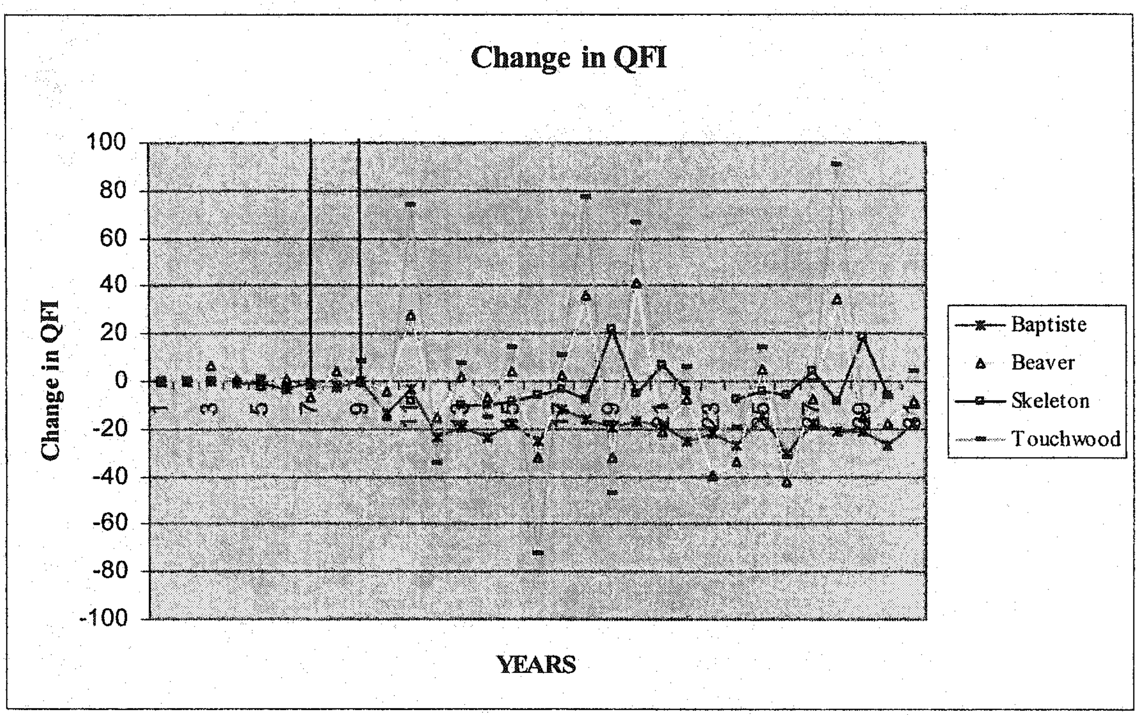

Figure 9. Change in QFI After Site (Population Specific) Closures

[27] This term is taken from the popular carnival game where the player is given a hammer and watches for moles to "pop-up" out of their burrow. The object of the game is to hit each mole as quickly as possible.

As expected, the drastic changes in QFI (due to the continual opening and closing of sites) motivate the anglers to switch sites accordingly. This causes the site visitation proportions and the site-specific angler effort to also be highly volatile. The variability of the angler effort to the lakes follows a similar pattern to the QFI; when the fish populations are high, the sites are reopened and the anglers frequent that site-- increasing fishing pressure at the reopened site.

An interesting observation from this policy instrument is the change in proportion of anglers that decide to not go fishing in a given year. Figure 10 shows the percentage of anglers that prefer to not go fishing rather than to stay in the highly volatile system. In some years when more sites are open, more anglers want to fish. However, when an angler's favourite sites are closed, there is less benefit for the angler to go fishing. Figure 10 shows that the percentage of anglers who stop fishing (due to the regulation) reached as high as 6% in the seventh year of the simulation.

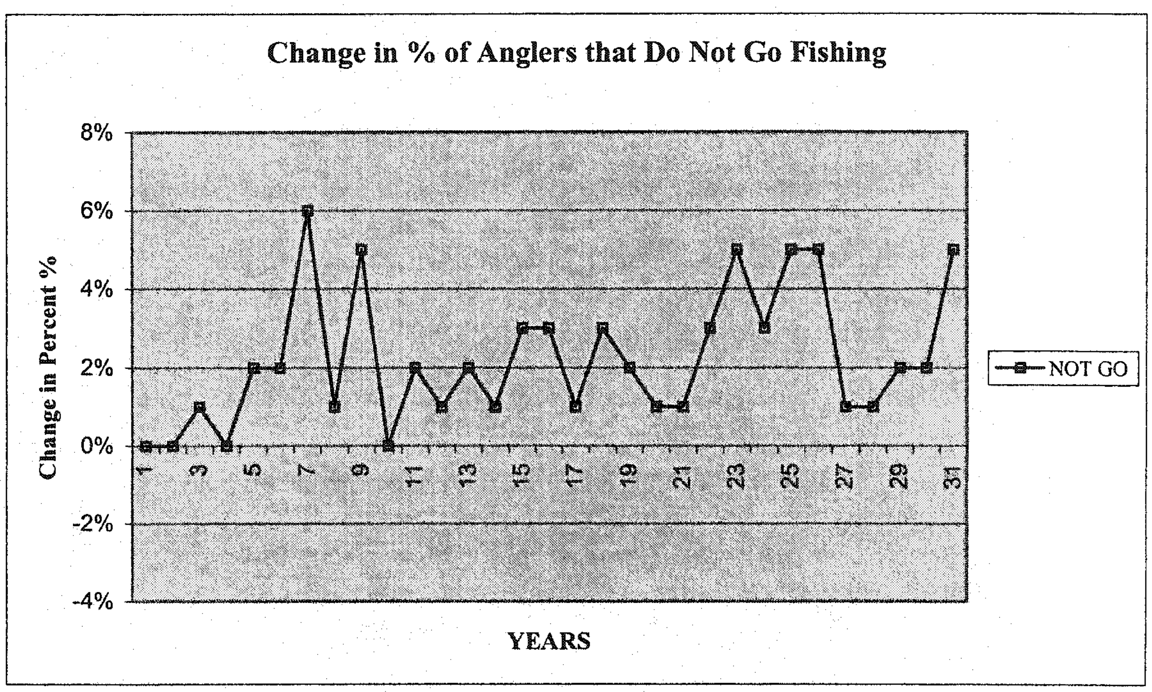

Figure 10. % of Anglers that Stop Fishing after Site (Population Specific) Closures

6.2.3 Lake Quota

An alternative to using a reactionary / responsive measure (such as site closure based on a poor fish population), is to use a preventative measure such as setting a quota on angler effort *before* the lake collapses. The quota is designed to "sustain" the fish populations and have a less volatile biological outcome and can be implemented on an individual lake or set for all the lakes within the choice set. In the results presented here, the effects are shown first for a lake quota on the aggregated set, then on one individual lake.

Figure 11 below depicts the average change in QFI for the entire choice set at 4 levels of limits. This means that for each simulated quota level, the changes in QFI for each year were averaged to find the mean effect that the policy has on the entire choice set fishing quality. The legend lists Limit 7 - Limit 10, which refers to the limit on the amount of angler effort per hectare. The lower that the limit is, the more strict the quota is. Likewise, a limit of 10 angler hours per hectare is a less strict policy than only allowing 7 angler hours per hectare.

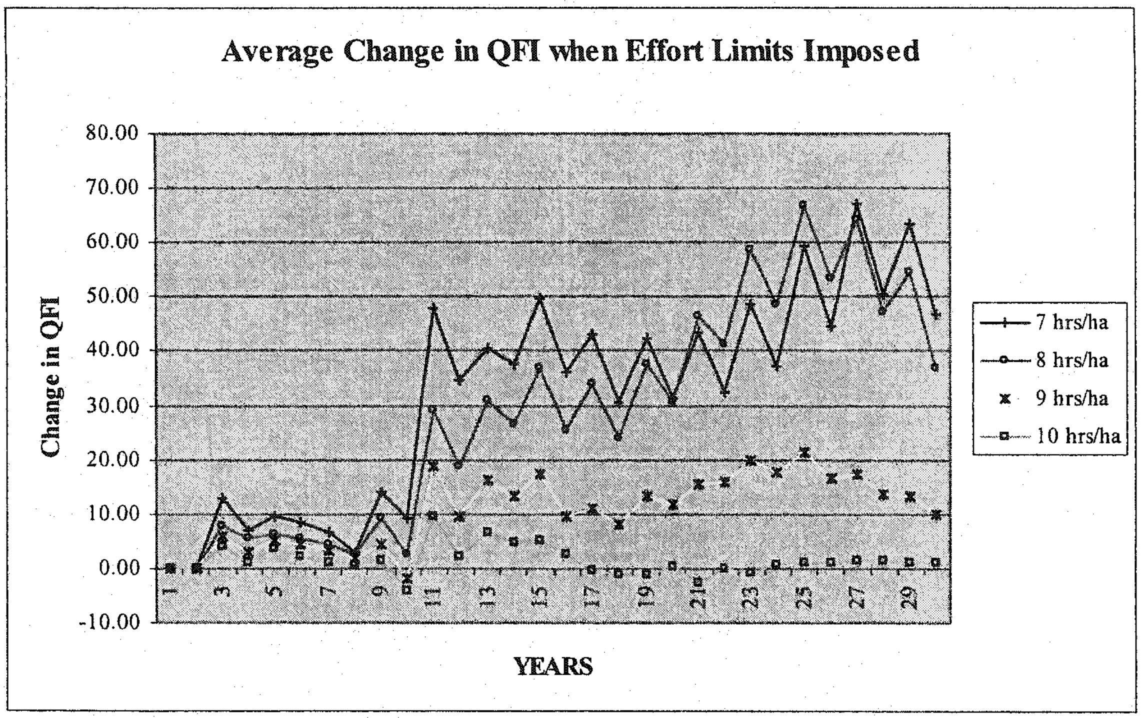

Figure 11. Average Change in QFI after Imposing Site Angler Effort Quotas

The limit of 7 hours per hectare and 8 hours per hectare lead to a higher QFI. This is because the anglers were forced to fish the lakes at a more constant pressure, rather than the volatile angler pressure that was seen in the Site Closure simulation. As the regulation becomes less strict (Limit 10), the impact on the resulting change in QFI is also lessened. This is because the anglers are not as restricted in their lake choice and most anglers are able to remain at the original site they chose before the regulations.

To examine the impact on angler behaviour, Figure 12 and Figure 13 depict the change in proportional site visits after imposing a quota at 7 hrs/ ha and a quota of 9 hrs/ ha respectively.

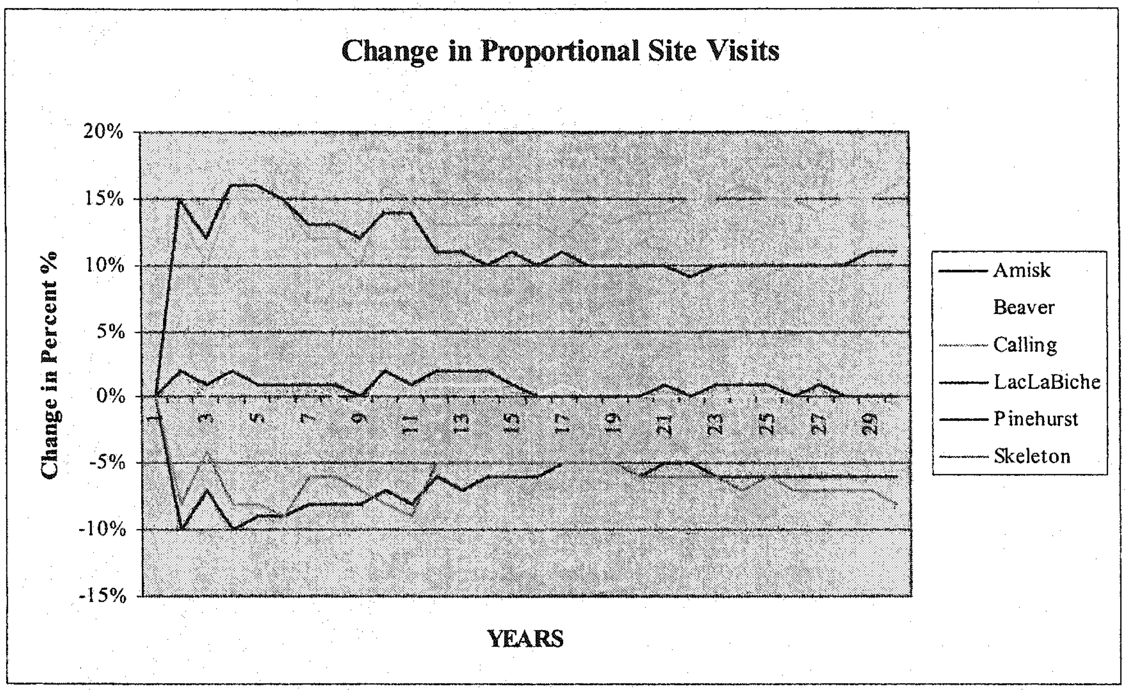

Figure 12. Change in Proportional Site Visits after Imposing Effort Quotas at 7 Hrs/Ha

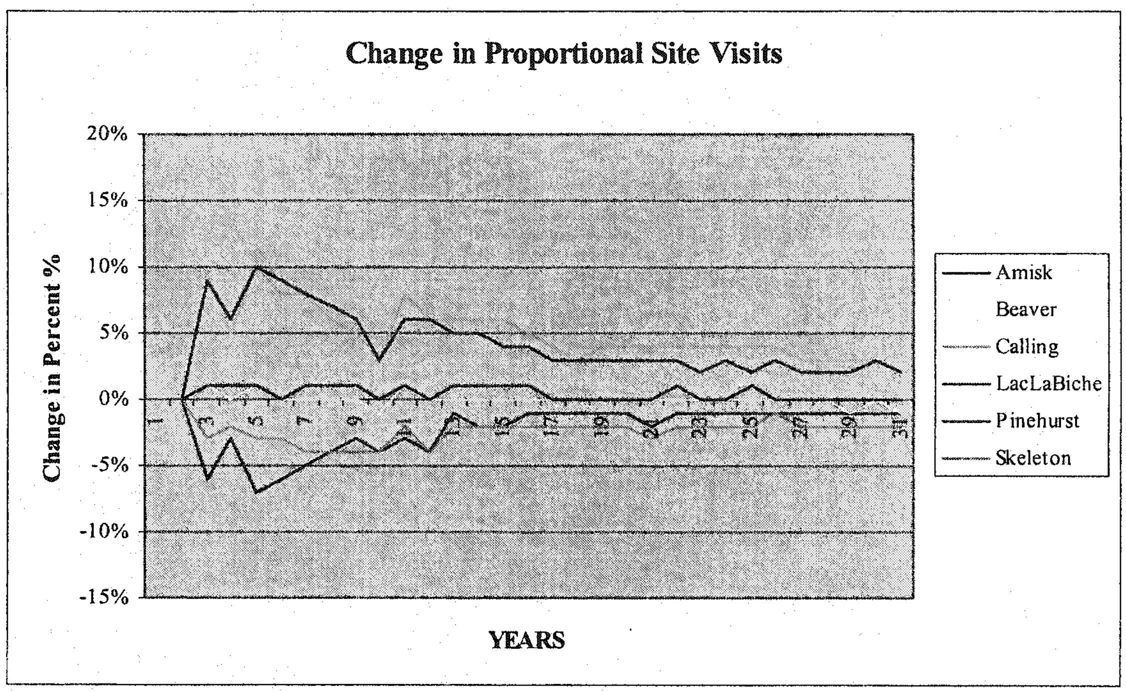

Figure 13. Change in Proportional Site Visits after Imposing Effort Quotas at 9 Hrs/Ha

Again, for simplicity only a select number of the lakes in the choice set are shown in order to give a clearer representation of the effects on angler trip distribution. The quota limits of 7 hrs/ ha and 9 hrs / ha were chosen as a midrange to show the general angler trend in response to the quotas. In Figure 12, Calling Lake and Lac LaBiche receive approximately 10-15% more angler trips each year after the 7 hr/ ha quota. These two lakes both have a large lake area so the proportional increase in anglers is to be expected when regulating based on angler effort levels as a function of area. Some lakes such as Amisk and Skeleton resulted in a lower proportion of the angler trips due to the implementation of the quota, perhaps due to their smaller lake area. Similarly, some lakes such as Pinehurst and Beaver were not greatly affected by the quotas. Figure 13 shows the exact same trends in the change in proportion of site visits, except that because the quota is less strict (limit of 9 angler hrs/ ha), there is a less noticeable difference in the changes in site destination.

Lastly, it is interesting to note the impacts on the anglers who decide to not go fishing due to the new policy levels. Figure 14 illustrates the percentage of anglers that previously had gone fishing, but then after the new regulation decided to not go. The percentage change is calculated for all four effort quota limit levels and ranges between an 8% decrease in angler trips to zero effect on angler trips. The stricter quota (7 hrs/ ha) has an initial high drop out of anglers and the least strict quota of 10 hrs/ ha has the least change resulting angler non-participation. Although the anglers stop fishing initially, the resulting increase in QFI causes some of the anglers that left to come back to fishing later in the simulation.

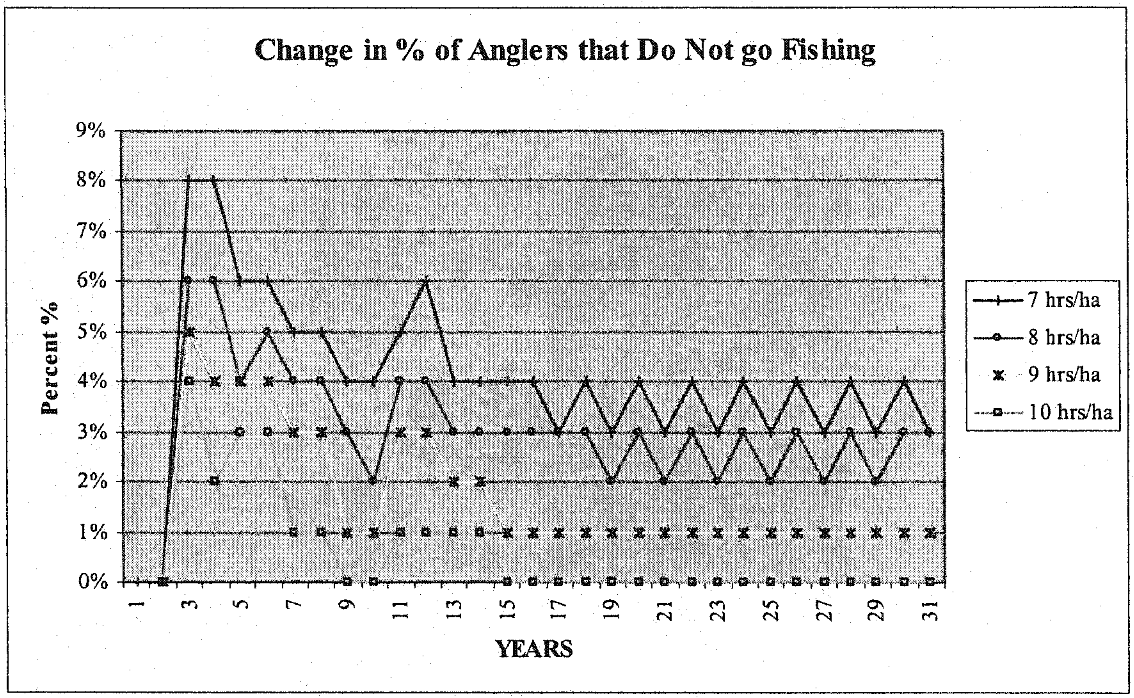

Figure 14. % of Anglers that Stop Fishing after Imposing Angler Effort Quotas

6.2.4 Individual Lake Quota

Perhaps more likely than implementing a quota on all lakes in an area is to start by regulating one lake as a trial, to see how the anglers and the fish populations respond. In this simulation, Skeleton Lake was chosen as the "test lake" because it has a low QFI and is a popular fishing destination. When regulating only one lake, it is possible (or at least more politically feasible) to make the policy stricter than when applying the regulation across all of the sites. In this simulation, the effort quota for Skeleton Lake is set to 6 hours per ha. Figure 15 shows the QFI change from before the regulation to after the quota was implemented.

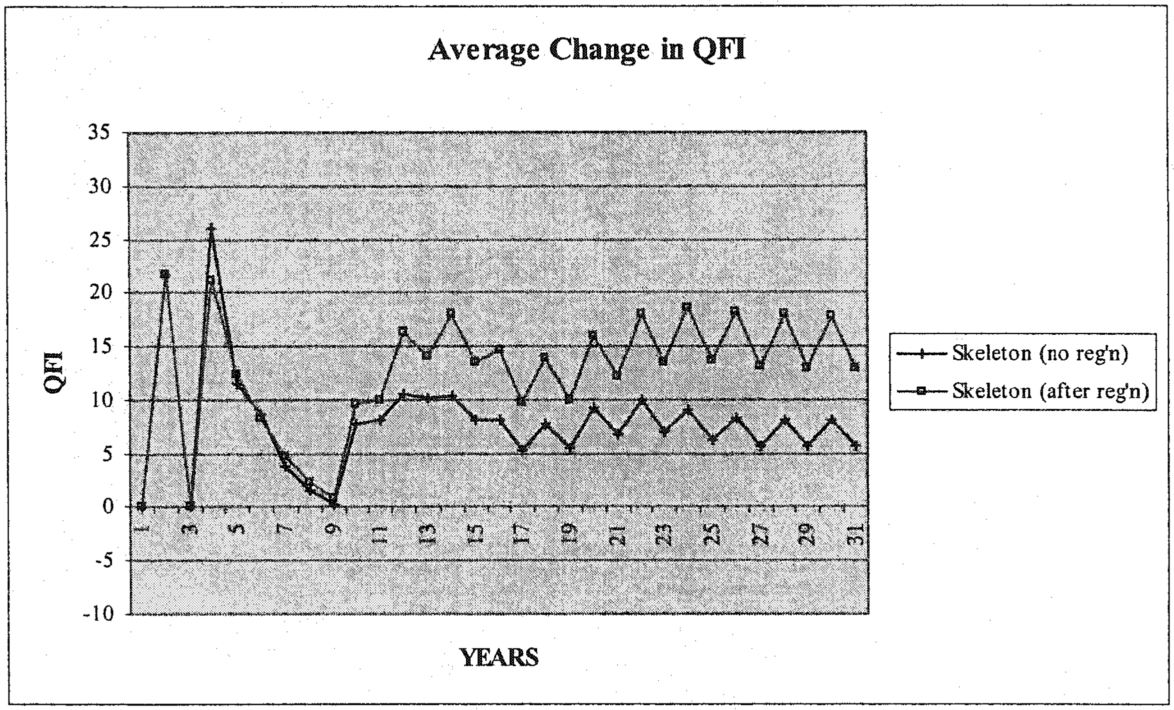

Figure 15. Change in QFI After An Effort Quota at Skeleton Lake

Initially, the QFI is unstable, having a large increase and decrease in the initial years. Once the population stabilizes, the QFI before the regulation fluctuates between 5 and 10. When the quota is implemented, the QFI at Skeleton Lake stabilizes between about 10 and 17. Figure 16 shows the change in angler pressure after the site-specific effort quota. However, this makes the assumption that the same behavioural model will apply in the situation with more complex regulation. It is possible that the increase in regulatory complexity may affect angler behaviour – perhaps causing some anglers to stop fishing or inducing other changes. This is an issue for further research.

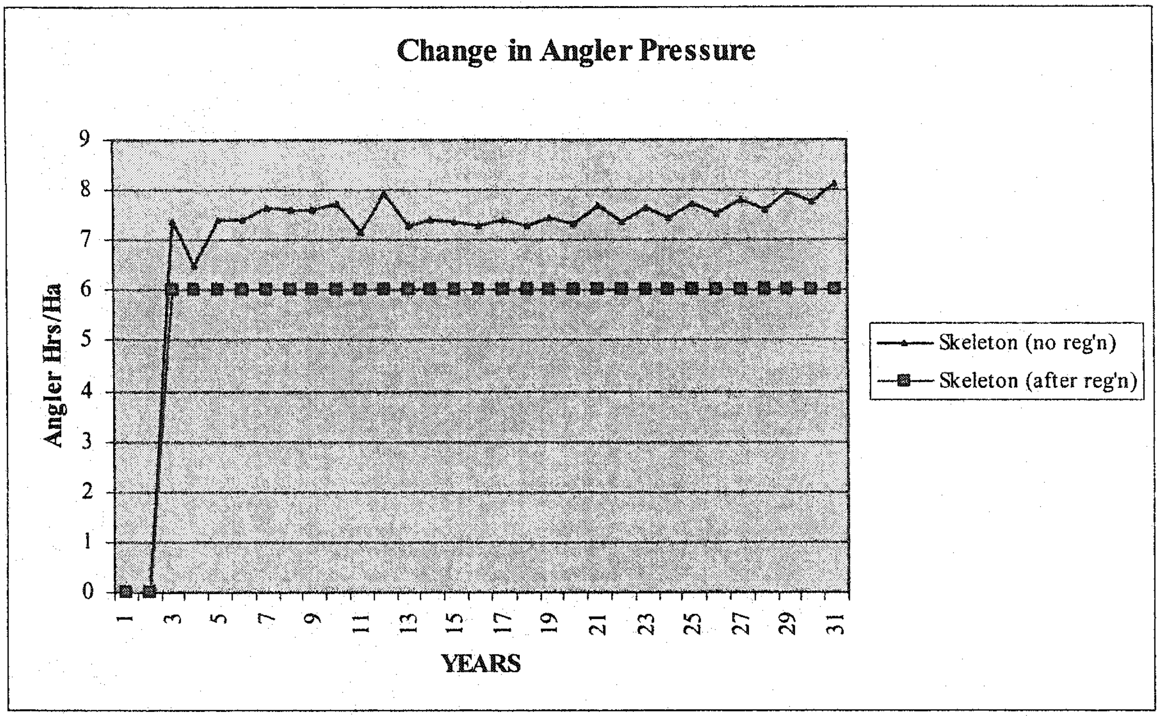

Figure 16. Change in Angler Pressure After An Effort Quota at Skeleton Lake

Before the effort quota was implemented, the angler pressure was ranged between 7 and 8 angler hours per hectare. The new angler pressure of 6 lowered the angler effort by approximately 1.5 hours per hectare. The resulting change in welfare measures will be mentioned later in this chapter.

6.2.5 Site Specific Constant Fees

Another method that can be used to reduce angler effort at a particular lake is to charge the anglers a fee for using a site. The fee can be set to any level at any or all of the lakes. In this simulation, Skeleton Lake is used again to compare the results from fees to that of the previous quota simulation. The first type of fee that is simulated is a site-specific constant fee. This means that the site (Skeleton Lake) is chosen before the simulation begins. (In the utility model, the fee is essentially an increase in distance, which was used as a proxy for price). The fee was set at –0.45 Utils, or $3.76 per angler site visit.

This specific fee was derived such that it would generate effort levels that are similar to those implements in the quota regulation. The site-specific effort quota at Skeleton Lake was set at 6 hrs/ha, therefore the fee was set to force the angler effort to levels to 6 hrs/ha. Figure 17 shows the new angler effort levels achieved by the fee. Although there are some fluctuations in the angler effort after the fee, the average effort does approach 6 angler hrs/ha.

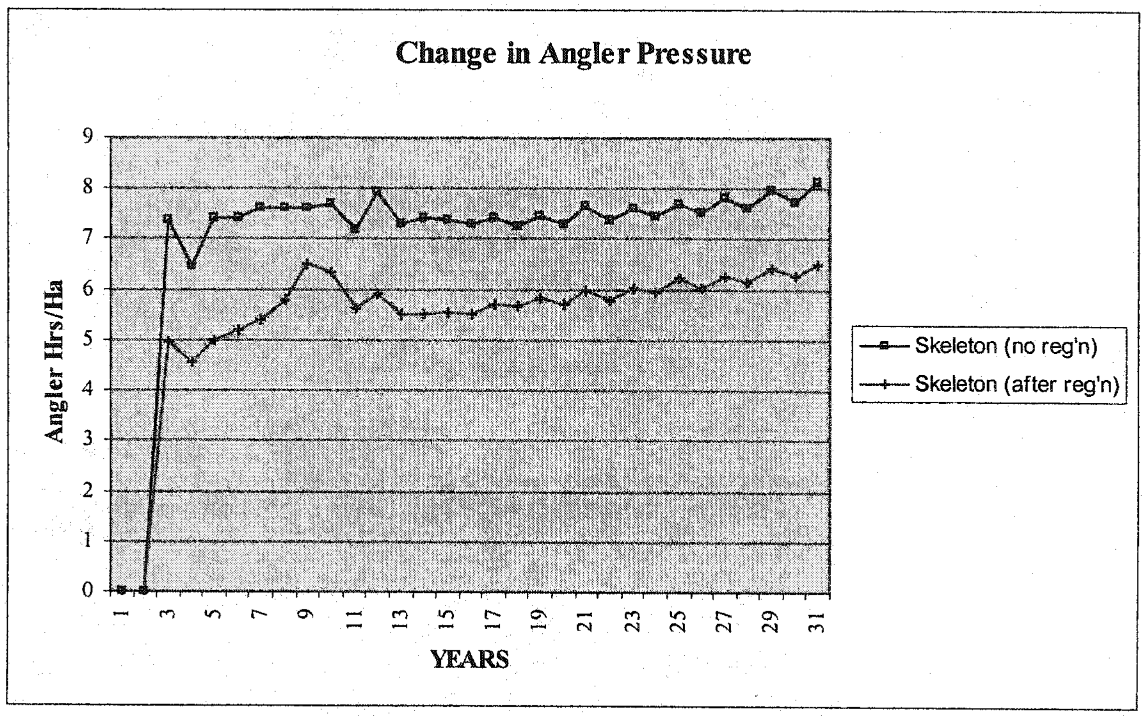

Figure 17. Change in Angler Pressure After A Constant Site Charge Imposed at Skeleton Lake

An interesting outcome of the site-specific fee is the results on the lake QFI. The QFI outcome of implementing this new fee is seen in Figure 18. The base case scenario is the same in Figure 18 as it was in Figure 16—it is simply the QFI for Skeleton lake with no regulations imposed. The new QFI for Skeleton Lake with the fee is significantly higher than before the fee, moving up to a QFI to between 15 and 30. Comparing the post-regulation QFIs in the case of the individual site quota and the case with the constant fee, the new QFI is much higher with the fee policy. The reason for this discrepancy could be because constant fees relocate people away "permanently" while quota is temporary. Thus, early in the period when QFI is low, anglers are driven away; the fee initially lowers effort overall, which causes an increase in QFI.

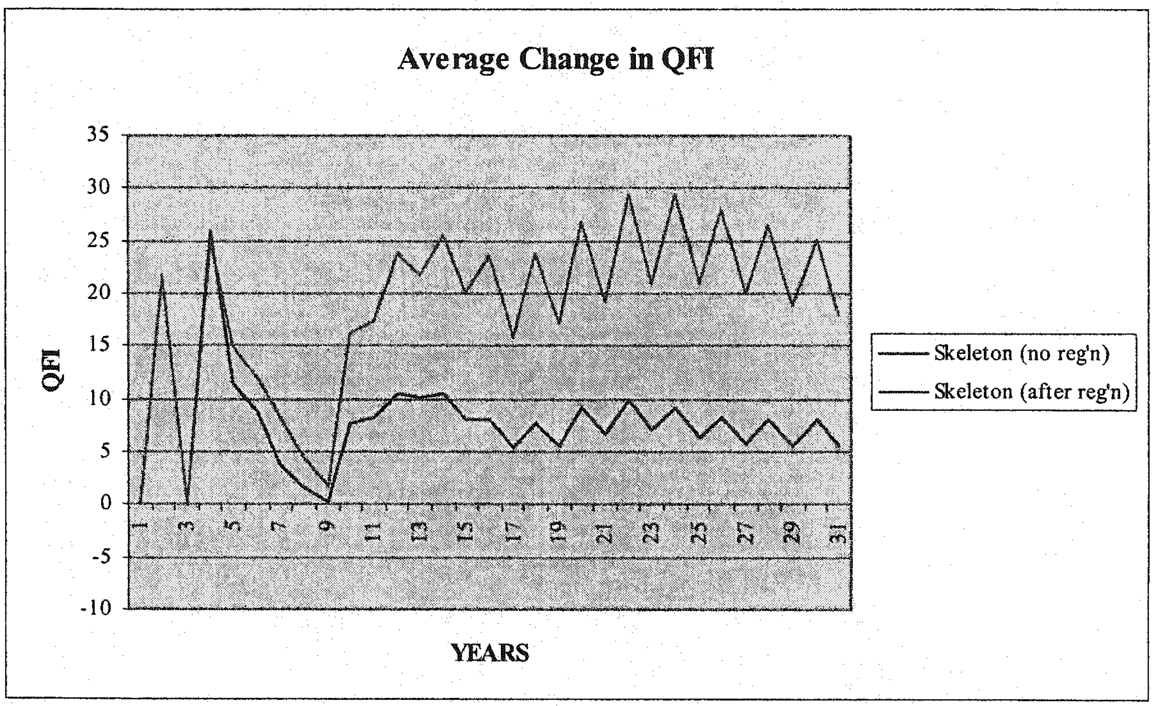

Figure 18. Change in QFI After A Constant Site Charge Imposed at Skeleton Lake

6.2.6 Site Specific Variable Fees

Another method that can be used to reduce angler effort at a particular lake is to charge the anglers different combinations of fees. In this simulation, Skeleton Lake was used again and the model used the previous year's population levels to determine whether or not a fee was necessary in the following year, and if the walleye populations were low enough to justify a fee, the model imposed 2 different rates, depending on the fish levels. (A lower population generates a higher fee so that fewer anglers will frequent the site; a high fish population results in a fee of zero). It is also worth noting that because the model uses distance as a proxy for travel cost, the "fee" imposed is essentially equivalent adding more distance to get to the site. Figure 19 shows the effect of a site fee on the QFI of Skeleton Lake.

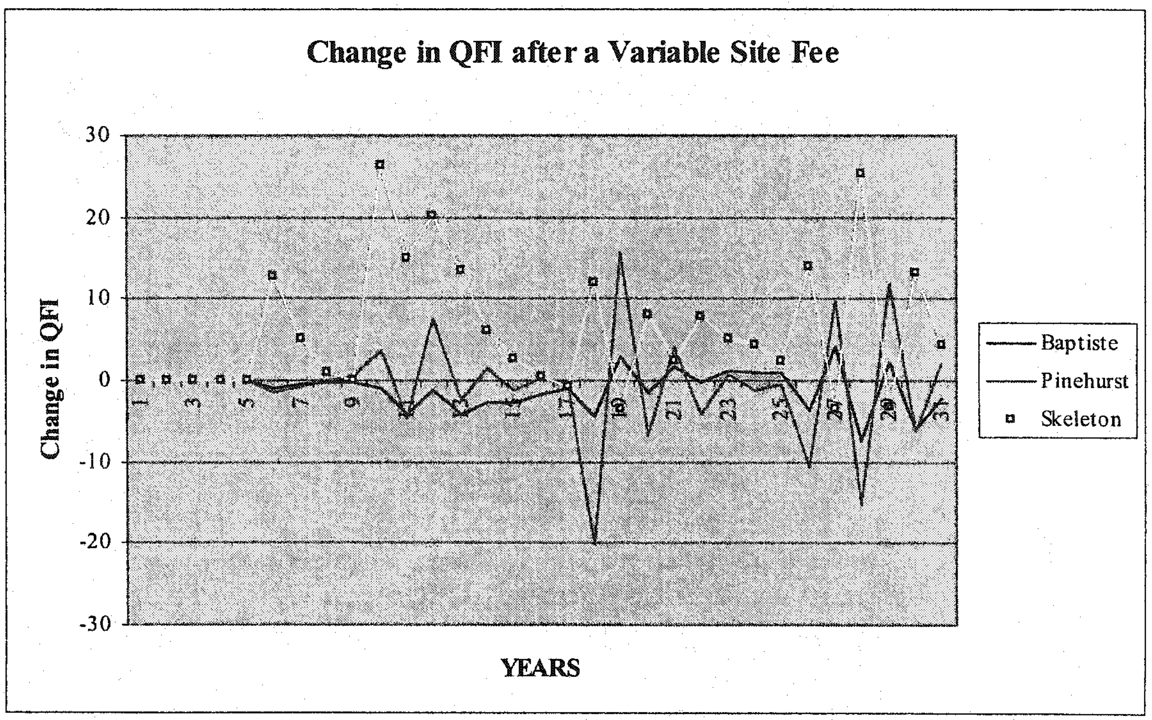

Figure 19. Change in QFI After A Variable Site Fee Imposed at Skeleton Lake

The QFI levels for Skeleton Lake appear to increase overall during the simulation, while the QFIs at the other sites were not affected much at all. It appears in Figure 15 that Pinehurst Lake has nearly the inverse of the change in QFI from Skeleton Lake. (However, also note that the QFI change at Pinehurst was centered about the axis and the fluctuations from year to year do not imply an overall change in QFI—in fact, the QFI at Pinehurst did not changed significantly and the fluctuations could also be partially due to the fee causing a lag in angler effort for other lakes.) The percentage of anglers that stopped fishing because of the site fee was small, ranging between 0-1%. Since anglers still have other fishing options, not many were drastically affected. The change in angler effort is evident by examining Figure 20 below.

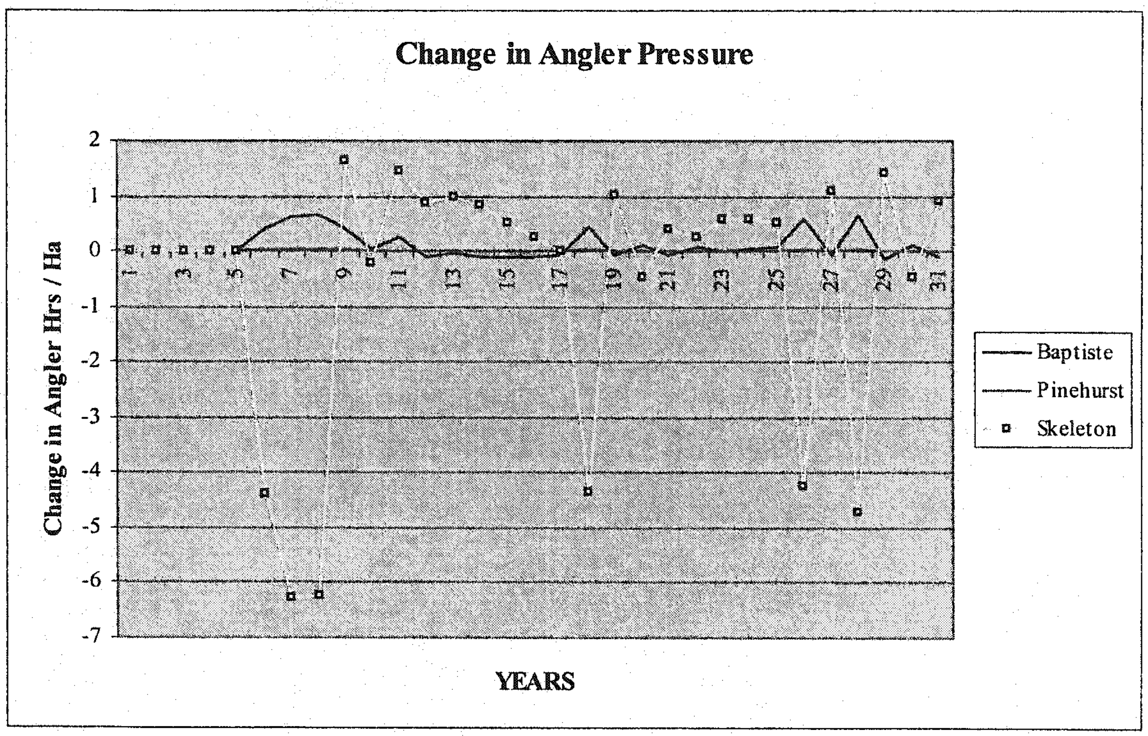

Figure 20. Change in Angler Pressure After A Site Fee Imposed at Skeleton Lake

The site fee causes a very noticeable change in angler pressure at Skeleton lake. When the fee is charged in a given year, the angler effort falls steeply. Then, as the QFI increases, the fee is not charged that year and angler effort is slightly higher than it was before the regulation. Other sites (such as Baptiste), absorbed some of the extra angler pressure that was diverted from Skeleton Lake, while sites like Pinehurst were not affected much at all by the fee at Skeleton Lake.

6.2.7 Change in Bag Limit / Catch and Release

A common method used by policy makers is to limit the number of fish kept by the angler, or to limit to zero the number of fish taken home or kept. Recall that the catch and release method is different than site closure because with a zero bag limit, the site is not closed; anglers are still allowed to fish (but not keep their catch).

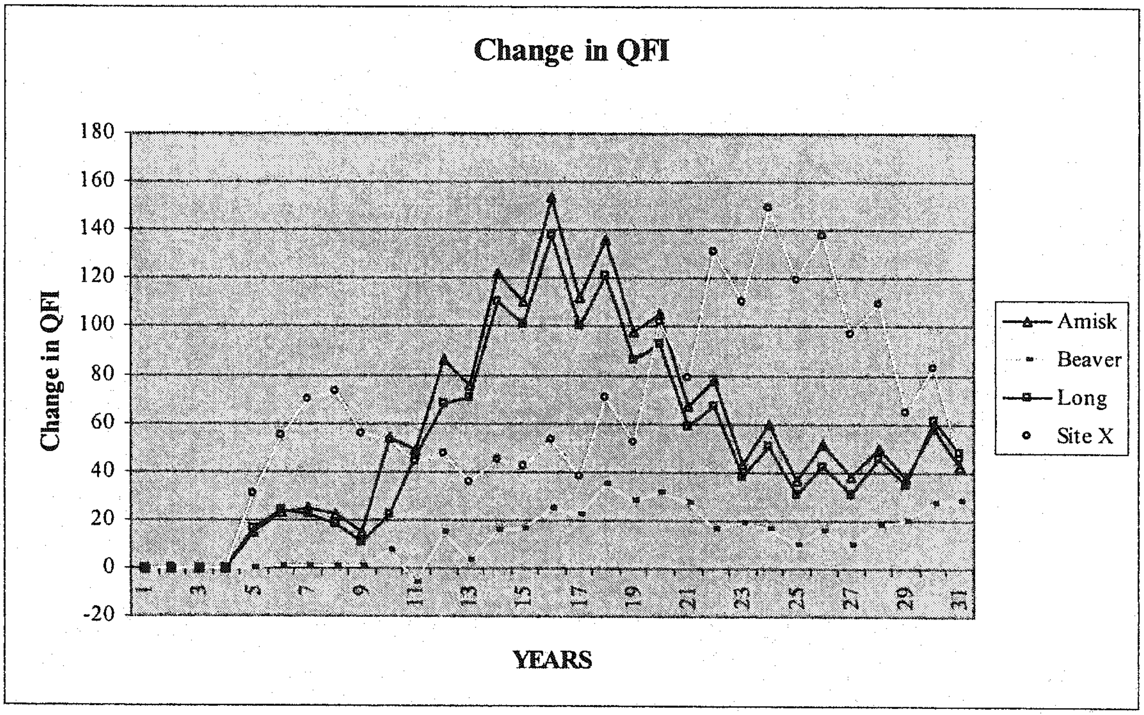

Figure 21. Change in QFI After Catch and Release Regulation at all Lakes

Figure 21 shows the general trend in the lakes when the zero bag limit (catch and release) regulation is imposed. The fish populations grow for several years and continue to have biological cycles of growth and mortality. It takes several years for the populations to have a significant population growth and the fish populations to become stable.

Although this simulation is good for predicting the change in QFI from this policy, there were no data pertaining to aspects of the angler's decision to go fishing or stay home. For instance, the model includes preferences for total fish caught, not the total catch kept. Undoubtedly there are some anglers that would choose to stop fishing or not comply with the regulations upon confronting this regulation.

6.3 WELFARE MEASURES

The welfare measures calculated from the results in this simulation model are the angler per trip compensating variation (CV) of a change in regulation. These regulations affected the angler in terms of site choice and site availability, and as well as by the quality of fishing index (QFI). CV was calculated by incorporating the coefficients from Table 2. These values were incorporated into Equation 11 from Chapter 3. Equation 11 measures the difference in an angler's utility before and after the regulatory (fish quality and site choice) change.

CV is a money measure created by dividing the difference in utility between the base case and the regulated case by the marginal utility of money, μ. The value of μ is calculated by dividing the estimated coefficient for distance by the average cost of travel per kilometre of $0.45 per km[28] (CAA 2002). Therefore, $\mu = 0.0529/0.45$. (Since the coefficients were calculated using round trip values for distance, the travel costs do not need to be doubled.) This results in the marginal utility of money to be 0.11755 (a positive value because a positive change in utility after a policy change is a positive gain in welfare measures).

[28] The cost of travel per km was based on annual driving costs based on a Chevrolet Cavalier LS four door sedan. A midrange between 18,000 - 24,000 annual km was used to calculate the 45 cents per km.

To examine how CV changes across simulations of various regulations, the utility measures were converted into welfare measures to assess the effect per angler trip. The welfare measures are calculated by using the average change in utility for all sites and then converting to monetary values using the marginal utility of income. Figures 22-25 show the welfare loss and gain to anglers for the simulations discussed earlier in this chapter. (Please note that for each of these figures, the welfare change goes to zero in the last year of the simulation. This is simply an artifact of the model, where all the values go to zero on the last year of the simulation.)

The angler welfare change from an increase of access to a previously inaccessible lake is shown in Figure 22 below. There is an initial $3.50 increase in angler welfare per trip, then as the fish populations drop, there is less of a welfare gain. It is somewhat surprising that the new welfare measures remain so high in spite of the declining fish populations, as one might expect the increase in welfare to approach zero as the simulation continues. However, anglers also experience an increase in welfare simply from having an additional alternative added to their choice set.

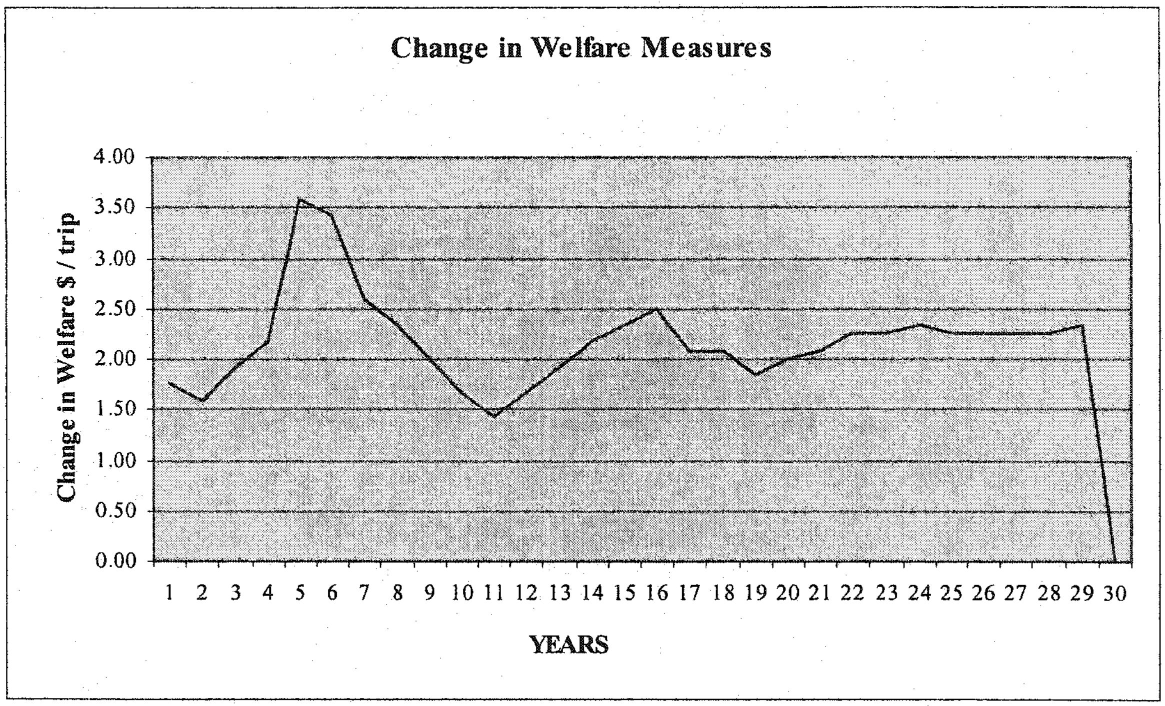

Figure 22. Change in Welfare Measures After Opening a Previously Inaccessible Lake

In Figure 23 the change in welfare measures is illustrated for the walleye population-dependent site closures. This is the least "popular" regulation of any of the simulations performed in the integrated model. If the fishing sites in the choice set happen to all be closed during the same year, the angler would either have to stop fishing altogether or find another set of lakes from which to choose. The temporary increases in QFI do not appear to create a large enough increase in utility to cause a change any dynamic positive change welfare measures.

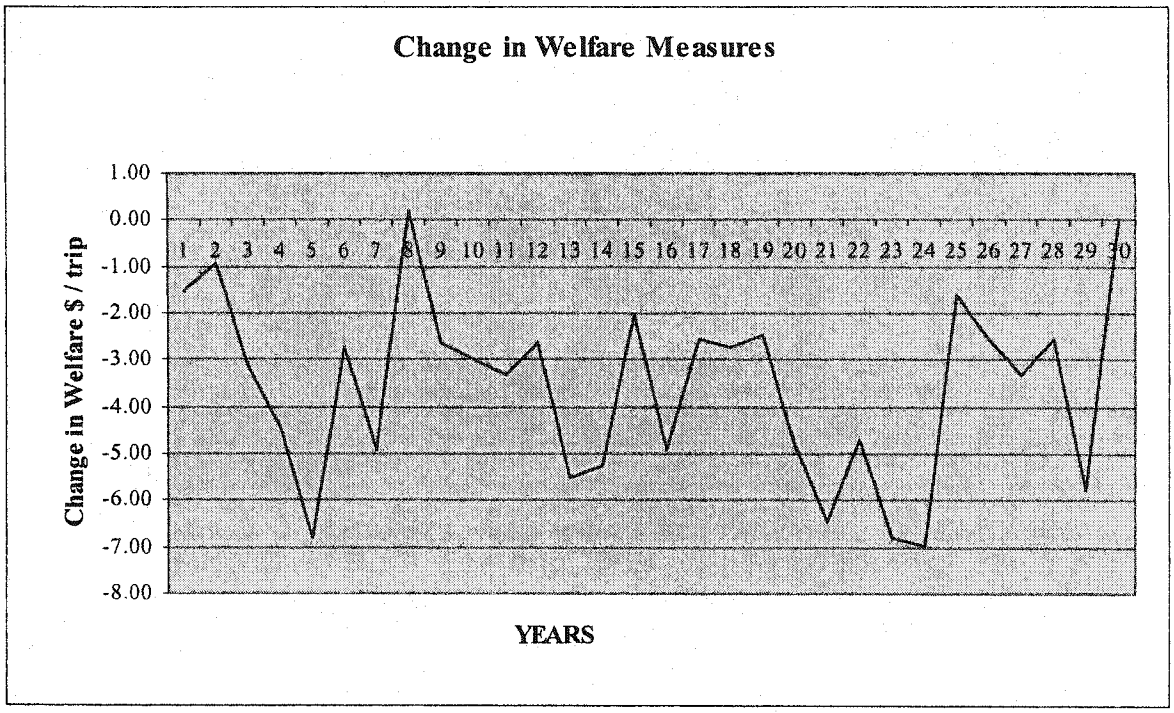

Figure 23. Change in Welfare Measures after Site (Population Specific) Closures

The lake quota system had a more sustainable effect on both the walleye populations and the anglers. In Figure 24, the welfare measures arising from lake limit quotas are depicted.

Each of the angler effort quota limits followed the same pattern in terms of welfare measures. The trend was that there was an initial steep decrease in welfare (approximately between $4.50 to $2.30 per angler visit.) The higher the limit and the closer that the policy was to the pre-policy scenario, the less loss the anglers experienced. However, this model does not include the total economic value from each regulation (see Discussions, Chapter 6.4). It is comforting to see that this regulation seems to have a stabilising effect on the walleye populations and does not have the volatility seen in the site closure model.

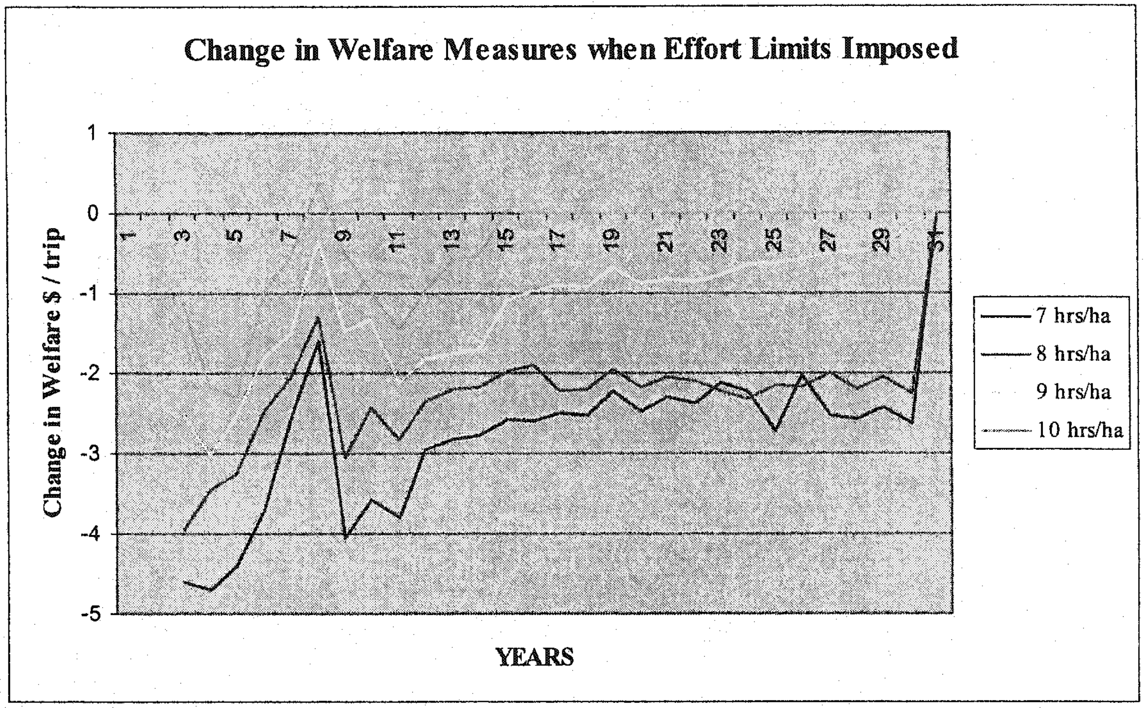

Figure 24. Change in Welfare Measures after Imposing Site Angler Effort Quotas

When examining the welfare change due to an angler effort quota at a single site, the results in Figure 25 follow a similar trend. Initially there is some volatile behaviour, with loss of welfare reaching -$2.50 per angler trip. As the walleye populations stabilize, the average welfare change is between $1.00-$2.00 loss per trip.

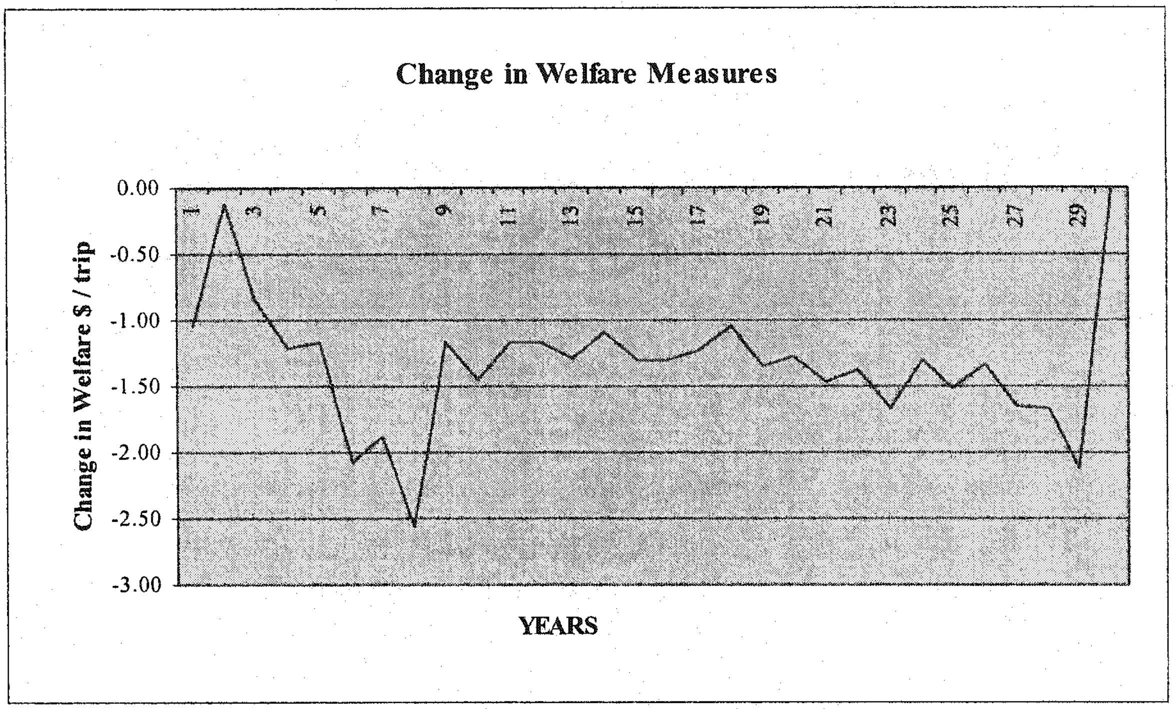

Figure 25. Change in Welfare Measures After A 6 hrs/ ha quota at Skeleton Lake

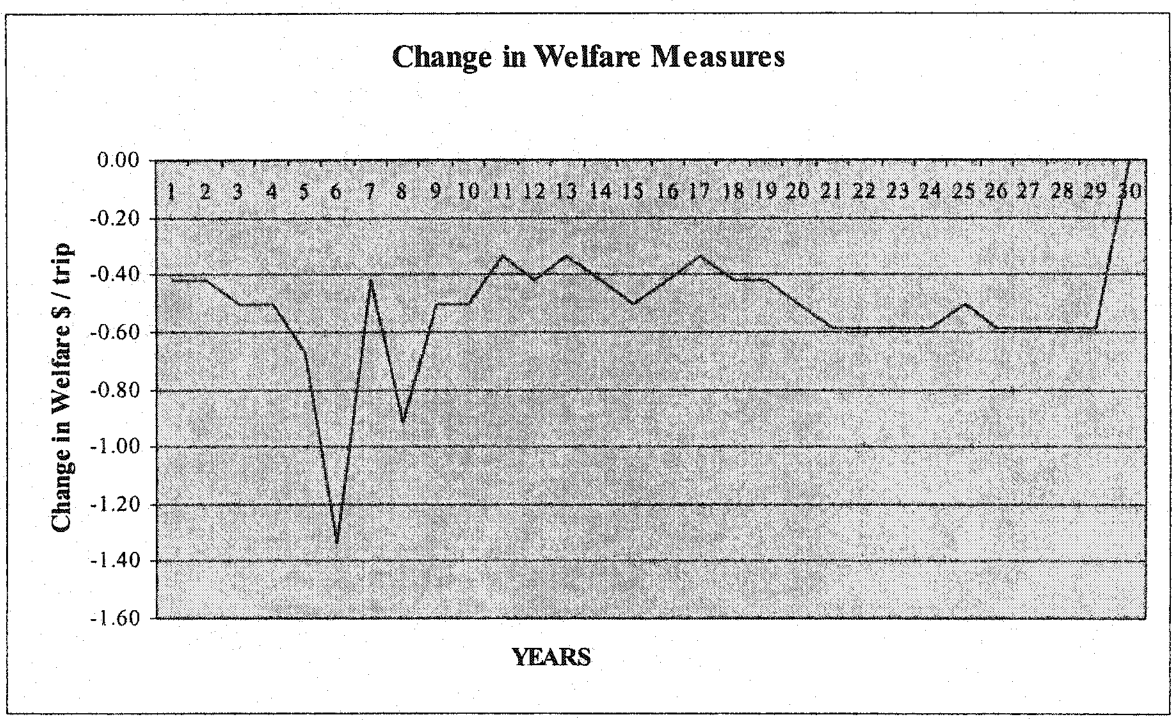

Figure 26. Change in Welfare Measures After A Site Constant Charge Imposed at Skeleton Lake

A surprising comparison between the quota and the fee is the difference in the changes in welfare measures, before and after the regulation. As depicted in Figure 26, the initial welfare loss for the site charge is approximately $1.37, and as the fish populations stabilize in the simulations, the welfare loss is between $0.30 and $0.60 per angler site visit. Comparing this value to the quota welfare loss, it appears that the fee regulation not only has a higher resulting QFI, but also a lower loss in angler utility. In the theory in environmental economics, fees and quotas should have the same overall net effect (Field and Olewiler 2002) but in this case, the reason for this difference is because the fee is created to approximate the quota over a 30 year simulation. Therefore, the lower effort resulting from the quota and the lower angler effort due to the fee are not identical. As well, by decreasing utility at one site for all users, the change in welfare is spread out over all of the anglers. In the quota case, only select anglers going to the site have a resulting welfare impact, but it is much larger.

The final welfare measure generated from the simulation is derived from the change in total angler utility at all sites, where one site (Skeleton Lake) has a potential fee. It is worth mentioning that the fee imposed was very high; when the populations are very low, the fee imposed to one angler visit is $16.70. When the populations are somewhat higher, the fee charged at the site is $8.35. (When the populations are recovered, there is no fee for fishing at this site.)

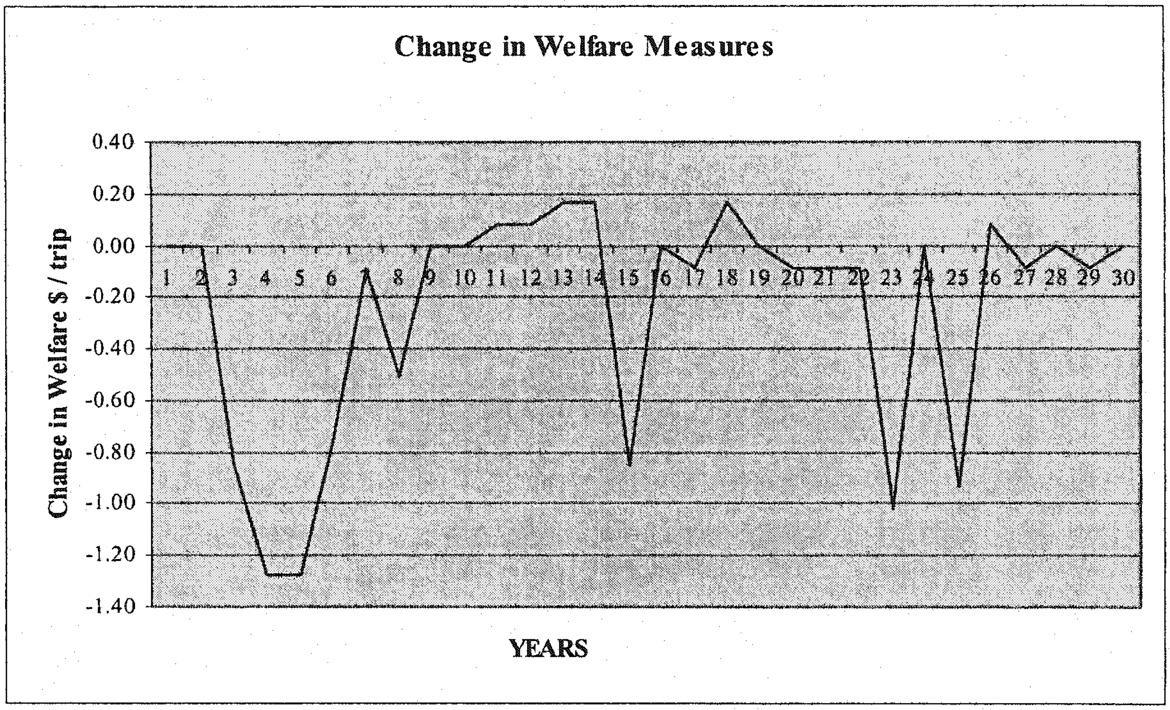

Figure 27. Change in Welfare Measures After A Site Charge Imposed at Skeleton Lake

In Figure 27, the change in welfare is mostly negative. However, the change in welfare to each angler visit ranges between -$1.30 and $0.20. The welfare loss from these regulations are not extremely high because the costs of the site fee are shared amongst the anglers from all sites in the calculation of aggregate change in utility. This means that the welfare loss to the angler going to Skeleton Lake would be high, but when averaging the change in welfare from all 50,000 anglers, the welfare loss appears to be less because it is "diluted". Table 4 gives a summary of the resulting welfare changes from the various policy measures. The policies are separated into those that can be compared across all sites, those policies that are site specific, and lastly, the other 2 regulatory instruments.

Table 4. Summary of Welfare Change

Type of Policy	Policy Simulation	Average welfare change ($/ angler trip)	Welfare change over 30 years for summed angler trips[29] ($)	Average change for 50,000 anglers ($/50000 anglers)
POLICY ON ALL SITES	Site Closure, All	-3.70	-107.36	-185,100.98
	Quota, All 7 hrs /ha	-2.89	-83.74	-144,378.36
	Quota, All 8 hrs /ha	-2.29	-66.51	-114,680.52
	Quota, All 9 hrs /ha	-1.17	-34.06	-58,728.461
	Quota, All 10 hrs /ha	-0.47	-13.59	-23,432.522
POLICY ON SINGLE SITE	Quota, Skeleton Lake 6 hrs/ha	-1.37	-39.82	-68,653.91
	Constant Site Fee, Skeleton Lake	-0.53	-15.45	-26,629.73
	Variable Site Fee, Skeleton Lake	-0.25	-7.32	-12,613.86
OTHER	Add Access	1.96	56.94	98,170.12
	Change in Bag Limit	N/A	N/A	N/A

Column three of Table 4 shows the average change in welfare per angler trip for each of the simulations. The next column is a summation of the total amount of welfare change experienced by an angler over the whole 30-year simulation. The third column is the average welfare change experienced by the angling community—the average welfare change in one year for all 50,000 anglers.

When comparing the regulations imposed on all sites collectively, one can compare the site closure and the various effort quotas. The site closure option creates the largest loss in angler welfare. The effort quotas also cause a decrease in welfare, with the strictest policy (7 hrs/ha) causing the largest welfare loss and the least strict quota (10 hrs/ha) making the least change on angler welfare.

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[29] This column of values refers to the area between the "Change in Welfare" line and the horizontal axis in each of the corresponding welfare graphs.

Comparing the single site regulations, one can assess a single site quota, a variable fee, or a constant fee. In this study it was found that the variable site fee caused the least loss of welfare to anglers, followed by the site constant fee, and then by the site effort quota of 6 hr/ha.

The only simulated change that caused a gain in welfare was the addition of access. This is intuitive because it is the only policy implemented that increased the anglers choice set and fishing quality. The welfare loss due to change in bag limit is not available because of data limitations.

6.4 DISCUSSION OF RESULTS

An important aspect to note in the angler welfare measures is that the calculated measures do not encompass the total economic value associated with the regulation and policy change. Namely the issue of concern is the exclusion of non-use values, which unfortunately, are difficult to calculate. Bateman and Willis (1999) define non-use values as "situations in which individuals who do not make use, or intend to make use, of any given environmental asset or attribute would nevertheless feel a 'loss' if such things were to disappear." Reasons for wanting to preserve environmental entities are that people may believe that the entity in question should be conserved 'in its own right' and that it has an existence value. Others wish to retain the environmental good for future generations for its bequest value (Bateman and Willis 1999). These values are difficult to quantify monetarily, but should nonetheless be added (at least qualitatively) to the value of a protected fish population. These values are the main motivation for a policy that prevents dramatic declines or extirpations of fish species.

Opening a new site increased welfare measures by a significant level. The results also suggested that when a site is closed, the values of the losses are small if the study assumes the presence of other substitutes. However, values of access would be much higher if an entire region or choice set were closed, due to increased travel distance to another site (Greene, Moss, and Spreen 1997).

Of the regulatory instruments simulated, the one that had the greatest welfare loss for anglers was the site closure strategy. This was the simulation that closed a site when the previous year's QFI was low and reopened the sites as soon as the QFI had improved. This causes high volatility in trip patterns and results in the "whack-a-mole" effect. A method that also was used for reallocation (as a means to improve walleye QFI) that had less of an angler welfare loss was the lake quota method. From Figure 20, it is clear that the less strict the regulations were, the less that the anglers lost in welfare because they could largely continue what they were doing "pre-regulation."

Existing literature provides different view points on both the benefits and logistics of using a quota / effort reallocation system. Some literature says that by placing a quota on the total number of anglers using the harvest, there is better control than simply limiting fish size or per angler daily harvest (Post et al. 2002). However, if the new regulations impose a large cost on the anglers or impose a significant change in their behaviour, there will be lower benefits to the fishing community, even if there is complete acceptance of the program (Anderson 1989). Prior to implementing a new regulation, the costs of monitoring and enforcement must be considered to provide an accurate assessment of the net benefits of management. The more that a program or regulation differs from the existing rules, the more effort will be necessary for implementation (Anderson 1989). If the new regulations impose a large cost on the anglers, have large transactions costs, or impose a significant change in behaviour, there may be lower benefits to the fishing community, even if there is complete acceptance of the program (Anderson 1993).

Higher costs also encourage deliberate non-compliance and/or avoidance activities to conceal non-compliance. For example, anglers are shown to respond to economic incentives, but at the same time, show a strong tendency toward the same fishing location over time (Opaluch and Bockstael 1984). A policy designed to reallocate effort from an over-utilized lake to an under-utilized lake will need to be substantial to have any significant effect. A policy may need to be so extreme that it would be politically infeasible (Bockstael and Opaluch 1983). Furthermore, the size and rate of angler adjustment to stocks and catch rates may be too slow and therefore overshadow the importance of the biological parameter estimates in calculating change in stock-enhancing policies.

A simulation that was beyond the scope of this project was the periodic implementation of size restrictions. In other literature it was found that by incorporating size restrictions into a recreational fishing model, in the short run, the regulation diminishes harvest levels and reduces angler utility. However, as the fish population recovers due to reduced harvest, the move "unequivocally increases angler welfare in the long run" (Bose 1995; Homans and Ruliffson 1999).

Another factor not included in the integrated model was the additional cost of implementation and administration of the new regulations. In order to create better and more workable sportfishing regulations, it is necessary to examine both the political and enforcement issues. The ease with which a regulation can be implemented influences the costs of monitoring and enforcement costs, and therefore, the net benefits of management. The more that a program or regulation differs from the existing rules, the more effort will be necessary for implementation (Anderson 1989).

Compliance with regulations imposed by an external authority has been shown to be significantly dependent on the perception of legitimacy of the authority and the law itself (Hatcher, Jaffry, Thebaud, and Bennett 2000). The more legitimacy that is accorded with the regulation, the greater is the propensity of the individual to comply (Hatcher et al. 2000). Thus, programs that are perceived as providing benefits to the lake as a unit or to society as a whole will be easier to enforce on those individuals who consider these things to be important. If the anglers agree with the goals of these organizations, they will be more likely to comply. A management program may prohibit several activities and each of these regulations is targeting some aspect of the fishery or lake. The gains in terms of increased benefits due to behavioural change need to be identified. Not only do the improvements need to be identified, but the anglers also need to see the results to help instill respect for the management program and agency. If the program is seen as illegitimate, there may be an increase in violations and the net benefits of management will be reduced.

CHAPTER 7: CONCLUSIONS AND LIMITATIONS

7.0 MODEL SUMMARY

This research incorporates angler data with a walleye population model in order to simulate the impact of various regulatory instruments on walleye populations and angler welfare. The theoretical framework of the random utility/ travel-cost approach provides an excellent framework from which to construct an econometric model. The results from the econometric model provided the basis for the human component of the integrated ecological economic model for which both ecological and economic sustainability can be examined. This integration of economics and ecology in a dynamic framework is both innovative and useful in providing insight to both the underlying choice behaviour of recreational anglers, as well as to estimate angler welfare changes and walleye population changes due to a policy change.

Although the integrated model was developed for Alberta residents and walleye populations in Northern Alberta lakes, this research can be modified to simulate other regulatory scenarios. The choice set can be altered to add or change to other lakes and new angler preference structures. As well, the model can be further adjusted to incorporate other fish species and feedback systems.

7.1 SUMMARY OF RESULTS

The integrated model in this study examines policy change for a choice set of 10 lakes in Northern Alberta. The simulated regulatory mechanisms help to evaluate policies for a single site, for the entire choice set, and for other regulatory options. When comparing the results from the simulations of the regulatory strategies, one can speculate as to which policy would be the most effective to implement in order to achieve biological and economic sustainability.

When comparing regulations for a single site, the variable site fee gives the lowest welfare loss, the constant site fee a slightly larger loss, and the effort quota a bigger welfare loss. However, the methods that appeared to be the most effective overall in walleye population stability were the angler effort quotas and the constant site fee. The common factor between these two regulatory instruments is that rather than using policy as a responsive measure, they are used as preventative measure. Therefore, it is inconsequential if the QFI for one year is high, the site is not left unrestricted—it remains restricted to ensure that the lake does not collapse that year from overfishing. However, when comparing administrative costs of the fee and quota systems, the quota could be a less costly system to implement because the fee would then not have to be collected at the site. Instead, the quota could be treated as a lottery/draw system, similar to the existing hunting programs in Alberta.

In the regulation of all sites, various angler effort quota levels and a site closure option were simulated. The quota system helps in increasing lake QFIs but creates a higher angler welfare loss as the policy becomes stricter. The site closure policy, which is dependent on the fish populations from the year prior, causes high angler disutility and creates highly volatile fish populations because of the "whack-a-mole" effect. In agreement with this result is Pena-Torres (1997) stating that when annual catch quotas and biologically oriented controls on fishing effort are used as core instruments of control, these tend to be inefficient in solving over-fishing problems. However, it is important to note that while one may speculate which policy is best, it is not possible to generalize about conditions when one instrument will be preferred, except in highly restrictive cases (Anderson 1988).

The other simulations that were done as policy were the catch and release simulation and the new site access. Both of these simulations were examined by looking at the effects to all sites. As expected, the new site access increased angler welfare and dramatically decreased fish populations at that lake. The catch and release simulation also showed an increase in QFI, thus maintaining walleye levels, but the results do not provide changes in angler welfare measures.

Besides providing insight into preferred regulatory mechanisms, this research provides other interesting findings. Firstly, low QFIs do not mean that the site provides no utility to the angler; this means that even if a lake has a low walleye population, the angler will still receive benefit from fishing at that lake. This has interesting ecological implications in that it may not ever be possible, without stringent angler populations, to deter anglers from fishing at lakes with near-collapsed walleye populations. The results from the simulation model show that each of the regulatory policies (quotas, fees, closures) result in a net welfare loss, even with an overall increase in walleye populations. Also, it is necessary to note that while in the model QFI was able to regain its stability after being very low, due to other external stochastic factors, in reality it is not likely that the QFI will regain as quickly as it does in the model and may collapse completely (Johnson and Carpenter 1994).

7.2 LIMITATIONS AND FUTURE RESEARCH

Generally speaking, computer simulations are an excellent tool for analyzing the dynamic implications of policy alternatives. Although modelling does not provide a *perfect* estimate of reality, it is largely agreed that modelling is a practical approach in management and gives solid crude estimates of trade-offs and decisions over time (Walters 1994). This known, it is important to recognize the limitations inherent in a simulation model.

A common limitation associated with both ecological and economic research is the lack of available data. Since good data are expensive and time-consuming to obtain, the data used are seldom ideal. In the case of this project, the regulatory instruments have only been explored with the use of one data set, which does not necessarily generalize to other data sets. Also, the number of anglers who visited the choice set was relatively small and the angler preferences were determined using revealed preference data. Rather than only using revealed preference data, a combined stated preference/ revealed preference approach may be a better predictor (Adamowicz, Louviere, and Williams 1994). A better data set would also make modelling dynamic movements of anglers more effective in order to learn their perceptions and preference changes (as regulations change.) The preference changes would also need to include the angler's preference for not only the number of fish caught, but the preference for fish that are caught but released. With these data, one could calculate more realistic values for welfare measures associated with regulations.

Within the integrated model, there are also additions that could improve model performance. The description of angler choices would be improved by allowing for a variety of different types of anglers. Separating anglers into groups with identifiable demographics or different preference categories would improve the explanatory power of the model. As well, some anglers may have no preference regarding the species of fish caught. A model that included various angler species preferences as well as multi-species fish biology would be an improvement but would also be very complex. Various other site attributes that were excluded could be incorporated into the angler preference model. For example, facilities at sites (campgrounds, picnic sites, etc) or measures of scenery could be used to improve the explanation of site choice behaviour. Other elements could be added to the model, such as congestion, which is often a significant factor in angler site choice (Boxall and Adamowicz 2000). As well, it would be helpful to account for uncertainty both in terms of ecological parameters as well as economic demands in order to assess option prices associated with uncertain future demands (Greene et al. 1997).

A limitation that has been mentioned in various places in this study is the assumption of instantaneous information transmission / learning at the angler level. The model does not incorporate lags to account for the time that it takes for the knowledge of a high QFI to reach the angling community. Although radio fishing reports and internet fishing sites provide a fast effect on perceived fishing quality, information flows would likely be slower than illustrated and may cause a less severe "whack-a-mole" volatility problem. As well, anglers develop habitual behaviour and may continue to stay at one fishing location, regardless of the other alternatives given.

The model could also be enhanced to simulate policies on a much more detailed level and smaller scale. Periodic regulatory measures can be implemented to alter the regulation each year manually, rather than using a 30-year continuous simulation. The spatial scale of the model could also be adjusted to encompass a larger choice set of lakes, perhaps at a provincial scale. This would better represent the true decisions and substitutions that anglers must make. Likewise, the costs of administration and costs of enforcement (which were not incorporated in this model) could be added to the model each year. As well, there are other, more complicated relationships between anglers and walleye populations that were not considered in my model. For example, Andrews and Wilen (1988) examine effort responsiveness to success in a sport fishery and conclude that the proportional increase in anglers generates more than proportion increases in catch. This means that current practices probably underestimate how many fish will be taken by anglers when abundance increases, and will also underestimate the decrease associated with abundance decreases. These feedback systems are not incorporated in the current integrated model. Finally, it is important to note that our understanding of fish-angler interactions is relatively low, and that to construct predictive models, we need better understanding of functional relationships of catch rate, fish density, and response of anglers to fishing success (Johnson and Carpenter 1994). Finally, a limitation of this model is that it does not assess equity effects. It only examines economic efficiency and does not assess who gains and who loses from policy change.

7.3 FINAL REMARKS

Information and knowledge is vital in making recommendations to the managers to enhance the efficiency and effectiveness of recreational fishing policy. One must realise that in policy debate, the primary issue is not whether the policy is exactly correct, but whether it is "better" than the existing regulations (Walters 1994). With this in mind, it is less intimidating for regulators to make change—not necessarily with the intent of a hypothetical optimum, but to a realistic and more economically efficient outcome.

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APPENDIX A: Calculating Site Distances

Table 4. Angler Origins, Trip Numbers, and Distances to Lakes

	Peace River	Peace River	Edson	Edson	Athabasca	Athabasca	Boyle	Boyle	LacLabiche	LacLaBiche	Perryvale	Perryvale
	# trips	DISTANCES	# trips	DISTANCES	# trips	DISTANCES	# trips	DISTANCES	# trips	DISTANCES	# trips	DISTANCE
Amisk	0	425	0	349	0	54	84	10	0	84	0	63
Baptiste	10	342	0	357	24	27	16	72	0	101	2	57
Beaver	0	464	0	414	0	94	0	78	140	4	0	124
Calling	0	428	0	387	38	58	0	103	0	132	0	88
LLB	0	476	0	426	0	106	0	90	27	16	0	136
Long	0	424	16	349	5	54	7	20	1	83	8	62
NBuck	0	438	0	362	0	68	0	23	0	45	0	76
Pinehurst	0	511	0	429	0	141	0	125	24	51	0	171
Skeleton	0	421	0	345	0	51	106	6	0	55	0	59
Touchwood	0	503	0	453	0	133	0	117	10	43	0	163
# angler trip	10		16		67		213		202		10	

	Ft. McMurra	Ft. McMurra	Hinton	Hinton	Jarvie	Jarvie	Westlock	Westlock	Plamondon	Plamondon	Peers	Peers
	# trips	DISTANCES	# trips	DISTANCES	# trips	DISTANCES	# trips	DISTANCES	# trips	DISTANCES	# trips	DISTANCE
Amisk	0	290	0	441	0	158	0	122	0	59	0	330
Baptiste	0	307	0	449	0	112	0	114	0	77	0	321
Beaver	0	287	8	506	0	216	0	181	3	31	0	388
Calling	0	338	0	479	0	180	0	144	0	107	0	352
LLB	0	299	0	518	0	228	2	193	27	43	0	400
Long	3	289	0	440	0	157	2	122	0	59	10	329
NBuck	0	303	0	454	31	171	0	135	1	72	0	343
Pinehurst	0	334	0	521	0	263	0	228	0	78	0	435
Skeleton	0	286	0	437	0	154	0	118	0	55	0	326
Touchwood	0	326	0	545	0	255	0	220	2	70	0	427
# angler trip	3		8		31		4		33		10	

APPENDIX A: Calculating Site Distances Continued

Table 4 (Cont). Angler Origins, Trip Numbers, and Distances to Lakes

	Clyde	Clyde	Meanook	Meanook	Island Lake	Island Lake	Canyon C	Canyon Creek	
	# trips	DISTANCES	# trips	DISTANCES	# trips	DISTANCES	# trips	DISTANCES	
Amisk	0	108	0	50	0	82	0	205	
Baptiste	0	99	0	54	4	10	3	123	
Beaver	0	166	0	121	0	121	0	244	
Calling	0	130	1	85	0	85	0	208	
LLB	0	178	0	133	0	133	0	256	
Long	0	107	31	49	0	82	0	205	
NBuck	0	121	0	63	0	95	0	218	
Pinehurst	0	213	0	168	0	168	0	291	
Skeleton	3	104	0	46	0	78	0	201	TOTAL
Touchwood	0	205	0	160	0	160	0	283	TRIPS
# angler trip	3		32		4		3		649

APPENDIX A: Calculating Site Distances Continued

The anglers were seperated into 4 groups by origin proximity:

Group 1 (40 anglers)	Athabasca, Boyle, LacLaBiche, Perryvale, Jarvie, Island Lake, Westlock, Plamondon, Clyde, Meanook			
Group 2 (2 anglers)	Peace River, Canyon Creek			
Group 3 (3 anglers)	Edson, Hinton, Peers			
Group 4 (1 angler)	Ft. McMurray			

Since 40/46 anglers were from the Group 1, only those origins were used in calculating average distance:

Table 5. Calculating Average Distance from Origin to Site

	Athabasca Distances	Boyle Distances	Laclabic Distance	Perryvale Distances	Jarvie Distances	Westlock Distances	Plamond Distance	Clyde Distances	Meanook Distances	Island Lake Distances	**AVERAGE Distances**
Amisk	54	10	84	63	158	122	59	108	50	82	**79**
Baptiste	27	72	101	57	112	114	77	99	54	10	**72.3**
Beaver	94	78	4	124	216	181	31	166	121	121	**113.6**
Calling	58	103	132	88	180	144	107	130	85	85	**111.2**
LLB	106	90	16	136	228	193	43	178	133	133	**125.6**
Long	54	20	83	62	157	122	59	107	49	82	**79.5**
Nbuck	68	23	45	76	171	135	72	121	63	95	**86.9**
Pinehurst	141	125	51	171	263	228	78	213	168	168	**160.6**
Skeleton	51	6	55	59	154	118	55	104	46	78	**72.6**
Touchwoo	133	117	43	163	255	220	70	205	160	160	**152.6**

APPENDIX B: Habitual Behaviour Calculation

The coefficients for habitual behaviour in the integrated model are based on (Adamowicz 1994), concentrating on Naïve Model 2. The Naïve model suggests that previous choices affect current choices and that consumer history helps determine current demand.

- The coefficient found in Table 1 in Adamowicz (1994) for the Naive Model 2 is –6.49.
- When the estimated coefficients were averaged for the alternative specific parameters, the average was approximately 1.
- Average for habit formation in Naïve Model 2 was approximately 1.00
- The travel cost used in the Naïve Model 2 was $0.27/km.
- Distance coeffiecient in my RUM is –0.0529

Converting my distance estimate to a travel cost is therefore

-0.0529/0.27= -0.20

-0.20 * ratio of 1/-6.49 is 0.03

Therefore, habit for one year coefficient is **0.03**

Habit from 2 years back, is half of habit from one year, so **0.015**.

APPENDIX C: Summary of Values for Sites and Lake X

*Table 7: **Summary of Values for Sites and Lake X***

Lake	Average Distance To Lake	Lake Area (ha)	Cottage Access	Gravel + Paved Access	Access Squared	Secchi Depth
Amisk	79	515	1	2	4	1.5
Baptiste	72	981	1	1	1	2
Beaver	114	3310	1	4	16	2.9
Calling	111	13800	1	4	16	2.7
Lac La Biche	126	23400	1	6	36	2.5
Long	80	584	0	1	1	2.3
North Buck	87	1900	1	2	4	2.3
Pinehurst	161	4070	0	2	4	1.1
Skeleton	85	789	1	3	9	2.3
Touchwood	153	2900	0	1	1	3.4
Lake X	100	900	0	N/A	N/A	N/A

APPENDIX D: Calculating New Utility From the Quota System

Because the change to the proportion of anglers at each site occurs exogenously to the model, the implementation of the policy is not captured by using a simple logsum. The resulting change in utility (U) is calculated as:

(16) Change in $U = U_1 - U_0$ where

(17) U_1=(% not affected* logsum, all, after) + ((% affected* logsum, unaffected, new)

In Equation 15, U_0 is the logsum of the utilities derived from each site without the regulation. In Equation 16, "% not affected" is the % of anglers that did not have to change their site destination. For example, if there were originally 15% of anglers going to the restricted site and the quota only allowed 10% of anglers to go there, the % unaffected would be 1-(15-10) = 0.95. The "logsum, all, after" is the logsum of all sites after the quota is imposed. Thus, the first term is simply the utility from the sites after the regulation by those who it did not restrict. The second part of Equation 16 finds the utility of the anglers who were affected by the quota. The term "% affected" is the % of anglers who were not able to go their site of choice. In the earlier example, the % affected is 5%. The last term "logsum, new, unaffected" is the logsum of the site attributes after the regulation for the all sites except for the one that is restricted.