1 Introduction

The Salmon Industry of the Pacific Northwest has been a major source of economic progress throughout much of the coastal regions of both Canada and the United States. A fishery that started mainly for subsistence use by regional native populations has grown to be a major source for commercial and recreational fishing. As is often the case, this growing fishery observed declines in populations which led to strict policies targeted at preserving salmon. Regulations have been implemented both in commercial and recreational fisheries to maximize the economic benefits of the fishery while simultaneously preserving Salmon populations to ensure future availability.

Salmon fisheries are plagued by unique regulatory challenges because of the constant movement which occurs within the life cycle of a salmon. Most of a salmon's life will be spent in the ocean, however, most interactions with humans occur as they move into freshwater rivers where they breed and lay eggs. Therefore, it is not feasible to measure a salmon stock by the total population, as the location of a particular population is constantly changing and difficult to measure. To set regulations Alaska focuses on the number of salmon breeding in a particular location each season. They define bag limits using escapement goals which target the number of fish that escape being caught and are able to breed. There are different types of escapement goals used across the state for varying situations but at the minimum these goals attempt to ensure a sustainable salmon yield that will not adversely affect populations in the near future. That is, regulations are set in such a way that the same number of salmon can be caught each year without adversely affecting future populations.

In Alaska, regulators go one step further to ensure salmon populations are harvested at sustainable rates, by actively adjusting bag limits to ensure sustained populations. To account for the variation in salmon stocks and to ensure the fisheries are being exploited in an optimal way, emergency orders are used. An emergency order is an announcement by the Alaska Department of Fish and Game which can be made at any time to change catch and bag limits for recreational fisheries. These orders can be applied to the entire state or specifically to particular regions or rivers and can increase or decrease catch and bag limits or shut down a fishery all together. This policy instrument allows the state to ensure escapement goals are met when there are relatively low numbers of returning salmon and fishing opportunities are exploited when there is a larger than expected salmon run.

Emergency orders are a fundamental part to the management of salmon populations in Alaska. While significant scientific research is done to estimate exactly what level of harvest is sustainable, relatively less research has been done on the welfare effects of these policies. Emergency orders adversely affects recreational fishers by reducing the amount of fish they are able to harvest and possibly impacting their decision to fish at all. In order to understand the true impact of these regulations, there is two key results that must be estimated: the change in salmon populations as a result of the policies and the change in the consumer welfare from the policies. My research will focus on the second of these two and try to answer: *What is the impact of emergency orders on consumer welfare in recreational fisheries in Alaska?* Understanding the answer to this question is fundamental in the optimal implementation of emergency orders.

While Alaska has put significant resources into ensuring salmon industries continue to flourish in the state, relatively less attention has been given to the most cost effective way to achieve these goals. My research will help identify the impact the state regulations are having by looking specifically at the impact to recreational fisheries through a travel cost demand estimation. The paper will proceed as follows, Section 2 will provide some background on previous literature, section 3 will contain a model, section 4 will discuss the data, section 5 will discuss empirical strategy, section 6 will provide results and section 7 will conclude.

2 Previous Literature

The value of increasing harvest rates in the recreational fisheries of Alaska has been investigated in previous literature. Layman et al. (1996) use a hypothetical travel cost model to estimate the impact to consumer welfare of implementing 3 different policies with respect to harvest limits of Chinook salmon on the Gulkana River in Alaska. When the paper was written the current policy was a daily bag limit of one Chinook salmon with a limit of one in possession. The three goals of the paper are to: estimate the value of Chinook salmon using travel cost estimation under the current policy, estimate the change in benefit from a change in Chinook abundance and finally estimating the change in benefits from fisheries under 3 hypothetical policies which raise catch limits.

Layman et al. (1996) find that implementing each policy increases the consumer surplus of a trip and daily consumer surplus of fishing. They collect data on travel costs, demographic information, number of trips taken to the river and hypothetical trips given a policy change. They used both OLS and Tobit models, controlling for different estimates of travel costs and other variables to estimate the effect on the number of trips taken under each hypothetical policy. In all cases, the actual number of trips taken is lower than under the hypothetical policy. Finally, the paper estimates the effect to consumer surplus from the change in policy by looking at the difference in travel costs that will occur from additional trips, showing all three policies have benefits to consumer surplus.

A similar question is investigated in Carson et al. (1990) which uses a contingent valuation model to value King Salmon on the Kenai River in Alaska. The authors of this paper argue that a travel cost methodology is not appropriate because it cannot assess the potential value of increasing catch limits. This paper rather uses survey data where respondents indicate the amount of fish they would catch if they had to pay certain amounts for each quantity of fish.

The paper then develops a theoretical model which places consumers into groups based on their responses. The groups consist of how many fish they would want to catch and keep in the absence of any license. They use these groups to derive an expression for how much an angler would be willing to pay for an additional Salmon given that the limit is below their desired catch. Empirically, they estimate these results by using survey data on the amount of Salmon anglers desire to harvest and their willingness to pay for each Salmon. The results show that anglers have positive willingness to pay for each fish but it diminishes as the number of fish increases. This is consistent both with the previous paper discussed as well as the theoretical expectations.

An important consideration that the previously mentioned papers fail to incorporate is the existence of substitutes. Both papers analyse the welfare effect of changing bag limits in a specific region of Alaska as if it exists in isolation. In reality, people have the potential to consider a wide range of options when selecting an area to fish, and because of the existence of emergency orders, the bag limits have the potential to fluctuate regionally. Therefore, my research attempts to add to this existing literature in two main ways. First, it will incorporate substitution decisions into the estimation to estimate a more realistic value of bag limits in a fishery. Second, it will use revealed preferences from fluctuating bag limits as a result of emergency orders rather than the stated preferences from hypothetical policies given in the previously stated literature.

In order to get the true effect of fluctuating bag limits empirical models must incorporate substitution between fisheries in their estimation. There is existing literature which attempts to value recreational fisheries allowing for substitution patterns. Specifically, Morey et al. (1993) attempts to estimate the economic value of recreational salmon fishing on the Penobscot River in New England using a repeated nested logit model. The main result of this paper is that the value of this recreational fishery may be below the preservation costs due to the relatively low number of anglers. However, more relevant to my research it notes that the value of a fishery can be significantly over estimated when not accounting for substitution between fisheries. They find that the logit model which implicitly assumes the Independence of Irrelevant Alternatives does significantly worse at predicting actual trips taken then the nested logit model which allows substitution between fishing sites. The results of this paper show that allowing for substitution in a market for fishing sites is important in obtaining the true value.

Hausman et al. (1995) use a similar estimation strategy to estimate environmental damages of an oil spill with respect to recreational activities. Specifically, it estimates the damage to consumer welfare of fisheries in Alaska from a large oil spill by using a discrete choice model comparing different sites and their changing values when the oil spill occurs. The model uses data on the number of trips taken to Alaska and the travel costs of these trips to estimate the effect of the oil spill on welfare, allowing for substitution between recreation sites.

To analyse this issue the authors use a 2-stage estimation. First, the individual decides the number of trips, then decides which recreational sites to visit on these trips. Using this model they estimate consumer welfare before and after an oil spill using a nested multinomial logit model, to allow for substitution between sites, to see the total impact of the environmental incident on welfare. Data on travel costs to a particular site is used as the implicit price in the model and the effect desired can be estimated using a panel data-set from before and after the spill occurred.

The paper concludes that allowing for substitution significantly lowers the effect to consumer surplus from environmental damages. By estimating two models, one which allows for significantly more substitution between recreational sites, the authors show that the damages can be substantially mitigated by consumers substituting between sites. This implies that consumers responses to damages are important to consider in the assessment of damages following an environmental disaster. If consumers can respond accordingly it may not be necessary to compensate them from these incidents.

In relation to my research this paper presents an important point: environmental damages can be mitigated through substitution. While this paper provides a good framework for a particular incident and how it affects a recreational site, it does not specifically consider the impact of bag limits. There is no previous literature to my knowledge specifically investigating the effects of bag limits that accounts for substitution between fisheries. My research will implement the nested-multinomial logit model discussed as a way of getting a more precise estimate of a changing bag limit to the value of a fishery.

3 Theoretical Model

The empirical approach presented in this paper is, in part, motivated by the theoretical model presented in (Cox et al., 2002). In this paper a model is developed to understand fishing effort. They assume that people care about the number of vulnerable fish (fish that can be caught) in a given fishery, the change in vulnerable fish can be modelled as

$$\frac{dV}{dt} = v_1(N - V) - v_2V - qeV$$

Where V is the density of vulnerable fish, N is the total fish density, v_1 and v_2 represent how fish change between responsive and not responsive, q represents "catchability" and e is fishing effort. Then the total density of vulnerable fish is given by

$$V = \frac{v_1 N}{v_1 + v_2 + qe} \tag{1}$$

From here the model assumes that the total catch c for any fishery is given by $c = qV$, further if a certain fishery has above average catches then effort will adjust in order to make catch rates constant across all fisheries, we can therefore represent the catch rate across all fisheries as c_0. Therefore using equation (1) the effort in any fishery can be characterized by

$$e = \frac{v_1}{c_0} N - \frac{v_1 + v_2}{q}$$

Then to get season effort integrate this equation over time T which yields

$$E = \frac{N_0 - N_\infty}{c_0}(1 - e^{-v_1 T})$$

where N_∞ is the minimum fish density which will attract any fishing effort and N_0 is the fish density at the beginning of a season. The final piece of the theoretical model is to relate this to regulatory changes. (Cox et al., 2002) assume a linear relationship to model regulatory changes, however they note this could take different functional forms. For simplicity we will display the simple linear relationship here

$$c_0 = \alpha + \beta B$$

where B is the bag limit. They assume β will be negative which is to say as bag limits increase the catch rate will decrease. Therefore increasing a bag limit will reduce the catch rate and increase effort in a fishery. In this framework people care significantly about harvesting fish. As effort rises the amount of available fish will decline and reduce the quality of the fishery over time, meaning that eventually effort will decrease.

This theoretical model captures the type of relationship we wish to capture in the data, where effort decreases in a fishery when a stricter bag limit is implemented. Unfortunately, the natural variation we see from emergency orders does not allow us to estimate the effects over time that are predicted in this model. While we do have natural variation in the catch limits, emergency orders are seasonally based, and the lack of permanence does not allow the quality of the fishery to adjust.

4 Data

A variety of data is needed to estimate this model and most of it is publicly available. The data with respect to fishing measures is available through the Alaska Department of Fish and Game. This includes drainage level data on the number of days fished and the total number of anglers, which both can be used as measures of fishing effort. Additionally, drainage level data on total catches and total harvests are available for all types of salmon. Finally, announcements of emergency orders for every year are available on the Alaska Department of Fish and Game website dating back to 1998. All data from the Alaska Department of Fish and Game is annual data except for emergency orders where the exact release date is available.

Weather is an important factor that will be considered in this model. Regional weather data is available through the National Oceanic and Atmospheric Administration. There is hourly observations for surface temperature available and total hourly precipitation dating back to 1951.

The two empirical strategies are described in the next section and the data presented here is not sufficient to use either strategy. In order to implement the preferred strategy, the multinomial logit model, I would need to acquire travel cost data at the individual level for all fisheries in Alaska. It is unlikely that this data exists but it may be possible to match different data sets to come close to this. Regardless acquiring this data is extremely difficult, it is hard to find data on travel costs from the same years and it is likely not feasible to construct this data set.

The second approach I describe is a regression discontinuity design, again the available data will not suffice. However, the data described would be sufficient if it consisted of daily or at least weekly observations. Implementing a similar strategy with annual data is not feasible because it is not clear whether fishing occurred before or after emergency orders are implemented. There is not an effective empirical strategy which can estimate the desired effects with the data available.

5 Empirical Approaches

There are 2 main empirical approaches I will discuss here each with unique benefits and drawbacks. The first approach involves a nested-multinomial logit model as has been discussed in the previous literature section. While this approach is ideal, data availability could be an issue since micro-level data on trips and costs is necessary for this approach to be implemented. I have also considered some empirical models which allow for demand estimation with macro level data, such as the one developed by Berry et al. (1995). The major issue with this approach is the variation in price. Macro data on fishing effort (which here would act as quantity purchased) is readily available, but travel prices vary significantly at the individual level making a macro level price an inaccurate measure of the true cost.

The second approach would use a simpler empirical strategy. To reduce the amount of data required we could implement a regression discontinuity approach with time as the running variable. This strategy will attempt to estimate discontinuous jumps in fishing effort when an emergency order is implemented. While the approach does not estimate explicitly estimate the effects given by the multinomial logit model, it can provide more general insight into how fishing effort changes when emergency orders are implemented.

5.1 The Multinomial Logit Approach

The multinomial logit model is one of the most commonly applied models to empirically estimate a decision between multiple products. The general set up is given by the simple equation

$$y_{it,k} = \beta x_{it,k} + \alpha D_{it,k} + \epsilon_{it,k}$$

The outcome variable $y_{it,k}$ can be thought of as a score representing the probability that a site k will be chosen by individual i in time t. Then $x_{it,k}$ represents characteristics of the particular fishing site in time t for individual i, this will include weather variables for the year, fish catch rate, the travel cost, the catch limit at that site and the a change in catch limit as a result of emergency orders which apply to that site. $D_{it,k}$ represents demographic characteristics of the individual such as income, gender etc. The actual probability that site k is chosen by individual i in time t is given by

$$s_{it,k} = \frac{e^{\beta x_{it,k} + \alpha D_{it,k}}}{1 + \sum_j e^{\beta x_{it,j} + \alpha D_{it,j}}}$$

The main drawback of using the multinomial logit approach is the independence or irrelevant alternatives assumption. This means that a particular individual is equally willing to substitute between any two fishing sites. This assumption is not likely realistic due to the nature of Alaskan fisheries. The area covered is extremely vast and it is not necessarily feasible to substitute between certain fisheries.

To deal with this issue I use a nested multinomial logit model where individuals first choose whether or not to take a trip, they next select a region which includes a group of sites and then select between the available sites within that region. The advantage to this approach is that it allows for certain sites to substitute more closely to sites within their region and not as closely with others. The probability that a site is chosen can be broken down into separate logit models. The lowest level model is the same as before but now only occurs within the region for a particular season and is therefore given by

$$s_{it,k|J|T} = \frac{e^{\beta x_{it,k} + \alpha D_{it,k}}}{1 + \sum_{j \in J} e^{\beta x_{it,j} + \alpha D_{it,j}}}$$

where J is region and T is that a trip is taken. The difference is the sum in the denominator includes only alternatives within the same nest and $x_{it,k}$ will only include drainage specific emergency order changes rather than any change that affects that region. The middle level model or the second decision stage is the probability that an individual chooses a specific region J and is given by

$$s_{it,J|T} = \frac{e^{\gamma Z_{it,J} + \lambda_J C_{it,J}}}{1 + \sum_{L \in T} e^{\gamma Z_{it,L} + \lambda_J C_{it,L}}}$$

where $C_{it,J}$ is the inclusive value of the options within the region. Mathematically it is the log of the denominator of the lower level model, it is meant to act as an index for the controls of all the sites in region J. $Z_{it,J}$ represents region level characteristics, since most of this is captured in the $C_{it,J}$ variable $Z_{it,J}$ will represent region wide changes to bag limits as a result of emergency orders.

The upper level model represents the decision to take a trip or not and is given by

$$s_{it,T} = \frac{e^{\xi Z_{it,T} + \lambda_J C_{it,T}}}{1 + e^{\xi Z_{it,T} + \lambda_J C_{it,T}}}$$

Here the inclusive value is defined the same as before but for the middle level model rather than the bottom. $Z_{it,T}$ will include changes to bag limits from statewide emergency orders if one was implemented in that year. Then the probability of taking a trip to site k is given by

$$Pr(k) = s_{it,k|J|T} \cdot s_{it,J|T} \cdot s_{it,T}$$

Therefore an emergency order at a statewide level for an entire year will reduce the number of trips taken in that year, while an emergency order implemented at a lower level may result in reduced trips or may result in substitution between regions or sites. Any regulation that is implemented we can get the change in probability of visiting a particular site and a change in probability of taking a trip which allows us to compare the total welfare losses from that regulation.

There is a couple main issues with this type of analysis. The first and most obvious is the availability of data. In order to implement this type of model we would need micro level data on the number of trips taken, where trips were taken and costs of those trips for all drainages in Alaska. This is not readily available and would require significant investment to collect. The second issue is the selection of nests. This model relies on two assumptions: independence or irrelevant alternatives within a nest and no direct substitution of sites between nests. This makes the selection of nests extremely important and is unlikely to accurately represent the consideration of different trips by individuals. Different individuals may select sites and trips for different reasons and this model implicitly assumes all decisions are made in the same way as described above, which may be unrealistic in practice.

5.2 Regression Discontinuity Model

The alternative to the multinomial logit model would be a regression discontinuity model. The advantage to this type of model is that it can be estimated with more general data. We could use macro level data however, we would need more frequent observations, such as daily data. The exact specification would be

$$y_{it} = \beta_0 + f(t) + E_{it}(\alpha_0 + g(t)) + \gamma x_{it} + \epsilon_{it}$$

Here y_{it} represents fishing effort, which acts as a measure of the number of people fishing and is measured by number of angler days fished. $f(t)$ and $g(t)$ are polynomials for time trends, while E_{it} is before and after an emergency order was implemented.

There are two main assumptions that must hold for this approach to be valid, first all things must trend smoothly across the threshold other than the implementation of an emergency order. This is likely to hold as much of what determines the decision to fish is natural phenomenon and exogenous and therefore unlikely to adjust at the same time as the emergency order. Things like weather are being controlled for and therefore not likely to affect the results. The second is that crossing the threshold must reduce the catch limit for all individuals.

With respect the first assumption there could be multiple problems causing this assumption to fail. First, if the state implements other policies other than emergency orders than the assumption does not hold. While this may be likely, emergency orders are the main thing that will affect the choice to fish and therefore the estimate is likely close to causal. Second, emergency orders are not random and are somewhat predictable. Since the emergency orders are decided based on escapement targets, avid anglers will likely be able to predict certain emergency orders based on season patterns and adjust habits accordingly.

With respect to the second assumption, it is less likely to be violated. The main threat is that these emergency orders are not enforced and people can continue harvesting at rates they see fit. This is highly unlikely, conservation efforts are prominent in Alaska and the penalties for breaking these rules are harsh. Monitoring is consistent and thorough, making cheating extremely difficult. Further, within angler culture there is self enforcement where more experienced anglers are aware of the actions of others. All of this combines to make harvest laws difficult and costly to break making the second assumption likely to hold.

6 Results

The main thing that is expected from the results is that we observe lower declines in consumer welfare from previous literature. Within our preferred specification, the multinomial logit model, we would expect to see that an emergency order reduces the probability that a specific fishery is chosen but does not greatly reduce the total days spent fishing. From these results we could estimate the welfare changes that would occur by summing the total lost value at sites where trips went down and total gained value at sites where trips increased.

The second model does not have a clear description of substitution patterns. We can estimate total welfare changes by looking at the statewide change in days fishing although this does not really give an accurate picture as we do not have an accurate measure of these days. Alternatively, to see if this substitution pattern exists we can consider the change at the threshold for areas where the emergency order takes effect, we would expect to see a negative effect. Then, perform the same regression for areas not affected by the emergency order and we would expect to see a positive effect of the emergency order. These results do not get at the welfare changes we are trying to estimate but give a better picture of how the change in bag limits is affecting fishing habits.

7 Discussion

Alaska is one of the most desired places in terms of the opportunities for recreational fishing. The opportunities are abundant and prosperous for the state making the preservation of these opportunities extremely important. Something that has been largely overlooked in the literature so far, is the role that anglers have in this responsibility for preservation. It has been assumed for a long time that, given the opportunity, fisheries will be over exploited as the costs of destroying the fishery are external. Through some of the literature discussed there seems to be an argument, that given sufficient information and incentives, anglers will adjust behaviour to maximize welfare while simultaneously preserving natural resources. Empirically estimating if these behavioural responses exist is important for assessing consumer welfare and therefore in setting optimal conservation studies.

The largest barrier to performing this analysis is the availability of data, there is a few ways in which this problem can be addressed. The multinomial logit model described above would be the optimal way to consider these problems but collecting this data may not be feasible. Alternatively, one could pursue using a model consistent with macro level data such as (Berry et al., 1995). As mentioned previously the main problem with this type of approach is the lack of an explicit price. If an accurate measure of the price of fishing can be acquired other than individual travel costs, this approach may be the best. An interesting approach could be average travel time or cost from the nearest major airport, which would give a somewhat consistent measure of the average travel cost of the measure.

As mentioned, other empirical approaches may be feasible if data is collected at more regular intervals. If daily observations of fishing effort are acquired, a regression discontinuity design or a difference-in-difference approach may be useful. In reality, the large amounts of data needed to carry out the empirics in this paper likely does not exist and is too difficult to collect. A more realistic, opportunity could be to reduce the scope of the paper to focus on a smaller area than the entire state of Alaska. Regardless, a more accurate understanding of how anglers respond to regulation is important to understand, however a more detailed data set is required to add to the existing literature on this topic.

References

Berry, S., J. Levinsohn, and A. Pakes (1995). Automobile prices in market equilibrium. *Econometrica: Journal of the Econometric Society*, 841–890.

Carson, R., M. Hanemann, and D. Steinberg (1990). A discrete choice contingent valuation estimate of the value of kenai king salmon. *Journal of Behavioral Economics 19*(1), 53–68.

Cox, S. P., T. D. Beard, and C. Walters (2002). Harvest control in open-access sport fisheries: hot rod or asleep at the reel? *Bulletin of Marine Science 70*(2), 749–761.

Hausman, J. A., G. K. Leonard, and D. McFadden (1995). A utility-consistent, combined discrete choice and count data model assessing recreational use losses due to natural resource damage. *Journal of Public Economics 56*(1), 1–30.

Layman, R. C., J. R. Boyce, and K. R. Criddle (1996). Economic valuation of the chinook salmon sport fishery of the gulkana river, alaska, under current and alternate management plans. *Land Economics*, 113–128.

Morey, E. R., R. D. Rowe, and M. Watson (1993). A repeated nested-logit model of atlantic salmon fishing. *American Journal of Agricultural Economics 75*(3), 578–592.