Measuring the Impacts of Wolves on the "Market" for Elk Hunting: Hunter Adjustment and Game Agency Response*

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I. Introduction.

> *Some hunters, outfitters and politicians have blamed wolves for declining elk numbers. Park scientists maintain there are a variety of factors, like drought and other predators, at play…(McMillion 2003, "Elk...It's what's for Dinner")*

The reintroduction of the gray wolf to Montana and other western states has to date largely pitted ranchers against environmental groups, with the U.S. Fish and Wildlife Service (USFWS) as the central agency for this reintroduction.[1] There is also another group affected by wolves that to date have had little influence on this reintroduction. Hunters and outfitters have diverse views on wolves, and accordingly have not spoken with one voice concerning their reintroduction.[2] This lack of a common view is mirrored by the Rocky Mountain Elk Foundation's (one of the largest hunting groups in North America) evolving policy statements in 1995 and 2003 that specifically addresses that their membership will take different sides to wolf reintroduction, and that the group supports state control of wolves, "ultimately achieving an appropriate balance between wildlife, habitat, and people" (Rocky Mountain Elk Foundation, 2005).

Part of the ambivalence of hunters towards wolves stems from the general lack of published knowledge regarding the actual impacts of wolves on game populations, game behavior, and ultimately hunters' satisfaction. This lack of knowledge arises due to the

[1] The USFWS is in the process of passing management of wolves to Montana and Idaho. Wolves are still listed as threatened under the Endangerd Species Act (Montana Fish, Wildlife and Parks, 2005). This agency transfer was made after Montana's and Idaho's wolf management plan were accepted by the USFWS. Wyoming's plan has not been accepted, and wolves remain under federal control there.

[2] The wide range of hunter attitudes toward wolves are evident in popular hunting magazines such as Field and Stream (McCafferty; McIntyre) and Outdoor Life (Zumbo).

complex nature of the predator/prey relationships, the extensive movements of wolves and their prey, and the difficulty of obtaining good population estimates of both wolves and particularly their prey. Additionally from an economic perspective, hunters' property rights to game are ill-defined, with the political strength of hunting "rights" and their values quite difficult to determine.

This paper provides estimates of the effects of wolves on hunter opportunities, where these opportunities are influenced by actions taken by both the game agency and hunters in response to the spread of wolves. We utilize permit availability, hunter success, and measures of hunter competition as published by Montana Fish, Wildlife and Parks (MFWP) to assess the impacts of wolves on hunters. We focus on elk − a game species that is both vulnerable to wolves and that is in high demand in Montana.

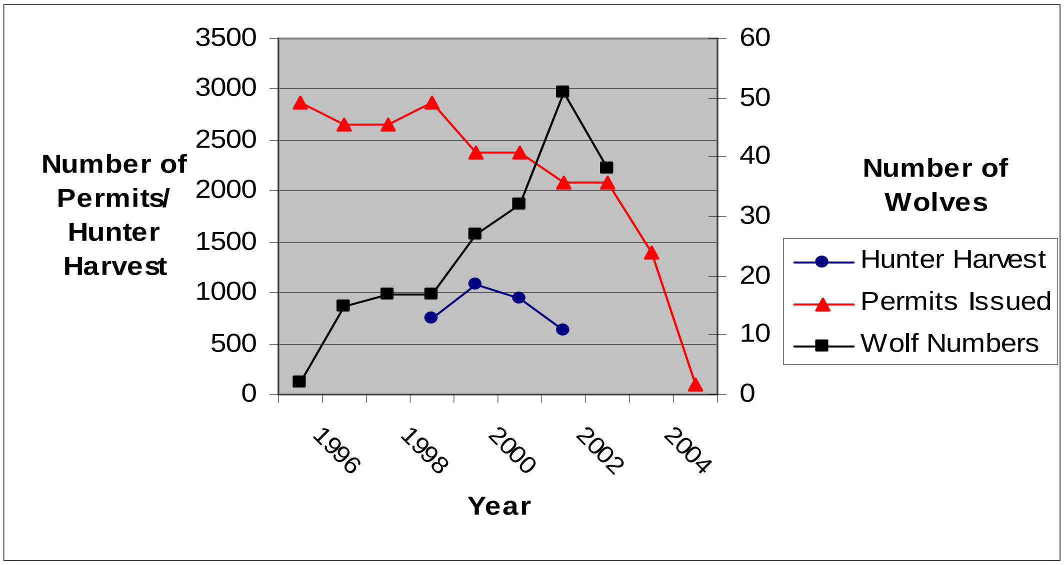
Our estimation approach draws from a hedonic model in which hunters compete for a rivalrous good (an elk hunting opportunity) that is not allocated through a price mechanism. Hunters in most western states compete for hunting rights by entering a special permit lottery in some cases, while they compete in other cases by undertaking costly activities to obtain a right under open access. Hunters compete for these rights under open access by racing to reach hunting areas early, establishing expertise and customary areas, and in other ways consistent with Barzel (1974). Both types of competition are observable as in Nickerson (1990), by Buschena, Anderson, and Leonard (2001), and by Scrogin, Berrens, and Bohara (2000). Hunters are modeled empirically so that they can benefit from elk and also from experience value of wolves.

The paper provides not only a study of agency decisions in response to impacts of a threatened species, but also applies a relatively little-studied method of determining factors of demand and agency decision for goods distributed via a non-price mechanism. Our application (1) uses observable measures of hunter competition that reflect good valuation, (2) statistically accounts for the endogeneity of hunter and agency decision, and (3) models the simultaneous equilibria across numerous and diverse hunting districts (the "goods" being competed for in this case).

Our empirical estimation shows that as wolf populations in a particularly high profile region outside Yellowstone National Park become established in a hunting district, (1) the state game agency reduces the supply of special hunting permits, (2) there is lower demand for hunting in that district under special permit licenses, and (3) hunter success rates for both special permits and open access decline with increased wolf pressure. We find that the game agency and hunters respond as hypothesized to reduced hunting opportunities, and that their responses are larger in magnitude for wolf populations with high political profiles.

To presage our results, key statistics from Montana Elk Hunting Districts 313 and 314 adjacent to Yellowstone National Park are illustrated in Figure 1. Readers are encouraged to compare these data with averages for selected periods reported in White *et alia*. Since the reintroduction of wolves and their rapid increase in the Greater Yellowstone area, special cow elk permit numbers have dropped from 2,870 permits in 1996 to 100 in 2005 and zero permits in 2006 (MFWP Big-Game Hunting Regulations, various years). Hunter harvest for these permits has declined by 50% from over 1000 in year 2000 to less than 500 in 2003. Because there were additional factors such as drought that may have influenced elk population, state and federal biologists have been reluctant to attribute these declines to wolves (see the diverse opinions in McMillion, 2005 and also Smith, 2005). Our analysis will statistically determine the effects of wolves on elk hunting opportunities and success rates in these and other hunting districts in Montana, accounting for other factors such as weather.

Figure 1.1. Districts 313 and 314 wolves, cow permits, and hunter harvest.



Sources: Rocky Mountain Wolf Recovery Annual Reports (various years), the Yellowstone Wolf Project (various years), and Montana Fish, Wildlife, and Parks.

II. Wolf Predation Patterns and Wolf Reintroduction in the Rocky Mountain West.

Wolves and others species found protection in the U.S. with the passage of the Endangered Species Act (ESA) in 1973. Wolves began re-migrating from Canada into the Glacier National Park area during the 1980s, with six packs inhabiting the area by 1995 (USFWS 2002, 2003). In addition to this naturally occurring reintroduction, the federal government transplanted sixty-six wolves from southwestern Canada into Yellowstone National Park and Central Idaho throughout the mid-1990s under the Northern Rocky Mountain Recovery Area (NRMRA) wolf restoration plan. Wolves are known to disperse over wide ranges, thus allowing the population to spread fairly quickly

(MFWP Final EIS, 2003). By the end of 2003, an estimated 761 wolves inhabited the NRMRA; there were an estimated 1300 wolves in 2006 (USFWS; 2003, 2004, 2007). The criteria established by the USFWS for a recovered wolf population in the NRMRA were met in 2002 (USFWS, 2007), although wolves have not yet been delisted. The wolves transplanted into Yellowstone National Park have been particularly fecund, have garnered considerable attention, and have dispersed widely outside the park's borders.

The wolf is a very effective predator, with high rates of kill (Mech and Peterson, 2003; Mader, 2004). Estimating the wolf's impacts on big-game herds in the NRMRA is difficult, particularly for estimates over large and heterogeneous areas. The initial Environmental Impact Statement produced by the USFWS was released in May of 1994 prior to the reintroduction of wolves into Yellowstone National Park. In the report, the USFWS stated that a population of 100 wolves in the Yellowstone area would reduce elk populations by 5 percent to 20 percent, mule deer by 10 percent, bison by 5 percent to10 percent, and leave other big-game species populations unaffected (USFWS, 1994). Scientists from the University of Wyoming alternatively estimated reductions in elk populations from 15 percent to 25 percent, while a separate panel estimated reductions in moose populations by 10 percent to 15 percent and mule deer populations by 20 percent to 30 percent (United States National Park Service, 2003).

Population Surveys. Although widely viewed as inaccurate, elk population data from surveys conducted by MFWP points to some potential wolf predation effects.[3] The long-term average elk population for the northern Yellowstone herd from 1968 to 2002

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[3] Annual counts of the northern Yellowstone herd can fluctuate up to 30 percent to 40 percent, with average annual fluctuations of 10 percent to 20 percent.

was 13,846 elk. However, counts from recent years show this number declining quickly. In 2001, there was a count of 11,969 elk in the herd. In 2002, the count was 9,215 elk (MFWP Final EIS 2003). There has also been a decline in calf recruitment, measured by the number of calves (young) per 100 cow elk (mature females).

Biologists have concluded that elk populations in the Greater Yellowstone Area (GYA) of Montana have decreased, but that numerous factors have contributed to the decline of the northern Yellowstone elk herd. Some of these factors are predation, population effects of the drought, winterkill due to snow deep snow pack, as well as hunting, but the importance of these multiple factors have not been quantitatively assessed (MFWP Final EIS 2003).

The Yellowstone Wolf Project (Smith, Stahler, and Guernsey 2003) and work by Creel and Winnie (2004) provide very specific evidence of the effects of wolf predation on relatively small study areas. Combined studies from 1995 to 2002 showed that the composition of wolf-killed elk in the Northern Range of the greater Yellowstone area was comprised of 39 percent calves, 11 percent cows ages 1 to 9 years old, 29 percent cows of ages over 10 years, and 21 percent bulls. Wolves in the GYA area of Montana, like those in Alaska and Canada, are opportunistic, preying on young elk, old elk, and interestingly bull elk in their prime breeding and reproductive lives.

Not all areas of the NRMRA exhibit the same big-game population structure as that of the GYA. Northwest Montana, for example, has a significantly different big-game population than southwest Montana does, with deer comprising most the primary big-game species in Northwest Montana. In the these districts the wolf's diet consists of 83 percent white-tailed deer, 14 percent elk, and 3 percent moose (MFWP Final EIS 2003, 22). These prey composition differences mean that our evaluation of the impacts of wolves on elk hunting in the NWMRA may be quite different for that of the populations in the GYA.

An additional factor accounted for in our estimations, and that amplifies the effect of wolf predation on big-game populations is the presence of other large predators such as bears (grizzly and black) and mountain lions in wolf-inhabited areas. Both species of bears may prey on ungulate calves in the spring and male ungulates weakened from the fall rut (Griztrax.net 2004; Alaska Department of Fish and Game, 2004). In addition, bears scavenge ungulate carcasses when available, often displacing feeding wolves from ungulate carcasses and thus reducing the amount of meat a kill might provide to a wolf pack. Human hunting pressure can likewise influence the impacts that wolves have on elk, and *vice versa*.

III. Hunter Equilibrium Under Non-Price Allocation Methods

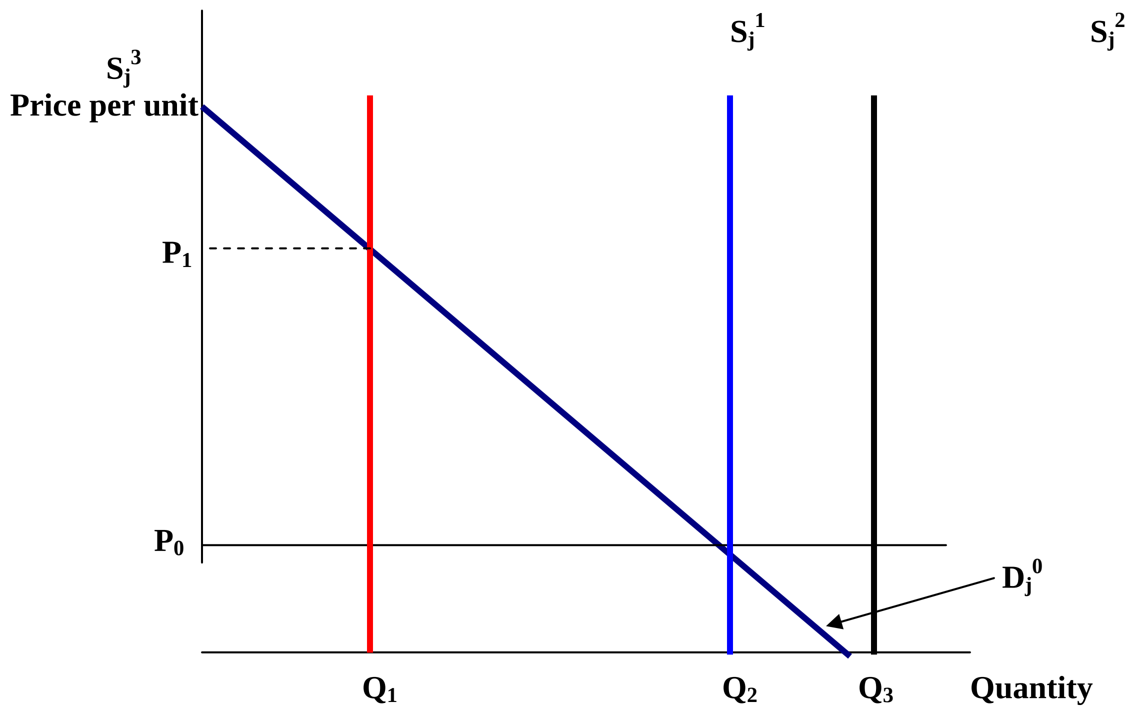
The Market for Limited Hunting Permits

In many western states the "market" for hunting permits does not reach equilibrium using prices. The quantity of permits is set administratively by the state game agency. The agency also defines the dimensions in which hunters can compete for hunting opportunities. The demand for a hunting permit is constructed as a function of the prices associated with obtaining the permit ($\underline{p}$), its characteristics ($\underline{c}$), and the regulations affecting the permit ($\underline{r}$):

(1) $D(\underline{p}, \underline{c}, \underline{r})$.

Consider demand D^0 in Figure 2. The supply of permits is set by the game agency based on area biological studies, as well as constituency pressure from hunters. The supply is represented by a vertical line, and is fixed at the pre-announced quota level. If the price was allowed to adjust to clear the market, the quota level Q_1 would give rise to a price of P_1.

Figure 2. Market supply and demand for hunting permit *j*.



However, rather than adjusting, the price a hunter pays for a permit is fixed at price P_0 in Figure 2. This price is typically uniform over permits for the same species. At this fixed price a shortage exists and is equal to the difference between the fixed quantity supplied, Q_1, and the quantity demanded at that price, Q_2. From Barzel (1974) we know that the market will clear by consumers competing, perhaps by queuing, resulting in a total price of P_1. This total price is comprised of P_0 paid in monetary units, and P_1 minus P_0 being paid in queuing or other costs.

Two other types of equilibria might be observed in this market. If the quota level were fortuitously set at Q_2, a fixed price of P_0 would lead to the market reaching equilibrium in prices. If the quota level were instead set at Q_3, a fixed price of P_0 would give rise to a surplus of Q_3 minus Q_2 and the market reaches equilibrium at Q_2. This surplus equilibrium occurs for some elk permits in several states.

Market Clearing under a Random Lottery

Most special hunting permits are allocated by lottery in western states. Nickerson (1990) analyzed Washington State's lottery system and estimated factors affecting the demand for hunting. Nickerson's model allows inference of the value of a given hunting permit to the marginal hunter using the number of applicants for a permit and the number of permits issued by the game agency. Nickerson's key insight is, *ceteris paribus,* because more hunters enter permits for desirable hunts, the odds ratios of drawing a hunt permit reflects its demand.

The value of permit j, V_j, is a function of permit characteristics ($\underline{x}_j$) and the permit regulations ($\underline{r}_j$). Let the fixed supply of the permit be Q_j, and the number of entrants in the lottery for the permit be N_j. Therefore, Q_j/N_j represents a lottery entrant's likelihood of being drawn and receiving permit j. There is a non-refundable fee associated with the lottery for any permit, P_L. Hunters can only enter the drawing lottery for one permit per year; i.e., they must select the lottery in which to place their single entry.[4]

[4] There are in some states methods that allow a hunter to build up "points" over time that increase their drawing odds. Such a system in Colorado was analyzed in Buschena, Anderson and Leonard. Montana did not have such a system during the years we evaluate here.

The expected value of entering the lottery for permit *j*, λ_j, can be written as the sum of the values of its outcomes weighted by their likelihoods:

(2) $\lambda_j = (Q_j/N_j)*(V_j - P_L) - [1-(Q_j/N_j)]*(P_L)$

$= (Q_j/N_j)*(V_j) - P_L$.

An individual will choose to enter a lottery as long as $\lambda_j > 0$, and the expected value of entering the lottery for permit *j* is greater than the expected value of entering the lottery for any other permit. The equilibrium values for each permit, and their odds, will depend on each permit's price, p_j, characteristics, $\underline{x}_j$, and the regulations for each permit $\underline{r}_j$. In equilibrium, the marginal hunter will equate the expected value of entering a lottery for permits *i* and *j*. If these two permits have the same values, their drawing odds are predicted to be equal:

(3) $\lambda(p_i, \underline{x}_i, \underline{r}_i) = \lambda(\underline{p}_j, \underline{c}_j, \underline{r}_j)$

"Market Clearing" Under Open Access

General license holders in Montana have numerous districts in which to hunt elk at zero marginal monetary costs once the license has been purchased (ignoring travel, time and other costs).[5] Hunting in these open access areas without a special permit is the norm, and the typical problems of overcrowding and overuse result. There is an interesting equilibrium under this open access for which hunters weigh the characteristics of hunting in one area vs. another (or they may alternatively forego hunting), and the marginal hunter in a district defines the equilibrium. The marginal hunter indifferent between open access districts *i* and *j* has the following equality in net values:

(4) $V(p_i, \underline{x}_i, \underline{r}_i) = V(p_j, \underline{x}_j, \underline{r}_j)$.

[5] General license fees are quite small. Montana's elk license fee was $16 in 2003 and $20 in 2006.

The Effects of Wolves on the Non-Price Equilibrium

Wolves can change the hunt characteristics by reducing prey species and also may change the value of the hunt beyond their effect on prey. Wolves in district *i* but not district *j* may therefore change the decision of the marginal hunter under either the permit lottery (Equation 3) or the open access system (Equation 4). If wolves have a negative (positive) net effect on the marginal hunter's value fewer (more) hunters will apply for that permit and fewer hunters will enter the district under open access. We will consider the impacts on both equilibria in our empirical estimations.

Predicted Effects of Wolves on Game Agency Behavior

Batastini (2005) models the response by the game agency to wolf pressure on elk. This two-period model considers support for the game agency for both hunter and general recreational users. The comparative statics results of this constrained optimization model are complex and can not be theoretically be signed. Considerations of anticipated signs and magnitudes provide a few hypotheses that we test here.

Permit numbers in the district with newly existent wolves, district *j*, will likely decrease with wolf numbers if: (a) total hunter net present value from hunting in that district decreases with wolves; (b) hunter and general user value decreases with additional hunting permits; (c) the second order effect of wolves on the effects of permits in (b) are negative; (d) the marginal value of elk in period t+1 is positive for both hunters and general users, and this marginal value decreases with wolves; (e) cross-district effects on marginal values are relatively small; and (6) both additional wolves and additional hunters (permits) decrease elk numbers in period t+1, both at a decreasing rate.

There are no signs reasonably obtainable for the impacts of wolves in district j on the agency's decision to set permits in the district without wolves, district *i*. A critical empirical issue is that appropriate measurement of "wolf pressure" presents an interesting empirical challenge as biologists (e.g., Creel and Winnie) have found wolf effects to have complicated temporal patterns.

IV. Data and Empirical Model

We use three categories of data for our empirical tests. The dependent variables provide measures of hunting opportunity quality, quantity, and demand. The set of explanatory variables of primary interest measure current and longer-term wolf pressure. A set of supportive secondary explanatory variables account for additional factors affecting hunting quality, quantity and demand, but are unrelated to wolf pressure. Observations are by administratively defined hunting districts.

Dependent Variables. Our dependent variables of hunt quality and permit quantity are defined as annual percentage changes during the period 1999-2003, while demand is observed for a single year (2003). The use of percentage changes for a particular district allows us to abstract from land access, travel cost, and unobserved variables while focusing on the critical effects of wolves. The available wolf data and lack of very good annual hunter demographic data combined to lead us to estimate hunter demand for a single year.[6] All of the dependent variables are provided in MFWP's Hunting and Harvest Reports, an annual publication that reports permit numbers, hunter

[6] We also carried out a hunter demand regression for 2000 using the same set of explanatory variables and found qualitatively the same results as for 2003.

success (from extensive surveys of hunters), and the number of applicants for lotteries allowing special permit hunts.

MFWP's Hunting and Harvest reports are released annually, but the reports from the license years 1996 through 1998 have not been released. These years are rather important as they are the years just after the release of wolves into Yellowstone National Park and provide a pre-wolf snapshot for most districts. We use the annual hunting and harvest data from the license years 1999 through 2003 in our analysis.

Hunt quality is measured by the percentage change in annual hunter success rates for both special permits and hunters using a (open-access) general license. If MFWP adjusts incompletely to (overcompensates for) predation by wolves by not reducing permit numbers enough given predation (reducing them too much), then special permit success rates are predicted to decline (increase). If (1) hunters under general licenses adjust incompletely to wolves given predation pressure (too many hunters continue to hunt in areas with wolves), or (2) if hunters place high experience value on hunting in areas with wolves, harvest rates could decline as wolf pressure in a district increases.

Hunt quantity is measured by the number of hunting permits determined prior to the season by the state game agency, MTFWP.

Demand for special permits is measured by the number of applicants for the lottery divided by the number of permits available, the drawing odds. In the event that there are net positive experience effects of hunting in areas with wolves, wolf pressure is predicted to increase hunter demand after hunting success rates are accounted for.

The special permits were split into cow-only tags and either-sex tags that allowed hunters to hunt either cow or bull elk.[7] Most cow hunts are held in the late season, while the either-sex tags apply during the regular season (Oct.-Nov.). The late season cow permit numbers in the districts north of Yellowstone National Park are perceived as being particularly impacted by wolf pressure.

Primary Explanatory Variables: Wolf Predation Pressure

Wolf pressure was measured by a set of four variables intended to capture both the immediate and cumulative effects of wolves on elk and hunters. Because these four variables are necessarily closely related, we will test their joint significance for all three regressions rather than to rely on test of significance for the variables singly.

Some wolves inhabit a single district, with others inhabit multiple districts. Wolves in multiple districts typically follow seasonally migrating elk herds such as those in or near Yellowstone National Park. We used two indicators for the presence of wolves, one for single-district and the other for multiple-district packs. These separate indicators allow us to distinguish between wide-ranging wolves and those with more limited distributions.

The five-year average wolf population within a district measures longer-term predation effects and is the third wolf variable. Finally, the difference between the current number of wolves and the five year average indicates recent increases in wolf numbers.

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[7] We were unsuccessful in defining a model that pooled these two types of permits using intercept and wof/permit type interaction terms.

Wolf pack data for Montana is reported by the USFWS in their Northern Rocky Mountain Wolf Recovery annual reports. Addition data for wolves in the GYA are provided in the Yellowstone Wolf Project's Annual Reports (Smith and Stahler). Wolf pack size and distributions in Northwest Montana for 1998 were estimated using the USFWS reports available for these populations in 1996 and 1999 after consultation with Ed Bangs (October 2004), the lead wolf biologist with the USFWS.

Wolf pack sizes and distributions were combined with hunting district maps to determine which districts were inhabited by wolves each year. Because as discussed earlier wolf packs and their prey differ among various regions in Montana, the four wolf variables will be split for districts in (1) Southwestern Montana, (2) Northcentral Montana, and (3) Northwestern Montana.

Additional Explanatory Variables: Permit Restrictions.

Indicator variables (taking the value 1 if true, 0 otherwise) will control for a particular type of special permit for elk, particularly important for the hunter demand regression. All of the data needed to define these variables is from MFWP's Hunting and Harvest Reports. An A7 license is a special permit for cow elk hunting that reduces other hunting opportunities for elk, and is thus less valuable to hunters, *ceteris paribus*. A multi-district indicator defines a permit that allows hunting in more than one district. Early and late season indicator variables define generally desirable hunts for periods outside the regular hunting season. Youth hunts, archery only hunts, a restricted type of either sex hunt, and brow-tined bull only indicators control for hunting restrictions that reduce the value of special permits, *ceteris paribus*.

Additional Explanatory Variables: Weather Variables.

The National Oceanic and Atmospheric Administration (NOAA) provides annual summaries of climatological data for all weather stations in the United States, including the monthly precipitation and average monthly temperatures for all Montana weather stations (NOAA, Climatological Data Annual Summary, various years). The most proximate weather station was selected for each hunting district. The precipitation and temperature data measures we selected are expected to affect elk populations and hunting success rates. Precipitation variables included inches of moisture during the January-March period (and its square), the April-August precipitation level, the difference (from the previous year) in September precipitation, the difference in October precipitation, the difference in November precipitation, and for late season hunts the difference in December precipitation. Temperature variables included the average temperature from January to March, the change in the September temperature (from the previous year), the change in the October temperature, the change in the November temperature, and for late season hunts the change in the December temperature. January-March weather data accounts for winter conditions during the most stressful period for elk survival. April-August precipitation accounts for summer forage critical for calf survival. Differences from the previous year in precipitation and temperature account for the important effects of weather on hunting success in areas of varied elevation and terrain.

Additional Explanatory Variables Considered: Pressure by Other Predators. Mountain lions, grizzly bears, and black bears all prey on elk. Bears, particularly grizzlies, prey on elk calves in the spring. Only black bears have a useful published measure (lagged harvest rates for bears) that changes much annually. This lagged black bear harvest level did not add any explanatory power to the regression estimates in preliminary runs and was therefore excluded from the estimation.

V. Estimation Procedures and Results.

Three-stage least squares procedures with White's heteroscedasticity correction were used to estimate a system of two equations for the special permits for cow elk and for the either sex permits.[8] The two dependent variables in these systems were the percent change in hunter harvest rates and the percentage change in the number of permits issued. Hunter harvest was measured for both special permits (cow permits and either sex/bull permits) and general license harvest. A separate instrumental variables regression was run for special permit demand (lottery applications) for 2003. A White corrected GLS model was also estimated for the change in hunter harvest rates for general elk licenses. Descriptive statistics are given in Table 1.

A. Percentage Change in Hunter Harvest.

The results for the percentage change in hunter harvest are given in Table 2. We focus our discussion on the joint effects of the wolf variables. The weather variables were jointly significant at their means, and increases in permits issue significantly decrease success rates. Results for the group of variables measuring the effects of wolves are presented by geographic area.

Southwestern Montana. The set of wolf variables were jointly significant at 5% level with a negative effect for the success rates for cow permits at the means in this area.

[8] Preliminary (OLS) runs revealed some heteroscedastic error problems, but not statisically related to the explanatory variables.

These wolf variables were not jointly significant for the number of either-sex permits or for general hunter success at the means. These results are consistent with a model were the agency reduces (cow) permits due to wolf pressure, some general license hunters avoid districts with wolves and thus equilibrate the success rates across regions with and without wolves. The number of hunters was instrumented for the success rates for general license holders in a GLS regression.

Central Montana. The set of wolf variables was not jointly significant at the 5% level for either the percentage change in hunter success rates for hunters with cow permits, or for success rates for general license holders.

Northwestern Montana. The set of wolf variables was jointly *positive* and significant at the means for the change in hunter harvest rates for cow permits in Northwest Montana at less than 1 percent. Recall that elk are not the primary prey species of wolves and the number of cow permits is quite small in this area. There were no significant joint effects of wolves on general hunter success in this district.

B. Percentage Change in Permits Issued.

The estimated joint effects of wolves on permits issued in Table 3 indicate that MTFWP significantly (p-value .016) decreased cow elk permit numbers in response to wolves for the high profile and high growth wolf packs in Southwest Montana. These significant effects occurred after measures for weather was accounted for. We found no significant effects of wolves on elk permits in either Northwest Montana, or in Central Montana.

The increase in wolf pressure as measured by the set of Southwest Montana wolf variables resulted in a cumulative estimated decrease of xxx permits in the number of cow permits at the means from 1999 to 2003. There was also a significant decrease in the percentage change in either-sex elk permits in Southwest Montana due to the wolf variables (p-value less than 1%).

There were no significant joint effects of the wolf variables on the percentage change in the number of cow permits in Central or in Northwest Montana. Note also that the hunter success rates (Table 2) in these areas also did not show significant negative effects from wolves. Wolf pressure in these areas has been lower than in the Southwest Montana area, particularly in hunting districts adjacent to Yellowstone National Park. As previously discussed the prey composition of wolves in these districts also differs.

C. Special Permit Hunter Demand

The statistical estimates for the effects of wolves and other variables on the number of first choice applicants on hunter demand for special permits are given in Table 4 for cow permits and either-sex permits for 2003. These regressions were run using White's heteroscedasticity-corrected GLS model.

Southwest Montana. Wolves statistically significantly (1% level) reduced hunter demand for special permits at the means for cow and either sex permits by a cumulative xxxx permits in Southwest Montana during the period studied. Applications were reduced by xx% for cow permits (a decline of xxxx permits) and increased xxx% for either-sex tags (an increase of xxx permits). Recall that most cow permits are late season hunts, many for areas adjacent to Yellowstone National Park, while the either sex permits are generally held during the regular season for resident elk.

Central and Northwest Montana. The set of wolf variables significantly (less than the 1% level) *increased* permit applications per permits issued for cow permits in

Central (a 16% increase in applicants) and Northwest Montana (a 32% increase in applicants).

V. Conclusions and Caveats.

This analysis utilizes observable measures of game agency response, hunter demand and hunter success to measure how an agency and recreational users adjust their behavior in the presence of a new factor impacting the resource. Although the subject of our analysis is a resource that is not allocated via a pricing mechanism, we are able to identify and empirically evaluation changes in value by careful consideration of the ways in which agents compete for the scarce rivalrous open-access good. The theoretical basis for this empirical evaluation lies with Barzel's (1974), with related applications by Nickerson (1990), Buschena, Anderson, and Leonard (2001), and Scrogin, Berrens, and Bohara (2000).

We find quite significant negative effects of reintroduced wolves on hunting permits offered by the agency, hunter success, and special permit demand. These reintroduced wolves were transported into Yellowstone National Park in the mid-1990's by the U.S. Fish and Wildlife Service and have subsequently established vibrant packs outside of the Park. Interestingly, we do not find similar significant negative effects of "naturally" occurring wolves in other hunting areas; wolves in these other areas have established packs on their own without a capture and transport program.

Our empirical analysis attempts to correct for other factors, such as weather and predation by other animals, on the impacts of wolves on elk hunting. Although we have established some arguably useful weather proxies, proxies for predators other than wolves are quite difficult to establish. The time-series and cross section characteristics of our data should to some extent mitigate the unobserved predator effects in the event that predation by other species can be viewed as a roughly consistent levels effect.

Data availability limited our analysis. The Montana Department of Fish, Wildlife, and Parks have not released hunting reports for critical years 1996-1998, the years just before the reintroduced years were emerging from Yellowstone National Park. Additionally, at the time of the analysis 2003 was the most recent year of data; future efforts will extend the years analyzed as the data becomes available.

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Table 1: Descriptive Statistics [to be added]

Table 2: Percentage Change in Hunter Harvest

Variable	Cow Permits	Either-Sex/Bull Permits	General License
Northwest Montana Wolf Variables			
Joint Effect, p-value	**0.000**	#	**0.93**
Single District Wolf Initial Inhabitance Dummy	1769.93* (806.81)	#	0.87 (13.19)
Multiple District Wolf Initial Inhabitance Dummy	402.21* (201.32)	#	1.05 (5.18)
Five Year Average Wolf Population	-77.01** (18.45)	#	0.63 (0.76)
Difference from Five Year Average Wolf Population	8.33 (25.75)	#	0.35 (1.40)
Central Montana Wolf Variables			
Joint Effect, p-value	**0.135**	#	**0.42**
Single District Wolf Initial Inhabitance Dummy	74.22 (471.56)	#	15.46 (11.36)
Multiple District Wolf Initial Inhabitance Dummy	-213.01 (285.86)	#	9.28 (11.08)
Five Year Average Wolf Population	-33.29* (16.73)	#	-0.40 (1.60)
Difference from Five Year Average Wolf Population	-80.86 (55.85)	#	-3.80 (2.31)
Southwest Montana Wolf Variables			
Joint Effect, p-value	**0.05**	**0.25**	**0.88**
Single District Wolf Initial Inhabitance Dummy	- 1980.19** (1010.22)	-2.89 (1.86)	-2.22 (22.15)
Multiple District Wolf Initial Inhabitance Dummy	-434.88 (1137.13)	-1.45 (1.12)	-9.19 (9.65)
Normalized Five Year Average Wolf Population	-719.01 (526.13)	0.06 (0.19)	-0.34 (2.05)
Normalized Difference from Five Year Average Wolf Population	2.76 (203.49)	0.02 (0.08)	0.63 (1.46)
Other Model Variables			
Normalized Change in Permits Issued or number of hunters	-3.03** (0.51)	-0.75** (0.24)	0.15** (0.02)
January through March Precipitation	10.92 (7.31)	-0.05 (0.08)	0.06 (0.05)
January through March Precipitation Squared	-0.65 (0.68)	0.01 (0.01)	-0.003 (0.005)
April through August Precipitation	0.87 (1.88)	0.01 (0.02)	-0.03 (0.02)
January through March Average Temperature	-0.04 (0.72)	0.003 (0.004)	0.01** (0.01)
Change in September Precipitation	1.63 (3.46)	#	-0.07 (0.06)
Change in October Precipitation	-9.39 (5.90)	0.13* (0.06)	-0.01 (0.04)
Change in November Precipitation	-3.60 (8.35)	0.08 (0.07)	-0.05 (0.07)
Change in December Precipitation	1.33 (1.79)	0.52* (0.23)	#
Change in September Temperature	#	-0.002 (0.007)	-0.01 (0.01)
Change in October Temperature	-3.22** (0.63)	-0.002 (0.005)	-0.01 (0.01)
Change in November Temperature	-2.34** (0.67)	-0.007 (0.004)	-0.02** (0.004)
Change in December Temperature	-0.53 (2.39)	-0.07 (0.15)	#
Observations	518	327	492

Notes: The continuous wolf variables and the Change in Permits Issued variable is divided by the lagged number of elk harvested. * Denotes significance at the 5% confidence level. **Denotes significance at the 1% confidence level. # Denotes a lack of observations, allowing no estimation of the variable.

Table 3: Percentage Change in the Number of Permits Issued

Variable	Cow Permits	ES/Bull Permits
Northwest Montana Wolf Variables		
Joint Effect, p-value	**0.30**	**#**
Single District Wolf Initial Inhabitance Dummy	2094.27 (1255.66)	#
Multiple District Wolf Initial Inhabitance Dummy	193.09 (234.61)	#
Normalized Five Year Average Wolf Population	-19.38 (18.97)	#
Normalized Difference from Five Year Average Wolf Population	20.61 (32.35)	#
Central Montana Wolf Variables		
Joint Effect, p-value	**0.919**	**No Observations**
Single District Wolf Initial Inhabitance Dummy	623.32 (858.66)	#
Multiple District Wolf Initial Inhabitance Dummy	-95.67 (793.76)	#
Normalized Five Year Average Wolf Population	-3.61 (30.98)	#
Normalized Difference from Five Year Average Wolf Population	-75.87 (99.28)	#
Southwest Montana Wolf Variables		
Joint Effect, p-value	**0.02**	**0.000**
Single District Wolf Initial Inhabitance Dummy	-1939.90** (979.94)	-0.43 (0.43)
Multiple District Wolf Initial Inhabitance Dummy	-1219.05 (1700.81)	0.93** (0.16)
Normalized Five Year Average Wolf Population	-286.78 (416.86)	-0.03 (0.03)
Normalized Difference from Five Year Average Wolf Population	-129.06 (186.396)	0.001 (0.02)
Other Model Variables		
Constant	2.43 (3.97)	0.006 (0.01)
January through March Precipitation	0.91 (2.54)	0.01 (0.01)
January through March Precipitation Squared	0.07 (0.30)	-0.001 (0.001)
Descriptive Statistics		
Adjusted R-Squared	-0.02	0.10
Standard Error of Regression	42.37	0.21
Observations	518.00	318

Notes: Each wolf variable is divided by the lagged number of permits issued. * Denotes significance at the 5% confidence level. **Denotes significance at the 1% confidence level. # Denotes a lack of observations, allowing no estimation of the variable.

Table 4: Hunter Demand: Number of First Choice Applicants per Permit Issued

Variable	Cow Demand 2003	ES/Bull Demand 2003
Northwest Montana Wolf Variables, p-value	**0.00**	#
Single District Wolf Initial Inhabitance Dummy	0.43 (25.61)	#
Multiple District Wolf Initial Inhabitance Dummy	-1.22 (7.42)	#
Normalized Five Year Average Wolf Population	36.68** (4.11)	#
Normalized Difference from Five Year Average Wolf Population	42.13** (4.54)	#
Central Montana Wolf Variables, p-value	**0.01**	#
Single District Wolf Initial Inhabitance Dummy	472.00** (174.54)	#
Multiple District Wolf Initial Inhabitance Dummy	265.02* (102.61)	#
Normalized Five Year Average Wolf Population	-74.72** (26.65)	#
Normalized Difference from Five Year Average Wolf Population	-113.53** (41.81)	#
Southwest Montana Wolf Variables, p-value	**0.001**	**0.000**
Single District Wolf Initial Inhabitance Dummy	395.24** (131.08)	2011.61* (919.22)
Multiple District Wolf Initial Inhabitance Dummy	153.61 (181.08)	23.85 (15.32)
Normalized Five Year Average Wolf Population	-10.65 (5.96)	-9.18** (3.23)
Normalized Difference from Five Year Average Wolf Population	-108.99** (33.25)	5.12 (4.66)
Constant	0.22 (0.22)	-5.59* (2.75)
Late Season Dummy	0.02 (0.24)	25.67** (3.43)
A7 License Dummy	-0.04 (0.41)	#
Multiple District Dummy	0.47 (0.31)	#
Distance from Major Population Center	0.14 (0.10)	2.62** (0.96)
33 to 66 Percent Private Land Dummy	0.81** (0.28)	-2.47 (2.08)
67 to 100 Percent Private Land Dummy	0.24 (0.24)	-6.11* (2.87)
Percent Success of Harvest Lagged	0.03** (0.01)	0.26** (0.07)
Archery Only Dummy	#	-1.63 (4.43)
Brow-tined Bull Regulation Dummy	#	-3.28 (1.68)

Either-sex Partial Season Dummy	#	-2.03 (2.81)
Youth Hunt Dummy	#	#
Observations	104.000	76

Notes: Each wolf variable is divided by the advertised quota. * Denotes significance at the 5% confidence level. **Denotes significance at the 1% confidence level. # Denotes a lack of observations, allowing no estimation of the variable.