EFFECTS OF REMEDIAL SPORT HUNTING ON COUGAR COMPLAINTS AND LIVESTOCK DEPREDATIONS

By

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To the Faculty of Washington State University:

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EFFECTS OF REMEDIAL SPORT HUNTING ON COUGAR COMPLAINTS AND LIVESTOCK DEPREDATIONS

Abstract

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I assessed a set of variables that influenced cougar reports and livestock depredations as collected by the Washington Department of Fish and Wildlife. I also assessed the effectiveness of remedial sport harvest in reducing cougar reports and depredations. The number of complaint reports, livestock depredations, cougars harvested, estimated cougar populations, human population and livestock populations were calculated from 2005- 2010 (5.5yrs) for all counties and GMUs in Washington. This data was then analyzed using GLMs negative binomial distribution to determine if there was a relationship between the number of reports or depredations in the current year with the number of cougars harvested, year, human population, and livestock populations the previous year. I found that verified reports were positively associated with human population ($p=0.022$), cougar population ($p<0.001$) cougars harvested ($p<0.001$) and negatively associated with year ($p=0.005$). I also determined that livestock depredations were positively related to human population ($p=0.044$), cougar population ($p=0.005$), large livestock ($p<0.001$), and cougars harvested the previous year ($p=0.003$). Contrary to the belief that remedial sport hunting will reduce cougar reports and depredations my

study found that remedial hunting was associated with increased reports and livestock depredations.

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Dedication

This thesis is dedicated to my mother for her love and support.

Without their encouragement I wouldn’t have made it to where I am today.

I hope I make you proud.

INTRODUCTION

Historically, cougars (*Puma concolor*) had one of the broadest distributions of any mammal in the Western Hemisphere with a range that included most of the North and South American continents (Dawn 2002). This large, solitary carnivore is highly adaptable and capable of occupying a wide variety of habitats (Sunquist and Sunquist 2002). However, following European colonization of the Americas their populations and range have diminished due to extensive harvest and population control (Dawn 2002). Cougars were often viewed as unacceptable threats to life and property; thus were hunted with bounties through the mid-1900's (Dawn 2002).

After the bounty era ended cougars were still often viewed as potential threats to life and property. This view led to management plans that were focused on reducing cougar populations and cougar-human interactions primarily through increased hunting (Washington Department of Fish and Wildlife 2008). Many of these management plans base their cougar population estimates, management plans and harvest objectives solely or in part on the number of reports and depredations (Idaho Department of Fish and Game 2002, Texas Parks and Wildlife 2008, Wyoming Game and Fish Department 2006, Oregon Department of Fish and Wildlife 2006, Washington Department of Fish and Wildlife 2008).

Until recently, the Washington Department of Fish and Wildlife managed cougar populations and determined harvest objectives based on the number of cougar-human interactions (Washington Department of Fish and Wildlife 2008). As the number of cougar-human interactions increased, the hunter effort and opportunity through lengthened seasons and increased bag limits increased in response to what was thought to be a rapidly growing cougar population (Washington Department of Fish and Wildlife 2008).

However, contrary to the public perception of increasing cougar populations due to increased reports, several areas with increasing numbers of cougar reports corresponded with declining cougar populations (Lambert et al. 2006, Robinson et al. 2008). Heavy hunting caused the survival, fecundity, growth rate to decline (Lambert et al. 2006, Robinson et al. 2008). However, compensatory immigration (Robinson et al. 2008) and emigration (Cooley et al. 2009) resulted in stable cougar numbers with no change in observed growth rate and net change in cougar population size. Heavy remedial hunting simply changed the cougar population structure towards younger immigrant cougars in a source-sink dynamic (Cooley et al. 2009). This shift in age structure, yet similar densities, suggests that hunting might not reduce cougar reports and livestock depredations. In this paper we test the widely accepted hypothesis that remedial, sport hunting will decrease cougar-human interactions and depredations.

STUDY AREA

The state of Washington encompasses approximately 172,111 km^2 with natural regions ranging from a sea level coastal temperate rainforest to the Cascade mountain range to the Palouse prairie (United States Census Bureau 2010). Cougars inhabited approximately 60.72% of the land mass of the state (Washington Department of Wildlife, unpublished data).

The Cascade Range reaches elevations of 4,395m and divides the state into two distinct climate regions. The areas west of the Cascades have a temperate maritime climate characterized by mild wet winters and cool summers (Carpenter and Provorse 1998). Average temperatures in the western regions of Washington range from 0°C in January to above 16°C in July. The areas east of the Cascade mountain range has a much drier climate with hot summers and much colder winters compared to the western portion of the state. Average temperatures in eastern Washington range from -18°C in January to 32°C in July. Forest vegetation covers approximately 51% of the total land area of Washington with the majority of forested regions located in the mountainous sections of Western and Northeastern Washington (Carpenter and Provorse 1998).

METHODS

Data Collection

Reports

I obtained the total number of reports and depredations from the Washington Department of Fish and Wildlife's Cougar Incident Database and separated them based on the confidence level (verified, possible, and unlikely) provided by Washington Department of Fish and Wildlife personnel (WDFW). Verified reports and depredations are confirmed cougar activity and sightings while total reports encompass all reports whether verified or not. Depredation events consist of attacks or killings of domestic animals. I then compiled the tallies for all 39 counties and 136 GMUs, in Washington for the six year time series (2005-2010), and removed all blank and duplicate reports.

Cougar Populations

I calculated the estimated number of adult cougars (>2 years old) and total cougar population (includes kittens, <2 years old) in each county and GMU using the amount of cougar habitat available and cougar population densities for Washington (Washington Department of Fish and Wildlife unpublished data, Cooley et al. 2009). The overall density of cougars fluctuated little in response to increased harvest levels in Washington due to effects from increased immigration (Cooley et al. 2009, Beausoleil et al. 2013); therefore densities could be extrapolated across the state. To calculate the total population of cougars in each area I divided the amount of cougar habitat available by 100 then multiplied the resulting number by 3.5 which is the average density of total cougars ($3.5/100km^2$) on the landscape (Cooley et al. 2009). The number of adult cougars in each area was calculated by dividing the amount of cougar habitat available by 100 then multiplying the resulting value by the average density of adult cougars (1.7/100km^2) on the landscape (Cooley et al. 2009, Beausoleil et al. 2013).

Human Population

The number of people in each county and GMU during each year was obtained from the United States Census Bureau Quick Facts (2010). I converted the census data from census block polygons into centroids with the number of people per census block (U.S. Census Bureau 2000). I then used a spatial join in ArcMap 9.3 to determine the number of people per GMU and calculated density by dividing by the area of each GMU.

Livestock Numbers

The numbers of varying types of livestock were obtained from the United States Department of Agriculture National Agricultural Statistics Service for each county in Washington. I tallied the livestock numbers and placed them into two categories for each county: large or deer sized livestock and small livestock. The category for large or deer sized livestock consisted of alpacas, llamas, cattle, equine, goats, hogs and sheep. Small livestock consisted of chickens, ducks, geese, pheasants, and turkeys.

Cougars Harvested

I obtained the number of cougars harvested through sport harvest in each GMU each year from the Washington Department of Fish and Wildlife's Game Harvest Report Database (http://wdfw.wa.gov/hunting/harvest/). The number of cougars harvested across the state was only available by GMU and thus were not used in county level analysis.

I then calculated the proportion of adult cougars (older than 1.5yrs) harvested in each GMU by taking the number of cougars harvested by sport harvest divided by the number of adult cougars estimated to be on the landscape for that GMU. Washington Department of Fish and Wildlife ages cougar mortalities via cementum annuli by taking a tooth during the mandatory sealing process (Washington Department of Fish and Wildlife 2012). I only used cougars that were >1.5 years old in harvest calculations since they are the basis for harvest objectives in Washington (Beausoleil et al. 2013).

Data Analysis

Statistical Analysis

I selected a negative binomial regression rather than a Poisson distribution because the data consisted of 0 to positive integer count data. A negative binomial regression is appropriate for count data. The most appropriate statistical model was then selected using the AIC and log-likelihood values. The rate ratio, analogous to odds-ratio, was computed from the coefficients to aid in interpreting the results. For example, a rate ratio of 1.0 for any independent variable means the effect on the dependent variable is unchanged. A rate ratio of 1.5 means the odds are increased 50%, a ratio of 2.0 means the odds are increased 100% etc. Any detected two-way interactions were plotted in order to determine the general trends causing the interaction. Descriptive statistics for all variables and negative binomial regression models were generated for verified reports, verified livestock depredations, and verified total depredations using Statistical Program R (R: A language and environment for statistical computing, R Foundation for statistical computing, Vienna, Austrailia).

County Based Tests

I assessed several independent variables because these may have a variable impact on cougar reports and depredations. The confounding factors were reports, depredations, human population, livestock numbers, and number of cougars. To determine which factors have a statistically significant relationship with cougar reports and depredations we used a negative binomial regression with $\alpha=0.05$. Reports and depredations were the dependent variable and all other variables were considered independent variables.

GMU Based Tests

The main independent variables (number of cougars, number of cougars harvested, proportion of cougars harvested) and human population were done on a GMU basis. The number of livestock was not available by GMU, but comparing the odds ratio between the county and the GMU level allows for direct comparison. For example, if the odds of a livestock depredation are increased from 1 to 1.5 with each additional livestock individual, and the odds of a depredation are increased from 1 to 2.5 with each additional cougar, we can conclude that the number of cougars have a larger effect than additional livestock on the probability of livestock depredations occurring. Tests completed at the GMU level used the factors: reports, depredations, number of cougars, human population, the numbers of cougars harvested and proportion of cougars harvested. To determine which factors have a statistically significant relationship with cougar reports and depredations we used a negative binomial regression with $\alpha=0.05$. Reports and depredations were considered dependent variables while the remaining variables were classified as independent variables.

RESULTS

County Based Tests

The total number of non-duplicated complaint reports between January 2005 and May 2010 was 2648; 432 reports were verified and 166 of those verified reports were livestock depredations. Over the course of the 6 year time series the number of total and verified reports generally declined while depredations remained relatively constant (Table 1& 2, Appendix). No county exceeded 100 total reports, 30 verified reports, or 11 livestock depredations in any year during our study. For a distribution map of reports by county across the state see appendix.

Analysis of factors possibly influencing the number of reports at the county level revealed several factors that have a positive association with reports and depredations. The model for the number of total reports revealed that human population, the total cougar population and the number of large livestock were positively associated with an increased number of total reports. Consequently as the number of people, cougars and livestock increased the total number of complaints increased. However, total reports are not a reliable indicator of the number of cougar-human interactions or the number of cougars because they are not verified cougar activity and a single cougar can generate multiple reports. Since the number of total reports filed is not indicative of reliable cougar activity and population numbers it should not be used as a basis for cougar population management.

Verified reports, contrary to total reports, consist of confirmed cougar activity. The county based model revealed that the primary factors influencing verified reports were the year and total cougar population. Verified reports were also influenced by the total cougar population in the area, as the number of cougars and habitat within each county increased the number of verified reports in that county also increased. Based on the model, for every additional cougar on the landscape the chance of verified reports increased by 1.00847 times.

Several variables also influenced the number of livestock depredations at the county level including human population, total cougar population and the number of large livestock on the landscape. As the human population increased in an area the number of livestock depredations also increased in that area. With each increase in 10,000 people in an area the probability of a livestock depredation occurring in that area increased by 1.018 times or approximately 2%. However, it is important to note that the highest levels of livestock depredations occurred in counties with less than 30,000 people and that the interaction effects are more significant than the main effect of human population. This means that the effects of increasing human populations alone are lessened by the interactions between human population-large livestock and human population-cougar populations. The total number of cougars on the landscape also appeared to influence the number of livestock depredations. For each additional cougar on the landscape the chance of a livestock depredation occurring increased 1.0446 times or approximately 5%. For each additional 2000 large livestock in the area the chance of a livestock depredation occurring increased by 1.0002 times or less than 1%.

The final county level model analyzed possible factors that influence the number of total verified depredations. This model revealed that human population, the total cougar population and the number of large livestock present all influence the number of depredations. As the human population in an area grows for each additional 10,000 people present the probability of a depredation increases 1.016 times. The number of cougars on the landscape also influenced the number of depredations in this model. For each additional cougar present the chance of a depredation occurring in that area increased 1.042. The final factor in our model that influenced depredations was the number of large livestock present, for each additional livestock animal the probability of a depredation being reported increased by 1.00022 times.

Overall, the effects of these independent variables on the odds of total reports, verified reports, livestock depredation and total depredations were marginal, averaging from less than 1% to 5%.

GMU Based Tests

The total number of non-duplicated reports between January 2005 and May 2010 was 2647; 429 reports were verified and 166 of those verified reports were livestock depredations (Table 3, Appendix). Over the course of 6 years the number of total and verified reports generally declined while depredations remained relatively constant. Descriptive statistics for all factors tested were also generated in statistical program R (Table 4, Appendix). No GMU exceeded 71 total reports, 11 verified reports, or 9 livestock depredations for any given year. For the distribution of reports across the state by GMU see appendix.

The model selected for determining which factors were related to the total number of cougar reports per GMU was $g(y) = 0.4529 + 0.440$ (proportion of adult cougars harvested) + 3.788×10^{-6} (human population) + 1.925×10^{-5} (proportion of cougars harvested*human population). The proportion of adults harvested was significant and positively related to total reports in this model (rate ratio= 1.55271, $z = 1.948$, $p = 0.051$). Human population was positively related with the total number of reports (rate ratio =1.000003788, $z = 10.280$, $p < 0.001$). For each additional 10,000 people in an area the chance of a report being filed increased by 1.0000038. However, total reports are not reliable indicators of cougar activity or population numbers.

There was one significant two-way interaction present between the proportion of adult cougars harvested and the human population in each GMU. This interaction was positively related to the total number of reports (rate ratio = 1.00002, $p<0.001$). Further analysis of this interaction revealed that as an overall trend when the number of people in a GMU was high, the proportion of adult cougars harvested was low. However, when the number of people was relatively low in a given GMU generally the proportion of adult cougars harvested was higher (Figure 10).

Two models were selected for determining which factors are related to the number of verified reports in each county. The first model was $g(y) = -1.970170 + 0.308764$ (number of cougars harvested) + 0.031093 (total cougar population) – 0.003842 (cougars harvested*total cougar population).

The number of cougars harvested appeared to be positively related to the number of verified reports per GMU (rate ratio= 1.36174, $z=5.081$, $p<0.001$). For each additional adult cougar harvested during the previous year in a region the chance of a report occurring increased by 1.36174. The total population of cougars was also found to be positively associated with increased numbers of verified reports (rate ratio = 1.03158, $z=5.819$, $p<0.001$). For each additional cougar on the landscape the probability of a verified report being filed increased by 1.03158. The effect of cougars harvested on the odds of verified reports is 10 times higher (1.36 vs 1.03) for number of cougars harvested than the number of cougars.

There was one significant negative two-way interaction present in this model between the number of cougars harvested and the total population of cougars (rate ratio = 0.996165, $p= 0.001$). The graph of this interaction revealed that when the number of cougars present on the landscape was low, a given amount of harvest resulted in a high proportion of cougars killed.

However, when the number if cougars present were high in an area the number of cougars killed tended to be low resulting in a small proportion of cougars killed. So, an increasing proportion of cougars harvested appear to have a positive relationship with increased numbers of verified reports (Figure 11).

The second model selected for determining which factors may influence the number of verified reports per GMU was g(y) = -1.081 + 0.9571 (proportion of adult cougars harvested) + 1.066×10^{-6} (human population) + 1.453×10^{-5} (proportion of adult cougars harvested*human population).

The proportion of adult cougars harvested appeared to be positively associated with the number of verified reports (rate ratio = 2.60413, z=3.429, p<0.001). For each 100% increase in harvest the odds of a verified report the following year increased by a factor of 160% or 2.6 or similarly for each 10% increase in harvest the odds a verified complaint increased by 16%. The number of people residing in each GMU was also positively related to an increased number of verified reports (rate ratio = 1.000001066, z=2.285, p= 0.022). For each additional 10,000 people in an area the chance of a verified report being filed increased by a factor of 1.000001066.

There was only one positive significant two-way interaction present in this model between the proportion of adult cougars harvested and the human population (rate ratio= 1.00001, p= 0.031). This interaction had the same trends as the total reports model (Figure 12).

Two models were also selected for determining which factors may be related to the number of livestock depredations in each GMU. The first model chosen was g(y) = -3.155876 + 0.428854 (number of cougars harvested) + 0.038094 (total cougar population) – 0.005630 (cougars harvested*total cougar population).

Both of the main effects were found to be significant in this model. The number of adult cougars harvested appeared to be positively related to the number of livestock depredations in each GMU (rate ratio = 1.5355, z=5.097, p<0.001). The total cougar population was also found to be positively associated with the number of verified livestock depredations (rate ratio = 1.03883, z=5.02, p<0.001). For each additional adult cougar harvested the odds of a livestock depredation occurring the following year increased by 50% while for each additional cougar on the landscape the odds went up 4%.

Only one negative two-way interaction was present in this model. The interaction between the total number of cougars harvested and the total cougar population had a rate ratio =0.994386 and a p-value <0.001. This interaction showed the same trends as the verified reports model (Figure 13).

The second model selected to determine which factors may influence livestock depredations was g(y) = -2.019 + 1.216(proportion of adult cougars harvested) + 1.278×10^{-6} (human population) + 2.248×10^{-5} (proportion of adult cougars harvested*human population).

Both main effects were statistically significant in this model. The proportion of adult cougars harvested appeared to be positively related to the number of livestock depredations (rate ratio = 3.37367, z=3.186, p= 0.001). The human population in each GMU was also significantly positively related to increased livestock depredations with a rate ratio=1.000001278, z-value= 2.012 and a p-value=0.044. For each 100% increase in harvest rate of cougars (removal of all adult animals) the odds increased by a factor of 3.5 or 250%. Similarly a 10% increase in proportion of adult cougars harvested increased the odds of a livestock depredation occurring the following year by 25%.

Only one positive interaction was present in this model between both main effects. The interaction between proportion of adult cougars harvested and the human population had a rate ratio=1.00002 and a p-value=0.013 (Figure 14).

The final models were selected to determine which factors influenced the number of total depredations reported in each GMU. The model was g(y) = -2.910767 + 0.386019 (number of cougars harvested) + 0.038721 (total cougar population) – 0.005189 (cougars harvested*total cougar population). The main effects in this model were found to be significant and positively associated with the number of total depredations. The number of adult cougars harvested had a rate ratio of 1.47111, z-value of 5.057 and a p-value of <0.001 while the total cougar population had a rate ratio of 1.03948, z-value of 5.716 and a p-value <0.001. Once again for each adult cougar harvested the odds of a depredation occurring the following year were 1.5 or increased by 50%. This model contained only one negative two-way interaction between the number of cougars harvested and the total cougar population (rate ratio = .994824, p<0.001) (Figure 15).

The other model selected for total depredations was g(y) = -1.753 + 0.9633 (proportion of adult cougars harvested) + 1.164×10^{-6} (human population) + 2.206×10^{-5} (proportion of adult cougars harvested*human population).

All of the main effects were significant in this model. The proportion of adult cougars harvested appeared to be positively related to the number of total depredations (rate ratio = 2.62, z=2.747, p= 0.006). So for each 100% increase in resident adult cougar harvest the odds of a depredation occurring the following year increased by 62%. Similarly for each 10% increase in resident adult cougar harvest the odds of a depredation being filed the following year increase 6%. The human population in each GMU was also positively associated with total depredations (rate ratio = 1.000001164, z=1.999, p=0.045).

Only one positive two-way interaction was present in this model between the proportion of adult cougars harvested and the human population (rate ratio = 1.00002, p= 0.008). This interaction was determined to be the same as the total reports interaction terms (Figure 16).

DISCUSSION

My results suggest that there are several different social and environmental factors that influence the number of cougar reports and depredations across the state of Washington. These factors include the human population, the number of livestock and the number of cougars, which is based on the amount of habitat present on the landscape.

Our results also suggest that remedial sport hunting of cougars does not appear to be effective in reducing and addressing the number of verified cougar reports and depredations. Instead, it may actually be associated with increased verified reports and livestock depredations. Remedial sport hunting to reduce the cougar population in an area typically fails to account for other factors such as the amount of habitat, human density, the number of livestock and the unforeseen effect of hunting on the behavior and biology of cougar populations (Cougar Management Working Group 2005). Perhaps most importantly it fails to account for compensatory immigration and the shift in the sex-age structure towards younger cougars which may be responsible for increased reports and depredations (Robinson et al.2008, Lambert et al. 2006. Cooley et al. 2009).

Reasons for increased verified reports and livestock depredations following remedial hunting could be the social disruption associated with hunting. Within Washington Robinson et al. (2008) found that heavy hunting resulted in increased compensatory immigration by younger males. Kertson et al. (2010, 2011a, 2011b) found that young cougars are more likely to be found in human-occupied areas then their older counterparts. Cooley et al. (2009) found that light hunting resulted in compensatory emigration by young males and a stable older male structure in the population. Maletzke (2010) found that heavy hunting resulted in a doubling of young male cougars home range size and home range overlap. This increased size and overlap of home ranges doubled the encounter probability of human-occupied areas being inhabited by young males. Beier (1991) found that juvenile and young adults may be responsible for the majority of the cougar-human conflicts in many areas. Keehner (2010) found that heavy hunting of cougars corresponded with females and kittens moving into sub-optimal habitats and killing sub-optimal prey species in order to avoid potentially infanticidal immigrant males.

These results are supported by a case study from two Washington cougar populations, where one was lightly hunted and one heavily hunted. The lightly hunted population was located in Kittitas County where the average number of reports in our six year time series was: verified 2.1167/year, total 6.33/year, livestock depredations 0.66/year and total depredations 0.833/year (Table 5). The average number of people inhabiting Kittitas County was 38,842 as well as 21,441 large livestock. The lightly hunted population had a total population survival rate of 0.71 ± 0.06, a hunting mortality rate of 0.11 ± 0.04, mean age of 3.2 years, kitten survival rate of 0.58 and no change in the proportion of male and female cougars(Cooley et al.2009). However, the heavily hunted population located in Stevens County had a higher average number of reports: verified 6/year, total 38.167/year, livestock depredations 2.667/year and total depredations 3.667/year (Table 6). Stevens County has 42,032 inhabitants and 22,293 large livestock. The heavily hunted population had a total population survival rate of 0.56 ± 0.05, hunting mortality rate of 0.24 ± 0.065, mean age of 2.3 years, kitten survival rate of 0.32 and significant changes in the proportion of male and females; decline in females while males remained unchanged due to an increased juvenile male immigration. Both areas had similar number of people and livestock, while the differences in reports and depredations may have been due to differences in cougar harvest.

Remedial hunting of cougars, at least in Washington, was associated with stable or increased, not decreased, reports and depredations. I encourage other researchers to test the effects of remedial hunting on other carnivore species such as black bears, grizzly bears, leopards, etc.

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Table 1. Total reports collected for all 39 counties in Washington between 2005- May 2010.

Year	Verified Reports	Total Reports	Livestock Depredation	Total Depredation
2005	114	743	28	38
2006	88	581	32	42
2007	73	418	27	37
2008	63	408	30	34
2009	63	426	36	39
2010	31	110	13	19

Table 2. Basic descriptive statistics for county level data. Statistics shown are for the number of reports in each county for each year.

Factor	Minimum	Maximum	Range	Arithmetic Mean	Standard Error	95% Confidence Interval	Standard Deviation
Verified Reports	0	28	28	1.846	0.211	1.429-2.263	3.235
Total Reports	0	82	82	11.479	0.975	9.558-13.399	14.913
Livestock Depredations	0	11	11	0.709	0.105	0.503-0.916	1.602
Total Depredations	0	12	12	0.889	0.122	0.648-1.130	1.870
Population	2091	1931249	1929158	166894.551	21461.009	124612.122-209176.981	328290.305
Habitat (km^2)	190.447	11357.910	11167.463	2679.532	150	2384.002-2975.062	2294.562
Deer Sized Livestock	1549	139244	137695	18925.333	1555.954	15859.796-21990.871	23801.526
Small Sized Livestock	20	1510438	1510418	61626.205	16455.393	29205.828-94046.582	251719.109

Table 3. Total reports collected for all 136 GMUs in Washington from Jan. 2005 to May 2010.

Year	Verified Reports	Total Reports	Livestock Depredation	Total Depredation	Cougars Harvested
2005	111	674	28	37	182
2006	86	569	32	41	199
2007	72	416	28	38	198
2008	61	398	28	31	188
2009	63	416	37	40	140
2010	30	106	13	19	161

*107 total reports and 9 verified reports removed because no GMU was listed in the complaint.

Table 4. Basic descriptive statistics for GMU level tests. Statisitcs shown are for each GMU for each year.

Factor	Minimum	Maximum	Range	Arithmetic Mean	Standard Error	95% Confidence Interval	Standard Deviation
Verified Reports	0	11	11	0.526	0.042	0.443-0.608	1.197
Total Reports	0	71	71	3.244	0.251	2.751-3.737	7.713
Livestock Depredations	0	9	9	0.203	0.025	0.155-0.252	0.708
Total Depredations	0	10	10	0.255	0.027	0.201-0.309	0.782
Cougars Harvested	0	15	15	1.331	0.077	1.180-1.482	2.194
Habitat (km^2)	2.759	2713.761	2711.003	667.545	19.033	630.185-704.904	543.689
Proportion of Adult Cougars Harvested	0.000	1.9101	1.9100	0.117	0.007	0.103-0.132	0.210

Table 5. Reports filed in Kittitas County from 2005- May 2010.

	Verified Reports	Total Reports	Livestock Depredations	Total Depredations
2005	5	11	1	1
2006	3	9	1	1
2007	0	1	0	0
2008	0	3	0	0
2009	4	10	2	2
2010	1	4	0	1

Table 6. Reports filed in Stevens County from 2005- May 2010.

	Verified Reports	**Total Reports**	**Livestock Depredations**	**Total Depredations**
2005	5	50	2	3
2006	8	47	4	5
2007	8	21	2	3
2008	3	25	1	1
2009	3	41	2	2
2010	9	15	5	8

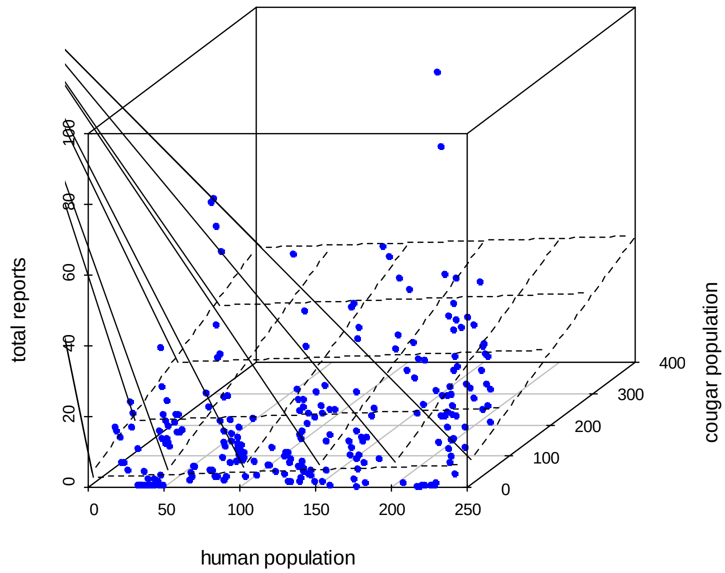


Figure 1. 3-Dimensional plot showing the interaction between human population and total cougar population in relation to total reports. (Multiple the human population axis by 10,000).

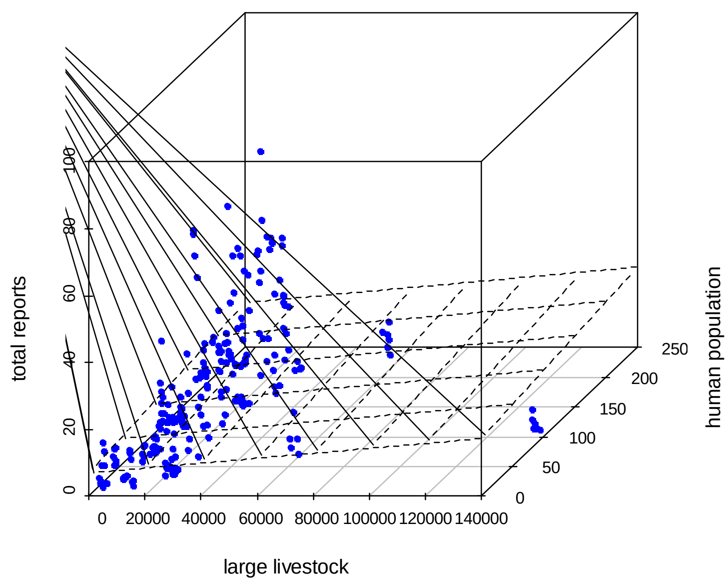


Figure 2. 3-Dimensional plot showing the interaction between human population and the number of large livestock in relation to total reports. (Multiple the human population axis by 10,000).

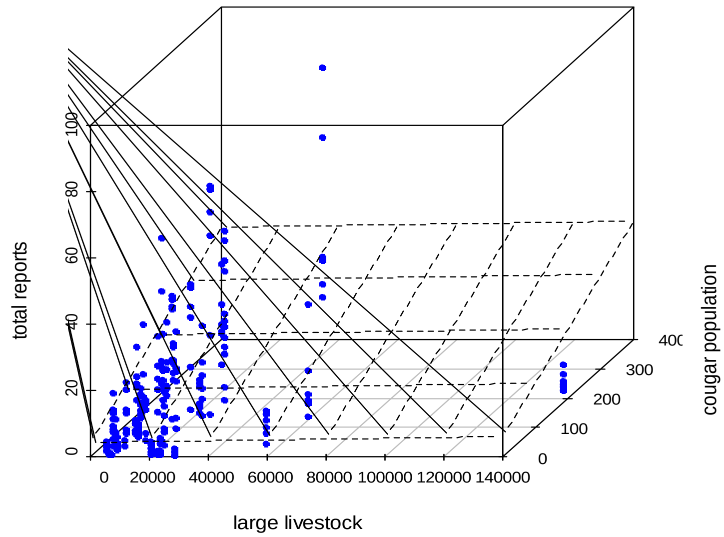


Figure 3. 3-Dimensional plot showing the interaction between cougar population and the number of large livestock in relation to total reports.

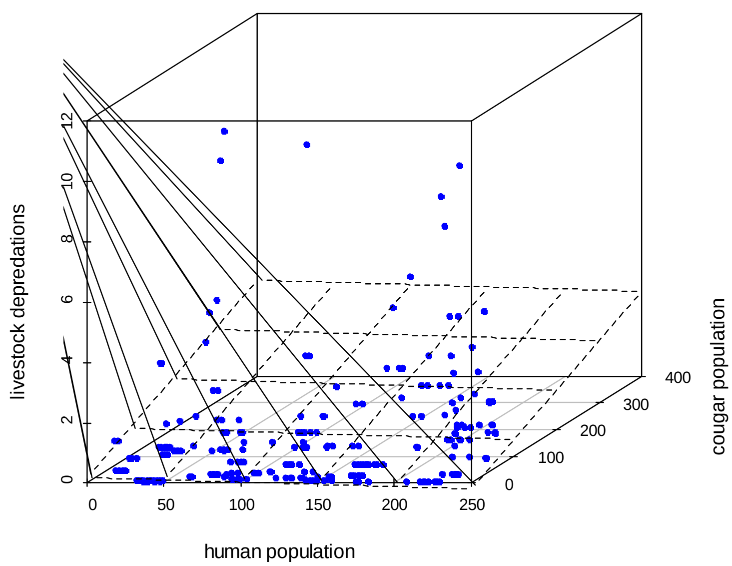


Figure 4. 3-Dimensional plot showing the interaction between cougar population and the human population in relation to livestock depredations. (Multiply human population axis by 10,000).

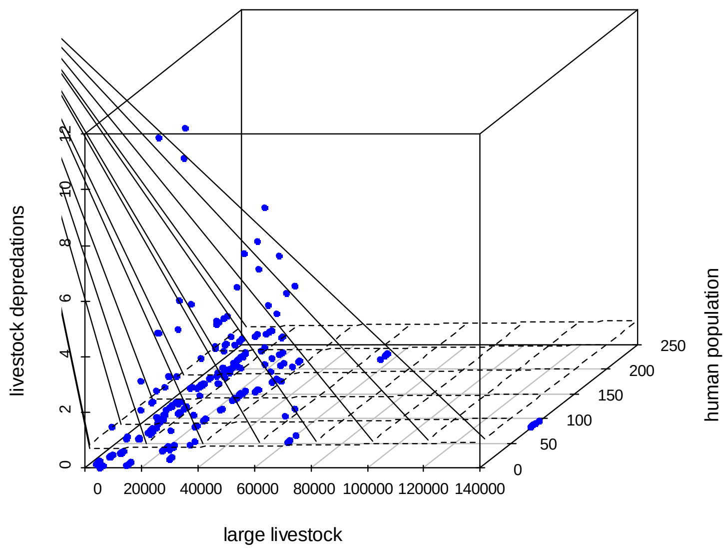


Figure 5. 3-Dimensional plot showing the interaction between human population and the number of large livestock in relation to livestock depredations.

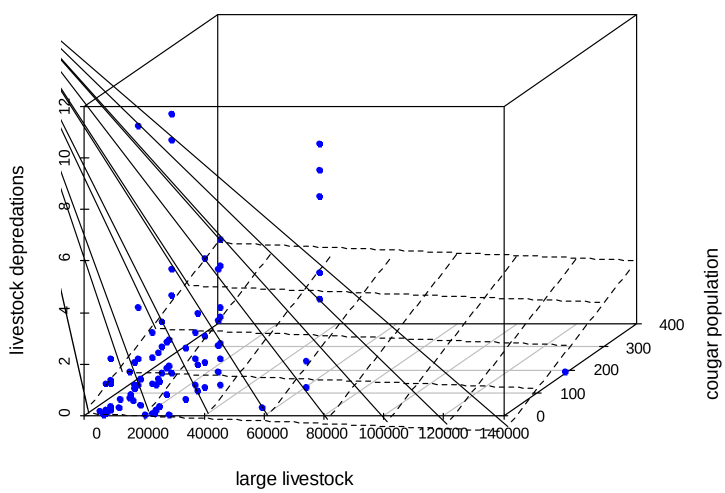


Figure 6. 3-Dimensional plot showing the interaction between cougar population and the number of large livestock in relation to livestock depredations.

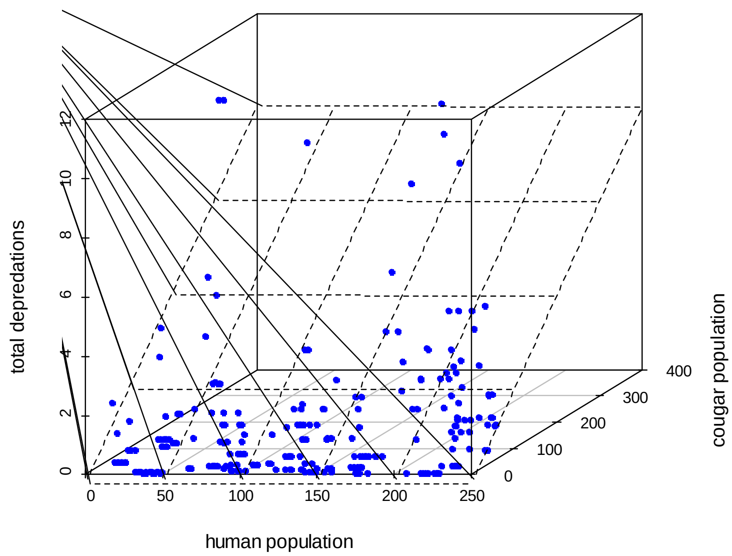


Figure 7. 3-Dimensional plot showing the interaction between cougar population and human population in relation to total depredations. (Multiply human population axis by 10,000).

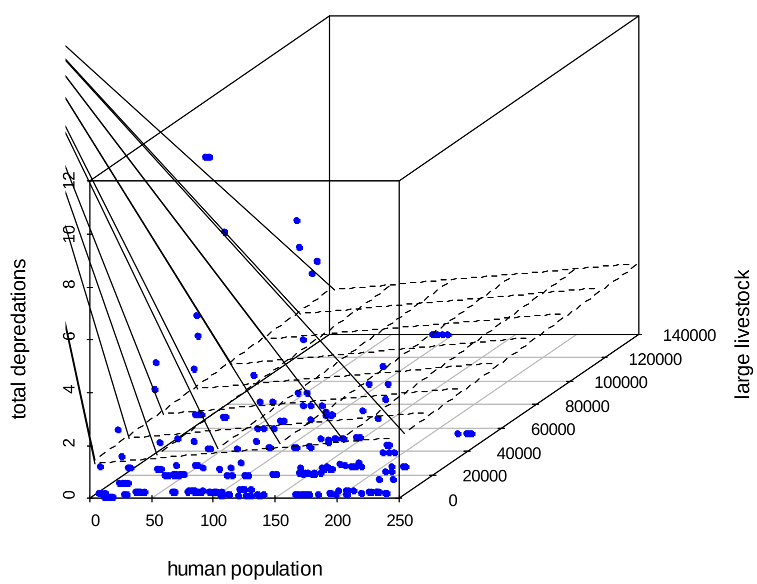


Figure 8. 3-Dimensional plot showing the interaction between human population and the number of large livestock in relation to total depredations. (Multiply human population axis by 10,000).

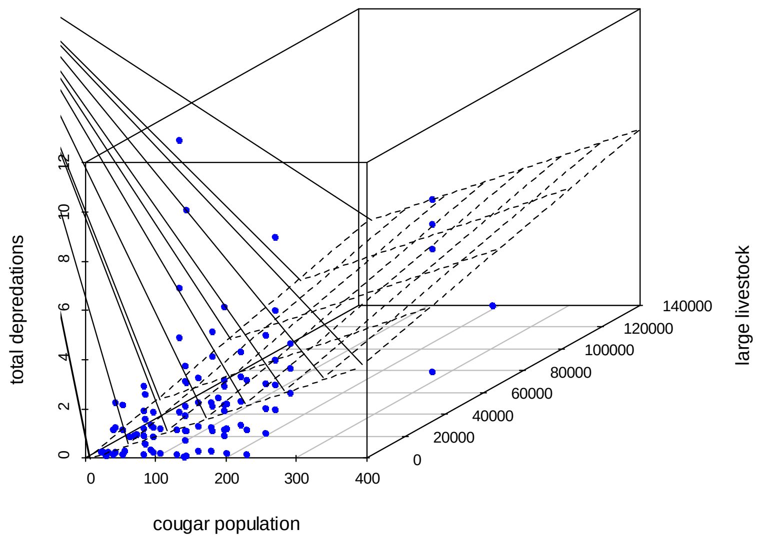


Figure 9. 3-Dimensional plot showing the interaction between cougar population and the number of large livestock in relation to total depredations.

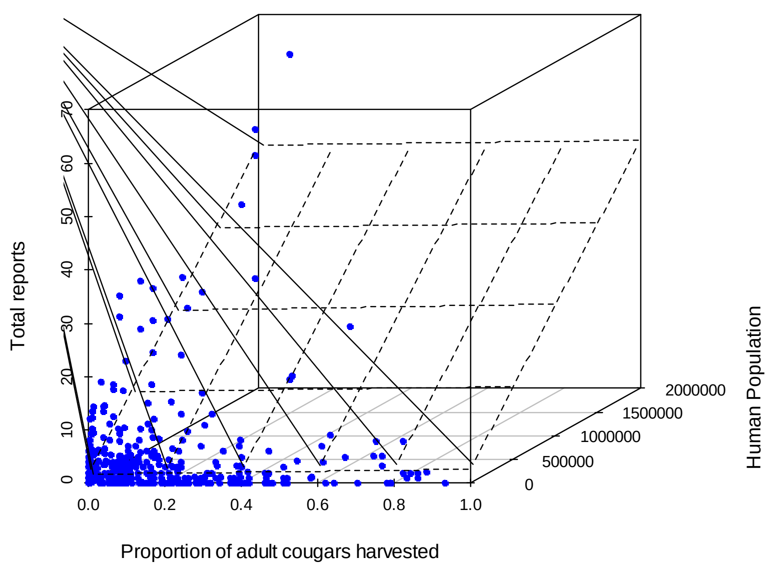


Figure 10. 3-Dimensional plot showing the interaction between human population and the proportion of adult cougars harvested in relation to total reports.

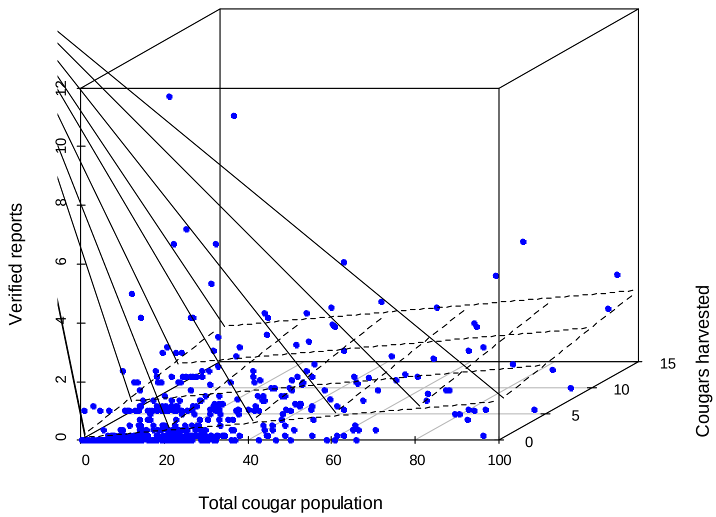


Figure 11. 3-Dimensional plot showing the interaction between the number of cougars harvested and the total cougar population in relation to verified reports

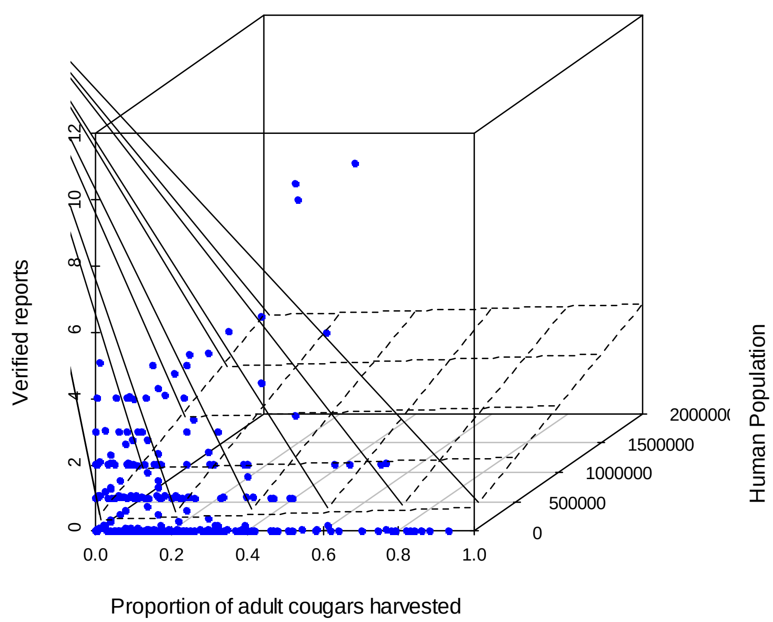


Figure 12. 3-Dimensional plot showing the interaction between the human population and the proportion of adult cougars harvested in relation to verified reports

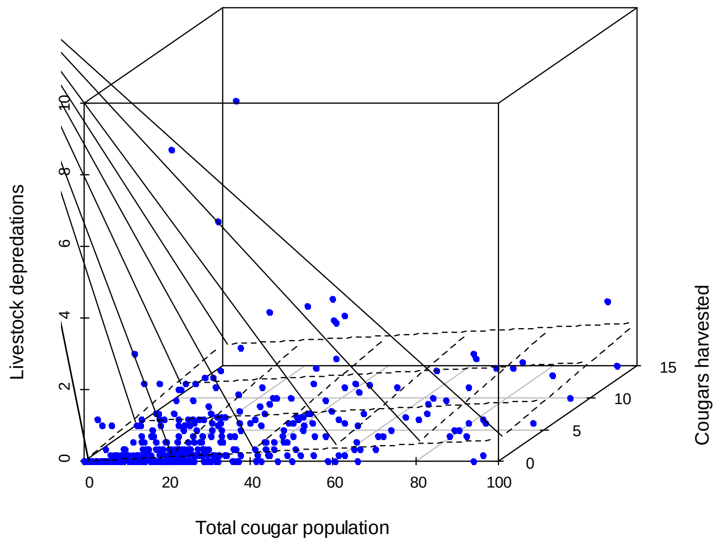


Figure 13. 3-Dimensional plot showing the interaction between the number of cougars harvested and the total cougar population in relation to livestock depredations

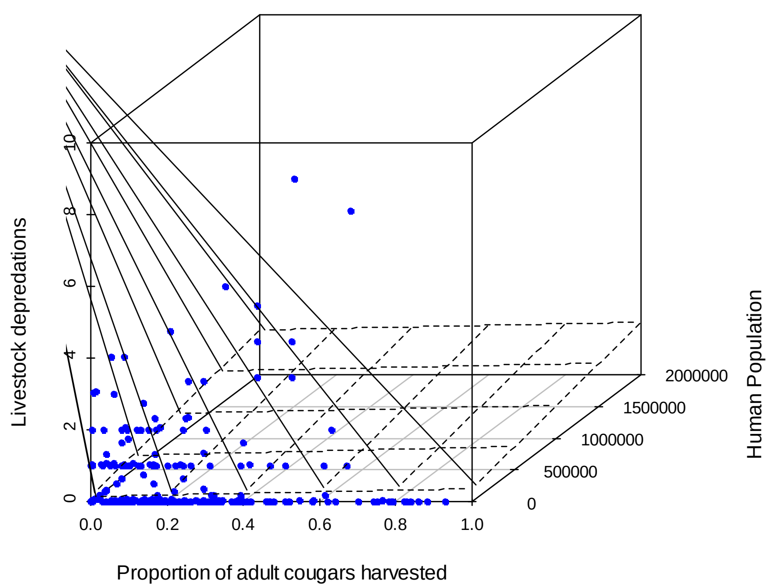


Figure 14. 3-Dimensional plot showing the interaction between the human population and the proportion of adult cougars harvested in relation to livestock depredations

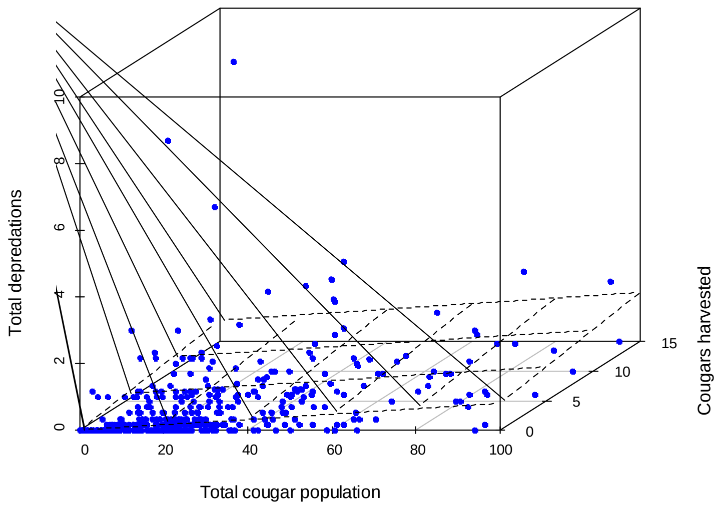


Figure 15. 3-Dimensional plot showing the interaction between the number of cougars harvested and the total cougar population in relation to total depredations

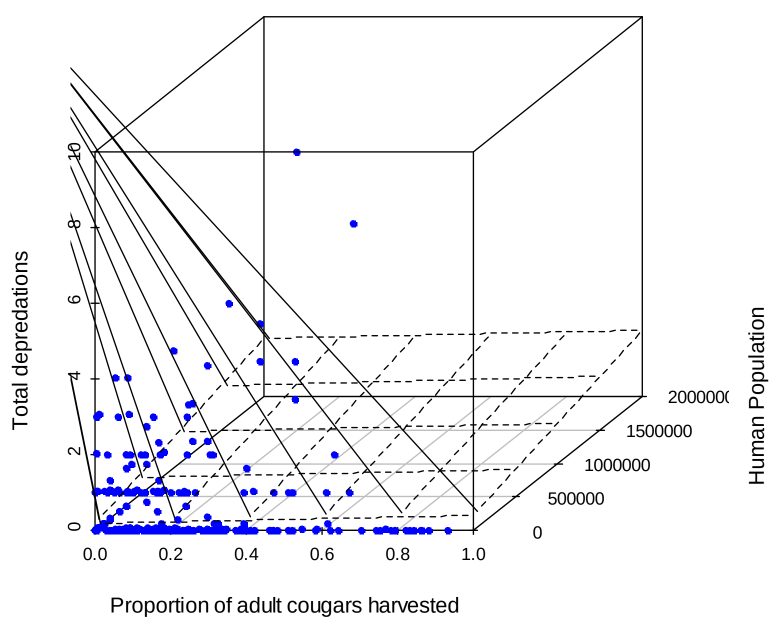
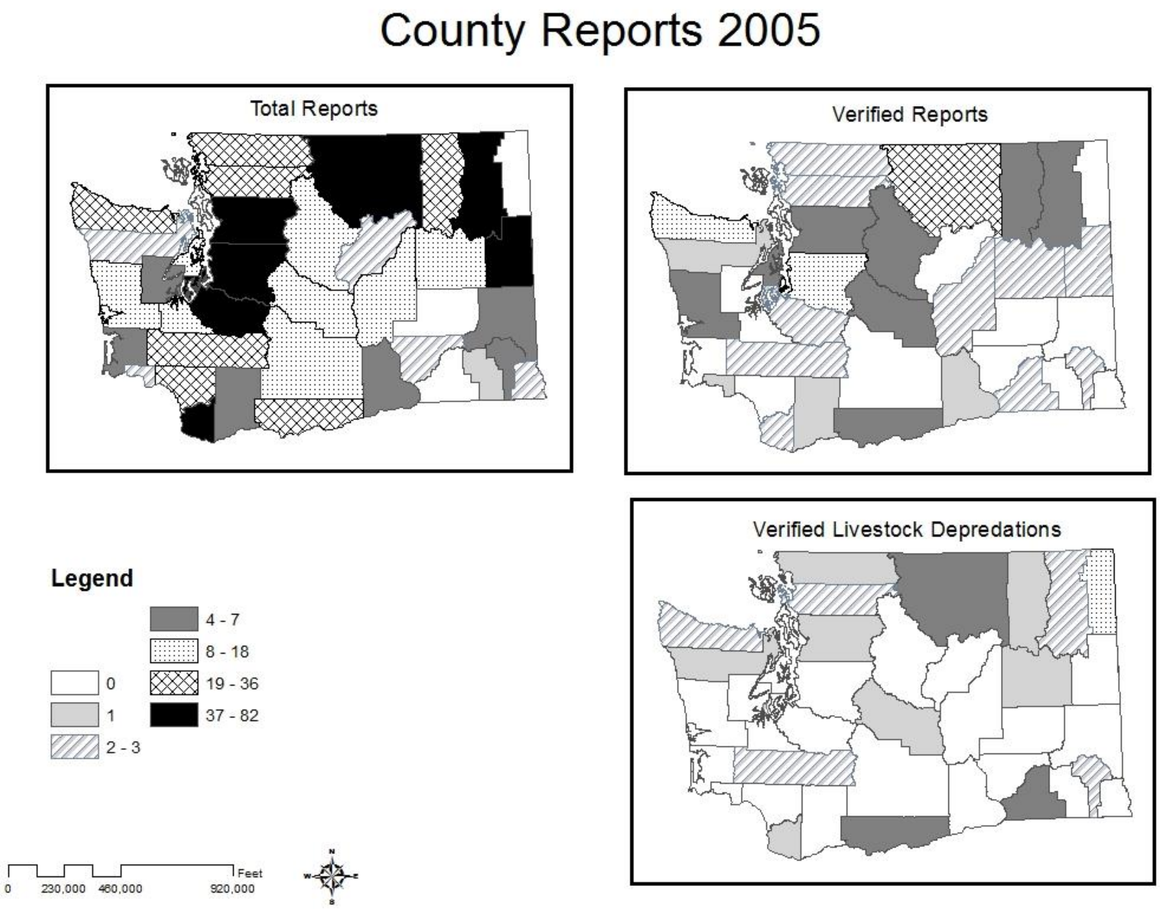


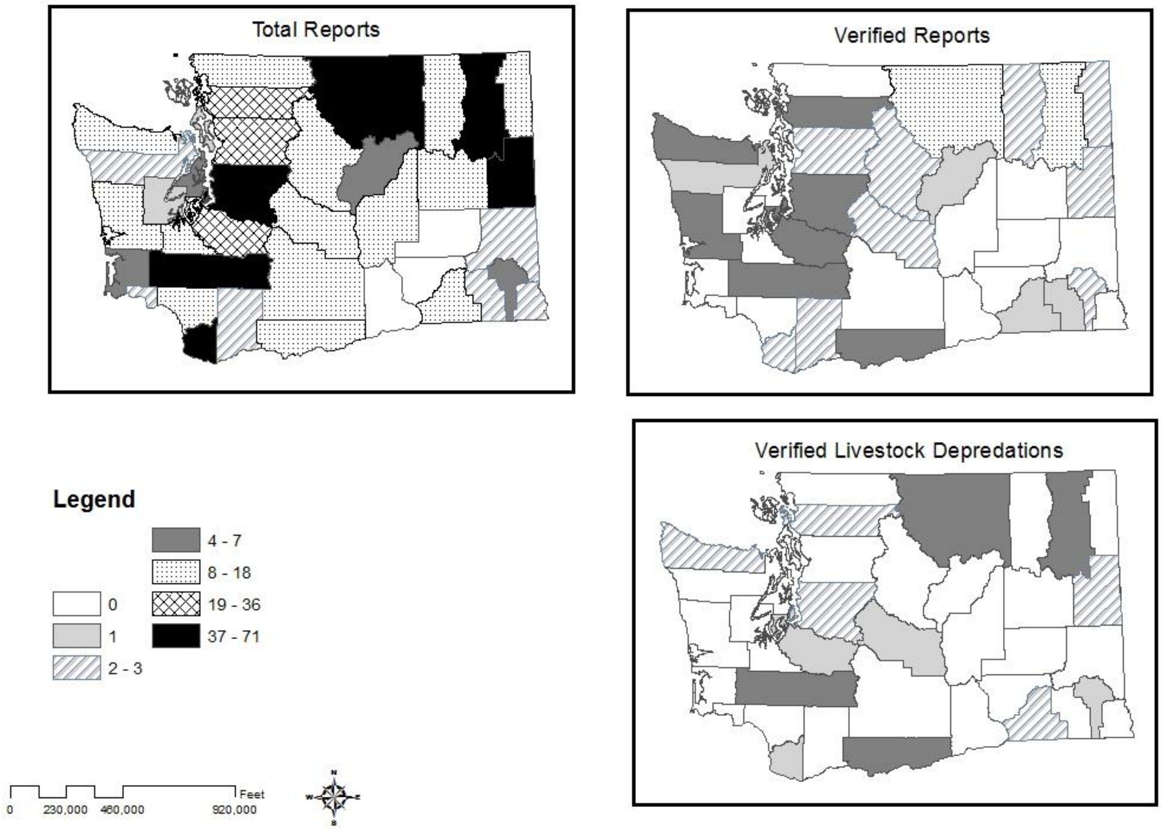
Figure 16. 3-Dimensional plot showing the interaction between the human population and proportion of adult cougars harvested in relation to total depredations

APPENDIX

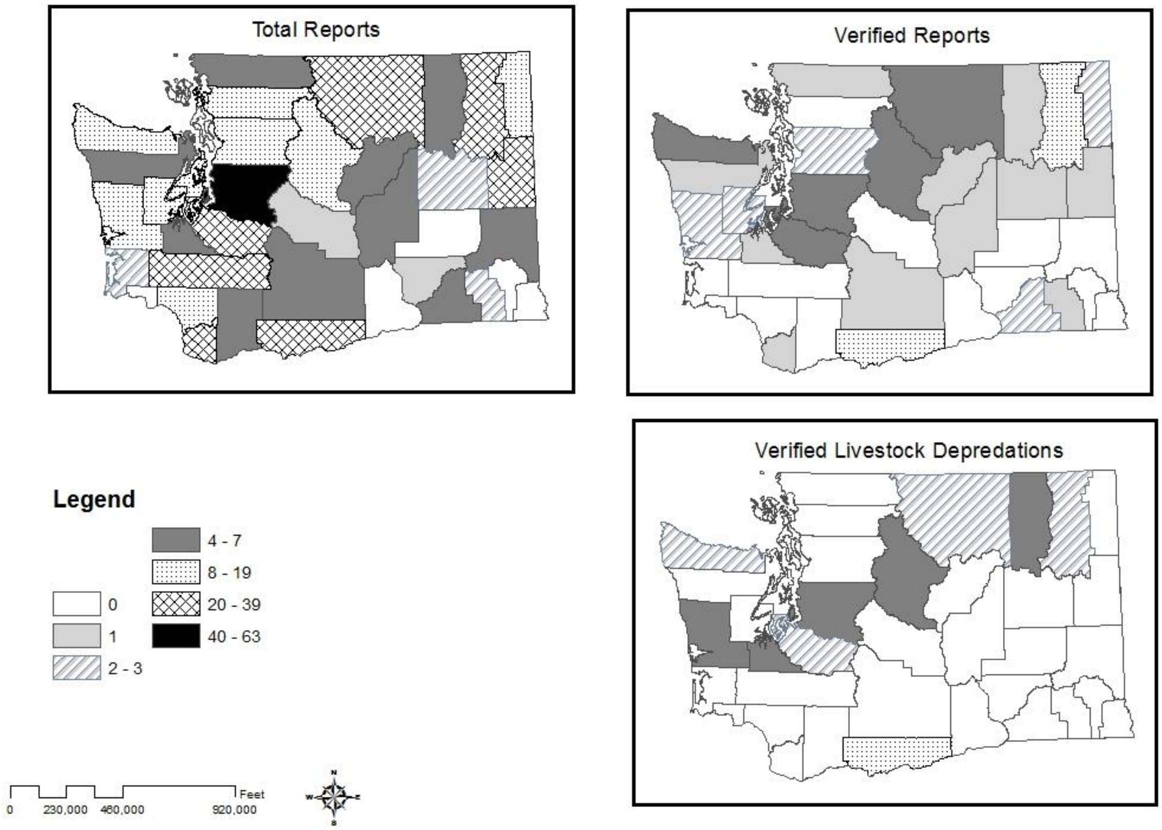
Maps of Reports in Washington



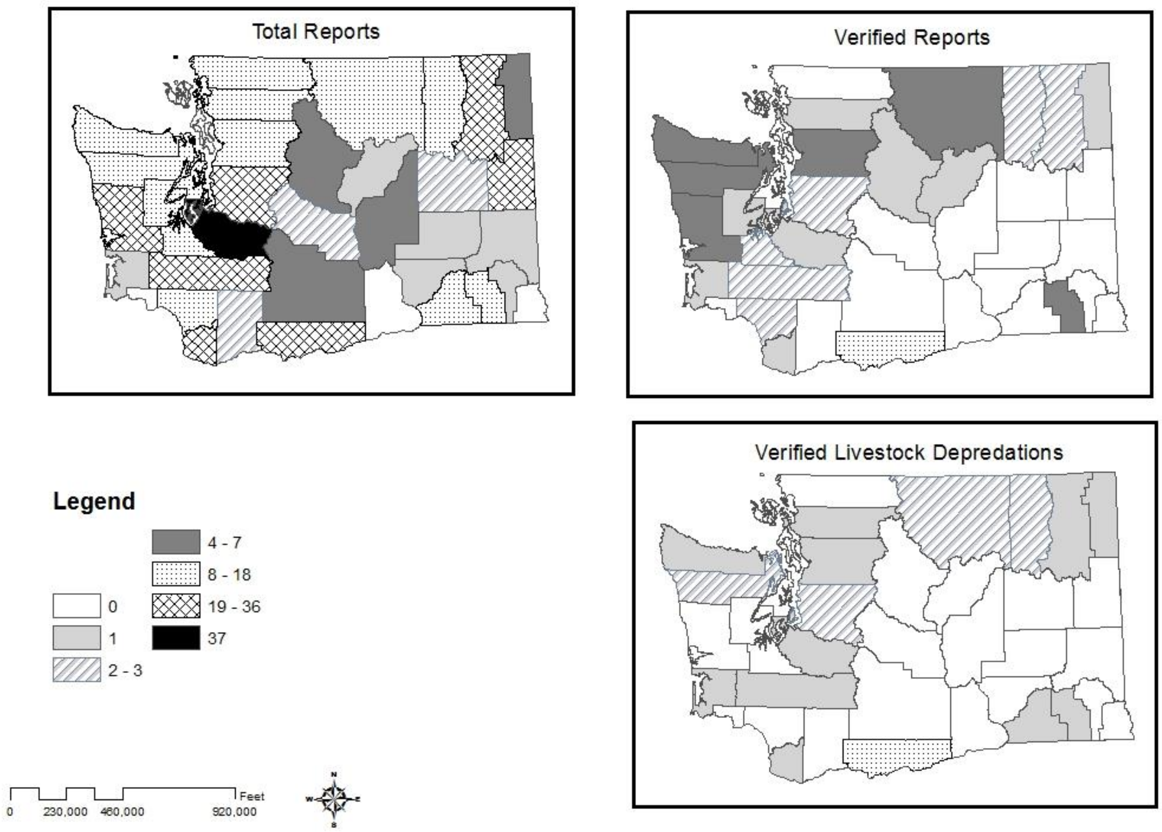
County Reports 2006



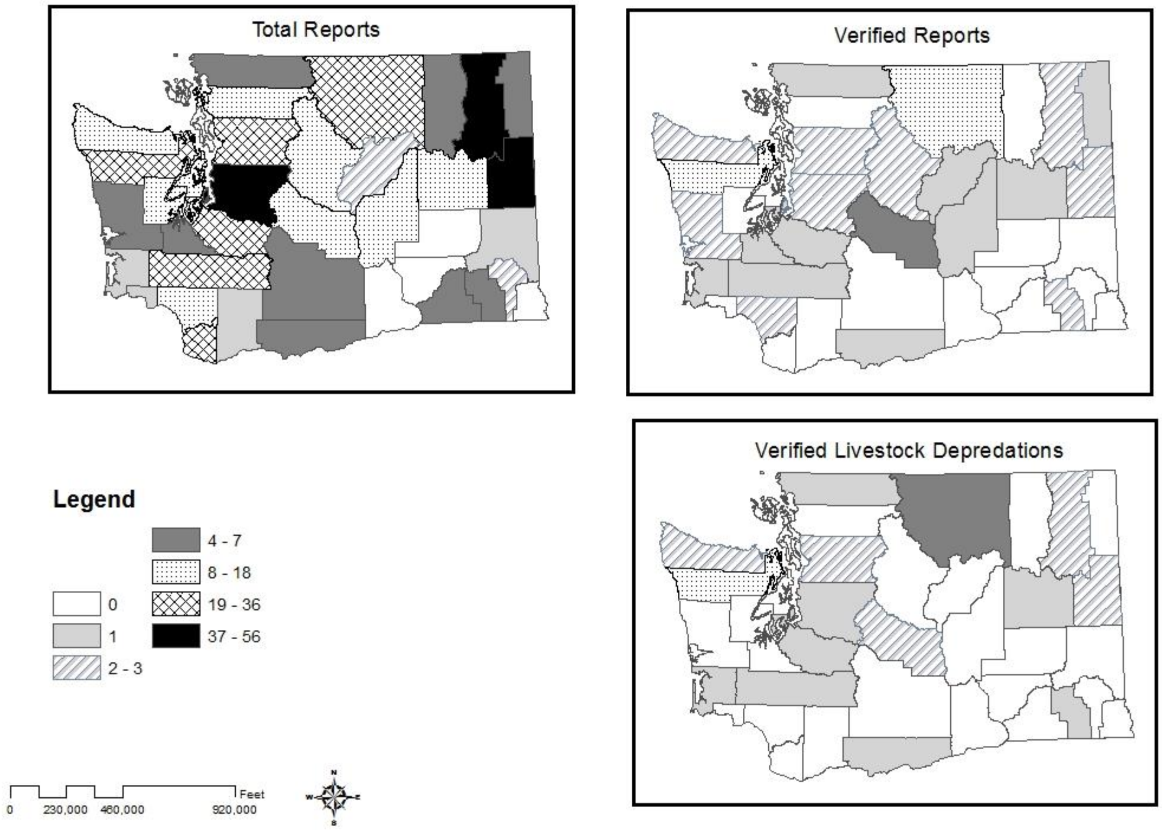
County Reports 2007



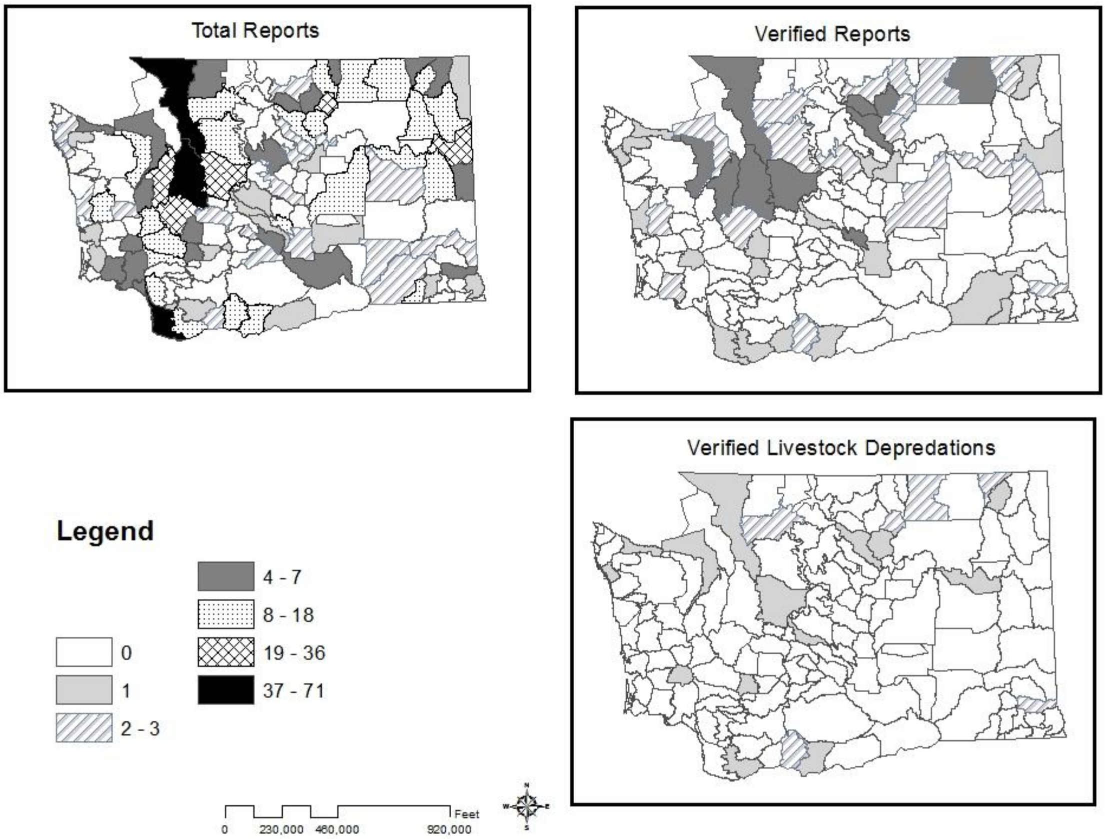
County Reports 2008



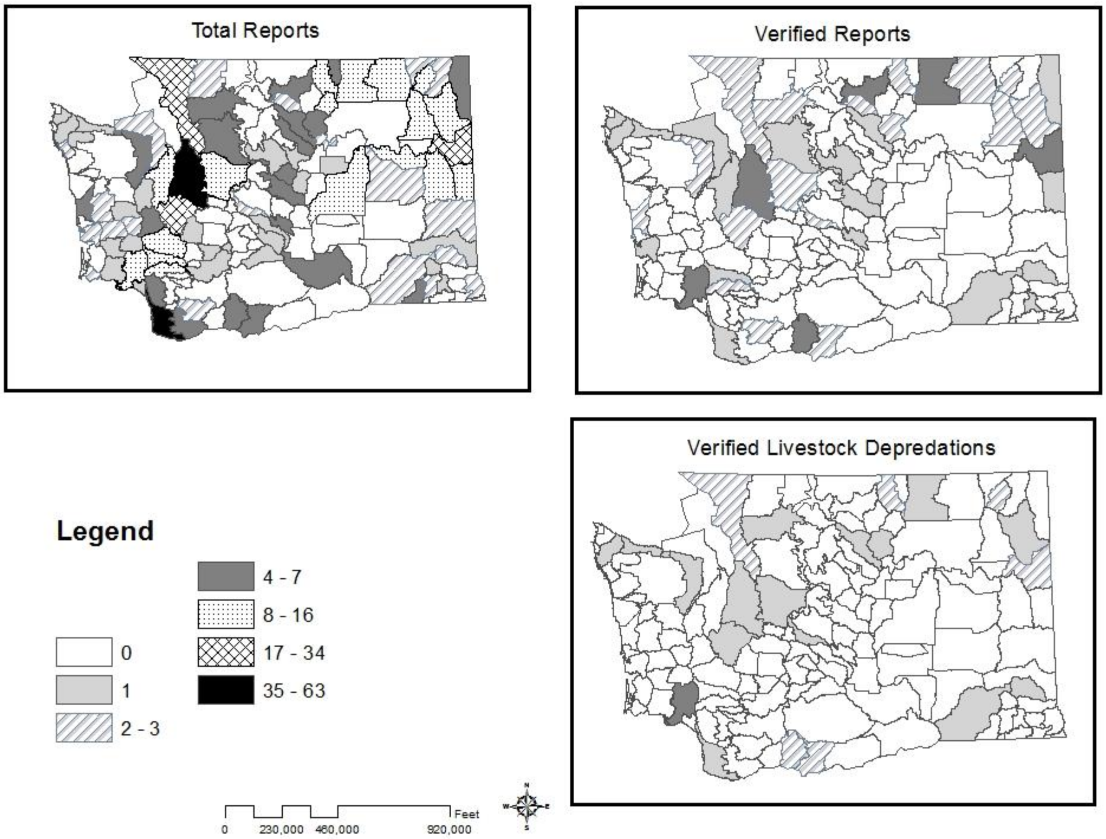
County Reports 2009



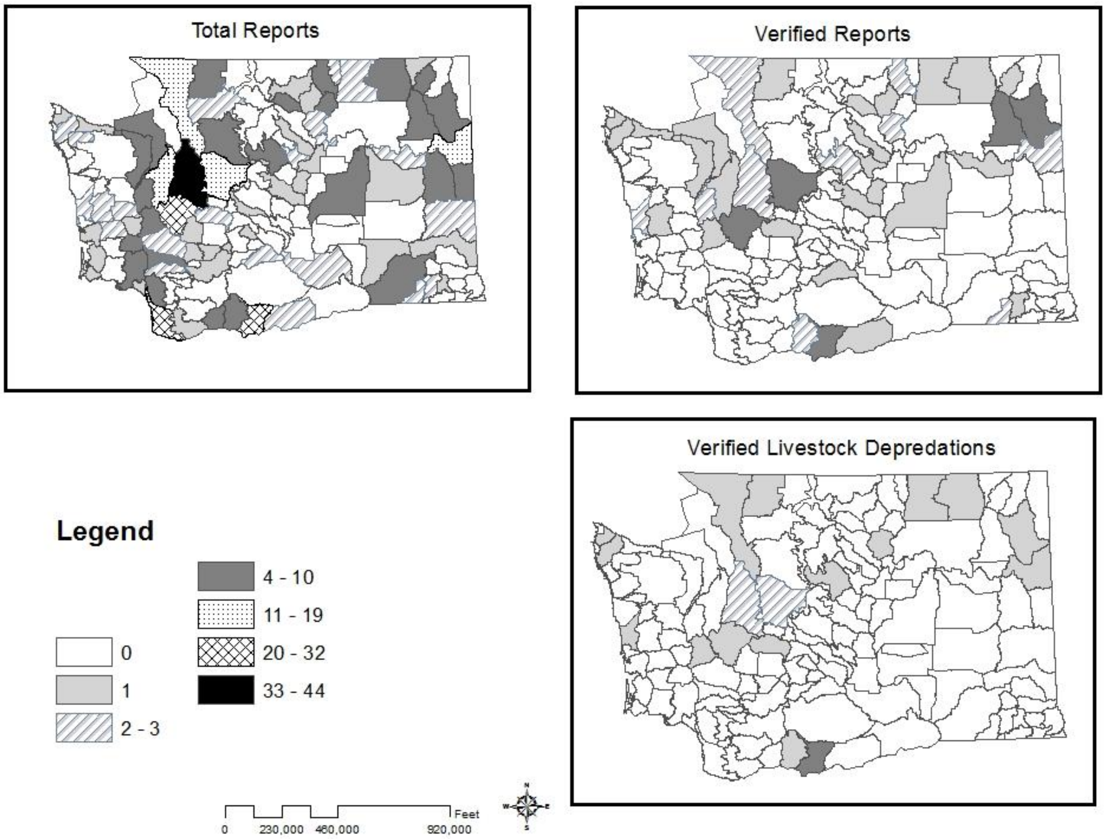
GMU Reports 2005



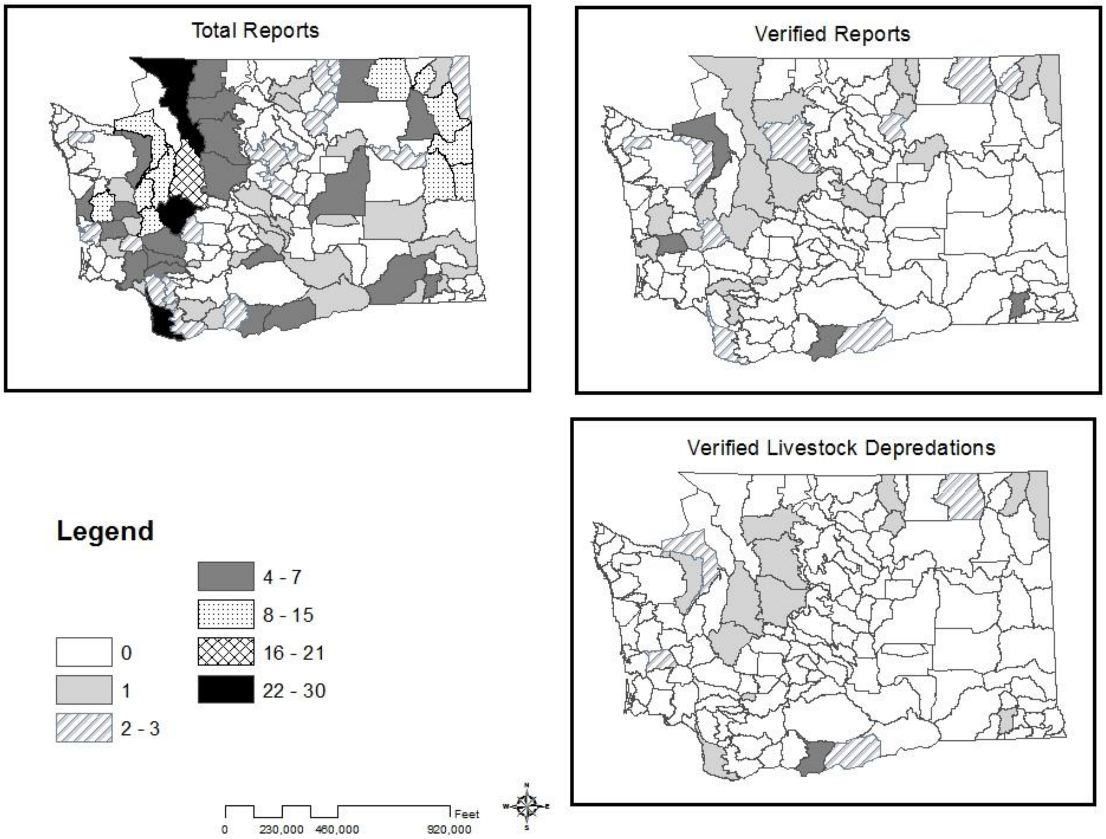
GMU Reports 2006



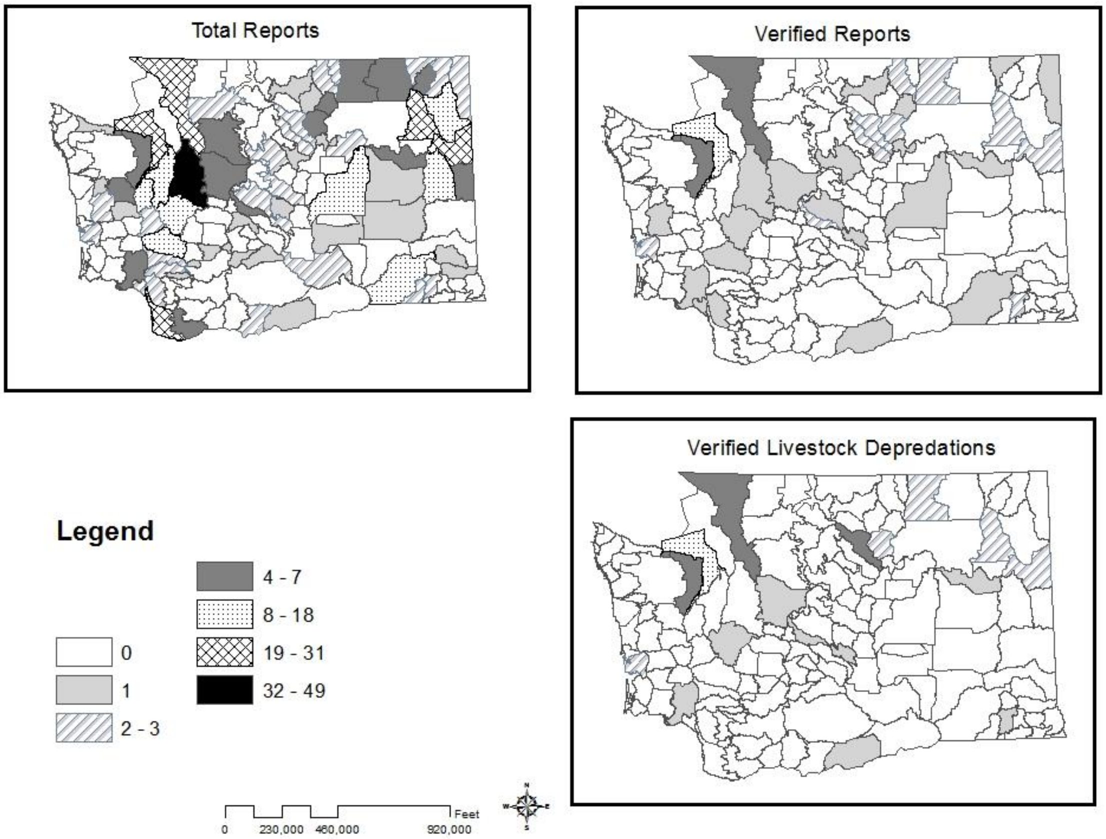
GMU Reports 2007



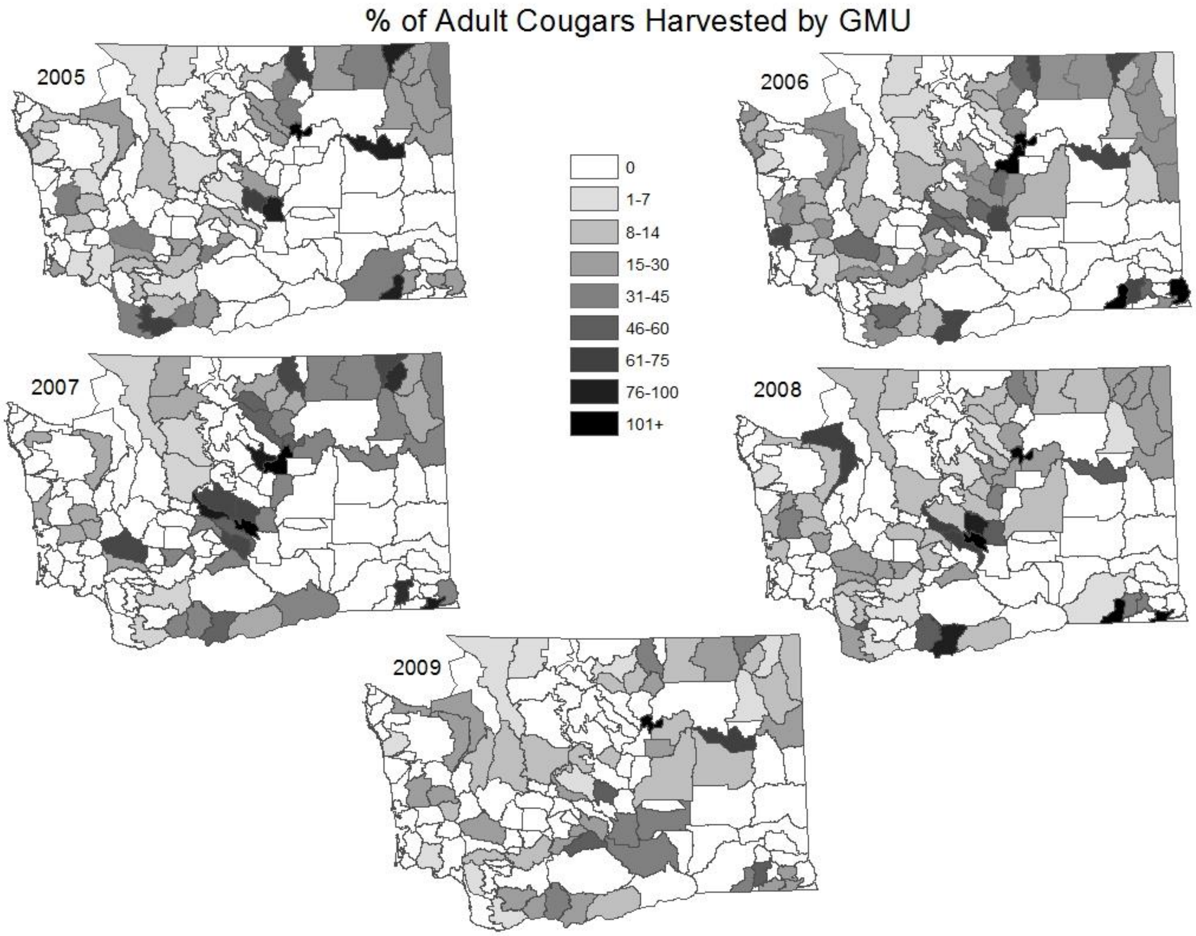
GMU Reports 2008



GMU Reports 2009



Maps of Percent of Adult Cougars Harvested



Statistical Program R Outputs of Results

County Based Tests

Total Reports~ human population, total cougar population, large livestock

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.225e+00	4.605e-01	-2.660	0.00781 **
humpop	1.641e-02	3.125e-03	5.253	1.50e-07 ***
poptot	2.809e-02	3.965e-03	7.084	1.40e-12 ***
livelarg	1.458e-04	2.475e-05	5.892	3.81e-09 ***
humpop:poptot	-1.334e-04	2.712e-05	-4.919	8.72e-07 ***
humpop:livelarg	-7.117e-07	1.453e-07	-4.898	9.66e-07 ***
poptot:livelarg	-1.010e-06	1.815e-07	-5.564	2.64e-08 ***
humpop:poptot:livelarg	5.973e-09	1.364e-09	4.379	1.19e-05 ***

(Dispersion parameter for Negative Binomial(0.8988) family taken to be 1)

Null deviance: 357.85 on 233 degrees of freedom
Residual deviance: 269.53 on 226 degrees of freedom
AIC: 1549.8

Number of Fisher Scoring iterations: 1

Theta: 0.8988
Std. Err.: 0.0946

2 x log-likelihood: -1531.7690

Verified Reports~ year, total cougar population

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.2129444	0.3153187	0.675	0.49947
year2	-0.2480663	0.0874987	-2.835	0.00458 **
poptot	0.0084313	0.0022334	3.775	0.00016 ***
year2:poptot	0.0003281	0.0005979	0.549	0.58314

(Dispersion parameter for Negative Binomial(0.9624) family taken to be 1)

Null deviance: 337.30 on 233 degrees of freedom
Residual deviance: 228.09 on 230 degrees of freedom
AIC: 761.68

Number of Fisher Scoring iterations: 1

Theta: 0.962
Std. Err.: 0.178

2 x log-likelihood: -751.682

Livestock Depredations~ human population, total cougar population, large livestock

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-5.050e+00	1.207e+00	-4.182	2.88e-05 ***
humpop	1.789e-02	7.895e-03	2.266	0.023473 *
poptot	4.363e-02	1.031e-02	4.230	2.33e-05 ***
livelarg	2.336e-04	6.203e-05	3.766	0.000166 ***
humpop:poptot	-1.940e-04	6.396e-05	-3.032	0.002425 **
humpop:livelarg	-1.317e-06	4.191e-07	-3.143	0.001673 **
poptot:livelarg	-1.873e-06	4.991e-07	-3.753	0.000175 ***
humpop:poptot:livelarg	1.151e-08	3.399e-09	3.385	0.000712 ***

(Dispersion parameter for Negative Binomial(0.5881) family taken to be 1)

Null deviance: 226.31 on 233 degrees of freedom
Residual deviance: 162.28 on 226 degrees of freedom
AIC: 476.86

Number of Fisher Scoring iterations: 1

Theta: 0.588
Std. Err.: 0.139

2 x log-likelihood: -458.857

Total Depredation~ human population, total cougar population, large livestock

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-4.629e+00	1.064e+00	-4.352	1.35e-05 ***
humpop	1.583e-02	7.016e-03	2.257	0.024038 *
poptot	4.137e-02	9.056e-03	4.568	4.92e-06 ***
livelarg	2.176e-04	5.407e-05	4.025	5.70e-05 ***
humpop:poptot	-1.709e-04	5.644e-05	-3.029	0.002454 **
humpop:livelarg	-1.195e-06	3.619e-07	-3.302	0.000961 ***
poptot:livelarg	-1.707e-06	4.331e-07	-3.941	8.13e-05 ***
humpop:poptot:livelarg	1.013e-08	2.950e-09	3.433	0.000596 ***

(Dispersion parameter for Negative Binomial(0.7172) family taken to be 1)

Null deviance: 258.05 on 233 degrees of freedom
Residual deviance: 176.97 on 226 degrees of freedom
AIC: 533.53

Number of Fisher Scoring iterations: 1

Theta: 0.717
Std. Err.: 0.159

2 x log-likelihood: -515.527

GMU Based Tests

Total Reports~ proportion of adult cougars harvested, human population

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	4.529e-01	7.115e-02	6.365	1.95e-10 ***
harvest_adlt	4.400e-01	2.259e-01	1.948	0.05141 .
Hum_Pop	3.788e-06	3.685e-07	10.280	< 2e-16 ***
harvest_adlt:Hum_Pop	1.925e-05	5.428e-06	3.547	0.00039 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Negative Binomial(0.4614) family taken to be 1)

Null deviance: 815.62 on 674 degrees of freedom
Residual deviance: 647.43 on 671 degrees of freedom
AIC: 2568.2

Number of Fisher Scoring iterations: 1

Theta: 0.4614
Std. Err.: 0.0378

2 x log-likelihood: -2558.2230

Verified Reports~ number of cougars harvested, total cougar population

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.970170	0.172525	-11.420	< 2e-16 ***
hvst	0.308764	0.060773	5.081	3.76e-07 ***
poptot	0.031093	0.005343	5.819	5.92e-09 ***
hvst:poptot	-0.003842	0.001173	-3.274	0.00106 **

(Dispersion parameter for Negative Binomial(0.4333) family taken to be 1)

Null deviance: 496.17 on 679 degrees of freedom
Residual deviance: 422.43 on 676 degrees of freedom
AIC: 1123.1

Number of Fisher Scoring iterations: 1

Theta: 0.4333
Std. Err.: 0.0697

2 x log-likelihood: -1113.0980

Verified Reports~ proportion of adult cougars harvested, human population

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.081e+00	1.006e-01	-10.738	< 2e-16 ***
harvest_adlt	9.571e-01	2.791e-01	3.429	0.000606 ***
Hum_Pop	1.066e-06	4.668e-07	2.285	0.022340 *
harvest_adlt:Hum_Pop	1.453e-05	6.718e-06	2.163	0.030580 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Negative Binomial(0.3399) family taken to be 1)

Null deviance: 444.32 on 674 degrees of freedom
Residual deviance: 416.63 on 671 degrees of freedom
AIC: 1157.1

Number of Fisher Scoring iterations: 1

Theta: 0.3399
Std. Err.: 0.0510

2 x log-likelihood: -1147.0810

Livestock Depredations~ cougars harvested, total population of cougars

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-3.155876	0.264796	-11.918	< 2e-16 ***
hvst	0.428854	0.084144	5.097	3.46e-07 ***
poptot	0.038094	0.007586	5.02	2 5.12e-07 ***
hvst:poptot	-0.005630	0.001659	-3.394	0.000689 ***

(Dispersion parameter for Negative Binomial(0.2555) family taken to be 1)

Null deviance: 310.00 on 679 degrees of freedom
Residual deviance: 253.63 on 676 degrees of freedom
AIC: 644.87

Number of Fisher Scoring iterations: 1

Theta: 0.2555
Std. Err.: 0.0561

2 x log-likelihood: -634.8710

Livestock Depredations~ proportion of adult cougars harvested, human population

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-2.019e+00	1.466e-01	-13.772	< 2e-16 ***
harvest_adlt	1.216e+00	3.817e-01	3.186	0.00144 **
Hum_Pop	1.278e-06	6.348e-07	2.012	0.04417 *
harvest_adlt:Hum_Pop	2.248e-05	9.063e-06	2.480	0.01313 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Negative Binomial(0.1848) family taken to be 1)

Null deviance: 268.75 on 674 degrees of freedom
Residual deviance: 247.24 on 671 degrees of freedom
AIC: 668.72

Number of Fisher Scoring iterations: 1

Theta: 0.1848
Std. Err.: 0.0377
Warning while fitting theta: alternation limit reached

2 x log-likelihood: -658.7200

Total Depredations~ cougars harvested, total cougar population

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-2.910767	0.236055	-12.331	< 2e-16 ***
hvst	0.386019	0.076338	5.057	4.27e-07 ***
poptot	0.038721	0.006774	5.716	1.09e-08 ***
hvst:poptot	-0.005189	0.001488	-3.488	0.000488 ***

(Dispersion parameter for Negative Binomial(0.3136) family taken to be 1)

Null deviance: 360.63 on 679 degrees of freedom
Residual deviance: 295.05 on 676 degrees of freedom
AIC: 743.66

Number of Fisher Scoring iterations: 1

Theta: 0.3136
Std. Err.: 0.0647

2 x log-likelihood: -733.6630

Total Depredations~ proportion of adult cougars harvested, human population

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.753e+00	1.316e-01	-13.315	< 2e-16 ***
harvest_adlt	9.633e-01	3.506e-01	2.747	0.00601 **
Hum_Pop	1.164e-06	5.823e-07	1.999	0.04559 *
harvest_adlt:Hum_Pop	2.206e-05	8.306e-06	2.655	0.00792 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Negative Binomial(0.2218) family taken to be 1)

Null deviance: 310.50 on 674 degrees of freedom
Residual deviance: 288.64 on 671 degrees of freedom
AIC: 775.32

Number of Fisher Scoring iterations: 1

Theta: 0.2218
Std. Err.: 0.0421

2 x log-likelihood: -765.3180