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Effects of predator urine on deterring ungulate browsing of aspen on the Turnbull National Wildlife Refuge

Savanah Walker
Eastern Washington University

EFFECTS OF PREDATOR URINE ON DETERRING UNGULATE BROWSING OF ASPEN ON THE TURNBULL NATIONAL WILDLIFE REFUGE

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THESIS OF SAVANAH L. WALKER APPROVED BY

____ Date: _______________

Dr. Margaret A. O'Connell, Graduate Study Committee

____ Date: _______________

Dr. Robin L. O'Quinn, Graduate Study Committee

____ Date: _______________

Dr. Nancy J. Birch, Graduate Study Committee

MASTER'S THESIS

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Abstract:

In the Pacific Northwest, quaking aspen (*Populus tremuloides*) support large amounts of biodiversity and are considered second only to riparian zones. Due to aspen's ecological importance and recent decline on Turnbull National Wildlife Refuge (TNWR), increasing aspen regeneration is of high priority. The elk (*Cervus elaphus*) population on TNWR has greatly increased over the last decade and over browsing is attributed as a factor affecting aspen regeneration. In response to the decline of aspen regeneration, TNWR initiated an elk hunt in 2010 to cull and disperse elk. However, hunting is not a viable solution in public use areas of the refuge, and previous data have shown that elk may be moving into those areas. To determine if elk are found more frequently in non-hunt areas of TNWR, radio-collared cow elk were tracked bi-weekly from July 2011 to March 2012. I found that the frequency of elk locations in non-hunt areas of the refuge was greater when compared to their frequencies in hunt areas and off refuge, before and during early-hunt. During the late-hunt, elk frequencies in the non-hunt and off refuge sites were significantly greater than hunt areas, and following the hunt elk frequencies on off refuge sites were significantly greater than hunt areas. Elk seem to be using non-hunt areas of the refuge more than other areas during the hunt, which may increase browsing pressure on aspen in those areas. I examined if cougar and/or wolf urine were effective at deterring elk browsing in non-hunt areas of the refuge where there may be higher browsing pressure. I established 24 6x6m aspen plots throughout non-hunt areas with 8 plots per treatment (control, wolf, and cougar), and with half of each plot area fenced to provide an internal control. Aspen were measured and placed into size and browse classes prior to the addition of deterrents in November 2011 and following treatments in July 2012. There were no measureable differences in size or browse class between fenced areas across treatments. Non-fenced areas were more browsed than associated fenced areas, however there were no measureable changes in size or browse class for non-fenced areas across treatments. While alternative measures need to be taken to help decrease aspen browse, it is not clear if wolf or cougar urine effectively deter browsing.

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Introduction:

In the Pacific Northwest, quaking aspen (*Populus tremuloides*) stands are second only to riparian zones in overall biodiversity (Mitton and Grant 1996, White et al. 1998). Aspen stands are associated with increased moisture, rich soils, and lush undergrowth which contribute to desirable habitat for other plants and can lead to greater levels of species diversity (Rogers et al. 2007). A wide variety of animals, including large herbivores, small mammals, birds, and insects use aspen for food, shelter, and protection (White et al. 1998). Several cavity nesting birds utilize aspen, many of which are insectivores and help manage insect populations (DeByle and Winokur 1985). In the mountainous west, beavers (*Castor canadensis*) are dependent almost entirely on aspen stands for food and shelter during winter months (DeByle and Winokur 1985). Maintaining regional biodiversity is therefore linked to the protection and promotion of aspen stands.

Reduction of aspen has negative consequences for regional biodiversity. Regeneration success of aspen stands is influenced by a variety of factors including climate cycles, fire suppression, conifer encroachment, and over browse by ungulates (Romme et al. 1995). Aspen reproduce primarily by asexual root sprouting, where stems (ramets or suckers) originate from a single parent root (Barnes 1966). This reproductive strategy allows aspen to reestablish quickly after some disturbances, like fire (Rogers et al. 2007). Due to its high palatability (White et al. 1998), a variety of ungulates such as moose (*Alces alces*), deer *(Odocoileus spp.)*, and especially elk (*Cervus elaphus*) preferentially forage on quaking aspen (DeByle and Winokur 1985, Mansson et al. 2007a, Mansson et al. 2007b). During the growing season these ungulates feed primarily on twigs and leaves (Durham and Marlow 2010), however during winter months when understory forage is minimal or covered in snow, elk will also strip the bark off of the trees, which can lead to increased rate of disease and infection in larger aspen ramets (Baker et al. 1997). Additionally, extensive browsing can decrease growth, reduce sucker densities, and increase rates of fungal infections that ultimately result in the death of young trees (Durham and Marlow 2010). Bailey et al. (2007) found that 4 years after the removal of a large exclosure, elk had browsed 73% of the aspen and 61% of those trees died. Browsing by large ungulates is considered the primary cause affecting change in aspen populations (Baker et al. 1997; Romme et al. 1995). In light of the importance of aspen stands to regional biodiversity and the impact of elk on aspen stand health, effective methods to reduce elk over browsing is a paramount conservation goal.

Reduction of over browsing can be accomplished by either lethal or non-lethal approaches. Traditionally elk populations, and by extension elk over browsing, have been reduced by lethal methods such as the reintroduction of natural predators or human hunting. However in many areas these lethal deterrents are not feasible due to high human use and non-lethal deterrents are necessary. Although fences are an effective way of protecting vegetation from over browsing (Andelt et al. 1991), this option may not be practical, is generally expensive, and unattractive (Osko et al. 1993). Alternatives to fencing to reduce ungulate over browsing have included methods to scare or repel the animal, such as shell crackers, gunfire, and propane cannons; however most of these have not been successful or have not been scientifically tested (VerCauteren et al. 2005).

Of the non-lethal deterrent methods, chemical repellents have shown the greatest promise. The chemicals predominantly used have included several commercial animal repellents which are primarily composed of putrescent eggs, lithium chloride, predator feces, and predator urine (Andelt et al. 1991, Osko et al. 1993). These repellents, which are meant to have an unpleasant odor or unattractive taste, have shown success in captive animal studies (Andelt et al. 1991). Brown et al. (2000) compared Wolfin®, Deer Away Big Game Repellent®, and lithium chloride effects on captive caribou (*Rangifer tarandus*), and found lithium chloride, applied directly to the food, to be most successful deterrent; however this may not be practical in a field setting. Muller-Schwarze (1972) found that when odors from different predators were present around feed dishes of captive deer, it led to a significant reduction in feeding or approaching compared to those without odors. Melchiors and Leslie (1985) used a variety of predator odors to determine effectiveness at deterring captive black-tailed deer (*Odocoileus hemionus columbianus*) from browsing salal (*Gaultheria shallon*) branches and found that mountain lion (*Felis concolor*) and bobcat (*Felis rufus*) odors were the most effective, followed by wolf (*Canis lupus*) and coyote (*Canis latrans*). Although these deer had never been exposed to predators, they appeared to have an innate response to their odors. While repellents have sown success in captive animal studies, they have not been tested in free-ranging ungulates, including elk, nor is it entirely clear what type of predator odor is the better deterrent.

There have been no examples using chemical deterrents in the field, however wolf reintroduction in Yellowstone National Park (YNP) has allowed for some analysis on how elk have responded to wolf presence. Kimble et al. (2011) compared aspen recruitment in YNP before and after wolf reintroduction and found no significant difference in aspen growth, concluding that wolves are not deterring elk from browsing aspen in those areas. Kauffman et al. (2010) examined aspen growth in relation to wolf density in YNP and observed aspen regeneration was no greater in areas of higher wolf density. Regardless of predation risk, it did not seem to deter elk from browsing aspen, and they suggested it was due hunting style of wolves, and that feline predators may evoke a greater response (Kauffman et al. 2010). Wolves and cougars are two primary predators of elk; however they differ in hunting style (Atwood et al. 2006). Wolves are coursing pack predators that thrive in open habitats, while cougars are ambush predators that rely on structurally complex habitats (Atwood et al. 2006). This difference in hunting strategy could provide an interesting comparison in how prey would respond to the perceived presence of a predator in a field setting.

Aspen populations on Turnbull National Wildlife Refuge (TNWR) have been greatly reduced in recent years, putatively coinciding with an increase of elk (USFWS 2007). Elk populations on the TNWR have grown from less than 100 in the early 1980's (USFWS 2007) to over 450 in 2010 (Mike Rule, TNWR Biologist, pers. com.). At high population densities large ungulates exceed their available resources. Turnbull National Wildlife Refuge provides wildlife viewing opportunities to the public, and therefore maintaining high amounts of biodiversity is important to sustaining visitor interest. To mitigate the detrimental impact of elk on the health of aspen stands and the subsequent threat of loss to regional biodiversity, TNWR initiated a hunt in 2010 with the management goal of culling and dispersing the elk. In both 2010 and 2011, 63 tags were issued, one of which was a bull tag. Following the 2010 and 2011 hunting seasons 20 and 24 elk were taken, respectively.

Preliminary data from the first hunting season suggested that the hunt may have simply caused high numbers of elk to congregate in areas on the refuge where hunting is not permitted (Dwight 2012), which is similar to what Proffitt et al. (2010) observed following two hunting seasons in Montana. Dwight (2012) also measured aspen in different areas of TNWR to determine if elk response to the hunt was impacting aspen growth, but was unable to detect any differences. Whereas hunting is an effective and cost efficient way of deterring elk from foraging where hunting is permitted, this technique is not be feasible in all portions of the refuge, especially in public use areas. Prescribed burns would likely help aspen regeneration (Romme et al. 1995), however that regeneration would still not result in healthy stands if they experienced over browsing. This leads to the need for a non-lethal alternative of preventing extensive browsing on aspen stands in these areas. My study objectives were to 1) determine if hunting on the refuge increased elk use of non-hunt areas and 2) determine if wolf and cougar urine decrease browsing on aspen.

Methods:

Study Area

Turnbull National Wildlife Refuge is a 6,626 ha tract of land located on the edge of the Columbia River Basin (USFWS 2007). The refuge is comprised of wetland, with shrub steppe, grasslands, ponderosa pine (*Pinus ponderosa*) woodlands, and scattered stands of aspen (USFWS 2007). Most of the area surrounding the refuge is privately owned and used as pastureland for cattle (USFW 2007). The refuge is split into three sections: 1) public use areas where hunting is not allowed (non-hunt), 2) reserve hunt areas, where hunting may be allowed in the future (non-hunt), and 3) areas where hunting is annually permitted (hunt; Figure 1). For the purposes of this study I divided the refuge into two areas designated hunt and non-hunt respectively (Figure 2).

Elk Telemetry

To address my first objective I used radio telemetry to track elk locations before, during, and after the hunting periods. In February 2010, prior to the first hunt, 34 cow elk were collared and their locations were monitored bi-weekly. Following the 2010 hunting season 5 collared animals were taken, and 3 died of natural causes with 26 collared females remaining. I continued radio-tracking the 26 remaining collared elk, and their locations were estimated from July 2011-April 2012, which encompassed before, during, and after hunting season. Following the 2011 hunt, 3 collared elk were hunted and 2 died from natural causes leaving 21 in April 2012. I tracked twice weekly, rotating between morning, afternoon, and evening. I used a directional antenna to determine the relative direction of each individual from several locations.

I used the Locate III program to triangulate the data and identify the approximate location for each elk detected. Tracking data were input into ArcGIS 10 to determine location and movement of the elk over the tracking period. This information was used to determine if the elk are increasing their use of non-hunt areas of the refuge by comparing the frequency of locations in each area over the different time periods. I used a Chi-Square Goodness-of-Fit analysis, using equal expected frequencies, to compare three areas (non-hunt, hunt, off refuge) over the four different time periods: 1) pre-hunt (June-Sept 6), 2) early-hunt (Sept 6-Oct), 3) late-hunt (Nov-Dec), and 4) post-hunt (Jan-March). I also ran a Chi-Square Goodness-of-Fit on non-hunt vs hunt areas over the time periods to incorporate the size, therefore expected frequencies were 65 and 35 percent respectively. A two-way analysis of variance (ANOVA) was used to determine which areas and time periods were different from one another. The dependent variable was proportion of elk, which were determined by taking the number of elk locations in that area divided by the total of number of locations per tracking effort for each time period. For all analyses I assigned an α value of 0.05 to establish significance.

Deterrent Trials

To address my second objective, I identified 24 aspen stands within the non-hunt areas of the refuge. The stands were designated as either control or treatment using randomized block design of location and stand characteristics (size, density, and proximity to water) (Figure 2). The treatment stands were divided equally between wolf and cougar urine. Both types of treatment urines were purchased from predatorpee.com. I established a square 6x6m plot within each stand, which was a minimum of 150m from main roads and from other plots. I attempted to choose stands that had similar characteristics to reduce differences due to site location; any differences in overall size of stand and density of trees were stratified across treatments. Within each plot I erected an exclosure constructed from Deer-D-Fence fencing to prevent elk browsing. The exclosure was 3x6m, half of the total plot area. Plots were arranged perpendicular to the moisture gradient, and fenced areas were arranged so that they were also perpendicular to the moisture gradient. The fencing was approximately 2.5m tall and paired fenced and non-fenced plots within a single plot provided further comparison within and between treatment and control stands. In each aspen stand, 1oz predator urine dispensers were spaced 6m apart around the perimeter. Each urine dispenser had an effective radius of 3m in all directions. The control plots had dispensers but no urine, to eliminate effects due to presence of dispenser alone. The urine dispensers were checked every 30 days, and refilled as needed.

To examine if stands were browsed, measurements on aspen trees were taken prior to the start of deterrent trials in November 2011 and immediately upon removing deterrents in July 2012. Stand health was assessed by determining: 1) if aspen is alive or dead, 2) height of aspen suckers (trees < 2m), 3) the number of trees of each size class, and 4) evidence of browsing (modified protocol from Ripple et al. 2001). Size classes were split into the following categories; 1) 0-1m height, 2) 1-2m height, 3) > 2m and < 5 cm diameter at breast height (DBH), and 4) > 5cm DBH (White et al. 2003). Stems 0-1 and 1-2m in height were then placed in a browse class based on proportion browsed: 1) < 20%, 2) 20-50%, 3) 50-80%, and 4) > 80% (White et al. 2003).

For all aspen data, ANOVA tests were performed to determine if there were significant differences between treatments and control plots. All analyses were performed on proportion of trees that occurred in each size or browse class before and after deterrent trials. To determine this, I took the proportion of trees in a particular class at the end of the study and subtracted the starting proportion of trees, this gave me a change in proportion for each size and browse class. Fenced areas within plots across treatments were compared using a multivariate analysis of variance (MANOVA) test to determine if trees responded similarly to being fenced and therefore not browsed. In order to see if there was any effect due to size or browse for either fencing or treatment, repeated measures ANOVA was run on fencing and treatment as the independent variables and the difference in proportion for each size or browse classes as the dependent variables. MANOVA was also used to compare the difference in proportion of browse in fenced areas to their corresponding non-fenced areas. I ran MANOVA on non-fenced areas by treatment for size and browse classes, to determine if the urine treatments were significantly different from the control. All ANOVA analyses again used $\alpha = 0.05$. Due to a relatively small sample, to help measure the magnitude of treatment effect relative to sample size I assessed the effective size following Keppel et al. (1992). This analysis compares the proportion of sum of squares between treatment means to the total sum of squares, and this proportion is compared to the Cohen's Standard to estimate the magnitude of treatment effect (Keppel et al. 1992).

All evidence of ungulate presence (e.g. visual sightings, tracks, and scat) was noted throughout the trials. From April 2012 until July 2012, three motion sensor trail cams were rotated through different stands, with one at each treatment type.

Results:

<u>*Elk Telemetry*</u>

Elk frequencies in the non-hunt areas of the refuge were higher than hunt areas before and during the hunt. Between July 2011 and March 2012, I recorded a total of 705 locations from the 26 collared elk. Results from my Chi-square analyses, using an expected frequency of 33.33 in each, are shown in Table 1. This analysis assumes elk locations are equally likely in both areas of the refuge and off refuge. During all four time periods elk frequencies differed significantly between areas: $\chi^2 = 30.64$, $p < 0.0001$; $\chi^2 = 46.27$, $p < 0.0001$; $\chi^2 = 62.77$, $p < 0.0001$; $\chi^2 = 17.56$, $p = 0.0002$. Elk frequencies were higher than expected for pre-hunt, early-hunt, and late-hunt in non-hunt areas, did not differ from expected off refuge, and were lower than expected in hunt areas. Results from the Chi-square on hunt and non-hunt areas alone, using expected frequency based on area, found similar results. There were significant differences in the pre-hunt, early-hunt, and late-hunt but not in the post-hunt: $\chi^2 = 9.71$, $p = 0.0018$; $\chi^2 = 7.39$, $p = 0.0066$; $\chi^2 = 18.16$, $p < 0.0001$; $\chi^2 = 0.002$, $p = 0.96$. This suggests that elk were found more often in non-hunt areas than expected and less often in hunt areas; however during the post-hunt frequencies did not differ.

To further explore how elk were utilizing different areas, ANOVA was used to compare mean elk frequencies across the time periods. ANOVA results were significant between areas and time periods ($F_{11,141} = 14.30$, $p < 0.0001$). Elk were found more often in non-hunt areas than hunt areas and off refuge for the pre-hunt, and early-hunt time periods (Figure 3-6, $p \leq 0.014$). For the late-hunt time period there was a significantly higher proportion of elk in non-hunt areas and off refuge compared to hunt areas ($p = 0.026$) but non-hunt was not significantly different than off refuge. During the post-hunt time period there was a significantly higher proportion of elk off refuge compared to hunt areas (Figure 6, $p = 0.0002$).

Deterrent Trials

Several general observations were made throughout the deterrent trial period. During the spring of 2012 several of my plots had water in them, from a few centimeters to about 45cm. By the time plots were measured in the summer, there was no longer standing water in any of the stands. Based on my telemetry data, elk were likely to have encountered all plots, at some point in time. I observed elk at one control plot and a moose was frequently spotted near another. A cow and calf moose, and a young cow moose were spotted near wolf urine plots, and one moose was spotted twice near another wolf urine plot. A herd of elk was seen running near a cougar plot, as well as two deer spotted on a different occasion near the same plot. Elk, moose, and deer pellets were commonly found around or in many stands of all treatment types.

Motion sensor trail cameras were set out one per treatment and were set to capture 5 frames when triggered. Elk, deer, and moose were captured on the cameras in cougar and control plots. One cougar plot captured one cow elk walking past, and another cougar plot caught a moose walking through. There was no visual evidence that the animal stopped to browse in the stand. One control plot captured a collared cow elk on two different occasions, and a moose, and on all occasions the animals appear to be lingering in the stand. A second control plot found a total of 3 white tail deer on two occasions, and a cow elk. All of the animals appear to be browsing in and around the plotted area. There were no photos of ungulates in the wolf stands while cameras were there.

Based on over 1500 aspen measurements taken for the aspen, I observed that there were few dead trees with little to no change in the number over the time period. Height and DBH measurements were used to assign trees to size class. Most of the trees within plots were in size classes 1 and 2, and in browse classes 1 and 2. There were no significant differences found in either size or browse class for fenced areas between treatments (Table 2). This suggests that all plots responded similarly to fencing over that period of time. Repeated measures ANOVA results showed a significant effect due to browse and in particular browse due to fencing with $F_{3,126} = 4.39$, $p = 0.024$ and $F_{3,126} = 4.84$, $p = 0.017$ respectively (Table 3). There appears to be no significant difference in size classes for either fencing or treatment.

Comparing browse between fenced areas to their corresponding non-fenced areas (Figures 7-9), I found an increase in the proportion of aspen < 20% browsed in the fenced areas of the wolf urine treatment plots whereas the proportion of aspen < 20% browsed in the non-fenced areas decreased (Figure 8; $F_{1,14} = 6.85$, $p = 0.02$). I observed a similar trend for the proportion of aspen 20-50% browsed in both the wolf treatment ($F_{1,14} = 4.10$, $p = 0.062$) and cougar treatment for 20-50% browsed ($F_{1,14} = 4.19$, $p = 0.06$). There were no changes in proportion of aspen browsed across the control treatments; however there was a high amount of variability. These results suggest that non-fenced aspen were browsed more than their associated fenced areas.

Finally I observed no differences between non-fenced areas across treatments for either size or browse class (Figure 10, 11). Although MANOVA showed no significant differences in size class the data do suggest a trend that more trees in the wolf and cougar treatments increased in size class (Figure 10) compared to control plots. Control plots had an increase in trees in size class 1, which could be due to browse, or more recruitment with fewer trees increasing to size class 2. The wolf treatment had the least amount of change in browse compared to the control and cougar plots (Figure 11).

Effective size analysis on non-fenced areas for both size and browse classes resulted in $\square^2 \leq 0.22$. According to Cohen's Standard, all values were classified as having a small effect, meaning small sample size might not have been a major contributing factor to lack of significance. The greater the proportion, the greater the effect due to treatment, therefore there is only a small effect due to treatment compared to random experimental error (Keppel et al. 1992).

Discussion:

The increasing number of elk on and around TNWR, and their over browsing of aspen, has contributed to the reduction of aspen regeneration. Due to aspen stand importance in supporting regional biodiversity a potential solution to reducing ungulate browse was explored in my study. Following the second year of hunting on TNWR, elk are spending more time in non-hunt areas of the refuge, and have decreased their use of hunt areas. Since hunting is not feasible in human use non-hunt areas, I investigated an alternative non-lethal deterrent. Following an 8 month trial of wolf and cougar urine deterrents around aspen stands, I could not conclude that these were effective deterrents.

After the first season of hunting on TNWR, Dwight (2012) found that elk decreased their use of the refuge and shifted to off refuge locations as the season progressed. The first half of the hunt included primarily archery and muzzleloader while the later half was mostly modern firearm and is considered to have greater impact on elk movement (Christensen et al. 1991). Following a second year of tracking I found elk more often in non-hunt areas before and during the hunting season compared to hunt areas and off refuge sites. It was not until late in the hunting season and primarily after the hunt that I observed a significant shift to off refuge sites. Typically high human use areas, like the public use areas of the refuge, have lower elk usage (Cole et al. 1997). This was also seen in a study on TNWR in 2003, when Albrecht (2003) used elk telemetry to determine areas of high and low elk use, and found high human use was associated with low elk use. It now seems that elk have increased their use of these previously low use areas in response to hunting pressure on the refuge, which is consistent with other studies that found hunting pressure causes elk to seek areas with the least amount of disturbance (Burcham et al. 1999).

Seasonal elk movement on and off TNWR has not been well documented (Dwight 2012), which makes it difficult to say if the perceived pattern in elk frequency is due to hunting alone. Dwight (2012) found that the elk spent less time in hunt areas and move off refuge or to non-hunt areas as the hunting season progressed. Whereas I found elk less frequently in hunt areas throughout most of my study, however I did see the same increase in use of the non-hunt areas and the same shift off refuge in the later part of and following the hunting season. Other environmental factors that influence elk winter movement, such as food availability and snow depth (Sweeney and Sweeney 1984), and the latter is considered second only to human disturbance in determining elk winter ranges (Hayden-Wing 1979). Snow depth is a factor that can impact elk movement and browsing, and heavy snow fall years tend to increase browsing pressure on aspen (DeByle and Winokur 1985). The winter of 2011/2012 had normal amounts of snow fall for this area (National Climate Data Center 2012), therefore browsing pressure on the aspen should represent an average year. It is reasonable to suggest that elk usage of TNWR is in response to hunting; however other factors may be influencing their movement.

My objective was to determine if wolf or cougar urine are effective at deterring ungulates and therefore reducing browse. Given my results, I was unable to detect a difference between treatment and control plots. There were no significant differences in browse across treatments; however wolf urine treatments did appear to have less change in browse compared to the control and cougar urine treatment. Wolf and cougar treatment stands had trees that were more browsed in the non-fenced plots compared to the associated fenced plots. Non-fenced control plots appear have increased in browse as well, however due to high variability in these stands, no significant differences were detected. With a modest sample size, high variability greatly affected my statistical analysis. Using effective size analysis, I was only able to detect small effects due to treatment, suggesting there is little of the variation explained by treatment effects. If the urine was deterring, I would see the treatment stands be less browsed and more similar to the fenced areas. Wolf urine treatment seemed to be the most consistent across browse classes with the least amount of change over time. These data do not conclusively support the hypothesis that wolf and cougar urine are effective at deterring ungulate browsing.

I was unable to detect differences across treatments with respect to size class, and several factors could have contributed to this. There were noticeable changes in height and in many cases I did see trees increase in size class, however there were no difference across treatments. Deterrent trials occurred over the course of about 8 months, which may not have been long enough to identify significant differences between treatments. Aspen may also be experiencing competition with ponderosa pine, which block sunlight to shade intolerant aspen (Kay 1994, Romme et al. 1995). Turnbull National Wildlife Refuge has implemented prescribed burns in some areas; however it will only help reduce competition at those sites. Aspen are typically considered a fast growing tree, but due to competition and continued use by ungulates, aspen communities can experience stunted growth and reduced recruitment (Romme et al. 1995, Kay 1997, White et al. 1998, Ripple et al. 2001). Since aspen in the area may already be experiencing reduced annual growth, it would be difficult to detect significant size differences in a short amount of time.

Whereas most browsing damage has been attributed to elk due to their large population, other ungulates might also be contributing to aspen stand degradation. While in the field I saw deer and moose, in addition to elk, and their fecal pellets were common in or around my aspen plots. In particular, there were moose that seemed to frequent certain stands, and were repeatedly spotted in the surrounding area. Two of the frequented moose plots did experience an increase in browse for non-fenced areas. The moose population is estimated to be between 8 and 16 animals, and that number has been fairly consistent over the last few years (Mike Rule, TNWR Biologist, pers. com.). While cougar and wolf urine could be deterring for elk or deer, it may not have the same effect on moose. In Washington State the primary predators of moose calves are black bear and cougar, but in other areas grizzly bear and wolves are the primary predators (Link 2004). While I cannot say if any animals were being deterred, if some ungulates were, it would be difficult to determine.

In order to better assess which animals are having the greatest impact on aspen stands, the use of motion sensor cameras would have been beneficial at all aspen plots. This would have provided information on which animals are foraging most frequently, and exactly how or if they are reacting to the deterrents. I was able to use a few cameras toward the end of my study, which captured pictures of animals at cougar urine and control plots, but not at wolf urine plots. This helps support the results of less browse at wolf urine plots, however this would have greater weight if they were at all sites throughout the whole study.

Several insect species utilize aspen stands and may be contributing to poor stand health. During late spring and summer, insect eaten leaves and enormous numbers of ants were observed in many stands regardless of treatment, all over the refuge. The ants are likely responding to high aphid infestation on the aspen trees (DeByle and Winokur 1985). Aphids can cause leaf drop by feeding on apical twigs and leaves of aspen

(DeByle and Winokur 1985). Future studies should further explore the impacts insects are having on aspen stand health to gain a more complete picture of all factors negatively affecting aspen stand regeneration.

Management Implications:

Elk were found more often in the non-hunt areas of the refuge throughout the hunt season, suggesting elk are seeking areas with the least hunting pressure. Land surrounding TNWR include both hunting and non-hunting property, and exploration of how elk may be utilizing these areas would give us a better idea of overall elk movement and utilization of the area. While hunting does have some culling and dispersal effects, it seems that an alternative measure needs to be adopted in these non-hunt areas. Aspen in hunt areas of the refuge may see a decrease in browsing over winter, since elk frequency has decreased, and non-hunt areas may see no change or even increased browse pressure. It is not clear if cougar or wolf urine would be an effective deterrent in the non-hunt areas for all browsing ungulates, however wolf urine did show the most potential and may be worth exploring further in a long term study. Additional exploration is needed to find a way to reduce ungulate browsing in non-hunt areas of the refuge to promote aspen health and biodiversity.

This study will help inform the refuge on how the hunt has affected elk movement and dispersal and supports the need for a non-lethal deterrent in non-hunt areas. Future studies could follow aspen growth over a longer period of time to determine if the hunt areas have more aspen regeneration compared to non-hunt areas, or if alternative deterrents would work in those non-hunt areas. Longer term use of motion sensor cameras would help better identify which ungulates are browsing the stands and if a deterrent is effective.

Fencing should be considered for high priority stands. Protecting aspen by fencing reduces browsing as seen in this and other studies (Andelt et al. 1991, Albrect 2003) and allows young aspen to grow to maturity (Andelt et al. 1991). Fencing would also enable managers to compare nutrient levels of aspen between fenced and non-fenced plots. Plants such as aspen are able to alter their palatability in response to browse pressure (Rooney and Waller 2003). If aspen palatability decreases in response to browsing, managers should monitor vegetation to determine if elk are shifting use to other plant species.

Finally to mitigate over browse, increasing human activity in non-hunt areas during the hunt may aid in elk dispersal if elk reduce their use of areas with high human disturbance. In conclusion, a combination of methods to disperse the elk population and reduce over browsing will be necessary to increase aspen regeneration and maintain biodiversity.

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Tables

Table 1: Comparison of proportions in different areas during each time period with associated chi-square value. The expected proportion for each was 33.33. Variables with $p < 0.05$ are bold.

Time Period	Non-hunt	Hunt	Off Refuge	df	N	χ^2	p
Pre-hunt	59.09	11.36	29.55	2	88	30.64	**<.0001**
Early-hunt	54.09	17.73	28.18	2	220	46.27	**<.0001**
Late-hunt	52.9	12.74	34.36	2	259	62.77	**<.0001**
Post-hunt	34.31	18.25	47.45	2	137	17.56	**0.0002**

Table 2: Comparison between mean (± SE) difference in proportion for size and browse classes of fenced plots in each treatment. MANOVA analysis found no significant differences ($\alpha = 0.05$) in fenced areas between treatments.

	Control	Wolf	Cougar			
Attribute	**Mean ± SE**	**Mean ± SE**	**Mean ± SE**	**df**	**F**	**p**
Size Class 1	(-0.049) ± 0.047	(-0.031) ± 0.082	(-0.031) ± 0.076	2	0.17	0.8485
Size Class 2	0.055 ± 0.063	(-0.016) ± 0.075	0.051 ± 0.107	2	0.23	0.8002
Size Class 3	0.013 ± 0.040	0.004 ± 0.017	(-0.020) ± 0.061	2	0.16	0.8554
Size Class 4	0.024 ± 0.039	0.006 ± 0.015	0.001 ± 0.016	2	0.21	0.8089
Browse Class 1	0.073 ± 0.060	0.236 ± 0.084	0.082 ± 0.083	2	1.44	0.2604
Browse Class 2	(-0.121) ± 0.067	(-0.192) ± 0.087	(-0.161) ± 0.099	2	0.17	0.8427
Browse Class 3	0.028 ± 0.024	0.075 ± 0.126	0.039 ± 0.029	2	0.1	0.9044
Browse Class 4	0.020 ± 0.016	(-0.016) ± 0.022	0.014 ± 0.014	2	1.21	0.3192

Table 3: Repeated Measures ANOVA with independent variables of fencing and treatment and dependent variables of size class (1-4) or browse class (1-4). Significant variables are in bold ($p \leq 0.05$).

Attribute	**df**	**F**	**p**
Size Classes			
size	3	0.41	0.687
size*treatment	6	0.06	0.996
size*fence	3	0.30	0.766
size*treatment*fence	6	0.49	0.767
Browse Classes			
browse	3	4.39	**0.024**
browse*treatment	6	0.66	0.584
browse*fence	3	4.84	**0.017**
browse*treatment*fence	6	1.02	0.392

Figures

Turnbull NWR Elk Hunt Units

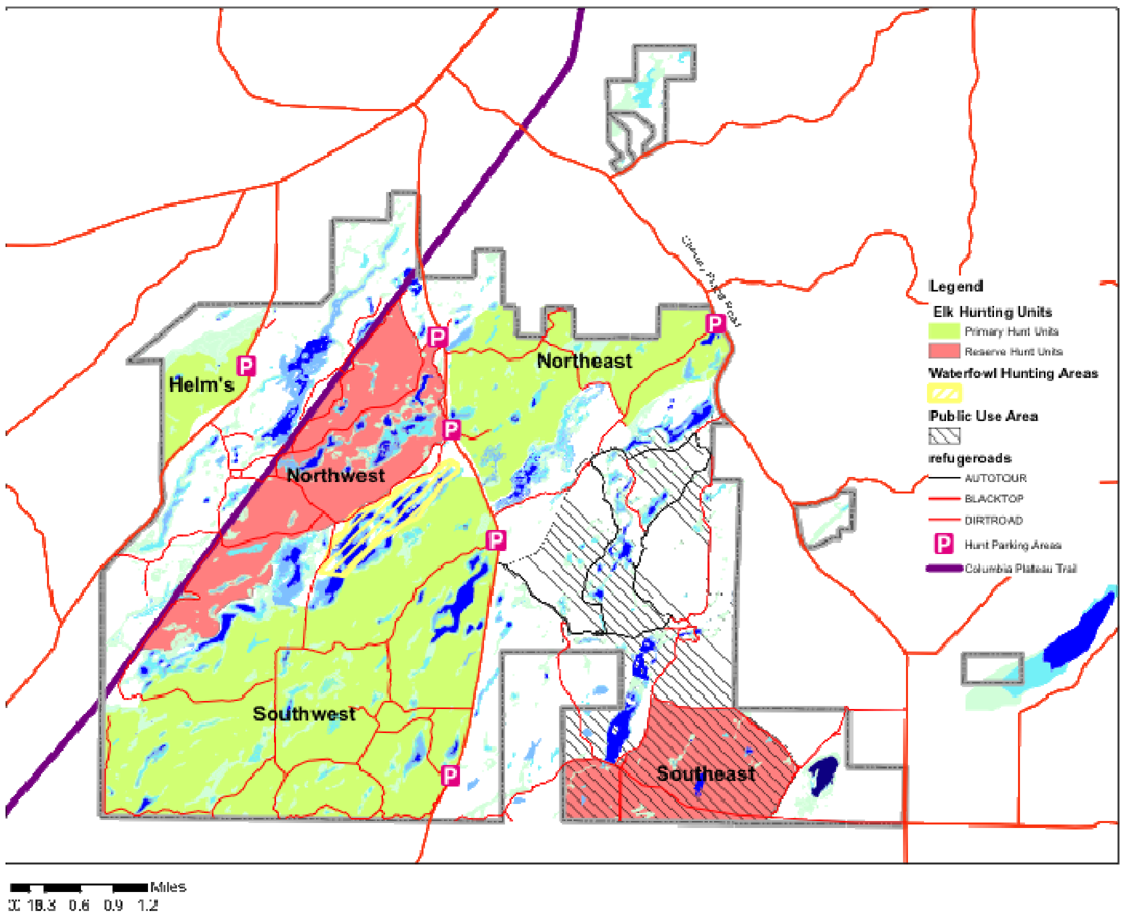

Figure 1: TNWR map of hunting and non-hunting areas. The Northwest, Southeast (pink), and diagonal lined non-shaded areas (white) currently do not allow hunting. The Northeast, Southwest, and Helm's areas (green) are those in which hunting is permitted. Image courtesy of USFWS.

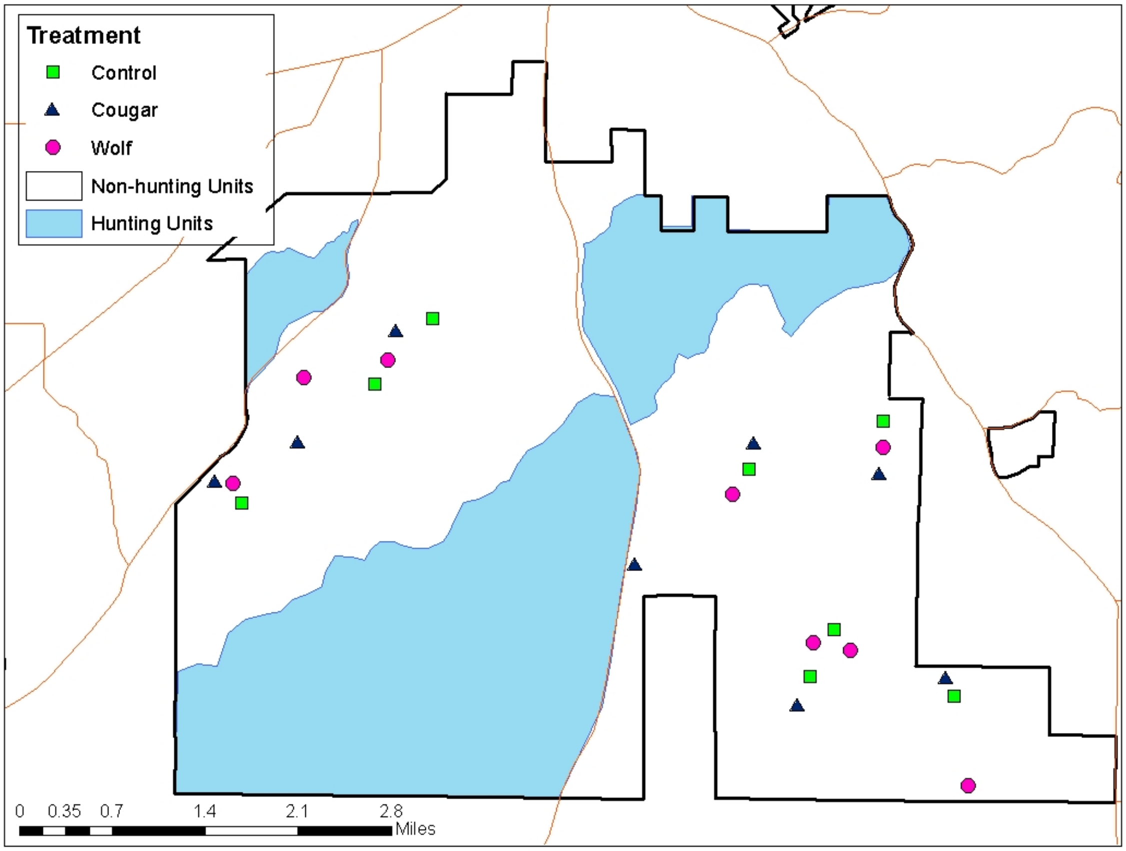

Figure 2: TNWR map with aspen stand study sites locations. Twenty-four stands were dispersed throughout the non-hunt (white/non-shaded) areas of the refuge, and their proximity to main roads, refuge boundary, and hunting areas (orange/shaded). Control stands are designated by green squares, cougar with blue triangles, and wolf with pink circles.

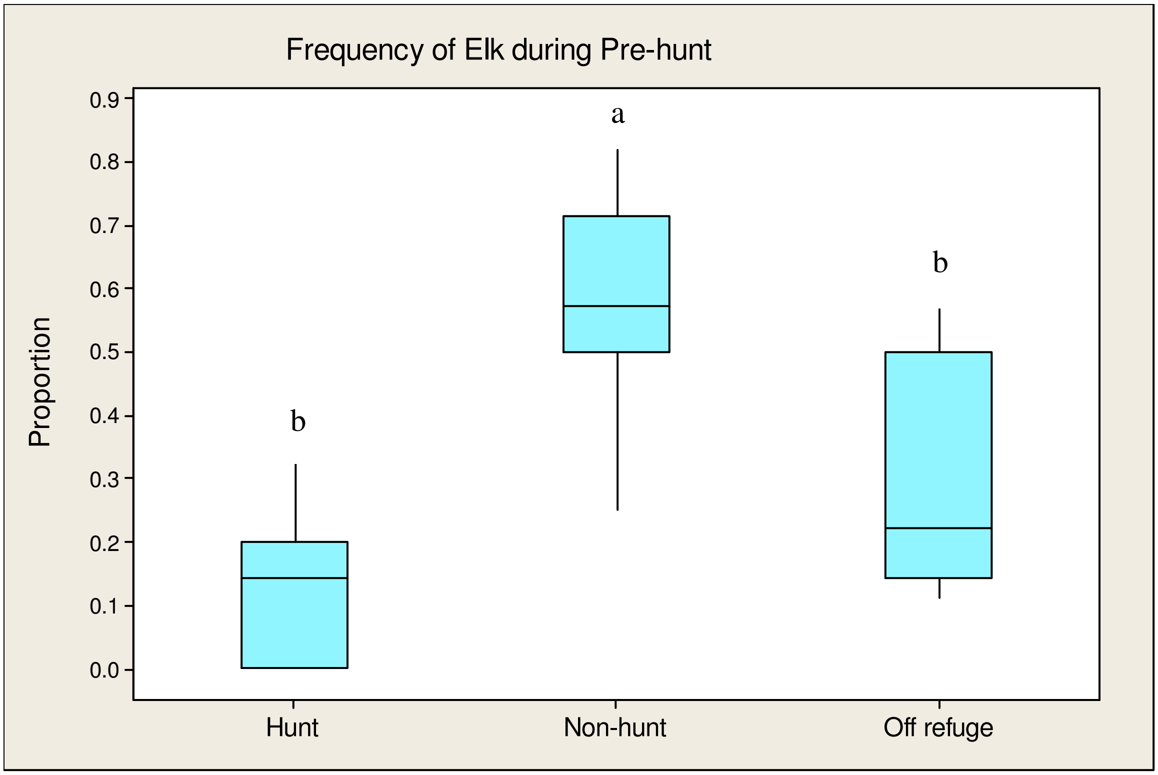

Figure 3: Proportion of elk found in each area of the refuge or off refuge during the pre-hunt time period (June-Sept-6). Frequencies are based on locations of 26 live elk. There are significant differences between variables with different letters ($p < 0.0008$).

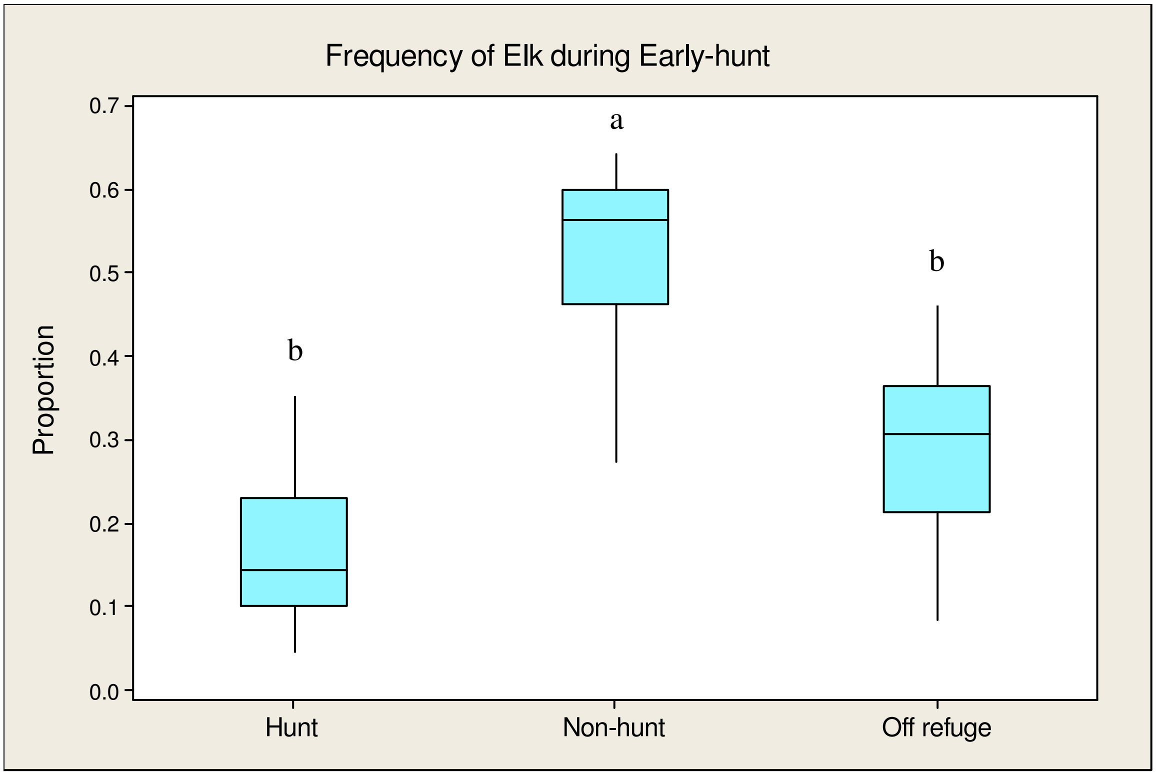

Figure 4: Proportion of elk found in each area of the refuge or off refuge during the early-hunt time period (Sept-6-Oct). Frequencies are based on locations of 25 live elk. There are significant differences between variables with different letters ($p < 0.0011$).

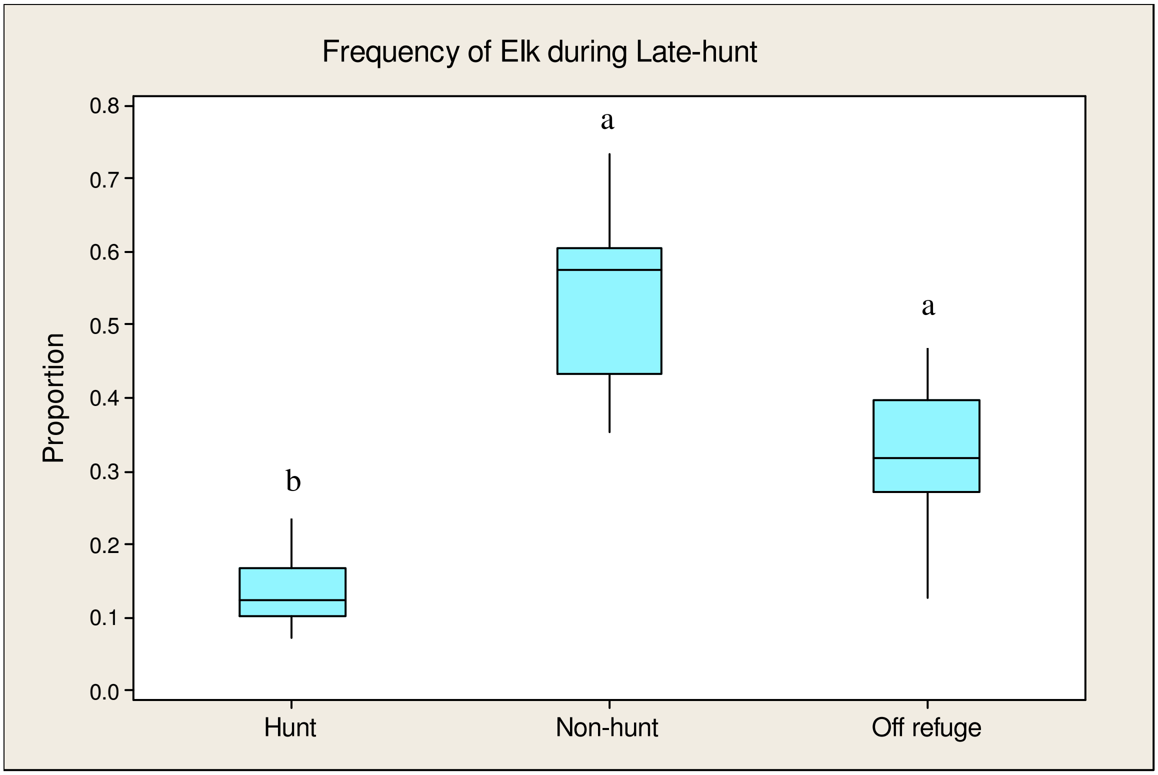

Figure 5: Proportion of elk found in each area of the refuge or off refuge during the late-hunt time period (Nov-Dec). Frequencies are based on locations of 23 live elk. There are significant differences between variables with different letters ($p < 0.0001$).

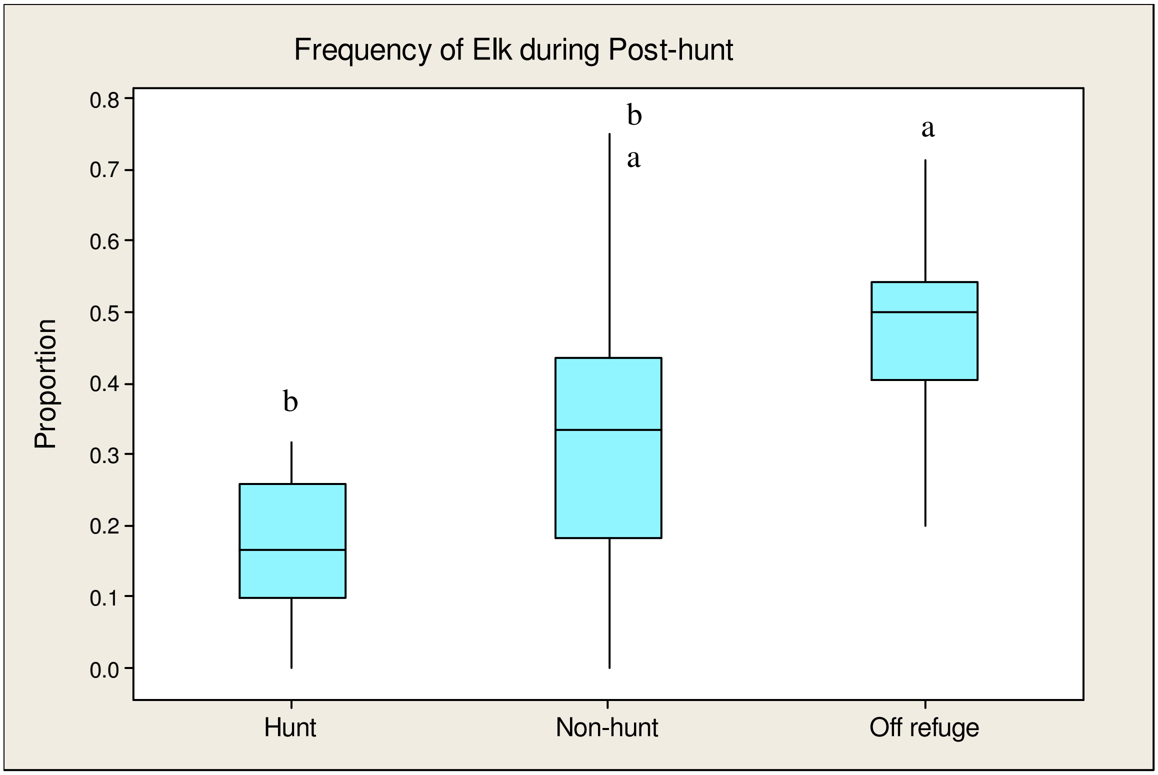

Figure 6: Proportion of elk found in each area of the refuge or off refuge during the post-hunt time period (Jan-March). Frequencies are based on locations of 21 live elk. There are significant differences between variables with different letters ($p = 0.0002$).

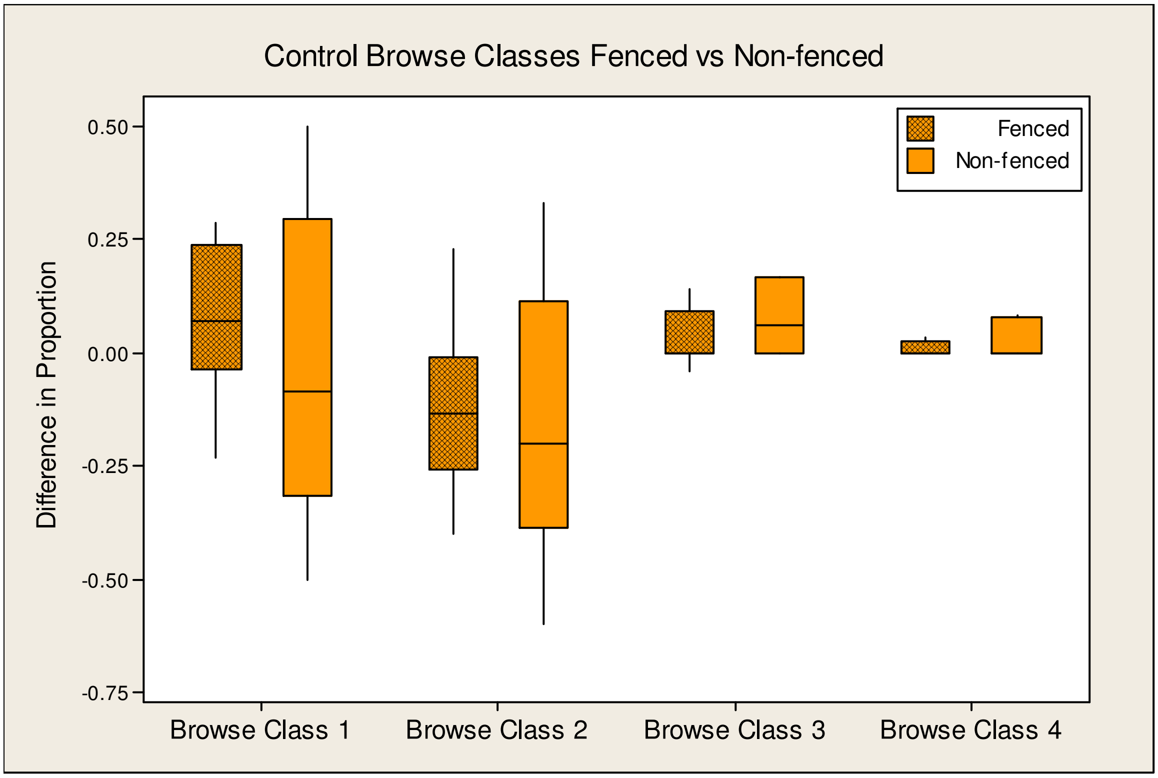

Figure 7: Changes in proportion of trees in control stands over the different browse classes. There are no significant differences between the fenced and non-fenced plots in control stands (n = 8).

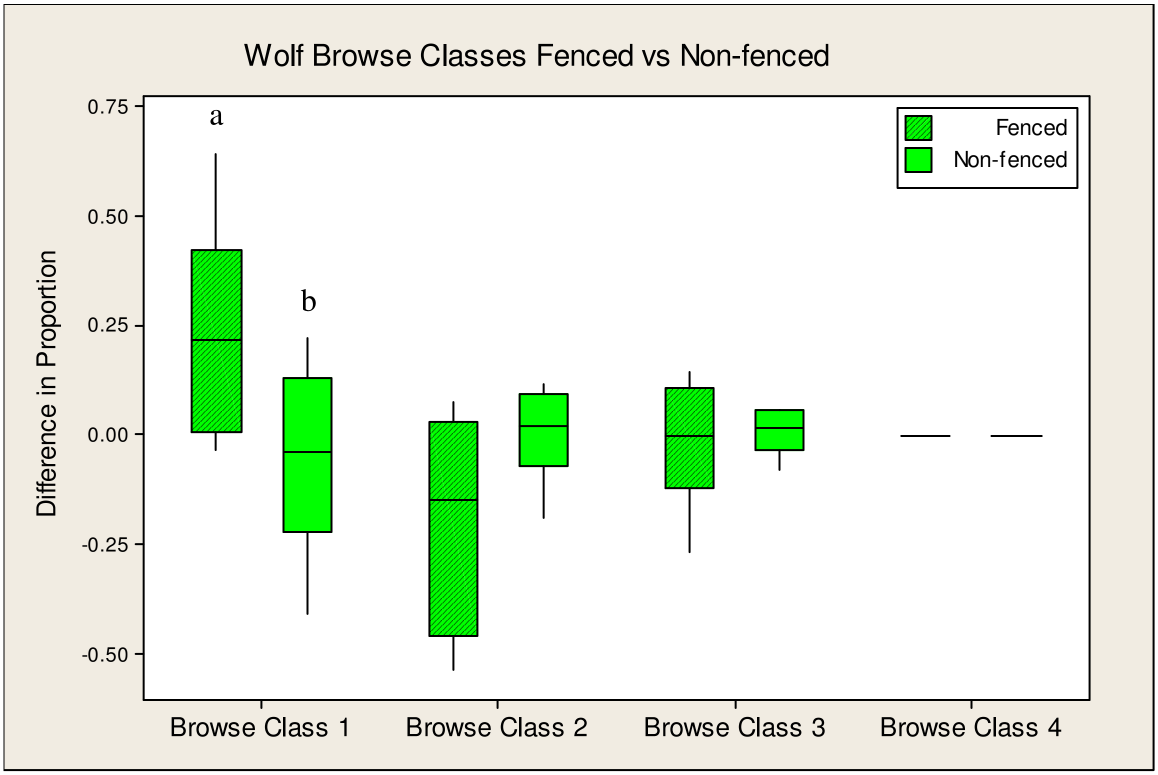

Figure 8: Changes in proportion of trees in wolf stands over the different browse classes. Significant differences are found between variables with different letters (n = 8, p = 0.02).

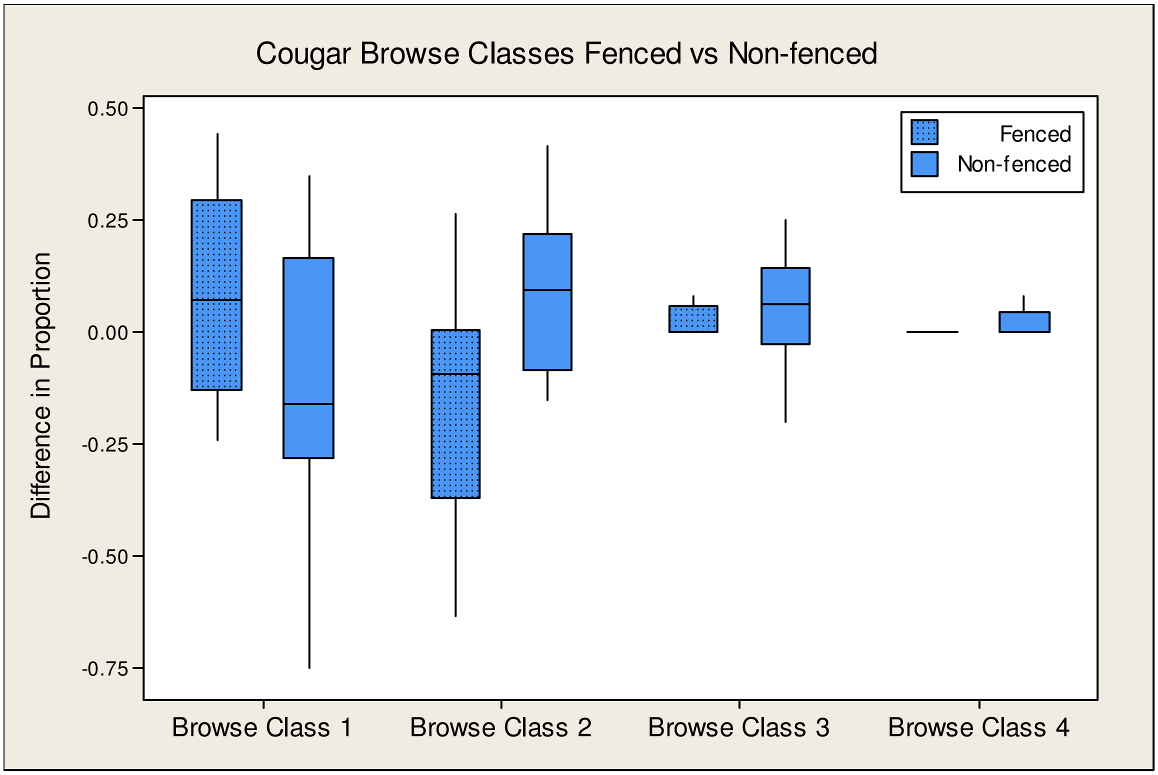

Figure 9: Changes in proportion of trees in cougar stands over the different browse classes. There are no significant differences between the fenced and non-fenced plots in cougar stands (n = 8).

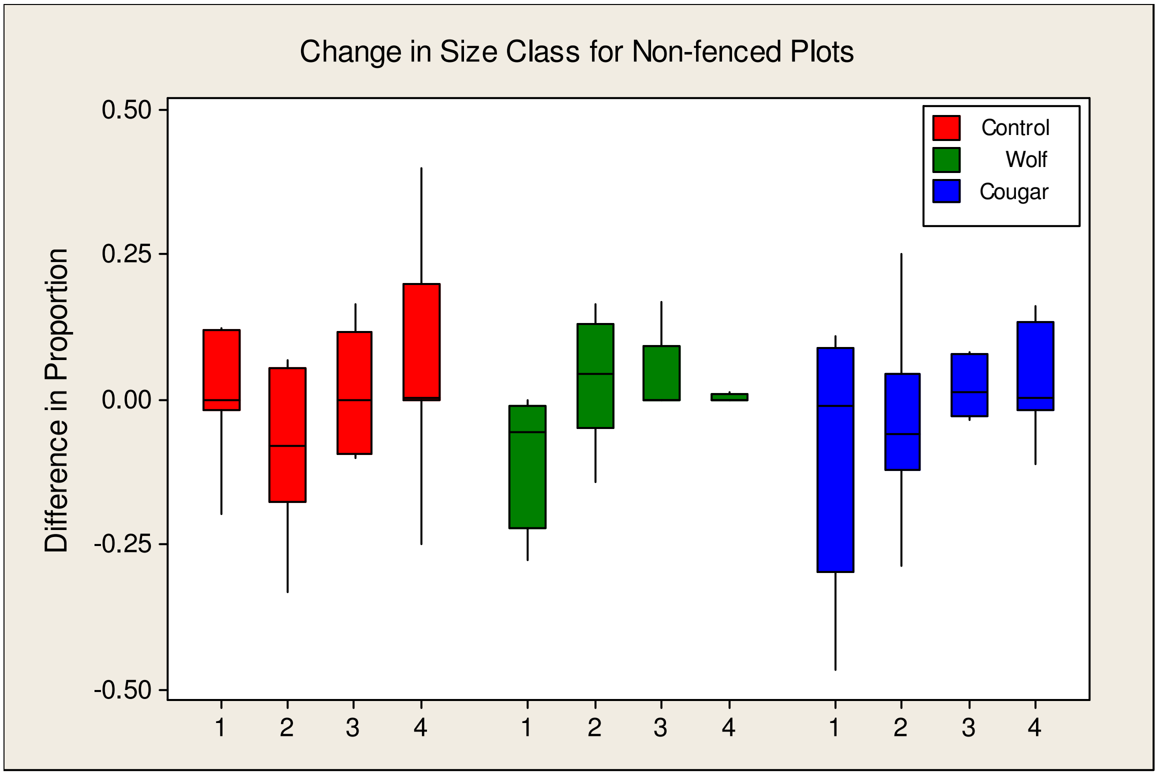

Figure 10: Changes in proportion of trees in non-fenced plots for each size class over different treatments. There are no significant differences between treatments (n = 8).

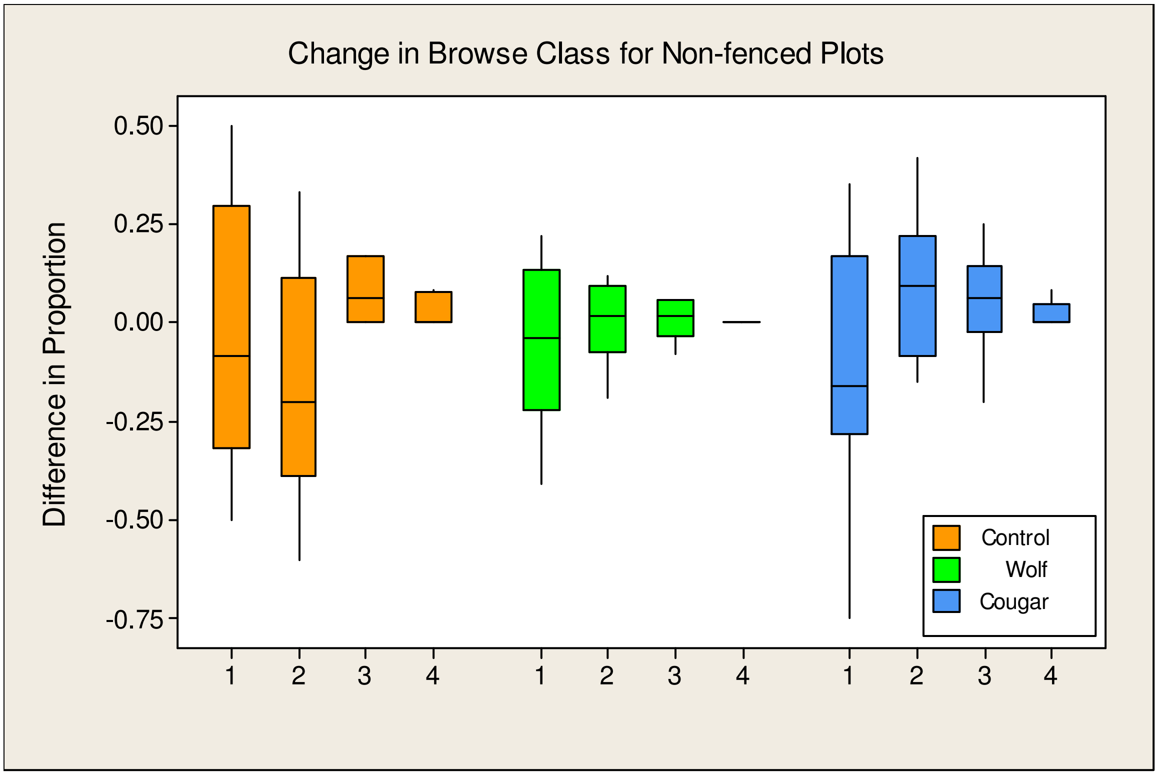

Figure 11: Changes in proportion of trees in non-fenced plots for each browse class over different treatments. There are no significant differences between treatments (n = 8).

VITA

Author: Savanah L. Walker

Place of Birth: Yakima, WA

Undergraduate Schools Attended: Central Washington University
Washington State University

Degrees Awarded: Bachelor of Science in Zoology, 2009, Washington State University

Honors and Awards: Graduate Assistantship, Biology Department, 2010-2011, Eastern Washington University

Graduated Magna Cum Laude, Washington State University, 2009