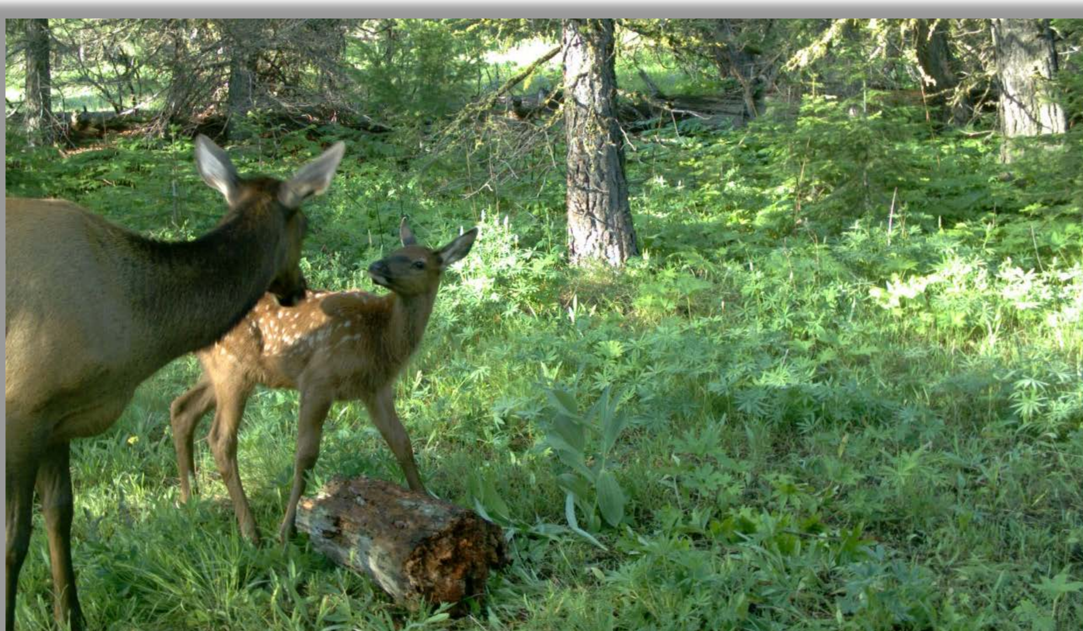
Blue Mountains Elk Herd: At-Risk Assessment

July 2021



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Introduction

The Washington Department of Fish and Wildlife (*hereafter* the Department) is instructed to identify "at-risk" ungulate herds as defined by their 2015-2021 Game Management Plan *(hereafter*, GMP) and assess limiting factors to identify potential management alternatives to aid rebuild the herd. The Blue Mountains elk herd is managed within ten percent of 5,500 (4,950-6,050) animals as described in the recently adopted (2020) Blue Mountains Elk herd plan (Fig. 1). Managers annually collect and review population abundance, demographic, and harvest data to adjust hunting opportunity to maintain the Blue Mountains elk herd within this objective. When populations are 25% or more below herd objective for two consecutive years, or if harvest decreases by 25% below the ten-year average for two consecutive years, then the population is considered "at-risk" (Washington Department of Fish and Wildlife 2015). This document will determine if the Blue Mountains elk herd should be designated as "at-risk", assess the viability of carnivore/ungulate management, and develop carnivore management alternatives.

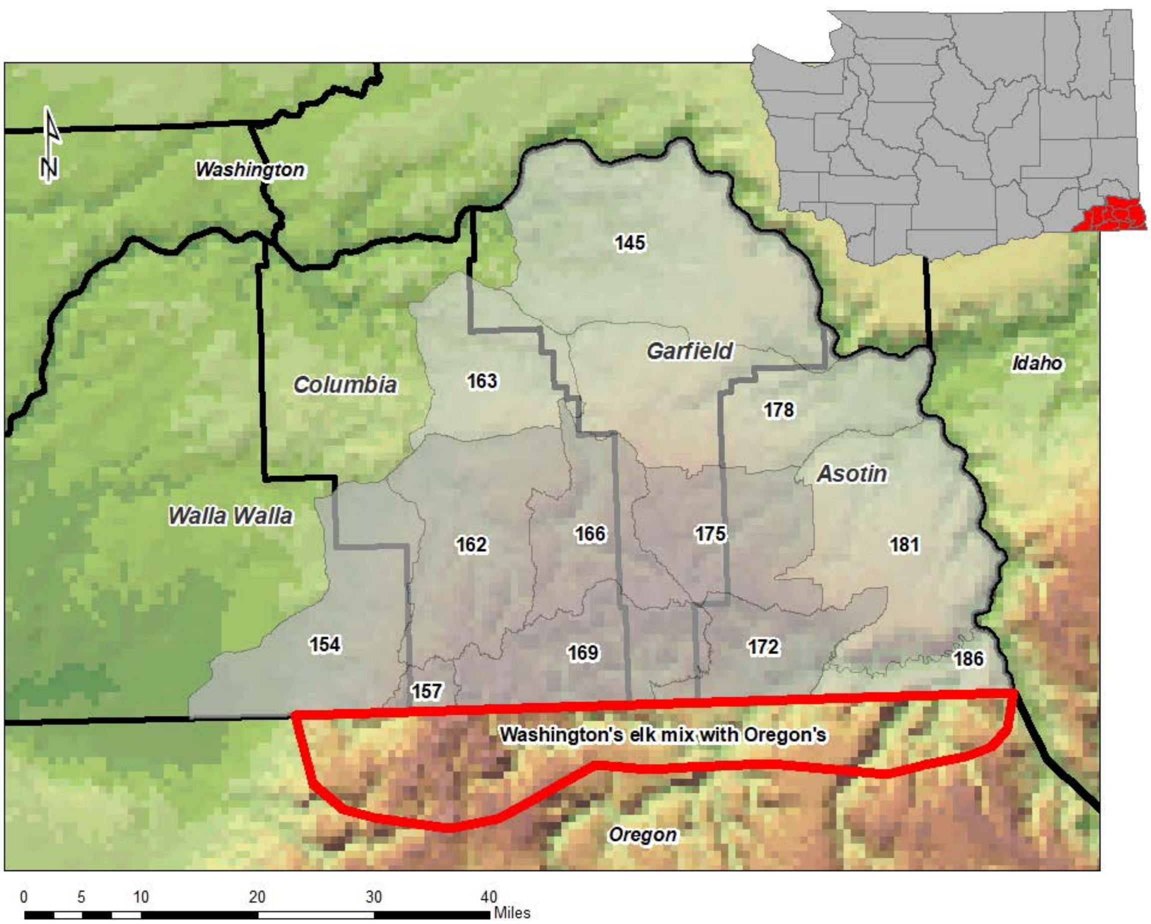


Figure 1. Blue Mountains Elk Herd with all Game Management Units (GMUs) identified and core GMUs highlighted in dark gray. Boundary of continuous habitat between Washington and Oregon illustrated within red polygon.

The Blue Mountains elk herd has a long history of annual population monitoring; therefore an "at-risk" designation will be determined from population estimates and not harvest metrics. The Department conducts aerial sightability corrected abundance estimates using a stratified random sampling design. Sightability models apply group-specific correction factors to observational count data to account for groups which were likely missed during the survey (McCorquodale et al. 2013). Correction covariates include group size, percent snow cover, and percent canopy cover (e.g., smaller groups in thick canopy cover are difficult to detect compared with large groups in the open). Sample units are classified a priori by expected density (high ≥ 86 elk, medium 36-85 elk, low < 36) and sampling allocation focuses on a greater proportion of the high-density units to be flown in comparison to medium or low (e.g., annual survey goals are to fly 100% of high, 80% of medium, 50% of low). In-flight covariate data are recorded to inform the abundance corrections and total abundance (including un-flown units) is estimated from flown units within stratum.

The elk population in the Blue Mountains is suited for sightability surveys, although variance and precision of annual population estimates are influenced by model assumptions and inherent methodological weaknesses. This elk herd ranges across 3,500 square miles (11 GMUs) and shares continuous habitat with Oregon on the herd's southern border. Elk move freely across this political boundary and although surveys are restricted by winter conditions, the population is not geographically and demographically closed between years. Immigration and emigration from Washington and Oregon occur and may affect annual population abundance estimates. Furthermore, snowpack and weather influence elk habitat selection, their distribution on the landscape and survey conditions. Such annual variation may alter local densities at the sampling unit scale resulting in unit misclassification (e.g., a unit expected to belong to the medium density stratum can, temporarily, become low or high density during the survey). The impact of misclassification on the total estimate can be compounded by the fact annual estimates are extrapolated from a fraction of the units in the low and medium strata that were flown in any given year.

Managers attempt to minimize sources of sampling error, but it is not uncommon for sightability models to have sampling uncertainty contribute largely to the variations in annual point estimates as illustrated by the associated 90% confidence intervals. This is a potential explanation for the population estimate fluctuation from 2020 to 2021. Given the shortfalls described above, data trends are more valued as compared to a single point estimate. Population trend with annual point estimates will be considered when evaluating "at-risk" status for the Blue Mountains elk herd.

The "at-risk" designation prompts the Department to perform an assessment in concert with the predator-prey guidelines outlined in the GMP. This includes providing evidence of predation as the principal limiting factor inhibiting the prey population from maintaining population objectives. Population dynamics occur in complex ecological systems involving many independent and interactive factors such as age specific vital rates (e.g., survival and reproduction), climate (e.g., severe drought or winter), bottom-up (e.g., nutrition, habitat), and top-down (e.g., predation and harvest) forces which vary depending on population densities and life stage (Proffitt et al. 2015). Johnson (2019) illustrates this entanglement with an example of climate influence on ungulate survival directly through exposure (e.g., hypothermia), or indirectly from increased vulnerability of prey to predation due to loss of mobility in deep snow (i.e., top-down), or by the varying amounts and timing of precipitation and temperature limiting nutritional resources (i.e., bottom-up).

Furthermore, mortality within the population due to a given factor does not necessarily provide evidence of it being additive or reducing the population's survival rate. One mortality factor may simply off-set another resulting in compensatory mortality with survival rates remaining unchanged. For example, an elk that succumbs to predation (a top-down factor) in the winter because of poor physical condition (a result of bottom-up food limitation) and reduced mobility in deep snow (an abiotic factor) would be considered a compensatory mortality. Under these circumstances, this mortality was likely to occur independent of the predation event, resulting in no change in the population's survival rate. Conversely, if the elk entered winter in adequate condition and was predated upon nonetheless, then this mortality would be considered additive as it is likely to reduce the survival rate of the population. Collecting data to determine additive versus compensatory mortality requires dedicated research with clear objectives over a timeframe of multiple years.

Large, multi-year research projects undertaken to disentangle the relative impacts of predation, habitat quality, and abiotic factors on ungulate population dynamics have frequently produced complicated, situation-specific results that limit their direct application to other predator-prey systems. Nonetheless, there is an expansive body of knowledge of elk population dynamics within the scientific literature and our "at-risk" assessment will rely on this work along with existing Blue Mountains survey estimates, harvest data, and research to inform the assessment.

Problem Statement

The Blue Mountains elk herd declined by approximately 20% from 2015 to 2017. The herd has been unable to reach desired population levels despite reductions of antlerless harvest to increase adult female survival and was estimated at 25% below its population management objective in 2019. The population trended modestly upward in 2020 to 4,614 with the abundance estimate being only 16% below objective, but the 2021 survey estimate of 3,600 was 35% below. Differences in abundance estimates from 2020 to 2021 are likely due to survey sampling variance as discussed in the introduction. Regardless, the Blue Mountains elk herd does not provide a consistent indication of reaching its potential and remains well below management objective (Fig. 2).

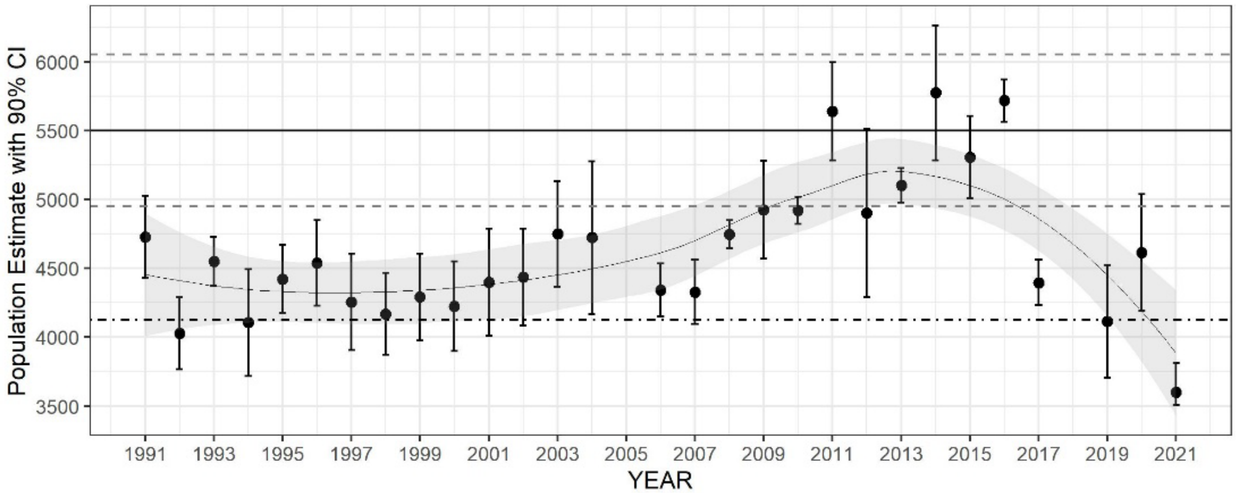


Figure 2. Blue Mountains elk herds population estimates with 90% confidence intervals and LOESS* smoothing derived from spring aerial surveys from 1991-2021. Line representations are, solid line equals herd population objective, dashed lines equal +/- 10% of objective and dot-dashed line equals 25% below objective or "at-risk" threshold. Aerial surveys were not conducted in 2005 and 2018.

*Locally estimated scatterplot smoothing (LOESS) is a common technique applied when fitting a curve to data. This process in similar to fitting a line to data using least squares regression but applies an iterative moving window to fit lines or polynomials across a weighted subset of data. This technique will generate a curve and confidence interval which best fits the given data. The LOESS function in R version 4.0.3 has been used for all plots illustrating LOESS which applies a polynomial to generate the smoothing line (gray curve) and 95% confidence interval (gray band). A demonstration of this technique can be viewed at: https://www.youtube.com/watch?v=Vf7oJ6z2LCc

While not explicitly identified as a management objective within the Blue Mountains Elk Herd Plan or assessment criteria in the GMP, persistently low numbers of juvenile elk surviving to one year of age (*hereafter* recruitment) since 2017 is a concern. Recruitment ratios (juveniles per 100 adult females) are not established objectives because they are inherently variable year to year, however, ratio data provides a useful index to managers on the potential for an elk population to grow, remain stable, or decline (Bender, 2006). Recruitment ratios observed from 2017-2021 were 22 (± 3.0) or 11% below the 30-year average of 24.7 (± 1.7) juveniles per one hundred adult females. Ratios of greater than 25-30 are generally required, dependent on adult female survival rates, to promote population growth. Therefore, population is not expected to reach its objective while recruitment remains at this level (Raithel et al. 2007; McCorquodale et al. 2011; Brodie, 2013; Hatter, 2020). We have not observed indications of rebounding and we expect a stable but below objective or declining population trend; therefore, the herd is considered "at-risk", and an assessment has been initiated.

This assessment reviews current literature and available data for each potential limiting factor independently and attempts to eliminate those which do not appear to be significant, narrowing focus to only those which may be inhibiting population growth. A brief overview, presentation of available data, and discussion will be presented for the following topics:

- Survival
- Carnivore Impacts
- Habitat Condition
- Human Use Impacts
- Climatic Impacts

The "at-risk" assessment provides documentation of the review of population limiting factors and proposed management action and monitoring to aid in rebuilding the Blue Mountains elk herd population. If carnivore management is adopted as a management strategy to aid elk reach management objectives, then management implementation will occur in the Fall of 2022 and the Department will continue for 2-4 years with continued monitoring of both elk and carnivore species to determine management effectiveness.

Survival

For long-lived species such as elk, adult female survival has the greatest impact on population dynamics (i.e., a force that stimulates change such as increasing or decreasing population size). For example, equivalent changes in other vital rates such as reproduction (i.e., fecundity) and recruitment will not have as large of an impact on population growth rates (i.e., change in population over a specific unit of time, often annual growth rate) as adult female survival (Morris & Doak 2002). Wildlife managers may influence population size by manipulating harvest of primarily adult female elk due to their greater impact on population dynamics relative to adult males (Morris & Doak 2002). Moreover, in a study of western elk populations, harvest was the only source of mortality that induced an absolute change in adult female survival (Brodie et al. 2013). Generally, harvest tends to target prime-aged females that have a high reproductive value and subsequently greater impact on population growth rates (Evans et al. 2006; Wright et al. 2006). Whereas predation mortality is often distributed across different age and sex classes that include less reproductively valuable individuals such as the young and old (Evans et al. 2006; Wright et al. 2006). In areas where the predator community is diverse, wildlife managers were inclined to reduce harvest of adult female elk to compensate for increased predator-caused mortality (Brodie et al. 2013). However, in areas where harvest is already minimal, reducing harvest will have little to no effect on populations that are experiencing additive mortality from predators.

While we recognize the potential for adult female survival to dramatically change population growth rates, this vital rate is generally robust in most elk populations (Gaillard et al. 2000; Raithel et al. 2007). Juvenile survival is highly variable and thus, survival of calves to one year of age often determines population trajectories (Gaillard et al. 2000; Raithel et al. 2007). Variability in juvenile survival is a combination of multiple factors that interact to cause annual fluctuations in juvenile mortality rates. Proximate cause of mortality of juvenile elk is predominantly predation (Griffin et al. 2011). However, climate and habitat may interact with predation to influence vulnerability of juveniles to predator-caused mortality (Griffin et al. 2011). So, while predation is implicated as the leading cause of mortality, climate and habitat may ultimately drive population dynamics (Brodie et al. 2013). This interaction among climate, habitat, and predation presents challenges to increasing juvenile survival with management strategies that only focus on a single source of mortality. Additionally, isolating each factor that affects juvenile survival requires long-term, intensive, and expensive research efforts. Without dedicated research to investigate the degree to which these factors interact and ultimately drive population dynamics, wildlife managers rely on indices such as calf-cow ratios rather than direct measures of juvenile survival and recruitment to identify populations that are at risk. Using calf-cow ratio data will only identify trends in population growth rates and are not useful for identifying specific drivers of those population trends.

Blue Mountains Elk Herd Survival

The severe winter of 2017 coincided with a reduction in the adult female population from a near high in 2016 (3,346) to a record low of 2,619 in 2017 which is well below the 30-year average of 3,071 (Figure 3). The population is continuing a downward trend and rebuilding the adult female population is essential to bring the Blue Mountains elk herd out of “at-risk” status. The two-essential components in achieving this goal involve reducing antlerless harvest to increase prime-aged adult female survival and increasing recruitment.

Given the severe winter conditions of 2017, adult female population reduction was not consistent throughout the core Blue Mountains elk GMUs (154, 157, 162, 166, 169, 172, 175 *hereafter* core GMUs: Fig. 1). Interestingly, some core GMUs (154, 172) retained much of the adult female population despite winter severity (described under climate) being consistent throughout the herd’s range. Based on survey results, all other GMUs experienced declines in cow numbers, in addition to declines in calf to cow ratios (Fig. 4).

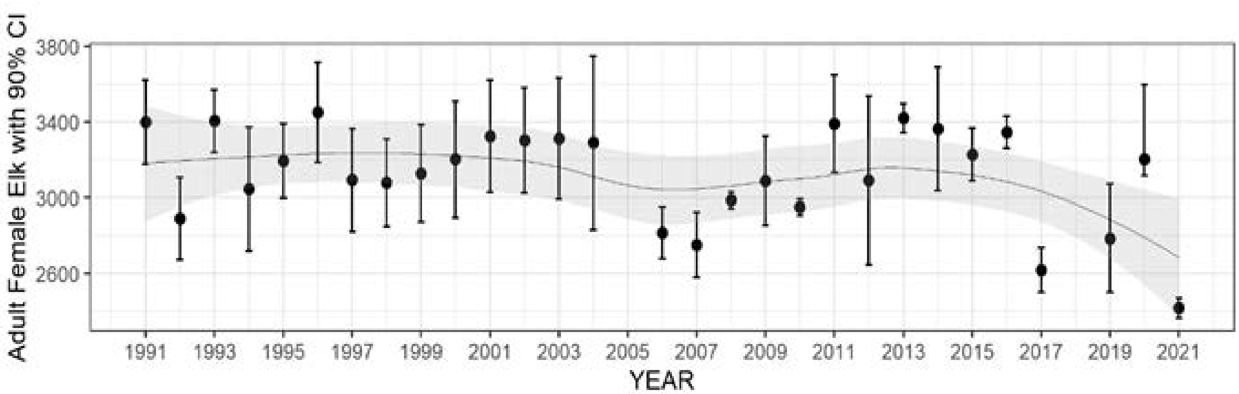


Figure 3. Adult female elk population with 90% confidence intervals and LOESS smoothing derived from spring aerial surveys from 1991-2021. Aerial surveys were not conducted in 2005 and 2018.

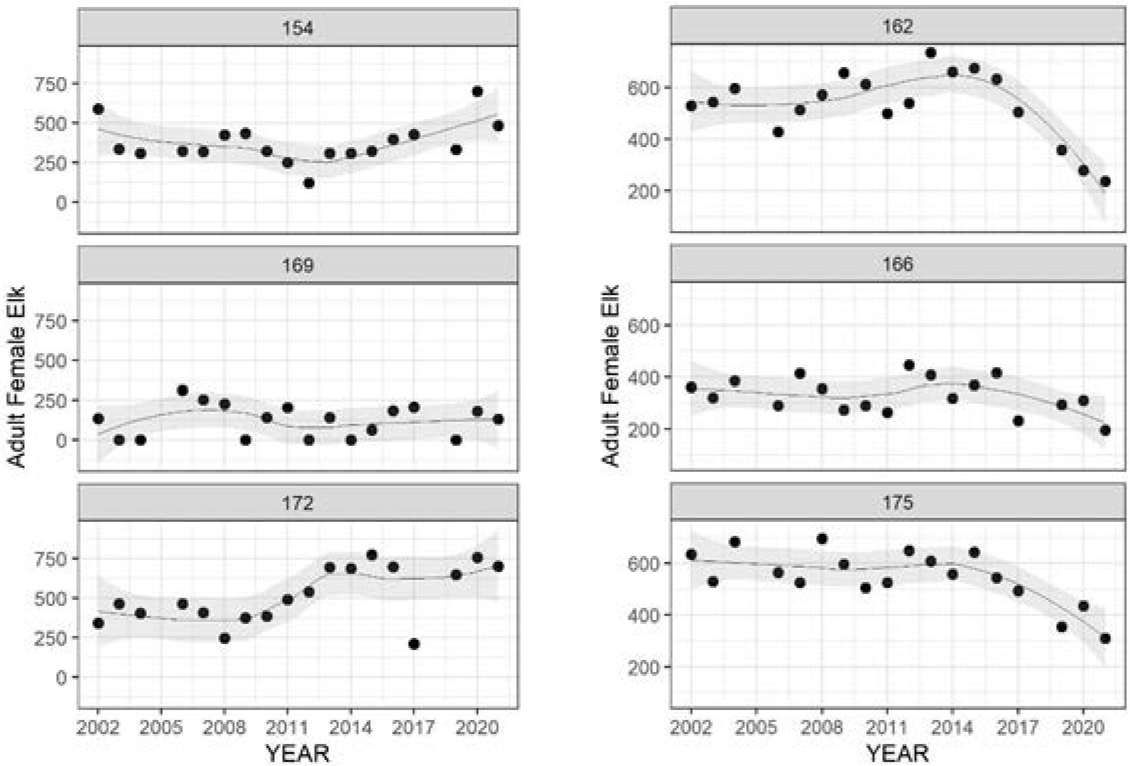


Figure 4. GMU specific adult female elk point estimates illustrating population trend using LOESS smoothing derived from spring aerial surveys from 1991-2021. Left panel depicts GMUs with increasing or stable populations since 2017. Right panel depicts GMUs with decreasing populations since 2017. Aerial surveys were not conducted in 2005 and 2018. The low value in GMU 172, 2017, was due to 442 animals being unclassified, resulting in a much lower count of adult female elk.

The Department has attempted to maintain and increase adult female population levels by reducing annual recreational and damage antlerless harvest. Initially, recreational antlerless permit reductions were conservative with 10% in 2017 (220 permits) but annual incremental decreases continued and by 2020 permits were reduced by 75% (61 permits) when compared to 2016 (244 permits) within the core Blue Mountains elk GMUs. All general season archery antlerless opportunity was removed from the core GMUs in 2018.

Damage permits allow for antlerless-only harvest and is regulated by Washington Administrative Code 220-440-200 (hereafter WAC 220). Damage harvest is not as flexible to management manipulation when compared to recreational harvest since it involves the variability of elk use resulting in damage to commercial crops and the social tolerance of the landowner. Once crop damage occurs, the Department and the landowner negotiate compensation which may result in antlerless permits or monetary reimbursements. The ability for the Department to completely remove antlerless harvest due to damage is not a viable option, but attempts can be made to reduce the level of damage permits issued. Damage harvest was controlled by the Department's Enforcement Program until 2011 when it was transitioned to the Wildlife Program's Conflict Section, therefore harvest record systems were not consistent until 2011.

The Nez Perce and Confederated Tribes of the Umatilla Indian Reservation (*hereafter* CTUIR) exercise their treaty hunting rights on all public lands within the Blue Mountains. Reporting of their harvest activity is not required, and data is not collected by tribal governments. The Department conducted radio-collared survival research from 1990-1995 and 2003-2006 and findings from both efforts suggests tribal harvest of adult females is relatively low. Although, it has been suggested harvest has increased over the last 3-5 years, but this cannot be quantified or verified. (WDFW, 2001; McCorquodale et al. 2011, personal communication, Paul Wik, WDFW).

The Department's antlerless harvest (recreational and damage) has decreased to its lowest levels in 20-years with the last three years being 58% less than the 2000-2016 average. (Fig. 5). Antlerless harvest that remains has been predominately in GMU 154, with minimal levels in GMUs 162, 172 and 175 and no harvest in GMUs 157, 166 and 169 (Fig. 6). Most harvest in GMU 154 occurs south of Mill Creek adjacent to the border with Oregon. In this area, a large group of elk (approximately 400), cause regular crop damage and move between states depending upon pressure. The reduction of elk numbers in this small area is still a priority for both states.

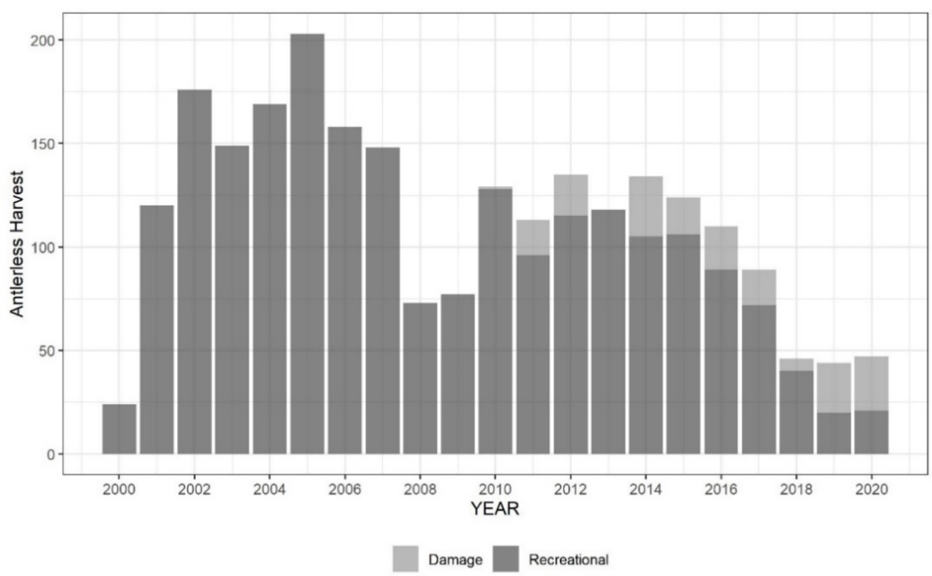


Figure 5. The Department's recreational and damage core GMU antlerless elk harvest from 2000 to 2020. Estimates of damage harvest are only available for 2011-2020.

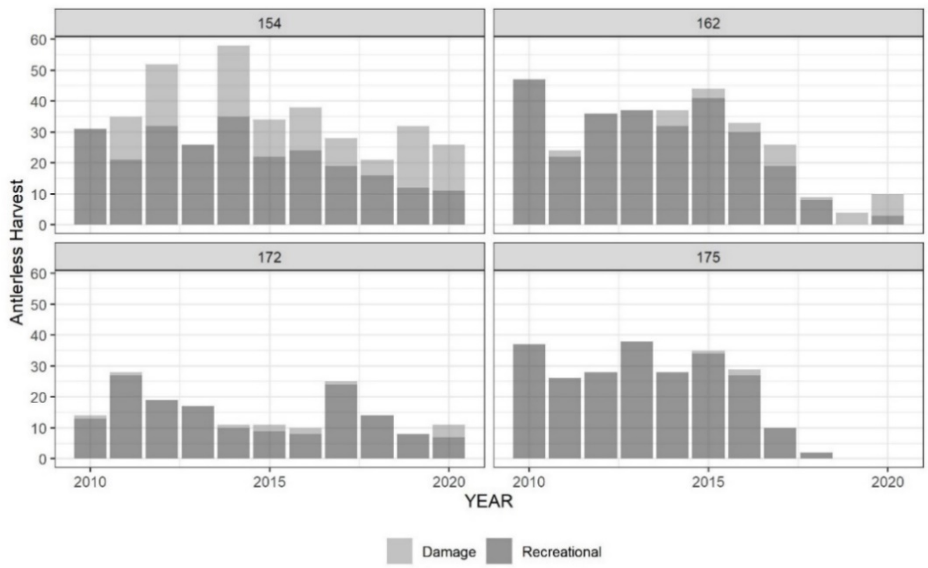


Figure 6. The Department's antlerless elk harvest by GMU from 2010 to 2020. Core GMUs not represented had zero harvest during this period.

The Department does not have current estimates of adult female or juvenile survival, with the most recent documentation occurring during 2003-2006 and 1993-1997, respectively. Adult sample sizes were small (n=39) but estimates of annual survival rates for prime-aged females was 0.81 (0.70 – 0.88) (McCorquodale et al. 2011). This estimate is comparable to other hunted populations with survival of adult females estimated at 0.85 (+/- 0.005) across several western U. S. populations. Moreover, Brodie (2013) established survival estimates when hunting harvest is removed but predation by cougar and wolves remains, as is the situation in the Blue Mountains, and survival rates increased to 0.934 (+/- 0.006). Myer (1999) observed an average annual juvenile survival rate of 0.47 when monitoring 240 calves between 1993 to 1997 (range .41 to .55). These values are typical with ranges of 0.17 to 0.57 being reported (Johnson et al. 2019, Barber-Meyer et al. 2008).

The Department is attempting to promote population growth by reducing recreational and damage antlerless harvest throughout the core GMU's where possible. Although, juvenile recruitment that exceeds adult female mortality is necessary to influence population growth (Raithel et al. 2007). McCorquodale (2011) and Brodie (2013) have provided informed estimates of adult female survival, which will aid in our understanding of recruitment rates required to rebuild this population. The original Hatter and Bergerud recruitment-mortality equation provides a method to illustrate these dynamics (Hatter, 2020). Where in this example, lambda will equal the female population growth rate with values of 1 representing population stability, and less than or greater than 1 illustrating population reduction or growth, respectively. For this exercise, M represents adult female mortality rates and R equals recruitment represented as a ratio (e.g., 30 juveniles/100 adult females = .30) multiplied by 0.5 to account for a 50:50 sex ratio.

$$\lambda = (1 - M)/(1 - R)$$

The Blue Mountains still maintains some antlerless elk harvest through the Department recreation and damage permits as well as unknown levels of Tribal harvest, therefore it should not be considered an unharvested population. Given the adult female survival bounds suggested by Brodie (2013), the slightly lower estimate provided by McCorquodale (2011), and reduced but continued antlerless harvest by the Department, CTUIR and the Nez Perce Tribe, an estimate of current adult female survival of 0.87-0.88 would be a reasonable approximation. If adult female survival is near these levels (e.g., 0.12-0.13 adult female mortality) then stability would be achieved if juvenile recruitment were at 25 juveniles per 100 adult females assuming a 50:50 sex ratio. Recruitment of approximately 12-13 female juveniles per 100 adults annually will compensate for the losses in the adult female population. The true survival rate is unknown, but this exercise creates a benchmark of 25 juveniles per 100 adult females as population stability. Increases or decreases from the benchmark should translate to population growth or reduction and provide an understanding of the requirements necessary for rebuilding this herd.

The Blue Mountains adult female population has remained relatively stable and generally above 3000 animals between 1991 to 2016, after which a decreasing trend began in 2017 that has been difficult to reverse despite significant reductions in antlerless harvest (Fig. 3-6). Recruitment has averaged 24.7 juveniles to 100 adult females over the last 30 years, and significant gains will be difficult to achieve with recruitment at this level (Fig. 7). These data are consistent with research documented in Lukas (2018) which evaluated changes in elk recruitment across 7 states and 3 ecotypes between 1989-2010. They found recruitment in northern mountain ecotypes, which include Washington, Oregon, Idaho, and Montana, to be the lowest across the western United States with an average of 30.8, while also documenting the lowest ratio of 25.1 in Washington.

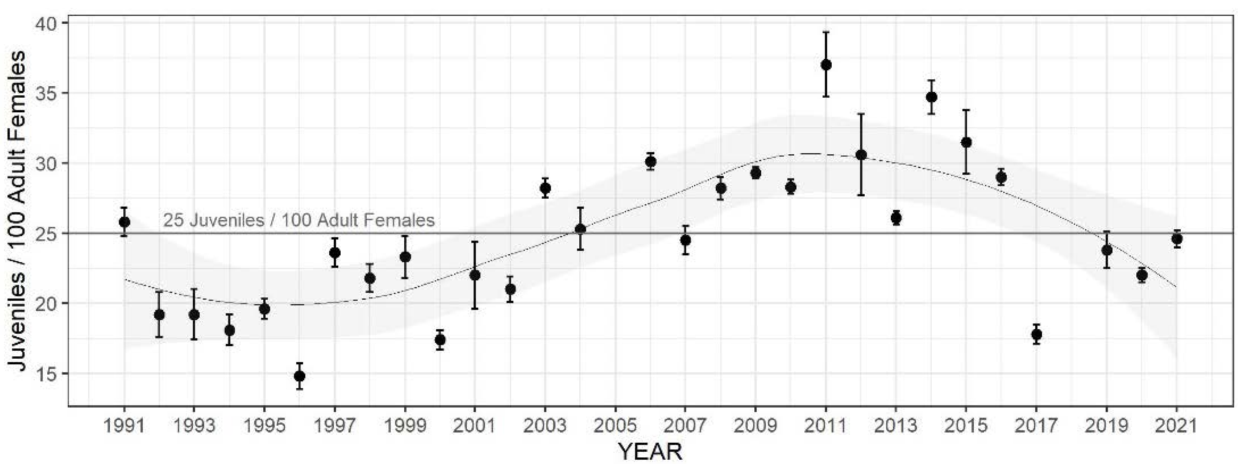
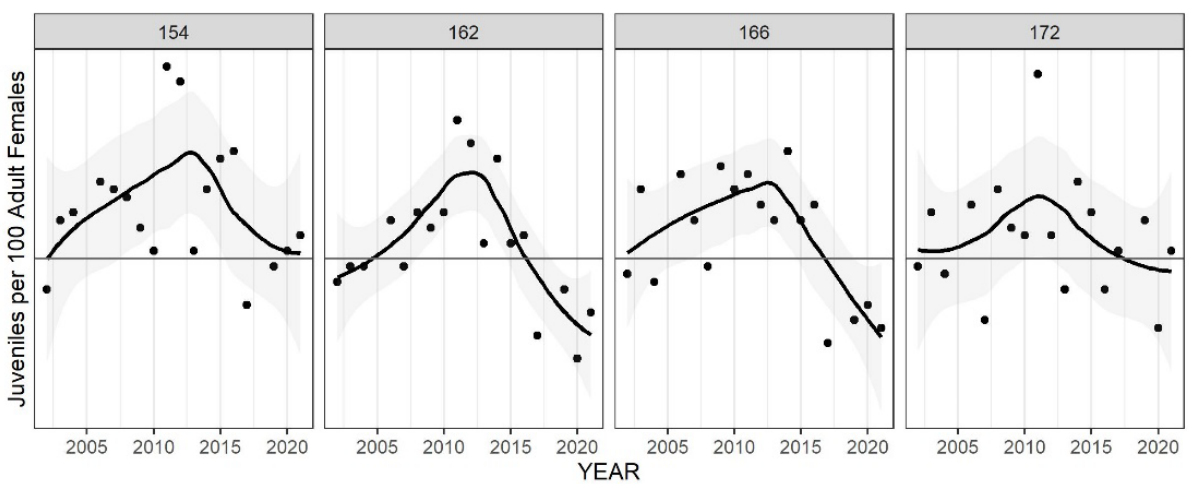


Figure 7. Recruitment ratios with 90% confidence intervals and LOESS smoothing derived from March aerial surveys from 1991-2021. Gray horizontal line represents recruitment required to maintain adult female population stability (25 juveniles per 100 adult females) if survival rates are held near 0.87-0.88

The Blue Mountains 30-year herd wide average of 24.7 juveniles per 100 adult females provides an example of the long-term potential for recruitment. Moreover, herd wide recruitment rates during the last five years are within this range, but consistency is not observed across all core

GMUs. Two core GMUs are well below the 30-year average with GMUs 162 and 166 averaging 16.5 juveniles per 100 adult females from 2017-2021, with a range from 12-21 and 14-19, respectively. During this time other GMUs have remained near maintenance levels with 154 and 172 averaging 24.3 and 24.5 with a range of 19-28 and 16-30, respectively (Fig. 8). Furthermore, the adult female component within these GMUs have substantially different population trends with GMUs 162 and 172 illustrating the most divergence (Fig. 9). These data indicate some portions of the Blue Mountains elk herd are maintaining stability or growth while other GMUs are declining (Table 1).

Since 2017, attempts to increase adult female survival and overall population by reducing antlerless harvest has shown mixed success throughout the core GMUs. As suggested by our benchmark of adult female population stability, those GMUs with recruitment averages of 24-25 since 2017 with one year greater than 28 have stable or increasing populations (Table 1, Max Recruitment). Conversely, GMUs below the benchmark recruitment average have adult female populations which illustrate a declining trend. In response to these declines, GMUs 162, 166, and 175 have minimal or no Department antlerless harvest to potentially increase adult female survival. Continued management actions to support population recovery should focus on these specific GMUs and include alternatives which attempt to reduce mortality of prime-aged females and promote recruitment.



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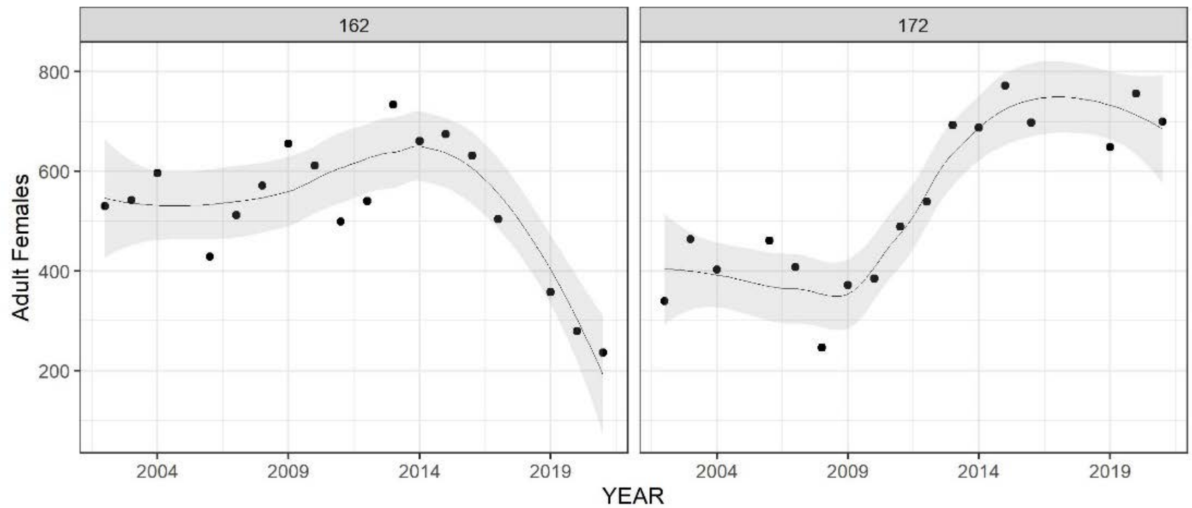

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Table 1. Blue Mountains core GMU recruitment rates and adult female population trends from 2017 to 2021.

GMU	Avg. Recruitment	Min. Recruitment	Max Recruit	Adult Female Pop. Trend
154	24.3	19	28	Increasing
157	23.0	15	28	*Stable, BPL
162**	16.5	12	21	Declining
166**	16.5	14	19	Declining
169	25.0	15	34	Stable
172	24.5	16	30	Stable
175**	22.3	17	27	Declining

*SBPL = Stable, Below Previous (2017) Levels; ** GMUs with declining adult female population

Since 2017, attempts to increase adult female survival and overall population by reducing antlerless harvest has shown mixed success throughout the core GMUs. As suggested by our benchmark of adult female population stability, those GMUs with recruitment averages of 24-25 since 2017 with one year greater than 28 have stable or increasing populations (Table 1, Max Recruitment). Conversely, GMUs below the benchmark recruitment average have adult female populations which illustrate a declining trend. In response to these declines, GMUs 162, 166, and 175 have minimal or no Department antlerless harvest to potentially increase adult female survival. Continued management actions to support population growth should focus on these specific GMUs and include alternatives which attempt to reduce mortality of prime-aged females and promote recruitment.

Carnivores

The effects of predation on elk populations in western North America are complex, dynamic, and frequently debated (Griffin et al. 2011; Brodie et al. 2013; Lukacs et al. 2018). Predation can be a proximate limiting or regulating factor for many elk populations but assessing the effects of predation can be difficult because factors acting on the population rarely act independent of each other (Hebblewhite et al. 2002; Garrott et al. 2008; Horne et al. 2019; Proffitt et al. 2020). For example, increased snow depth can increase elk vulnerability to gray wolf (*Canis lupus*) predation during winter months (Garrott et al. 2003, Hebblewhite et al. 2005). Predation effects on elk populations are commonly a function of elk population size relative to habitat quality and predation rate (Messier 1994). Predation on elk typically occurs within juvenile and neonate classes (Linnell et al. 1995, Griffin et al. 2011), but risks to adults can increase with increased winter precipitation and severity and increased carnivore species diversity or density (Garrott et al. 2005; Barbara-Meyer et al. 2008; Garrott et al. 2009; Brodie et al. 2013; Johnson et al. 2013). Gray wolves, black bears, cougars, and grizzly bears (*Ursus arctos horribilis*) are the principal predators of elk in western North American and the Blue Mountains are currently inhabited by wolves, black bears, and cougars. Each species employs a different strategy for hunting elk and this in turn creates a spatio-temporal mosaic of risk and the potential for disparate impacts on various elk sex and age classes (Kohl et al. 2019).

Blue Mountains Carnivores

Wolves likely began recolonizing the Washington portion of the Blue Mountains in 2012 and 2013 with the first pack confirmed in 2014. Currently, four packs – Butte Creek, Grouse Flats, Touchet, and Tucannon, comprised of at least 22 individuals' range across core elk GMUs in Washington (WDFW et al. 2021; Figure 10). The number of packs has been stable since 2018, but the wolf population has steadily increased since recolonization (Figure 11). The majority of wolves (n =13) are affiliated with the Touchet pack that primarily occupies GMU 162, but also portions of GMU 154, 157, 166, and 169 while also ranging south into Oregon. The remaining wolves are distributed approximately equally among the remaining wolf packs and core elk GMUs 166, 169, 172, and 175, although there is no pack estimate for the Butte Creek pack within the Wenaha-Tucannon Wilderness (WDFW et al. 2021, Figure 10). Wolves are currently listed as State Endangered, so recreational harvest is prohibited. To date, management removals have been limited to a single female from the Grouse Flats pack in 2019.

Wolves are social, coursing predators that are best suited to hunt elk in open, gentle terrain over an extended chase (Kunkel e al. 1999, Husseman et al. 2003). The effects of wolf predation on elk populations have received considerable attention in recent years with demonstrated impacts largely occurring during winter months and range from minor (Vucetich et al. 2005; Barbara-Meyer et al. 2008; White et al. 2010; Eacker et al. 2016) to significant (Hebblewhite et al. 2002; Garrott et al. 2008; Horne et al. 2019). The potential for impacts on elk stemming from recent growth in the Blue Mountains wolf population, warrants additional investigation. However, wolf population growth alone is not sufficient evidence to demonstrate limitation and there is no information, historic or current, on the impacts of wolves on the Blue Mountains elk herd.

Black bears are present throughout forested habitats within the Blue Mountains. The GMUs occupied by the Blue Mountain elk herd are located within WDFW's identified Black Bear Management Unit (BBMU) #8. Estimates of black bear population size or density are currently unavailable for this area, but density may increase along an east-to-west gradient reflecting the effects of increased precipitation on habitat quality (Welfelt et al. 2019).

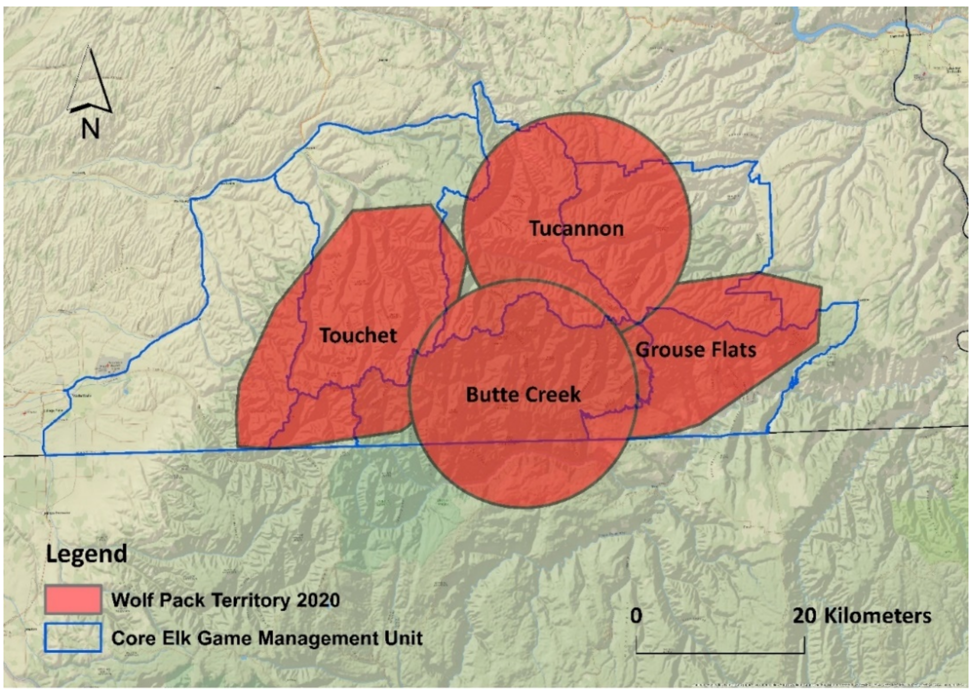

Figure 10. Wolf pack territories in the Washington portion of the Blue Mountains in 2020. Irregular shapes are minimum convex polygons derived from GPS collar data while circles represent proximate territories for uncollared packs.

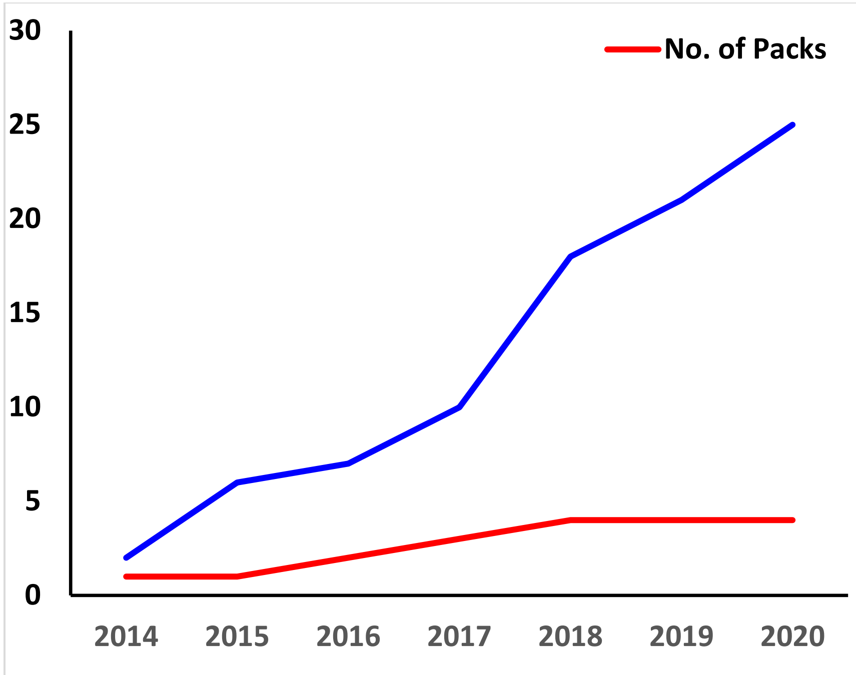

Figure 11. Minimum number of wolf packs and individuals present in the Blue Mountains of Washington, 2014-2020.

A regulated black bear general hunting season in the fall has been in place since the 1930's. In 1980, the season dates were shortened to August through October except in areas of the Blue Mountains which started in early September. In 1997, season dates were extended from August through mid-November statewide and the big game package (a group of hunting licenses offered at a reduced rate) was established, increasing the number of black bear licenses sold from 11,000 to approximately 60,000 statewide. In 2000, fall season dates were reduced in the Blue Mountains from September through mid-November. That remained in place until 2019 when the fall hunting season was extended by 30 days to include August and the bag limit was increased from 1 to 2 throughout eastern Washington.

A spring special permit black bear hunting season was initiated in the Blue Mountains in 1999 with 70 permits issued, the first spring hunting season in Washington since the 1970s. The number of spring special hunting permits gradually increased to 100 in 2002 and to 155 in 2007 where it remained through 2010. Spring permits numbers were relatively stable 2011-2019 with 115-119 permits and increased to 158 in 2020.

Black bear mortality in the Blue Mountains from hunter harvest reports for spring (special permit) and fall (general season) hunting seasons averaged 99 (sd ± 18.76) bears annually, 2002-2020. Spring permit harvest has remained relatively consistent throughout the timeframe, whereas fall general season harvest has fluctuated, peaking in 2002, and exhibiting cyclical highs and lows since that time and through 2020 (Figure 12). Tribal harvest of bears in the Blue Mountains elk herd area remains unknown.

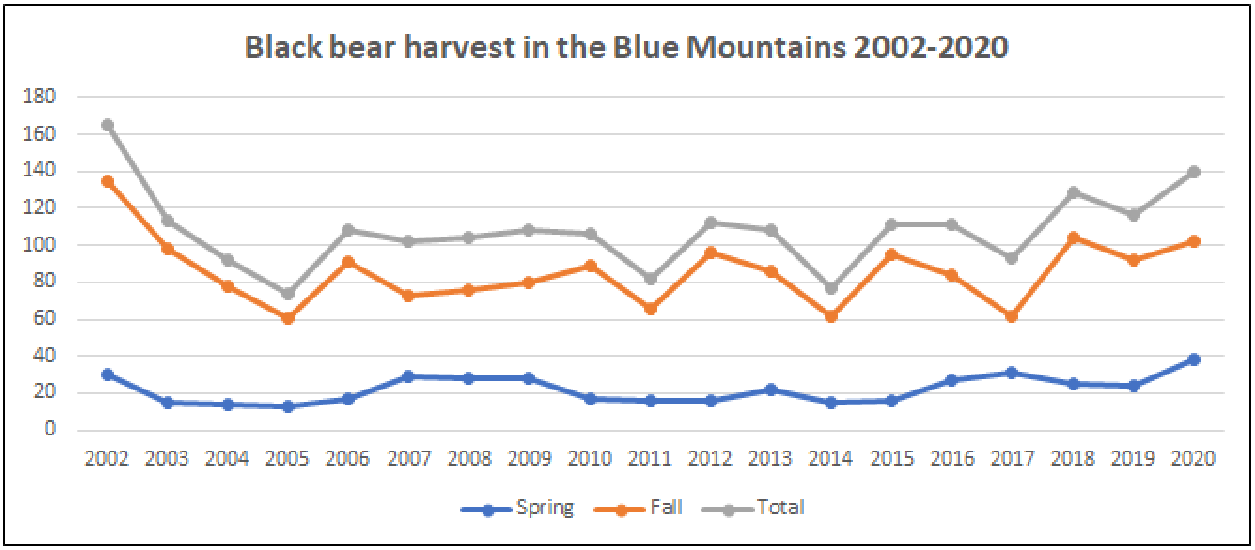

Figure 12. Annual spring (blue), fall (orange), and total (grey) black bear harvest in the Blue Mountains, 2002-2020.

Harvest density (i.e., total harvest compared to the available primary black bear habitat; Scheick and McCown 2014) in the Blue Mountains is variable between GMU's, but collectively this BBMU has the highest harvest density in Washington when compared to other BBMUs. At 15.1 (sd ± 3.45) bear harvests/100 km^2, harvest density in GMU 154 is 3 times as high as it is for GMU 162 at 5.3 (sd ± 1.59) bear harvests/100 km^2, which is the second highest in the Blue Mountains (Figure 13 & 14). Harvest density is not simply a proxy for bear density as it is affected by numerous factors including bear density, access, and hunting pressure; each of which is likely to contribute differently depending on the area. No current estimates of black bear density are available for the Blue Mountains (monitoring is occurring summer 2021). Bear habitat in the Blue Mountains is estimated at 2,791 km^2. A recent 4- year estimate of density on the east slope of the North Cascade mountains produced an average density of 19 bears/100km^2 (Welfelt et al. 2019). A recent survey in Northeastern Washington resulted in a density estimate of 31 bears/100km^2. While extrapolating these densities to the Blue Mountains may be helpful, it would be more appropriate to use data from the current density survey being implemented this year.

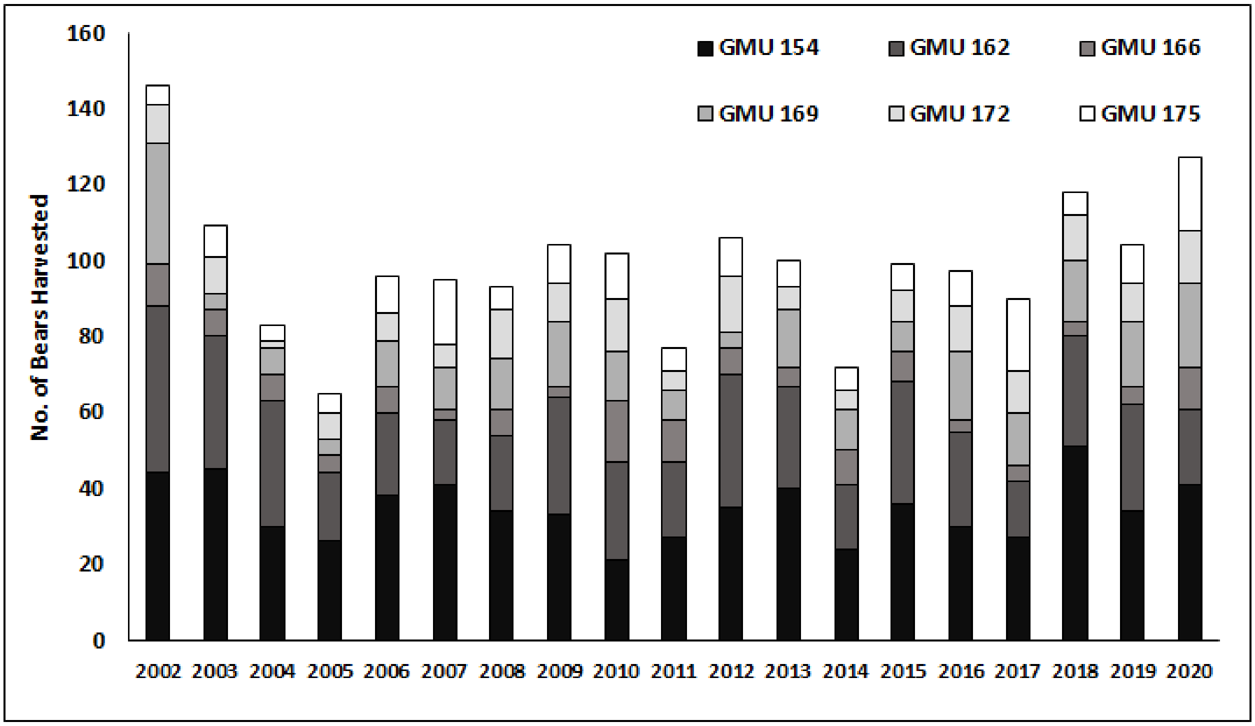

Figure 13. Annual black bear harvest in core elk Game Management Units (GMU) of the Blue Mountains, 2002-2020.

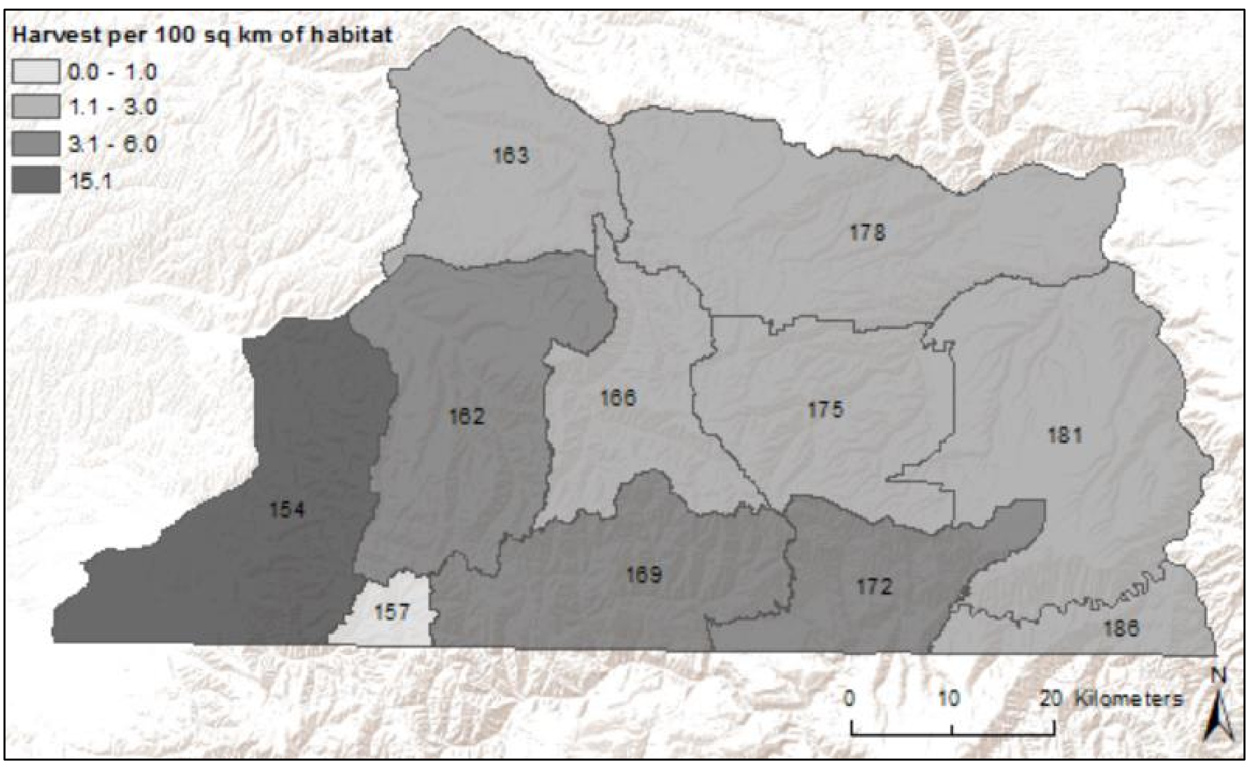

Figure 14. Harvest density of black bears within Game Management Units (GMU) of the Blue Mountains, 2002-2019; bear harvest was not permitted in GMU 157.

Black bear predation is largely opportunistic and generally limited to juvenile elk during a 28-day period immediately following parturition (White et al. 2010). The effects of black bear predation on vital rates vary both in their significance and spatial distribution (Griffin et al. 2011, Lukacs et al. 2018). For example, black bear predation had a relatively minor impact on elk calf recruitment in western Montana (Eacker et al. 2016, Forzley 2019), but black bears were the primary proximate cause of mortality in a nearby study in Idaho (White et al. 2010). Previous investigations of cause-specific mortality of juvenile elk in the Blue Mountains attributed 16% (Myers et al. 1999) and 14% (Johnson et al. 2019) of deaths to black bears with Johnson et al. (2019) concluding that black bear predation was largely compensatory. The significance of black bear predation can increase in the presence of wolves (Griffin et al. 2011) and may be of greater consequence now compared to previous investigations. However, the potential of high harvest rates for black bears and the lack of predator-prey research following wolf recolonization means the current impacts of black bear predation on juvenile elk in the Blue Mountains are unknown.

Cougars are present throughout forested, riparian, steep, and rocky habitats in the Blue Mountains with seasonal distributions closely aligned with their ungulate prey base. Previous research in both Washington and Oregon portions of the Blues provide reliable density estimates for various segments of the cougar population. Specifically, Beausoleil et al. (2021) used live-captures and population reconstruction to generate annual densities of independent-aged animals (i.e., ≥ 18 months of age) in GMU 162 (Dayton) and 166 (Tucannon) between 2009 and 2013 that ranged from 2.35 – 3.07 cougars/100 km^2 (Table 2). Working within the Sled Springs and Wenaha Wildlife Management Areas of Oregon, Johnson et al. (2019) used live-captures and population reconstruction to generate annual densities of adult cougars and subadult females > 12 months old between 2002 and 2007. Oregon densities ranged from a low of 2.25 cougars/100 km^2 in the Wenaha in 2005 to a high of 4.29 cougars/100 km^2 in Sled Springs in 2006 and 2007 (Table 2). Key differences in methodologies (e.g., different segments of the population quantified, proportional vs. threshold contributions of individuals) prevent the direct comparison of Washington and Oregon estimates, but similar physiographic characteristics, prey communities, and geographic proximity suggest the total density of cougars within study areas are unlikely to differ significantly.

Table 2. Annual density estimates (cougars/100 km^2) for Washington and Oregon portions of the Blue Mountains. Estimates represent different segments of the cougar population and were derived using different methodologies.

	Density (cougars/100 km^2)										
Study Area	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2009**	**2010**	**2011**	**2012**	**2013**
Tucannon[a] (WA)							2.99	3.07	3.06	2.48	2.35
Sled Springs[b] (OR)	2.53	2.53	3.28	3.79	4.29	4.29					
Wenaha[b] (OR)	4.16	3.64	3.12	2.25	2.77	3.12					

[a] Densities of independent-aged animals (≥ 18 months of age) derived using live-captures and population reconstruction with proportional contributions for all known individuals present in the study area (Beausoleil et al. 2021).

[b] Densities of adult cougars and subadult females ≥ 12 months of age derived using live captures and population reconstruction for all known individuals with > than 50% of their 95% kernel home range estimate overlapping the study area (Johnson et al. 2019).

The length of the cougar hunting season in the Blue Mountains, fluctuated between 60 and 70 days from 1977 through 1996 with the use of hounds. In 1997 season dates were extended from August through mid-March statewide (227 days). From 2009 to the 2011-12 season, the cougar hunting dates were reduced from September through March (212 days) and weapon restrictions were put in place (i.e., archery only in September). In 2012-13 seasons were structured into an early season (Sept 01 – 31 December with no harvest guideline) and Late season (January 01-March 31 with harvest guidelines). In 2015, the late season was increased through April (242 days) where it remains through today.

Cougar mortality in the Blue Mountains from mandatory inspections averaged 17 cougars annually, 2002-2020. Cougar harvest has increased under the contemporary hunting structure when compared to previous management. Hunting seasons from the 2002-03 through the 2011-12 seasons were managed by season dates with no harvest limit. Currently, hunting is managed by season dates and harvest guidelines within three Population Management Units (PMUs; each made up of 4-6 GMUs) and closed on January 1 if the harvest guideline has been reached. Harvest from 2002-03 through 2011-12 averaged 12 cougars annually, and 22 annually from 2012-13 through 2020-21, an 83% increase.

In the Blue Mountains, mortality rates regularly exceeded the 12-16% harvest guideline, primarily in the PMU with GMUs 154 and 162 (Figures 15-17). Over the past 9 seasons (since 2012), this PMU exceeded the guideline 7 times. The PMU containing GMUs 166 and 175 exceeded the harvest guideline 5 times, while harvest rates below 12% were observed in 3 seasons. The PMU containing GMUs 169 and 172 exceeded harvest guidelines 2 times, below a 12% harvest rate in 3 seasons, and within the 12-16% guideline in 4 seasons (Figure 15). It is worth noting that the PMU containing GMUs 154 and 162 has exceeded the harvest guideline more drastically than the other 2 PMUs, averaging a 32% harvest rate, more than double the prescribed rate over the past 9 seasons.

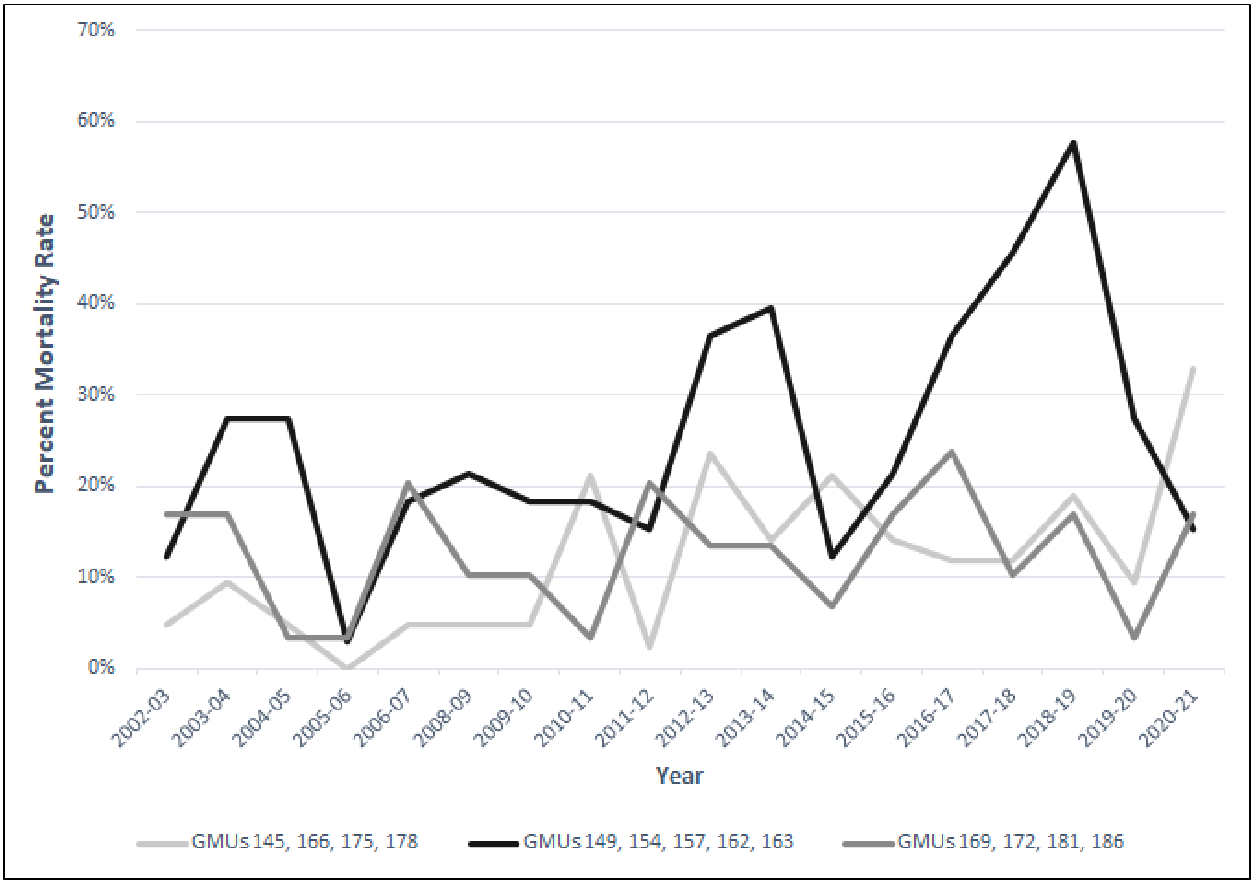

Figure 15. Estimated cougar mortality rates by PMU for the Blue Mountains, 2002-2020.

Cougars employ a stalk and pounce hunting strategy when targeting elk in densely vegetated, rugged, or structurally complex terrain (Seidensticker et al. 1973). The effects of cougar predation on elk survival and population growth have received less attention from researchers than those of wolves and bears, but recent investigations suggest impacts, particularly on elk calf survival, can exceed those of sympatric carnivores (Horne et al. 2019, Proffitt et al. 2020). Within the Blue Mountains, cougar impacts also manifest primarily as predation on juvenile elk (Myers et al. 1999, Johnson et al. 2019) and Clark et al. (2014) documented strong seasonal and demographic patterns of cougar predation on elk driven primarily by the selection of juveniles by both sexes during the summer and males during the winter. The extent to which cougar predation is limiting elk populations in the Blue Mountains is not clear, but previous investigations of the roles of top-down, bottom-up, and abiotic factors on elk in the Oregon portion of the Blue Mountains indicated the population was primarily limited by cougar predation, albeit in concert with nutritional limitations that strongly influenced juvenile survival (Clark 2014, Johnson et al. 2019). This previous work suggests cougars may be limiting elk population growth following the severe winter of 2016-2017 but increases in both cougar harvest and overall mortality since 2012 are likely reducing the impacts of cougar predation on elk throughout the Blue Mountains and within some core elk GMUs with poor recruitment (e.g., GMU 162).

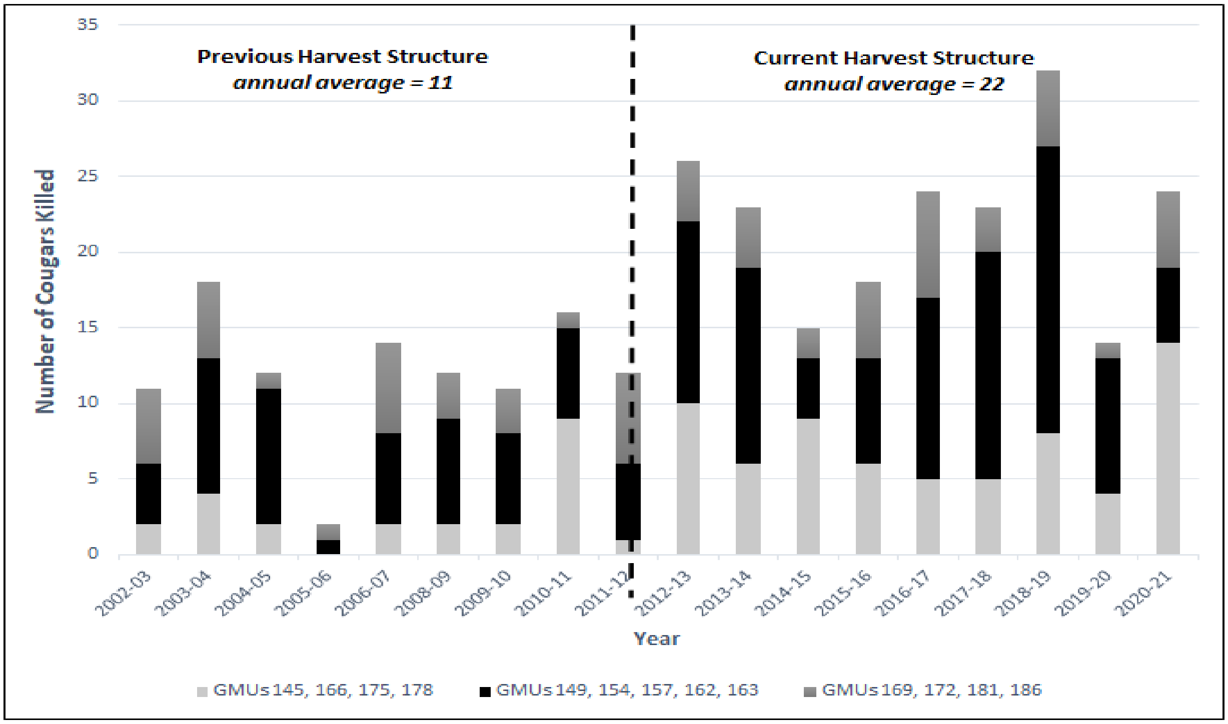

Figure 16. Estimated cougar mortality rates by PMU for the Blue Mountains, 2002-2020. The dark grey dashed vertical line represents the harvest management of early (without guidelines) and late (with guidelines) season structure.

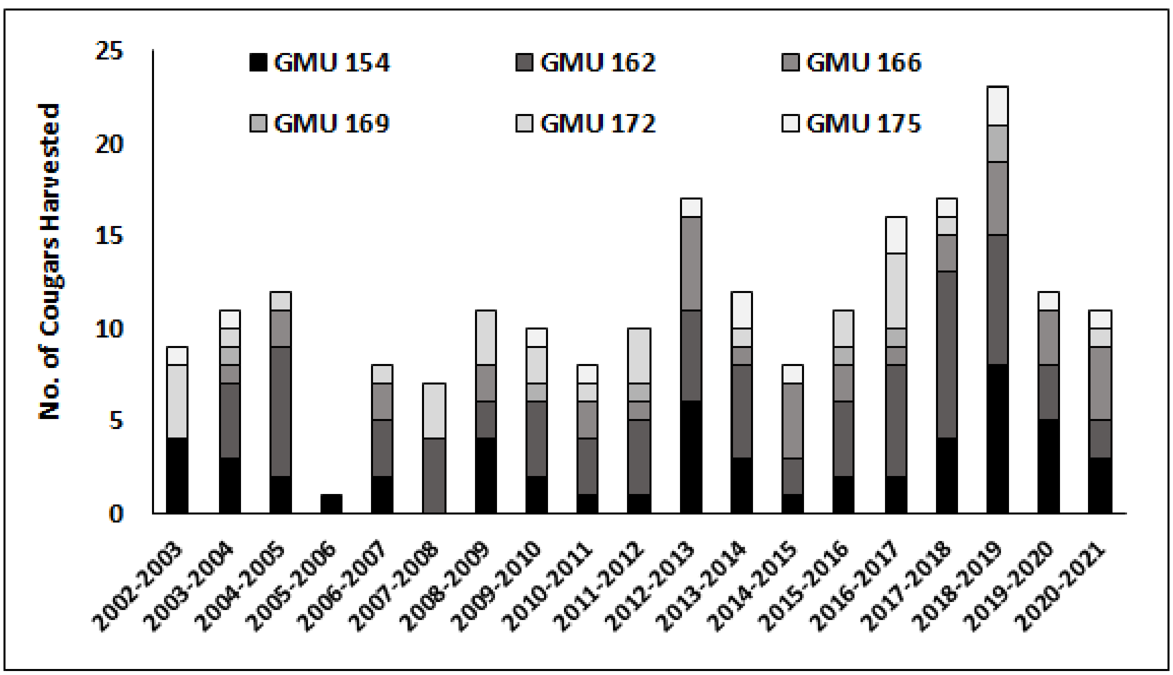

Figure 17. Annual cougar harvest within core elk Game Management Units (GMU) of the Blue Mountains, 2002-2020.

The effect of harvest on the cougar population in the Blue Mountains has not been monitored since population estimation efforts ended in 2013. As such, it is unknown what effect increased harvest has had on cougar densities. If we assume the average cougar density derived from the 5-year project in the Tucannon (2.79 cougars/100 km^2) is representative of current cougar densities across the Blue Mountains and immigration rates have not offset harvest mortality, then it is possible that cougar populations have declined. Comparing current harvest levels to the number of removals in west-central Montana that resulted in a 29% cougar population decline (Proffitt et al. 2020), similarly indicates a potential decline. Nonetheless, without directly monitoring cougars, we are unable to definitively state what, if any, effect increased harvest has had.

While each carnivore species present in the Blue Mountains has a demonstrated ability to impact elk survival and affect elk population growth, the impacts of individual species and predation are typically mediated or mitigated by summer precipitation, winter severity, carnivore community richness, and human harvest (Griffin et al. 2011; Brodie et al. 2013; Lukacs et al. 2018). This complex interplay combined with the recent recolonization of the Blue Mountains by gray wolves and the completion of previous cougar research efforts creates additional uncertainty for wildlife managers. The addition of wolves in a predator-prey community does not universally increase predation rates for elk (Griffin et al. 2011), but often results in important changes to spatial, temporal, and demographic patterns of predation (Kohl et al. 2019). Consequently, changes in the population size or density of individual carnivore species may not translate into proportional changes in elk population size or juvenile recruitment (Garrott et al. 2005).

Elk Habitat Condition

Habitat is generally considered the mechanism that regulates ungulate populations from the bottom-up, as opposed to top-down regulation by predation and hunting. Elk population performance is a function of forage quantity and quality that mediate bottom-up forces. Habitats, especially on summer range that provide high-quality and abundant forage can prevent reduced pregnancy rates, delayed breeding, and reduced overwinter survival in elk (Cook et al. 2004, 2013). Forest management practices can improve habitats to meet or exceed basic nutritional requirements, and elk are capable of finding the most nutritious forage in response to environmental change (Morrison et al. 2020). Natural and human-caused disturbances such as fire and timber harvest generally transition forests back to early or mid-seral stages providing abundant palatable forage for elk. Elk generally increase their use of recently burned areas within their home range to take advantage of the abundant new forage (Biggs et al. 2010). However, elk distribution may vary depending on fire type (e.g., wild vs. prescribed burns), terrain, and forest cover types burned (Proffitt et al. 2019). Additionally, after a fire, ecological succession (i.e., forest recovery) dictates elk use spatially and temporarily (Proffitt et al. 2019). Thus, elk distribution and productivity are dynamic, and population management must adapt to changes in landscapes over time.

While areas burned by wildfire annually have increased in the United States (Dennison et al. 2014), timber harvest on public lands has declined (U.S. Department of Agriculture, Forest Service 2016). Timber harvest can provide many benefits to elk by promoting growth of early-seral vegetation and creating forest-edge. Conversely, timber harvest increases human disturbance associated with timber management activities and elk vulnerability to hunter harvest with increased road accessibility (Wisdom et al. 2004) and increased sight distances. Increased road access and declining early seral vegetation on public lands have shifted elk use to privately-owned lands with fewer disturbances and food resources in the form of crops (Conner et al. 2001, Proffitt et al. 2010). In turn, elk use of agricultural lands increases conflict with people due to increases in crop-damage and food competition with livestock (Heydlauff et al. 2006). To mitigate these issues, managers benefit from examining the availability and quality of habitats across landscapes owned and managed by different entities and how those habitats affect elk distribution. Shifts in elk distribution and utilization of different landscapes in response to land management activities do not always reflect equal changes to individual fitness and population performance (Wisdom et al. 2004). Therefore, understanding how the use of different habitats affects elk survival and productivity is essential for managers.

Blue Mountains Habitat Conditions

Elk habitat within the Blue Mountains has experienced substantial changes over the past 20-years from wildfire, prescribed fire, noxious weed invasions and treatments, and forest management activities (Table 3). In the past 20 years, wildfires have affected the largest amount of acreage, with the majority being associated with the School Complex fire that predominately occurred in GMU 166 (2005) and the Columbia Complex fire that predominately occurred in GMUs 162 and 166 (2006). Collectively, these two wildfires accounted for more than 100,000 acres being burned. It is unknown to what extent the School and Columbia Complex fires benefited elk, but it is unlikely these events are benefitting the Blue Mountains elk herd today. Profitt (2019) found that in Montana, fire affected summer more than winter forage and benefits peaked 6-15 years post fire in dry forests, and 5 years post fire in mesic forests. Similarly, Spitz et al. (2018) reported in northeast Oregon that the probability of elk using habitats altered by prescribed fire peaked 5 years post burn and returned to pre-treatment levels after 15 years.

Table 3. USFS management activities by acre and GMU (2000-2020). Wildfire acreage is across all ownerships at the GMU scale. Private land forest management activities are not available.

	GMU 162	GMU 166	GMU 172	GMU 175
Total GMU Acres	134,400	83,840	69,120	101,120
Prescribed Fire	4,694	5,545	5,453	15,572
Commercial Thin	483	226	0	1,128
Precommercial	807	1,213	198	5,915
Salvage Cut	474	2,945	202	1,326
Harvest	313	1,496	4	4,271
Wildfire	73,191	64,439	1,950	8,474
Percent of GMU	59.4%	90.4%	11.3%	36.3%

The Umatilla National Forest (UNF) actively manages portions of the National Forest lands to generate economic opportunity and maintain healthy forests. Within the Washington portion of the UNF, most of this activity in the past 20 years has occurred in GMU 175. During this time, forestry practices shifted from clear-cuts being the predominant harvesting method to thinning. The current goals for USFS are to manage for the Historical Range of Variation on the landscape, which focuses on healthy forests and species, and structural compositions that were present prior to fire suppression efforts beginning in the early portion of the 20th century.

Managed forests change the canopy coverage, which affects forage growth within the stand. Cook et al. (2013) found that digestible energy intake decreased significantly when canopy coverage exceeded 60%, resulting in a nutritional landscape that can reduce the lactation and body fat condition of female elk during late summer and early fall. We examined canopy coverage trends from 2001-2016 (Landfire.com) in GMUs 162, 166, and 175 as surrogate for late-summer, early-fall nutrition (Figure 18). Tree canopy coverage from 20-50% has generally increased across the 3 GMUs, which could indicate an increase in the availability of forage over time.

Rangelands are lands dominated by grasses, grass-like plants, forbs, and sometimes shrubs or dispersed trees. Existing plant communities may include both native and introduced plants. Management of rangeland occurs primarily through indirect processes, rather than direct agronomic applications. Rangeland habitats can consist of one or several ecological systems. Rangelands comprise more than 600,000 acres, or about 27% of the entire land cover in the Blue Mountains elk herd area (Figure 19). Much of this rangeland contributes little to the support of Blue Mountains elk, because it is well outside the core use areas. However, when rangeland is within the winter range of elk, it plays an important part in the distribution of some sub-populations (Wisdom & Thomas, 1996). While only 15% (90,500 acres) of the total rangeland in the Blue Mountains Herd area is publicly or tribally owned, most (66%) of this rangeland occurs within important elk use areas. The USFS rangeland is a minor component within forested lands, whereas the Department-owned wildlife areas can be classified as rangelands with interspersion of trees, especially along riparian areas.

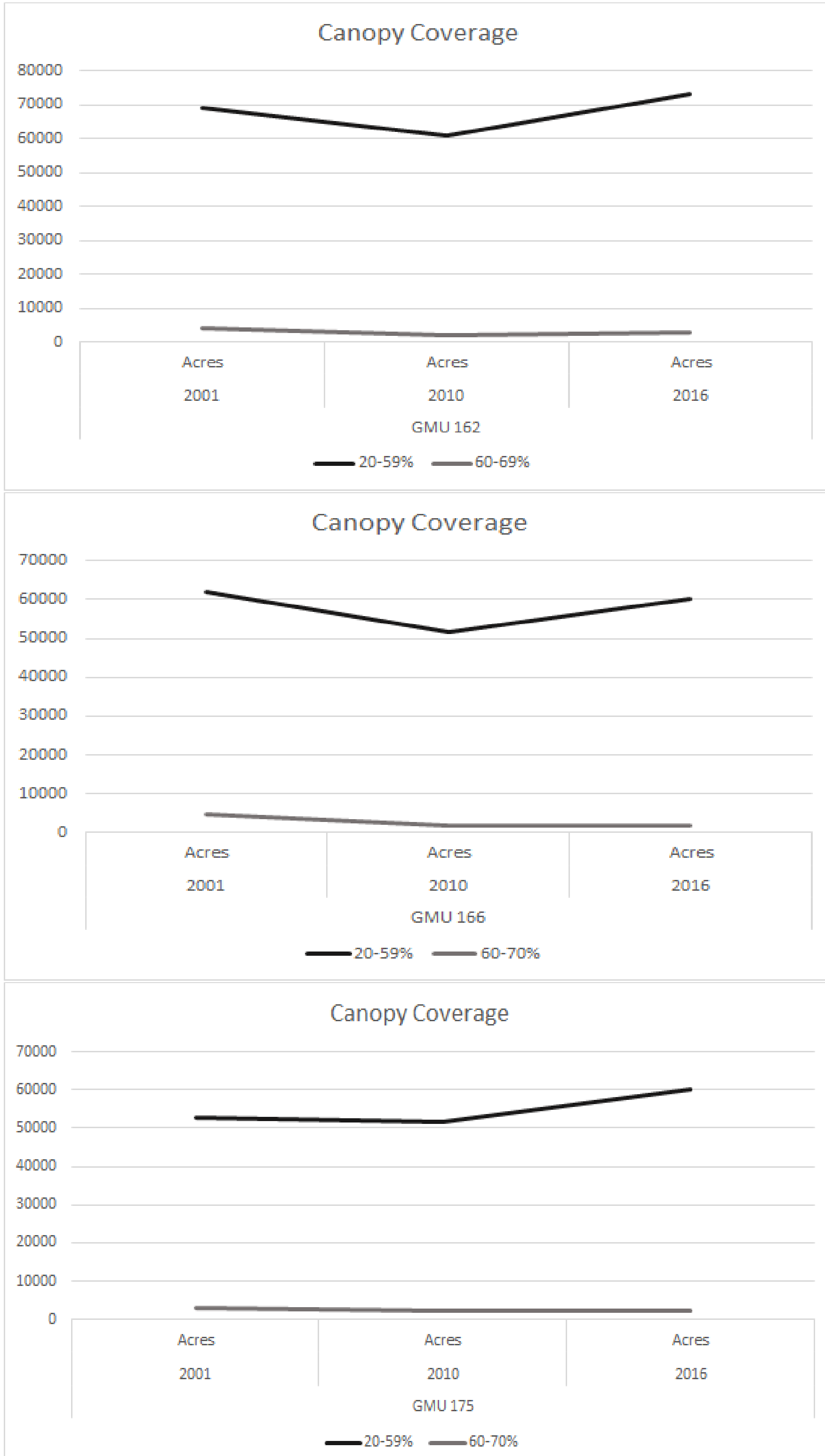

Figure 18. Tree canopy coverage in GMUs 162, 166, 175 defined in acres for years 2001, 2010, and 2016. Derived from Landfire.com data. GMUs 162 and 166 show the decline in canopy coverage following the large landscape fires of 2005 and 2006.

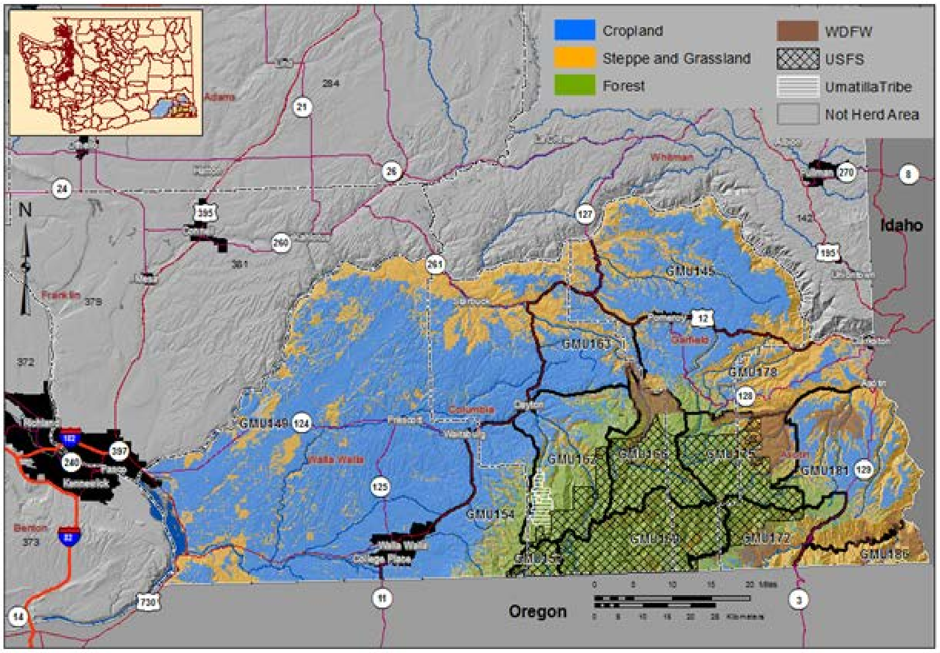

Figure 19. Forest, cropland, and rangeland (e.g., steppe and grassland) of the Blue Mountains Herd area.

Grazing by wildlife, fire, and weather extremes are important ecological factors affecting rangelands (Brown & McDonald, 1995). Grazing by domestic livestock is the most common use of managed rangelands and will alter current ecologic site conditions (Krausman et al. 2009). The effects of grazing by elk and cattle in the Blue Mountains have been investigated by several authors (Westenskow-Wall et al. 1994, Clark et al. 1998a, 1998b, 2000), and Anderson and Scherzinger (1974) reported a relevant case study. In general, their findings indicated that careful management of livestock grazing may increase the number of elk using winter range and improve forage. Anderson and Scherzinger (1974) reported that their cattle grazing system, designed to reduce dietary overlap between cattle and elk, resulted in improved vegetation, more elk using the range and increased cattle Animal Unit Months. Other studies have also suggested that livestock can have a positive effect on condition (crude protein, digestibility) of forage for elk (Grover and Thompson 1986, Yeo et al 1993, Danvir and Kearl 1996, Ganskopp et al. 2004, Taylor et al. 2004) when the timing, intensity, and duration of livestock grazing are controlled. Clark et al. (1998a, 1998b) reported that both the timing and level of grazing was important to quality and quantity of forage in a bluebunch wheatgrass (*Pseudoroegneria spicatum*) rangeland.

When both elk and cattle forage on the same rangeland, conflicts often arise concerning forage allocation. Holechek (1980) states that through proper management, degrees of dietary overlap between elk and cattle may be reduced, but consideration should be given to maintenance and improvement of the forage resource. Strategies such as the reduction of wild or domestic animals, acquiring parcels of private land to expand elk wintering areas, and brush control, seeding, and burning are ways to reduce dietary overlap and improve habitat (Holechek 1980). Sheehy and Vavra (1996) found that in their Blue Mountains study area there was little direct temporal overlap between cattle and elk. Cattle used shared areas in late spring-early summer and fall, while elk exhibited greatest use in shared areas during the winter and spring seasons. They also reported that elk in their study area preferred bluebunch wheatgrass-annual grass and Idaho fescue-bluebunch wheatgrass communities that occurred at higher elevations near the forest edge, whereas cattle selected Idaho fescue-annual grass communities on higher elevations at moderate distances from the forest edge. Although reporting some spatial and temporal separation between elk and cattle, they stated that dietary overlap will occur, and interactions will likely increase with an increase in ungulate grazing intensity.

The grazing of livestock on public lands, even with the objective of improving habitat for wildlife, is a complicated issue. A review of literature by Edge and Marcum (1990) found that the compatibility of elk and livestock is questionable because of biological, economic, and societal factors. They further report that research findings investigating this uncertainty have been complicated by contradictory observations suggesting both compatibility and interference between elk and cattle. Grazing on conservation areas, such as Department wildlife areas, also requires consideration of the well-being of sensitive habitats and species beyond just elk (WDFW, 2009).

Grazing on public lands has remained relatively stable over the past 10 years (pers. comm., USFS), with utilization changes being dependent upon climatic variables between years. There is no data available for changes in domestic grazing on public lands. How grazing has affected elk is not clearly understood at the herd level.

Blue Mountains Habitat Enhancement

From 2002 through 2018, more than 32,000 acres of habitat projects costing more than $1.3 million have been completed in the Blue Mountains herd area (Blue Mountains Elk Plan, 2020). These projects were developed by the Department, USFS, RMEF, and Blue Mountains Elk Initiative (BMEI) to improve habitat for elk on National Forest and Department lands, and to reduce elk damage on private lands. The project activities included prescribed fire, weed control, forage seeding, fertilization, and water development. The Department will continue to develop habitat improvement projects through partnerships with the RMEF, USFS, and the BMEI. The BMEI is a consortium of the Department, ODFW, USFS, tribes, and private landowners whose main objective is to initiate projects to improve elk habitat and maintain, or change, elk distribution onto public lands in southeast Washington and northeast Oregon.

Human Use Impacts

Managing elk in areas subject to human activity is becoming increasingly challenging. Human activity resulting from recreation, resource extraction and urbanization can alter the behavior of elk and have negative consequences. When human activity is frequent the cumulative effects may impact elk fitness by causing shifts in distribution, increasing flight responses, increasing vigilance, decreasing forage time, increasing stress and reducing reproductive success. Most elk in Washington, including those in the Blue Mountains, spend a portion of their time on a landscape where humans will influence their behavior and abundance.

Recreation

Recreation comes in many forms, whether driving on roads, using motorized or non-motorized trail systems, or recreating off trail. In general, elk respond to recreation by taking flight and increasing distance between themselves and human activity or by becoming more vigilant (Johnson et al. 2000; Wisdom et al. 2005: Ciuti et al. 2012). This response is scaled by the type, proximity, and frequency of the recreational disturbance. Activities such as hiking, or horseback riding will elicit a lesser response when compared to off-road vehicle riding or automobile traffic (Gaines et al. 2003; Wisdom et al. 2018). Flight response distances may range from 0.06 to well over 0.62 miles depending on the recreational type and intensity (Johnson et al. 2000; Wisdom et al. 2005; Naylor et al. 2009; Wisdom et al. 2018). Johnson et al. (2000) found road use (high use >4 vehicles per 12 hours, medium use 2-4 per hour) was a valuable predictor in modeling elk use. When elk do not or are unable to move away, they become more vigilant and reduce their normal daily behaviors such as feeding or grooming (Ciuti et al. 2012). Topographic complexity and dense forests may allow elk to screen themselves from recreation without drastically increasing their distance, although the lack of these two landscape features will cause elk to substantially increase distances in open habitats (Montgomery et al. 2012; Sawyer et al. 2007). In addition to energy loss due to the flight response and increased vigilance, displacement from preferred habitats may increase an elk's vulnerability to other, more lethal disturbances such as predation and harvest.

Less obvious effects have been given some attention by researchers, but these topics are more difficult to quantify and interpret. Elk residing in areas with well used road systems illustrate an increased stress response measured in fecal glucocorticoids levels as compared to animals found away from roads. This suggests these animals are experiencing more stress, possible alterations in normal behavior, reduced resistance to disease, and the potential for impacted population performance (Millspaugh et al. 2001). Human disturbance during the calving period can also reduce reproductive success (Phillips & Alldredge, 2000, Shivley et al. 2005). Both topics illustrate much more is occurring when elk are disturbed by humans but is difficult to make conclusive findings when attempting to control all the confounding factors within these complex systems (Millspaugh & Washburn, 2004).

Blue Mountains Recreation

Forms of recreation within the Blue Mountains that may be negatively affecting the elk population are motorized travel (e.g., off-road vehicles (ORVs), vehicles), shed antler hunting, hunting (spring turkey, spring special permit hunts April 15 – June 15, fall bear seasons starting in August, big game seasons through November, etc.) and winter travel (snowmobiles, skiers, etc.). Unfortunately, little to no quantifiable information is available on these activities that allow us to understand their trends over time except hunter numbers and harvest effort. Hunter numbers have shown a consistent decline since 2010 in the Blue Mountains (Figure 20). With fewer hunters, presumably there is less overall disturbance during hunting season but there is no information on hunter distribution and overlap with elk home ranges. Harvest effort, which is the number of days to harvest an elk, increased in 2016 and peaked in 2017 (Figure 20), suggesting protracted disturbance as it took hunters more days afield to harvest an elk.

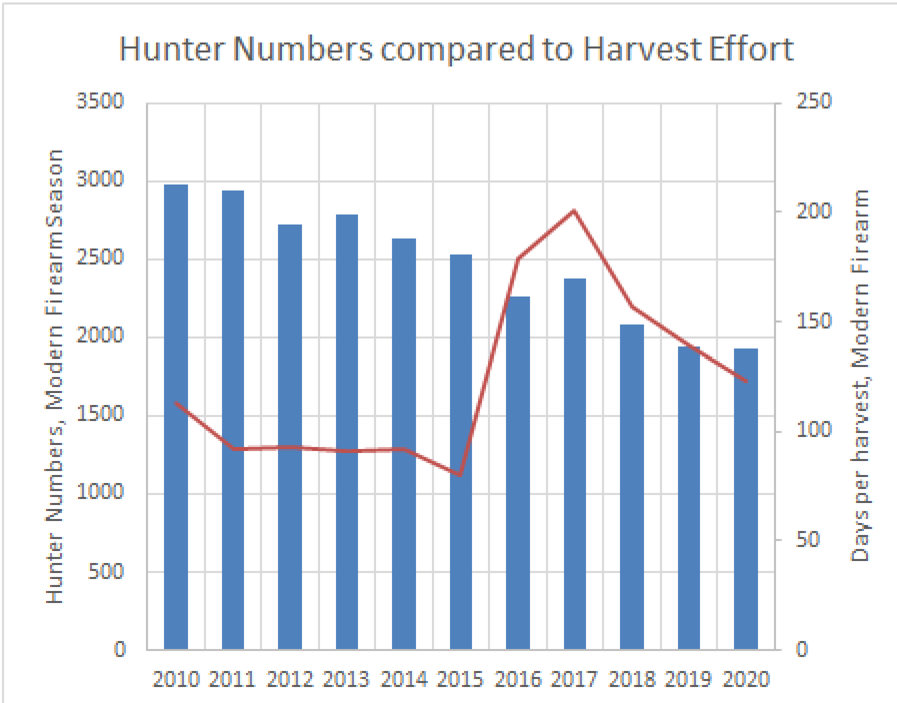

Figure 20. General season, modern firearm hunter numbers 2010-2020 (blue bars). Harvest effort (i.e., days per harvest; red line) shows the sudden increase in the number of days required per elk harvested.

Other forms of recreational activities are not monitored or formally documented, preventing evaluation of their long-term impacts. Anecdotally, spring bear special permit hunts, activities like shed antler hunting, ORV use, and winter travel are thought to be increasing over time. Observations by Department staff indicate that shed antler hunting has been increasing substantially over the past 5-8 years. The popularity of shed antler hunting has created greater competition among shed hunters, and now involves the use of small commercial aircrafts (e.g., planes and helicopters) to fly over elk winter ranges in February and March to locate antlers prior to ground access, increasing the temporal disturbance due to this activity. Over the snow travel near elk winter ranges has increased due to the advancements in motorized equipment allowing people to access areas once considered unreachable. Observations of tracked ATVs have been increasing annually, predominantly near the upper elevations of elk winter range where bull elk are more common.

Little research has been conducted on the effects of shed hunting on elk, but research has been conducted on other species or the effects of motorized and nonmotorized access with elk. Bates et al. (2021) found large increases in movement of mule deer when exposed to shed antler hunting. Naylor et al. (2009) found that travel time increased and feeding time decreased when exposed to ATVs, hikers, and horseback travel, all of these travel methods are employed by shed hunters in the Blue Mountains. While elk are typically at a low nutritional state during the peak of shed antler hunting (March-April), it is unknown whether this disturbance causes direct mortality or reduced recruitment.

Internal department discussions regarding restrictions during the peak of shed antler drop have occurred but no restrictions have been adopted. The states of Colorado, Wyoming, Montana, and Nevada have implemented landscape level restrictions that limit the collection of antlers during the winter and early-spring. If the landscape is failing to provide adequate nutrition and escape cover for elk, this would be one tool that may mitigate the risks of direct and indirect mortality associated with human disturbance.

Development & Land Modifications

The expanding footprint of human activity within Washington's elk habitat is occurring with increased development of urban areas and energy generation facilities such as solar or wind. Human activities in these areas are a driving force for elk habitat selection patterns in space and time (Dzialak et al. 2011). Elk residing in these areas alter their behavior, similarly as when dealing with human recreation, by moving away from roads and human activities and selecting habitats that provide security (Harju et al. 2011, Buchanan et al. 2014). Parturient elk exhibited this behavior more strongly and juveniles born in proximity to developed areas will move greater distances, make greater elevational changes, and use a larger area when compared to elk in less developed areas (Dzialak et al. 2011; Kuck et al. 1985).

Long term predictable exposure to human activity may allow elk to habituate to disturbances but clear answers are difficult to obtain and there is not consensus within the current research. Elk selecting for more secure habitats within a gas field energy development during the day resumed normal activity patterns at night when human presence was reduced (Dzialak et al. 2011). Walter and Leslie (2012) suggested elk remained onsite with consistent home range sizes during a wind-power development in southwestern Oklahoma. This information is contrary to a robust study which suggests significant summer and winter habitat loss during the development of a natural gas field in northeastern Wyoming (Buchanan et al. 2014). A single long-term effort investigated mule deer habitat selection prior to, during and 15 years post development of a natural gas field found ungulates do not habituate and regain habitat lost once the landscape is developed, thus leading to reduced population abundance (Sawyer et al. 2006; Sawyer et al. 2017).

Blue Mountains Development & Land Modifications

There are about 44,000 acres of developed land in the Blue Mountain elk herd area (Blue Mountains Elk Herd Plan, 2020). This is a bit misleading, however, because the amount of elk habitat affected by development is actually greater, as human presence influences a larger footprint than the developed area alone would indicate. Division of large tracts of land has contributed to the loss of elk habitat in some areas. Beginning in the early 1990s many acres of industrial timber land and rangeland in the four counties of the Blue Mountains herd area were converted to residential parcels. Habitat conditions in GMU 154 are a concern due to the large amount of land that has been sub-divided, especially in the Lewis Peak-Jasper Mountain area. Some development has also occurred in GMU 172, which is directly impacting year-round elk habitat.

Climatic Impacts

The performance of an elk population is strongly influenced by the climate in which it resides. The common thought is to consider periodic severe winter or drought events as the primary limiting factor, but less obvious changes in temperature and precipitation which affects summer nutrition contributing to successful pregnancy and calf survival have a greater effect on population productivity (Parker et al. 2009; Griffin et al. 2011; Cook et al. 2013). Abundant high-quality forage during the growing season is essential for providing nourishment during critical periods. It is linked to a female's reproductive potential and increased fall calf body weight which translates to higher survival. (Cook et al. 2004). Spring forage abundance tends to be relatively stable, although forage production resulting from summer and fall precipitation has shown to be highly variable and extremely important. These rains allow for additional forage growth and delays senescence providing ungulates extended access to high quality forage (Griffin et al. 2011, Hurley et al. 2014, Cook et al. 2004, Rickbeil et al. 2019). Nutritional resources on summer range are a vital component for population performance by generating subtle but cumulative effects on reproduction and survival (Cook et al. 2013).

Nutritional increases provided by summer and fall precipitation will affect cow and calf performance. Increased forage quality during these months will allow prime-aged adult females to gain adequate body fat levels required for successful pregnancy and winter survival. Prime-age female fall body fat levels ≥12 % and pregnancy rates of near 90% are observed in populations which are not nutritionally limited. Moreover, fall body fat levels < 9% reduces successful breeding and when below 8%, survival over an average winter decline (Cook et al. 2004). Calf elk tend to be more vulnerable to overwinter starvation and their ability to survive is directly related to their fall body mass (Loison et al. 1999, Cook et al. 2004, Kautz et al. 2018, Johnson et al. 2019). Juveniles that weigh <85kg in the fall are highly susceptible to overwinter starvation, while those weighing >110 kg have an increased probability of survival (Cook et al. 2004).

As wildlife professionals manage elk populations, they are doing so during unprecedented climate change which is altering habitat conditions. Investigations of elk range conditions across the west suggest most populations are experiencing some level of nutritional limitation and additional stress due to climate change that may have negative effects on population performance (Cook et al. 2013, Johnson et al. 2019) Climate-induced changes with increased temperature and altered precipitation patterns may create difficulties for elk. For example, resource availability during critical times such as parturition and while females are lactating could become mismatched with peak spring green-up (Post & Forchhammer, 2007). Snow accumulation, snow melt, green-up magnitude and duration is changing but not consistently across all western herds. In some cases, elk can match their need with the available resources by interpreting environmental cues (Rickbeil et al. 2019), and by altering their site fidelity based on experience with resource tracking the previous spring (Morrison et al 2020). Although, examples of additional stress from climate change resulting in poor population performance have been documented. Investigations of a migratory elk herd in the Greater Yellowstone Ecosystem revealed a shift of green-up duration by 27 days over the last two decades. The shift was linked to increases in April-August temperature concurring with April-May precipitation declines. These climatic changes facilitate a rapid, but short green-up period and reduced forage availability for migrating elk which was a contributing factor to poor annual reproductive success (Middleton et al. 2013).

Blue Mountains Climatic Impacts

Climate is one factor which drives bottom-up regulation by influencing forage and subsequently an elk's nutritional condition. The ideal measure of climates impact involves direct sampling of forage plant communities to determine dietary digestible energy (*hereafter* DDE), although this is rarely conducted since it is time consuming and difficult due to temporal and spatial variability. Therefore, researchers directly assess elk nutritional condition with measures of Ingesta-Free Body Fat (*hereafter* IFBF) and pregnancy rate of prime-aged females. IFBF is not a direct measure of climates influence on forage, but instead the balance of energy expenditure and the nutritional value of summer and fall forage (Cook et al. 2004, 2013; Johnson et al. 2019). Energy expenditure of lactation is substantial; therefore, they are separated from non-lactating individuals in analyses. IFBF and pregnancy data with well supported nutritional thresholds provides managers tools to evaluate herd condition. Thresholds for autumn IFBF and pregnancy are (Cook et al. 2004, 2013; Johnson et al. 2019):

- >17% IFBF indicates excellent nutrition without limitation,
- 12-16% IFBF indicates good nutrition but with reduced growth rates of juveniles and yearlings and low pregnancy rate of yearlings.
- 7-11% IFBF indicates reduced pregnancy rates of adults, reduced growth of juveniles and yearlings, delayed breeding, and loss of resilience to winter.
- <6% IFBF suggests reproductive pauses, depressed rates of growth in sub-adults and increased risk of winter mortality.
- ≥ 90% pregnancy is excellent to good summer-autumn nutrition.
- 70-90% pregnancy is marginal summer-autumn nutrition.
- 40-70% pregnancy is poor summer-autumn nutrition.

WDFW does not have DDE, IFBF or pregnancy data for the Blue Mountains elk herd, but research proximal to this area published by Cook (2013) investigated two populations in Oregon's Blue Mountains, Wenaha, and Sled Springs, which provides insight to the potential nutritional condition of elk in Washington (Table 4). These results indicate evidence of nutritional limitation with the consequences of reduced pregnancy rates for lactating females, delayed breeding which can indirectly influence juvenile survival, and poor pre-winter condition which may influence survival of adults and juveniles (Johnson et al. 2019). These data are consistent with findings throughout the west where 11 of the 17 herds assessed averaged ≤8% autumn IFBF (Cook et al. 2013). The

Washington Blue Mountains elk herd is likely in a similar situation, and it should be evaluated as having nutritional limitations.

Table 4. Autumn Ingesta-Free Body Fat and Pregnancy rates from two populations in the Oregon Blue Mountains between 2002-2007 (Cook et al. 2013, Johnson et al. 2019).

	%IFBF				Pregnancy Rate		
	Not Pregnant		Pregnant				
Elk Population	Non-lactating	Lactating	Non-lactating	Lactating	All	Non-lactating	Lactating
Wenaha	7.9	5.1	12.2	7.5	87.5	88.5	86.0
Sled Springs	6.7	7.8	12.8	9.4	84.0	89.7	76.2

Late summer precipitation, especially in drier ecosystems, have illustrated significant positive effects on body fat accretion of lactating elk and body mass of juveniles prior to winter and may indirectly influence population performance (Johnson et al. 2019). August precipitation data from Parameter-elevation Regression on Independent Slope Model (*hereafter* PRISM), as described in Johnson (2019) for the Blue Mountains was collected by GMU from 1991 to 2020 and indicate an overall mean of .697 inches (+/- 0.200) (Fig. 21). Identification of specific precipitation values necessary for individual or population benefits are not defined, but literature suggests using a comparison to the long-term mean. Years with values equal to or above the 75th percentile could be suggested as better than average precipitation. This would equal 0.9 inches of precipitation, and when plotted with the Blue Mountains population data identifies no precipitation events greater or equal to the 75th percentile occurring in one or more GMU since 2014 (Fig. 21). Furthermore, events where $\geq$ 2 inches precipitation (94th percentile) coincide with a time of substantial elk population growth between 1999 and 2009 (Fig. 22). A correlation analysis of adult cow and juvenile recruitment with August precipitation was conducted at the GMU and herd-wide levels and all results indicated no correlation, therefore the observation of precipitation and population is a qualitative assessment only. Using August precipitation as an indicator of climatic effects on bottom-up regulation suggests the last four years have not been as good as previous years with a mean of only 0.4 inches (+/- 0.34).

Winter can have a dramatic impact on elk populations with juvenile survival being the most susceptible, although winter conditions within the long-term mean should not reduce survival (Johnson et al. 2019). December through February PRISM precipitation and temperature data was standardized to generate a winter severity index, where increasing precipitation and decreasing temperature result in higher values to indicate severe winter conditions (Johnson et al. 2019) (Fig. 23). Winters of 1996, 1997 and 2017 were events beyond the 95th percentile and significant elk winterkills were documented. Since 2017, index values were within the normal range with 2019 being slightly above average and winter mortality was minimal.

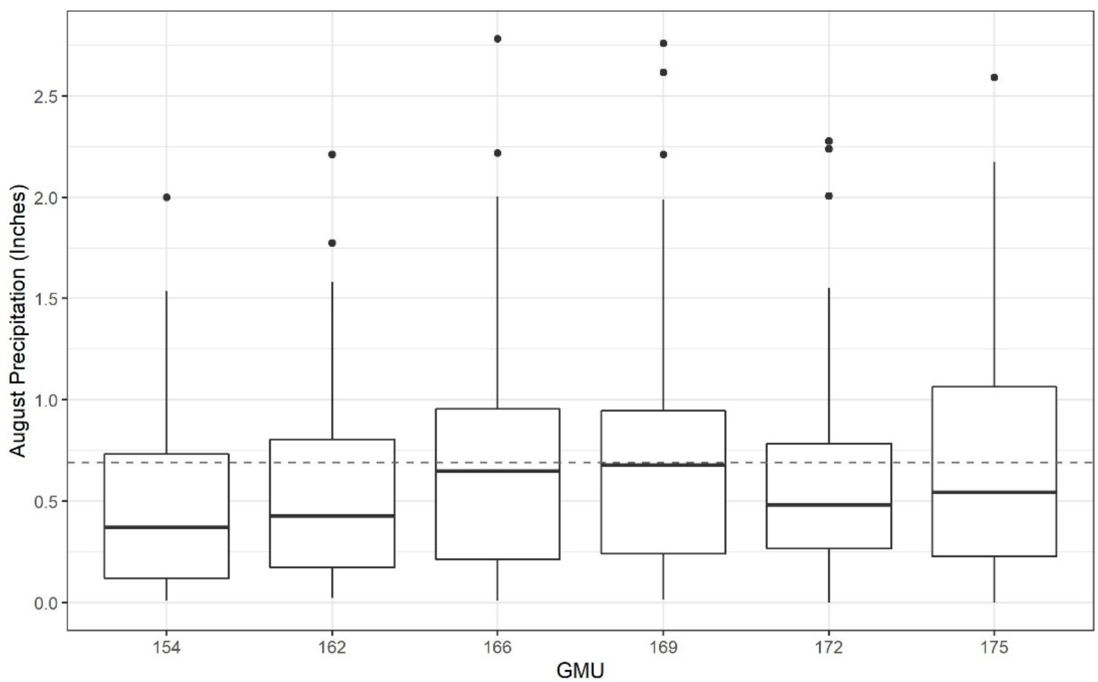

Figure 21. PRISM, August precipitation data from 1991 to 2020 collected and summarized by GMU. The dashed blue line represents the 29-year mean 0.697 inches.

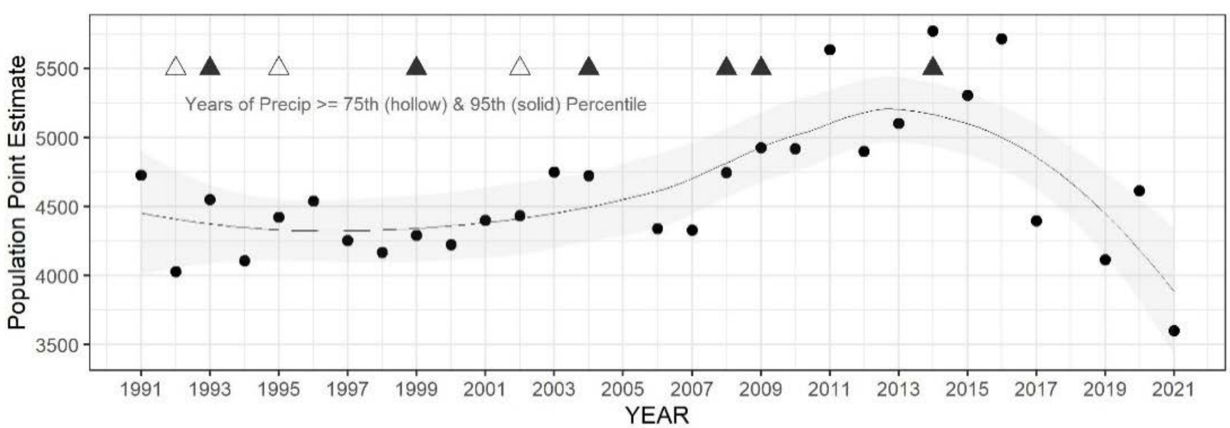

Figure 22. Blue Mountains elk herd population point estimates from aerials surveys with precipitation events of ≥ the 75th (0.9 inches) and 95th percentile, represented with hollow and solid triangles, respectively.

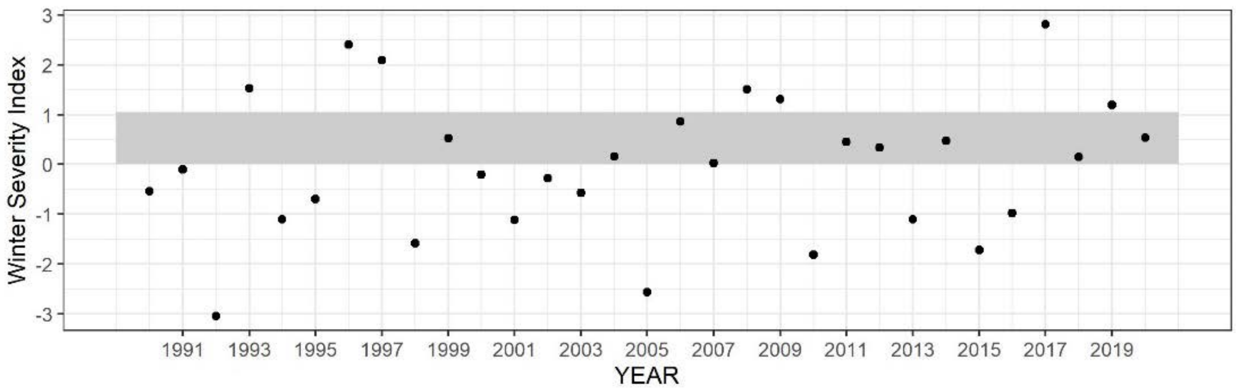

Figure 23. Blue Mountains averaged winter severity index using December through February PRISM precipitation and temperature data. Higher values document increased winter severity. Standardized with a mean = 0 and standard deviation = 1 and with gray band representing winter severities within the 75th percentile.

Climate change is an ongoing global issue which is impacting the western United States more than the east (Saunders et al. 2006, Diaz and Eischeid 2007, Knowles et al. 2006, Pederson et al. 2010). Reports for the Columbia River Basin, in which the Blue Mountains resides, suggest this area has a mean-annual temperature increase of approximately 2° F (Knowles et al. 2006, Regonda et al. 2004). Trends of overall precipitation have not changed but are increasingly falling as rain instead of snow (Knowles et al. 2006, Regonda et al. 2004). This decreases the amount of snowpack and commonly brings an earlier snow melt-off. In an analysis between 1948 to 2006 of streamflow, Luce and Holden, (2009) documented dry years are becoming increasingly drier for the area. The trend over the next 60 years predicts continued rises in temperature during warm and cool seasons with increases in cool season rain and reduced precipitation during the warm months (Reclamation, 2016).

Changes in precipitation type and timing as well as increases in temperature present many challenges for elk (Post & Forchhammer, 2007; Rickbeil et al. 2019; Middleton et al. 2013). The common methodology for monitoring precipitation and temperature changes as related to elk employs the use of remote sensed satellite data. Using these data, calculations can be applied to estimate forage quantity and quality and allowing for reconstruction of vegetation pattern from the 1980’s to the present (Pettorelli et al. 2011). Ideally, sampling will take place in locations of adult female elk without significant canopy cover (Brodie et al. 2013; Middleton et al. 2013; Hurley et al. 2014). These data will allow for an annual comparison of duration and magnitude of forage production. Washington does not currently have adequate spatial data of adult female use for the Blue Mountains to conduct a refined analysis of this type.

Discussion

Concerns surrounding elk recruitment have been persistent in the Blue Mountains for more than three decades, with investigations focusing on conception timing, pregnancy rates and predation. During the 1980's and early 1990's the Department identified asynchronous conception timing and low pregnancy rates (65% in 1987) which were attributed to the low bull to cow ratios (Zahn, 1993; Myers et al. 1999). Management actions to increase bull to cow ratios were successful and this led to synchronized conception timing. Pregnancy rates appeared to rise (89% in 1992) although during this time recruitment remained depressed at only 18 and 19 juveniles per 100 adult females in 1992 and 1993, respectively. In response, the Department conducted a juvenile survival and cause-specific mortality study from 1993-1997. They identified an average annual juvenile survival rate of 0.47 (0.44 – 0.55) and when combined with high pregnancy rates, as documented in 1992, should have resulted in recruitment levels that would allow for population growth, but that did not occur. It is believed these contradictory findings may have been related to the fact that researchers were unable to capture a significant number of newborn calves, less than 24 hours old, which has been shown to potentially increase survival estimates if uncorrected over shorter timeframes of less than 70 days (Gilbert et al. 2014; Chitwood et al. 2017). Regardless, this earlier study determined that predation events primarily occurred during the summer season and therefore were compensatory.

Currently, three core GMU's in the northern portion of the Blue Mountain elk herd's range are struggling to reach objective due to poor recruitment (162, 166, 175; *hereafter* northern core). This assessment attempted to disentangle climate, bottom-up and top-down effects to identify which factors were inhibiting population growth, but this approach is a simplification of a complex ecological system. As such our limited data did not allow for a clear determination of which factors were limiting this herd and additional work is needed to collect information that can be used to inform the development of management alternatives.

Human use and development data for the area are limited but the literature has not provided an indication of population level impacts. Moreover, other Washington herds have stable or increasing population trends despite substantial recreational activities occurring within their respective herd areas. Although these activities are additional stressors, they are unlikely to be a principal limiting factor. As such, collecting additional information regarding these factors is likely to provide minimal insights. Alternatively, nutrition and predation have been identified as limiting elk populations throughout the west and are likely to be the two primary factors limiting the Blue Mountains elk herd.

The information the Department has available regarding the nutritional condition of elk in the Blue Mountains is limited, but a qualitative comparison of trends in climatic conditions before and after the Blue Mountains elk herd declined provides at least some insight. The 2005 School and 2006 Columbia Complex fires converted large, forested stands in the northern core to an earlier seral stage. Additionally, precipitation during the month of August was near average in most years following these wildfire events (2005-2016 average = 0.65 inches; 30-year average = 0.697 inches), with some years being well above average (ranging from 1.5 -2.17 inches in 2008, 2009 and 2014; Figure 22). Collectively, these conditions likely created advantageous environments for elk and contributed to the population growth that was documented during this period (Figure 22). Nutritional benefits from the complex fires have continued to diminish as forests continue to move towards pre-fire conditions and precipitation has been less than average since 2017 (0.415 inches), without any exceptional precipitation events (Fig. 24). The lack of specific August precipitation requirements for elk makes it difficult to determine the effect below average precipitation has had on elk, but it seems likely that forage quality has been reduced in recent years, or at least limited due to below average precipitation. Myers (1999) was also concerned with the effect of drought on calf survival in the Blue Mountains and documented reduced survival in years when drought conditions persisted. Nonetheless, it remains difficult to conclude that nutrition is the primary limiting factor in the northern core because elk populations in the southern core (GMUs 154, 157, 169, 172; *hereafter* southern core) have remained stable, with the exception of 2017, despite the fact that habitat and climatic conditions are currently perceived to be similar between the two areas. More in-depth investigations of nutritional limitations in the Blue Mountains would be beneficial but would also require a multi-year effort to capture adult female elk during autumn months to assess pregnancy and nutritional status.

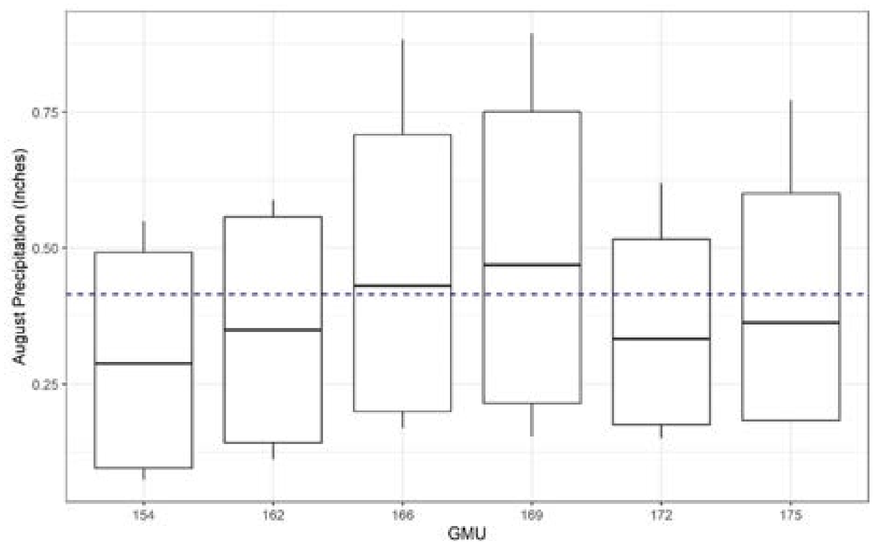

Figure 24. PRISM, August precipitation data from 2017 to 2020 collected and summarized by GMU. The dashed blue line represents the 4-year mean 0.415 inches.

It is similarly difficult to conclude that predation is the primary limiting factor for the Blue Mountains elk herd because cause-specific mortality rates for juvenile elk are unknown. In addition, cougars and black bears are currently being harvested at increased rates. The Department's cougar management guidelines adopted in 2012 and subsequent changes since have resulted in a doubling of historic cougar harvest in the Blue Mountains with a significant portion of the annual harvest consistently occurring in GMU 162. Harvest rates derived in this assessment using cougar density estimates from GMU 166, for 2009-2013, are equal to cougar population reduction treatments implemented by Proffitt (2020) in Montana to promote elk population growth. Clark (2014) also suggests these rates should result in a reduction of cougar populations if continued for 3 years, even when maximum immigration is considered. The Department also amended the cougar harvest guidelines in 2020 to potentially allow for the harvest of more cougars. The Department does not have contemporary cougar density estimates in the northern core to validate our assumed harvest rates and reductions of cougar populations, but given current harvest levels, it is unlikely they haven't declined at least somewhat. Deriving contemporary estimates of cougar density would increase the Department's understanding of current cougar population status but would require an intensive multi-year effort to capture and mark individuals.

In 2020, the Department also increased the number of spring bear special permits and increased the bag limit to two bears during the fall general season, which may allow for an increase in bear harvest. Whether increased bear harvest would benefit the Blue Mountains elk herd is unknown, but any benefit is likely to be more strongly associated with increasing harvest during special permit seasons in the spring since harvest rates tend to be higher and occur prior to or during the calving season (White 2010). Although using harvest density estimates as was done in this assessment would allow the Department to continue to monitor harvest rates, formal estimates of black bear density would be a superior metric for assessing the status of populations.

Wolves are not currently hunted in the Blue Mountains and there has only been one management removal since they began recolonizing the area in 2009. Wolf predation rates of juvenile elk have not been assessed, but wolf numbers have steadily increased over the past 10 years, so it is likely predation rates have also increased. However, population level impacts usually only occur when the correct combination of abiotic, bottom-up and top-down conditions are present. For example, Horne (2019) determined that as pack size and snow depth increases so does adult elk mortality risk and under these conditions, smaller elk calves become more vulnerable. If wolves are a limiting factor in the northern core it is most likely to be associated with the Touchet Pack, which most recent estimates indicate is comprised of 13 wolves and resides predominately in GMU 162.

Appendix (March 2022)

Background

Department employees initiated an elk calf mortality monitoring effort in May of 2021 to provide contemporary information on survival and cause-specific mortality of calves from birth to recruitment. We selected GMUs 162 (Dayton) and 175 (Lick Creek) as primary capture areas. These GMUs represent significant habitat, ownership, and recruitment differences. The vegetative communities and ownership within GMU 162 contain more closed forests and private agricultural lands (67% private), while GMU 175 is a mix of shrub and grasslands transitioning to forest under predominately public ownership (9% private). Both GMUs have the same carnivores with GMU 162 thought to contain a higher density of wolves than GMU 175. Game management unit 162 had the lowest juvenile elk recruitment ratio since 2017 (average = 16.5) while GMU 175's recruitment (average = 22.3) has been only slightly below the level necessary to maintain stability (Table 1). Both GMUs provide reasonable access to allow for timely mortality investigations. Due to the difficulty of finding calves in heavily forested and steep terrain in GMU 162, we extended sampling into GMU 166 (Tucannon) (Figure 1). This GMU lies between GMU 162 and GMU 175 and has exhibited low juvenile recruitment (average = 16.5). These three GMUs represent the northern core of the Blue Mountains elk herd's range.

Monitoring Methods

We conducted neonate captures in the northern core of the Blue Mountains during parturition as documented in Myers et al. (1999) and Johnson et al. (2019). We employed two methods for capture: 1) locate and capture calves by hand by observing behavior of solitary adult females from the ground; and 2) capture calves by helicopter net-gunning by locating adult females with calves from the air. We began ground captures on May 18 with helicopter operations beginning on June 2. We delayed Aerial captures until after June 11th because of the difficulty of locating juvenile elk. Delay of capture by 1 week improved our ability to locate and capture juvenile elk, allowing us to meet our goals within the available budget. All captured neonates were blindfolded, fitted with a MINI GPS neck collar, weighed, ear tagged, and hooves were assessed and photographed to verify age. Age classes were assigned by the capture crews (WDFW and Helicopter Vendor) based on activity, size, and hoof and navel appearance (Johnson 1951) and verified by photo evaluation of hooves (Ganz, pers. comm.) before being binned in one of four age categories. We estimated birth dates by subtracting estimated age at capture from the capture dates.

Department staff received mortality notifications when a GPS collar remained motionless for 4 hours and we attempted field necropsies within 24 hours of notification to identify cause of death. We categorized mortality sources as the following: predation (cougar, black bear, coyote, wolf, bobcat, or unknown predator), unknown, non-predation, and human-caused. We classified mortalities as predation where we found clear evidence of pre-mortem hemorrhaging at bite or claw wounds and classified the predator as described by Stonehouse et al. (2016). We collected presumed saliva DNA samples from wounds with hemorrhage, locations of chewing on the collar, ear tag, or remaining bone, and any other location of interest (Murphy et al. 2000; Dalén et al. 2004; Davidson et al. 2014). We used conclusive single carnivore DNA analysis results to verify the carnivore species when field investigators concluded predation was the mortality cause, but the predator was unknown. We used only DNA from lethal wounds (sites with hemorrhage) for carnivore species identification. Although DNA from non-hemorrhagic sites were informative, we did not use it to identify species of carnivore responsible for mortality, since scavengers could also leave behind DNA at the carcass. We transported juvenile elk found intact, where cause of death was difficult to determine via field methods to Washington Animal Disease Diagnostic Laboratory (*hereafter* WADDL) at Washington State University for necropsy and tests to determine cause of death.

We estimated survival rates at 30-day intervals using the Kaplan-Meier (KM) estimator with the R-4.0.3 package *survival* (R Core Team, 2019; Therneau, 2021). We investigated survival differences based on sex, capture GMU, capture method, and capture age class.

Monitoring Results

We captured 125 juvenile elk with a GMU distribution of 65 (GMU 175), 33 (GMU 162), 26 (GMU 166) and 1 (GMU 181) being just outside the border of GMU 175. We captured 65 females and 57 males with the sex of the remaining three being unidentified by the capture crew. We categorized juvenile elk into four age categories of 0-3 (*n* = 39), 4-6 (*n* = 30), 7-10 (*n* = 35) and greater than 11 (*n* = 21) days with average weights for each category of (19.7, *SD* = 3.5), (27.3, *SD* = 3.6), (33.0, *SD* = 3.0) and (38.0, *SD* = 2.9) kilograms, respectively. The average date of birth occurred on May 31, 2021 (+/- 11 days).

We right-censored (removed at the time of occurrence) 13 juvenile elk from our analysis due to GPS collars being prematurely shed (e.g., found caught on barbed-wire), collars not recovered due to wildfire, and contact with the collar being lost during the observational window (GPS data failed to upload and the VHF signal could not be found). We also left-truncated (removed from analysis) four juvenile elk because cause of death was determined to be associated with capture. Nine juvenile elk still had functioning transmitters at the time of writing (February 2022).

We documented 99 mortalities of juvenile elk prior to recruitment with the most proximate cause of death being predation (*n* = 77; 77.8%) with the following predators identified (% of all mortalities respectively): cougar (*n* = 57; 57.6%), bear (*n* = 9; 9.1%), cougar/bear (*n* = 5, 5.1%), coyote (*n* = 3, 3.0%), wolf (*n* = 1, 1.0%), wolf/bear (n = 1, 1.0%), and bobcat (*n* = 1, 1.0%). Other sources of mortality were infection (*n* = 5, 5.1%), starvation (*n* = 1, 1.0%), exertional myopathy (i.e., a metabolic condition most commonly associated with a flight response, capture, restraint and transportation of animals, which may result in increased acid within bodily fluids, destruction of muscle fibers and acute kidney injury; *n* = 1, 1.0%), and a variety of unknown mortalities which includes unknown scavenged (*n* = 7, 7.1%), and unknown intact (n = 8, 8.1%), with three of those suspected to be due to direct fire effects. Among all mortality notifications (i.e., actual mortalities, collar loss, and delayed notifications caused by software), we conducted 81 of 111 site-investigations within one day of notification. We averaged 1.4 days to site investigation over all notifications.

We submitted DNA samples from 32 predation mortalities and one unknown scavenged mortality to University of Washington (*hereafter* UW). Field investigators could not identify a definitive predator on twelve of the mortalities. Laboratory analysis confirmed the presence of predator DNA in all 12 cases: cougar (6 mortalities), bear (two mortalities), cougar/bear mix (three mortalities), and wolf/bear mix (one mortality). In addition, DNA results changed the field investigation determination of one case from coyote to bobcat and a second case from wolf to cougar. All remaining DNA samples (n = 18) confirmed the field determination of predator-specific cause of mortality.

We investigated 16 mortalities where the carcass was intact and transported 13 of those to WADDL for cause of death determination. WADDL pathologists diagnosed three incidences of exertional myopathy: one attributed to acute severe skeletal necrosis twenty days post capture and identified as non-capture related; one that exhibited severe myocardial and renal necrosis twelve days post-capture, with the chronic nature indicating possible relation to the capture event; and one case of myopathy four days post-capture that exhibited signs of starvation, attributed to capture-related abandonment. The lab identified five cases as infection with one involving a protozoan, one viral pneumonia, one umbilical infection, and two with clinical signs of hemorrhagic disease but no clinical confirmation. One case was identified as starvation, and four cases had various clinical findings that could not be attributed to any specific cause of death. One additional sample of the respiratory tract, heart, and rumen was submitted where predation was the field investigation determination and the lab found no significant findings to alter that determination. This was the only predation mortality for which we submitted samples to WADDL to rule out myopathy or disease as an underlying pathology. Two intact carcasses were determined as unknown after field investigation only, and one intact carcass was determined as starvation based on the field investigation.

We estimated a pooled juvenile elk survival rate of 13.6% at 240 days (i.e., ≈Jan. 26, 2022). Survival estimates did not significantly vary by sex, but we identified differences when comparing survival estimates of capture GMU, age class and capture method. Survival by game management unit was 10.6%, 10.3% and 26.3% in units 175, 162 and 166, respectively. Estimates of survival by age-at-capture class were 9.0% (95% CI: 3.0 – 26.0) for 0-3 days, 6.0% (95% CI: 1.0 – 33.0) for 4-6 days, 17.0% (95% CI: 8.0 – 37.0) for 7-10 days and 22.0% (95% CI: 8.0 – 56.0) for 11-14 days. Our data also suggest capture method (ground or aerial) may influence survival rates for the 0-3 days age class. However, our inferences are limited by small, unbalanced sample sizes among groups. Further, GMU-level differences are potentially a function of the age-at-capture because we captured juveniles in GMU 166 later than GMUs 162 and 175. In GMU 166, the average age-at-capture was 8.9 days and only 8% of juveniles captured in that GMU were ≤ 3 days old. The average age-at-capture was 5.4 and 6.8 days in GMUs 175 and 162, respectively, and the percentage of juveniles captured ≤ 3 days old was 37% (GMU 175) and 27% (GMU 162).

Table 5. Kaplan-Meier estimates of 30-day survival probabilities and associated 95% confidence intervals for juvenile elk in the northern core GMUs of the Blue Mountains of Washington May 18, 2021 – January 26, 2022.

≈Calendar Date	*Days Since Birth*	$\hat{S}$	*Lower CI*	*Upper CI*
June 30, 2021	30	0.62	0.54	0.71
July 30, 2021	60	0.44	0.36	0.54
Aug. 29, 2021	90	0.29	0.22	0.38
Sept. 28, 2021	120	0.20	0.14	0.29
Oct. 28, 2021	150	0.15	0.09	0.23
Nov. 27, 2021	180	0.136	0.08	0.22
Dec. 27, 2021	210	0.136	0.08	0.22
Jan. 26, 2022	240	0.136	0.08	0.22

Monitoring Discussion

The Department’s elk management generally relies on annual aerial surveys in late February-early March to estimate herd abundance, composition, and juvenile recruitment ratios. Recruitment ratios index juvenile elk survival but are a function of both juvenile and adult female survival, in addition to potential observation or sampling error. The 2021-2022 juvenile elk monitoring is a direct measure of juvenile survival until recruitment. Annual population change is predominately influenced by adult female and juvenile survival along with pregnancy rates (Proffitt et al. 2015). When estimates of these parameters are available managers can model population performance to determine growth, otherwise known as Lambda (λ). Lambda represents the population's annual proportional change, where $\lambda = 1.0$ identifies population stability and $\lambda < 1.0$ or $\lambda > 1.0$ represents population decline or growth, respectively.

Montana Fish Wildlife and Parks (*hereafter* MFWP) recently estimated adult female survival and pregnancy rates to determine λ given aerial-survey-estimated juvenile recruitment rates (Proffitt et al. 2015). The MFWP investigators wanted to determine recruitment ratios and corresponding annual juvenile elk survival rates necessary to achieve stability and growth for two elk populations with similar adult female annual survival (0.93 & 0.94) but different pregnancy rates (0.74 & 0.85; Proffitt et al. 2015). The MFWP authors report annual juvenile survival rates of 0.31-0.35 (i.e., 31-35%) were necessary for population stability (e.g., $\lambda = 1.02$), which equaled a juvenile recruitment rate of approximately 25 juveniles per 100 adult females. Moreover, when juvenile survival increased to 0.50 – 0.55 ($\lambda = 1.13$) the juvenile recruitment ratio was 40 per 100 adult females. In general, every 1.25% increase in juvenile elk survival equals approximately an increase of 1 juvenile:100 adult females (Proffitt et al. 2015).

Using the MFWP analysis above, stability for the Blue Mountains elk population should be achieved with an annual juvenile survival rate of 35% and population increase should occur when juvenile survival is above 35%. Survival rates of 0.40, 0.45 and 0.50 should equate to juvenile recruitment levels of 29, 33 and 37 juveniles per 100 adult females, respectively. These modeling benchmarks are supported in the population trend of the Blue Mountains elk herd, where population increases were observed when juvenile recruitment rates were greater than 25 per 100 adult females (e.g., Figures 3 & 7 from years 2003 – 2016).

Our estimated juvenile survival rate to-date (June 2021-January 2022; 0.136) is expected to produce an additional year of population decline for the northern core of the Blue Mountains Elk Herd. This estimate is lower than documented rates where juvenile recruitment has been evaluated as a limiting factor for population growth in the Blue Mountains (Myers et al. 1999, Johnson et al. 2019; Figure 25). Predation (77.8%), specifically by cougars (74.0% of all predation mortality and 57.6% of all mortalities), is the highest cause-specific rate of mortality that we documented. Our survival estimate is lower than what has been documented in the nearby Oregon Blue Mountains (Johnson et al. 2019), where predation was determined to be partially additive, and higher than previously documented in the Washington Blue Mountains (Myers et al. 1999), where predation was suggested to be compensatory (Figure 26).

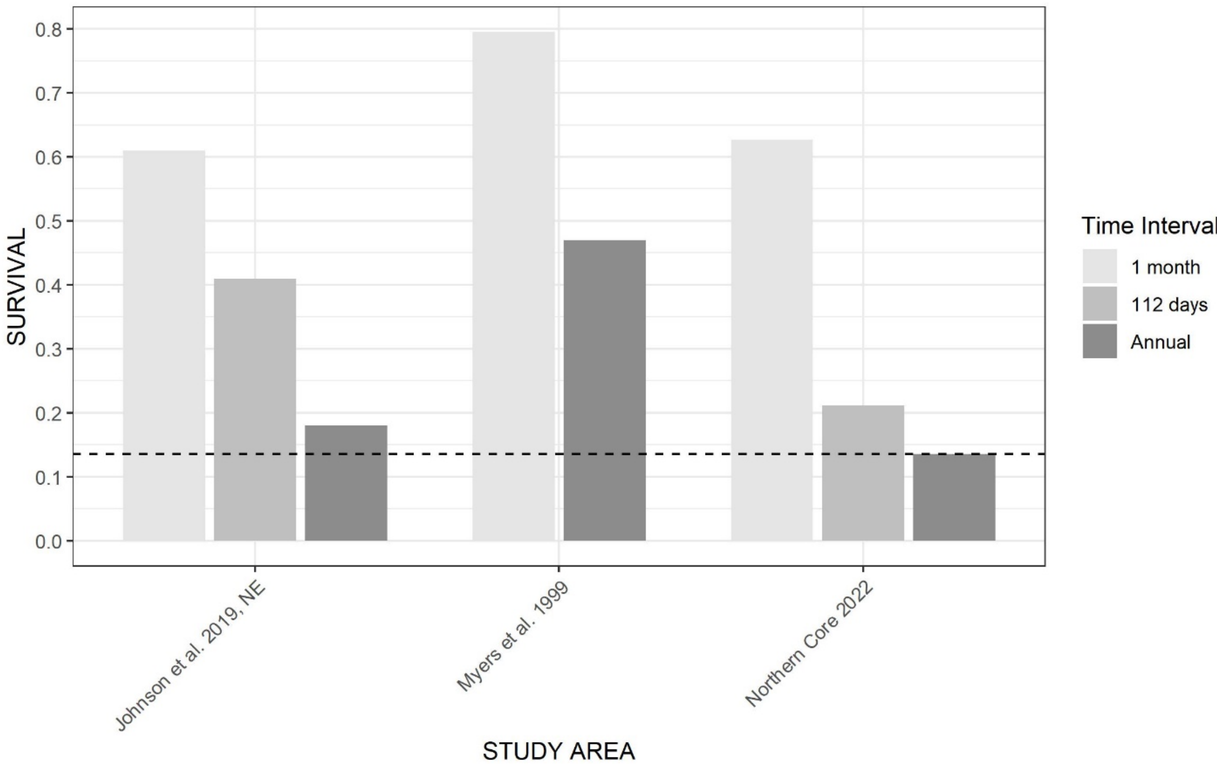

Figure 25. Juvenile elk survival comparison at various time frames: 1) Johnson et al. 2019 encompasses research conducted from 2001-2007 in Northeast study area units (Wenaha and Sled Springs) of Oregon's Blue Mountains (n= 360); Myers et al. 1999 encompasses research conducted from 1992-1997 in predominately GMUs 162, 166 and 175 in Washington's Blue Mountains (n=242); northern core 2022 encompasses the Department's current monitoring effort (n=125). The 112 days increment provides a direct comparison for Johnson and Northern Core but was not available for Myers. The black dashed line represents the estimated 0.136 annual survival rate of the northern core during our 2021-2022 monitoring effort.

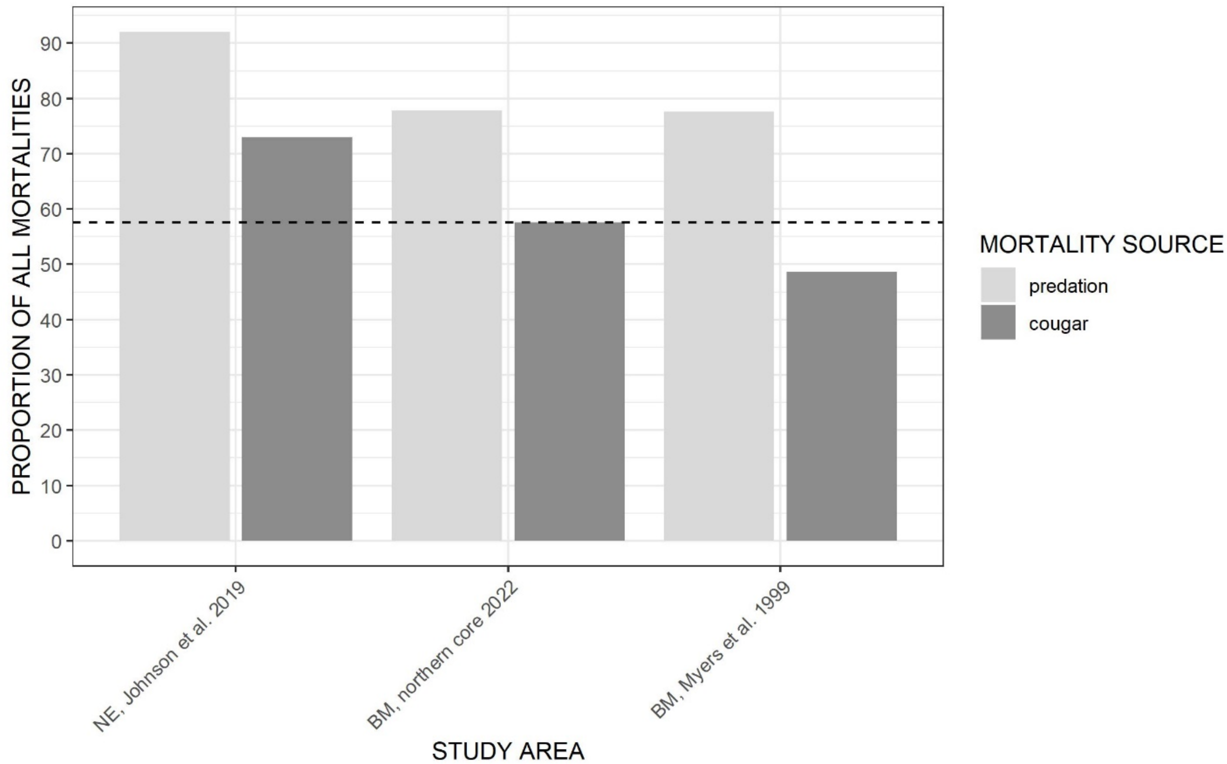

Figure 26. Proportion of total mortalities of juvenile elk attributed to predation and cougar for three research efforts: 1) Johnson et al. 2019 encompasses research conducted from 2001-2007 in Northeast study area units (Wenaha and Sled Springs) located in Oregon's Blue Mountains (n= 360); Myers et al. 1999 encompasses research conducted from 1992-1997 in predominately GMUs 162, 166 and 175 in Washington's Blue Mountains (n=242); and the Department's current monitoring effort in Washington's Blue Mountains northern core during 2021-2022 (n=125). The dashed black line represents the 57.6%of cougar mortalities documented in the northern core (% of all documented mortalities). (The Department's monitoring is ongoing as of March 2022, therefore this does not represent a final annual estimate).

Monitoring conclusions

Our single season of calf monitoring occurred when the study area experienced drought, wildfire, and a severe hemorrhagic disease outbreak in ungulates. Even in this relatively straightforward monitoring effort, conclusions are complicated by apparent differences in survival of juvenile elk among GMUs and potentially by an interaction between age-at-capture and capture method (i.e., ≤ 3-day old juveniles captured by ground vs. aerial methods).

Despite this complexity, our estimate of overall juvenile elk survival in the northern core of the Blue Mountains elk population is insufficient to achieve population growth or stability. The survival estimates from our monitoring support consideration of management actions to increase juvenile elk survival.

Management Alternatives

The Department's management alternatives will represent a range of reasonable approaches to rebuild the northern core elk population of the Blue Mountains. These alternatives will be developed with concepts identified by best-available science, in accordance with the Department's Game Management and Blue Mountains Elk Herd Plans and maintain the Department's legal requirements as outlined in WAC 220-400 through WAC 220-500 and Revised Code of Washington (*hereafter* RCW) 77.15.245. Alternatives will be considered and evaluated for short and long-term efficacy, designated as 1-3 and 4-10 years, respectively. Alternatives will address principal limiting and contributing factors. Principal limiting factors are those items identified in the "at-risk' assessment and potentially have a direct impact on elk population performance. Contributing limiting factors have an indirect negative impact on elk population performance.

The "at-risk' assessment identified poor recruitment as limiting population growth, therefore juveniles will be monitored throughout the implementation of all short-term alternatives by either directly measuring juvenile survival (e.g., collaring neonate elk and monitoring through the first year of life) or by inferring juvenile survival with recruitment ratios generated during annual population surveys. Annual survival estimates of greater than 0.35 or recruitment ratios greater than 25 will indicate the potential for population growth.

Status Quo Harvest Management

Elk harvest management:

Adult female survival has the greatest impact on population dynamics and harvest is typically the highest source of adult female elk mortality. As such, the Department incrementally reduced antlerless harvest to promote adult female survival starting in 2017 to its lowest levels in the past 20 years, while maintaining legal requirements to address agricultural damage (i.e., some "damage" harvest still occurred post-2017; see figures 5 & 6 in the Assessment). Maximizing adult female survival through harvest management is an essential component of the Department's strategy to rebuild of the northern core elk population.

As such, status quo elk harvest management would maintain no recreational harvest of antlerless elk in the northern core until minimum objective levels defined by the Blue Mountains Elk Herd Plan are achieved. During such time, the Department will maintain its legal requirement to address agricultural damage through targeted "damage" harvest (WAC 220-440-200).

Expectation of Success

- Short-term- managing antlerless harvest to promote population growth is unlikely to result in the population achieving objective range (within 10% of 5,500 elk) over the next 1-3 years. The mechanism resulting in consistently low juvenile recruitment, as seen since 2017, is not addressed by adult female elk harvest management. Assuming high (i.e., >90%) survival of adult female elk, population growth is still unachievable with juvenile recruitment ratios below 25:100 or annual juvenile survival below ~30%.

- Long-term- managing antlerless harvest to promote population growth when considering a 5 – 10-year timeframe has a higher likelihood of being successful. As discussed in the Assessment, juvenile survival can be highly variable. Low recruitment ratios have been documented in the past, and the population eventually rebounded, although not without intervention by the Department (e.g., addressing poor age structure of bulls to synchronize birth pulse).

Carnivore harvest management:

During the time the risk-assessment was conducted, all carnivores, except for wolf, were hunted during regulated hunting seasons. The Blue Mountains area is located within Black Bear Management Unit 8. Black bear hunts occurred in spring (April 15-June 15; under a spring special permit) and fall (August 01 – November 15, under a general fall season) during 2021. Harvest estimates show an average of 99 black bears harvested for spring (special permit) and fall (general season) annually (2002-2020). The spring black bear special permit season harvest is relatively consistent over time and the fall general season harvest exhibits cyclical highs and lows. The cougar season is open 8 months annually from September 1 through April 30 of the following year; thus, crossing two license years. The Department uses a harvest guideline system to manage cougar harvest at a population management unit level (PMU). Three PMUs comprise the entire Blue Mountains. Harvest estimates show an average of 22 cougars harvested annually (2013-2021) across the three PMUs. The current range for harvest is 18-26 cougars combined for the three PMUs. Cougar mortality rates vary in the GMUs assessed, ranging from below 12% to an average of 32% (based on original density estimates) over the past 9 seasons. Wolves are a protected species in Washington and no regulated hunting occurs. Maintaining viable carnivore populations while offering recreational opportunities is a primary focus of the Department's carnivore management efforts.

Status quo carnivore harvest management would maintain the current regulated hunting framework and harvest guidelines for a fall black bear general season (WAC 220-415-090) and a cougar season (WAC 220-415-100). In addition, the Commission could consider retaining a spring black bear special permit hunt (WAC 220-415-080) within the identified GMUs. A two black bear bag limit and a single cougar bag limit would remain. During such time, the Department will maintain its legal requirement to address damage/public safety through non-hunting removals of black bears or cougars (WAC 220-440-050 and WAC 220-440-060).

Expectation of Success

- Short-term- remaining status quo postpones any changes to cougar and bear harvest which would allow additional time to conduct aerial surveys for elk and further elk calf capture/collaring events beyond a single summer. The added data will further inform the assessment of elk recruitment and production and impact from predation on the elk population. Continual monitoring of these factors many provide mechanisms to understand the problems at scales that are more applicable to specific management actions. Maintaining status is likely to result in continued juvenile elk mortalities and poor juvenile elk recruitment.

- Long-term- current data does not indicate bears as being a primary cause of elk calf mortality. Remaining status quo would provide the ability to detect any changes in the role black bears may have in juvenile elk mortality. It is unknown the extent to which the potential elimination spring black bear special permits may influence the level of black bear caused calf mortality. Current data suggest cougars as the primary predator on juvenile elk. The current cougar harvest guidelines were adjusted beginning in 2020 in an attempt to increase cougar harvest. Leaving the current harvest guidelines in place will allow additional time to determine the effect of the recent changes on the cougar population while allowing for additional inferences and certainty around cougar-specific predation rates.

ADAPTIVE MANAGEMENT

Considerations for an adaptive management approach for the Blue Mountains elk population: Cougar population management actions

Adaptive management allows the department an opportunity to use the scientific method as a process to understand specific wildlife management problems at appropriate scales. This mechanism incorporates existing knowledge to develop and test hypotheses through implementing treatments and monitoring outcomes. Proposed management actions under the adaptive management approach allows for time-specific implementation, monitoring, and evaluation. Based on the risk-assessment, bear and wolf were not identified as principal sources of juvenile elk mortality; therefore, management alternatives are focused on cougar.

Alternatives for adaptive “non-status quo” cougar management actions, include the following:

1) maintain or seek to improve cougar population spatial dynamics
2) increase mortality and reduce the resident cougar population

Maintain cougar population spatial dynamics:

Promote resident territories

Reinstate the original harvest guidelines developed for the PMUs that encompass the Blue Mountains. Cougar habitat across the Blue Mountain GMUs suggests connectivity and continuity; likely enabling cougar movement and dispersals across the area. In areas with adequate prey, cover, and permanency, cougar populations can remain robust, even with high levels of mortality, due to reproduction and immigration. Decreasing the level of cougar mortality to maintain spatial dynamics of the resident cougar population with the intent to reduce immigration, increase rates of emigration by subadults and transients, and reduce predation on elk calves (Newby et al. 2013, Elbroch et al. 2016). Decreasing cougar mortality may elicit a response where male cougars exhibit territoriality and defend female cougars while females defend food resources (Elbroch et al. 2016). Based on the initial efforts in developing the cougar harvest guidelines the level of allowable harvest was less than is currently occurring.

Expectation of Success

- Short-term- attempt to shift the existing cougar population toward an older age population to reduce immigration, promote emigration. This action would allow harvest to mimic the cougar intrinsic growth rate which would attempt to maintain lower cougar numbers in the area and minimize variability in predation. This will not increase juvenile elk survival in the short-term and will likely be similar to status quo.

- Long-term- through stabilizing the resident population, emigration into other surrounding GMUs should occur and harvest guidelines would be met in those GMUs. Implementation of this effort should be considered at the larger PMU scale to effectively influence the resident cougar population. Additionally, trend data would be available to determine if elk calf mortality and survival are responding to maintaining an older age structure in the cougar population. It is unclear how this regulation of the cougar population will affect juvenile elk survival since we do not know what the current cougar age structure is.

Translocation removals (note: this strategy is further considered below under cougar population reduction)
Another action which could be implemented to maintain stability to the resident cougar population is to use non-lethal measures such as capture and translocation (i.e., purposefully move an animal out of its home range within one population and move it into a different location outside of its home range in another population). The primary focus would be on capturing and translocating subadult cougars to maintain resident adult cougars in the area. The benefit of translocating subadults is that they are more likely than adult male cougars to remain within the area of translocation. Leaving the adult males in their range allows for behavioral defense of the area. There are a number of logistical concerns with translocation efforts which include, but are not limited to: 1) the ability to capture cougars without the use of dogs, unless this was a fully vetted research project where dogs may be deployed, 2) ensuring capture of full family groups or pre-determining sex and age classes of cougars suitable for translocation, 3) the logistics for transport and the measurable risks for personnel and cougars in transport, 4) finding suitable release locations that are less likely to create collateral impacts on people, other cougars, or wildlife species in the area of release, 5) animal welfare concerns associated with disoriented cougars seeking suitable prey, habitats, and perhaps attempting to return to point of origin, and 6) requiring public notice and hearing prior to action by department staff if the action is intended as population enhancement (per RCW 77.12.266); which is the most viable justification for release of cougars in areas previously unoccupied or sparsely occupied by cougars.

Expectation of Success

- Short-term- the assumption is that reducing cougar numbers will increase juvenile elk survival. Removing cougars from the affected Blue Mountains GMUs will reduce cougar numbers initially and likely for a short period of time. However, like harvest removals, the habitat vacated by the translocated cougar will become viable habitat for an immigrating cougar and is likely to be occupied within 1-3 years depending upon the level of cougar removals. In addition, the translocated cougars are not likely to stay where they are released, adult cougars (particularly males) exhibit considerable home range fidelity and are likely to return (Ruth et al. 1998) and both adults and subadults are likely to have encounters with people, vehicles, and other cougars as they navigate unfamiliar terrain.

- Long-term- not unlike removals through regulated harvest, continual removals are likely to be necessary after the initial effort. Creating an area with high cougar removal through translocation will allow adjacent areas to act as source populations to the removal area. The ability to use translocation long-term is limited by suitable recipient locations, cost, and resources required to successfully conduct this effort. Over time translocations are likely less effective than a regulated harvest action, even with reduced level of take from harvest.

Decrease the resident cougar population:

A few different methods could be implemented to reduce the resident cougar population within the affected Blue Mountain GMUs or the 3 PMUs that comprise the core area for the Blue Mountains elk herd. Actions such as increasing legal harvest, department removals, and translocation are all methods used by wildlife management agencies. The GMP outlines that management actions would be directed at either individuals or populations and managed through recreational hunting and predator removal. The GMP further defined predator removals as occurring through 1) licensed hunters or trappers, 2) professional contractors (such as USDA Wildlife Services) monitored and supervised by WDFW, and 3) department staff. Under RCW 77.12.240 the department can remove or kill wildlife when it is necessary for wildlife management or research. However, RCW 77.15.245 limits the methods and circumstances by which the department is authorized to remove cougars. No dogs may be used when the removal action is not for property protection, public safety, research, or protection of endangered or threatened species. Although, the use of dogs is an effective management tool, without substantive changes to the laws, this option for reducing cougar populations within the affected area of the Blue Mountains can only be attempted through increasing the regulated harvest of cougars in those GMUs, capture and lethally remove, or capture and translocate cougars to an area outside of the feasible ranges of the affected Blue Mountains GMUs. Any attempt to reduce cougar densities should be implemented under a specified timeframe, have measurable predictions, and include monitoring and evaluation of the management action(s). The option exists to implement a single management action or a combination of management actions. Management actions may need to be modified or concluded based upon the evaluation. The scale and length of time at which the management actions are applied is critical for strengthening the ability to succeed.

Harvest removals

There are several actions to consider for direct cougar removals through harvest. All actions should only be considered for a short period of time before re-assessing. The objective is to grow the elk population rather than focus on a specific level of predator-caused mortality. Therefore, these management actions are recommended initially for 3-consecutive years. To promote increased harvest removals the option is to liberalize the cougar season within the PMUs or specific GMUs of the Blue Mountains. All these options are intended to be short-term actions that attempt to increase juvenile elk survival. One or more of the actions may be considered for implementation. If these strategies prove effective in reducing cougar densities in the short-term, we should see a corresponding increase in juvenile elk survival. It is unclear what the long-term effect is going to be, and continued monitoring will be essential.

This action may be achieved through:

1) eliminating the harvest guidelines for those specific GMUs (162, 166, 175) where cougar-caused juvenile elk mortality is high,
2) eliminating the harvest guidelines for all 3 PMUs that encompass the Blue Mountains,
3) increase the bag limits to two cougars within the affected GMUs or across one or more of the 3 PMUs,
4) increase the general season length to include May,
5) offer a limited spring special permit hunt during the month of May within those affected GMUs or one or more of the 3 PMUs to encourage harvest just prior to elk calving and the summer pulse in cougar kitten production,
6) offer an add on cougar tag for spring turkey or bear hunters in GMUs 162, 166, and 175

Expectation of Success

- Short-term- attempts to reduce the cougar population within the affected Blue Mountain GMUs will require intense effort to increase regulated harvest. The difficulty will be the ability to incentivize hunters to harvest at a higher rate than is currently occurring. This rate needs to be high enough to offset immigration into the newly void habitat. Increasing pressure on cougars through increased harvest should increase juvenile elk survival.

- Long-term- continual removals at the increased level or slightly lower will likely be necessary after the first initial effort to prevent the cougar population from recovering to the preexisting level. Monitoring elk calf mortality during active cougar removals will be required to determine if there is an increase in juvenile elk survival. Long-term, continuous manipulation and removals of cougars in the affected and perhaps the adjacent GMUs is likely to provide ample time for the elk herd to indicate a response.

Cougar capture and lethal removal

Attempts to reduce the cougar densities in the Blue Mountains may occur through live capture (using cage traps) and humane removal of individual cougars. The target the demographic would be female and subadult cougars to avoid an influx of younger male cougars attempting to establish residency. Due to the confounding effect of immigration this management action will require a sustained effort to suppress the cougar population density enough to influence a positive response in elk calf survival and recruitment. An intensive effort is required to run trap lines, capture enough cougars, and remove captured cougars. This action could be achieved through collaboration with contract services to capture cougars. Lethal removal would require agency response.

Expectation of Success

- Short-term- Department personnel would be required to implement this management action. Like harvest, the capture rate needs to be high to elicit a response of juvenile elk survival. The difficulty in the short term will be deploying enough traps to capture ample numbers of cougars due to limited availability for suitable conditions (i.e., terrain and accessibility). This management action is likely to be less successful in the short term as a stand-alone action than regulated harvest. If combined with regulated harvest this management action would be more effective in the short-term.

- Long-term- this effort will likely require continual removals over a longer duration to suppress the cougar population and elicit an effective response in juvenile elk. The difficulty will be the ability to maintain the appropriate level of personnel to implement a continual removal effort that will offset immigration of cougars long-term. If continuous manipulation can be achieved over time a positive response should be observed in juvenile elk survival. This management action is not likely to be sustained over a long period without increasing personnel capacity, which may include contracting or hiring additional labor.

Translocation removals
As stated earlier, under Maintain Cougar Population Stability, a non-lethal measure such as capture and translocate could be used to decrease the resident cougar population. The primary focus would be on capturing and translocating subadult cougars and females with kittens. Both subadults and females with kittens are more likely than adult male cougars to remain within the area of translocation. The same logistical concerns and expectations of success as previously listed would apply.

Expectation of Success

- Short-term- the assumption is that reducing cougar numbers will increase juvenile elk survival. Certainly, removing cougars from the affected Blue Mountains GMUs will reduce cougar numbers initially and likely for a short period of time. However, like harvest removals, the habitat vacated by the translocated cougar will become viable habitat for an immigrating cougar and is likely to be occupied within 1-3 years depending upon the level of cougar removals. In addition, the translocated cougars are not likely to stay where they are released, adult cougars (particularly males) exhibit considerable home range fidelity and are likely to return (Ruth et al. 1998) and both adults and subadults are likely to have encounters with people, vehicles, and other cougars as they navigate unfamiliar terrain.

- Long-term- not unlike removals through regulated harvest, continual removals are likely to be necessary after the initial effort. Creating an area with high cougar removal through translocation will allow adjacent areas to act as source populations to the removal area. The ability to use translocation long-term is limited by suitable recipient locations, cost, and resources required to successfully conduct this effort. Over time translocations are likely less effective than a regulated harvest action, even with reduced level of take from harvest.

Additional considerations for long-term management of the Blue Mountains elk population: monitoring nutritional condition and augmenting current habitat management activities

As discussed in the Assessment, many factors can influence the dynamics of elk populations. Weather and forage availability can contribute to and influence ungulate survival and population levels. Bottom-up factors, like forage quality and availability, influence the nutritional condition of elk. Nutritional condition then influences prime-aged female survival and pregnancy rates and juvenile survival. Reduced pregnancy rates of prime-aged adult females must be offset by higher juvenile survival to achieve juvenile recruitment necessary for population growth, therefore nutrition can be a principal limiting factor. Secondarily, displacement or stress of prime-age adult females and juvenile elk resulting from disturbance is negatively associated with nutritional condition and can be a contributing limiting factor.

While our juvenile elk monitoring and aerial survey data suggest population declines are a function of poor juvenile recruitment (with predation as the largest source of mortality), a better understanding of nutritional limitations, if any, experienced by the Blue Mountains elk herd may assist in the long-term management of this population. Similarly, the Blue Mountains elk herd may benefit from management activities that address factors known or suspected to influence nutritional condition.

Nutritional condition monitoring is best achieved by capturing elk (typically adult females) to directly measure condition metrics (e.g., fat depth). While in-hand, we would determine pregnancy and lactation status and place a GPS collar on the adult female. Individual condition data allow managers to make inference about nutritional limitations, if any, experienced by the population. Pregnancy rate provides insight into productivity. Data from GPS collars can be used to develop habitat use models (e.g., to identify parturition and juvenile rearing habitat) that can inform management activities (e.g., habitat improvement). Taken together, monitoring of juvenile and adult female survival and quantifying pregnancy rate, nutritional condition, and habitat use can provide managers with considerable insight into factors that may be limiting the growth of the Blue Mountains elk population. That insight, however, will come at great expense and resource commitment. Augmenting our current monitoring efforts will have no near-term influence on population growth.

Habitat and recreation management throughout the Blue Mountains has been consistent and increasing over the last 25 to 30 years but is often limited to public lands owned by the United States Forest Service, Washington Department of Natural Resources, and the Department. As identified in the Department's Blue Mountains Elk Herd Plan, private lands contain critical elk habitat in the herd area but management of these lands is outside the Department's control. As such, the Department strives to maintain elk on public lands where feasible. Maintaining elk on public lands not only maximizes recreational access to elk, but also reduces crop damage issues on private lands.

To facilitate elk use of public lands, the Department is committed to: improving habitat quality through weed control (a major threat to elk habitat); maintaining security habitat through road-use management; regulating and mitigating late-winter disturbance (e.g., shed hunting); and working with other public land managers (listed above) to maintain or improve elk habitat and forest health. The Department is also committed to working with private landowners, where feasible, to benefit elk through: cost sharing critical winter range habitat projects with private landowners (e.g., through the Blue Mountains Elk Initiative and increased Private Lands Biologist activity related to elk habitat improvement); and working with private landowners to mitigate elk conflict and increase social tolerance of elk on private lands. Continued habitat and recreation management activities will benefit the Blue Mountains elk population, but those benefits are unlikely to result in near-term population growth.

MANAGEMENT DIRECTION

The Department's management priority is to increase juvenile elk (i.e., calves) survival in the near-term (i.e., 1-3 years) to increase recruitment and, ultimately, population abundance. Outlined above, the management alternatives available to the Department vary in their likelihood of success in promoting increased elk calf survival. Based on our elk calf monitoring, management actions that reduce the cougar predation rate are most likely to achieve an increase in calf survival. The most feasible strategy to reduce cougar predation on elk calves in the near-term is to reduce the resident cougar population. A reduction in the cougar population may be achieved through actions authorized under the Director's authority and/or through modified hunting seasons or bag limits, the latter contingent on the Department's rule-making process.

Literature Cited

Anderson, E.W., and R.J. Scherzinger. 1974. Improving quality of winter forage for elk by cattle grazing. Journal of Range Management 28:120-125.

Bates, S.B., J.C. Whiting, R.T. Larsen. 2021. Comparison effects of shed antler hunting and helicopter surveys on ungulate movements and space use. Journal of Wildlife Management 85:437-448.

Barber-Meyer, S.M., D.L. Mech, P.J. White. 2008. Elk calf survival and mortality following wolf restoration to Yellowstone National Park. Wildlife Monographs. 169:1-30.

Bender, L.C. 2006. Uses of herd composition and age ratios in ungulate management. Wildlife Society Bulleting 34:1225-1230.

Beausoleil, R. A., L. S. Welfelt, I. N. Keren, B. N. Kertson, B. T. Maletzke and G. M. Koehler. 2021. Long-Term Evaluation of Cougar Density and Application of Risk Analysis for Harvest Management. Journal of Wildlife Management 85(3):462–473.

Biggs, J. R., Dawn M. VanLeeuwen, Jerry L. Holechek, Raul Valdez "Multi-Scale Analyses of Habitat Use by Elk Following Wildfire," Northwest Science, 84(1), 20-32, (1 January 2010)

Brodie, J., H. Johnson, M. Mitchell, P. Zager, K. Proffitt, M. Hebblewhite, M. Kauffman, B. Johnson, J. Bissonette, C. Bishop, J. Gude, J. Herbert, K. Hersey, M. Hurley, P. M. Lukacs, S. McCorquodale, E. McIntire, J. Nowak, H. Sawyer, D. Smith, P. J. White. 2013. Relative influence of human harvest, carnivores, and weather on adult female elk survival across western North America. Journal of Applied Ecology. 50:295-305.

Brown, J. H. and W. McDonald. 1995. Livestock grazing and conservation on southwestern rangelands. Conservation Biology. 9(6):1644-1647

Buchanan, C. B., J. L. Beck, T. E. Bills, S. N. Miller. 2014. Seasonal resource selection and distributional response by elk to development of a natural gas field. Rangeland Ecol Manage 67:369-379.

Chitwood, M.C., M.A. Lashley, C.S. DePerno, C.E. Moorman. 2017. Considerations on neonate ungulate capture method: potential for bias in survival estimation and cause-specific mortality. Wildlife Biology 2017: wlb.00250

Ciuti, S., J. M. Northrup, T. B. Muhly, S. Simi, M. Musiani, J. A. Pitt, and M. S. Boyce. 2012. Effects of humans on behavior of wildlife exceed those of natural predators in a landscape of fear. PLos ONE 7(11): e50611. doi:10.1371 / journal. pone. 0050611.

Clark, J. D. 1999. Black bear population dynamics in the Southeast: some new perspectives on some old problems. Eastern Black Bear Workshop Proceedings 15:97–115.

Clark, D. A. 2014. Implications of cougar prey selection and demography on population dynamics of elk in northeast Oregon. Dissertation, Oregon State University, Corvallis, USA.

Clark, P.E., W.C. Krueger, L.D. Bryant, and D.R. Thomas. 2000. Livestock grazing effects on forage quality of elk winter range. Journal of Range Management 53:97-105.

Clark, P.E., W.C. Krueger, L.D. Bryant, and D.R. Thomas. 1998a. Spring defoliation effects on bluebunch wheatgrass: I Winter forage quality. Journal of Range Management 51:519-525.

Clark, P.E., W.C. Krueger, L.D. Bryant, and D.R. Thomas. 1998b. Spring defoliation effects on bluebunch wheatgrass: II Basal area. Journal of Range Management 51:526-530.

Coe, P.K., B.K. Johnson, K.M. Stewart, and J.G. Kie. 2005. Spatial and temporal interactions of elk, mule deer, and cattle. Pages 150-158 in The Starkey Project: a synthesis of long-term studies of elk and mule deer. M.J. Wisdom (editor). Alliance Communications Group, Lawrence, Kansas.

Conner, M. M., G. C. White, and D. J. Freddy. 2001. Elk movement in response to early season hunting in northwest Colorado. Journal of Wildlife Management 65:926–940.

Cook, J. G., B. K. Johnson, R. C. Cook, R. A. Riggs, T. DelCurto, L. D. Bryant, and L. L. Irwin. 2004. Effects of summer-autumn nutrition and parturition date on reproduction and survival of elk. Wildlife Monographs 155.

Cook, R. C., J. G. Cook, D. J. Vales. B. K. Johnson, S. M. McCorquodale, L. A. Shipley, R. A. Riggs, L. L. Irwin, S. L. Murphie, B. L. Murphie, K. A. Schoenecker, F. Geyer, P. B. Hall, R. D. Spencer, D. A. Immell, D. H. Jackson, B. L. Tiller, P. J. Miller, L. Schmitz. 2013. Regional and seasonal patterns of nutritional condition and reproduction in elk. Wildlife Monographs. 184:1-44.

Dalén, L., Götherström, A., & Angerbjörn, A. (2004). Identifying species from pieces of faeces. Conservation genetics, 5(1), 109-111.

Danvir, R.E. and S.L. Kearl. 1996. A holistic approach to managing wildlife and big game movements with livestock: the Lost Creek Foundation. Pages 65-69 *in* Sharing common ground on western rangelands: Proceedings of a livestock/big game symposium. U.S.D.A. Forest Service, Intermountain Research Station, Ogden, Utah.

Davidson, G. A., Clark, D. A., Johnson, B. K., Waits, L. P., & Adams, J. R. (2014). Estimating cougar densities in northeast Oregon using conservation detection dogs. The Journal of Wildlife Management, 78(6), 1104-1114.

Dennison, P.E., Brewer, S.C., Arnold, J.D. and Moritz, M.A. 2014 Large wildfire trends in the western United States, 1984–2011. Geophys. Res. Lett. 41, 2928–2933.

Diaz, H. F., J. K. Eischeild. 2007. Disappearing “alpine tundra” Koppen climatic type in the western United States. Geophysical research letters. 34: L18707. 4 pp.

Dzialak, M. R., S. M. Harju, R. G. Osborn, J. J. Wondzell, L. D. Hayden-Wing. 2011. Prioritizing conservation of ungulate calving resources in multiple-use landscapes. PLoS One 6(1): e14597. Doi: 10.1371/journal.pone.0014597

Eacker, D. R., M. Hebblewhite, K. M. Proffitt, B. Jimenez, M. S. Mitchell, and H. S. Robinson. 2016. Landscape-level effects of risk factors on annual elk calf survival in a multiple carnivore system. The Journal of Wildlife Management 80: 1345-1359.

Edge, W.D. and C.L. Marcum. 1990. Elk and cattle on public lands: A new look at an old conflict. Western Wildlands, Summer:12-15.

Elbroch, L. M., Lendrum, P. E., Newby, J., Quigley, H., & Craighead, D. (2013). Seasonal foraging ecology of non-migratory cougars in a system with migrating prey. *PLoS One*, *8*(12), e83375.

Elbroch, L. M., Lendrum, P. E., Quigley, H., & Caragiulo, A. 2016. Spatial overlap in a solitary carnivore: support for the land tenure, kinship or resource dispersion hypotheses?. Journal of Animal Ecology, 85(2), 487-496.

Elbroch, L. M. and H. Quigley. 2019. Age-specific foraging strategies among pumas, and its implications for aiding ungulate populations through carnivore control. Conservation Science and Practice 2019 (1): e23.

Evans, S.B., Mech, L.D., White, P.J. & Sargeant, G.A. (2006) Survival of adult female elk in Yellowstone following wolf restoration. Journal of Wildlife Management, 70, 1372–1378.

Forzley, M. J. 2019. Spatiotemporal covariates, individual characteristics, and mountain lion harvest as potential sources of variation in elk calf survival. Thesis, Montana State University, Bozeman, MT, USA.

Gaillard, J.M., Festa-Bianchet, M., Yoccoz, N.G., Loison, A. & Toigo, C. (2000) Temporal variation in fitness components and population dynamics of large herbivores. Annual Review of Ecology and Systematics, 31, 367–393.

Gaines, W. L., P. H. Singleton, and R. G. Ross. 2003. Assessing the cumulative effects of linear recreation routes on wildlife habitats on the Okanogan and Wenatchee National Forests. U. S. Forest Service General Technical Report PNW-GTR-586. 81 pp.

Ganskopp, D., T. Svejcar, and M. Vavra. 2004. Livestock forage conditioning: bluebunch wheatgrass, Idaho fescue, and bottlebrush squirreltail. Journal of Range Management 57:384-392.

Ganz, T. 2020 predator prey study protocol and elk calf hoof regressions (unpublished).

Garrott, R. A. L. L. Eberhardt, P. J. White, and J. J. Rotella. 2003. Climate-induced variation in vital rates of an unharvested large-herbivore population. Canadian Journal of Zoology 81: 33-45.

Garrott, R. A., J. A. Gude, E. J. Bergman, C. Gower, P. J. White, and K. L. Hamlin. 2005. Generalizing wolf effects across the Greater Yellowstone Area: a cautionary note. Wildlife Society Bulletin 33: 1245-1255.

Garrott, R. A., P. J. White, and J. J. Rotella. 2008. The Madison headwaters elk herd: transitioning from bottom-up regulation to top-down limitation. Pages 489-518 in R. A. Garrott, P. J. White, and F. G. R. Watson, editors. The ecology of large mammals in central Yellowstone: 16 years of integrated studies. Academic Press, New York, New York, USA.

Gilbert, S.L., M.S. Lindberg, K.J. Hundertmark, D.K. Person. 2014. Dead before detection: addressing the effects of left truncation on survival estimation and ecological inference for neonates. Methods in Ecology and Evolution. 5, 992-1001.

Grover, K.E., and M.J. Thompson. 1986. Factors influencing spring feeding site selection by elk in the Elkhorn Mountains, Montana. Journal of Wildlife Management 50:466-470.

Griffin, K.A., Hebblewhite, M., Robinson, H.S., Zager, P., Barber-Meyer, S.M., Christianson, D. Creel, S., Harris, N.C., Hurley, M.A., Jackson, D.H., Johnson, B.K., Mech, L.D., Myers, W.L., Raithel, J.D., Schlegel, M., Smith, B.L., White, C.G. & White, P.J. 2011. Neonatal mortality of elk driven by climate, predator phenology and predator community composition. Journal of Animal Ecology, 80, 1246–1257.

Hatter, I. W. 2020. Revisiting the recruitment-mortality equation to assess moose growth rates. Alces, 56:39-47

Hebblewhite, M., D. H. Pletscher, and P. C. Paquet. 2002. Elk population dynamics in areas with and without predation by recolonizing wolves in Banff National Park, Alberta. Canadian Journal of Zoology 80: 789-799.

Hebblewhite, M., E. H. Merrill, and T. L. McDonald. 2005. Spatial decomposition of predation risk using resource selection functions: an example in a wolf-elk predator-prey system. Oikos 111: 101-111.

Heydlauff, A. L., P.R. Krausman, W.W. Shaw, and S. E. Marsh. 2006.Perceptions regarding elk in northern Arizona. Wildlife Society Bulletin 34:27–35.

Holechek, J.L. 1980. Concepts concerning forage allocation to livestock and big game. Rangelands 2:158- 159.

Horne, J.S., M.A. Hurley, C.G. White, J. Rachael. 2019. Effects of wolf pack size and winter conditions on elk mortality. Journal of Wildlife Management 83:1103-1116.

Hurley M. A., M. Hebblewhite, J. M. Gaillard, S. Dray, K. A. Taylor, W. K. Smith, P. Zager, and C. Bonenfant. 2014. Functional analysis of normalized difference vegetation index curves reveals overwinter mule deer survival is driven by both spring and autumn phenology. Philosophical Transactions of the Royal Society Bulletin. 369.

Husseman, J. S., D. L. Murray, G. Power, C. Mack, C. R. Wenger, and H. Quigley. 2003. Assessing differential prey selection patterns between two sympatric large carnivores. Oikos 101: 591-601.

Johnson, B. K., P. K. Coe, and R. L. Green. 2013. Abiotic, bottom-up, and top-down influences on recruitment of Rocky Mountain elk in Oregon: a retrospective analysis. The Journal of Wildlife Management 77: 102-116.

Johnson, B.K., D.H. Jackson, R.C. Cook, D.A. Clark, P.K. Coe, J.G. Cook, S.N. Rearden, S.L. Findholt, and J.H. Noyes. 2019. Roles of maternal condition and predation in survival of juvenile elk in Oregon. Wildlife Monographs 201:3-60

Johnson, B. K., J. W. Kern, M. J. Wisdom, S. L. Findholt, and J. G. Kie. 2000. Resource selection and spatial separation of mule deer and elk during spring. Journal of Wildlife Management 64:685-697

Johnson, D.E. 1951: Biology of the elk calf Cervus canadensis nelson. - Journal of Wildlife Management 15: 396-410.

Kautz, T. M., J. L. Belant, D. E. Beyer Jr. B. K. Strickland, J. F. Duquette. 2018. Influence of body mass and environmental conditions on winter mortality risk of a northern ungulate: Evidence for late-winter survival bottleneck. Ecology and Evolution. 10:1666-1677.

Knowles, N. M. D. Dettinger, D. R. Cayan. 2006. Trends in snowfall versus rainfall in the western United States. Journal of Climate. 19:4545-4559.

Kohl, M. T., T. K. Ruth, M. C. Metz, D. R. Stahler, D. W. Smith, P. J. White, and D. R. MacNulty. 2019. Do prey select for vacant hunting domains to minimize a multi-predator threat? Ecology Letters (2019) doi: 10.1111/ele.13319.

Kuck, L., G. H. Hompland, and E. H. Merrill. 1985. Elk calf response to simulated mine disturbance in southeast Idaho. Journal of Wildlife Management 49:751-757. Millspaugh, J. J., R. J. Woods, K. E. Hunt, K, J. Raedeke, G. C. Brundige, B. E.

Kunkel, K. E., T. K. Ruth, D. H. Pletscher, and M. G. Hornocker. 1999. Winter prey selection by wolves and cougars in and near Glacier National Park, Montana. The Journal of Wildlife Management 63: 901-910.

Krausman, P. R., D. E. Naugle, M. R. Frisina, R. Northrup, V. C. Bleich, W. M. Block, M. C. Wallace, and J. D. Wright. 2009. Livestock grazing, wildlife habitat, and rangeland values. Society for Range Management 31(5) 15-19 https://doi.org/10.2111/1551-501X-31.5.15

Linnell, J. D. C., R. Aanes, and R. Andersen. 1995. Who killed bambi? The role of predation in neonatal mortality of temperate ungulates. Wildlife Biology 1: 209-223.

Loison, A., R. Langvatn, E. J. Solberg. 1999. Body mass and winter mortality in red deer calves: disentangling sex and climate effects. Ecography 22:20-30.

Luce, C. H. and Z. A. Holden. 2009. Declining annual streamflow distributions in the Pacific Northwest, United States, 1948-2006. Geophysical research letters. 36: L16401. 6 pp.

Lukacs, P.M., M. S. Mitchell, M. Hebblewhite, B.K. Johnson, H. Johnson, M. Kauffman, K.M. Proffitt, P. Zager, J. Brodie, K. Hersey, A.A. Holland, M. Hurley, S. McCorquodale, A. Middleton, M. Nordhagen, J.J. Nowak, D.P. Walsh, and P.J. White. 2018. Factors influencing elk recruitment across ecotypes in the Western United States. The Journal of Wildlife Management 10:698-710.

Mackie, R.J. 1970. Range ecology and relations of mule deer, elk and cattle in the Missouri River breaks, Montana. Wildlife Monograph 20. 79 pp.

Messier, F. 1994. Ungulate population models with predation: a case study with the North American moose. Ecology 75: 478-488.

McCorquodale, S.M., P.A. Wik, P.E. Fowler. 2011. Elk survival and mortality causes in the Blue Mountains of Washington. The Journal of Wildlife Management 75:897-904

McCorquodale, S.M., S.M. Knapp, M.A. Davison, J.S. Bohannon, C.D. Danilson, W.C Madsen. 2013. Mark-resight and sightability modeling of a western Washington elk population. The Journal of Wildlife Management 77(2):359-371.

Middleton, A. D., M. J. Kauffman, D. E. McWhirter, J. G. Cook, R. C. Cook, A. A. Nelson, M. D. Jimenez, R. W. Klaver. Animal migration amid shifting patterns of phenology and predation: lesson from a Yellowstone elk herd. Ecology. 94(6):1245-1256.

Millspaugh, J. J., R. J. Woods, K. E. Hunt, K, J. Raedeke, G. C. Brundige, B. E. Washburn, and S. K. Wasser. 2001. Fecal glucocorticoid assays and the physiological stress response in elk. Wildlife Society Bulletin 29:899-907.

Millspaugh, J. J., B. E. Washburn. 2004. Use of fecal glucocorticoid metabolite measures in conservation biology research: considerations for application and interpretation. General and Comparative Endocrinology 138:189-199.

Montgomery, R. A., G. J. Roloff, J. J. Millspaugh. 2012. Importance of visibility when evaluating animal response to roads. Wildl. Biol. 18:393-405.

Morris, W. F., and D. F. Doak. 2002. Quantitative Conservation Biology, Sinauer Associates, Sunderland, MA. Raithel, J., Kauffman, M. and D. Pletscher. 2007. Impact of spatial and temporal variation in calf survival on the growth of elk populations. Journal of Wildlife Management, 71, 795–803.

Morrison TA, Merkle JA, Hopcraft JGC, et al. Drivers of site fidelity in ungulates. Journal of Animal Ecology. 2021; 90:955–966.

Murphy, M. A., Waits, L. P., & Kendall, K. C. (2000). Quantitative evaluation of fecal drying methods for brown bear DNA analysis. Wildlife Society Bulletin, 951-957.

Myers, W.L., B. Lyndaker, P.E. Fowler, and W. Moore. 1999. Investigations of calf elk mortalities in southeast Washington Final Federal Aid to Wildlife. Restoration report PR Project WW-96-R. Olympia, Washington. 21 pp.

Newby, J. R., L. S. Mills, T. K. Ruth, D. H. Pletscher, M. S. Mitchell, H. B. Quigley, K. M. Murphy, R. Desimone. 2013. Human-caused mortality influences spatial population dynamics: Pumas in landscapes with varying mortality risks. Biological Conservation. 159:230–239.

Naylor, L. M., M. J. Wisdom, and R. G. Anthony. 2009. Behavioral responses of North American elk to recreational activity. Journal of Wildlife Management 73:328-338.

Parker, K. L., P. S. Barboza, M. P. Gillingham. 2009. Nutrition integrates environmental response of ungulates. Functional Ecology. 23:57-69.

Pederson, G. T., L. J. Graumalich, D. B. Farge, T. Kipfer, C. C. Muhlfeld. 2009. A century of climate and ecosystem change in western Montana: what do temperature trends portend? Climatic Change. 98:133-154.

Pettorelli, N., S. Ryan, T. Mueller, N. Bunnefeld, B. Jedrzejewska, M. Lima, K. Kausrud. 2011. The Normalized Difference Vegetative Index (NDVI): unforeseen successes in animal ecology. Climate Research. 46:15-27

Post, E. & M. C. Forchhammer. 2007. Climate change reduces reproductive success of an Arctic herbivore through trophic mismatch. Philosophical Transactions of the Royal Society Bulletin. 363:2369-2375.

Phillips, G. E., and A. W. Alldredge. 2000. Reproductive success of elk following disturbance during calving season. Journal of Wildlife Management 64:521-530.

Proffitt, K. M., B. Jimenez, C. Jourdonnais, J. A. Gude, M. Thompson, M. Hebblewhite, and D. R. Eacker. 2015. Evaluating bottom-up and top-down effects on elk survival and recruitment in the southern Bitterroot Valley, Montana. Final Report, Montana Fish Wildlife and Parks, Helena, USA.

Proffitt, K. M., J. DeVoe, K. Barker, R. Durham, T. Hayes, M. Hebblewhite, C. Jourdonnais, P. Ramsey, J. Shamhart. 2019. A century of changing fire management alters ungulate forage in a wildfire-dominated landscape, Forestry: An International Journal of Forest Research, Volume 92 (5): Pages 523–537.

Proffitt, K. M., R. Garrott, J. A. Gude, M. Hebblewhite, B. Jiminez, J. T. Paterson, J. Rotella. 2020. Integrated carnivore-ungulate management: a case study in west-central Montana Wildlife Monographs 206: 1-28.

Proffitt, K. M., J. L. Grigg, R. A. Garrott, K. L. Hamlin, J. Cunningham, J. A. Gude, and C. Jourdannais. 2010. Changes in elk resource selection and distributions associated with a late-season elk hunt. Journal of Wildlife Management 74:210–218.

Raithel, J. D., M. J. Kauffman, and D. H. Pletscher. 2007. Impact of spatial and temporal variation in calf survival on the growth of elk populations. Journal of Wildlife Management 71:795–803

Reclamation. 2016. West-wide Climate Risk Assessment, Columbia River Basin, Climate Impact Assessment, Final Report. Prepared by the U.S. Department of the Interior. Bureau of Reclamation, Pacific Northwest Regional Office, Boise Idaho. March 2016.

Regonda, S. K., B. Rajagopalan, M. Clark, J. Pitlick. 2004. Seasonal cycle shifts in hydroclimatology over the western United States. Journal of Climate 18:372-384.

Rickbeil, G. J., J. A. Merkle, G. Anderson, M. P. Atwood, J. P. Beckmann, E. K. Cole, A. B. Courtemanch, S. Dewey, D. D. Gustine, M. J. Kauffman, D. E. McWhirter, T. Mong, K. Proffitt, P. J. White, A. D. Middleton. 2019. Plasticity in elk migration timing is a response to changing environmental conditions. Global Change Biology. 25:2368-2381.

R Core Team (2019) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Ruth, T. K., Buotte, P. C., & Hornocker, M. G. 2019. Yellowstone cougars: ecology before and during wolf restoration. University Press of Colorado, Boulder, CO.

Saunders, S., T. Easley, J. A. Logan, T. Spencer. 2006. Losing Ground: Western National Parks Endangered by Climate Disruption. The Rocky Mountain Climate Organization https://www.rockymountainclimate.org/

Sawyer, H., R. M. Nielson, F. G. Lindzey, L. L. McDonald. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. Journal of Wildlife Management 70(2):396-403.

Sawyer, H., R. M. Nielson, F. G. Lindzey, L. Keith, J. H. Powell, and A. A. Abraham. 2007. Habitat selection of Rocky Mountain elk in a non-forested environment. Journal of Wildlife Management 71:868-874.

Sawyer, H. N. M. Korfanta, R. M. Nielson, K. L. Monteith, D. Strickland. 2017. Mule deer and energy development – Long-term trends of habituation and abundance. Glob Change Biol.23:4521-4529.

Scheick. B. K., and W. McCown. 2014. Geographic distribution of American black bears in North America. Ursus 25(1): 24-33.

Sheehy, D., and M. Vavra. 1996. Ungulate foraging areas on seasonal rangeland in northeastern Oregon. Journal of Range Management 49:16-23.

Seidensticker, J. C., M. G. Hornocker, W. V. Wiles, and J. P. Messick. 1973. Mountain lion social organization in the Idaho Primitive Area. Wildlife Monographs 35: 3-60.

Shively, K. J., A. W. Alldredge, and G. E. Phillips. 2005. Elk reproductive response to removal of calving season disturbance by humans. Journal of Wildlife Management 69:1073 -1080.

Skovlin, J.M., P.J. Edgerton, and B.R. McConnell. 1983. Elk use of winter range as affected by cattle grazing, fertilizing, and burning in southeastern Washington. Journal of Range Management 36:184-189.

Spitz, D.B., D. A. Clark, M.J. Wisdom, M.M. Rowland, B.K. Johnson, R.A. Long, and T. Levi. 2018. Fire history influences large-herbivore behavior at circadian, seasonal, and successional scales. Ecological Applications 28:2082-2091.

Stonehouse, K.F., Anderson, C.R., Peterson, M.E., and Collins, D.R. 2016. Approaches to field investigations of cause-specific mortality in mule deer. Tech. Pub. No. 48, Colorado Parks and Wildlife.

Taylor, N., J.E. Knight, and J.J. Short. 2004. Fall cattle grazing versus mowing to increase big-game forage. Wildlife Society bulletin 32:449-455

Therneau, T. (2021). *A Package for Survival Analysis in R*. R package version 3.2-13, https://cran.r-project.org/package=survival

U.S. Department of Agriculture, Forest Service. 2016. U.S. Forest Service Cut and Sold Reports. U.S. Department of Agriculture, Forest Service http://www.fs.fed.us/forestmanagement/products/sold-harvest/cut-sold.shtml

Vucetich, J. A., D. W. Smith, and D. R. Stahler. 2005. Influence of harvest, climate, and wolf predation on Yellowstone elk, 1961-2004. Oikos 111: 259-270.

Wambolt, C.L., M.R. Frisina, K.S. Douglass, and H.W. Sherwood. 1997. Grazing effects on nutritional quality of bluebunch wheatgrass for elk. Journal of Range Management 50:503-506.

Walter, W. D., L. M. Leslie. 2012. Response of rocky mountain elk (*Cervus elaphus*) to wind power development. Am. Midl. Nat. 156:363-375.

Wagoner, S.J., 2011. The effects of spring cattle grazing on the nutritional ecology of mule deer (*Odocoileus hemionus*) in eastern Washington. M.S. Thesis. Washington State University, Pullman, WA. 84 pp.

Washington Department of Fish and Wildlife. 2001. Blue Mountains Elk Herd. Wildlife Program, Washington Department of Fish and Wildlife, Olympia. 47pp.

Washington Department of Fish and Wildlife. 2009. Draft Environmental Impact Statement for Livestock Grazing Management on the Washington Department of Fish and Wildlife's Quilomene and Whiskey Dick Wildlife Areas in Kittitas County, Washington. Prepared by: Ecology and Environment, Inc. and Washington Department of Fish and Wildlife, Olympia Washington. 135 pp.

Washington Department of Fish and Wildlife. 2015. Game Management Plan, July 2015 – June 2021. Wildlife Program, Washington Department of Fish and Wildlife, Olympia. 159pp.

Washington Department of Fish and Wildlife. 2020. Blue Mountains Elk Herd. Wildlife Program, Washington Department of Fish and Wildlife, Olympia. 71pp.

Welfelt, L. S., R. A. Beausoleil, and R. B. Wielgus. 2019. Factors associated with black bear density and implications for management. The Journal of Wildlife Management 83: 1527-1539.

Westenskow-Wall, K.J., W.C. Krueger, L.D. Bryant, and D.R. Thomas. 1994. Nutrient quality of bluebunch wheatgrass regrowth on elk winter range in relation to defoliation. Journal of Range Management 47:240-244.

White, C. G., P. Zager, and M. W. Gratson. 2010. Influences of predator harvest, biological factors, and landscape on elk calf survival in Idaho. The Journal of Wildlife Management 74: 355-369.

Wisdom, M. J., A. A. Ager, H. K. Preisler, N. J. Cimon, and B. K. Johnson. 2005. Effects of Off- Road Recreation on Mule Deer and Elk. Pages 67-80 in Wisdom, M. J., technical editor, The Starkey Project: a synthesis of long-term studies of elk and mule deer. Reprinted from the 2004 Transactions of the North American Wildlife and Natural Resources Conference, Alliance Communications Group, Lawrence, Kansas, USA.

Wisdom, M. J., J. W. Thomas. 1996. Chapter 10 Elk, In Krausman P. R., Rangeland Wildlife. Society for Range Management.

Wisdom, Michael & Johnson, Bruce & Vavra, Martin & Boyd, Jennifer & Coe, Priscilla & Kie, John & Ager, Alan & Cimon, Norman. (2004). Cattle and Elk Responses to Intensive Timber Harvest.

Wisdom, M. J., H. K. Preisler, L. M. Naylor, R. G. Anthony, B. K. Johnson, M. M. Rowland. 2018. Elk responses to trail-based recreation on public forests. Forest Ecology and Management 411:223-233

Wright, G.J., Peterson, R.O., Smith, D.W. & Lemke, T.O. (2006) Selection of northern Yellowstone elk by gray wolves and hunters. Journal of Wildlife Management, 70, 1070 – 1078.

Yeo, J.J., J.M. Peek, W.T. Wittenger, and C.T. Kvale 1993. Influence of rest-rotation cattle grazing on mule deer and elk habitat use in east-central Idaho. Journal of Range Management 46:245-250.

Zahn, H. M. 1993. An initial analysis of elk reproductive tracts collected in Washington state. Washington Department of Fish and Wildlife, Olympia. 19pp.