Wildlife Program
2015-2017 Ungulate Assessment

Washington Department of FISH and WILDLIFE

Wildlife Program 2015-17 Ungulate Assessment

Program Plan Initiative Charter 6

Identify herds or local populations of elk, moose, deer and bighorn sheep where predation effects may be unacceptably affecting demographics and invoke the predator prey guideline, as appropriate.

December 2016

Compiled by Brock Hoenes – Statewide Elk Specialist; Sara Hansen – Statewide Deer Specialist; Richard Harris – Mountain Goat, Bighorn Sheep and Moose Section Manager; and Jerry Nelson – Deer and Elk Section Manager.

Acknowledgements

We would like to thank the District Biologists, Assitant District Biologists, and Regional Wildlife Managers of the Washington Department of Fish and Wildlife for providing the information that has been assembled in this document. We would like to express a special thank you to WDFW Game Data Manager, Sarah Kindschu for providing the harvest and hunter effort estimates. We would also like to thank Dr. Aaron Wirsing, Dr. Laura Prugh, and Dr. Beth Gardner from the University of Washington's School of Environmental and Forest Sciences for their comments and edits.

Contents

EXECUTIVE SUMMARY

In the Game Management Plan July 2015-June 2021, the Washington Department of Fish and Wildlife made the commitment to assess ungulate populations that have the potential to be held below a desired population level due to predation. This document represents that assessment; it uses only data and information presently available.

The Washington Department of Fish and Wildlife is responsible for the management of white-tailed deer, mule deer, black-tailed deer, Rocky Mountain elk, Roosevelt elk, moose, bighorn sheep, mountain goats, and pronghorn. The Department coordinates management of the Columbian white-tailed deer with the U.S. Fish and Wildlife because it is both federally and state listed as an endangered species.

Depending on location, the suite of predators occurring in the state of Washington that prey upon ungulates may include gray wolf, cougar, black bear, grizzly bear, coyote, bobcat, and lynx. Increasingly conservative management of hunting seasons and harvest opportunities for cougars and black bears, since they were designated as big game species in 1966 and 1969 respectively, has resulted in sustainable populations of both species which are hunted annually. Gray wolves began recolonizing Washington during the mid-2000s and the Department confirmed the first documented wolf pack in 2008. The distribution of recolonizing wolves does and will continue to overlap with black bear, cougar, and coyote populations. This development, as it has in other states, has elevated interest in knowing more about the impact on prey populations when an additional apex predator establishes itself in an ecosystem. Both lynx and grizzly bears occur in low numbers and have limited distributional range in Washington; thus, we have not considered either in this assessment.

This assessment covers white-tailed deer, mule deer, black-tailed deer, Rocky Mountain elk, Roosevelt elk, bighorn sheep, and moose. The remaining ungulate species in Washington are unique enough in their distribution, abundance, natural history, and management that except for rare instances we considered their populations unlikely to be affected by predation.

The intensity of management and the available data differ among ungulate species in Washington. We used existing available data from a number of sources. Not all data were deemed appropriate for this assessment. In this assessment, we considered population estimates obtained from aerial surveys; composition counts that provide minimum-known-alive counts and age and sex ratios that were conducted either from the air or on the ground; harvest; hunter numbers; and hunter effort depending upon the available information for each population. We also looked at the results of ungulate research conducted both in and outside Washington by a number of different entities. In some cases, these provided herd-specific vital rates (i.e., survival, productivity, recruitment), but in most cases, our assessments were necessarily based on indirect measures. In the Wolf Conservation and Management Plan and also reiterated in the recent Game Management Plan, the Department defined an at-risk ungulate population as one that falls 25% below its population objective for two consecutive years, and/or one in which the harvest decreases by 25% below the 10-year average harvest rate for two consecutive years. These measures were also used in the assessments.

Using the data at our disposal, none of the ungulate populations in this assessment appear to show clear signs of being limited by predation. However, the limitations of some of these data might preclude the ability to detect impacts of predation on a specific ungulate population. One subpopulation of moose that is currently suffering low recruitment and is the subject of active research requires additional resources to better understand the population impacts of predation.

Introduction

Gray wolves (*Canis lupus*) began recolonizing Washington during the mid-2000s and the Department confirmed the first documented wolf pack in 2008 (Wiles et al. 2011). The recolonization of gray wolves in Washington, in conjunction with management strategies that fostered black bear (*Ursus americanus*) and cougar (*Puma concolor*) populations increasing to relatively stable levels that could support sustainable harvest (WDFW 2014), has revitalized concerns among the public that predators will cause ungulate population declines or result in reduced opportunities for hunters pursuing ungulates. In response to these concerns, the Department identified objectives for elk (*Cervus elaphus*), deer (*Odocoileus spp.*), moose (*Alces alces*), and bighorn sheep (*Ovis canadensis*) in the 2015–2021 Game Management Plan that directed biologists and managers to "Identify herds or local populations that are below population objectives where predation effects might be a limiting factor by 2015 (WDFW 2014)." Using existing data that are already in hand, we are completing this review to meet that objective.

Some may interpret the above objective to mean the Department would determine whether predators were preventing a particular ungulate population from growing to the full potential of the habitat occupied, but that is not its intent. Determining whether ungulate populations are limited by top-down or bottom-up effects would require large-scale, rigorously designed empircal studies that consider the full suite of variables (e.g., predators, weather, habitat, wildfire, etc.) that interact concurrently to influence ungulate population dynamics (*see* Sinclair and Krebs 2002, White et al. 2010, Griffin et al. 2011, Brodie et al. 2013, Johnson et al. 2013, Proffitt et al. 2014).

The Department has also articulated the predatory-prey management guidelines when it comes to managing the species discussed in this assessment (WDFW 2014). Although more than can be included here, the guidelines spell out the assumptions, the guiding principles, the actions that can be considered, and the strategies to be implemented when certain thresholds and criteria are met.

First defined in the Washington Gray Wolf Conservation and Management Plan and then re-stated in the recent Game Management Plan, the Department defined at-risk ungulate populations as any that are federal or state listed as threatened or endangered. Also included are ungulate populations that fall 25% below its population objective for two consecutive years, and/or one in which the harvest decreases by 25% below the 10-year average harvest rate for two consecutive years. The latter metric is used extensively throughout this report for species (deer and elk) that support general season hunting.

If the Department determines that wolf predation is the primary limiting factor for an at risk ungulate population and the wolf population in that recovery region has 4 or more breeding pairs, reducing wolf abundance in localized areas can be considered before wolves are state delisted.

The intent of this review is to identify ungulate populations that are below management objective or may be negatively affected by predators. Although the existing time series data available for this review may be useful when formulating new hypotheses to be tested experimentally, they are not appropriate as a dataset to be used for experimental hypothesis testing. Using empirical data to fully understand how the effect of predators interacts with other factors like weather, habitat, harvest, and alternate prey species to influence the population dynamics of ungulates is extremely difficult (Krebs 2002), and outside the purview of this review.

Literature Cited – Introduction

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. Lukacs, S. McCorquodale, E. McIntire, J. Nowak, H. Sawyer, D. Smith, and 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.

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

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. Journal of Wildlife Management 77:102–116.

Krebs, C. J. 2002. Beyond population regulation and limitation. Wildlife Research 29:1-10.

Proffitt, K. M., J. A. Cunningham, K. L. Hamlin, and R. A. Garrott. 2014. Bottom-up and top-down influences on pregnancy rates and recruitment of northern Yellowstone elk. Journal of Wildlife Management 78:1383–1393.

Sinclair, A. R. E. and C. J. Krebs. 2002. Complex numerical responses to top–down and bottom–up processes in vertebrate populations. Philosophical Transactions of the Royal Society B. Biological Sciences. Published 29 September 2002.DOI: 10.1098/rstb.2002.1123.

Washington Department of Fish and Wildlife. 2014. 2015–2021 Game Management Plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

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

Wiles, G. J., H. L. Allen, and G. E. Hayes. 2011. Wolf conservation and management plan for Washington. Washington Department of Fish and Wildlife, Olympia, WA.

ELK

Introduction

The Washington Department of Fish and Wildlife (hereafter the Department) formally recognizes and manages 10 elk herds that collectively represent 50,000–60,000 elk and consist of two sub-species (Figure 1). Rocky Mountain elk (*C. e. nelsoni*) occur east of the Cascade crest and Roosevelt elk (*C. e. roosevelti*) occur on the Olympic Peninsula and in the northern range of the Willapa Hills elk herd area; all other Roosevelt elk in western Washington have interbred with Rocky Mountain elk (WDFW 2014a).

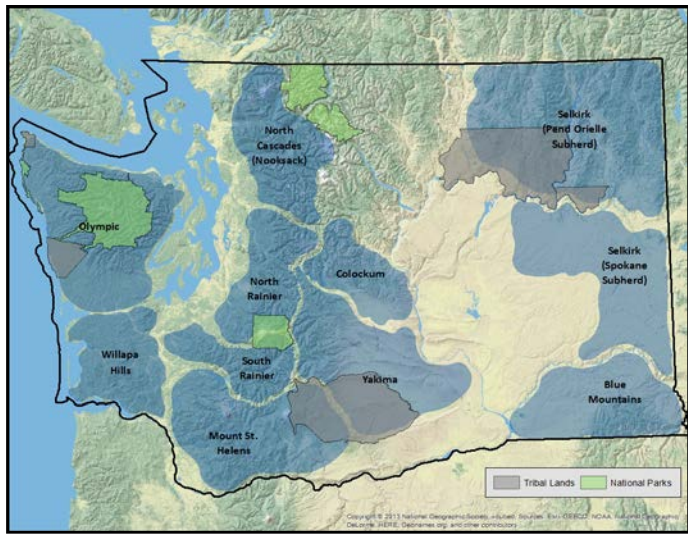


Figure 1. Map depicting the location and generalized range of the 10 elk herds formally recognized and managed by the Washington Department of Fish and Wildlife.

Our objective in this assessment is to collate and review available data to determine whether elk herds are above, meeting, or below management objectives defined in each associated elk herd plan and to determine if they meet the criteria of an "at-risk" ungulate population (see below). However, we also appreciate there is interest in gaining a better understanding of the factors that may be affecting the population dynamics of each elk herd, regardless if that herd is at objective or not. As such, we also summarize any recent survival studies and provide general information on factors that have the potential to affect elk population dynamics in each herd area (e.g., weather, land-use practices, disease, etc.).

We limited our summary of available data to the herd level and for the period of 2005–2015 for several reasons. First, population objectives the Department has defined in most associated elk herd plans are restricted to a herd-level assessment—exceptions include the North Rainier and Yakima elk herds. Second, the Department surveys most elk herds during times of the year when elk are concentrated on core winter range, which prevents extrapolation of those data for inferences at a smaller scale (e.g., Game Management Unit [GMU] or watershed). Third, the

Department's definition of an "at-risk" ungulate population is associated with a 10-year average (see below), which precludes the need for data collected prior to 2005. Finally, we felt the inclusion of data prior to 2005 would do little to inform our assessment. Although we completed our review at the herd level, we also recognize that represents a coarse level assessment that does not allow for the identification of local populations (e.g., elk within a GMU or watershed) that are currently being limited by biotic or abiotic factors. To address the coarseness of the assessment, we asked local Department biologists to identify local populations of concern and provide supporting information when appropriate. We did not contact local tribal biologists and acknowledge they may have additional information on local populations of concern.

The Department uses a variety of techniques to monitor the status of elk herds in Washington, including sightability models (Samuel et al. 1987, Unsworth et al. 1999, McCorquodale et al. 2014), variants of mark-resight (McCorquodale et al. 2011, 2013), aerial surveys without sightability corrections, ground counts, and harvest data. Which method we employ depends on the survey conditions present within each herd area. For this assessment, and in instances where the Department implements formalized monitoring programs to estimate elk abundance and herd composition, we primarily relied on survey data to make inferences about population status and trend. In instances where the Department does not implement formalized monitoring programs, we used harvest metrics (e.g., number of elk harvested, catch-per-unit effort [CPUE], etc.), to make inferences about population trend. Although the Department frequently uses harvest data to help guide management decisions, we fully acknowledge factors independent of population status (e.g., weather, elk movements, hunting regulations, hunter access) have the potential to influence hunter success (Crichton 1993, Bowyer et al. 1999, Solberg et al. 2000, Schmidt et al. 2005). Thus, harvest metrics, such as CPUE (the number of elk harvested per hunter day), may not always be reliable indicators of population status or trend, unless managers use them in concert with other indices or independent estimates of abundance (Hatter 2001, Uno 2006, IIjima et al. 2013). We took these considerations into account while completing this assessment and provide the necessary context as needed. Lastly, several Treaty Tribes with established natural resource programs also monitor local elk populations and share that information with the Department. We have included some of that information in our review and give credit accordingly.

The Department has defined objectives relating to herd abundance and bull:cow ratios for each elk herd. We do not establish objectives for calf:cow ratios because most factors that affect calf survival can rarely be addressed through the Department's short-term management activities. In addition, the Department primarily collects age ratios to assess the potential for a herd to grow, remain stable, or decline. Whether an estimated recruitment rate would result in population growth, however, also depends on the survival rate of adult female elk, which makes it difficult to identify a minimum calf:cow ratio that is needed to prevent population declines (Caughley 1974, Skalski et al. 2005). Nonetheless, survival of adult female elk populations is typically > 0.85 and is relatively constant (Raithel et al. 2007, Brodie et al. 2013), which means elk populations usually have the potential to increase if calf:cow ratios in spring are ≥ 30 calves:100 cows. Thus, even though the Department does not establish management objectives for calf:cow ratios, we do prefer to see ratios that are ≥ 30 calves:100 cows and become concerned when they are below 25 calves:100 cows in consecutive years.

We present three estimates of harvest data in our review, General State Harvest, Total State Harvest, and Total Harvest. General State Harvest includes the estimated number of elk (antlered and antlerless) harvested during general modern firearm, muzzleloader, and archery seasons administered by the Department, combined. Total State Harvest includes General State Harvest combined with the number of elk (antlered and antlerless) state hunters reported harvesting during permit seasons and damage mitigation hunts administered by the Department. Total Harvest includes Total State Harvest combined with the number of elk (antlered and antlerless) reportedly taken during established tribal seasons. We summarized harvest data in these three ways because permit harvest is often linked to mitigating damage issues or in response to a perceived increase in elk abundance, so we view General State Harvest as a more unbiased indicator of population trend. However, harvest during permit seasons established by the Department and during established tribal seasons accounts for a large proportion of harvest in some elk herd areas (e.g., Blue Mountains, North Cascades, Olympic, etc.) and must be included to reflect current harvest levels. We could not generate estimates of Total Harvest in 2015 because, at the time of this writing, the Northwest Indian Fisheries Commission (NWIFC 2015) had not yet published tribal harvest for the 2015 season. In addition, we could not generate estimates of Total Harvest for elk herds in eastern Washington because the NWIFC tribal harvest reports are only representative of the 20 member western Washington treaty tribes who primarily harvest in GMUs located in western Washington.

The Department defined an "at-risk" ungulate population in their Wolf Conservation and Management Plan to include "any ungulate population which falls 25% below its population objective for two consecutive years and/or if the harvest decreases by 25% below the 10-year average harvest rate for two consecutive years (Wiles et al. 2011)." However, the criterion used to define an "at-risk" ungulate population is somewhat ambiguous because it does not clearly define the time series managers should use to generate the 10-year average or which harvest data should be included to make the assessment. For the purpose of this review, we compared point estimates in 2014 and 2015 to the average harvest for 2005–2014 and 2006–2015, respectively, and completed the assessment using General State Harvest and Total State Harvest. We did not complete this assessment using estimates of Total Harvest because we did not have estimates of tribal harvest in 2015.

Carnivores that occur in Washington and prey on elk include cougars, black bears, grizzly bears (*Ursus arctos*), gray wolves, coyotes (*Canis latrans*), bobcats (*Lynx rufus*), and lynx (*Lynx canadensis*). We have excluded bobcats, coyotes, lynx, and grizzly bears from this review since their effects on elk populations would be minimal because they rarely prey on elk (e.g., bobcats and coyotes) or because they occur in very limited numbers (e.g., grizzly bears and lynx). We provide harvest data for black bears and cougars within each herd area to simply illustrate that harvest of these species does occur, can vary from year to year, and varies among elk herd areas. In no way do we intend for these data to be reflective of population trend for these species. In addition, we have restricted estimates of black bear and cougar harvest to harvest that occurred during general and permit seasons established by the Department; it does not include animals removed for public safety reasons, in response to depredation events, or during established tribal seasons.

Blue Mountains Elk Herd

General Overview

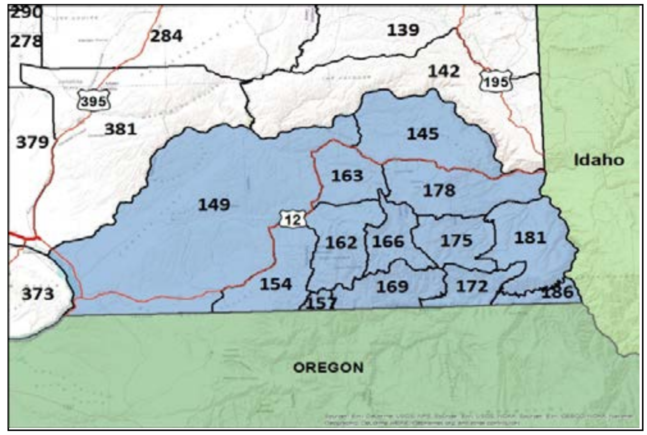


Figure 2. Location and boundaries of Game Management Units that comprise the Blue Mountains elk herd area.

The Blue Mountains elk herd area is located in southeast Washington and consists of 13 GMUs (Figure 2). The Department is currently in the process of updating the Blue Mountains Elk Herd Plan (WDFW 2001), which includes a population objective of maintaining herd size during spring between 4,950 and 6,050 elk. Additional objectives include maintaining a post-hunt population with a bull:cow ratio of 22–28 bulls:100 cows and maintaining an annual survival rate of 0.50 for bulls when bull mortality is monitored (WDFW 2014a).

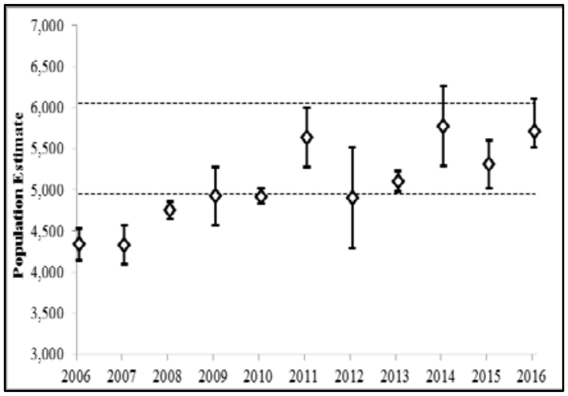
The Department monitors population status by conducting aerial composition surveys in spring and uses a sightability model developed for elk in Idaho (Unsworth et al. 1999) to generate estimates of elk abundance, age ratios, and sex ratios.

The Department restricts general season bull harvest to spikes and offers opportunities to harvest branch-antlered bulls under special permits in all GMUs. The Department generally focuses most opportunities to harvest antlerless elk in areas associated with private land to help alleviate agricultural damage.

Current Status and Trend

In spring 2016, the Department estimated total elk abundance to be 5,717 elk (90% CI 5,518–6,111), which is within the management objective of 4,950–6,050 elk. Abundance estimates indicate the Blue Mountains elk herd has been at objective since 2009 (Figure 3). The estimated bull:cow ratio in spring 2016 was 35 bulls:100 cows, which is above the management objective of 22–28 bulls:100 cows and the estimated calf:cow ratio in spring 2016 was 29 calves:100 cows

(Figure 3). Estimated calf:cow ratios were consistently below 30 calves:100 cows, 2006–2010, but averaged 32 calves:100 cows, 2011–2016 (Figure 3).

a) 

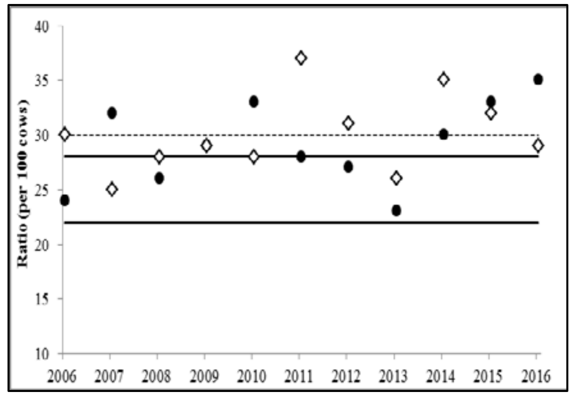
b) 

Figure 3. Sightability corrected estimates of (a) total elk abundance with associated 90% confidence intervals in the Blue Mountains elk herd area, 2006–2016. The dashed lines represent management objectives for total elk abundance (4,950–6,050 elk). Also included are estimates of (b) post-hunt calf:cow (◊) and bull:cow ratios (●), spring 2006–2016. The solid lines represent objectives for bull:cow ratios (22–28 bulls:100 cows), while the dashed line represents calf recruitment rates that should promote herd stability or growth (≥ 30 calves:100 cows).

Harvest

Estimates of General State Harvest and Total State Harvest have averaged 178 and 387 elk, respectively, 2005–2015, and have been relatively stable 2010–2015 (Figure 4). Both estimates were also greater than harvest levels that would be 25% below the 10-year average in 2014 and 2015 (Figure 4). Estimates of hunter effort have also been relatively stable since 2005, while estimates of CPUE have varied, but were similar in most years (Figure 4).

Survival and Cause-Specific Mortality

There are no ongoing research projects to estimate survival and cause-specific mortality rates for elk in the Blue Mountains elk herd area. The most recent elk survival study occurred 2003–2006 and we (McCorquodale et al 2010) estimated yearling bull survival across the herd area to be 0.41 (95% CI = 0.29–0.53), branch-antlered bull survival to be 0.83 (95% C.I. = 0.76–0.88), and adult cow survival to be 0.80 (95% C.I. = 0.69–0.88). The leading cause of mortality for all sex and age classes monitored was associated with human harvest.

a) b)

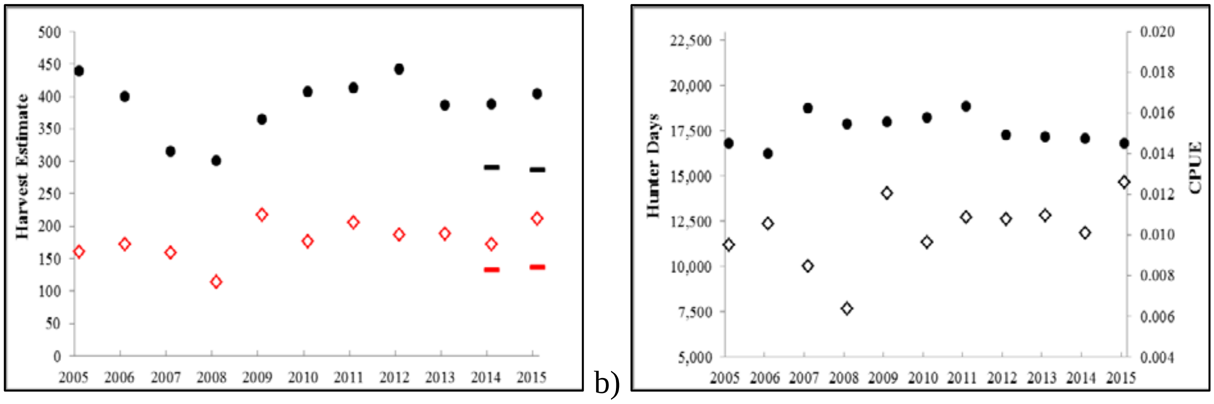


Figure 4. General State Harvest (◊) and Total State Harvest (●) estimates (a) in the Blue Mountains elk herd area, 2005–2015. The dashes associated with harvest estimates in 2014 and 2015 represent harvest levels that are 25% below the 10-year average (2005-2014 in 2014 and 2006-2015 in 2015) for General State Harvest (red) and Total State Harvest (black). Also included are estimates of (b) hunter days (●) and catch-per-unit-effort (CPUE) (◊), 2005–2015. We generated estimates of CPUE using estimates of hunter effort and elk harvest during general modern firearm, muzzleloader, and archery seasons combined. We did not generate estimates of Total Harvest because estimates of tribal harvest were not available.

Assessment

Both harvest and survey data indicate the Blue Mountains elk herd has been at objective the past 5-7 years, has been relatively stable, and does not meet the criteria of an “at-risk” ungulate population. Estimated calf:cow ratios also indicate calf recruitment rates are at levels that would promote population stability or growth. Lastly, biologists did not identify any local populations of concern.

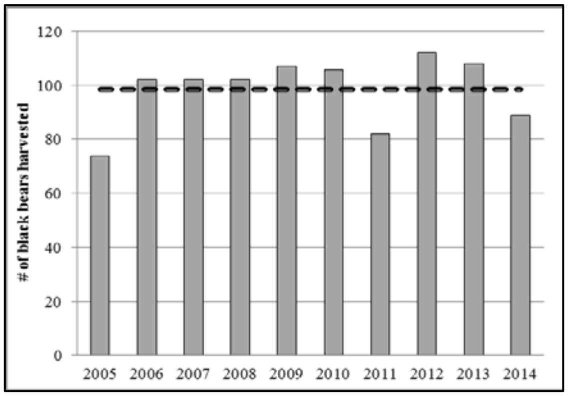
Factors That Potentially Influence Population Dynamics

Predators

Black Bear.—Black bears occur throughout the Blue Mountains elk herd area, but are more abundant in forested areas. Black bear harvest during state general and permit seasons has been relatively stable since 2005 (Figure 5).

Cougar.—Cougars occur throughout the Blue Mountains elk herd area. Estimated cougar harvest during general seasons has been variable and averaged 12 cougars per year (Figure 5).

Gray Wolf.—At the time of this writing, there was one confirmed wolf pack within the Blue Mountains elk herd area (Becker et al. 2016).

a) 

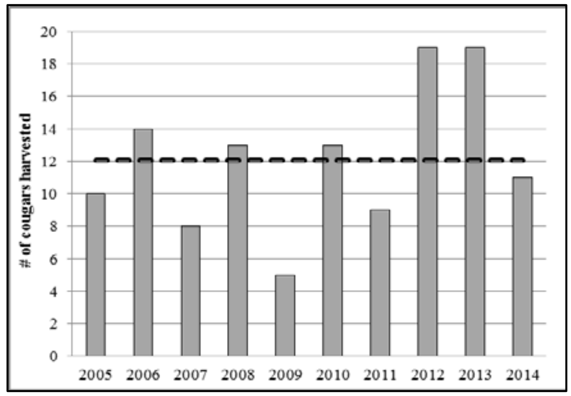
b) 

Figure 5. Estimated number of black bears (a) and cougars (b) harvested during general and permit seasons in the Blue Mountains elk herd area, 2005–2014. The dashed line represents the 10-year average.

Forest Management Practices

The Umatilla National Forest Access Management and Fire Management Plans should improve habitat conditions over time, and the U.S. Forest Service (USFS) is implementing prescribed burns throughout the forest to reduce fuel loads and improve stand conditions.

Wildfires

Habitat conditions on 163,000 acres of lands administered by the USFS and private landowners will continue to improve over the next 10 years due to extensive wildfires that occurred in 2005 and 2006 (School Fire-2005, Columbia Complex Fire-2006). In addition, large areas of the Wenaha-Tucannon Wilderness historically provided poor habitat conditions for elk, but that trend is likely to change since wildfires occurred in this area in 2015.

Weather

Extreme weather events that strongly affect the survival of elk in the Blue Mountains elk herd area are rare. Nonetheless, severe droughts that persist through summer and fall and severe winter conditions have the potential to affect the population dynamics of this herd when they occur.

Human Disturbance

Road densities in some portions of the Blue Mountains elk herd area are quite high and have the potential to reduce use of important summer range because of human disturbance associated with those roads. The USFS has closed several old roads and reduced overall road densities, but more work is needed to address elk habitat and security needs. In addition, anecdotal evidence suggests elk habitat use in early spring has changed in some portions of the Blue Mountains elk herd area due to disturbance caused by people looking for shed antlers.

Colockum Elk Herd

General Overview

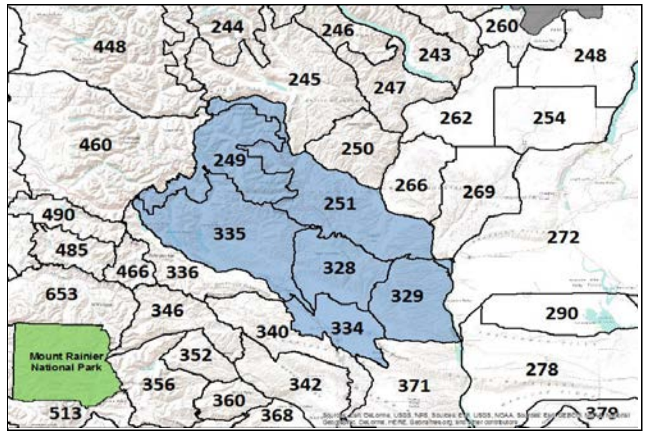


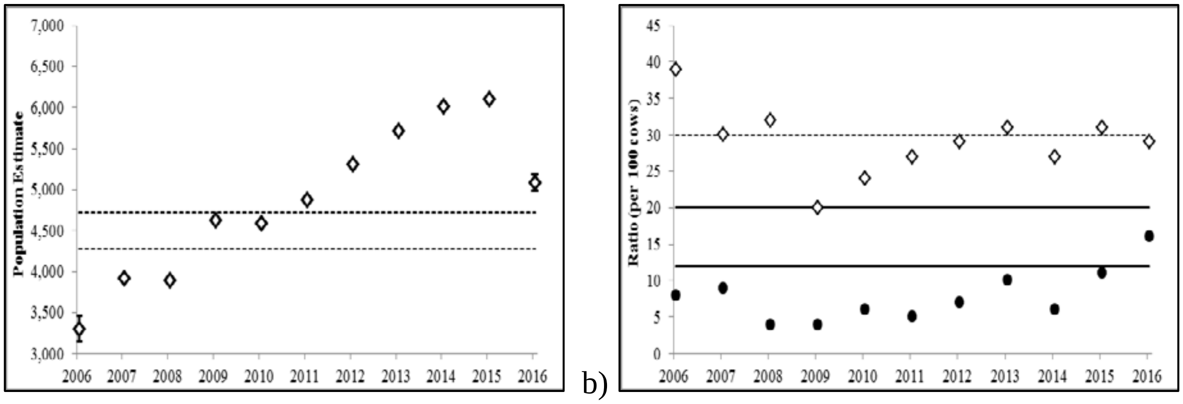
Figure 6. Location and boundaries of Game Management Units that comprise the Colockum elk herd area.

The Colockum elk herd area is located in central Washington along the eastern foothills of the Cascades and consists of 6 GMUs (Figure 6). The Department's current objective is to maintain elk abundance in spring between 4,275 and 4,725 elk (WDFW 2006). Additional objectives include maintaining a post-hunt population with a bull:cow ratio of 12–20 bulls:100 cows and maintaining an annual survival rate of 0.50 for bulls when bull mortality is monitored (WDFW 2014a).

The Department monitors population status by conducting aerial composition surveys in the spring and uses a sightability model developed for elk in Idaho (Unsworth et al. 1999) to estimate elk abundance, age ratios, and sex ratios. The Department restricts general season bull harvest to true-spikes and offers opportunities to harvest branch-antlered bulls under special permits in all GMUs. However, in 2012, the Department began to increase opportunities to harvest antlerless elk throughout the herd area to bring the herd within management objective.

Current Status and Trend

The Department conducted post-hunt aerial surveys in March 2016 and using a sightability model estimated total elk abundance on core winter range to be 5,087 elk (90% CI = 5,054–5,185), which is approximately 300–400 elk above objective. Estimates of total elk abundance steadily increased 2006–2015, but declined in 2016 (Figure 7) as a result of increased antlerless hunting opportunity offered in 2015 that was designed to bring the population more in line with the objective. From those same surveys, the Department estimated post-hunt calf:cow and bull:cow ratios in March 2016 to be 28:100 and 16:100, respectively. Age ratios have shown an increasing to stable trend 2009–2016, while estimated bull:cow ratios have steadily increased 2008–2016 (Figure 7). Both age and sex ratios during 2013–2016 increased relative to the period 2009–2012, but these increases are likely correlated with substantially higher harvest of antlerless elk rather than simply being the result of increases in the survival of calves and bulls.



a) b)

Figure 7. Sightability corrected estimates of (a) total elk abundance with associated 90% confidence intervals in the Colockum elk herd area, 2006–2016. The dashed lines represent management objectives for total elk abundance (4,275–4,725 elk). Also included are estimates of (b) post-hunt calf:cow (◊) and bull:cow ratios (●) in the Colockum elk herd area, spring 2006–2016. The solid lines represent objectives for bull:cow ratios (12–20 bulls:100 cows), while the dashed line represents calf recruitment rates that should promote herd stability or growth (≥ 30 calves:100 cows).

Harvest

General State Harvest and Total State Harvest have averaged 442 and 610 elk, respectively, 2005–2015. Both estimates steadily declined 2005–2010, while Total State Harvest increased sharply 2011–2015 and General State Harvest increased sharply in 2015 (Figure 8). Both increases are a result of the Department increasing opportunities to harvest antlerless elk. Hunter effort declined precipitously in 2010, likely in response to the Department implementing "true-spike" restrictions in 2009, but has increased sharply 2012–2015 as opportunities to harvest antlerless elk have increased (Figure 8). Estimates of CPUE also steadily declined 2005–2010, but have increased in recent years (Figure 8).

Survival and Cause-Specific Mortality

The Department monitored the survival of 105 adult cow elk captured on core winter range 2008–2012, estimated annual survival rates to be 0.92 (95% CI = 0.87–0.96), and attributed 73% of all mortalities to hunter-harvest (S. McCorquodale, WDFW, unpublished data). The Department is also currently monitoring the survival and movements of mature branch-antlered bulls. We have radio-collared 55 bulls since 2013, preliminarily estimated annual survival rates to be 0.62, and at the time of this writing, documented 17 mortalities, all of which we have attributed to harvest (S. McCorquodale, WDFW, unpublished data).

a) b)

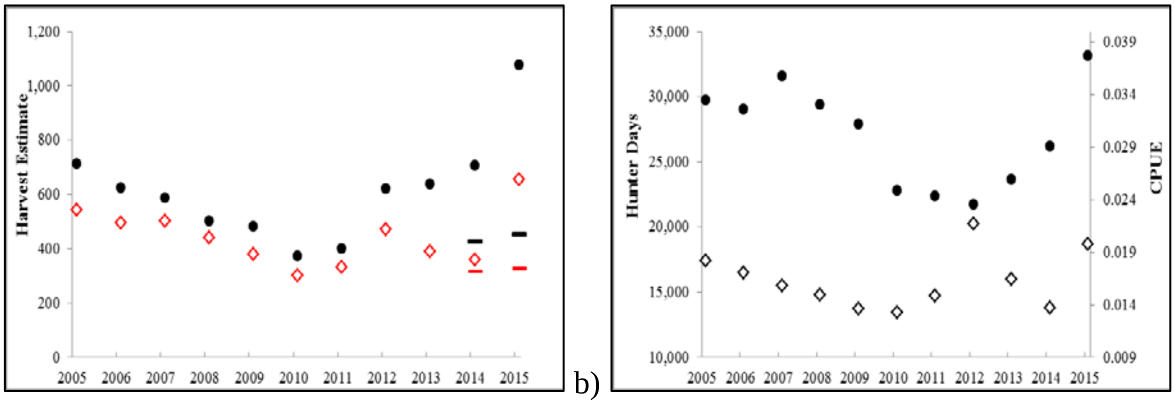


Figure 8. General State Harvest (◊) and Total State Harvest (●) estimates (a) in the Colockum elk herd area, 2005–2015. The dashes associated with harvest estimates in 2014 and 2015 represent harvest levels that are 25% below the 10-year average (2005-2014 in 2014 and 2006-2015 in 2015) for General State Harvest (red) and Total State Harvest (black). Also included are estimates of (b) hunter days (●) and catch-per-unit-effort (CPUE) (◊), 2005–2015. We generated estimates of CPUE using estimates of hunter effort and elk harvest during general modern firearm, muzzleloader, and archery seasons combined. We did not generate estimates of Total Harvest because estimates of tribal harvest were not available.

Assessment

Recent estimates of elk abundance on core winter range indicate the Colockum elk herd still remains above objective, decreased substantially in 2015 in response to the Department's efforts to reduce herd size, and does not meet the criterion of an "at-risk" ungulate population. Overall, inferences that we could make about population trend from harvest data and survey data are quite different. However, substantial changes in hunter effort coupled with recent changes to harvest restrictions likely explains the inability of harvest metrics to accurately index population trend. Although bull:cow ratios have historically been below objective, ongoing research indicates this is because many of the adult bulls are wintering in areas not associated with the survey area, rather than a result of low bull survival (S. McCorquodale, WDFW, unpublished data). In addition, preliminary estimates of bull survival indicate the Department is meeting its objective of maintaining annual survival rates of 0.50 for bulls. Estimated calf:cow ratios in conjunction with recently derived estimates of adult cow survival, indicate calf recruitment rates are at levels that would promote population stability or growth once harvest of antlerless elk is reduced. Lastly, district biologists did not identify any local populations of concern.

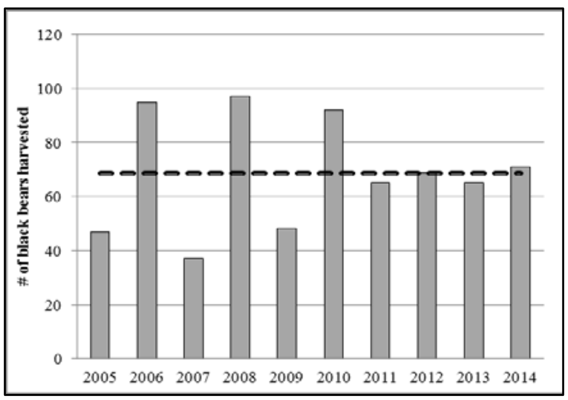
Factors That Potentially Influence Population Dynamics

Predators

Black Bear.—Black bears occur throughout the Colockum elk herd area, but are probably more abundant in forested regions. The estimated number of black bears harvested during general and permit seasons varied considerably 2005–2010, but have been more consistent 2011–2015 (Figure 9).

Cougar.—Cougars occur throughout the Colockum elk herd area. Cougar harvest fluctuates annually, but typically consists of 10–14 animals (Figure 9).

Gray Wolf.—At the time of this writing, there was one confirmed wolf pack within the Colockum elk herd area (Becker et al. 2016).

a)


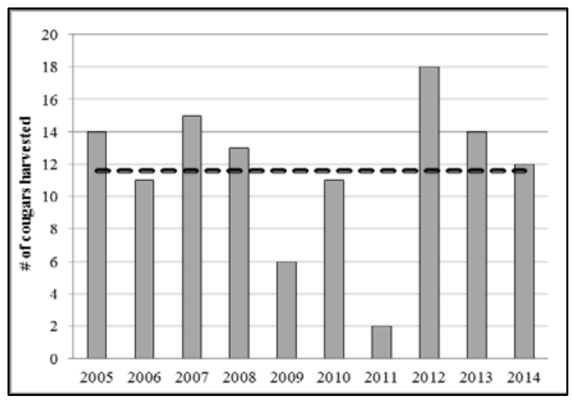
b)


Figure 9. Estimated number of black bears (a) and cougars (b) harvested during general and permit seasons in the Colockum elk herd area, 2005–2014. The dashed line represents the 10-year average.

Forest Management Practices

Timber harvest in the Colockum elk herd area has been increasing in recent years, which should improve forage quantity and quality for elk.

Wildfires

Recent wildfires have improved the foraging conditions on more than 100,000 acres. However, the fire that occurred in 2012 also removed much of the security cover within the burn perimeter, which may limit the use of this area by elk if human disturbance is high (see below).

Weather

The Colockum elk herd is susceptible to severe winter conditions that could result in higher than normal overwinter mortality. However, winter conditions in 2013-2014 and 2014-2015 were extremely mild, which likely resulted in higher than normal overwinter survival for all sex and age classes. In addition, drought conditions that persist through late summer and fall have the potential to affect the Colockum elk herd by reducing the availability of high quality forages needed to accrue adequate fat stores for winter.

Human Disturbance

Much of the Colockum elk herd area lacks adequate hiding cover, which increases the vulnerability of elk to human disturbance. Human disturbance can be quite high, especially during late summer, during fall hunting seasons, and in late winter when people begin hunting for shed antlers. Elk are widely distributed during times of the year when human disturbance is low, but they become concentrated in areas associated with the Coffin Reserve when human disturbance is high.

Mount St. Helens Elk Herd

General Overview

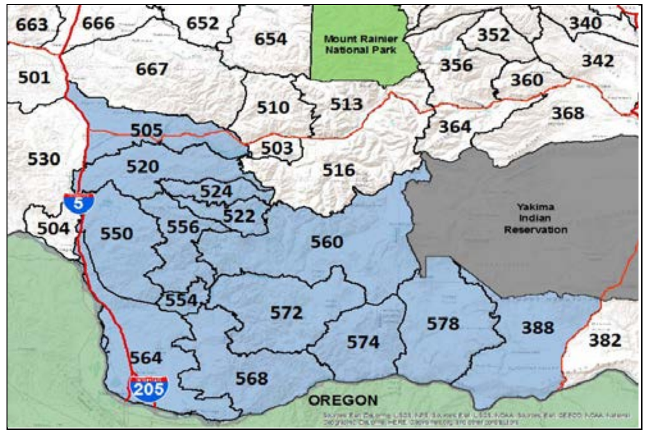


Figure 10. Location and boundaries of the 14 Game Management Units that comprise the Mount St. Helens elk herd area.

The Mount St. Helens elk herd is located in southwest Washington and is comprised of 14 GMUs (Figure 10). In response to the frequency and magnitude of winter mortality events in the 2000s, the Department began liberalizing opportunities to harvest antlerless elk in 2007 with the objective of reducing the Mount St. Helens elk herd by 35% (Miller and McCorquodale 2006). The Department began monitoring population trend in 2009 by indexing total elk abundance within the core herd area (GMUs 520, 522, 524, 550, 556) using a sightability model developed specifically for the Mount St. Helens elk herd (McCorquodale et al. 2014). The Department's current objective is to promote population stability as indexed by estimates of total elk abundance in spring. Additional objectives include maintaining a post-hunt population with a bull:cow ratio of 12–20 bulls:100 cows and maintaining an annual survival rate of 0.50 for bulls when bull mortality is monitored.

The Department limits most general season harvest opportunities in the Mount St. Helens elk herd area to branch-antlered bulls and offers most opportunities to harvest antlerless elk through their permit system. However, limited opportunities to harvest antlerless elk during general seasons do occur in areas where the Department's objective is to maintain low numbers of elk. During the period of time this review covers, the Department restricted all elk harvest in GMUs 522 and 556 to permit only opportunities. We restricted elk harvest in GMU 524 to permit only, 2005–2014, and offered general season opportunities in 2015.

Current Status and Trend

In March 2016, the Department estimated total elk abundance within the core herd area to be 2,943 elk (95% CI = 2,628–3,777). Estimates of total elk abundance have been relatively stable since the Department reduced opportunities to harvest antlerless elk following the 2012 season (Figure 11). In March 2016, the Department estimated post-hunt bull:cow and calf:cow ratios to be 49:100 and 32:100, respectively. Bull:cow ratios have been increasing since 2010 and are well above management objective, while calf:cow ratios have been similar 4 of the past 5 years (Figure 11).

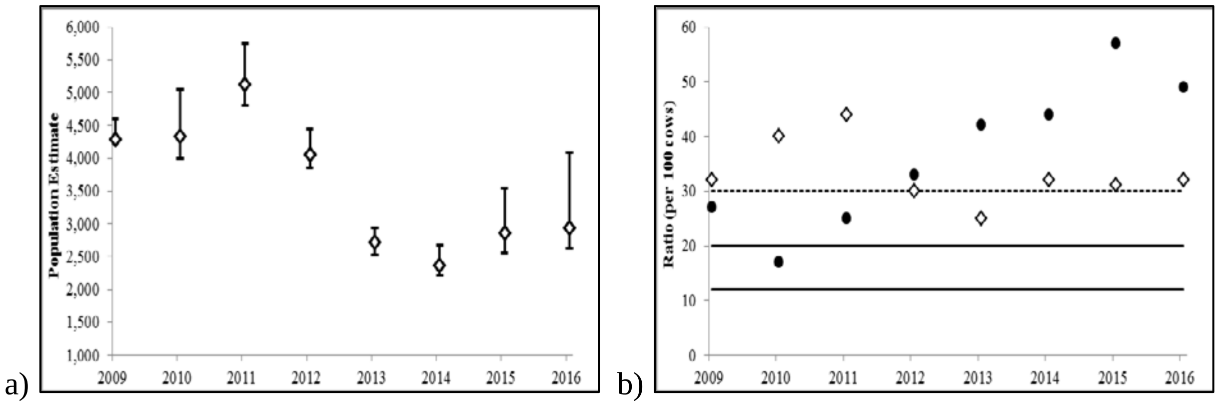


Figure 11. Sightability corrected estimates of (a) total elk abundance with associated 95% confidence intervals in the Mount St. Helens elk herd area, 2009–2016. Also included are estimates of (b) post-hunt calf:cow (◊) and bull:cow ratios (●), spring 2009–2016. The solid lines represent objectives for bull:cow ratios (12–20 bulls:100 cows), while the dashed line represents calf recruitment rates that should promote herd stability or growth (≥ 30 calves:100 cows).

Harvest

Estimates of General State Harvest have averaged 1,442 elk since 2005, and steadily declined 2005–2013 (Figure 12). Estimates of Total State Harvest have averaged 2,157 elk since 2005, varied widely 2005–2012, and declined precipitously after the Department reduced opportunities to harvest antlerless elk in 2012 (Figure 12). In addition, both estimates of harvest were more than 25% below the 10-year average in 2014 and estimates of Total State Harvest were below that level in 2015 (Figure 12). Hunter effort has been steadily declining since 2008, while CPUE was declining 2005–2011, but has been more stable in recent years (Figure 12).

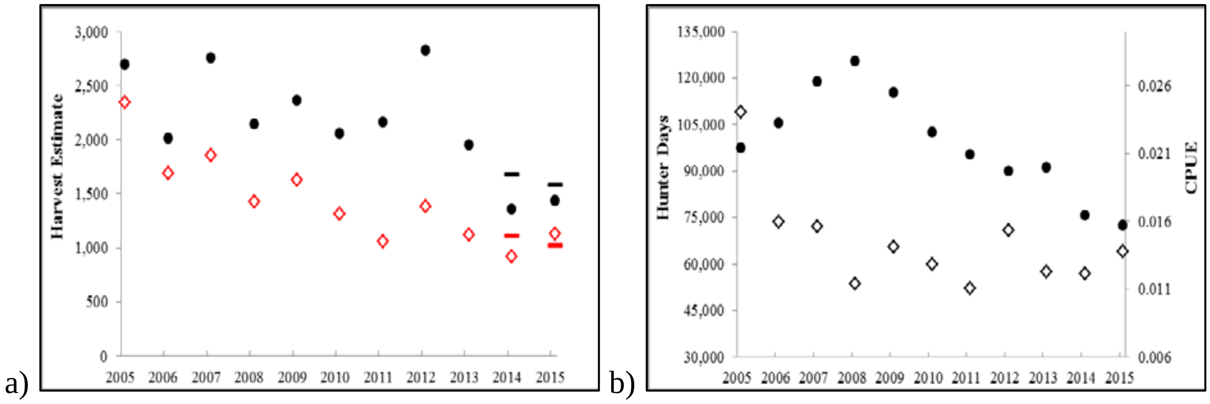


Figure 12. General State Harvest (◊) and Total State Harvest (●) estimates (a) in the Mount St. Helens elk herd area, 2005–2015. The dashes associated with harvest estimates in 2014 and 2015 represent harvest levels that are 25% below the 10-year average (2005-2014 in 2014 and 2006-2015 in 2015) for General State Harvest (red) and Total State Harvest (black). Also included are estimates of (b) hunter days (●) and catch-per-unit-effort (CPUE) (◊), 2005–2015. We generated estimates of CPUE using estimates of hunter effort and elk harvest during general modern firearm, muzzleloader, and archery seasons combined. We did not generate estimates of Total Harvest because estimates of tribal harvest averaged <5 elk per year.

Survival and Cause-Specific Mortality

The Department is currently monitoring the survival and movements of adult cow elk in the Mount St. Helens elk herd area in an effort to determine the effects of treponeme-associated hoof disease (TAHD) on elk survival and reproduction (Hoenes et al. 2014). That project began in March 2015, so the Department has collected very little information to date. However, at the time of this writing, we have documented 24 mortality events, 3 of which we attributed to cougar predation.

The Department (McCorquodale et al. [2014]) monitored the survival of branch-antlered bulls and adult female elk, 2009–2013, but we were not able to account for elk mortalities by cause, beyond distinguishing between hunting-related and natural causes (e.g., predation, disease, winter mortality, etc.). Nonetheless, we estimated annual survival of adult female elk in GMUs 520, 522, 524, and 556 to be 0.85 (95% CI = 0.78–0.91), 2009–2011 and 0.52 (95% CI = 0.38–0.65) in 2012. We estimated annual survival rates of adult female elk in GMU 550, 2009–2011, to be 0.64 (95% CI = 0.48–0.78) and 0.52 (95% CI = 0.38–0.65) in 2012. We estimated branch-antlered bull survival to be 0.56 (95% CI = 0.43–0.67) across years and GMUs. Finally, we attributed most mortality events to harvest-related causes, 2009–2011, and reduced survival in 2012 to an increased winter-mortality event.

Assessment

Both harvest and survey data indicate the Mount St. Helens elk herd has declined and harvest data indicates this herd meets the criterion of an "at-risk" ungulate population. However, those declines were in accordance with the Department's objective of reducing herd size by 35%. The Department began managing for population stability in 2012 and estimates of total elk abundance indicate we have achieved that objective, 2012–2015. Estimated calf:cow ratios also indicate calf recruitment rates are at levels that would promote population growth or stability. In addition, recent estimates of bull survival indicate the Department is achieving its management objective of maintaining annual survival rates of 0.50 for bulls. Lastly, biologists did not identify any local populations of concern.

Factors That Potentially Influence Population Dynamics

Predators

Black Bear.—Black bears occur throughout the Mount St. Helens elk herd area. The estimated number of bears harvested during general and permit seasons has averaged slightly less than 140 bears, 2005–2014, but the trend in harvest has been declining, 2010–2014 (Figure 13).

Cougar.—Cougars occur throughout the Mount St. Helens elk herd area and the estimated number of cougars harvested during general seasons is typically between 10 and 15 animals (Figure 13).

Gray Wolf.—At the time of this writing, there were no documented wolf packs in the Mount St. Helens elk herd area (Becker et al. 2016).

a) b)

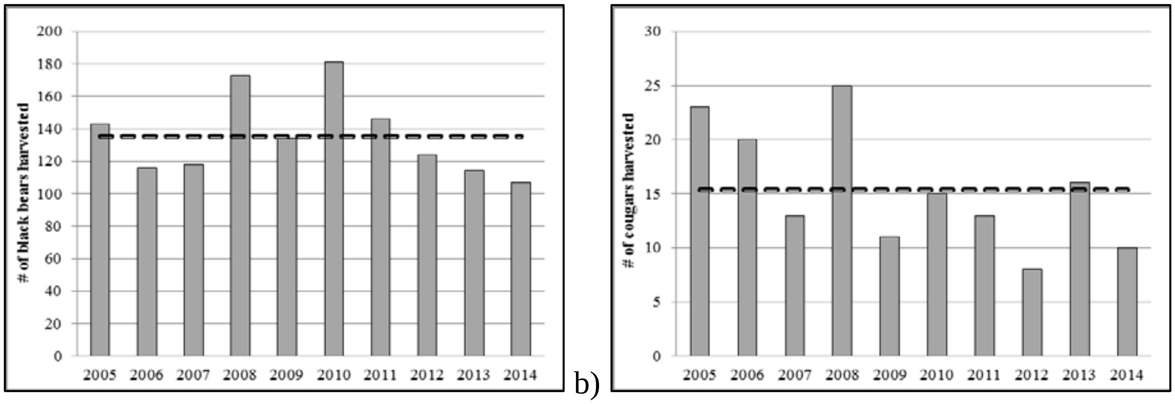


Figure 13. Estimated number of black bears (a) and cougars (b) harvested during general and permit seasons in the Mount St. Helens elk herd area, 2005–2014. The dashed line represents the 10-year average.

Forest Management Practices

A large portion of the Mount St. Helens elk herd area is comprised of private industrial forestlands that consist of a mosaic of clearcuts, relatively open young regeneration stands, and second growth forests. Industrial timber management practices benefit elk by increasing the quantity of early seral habitats and the subsequent forage base. Conversely, limited timber harvest on federal forests in the last three decades has led to a generally declining trend in habitat quality for elk.

Habitat Enhancements

The Department continues to take steps to enhance forage quality on the North Toutle mudflow in GMU 522. Forage enhancement efforts have included planting and fertilizing forage plots, mowing pastures, controlling scotch broom and non-native invasive blackberries, planting trees in upland areas and along the banks of the North Fork Toutle River to reduce bank erosion and reestablish tree cover in areas where scotch broom had been removed, and controlling yellow and mouse-ear hawkweed.

In addition, activities on approximately 13,000 acres of mitigation lands managed by Pacificorps include forest canopy removal, fertilization, establishment of forage plots, treatment of invasive plants, maintenance of farmlands and meadows for elk habitat, and creation of meadows and openings within the forested landscape.

Weather

The Mount St. Helens elk herd is susceptible to increased overwinter mortality events when severe winter and dry summer-fall conditions persist (McCorquodale et al 2014). Since 1999, the Department has conducted an annual winter elk mortality survey on the Mount St. Helens Wildlife Area and documented the number of elk carcasses detected. Since that time, the number of elk carcasses detected has varied annually and been above the 17-year average on 5 separate occasions, most recently in 2013 (Figure 14).

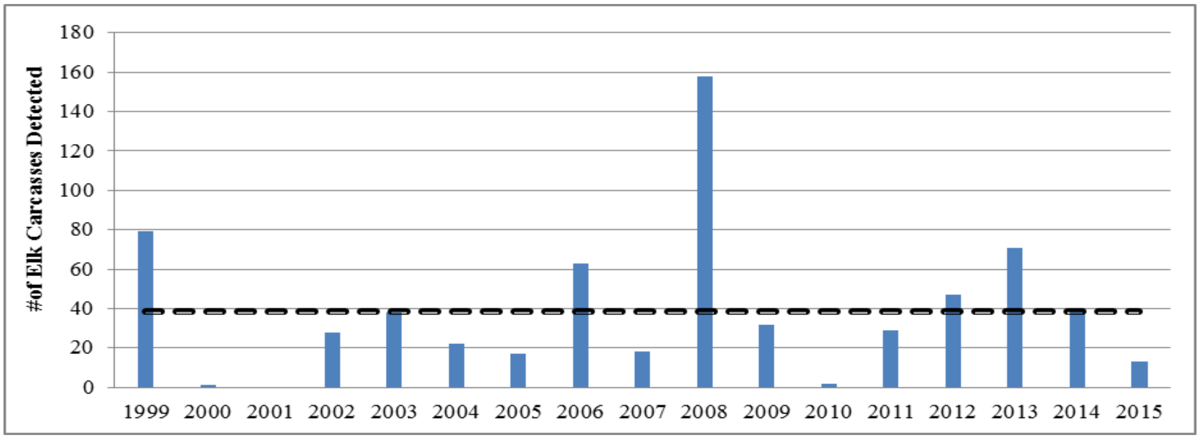


Figure 14. The number of elk carcasses detected during annual winter elk mortality surveys on the Mount St. Helens Wildlife Area, 1999–2015. The dashed line represents the 17-year average.

Treponeme-Associated Hoof Disease

Treponeme-associated hoof disease (TAHD) of elk results in abnormal hoof growth, cavitating sole ulcers, and in severe cases, eventual sloughing of the hoof capsule. Elk severely affected by TAHD often times have reduced mobility and condition. Consequently, it seems reasonable to assume they would have a reduced probability of survival or reproductive potential. However, it is unknown how TAHD affects the population dynamics of herds where TAHD occurs, but that is the focus of ongoing research (Hoenes et al. 2014). The Department is also conducting research to better estimate the distribution and prevalence of TAHD. To learn more about the Department's efforts associated with investigating TAHD, please visit the Department's hoof disease webpage: http://wdfw.wa.gov/conservation/health/hoof_disease/

North Cascades Elk Herd

General Overview

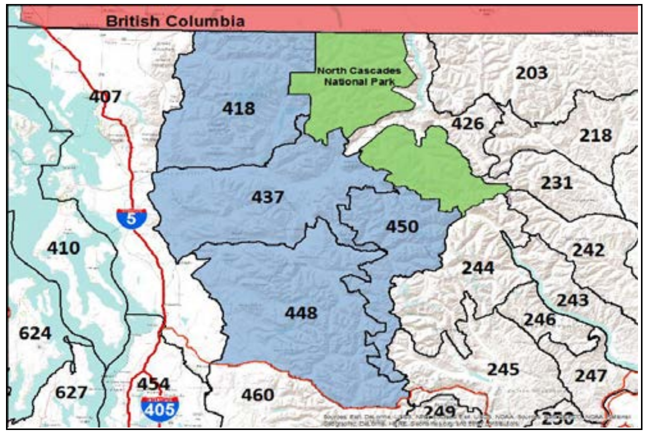


Figure 15. Location and boundaries of Game Management Units that comprise the North Cascades elk herd area.

The North Cascades elk herd area is located in northwest Washington, consists of 4 GMUs (Figure 15), and is the smallest of 10 herds formally managed by the Department. The Department is currently updating the North Cascades Elk Herd Plan (WDFW 2002a), but at the time of this writing, has not finalized a revised population objective. Additional objectives that have been finalized, however, are maintaining a post-hunt population with a bull:cow ratio of 12–20 bulls:100 cows and maintaining an annual survival rate of 0.50 for bulls when bull mortality is monitored.

The Department, in cooperation with the Point Elliot Treaty Tribes, conducts aerial composition surveys during March–April in areas associated with the core herd area. We derive estimates of total elk abundance and estimates of the bull and cow subpopulations within the survey area using a logit-normal mixed effects (LNME) mark-resight model (McCorquodale et al. 2011, 2013).

The Department and Point Elliot Treaty Tribes implemented a harvest moratorium throughout most of the herd area 1997–2006 because managers believed the herd had declined to as few as 300 elk. Managers reinstated limited opportunities to harvest bulls in 2007 and allocated those opportunities equally between state and tribal hunters; that approach continues to this day. General season opportunities continue to be limited, but managers have increased permit opportunities as the population has increased. Antlerless harvest is primarily limited to situations involving agricultural damage complaints, but harvest levels have been substantial in some years (e.g., 2013, see below) when abnormal winter conditions concentrated elk in the Skagit River Valley, where conflict with agricultural producers can be high.

Current Status and Trend

In spring 2016, biologists estimated total elk abundance within the core herd area to be 1,268 elk (95% CI = 1,170–1,374). Estimates of the cow and branch-antlered bull subpopulations in spring 2016 were 782 cows (95% CI = 721–849) and 390 bulls (95% CI = 274–482). Estimates of bull:cow and calf:cow ratios derived from uncorrected observation data were 25:100 and 22:100, respectively. Bull:cow ratios remain at levels above the post-hunt management objective of 12–20 bulls:100 cows, while calf:cow ratios have represented good-excellent calf recruitment rates in most years (Figure 16).

a) b)

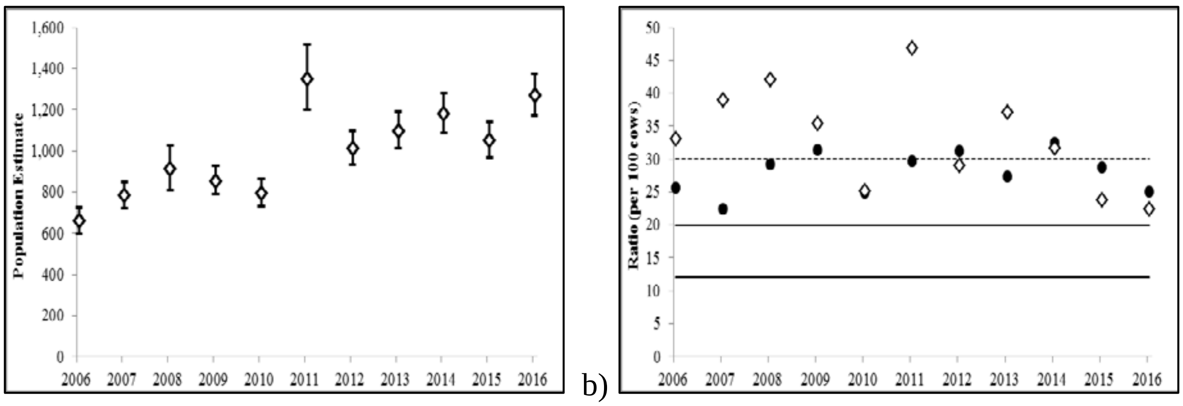


Figure 16. Estimates of (a) total elk abundance using LNME mark-resight with associated 95% confidence intervals in the North Cascade elk herd area, 2006–2016. Also included are estimates of (b) post-hunt calf:cow (◊) and bull:cow ratios (●), spring 2006–2015. The solid lines represent objectives for bull:cow ratios (12–20 bulls:100 cows), while the dashed line represents calf recruitment rates that should promote herd stability or growth (≥ 30 calves:100 cows).

Harvest

Estimates of General State Harvest and Total State Harvest in the North Cascades elk herd area have averaged 25 and 73 elk, respectively, 2005–2015, while estimates of Total Harvest have averaged 103 elk, 2005–2014. Estimates of General State Harvest have remained low as general season harvest opportunities have been limited, while estimates of Total State Harvest and Total Harvest increased sharply 2010–2013 and then decreased precipitously 2013–2015 (Figure 17). The wide variability in harvest estimates 2011–2015 have largely been associated with increased opportunities to harvest antlerless elk to mitigate damage to agricultural crops. We did not generate estimates of hunter effort or CPUE because estimates of harvest and hunter effort during general seasons are very low.

Survival and Cause-Specific Mortality

The Department (McCorquodale et al. [2011]) monitored the survival of adult female elk and branch-antlered bulls in the North Cascade elk herd area 2005–2011 and estimated annual survival rates to be >0.90 for both sex classes prior to the reinstatement of harvest opportunities in 2007. Following the resumption of opportunities to harvest bulls, we estimated survival of branch-antlered bulls to be 0.68 (95% CI = 0.50–0.82). In addition, of the 270 mortality events we documented during that study, we attributed 77% to harvest-related causes, 14% to elk-vehicle collisions, and only 4% to natural causes (e.g., predation, disease, accidents, etc., combined).

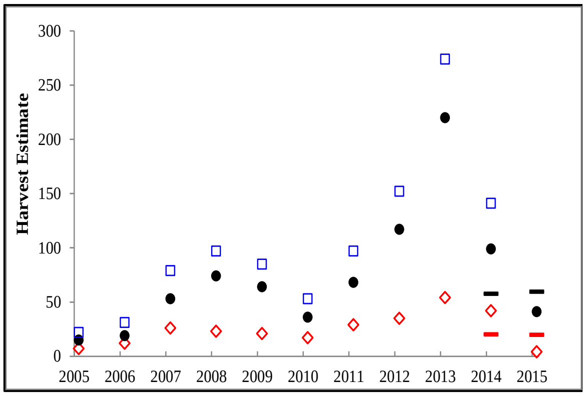


Figure 17. General State Harvest (◊), Total State Harvest (●), and Total Harvest (□) estimates in the North Cascades elk herd area, 2005–2015. The dashes associated with harvest estimates in 2014 and 2015 represent harvest levels that are 25% below the 10-year average (2005-2014 in 2014 and 2006-2015 in 2015) for General State Harvest (red) and Total State Harvest (black). We did not generate estimates of Total Harvest in 2015 because estimates of tribal harvest in 2015 were not available.

Assessment

The Department will assess the North Cascades elk herd's "at-risk" status when a final population objective is developed in the revised herd plan. Estimates of total elk abundance and calf:cow ratios within the core herd area indicate the North Cascades elk herd has steadily increased since 2006 and that calf recruitment rates have been at levels that would promote population growth or stability in most years. In addition, estimated bull:cow ratios and recent estimates of bull survival indicate the Department is exceeding its objective of maintaining an annual survival rate of 0.50 for bulls. Consequently, in the absence of abnormal weather conditions or exceedingly high harvest rates for adult female elk, the Department expects the North Cascades elk herd to continue to increase. Lastly, biologists did not identify any local populations of concern.

Factors That Potentially Influence Population Dynamics

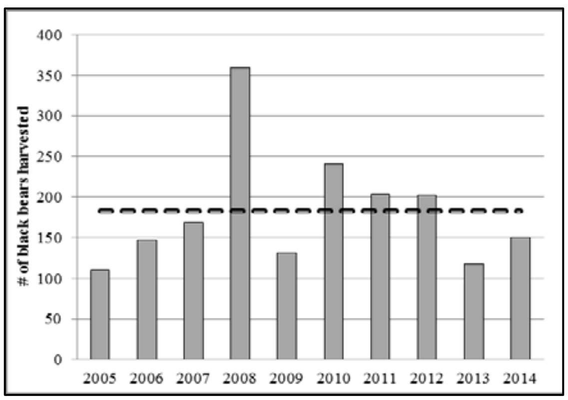
Predators

Black Bear.—Black bears are common throughout the North Cascades elk herd area. Estimated black bear harvest during state general and permit seasons has averaged nearly 200 bears over the past 10 years, but has been declining 2010–2014 (Figure 18).

Cougar.—Cougars occur throughout the North Cascades elk herd area, but cougar harvest has averaged less than three animals, 2005–2014 (Figure 18).

Gray Wolf.—The Department has documented the presence of wolves in the upper Skagit River system near the U.S./Canada border since the early 1990’s, but at the time of this writing there were no documented wolf packs within the North Cascades elk herd area (Becker et al. 2016).

a)



b)

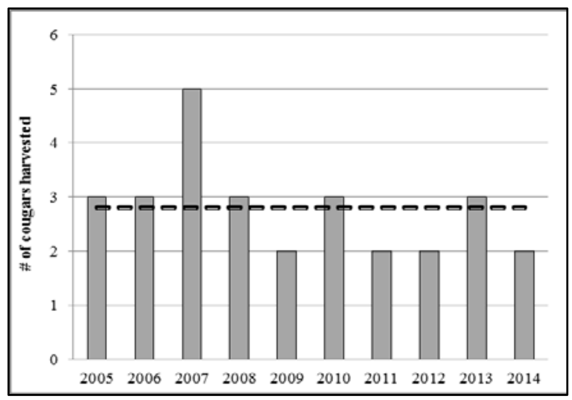


Figure 18. Estimated number of black bears (a) and cougars (b) harvested during general and permit seasons in the North Cascades herd area, 2005–2014. The dashed line represents the 10-year average.

Forest Management Practices

Forest management practices on private industrial and state forestlands continue to benefit the North Cascades elk herd by creating a mosaic of habitat types. Specifically, clearcuts and young regenerating stands provide a forage base that is commonly absent in mature forests. Conversely, a large portion of the North Cascades elk herd area is under federal ownership and dominated by mature timber that provides little benefit to elk.

Weather

Although biologists have never documented a substantial winter effect on elk survival, it can influence the distribution of this herd. When severe winter conditions persist, elk become concentrated in the Skagit River Valley, where the potential for conflict with agricultural producers is high. The North Cascades elk herd is still relatively small and susceptible to overharvest. Consequently, harvesting a large number of adult female elk to mitigate damage claims has the potential to have a negative effect on the population dynamics of this herd.

North Rainier Elk Herd

General Overview

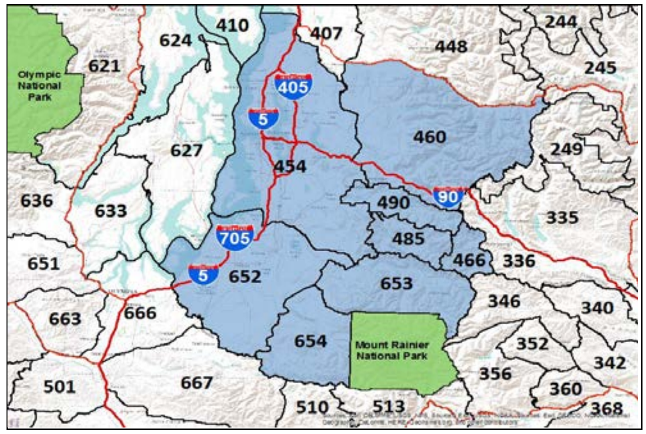


Figure 19. Location and boundaries of Game Management Units that comprise the North Rainier elk herd area.

The North Rainier elk herd area is located in west-central Washington and consists of 8 GMUs (Figure 19). The Department is currently updating the North Rainier Elk Herd Plan (WDFW 2002b) and has proposed a population objective during spring of 3,870–4,730 elk. However, a formalized monitoring program to estimate elk abundance for the entire herd area is lacking.

The Muckleshoot Indian Tribe (MIT) conducts aerial composition surveys in GMUs 485 and 653 and annually estimates elk abundance using the Lincoln-Petersen mark-resight model, in addition to collecting information on elk abundance in GMU 490 using ground and aerial surveys. The Upper Snoqualmie Valley Elk Management Group conducts annual ground surveys to estimate elk abundance in Elk Area 4601 using mark-resight. The Department has also collaborated with MIT, the U.S. Geological Survey, National Park Service, and Puyallup Tribe of Indians to estimate elk abundance in the high alpine meadows of Mount Rainier National Park (MRNP) (Lubow et al. 2015). However, those surveys only include a small portion of the North Rainier elk herd (<400 elk) and it is unknown what proportion of those elk move outside MRNP and are available for harvest.

Current Status and Trend

Although there are numerous efforts to estimate elk abundance at a localized scale, inferences the Department can make from these data about population trend or composition may not be reflective of the entire herd. Because the Department has not identified a comprehensive monitoring strategy, we primarily depend on harvest data to make inferences about population trend at the herd level.

The Department limits most general season harvest opportunities in the North Rainier elk herd area to branch-antlered bulls and offers most opportunities to harvest antlerless elk through their permit system. However, limited opportunities to harvest antlerless elk during general seasons do occur during general archery and muzzleloader seasons and in areas where the Department's objective is to maintain low elk numbers. The Department restricts all elk harvest in GMUs 485 and 653 to permit only opportunities.

Harvest

Estimates of General State Harvest and Total State Harvest in the North Rainier elk herd area have averaged 281 and 322 elk, respectively, 2005–2015, while estimates of Total Harvest have averaged 393 elk, 2005–2014. All three harvest estimates steadily increased 2005–2013, but General State Harvest and Total State Harvest have declined slightly the last two years (Figure 20); we anticipate Total Harvest to follow a similar trend when tribal harvest data is published for the 2015 season. Estimates of General State Harvest and Total State Harvest were also greater than harvest estimates that would be 25% below the 10-year average in 2014 and 2015 (Figure 20). Hunter effort steadily increased, 2005–2015, while CPUE was stable, 2008–2011, increased sharply in 2012, and declined the past couple of years (Figure 20).

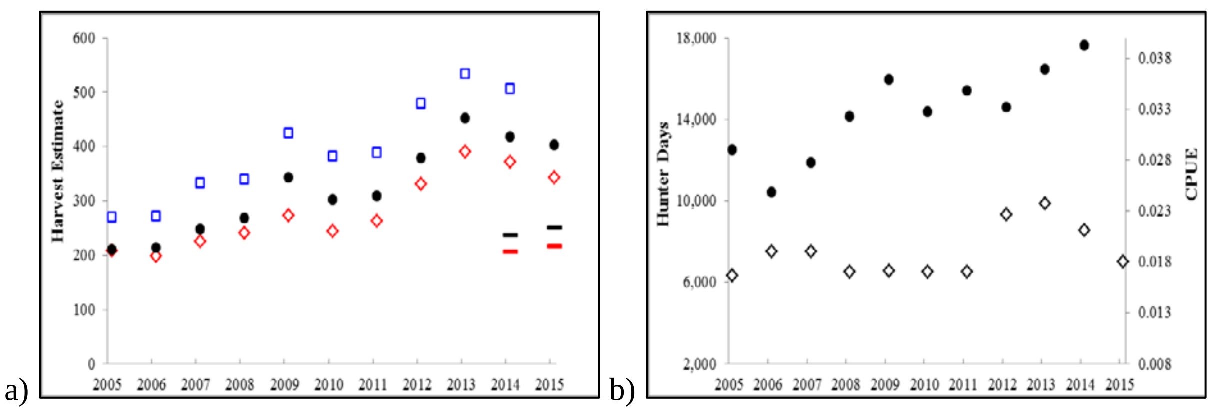


Figure 20. General State Harvest (◊), Total State Harvest (●), and Total Harvest (□) estimates (a) in the North Rainier elk herd area, 2005–2015. The dashes associated with harvest estimates in 2014 and 2015 represent harvest levels that are 25% below the 10-year average (2005-2014 in 2014 and 2006-2015 in 2015) for General State Harvest (red) and Total State Harvest (black). Also included are estimates of (b) hunter days (●) and catch-per-unit-effort (CPUE) (◊), 2005–2015. We generated estimates of CPUE using estimates of hunter effort and elk harvest during general modern firearm, muzzleloader, and archery seasons combined. We did not generate estimates of Total Harvest in 2015 because estimates of tribal harvest in 2015 were not available.

Survival and Cause-Specific Mortality

MIT has monitored the survival of adult female elk and calves in GMUs 485, 490, and 653, 1998–present (D. Vales, MIT, unpublished data). During that same period, they estimated annual adult female survival rates that were as low as 0.70–0.75 in some years, but typically ranged between 0.80–0.90. Cougars accounted for 63% and 33% of all adult cow mortalities in GMUs 485 and 653, respectively, prior to MIT implementing a cougar reduction program (see below) and 33% and 25%, respectively, following cougar removals.

Estimates of calf survival were quite variable and ranged from a low of 0.09 in 1999 to a high of 0.82 in 2006. Cougars accounted for 43–88% of all calf mortalities; bears only accounted for 6–11% of calf mortalities. Calf annual mortality rates due to cougar ranged 0.20–0.71.

Assessment

Harvest data indicate the North Rainier elk herd has been increasing, or at least remained stable as hunter effort increased, and does not qualify as an "at-risk" ungulate population. In addition, biologists did not identify any local populations of concern.

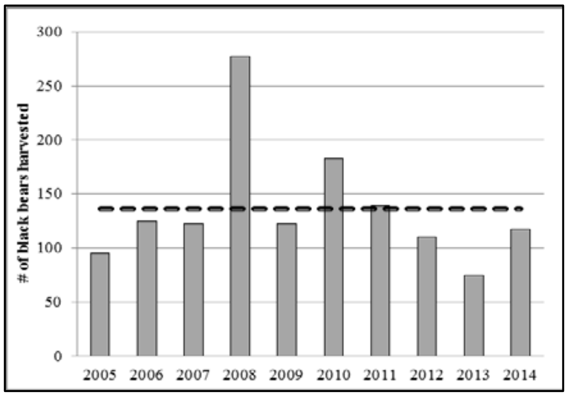
Factors That Potentially Influence Population Dynamics

Predators

Black Bear.—Black bears occur throughout the North Rainier elk herd area. The estimated number of black bears harvested during general and permit seasons has averaged close to 150 bears, 2005–2014, but harvest has been below the 10-year average the past three years (Figure 21).

Cougar.—Cougars occur throughout the North Rainier elk herd area, but harvest has only averaged 4 animals per year, 2005–2014 (Figure 21). The lowest estimates of cow and calf survival from the MIT research occurred in the late 1990s and early 2000s and indicated cougars were the leading cause of mortality for both adult females and calves. In response to these findings, MIT implemented a cougar reduction program from 2001 to 2007 to reduce cougar densities in GMUs 485, 466, and 653. Elk survival rates increased during the same time period. In addition to more conservative hunting season structures and ongoing habitat improvement projects during that same time period, this work does suggest that predation was one factor affecting the overall performance of the elk population. In 2016, female and calf survival still occur at levels that should promote population growth and stability (D. Vales, MIT, unpublished data).

Gray Wolf.—At the time of this writing there were no documented wolf packs in the North Rainier elk herd area (Becker et al. 2016).

a) 

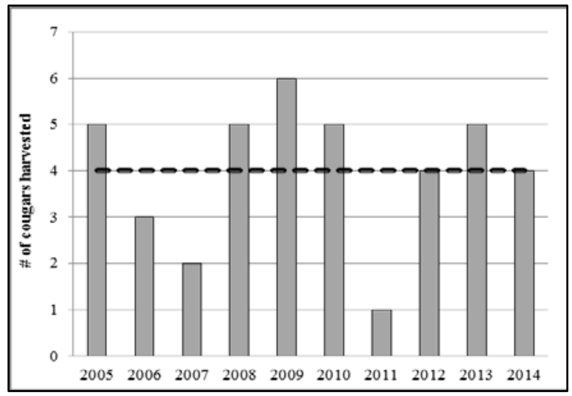
b) 

Figure 21. Estimated number of black bears (a) and cougars (b) harvested during general and permit seasons in the North Rainier elk herd area, 2005–2014. The dashed line represents the 10-year average.

Forest Management Practices

A large portion of the North Rainier elk herd area consists of lands administered by the USFS, where timber harvest is limited and provides very little value from the perspective of supporting robust elk herds. Consequently, the North Rainier elk herd benefits most from forest management practices on private and state industrial forestlands, where frequent harvesting of mature timber creates a mosaic of early seral habitats that provide an important forage base for this herd.

Weather

Severe winter conditions are rare in the North Rainier elk herd area and are unlikely to influence the population dynamics of this herd. However, extreme drought conditions that persist through summer and fall have the potential to reduce the availability of high quality forages that elk need to accrue adequate fat stores for winter.

Olympic Elk Herd

General Overview

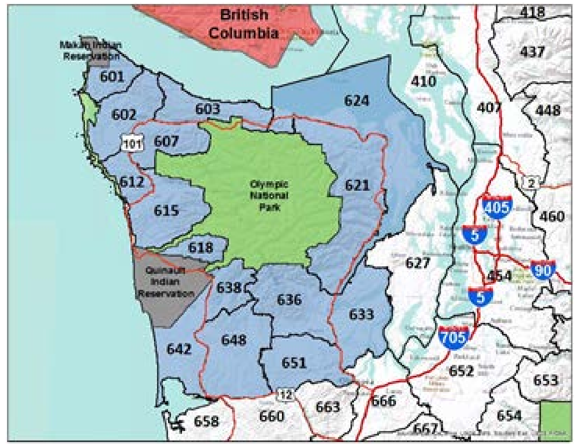


Figure 22. Location and boundaries of Game Management Units that comprise the Olympic elk herd area.

The Olympic elk herd area is located on the Olympic Peninsula and consists of 15 GMUs (Figure 22). The Olympic Elk Herd Plan identifies a population objective of 11,350 elk outside Olympic National Park (WDFW 2004). However, that objective is likely to change when the plan is updated. Moreover, the Department has not identified a formalized monitoring strategy to estimate elk abundance or composition at the herd level. Consequently, the Department generally manages for stable to increasing elk populations in the Olympic elk herd area. Additional objectives include managing for a pre-season population with 15–35 bulls:100 cows and/or a post-hunt population with 12–20 bulls:100 cows and maintaining an annual survival rate of 0.50 for bulls when bull mortality is monitored (WDFW 2014a).

The Department has periodically conducted aerial composition surveys in the Olympic elk herd area, but not since 2011. Several Treaty Tribes that have hunting rights on the Olympic Peninsula conduct aerial composition or ground-based surveys in some GMUs, but, with exception to the Makah Tribe, do not consistently apply formalized estimators (e.g., sightability models, mark-resight, distance sampling, etc.) to correct observed data for detection probabilities that vary among age and sex classes. Even though those data are likely biased and managers must make conservative inferences, it still provides some insight into the current composition of this herd. The Department and Treaty Tribes have both conducted pre-season and post-season surveys through the years.

The Department limits most general season harvest opportunities in the Olympic elk herd area to branch-antlered bulls and offers most opportunities to harvest antlerless elk through their permit system. However, limited opportunities to harvest antlerless elk do occur during general archery seasons and in areas where the Department's objective is to maintain low elk numbers.

Current Status and Trend

Estimates of pre-hunt bull:cow ratios have steadily declined 2008–2014 to levels at, or just below, the management objective of 15–35 bulls:100 cows (Figure 23). Estimates of post-hunt bull:cow ratios have been more stable, but have consistently been below the management objective of 12–20 bulls:100 cows (Figure 23). Estimates of calf:cow ratios during pre-hunt surveys have been declining 2010–2014, while estimates of post-hunt calf:cow ratios, 2011–2014, were consistently lower than estimated calf:cow ratios, 2006–2010 (Figure 23).

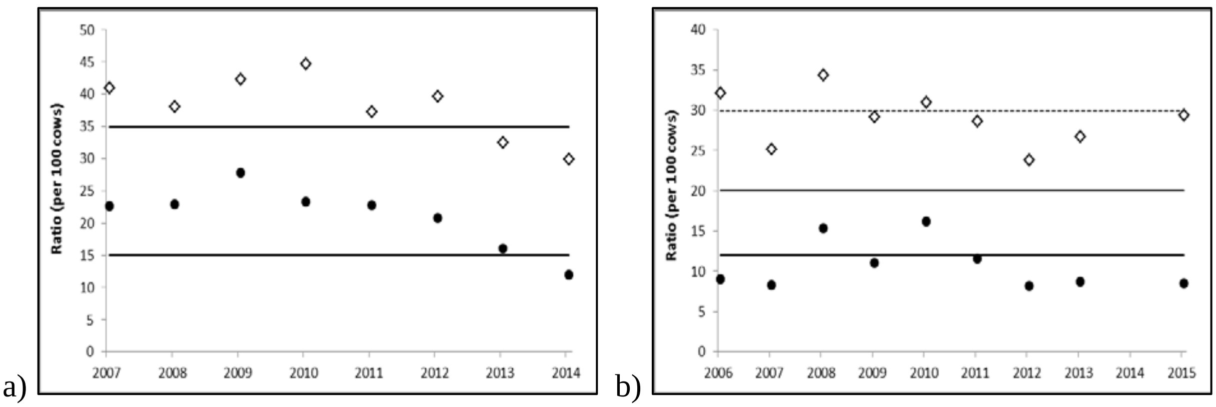


Figure 23. Estimates of (a) pre-hunt bull:cow (●) and calf:cow (◊) ratios in the Olympic elk herd area, 2007–2014; and (b) post-hunt bull:cow (●) and calf:cow ratios (◊), 2006–2015. The solid lines represent objectives for pre-hunt (15–35 bulls:100 cows) and post-hunt (12–20 bulls:100 cows) sex ratios, while the dashed line represents calf recruitment rates that should promote herd stability or growth (≥ 30 calves:100 cows). Post-hunt ratios from 2014 are not included because biologists only conducted surveys in a single GMU in that year, while we did not provide pre- and post-hunt ratios for 2015 because survey data were not available.

Harvest

Estimates of General State Harvest and Total State Harvest have averaged 251 and 288 elk, respectively, 2005–2015, while estimates of Total Harvest have averaged 464 elk, 2005–2014. All three harvest estimates were gradually declining, 2010–2013, but estimates of General State Harvest and Total State Harvest have increased the last couple of years (Figure 24). In addition, estimates of General State Harvest and Total State Harvest were above harvest levels that would be 25% below the 10-year average in 2014 and 2015 (Figure 24). Estimates of CPUE similarly declined 2010–2013 and increased in recent years, while hunter effort has been relatively stable (Figure 24).

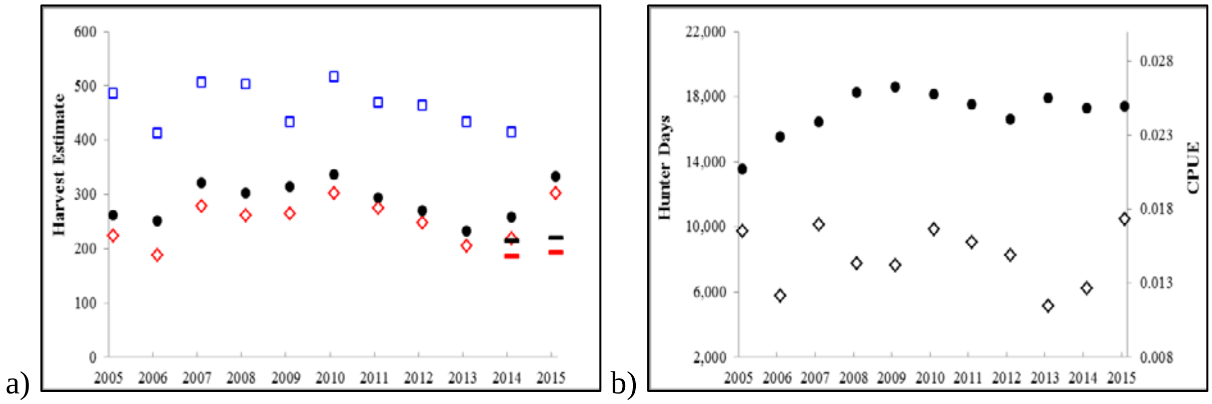


Figure 24. General State Harvest (◊), Total State Harvest (●), and Total Harvest (□) estimates (a) in the Olympic elk herd area, 2005–2015. The dashes associated with harvest estimates in 2014 and 2015 represent harvest levels that are 25% below the 10-year average (2005-2014 in 2014 and 2006-2015 in 2015) for General State Harvest (red) and Total State Harvest (black). Also included are estimates of (b) hunter days (●) and catch-per-unit-effort (CPUE) (◊), 2005–2015. We generated estimates of CPUE using estimates of hunter effort and elk harvest during general modern firearm, muzzleloader, and archery seasons combined. We did not generate estimates of Total Harvest in 2015 because estimates of tribal harvest in 2015 were not available.

Survival and Cause-Specific Mortality

There have been no comprehensive studies to estimate the survival of elk throughout the Olympic elk herd area. However, the Department and several Treaty Tribes have conducted numerous projects in some GMUs. The Department radio-collared 28 adult female elk in GMUs 607 and 615 in 2011, and estimated annual survival rates, 2011–present, to be ≥ 0.89 (Anita McMillan, WDFW, unpublished data). The Department also estimated annual survival to be 0.94 in 2004 and 0.81 in 2005 for 40 adult female elk in GMUs 636 and 648 (B. Murphie, WDFW, unpublished data). Among the 8 mortalities documented in GMUs 636 and 648, nutritional stress comprised the largest component of mortality followed by tribal harvest and poaching; cougar predation was a factor in the death of only 1 cow, but biologists believed nutritional stress was a contributing factor. The Makah Tribe monitored elk survival in GMU 601 and northern portion of GMU 602, 2010–2012, and estimated annual cow survival to be 0.88, bull survival to be 0.29, and calf survival ranged 0.27–0.40 (R. McCoy, Makah Tribe, unpublished data). Cougars were the primary cause of mortality for calves (74%) and adult females, while harvest was the primary cause of mortality for bulls.

Assessment

Harvest data indicate the Olympic elk herd may have been declining 2010–2014, which coincided with a period of below average recruitment rates and declining pre-hunt bull:cow ratios. However, harvest estimates and CPUE have increased the past couple years, the Olympic elk herd does not meet the criteria of an “at-risk” ungulate population, and biologists did not identify any local populations of concern. However, survey data indicates the Department may not be meeting its management objective of maintaining a post-hunt population with 12–20 bulls:100 cows.

Factors That Potentially Influence Population Dynamics

Predators

Black Bear.—Black bears are abundant throughout the Olympic elk herd area. The estimated number of black bears harvested during general and permit seasons has averaged close to 200 bears, but has been declining the past 5 years (Figure 25).

Cougar.—Cougars occur throughout the Olympic elk herd area and state hunters during general and permit seasons, on average, harvest 12 cougars each year (Figure 25). The Makah Tribe has been conducting research on cougars in the northwest corner of the Olympic Peninsula since 2010 (Murphie and McCoy 2015). Their work has shown that male cougars primarily target elk, female cougars primarily target black-tailed deer (*O. hemionus columbianus*), and that both sexes prey on smaller mammals, including raccoon (*Procyon lotor*) and beaver (*Castor canadensis*).

Gray Wolf.—At the time of this writing, there were no documented wolf packs within the Olympic elk herd area (Becker et al. 2016).

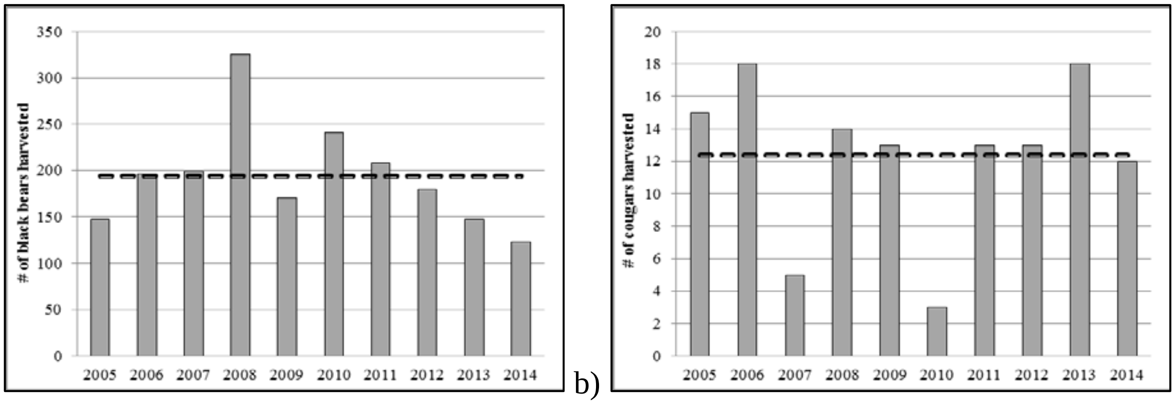


Figure 25. Estimated number of black bears (a) and cougars (b) harvested during general and permit seasons in the Olympic elk herd area, 2005–2014. The dashed line represents the 10-year average.

Forest Management Practices

The population dynamics of the Olympic elk herd are strongly associated with forest management practices on private industrial forestlands, state lands, and USFS lands. Forest management practices on private and state industrial forestlands continue to benefit the Olympic elk herd by increasing the amount of early seral habitats. Conversely, forest management practices on USFS lands have changed to promote the persistence of late seral forests, which are of little value to elk.

Weather

With exception to elk that use higher elevations in Olympic National Park, severe winter events rarely affect the population dynamics of the Olympic elk herd. However, extreme drought conditions that persist through summer and fall have the potential to reduce the availability of high quality forages that elk need to accrue adequate fat stores for winter.

Selkirk Elk Herd

Pend Oreille Sub-Herd

General Overview

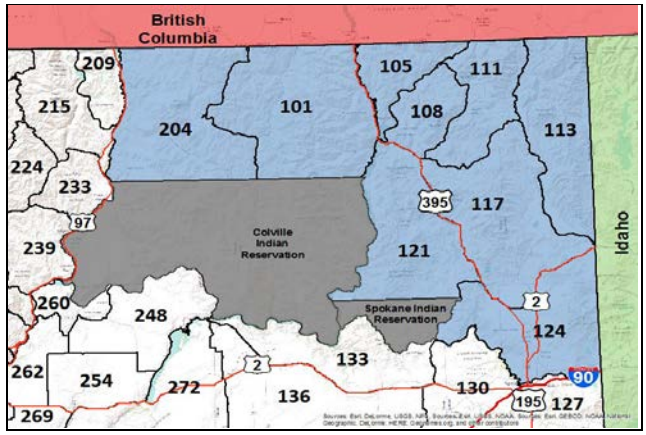


Figure 26. Location and boundaries of Game Management Units that comprise the Selkirk-Pend Oreille sub-herd area.

The Selkirk elk herd is located in northeast Washington and includes the Pend Oreille and Spokane sub-herds. The Pend Oreille sub-herd consists of 9 GMUs in the northeast corner of the state (Figure 26). The Department's objective for the Pend Oreille sub-herd is to increase elk abundance to 1,500–2,500 elk and to maintain populations with a pre-hunt bull:cow ratio of 15–35 bulls:100 cows or post-hunt bull:cow ratio of 12–20 bulls:100 cows (WDFW 2014b). However, habitats associated with this area present a sampling environment that is not conducive to conducting typical aerial composition surveys because the dense forests significantly impede the ability of observers to detect elk. Consequently, the Department relies on harvest data to make inferences about population trend.

Status and Trend

The Department limits most general season harvest opportunities in the Pend-Oreille sub-herd area to any bull and offers most opportunities to harvest antlerless elk through their permit system. However, opportunities to harvest antlerless elk do occur throughout the sub-herd area during general archery seasons and for all weapon types in GMU 124 where the Department's objective is to maintain elk numbers within landowner tolerance.

Harvest

Estimates of General State Harvest and Total State Harvest have averaged 264 and 287 elk, respectively, 2005–2015, and have been relatively stable 2009–2015 (Figure 27). Both estimates were also greater than harvest levels that would be 25% below the 10-year average in 2014 and

2015 (Figure 27). Hunter effort and CPUE have also been relatively stable during that same period (Figure 27).

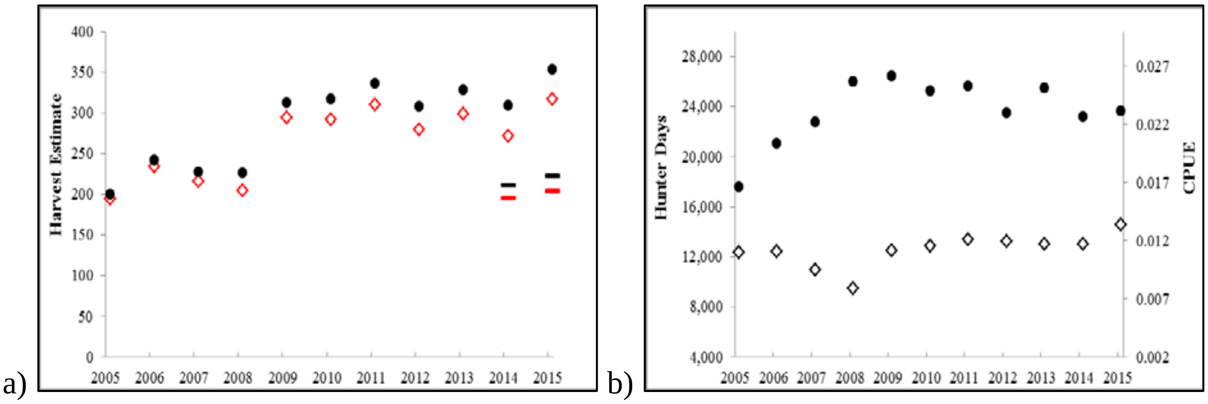


Figure 27. General State Harvest (◊) and Total State Harvest (●) estimates (a) in the Selkirk Pend Oreille sub-herd herd area, 2005–2015. The dashes associated with harvest estimates in 2014 and 2015 represent harvest levels that are 25% below the 10-year average (2005-2014 in 2014 and 2006-2015 in 2015) for General State Harvest (red) and Total State Harvest (black). Also included are estimates of (b) hunter days (●) and catch-per-unit-effort (CPUE) (◊), 2005–2015. We generated estimates of CPUE using estimates of hunter effort and elk harvest during general modern firearm, muzzleloader, and archery seasons combined. We did not generate estimates of Total Harvest because estimates of tribal harvest were not available.

Survival and Cause-Specific Mortality

There have been no recent studies to monitor the survival of elk in the Pend Oreille sub-herd area.

Assessment

Harvest data indicate the Pend Oreille sub-herd does not qualify as an “at-risk” ungulate population. In addition, biologists did not identify any local populations of concern.

Factors That Potentially Influence Population Dynamics

Predators

Black Bear.—Black bears occur throughout the Pend Oreille sub-herd area and the estimated number of bears harvested during general and permit seasons has averaged close to 400 bears annually (Figure 28).

Cougar.—Cougars occur throughout the Pend Oreille sub-herd area and estimates of total harvest during general and permit seasons has increased sharply during the last 5 years (Figure 28).

Gray Wolf.—The Department documented the first wolf pack in the Pend Oreille sub-herd in 2009. At the time of this writing, the Department had documented 14 wolf packs whose range currently occurs wholly or partially within the Pend Oreille sub-herd area (Becker et al. 2016).

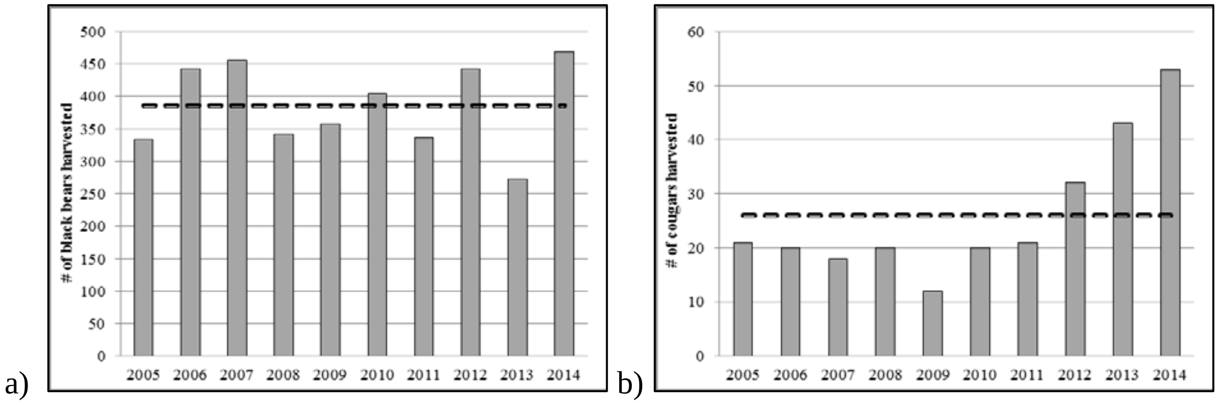


Figure 28. Estimated number of black bears (a) and cougars (b) harvested during general and permit seasons in the Selkirk-Pend Oreille sub-herd area, 2005–2014. The dashed line represents the 10-year average.

Forest Management Practices

Logging continues on federal and state forestlands and even more intensively on private lands, which benefits the Pend Oreille sub-herd by increasing the amount of early seral habitats.

Habitat Enhancement

The Colville National Forest, with grant money from the Rocky Mountain Elk Foundation (RMEF), has implemented habitat enhancement projects on approximately 58,000 acres to benefit elk. Most of the projects involved prescribed burning to enhance winter forage production, but there were also projects to restore aspen stands and reclaim roadbeds for improved habitat.

Wildfires

Over 350,000 acres within the Pend Oreille sub-herd area burned in the summer of 2015. These burns will likely benefit elk in the long term, but some areas burned completely and with high intensity, so it may be several years before any benefits to elk are realized.

Weather

Although the Department has never documented any increased mortality events, severe winter events do occur within the Pend Oreille sub-herd area and likely have the potential to reduce the overwinter survival of elk. In addition, extreme drought conditions that persist through summer and fall have the potential to reduce the availability of high quality forages that elk rely on to accrue adequate fat stores for winter.

Human Disturbance

Elk were not utilizing some areas that provided quality elk habitat because of the amount of human disturbance associated with these areas. Federal, state, and private land managers implemented numerous road closures in recent years that have likely benefited this herd by reducing human disturbance in areas that provide quality elk habitat.

Selkirk Elk Herd

Spokane Sub-Herd

General Overview

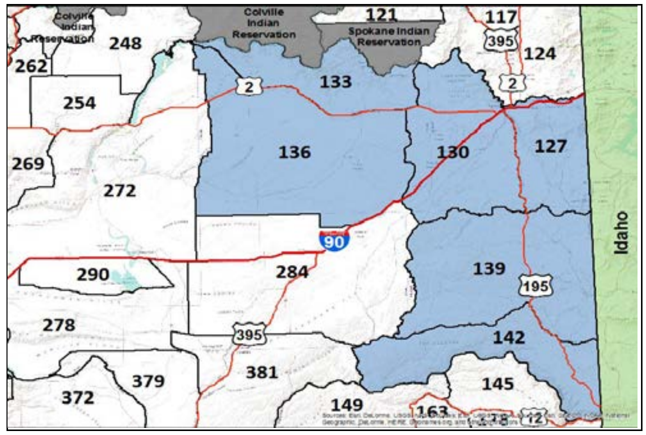


Figure 29. Location and boundaries of Game Management Units that comprise the Selkirk-Spokane sub-herd area.

The Selkirk elk herd is located in northeast Washington and includes the Pend Oreille and Spokane sub-herds. The Spokane sub-herd consists of 6 GMUs located in east-central Washington (Figure 29). The Department's objective for the Spokane sub-herd is to maintain elk numbers between 1,000–1,500 elk. Additional objectives include maintaining populations with a pre-hunt bull:cow ratio of 15–35 bulls:100 cows or post-hunt bull:cow ratio of 12–20 bulls:100 cows (WDFW 2014b).

Status and Trend

Although the Department collaborates with the U.S. Fish and Wildlife Service (USFWS) to conduct pre-hunt aerial composition surveys on the Turnbull National Wildlife Refuge, these surveys only include a small portion of the Spokane sub-herd. Thus, data are not likely to be representative of the entire sub-herd.

Because the Department has not identified a monitoring strategy to estimate elk abundance or herd composition at the herd level, we rely on harvest data to make inferences about population trend. The Department allows the harvest of any elk during all general seasons.

Harvest

Estimates of General State Harvest and Total State Harvest averaged 218 and 230 elk, respectively, 2005–2015. Both harvest estimates were relatively stable 2005–2009, but have been quite variable 2010–2015 (Figure 30). In addition, both estimates were also greater than harvest levels that would be 25% below the 10-year average in 2014 and 2015 (Figure 30). Estimates of

CPUE steadily increased 2007–2012 and varied widely 2012–2015, while estimates of hunter effort have steadily increased, 2005–2015 (Figure 30).

a) b)

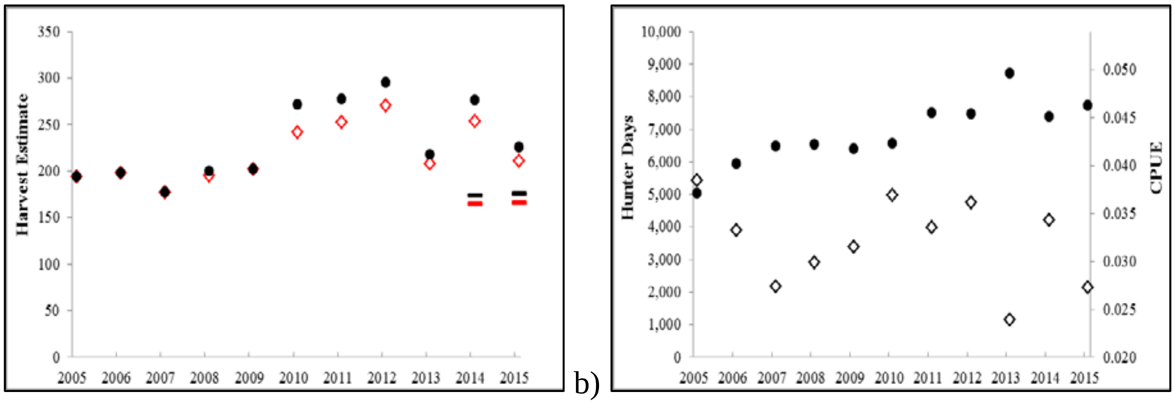


Figure 30. General State Harvest (◊) and Total State Harvest (●) estimates (a) in the Selkirk Spokane sub-herd herd area, 2005–2015. The dashes associated with harvest estimates in 2014 and 2015 represent harvest levels that are 25% below the 10-year average (2005-2014 in 2014 and 2006-2015 in 2015) for General State Harvest (red) and Total State Harvest (black). Also included are estimates of (b) hunter days (●) and catch-per-unit-effort (CPUE) (◊), 2005–2015. We generated estimates of CPUE using estimates of hunter effort and elk harvest during general modern firearm, muzzleloader, and archery seasons combined. We did not generate estimates of Total Harvest because estimates of tribal harvest were not available.

Survival and Cause-Specific Mortality

There have been no recent studies to estimate elk survival in the Spokane sub-herd area.

Assessment

Harvest data indicate elk abundance in the Spokane sub-herd area may have decreased in recent years, but it does not qualify as an "at-risk" ungulate population. In addition, biologists did not identify any local populations of concern.

Factors That Potentially Influence Population Dynamics

Predators

Black Bear.—Black bears can occur throughout the Spokane sub-herd area, but are more likely to occur in forested areas. The estimated number of black bears harvested during general and permit seasons has only averaged 12 bears, 2005–2014 (Figure 31).

Cougar.—The Department believes cougar densities are low in most parts of the Spokane sub-herd area, which is reflected by the low number of cougars harvested during general and permit seasons (Figure 31).

Gray Wolf.—At the time of this writing, there were no documented gray wolf packs in the Spokane sub-herd area (Becker et al. 2016).

a) b)

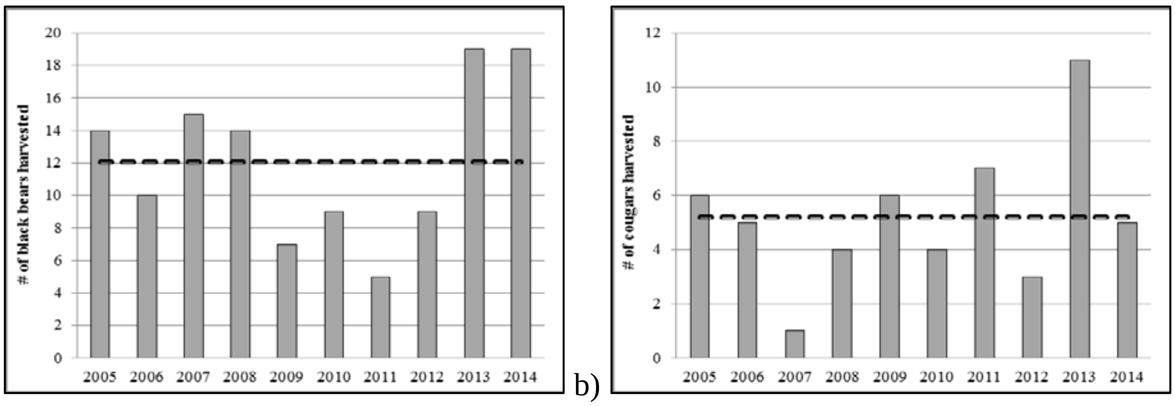


Figure 31. Estimated number of black bears (a) and cougars (b) harvested during general and permit seasons in the Selkirk-Spokane sub-herd area, 2005–2014. The dashed line represents the 10-year average.

Habitat Loss

Conversion of native Palouse Prairie and shrub-steppe habitat in the Spokane sub-herd area to agricultural lands has and continues to reduce the amount of native elk habitat. In addition, the expansion of urban populations associated with the main Spokane metropolitan area continues to result in habitat degradation or loss in GMUs 124, 127, and 130. Consequently, it is likely that social tolerance within agricultural and suburban areas will limit the growth and expansion of the Spokane sub-herd.

Weather

Although the Department has never documented any increased mortality events, severe winter events do occur within the Spokane sub-herd area and likely have the potential to reduce the overwinter survival of elk. In addition, extreme drought conditions that persist through summer and fall have the potential to reduce the availability of high quality forages that elk rely on to accrue adequate fat stores for winter.

South Rainier Elk Herd

General Overview

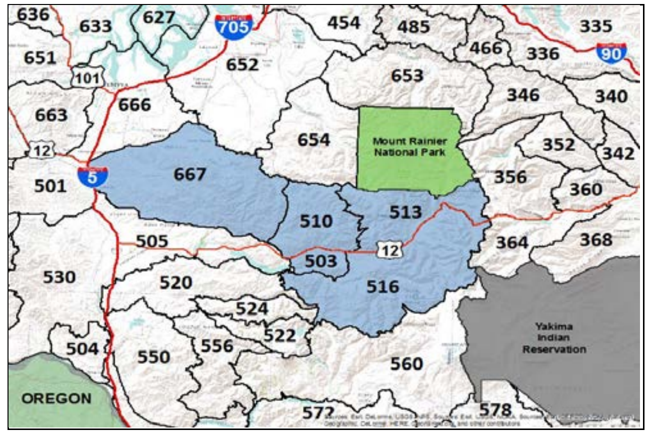


Figure 32. Location and boundaries of Game Management Units that comprise the South Rainier elk herd area.

The South Rainier elk herd is located in west-central Washington and consists of 5 GMUs (Figure 32). The Department identified a management objective of 3,000 elk in the South Rainier Elk Herd Plan (WDFW 2002c), but that plan is nearly 14 years old and management objectives are likely to change when it is updated. In addition, the Department has not identified a formalized monitoring strategy to estimate elk abundance and herd composition in the South Rainier elk herd area.

Status and Trend

The Puyallup Tribe of Indians conducts aerial composition surveys and estimates elk abundance in the upper Cowlitz River basin, which includes areas associated with GMUs 503, 510, 513, and 516, using a sightability model they developed specific to that area (Gilbert and Moeller 2008). However, those surveys occur in a small geographic area and may not be representative of the entire herd.

The Department has also collaborated with MIT, the U.S. Geological Survey, National Park Service, and Puyallup Tribe of Indians to estimate elk abundance in the high alpine meadows of Mount Rainier National Park (MRNP) (Lubow et al. 2015). However, those surveys only include a small portion of the South Rainier elk herd (<550 elk) and it is unknown what proportion of those elk move outside MRNP and are available for harvest. Consequently, inferences the Department can make from those data about population trend or composition are also not likely to be reflective of the entire herd. Because the Department has not identified a comprehensive monitoring strategy that is representative of the entire herd, we primarily depend on harvest data to make inferences about population trend at the herd level.

The Department limits most general season harvest opportunities in the South Rainier elk herd area to branch-antlered bulls and offers most opportunities to harvest antlerless elk through their permit system. However, limited opportunities to harvest antlerless elk do occur during general archery seasons and in areas where the Department's objective is to maintain low elk numbers.

Harvest

Estimates of General State Harvest and Total State Harvest have averaged 280 and 305 elk, respectively, 2005–2015, while estimates of Total Harvest have averaged 384 elk, 2005–2014. All three harvest estimates varied annually, 2005–2012, but General State Harvest and Total State Harvest have been more stable 2013–2015 and were greater than harvest levels that would be 25% below the 10-year average in 2014 and 2015 (Figure 33). Estimates of hunter effort increased 2005–2008, declined 2008–2011, and have been stable 2011–2015 (Figure 33). Estimates of CPUE varied annually 2005–2012, but have been steadily declining 2012–2015 (Figure 33).

a) b)

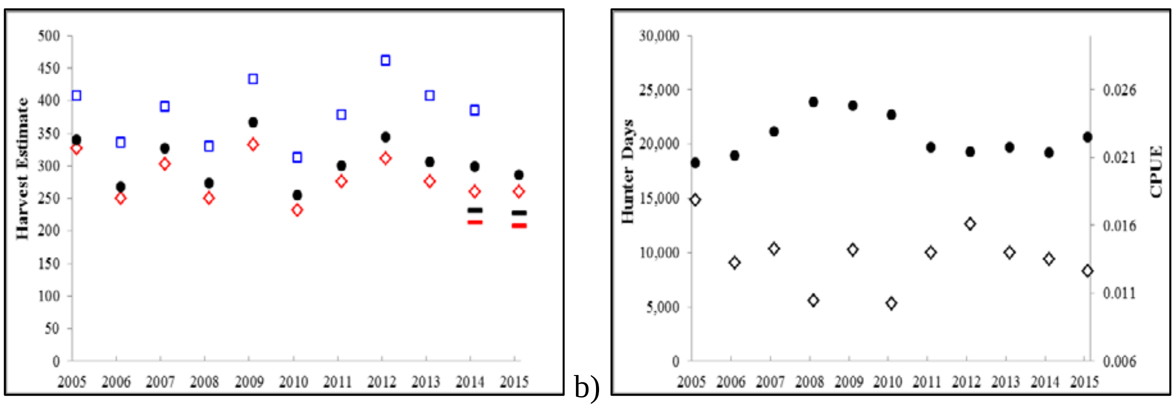


Figure 33. General State Harvest (◊), Total State Harvest (●), and Total Harvest (□) estimates (a) in the South Rainier elk herd area, 2005–2015. The dashes associated with harvest estimates in 2014 and 2015 represent harvest levels that are 25% below the 10-year average (2005-2014 in 2014 and 2006-2015 in 2015) for General State Harvest (red) and Total State Harvest (black). Also included are estimates of (b) hunter days (●) and catch-per-unit-effort (CPUE) (◊), 2005–2015. We generated estimates of CPUE using estimates of hunter effort and elk harvest during general modern firearm, muzzleloader, and archery seasons combined. We did not generate estimates of Total Harvest in 2015 because estimates of tribal harvest in 2015 were not available.

Survival and Cause-Specific Mortality

There have been no recent studies to monitor the survival of elk in the South Rainier elk herd area.

Assessment

Harvest data indicate the South Rainier elk herd does not qualify as an "at-risk" ungulate population and has been relatively stable, 2005–2015. In addition, biologists did not identify any local populations of concern.

Factors That Potentially Influence Population Dynamics

Predators

Black Bear.—Black bears occur throughout the South Rainier elk herd area. The estimated number of black bears harvested during general and permit seasons declined 2008–2013, but increased to historical levels in 2014 (Figure 34).

Cougar.—Cougars occur throughout the South Rainier elk herd area. The estimated number of cougars harvested decreased precipitously 2006–2012, but increased sharply in 2013 and 2014 (Figure 34).

Gray Wolf.—At the time of this writing, there were no documented gray wolf packs in the South Rainier elk herd area (Becker et al. 2016).

a) b)

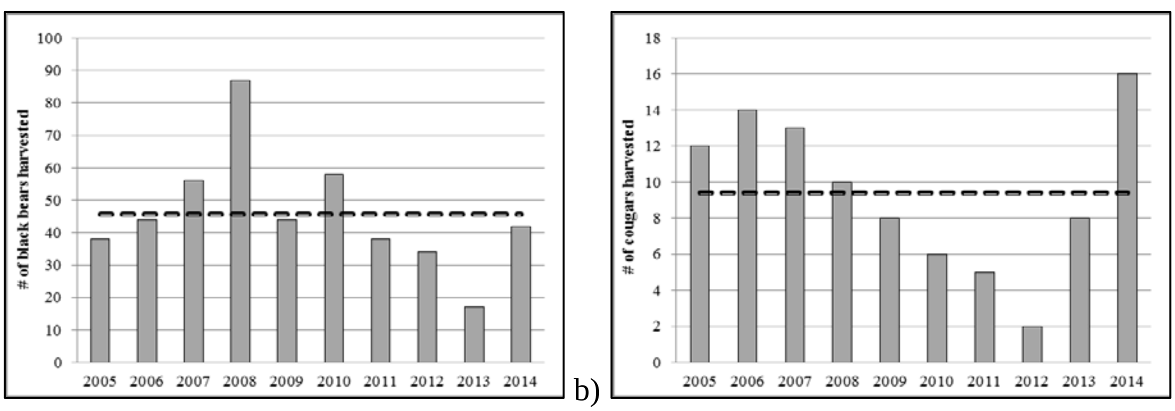


Figure 34. Estimated number of black bears (a) and cougars (b) harvested during general and permit seasons in the South Rainier elk herd area, 2005–2014. The dashed line represents the 10-year average.

Forest Management Practices

Much of the South Rainier elk herd area consists of private industrial forestlands or lands administered by the USFS. The herd continues to benefit from the creation of early seral habitats on private industrial forests. Conversely, the establishment of extensive late-successional reserves on USFS lands has significantly reduced the ability of those lands to support elk.

Habitat Loss

A large number of elk in the South Rainier elk herd area concentrate in the Cowlitz River Basin during winter. However, the continued development of this area for agricultural and housing purposes continues to result in a loss of critical winter habitat. Currently, elk numbers in the Cowlitz River Basin are higher than public tolerance will allow.

Weather

Severe winter events rarely affect the South Rainier elk herd. However, extreme drought conditions that persist through summer and fall have the potential to reduce the availability of high quality forages that elk rely on to accrue adequate fat stores for winter.

Willapa Hills Elk Herd

General Overview

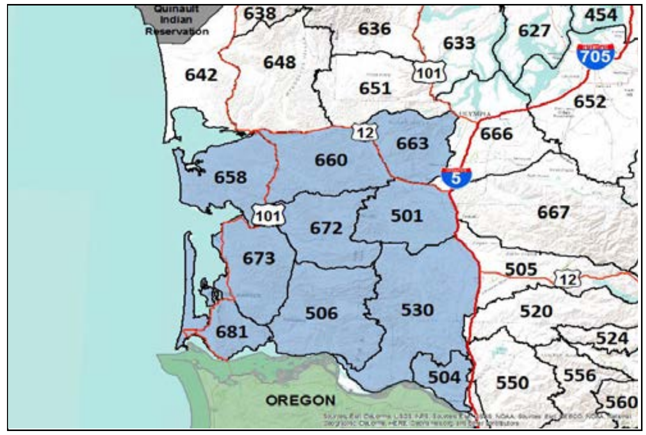


Figure 35. Location and boundaries of Game Management Units that comprise the Willapa Hills elk herd area.

The Willapa Hills elk herd is located in southwest Washington and consists of 12 GMUs (Figure 35). In the absence of a formal population estimate, WDFW believes current herd size is 8,000–10,000 elk. The Department completed the Willapa Hills Elk Herd Plan in 2014 and identified a population objective of managing this herd for a stable to increasing population (WDFW 2014c). Additional objectives include managing for a pre-hunt population with 15–35 bulls:100 cows or a post-hunt population with 12–20 bulls:100 cows and maintaining an annual survival rate of 0.50 for bulls when bull mortality is monitored (WDFW 2014a).

Historically, the Department conducted pre-hunt (August-September) or post-hunt (March-April) aerial composition surveys to assess trends in age and sex ratios. However, surveys lacked a formalized sampling design and did not account for biases that are commonly associated with observing elk in densely vegetated habitats (Samuel et al. 1987). Consequently, estimated ratios were not reflective of the entire herd and were likely biased (WDFW 2014c).

In 2014, the Department began efforts to develop a formalized sampling design that will index total elk abundance across the entire herd area using a sightability model developed for elk in the Mount St. Helens elk herd area (Hoenes et al. 2015). However, the Department continues to develop that survey protocol so we also use trends in harvest data to make inferences about population trend.

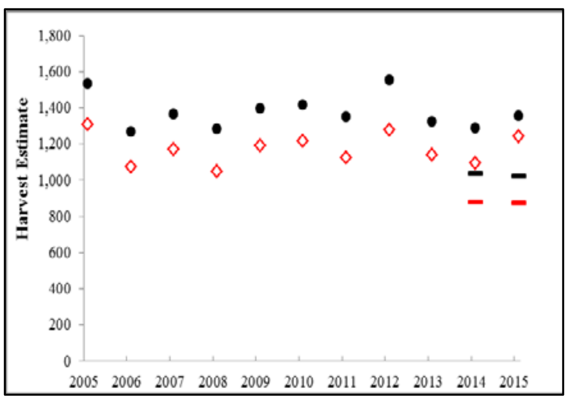
The Department limits most general season harvest opportunities in the Willapa Hills elk herd area to branch-antlered bulls and offers most opportunities to harvest antlerless elk through our permit system. However, limited opportunities to harvest antlerless elk do occur during general archery seasons and in areas where the Department's objective is to maintain low elk numbers.

Current Status and Trend

The Department conducted aerial composition surveys in GMUs 506 and 530 in 2014 and estimated total elk abundance to be 1,643 (95% CI = 1,490–1,959) elk, with a resulting bull:cow ratio of 17 bulls:100 cows. We surveyed portions of GMUs 658, 660, 672, and 673 in 2015 and estimated total elk abundance to be 2,076 (95% CI = 1,653–3,859) elk, with a resulting bull:cow ratio of 21 bulls:100 cows. In 2016, we surveyed portions of GMUs 506, 530, 673, and 681 and estimated total elk abundance to be 3,666 (95% CI = 3,151–4,512) elk with a resulting bull:cow ratio of 20 bulls:100 cows. Estimated calf:cow ratios were 39, 37, and 43 calves:100 cows, 2014–2016, respectively.

Harvest

Estimates of General State Harvest and Total State Harvest have averaged 1,172 and 1,376 elk, respectively, 2005–2015, have been stable, and were greater than harvest levels that would be 25% below the 10-year average in 2014 and 2015 (Figure 36). Hunter effort has slowly declined 2008–2015, while CPUE steadily increased during that same period (Figure 36).

a)


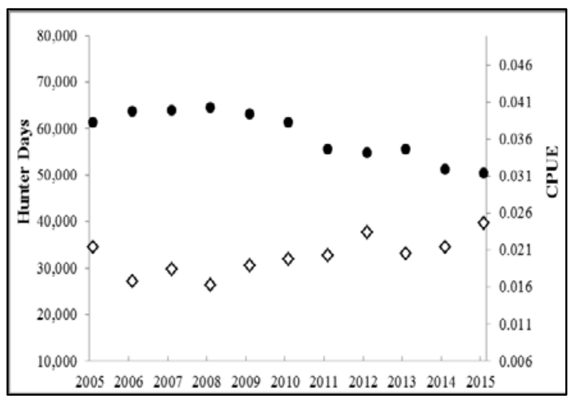
b)


Figure 36. General State Harvest (◊) and Total State Harvest (●) estimates (a) in the Willapa Hills elk herd area, 2005–2015. The dashes associated with harvest estimates in 2014 and 2015 represent harvest levels that are 25% below the 10-year average (2005-2014 in 2014 and 2006-2015 in 2015) for General State Harvest (red) and Total State Harvest (black). Also included are estimates of (b) hunter days (●) and catch-per-unit-effort (CPUE) (◊), 2005–2015. We generated estimates of CPUE using estimates of hunter effort and elk harvest during general modern firearm, muzzleloader, and archery seasons combined. We did not generate estimates of Total Harvest because estimates of tribal harvest averaged <5 elk per year.

Survival and Cause-Specific Mortality

There have been no comprehensive studies to estimate the survival of elk in the Willapa Hills elk herd area. However, the Department monitored bull survival using radio telemetry in GMU 673, 2005–2009 and estimated annual bull survival to be 0.37 (95% CI = 0.27–0.48), and attributed 93% of all mortalities to legal harvest (W. Michaelis, WDFW, unpublished data).

Assessment

Harvest data indicate the Willapa Hills elk herd does not qualify as an "at-risk" ungulate population and this herd has been relatively stable, 2005–2015. Survey data indicate that the Department is meeting its management objective of maintaining populations with a post-hunt bull:cow ratio of 12–20 bulls:100 cows and that calf recruitment rates in recent years have been at levels that should promote population stability or growth. Recent monitoring of bull survival rates in one GMU showed bull survival not meeting the objective of maintaining an annual survival rate of 0.50 for bulls for a 5-year period ending in 2009, but similar information was not collected across the entire herd area. Lastly, biologists did not identify any populations of concern.

Factors That Potentially Influence Population Dynamics

Predators

Black Bear.—Black bears are abundant and occur throughout the Willapa Hills elk herd area. The estimated number of black bears harvested during general and permit seasons has averaged just under 120 bears, 2005–2014, but has also been quite variable (Figure 37).

Cougar.—Cougars occur throughout the Willapa Hills elk herd area, but the estimated number of cougars harvested across the entire herd area has only averaged approximately 4 animals per year, 2005–2014 (Figure 37).

Gray Wolf.—At the time of this writing, there were no documented wolf packs in the Willapa Hills elk herd area (Becker et al. 2016).

a) b)

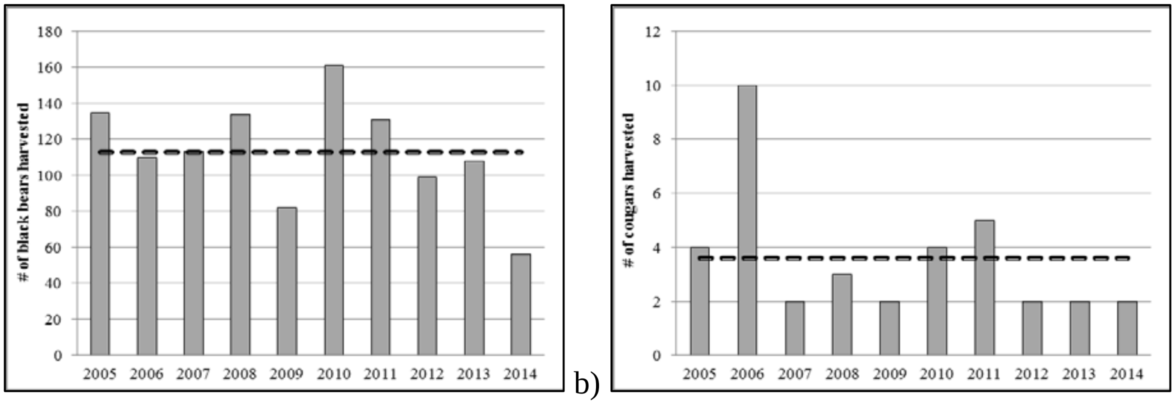


Figure 37. Estimated number of black bears (a) and cougars (b) harvested during general and permit seasons in the Willapa Hills elk herd area, 2005–2014. The dashed line represents the 10-year average.

Forest Management Practices

Forest management practices on private industrial and state forestlands have always benefited the Willapa Hills elk herd by creating a mosaic of habitats and increasing the forage base for this herd.

Weather

Severe winter conditions rarely occur and affect the overwinter survival of elk in the Willapa Hills elk herd area. However, extreme drought conditions that persist through summer and fall have the potential to reduce the availability of high quality forages that elk rely on to accrue adequate fat stores for winter.

Yakima Elk Herd

General Overview

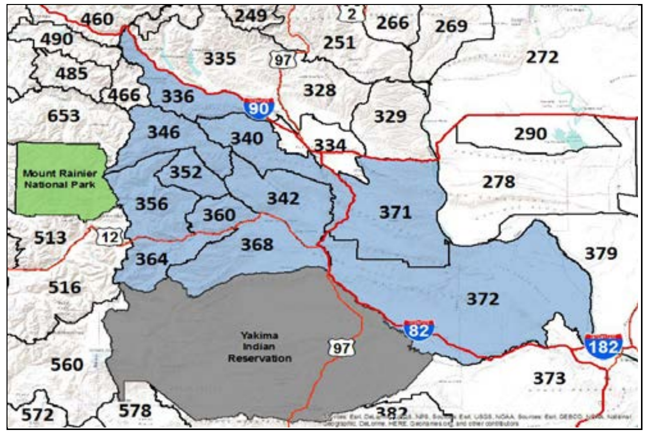


Figure 38. Location and boundaries of Game Management Units that comprise the Yakima elk herd area.

The Yakima elk herd is located in central Washington and consists of 11 GMUs (Figure 38). The Department's current management objective is to manage for a spring population of approximately 9,000–10,000 elk (not including elk in the Rattlesnake Hills sub-herd) with an associated post-hunt sex ratio of 12–20 bulls:100 cows (WDFW 2002d). An additional objective includes maintaining an annual survival rate of 0.50 for bulls when bull mortality is monitored (WDFW 2014a). The Yakima elk herd is also the only herd in the state where the Department maintains a winter feeding program.

The Department conducts aerial surveys in March to estimate elk abundance and herd composition in areas associated with winter-feed sites (includes areas adjacent to feed sites). However, the Department did not conduct surveys in 2014 or 2015 because winter conditions were mild and elk did not concentrate at feed sites.

The Yakima elk herd also includes the Rattlesnake Hills sub-herd that is located on the Arid Lands Ecology Reserve (ALE) in GMU 372. The Department collaborates with the USFWS to estimate elk abundance in the sub-herd area using a sightability model developed for elk in Idaho (Unsworth et al. 1999) and estimated elk abundance in February 2015 to be 1,109 elk (Newsome 2015), which far exceeds the management objective of 350 elk (WDFW 2002b). The Rattlesnake Hills sub-herd remains well above objective because hunting is not allowed on ALE, which limits the Department's ability to manage this sub-herd. Because the Rattlesnake Hills sub-herd is so far above objective and relatively removed from other elk that comprise the Yakima elk herd, we did not include it in our review. We also did not include harvest data from GMUs 371 and 372 in summation of harvest data below because harvest in these GMUs is associated with this sub-herd.

The Department restricts most general season opportunities to harvest elk to spikes and offers opportunities to harvest branch-antlered bulls under special permits in all GMUs. The Department generally focuses most opportunities to harvest antlerless elk in areas associated with private land to help alleviate agricultural damage.

Current Status and Trend

In March 2016, the Department estimated elk abundance within the survey area to be 10,856 (90% CI = 10,733–10,939) elk, which is approximately 800 elk above objective (Figure 39). Estimates of post-hunt calf:cow ratios were relatively stable 2007–2016, while estimates of post-hunt bull:cow ratios were at objective and stable 2006–2016 (Figure 39).

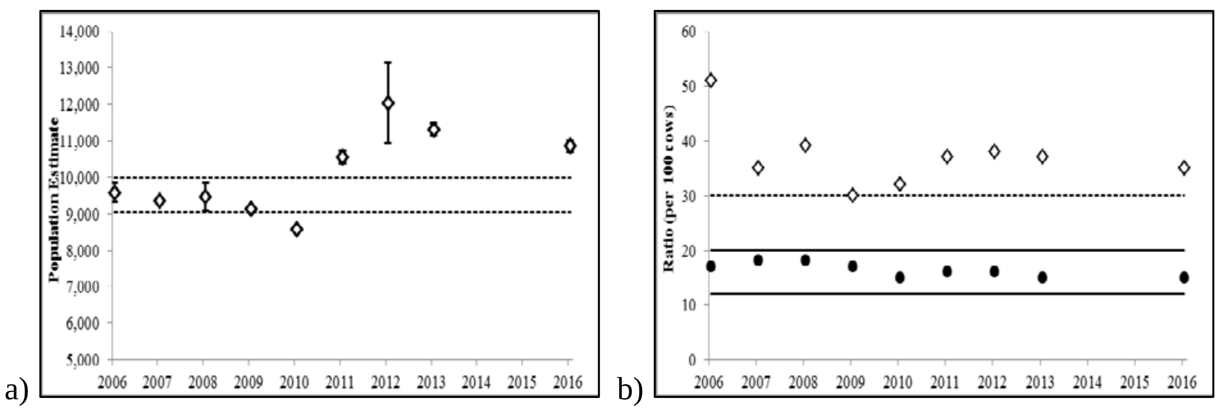


Figure 39. Sightability corrected estimates of (a) total elk abundance with associated 90% confidence intervals in the Yakima elk herd area, 2006–2016. The dashed lines represent management objectives for total elk abundance (9,025–9,975 elk). Also included are estimates of (b) post-hunt calf:cow (◊) and bull:cow ratios (●), spring 2006–2015. The solid lines represent objectives for bull:cow ratios (12–20 bulls:100 cows), while the dashed line represents calf recruitment rates that should promote herd stability or growth (≥ 30 calves:100 cows). We did not present estimates for 2014 and 2015 because the Department did not conduct surveys in those years due to mild winter conditions.

Harvest

Estimates of General State Harvest and Total State Harvest have averaged 889 and 1,620 elk, respectively, 2005–2015. Both estimates have varied annually, but were greater than harvest levels that would be 25% below the 10-year average in 2014 and 2015 (Figure 40). Hunter effort steadily declined 2005–2012, but has increased in recent years (Figure 40). Estimates of CPUE have also increased in recent years (Figure 40).

a) b)

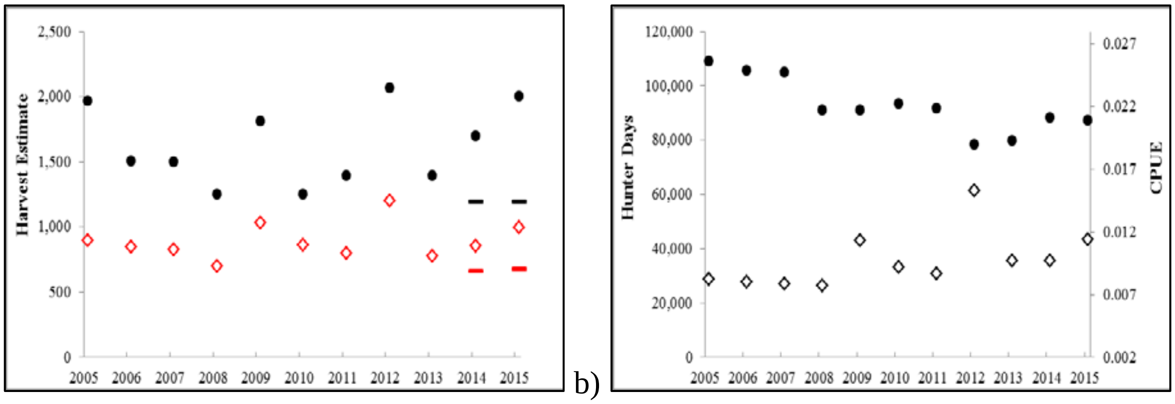


Figure 40. General State Harvest (◊) and Total State Harvest (●) estimates (a) in the Yakima elk herd area, 2005–2015. The dashes associated with harvest estimates in 2014 and 2015 represent harvest levels that are 25% below the 10-year average (2005-2014 in 2014 and 2006-2015 in 2015) for General State Harvest (red) and Total State Harvest (black). Also included are estimates of (b) hunter days (●) and catch-per-unit-effort (CPUE) (◊), 2005–2015. We generated estimates of CPUE using estimates of hunter effort and elk harvest during general modern firearm, muzzleloader, and archery seasons combined. We did not generate estimates of Total Harvest because estimates of tribal harvest were not available.

Survival and Cause-Specific Mortality

The Department (S. McCorquodale, WDFW, unpublished data) estimated the survival of adult female elk and branch-antlered bulls in the Yakima elk herd area 2003–2006 and estimated bull survival to be 0.63 (95% CI = 0.52–0.73). Estimated cow survival was 0.58 (95% CI = 0.39–0.75) in GMUs 336, 340, 342, and 346 in 2005 and 0.83 (95% CI = 0.73–0.90) during 2003, 2004, and 2006. Estimated cow survival across other portions of the herd area and across all study years was 0.88 (95% CI = 0.84–0.92). We documented cause of mortality for 69 elk during that study and attributed 88% of all mortalities to human causes; we only attributed one (<2%) mortality event to predation (S. McCorquodale, WDFW, unpublished data).

Assessment

Both harvest and survey data indicate the Yakima elk herd does not qualify as an "at-risk" ungulate population. In addition, recent survey data indicate the Department is meeting its management objective of maintaining a population with 12–20 bulls:100 cows in the post-hunt population and calf recruitment rates continue to occur at levels that would promote population stability or growth. Recent survival studies also indicate the Department is meeting its management objective of maintaining annual bull survival at 0.50. Lastly, biologists did not identify any local populations of concern.

Factors That Potentially Influence Population Dynamics

Predators

Black Bear.—Black bears occur throughout the Yakima elk herd area, but are more common in forested regions. Estimated black bear harvest during general and permit seasons has averaged 45 bears since 2005 but has also varied considerably in some years (Figure 41).

Cougar.—Cougars occur throughout the Yakima elk herd area. With the exception of 2005 and 2011, estimated cougar harvest has consistently been between 9 and 12 cougars, 2005–2014 (Figure 41).

Gray Wolf.—At the time of this writing there were no documented wolf packs in the Yakima elk herd area (Becker et al. 2016).

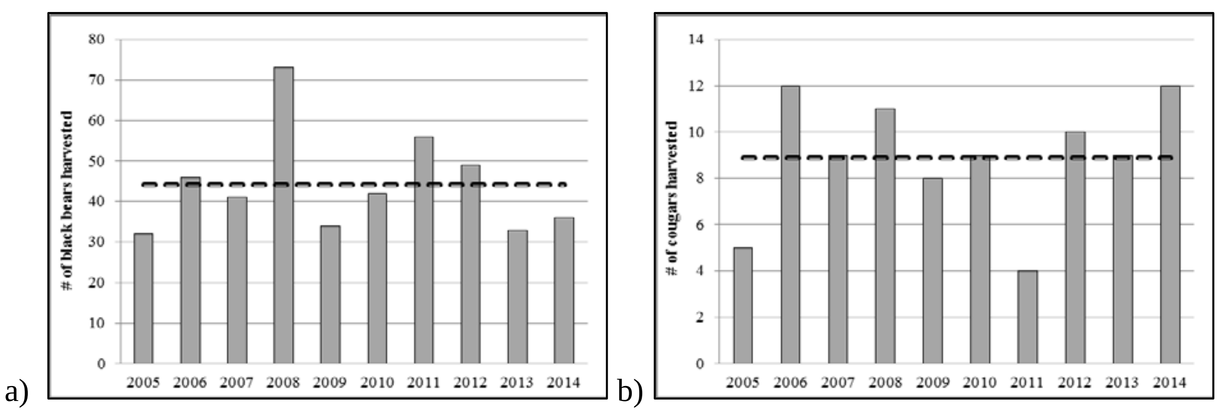


Figure 41. Estimated number of black bears (a) and cougars (b) harvested during general and permit seasons in the Yakima elk herd area, 2005–2014. The dashed line represents the 10-year average.

Forest Management Practices

The USFS, Washington Department of Natural Resources (DNR), and Department manage the majority of summer range within the Yakima elk herd area. Habitat quality for elk varies across these ownerships depending on management emphasis and underlying land cover types. The

USFS shifted toward a late seral stage management emphasis over 20 years ago, which has decreased forage production on a portion of summer range.

Weather

The Yakima elk herd is susceptible to severe winter conditions that could result in higher than normal overwinter mortality. However, the Department likely reduces those effects with their winter feeding program. In addition, extreme drought conditions that persist through summer and fall have the potential to reduce the availability of high quality forages that elk rely on to accrue adequate fat stores for winter.

Human Disturbance

Human disturbance within the Yakima elk herd area can be quite high in some areas and at certain times of the year. Specifically, human disturbance on winter and spring range has increased drastically with increased bull numbers and the resultant increased number of people hunting for shed antlers.

Literature Cited – Elk

Becker, S.A., T. Roussin, W. Jones, E. Krausz, S. Walker, S. Simek, D. Martorello, and A. Aoude. 2016. Washington Gray Wolf Conservation and Management 2015 Annual Report. Pages WA-1 to WA-24 *in* U.S. Fish and Wildlife Service Rocky Mountain Wolf Program 2015 Annual Report. USFWS, Ecological Services, 585 Shepard Way, Helena, Montana, 59601.

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. Lukacs, S. McCorquodale, E. McIntire, J. Nowak, H. Sawyer, D. Smith, and 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.

Caughley, G. 1974. Interpretation of age ratios. Journal of Wildlife Management 38:557–562.

Clark, D. A. 2014. Implications of cougar prey selection and demography on population dynamics of elk in northeast Oregon. Dissertation. Oregon State University, Corvallis, OR, USA. 228 p.

Crichton, V. 1993. Hunter effort and observations-the potential for monitoring trends of moose populations: a review. Alces 29:181–185.

Doak, D. F., J. A. Estes, B. S. Halpern, U. Jacob, D. R. Lindberg, J. Lovvorn, D. H. Monson, M. T. Tinker, T. M. Williams, J. T. Wootton, I. Carroll, M. Emmerson, F. Micheli, and M. Novak. 2008. Understanding and predicting ecological dynamics: are major surprises inevitable? Ecology 89:952–961.

Gilbert, B. A. and B. J. Moeller. 2008. Modeling elk sightability bias of aerial surveys during winter in the central Cascades. Northwest Science, 82:3, 222-228.

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

Hatter, I. W. 2001. An assessment of catch-per-unit effort to estimate rate of change in deer and moose populations. Alces 37:71–77.

Hoenes, B., E. Holman, A. Novack, S. Bergh, N. Stephens, W. Michaelis, and T. Christopher. 2015. Developing a formalized monitoring strategy for the Willapa Hills elk herd. Project Update. Washington Department of Fish and Wildlife, Olympia, WA, USA. 19p.

Hoenes, B., K. Mansfield, I. Keren, B. George, E. Holman, N. Stephens, and S. Bergh. 2014. Assessing the potential effects of treponeme associated hoof disease (TAHD) on elk population dynamics in southwest Washington. Research Proposal. Washington Department of Fish and Wildlife, Olympia, WA, USA.

IIjima, H., T. Nagaike, and T. Honda. 2013. Estimation of deer population dynamics using a Bayesian state-space model with multiple abundance indices. Journal of Wildlife Management 77:1038–1047.

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. Journal of Wildlife Management 77:102–116.

Lubow, B., K. Jenkins, P. Happe, P. Griffin, and K. Beirne. 2015. Double-observer sightability model update for Mount Rainier and Olympic National Parks, 2014. U. S. Geological Survey Administrative Report to U. S. National Park Service. U.S. Geological Survey, Reston, Virginia, USA. 18 p.

McCorquodale, S., S. Knapp, M. Davison, J. Bohannon, and C. Danilson. 2011. A population assessment for the North Cascades elk herd: 2006–2011. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

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

McCorquodale, S. M., P. J. Miller, S. M. Bergh, and E. W. Holman. 2014. Mount St. Helens elk population assessment: 2009–2013. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

McCorquodale, S. M., P. A. Wik, and P. E. Fowler. 2010. Elk survival and mortality causes in the Blue Mountains of Washington. Journal of Wildlife Management 75:897–904.

Miller, P. J., and S. M. McCorquodale. 2006. Washington state elk herd plan: Mount St. Helens elk herd. Washington Department of Fish and Wildlife, Olympia, Washington, USA. 52 pp.

Murphie, S and R. McCoy. 2015. Tribal Wildlife Grant final report, Makah cougar and bobcat research. Makah Wildlife Division, Makah Tribal Council, Neah Bay, WA, USA.

Myers, W. L. 1999. An assessment of elk population trends and habitat use with special reference to agricultural damage zones in northern Blue Mountaind of Washington. Final Report Washington Department of Fish and Wildlife, Olympia, WA, USA. 172 p.

Newsome, H. 2015. Annual summary and evaluation of the sightability survey for Rocky Mountain elk on the Arid Lands Ecology Reserve unit of the Hanford Reach National Monument, 2015. U. S. Fish and Wildlife Service Progress Report, U.S. Fish and Wildlife Service, Burbank, Washington, USA. 14 p.

Northwest Indian Fisheries Commission [NWIFC]. 2015. NWIFC homepage. <http://nwifc.org>. Accessed 2 Nov 2015.

Proffitt, K. M., J. A. Cunningham, K. L. Hamlin, and R. A. Garrott. 2014. Bottom-up and top-down influences on pregnancy rates and recruitment of northern Yellowstone elk. Journal of Wildlife Management 78:1383–1393.Bowyer, R. T., M. C. Nicholson, E. M. Molvar, and J. B. Faro. 1999. Moose on Kalgin Island: are density-dependent processes related to harvest? Alces 35:73–89.

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.

Rearden, S. N. 2005. Juvenile survival and birth-site selection of Rocky Mountain elk in northeastern Oregon, M. S. Thesis, Oregon State University, Corvallis, Oregon, USA.

Samuel, M. D., E. O. Garton, M. W. Schlegel, and R. G. Carson. 1987. Visibility bias during aerial surveys of elk in north central Idaho. Journal of Wildlife Management 51:622–630.

Schmidt, J. I., J. M. Ver Hoef, J. A. Maier, and R. T. Bowyer. 2005. Catch per unit effort for moose: a new approach using Weibull regression. Journal of Wildlife Management 69:1112–1124.

Skalski, J. R., K. E. Ryding, and J. J. Millspaugh. 2005. Wildlife Demography: Analysis of sex, age, and count data. Elsevier Academic Press, Burlington, Massachusetts, USA.

Solberg, E., B. Saether, O. Strand, and A. Loison. 1999. Dynamics of a harvested moose population in a variable environment. Journal of Animal Ecology 68:186–204.

Uno, H., K. Kaji, T. Saitoh, H. Matsuda, H. Hirakawa, K. Yamamura,and K. Tamada. 2006. Evaluation of relative density indices for sika deer in eastern Hokkaido, Japan. Ecological Research 21:624–632.

Unsworth, J. W., F. A. Leban, E. O. Garton, D. J. Leptich, and P. Zager. 1999. Aerial Survey: User's Manual. Electronic Edition. Idaho Department of Fish and Game, Boise, Idaho, USA.

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.

Washington Department of Fish and Wildlife. 2001. Blue Mountains Elk Herd Plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2002a. North Cascade Elk Herd Plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2002b. North Rainier Elk Herd Plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2002c. South Rainier Elk Herd Plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2002d. Yakima Elk Herd Plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2004. Olympic Elk Herd Plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2006. Colockum Elk Herd Plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2014a. 2015–2021 Game Management Plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2014b. Selkirk Elk Herd Plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2014c. Willapa Hills Elk Herd Plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

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

Wiles, G. J., H. L. Allen, and G. E. Hayes. 2011. Wolf conservation and management plan for Washington. Washington Department of Fish and Wildlife, Olympia, WA.

MOOSE

Introduction

This document presents a review of our current understanding of the extent to which predators may be having a negative effect on the moose (*Alces alces*) population in Washington that is severe enough to be considered unacceptable. Fully understanding how the effects of predators interacts with other factors (e.g., weather, habitat, harvest, alternate prey species) to influence the population dynamics of moose is extremely difficult and outside the purview of this review. Consequently, we have limited this review to the following:

1) Identifying whether moose are meeting management objectives the Department has defined in the 2 most recent Game Management Plans;

2) Summarizing recent trends in harvest metrics (e.g., total harvest, hunter days);

3) Summarizing available data from recent survival studies;

4) Determining whether moose in Washington meet the criteria of an at-risk ungulate population, as defined in the 2015–2021 Game Management Plan (WDFW 2014a).

The secondary objective of this exercise is to identify potential actions for moose that are consistent with the guiding principles identified in the 2015–2021 Game Management Plan (WDFW 2014).

Brief Overview of Moose in Washington

The distribution of Washington moose as of mid-2015 is shown in Figure 1. Moose are present in adjacent Idaho and east of the Cascades in British Columbia. Moose are present in low numbers in the Blue Mountains of Oregon as well.

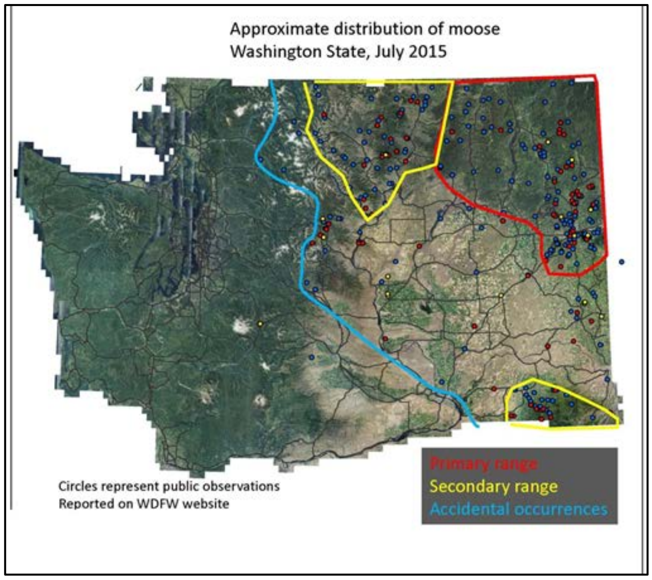


Figure 1. Moose distribution within Washington as of 2015, categorized as primary (red boundary; hunted population), secondary (yellow boundary; moose population present, no hunting seasons) and tertiary (blue boundary; being colonized, or unlikely to hold a sustainable population) ranges. Colors of circles represent year of citizen observation.

Moose, being primarily residents of boreal forests further north, are newcomers to Washington (Poelker 1972). The history of moose colonization and increase in Washington was summarized by Base et al. (2008). The first documentation of moose in the state dates from 1929, with occasional records during the subsequent decades. However, it was not until the 1970s that it became clear that moose had become resident in Washington, first in Pend Oreille County, and later in adjacent counties. Limited hunting began in 1977, and has increased steadily since that time (Figure 2). All moose hunting in Washington has been by limited permit. In addition to lottery draw permits, Washington currently offers special opportunities via a statewide auction tag, 2 statewide raffle tags, and 2 hunter education instructor incentive tags. Moose hunting units as of 2015 are illustrated in Figure 3.

Moose and Predation

Moose are susceptible to predation by wolves (*Canis lupus*), brown bears (*Ursus arctos*), black bears (*U. americanus*), and cougars (*Puma concolor*). The literature on relations and interactions between moose and these 4 predator species is voluminous and replete with conflicting conclusions that reflect not only alternative analytical approaches and underlying assumptions, but true differences in systems under study. Recent summaries include Ballard and Van Ballenberghe (1998), Person el al. (2001), Bowyer et al. (2003), Schwartz et al. (2003), and

Vucetich et al. (2011). Summarizing this literature is beyond the scope of this review. A few salient points are relevant to assessing the effects of predation on moose in Washington:

- Previous studies have documented the effects of predation on moose as varying from inconsequential to dramatic, depending on a number of biological and non-biological factors.

- Most studies have been conducted where moose were the primary, or in some cases the only species of prey, and wolves the primary, and in some cases the species of predator. Where multiple prey and multiple predators coexist, relationships are inevitably more complex.

- Wolves are capable of killing moose of all ages, but most often are common predators on adult moose only when moose are compromised by their nutritional status or by environmental conditions conducive to predation (e.g., snow conditions). Wolves are capable of killing moose calves throughout the year.

- Grizzly bears are capable of killing moose of all ages, but rarely kill adults. In some studies, however, grizzly bears have been shown to reduce moose calf survival considerably.

- Black bears are generally considered incapable of killing healthy adult moose; however, in some studies, black bear predation on calves has been considerable.

- Cougars are rarely considered important predators of healthy adult moose. However, in Montana (Kunkel et al. 1999), and particularly in southwestern Alberta (Ross and Jalkotzy 1996), cougars have been documented as having substantial effects on calf survival.

- The effects of predation are unlikely to be independent of other factors, including nutritional condition of moose (presumably driven by habitat quality), other debilitating factors (notably for moose, parasites), and weather.

Moose populations in many other jurisdictions have declined, due to a number of complex factors that remain incompletely understood. Some declines have occurred where multiple predators occur, others where only a single predator occurs, and yet others where no important predators of moose occur. Factors that have been hypothesized as causing declines include forest maturation (McArt et al. 2004, Musante et al. 2010), excessive poaching (R. Rea, University of Northern British Columbia, pers. comm., 2015), parasite and diseases (Murray et al. 2006, Musante et al. 2010), and the effects of climate change generally (Monteith et al. 2015).

WDFW Management Objectives

Because moose primarily adopt a solitary lifestyle, distributing themselves across appropriate habitats rather than congregating in identifiable 'summer' or 'winter ranges', and because moose hunting in Washington has responded gradually to general population increases, WDFW has not identified distinct 'herds'. Moose hunting has been managed on the basis of Game Management Units (GMU) to provide structure to surveys, harvest management, and distribute hunting pressure, but there is no presumption that these represent biologically distinct units. Because the abundance of moose in Washington has only been indexed and never estimated, WDFW has not articulated quantitative population objectives. Efforts currently underway (see below, "Density and abundance" and "Adult survival and calf recruitment" sections) may provide the basis for developing population abundance objectives.

Instead, WDFW, through its series of Game Management Plans (GMP), has identified objectives and guidance for population management based on hunter success metrics, rough indices of population trend, age and sex ratios as obtained from index counts, and median age of harvested bulls. Objective 54 in the 2009-2015 GMP (WDFW 2008) was: "*Provide recreational hunting opportunities in individual moose herds where harvest success averages > 85% over a three-year period, while at the same time moose population size remains stable or increasing*". In addition, strategies were articulated that included maintaining 90% or greater bulls within harvests allowing moose of either sex to be taken (except that a greater proportion of cows would be allowable where moose presented a conflict to human safety or property). Based on index counts, a rough guide to increasing or decreasing permit levels was offered (Table 1).

In anticipation that moose abundance would be clarified via aerial surveys conducted during 2014-2016, and that ongoing research (see below) would provide a basis for improving our management strategies, these objectives and strategies were not retained in the 2015-2021 GMP (WDFW 2014), but were replaced with the objective to develop new harvest strategies based on this new information.

Table 1. Moose harvest guidelines, applicable during the 2009-2015 time period (WDFW 2008).

	Harvest		
Parameter	**Liberalize**	**Acceptable**	**Restrict**
Average bull:100 cow ratio	>75 bulls	60-75 bulls	<60 bulls
Average calf:100 cow ratio	>50 calves	30-50 calves	<30 calves
Median age of harvested bulls	>6.5 years	4.5-5.5 years	<4.5 years

Harvest

Permit and harvest trends

Broadly speaking, moose harvest levels in Washington can be categorized into 4 periods: 1) 1991-2000, when permit levels increased gradually each year from a mere handful to ~ 70; 2) 2001-2007, when permit levels remained steady at slightly over 90; 3) 2008-2014, when permit levels remained steady at approximately 130; and 4) 2015, when permit levels were increased to approximately 165 (Figure 2). Increased permit levels generally followed the perceptions of local biologists, based in part on aerial surveys that moose in NE Washington increased during the period. Neither the hunting units (i.e., spatial extent of hunting [Figure 3]) nor the proportion of permits allowing harvest of antlerless animals varied appreciably from 2001 through 2016. Additional moose hunting occurs on the Colville and Spokane Indian Reservations, managed by the respective tribes.

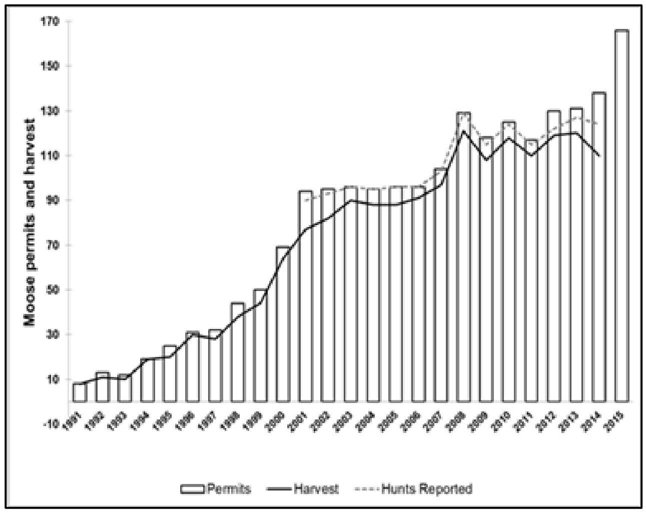


Figure 2. Number of permits (vertical bars), hunts reported (dashed lines), and moose harvested (solid line) in Washington, 1991-2015. Shown are total permits, which included 'any' and 'antlerless' permits.

Hunter success and effort required to successfully harvest a moose

In WDFW District 1, the days required/successful hunt ($\bar{x}$ = 6.33 days, s. d. = 1.72) declined slightly (β = -0.231, SE = 0.132, n = 12, t = -1.75 P = 0.111; Figure 4, top panel) during 2001-2012, while during these same years hunter success rate, which averaged 93%, increased (β = 0.012, SE = 0.003, n = 12, t = 3.63, P = 0.005). Similarly, in WDFW District 2, the days required/successful hunt ($\bar{x}$ = 4.34 days, s. d. = 1.07) declined slightly (β = -0.295, SE = 0.164, n = 11, t = -1.8, P = 0.102; Figure 4, bottom panel) during 2001-2012, while hunter success rate, which averaged 93%, increased (β = 0.009, SE = 0.001, n = 11, t = 4.27, P = 0.002) during these same years.

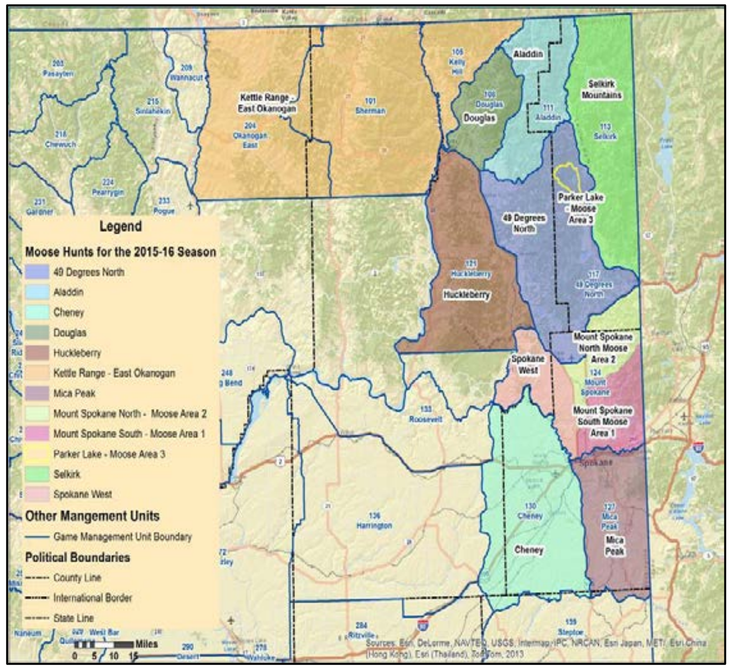


Figure 3. Moose hunting units in Washington, as of 2015. Units 101, 105, 108, 111, 113, 117, and 121 are in WDFW District 1 (204 is managed together with these); Units 124, 130, and 127 are in WDFW District 2.

Ages of harvested moose

Other factors being equal, one would expect to find the age of harvested animals increase when harvest rate (defined as proportion of standing population removed by hunting) declines; conversely, age of harvested animals should decline with increasing harvest intensity. In WDFW District 1, the median age of harvested bull moose during 2001-2014 was 5 years, and of a harvested female moose 4 years. In WDFW District 2, the median age of harvested bull moose during 2001-2014 was 3 years, and of a harvested female moose was also 3 years.

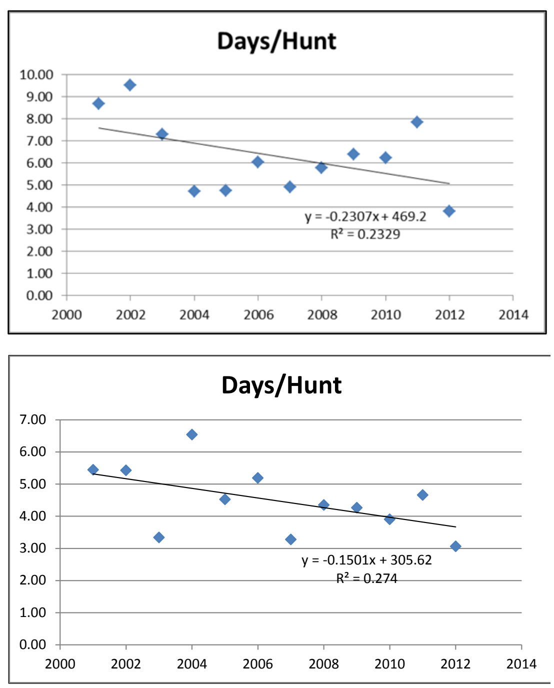


Figure 4. Days per successful moose hunt in District 1 (top panel) and District 2 (bottom panel), 2000-2012.

Although differing by district, ages of both harvested males (Figure 5, top panel) and females (Figure 5, bottom panel) increased significantly during 2001-2014 (males: $\beta = 0.087$, SE = 0.024, n = 14, $t = 3.53$, P < 0.001; females: $\beta = 0.112$, SE = 0.046, n = 14, $t = 2.42$, P = 0.016). The trend did not depend on WDFW district for either males or females.

However, the sampling fraction of hunters providing a tooth for aging also declined during this time period, from as high as > 80% in 2004-2005 to a low of 60% in 2013 (Figure 6). Declining participation could have produced an increasing trend in mean age of harvested animals -- even if the true underlying trend differed from this -- if hunters providing teeth were more likely to do so when they perceived that they had harvested a relatively old animal. In fact, mean age of harvested animals was negatively predicted by the proportion of successful hunters providing a tooth for ageing (for cows: $\beta = -6.52$, SE = 2.79, $t = -2.34$, $P = 0.02$; for bulls $\beta = -5.15$, SE = 1.60, $t = -3.22$, $P = 0.001$). Analyses that incorporated the sampling fraction (proportion of total reported hunts that yielded ages from teeth) continue to support the conclusion that mean age of harvested males increased during the time period (although more slowly than suggested above), but there was no significant trend for females. The confounding of these 2 sources of variation in age of harvested animals makes interpretation ambiguous.

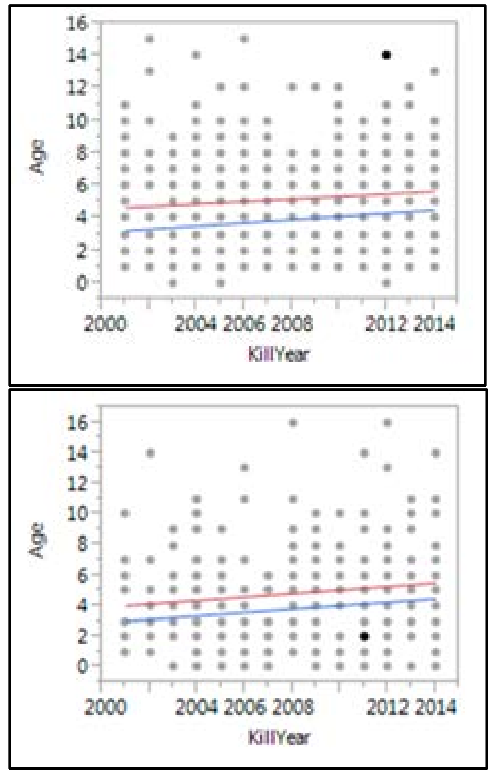


Figure 5. Ages of male (top panel) and female (bottom panel) moose killed by hunters returning teeth for ageing in Washington, 2000-2014. Red lines represent trends of harvested moose in District 1; blue lines represent trends of harvested moose in District 2.

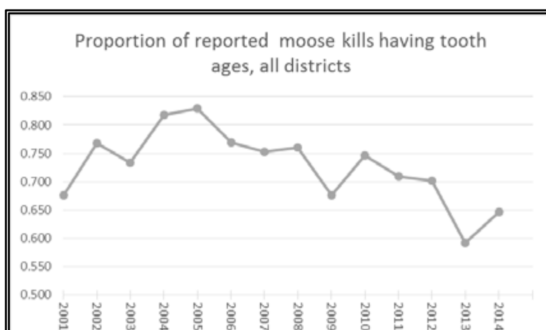


Figure 6. Proportion of total known moose kills with reported ages, WDFW Districts 1 and 2, 2001-2014.

Estimated sex/age structure of standing *population*

Index surveys from helicopters have been conducted in both Districts 1 and 2 most years (usually in December or January, weather permitting). These surveys have been used to estimate calf:cow and bull:cow ratios. In District 1 during 2003-2012, the mean calf:cow ratio was 39.5 (90% confidence limits = 28.8 – 50.2; Figure 7); the mean bull:cow ratio was 75.9 (90% confidence limits = 58.9 – 92.9; Figure 8).

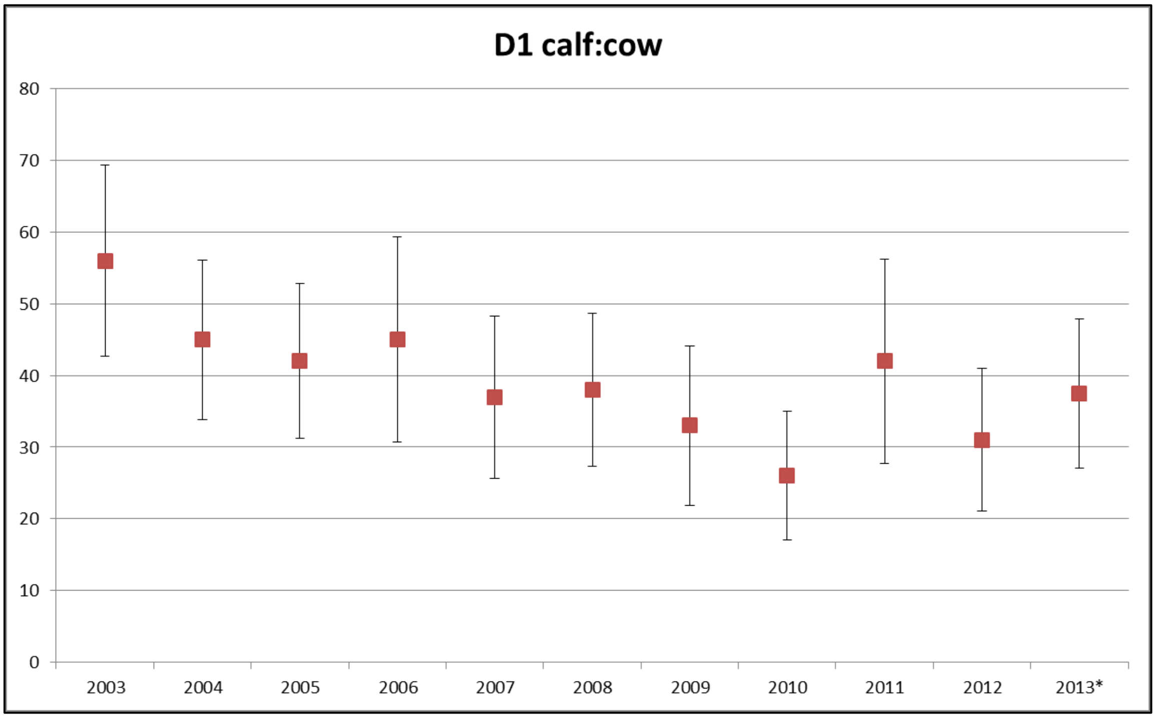


Figure 7. Annual mean (symbol) and 90% confidence intervals (vertical bars) of moose calf:cow ratios, as obtained from winter helicopter surveys in WDFW District 1. In 2013 (asterisk), data were collected as part of the MRDS density estimation project (see below).

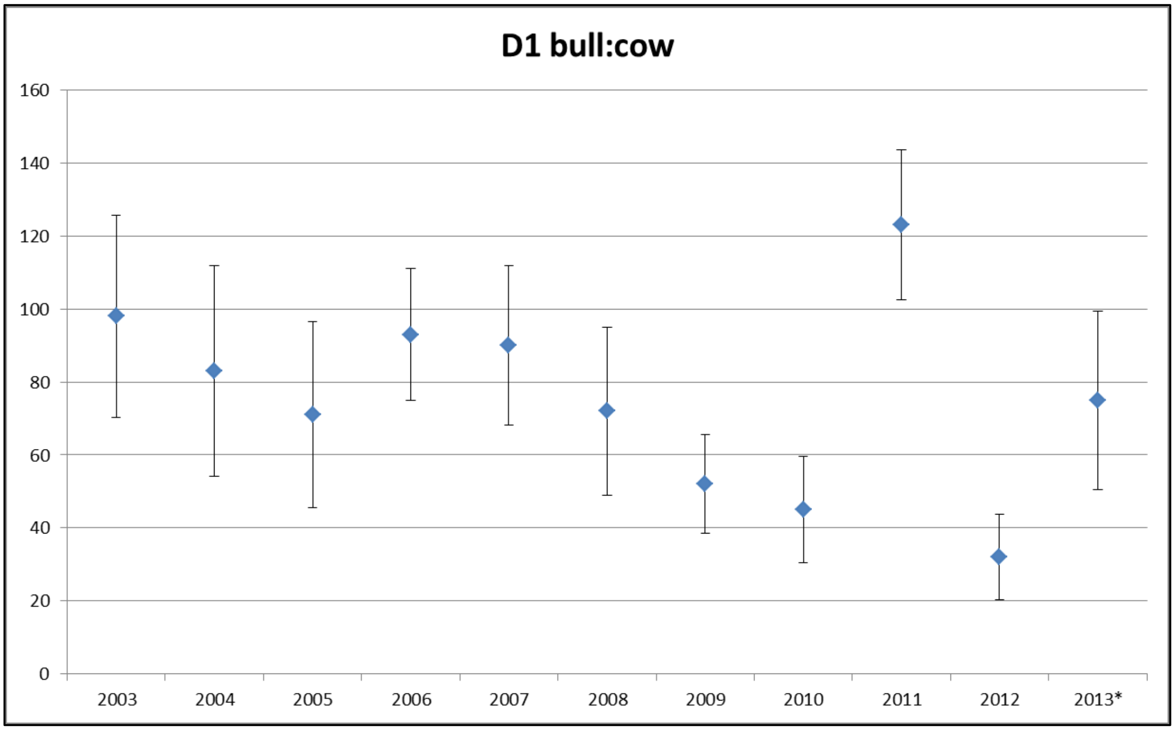


Figure 8. Annual mean (symbol) and 90% confidence intervals (vertical bars) of moose bull:cow ratios, as obtained from winter helicopter surveys in WDFW District 1. In 2013 (asterisk), data were collected as part of the MRDS density estimation project (see below). Survey in 2012 may have occurred too late in the year to accurately identify bulls.

In District 2, biologists distinguished between moose occurring south of the city of Spokane (termed "Hangman" hereafter), and north of Spokane (termed "Mt. Spokane" hereafter). In the Hangman area during 2003-2012, the calf:cow ratio averaged 52.4 (90% confidence limits = 41.7 – 63.1; Figure 9) and the bull:cow ratio averaged 50.3 (90% confidence limits = 33.3 – 67.3; Figure 10). In the Mt. Spokane area during 2003-2012, the calf:cow ratio averaged 46.9 (90% confidence limits = 36.2 – 57.6; Figure 11), and the bull:cow ratio averaged 51.7 (90% confidence limits = 34.7 – 68.7; Figure 12).

Given the broad confidence limits on all of these ratios, definitive conclusions are difficult to make. Generally, these metrics were in the "acceptable" range according to earlier guidance provided in the 2009-2015 GMP (WDFW 2008). In District 1, bull:cow ratios, as estimated from surveys, were lower than acceptable during 2009, 2010, and 2012, but high in 2011 and 2013 as well as all previous years. Bull:cow ratios were lower than optimal in the more heavily harvested District 2 areas.

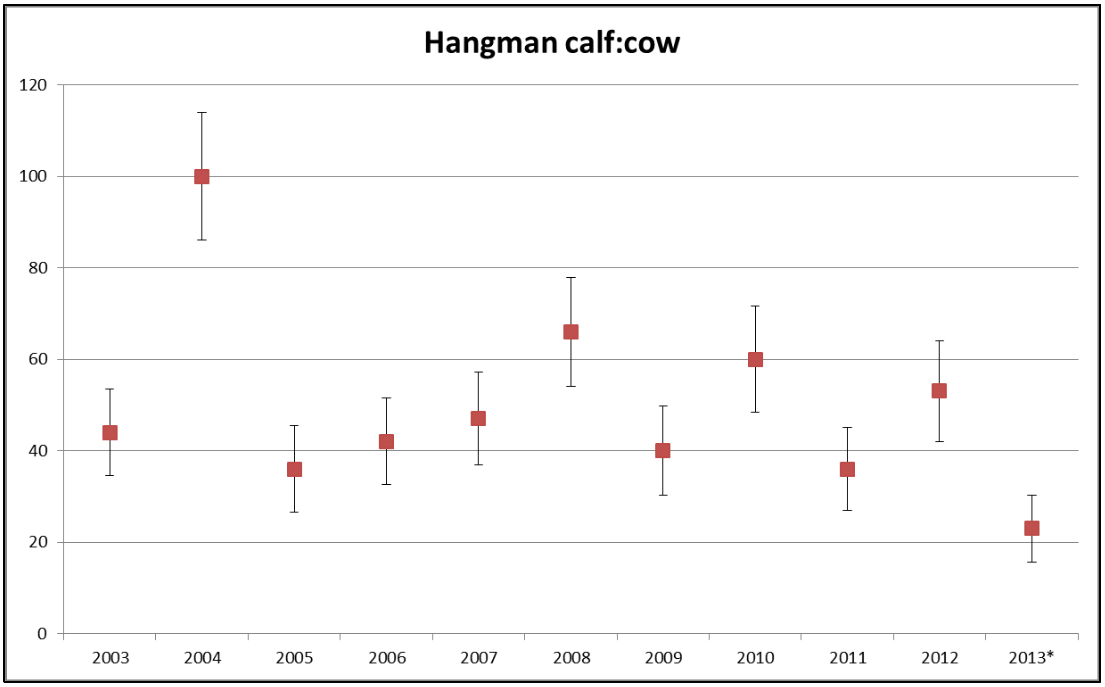


Figure 9. Annual mean (symbol) and 90% confidence intervals (vertical bars) of moose calf:cow ratios, as obtained from winter helicopter surveys in WDFW District 2, "Hangman" units (south of Spokane). In 2013 (asterisk), data were collected as part of the MRDS density estimation project (see below).

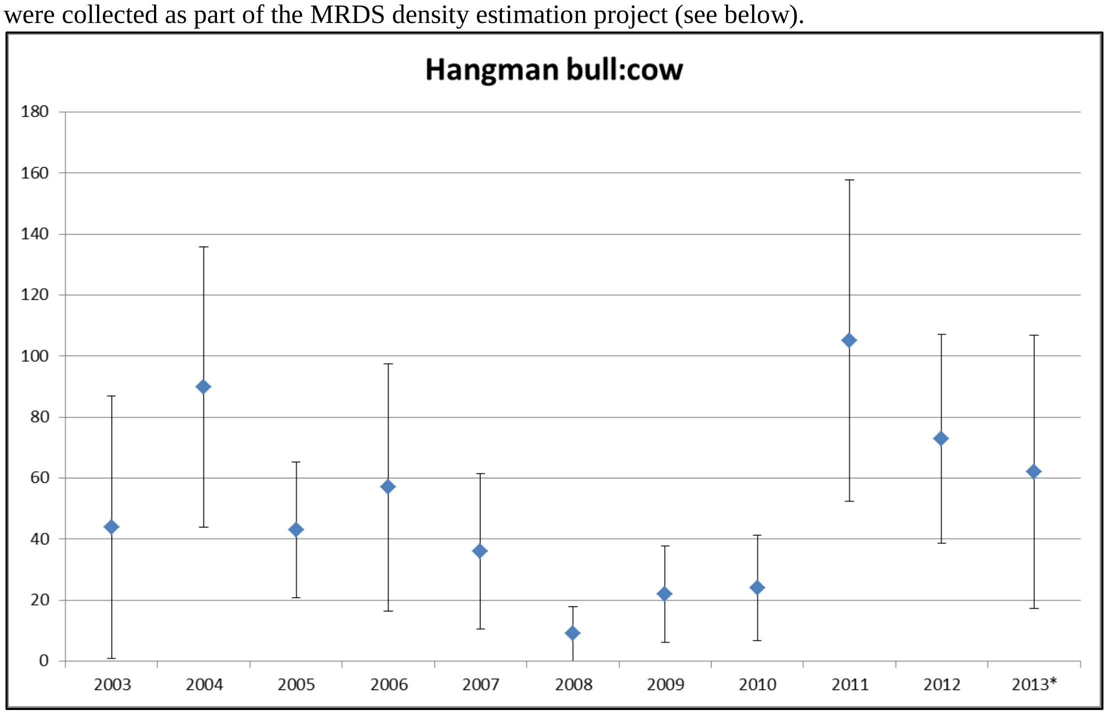


Figure 10. Annual mean (symbol) and 90% confidence intervals (vertical bars) of moose bull:cow ratios, as obtained from winter helicopter surveys in WDFW District 2, "Hangman" units (south of Spokane). In 2013 (asterisk), data were collected as part of the MRDS density estimation project (see below).

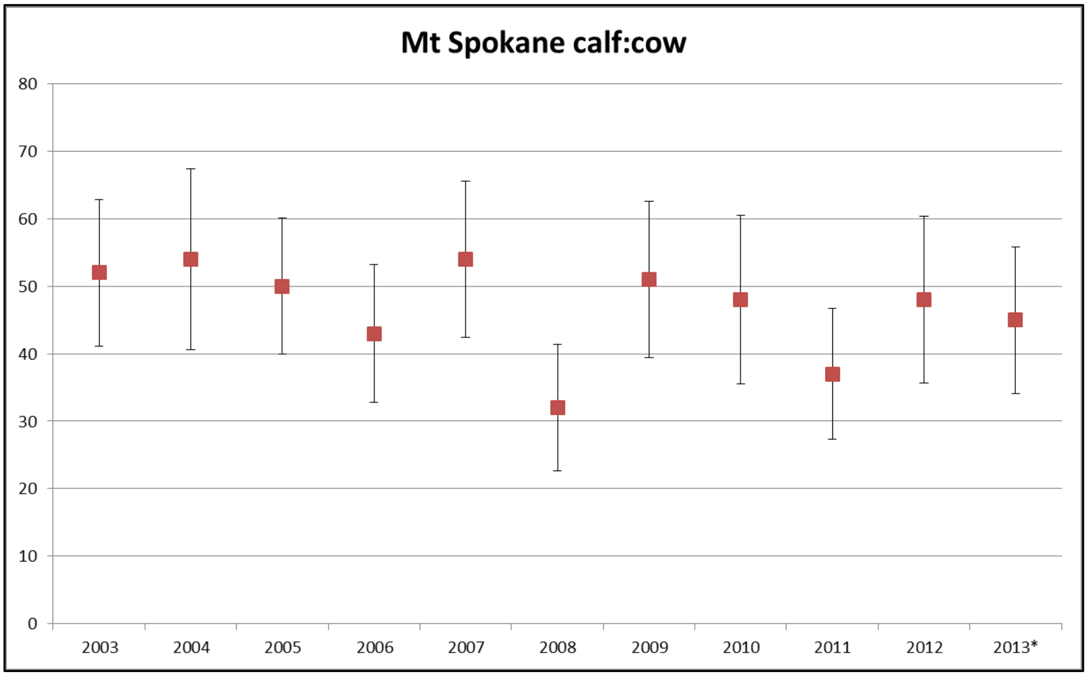


Figure 11. Annual mean (symbol) and 90% confidence intervals (vertical bars) of moose calf:cow ratios, as obtained from helicopter surveys in WDFW District 2, "Mt. Spokane" units (north of Spokane). In 2013 (asterisk), data were collected as part of the MRDS density estimation project (see below).

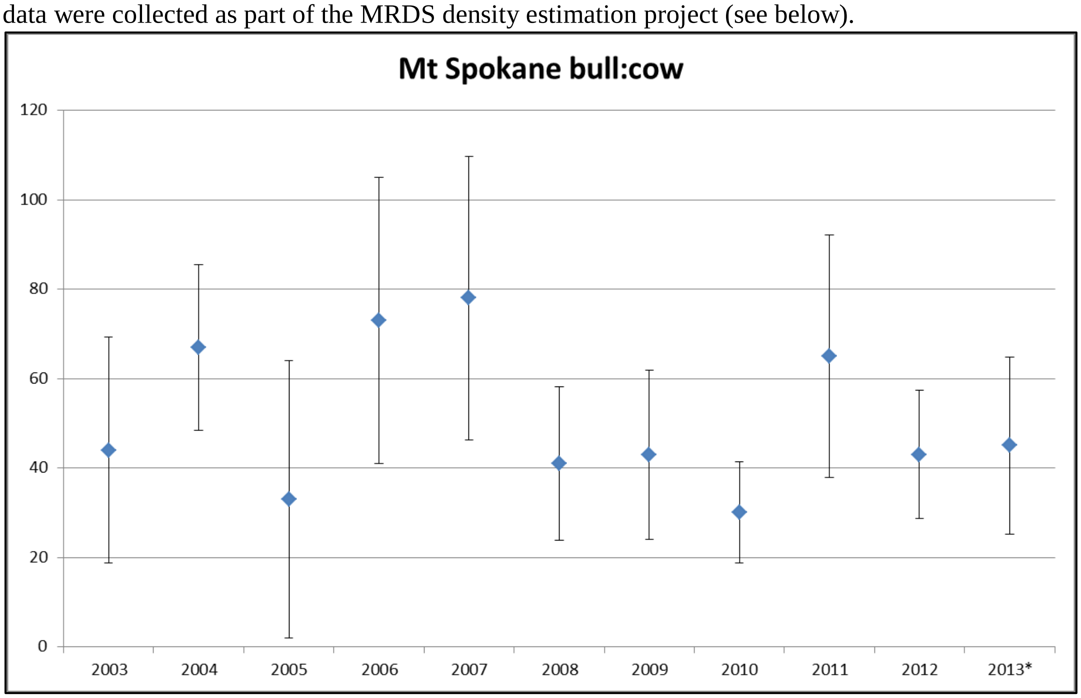


Figure 12. Annual mean (symbol) and 90% confidence intervals (vertical bars) of moose bull:cow ratios, as obtained from helicopter surveys in WDFW District 2, "Mt. Spokane" units (north of Spokane). In 2013 (asterisk), data were collected as part of the MRDS density estimation project (see below).

Population Trend

Aerial surveys to index population trend have been conducted from helicopters most winters, beginning in 1994. For District 1, because effort, areas surveyed, and sightability conditions varied (but only effort was quantified), total numbers seen are likely to reflect trends in true population abundance only at a coarse scale, and thus are not repeated here (see Base et al. 2008 for counts during 1994-2005). That said, there is consensus among all biologists that moose abundance in WDFW District 1 has increased, at least through 2012.

For WDFW District 2, information was collected as part of helicopter surveys during 2002-2012 that facilitated analyses accounting for covariates other than true underlying abundance likely to have affected the counts (Harris et al. 2015a). These were used to adjust raw counts in a multiple regression context that accounted for auto-correlation among yearly counts, and models were evaluated for parsimony using Akaike's Information Criterion (Harris et al. 2015a). The model averaged slope of counts of time incorporating these covariates, and accounting for all possible models (and thus representing the estimated instantaneous growth rate r) was 0.077 (with an approximate standard error of 0.075). This was slightly lower than the 0.084 suggested by raw counts unadjusted for covariates and auto-correlation. That is, our best estimate of population trend (λ) of moose in District 2 was approximately 1.08 during the 2002-2012 time-period, i.e., approximately 8% increase/year. However, none of the top-ranking models, nor the modeled averaged estimate, provided evidence that would reject the conventional null hypothesis that $r = 0$ (i.e., the population trend was flat) at the customary Type I error rate of $\alpha = 0.05$.

Population Density and Abundance

In winter 2013-2014, WDFW began testing the efficacy of a line transect-based, aerial mark-recapture distance sampling approach (MRDS) to provide a standardized and more precise survey protocol that would allow for regional- and district-level estimates of moose in northeast Washington. Our design called for adding sample size during winter 2014-15, but lack of suitable weather and snow conditions delayed this until winter 2015-16. Additional work is currently ongoing. What follows is a preliminary progress report. Final results will differ from this.

Survey Protocol

All potential transects were spaced 1 km apart in District 1, and 500 m apart in District 2. To ensure independence among surveys flown in District 2, we surveyed only transects spaced at 1-km intervals during any single day, returning at least 1 day later when surveying alternately (500m) spaced transects. Transects varied in length depending on available habitat and survey unit size (range = 2 km – 29 km). Surveys were conducted using a Robinson R44 helicopter during January-March 2014. We considered acceptable survey conditions to be days with low winds (<10 mph), temperatures below 2°C, and sufficient snow to cover stumps and low-lying vegetation in open areas. The pilot was instructed to maintain an altitude of approximately 400 ft. AGL (above ground level) and air speed of approximately 40 mph during all survey periods.

Results

We completed 175 line-transect surveys during 7 non-consecutive survey days (effort = 1,924 km) that covered District 1 (n = 89, effort = 1,200 km) and District 2 (n = 86, effort = 724 km). Overall, 238 moose were counted during 132 independent detections including bulls (n = 74), cows (n = 108), calves (n = 44), and adults of unknown sex (n = 12). Of the 42 cow-calf pairs observed, twins were recorded on 2 occasions. Mean group size was 1.43 moose (SE = 0.075) There was no evidence of cluster size bias, (slope of cluster size on distance β = 0.372, SE = 0.206, t = 1.81); thus, mean cluster size was used to estimate density of individual animals.

The detectability-corrected estimate of moose density, pooled across all presumed density strata was 0.27 moose/km^2 (95% CI: 0.186 – 0.377; CV = 18.1%). At first glance, this density appears considerably lower than many in the published literature. It should be borne in mind that this density applies over a large area that includes areas of poor moose habitat.

We reclassified land cover data from the 2010 LANDFIRE database to estimate the area of moose habitat (including grassland, shrubland, exotic herbaceous, riparian, conifer, hardwood, and conifer-hardwood cover types) and non-habitat (all other cover types) available within each surveyed GMU. Available habitat within the surveyed area was estimated as 10,497 km^2. We then multiplied the area of habitat by the estimated moose density from the best-fitting analyses to estimate overall abundance of moose in the 5 GMUs surveyed. This produced a rough and preliminary estimate of 2,771 moose (95% CI: 1,945–3,942) within the 5 GMUs surveyed.

Adult Survival and Calf Recruitment

Between 2000 and 2007, WDFW captured and fitted 37 moose with VHF transmitters (not including moose captured in conflict situations); most were females. During this time period, mean survival was 0.91 (Myers et al. 2013).

In 2013, WDFW, in cooperation with the University of Montana (UM) and with assistance from the Kalispel Tribe, began a study of moose demography north of Spokane, with the objectives of relating adult female survival and calf recruitment to various hypothesized drivers, including predation (Harris et al, 2015b). In December 2013, we fitted 27 adult female moose with GPS collars; in December 2014, we fitted an additional 24 adult females with GPS collars. We defined a "northern" study area (north of U.S. Highway 2), and a "southern" study area (south of U.S. Highway 2) as approximating areas with greater (north) and lesser (south) predation pressures on moose (Figure 13). Land ownership, land use patterns, and habitat conditions also vary between the 2 study areas. UM students and staff have subsequently monitored all marked adult cows for calf production and survival. These efforts have allowed some preliminary estimates. We used the Kaplan-Meier product-limit survival approach (Program R, package survival) to estimate survival for both adult females and calves.

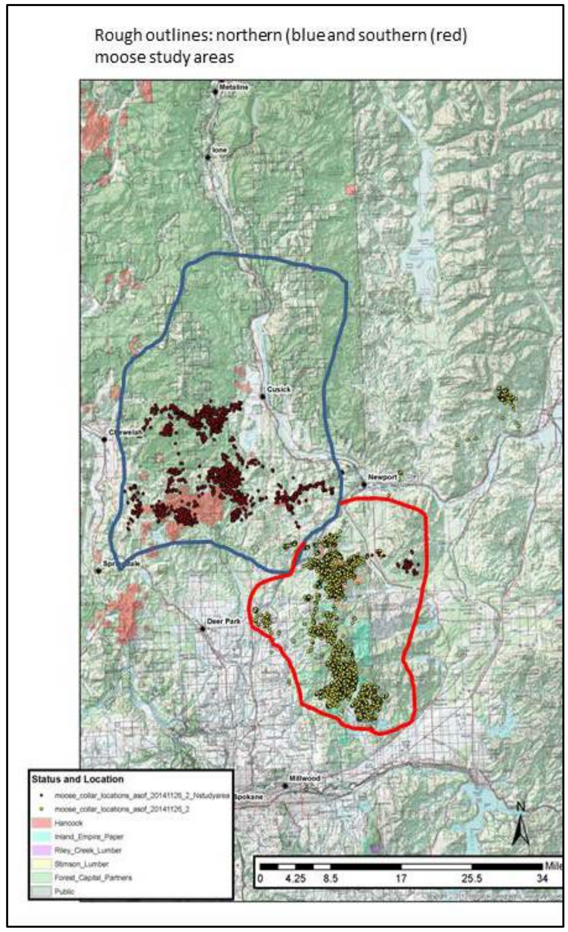


Figure 13. Moose research study areas, 2013-2015, north of Spokane, WA. Blue border demarcates northern and red border southern study areas.

Adult females

The point estimate of annual cow survival during December 2013-November 2014 was 0.85 (95% CI = 0.72-0.99; *n* = 27), and during December 2014-November 2015 was 0.89 (95% CI 0.80-0.98; *n* = 46). Of 10 radio-marked adult female moose that died between December 2013 and December 2015, causes of mortality were: hunter-harvest (4), malnutrition (3), unknown non-predation (2), and wolf predation (1). The moose cow killed by wolves was 14 years old and in poor body condition at the time she was captured and collared by WDFW.

Calves

Combining 2014 and 2015 seasons (defined as 1 June 2014 to 31 May 2015, and 1 June 2015 to November 2015 for 2015), we noted evidence of both an area and a year effect in calf survival. Calf survival was lower for the cohort born in 2014 than to-date for the 2015-born cohort, and lower in the northern area than southern area. Combining both years, there is evidence that calf survival was lower in the north than south study area. Calf-survival in the northern area, particularly during 2014, was low enough to elicit concern for population stability. Calf mortality occurred irregularly, with no discernible seasonal concentration. We are unable to attribute specific causes to any of the calf deaths (the study is not designed to attribute specific causes to any of the calf deaths). That said, it is likely that at least some of the calf deaths were caused by predators.

Overall Assessment: Effects of Predation on Moose Population Size or Growth Rate

At this point, we have no quantitative indication that moose in areas with multiple predators have declined, but we acknowledge that our estimates of current population trajectory trends are imprecise and likely subject to a time-lag of a few years. There are indications that moose calf recruitment in our northern study area has been low during 2014-2015; it is possible that predation is responsible for some or all of this.

Our ongoing study is scheduled to continue gathering field data through May 2017. Later in 2017, our colleagues at UM will be preparing a report that will help us interpret whether, and if so to what extent, predators are contributing to a reduction in moose abundance. Assessing the relative contribution of predation in light of other factors likely to affect vital rates is very difficult, all the more so when sample sizes are limited by budget constraints. We suspect that additional years of monitoring calf-recruitment after 2017 would assist our understanding of this complex system.

At-risk Designation

At-risk ungulate populations are any that are federal or state listed as threatened or endangered, as well as any ungulate population that falls 25% below its population objective for two consecutive years, or in which the harvest decreases by 25% below the 10-year average harvest for two consecutive years. Based on this definition, moose in Washington are not considered to be at-risk. However, we recommend additional information on body condition of moose, as well as continued monitoring of calf survival.

Proposed Actions

Continue the existing study, with the University of Montana as the primary implementing agent, through 2017. If possible, continue to monitor adult female moose survival following the formal completion of this study, as well as moose calf recruitment. Continue to develop alternative ways to index moose population trends.

Literature Cited – Moose

Ballard, W. B. and V. Van Ballenberghe. 1998. Predator/prey relationships. Pages 247-272 in A. W. Franzmann and C. C. Schwartz, editors. Ecology and Management of the North American Moose. Smithsonian Institution Press, Washington, D.C., USA.

Base, D. L., S. Zender, and D. Martorello. 2006. History, status, and hunter harvest of moose in Washington State. *Alces* 42: 111-114.

Bowyer, R.T., V. Van Ballenberghe, and J. G. Kie. 2003. Moose. Pp. 931-964 in Feldhammer, G. A., B. C. Thompson, and J. A. Chapman, Editors. Wild Mammals of North America, 2nd Edition, The Johns Hopkins University Press, Baltimore.

Harris, R. B., M. Atamian, H. Ferguson, and I. Keren. 2015a. Estimating moose abundance and trends in northeastern Washington State: Index counts, sightability models, and reducing uncertainty. *Alces* 51: 1-13.

Harris, R. B., S. Hansen, J. Oyster, K. Mansfield, E. Rowan, J. Goerz, and M. Mitchell. 2015b. Moose abundance, distribution, and demographic characteristics in eastern Washington. Progress report – Year 1. Unpublished WDFW report.

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. J. Wildlife Management 63:901-910.

McArt, S.H., D. E. Spalinger, W. B. Collins, E. R. Schoen, T. Stevenson, and M. Bucho. 2009. Summer dietary nitrogen availability as a potential bottom-up constraint on moose in south-central Alaska. Ecology 90: 1400-1411.Monteith, K.L., R. W. Klaver, K. R. Hersey, A. A. Holland, T. P. Thomas, and M. J. Kauffman. 2015. Effects of climate and plant phenology on recruitment of moose at the southern extent of their range. Oecologia DOI 10.1007/s00442-015-3296-4.

Murray, D. L., E. W. Cox, W. B. Ballard, H. A. Whitlaw, M. S. Lenarz, T.W. Custer, T. Barnett, and T. K. Fuller. 2006. Pathogens, nutritional deficiency, and climate influences on a declining moose population. Wildlife Monographs 166:1–30.

Musante, A. R., P. J. Pekins, and D. L. Scarpitti. 2010. Characteristics and dynamics of a regional moose *Alces* population in the northeastern United States. Wildlife Biology 16: 184-204.

Myers, W. L., M. Sederstrom, and E. Rowan. 2013. Survival rates, spring home range size, herd boundaries, and relocation rates of a pioneering moose population in Eastern Washington. Unpublished draft report, WDFW, Spokane.

Person, D. K., R. T. Bowyer, and V. Van Ballenberghe. 2001. Density dependence of ungulates and functional responses of wolves: effects on predator-prey ratios. Alces 37: 253-273.

Poelker, R. J. 1972. The Shiras moose in Washington. Unpublished administrate report. Washington Department of Game, Olympia, Washington, USA.

Ross, P. I., and M. G. Jalkotzy. 1999. Cougar predation on moose in southwestern Alberta. Alces 32: 1-8.

Schwartz, C. C., J. E. Swenson, and S. D. Miller. 2003. Large carnivores, moose, and humans: a changing paradigm of predator management in the 21st century. Alces 39: 41-63.

Smith, M. A., S. Kilpatrick, B. Younkin, L. Work, and D. Wachob. 2011. Assessment of crucial moose winter habitat in western Wyoming. Alces 47: 151-162.

Vucetich, J. A., M. Hebblewhite, D. W. Smith, and R. O. Peterson. 2011. Predicting prey population dynamics from kill rate, predation rate, and predator-prey rations in three wolf-ungulate systems. J. Animal Ecology 80: 1236-1245.

Washington Department of Wildlife. 2008. 2009-2015 Game Management Plan. Wildlife Program, WDFW, Olympia, Washington, USA.

Washington Department of Wildlife. 2014. 2015-2021 Game Management Plan. Wildlife Program, WDFW, Olympia, Washington, USA.

DEER

Introduction

The Washington Department of Fish and Wildlife (hereafter the Department) manages two species (mule deer [*Odocoileus hemionus hemionus*] and white-tailed deer [*O. virginianus*]) and one subspecies (black–tailed deer [*O. h. columbianus*]) of deer in Washington (WDFW 2014) as harvestable game species. These three species represent a statewide total of approximately 300,000 to 320,000 deer. Black-tailed deer occur west of the Cascade Crest and mule deer occur east of the Cascade Crest, while white-tailed deer occur primarily in the eastern-most third of the state. Management plans for both white-tailed deer and mule deer have been completed and their populations are currently managed within ecoregional-based management zones (6 white-tail zones and 7 mule deer zones) specific to each species. While there are no formal management zones for black-tailed deer as of this writing, for consistency within this report, populations have been assessed within 5 zones using similar criteria to those for white-tailed and mule deer. Primary factors the Department believes are currently affecting populations include habitat, weather, harvest, predation, and land-use practices.

The primary objective of this review is to identify deer management zones or local populations (e.g., deer herds within specific Game Management Unit(s) [GMUs]) that are below management objective or may be negatively affected by predators. However, fully understanding how the effect of predators interacts with other factors (e.g., weather, habitat, harvest, and alternate prey species) to influence the population dynamics of deer is extremely difficult (Krebs 2002) and outside the purview of this review. Consequently, we have limited this review to the following primary objectives:

1) Determine if deer populations are meeting management objectives the Department has defined in each associated management plan

2) Determine recent trends in harvest metrics (e.g., total harvest, hunter days, and kills/day)

3) Summarize any available data from recent survival studies

4) Identifying other factors that have the potential to influence population dynamics within each management zone

5) Determine if each management zone meets the criteria of an at-risk ungulate population as defined in the 2015–2021 Game Management Plan (WDFW 2014), which would include any management zone that falls 25% below its population objective for two consecutive years or if the harvest decreases by 25% below the 10-year average harvest for two consecutive years.

The secondary objective of this exercise is to identify potential actions for management zones or local populations of concern that are consistent with the guiding principles identified in the 2015–2021 Game Management Plan (WDFW 2014).

The Department has established objectives relating to general population trend and buck:doe ratios for each deer management zone and uses a variety of techniques to monitor the status of deer populations in Washington according to the landscape and habitat structure of each zone for each species. Monitoring techniques currently used include sightability models (Samuel et al. 1987, Unsworth et al. 1999), aerial surveys without sightability corrections, ground counts, and harvest data. In addition, some Treaty Tribes with established natural resource programs also monitor local deer populations and share that information with the Department. We have included that information in our review when availible and give credit accordingly.

We include two estimates of harvest data for all deer management zones in our review, general season state harvest and total state harvest (general season and permit). General season state harvest estimates include the estimated number of deer (antlered and antlerless) harvested during general modern firearm, muzzleloader, and archery seasons from 2005 to 2015. Estimates of total state harvest include general season state harvest estimates and number of deer harvested during special permit seasons between 2005 and 2015. We summarized harvest data in these two ways because permit harvest is often linked to mitigating damage issues or in response to a perceived increase in deer abundance and is consequently less suitable as an indicator of population trends than general harvest. However, harvest during permit seasons accounts for a large proportion of harvest in some deer management zones and must be included to reflect current harvest levels. Additionally, total harvest (general season, permit, and tribal harvest) is provided for black-tailed deer populations, where tribal harvest information is available.

We provide estimates of hunter days and kills per day as rough indicators of hunter effort and harvest rate over time in each zone. Although these metrics are sometimes informative tools that help guide management decisions, they can be influenced by changes in private land access, duration of the hunting season, weather, and other events unrelated to deer population status (Hatter 2001, Van Deelen and Etter 2003, Schmidt et al. 2005, Sunde and Asferg 2014). These considerations must be taken into account when interpreting any apparent changes in trend and we provide the necessary context as needed.

Carnivores that occur in Washington and prey on deer include cougars, black bears, grizzly bears, gray wolves, coyotes, bobcats, and lynx. We provide harvest data for black bears and cougars within each management zone (2005 – 2014, 2015 data were not available at the time of this writing) to illustrate that harvest of these species does occur, can vary from year to year, and varies among regions. These data are not intended to be reflective of population trend for these species. Given the conservative management structures used to manage these species, the Department assumes available black bear and cougar habitat is fully occupied throughout the state. In addition, we have restricted estimates of black bear and cougar harvest to harvest that occurred during general and special permit seasons established by the Department; it does not include animals removed for public safety reasons and in response to depredation events.

MULE DEER

Mule deer range in Washington is divided into 7 ecologically distinct mule deer management zones (MDMZ; Figure 1) and we provide a population assessment for each zone. For an in-depth discussion of mule deer population dynamics please see the Washington State Mule Deer Management Plan (WDFW 2016).

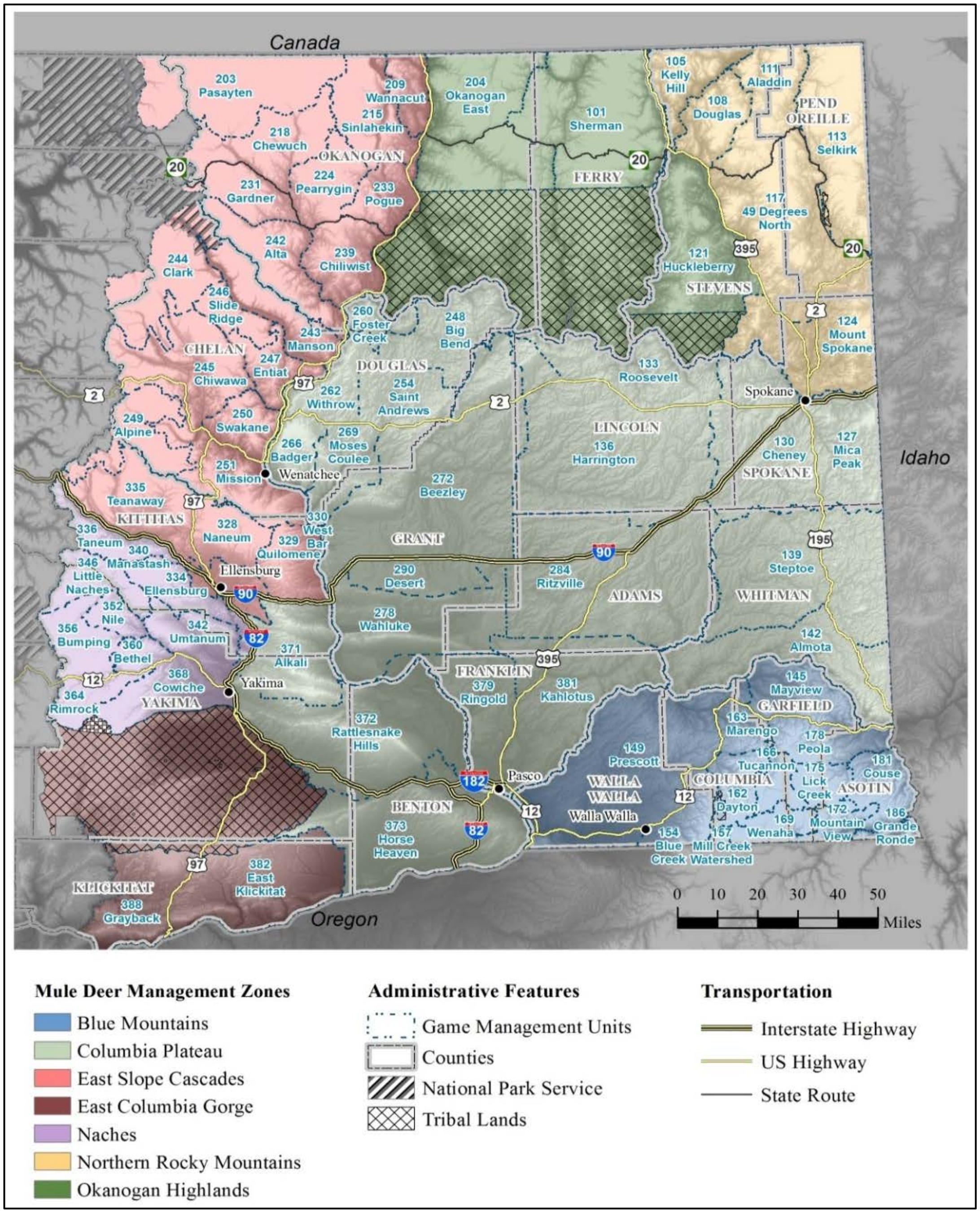


Figure 5. Mule Deer Management Zones established in the Washington State Mule Deer Management Plan.

Blue Mountains MDMZ

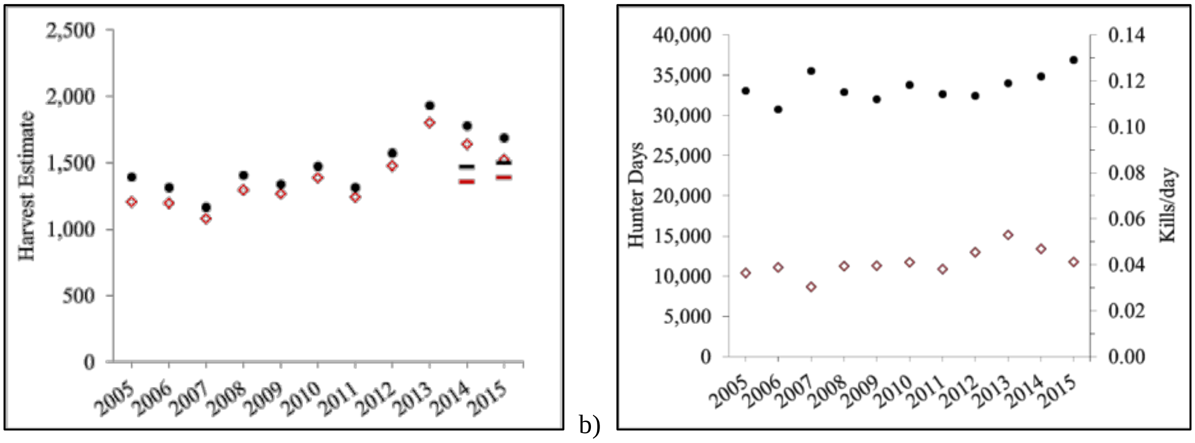
General Overview

The Blue Mountains MDMZ is located in southeast Washington and consists of 13 GMUs (145, 149, 154, 157, 162, 163, 166, 169, 172, 175, 178, 181, and 186; Figure 1). The Department's objective within this MDMZ is to maintain a stable population based on abundance surveys and harvest estimates. Additional management objectives include managing for a post-hunt population with a sex ratio of 15-19 bucks:100 does in predominantly agricultural areas and 20-24 bucks:100 does in public land units.

Current Status and Trend

Population Monitoring

Aerial surveys conducted between 2012 and 2014 in portions of the Snake River Breaks indicate a population of approximately 19,000 mule deer in those units surveyed. While there are no large-scale population estimates prior to this effort, harvest estimates for the past 10 years (Figure 2a) have been stable to slightly increasing. Rough indicators of hunter effort (hunter days; Figure 2b) and harvest rate (kills/day; Figure 2b) also indicate stable population conditions. It is important to note that hunter days and kills/day represent all deer hunting in the zone, including white-tailed deer. The buck:doe ratio estimate from ground and aerial surveys during the last 10 years has averaged 19:100. Aerial surveys conducted in 2014 indicate a buck:doe ratio of 20:100 (90% CI: 19-22). While these surveys cover ~70% of the zone, where habitat is more open and current survey methods are most effective, mule deer that occur in the higher-elevation forested areas are difficult to monitor and population information is limited to that gleaned from annual harvest estimates.

a) 

b)

Figure 2. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Blue Mountains MDMZ, 2005–2015.

Survival and Mortality

No estimates of pregnancy, fetal, or survival rates are available for mule deer herds in the Blue Mountains MDMZ. In addition to legal hunter harvest, other potential sources of mule deer mortality include predators such as cougars and coyotes, collisions with vehicles, and poaching. Other predator species living within this zone include bobcat, black bear, gray wolf (one pack has been documented in this zone as of this writing), golden eagles, and domestic dogs. While these mortality sources may influence population size, habitat condition and availability have the greatest impact to mule deer populations, particularly in the Blue Mountains MDMZ where most of the population is likely to be summer range limited.

Black bear and cougar occur most often in the foothills and mountains of the Blue Mountains MDMZ. Black bear harvest during state general and permit seasons has been stable since 2005 (Figure 3). Cougar harvest during general season has been variable since 2005 and averaged 12 cougars per year (Figure 3).

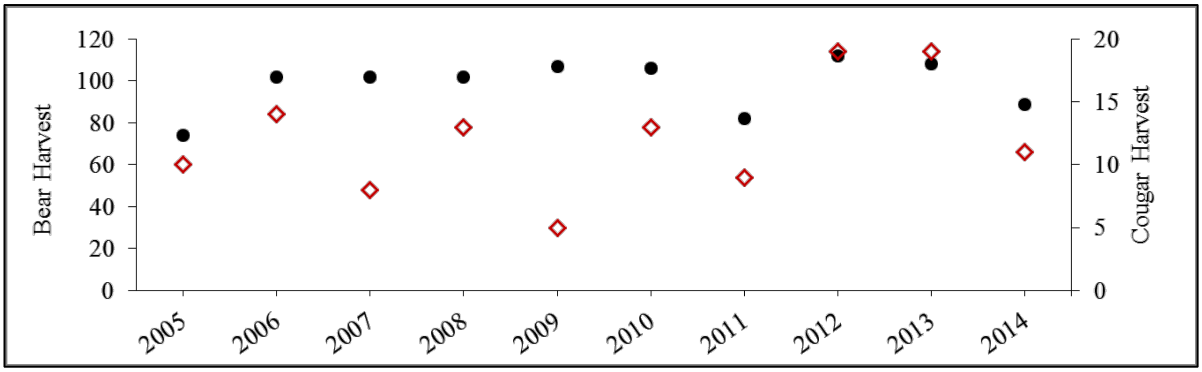


Figure 3. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the Blue Mountains MDMZ, 2005–2014.

Other Factors That Potentially Influence Population Dynamics

Limited habitat is the major impediment to increasing deer numbers and hunting opportunity within the Blue Mountains MDMZ. The Blue Mountains MDMZ has been altered by landscape changes including conversion to croplands, grazing by domestic livestock, wildfire suppression, highway or road construction, invasion of noxious weeds, extensive wind power development, and urban-suburban development. Although no single factor has had a direct, large-scale effect on mule deer populations in the Blue Mountains, the cumulative effects of such alterations have likely been detrimental to mule deer habitat over time.

Sub-herd Concerns

None at this time.

Management Conclusions

Mule deer populations in the Blue Mountains MDMZ are currently at management objective currently at management objective based on the buck:doe ratio estimate, and available survey data indicate stable to increasing populations where habitat availability and quality allow.

Northern Rocky Mountains MDMZ

General Overview

The Northern Rocky Mountains MDMZ is located in northeast Washington and consists of six GMUs (105, 108, 111, 113, 117, and 124; Figure 1). The Department's objective within this MDMZ is to maintain a stable population, based on harvest estimates and other best-available information. Additional management objectives include managing for a post-hunt population with a sex ratio of 15-19 bucks:100 does.

Current Status and Trend

Population Monitoring

No estimates of mule deer abundance are available for populations within this zone, but densities are likely low given the limited mule deer habitat and predominence of white-tailed deer on the landscape. Consequently, mule deer are found in small, scattered groups within the zone and harvest is generally low compared to other MDMZs.

Harvest estimates have been relatively stable over time (Figure 4a). It is important to note that estimates of hunter effort (i.e., hunter days; Figure 4b) and harvest rate (i.e., kills/day; Figure 4b) in this zone include days spent hunting white-tailed deer as well, and are consequently skewed with regard to mule deer-specific harvest. Because this zone is predominantly hunted for white-tailed deer, the true number of days spent hunting only mule deer are substantially lower, and harvest rates higher, than indicated.

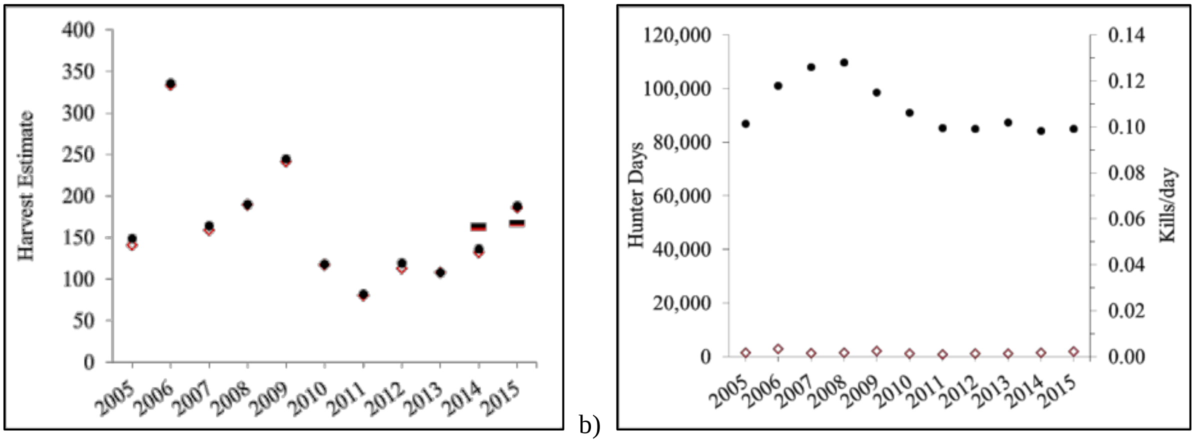


Figure 4. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Northern Rocky Mountains MDMZ, 2005–2015.

Survival and Mortality

No estimates of pregnancy, fetal, or survival rates are available for mule deer herds in the Northern Rocky Mountains MDMZ.

Other Factors That Potentially Influence Population Dynamics

Cougars, black bears, grizzly bears, and coyotes occur within this MDMZ, as well as seven wolf packs as of this writing. Although the effects of predation on this population of mule deer are unknown, mule deer harvest metrics have remained stable. Black bear harvest has remained generally stable while cougar harvest has increased in recent years (Figure 5).

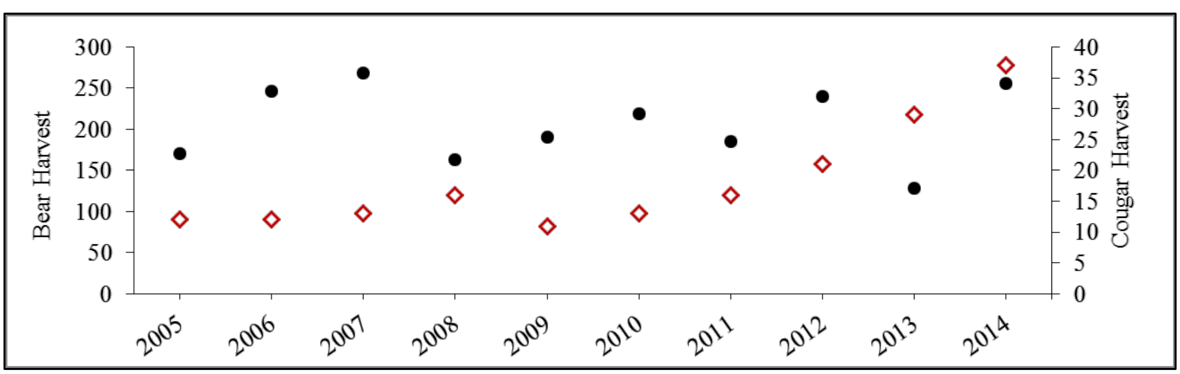


Figure 5. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the Northern Rocky Mountains MDMZ, 2005–2014.

Sub-herd Concerns

None at this time.

Management Conclusions

Mule deer populations in the Northern Rocky Mountains MDMZ are considered stable based upon harvest metrics.

Columbia Plateau MDMZ

General Overview

The Columbia Plateau MDMZ is located in east-central Washington and consists of 21 GMUs (127, 130, 133, 136, 139, 142, 248, 254, 260, 262, 266, 269, 272, 278, 284, 290, 371, 372, 373, 379, and 381; Figure 1). The Department's objective within this MDMZ is to maintain a stable population based on abundance surveys and harvest estimates. Additional management objectives include managing for a post-hunt population with a sex ratio of 15 - 19 bucks:100 does.

Current Status and Trend

Population Monitoring

Mule deer are present throughout most of the Columbia Plateau MDMZ at varying densities depending upon locality and habitat quality. While no estimates of mule deer abundance exist for the entire zone, estimates are available for portions of the MDMZ. Population estimates from aerial sightability surveys conducted from 2012 to 2014 for mule deer wintering in Crab Creek and along Lake Roosevelt in the Columbia Plateau MDMZ ranged from 11,142 ± 1,386 in 2014 to 13,597 ± 1,532 in 2013 (90% CI). Similar surveys conducted from 2009 to 2011 for mule deer wintering in Palouse and along Snake River Breaks in the Columbia Plateau MDMZ ranged from 11,977 ± 1,818 in 2010 to 13,589 ± 2,199 in 2011 (90% CI). Based on values provided in Status and Trend reports for populations within this MDMZ, mean buck:doe ratio for the Columbia Plateau in 2014 was 21:100.

More mule deer are harvested in the Columbia Plateau MDMZ than in any other zone and harvest has remained stable over the past decade (Figure 6a). Measures of hunter effort and relative success (Figures 6a and 6b) in the zone have generally been stable during the past 10 years.

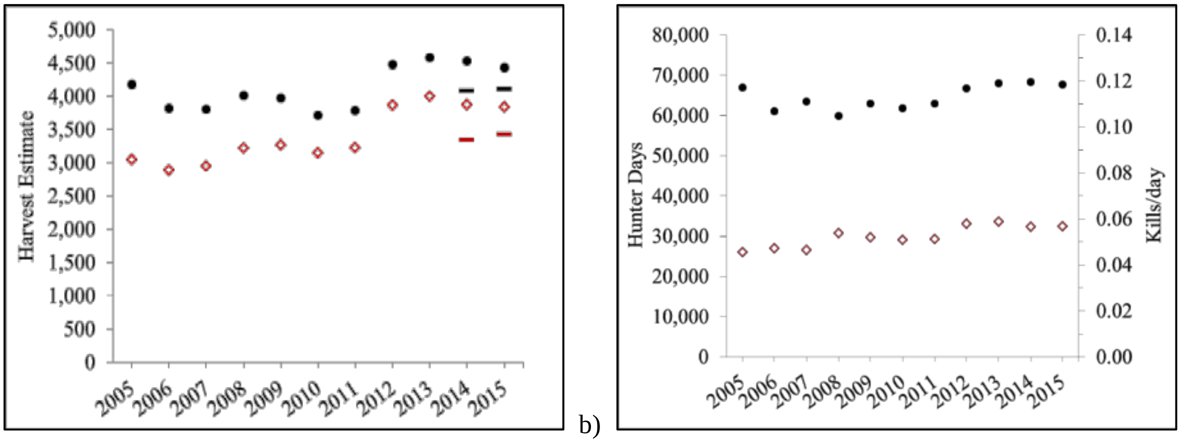


Figure 6. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Columbia Plateau MDMZ, 2005–2015.

Survival and Mortality

Recent field studies conducted in the eastern portion of this zone, between 2000 and 2008, indicated mean annual survival ($\hat{s}$ = 0.94), pregnancy ($\hat{p}$ = 0.96), and fetal ($\hat{f}$ = 1.44) rates of adult female does were sufficient to maintain stable populations (WDFW 2016). Cause-specific mortality for radio-marked juvenile mule deer (30 marked as neonates, 35 marked at 6 months of age) indicated legal hunting and coyotes were the most frequent sources of mortality (n = 28), and mean juvenile survival rates during the first summer ($\bar{x}$ = 0.52) and the first winter (fawns transitioning into the yearling age class; $\bar{x}$ = 0.90) were sufficient to maintain stable populations as well (Johnstone-Yellin et al. 2009, WDFW 2016).

Other Factors That Potentially Influence Population Dynamics

While not observed during recent field studies of marked deer, other sources of mule deer mortality likely include predation (by species other than coyotes), collisions with vehicles, drowning in irrigation canals, and poaching. Predator species living within this zone include cougars, bobcats, black bears, coyotes, golden eagles, gray wolves (transients have been observed but there are no known packs confirmed within this MDMZ at the time of this writing), and domestic dogs. Black bear and cougar occur at low levels in the Columbia Plateau and harvest of these species has been relatively stable (Figure 7).

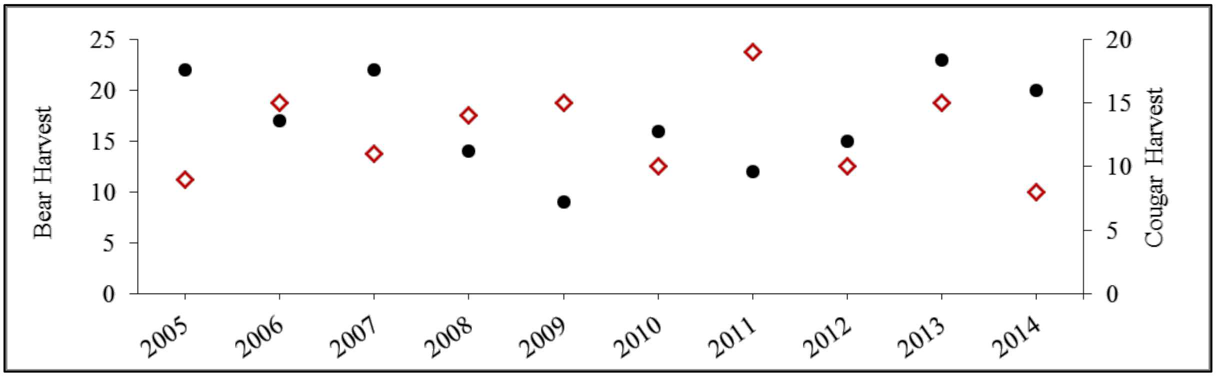


Figure 7. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the Columbia Plateau MDMZ, 2005–2014.

Loss of important habitat, particularly shrub-steppe, riparian, and wet meadow habitat, is the most important issue facing wildlife managers in the Columbia Plateau MDMZ. Land conversion is the most obvious source of habitat loss, but in this zone, wildfires have become more frequent and more intense in recent years. These fires often result in a rapid invasion of exotic plant species that have little or no nutritional value to mule deer, and restoration of native vegetation requires intensive, long-term effort to be successful. In some areas of the zone, crop fields enrolled in the CRP (Conservation Reserve Program) have mitigated the loss of shrub-steppe by providing cover and forage, especially important during fawning season.

Sub-herd Concerns

None at this time.

Management Conclusions

Mule deer populations in the Columbia Plateau MDMZ are currently at management objective based on the buck:doe ratio, and survey data indicate stable population growth where habitat availability and quality allow.

East Columbia Gorge MDMZ

General Overview

The East Columbia Gorge MDMZ, located in south central Washington, is smallest of the seven mule deer management zones and consists of two GMUs, 382 and 388 (Figure 1). The Department's objective within this MDMZ is to maintain a stable population based on field surveys and harvest estimates. Additional management objectives include managing for a post-hunt population with a sex ratio of 15 - 19 bucks:100 does.

Current Status and Trend

Population Monitoring

Mule deer are present throughout the East Columbia Gorge MDMZ with the highest densities observed during January through March and April on the low elevation winter ranges. Post-hunt aerial surveys in GMU 382 indicate the buck:doe ratio estimate for 2014 (21:100) is greater than that of the 10-yr average (14:100) and within objective. Post-hunt aerial surveys in GMU 388 indicate the buck:doe ratio estimate for 2014 (15:100) is equal to that of the 10-yr average (15:100) and within objective.

Harvest estimates indicate a slightly declining harvest (Figure 8a) that likely reflects, in part, lower hunter numbers and related hunter effort (Figure 8b) as well as small population declines within the zone in recent years. Estimates of kills/day have remained relatively stable over time (Figure 8b).

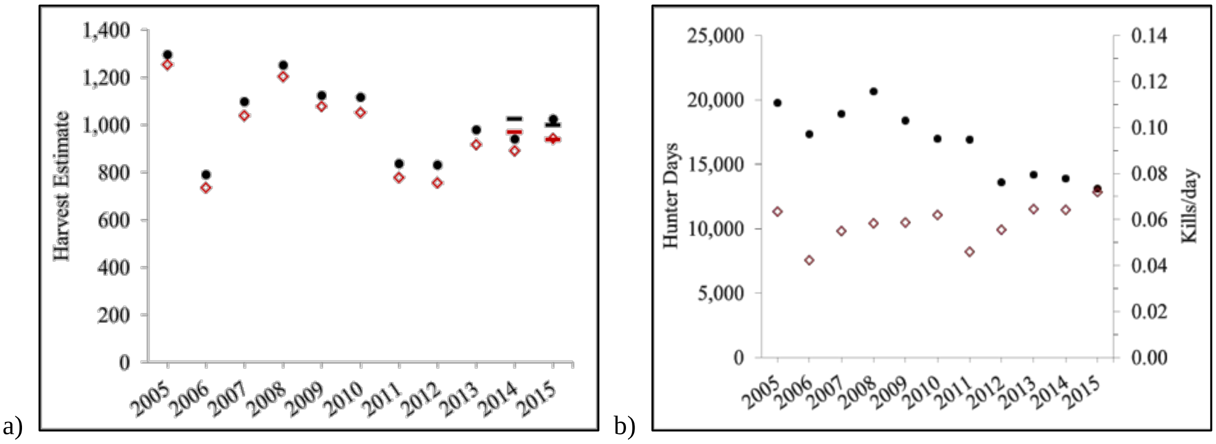


Figure 8. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the East Columbia Gorge MDMZ, 2005–2015.

Survival and Mortality

There are no current data on annual survival rates of mule deer in East Columbia Gorge MDMZ, however McCorquodale (1996) reported results from telemetry studies here during the early 1990s with estimated survival rates for adult females and males at 0.82 and 0.50, respectively. Hunting mortality and poaching were major causes of death in marked deer using the Klickitat Basin (McCorquodale 1996).

Other Factors That Potentially Influence Population Dynamics

In addition to legal hunting, common mortality sources include disease, predation, and deer-vehicle collisions. Lice infestations and hair loss syndrome have been documented in mule deer (Bernatowicz et al. 2011) and likely contribute to the decline in mule deer numbers. Common predator species include cougar, bobcat, black bear, and coyote. Wolves have not been detected in this MDMZ as of this writing. Because of the small area covered by the East Columbia Gorge MDMZ, harvest of black bear and cougar (Figure 9) are also low.

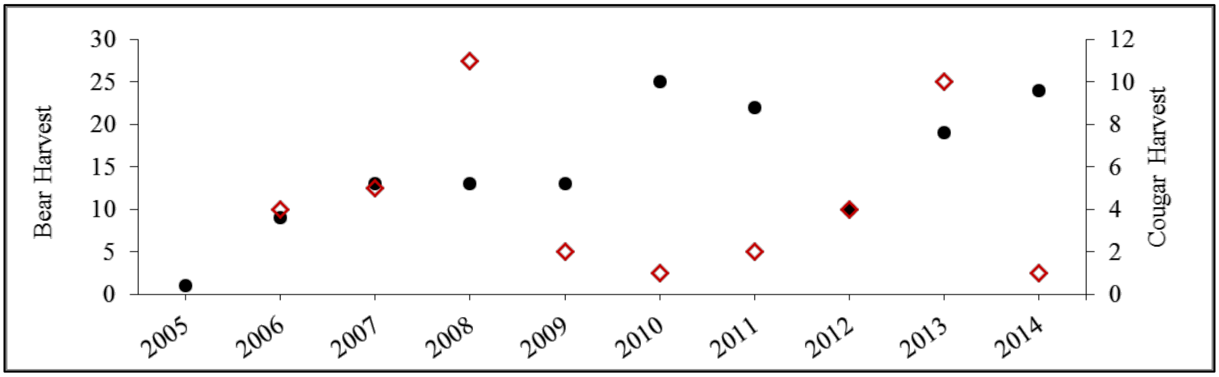


Figure 9. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the East Columbia Gorge MDMZ, 2005–2014.

The East Columbia Gorge MDMZ has experienced extensive alternative energy development and agricultural land conversion in recent years. Electricity generated by wind power currently is one of the fastest growing alternative energy sources in the region with large wind power sites already in operation along the Columbia River breaks. Although wind power is generally considered a "green energy" source, there may well be effects on mule deer and the habitat upon which they depend (Sawyer et al. 2002). More direct effects on the population have occurred in the form of habitat loss from agricultural conversion and associated roadways necessary to access such development, as well as increased mortality from vehicle collisions.

Sub-herd Concerns

None at this time.

Management Conclusions

Mule deer populations in the East Columbia Gorge MDMZ are currently within the established buck:doe ratio objective, though harvest estimates indicate a slight decline in GMU 382. In response to this decline, managers have reduced antlerless harvest permits for the 2016 season and reduced some early season antlered harvest opportunity to support a more stable population. Annual survey efforts will allow managers to continue monitoring the population and determine future management needs.

East Slope Cascades MDMZ

General Overview

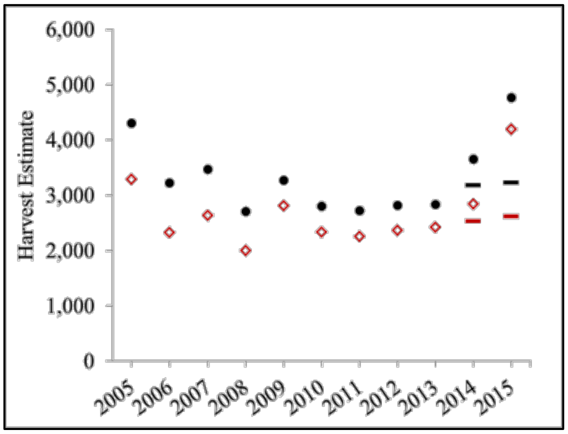
The East Slope Cascades MDMZ, comprised of 22 GMUs in north-central Washington (203, 209, 215, 218, 224, 231, 233, 239, 242, 243, 244, 245, 246, 247, 249, 250, 251, 328, 329, 330, 334, and 335; Figure 1), is home to Washington's major migratory mule deer populations. The Department's objective within this MDMZ is to maintain stable populations based on field surveys and harvest estimates. Additional management objectives include a post-hunt ratio of 15-19 bucks:100 does east of the Okanogan River and a post-hunt ratio of ≥ 25 bucks:100 does west of the river.

Current Status and Trend

Population Monitoring

Mule deer are present throughout the East Slope Cascades MDMZ with the highest densities observed during January through March on the low elevation traditional winter ranges. Recent post-hunt aerial sightability surveys estimated 47,000 mule deer within the East Slope Cascades MDMZ (WDFW 2013). The post-hunt buck:doe ratio for the northern portion of the zone in 2014 was 23:100 (10-yr average = 22:100). Inadequate snow cover and poor flying conditions in the southern portion of the zone have limited completion of aerial survey efforts but the most recent buck:doe ratio estimate available, from 2011, was 29:100.

Mule deer harvest in much of the East Slope Cascades MDMZ is greatly influenced by weather conditions during the hunting season and weather conditions during fall and early winter for the past 6 years have been average or below average in severity. Conservative harvest of antlerless mule deer is generally designed to maintain population stability while still providing some recreational opportunity. It is also used at times to limit herd growth, or reduce deer numbers in damage areas, or for responses to dramatic changes in carrying capacity such as those associated with large wildfires. Harvest trend for the past 10 years has increased in recent years (Figure 10a) despite a slow decline in hunter effort, as indicated by decreasing hunter days (Figure 10b). Estimates of kills/day have correspondingly increased in the last two years (Figure 10b).

a) 

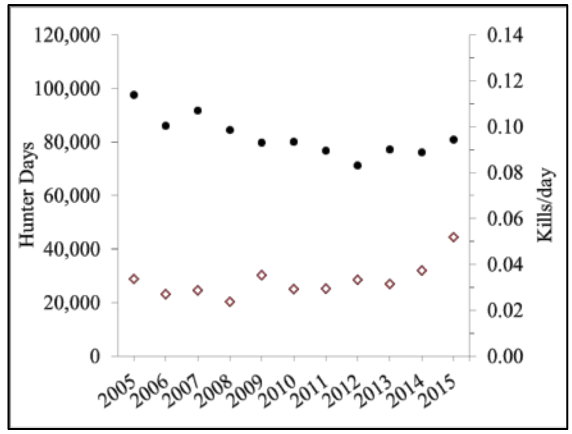
b) 

Figure 10. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the East Slope Cascades MDMZ, 2005–2015.

Survival and Mortality

Recently observed pregnancy and fetal rates in East Slope Cascades MDMZ were 0.95 and 1.66, respectively (WDFW 2016). Mean annual survival rate observed during recent field studies of adult female mule deer from 2000-2007 (n = 50) was 0.92 within East Slope Cascades MDMZ. Investigations of deaths of radio marked adult female mule deer showed cougars, poaching, deer-vehicle collisions, and unidentified predators to be common sources of mortality, although the high survival rates would suggest these mortality sources are not limiting the adult female segment of the population.

Other Factors That Potentially Influence Population Dynamics

Habitat quality has a great effect on potential mule deer abundance and recruitment. Mule deer habitat within the East Slope Cascades MDMZ can be divided into areas based upon seasonal use. Most (80 - 90%) of the mule deer within the East Slope Cascades MDMZ spend the summer season in lush, high mountain meadows and subalpine basins (Zeigler 1978, Myers et al. 1989). These productive, high mountain habitats make the East Slope Cascades MDMZ extremely important to mule deer. These optimal habitat conditions provide nutritious forage for lactating does and contribute to high fawn survival and recruitment. These habitats are not limited, face little threat of alteration, and are at present self-sustaining. On winter ranges, mule deer move to a small portion of their annual range to find forage and thermal cover. Because mule deer are geographically restricted during winter, the quality of the winter range can affect deer survival and recruitment (Sawyer et al. 2006), and nutritional stress can also leave them vulnerable to disturbance.

Other habitat related considerations include continued development and fragmentation of low-elevation habitats, growing use and distribution of off-road vehicles, and increasing disturbance on winter ranges. This is compounded by shorter fire return intervals and increasing spread of invasive weeds, which result in a reduction of shrub vegetation communities.

Many predators occur within the East Slope Cascades MDMZ including coyotes, black bears, cougars, and wolves. The effects of predators on deer within this zone are not expected to limit mule deer populations given current deer abundance and the availability of multiple prey species within the system. As of this writing, there are three documented wolf packs within the zone (Becker et al. 2016), and harvest of black bears (Figure 11) has been relatively stable. Harvest of cougars has increased slightly in recent years (Figure 11).

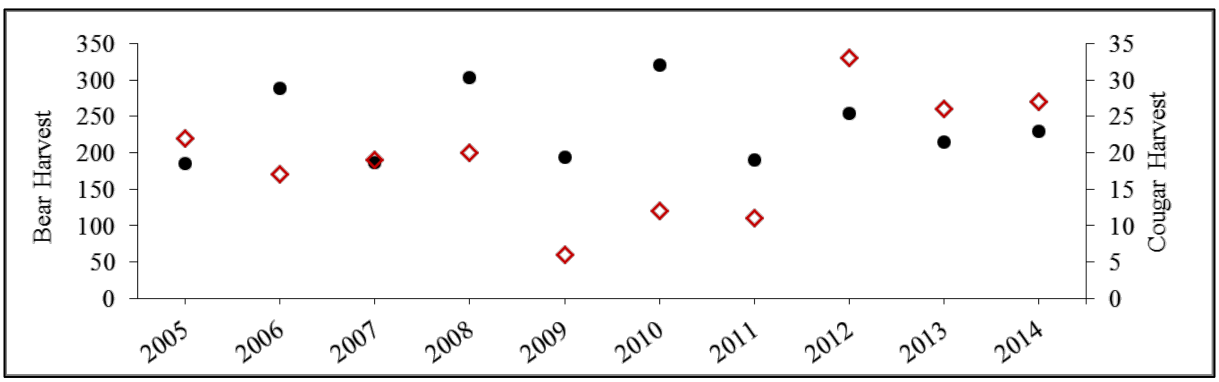


Figure 11. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the East Slope Cascade MDMZ, 2005–2014.

Sub-herd Concerns

None at this time.

Management Conclusions

Mule deer populations in the East Slope Cascades MDMZ are currently above the minimum management objective of 15-19 bucks per 100 does, and survey data indicate stable to increasing population growth.

Naches MDMZ

General Overview

The Naches MDMZ is located in central Washington (Figure 1) and includes GMUs 336, 340, 342, 346, 352, 356, 360, 364, and 368. The Department's objective within this MDMZ is to maintain stable populations based on field surveys and harvest estimates. Additional management objectives include managing for a post-hunt population with a sex ratio of 15-19 bucks:100 does.

Current Status and Trend

Population Monitoring

Mule deer are present throughout the Naches MDMZ with the highest densities observed during January through March and April on the low elevation traditional winter ranges. Since 2011, aerial survey and modeling results provided a spring population estimate of 5,400 mule deer within the Naches MDMZ (WDFW 2013). The post-hunt buck:doe ratio for the zone in 2014 was 23:100 (10-yr average = 17:100).

Harvest trend for the past 10 years has been slowly declining (Figure 12a) as have hunter numbers, indicated by decreasing hunter days (Figure 12b). Estimates of kills/day have remained relatively stable (Figure 12b).

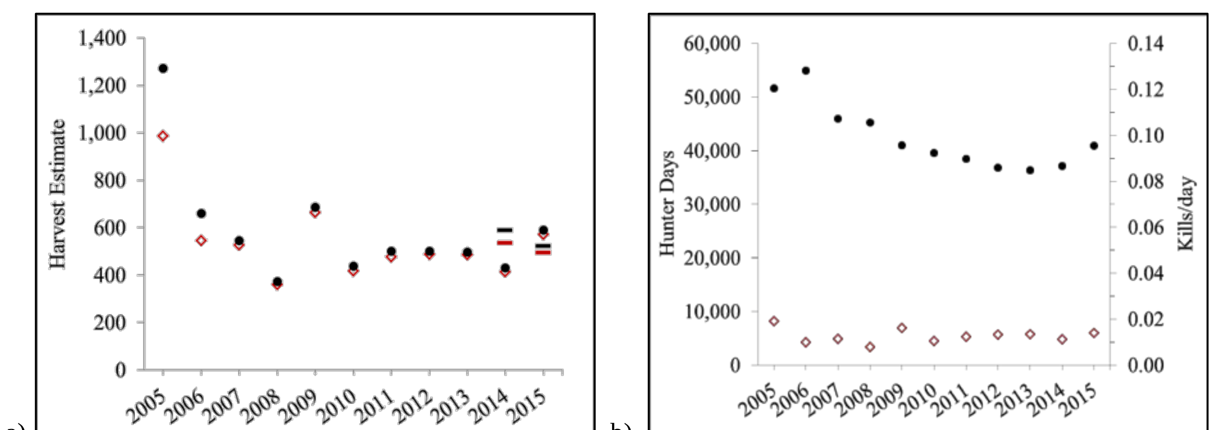


Figure 12. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Naches MDMZ, 2005–2015.

Survival and Mortality

Telemetry studies conducted by the Muckleshoot Indian Tribe (MIT) started in 2013 are ongoing and will provide managers with some zone-specific survival and movement information. A total of 160 adult female mule deer have been radio-marked by the MIT, and 82 mortalities have been documented to date. Estimates of annual survival rates for adult female mule deer were 0.82 (CI = ± 0.07), 0.81 (CI = ± 0.07), and 0.67 (CI = ± 0.08) for the first 3 years of field study, respectively (D. Vales, unpublished data). Survival estimates are based on a biological year running from 05/15 to 05/14. These estimates are consistent with adult female survival documented in other mule deer populations throughout the west (Bleich and Taylor 1998, Unsworth et al. 1999, Bishop et al. 2005, Hurley et al. 2011, Monteith et al. 2014). However, the survival estimates are lower than observed in the Department's research conducted in the Columbia Plateau, East Slope Cascades, and Okanogan Highlands MDMZs (WDFW 2016). Predation by cougars accounted for the highest proportion of the mortalities in this MDMZ (≈40%). The second and third highest proportions of total mortality were attributed to malnutrition and human-caused mortality at 26% and 16% of total mortalities, respectively.

Since 2004, deer in this zone have been observed with hair-loss syndrome, a condition caused by an exotic louse. The mule deer population declined in the mid-2000s in this MDMZ and the contributing factors could have been hair loss syndrome, winter mortality, and other undocumented disease (Bernatowicz et al. 2011). In recent years, the population has slowly started to rebound.

Other Factors That Potentially Influence Population Dynamics

Predators within the Naches MDMZ including coyotes, black bears, bobcats, and cougars. As of this writing, there are no documented wolf packs within the zone but they are likely to colonize in the near future. Harvest of black bears (Figure 13) has been relatively stable. Harvest of cougars has increased slightly in recent years (Figure 13).

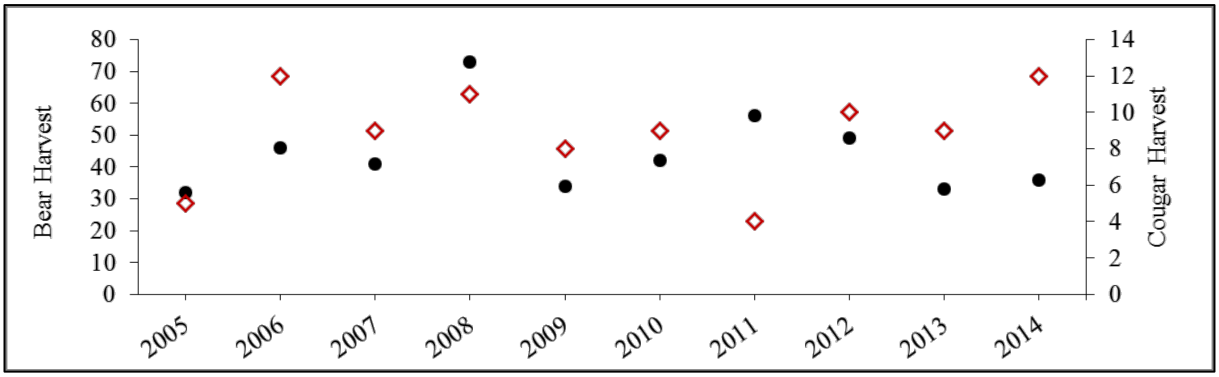


Figure 13. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the Naches MDMZ, 2005–2014.

Sub-herd Concerns

None at this time.

Management Conclusions

Mule deer populations in the Naches MDMZ are currently well above the minimum management objective of 15-19 bucks per 100 does, and survey data indicate slowly improving populations.

Okanogan Highlands MDMZ

General Overview

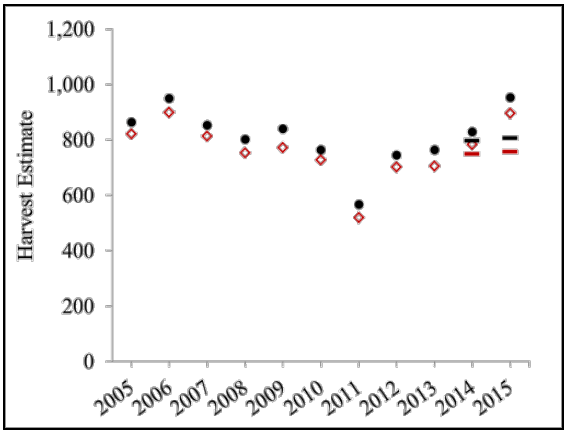
The Okanogan Highlands MDMZ is located in north-central Washington and includes GMUs 101, 121, and 204 (Figure 1). The Department's objective within this MDMZ is to maintain stable populations based on field surveys and harvest estimates. Additional management objectives include managing for a post-hunt population with a sex ratio of 15-19 bucks:100 does.

Current Status and Trend

Population Monitoring

While no estimates of mule deer abundance are available for populations within this zone, local Department managers believe densities vary from low to moderate in numbers based upon limited survey data and incidental observations. Mule deer are present throughout the Okanogan Highlands MDMZ but densities are greatest in the northwest portion of the zone where habitat is best suited to mule deer. There are no current estimates of the post-hunt buck:doe ratio for this zone but, based on harvest information and recent survival estimates, managers expect buck:doe ratios to be within objective.

Harvest trends for the past 10 years has been relatively stable (Figure 14a). Hunter days have declined in recent years due to shortened season length while kills/day have remained stable (Figure 14b).

a) 

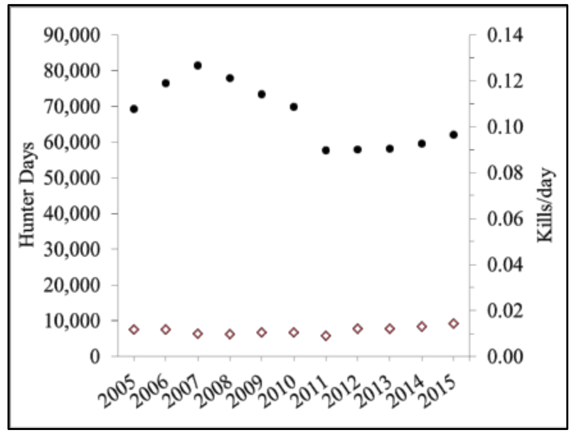
b) 

Figure 14. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Naches MDMZ, 2005–2015.

Survival and Mortality

Recently observed pregnancy and fetal rates in Okanogan Highlands MDMZ from 2000 to 2007 were 0.93 and 1.44, respectively (WDFW 2016). The mean annual survival rate observed during recent field studies of adult female mule deer was 0.89 within the Okanogan Highlands MDMZ. Investigations of deaths of radio-marked adult female mule deer indicated cougars were the most common source of mortality along with deer-vehicle collisions, although the high survival rates suggest these mortality sources are not limiting the adult female segment of the population. Other potential sources of mule deer mortality include legal hunting harvest and poaching, although neither source was documented during field studies of marked deer in this MDMZ.

Okanogan Highlands are also subject to predation by wolves (seven wolf packs have been documented as of this writing [Becker et al. 2016]) and golden eagles. Recreational harvest of black bear has been stable, while cougar harvest in the zone has increased in recent years (Figure 15).

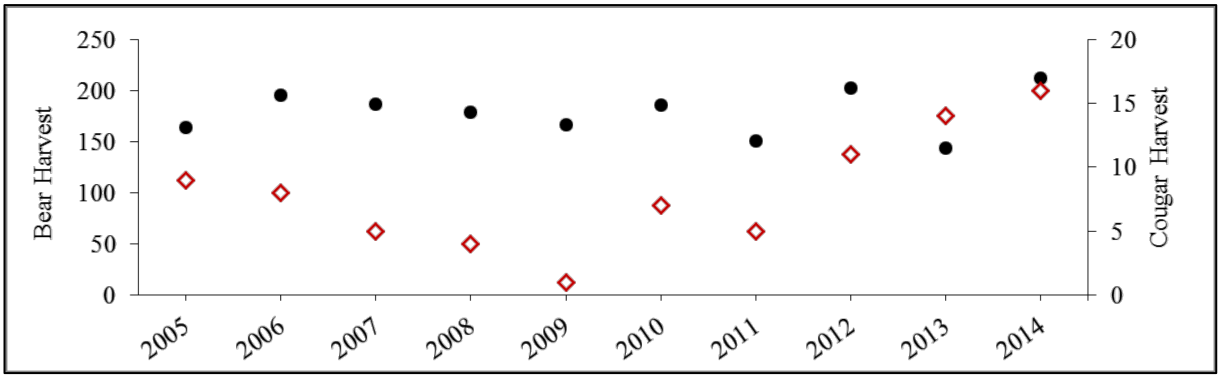


Figure 15. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the Okanogan Highlands MDMZ, 2005–2014.

Other Factors That Potentially Influence Population Dynamics

Another potential influence to mule deer numbers in the Okanogan Highlands MDMZ documented elsewhere is interference competition with elk (Stewart et al. 2002). Recent changes in harvest management strategies for elk within this zone are likely to result in increased elk numbers and distribution.

Sub-herd Concerns

None at this time.

Management Conclusions

Mule deer populations in the Okanogan Highlands MDMZ are currently within the management objective of 15-19 bucks:100 does and survey data indicate stable to slowly increasing population growth.

BLACK-TAILED DEER

Black-tailed deer range in Washington is divided into 5 black-tailed deer management zones (BDMZ; Figure 16) and population assessments are provided for each zone.

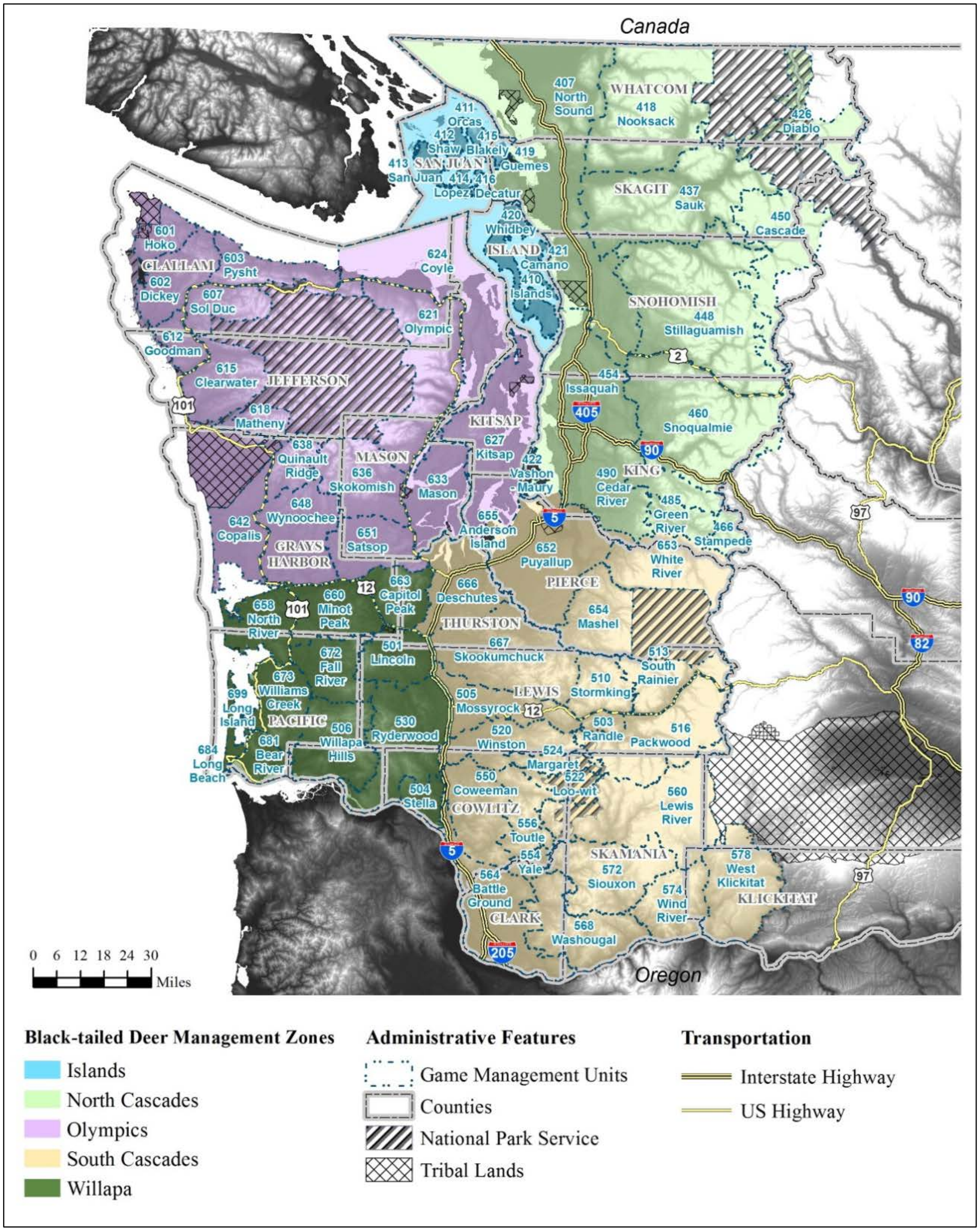


Figure 16. Black-tailed Deer Management Zones established for this report.

Islands BDMZ

General Overview

The Island Black-tailed Deer Management Zone is located in the Puget Sound in northwest Washington and consists of 11 GMUs (410-417 and 419-422; Figure 16). The Department's objective within this BDMZ is to maintain or reduce the population based on best available knowledge for each island.

Current Status and Trend

Population Monitoring

Harvest estimates over the last decade indicate an increasing trend (Figure 17a) similar to the number of hunter days (Figure 17b) and harvest rates (kills/day; Figure 17b).

a)

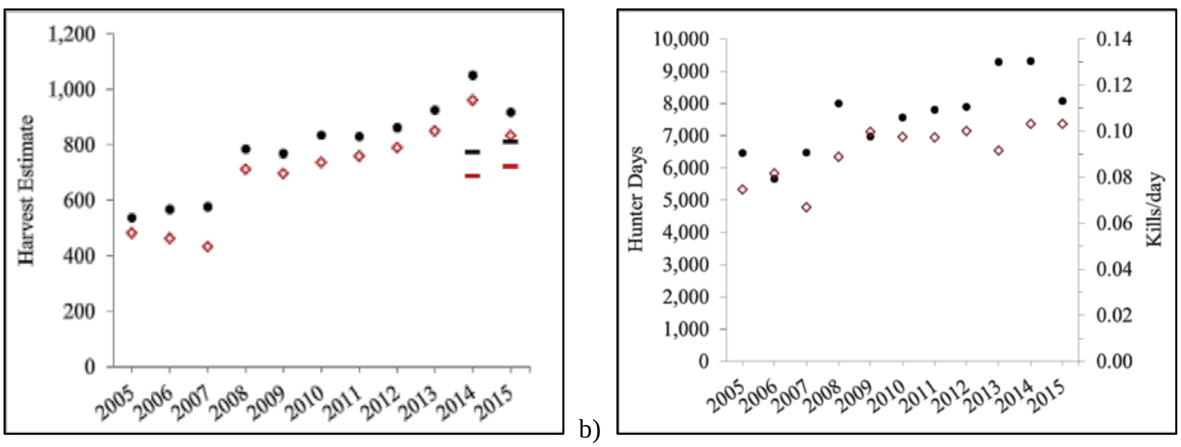


Figure 17. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Islands BDMZ, 2005–2015.

Survival and Mortality

No information regarding vital rates is available for black-tailed deer in the Islands BDMZ.

Other Factors That Potentially Influence Population Dynamics

In addition to legal hunter harvest, other potential sources of mortality include predation by coyotes (the sole large predator in this zone), collisions with vehicles, and poaching.

Sub-herd Concerns

None at this time.

Management Conclusions

Black-tailed deer populations in the Islands BDMZ are currently at or above management objective and harvest data indicate increasing population growth.

North Cascade Mountains BDMZ

General Overview

The North Cascade Mountains BDMZ is located in northwest Washington and consists of 11 GMUs (407, 418, 426, 437, 448, 450, 454, 460, 466, 485, and 490; Figure 16). The Department's objective within this BDMZ is to maintain a stable population, based on harvest estimates and other best available information. Additional management objectives include managing for a post-hunt population with a sex ratio of approximately 15 - 19 bucks:100 does.

Current Status and Trend

Population Monitoring

While no estimates of black-tailed deer abundance are available for populations within this zone, local managers believe populations are stable. Harvest estimates for the past 10 years indicate a slow rise in harvest, commensurate with increases in hunter effort in the zone (Figures 18a and 18b). Overall population stability in the zone is further supported by consistent long-term harvest rates (kills/day; Figure 18b).

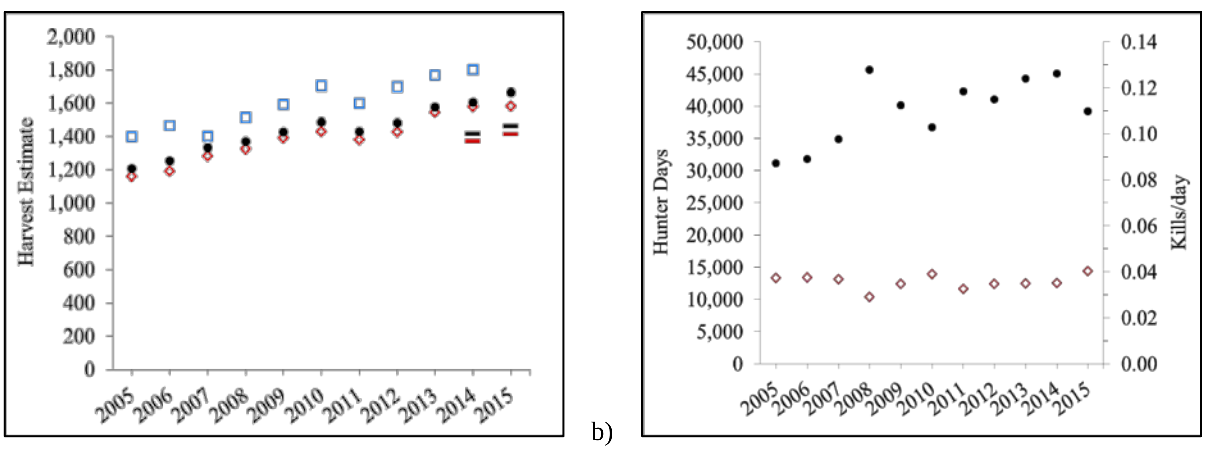
a)  b)

Figure 18. General State Harvest (◊), Total State Harvest (●) , and Total Harvest (□) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the North Cascade Mountains BDMZ, 2005–2015.

Survival and Mortality

No estimates of pregnancy, fetal, or survival rates are available for black-tailed deer herds specific to the North Cascade Mountains BDMZ. However, vital rates of adult does are thought to be sufficient based on harvest trends. In general, estimates of annual survival of black-tailed bucks in Washington State have averaged 50% in forested landscapes with hunting identified as the primary source of mortality (Bender et al. 2004).

Other Factors That Potentially Influence Population Dynamics

Cougars, black bears, and coyotes occur within this BDMZ. Although the effects of predation on this population of black-tailed deer are unknown, harvest metrics have remained stable. Black bear harvest has remained relatively stable over the past 10 years, as has cougar harvest (Figure 19).

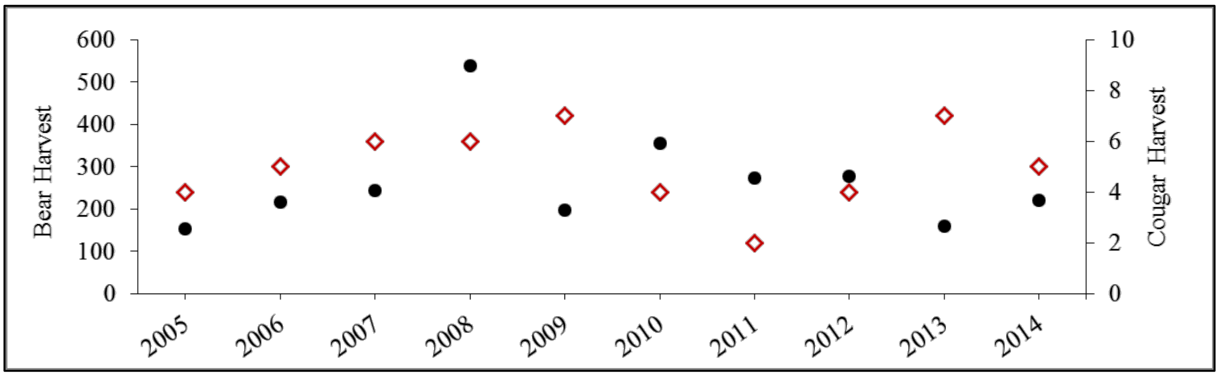


Figure 19. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the North Cascade Mountains BDMZ, 2005–2014.

Sub-herd Concerns

None at this time.

Management Conclusions

Limited information is available for black-tailed deer populations in the North Cascade Mountains BDMZ but populations are considered stable based upon harvest metrics.

Olympic Peninsula BDMZ

General Overview

The Olympic Peninsula BDMZ is located in coastal western Washington and consists of 16 GMUs (601, 602, 603, 607, 612, 615, 618, 621, 624, 627, 633, 636, 638, 642, 648, and 651; Figure 16). The Department's objective within this BDMZ is to maintain a stable population based on field surveys and harvest estimates. Additional management objectives include managing for a post-hunt population with a sex ratio of approximately 15 - 19 bucks:100 does.

Current Status and Trend

Population Monitoring

While estimates of black-tailed deer abundance and post-season ratios are not available for populations within this zone, pre-season surveys conducted periodically by Department and Tribal staff provide some insight as to the level of harvest intensity, assuming average buck mortality. Pre-season buck:doe ratio estimates indicate an average of approximately 30 bucks:100 does over the last decade (WDFW 2015). Estimates from harvest reports for the past 10 years indicate harvest and kills/day have been relatively stable and hunter effort slightly declining (Figure 20).

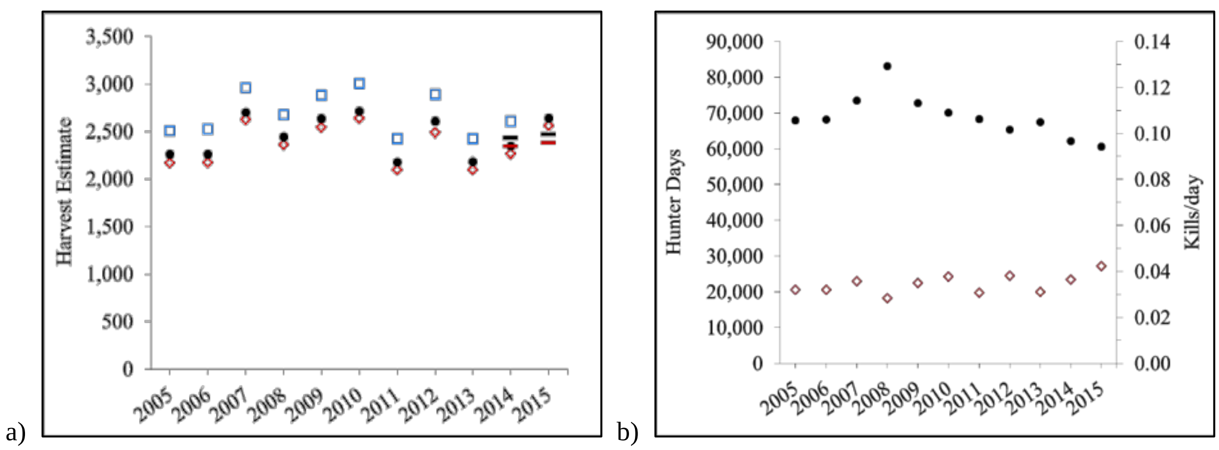


Figure 20. General State Harvest (◊), Total State Harvest (●) , and Total Harvest (□) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Olympic Peninsula BDMZ, 2005–2015.

Survival and Mortality

Survival estimates in GMU 601 indicate adult doe survival is likely sufficient to sustain current populations (79 – 87%; McCoy et al. 2014). However, the same study also reported that over-winter fawn survival was affected by presence of hair loss syndrome, and might limit populations where exotic lice, that cause the disease, occur. Primary sources of black-tailed deer mortality likely include legal harvest, predation (from coyotes, bobcats, black bears, and cougars), poaching, and collisions with vehicles. Black bear harvest has declined in recent years while cougar harvest has been relatively stable (Figure 21).

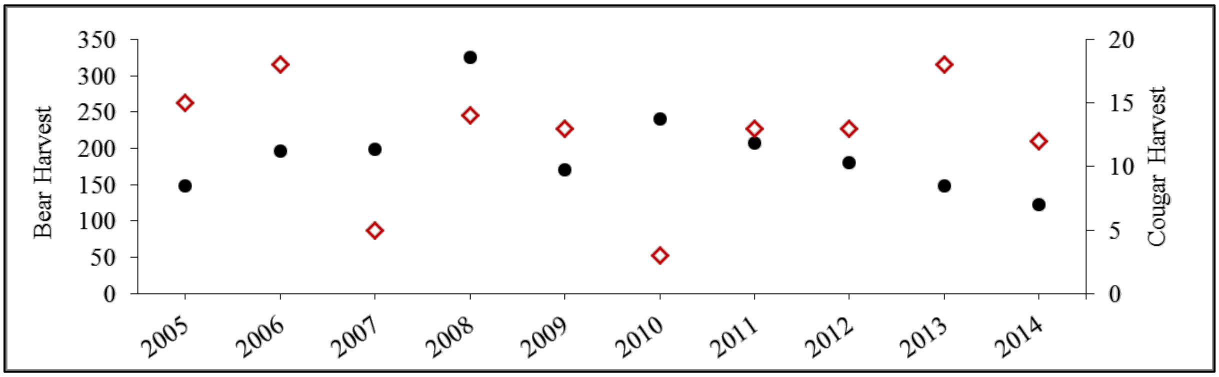


Figure 21. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the Olympic Peninsula BDMZ, 2005–2014.

Other Factors That Potentially Influence Population Dynamics

Forest management practices can have a substantial effect on forage availability for ungulates. Timber harvest that results in large areas of mid- to late-seral stage, single-age forest, as well as use of herbicides, can reduce forage availability and limit deer productivity. The magnitude of those effects is influenced by site specific post- timber harvest treatments and the number of years since timber harvest (Ulappa 2015). Studies conducted by the Department and Tribal managers that might provide insight on the role of forest management in ungulate productivity are nearing completion.

Sub-herd Concerns

None at this time.

Management Conclusions

Black-tailed deer populations in the Olympic Peninsula BDMZ are currently within management objectives based on buck:doe ratio information and harvest data that indicate stable population growth where habitat allows.

South Cascade Mountains BDMZ

General Overview

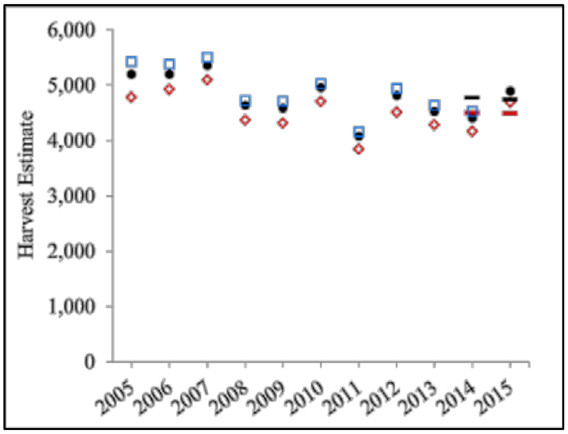
The South Cascade Mountains BDMZ is located in the southwest portion of the Cascade Mountains and consists of 22 GMUs (503, 505, 510, 513, 516, 520, 522, 524, 550, 554, 556, 560, 564, 568, 572, 574, 578, 652, 653, 654, 666, and 667; Figure 16). The Department's objective within this BDMZ is to maintain a stable population based on field surveys and harvest estimates and a post-hunt population with a sex ratio of approximately 15 - 19 bucks:100 does.

Current Status and Trend

Population Monitoring

Estimates of black-tailed deer abundance and post-season ratios are not available for all populations within South Cascade Mountains BDMZ, but deer are generally more abundant at lower elevations in the zone. Best available estimates of pre-season buck to doe ratios (which can provide some indication of harvest intensity from the previous year) for GMU 667, in the northeast portion of the zone, indicate an average of 21 bucks:100 does between 2005 and 2009. Post-season buck:doe ratios in GMU 578, in the south-west portion of the zone, indicate an average of 18 bucks:100 does.

Harvest estimates indicate a slight decline (Figure 22a) that likely reflects lower hunter numbers and related hunter effort (Figure 22b). Estimates of kills/day have remained stable (Figure 22b).

a) 

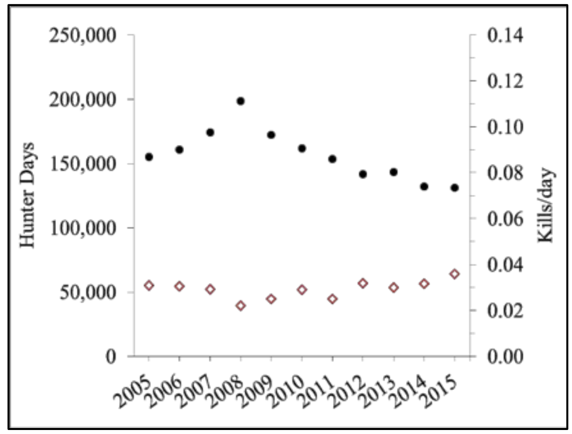
b) 

Figure 22. General State Harvest (◊), Total State Harvest (●) , and Total Harvest (□) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the South Cascade Mountains BDMZ, 2005–2015.

Survival and Mortality

Previous estimates of annual survival of black-tailed bucks in Washington have averaged 50% in forested landscapes, with mortalities primarily due to legal harvest (McCorquodale 1999, Bender et al. 2004). In more urbanized habitat, annual buck survival is closer to 86% and mortalities are generally not the result of harvest (Bender et al. 2004). Preliminary estimates of adult doe survival during 2013 in GMU 653, from a study being conducted by the Muckleshoot Tribe in the South Cascade Mountains BDMZ, indicate a mean annual survival of 85% (D. Vales, personal communication).

Common predator species in the South Cascade Mountains BDMZ include cougar, bobcat, black bear, and coyote. Black bear and cougar harvest have varied but, in general, have remained relatively stable over the last decade (Figure 23).

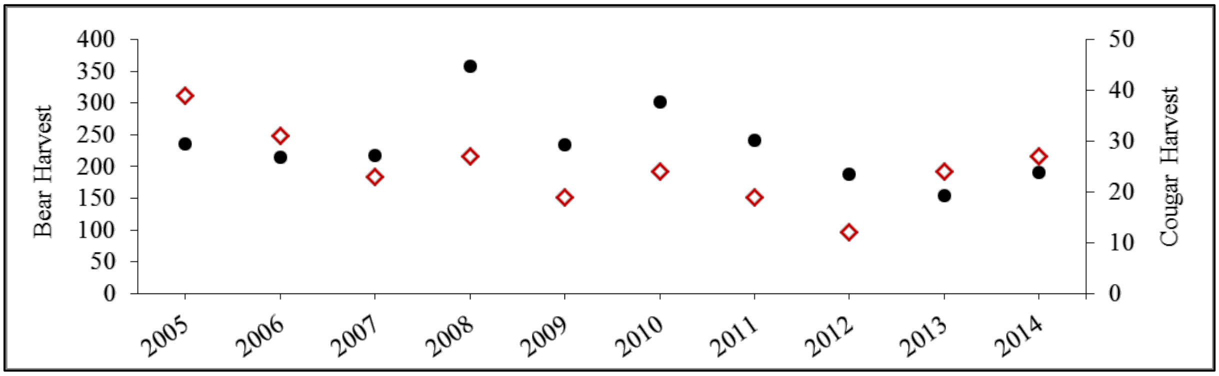


Figure 23. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the South Cascade Mountains BDMZ, 2005–2014.

Other Factors That Potentially Influence Population Dynamics

Increasing urbanization in much of the South Cascade Mountains BDMZ has resulted in loss of quality habitat for black-tailed deer. Forest management practices may also be affecting overall deer productivity due to reduced forage quality and availability. The magnitude of those effects is influenced by site specific post- timber harvest treatments and the number of years since timber harvest (Ulappa 2015).

Sub-herd Concerns

None at this time.

Management Conclusions

Black-tailed deer populations in the South Cascade Mountains BDMZ are currently within management objective and survey data indicate stable population growth where habitat allows.

Willapa Hills BDMZ

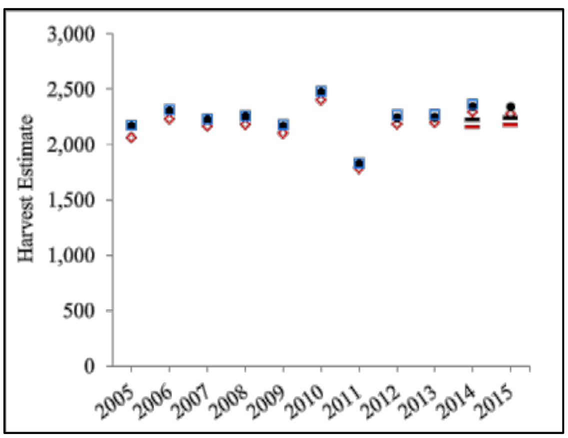
General Overview

The Willapa Hills BDMZ is located in the coastal portion of southwest Washington and consists of 12 GMUs (501, 504, 506, 530, 658, 660, 663, 672, 673, 681, 684, and 699; Figure 16). The Department's objective within this BDMZ is to maintain stable populations based on field surveys and harvest estimates. Additional management objectives include a post-hunt sex ratio of approximately 15 - 19 bucks:100 does.

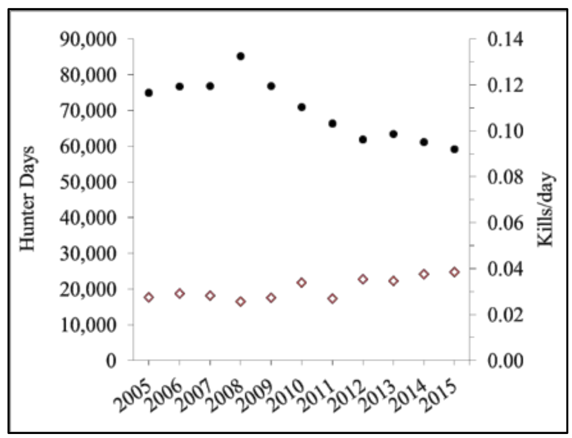
Current Status and Trend

Population Monitoring

Estimates from harvest reports for the past decade indicate harvest has been stable (Figure 24a), while hunter effort has declined and kills/day shows a very slight increase (Figure 24b).



a)



b)

Figure 24. General State Harvest (◊), Total State Harvest (●) , and Total Harvest (□) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Willapa Hills BDMZ, 2005–2015.

Survival and Mortality

No estimates of pregnancy, fetal, or survival rates are available for black-tailed deer in the Willapa Hills BDMZ.

Other Factors That Potentially Influence Population Dynamics

The effects of forest management strategies, particularly the use of herbicides and decreased burning are poorly understood, but may negatively influence ungulate forage and, ultimately, deer abundance. The magnitude of those effects is influenced by site specific post- timber harvest treatments and the number of years since timber harvest (Ulappa 2015).

Common predator species in the Willapa Hills BDMZ include cougar, bobcat, black bear, and coyote. Harvest of black bears has declined in recent years and harvest of cougars has generally been consistently low (Figure 25).

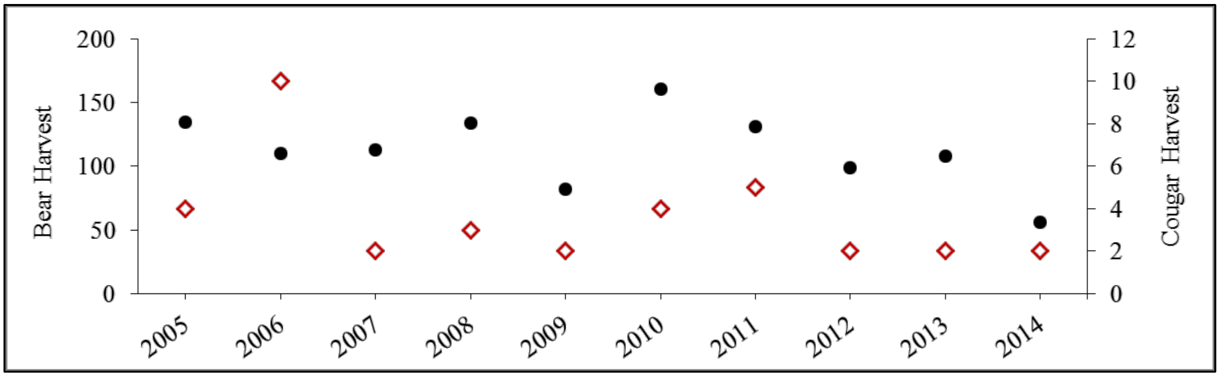


Figure 25. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the Willapa Hills BDMZ, 2005–2014.

Sub-herd Concerns

None at this time.

Management Conclusions

Black-tailed deer populations in the Willapa Hills BDMZ are currently within management objective based on a harvest trend that indicates stable population growth.

WHITE-TAILED DEER

White-tailed deer range in Washington is divided into six ecologically distinct White-tailed Deer Management Zones (WDMZs; Figure 26) and population assessments are provided for each zone. For an in-depth discussion of white-tailed deer population dynamics please see the WDFW White-tailed Deer Management Plan (2010).

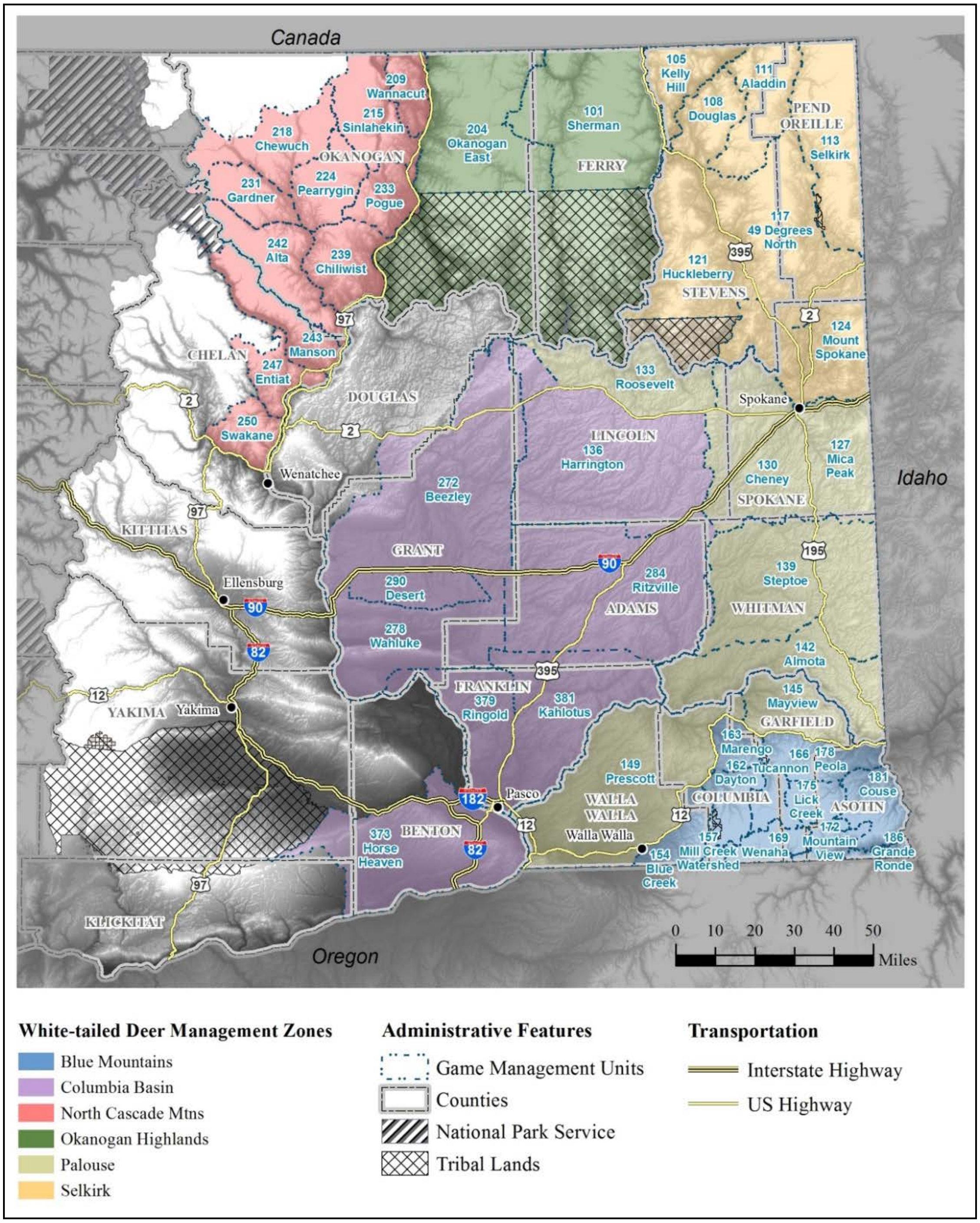


Figure 26. White-tailed Deer Management Zones established in the WDFW White-tailed Deer Management Plan.

Blue Mountains WDMZ

General Overview

The Blue Mountains WDMZ is located in southeast Washington and consists of 11 GMUs (154, 157, 162, 163, 166, 169, 172, 175, 178, 181, and 186; Figure 26). The Department's objective within this WDMZ is to maintain a stable population based on available survey data and harvest estimates. Additional management objectives include managing for a post-hunt population with a sex ratio of 15 - 19 bucks:100 does.

Current Status and Trend

Population Monitoring

White-tailed deer occur throughout the zone but densities are generally greater in the lower-elevation agricultural areas. Aerial surveys for mule deer are conducted in parts of this zone but do not provide sufficient information for monitoring white-tailed deer populations. Harvest estimates for the past 10 years (Figure 27a) have been stable, as have the number of hunter days and kills/day (Figure 27b).

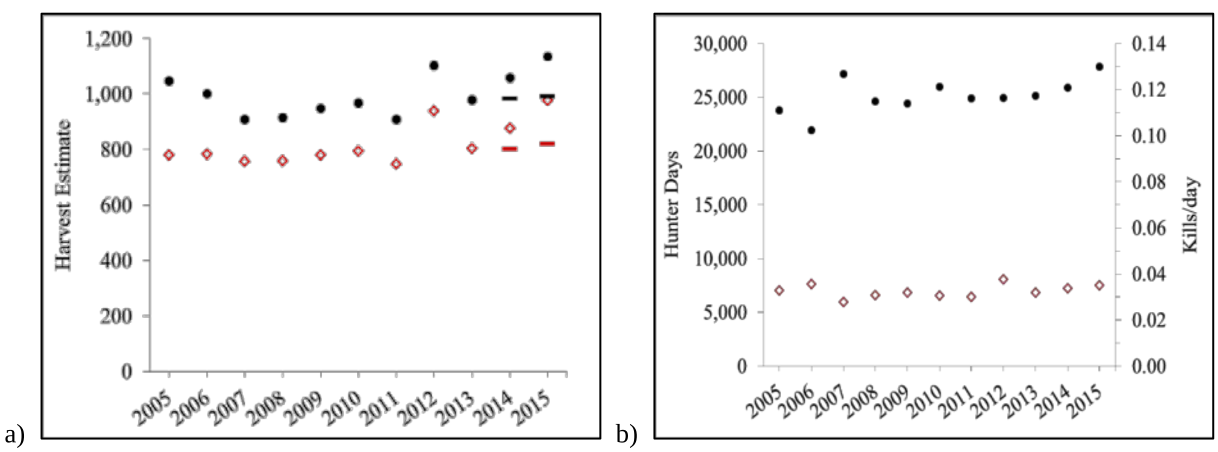


Figure 27. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Blue Mountains WDMZ, 2005–2015.

Survival and Mortality

No estimates of pregnancy, fetal, or survival rates are available for white-tailed deer herds in the Blue Mountains WDMZ. In addition to legal hunter harvest, other potential sources of white-tailed deer mortality include predation, collisions with vehicles, disease, and poaching. Predator species living within this zone include cougar, bobcat, black bear, gray wolf (one pack has been documented at the time of this writing), coyote, golden eagles, and domestic dogs.

Black bears and cougars occur most often in the higher elevation forested areas found within the zone. Black bears harvest during state general and permit seasons has been stable since 2005 (Figure 28). Estimated cougar harvest during general seasons has been variable and averaged 11 cougars per year (Figure 28).

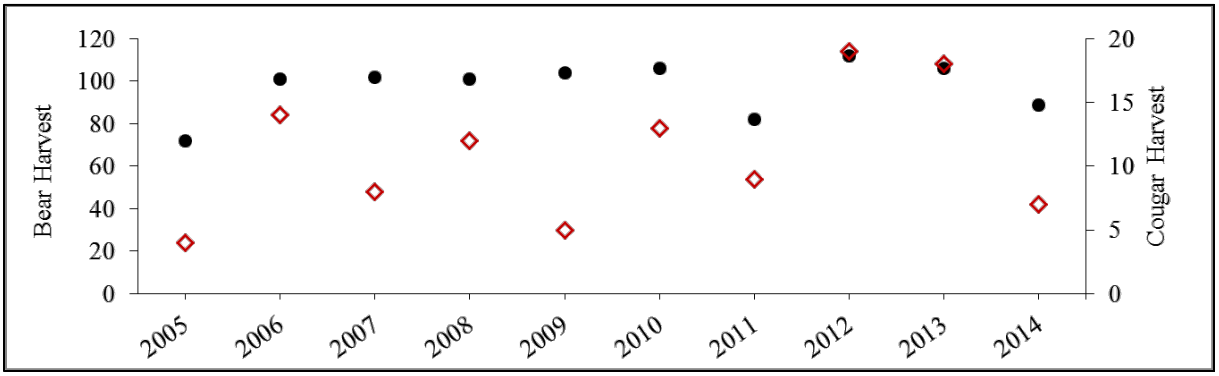


Figure 28. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the Blue Mountains WDMZ, 2005–2014.

Other Factors That Potentially Influence Population Dynamics

Similar to mule deer in this area, white-tailed deer populations are generally limited by habitat availability. Landscape changes including conversion to croplands, grazing by domestic livestock, wildfire suppression, road construction, invasion of noxious weeds, extensive wind power development, and urban-suburban development have had detrimental to habitat in this zone. Dry conditions that develop during the summer growing season, particularly on the east side of the Blue Mountains, have been amplified by recent droughts and are likely to be exacerbated further by climate change as time goes on.

Sub-herd Concerns

None at this time.

Management Conclusions

White-tailed deer populations in the Blue Mountains WDMZ are currently at management objective and harvest data indicate stable to increasing populations where habitat availability and quality allow.

Columbia Basin WDMZ

General Overview

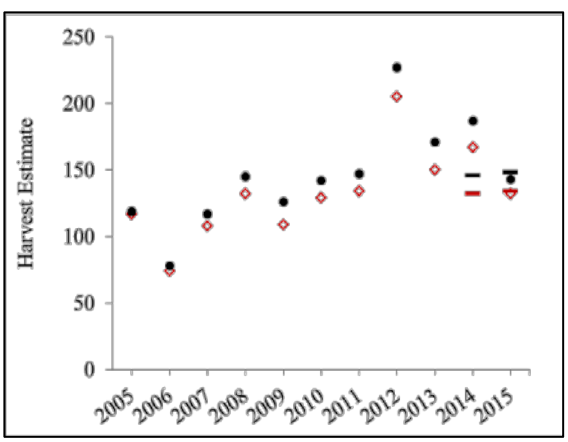
The Columbia Basin WDMZ is located in east-central Washington and consists of 8 GMUs (136, 272, 278, 284, 290, 373, 379, and 381; Figure 26). The Department's objective within this WDMZ is to maintain a stable population based on harvest trends. Additional management objectives include managing for a post-hunt population with a sex ratio of 15 - 19 bucks:100 does.

Current Status and Trend

Population Monitoring

GMUs within this zone are primarily managed for mule deer, but white-tailed deer are present at low densities throughout the Columbia Basin WDMZ, commensurate with availability of preferred habitat. Harvest estimates have remained low and variable over the past decade (Figure 29a). Measures of hunter effort (hunter days; Figure 29b) and harvest rate (kills/day; Figure 29b) in the zone include days spent hunting all deer (i.e., mule deer) so are less useful as indicators of population trend, but suggest increasing effort and a relatively stable harvest rate.

a)



b)

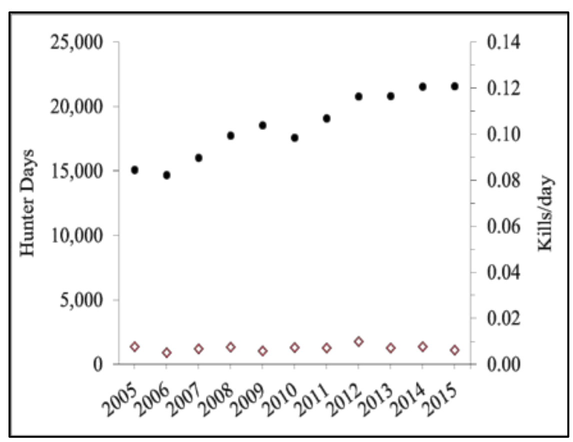


Figure 29. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Columbia Basin WDMZ, 2005–2015.

Survival and Mortality

No estimates of pregnancy, fetal, or survival rates are available for white-tailed deer in the Columbia Basin WDMZ.

Predator species living within this zone include cougars, bobcats, black bears, gray wolves (transients have been observed but there are no known packs confirmed within this WDMZ at the time of this writing), coyotes, golden eagles, and domestic dogs. Black bears are not common in open shrub-steppe landscapes but do occur at low levels in some parts of the Columbia Basin, as indicated by low harvest (Figure 30). Cougars are comparatively more common, as reflected by the low, but gradually increasing, recreational harvest over the last decade (Figure 30). Similar to mule deer, other sources of mortality in this zone likely include collisions with vehicles, drowning in irrigation canals, and poaching.

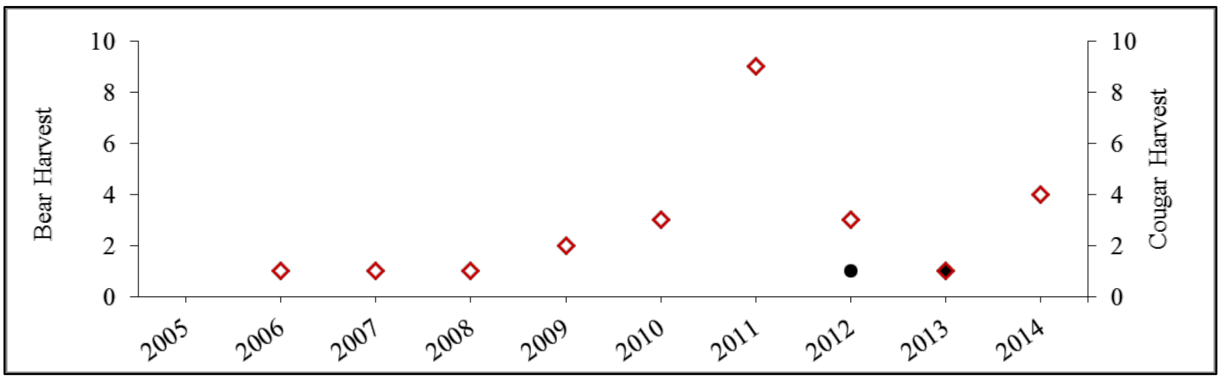


Figure 30. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the Columbia Basin WDMZ, 2005–2014.

Other Factors That Potentially Influence Population Dynamics

Drought and loss of riparian habitat are the most important issue facing wildlife managers in the Columbia Basin WDMZ.

Sub-herd Concerns

None at this time.

Management Conclusions

White-tailed deer in the Columbia Basin WDMZ are at low densities and occur where limited, appropriate habitat allows. This management zone supports a low, sustainable white-tailed deer harvest. The Columbia Basin is much more conducive to mule deer presence and mule deer are the priority deer species in this zone.

North Cascade Mountains WDMZ

General Overview

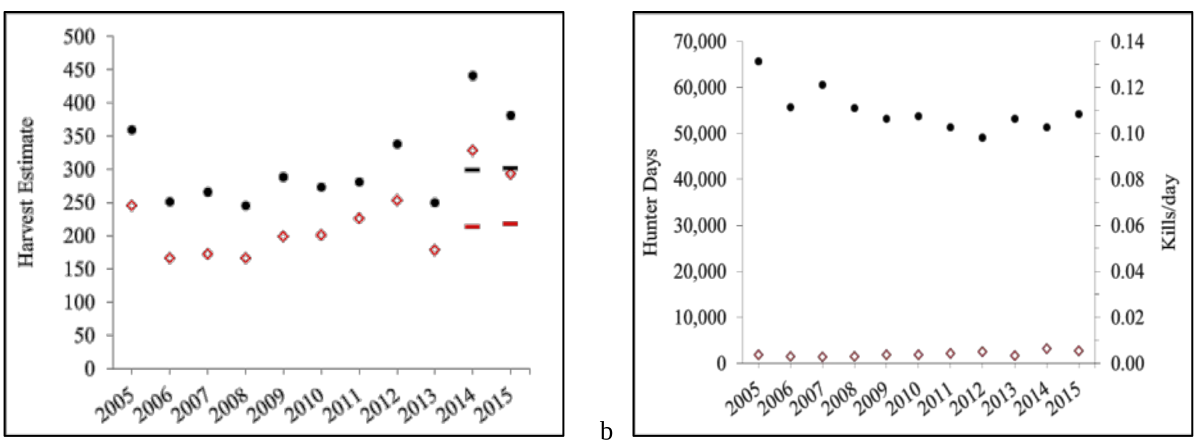
The North Cascade Mountains WDMZ is located in north-central Washington and consists of 11 GMUs (209, 215, 218, 224, 231, 233, 239, 242, 243, 247, and 250; Figure 26). The Department's objective within this WDMZ is to maintain stable populations based on harvest estimates.

Current Status and Trend

Population Monitoring

GMUs within the North Cascade Mountains WDMZ are primarily managed for mule deer but white-tailed deer are present at low densities throughout the zone. Harvest estimates for the last 10 years have been correspondingly low but stable (Figure 31a). Estimates of hunter effort (which include mule deer hunters as well) have declined slightly in recent years, as indicated by decreasing hunter days, while harvest rates indicate little change (Figure 31b).

a)



b

Figure 31. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the North Cascade Mountains WDMZ, 2005–2015.

Survival and Mortality

No estimates of pregnancy, fetal, or survival rates are available for white-tailed deer in the North Cascade Mountains WDMZ. Mortality sources in this zone include legal hunting, predation, vehicle collisions, domestic dogs, and poaching.

Many predators occur within the North Cascade Mountains WDMZ including coyotes, black bears, cougars, and wolves (2 wolf packs have been documented within the zone as of this writing) but the effects of predation on white-tailed deer in this zone are unknown. Harvest of black bears has been relatively stable and harvest of cougars has increased in recent years (Figure 32).

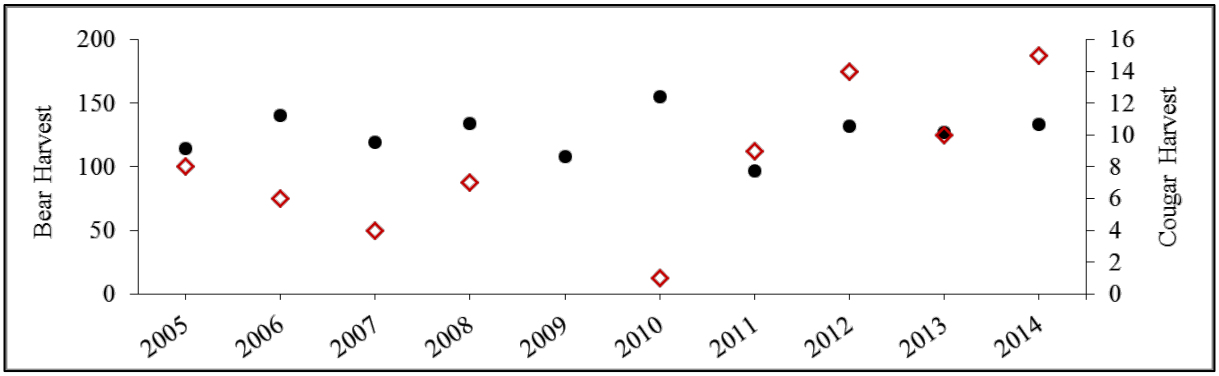


Figure 32. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the North Cascade Mountains WDMZ, 2005–2014.

Other Factors That Potentially Influence Population Dynamics

Habitat related considerations in this zone include continued development and fragmentation of low-elevation habitats, increasing use and distribution of off-road vehicles, and increasing prevalence of invasive weeds.

Sub-herd Concerns

None at this time.

Management Conclusions

White-tailed deer populations in the North Cascade Mountains WDMZ are currently at management objective and harvest estimates indicate stable population growth.

Okanogan Highlands WDMZ

General Overview

The Okanogan Highlands WDMZ is located in north-central Washington and includes GMUs 101 and 204 (Figure 26). The Department's objective within this WDMZ is to maintain stable populations based on field surveys and harvest estimates. Additional management objectives include managing for a post-hunt population with a sex ratio of 15-19 bucks:100 does.

Current Status and Trend

Population Monitoring

White-tailed deer are present throughout the Okanogan Highlands WDMZ but are more common in the eastern portion. Harvest estimates have been stable over the last decade but an increase in harvest in 2014 may indicate potentially increasing populations due to recent mild winters (Figure 33a). Number of hunter days reported have been stable and estimates of kills/day have increased in the last few years, also potentially indicating population growth (Figure 33b).

a) b)

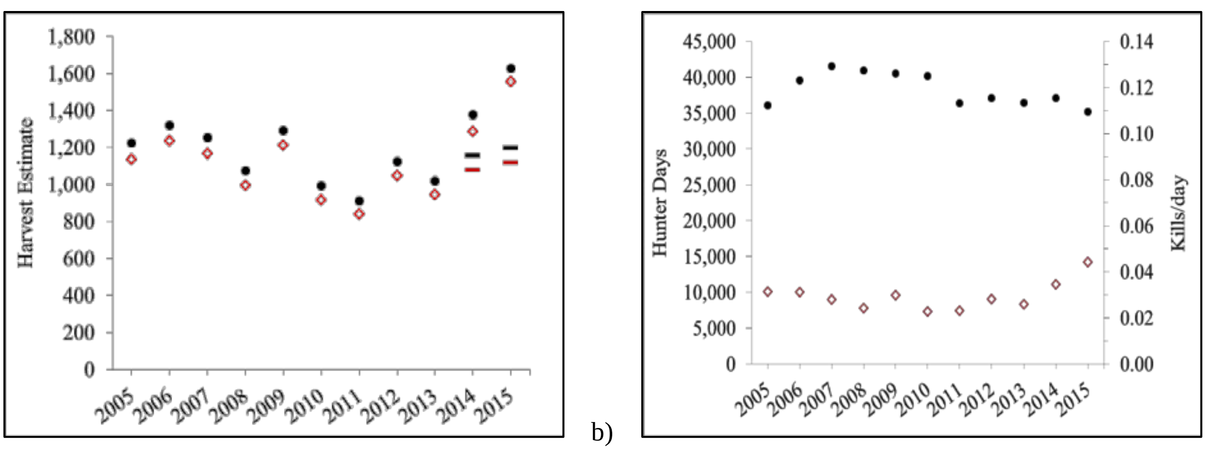


Figure 33. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Okanogan Highlands WDMZ, 2005–2015.

Survival and Mortality

No estimates of pregnancy, fetal, or survival rates are available for white-tailed deer in the Okanogan Highlands WDMZ.

In addition to legal hunter harvest, other potential sources of white-tailed deer mortality include predation, collisions with vehicles, and poaching. Predator species living within this zone include cougar, bobcat, black bear, gray wolf (five packs have been document as of this writing [Becker et al. 2016]), coyote, golden eagles, and domestic dogs.

Recreational harvest of black bear has increased over the last decade (Figure 34). Cougar harvest in the zone has fluctuated over time but increased in recent years (Figure 34).

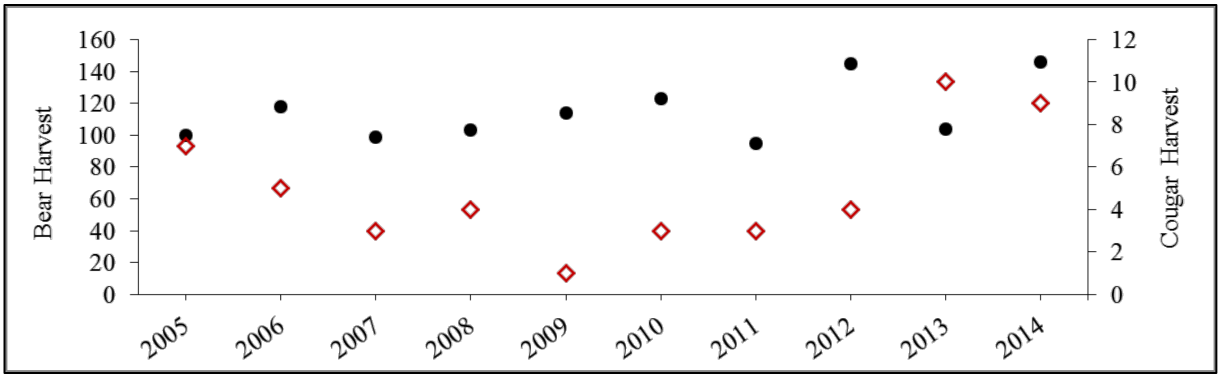


Figure 34. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the Okanogan Highlands WDMZ, 2005–2014.

Other Factors That Potentially Influence Population Dynamics

Habitat related considerations in this zone include continued development and fragmentation of low-elevation habitats, increasing use and distribution of off-road vehicles, and increasing prevalence of invasive weeds.

Sub-herd Concerns

None at this time.

Management Conclusions

White-tailed deer populations in the Okanogan Highlands WDMZ are currently at management objective and harvest data indicate stable to slowly increasing population growth.

Palouse WDMZ

General Overview

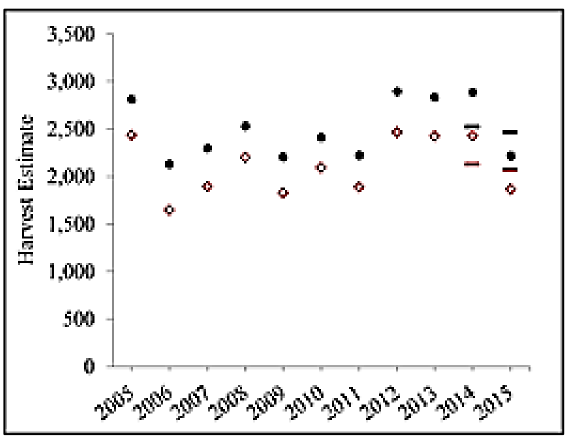
The Palouse WDMZ is located in east-central Washington and consists of 7 GMUs (127, 130, 133, 139, 142, 145, 149; Figure 26). The Department's objective within this WDMZ is to maintain a stable population based on available survey data and harvest trends. Additional management objectives include managing for a post-hunt population with a sex ratio of 15 to 19 bucks:100 does.

Current Status and Trend

Population Monitoring

White-tailed deer are present at moderate to high densities throughout the Palouse WDMZ. No formal estimates of abundance are available. Harvest has fluctuated but remained relatively stable over the past decade (Figure 35a). Estimates of hunter effort for the zone have generally been stable during the past 10 years while estimates of kills/day have fluctuated in response to with absolute harvest values (Figure 35b).

a)



b)

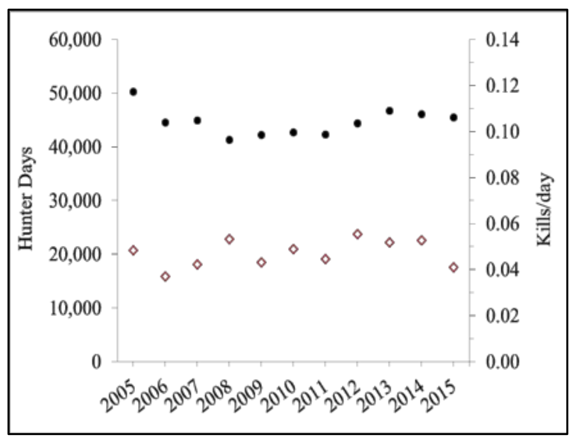


Figure 35. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Palouse WDMZ, 2005–2015.

Survival and Mortality

No estimates of pregnancy, fetal, or survival rates are available for white-tailed deer in the Palouse WDMZ.

Predator species living within this zone include cougars, bobcats, black bears, coyotes, golden eagles, and domestic dogs. Black bear harvest and cougar harvest have fluctuated over the past decade (Figure 36). Similar to mule deer, other sources of mortality in this zone likely include collisions with vehicles and poaching.

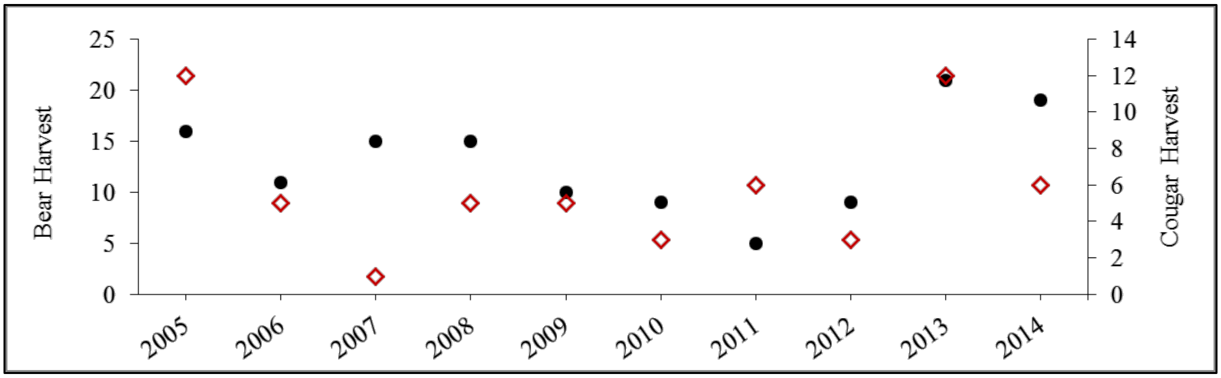


Figure 36. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the Palouse WDMZ, 2005–2014.

Other Factors That Potentially Influence Population Dynamics

Bluetongue and Epizootic Hemorrhagic Disease (EHD) occur in this zone and have caused a relatively small number of mortalities every year. During severe droughts, these disease events can be more severe and affect localized white-tailed deer herds across other Management Zones as well.

Sub-herd Concerns

None at this time.

Management Conclusions

White-tailed deer populations in the Palouse WDMZ are currently within management objective and harvest data indicate stable to increasing population growth.

Selkirk WDMZ

General Overview

The Selkirk WDMZ is located in northeast Washington and consists of 7 GMUs (105, 108, 111, 113, 117, 121, and 124; Figure 26). The Department's objective within this MDMZ is to maintain a stable population based on harvest estimates and available survey data. Additional management objectives include managing for a post-hunt population with a sex ratio of 15 to 19 bucks:100 does.

Current Status and Trend

Population Monitoring

Because estimates of total white-tailed deer abundance in this zone are not practical, standardized, pre-hunt ground surveys have been conducted since 2011 that provide a rough index of population trend and buck:doe ratios over time. Estimates of white-tailed deer harvest in this zone indicate a decline between 2008 and 2011. These harvest estimates were coincident with two consecutive harsh winters in 2008 and 2009 which suppressed fawn recruitment. The Fish and Wildlife Commission responded with subsequent rule changes reducing harvest opportunity to support faster recovery of affected populations (Figure 37a). White-tailed deer populations generally rebound quickly from such temporary weather- and disease-related events, due to their naturally high reproductive potential. Accordingly, harvest estimates, as well as ground surveys begun in 2011, indicate populations have steadily increased (Figure 37a) as have hunter numbers and harvest rate (i.e., kills/day) as harvest opportunity has been adjusted to reflect improving population levels (Figure 37b). The estimated pre-hunt buck:doe ratio averaged 27:100 between 2005 and 2014, the buck:doe ratio estimate for 2015 was 27:100 (90% CI: 22-32).

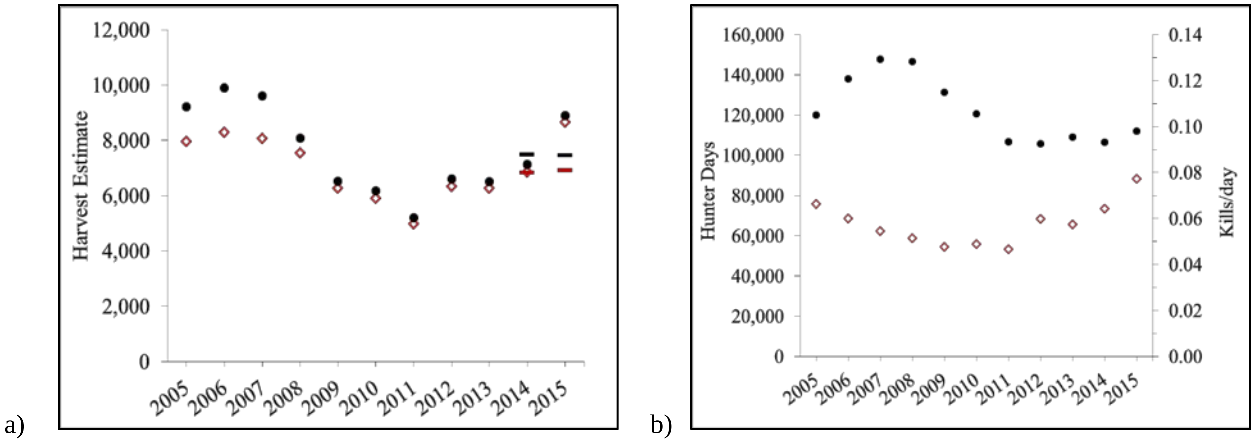


Figure 37. General State Harvest (◊) and Total State Harvest (●) estimates (a) (dashes represent the 10-yr mean for General State Harvest [red] and Total State Harvest [black]; and general season estimates of (b) hunter days (●) and kills/day (◊) in the Selkirk WDMZ, 2005–2015.

Survival and Mortality

Recent research conducted in this zone has provided estimates of mean annual survival rate for fawns ($\hat{s}$ = 0.56, SD = 0.16) and adult does ($\hat{s}$ = 0.87, SD = 0.05; Henderson 2014). These survival rates indicate recruitment is sufficient to support continued population growth in the Selkirk WDMZ. Mortalities documented during the study were predominantly due to cougars, domestic dogs, and deer-vehicle collisions (Henderson 2014). Other predators in this zone include black bear, grizzly bear, coyote, wolves (nine packs are documented in this zone as of this writing [Becker et al. 2016]), and golden eagles. Recreational black bear harvest has remained generally stable while cougar harvest has increased dramatically in recent years (Figure 38).

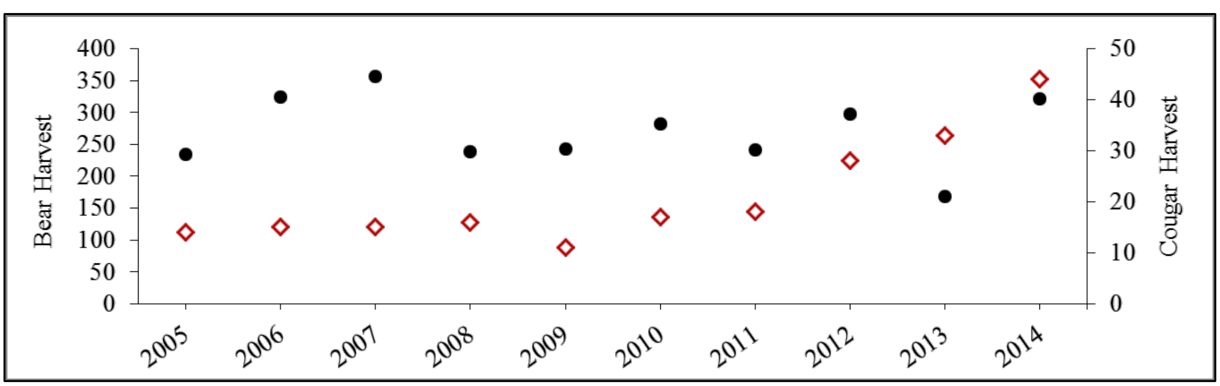


Figure 38. Estimated harvest of black bear (●) and cougar (◊) during general and special permit seasons in the Selkirk WDMZ, 2005–2014.

Other Factors That Potentially Influence Population Dynamics

The Selkirk WDMZ is home to the largest populations of white-tailed deer in the state. Areas with large concentrations of agricultural and suburban land uses tend to attract and perpetuate greater densities of white-tailed deer than would normally occur in the wild. This interaction often leads to increased incidence of human-wildlife conflict and increased deer mortality due to vehicle collisions. A study looking at collision rates in Washington indicates that deer-vehicle collisions in this zone are consistently among the highest in the state (Myers et al. 2008). To reduce vehicle collision rates and complaints due to deer damage, the Department has worked with local landowners and county and municipal stakeholders to provide increased antlerless harvest opportunity and reduce deer densities in specific high-risk Deer Areas (as described in WAC 232-28-624).

White-tailed deer populations throughout the country can be affected, to varying degrees, each fall by different hemorrhagic diseases (most often Epizootic Hemorrhagic Disease [EHD] and Bluetongue Disease). Bluetongue and EHD both occur in this zone and have caused a relatively small number of mortalities every year. During severe droughts, these disease events can be more pronounced and affect localized white-tailed deer herds in multiple Management Zones.

Because regional weather patterns can substantially affect the scale and locality of an outbreak, incidences are neither predictable nor preventable. As mentioned above, white-tailed deer are well adapted to survive such ecological challenges due to high reproductive potential and populations generally recover within a few years.

Sub-herd Concerns

None at this time.

Management Conclusions

White-tailed deer populations in this zone are considered stable based on survey data, recent survival estimates, and harvest metrics.

Literature Cited – Deer

Becker, S. A., T. Roussin, W. Jones, E. Krausz, S. Walker, S. Simek, D. Martorello, and A. Aoude. 2016. Washington Gray Wolf Conservation and Management 2015 Annual Report. Pages WA-1 to WA-24 *in* U.S. Fish and Wildlife Service Rocky Mountain Wolf Program 2015 Annual Report. USFWS, Ecological Services, 585 Shepard Way, Helena, Montana, 59601.

Bender, L. C., G. A. Schirato, R. D. Spencer, K. R. McAllister, and B. L. Murphie. 2004. Survival, cause-specific mortality, and harvesting of male black-tailed deer in Washington. Journal of Wildlife Management 68:870–878.

Bernatowicz, J. A., K. Mansfield, J. W. Mertins, and W. Moore. 2011. Hair-loss syndrome in deer in south central Washington. S. M. McCorquodale, editor. Proceedings of the 8th Western States and Provinces Deer and Elk Workshop – 2009. Washington Department of Fish and Wildlife. Olympia, WA.

Bishop, C. J., J. W. Unsworth, and E. O. Garton. 2005. Mule deer survival among adjacent populations in southwest Idaho. Journal of Wildlife Management 69:311-321.

Bleich, V.C., and Taylor, T.J. 1998. Survivorship and cause-specific mortality in five populations of mule deer. Great Basin Naturalist 58:265–272.Hatter, I. W. 2001. An assessment of catch per unit effort to estimate rate of change in deer and moose populations. Alces 37:71–78.

Henderson, C. R. 2014. Habitat quality influences migratory strategy of female white-tailed deer. Thesis, University of Montana, Missoula, USA.

Hurley, M. A., J. W. Unsworth, P. Zager, M. Hebblewhite, E. O. Garton, D. M. Montgomery, J. R. Skalski, and C. L. Maycock. 2011. Demographic response of mule deer to experimental reduction of coyotes and mountain lions in southeastern Idaho. Wildlife Monographs 178.

Johnstone-Yellin, T. L., L. A. Shipley, W. L. Myers, and H. S. Robinson. 2009. To twin or not to twin? trade-offs in litter size and fawn survival in mule deer. Journal of Mammalogy 90:453–460.

Krebs, C. J. 2002. Beyond population regulation and limitation. Wildlife Research 29:1-10.

McCorquodale, S. M. 1996. Ecology and comanagement of black-tailed deer in the Klickitat Basin of Washington. Yakama Nation Wildlife Program Report. Yakima, WA. 118 p.

McCorquodale, S. 1999. Movements, survival, and mortality of black-tailed deer in the Klickitat Basin of Washington. Journal of Wildlife Management 63:861–871.

McCoy, R. H., S. L. Murphie, M. Szykman Gunther, and B. L. Murphie. 2014. Influence of hair loss syndrome on black-tailed deer fawn survival. Journal of Wildlife Management 78:1177–1188.

Monteith, K. L., V. C. Bleich, T. R. Stephenson, B. M. Pierce, M. M. Conner, J. G. Kie, and R. T. Bowyer. 2014. Life-history characteristics of mule deer: effects of nutrition in a variable environment. Wildlife Monographs 186.

Myers, W. L., W. Y. Chang, S. S. Germaine, W. M. Vander Haegen, and T. E. Owens. 2008. An analysis of deer and elk-vehicle collision sites along state highways in Washington State. Completion Report. Washington Department of Fish and Wildlife. Olympia, WA. 40 p.

Myers, W. L., R. H. Naney, and K. R. Dixon. 1989. Seasonal movements and home ranges of female mule deer in western Okanogan County, Washington. Washington Department of Wildlife P-R Completion Report W-95-R. 34 p.

Robinson, H. S., R. B. Wielgus, and J. C. Gwilliam. 2002. Cougar predation and population growth of sympatric mule deer and white-tailed deer. Canadian Journal of Zoology 80:556-568.

Samuel, M. D., E. O. Garton, M. W. Schlegel, and R. G. Carson. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. Journal of Wildlife Management 51:622–630.

Sawyer, H., F. Lindzey, D. McWhirter, and K. Andrews. 2002. Potential effects of oil and gas development on mule deer and pronghorn populations in western Wyoming. Transactions of the 67th North American Wildlife and Natural Resources Conference. 67:350-365.

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

Schmidt, J. I., J. M. Ver Hoef, J. A. K. Maier, and R. T. Bowyer. 2005. Catch per unit effort for moose: a new approach using Weibull regression. Journal of Wildlife Management 69:1112–1124.

Stewart, K. M., R. T. Bowyer, J. G. Kie, N. J. Cimon, and B. K. Johnson. 2002. Temporospatial distributions of elk, mule deer, and cattle: resource partitioning and competitive displacement. Journal of Mammalogy 83:229–244.

Sunde, P., and T. Asferg. 2014. How does harvest size vary with hunting season length? Wildlife Biology 20:176–184.

Ulappa, A. 2015. Using foraging dynamics to answer landscape management questions: the nutritional ecology of black-tailed deer. Dissertation, Washington State University, Pullman, WA, USA.

Unsworth, J. W., D. F. Pac, G. C. White, and R. M. Bartmann. 1999. Mule deer survival in Colorado, Idaho, and Montana. Journal of Wildlife Management 63:315–326.

Van Deelen, T., and D. Etter. 2003. Effort and the functional response of deer hunters. Human Dimensions of Wildlife 8:97–108.

Washington Department of Fish and Wildlife. 2010. Washington State deer management plan: white-tailed deer. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA. 124 p.

Washington Department of Fish and Wildlife. 2013. Game status and trend report. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2014. 2015-2021 Game management plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2015. Game status and trend report. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2016. Washington State mule deer management plan. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA. 144 p.

Zeigler, D. 1978. The Okanogan mule deer. Biological Bulletin No.15. Washington Department of Game, Olympia, WA.

BIGHORN SHEEP

Bighorn Sheep in Washington

Washington State has approximately 1,670 bighorn sheep distributed in 16 identified herds, exclusive of those managed by tribal governments. Of these, we categorize sheep in 11 herds as 'California bighorns' and 5 as 'Rocky Mountain bighorns', although the biological importance of these designations are subject to dispute (Wehausen and Ramey 2000). As of early 2015 herds vary from as few as 21 to as many as about 250 sheep. Populations are considered to be approximately stable in 8 herds, increasing in 5 herds and declining in 3 herds. A majority of herds are below the carrying capacity of the habitat. Although predators may be locally important limiting factors during some years and for some herds, the overwhelming management concern for bighorns in Washington during the immediate future will continue to be mortality caused by pneumonia.

The 4 herds in Washington considered to be part of the Hells Canyon meta-population (including herds in Oregon and Idaho) have all declined since the 1990s due to pneumonia, and continue to suffer periodic poor lamb recruitment. In 2009, the Umtanum/Selah Butte herd between Ellensburg and Yakima suffered a pneumonia outbreak. Although the herd subsequently rebounded, it is still considered infected and susceptible to future declines and poor recruitment. In 2013, a severe outbreak caused considerable mortality in the Tieton herd, near Naches. Concern about the potential spread of disease to the adjacent Cleman Mountain herd prompted WDFW to remove this herd entirely. Similarly, in 2014, a portion of the Black Butte herd in the middle of the Hells Canyon meta-population was removed due to the detection of a new strain of pneumonia-causing bacteria. Declines that do not appear to be related directly to pneumonia have recently been documented in the Sinlahekin, Tucannon, Hall Mountain, and Vulcan Mountain herds. Herds unaffected by diseases and that have sufficient habitat have thrived, and provided both consumptive and non-consumptive recreational opportunity. Unlike in the Rocky Mountain states, most bighorn herds in Washington live at relatively low elevations, often near public highways (e.g., Cleman Mountain, Swakane, Umtanum/Selah, Lincoln Cliffs), and thus provide excellent opportunities for the general public to view these animals in their natural habitat.

Scientific Background: Predation Effects on Bighorn Sheep

Although bighorn sheep can be killed by wolves, coyotes, grizzly bears, black bears, and golden eagles, there is little evidence from the literature that any of these species are likely to induce or exacerbate population declines (Sawyer and Lindzey 2002). Wolves have only recolonized areas of the lower 48 states where bighorns occur during the past ~ 20 years (and even now do not occur in most bighorn ranges), so it is possible that the paucity of documentation stems, in part, from lack of opportunity. However, even in the case of Dall sheep in Alaska, where wolves have never been extirpated, they have been found to have negligible impacts on wild sheep populations (Gasaway et al. 1983). The scientific consensus suggests that the ability of bighorn sheep to find topographic refuge in steep terrain severely limits the effectiveness of both wolves and coyotes as bighorn predators. As with coyotes, wolves may occasionally kill bighorns that stray from escape terrain, or which inhabit ranges without a sufficient abundance of it. Bears have rarely if ever been documented to prey on bighorn sheep. Where escape terrain is limiting, coyotes have sometimes been implicated as significant predators on lambs (e.g., Hebert and Harrison 1988).

In contrast, there is considerable evidence from the peer-reviewed literature that, in certain situations, individual cougars can become specialist-predators on bighorn sheep. Particularly where bighorn populations are small and isolated, a specialist cougar can have a disproportionate impact on the growth rate of the sheep population (Sawyer and Lindzey 2002). For example, Ross et al. (1997) monitored 5 cougars in southern Alberta intensively, and found that 2 never killed a bighorn and a third killed only a single animal. However, a female cougar killed 9% of the bighorn population (and 26% of the lamb component) herself during the winter of 1993-94. Cougars in this area preyed primarily on mule deer, but the individually-learned behavior among the cougar specialists (particularly on lambs in this case) had a substantial effect on the bighorn population. Logan and Sweanor (2001) working in the San Andres mountains of New Mexico documented that cougars were responsible for 10 of 26 deaths of radio-collared bighorns during 1985-95. One male cougar was known to have caused at least 3 of these 10, and cougar predation declined following his removal. Beginning in 1996, mule deer in the area declined markedly, and cougar predation on bighorns increased again, with 6 radio-collared bighorns killed by cougars within 19 months. This bighorn population declined to only a single animal during this time period. Rominger et al. (2004) contrasted the dynamics of 2 recently translocated bighorn populations in New Mexico (both of which began with the same number of animals). The population in which cougar predation was not documented increased rapidly while the population exposed to considerable cougar predation (75% of documented mortalities) never increased from its small founding number.

Festa-Bianchet et al. (2006) documented episodes of substantial cougar predation on 2 bighorn sheep herds monitored over 24 to 28 years. During these episodes, predation rates were unrelated to sheep density (i.e., did not decline when sheep numbers declined), and survival rates among most sheep sex/age classes were significantly lower than before and after predation episodes. These episodes appeared to cease when specific cougars were known to have died or emigrated. These authors concluded that "*The sudden onset and cessation of all other episodes is consistent with a pattern of specialization by individual predators, ending with the death or emigration of the specialist…once they started preying on bighorns, cougars concentrated on this species*". Simulations showed the cougar predation at the intensity quantified in the Alberta examples was capable of leading to the "*extinction of small bighorn populations*". Bourbeau-Lemieux et al. (2011) concluded, based on additional modeling, that a "*predator-driven component Allee effects* [in this case, episodic predation of cougars on bighorn sheep] *may exacerbate the effects of other environmental drivers and increase the risk of extinction of small populations*".

There is considerably less evidence that reducing cougars generally (without attempting to identify likely specialists) would be effective in halting a bighorn sheep population decline. Summarizing the literature available to them at the time, Sawyer and Lindzey (2002) wrote "*in studies where cougars have been radio-collared, researchers have found that predation on bighorn sheep is largely a function of the behavior of individual cougars…rather than the total number of cougars.* Further, that "*Indiscriminate removal or population-level reductions of cougars may not be successful in reducing the number of cougar-related bighorn sheep deaths. However, identification and removal of individual cougars appears an effective method for minimizing cougar predation on bighorn sheep. Management based on the selective removal of problem individuals is dependent on the ability to define and identify them. This type of management may be challenging with coyotes or wolves because they hunt in packs, or with bears because they are often difficult to trap and males may not be territorial. However, because* *cougars hunt individually, maintain consistent home ranges, and can be easily tracked with trained dogs, their identification and removal seems a viable management option*."

Where individual cougars learn to specialize on killing bighorn sheep, it is most likely to affect the herd's population trajectory only where the herd is already small and isolated. A few of Washington's bighorn herds are appropriately considered small and isolated (e.g., Hall Mountain, Vulcan Mountain, Tucannon, Sinlahekin), but it should be kept in mind that such isolation more often stems from land-use patterns that make bighorn population expansion difficult. If cougar predation is a concern, it is more likely to represent a proximate cause of population limitation whose ultimate cause lies elsewhere. As well, when predation is an issue it is usually because an individual cougar has learned to specialize on bighorns. In some documented cases, population declines have resolved themselves without intervention when a particular cougar died or moved away.

Bighorn Herds and Possible Effects of Cougar Predation

Methods

Because bighorn sheep hunting in the state of Washington is conducted predominantly by limited draw permit, and because hunter success has almost always exceeded 90%, neither the number of hunters, nor their success are useful data in evaluating bighorn herd status. In contrast to most big game species, the sizes of bighorn herds are amenable to estimation, either via helicopter-based survey (in some cases, using a sightability model that accounts for imperfect detection), or repeated ground surveys. We have more confidence in our estimate of the number and trend of our bighorns than for most other big-game populations. For most herds, WDFW or cooperators have also captured and radio-collared a sample of ewes and rams, allowing a rough, albeit imprecise, estimate of annual survival rates. In some cases, herds are monitored sufficiently and intensively enough that causes of specific mortalities can be identified. Unlike for some species, anecdotal reports and unquantified assessments can often provide a qualitative indication of whether predation is an important influence in population dynamics.

Individual Herd Descriptions

Table 1. Summary of Washington State bighorn herds, showing WDFW region, recent population estimates, whether or not the herd is currently affected by pneumonia, and a qualitative assessment of likely population-level effects of cougar predation.

Herd Name	Region	Short-term population objective (within lifetime of GMP)	Estimated long-term objective	Herd size (most recent estimate)	Pneumonic?	Best assessment of cougar effects with population-level consequences
Hall Mtn.	1	25-35	-	21	No	Possible, evidence of mortality, but unknown population effects
Vulcan Mtn.	1	70-90	80-110	45	No	Possible, no direct evidence
Lincoln Cliffs	1	100-120	180-220	96	No	Possible, limited evidence; patterns consistent with occasional cougar-related declines
Asotin	1	130-170	240	65	Yes	Likely; probably now

						resolved
Black Butte	1	60-100	585	17	Yes	Possible, little direct evidence
Mtn View - Wenaha	1	130-170	375	111	Yes	Possible, limited evidence
Tucannon	1	40-80	160	22	No	Possible, evidence of predation, but unknown population effects
Mt. Hull	2	80-100	80-100	128	No	None
Sinlahekin	2	50-80	100-150	63	No	Possible, no direct evidence
Manson	2	100-120	200	113	No	None
Chelan Butte	2	150-170	150-170	191	No	Inconsequential
Swakane	2	130-170	150-180	156	No	Inconsequential
Cleman Mtn.	3	170-220	170-220	235	No	Inconsequential
Quilomene	3	150-170	150-170	160	No	Possible, limited evidence, but unclear population effects

Tieton	3	-	250	0	Yes	Inconsequential
Umtanum – Selah Butte	3	250-300	300-350	254	Yes	Inconsequential

Hall Mountain

Rocky Mountain bighorn sheep were introduced to Hall Mountain in Pend Oreille County, Washington from Alberta, Canada in 1972 (Johnson 1983). The founder herd included 5 rams and 13 ewes. Informal winter feeding of this herd began shortly thereafter, and was later implemented by WDFW until 2003. The Hall Mountain herd reached an estimated 70 animals in 1982 but declined subsequently. In recent years the population has remained at roughly 20-25 animals. During the era of winter feeding, this population was used primarily as a source for Rocky Mountain bighorn sheep translocations into other areas of Washington State.

During 1995-98, 13 bighorns were captured and monitored using VHF collars (Aluzas 1997, 1998; Baldwin 1999). Five animals were known to have died during this time (four collared animals, one unmarked). Of these, cause of death could not be determined for 2 animals. Of the remaining 3, none were attributed to predation. Earlier, however, Johnson (1983) documented 2 Hall Mtn. sheep mortalities that he believed were caused by cougars. Depredation of a bighorn sheep ewe at the Noisy Creek Feeding Station was documented by WDFW staff in on February 2, 2001. The following winter on December 31, 2001 a bighorn lamb was confirmed to be preyed upon by a cougar at the feeder area. Additional circumstantial evidence of cougars likely preying on Hall Mountain bighorn sheep has also been noted through the years. Bacterial pneumonia has not been documented in this herd.

The winter feeding operation for Hall Mountain bighorn sheep was discontinued in 2003 as artificial feeding was deemed to be inconsistent with agency policy. Furthermore feeding had an adverse effect on bighorn sheep by concentrating them and subjecting the sheep to greater risk of disease and predation. The small size of the Hall Mountain bighorn population has elicited concern, and discussion currently focuses on ways to better understand why it remains so small. However, there is inconclusive evidence that cougar predation is a limiting factor herd-wide. Unlike other herds in Washington, appropriate escape terrain for bighorns is limited for this herd; in fact, we hypothesize that a relatively small area of escape terrain may constitute a long-term constraint on bighorn population size. Thus, if the morality rate of bighorns from cougars is higher in the Hall Mountain herd than elsewhere, that may in part reflect its inherent habitat limitations. We thus categorize the effect of predators on the Hall Mountain bighorn herd as possible, but lacking clear evidence. We do not consider predation of sufficient concern to suggest additional research or actions specifically focused on it.

Vulcan Mountain

California Bighorn Sheep were introduced to the Vulcan Mountain area of northern Ferry County, Washington in 1971. Eight bighorn sheep, consisting of 2 rams and 6 ewes, were translocated from the Colockum State Wildlife Area to U.S. Bureau of Land Management land near Little Vulcan Mountain. This population increased to an estimated maximum of 107 bighorns in 1990. It has since declined, in recent years to between 30 and 45 animals. A recently completed count (in late October 2015) documented 45 animals (of which 19 were ewes and 13 lambs, suggesting adequate summer lamb survival).

Eleven animals (7 ♀, 4 ♂) were captured and radio-marked between spring 2002 and winter 2004. Fates of these animals were not well documented. Bacterial pneumonia has not been documented in this herd. An additional juvenile ram was captured and fitted with a GPS radio-collar in February 2015. WDFW plans to capture, test for pathogens, and fit with GPS collars up to 6 additional animals in February 2016; this will help us understand why the herd has remained relatively small.

Although cougars no doubt kill occasional bighorn sheep at Vulcan Mountain, we have limited documentation of it. We thus categorize the effect of predators on the Vulcan Mountain bighorn herd as possible, but lacking clear evidence. We do not consider predation of sufficient concern to suggest additional research or actions specifically focused on it.

Lincoln Cliffs

The Lincoln Cliffs population was started with an introduction of 11 California bighorns from Northwest Trek in December 1990. Three additional sheep from Vulcan Mountain were released in March 1991 and 5 from Kamloops, British Columbia in 1996. By 1998 the population had reached ~100 animals. Having exceeded the original population goal, this herd was used to augment other herds; 10 ewes and 1 lamb were translocated to Lake Chelan in 1999, 6 ewes to Lake Chelan in 2000, and 11 ewes to Cleman Mountain in 2001. Subsequent surveys indicated the population was not recovering from these translocations, and in 2003 12 ewes, 1 ram, and 2 lambs from Nevada were released at the original Lincoln Cliffs site and at Whitestone Rock, about 7 miles downriver. Observations of bighorn sheep have been reported as far east as Porcupine Bay on the Spokane Arm of Lake Roosevelt and to the east side of Banks Lake in Grant County. The sheep now regularly occupy two main areas throughout the year: the original Lincoln Cliffs area and the cliffs around Whitestone Rock. Sheep have also been observed frequently using Whitestone Rock.

The Lincoln Cliffs population has shown a gradual but fairly continuous increase since the 2003 augmentation, and is currently at an historic high. However, in spring 2014, the Lincoln sub-group of ewes evidently experienced a near-total lamb recruitment failure. We were not monitoring this herd closely enough to understand the reasons for this loss (which did not affect the Whitestone area ewe sub-group).

To better understand the dynamics of this herd, WDFW placed GPS collars on 10 bighorns (8 ewes and 2 rams) in early February 2015, and has increased ground-based monitoring efforts since that time. Veterinary testing suggested that the Lincoln Herd remained free of pneumonia-causing bacteria, and there is similarly no field-based evidence of pneumonia in this herd. We hypothesize – but have no direct evidence – that cougar predation may have played a part in the 2014 lamb mortality event among the Lincoln ewe sub-group, as no other causative factors have emerged. Cougars are known to have killed individual bighorns in this herd during earlier years. However, lamb recruitment to late September was back to acceptable levels in 2015, when 29 lambs were observed with 46 ewes. The total herd size in late September 2015 had not changed appreciably from the 2014 estimate.

One of the 8 radio-collared ewes was killed by a cougar on about September 27, 2015. However, WDFW biologists had been monitoring this ewe for a few days before-hand, and noted that it appeared lethargic and unhealthy. Pathology and serology results from the Washington Disease and Diagnostic Laboratory at WSU later confirmed the presence of the blue-tongue virus in this animal. We consider this a case in which a cougar completed what had in truth been a disease-related mortality. We thus categorize the effect of predators on the Lincoln Cliffs bighorn herd as possible, but with only circumstantial evidence. We do not consider predation of sufficient concern to suggest additional research or actions specifically focused on it, although we will continue to mobilize the necessary resources to monitor the population periodically. If multiple cougar predations are documented, an attempt would be made to track, find, and collar that individual.

Asotin

This herd was begun in 1991 with the reintroduction of 6 animals from Hall Mountain, followed by an additional 9 in 1994. The herd subsequently increased to ~ 100 animals in 2011. As one of the research herds of the tristate Hells Canyon Initiative, the Asotin herd was intensively monitored, and a radio-collared sample was routinely maintained. The strain of *Mycoplasma ovipneumoniae* (*M. ovi*.), unique to Hells Canyon, arrived in Asotin in 2012, causing a substantial but not catastrophic all age die-off. Lamb recruitment in 2013 was poor, and the population remained at approximately 50-60 animals.

Despite the pneumonia outbreak in the Asotin herd, lamb recruitment was surprisingly good in 2014 with 13 lambs associated with 25 ewes in mid-winter, although extensive testing was being done to identify and remove the ewes or yearlings that might be shedding *M. ovi*. bacteria. Historically, lamb recruitment rebounds for 1–3 years following an initial disease die-off, but rarely lasts. In the Asotin herd, we have been researching which animals within the herd are the "chronic" carriers of *M. ovi*. and removing identified animals within the year. It is still unclear if this research effort will result in continued improved lamb recruitment.

In February and March of 2015, 4 collared bighorn ewes were killed by a cougar in the Asotin Herd. This rate of mortality in a 4 week period amounted to 20% of the marked female population being lost. Following the fourth confirmed cougar depredation, WDFW removed one adult female cougar from the 1-2 day old carcass of the last bighorn mortality. No additional mortalities were detected in the following 3 months.

Although we cannot definitively rule-out other causes for the cessation of cougar kills, it appears that the Asotin Herd provides an example of a small herd, battling with disease as its primary limiting factor, which nonetheless was negatively affected by cougar predation. Like most other cases documented in the literature, it appears that a single cougar was responsible for the pulse of adult ewe mortalities, and that after this cougar was removed, ewe survival returned to baseline levels (estimated as 88% annual survival during 1997-2010 by the Hells Canyon Initiative. About one-quarter of mortalities during this time period were attributed to cougars). Because this herd is already monitored intensively as part of the Hells Canyon Initiative, we do not anticipate needing further resources to detect any future return of excessive cougar predation. Because the cougar predation episode was actively monitored and quickly resolved, we do not consider that predation is of sufficient concern to require additional research or actions specifically focused on it.

Black Butte

Initially called the Joseph Creek herd, this group of bighorns at one time constituted the largest herd in the state of Washington. However, when pneumonia occurred in this herd in 1995, the Black Butte herd was hit hard. After an initial all-age die-off, lamb recruitment has been too low to balance deaths (i.e., most often < 10%), and the herd has dwindled. The ewe sub-group at Heller Bar had failed to recruit a lamb for a number of years.

Eight ewes were removed from the Heller Bar ewe subgroups of the Black Butte herd in October 2014 following the detection of a new strain of *M. ovi*, in addition to the original strain that caused chronic infection and nearly 100% lamb mortality. Spring and summer monitoring within the Black Butte herd during 2014 documented a 25% loss of adult ewes within less than 3 months due to pneumonia. These 8 ewes were removed prior to the rut and expected increase in male movement, due to the risk that this new strain would generate a new pulse of all age die-offs among nearby Hells Canyon herds. All 8 were transferred to a captive research facility at South Dakota State University to aid in the ongoing research. Unfortunately, this same strain of *M. ovi* was detected further up the Grande Ronde River in the Shumaker section of the Black Butte herd range during winter captures. We have not documented any mortalities in this group from the single animal that tested positive, and that animal disappeared from the herd soon after capture.

Although mortality has in the past been attributed to cougars, there is no recent documentation of cougar mortality, nor any reason to suspect that it constitutes an important source of mortality for this herd. However, because the herd is so small, predation could become a limiting factor should one or more cougars begin killing bighorns here.

Mountain View/Wenaha

This herd of Rocky Mountain sheep was initiated in 1983 with the reintroduction of 15 animals from Hall Mountain; an additional 14 animals were added in 1986. Fifteen bighorn sheep from the Lostine Herd in Oregon were reintroduced on the Oregon side of this area by ODFW in 1983, and additional 28 animals added in December 1984. The herd experienced rapid growth, peaking at about 140 animals in 1990. Pneumonia was first discovered in 1995, and this population has gradually declined since then. Lamb recruitment, although inconsistent, has generally been sufficient only to replace ageing and dying ewes, leaving the population at its currently depressed level. Information on possible cougar predation is lacking, in part because most focus has been on the effects of pneumonia. Currently, the Hells Canyon Initiative research project is attempting to identify and remove individual ewes hypothesized to be active shedders of bacterial pathogens, and thus maintaining disease in the population.

Although mortality has in the past been attributed to cougars, there is no recent documentation of cougar mortality, nor any reason to suspect that it constitutes an important source of mortality for this herd. However, because the herd is small, predation could become a limiting factor should one or more cougars begin killing bighorns here.

Tucannon

The Tucannon Herd originated from the introduction of 6 (California) bighorns from Sinlahekin in 1960. The herd peaked at approximately 75 in 1970-71, but plummeted thereafter to < 20 animals in the mid-1970s. Causes were said to be dispersal, drought, and poor lamb survival. The herd evidently increased during the 1980s, peaking again in 1992 at an estimated 67, but in 1994 was back to 50. Evidently there was another decline in the late 1990s attributed to scabies mites (*Psoroptes ovis*), so that by 2004, the population was again < 20 individuals. The lowest count occurred in 2007 when only 5 individuals were counted, although this was not thought to be a complete census. Counts remained ~ 10 through 2010 when results of testing from a capture effort eliminated disease as a limiting factor. In 2011, five (Rocky Mountain bighorn) ewes from Asotin were brought in to bolster the herd. Counts in both 2012 and 2013 were 21 animals. Both lamb recruitment and subsequent survival during the past 3 years have been poor. In a recent estimate, the herd consisted of only 10 ewes, 1 lamb, and 9 rams. There is currently substantial risk that the herd could disappear altogether. Unlike other herds in the Blue Mountains, the Tucannon herd was free of pneumonia when last tested in 2010. It is affected by the scabies mite, *Psoroptes ovis*, but this itself is unlikely to explain the difficulty this herd has experienced in regaining its former strength. We suspect that predation on lambs from a suite of predators including cougars, golden eagles, and coyotes and/or a genetic bottleneck evidently experienced a few years ago, may be preventing the Tucannon herd from rebounding. Either way, small population size is likely at the root of the problem. For that reason, efforts to augment the Tucannon Herd are currently ongoing.

Mt. Hull

This population of California-type bighorns was initiated in 1970, and appears to have increased slowly but steadily since that time with the exception of a short-lived decline in the early 1990s thought to be caused by a particularly harsh winter. It has been estimated to number > 100 animals for the past 10 years, and the record high count occurred in 2014 when 128 animals were counted (including 38 lambs from 52 ewes). The Mt. Hull area is directly surrounded by agricultural areas or other habitats lacking escape terrain; however, it appears to be part of a historic meta-population along the Okanogan River, from south as far as Omak lake, north well into British Columbia. To reduce agricultural complaints and vehicle collisions associated with the herd, ewe permits have been offered for the past few years. There is no recent documentation of cougar mortality, nor any reason to suspect that it constitutes an important source of mortality for this herd.

Sinlahekin

The Sinlahekin Herd was the first reintroduced herd in the state of Washington (1957). In 2010, WDFW and WSU cooperated on a habitat use study in this population, involving the capture and collaring of 21 animals. Although adult survival appeared to be low, no indications of a population-level problem were identified by this work (Baker 2015).

The population reached a high in 2011 at an estimated 90-95 animals, but seemingly declined precipitously sometime after the 2011 count. WDFW was unable to confirm causes of death, as no carcasses were discovered coincident with the decline. In analyses conducted subsequent to the completion of this study (Baker 2015), we found no differences in the use of open habitat between ewes that lived throughout the study period ($\bar{x}$ = 0.827, SE = 0.087) and ewes that died ($\bar{x}$ = 0.928, SE = 0.029; t = -1.06, P = 0.302). Similarly, proportional use of open canopy was not a significant predictor of days known to have lived (t = -0.81, P = 0.0426).

Current surveys indicate an estimated herd size of ~65 animals. This decline occurred in association with the discovery of the ectoparasitic mite *Psoroptes ovis* in the herd, although it is unclear whether there is a causative relationship. The current objective for the Sinlahekin herd is to increase population size.

In an attempt to shed light on the sudden decline of the Sinlahekin herd noted between 2011 and 2012, WDFW captured and fitted with GPS collars on 11 animals, of which 5 where in the Blue Lake (southern) area, 5 in the Palmer Lake (northern) area, and 1 near the hamlet of Loomis. To our surprise and relief, no evidence was found that these animals were either infected, or had been exposed to *Mycoplasma ovipneumoniae*. Most animals showed infection with *Psoroptes ovis*, although the degree of involvement varied considerably. Psoroptes-caused scabies doubtless reduces body condition of affected individuals, but has only rarely been implicated as a cause of population-level declines. Body condition similarly varied from excellent to poor among captured animals. To date, this recent radio-telemetry monitoring has not provided insight into the cause of the decline, although it has suggested that some of the changes in numbers may have resulted from unexpected changes in herd distribution. At least one collared ram has emigrated to Canada. *Psoroptes* affects bighorns on the British Columbia side as well, and interaction between these herds is being monitored.

WDFW Game Division staff consulted with regional biologists on the Sinlahekin herd's problem by telephone conference call in March 2014, and again in November 2014, where possible cougar predation was a focus. The consensus was that although cougars are common in the area, pressure on them from hunters is also high. There has been no direct evidence linking cougar predation to the Sinlahekin decline, and no reason to support a pre-emptive, non-selective reduction of cougars. We agreed that if a collared bighorn were to die from what appeared to be cougar predation and this could be documented in a timely manner, efforts would be made to attempt to capture 1 or more cougars likely involved. If 1 or more cougars could be radio-monitored and additional bighorn predation were to be documented, WDFW would strongly consider arranging for lethal removal of that animal, as occurred in the Asotin herd (see above). We categorize the effect of predators on the Sinlahekin bighorn herd as possible, but lacking evidence.

Manson

Initiated in 1999 using founder animals from Lincoln Cliffs and Quilomene herds (and later supplemented by animals from Umtanum, Cleman, and Kamloops, B.C.), the Manson herd on Lake Chelan exhibited rapid population growth typical of a founder population in excellent quality, unoccupied habitat. In 2004, June survey data were used to calculate 2002-2004 population trends, indicating a 3-year average annual population growth rate of roughly 38%. This increase seems to have slowed, based on decreased observed lamb production/survival. Twelve animals were outfitted with VHF collars in March 2009 to assist in understanding habitat use and herd growth. Locations from telemetry data show that several bands have moved westward up lake into steeper, rockier, unoccupied habitat. Compared to the other herds, the Manson herd consistently has exhibited relatively low lamb recruitment. Due to the remote nature of the habitat of this herd, and the difficulty in locating sheep from the water, the population estimate of 101-122 is used from 2009, as a conservative estimate. The collars allowed for a productive aerial survey, where we documented the herd's highest observed count (Table 1). In February 2014, an additional 13 sheep were outfitted with GPS telemetry collars in the Manson herd to continue monitoring efforts. Pathogen screening at this time indicated no presence of *M. ovi*. With the addition of new GPS collars we hope to have more accurate counts in the near future. Low lamb recruitment continues to be a concern in this herd, but there is currently no indication that predation is the cause.

Chelan Butte

In the early 2000s, WDFW investigated the potential for sites other than those occupied at the time to support new herds of bighorn sheep. Of those considered, Chelan Butte, just southwest of the town of Chelan, emerged as the most promising candidate, and was selected for a new herd. Thus, the Chelan Butte is the youngest of Washington's reintroduced bighorn sheep herds. It has expanded from an original release of 35 animals in 2004, to a current estimate of nearly 200 bighorns. Musser and Dauer (2003) suggested that sufficient habitat exists for a population of 195-390 sheep. The presence of "backyard" flocks of domestic sheep and goats continues to pose a risk of disease transmission to this herd. However, no disease events have evidently occurred at this time, and the population appears to be healthy and robust. We are unaware of any indications that predation has caused, or is causing population-level concerns.

Swakane

The Swakane herd was initiated in 1969 with 9 animals from Sinlahekin, and grew sporadically and haltingly through its first 3 decades. In the mid-2000s however, the population began to expand in distribution and increase in size. There were an estimated 156 bighorn sheep in the Swakane herd as of early autumn 2015. The existing population objective for Swakane is 50-60 adult sheep (WDFW 2008), although we believe that the herd demonstrated that available habitat can sustain considerably more animals. No disease events have evidently occurred at this time, and the population appears to be healthy and robust. Due to its proximity to Highway 97A, road-kills are a concern for this population, and efforts by WDFW and partner organizations have been directed at building and maintaining a fence to discourage bighorns from crossing the highway. The threat of a future infection from pneumonia-causing bacteria is always present, in this case from both domestic sheep grazed on nearby federal allotments, and from small, privately held sheep and goats. We are unaware of any indications that predation has caused, or is causing population-level concerns.

Cleman Mountain

The Cleman Mountain population was established in 1967 with the release of 8 animals. The herd remained relatively unchanged for over 20 years. A portion of the population was captured, tested, and treated with antibiotics in 1990. Augmentation included 27 animals during 1989-96. Production increased after 1996, and the population exceeded the goal of 150 animals by 2000. Over 165 sheep have been captured and translocated from this herd since 2001. Over 140 were harvested during that period and the population is still above objective. The Cleman Mountain herd is considered at fairly high risk of a pneumonia outbreak due to recent disease problems in Tieton, Yakima River Canyon, and nearby domestic sheep grazing allotments. Concerns have led to frequent testing; the most recent testing in January 2013 indicated no evidence of pneumonia or the bacteria associated with it. Sheep at Cleman Mountain are fed during the winter, mostly for trapping purposes. Between 2010 and 2014, 6 GPS and 5 VHF collars were placed on sheep. Two sheep were harvested and one died of unknown causes. Cougars are frequently seen on the mountain and few sheep are known to have been killed by cats. Predation has not been identified as a significant issue for this herd, which remains healthy and robust.

Quilomene

The Quilomene reintroduction was the first of the Cascade foothills populations (early 1960s) and the population was estimated at over 100 animals by the late 1960s. The population then crashed in the early 1970s. The cause of the decline was unknown, but the population had reportedly died out by 1990. Reintroductions occurred again in 1993. By 1996, 41 bighorns had been released in the area. The Quilomene population quickly grew to over 160 sheep (Table 1). Poor recruitment, observations of coughing sheep, and reports of mortalities indicated a disease problem circa 2004-2006. Adult ewe counts had been declining and reached lows in 2014. In 2013, a large, fast moving fire went through the north portion of the herd area. Post-fire, sheep became hard to find. This was apparently due to a shift in range as numbers rebounded to expected levels in 2015. In 2012, 6 VHF and 2 GPS collared sheep were translocated from Cleman to Quilomene. Radio tracking was not frequent, but 2 of the collared sheep likely died from cougar predation. Cougar sightings within the herd are fairly common and sheep that appear to have escape predation attempts photographed. The herd is apparently now stable, but it is unknown if predation is limiting growth. The Quilomene herd has been difficult to monitor closely. We plan to move more sheep from Cleman to Quilomene and GPS collar 8 translocated sheep. For now, we have no data that would specifically suggest that predation is a significant issue for this herd.

Tieton

The Tieton herd was established with the release of 54 sheep during 1998-2002. Twenty-five sheep were radioed when released. Four GPS collars were added to this herd in 2010. The 29 collars provided over 100 “collar years” of data. Human related (legal harvest, poaching, and road-kill) accounted for 8 mortalities. One radioed animal was fed upon by a bear; the cause of its death was unknown, but the location suggested it may have been hit by a vehicle, wandered part way back to escape terrain, and then died.

Prior to 2013, the Tieton herd had low mortality and high lamb recruitment. By 2008, the herd was over objective. Sixty-five animals were removed for translocation since 2009-2012. During the capture, crews confirmed population estimates, and the herd was found to be disease free as of March 2012. Harvest removed 49 animals during 2009-2012 in an attempt to keep the population near population objectives. In March 2013, a pneumonia outbreak was confirmed. Mortality appeared to be high, and a decision was made to euthanize the remaining animals to prevent spread to the nearby Cleman Mountain herd. A total of 57 bighorns were euthanized. Pneumonia and *M. ovi* were confirmed in all samples. The strain of *M. ovi* in the Tieton herd was different than that found in the Yakima River Canyon sheep.

Predation was not a limiting factor for this herd during either the build-up phase or when the population has at relatively high density. Predation was not implicated in the disease die-off of March 2013, when many carcasses of pneumonic animals remained on the landscape for some time before being scavenged.

Umtanum/Selah (Yakima Canyon)

The Umtanum herd was established in 1970 with the release of 8 bighorns west of the Yakima River. Within 15 years, the population grew to an estimated 200 animals, and some sheep crossed the Yakima River. Originally, sheep on the east side of the river were considered a separate herd (Selah Butte). Surveys have shown large numbers of animals crossing the river in both directions, and it is now considered a single herd. In 2001, 11 sheep were released at the south end of the canyon, near Roza Dam.

Population estimates for Umtanum/Selah Butte varied between 170 and 200 animals until 2002. Dispersal, winter mortality, and the removal of 52 sheep for augmenting other populations probably kept the herd stable. The increase, after 2002, was largely due to the release of 11 animals and a subsequent increase in lamb production. Harvest was being increased during this period to maintain a stable population.

In December 2009, an outbreak of pneumonia was discovered at the north end of Umtanum. Disease loss and culling removed approximately 50% of the Umtanum herd by April 2010. The bacterial pneumonia jumped to the east of the river (Selah Butte) in summer 2010, but no significant adult mortality was noted. By August 2010, low lamb survival was apparent on both sides of the river. Lamb and adult survival was very high in 2011 and 2012. It appeared the herd had recovered and was back at objective. Testing of 30 animals in February 2013 found *Mycoplasma ovipneumoniae* in one young ram.

In 2013, 25 ewes (VHF) and 5 rams (GPS) were radioed collared. Since 2013, almost all mortality has been human related (harvest, suspected poaching, or road-kill). One animal died of unknown causes (possibly pneumonia) and one died in a location that wasn't accessible. Adult survival has been high since 2013 and no predation has been confirmed. Lamb recruitment has been low the last 3 years. Observations in additional to samples collected from sheep on both sides of the river has confirmed that pneumonia was still present, was due the same strain of *M. ovi* as in 2010, and has been the main cause of high lamb mortality.

Predation was not identified as a limiting factor for this herd during either the build-up phase or when the population has at relatively high density. Predation was not implicated in the disease die-off of December 2010, or of lamb recruitment failures in summers 2013, 2014, and 2015.

Coyotes were suspected of killing 2 rams in early autumn 2015, but laboratory diagnostics revealed that both animals were infected by the blue tongue virus, which likely was the ultimate cause of death.

Potential Actions for Herds of Concern

Hall Mountain

None.

Vulcan Mountain

We plan to place GPS collars on approximately 8 adult ewes during February 2016. We will monitor survival of these animals, and opportunistically, recruitment of their lambs. We will attempt to determine causes of any adult mortalities documented.

Lincoln Cliffs

Continue to monitor GPS-collared adults, and monitor lamb recruitment during spring/summer 2016 and 2017. If multiple cougar predations are documented, an attempt would be made to track, find, and collar that individual.

Asotin

Continue monitoring. If additional mortality attributable to cougars recurs and threatens to depress population growth or unduly interfere with disease-focused research, WDFW will use a similar process to that invoked in 2015. If as in spring 2015, evidence pointed to a single bighorn-specialist, would have that cougar lethally removed.

Black Butte

None.

Mountain View – Wenaha

None.

Tucannon

The 2005 School Fire has probably rejuvenated plant growth, and thus provided a good basis for future herd growth. But if either low genetic diversity or cougar predation is problematic, the Tucannon herd will be unlikely to take advantage of new plant growth without an infusion of new animals, as it appears has been the case over the past 10 years. Thus, we are implementing augmentation of this herd. However, to learn from the experiment, we need to increase our monitoring beforehand and afterward.

Because this population is at a critically low size but we are currently unsure of the relative roles of genetic impoverishment and predation in perpetuating this, we have begun a program of genetic rescue/demographic augmentation. During the winter of 2014-2015, the Tucannon herd was augmented with 2 young rams from the Lookout Herd in Oregon; an additional 7 ewes were added in January 2016. All translocated animals were fitted with Vectronics GPS/Satellite collars to monitor their movements. All animals are still alive and within the Tucannon herd range as of February 2016. Because this herd is often easily monitored from the Wooten Wildlife Area staff, we are in a good position to continue active monitoring of these translocations.

To further our understanding of a possible genetic bottleneck, we have collected blood, tissue, and fecal material from all except 2 individuals in the herd (including some animals that have recently died and excluding 2 new lambs), and have had DNA extracted from all. The University of Idaho Genetics Laboratory is under contract to analyze and report to WDFW estimates of genetic diversity within this herd, which can be compared with other baseline values. In addition, complete genetic identities should facilitate our ability to perform paternity analysis on future lambs (if we can continue to obtain fecal material from them for future DNA extraction), and thus relate their fates not only to their mothers, but whether they were sired by a newly translocated ram. Additionally, in spring 2015, we fitted 3 neonate lambs with drop-off radio collars and ear-tags. This allowed us to obtain genetic material, as well as to investigate early mortality. One of the lambs was killed by an unidentified predator shortly after marking; one was abandoned by its mother and died within 2 days of the initial capture, and one is still alive along with 2 uncollared lambs.

Mt. Hull

None.

Sinlahekin

If cougar predation is documented, an attempt would be made to track, find, and collar that individual. If we document multiple instances of predation attributable to cougars (either with or without having collared any), we would track, find, and remove the repeat-offending cougar implicated.

Manson

None.

Chelan Butte

None.

Swakane

None.

Cleman Mountain

None.

Quilomene

We plan to add radio-collars and animals to this population at the same time by moving collared animals from the over-abundant Cleman Herd to Quilomene when winter weather conditions allow for it. This may help us assess the relative magnitude of predation on this herd.

Tieton.

None.

Umtanum/Selah (Yakima Canyon)

None.

Literature Cited – Bighorn Sheep

Aluzas, K. 1997. Bighorn sheep radio-telemetry monitoring. Progress Report 2: November 1996-October 1997. Unpublished report, U.S. Forest Service, Colville National Forest.

Aluzas, K. 1998. Bighorn sheep radio-telemetry monitoring. Progress Report 3: October 1997-August 1998. Unpublished report, U.S. Forest Service, Colville National Forest.

Baker, T. 2015. Habitat selection and spatial responses of bighorn sheep to forest canopy in north-central Washington. Unpublished M.S. Thesis, Washington State University. 65 pp.

Baldwin, T. 1999. Bighorn sheep radio-telemetry monitoring. Progress Report 4: May 1999-November 1999. Unpublished report, U.S. Forest Service, Colville National Forest.

Bourbeau-Lemieux, A., M. Festa-Bianchet, J-M. Gaillard, and F. Pelleteir. 2011. Predator-driven component Allee effects in a wild ungulate. Ecology Letters 14: 358-363.

Festa-Bianchet, M. T. Coulson, J-M. Gaillard, J. T. Hogg, and F. Pelletier. 2006. Stochastic predation events and population persistence in bighorn sheep. Proceedings of the Royal Society B. 273: 1537-1543.

Gasaway, W.C., R.O. Stephenson, J.L. Davis, P.E.K. Shepherd, and O.E. Burris. 1983. Interrelationships of wolves, prey, and man in interior Alaska. Wildlife Monographs 84:1-50.

Hebert, D., and S. Harrison. 1988. The impact of coyote predation on lamb mortality patterns at the Junction Wildlife Management Area. Biennial Symposium of the Northern Wild Sheep and Goat Council 6: 283-291.

Johnson, R. 1983. Mountain goats and mountain sheep in Washington, Washington Department of Game, Olympia.196 pp.

Logan, K. and L. Sweanor., eds. 2001. Puma and Desert Bighorn Sheep, pages 341-358 in Desert Puma: evolutionary ecology and conservation of an enduring carnivore. Hornocker Wildlife Institute, Island Press, Washington.

Musser, J., and P. Dauer. 2003. Bighorn reintroduction site evaluation. USDI-BLM Wenatchee Resource Area. 14p.

Rominger, E.M, H. A. Whitlaw, D. L. Weybright, W. C. Dunn, and W. B. Ballard. 2004. The influence of mountain lion predation on bighorn sheep translocations. Journal of Wildlife Management 68: 993-999.

Ross, P.I., M.G. Jalkotzy, and M. Festa-Bianchet. 1997. Cougar predation on bighorn sheep in southwestern Alberta during winter. Canadian Journal of Zoology 74:771-775.

Sawyer, H. and F. Lindzey. 2002. A review of predation on bighorn sheep (*Ovis canadensis*). Wyoming Cooperative Fish and Wildlife Research Unit. Laramie, WY, USA.

Wehausen, J. D. and R. R. Ramey II. 2000. Cranial morphometric and evolutionary relationships in the northern range of *Ovis canadensis*. Journal of Mammalogy, 81(1):145–161.