Issues and Strategies Section 8: Predation

Predation, from a suite of carnivores, is frequently identified as a primary source of mortality for mule deer (*Odocoileus hemionus*) and because of this is often implicated in the declines of mule deer populations in Oregon, as well as other western states (e.g., Utah Division of Wildlife Resources 2019). Despite this assumption, the influence of predation on deer populations is complex, and the effects can vary widely depending on a multitude of factors specific to that population. Predation rate (proportion of a population killed by a specific predator during a defined time period; Vucetich et al. 2011) can vary by carnivore species and behavior. Factors that can influence predation rate include preference for specific sex and age classes, increased similarity and habitat use or overlap with prey, availability of alternative prey, and interspecific (interactions between two different species; e.g., cougars [*Puma concolor*] and coyotes [*Canis latrans*]) and intraspecific (interactions between individuals of the same species) interference competition from other carnivores (Hurley et al. 2023). Prey also can influence outcomes of predation where vulnerability to predation can be influenced by behavioral choices in habitat selection, body size, nutritional condition, social organization, and parturition and young rearing behavior. All these components shape predation patterns and ultimately interact with other environmental factors to determine deer population performance.

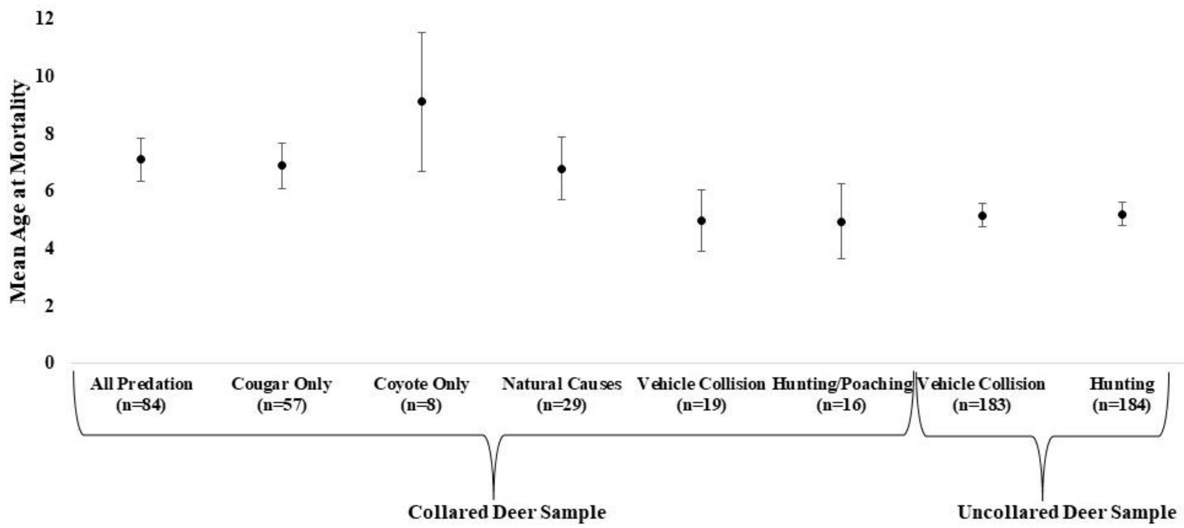
When determining the effects of predation on mule deer populations, the magnitude will depend on whether predation is compensatory (i.e., deer killed by predators would have died from other causes even without predation) or additive (i.e., deer killed by predators would have otherwise survived; Errington 1956, Ballard et al. 2001). When predation is compensatory, it is predicted that predation has little influence on prey populations because predation has no effect on observed prey survival rates. In contrast, when predation is additive, it is predicted that predation is a limiting factor on the population or predation directly reduces survival rates and can limit the ability of the prey population to increase. By the same token, it is also important to consider ultimate versus proximate causes of mortality. For example, an individual that is malnourished or diseased (ultimate cause of mortality) is more likely to be killed by a predator (proximate cause of mortality; Husseman et al. 2003, Krumm et al. 2010, Metz et al. 2012). In these situations, predation is likely to be compensatory and have little effect on the deer population because those individuals would have died otherwise. In a review of more than 40 studies of mule deer and black-tailed deer (O. *h. columbianus*) populations, predation was the most widely reported proximate cause of mortality for adult and juvenile deer, yet there was little evidence for whether predation was additive to other forms of mortality (Forrester and Wittmer 2013). Predation also is not necessarily always additive or always compensatory, but rather can occur along a continuum from completely additive, partially additive, to completely compensatory and can shift over time based on habitat and forage condition, weather, and disease (Laundre et al. 2006, Pierce et al. 2012). As such, the outcomes of predation on prey populations will vary over time in response to changing factors on the landscape.

Habitat quality and weather

Forage availability and quality influences nutritional condition of deer (Chapter 6) and can have cascading behavioral and demographic effects that increase an individual's risk to predation. For example, in areas with less available forage, black-tailed deer foraged in riskier areas and experienced higher rates of mountain lion predation (Forrester et al. 2015). Similarly, in Colorado, Bishop et al. (2009) reported that mortality from all sources, including predation, decreased in response to large-scale food supplementation over winter. In this same area years later, mule deer fawn survival overwinter increased in response to habitat treatments that included mechanical tree and brush removal, the planting of forage species, and chemical weed control (Bergman et al. 2014). Further, in California, nutritional condition of females was the strongest predictor of mule deer population growth rates compared to the effects of predation (Monteith et al. 2014).

Low birth mass of neonatal fawns is also associated with increased early mortality (Lomas and Bender 2007, Bishop et al. 2009, Monteith et al. 2014) and is related to female nutrition in summer and winter (Bishop et al. 2009). Females in better condition also are more likely to produce twins (Tollefson et al. 2010, Shallow et al. 2015), offspring with greater birth mass, higher growth rates, and increased survival (Lamb et al. 2023). Reduced body condition or increased age has been documented to increase risk of predation in all age and sex classes of mule deer. In Oregon, adult female mule deer that succumbed to predation were older than females killed by vehicles or hunters which is typically indicative of the age distribution of the general population (Figure 1), suggesting as prey animals age their vulnerability to predation increases. Predation on mule deer, particularly from coyotes, also tends to increase in late winter when mule deer body condition is lowest (Bishop et al. 2009, Hurley et al. 2011, ODFW unpublished data).

Figure 1. Mean age of adult female mule deer (>1yr) collected from incisors at mortality events in Oregon from 2005 to 2021.



Seasonal, annual, and long-term weather patterns may influence the degree of spatial overlap between predators and prey. Precipitation and temperature alter forage quality on the landscape for mule deer, particularly in late summer and early fall. In years with below average precipitation and above average temperatures, vegetation loses its nutritional value quicker (senescence; Brown et al. 2022) which can lead to increased mortality in mule deer neonates (newborn; Hurley et al. 2011). Several factors related to drought may interact to increase mortality risk. Deer may move from more secure habitats to access higher quality forage or water outside their typical home range, which can increase their risk to predation (Forrester et al. 2015). Reduced precipitation ultimately influences habitat quality and quantity (Brown et al. 2022) with cascading effects on mule deer nutritional condition and vulnerability to predation. Females may become more nutritionally stressed during drought years increasing risk of predation. Additionally, females in poor condition produce less milk which reduces growth rates of fawns, increases female feeding time away from fawns, and increases alert calls between fawns and does; all of which will likely increase predation risk for fawns. Similarly, in winters with above average snow accumulation deer may be forced to forage in areas with denser cover to minimize energy expenditure and potentially increase overlap with a higher density of carnivores. Kill sites of mountain lions on mule deer have been linked to forested habitats

(Atwood et al. 2009) and deer are more likely to move into these areas in winters with deep or crusted snow. Deep snow conditions also make hunting easier for coursing predators (e.g., coyotes) as they are able to walk on top of crusted snow and this occurs at a time when mule deer are most nutritionally stressed. Concentration of prey due to environmental conditions (e.g., drought, severe winters) will likely also increase concentrations and overlap of predators and prey, increasing encounter rates and vulnerability to predation for prey.

Multiple predator and multiple prey effects

Interactions among carnivores has potential to affect predation on mule deer, although the degree to which these interactions increase or decrease predation risk is somewhat uncertain. Several researchers have reported increasing wolf (*Canis lupus*) populations can lead to increased predation of mule deer from cougars; Kortello et al. 2007, Bartnick et al. 2013, Elbroch et al. 2015), although Atwood et al. (2007) documented elk (*Cervus elaphus*) shifting to more forested habitats in response to recolonizing wolves which resulted in cougars killing more elk and fewer deer. Black bears (*Ursus americanus*), wolves, and coyotes may also take over cougar kills (kleptoparasitism) before cougars are finished feeding (Allen et al. 2014, Ruprecht et al. 2021), yet there is little evidence this increases cougar kill rates (Elbroch et al. 2015). While scavenging of cougar-killed prey can provide energetic rewards for other carnivores, this behavior can be risky as both black bears and coyotes have been killed attempting to usurp cougar prey items (Clark et al. 2014, Ruprecht et al. 2021). Additionally, wolves (Berger et al. 2008) and cougars (Ruprecht et al. 2021) may reduce coyote populations, which has been shown to reduce predation on juvenile pronghorn (*Antilocapra americana*; Berger and Conner 2008). This phenomenon is not well studied or documented for mule deer. Collectively, interactions among carnivores have the potential to alter effects of predation in unanticipated or difficult to predict ways depending on the outcome of the interaction. For example, increases in one predator population that has minimal effects on mule deer may decrease another population that has greater effects on mule deer.

Multiple prey species can alter predation patterns through both apparent competition and prey switching. Apparent competition occurs when two species that do not directly compete for the same resources affect each other indirectly by being prey for the same predator (Hatcher et al. 2006). An example of apparent competition was documented in an area where mule deer and white-tailed deer (*O. virginianus*) are sympatric (Robinson et al. 2002, Wielgus 2017). White-tailed deer populations provided an alternative prey source allowing a larger cougar population to be supported that selectively preyed on mule deer and lowered their survival (Robinson et al. 2002, Cooley et al. 2008, Wielgus 2017). In this scenario, apparent competition was likely occurring (Holt 1977, DeCesare et al. 2010), and may have been assumed to be a competitive interaction between increasing white-tailed deer and declining mule deer populations in the area. With reduced white-tailed deer populations, a lower number of predators could be supported, which may reduce predation effects on mule deer. Similar effects may occur with elk as research in eastern Oregon has documented movement of cougars and male black bears exhibited behavior consistent with actively searching for neonate elk but exhibited no relation to neonate mule deer (Ruprecht et al. 2022), and elk composition in cougar diets are higher in summer compared to winter when they are actively selecting for elk calves (Clark et al. 2014). This would tend to indicate abundant elk populations may support higher cougar numbers leading to apparent competition, although it could be evidence of prey switching (see below) and result in reduced predation pressure on mule deer if there is not an increase in predator populations (i.e., numeric response).

Prey switching is the change in primary prey for a carnivore based on availability and occurs when one prey species increases or decreases in magnitude, either seasonally or annually, enough to alter predation patterns (Garrott et al. 2007). Evidence for this affecting mule deer populations primarily involves coyotes and availability of small mammals. Research from Montana indicated fawn survival was closely related to microtine rodent (e.g., voles) abundance with lower fawn mortality when rodents were abundant (Hamlin et al. 1984). Hurley et al. (2011) reported a similar relationship in Idaho between coyotes and lagomorphs (e.g., rabbits and pikas) and found coyote removals were only effective at increasing fawn survival when lagomorphs were less abundant. Furthermore, Lingle (2000) also reported higher rates of fawn mortality where ground squirrels were unavailable in Alberta. Prey switching for cougars is somewhat more contradictory. Villepique et al. (2011) found no evidence for prey switching, while Logan and Sweanor (2001) observed switching as mule deer declined. In Oregon, cougars showed evidence of prey switching seasonally, as cougars selected for elk calves during summer and switched to selecting for deer fawns during winter (Clark et al. 2014). Despite this, there are more reports of cougars and wolves taking prey in proportion to (Kunkel et al. 1999, Husseman et al. 2003, Atwood et al. 2009, Metz et al. 2012). This pattern of killing prey in proportion to availability would imply increasing alternative prey (e.g., elk or white-tailed deer) could lead to a decrease in predation pressure on mule deer if there is not a numeric response from carnivores. Both apparent competition and prey switching can be difficult to identify in populations because of the complexity of indirect interactions that involve multiple species and changing environmental conditions.

Age and sex structure

The age and sex structure of both prey and predator populations can influence overall predation rates and prey population growth. Predation's effects on prey population growth are greatest for prime age adult females, followed by older adult females, juvenile females, adult males, and finally juvenile males (Gaillard et al. 2000). Consequently, highly productive populations with numerous young may maintain population growth as juveniles buffer the most important segments (i.e., reproductively active females) of the population from predation. In this scenario, predation on juveniles is more likely to be compensatory because more fawns are produced than can be supported by the available habitat, which typically occurs when deer are at or near carrying capacity. In contrast, when productivity is reduced due to poor habitat conditions predation may focus on the adult female segment of the population and predation is more likely to be additive.

Predation also varies by predator species across age classes (Figure 2). Black bears primarily take newborn fawns during the first few weeks of life when fawns are in the hider phase, and in areas with high bear density this can represent a substantial source of additive mortality (Monteith et al. 2014). While coyotes can kill all age classes of mule deer, risk of predation declines as deer transition from newborn fawns (18.9% mortality) to juveniles (11.4% mortality) and drops sharply once they are adults (1.9%; Figure 2). Furthermore, when coyotes do kill adult females, they tend to be older (Figure 1) and in poorer nutritional condition which is more likely to result in compensatory mortality. Wolves are generally not a major source of mortality for mule deer with an average of 2% predation rate documented from a recent review where wolves were present (Hurley et al. 2023). Of over 300 documented mule deer mortality investigations in Oregon across all age classes, there has only been one confirmed case of wolf predation (Figure 2). Wolf predation is, however, likely to be variable depending on wolf densities and alternative prey availability. In eastern Oregon elk constituted 62% of wolf diets in the summer and 74% in the winter, although this varied by pack and season (Orning et al. 2021).

Given the relatively small population of wolves in Oregon (minimum population count of 178 in 2022) compared to cougars (~7,000), wolves apparent selection for elk (Orning et al. 2021), and the amount of direct mortality observed on mule deer (<1%), wolves do not appear to be a significant source of mortality in Oregon at this time.

In contrast to other predators of mule deer in Oregon, cougars have the greatest potential to effect mule deer populations. Cougars readily take all age classes and cougar predation represents the biggest source of known mortality for adult females (Figure 2). Relative to the general population, adult female mule deer taken by cougars tend to be older, although not as old as mortalities from coyotes (Figure 1). Cougars are also strongly dimorphic with males able to effectively capture larger prey because of their physical strength, which likely reduces risk of injury (Sunquist and Sunquist 1989, Iriarte et al. 1990) but also reduces the frequency at which they kill prey, particularly compared to females with dependent kittens (Clark et al. 2014). Coupled with their reduced frequency of killing prey, the proportion of elk documented at male feeding sites (52%) was more than double that of females (25%) in northeast Oregon (Clark et al. 2014) suggesting male cougars will have less of an effect on deer populations. The biggest driver of kill rates for female cougars is kitten status and age of kittens, with the highest kill rates for females with older age kittens (>6 months) followed by those with younger kittens, and finally adult females without kittens (Knopff et al. 2010, Clark et al. 2014, Smith 2014). As such, in areas with high reproduction in cougar populations, the number of prey killed by cougars will be greater as females will need to kill more frequently to support dependent offspring. Susceptibility to predation by sex of adult deer varies seasonally with males more likely to be killed immediately prior to or during the rut (August to November), and females more susceptible prior to parturition (April to July; Clark et al. 2014). The ambush style hunting employed by cougars may contribute to cougar predation being more additive than predation from other predators that employ coursing tactics to chase and run down prey, which should target more vulnerable (i.e., diseased, old, malnourished) prey that would be less likely to survive in the absence of predation.

Predation effects and management

Hunting seasons are the primary population management tool used in Oregon, as well as other states. Hunting seasons are manipulated to manage effects of hunter harvest on populations while accounting for other factors effecting populations. Because adult female mortality has the largest influence on population growth rates (Ruprecht et al. In Prep), antlerless harvest (e.g., mostly female harvest) can be increased or decreased to reduce or maintain mule deer populations. Unlike other ungulates such as elk and bighorn sheep (*Ovis canadensis*) that predominately give birth to one offspring annually, mule deer typically have high fecundity ($\bar{x}$ = 1.7 fawns/year; Forrester and Wittmer 2013). Given favorable weather conditions and quality habitat, high fecundity can lead to stable or increasing populations even in areas with high predation pressure. Nevertheless, when mule deer are below carrying capacity due to poor habitat quality, extreme weather (e.g., drought, harsh winter), or other limiting factors predation is more likely to be additive and affect population performance (Ballard et al. 2001). Oregon currently allows very limited antlerless mule deer harvest due to long-term population declines. While there are a number of factors contributing to these declines, predation may eliminate some hunting opportunities because they are killing a portion of the 'harvestable surplus'. ODFW has recently transitioned to using integrated population models (IPMs) to model mule deer populations. These models have improved predictive power and flexibility in terms of model structure and input, that allow for integration of carnivore-specific mortality rates such as those presented in this chapter (Figure 2) to project the likely impacts of hunting seasons on population size and demographics while accounting for limiting factors such as predation.

Managing predators to increase mule deer populations is a complex issue and can range from active removal of carnivores by wildlife agencies to modifications of harvest seasons for carnivores. Management actions related to predators is further complicated as differing segments of Oregonians have contrasting views of predators. Additionally, investigating the topic and making decisions about the efficacy of predator control is difficult because success is variable depending on other factors limiting deer populations including the composition of the carnivore community and alternative prey, carnivore-specific mule deer mortality rates, carnivore harvest intensity, mule deer population status relative to carrying capacity, and the degree of to which predation is additive or compensatory (Hamlin et al. 1984, Ballard et al. 2001, Hurley et al. 2011). In Oregon the preferred method to manage predator populations is through hunter harvest as it is the most effective method over a large scale, provides additional hunting opportunities throughout the year, and is implemented every year. In 1994, Oregon voters passed Measure 18, a citizen-sponsored ballot initiative that banned the use of hounds for hunting black bears and cougars which can alter the composition (e.g., number of males vs females) of the harvested predator population (ODFW 2017). In response to cougar population increases post-Measure 18 and low success of hunters hunting cougars without dogs, hunting seasons, harvest quotas, and bag limits for cougars have become increasingly liberal in Oregon. Similar liberalizations also occurred for black bears, and tag fees have gone down for both species. These changes were implemented to help ODFW maintain sustainable predator populations within the state while managing at a level consistent with other game mammals.

ODFW also can implement administrative removals of predators to benefit ungulates populations. For cougars, state statute (ORS 496.162) directs the use of regulated harvest as the tool for population reductions, however, in areas where hunting has not been sufficient to reduce populations ODFW staff and agents have conducted coordinated removals (Table 1). Guidance for when ODFW can implement cougar target areas (e.g., removal of cougars by ODFW or their agents for a specific objective) are outlined in the 2017 Oregon Cougar Management Plan (ODFW 2017) and then proposals must be approved by the Oregon Fish and Wildlife Commission. Regarding target areas to improve native ungulate populations, previous efforts in the state to improve elk population performance through cougar target areas have yielded favorable results. Conversely, mule deer population response to cougar removal in target areas, and a lesser extent coyote removal, have failed to exhibit measurable responses (Table 1; also see 2017 Oregon Cougar Management Plan Appendix J and K). Although specific vital rates may be increased (Hall 2018), research in other states have shown similar response of mule deer to predator control efforts (Brown and Conover 2011, Hurley et al. 2011).

In a recent synthesis of results from mule deer predator removal studies, Hurley et al. (2023) outlined four criteria that must be met to positively influence population trend or increase mule deer density.

1. Predation must be additive and of sufficient magnitude to be a limiting factor (Ballard et al, 2001). This condition will likely be met only when mule deer populations are below carrying capacity because resources existed to support most of the animals lost to predation.
2. Carnivore removal must be consistent, intensive, and long-term enough to reduce the carnivore population (Ballard at al. 2001). For this reason, programs must be focused on an area small enough where it is logistically feasible to reduce carnivore density.

Table 1. Location and results from Oregon cougar target areas from 2009 to 2017.

Location	General location	Target Area Objective	Met objective	Met removal objective	Mule deer response
Heppner WMU	NE Oregon	Improve elk populations	Yes	No	No effect
Heppner WMU*	NE Oregon	Improve mule deer populations	No	Yes	N/A
Ukiah WMU	NE Oregon	Improve elk populations	Yes	No	Not measured
Wenaha WMU	NE Oregon	Improve elk populations	No	No	No effect
Steens Mtn WMU	SE Oregon	Improve mule deer populations	No	No	N/A
Warner WMU	S central Oregon	Improve mule deer populations	No	No	N/A
Interstate WMU	S central Oregon	Improve mule deer populations	No	No	N/A

*Coyote control area

3. Timing and location of carnivore control should coincide with the season and areas in which the limited mule deer age-sex classes are most vulnerable (Mahoney et al. 2018). Depending on the carnivore(s) involved, this might favor carnivore control in winter, fawning, or summer habitat. Information concerning migration or phenological shifts in habitat quality that may change the spatial distribution of a deer population will be important to meet this criterion. Targeted control of carnivores that are unable to move because of land tenure or territory systems will reduce the effectiveness of the effort because deer migrating or moving to better habitat will encounter predators from a non-controlled population.
4. Carnivore removal will be less successful in increasing mule deer populations if carnivores are supported by alternative prey (Hamlin et al. 1984, Hurley et al. 2011).

Each of the above conditions will influence the effectiveness of carnivore control at reducing the limiting effects of predation on specific age and sex classes of mule deer but may not translate into increased population growth. For example, coyote removal in southeastern Idaho led to increased survival of neonate fawns but failed to increase December fawn ratios or result in an increase in population growth (Hurley et al. 2011). Cougar removals in this same area did lead to increased December fawn:doe ratios, over-winter survival, and adult female survival, but again failed to result in significant population growth as other environmental factors (e.g., severe winters) eliminated any potential benefits (Hurley et al. 2011).

In contrast, predator removal may have a stronger impact on population growth rates where adult female survival is limited due to predation because adult females exhibit the strongest influence on population trajectories (Gaillard et al. 2000, Ruprecht et al. In Prep). In Oregon adult female survival is lower (~77% annual survival) than what is predicted for a stable to increasing population (~83% annual survival; Ruprecht et al. In Prep), and predation from cougars and coyotes accounts for ~11% of total mortality (Figure 1A). However, the degree to which predation is additive or compensatory is difficult to ascertain currently. Given the results of predator removal studies in Oregon (Table 1) and elsewhere (Bartmann et al. 1992, Harrington and Conover 2007, Brown and Conover 2011, Hurley et al. 2011), the weight of available evidence suggests mule deer populations will not significantly improve through predator management alone.

Predation: Issues and Strategies

Oregon's mule deer populations have experienced significant declines over the past several decades (Chapter 2) and predation from cougars (for adult mule deer) and coyotes (for newborn and juvenile mule deer) have been documented as the principal source of mortality (Figure 1). Because of this, predation is often implicated as the main driver of population declines, yet efforts in Oregon and other states have failed to show long-term increases in mule deer population growth resulting from predator removal efforts. Ultimately, predation interacts with a range of other factors (e.g., weather, habitat quality, disease) that will influence how much it is either additive or compensatory and effects population growth. All these interacting effects should be considered when attempting to manage predator populations to influence mule deer population performance.

Issue 1: Develop a more comprehensive assessment of the degree predation is additive or compensatory for mule deer relative to other limiting factors. To make informed decisions regarding predation effects on mule deer populations it is paramount to understand how predation interacts with other limiting factors such as weather, habitat quality, and climate change.

Strategy 1*:* ODFW recently started a long-term research project in the Murderer's Creek (winter 2022) and Klamath Basin (begins winter 2023) herd ranges to gain a better understanding of how predation interacts with habitat quality, weather, nutritional condition of adult females, survival of neonates and juveniles, pregnancy rates, and fecundity (i.e., # of fawns/doe). Expected outcomes include:

a) Determine how available habitat effects nutritional condition of adult females and their ability to survive and avoid predation.
b) Determine how available habitat effects adult female nutritional condition and subsequent growth rates, survival, and risk of predation for fawns born to mothers of known nutritional condition.
c) Quantify the degree to which predation from different carnivore species is additive or compensatory to other mortality sources in a range of environmental scenarios (e.g., drought years, harsh winters).
d) Develop population models that will be used to quantify the degree to which nutrition and habitat compared to predation influence population growth rates of mule deer to guide efforts to increase mule deer populations.

Strategy 2: Continue to monitor adult female and juvenile survival in a subsample of herd ranges to document cause-specific mortality and understand if causes of mortality attributable to predators change over time. Improved identification of predator species responsible for mortality and any emerging trends in mortality sources will aid in determining overall mortality rates by predator species and allow for more informed management decisions.

Issue 2: Using hunter harvest to manage predators consistent with management objectives for mule deer. ODFW is directed by state statute (ORS 496.162) to use regulated harvest as the primary tool for predator population management. Since passage of Measure 18 banning the use of hounds for hunting cougars and black bears in the state, ODFW currently sells ~70K tags for bears and cougars each, tag prices for both species have been lowered, a bear tag and a cougar tag are included in a Sports Pac, season lengths increased for cougars, 2 tags for both species are allowed, cougar quotas increased, hunt areas for both species expanded, and a controlled spring and general season bear hunts implemented. These liberalizations are in response to the lower success rate for pursuing these species without the use of hounds and provides ODFW the greatest flexibility in managing at levels consistent with other prey species including mule deer. In 2022, roughly 77,000 bear tags and 75,000 cougar tags were issued with a participation rate of

37% and 22% respectively. For both species, there is a substantial opportunity for increased hunter participation and harvest, indicating the use of hunters could indeed be a feasible tool under current circumstances.

Strategy 1: In areas where cougar predation is determined to be the primary limiting factor for mule deer, ODFW may implement strategies to increase hunter harvest of cougars by:

a) Providing hunters and hunter organizations educational material describing successful hunting strategies and continuing public outreach regarding potential impacts of cougars to mule deer populations,

b) Managing hunts (e.g., quotas) to increase predator harvest in focal areas.

Strategy 2: Observed mortality rates in Oregon from black bears is very limited compared to other sources of predation and is generally restricted to the neonate age class of mule deer (Figure 2).

a) Black bear predation can be a significant source of mortality at high bear densities (Monteith et al. 2014), and efforts to reduce bear predation would be most beneficial in areas with higher bear densities. If black bear predation is identified as a primary factor reducing fawn survival and recruitment management of black bear populations through increased hunter opportunity (e.g., increased control tags) and harvest could be implemented to benefit mule deer populations.

Issue 3: Active predator removal by ODFW or their agents. ODFW has the ability to use administrative removals of predators as a tool to increase mule deer populations. Nevertheless, ODFW prefers, and is directed, to use hunter harvest as the primary tool to increase predator take in focal areas and will consider administrative removal only in areas where hunting alone has not proved effective at reducing effects of predation on mule deer populations.

Strategy 1: Cougar removal areas (target areas) may be considered for improving mule deer populations in areas where criteria from cougar management plan are met, cougar harvest by hunters has not met hunt objectives, and where mule deer population monitoring sensitivity is sufficient. Any efforts to implement would also require commission approval.

Strategy 2: Coyotes in Oregon are classified as a predatory animal or unprotected mammal depending on the situation. Coyotes are thus able to be hunted year-round with no bag limits, restricting options for manipulating hunter harvest to manage coyote populations. If coyotes are identified as a primary limiting factor for mule deer populations, efforts to manage coyote populations through administrative removals would be coordinated with ODFW agents.

Strategy 3: Mule deer predation from wolves in Oregon is very limited currently (Figure 2). Any management actions related to wolves and mule deer population performance would be guided by the Oregon Wolf Conservation and Management Plan and status (Federally or state listed) in the area.

a) ODFW will initiate additional mule deer collaring efforts in the Northeast herd range, where wolf densities are the highest in the state, beginning in 2024 to gain a better understanding of mule deer mortality rates from wolves in areas with established wolf populations.

Issue 4: Guidance for future predator removal efforts if/when they are implemented to increase mule deer population performance. Target area removal efforts in Oregon have failed to document measurable responses from mule deer populations (Table 1).

Strategy 1: Efforts in the future may be warranted and likely more effective when:

a) Predation is clearly identified as mostly additive and a significant limiting factor to population growth,
b) Mule deer have been documented to have sufficient habitat quality and in good body condition but still exhibit low survival/recruitment,
c) Paired with habitat work in a local area.

Strategy 2: Improved monitoring of mule deer response to predator control.

a) Scale of monitoring should be at the scale of removal efforts (i.e., herd range),
b) Increased monitoring of adult female survival (e.g., GPS collars) in target areas,
c) Document changes in cause-specific mortality in target areas,
d) Identify metrics to document overall population growth and not just tie to metrics that are less likely to influence abundance,
e) Mule deer harvest metrics should be used with caution and only used if similar harvest structure is implemented during time frames of monitoring removal

efforts. For example, tag reductions during predator removal monitoring efforts will likely result in increased hunter success, buck:doe ratios, and older aged bucks in the harvest that is unrelated to predator removal.

f) Document changes in predator abundance/density, not just numbers removed, to ensure objectives of removal effort are met.

Literature Citations

Allen, M. L., L. M. Elbroch, C. C. Wilmers, and H. U. Wittmer. 2014. Trophic facilitation or limitation? Comparative effects of pumas and black bears on the scavenger community. PLoS One 9:e102257.

_______. 2007. Comparative patterns of predation by cougars and recolonizing wolves in Montana's Madison Range. The Journal of Wildlife Management 71:1098-1106.

Atwood, T. C., E. M. Gese, and K. E. Kunkel. 2009. Spatial partitioning of predation risk in a multiple predator-multiple prey system. The Journal of Wildlife Management 73:876-884.

Ballard, W. B., D. Lutz, T. W. Keegan, L. H. Carpenter, and J. C. deVos Jr. 2001. Deer-predator relationships: a review of recent North American studies with emphasis on mule and black-tailed deer. Wildlife Society Bulletin:99-115.

Bartmann, R. M., G. C. White, and L. H. Carpenter. 1992. Compensatory mortality in a Colorado mule deer population. Wildlife Monographs:3-39.

Bartnick, T. D., T. Van Deelen, H. B. Quigley, and D. Craighead. 2013. Variation in cougar (Puma concolor) predation habits during wolf (Canis lupus) recovery in the southern Greater Yellowstone Ecosystem. Canadian Journal of Zoology 91:82-93.

Bender, L. C., L. A. Lomas, and J. Browning. 2007. Condition, survival, and cause-specific mortality of adult female mule deer in north-central New Mexico. The Journal of Wildlife Management 71:1118-1124.

Berger, K. M., and M. M. Conner. 2008. Recolonizing wolves and mesopredator suppression of coyotes: impacts on pronghorn population dynamics. Ecological applications 18:599-612.

Berger, K. M., E. M. Gese, and J. Berger. 2008. Indirect effects and traditional trophic cascades: a test involving wolves, coyotes, and pronghorn. Ecology 89:818-828.

Bergman, E. J., C. J. Bishop, D. J. Freddy, G. C. White, and P. F. Doherty Jr. 2014. Habitat management influences overwinter survival of mule deer fawns in Colorado. The Journal of Wildlife Management 78:448-455.

Bishop, C. J., G. C. White, D. J. Freddy, B. E. Watkins, and T. R. Stephenson. 2009. Effect of enhanced nutrition on mule deer population rate of change. Wildlife Monographs 172:1-28.

Boulay, M. C., D. H. Jackson, and D. A. Immell. 1999. Preliminary assessment of a ballot initiative banning two methods of bear hunting in Oregon: effects on bear harvest. Ursus:179-184.

Brown, C. L., P. K. Coe, D. A. Clark, M. J. Wisdom, M. M. Rowland, J. P. Averett, and B. K. Johnson. 2022. Climate change effects on understory plant phenology: implications for large herbivore forage availability. Environmental Research: Ecology 1:011002.

Brown, D. E., and M. R. Conover. 2011. Effects of large-scale removal of coyotes on pronghorn and mule deer productivity and abundance. The Journal of Wildlife Management 75:876-882.

Clark, D. A., G. A. Davidson, B. K. Johnson, and R. G. Anthony. 2014. Cougar kill rates and prey selection in a multiple-prey system in northeast Oregon. The Journal of Wildlife Management 78:1161-1176.

Cooley, H. S., H. S. Robinson, R. B. Wielgus, and C. S. Lambert. 2008. Cougar prey selection in a white-tailed deer and mule deer community. The Journal of Wildlife Management 72:99-106.

DeCesare, N., M. Hebblewhite, H. Robinson, and M. Musiani. 2010. Endangered, apparently: the role of apparent competition in endangered species conservation. Animal conservation 13:353-362.

Elbroch, L. M., P. E. Lendrum, J. Newby, H. Quigley, and D. J. Thompson. 2015. Recolonizing wolves influence the realized niche of resident cougars. Zoological Studies 54:1-11.

Errington, P. L. 1956. Factors limiting higher vertebrate populations. Science 124:304-307.

Forrester, T. D., D. S. Casady, and H. U. Wittmer. 2015. Home sweet home: fitness consequences of site familiarity in female black-tailed deer. Behavioral Ecology and Sociobiology 69:603-612.

Forrester, T. D., and H. U. Wittmer. 2013. A review of the population dynamics of mule deer and black-tailed deer O docoileus hemionus in N orth A merica. Mammal Review 43:292-308.

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

Garrott, R. A., J. E. Bruggeman, M. S. Becker, S. T. Kalinowski, and P. J. White. 2007. Evaluating prey switching in wolf–ungulate systems. Ecological applications 17:1588-1597.

Hall, J. T. 2018. Survival of neonate mule deer fawns in southern Utah: Effects of coyote removal and synchrony of parturition. Brigham Young University.

Hamlin, K. L., S. J. Riley, D. Pyrah, A. R. Dood, and R. J. Mackie. 1984. Relationships among mule deer fawn mortality, coyotes, and alternate prey species during summer. The Journal of Wildlife Management:489-499.

Hatcher, M. J., J. T. Dick, and A. M. Dunn. 2006. How parasites affect interactions between competitors and predators. Ecology Letters 9:1253-1271.

Holt, R. D. 1977. Predation, apparent competition, and the structure of prey communities. Theoretical population biology 12:197-229.

Hurley, M. A., C. R. Anderson Jr, T. D. Forrester, and J. A. Gude. 2023. Carnivore-Prey Relationships. Pages 125-140 *in* Ecology and Management of Black-tailed and Mule Deer of North America. CRC Press.

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: Réponse Démographique du Cerf Mulet à la Réduction Expérimentale des Populations de Coyotes et de Pumas dans le Sud de l'Idaho. Wildlife Monographs 178:1-33.

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

Iriarte, J. A., W. L. Franklin, W. E. Johnson, and K. H. Redford. 1990. Biogeographic variation of food habits and body size of the America puma. Oecologia 85:185-190.

Knopff, K. H., A. A. Knopff, A. Kortello, and M. S. Boyce. 2010. Cougar kill rate and prey composition in a multiprey system. The Journal of Wildlife Management 74:1435-1447.

Kortello, A. D., T. E. Hurd, and D. L. Murray. 2007. Interactions between cougars (Puma concolor) and gray wolves (Canis lupus) in Banff National Park, Alberta. Ecoscience 14:214-222.

Krofel, M., I. Kos, and K. Jerina. 2012. The noble cats and the big bad scavengers: effects of dominant scavengers on solitary predators. Behavioral Ecology and Sociobiology 66:1297-1304.

Krumm, C. E., M. M. Conner, N. T. Hobbs, D. O. Hunter, and M. W. Miller. 2010. Mountain lions prey selectively on prion-infected mule deer. Biology Letters 6:209-211.

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

Lamb, S., B. R. McMillan, M. van de Kerk, P. B. Frandsen, K. R. Hersey, and R. T. Larsen. 2023. From conception to recruitment: Nutritional condition of the dam dictates the likelihood of success in a temperate ungulate. Frontiers in Ecology and Evolution 11:1090116.

Laundré, J., L. Hernández, and S. Clark. 2006. Impact of puma predation on the decline and recovery of a mule deer population in southeastern Idaho. Canadian Journal of Zoology 84:1555-1565.

Lingle, S. 2000. Seasonal variation in coyote feeding behaviour and mortality of white-tailed deer and mule deer. Canadian Journal of Zoology 78:85-99.

Logan, K. A., and L. L. Sweanor. 2001. Desert puma: evolutionary ecology and conservation of an enduring carnivore. Island press.

Mahoney, P. J., J. K. Young, K. R. Hersey, R. T. Larsen, B. R. McMillan, and D. C. Stoner. 2018. Spatial processes decouple management from objectives in a heterogeneous landscape: predator control as a case study. Ecological applications 28:786-797.

Metz, M. C., D. W. Smith, J. A. Vucetich, D. R. Stahler, and R. O. Peterson. 2012. Seasonal patterns of predation for gray wolves in the multi-prey system of Yellowstone National Park. Journal of Animal Ecology 81:553-563.

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 186:1-62.

Oregon Department of Fish and Wildlife. 2017. 2017 Oregon cougar management plan. ODFW. Salem, Oregon. 205 pp.

Orning, E. K., K. M. Dugger, and D. A. Clark. 2021. Gray wolf (Canis lupus) predation patterns following recent recolonization in a multi-predator, multi-prey system. Canadian Journal of Zoology 99:902-911.

Pierce, B. M., V. C. Bleich, K. L. Monteith, and R. T. Bowyer. 2012. Top-down versus bottom-up forcing: evidence from mountain lions and mule deer. Journal of Mammalogy 93:977-988.

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.

Ruprecht, J., C. E. Eriksson, T. D. Forrester, D. B. Spitz, D. A. Clark, M. J. Wisdom, M. Bianco, M. M. Rowland, J. B. Smith, and B. K. Johnson. 2021. Variable strategies to solve risk–reward tradeoffs in carnivore communities. Proceedings of the National Academy of Sciences 118:e2101614118.

Ruprecht, J., T. D. Forrester, N. J. Jackson, D. A. Clark, M. J. Wisdom, M. M. Rowland, J. B. Smith, K. M. Stewart, and T. Levi. 2022. A seasonal pulse of ungulate neonates influences space use by carnivores in a multi-predator, multi-prey system. Ecology and Evolution 12:e9389.

Shallow, J. R., M. A. Hurley, K. L. Monteith, and R. T. Bowyer. 2015. Cascading effects of habitat on maternal condition and life-history characteristics of neonatal mule deer. Journal of Mammalogy 96:194-205.

Smith, J. B. 2014. Determining impacts of mountain lions on bighorn sheep and other prey sources in the Black Hills.

Sunquist, M. E., and F. C. Sunquist. 1989. Ecological constraints on predation by large felids. Pages 283-301 *in* Carnivore behavior, ecology, and evolution. Springer.

Tollefson, T. N., L. A. Shipley, W. L. Myers, D. H. Keisler, and N. Dasgupta. 2010. Influence of summer and autumn nutrition on body condition and reproduction in lactating mule deer. The Journal of Wildlife Management 74:974-986.

Utah Division of Wildlife Resources. 2019. Utah mule deer statewide management plan. Utah Department of Natural Resources, Division of Wildlife Resources, Salt Lake City, USA.

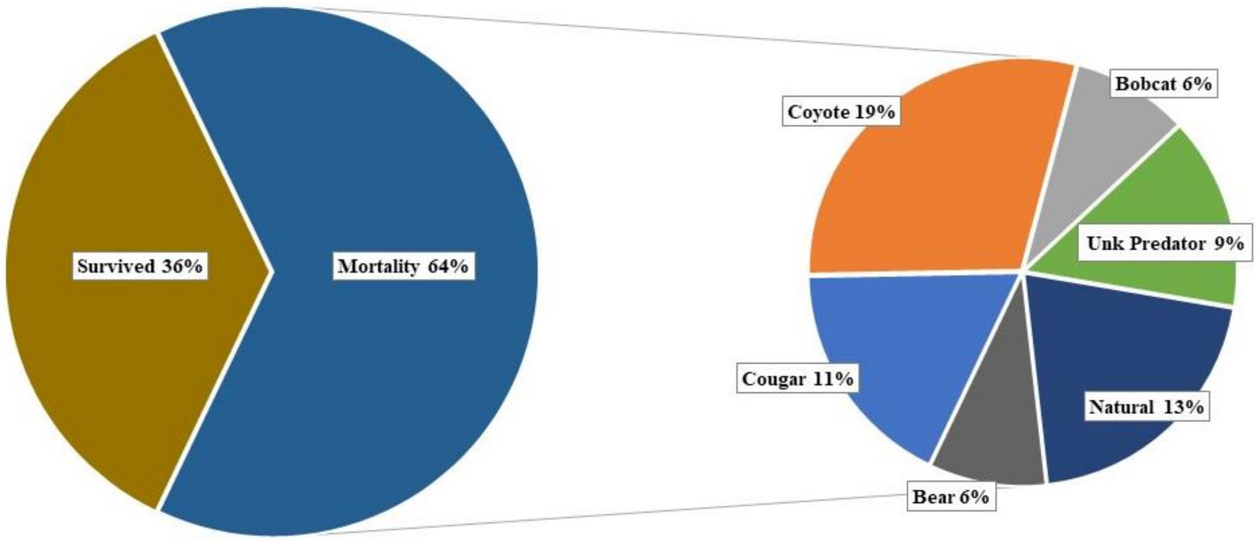
Villepique, J. T., B. M. Pierce, V. C. Bleich, and R. T. Bowyer. 2011. Diet of cougars (Puma concolor) following a decline in a population of mule deer (Odocoileus hemionus): lack of evidence for switching prey. The Southwestern Naturalist 56:187-192.

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 ratios in three wolf-ungulate systems. Journal of Animal Ecology 80:1236-1245.

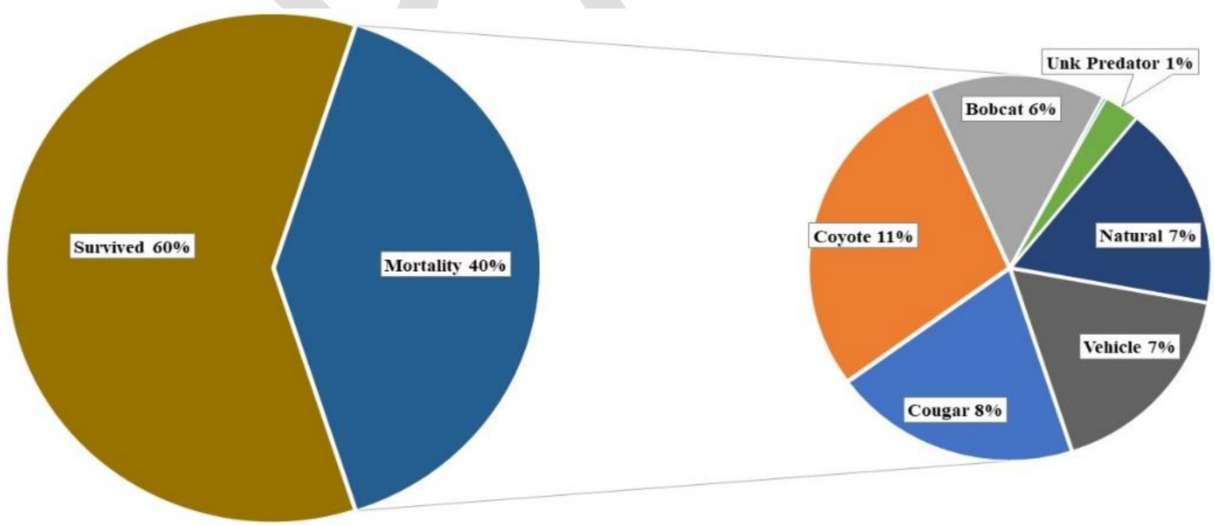
Wielgus, R. B. 2017. Resource competition and apparent competition in declining mule deer (Odocoileus hemionus). Canadian Journal of Zoology 95:499-504.

Figure 2. Known cause-specific mortality rates (e.g., unknowns were removed from sample) from mule deer A) neonates (0-4 months) from research project in Starkey Experimental Forest in eastern Oregon from 2014-2016 (Jackson et al. 2021), B) juveniles (6-12 months) from monitoring and research projects in eastern Oregon from 2019-2023, and C) adult female from monitoring and research projects in eastern Oregon from 2005-2023.

A) Newborn fawns (0-4 months) fates.



B) Juvenile (6-12 month old) fates.



C) Adult female fates.