Idaho Climate-Economy Impacts Assessment
Climate Effects on Ungulates

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Introduction

Ungulates, such as elk (*Cervus elaphus*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), moose (*Alces alces*), and pronghorn (*Antilocapra americana*) are ecologically and economically important in Idaho. Many ungulate populations also provide hunting and tourism opportunities. Understanding potential effects that climate change will have on ungulates is important to make sure that herds remain healthy. Understanding climate effects on winter survival is particularly important because winter is the season with the highest mortality rates (Kautz et al., 2020).

Snow and winter survival

Ungulates have been shown to select habitats with shallower snow (Kittle et al., 2008). However, with the exception of reindeer (*Rangifer tarandus*) and caribou (*Rangifer arcticus*), data on how ungulates respond to changes in snow density and hardness are generally lacking. Greater snow density and hardness because of frequent rain-on-snow and freeze-thaw events will increase the amount of energy that ungulates must expend while moving, escaping predation, and finding food over winter. Changes in snowpack may also indirectly affect ungulates through changes in migration timing and migration distance, vegetation phenology, fire regimes, and insect density and survival.

Snow increases the energetic cost of movement for many wildlife species. Movement costs grow as the depth, density, and hardness of the snow increase, either by intensifying the drag on the legs as an animal wades through snow or by compelling an animal to lift its legs higher to avoid having to wade through unfavorable snow (Parker et al., 1984). However, snow that is dense or hard enough may support an animal’s body weight so that they are able to walk on top of the snowpack rather than sink into it, allowing that animal to move efficiently even where snow is deep (Parker et al., 1984). Movement efficiency is further influenced by foot size, body size, and weight of an animal. The effects that greater snow density and hardness will have on ungulate movement is very dependent on the species, the size of individuals, and the speed at which animals are moving; regardless, greater snow density and hardness as a result of rain-on-snow and freeze-thaw events will generally increase energetic demands of ungulate movement over winter.

Blocked access to forage because of rain-on-snow and freeze-thaw events will prevent ungulates from keeping up with the energetic demands of winter. Access to forage can slow the rate at which an ungulate’s body weight decreases and prolong their survival (Hurley et al., 2014). Shrubs and tree limbs are often available above snow cover without much effort (Christenson et al., 2014). But for species that prefer to graze, such as elk and, to a lesser degree, deer, moving snow aside to access buried grasses can have substantial energetic costs (Christianson and Creel, 2007). As with movement, energetic costs associated with cratering increase as the depth, density, and hardness of the snow increase. When snow becomes too dense and hard, digging through it may not be possible or worth the energetic cost (Bruns, 1977; Skogland, 1978; Fortin et al., 2005).

Both greater cost of movement and decreased access to forage increase an ungulate's susceptibility to predation. Elk, deer, and moose sink deeper into snow than wolves (*Canis lupus*) and are thus hindered from escaping predation (Telfer and Kelsall, 1984). Escaping from wolves is even more difficult in the late winter when ungulates are already weak and the high density and hardness of the snow further limits their movement and foraging ability (Mech et al., 2001; DelGiudice et al., 2002; Kautz et al., 2020). However, wolves prefer to hunt either very young or very old individuals that are already at great risk of dying by other causes. Thus, wolves likely hunt animals that would have died that winter (Horne et al., 2019; Wilmers et al., 2019). By contrast, cougars (*Puma concolor*) are a stalking predator, so risk of predation by cougars probably will not change with changes in snow conditions. Cougar predation likely has a greater effect on ungulate populations because cougars also hunt healthy breeding-age individuals (Horne et al., 2019).

Growing seasons and foraging

Advancement of snowmelt timing also has advanced the timing of spring green-up, leading to a longer growing season (Klos et al., 2014). For ungulates, this means that forage is becoming available earlier in the spring as a result of climate change. Mule deer fawns have a higher overwinter survival rate after long growing seasons (Hurley et al., 2014). While longer growing seasons may be a benefit to ungulates in the short-term, these changes may have longer-term consequences. If plants are browsed on by ungulates for a long period of time, the quality of forage over time can decrease. Other factors, such as longer periods of drought, higher temperatures, greater fire frequency and severity, and more frequent soil freezing events, will place additional stress on vegetation communities and limit nutritional quality of forage available to ungulates (Christenson et al., 2014). Vegetation with low nutritional quality prevents ungulates from putting on the fat they need to survive the winter. Furthermore, a female in poor body condition may give birth to smaller offspring or give birth later in the year, both of which will increase their offspring's susceptibility to predation. Females may even choose not to breed at all (Horne et al., 2019).

Greater prevalence of exotic plant species as a result of climate change may further affect foraging opportunity for ungulates, though, interestingly, this effect is not necessarily negative. Medusahead (*Taeniatherum caput-medusae)* limits the growth of native plants in the places where it grows (Davies and Svejcar, 2008). Medusahead is rarely eaten by ungulates (Bodurtha et al., 1989; Davies and Svejcar, 2008). Two other high-profile invasives in Idaho, cheatgrass (*Bromus tectorum*) and spotted knapweed (*Centaurea stoebe*), may provide suitable forage for ungulates. Cheatgrass has been shown to be a major component of the diets of deer (Austin et al., 1994) and elk (Kohl et al., 2012) but not of pronghorn (Robinson et al., 2010). Spotted knapweed can be a major component of the diets of white-tailed deer, mule deer, and elk (Wright and Kelsey, 1997; Kohl et al., 2012). Spotted knapweed also is often available above snow when other forage species are buried (Wright and Kelsey, 1997). Though undesirable for a multitude of other wildlife species, the negative effects of cheatgrass and knapweed on ungulates may be limited. However, Kohl et al. (2012) caution that ungulates may help growth of invasive plants by intensifying soil disturbance and transmitting seeds.

Migration patterns and habitat

Ungulates also may slightly modify their migration behavior in response to climate change. Ungulates are short-distance migrants that generally occupy higher-elevation or cooler sites in the summer and warmer sites with minimal snow in the winter. White-tailed deer and pronghorn may not migrate if winter conditions are mild enough (Bruns, 1977; Weiskopf et al., 2019). In elk, timing of migration is driven by green-up in the spring and snow cover in the fall (Rickbeil et al., 2019). Changes in migration timing and distance will affect when and where ungulates will be found, which may affect vegetation structure, predator populations, and tourism and hunting opportunities (Rickbeil et al., 2019).

Limitations in winter habitat selection by white-tailed deer, mule deer, elk, and pronghorn have been attributed to snow cover and depth (Jenkins et al., 2007). Reductions in snow cover and depth may allow deer, elk, and pronghorn to expand their winter ranges northward and upslope (Weiskopf et al., 2019; Deb et al., 2020). But coyotes (*Canis latrans*) and wolves also are favored by lower snow cover and depth, as well as by increased density of snow on trails (Murray and Boutin, 1991; Droghini and Boutin, 2018). Pronghorn have been shown to migrate into higher-elevation sites with deeper snowpack to avoid fawn predation by coyotes (Barnowe-Meyer et al., 2010). Higher temperatures and spring moisture also will favor ticks and mosquitos, and heightened prevalence of tick- and mosquito-borne diseases may increase mortality rates in ungulates (Sonenshine, 2018; Ludwig et al., 2019).

Of Idaho's ungulates, moose are the best adapted to snow. However, changes in snow conditions are coincident with increases in average temperatures. Idaho is already on the southern edge of the moose's range; further increases in temperature are expected to push moose out of Idaho by 2080 (Deb et al., 2020). Additionally, moose are very susceptible to being parasitized by winter ticks (*Dermacentor albipictus*), which are favored by low snow cover (Holmes et al., 2018). High tick abundance is thought to be a major contributor to widespread moose population declines in the southern parts of their range (Jones et al., 2019).

<table>
<tr><th>Species</th><th>Movement</th><th>Foraging</th><th>Predation</th><th>Migration</th><th>Disease</th></tr>
<tr><td>White-tailed deer (Odocoileus virginianus)</td><td rowspan="2">Moderately adapted to movement in snow (Telfer and Kelsall, 1984).

Possible range expansion with losses in snow cover (Weiskopf et al., 2019; Deb et al., 2020).

Selection against areas with snow deeper than 38cm (DelGiudice et al., 2002; Christie et al., 2015).

Negative effects on energy expenditure with increases in snow density and hardness (Parker et al., 1984).</td><td rowspan="2">Browser and grazer.

Decreased ability to graze with increases in snow density and hardness (Bruns, 1977; Skogland, 1978).

Longer growing season gives longer access to vegetation but may also decrease vegetation quality over time (Rickbeil et al., 2019).

Positive effect of summer and fall forage quality and access on winter fawn survival (Hurley et al., 2014).</td><td rowspan="5">More predation by wolves on individuals in poor body condition. Increased relative predation risk in deeper snow. Increased snow density and hardness may quicken the rate at which ungulate body condition declines over winter (Mech et al., 2001; Horne et al., 2019; Kautz et al., 2020; Olson et al., 2021).

Possible range expansion of coyotes with decreases in snow depth and cover (Murray and Boutin, 1991; Barnowe-Meyer et al., 2010).

No change to cougar predation dependent on snow cover (Horne et al., 2019).</td><td rowspan="2">Non-migratory in mild winters (Nicholson et al., 1997; Weiskopf et al., 2019).</td><td rowspan="4">Susceptible to tick- and mosquito-borne diseases, which may become more prevalent with warmer temperatures and more precipitation (Sonenshine, 2018; Ludwig et al., 2019).</td></tr>
<tr><td>Mule deer (Odocoileus hemionus)</td></tr>
<tr><td>Rocky Mountain elk (Cervus elaphus)</td><td>Moderately adapted to movement in snow, but unable to spread toes to decrease foot loading (Telfer and Kelsall, 1984).

Selection against areas with snow deeper than 46cm (Parker et al., 1984).

Negative effects on energy expenditure with increases in snow density and hardness (Parker et al., 1984).</td><td rowspan="2">Browser and grazer, with strong preference for grazing (Bruns, 1977; Christianson and Creel, 2007).

Decreased ability to graze with increases in snow density and hardness (Bruns, 1977; Skogland, 1978).

Spend more time digging or dig larger craters when snow is shallower (Bruns, 1977; Fortin et al., 2005).

Longer growing season gives longer access to vegetation but may also decrease vegetation quality over time (Rickbeil et al., 2019).</td><td>Shifts in migration timing and distance dependent on foraging conditions (Rickbeil et al., 2019).</td></tr>
<tr><td>Pronghorn (Antilocapra americana)</td><td>Poorly adapted to movement in snow (Telfer and Kelsall, 1984).

Possible range expansion with losses in snow cover (Weiskopf et al., 2019; Deb et al., 2020).

Selection against areas with snow deeper than 36cm (Christie et al., 2015).

Negative effects on energy expenditure with increases in snow density and hardness (Parker et al., 1984).</td><td>Non-migratory in mild winters (Weiskopf et al., 2019).

Will migrate to places with deeper snow to avoid fawn predation by coyotes (Barnowe-Meyer et al., 2010).</td></tr>
<tr><td>Moose (Alces alces)</td><td>Well-adapted to movement in snow (Telfer and Kelsall, 1984).

Selection against areas with snow deeper than 60cm (Kittle et al., 2008).

Negative effects on energy expenditure with increases in snow density and hardness (Parker et al., 1984).</td><td>Browser.

Preference for browsing on snow-free vegetation (Christenson et al., 2014).

Longer growing season gives longer access to vegetation but may also decrease vegetation quality over time (Rickbeil et al., 2019).</td><td>Migrate in response to snowpack (Demarchi, 2003).</td><td>Heavily parasitized by winter tick; winter tick survival expected to increase with declines in snow cover (Holmes et al., 2018).</td></tr>
</table>

Table 1: Summary of climate effects on ungulate species.

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