Sensitivity

Climate stressors and disturbance regimes

Native ungulates, including Roosevelt Elk (Cervus elaphus roosevelti), Tule elk (C. Canadensis nannodes) California mule deer (Odocoileus hemionus californicus), and Columbian black-tailed deer (O. hemionus columbianus), are most sensitive to climate stressors and disturbances that affect forage availability or contribute to shifts in phenology or weather patterns that affect their migration timeline.

- **Increasing air temperatures and reductions in snowfall** may cause changes in plant phenology, which could alter patterns of seasonal migration (Walther et al. 2002; Bolger et al. 2008).
- **Warmer temperatures** in the fall may delay autumn migration, and leave animals at greater risk of sudden severe winter storms, which may increase nutritional, thermoregulatory, and movement costs, (Parker et al. 1984), and may increase the likelihood of predation (Bleich & Pierce 2001).
- **Increasing air temperatures and increased precipitation** in the spring promote rapid vegetation growth, accelerating the peak and decline of vegetation, and shortening the period of high quality forage (Post & Stenseth 1999). This could be detrimental to females if periods of high quality forage do not coincide with highest nutritional demand due to gestation and lactation (Post & Stenseth 1999).
- **Warming air temperatures and increases in humidity** may allow for range expansion and accelerated rates of development of parasitic nematodes and trematodes that infect ungulates (Jenkins et al. 2006), as well as increased emergence and infection rates of viral and bacterial pathogens (Gubler et al. 2001).
- **Warmer winters with less snowfall** tend to decrease the mortality rate of adults, but may lead to increased densities of ungulates, resulting in more competition and poorer body condition (Post & Stenseth 1999).
- **Increased frequency of drought** may decrease available vegetation and consumption by grazers, which could reduce body condition and nutrient flux from ungulates to the soil (Frank & McNaughton 1992).
- **High severity wildfires** damage habitat and burn vegetation, reducing winter forage (Frank & McNaughton 1992), and may force native ungulates to seek other forested areas in which to find cover. However, smaller patches of high severity fire that maintain more open habitats promote higher quality forage (Karuk Tribe Department of Natural Resources 2016).

Non-climate stressors

Non-climate stressors that contribute to the loss of habitat and forage availability, decrease foraging efficiency, and create barriers that affect migration exacerbate the effects of climate stressors.

- **Anthropogenic barriers including fencing, reservoir and road construction** interfere with ungulate migrations, and may lead to a rapid decline in populations (Bolger et al. 2008).
- **Agricultural expansion** causes habitat loss, and disturbs migrating ungulates (Bolger et al. 2008).
- **Logging and mining** create disturbances that can be detrimental to ungulates, particularly affecting deer during the fawning season, while clear-cuts reduce available cover (Loft et al. 1984).
- **Residential or commercial development** causes habitat loss and fragmentation, and may leave ungulates unable to descend to lower elevations when weather conditions become severe (Bolger et al. 2008).
- **Roads and trails** fragment habitat and cause some ungulates such as elk to move away from these human disturbances (Prokopenko et al. 2017). This movement increases energy expenditures, reduces fat reserves and decreases body condition, leading to lower winter survival rates (Prokopenko et al. 2017).
- **Human recreation, from hiking to hunting**, creates disturbances which affect the condition of some ungulates, especially elk, who forage less efficiently as they lose time to vigilance (Fortin et al. 2004).
- **Fire suppression practices** have led to declines in forage quantity and quality as well as tree encroachment of meadows, reducing ungulate habitat (Karuk Tribe Department of Natural Resources 2016).
Dependence on habitat and prey/forage species
Native ungulates are dependent on adequate forage, leaving them susceptible to phenological shifts (Walther et al. 2002). Inadequate forage will reduce the rate of nutrient flux through grazers, resulting in reduced nutrient cycling throughout the ecosystem, and reduced ecosystem function (Frank & McNaughton 1992).

Adaptive Capacity

Geographic extent
California mule deer are found west of the Sierra Nevada and south to the south coast, while the Columbia black-tailed deer are found in Northern California and the Pacific Northwest (CDFW 2017). Tule elk historically had a much larger range, but are now found in the Sacramento and San Joaquin Valleys, while Roosevelt elk are found in the lowland forests and heavy rain forests of the Pacific coast (Murie 2017).

Overall health and functional integrity
Habitat disturbance or loss occurring in migratory routes or calving grounds may lead to rapid population decline from which ungulates, with their delayed reproductive maturity, may not recover (Bolger et al. 2008).

Dispersal ability
Ungulates have a high dispersal ability, and relatively short dispersal distances compared to those of other mammals (Schloss et al. 2012). However, their dispersal may be affected by habitat loss, fragmentation, anthropogenic barriers to movement (Bolger et al. 2008), and resource availability (Schloss et al. 2012).

Life history diversity
Native ungulates have similar strategies and timing of reproduction (Tollefson et al. 2010), with varying timing, distances, and patterns of migration (Bolger et al. 2008).

Ability to resist/recover from stressors
Native ungulates may be able to keep pace with climate stressors (Schloss et al. 2012), but habitat loss or fragmentation combined with anthropogenic barriers blocking their ability to migrate may cause rapid population declines (Bolger et al. 2008). Juveniles are the most likely to be affected by stressors due to climate and non-climate related changes, while survival of adult females is largely unaffected (Gaillard et al. 1998).

Literature Cited

Draft vulnerability briefing for the Northern California Climate Adaptation Project.