

# Functional Diversity and Benchmarks

While each plant functions differently in an ecosystem context, the degrees of dissimilarity which exist between all species are unequal allowing them to clump together into groups. This observation has given rise to the notion of *Plant Functional Types*, shared attributes which unite similar species, and which bind how they affect ecosystems. Oftentimes, form follows function, and functions are hence referred to as forms. For example, Trees provide large amounts of shade, which in combination with their transpiration lower the temperature of areas. Plant functional types are quite often the easiest form of vegetation data to measure, and accordingly great amounts of work have been conducted on how they affect ecosystem function.

In Western Colorado, five major forms of plant functional types are often used to evaluate range conditions. These forms are: Trees, Shrubs, Grasses, and Forbs (or herbs), and each has been linked to affecting rangelands in multiple ways; theoretically their distributions and abundances are driven by variations in soil moisture throughout horizons (Sala et al. (1997)). Accordingly, in nearly all instances a mix of each of these groups, less trees, is best to maintain ecosystem services on BLM Land. In our area which features massive extents of Pinon-Juniper Woodland, trees when present, are included in this mix on ecological sites which they are more capable of surviving on over long periods relative to shrubs.

Semi-arid lands which are utilized as rangelands across the world are experiencing several common issues relating to shifts in the composition of their plant functional types (Archer & Predick (2014), Eldridge et al. (2016), Maestre et al. (2016), Diaz et al. (2007), Dalglish et al. (2010)). Namely, decreases in grasses whilst increases in woody species are occurring. In certain areas, the increases - or encroachment of - woody species may be split into encroachment of trees, and the transition to a shrub state in ecological sites which do not support trees. In nearly all lands utilized as rangelands around the world the cover of and species richness of perennial forbs decreases, while the cover of annual forbs increases (Diaz et al. (2007), West & Yorks (2006)).

The current increases in shrub cover relative to the cover of the herbaceous strata, grasses and forbs, are problematic for a variety of reasons. The increase in Trees at mixed grass-shrublands sites may decrease water available to grasses and shrubs but not non-native annual grasses (McIver et al. (2022)), as cattle depend on grasses and wildlife shrubs these decrease the ability of our lands to support either. Increases in shrubs at the expense of perennial grasses and forbs may increase the severity of site level drought (Wilson et al. (2018)), further shrubs and trees may foster higher severity fires (CITE). Increases in shrubs decrease soil stability, allowing increased erosion, increasing DUST ON SNOW, and is an irritant to human breathing (Munson et al. (2011)). Decreases in perennial grass may reduce competing non-native annuals from overtaking sites (Sheley & James (2010), Corbin & D'Antonio (2004), although a diversity of species may be best (Belnap & Sherrod (2008)). A decreases in forbs adversely affect wildlife feeding both directly and indirectly, and by decreasing the quality of habitats, the lack of perennial forbs are widely evident for species such as the Gunnison Sage-Grouse (Pennington et al. (2016)). These issues we are currently facing may be compounded in the future by problems which are only begin to become apparent.

While the major functional groups are capable of capturing considerable variation which predicts rangeland responses, they often maintain large amounts of variation with them (Lavorel et al. (2007), Funk et al. (2017)). And we believe that additional functional groups warrant attention in our area. As mentioned above C3 and C4 grasses have different responses to many environmental cues. Sprouting and non-sprouting shrubs differ widely in their responses to wildfire, and sites require different post fire management strategies. Annual and perennial forbs (life cycles), differ in their responsiveness to precipitation, with annuals declining rapidly in times of low precipitation.

# Methods

## Append Functional group information

# Results

Benchmark forb cover is generally low across all Ecological Sites in the study area, with a maximum expected cover at any site of 15% and the median mean value across all sites being 5.5%. In general these estimates focus on perennial species, as after they germinate nearly all of these species will retain some above ground biomass across each active growing season of their lives, whereas annual forbs may not germinate in drier years and hence have more across year variation in their abundance. As these values are intended to capture the variation of these Ecological Sites, and these estimates were presumably created within the last 20 years (see SECTION XX on ESD development), we would expect that the covers observed on AIM plots were close to the lower estimates of variability.

While nearly all plants produce less above-ground biomass during drought, additional complications with natural and climate induced mortality and the subsequent lack of recruitment of perennial forbs from the soil seed bank may contribute to sites not meeting benchmarks (Eziz et al. (2017), Casper (1996)). The establishment of both long and short lived forbs seems hampered during drought periods, and it may take several years after the cessation of a drought for the cover of perennial forbs to return to pre-drought conditions (Anderson & Inouye (2001)).

In particular it is probable that short lived perennial forbs, which generally only live a total of 2-4 years past their germination (Dalglish et al. (2010)) have widely decreased in areas during the drought (Torang et al. (2010), Anderson & Inouye (2001)). While they appear to be few scientifically conducted observations on perennial forb longevity, many perennial forbs seem to generally persist for one to two decades (but up to four are noted), and once established (i.e. they reach reproductive maturity) are able to survive a couple types of disturbances, such as drought (Treshow & Harper (1974), Lauenroth & Adler (2008), Morris et al. (2008)). However, given the duration of the current drought, and the merely episodic periods of normal moisture balances (SECTION XX), required to recruit new individuals, it is possible many of the long lived perennials have suffered non-drought induced mortality, and have not recruited individuals from the seed bank. Recovery of the above ground cover of both forms of perennial forbs may require periods of from 2-5 years in more mesic sage-steppe areas (Anderson & Inouye (2001)).

Particular areas across the field office which may be the most affected by forb declines may be those inherently lower water storing capacity; such as those with skeletal soils and short depths to bedrock, e.g. Salt Desert and considerable portions of Pinyon-Juniper Woodland. It has been observed that the soil depth of sites can be a highly, or the most, influential factor on survival of perennial forbs during times of drought (Davison et al. (2010), Nicole et al. (2011)). Accordingly, sites supporting Wyoming Big-Sage, some of which constitute our Gunnison Sage-Grouse habitat should be less affected.

The cover of shrubs, regardless of the drought conditions, is expected to be at the upper end and beyond the reference benchmark values (Figure XX). While some disagreement over the mechanistic causes of increases in shrub cover exist in the literature, from a management context the drivers may largely be attributed to: 1) An altered fire-cycle 2) increasing atmosphere CO<sub>2</sub> 3) improper grazing by livestock

which all lead to feedback loops enforced by changes in nutrient availability and cycling (Bestelmeyer et al. (2018))

Non-vascular plants mentioned .... -> -> enhance other veg which restores at shorter time periods, allow crust to come back in slowly, as restoration approaches still nascent?

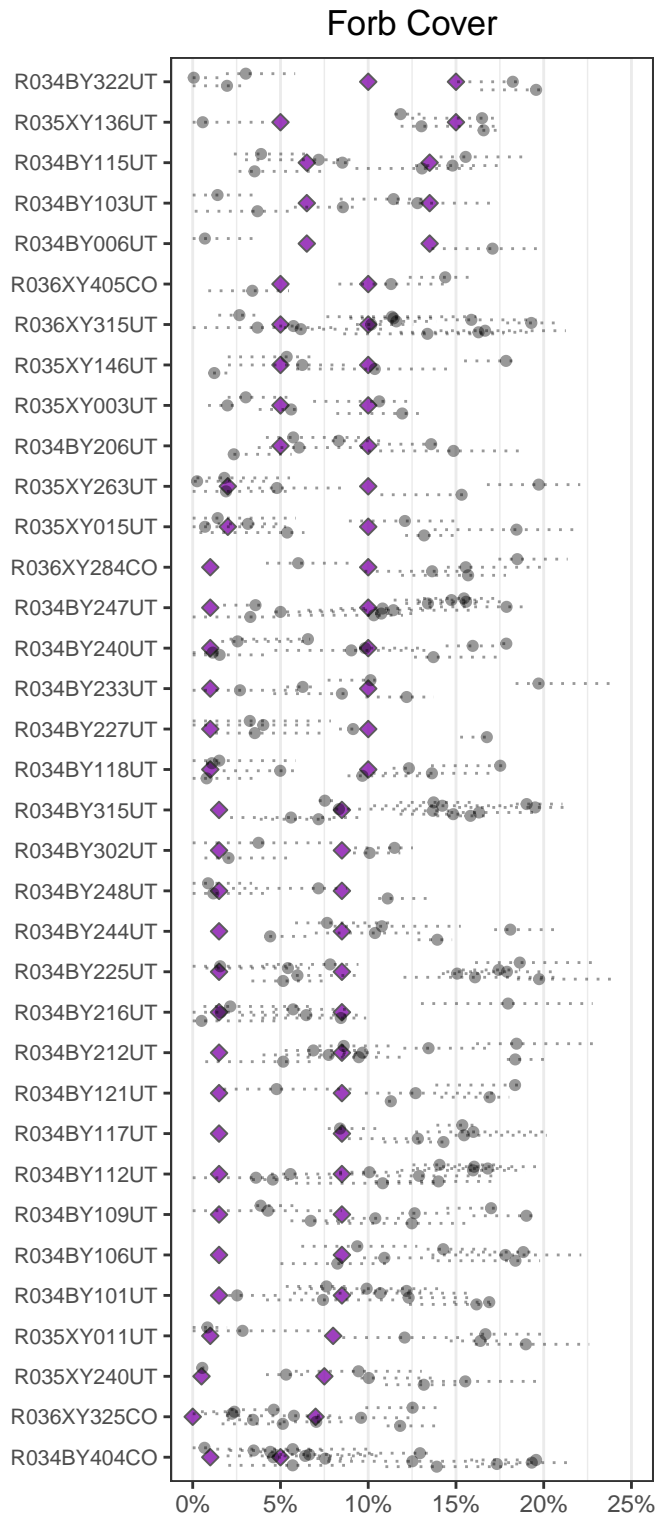


Figure 1: Forb Cover Benchmarks

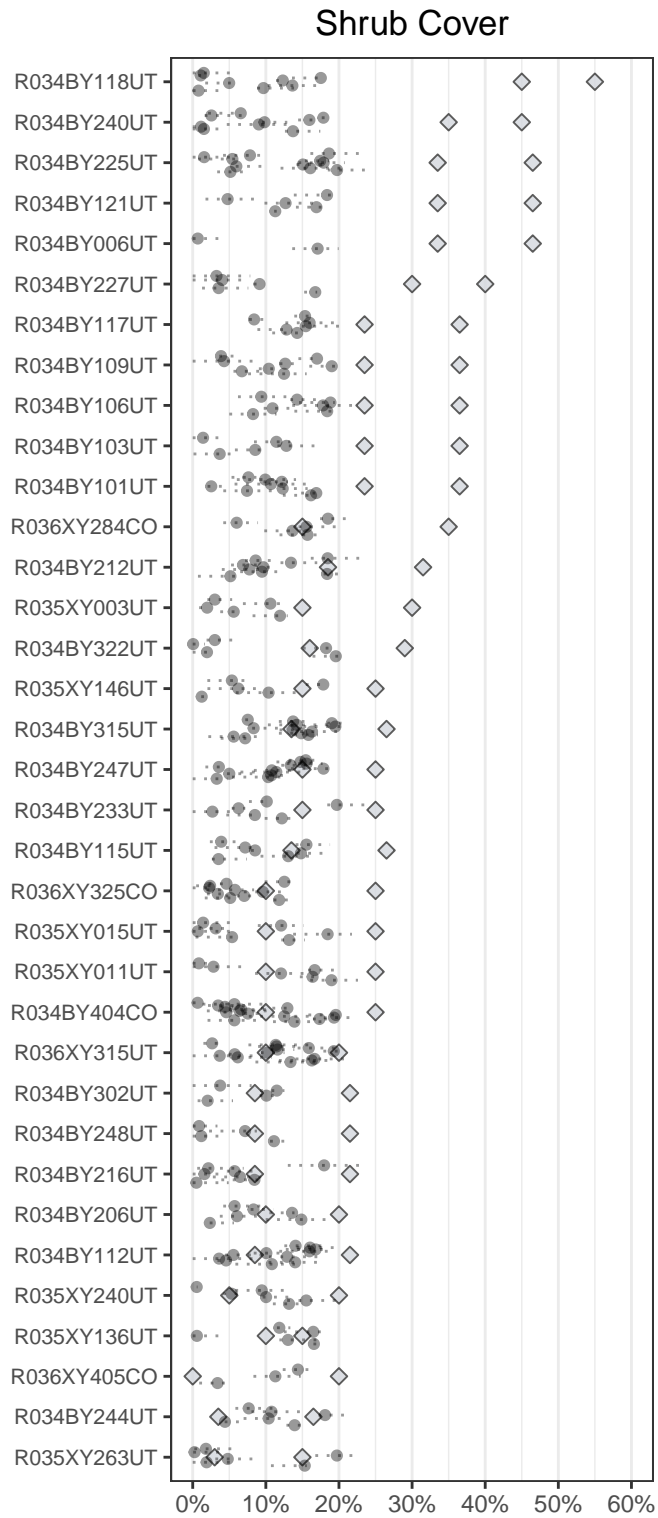


Figure 2: Shrub Cover Benchmarks

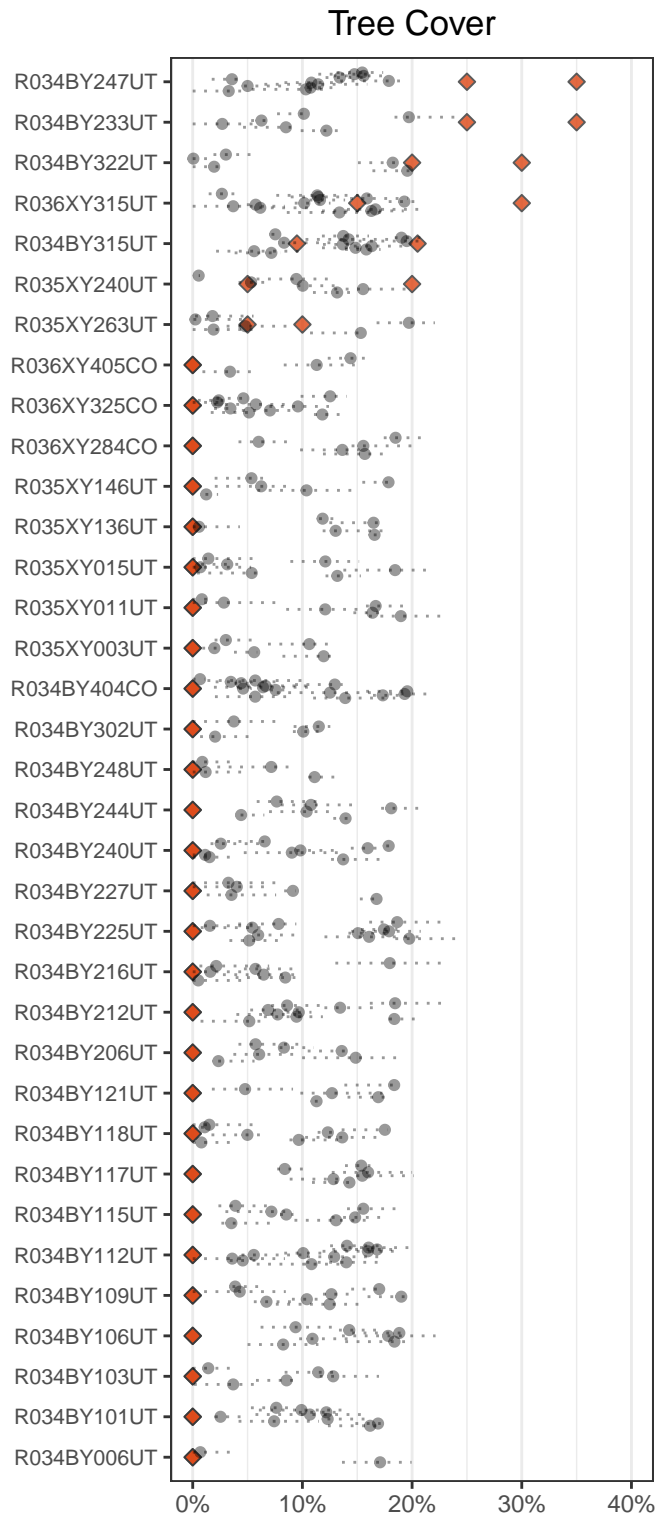


Figure 3: Tree Cover Benchmarks

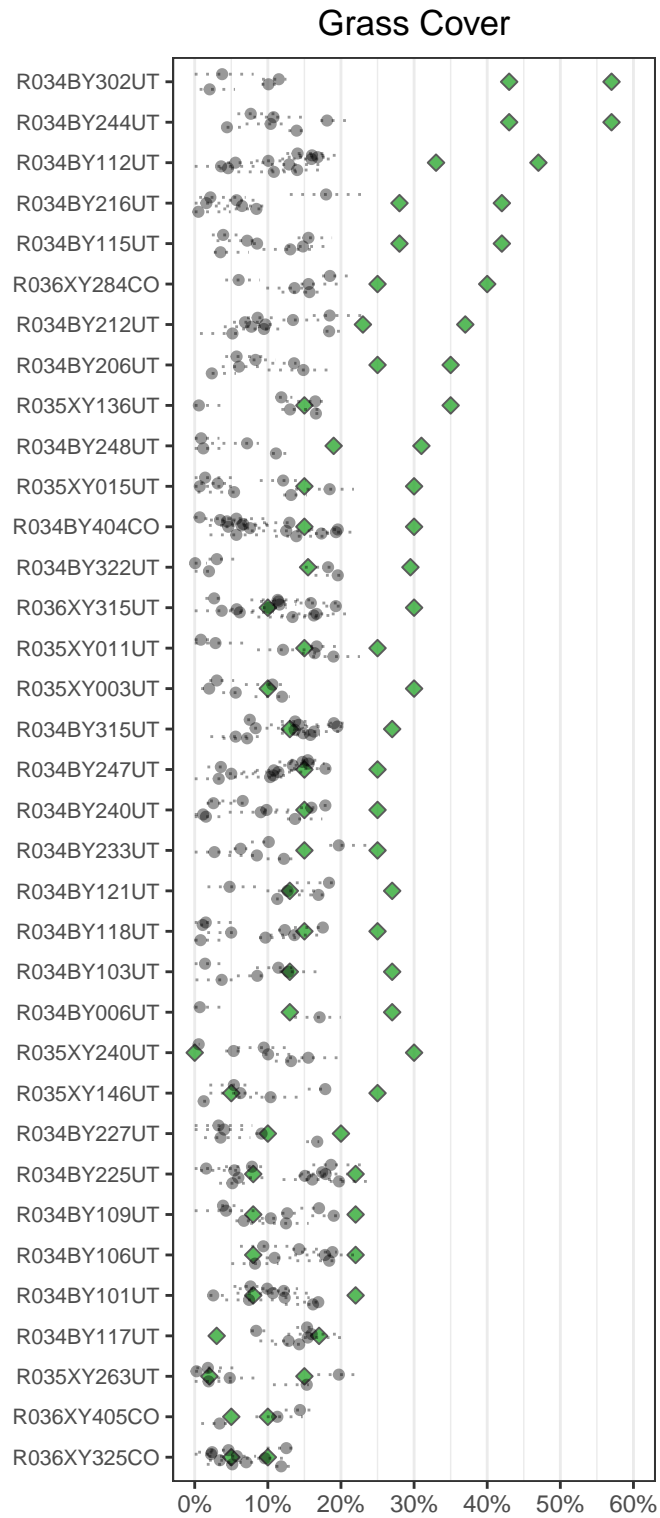


Figure 4: Grass Cover Benchmarks

## References

- Anderson, J. E., & Inouye, R. S. (2001). Landscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. *Ecological Monographs*, 71(4), 531–556.
- Archer, S. R., & Predick, K. I. (2014). An ecosystem services perspective on brush management: Research priorities for competing land-use objectives. *Journal of Ecology*, 102(6), 1394–1407.
- Belnap, J., & Sherrod, S. K. (2008). Soil amendment effects on the exotic annual grass *bromus tectorum* L. And facilitation of its growth by the native perennial grass *hilaria jamesii* (torr.) benth. In *Herbaceous plant ecology* (pp. 345–357). Springer.
- Bestelmeyer, B. T., Peters, D. P., Archer, S. R., Browning, D. M., Okin, G. S., Schooley, R. L., & Webb, N. P. (2018). The grassland–shrubland regime shift in the southwestern united states: Misconceptions and their implications for management. *BioScience*, 68(9), 678–690.
- Casper, B. B. (1996). Demographic consequences of drought in the herbaceous perennial *cryptantha flava*: Effects of density, associations with shrubs, and plant size. *Oecologia*, 106(2), 144–152.
- Corbin, J. D., & D’Antonio, C. M. (2004). Competition between native perennial and exotic annual grasses: Implications for an historical invasion. *Ecology*, 85(5), 1273–1283.
- Dalgleish, H. J., Koons, D. N., & Adler, P. B. (2010). Can life-history traits predict the response of forb populations to changes in climate variability? *Journal of Ecology*, 98(1), 209–217.
- Davison, R., Jacquemyn, H., Adriaens, D., Honnay, O., De Kroon, H., & Tuljapurkar, S. (2010). Demographic effects of extreme weather events on a short-lived calcareous grassland species: Stochastic life table response experiments. *Journal of Ecology*, 98(2), 255–267.
- Diaz, S., Lavorel, S., McIntyre, S., Falczuk, V., Casanoves, F., Milchunas, D. G., Skarpe, C., Rusch, G., Sternberg, M., Noy-Meir, I., et al. (2007). Plant trait responses to grazing—a global synthesis. *Global Change Biology*, 13(2), 313–341.
- Eldridge, D. J., Poore, A. G., Ruiz-Colmenero, M., Letnic, M., & Soliveres, S. (2016). Ecosystem structure, function, and composition in rangelands are negatively affected by livestock grazing. *Ecological Applications*, 26(4), 1273–1283.
- Eziz, A., Yan, Z., Tian, D., Han, W., Tang, Z., & Fang, J. (2017). Drought effect on plant biomass allocation: A meta-analysis. *Ecology and Evolution*, 7(24), 11002–11010.
- Funk, J. L., Larson, J. E., Ames, G. M., Butterfield, B. J., Cavender-Bares, J., Firn, J., Laughlin, D. C., Sutton-Grier, A. E., Williams, L., & Wright, J. (2017). Revisiting the holy grail: Using plant functional traits to understand ecological processes. *Biological Reviews*, 92(2), 1156–1173.
- Lauenroth, W. K., & Adler, P. B. (2008). Demography of perennial grassland plants: Survival, life expectancy and life span. *Journal of Ecology*, 96(5), 1023–1032.
- Lavorel, S., Diaz, S., Cornelissen, J. H. C., Garnier, E., Harrison, S. P., McIntyre, S., Pausas, J. G., Perez-Harguindeguy, N., Roumet, C., & Urcelay, C. (2007). Plant functional types: Are we getting any closer to the holy grail? In *Terrestrial ecosystems in a changing world* (pp. 149–164). Springer.
- Maestre, F. T., Eldridge, D. J., Soliveres, S., Kefi, S., Delgado-Baquerizo, M., Bowker, M. A., Garcia-Palacios, P., Gaitan, J., Gallardo, A., Lazaro, R., et al. (2016). Structure and functioning of dryland ecosystems in a changing world. *Annual Review of Ecology, Evolution, and Systematics*, 47, 215.
- McIver, J., Grace, J. B., & Roundy, B. (2022). Pion and juniper tree removal increases available soil water, driving understory response in a sage-steppe ecosystem. *Ecosphere*, 13(11), e4279.
- Morris, W. F., Pfister, C. A., Tuljapurkar, S., Haridas, C. V., Boggs, C. L., Boyce, M. S., Bruna, E. M., Church, D. R., Coulson, T., Doak, D. F., et al. (2008). Longevity can buffer plant and animal populations against changing climatic variability. *Ecology*, 89(1), 19–25.
- Munson, S. M., Belnap, J., & Okin, G. S. (2011). Responses of wind erosion to climate-induced vegetation changes on the colorado plateau. *Proceedings of the National Academy of Sciences*, 108(10), 3854–3859.
- Nicole, F., Dahlgren, J. P., Vivat, A., Till-Bottraud, I., & Ehrlén, J. (2011). Interdependent effects of habitat quality and climate on population growth of an endangered plant. *Journal of Ecology*, 99(5), 1211–1218.
- Pennington, V. E., Schlaepfer, D. R., Beck, J. L., Bradford, J. B., Palmquist, K. A., & Lauenroth, W. K. (2016). Sagebrush, greater sage-grouse, and the occurrence and importance of forbs. *Western North American Naturalist*, 76(3), 298–312.
- Sala, O., Lauenroth, W., & Golluscio, R. (1997). 11 plant functional types in temperate semi-arid regions. *Plant Functional Types: Their Relevance to Ecosystem Properties and Global Change*, 1, 217.

- Sheley, R. L., & James, J. (2010). Resistance of native plant functional groups to invasion by medusahead (*taeniatherum caput-medusae*). *Invasive Plant Science and Management*, 3(3), 294–300.
- Torang, P., Ehrlen, J., & Aagren, J. (2010). Linking environmental and demographic data to predict future population viability of a perennial herb. *Oecologia*, 163(1), 99–109.
- Treshow, M., & Harper, K. (1974). Longevity of perennial forbs and grasses. *Oikos*, 93–96.
- West, N. E., & Yorks, T. P. (2006). Long-term interactions of climate, productivity, species richness, and growth form in relictual sagebrush steppe plant communities. *Western North American Naturalist*, 66(4), 502–526.
- Wilson, S. D., Schlaepfer, D., Bradford, J., Lauenroth, W., Duniway, M., Hall, S., Jamiyansharav, K., Jia, G., Lkhagva, A., Munson, S., et al. (2018). Functional group, biomass, and climate change effects on ecological drought in semiarid grasslands. *Journal of Geophysical Research: Biogeosciences*, 123(3), 1072–1085.