Plant Species Diversity

Diversity, which after evolution - a process inextricably linked to it, may be the penultimate topic of interest in the Natural Sciences. Diversity, the variety of form and features in each dimension of our existences, extends in myriad directions. The diversity of the natural world is recognizable to the non-specialist as a variety of habitats, *physiognomic* types of plants, and oftentimes species. The diversity of organisms may be recognized by specialists with the use of their tools to detect the presence of genes in species, and the copies of variants of these genes. Accordingly a whole slew of metrics to measure and discuss diversity exist. In this section we discuss two very simple forms of diversity.

Alpha-diversity - or species richness, is simply the number of species in a space at a point in time. The scale at which we discuss $\alpha - diversity$ is usually up to a few footballs in size. This metric refers to areas which we are intimately familiar with and may traverse readily on foot. *Gamma-Diversity*, represents the richness of species in a larger area, generally a landscape. For example, we may readily discuss the $\gamma - diversity$ of the Dominguez-Escalente National Monument. In all instances the alpha diversity of many sites are nested within the gamma diversity of an area. Gamma diversities -in this case the number of species- exceed those of alpha diversities, both due to the relative uncommonness of many species, these uncommon species are often not present across the entirety of the landscape, and due to the large changes in the type of species supported by the habitats. These turnovers across the alpha diversity of sites, the difference in species present at sites, comprise *beta-diversity*. High rates of $\beta - diversity$, or dissimilarity of sites, foster high rates of gamma-diversity. We will not discuss it in depth here (Whittaker (1972)).

Evolution, the process largely mediating the maintenance of diversity, is survival of the fittest. However, the conditions of the test which may constitute the 'fittest' are nearly as numerous as the forms of diversity. Many species which exist in the same location in space, have distinct characteristics which allow for them to persist; dry years favor some species, while wet years favor others, some require more sun, while others thrive with less, the permutations and combinations of these settings go on *ad nauseum*. The cover of these species ebb and flow with the usual weather and disturbances within the climate zone of the site (Hoover et al. (2014), . . .). These trends are especially important for the production of forage and browse, over the life of most large animals, they will have to feed on what they have available. No single species is the fittest at a site on a time scale which the BLM manages land, having multiple species which function similarly in space is the only stable strategy for management.

While Ecological Site Descriptions do not provide true measures of $\alpha - diversity$ - a list of all taxa which may grow at a site - many of them do contain lists of taxa which may be considered *dominant* or *subordinate* at a site (Avolio et al. (2019), Grime (1998)). In general, it seems that the Shrubs, Trees, and Grasses at an Ecological Site would be considered *dominant*, and the forbs *subordinate*; keep in mind these terms refer to immediate ecosystem cycling effects, and the services offered by forbs to insects and then larger animals remain substantial (Avolio et al. (2019)). These species which have high amounts of biomass, and ground cover, may be thought of as a core groups of species which are essential for the functioning of an ecosystem (Grime (1998)), and each of the dominant species have been theorized to have conceptual effects as large as their cover. When dominant and subordinate species are lost from an area, it also has effects on the remaining species - most of which are relatively uncommon across the landscape (Grime (1998), Whittaker (1965)). Considerable research has shown that having a diverse suite of plant species allows areas to: 1) Produce more forage in both a single year, and across different weather scenarios (Vogel et al. (2012), Hoover et al. (2014)), 2) recover from disturbances such as fire, or compaction (Tilman & Downing (1994)) 3) and resist degradation such as from the encroachment of noxious weeds (Weisser et al. (2017), Avolio et al. (2019), Allan et al. (2011), Gaitan et al. (2014), Sheley & James (2010), Isbell et al. (2011), Oakley & Knox (2013), *and reviewed in* Maestre et al. (2016), Oliver et al. (2015)).

Recruitment of native species back following drought may have issues pertaining to seed recruitment. . . Tilman & El Haddi (1992) .. although soil seeds banks in arid systems well.

Given the generally high % abundance of the taxa listed in the species tables ESD's it is unlikely that they are truly lost, and should at least show in species richness meanders which have higher probability of uncovering more microhabitats, areas which individuals may have more access to water or other . . . Hooper et al. (2005)

Information on production at Ecological Sites implies some superficial, yet essential, components of plant diversity. Here we determine what proportion of species identified in ESD production tables are present at each AIM plot, how many are missing, and whether any species are uniformly missing. We also combine plots by ES to determine $\gamma - diversity$ by site, and compare the relative turn over in species composition within each Ecological Site which has replicate plots.

Methods

In order to determine which, and how many, species are noted to be dominant members of the vegetation at an Ecological Site, all ESD's for which an AIM plot was verified to were checked. All conditions (e.g. all State/Phase combinations which were present) of the reference tables were copied from these manually into spreadsheets, and data were cleaned using R. The USDA symbols utilized in these tables, were verified to match to the look up tables which were created for our project, to ensure that the same species between the two data sources could not be 'missed' due to using different abbreviation codes. Given that only two species (*Pinus monophylla*, *Junipers osteosperma*) were ever considered to be true 'Trees' under both systems, this lifeforms was dropped from all analyses to focus on the more variable groups.
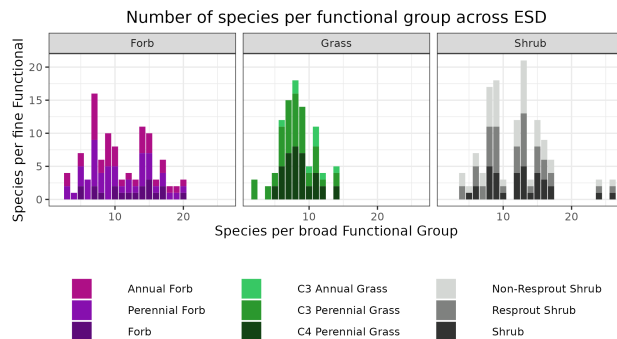

Figure 1: Number of Species Per Functional Groups

In order to be able to make comparisons across functional groups, for each species present in both the ESD's and our plot based data, we ensured that they drew from the same attribute table. This was especially important for situations where sub shrubs are alternatively classified as forbs or shrubs depending on context. After performing this, we recovered both the 'coarse' functional groups used by the AIM team, which correspond largely to the botanical notion of 'lifeforms'. Subsequently, using the developed attribute tables finer functional groups, developed locally, which reflect the propensity of major groups of these lifeforms to respond to various disturbances, such as drought (e.g. C3 and C4 grasses), and fire (non-resprout and re-sprouting shrubs). In instances where more fine scale functional data were not available, such as was the case for sprouting potential of many shrub species, than species were left at this level rather than attempting to determine an appropriate group for them.

The calculation of all, previously mentioned, forms of diversity were not carried out for each individual plot. All plots had $\alpha - diversity$, the number of unique species per plot calculated. However, plots which lacked Ecological Sites, were unable to have $\gamma - diversity$, and subsequently $\beta - diversity$ calculated. Ecological Sites which lacked reference tables were able to have these calculations performed, as they are independent of the Descriptions. Calculations of $\beta - diversity$, wherein only plots belonging to the same Ecological Sites were compared, were performed using the 'vegdist' function from the package 'vegan', with standard defaults and as Sorenson-Dice dissimilarity (Oksanen et al. (2022), Sorensen (1948), Dice (1945)).

$$\text{Sorenson-Dice Index} = \frac{(2 \times \text{No. Species Site 1} \cap \text{Site 2})}{(\text{No. Species Site 1} + \text{No. Species Site 2})}$$

Wherein the number of species which are shared ("∩") between two sites are multiplied by 2, and divided by the total number of species at both sites.

The data collected by two distinct methods, Line-Point Intercept, and Species Richness, were both compared to the ESD reference data to determine which more closely reflected the benchmark values. After visual exploration of these data displayed in several plots (including Figure 2), it was determined that the Species Richness data more adequately reflected the Benchmarks values and it was used for all subsequent analyses.
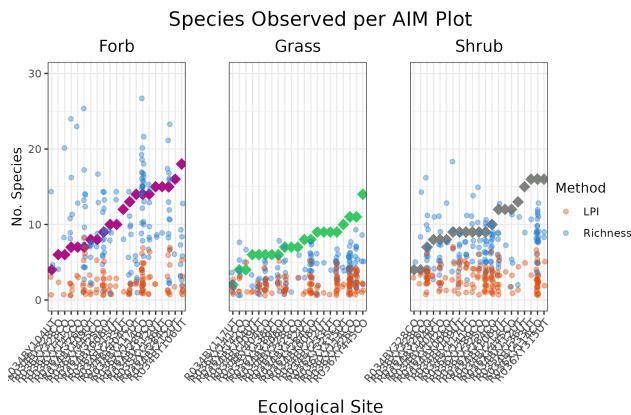
Discussion

Figure 2: Number of Species Per Coarse Functional Groups

Species richness data contained a total 7525 records, which after removal of unidentified material left ~~6417~~ 6227 species records at 276 plots which were verified to Ecological Sites. 30 Ecological Sites had more than two AIM plots located in them, and had $\beta - diversity$ calculated for all plots 224 located in them.

While the species within any one reference table in an Ecological Site Descriptions are noted to represent the dominant species across a gradient which stratifies the Ecological Site, such as elevation, many of our plots contained an adequate number of these species per functional group. In fact, when considering the richness data, which we suspect is a more apt dataset for comparing to the ESD taxa, many of our plots had the number of species expected in the reference table, for both the Forb and Shrub functional groups. For Shrubs it appears that the Ecological Sites which are meant to have the greatest number of shrub species do not reach these goals; and that perhaps only for these sites is the species representing the gradients of the Ecological Site utilized. Accordingly, it is unlikely that these tables represent variables collected in a consistent manner; regardless they offer clear insights. The number of grass species, in only a handful of plots, meets or exceeds the numbers of grass species noted present in reference conditions in all ESD's. Anecdotally, grass species which appear to be missing from expanses of the field office include two species of *Sporobolus* (*C. airoides*, and *C. cryptandrus*), *Koeleria macrantha*, with noted declines in *Hesperostipa comata* in areas as well.

The number of identified plant species varied widely by plot, from 2 - 54 (Med = 23), with a simple linear model indicating that elevation was a strong predictor. The number of plant species per ecological site varied mostly as a function of the number of plots which had been sampled per Ecological Site. This, alongside rarefaction curves, indicate that we do not yet have enough replicates per Ecological Site to identify their capacity to hold amounts of species. Currently, two Ecological sites with 29, 28 sampled plots contain 187, 201 unique identified species. Given the total number of plants observed on AIM plots (Section X.X), this constitute environments holding nearly a 1/3 of this $\alpha - diversity$ themselves. Estimates of $\beta - diversity$ appear less influenced by the number of plots sampled and $\gamma - diversity$, or surprisingly elevation. The discord between elevation is surprising given that $\beta - diversity$ was initially conceived to largely operate along elevation gradients, and oftentimes does. The mean beta diversity, that is the dissimilarity between plots varied from 0.54 - 0.88, with lower values indicating greater differences between plots; and where the Ecological site with the most dissimilar plots, on average, containing just over half (0.54) of the same species as each other.

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References

Allan, E., Weisser, W., Weigelt, A., Roscher, C., Fischer, M., & Hillebrand, H. (2011). More diverse plant communities have higher functioning over time due to turnover in complementary dominant species. *Proceedings of the National Academy of Sciences*, *108*(41), 17034–17039.

Avolio, M. L., Forrestel, E. J., Chang, C. C., La Pierre, K. J., Burghardt, K. T., & Smith, M. D. (2019). Demystifying dominant species. *New Phytologist*, *223*(3), 1106–1126.

Dice, L. R. (1945). Measures of the amount of ecologic association between species. *Ecology*, *26*(3), 297–302.

Gaitan, J. J., Oliva, G. E., Bran, D. E., Maestre, F. T., Aguiar, M. R., Jobbagy, E. G., Buono, G. G., Ferrante, D., Nakamatsu, V. B., Ciari, G., et al. (2014). Vegetation structure is as important as climate for explaining ecosystem function across p atagonian rangelands. *Journal of Ecology*, *102*(6), 1419–1428.

Grime, J. (1998). Benefits of plant diversity to ecosystems: Immediate, filter and founder effects. *Journal of Ecology*, *86*(6), 902–910.

Hooper, D. U., Chapin III, F. S., Ewel, J. J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J. H., Lodge, D., Loreau, M., Naeem, S., et al. (2005). Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. *Ecological Monographs*, *75*(1), 3–35.

Hoover, D. L., Knapp, A. K., & Smith, M. D. (2014). Resistance and resilience of a grassland ecosystem to climate extremes. *Ecology*, *95*(9), 2646–2656.

Isbell, F., Calcagno, V., Hector, A., Connolly, J., Harpole, W. S., Reich, P. B., Scherer-Lorenzen, M., Schmid, B., Tilman, D., Van Ruijven, J., et al. (2011). High plant diversity is needed to maintain ecosystem services. *Nature*, *477*(7363), 199–202.

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.

Oakley, C. A., & Knox, J. S. (2013). Plant species richness increases resistance to invasion by non-resident plant species during grassland restoration. *Applied Vegetation Science*, *16*(1), 21–28.

Oksanen, J., Simpson, G. L., Blanchet, F. G., Kindt, R., Legendre, P., Minchin, P. R., O'Hara, R. B., Solymos, P., Stevens, M. H. H., Szoecs, E., Wagner, H., Barbour, M., Bedward, M., Bolker, B., Borcard, D., Carvalho, G., Chirico, M., Caceres, M. D., Durand, S., . . . Weedon, J. (2022). *Vegan: Community ecology package*. https://CRAN.R-project.org/package=vegan

Oliver, T. H., Heard, M. S., Isaac, N. J., Roy, D. B., Procter, D., Eigenbrod, F., Freckleton, R., Hector, A., Orme, C. D. L., Petchey, O. L., et al. (2015). Biodiversity and resilience of ecosystem functions. *Trends in Ecology & Evolution*, *30*(11), 673–684.

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.

Sorensen, T. A. (1948). A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on danish commons. *Biol. Skar.*, *5*, 1–34.

Tilman, D., & Downing, J. A. (1994). Biodiversity and stability in grasslands. *Nature*, *367*(6461), 363–365.

Tilman, D., & El Haddi, A. (1992). Drought and biodiversity in grasslands. *Oecologia*, *89*(2), 257–264.

Vogel, A., Scherer-Lorenzen, M., & Weigelt, A. (2012). Grassland resistance and resilience after drought depends on management intensity and species richness. *PloS One*, *7*(5), e36992.

Weisser, W. W., Roscher, C., Meyer, S. T., Ebeling, A., Luo, G., Allan, E., Bessler, H., Barnard, R. L., Buchmann, N., Buscot, F., et al. (2017). Biodiversity effects on ecosystem functioning in a 15-year grassland experiment: Patterns, mechanisms, and open questions. *Basic and Applied Ecology*, *23*, 1–73.

Whittaker, R. H. (1965). Dominance and diversity in land plant communities: Numerical relations of species express the importance of competition in community function and evolution. *Science*, *147*(3655), 250–260.

Whittaker, R. H. (1972). Evolution and measurement of species diversity. *Taxon*, *21*(2-3), 213–251.