**Bold text is rough paragraph topics/potential topic sentence ideas**

Normal text is rough ideas that could be discussed in a paragraph.

* **Biodiversity is declining because of global change and there is an asymmetry in the loss of biodiversity.**
  + Specifically, habitat loss and fragmentation, introduced species, and changing climates alter the composition of vector and plant communities.
  + Higher trophic levels tend to be more sensitive to change, so we may expect the loss of vector diversity to drive the change (vectors are the ones changing first as a result of global change).
* **Plants importance to ecosystems connected to animals.**
  + Why do we care about plants relationships with animals and how do they interact with each other.
* **There is increasing concern with seed vectors (e.g., frugivores) because they play a vital role in dispersing seeds in the environment, however, most of that work is in particular systems with more specialized mutualisms...**
  + Discuss examples of declining frugivore diversity.
  + Discuss how declining diversity will impair that functional role (seed dispersal)
  + Discuss examples of declining or extinct plant species as a result of the loss of vectors.
  + We tend to simplify the experiment (we look at dispersal of one plant species/vector as model systems) rather than focus on diversity.
  + Simple systems or more specialized dispersal relationships should be particularly sensitive to declining frugivore diversity ([Herrera and Jordano, 1981](https://doi.org/10.2307/2937263)).
  + However, most global dispersal mutualisms are diffuse and contain functional redundancies.
  + When we do focus on diversity of plants/animals or diffuse mutualisms the experiment tends to explore lower trophic level (i.e., plants).
  + It is less clear how impairment of vector diversity might influence this dispersal in diffuse mutualisms.
  + Declining frugivore diversity is hypothesized to impact dispersal negatively when some fruits can only be dispersed by a subset of dispersers ([Carvalho et al. 2020](https://doi.org/10.1111/1365-2745.13534)).
  + In the tropics, the loss of large frugivores can strengthen dispersal limitation and limit dispersal distances.
  + In other systems, there is more overlap/redundancy (i.e., other dispersers could compensate; [Stiles, 1980](https://www.journals.uchicago.edu/doi/abs/10.1086/283657); [Wheelwright, 1988](https://doi.org/10.1016/0169-5347(88)90061-4)).
  + Discuss examples of functional redundancy in diffuse mutualisms (i.e., many plants/animals species doing overlapping dispersal relationships, less dichotomy between large and small bodied dispersers).
  + This calls into question whether tropical dispersal research applies to other areas and indicates the need to identify general patterns describing how global change affects seed dispersal relationships.
* **In diffuse mutualisms with functionally redundant seed disperser assemblages, resource diversity may modulate seed dispersal more than the loss of individual species.**
  + A general underlying theme in dispersal ecology is that seeds are dispersed towards resources.
  + Define resources (not necessarily food).
  + There has been a lot of work for mechanisms explaining seed rain being attracted to resources because animals are attracted to resources.
  + There is a lot of work about abundance/quality (size, other characteristics), but less is done with resource diversity, which is particularly relevant to diffuse mutualisms.
  + In a diffuse mutualism, all three of those resource qualities are probably being influenced by the number of plant/animal species involved.
  + We don't know how robust that is to impairment of bird species.
  + We know that plant diversity declines can impair seed dispersal, but bird diversity is unknown.
  + Both should be robust due to functional redundancy.
* **what we did**
  + Diversity of plant resources leads to the diversity of vectors, and coevolution between vectors and plants is thought to be positive feedback.
  + So the diversity of resources should lead to diversity of bird vectors, which should increase the diversity of seed rain toward resources.
  + The concerning thing about global change is the loss of diversity, which is relevant for most species in diffuse mutualism.
  + In systems with a lot of functional redundancy, declining resource diversity may be more important than vector diversity.
  + Given the diffuse mutualisms in temperate forests often involve many bird species, which are important for seed dispersal, we focused on birds and plant species that are bird-dispersed.
  + One of the most important vectors is birds. A lot of work focuses on them. It is common to take groups of species to represent patterns in the larger community).
  + This system is useful for studying the role of vector and resource diversity in determining the magnitude and richness of seed rain because the low diversity of vectors allows for the effect of resource diversity to be isolated.
  + We hypothesized that resource diversity drives the magnitude and richness of seed dispersal by increasing bird activity.
  + First, we demonstrated that our resource (i.e., bird feeders) increases seed rain.
  + Next, we used varying levels of resource richness to assess the effect on seed dispersal and bird behavior.

**Diffuse mutualism text and citations:**

“Early researchers, observing variation in seed size and fruit nutritional content, as well as vertebrate behavioral and ecological traits, hypothesized that tradeoffs in investment toward plant reproduction would be reflected in dispersal quality, leading to coevolved, specialized relationships ([Snow, 1965](https://doi.org/10.2307/3565124); [Wenny, 2001](http://www.evolutionary-ecology.com/issues/v03n01/ggar1226.pdf)). Accordingly, they predicted large seeds from nutrient-rich fruit to be directly dispersed by restricted groups of animals, whereas small seeds from nutrient-poor fruit were thought to be randomly dispersed by large groups of animals (i.e., colonization: [Wheelwright & Orians, 1982](https://www.journals.uchicago.edu/doi/abs/10.1086/283918)). As more studies were conducted, however, researchers found no examples of exclusive “one to one” dispersal relationships and relatively few examples restricted to small groups of plants and animals (Wheelwright & Orians, 1982; [Howe, 1984](https://doi.org/10.2307/1942454); Herrera, 1985, 1986b; Malmborg & Willson, 1988), indicating a diffuse evolutionary history for most plant-animal dispersal relationships (Herrera, 1985; Wheelwright, 1988).”

Herrera, C. M. (1985). Determinants of plant-animal coevolution: The case of mutualistic dispersal of seeds by vertebrates. *Oikos* **44**, 132–141.

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Malmborg, P. K. & Willson, M. F. (1988). Foraging ecology of avian frugivores and some consequences for seed dispersal in an illinois woodlot’. *The Condor* **90**, 173–186.

**Resource tracking text and citations:**

“First, vector behavior is strongly skewed toward resources (i.e., resource tracking; e.g., Swihart, Slade, & Bergstrom, 1988; Fleming, 1992; García, Zamora, & Amico, 2011; Hampe, 2008; Telleri, Ramirez, & Pérez-Tris, 2008; [Côrtes & Uriarte, 2013](https://doi.org/10.1111/j.1469-185X.2012.00250.x); Gleditsch et al., 2017; Fontúrbel et al., 2019; Westlake et al., 2020). Second, seed shadows are strongly skewed within heterogeneous environments toward resources with increasing attractiveness to the vector (e.g., Levey, 1988; Fragoso, 1997; Jordano & Schupp, 2000; Armesto et al., 2001; García, Jordano, & Godoy, 2007; Martínez, García, & Obeso, 2008; Herrera & García, 2009).”

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García, C., Jordano, P. & Godoy, J. A. (2007). Contemporary pollen and seed dispersal in a *Prunus mahaleb* population: Patterns in distance and direction. *Molecular Ecology* **16**, 1947–1955.

Martínez, I., García, D. & Obeso, J. R. (2008). Differential seed dispersal patterns generated by a common assemblage of vertebrate frugivores in three fleshy-fruited trees. *Écoscience* **15**, 189–199.

Herrera, J. M. & García, D. (2009). The role of remnant trees in seed dispersal through the matrix: Being alone is not always so sad. *Biological Conservation* **142**, 149–158.

**Discussion considerations:**

"We acknowledge that only counting species detectable by camera traps does not represent all species within a fragment; however, using a subset of species richness has been determined to be representative of the true species richness and statistically sound for ecological studies on biodiversity (Vellend, Lilley, & Starzomski, [2008](https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.5360#ece35360-bib-0060)). " Ivey at al. 2019. Reduced vertebrate diversity independent of spatial scale following feral swine invasions.