**Presentation outline:**

1. **Introduction to California annual grasslands:**
   1. Perennial native life history
   2. Annual exotic grasses
2. **Temporal variation:**
   1. Characterization of temporal turnover in the system
   2. How do we think about some of the drivers of temporal variation in species composition?
      1. Life history strategies
         1. Priority and persistence
      2. Environmental variation
         1. Water limitation and drought stress
3. **How do conceptualize this turnover:**
   1. Species-specific patterns can be messy at small scales
   2. State-transition models
      1. Used to categorize rangeland vegetation into discrete “states” that best partition the total variance in composition within a system
      2. Link vegetation states to specific indicator species and describes transitions between these states often as a function of environmental variation and management.
      3. Also closely linked to the concept stability – some states are more stable than others, and understanding this stability and the factors that guide transitions between them can be critical to fostering states that are particularly desirable.
4. **Problems with state-change models:**
   1. While these models are great conceptually, they can be hard to put into an analytical framework:
      1. States:
         1. How many are there? What species define states? Reliance on expert opinions.
      2. Transitions:
         1. What governs transitions between states? Which states are the most stable? Can be difficult to conduct separate trials of state change.
   2. However, advances in statistics and computing have allowed us to evaluate these models in a more quantitative fashion, namely:
      1. Clustering analysis – determine an “optimal” number of states that best partitions the total variance seen in a dataset.
      2. Markov (or multi-state) models – a common tool in disease research, which can explicitly incorporate transitions between discrete states with multiple options.
   3. **Using this sort of analysis framework, we can complement expert models by providing a more quantitative assessment.**
5. **Classic models of California grasslands suggest that there are three key “states” in annual rangelands:**
   * 1. Naturalized Annuals – Strong priority effects, may not be as effective competitors
     2. Native Perennials – Difficult to recruit (seed limitation), but effective competitors when they establish – high stability?
     3. Invasive Species – Particularly effective in invading exotic annual communities, but may be sensitive to precipitation patterns (later phenology than many other species)
6. **Introduction to the WAPS data:**
   1. 3 species mixtures:
      1. Naturalized Annuals
      2. Native Perennials
      3. Invasive Species
   2. Observed consistently for 10 years with observations of percent areal cover
   3. Environmental data provided from a local CIMIS (California Irrigation Monitoring System)
7. **What questions can we ask with this data?**
   1. What states arise from different planting compositions?
   2. How do state assignments vary over time? Are transitions between states characterized by continuous, reversible changes, or non-reversible changes?
   3. What governs transitions between states? How do priority (contingency) and environmental variation interact to guide turnover over time?
8. **Simple figure of the relative abundance of different groups over time**
   1. Groups fluctuate in abundance dramatically over time
      1. Generally, annual grasses dominate when part of an initial planting community
      2. Invasives, when planted without annuals, seem to overwhelm natives
      3. Natives only are able to achieve high abundances quickly in their first year
9. **Characterizing temporal turnover:**
   1. Animated NMDS Figure
   2. Temporal trends are highly variable
      1. We see clustering of communities in the first year
      2. That then leads to dramatic fluctuations in time – communities are not static in any way.
10. **What defines each state?**
    1. Relative abundance of states over time and indicator species analysis
       1. What defines each state? The number of states that best define this system?
11. **How do states vary**
    1. State assignments over time
       1. Relative abundances of different states – natives stable or increasing, WAPS increase early but collapse in drought, drought tolerators expand later on
12. **Fitting Markov models to the data**
    1. Brief overview of Markov (or multi-state) models
       1. Go over stability and transition probabilities
    2. Priority/Contingency (does being part of the initial planting group increase the odds of a state assignment later on?)
    3. Environmental variation (drought stress)
       1. SPEI metric – standardized function of drought stress that offers flexibility in scale; compare droughts of 1, 2, 3, and 4 year duration
          1. Used in analysis by other analyses of drought stress in California
       2. Stability = e ^ -(q12 + q13 + q14)
       3. Transition = 1 – e ^ -(q12) + priority + covars
13. **Results of model fitting**
    1. Visualizations of resilience probabilities
14. **Some communities seem to really rely on priority for establishment**
15. **Others seem to need certain environmental conditions**