Outline

* Many natural resource disciplines have gradually shifted towards a systems based approach that seeks to maximize the health of and services provided by ecological aggregates, rather than individual components.
  + Example – ecosystem based management of multitrophic fisheries and forests
  + One of the principle benefits of system based management is reduced temporal variability in the provisioning of ecosystem services – the dynamics of the aggregate are buffered by components varying asynchronously with one another.
    - Portfolio effect 🡪 larger number of components, greater aggregate stability
* However, many ecological aggregates have exhibited evidence of increased temporal variability in recent years, despite containing the same number of components
  + Such collapsed aggregates are generally less capable of providing key ecosystem services and their individual components may be at increased risk of extirpation.
* Although changes in aggregate variability are generally associated with anthropogenic disturbance, it is rarely possible to identify specific events that lead to instability
  + Efforts are hampered by the observational nature of the data collected, as well as relatively low statistical power since it is difficult to directly compare aggregates to one another.
* Yet we can detect important clues about causal mechanisms by examining temporal trends in the processes that contribute to aggregate variability, rather than aggregate variability itself.
  + For example, while aggregate variability is clearly associated with the number of components it is also influenced by the attributes of the components themselves, namely their synchrony (i.e. covariance) and individual variability
    - E.g. assuming the number of components is stable, changes in aggregate variability may be driven by either process.
  + Recent work (Thibaut and Connolly) has provided a framework to estimate the relative contribution of each of these processes by decomposing aggregate variability into an index of synchrony and an estimate of component-level variability, weighted by abundance
    - Importantly these metrics are robust to differences in evenness, as well as abundance, allowing for comparisons among distinct aggregates
* Decomposing changes in aggregate variability into trends in synchrony and component variability may provide clues that are critical to identifying destabilizing ecological processes.
  + For example, if the variability of a subset of dominant components has dramatically increased, but synchrony has remained relatively stable, then it would suggest that localized processes are responsible.
  + Conversely, if synchrony and aggregate variability have increased in tandem, it would suggest that regional processes are at wrok.
* Moreover, temporal patterns in synchrony and component variability may be useful in guiding conservation efforts and management interventions.
  + A targeted effort to increase the productivity of an unstable subpopulation may lead to substantial benefits at the aggregate level, but these benefits may be dampened if the aggregate has become highly synchronized.
  + Similarly, a larger number of components may be required to stabilize the ecosystem functions of a highly synchronized aggregate
* We use an empirical dataset to first present evidence that increased aggregate variability in a Pacific salmon metapopulation is associated with greater levels of synchrony, rather than changes in the variability of the components.
* We then use a stochastic closed-loop simulation model to explore how long-term changes in aggregate variable (mediated by synchrony and component variability) may influence the outcomes of large-scale recovery efforts.

**Methods**

Sockeye salmon

* Generic information on biology
* Information on CUs as unit of management conservation

Population dynamics

* We explored trends in aggregate variability of per capita productivity throughout the Fraser River watershed.
  + Productivity defined as log(recruits/spawner)
* We examined temporal changes in three metrics defined by Loreau and de Mazancour 2008 and Thibaut and Connolly 2013
  + Synchrony – defined as the variance of total metapopulation abundance of *n* components (i.e. sum of all elements of variance-covariance matrix), divided by the variance of a hypothetical metapopulation with same component variances, but perfect covariance (i.e. synchrony)
    - Eq. 2
    - Makes no assumptions about distributions of pairwise correlation coefficients, is normalized (i.e. always varies between 0 and 1), and explicitly accounts for unequal component variances
  + Average component CV weighted by abundance
  + Aggregate variability – sqrt(synch) \* average component CV
    - Component and aggregate variability are linearly proportional to one another, with a constant of proportionality driven by synchrony of components
      * When highly synch, agg perfect tracks components
      * When asynch, agg variability strongly dampened