**Rationale**

Broadly accepted goals for salmon aggregates are to meet conservation benchmarks, then maximize spawner abundance and catches. However there are also substantial benefits to minimizing interannual variability of the aggregate, which can increase the profitability of fisheries and reduce management burdens. Although variability metrics are often considered when examining portfolio effects, generally these analyses are fairly superficial and fail to account for aggregate variability being driven by multiple processes, i.e. an interaction between the number of components, their individual degree of variability (weighted by abundance), and synchrony. Intuitively, which of these processes is driving aggregate variability could provide clues about the mechanisms driving greater variability and influence the efficacy of management interventions and rebuilding strategies.

**Research questions**

1. Fraser River case study
   * How has the relative contribution of component variability and synchrony to aggregate variability changed through time in the Fraser River watershed?
   * Preliminary analyses suggest initial spikes in aggregate CV predominantly due to component variability. Only recently has synchrony spiked.
   * Can we identify potential environmental drivers?
     + Either directly incorporate predictors into SR relationship and then look at variability metrics of residuals or compare TS of metrics to predictors directly?
   * If data are available from other watersheds, test whether this pattern is widespread
2. Simulation model – different synchrony OMs
   * Generate full factorial (3 x 3) set of operating models to produce different levels of aggregate variability, i.e. due to component variability (variance) or synchrony (covariance)
     + Test 1) whether PMs are strongly influenced and 2) how subset of MPs perform in each scenario
     + Could further complicate by having changes in covariance through time
3. Simulation model – different synchrony MPs
   * Generate three OMs (high variability due to CV, synch or moderate levels of both) and test how different MPs perform
   * Generate realistic representations of management interventions (e.g. manipulate carrying capacity/productivity of specific CUs)
4. Simulation model – identify processes that may lead to greater synchrony independently of variance/covariance changing
   * Manipulate exploitation rate, age structure, and straying (if it’s added)
   * This may be better suited to a lifecycle model where you can manipulate freshwater (local) vs. marine survival (shared)

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.