**Intro Outline (feel free to skip to methods)**

* Ecological aggregates, such as metapopulations or communities, consist of components whose dynamics vary due to life history, unique environmental interactions, or simply chance.
  + Such asynchrony tends to reduce variability in the dynamics of these ecological aggregates and results in positive diversity-stability relationships (Hooper REF), commonly referred to as portfolio effects (Tilman 1999 REF; Schindler 2015 REF).
  + The stability conferred by biodiversity is often associated with greater productivity and biomass, as well as increases in the availability of ecosystem services (Tilman, Isbell & Cowles 2014; Schindler, Armstrong & Reed 2015).
  + Increased recognition of these ecological benefits has resulted in a greater emphasis on the monitoring and conservation of aggregates, so called systems-based approaches (Link 2018), rather than component species or populations.
* Accounting for portfolio effects via systems-based approaches may be particularly useful in disciplines such as fishery science, where managers are often tasked with sustainably harvesting aggregates of distinct stocks.
  + At the coarsest level the relationship between diversity and stability is strongly influenced by statistical averaging (Doak *et al.* 1998). Thus there are tangible benefits to simply insuring that a relatively large number of stocks contribute to a fishery.
  + One of the most commonly cited examples of ecological portfolios is the Bristol Bay sockeye salmon fishery, where the sheer number of distinct populations in the region reduces aggregate variability in spawner abundance (Hilborn et al. 2003; Schindler et al. 2010). Since stock diversity is also correlated with fewer fishery closures, there are clear incentives to distribute fishing effort in such a way that the maximum number of populations is maintained.
* Yet the presence of an ecological portfolio does not guarantee stability indefinitely. For example, aggregate Chinook salmon returns to California’s Central Valley have simultaneously collapsed and become increasingly variable (Carlson & Satterthwaite 2011; Satterthwaite & Carlson 2015), even though the number of component stocks within the system has remained the same.
  + Reduced productivity, coupled with decreased stability at the aggregate level has resulted in substantial ecological and socio-economic costs.
  + While the region technically still exhibits a portfolio effect the buffering conferred by its diversity is substantially weaker than it was historically.
* The drivers and consequences of changes in aggregate variability can be better understood by decomposing it into two subordinate components.
  + Component variability, represents temporal variation in individual populations (species) within a metapopulation (community),
  + Synchrony describes the relative degree of similarity among components (Thibaut & Connolly 2013).
  + Each metric provides intuitive information about the scale at which destabilizing processes have occurred, clarifying how aggregate dynamics have changed through time.
    - A scenario where component variability has increased, while synchrony has remained relatively low and stable, suggests changes in aggregate dynamics are likely the result of local processes that could potentially be addressed in isolation.
    - Conversely, coherent increases in both synchrony and component variability might suggest that shared drivers have become increasingly dominant, as well as destabilizing.
* While patterns of covariance among populations have been frequently identified in ecological systems, and particularly in Pacific salmon (Peterman & Dorner 2012; Griffiths *et al.* 2014; Satterthwaite & Carlson 2015), links between covariance and the recovery or persistence of metapopulations are less certain.
  + Generally, the benefits of portfolio effects are quantified by testing the effects of sequentially removing component populations
    - (Schindler *et al.* 2010; Yamane, Botsford & Kilduff 2018)(Moore et al. 2010 REF compares synchrony and diversity interactions).
  + Though less dramatic, changes in component variability and synchrony may result in similarly strong negative effects.
    - High levels of component variability are likely to increase the probability of fishery closures or of overharvest if management targets fail to track changes in stock abundance.
    - These issues may be exacerbated if periodic years of high abundance create perverse incentives to maintain harvesting capacity, increasing the costs of tradeoffs when abundance later declines.
    - High levels of synchrony should intuitively magnify the negative effects of increased component variability because instead of the dynamics of component populations buffering one another, changes in abundance will increasingly occur in unison and prevent harvesters from shifting effort between stocks.
  + INSERT SENTENCE ON PRODUCTIVITY DECLINES HERE
* In this study, we explore how patterns of variability and synchrony influence long-term conservation and management objectives using Fraser River sockeye salmon as a case study.
  + Sockeye salmon biology
  + Socio-cultural benefits of sockeye
  + Despite the historical abundance of Fraser River sockeye salmon, the aggregate’s productivity strongly declined in the 1990s, resulting in frequent fishery closures and an emergency federal inquiry (REF).
    - While there have been signs of recovery in recent years, recruitment continues to be highly variable and several populations within the aggregate continue to be assessed as at risk (REF).
  + Since Fraser River sockeye salmon fisheries, like most Pacific salmon fisheries, are largely mixed-stock, abundant and depleted populations are inevitably harvested simultaneously (REF). Altogether these factors create a delicate framework, where managers must balance conservation goals with the desire to sustain economically and culturally significant fisheries, particularly during periodic years of high abundance. Changes in patterns of variability and synchrony may increase tension between these trade-offs if the fishery becomes increasingly concentrated on a smaller number of abundant years.
* We first conduct a retrospective analysis to demonstrate that aggregate temporal variability within the Fraser River has recently increased due to changes in both component variability and synchrony. We then use stochastic simulations to test whether increases in component variability and synchrony are associated with negative outcomes across a suite of performance metrics.