*Discussion Outline*

* We present evidence that aggregate variability in productivity within Fraser River sockeye salmon has increased in recent years due to increases in mean component variability, as well as greater synchrony among CUs
  + Coincides with a period in which spawner abundance has remained variable and fishery openings are less frequent, despite several decades of reduced exploitation relative to historic levels.
* Differences in the strength of portfolio effects (i.e. aggregate variability), through time and among regions, have been widely examined in Pacific salmon salmon
  + Generally stocks rearing in relatively pristine habitats and without a history of overexploitation appear to exhibit the greatest stability.
    - Bristol Bay (Hilborn et al. 2003; Schindler et al. 2010); Bristol Bay vs. Snake River (Moore et al. 2010); northern vs. southern populations (Griffiths et al. 2014)
  + Furthermore, increases in synchrony are thought to be associated with increased anthropogenic disturbance, particularly processes that increase genetic homogenization such as hatchery influences and hydropower development
    - Moore et al. 2010; Carlson and Satterthwaite (2015), Yamane et al. (2018)
* Like other Pacific salmon in the southern portion of their range, Fraser River sockeye salmon inhabit a heavily impacted watershed; however the specific mechanisms that resulted in increased synchrony remain unclear
  + Hatchery influences and mainstem dams are not widely spread
  + Changes in synchrony do coincide with a period where marine survival is considered broadly unfavorable
  + Assuming freshwater survival has remained stable or increased, periodic and synchronous declines in survival may suggest that variability in marine survival has increased relative to freshwater
  + These issues may be exacerbated by a relatively simple age structure
    - Refs on age structure for southern vs northern populations more generally?
* Regardless of the mechanisms that shape trends in variability and synchrony, it is widely predicted that weakened ecological portfolios will be less able to provide critical services.
  + Generally this has been demonstrated via increases in aggregate variability as individual components are sequentially removed
    - Non-salmon examples, followed by salmon examples
    - Yamane et al. exception
  + We expand these previous analyses by testing for negative effects of greater aggregate variability, assuming aggregate diversity (in this case component richness) is stable.
  + Specifically, we used stochastic, closed-loop simulations to determine how the relative status of the Fraser River aggregate would change if component variability and synchrony decline to previously observed values, remain elevated, or continue to increase.
* Generally increases in either component variability or synchrony lead to negative effects on conservation-based performance metrics.
  + Examples of simple patterns in con PMs (BMs)
* In many cases, greater CVC and synchrony had more severe impacts on catch-based than conservation-based performance metrics.
  + Examples of simple patterns in catch (BMs)
* In other instances performance metrics exhibited more complex relationships with CVC and synchrony.
  + For example, median recruit abundance and median catch actually increased when component variability increased and synchrony was low.
  + This initially counterintuitive result is likely driven by the fact that recruit abundance is necessarily bounded by zero.
    - Thus intermittent large, positive recruitment deviations in a handful of CUs have the potential to counterbalance recruitment failures in other CUs, increasing median abundance.
    - When synchrony increases to even moderate levels, aggregate variability also increases and the portfolio effect is weakened, causing the pattern to disappear.
    - Although these patterns may represent a statistical artifact in the model - they are consistent with recent observations in the Fraser River where despite a general decline in productivity and increased fishery closures, median abundance has actually increased due to several years with particularly large returns
* The negative effects of greater component variability or synchrony were particularly severe when both processes occurred simultaneously (i.e. aggregate variability was maximized) and when simulated dynamics incorporated skewed, heavy-tailed process variance.
  + I.e.
    - Cons: strong effects on recruit abundance, prop CUs above BMs
    - Catch: strong effects on median catch and prop years above threshold
  + Reducing productivity by directly manipulating per capita productivity also lead to a decline in median status across many PMs, but the effects of aggregate variability were less striking
    - E.g. Increasing synchrony, regardless of component variance, resulted in declines in the proportion of CUs above biological benchmarks when modeled with skewed process variance, but not under the reference or reduced productivity scenario.
  + This suggests that the relative impact of increased aggregate variability on conservation outcomes could be sensitive to the underlying structures regulating population dynamics.
    - If declines in productivity are driven by a shift to a new regime, even if it is less productive, aggregate dynamics will be less sensitive to changes in synchrony than if reduced abundance is driven by periodic, but inconsistent recruitment failures.
  + Interestingly differences in catch-based PMs between the skewed and low alpha regimes were more muted than conservation-based PMs
    - Catch-based PMs may be intrinsically sensitive to differences in synchrony, regardless of productivity regime, because harvest rates are strongly dependent on the dynamics of multiple CUs (more likely)
    - Relatively complex harvest control rule may buffer these metrics from dramatic changes in synchrony (less likely)