The effects of fish life histories on time scales of response to environmental change

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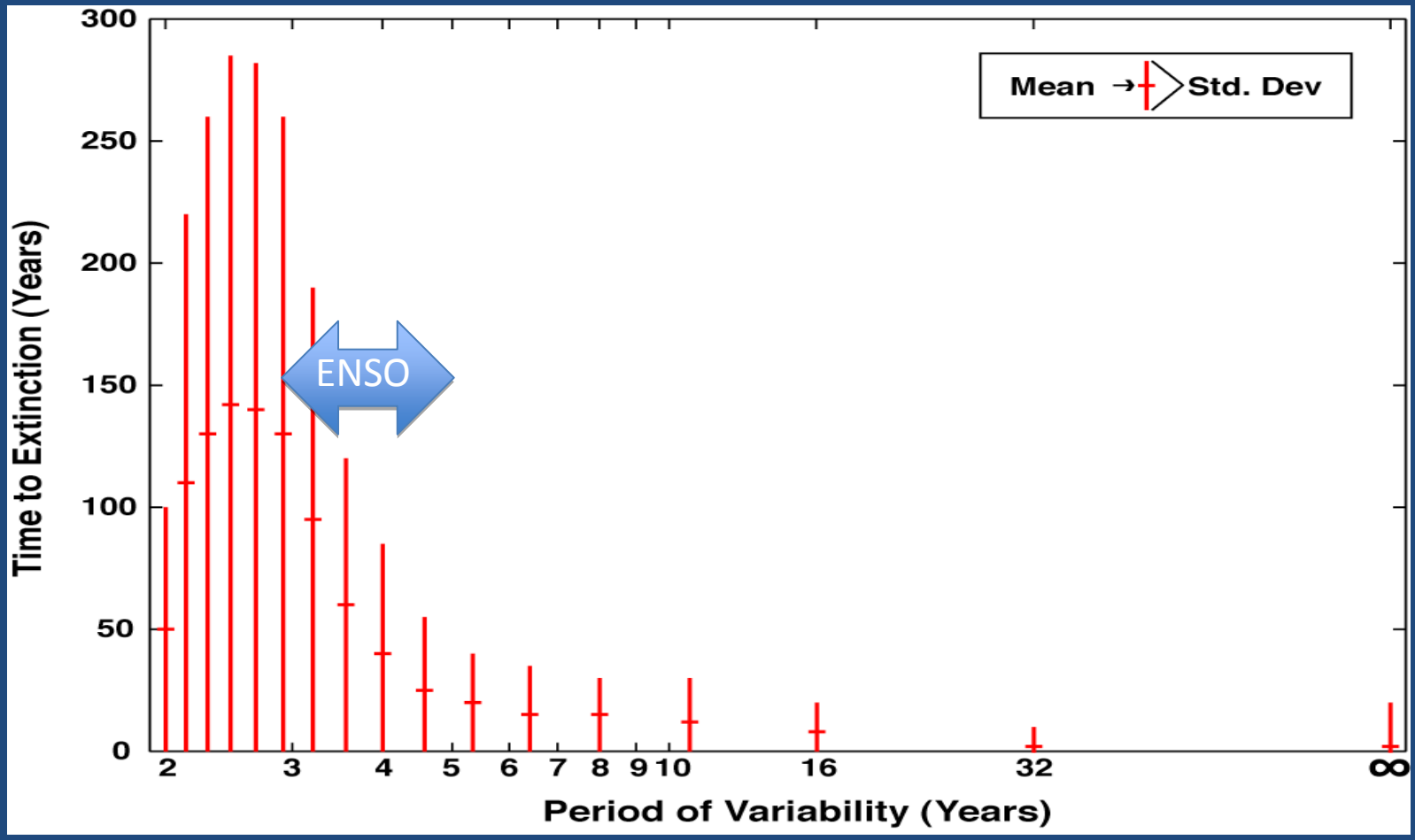
Goals

Describe the population dynamic aspects of responses of fish populations to environmental variability

Question: How do differences in life history affect observed population responses to environmental variability?

Synthesize observed responses of global salmon and cod, and project future responses.

Can view our results in terms of effects of time scales of variability on extinction.



Climate change problem: a shift in spectrum of forcing could lead to greater/less risk of extinction.

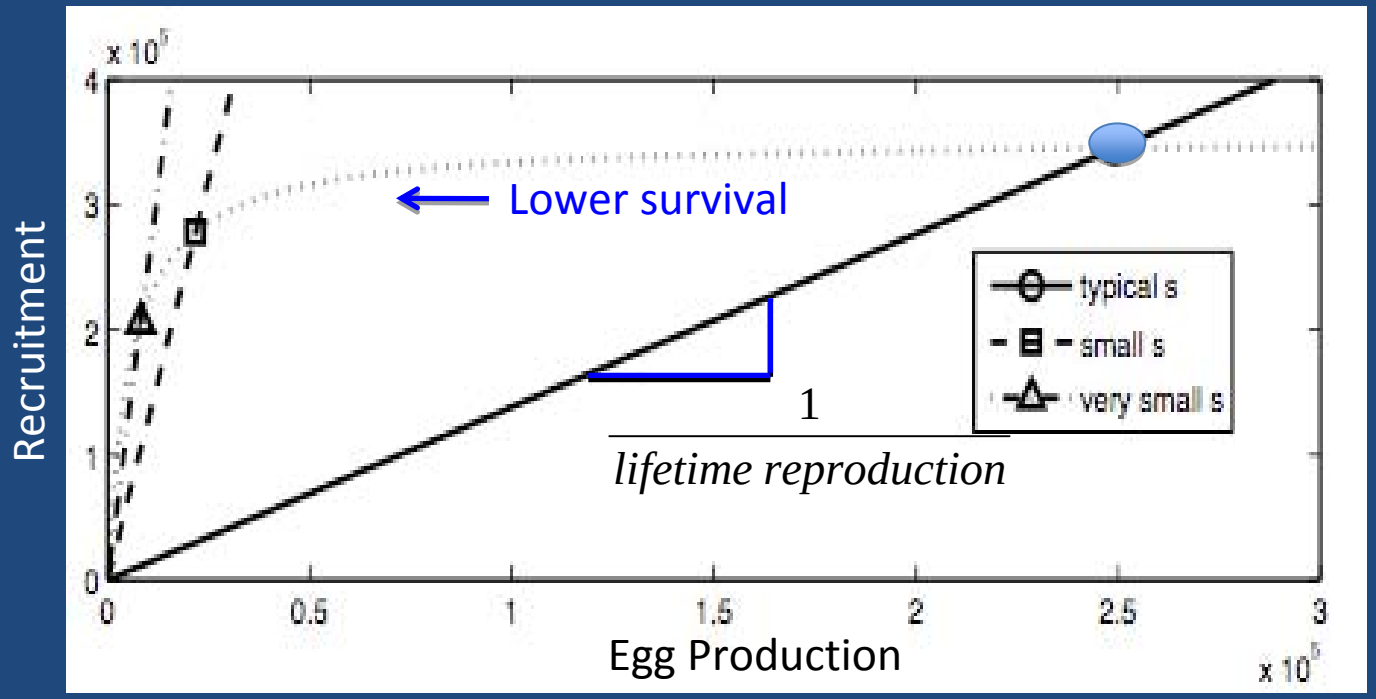
Outline

- Age-structured populations
- Historical synthesis
- Future projections

Age-structured Populations

- How do survival and reproduction determine equilibrium population level?
- How do life history and variable growth and survival determine the sensitivity to time scales of environmental variability about equilibrium?
- Use age structured model with density-dependent recruitment

Equilibrium depends on Lifetime Egg Production



Equilibrium declines with survival

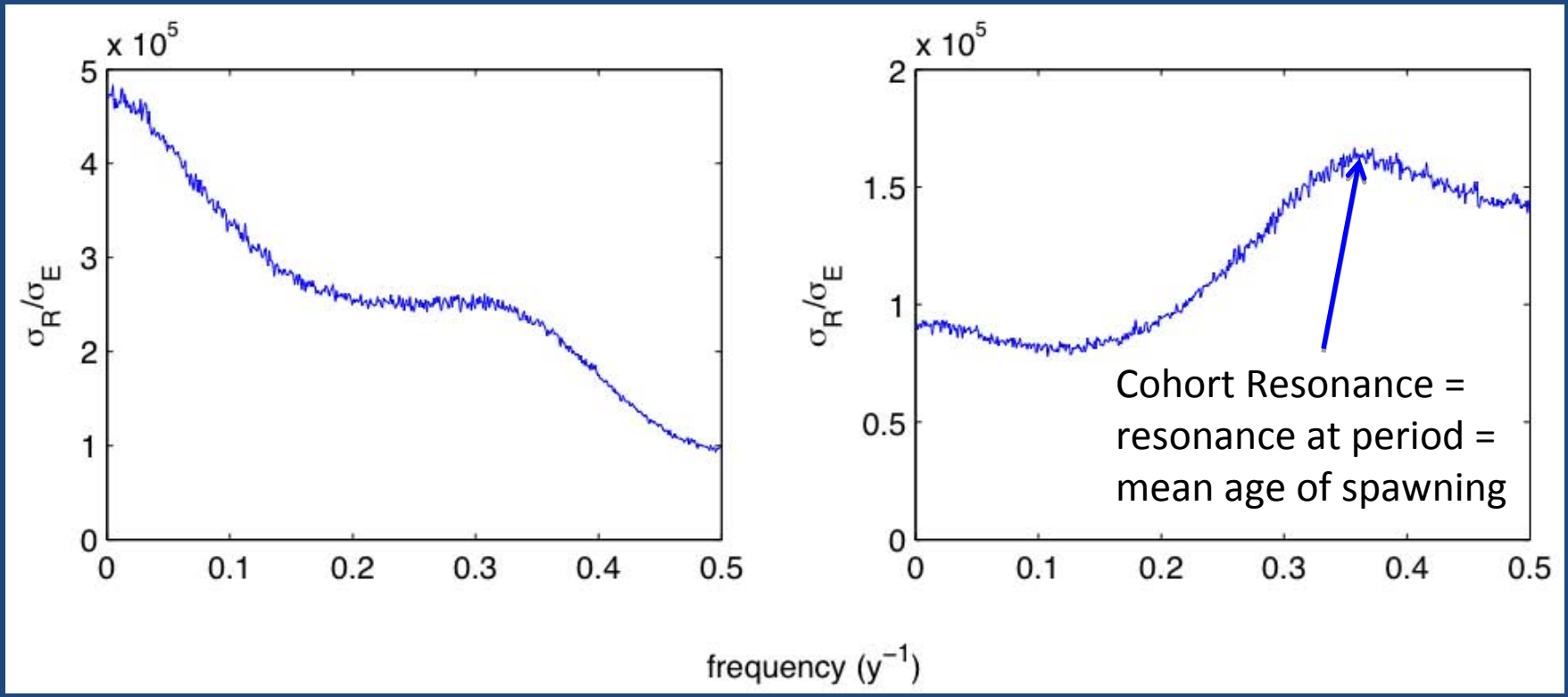
If survival becomes low enough, equilibrium is zero.

Result: Spectral sensitivity depends on point of variability.

e.g. coho salmon, which spawn predominantly at age 3 y

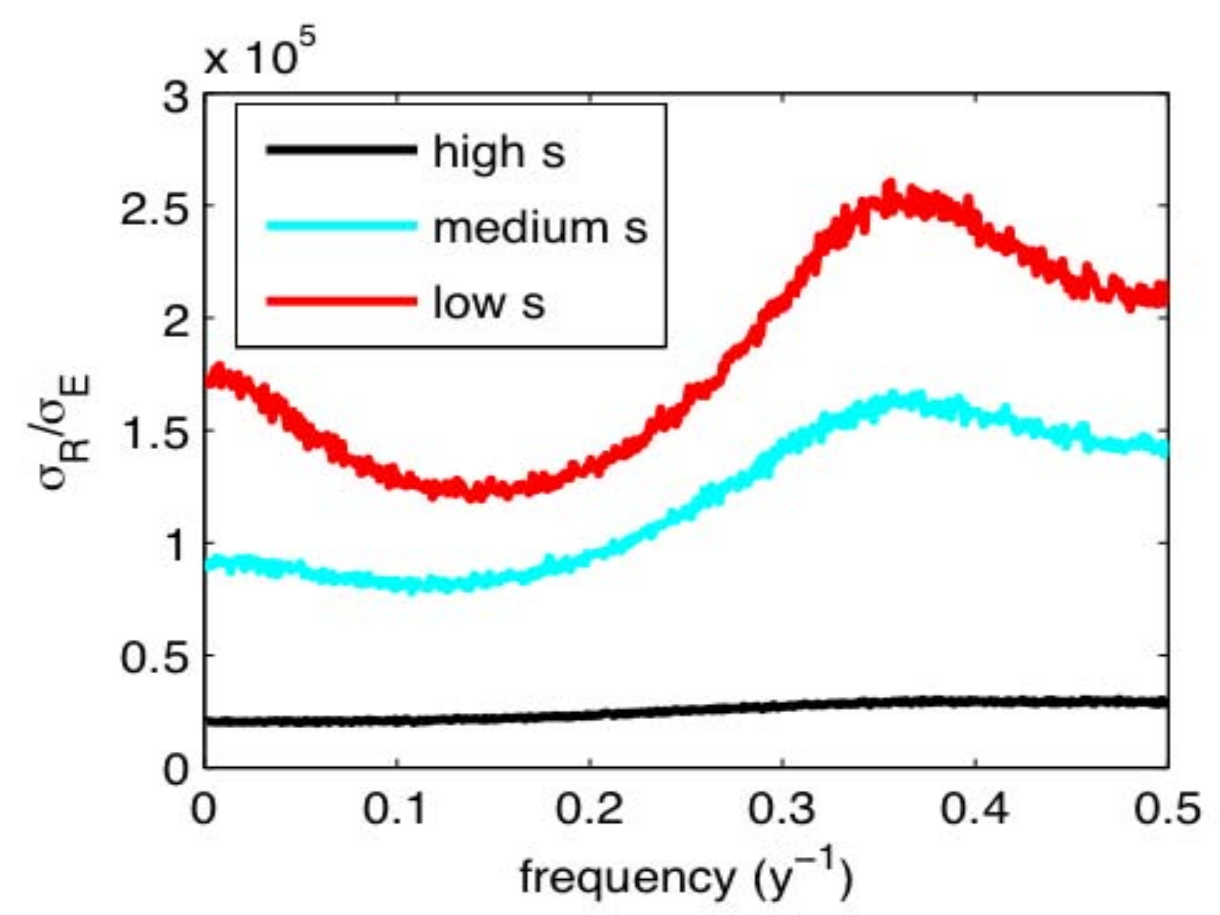
Variable survival

Variable growth rate



Results: Decreasing survival (by fishing or climate) increases overall sensitivity, cohort resonance and low frequency sensitivity, in addition to decreasing equilibrium.

e.g., coho salmon with variable growth rate



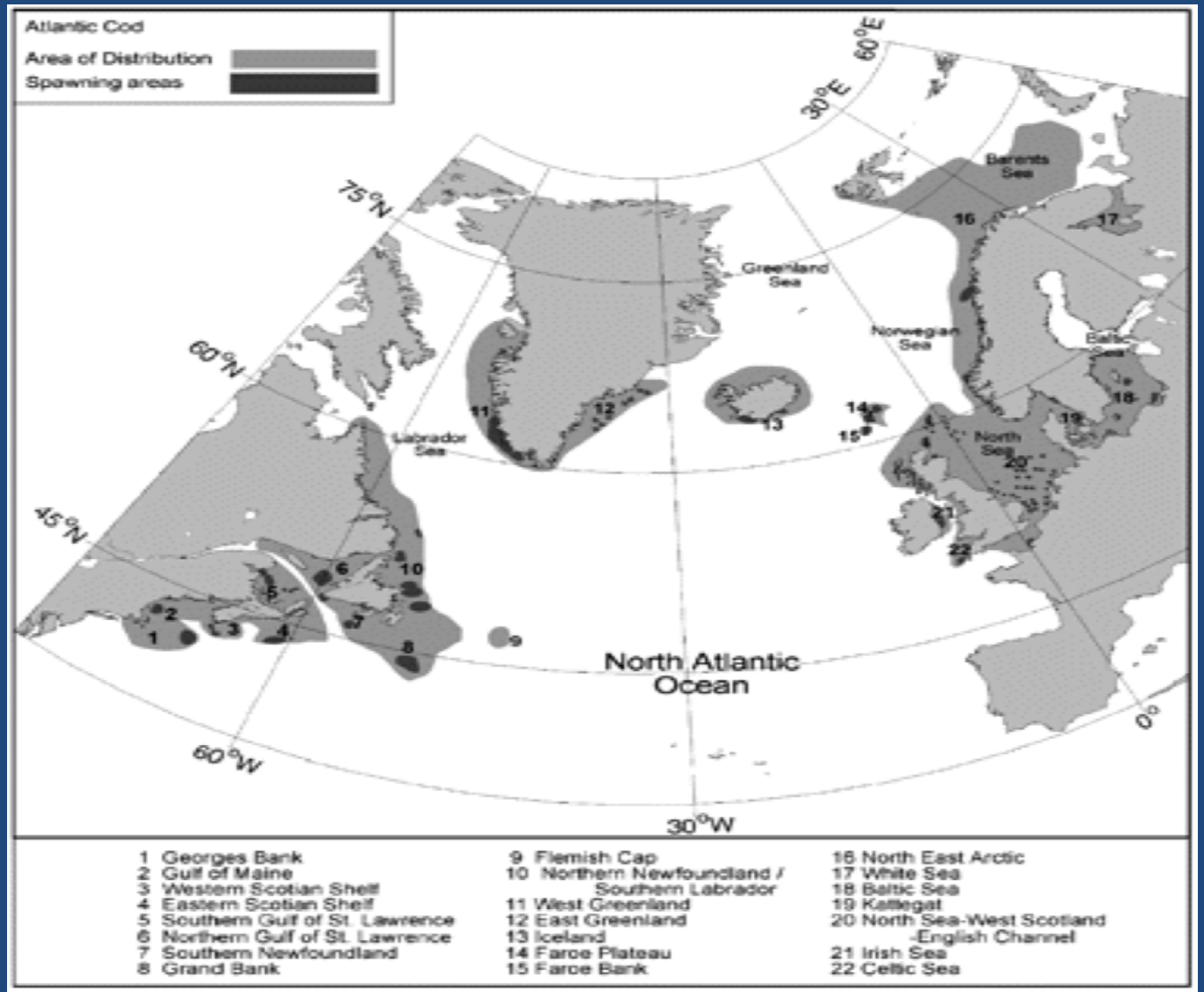
Historical Synthesis

In existing data, how do the different life histories of cod and salmon affect:

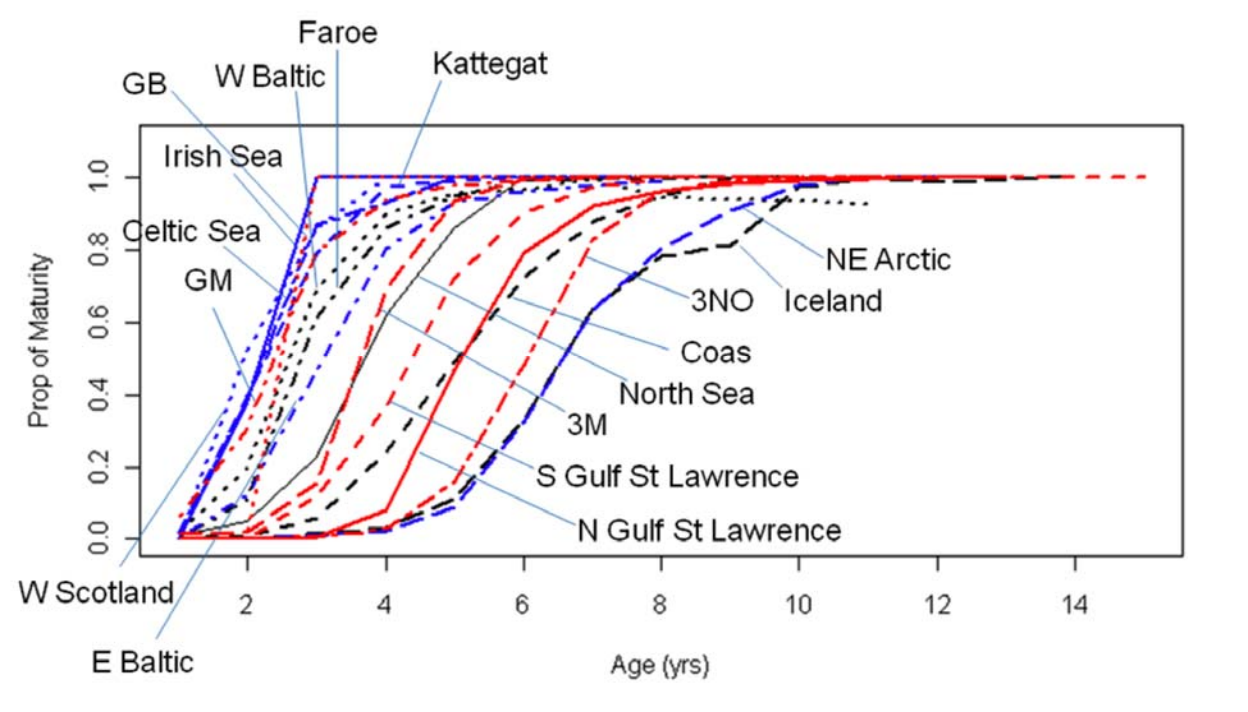
- Population equilibrium?
- Spectral sensitivity of salmon and cod?
- Effects of fishing?

Lifetime reproduction in cod

Examined relative lifetime reproduction 17 cod stocks



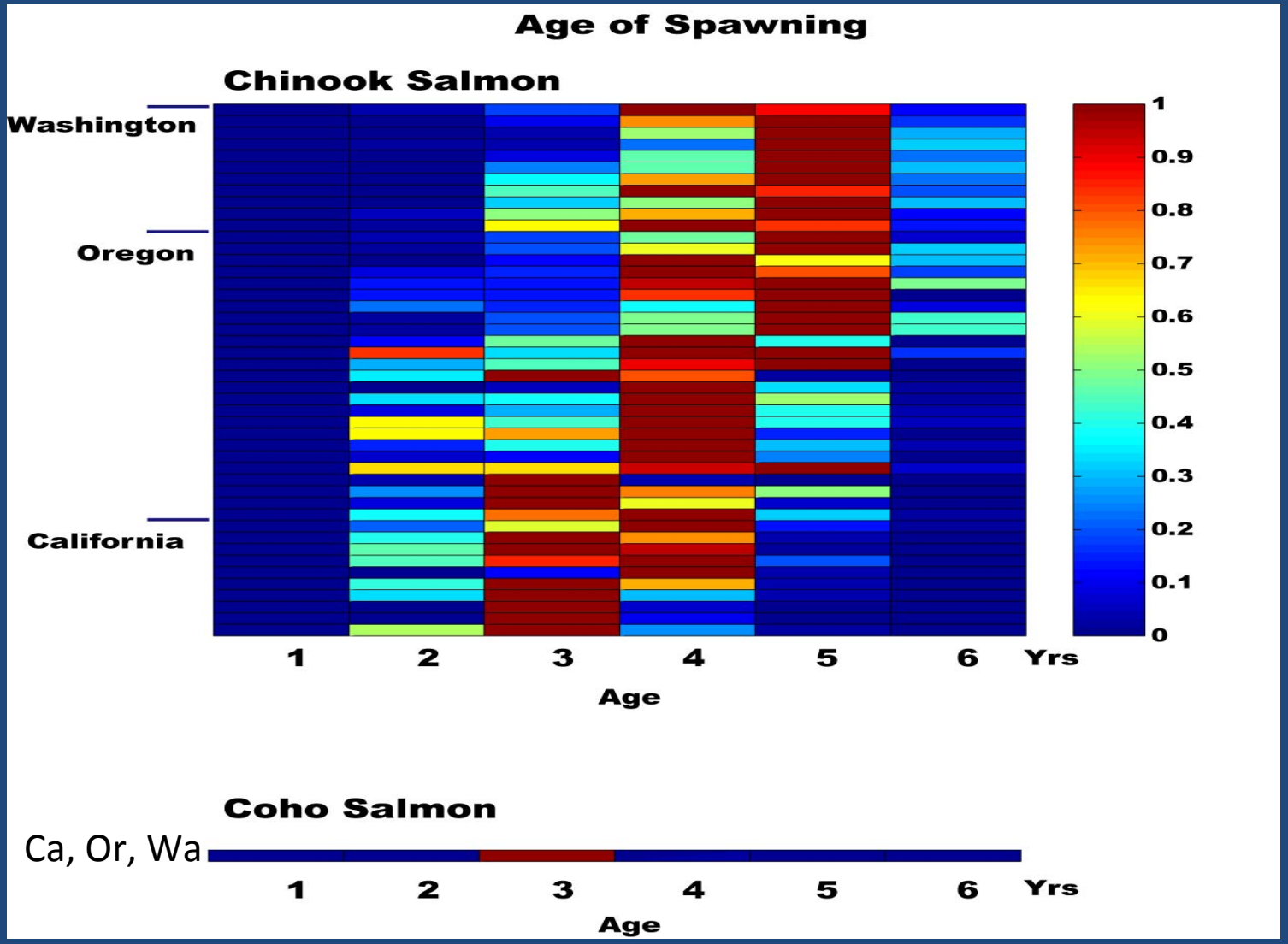
Cod maturity schedules vary over space



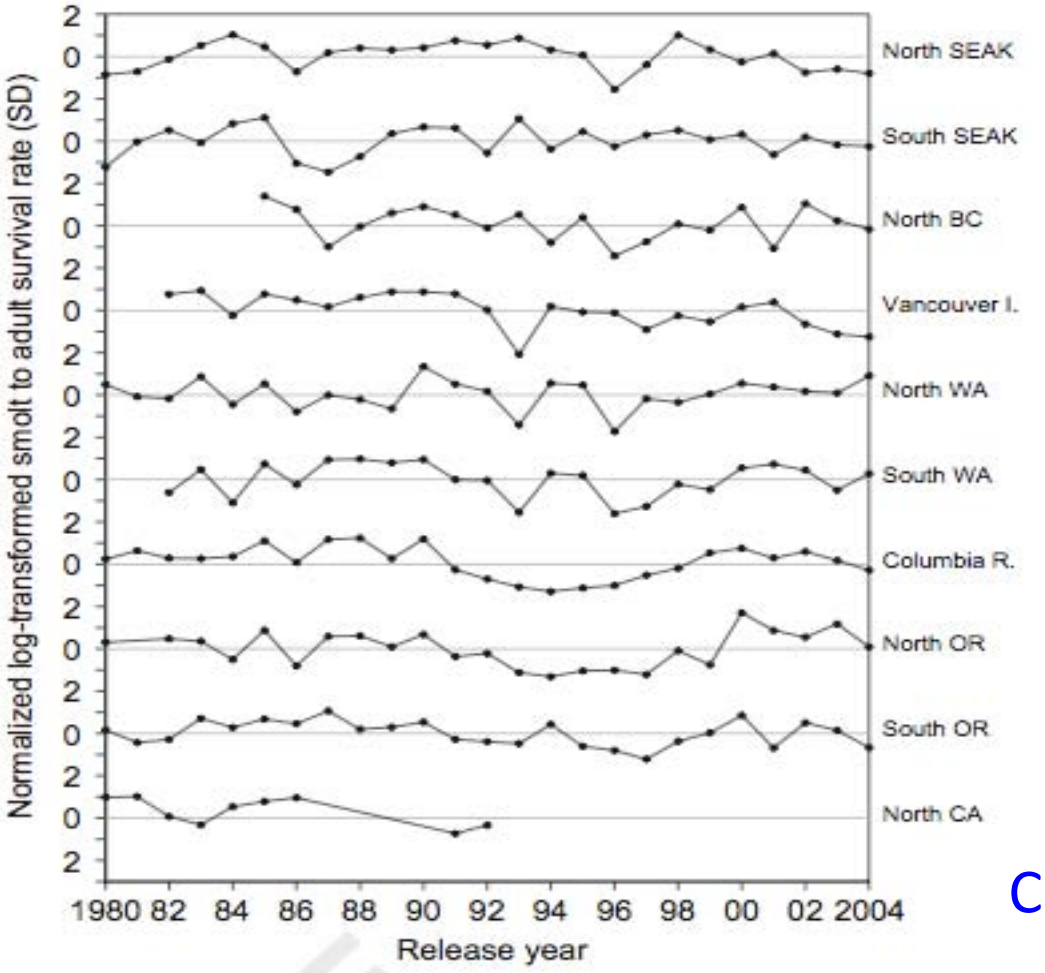
How does that affect their response to fishing? Equilibrium? Spectral sensitivity?

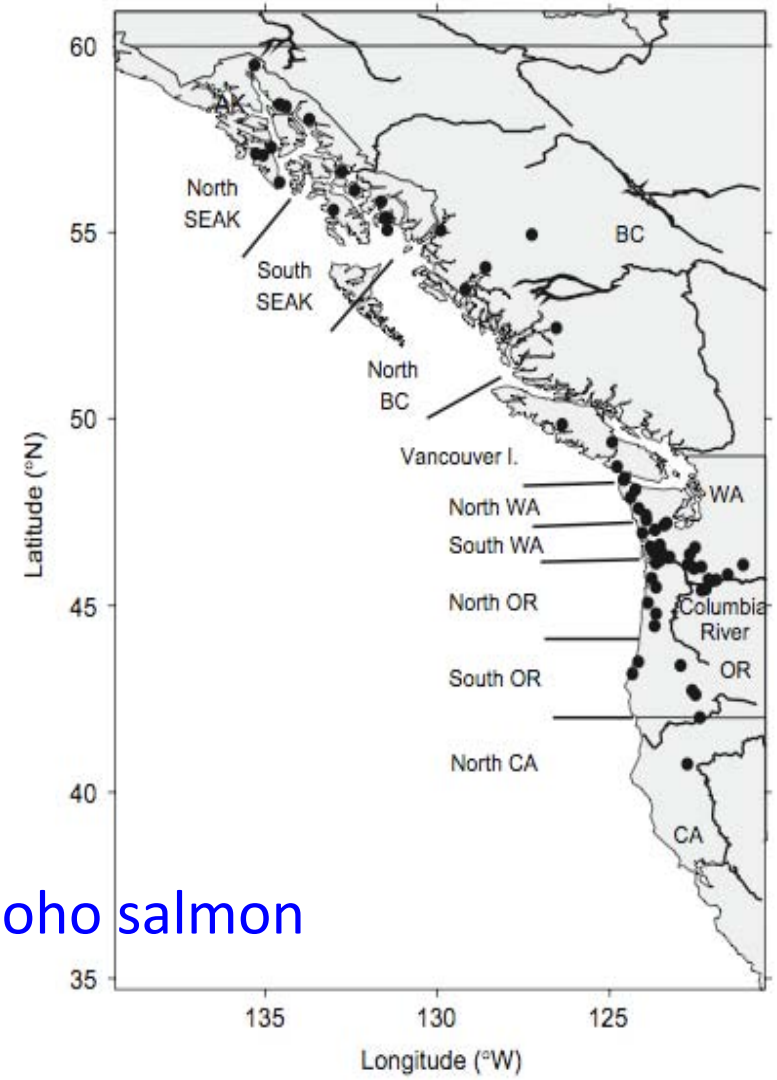
Varying responses of salmon populations

Salmon life history also varies with location



For salmon we have data on variability in growth and survival data from CWTs.



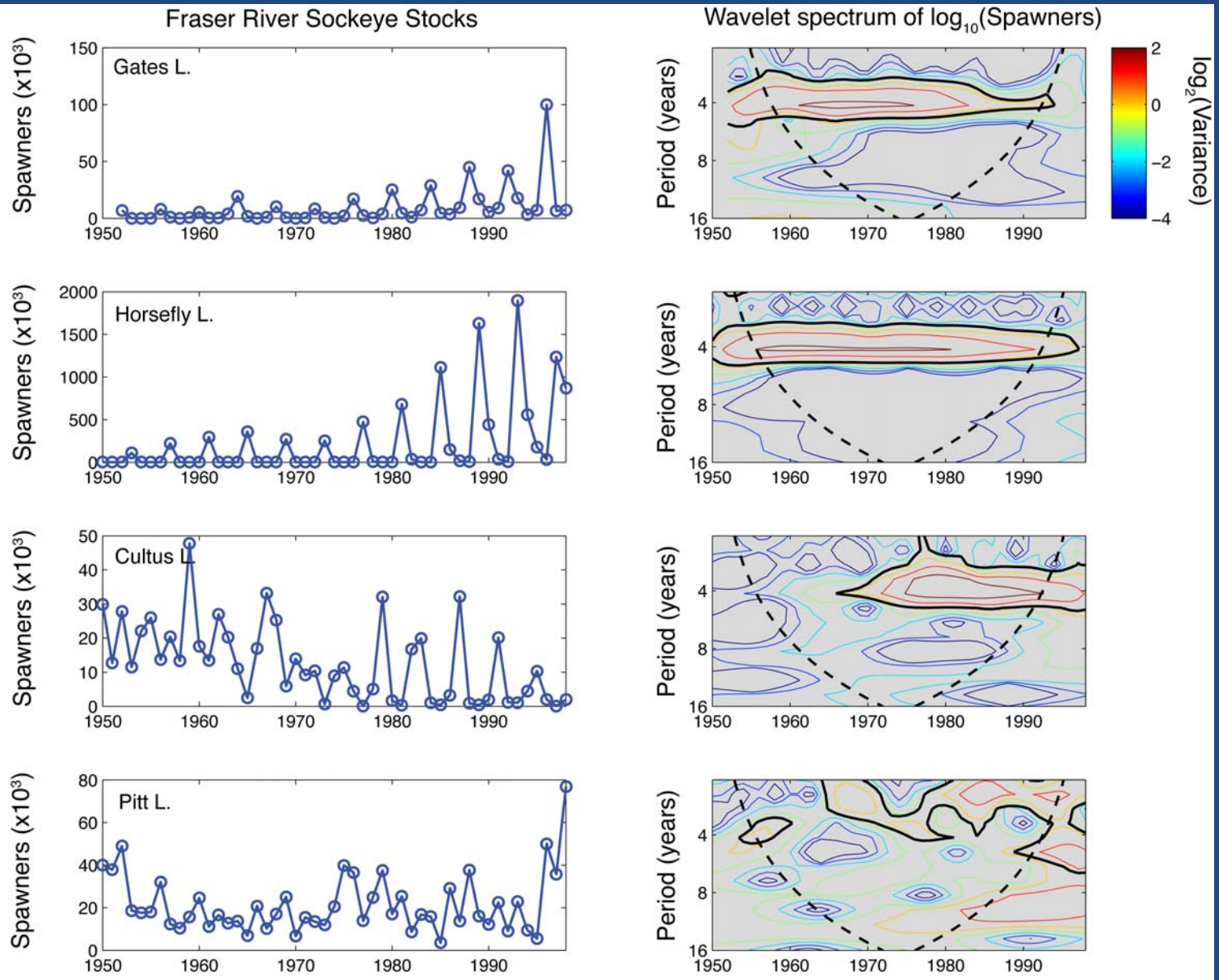


Coho salmon

Fig. 3. Time series of hatchery coho salmon survival from 10 geographical regions. Survivals were log-transformed and normalized ((value-mean)/SD).

Special kind of cohort resonance in sockeye salmon

Fraser River Sockeye Salmon: Cohort resonance with 1 high-3 low = “cyclic dominance” (peaky and cyclic).



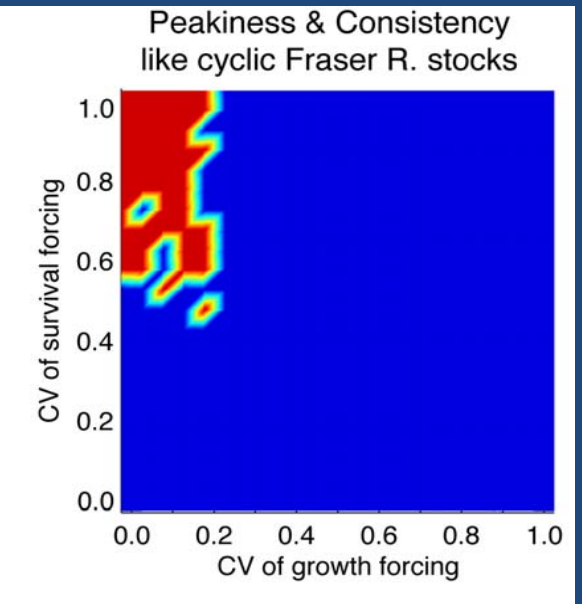
Historically inter-cohort mechanisms proposed

Result: Some combinations of variability can produce cyclic dominance without inter-cohort, density-dependent mechanisms

Cyclic Dominance

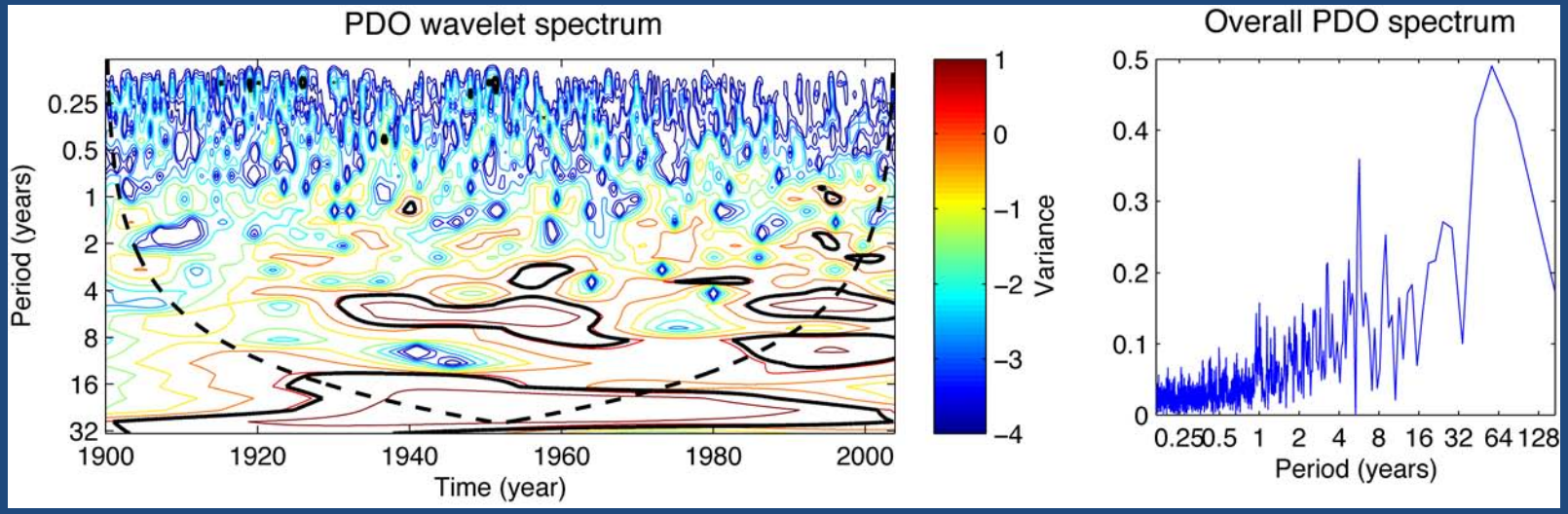
Both peaky and cyclic, like cyclic Fraser River stocks

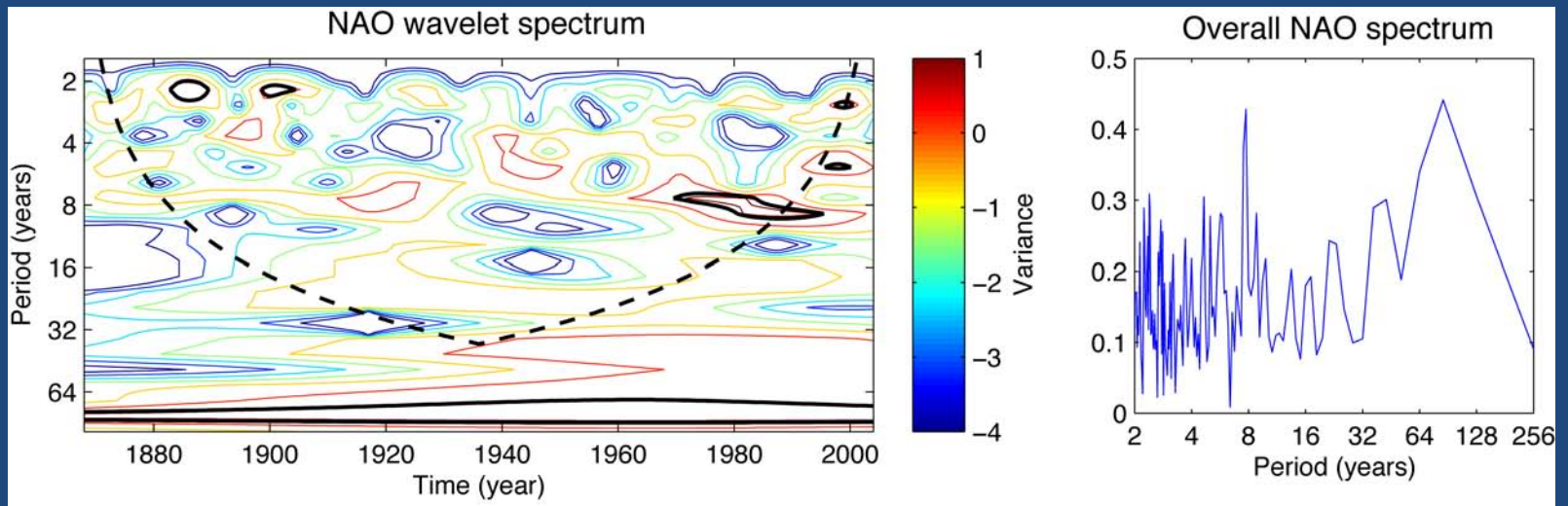
- Moderate to high survival forcing
- Low growth forcing



Future Projections

We know that spectra of environmental drivers vary with time.



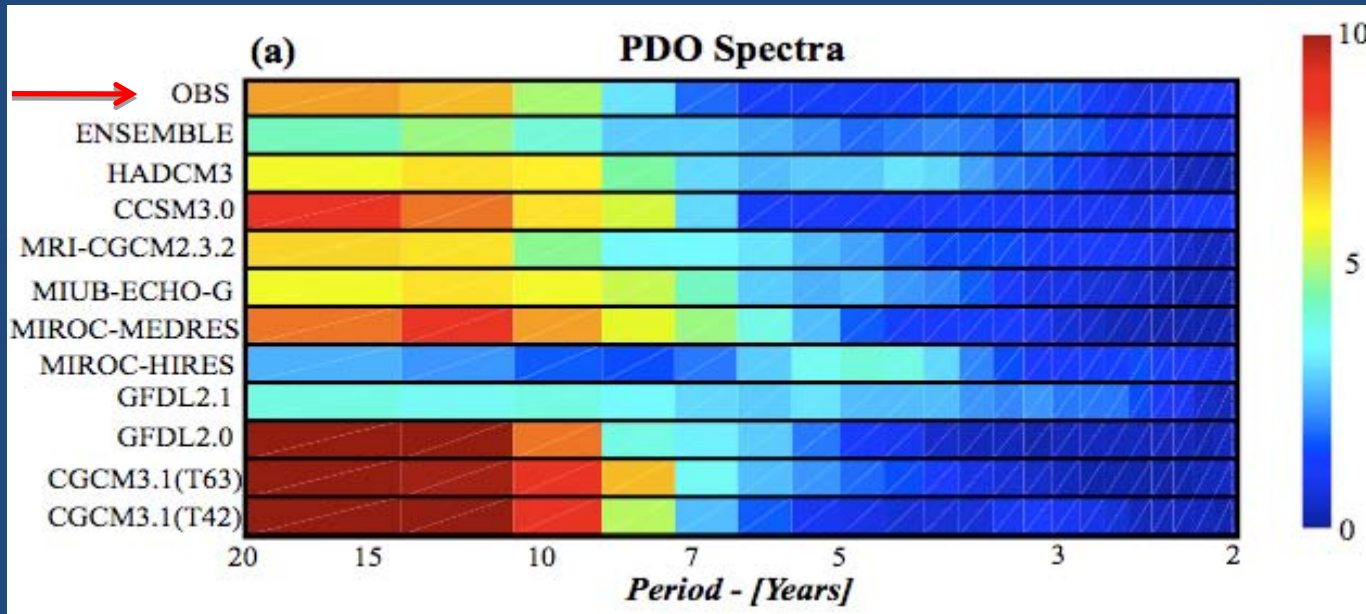


And spectra of important drivers may change in the future

Predicted spectra do not match 20th century

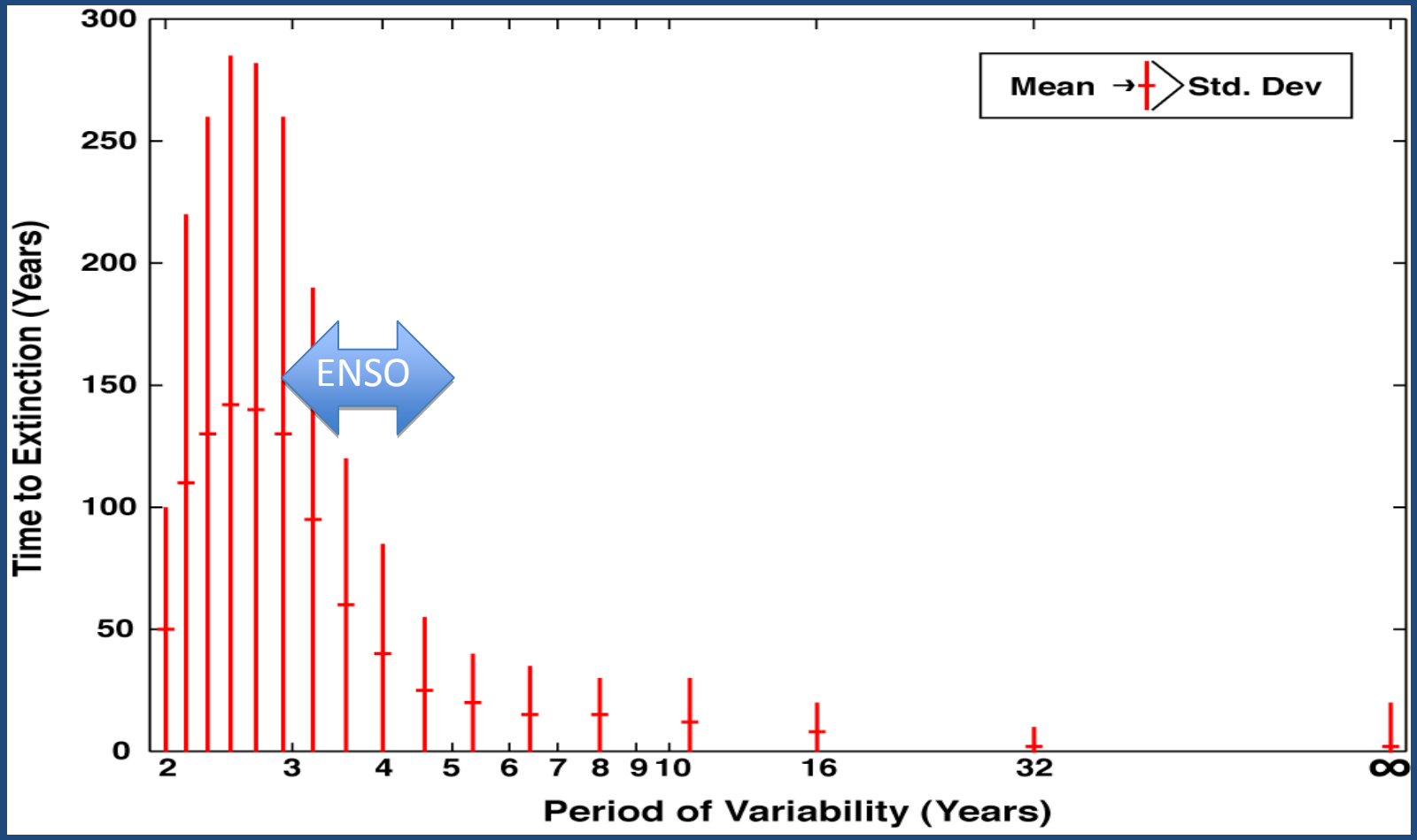
Evaluation of GCMs

Not significant change in spectra



Furtado, et al., in review

Dependence of risk on spatial scales of variability



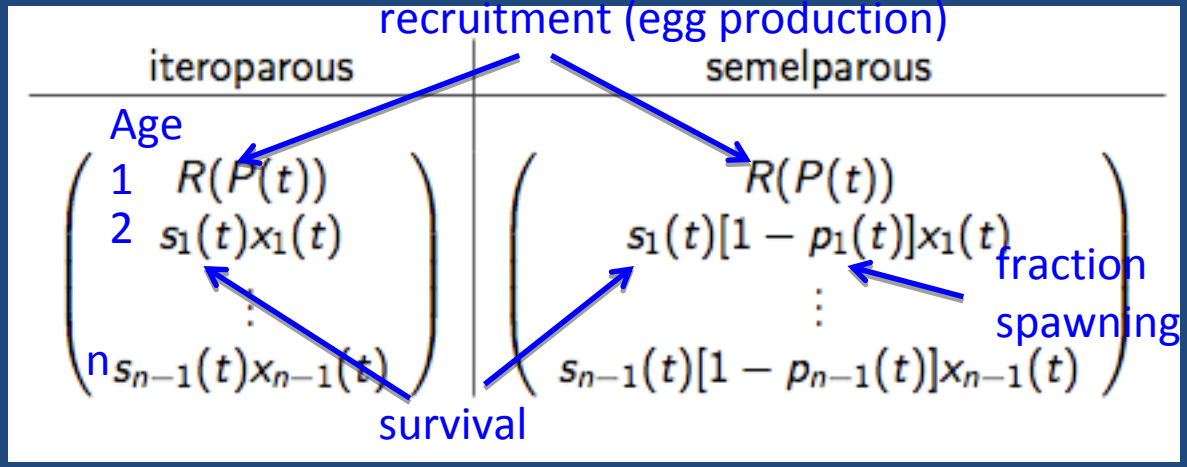
Climate change question: will a shift in spectrum of forcing lead to greater/less risk of extinction?

Thank You

Analysis

Age-structured model with density-dependent recruitment for both iteroparous (cod) and semelparous (salmon) species.

Vector of abundance at age, at time t+1 is:



Difference: For semelparous species, you spawn you die.