Stock-recruitment and population variability in a changing, uncertain world

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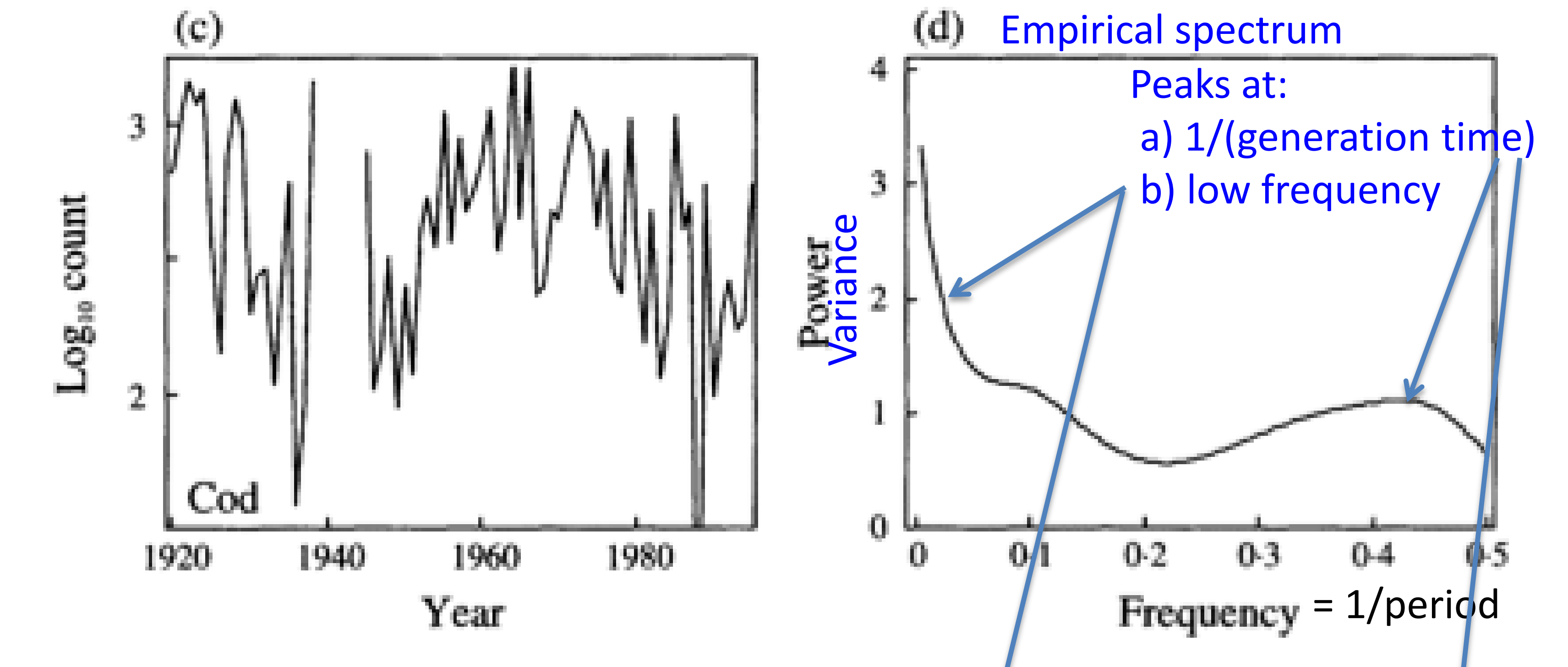
U.S. GLOBEC Synthesis: Comparative Analysis of Salmon and Cod

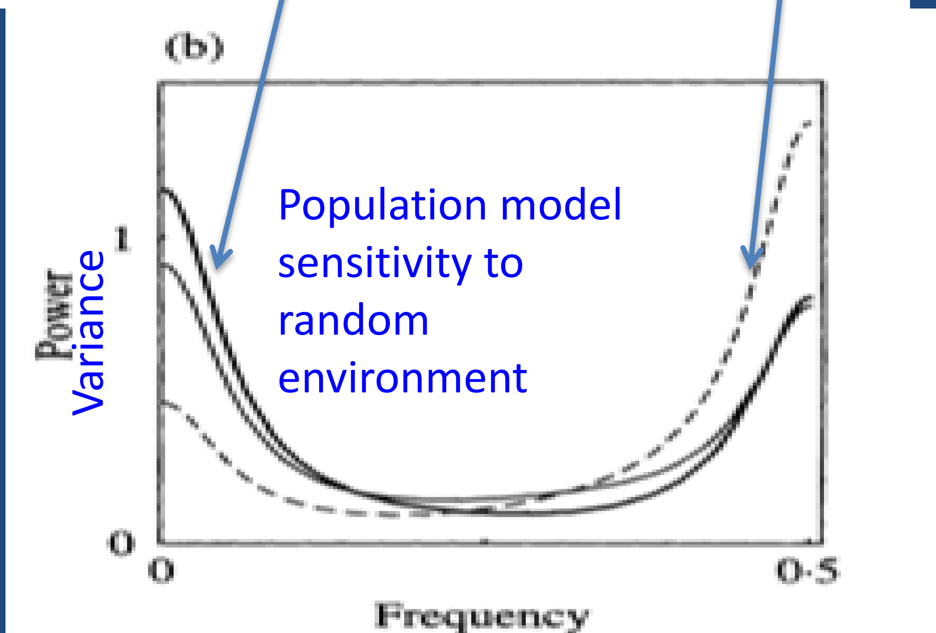
Cohort Resonance

- Brief historical introduction to CR
- How stock/recruitment affects CR
- Relationship between CR and other analyses of cycles and variability
- Recent results by our group



Coastal cod from the Skagerrak

Bjornstadt, Nisbet and Fromentin (2004) Journal Animal Ecology 73: 1157-1167



Fishing intensifies the effects of CR

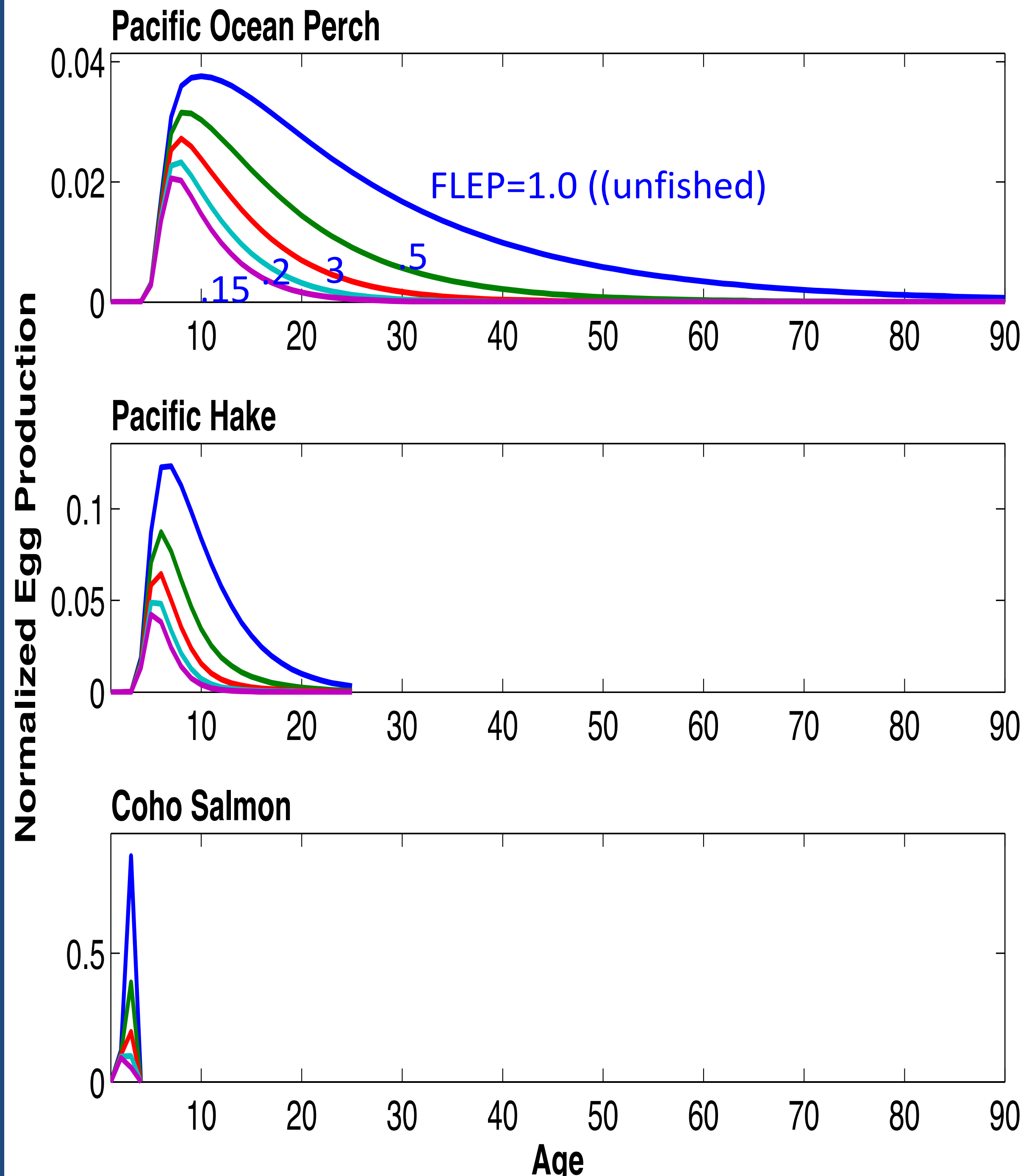
- Fishing increases peaks in spectral sensitivity due to CR
- Fishing increases overall variance due to environmental variability

Worden, et al. 2010

Effect of fishing on Cohort Resonance

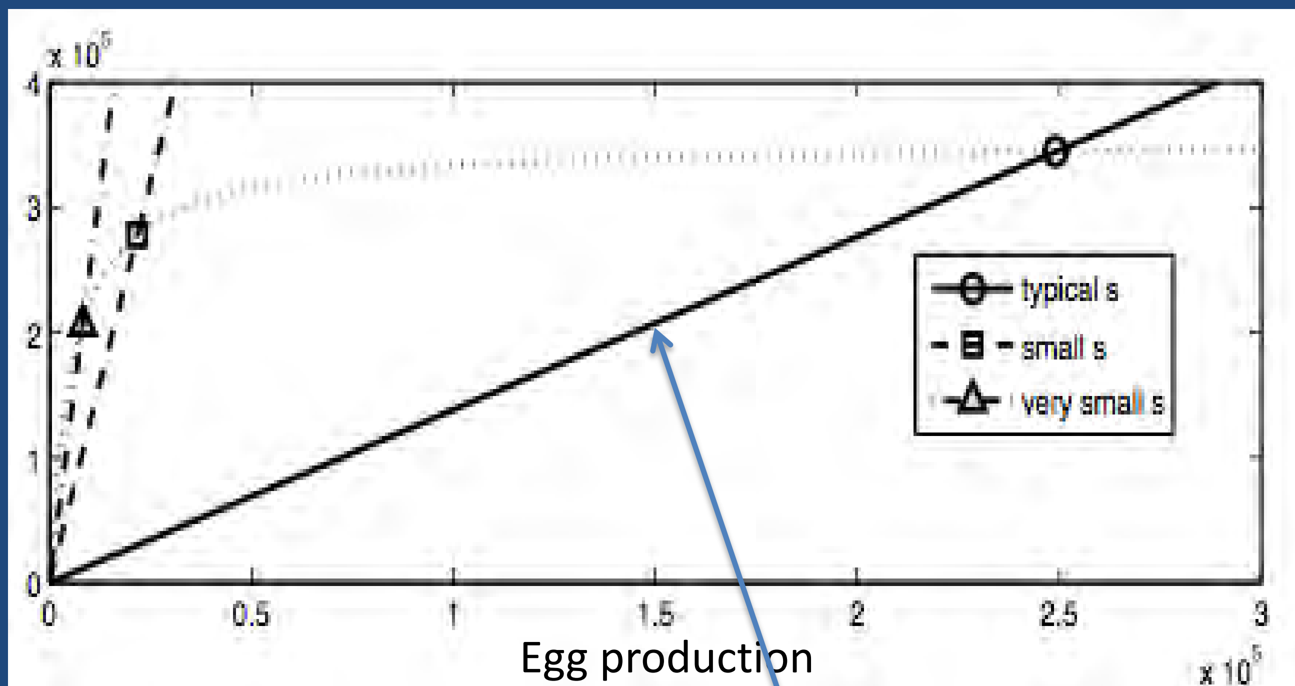
Spawning age structure is increasingly truncated with increased fishing

LEP = Lifetime Egg Production declines with fishing (FLEP = fraction)



Effect of fishing on equilibrium recruitment (e.g., coho salmon)

Recruitment



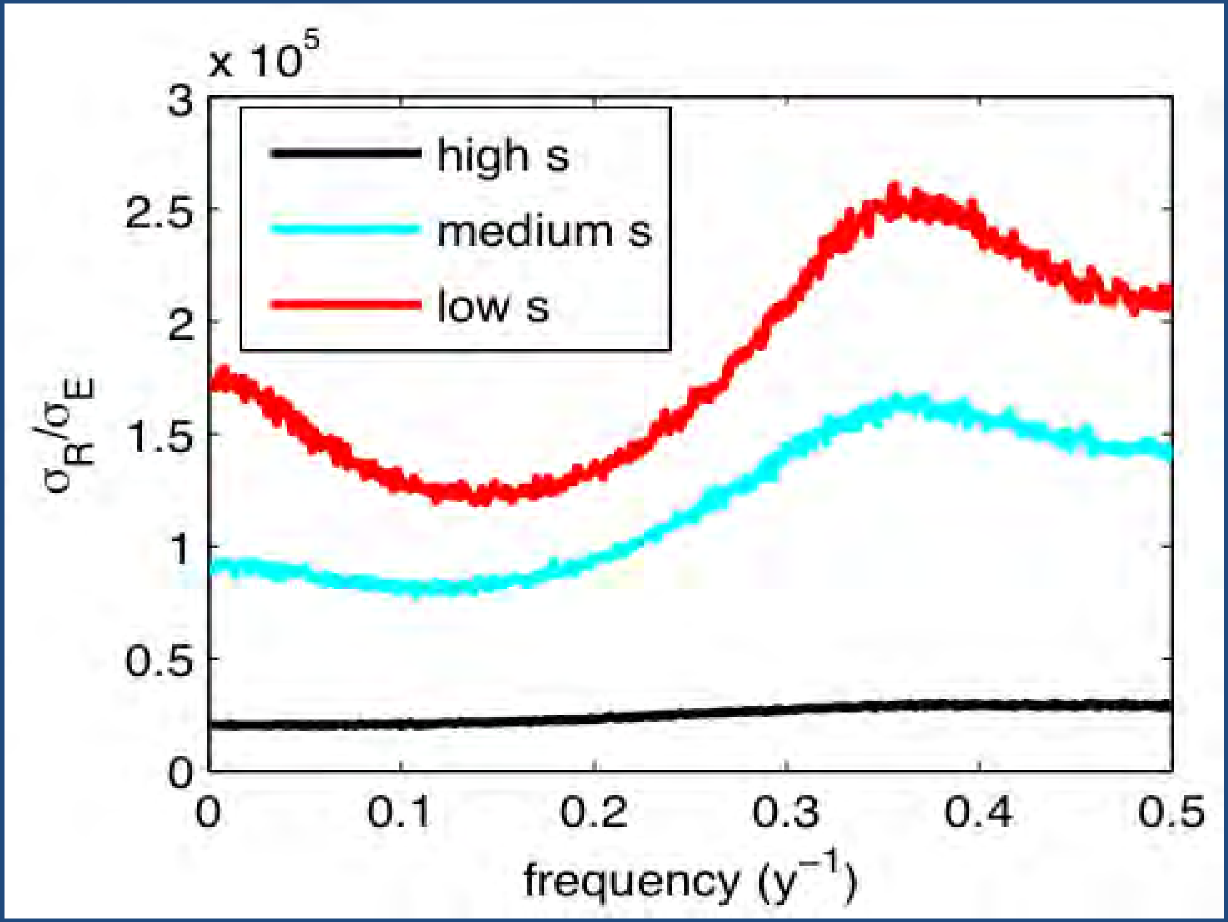
$$Slope = \frac{1}{Lifetime\_Egg\_Production} = \frac{1}{LEP} = \frac{1}{\sum_{age} survival(a) \times maturity(a) \times fecundity(a)}$$

Sissenwine & Sheperd (1987)

Effect of fishing on sensitivity of variability in recruitment

Increases peak in sensitivity at 1/T, and at low frequency, and overall sensitivity.

Sensitivity of Variability about equilibrium



e.g., coho salmon with variable growth rate

Worden, et al. (2010)

Effect of Cohort Resonance on Total Variance

Recruitment from egg-recruit relationship

Recruitment with random larval survival

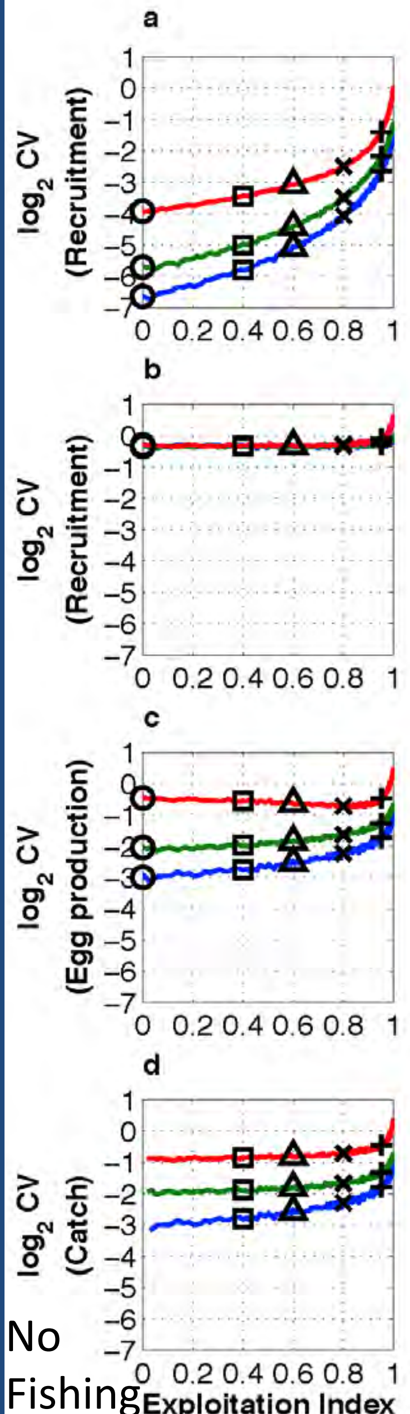
Egg production

Catch

Coho salmon

log$_2$ Pacific Hake

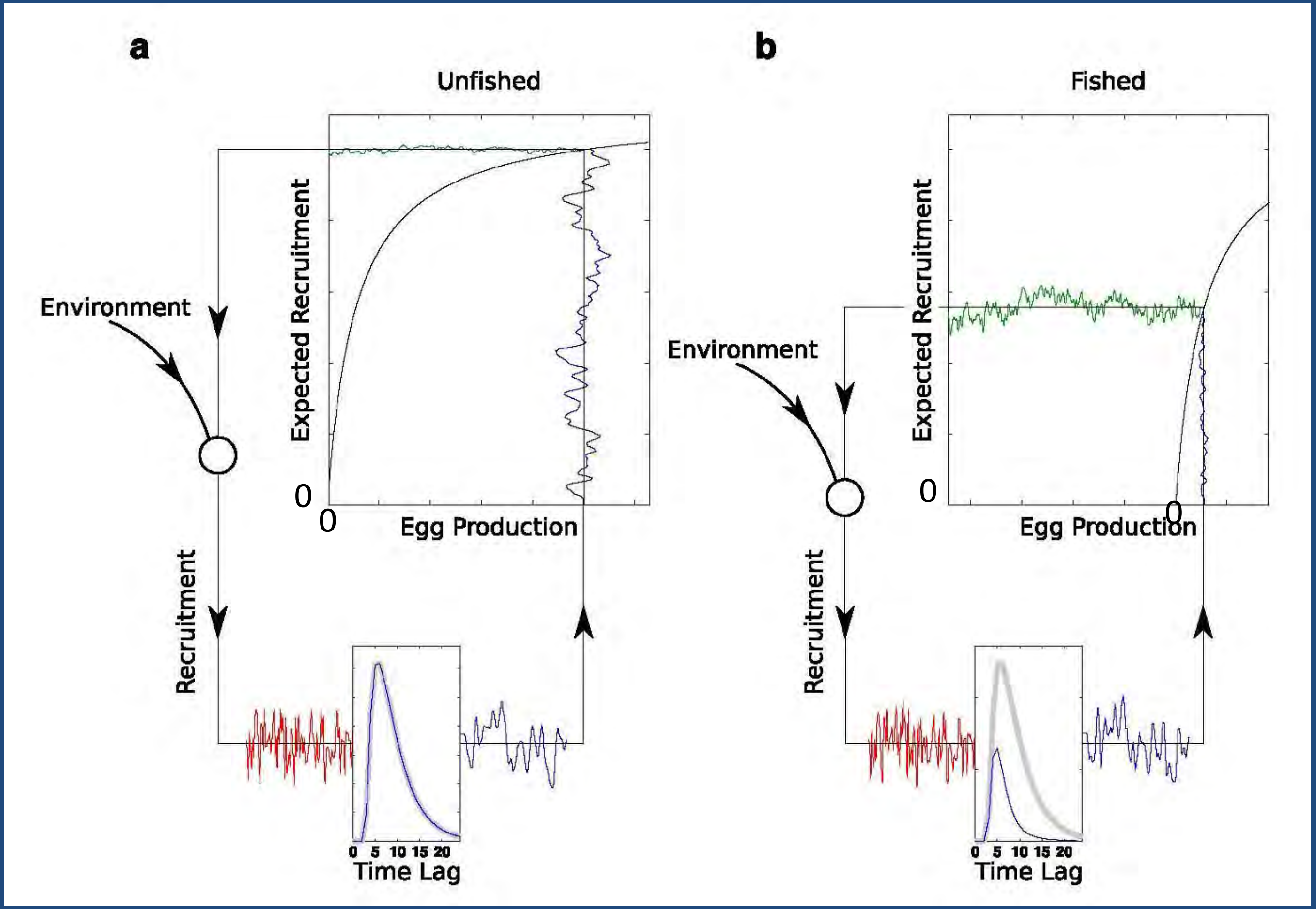
Pacific Ocean Perch



No Fishing

Collapse

How Stock/Recruitment affects Cohort Resonance



I. Slope of Egg-Recruit function at equilibrium "amplifies" variability.

II. Shape of Spawning Age Distribution "focuses" lagged signal.

Both increase with fishing

Stock-Recruitment and Cohort Resonance with fishing

- Peak near 1/T: variability in egg production amplified by slope of egg-recruit function at the equilibrium, which increases with fishing.
- Peak at low frequencies: Less density dependence, with increasing fishing. (wandering behavior of neutrally stable system).

Differences between Cohort Resonance and period 2T cycles (e.g., Dungeness crab and G. Kruse's talk)

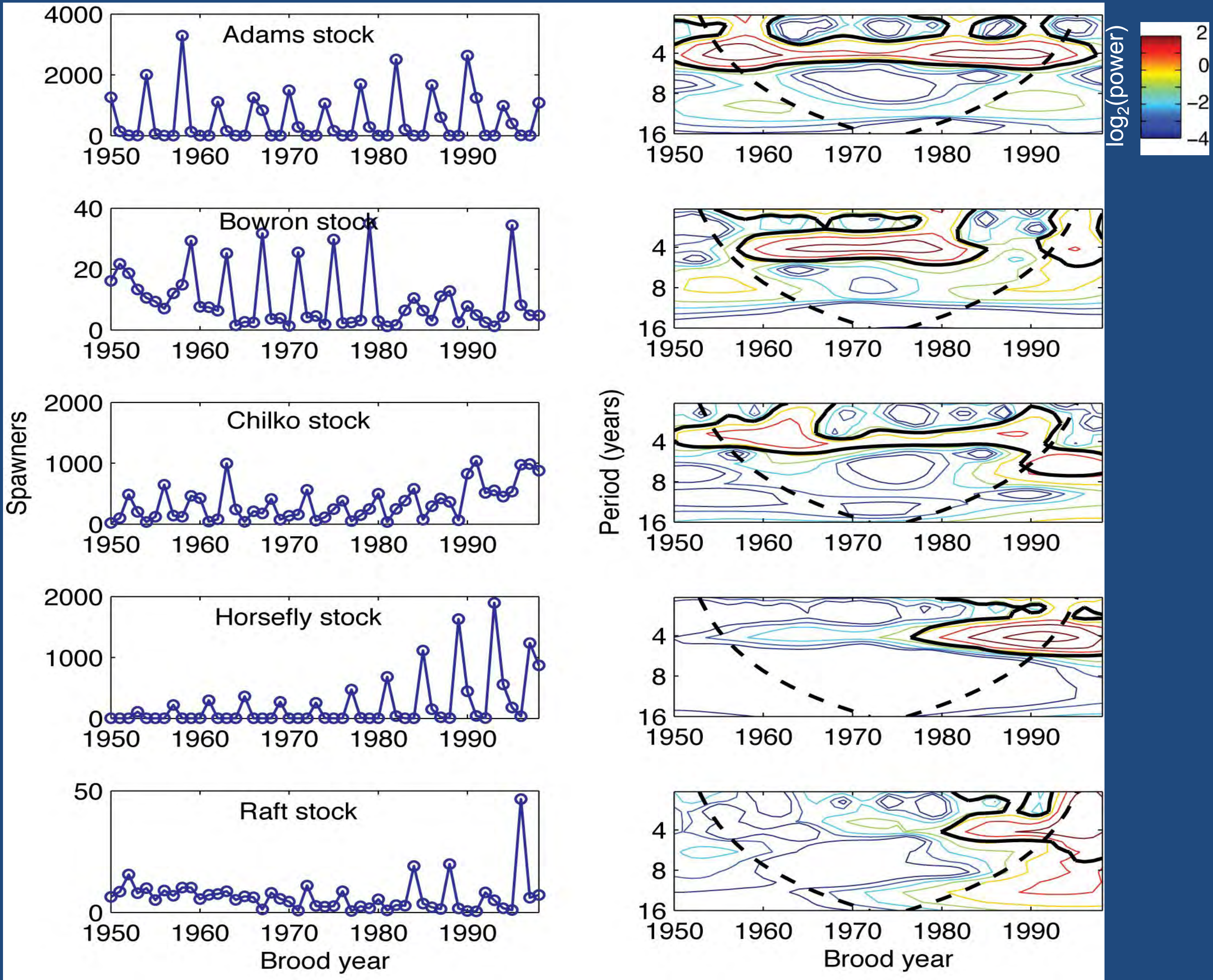
- Cohort resonance-compensatory part of the egg-recruit function,
- 2T cycles - over-compensatory part of function (if it exists)
- Cohort resonance-population stable about equilibrium,
- 2T cycles-population unstable about equilibrium
- Cohort resonance results from environmental variability driving stable modes of behavior
- In cohort resonance population may satisfy conditions but not show cohort resonance behavior; not the case with unstable 2T cycles.
- Difference between CR and other analyses of increasing variability with fishing (e.g., Anderson, et al. 2006, Shelton and Mangel, 2011, overcompensatory and unstable)

Recent Results

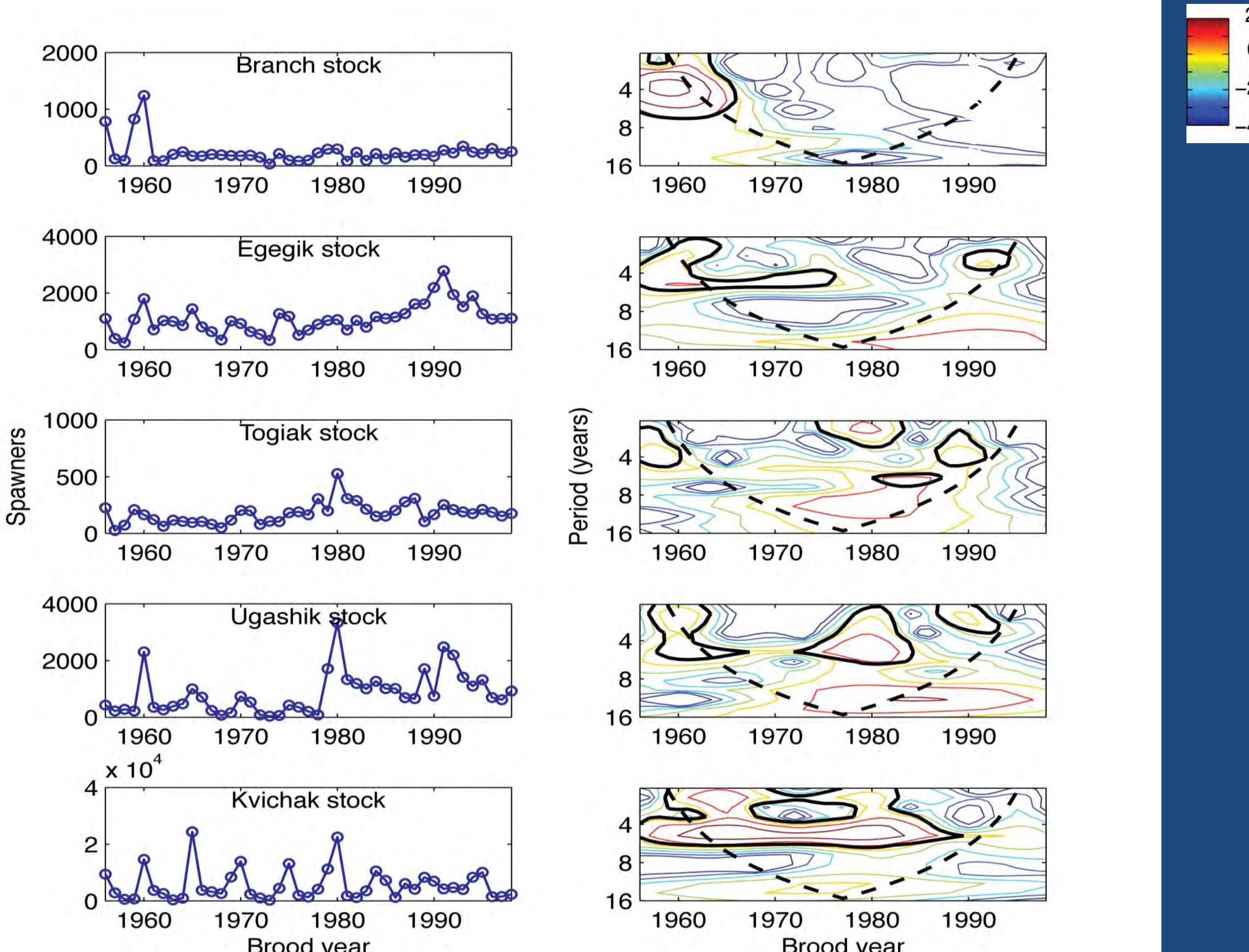
Sockeye salmon – Fraser River and Bristol Bay

- An extreme form of Cohort Resonance explains the cohort dominant cycles.
- Cohort dominant cycles – one year of high spawning abundance followed by 3 small ones (Fraser R.) or 4 small ones (Bristol Bay).

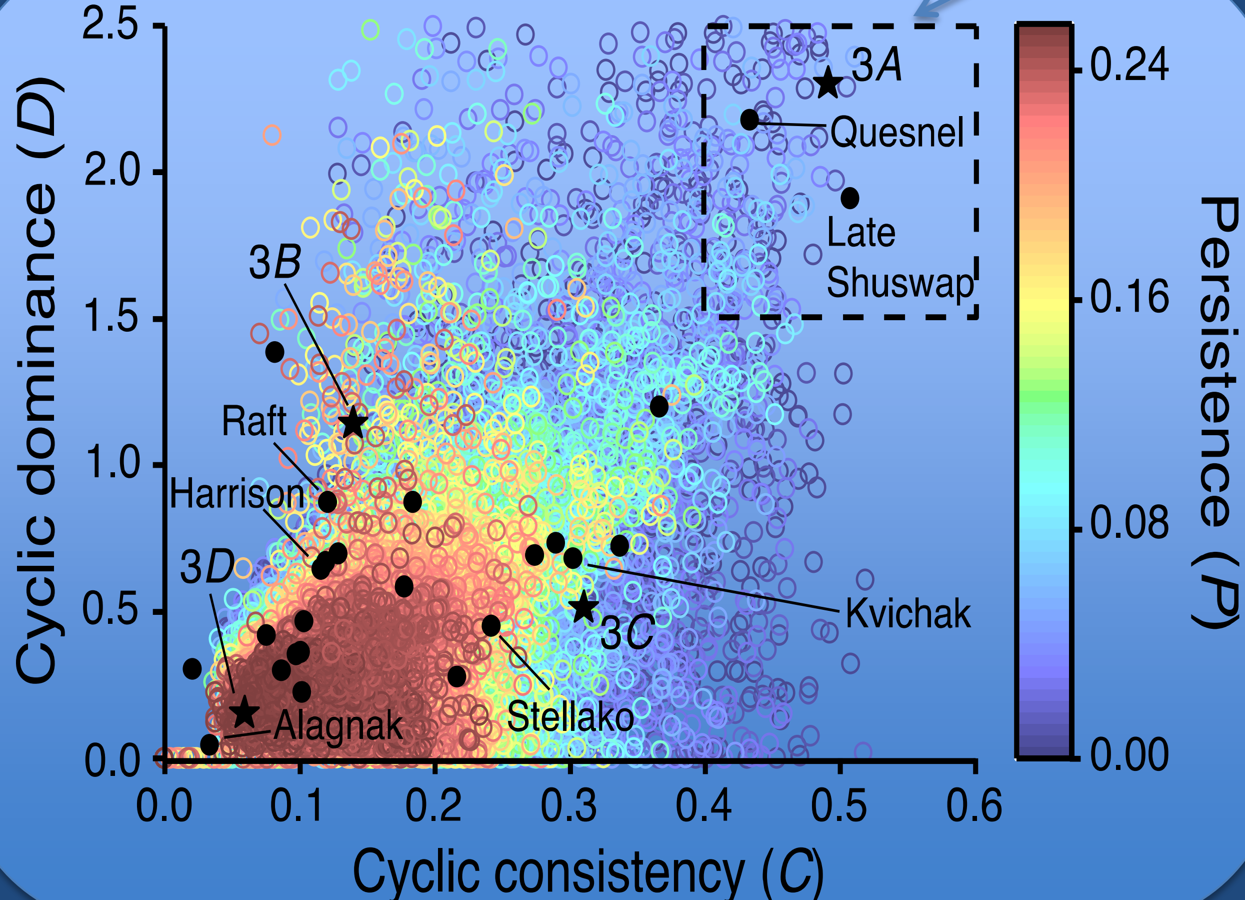
Fraser River sockeye (cycles common, period 4)



Bristol Bay sockeye (cycles rare, period 5)



Extreme cases



Test causes of high dominance and cyclicity

- Population persistence — Low
- Variability in survival — High
- Variability in growth
- Spread in spawning age distribution — Narrow

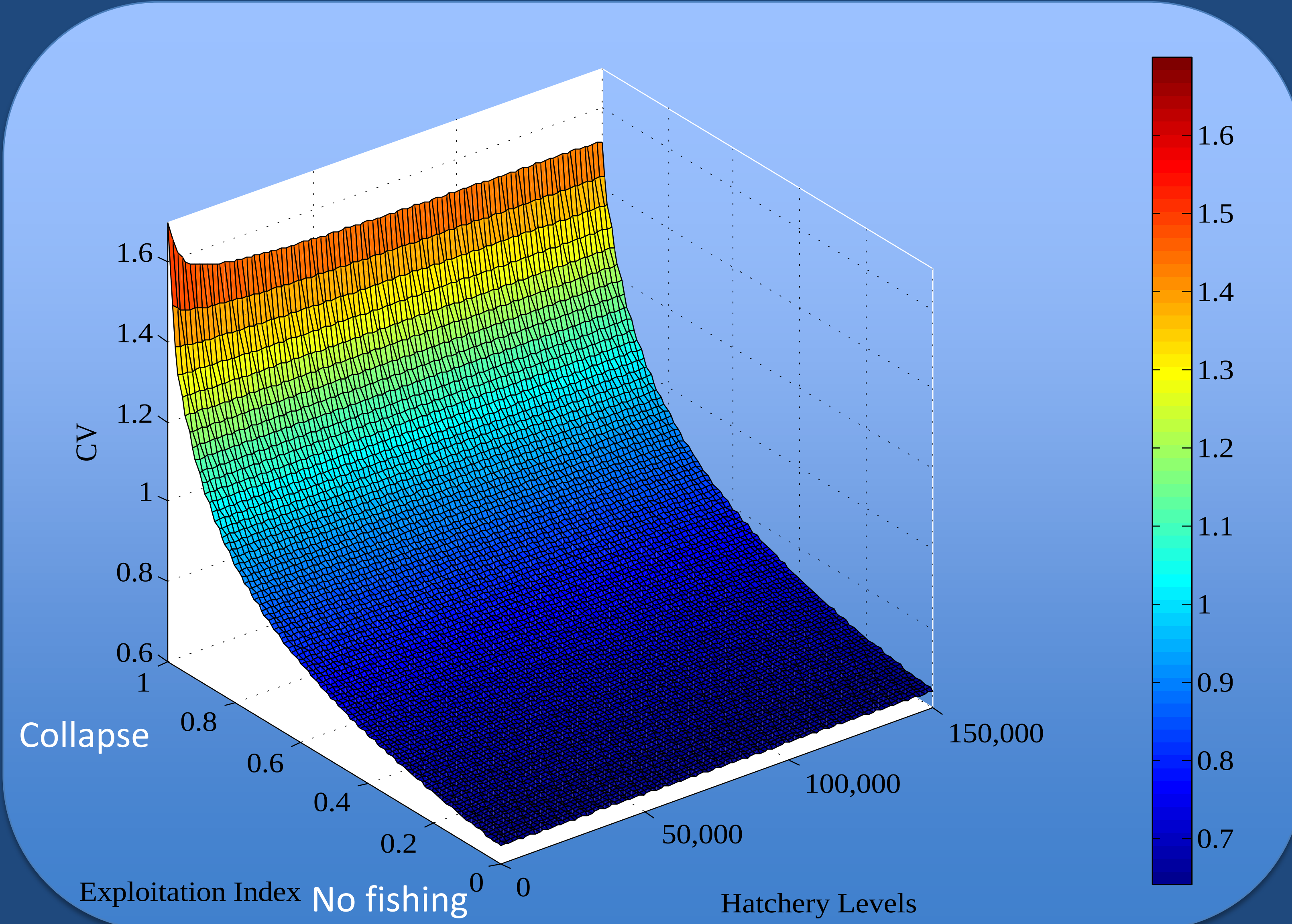
White, et al., in press, Ecological Monographs

Salmon populations with hatcheries

- Does the addition of constant numbers of hatchery smolts reduce the variability due to cohort resonance?
- Intuitive expectation: adding a constant reduces the Coefficient of Variation (σ/m)
- Actually very little effect on CV

Yamane, et al. ms

Chinook salmon with hatchery supplementation

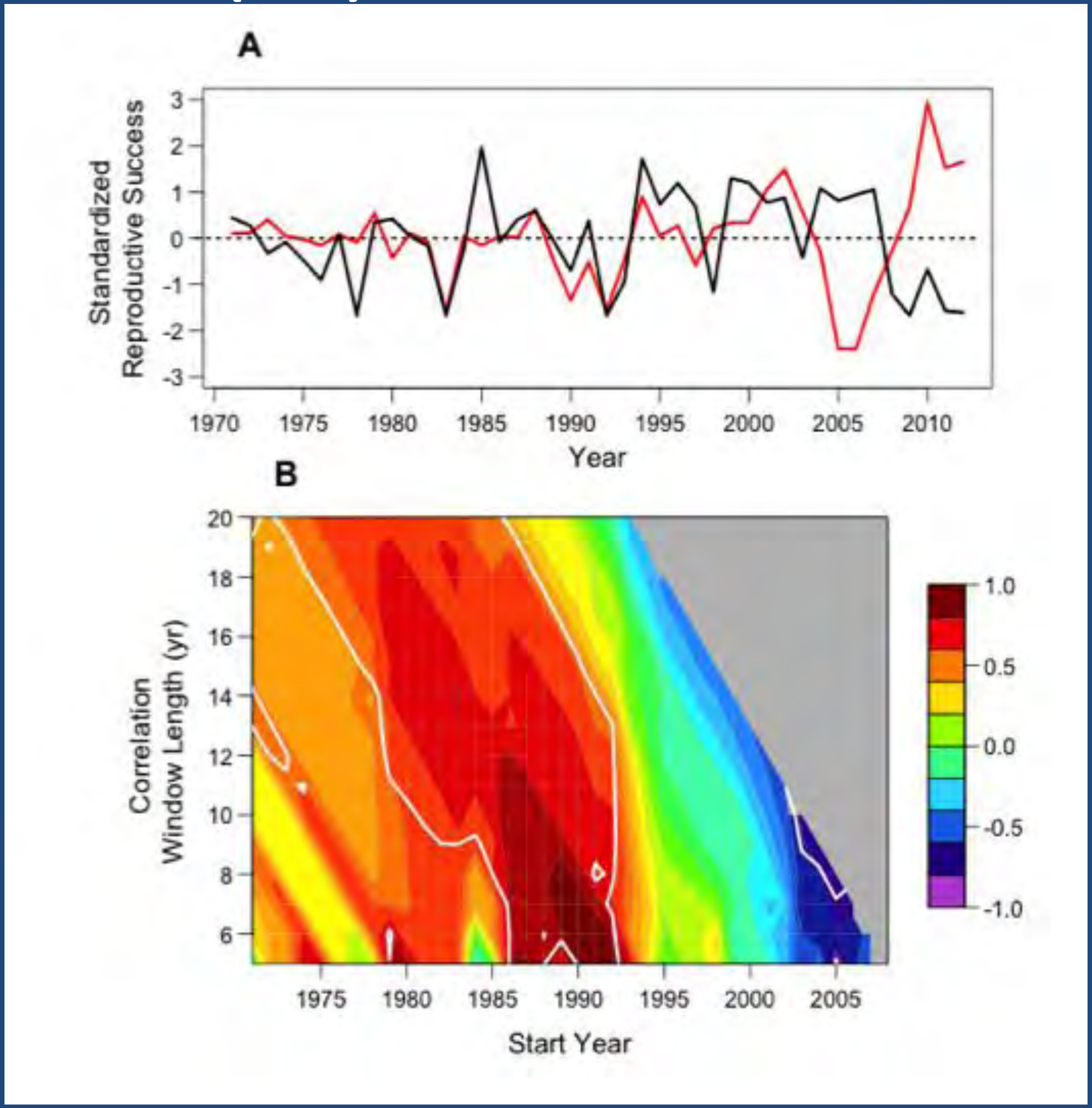


Yamane, et al. ms

Spectral sensitivity of marine birds

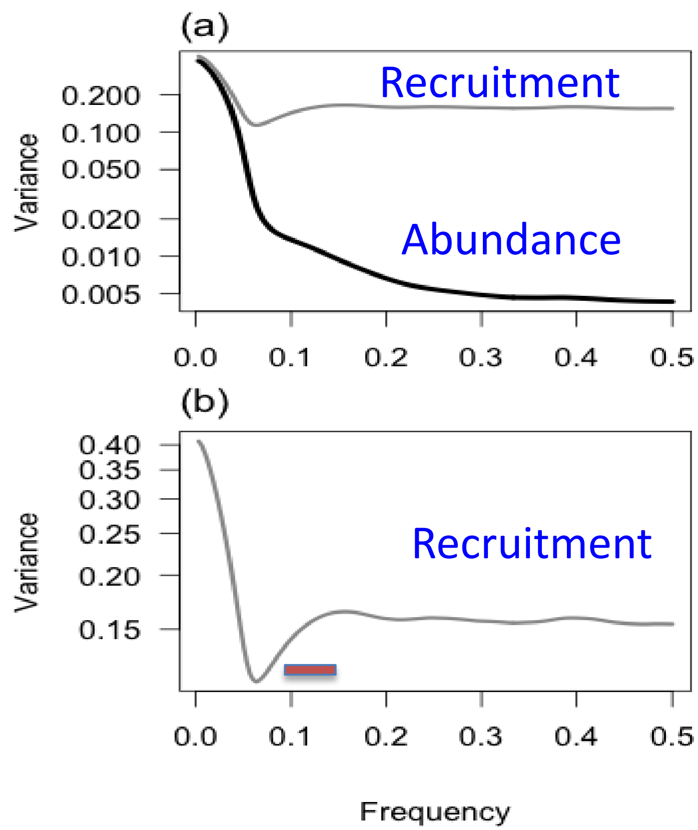
- Many marine birds nest on islands so that reproduction depends of variable productivity
- We examined frequency response of a typical marine bird, Brandt’s cormorant, nesting on Farallon Islands.
- Of interest because of recent non-stationary changes in dependence of two species on environmental forcing.

Variability in reproduction of Brandt's cormorant (—) and Cassin's auklet (—)



Schmidt, Botsford, Eadie, Bradley, Di Lorenzo, and Jahnecke, MEPS (soon)

Spectral sensitivity of Brandt's cormorant (early maturation, longevity 20y, 7<T<10, weak density dependence).

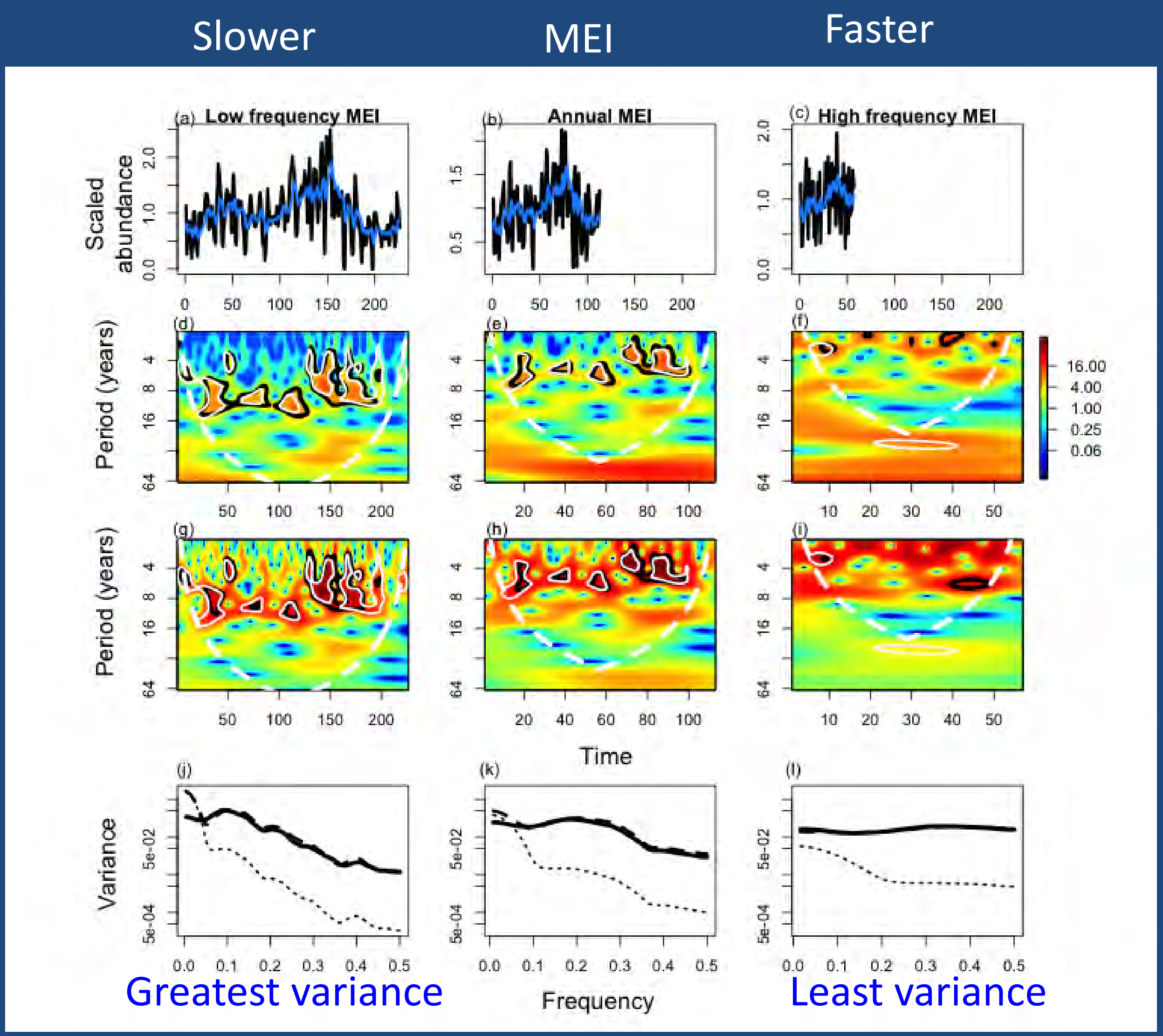


Schmidt, et al. (thesis, ms)

Future change in frequency of ENSO

- Seen in the past (e.g., Cobb, et al., 2003)
- Predicted by GCMs in the future (e.g., Timmerman, et al., 2003)
- How will that effect variability in Brandt's cormorant?

Doubled and halved frequency of ENSO



Summary
Cohort Resonance

- Greater sensitivity of populations to low frequencies and generational frequencies
- Sensitivity and overall variance increase with fishing
- Characteristic of populations stable about equiilibrium, on compensatory part of Stock Recruitment curve
- Differs from period 2T cycles and other explanations of variability increasing with fishing
- Provides an explanation for cycles in sockeye.
- Just as strong in populations with hatcheries
- Specific spectral sensitivity in marine birds
- In birds, slower ENSO frequency increases variance, and vice versa

THANKS!

A new Coastal Marine Science Institute

At the Ag School, UC Davis