Population dynamic effects of fishing and climate change on upper trophic levels in the northeast Pacific

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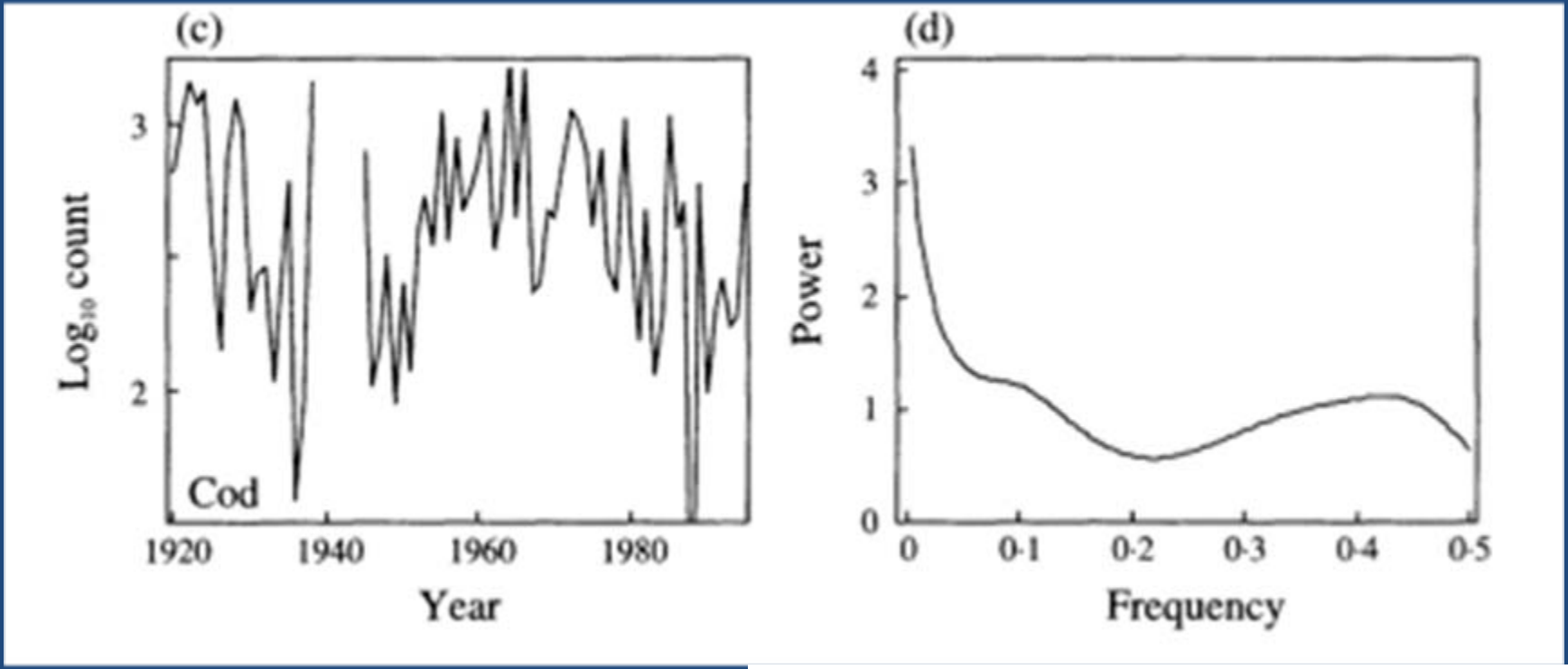
Outline

- How age-structured models respond to environmental variability (cohort resonance)
- How fishing affects that response
- Some examples
- What this means for choice of models to predict the effects of climate change on ecosystems

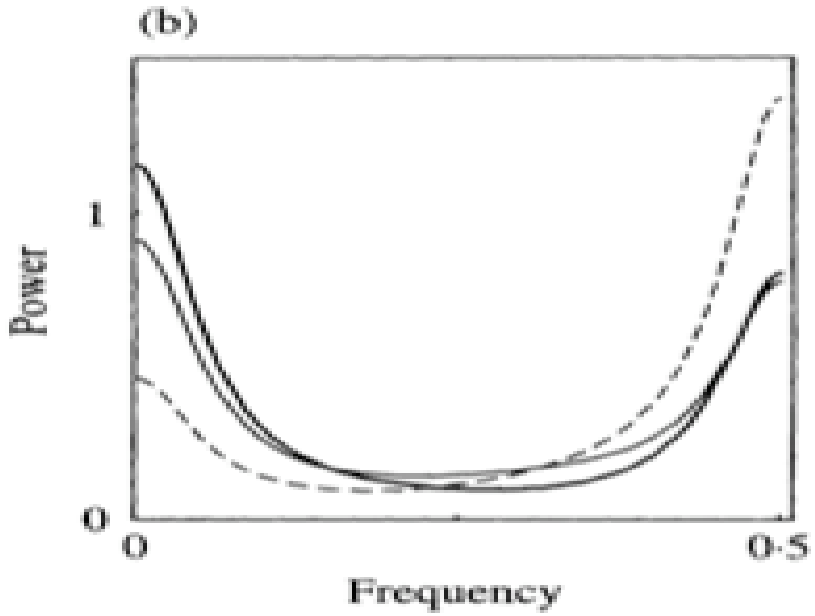
Recent Population dynamic result

- “Cohort resonance”: age structured populations are sensitive to variability on time scales of the mean age of spawning, and to very slow time scales (Bjornstadt, et al. 2004)



Coastal cod from the Skagerrak

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



New population results

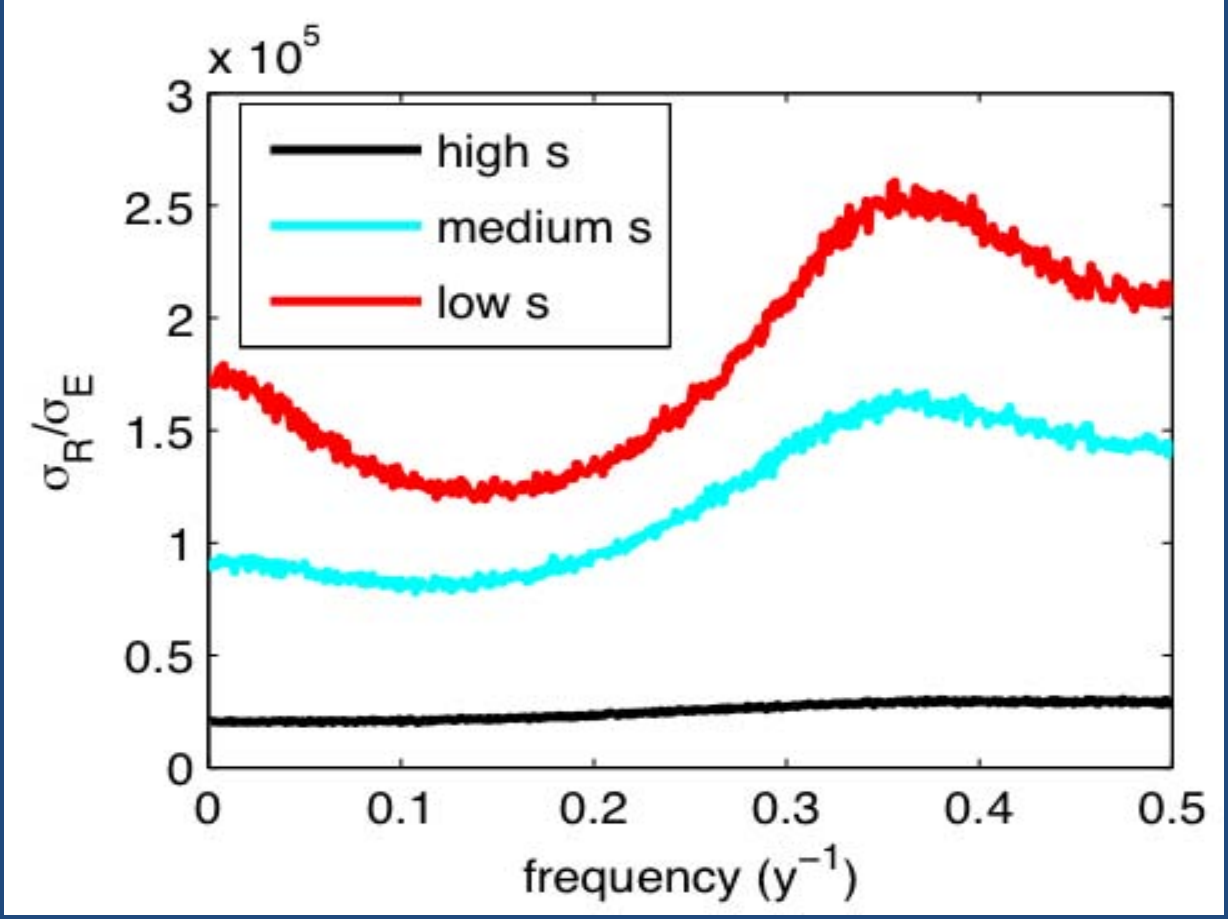
- 1. Cohort resonance increases with fishing
- 2. Random growth rate drives cohort resonance more than random survival does
- 3. Catch time series show less response at high frequencies than recruitment

Worden, Botsford, Hastings and Holland (2010)
Theoretical Population Biology 78: 239-249
Analysis of age-structured model with density-dependent recruitment, using salmon as an example

New result 1: Decreasing survival (by fishing or climate) increases variability, resonance and low frequency sensitivity, in addition to decreasing equilibrium.

e.g., coho salmon with variable growth rate

[variability about equilibrium]



Examples of:

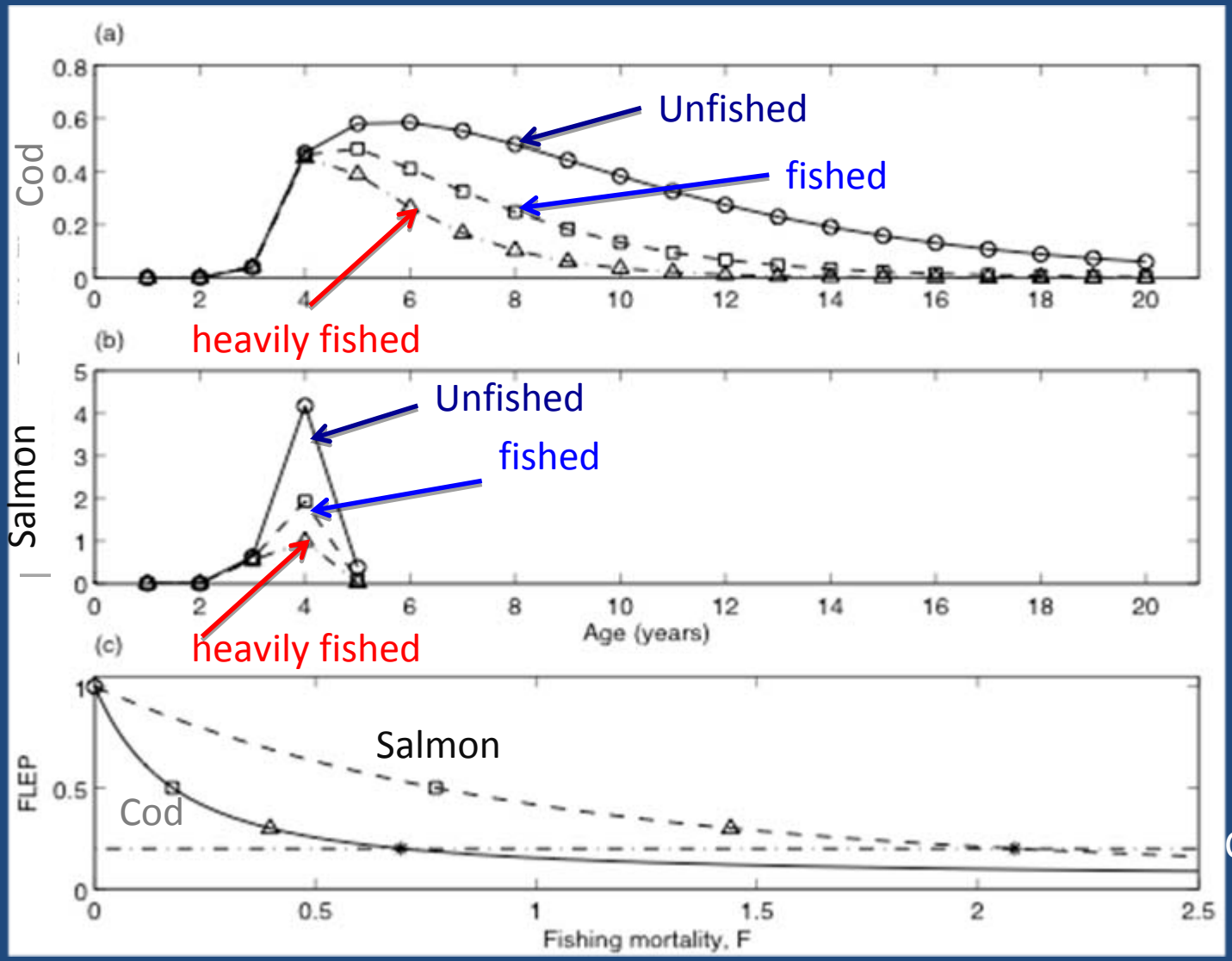
(1) short-lived semelparous (generic Pacific salmon) species

(2) longer-lived iteroparous (generic Pacific cod) species

- Forcing early survival with white noise
- Forcing early survival with PDO

Fishing changes age structure, changing dynamics, i.e., equilibrium and cohort resonance.

Lifetime Spawning (a) = survival(a) x maturity(a) x fecundity (a)

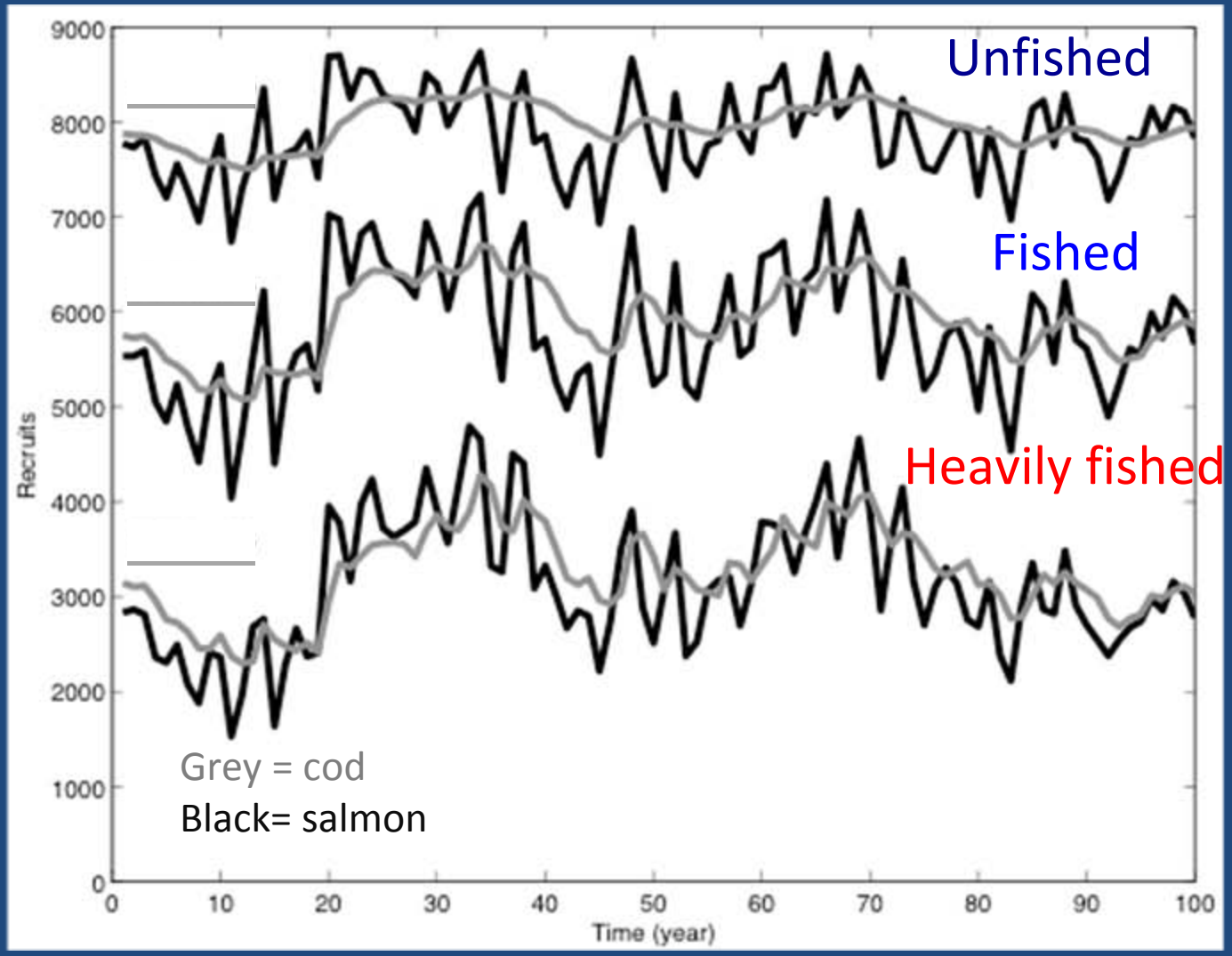


FLEP=SPR

Collapse value

Cod: mean age declines with fishing, broader spread over age.

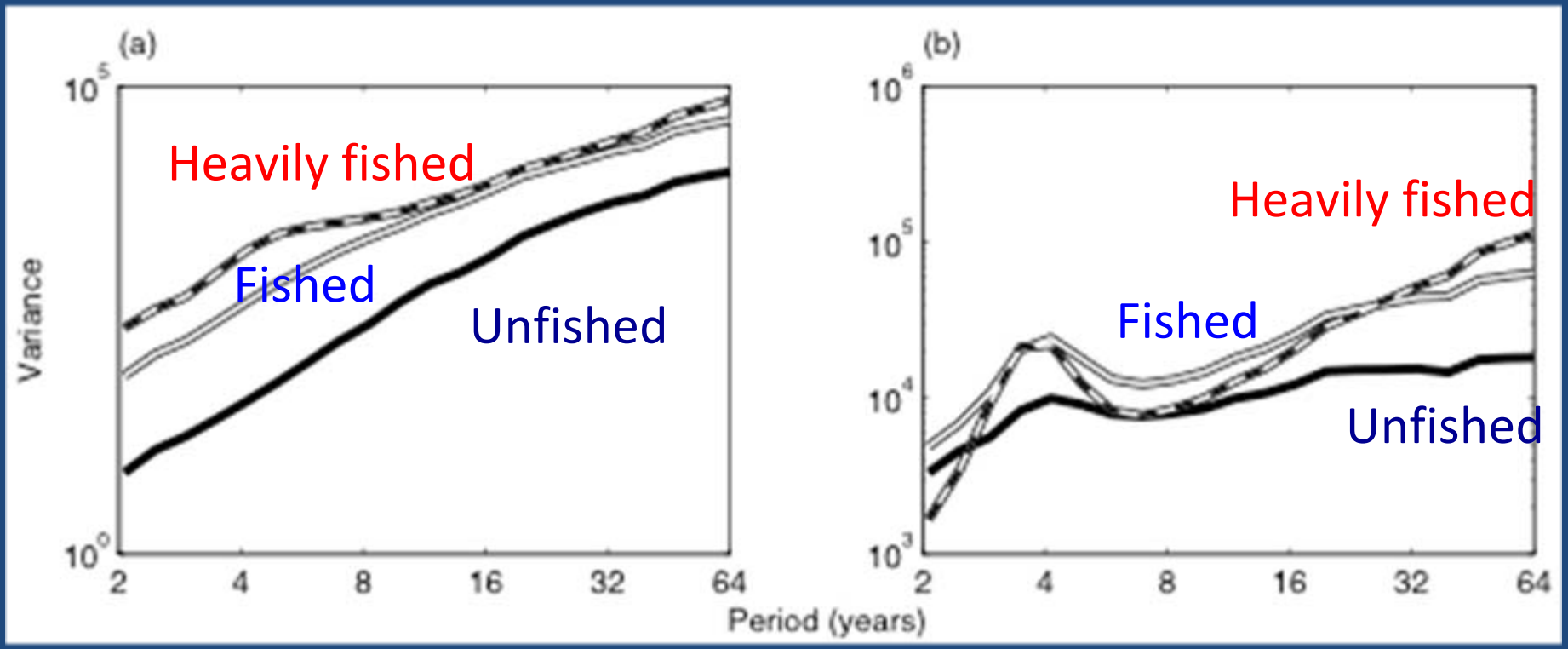
Recruitment time series with white noise forcing at different fishing levels



Variance spectra

Generic cod

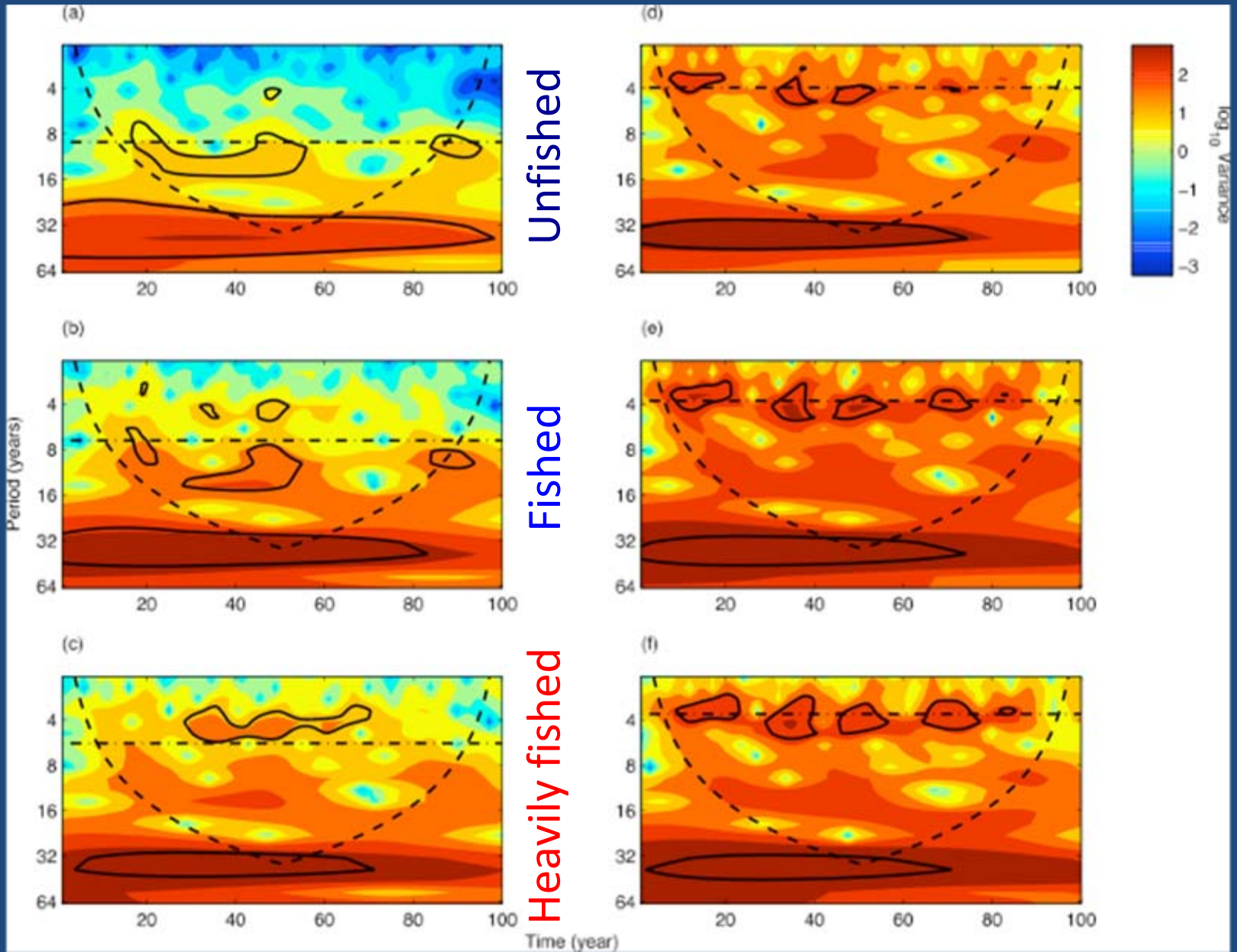
Generic salmon



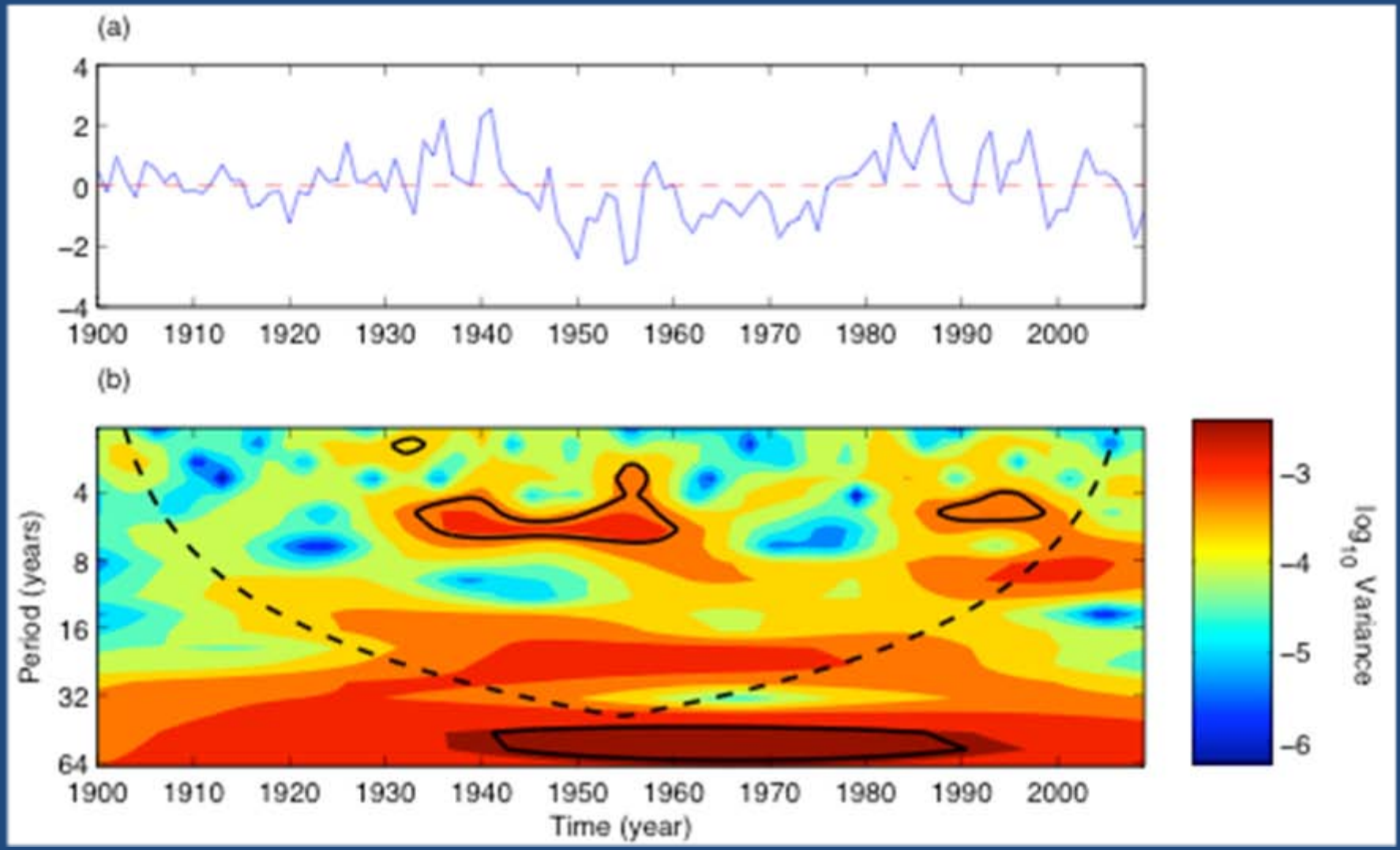
Wavelet spectra vs. time with white noise

Generic cod

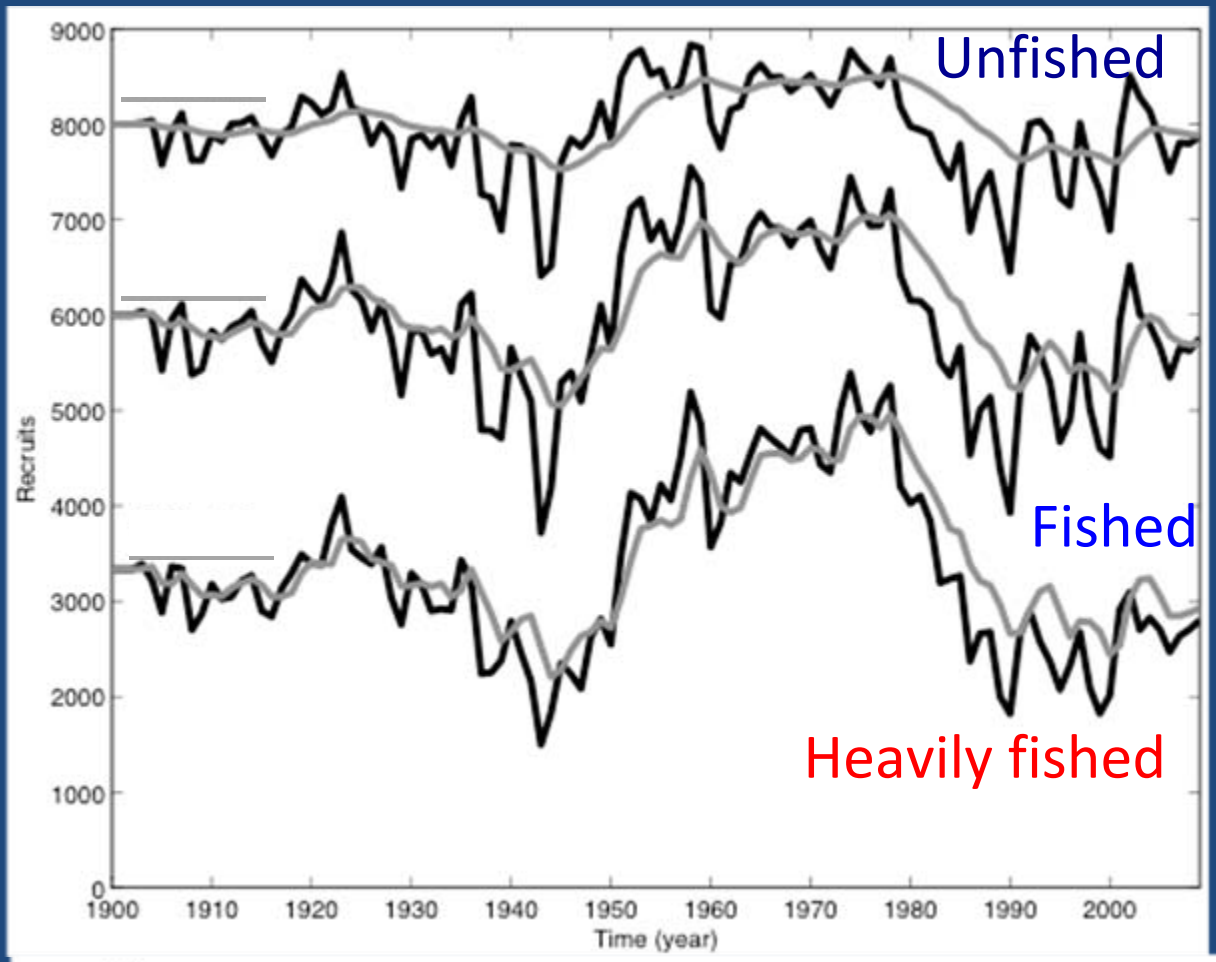
Generic salmon

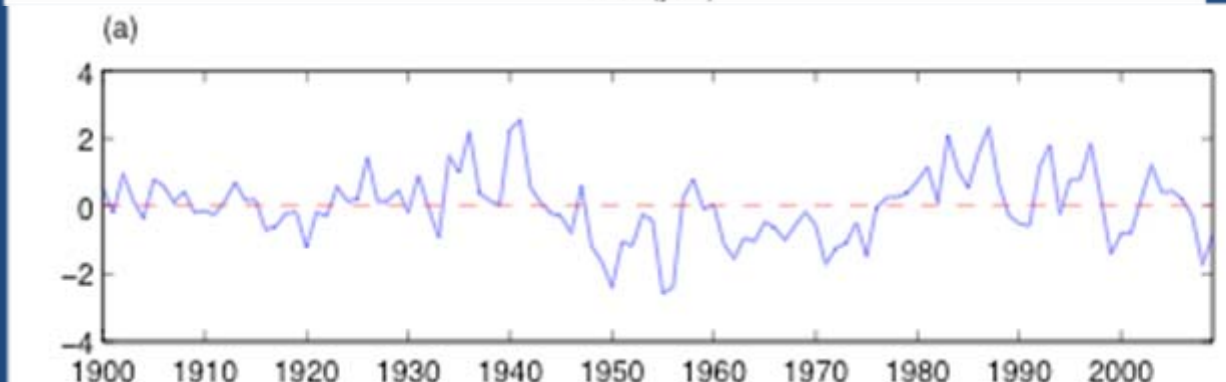


Wavelet spectrum of PDO



Time series with PDO forcing at different fishing levels



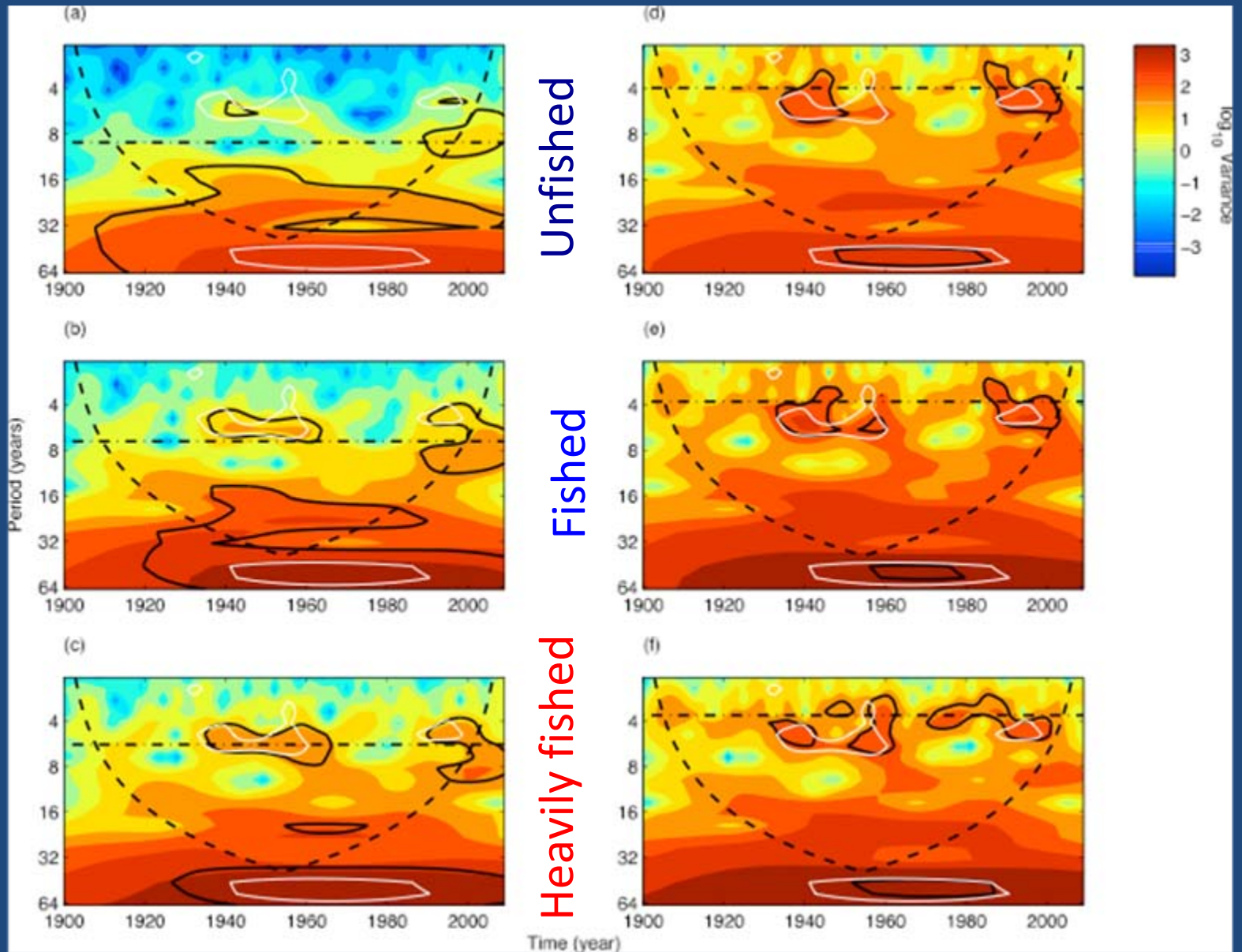


PDO

Wavelet spectra vs. time with PDO

Generic cod

Generic salmon

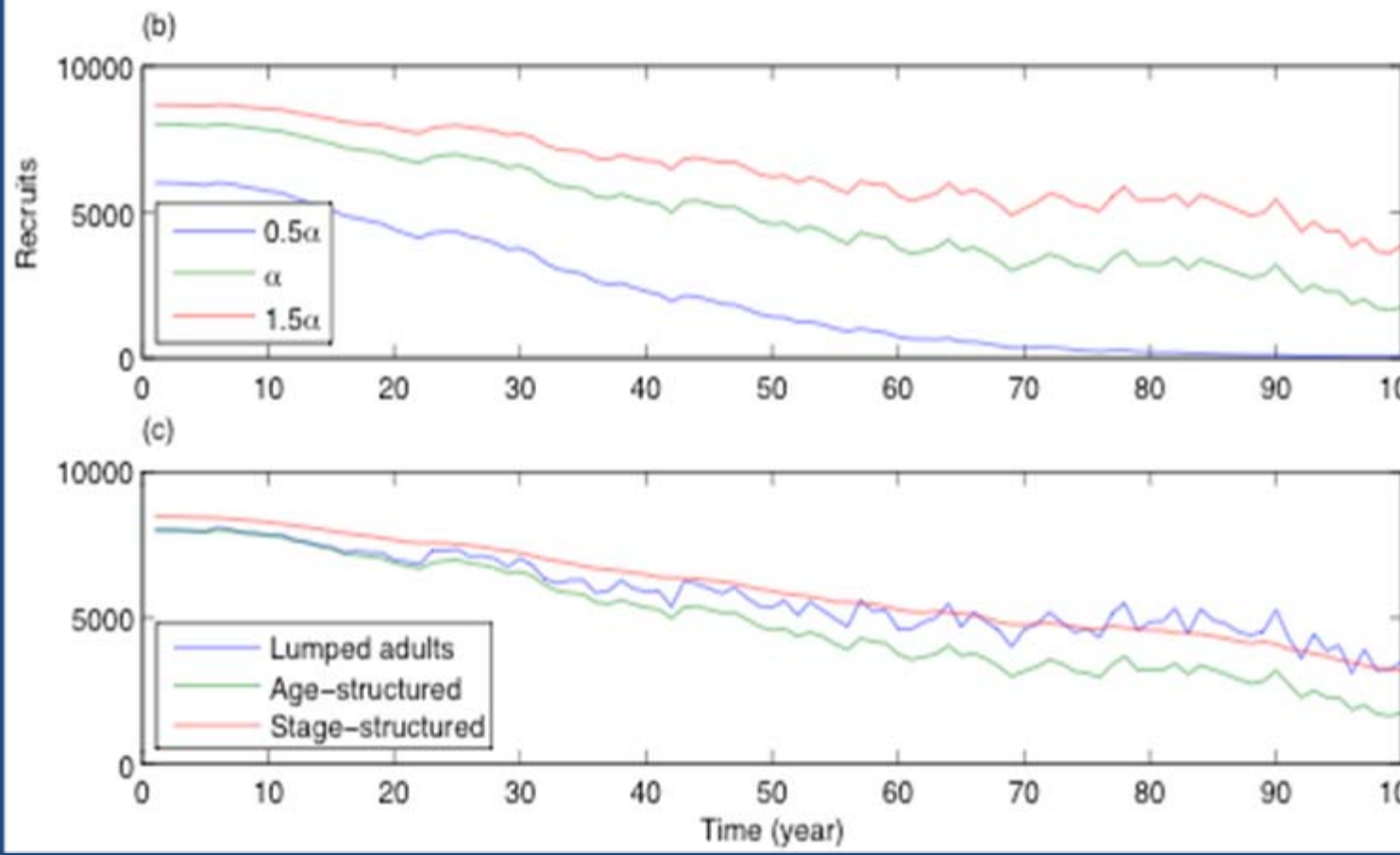


Cohort resonance=effect of age structure Potential problems predicting effects of climate change with Ecosystem models?

- Ecosystem models based on trophic relationships will estimate collapse points of FLEP (SPR) with substantial error (Plagányi and Butterworth 2004)
- Ecosystem models that use stage structured models of age structured UTLs will not depict cohort resonance

Errors in collapse point (slope of S/R at origin)

Errors in model structure: using stage-structured or lumped models



Linearly increasing fishing mortality rate with time

Botsford, et al. submitted ICES J Marine Science

Conclusions

- Cohort Resonance increases with increasing fishing
- Greater resonance effect for species spawning over narrower range of age (Northeast Pacific species?)
- Greater overall variance with increased fishing
- Important to include age structure in models predicting effects of climate change (i.e., in Ecosystem models)
- Next steps: Identify population variability on generational times scales (e.g., sockeye salmon, other salmon, Bering Sea snow crab?)