Effects of Shifting Population Demographics, Oceanography, and Predation on Apparent Stock-Recruitment Relationships for Tanner Crab in the Eastern Bering Sea

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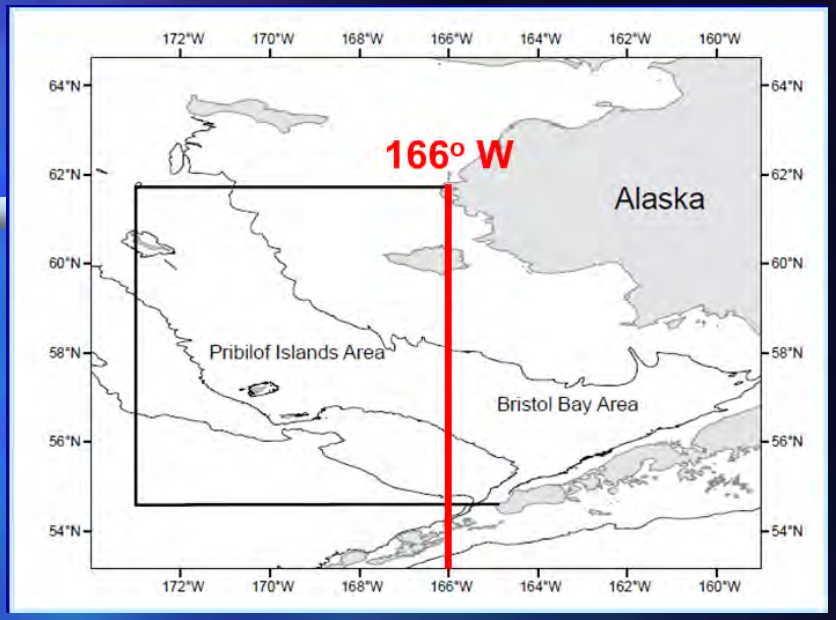
Tanner Crab
Chionoecetes bairdi


Photo: C. Botelho, ADF&G

- Size at maturity:
  - Males > 112 mm CW
  - Females > 79 mm CW
- Maturity molt is final
- Fertilization is internal; sperm may be retained up to 3 years
- Larvae hatch during late April – early June
- Two zoeal stages of ~ 1 mo duration each
- Megalops stage
- Males recruit to the fishery ~7 yr old

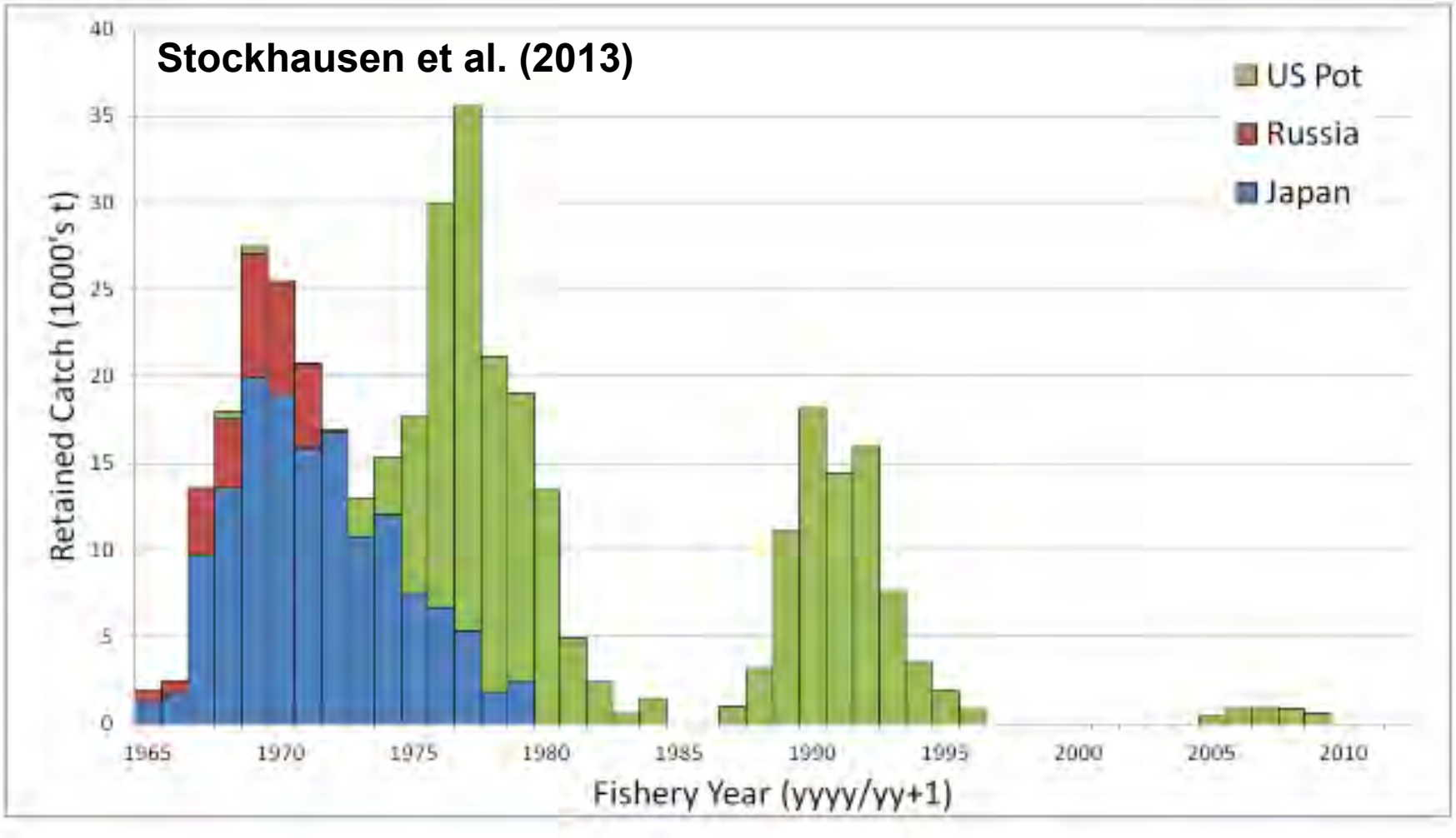
Distribution of *C. bairdi* & *C. opilio*

Fishery Management

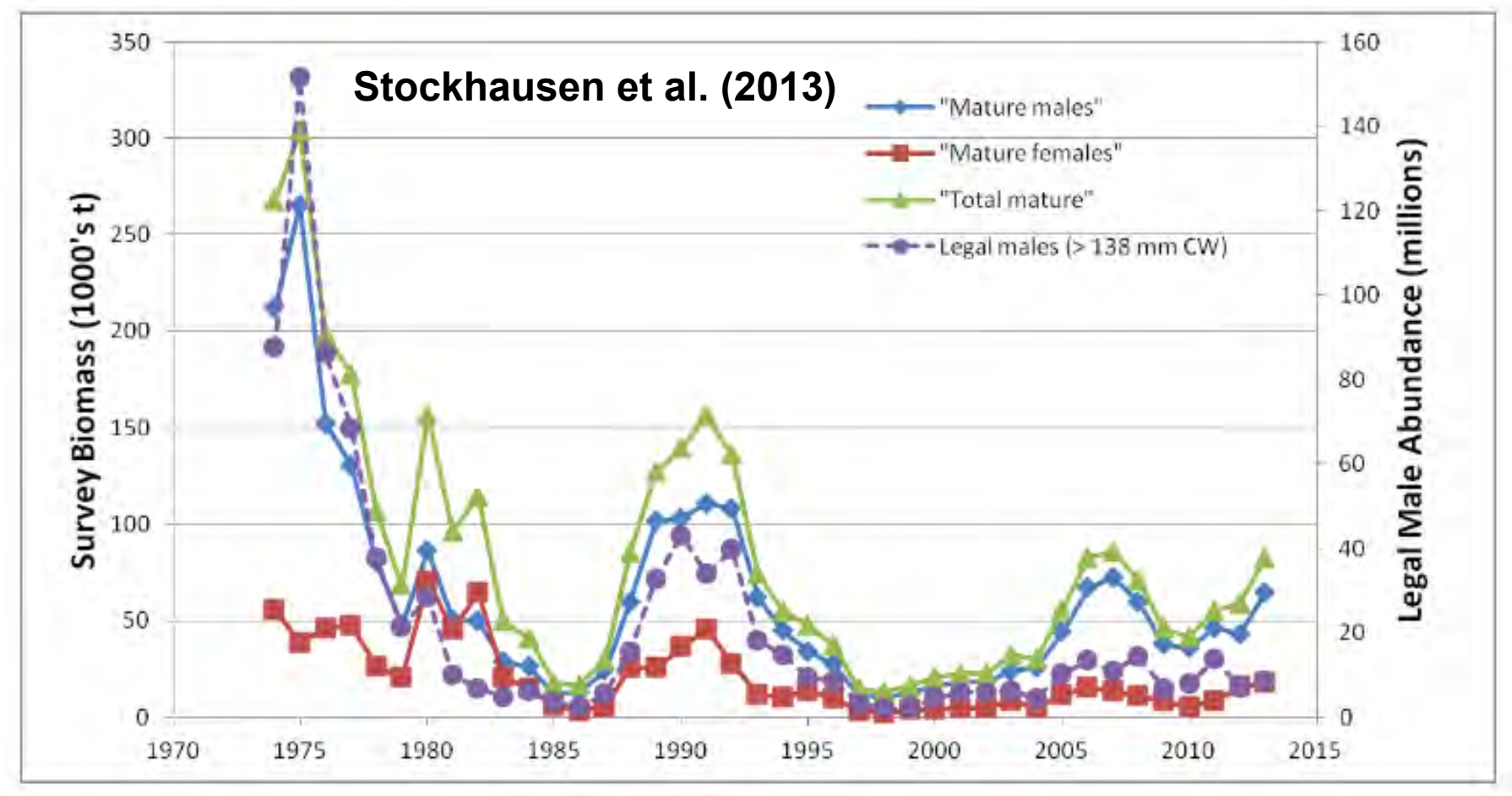


- Federal fishery management plan
- Length-based stock assessment model (EBS)
- Federal management – e.g., Individual Fishing Quotas (IFQs), overfishing limits (OFLs)
- State management – e.g., observer program, fishing seasons, size limits, harvest rate strategy, total allowable catch (TAC) split east and west of 166° W

Boom and Bust Fishery History



Volatile Stock History



Research Objectives

1. Estimate stock-recruit relationships for Tanner crabs in the eastern Bering Sea, if possible
2. Estimate potential relationships between recruitment and groundfish predators in the eastern Bering Sea

Data

- **Recruitment** – abundance of 30-50 mm CW crabs (~3 yr)
- **Stock** – abundance of reproductively active females of shell condition 3 (SC3, old shell) and 4 (SC4, very old shell)
- **Groundfish** – abundance estimates of species/ages consuming crab:
  - Pacific cod, ages 3-7
  - Yellowfin sole, ages 7+
  - Flathead sole, ages 3+

Methods: Autocorrelation

Owing to a significant positive autocorrelation at lag 1 yr and negative correlation at lag 6 yr, a first-order auto-regressive process was used in all regressions:

$$\varepsilon_t = \varphi + \varepsilon_{t-1} + v_t$$

where v_t is a Gaussian white noise term and φ is the autocorrelation parameter

Methods: S-R Models

- **Log-transformed non-linear Ricker model**

$$\ln(R) = \alpha + \ln(S) - \beta S + \varepsilon_t$$

- **Log-transformed Cushing model**

$$\ln(R) = \alpha + \beta * \ln(S) + \varepsilon_t$$

- **Log-transformed Shepherd model**

$$\ln(R) = \alpha - \ln(1 + e^{g} * S^{\beta}) + \varepsilon_t$$

where g controls the shape of the curve

Models were fitted by generalized non-linear least squares regression

Methods: Predator Models

- **Recruitment residuals, *r***

$$r = \frac{lnR - \overline{ln\ R}}{S_R}$$

where S_R is the standard error of the mean recruitment over 1978-2008

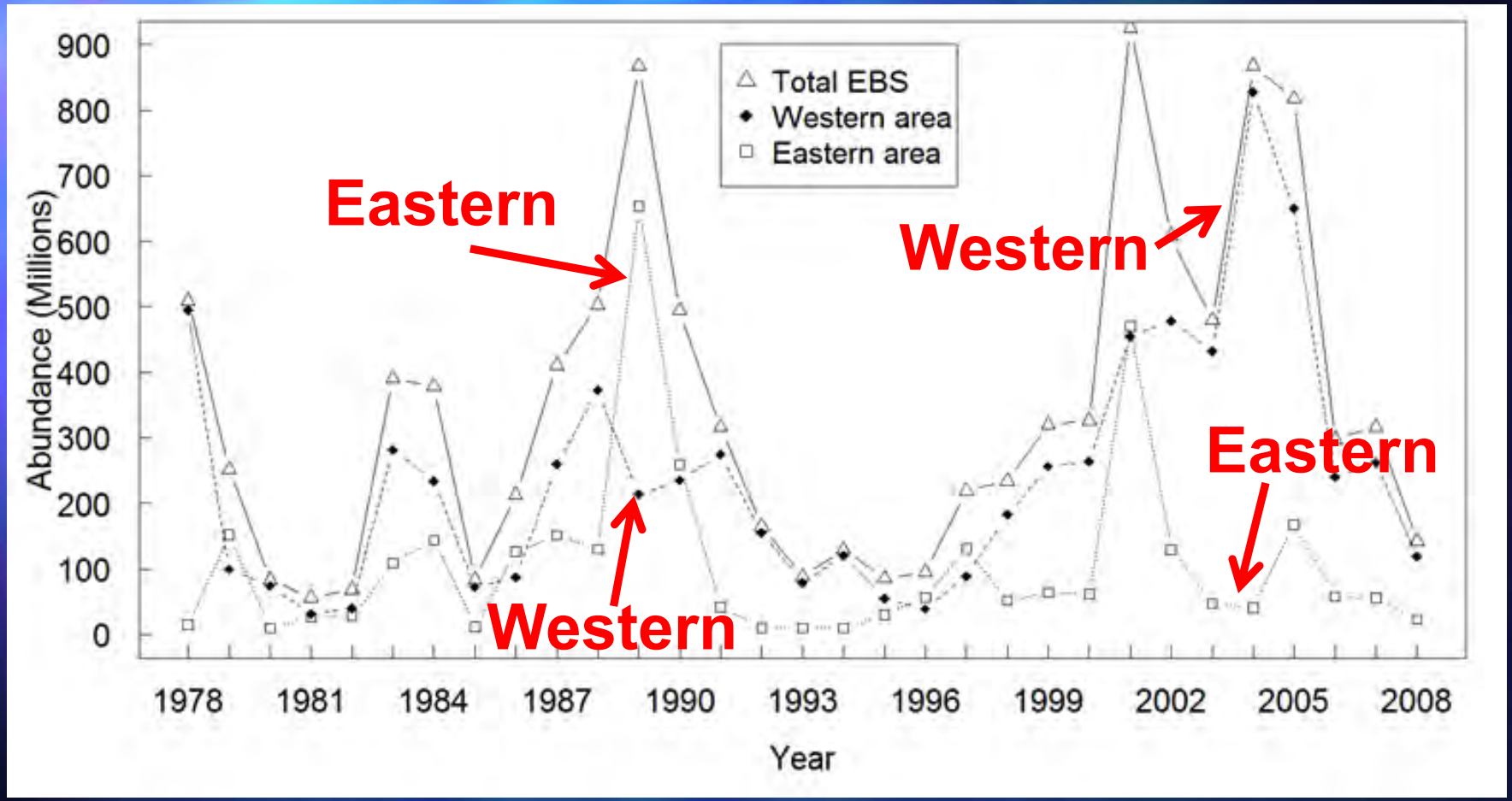
- **Linear and dome-shaped predator-prey relationships**

$$r = \beta_0 + \beta_1 X + \varepsilon_t$$

$$r = \beta_0 + \beta_1 X + \beta_2 X^2 + \varepsilon_t$$

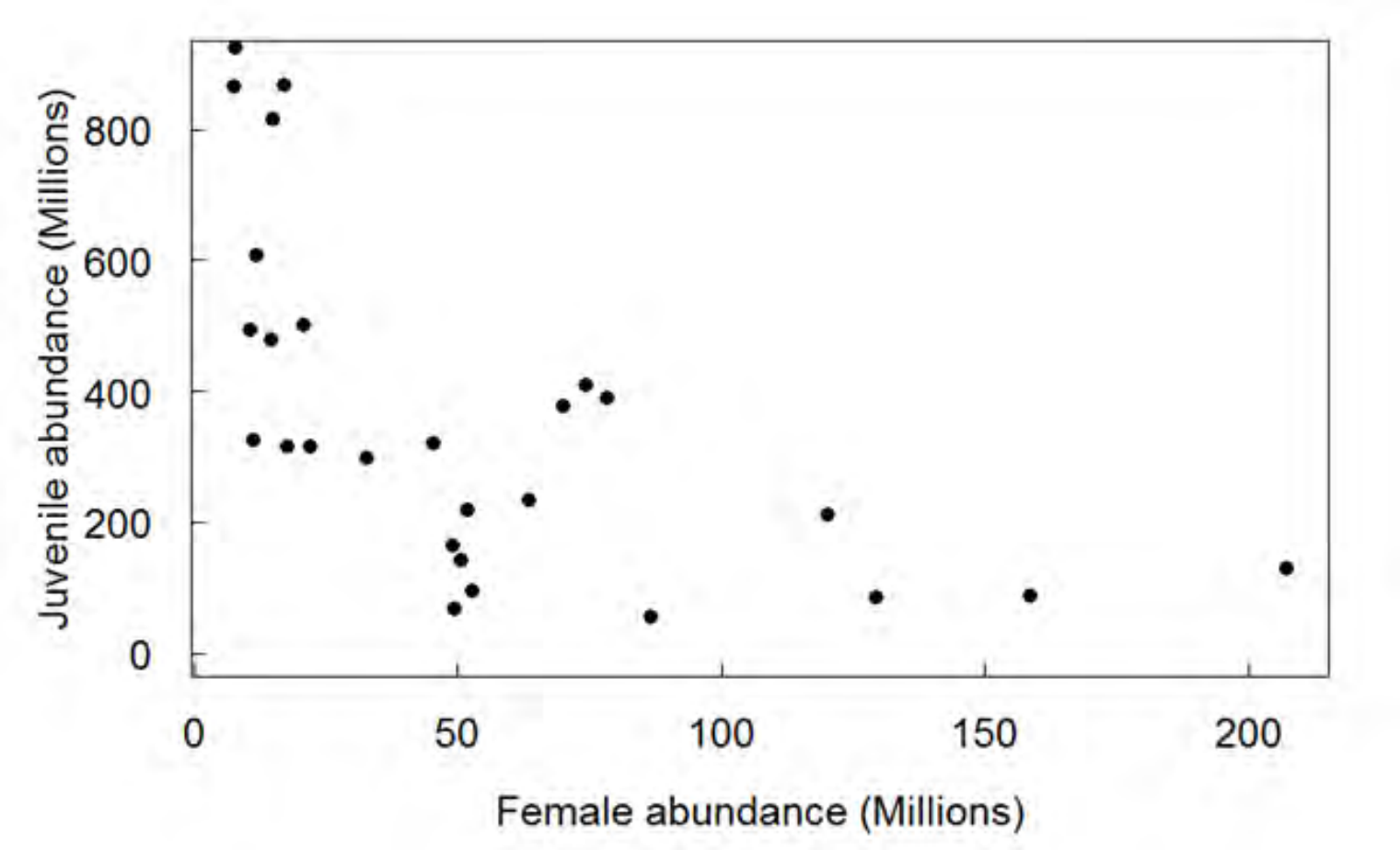
where X predator abundance. Models fitted by general least squares with AR(1)

Results: Crab Recruitment



- Note east → west shift

Results: S-R Relationship

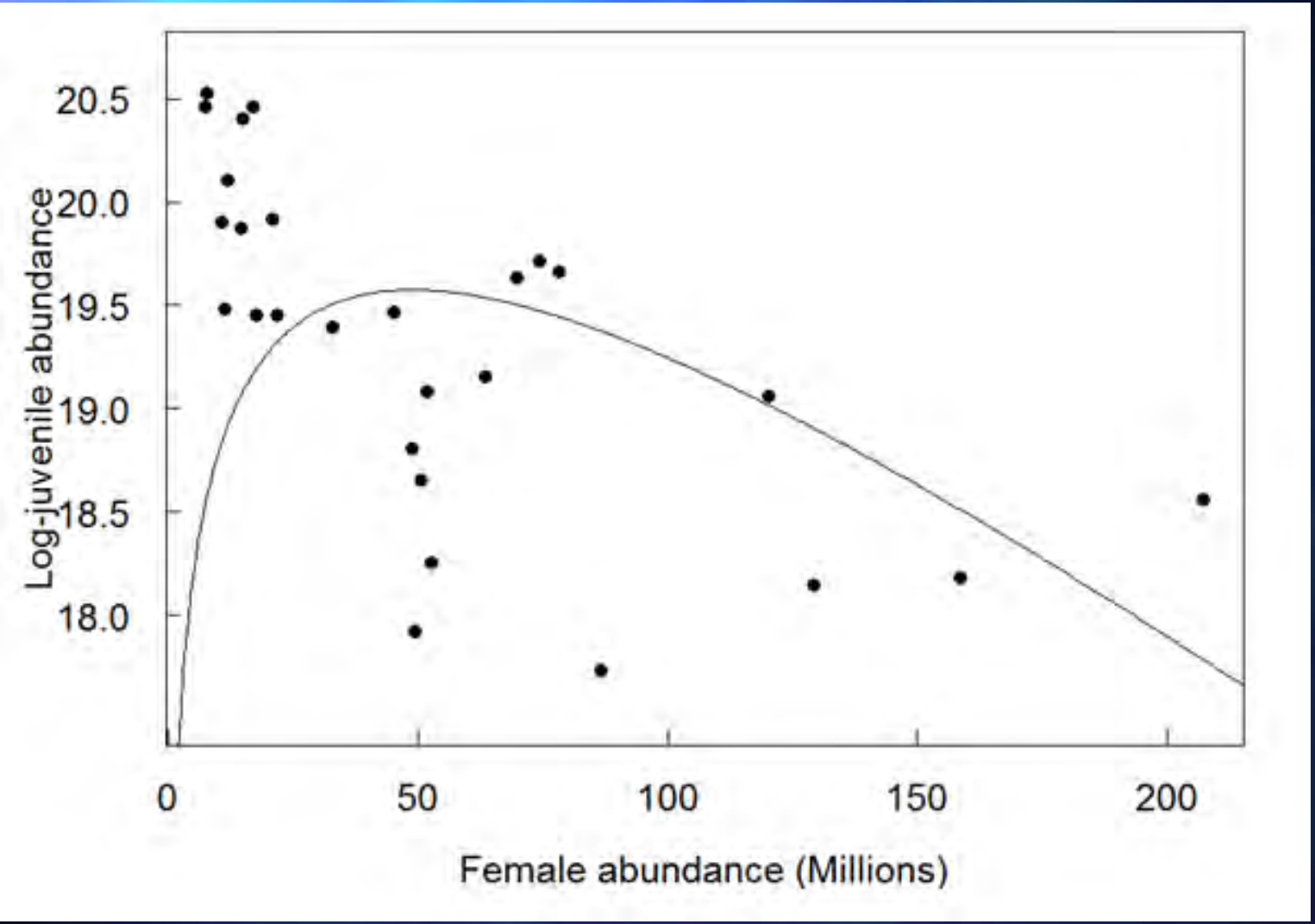


- Curvilinear relationship suggests density dependence

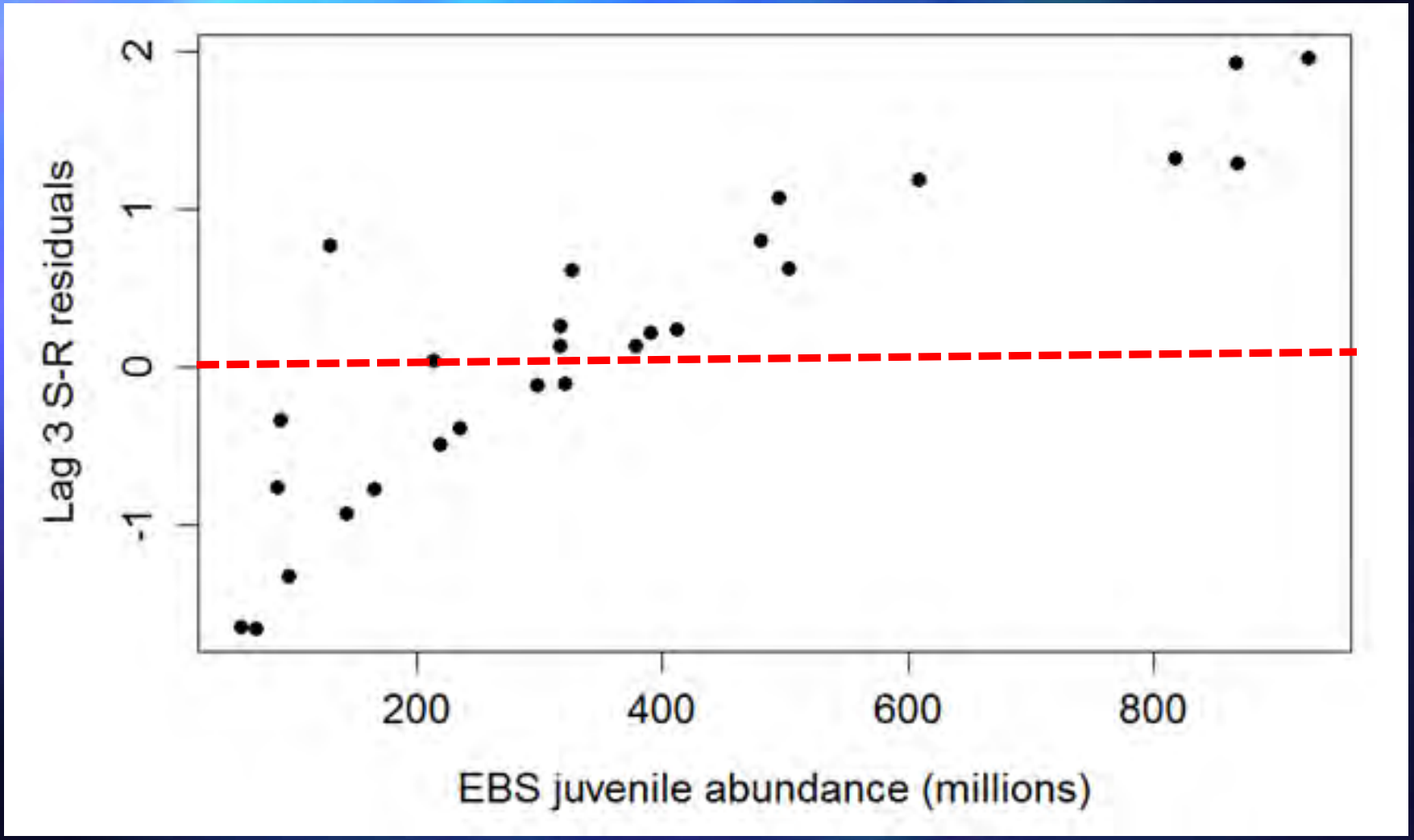
Results: Cushing & Shepherd

- Cushing model yielded good fits, but only with a negative β parameter, implying infinite recruitment at stock size of 0
- The Shepherd model could not be fitted to our data due to non-convergence
- Inherent in all stock-recruit models is the assumption of low recruitment at low stock sizes

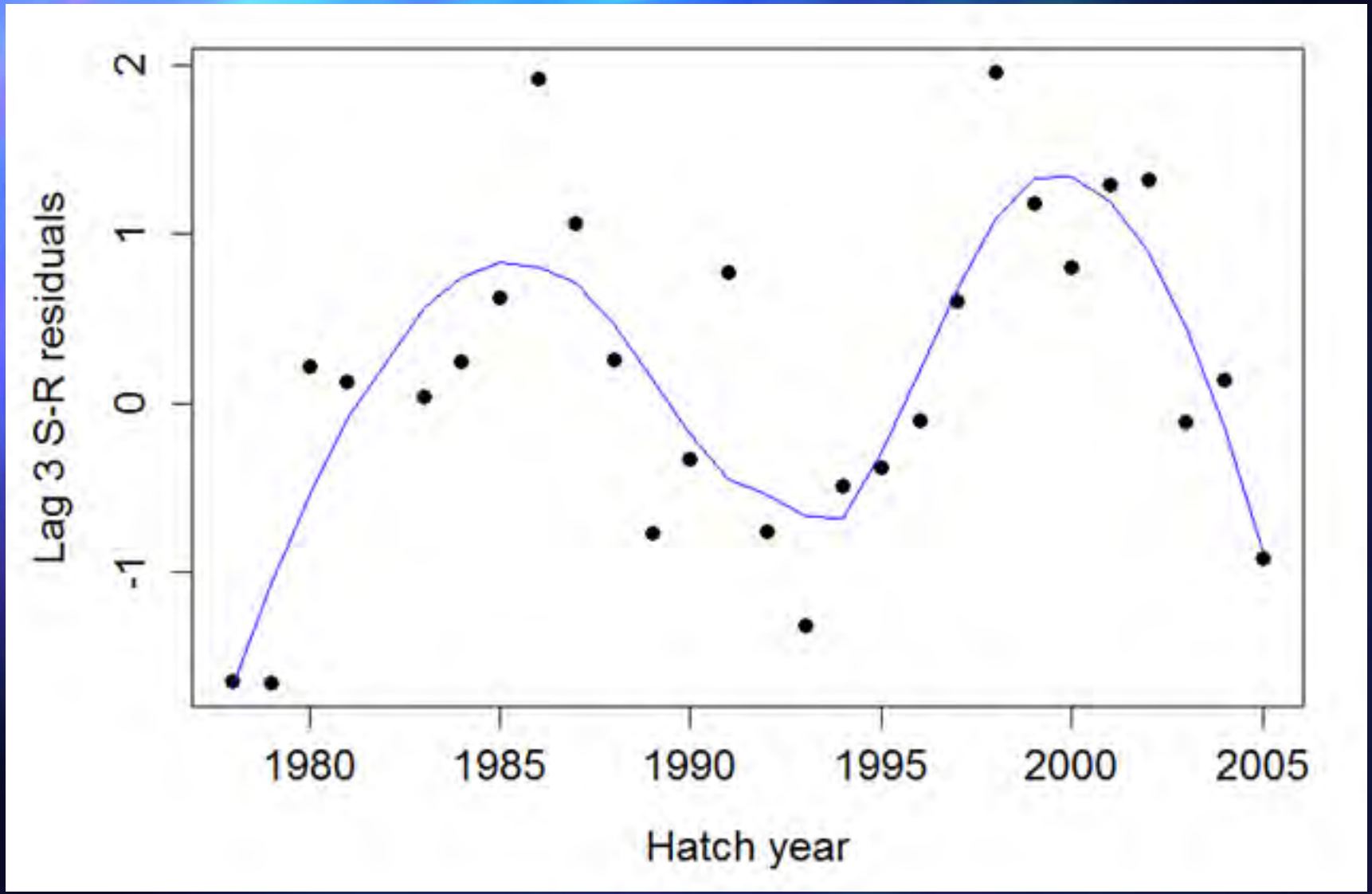
Results: Ricker Model



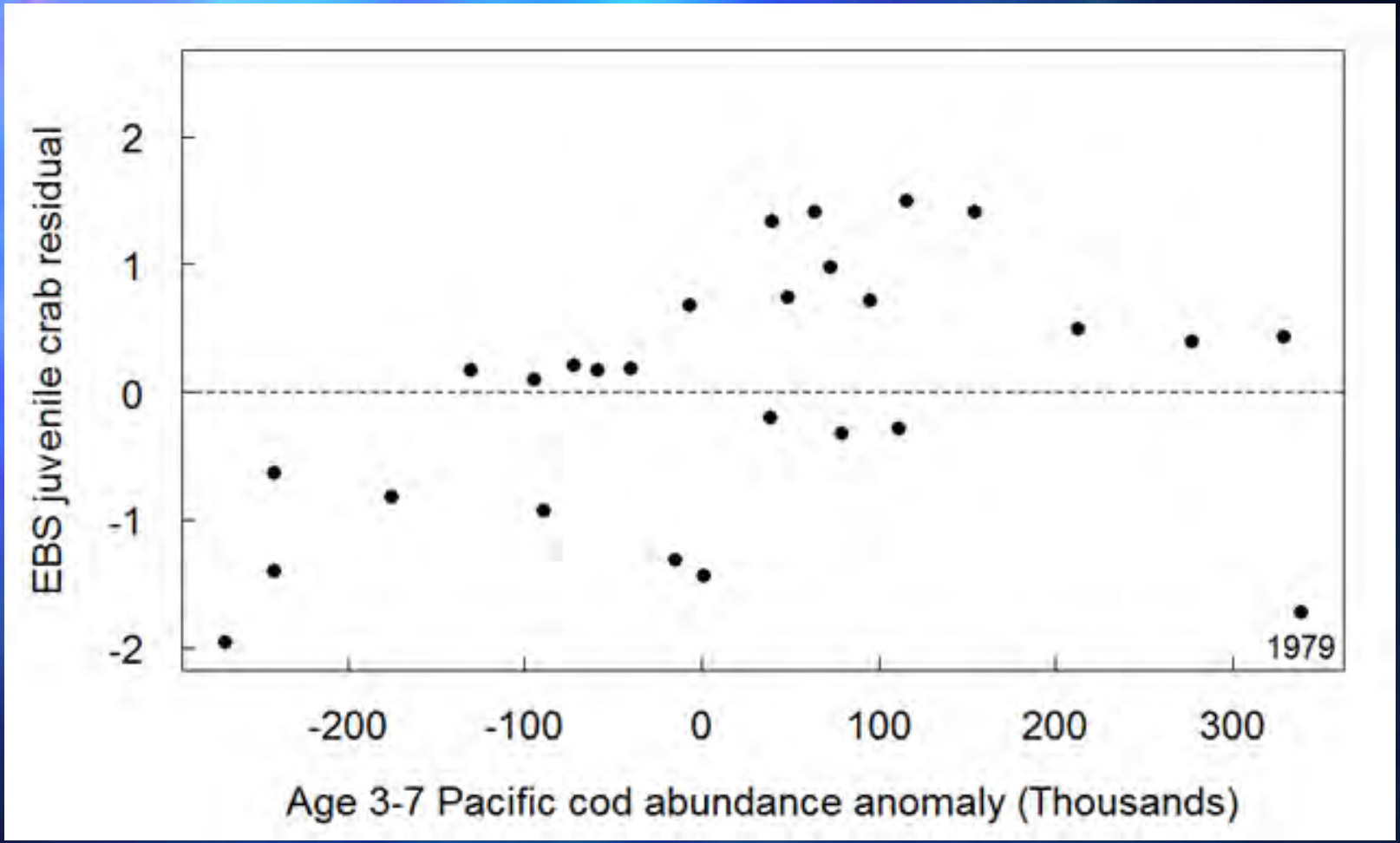
Results: Model Mis-specification?



Decadal Pattern in Residuals

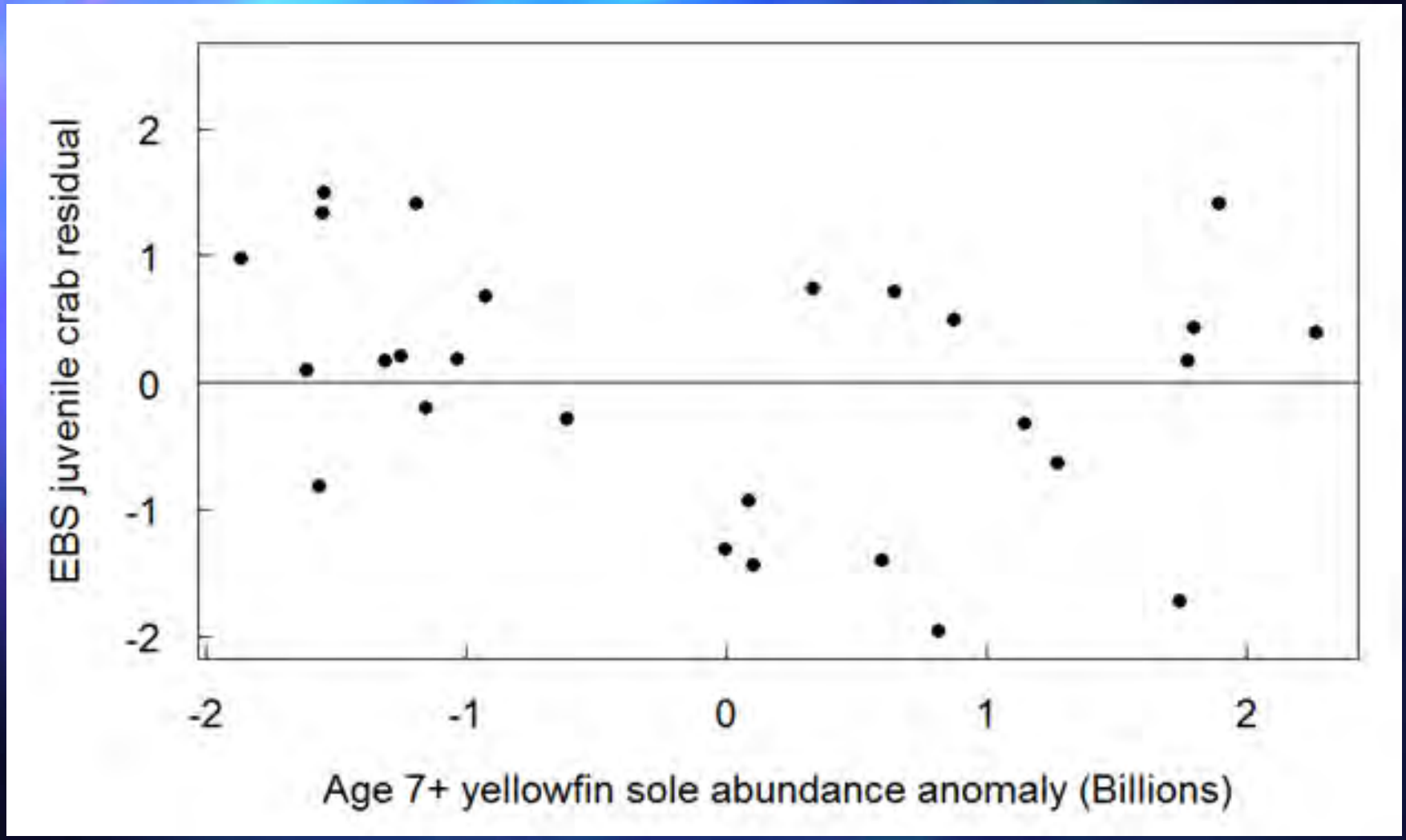


Relationship with Pacific Cod

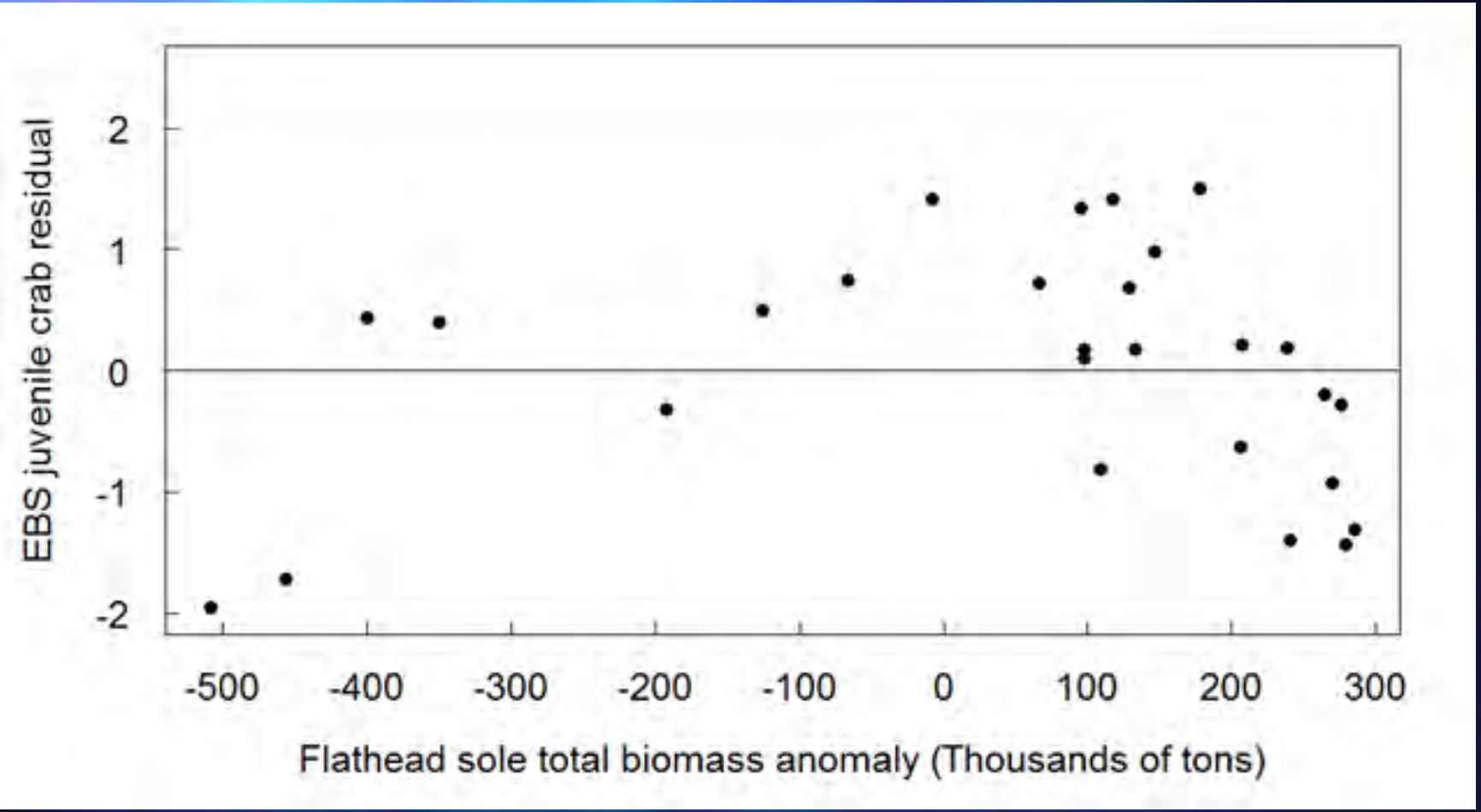


- Relationship is highly significant, if 1979 point is removed

No Relationship with Yellowfin Sole



Dome-shaped for Flathead Sole



- Quadratic terms are statistically significant

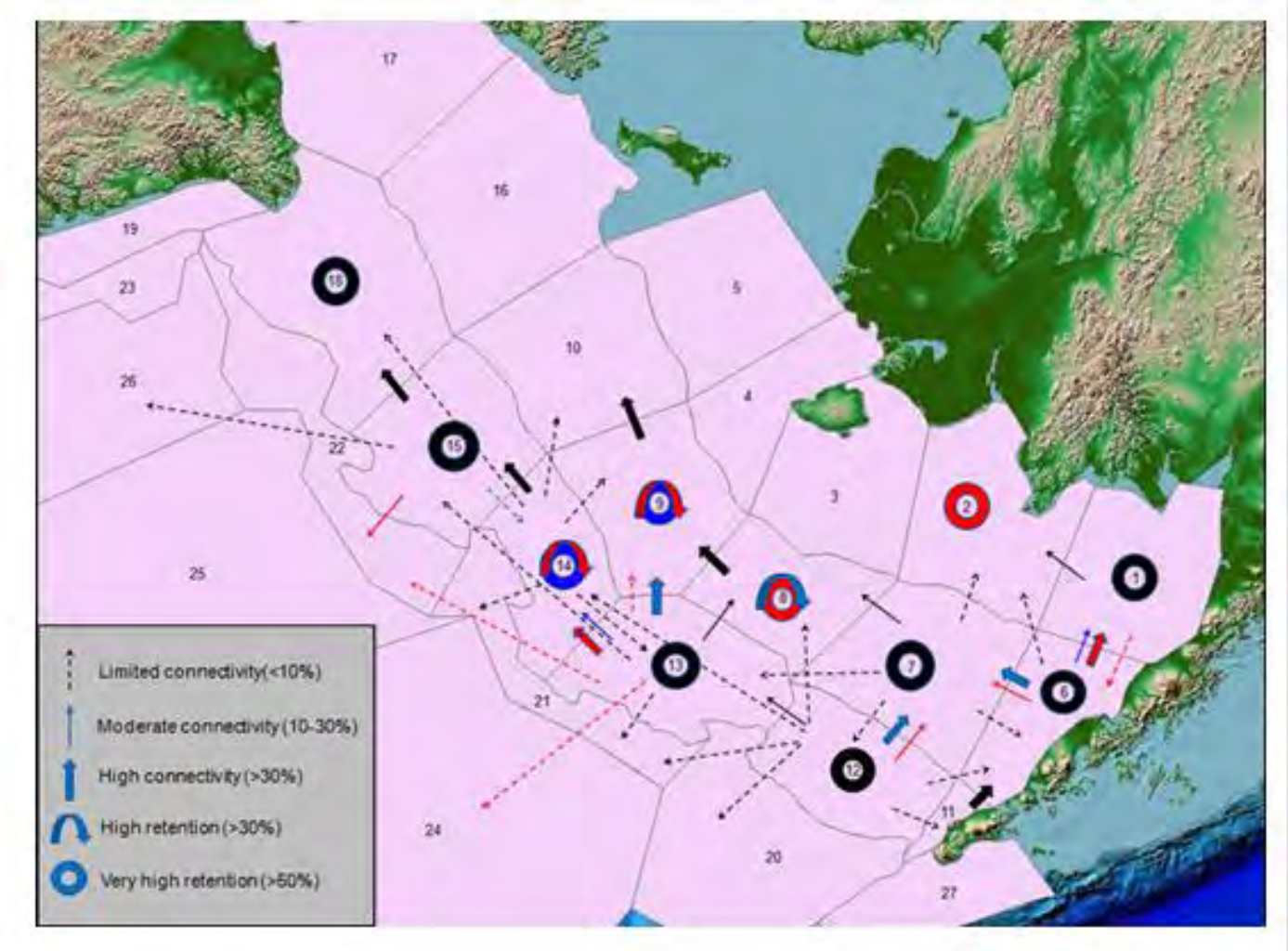
Discussion

- **One interpretation of results** – presence of strong density-dependent relationship
  - Potential mechanism – cannibalism
  - In abundant years, female distribution expands to outer shelf and to the northwest. ROMS modeling suggests larvae from these regions are vagrants
- **Alternative interpretation** – recruitment is environmentally driven with autocorrelated variability with periodicity about twice the mean generation time

Discussion

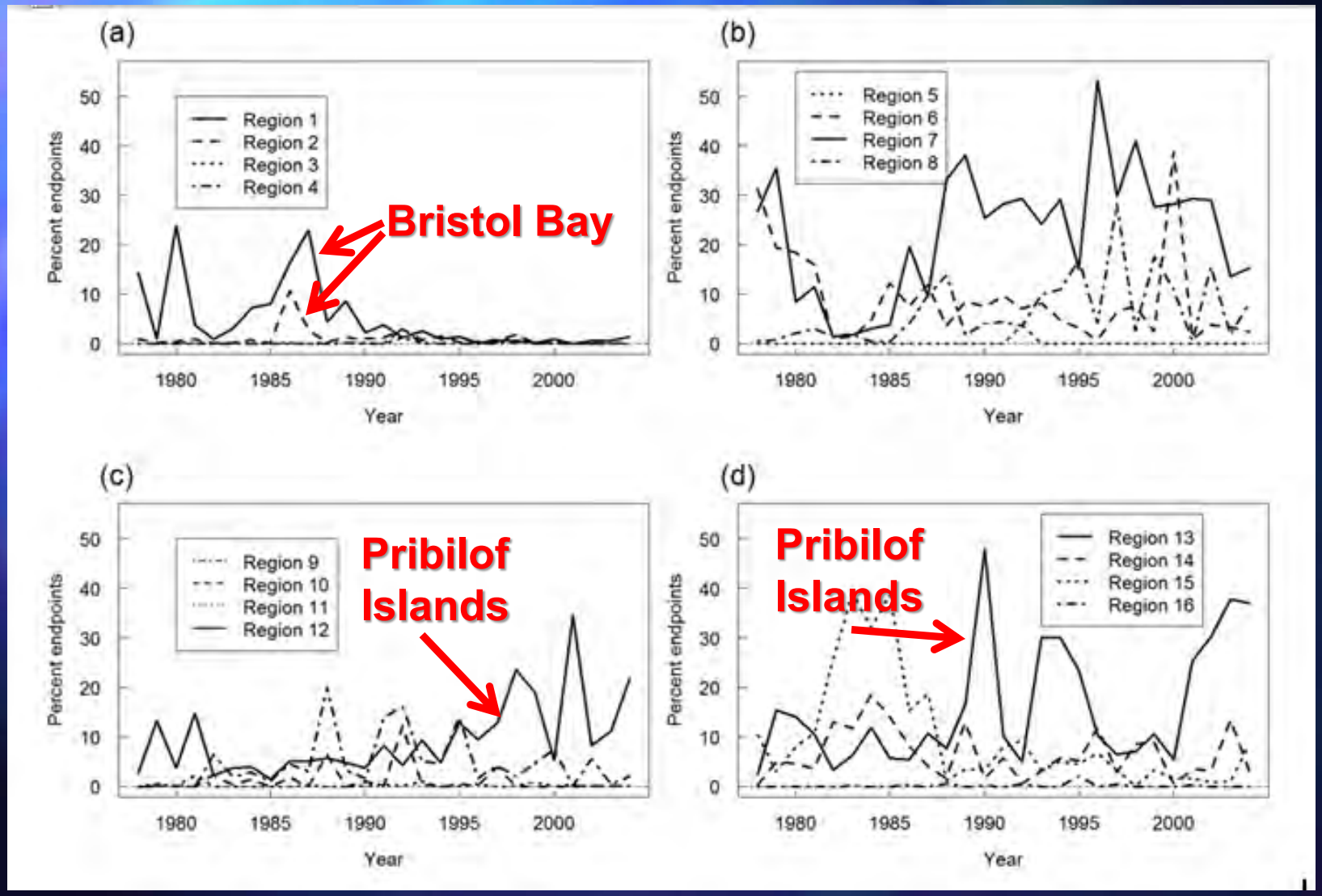
- Evidence for predation effect is weak or mixed:
  - **Positive** with cod is contrary expectations from top-down control
  - **Zero** with yellowfin sole suggests no effect
  - **Dome-shaped** with flathead sole could suggest prey switching behavior
- Finer-scale spatial models may be necessary owing to interannual shifts in distributions

Discussion: ROMS



- Bristol Bay depends on local retention

Discussion: ROMS



Ongoing Work

- Exploring ROMS-based gauntlet models in attempts to explain year-to-year variability in Tanner crab recruitment based on conditions at settling:
  - Groundfish predator density
  - Bottom temperature
  - Surficial sediments
  - Older juvenile crabs (cannibalism)

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Questions?