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*

- 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

Stockhausen et al. (2013)
Volatile Stock History

Stockhausen et al. (2013)
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 autoregressive process was used in all regressions:

\[ \varepsilon_t = \phi + \varepsilon_{t-1} + \nu_t \]

where \( \nu_t \) is a Gaussian white noise term and \( \phi \) 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**
  \[ \ln(R) = \alpha + \beta \times \ln(S) + \varepsilon_t \]

- **Log-transformed Shepherd model**
  \[ \ln(R) = \alpha - \ln(1 + e^g \times S^\beta) + \varepsilon_t \]

where \( g \) controls the shape of the curve

Models were fitted by generalized non-linear least squares regression
Methods: Predator Models

- **Recruitment residuals, $r$**
  
  \[ r = \frac{\ln R - \ln \bar{R}}{S_R} \]

  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

Diagram showing the abundance of Eastern and Western crab recruitment from 1978 to 2008.
Results: S-R Relationship

- Curvilinear relationship suggests density dependence
Results: Cushing & Shepherd

- Cushing model yielded good fits, but only with a negative $\beta$ 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

![Graph showing decadal pattern in residuals with hatch year on the x-axis and lag 3 S-R residuals on the y-axis. The graph displays a cyclic pattern with peaks around 1990 and 2000.]
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

Bristol Bay

Pribilof Islands

Pribilof Islands

Pribilof Islands
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?