Fishermen, Markets, and Population Diversity

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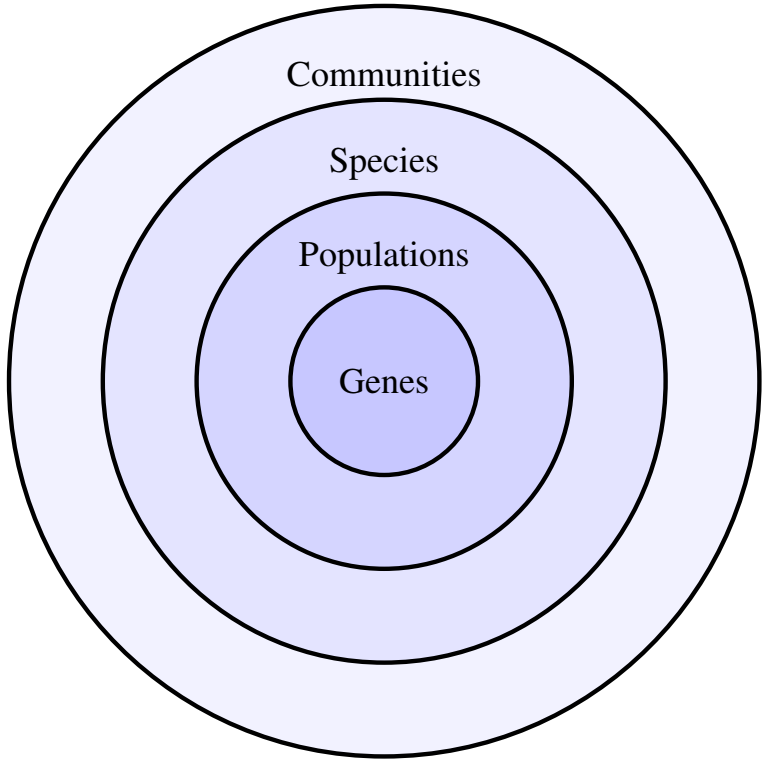
Population diversity

- Economic incentives & regulatory constraints $\Rightarrow$ targeting genetic traits, populations, and species
- Potential unintended consequences for the ecological dynamics and the economic performance of the fishery over time

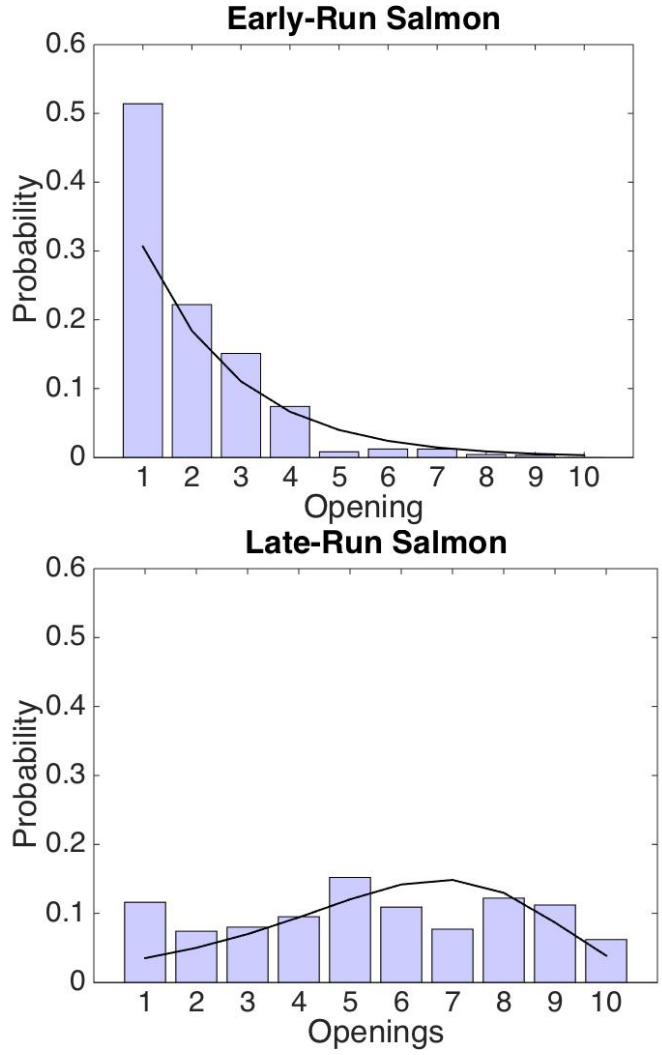


Population diversity

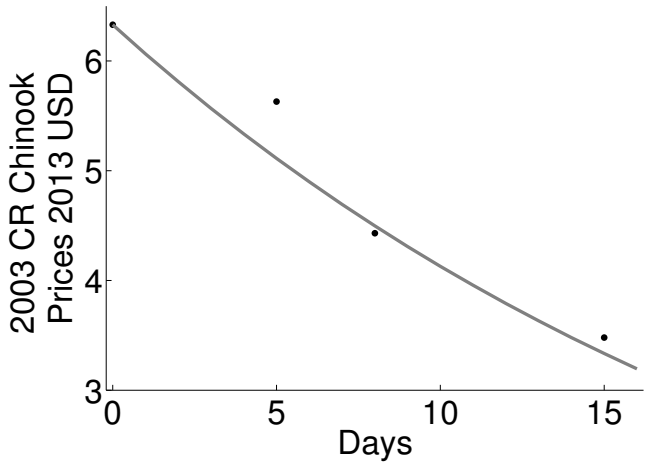
- Hilborn et al. (2003) PNAS: life history diversity leads to sustained productivity despite major environmental changes

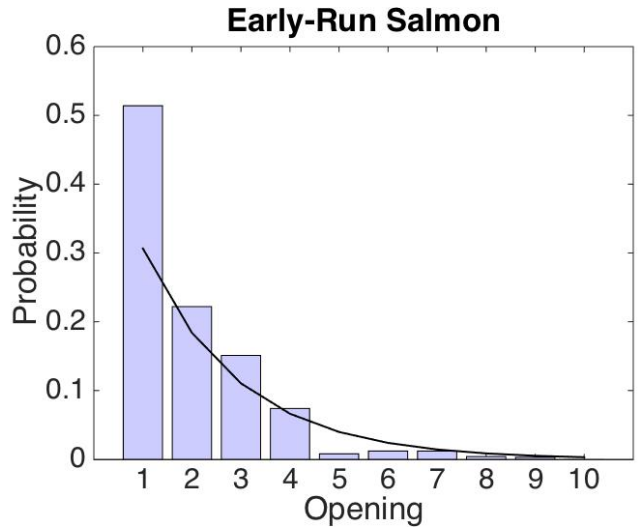
- Schindler et al. (2010) Nature: CV of the stock complex 0.55 and average CV for individual rivers 0.77

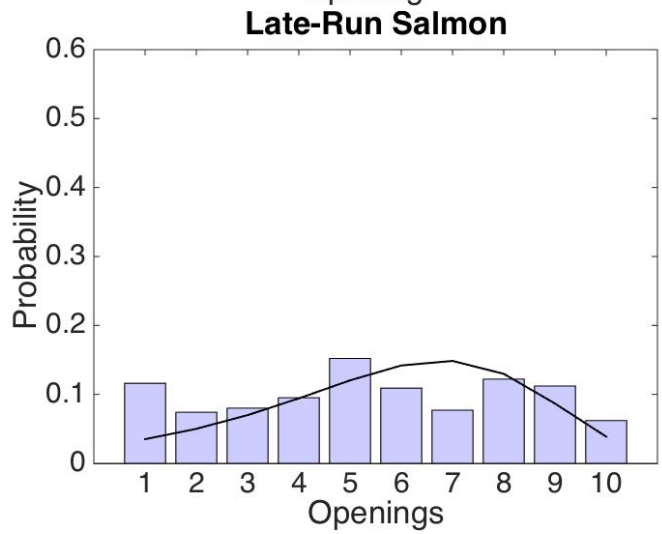
Population diversity



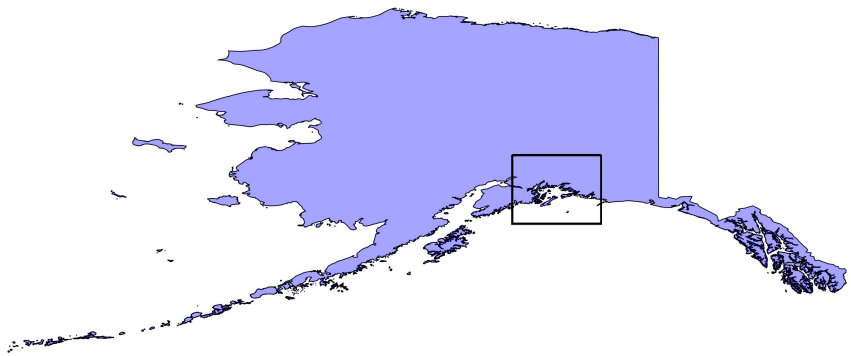
What happens when there are population-specific values?







Research Setting



- 1980s fishermen in the CR begin marketing and product quality improvements
- 1980s fishermen begin to target Chinook
- 1999 managers adopt a management plan and ISM for Chinook

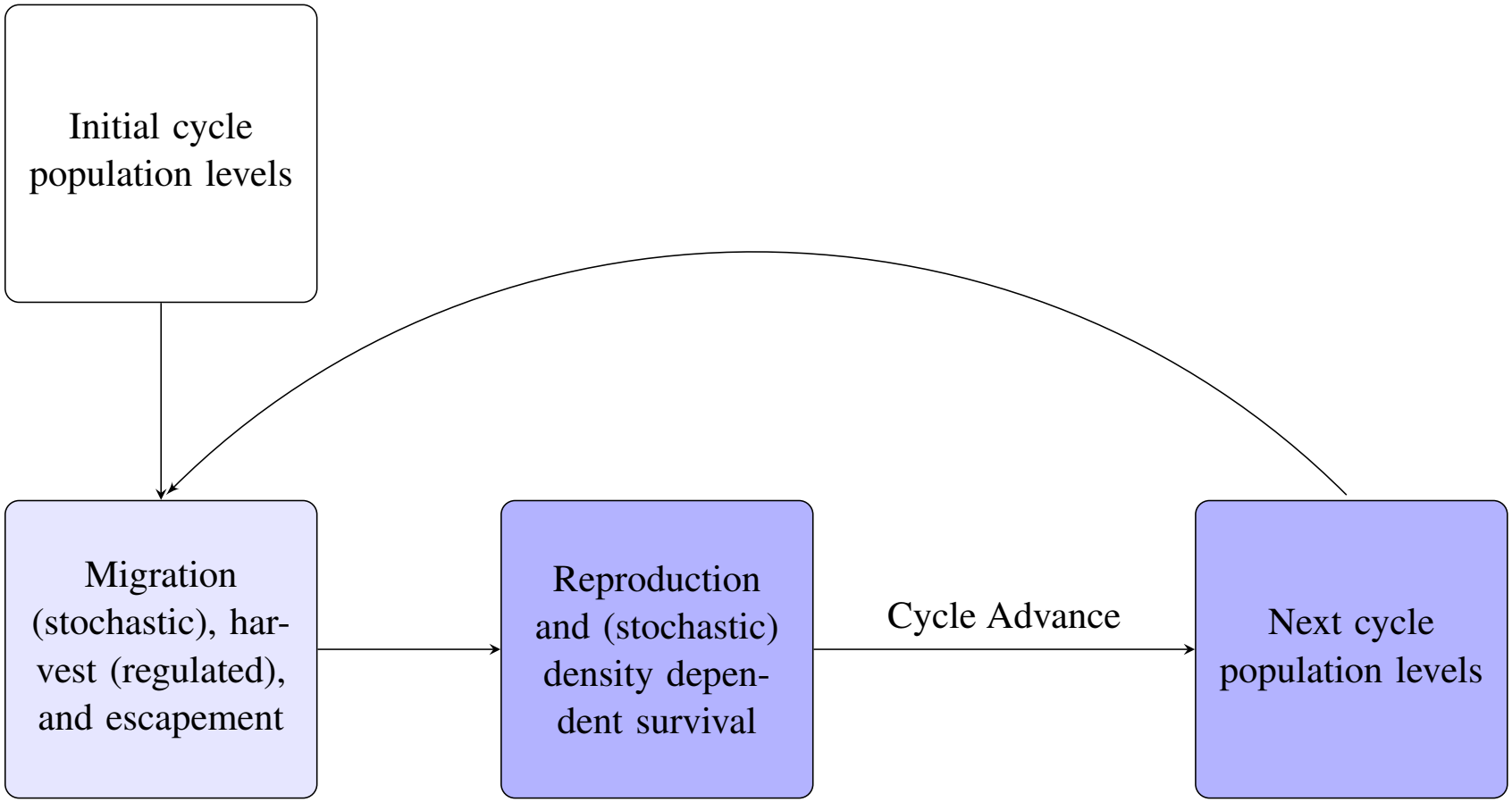
Research Questions

1. Can rule-of-capture incentives drive changes in population diversity?

2. If so, what are the impacts, i.e. mean and variance of economic returns?

3. How do outcomes depend on market dynamics, i.e. price seasonality and endogeneity?

Model Structure

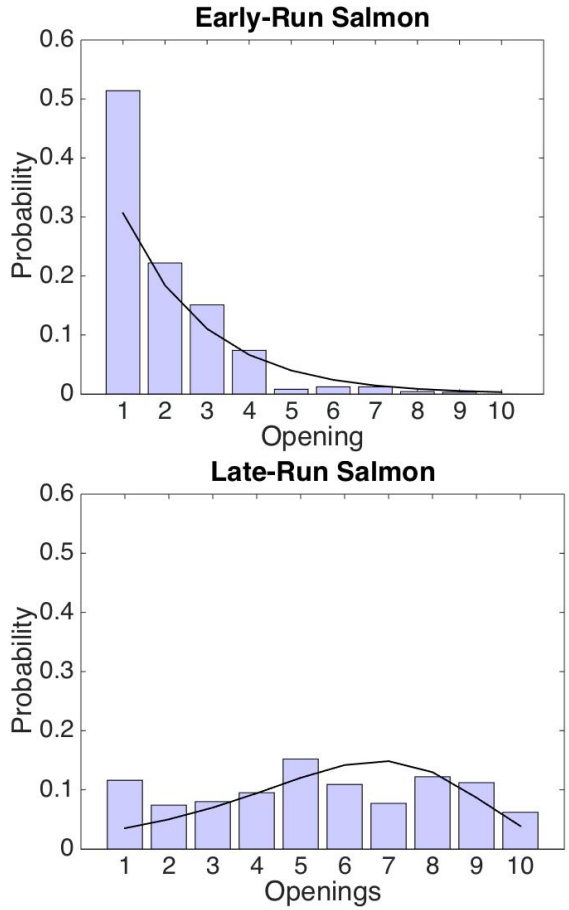


Biological Model: Within Season

We consider a two population model. Each population has a unique run time distribution as follows:

$$\psi_\tau^1 \sim Exp(\lambda + \epsilon^\lambda)$$

$$\psi_\tau^2 \sim EV(\mu, \sigma)$$



Biological Model: Within Season

$$\sigma_\tau^s(t) = \begin{cases} \frac{m_\tau^s(t)}{X(t)} & \text{if t=}\tau \\ \frac{1}{X(t)} \underbrace{\left[m_\tau^s(\tau) - \sum_{k=\tau}^{t-1} \sigma_\tau^s(k) H(k) \right]}_{\text{Remaining period } \tau \text{ arrivers}} & \text{if } \tau < t \leq \tau + \ell \\ 0 & \text{Otherwise} \end{cases} \quad (1)$$

$$E(t) = \sum_s E^s(t) = \sum_s \left\{ \underbrace{m_{t-\ell}^s(t-\ell)}_{\substack{\text{Number in } t-\ell \\ \text{migratory class}}} - \left[\sum_{k=t-\ell}^{t} \underbrace{\sigma_{t-\ell}^s(k) H(k)}_{\substack{\text{Harvest of } t-\ell \text{ arrivers} \\ \text{in all periods}}} \right] \right\} \quad (2)$$

$$\underbrace{X(t+1)}_{\substack{\text{Stock complex} \\ \text{numbers in } t+1}} = \underbrace{X(t)}_{\substack{\text{Stock complex} \\ \text{numbers in } t}} + \underbrace{M(t+1)}_{\text{In-migration in } t} - \underbrace{H(t)}_{\text{Harvest in } t} - \underbrace{E(t)}_{\text{Escapement in } t} \quad (3)$$

Biological Model: Across Season

$$\underbrace{P^s_{c+1}}_{\text{Recruitment in } c+1} = \underbrace{\alpha E^s_c exp(-\beta E^s_c)}_{\text{Escapement in } c} \underbrace{exp(\epsilon^s_c)}_{\text{Error term}}$$

- Population-specific density dependent stock-recruitment modeled with a Ricker (1954) equation
- Local-scale density dependence is a negative feedback in the model
- Assume ϵ^s_c are i.i.d. consistent with Schindler et al. (2010)

Economic Model: Fishermen's Entry Decision

We model bi-weekly entry decisions of heterogeneous fishermen.

$$U_{ij}(t) = \pi_{ij}(t) \tag{4}$$

$$\pi_{ij}(t) = \begin{cases} p(t) \underbrace{q_i X(t)}_{\text{Schaefer}} - \gamma & \text{if } j = 1 \\ \underbrace{v}_{\text{Opportunity cost}} & \text{if } j = 0 \end{cases} \tag{5}$$

Economic Model: Markets

Market dynamics considered are price seasonality (e.g. Wessells and Wilen, 1993, 1994) and endogenous prices (e.g. Jardine et al. 2014). Constant prices are included as a baseline.

$$\text{Seasonal:} \quad p(t) = p(0)exp(-\beta t),$$

$$\text{Endogenous:} \quad p(t) = \left(\sum_{n=0}^{t} \frac{H(n)}{B} \right)^{-\kappa}$$

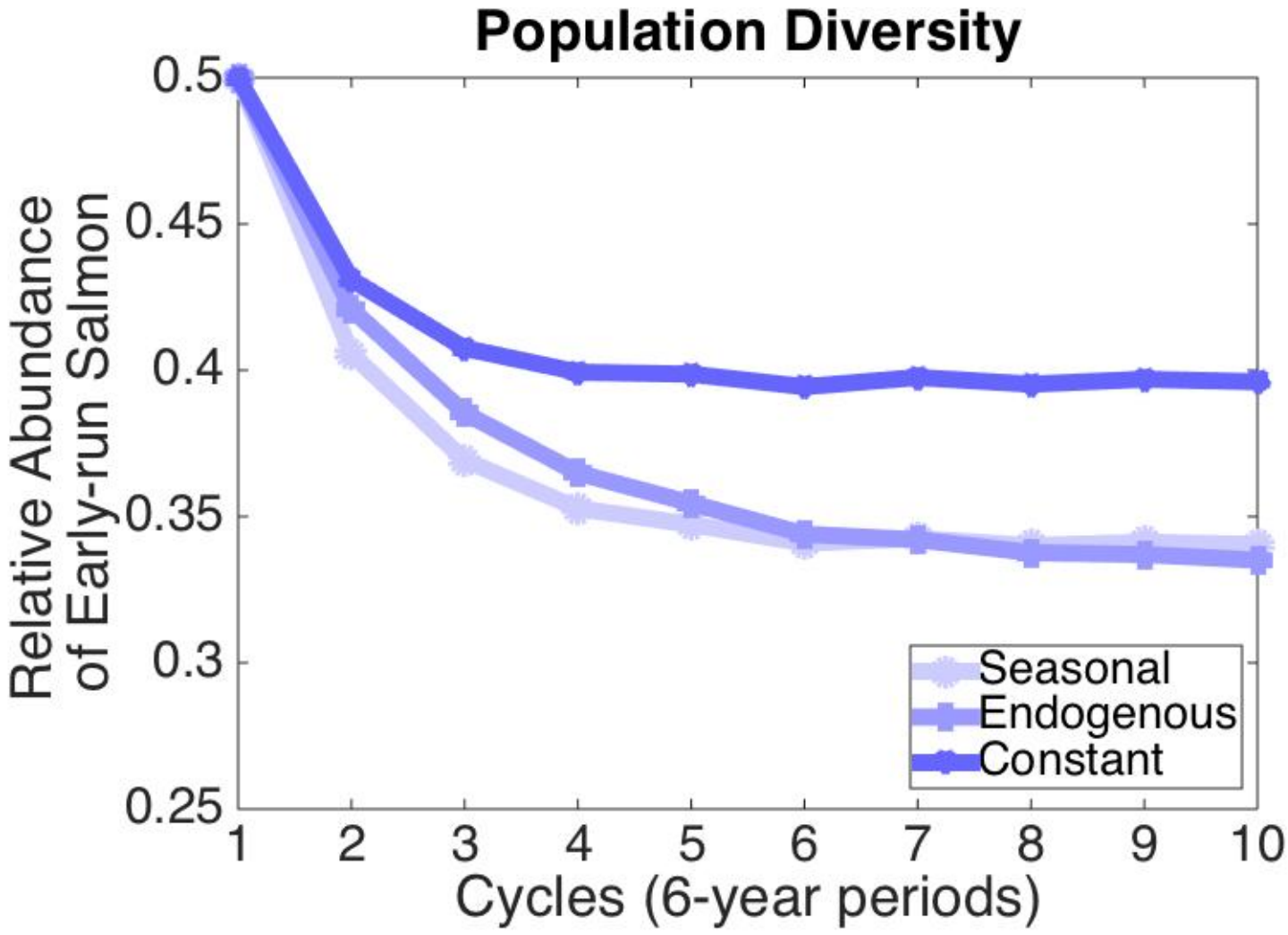
$$\text{Constant:} \quad \bar{p} = \frac{1}{T} \sum_{n=0}^{T} p(0)exp(-\beta n)$$

Management Model

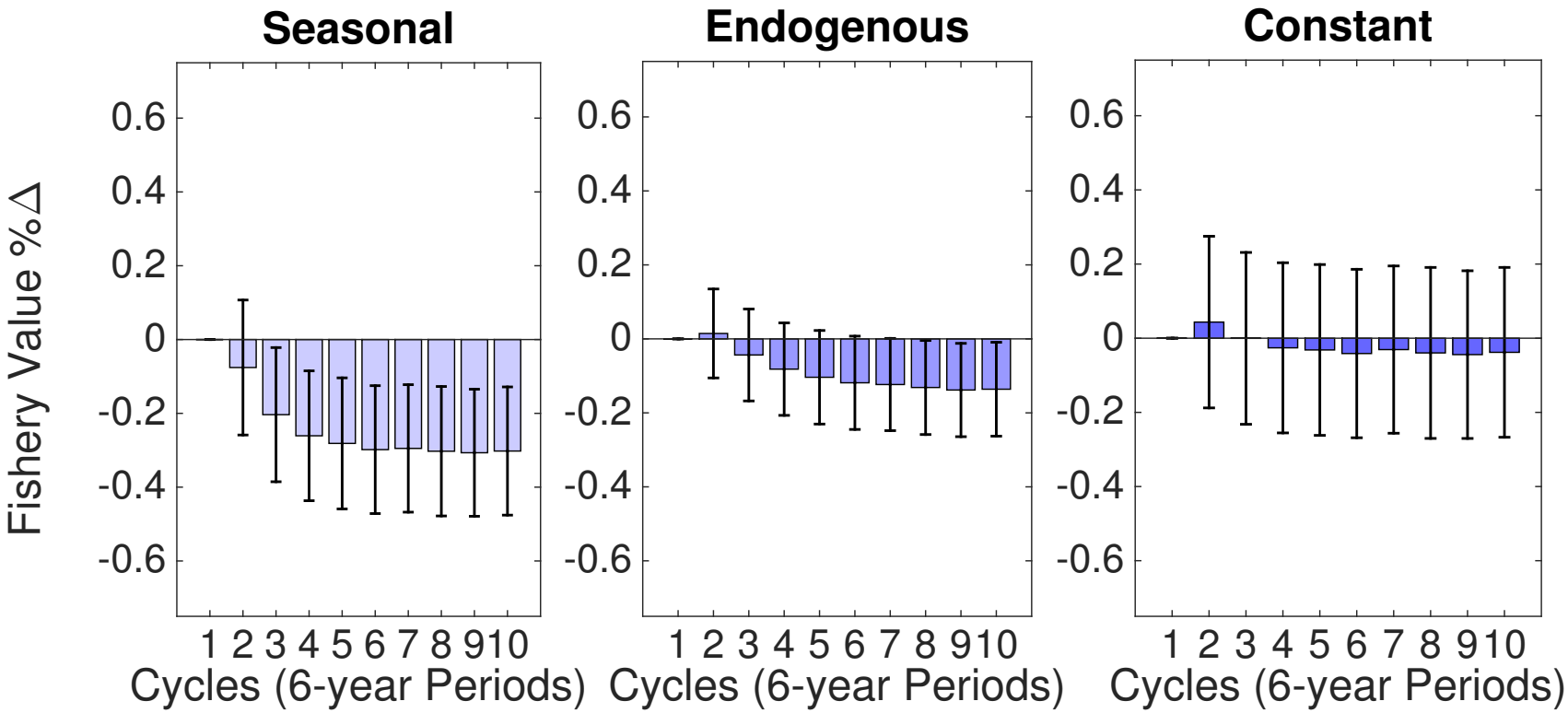
$$S_c(t) = \begin{cases} 1, & \text{if } \sum_{n=0}^{t-1} H_c(n) + \text{buffer} \geq TAC_c \\ 0, & \text{Otherwise.} \end{cases} \tag{6}$$

- Managers adjust season length (make a bi-weekly fishery shut-down decision) to meet a constant escapement goal
- The TAC_c is the difference between run size (assumed to be known) and escapement goal

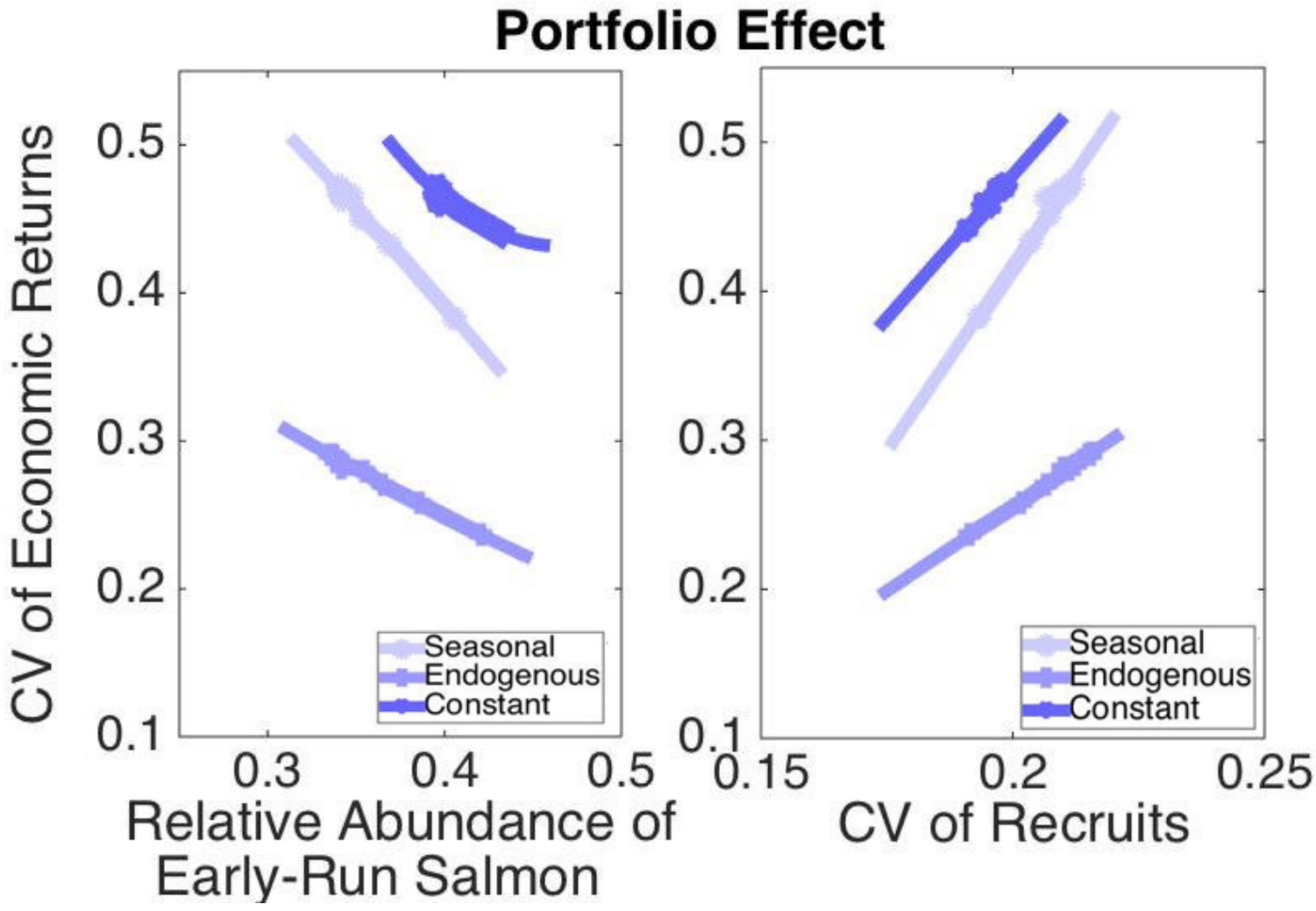
Results


Population Diversity
Relative Abundance of Early-run Salmon
0.5
0.45
0.4
0.35
0.3
0.25
1
2
3
4
5
6
7
8
9
10
Cycles (6-year periods)
Seasonal
Endogenous
Constant

Results


Seasonal
Endogenous
Constant
Fishery Value %Δ
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1 2 3 4 5 6 7 8 9 10
Cycles (6-year Periods)

Results


Portfolio Effect
CV of Economic Returns
0.5
0.4
0.3
0.2
0.1
0.3
0.4
0.5
Relative Abundance of Early-Run Salmon
Seasonal
Endogenous
Constant
0.15
0.2
0.25
CV of Recruits

Future Work

- What is the optimal harvest of populations that are valued differently in the market? In other words, how would a sole owner balance the costs and benefits of maintaining population diversity given population-specific values?
- What are the implications of a reduction in population diversity on the robustness of salmon populations to exogenous shocks, e.g. climate change?
- What is the empirical magnitude of fishery welfare losses due to biodiversity changes (population level) induced by price-seasonality?