# Is a [dead] fish a [dead] fish? Do kelt and pre-spawning fishing mortality affect populations equivalently?

PSMFC Steelhead Managers Meeting, Boise ID

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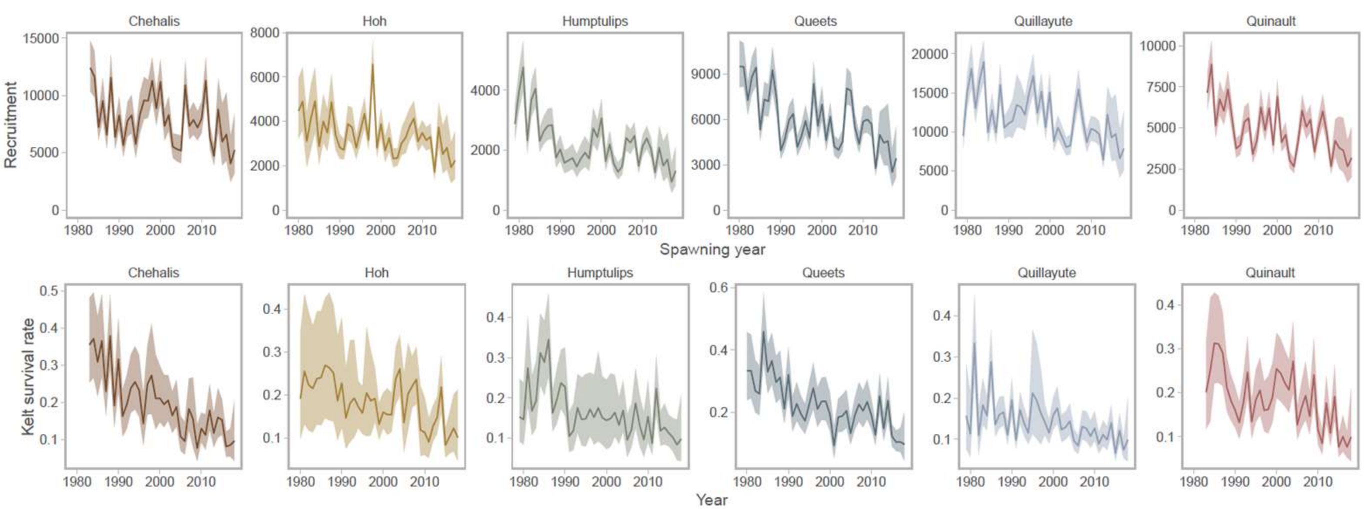
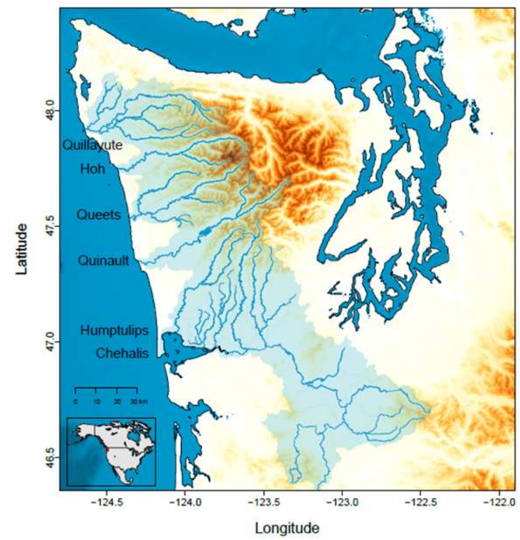
# Background

- Declining steelhead abundance
- Declining repeat spawners
- NOAA SRT (2024): *"Kelt survival rates went from ~20% to ~12% since 1996 (in the Big Four basins). This likely has had a negative effect on overall population reproductive potential, as kelts have a disproportionate influence on population productivity, spawning multiple times and with a higher fecundity than maiden (first-time) spawners"*
- WDFW has adopted precautionary permanent regulations for closing April fishing, in part to protect kelts



# Importance of Repeat Spawners

- More female (8:1; Christie et al. 2018, ~3:1; Seamons et al. 2007)
- Larger/more fecund, possibly bigger eggs, deeper redds→ 2.5X lifetime reproductive output (Christie et al. 2018)
- Age diversity (temporal portfolio effect to stabilize runs)→ large, old repeat spawning females had the greatest success when they were low in frequency (Christie et al. 2018).
- Possibly, genetic diversity

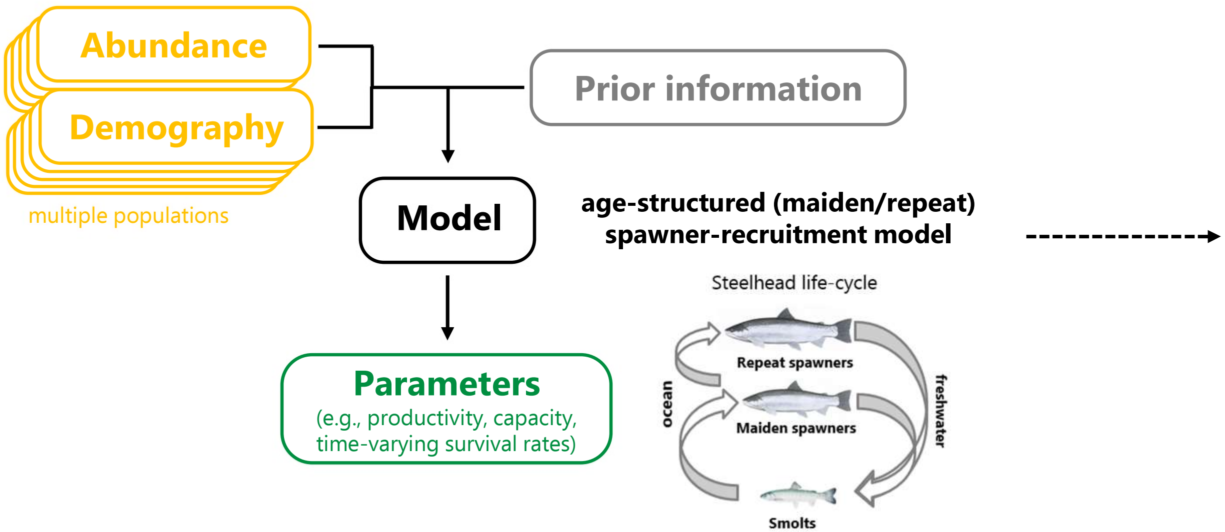
**Research Question:**

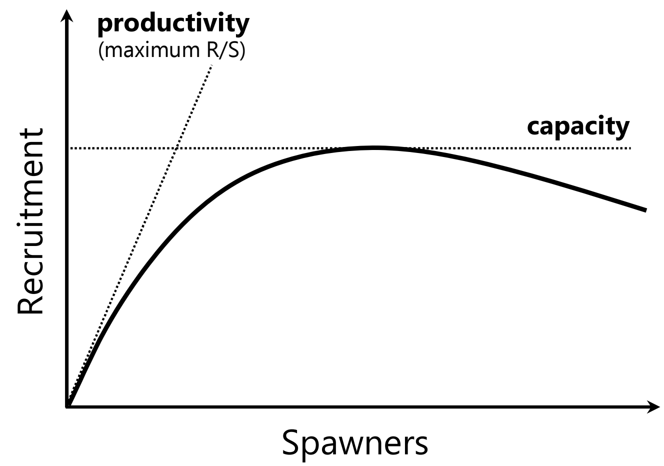
**1) what is cause of longterm declines in kelt survival?**

# Integrated Population Model

**A statistical population model that integrates multiple sources of information**

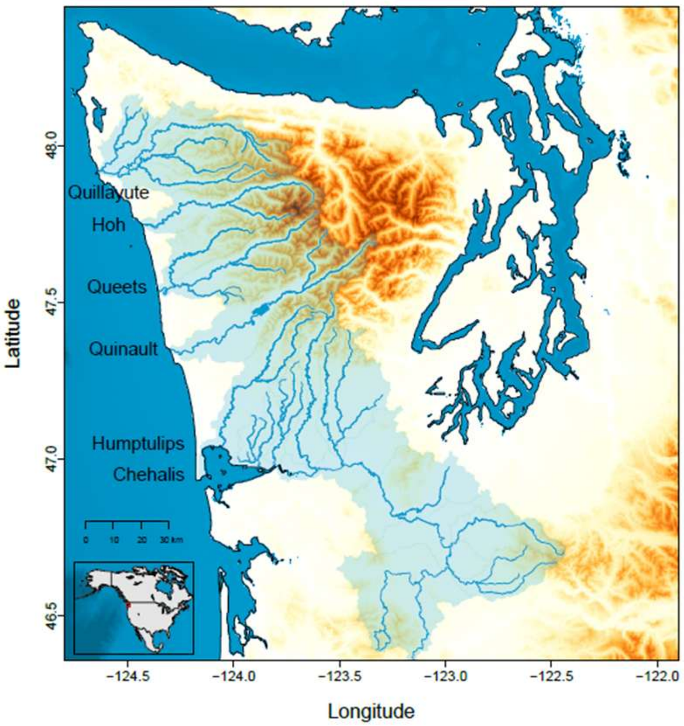
- Integrate information on population abundances and demography (e.g., age structure)
- Allow for sharing of information across populations when fit hierarchically ('Robin Hood' approach)
- Can incorporate independent prior information using a Bayesian approach (e.g., observation error)
- Parameters capture full uncertainty in the data by estimating a joint likelihood

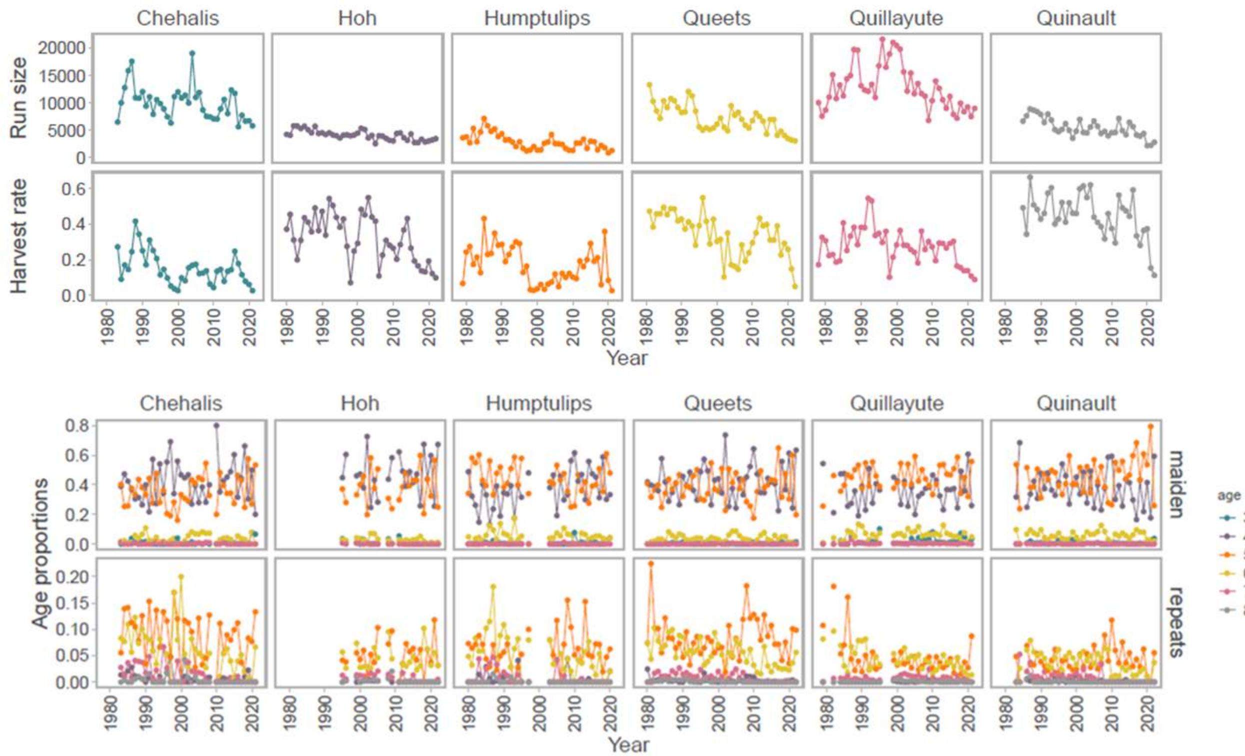


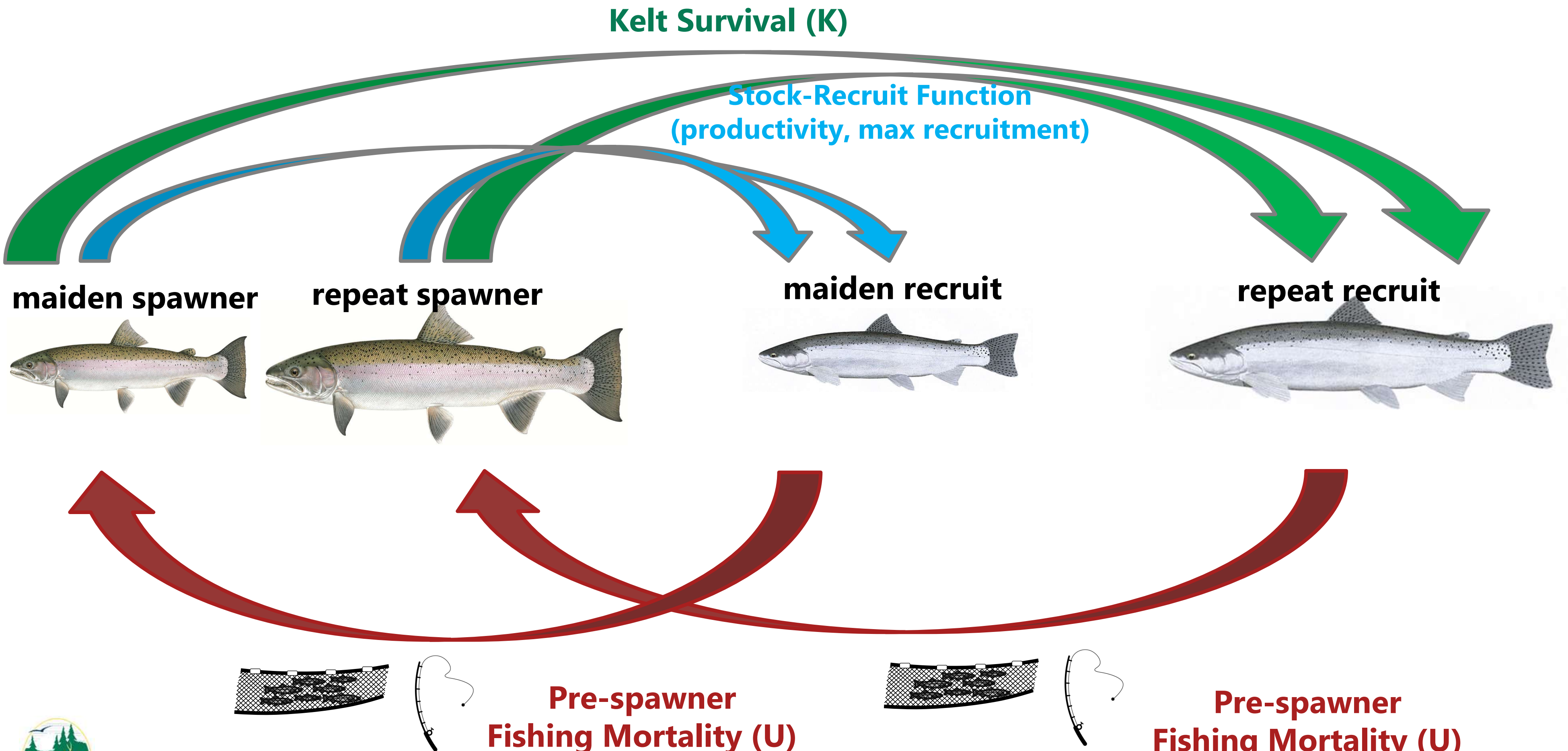
# Data

**Total run size (harvest + spawner abundance), harvest rate, and age proportions**



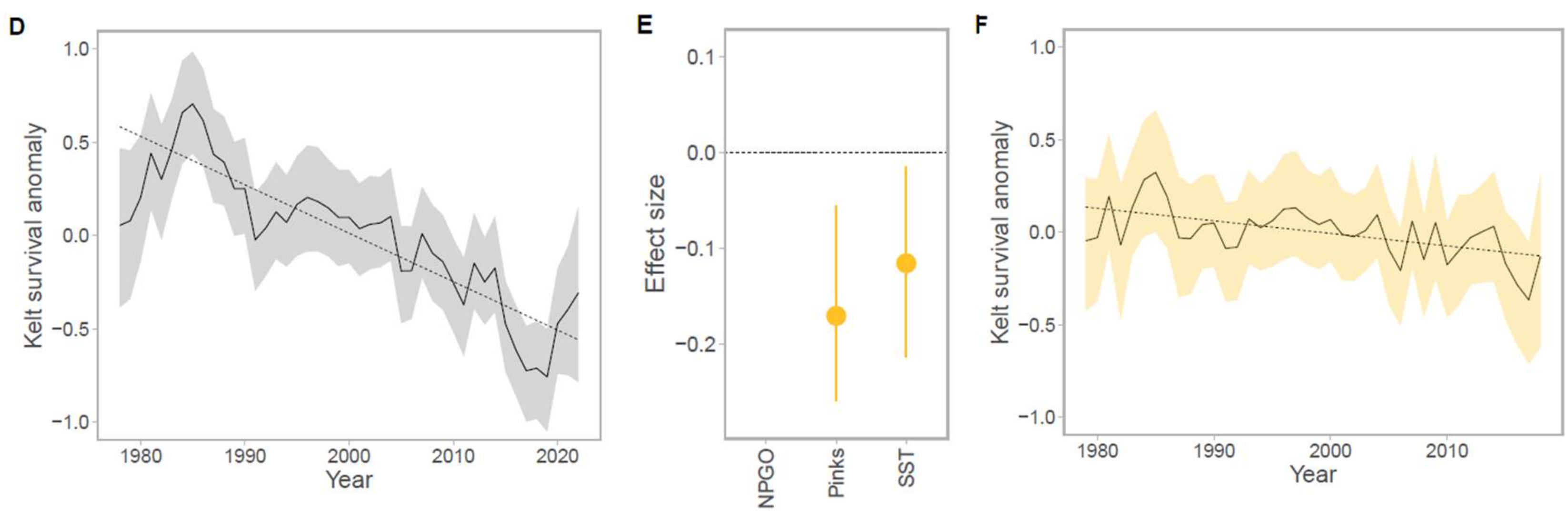



# Steelhead IPM (Ohlberger 2024)



# Kelt survival

- **Declined considerably since late 1970's**
- **Negatively correlated with pink salmon abundance at Gulf of Alaska SST**
- **Residual trend after including these variables barely negative**




Ohlberger, J., E.R. Buhle, T.W. Buehrens, N.W. Kendall, T. Harbison, A.M. Claiborne, J.P. Losee, J. Whitney, and M.D. Scheuerell. 2025. Declining marine survival of steelhead trout linked to climate and ecosystem change. *Fish and Fisheries.* doi:10.1111/faf.12878.

**Research Question:**

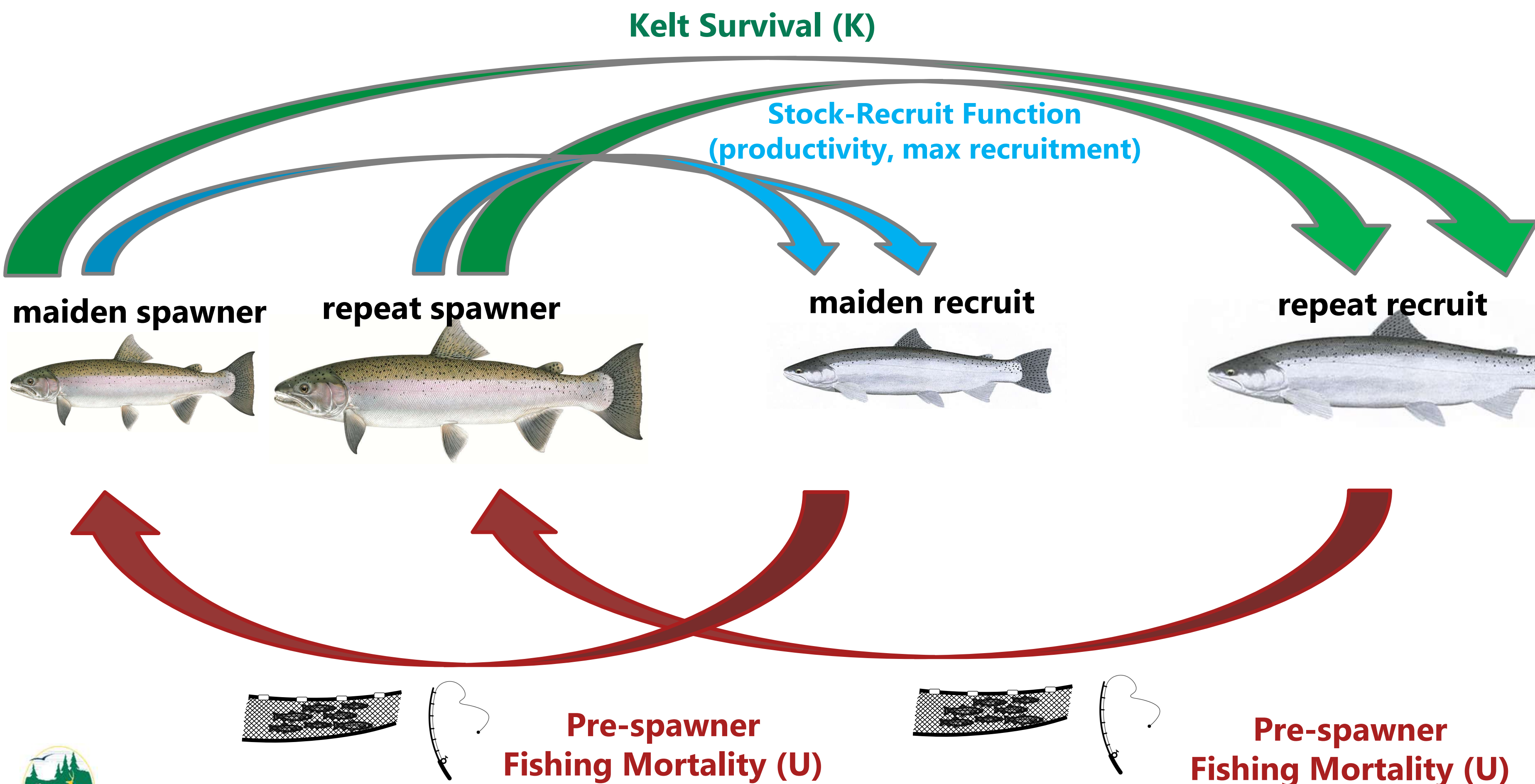
1) what is cause of longterm declines in kelt survival?

2) do pre-spawning vs. kelt fishing mortality have equivalent population dynamic effects (i.e., does protecting kelts without changing harvest rate help)?

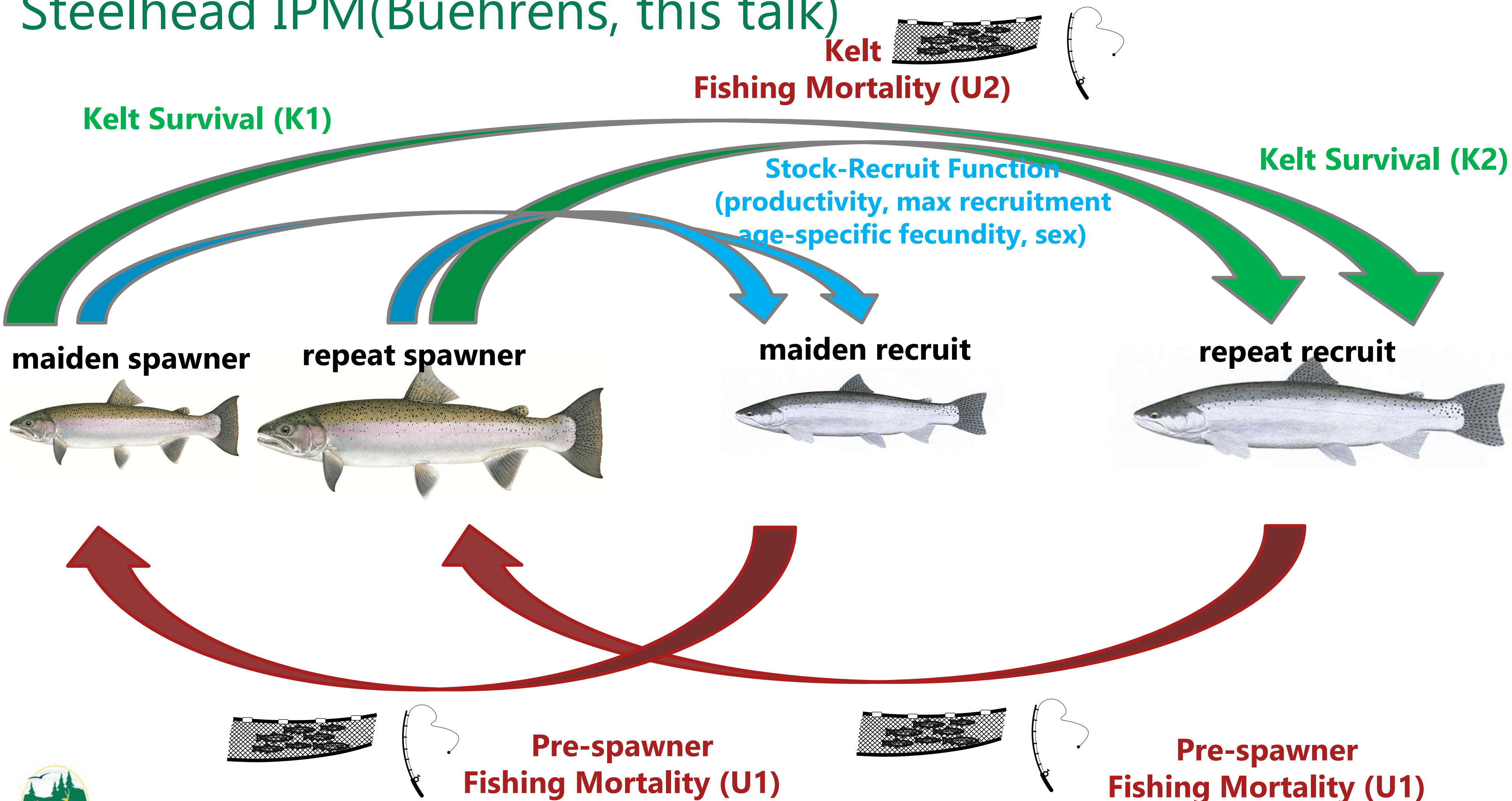
# Need to address limitations in IPM

- *IPM doesn't (yet!):*
    - Account for age-specific fecundity
    - Account for female biased sex ratio of repeat spawners
    - Allow for harvest to occur on kelts as they leave rivers ***before*** much/all of the natural mortality has occurred (assumes harvest is on pre-spawning maiden and repeat spawners after all pre-spawning natural mortality has occurred).

# Steelhead IPM (Ohlberger 2024)



# Steelhead IPM(Buehrens, this talk)



# New model

- Developed forward simulation model with structure that addresses limitations in IPM
- Compared scenarios:
  - different amounts of total harvest
  - harvest either solely pre-spawners (maiden and repeat), or of solely kelts (maiden and repeat)
- New model involves more parameters than IPM→ "tuned" new parameters to match IPM estimates from Ohlberger et al. (2024).

# A bit about parameters

- Pop level productivity = equilibrium age comp * age-specific fecundity * egg to adult max survival
  - if productivity is 3.4 (roughly avg. in Ohlberger 2024) and you have 50% female and mean fecundity of 5000 for females that equates to 0.001375 egg to adult max survival.

- Natural kelt mortality = 85% without kelt harvest

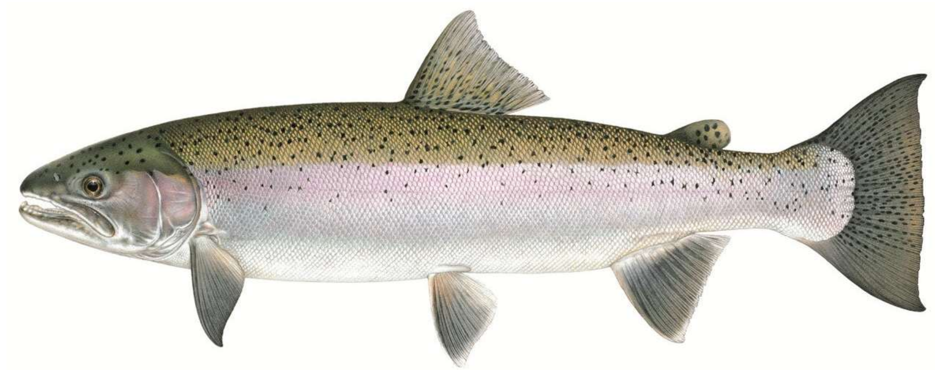
- Evaluated different scenarios for what proportion of natural kelt mortality occurred before kelt harvest vs. after (default 50%)

- Maturation probabilities: Age 3 = 1%, Age 4 = 40%, Age 5 = 35%, Age 6 = 15%, Age 7 = 9%

- Fecundity: Age 3 = 3000, Age 4 = 4000, Age 5 = 5000, Age 6 = 6000, Age 7 =7000, Age 8 = 8000, Age 9 = 9000 (roughly from Busby 1996)

# Outcome measures

- Spawner Abundance
- Recruit Abundance
- Ocean Entry Kelt Abundance (after kelt harvest)
- Repeat Spawner Abundance
- Proportion of Repeat Spawners



# Results

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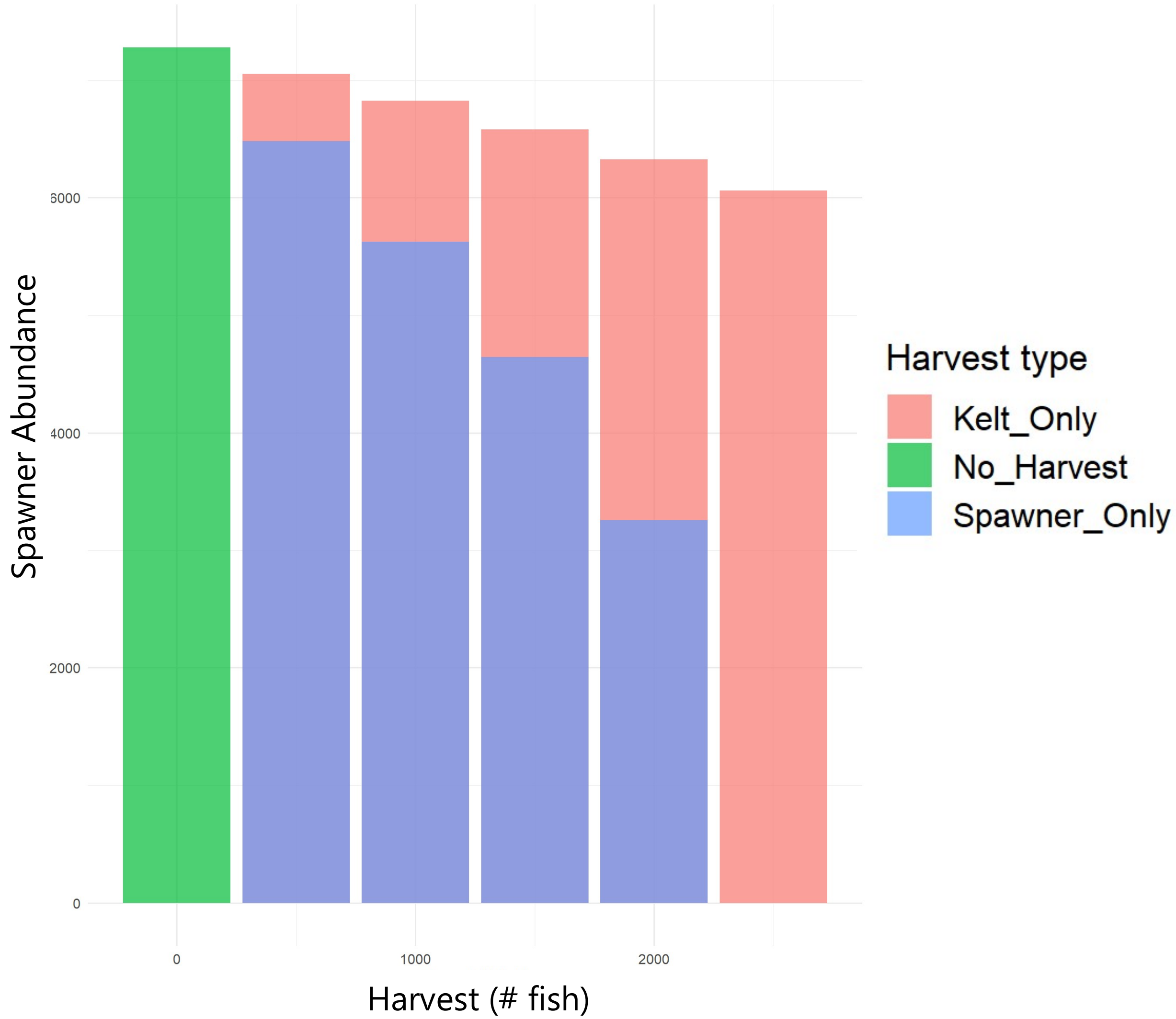
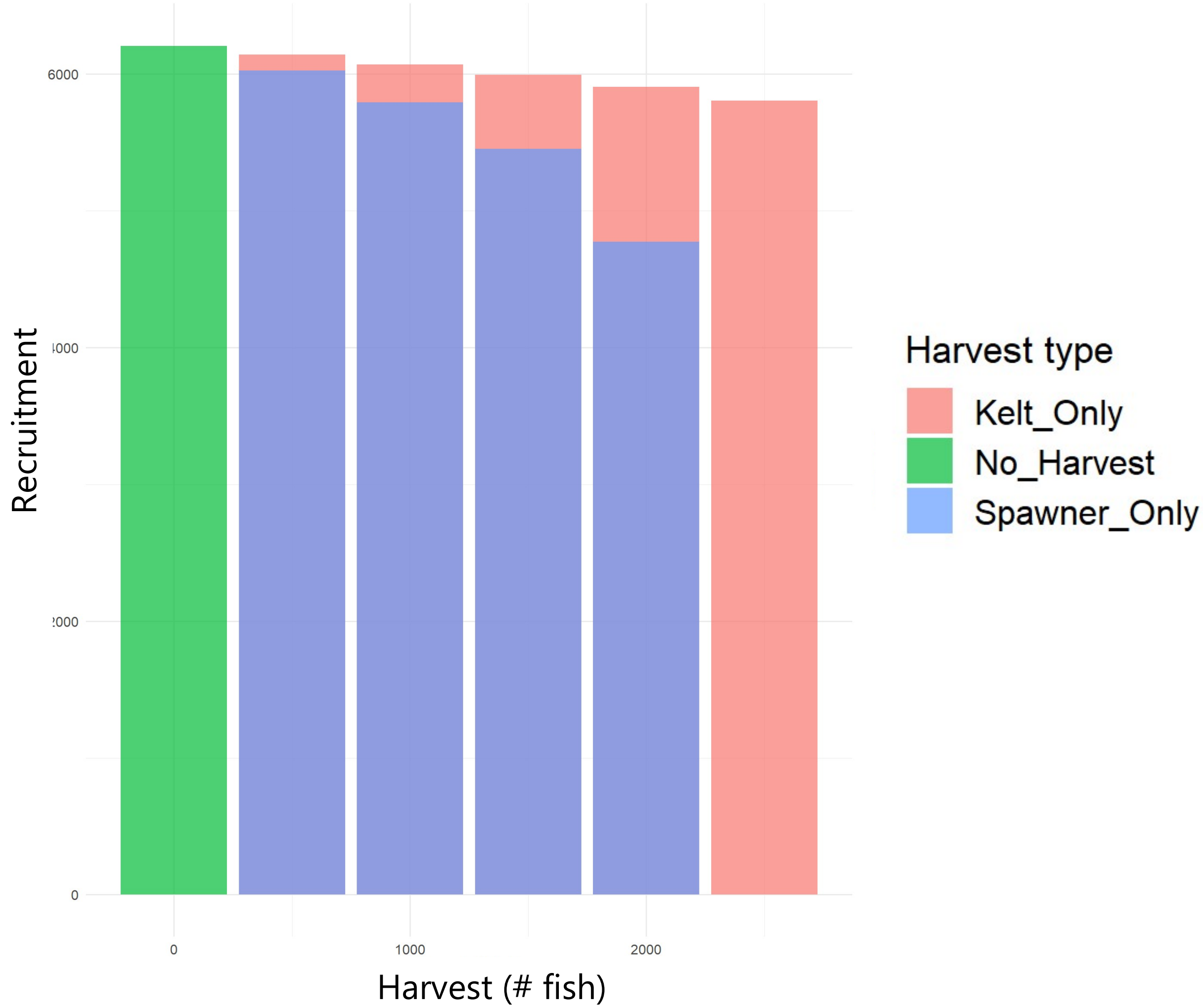


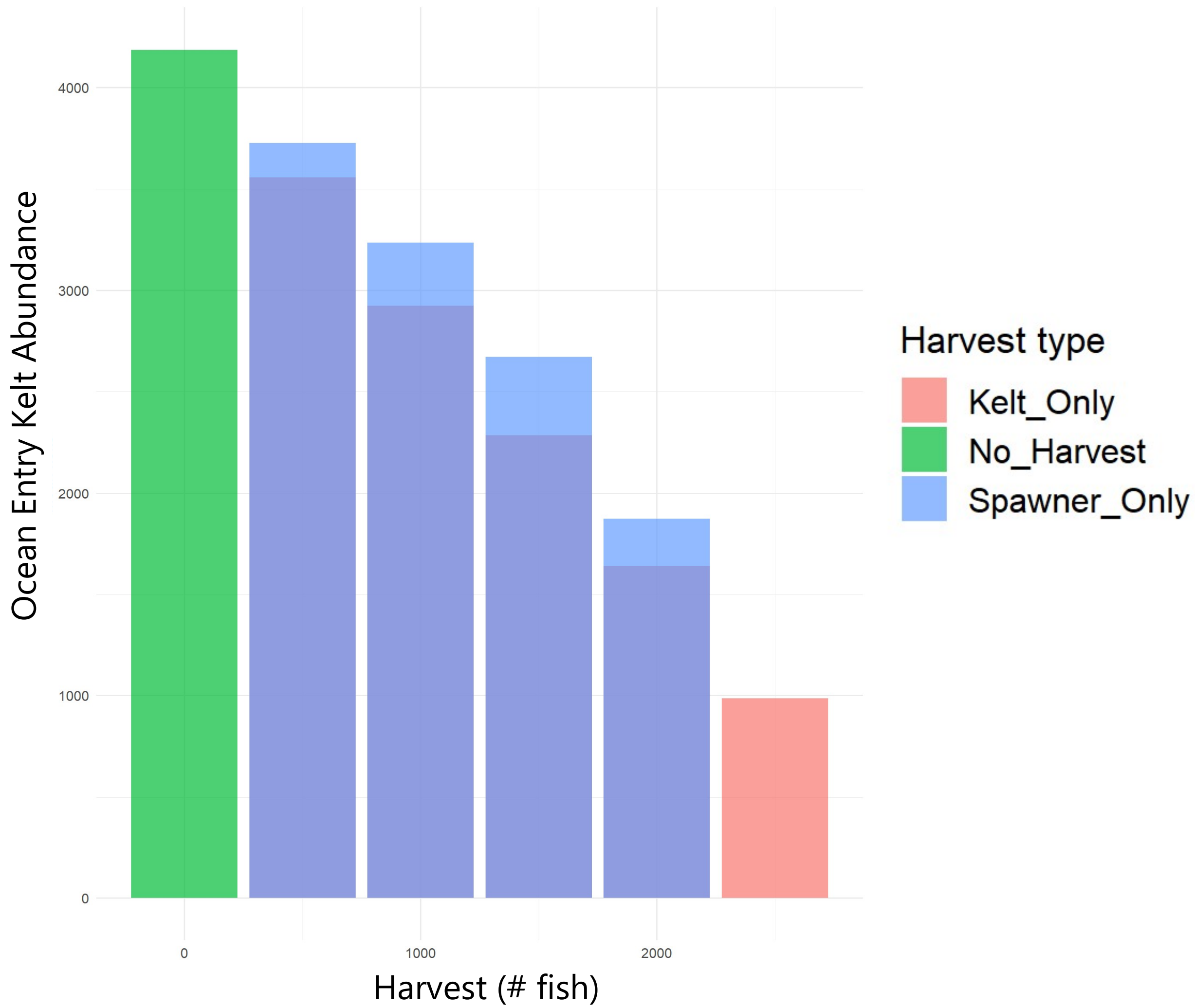
Spawner Abundance
6000
4000
2000
0
0
1000
2000
Harvest (# fish)
Harvest type
Kelt_Only
No_Harvest
Spawner_Only

# Results



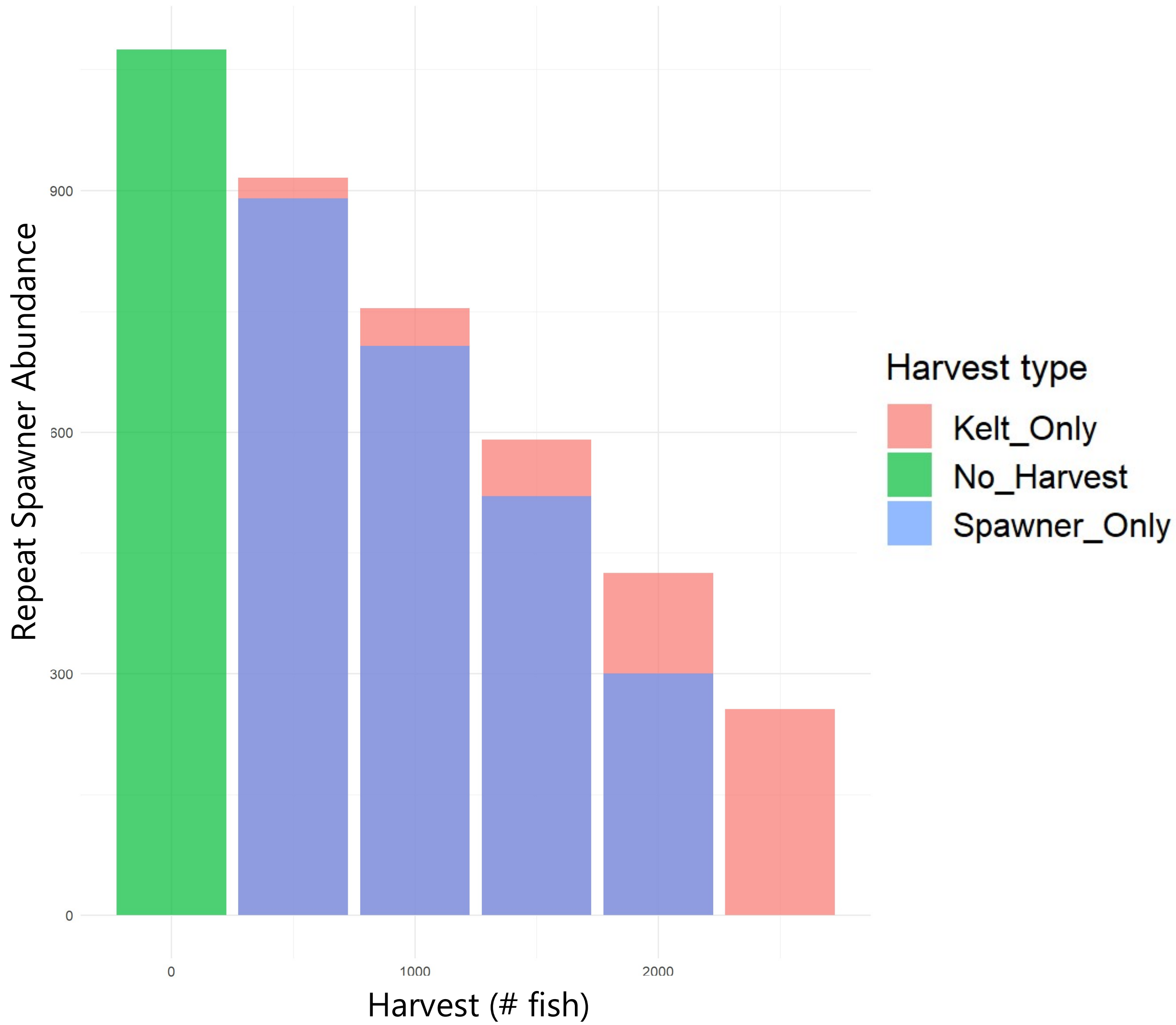
6000
4000
2000
0
Recruitment
0
1000
2000
Harvest (# fish)
Harvest type
Kelt_Only
No_Harvest
Spawner_Only

# Results



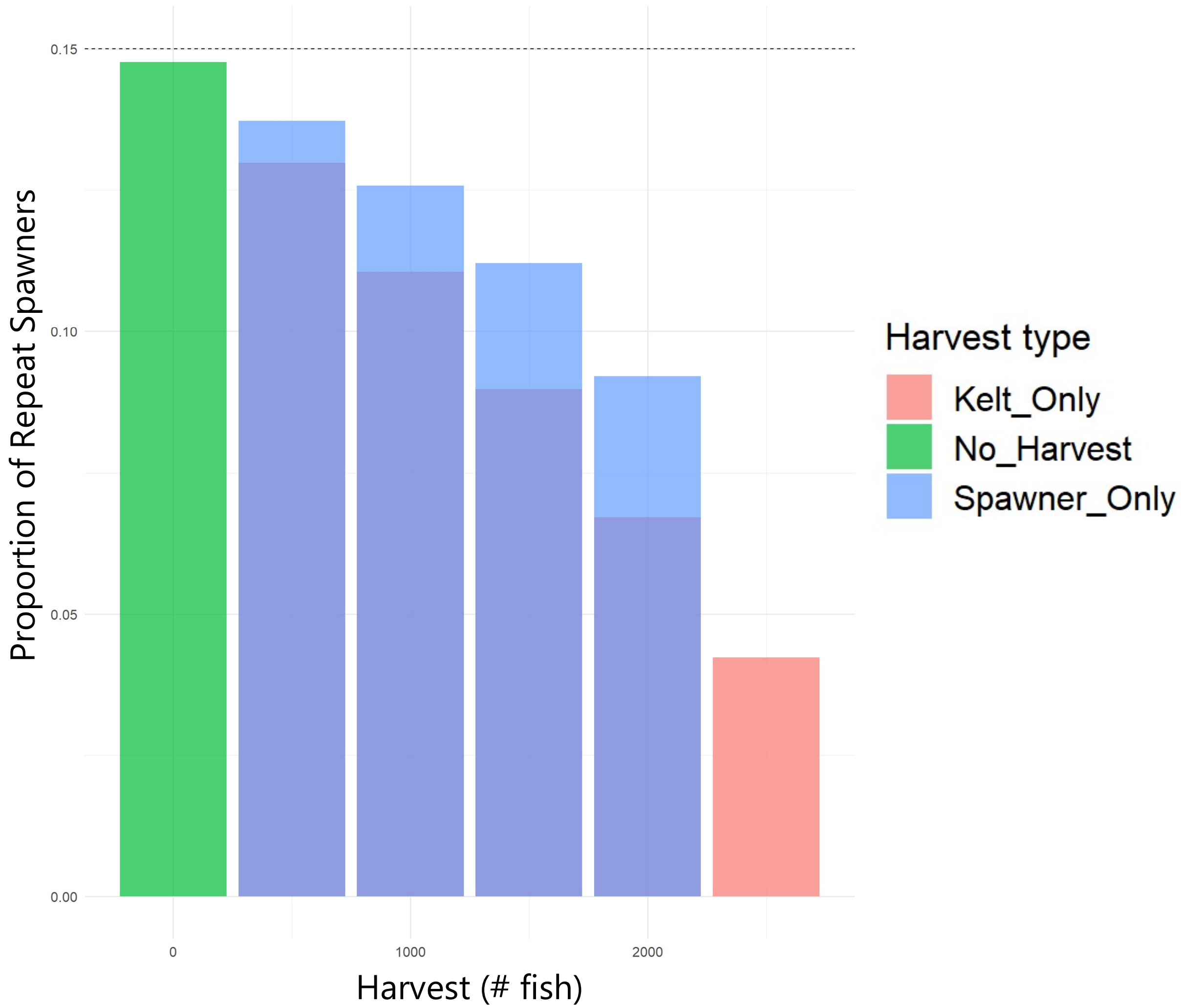
Ocean Entry Kelt Abundance
4000
3000
2000
1000
0
0
1000
2000
Harvest (# fish)
Harvest type
Kelt_Only
No_Harvest
Spawner_Only

# Results



Repeat Spawner Abundance
900
600
300
0
0
1000
2000
Harvest (# fish)
Harvest type
Kelt_Only
No_Harvest
Spawner_Only

# Results


0.15
0.10
0.05
0.00
Proportion of Repeat Spawners
0
1000
2000
Harvest (# fish)
Harvest type
Kelt_Only
No_Harvest
Spawner_Only

**Research Question:**

**1) what is cause of longterm declines in kelt survival?**

**2) do pre-spawning vs. kelt fishing mortality have equivalent population dynamic effects (i.e., does protecting kelts without changing harvest rate help)?**

# Conclusions

- Kelt survival decline nearly entirely explained by pinks, SST (little residual trend)
- Without changing total fishing mortality, **reducing the allocation of harvest to kelts will worsen nearly all conservation measures**…even the number of repeat spawners decreased
- Result is likely because biggest determinant of kelt abundance is first time spawners, which are a function of recruitment, and recruitment is much more negatively impacted by harvesting prespawn fish
- Evaluated sensitivity to higher kelt survival and lower SAR and same result
- Similarly, stochastic pop dynamics didn't affect results
- Better way to do this: fit modified IPM to the data rather than tune a population model based on a previous IPM fit and simply project forward—nonetheless unlikely to change overall conclusion
- Social considerations…most fishermen likely prefer targeting prespawners

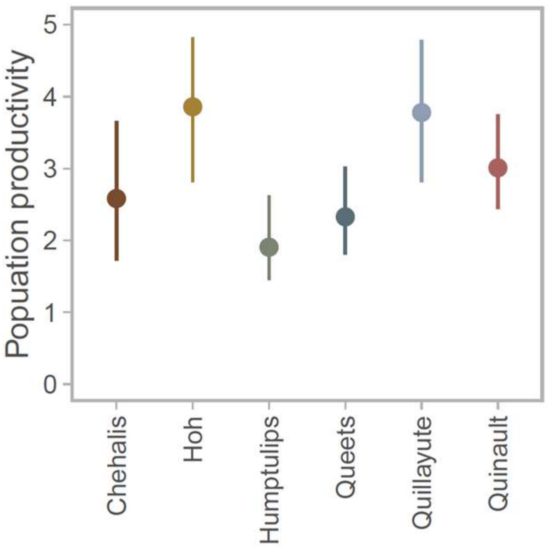
# Thanks!

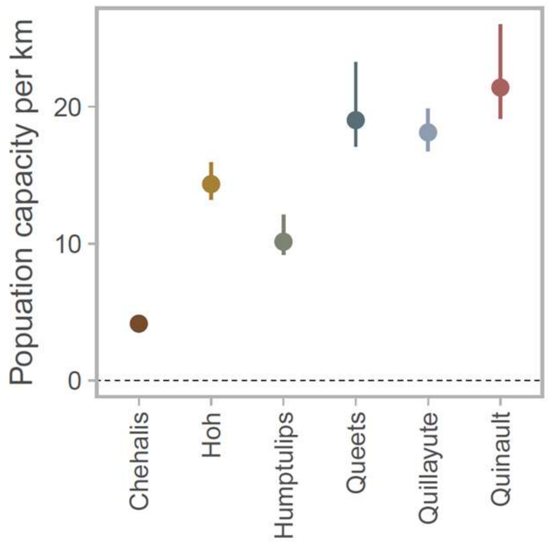
# Extra Slides

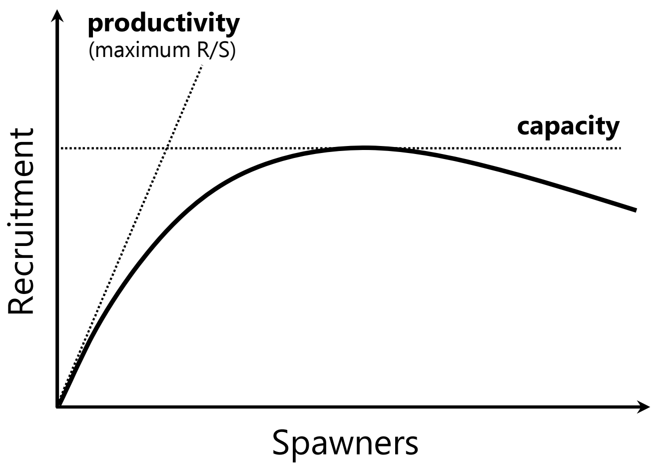
# Integrated Population Model

## Estimated population productivity and capacity

- Population productivity ranging from ~2 to 4 (medians) with 90% credible intervals above 1.0
- Capacity per km highly variable among rivers ranging from ~4 to 21 (medians)

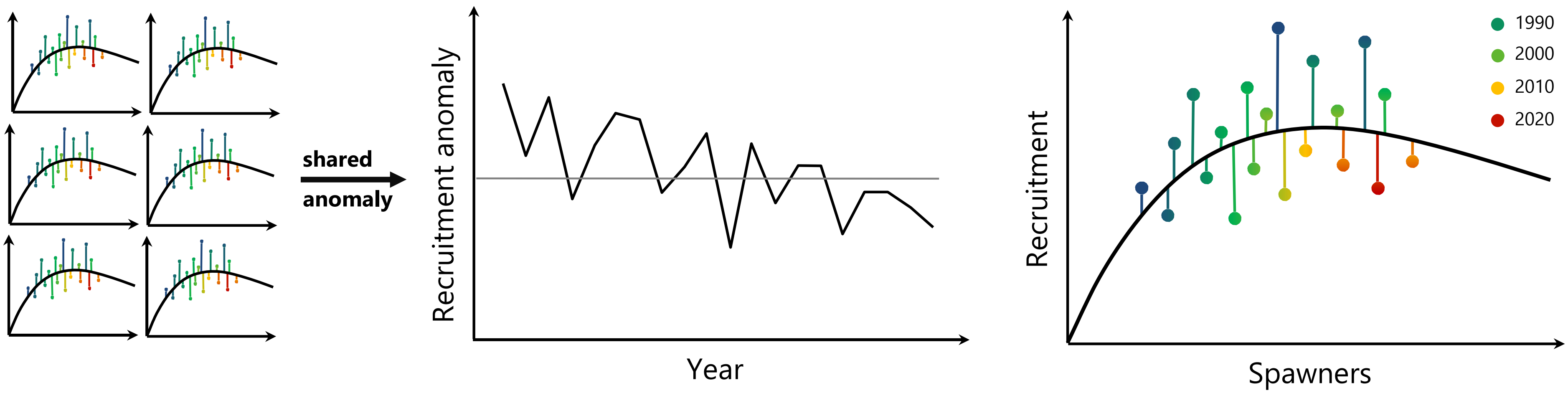


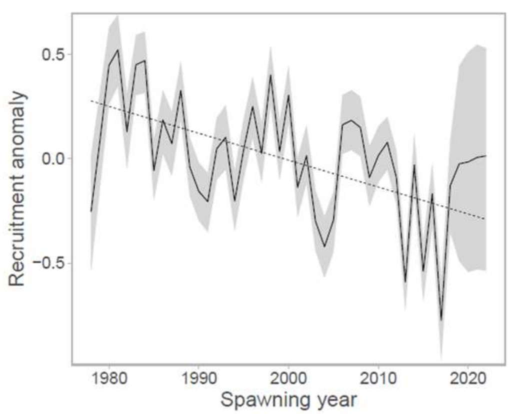
# Integrated Population Model

**Recruitment anomalies**



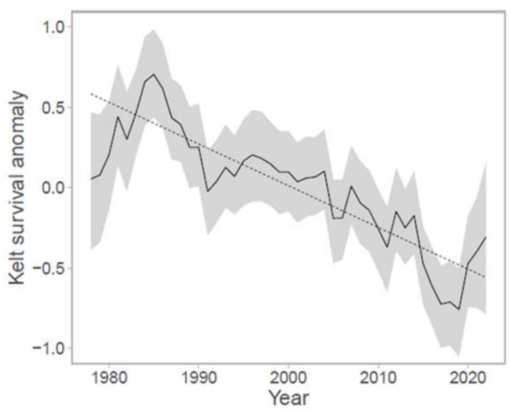
# Integrated Population Model

**Shared recruitment anomalies and kelt survival anomalies**




Shared variation in survival to first maturation due to environmental impacts occurring after population-level density dependence

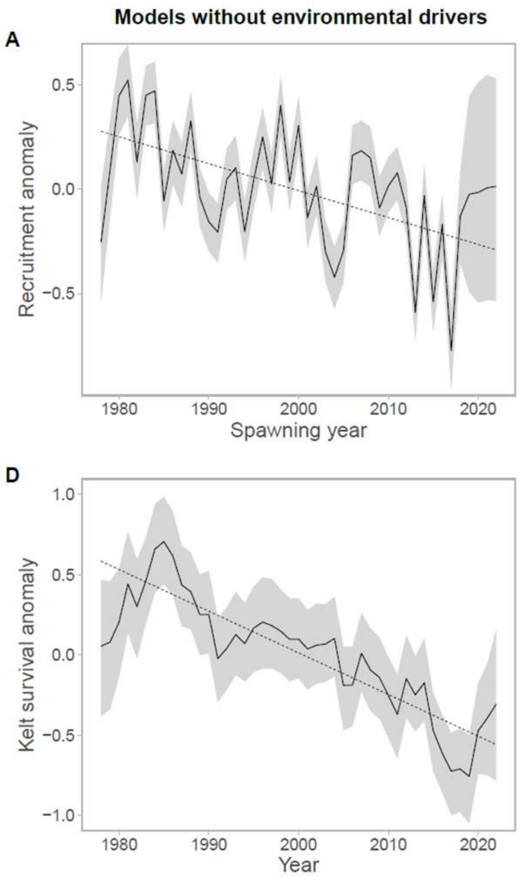
Are these negative trends over time in recruitment and kelt survival attributable to changes in ecological and environmental conditions?



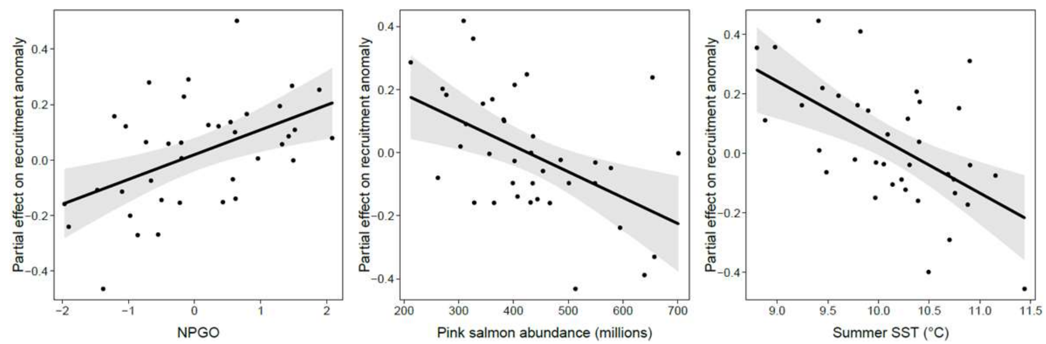

Shared variation in survival rates of kelts from spawning to returning

# Environmental drivers

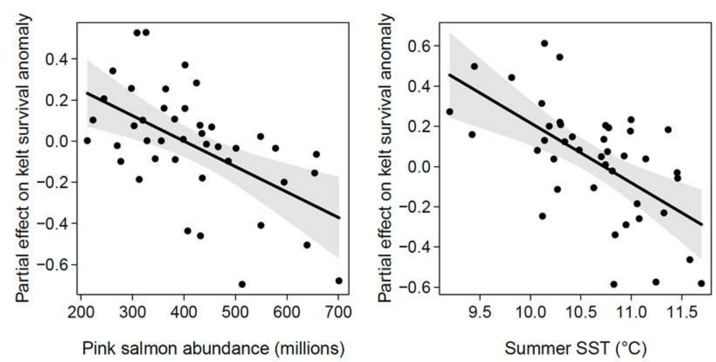
**Effects of covariates on time-varying recruitment and kelt survival anomalies**




Post-hoc model of recruitment and kelt survival anomalies as functions of covariates




~60% of variance in response explained

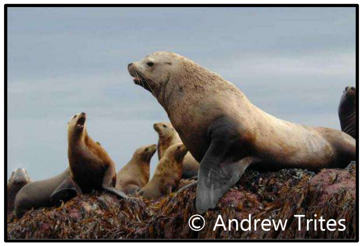


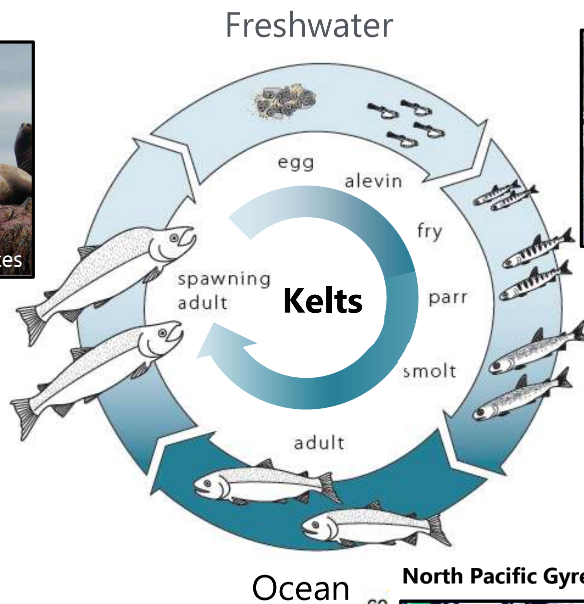

~60% of variance in response explained

# Environmental drivers

## Potential environmental and ecological effects on survival throughout the steelhead life cycle

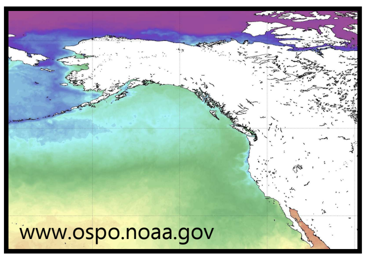
### Predation in the ocean
Harbor seals
Steller sea lions
California sea lions




### Freshwater conditions
Stream flow
Stream temperatures

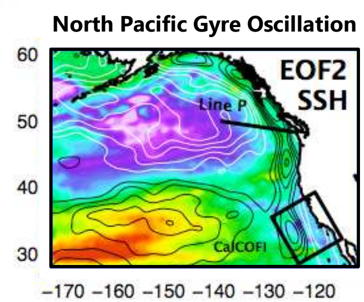
### Ocean temperatures
Coastal SST
NE Pacific SST





### Predation in freshwater
Cormorants
Other predators

### Food abundance & competition
NE Pacific salmon abundance, esp. pinks
Prey species abundance


### Large-scale climate indices
North Pacific Gyre Oscillation (NPGO)
Pacific Decadal Oscillation (PDO)