

# **Factors associated with the regional patterns of steelhead survival in the Columbia River Basin**

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# Key Questions:

**What are the spatial and temporal patterns in survival?**

**What factors are associated with the patterns in survival?**

**Can management efforts help achieve regional survival goals?**

**NPCC Goal: Smolt-to-Adult survival rates averaging 4%**

**Minimize Smolt-to-Adult survival rates < 1%**

# What are the spatial and temporal patterns in survival?

## Stocks?

Wild steelhead from Snake, Entiat & Methow, Yakima, and John Day rivers

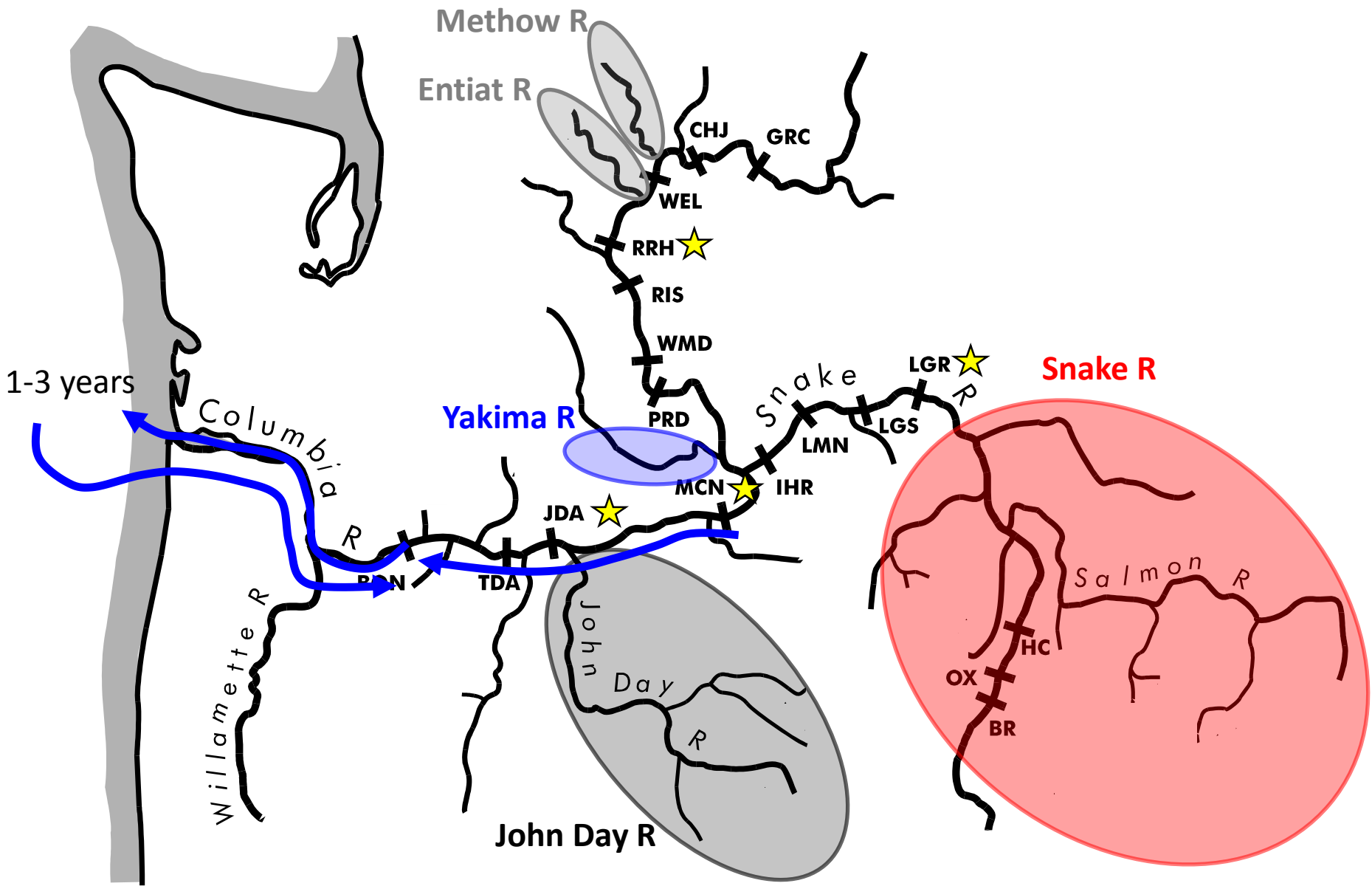
## Timeframe?

Juvenile outmigration years 2000-2017

## Tools?

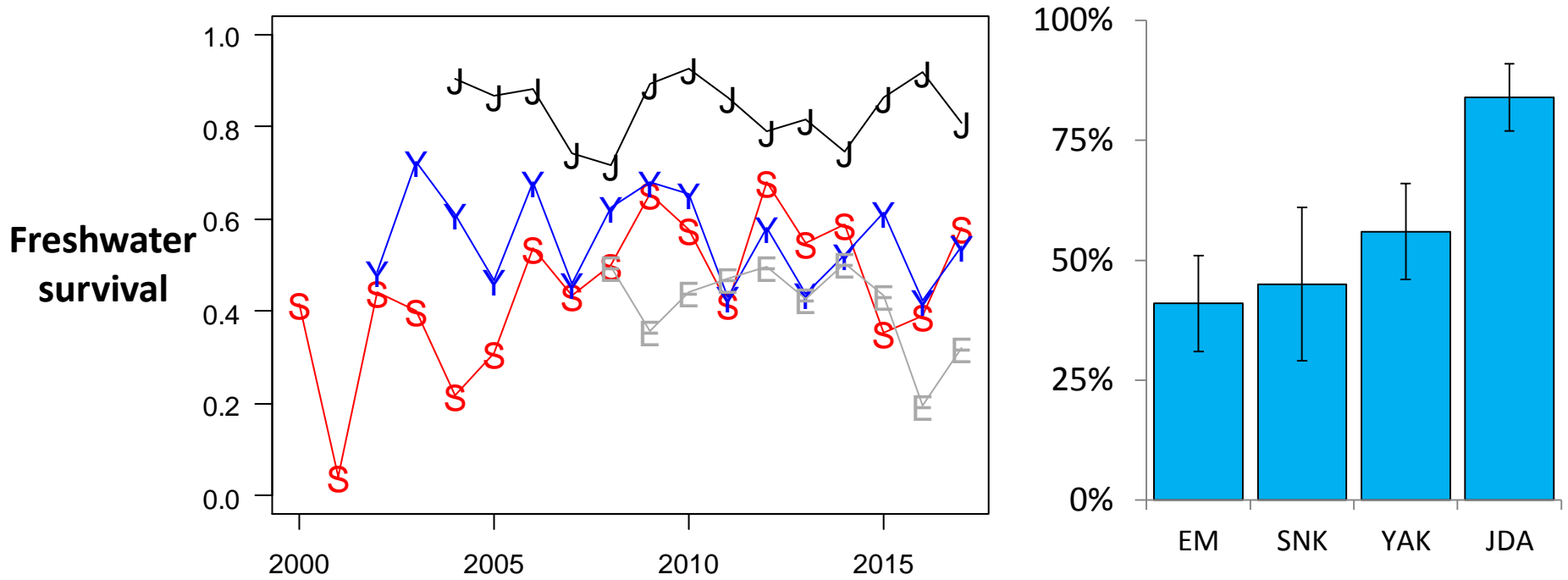
Mark-recapture methods using PIT tags (~500K tagged steelhead)  
Regression and multi-model inference

# Study Area



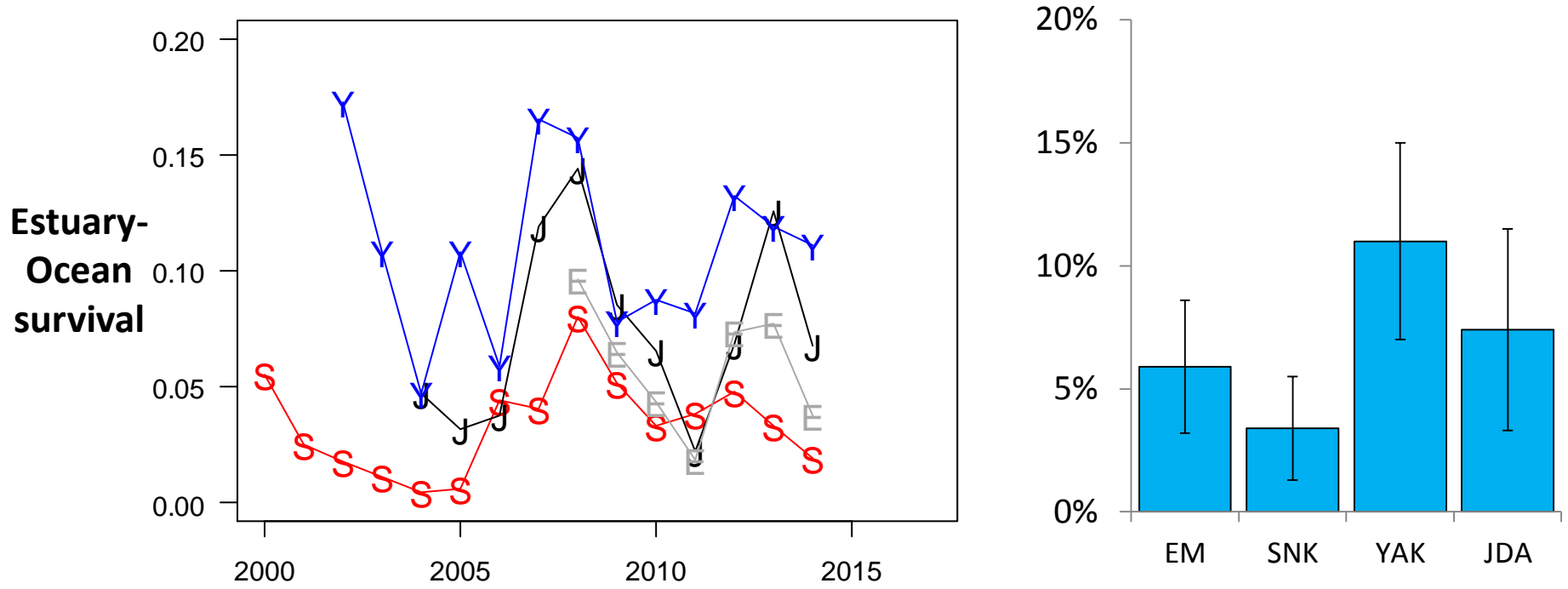
# What are the spatial and temporal patterns in survival?

## Freshwater survival



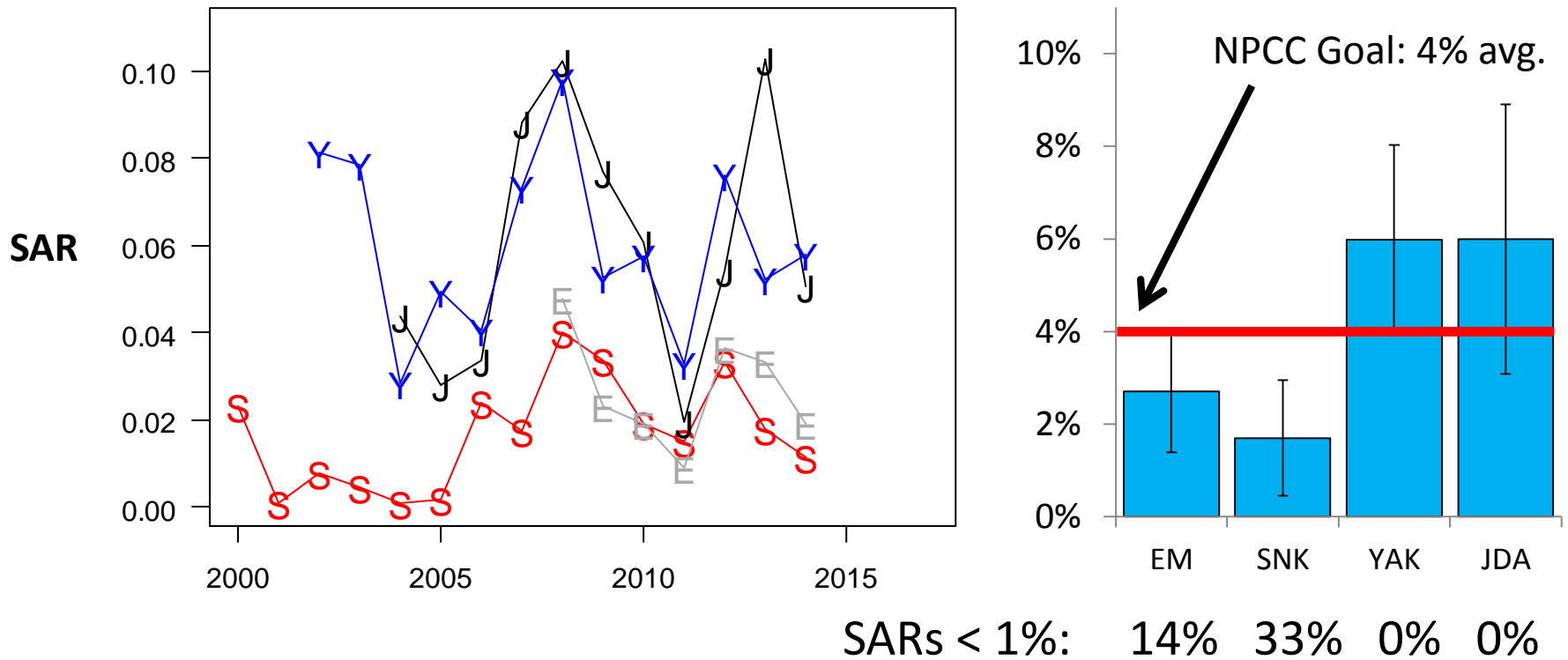
# What are the spatial and temporal patterns in survival?

## Estuary-Ocean survival



# What are the spatial and temporal patterns in survival?

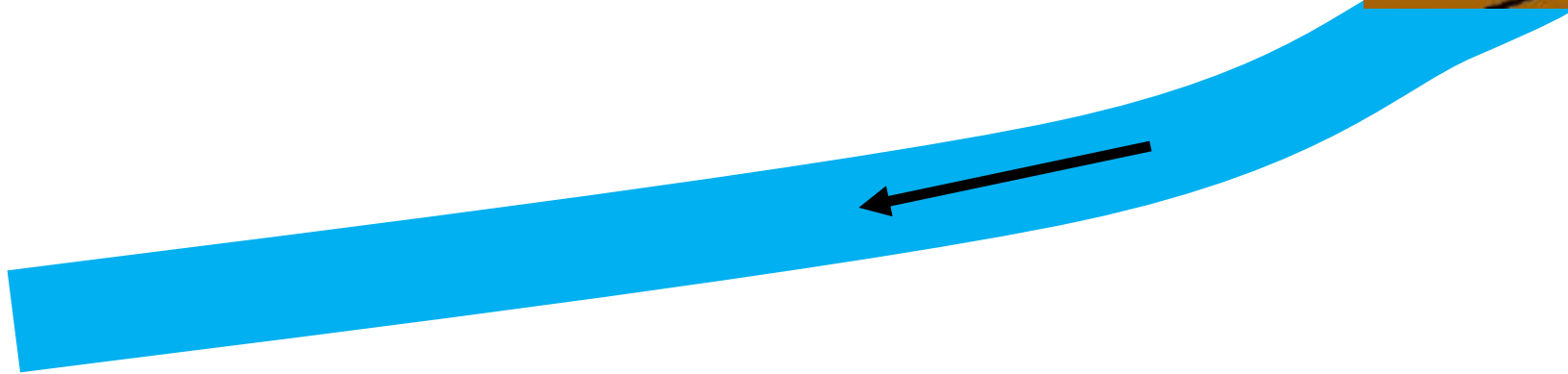
## Smolt-to-Adult Return (SAR)



# What are the factors that influence survival?

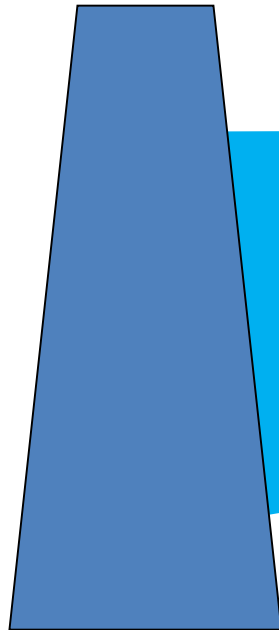
How do reservoirs affect the currents that fish rely on?

Current velocity = 7 miles/hour



# What are the factors that influence survival?

How do reservoirs affect the currents that fish rely on?

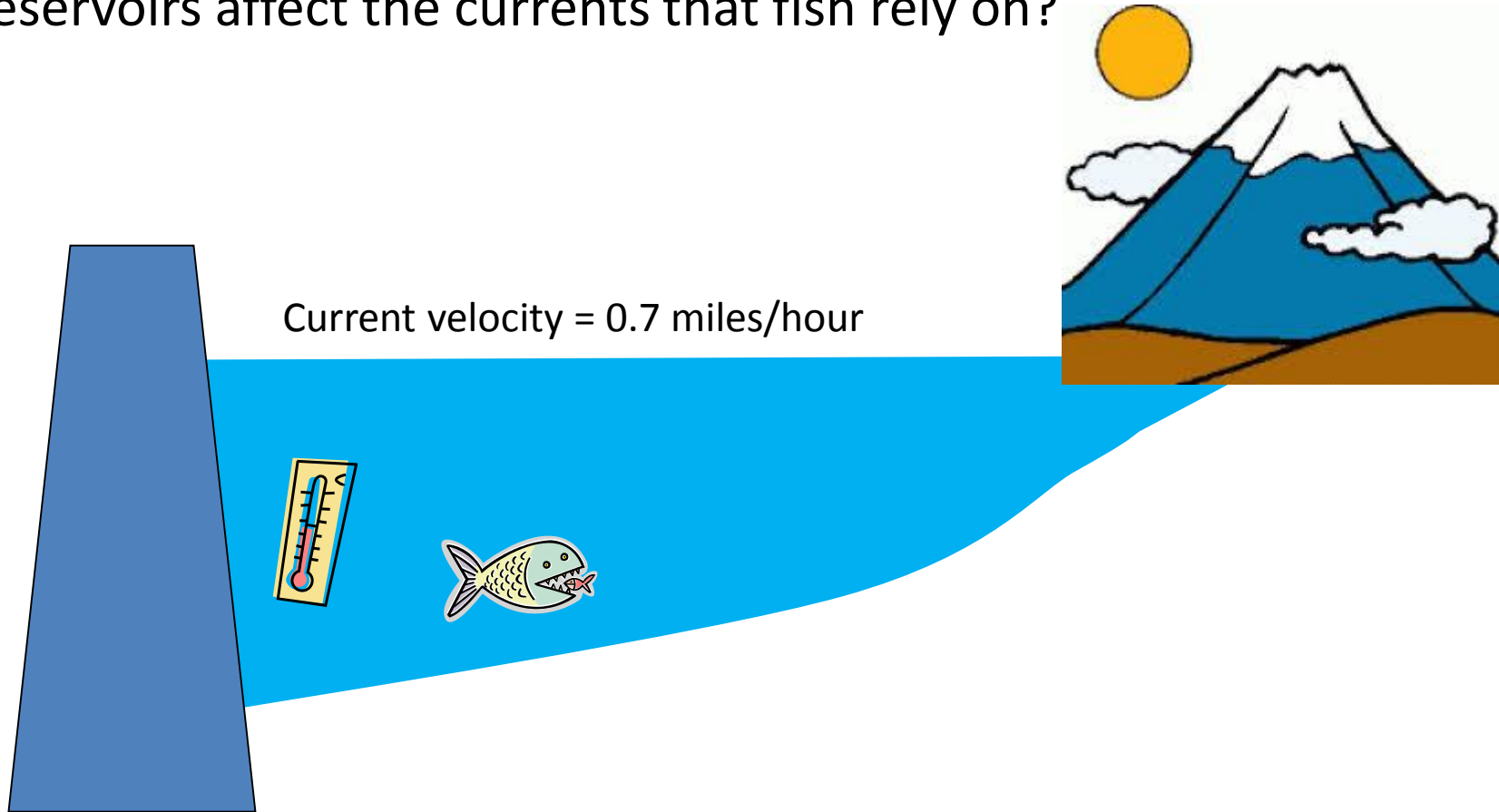


Current velocity = 0.7 miles/hour



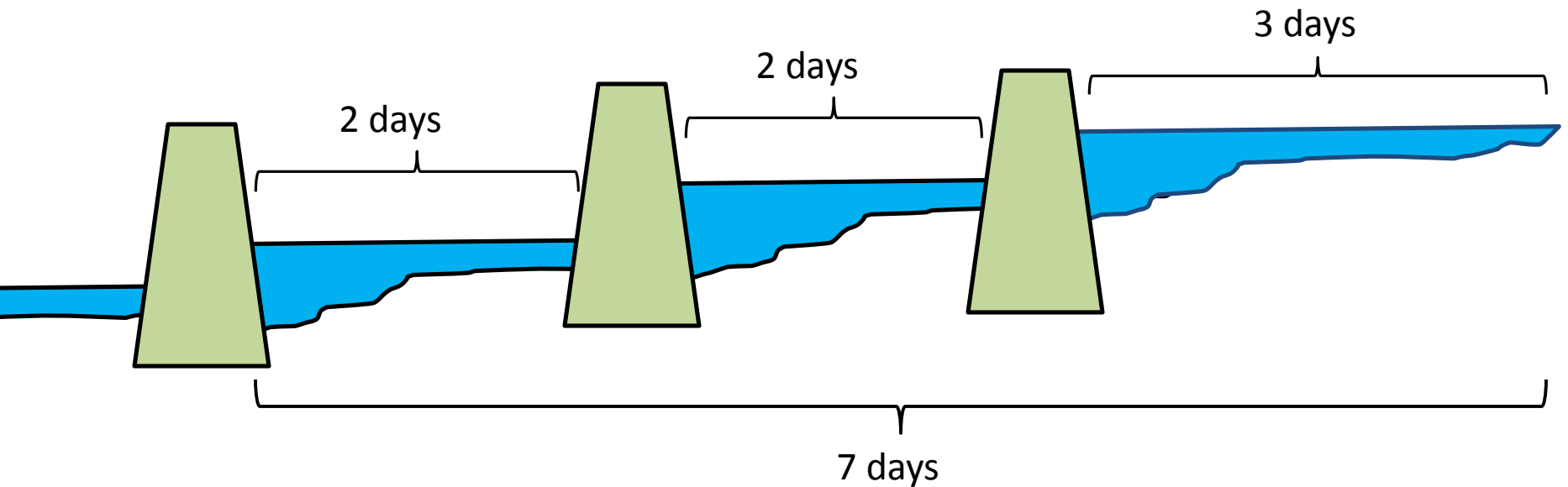
# What are the factors that influence survival?

How do reservoirs affect the currents that fish rely on?



# Water Transit Time (WTT)

Estimate of the number of days required for average water particle to transit a reservoir (volume/flow)



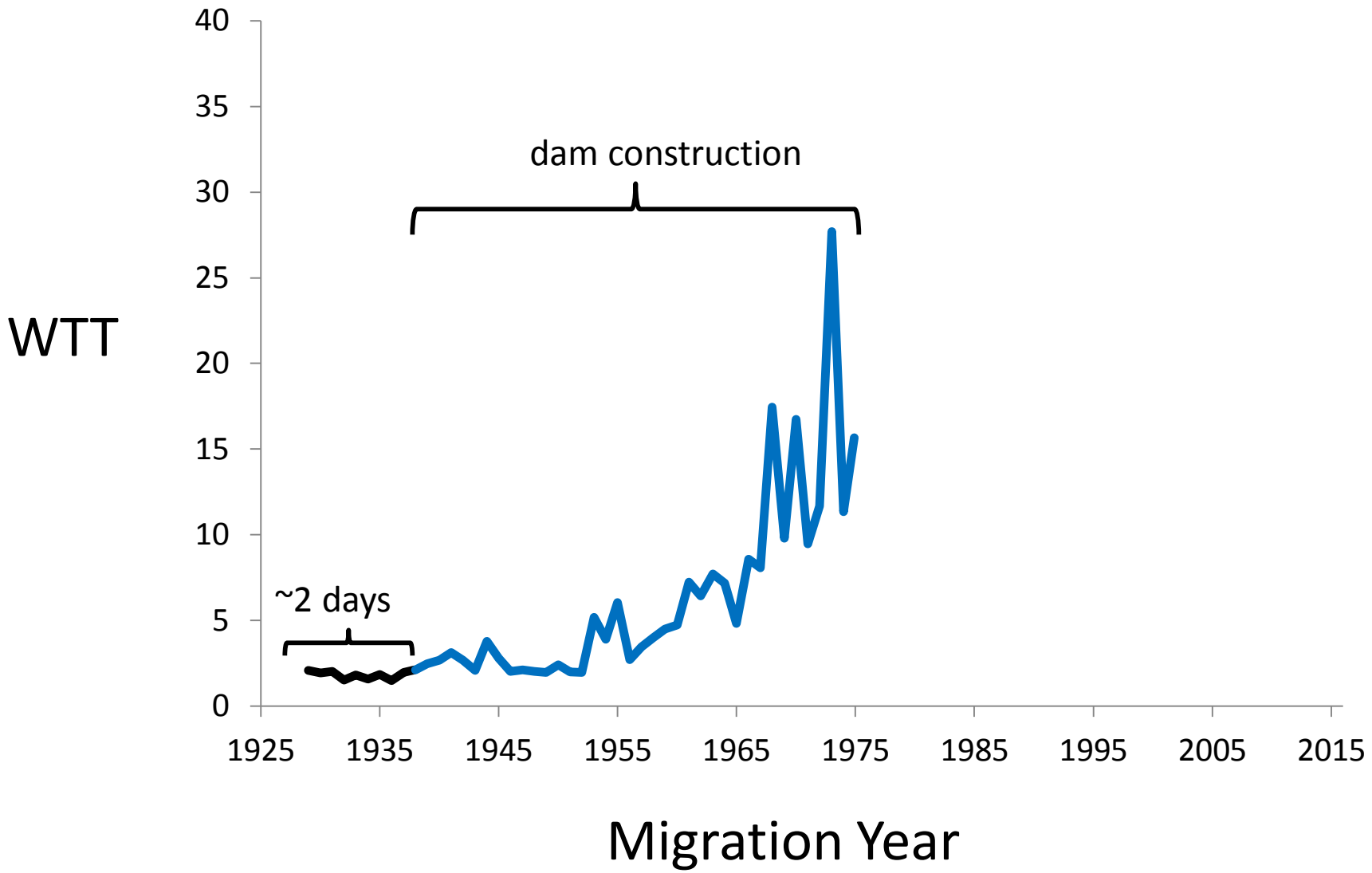
# Long-term changes in Lewiston-BON WTT

WTT

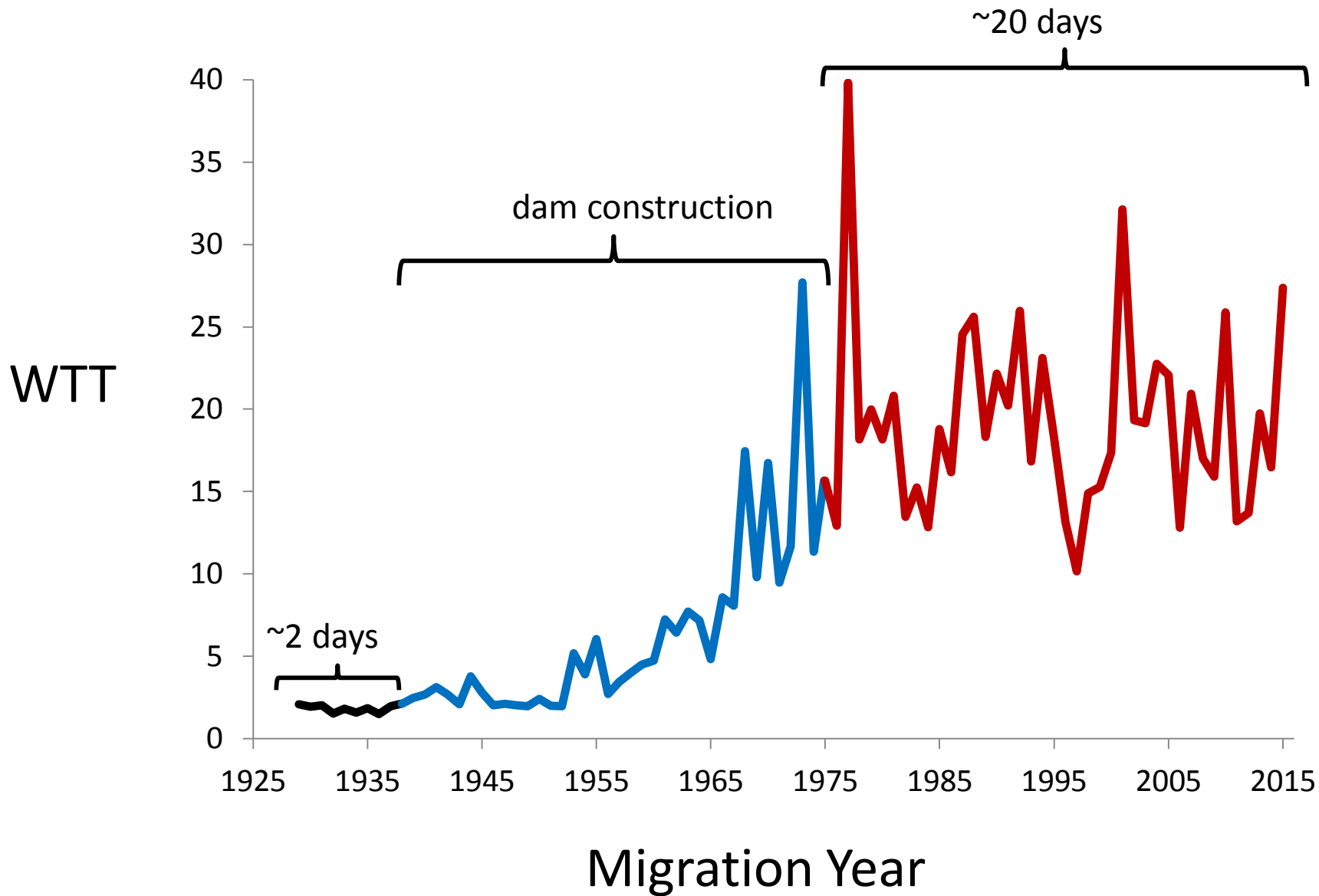


Migration Year

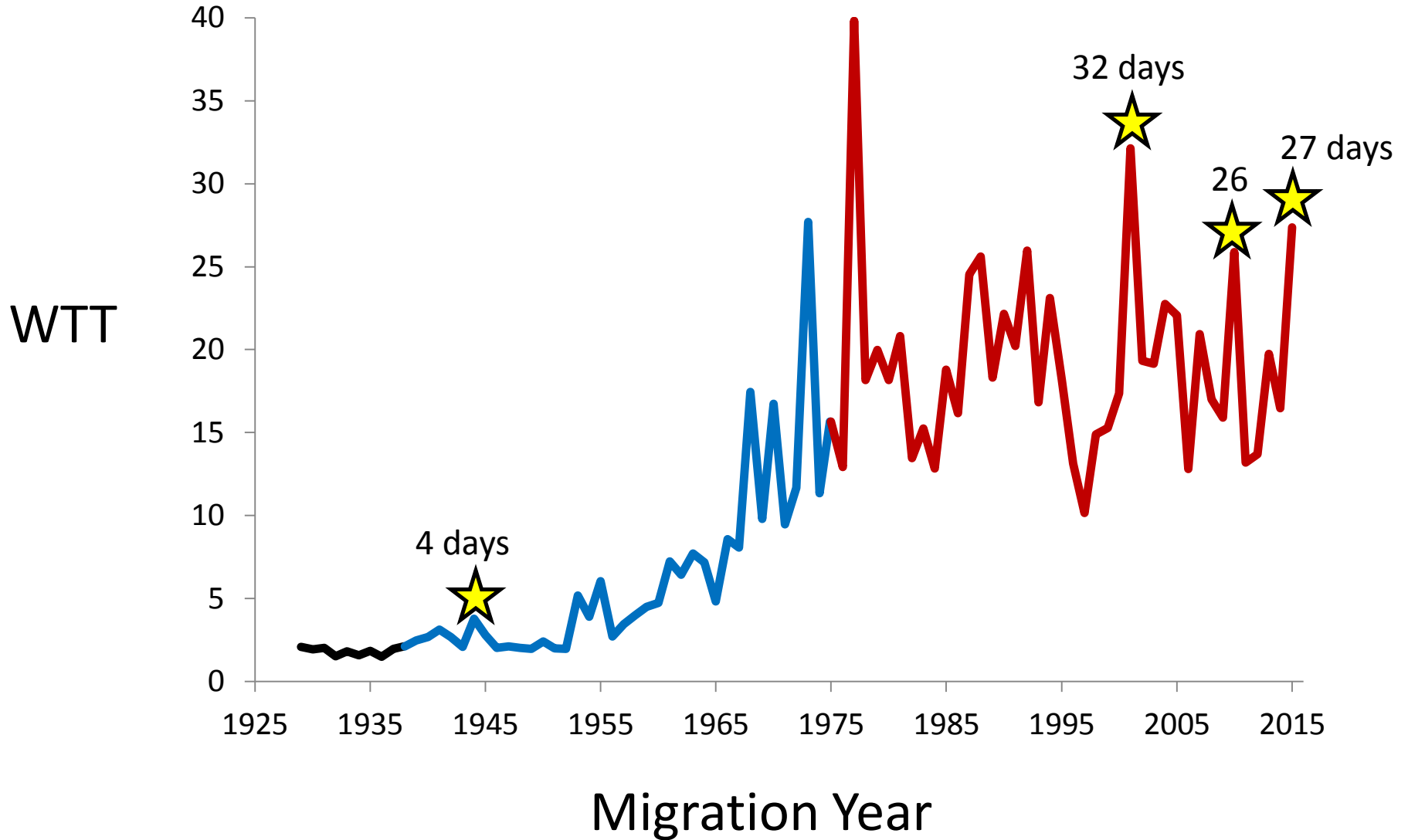
# Long-term changes in Lewiston-BON WTT



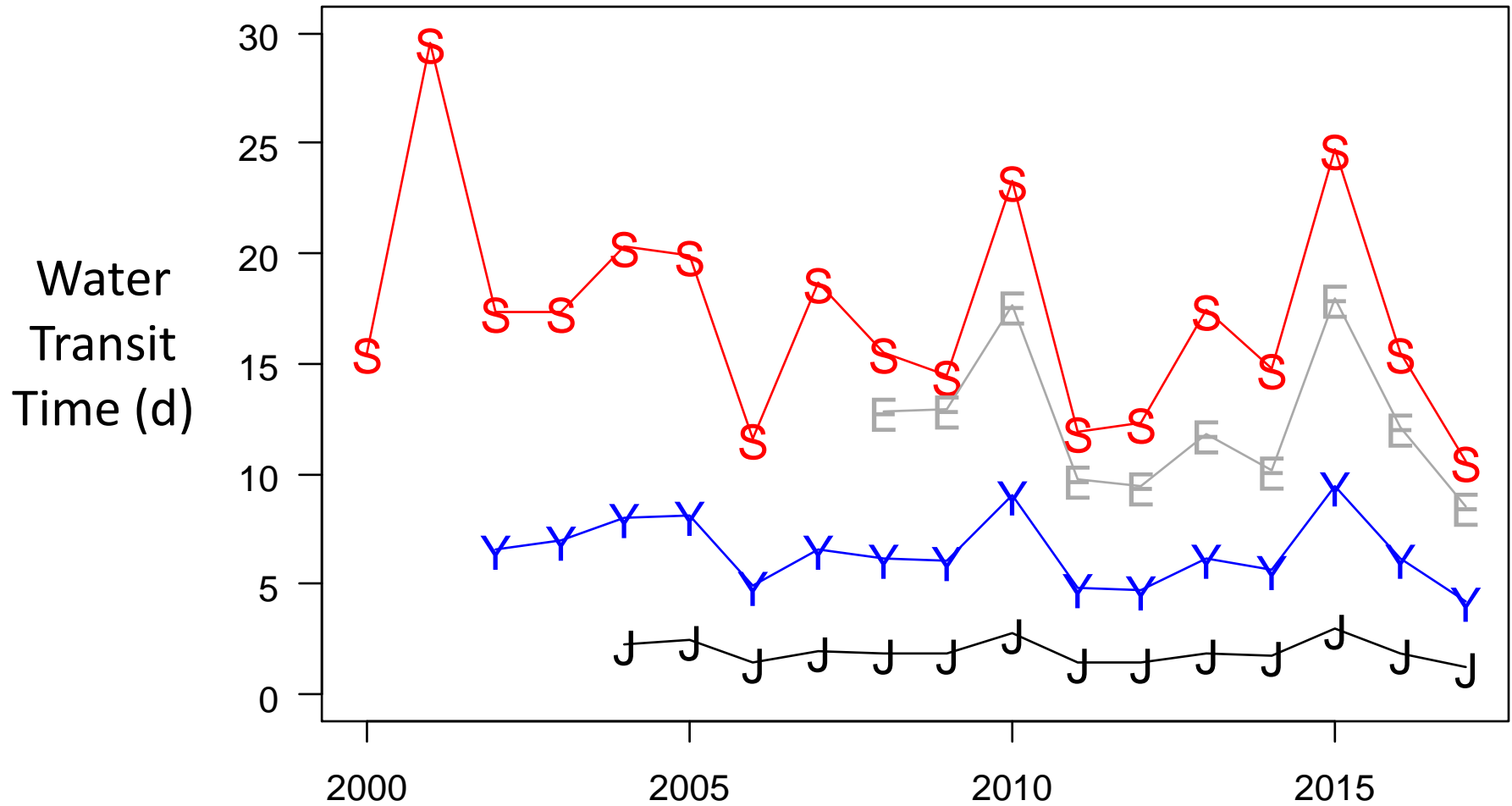
# Long-term changes in Lewiston-BON WTT



# Long-term changes in Lewiston-BON WTT



# Water transit times by stock and year



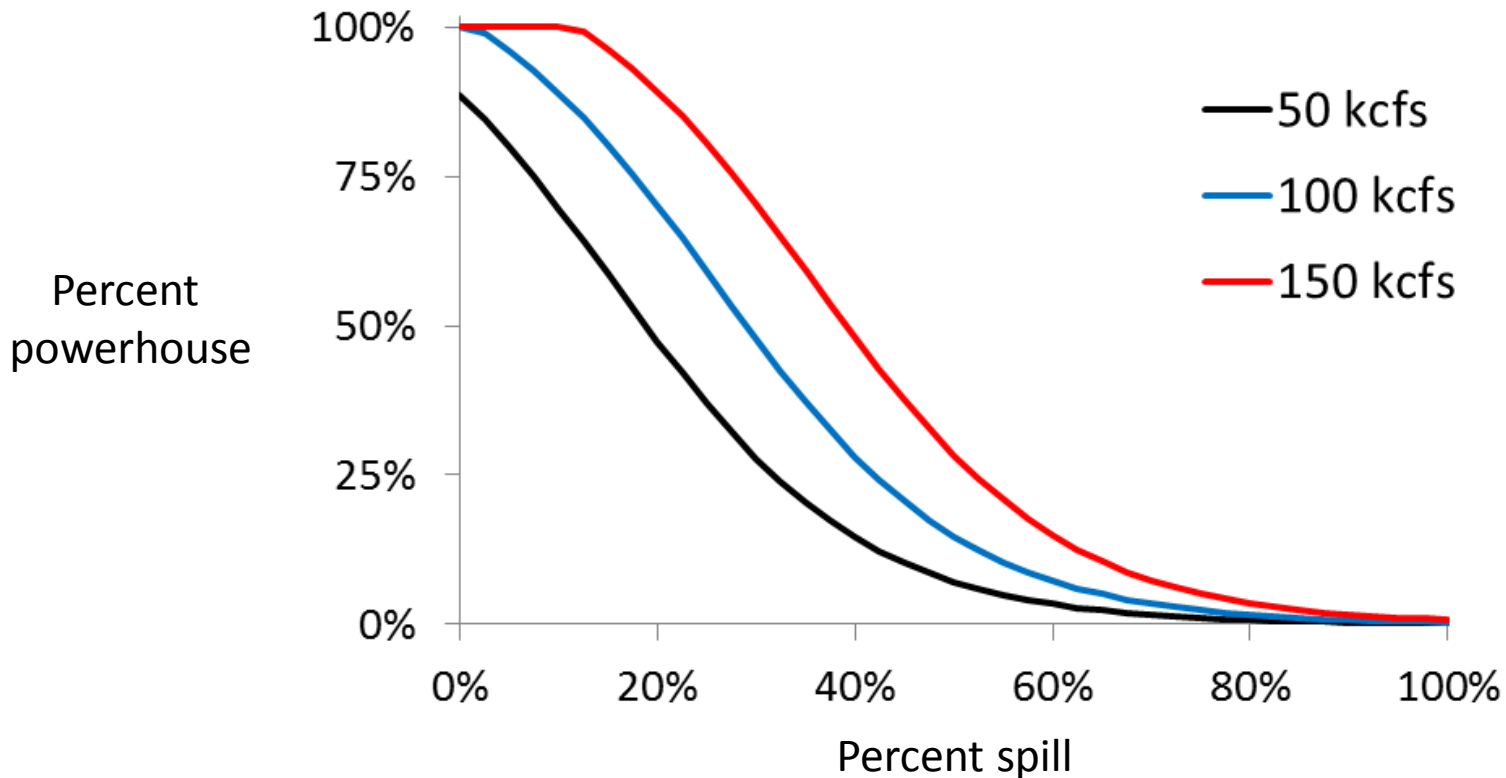
# Characterizing effects of spill, flow, and spillway surface passage

PowerHouse passage experiences (PITPH)

Incorporates spill proportion, flow, and spillway surface passage

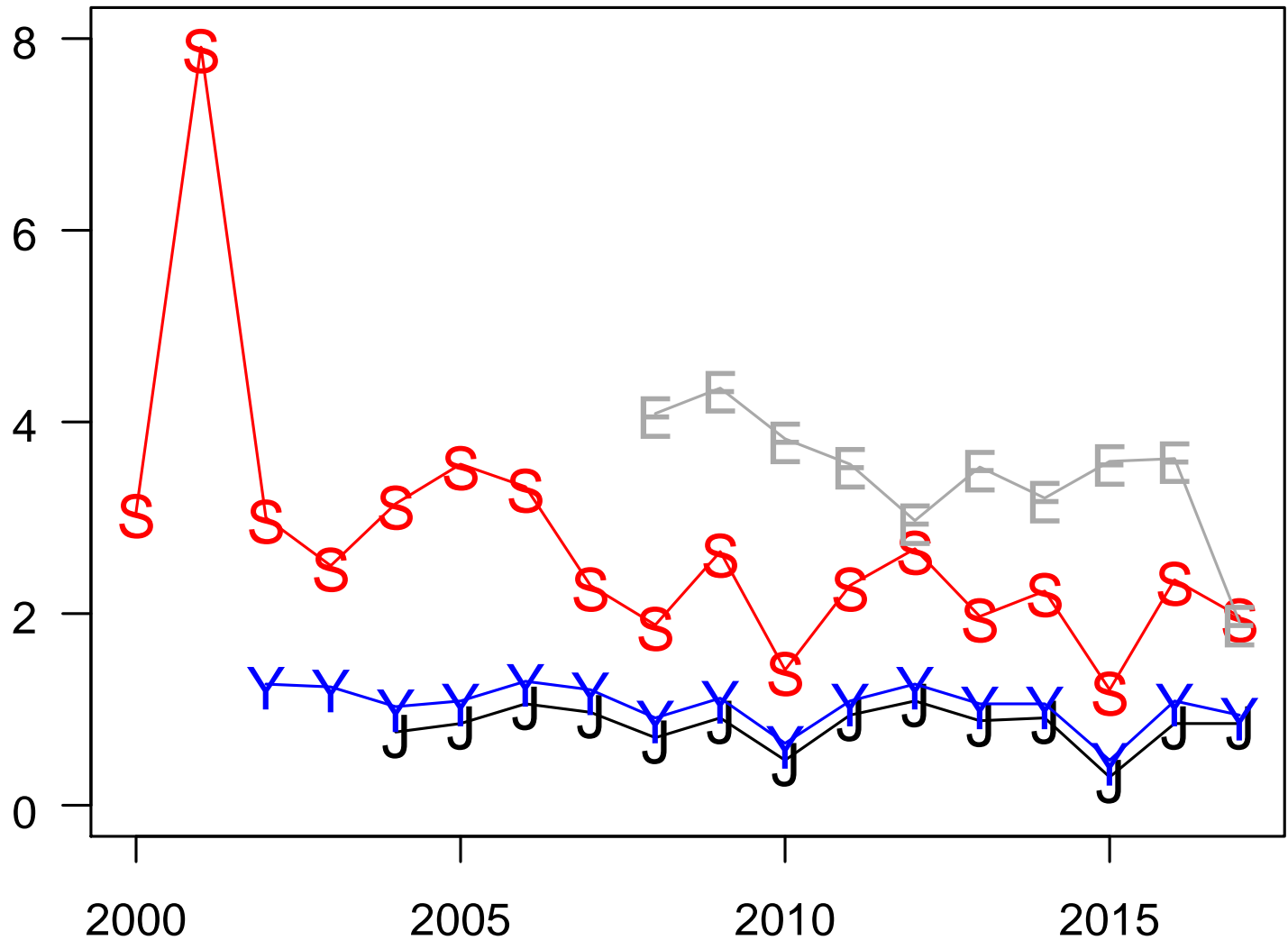
Powerhouse = Turbines + collection/bypass system

Spillway = 1 - Powerhouse



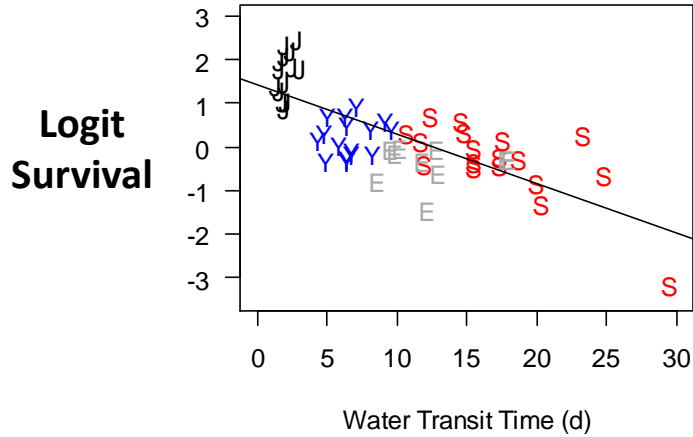
# Powerhouse passages by stock and year

Powerhouse  
Passages  
(PITPH)

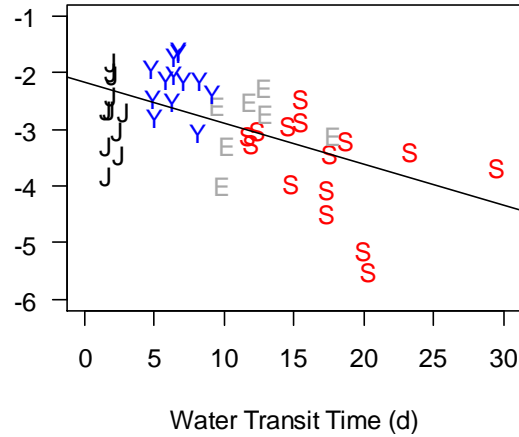


# Freshwater influences on life-stage survival

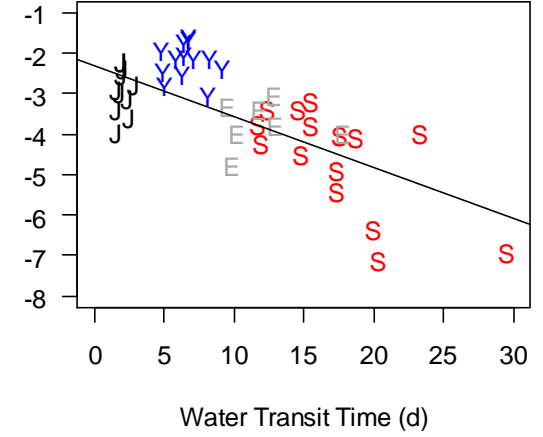
Freshwater survival



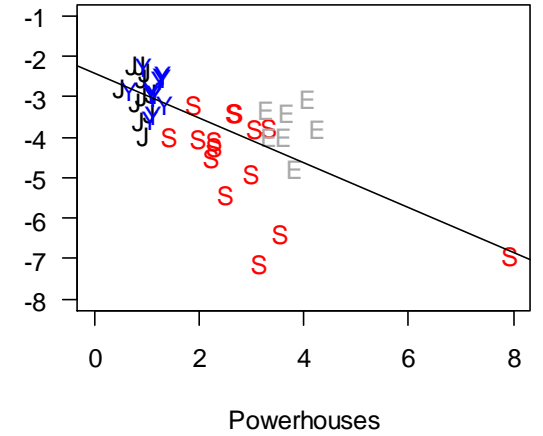
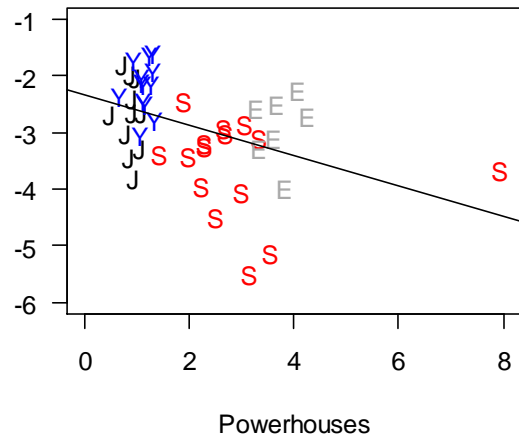
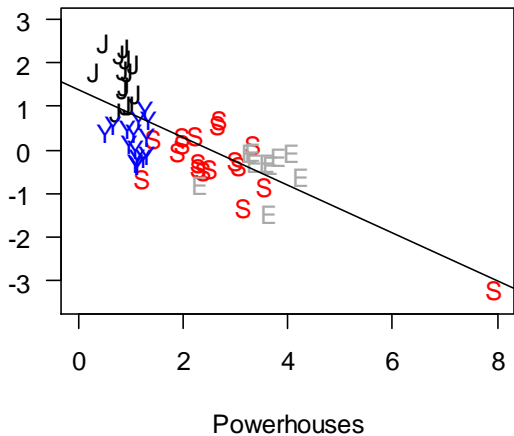
Estuary-Ocean survival



Smolt-to-Adult survival

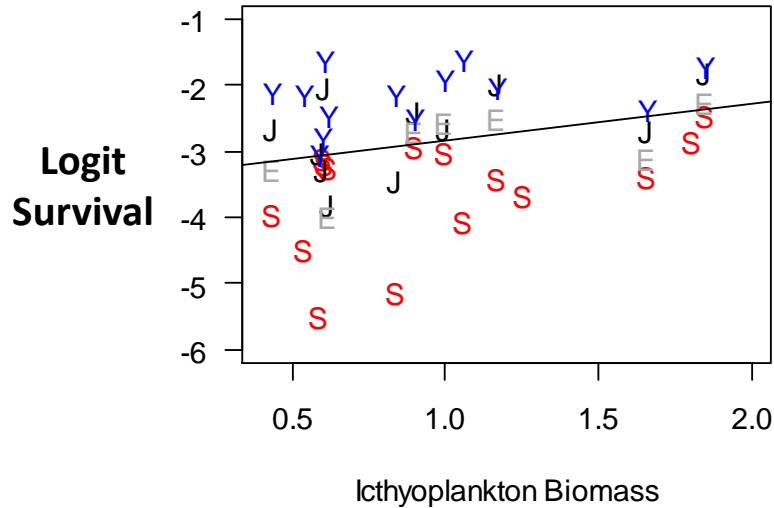


Logit Survival

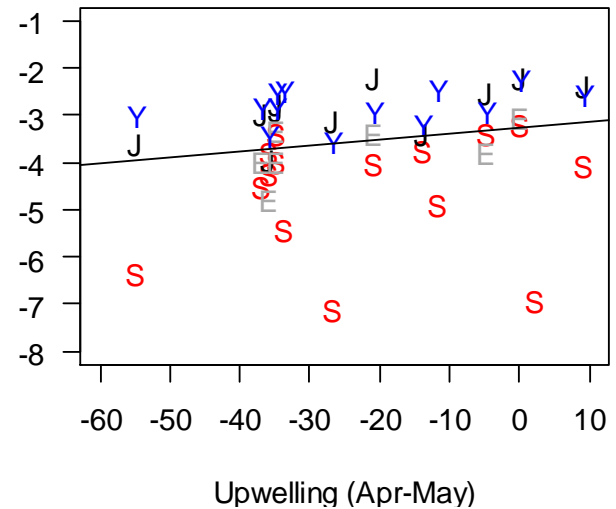
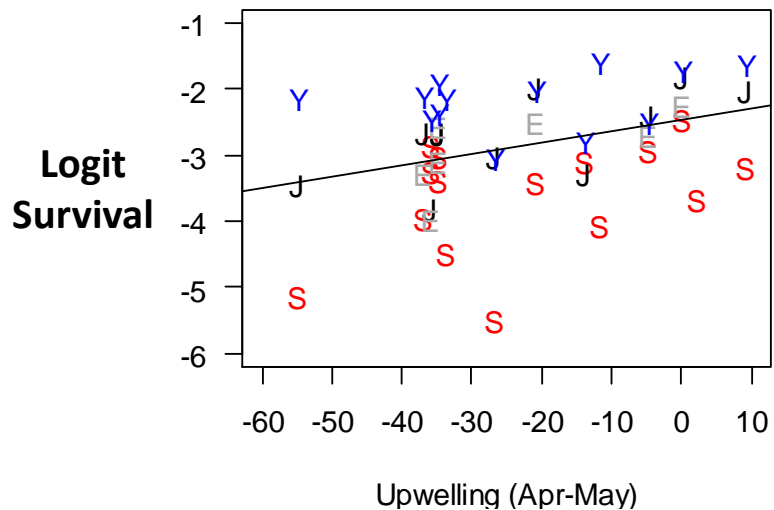
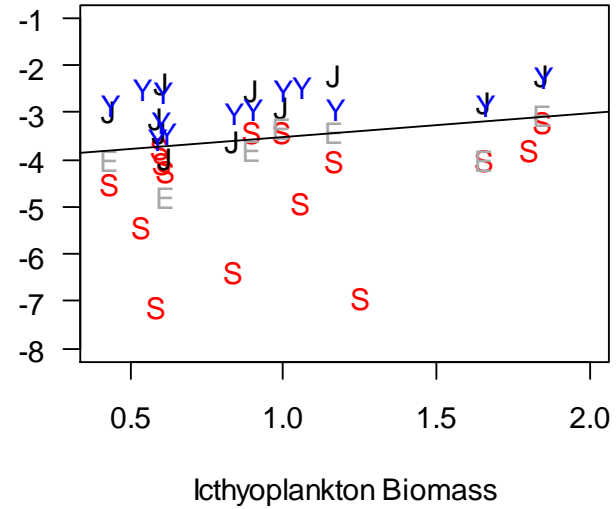


# Ocean influences on life-stage survival

## Estuary-Ocean survival



## Smolt-to-Adult survival



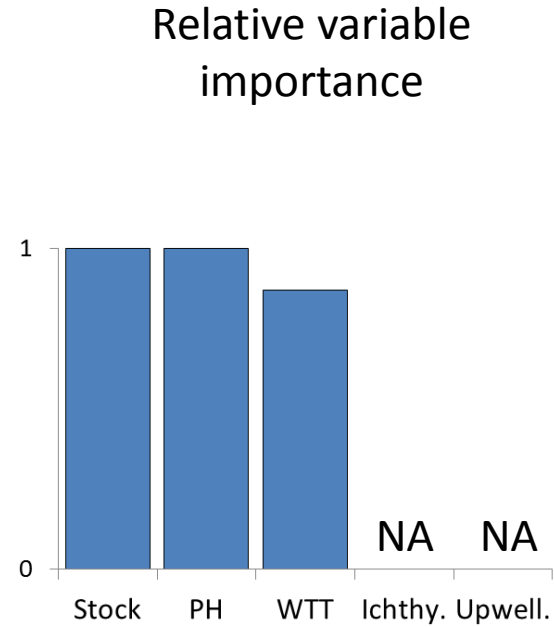
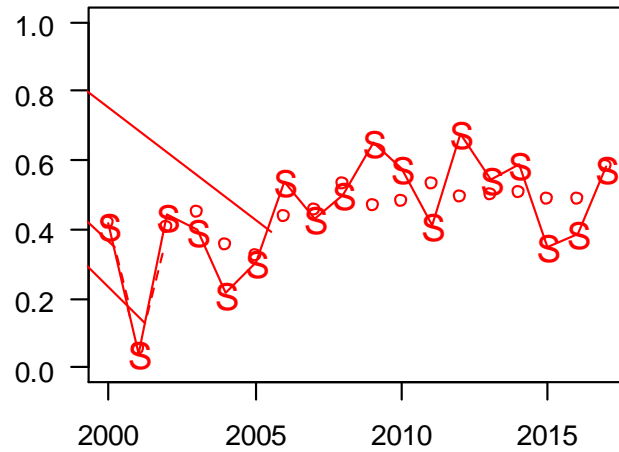
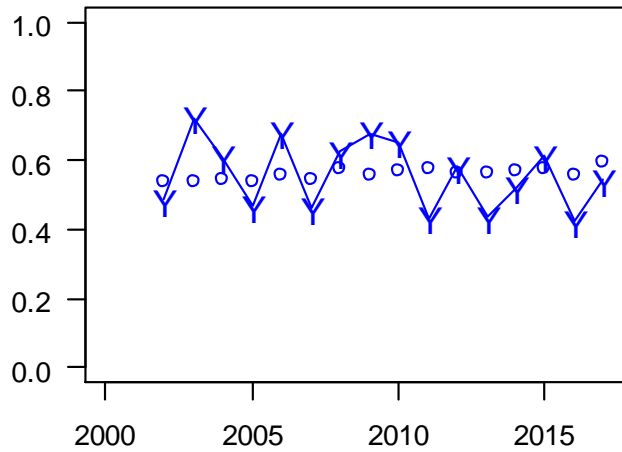
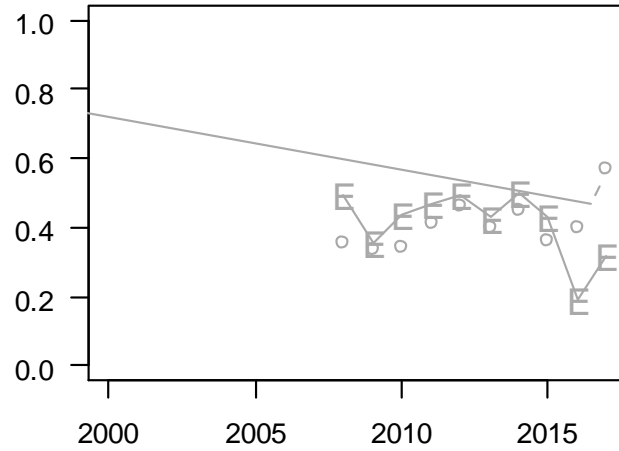
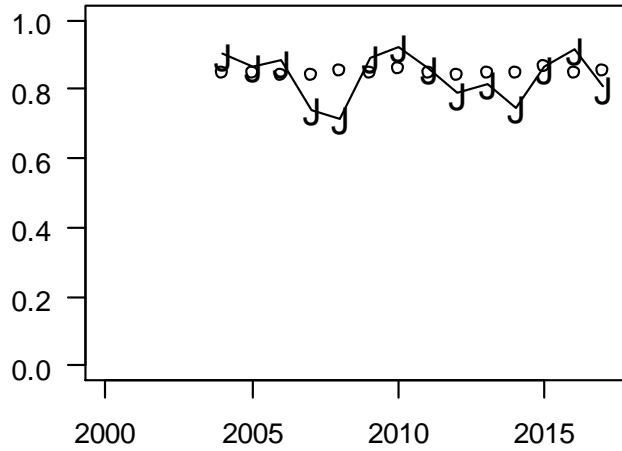
# What factors are associated with the patterns in survival?

## Multiple regression with multi-model inference

<b>Variables</b>	<b>Freshwater survival</b>	<b>Est.-Ocean survival</b>	<b>Smolt-to-Adult survival</b>
<b>Water Transit Time</b>	✓	✓	✓
<b>Powerhouse passages</b>	✓	✓	✓
<b>Stock</b>	✓	✓	✓
<b>Winter Ichthyoplankton</b>		✓	✓
<b>Upwelling (Apr-May)</b>		✓	✓

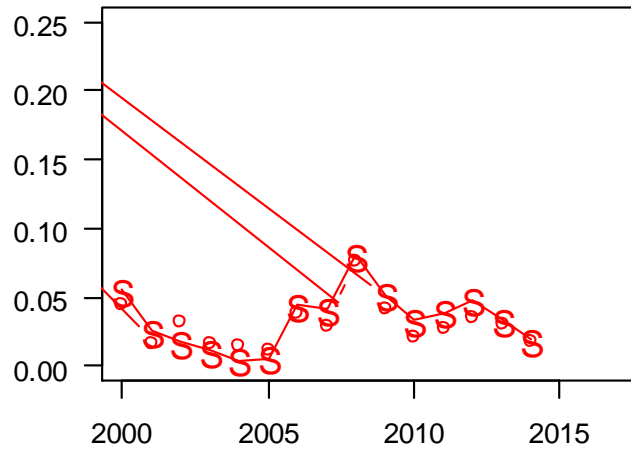
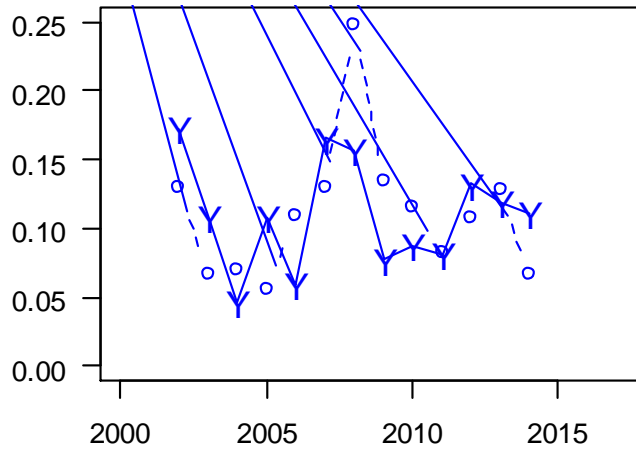
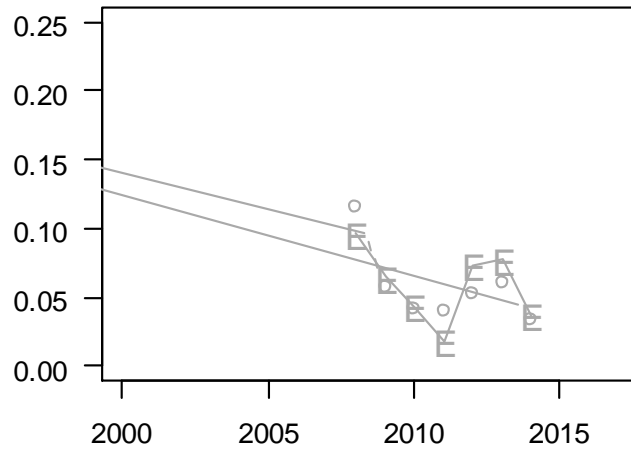
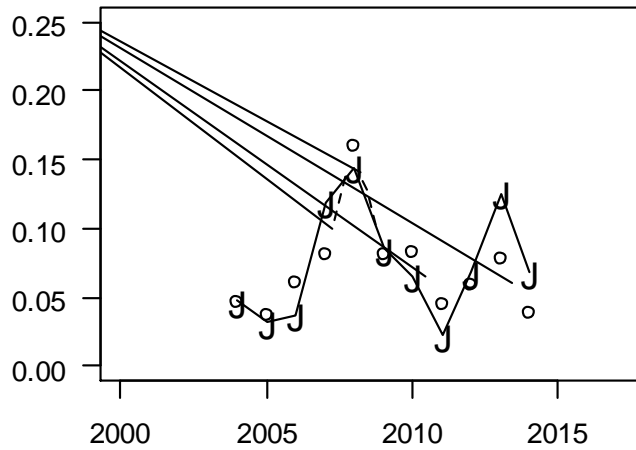
# Freshwater survival

$R^2 = 0.77$

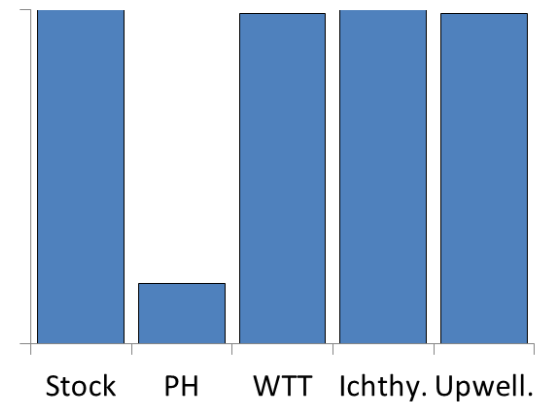


# Estuary-Ocean survival

$R^2 = 0.66$

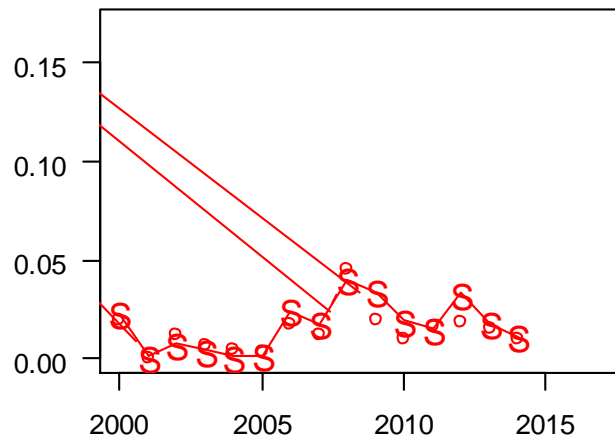
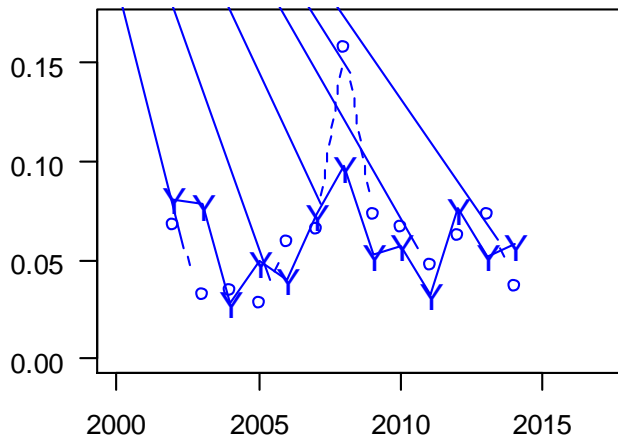
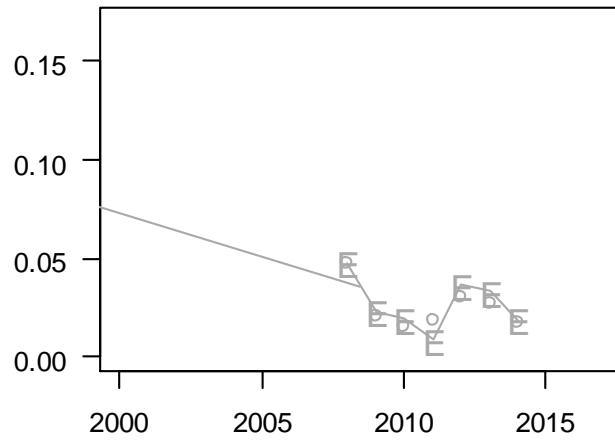
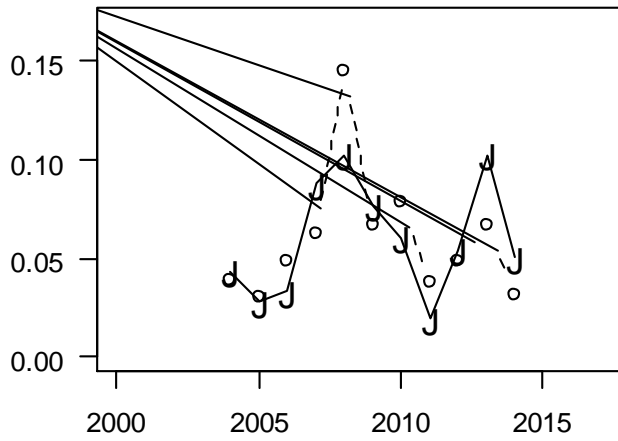


Relative variable importance

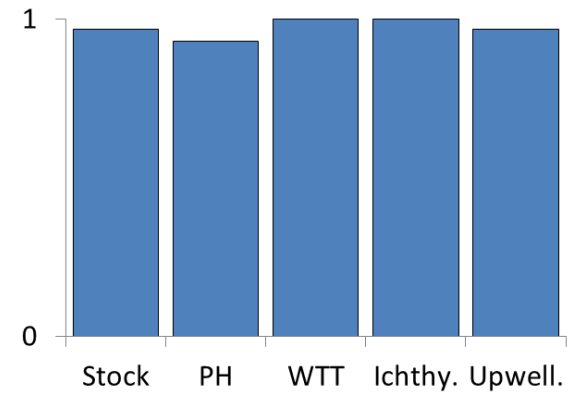


# Smolt-to-Adult survival

$R^2 = 0.70$



Relative variable importance



# Can management efforts help achieve regional survival goals?

Use model-averaged coefficients to forecast Smolt-to-Adult survival rates

Considered two management scenarios:

- Current Biological Opinion spill levels

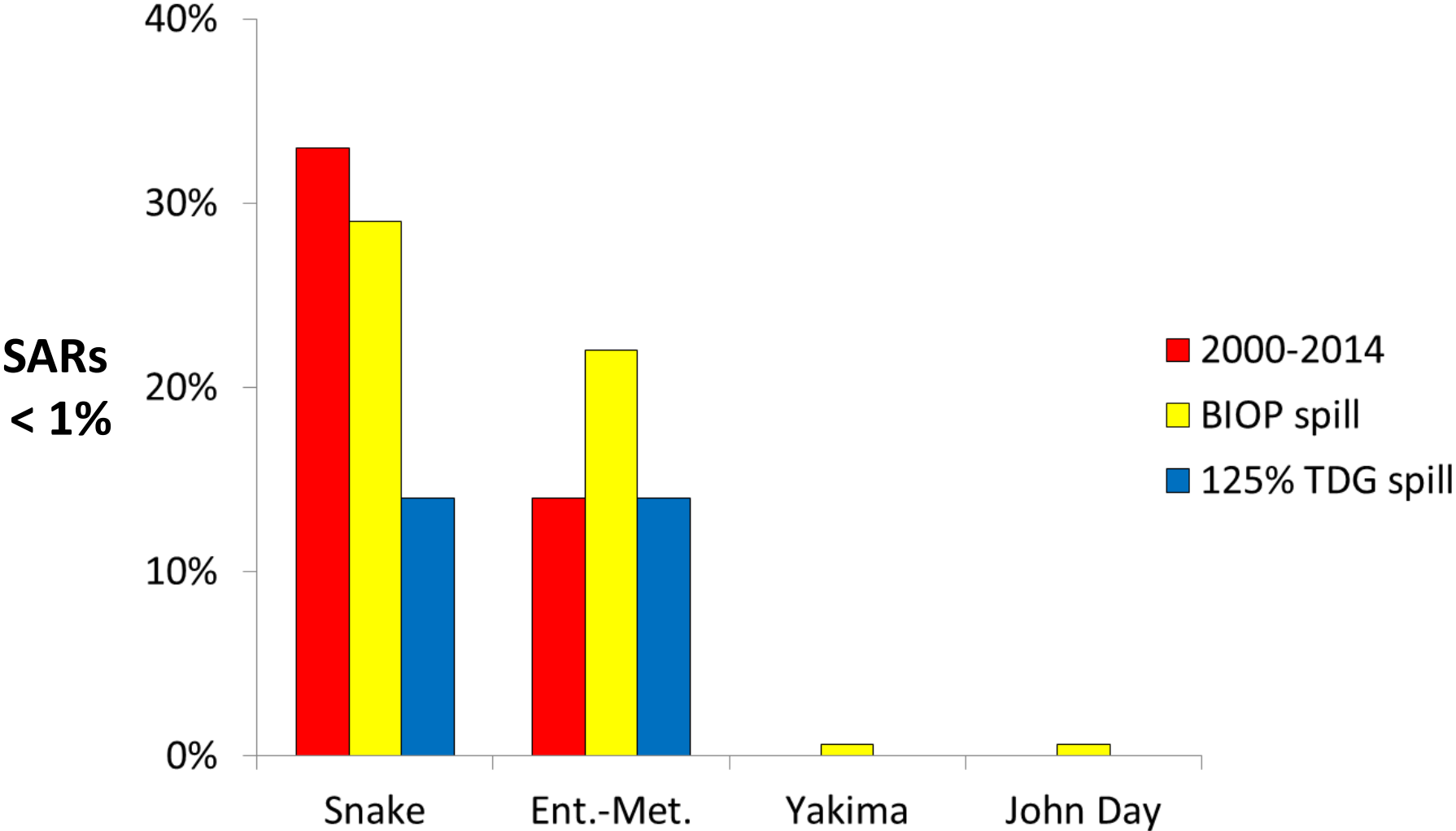
- Spill to 125% Total Dissolved Gas limits

Account for variable freshwater and ocean conditions:

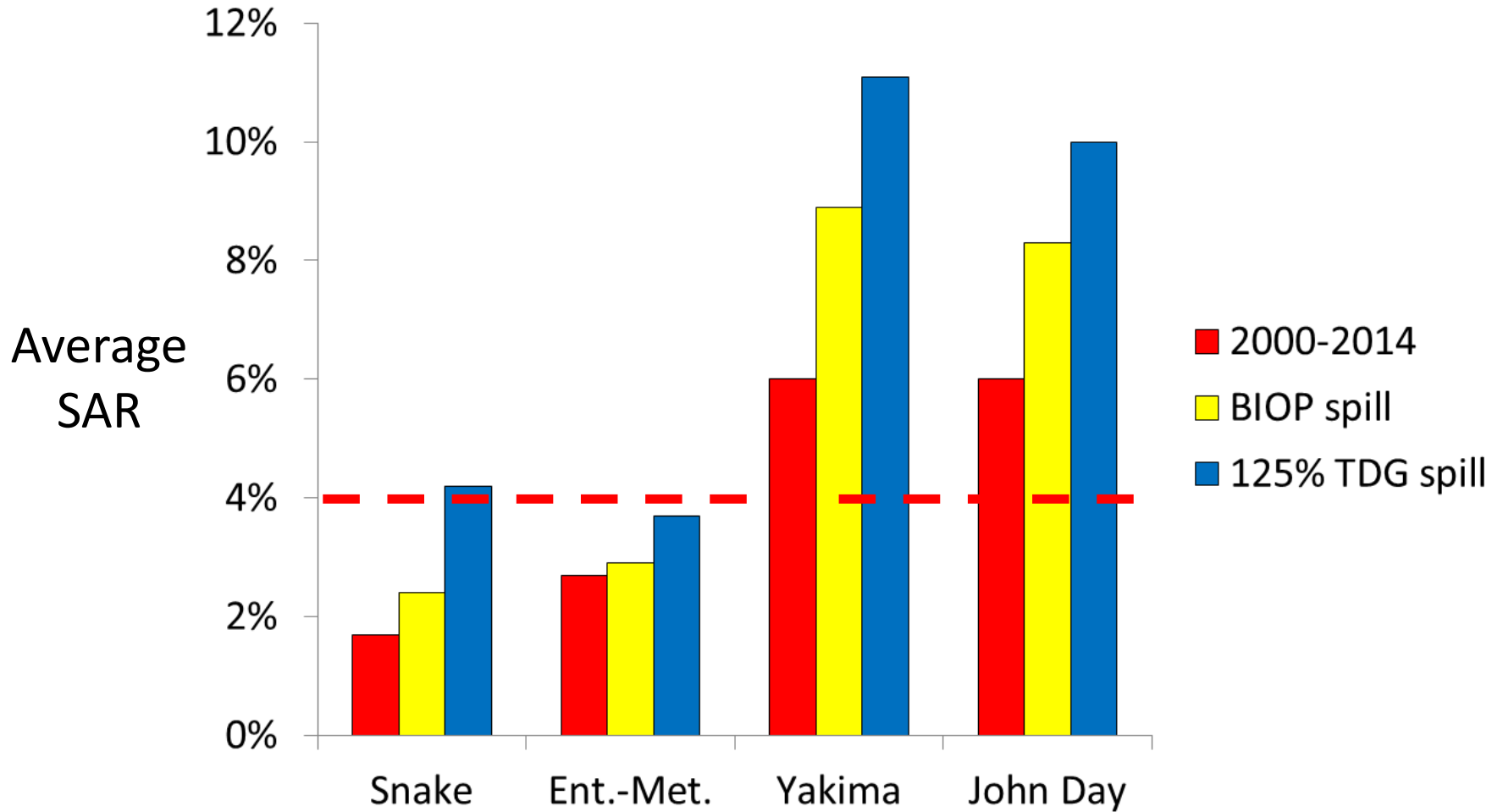
- High, average, low flow years

- Winter Ichthyoplankton, Pacific Decadal Oscillation

# Probability of low SARs (< 1%)



# Average SARs



# Conclusions

Models captured high degree of spatial and temporal patterns in variation

**Freshwater:** Stock + Powerhouses + Water Transit Time

**Estuary-Ocean:** Stock + Water Transit Time + Ichthyo. + Upwelling

**Smolt-to-Adult:** Stock + Powerhouses + Water Transit Time + Ichthyo. + Upwelling

**Snake:** 175% improvement in SARs with increased spill

**Ent.-Met.:** 128% improvement

**Yakima:** 125% improvement

**John Day:** 120% improvement

## **Adaptive Management Experiment:**

Ongoing tagging efforts provides framework for monitoring outcomes

