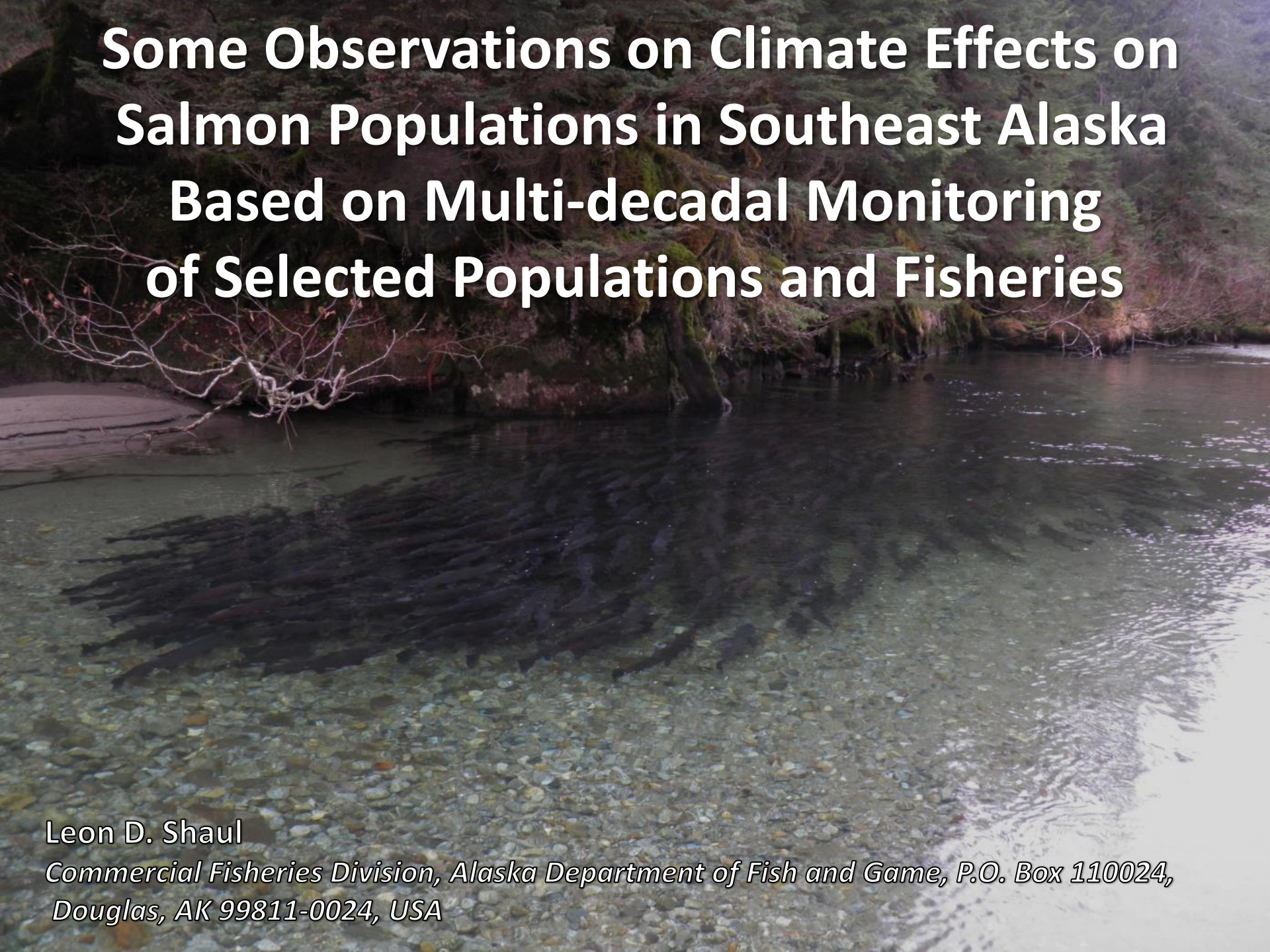




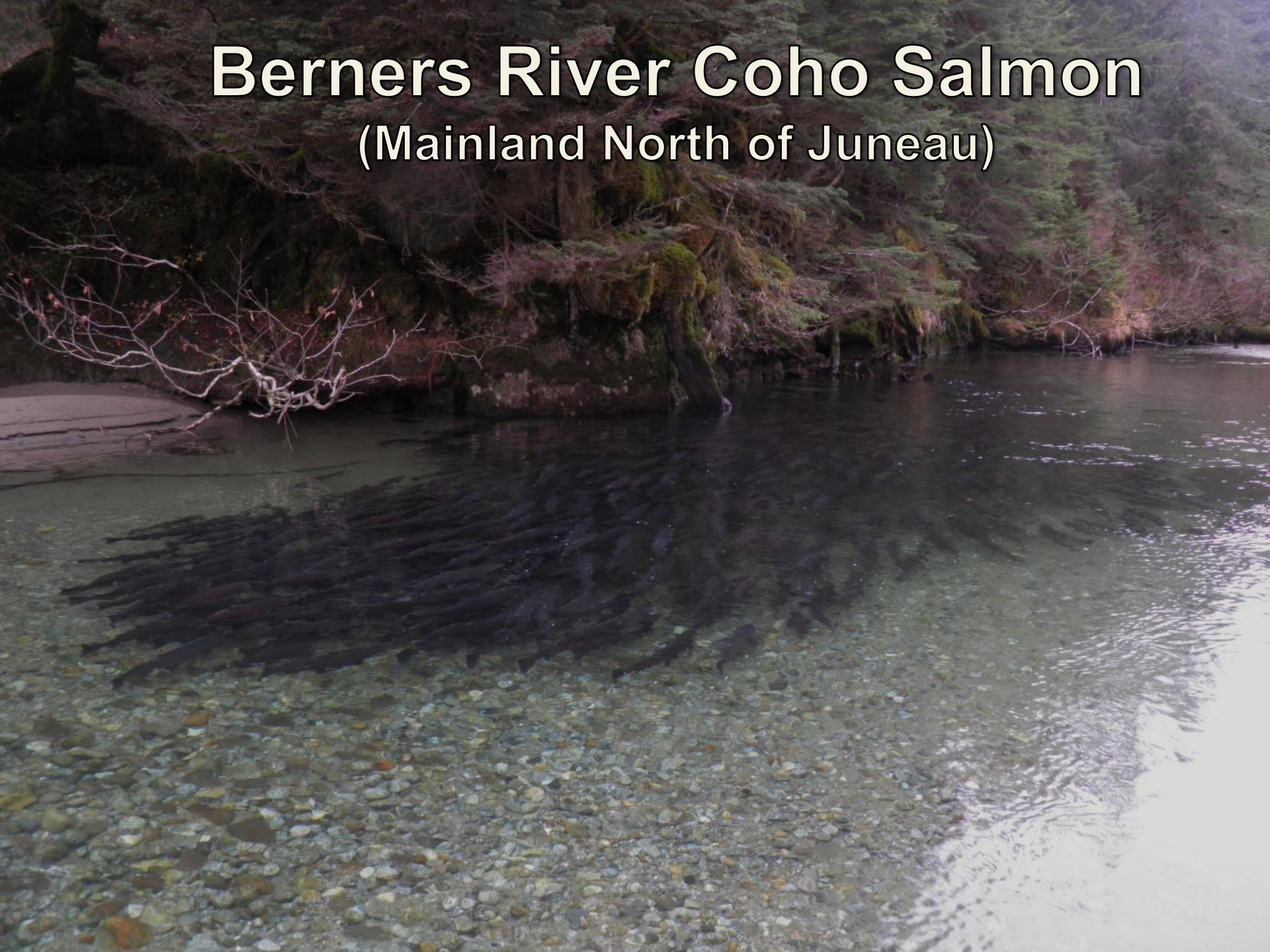
# Some Observations on Climate Effects on Salmon Populations in Southeast Alaska Based on Multi-decadal Monitoring of Selected Populations and Fisheries

Leon D. Shaul

*Commercial Fisheries Division, Alaska Department of Fish and Game, P.O. Box 110024,  
Douglas, AK 99811-0024, USA*

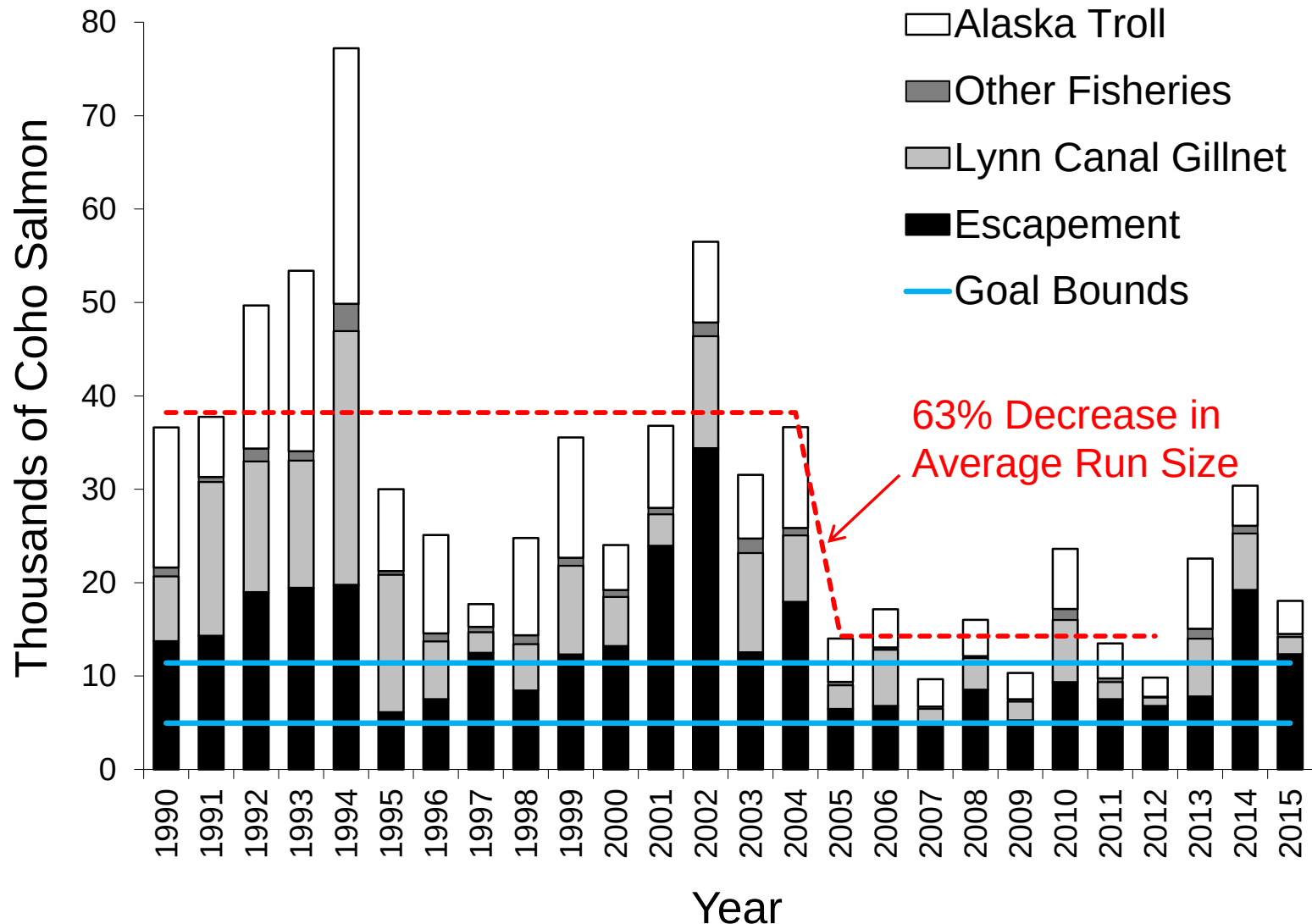
# Berners River Coho Salmon

(Mainland North of Juneau)

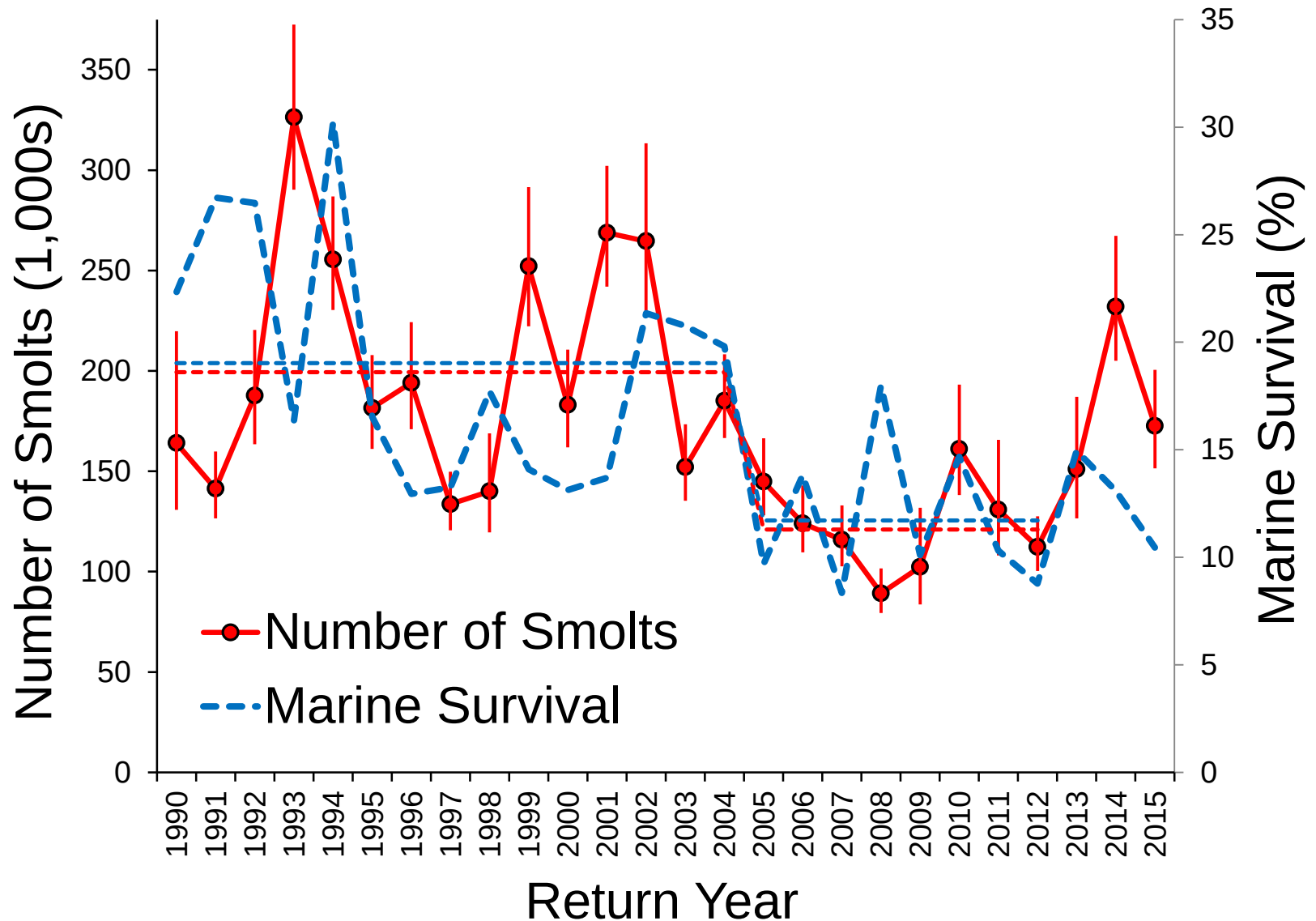


# Berners River Total Return

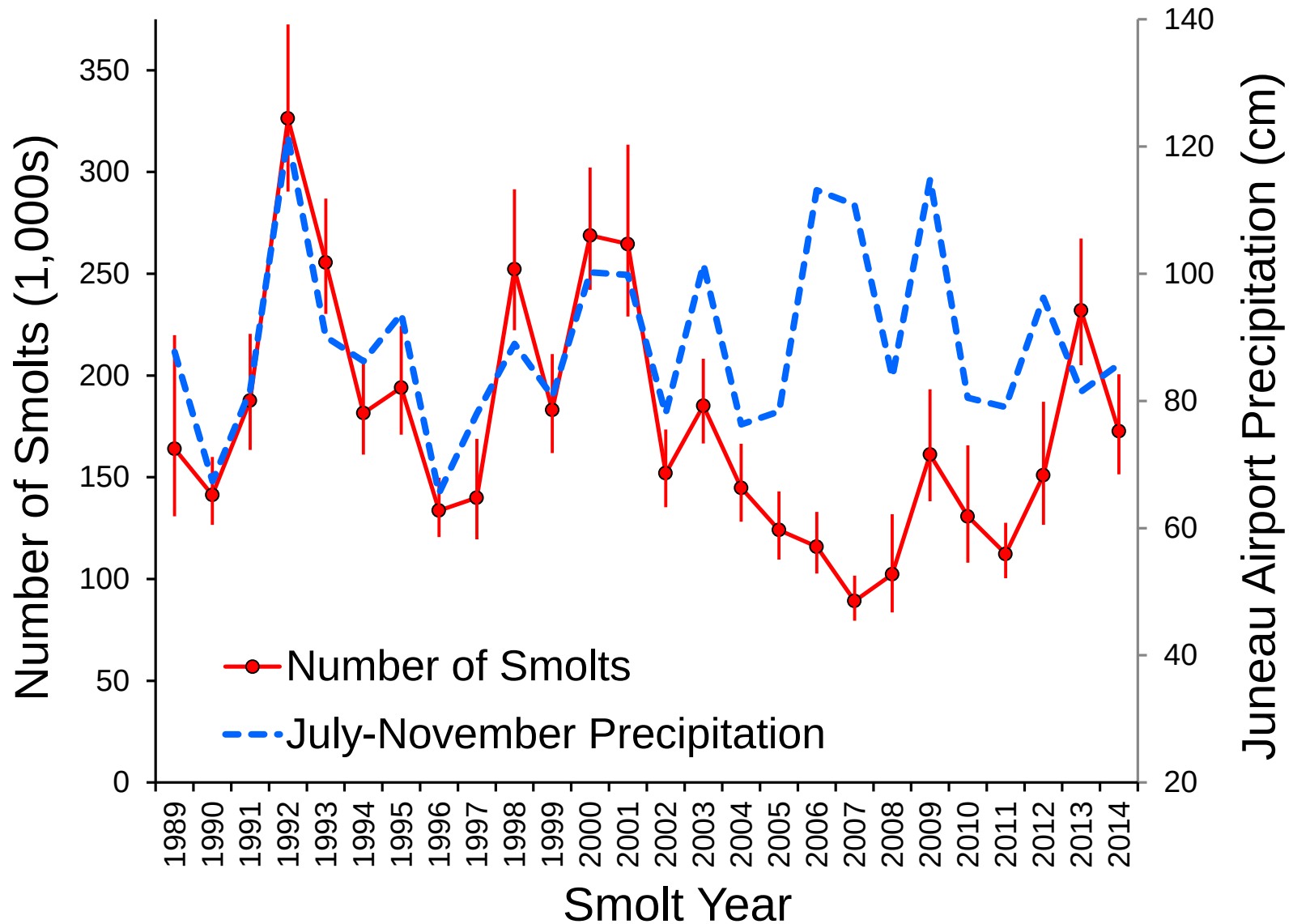
## (Sharp Decline from 1990-2004 to 2005-2012)



# Equal Decrease in Smolt Production and Marine Survival (39% decrease in average smolts; 38% decrease in Survival)

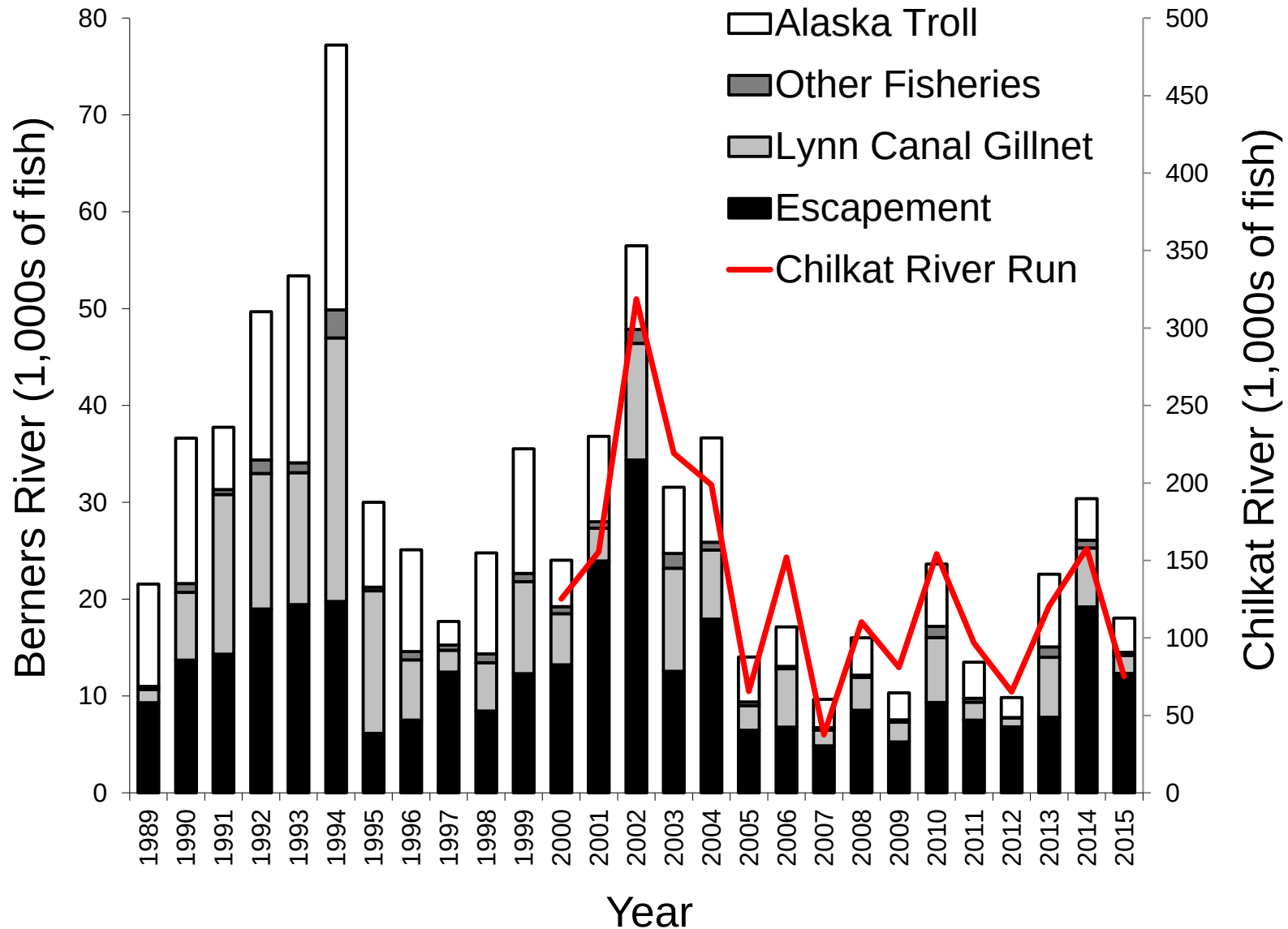


Smolt Production: strong correlation with summer-fall precipitation prior to mid-2000s; then production declined.

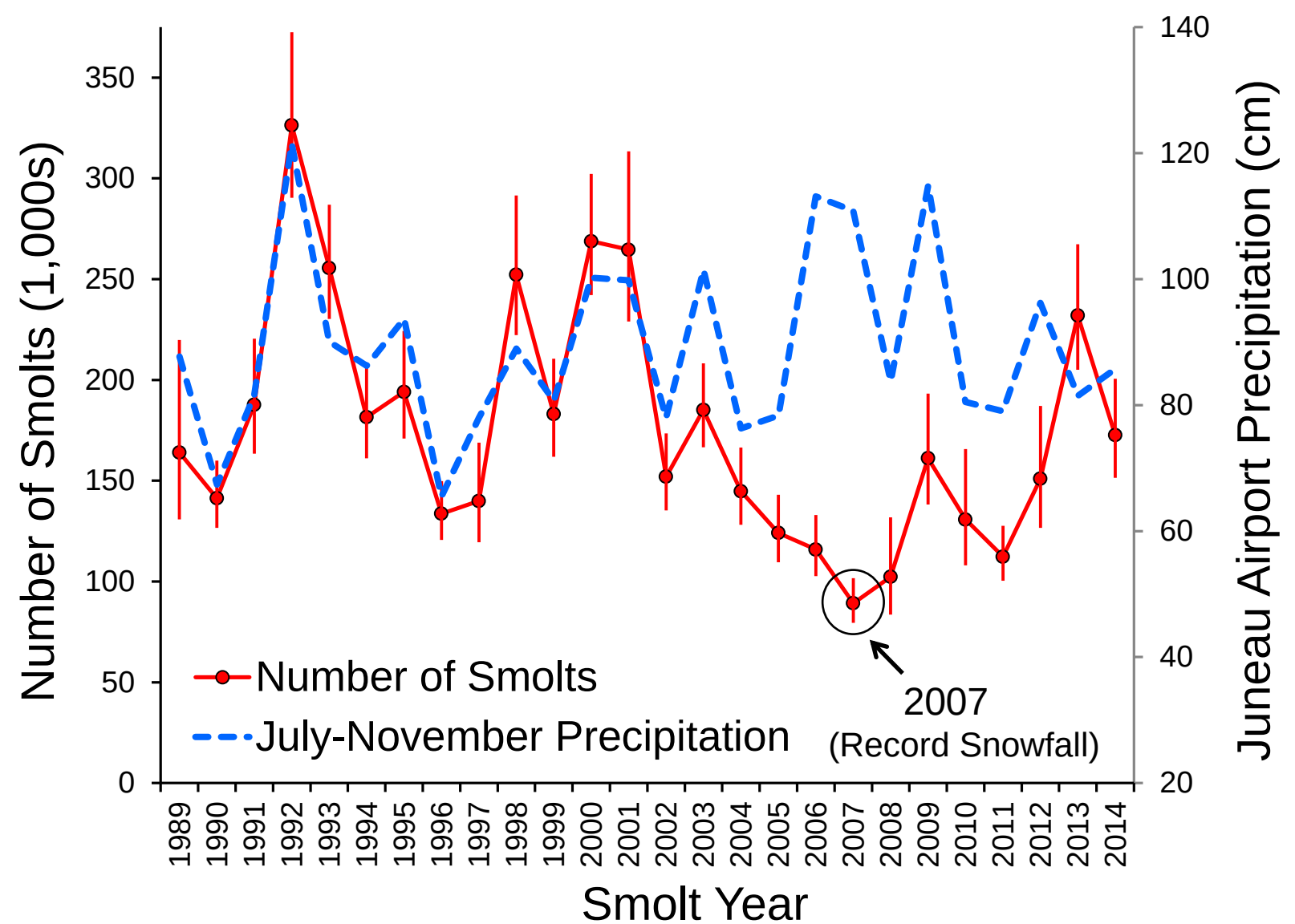




# Strong Correlation with Chilkat River Total Run ( $R^2 = 0.87$ ) (suggests broad-scale causal factors)



Smolt Production bottomed after record snowfall (2006-2007)  
but recovered to near-average after 2012.





Photos: Neil Barten (top)  
Kevin White (bottom)  
Berners Bay  
Spring 2007 & 2008



# Berners River, March 25, 2016



Photo: Kevin White

# Hypothesis: Winter-kill

- Isolated Off-channel Rearing
- Extended Ice and Snow Cover
- Few Winter-Spring Rain Events
- Bacterial Decomposition
- Oxygen Depletion → Mortality

Greenbank (1945) – Conditions leading to winter-kill  
in ice-covered lakes

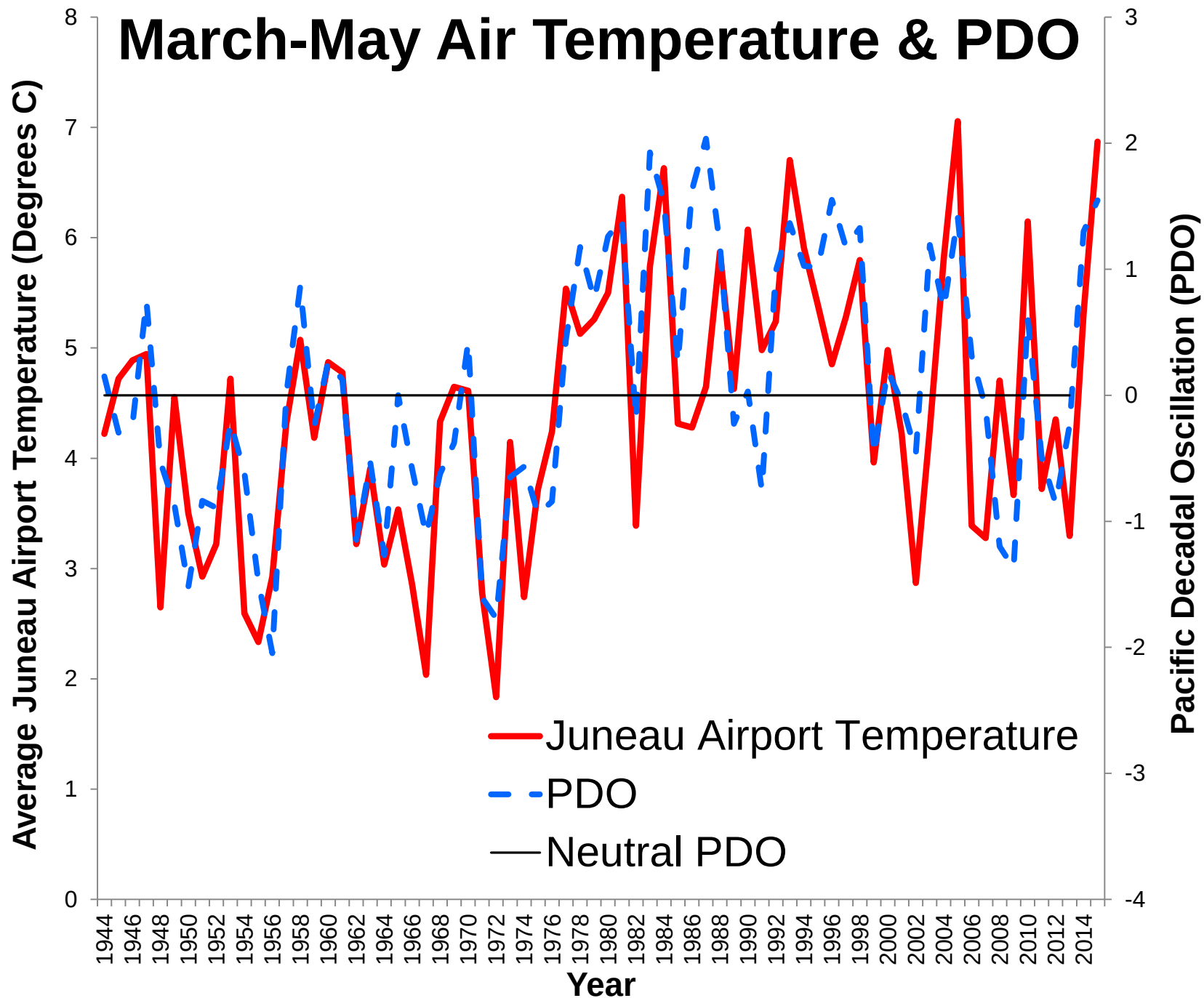
Josephson (1982) – Chilkat Pond Winter Coho Mortality

# Conclusion

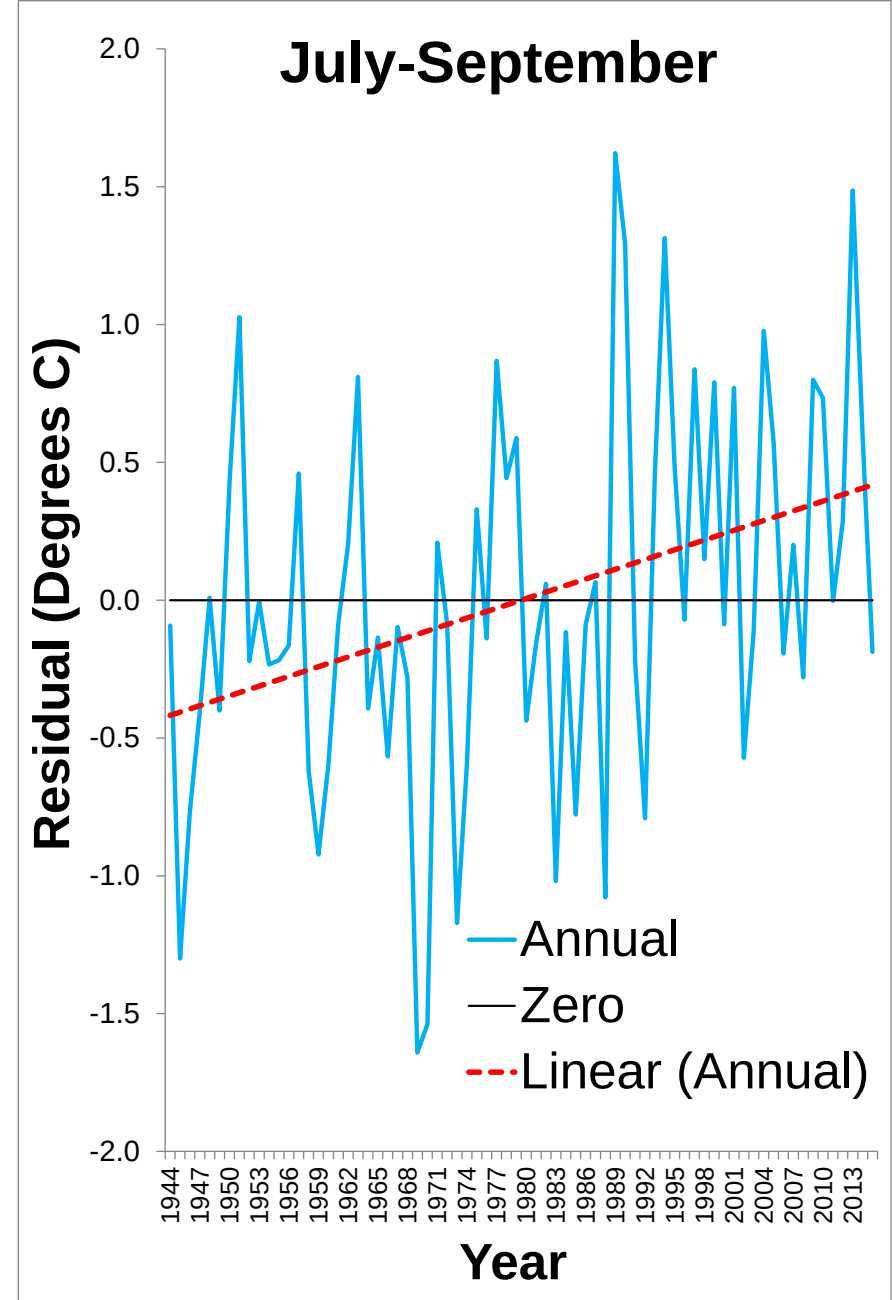
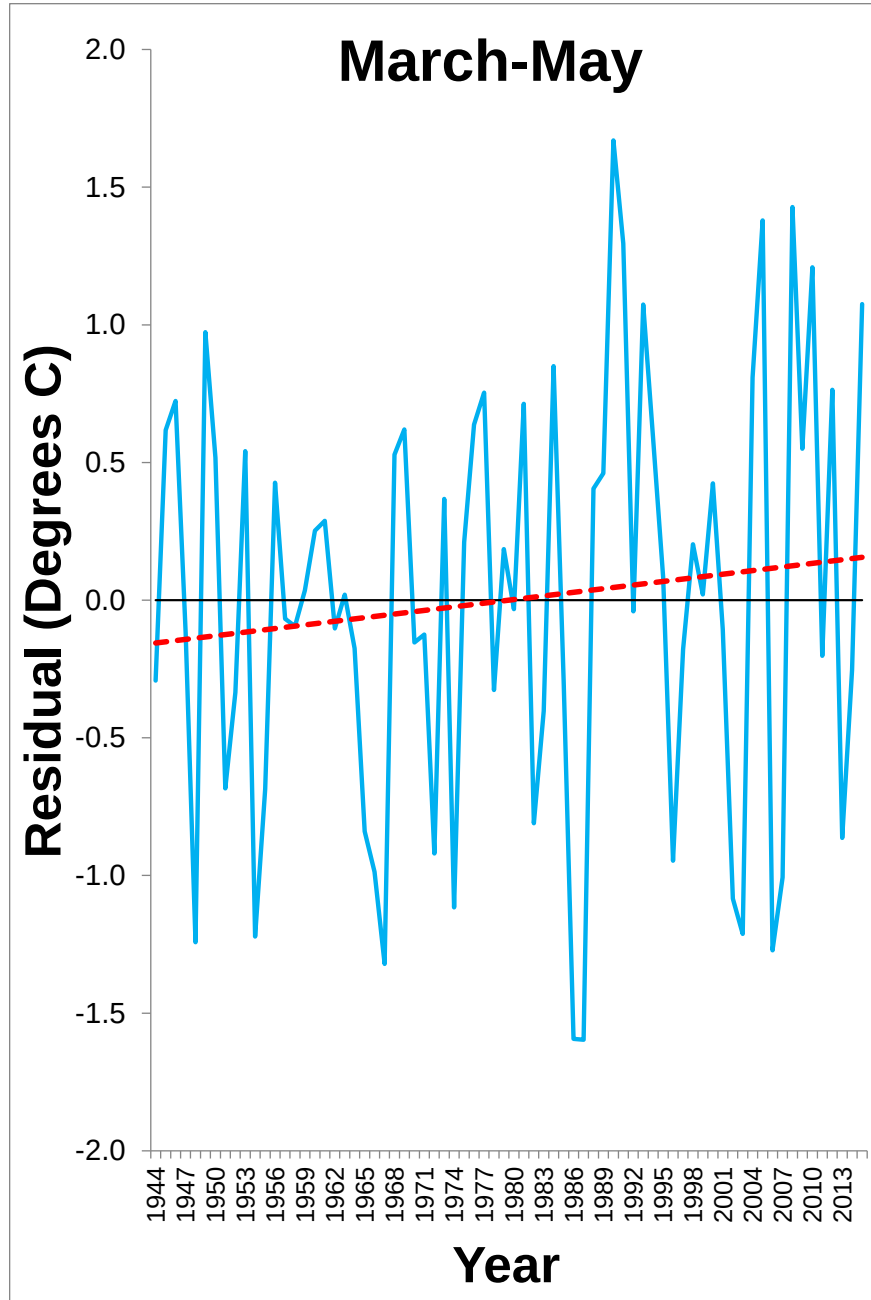
**Mainland river coho salmon may benefit in the short-to-intermediate term**

- Increase in Rainfall**
- Warmer Winters**

# March-May Air Temperature & PDO

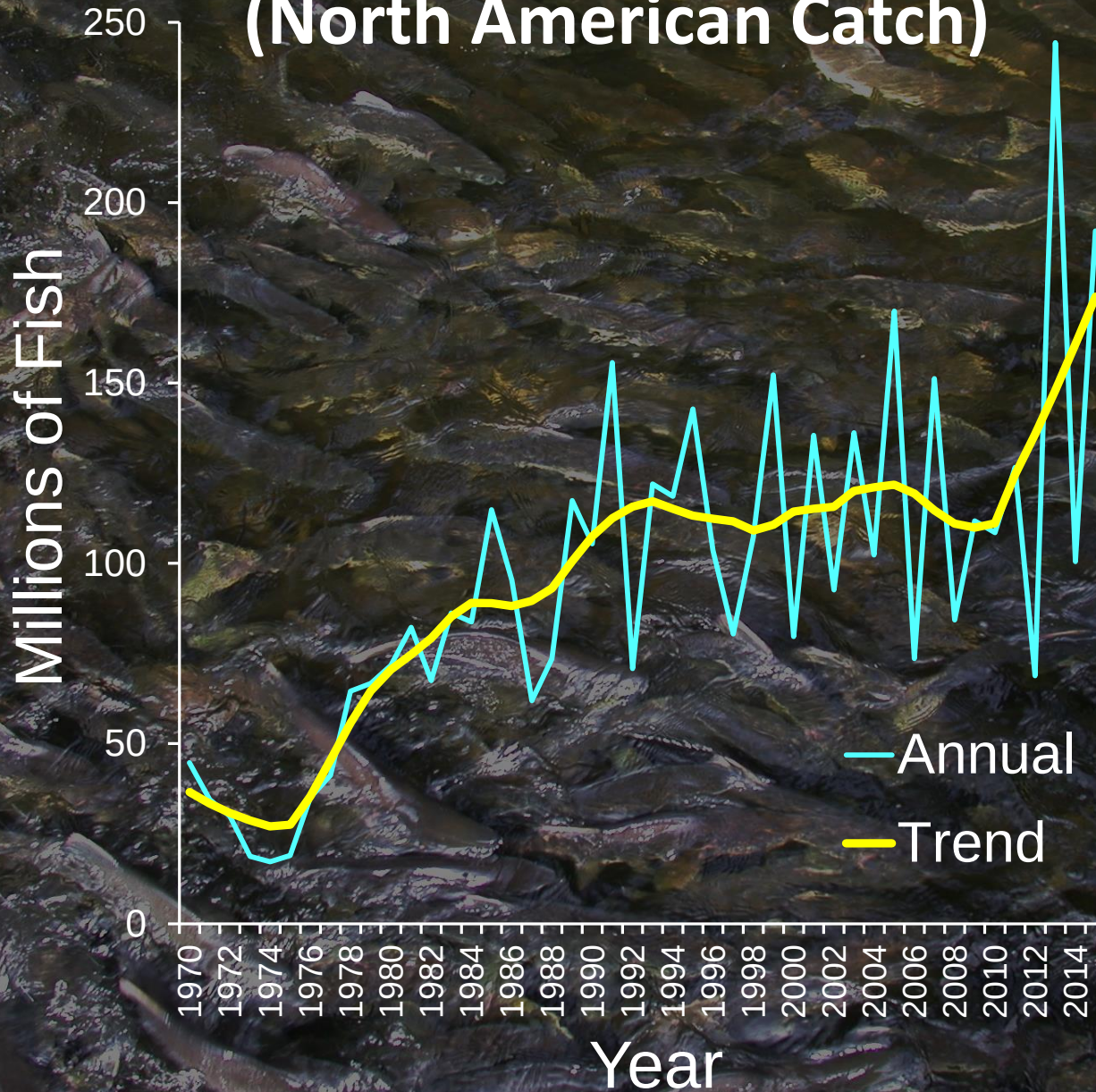


# Residual (Temperature change not accounted for by the PDO)



# Pink Salmon: Climate Change Winner?

## (North American Catch)



# Ford Arm Creek (W. Chichagof Is.)

**Small Pristine Watershed**  
25.4 km<sup>2</sup>

**Massive Marine Nutrient  
Subsidy (560 metric tons/yr)**  
220 kg/hectare  
43.6 metric tons per km of  
anadromous stream/lake

**Pink, Chum, Coho,  
Sockeye, Steelhead**

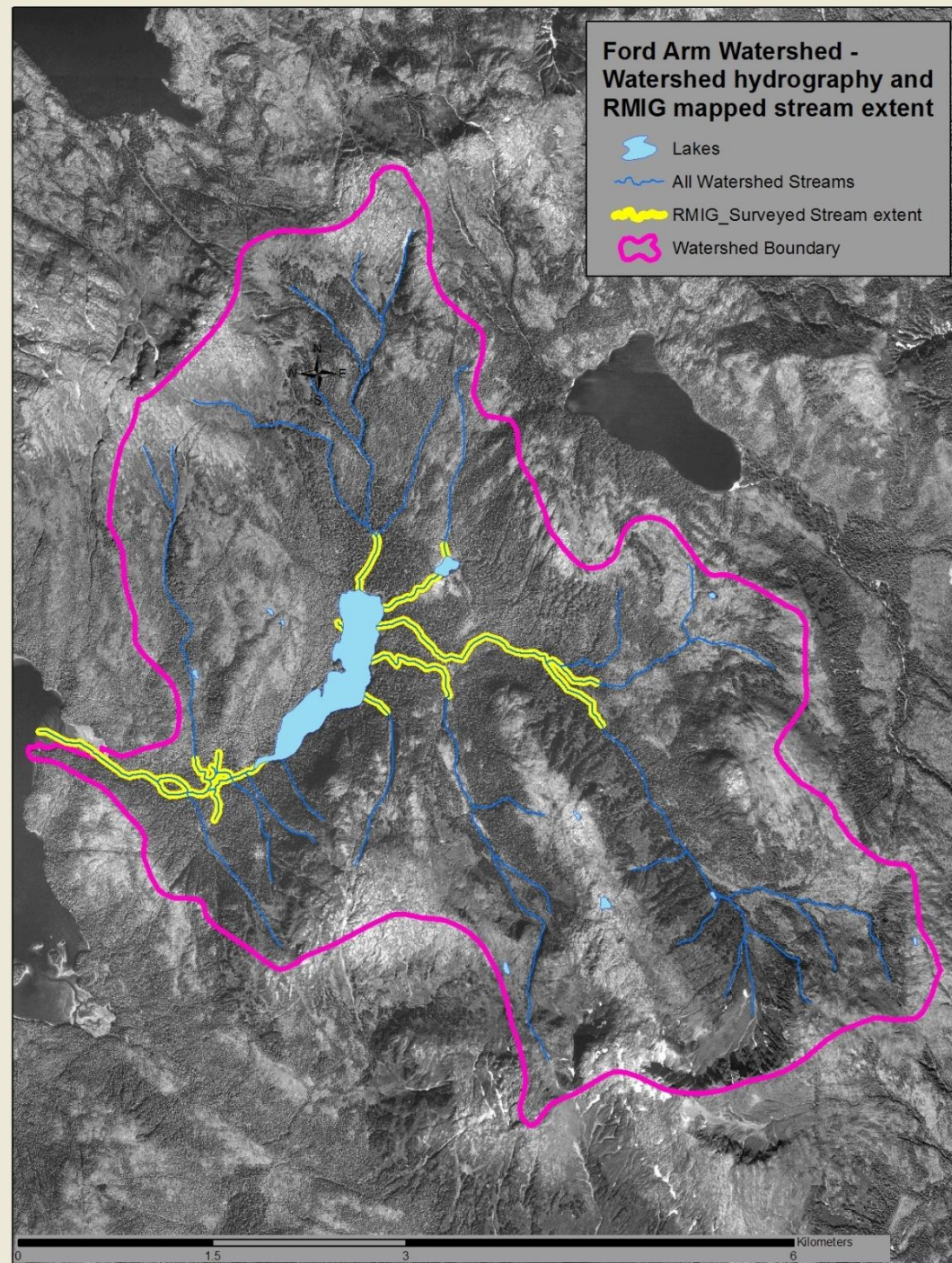






Photo: Ken Koolmo





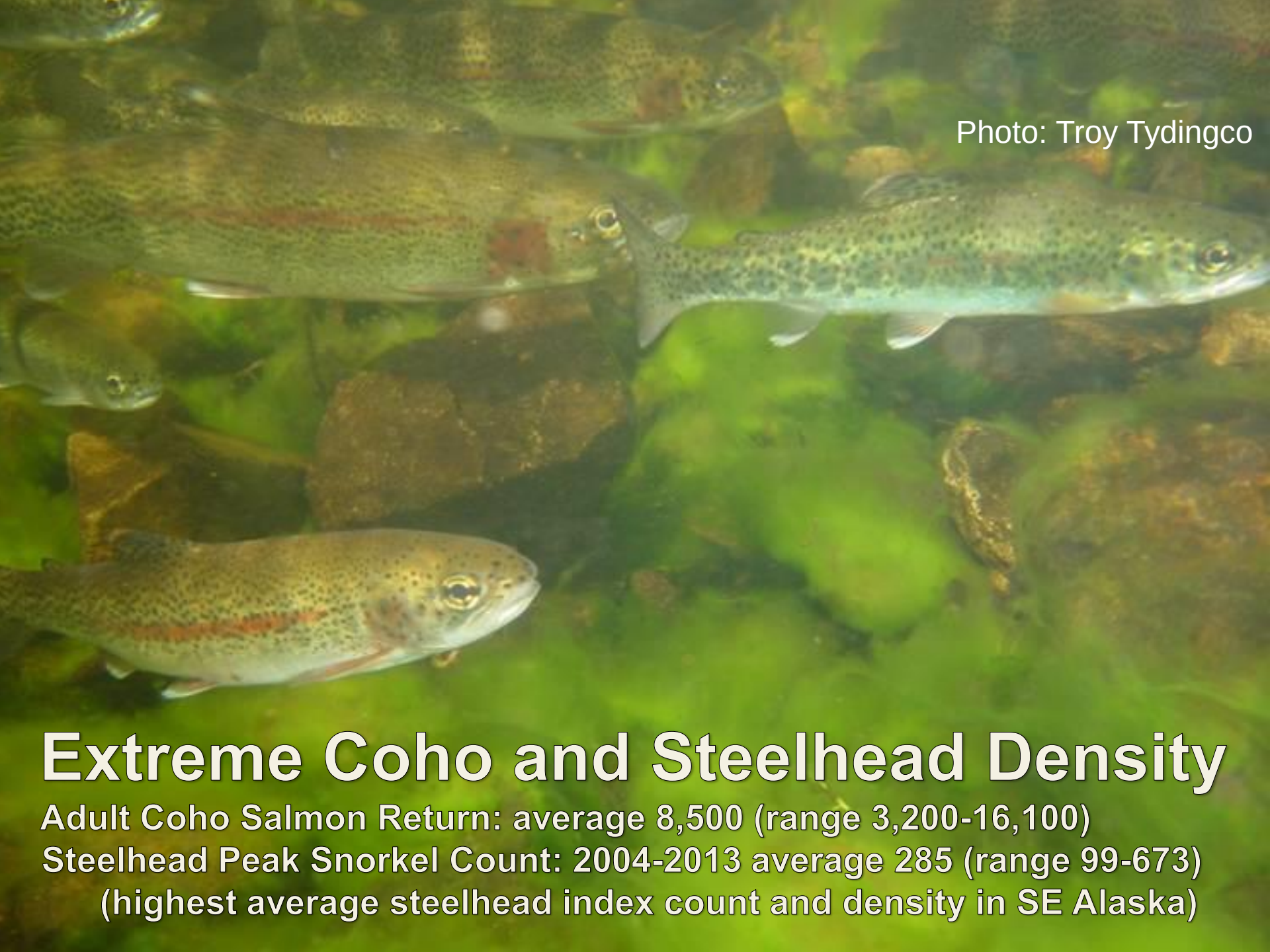


Photo: Troy Tydingco

# Extreme Coho and Steelhead Density

Adult Coho Salmon Return: average 8,500 (range 3,200-16,100)

Steelhead Peak Snorkel Count: 2004-2013 average 285 (range 99-673)  
(highest average steelhead index count and density in SE Alaska)

# Khaz Bay Pink Salmon Catch, Ford Arm Cr. Escapement

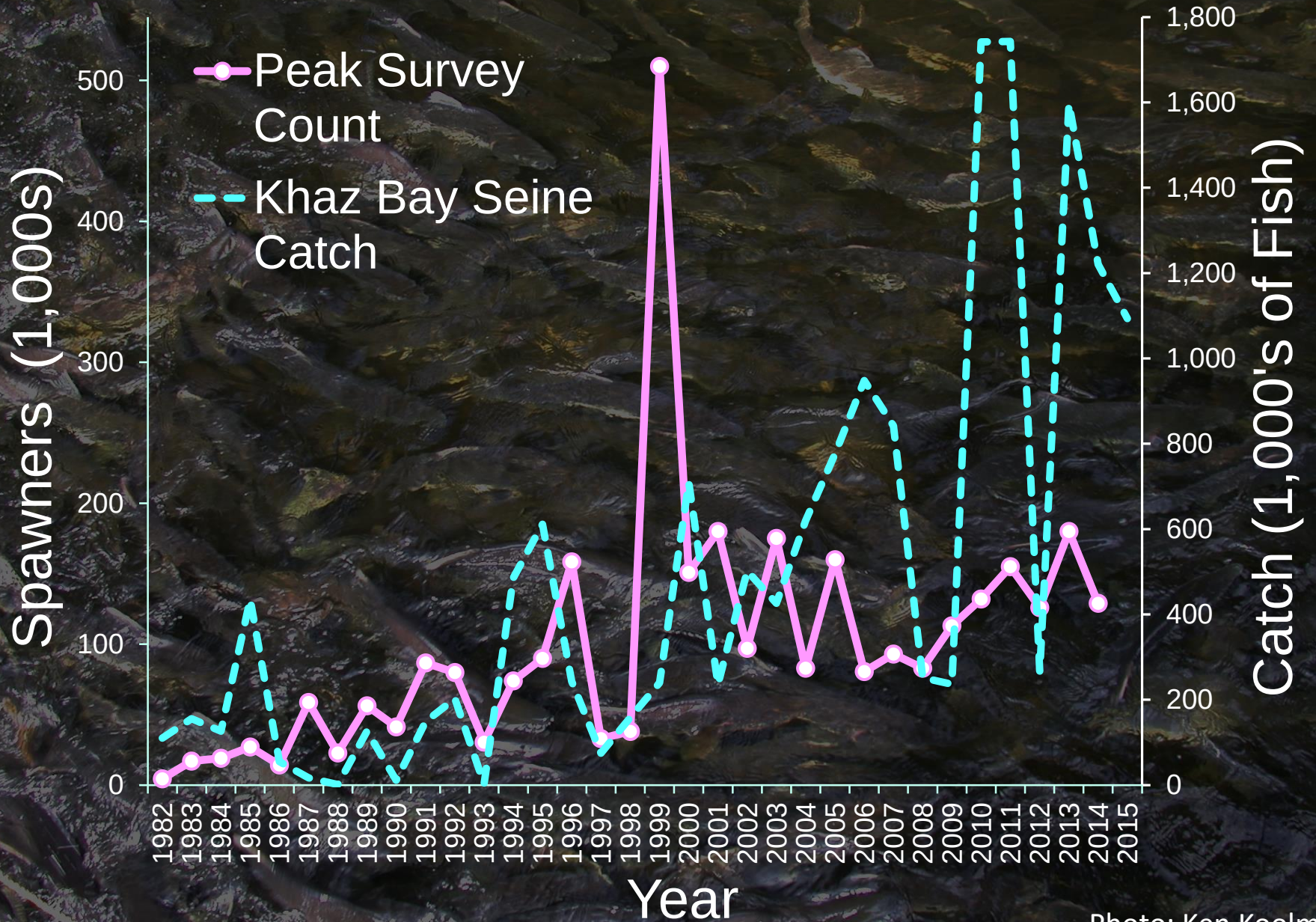




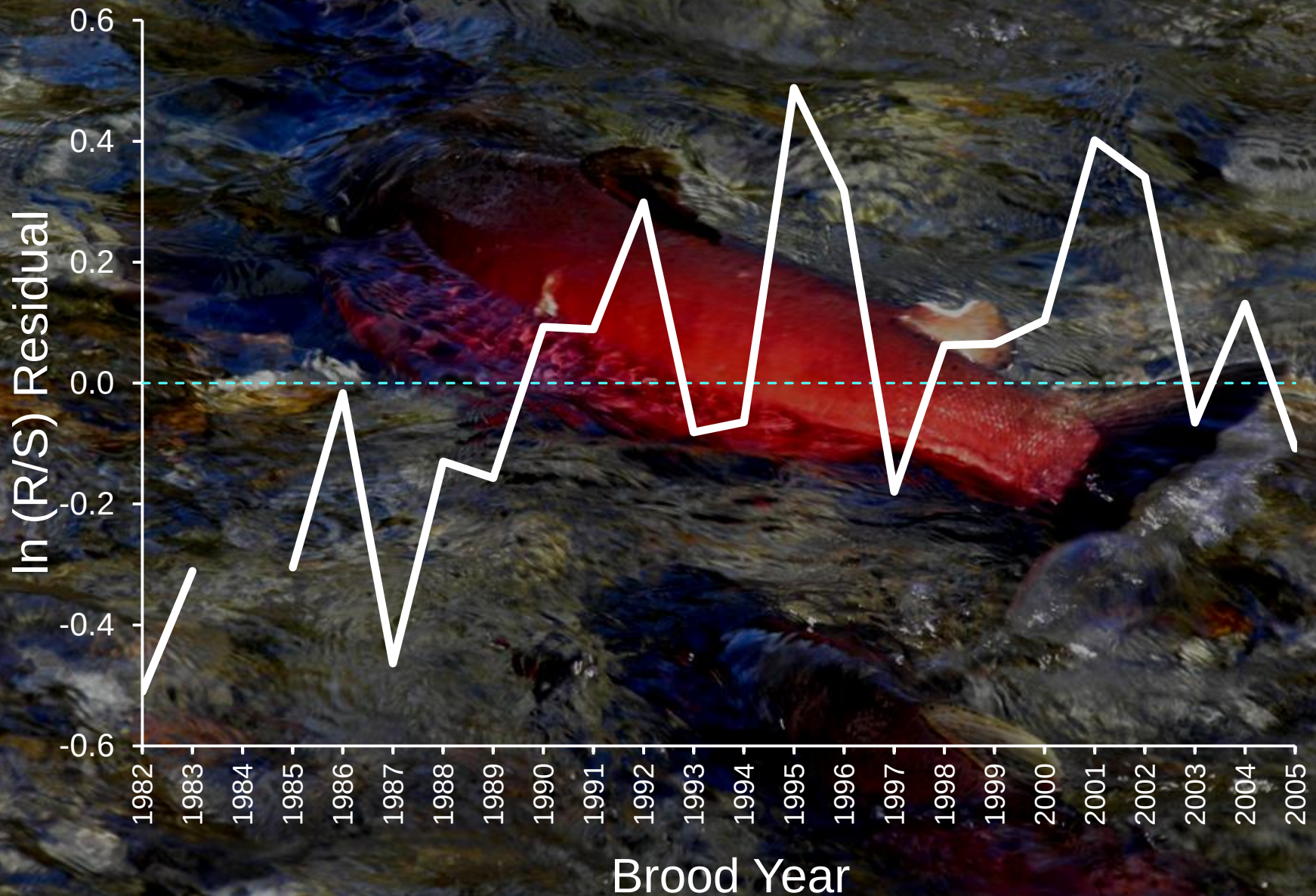
Photo: Ken Koolmo



Photo: Ken Koolmo

# Increase in Freshwater Coho Production Capacity

(adjusted to constant average pre-smolt to adult survival)



# **Pink salmon benefits for rearing species:**

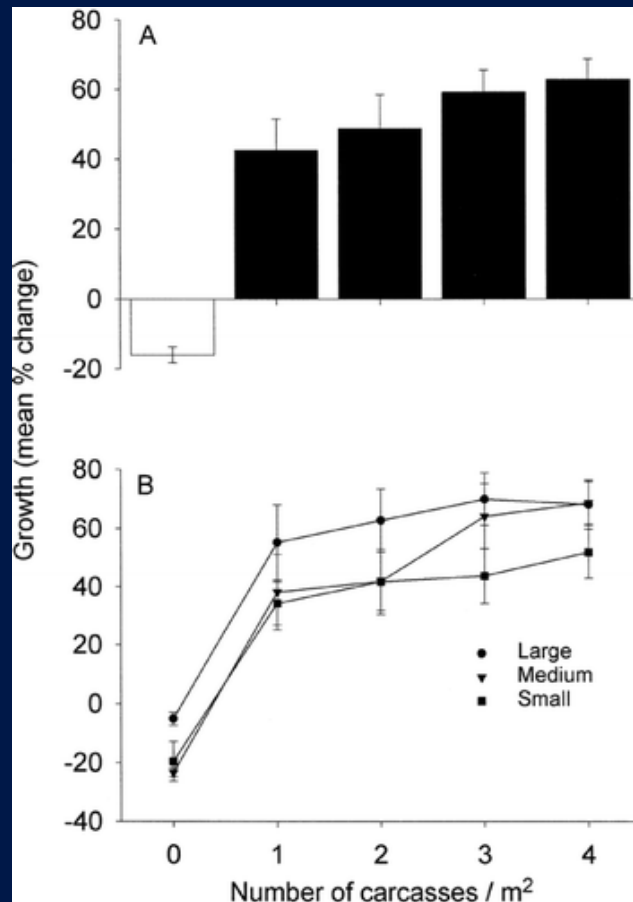
- Direct Food for Juveniles (eggs, carcasses, fry)**
- Nutrient Enrichment (freshwater & terrestrial food web)**



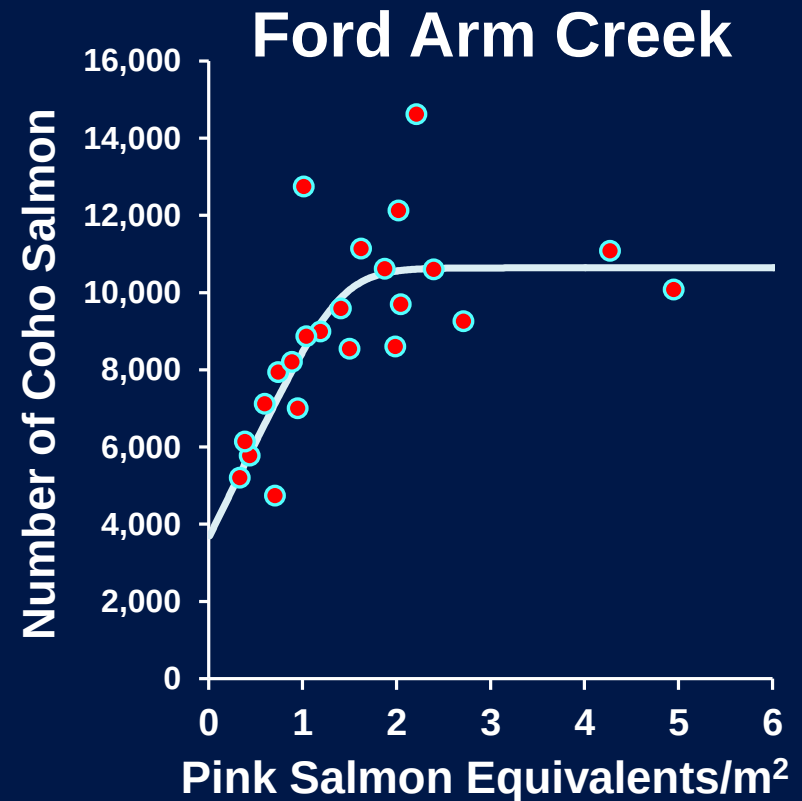
# Wipfli et al. (2003) – controlled experiment

## Age 0 coho growth as a function of pink salmon carcass density

### Carcass Density vs Growth



### Pink Equivalents vs Coho Abundance





# Pre-spawning Mortality Ford Arm Creek

- 100,000+ Breathing Salmon
- Absence of Rain (3+ days)
- Darkness (no photosynthesis)

Photos: Amy Hemenway

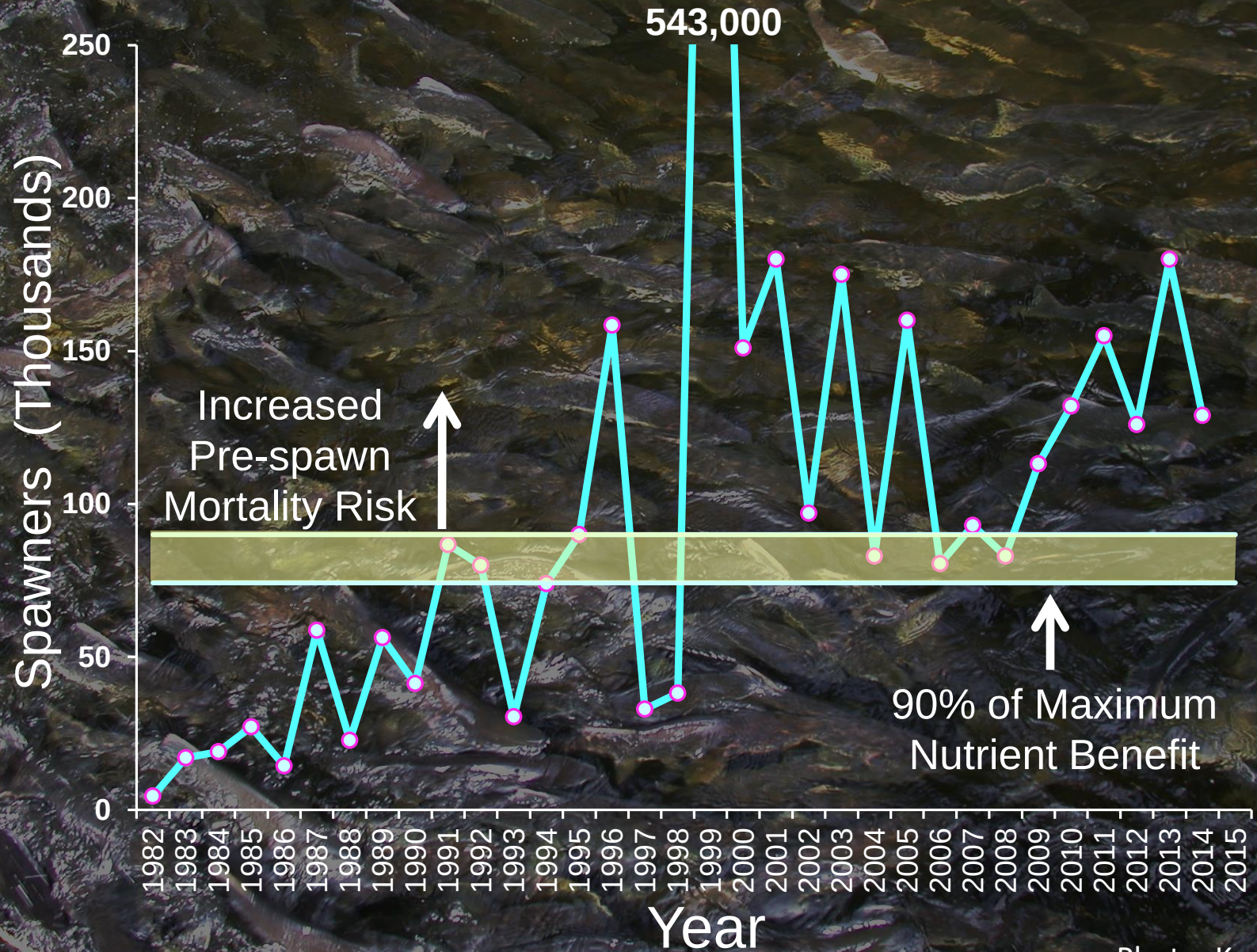


# Mortality: All Species; Multi-Generational

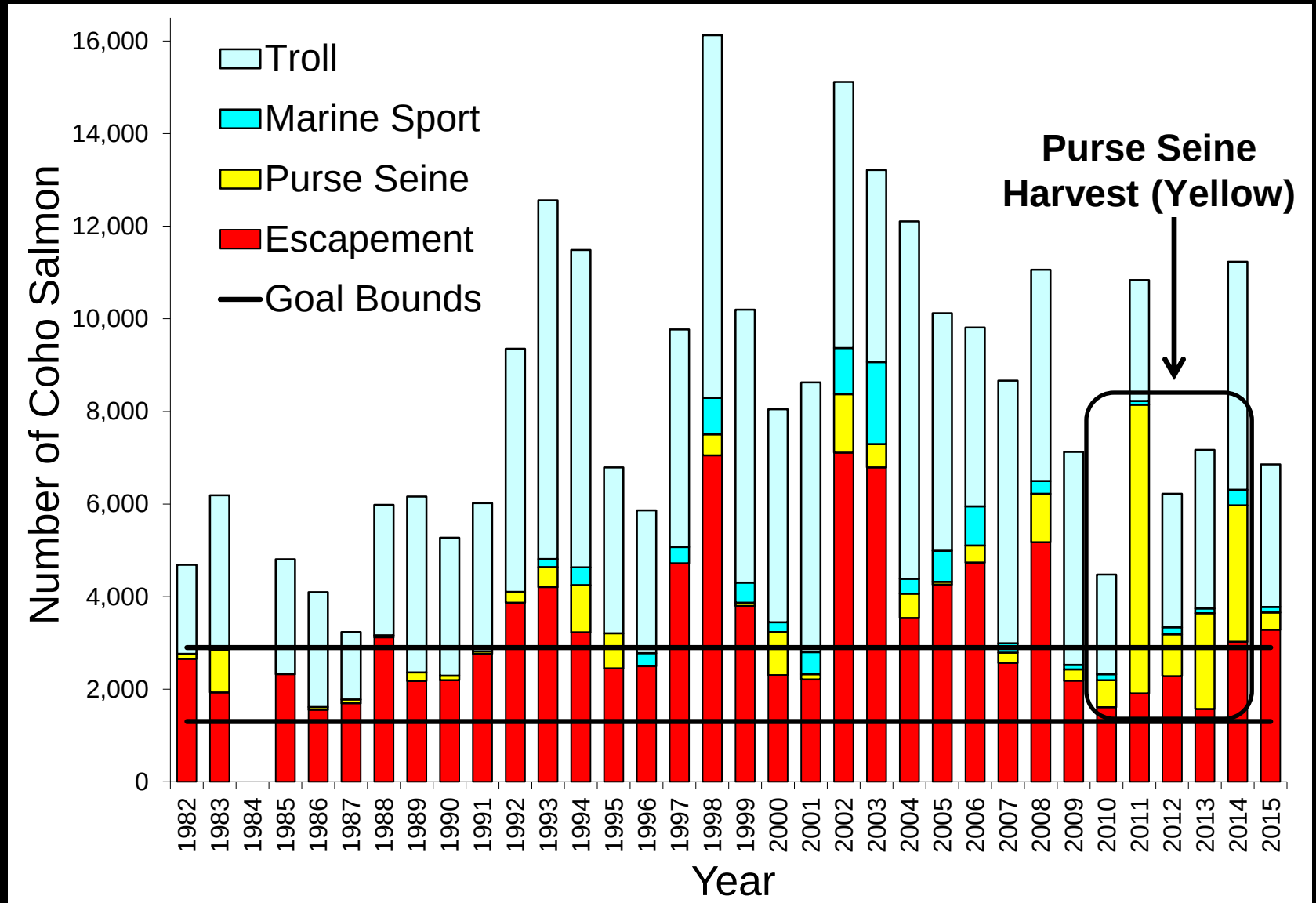


Photo: Amy Hemenway

# Ford Arm Creek Peak Pink Salmon Count



# Increased Purse Seine Coho Exploitation Rate, 2010-2014 (more intensive seining for pink salmon + earlier coho run timing)



# Pre-spawning Mortality Ford Arm Creek

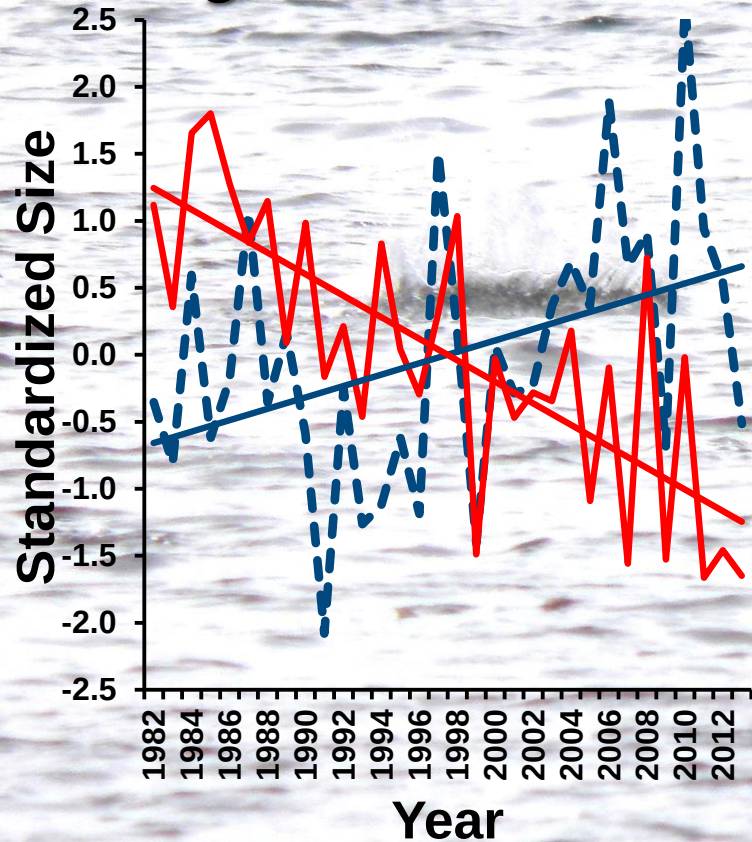
- 100,000+ Breathing Salmon
- Absence of Rain (3+ Days)
- Darkness (no photosynthesis)
- Bacterial decomposition  
(legacy of past escapements)
- Warming Climate

# Southeast Alaska Salmon Size Trends

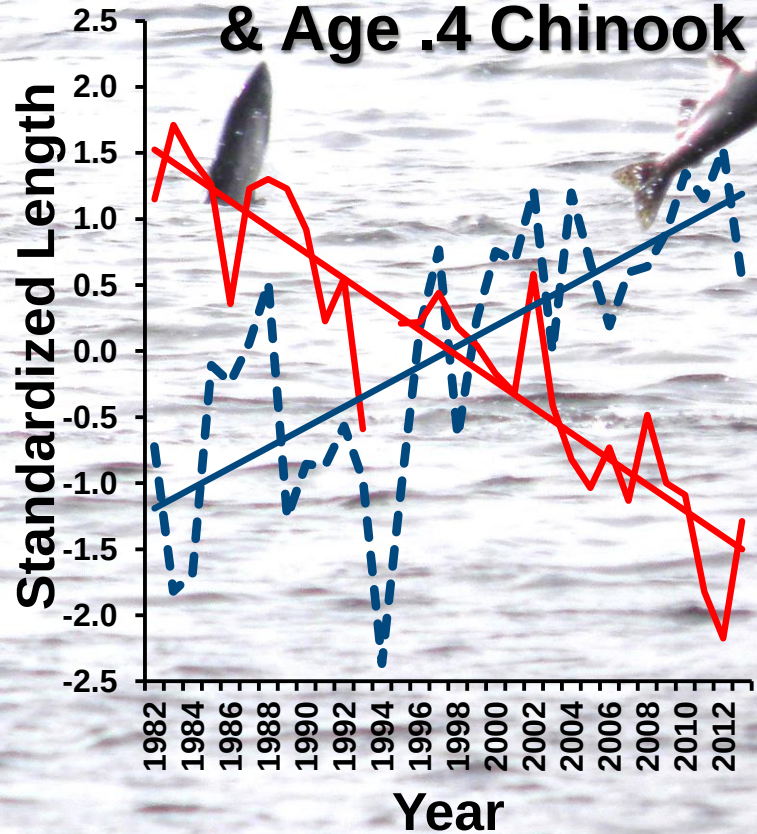
-- Flexible planktivores increasing

-- Obligate nektivores decreasing

## Age .1 Pink & Coho



## Age 1.2 Sockeye & Age .4 Chinook



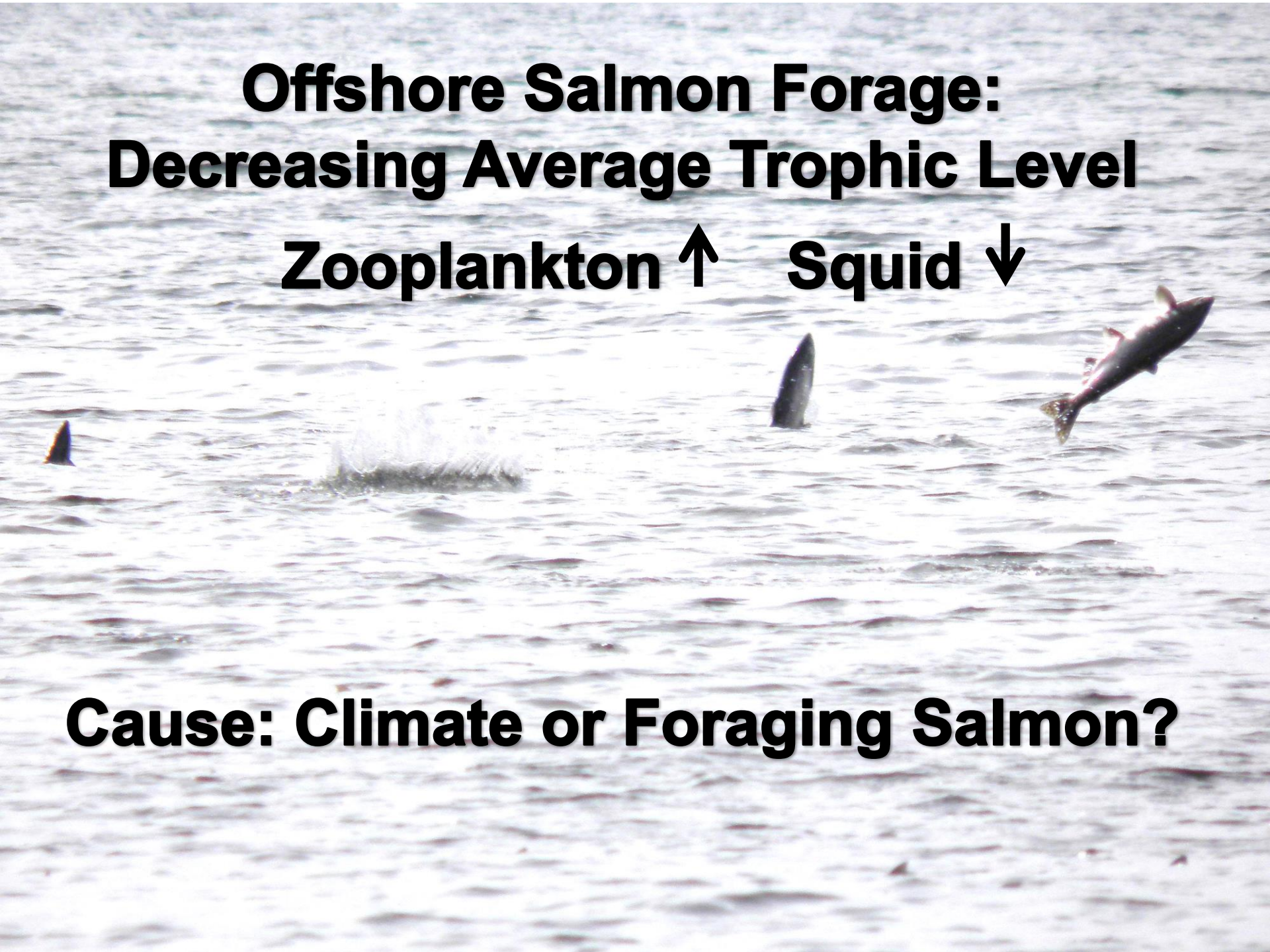
-- Pink Salmon Weight  
-- Coho Spawner Length (4 stocks)

-- Age 1.2 Sockeye Length (5 stocks)  
-- Age .4 July Troll Chinook Length

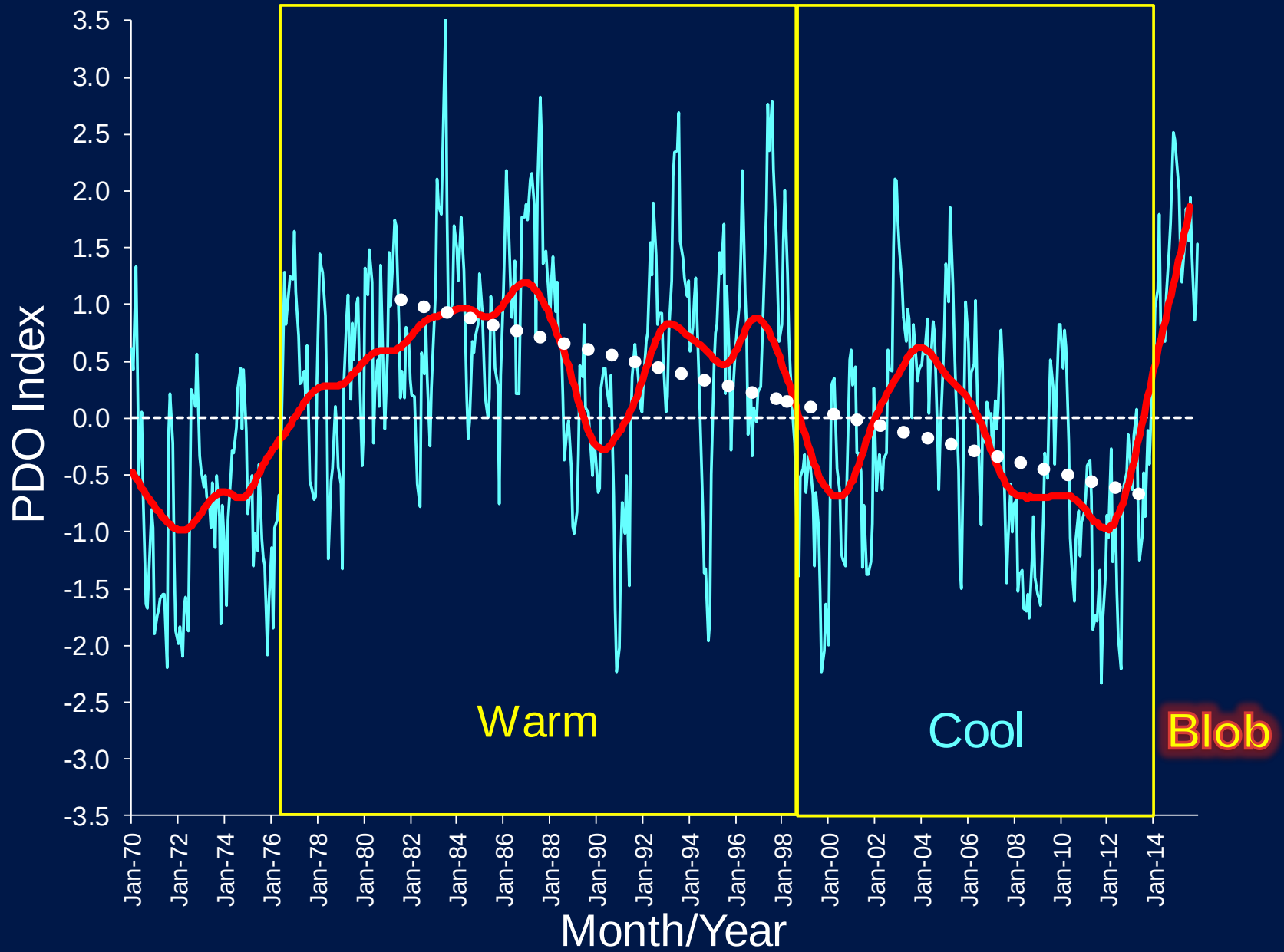
# **Offshore Salmon Forage: Decreasing Average Trophic Level**

**Zooplankton ↑      Squid ↓**

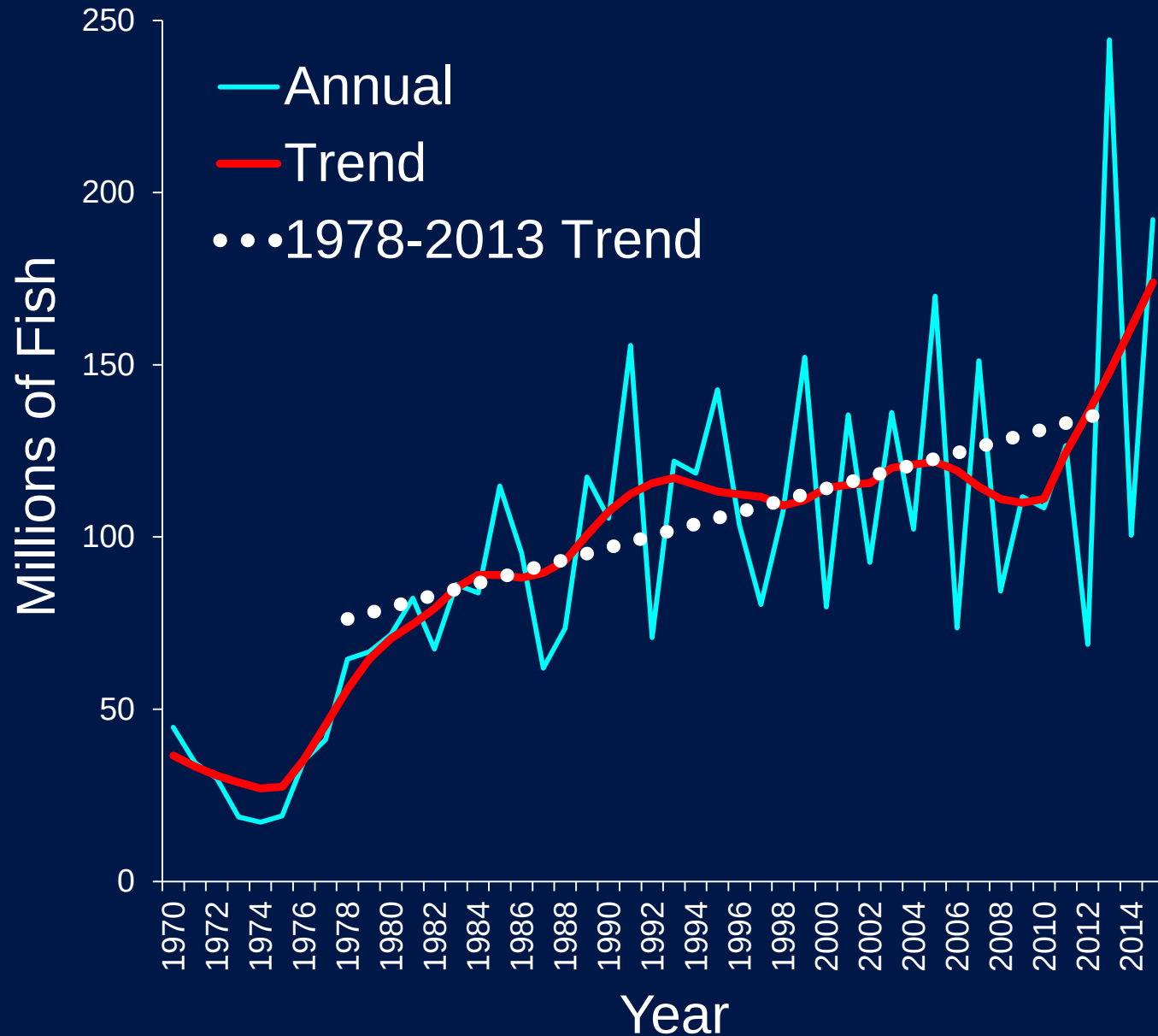
**Cause: Climate or Foraging Salmon?**



# Climate Hypothesis: Cooling North Pacific Climate



# Pink Salmon Hypothesis: Keystone Predator



# Why Divergent Size Trends?

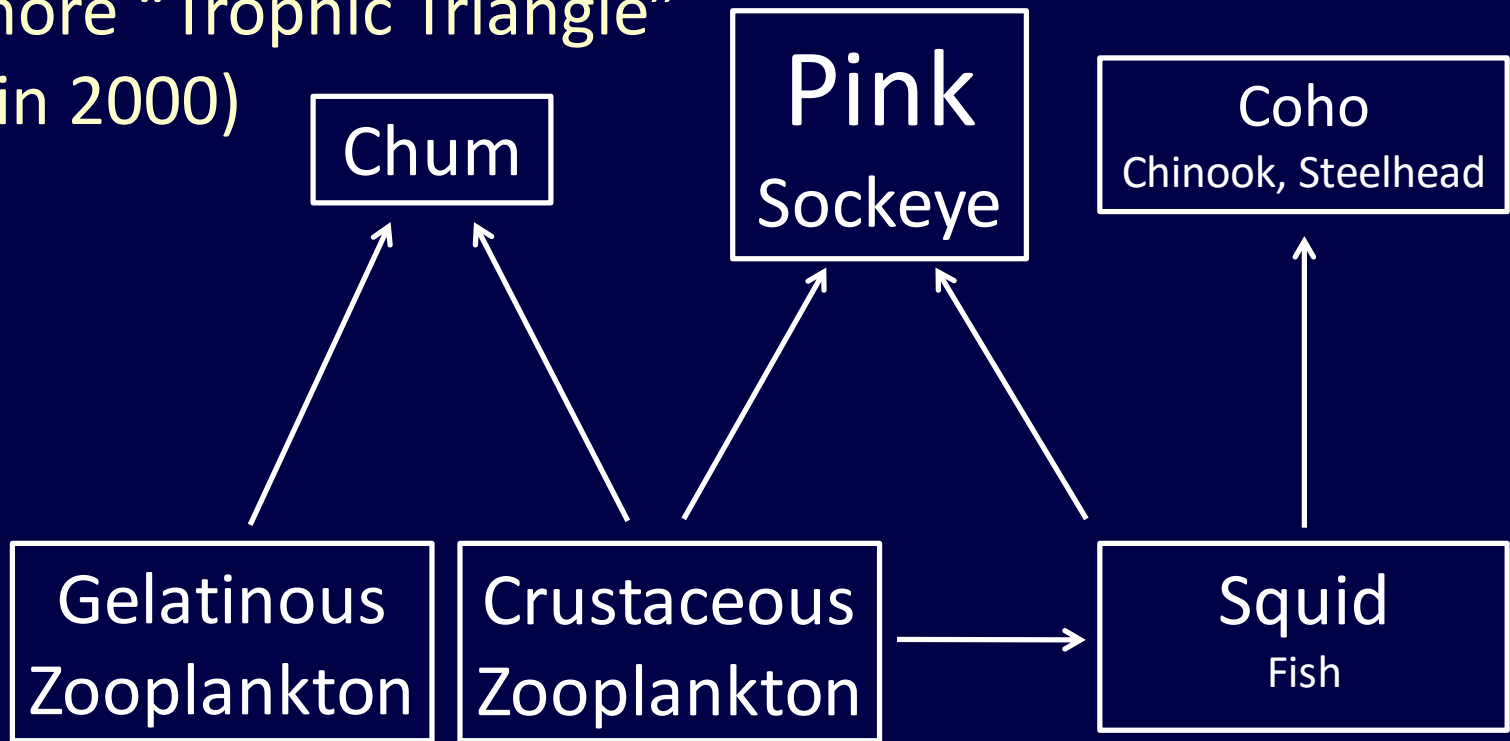
## Climate Hypothesis: Control by North Pacific Climate

- Recent Cooler conditions (1999-2013) favored growth of flexible plantivores
- Squid: reduced recruitment (Shaul and Geiger *In Press*)
- Zooplankton: higher energy density (Chiba et al. 2015 & others)
- Bioenergetics may favor species that eat less energy-rich foods like zooplankton (pink & sockeye)

## Keystone Species Hypothesis: Control by Pink Salmon

- Function as an intra-guild predator on squid
- Reduce average trophic level in a process similar to “fishing down marine food webs” (Pauly et al. 1998)
- Benefit if an increase in zooplankton more than offsets the reduction in squid

# Offshore "Trophic Triangle" (Aydin 2000)



**Coho**  
1-Ocean

**Sockeye**  
2-Ocean

**Chum**  
3-Ocean?

# Coho Salmon Weight: (Troll-Caught, Head-on Dressed)

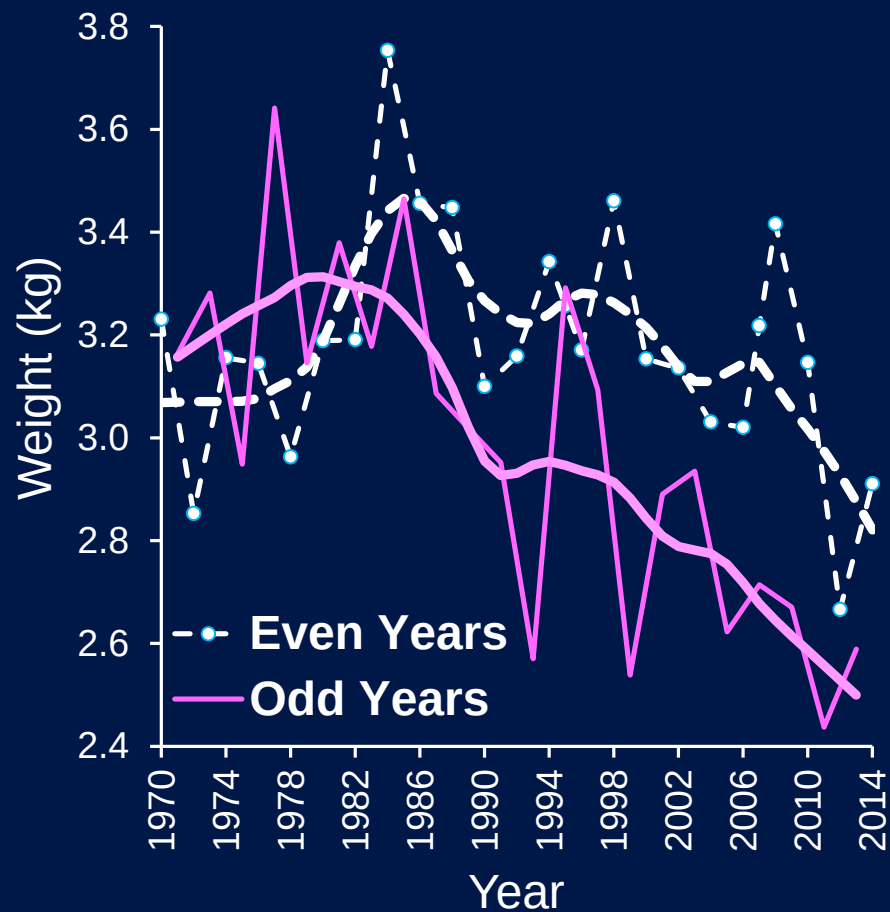


Photo: Amy Hemenway

# Miminal Armhook Squid: *Berryteuthis anonychus*

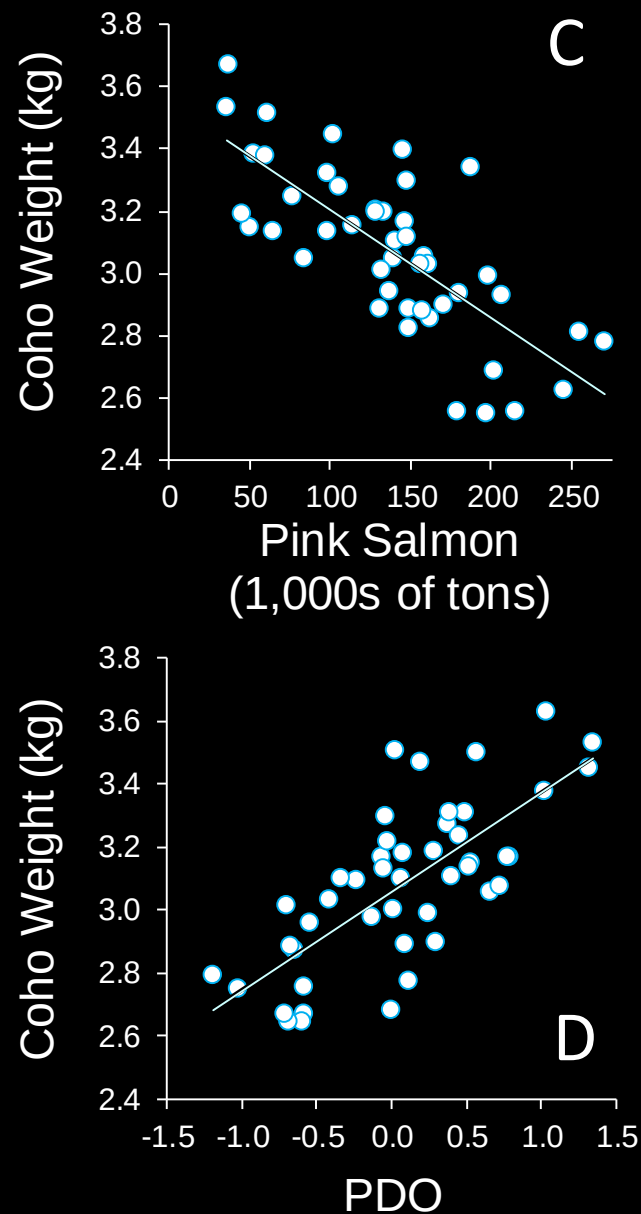
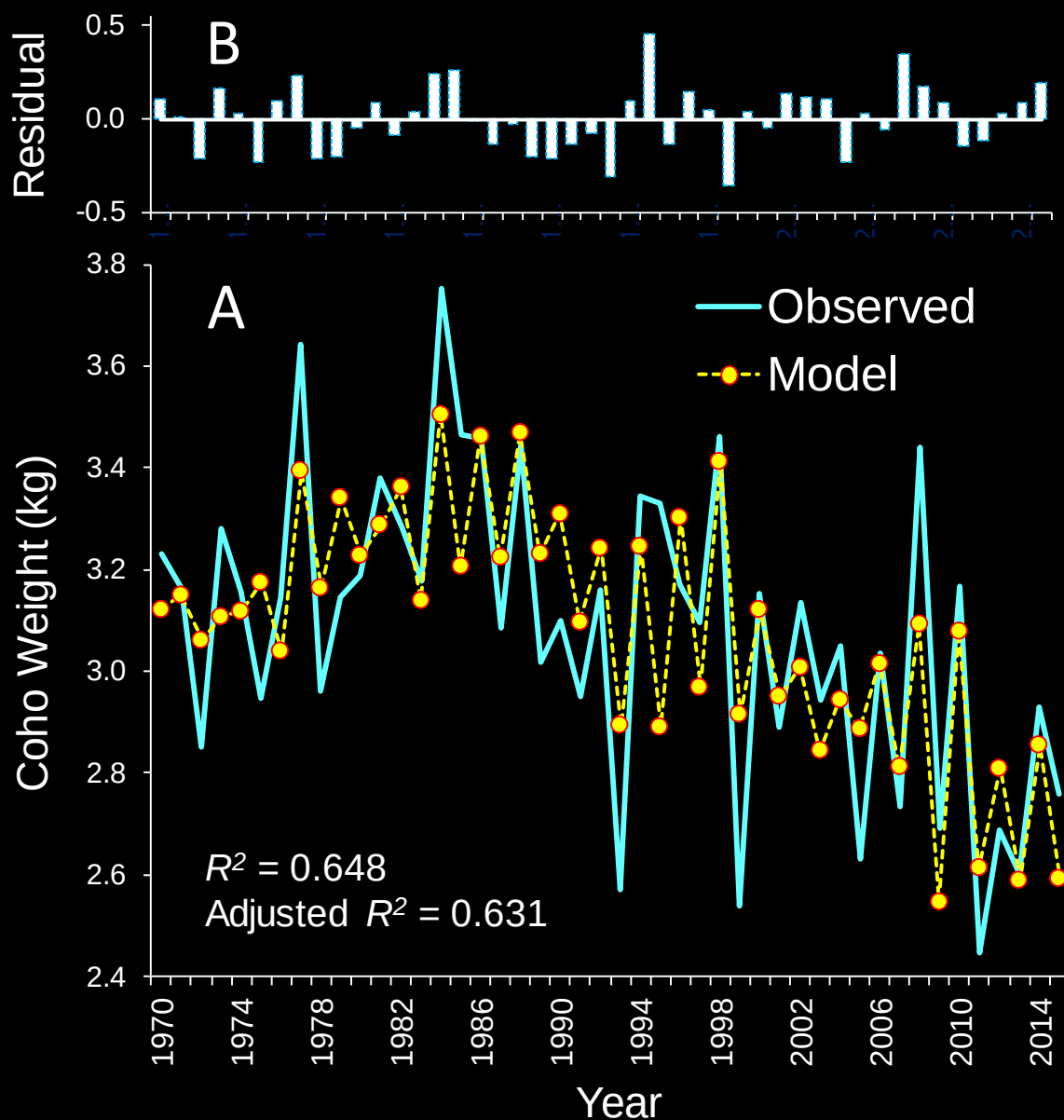
Primary Food of Coho Salmon in Offshore Waters  
(Lebrasseur 1966; Pearcy et al. 1988; Davis 2003; Kaeriyama et al. 2004)

Abundant, Epipelagic, Calorie-Rich (Davis et al. 1998)



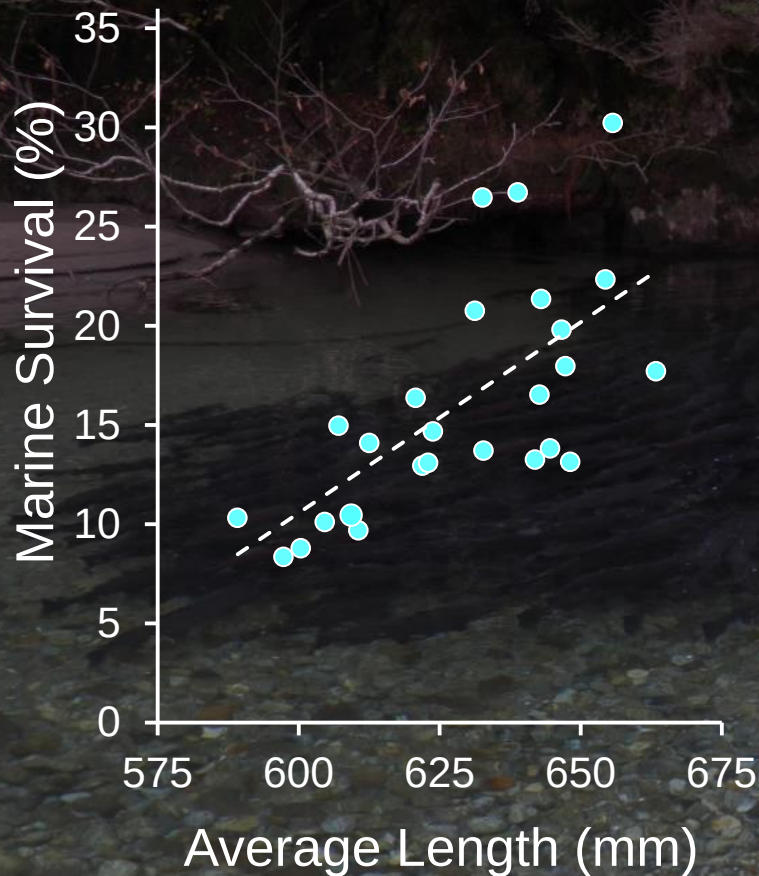
2-Year Life Cycle

# Troll Coho Weight Model (2 Variables: Gulf of Alaska Pink Salmon Catch Biomass & PDO)

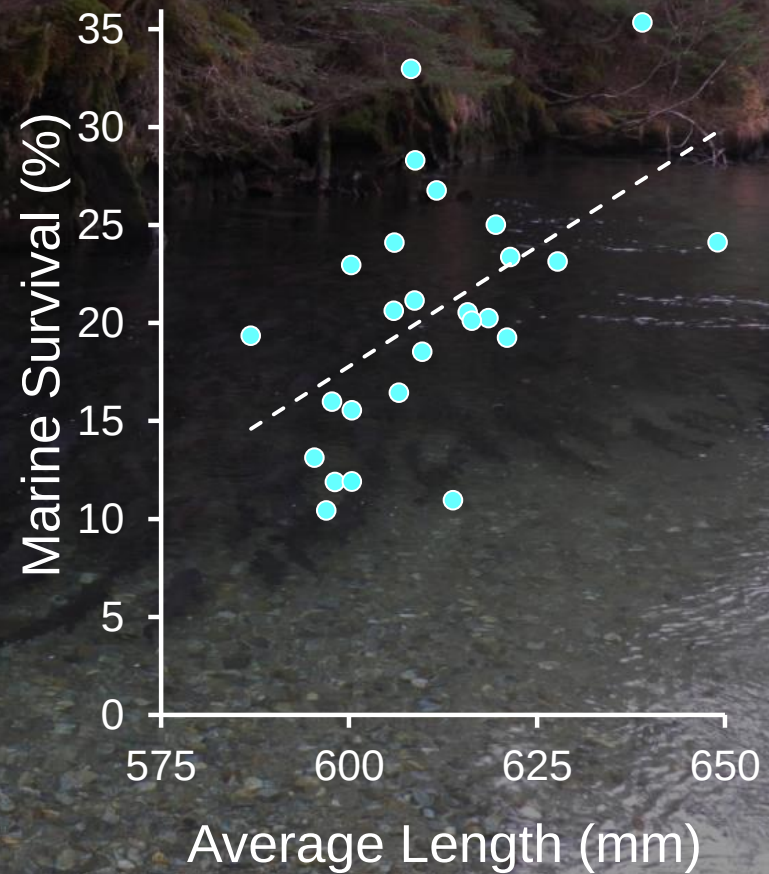


# Coho Salmon Marine Survival vs Average Spawner Length (mean-average length for males and females)

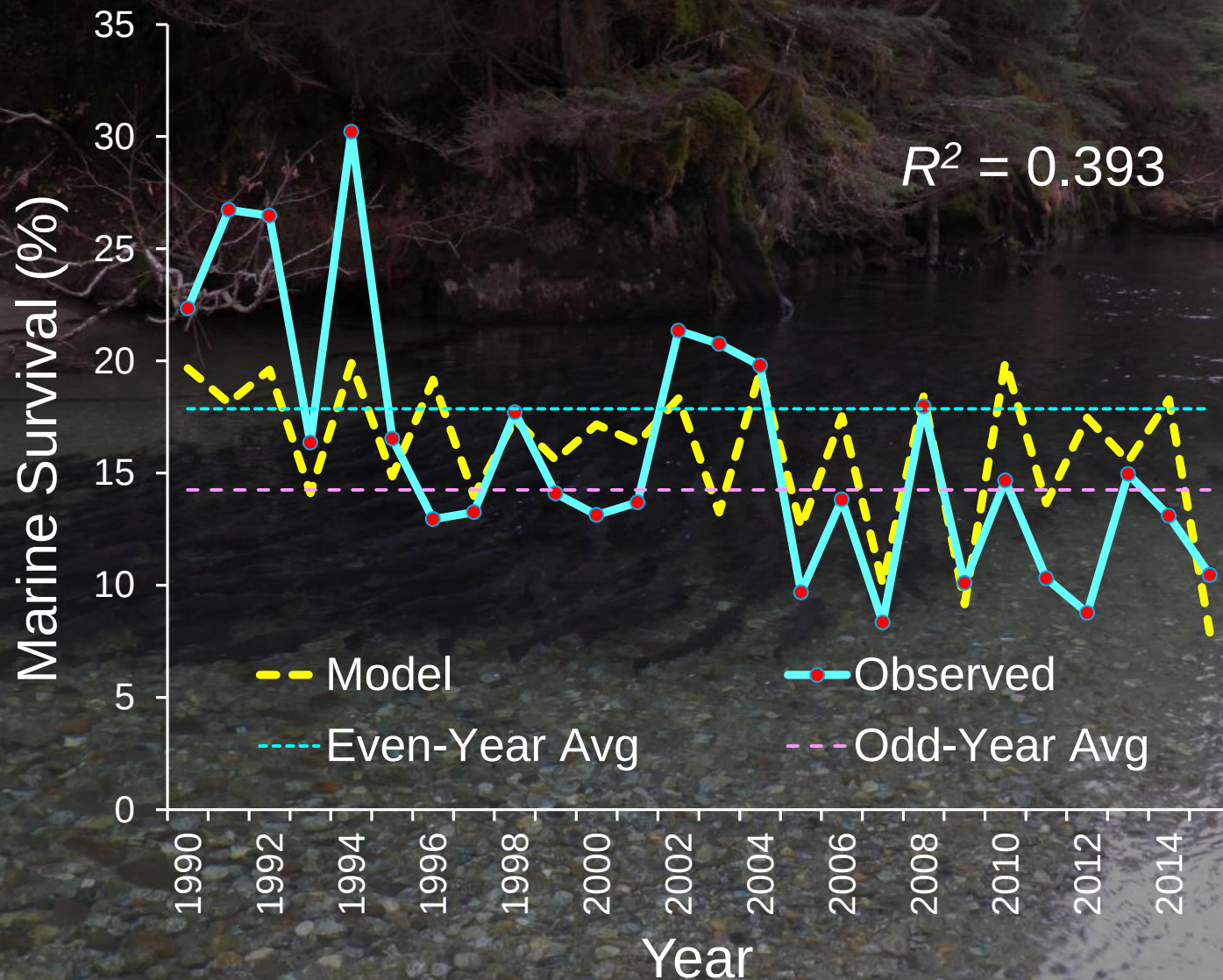
## Berners River



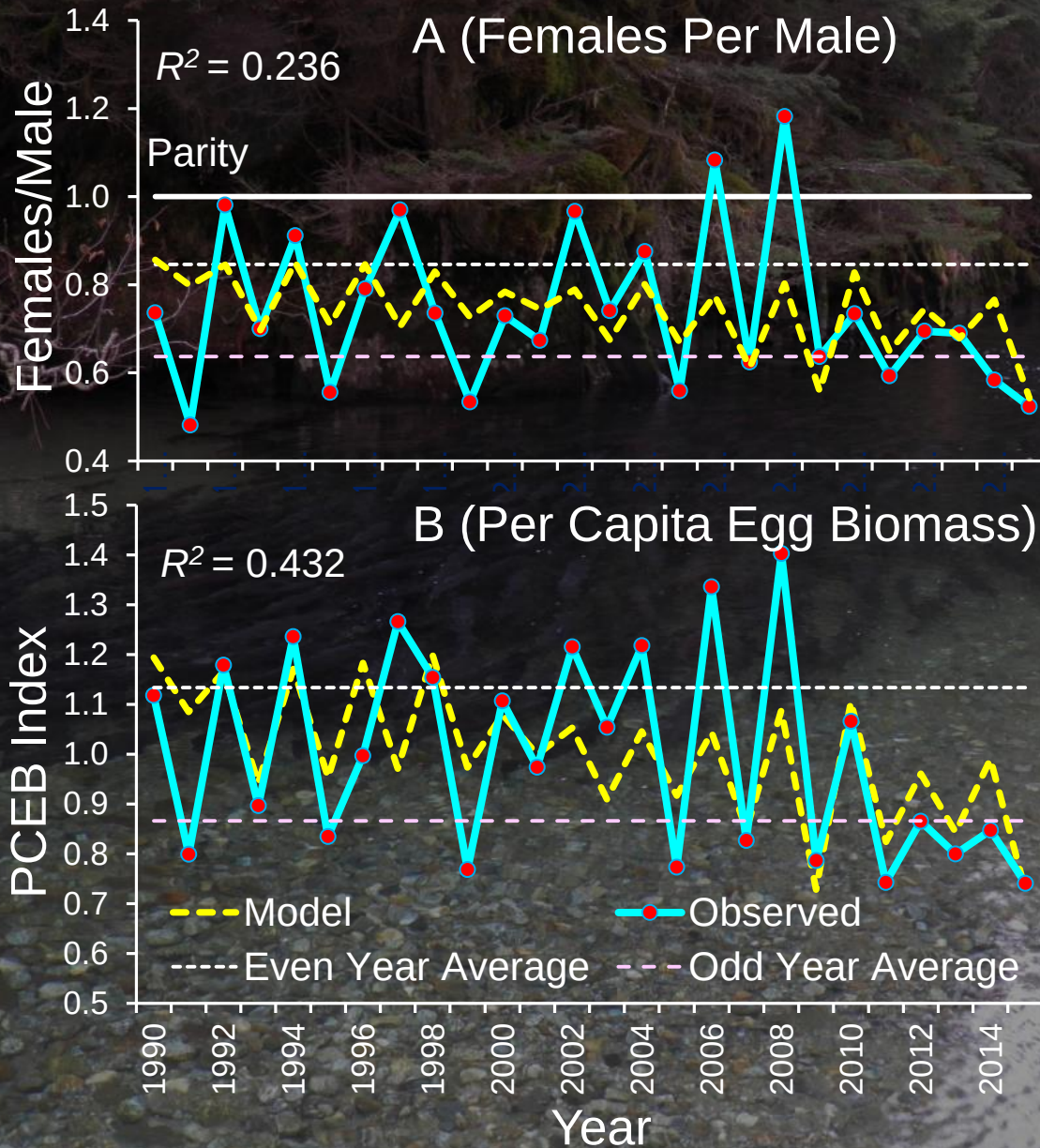
## Auke Creek



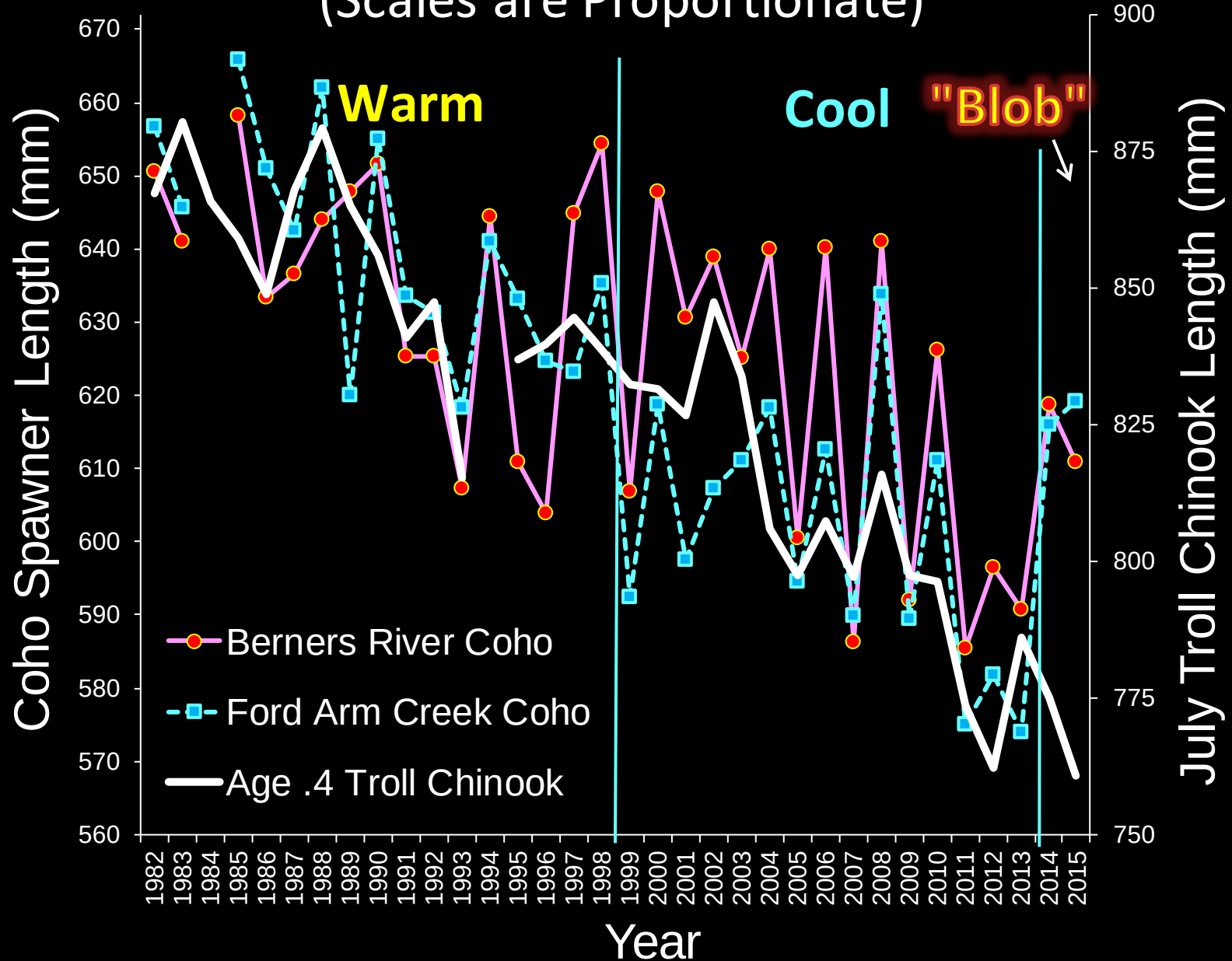
# Berners River Coho Marine Survival and Modeled Survival Based on Lagged Pink Salmon Biomass and PDO Index



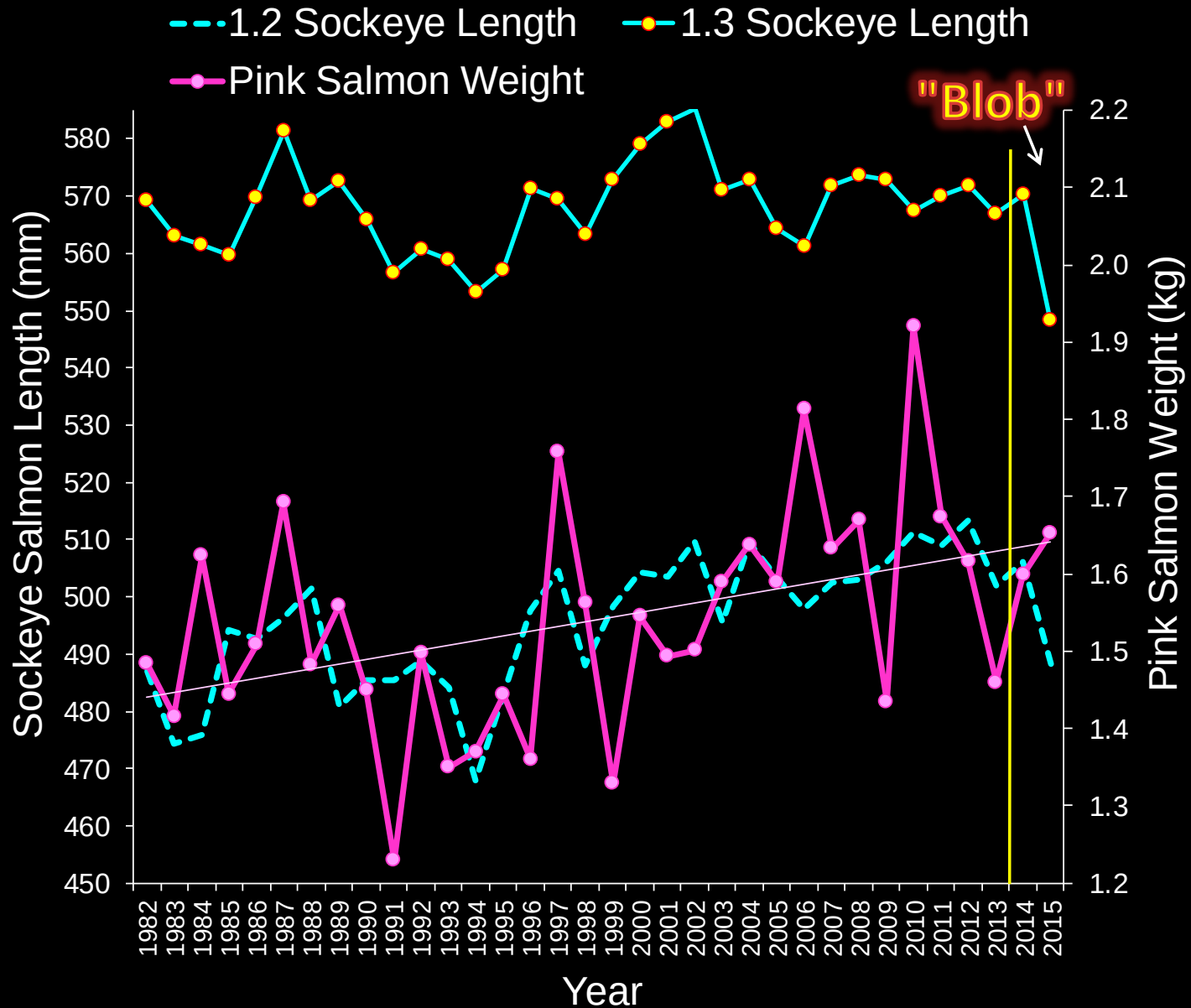
# Female Survival: proportionately lower when growth is poor (usually odd years)



# 4-Ocean Troll Chinook and Coho Spawner Length (Scales are Proportionate)



# Pink and Sockeye Salmon Size



# Conclusions

- Pink & Coho Salmon may do better under warming compared with Sockeye & Chinook
- Conditions for growth and survival may improve for some populations (and life stages) and deteriorate for others
- Climate change will likely intensify some interspecies interactions
- Need to think about both cyclical North Pacific Climate (PDO) patterns and the overall warming trend
- Need consistent long-term monitoring