

A large salmon is shown swimming in water, viewed from above. The fish is oriented towards the top left of the frame. Its body is a mix of silvery and brownish-green, with a lighter patch on its head. The water is dark and slightly rippled. The title text is overlaid on the top left of the image.

# **Growth of Western Alaska Chum Salmon in Relationship to Climatic Factors & Inter- and Intra-specific Competition**

**Bev Agler**

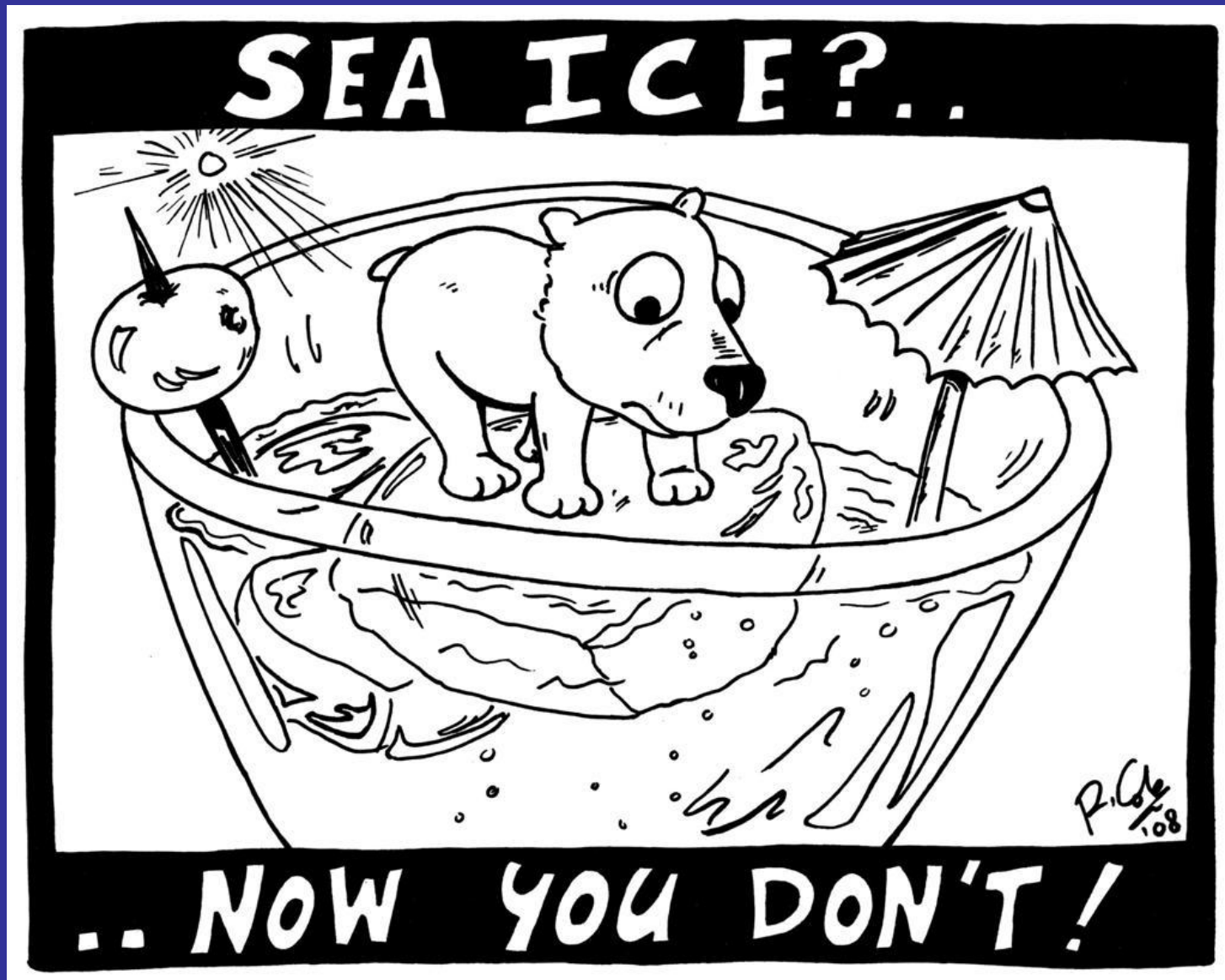
Alaska Department of Fish and Game

**Greg Ruggerone**

Natural Resources Consultants, Inc.

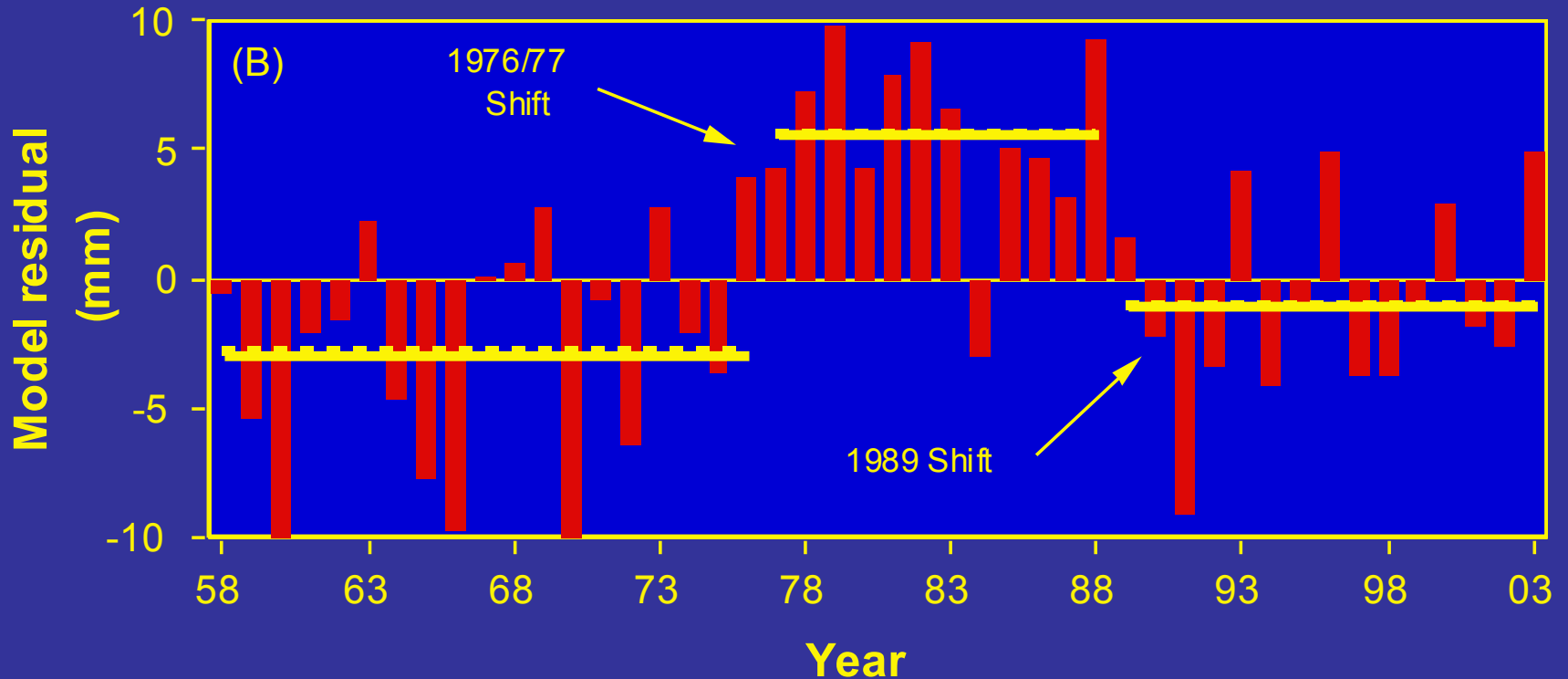
**Funding: NPMR, AYK SSI, SSSF & ADFG**

# Is it Climate Change?

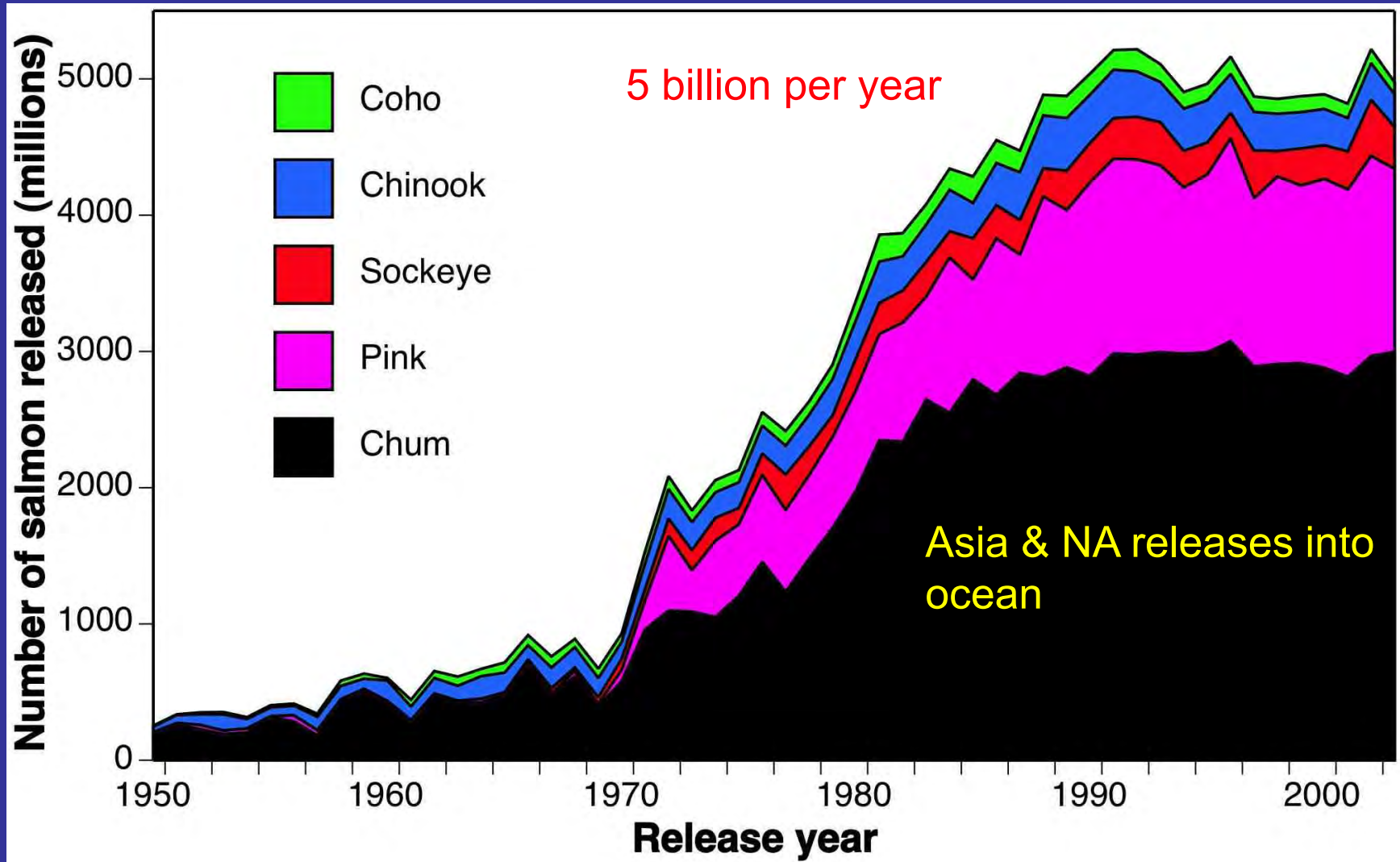


# BB Sockeye Length & Climate Change

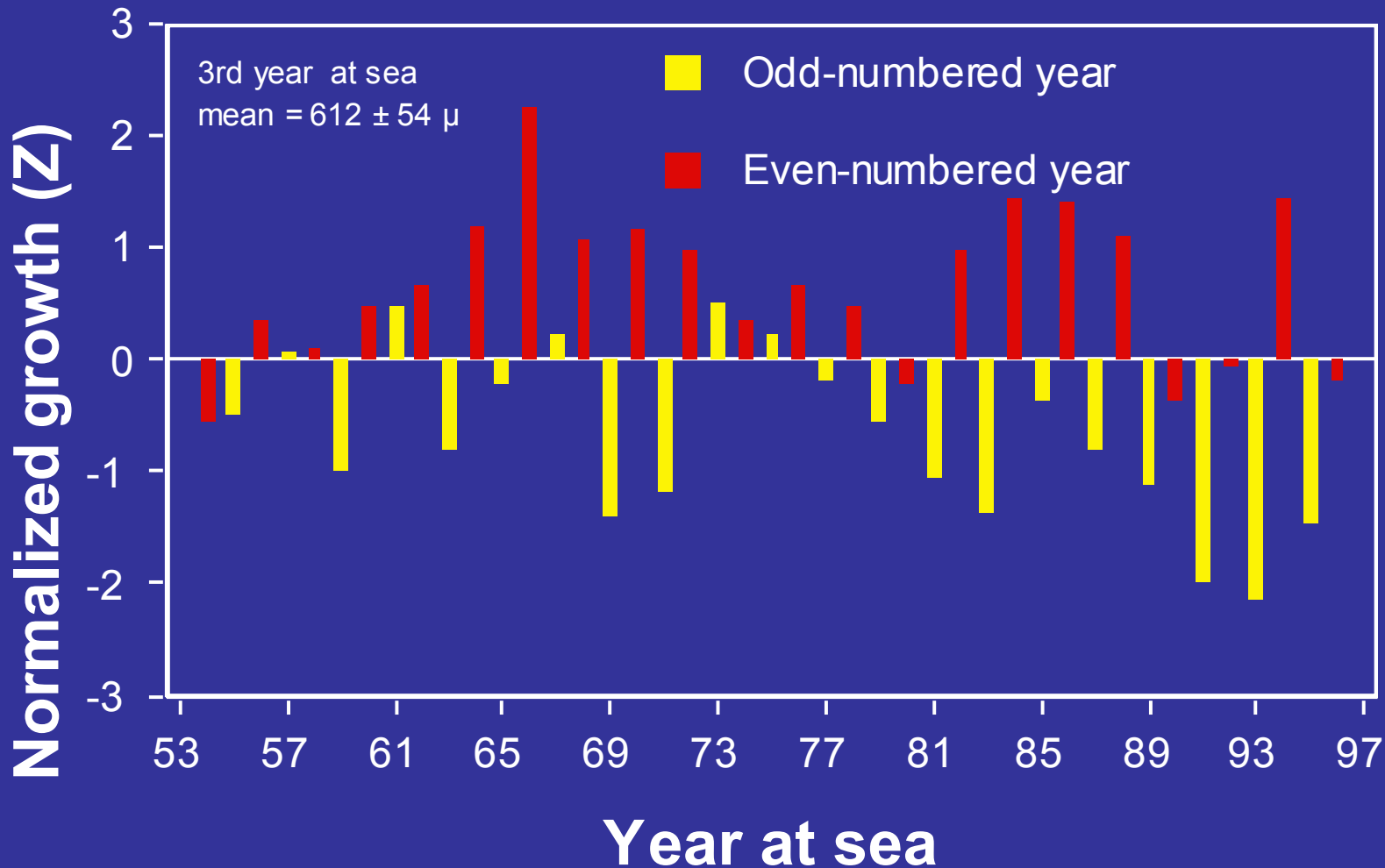
$$L = 550.9 - .178(\text{sockeye}) - .144(\text{pinks}), r^2 = .40$$



# No. of Hatchery Releases Is it Competition?



# Recent studies show sockeye growth reduced during odd years at sea due to Asian pink salmon abundance





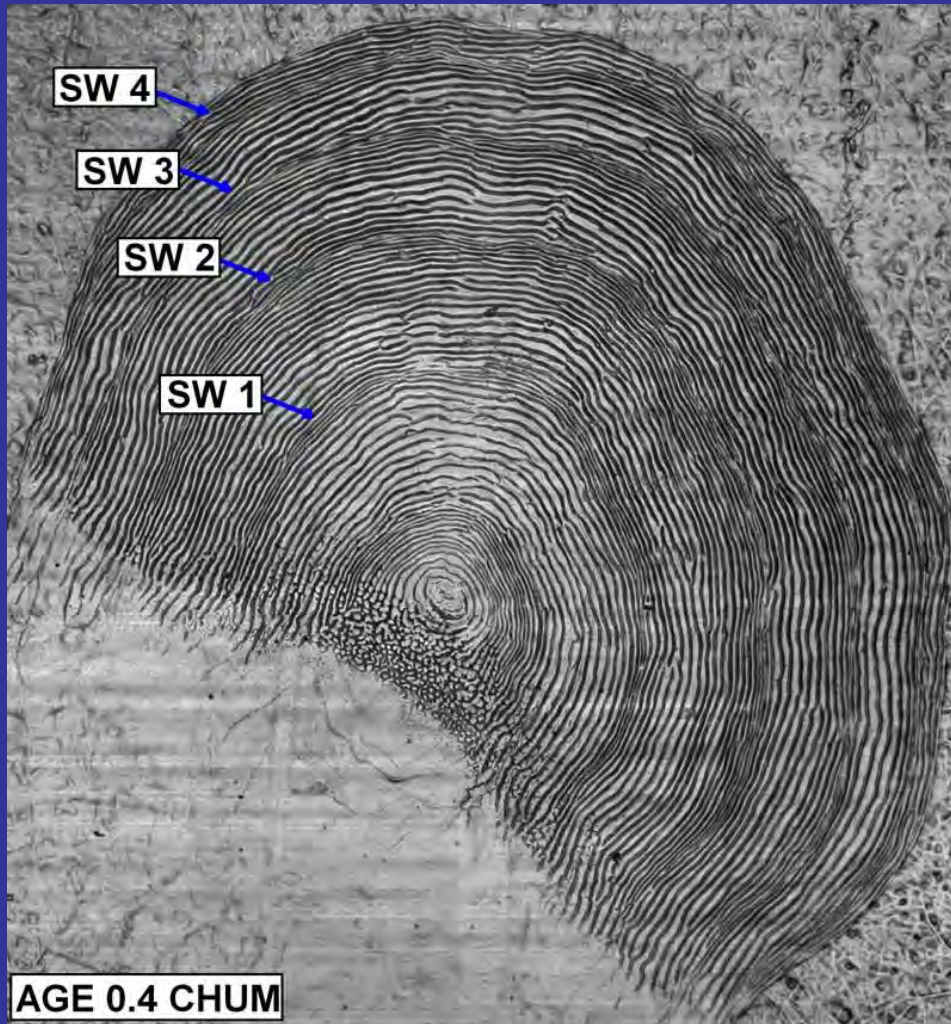
# Chum Salmon

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- Do climatic factors affect growth of western Alaska chum salmon?
  - Used several environmental variables for comparisons
- Do Asian pink salmon abundance inhibit growth of Alaska chum salmon?
- Does Asian chum salmon abundance inhibit growth of Alaska chum salmon?



# Annuli & Circuli Measurements



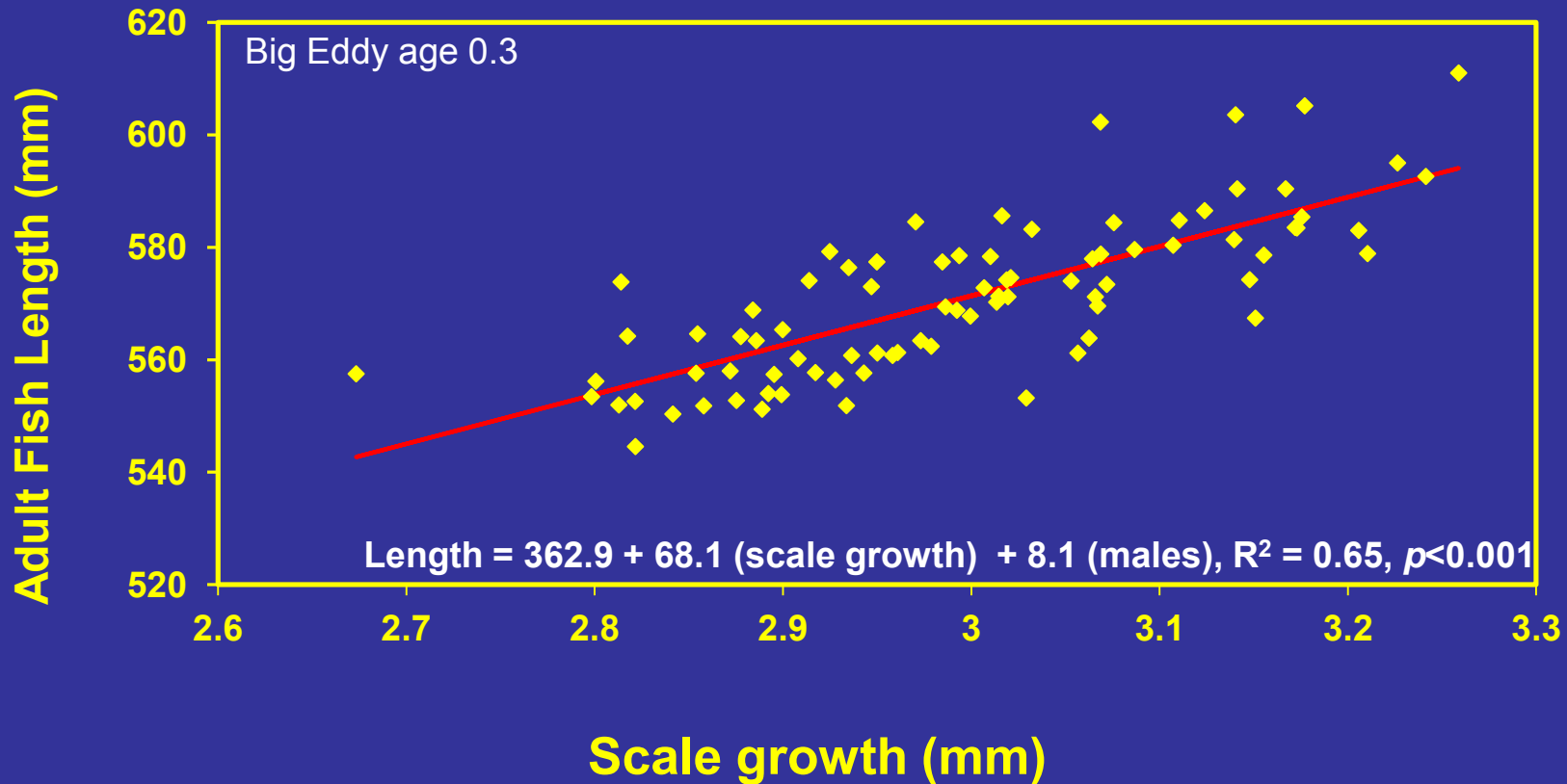
Chum Salmon scale

- Use average size of growth zone by year.
- Age 03 or 4-year old fish &
- Age 04 or 5-year old fish
- Examined 2 growth zones:
  - SW1: Critical period – Critical size hypothesis
  - SW3: Time when fish “choose” to stay in marine waters or return to spawn.



# Scale growth - proxy for overall growth

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Bristol Bay Length = 346.3 + 97.2 (Scale growth) + 10.9 (males)  $R^2 = 0.65$ ,  $p = < 0.001$



# Environmental Variables

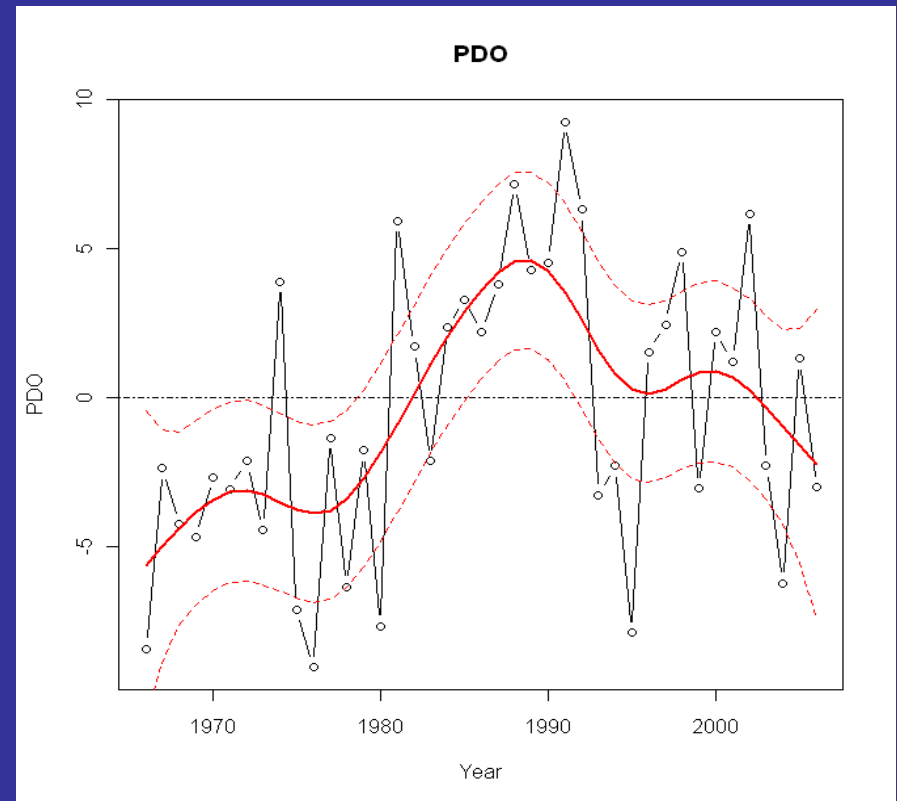
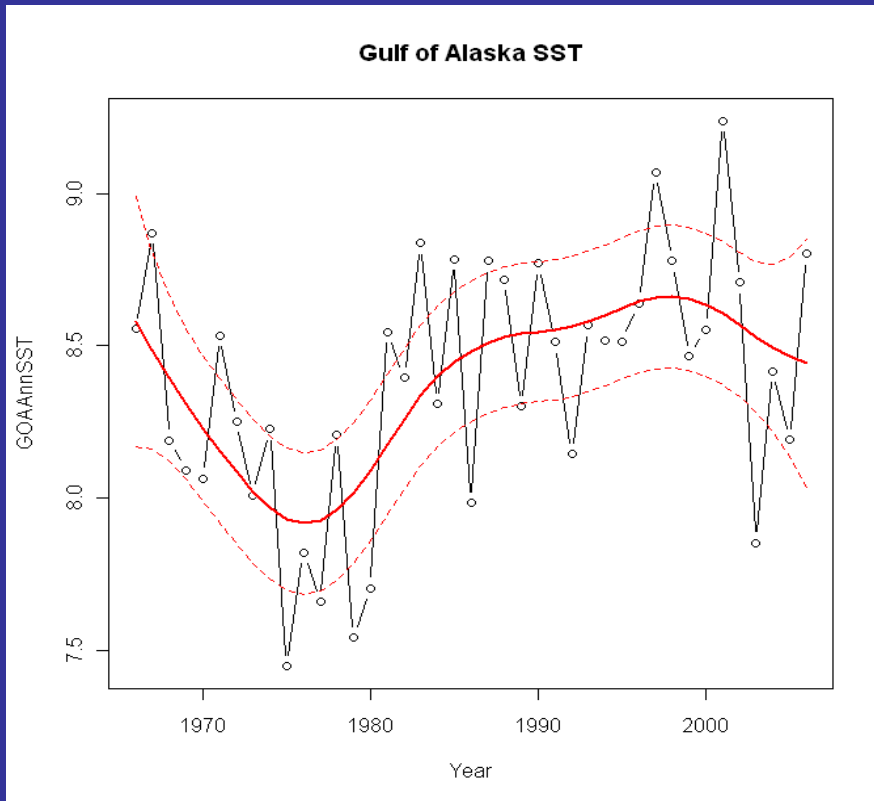
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- North Pacific Index (NPI)
- Aleutian Low Pressure Index (ALPI)
- Arctic Oscillation Index
- El Nino Index
- Annual Sea Surface Temperature (SST)
- Ice Cover
- Mean May SST
- 2 mixing indices
- Bering Sea Level Pressure (winter & spring)
- Air Temp (local by fish system)
- Pacific Decadal Oscillation Index
  - Winter index – November – March

# Explanatory Variables

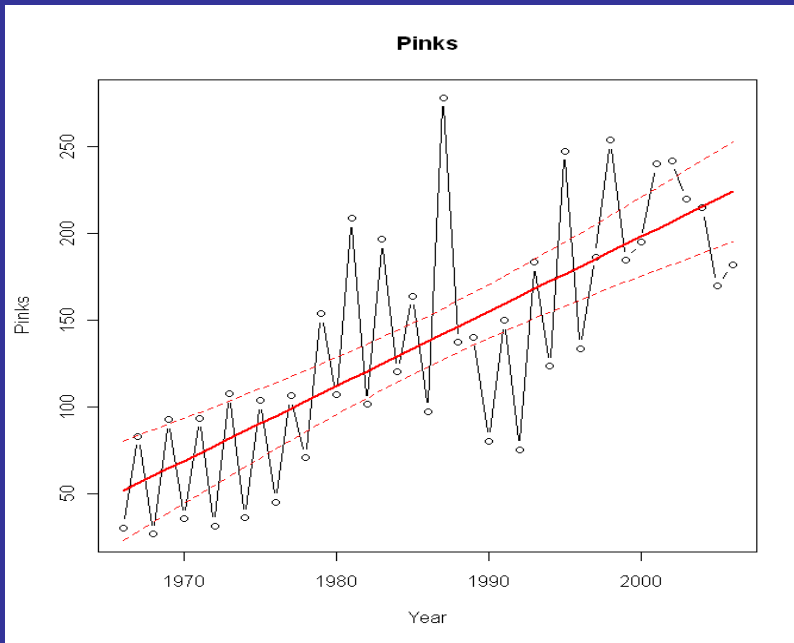
- Sea surface temperature from specific areas – annual, summer, winter

Mantua et al.



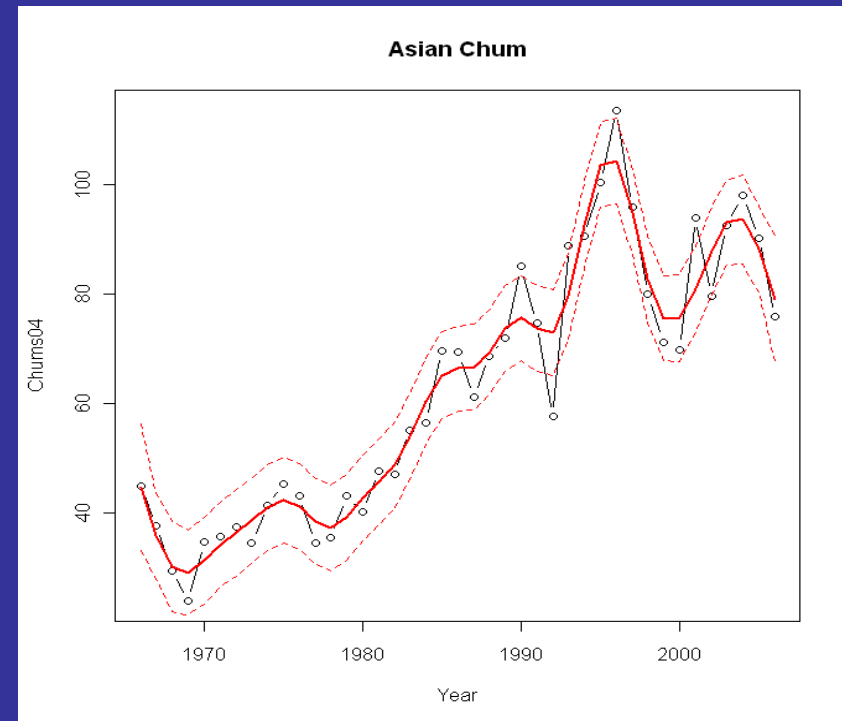
- Pacific Decadal Oscillation (PDO)
  - Used Winter Index, November – March

# Abundance Data Available



- Pink Salmon Abundance
  - Total catch and escapement from Russia

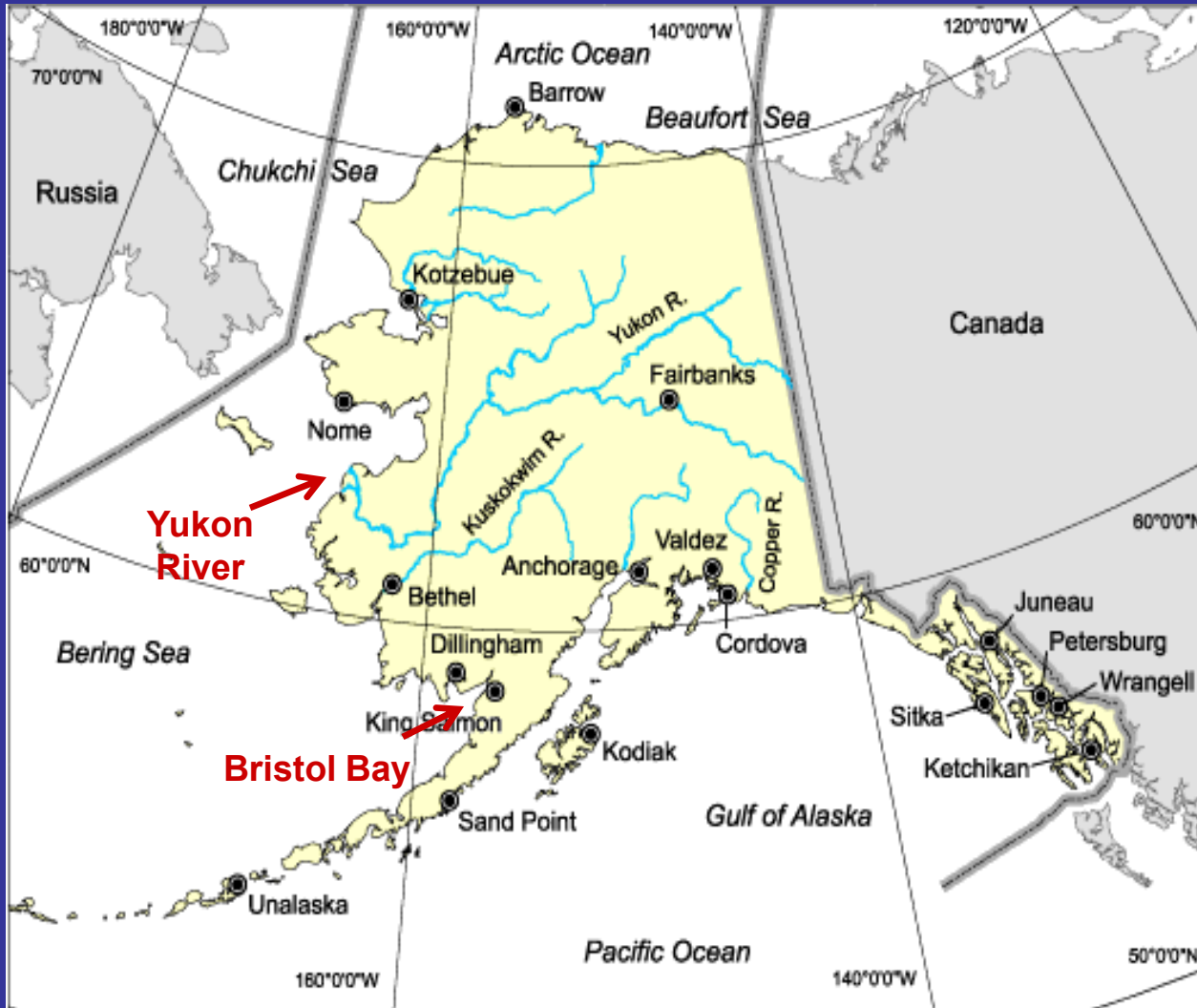
- Asian Chum Salmon Abundance
  - Catch and escapement data in millions of fish from Japan and Russia



# Areas Sampled

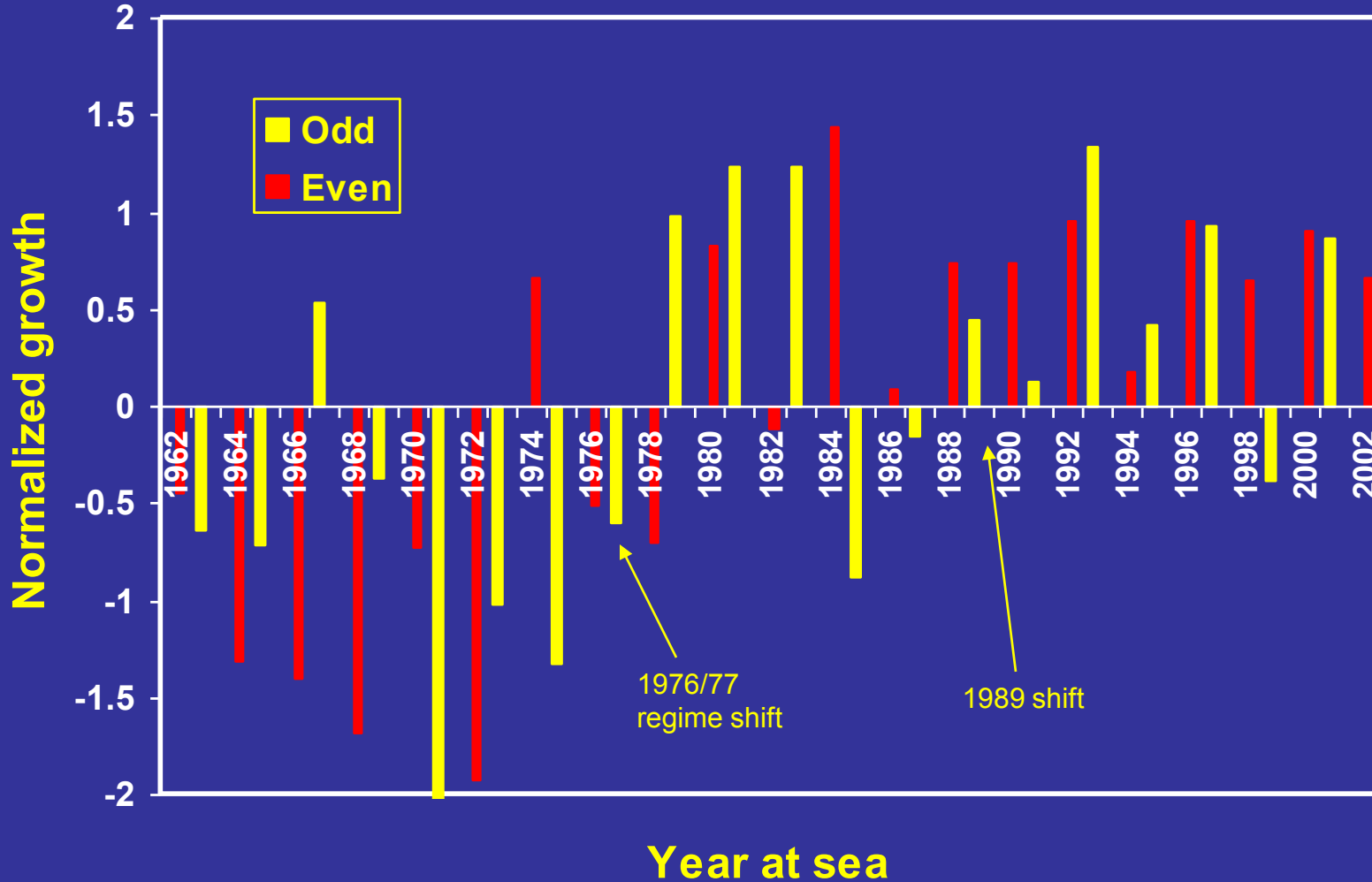
Scale Samples  
from 2 regions:

- Yukon River –  
Big Eddy (near mouth)  
1965-2006
- Bristol Bay –  
Nushagak River 1966-  
2006





# BB Chum SW1 Growth During Even vs. Odd Years at Sea



# Methods

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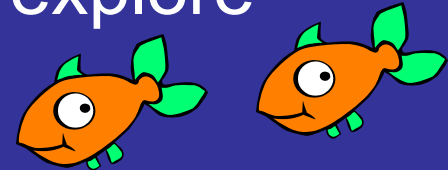
## Correlations

Compared salmon growth with environmental variables using correlation analysis



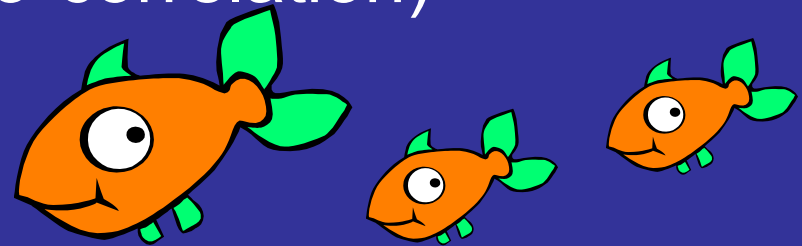
Used data re: significant p values to determine what to use in multiple regression models

Generalized additive models (GAMS) to explore data



Generalized Least Squares models (GLS) to model the data

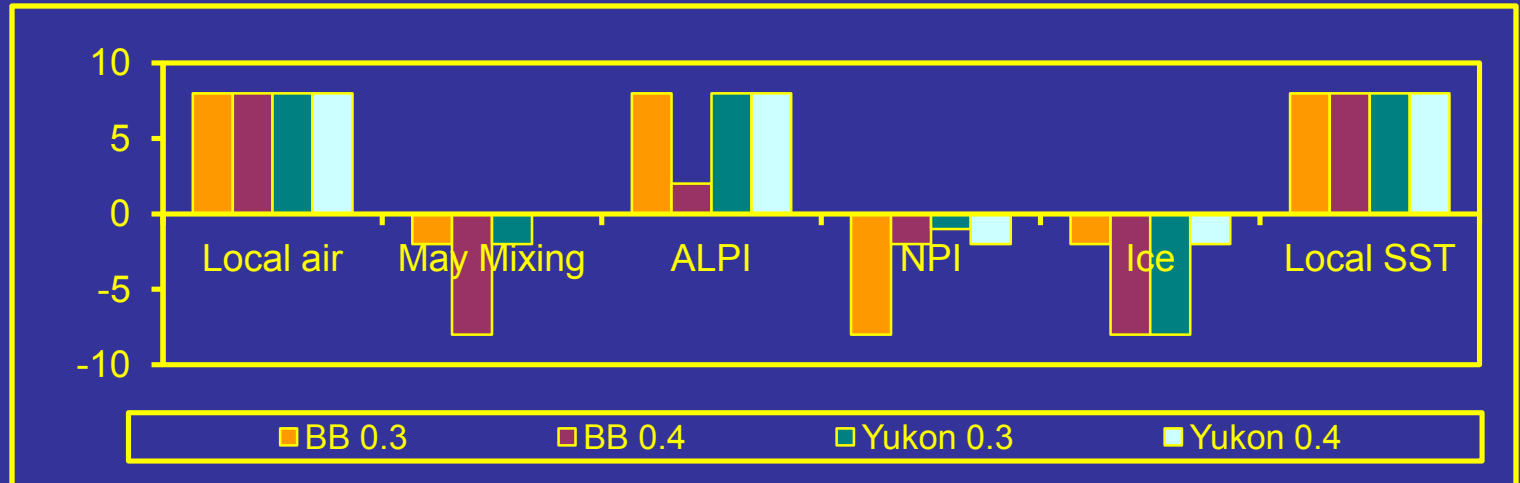
(why? – accommodate auto-correlation)



# Do climatic factors affect growth of chum salmon?

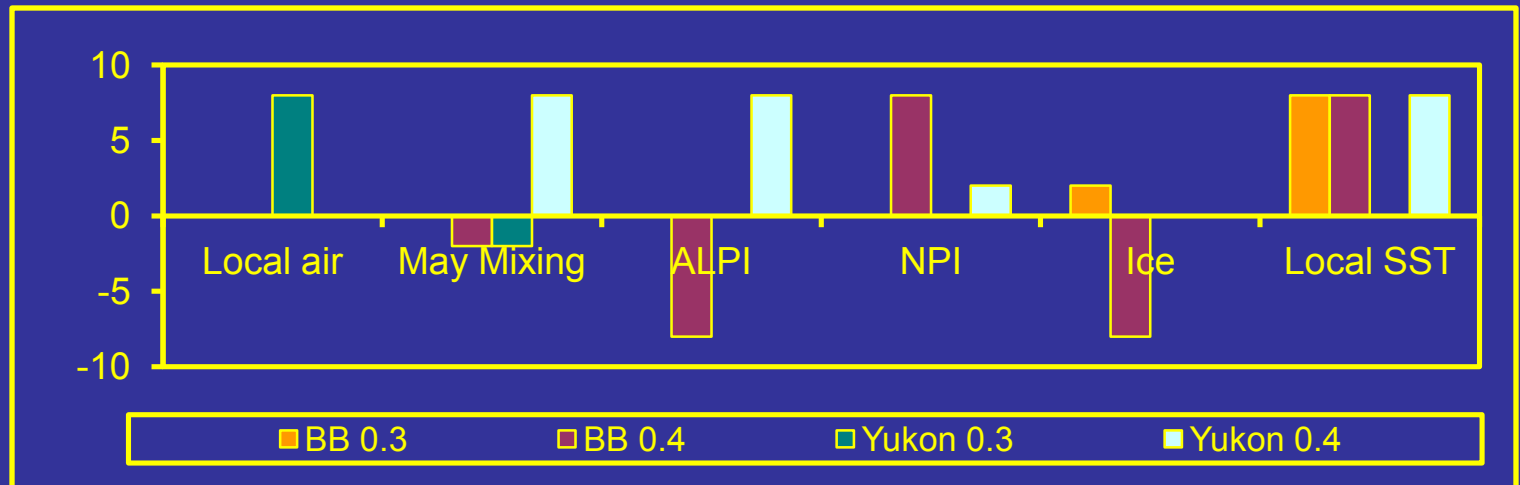
Individual variables – (SW1 ~ Local Annual SST)

SW1



Reduced Models

(SW1 ~ ALPI + NPI + Local Annual SST + May Mixing + Air Temperature)



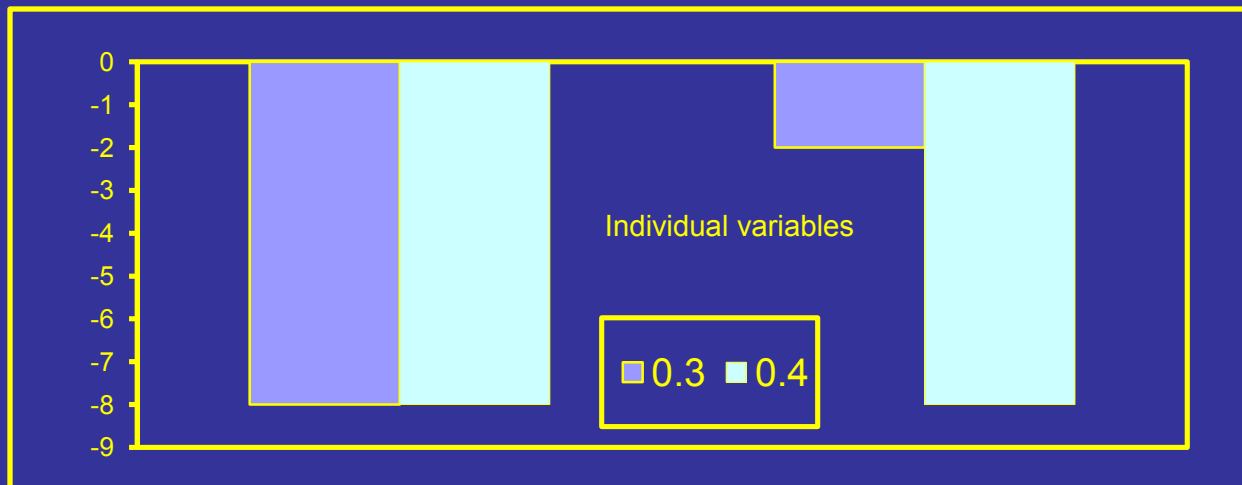
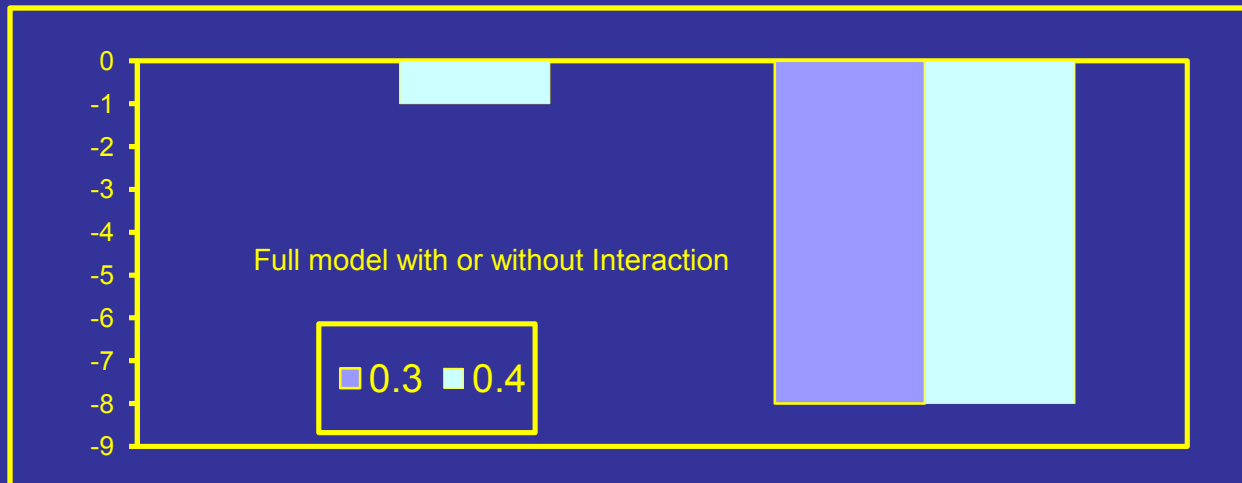
# Climatic factors?

SW3

## Gulf of Alaska Annual SST

Bristol Bay

Yukon

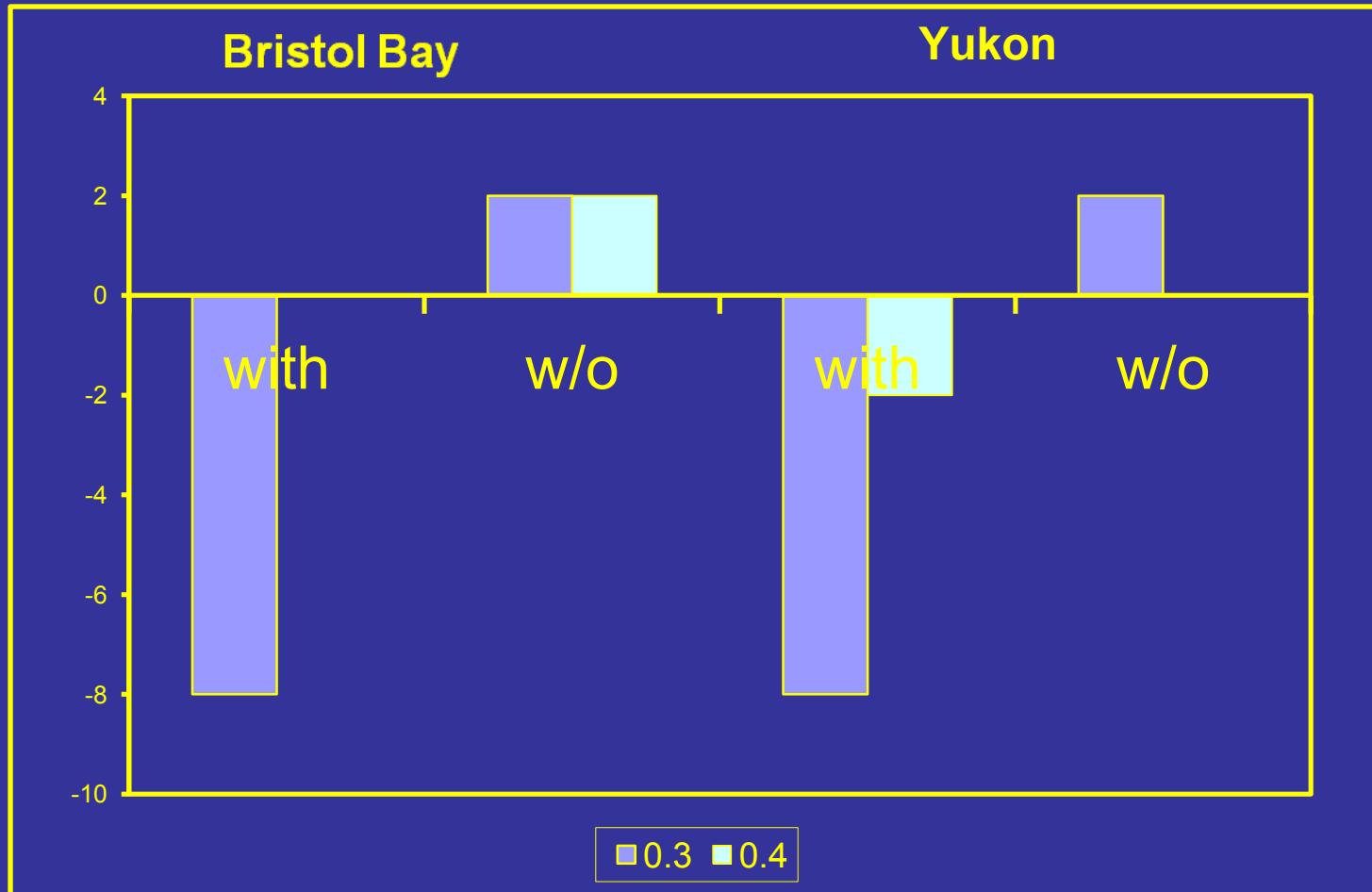




# Does Asian pink salmon abundance inhibit growth?

SW3

Yes or No? Depends on interaction factor

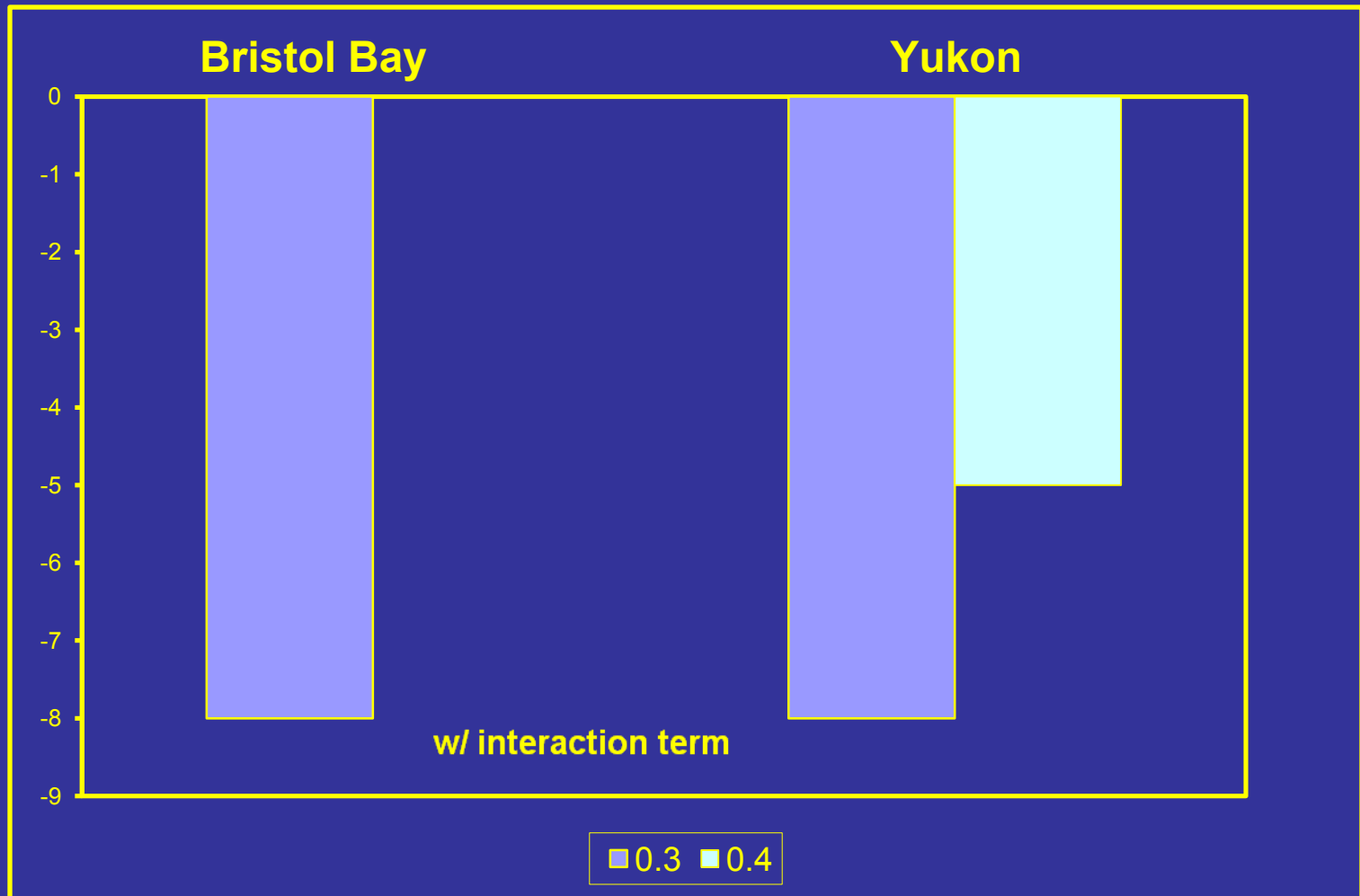


# Does Asian chum salmon abundance inhibit growth?

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SW3

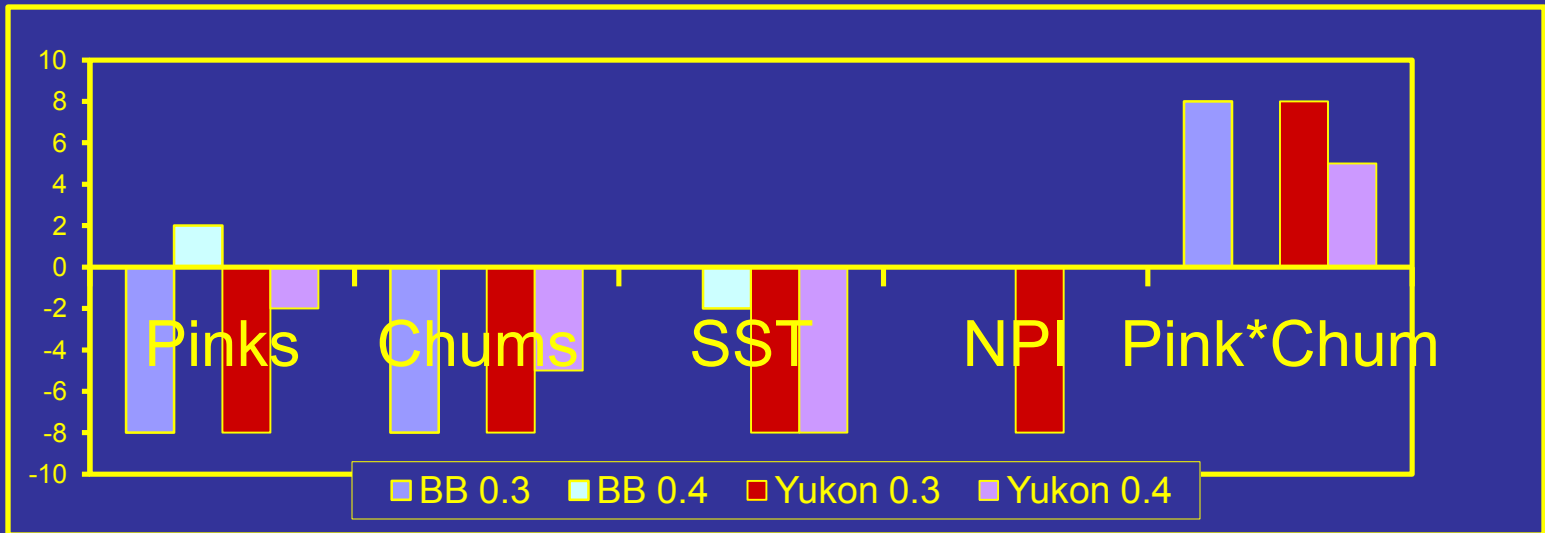
Not all ages



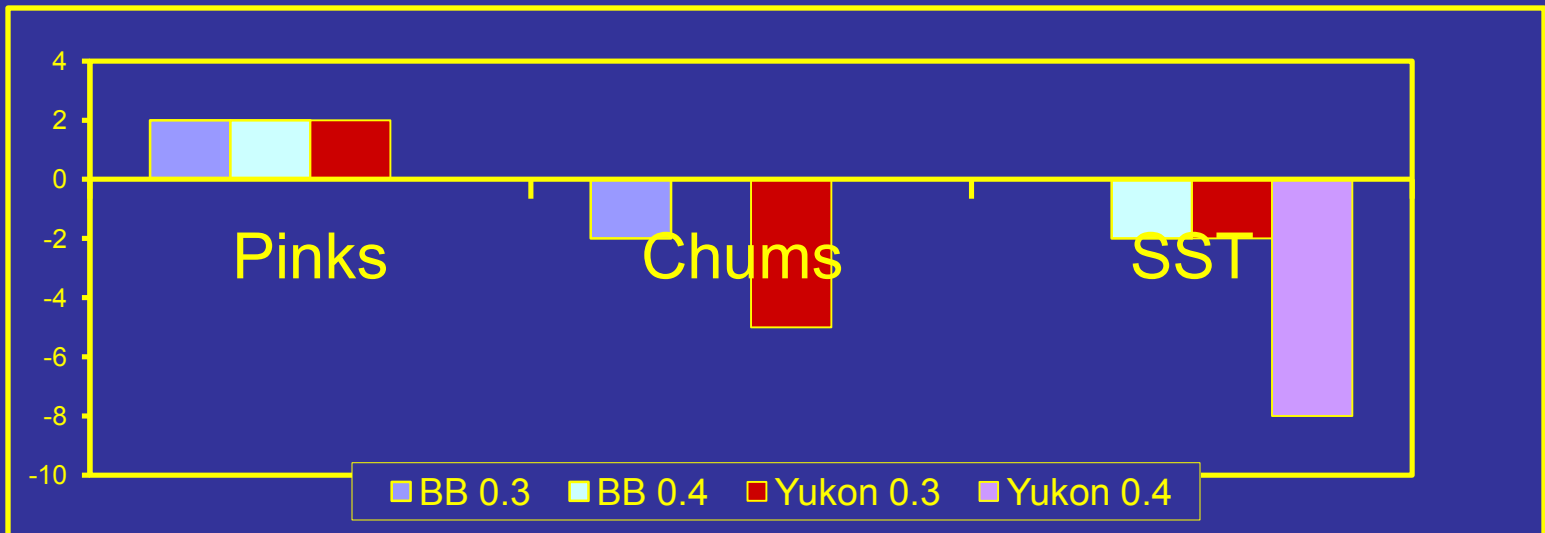
# What inhibits growth?

SW3 ~ Pinks + Chum + GOA Annual SST + NPI + Gender + Pinks:Chum

Reduced models w/ interaction term



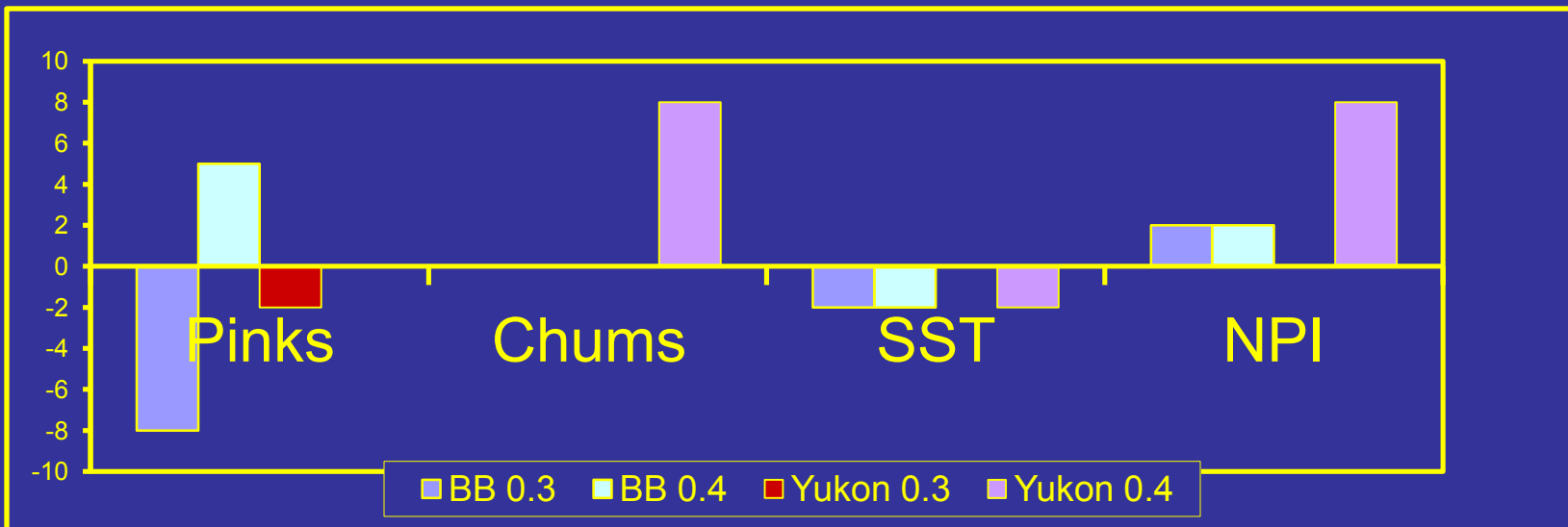
w/o interaction term



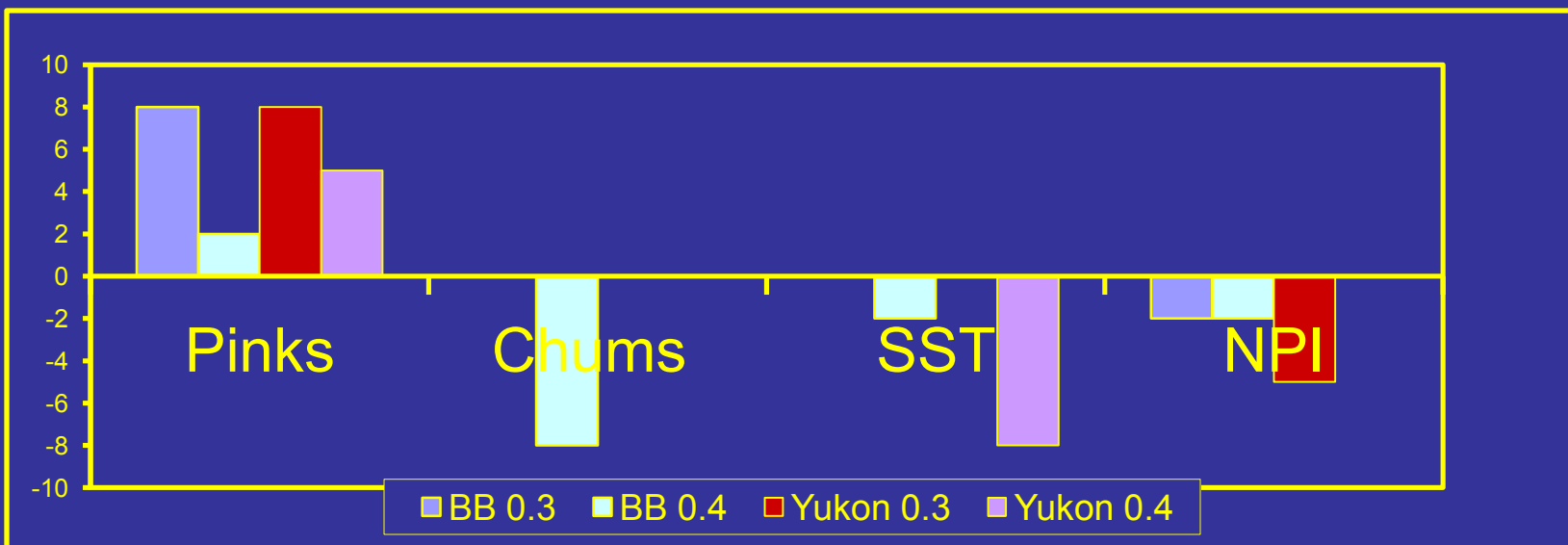
# How did growth change?

## SW3 – Individual Models

Pre-1977

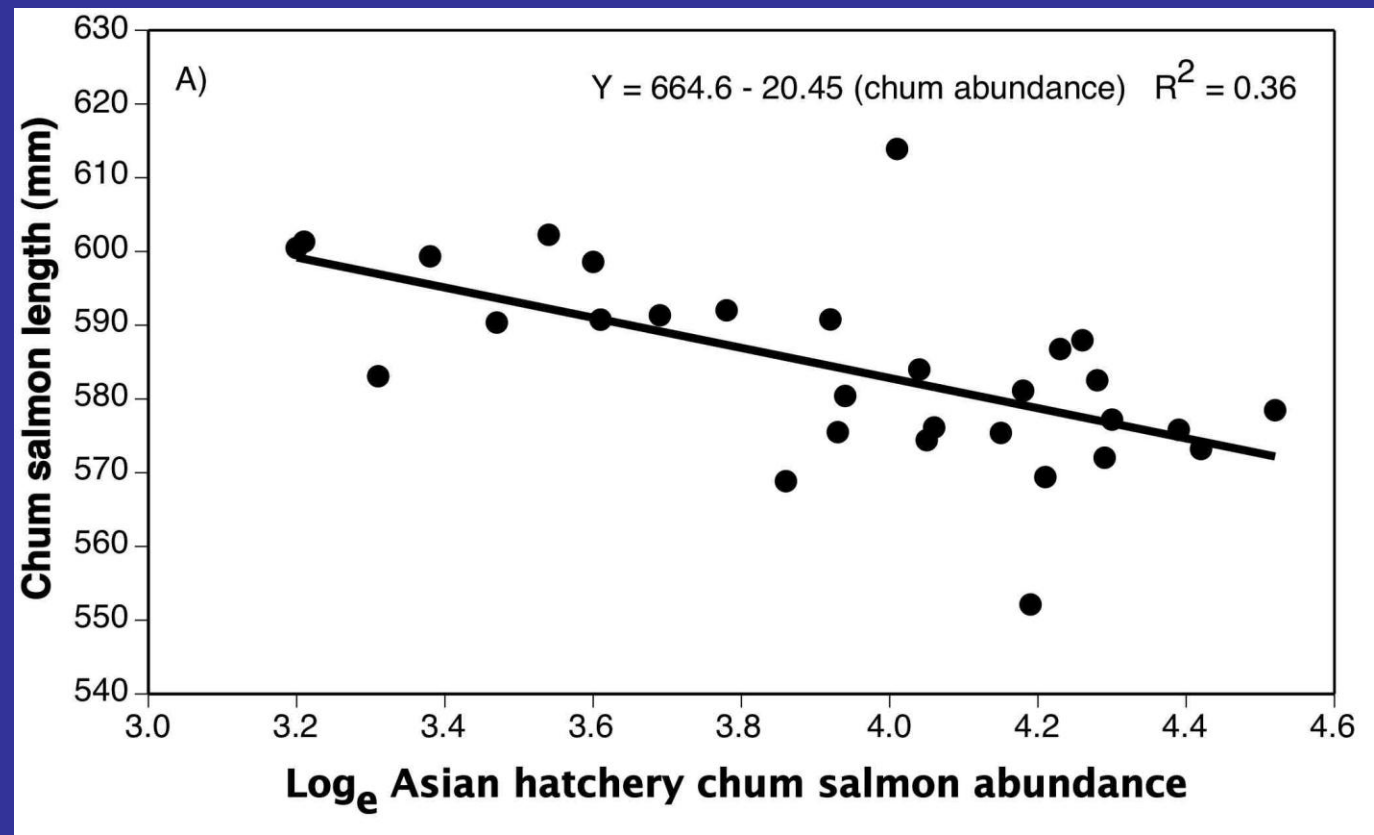


Post-1976



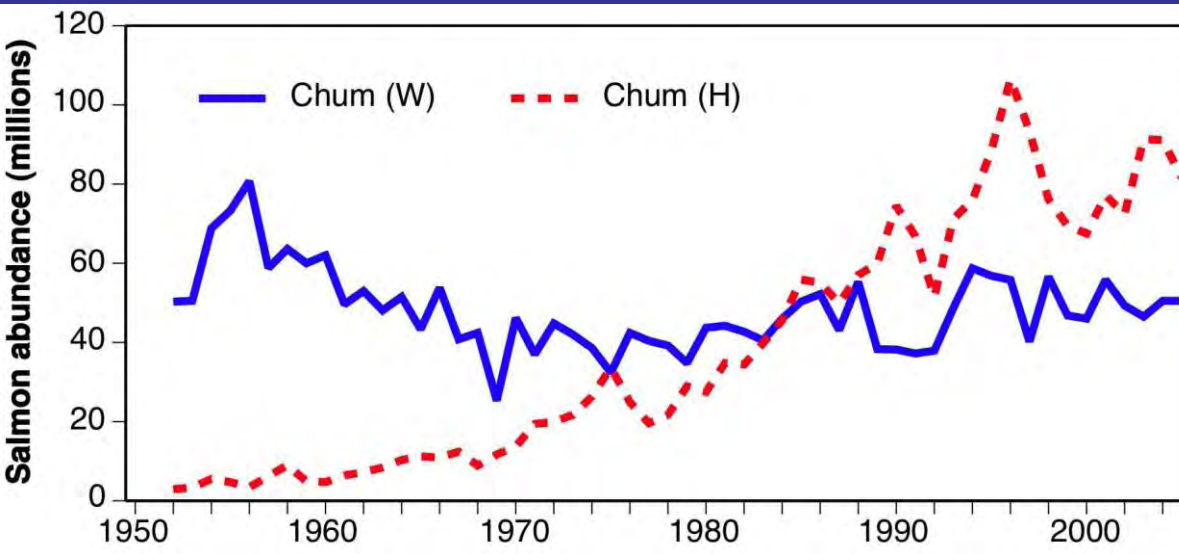


# Norton Sound Chum Length-at-age declined with greater Asian Hatchery Chum Abundance, 1974-2005



Also, Kwiniuk SW2 & SW3 scale growth inversely related to Asian chum abundance  $R^2 = 0.24, 0.12$

# Do AK Chum Salmon Compete with Asian Chum & Pink Salmon?

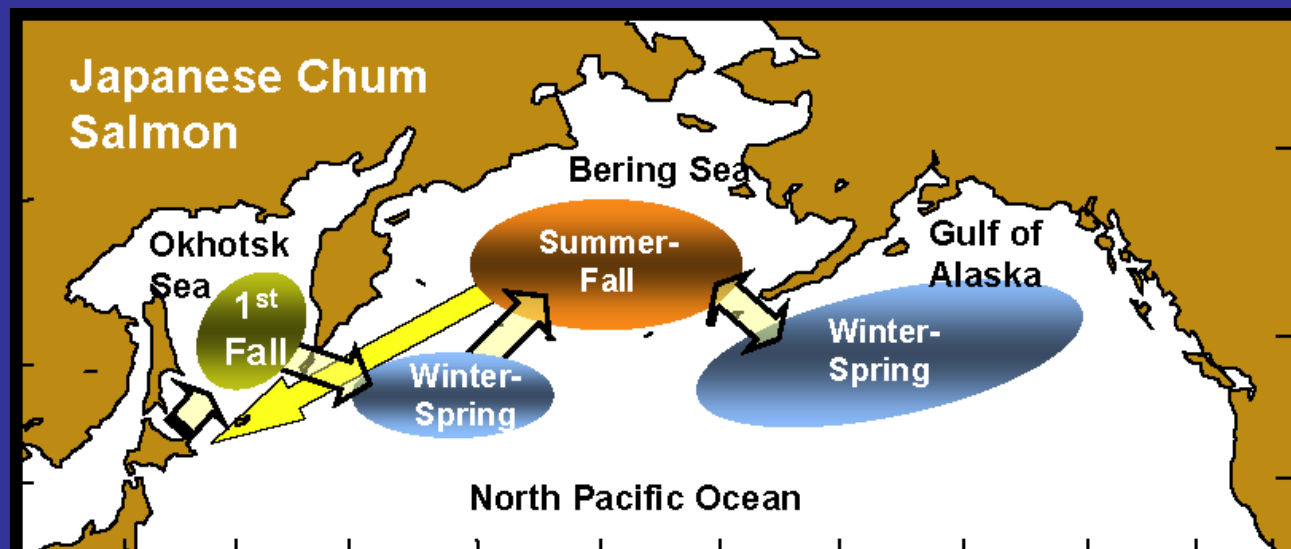


Wild chum did not increase after 1977; hatchery chum (mostly Japan)

Ruggerone et al. 2010

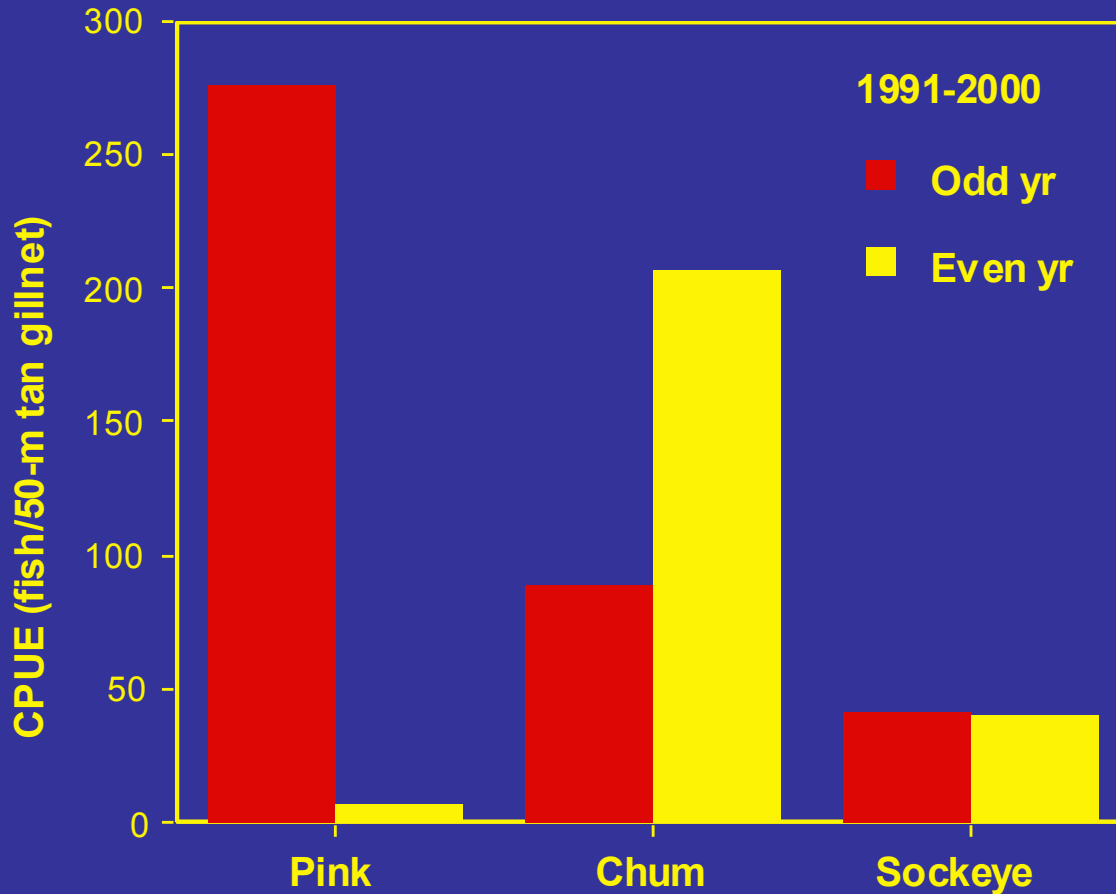
AYK chum overlap  
Japanese  
hatchery chum  
salmon

K. Myers, UW  
Urawa et al. 2008



# Salmon CPUE Bering Sea, 1991-2000

Davis et al. 2005



- Pinks dominate odd-yr catch.
- Chum much more abundant in even-numbered years.
- Chum distribution shifts away from Bering Sea in odd-years to avoid pink competition (Ogura and Ito 1994; Azumaya and Ishida 2000).

# Conclusions

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- **Several environmental variables are important during first year of growth.**
- **SST is important throughout life cycle.**
- **Dynamic system – conditions have changed over 45 year times series.**
- **Difficult to examine density-dependent interactions.**
- **Appears possible density-dependent interactions.**
- **Competition at sea may affect salmon growth & future productivity.**
- **If conditions change again, what will happen?**