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

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Photo: Greg Ruggerone

SCALE: Salmon Comparisons Across Large Ecosystems

Thanks to:

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- Gordon Kruse
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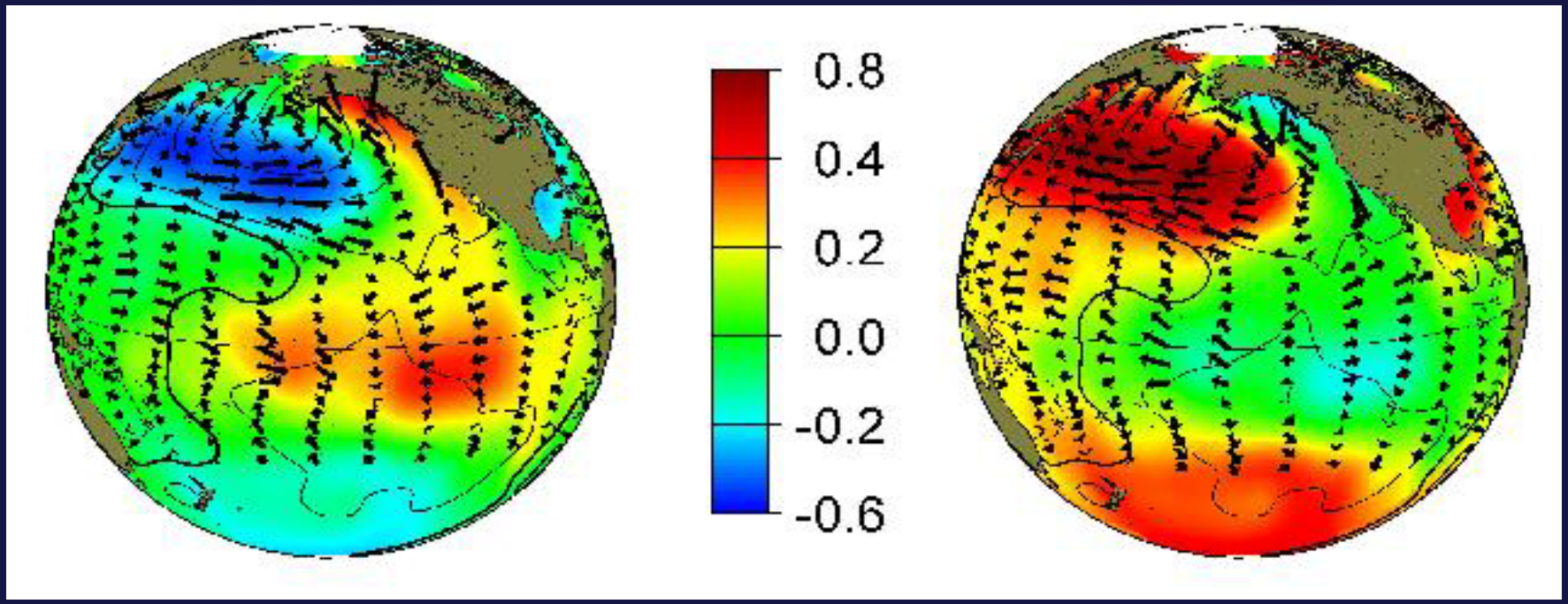
- AYK-SSI, Arctic-Yukon-Kuskokwim – Sustainable Salmon Initiative
- Alaska Department of Fish and Game

Pacific Decadal Oscillation

Warm phase **Cool phase**



PDO cool phase – 1947-1976

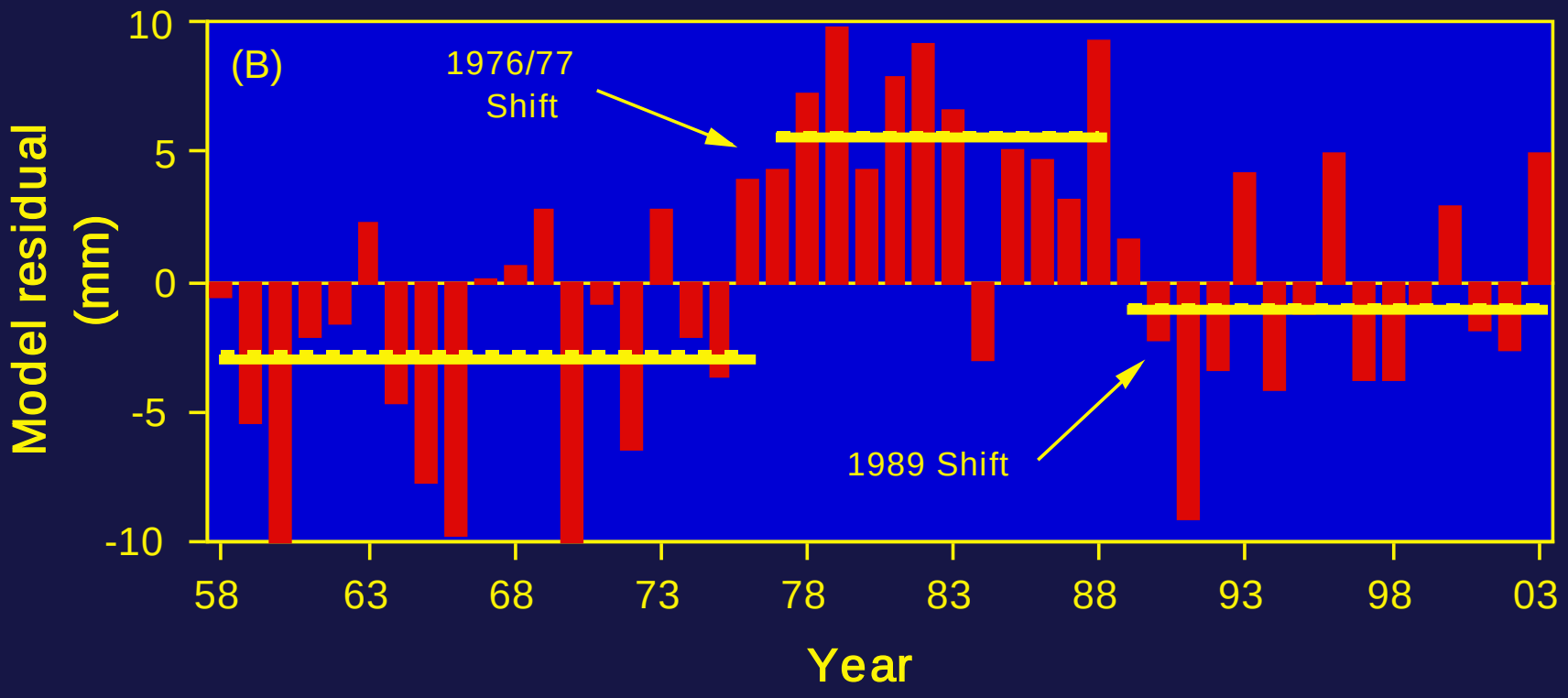
PDO warm phase – 1977 to mid-1990s

After Hare and Mantua

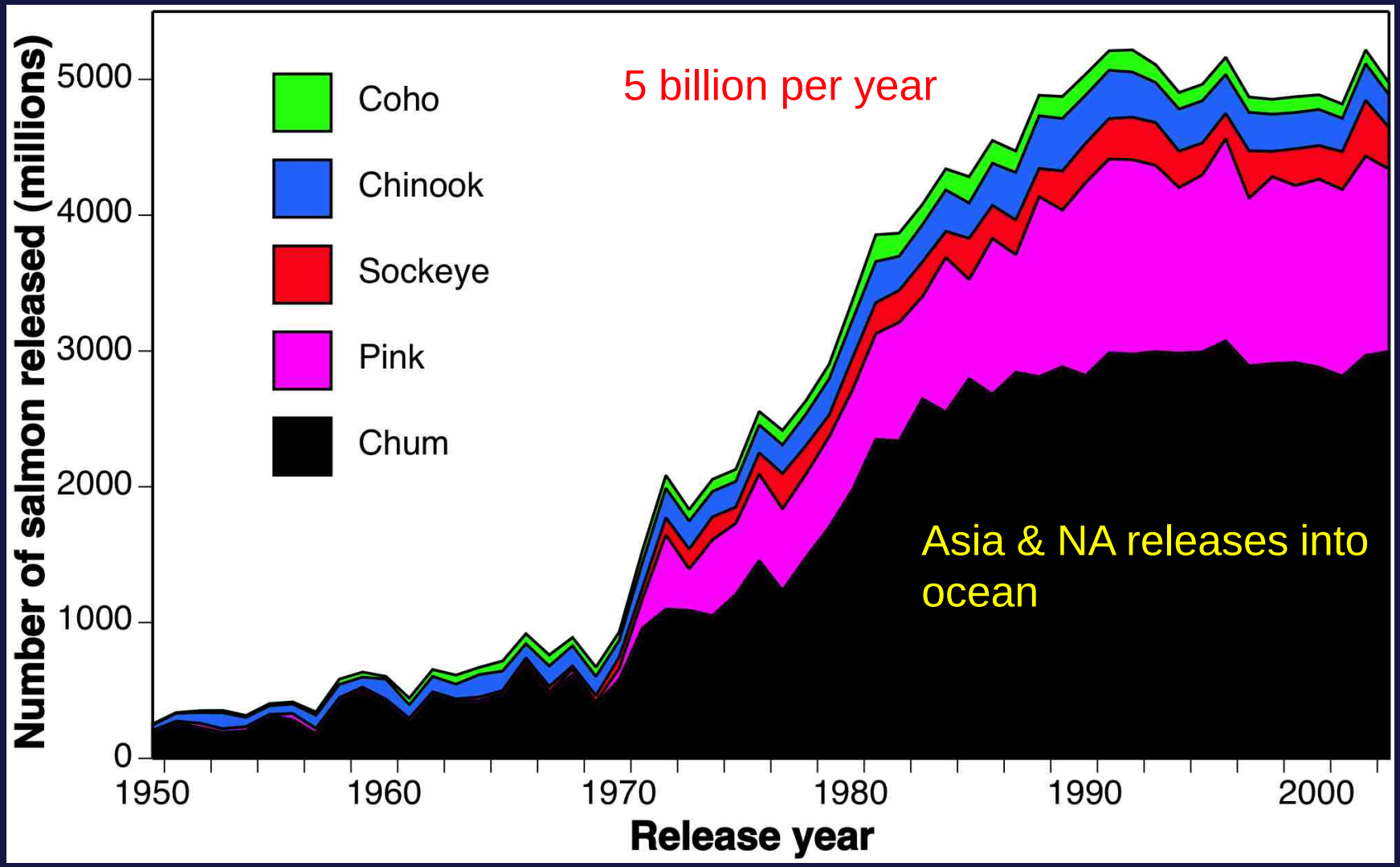
- During warm phase of PDO, it is warm along coast
- So expect better growth in juveniles
- Cold in ocean basin
- So…slower growth in SW3 growth zone
- Thus, we chose to focus on Sea Surface Temperature (SST)

BB Sockeye Length & Climate Change

L = 550.9 - .178(sockeye) - .144(pinks), r2 = .40

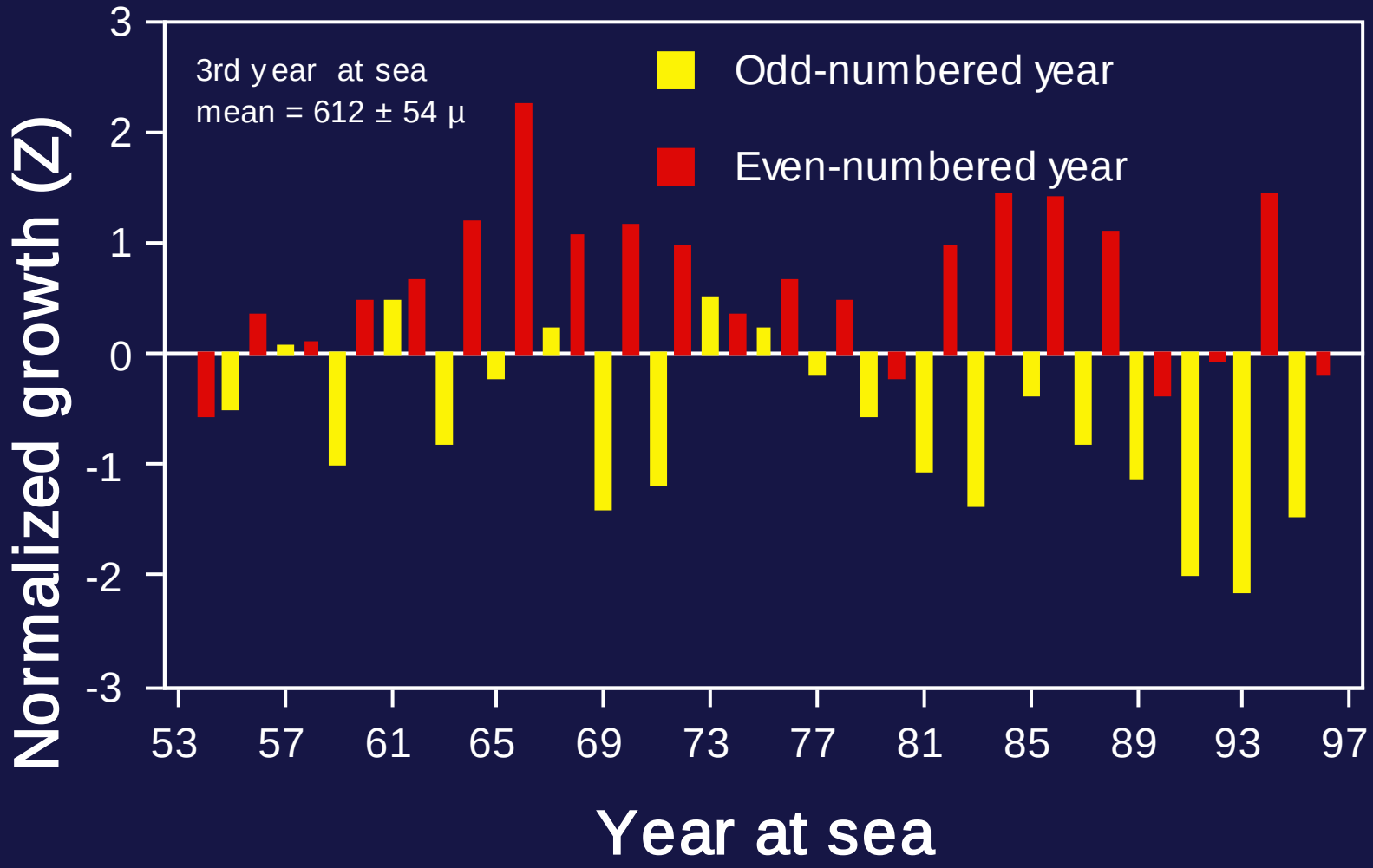


No. of Hatchery Releases
Is it Competition?



Updated from Mahnken et al. 1998

Studies show sockeye growth reduced during odd years at sea due to Asian pink salmon abundance



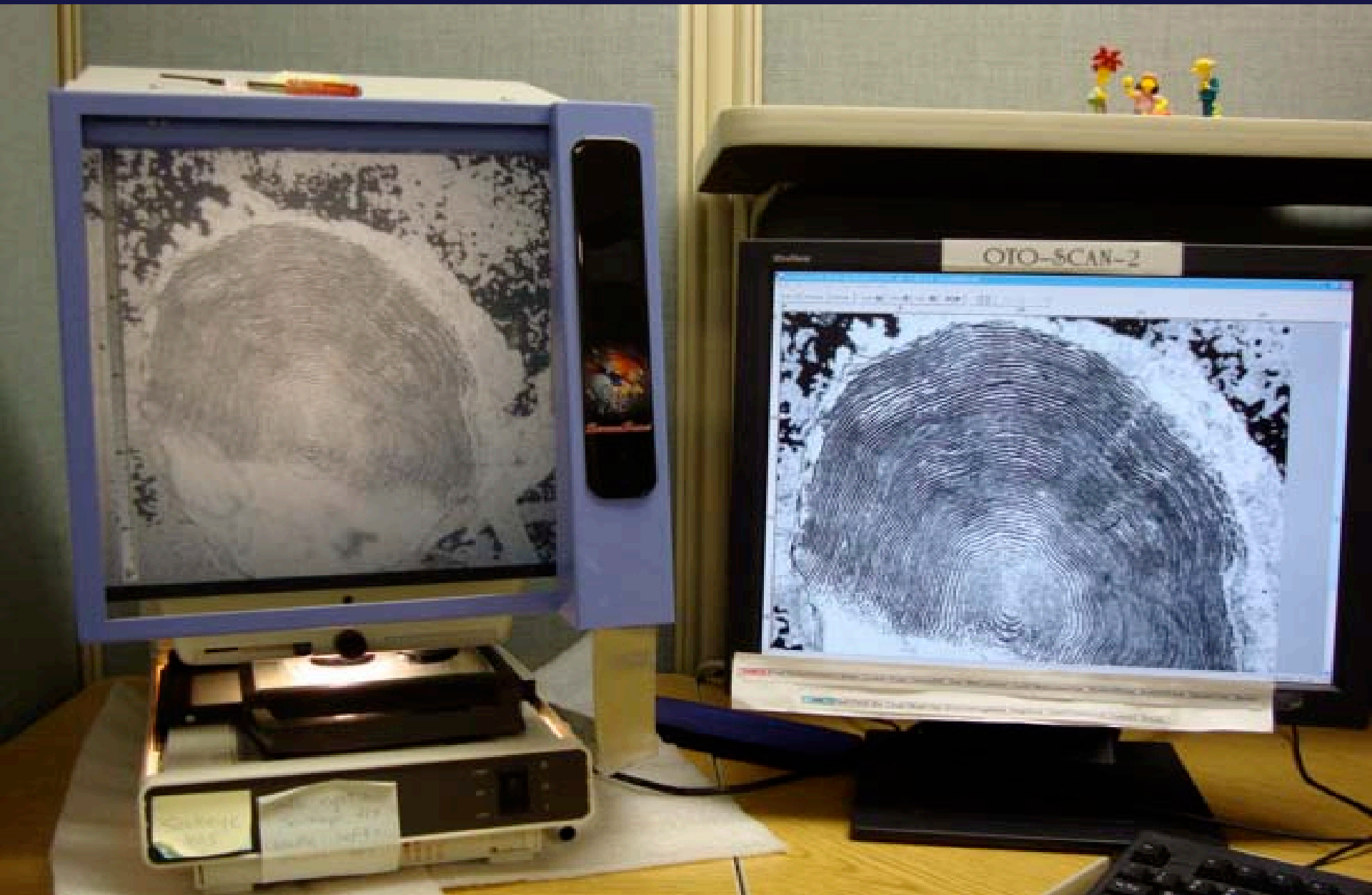
Hypotheses

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

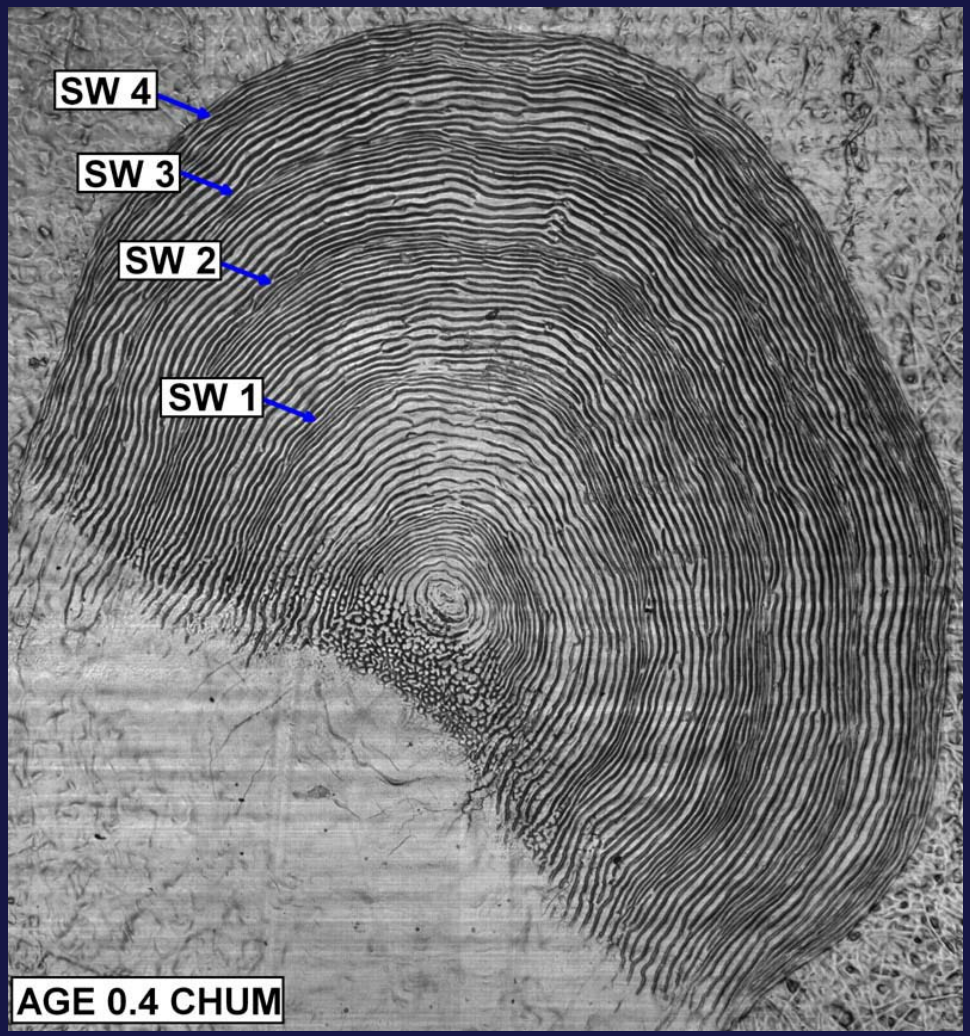
Study Areas

- **Norton Sound – Unalakleet R 1975-2006**
- **Yukon R – Big Eddy 1965-2006**
- **Kuskokwim R – Quinhagak 1967-2007**
- **Bristol Bay – Nushagak R 1966-2006**
- **Russia – Anadyr R 1962-2007**
- **Japan – Chitose R 1976-2008**

Scale Digitizing Equipment



Annuli & Circuli Measurements



Chum Salmon scale

- Used mean growth per year.

- Age 0.3 or 4-year old fish &
- Age 0.4 or 5-year old fish

- First compared all growth zones then chose to model 2 growth zones:
  - SW1: Critical period – Critical size hypothesis.

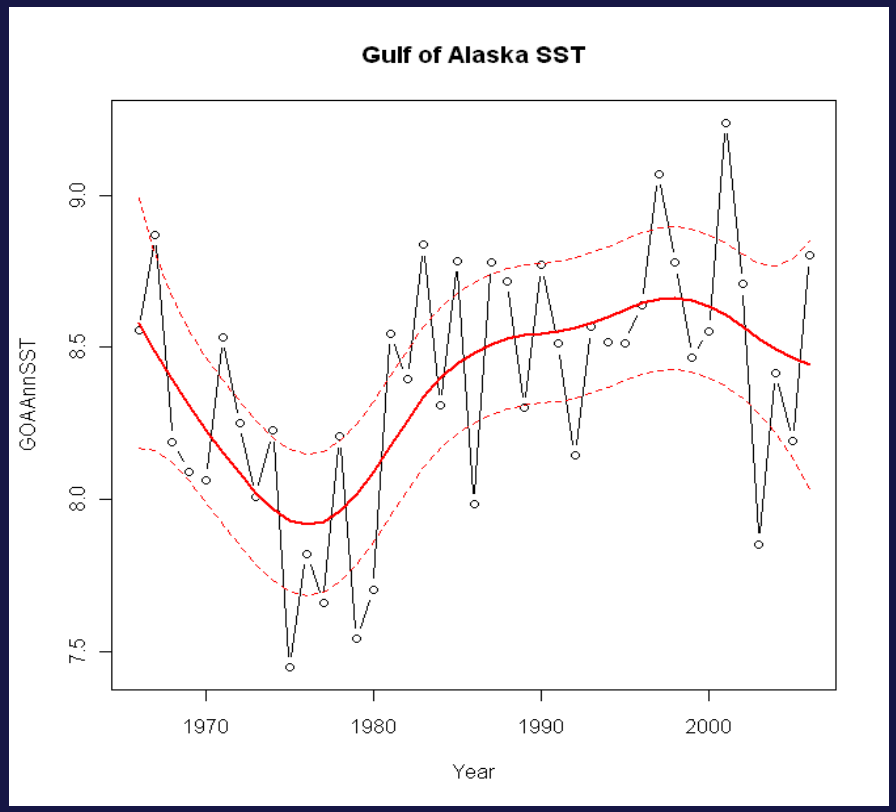
  - SW3: Time when fish "choose" to stay in marine waters or return to spawn.

Environmental Variables

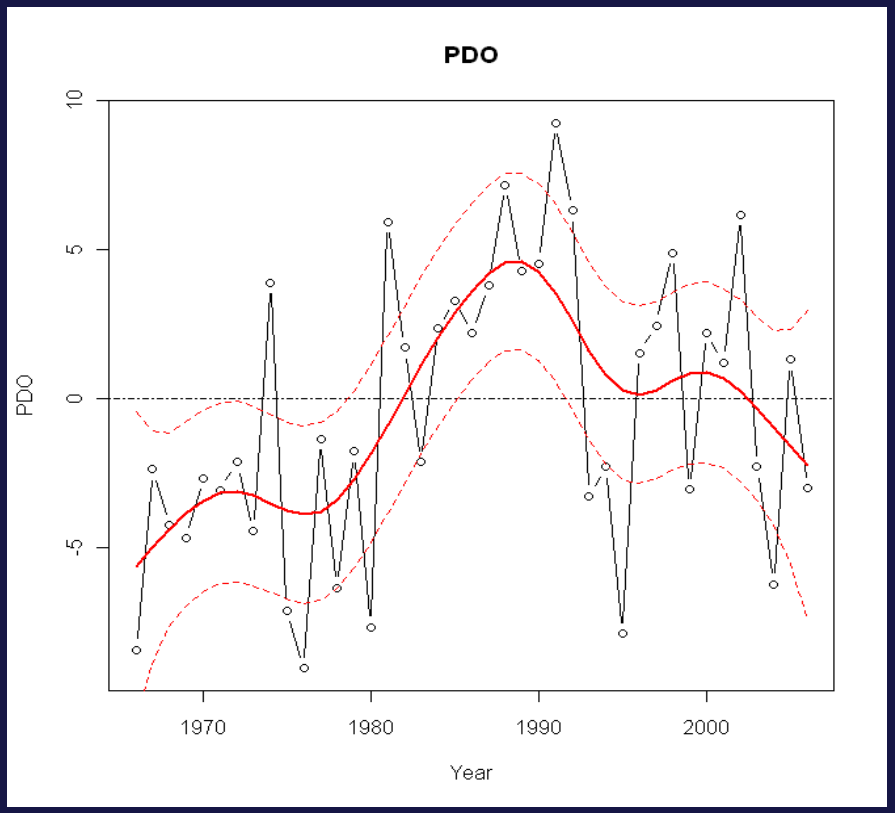
- North Pacific Index (NPI)
- Aleutian Low Pressure Index (ALPI)
- Arctic Oscillation Index (AO)
- El Nino – Southern Oscillation Index (ENSO)
- Annual Sea Surface Temperature (SST)
  - North Pacific & Gulf of Alaska
- Ice Cover Index
- 2 wind mixing indices
- Bering Sea Level Pressure (winter & spring)
- Local Air Temp (by system, summer, winter, annual)
- Pacific Decadal Oscillation Index (PDO)
  - Winter index – November – March

Explanatory Variables

- SST from specific areas – annual, summer

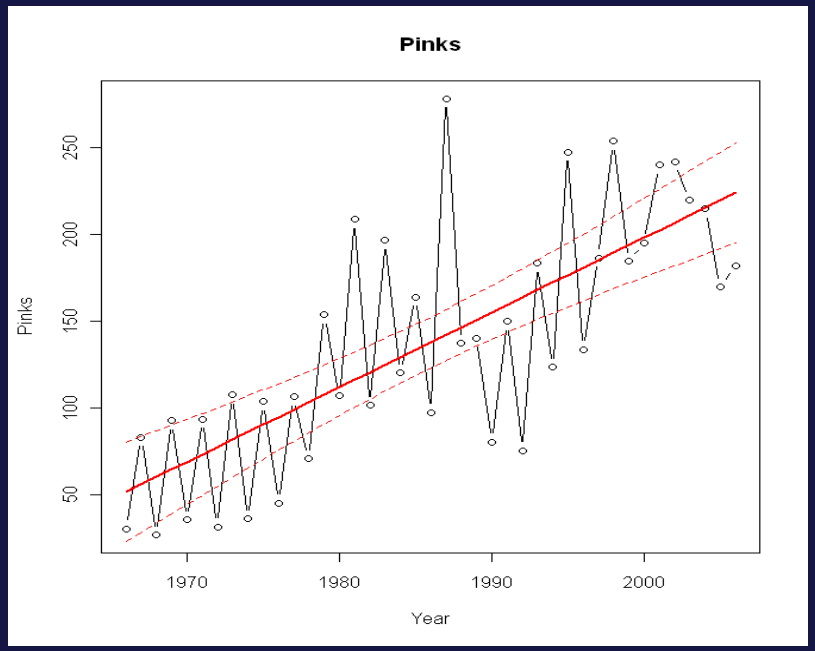


- Pacific Decadal Oscillation (PDO)
  - Used Winter Index, November – March



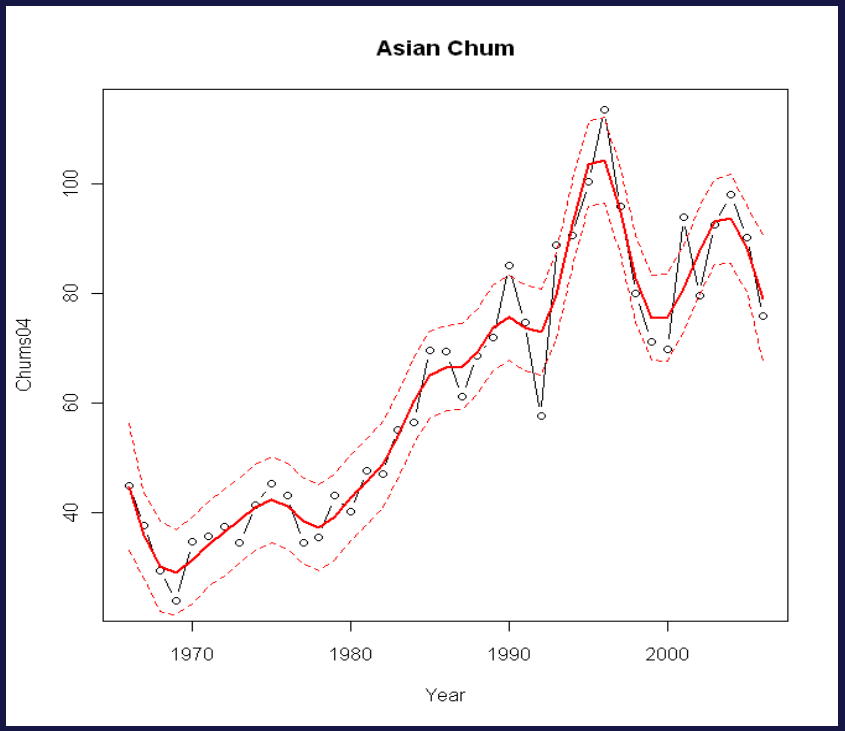
Mantua et al.

Abundance Data



Pink Salmon Abundance

- Total catch and escapement from Russia

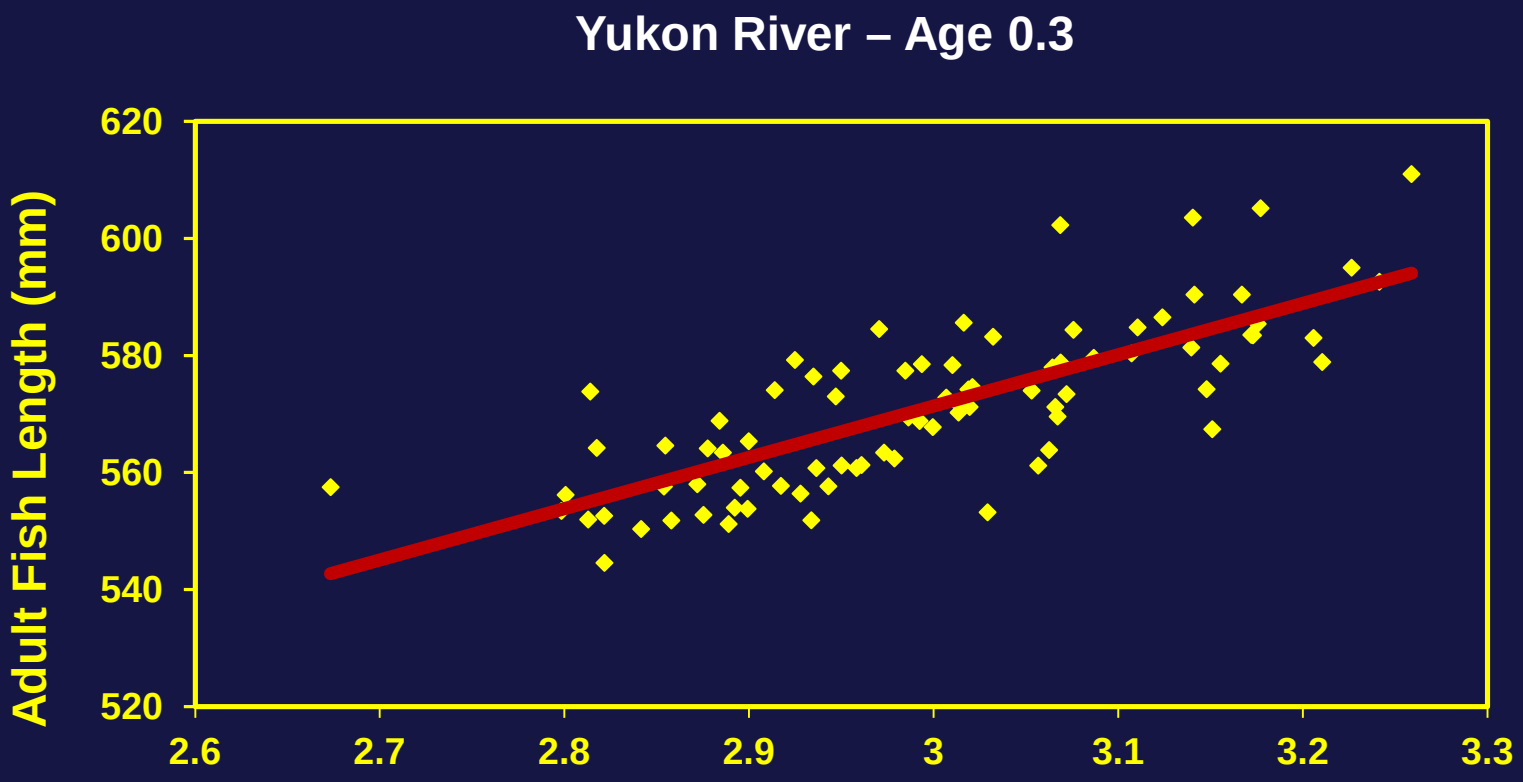


Asian Chum Salmon Abundance

- Catch and escapement data in millions of fish from Japan and Russia
- 4-year running average

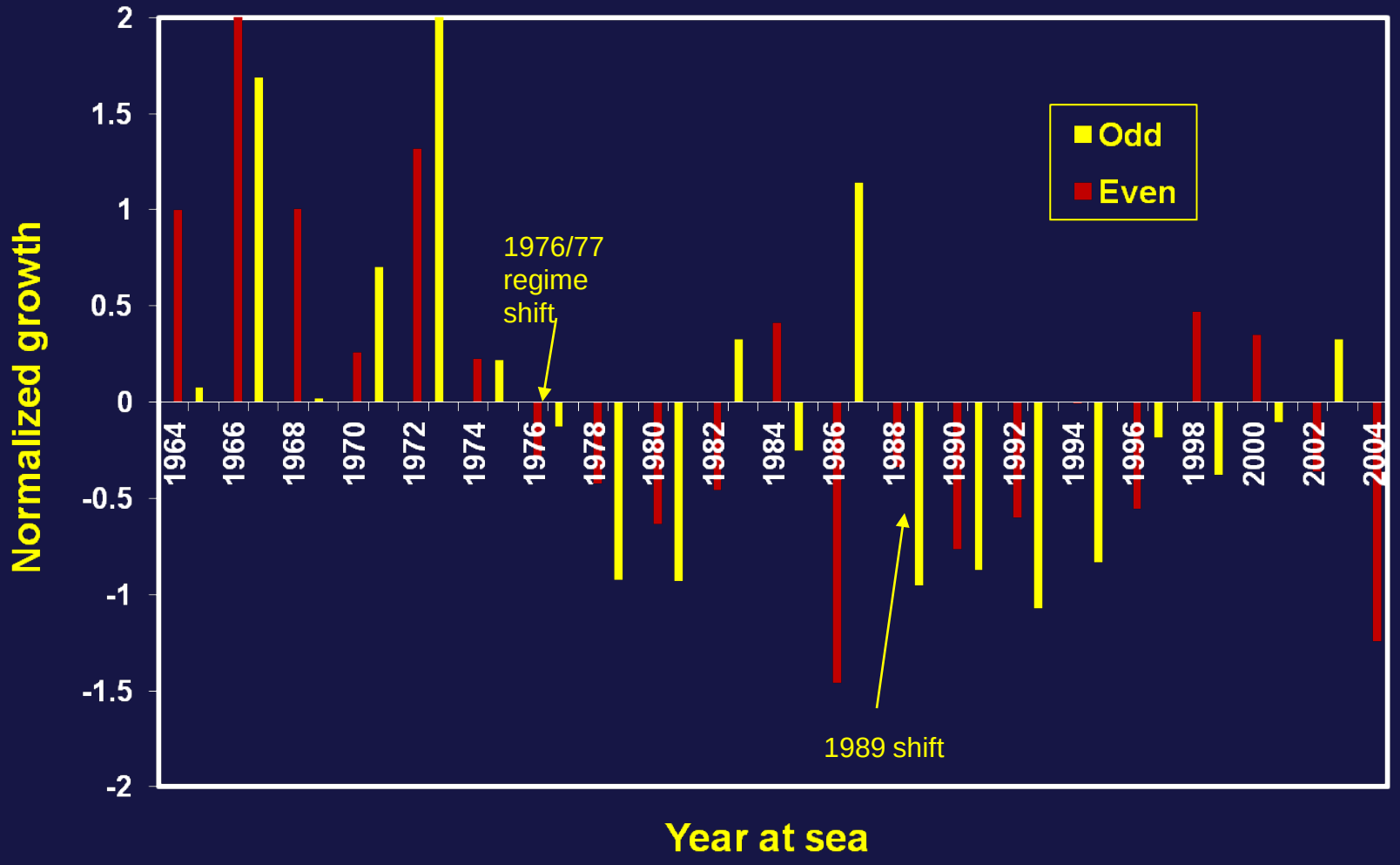
Data from Ruggerone et al. 2010 and NPAFC website

Scale growth - proxy for overall growth



Length = 362.9 + 68.1(scale growth) + 8.1(males), R^2 = 0.65, p < 0.001

BB SW3 Growth During Even vs. Odd Years at Sea

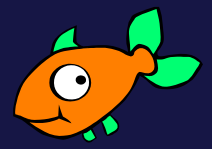


Methods

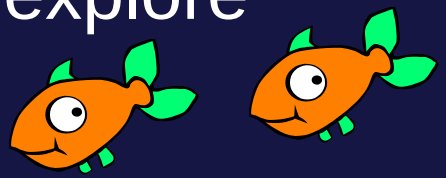
Correlations

Compared salmon growth with environmental variables using correlation analysis

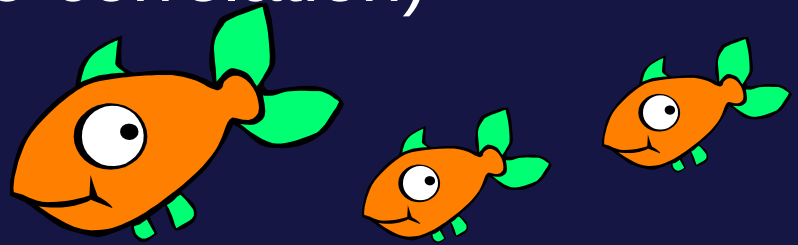
Used significant *p* values to assist in determining what to use in multiple regression models



Generalized additive models (GAMS) to explore data



Generalized Least Squares models (GLS) to model the data
(why? – accommodate auto-correlation)



Full models

SW1

SW1 ~ ALPI + NPI + Local annual SST + May wind mixing + Local air temperature + Ice Cover

SW3

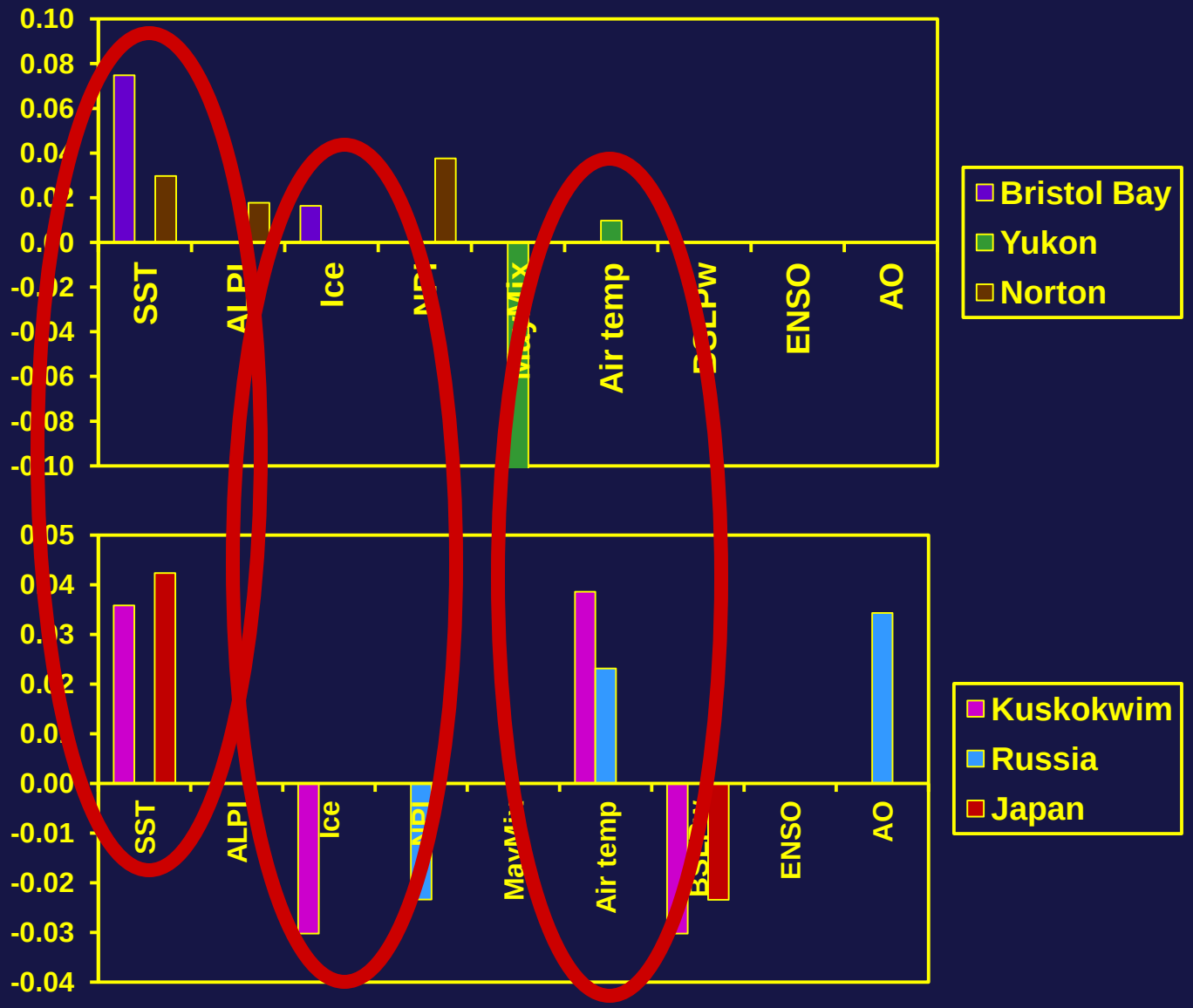
SW3 ~ Pinks + Asian chums + SST + NPI + Pinks*Asian chums + Gender

SW3 ~ Pinks + Asian chums + SST + NPI + Gender

Are there climatic factors that affect growth of chum salmon?

Final models

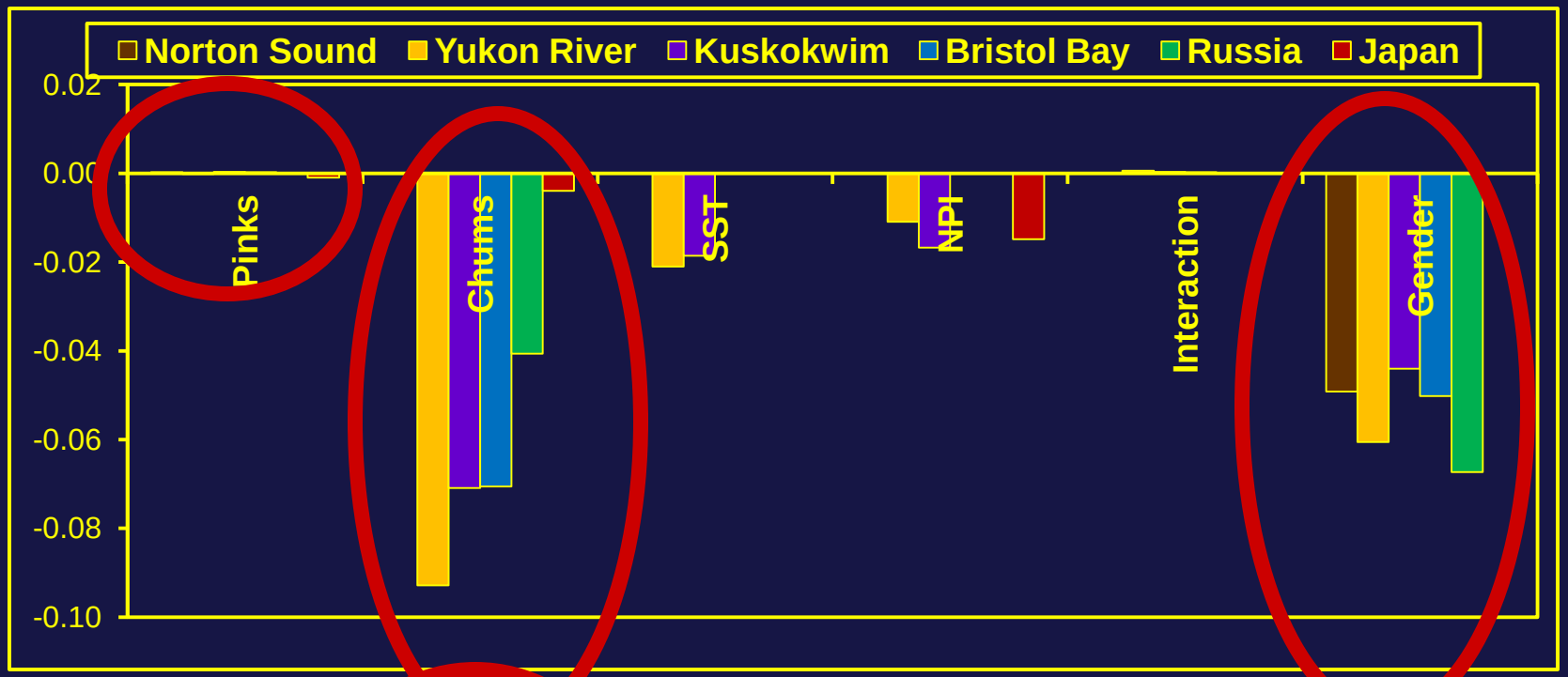
SW1
Age 0.3



What affects growth?

Final models

SW3 – Age 0.3



Norton Sound: SW3 = Pinks + Gender

Yukon River: SW3 = Pinks + Asian chums + NP SST + NPI + Interaction + Gender

Kuskokwim R: SW3 = Pinks + Asian chums + NP SST + Interaction + Gender

Bristol Bay: SW3 = Pinks + Asian chums + Interaction + Gender

Russia: SW3 = Asian chums + Gender

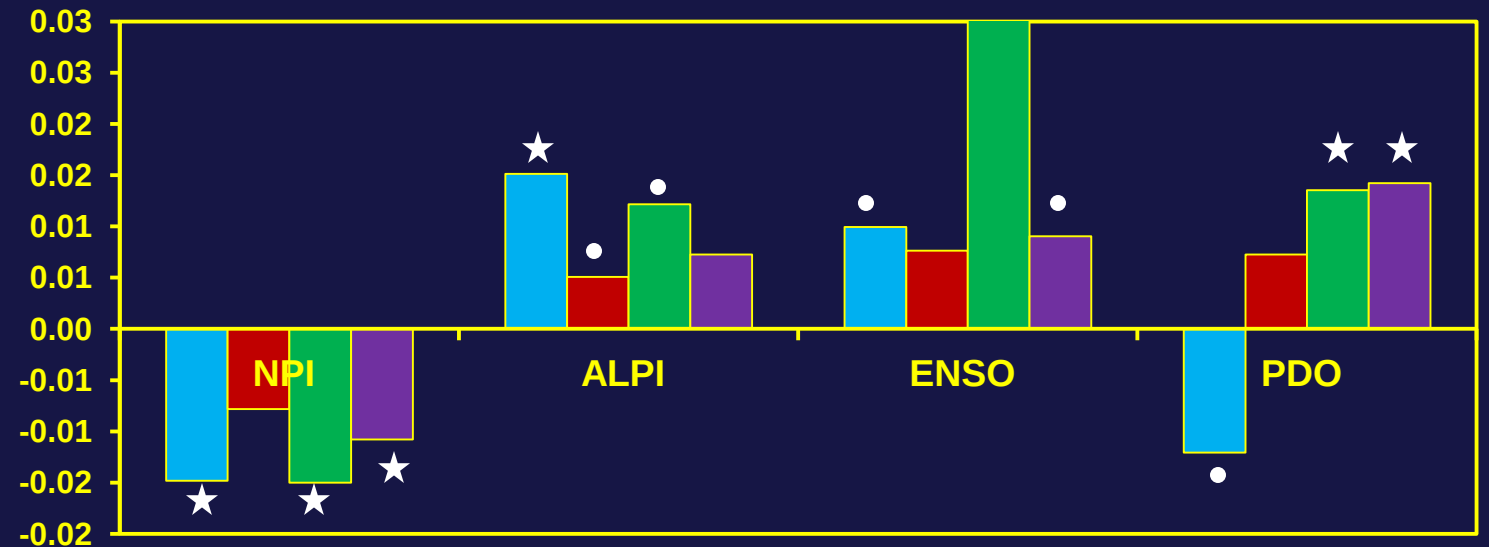
Japan: SW3 = Pinks + Asian chums + NPI + Interaction

How did growth change?

SW3 – Individual Models

Pre-1977

Post-1976

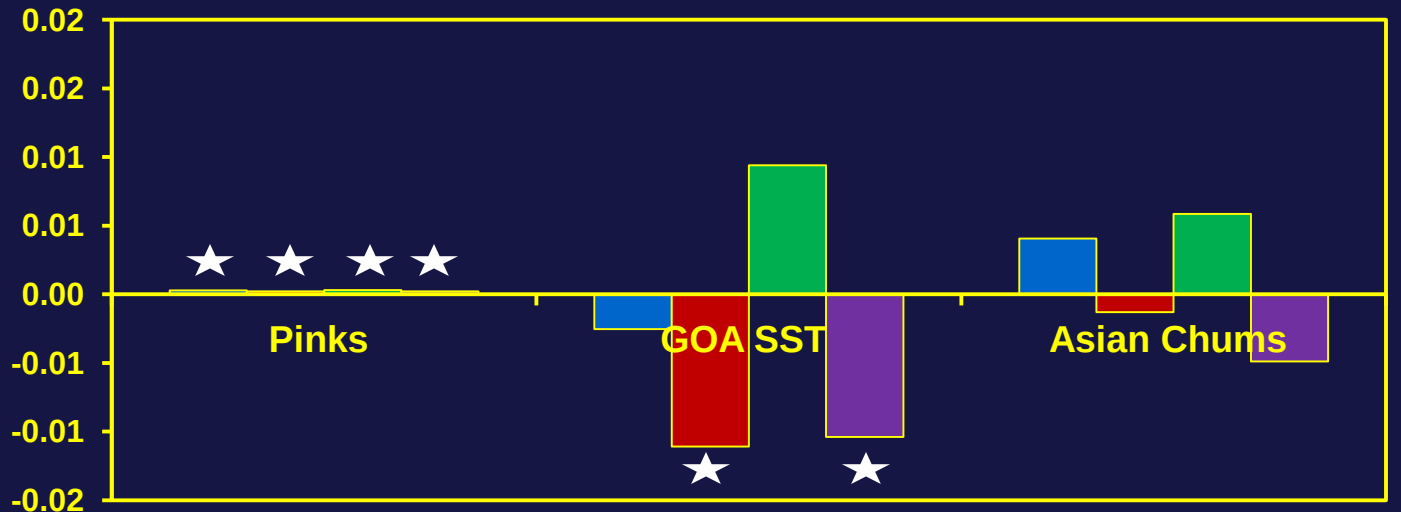


How did growth change?

SW3 – Individual Models

Pre-1977

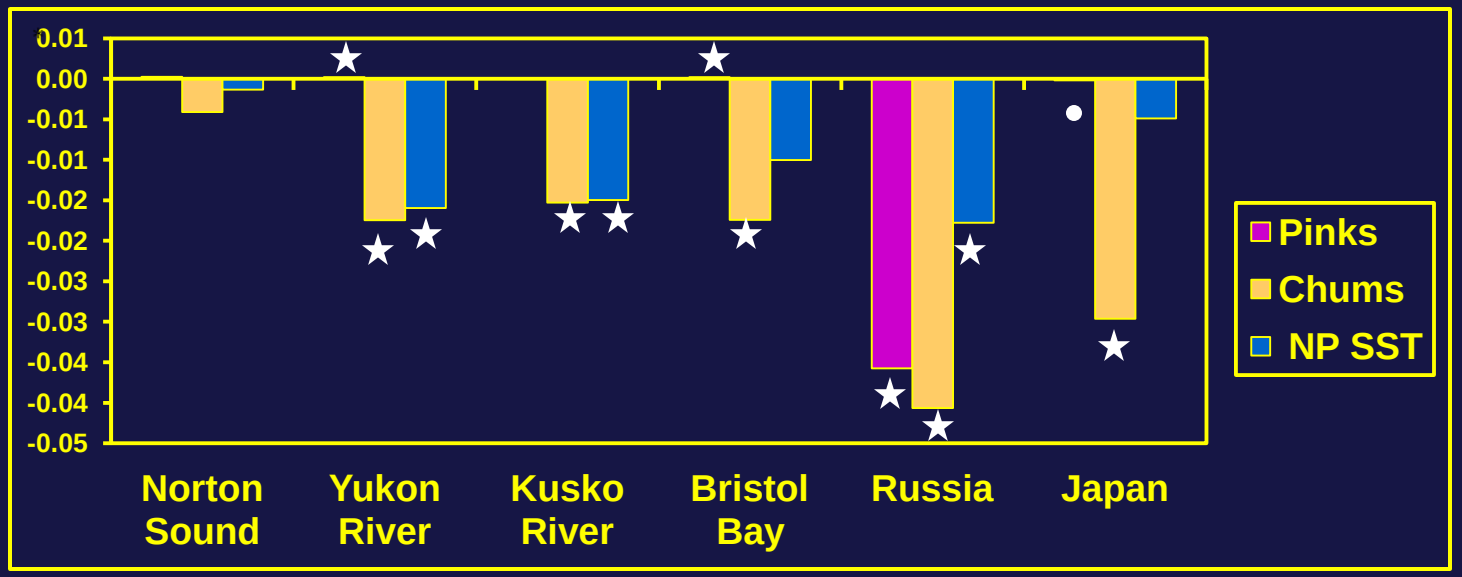
Post-1976



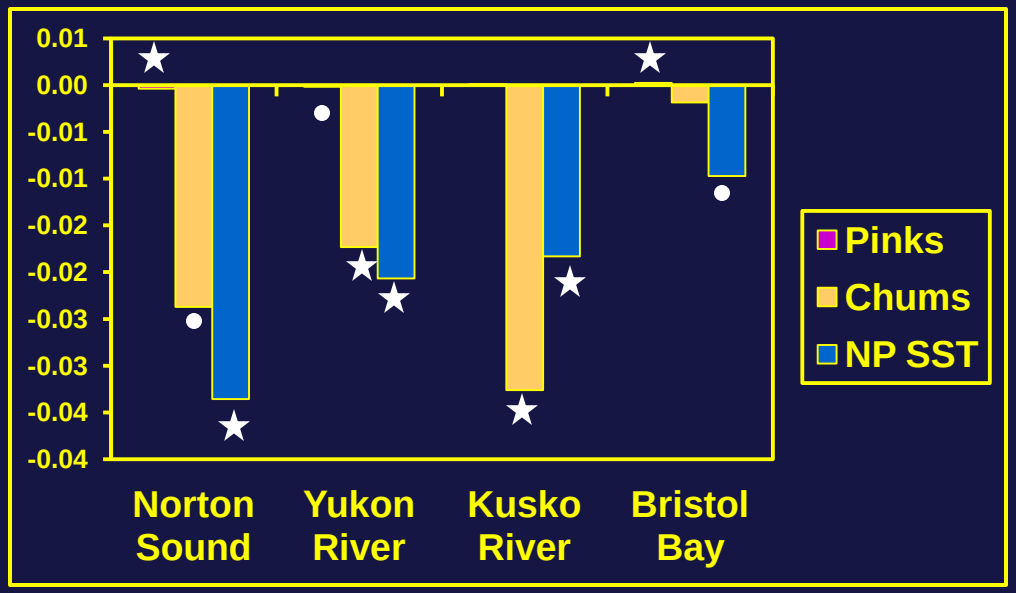
Does Asian pink & chum salmon inhibit growth?

SW3

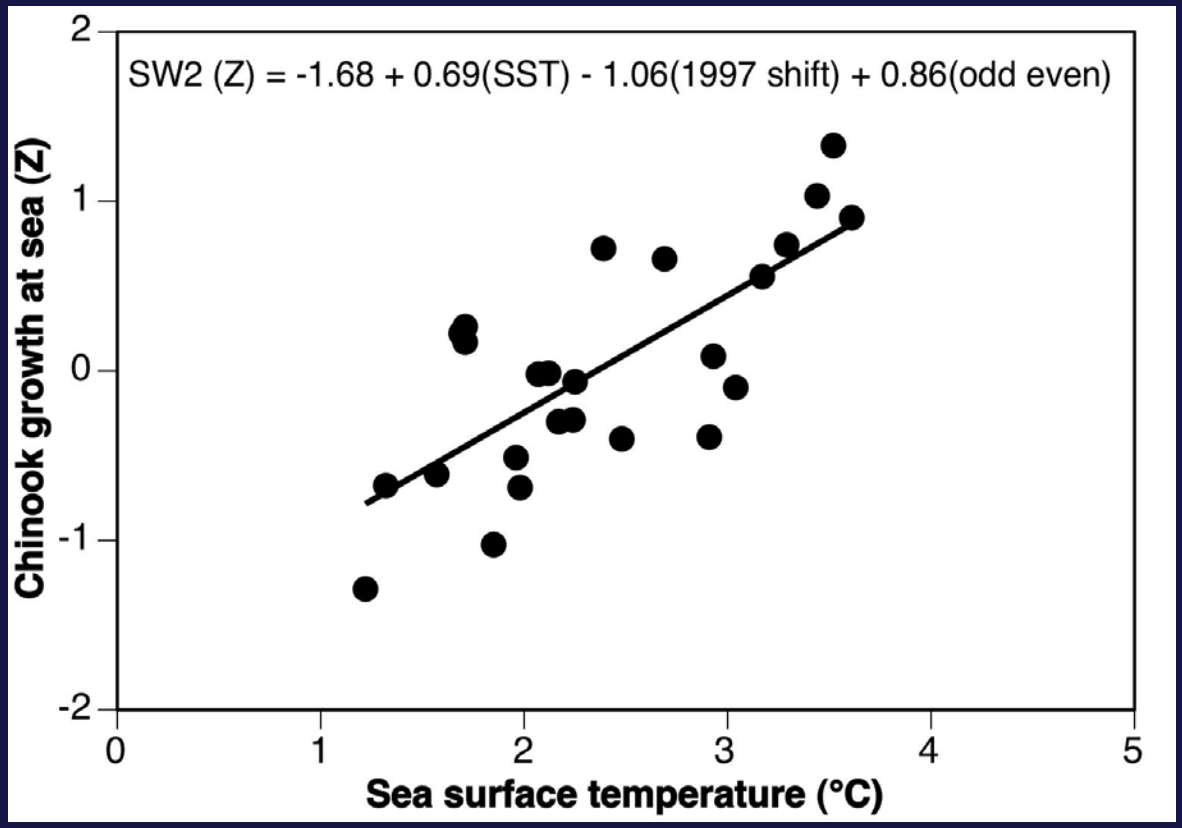
Age 0.3



Age 0.4



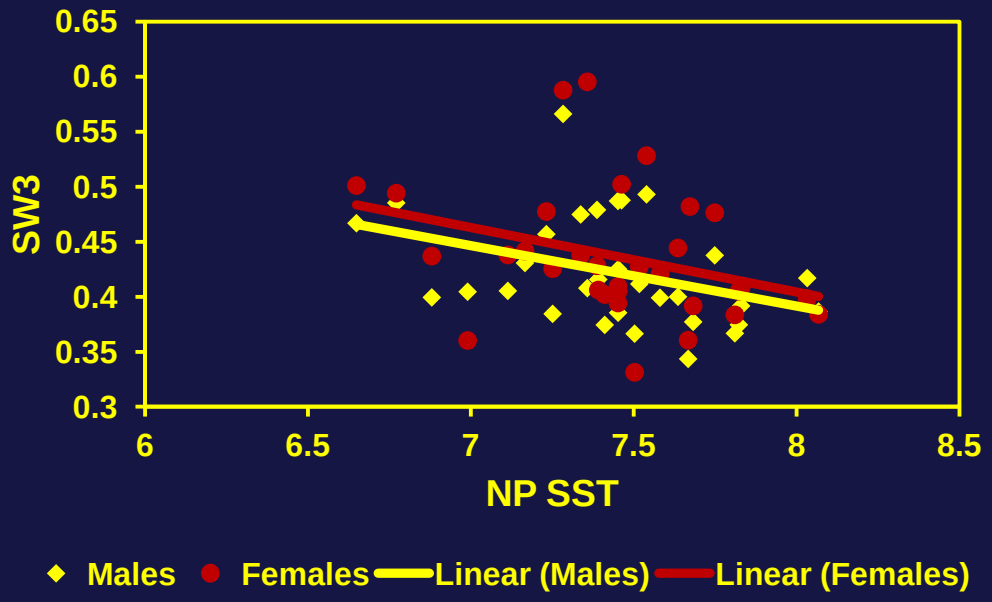
Bristol Bay Chinook SW2 Growth vs. SST



Ruggerone et al. 2012

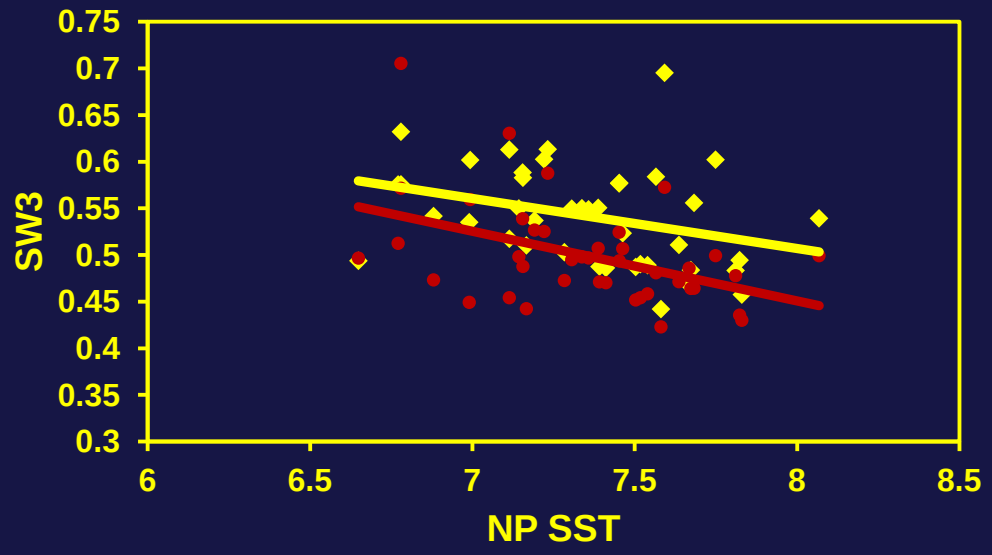
Chum SW3 Growth vs. SST

Japan
Age 0.3

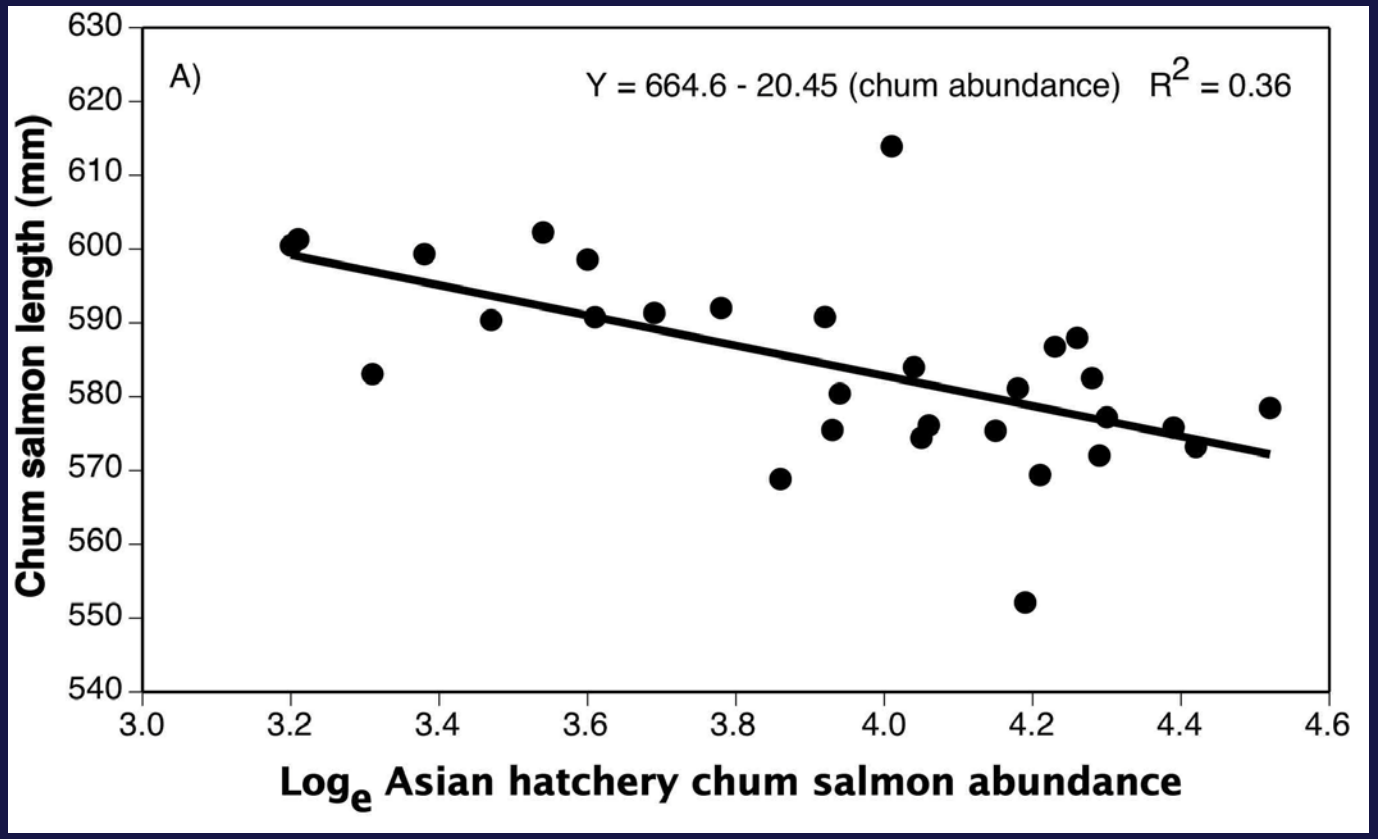


Most systems

Bristol Bay
Age 0.4



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



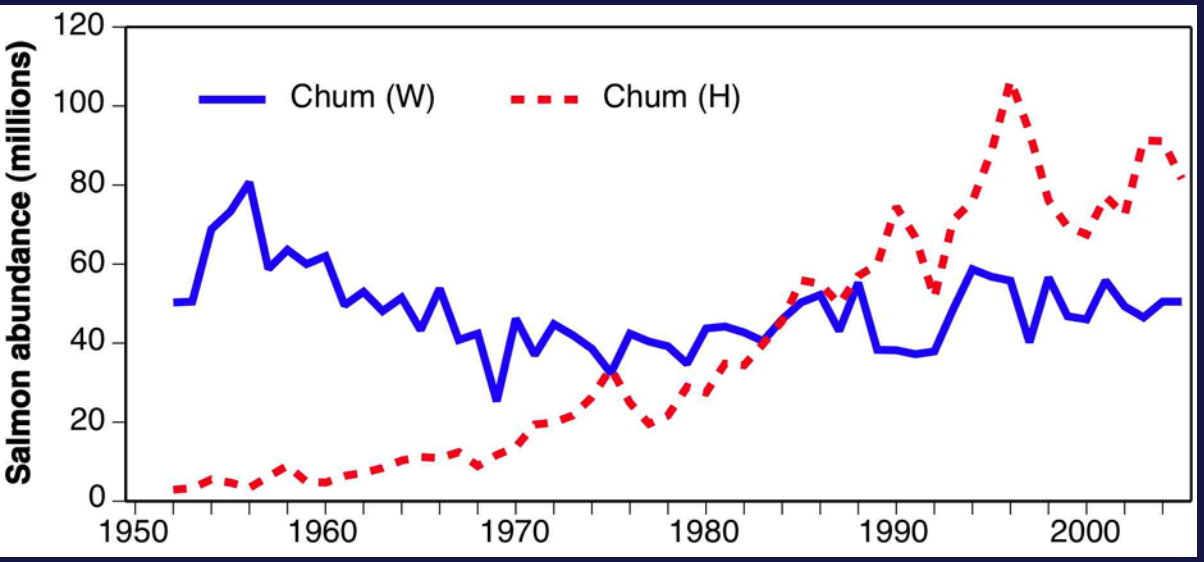
Also, Kwiniuk SW2 & SW3 scale growth inversely related to Asian chum abundance

R^2 = 0.24, 0.12

Length is mean of age 0.3 & 0.4 chum salmon

Ruggerone & Agler 2008

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



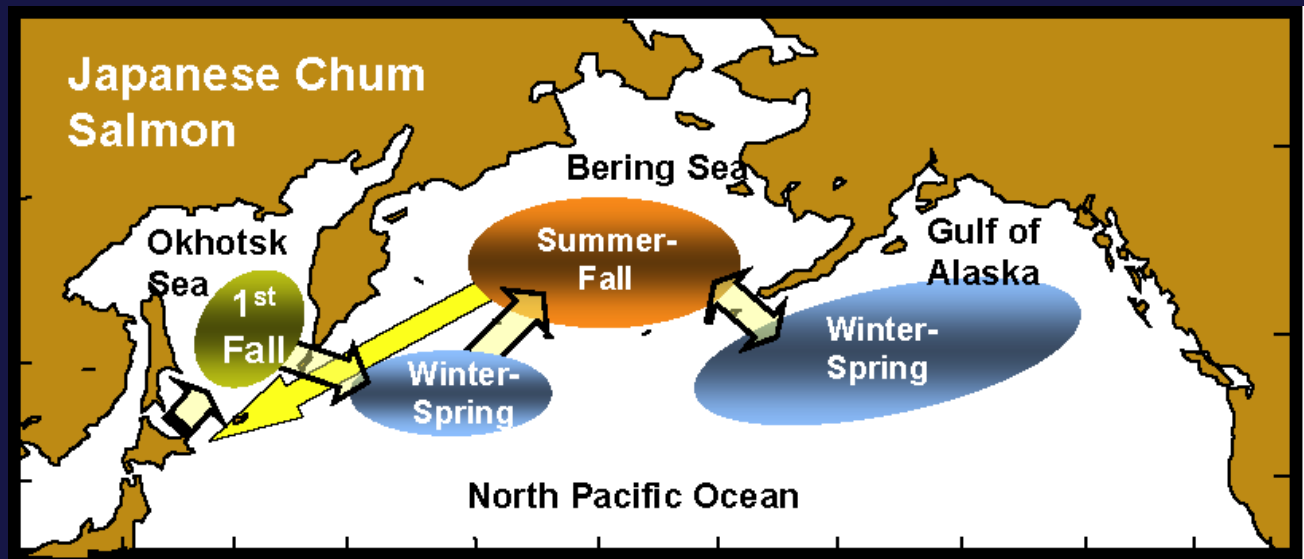
Wild chum did not increase after 1977; hatchery chum (mostly Japan)

Ruggerone et al. 2010

AYK chum overlap Japanese hatchery chum salmon

K. Myers, UW

Urawa et al. 2008



Conclusions

- SST is important throughout life cycle.
- Several environmental variables are important during first year of growth.
  - Determined by location & system.
- Dynamic system – conditions changed over these 45-year times series.
- Difficult to examine density-dependent interactions.
- For chum salmon, intraspecific competition appears likely.
  - Distributions overlap during SW3.
  - But what are the consequences of density-dependence?

Thanks & questions?

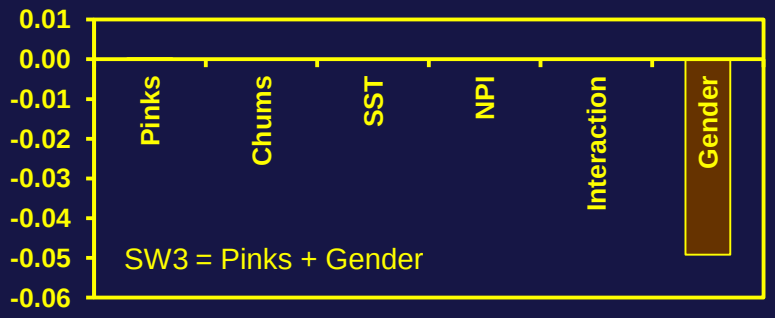
The many technicians and biologists who collected samples.
Mark, Tag, and Age Lab and ADFG staff who aged and read samples.

Samples
Dr. Zavolokin (Russia)
Dr. Saito (Japan)

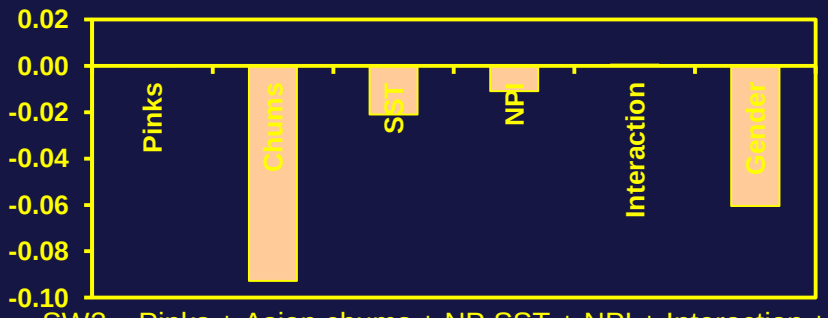
ADF&G
Megan Lovejoy, crew leader
Cathy Robinson & Ron Josephson, supervisors
Tim Frawley & Bill Rosky, IT Staff
Dion Oxman, Fishery Biologist

What affects growth?

Norton Sound



Yukon River

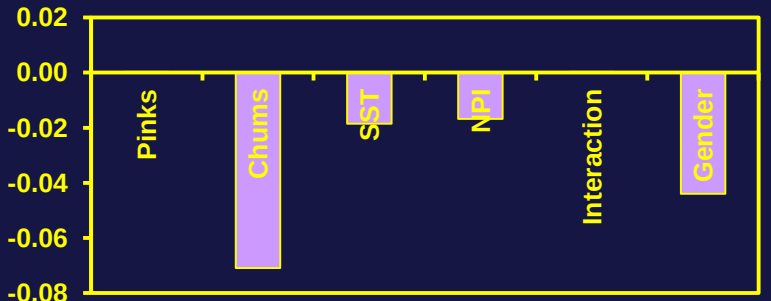


SW3 = Pinks + Asian chums + NP SST + NPI + Interaction + Gender

SW3

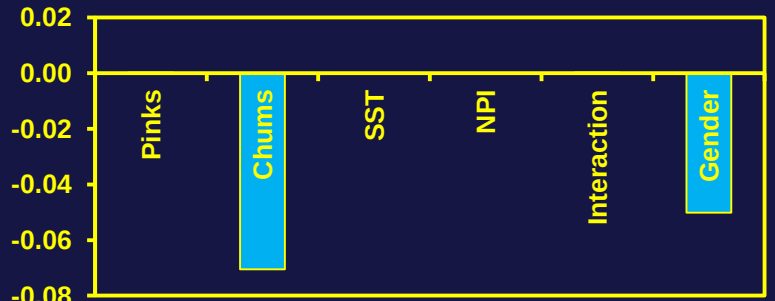
Age 0.3

Kuskokwim



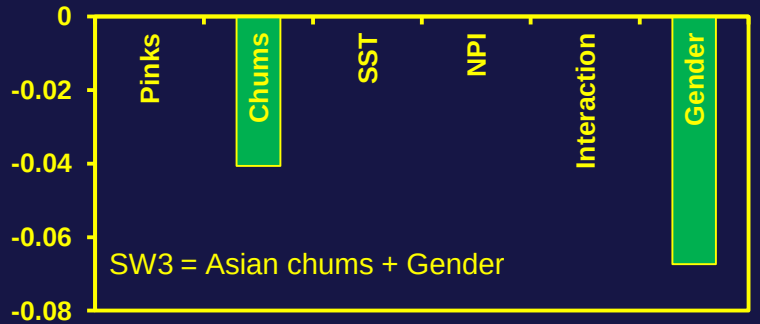
SW3 = Pinks + Asian chums + NP SST + Interaction + Gender

Bristol Bay



SW3 = Pinks + Asian chums + Interaction + Gender

Russia



Japan