Growth of Bristol Bay & Yukon River, Alaska Chum Salmon in Response to Climatic Factors & Inter-specific Competition

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Sockeye growth reduced during odd years at sea corresponding to Asian pink salmon abundance.

3rd year at sea mean = 612 ± 54 µ
BB Sockeye Length & Climate Change

$L = 550.9 - 0.178(\text{sockeye}) - 0.144(\text{pinks}), r^2 = 0.40$
Chum Salmon

– Are there climatic factors that affect growth of Bristol Bay & Yukon River, Alaska chum salmon?
  • Used several environmental variables for comparisons
– Does Asian pink salmon abundance affect growth of Alaska chum salmon?
– Does Asian chum salmon abundance affect growth of Alaska chum salmon?
Environmental Variables

- 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

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

Mantua et al.
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
  - Used a 4-year moving average
Areas Sampled

Scale Samples from 2 regions:

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

Collected 1965-2006
Scale growth - proxy for overall growth

Bristol Bay Length = 216.91 + 115.94 (Scale)  
$R^2 = 0.56$, $p = 3.6 \times 10^{-16}$

Yukon Length = 236.69 + 115.15 (Scale growth)  
$R^2 = 0.52$, $p = 9.4 \times 10^{-08}$
Scale Digitizing Equipment
Annuli & Circuli Measurements

- 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.

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

Year at sea

Normalized growth

1976/77 regime shift
1989 shift
BB Chum SW3 Growth During Even vs. Odd Years at Sea

Year at sea

Normalized growth


Odd
Even

1976/77 regime shift
1989 shift
Methods

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 Linear Models (GLMs)

- Linear model
- Why “generalized?”
  - Accommodates non-normal distribution
  - Allows violation of homogeneity
- “Ordinary” linear models are a special case of GLM
- Fits model using **iterative algorithm** (No closed-form solution as in linear model)
- Maximize likelihood **OR**, equivalently, minimize deviance
  More difficult to fit, may not always work!
SW1 – Bristol Bay

**Full model**
SW1 ~ Pinks + Chums + Local annual SST + May mixing + Local air temp

**Reduced model**
*Age 03 fish*
SW1 growth ~ Chums + Local annual SST

*Age 04 fish*
SW1 growth ~ Chums + Local annual SST + May Mixing
SW1 – Yukon River

**Full model – Age 03**
SW1 ~ ALPI + Local Annual SST + May Mixing + Nome Annual Temperature

**Reduced model**
SW1 growth ~ May Mixing + Nome Annual Temperature

**Full model – Age 04**
SW1 ~ ALPI + Local Annual SST + NPI + Nome Annual Temperature

**Reduced model**
SW1 ~ ALPI + Local Annual SST
SW3 – Bristol Bay

Full model
SW3 ~ Pinks + Chum + GOA Annual SST + ALPI + Gender + Pinks:Chum

Reduced model
Age 03 and 04 fish
SW3 ~ Pinks + Chum + GOA Annual SST + Gender + Pinks:Chum
SW3 – Yukon River

**Full model**
SW3 ~ Pinks + Chum + GOA Annual SST + NPI + Gender + Pinks:Chum

**Reduced model**
*Age 03 and 04 fish*
SW3 ~ Pinks + Chum + GOA Annual SST + Gender + Pinks:Chum
Are there climatic factors that affect growth of Bristol Bay & Yukon River, Alaska chum salmon?
Climatic factors?

Gulf of Alaska Annual SST

Bristol Bay

Yukon

SW3
Does Asian pink salmon abundance affect growth of Bristol Bay & Yukon chum salmon?

Yes, SW3 only, negative correlation
Asian chum salmon abundance & growth of Bristol Bay and Yukon chum salmon

Yes, SW3 Only, negative correlation
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

Japanese Chum Salmon
North Pacific Ocean
Stock Composition of Maturing Chum Salmon estimated by GSI June/July 2003

Asian chum much more abundant than Western AK chum

Urawa et al. 2008
Where next?

- Compare with other systems
  - Norton Sound
  - Kuskokwim
  - Japan
  - Russia

  - Few issues to examine
    - Simplify models?
      - Originally used on Pinks + PDO
    - Autocorrelation
Conclusions

• Environmental variables important during first year of growth.

• Appears to be density-dependent interactions among western Alaska chum salmon and Asian pink & chum salmon.

• Competition at sea can affect salmon growth & future productivity.

• Research is needed to better understand species interactions & mechanisms impacting salmon survival.