Growth & Survival of Salmon at Sea in Response to Competition & Climate Change

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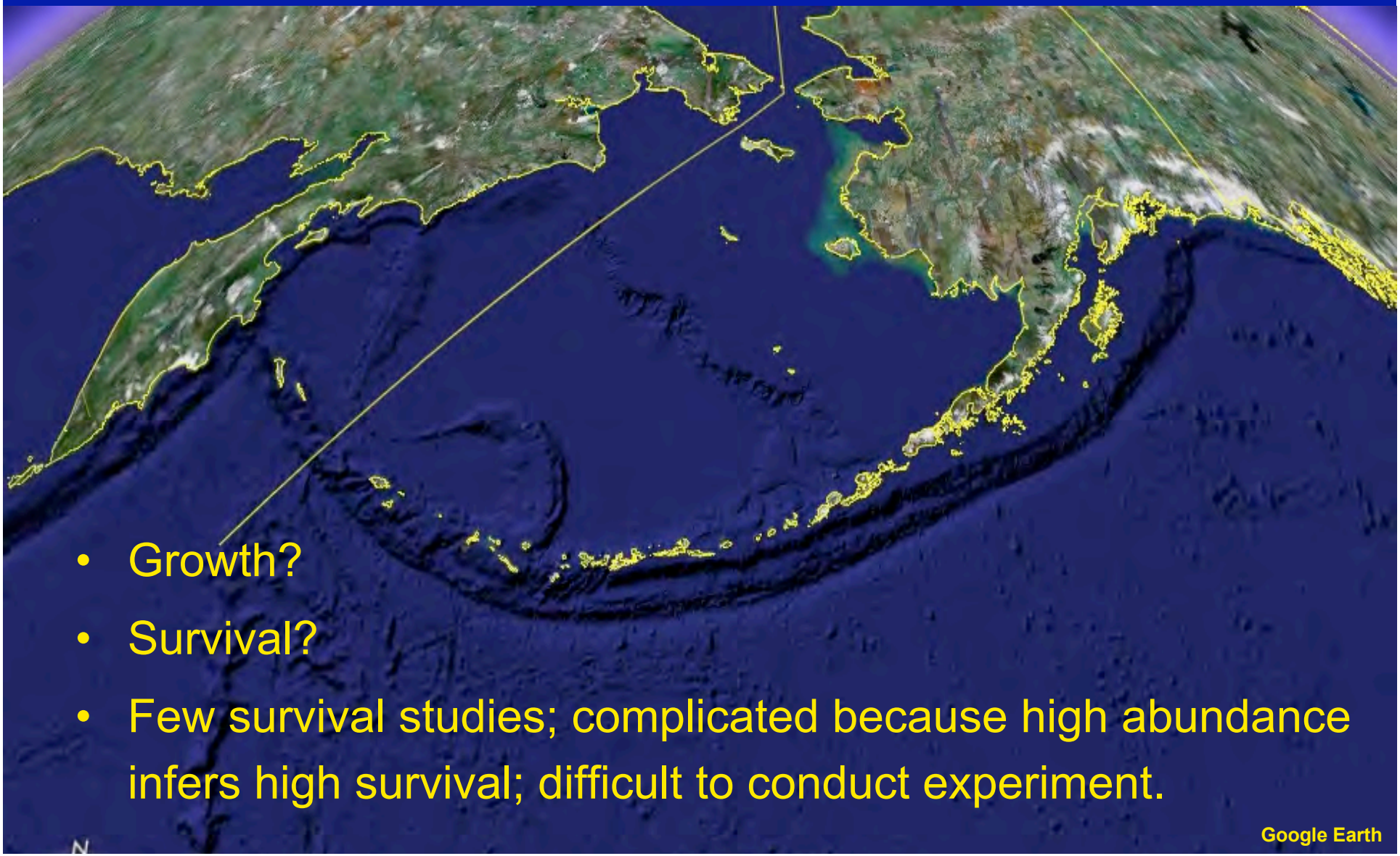
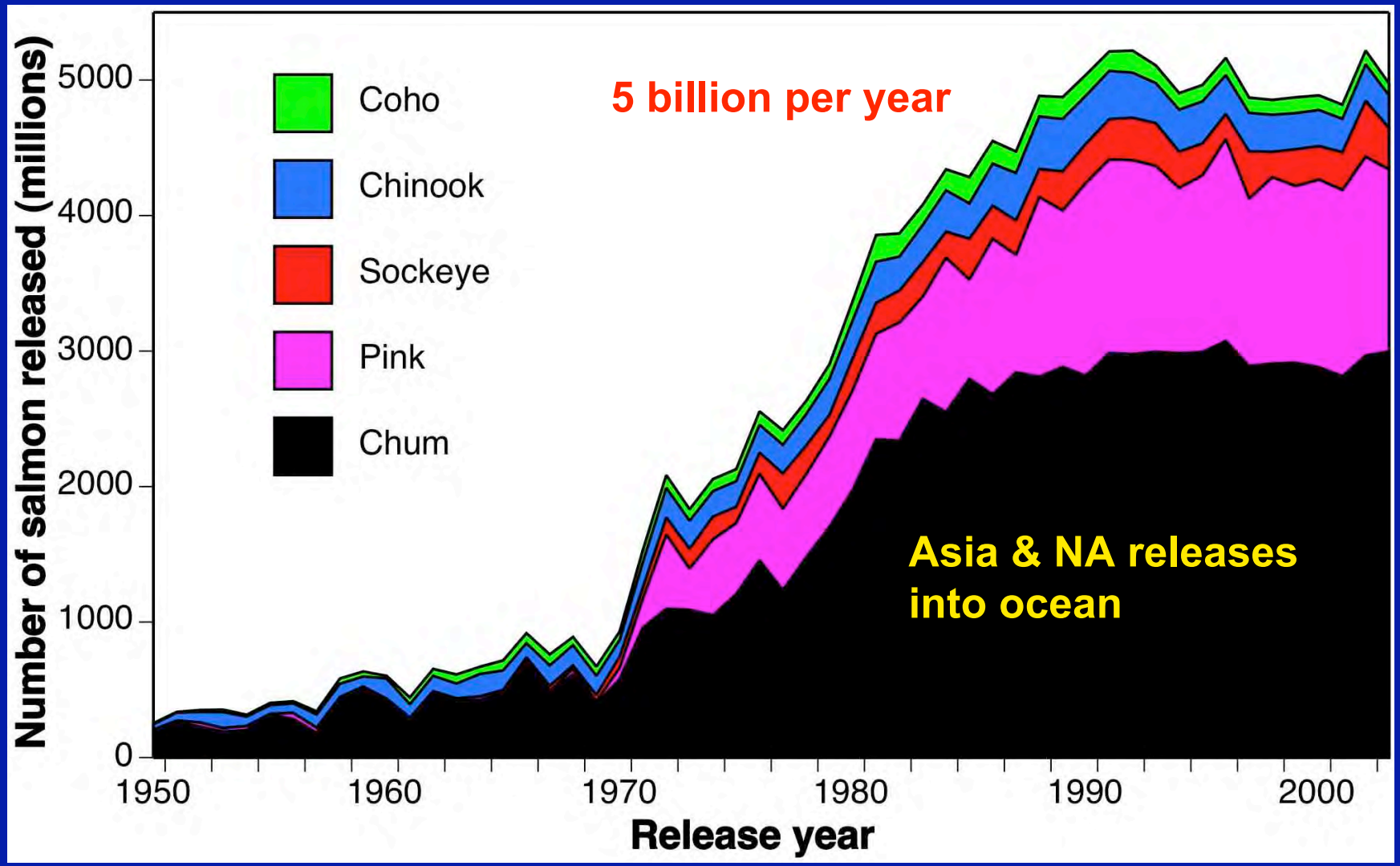
Does competition in the Ocean occur among or between salmon species?



- Growth?
- Survival?
- Few survival studies; complicated because high abundance infers high survival; difficult to conduct experiment.

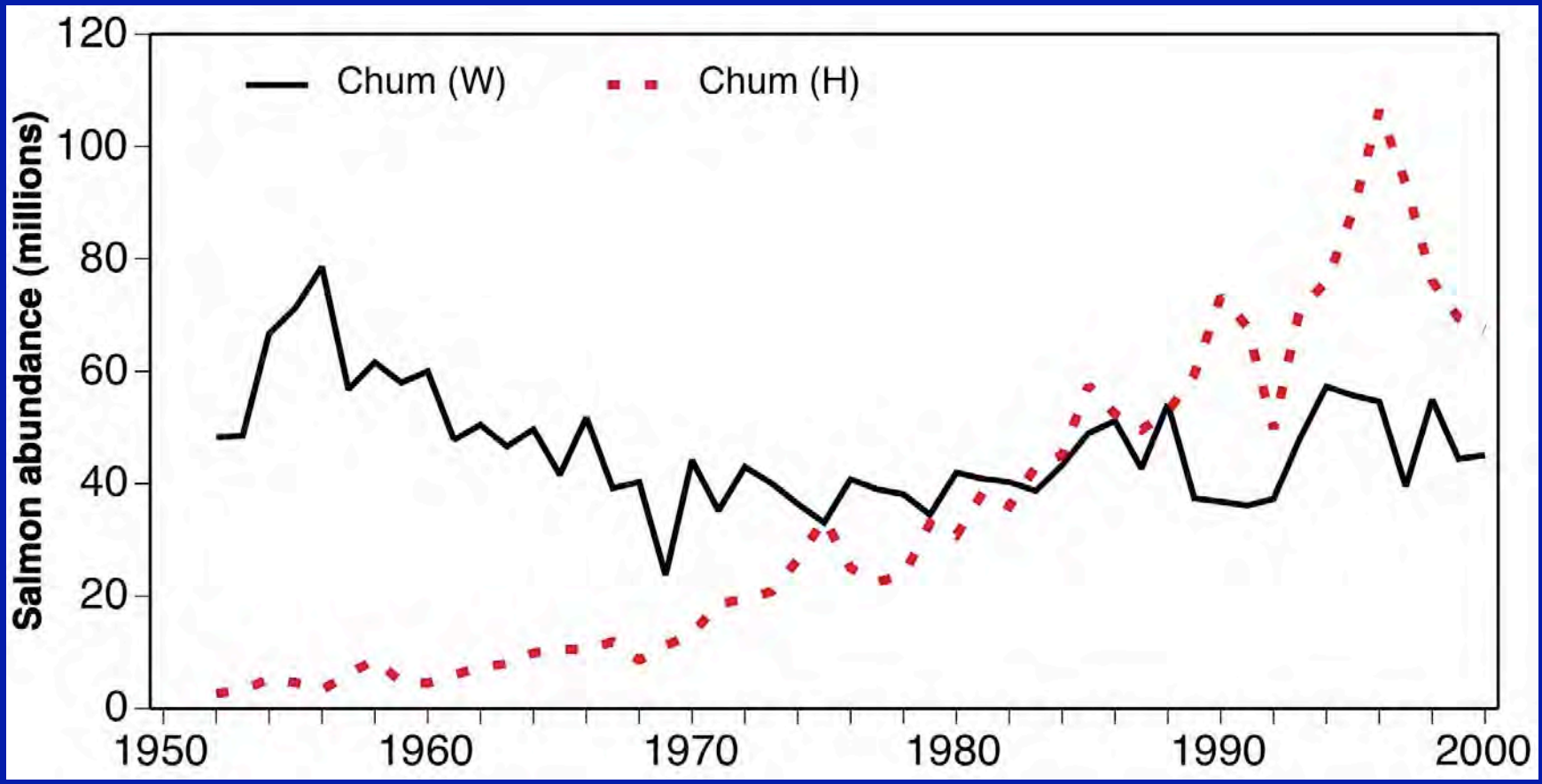
Google Earth

Hatchery Premise: No Competition



Updated from Mahnken et al. 1998

Wild v. Hatchery Chum Abundance: Competition?



Wild pink and sockeye salmon increased after mid-1970s
Why not wild chum salmon?

Competition Controversy

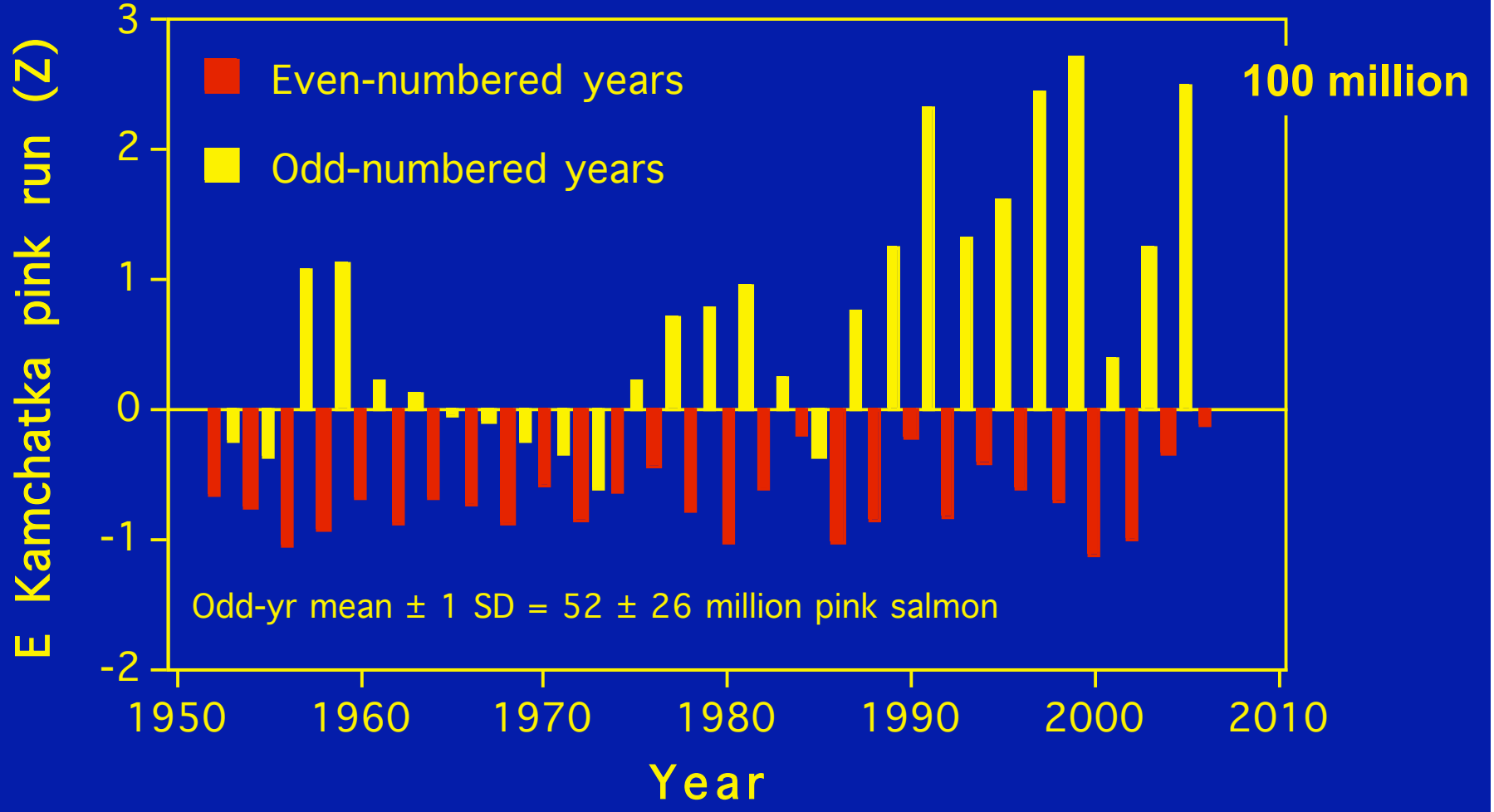
- Shuntov, Laevastu studies:
  - Many prey in ocean
  - Salmon consume <2% of prey eaten by all nekton
  - All nekton consume <10% of total prey production
  - Salmon do not shoal beyond coastal waters
  - Competition not likely important
- Correlation & modeling growth studies
  - Multiple species & regions suggest competition
  - Density-dependent growth (adults & juveniles)
  - Few survival studies
  - Effects of reduced size on future production?

Bristol Bay Sockeye Salmon

- Competition with Asian pink salmon
  - Growth
  - Survival
- Mechanism for AK sockeye salmon increase after 1977 ocean regime shift
  - Increase growth early marine life?
  - Competition?

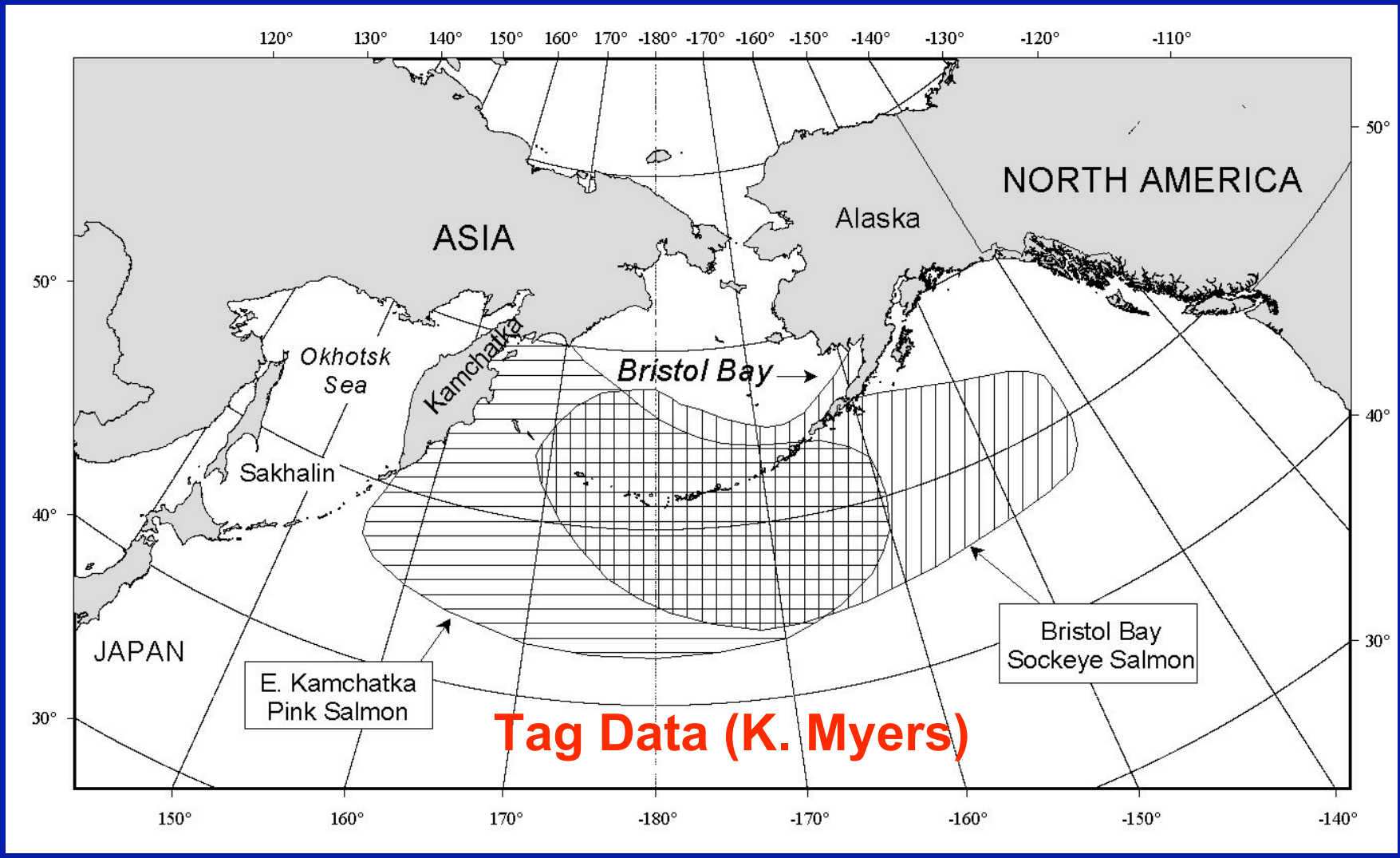
Eastern Kamchatka Pink Salmon Runs, 1952-2006

Natural Experimental Control

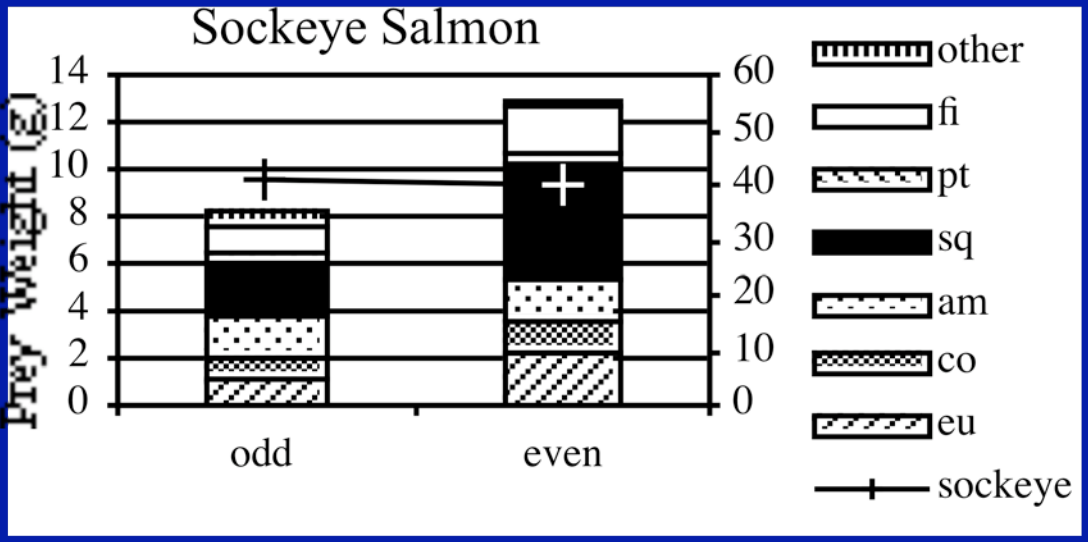


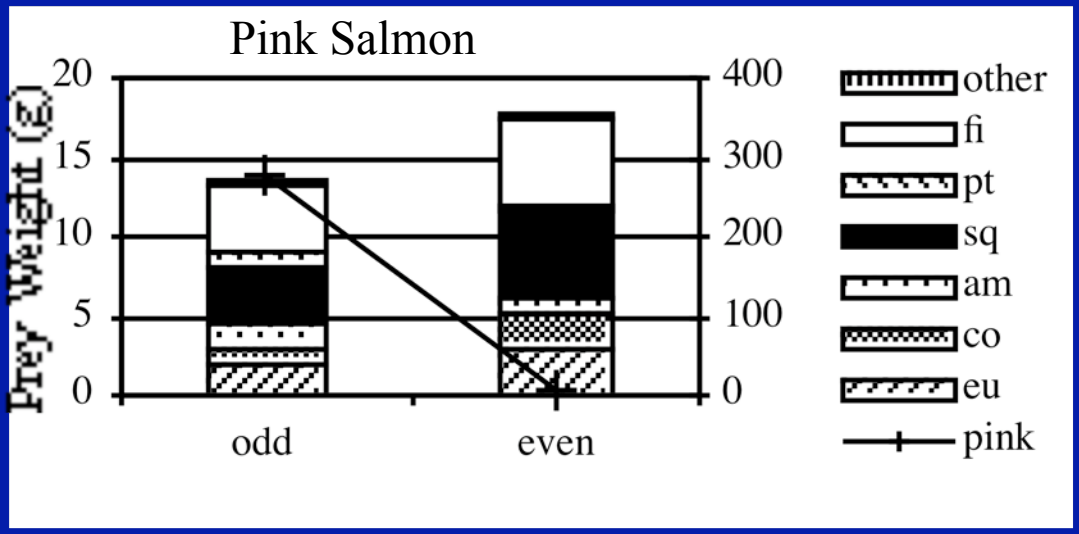
Odd-year pink salmon 39x more abundant in Bering Sea (Davis et al. 2005)

Overlap of E Kamchatka Pink & Bristol Bay Sockeye salmon



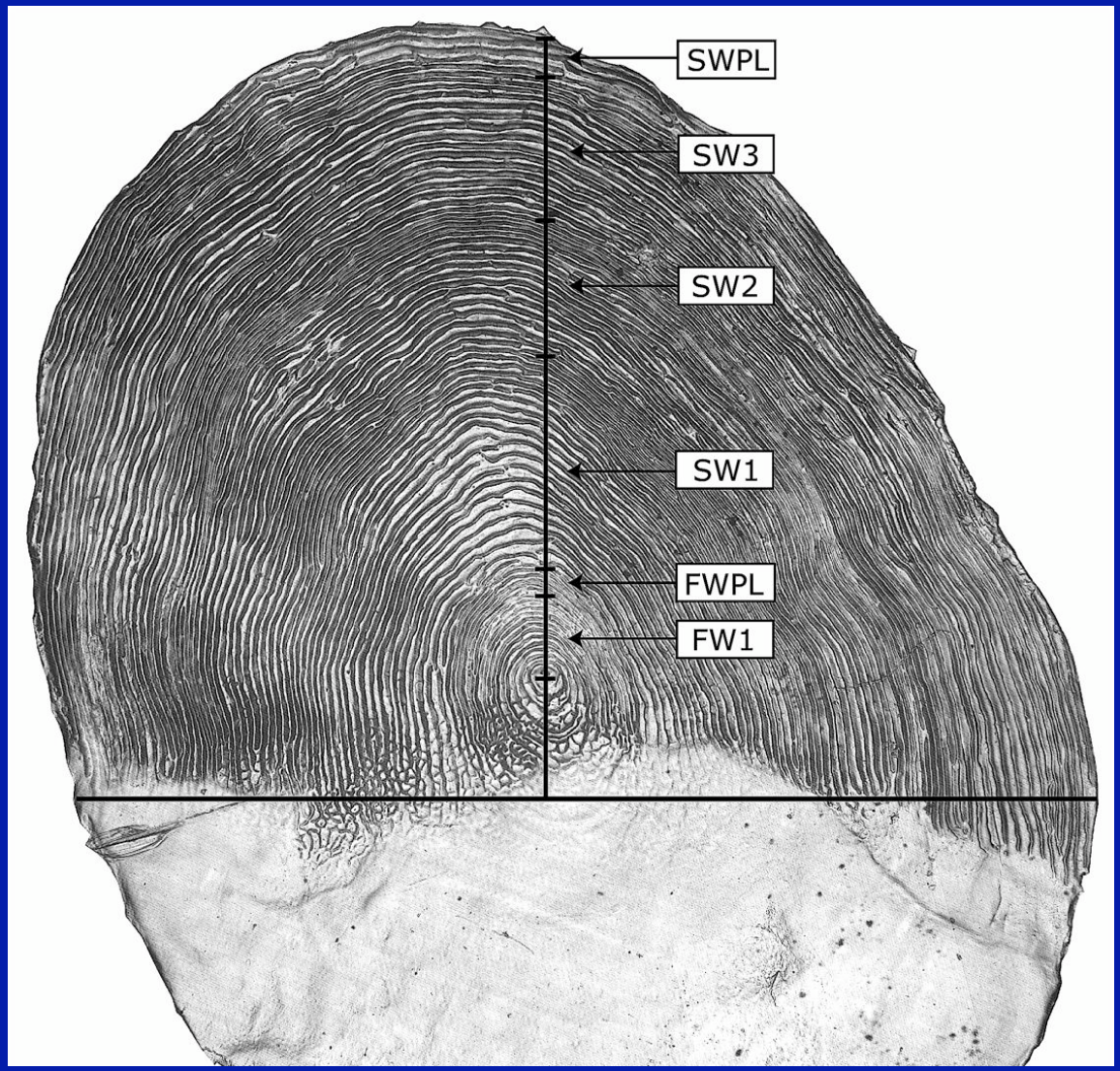
Sockeye & Pink Salmon Diet Overlap in Bering Sea, 1991-2000 (Davis et al. 2005)



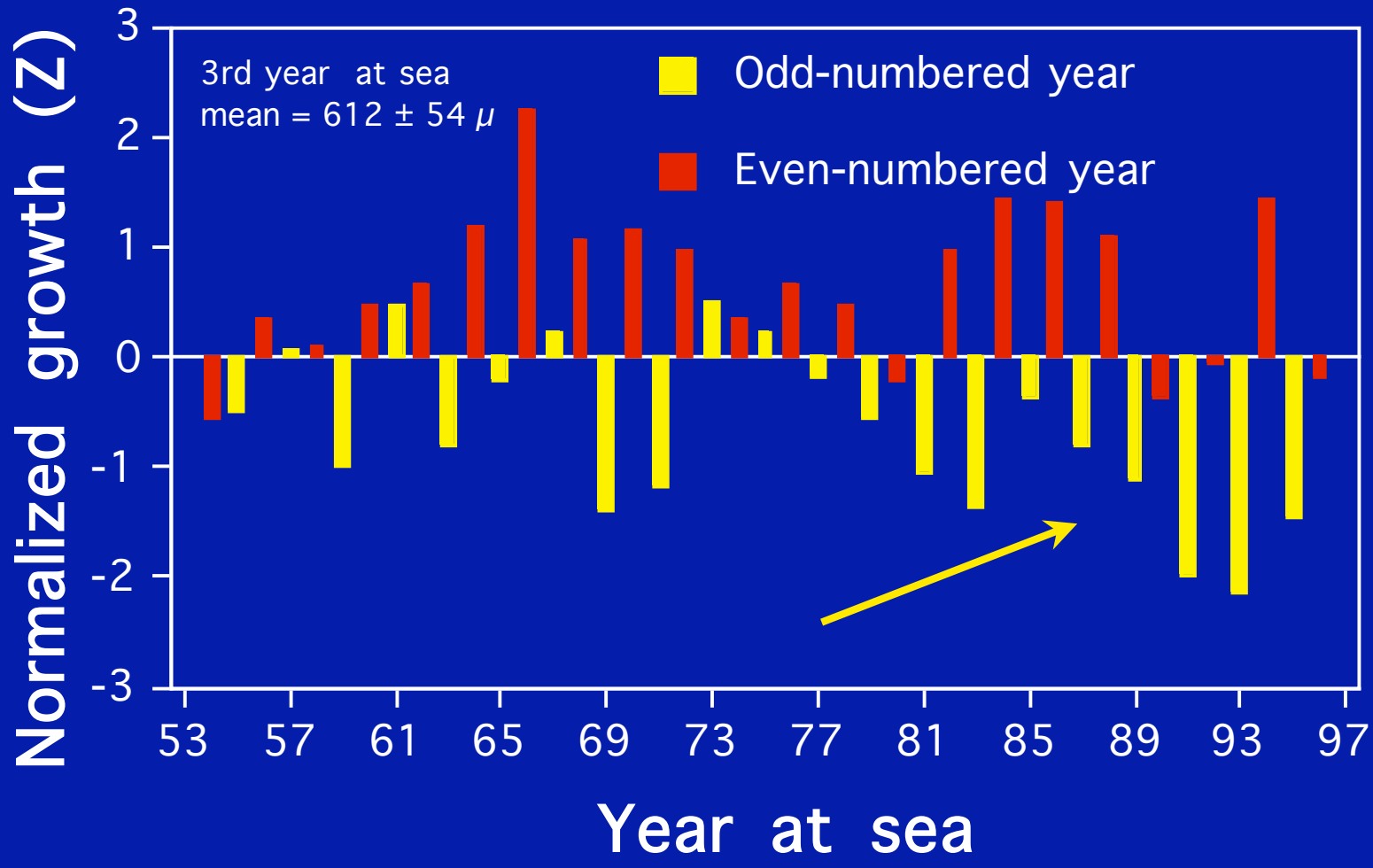


- Stomach content of sockeye & pink salmon declined 36% & 24%, respectively, in odd-years.
- Key prey (squid & fish) declined 27% in sockeye, 7% in pinks.
- Pink CPUE was 58x greater than sockeye.

Salmon Scales Record Growth Across Time & Broad Regions of Ocean



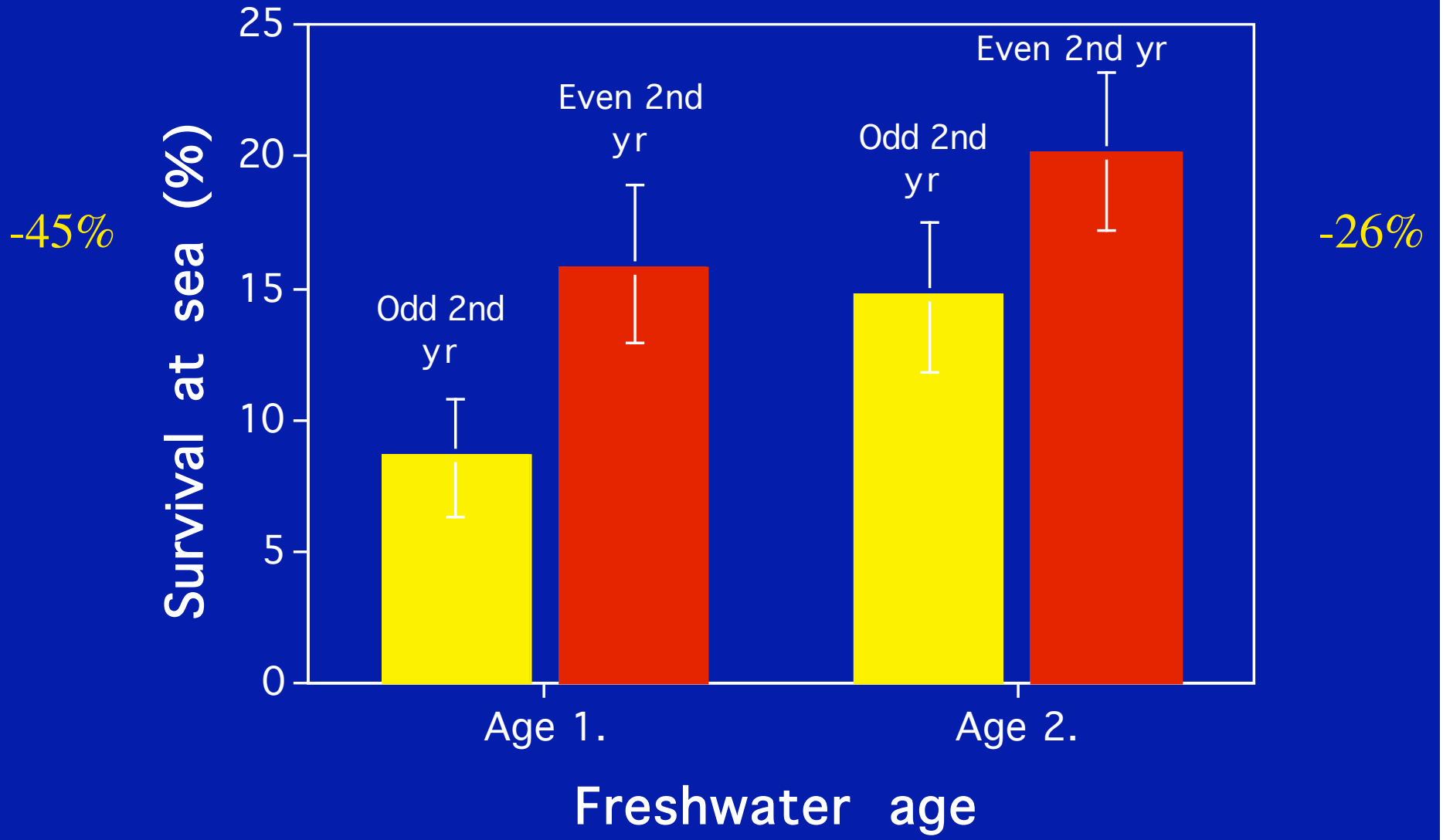
Bristol Bay sockeye growth reduced during odd years at sea (2nd & 3rd yrs)



Pinks increase after mid-1970s

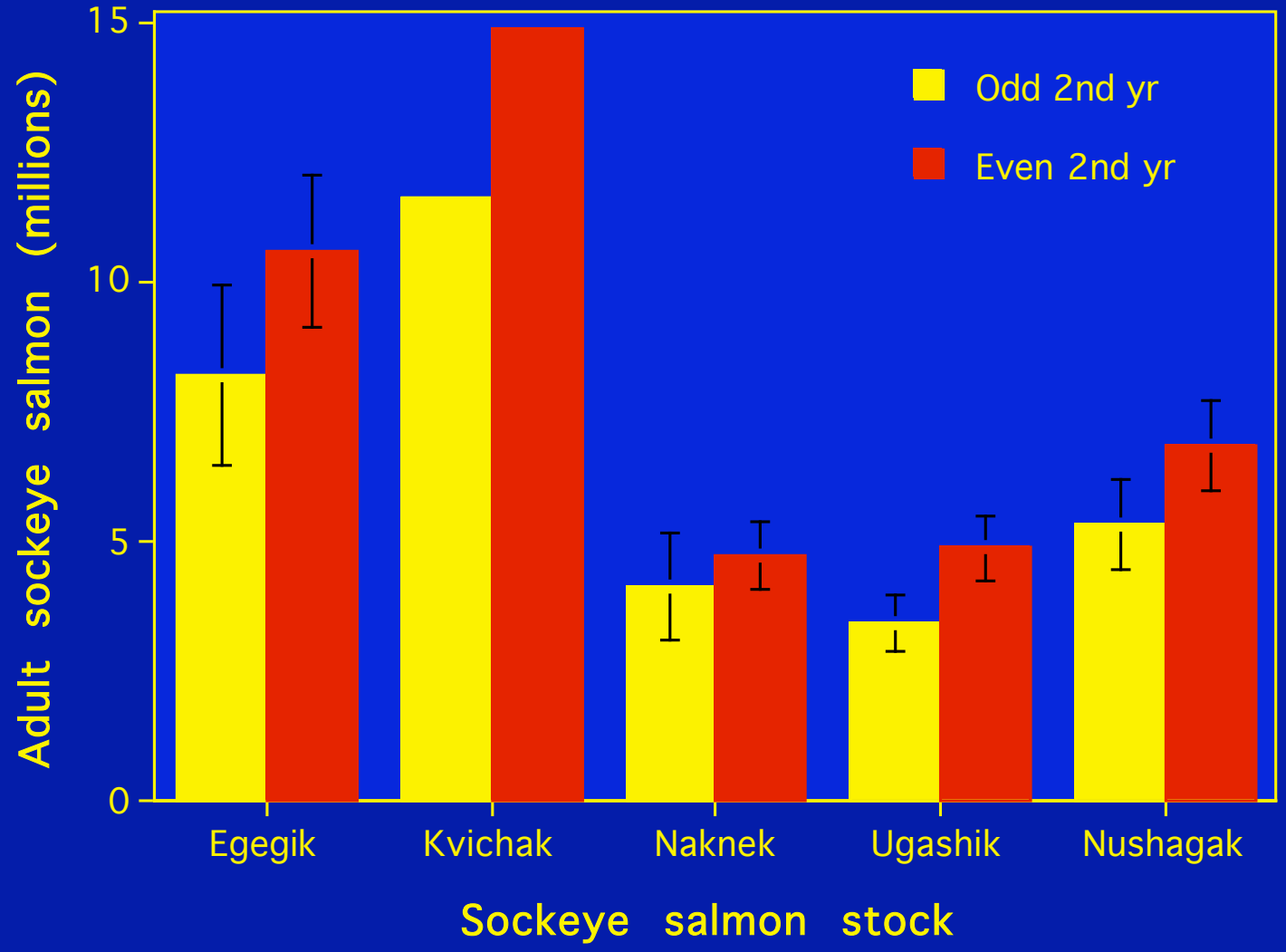
Ruggerone et al. 2003

Smolt to Adult Survival, 1977-1997



Ruggerone et al. 2003

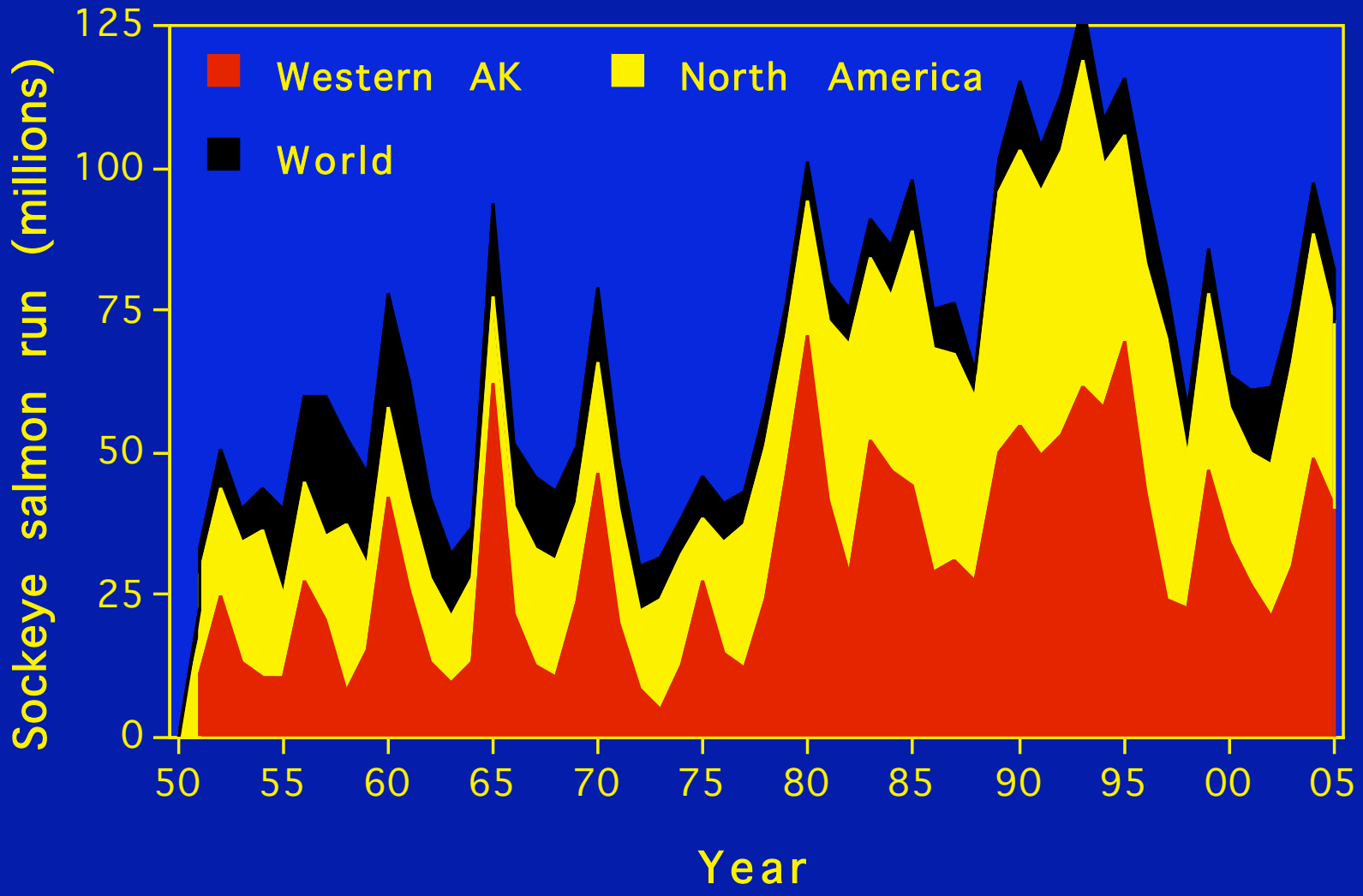
91 Million Fewer Sockeye, 1977-1997 ($482 million loss)



22% loss

Ruggerone & Nielsen 2004

Abundance of AK sockeye salmon doubled after 1977
Mechanism?



Hypothesis:

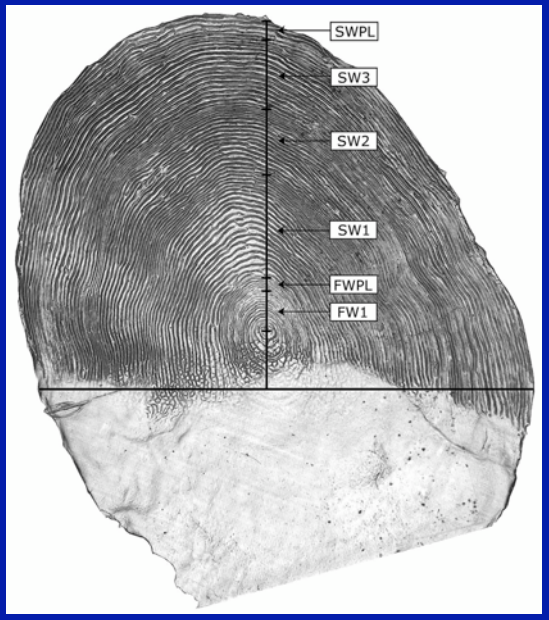
- 1976/77 climate shift led to greater growth at sea & greater survival & abundance.

- Problems:
  - Few long-term data on salmon prey abundance.
  - Adult size (all species) has declined over time & density-dependence.

- How do we know if salmon prey increased if adult size has decreased?

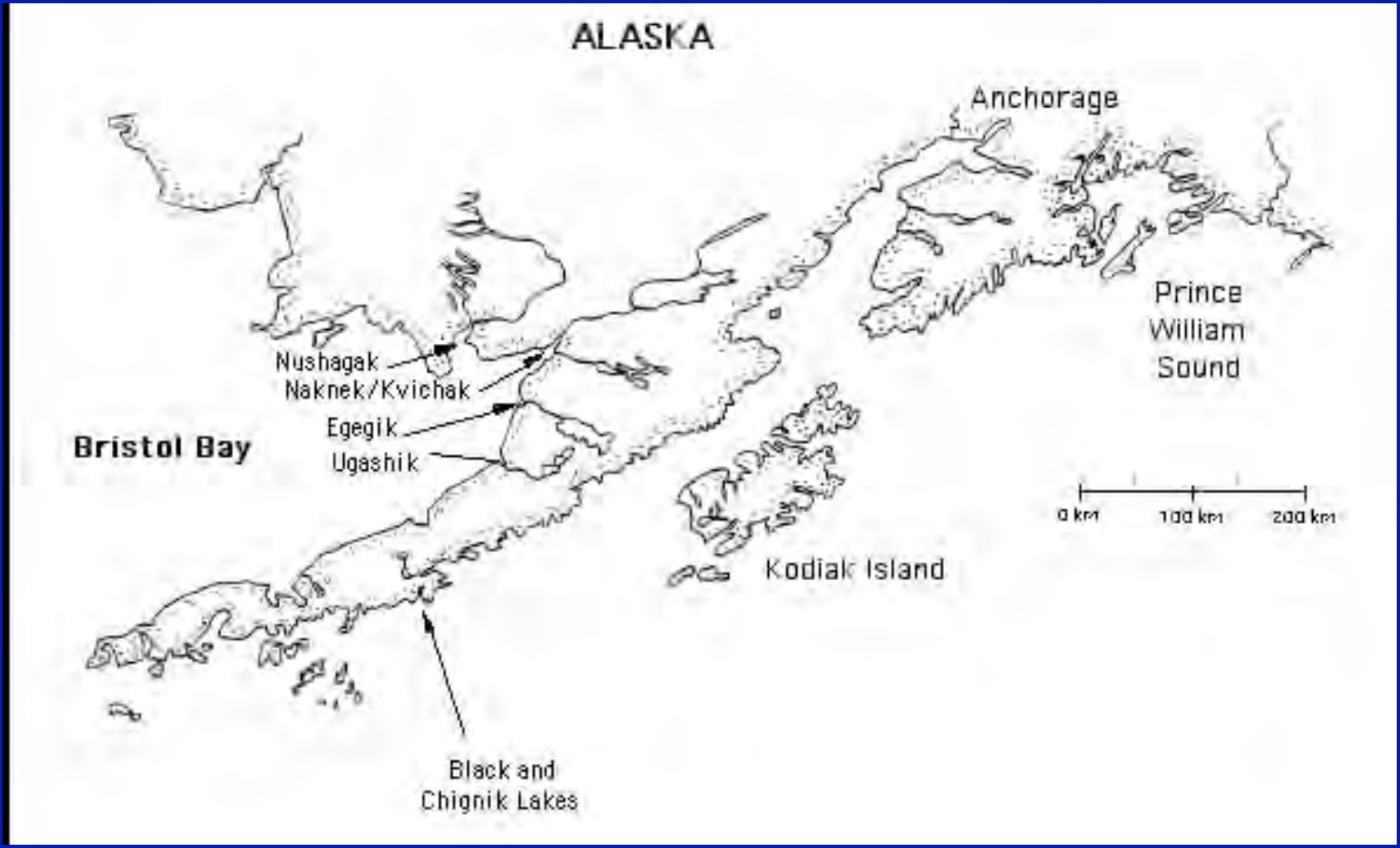
Test Hypothesis:

- 1976/77 climate shift led to greater growth at sea & greater survival & abundance.
- Bristol Bay & Chignik sockeye salmon scale growth 1955-2001.



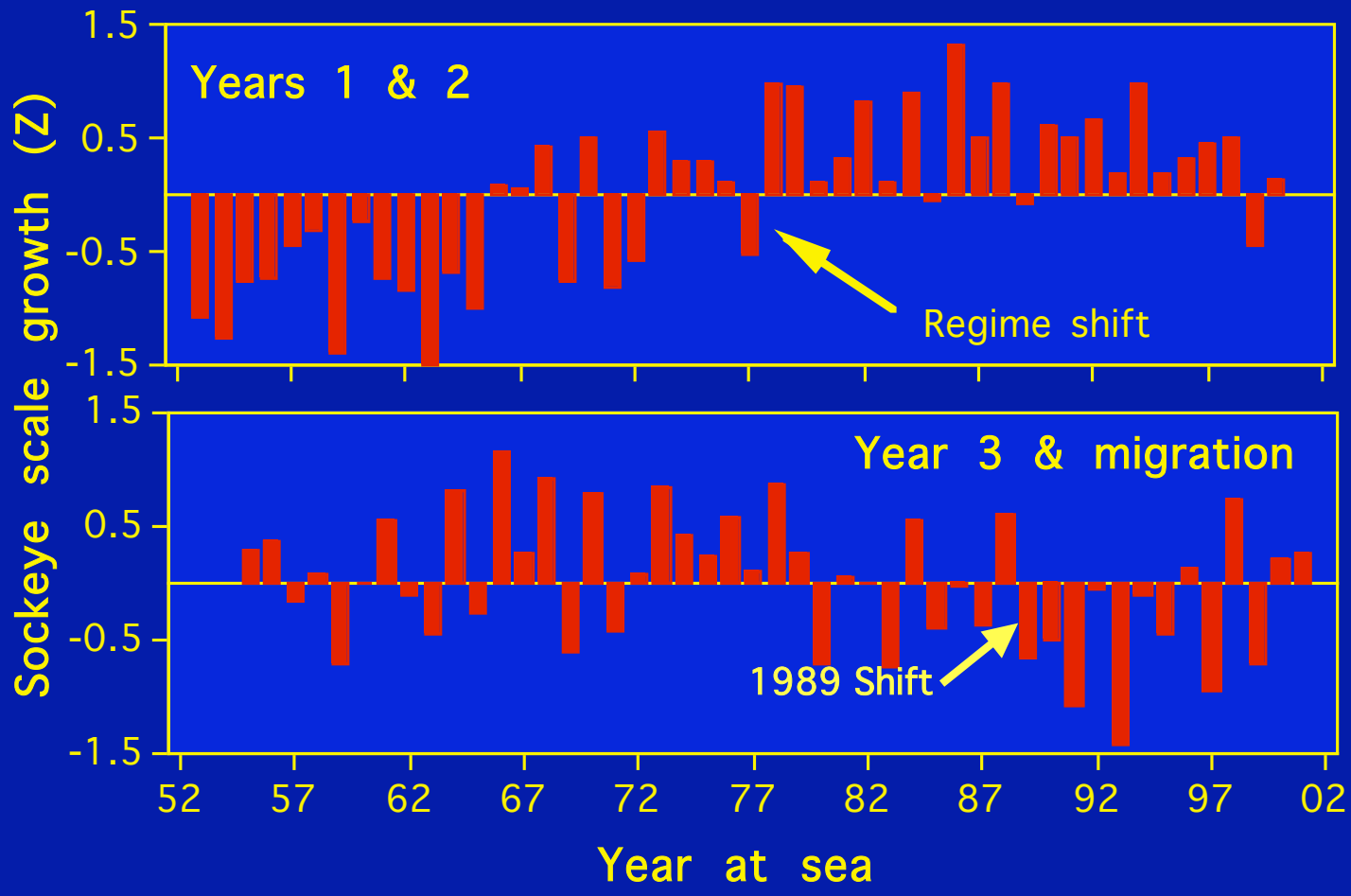
Bristol Bay & Chignik Sockeye

Broadly distributed in Bering Sea and North Pacific



Bristol Bay & Chignik Sockeye Growth:

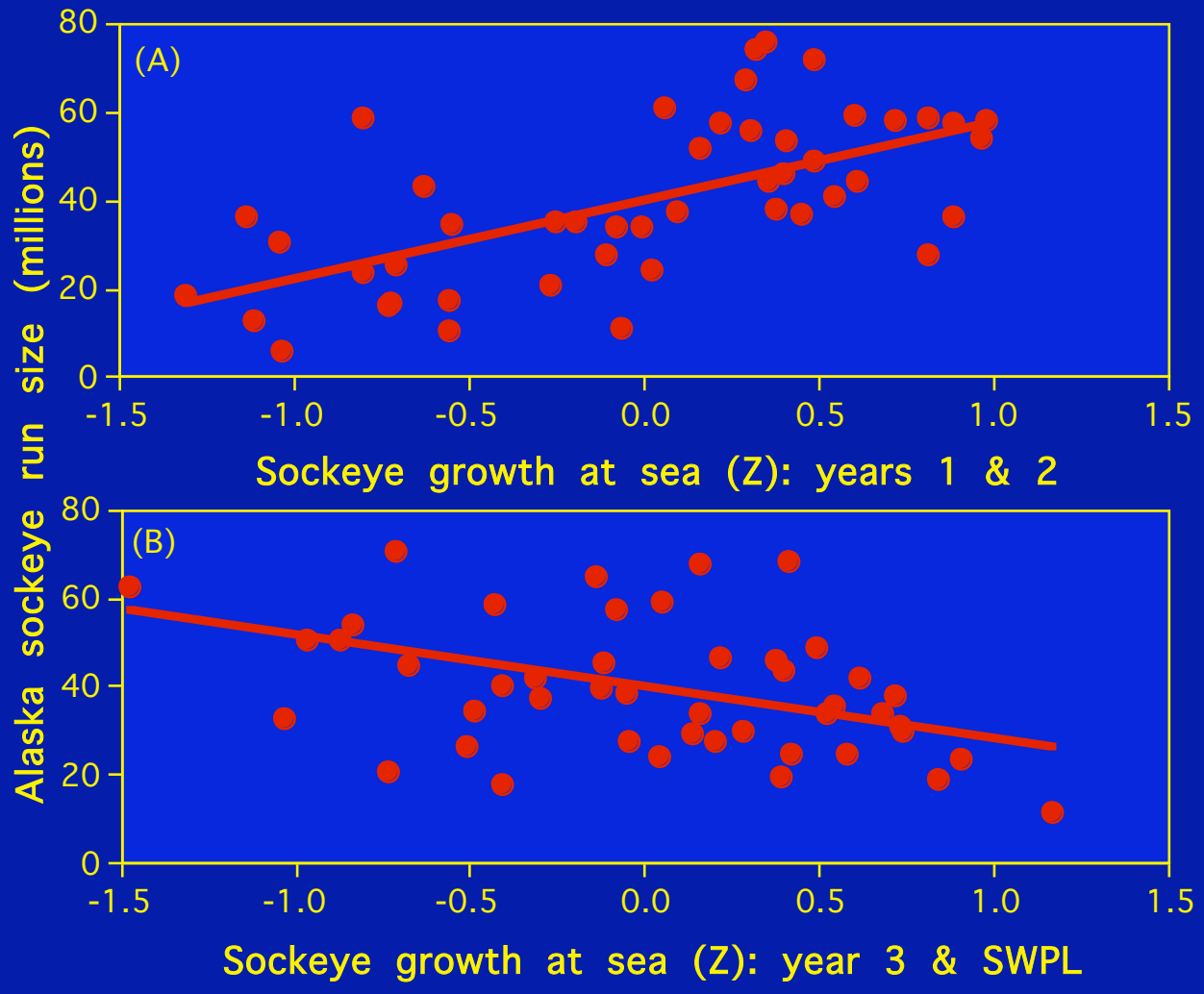
Regime Shift Effect on prey & salmon growth



Bristol Bay & Chignik correlated

Ruggerone et al. 2007

Sockeye Run Size vs. Growth at Sea, 1955-2001

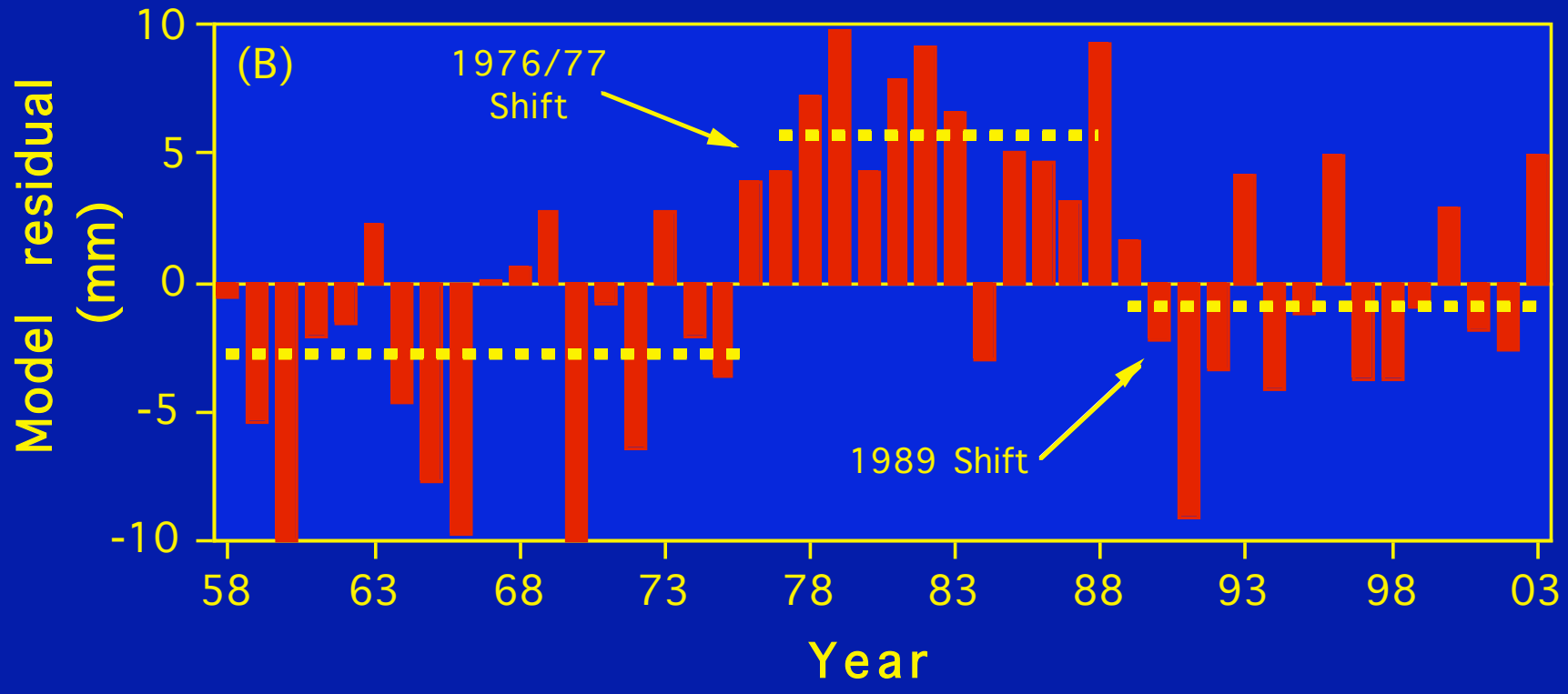


$y = 2.46 + 17.88(SW1\&2) - 11.78(SW3\&SWPL) - 13.91(\text{pink index}) + 12.18(SST)$, $R^2 = 0.56$

Ruggerone et al. 2007

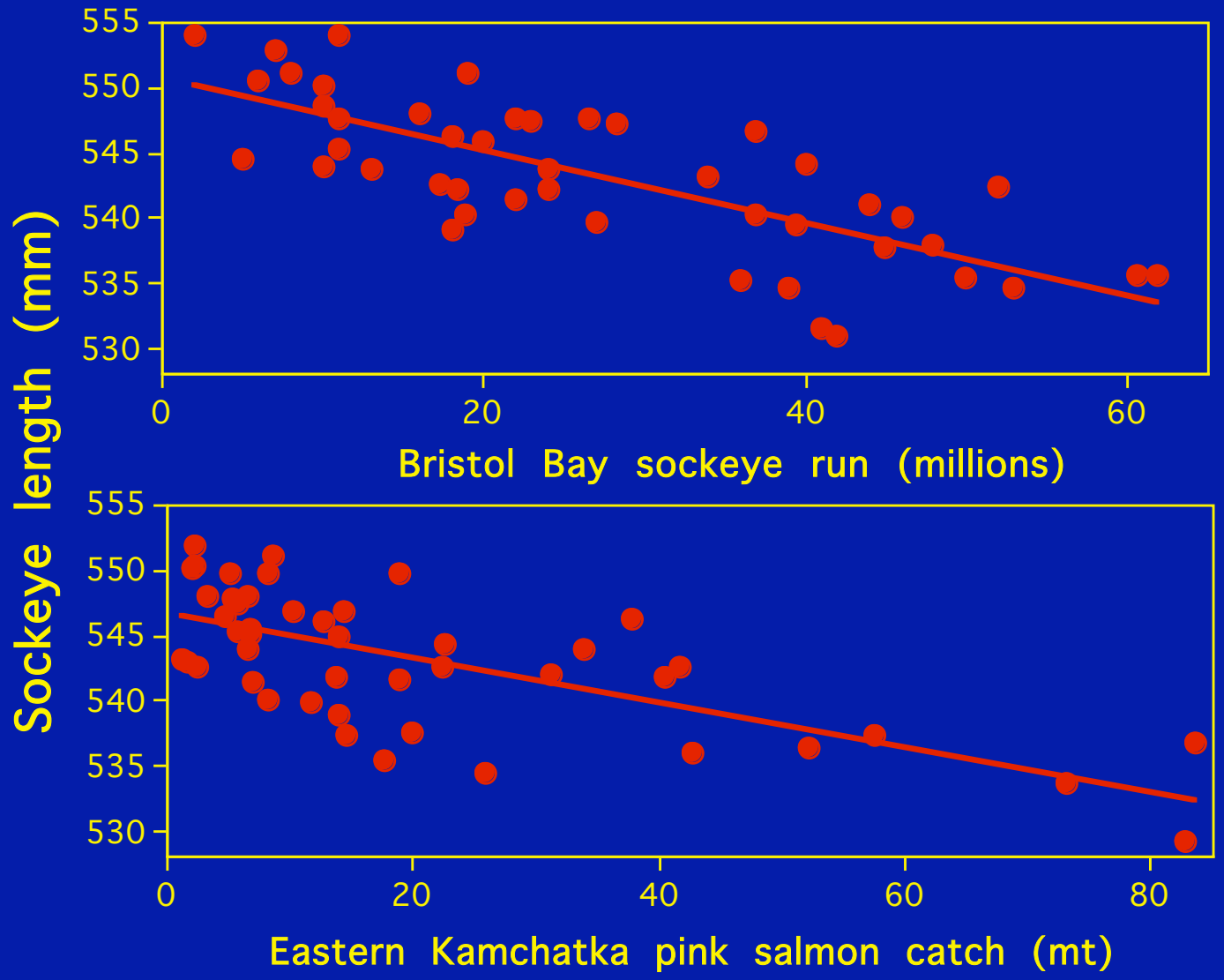
Climate, Competition & Sockeye Length-at-Age

L = 550.9 - .178(sockeye) - .144(pinks), r^2 = .40



Ruggerone et al. 2007

Sockeye Length vs Sockeye & Pink Abundance, 1958-2003



L (mm) = 550.0 - .275(sockeye) - .170(pink) + 10.3(period: 77-88) + 4.4(period: 89-03)

Ruggerone et al. 2007

Conclusions

- Climate and prey availability are key to salmon survival.
- Increasing evidence: competition at sea can affect salmon growth & possibly survival.
- Prey patches & large prey (squid, fishes) may be key to salmon growth.