Evidence for Competition Among Salmon at Sea

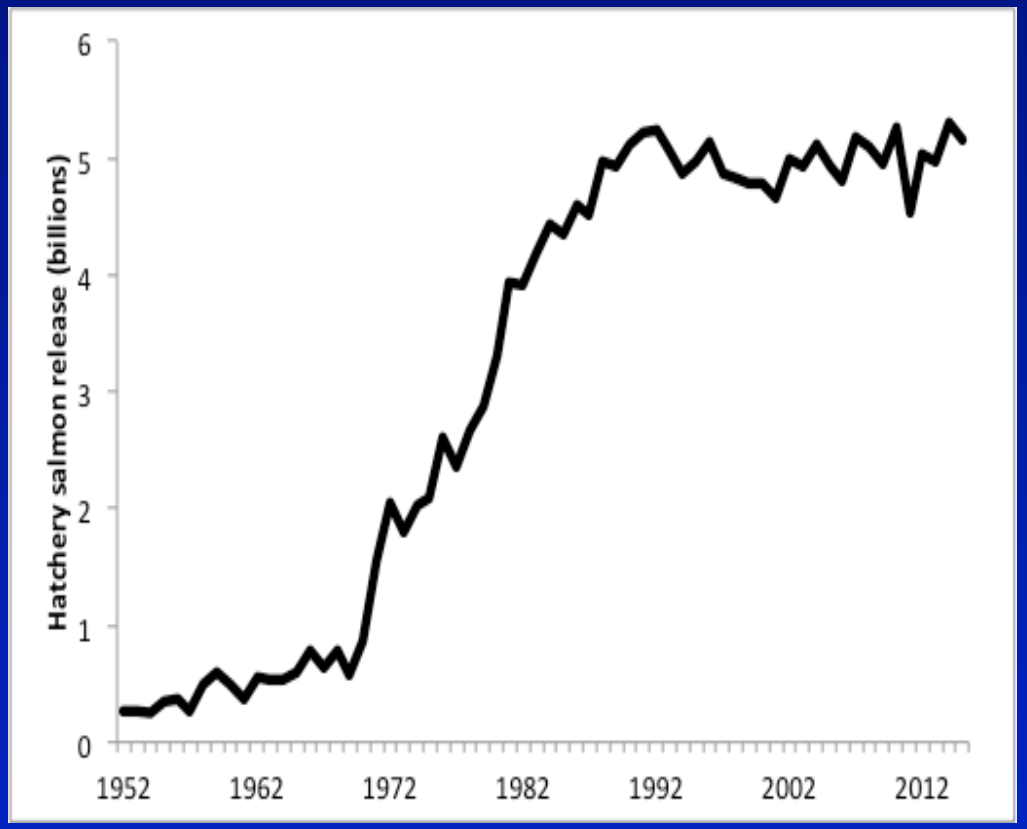
Greg Ruggerone & many collaborators

Natural Resources Consultants, Seattle, WA
GRuggerone@nrccorp.com

Support: USGS, NPRB, AKSSF, AYKSSI, NPAFC

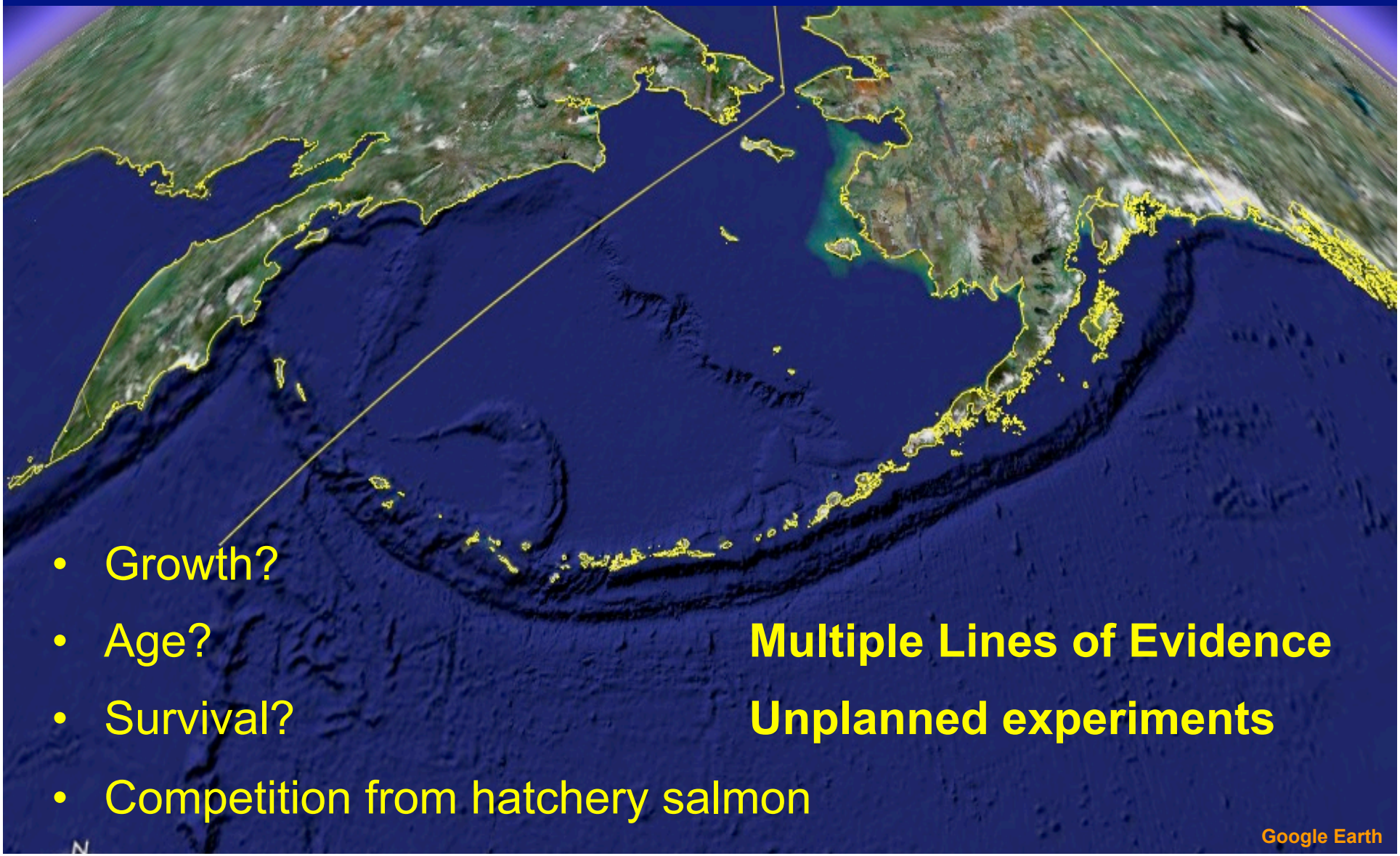
Why is Competition at Sea Important?

- Hatchery production beginning to increase again.
  - Alaska (up to 48% of commercial harvest is hatchery fish, Vercessi 2013)
  - “increase hatchery pinks (Kodiak) toil they equal or exceed wild pinks”
  - Russia hatchery expansion
- Unintended consequences 1000s of miles away.
- Holt et al. 2008
  - Marine Policy



NPAFC database 2016

Do salmon compete for prey at sea? How do we test this hypothesis?

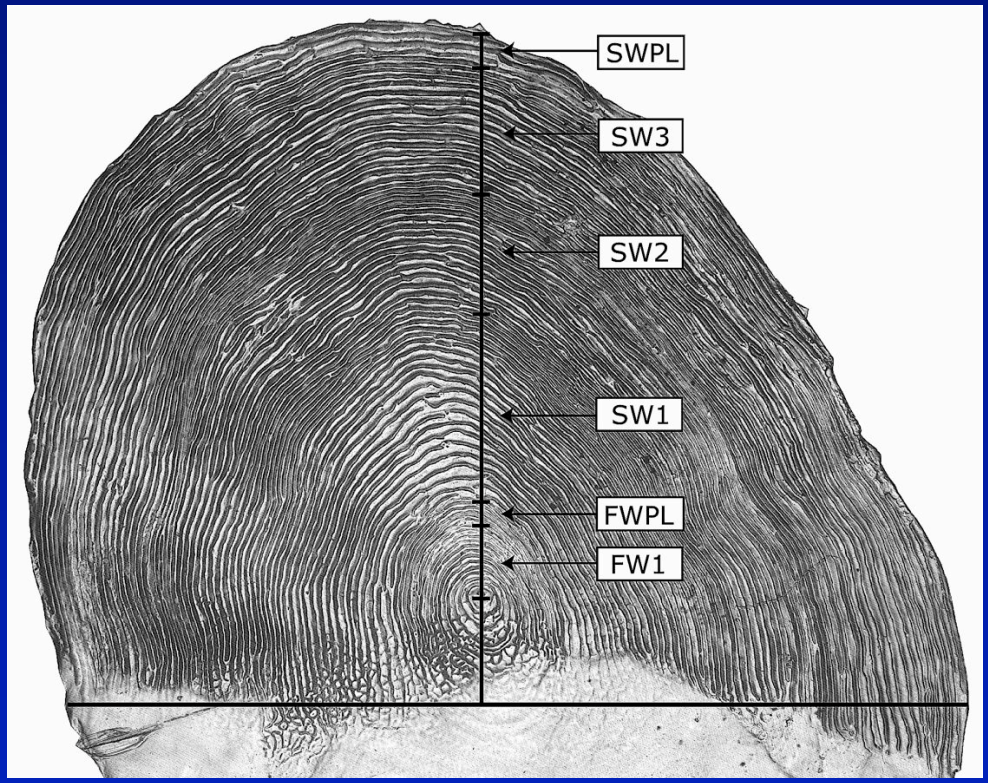


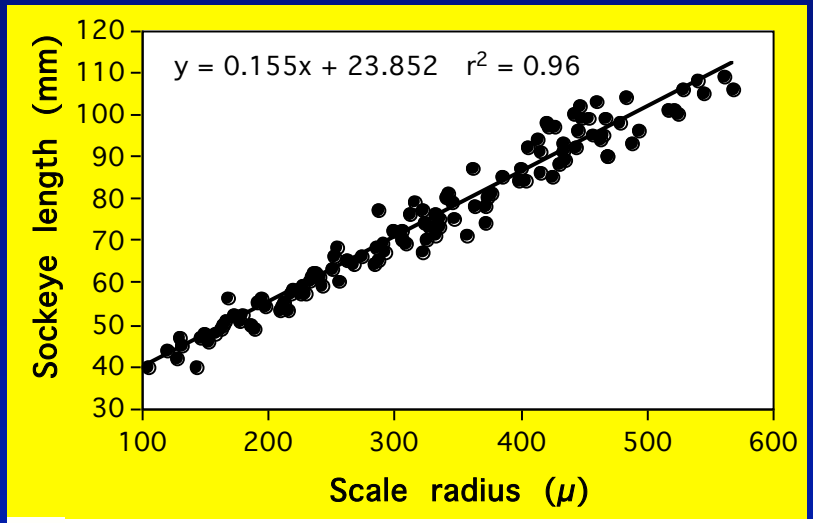
- Growth?
- Age?
- Survival?
- Competition from hatchery salmon

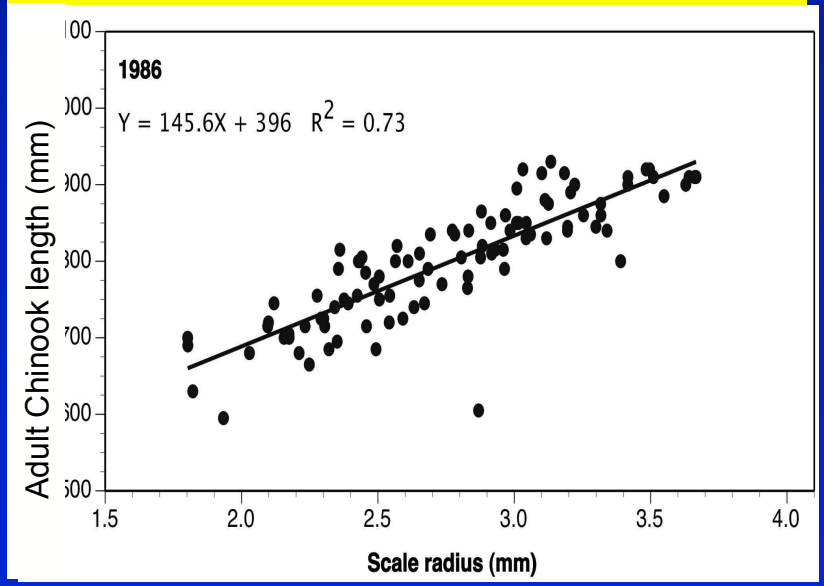
Multiple Lines of Evidence

Unplanned experiments

Salmon Scales: "the natural data logger"



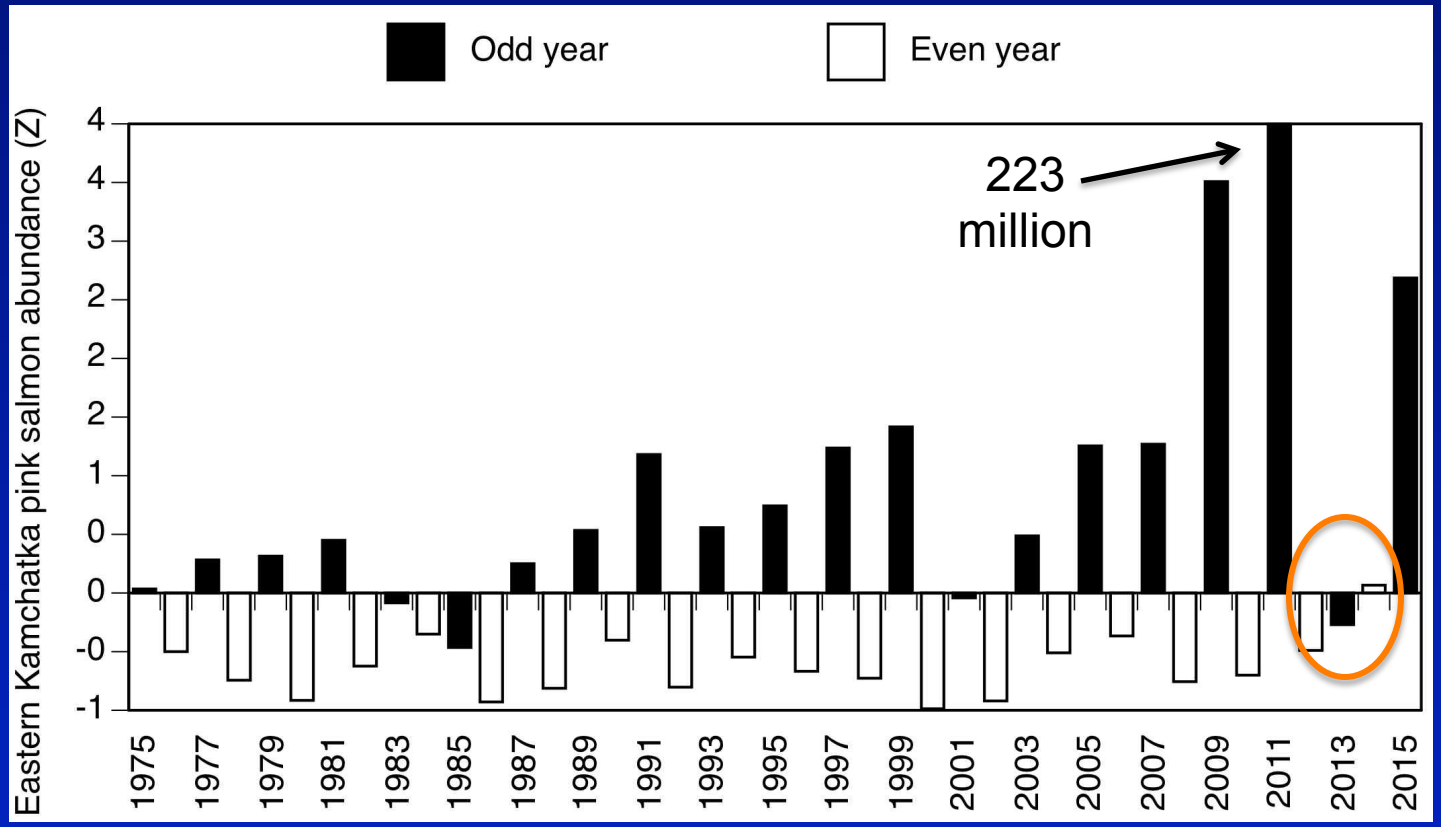




Collected by harvest managers

Long time series (since 1950s)

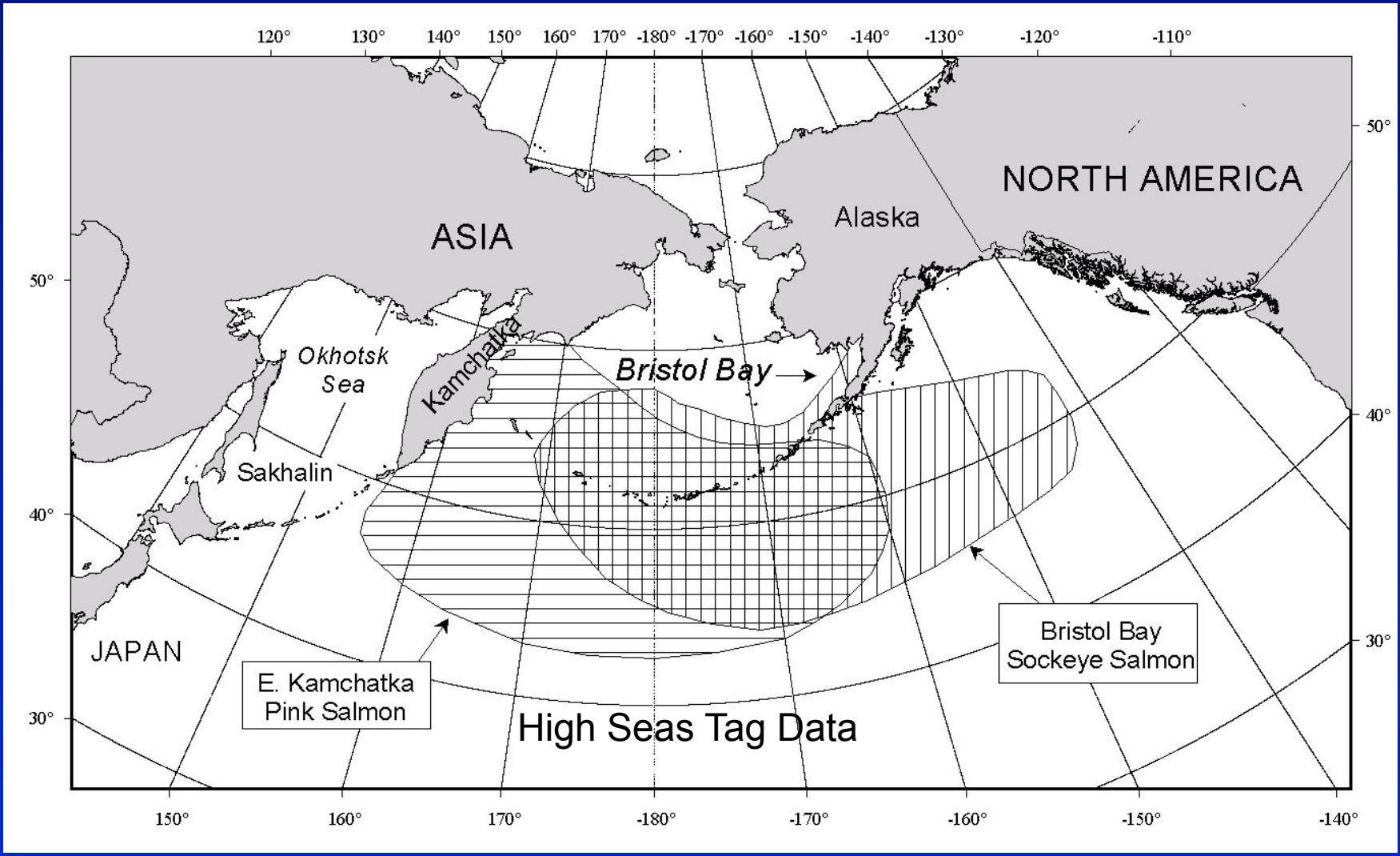
Pink Salmon is Key



- ~70% of all adult salmon
- 670 million pinks in 2009 (increasing hatchery pinks in AK)
- Strong alternating year pattern of abundance
- Odd-year pink salmon 39x more abundant in central Bering Sea
- High diet overlap with sockeye, pinks efficient

Irvine and Ruggerone 2016

Overlap of E Kamchatka Pink & Bristol Bay Sockeye Salmon

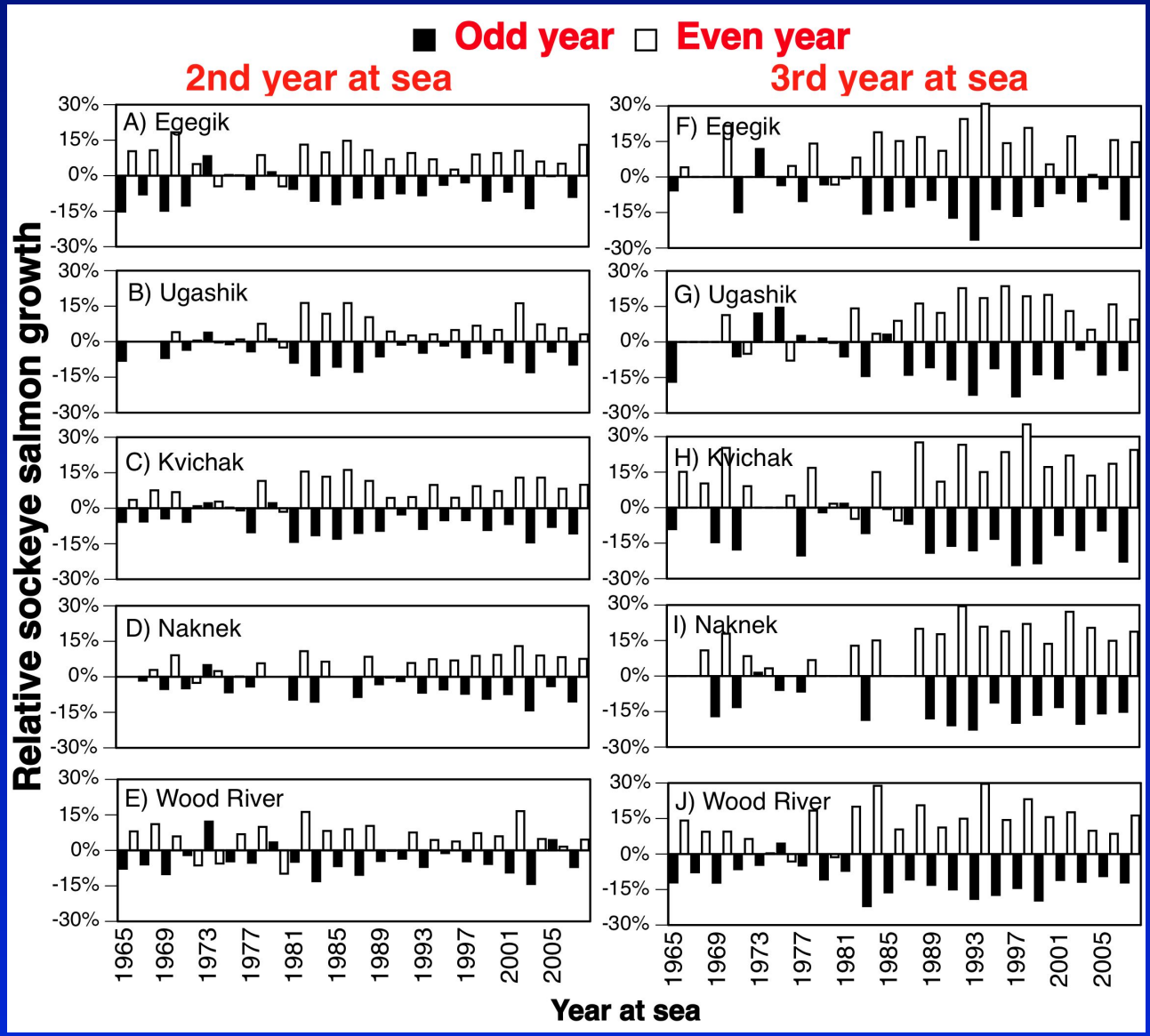


Sockeye genetic data indicate greater overlap, than this tag-based map

Bristol Bay Sockeye Scale Growth

relative to growth in year before & after

Tendency for stronger odd/even pattern after the mid-1970s ocean regime shift, a period of high salmon productivity and abundance



Ruggerone et al. 2003, 2016

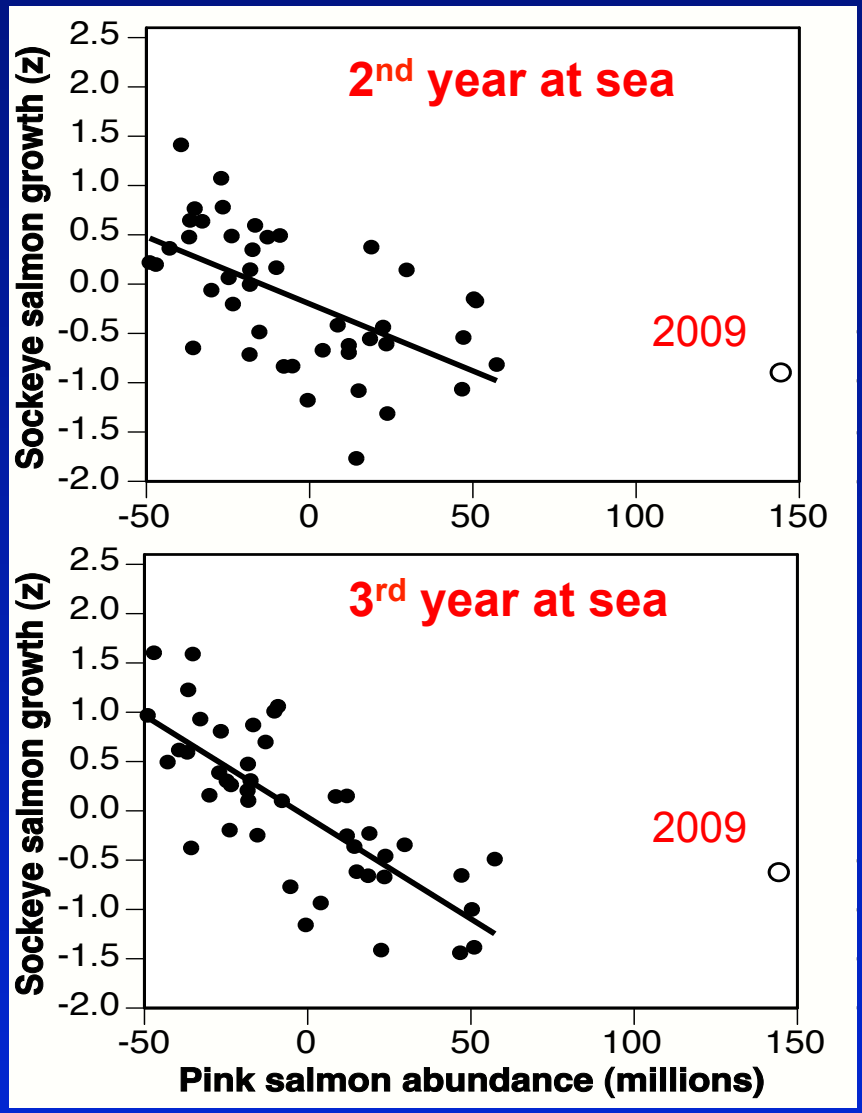
Bristol Bay sockeye growth vs pink salmon abundance

Normalized scale growth, 1965-2010 (28,000 measurements)

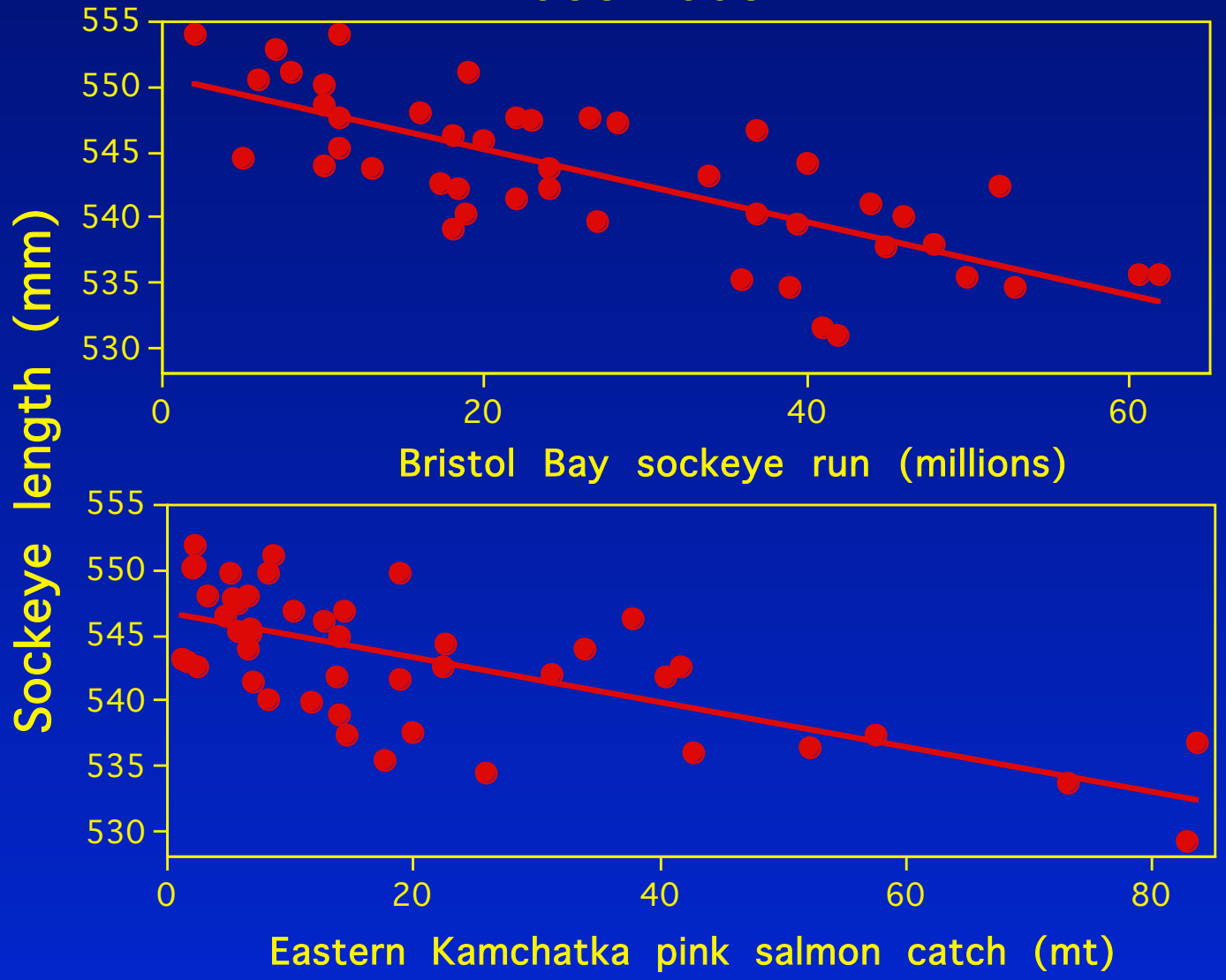
Eastern Kamchatka pink salmon abundance

No relationship 1st year at sea (few pinks)

Serial autocorrelation of residuals: P > 0.05.



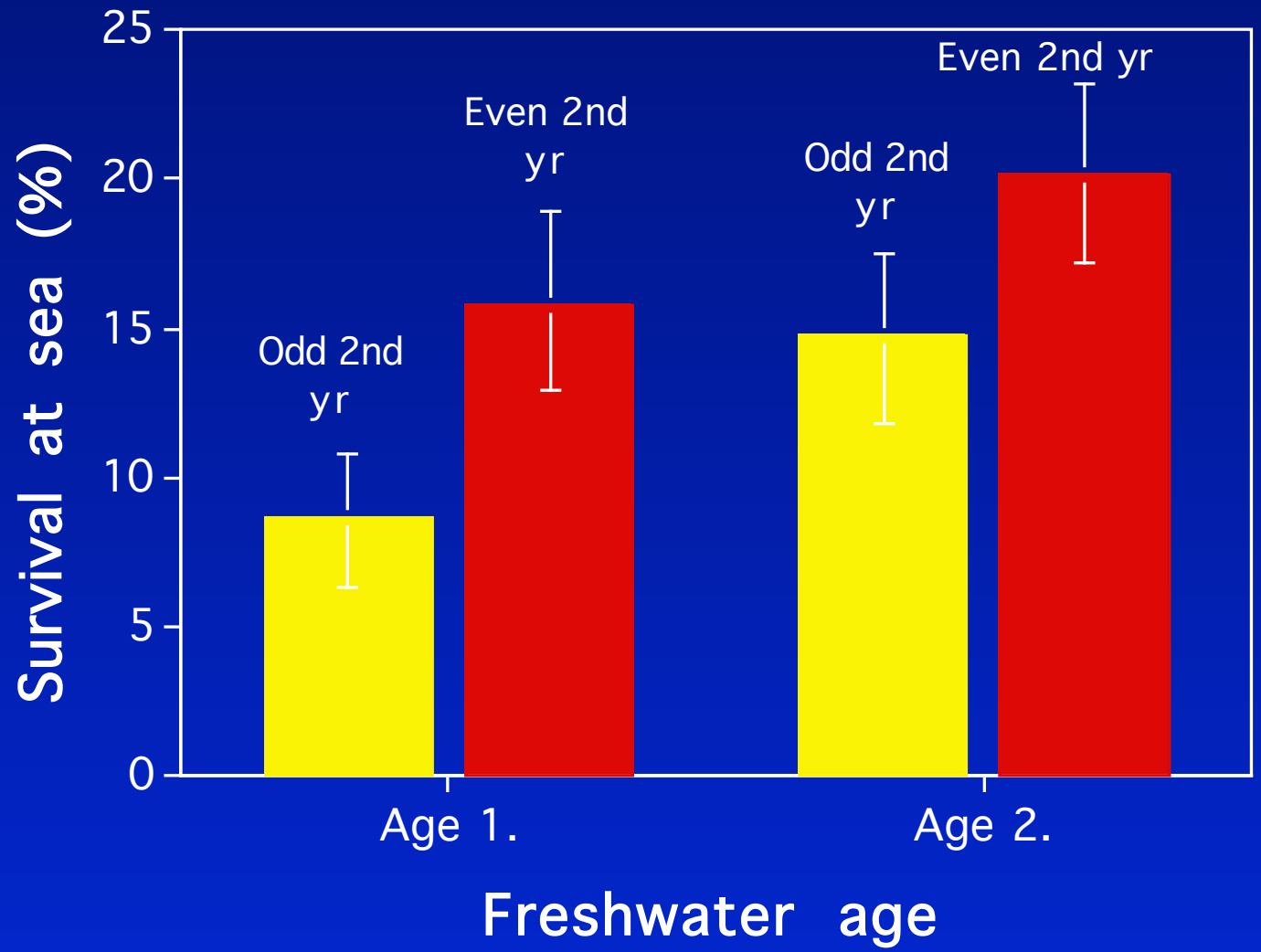
Sockeye Length-at-Age vs Sockeye & Pink Abundance, 1958-2003



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

Rogers 1980, Ruggerone et al. 2007

Smolt to Adult Survival, 1977-1997

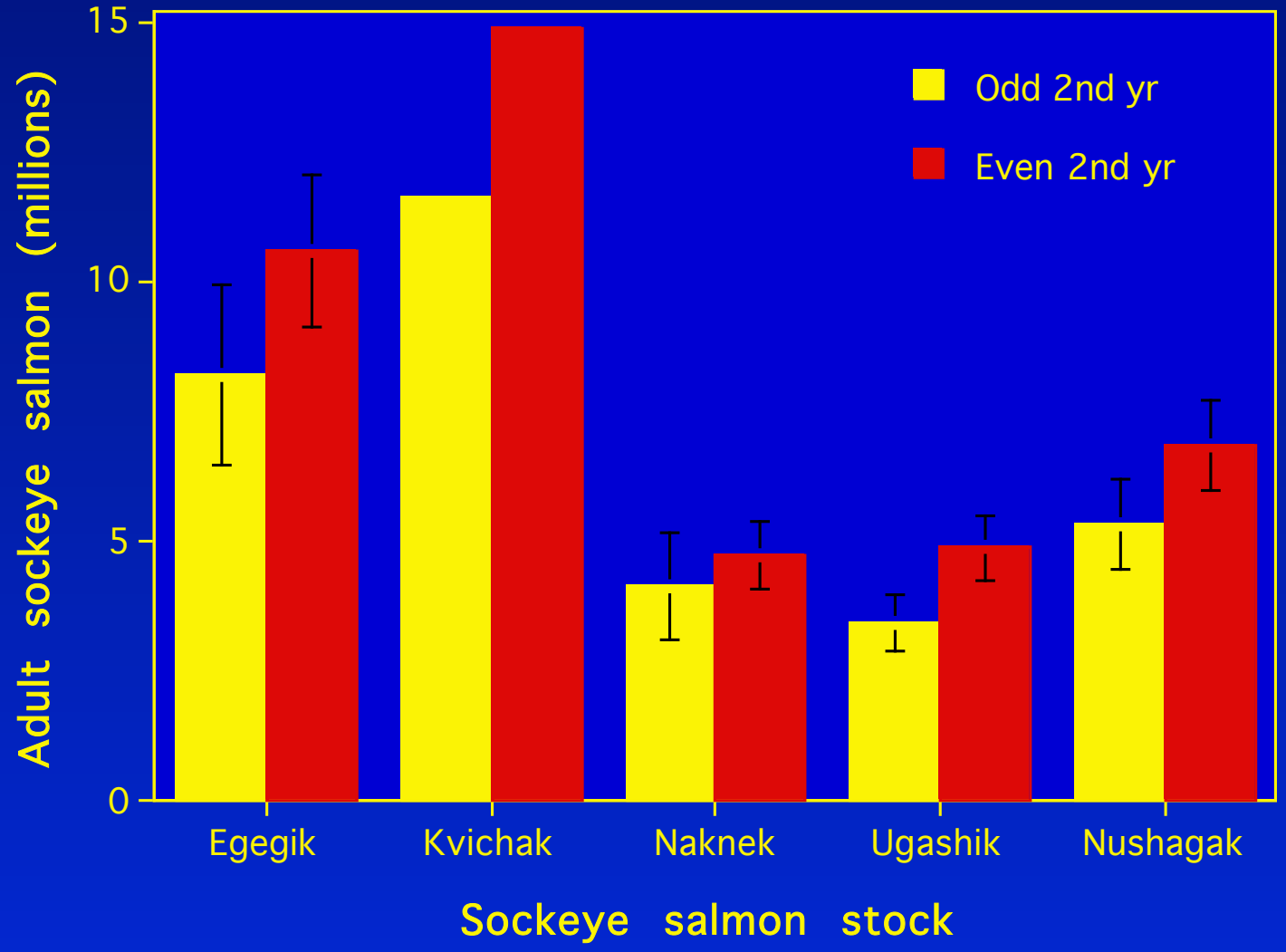


Age-1: -45% when pinks

Age-2: -26% when pinks

Ruggerone et al. 2003, 2012

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



22% loss

Ruggerone et al. 2003, Ruggerone & Nielsen 2004

Bristol Bay Forecast Error

relative to error in year before & after

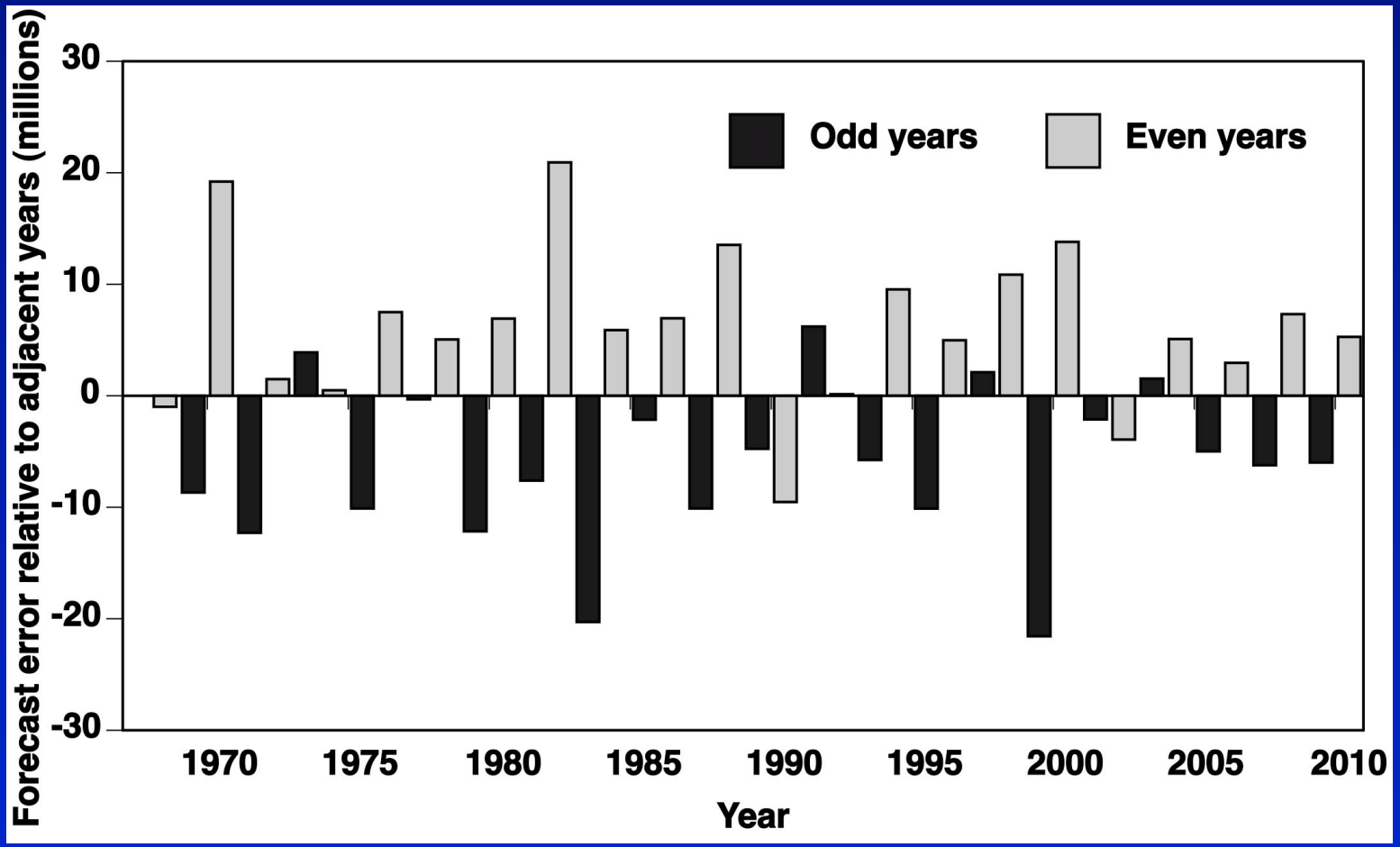
Stocks:

Kvichak

Naknek

Egegik

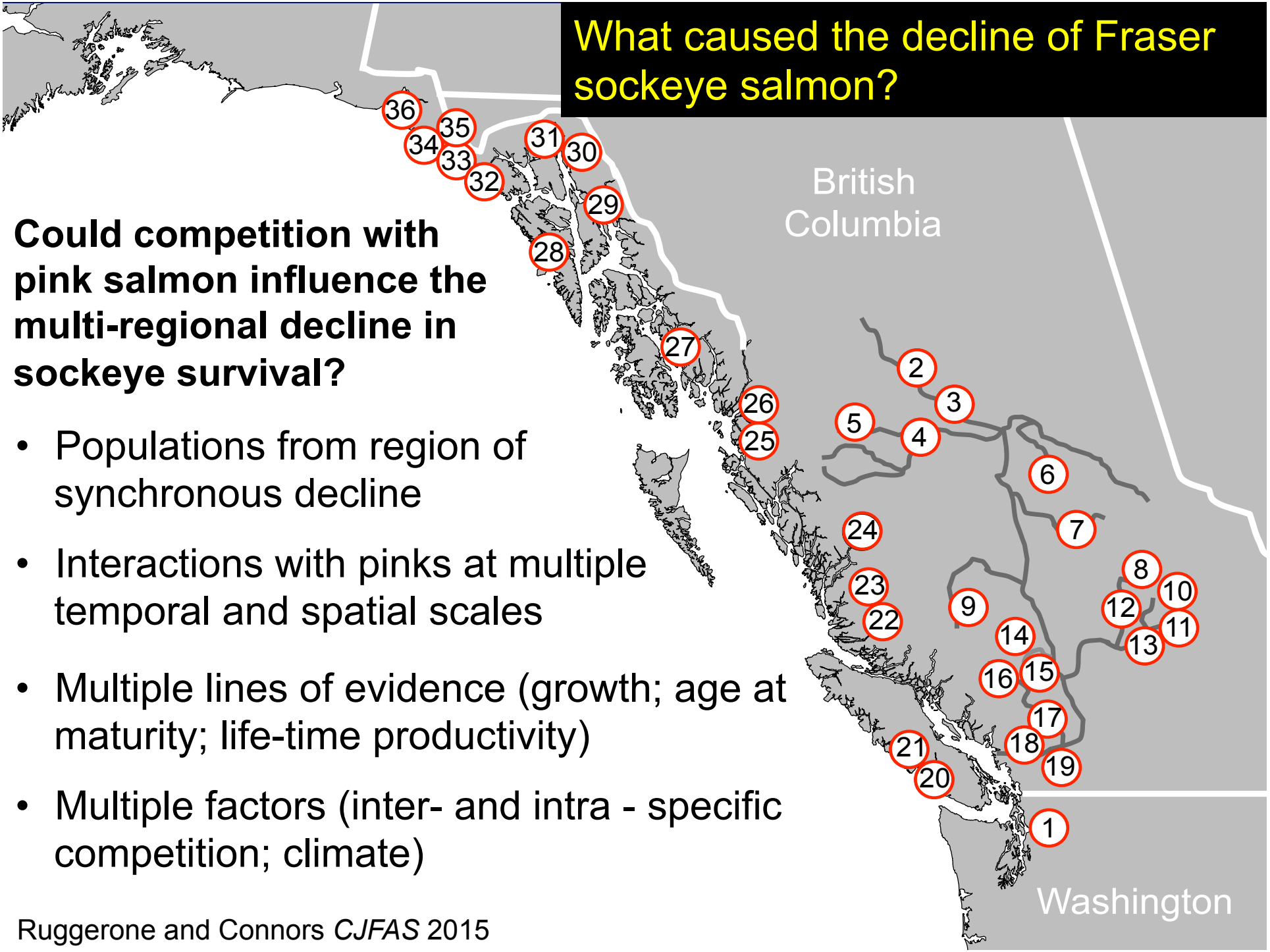
Ugashik



Relative error = Error Y_i – (avg. error Y_{i-1}, Y_{i+1})

Ruggerone et al. 2016

What caused the decline of Fraser sockeye salmon?

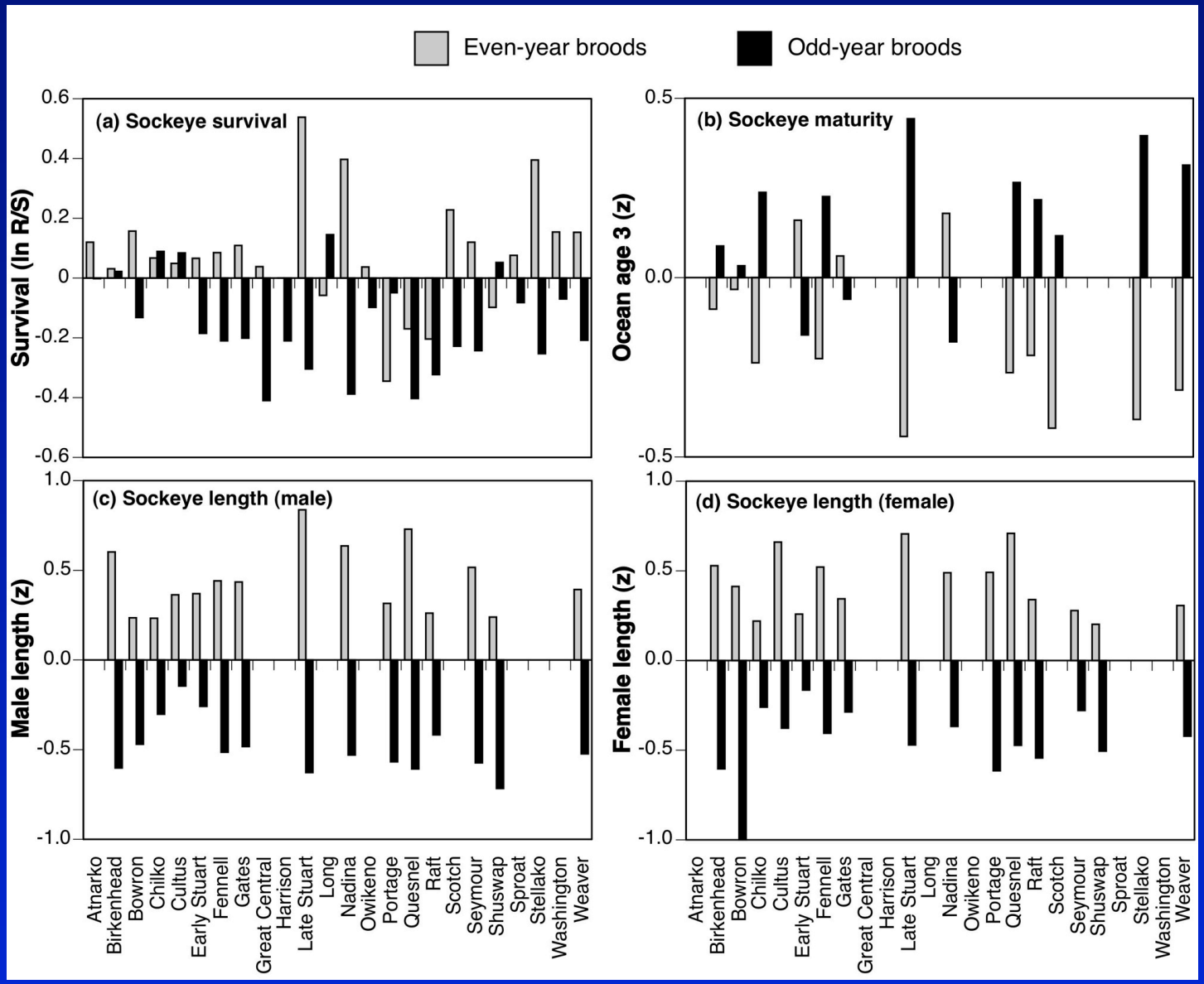


Could competition with pink salmon influence the multi-regional decline in sockeye survival?

- Populations from region of synchronous decline
- Interactions with pinks at multiple temporal and spatial scales
- Multiple lines of evidence (growth; age at maturity; life-time productivity)
- Multiple factors (inter- and intra - specific competition; climate)

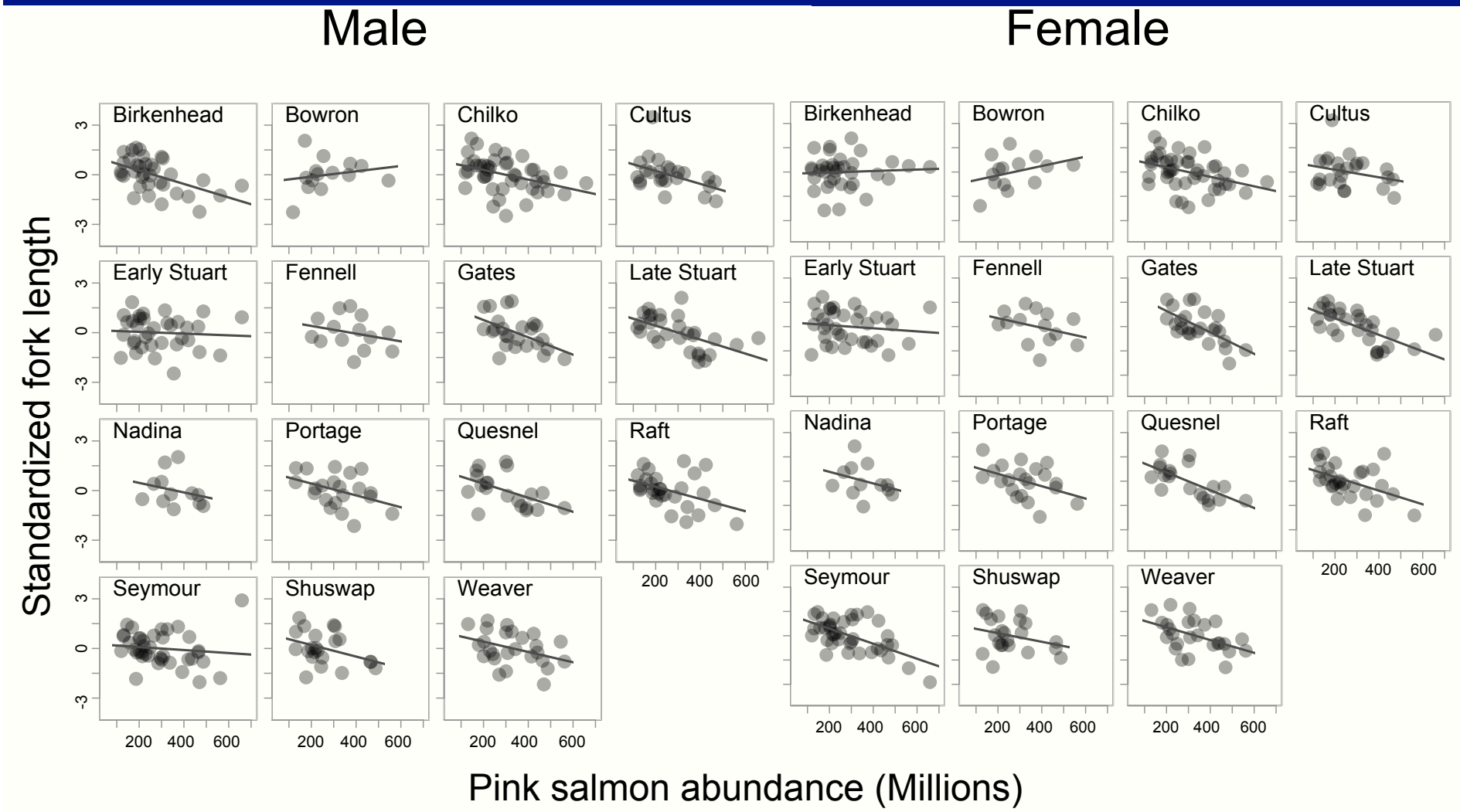
Ruggerone and Connors *CJFAS* 2015

Odd/even year patterns in sockeye salmon



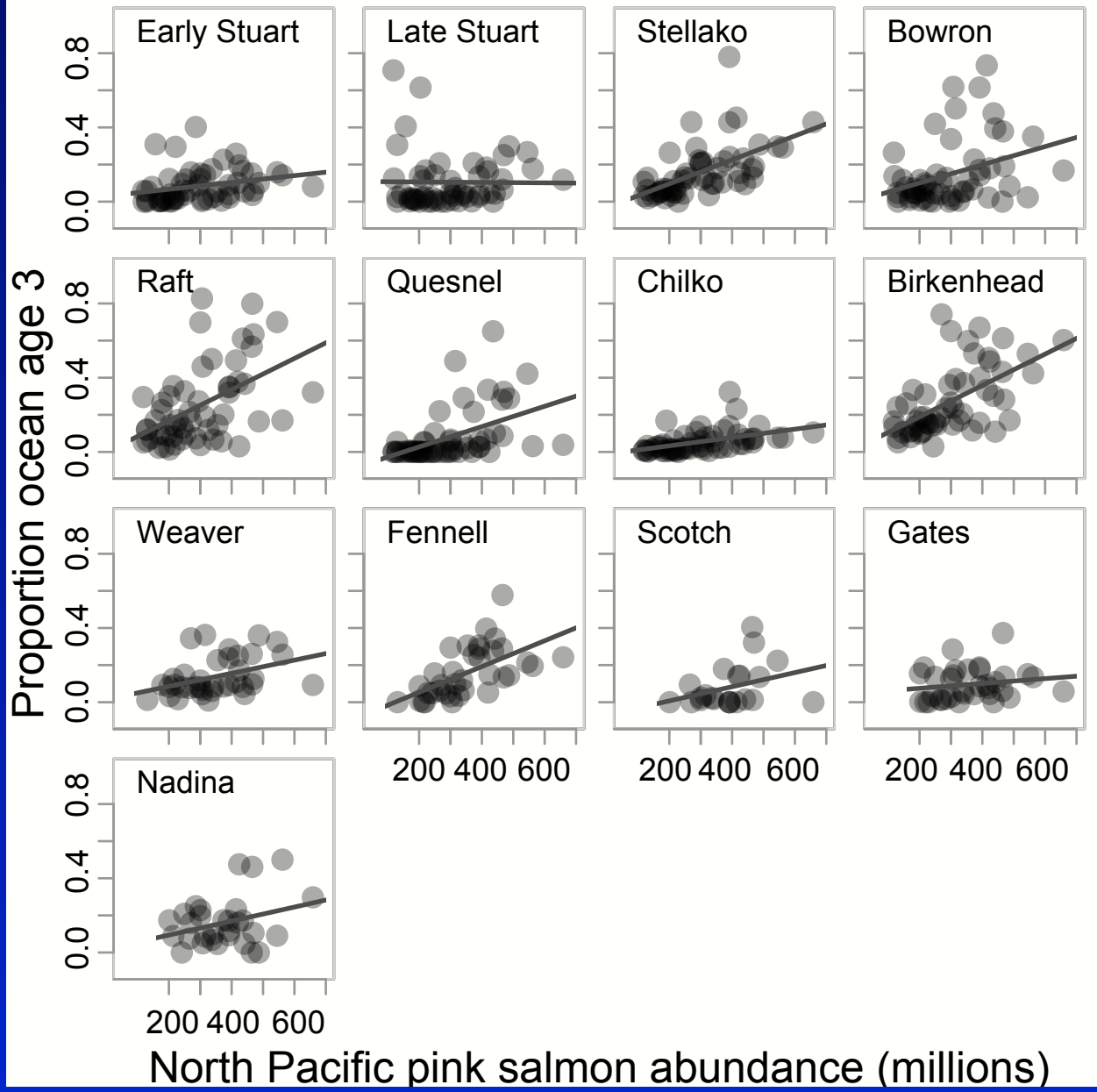
Ruggerone and Connors *CJFAS* 2015

Sockeye length-at-age declined with increasing abundance of pink salmon



Ruggerone and Connors *CJFAS* 2015

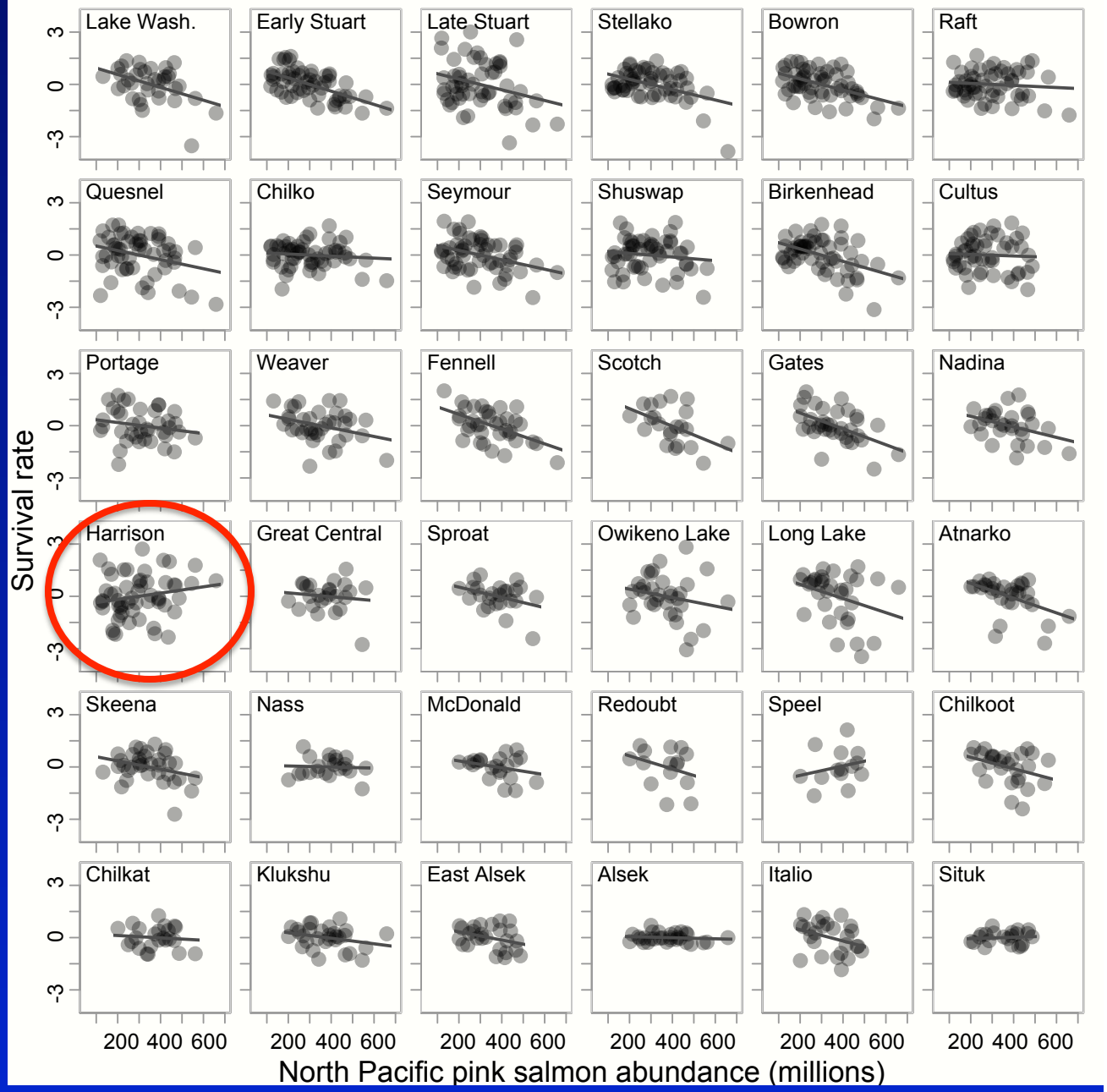
Sockeye delayed maturation with increasing abundance of pink salmon



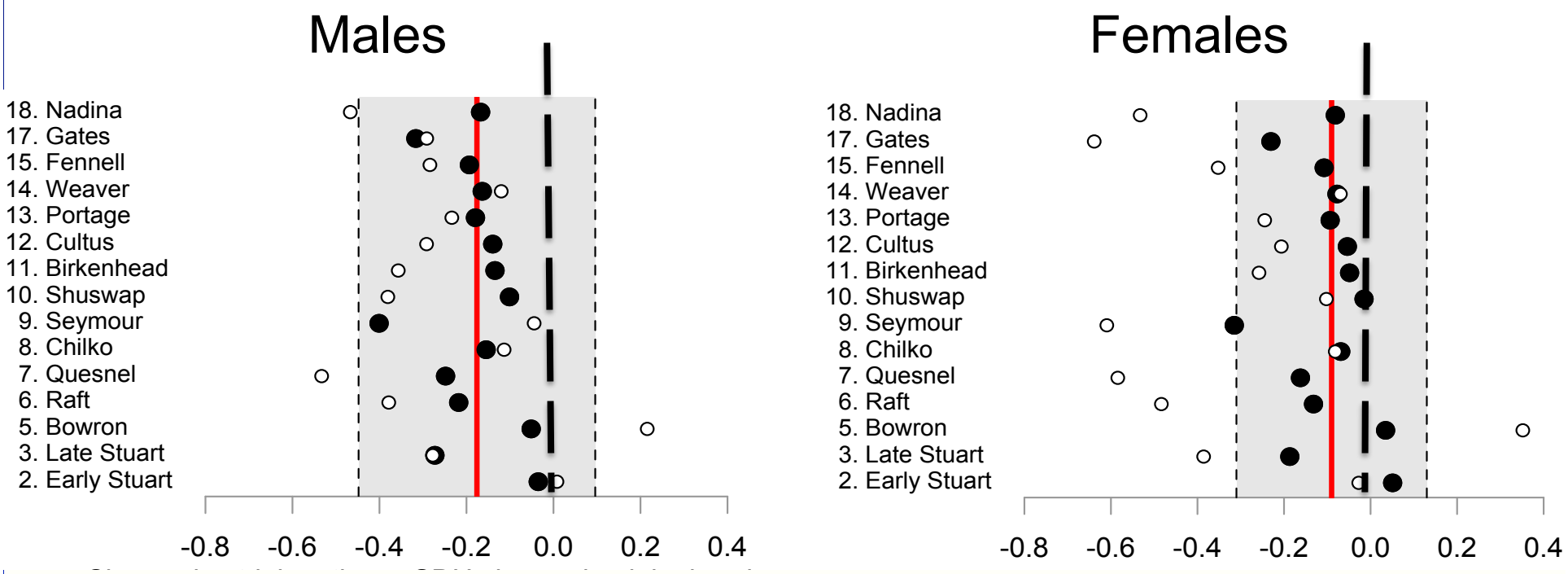
Ruggerone and Connors *CJFAS* 2015

Sockeye survival declined with increasing abundance of pink salmon

Survival = residual from Ricker curve

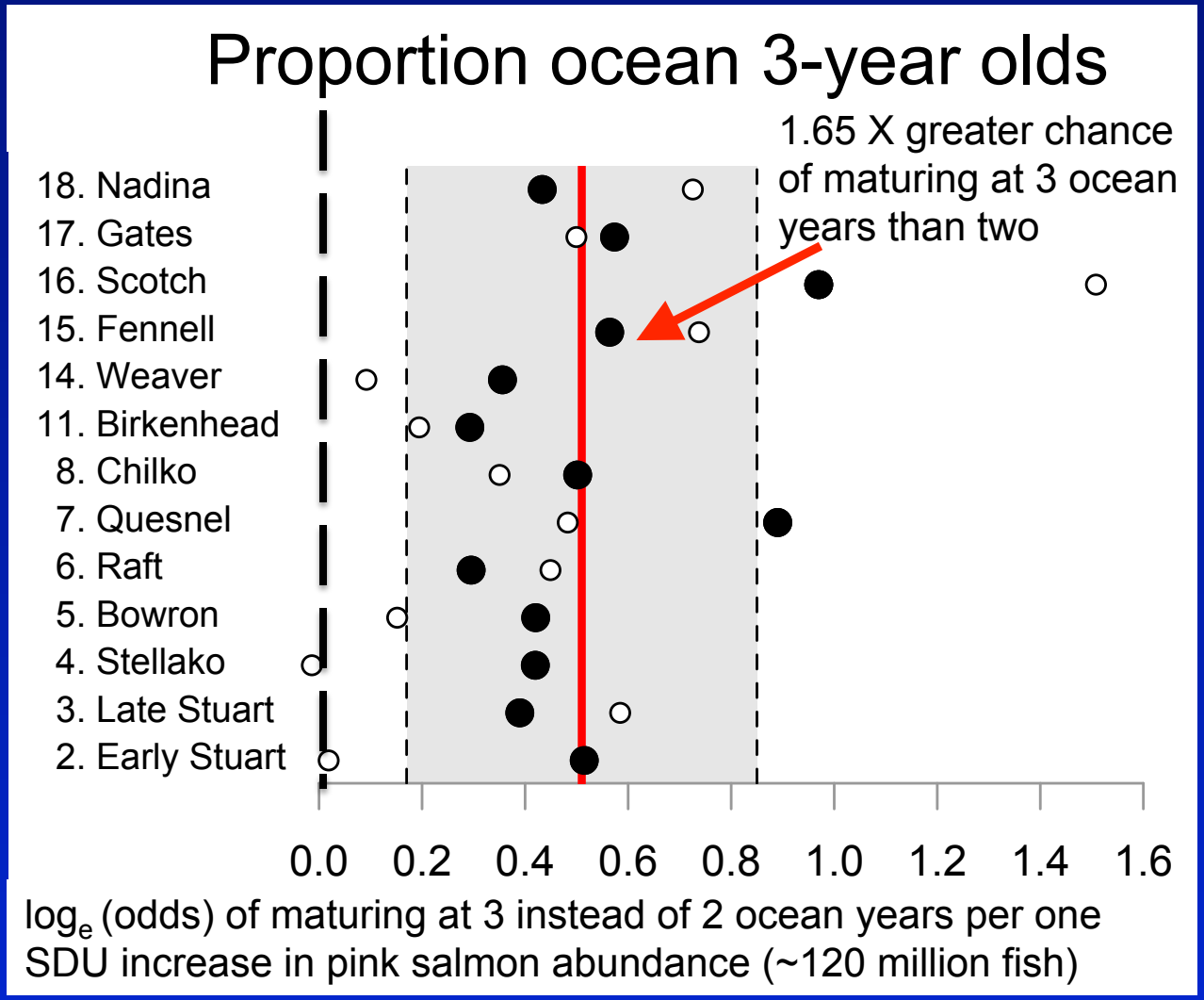


Multi-model average predicted relationship: Length



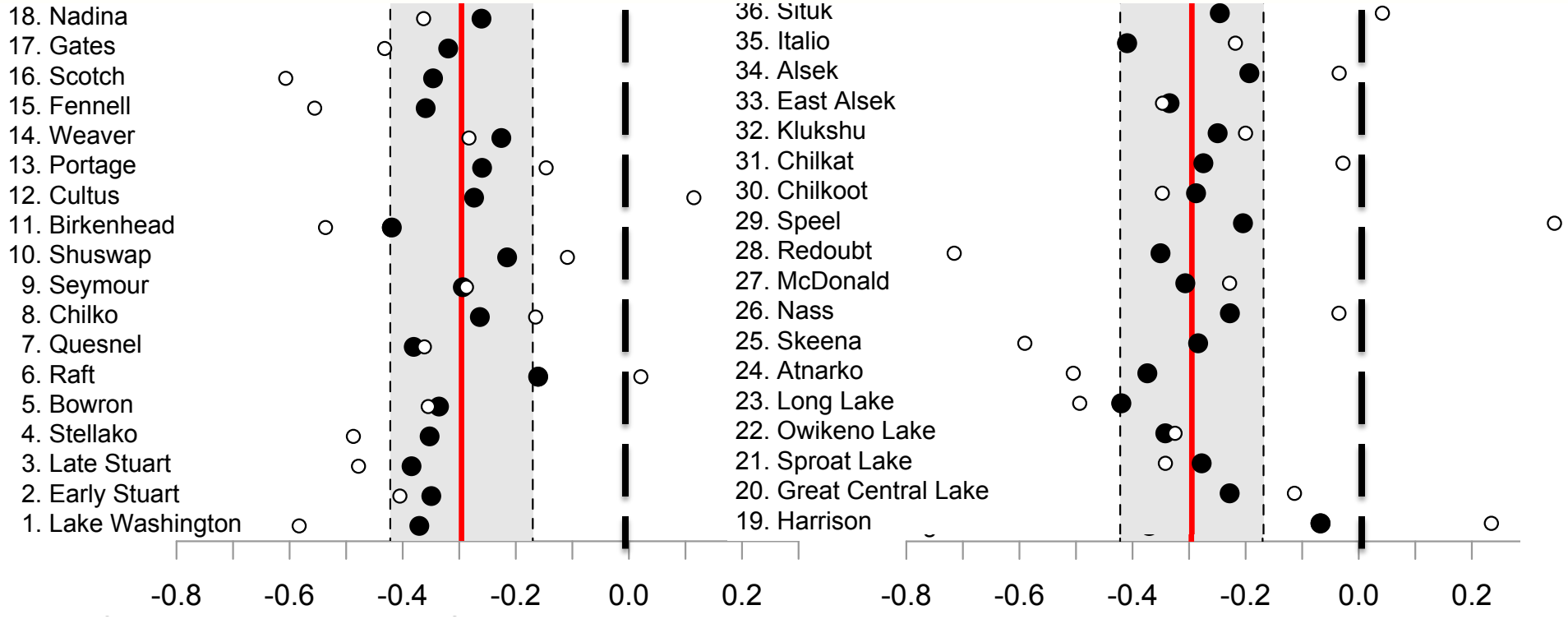
Ruggerone and Connors *CJFAS* 2015

Multi-model average predicted relationship: Maturity



Ruggerone and Connors *CJFAS* 2015

Multi-model average predicted relationship: Productivity



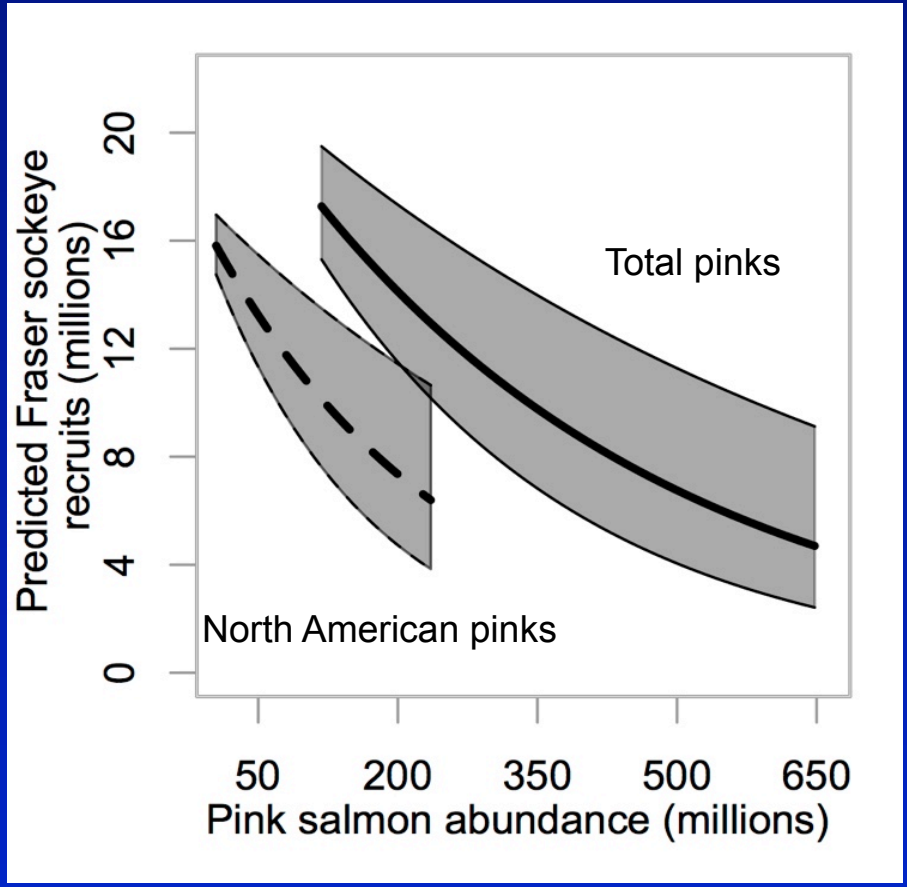
Ruggerone and Connors *CJFAS* 2015

Predicted effect of pink salmon on Fraser sockeye abundance

Tragedy of the Commons

The predicted decline in Fraser sockeye recruitment from an increase of 50 million HATCHERY pink salmon (150 to 200 million) salmon was 18% (or 1.83 million sockeye salmon),

Likewise, hatchery chum impact distant wild chum

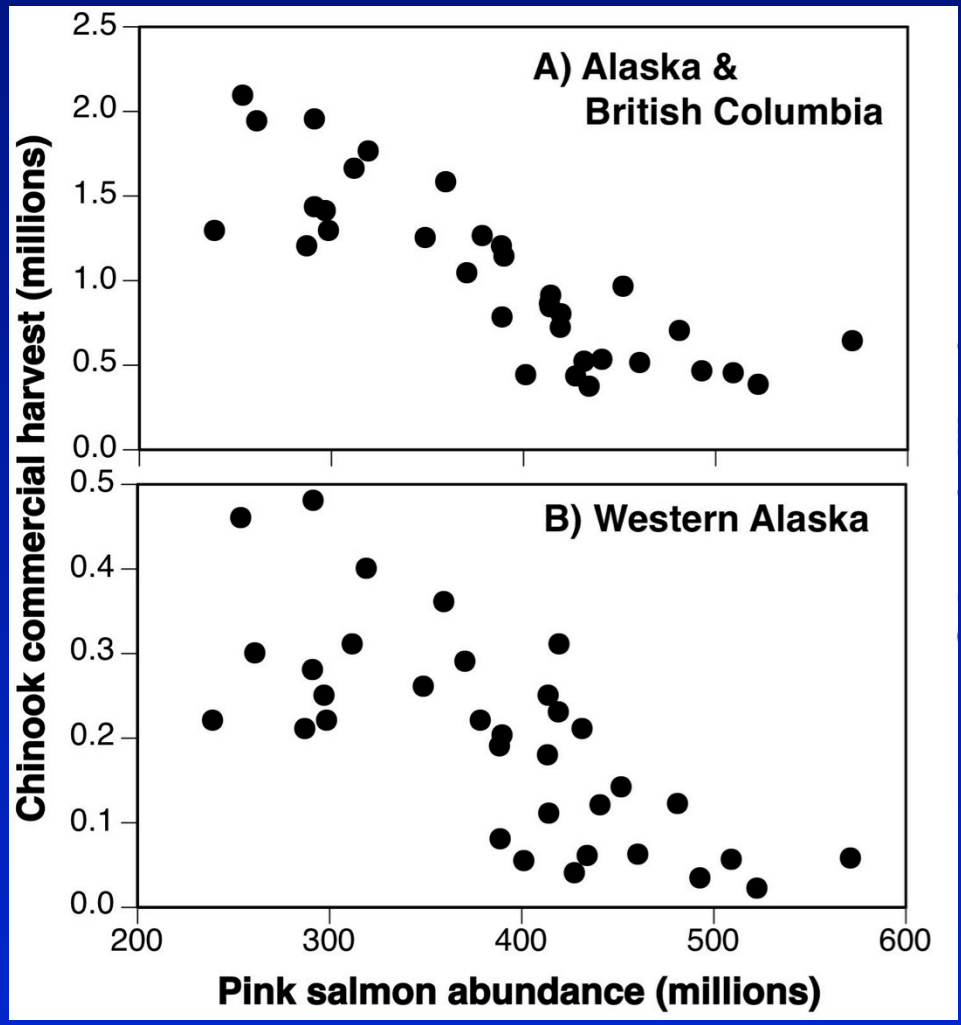


Per capita effect of North American pink salmon greater than per capita effect of North Pacific pink salmon.

Ruggerone and Connors 2015, Ruggerone et al. 2016

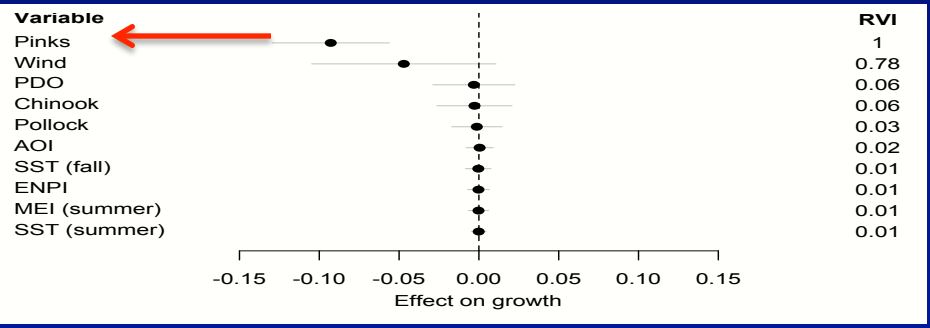
Are Pink Salmon Reducing Chinook Survival?

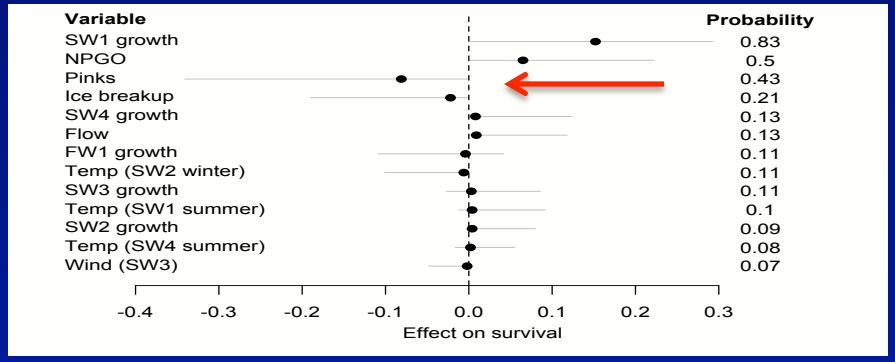
- Chinook feed at higher trophic level, but some diet overlap
- In odd-yrs, 56% decline in stomach fullness; 68% reduction in squid & fish, 1991-2000 (Davis 2003)
- Pink abundance averaged over 3 yrs of overlap with Chinook

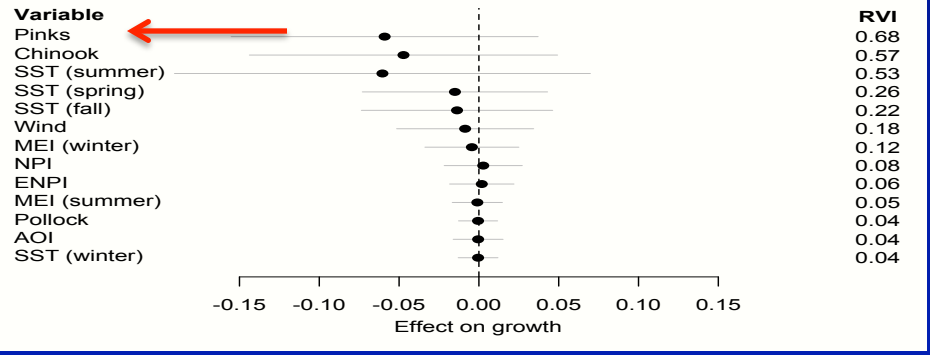


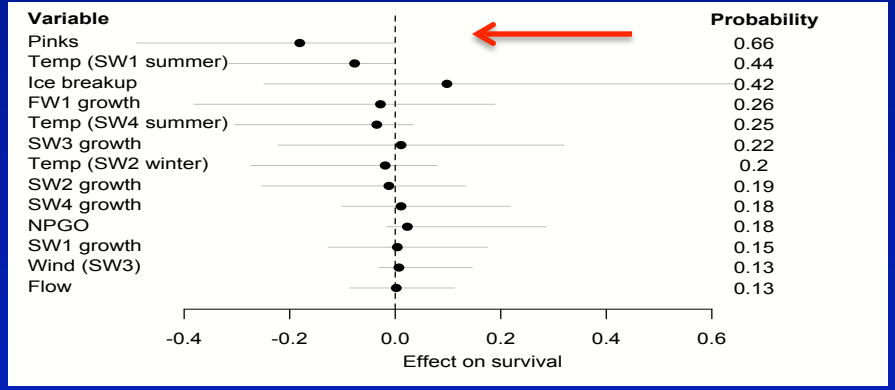
Ruggerone et al. 2016

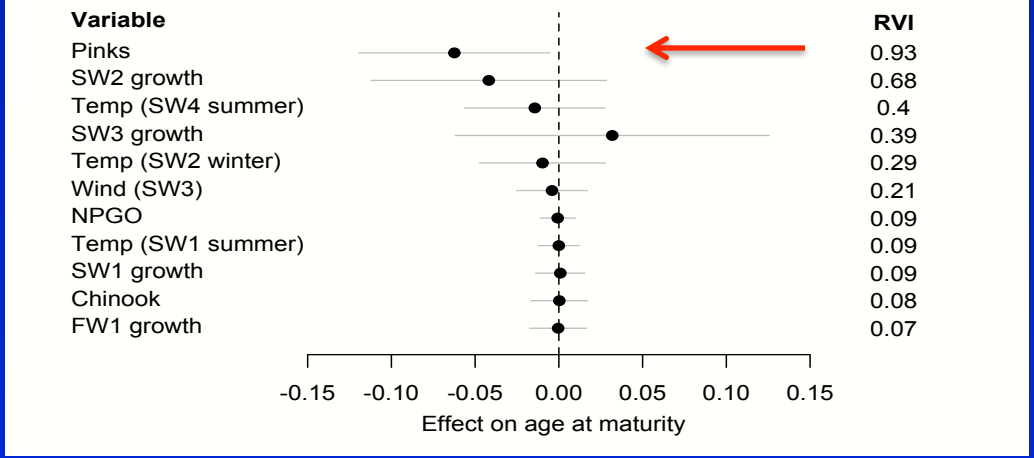
Pink salmon effects on W Alaska Chinook











Ruggerone et al. 2016b

New Research

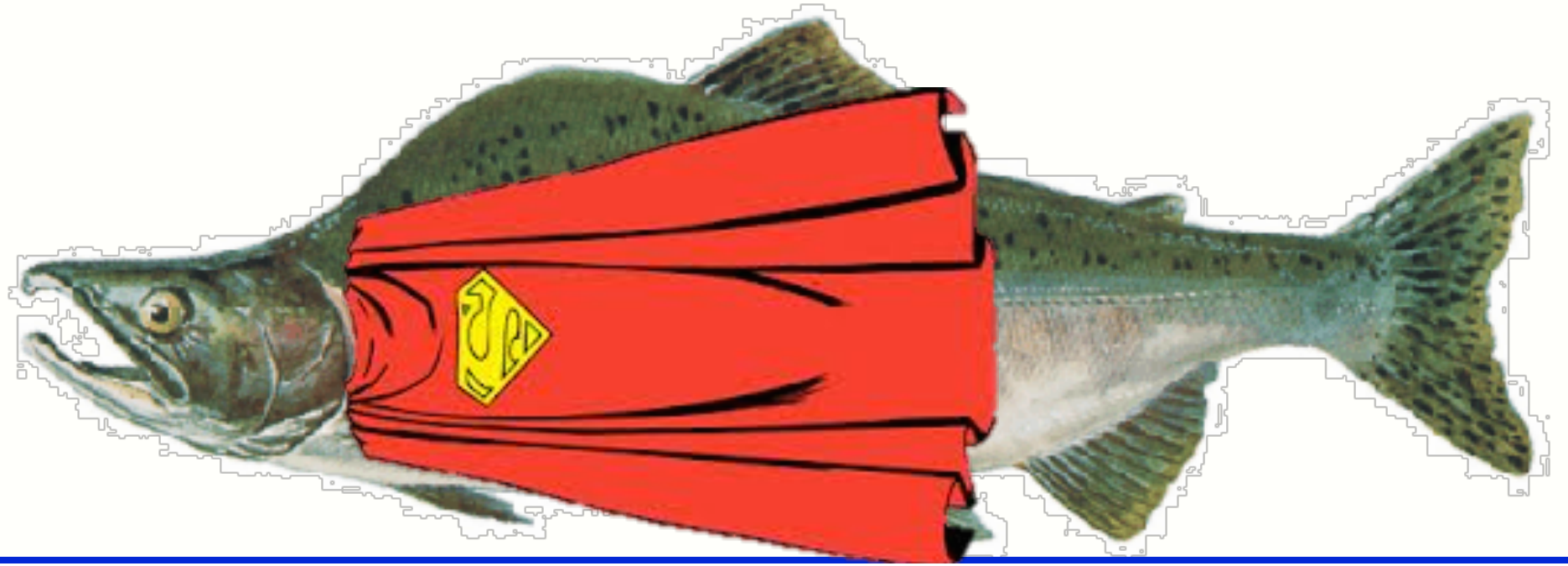
- NCEAS
  - pink/sockeye
- Ocean factors
- Pink competition
- ~64 sockeye populations, Lake WA to Bristol Bay

Can we overcome diverse sockeye life histories that provide stable populations in response to pink salmon and other factors?

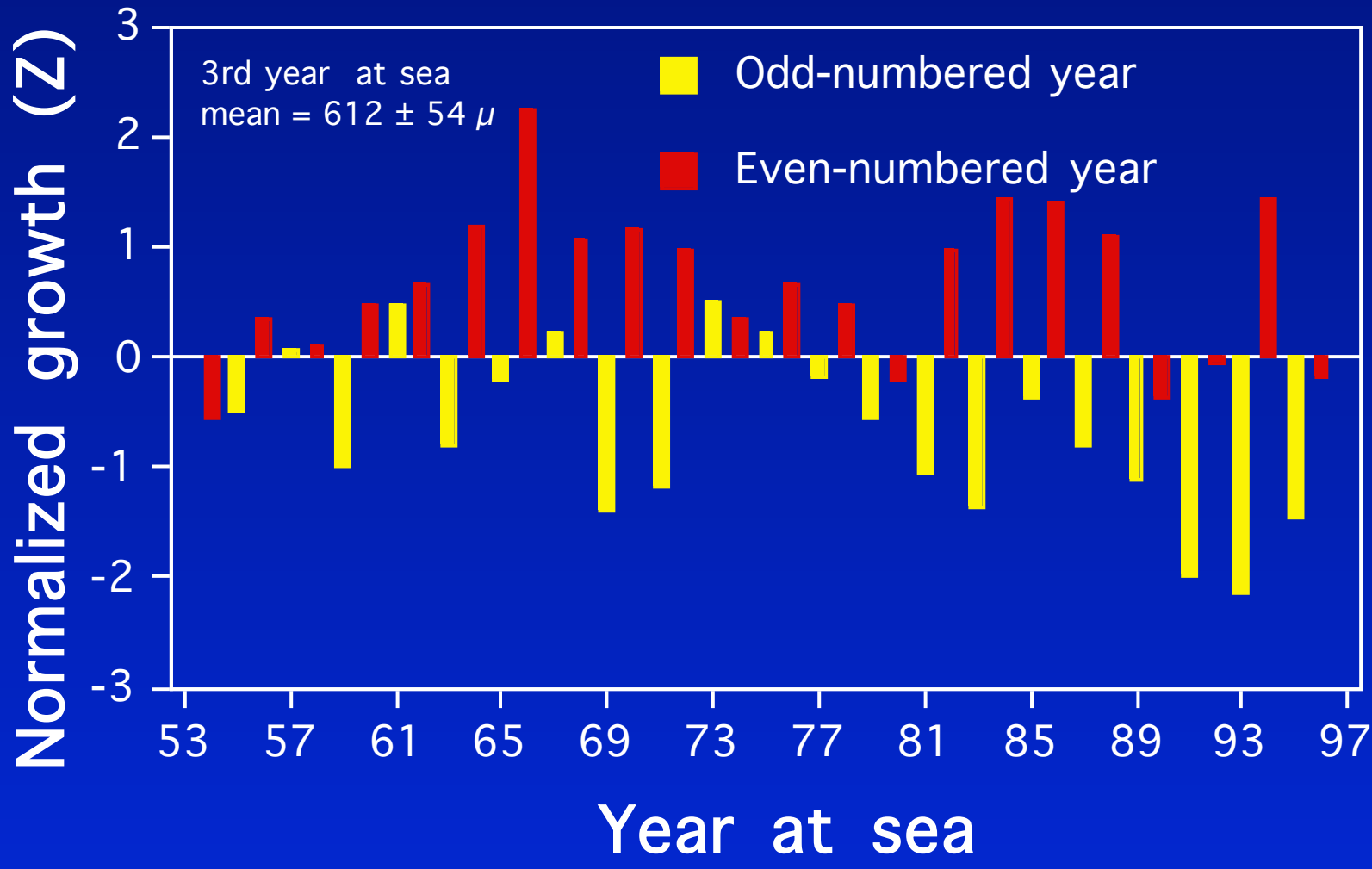
Questions?

"Nobody goes there anymore. It's too crowded."

Y. Berra 1998

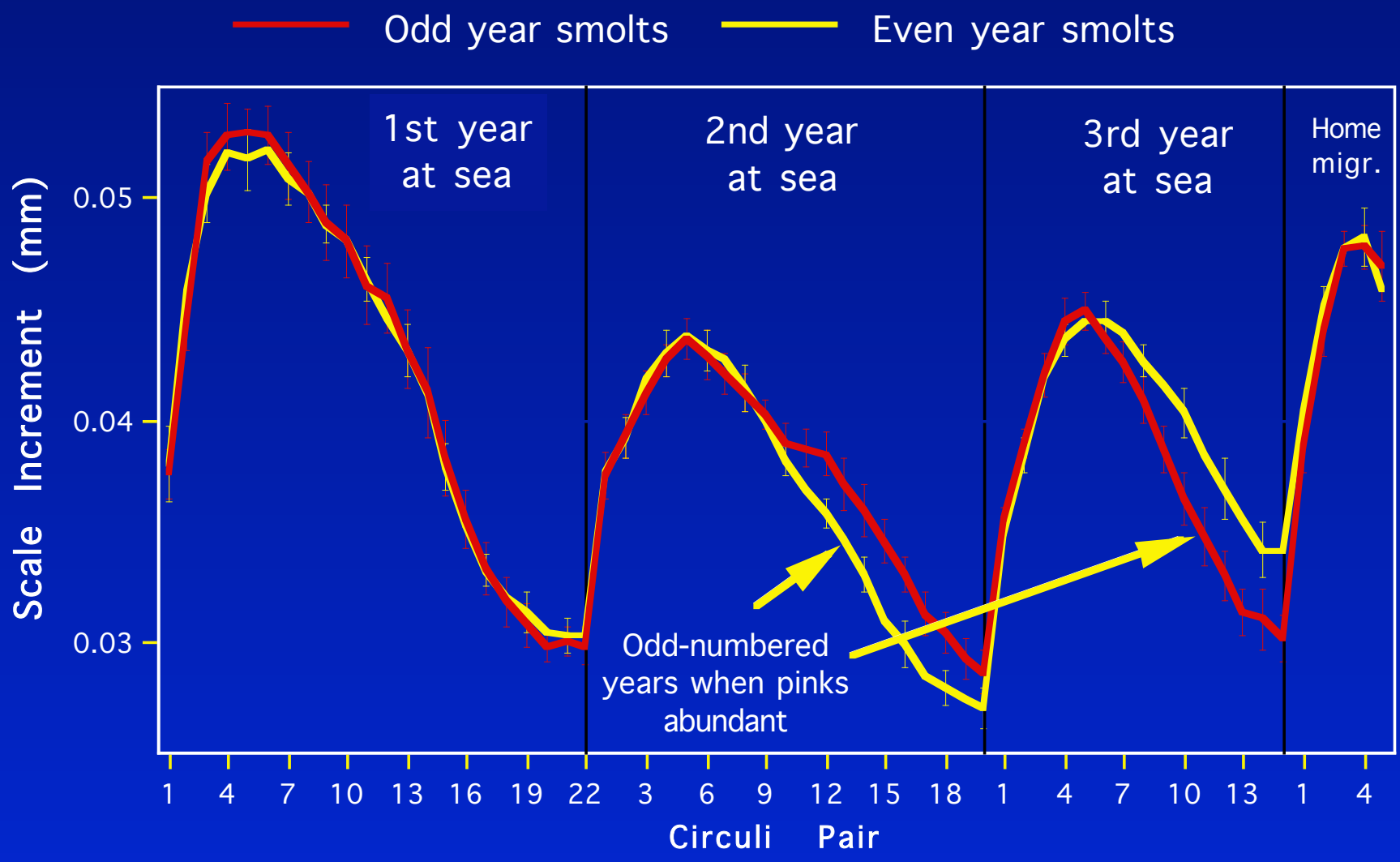


Sockeye growth reduced during odd years at sea (2nd & 3rd yrs)



Ruggerone et al. 2003

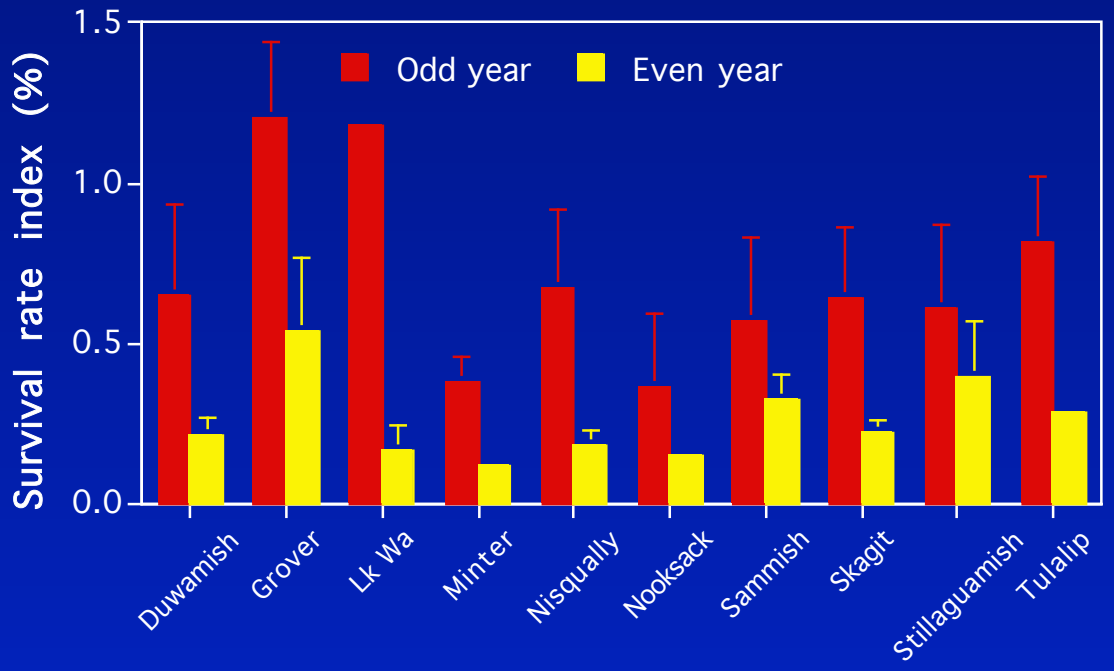
Seasonal Scale Growth during Odd & Even Years at Sea, 1955-2000

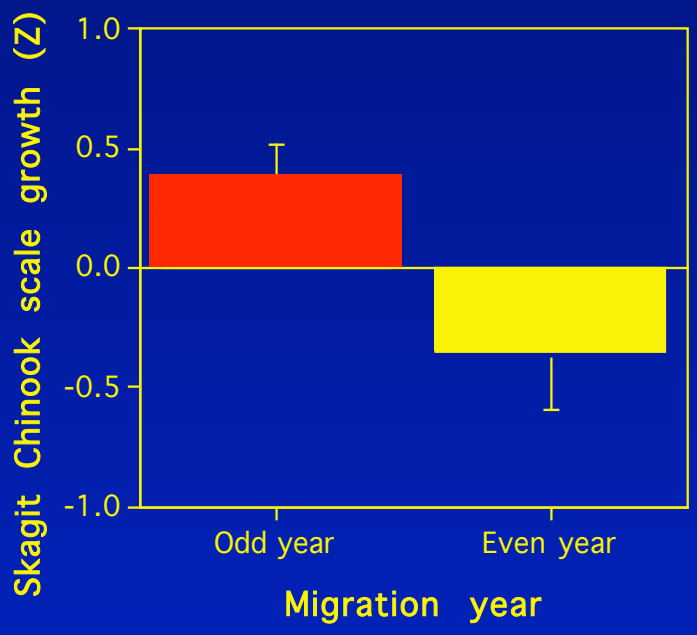


Response to climate shift?

Ruggerone et al. 2005

Puget Sound Chinook survival & growth lower when migrating in even years w/ Pinks, 1984-97



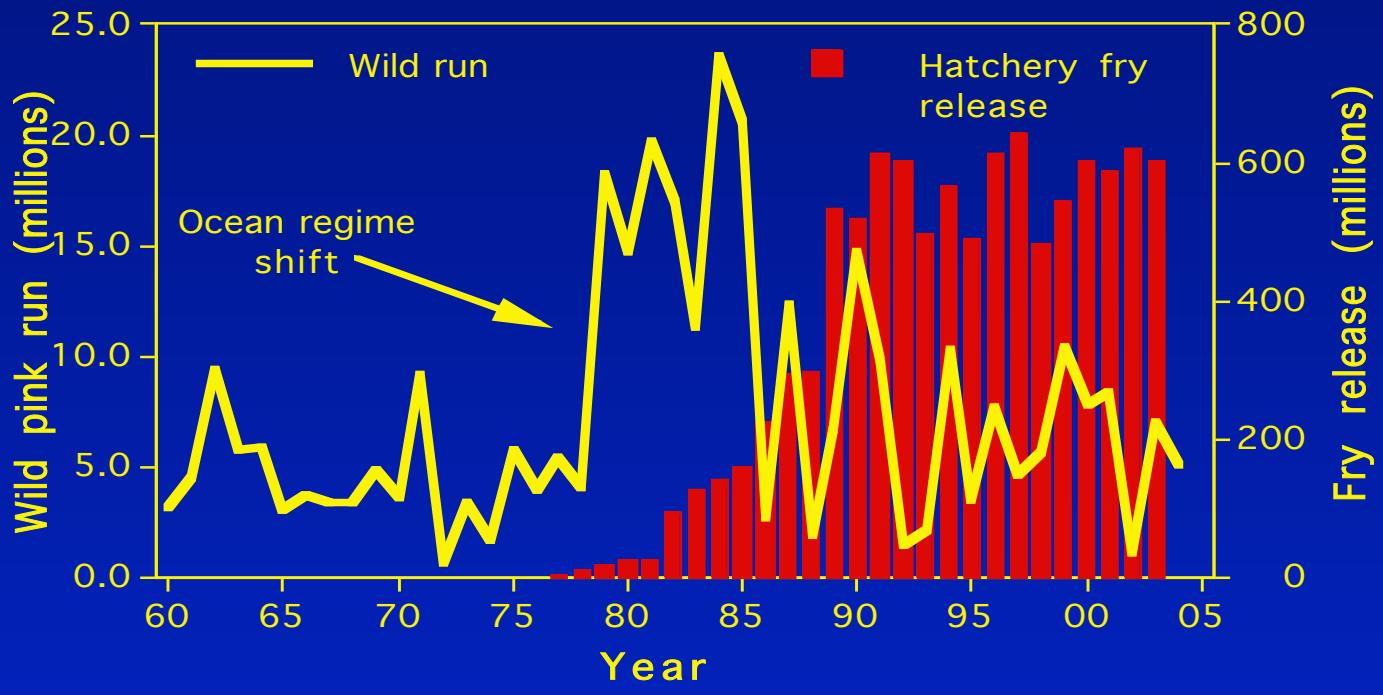


62% reduction release to recovery survival

Pattern may have changed after 1997

Ruggerone & Goetz 2004

Wild PWS Pink Salmon v. Hatchery Release: Competition?



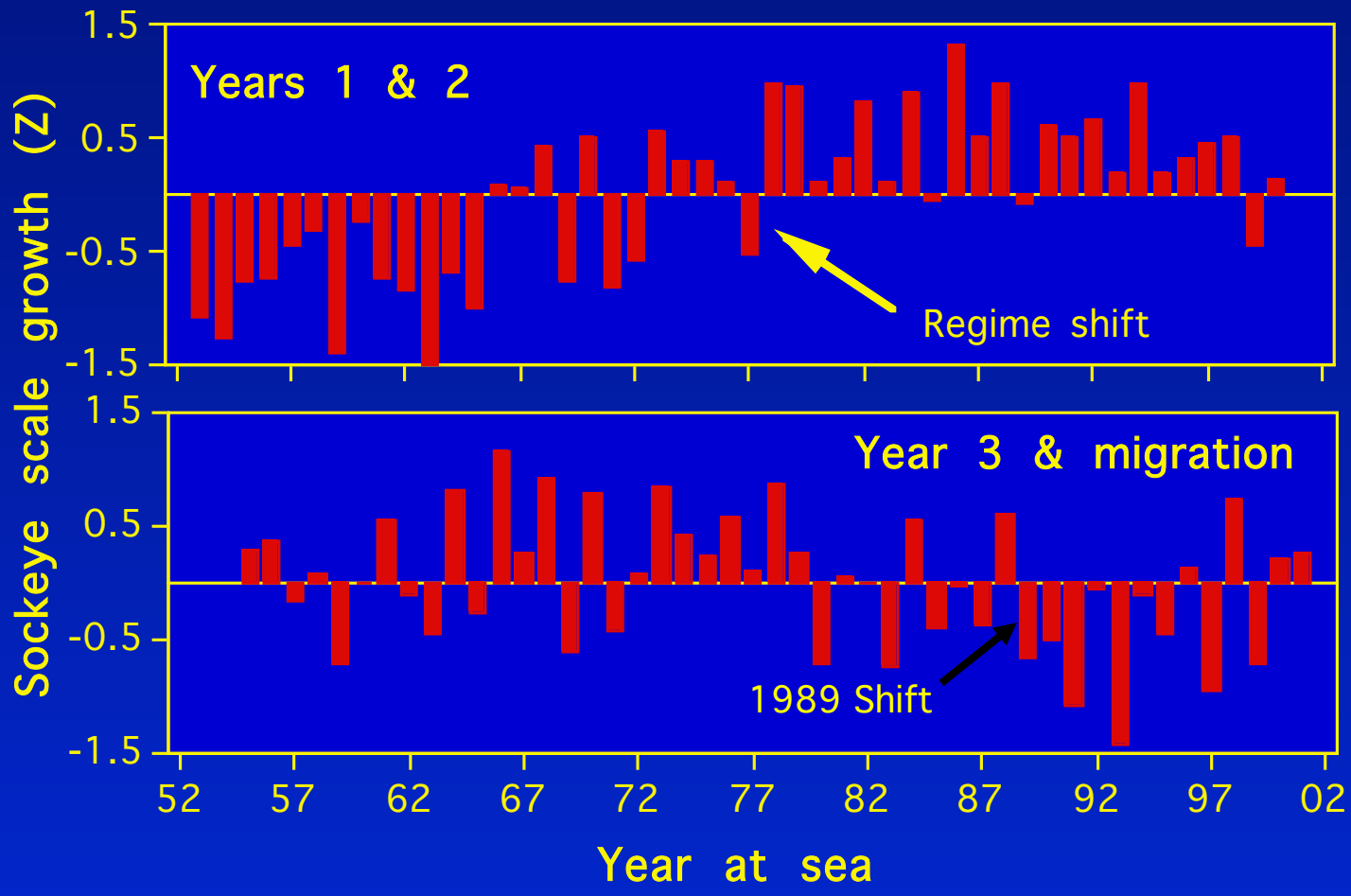
MSY of wild spawning pinks in PWS has increased **28%**, while in regions of Alaska without pink salmon hatchery programs the MSY has **tripled**.
~50% of PWS catch needed to pay for hatchery expenses.

Amoroso et al., in press. CJFAS.

Figure updated from Hilborn & Eggers by Ruggerone

Bristol Bay & Chignik Sockeye Growth:

Regime Shift Effect on prey & salmon growth

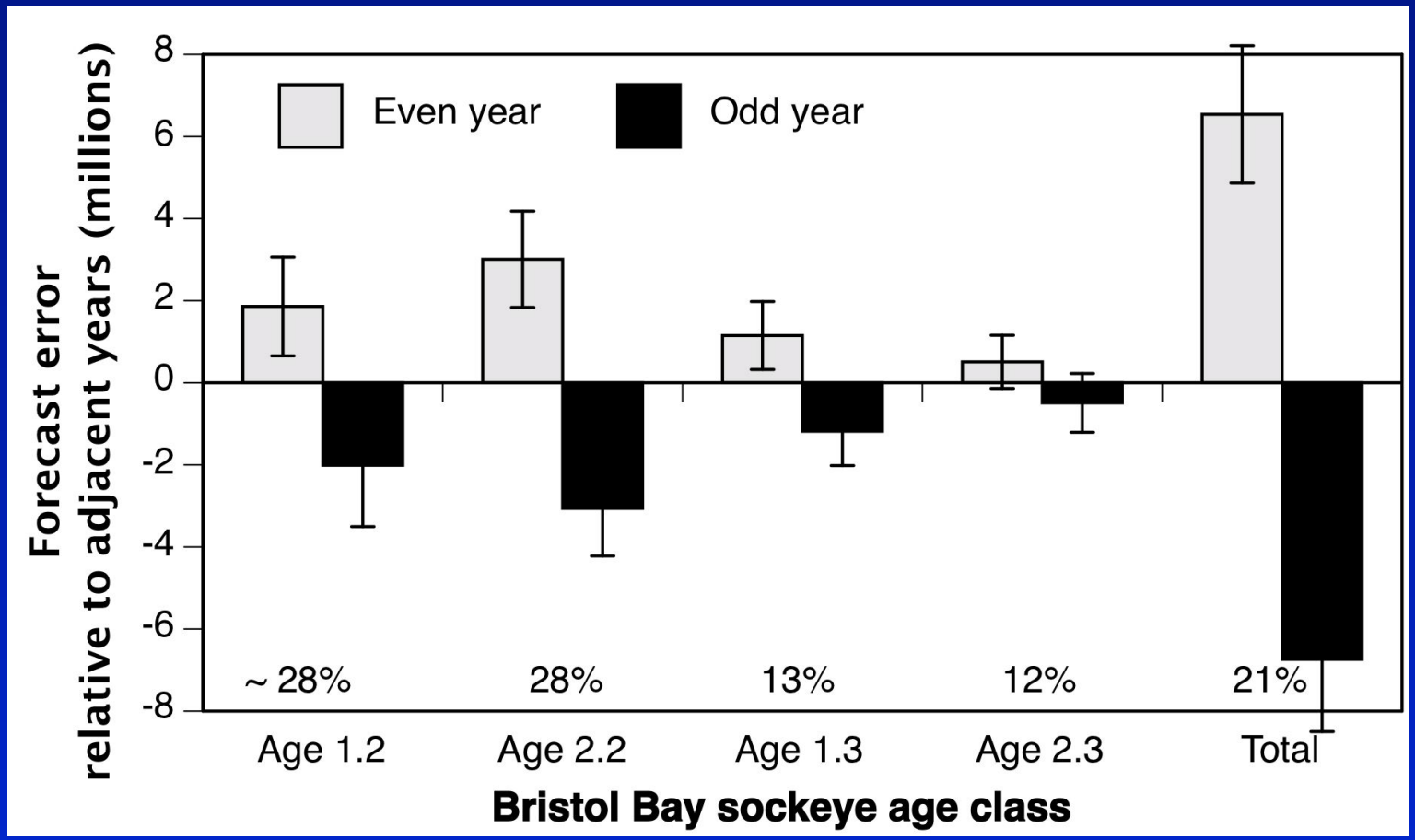


Bristol Bay & Chignik correlated

Ruggerone et al. 2007

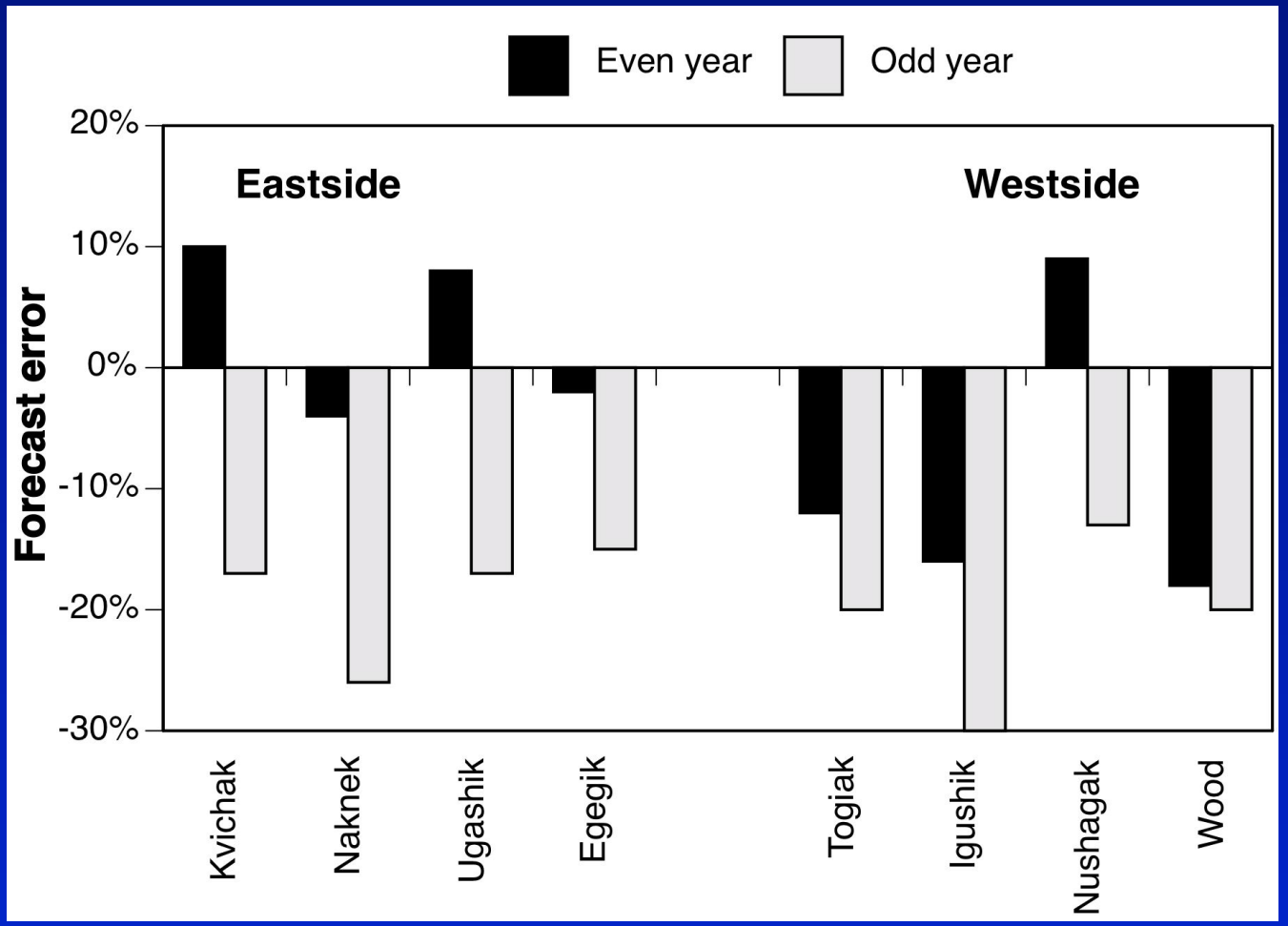
Bristol Bay Forecast Error

relative to error in year before & after



years: 1968-2010

Bristol Bay Sockeye Forecast Error
1977 to 2009



Forecast error (%) = (Forecast – Observed run) / Observed run
Forecasts by Alaska Department of Fish and Game

Ruggerone et al. 2016