Record-setting Abundances of Pink Salmon Impact Pacific Salmon and other Marine Species, including Southern Resident Killer Whales

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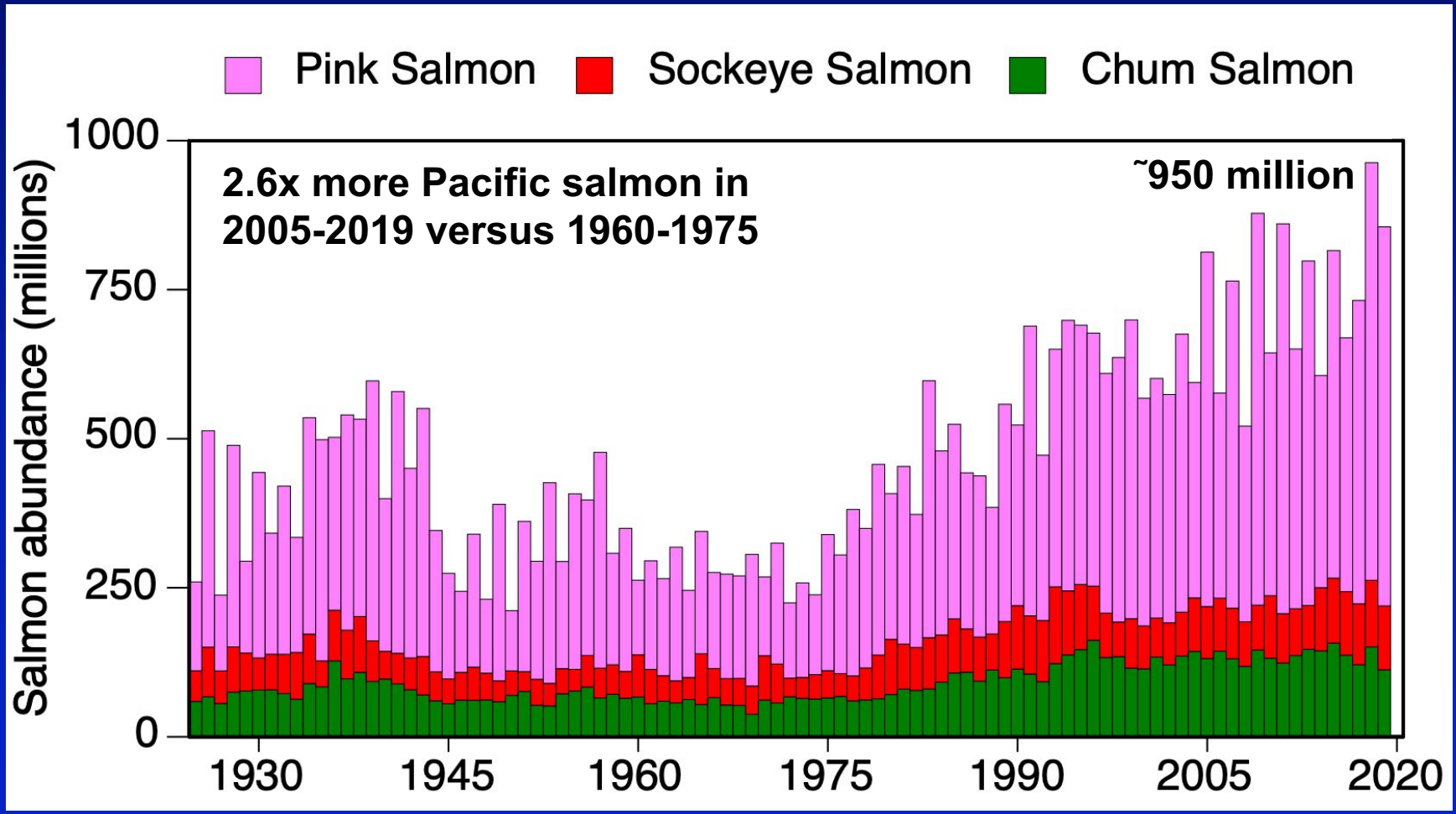
Plankton: Sonia Batten, Ivonne Ortiz **Seabirds: Alan Springer, Gus van Vliet**

Killer whale: Alan Springer, Leon Shaul, Gus van Vliet

Pink Salmon Dominate Pacific Salmon Abundance



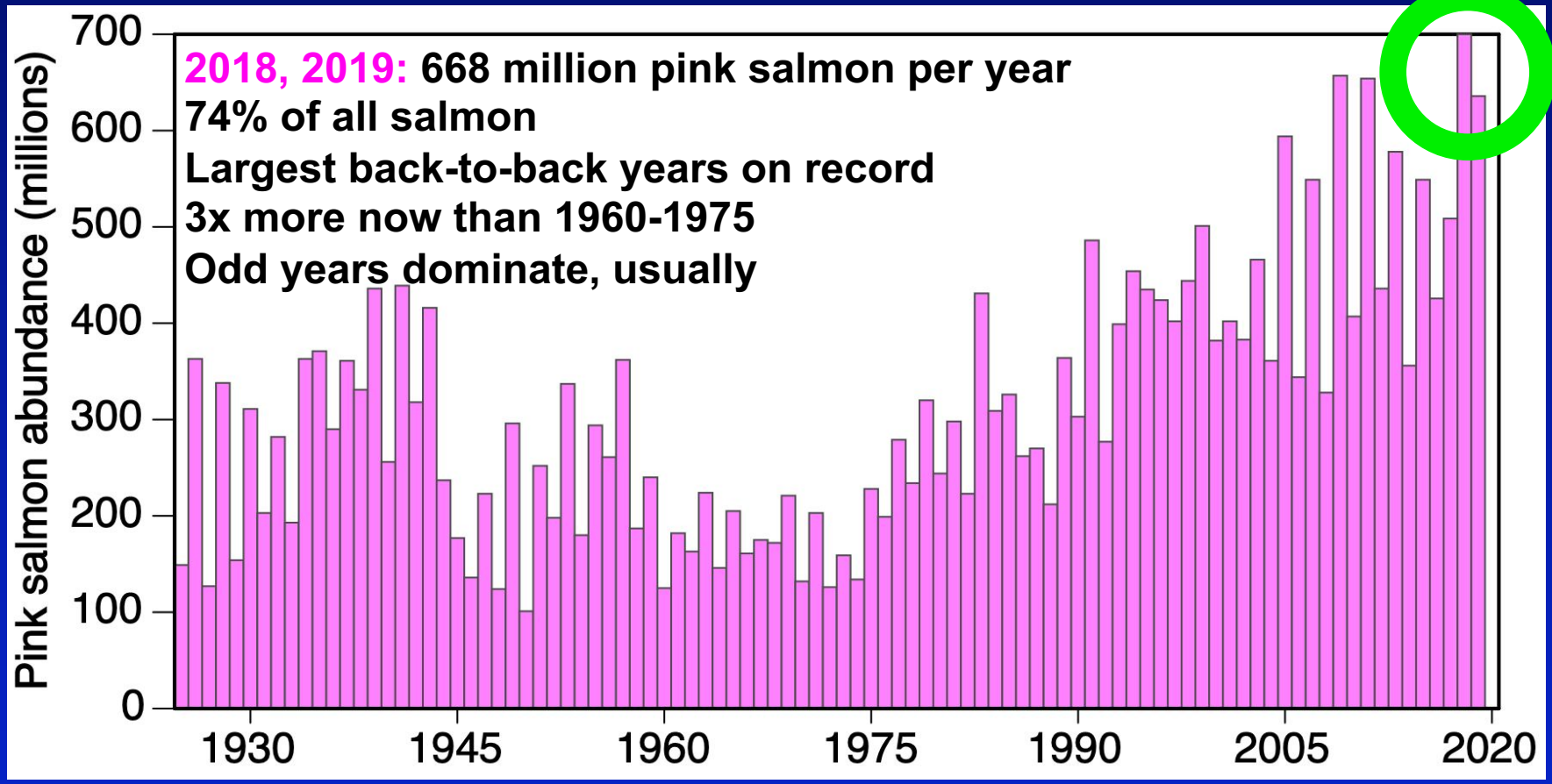
Chinook, coho, steelhead <3% of total catch biomass

Pink salmon ~70% of total

Abundance = catch + escapement

Ruggerone and Irvine 2018, preliminary update

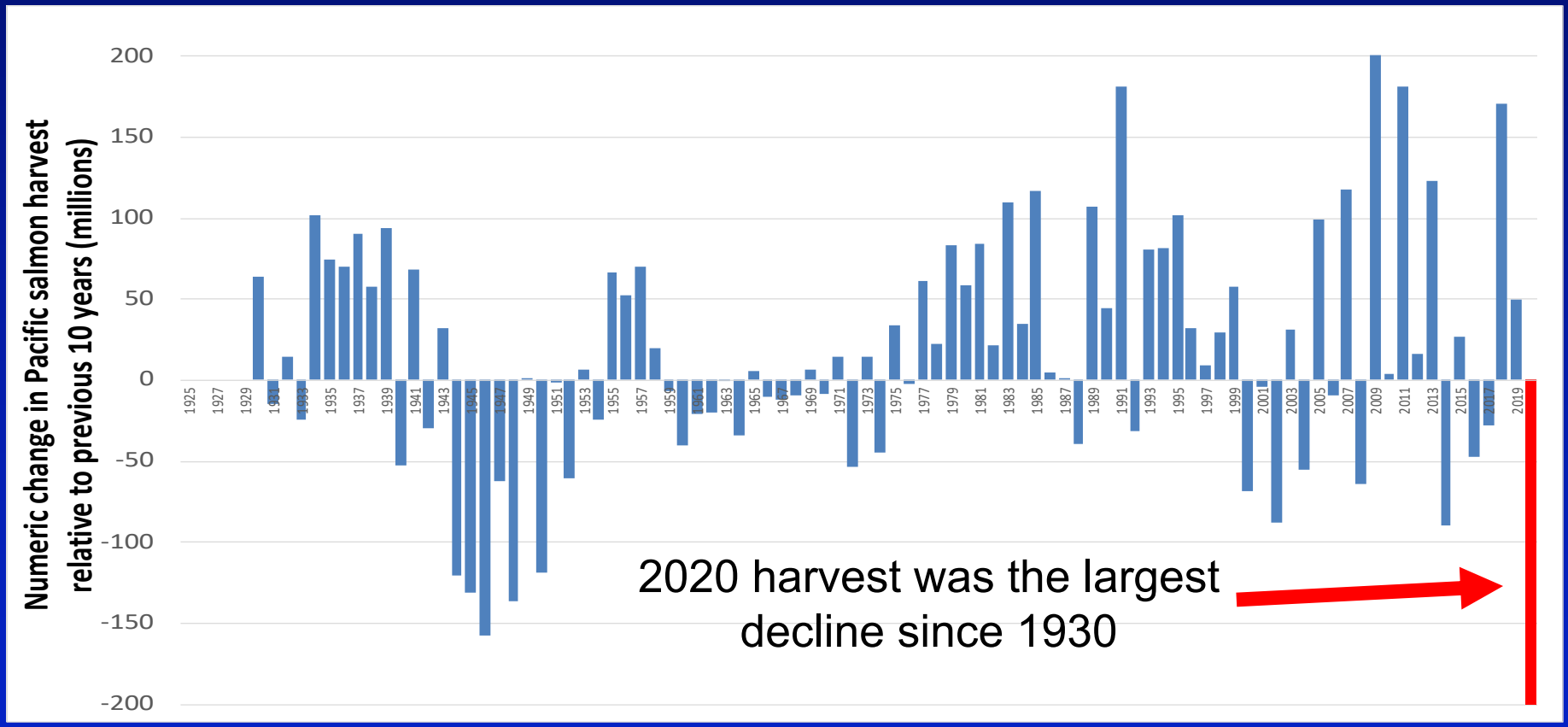
Pink Salmon Dominate Pacific Salmon Abundance



- ˜650 million pink salmon in peak odd-years
- Hatchery pink salmon = 82 million/yr, 2005-2015; > wild chum; = wild sockeye
- Alaska: up to 48% commercial catch = hatchery fish (mostly pinks)

Ruggerone and Irvine 2018, preliminary update

Did Pink Salmon Influence the North Pacific Harvest Collapse in 2020?

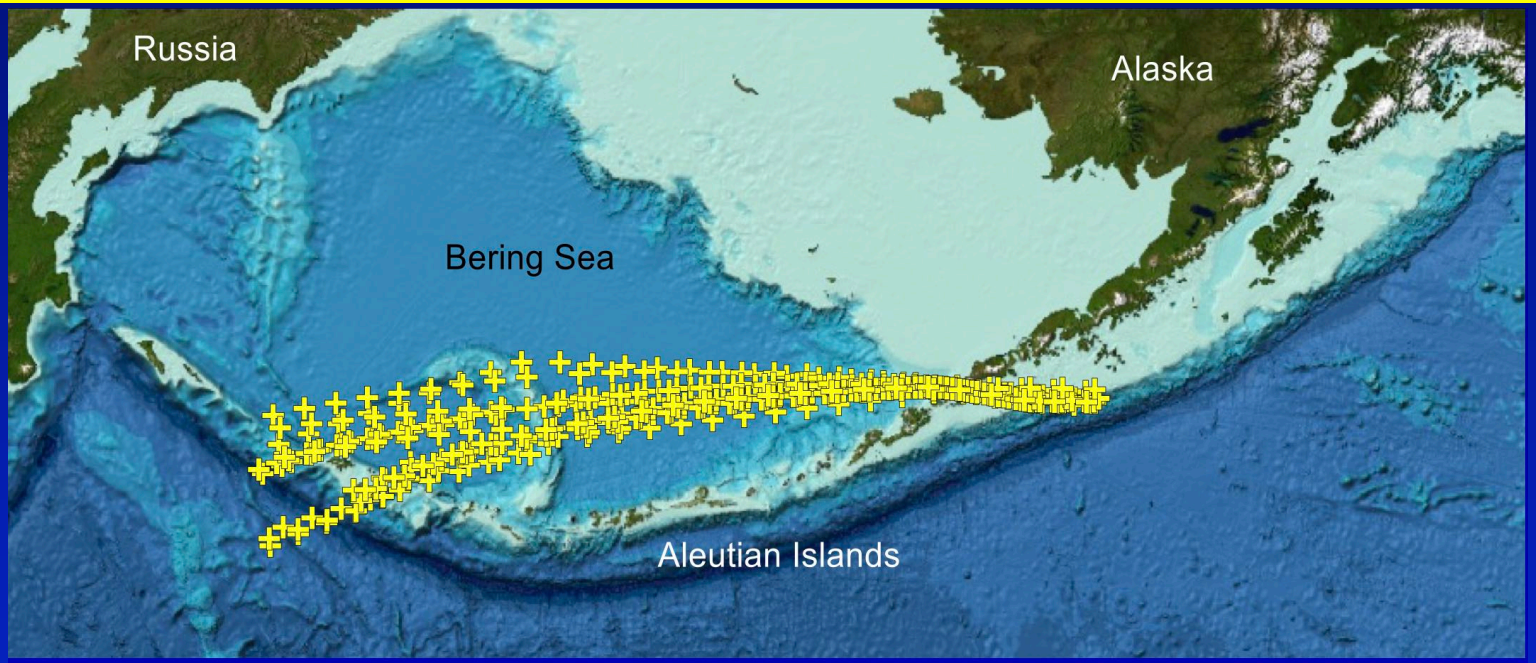


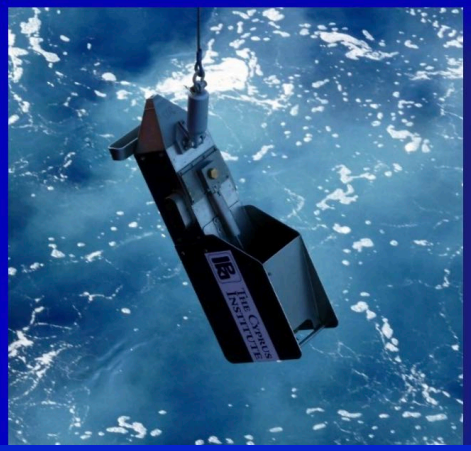
- 205 million fewer Pacific salmon harvested in 2020 compared with the mean from 2010-2019
- Harvests in 2020 followed the two largest consecutive years of pink salmon abundance on record.

Ruggerone and Irvine 2018, preliminary update. 2020 catch data are preliminary

Do Pink Salmon Cause a Trophic Cascade?

Continuous plankton recorder, June-Aug, 2000-2014



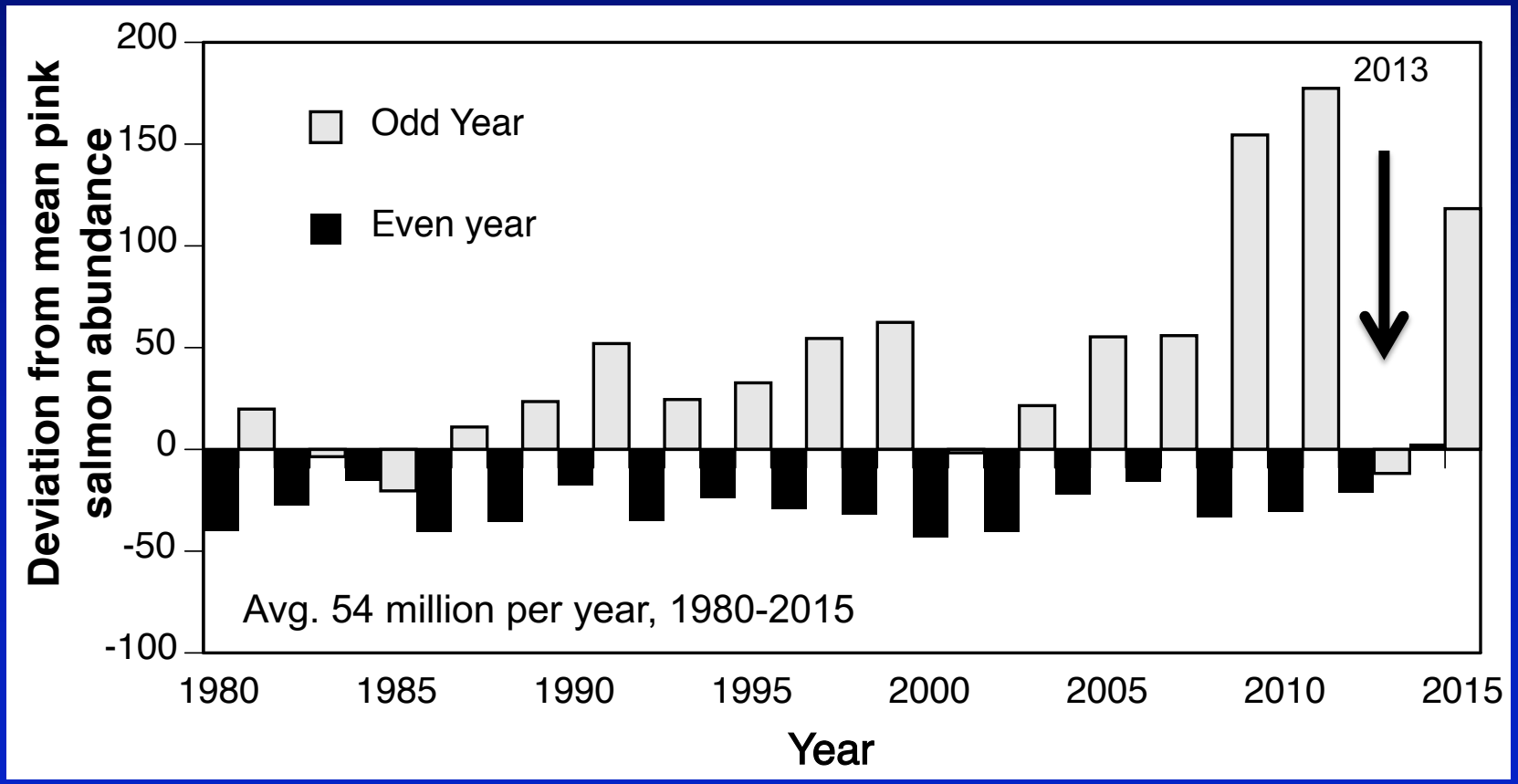


Batten, Ruggerone, Ortiz 2018

No data collected 2015, 2016, 2017

Eastern Kamchatka Pink Salmon Abundance

Major Population in Central Pacific/Bering Sea



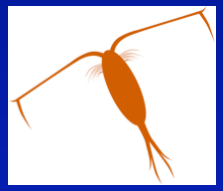
- Abundance exceptional in odd years on high seas
- Overlap with Bristol Bay sockeye and populations from south

Ruggerone and Irvine 2018

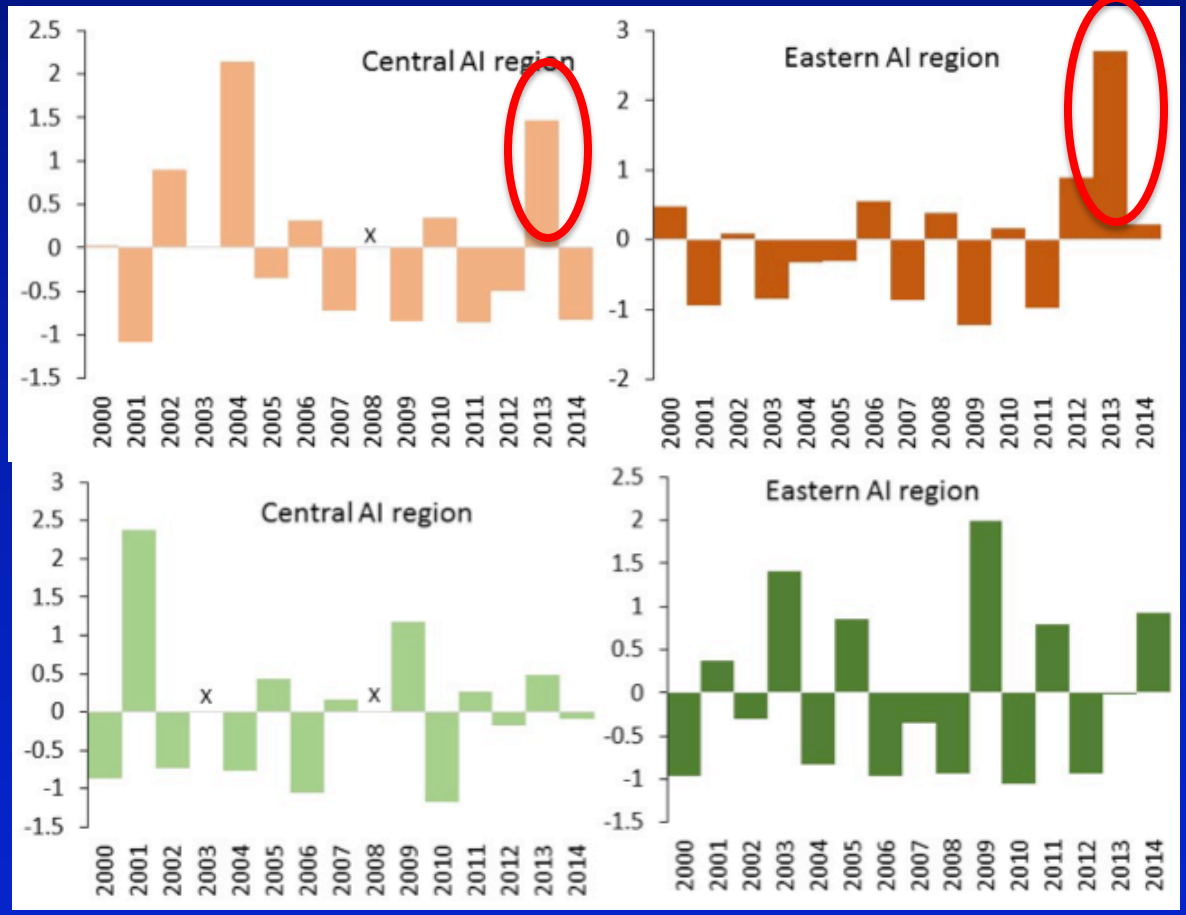
Do Pink Salmon Cause a Trophic Cascade?

Plankton Counts: June-Aug 2000-2014

Large copepods decline in odd years when pinks ~40x more abundant



Diatoms increase in odd years when more pinks and fewer zooplankton



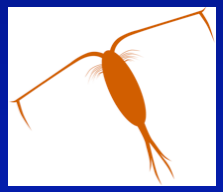
Climate cannot explain odd/even patterns
2013: Zooplankton boomed when pinks salmon “crashed”

Batten, Ruggerone Ortiz 2018

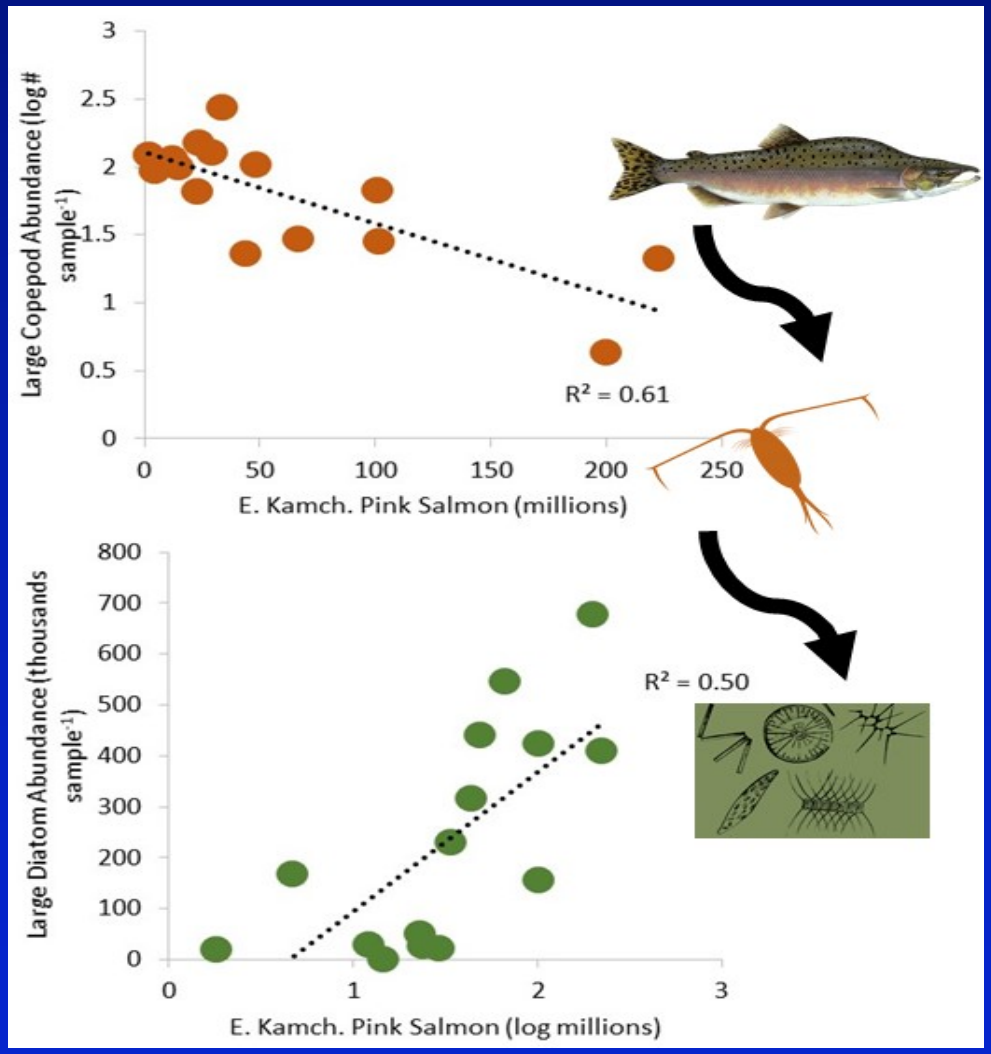
Do Pink Salmon Cause a Trophic Cascade?

Plankton response to Pink Salmon

Large copepods decline when pink salmon are abundant



Diatoms increase when few zooplankton and many pink salmon



Batten, Ruggerone, Ortiz 2018

Bristol Bay Sockeye Growth vs Pink Salmon Abundance

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

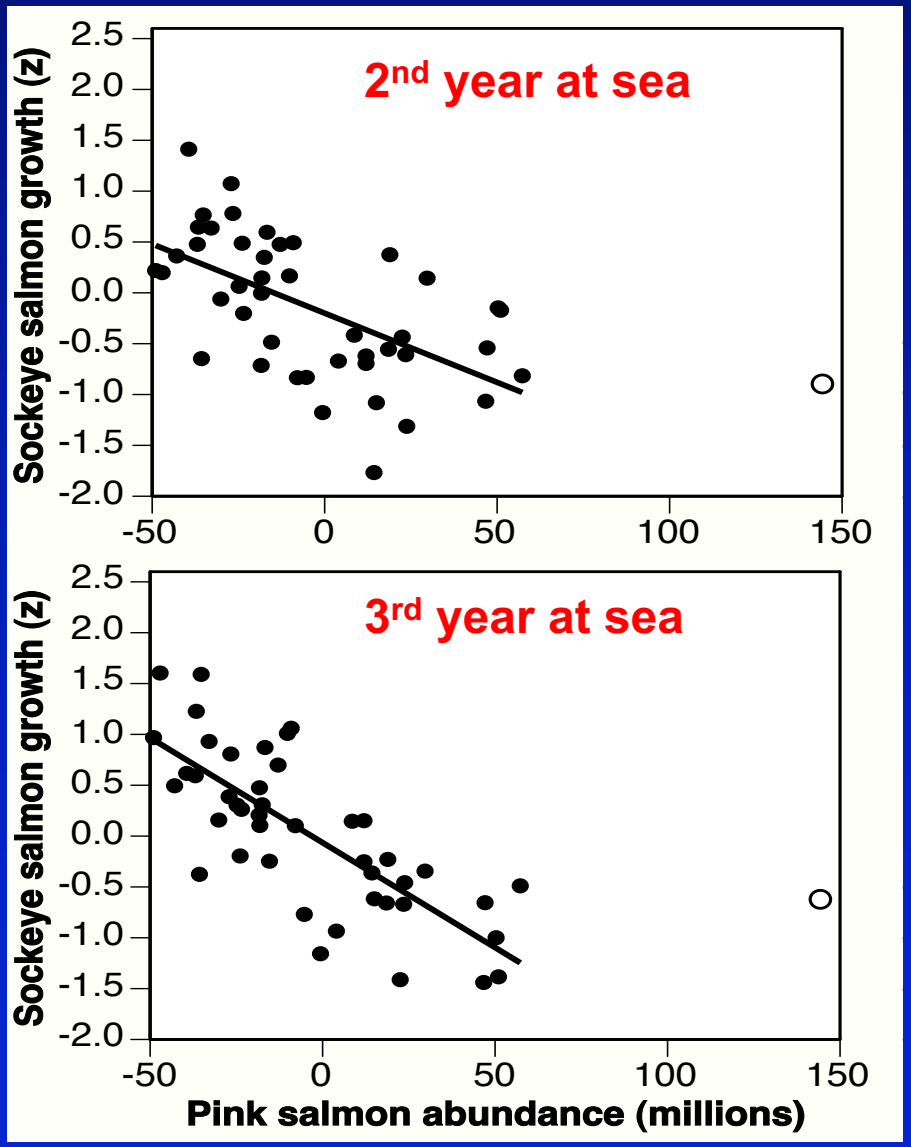
Eastern Kamchatka pink salmon abundance (detrended, 0 is mean)

No relationship 1st year at sea
(few pinks)

Serial autocorrelation of residuals:
P > 0.05.

SST: P > 0.05

Pink salmon abundance:
2 to 200 million per year



Ruggerone et al. 2016

Bristol Bay Sockeye Scale Growth

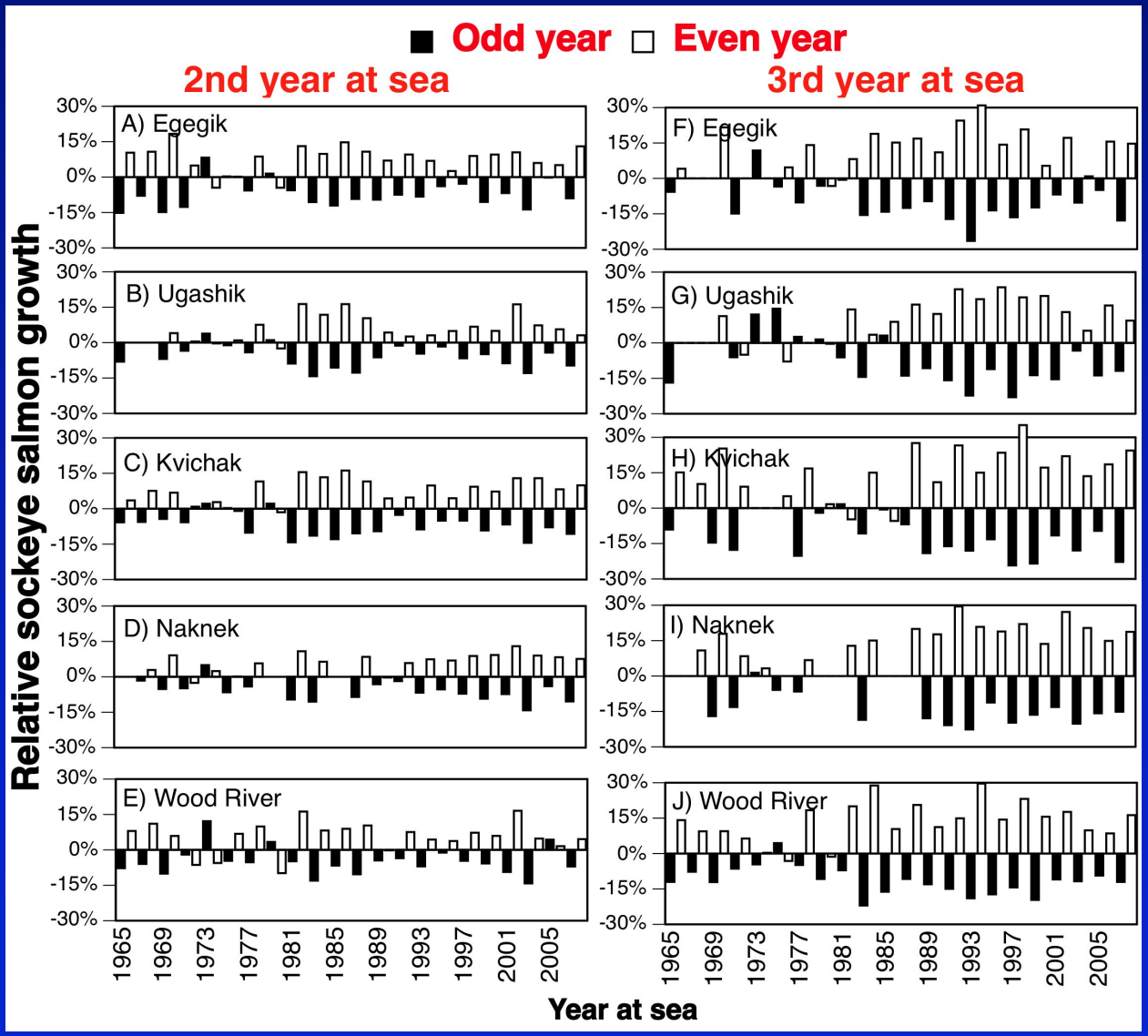
relative to growth in year before & after

Biennial growth is strong during 2nd and 3rd years at sea

Pink salmon 40% more abundant in odd-numbered years (sampling in Bering Sea)

Relatively few pink salmon in Bristol Bay. No biennial pattern in 1st year growth.

Same pattern observed in Chignik, Kenai, Copper, SEAK, & Fraser sockeye.

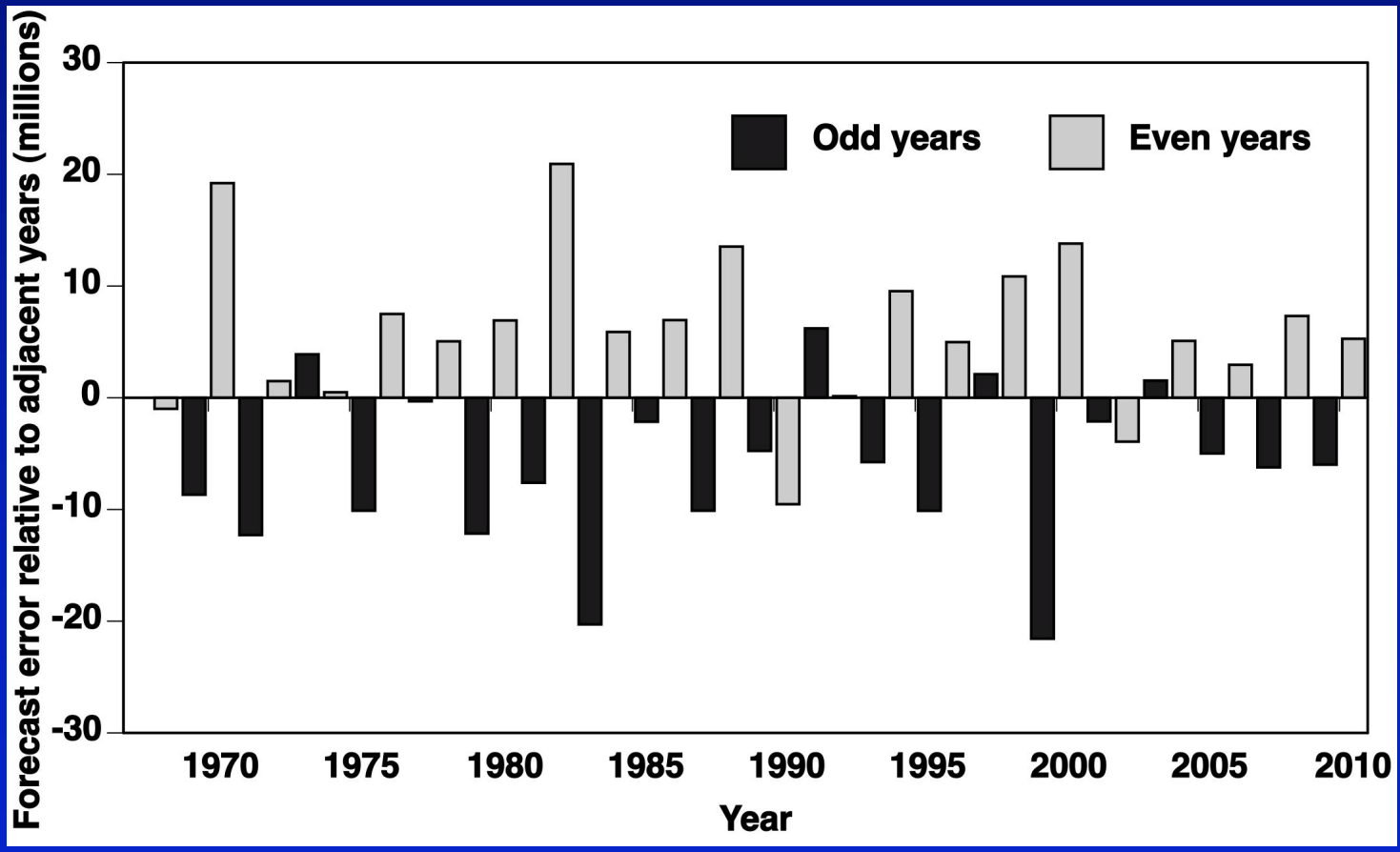


Ruggerone et al. 2003, 2016, unpublished analyses

Bristol Bay Sockeye Forecast Error
relative to error in year before & after

Stocks:

Kvichak,
Naknek,
Egegik,
Ugashik

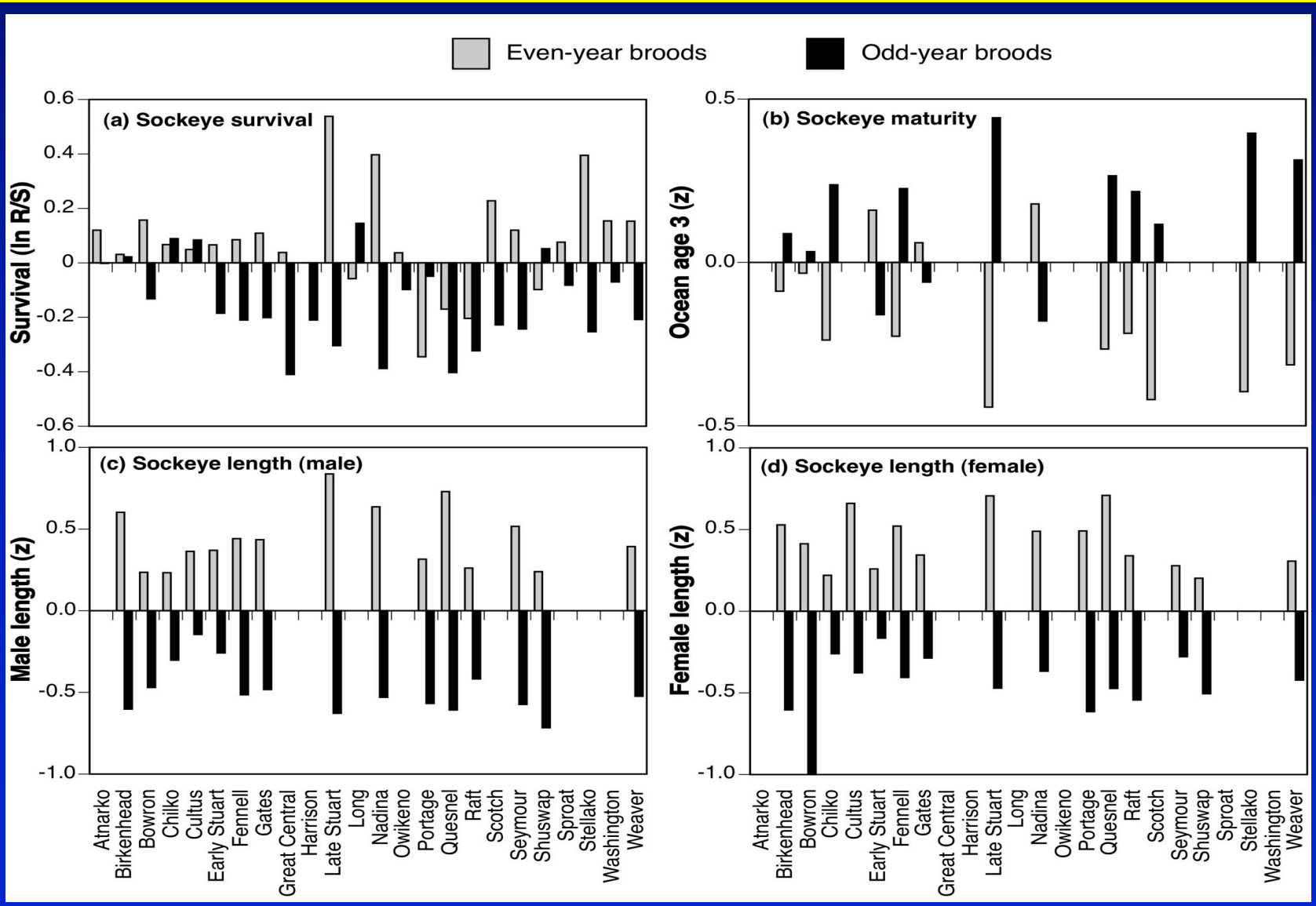


Relative error = Error Y_i – (avg. error Y_{i-1}, Y_{i+1})
Forecast error (%) = (Forecast – Observed run) / Observed run

Ruggerone et al. 2016

Sockeye Odd/Even Year Patterns:

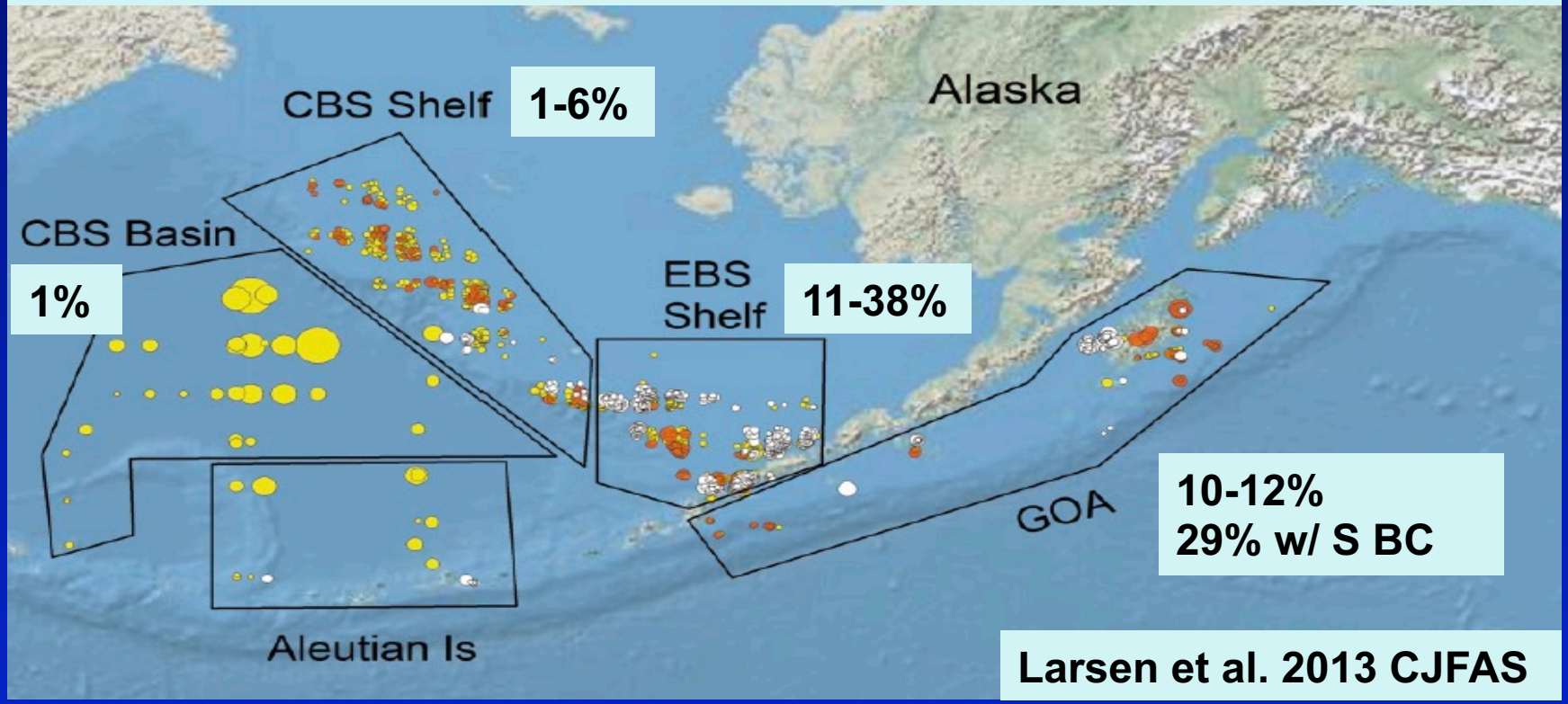
Fraser R, WCVI, central & northern BC, Lake WA (BY 1978-2005)



Ruggerone and Connors 2015

Do Pink Salmon affect Columbia River Chinook?

Proportion of Chinook from lower USA via GSI, summer/fall 2005-2010



"According to our estimates, a significant portion of stocks from California to Southeast Alaska overwinter in the Gulf of Alaska, then travel northward to the continental shelf region of the eastern Bering Sea during spring and summer" (values in graph above exclude SEAK)

"With temperatures rising in the Gulf of Alaska because of climate change, it is possible that this region will become even less hospitable to salmonids during the summer months, increasing the proportion of salmon stocks that spend the summer in the Bering Sea.....i.e., **pink salmon haven**

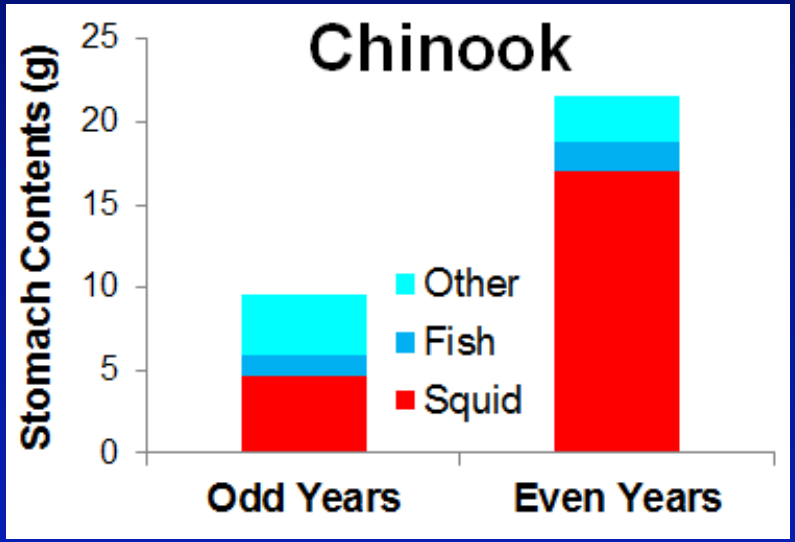
Do Pink Salmon Reduce Chinook Growth & Survival?

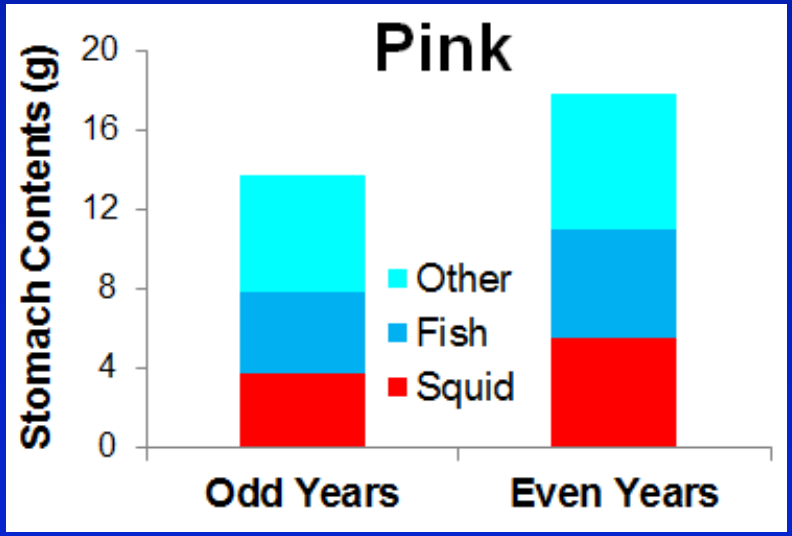
- Pink salmon ~40X more abundant in Bering Sea in odd years
- Chinook feed at higher trophic level, but considerable diet overlap: **Squid & Fish**
- **Bering Sea:** 1991-2000

  56% decline Chinook stomach fullness

  68% less squid & fish in Chinook

  in Odd Years

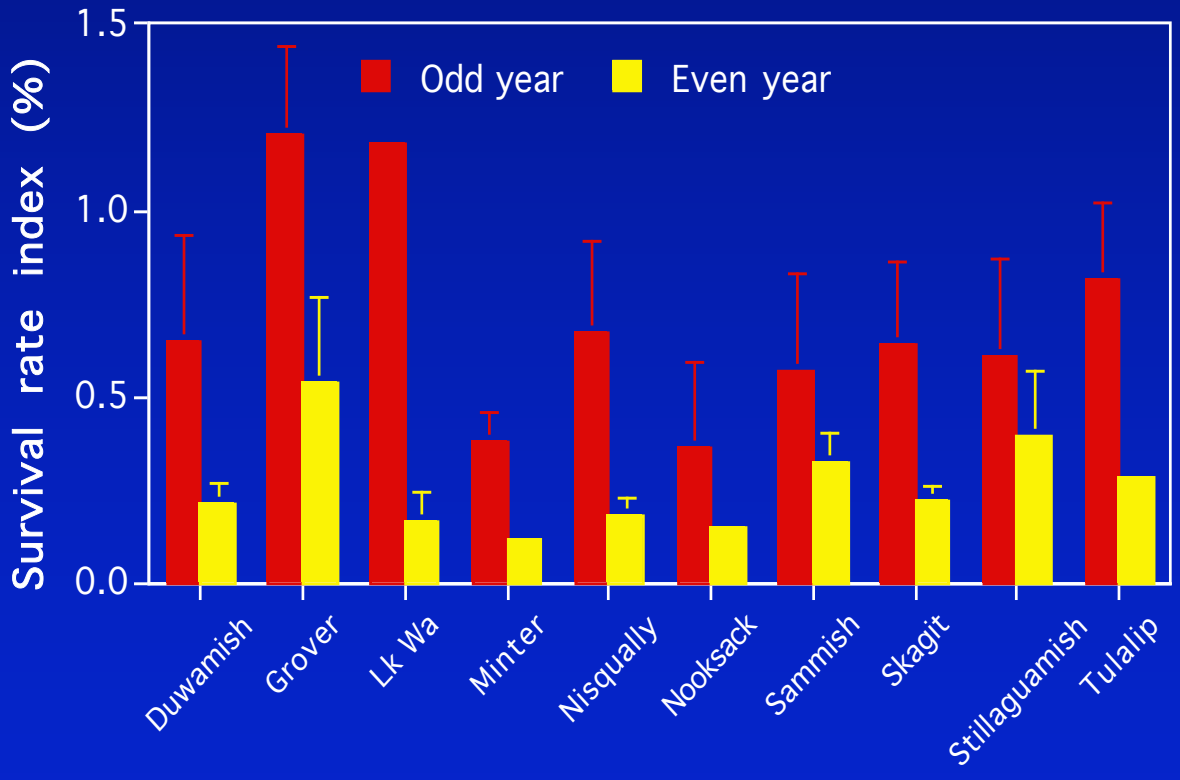


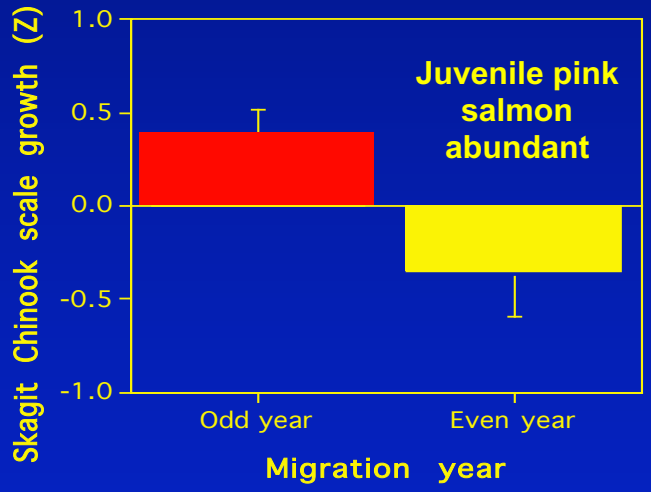


Data source: Davis 2003. Ruggerone et al. 2003, 2016

Pink Salmon Effect on Salish Sea Chinook

Puget Sound Chinook survival 62% lower when migrating in even years w/ juvenile pinks salmon, 1984-1997





Survival based on ~50 million code-wire-tags; biennial pattern established during 1st year at sea

Ruggerone and Goetz 2004, unpublished scale analysis

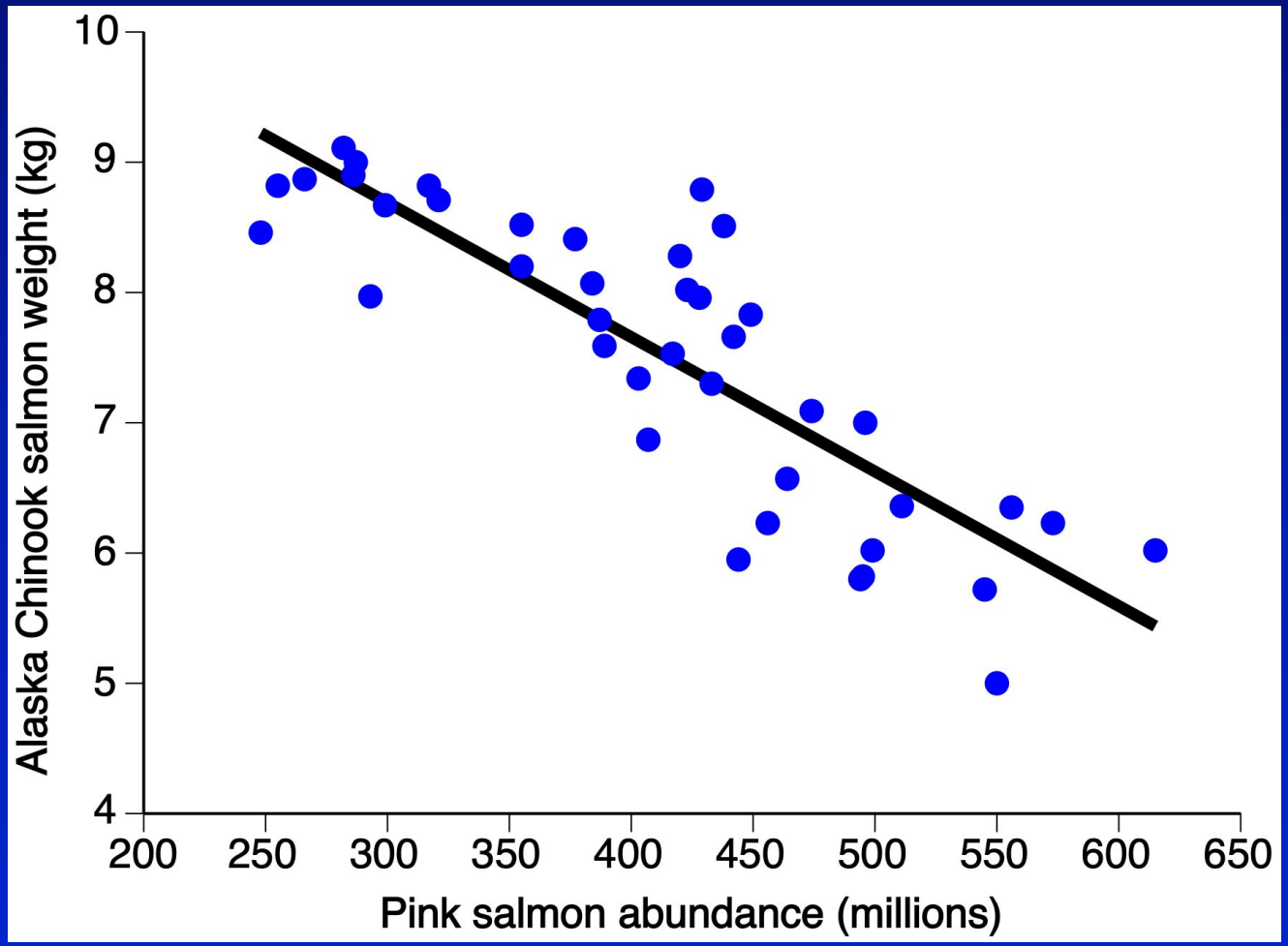
See recent analyses by Kendall et al. 2019

Do Pink Salmon Reduce Chinook Growth?

Average weight in **Alaska** commercial catch, 1980 to 2020

Includes many south-migrating Chinook

Moving 3 year mean pink salmon abundance



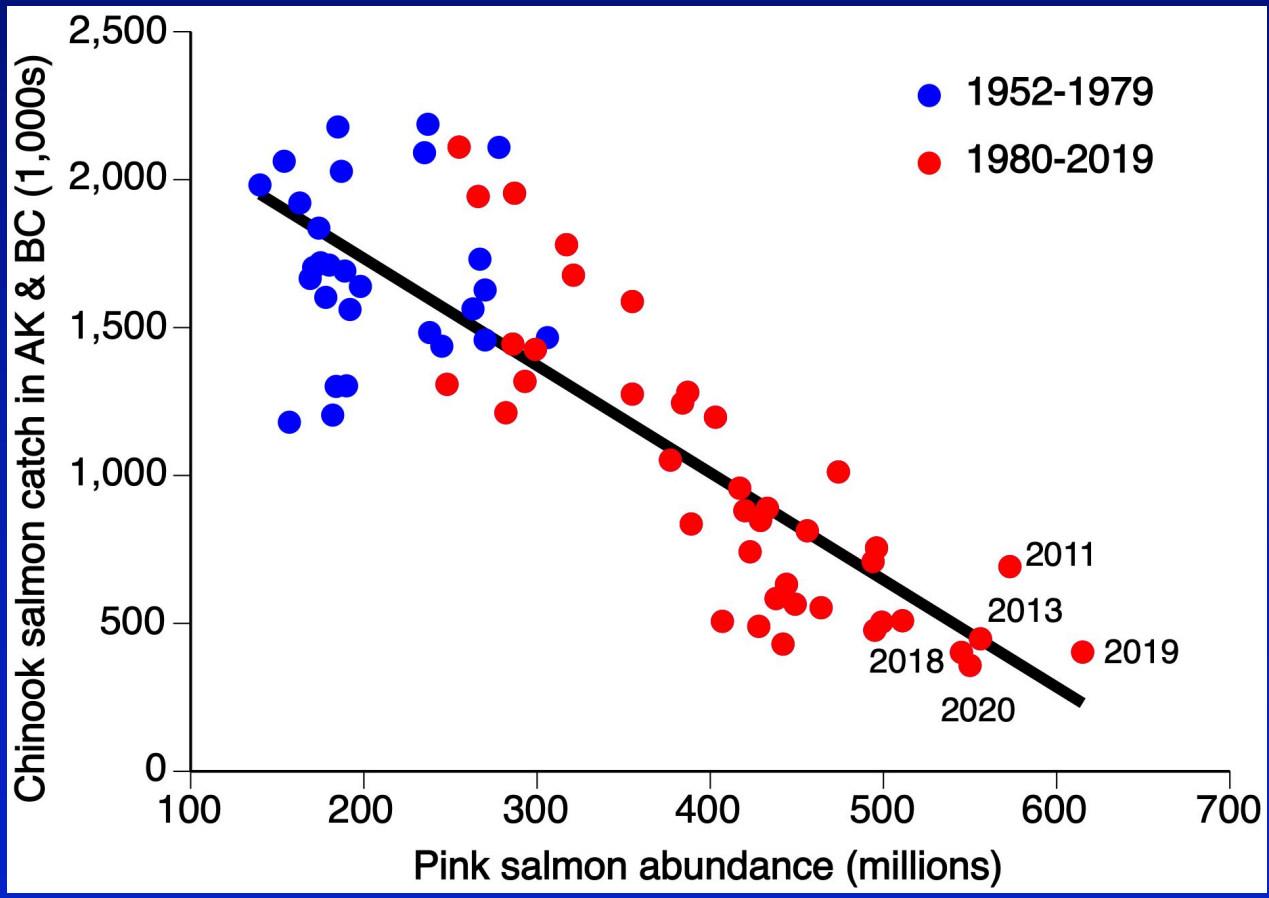
Ruggerone and Irvine 2018, updated; NPAFC Chinook data.

Do Pink Salmon Reduce Chinook Survival?

Commercial Chinook catch1952 to 2020

Includes many south-migrating Chinook

Moving 3 year mean pink salmon abundance



- Chinook abundance depressed throughout Alaska & BC, long-term decline in size at age & age at maturation (Lewis et al. 2015; Ohlberger et al. 2018, Cunningham et al. 2018)

Ruggerone et al. 2016, updated

Do Pink Salmon Affect Steelhead?

Interior Fraser R steelhead

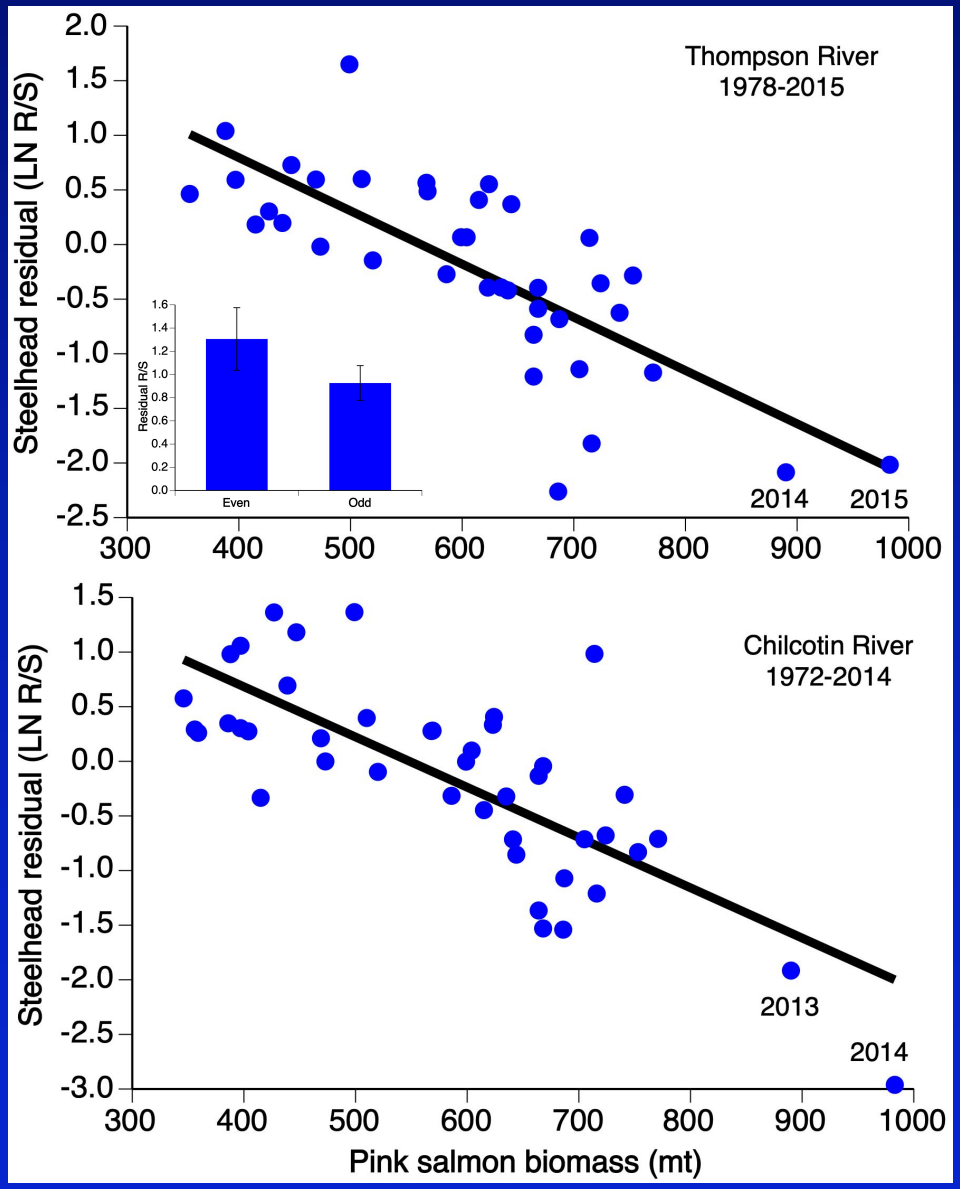
- Residuals from Ricker curve
- Pink salmon BY +3,4(T),+4,5(C) years

Korman et al. 2018;
R. Bison preliminary data update

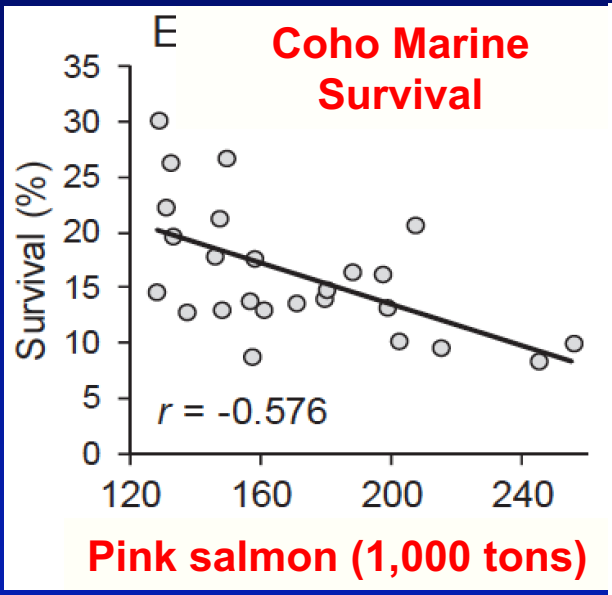
High Seas Diet:

- High caloric prey (squid) negatively correlated with pink salmon abundance
- Proportion empty stomachs correlated with pink salmon

Atcheson et al. 2012

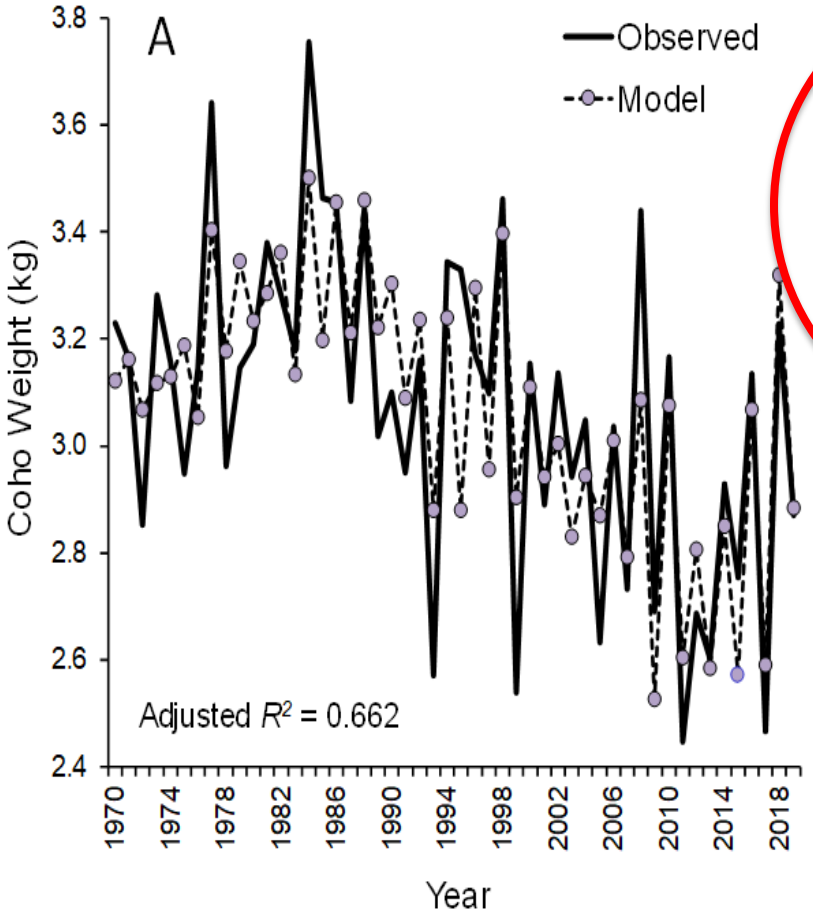


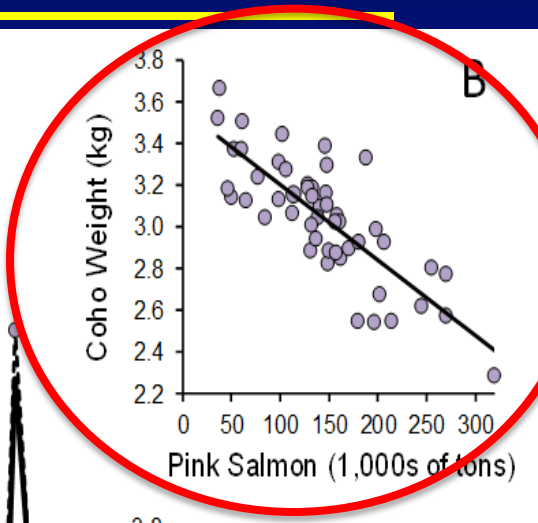
Do Pink Salmon Impact SEAK Coho Salmon?

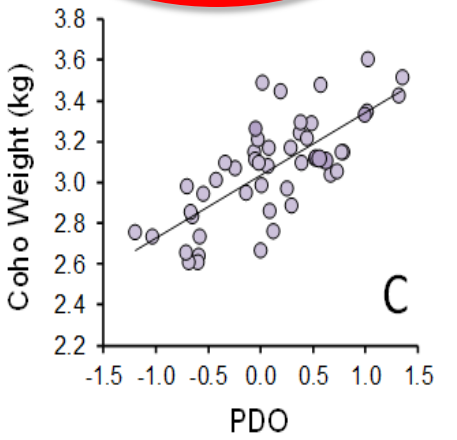


1970 to 2019

Shaul and Geiger 2014, updated



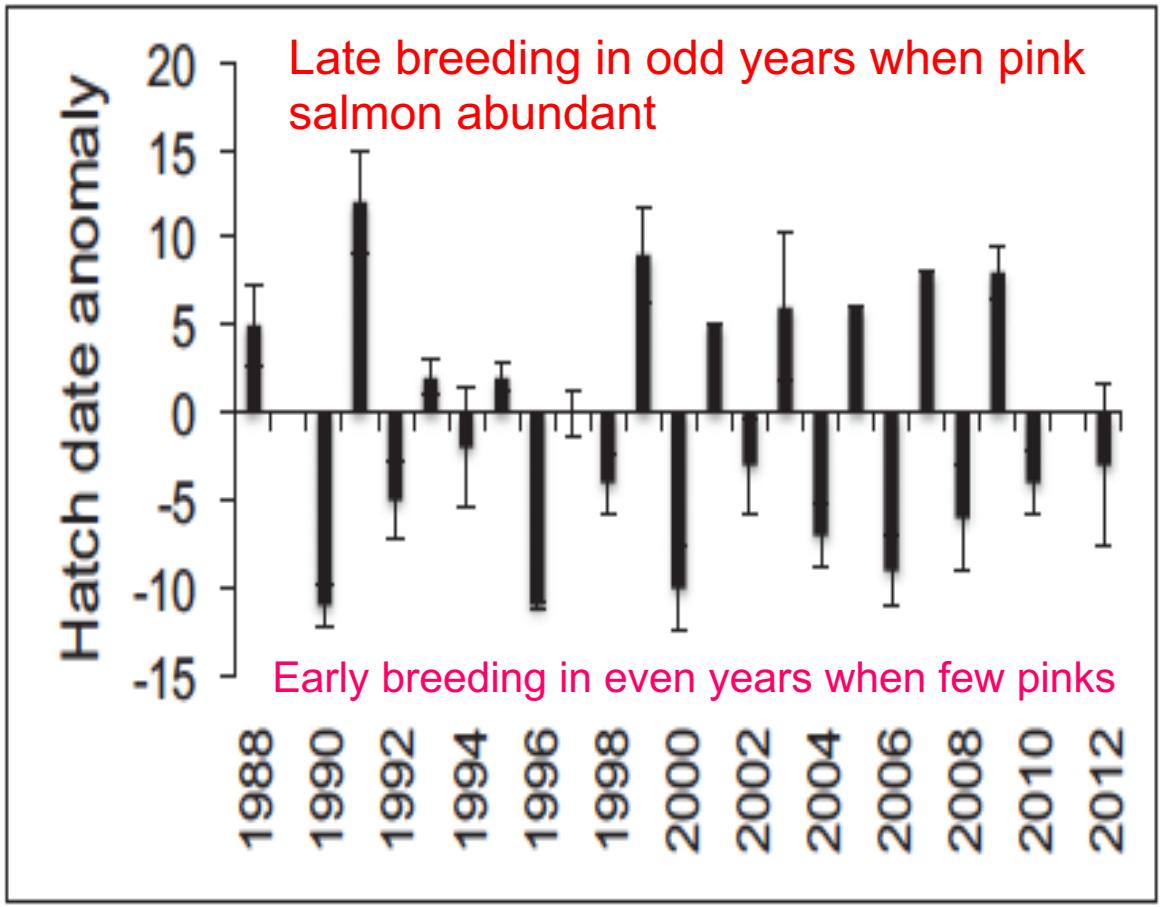




Do Pink Salmon Affect Seabirds?

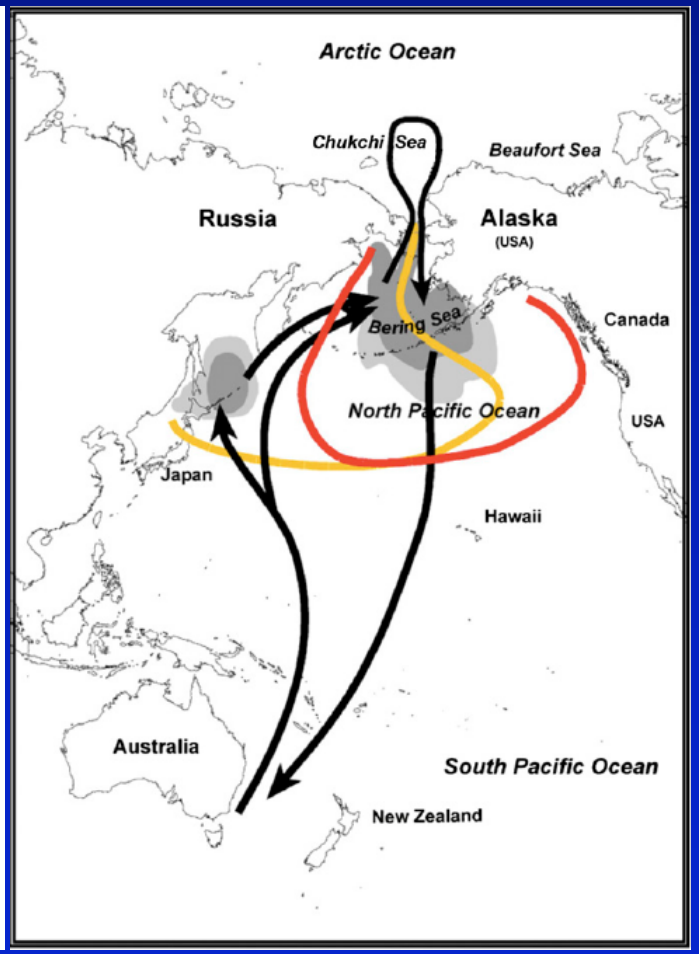
Seabirds eat same prey as pink salmon

Aleutian Islands: multiple species



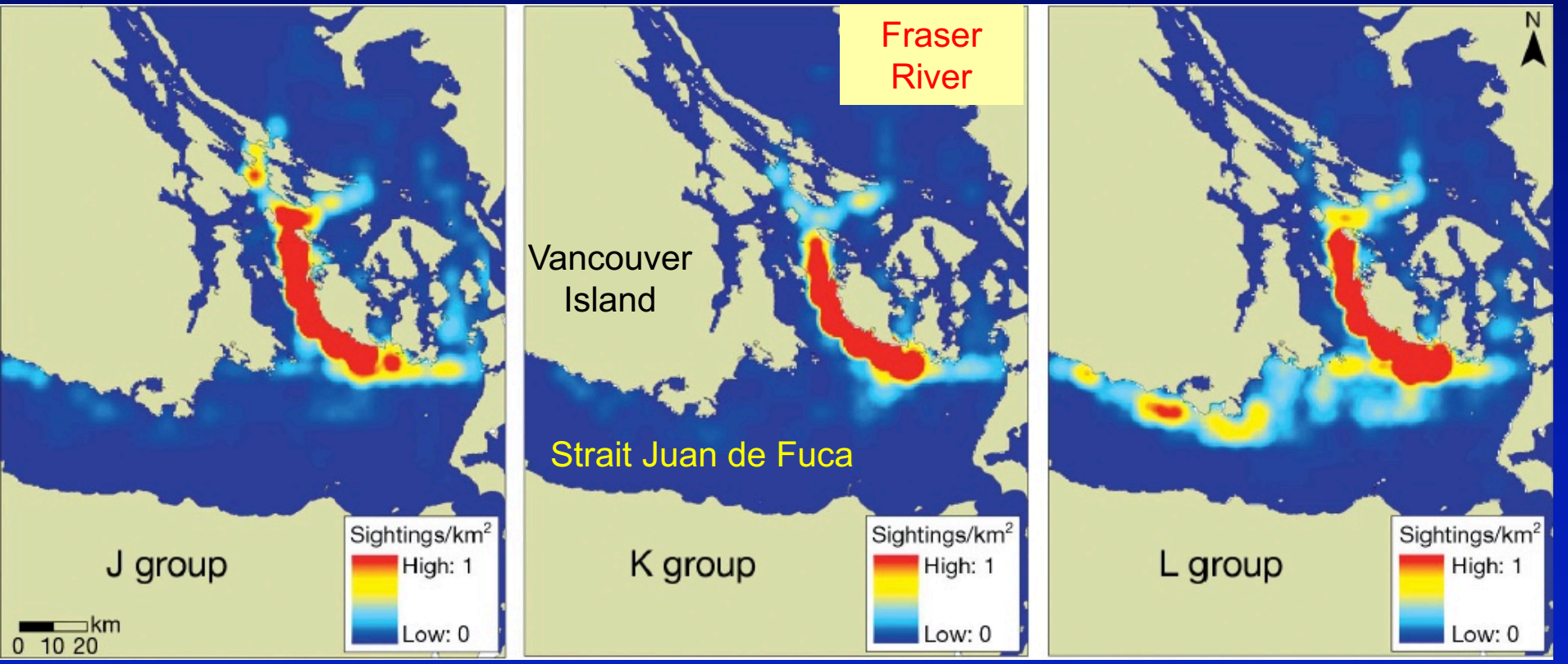
Springer and van Vliet (2014); Springer et al. 2018

Australia: shearwaters



no data in 1989, 2011

Southern Resident Killer Whale Core Foraging Area



May to September distribution (Hauser et al. 2007)

Chinook salmon: key prey. ~No pink salmon eaten

Chinook/Pink salmon overlap: late July to early Sept

18 million pink salmon in odd years; 0.4 million in even years

Pink salmon escapement increased 135% after 1997 due conservation concerns for Chinook and sockeye

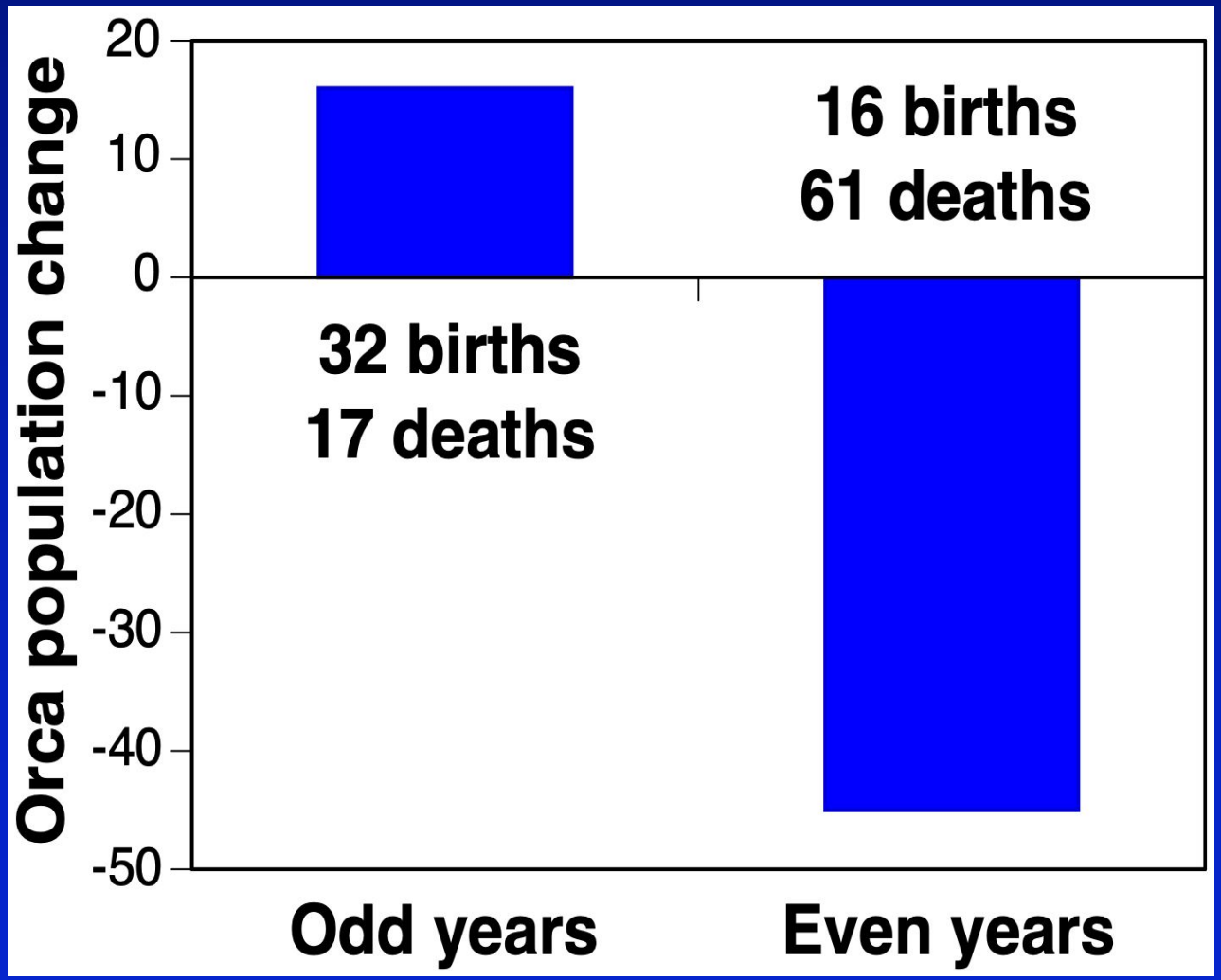
Do Pink Salmon affect Southern Resident Killer Whales?

Numbers of SRKW increased by 15 in odd years but declined by 45 in even years during the period of decline, 1998-2017.

Hypothesis: pink salmon escapement more than doubled and interfered with Orca foraging on Chinook. one year lag in mortality.

Understanding the mechanism of this biennial pattern is critical to the recovery of the endangered Orca.

1998 to 2017



Ruggerone, Springer, Shaul, and vanVliet 2019

Photo by A. Solonsky

Conclusions

Pink salmon abundance is exceptional and peaked in 2018 & 2019 (668 million).

Pink salmon can affect growth, survival and abundance of other marine species.

In 2020, commercial catch of Pacific salmon declined 205 million salmon versus previous 10 year average.

Harvest decline in 2020 was the greatest since 1930.

We hypothesize that exceptional pink salmon abundance in 2018 & 2019 contributed to the sharp salmon catch decline in 2020.

Thanks for your attention!

References

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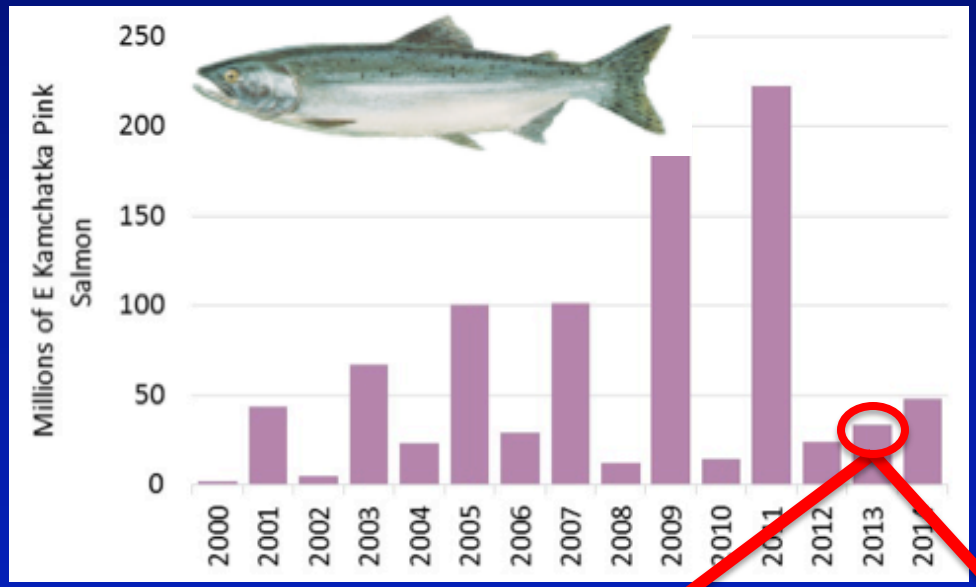
Do Pink Salmon Cause a Trophic Cascade?

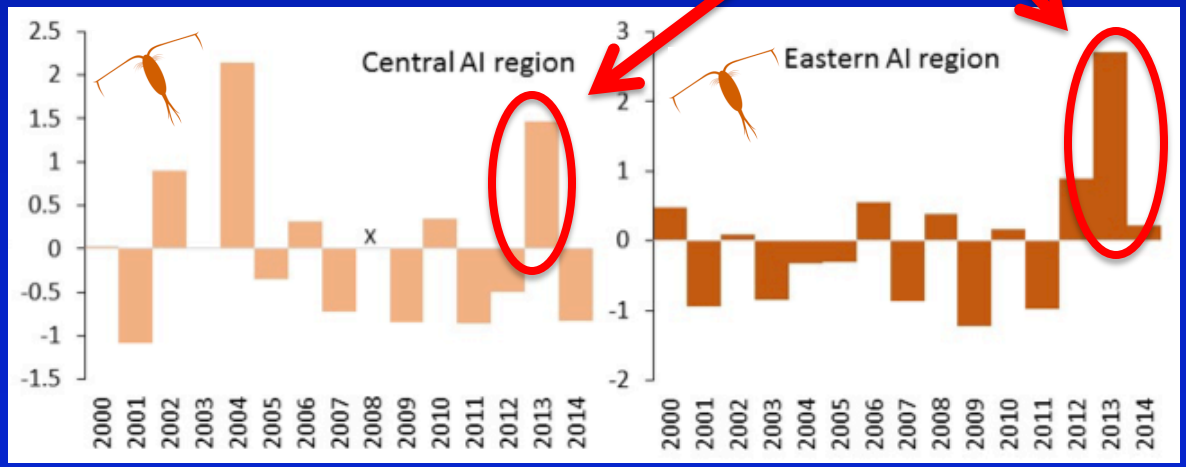
2013:

Eastern Kamchatka pink salmon crashed and zooplankton rebounded sharply

Patterns not apparent in Western Bering Sea

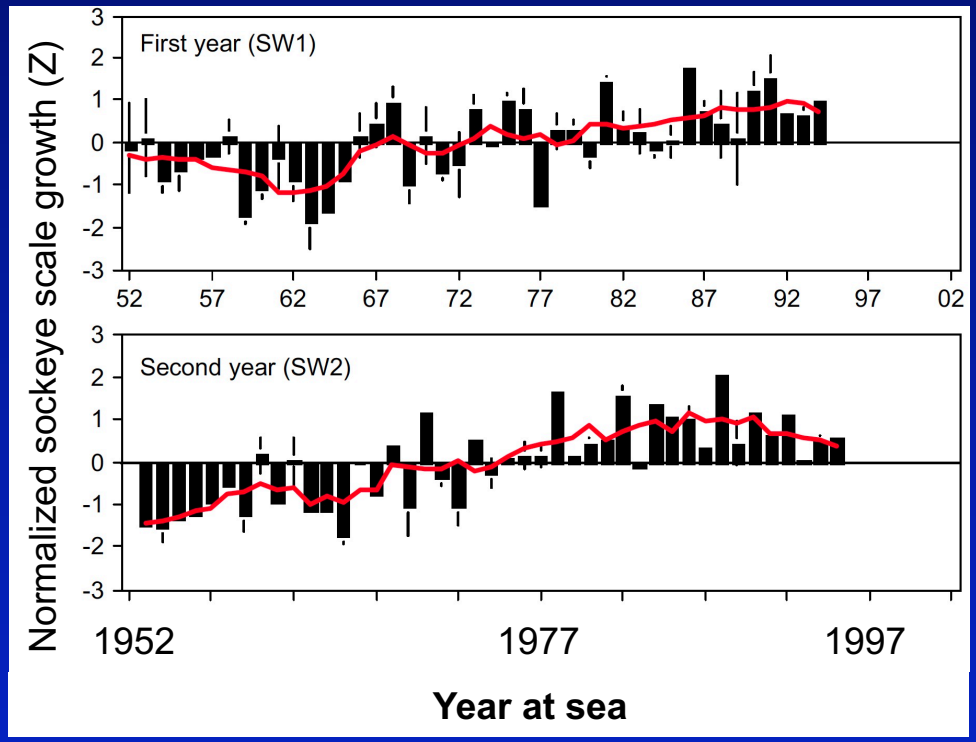
- Higher zooplankton counts
- Pinks less biennial

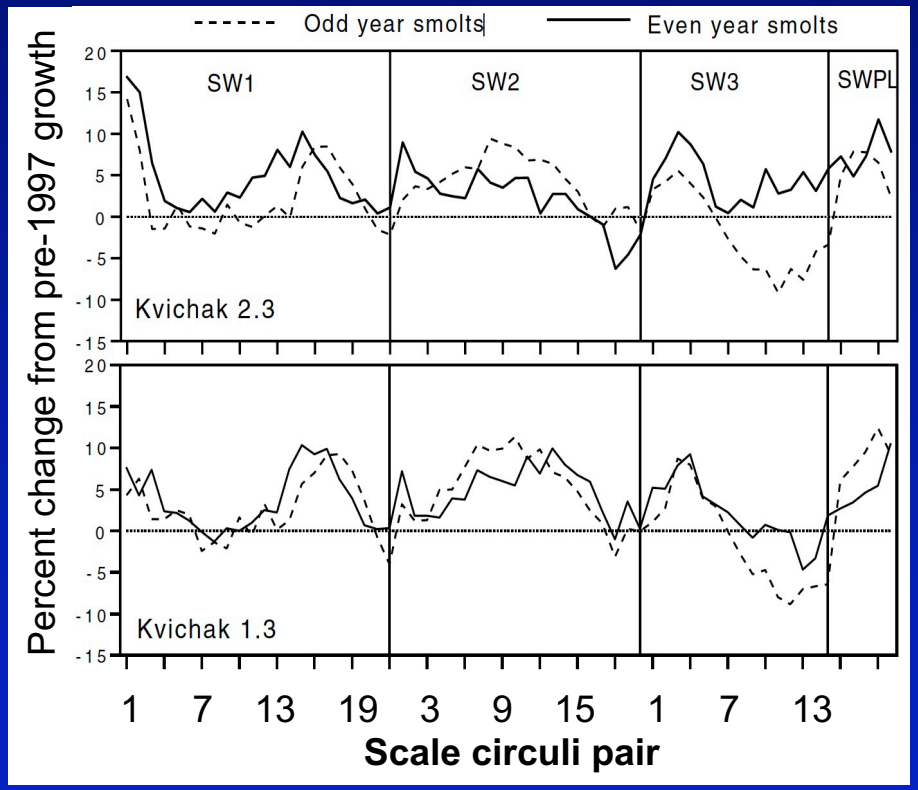




Batten, Ruggerone, Ortiz 2018

Increased Early Marine Growth of Alaska Sockeye after the 1977 Regime Shift



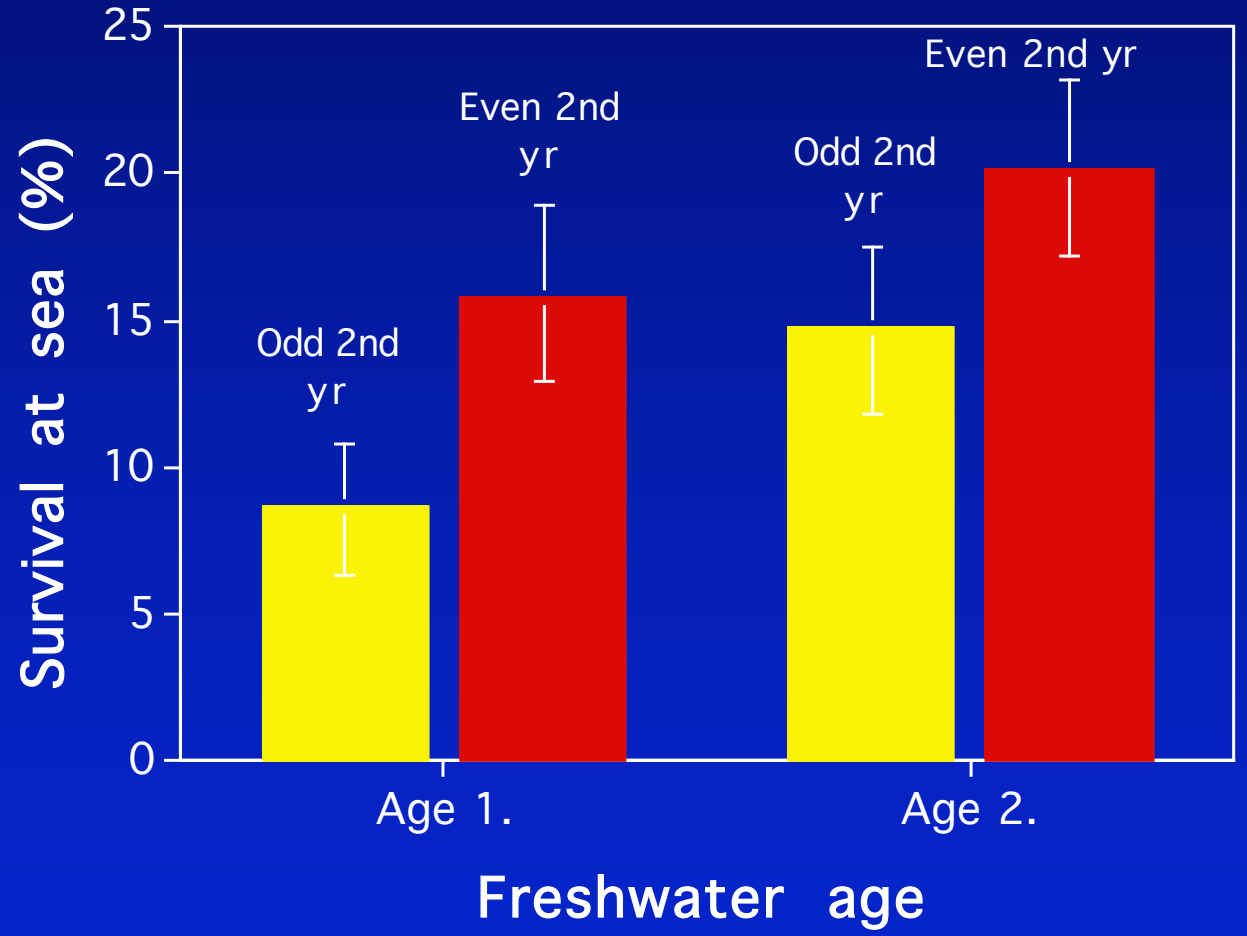


Greater annual (left) and seasonal (right) scale growth of Alaska sockeye salmon after the 1977 ocean regime shift that was associated with doubling of sockeye abundance.

Ruggerone et al. 2005, 2007

Bristol Bay Sockeye Smolt to Adult Survival, 1977-1997

Age-1:
45% decline
when pink
salmon

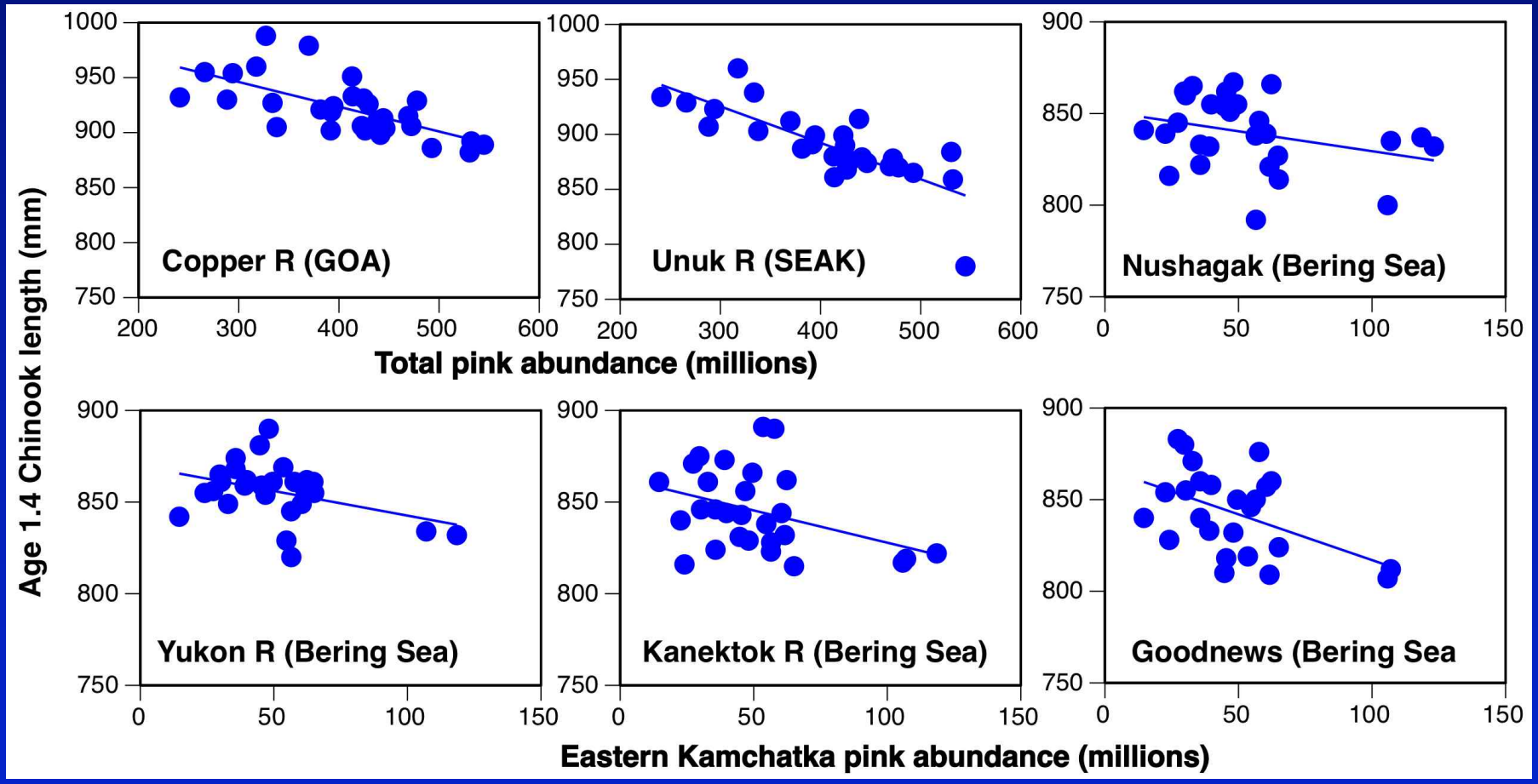


Age-2:
26% decline
when pink
salmon

Ruggerone et al. 2003

Do Pink Salmon Reduce Chinook Growth?

Chinook Length on pink salmon abundance



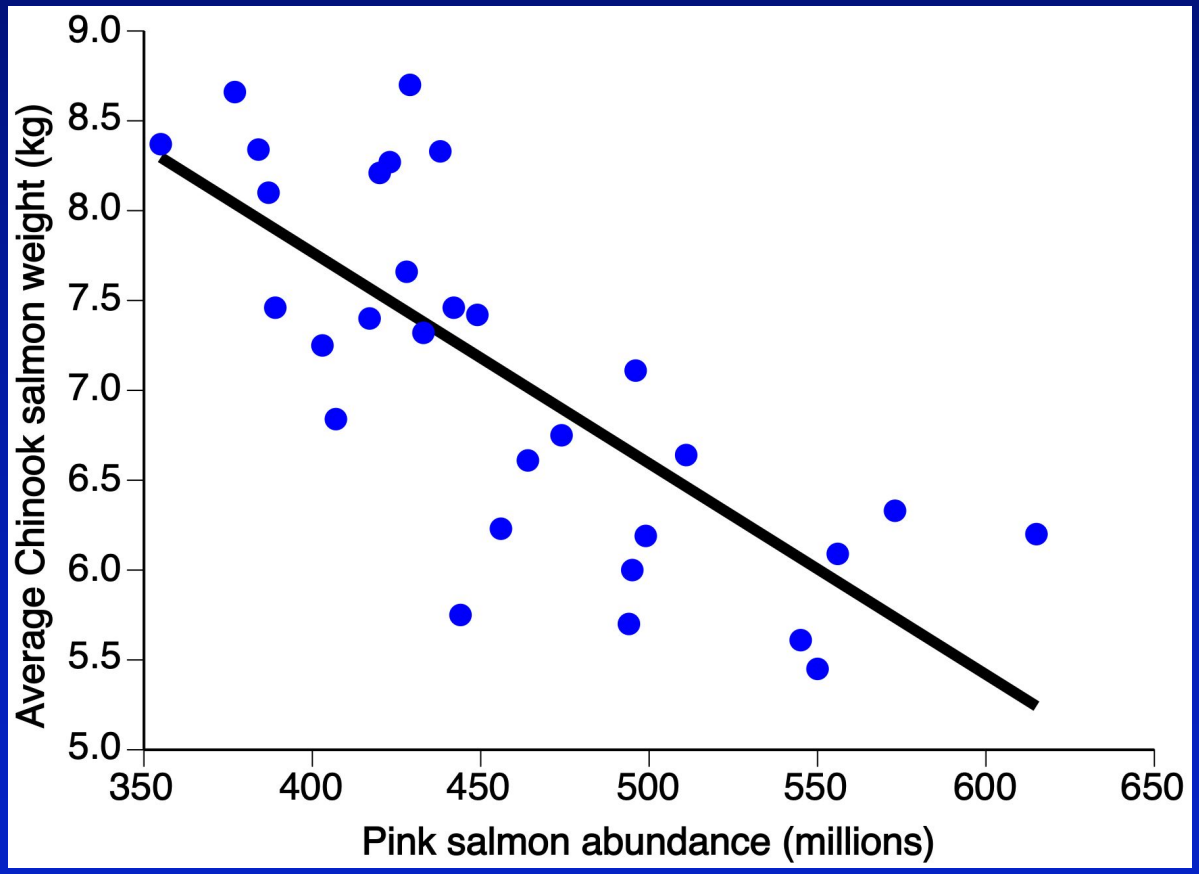
Chinook length data source: Lewis et al. 2015

Do Pink Salmon Reduce Chinook Size?

Commercial Chinook catch 1991 to 2020, Alaska & BC.

Includes many south-migrating Chinook

Moving 3 year mean pink salmon abundance

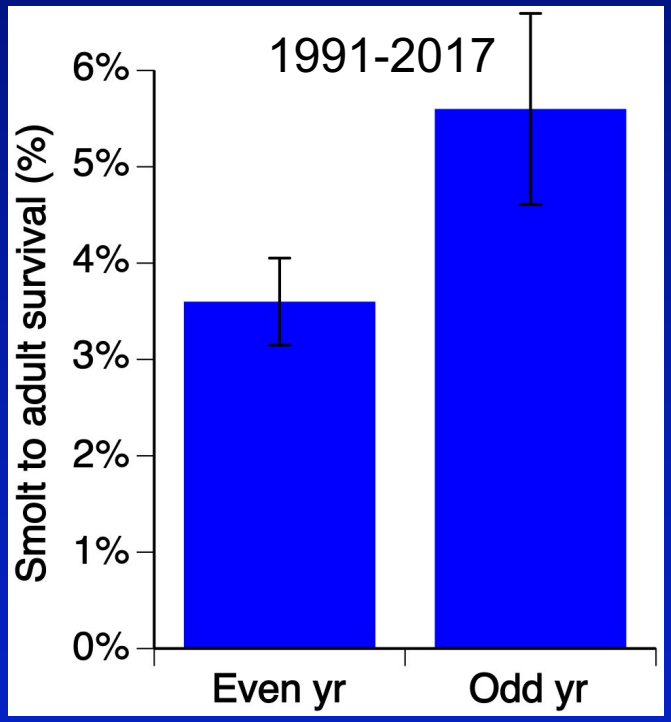


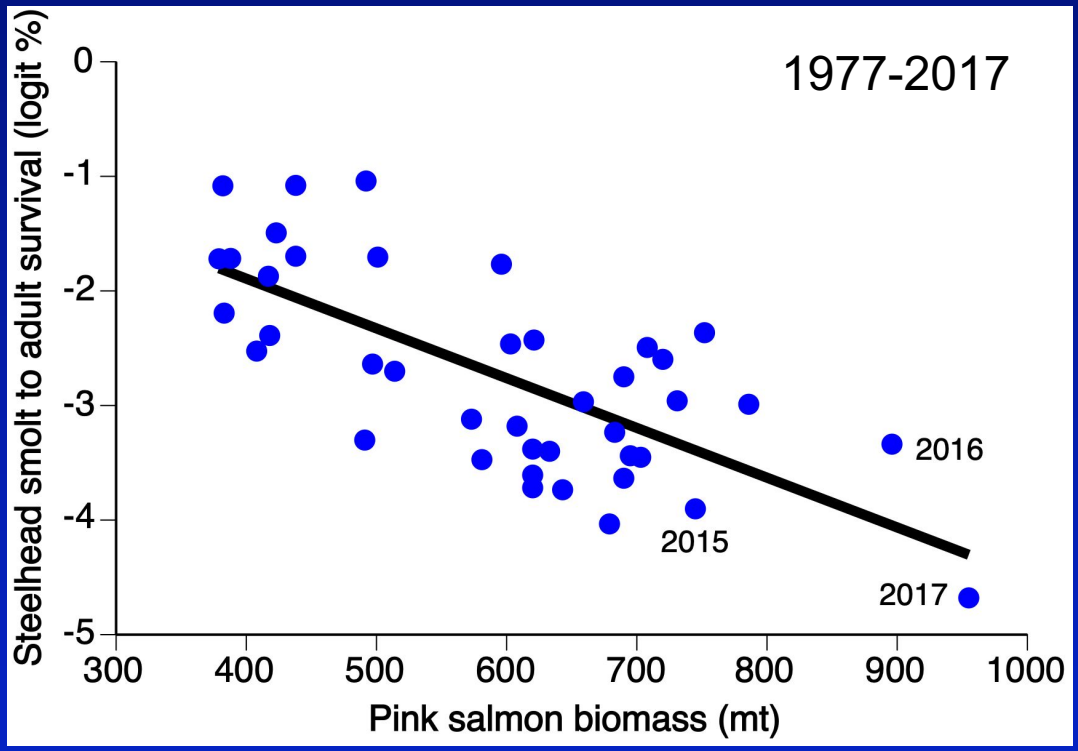
- Chinook abundance depressed throughout Alaska & BC, long-term decline in size at age & age at maturation (Lewis et al. 2015; Ohlberger et al. 2018, Cunningham et al. 2018)

Ruggerone and Irvine 2018, updated. 2020 avg wt in BC based on 2019 value.

Do Pink Salmon Affect Steelhead?

Keogh River Steelhead

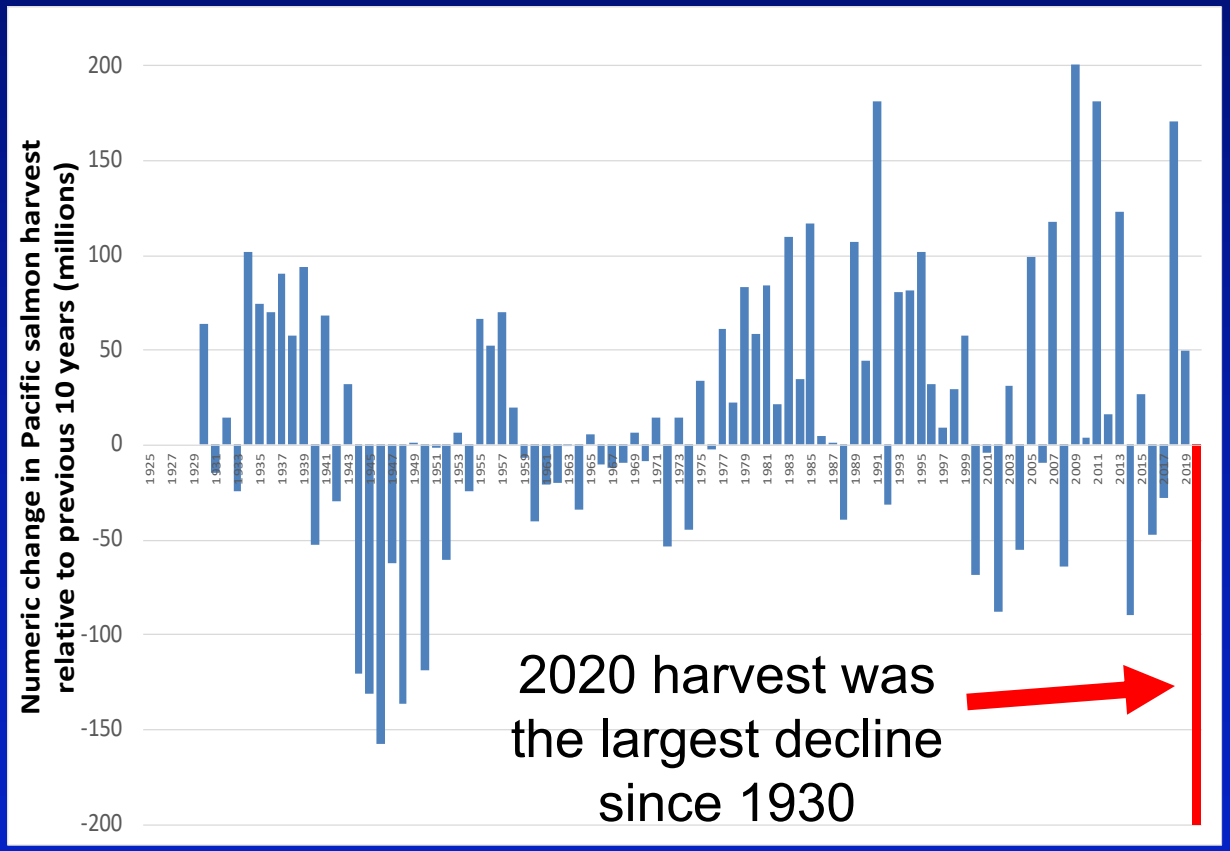


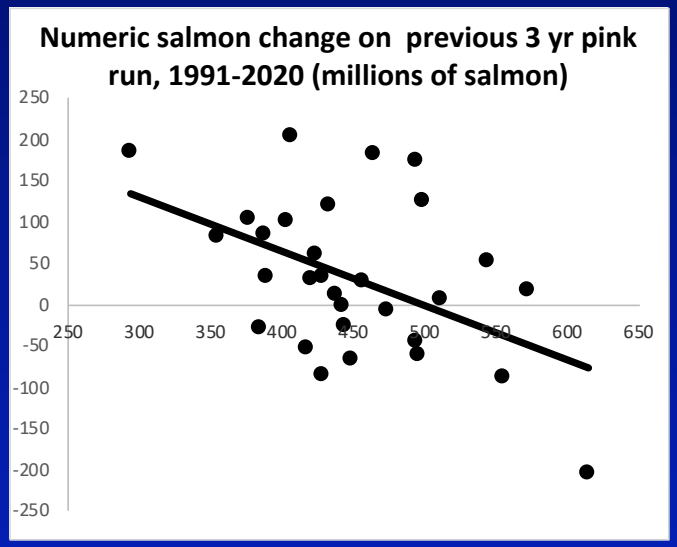


Odd year smolts feed on abundant pink salmon eggs in previous even year & potentially pink fry before migrating. Pink effect is positive in river, negative at sea. Pink salmon SY +1,2,3 years

Steelhead data: T. Davies, R. Bison, J. Korman

Did Pink Salmon Influence the North Pacific Harvest Collapse in 2020?





205 million fewer Pacific salmon harvested in 2020 compared with the mean from 2010-2019

Ruggerone and Irvine 2018, preliminary update. 2020 catch data are preliminary