Impacts of Pink Salmon on Other Pacific Salmon and Marine Species

Including Steelhead

2025 Pacific Coast Steelhead Management Meeting
Boise, Idaho, December 9 2025

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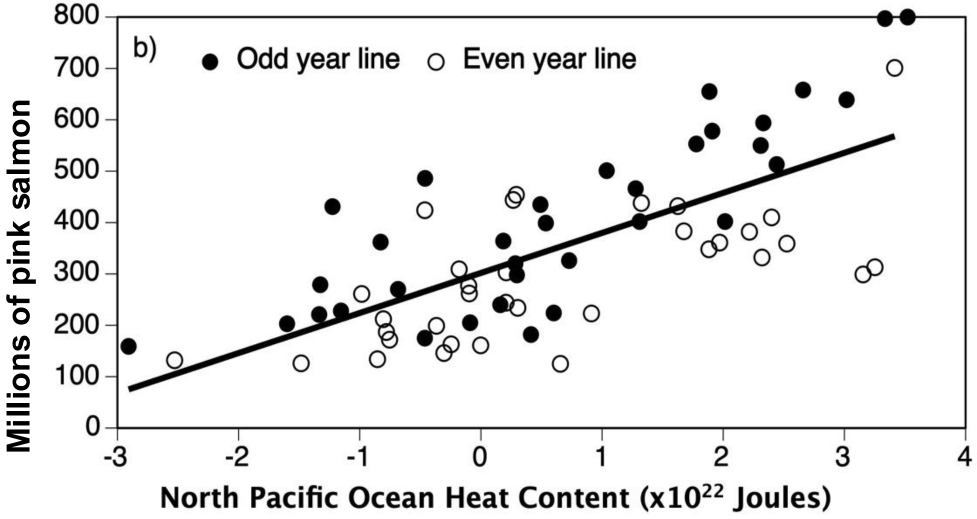
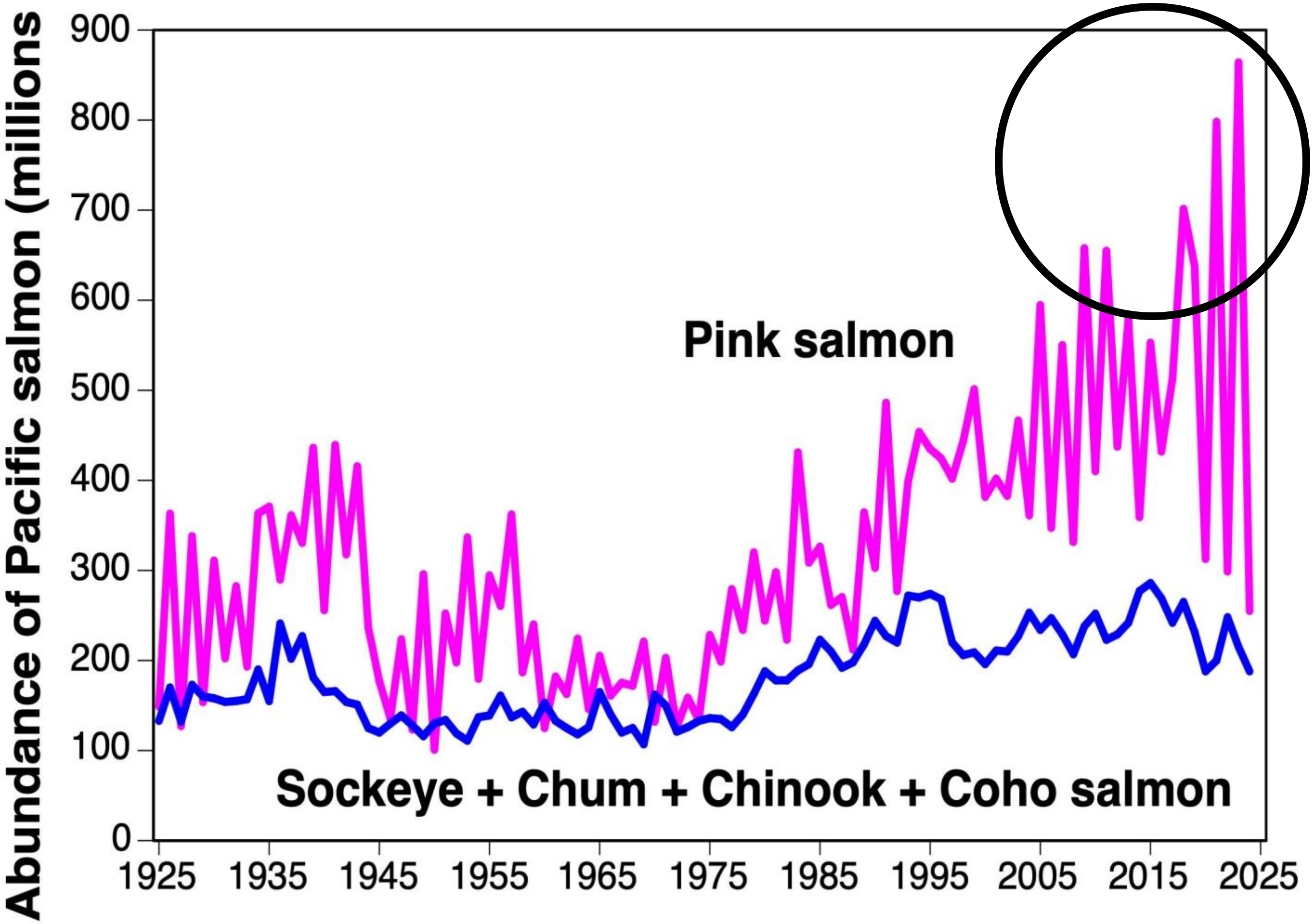
Record-high abundances of Pacific salmon in 2018+2019, 2021, 2023

- **~1 Billion** salmon returned from ocean in 2021 & 2023 (sum not shown)
- **80% pink salmon,** mostly Russia & Alaska
- **Pinks 1.6X more abundant in odd years; stronger in recent years (2 yr life cycle)**
- Climate warming, escapement, & hatcheries





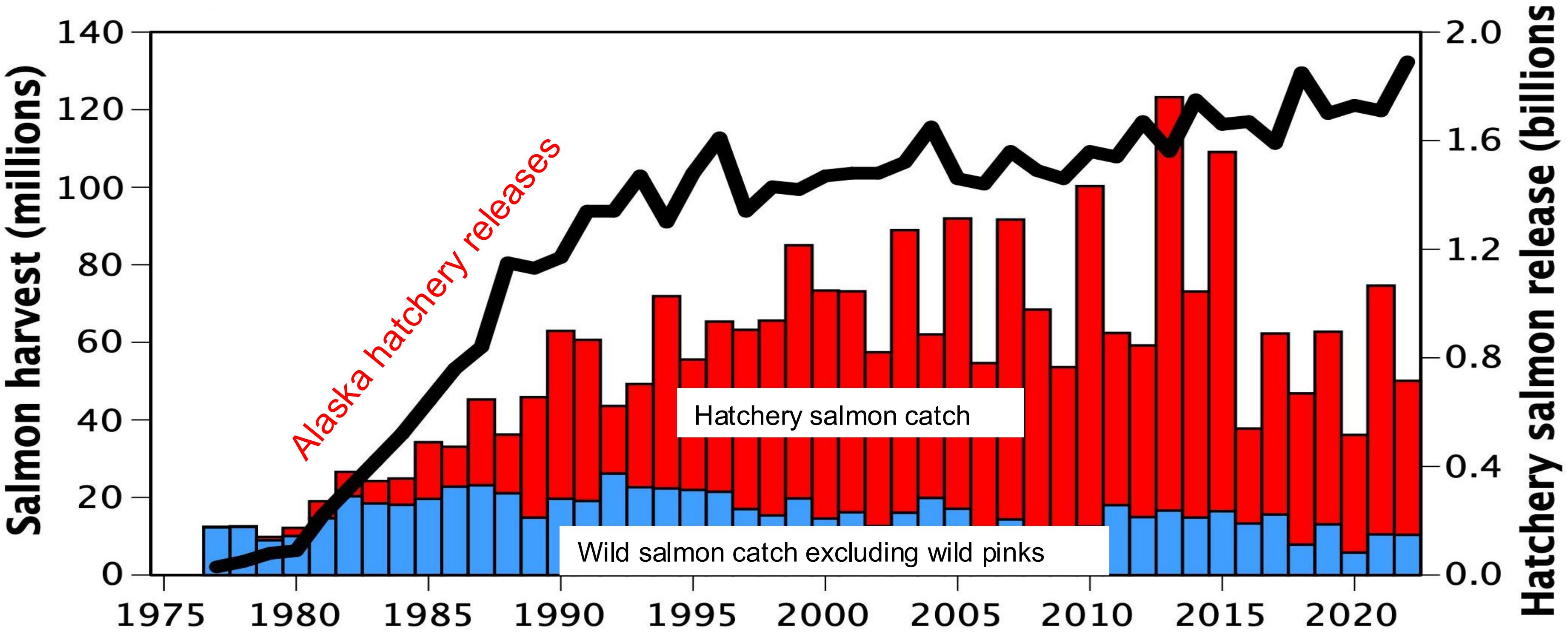
Ruggerone & Irvine 2018, Ruggerone et al. 2010, 2023

1.9 Billion hatchery salmon released in Alaska (World Leader) including 1 Billion pink salmon (70% of H Pink Total)

Alaska GOA Region:

5 hatchery salmon per wild salmon (excl. wild pinks), 2018-2022

Many salmon from PNW migrate to GOA & beyond



Hatchery-origin salmon in Alaska harvests in Gulf of Alaska region:

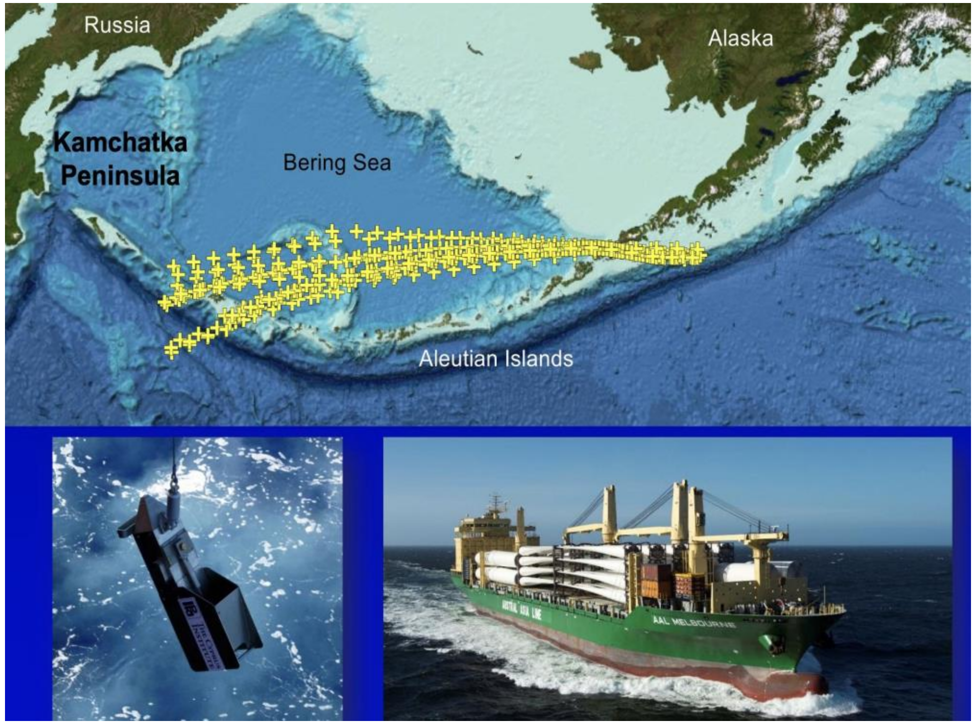
Chum: 80% (20% wild)
Pink: 43%
Coho: 29%
Sockeye: 24%
Chinook: 23% **excluding PNW hatchery Chinook**

Alaska: 1.9 Billion/year
Russia: 1.6 Billion/year
Japan: 1.4 Billion/year
Lower US: 0.3 Billion/year
BC: 0.09 Billion, excl. channels

4.2 times more hatchery salmon released by Alaska (2018-2022) than by the combined states of Washington, Oregon, Idaho, California, plus BC.
Ruggerone and Springer 2024

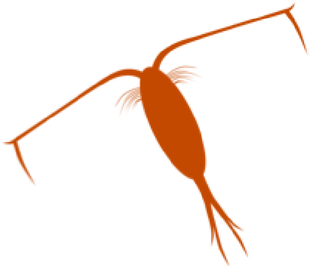
Pink salmon initiate Trophic Cascade:

Bering Sea & central N Pacific



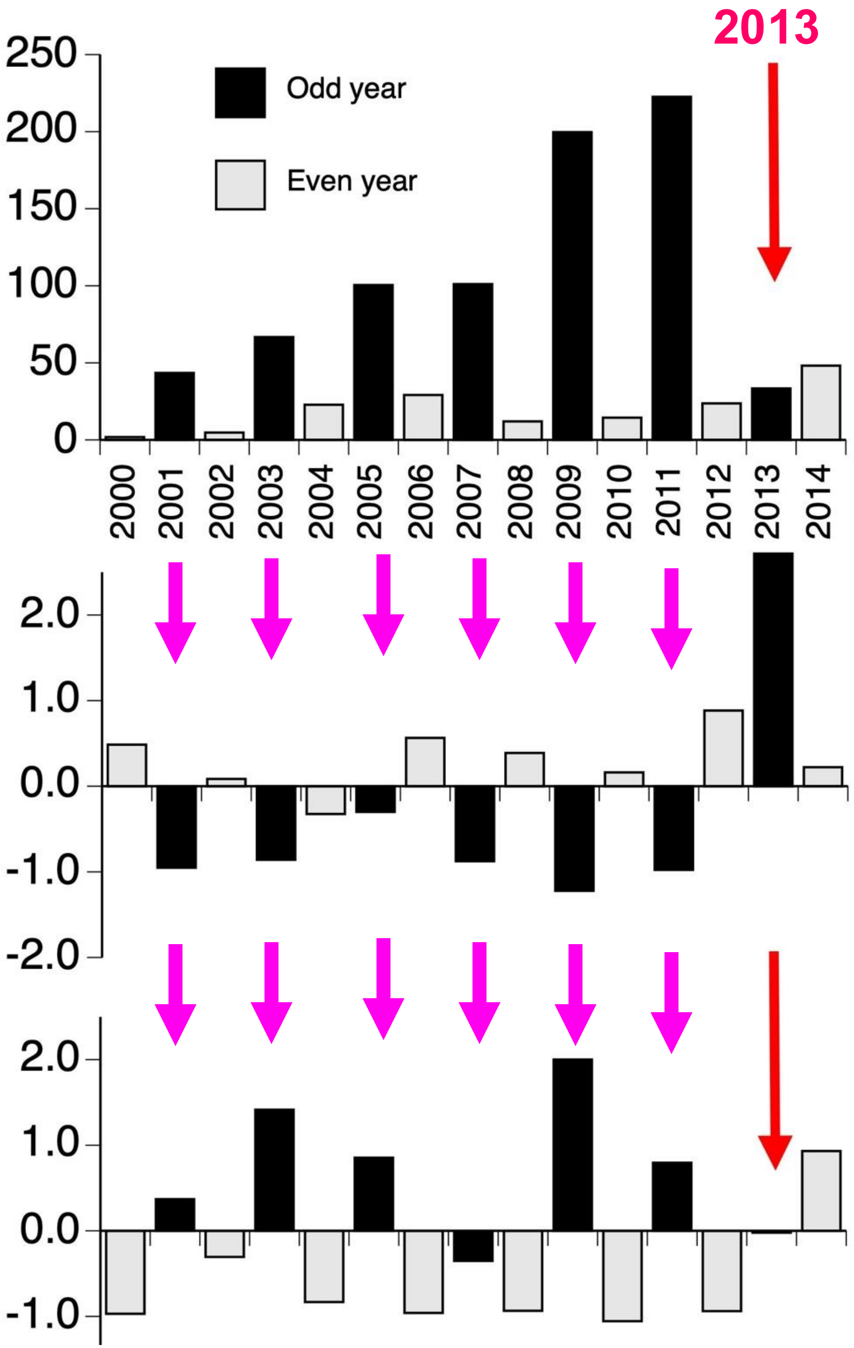
Batten, Ruggerone, Ortiz 2018 & Japanese studies

East Kamchatka
pink salmon
(millions)



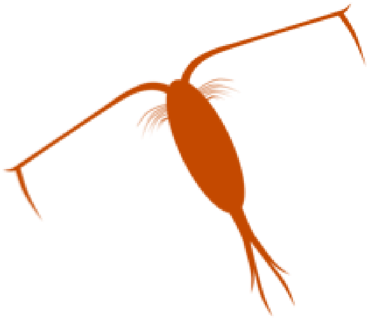
Large Copepod
density, Z

Large diatom
density, Z

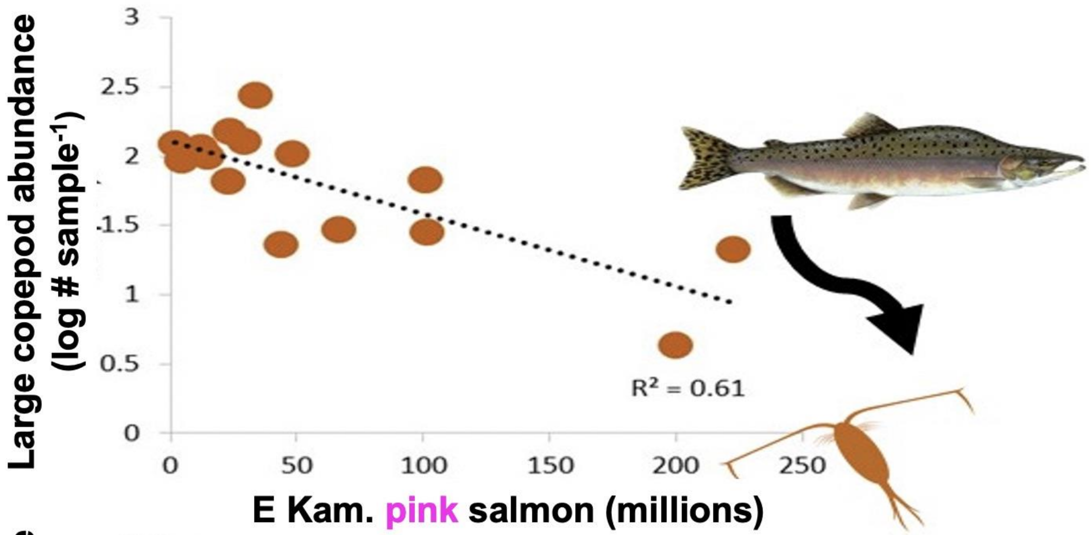


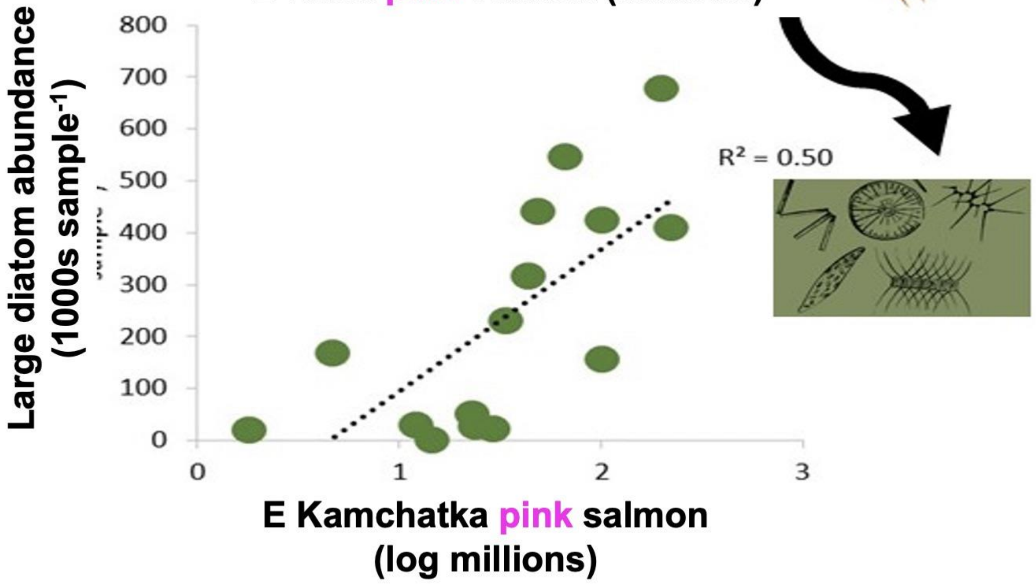
Plankton response to Pink Salmon abundance

Large copepods decline when pink salmon are abundant



Diatoms increase when few zooplankton and many pink salmon

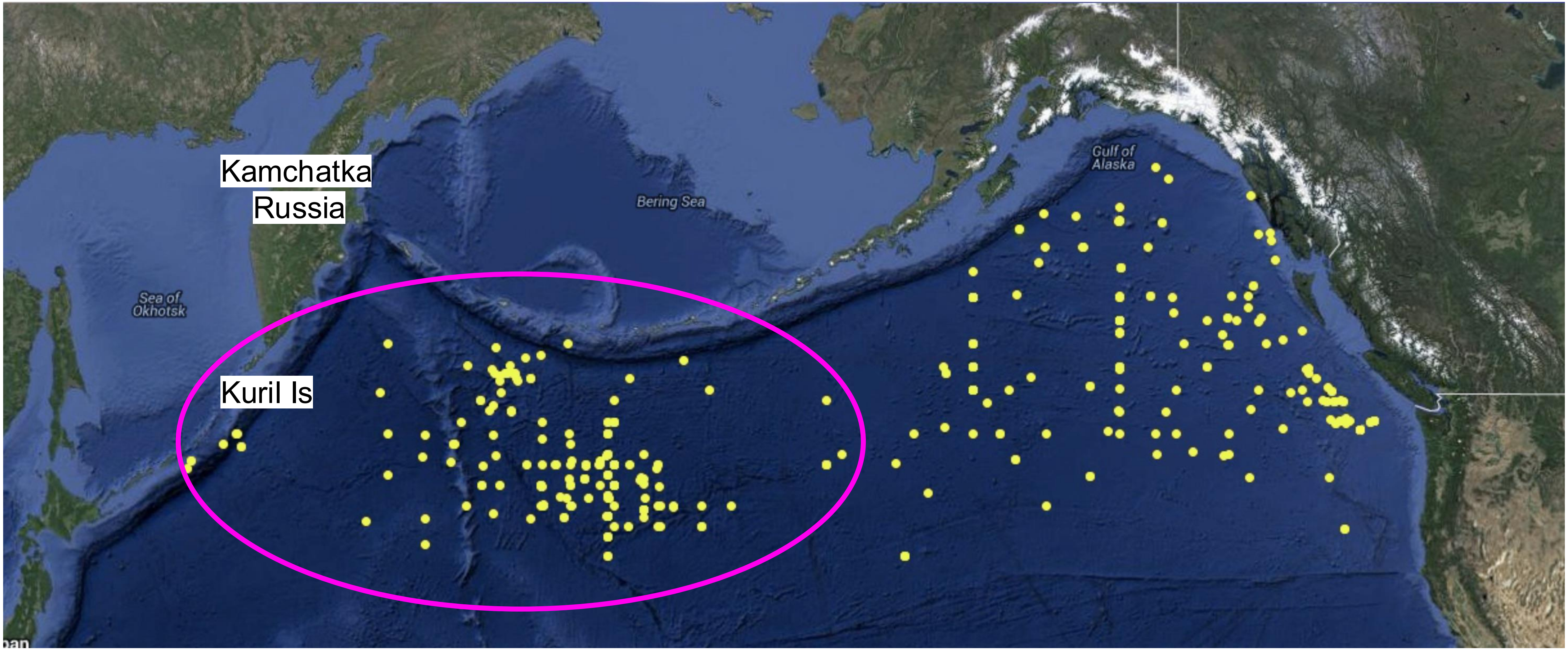




Batten, Ruggerone, Ortiz 2018

Salmon Migrate 1,000s km & Interact with Distant Pink Populations

Example: Known distribution of **North American steelhead** based on tag recoveries



Kate Myers (UW High Seas Salmon Group) presentation to PSMFC

Steelhead diet, growth, survival, and abundance affected by pink salmon

At sea consumption of forage fishes declined and empty stomachs increased with increasing pink salmon abundance (Atcheson et al. 2012)

A) Endangered Thompson R & Chilcotin R steelhead (Fraser R) productivity declined with increasing pink salmon abundance

B) Keogh R steelhead (Vancouver Is) survival declined with pink salmon abundance

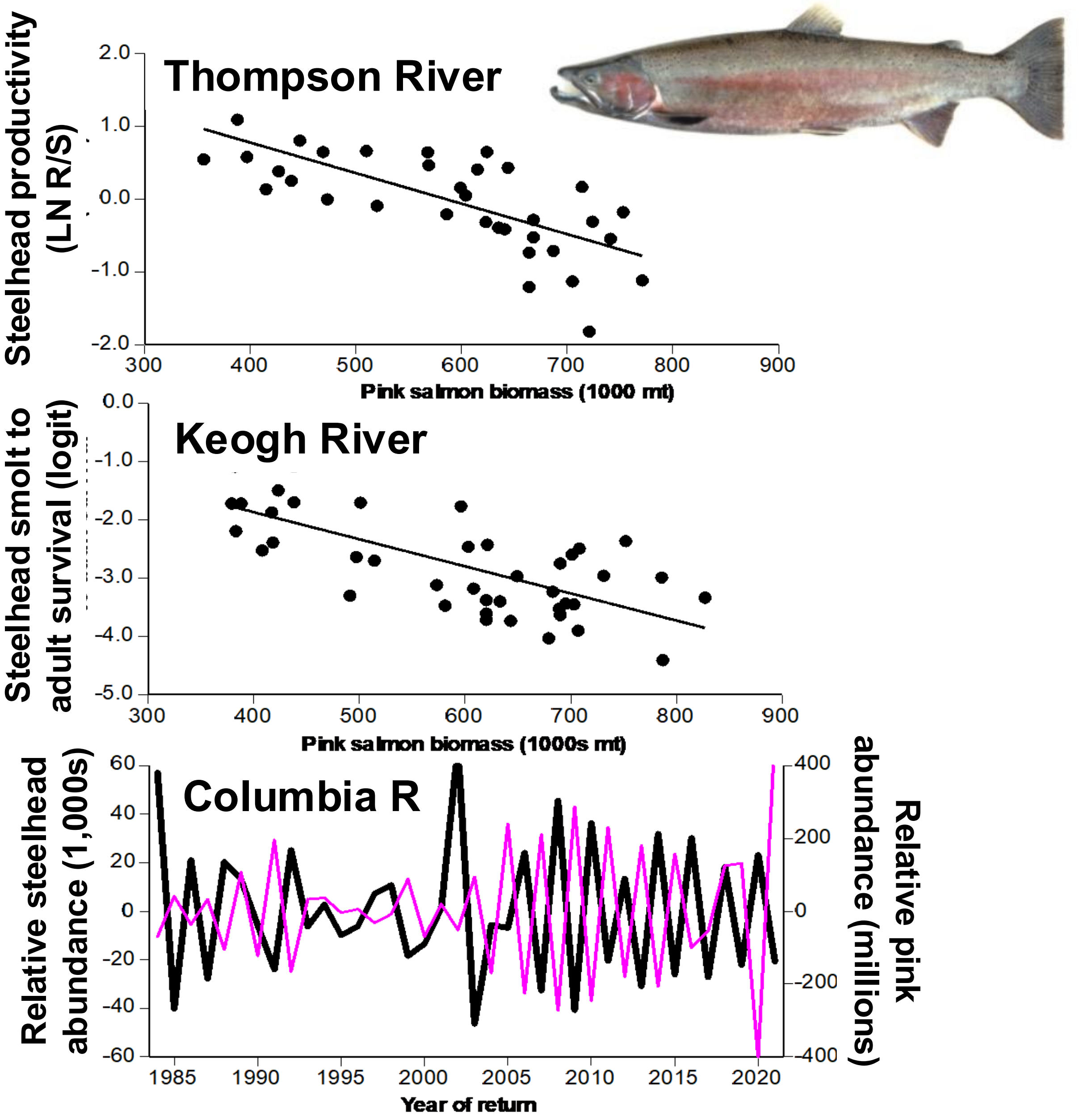
C) Columbia R steelhead (B-run, ESA-Threatened) abundance is biennial & opposite pink salmon abundance

D) Snake R steelhead body size declined with increasing pink abundance and was biennial (**Vosbigian et al. 2024**)

E) Snake R steelhead abundance declined with more pinks (**Cassinelli & McCormick 2024**)

F) Washington coast steelhead survival affected by pink salmon (**Ohlberger et al. 2025**)

See other presentations in Boise!



Ruggerone et al. 2023

Biennial growth of Bristol Bay sockeye salmon at sea

High degree of diet overlap

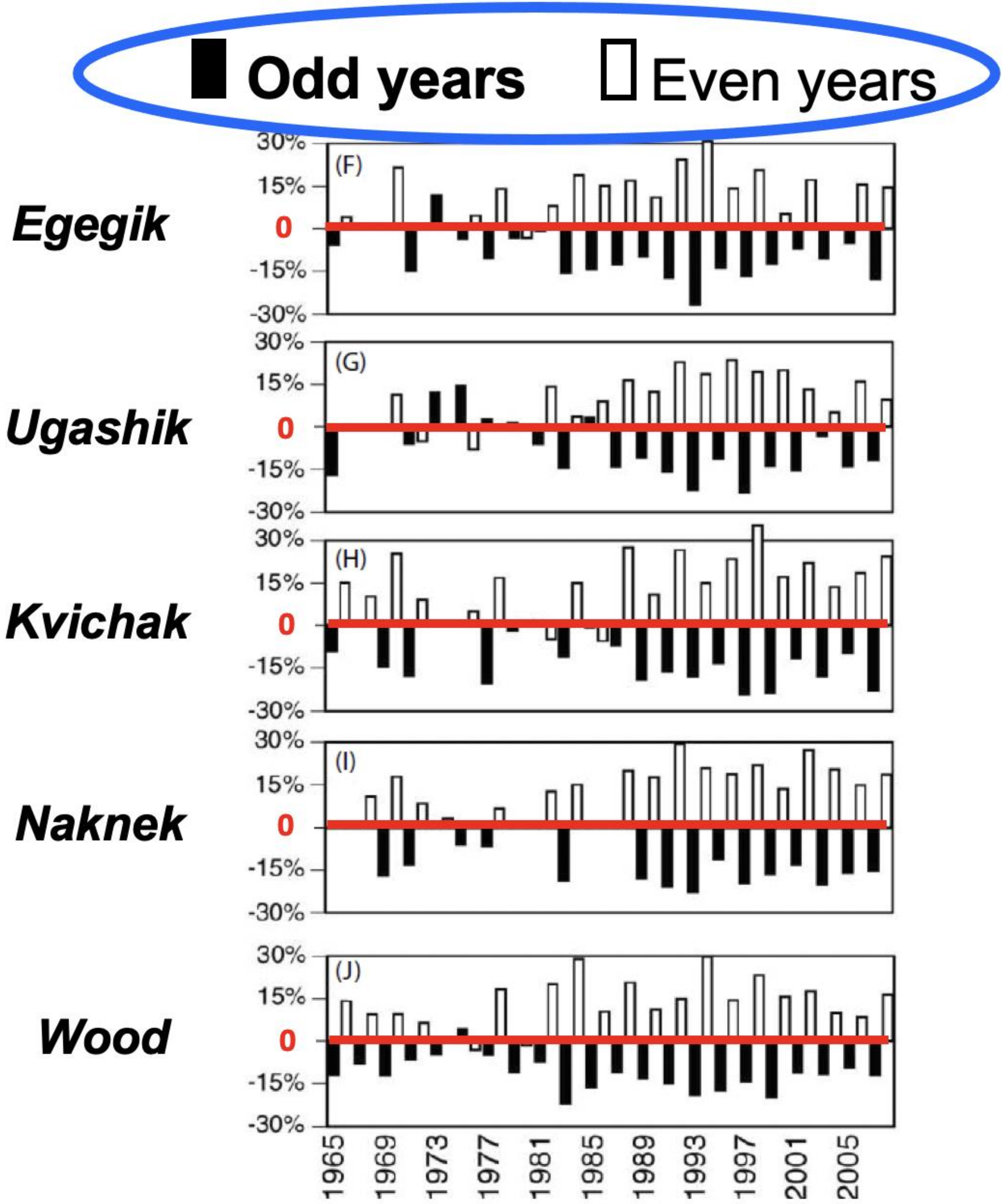
Interannual sockeye scale growth in 3rd year

Same pattern in 2nd year

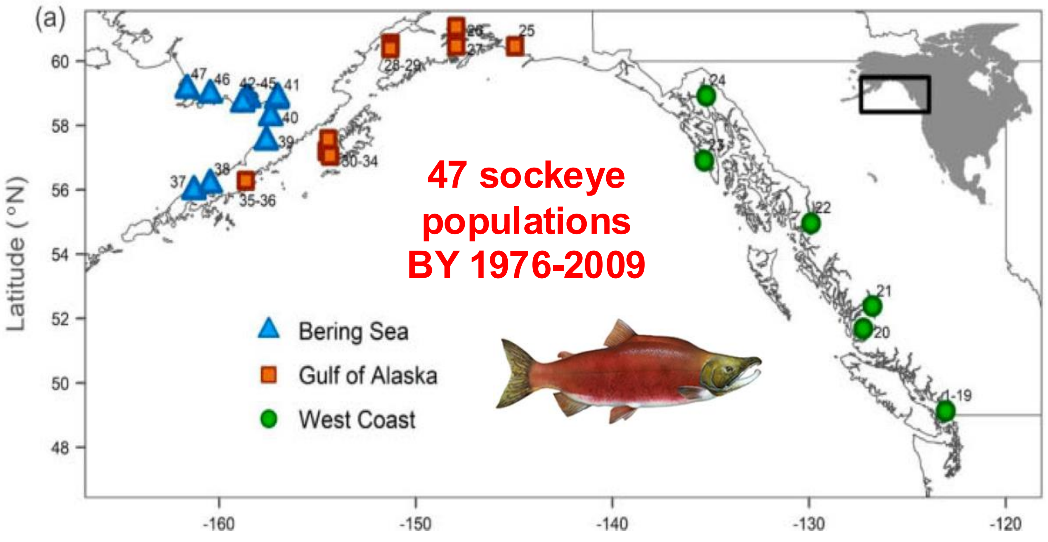
1st year: few pinks, no pattern

Adult sockeye length reduced by both sockeye & pink abundance

Ruggerone et al. 2003, 2016; Ohlberger et al. 2023

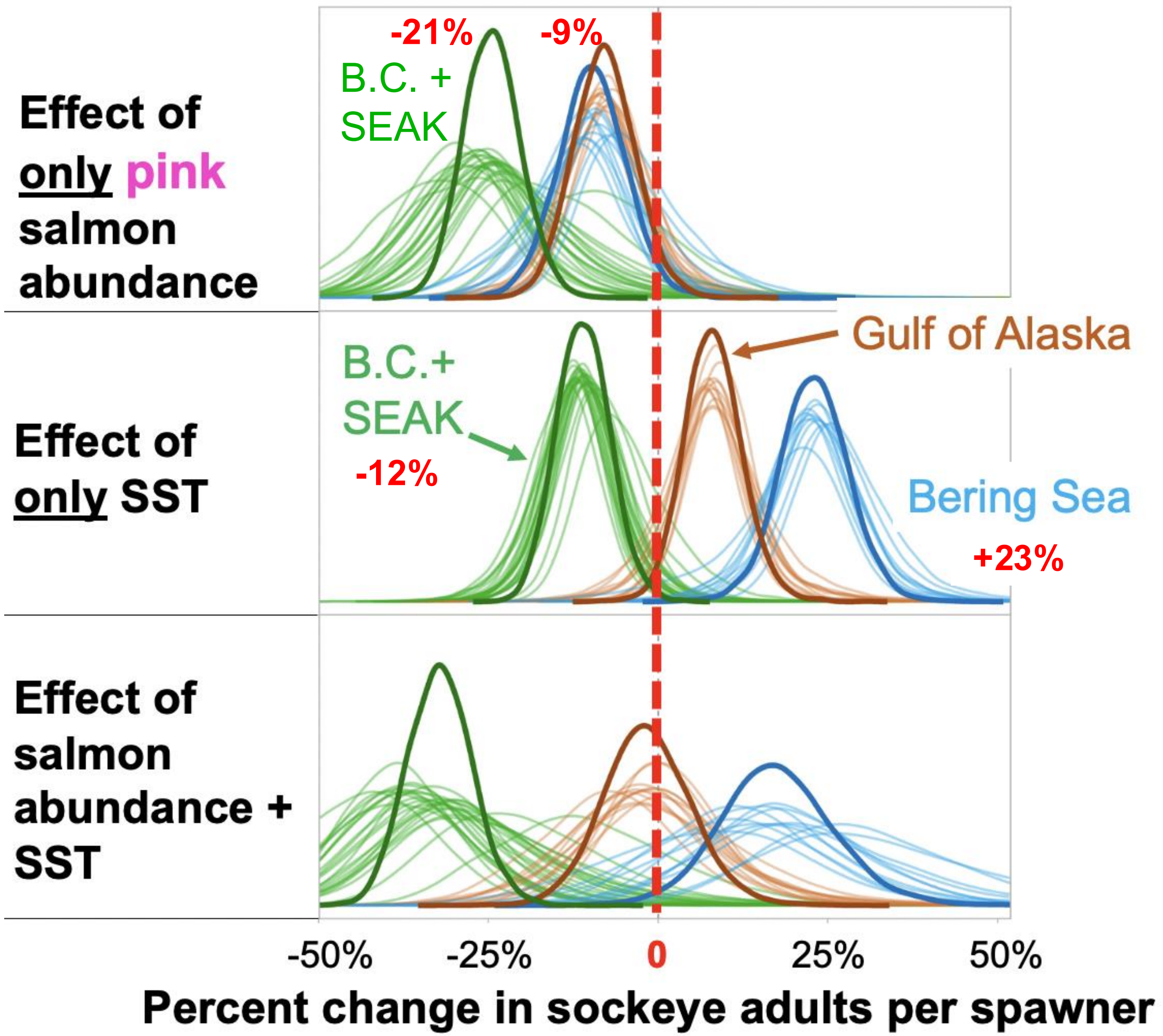


Pinks affect affect sockeye productivity across North America



- **Competition had ˜2x bigger effect on BC sockeye than SST**
- Alaska produced ~53 million adult hatchery pinks, suggesting 10% decline in BC sockeye productivity caused by AK hatchery pinks

Productivity decline with 119 million pink increase & 1.5°C increase above mean (i.e., 1 SD)



Ruggerone & Connors 2015, Connors et al. 2020, 2024

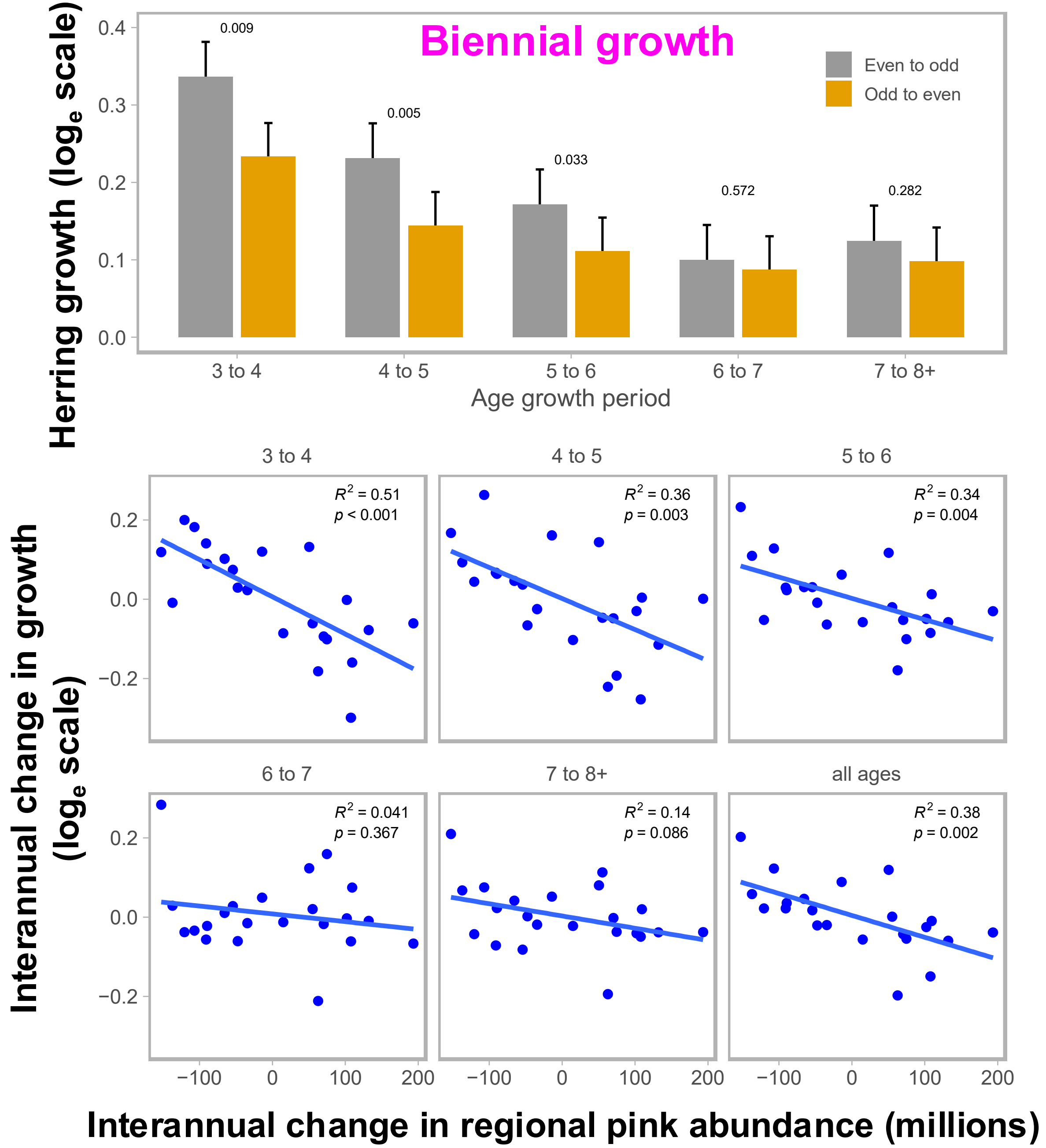
Pink salmon affect Herring

Sitka Sound Alaska herring
is a key forage fish

Reduced herring growth from odd to even years, i.e., after departing Sitka Sound in odd years when maturing pinks are abundant

Magnitude of year-to-year variation in growth negatively correlated with adult pink abundance (PWS, SEAK, BC)

Growth: proportional increase in mean annual body weight



Ruggerone et al. 2023

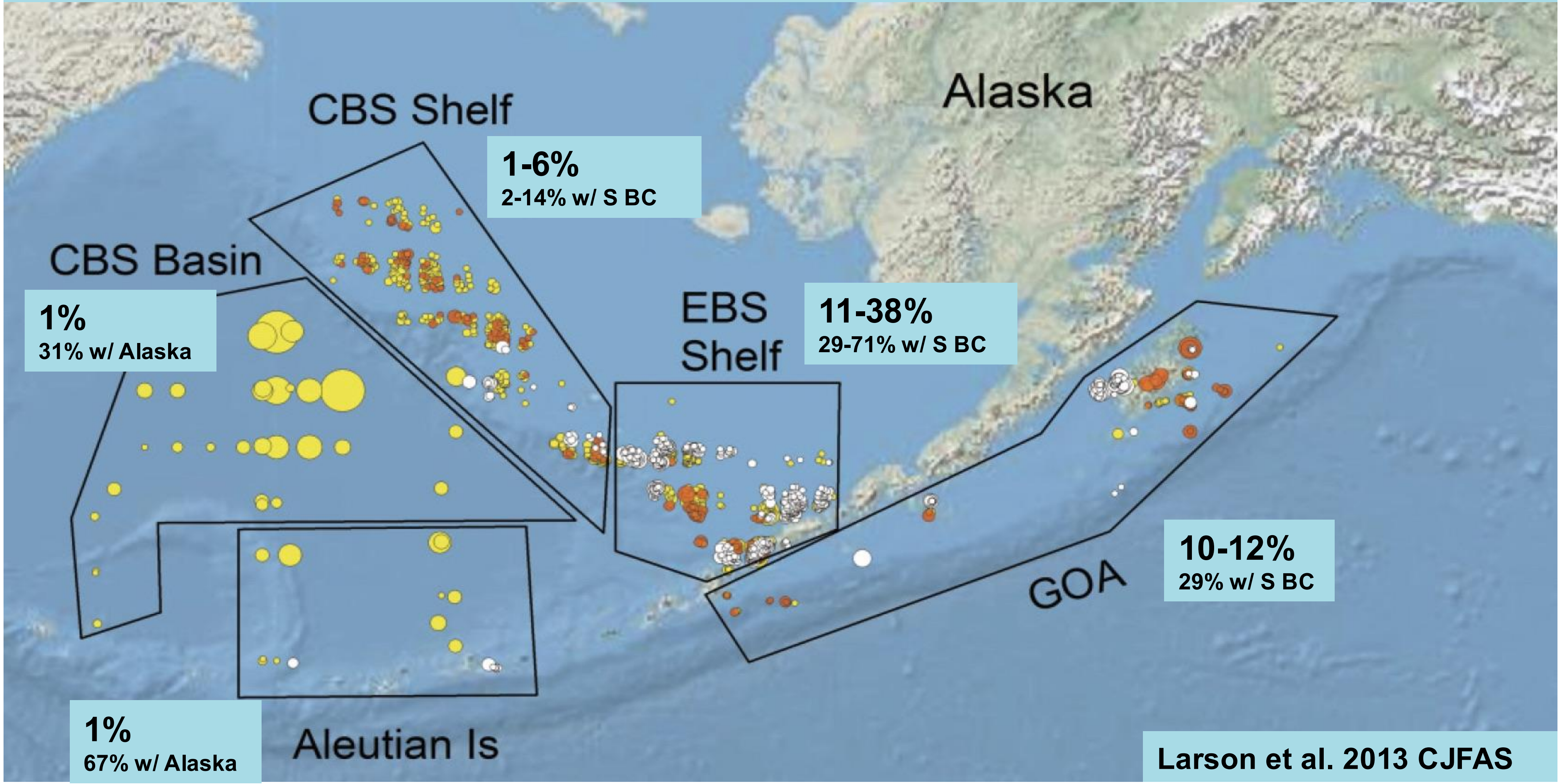
Pink salmon effects on Chinook salmon

Wild Chinook abundance & body size has declined everywhere, including Alaska and Russia

Pink salmon is one of many factors of decline

Chinook salmon from Pacific Northwest migrate to far North

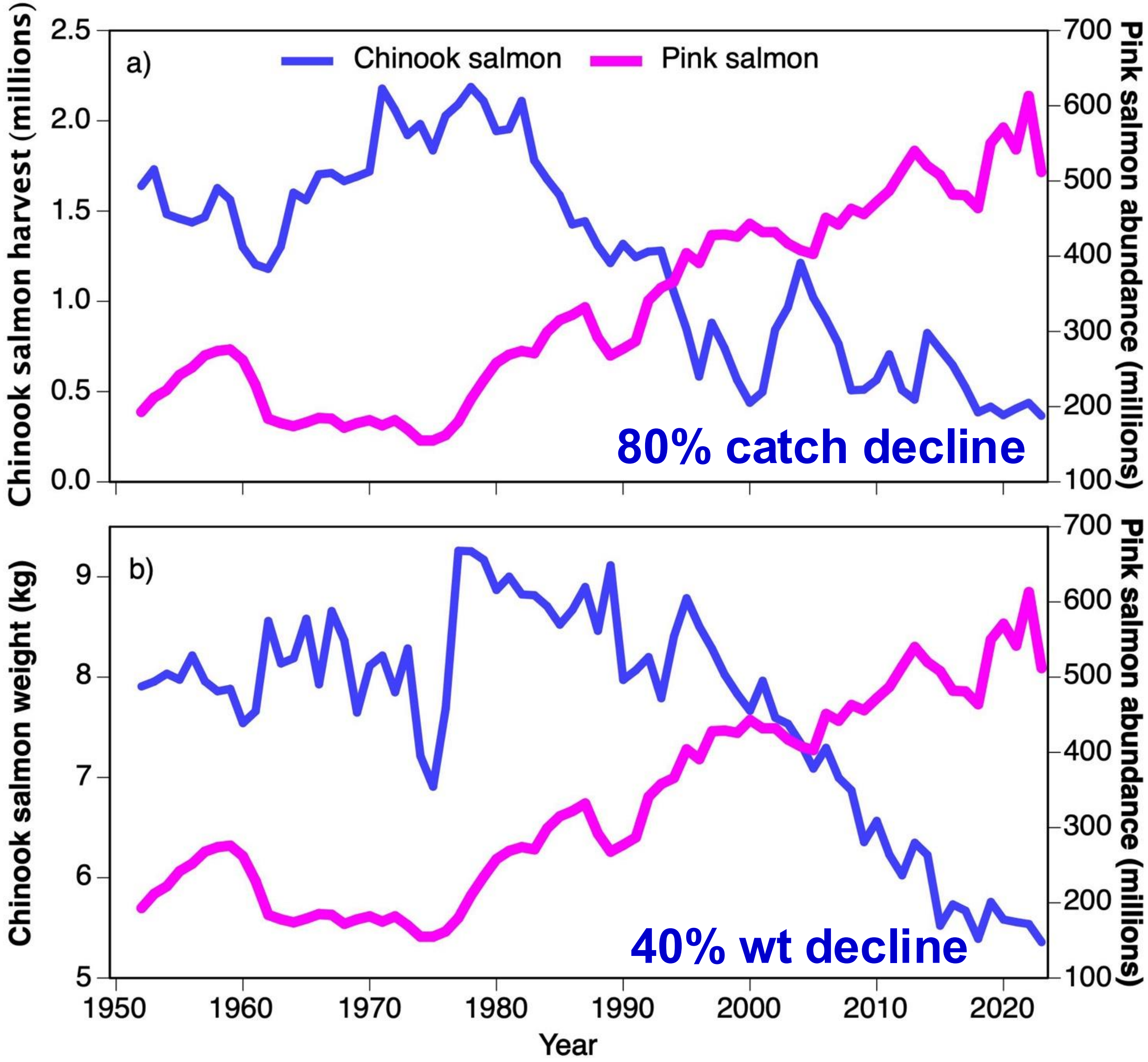
Proportion of Chinook from lower USA, summer/fall 2005-2010



"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" Larson et al. 2013

Do pink salmon affect Chinook abundance and size?

- Chinook harvests in AK & BC are opposite of 4-yr avg. pink salmon abundance, 1952-2023
- Chinook weight in Alaska is opposite of 4-yr avg. pink salmon abundance, 1952-2021
- ˜500 pink salmon adults (NA + Asia total) for each harvested Chinook salmon, 2015-2022



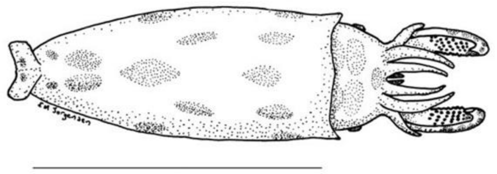
Ruggerone et al. 2023

Chinook diet overlap & competition

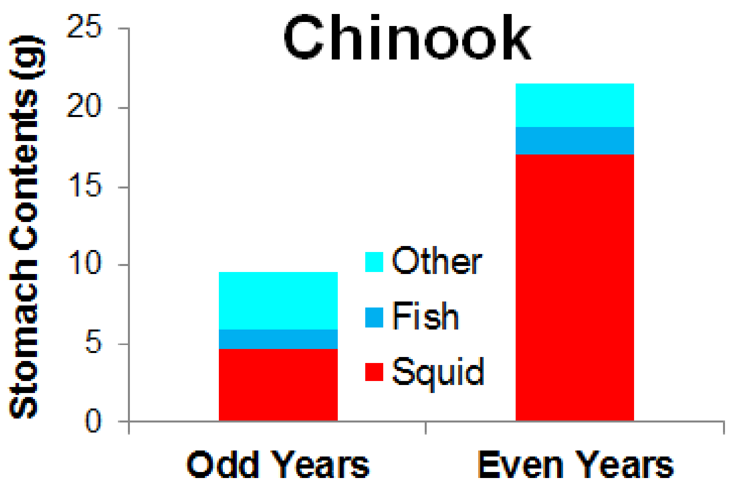
- Considerable diet overlap between Chinook & maturing pinks: **Squid & Fish**
- Stable isotopes do not reflect switch in maturing pink salmon diet to squid & fishes
- **56%** decline in Chinook prey weight
  68% less squid & fish in Chinook
  in Odd Years
- Only **23%** decline in Pink salmon prey weight in odd years
- Foraging pinks are efficient when few prey

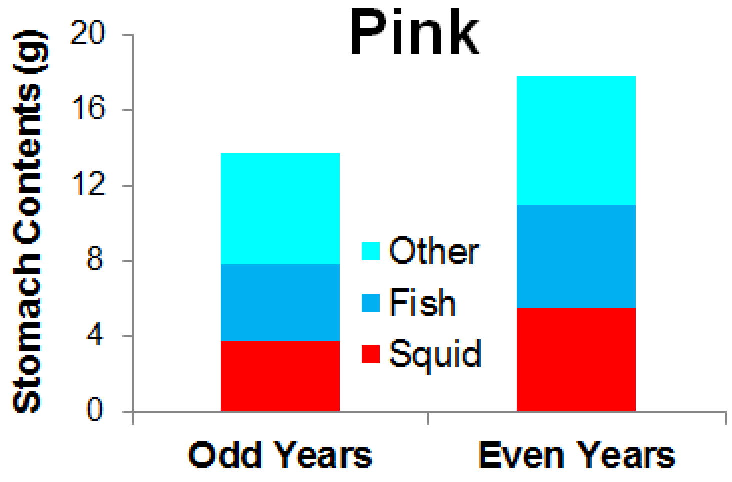
Berryteuthis anonychus squid, ˜6-9 cm

Key salmon prey



10 years of diet data: 1991-2000 (Bering Sea)

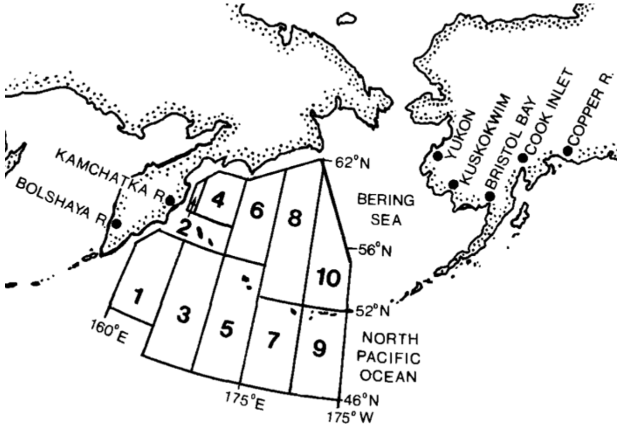




Davis 2003, Ruggerone et al. 2023

Chinook harvest on high seas inversely related to pink salmon

Chinook catch in Japanese high seas fishery in odd years (254,000/yr) was 39% less than in even years (417,000/yr), 1955-1981



Pink salmon ˜25X more abundant in odd versus even years in this region

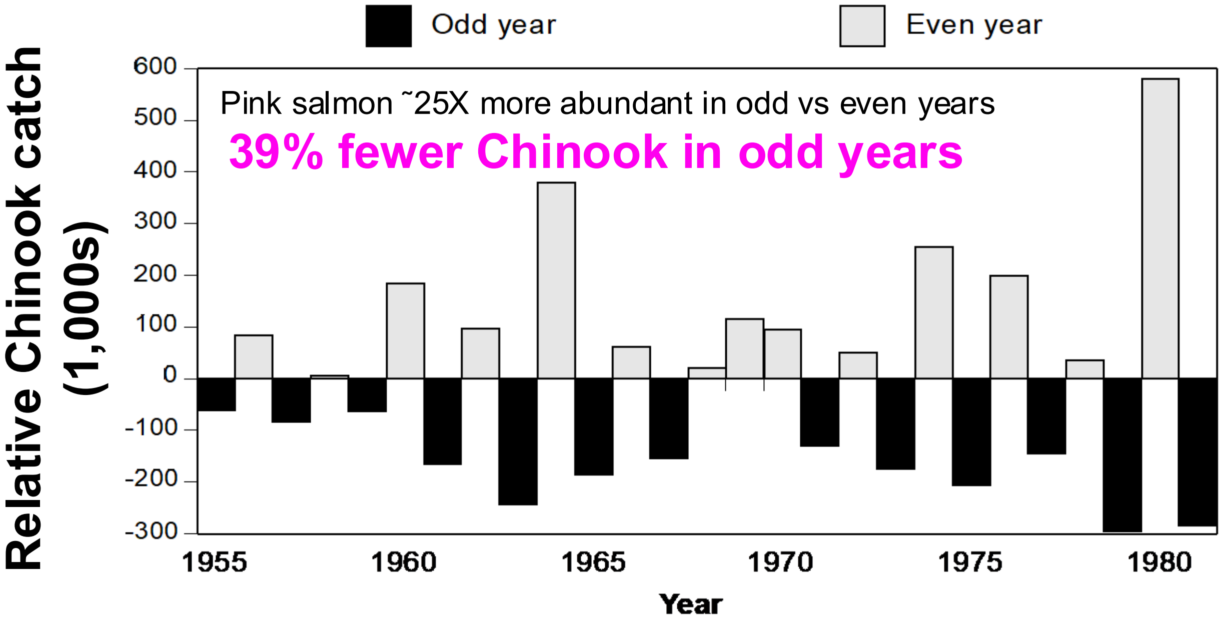
Average catch by region:

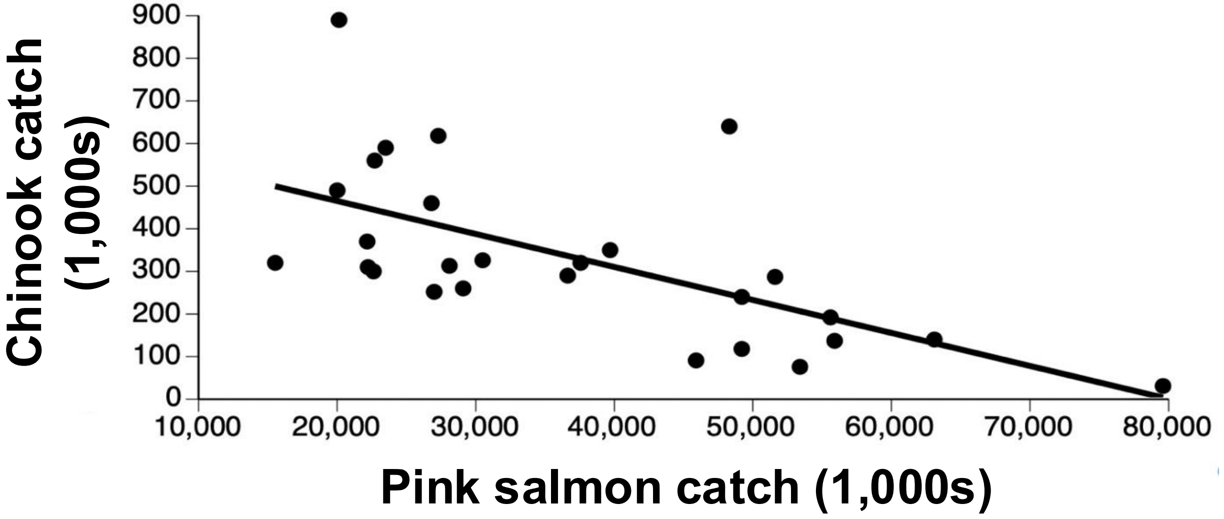
146,000 Western Alaska
117,000 Central Alaska
9,000 SEAK & BC
55,000 Asia
Based on UW FRI scale analysis

Recent AYK Chinook decline much greater than reported

Fishery declined after 1981 and has not operated since 1991

Relationship facilitated by gear that selected for ocean age-2 Chinook (85%), mostly immature.

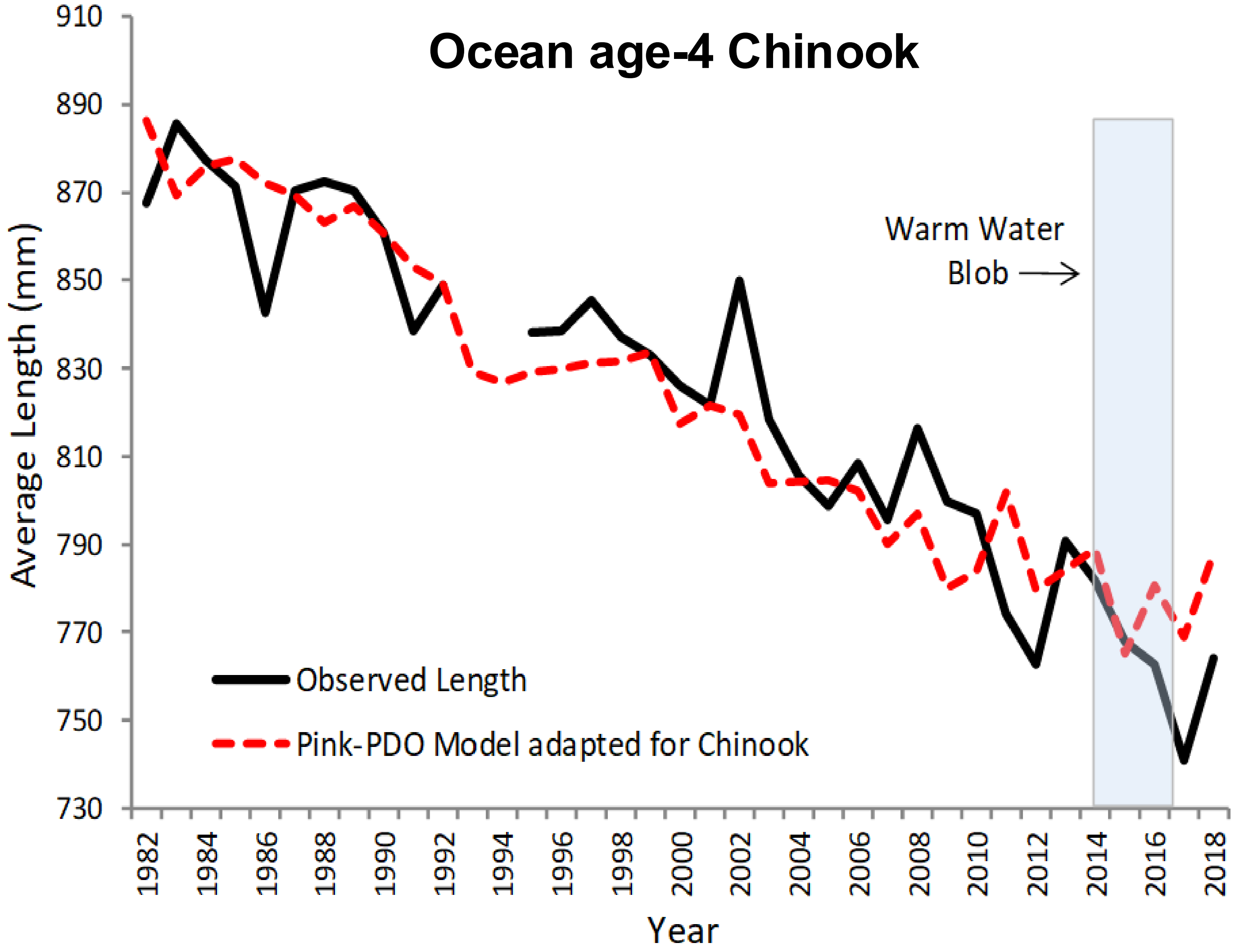




Ruggerone et al. 2023

Length-at-age of SE Alaska Chinook inversely correlated with pink abundance, 1982-2018

- Pink salmon abundance and the PDO explained 75% of annual length variability
- Troll caught Chinook: some from Pacific Northwest
- Southeast Alaska **coho** weight also affected by pink salmon.
- Coho weight consistently less in odd years, 1970 to present



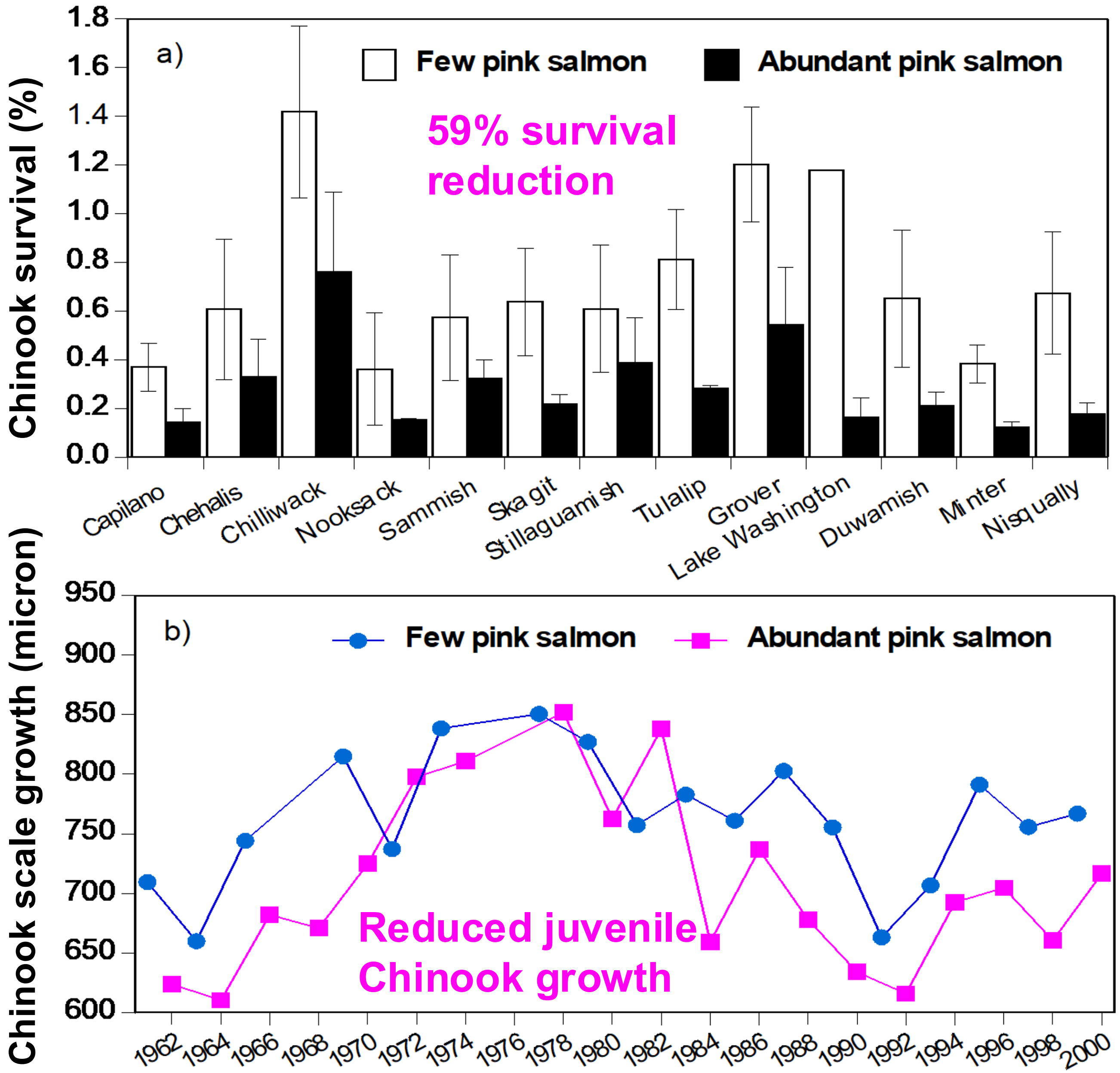
Shaul & Geiger 2016, Ruggerone et al. 2023

Pink salmon affect Salish Sea Chinook salmon growth & survival

- **Over 50 million coded-wire-tagged Chinook salmon analyzed**

- Survival of tagged subyearling Chinook salmon released into the Salish Sea, 1984-1997, was **59% lower when entering the Salish Sea with numerous juvenile pink salmon produced by odd-year parents**. (apparent opposite pattern prior to 1984)

- Scale growth of Salish Sea subyearling Chinook salmon declined when encountering numerous salmon declined when encountering numerous numerous juvenile pink salmon produced by odd-year parents



Ruggerone and Goetz 2005, Ruggerone et al. 2023, Losee et al. 2019, Kendall et al. 2020, Claiborne et al. 2021

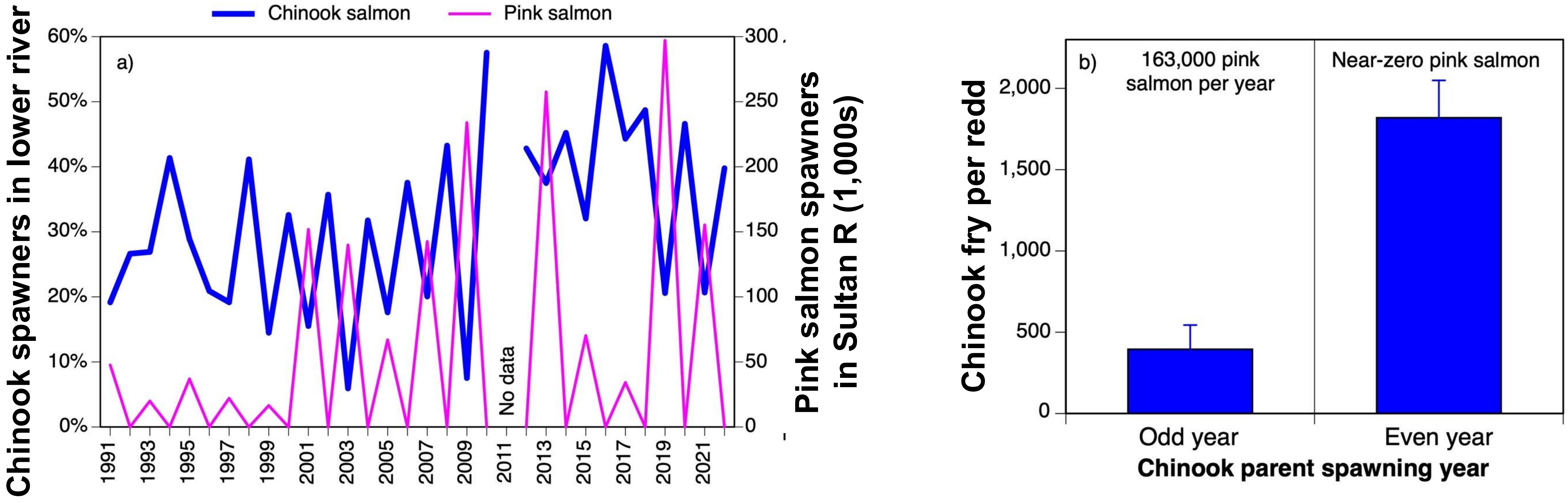
Pink Salmon Effects on Spawning Chinook in the Sultan River, Washington

Findings Relevant to Pink Salmon invasion into Northern Europe

Aggressive pink salmon on the spawning grounds

Photos from Sultan River, Washington

Pink salmon displace spawning Chinook salmon in Sultan River: lower reproductive success



In odd years, Chinook spawners moved upstream to avoid pinks in lower river, leading to fewer Chinook fry per redd

Entire Sultan River: 44% fewer Chinook spawners in odd vs even years. Avg ˜500 Chinook per year.

Ruggerone et al. 2025 CJFAS

Biennial “Wild” Puget Sound Chinook abundance since ˜1997

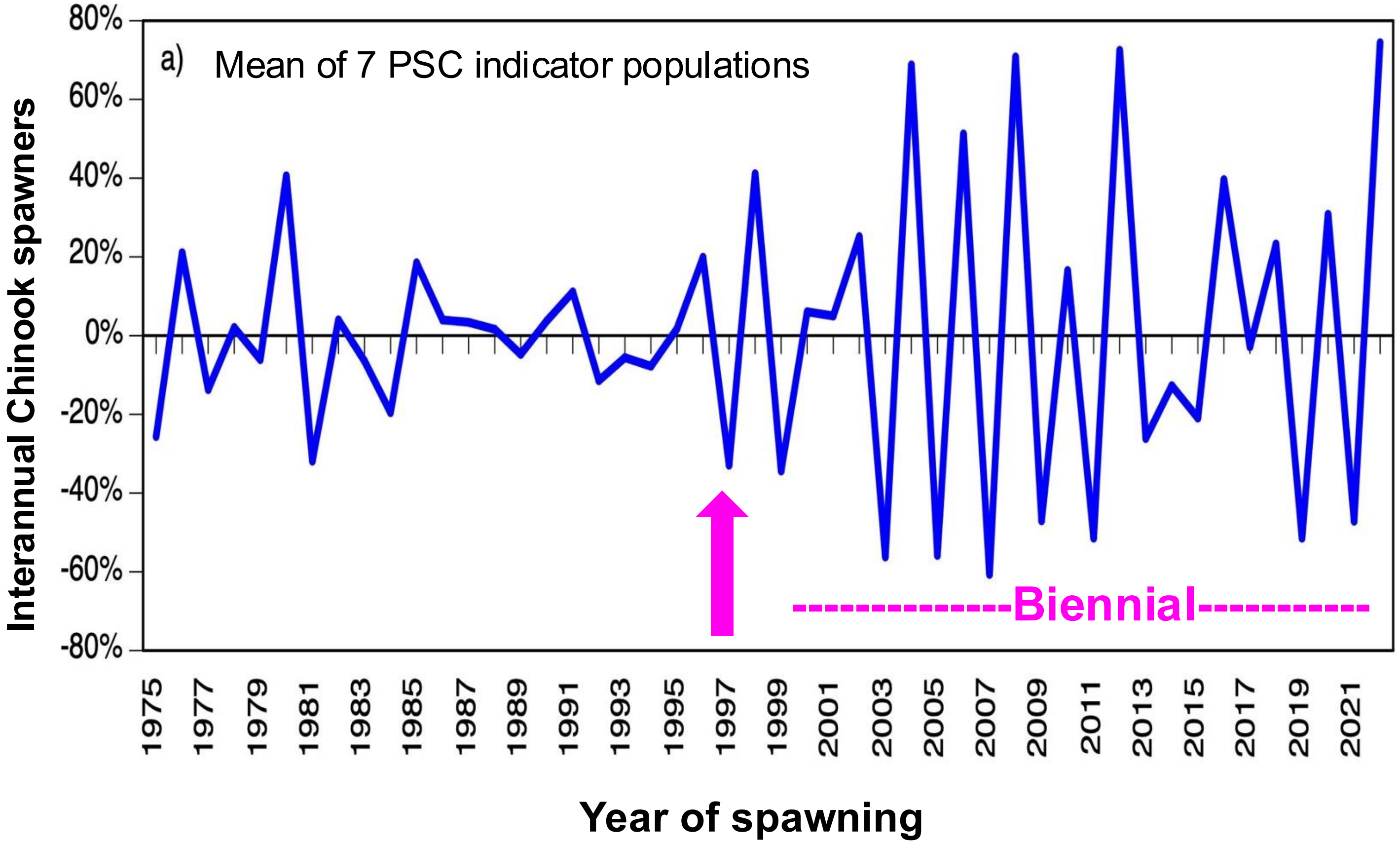
7 PSC Indicator Chinook populations (˜75% of total spawners)

Chinook spawners up to 60% less in odd compared with adjacent odd years beginning near 1997

Chinook total abundance (C + E) inversely correlated with pink abundance (see paper)

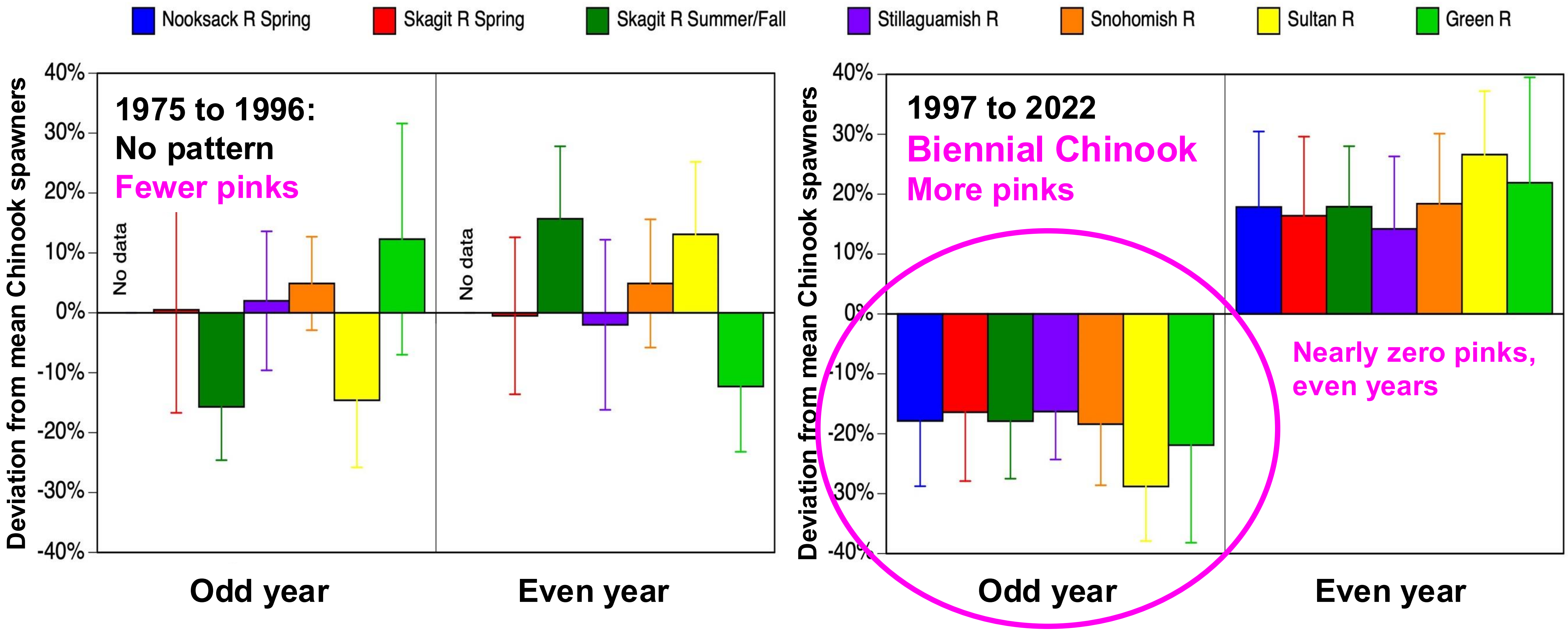
Chinook tend to spawn in bigger substrate, but timing is similar throughout Puget Sound. Spatial overlap in Skagit R

3X more pink spawners since 1997 likely leads to more interaction



Ruggerone et al. 2025 CJFAS

Biennial "Wild" Puget Sound Chinook spawners since 1997

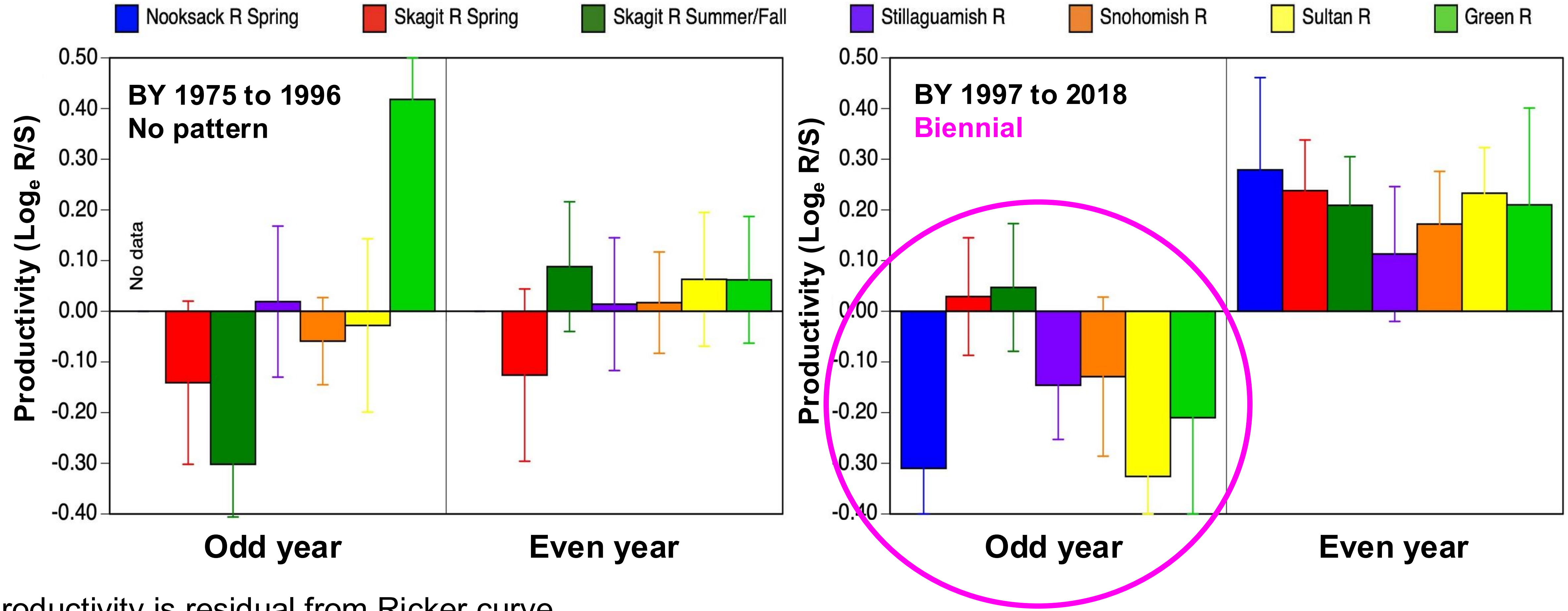


Biennial pattern facilitated by dominance of age 4 Chinook & tripling of pink spawners

Odd year parents primarily produce odd year returns

Ruggerone et al. 2025 CJFAS

Biennial “Wild” Puget Sound Chinook Productivity (R/S) since 1997



Productivity is residual from Ricker curve

Spawner to spawner here, but same finding for total recruits to Puget Sound)

Age data not consistently available, so assumed progeny returned 4 yr later. Age 4 is dominant.

Depensatory mortality inhibits recovery:
Productivity should increase when fewer spawners

Ruggerone et al. 2025 CJFAS

Do pink salmon affect endangered Southern Resident Killer Whales?

SRKW rarely eat pink salmon, which generally migrate with but above returning Chinook from late July to early September

Ruggerone et al. 2019, 2023, Stewart et al. 2021

Update: Do pink salmon affect Southern Resident Killer Whales?

- **1998 to 2020:** mortality 3.1 times higher (65 versus 21 deaths, births 42% lower (19 versus 33 calves) in even vs. odd years as the population decreased from 92 to 74 animals. (1 year delay)

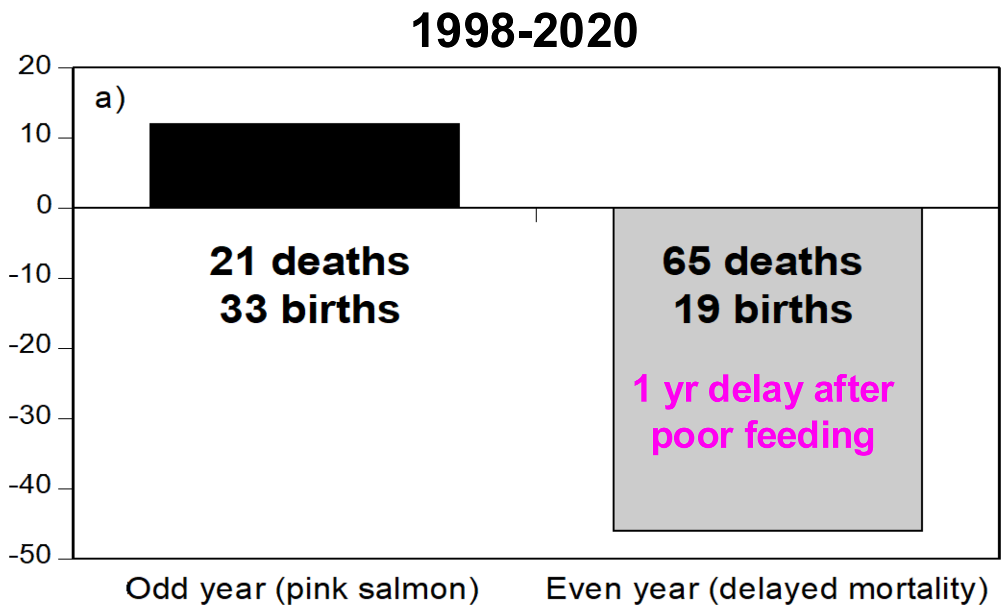
- **1976–1997:** Biennial pattern not apparent when SRKW increasing, Chinook salmon more abundant; pink salmon less abundant.

- Body condition of SRKW (L Pod) was low in fall of odd years (2008-2019), and correlated with PS Chinook abundance

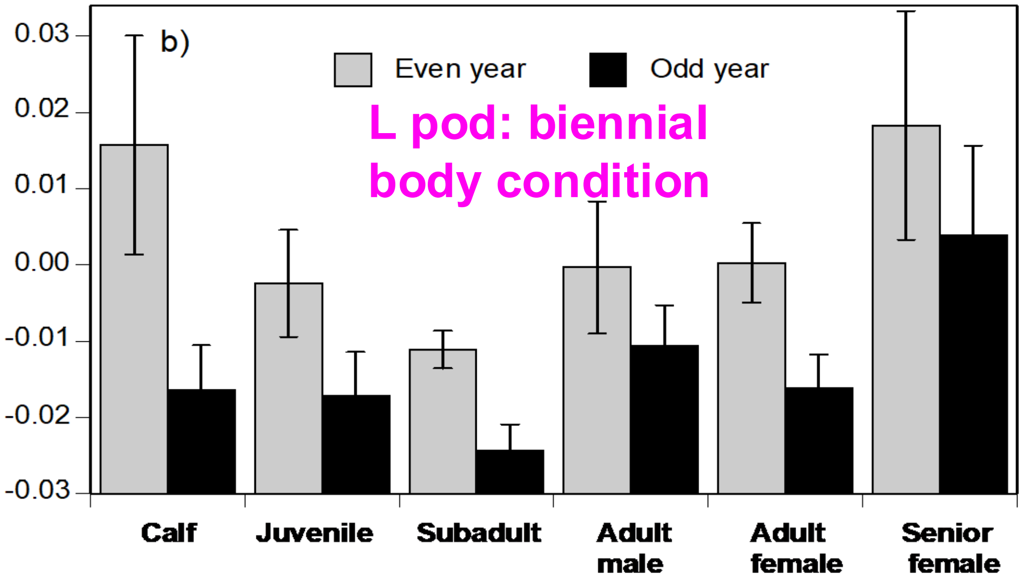
- Body condition of SRKW (K Pod, reproductive females and subadults) was low in fall of odd years.

Ruggerone et al. 2019, 2023, Stewart et al. 2021

SRKW population change

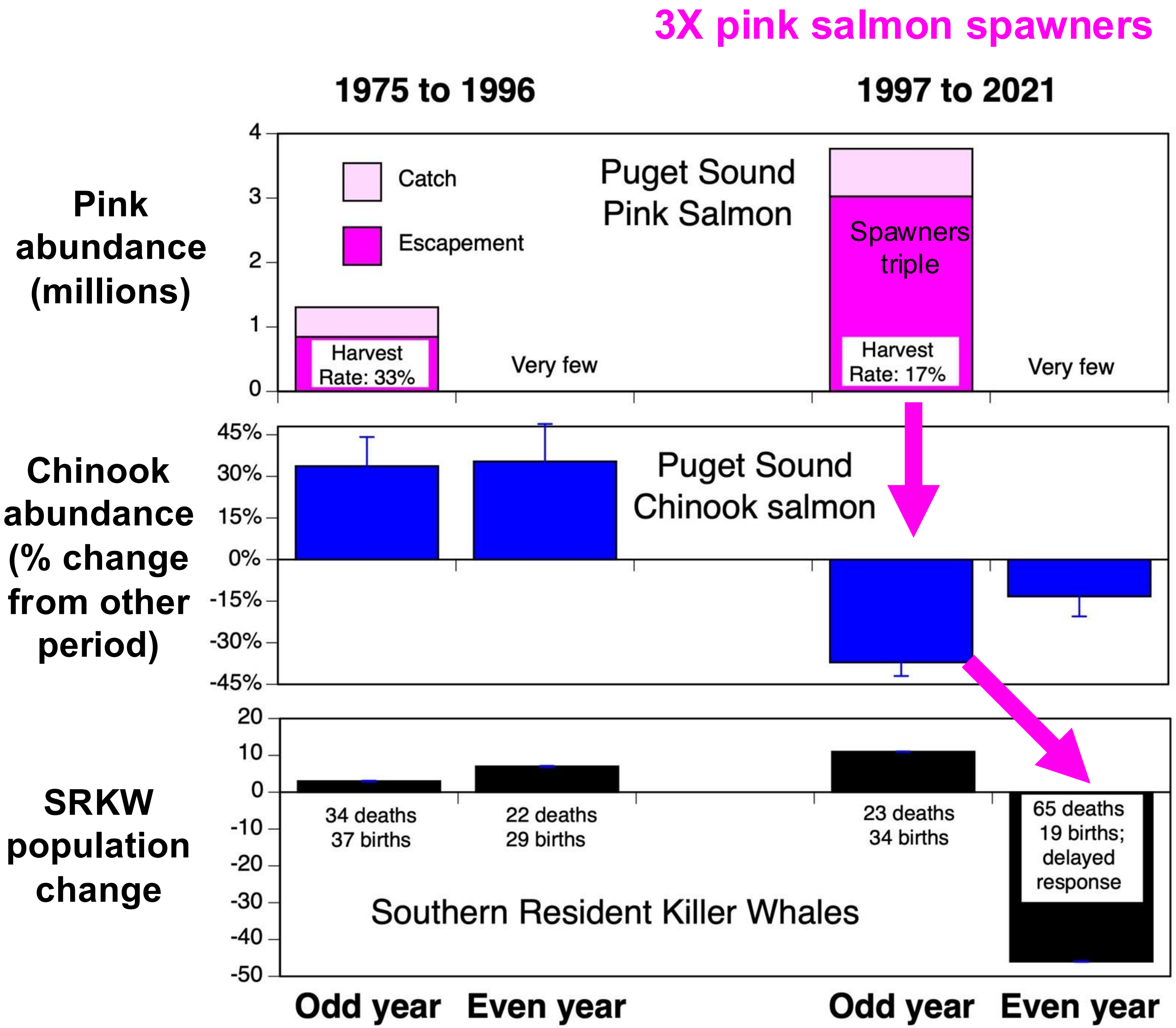


SRKW body condition index



Cascading Effect of Pink Salmon on Chinook & Southern Resident Killer Whales: 1997 to 2021

- Pink salmon spawning escapements <u>increased</u> in Puget Sound and Salish Sea after 1996
- “Wild” Puget Sound Chinook abundance <u>declined</u> ˜40% in recent odd years but only ˜12% in even years
- SRKW biennial patterns consistent with biennial Chinook salmon decline & pink salmon increase
- **Management Recovery Actions:**
  - Selectively/sustainably harvest pink salmon
  - **Minimize** bycatch mortality
  - Reduce pink hatchery production (AK)



Ruggerone et al. 2025

Find More Supporting Evidence here (Open Access):

Ruggerone, G.T, A. Springer, G.B. van Vliet, B. Connors, J.R. Irvine, L.D. Shaul, M.R. Sloat, and W.I. Atlas. 2023. From diatoms to killer whales: impacts of pink salmon on North Pacific ecosystems. Marine Ecology Progress Series 719:1-40. https://www.int-res.com/articles/feature/m719p001.pdf

Ruggerone, G.T., L. Lowe, K. Binkley, and A. McDonnell. 2025. Long-term biennial patterns in Puget Sound Chinook salmon and Southern Resident killer whales: the role of pink salmon and implications for ecosystem management. Canadian Journal of Fisheries and Aquatic Sciences. https://cdnsciencepub.com/doi/10.1139/cjfas-2024-0262

Connors, B., G.T. Ruggerone, and J.R. Irvine. 2024. Adapting management of Pacific salmon to a warming and more crowded ocean. ICES Journal of Marine Sciences. doi.org/10.1093/icesjms/fsae135

Ruggerone, G.T., and J.R. Irvine. 2018. Numbers and biomass of natural- and hatchery-origin pink, chum, and sockeye salmon in the North Pacific Ocean, 1925-2015. Marine & Coastal Fisheries 10:152-168