Climate and competition influence sockeye salmon population dynamics across the Northeast Pacific Ocean

Fishes without Borders II Workshop

AFS Idaho Chapter Meeting

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Fisheries and Oceans Canada | Pêches et Océans Canada

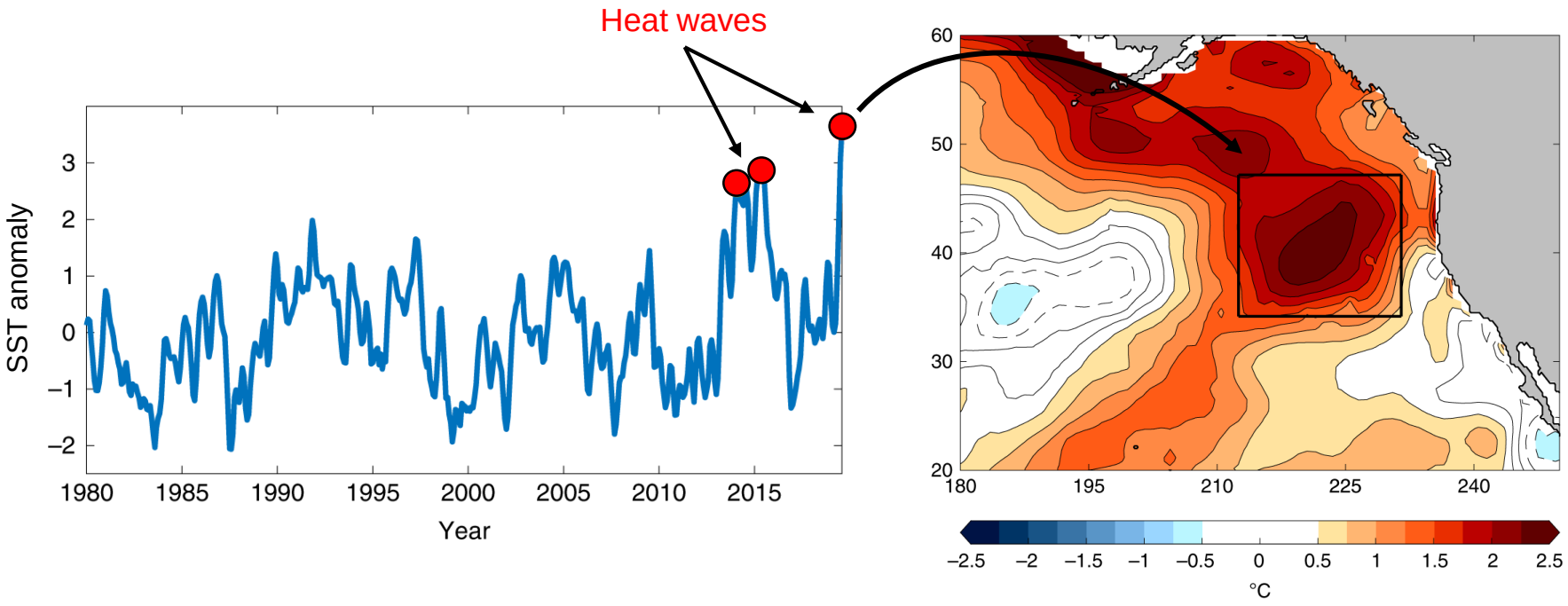
SASAP State of Alaska's Salmon and People

NCEAS National Center for Ecological Analysis and Synthesis

Take home messages

- the ocean is getting warmer and there are more salmon now, on average, than at any other point in past century
- a warming ocean, and increasing salmon competitors, combine to reduce sockeye survival in south
- in north a warming ocean improves survival, and buffers sockeye from negative effects of competition
- hatchery production in north likely contributes to reductions in survival in the south
- managing the number of salmon released into the ocean may help sockeye adapt to an uncertain future

The ocean is getting warmer



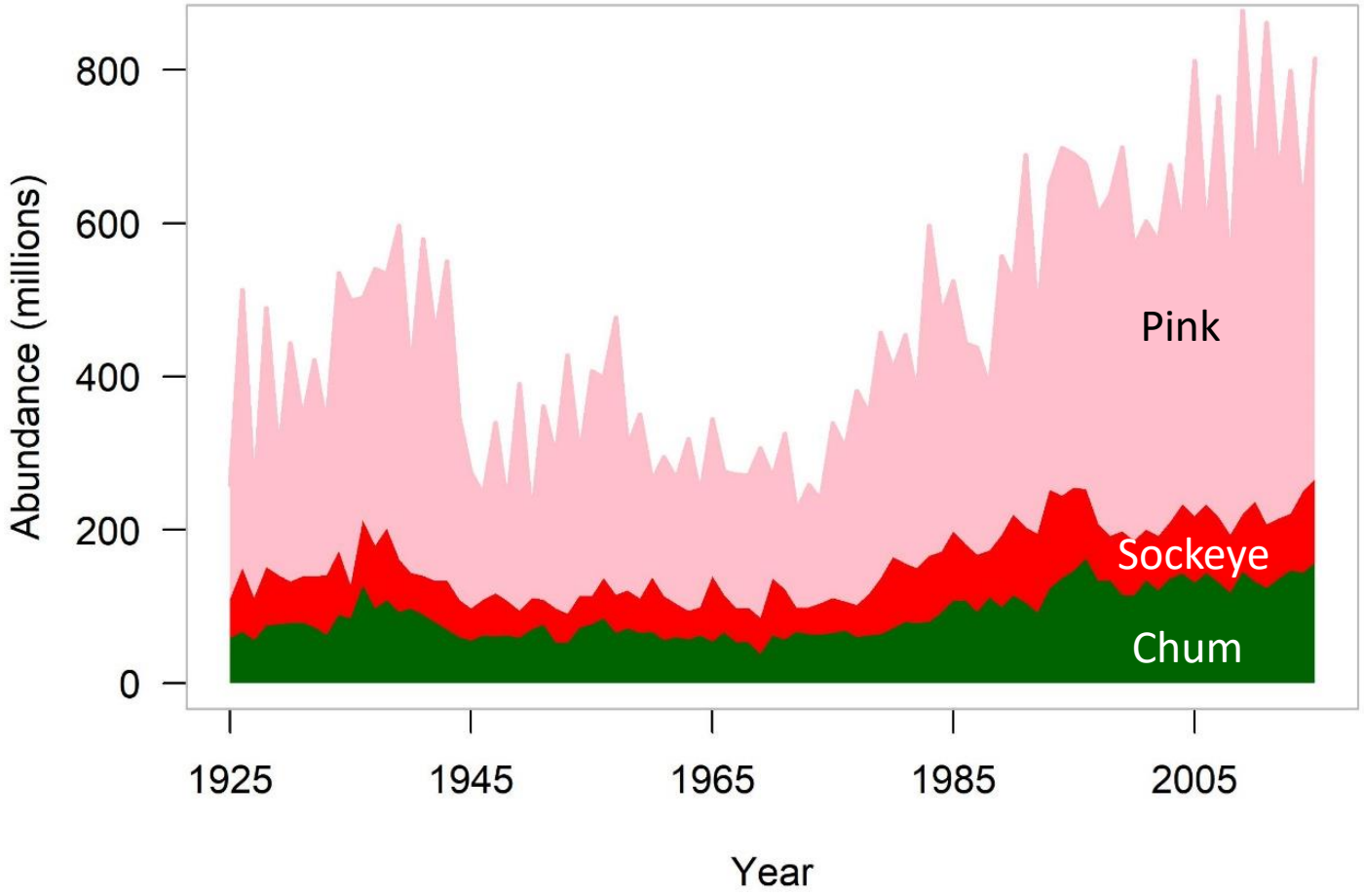
Amaya *et al*. 2020

Ocean temperature can influence the distribution, growth, maturation and survival of salmon

- In the “north” a warming ocean tends to lead to increased survival
- In the “south” a warming ocean tends to lead to reduced survival

e.g., Mantua *et al.* 1997, Mueter *et al*. 2002, Su *et al*. 2004, Stachura *et al*. 2014, Malick *et al*. 2017, 2020; Litzow *et al.* 2019, 2020

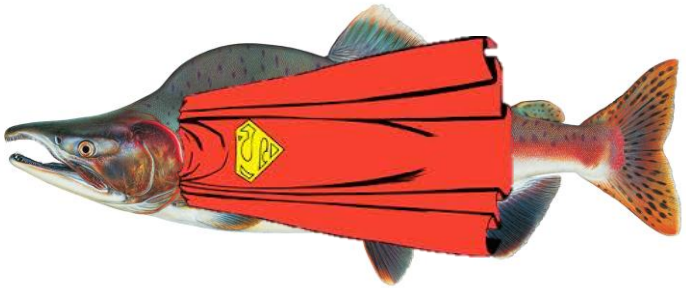
There are now more salmon in the ocean, on average, than anytime in past century



Ruggerone and Irvine. 2018

And they compete for a common pool of limited resources

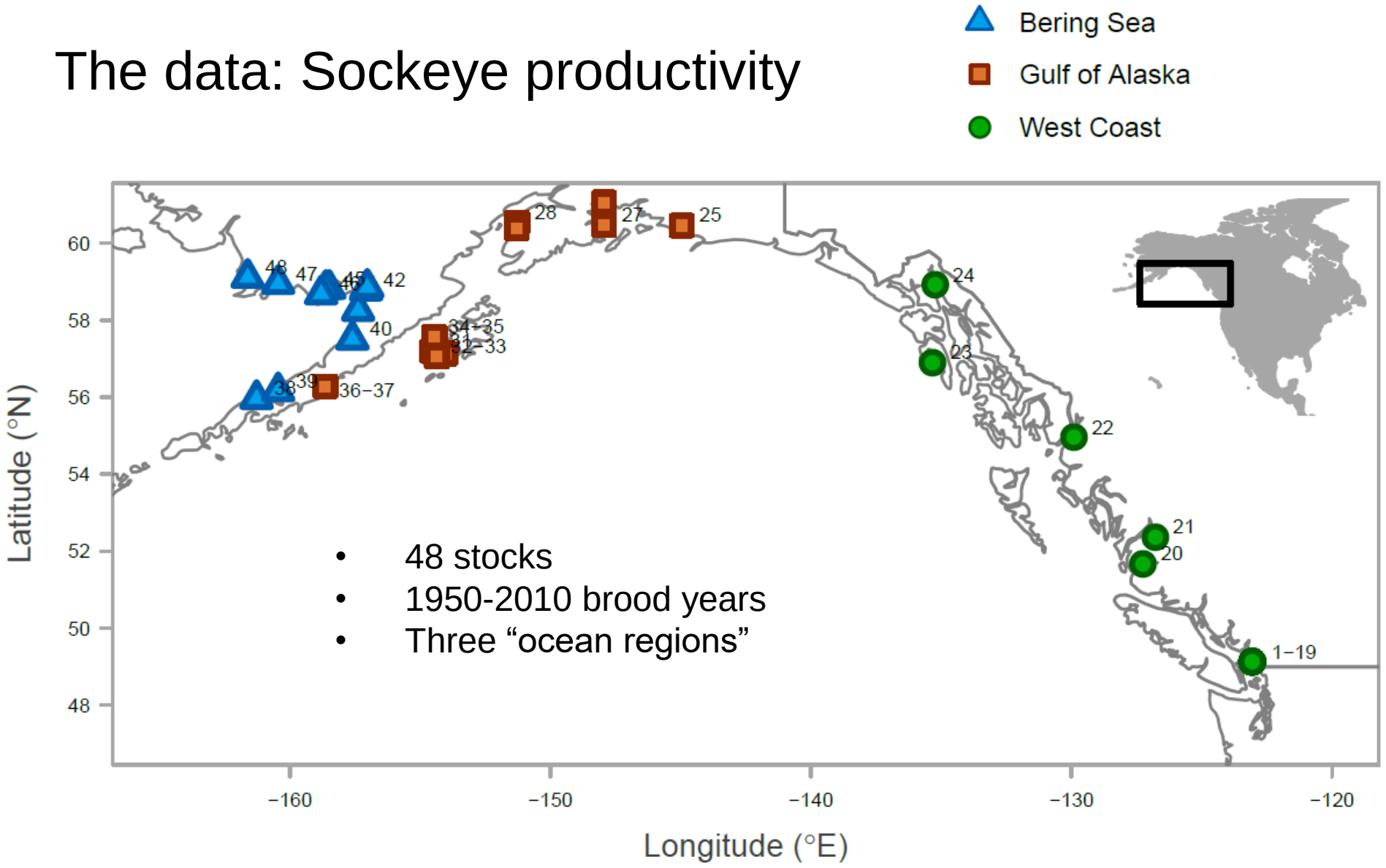
- Pink, chum and sockeye share common prey at sea
- Competition among salmon at sea can influence sockeye growth, age at maturity, and survival
- Most pronounced (easiest to detect?) for pink salmon competitors
  - because of strong odd-even year pattern in abundance and overlap in diet?



e.g, Davis *et al.* 2005, Ruggerone et al. 2003, Ruggerone and Connors 2015, Cline *et al.* 2019

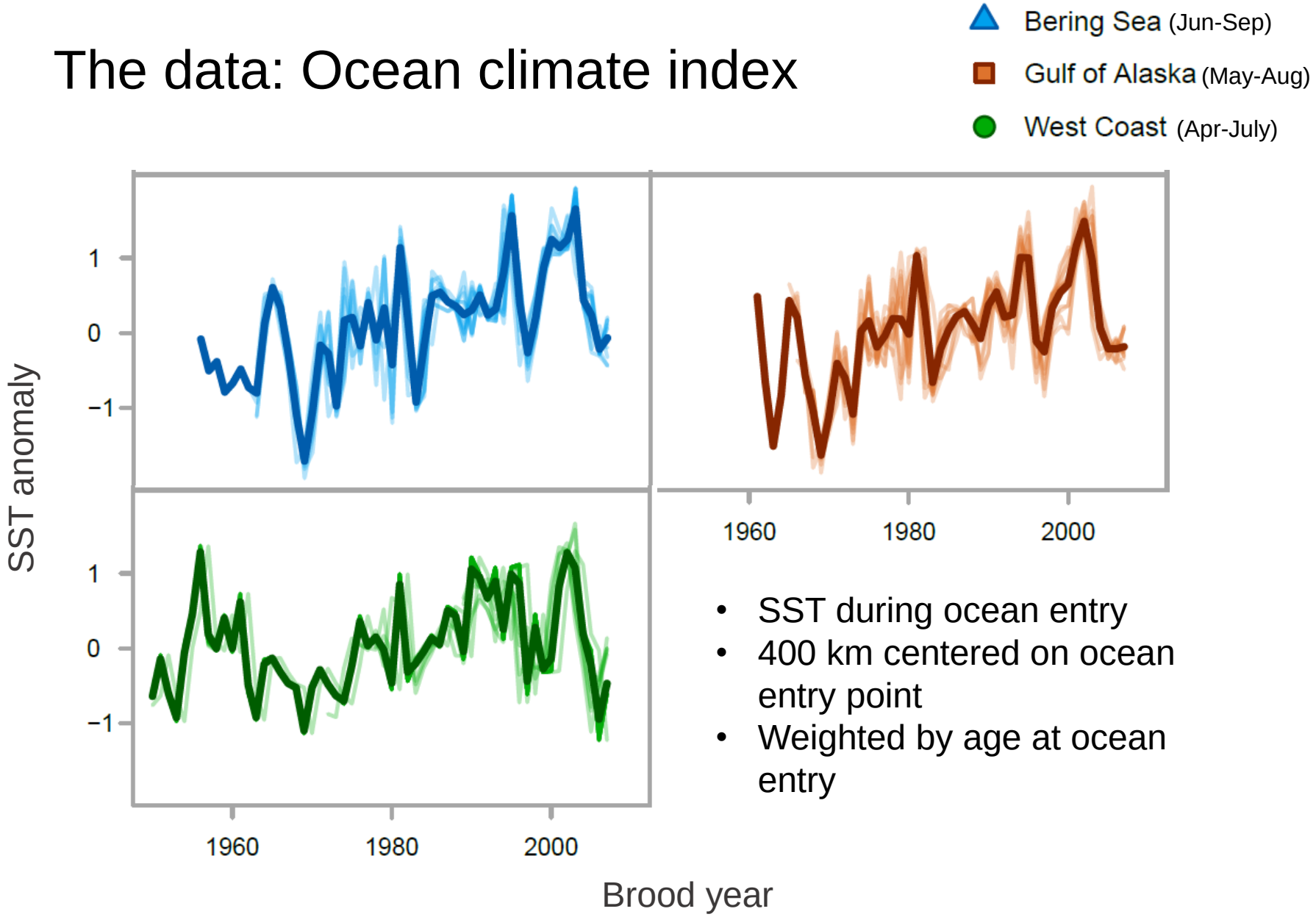
How does a warming ocean, and increasing competition with other salmon, interact to influence the survival of sockeye across their range?

The data: Sockeye productivity



- 48 stocks
- 1950-2010 brood years
- Three “ocean regions”

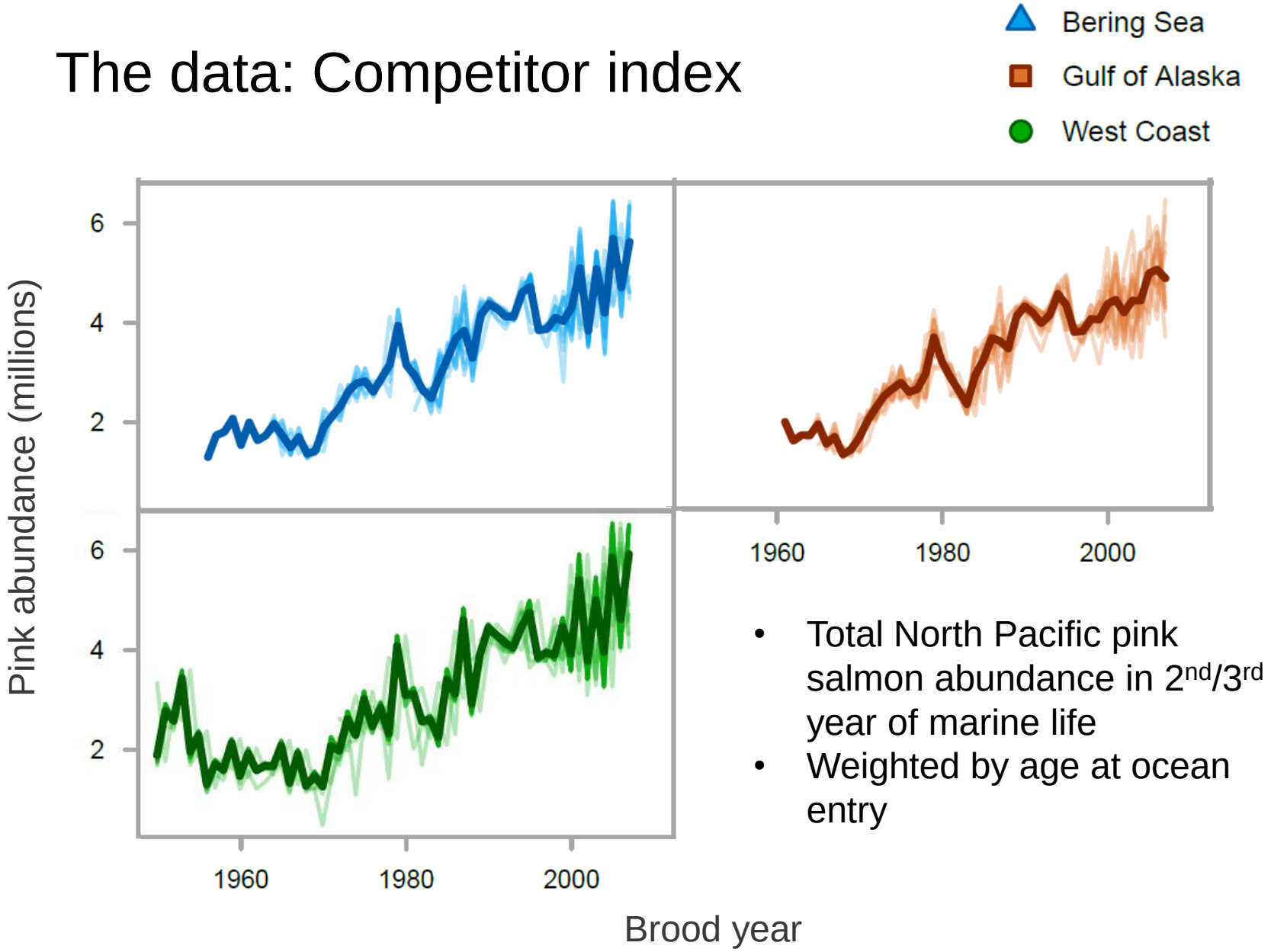
The data: Ocean climate index



- SST during ocean entry
- 400 km centered on ocean entry point
- Weighted by age at ocean entry

Mueter *et al.* 2002; Liu *et al*. 2015; Huang *et al*. 2017

The data: Competitor index

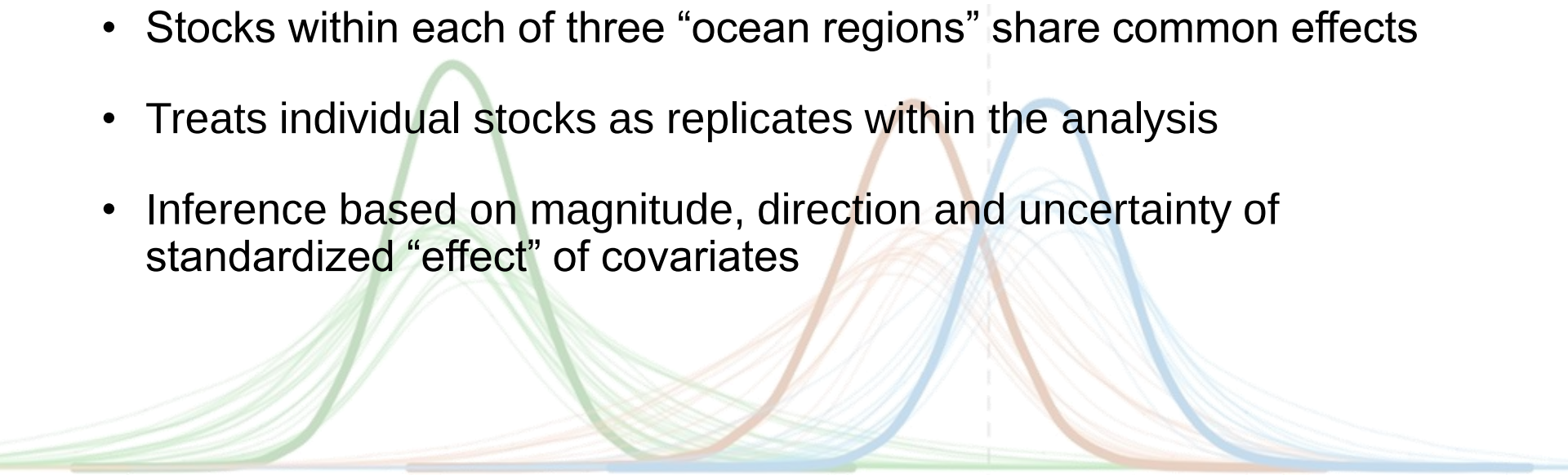


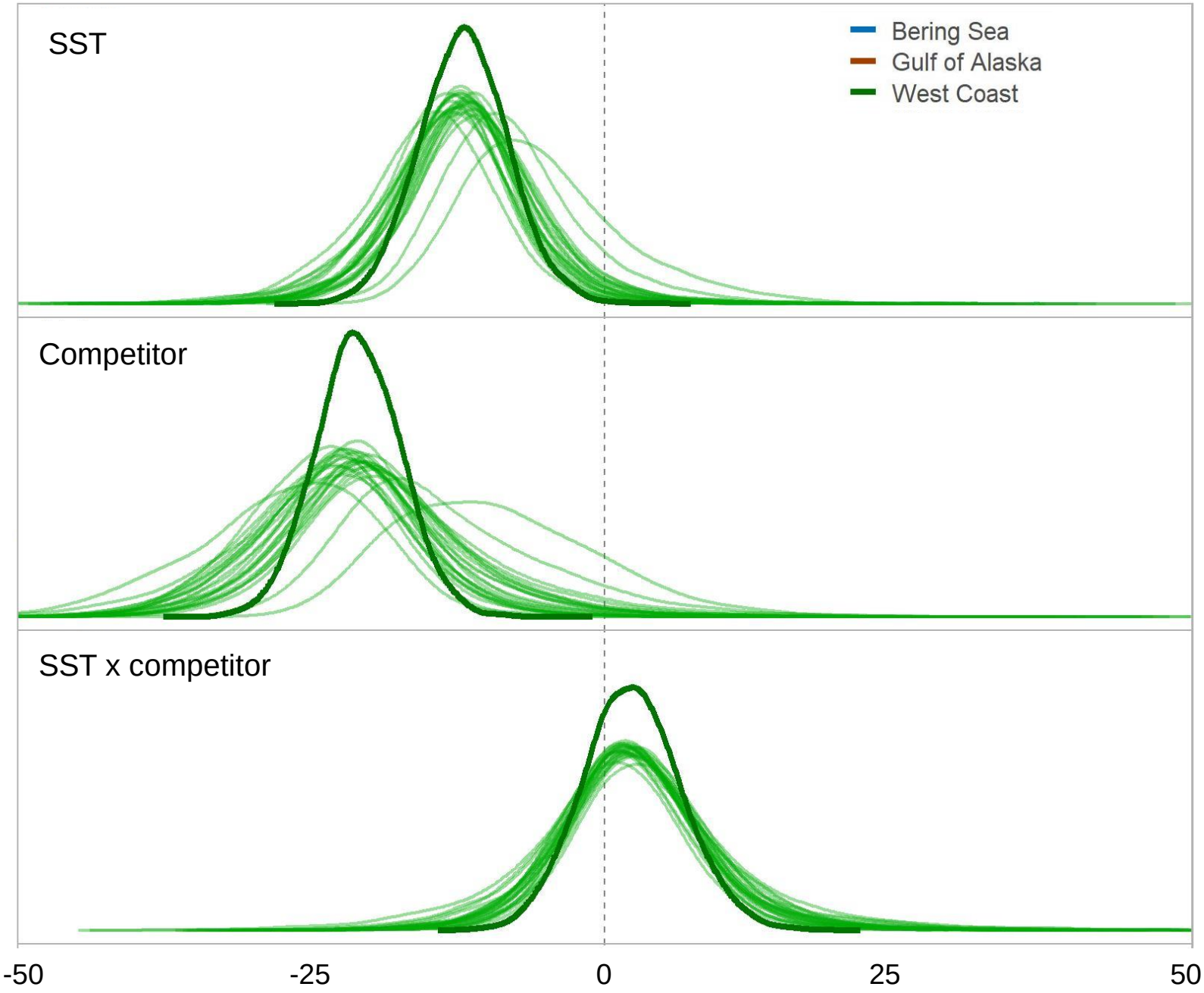
- Total North Pacific pink salmon abundance in 2nd/3rd year of marine life
- Weighted by age at ocean entry

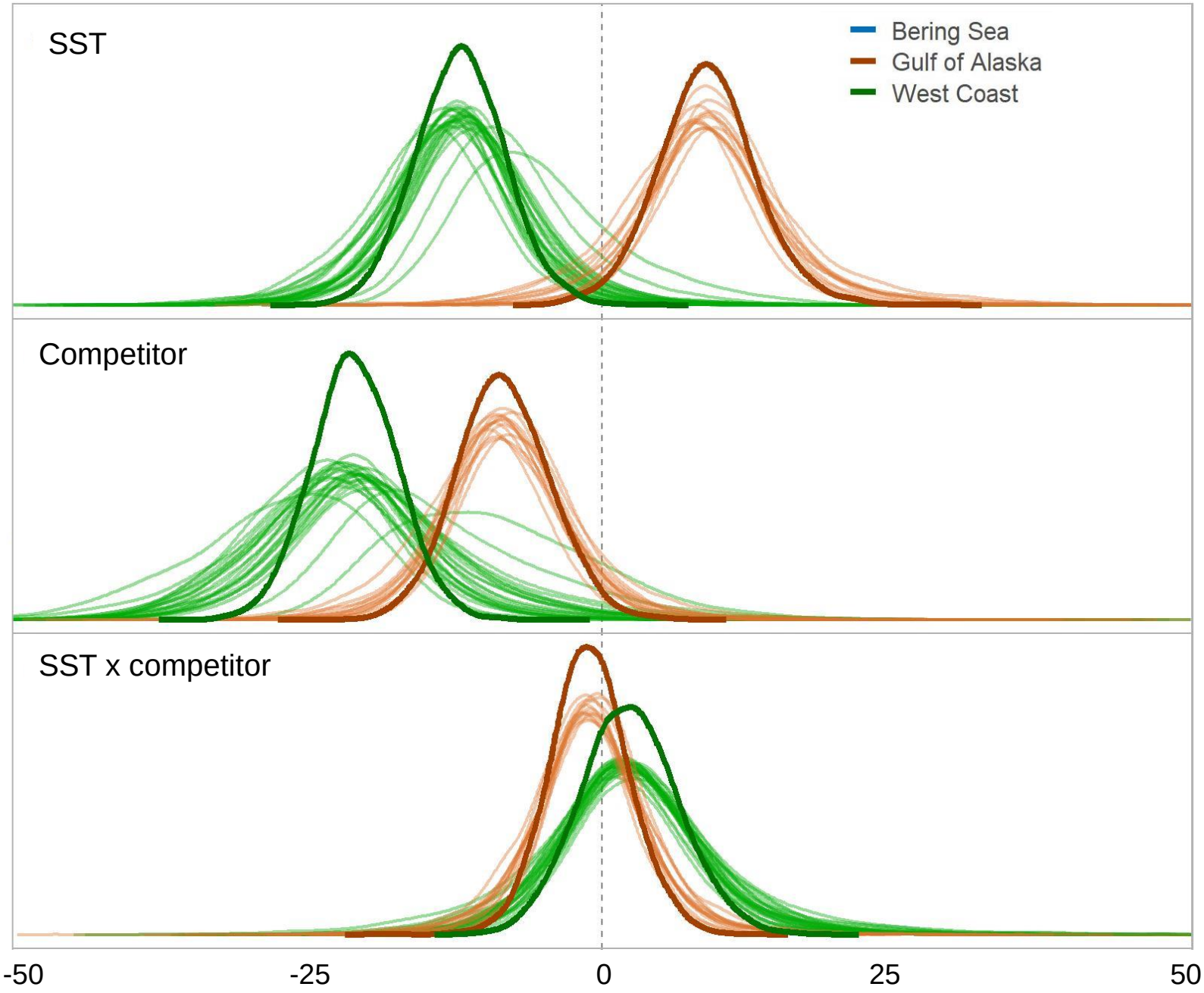
Ruggerone *et al.* 2003; Ruggerone and Connors 2015; Ruggerone and Irvine. 2018

The test: Bayesian hierarchical models

- Relate sockeye productivity to climate, competitors and interaction between the two
- Stocks within each of three “ocean regions” share common effects
- Treats individual stocks as replicates within the analysis
- Inference based on magnitude, direction and uncertainty of standardized “effect” of covariates




SST
Competitor
SST x competitor
Bering Sea
Gulf of Alaska
West Coast
-50
-25
0
25
50
Percent change in recruits produced per spawner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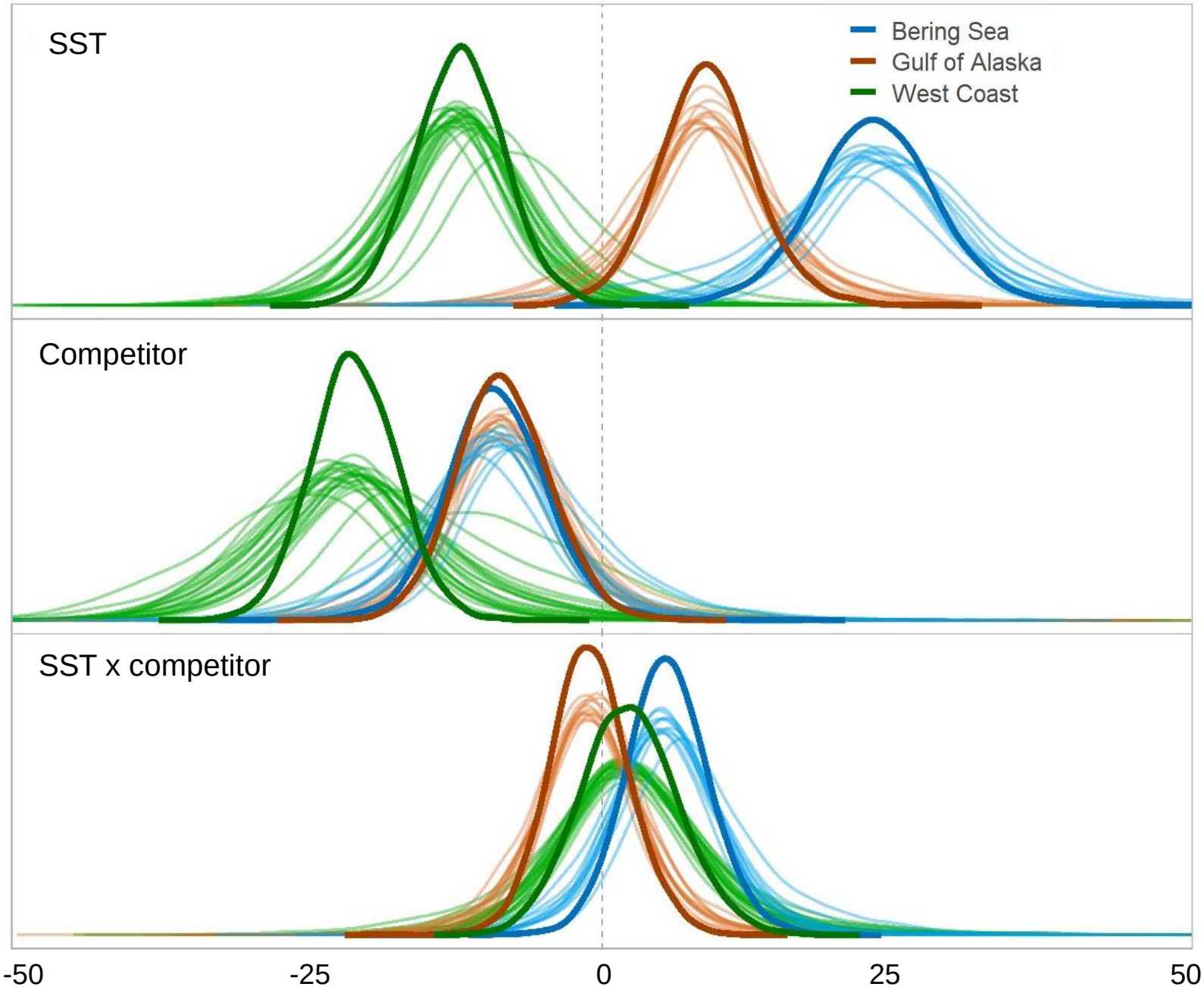
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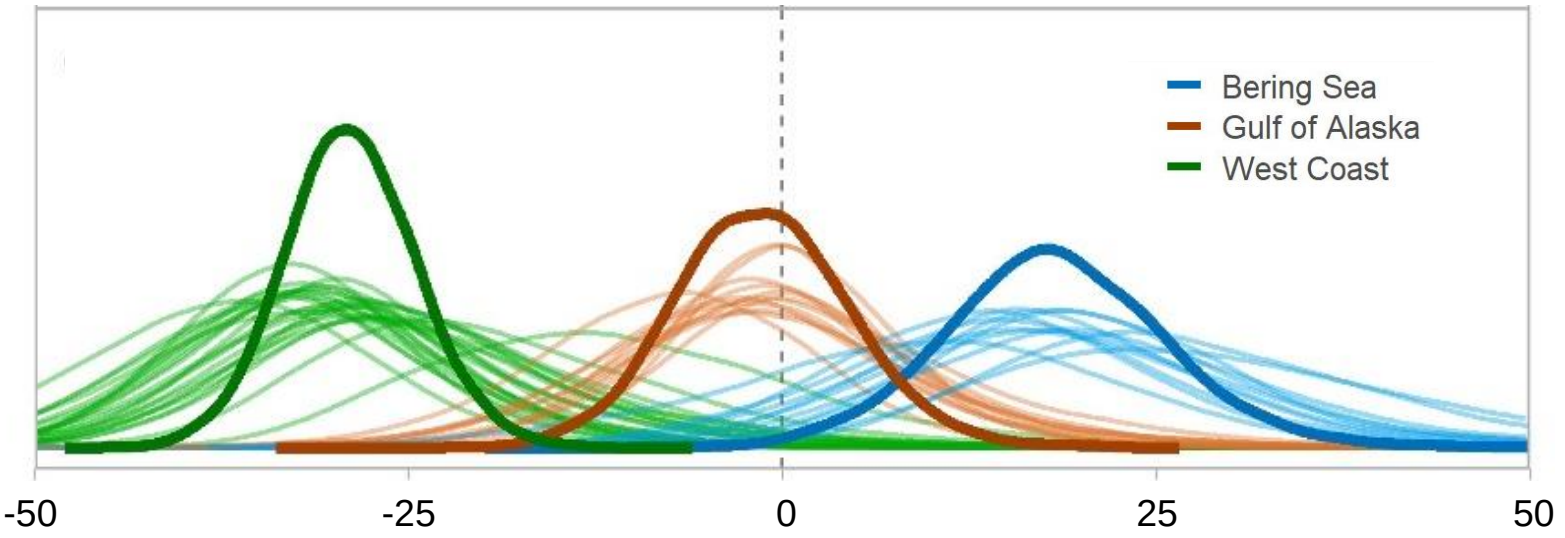
Combined effects*

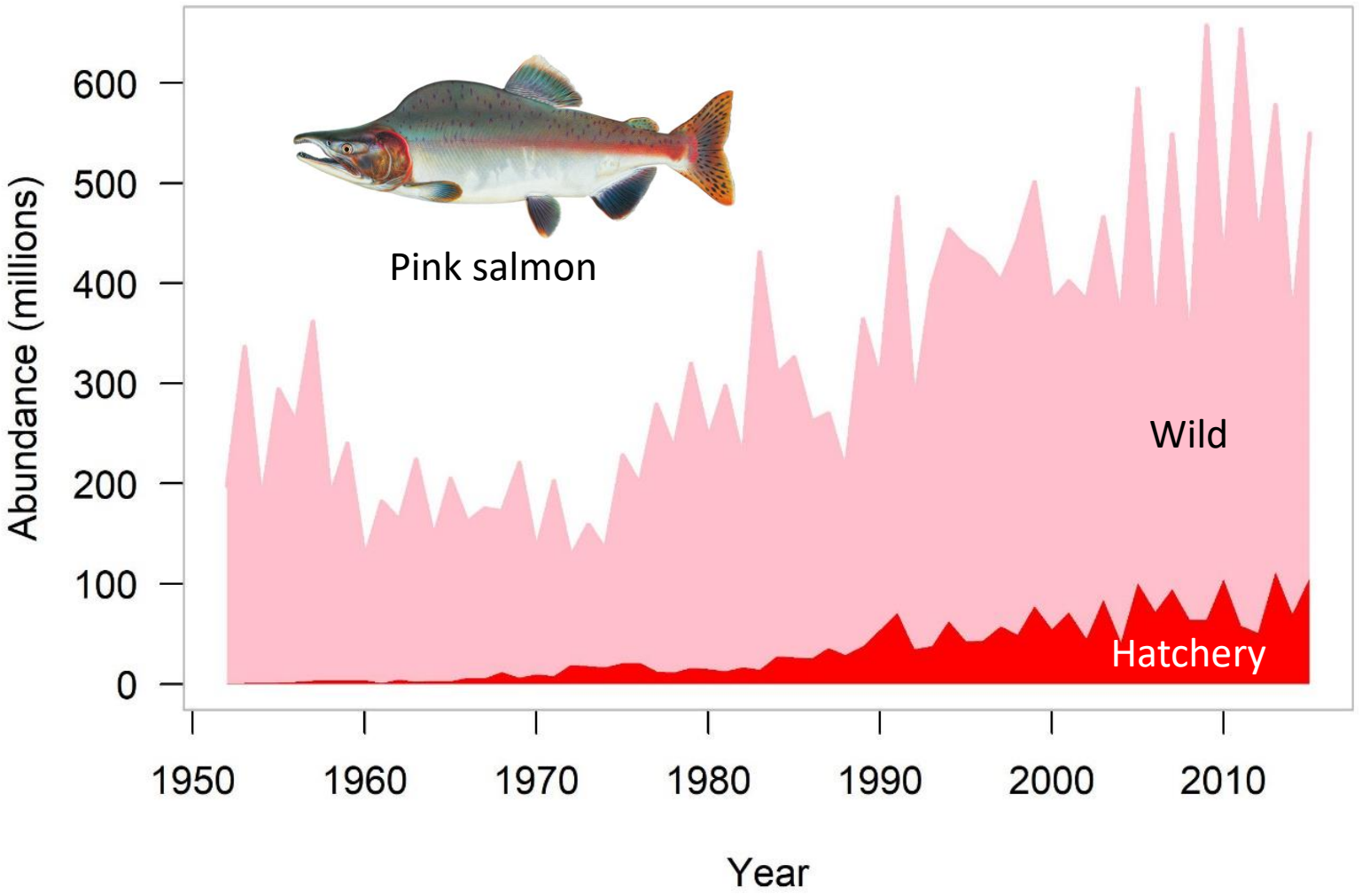


* per std. deviation unit increase in SST (1.5^{o}C) and competitors (136 million)

Results: summary of hierarchical modelling

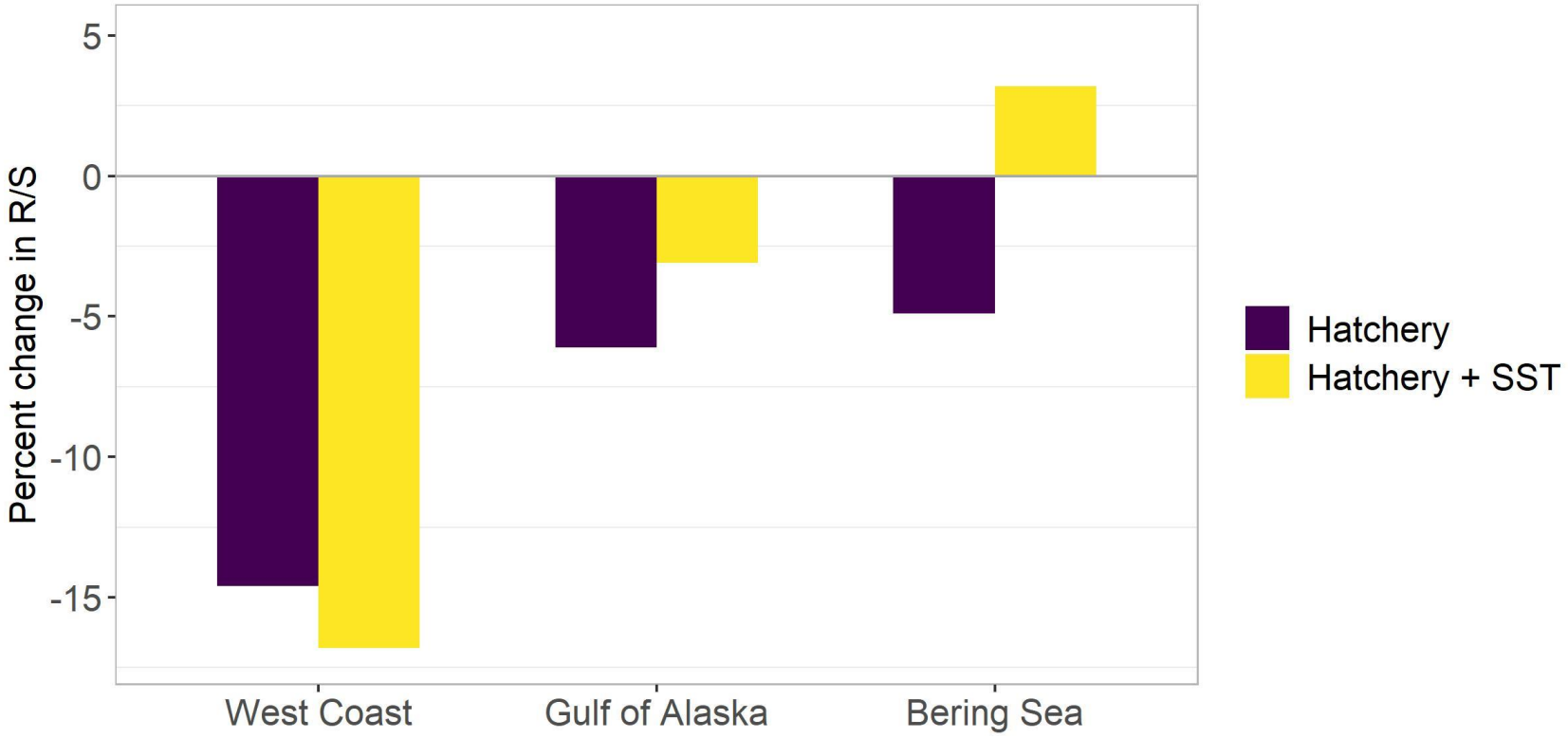
- warming ocean = reduced survival for **WC** stocks, increased survival for **GoA** and **BS** (effect is 2x greater for **BS** than other stocks)
- increasing competitors = reduced survival for **WC**, **GoA**, and **BS** (effect is 2x greater for **WC** than other stocks)
- interaction = as ocean warms negative effect of competition on survival becomes weaker for **BS**

Hatchery production is increasing



Ruggerone and Irvine. 2018

Predicted effect of increasing hatchery pink production on sockeye survival*



* At average wild pink salmon abundance, with and without considering recent SST anomalies

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More information

- Data and code for this analysis:

  https://github.com/brendanmichaelconnors/sockeye-climate-competition

- Publication:

  https://cdnsciencepub.com/doi/10.1139/cjfas-2019-0422

- Contact:

  brendan.connors@dfo-mpo.gc.ca

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