Effects of the North Pacific Current on Pacific salmon productivity vary across time and space

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Fishes Without Borders II Workshop

March 2021

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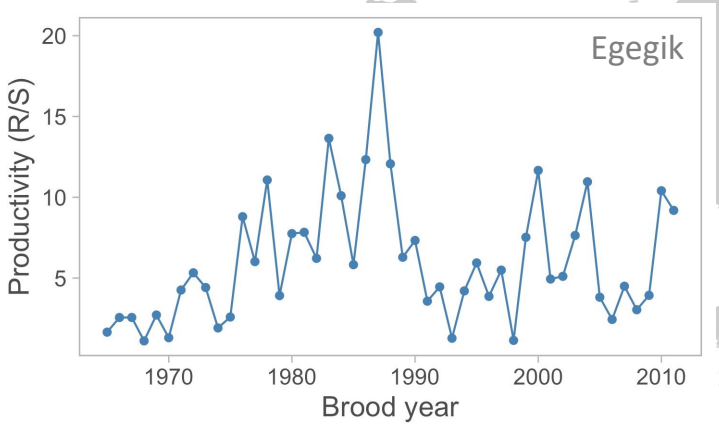
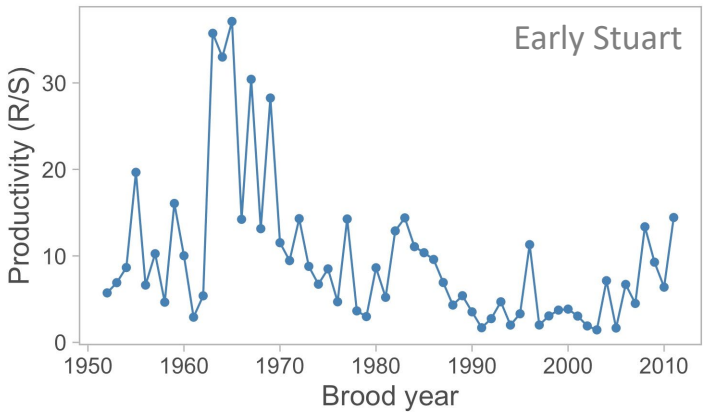
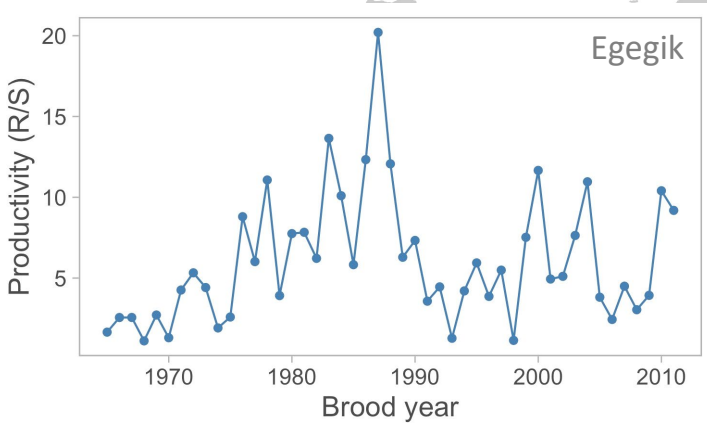
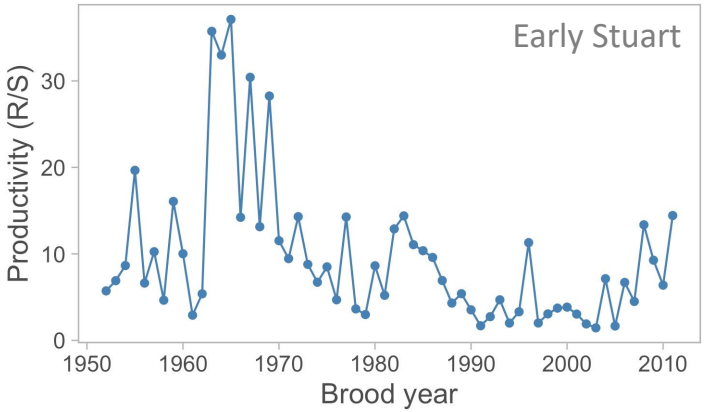
$$\text{Productivity} = \frac{\text{recruits}}{\text{spawner}}$$

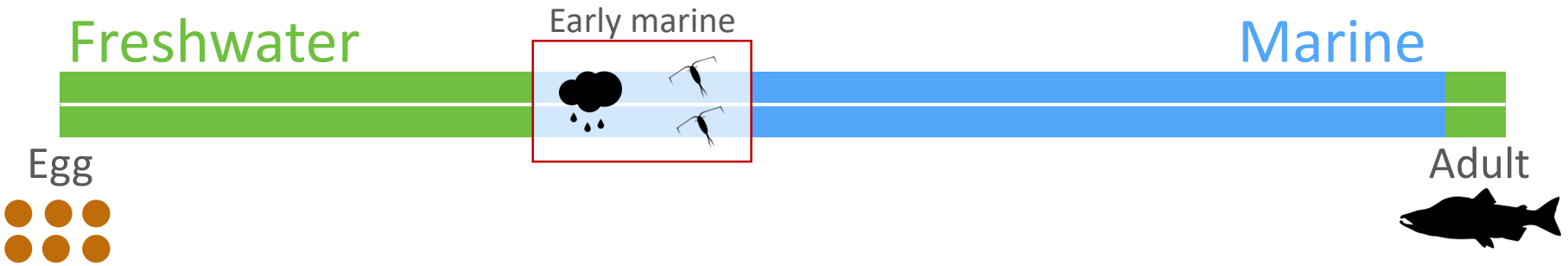




$$\text{Productivity} = \frac{\text{recruits}}{\text{spawner}}$$





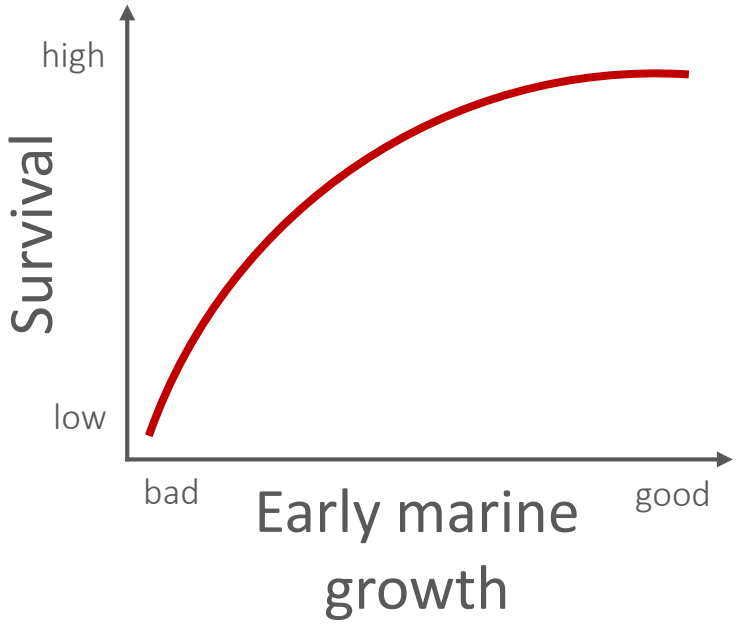


Climate effects on growth, phenology, and survival of sockeye salmon (*Oncorhynchus nerka*): a synthesis of the current state of knowledge and future research directions

Eduardo G. Martins · Scott G. Hinch · Steven J. Cooke · David A. Patterson

Rapid growth in the early marine period improves the marine survival of Chinook salmon (*Oncorhynchus tshawytscha*) in Puget Sound, Washington

Elisabeth J Duffy and David A Beauchamp



Climate processes

PDO, NPGO, NPI, AL

Vertical transport

upwelling, wind mixing,
tidal mixing, stratification

Growth of Juvenile Coho Salmon (*Oncorhynchus kisutch*) off Oregon and Washington, USA, in Years of Differing Coastal Upwelling

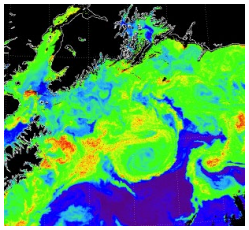
J. P. Fisher and W. G. Pearcy

Oregon State University, College of Oceanography, Corvallis, OR 97331, USA

Relationships between Coastal Ocean Conditions and Survival Rates of Northeast Pacific Salmon at Multiple Lags

FRANZ J. MUETER,[1] BRIAN J. PYPER,[2] AND RANDALL M. PETERMAN*

School of Resource and Environmental Management,
Simon Fraser University, Burnaby, British Columbia V5A 1S6, Canada



Lower trophic level processes

primary and secondary production,
Zooplankton composition

Salmon productivity

recruits/spawner

Climate processes

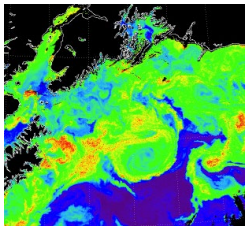
PDO, NPGO, NPI, AL

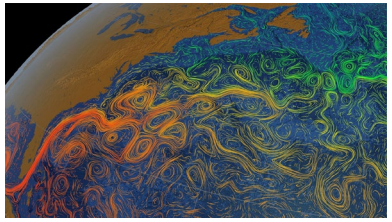
Vertical transport

upwelling, wind mixing,
tidal mixing, stratification

Horizontal transport

along-shore and cross-shelf,
currents, eddies



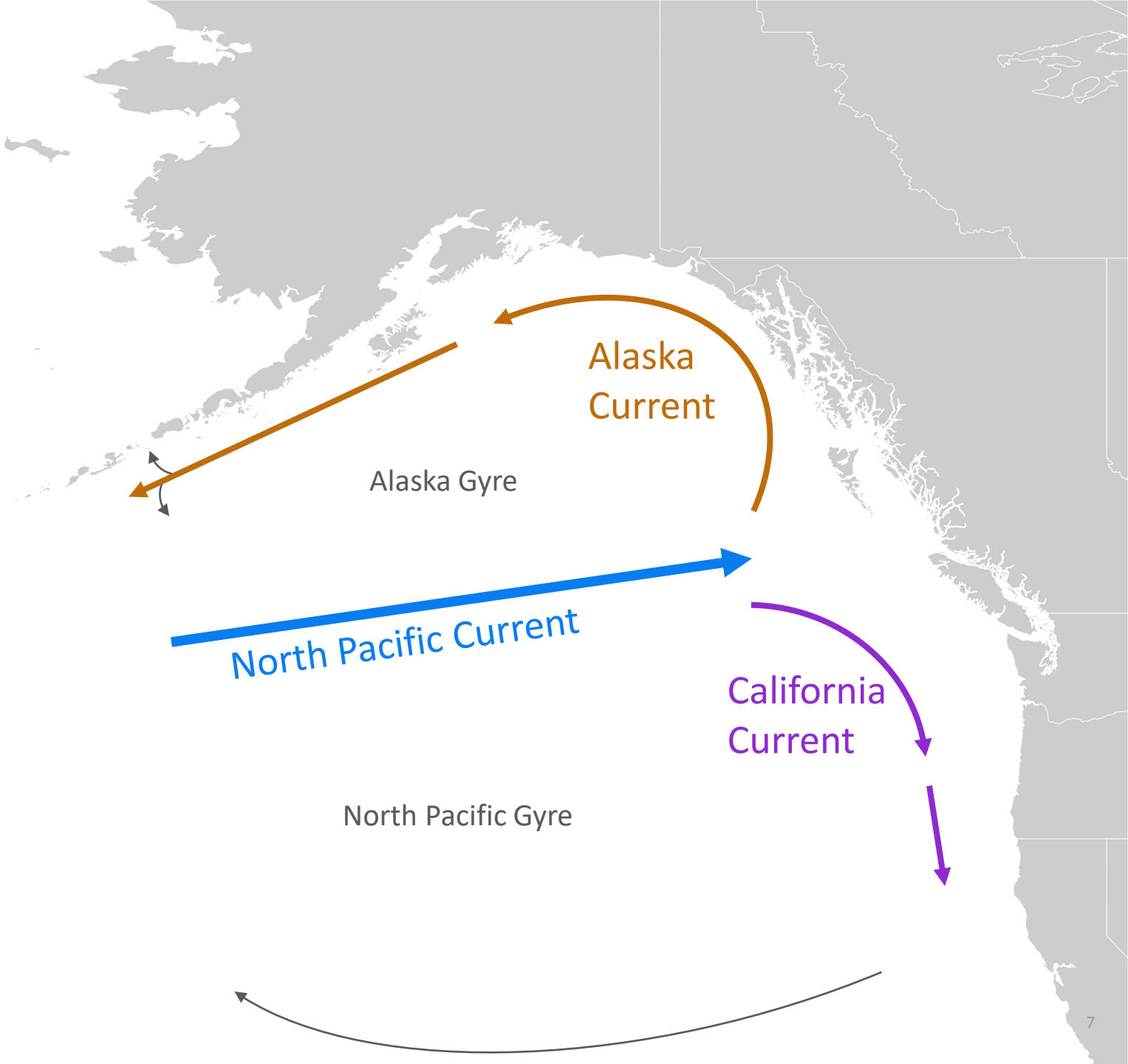


Lower trophic level processes

primary and secondary production,
Zooplankton composition

Salmon productivity

recruits/spawner


Alaska
Current
Alaska Gyre
North Pacific Current
California
Current
North Pacific Gyre

Does the north-south positioning of the North Pacific Current impact salmon productivity?

Current

Alaska Gyre

North Pacific Current

California Current

North Pacific Gyre

Bering Sea

Gulf of Alaska

West Coast

163 salmon stocks

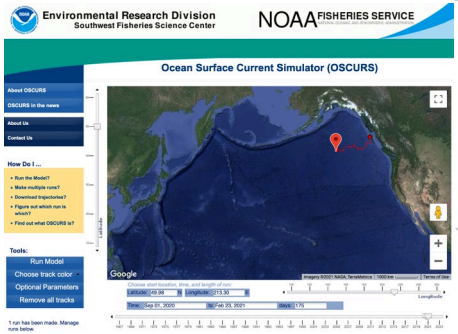
Pink: 46 stocks

Chum: 53 stocks

Sockeye: 64 stocks

Malick et al. (2017) Fish Oceanogr

OSCURS Model

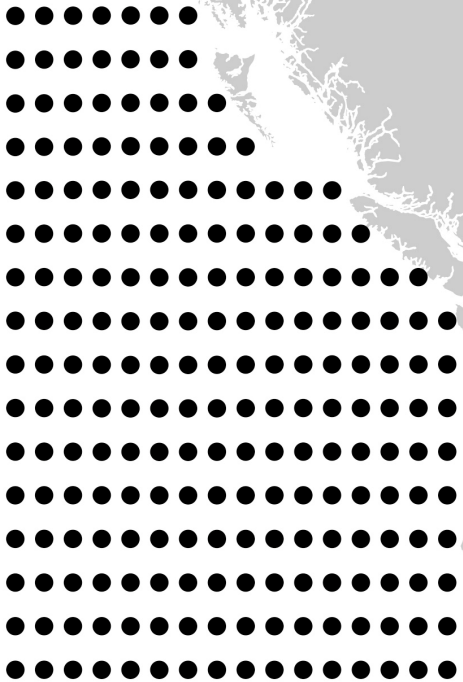


Drifter simulation

215 drifters

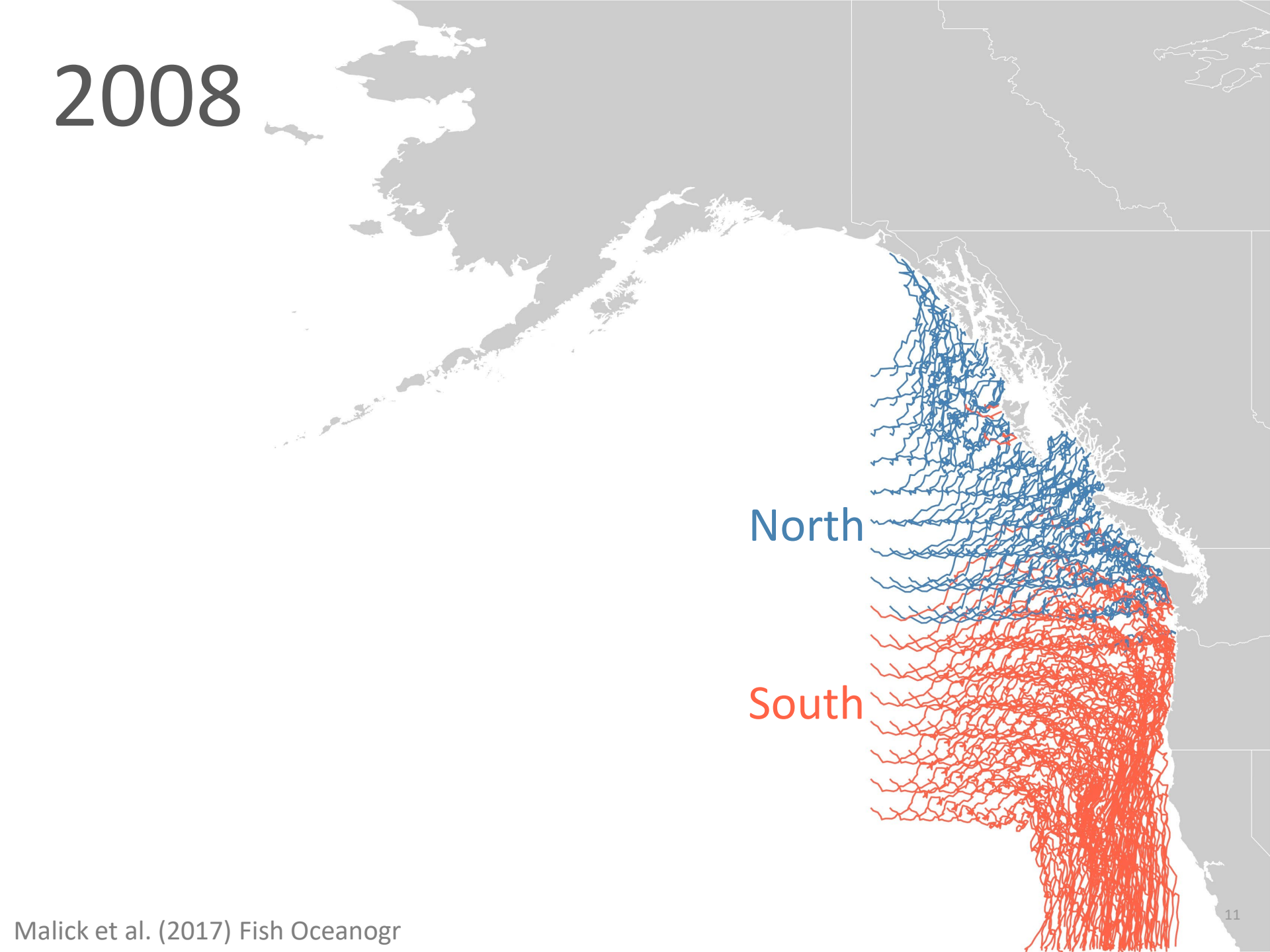
Feb 1 – June 30

1967 – 2010



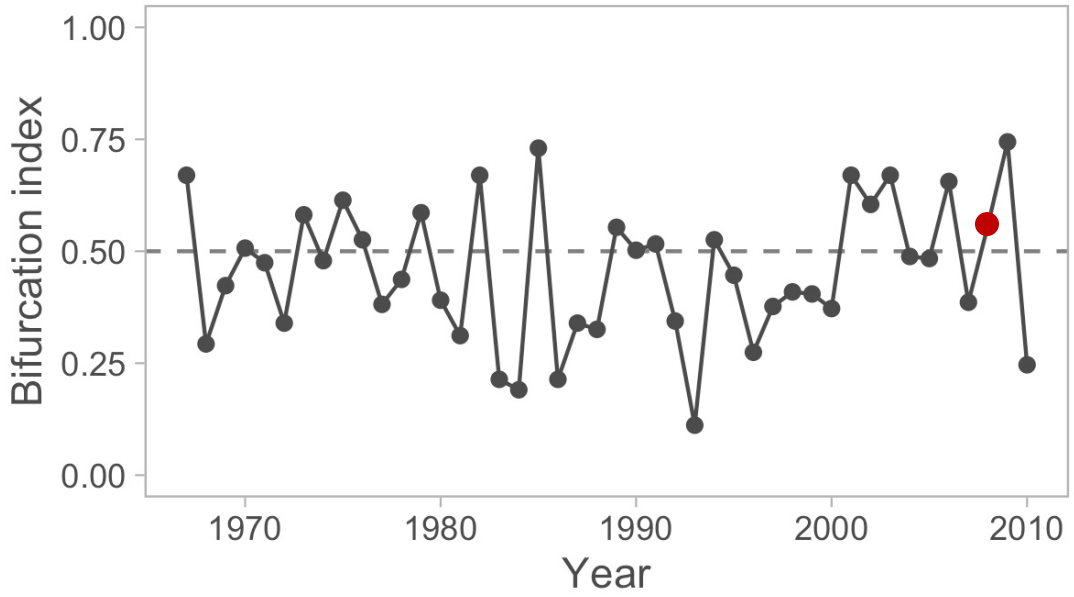
Malick et al. (2017) Fish Oceanogr

2008



Malick et al. (2017) Fish Oceanogr

2008



North

South

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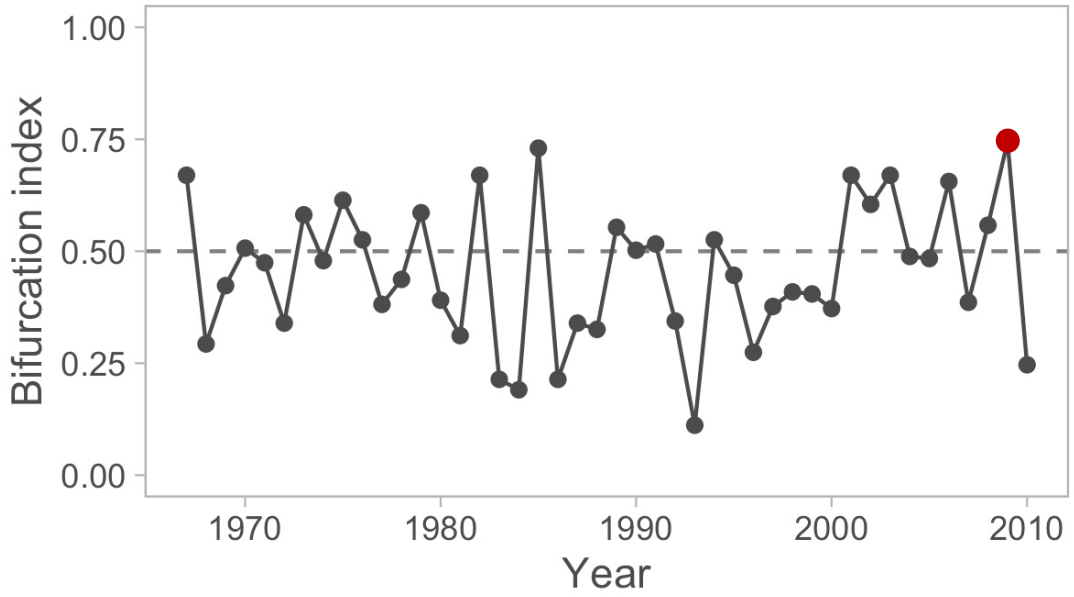
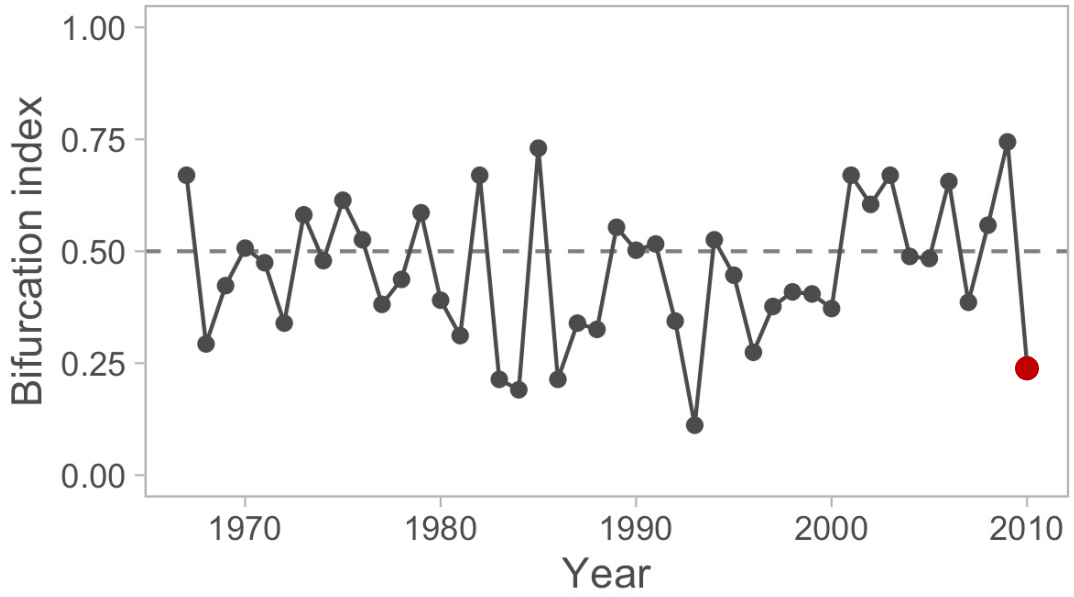
2009



Malick et al. (2017) Fish Oceanogr

2010



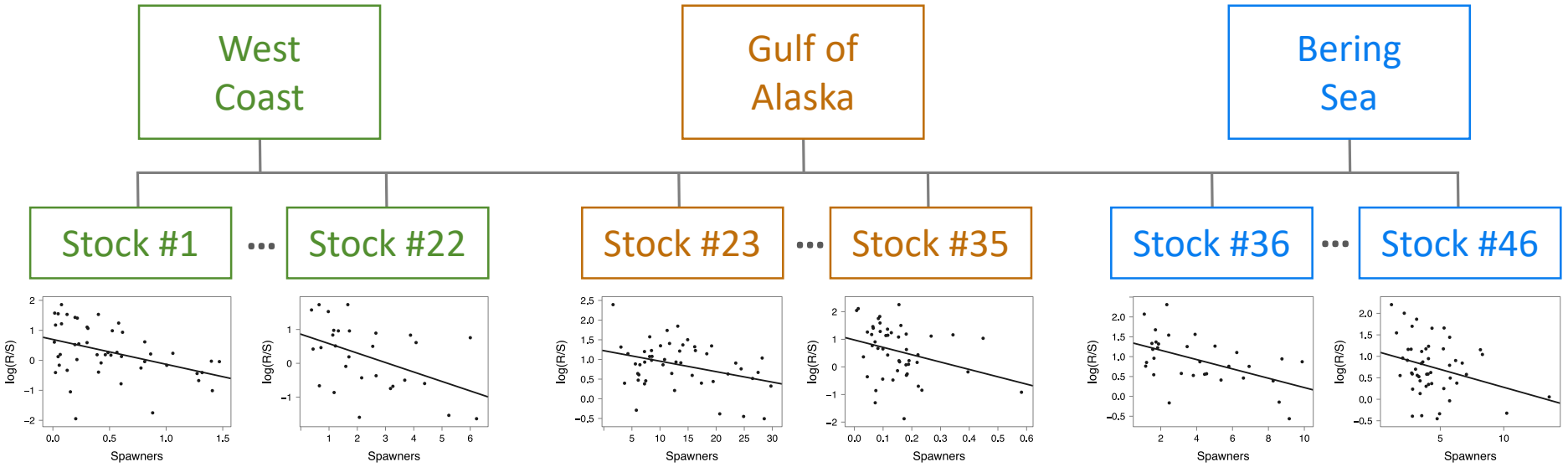
Malick et al. (2017) Fish Oceanogr

Bayesian hierarchical models

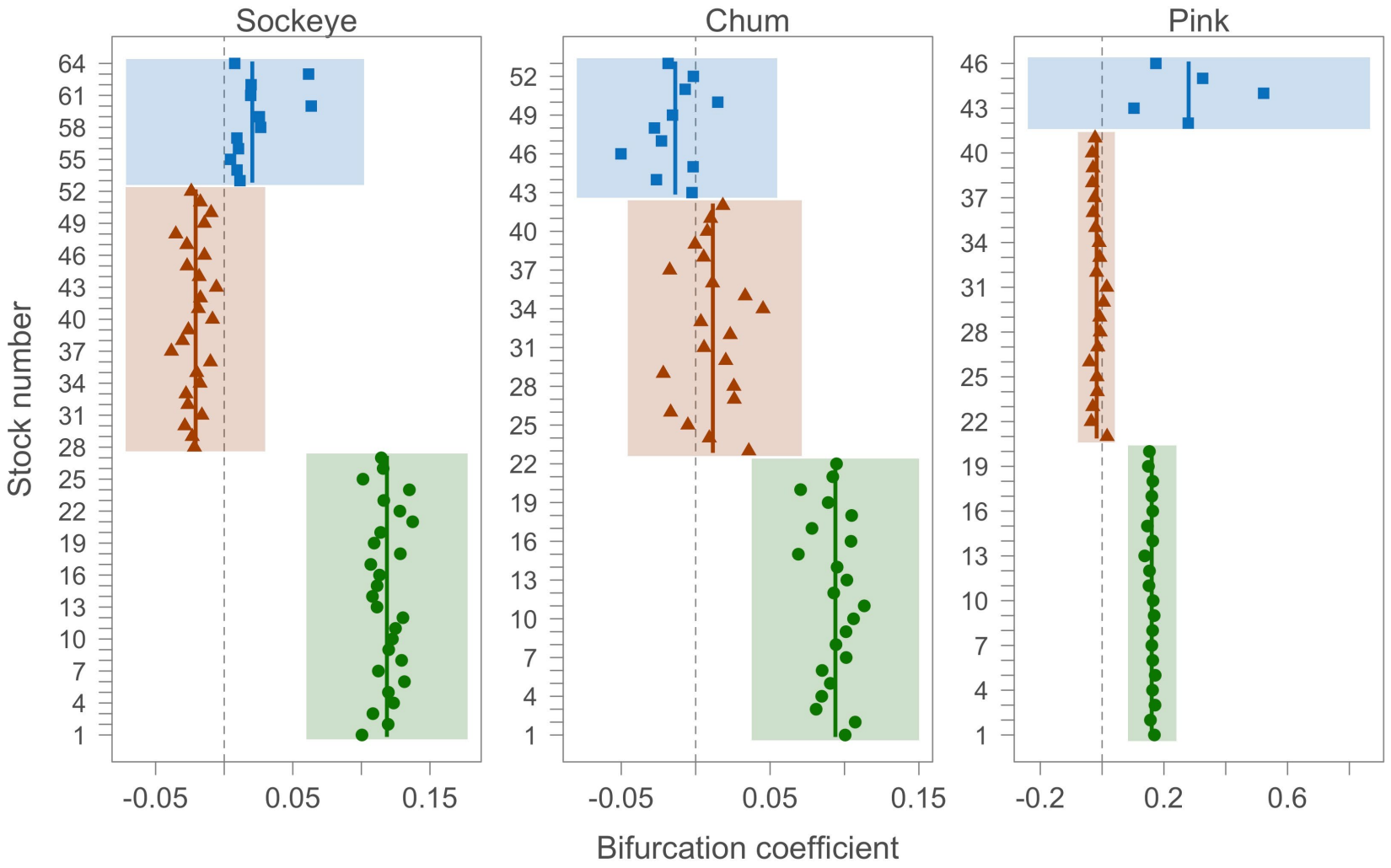
Productivity | Density dependence | Bifurcation covariate

$$\log\left(\frac{R_{i,t}}{S_{i,t}}\right) = \alpha_i + \beta_i S_{i,t} + \gamma_i X_{i,t} + \varepsilon_{i,t}$$

Intrinsic productivity | Bifurcation effect | Residual error

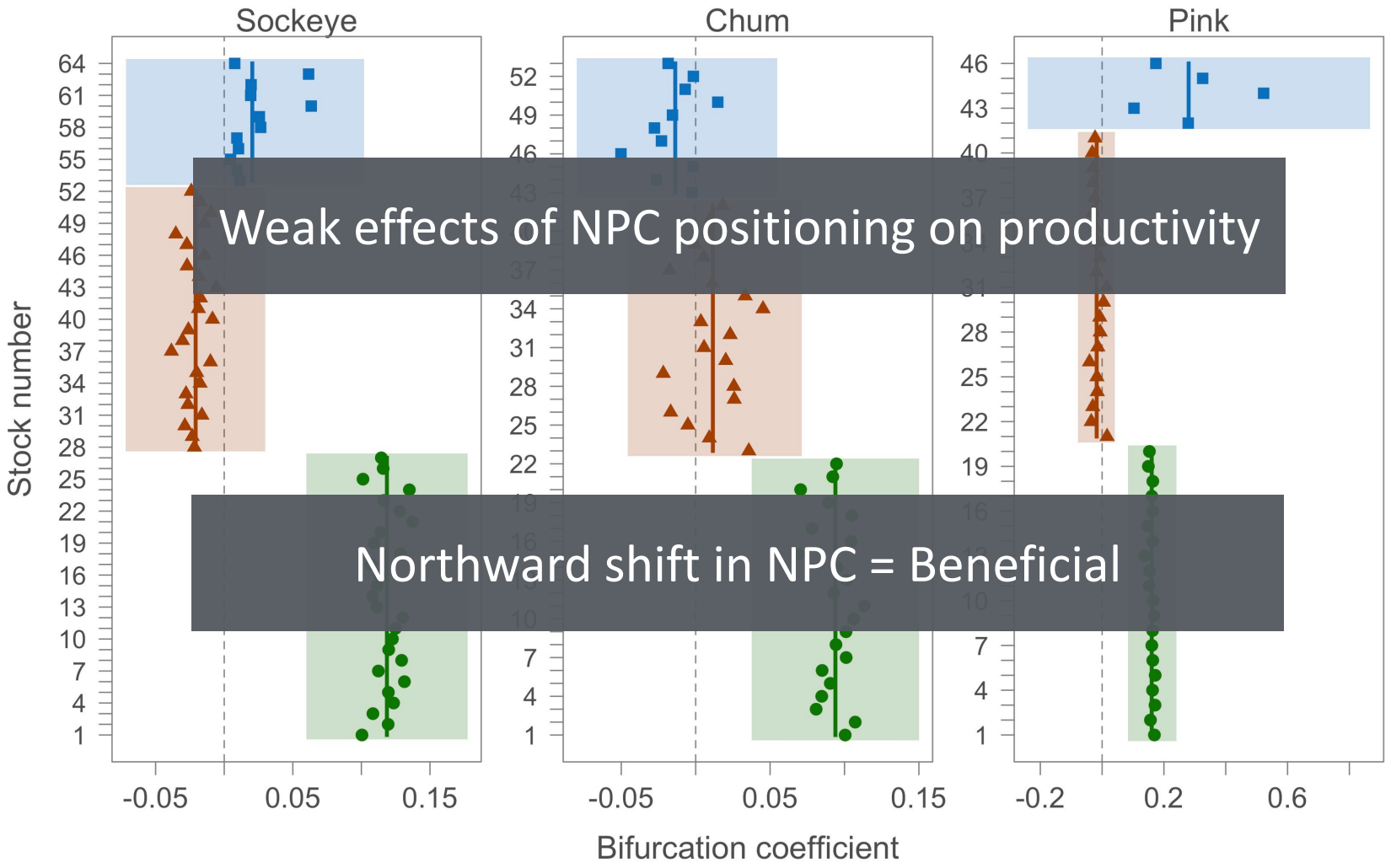


Malick et al. (2017) Fish Oceanogr



Malick et al. (2017) Fish Oceanogr





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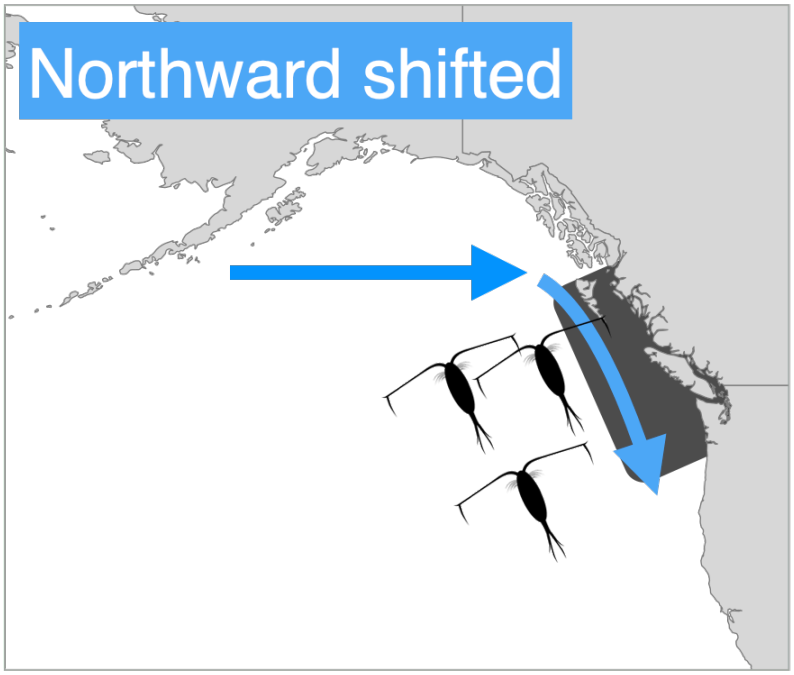
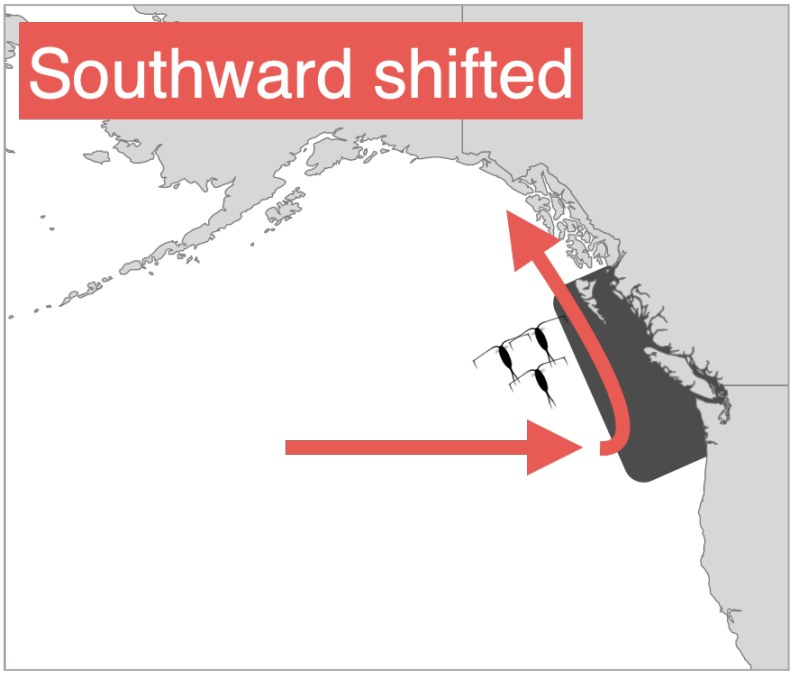
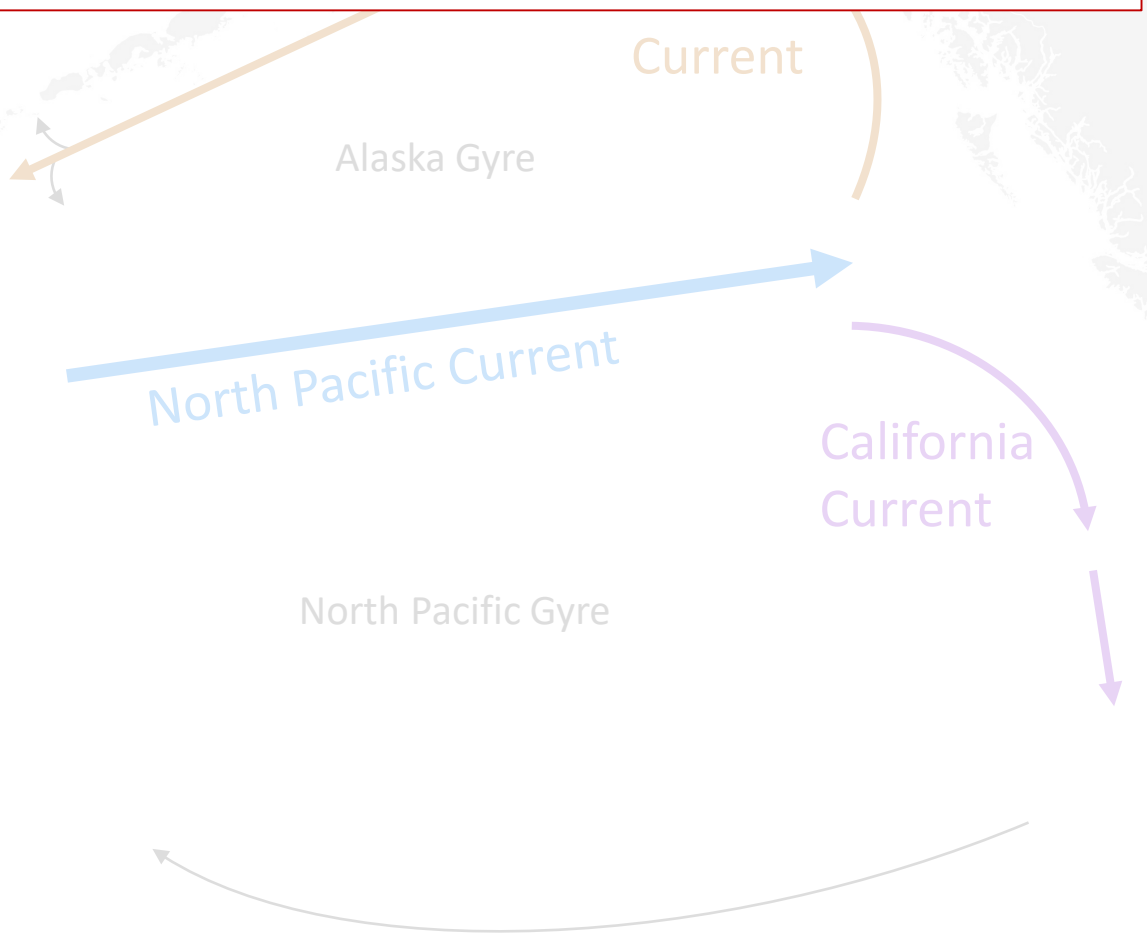
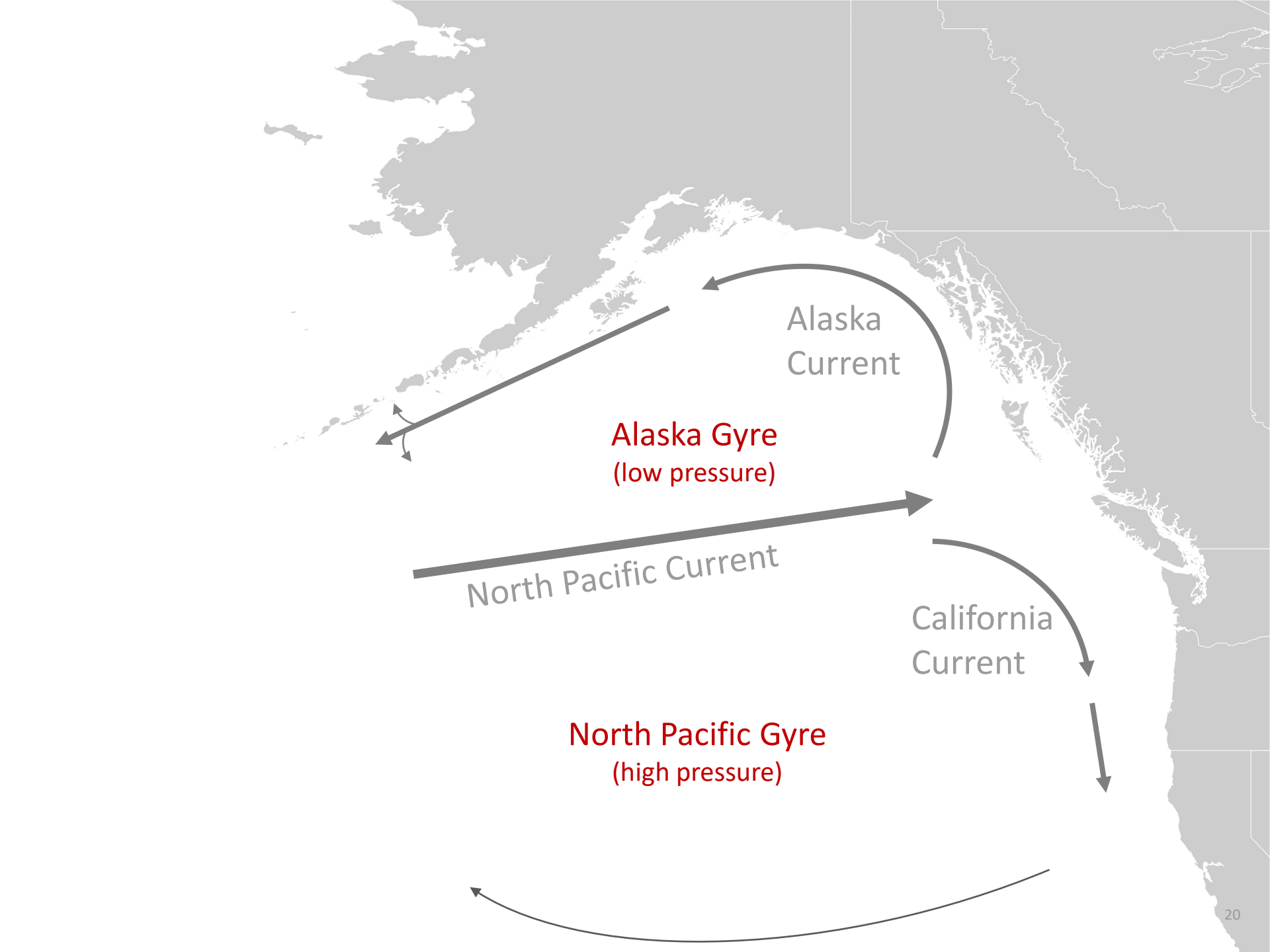
NPC bifurcation may impact quality of food resources in early marine period



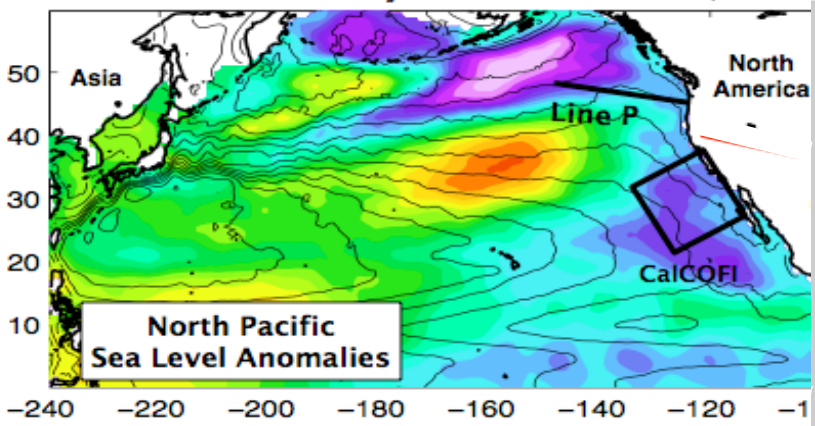


Does the intensity of the North Pacific Current impact salmon productivity?




Alaska
Current
Alaska Gyre
(low pressure)
North Pacific Current
California
Current
North Pacific Gyre
(high pressure)

NPGO



Di Lorenzo et al. 2008 GRL

Alaska Current

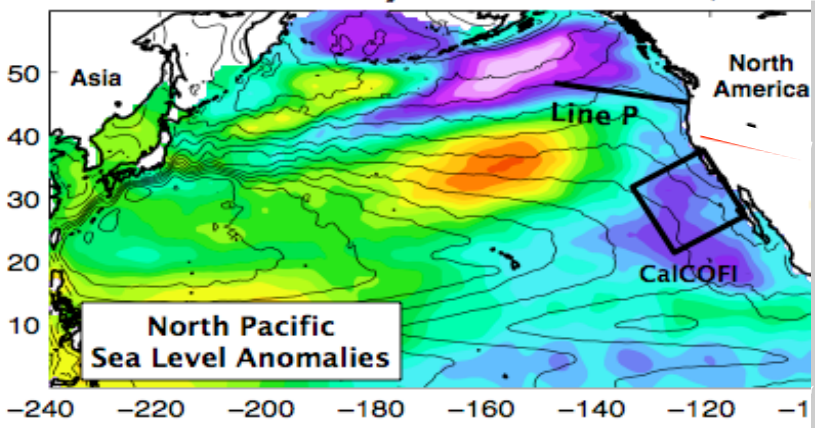
Alaska Gyre
(low pressure)

North Pacific Current

California Current

North Pacific Gyre
(high pressure)

NPGO



Di Lorenzo et al. 2008 GRL

Alaska Current

Alaska Gyre
(low pressure)

Quantifying a Novel Climate Through Changes in PDO-Climate and PDO-Salmon Relationships

Michael A. Litzow[1], Michael J. Malick[2], Nicholas A. Bond[3], Curry J. Cunningham[4], Jennifer L. Gosselin[5], and Eric J. Ward[2]

North Pacific Current

The changing physical and ecological meanings of North Pacific Ocean climate indices

Michael A. Litzow[a,1], Mary E. Hunsicker[b], Nicholas A. Bond[c], Brian J. Burke[d], Curry J. Cunningham[e], Jennifer L. Gosselin[f], Emily L. Norton[c], Eric J. Ward[d], and Stephani G. Zador[g]

California Current

North Pacific Gyre
(high pressure)

Non-stationary climate–salmon relationships in the Gulf of Alaska

Michael A. Litzow[1,2], Lorenzo Ciannelli[3], Patricia Puerta[3], Justin J. Wettstein[3,4,5], Ryan R. Rykaczewski[6] and Michael Opiekun[6]

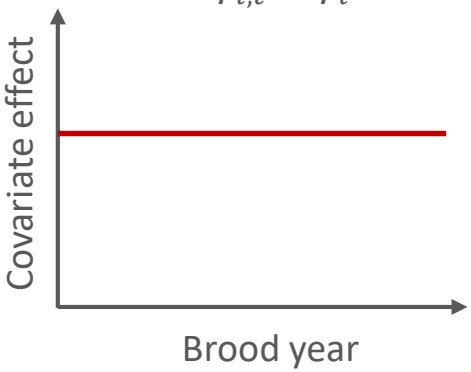
Time-varying hierarchical models

$$\log\left(\frac{R_{i,t}}{S_{i,t}}\right) = \alpha_i + \beta_i S_{i,t} + \gamma_{i,t} X_{i,t} + \varepsilon_{i,t}$$

- $\log\left(\frac{R_{i,t}}{S_{i,t}}\right)$: Productivity
- $\beta_i S_{i,t}$: Density dependence
- $\gamma_{i,t} X_{i,t}$: NPGO covariate
- α_i: Intrinsic productivity
- $\gamma_{i,t} X_{i,t}$: NPGO effect
- $\varepsilon_{i,t}$: Residual error

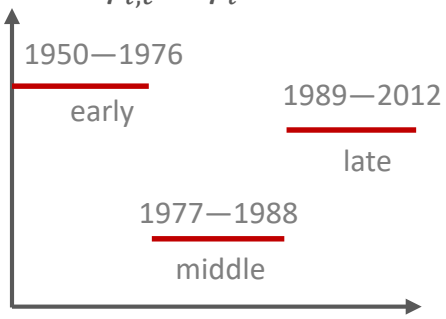
Constant model

$\gamma_{i,t} = \gamma_i$



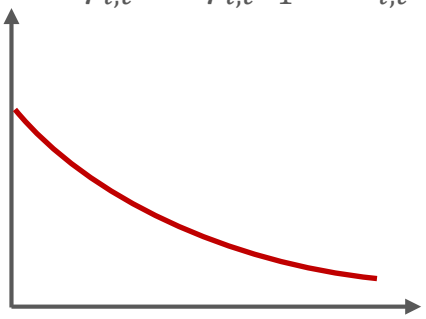
Era model

$\gamma_{i,t} = \gamma_i \cdot Era$



State-space model

$\gamma_{i,t} = \gamma_{i,t-1} + w_{i,t}$



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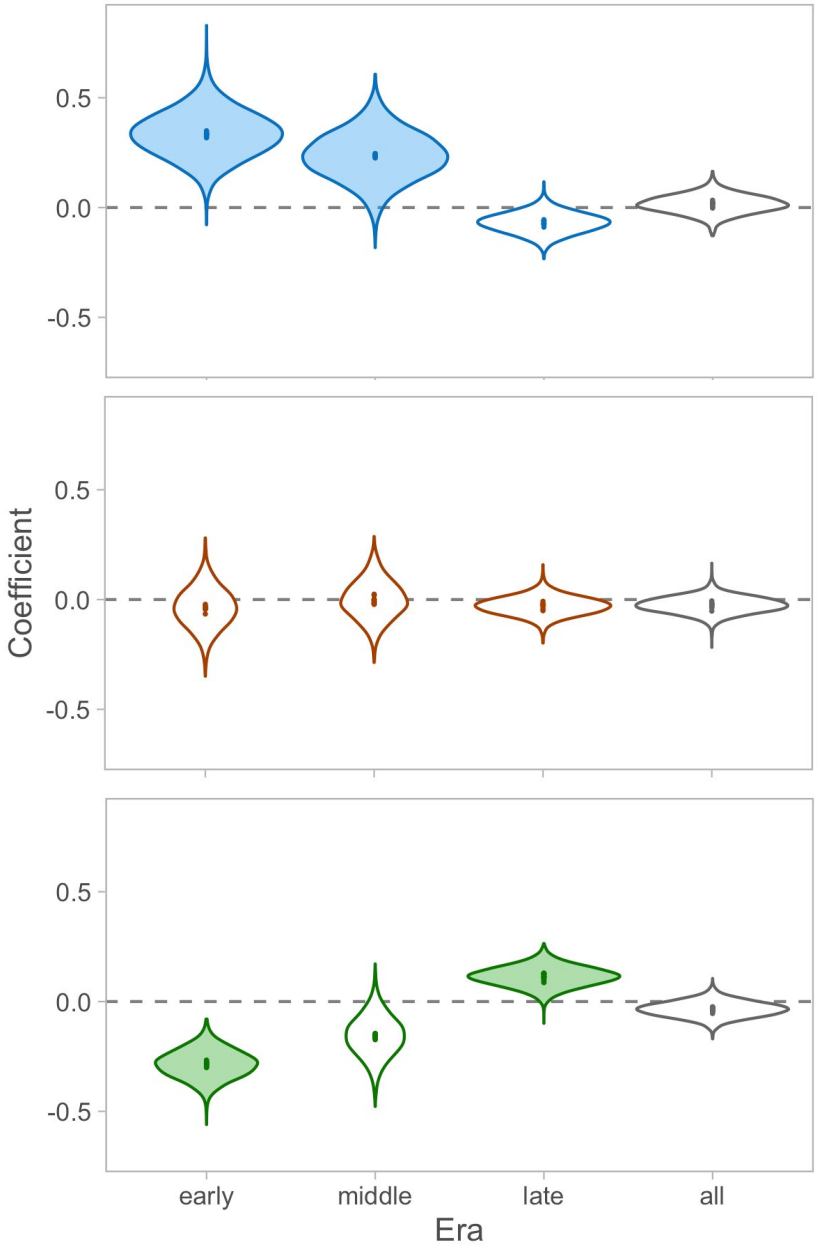
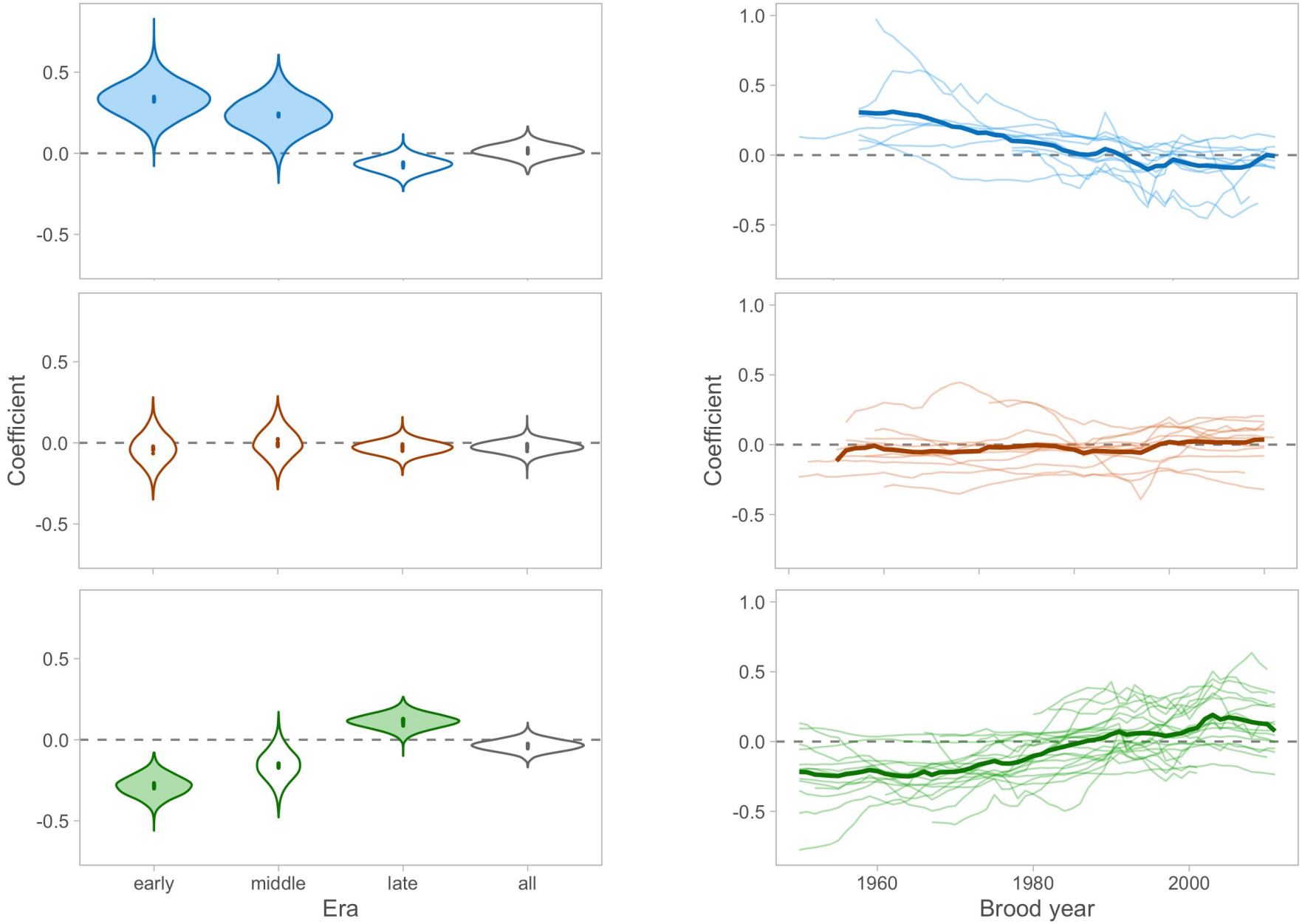
Era model



Malick (2020) Fish Oceanogr

Era model

State-space model



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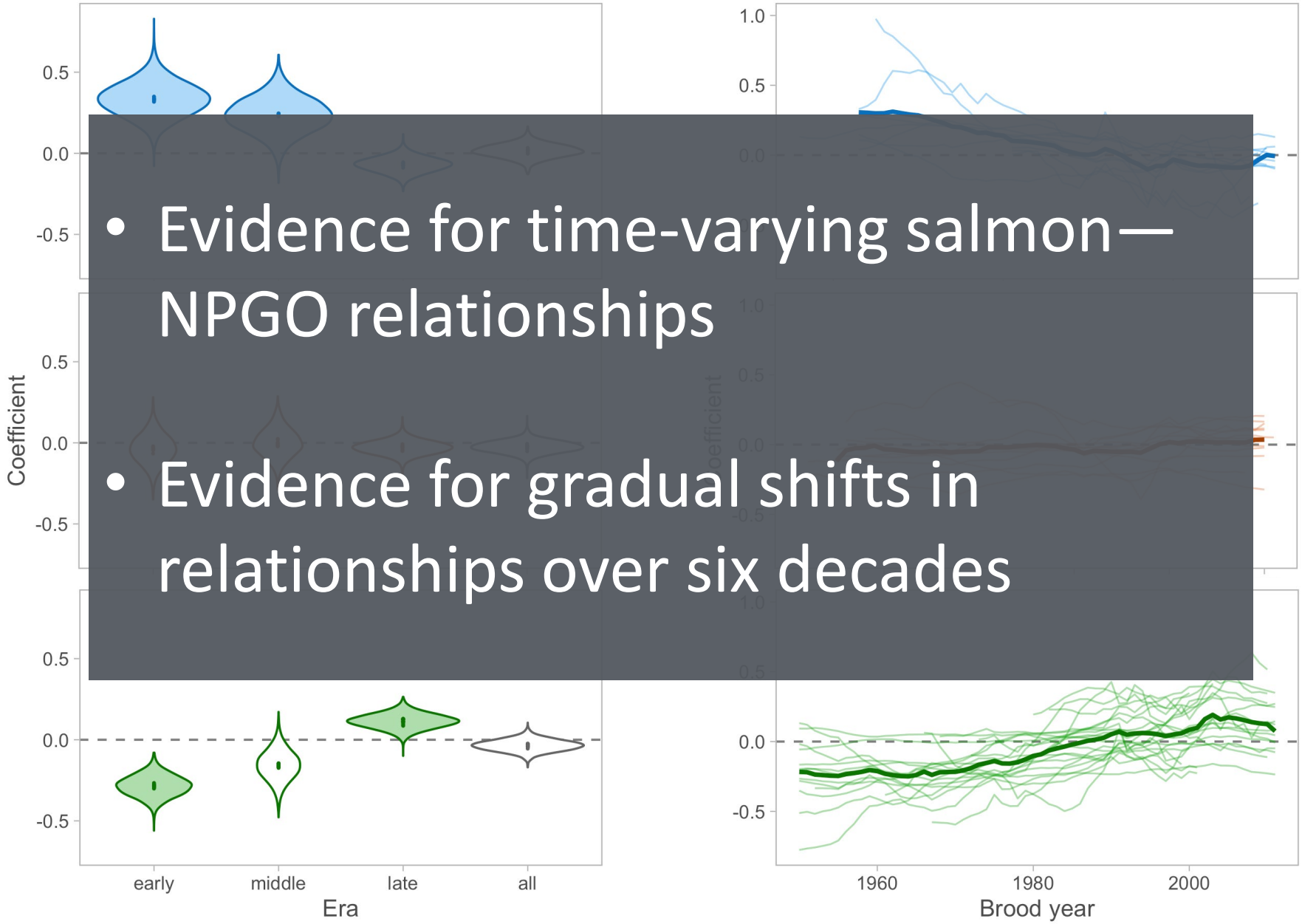
Era model

State-space model



- Evidence for time-varying salmon—NPGO relationships
- Evidence for gradual shifts in relationships over six decades

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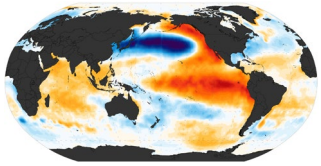
Mapping between basin scale ocean patterns and regional or local ocean processes is not temporally fixed

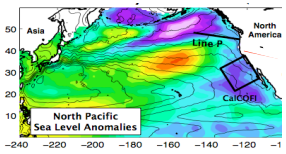
Aleutian Low variance declined in 1980's

Relative importance of PDO and NPGO shifted in 1980's

Regional-scale ocean processes indexed by PDO and NPGO shifted over time

Aleutian Low

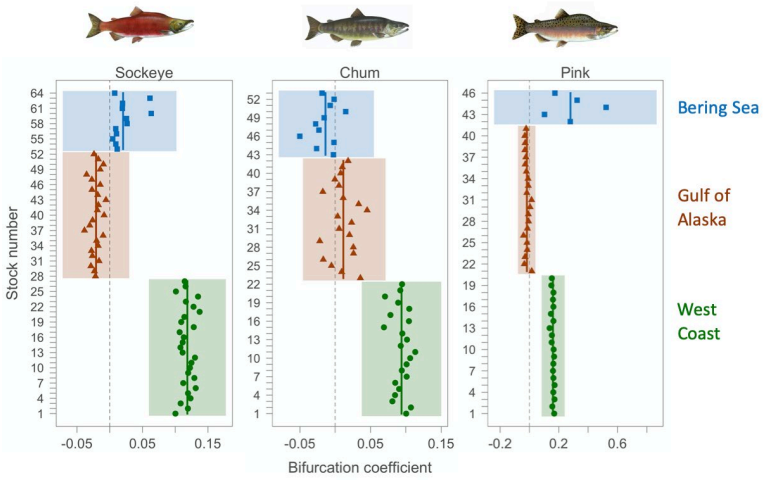




Temperature	Nutrients
Advection	Eddies
Wind mixing	Stratification

Horizontal ocean transport impacts salmon productivity, but the effects vary across space and time.

Bifurcation



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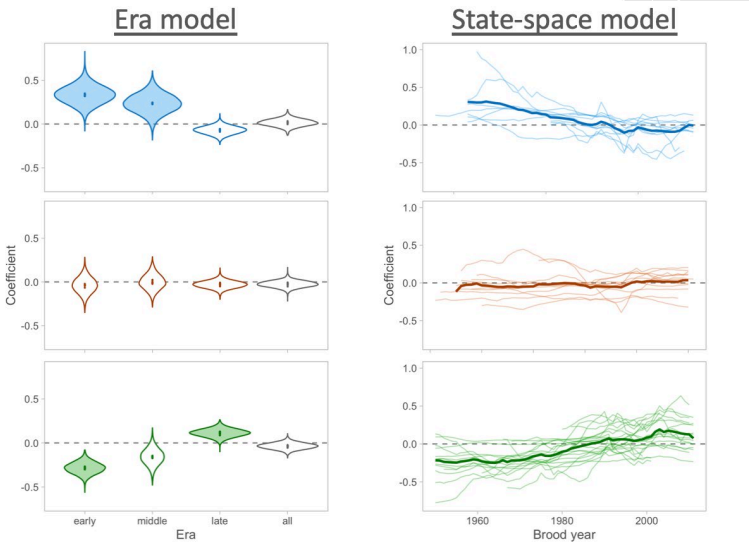
Intensity (NPGO)



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Acknowledgements

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Dr. Michael J. Malick

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Effects of the North Pacific Current on the productivity of 163 Pacific salmon stocks

MICHAEL J. MALICK,[1]* SEAN P. COX,[1]
FRANZ J. MUETER,[2] BRIGITTE DORNER[3]
AND RANDALL M. PETERMAN[1]

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ORIGINAL ARTICLE

FISHERIES OCEANOGRAPHY WILEY

Time-varying relationships between ocean conditions and sockeye salmon productivity

Michael J. Malick

GitHub

bifurcation-index

Code to calculate bifurcation index presented in Malick et al. (2017)

R Updated on Oct 22, 2020

https://github.com/michaelmalick/bifurcation-index