



Shifting Fish Stocks and Fishing Communities in the California Current Ecosystem

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NASEM Impacts on Shipping and Commercial, Tribal, and Recreational Fisheries from Development of Renewable Energy on the West Coast
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Introduction and Outline



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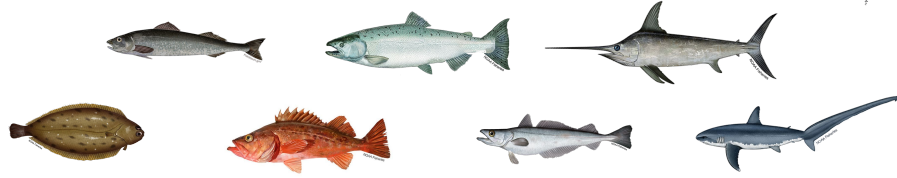
Where are fish shifting under climate change?

What might that mean for fishing-dependent communities?

What are some key remaining uncertainties and unknowns?

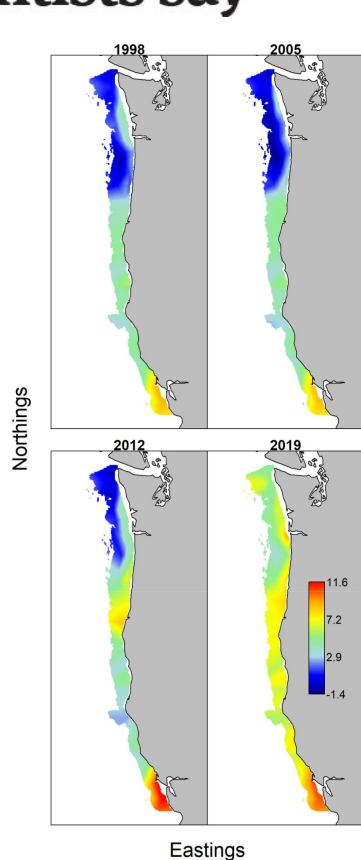
What are important considerations for renewable energy development?

Takehomes first



- Climate change is causing changes in the spatial distribution of fish and fisheries on the U.S. West Coast
- These changes are not spatially uniform, or the same for all species
- Assessing effects of these changes on fishers requires understanding how they will adapt; options include switching species and expanding fishing grounds
- Understanding of species responses to changing ocean conditions, and fisheries' responses to those changes, is still growing
- Decisions on renewable energy development will involve tradeoffs and imperfect information

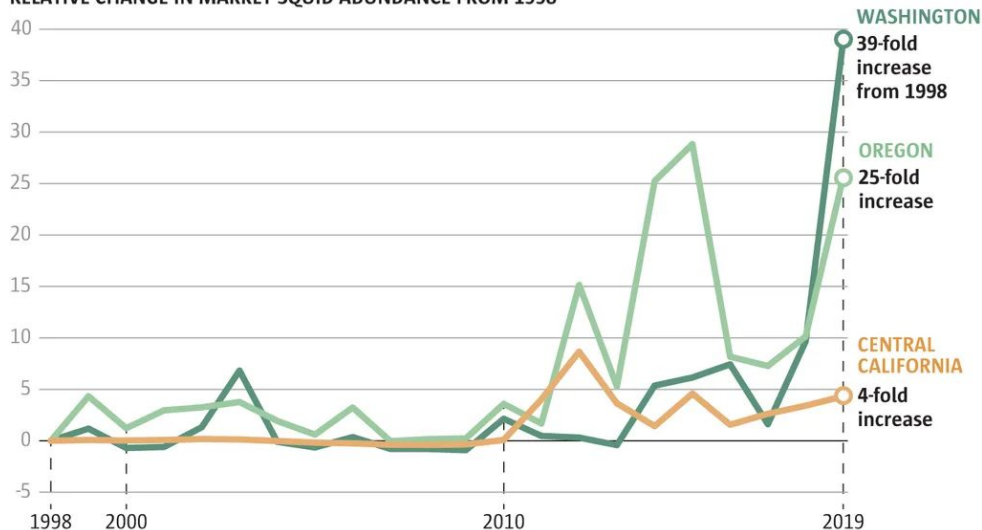
Ocean heat waves trigger 'squid bloom' along Pacific coast, scientists say



More market squid in Washington and Oregon

The index of abundance represents population density over time, and these models show an abrupt increase over a decade of market squid in Oregon and Washington.

RELATIVE CHANGE IN MARKET SQUID ABUNDANCE FROM 1998



Source: Chasco, Brandon E. et. al, "Evidence of Temperature-Driven Shifts in Market Squid *Doryteuthis opalescens* Densities and Distribution in the California Current Ecosystem," *Marine and Coastal Fisheries*.

EMILY M. ENG / THE SEATTLE TIMES

Chasco et al. 2022; Seattle Times, Feb. 3 2022

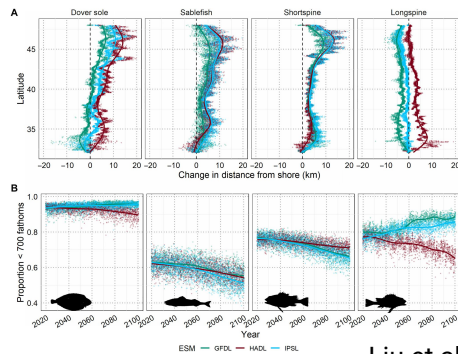
*“It started out with two of us, and now I believe we’ve got somewhere around ten or twelve of what I would call resident vessels that are participating...We’re all participating in it, and kind of getting our practice up if you will, and trying to learn this fishery. Like you said, sustaining has two levels: we’ve got the resource sustaining, and we’ve got the business models sustaining. I believe that it’s there. It’s just ...a little bit boom or bust. **You’re sometimes happy that you went into it. Other times, you’re happy that you also still have your bread and butter fisheries to continue to participate in.**”*

-Josh Whaley, commercial fisherman, *F/V Miss Emily*



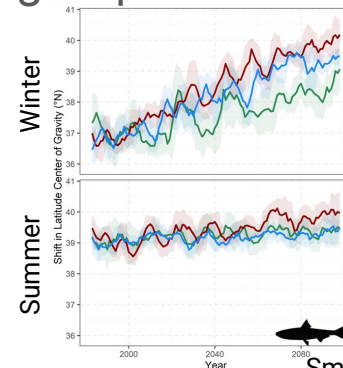
West coast species exhibit diverse responses to climate change

Groundfish



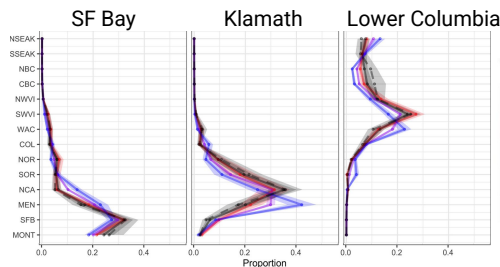
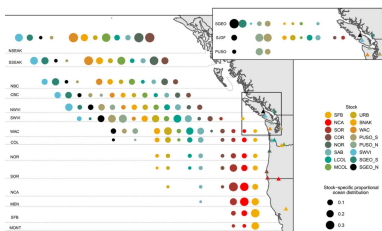
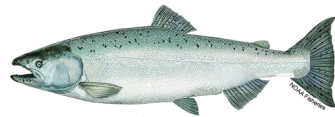
Liu et al. 2023

Coastal pelagic species



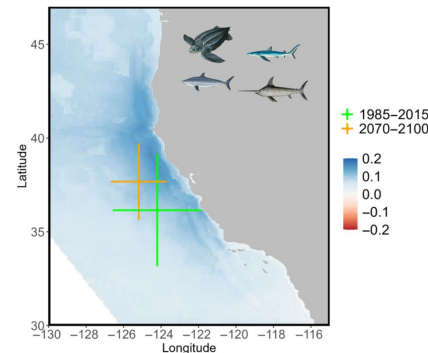
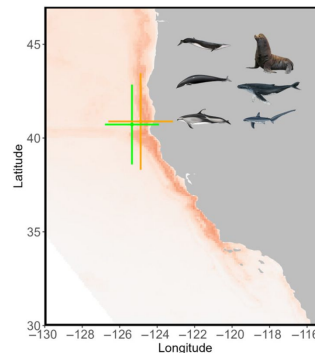
Smith et al. 2021

Salmon



Shelton et al. 2021

Highly migratory species

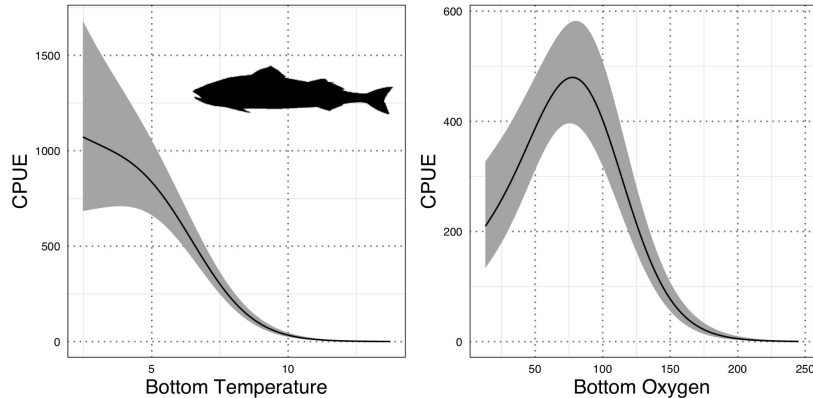


Lezama-Ochoa et al. 2023

Where are (ground)fish shifting?

We built species distribution models based on depth, temperature, and oxygen and then projected species distributions out to 2100 under multiple alternative climate model scenarios

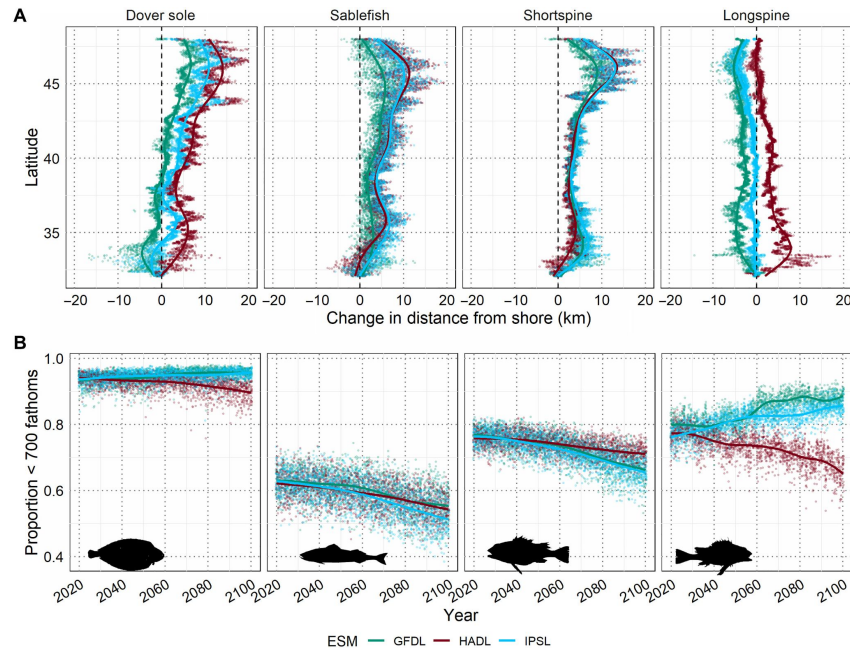
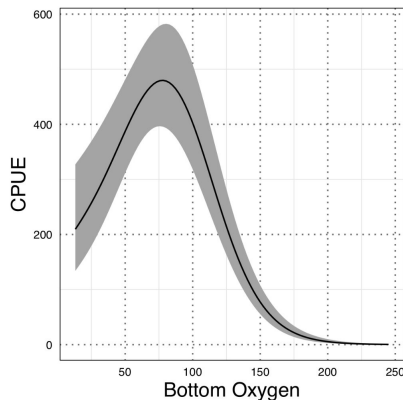
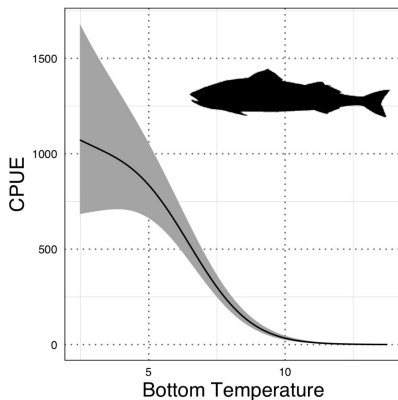
Key groundfish species projected to move **offshore** and **deeper**



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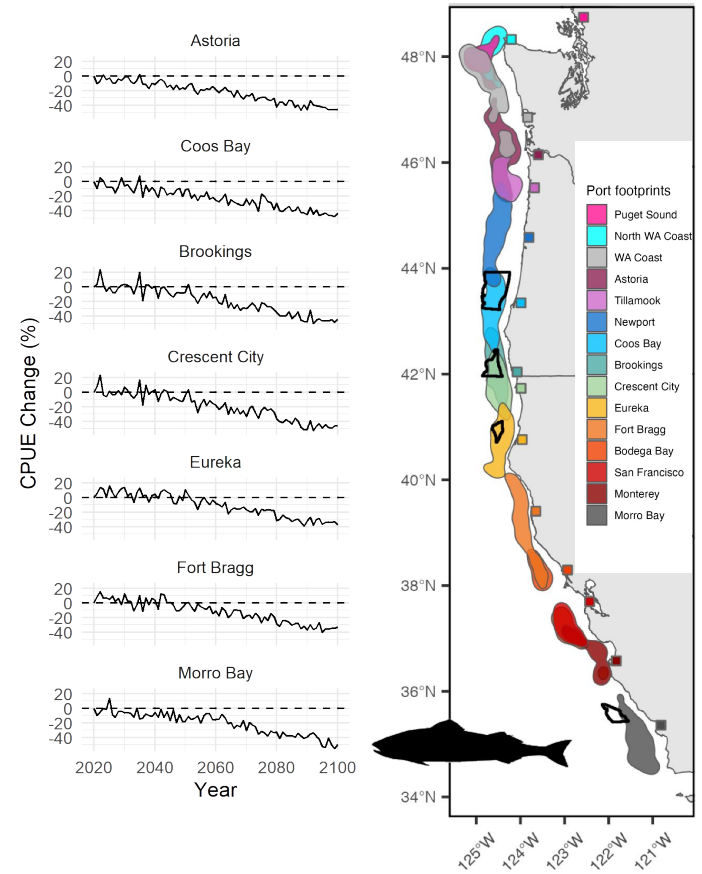
Key groundfish species projected to move **offshore** and **deeper**



Implications of distribution shifts

Used current-day “fishing footprints” to project changes in availability

Offshore shifts may lead to a decline in availability, and potentially changing overlap with offshore energy areas



How might fishers adapt to shifting stocks?

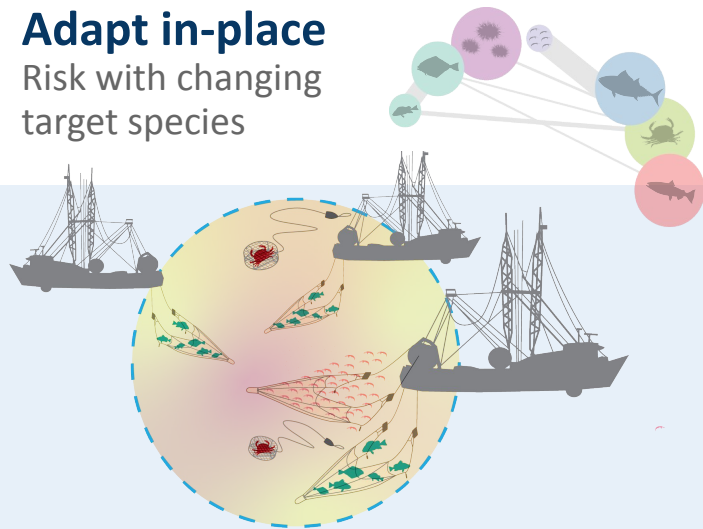
Samhuri et al. 2024 *PLoS Climate*

How might fishers adapt to shifting stocks?

Samhuri et al. 2024 *PLoS Climate*

Adapt in-place

Risk with changing target species



Exposure: Thermal change within fishing grounds



Vulnerability/Sensitivity: Economic dependence



Vulnerability/Adaptive capacity: Fisheries diversification

Adapt on-the-move

Risk with shifting fishing grounds



Exposure: Thermal displacement of fishing grounds



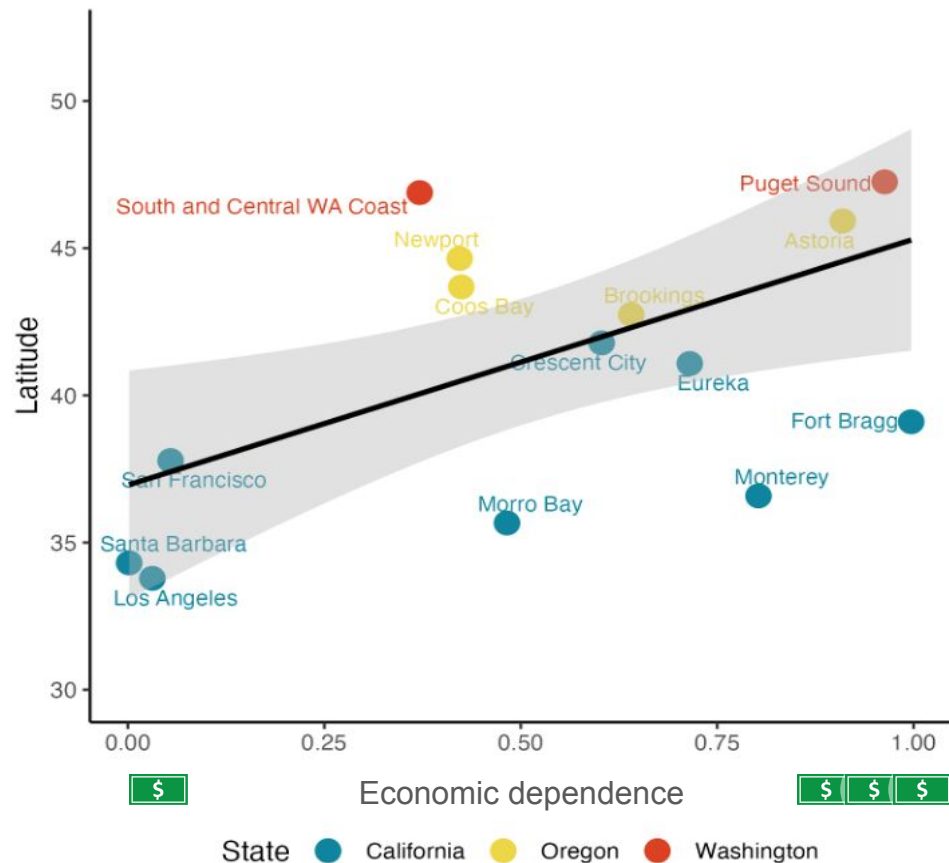
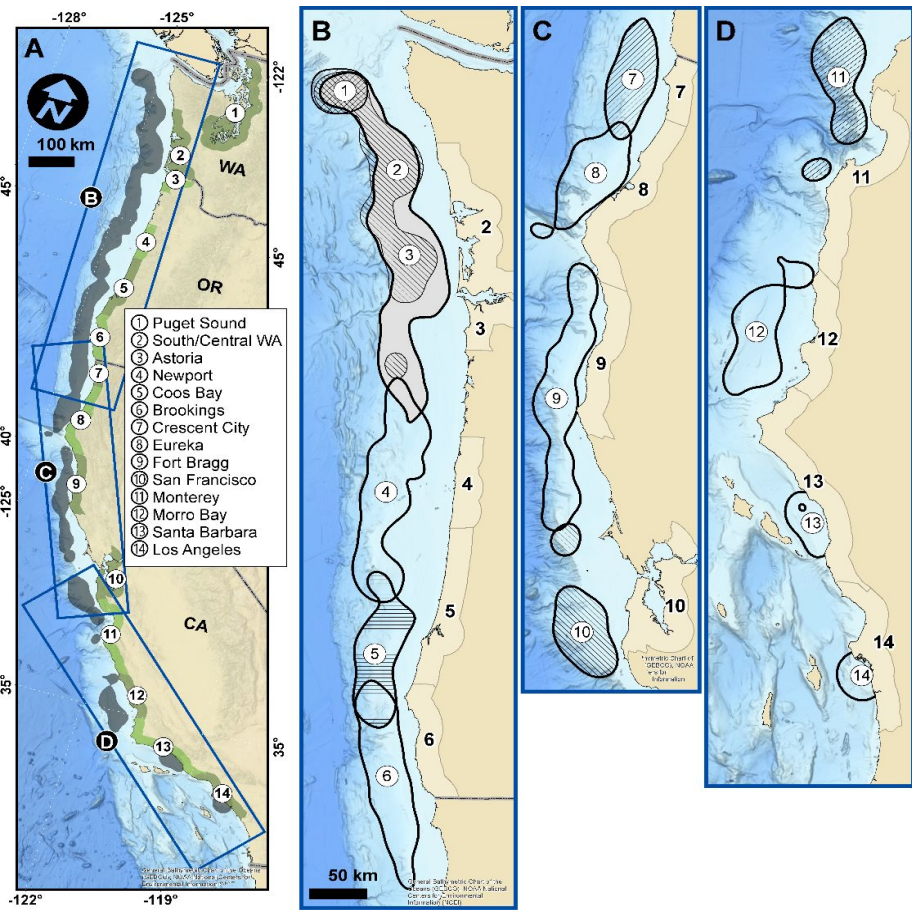
Vulnerability/Sensitivity: Economic dependence



Vulnerability/Adaptive capacity: Fleet mobility

More northern ports are more exposed to climate change and more dependent on groundfish

Samhuri et al. 2024 *PLoS Climate*

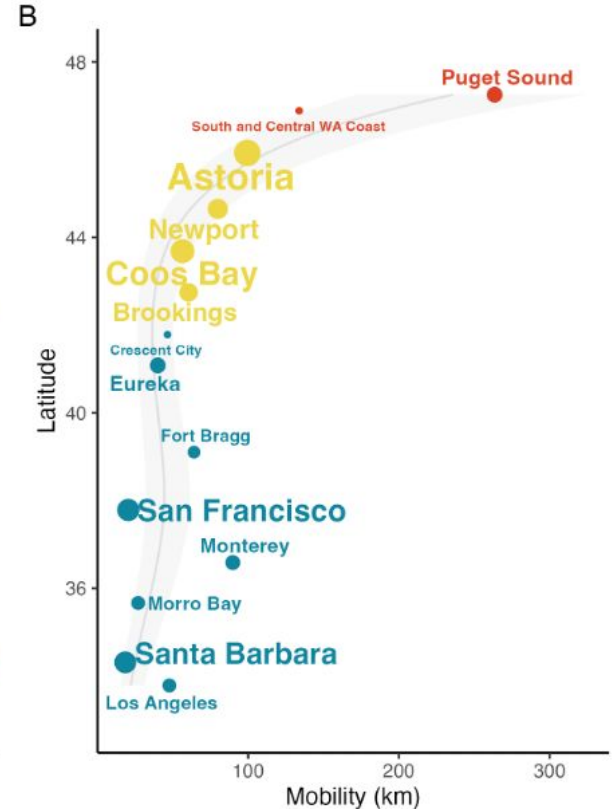


Higher mobility will dampen risk due to climate change for more northern groundfish ports if they adapt-on-the-move

- *But risk is still higher for more northern ports than more southern ports*

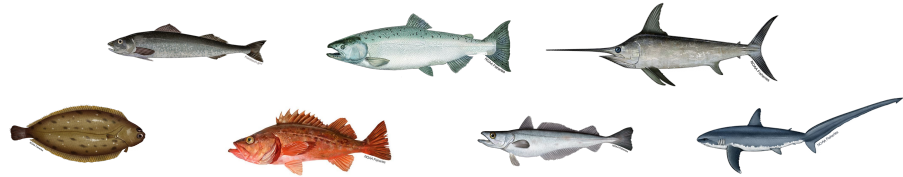


Samhuri et al. 2024 *PLoS Climate*



Uncertainty and unknowns

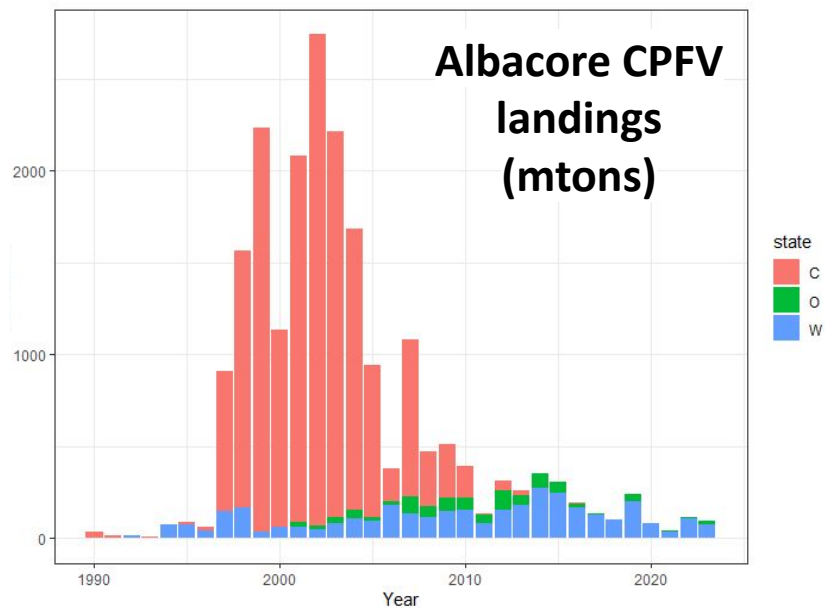
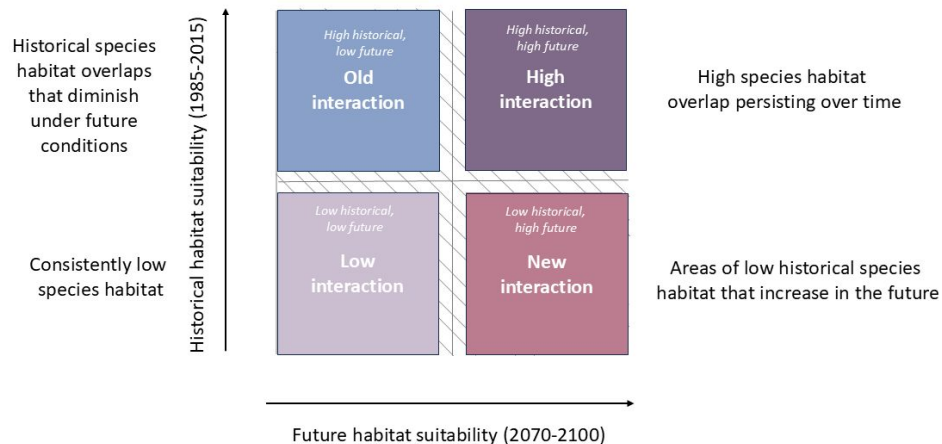
1. Changing ecological interactions as a result of distribution shifts
2. Multispecies redistribution will influence fisheries adaptation, including via changes in fishing portfolios
3. Variable impacts across the fleet of shifting stocks
4. Constraints on the speed and extent of feasible adaptation



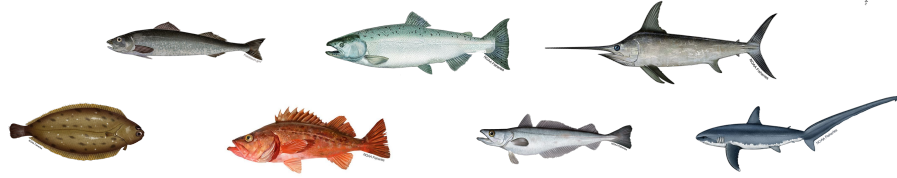
The way fish and fisheries respond to shifting stocks will affect interactions with renewable energy development

Species are on the move, energy development is committed to place

Enhanced flexibility helps fishers adapt to shifting stocks, absent constraints



Takehomes



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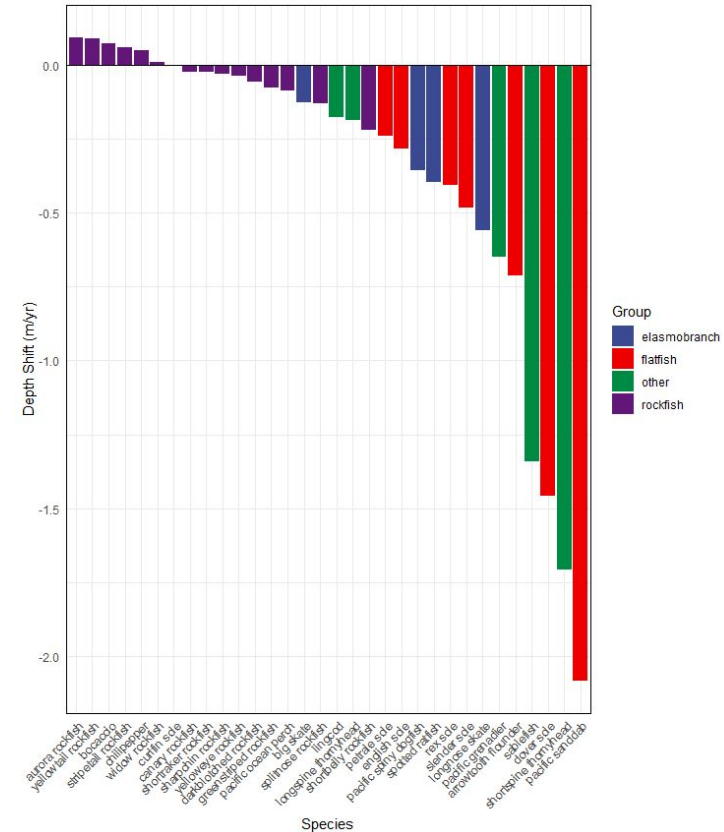
References

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Extra Slides

Where are (ground)fish shifting?

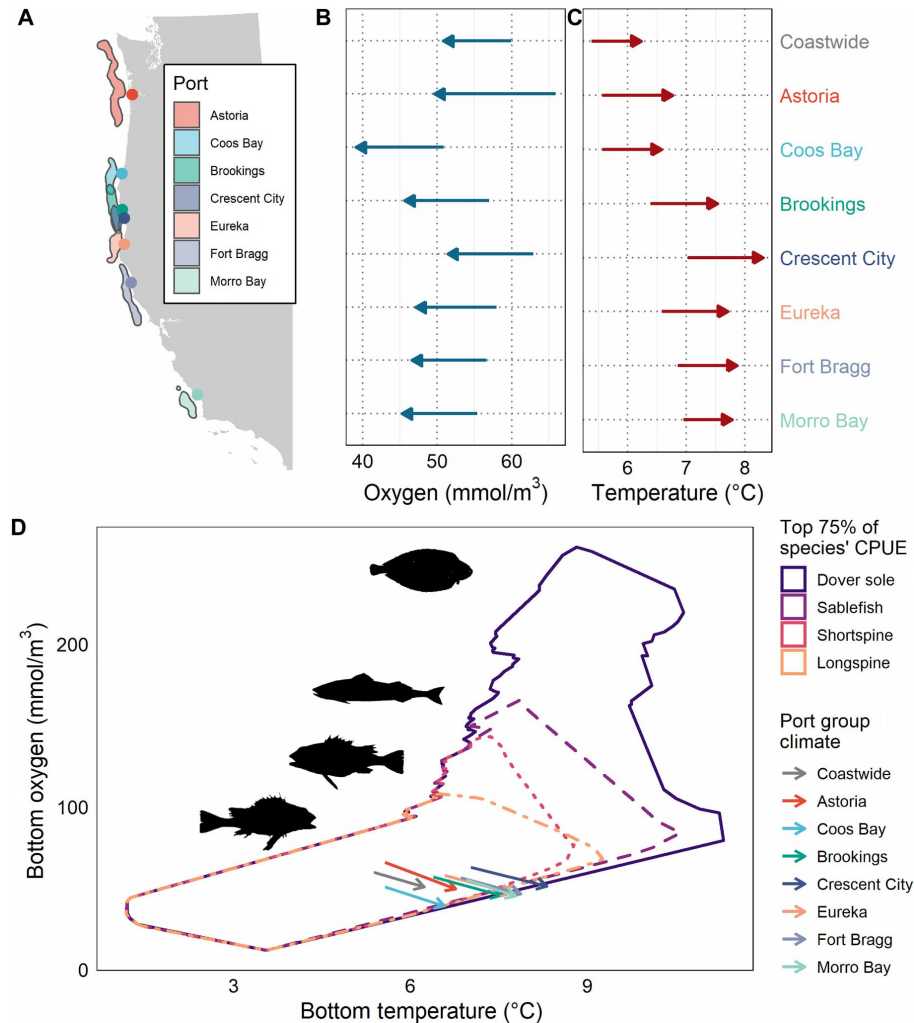
Groundfish could shift their average distributions deeper by up to ~2m/yr, including sablefish (black cod)



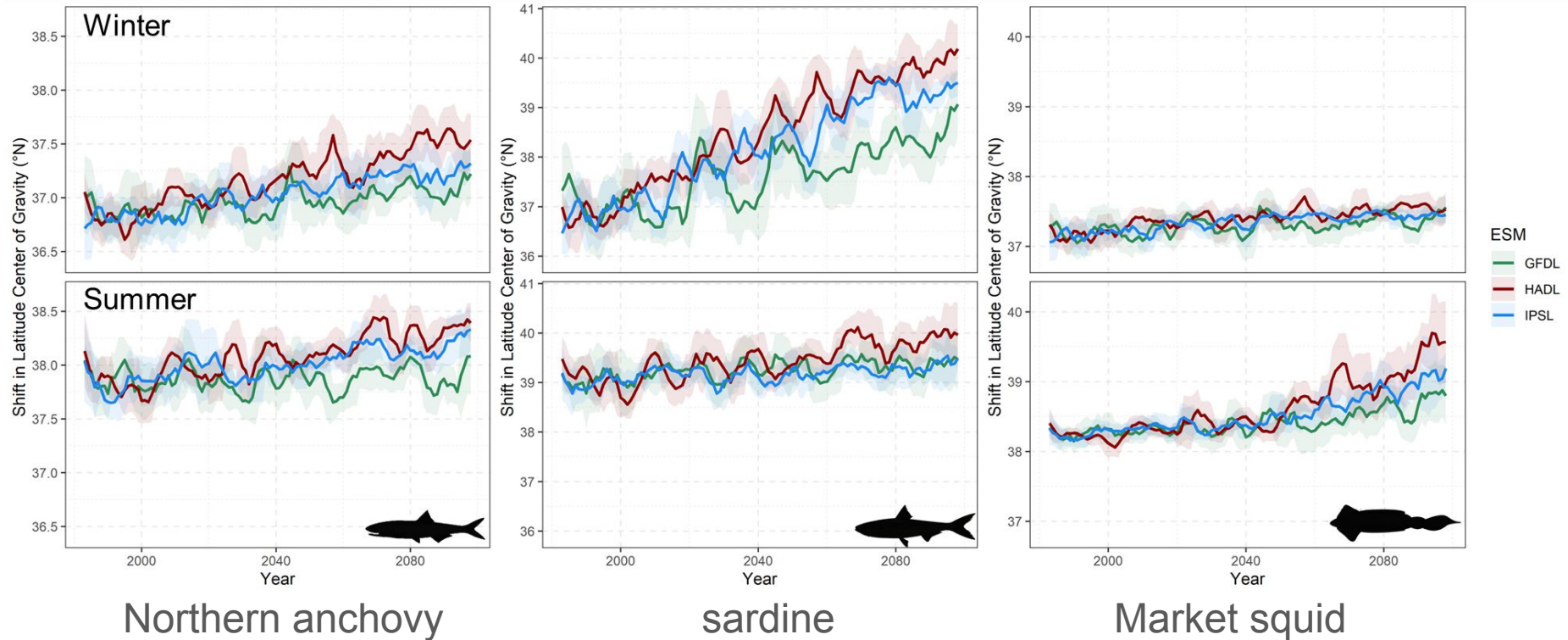
What do these shifts mean for fishers?

Used current-day “fishing footprints” to project changes in availability

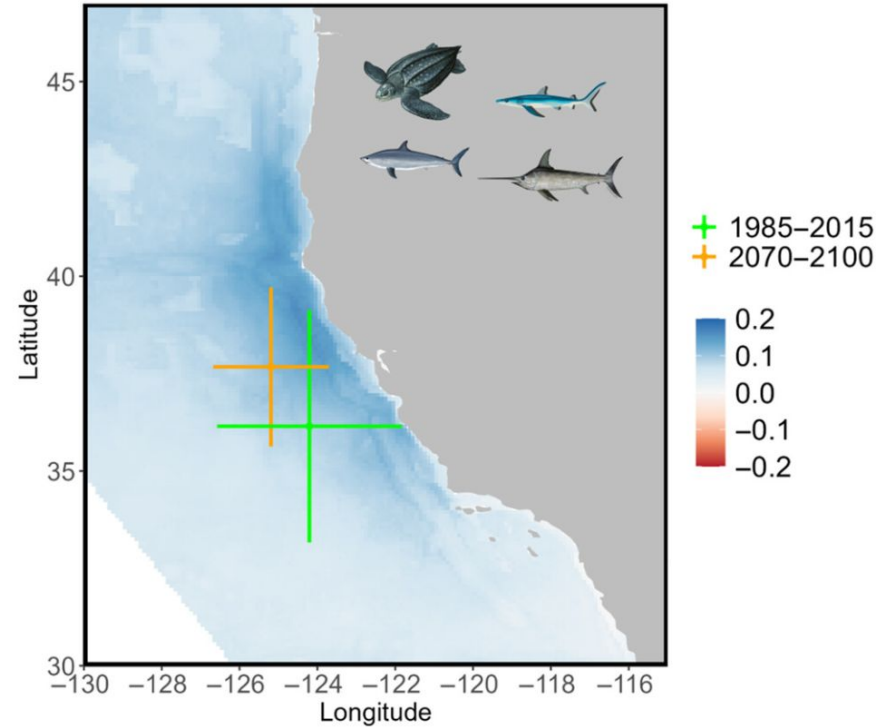
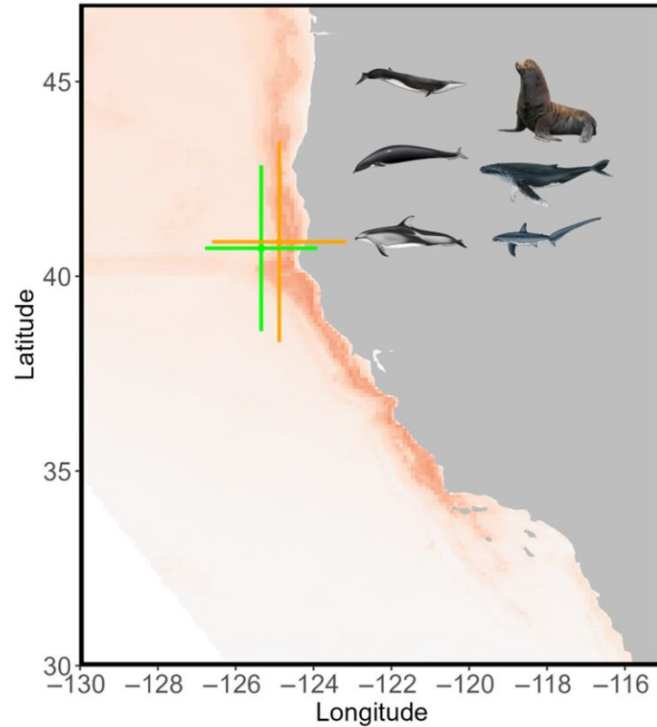
Sablefish (most valuable groundfish) expected to decline within current-day fishing footprints



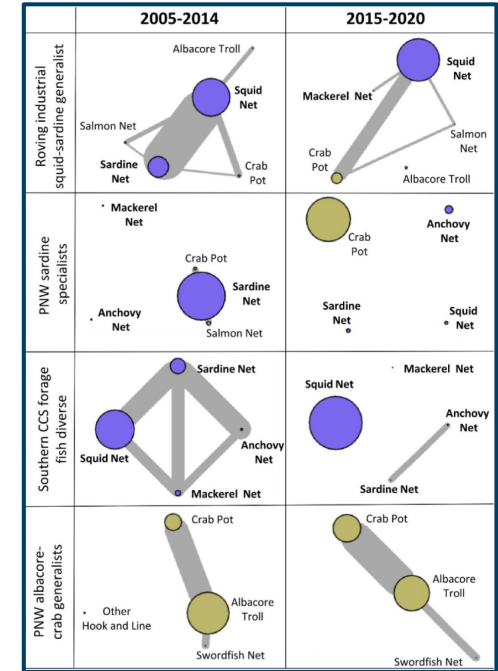
Coastal pelagic species- shifting north



Highly migratory species- divergent outcomes



Adaptation through portfolio switching

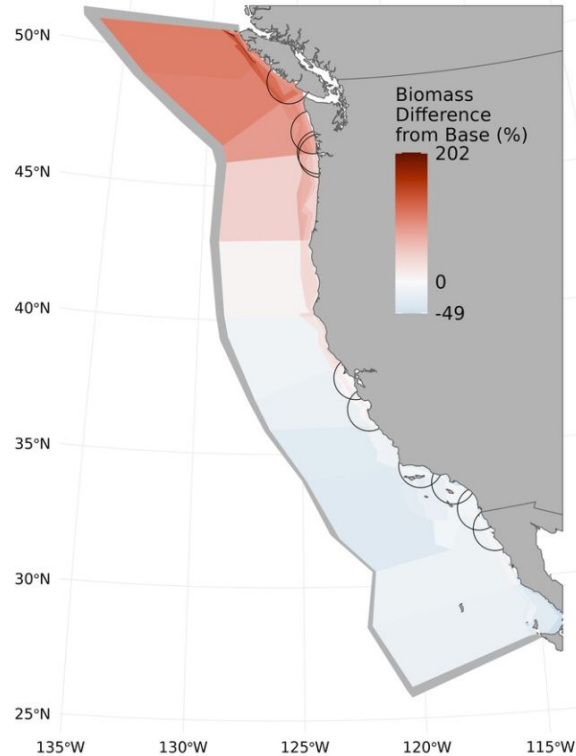


Participation networks for some CPS-associated fleets, before and after sardine closure. Quezada et al. 2023

Exploring multispecies outcomes- Atlantis

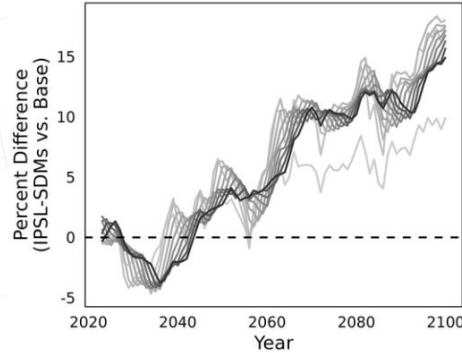


a



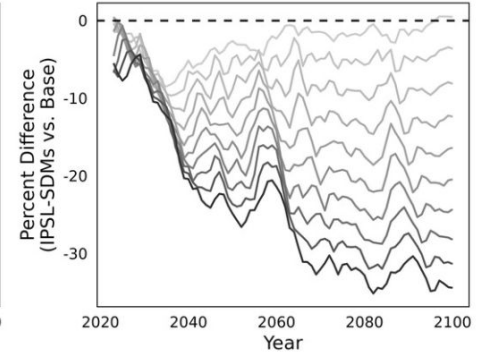
b

Weights at age



c

Abundance at age

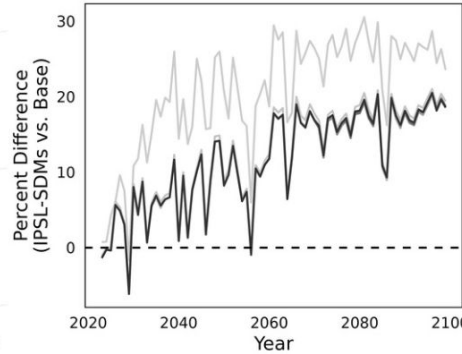


Age Class

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- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10

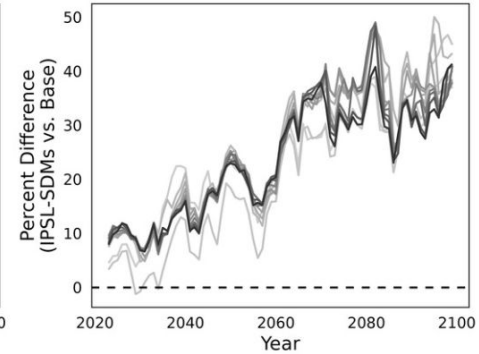
d

Fishing mortality

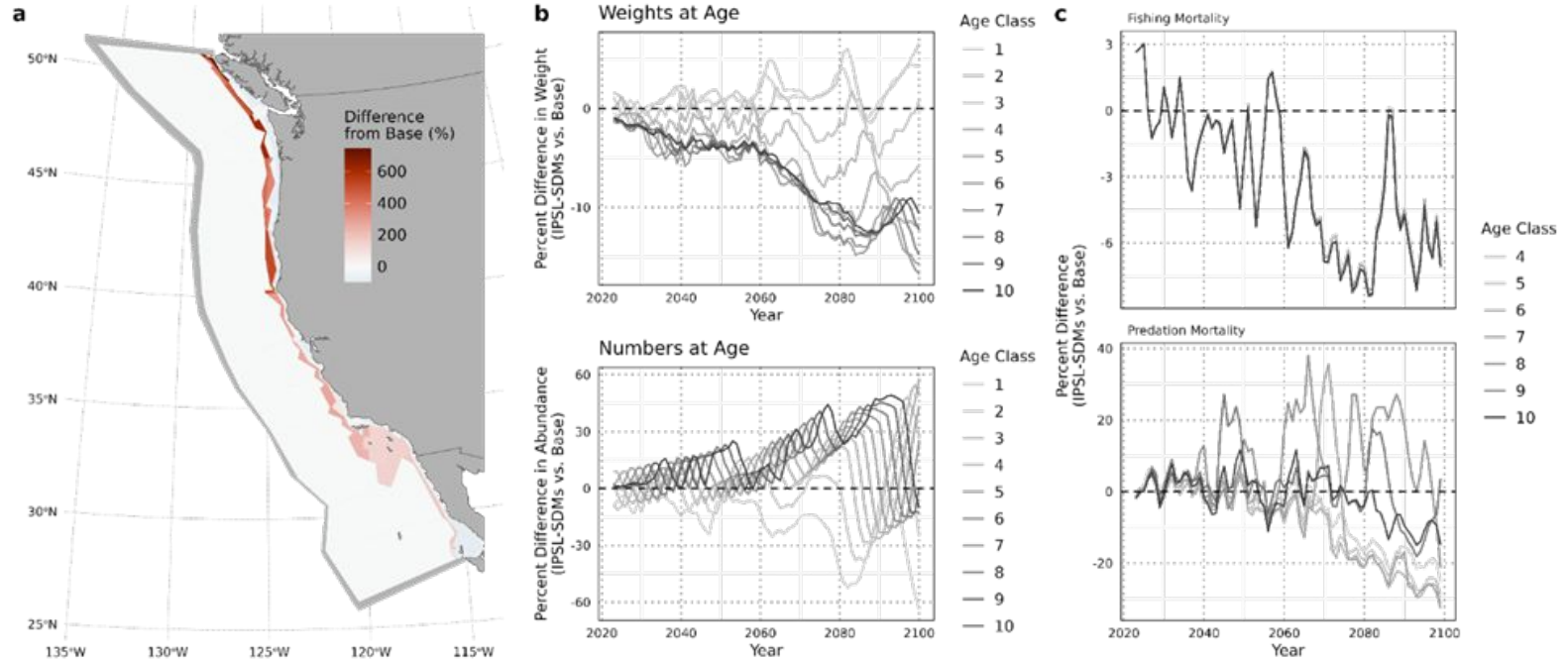


e

Predation mortality



Exploring multispecies outcomes- Atlantis



Exploring multispecies outcomes- Atlantis

