The importance of community interactions for predicting climate change impacts

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University of East Anglia

West Coast Vancouver Island Aquatic Management Board

Trilogy of papers

How will climate change impact marine ecosystems in the NE Pacific?

Ainsworth et al.

- What are the combined effects of multiple climate factors on the ecosystem?

Samhouri et al.

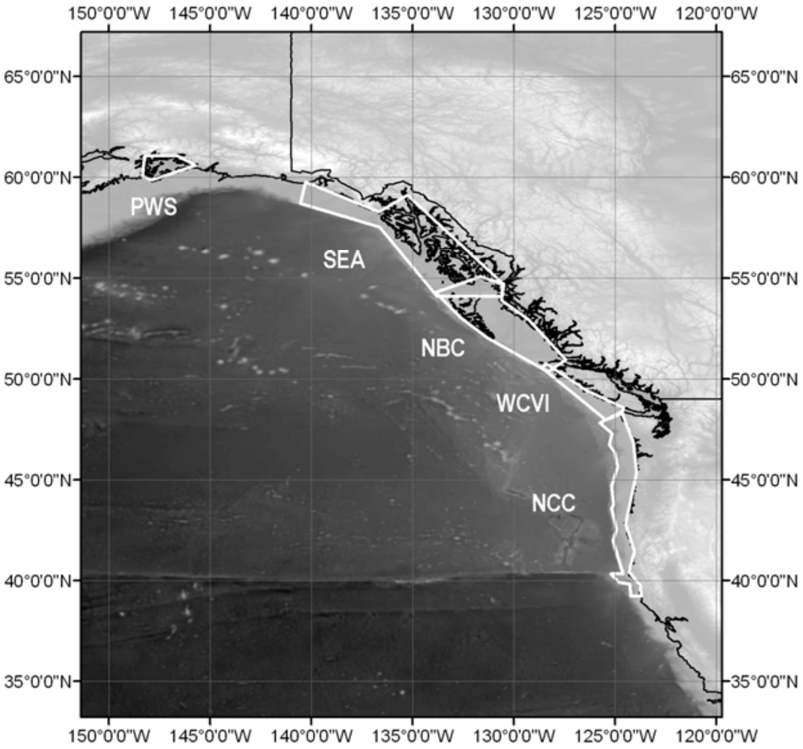
- Do trophic interactions change our predictions?

Busch et al.

- Could model uncertainties and combinatorial assumptions change the bottom line?

NE Pacific study area

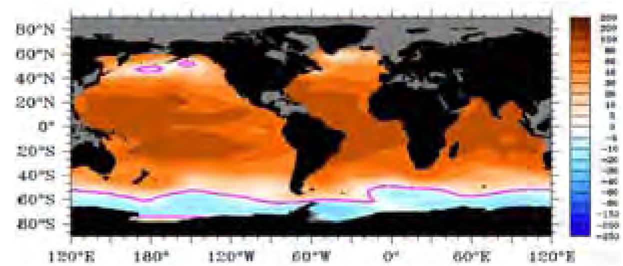
- Prince William Sound (PWS)
- Southeast Alaska (SEA)
- Northern British Columbia (NBC)
- West Coast Vancouver Island (WCVI)
- Northern California Current (NCC)



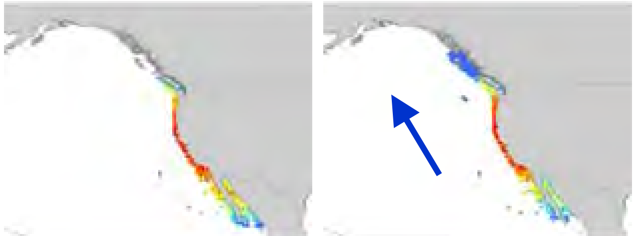
Review of 1st paper

- 5 climate effects simulated using increased or decreased organism productivity (Ecosim forcing functions)
- 3 levels of severity tested
- Impacts tested alone and in combination (additive)

Ocean acidification

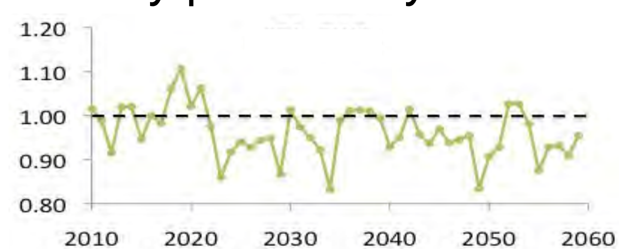


Species range shifts

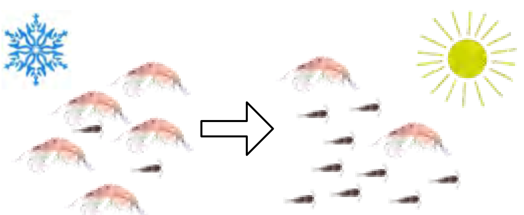


Cheung et al. 2009 (Fish and Fisheries)

Primary productivity



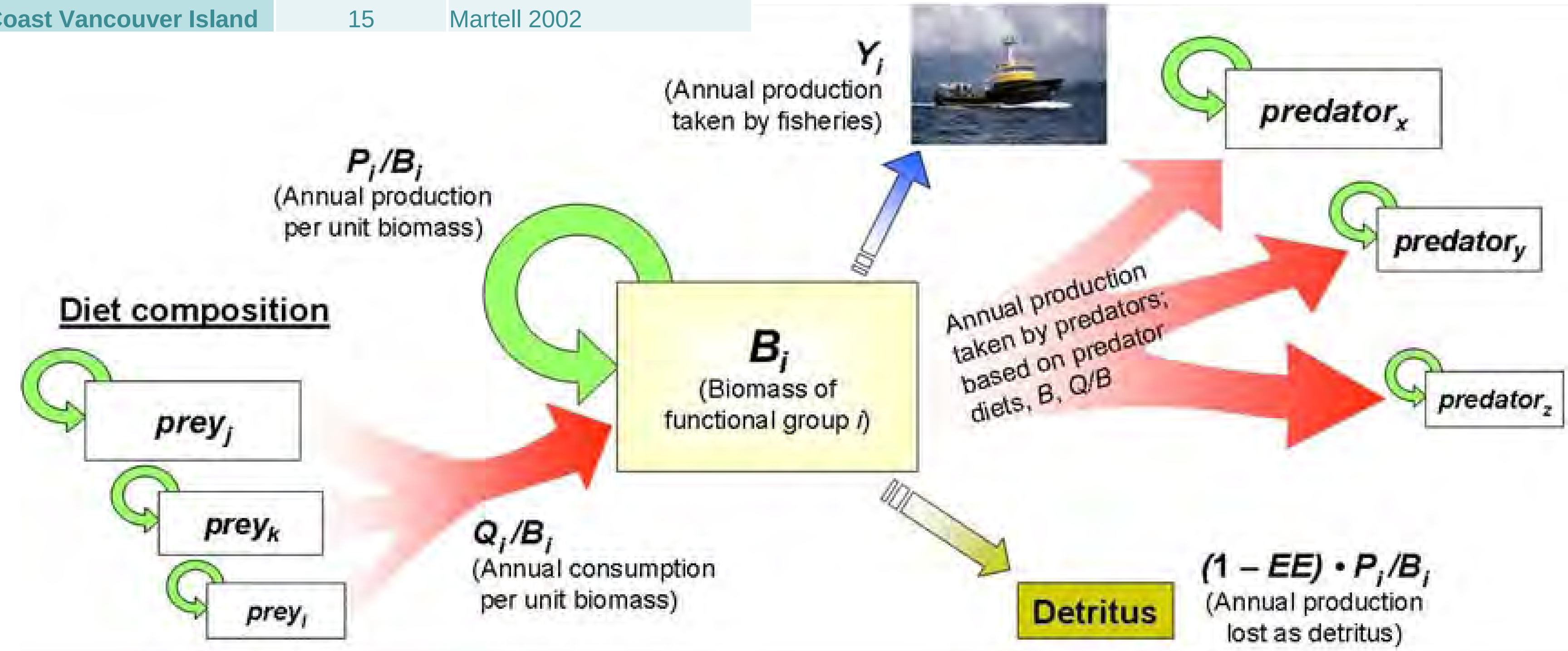
Plankton size structure



Deoxygenation

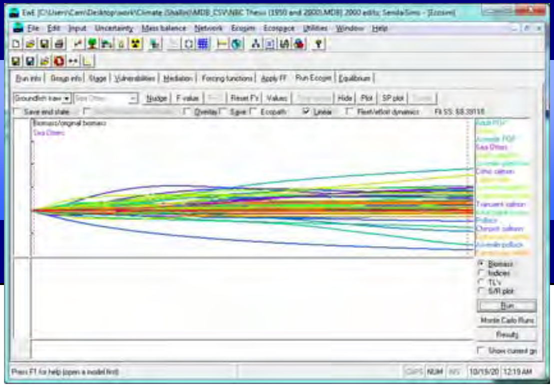
Ecopath with Ecosim

Model	# groups	Reference
Northern British Columbia	53	Ainsworth 2007
Northern California Current	65	Field et al. 2006
Prince William Sound	48	Okey and Pauly 1999
Southeast Alaska	40	Guenette et al. 2006
West Coast Vancouver Island	15	Martell 2002



Polovina, J.J., 1984. Coral Reefs, 3 (1): 1–11. ··· Christensen, V., Pauly, D., 1992.. Ecological Modeling, 61: 169–185. ··· Walters, C., Christensen, V., Pauly, D. 1997. Reviews in Fish Biology and Fisheries, 7: 139-172.

Ecopath with Ecosim



$$\frac{dB_i}{dt} = c\, g_i \sum_{j=1}^{n} f\left(B_j, B_i\right) - \sum_{j=1}^{n} f\left(B_i, B_j\right) + I_i - B_i\left(M_i + F_i + e_i\right)$$

Production — Predation losses — Fisheries and other mortality

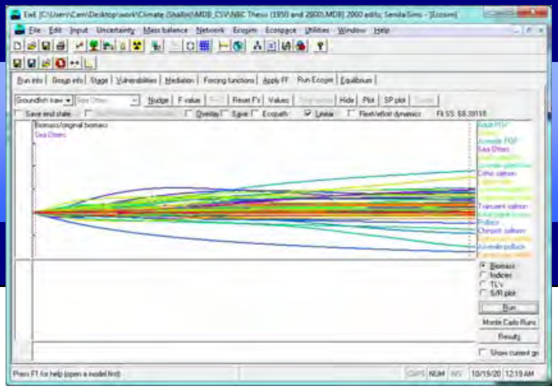
Ecopath master equations

Mass balance: $B_i \cdot (P/B)_i = Y_i + \sum_{j=1}^{n} B_j \cdot (Q/B)_j \cdot DC_{ji} + E_i + BA_i + B_i (P/B)_i \cdot (1 - EE_i)$

Conservation of energy: $B \cdot (Q/B) = B \cdot (P/B) + (1 - GS) \cdot Q - (1 - TM) \cdot P + B \cdot (Q/B) \cdot GS$

Ecopath: Polovina, J.J., 1984. Coral reefs, 3(1): 1-11. Christensen, V. and D. Pauly, 1992. Ecological Modeling, 61: 169-185.
Ecosim: Walters, C., V. Christensen and D. Pauly, 1997. Reviews in Fish Biology and Fisheries, 7: 139-172.

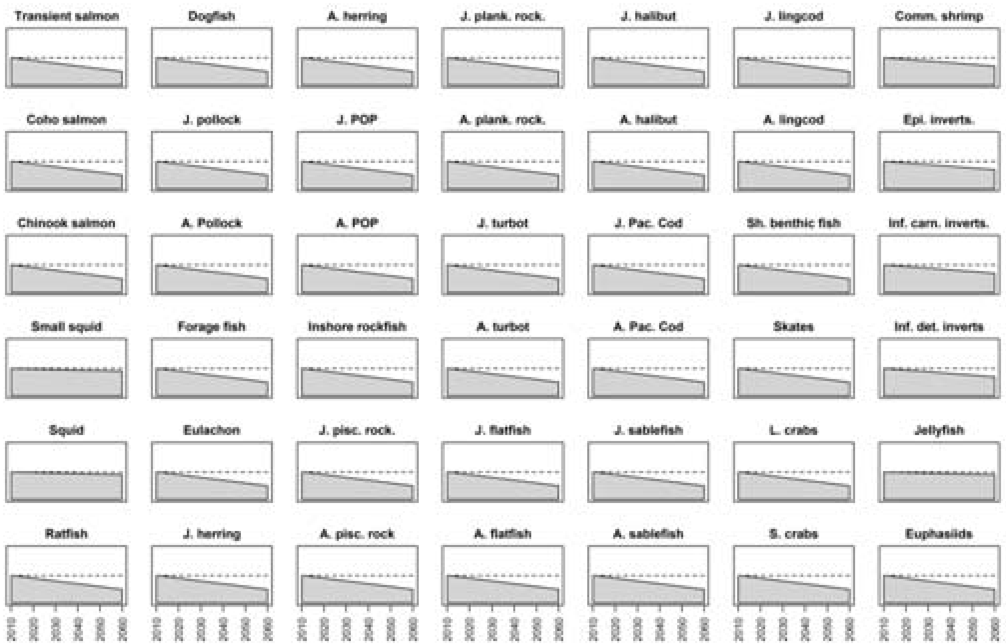
Ecopath with Ecosim



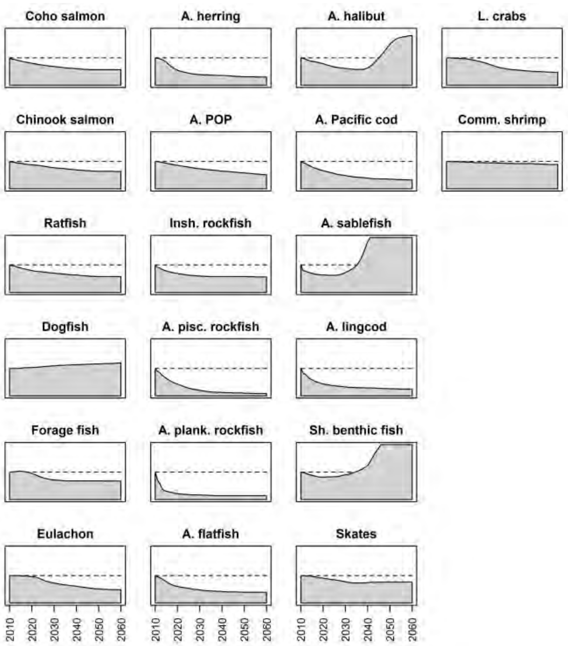
$$\frac{dB_i}{dt} = c\, g_i \sum_{j=1}^{n} f\left(B_j, B_i\right) - \sum_{j=1}^{n} f\left(B_i, B_j\right) + I_i - B_i\left(M_i + F_i + e_i\right)$$

Annual scalar multiplier of biological production

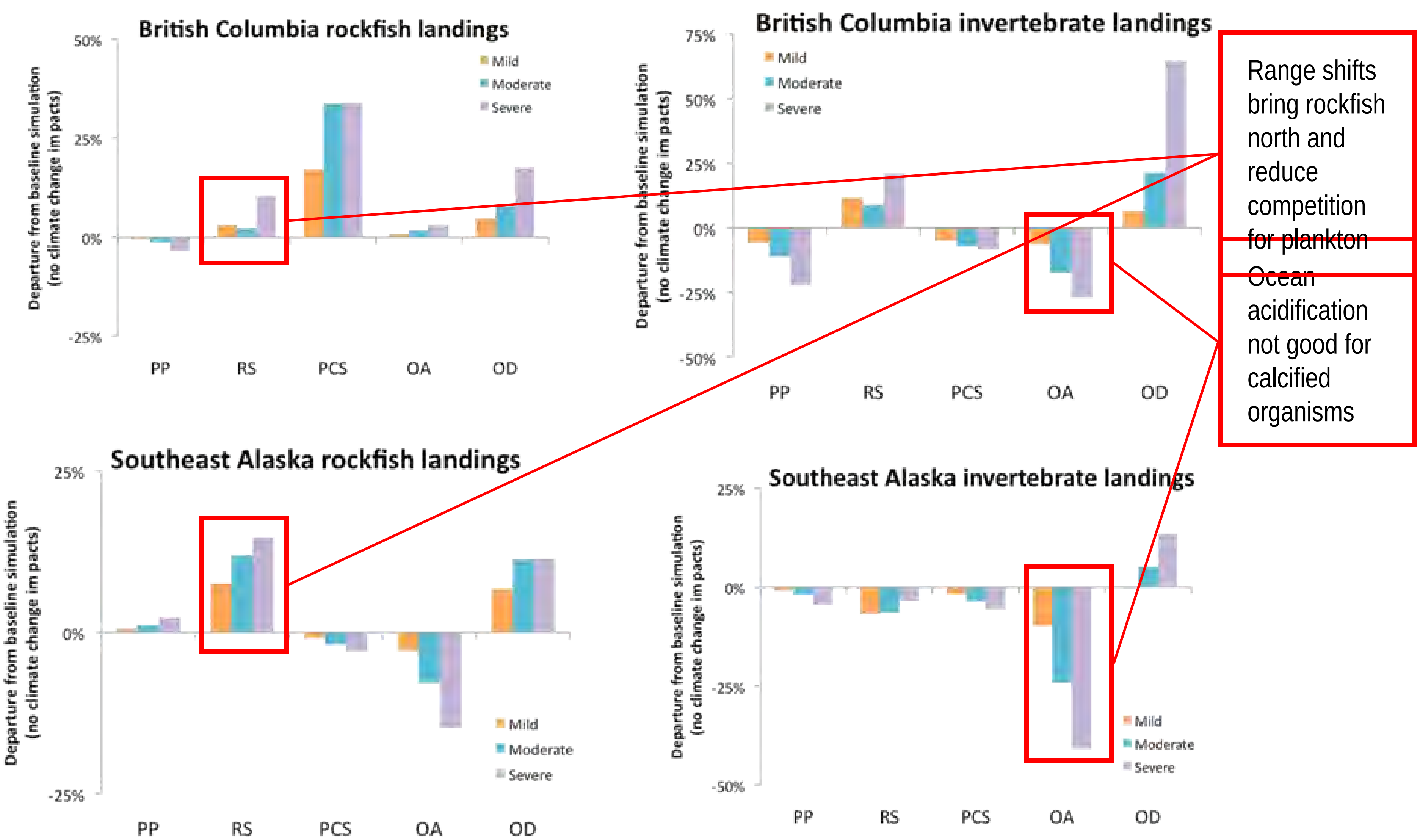
Dissolved oxygen forcings (NBC)



Range shift forcings (NBC)

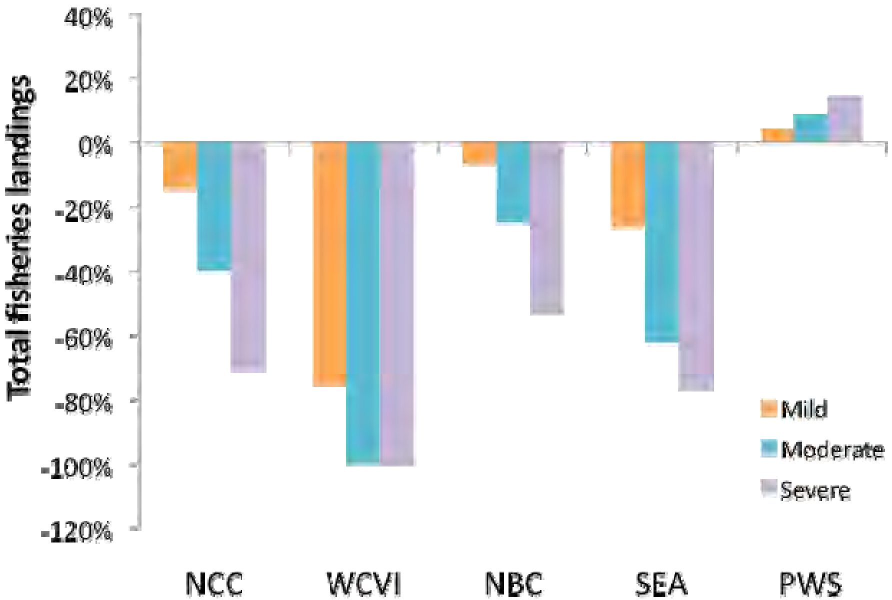


1st paper: Individual climate effects



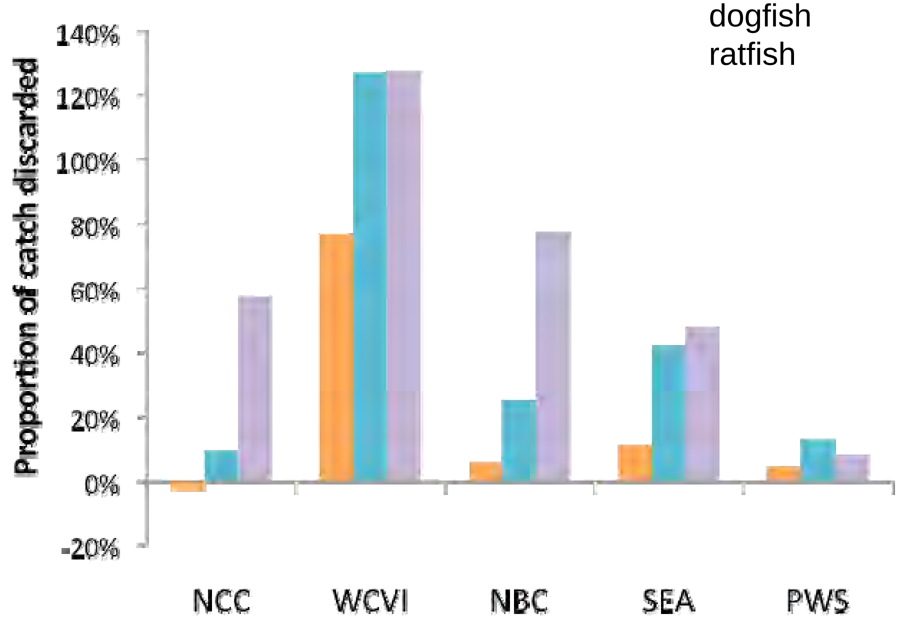
1st paper: Cumulative effects

Less catch overall



More low-value species

jellyfish
dogfish
ratfish



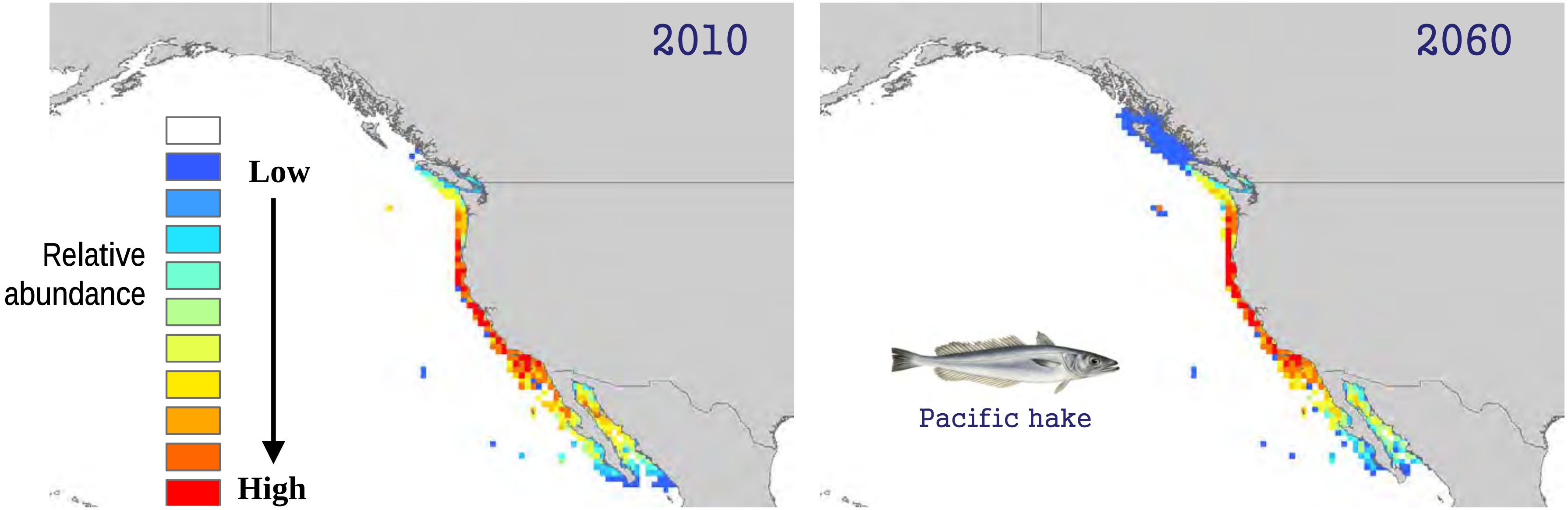
Doesn't include human opportunism

Now the current study

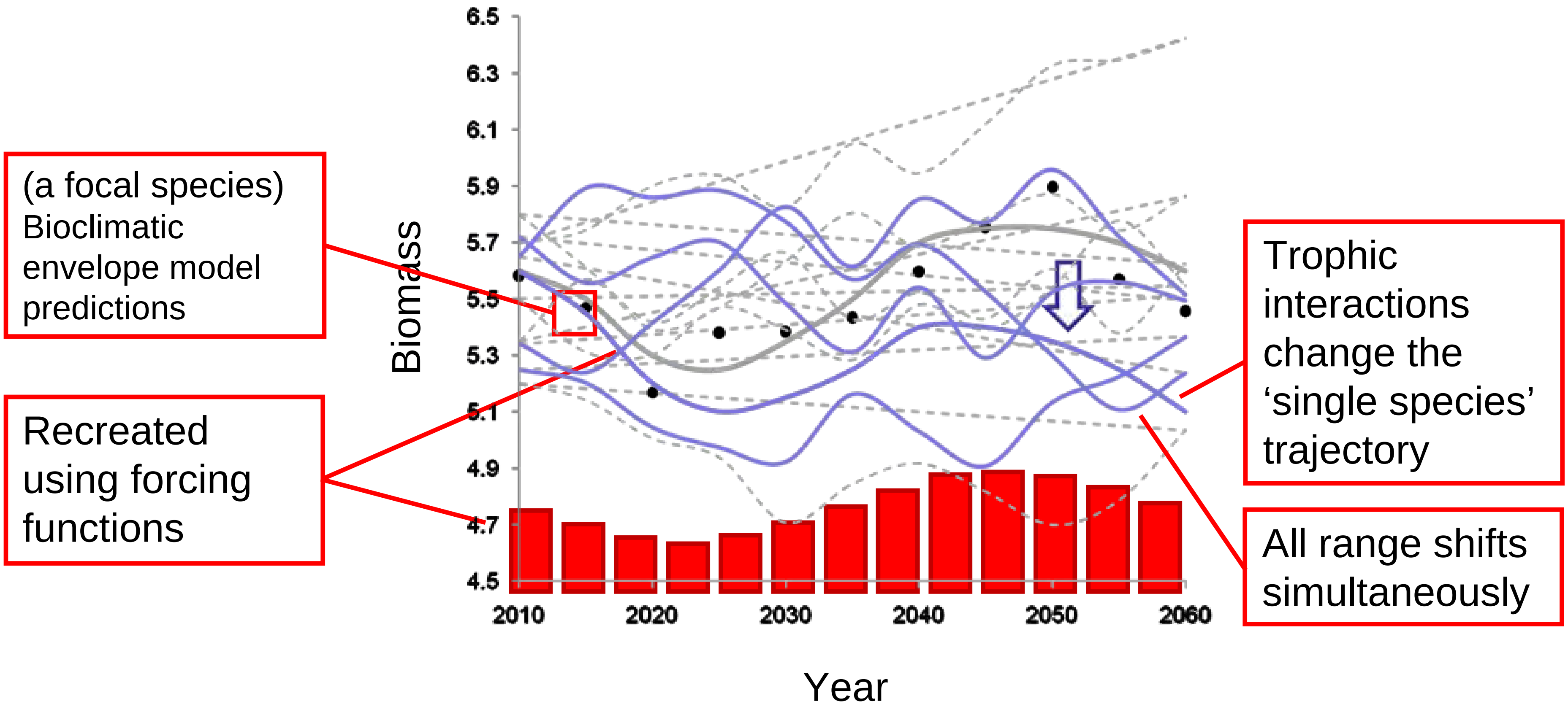
Do community interactions change our predictions?

Range shifts

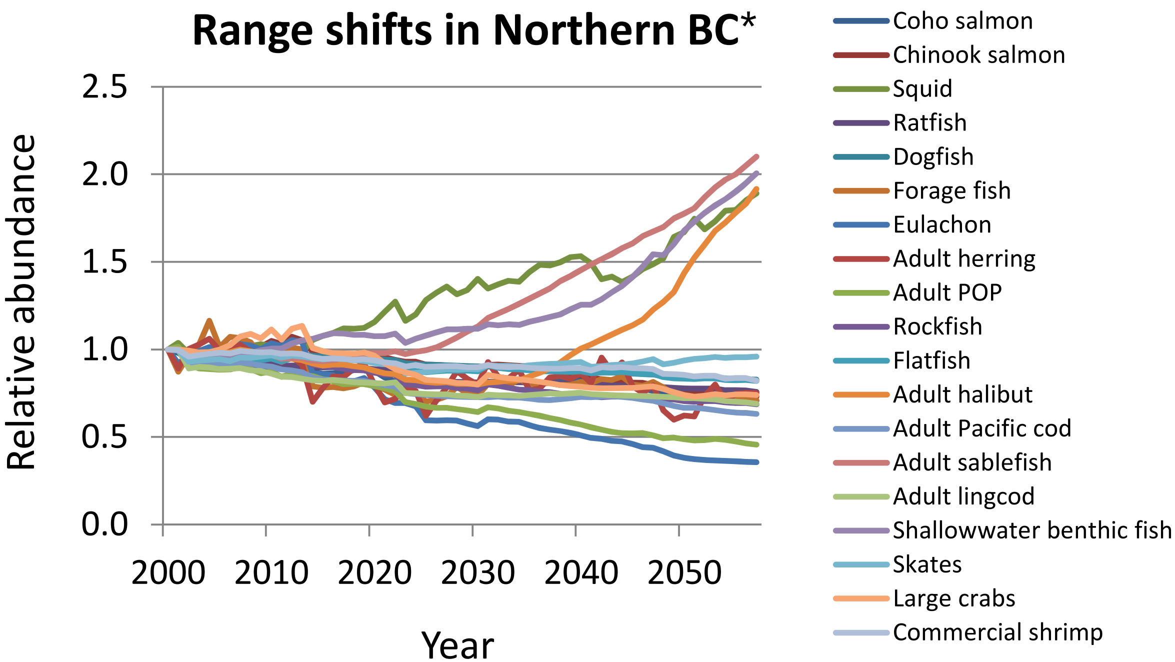
- Used bioclimatic envelope model (Cheung et al. 2009) to predict relative abundance of fished species in 0.5° x 0.5° grid
- Predicts distribution based on species' environmental preferences
- Based on ocean temperature, salinity from GFDL coupled model 2.1



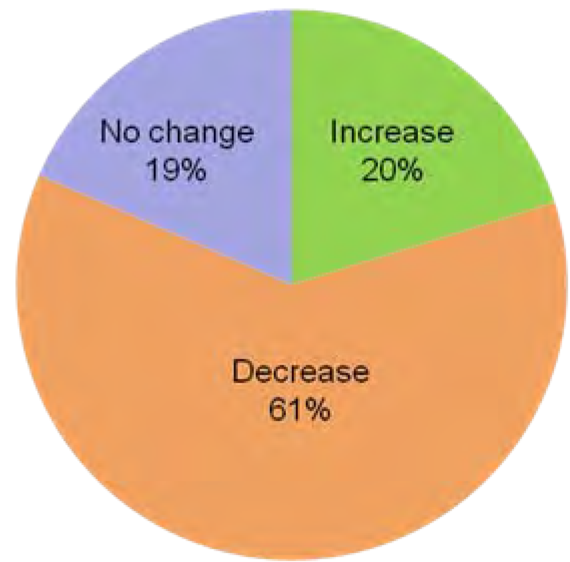
How we simulated range shifts



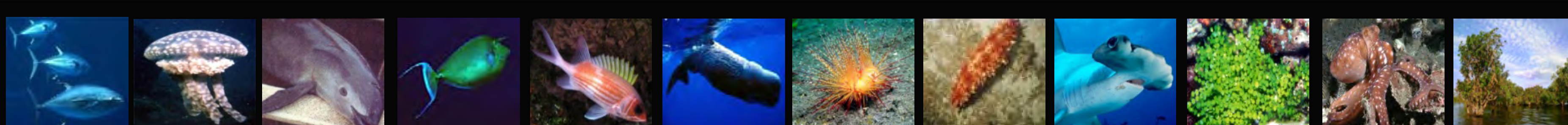
Range shifts



Some species increase, some decrease

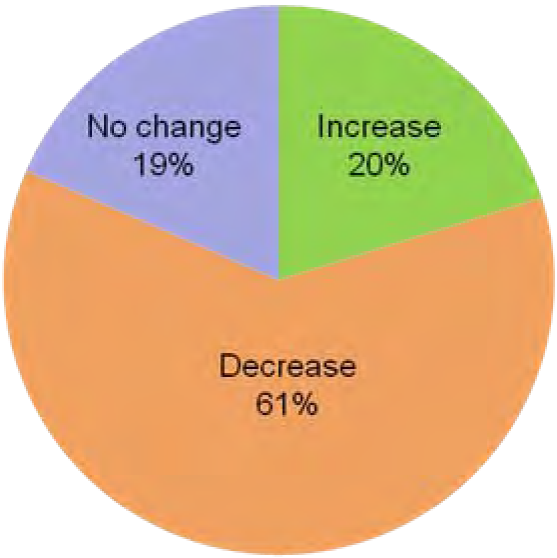


*Predicted by Cheung et al (2009) model in Ainsworth et al (2010)

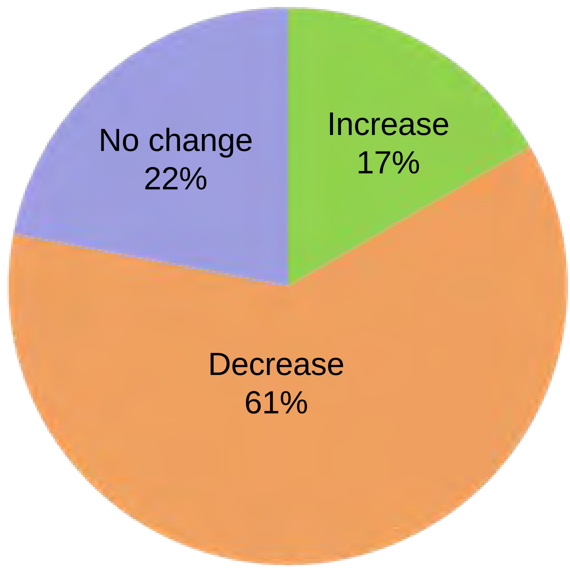


Range shifts

Did we get it right?



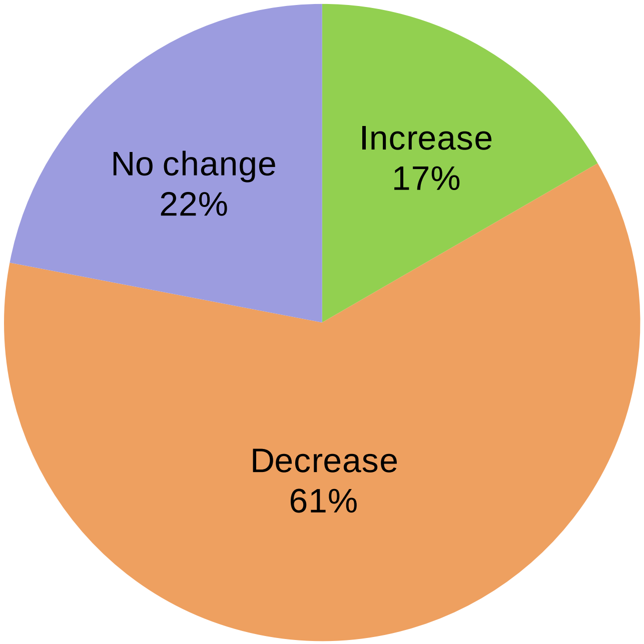
Not bad

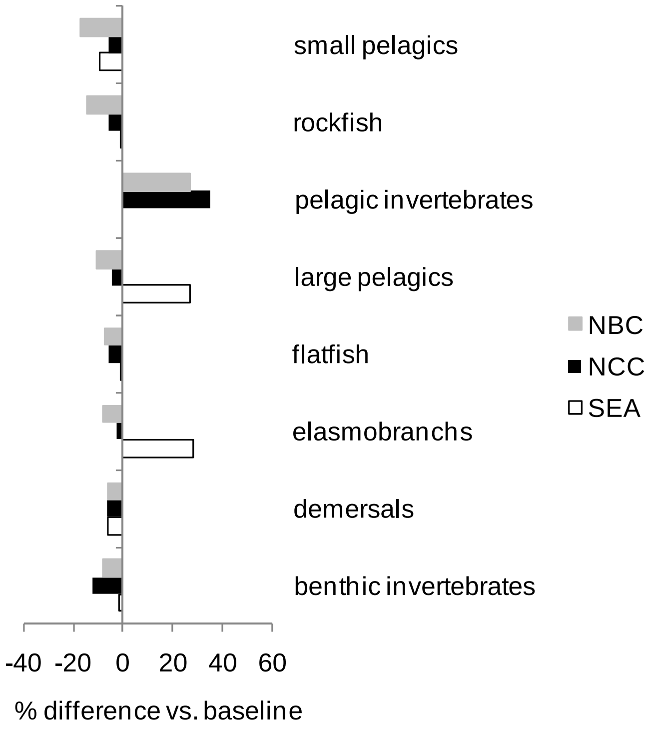


- Cheung's single species methodology is **recreated** here by holding other groups static

(no trophic interactions)

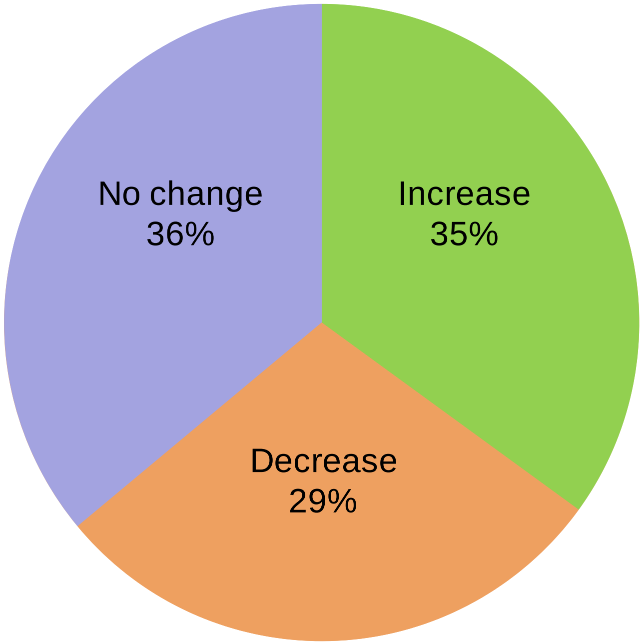
Range shifts

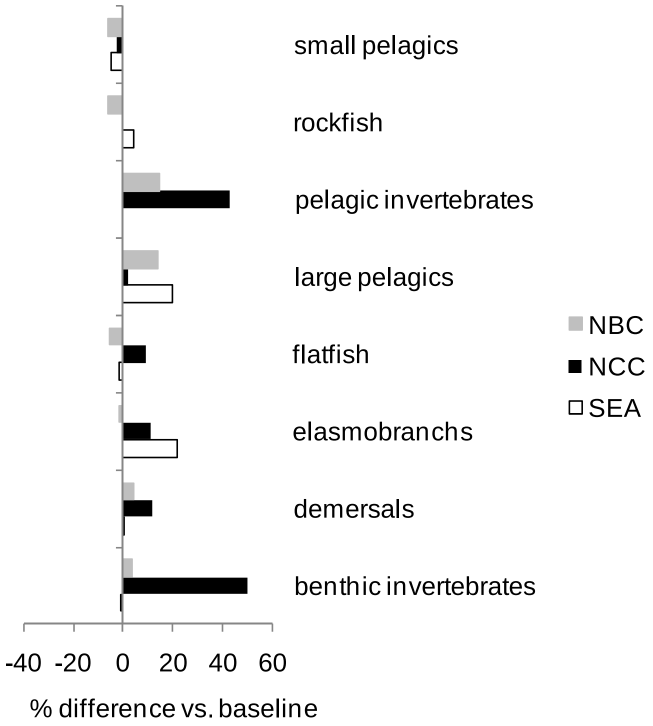




Single species trajectory

Range shifts





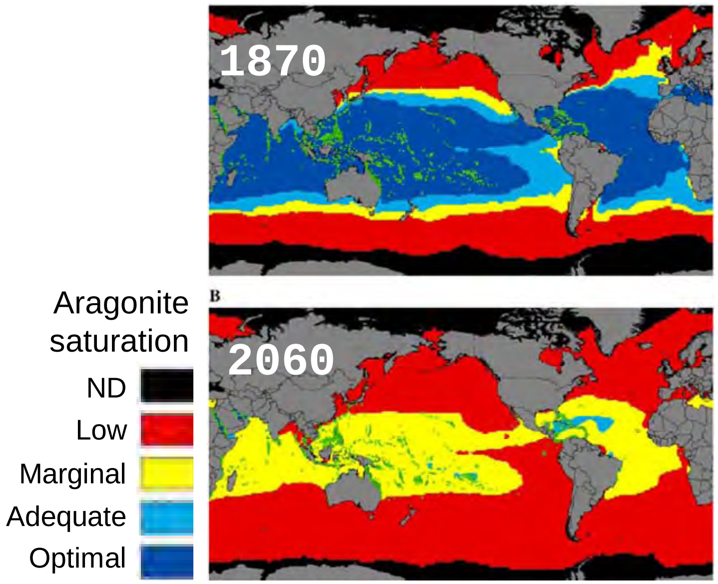
Now with all range shifts

Findings

- Community interactions might moderate range shifts across a wide range of exploited functional groups

Ocean acidification

Effect size	*Functional groups affected*
	Northern British Columbia
L	Commercial shrimp
S	Epifaunal invertebrates
S	Euphausiids
	Northern California Current
L	Benthic shrimp
S	Euphausiids
S	Infaunal invertebrates
L	Pandalid shrimp
	Southeast Alaska
S	Carnivorous epibenthic invertebrates
L	Shrimps

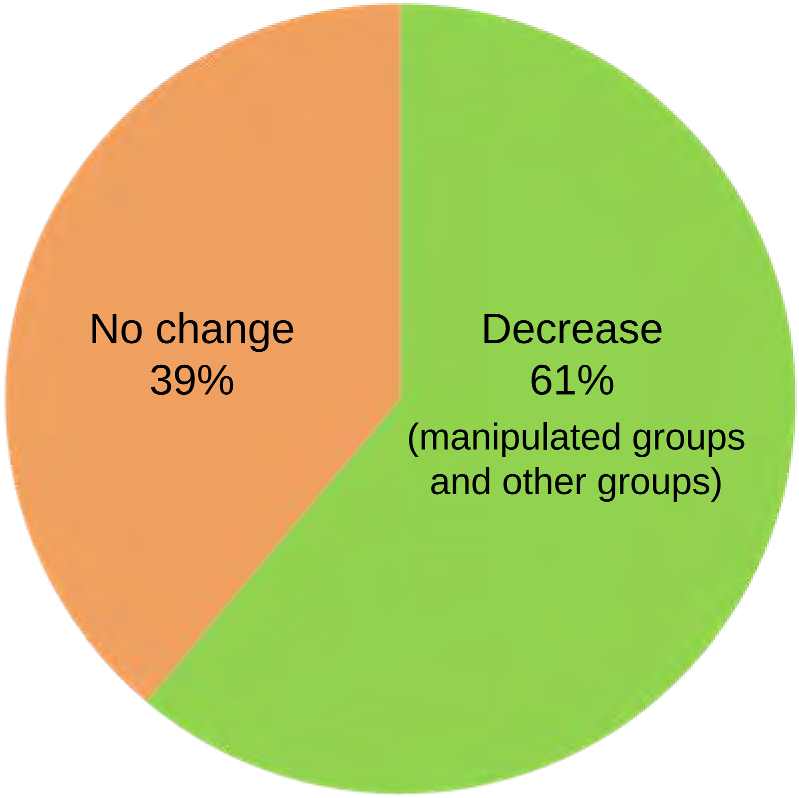


Guinotte & Fabry 2008

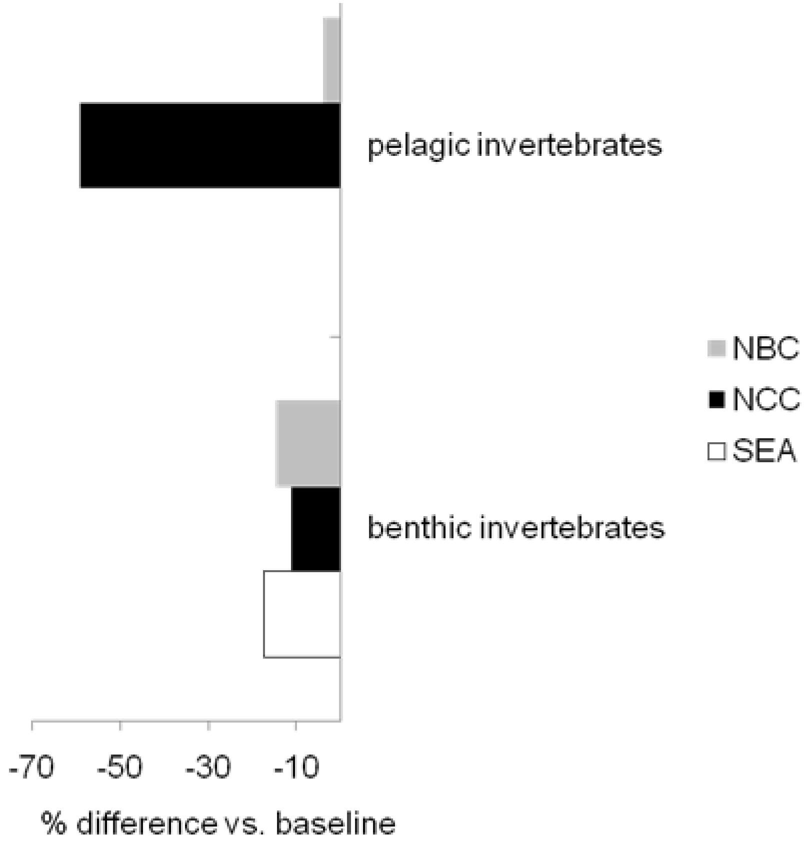
Guinotte, J.M, and Fabry, V.J., 2008. Ocean acidification and its potential effects on marine ecosystems. In: Ostfeld, R.S., Schlesinger, W.H. (Eds.), The Year in Ecology and Conservation Biology 2008, Annals of the New York Academy of Sciences, pp. 320–342.

Ocean acidification

Manipulated groups only



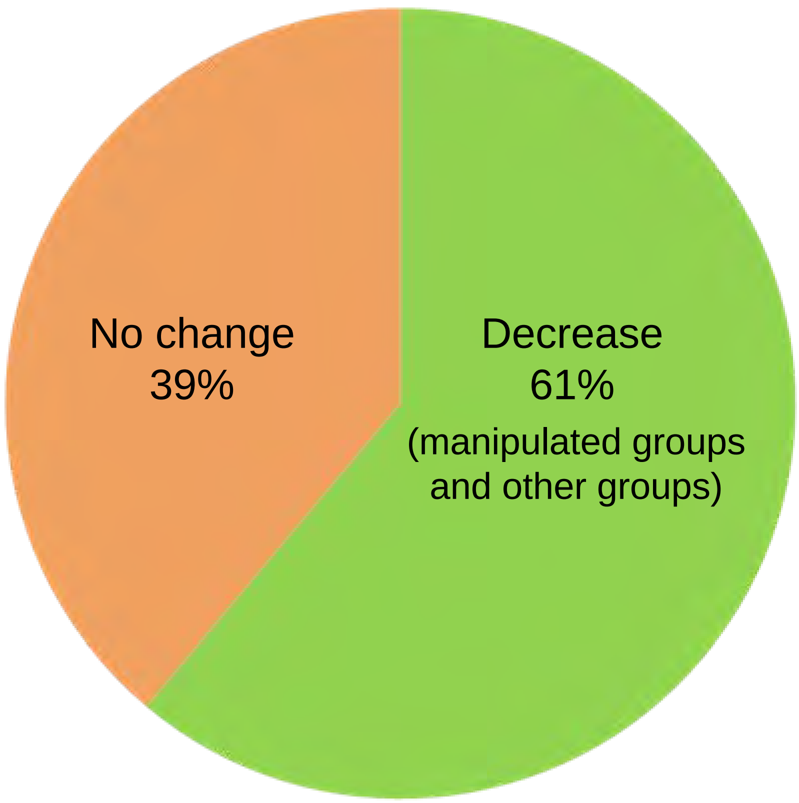
Manipulated groups only



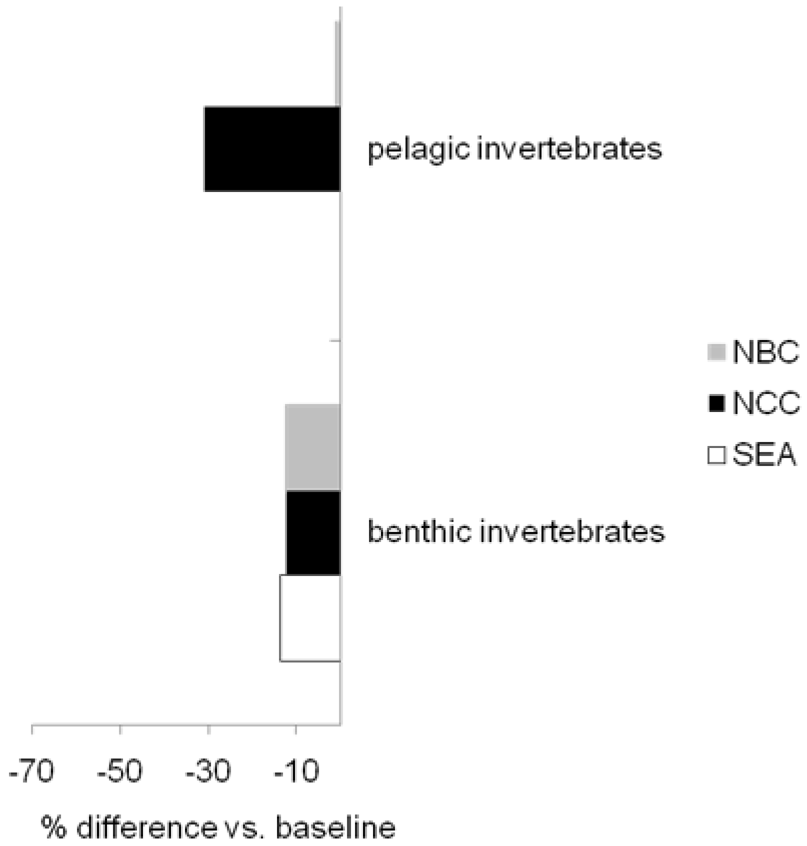
Single species trajectory

Ocean acidification

Manipulated groups only



Manipulated groups only

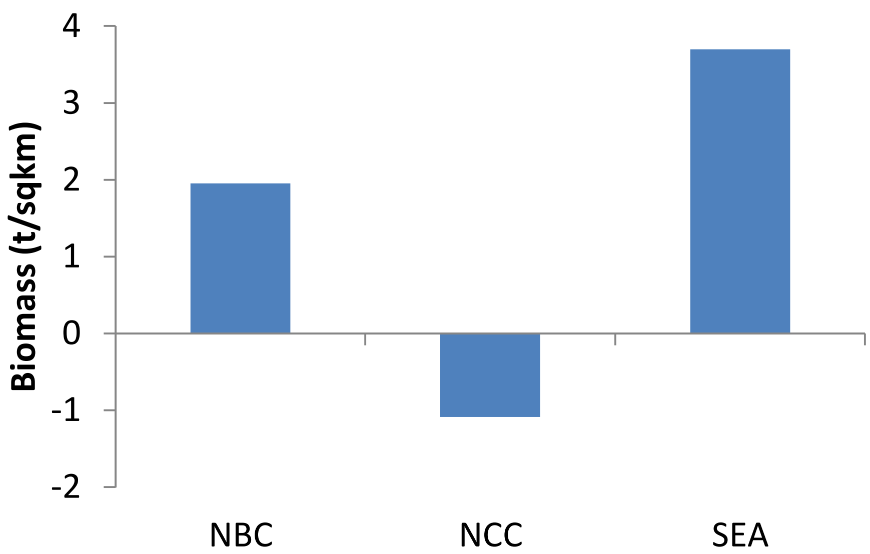


Now with all OA effects

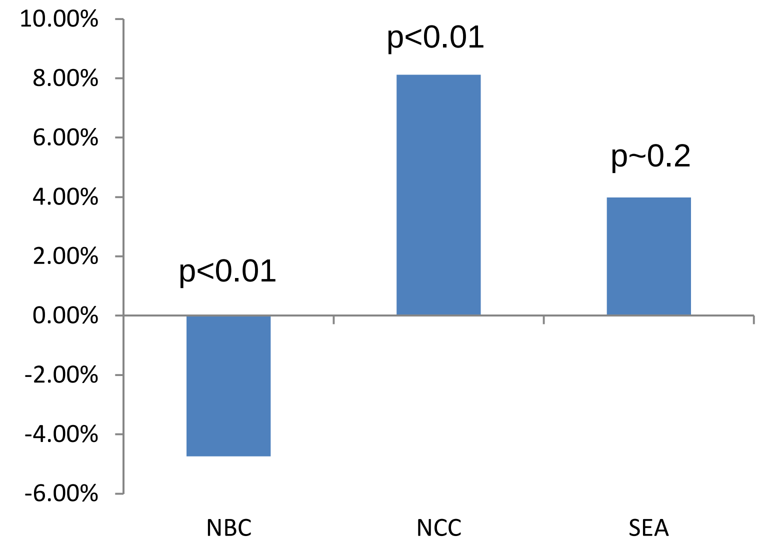
Multispecies effects reduce impacts on invertebrates relative to single-species expectations

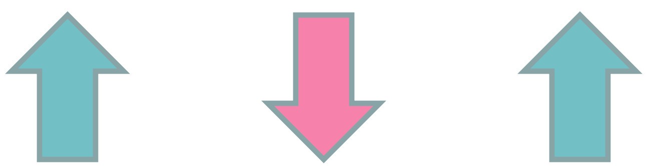
Ocean acidification

Benthos under multispecies impacts



Groups that depend on benthos





Multispecies impacts alleviate OA effects on benthos

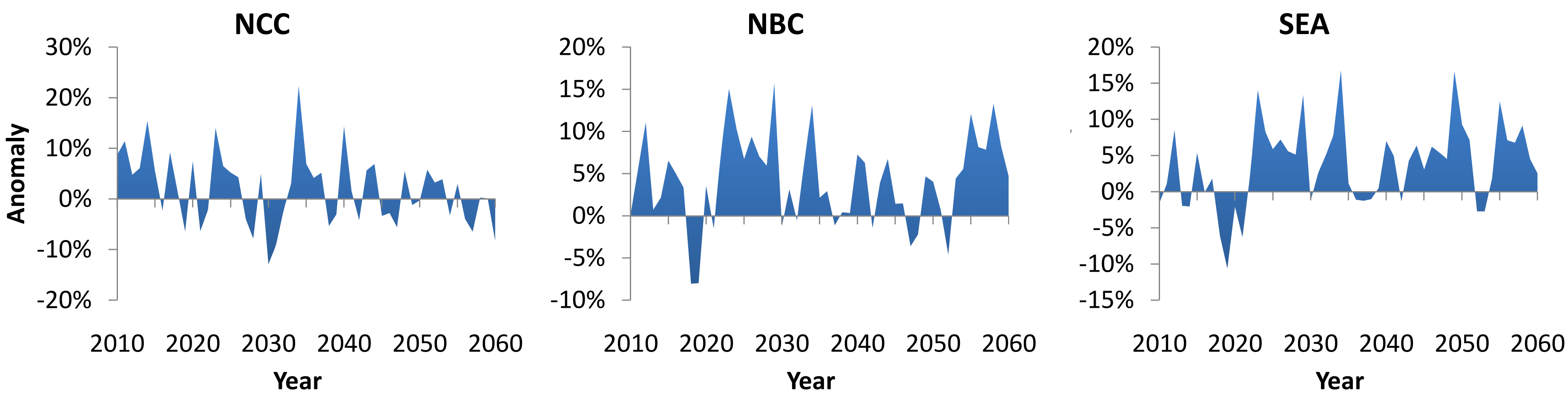
These groups are responding, but not how you would expect

Makes them worse

Findings

- Community interactions may reduce OA impacts on affected invertebrates
- Effects do not cascade up the food web as expected

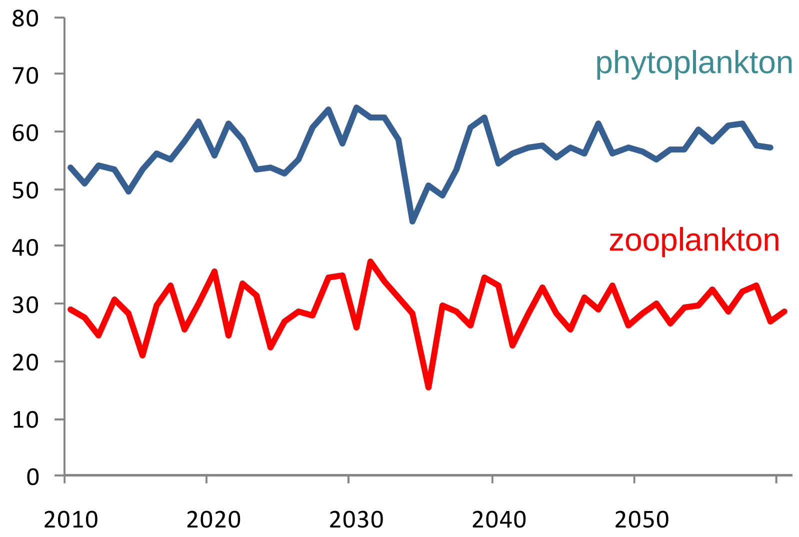
Primary production



- Geophysical Fluid Dynamics Laboratory (GFDL) Earth System Model (ESM2.1)
- Includes Tracers of Ocean Phytoplankton with Allometric Zooplankton (TOPAZ) model of ocean ecosystems and biogeochemical cycles
- Simulations based on the IPCC AR4 protocols (SRES A1B).

Primary production

NCC model



Vs. GFDL predictions, variability of phytoplankton has increased 6%

Phytoplankton variability decreased 15%

Zooplankton variability decreases 8%

Compensatory feeding dynamics by high TLs reduce variation in plankton

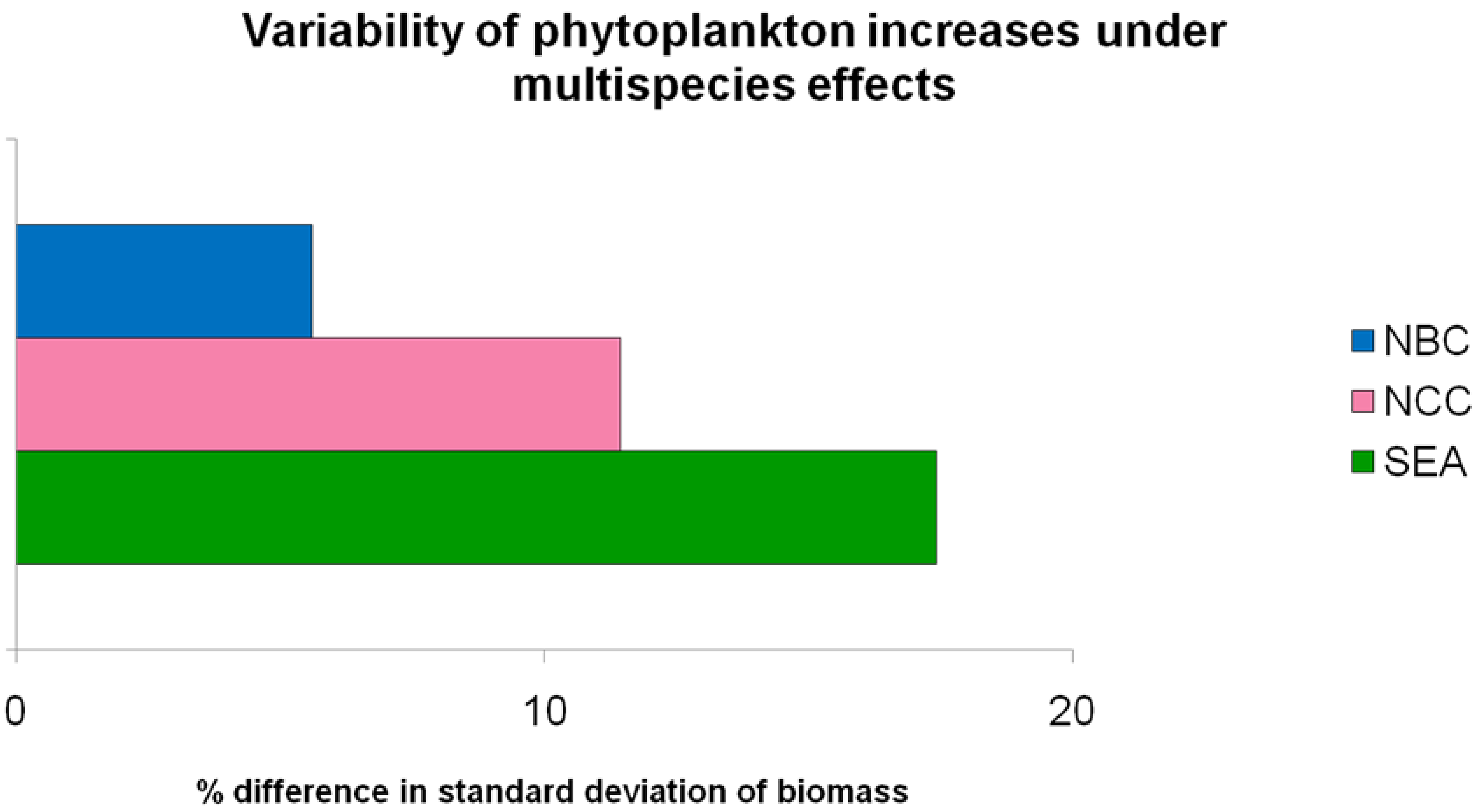
Zooplankton show 4 month lag with phytoplankton (R = 0.74)

NCC: Zooplankton variability decreases 8%

NBC: Zooplankton variability decreases 1%

Foraging arena: Walters, C.J. and F. Juanes, 1993. CJFAS, 50: 2058-2070.

Primary production



Findings

- Multispecies interactions increase variability of phytoplankton
- Higher TL interactions reduce variability of prey

Summary

Do community interactions change our predictions?

- Range shifts and ocean acidification impacts are ***moderated*** by multispecies interactions

- Variability of primary production ***increases***

Thank you