Evaluating uncertainty in estimates of how climate change may impact Northeast Pacific marine ecosystems

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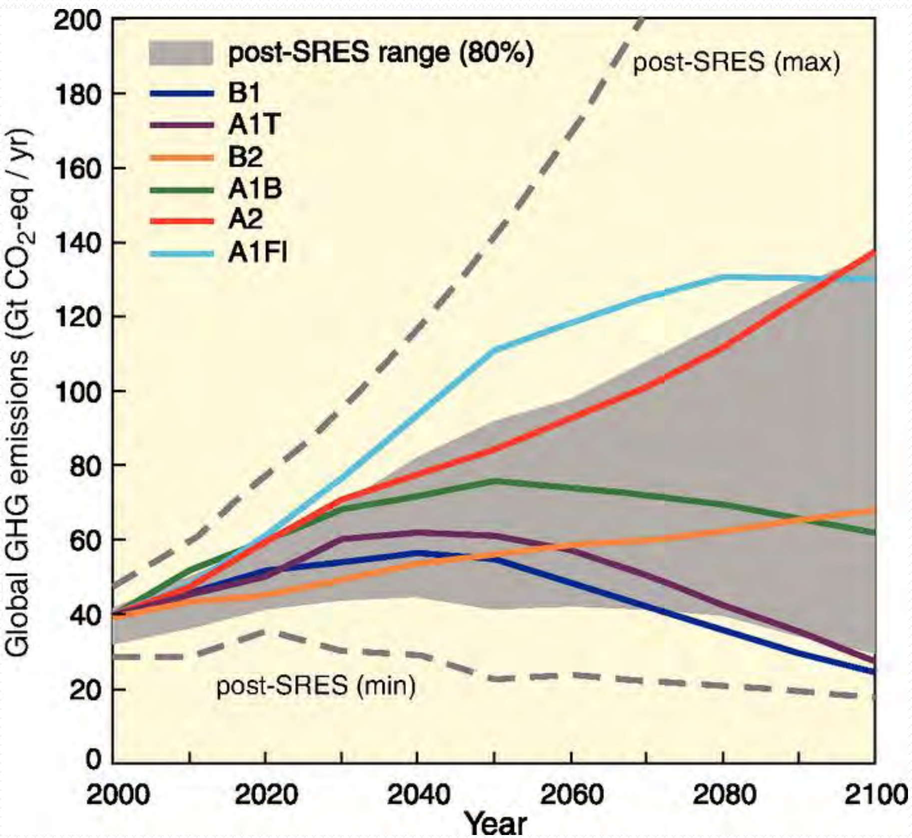
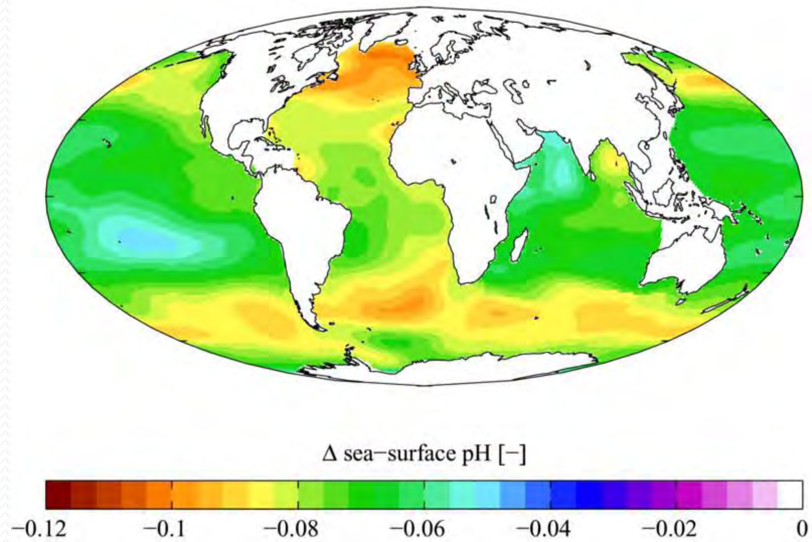
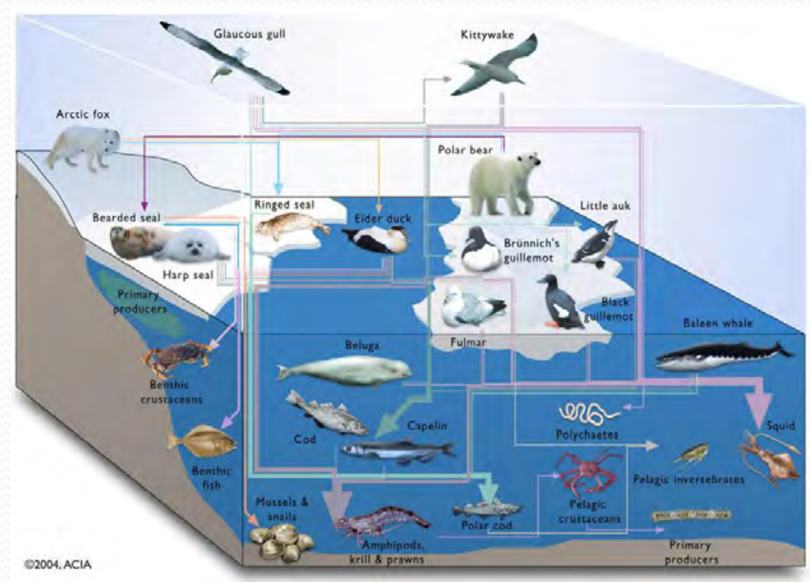
5. WCVI Aquatic Management Board

Uncertainty in estimating response to climate change



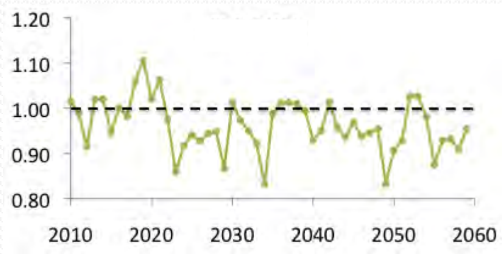




IPCC 2007

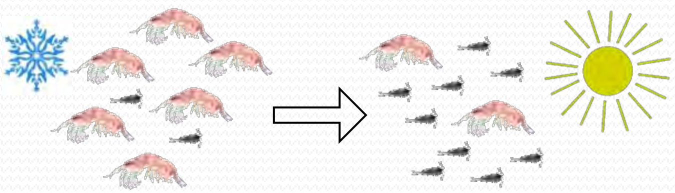
Biological impacts

Primary productivity



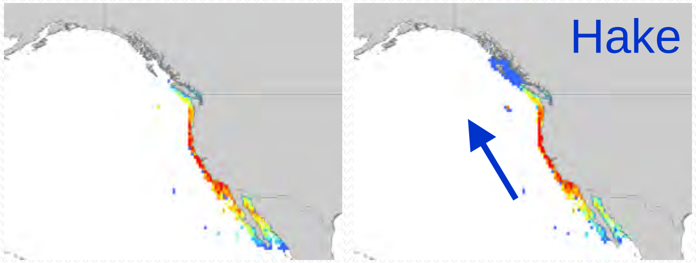
Geophysical Fluid Dynamics Laboratory CM2.1

Plankton community structure



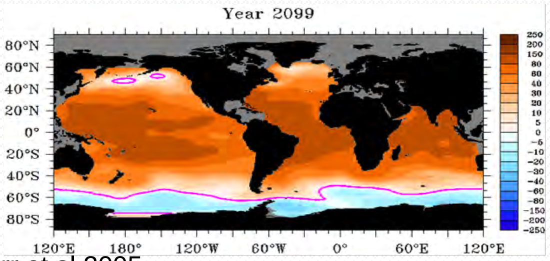
Deoxygenation

Species range shifts



Cheung et al. 2009 (Fish and Fisheries)

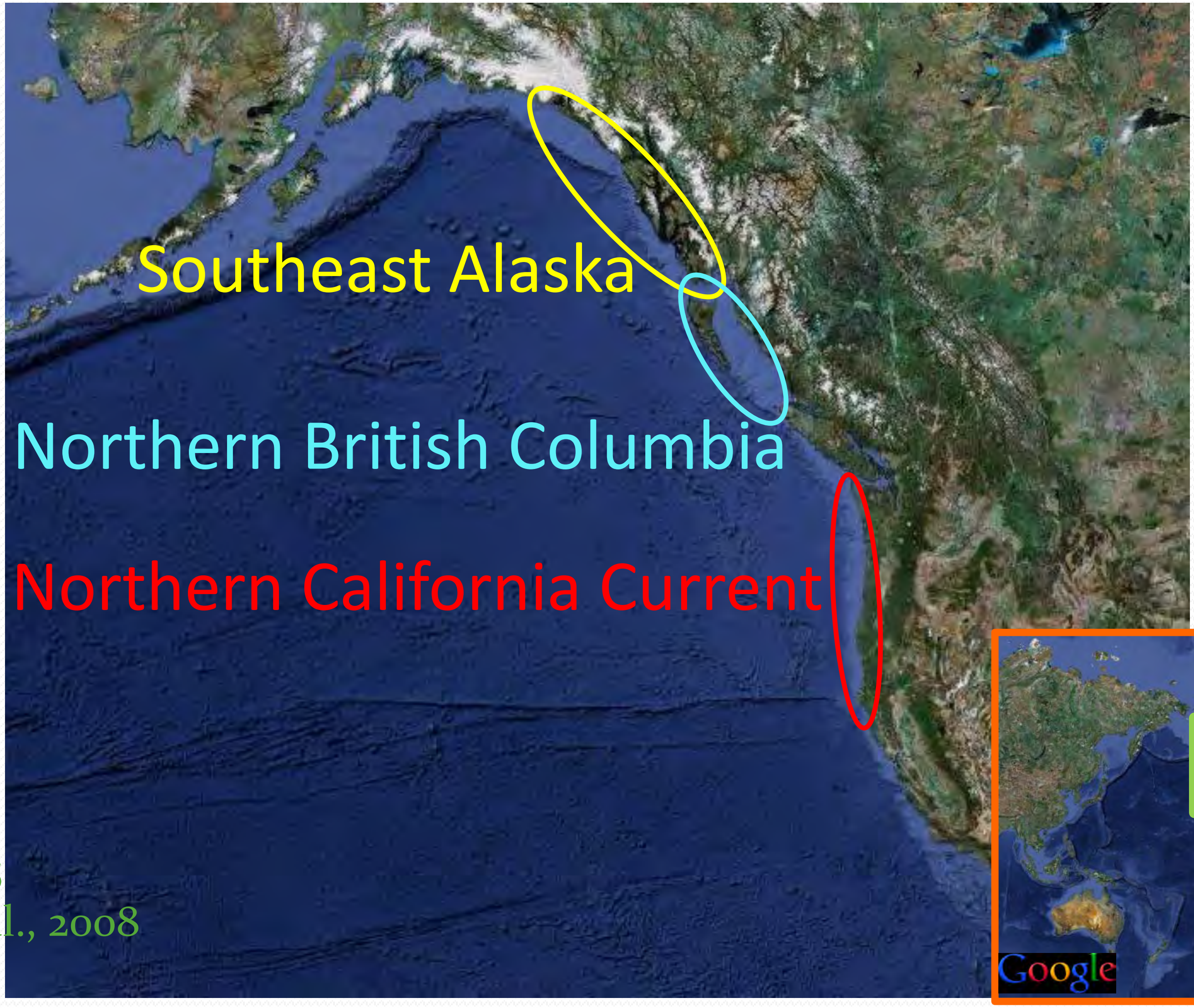
Ocean acidification



Orr et al 2005

Ainsworth et al., in review

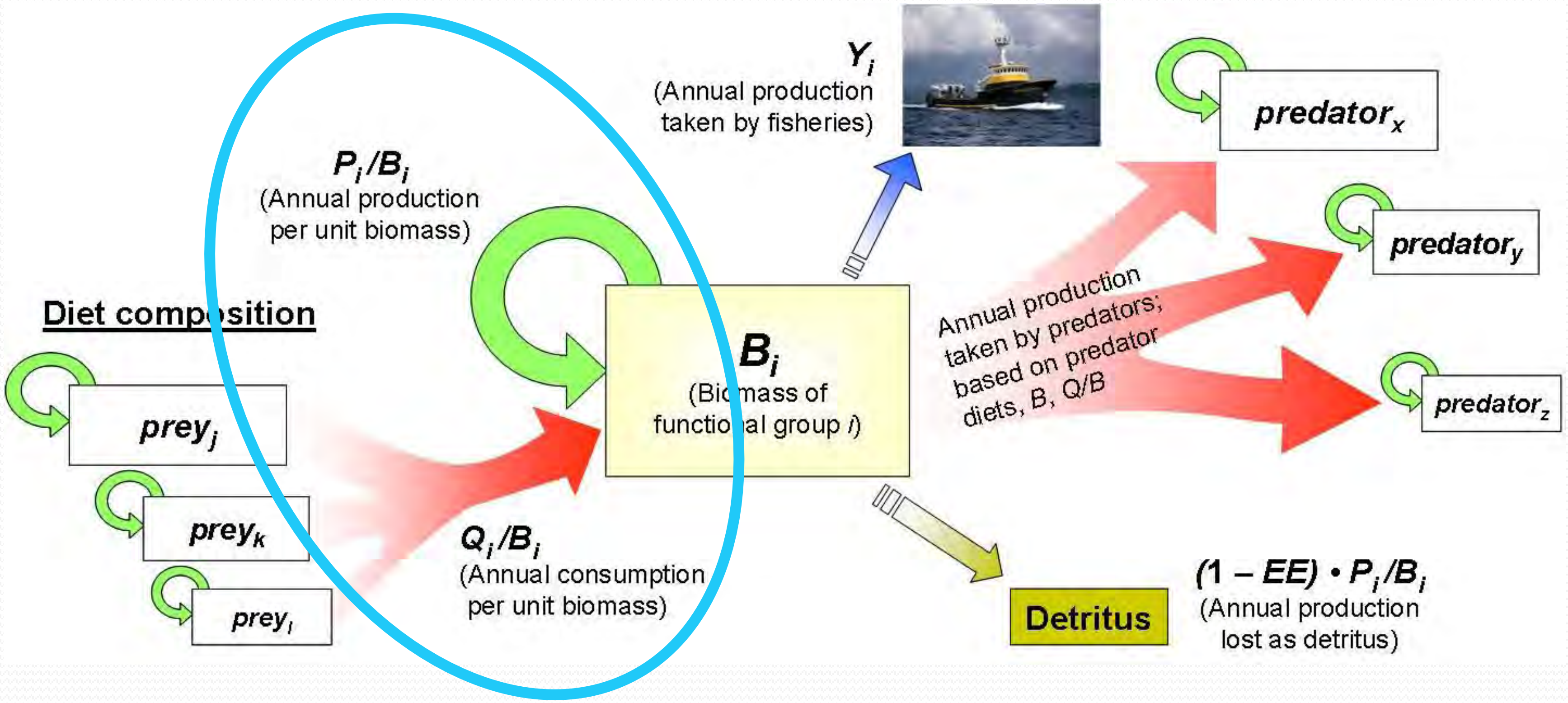
Three NE Pacific food web models



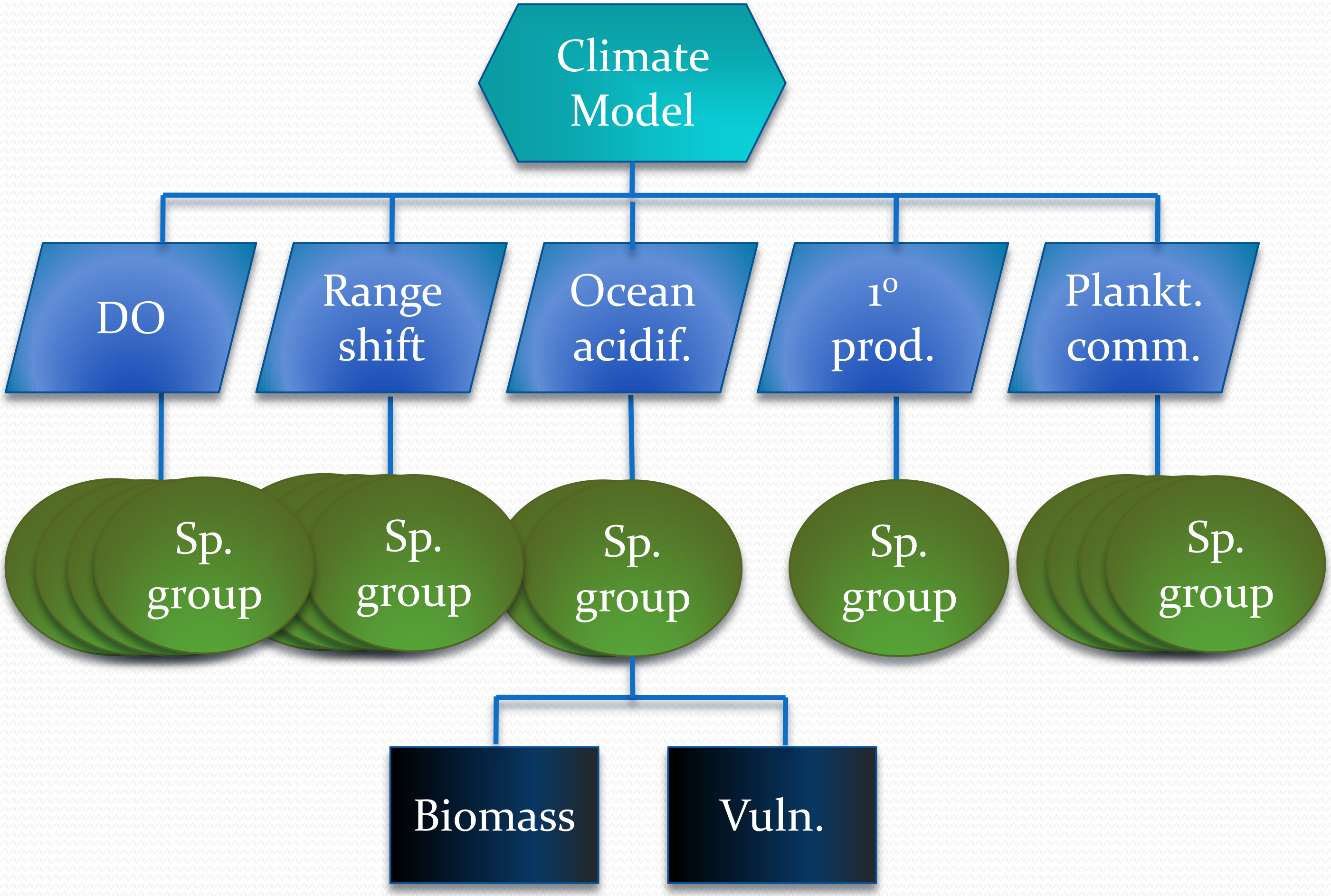
Guénette 2005
Ainsworth et al., 2008
Field 2004

Ecopath with Ecosim

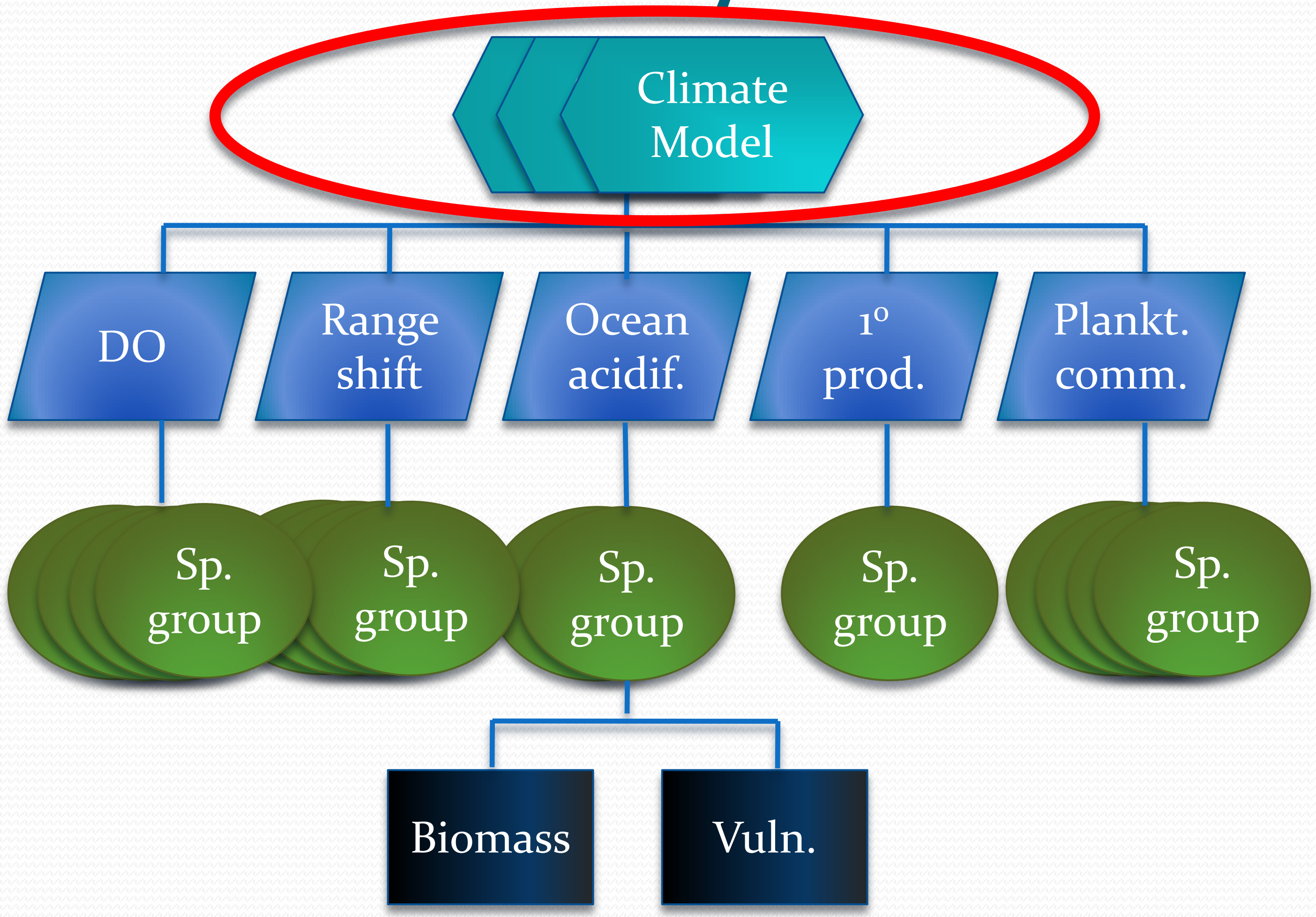
Polovina, Christensen, Pauly, Walters



Addressing uncertainty



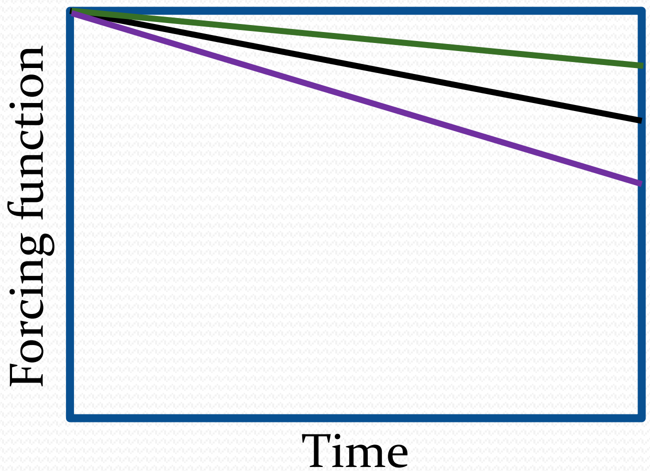
Model uncertainty



Model uncertainty

For all impacts, we ran scenarios of 3 different strengths:

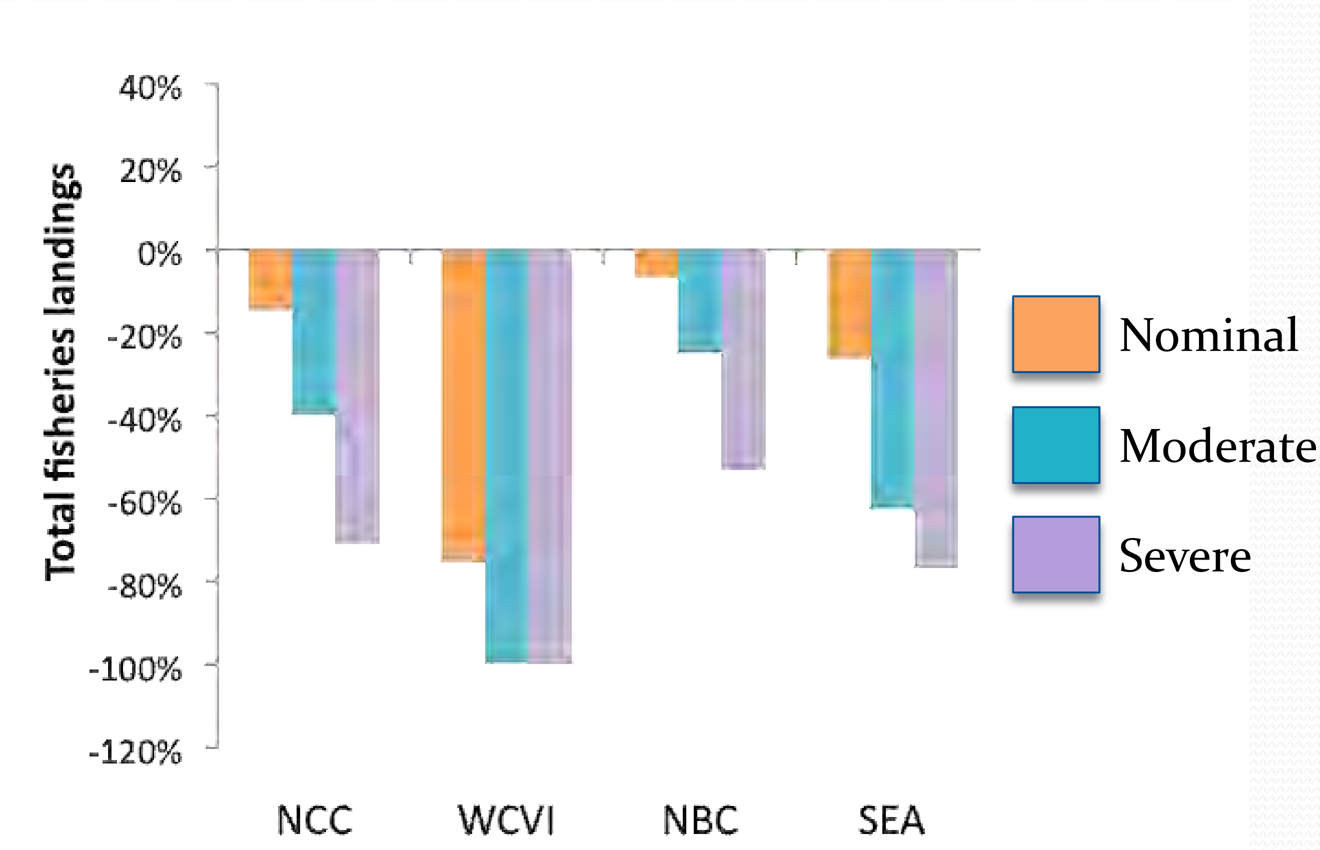
Scenario strength		
Nominal	Moderate	Severe
Effect – 50%	Effect	Effect + 50%



Ainsworth et al., in review

Model uncertainty

Models vary in their sensitivity to climate scenarios

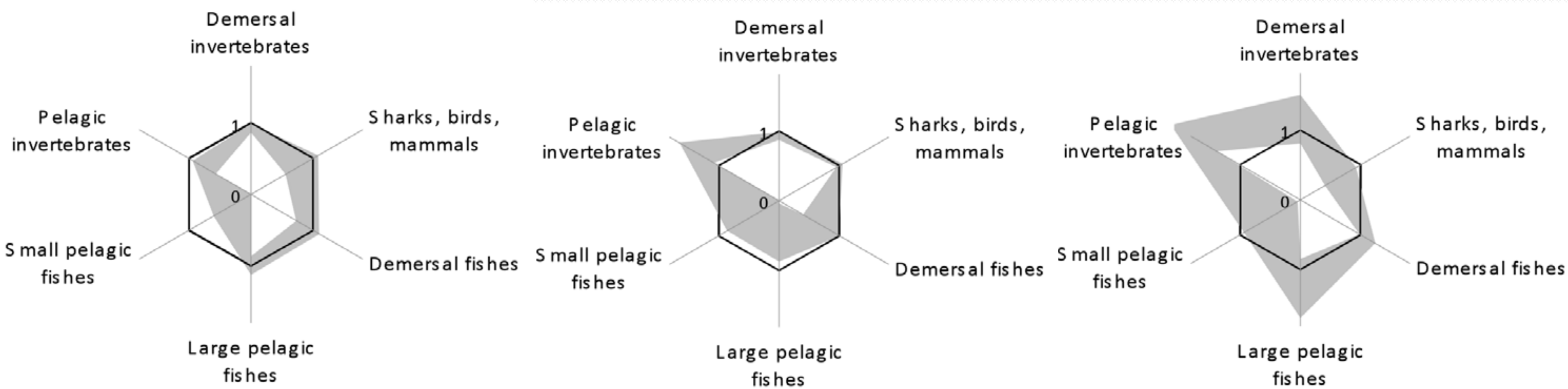


Ainsworth et al., in review

Model uncertainty

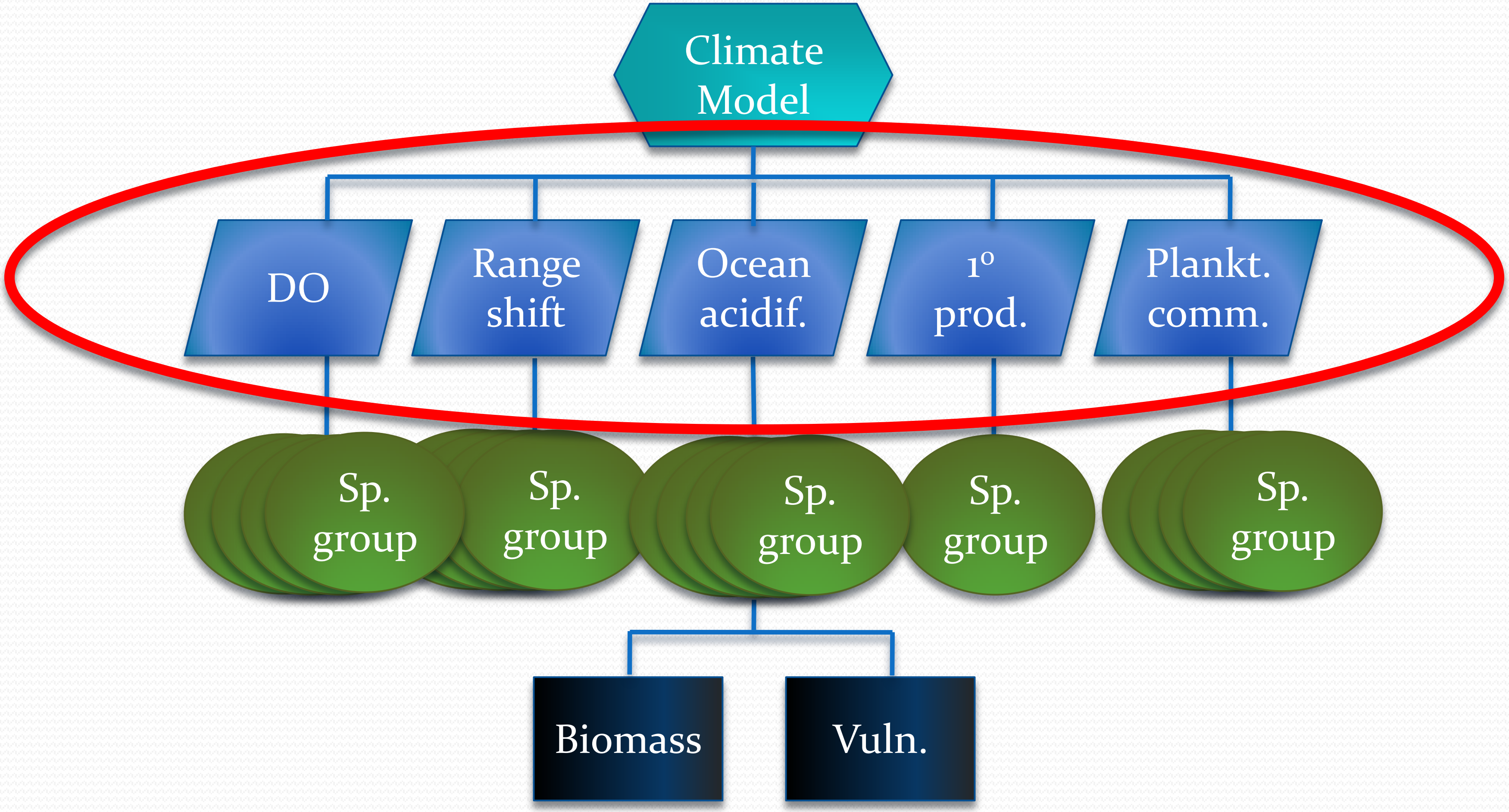
Functional groups vary in their sensitivity to climate scenarios

Southeast Alaska | N. British Columbia | N. Cali. Current

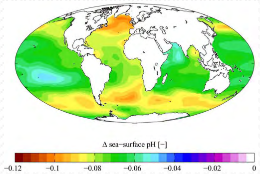


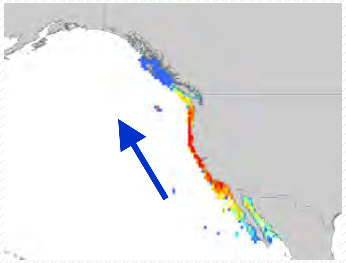
Ainsworth et al., in review

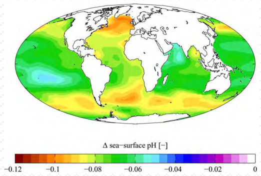
Process uncertainty

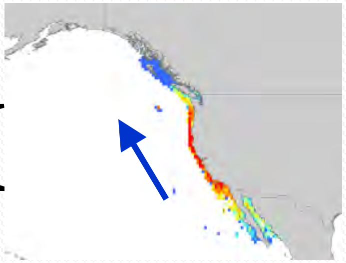


Cumulative effects

Additive= 

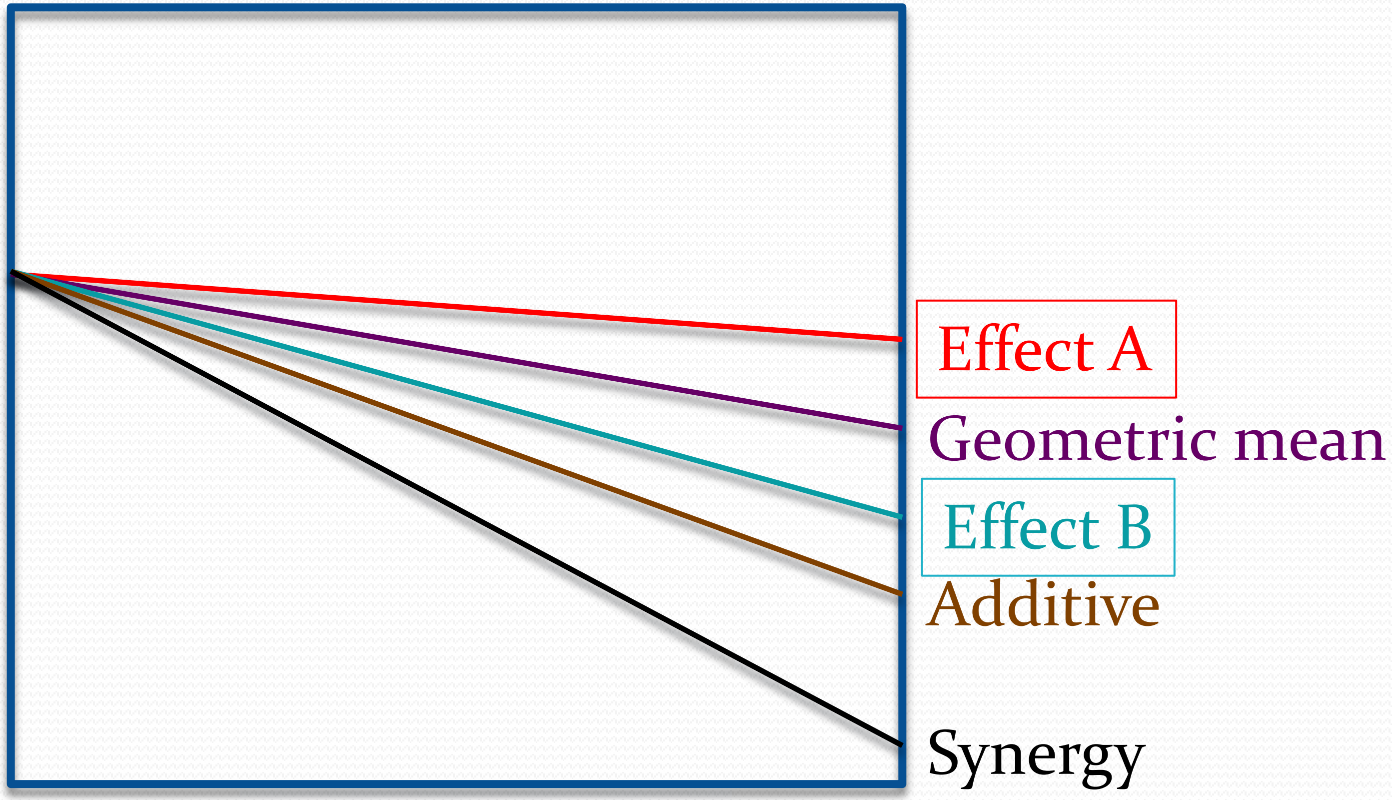
\+  + 

Geomean=(

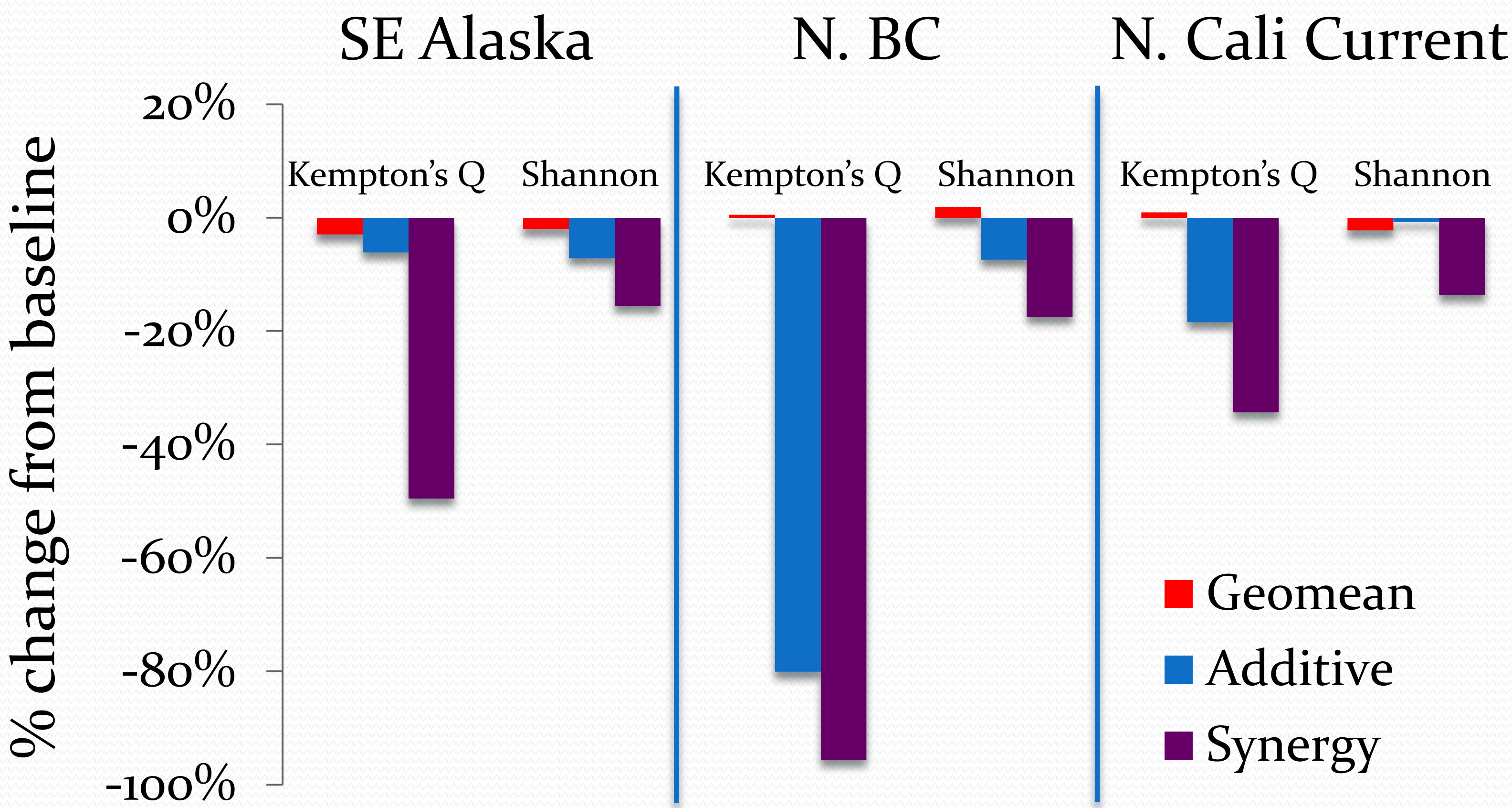
x  x  $)^{.3}$

Synergy=Additive + Geomean

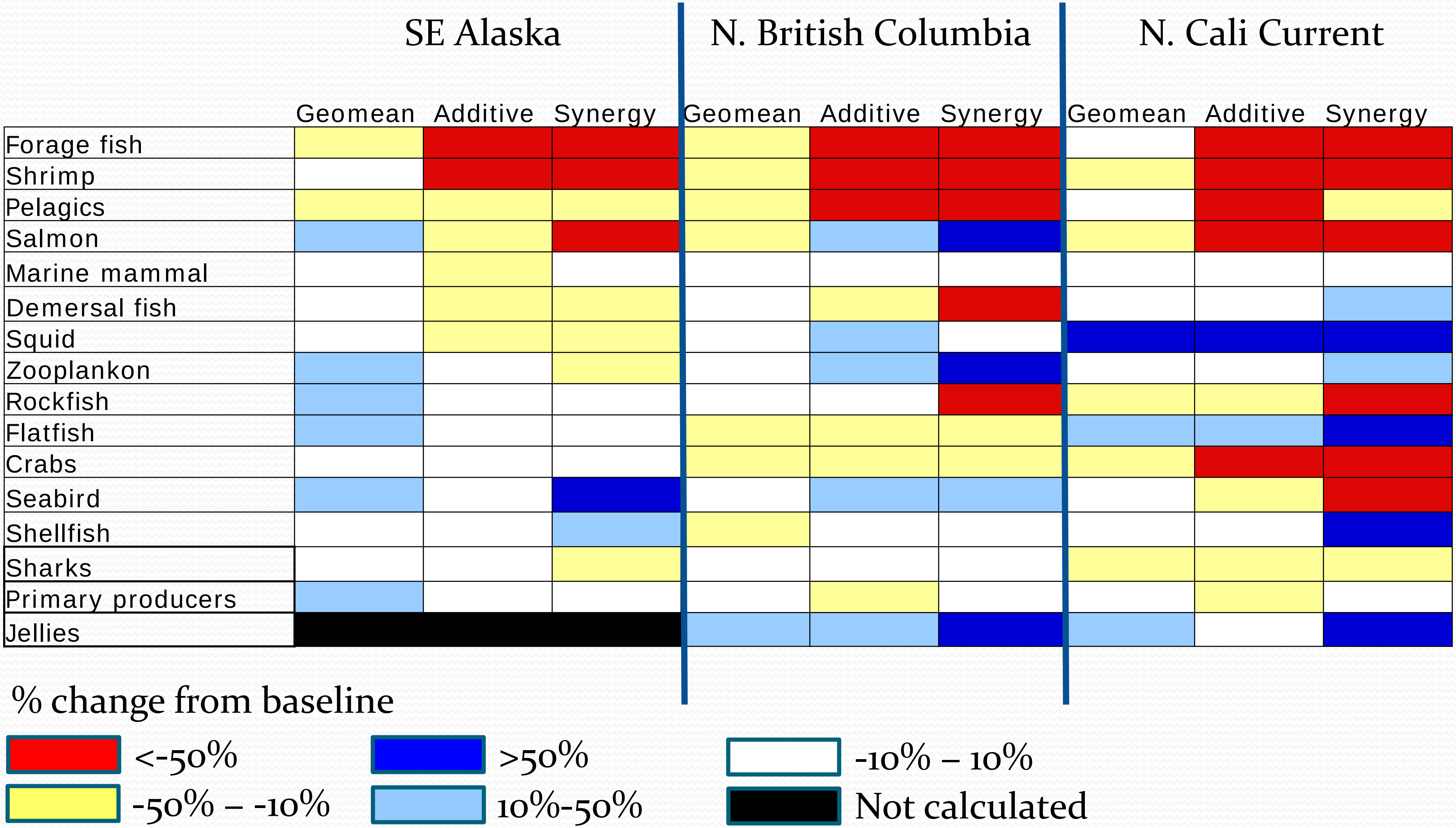
Cumulative effects



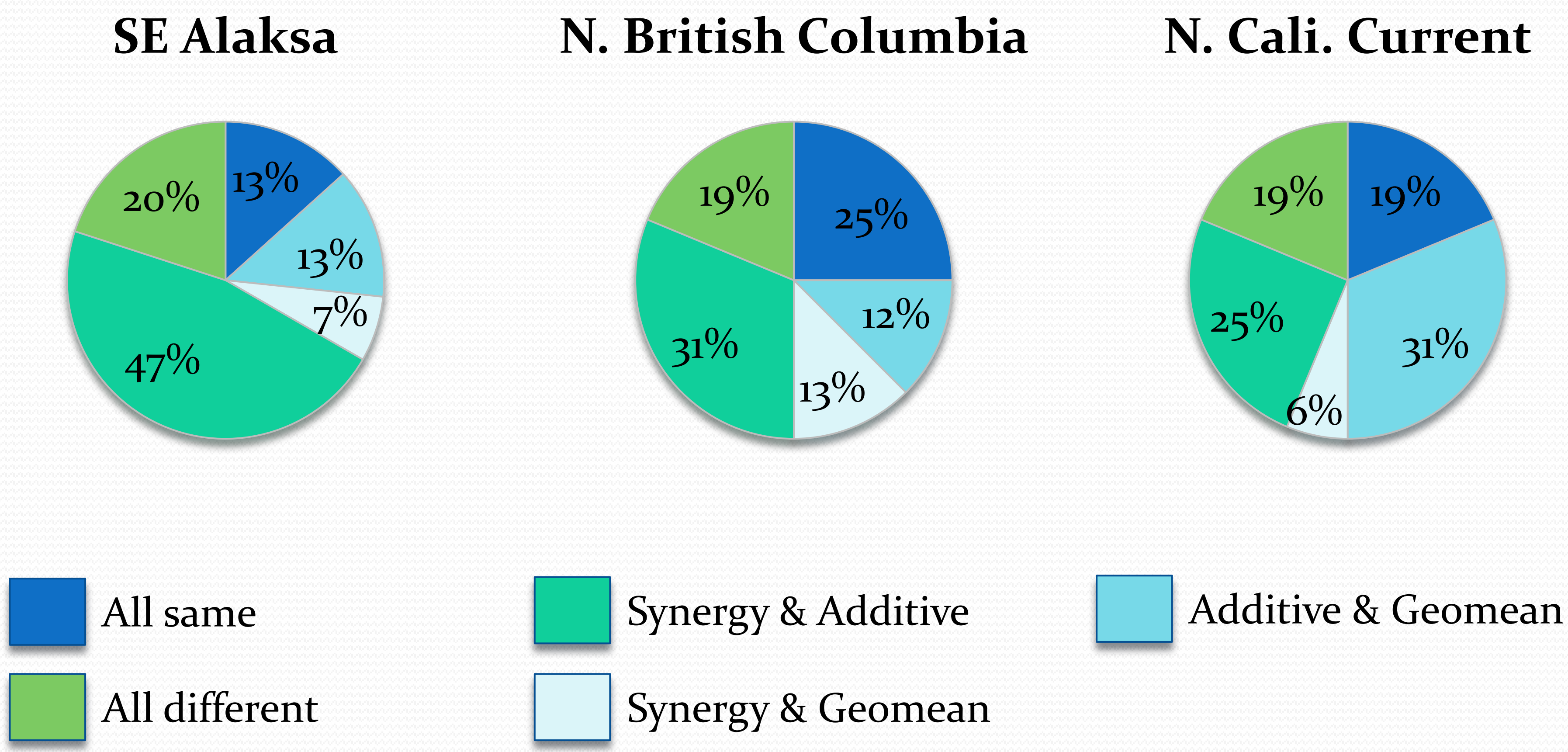
Diversity scores impacted by summation technique



(Dis)agreement among techniques on magnitude of change



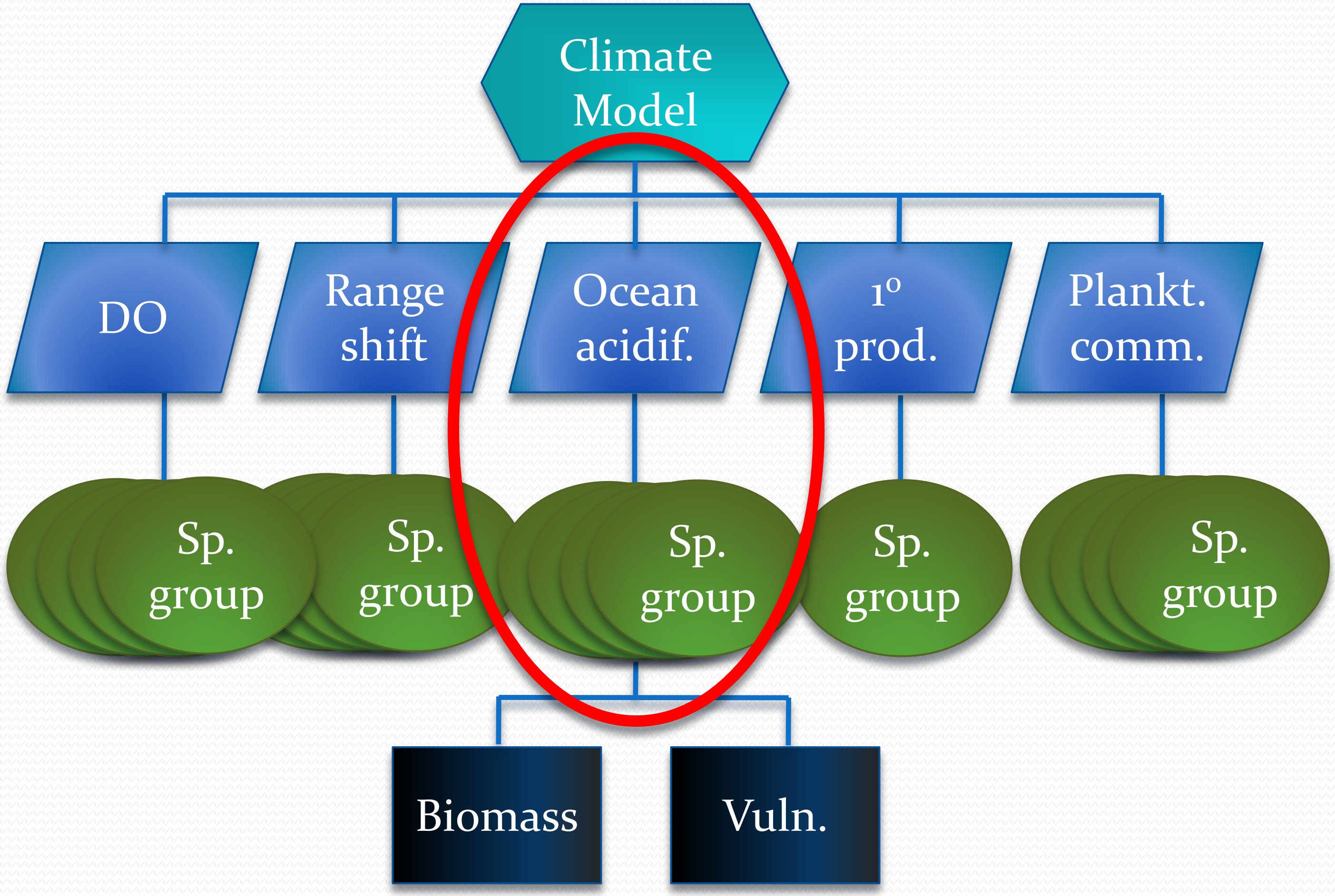
(Dis)agreement among techniques on magnitude of change



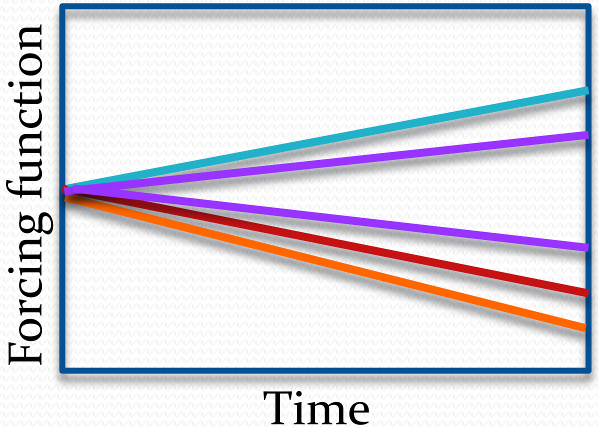
Process uncertainty

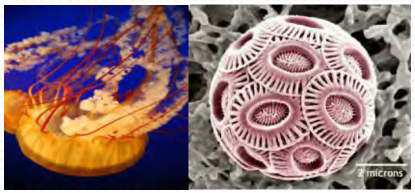
- Combinatorial techniques greatly affect magnitude of predicted change
- Agreement among techniques when results ranked is slightly better
- Must consider how well combination techniques capture physiological and population-level process of interest

Effect size uncertainty



Ocean acidification scenarios





Certain

Shrimp
Euphausiids
"Epifauna"
"Infauna"
"Carn. epibenthic inverts"

Uncertain – unidirection

Crabs
Copepods
"Infaunal detrital inverts"
"Epibenthic inverts"
"Carnivorous zooplankton"
"Small zooplankton"
Marine plants

Uncertain – multidirectional

Jellyfish
Phytoplankton
"Microzooplankton"
"Large zooplankton"

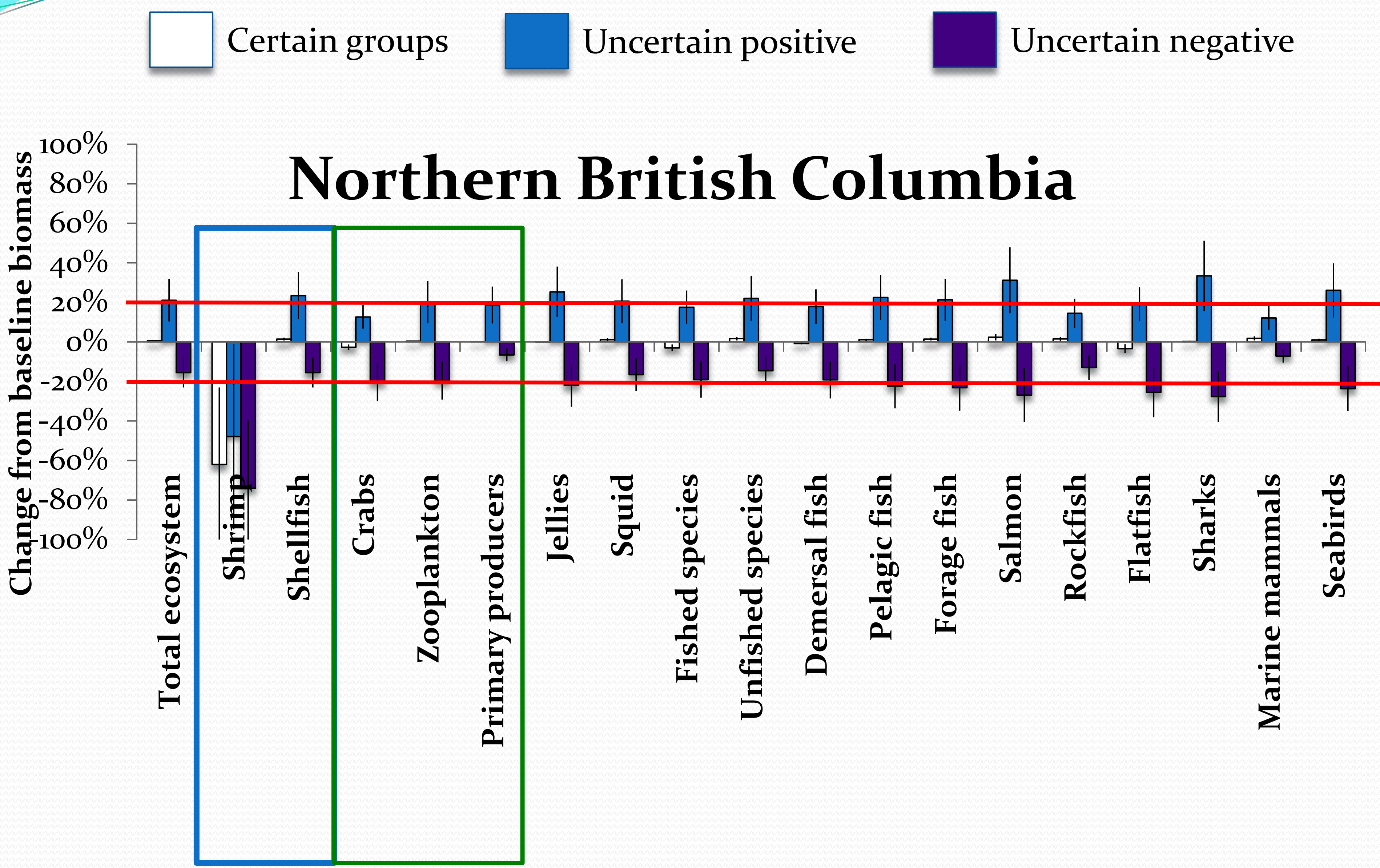
Busch et al., in prep.

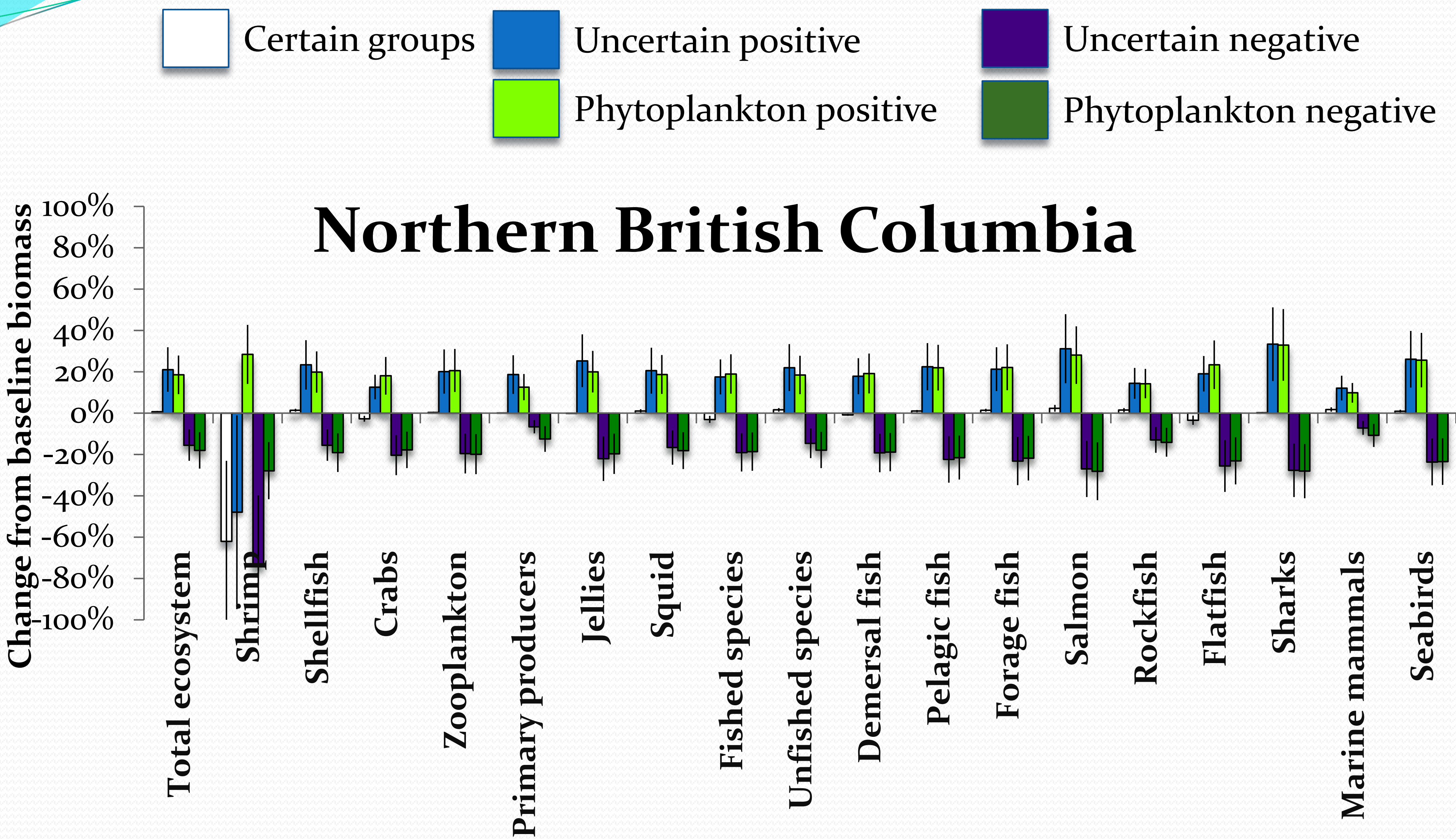
Ocean acidification scenarios

Linear change over 50 yrs.

	Climate scenario		
Effect size	Nominal	Moderate	Severe
Small	5%	10%	15%
Large	25%	50%	75%

Ainsworth et al., in review


Certain groups
Uncertain positive
Uncertain negative
Northern British Columbia
Change from baseline biomass
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Total ecosystem
Shrimp
Shellfish
Crabs
Zooplankton
Primary producers
Jellies
Squid
Fished species
Unfished species
Demersal fish
Pelagic fish
Forage fish
Salmon
Rockfish
Flatfish
Sharks
Marine mammals
Seabirds


Certain groups
Uncertain positive
Uncertain negative
Phytoplankton positive
Phytoplankton negative
Northern British Columbia
Change from baseline biomass
100%
80%
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40%
20%
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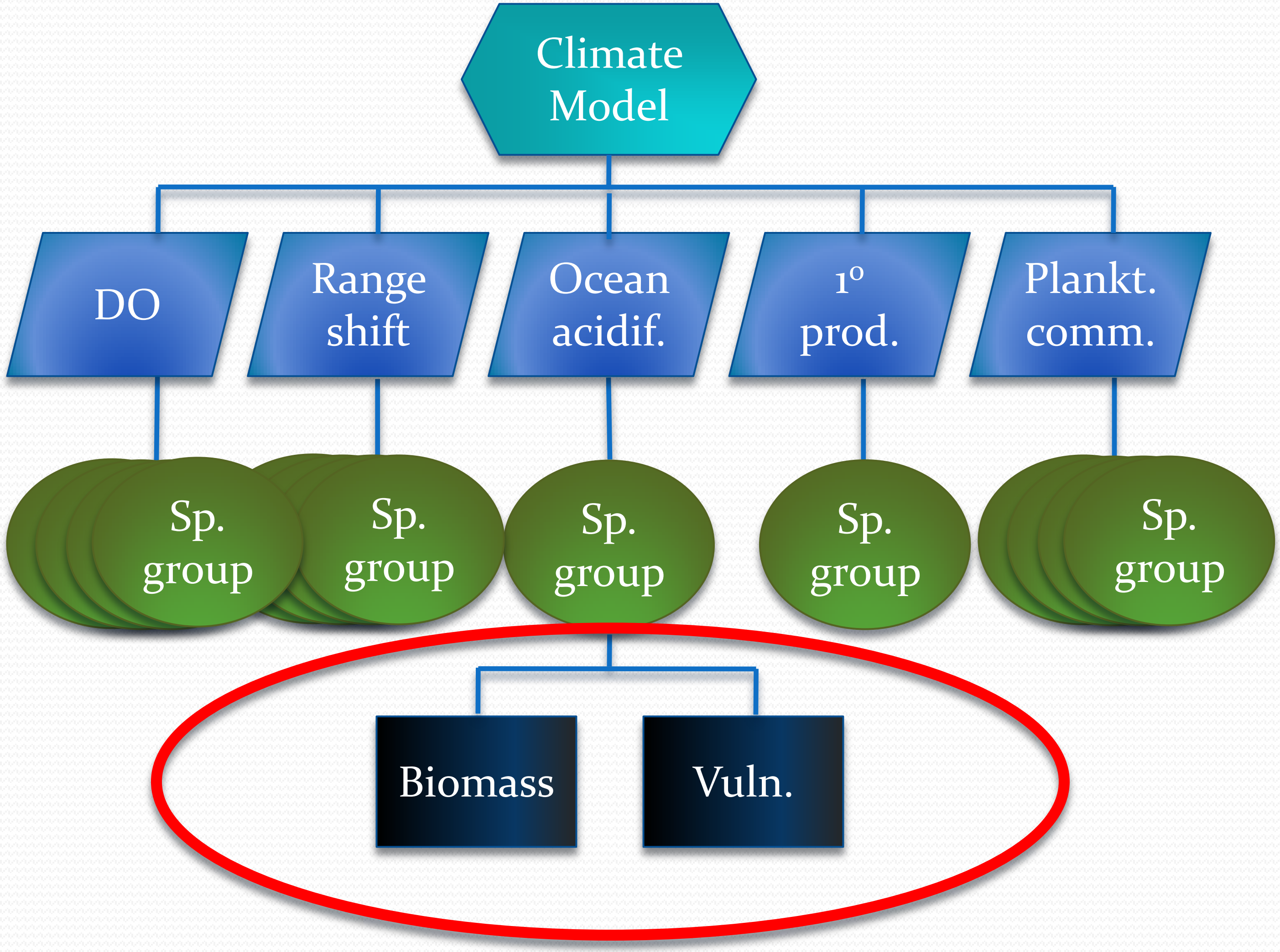
Pelagic fish
Forage fish
Salmon
Rockfish
Flatfish
Sharks
Marine mammals
Seabirds

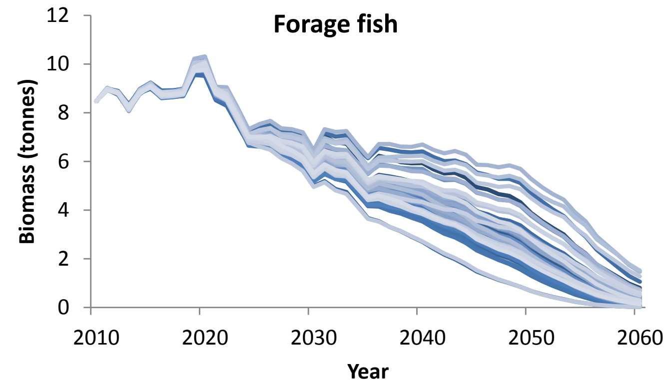
Effect size uncertainty

- Importance of understanding climate change impacts on primary producers
- Ecosystem impacts of change in non-primary producers can be dwarfed by change in primary producers

Parameter uncertainty



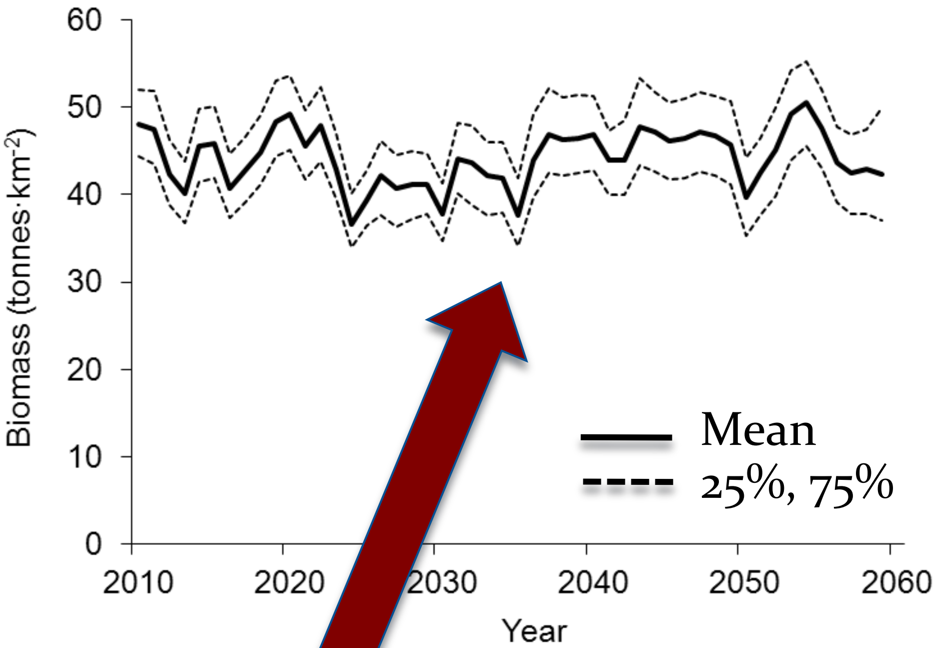
Monte Carlo methods



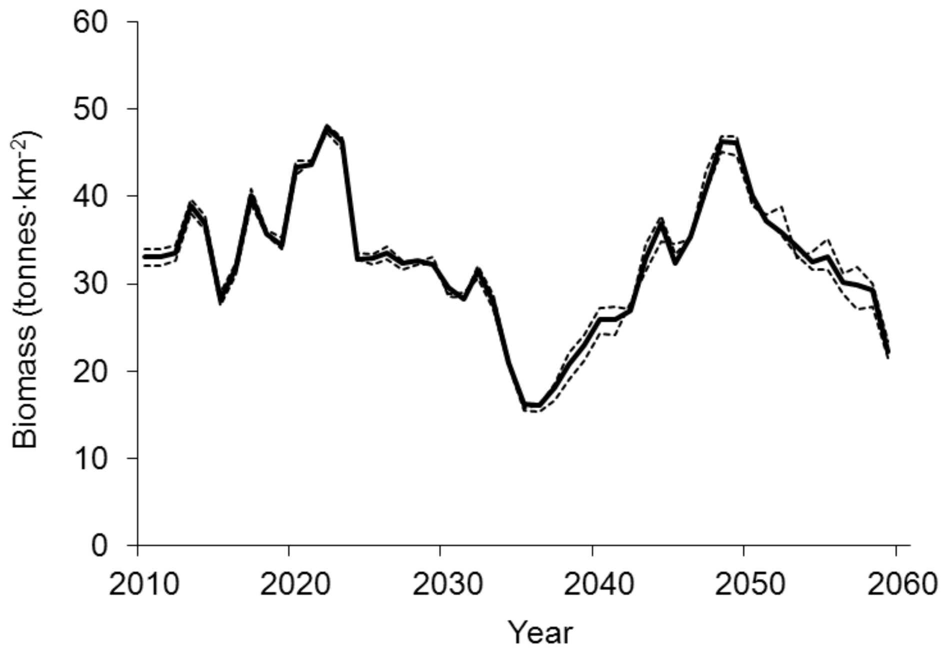
- Biomass
  - Ecopath with Ecosim Monte Carlo routine
  - Coefficient of variation dependent on functional group
    - 15% phytoplankton, zooplankton & benthic meiofauna
    - 5% all others
  - Uniform distribution, 200 trials
- Vulnerability
  - Manually implemented in Ecosim
  - Every predator-prey interaction varied independently
  - Coefficient of variation: 50% all groups
  - Uniform distribution, 200 trials
- Results: 1) functional group, 2) aggregated functional group

Monte Carlo results

Biomass Monte Carlo:
Southeast Alaska, benthic invertebrates



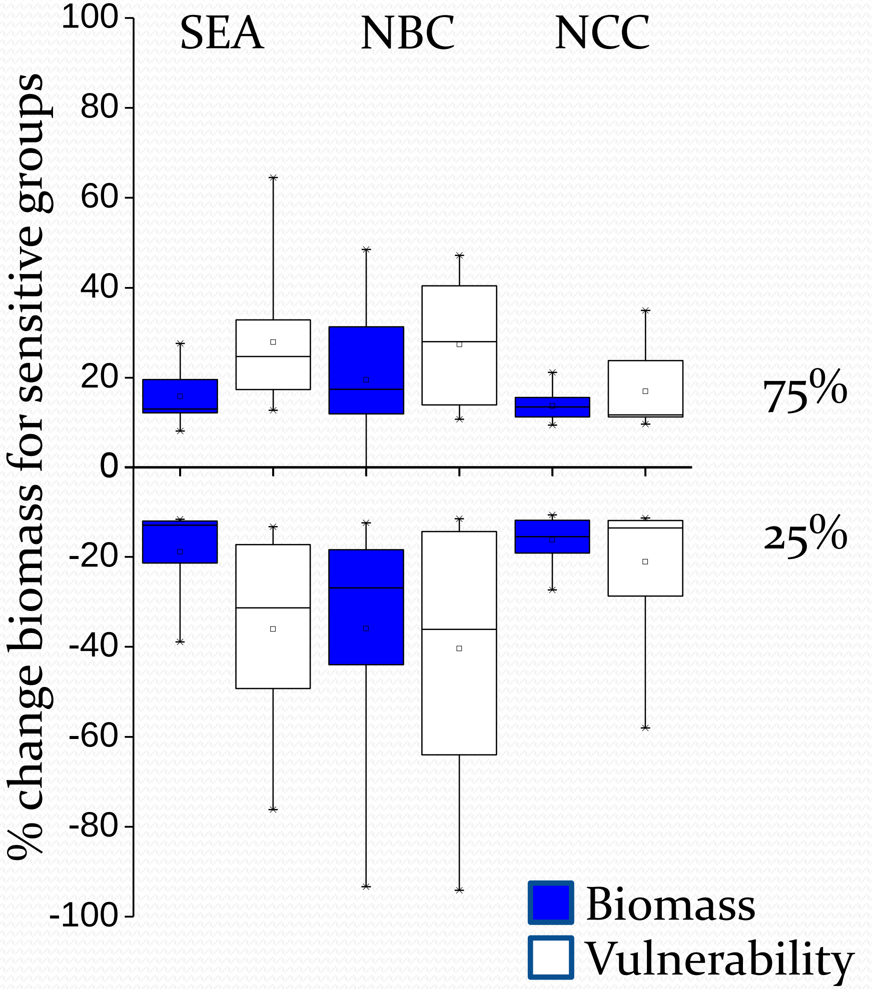
Biomass Monte Carlo:
N. Cali Current, small pelagic fish



Compounding impacts of trophic dynamics

Monte Carlo results

- About 30% of the functional groups and aggregated functional groups have >10% change in biomass
- Biomass change for vulnerability Monte Carlos less than forced variation
  - Magnitude of change
  - Number of groups



Sensitive functional groups: biomass change >10%

Functional groups

All models

Salmon
Pacific Ocean perch
Flatfish
Halibut
Crabs
Shrimp
Epifaunal inverts
Infaunal detritivores

2 models

Sharks
Forage fish
Herring
Rockfish
Pacific cod
Arrowtooth
Phytoplankton

Aggregated groups

All models

Benthic inverts

2 models

Large and small pelagics
Birds
Flatfish

1 model

Elasmobranches





Parameter uncertainty

- Knowing the biomass and vulnerability of some species groups matters more than others
- Sensitivity to biomass estimates is greater than to vulnerability estimates
- Sensitivity of specific functional groups to parameter uncertainty is fairly well captured in aggregated groups

Conclusions

- Modeling ecosystem impacts of multiple climate change impacts is messy
- Understanding how uncertainty impacts our results can help us target assumptions and data inputs that may matter most
- Recognize that modeling exercises tell us the **type of changes** we may expect, not the magnitude or the specific effects