Oregon State University
College of Earth, Ocean, and Atmospheric Sciences

NOAA FISHERIES

Modeling the multiple action pathways of projected climate change on the Pacific cod (*Gadus macrocephalus*) early life stages

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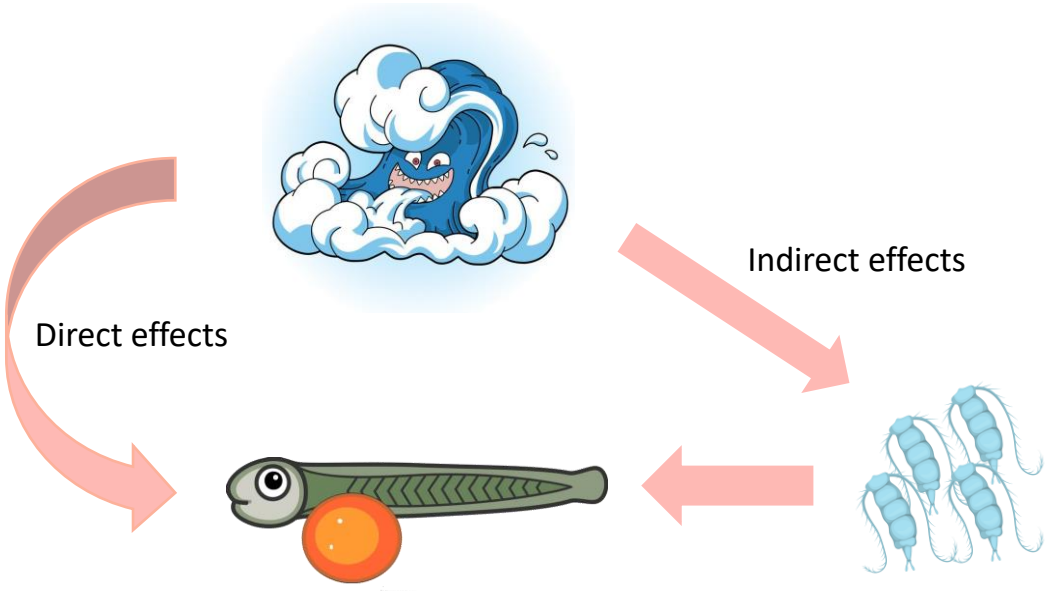
The Ocean in a High-CO_2 World
Ocean Acidification
An international science symposium series

Objective

Investigate the direct and indirect impacts of future ocean conditions on the early life stages of the Pacific cod in the eastern Bering Sea



How? Using a mechanistic model (IBM)

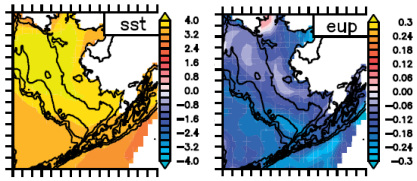
Two main sections:

1. **Hindcast period (2000-2020)**: tell us how bad or good our model is

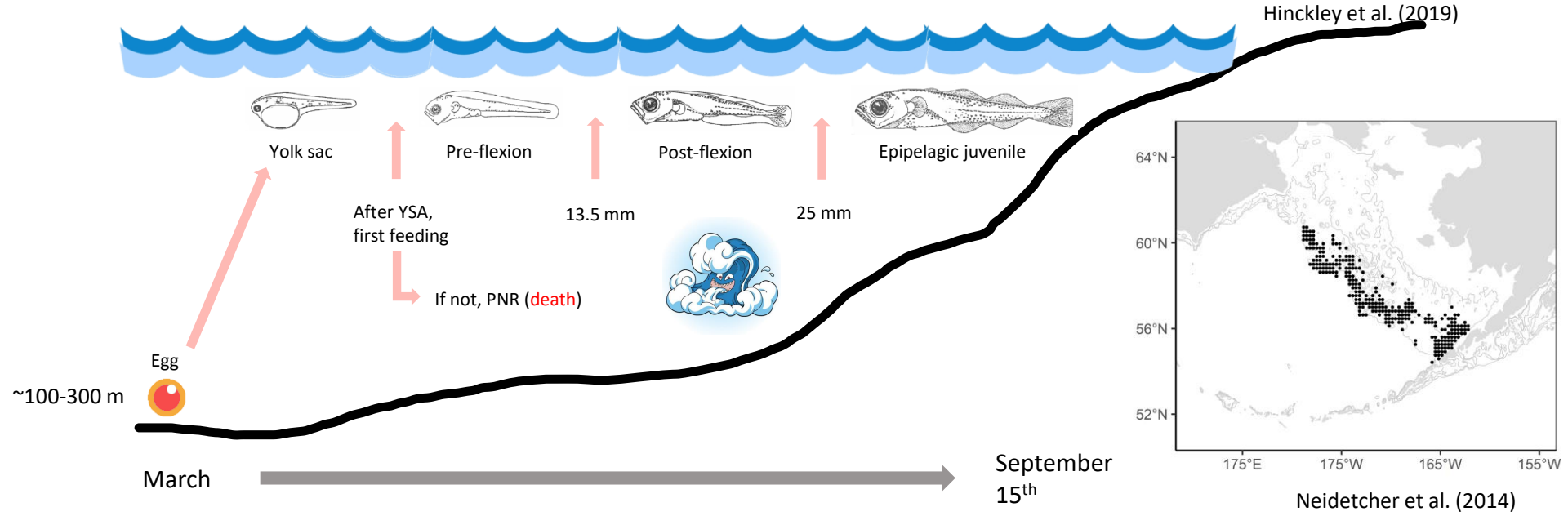
2. **Forecast period (2021-2100)**: possible future scenarios

Individual-based model (IBM)

3D input: Bering10K
(Kearney et al. 2020)



- IBM: DisMELS (Cooper et al., 2013; Gibson et al., 2019; Hinckley et al., 2019; Stockhausen et al., 2019b, 2019a)
- Eggs released from spawning (initial) locations
- Fish variables were calculated every hour

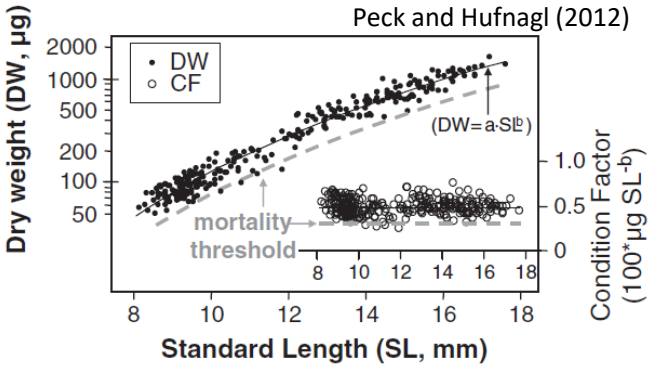


Individual-based model (IBM)

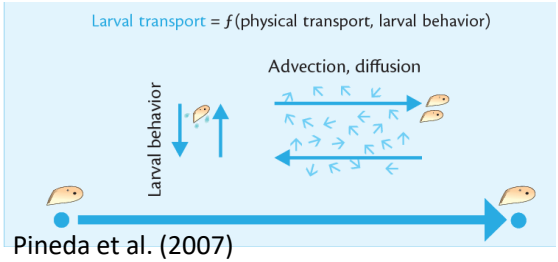
A particle was considered dead:

1. Starvation:
    - Reached the point-of-no-return (PNR)
        - Critical to pass from the YSL to FDL
    - Poor body condition (low growth performance index)

Peck and Hufnagl (2012)



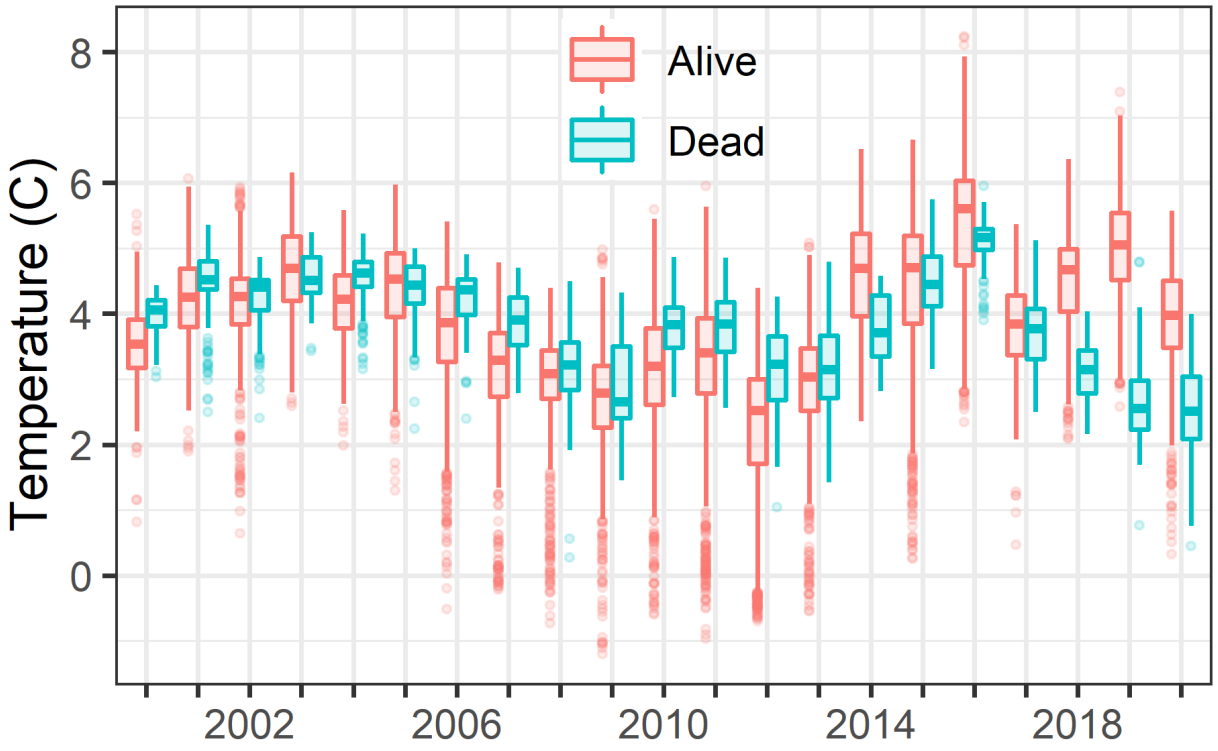
2. Advected out of the EBS



Pineda et al. (2007)

Results (hindcast)

Average temperature perceived by particles throughout their lifespan:

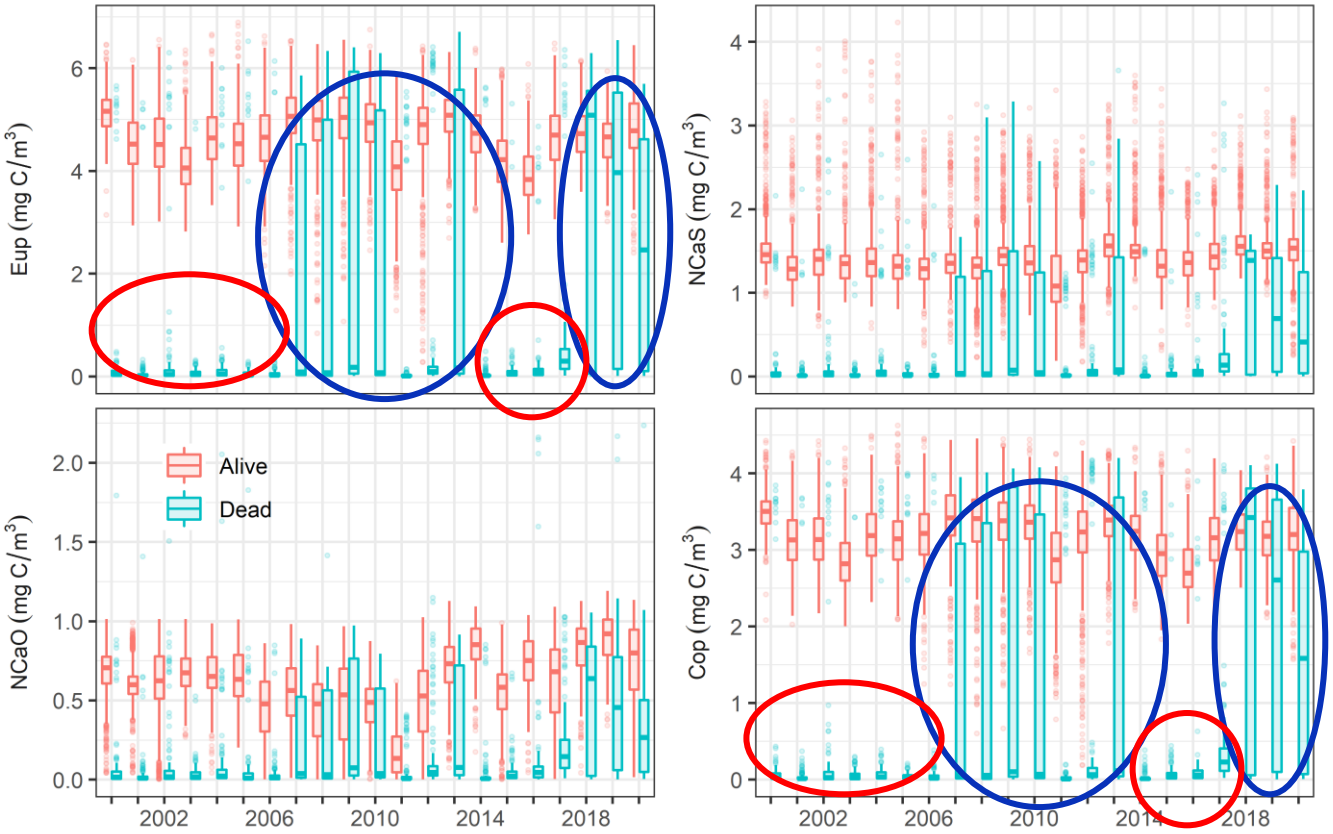


Alive particles lived in a slightly cooler environment until 2015.

Opposite pattern observed after 2015.

Results (hindcast)

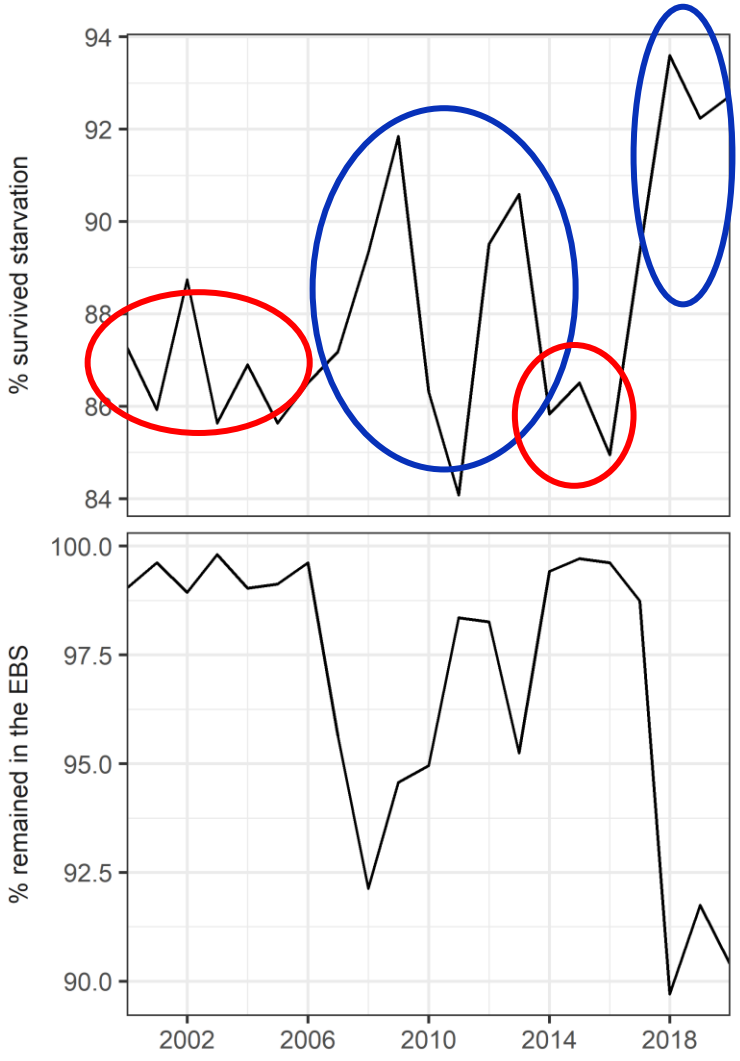
Average prey densities perceived by particles throughout their lifespan:



Alive particles lived in areas with higher prey density

Prey abundance in the environment well correlated with stanzas in the EBS

Results (hindcast)

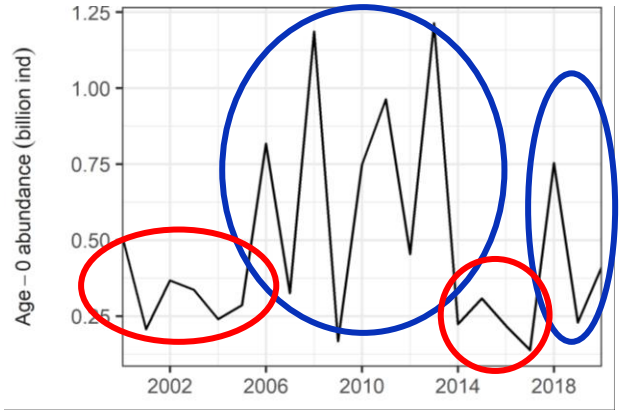


% particles that remained in the EBS negatively correlated with % particles that survived starvation

Is any of them a good recruitment index?

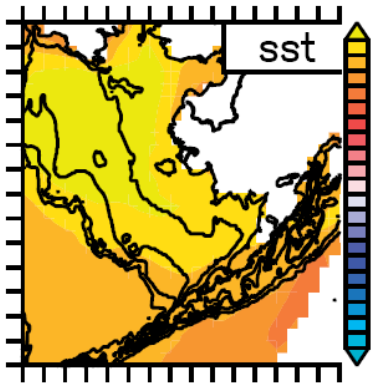
% particles that survived starvation might give signals of recruitment variability

Recruitment estimates from stock assessment model:

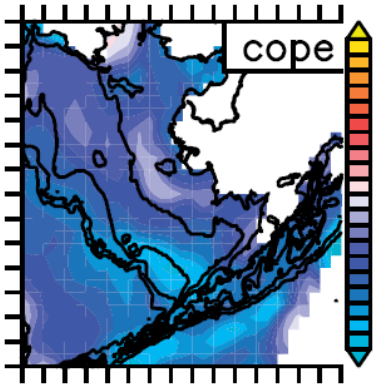


Eastern Bering Sea: future changes

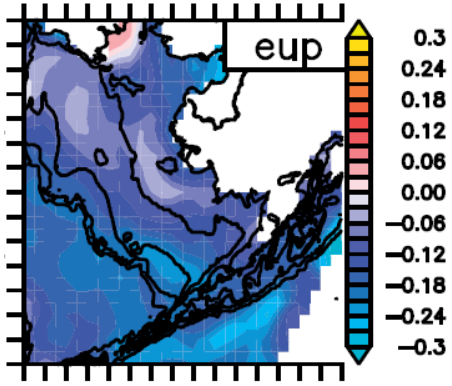
Surface temperature



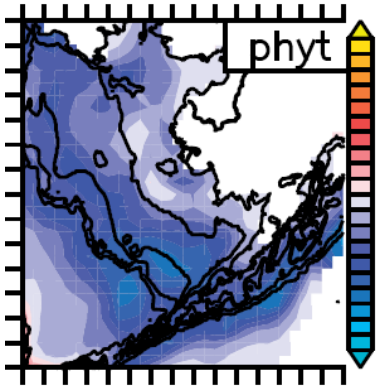
Small-bodied copepods



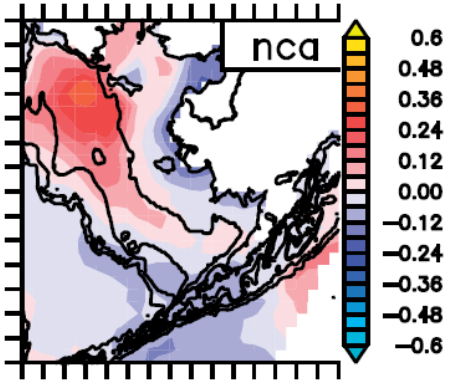
Euphausiids



Phytoplankton



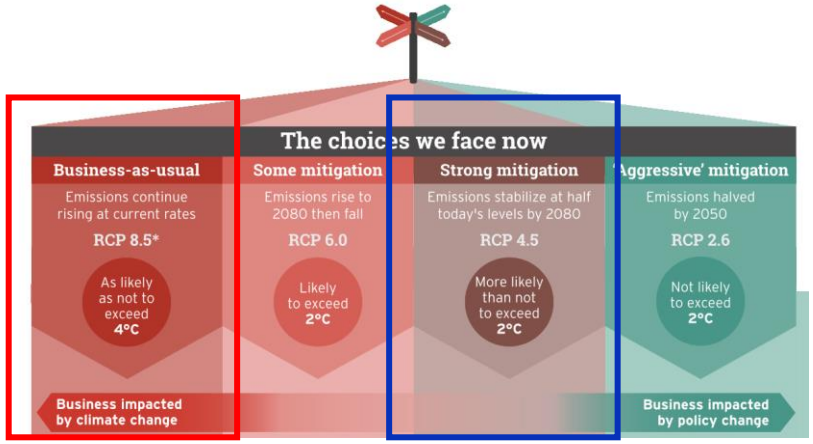
Large-bodied copepods



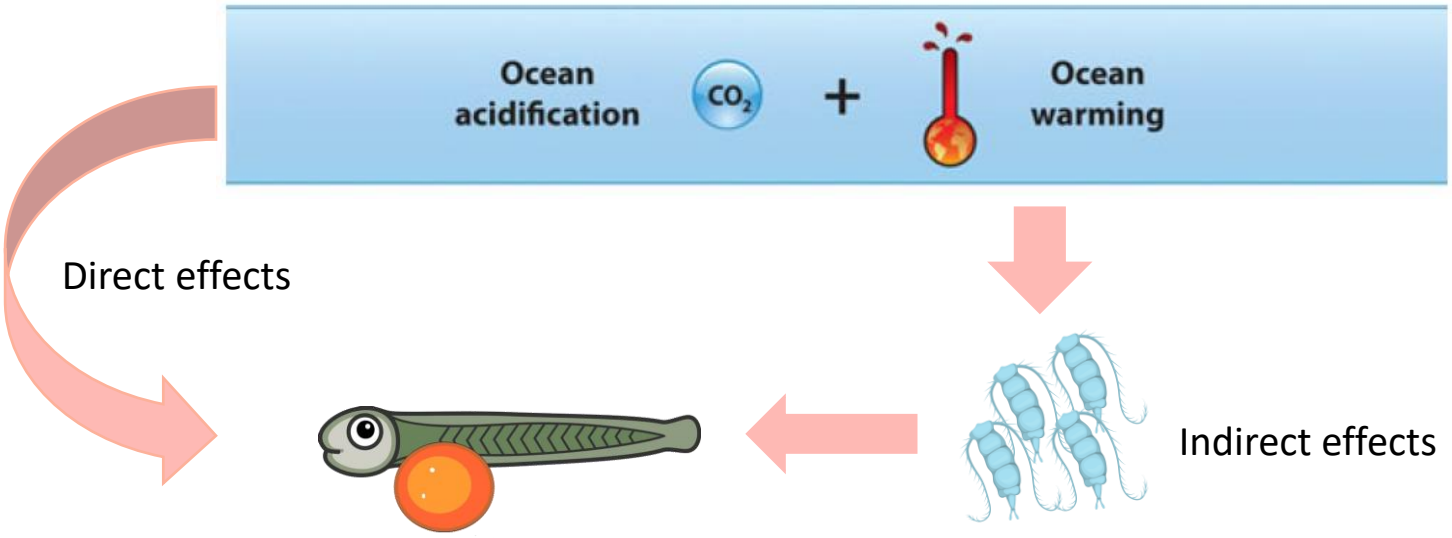
Hermann et al. (2019)

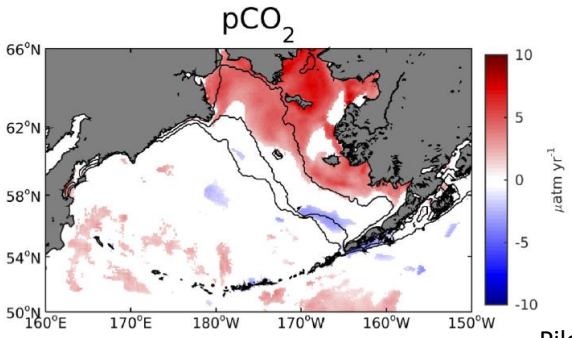
Decadal average change between 2010-2019 and 2090-2099 (RCP8.5) (CMIP5)

… and other environmental variables



Ocean acidification impacts on fish larvae



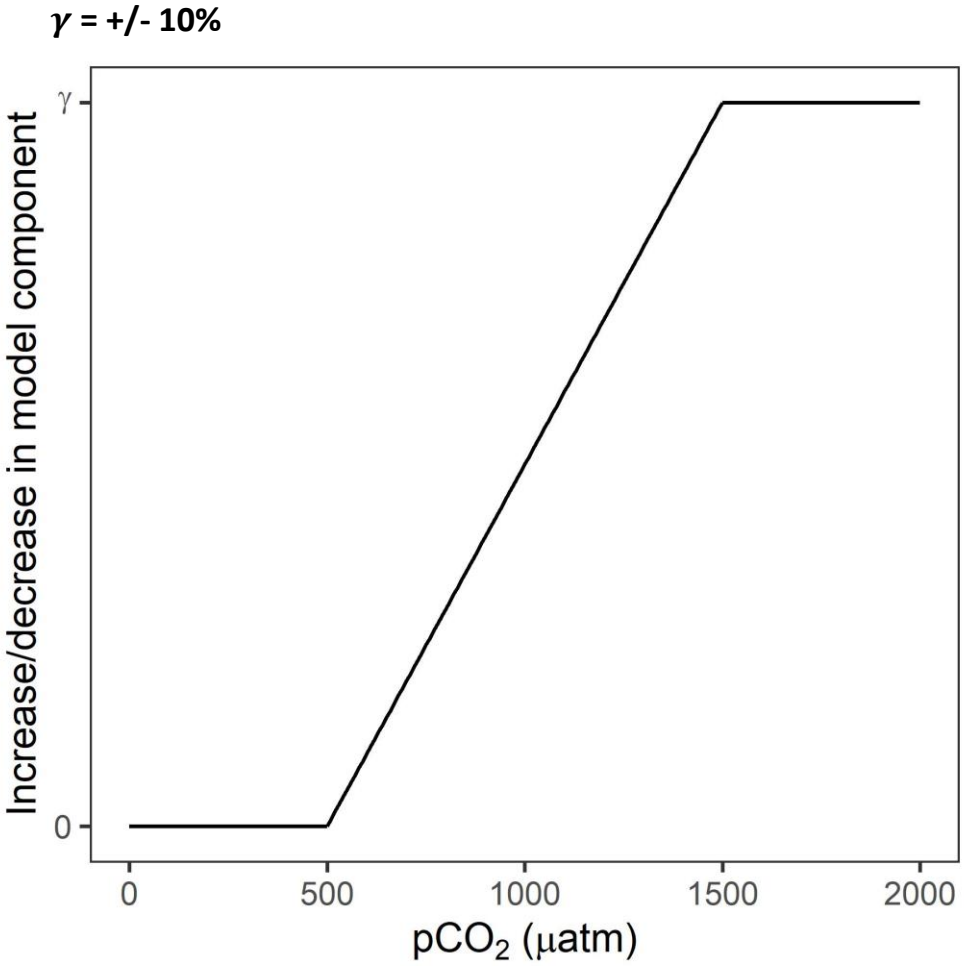


Pilcher et al. (2019)

Impacts of ocean acidification

From laboratory studies on Pacific cod and other gadids in similar ecosystems:

1. Growth rate (*direct*)
2. Metabolism (*direct*)
3. Probability of prey-capture success (*direct*)
4. Prey abundance (*indirect*)
5. Prey weight (*indirect*)

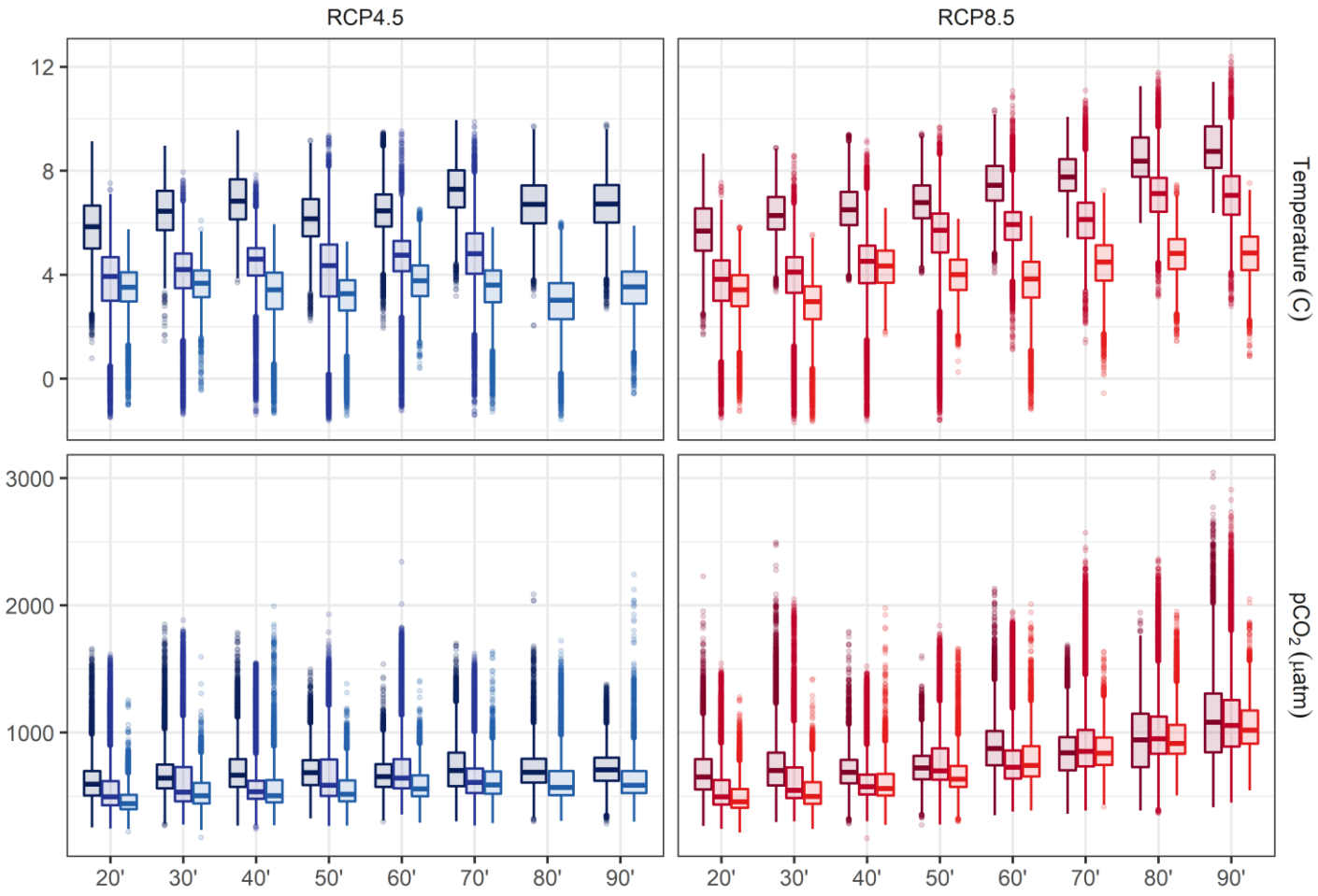


Results (forecast)

Average temperature and pCO_2 perceived by particles throughout their lifespan (alive + dead):

Most extreme scenario: MIROC

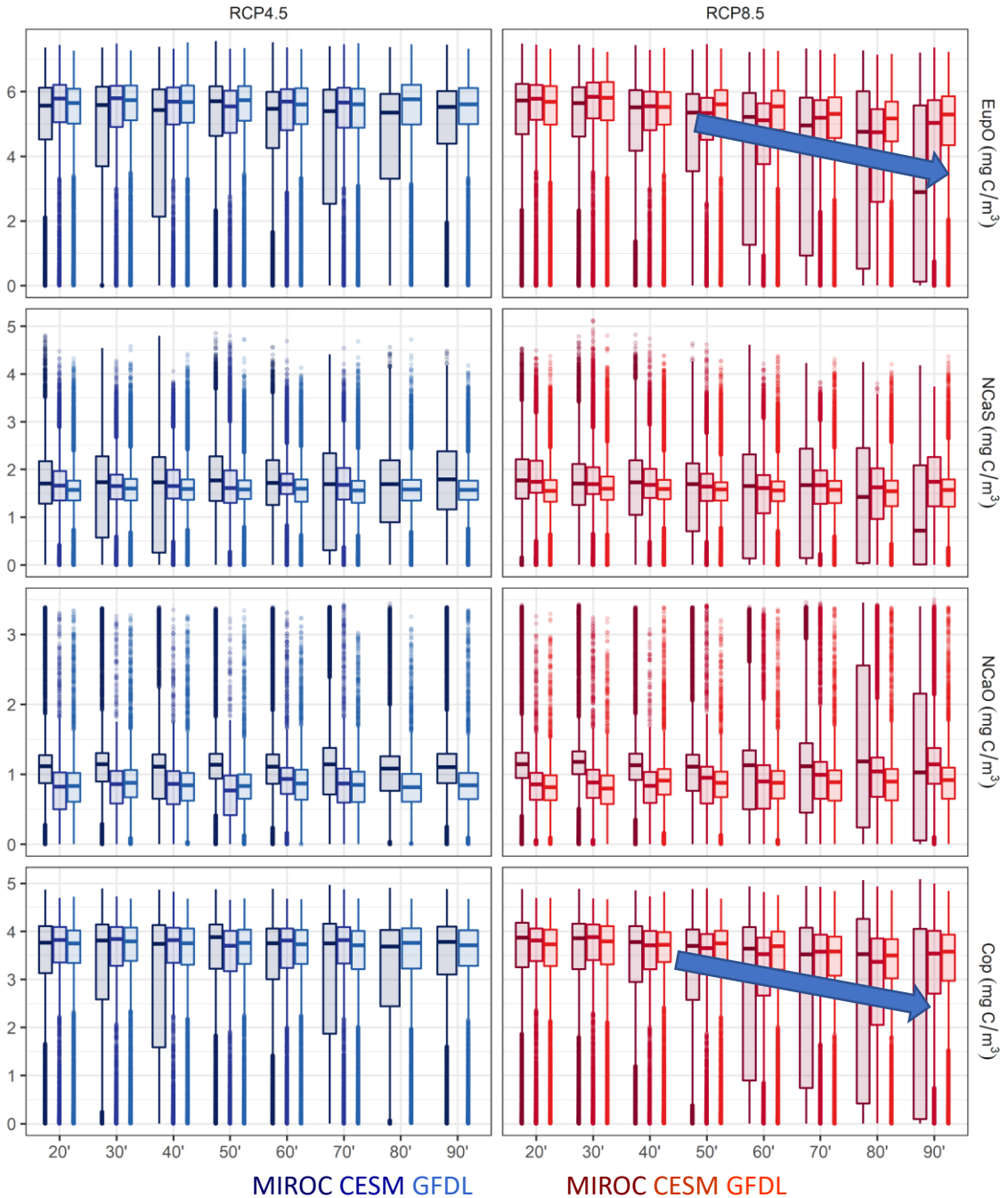
Less extreme scenario: GFDL



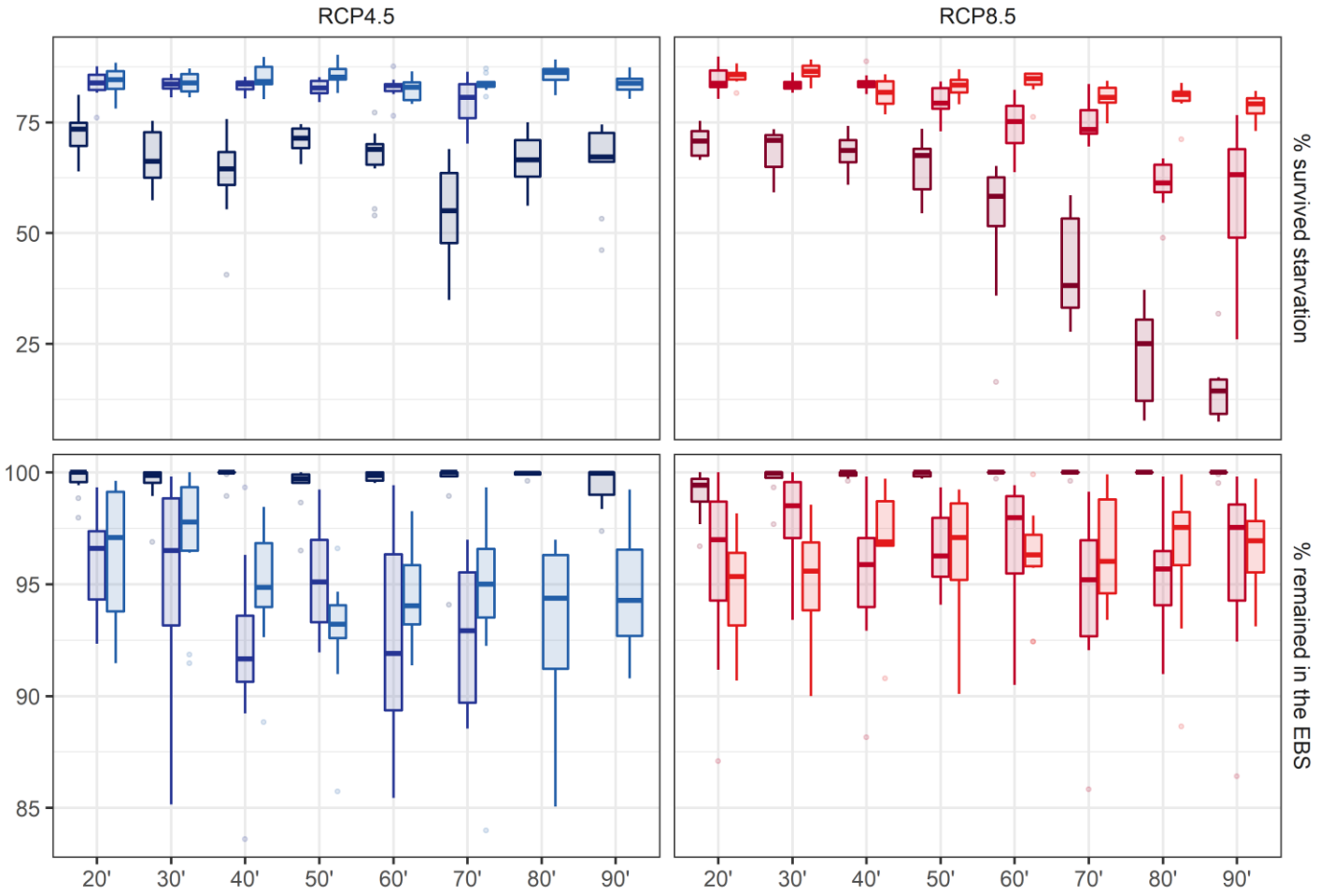
Results (forecast)

Average prey densities perceived by particles throughout their lifespan (alive + dead):

Severe decline in prey abundance under the RCP8.5 scenario.



Results (forecast)



Dramatic decrease!

Future decrease in prey abundance is the trigger

Future decrease in recruitment? Clear reduction under RCP8.5

MIROC CESM GFDL

MIROC CESM GFDL

Results (forecast)

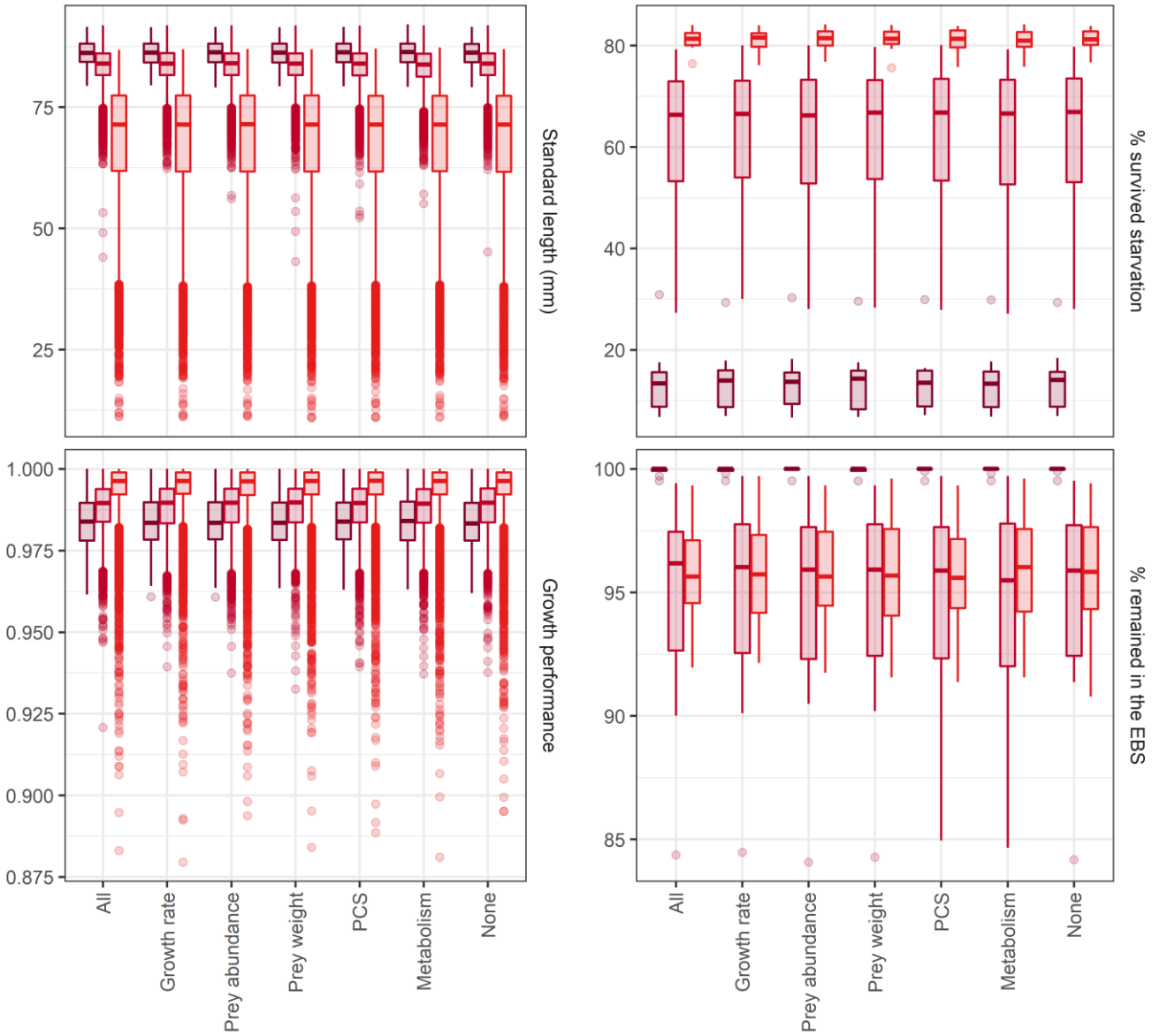
Strong assumptions on the impacts of OA on several components of the model. What are their individual impacts?

2090 decade, only RCP8.5:

Conclusion:

No significant impacts of ocean acidification on the analyzed variables.

Pacific cod might not be impacted by OA (?)



MIROC CESM GFDL

Thanks for listening!

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