The trophic Amplification revealed : an Inter-model comparison study

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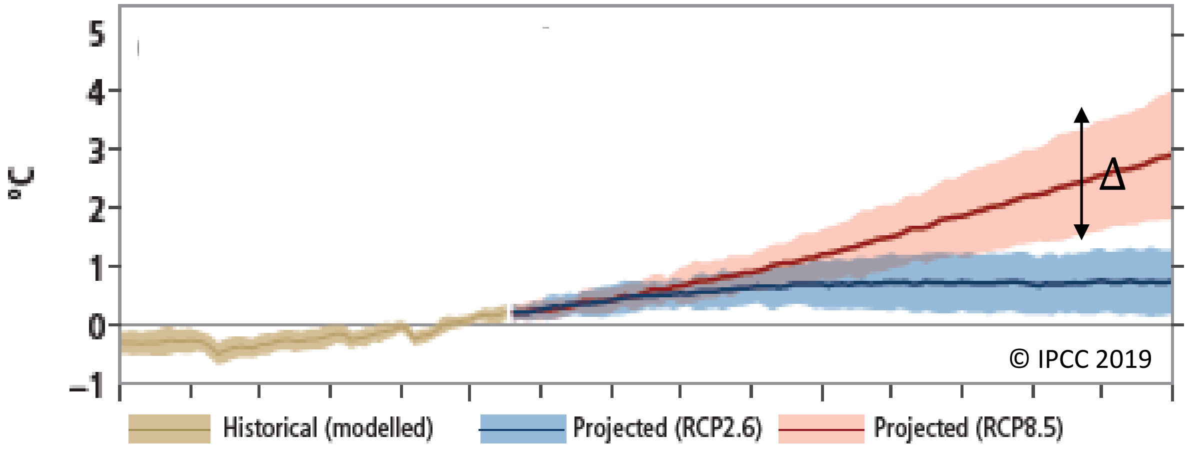
Virginie BORNAREL
Colaboration : Pr. William CHEUNG

Climate change effects on marine food web

Global mean sea surface temperature

Change relative to 1986-2005



Sea temperature increase

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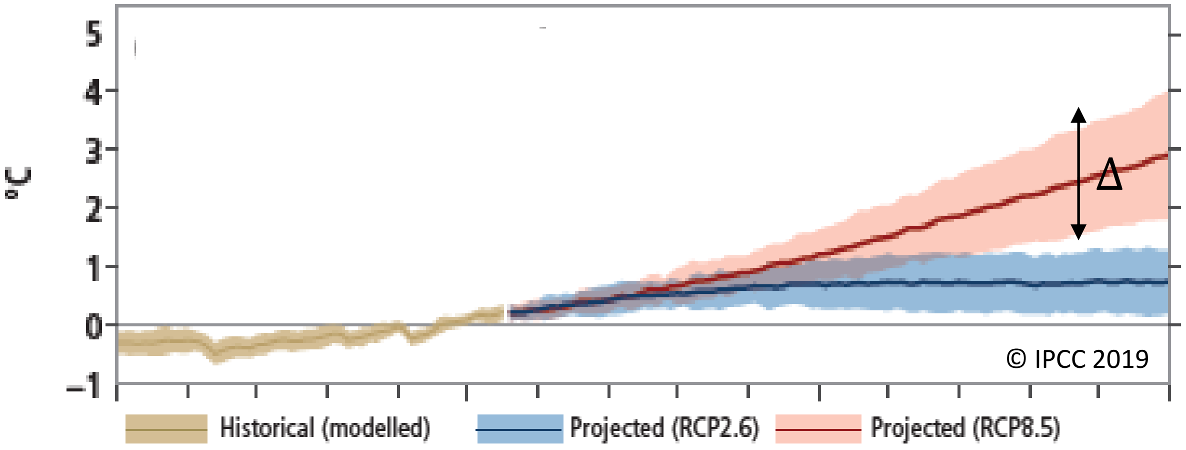
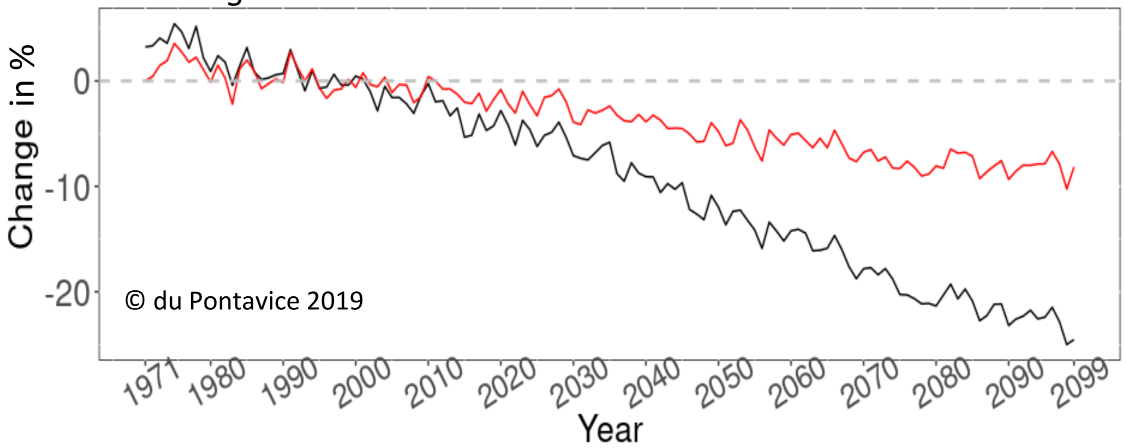
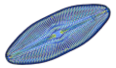


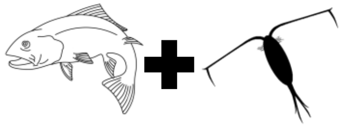
Sea temperature increase

Global mean primary production and biomass

Change relative to 1986-2005



Primary production  **overall decrease**

Biomass  **stronger decrease**

Climate change effects on marine food web

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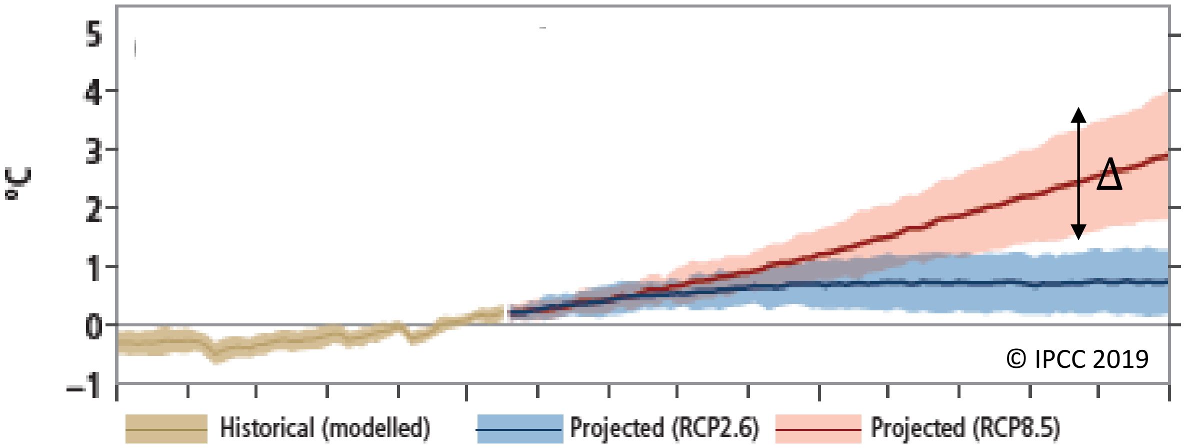

Sea temperature increase

Global mean primary production and biomass

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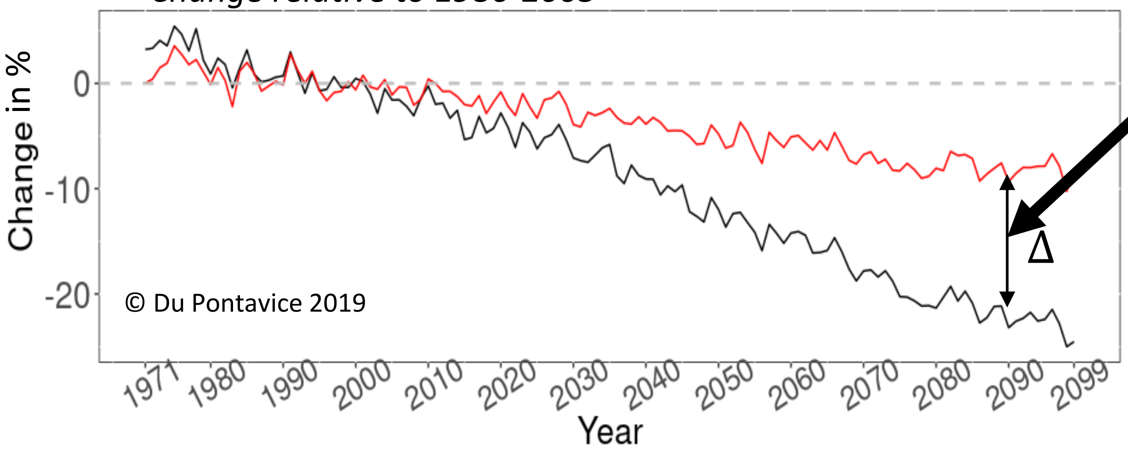
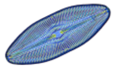
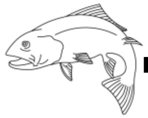


Trophic amplification

Primary production  **overall decrease**

Biomass  ✚  **stronger decrease**

Scientific question: repercussions/consequences of climate–induced NPP changes on biomass?

- What will be the temporal dynamics and spatial distribution of biomass responses?

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Challenges

- Ecological : Changes in ecosystem structure & functioning
- Fisheries : Impact on catch potential

What will be the temporal dynamics and spatial distribution of biomass responses?

Material & Method

Temporal dynamics and spatial distribution of biomass responses

2 climate models (Earth System Models)

NPP **Temperature**

- IPSL
- GFDL

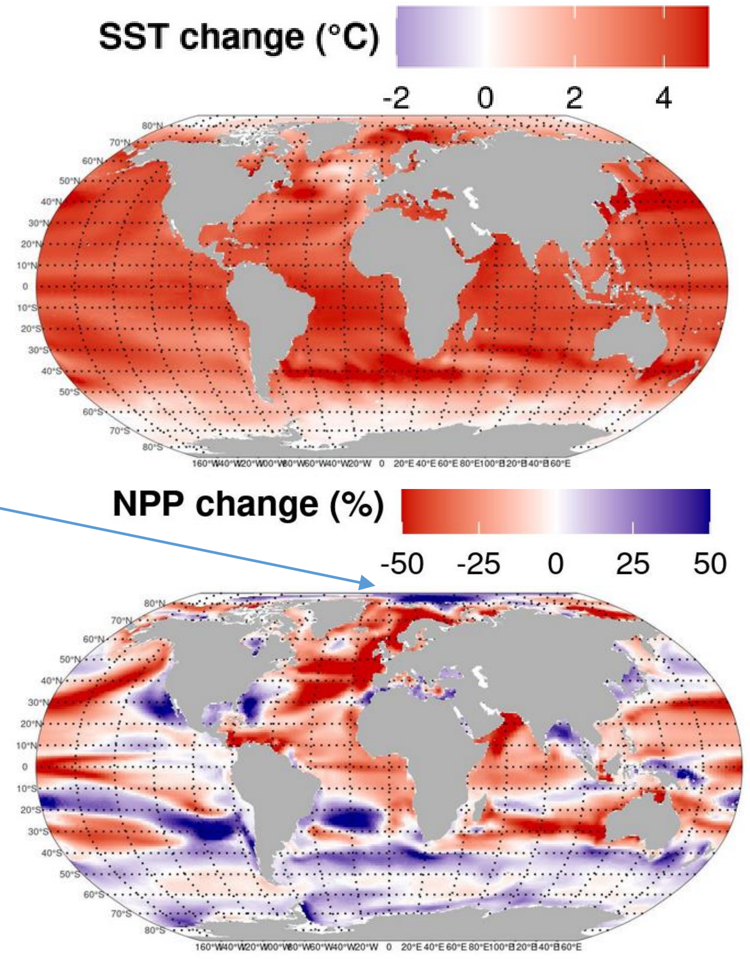
Material & Method

Temporal dynamics and spatial distribution of biomass responses

IPSL RCP8.5

2 climate models (Earth System Models)

NPP Temperature



2090-2099 relative to 1986-2005

- Spatial Resolution : 1°x1° cell (~40,000 cells)
- Time resolution : period 1970-2099
- Climate scenario:
  - RCP8.5 ("no mitigation" policy)

Material & Method

Temporal dynamics and spatial distribution of biomass responses

IPSL RCP8.5

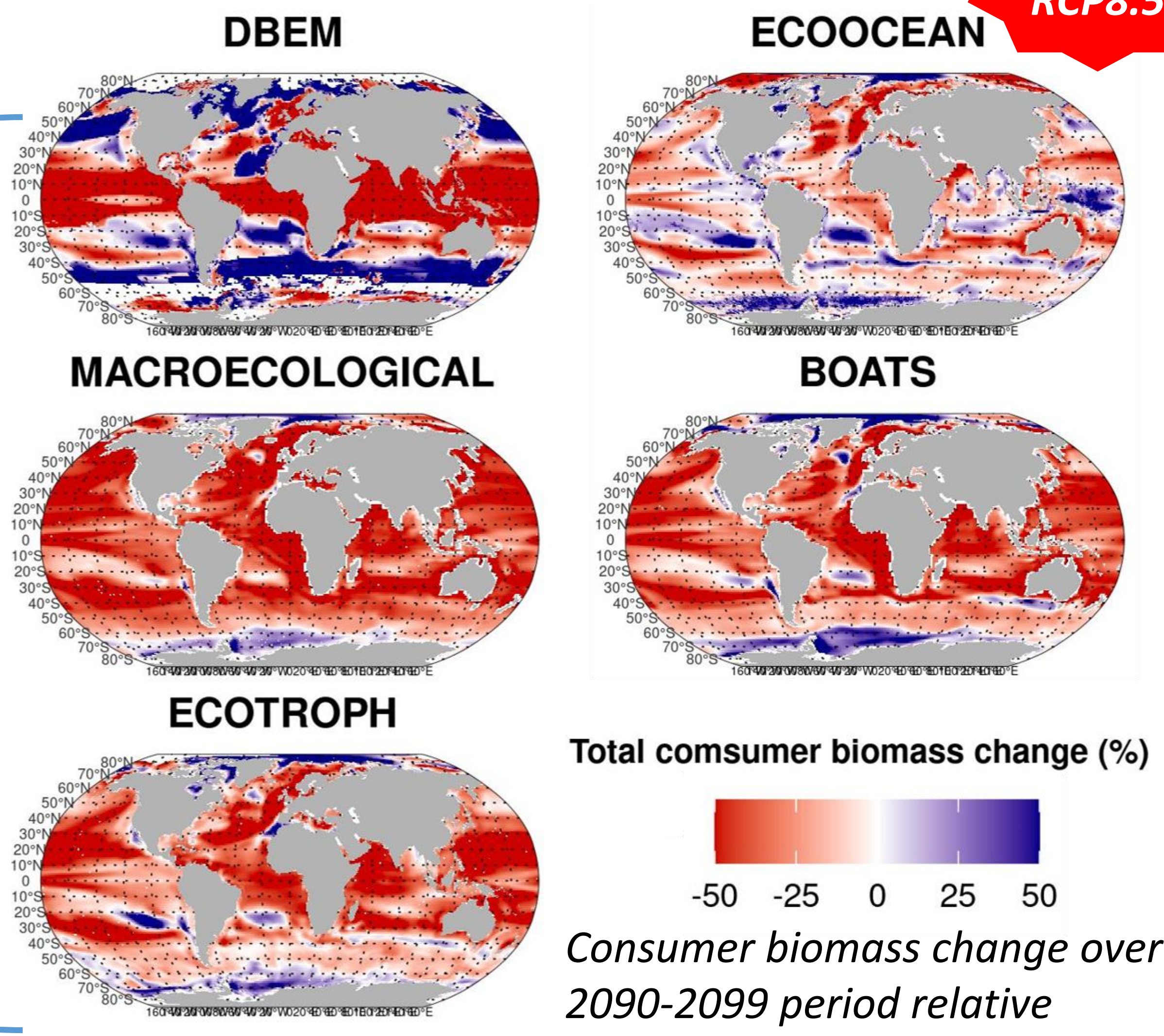
2 climatic models (Earth System Models)

NPP | Temperature

7 marine ecosystem models

Consumer biomass (TL>2)

- Spatial Resolution of 1°x1° cell (~40000 cells)
- For period 1970-2099
- Climate scenario:
  - ➢ RCP8.5



Consumer biomass change over 2090-2099 period relative to 1986-2005

Material & Method **Temporal dynamics and spatial distribution of biomass responses**

2 climatic models (Earth System Models)

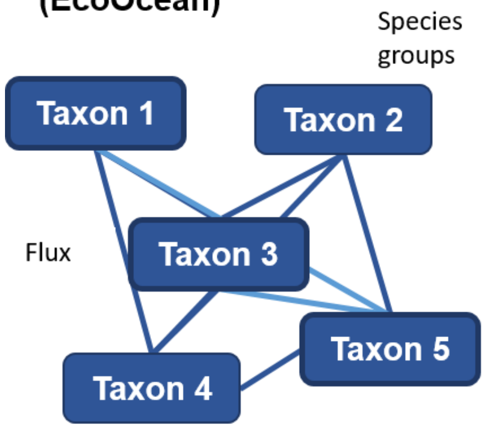
NPP | **Temperature**

7 marine ecosystem models

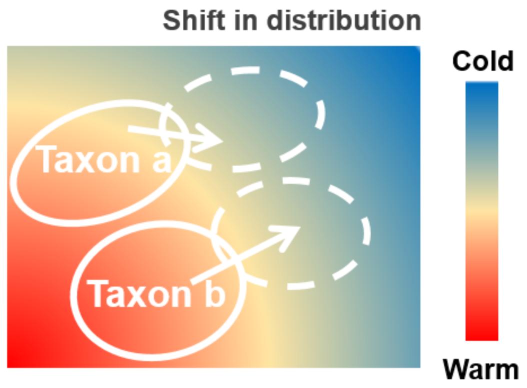
Consumer biomass (TL>2)

- Variable complexity and ecological approach:
  - ✓ Biological processes represented
  - ✓ Representation of biota
  - ✓ Interaction with environment

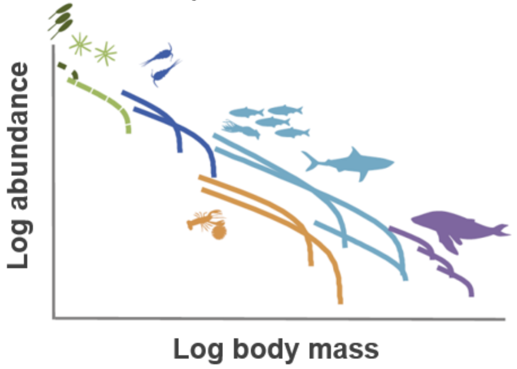
Trophodynamic model (EcoOcean)



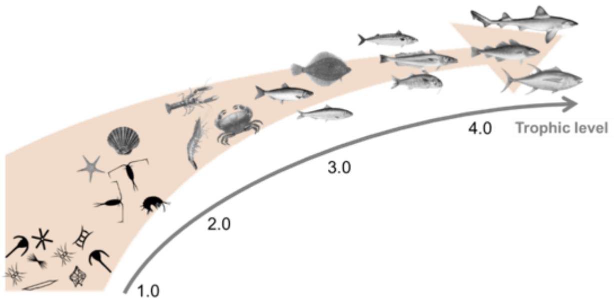
Species distribution model DBEM



Size-structure model (Macroecological & BOATS et DBPM)



Trophic level-based model EcoTroph



Material & Method

Temporal dynamics and spatial distribution of biomass responses

2 climatic models (Earth System Models)

NPP | Temperature

↓

7 marine ecosystem models

Consumer biomass (TL>2)

↓

$$Biomass\ change_{y,i} = \frac{Biomass_{y,i} - Biomass_{1986-2005,i}}{Biomass_{1986-2005,i}}$$

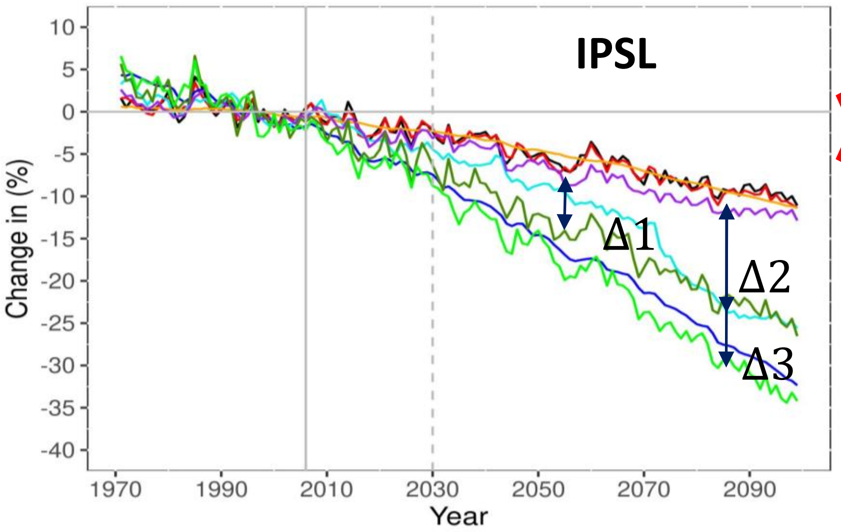
&

$$Net\ Primary\ Production\ change_{y,i} = \frac{NPP_{y,i} - NPP_{1986-2005,i}}{NPP_{1986-2005,i}}$$

Temporal dynamics and spatial distribution of biomass responses

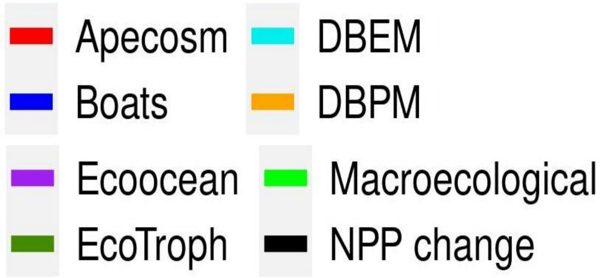
Result 1 **Temporal dynamics**

- Loss of primary production
- Greater loss of consumer biomass
- IPSL : -10% NPP change
  → Total consumer biomass change $\in [-15\%; -35\%]$



RCP8.5

Biomass and NPP relative change relative to 1986-2005



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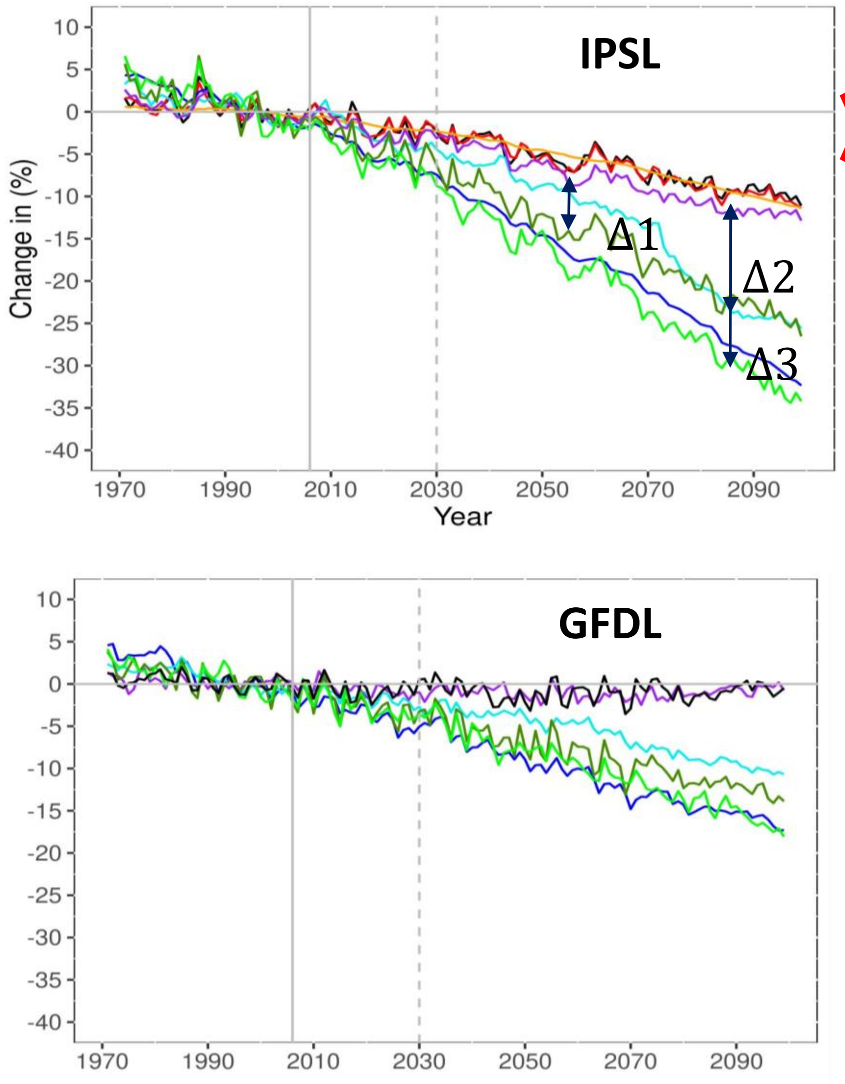

RCP8.5

Biomass and NPP relative change relative to 1986-2005

Apecosm, DBEM, Boats, DBPM, Ecoocean, Macroecological, EcoTroph, NPP change

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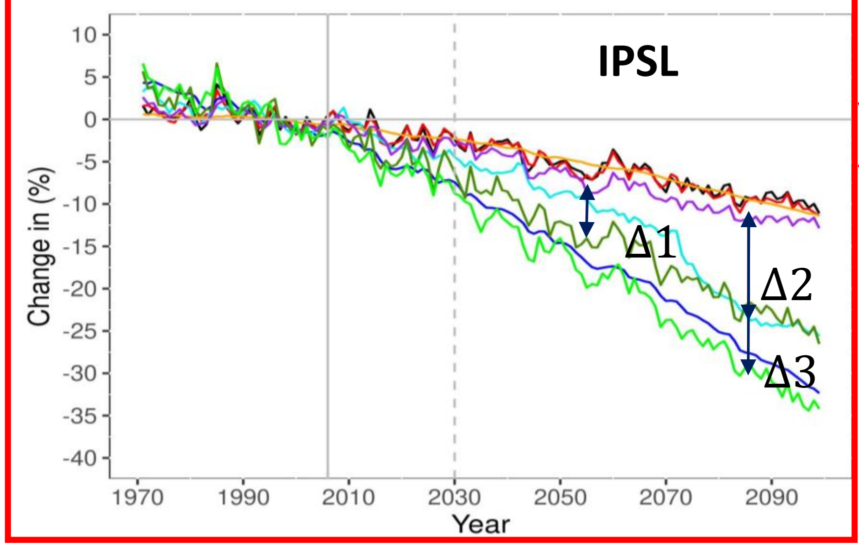

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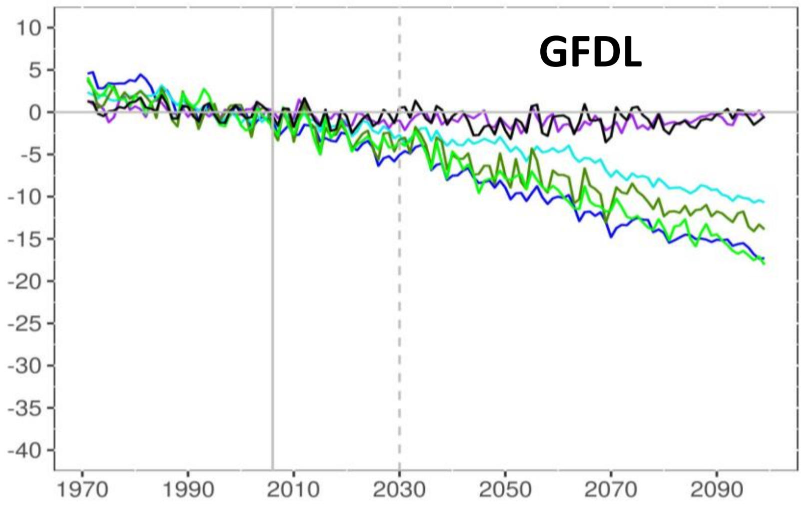

Biomass and NPP relative change relative to 1986-2005

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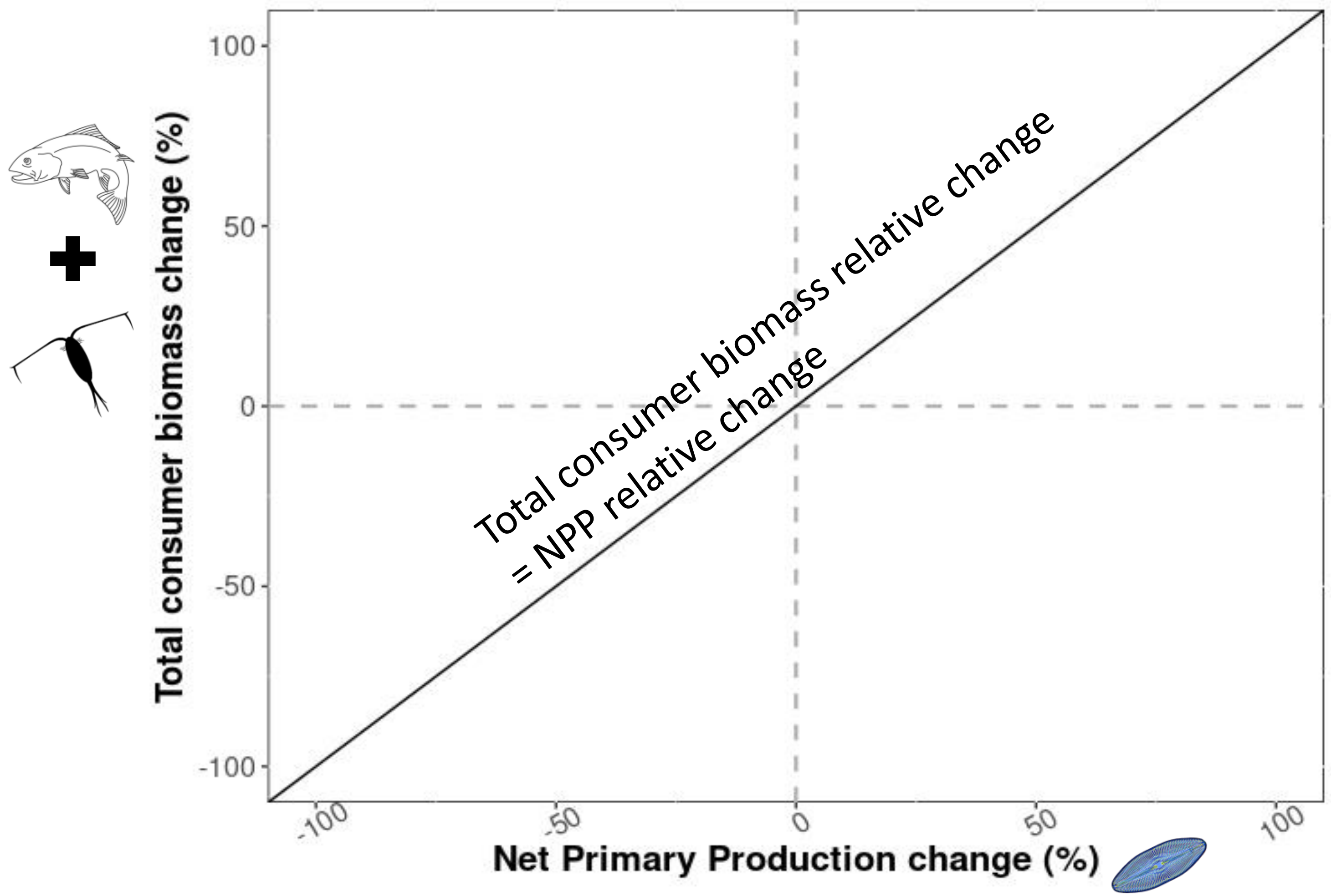
Material & Method

Temporal dynamics and spatial distribution of biomass responses

Biomass responses types definition



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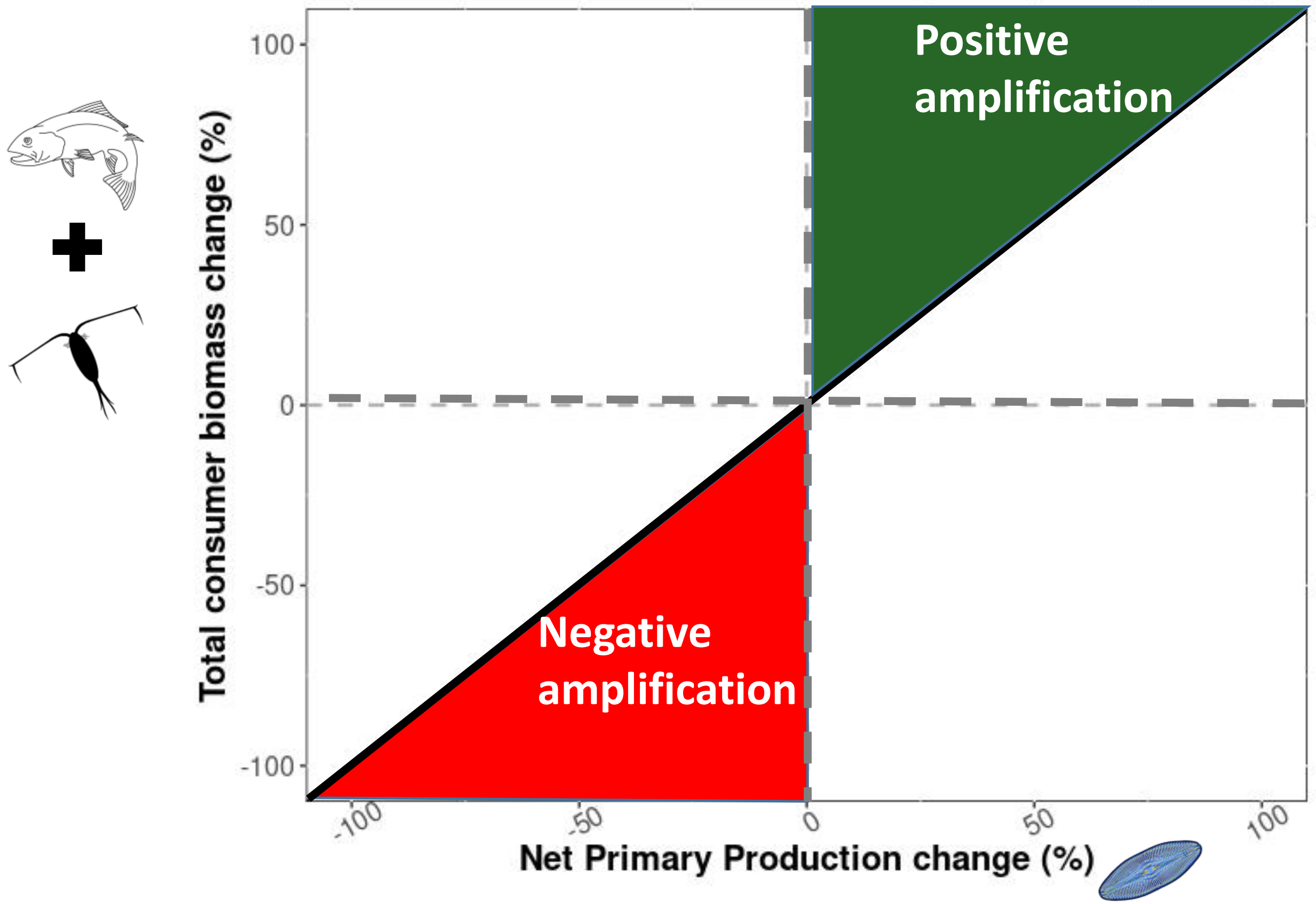

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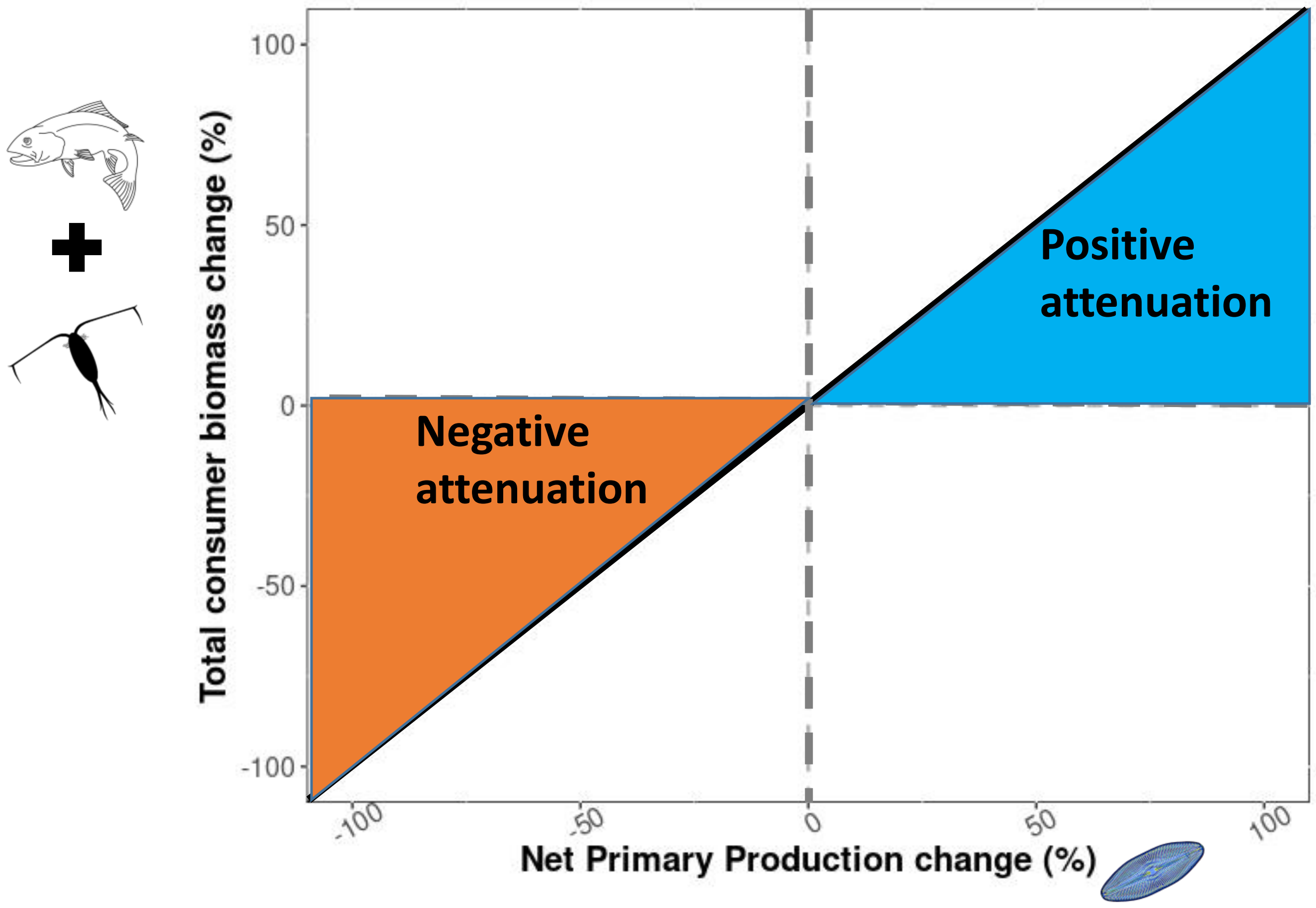

Material & Method

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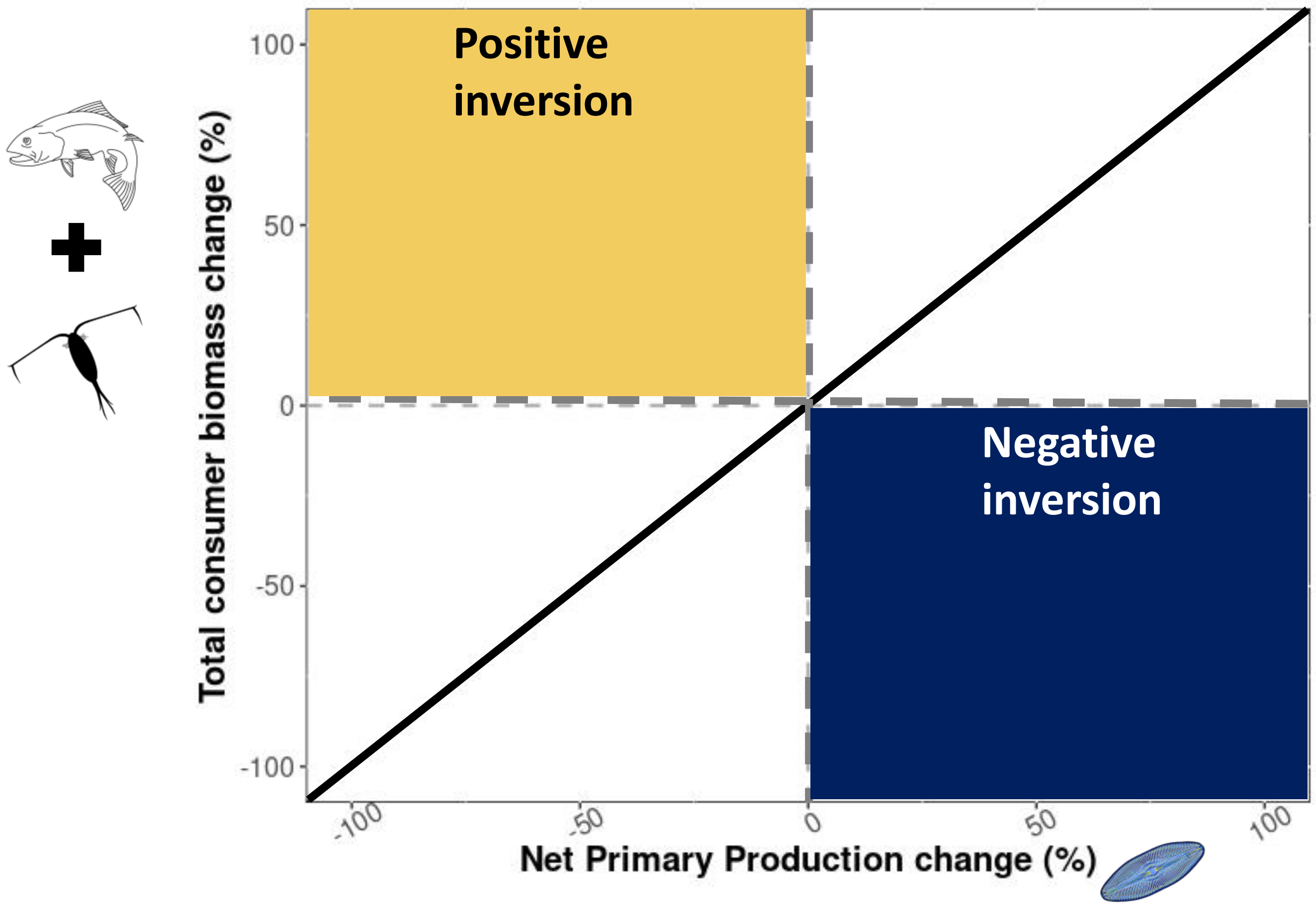

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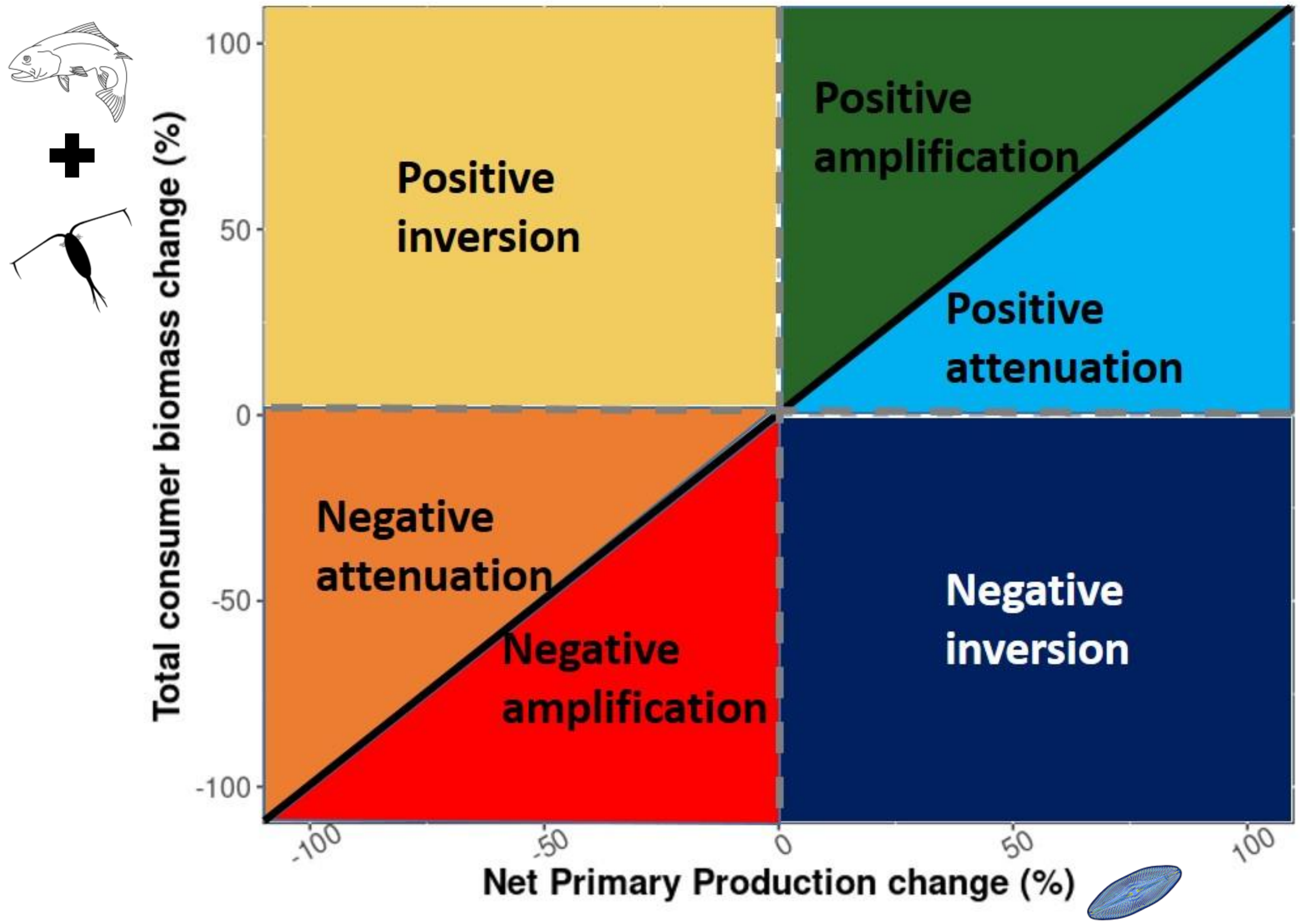
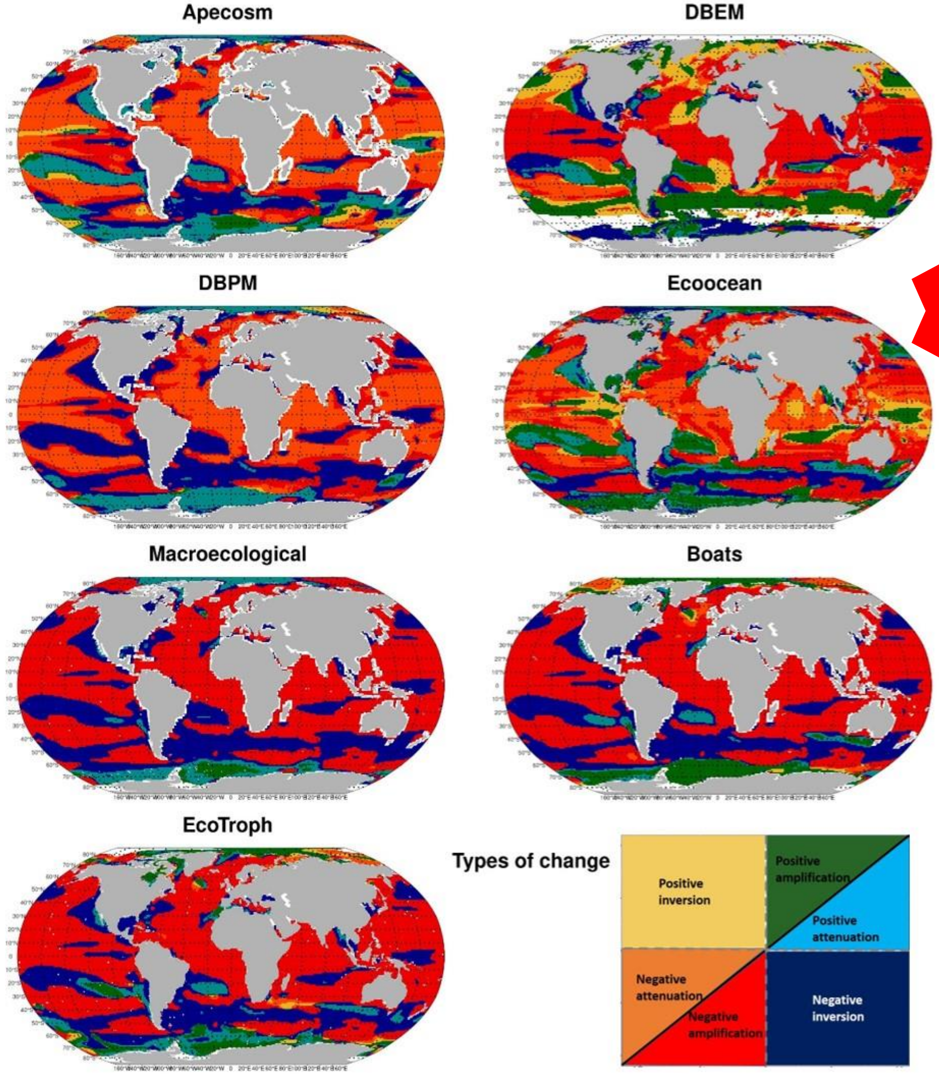


Temporal dynamics and spatial distribution of biomass responses

Result 2 **Different ecological responses over space**

- Mainly three types:
  - ➢ **Negative amplification**
  - ➢ **Negative attenuation**
  - ➢ **Negative inversion**



IPSL RCP8.5

Biomass responses types distribution over 2090s relative to 1986-2005

Temporal dynamics and spatial distribution of biomass responses

Result 2 **Different ecological responses over space**

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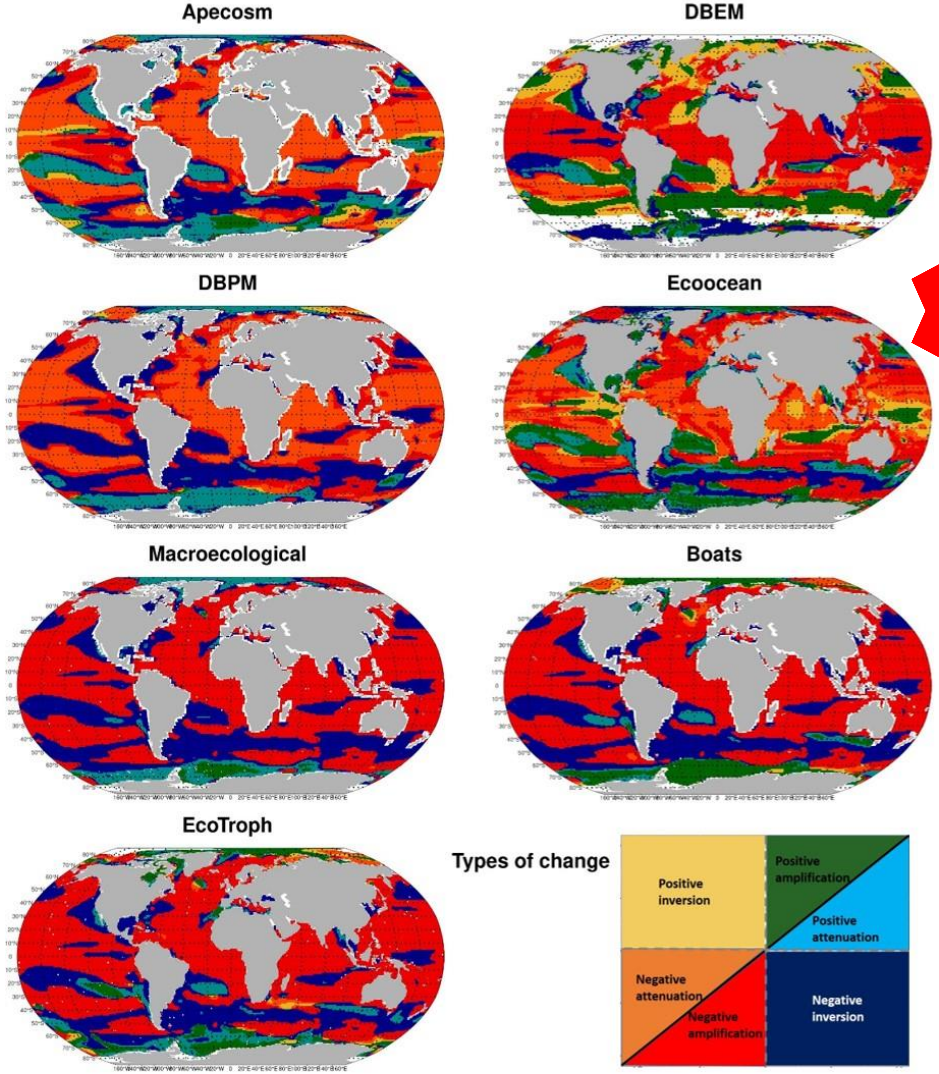
- Inter-marine ecosystem models variability



IPSL RCP8.5

Biomass responses types distribution over 2090s relative to 1986-2005

Material & Method

Temporal dynamics and spatial distribution of biomass responses

- Select cells with more than 4 given values
- Fixing threshold value for agreement to 4

Temporal dynamics and spatial distribution of biomass responses

IPSL
RCP8.5

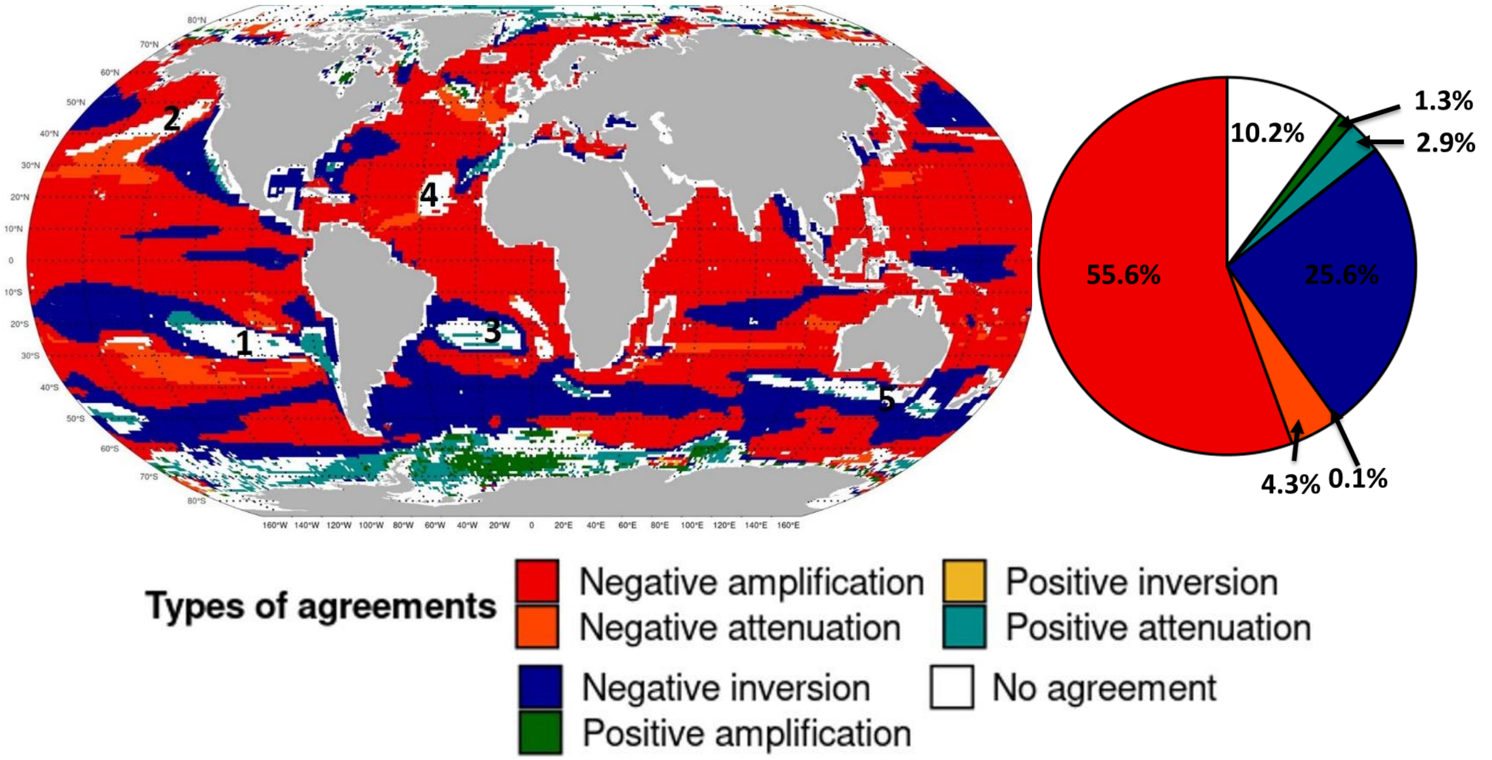
Result 3 **Consistent response over space among ecosystem models**

- 55.6% of negative amplification (red) :
  - ➢ NPP decrease
  - ➢ Biomass decrease > NPP decrease

  Consistent for ≥ 4 ecosystem model

- 25.6% of negative inversion (blue) :
  - ➢ NPP increase
  - ➢ Biomass decrease

  Consistent for ≥ 4 ecosystem model



MEMs biomass responses types agreement distribution over 2090s relative to 1986-2005

How are biomass responses driven by climate change?

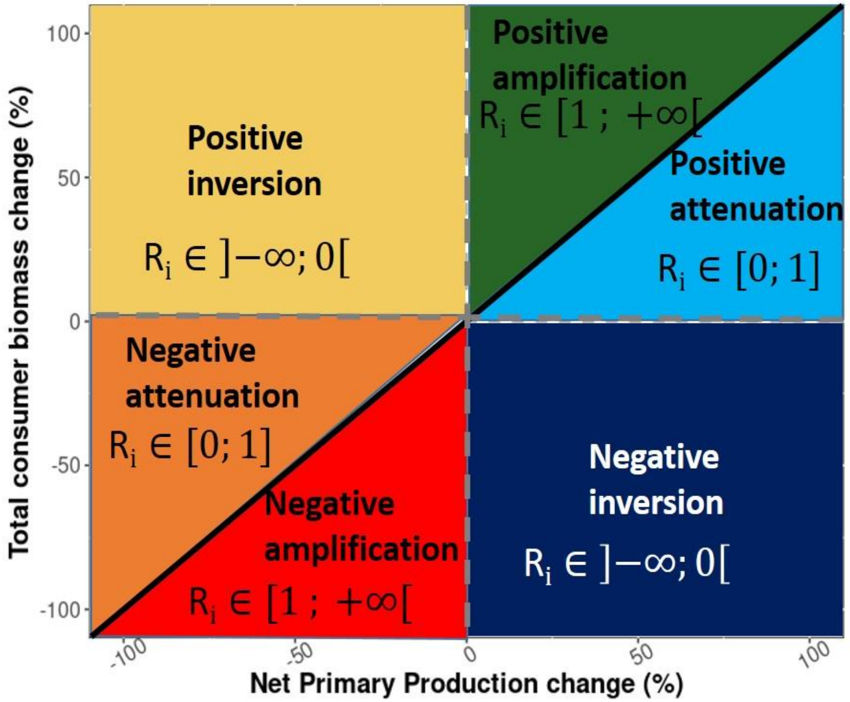
Material & Method

Biomass responses driven by climate change

Temperature effect biomass responses

- Analyse the relationship between sea temperature and ratio of consumer biomass change and NPP change:

$$R_i = \frac{Total\ consumer\ biomass\ change_i}{Net\ Primary\ Production\ change_i}$$



Material & Method

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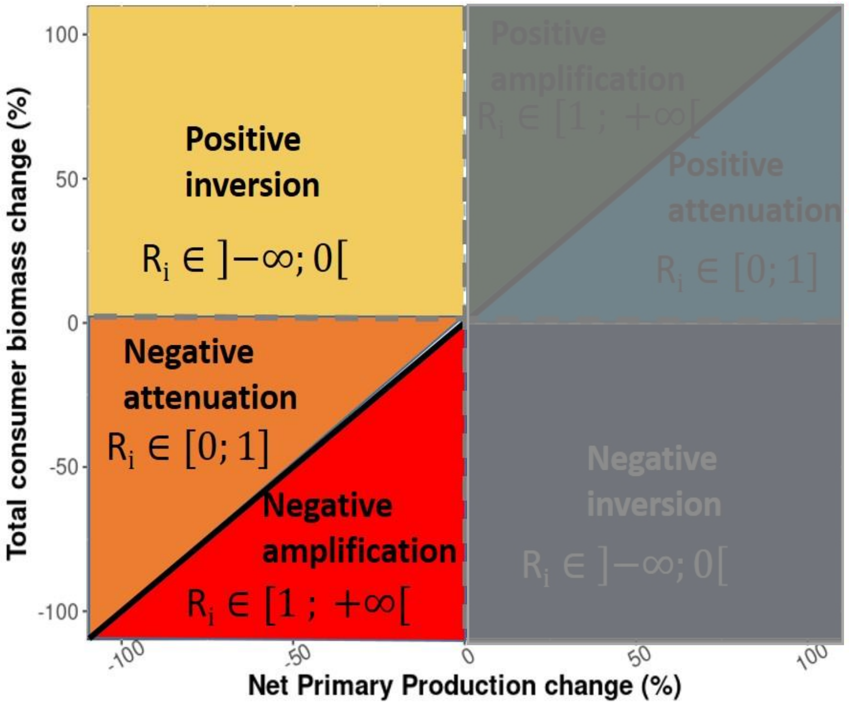
➢ Focus on areas where NPP decrease between 2006 & 2099



Material & Method

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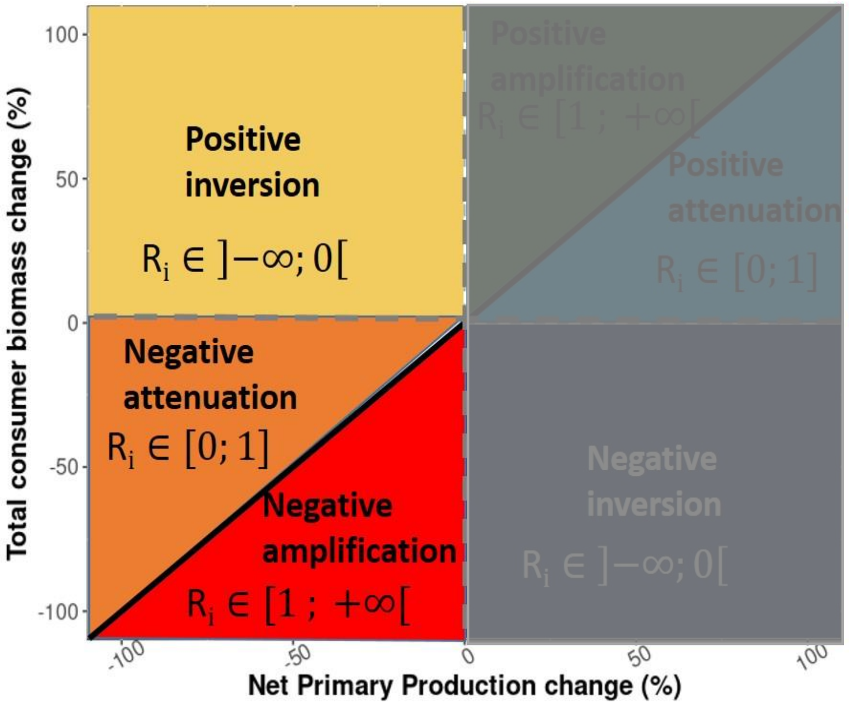
- ➢ Focus on areas where NPP decrease between 2006 & 2099
- ➢ Per MEM, per +Δ0.1 SST, R_i mean with associate standard error

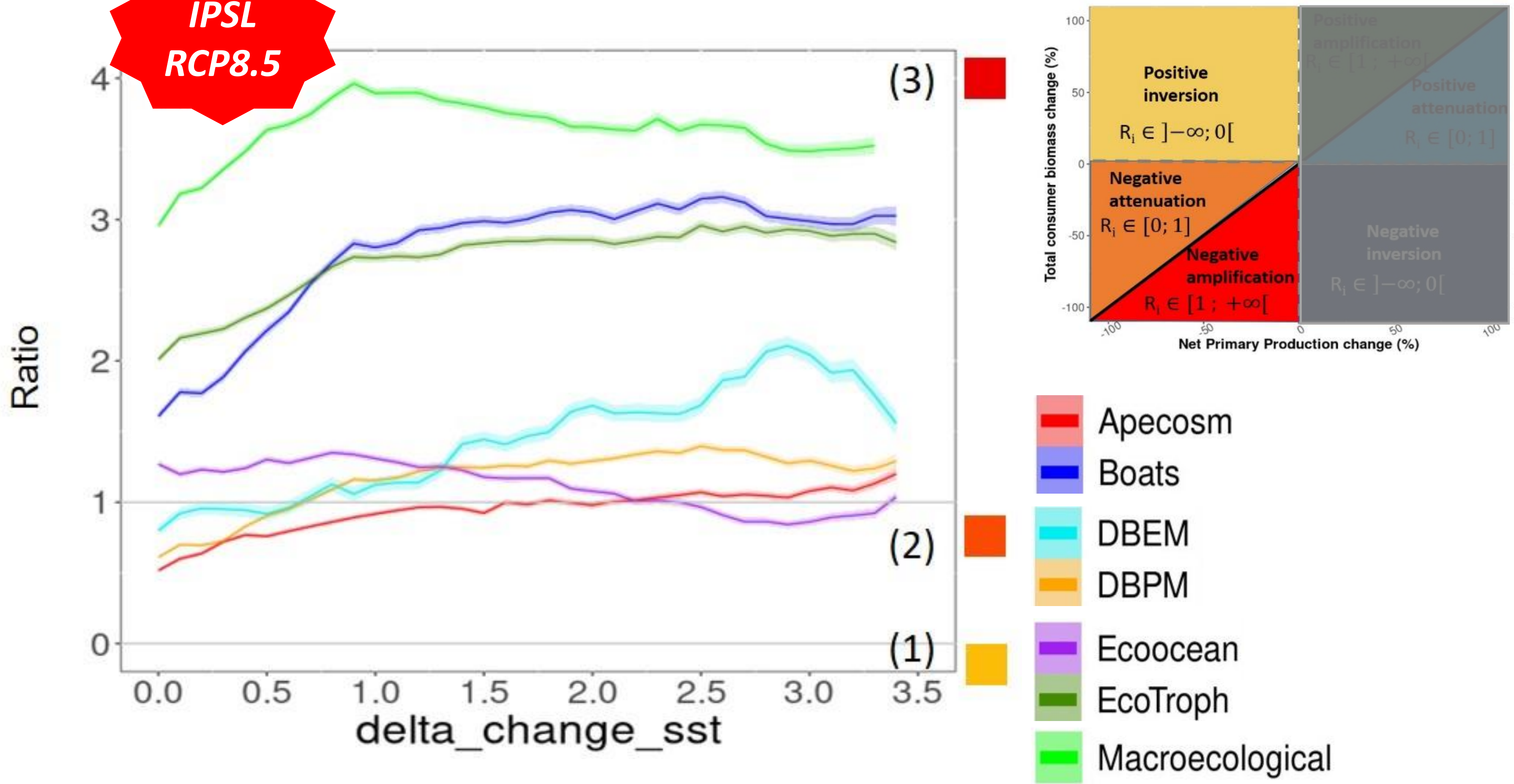


Biomass responses driven by climate change

Result 4 Temperature effect on trophic amplification at the end of the 21st century

IPSL RCP8.5

- Temperature thresholds



What are the processes at stake along the food web?

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Focus on EcoTroph

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Focus on EcoTroph

1. Where does trophic amplification stand: production vs biomass?

What are the processes at stake along the food web?

Focus on EcoTroph

1. **Where does trophic amplification stand: production vs biomass?**

2. **How does trophic amplification in production propagate along the food web?**

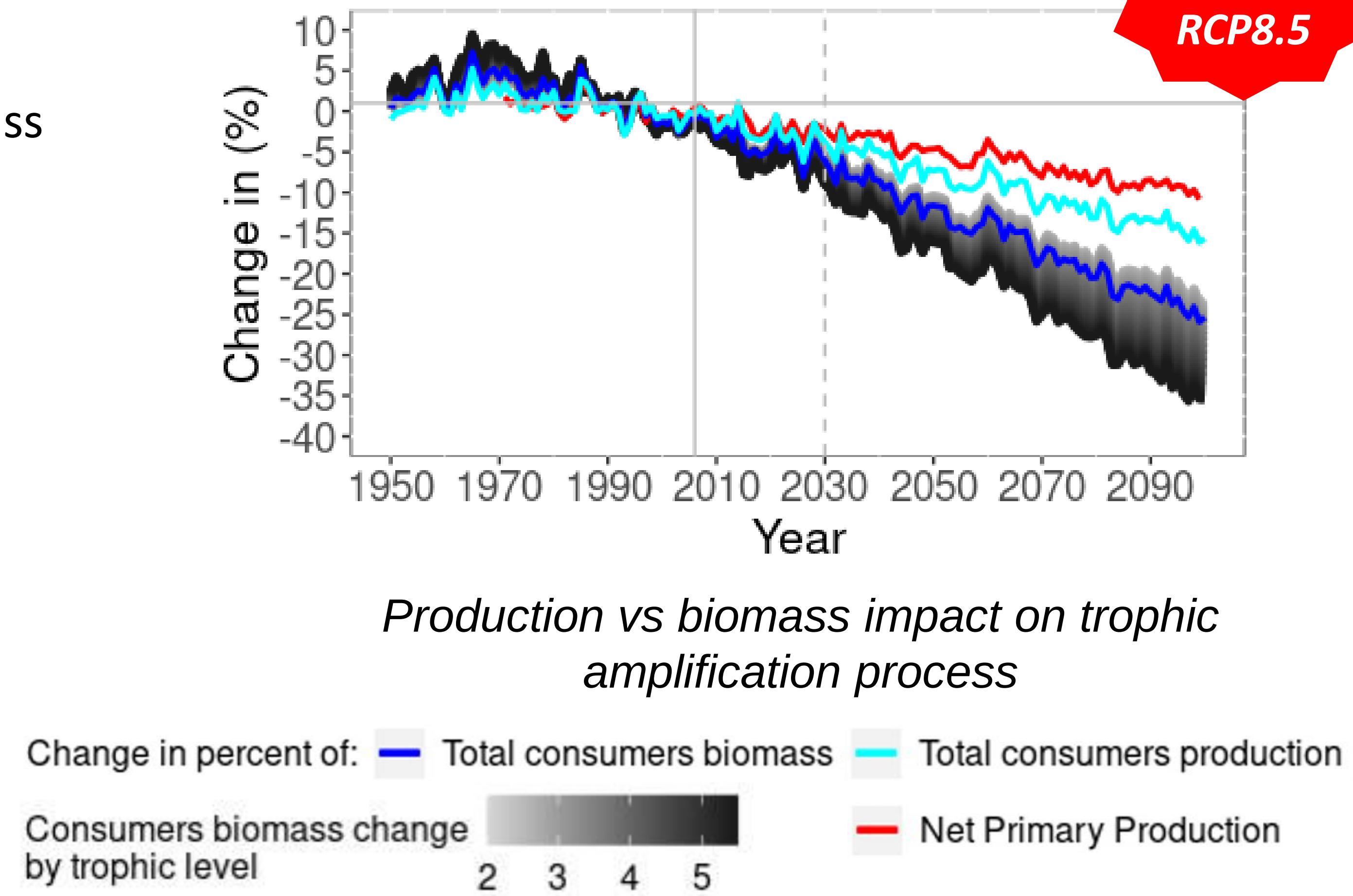
Trophic amplification performs along the food web

Result 5 **Where does trophic amplification stand: production vs biomass?**

Decrease in production and even more in biomass

11% NPP decrease
16% total consumer production decrease
26% total consumer biomass decrease

IPSL RCP8.5



Production vs biomass impact on trophic amplification process

Trophic amplification performs along the food web

Result 5 **Where does trophic amplification stand: production vs biomass?**

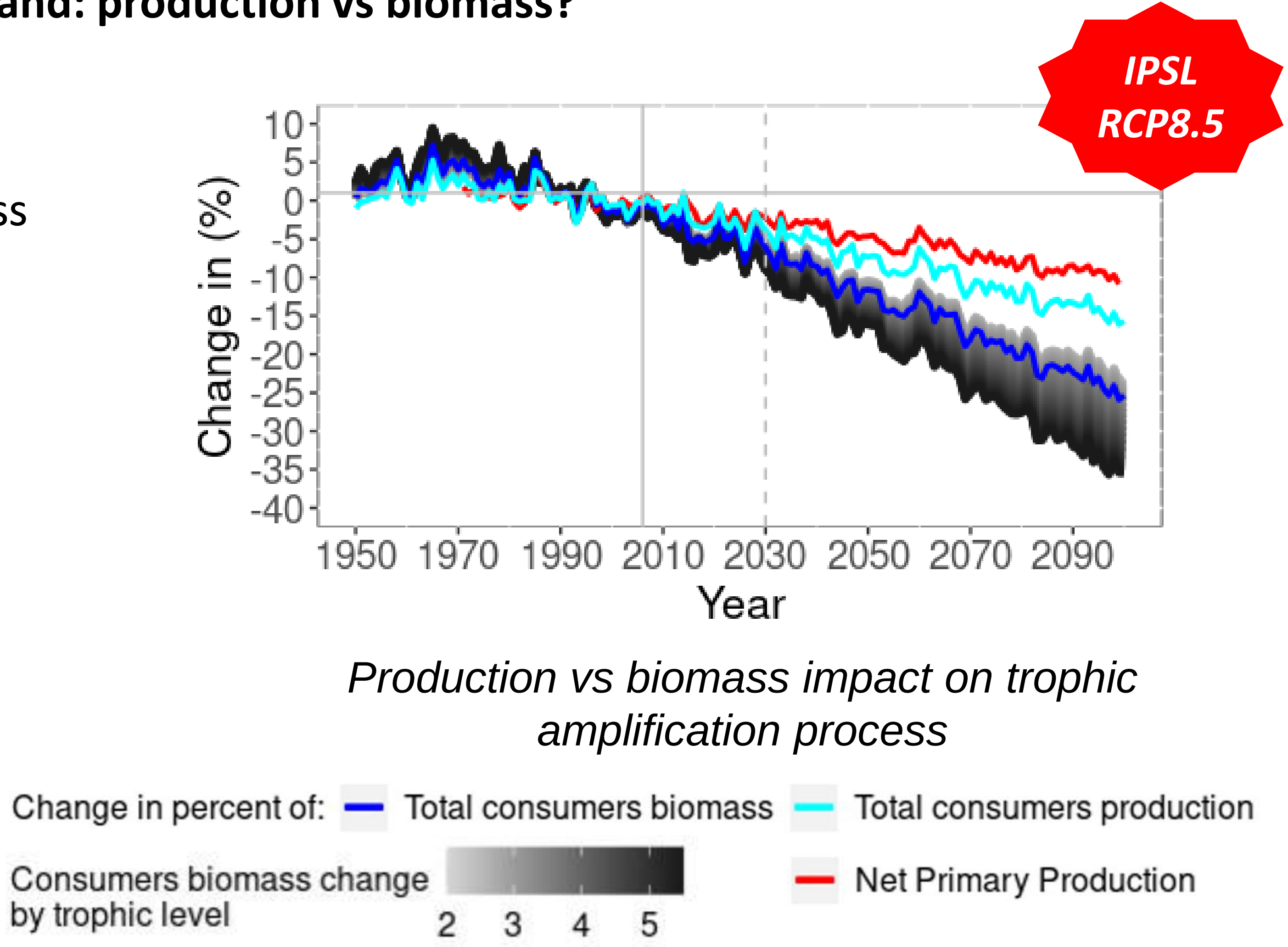
Decrease in production and even more in biomass

11% NPP decrease
16% total consumer production decrease
26% total consumer biomass decrease

→ Major role of production/biomass conversion

$$P_\tau = B\tau \times K_\tau$$

With P_τ the production of an trophic level
B_τ the biomass of an trophic level
K_τ the flow kinetic at an trophic level

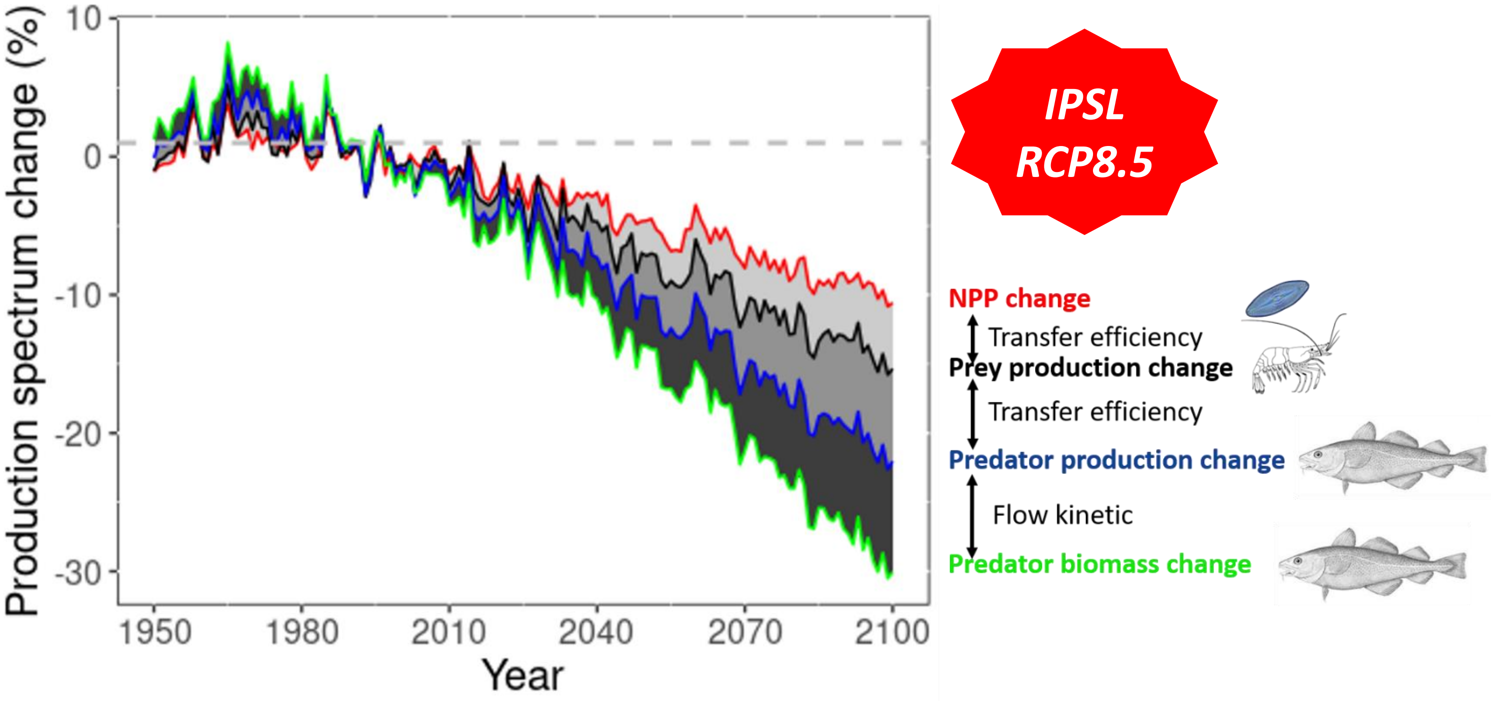


Production vs biomass impact on trophic amplification process

Result 5 **How does trophic amplification in production propagate along the food web?**

Decrease in production along the trophic chain

11% NPP decrease
15% Prey production decrease
20% Predator production decrease
30% Predator biomass decrease



Trophic amplification propagation along the food web

Trophic amplification performs along the food web

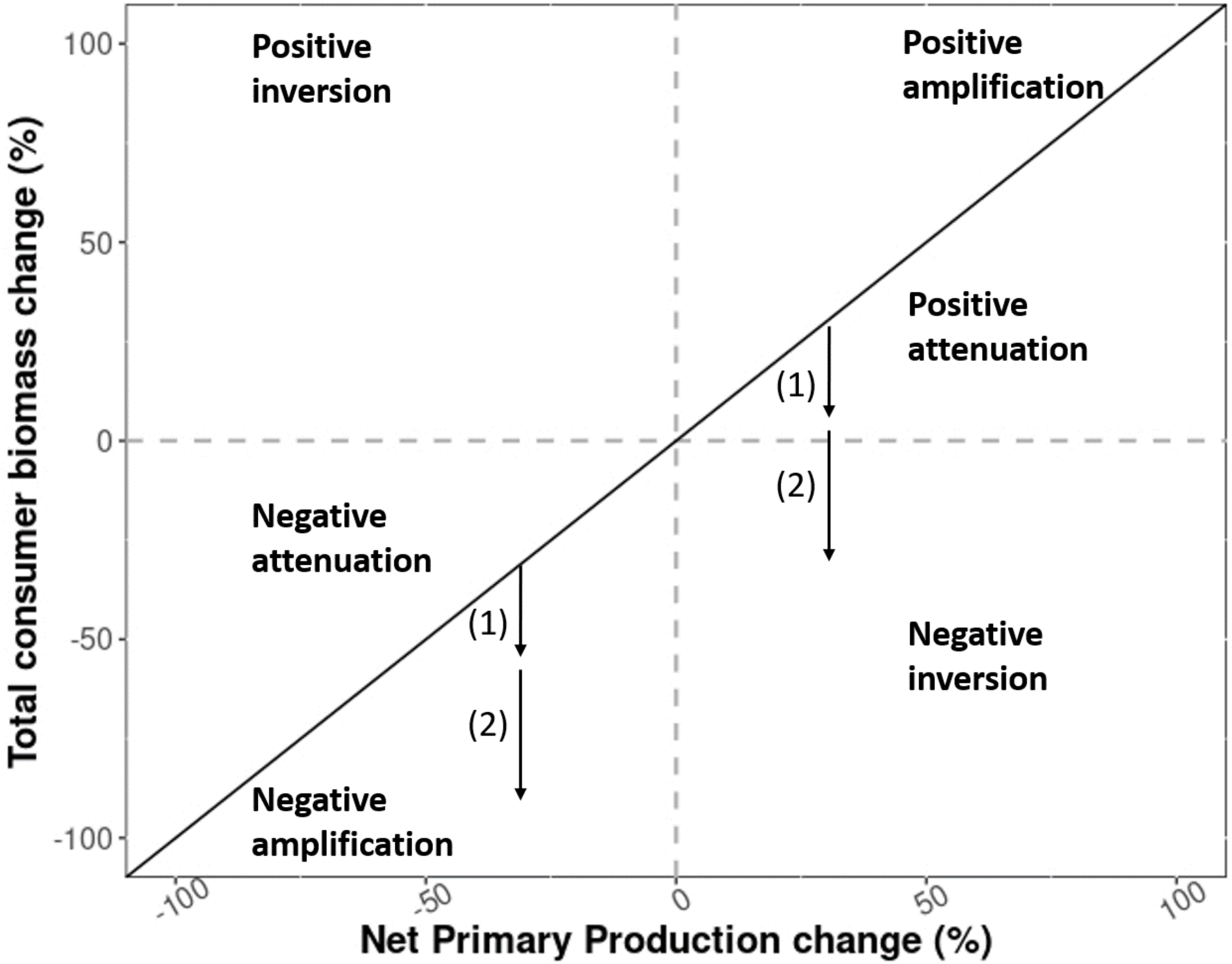
Result 5

How does trophic amplification propagate along the food web?

(1) Temperature induced decrease in transfer efficiency

(2) Kinetic affected by the temperature increasing

→ Amplification of NPP decrease
→ Compensation of NPP increase



Trophic amplification performs along the food web

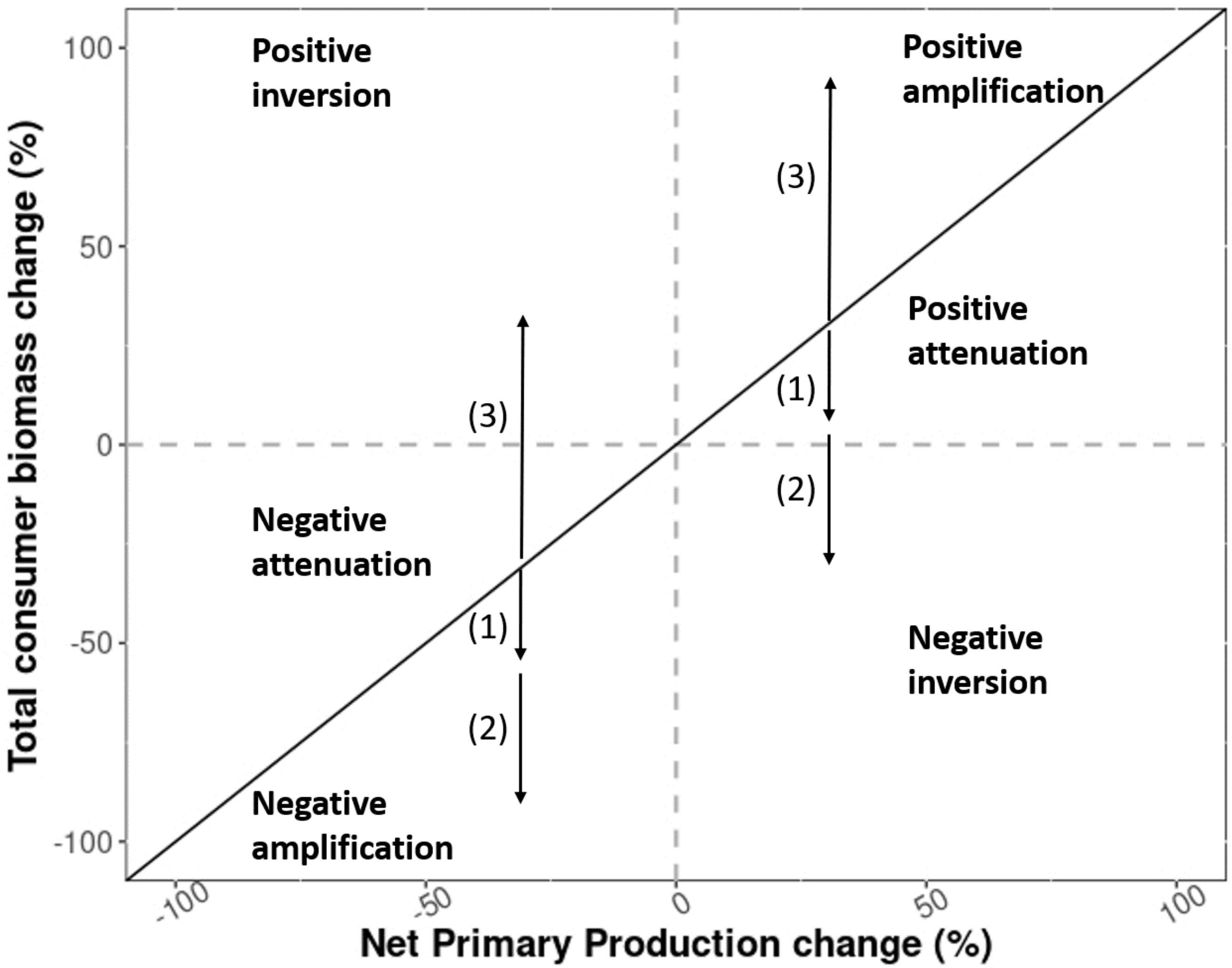
Result 5

How does trophic amplification propagate along the food web?

(1) Temperature induced decrease in transfer efficiency

(2) Kinetic affected by the temperature increasing

(3) Increase in the TE of low trophic levels



Summary

- At global scale, decrease of total consumer biomass much larger than the decrease in NPP, is expected throughout the 21st century

Total consumer biomass change near 3x NPP change

Summary

- At global scale, decrease of total consumer biomass much larger than the decrease in NPP, is expected throughout the 21st century
- But different reaction process at local scale (ecosystem)

Projection of 55.6% and 25.6% ocean surface for negative amplification and negative inversion, respectively

Summary

- At global scale, decrease of total consumer biomass much larger than the decrease in NPP, is expected throughout the 21st century

- But different reaction process at local scale (ecosystem)

- Consistent patterns of biomass responses across MEMs

Projection agreement of biomass responses type over 90% of ocean surface

Summary

- At global scale, decrease of total consumer biomass much larger than the decrease in NPP, is expected throughout the 21st century
- But different reaction process at local scale (ecosystem)
- Consistent trophic amplification across 3 MEMs
- Process getting stronger and stronger by going up in trophic levels

Ways of improvement

1. **New generation of Earth System Models**

   - Better constraint of NPP and secondary production projection
   - Consider other stressors such as the acidification and reduction in dissolved oxygen

Ways of improvement

1. **New generation of Earth System Models**
   - Better constraint of NPP and secondary production projection
   - Consider other stressors such as the acidification and reduction in dissolved oxygen
2. **Better understand of processes in each Marine Ecosystems Models**
   - DBEM does not account for trophic interaction
   - EcoOcean do not directly account for ocean temperature change

Next Steps

Study consequences of trophic amplification induced ecosystem structure change on :

- On Ecosystems health and stability

Next Steps

Study consequences of trophic amplification induced ecosystem structure change on :

- On Ecosystems health and stability
- On potential fisheries catches
  - Most of species with a trophic level above 3.5 are targeted …
- On human

  project less catches where country depend most of ocean resources

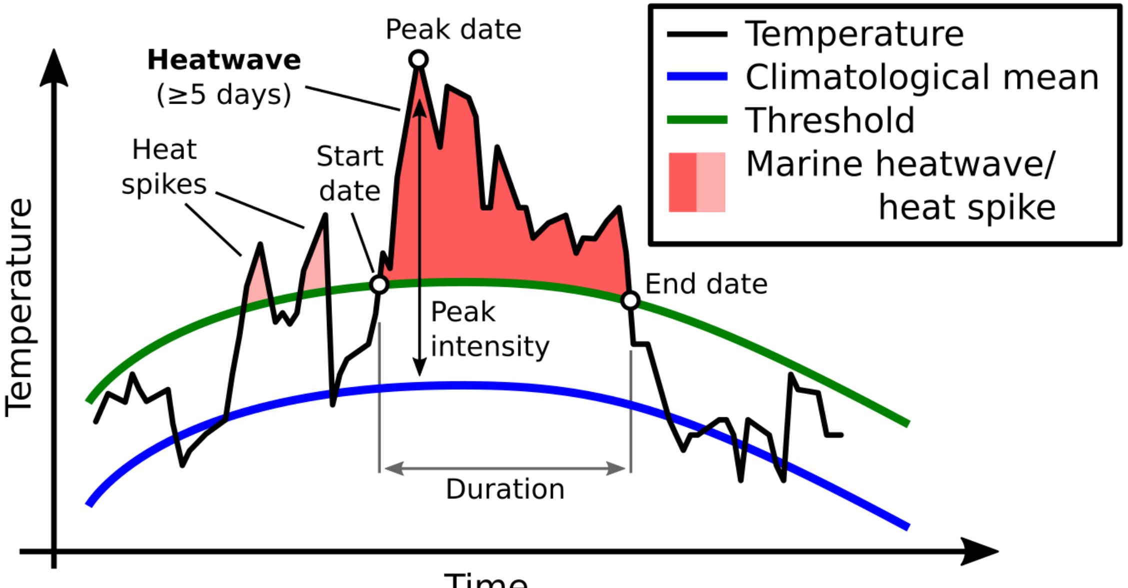
Current study (PhD)

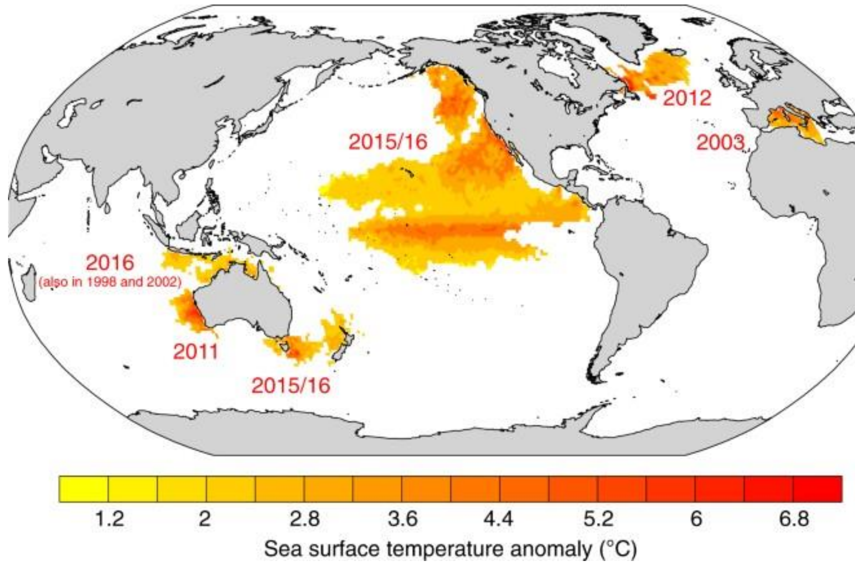
PhD on Marine heatwaves (MHW) :

What will be the projected effects of MHWs added to climate change on marine ecosystems functioning and stability?

Exact PhD tittle:

Climate change, food webs, and fishery resources: dynamic modeling of the impact of extreme events such as marine heatwaves.





Thank you for your attention