ECCWO Symposium - Session 12: Scenarios and models to explore the future of marine coupled human-natural systems under climate change

EcoTroph,

a quasi-physical ecosystem model to analyze the global impact of climate change on marine food-webs

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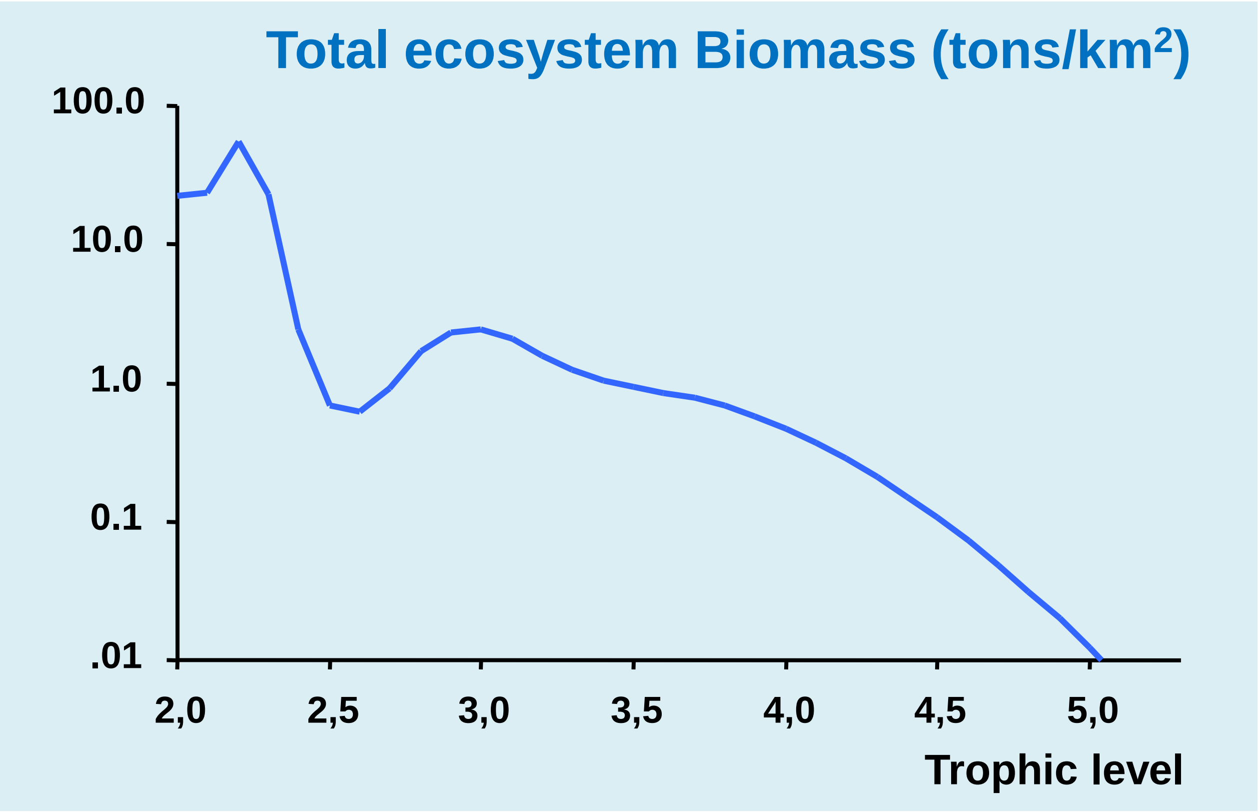
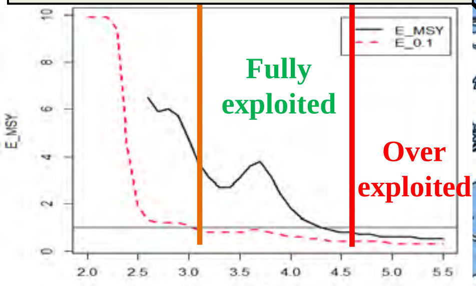
EcoTroph: an over-simplified ecosystem model

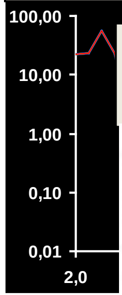


EcoTroph: applications

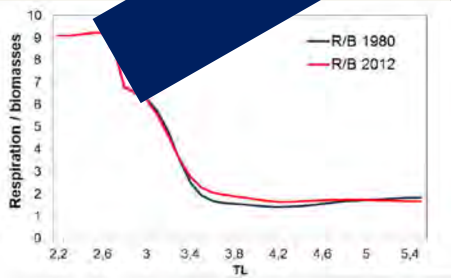
- to draw diagnostics
  (Meissa et al., 2015)

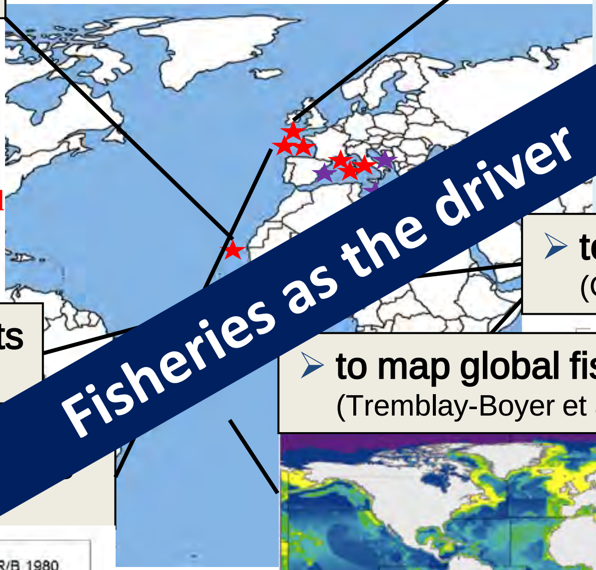


- to assess fishing impacts
  (Gascuel et al., 2005)



- to explore f…
  (Bentorcha e…



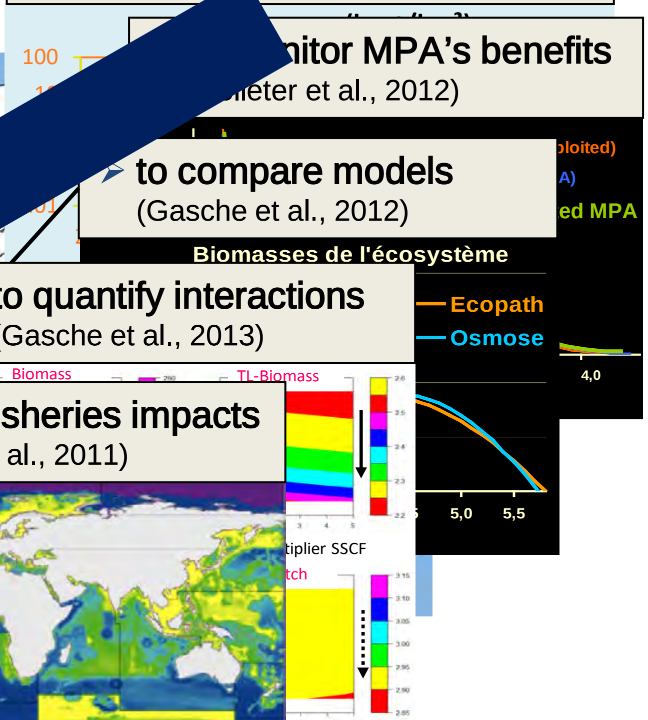


- to compare ecosystem's structure and dynamics
  (Moullec et al., 2016)

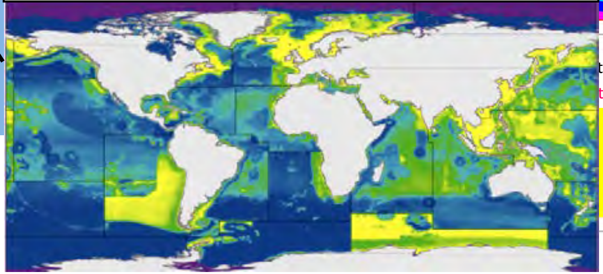
- …nitor MPA's benefits
  (…lieter et al., 2012)

- to compare models
  (Gasche et al., 2012)

- to quantify interactions
  (Gasche et al., 2013)



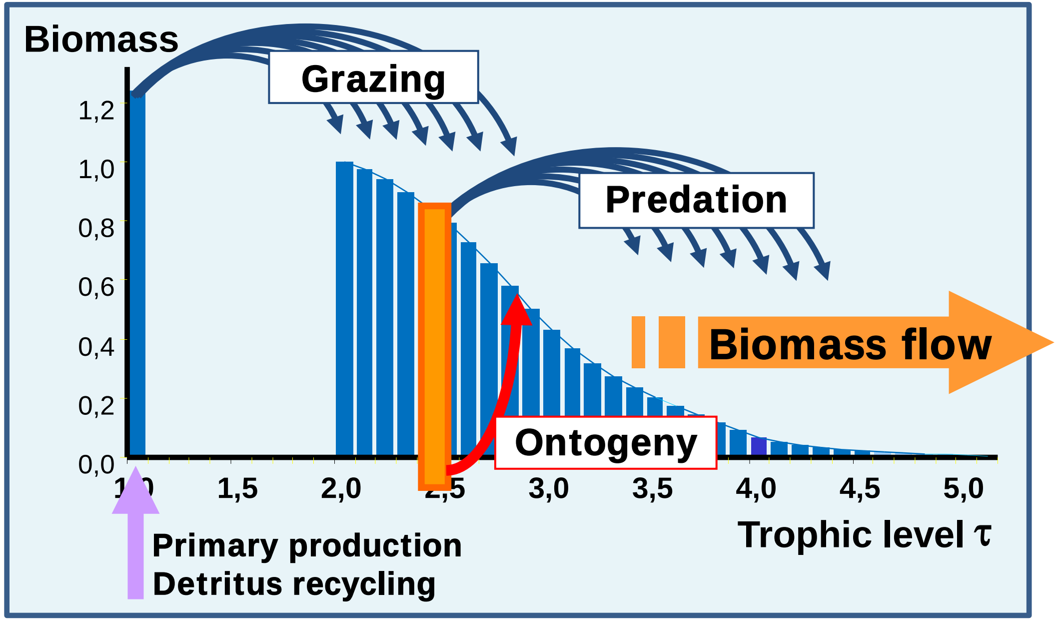
- to map global fisheries impacts
  (Tremblay-Boyer et al., 2011)



Fisheries as the driver

- **Climate change as the driver ?**

EcoTroph: how it works?



Gascuel, 2005 … Gascuel, Pauly, 2009 … Gascuel, Guénette, Pauly, 2011

- A continuous representation of the biomass distribution, according to trophic level τ

-> the Biomass Trophic spectrum

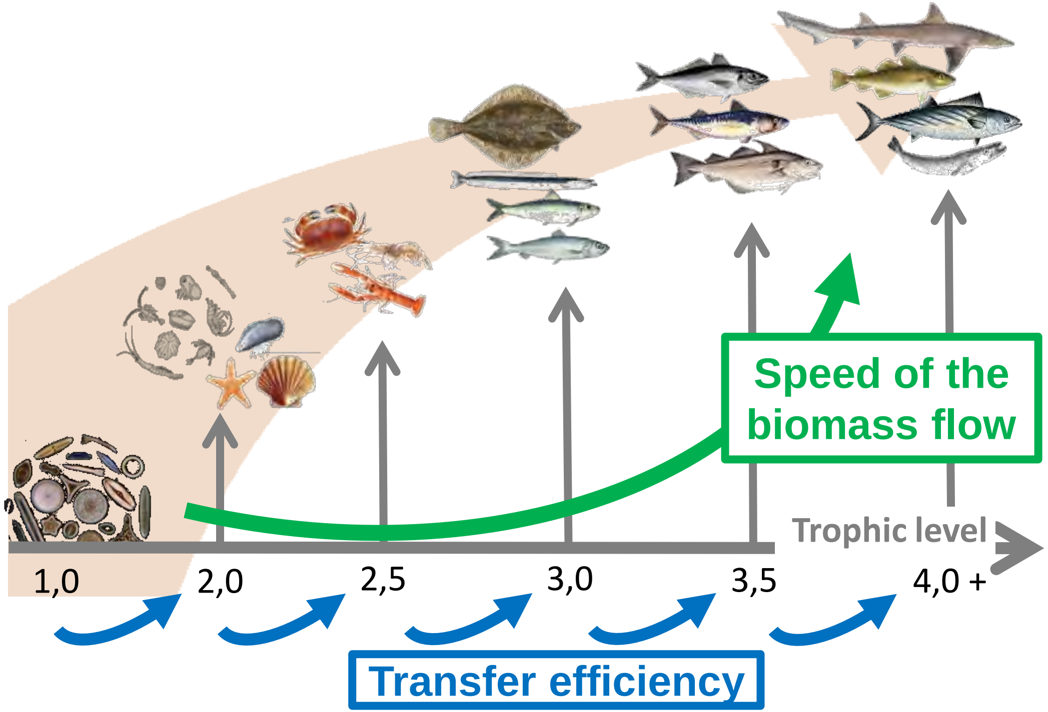
- The ecosystem functioning: a flow of biomass trough trophic levels

EcoTroph: two key parameters

- **The transfer efficiency TE**: defines the quantity of biomass flow (Φ_τ), at each trophic level

- **The flow kinetics K**: celerity of biomass transfers through the food web (in TL/y^{-1})

NB: 1/K is the residence time in the food web



EcoTroph: basic equations

- **The master equation:** $$\textbf{Biomass} = \frac{\textbf{flow}}{\textbf{speed}} \cdot \Delta\tau \qquad B_\tau = \Phi_\tau \cdot \Delta\tau / K_\tau$$

An explicit link between:

- ✓ the **biomass** present in the trophic class $[\tau, \tau+\Delta\tau[$ -> $B\tau$, in tonnes
- ✓ the **production**, which results from the biomass flow passing trough the trophic class -> $P\tau = \Phi\tau \cdot \Delta\tau$**,** in tonnes/year

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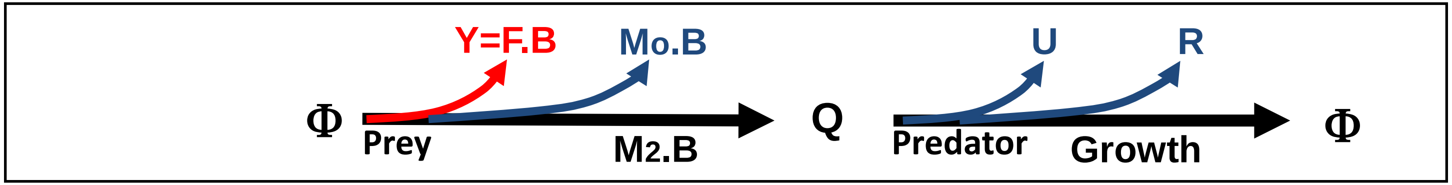
- **A non-conservative flow:** $\Phi_{\tau+\Delta\tau} = \Phi_\tau \cdot e^{-(\mu_\tau + \varphi_\tau)\cdot\Delta\tau}$

Natural losses (μ_τ)
. Non pred.mort. Mo.B
. Excretion U
. Respiration R

$e^{-\mu}$ =Transfer efficiency

Fishing losses (φ_τ)
. Catches Y



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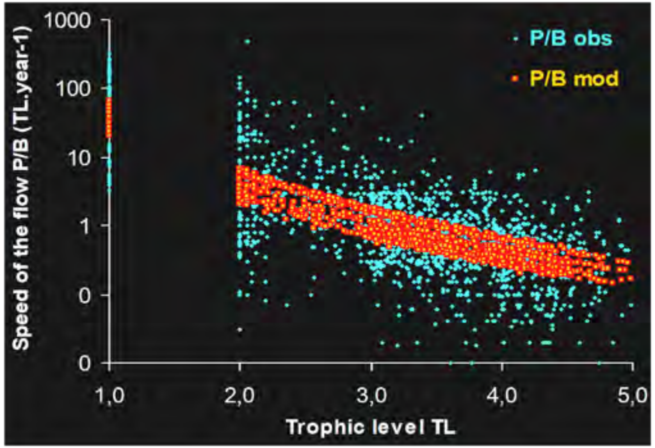
- **An empirical model for kinetics:** $K_{\tau,\text{unexpl.}} = a \cdot \tau^{-b} = 20.2 \cdot e^{0.041\,\theta} \cdot \tau^{-3.26}$

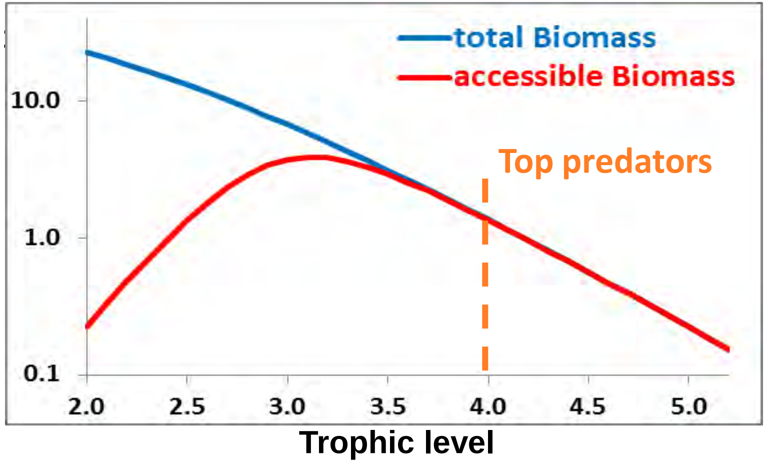
Gascuel et al. (2008, Ecol.Mod)

- 55 Ecopath models
- n = 1,718 groups
- $r^2 = 0.54$



EcoTroph: additional details

- **Fishing impact on kinetic** (higher mortalities -> shorter life expectancy -> faster transfers)
- **Feedback effects:**
  - Of predators on prey (Top-down control: more predator -> faster transfers)
  - Of the total biomass on detritus recycling (less biomass -> less recycling)
- **All organisms are (currently) not exploited**
  - The accessible biomass
  - A distinct kinetics for the accessible and the not-accessible biomass



EcoTroph: basic equations

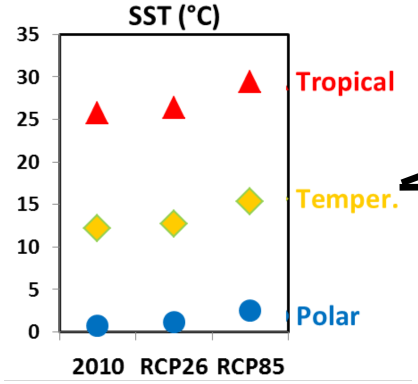
- The master equation: $\text{Biomass} = \frac{\text{flow}}{\text{speed}} \cdot \Delta\tau$ $\quad B_\tau = \Phi_\tau \cdot \Delta\tau / K_\tau$
- A non-conservative flow: $\Phi_{\tau+\Delta\tau} = \Phi_\tau \cdot e^{-(\mu_\tau + \varphi_\tau)\cdot\Delta\tau}$ $\quad \Phi 1 = NPP$
- An empirical model for kinetics: $K_{\tau,unexpl.} = a \cdot \tau^{-b} = 20.2\, e^{0.041\,\theta} \cdot \tau^{-3.26}$

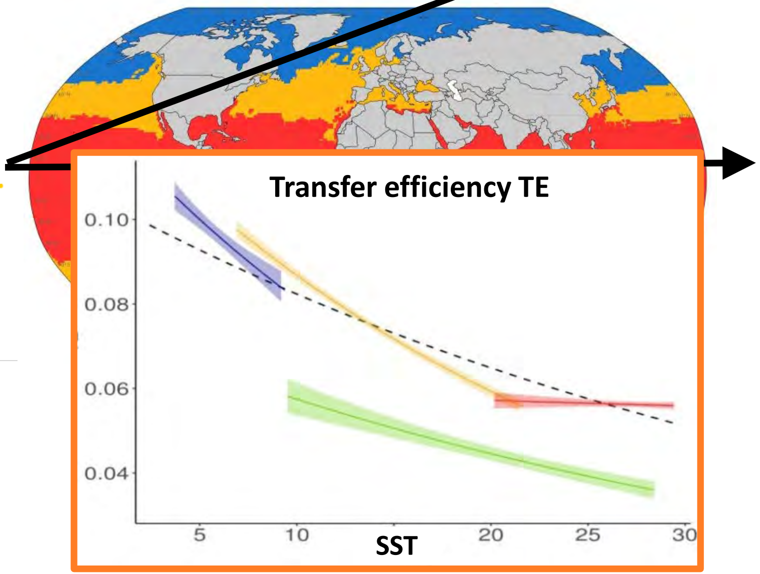
Climate change affects:

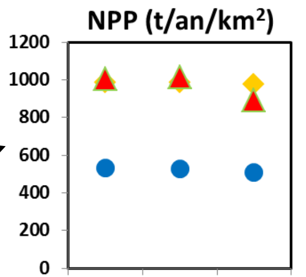
- Net Primary Production NPP
- Transfer efficiency TE
- Flow kinetics K

Using EcoTroph to simulate climate change

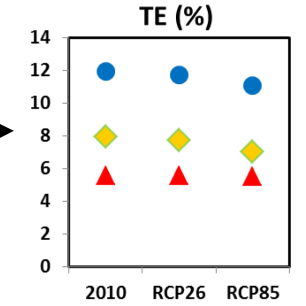
- **A global analysis**
  - Using 1° cells, aggregated by ecosystem type
  - And for 2 scenarios: RCP2.6 and RCP8.5 in 2100







- **From IPSL**



- **From Du Pontavice** (in prep., See **S11-1540**)

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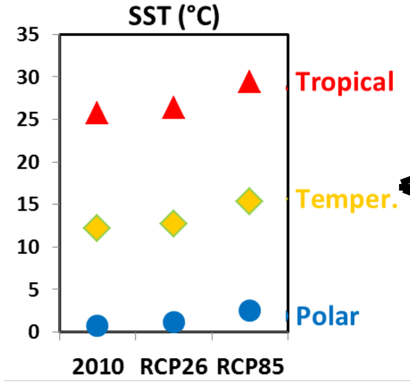
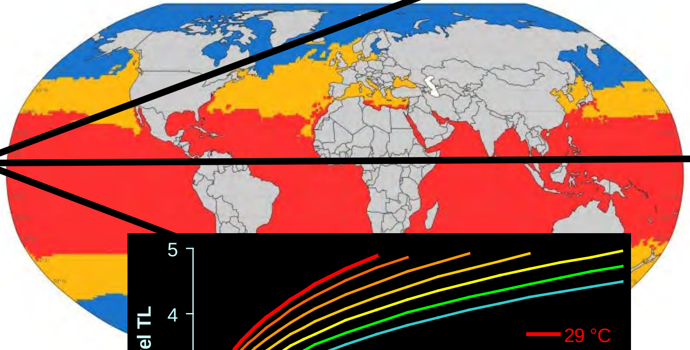
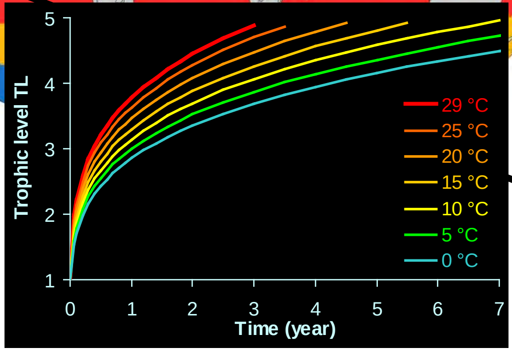
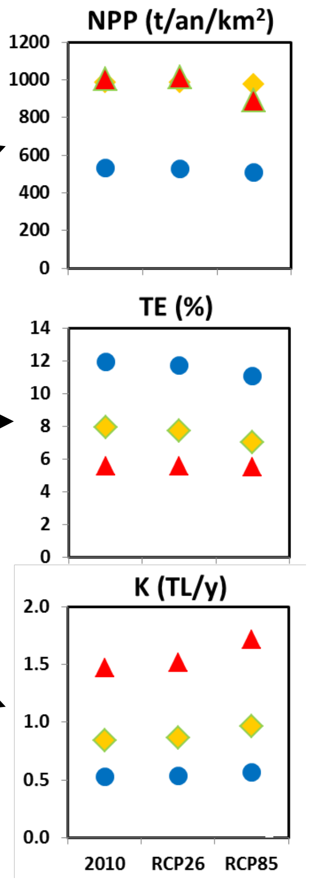




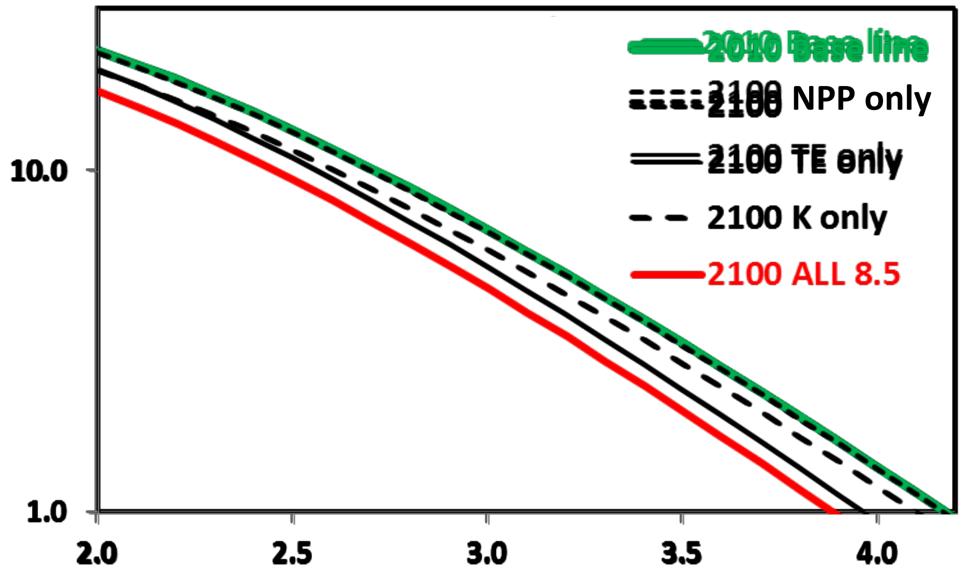




- From IPSL
- From Du Pontavice (in prep., See **S11-1540**)
- From Gascuel et al. (2008)

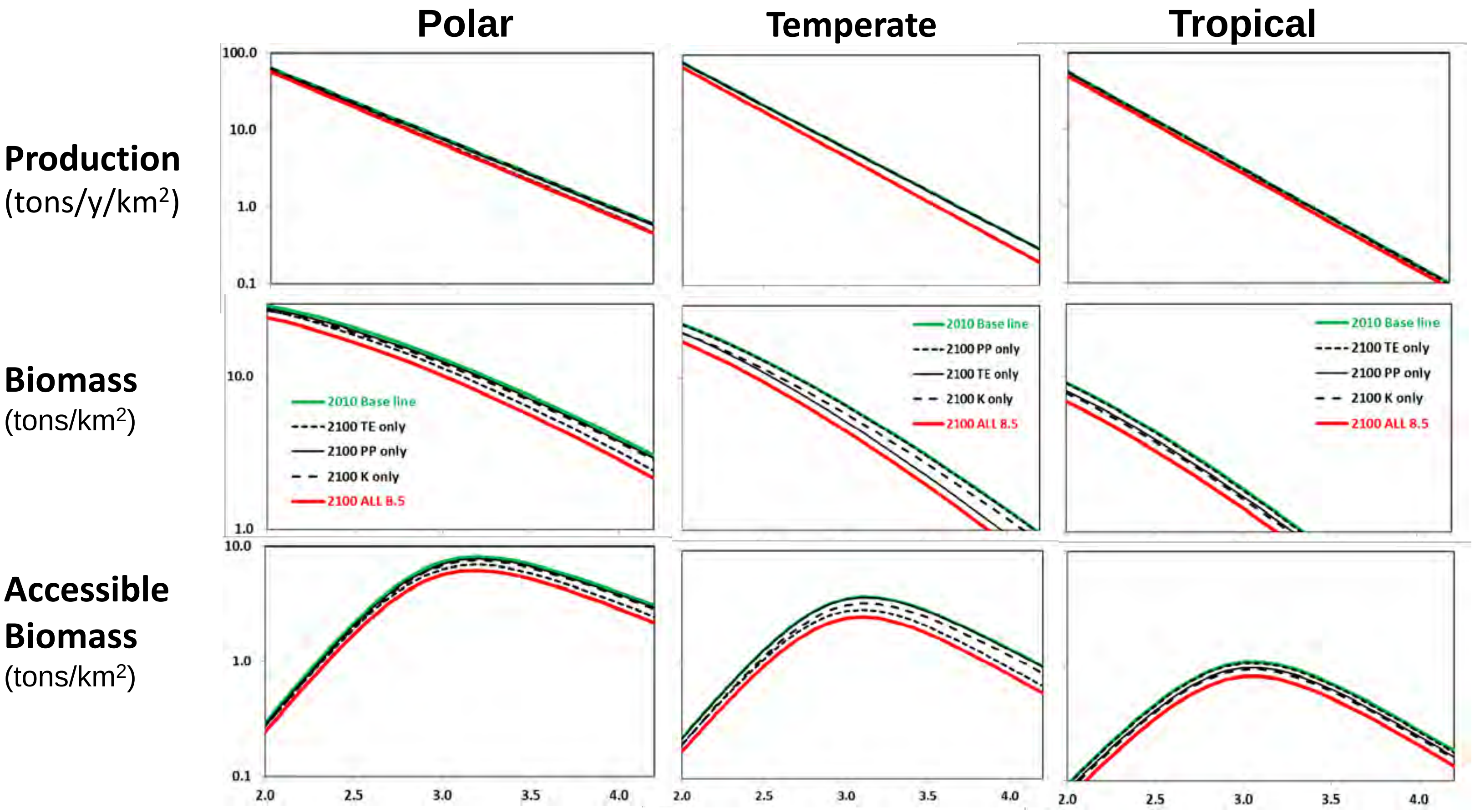
Climate change effects on the biomass trophic spectra

- **Temperate ecosystems, RCP 8.5, biomass in tons/km²**



- No change in NPP
- A large effect of changes in Transfer efficiency TE
- An additional effect of change in kinetics K
- A 29% decrease in the total consumer biomass

Effects on Production, Biomass & Accessible biomass



Effects on Production, Biomass & access.Biomass

Loss in total consumer Production

	2010 Base line	2100 RCP 2.6	2100 RCP 8.5
Polar	0%	3%	14%
Temperate	0%	3%	16%
Tropical	0%	-1%	12%

2100 RCP 8.5		
TE only	NPP only	K only
10%	4%	0%
15%	1%	0%
1%	11%	0%

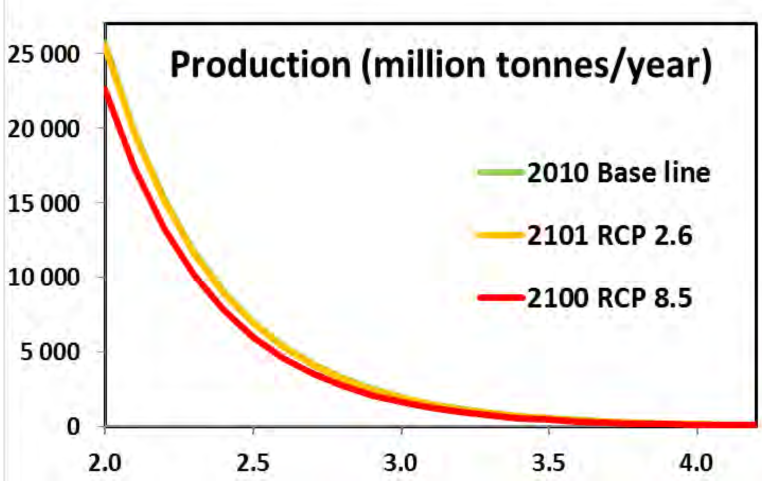
Loss in total consumer Biomass

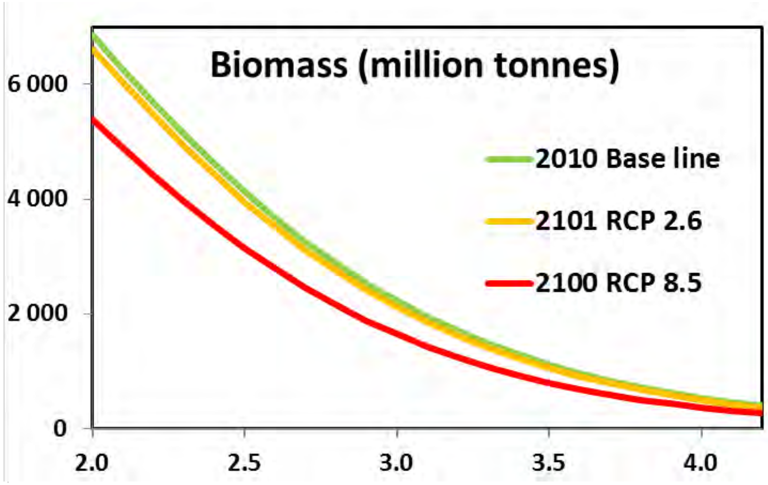
Polar	0%	5%	22%
Temperate	0%	6%	29%
Tropical	0%	2%	25%

Access. Biomass	Top-pred. Biomass	
12% 26%	4% 31%	7%
18% 35%	1% 44%	12%
2% 25%	11% 26%	14%

- A large impact on production and biomass, especially in temperate ecosystems
- Key role of NPP in tropical ecosystems, TE in temperate and polar, K everywhere
- Highest impacts on accessible and top-predator’s biomass

Global effects





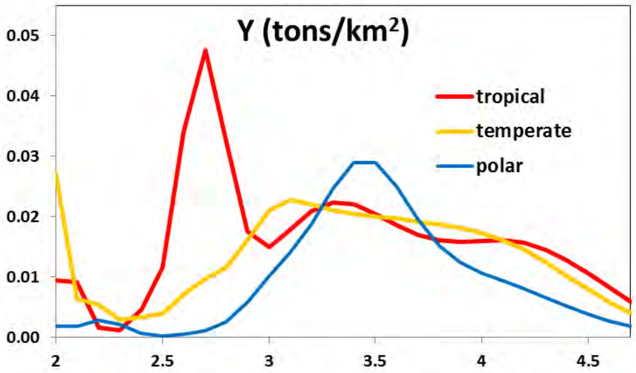
	Production	Biomass
RCP 2.6	-1 %	-5 %
RCP 8.5	-14 %	-25 %

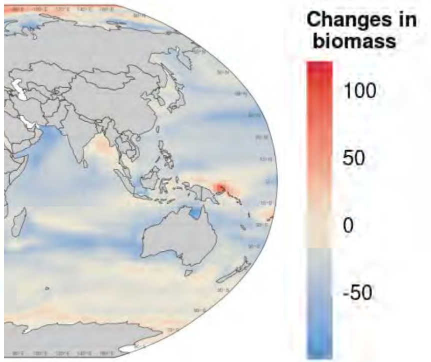
Accessible Biomass	**-28 %**
Top-predator biomass	**-33 %**

Discussion & Conclusion

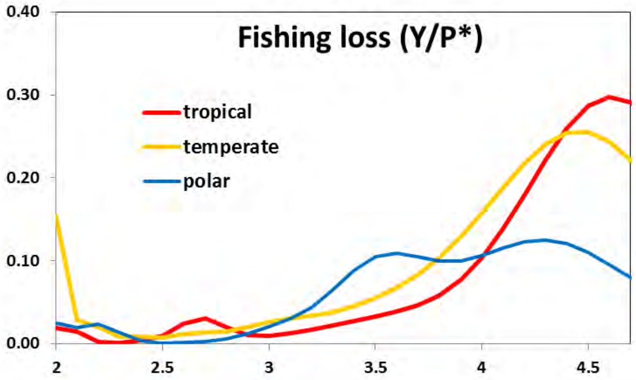
❑ **Next steps:**

- Include catches
- Run the model locally (:
- Sensitivity analyses (be
- Add changes (in TE and
  at the individual level





:avice et al., in prep.



❑ **Take-home messages**

- Simple model may prov ... ntegrative tool)
- Climate change will affe ... e mechanisms: changing NPP, decreasing Transfe ... v kinetics…
- … thus leading to a large decrease in total consumer production, biomass and structure

Thank you…

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