The potential of climate-smart fisheries management and good governance in climate adaptation

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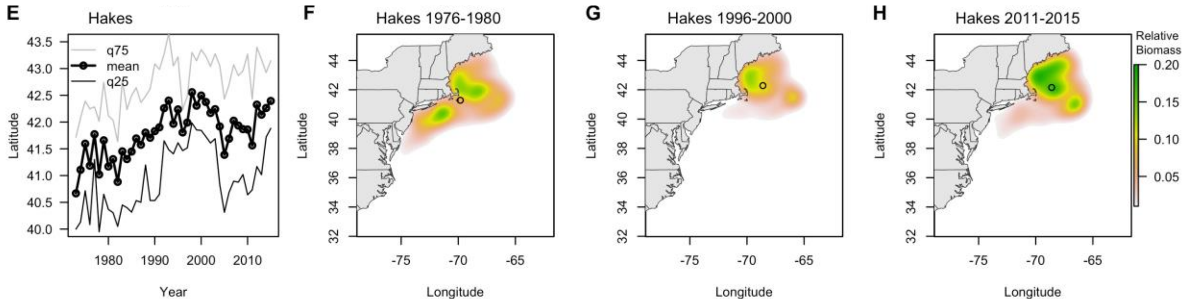
Climate change impacts on fisheries

Spatial distribution of fish stocks

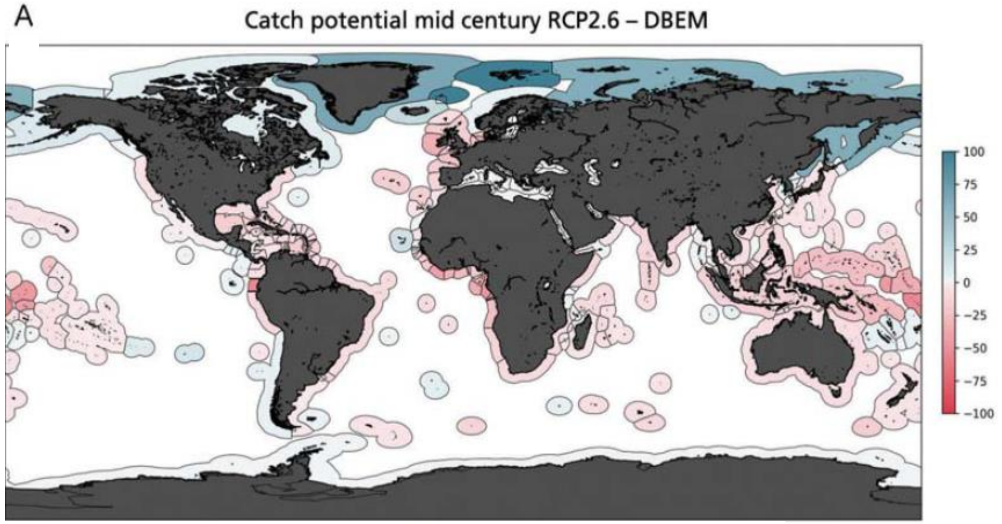
- Marine fish and invertebrates shift poleward and into deeper waters (Poloczanska et *al*. 2013, Lotze et *al*. 2019).



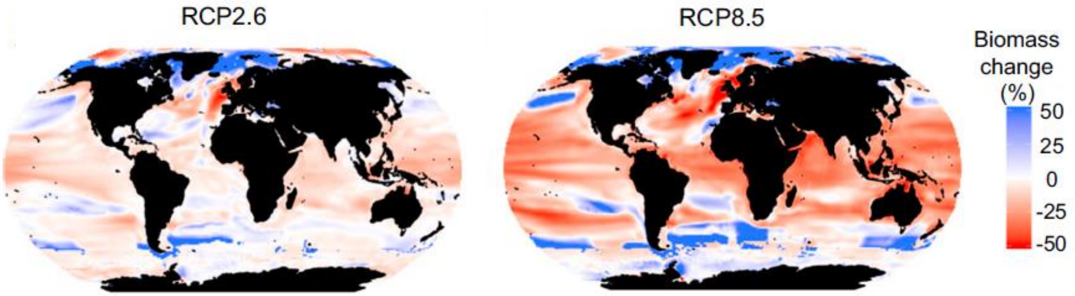
(Papaioannou et *al*. 2021)

Productivity of marine fisheries globally

- Changes in **carrying capacities** (Hollowed et *al*. 2013).
- Changes in **marine animal biomasses** by 2100 (Bryndum-Bochholz et *al.* 2019, Lotze et *al*. 2019) **:**
  - **15–30 % decline** in the North/South Atlantic, North/ South Pacific and Indian Ocean basins
  - **20–80 % increase** in the polar Arctic and Southern Ocean basins



(FAO et *al*. 2018)



(Lotze et *al*. 2019)

Economic & governance responses

- **Fishers often viewed as a passive force** in ecological studies (e.g. Cheung et al. 2010)

- Limited consideration of the **nature of adaptations** at play & adaptation is **often viewed as necessarily positive**

- **Growing research interest regarding economic adaptation** (Holsman et *al.* 2019, Bryndum-Bochholz et *al*. 2020, Free et *al.* 2020, Pinski et *al.* 2021, Papaioannou et al., 2021)

- **Lack of studies that explicitly consider both fishers/governance responses to CC**

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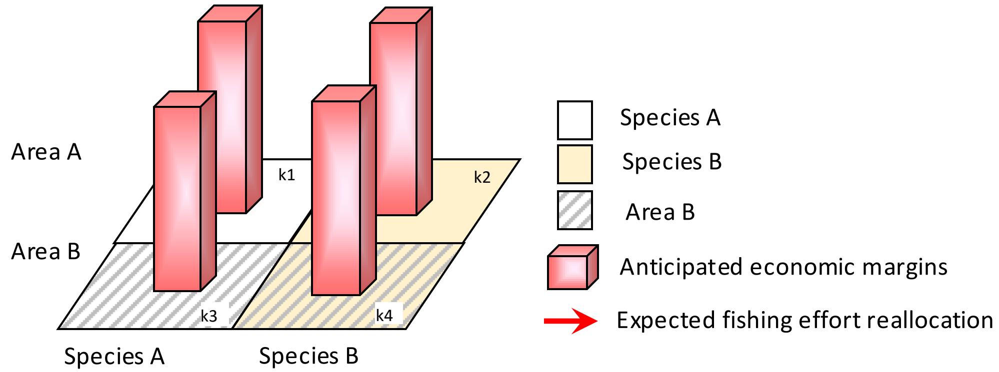
To what extent and under which circumstances can adaptation lead to positive or negative (ecological-economic) sustainability outcomes?

A stylized bio-economic model

2 areas & 2 species → 4 "métiers", each fishing a species in an area

Initial state



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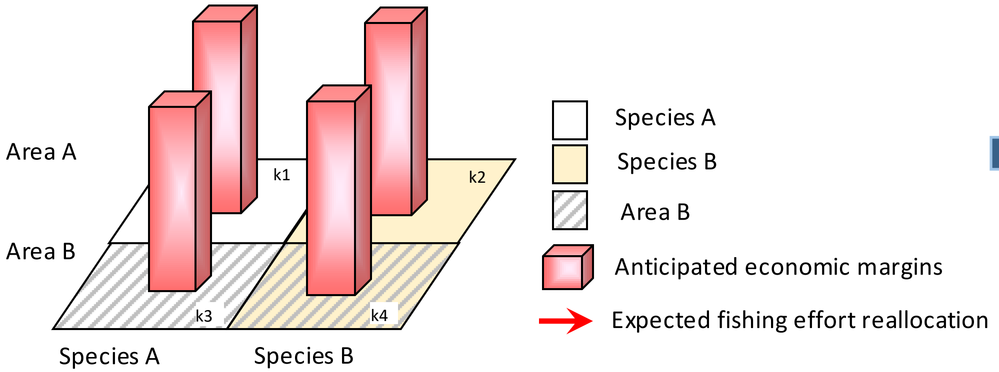
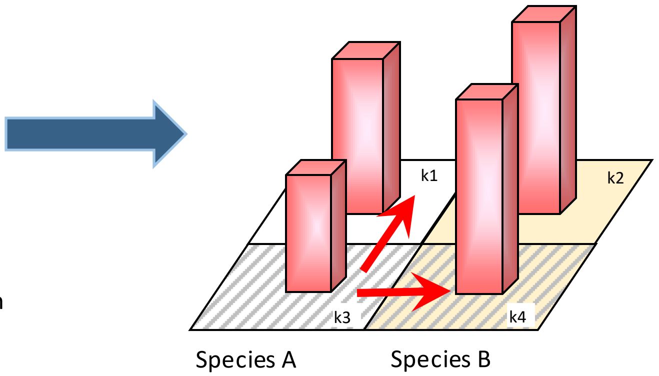


Climate change scenario: -25% drop in the carrying capacity for species of **Métier 3**



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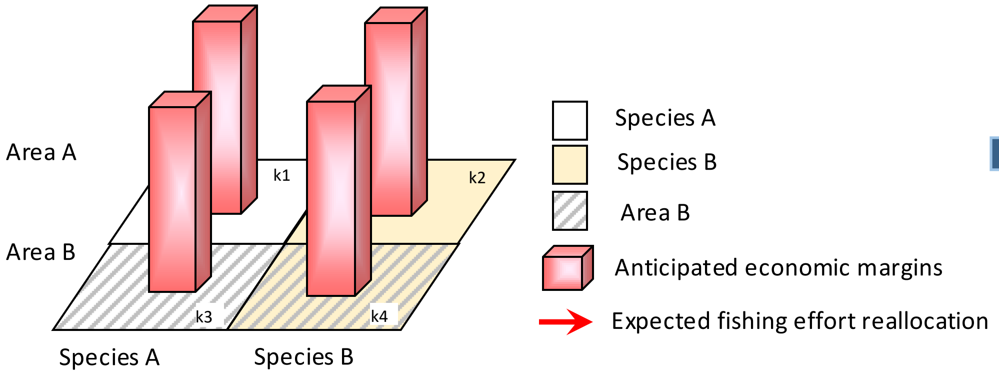

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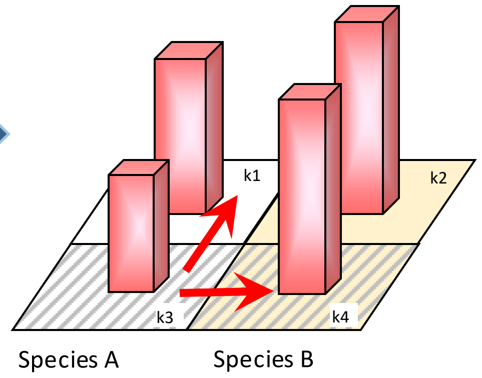
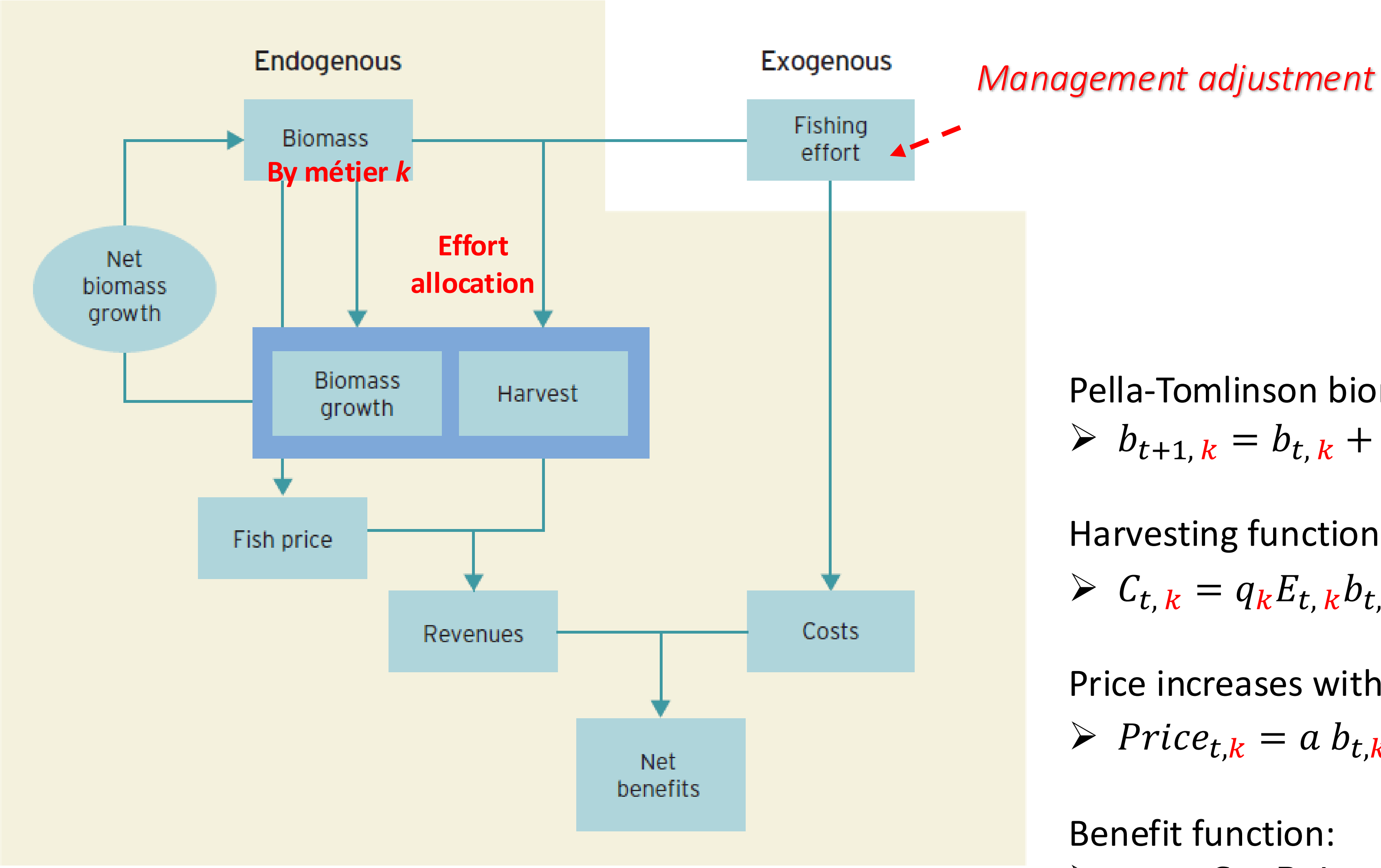


Outcomes at fishery level depending on management?

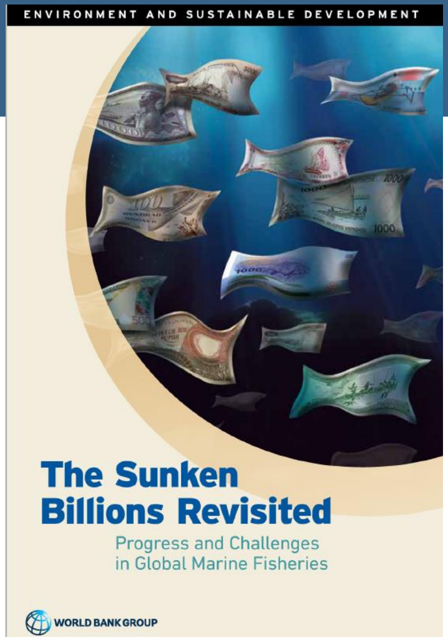
3 levels of responses:

1. Ecological drift: spatial distribution changes in harvested species (carrying capacity dependent)
2. Fishing effort allocation at local scale: spatial distribution response to anticipated economic margins
3. Global fishery scale: Overall fishery management and total effort adjustment

The bio-economic model



(World Bank 2017 Sunken Billion Revisited)



Pella-Tomlinson biomass growth function:

- $b_{t+1,\,k} = b_{t,\,k} + Gr_{t,\,k} + Flow_{t,\,k} - Catch_{t,\,k}$

Harvesting function:

- $C_{t,\,k} = q_k E_{t,\,k} b_{t,\,k}{}^{\beta}$

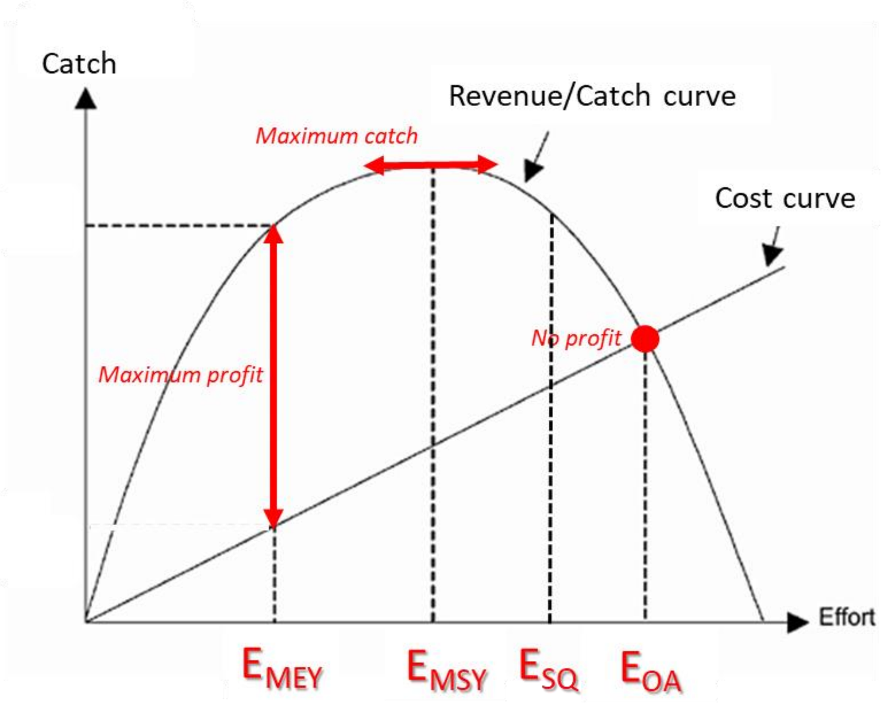
Price increases with biomass:

- $Price_{t,k} = a\, b_{t,k}{}^{d}$

Benefit function:

- $\pi_t = C_{t,\,k} Price_{t,\,k} - E_{t,\,k} Cost_k$

Management strategies



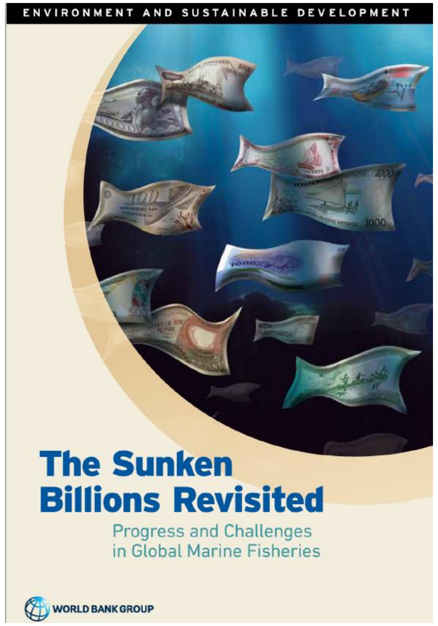
1. **Status quo:** fixed 2012 effort (Sunken Billion study)
   - ➢ Some regulation but low levels of economic returns

2. **Open access**: assuming no management, fishery still able to adapt
   - ➢ Targeted fishing effort leads to zero margin at t+1
   - ➢ Subject to inertia constraints

3. **MEY (MSY) Fixed:** targeted fishing effort is calculated such that initial profit (yield) is maximized
   - ➢ Unresponsive management: total effort is set initially and remains fixed

4. **MEY (MSY) Adapt:** targeted fishing effort is recomputed after a lag of 10 years
   - ➢ Adaptive management adjusts total effort to account for ecological change

Model calibration

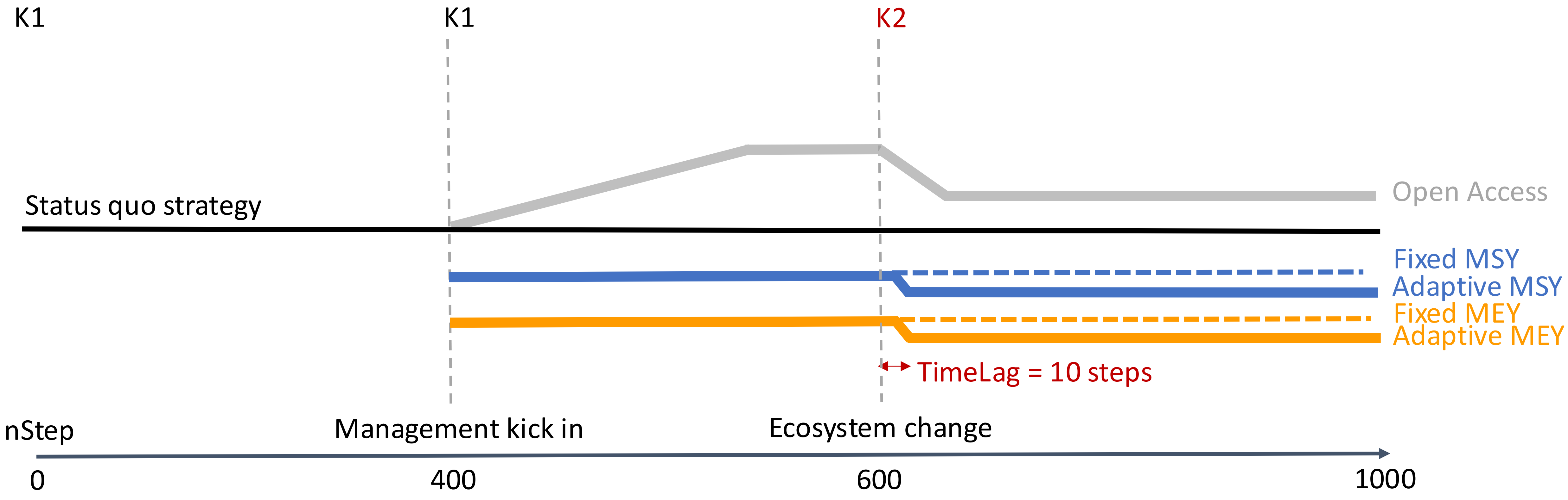


Status quo global fishery (2012): some management but limited profits

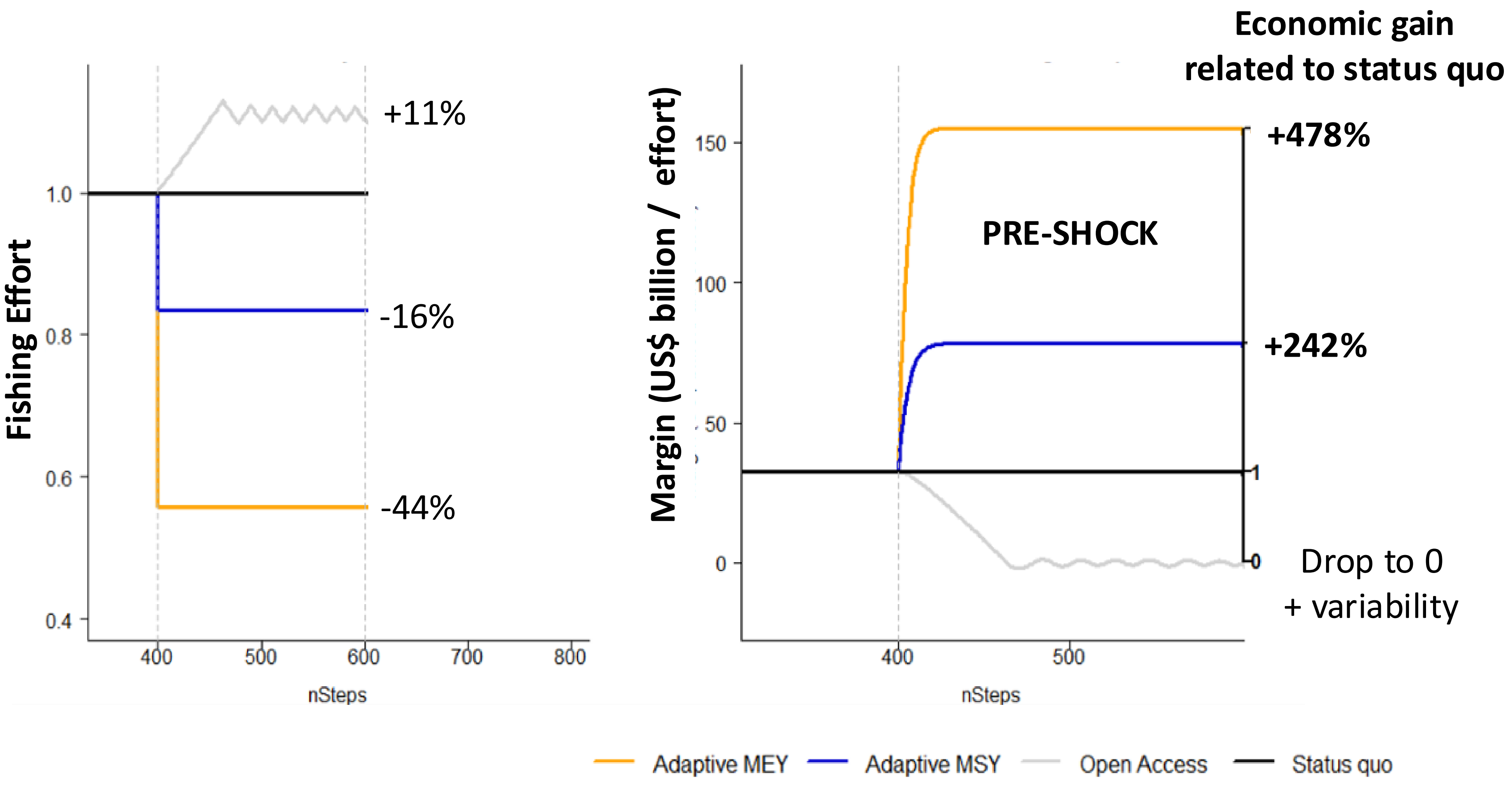
	MÉTIER 1	**MÉTIER 2**	**MÉTIER 3**	**MÉTIER 4**
Region	AREA A		AREA B	
Species	SPECIES 1	SPECIES 2	SPECIES 1	SPECIES 2
Biological parameters				
Baseline carrying capacity (Million tons)	980			
Carrying capacity (Million tons)	245	245	**245→ 183.75**	245
Starting biomass (Million tons)	61.25			
Growth rates	1.644			
Pella Tomlinson Exponent (γ)	1.188			
Schooling Exponent (δ)	0.71			
qq (enforcing biomass >0)	0.05			
Species mobility	1			
Economic parameters				
Cost per unit of effort	97.422			
Catchability coefficient	1.76			
Landing price parameter	0.387			
Price elasticity	0.22			
Inertia parameters				
Implementation Inertia	0.2			
Cost of changing zone	0.04			
Cost of changing species	0.05			
z_{In} controlling how much effort can enter the metier	0.2	0.2	0.2	0.2
z_{out} controlling how much effort can exit the metier	0.2	0.2	0.05	0.05

Main differences with Sunken Billion study

Simulation sequence



Results - Global fishery dynamics



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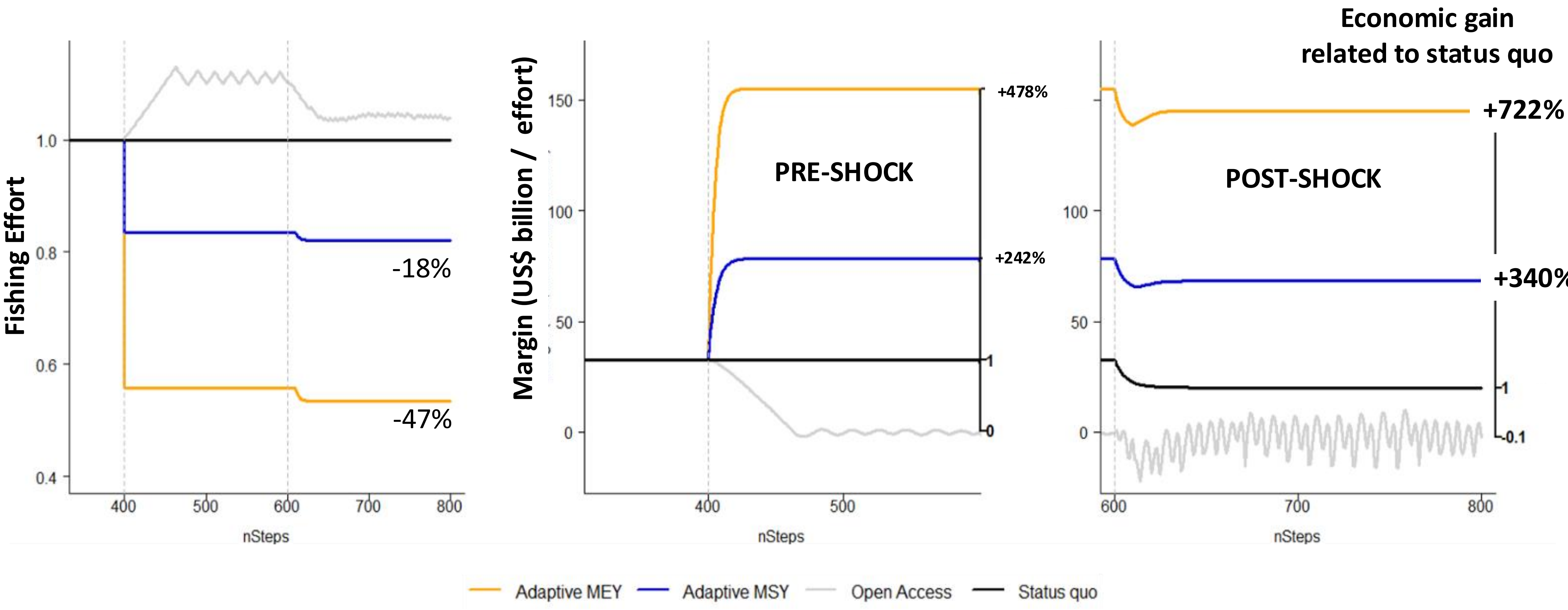
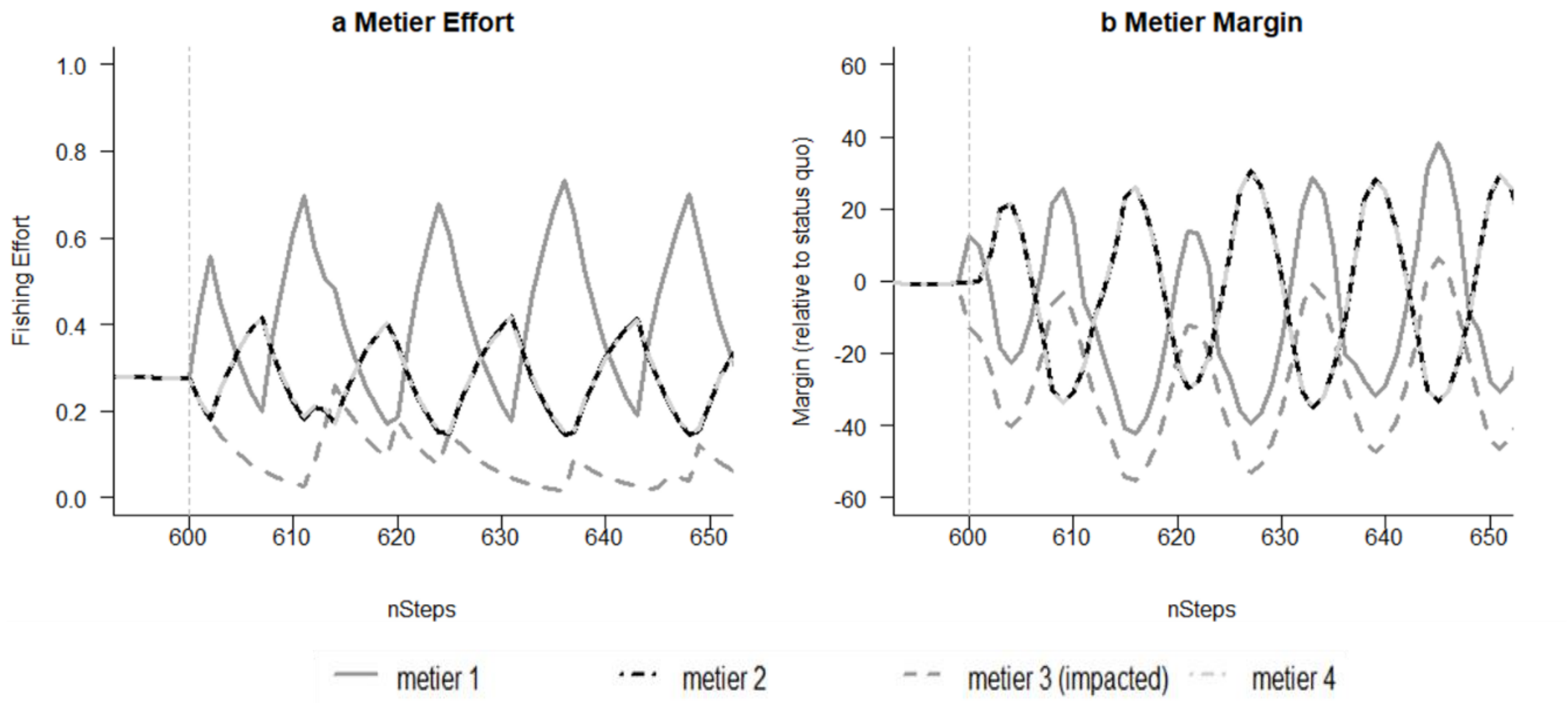
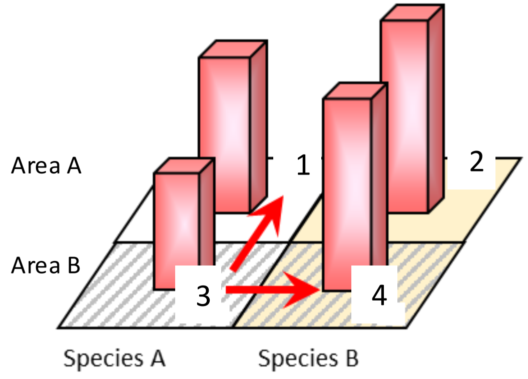


Results - Local effort responses at Métier scale under Open Access





- System the least controlled, where fishers can adapt freely, leads to more variability

- Dynamic responses <u>in every</u> metier
- Some transitional positive effects

TAKE AWAYS

1. Fishers left to adapt, with poor to inexistent management, will lead to fishery maladaptation

2. The benefits of management (as compared to lack of management) increase when the system is hit by an environmental shock

3. The MEY strategy provides for the greatest adaptation benefits

4. It is fundamental to better understand how fishers AND management institutions respond to changes

5. The drivers of these responses should be better incorporated into assessments, models and scenarios

→ **Model developments & calibration with data at finer resolution (eco-regions)**

Additional thoughts

1. **Good management is costly, and adaptive management potentially even more**: strong management (e.g. MEY) entails levels of economic returns that potentially provide more resources to support this (so more adaptive capacity) ?

2. **The effects of CC may come as gradual changes but also as shocks** (heat waves): strong management implies healthier fish stocks which may provide greater buffering capacity?

3. **CC impacts imply increased uncertainty wrt. the status of stocks / ecosystems & responses to fishing**: strong management may be more robust to such uncertainty?

4. Management adaptation is strongly related to cooperation (especially internationally), so **more adaptive management requires strengthened international cooperative institutions**?

Thank you for your attention

Questions or comments?

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Adaptive fisheries responses may lead to climate maladaptation in the absence of access regulations

Jennifer Beckensteiner[1,2]✉, Fabio Boschetti[3] and Olivier Thébaud[4]

Adaptive fishery responses to climate-induced changes in marine fish populations may lead to fishery maladaptation. Using a stylised bio-economic model of the global fishery, we demonstrate the importance of adaptive management regimes. We show how the losses resulting from poor access regulation increase in a fishery system negatively impacted by environmental change, and demonstrate the proportional benefits provided by management strategies that control the levels and allocation of fishing effort. Indeed, under poor to nonexistent access regulation, highly adaptive actors can generate significant bio-economic losses. This might lead to foregone benefits and cascading economic and ecological losses, whereas well-designed adaptive management regimes may enable making the most of the best, and the least of the worst, climate-induced outcomes for fisheries. These findings emphasize the need for integrated assessment approaches to the impacts of climate change on fisheries, that should incorporate not only ecological responses but also the industry and management responses.

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