3 Days MESSH Brest 2024

Bio-economic modelling of small-scale fishery in French Guiana : review and perspectives

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0- Introduction

LEEISA Laboratoire Ecologie, Evolution, Interactions des Systèmes amazoniens

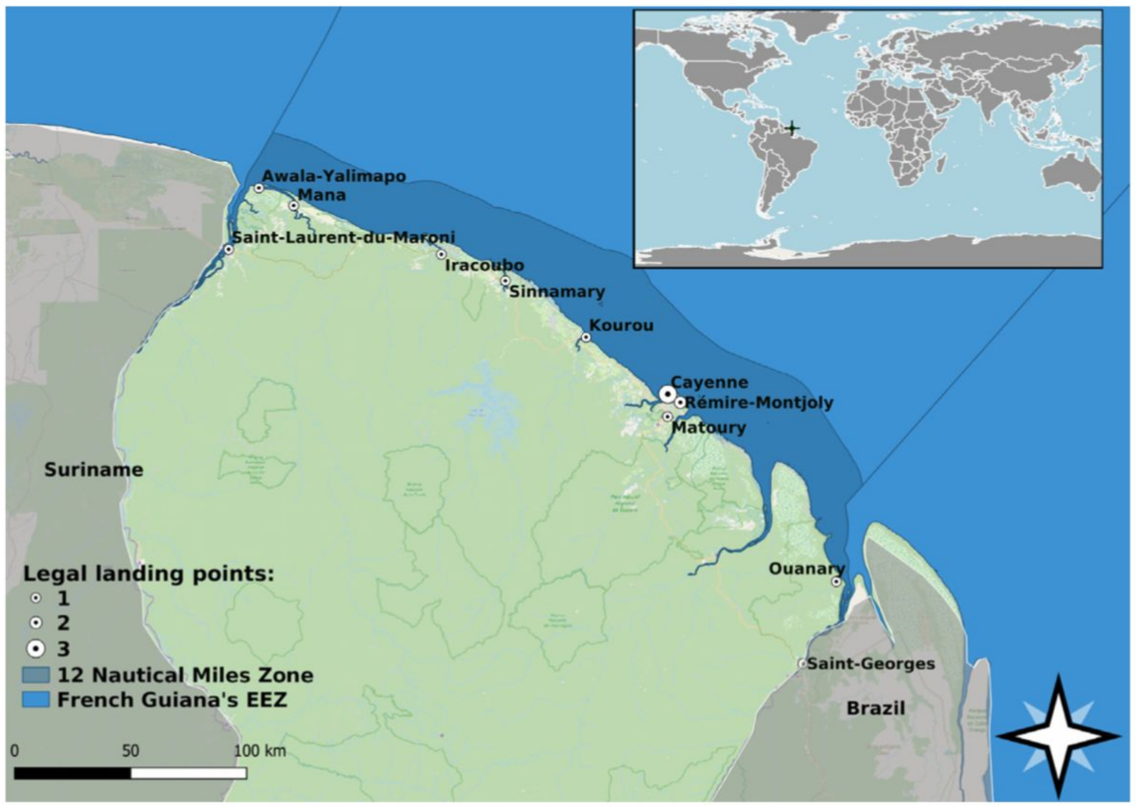
How to operationalize Ecosystem-Based Fishery Management for tropical Small Scale Fishery ?

- Bio-economic modelling
- MICE models (Plagányi *et al*., 2014)
- Scenarios for Viability (Bene *et al*., 2001)
- Scenarios for Resilience (Grafton *et al*., 2019) : Resistance, Robustness and Recovery

French Guiana coastal fishery as a perfect case study

(complexity, uncertainties, tropical SSF issues, data, etc.)

1- Case study: The French Guiana SSF



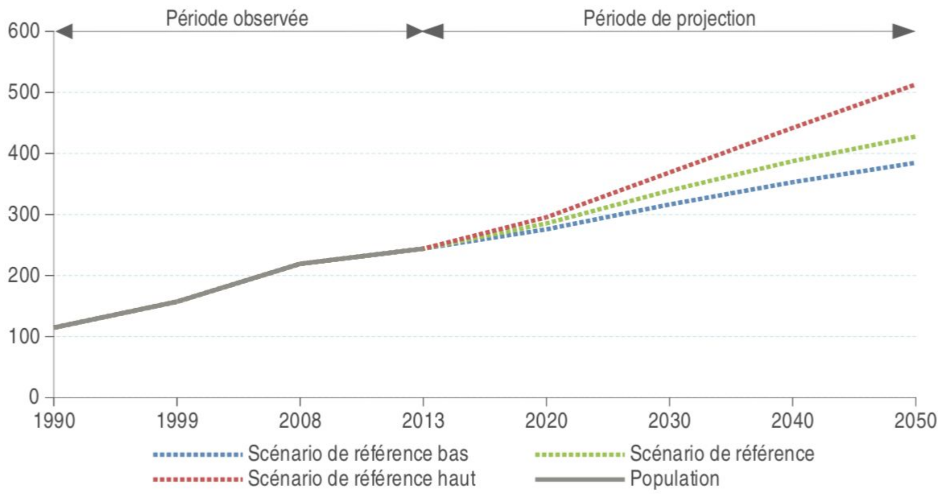
- 140 vessels (2022) / 2500 tones per year
- 450 fishermen
- Gross value of landings : 6 millions € (2021)
- Main landed species:
  - Acoupa Weak fish (31% Vol)
  - Green weakfish (26% Vol)
  - Crucifix catfish (18 % Vol)
- Main fleets:
  - "Canots créoles " (18%)
  - " Canots créoles améliorés " (74% TGV)
  - " Tapouilles " (6% TGV)

1- Case study: The issues of French Guiana SSF

- Issue of local seafood demand increase

5 Entre 385 000 et 513 000 habitants en Guyane à l'horizon 2050

Évolution de la population guyanaise à l'horizon 2050 selon les trois scénarios démographiques (en millier)

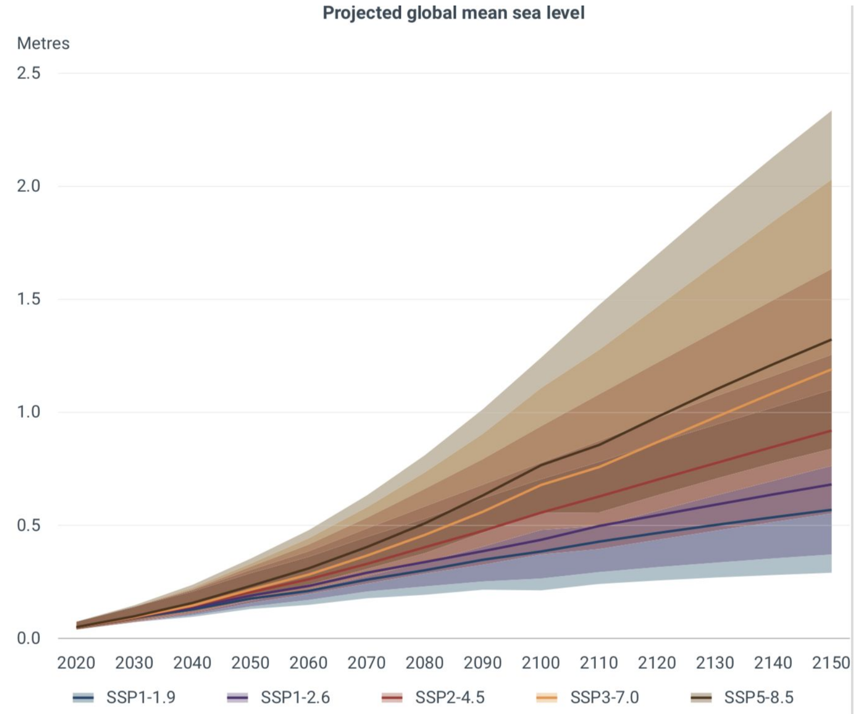


Lecture : la courbe grise représente l'évolution réelle de la population guyanaise entre 1990 et 2013, puis les courbes de couleur représentent les évolutions futures basées sur les trois scénarios envisagés dans cette étude.

Sources : Insee, Recensements de la population & projections de population Omphale 2017.

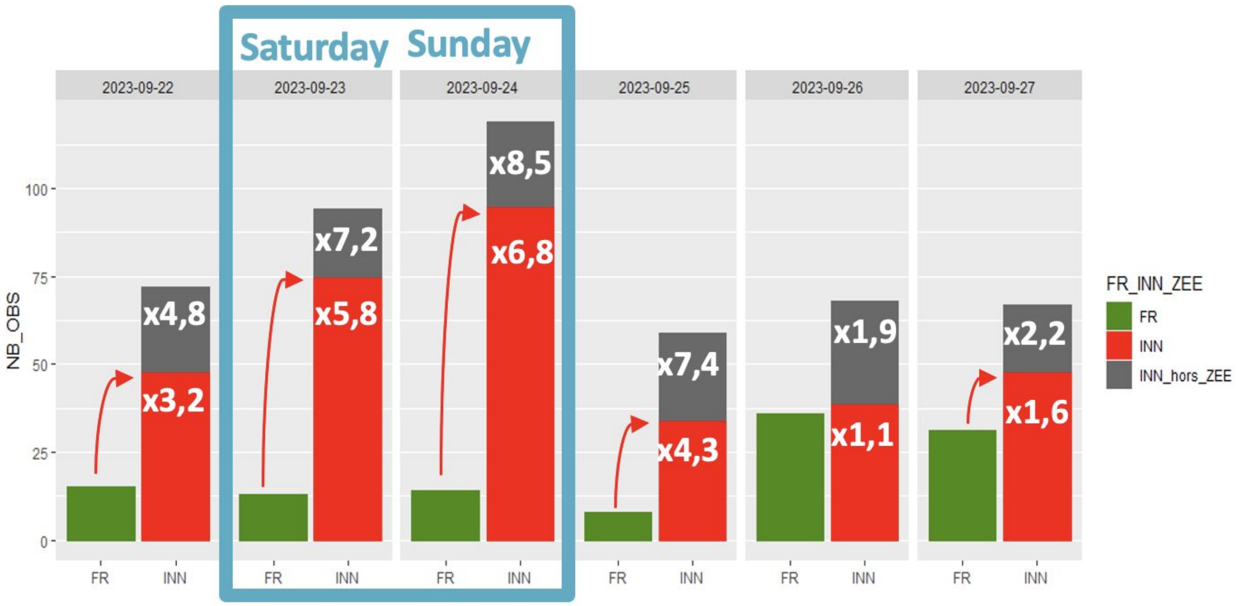
- Issue of profitability

- Issue of climate changes



- Issue of illegal fishing

Total number of illegal ships observed during aerial surveillance



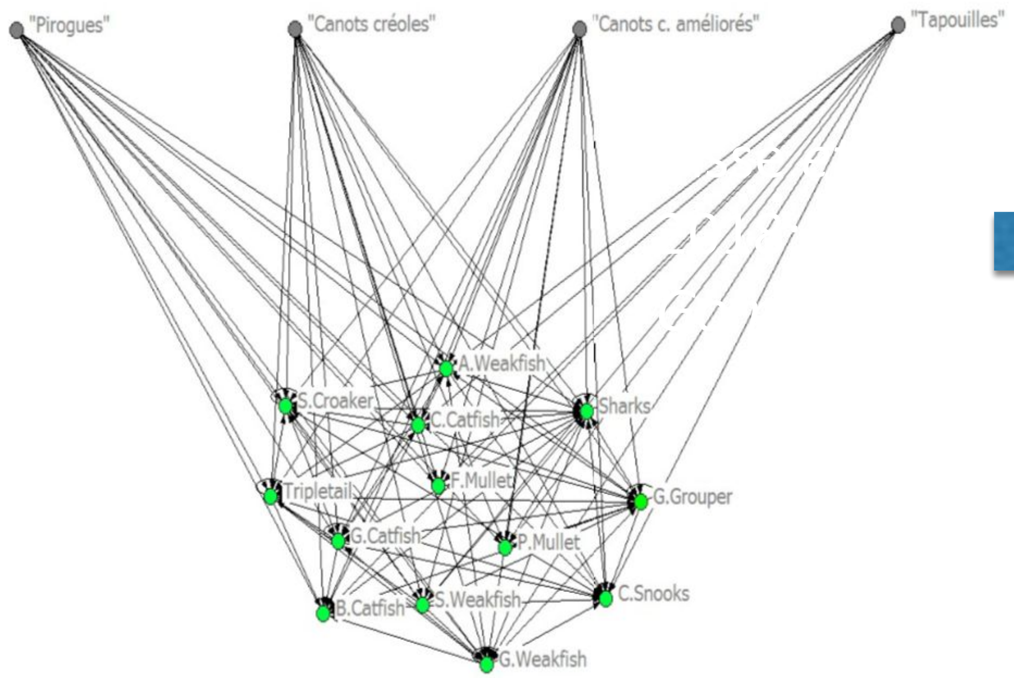
2- Methods: Multi-species and multi fleets bioeconomic models

- Lotka-Volterra prey-predator dynamics

$$B_i(t+1) = g_i(B(t) - H(t), \epsilon_i(t)),$$

with

$$g_i(B_1, \ldots, B_n, \epsilon_i) = B_i \cdot \left(1 + r_i - \frac{r_i}{K_i} B_i + \sum_{j \neq i} s_{i,j} B_j + \epsilon_i\right),$$



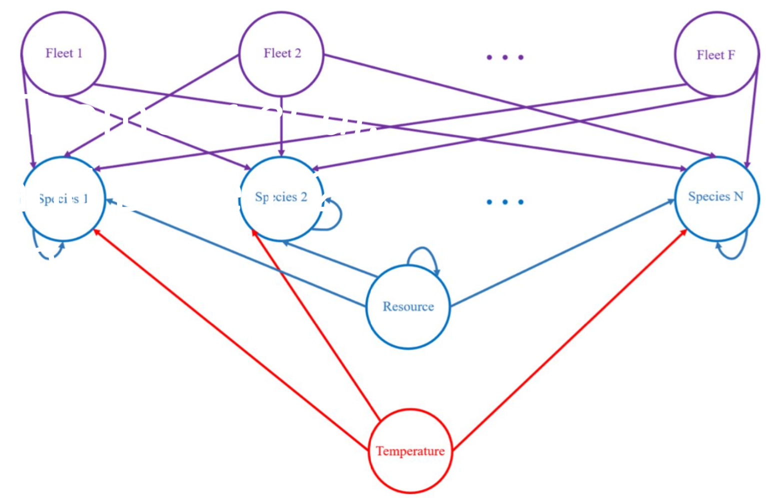
Cissé *et al.* 2013,2015; Tromeur and Doyen 2018

- Resource-based model (Tilman and Sterner, 1984)

$$B_i(t+1) = B_i(t)\big(1 - M_i + G_i(t)\big) - H_i(t).$$

with

$$G_i(t) = g_i a_{res,i} B_{res}(t) \gamma_i\big(\theta(t - \tau_i)\big)$$



Gomes *et al.* 2021; Kersulec *et al.* *2023*; Cuilleret *et al. 2022*

- Schaefer production function

$$H_{i,f}(t) = q_{i,f} E_f(t) B_i(t),$$

2- Methods: model calibration

- Data for calibration : quaterly catches by species and fleet and efforts by fleet since 2006

$$\min_{M_i;q_{i,f};a_{res,i};g_i;B_i(t_0);\tau_i} \sum_{t=t_0}^{t_1-1} \sum_{i=1}^{N} \sum_{f=1}^{F} (H_{i,f}^{data}(t) - H_{i,f}(t))^2,$$

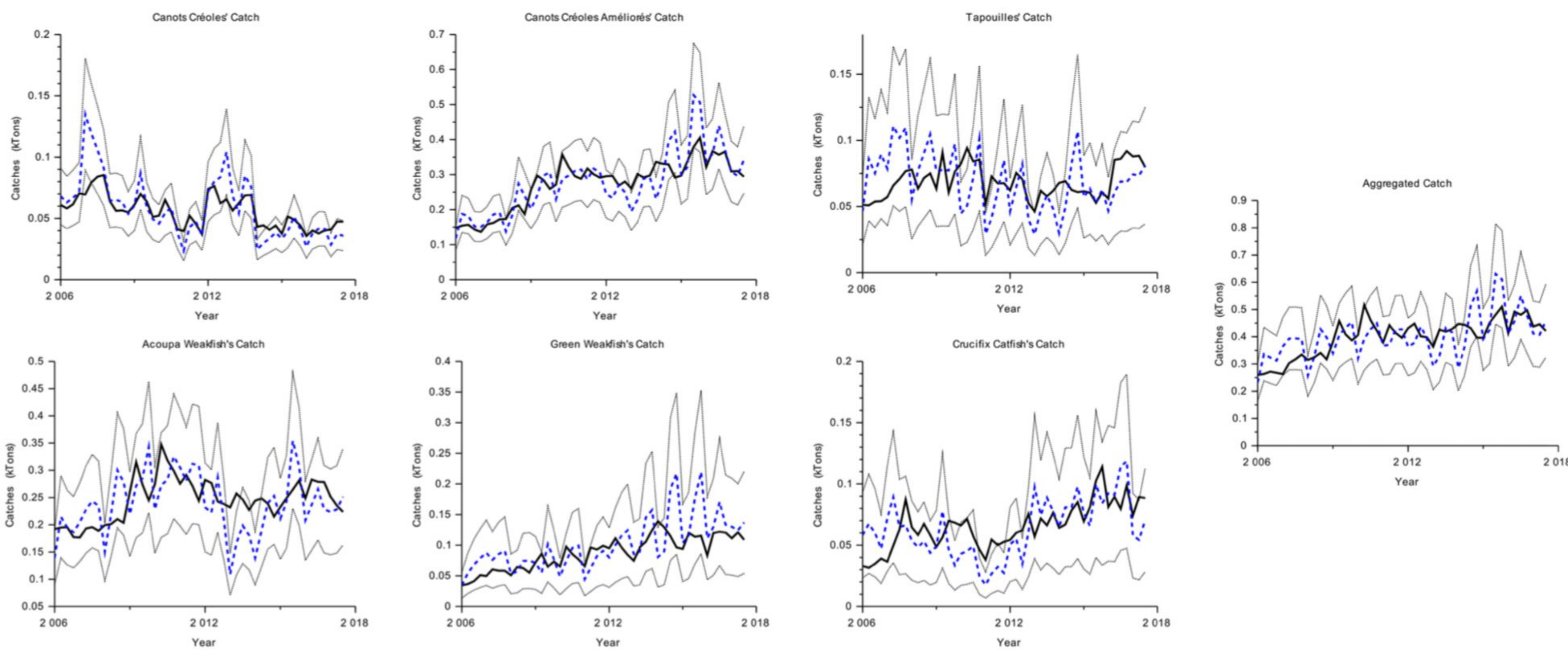


Fig. 5 Historical (dark blue points) and calibrated (black line) catch by fleet (first row), by stock (second row), and aggregated (last graph) with 95% confidence intervals (dotted black lines) from the first quarter of 2006 to the last quarter of 2017

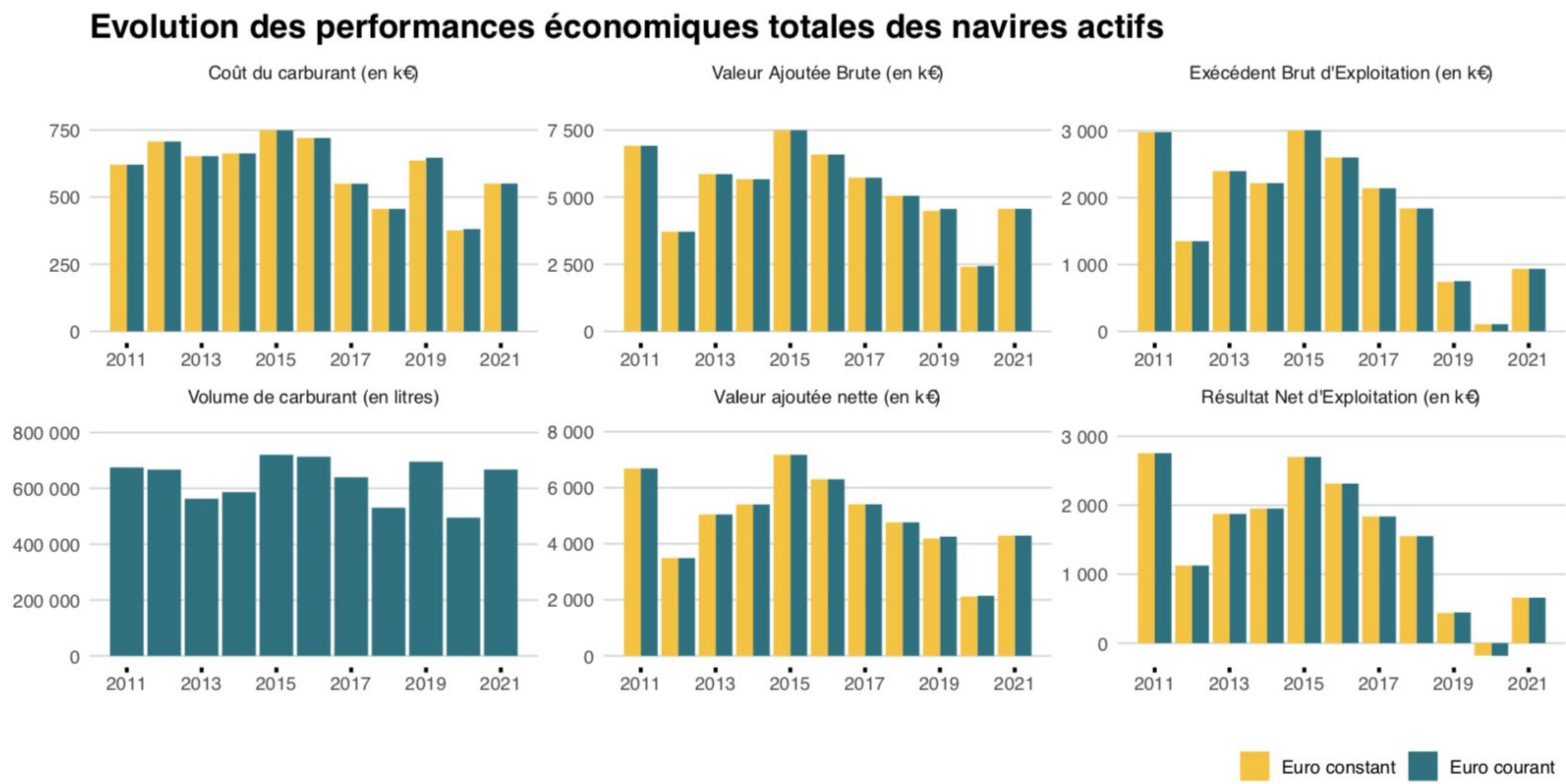
2- Methods : Economic compartment

- Economic data collection : 2010 and 2022
- Average species prices by fleet and marketing channel
- Fixed and variables costs by fleet
- Subsidies
- Revenues
- Profits

$$\pi(t) = \sum_{f=1}^{F} (1 - Bet_f)(Inc_f(t) - Co_f(t)).$$

$$Co_f(t) = E_f(t)\left(OilCon_f Coil(t) + Ice_f + Fix_f\right).$$

$$Inc_f(t) = \sum_{s=1}^{S} h_{s,f}(t) p_s(t) + Inc_{Ots}(t),$$



2- Methods : Scenarios

Explorative scenarios :

- Business as usual and Closure (Cissé *et al.* 2015; Cuilleret *et al.* 2022)
- Impacts of Climate changes (Gomes *et al.* 2021)
- Impacts of Illegal fishing (Kersulec *et al.* 2023)

Normative scenarios :

- Economic (NPV) (Cissé *et al.* 2015; Cuilleret *et al.* 2022)
- MMEY and MMSY (Tromeur and Doyen 2018; Cuilleret *et al.* 2022)
- Ecoviability (Cissé *et al.* 2015)

2- Methods and main results : Explorative scenarios

- Business as usual (status quo) scenario :

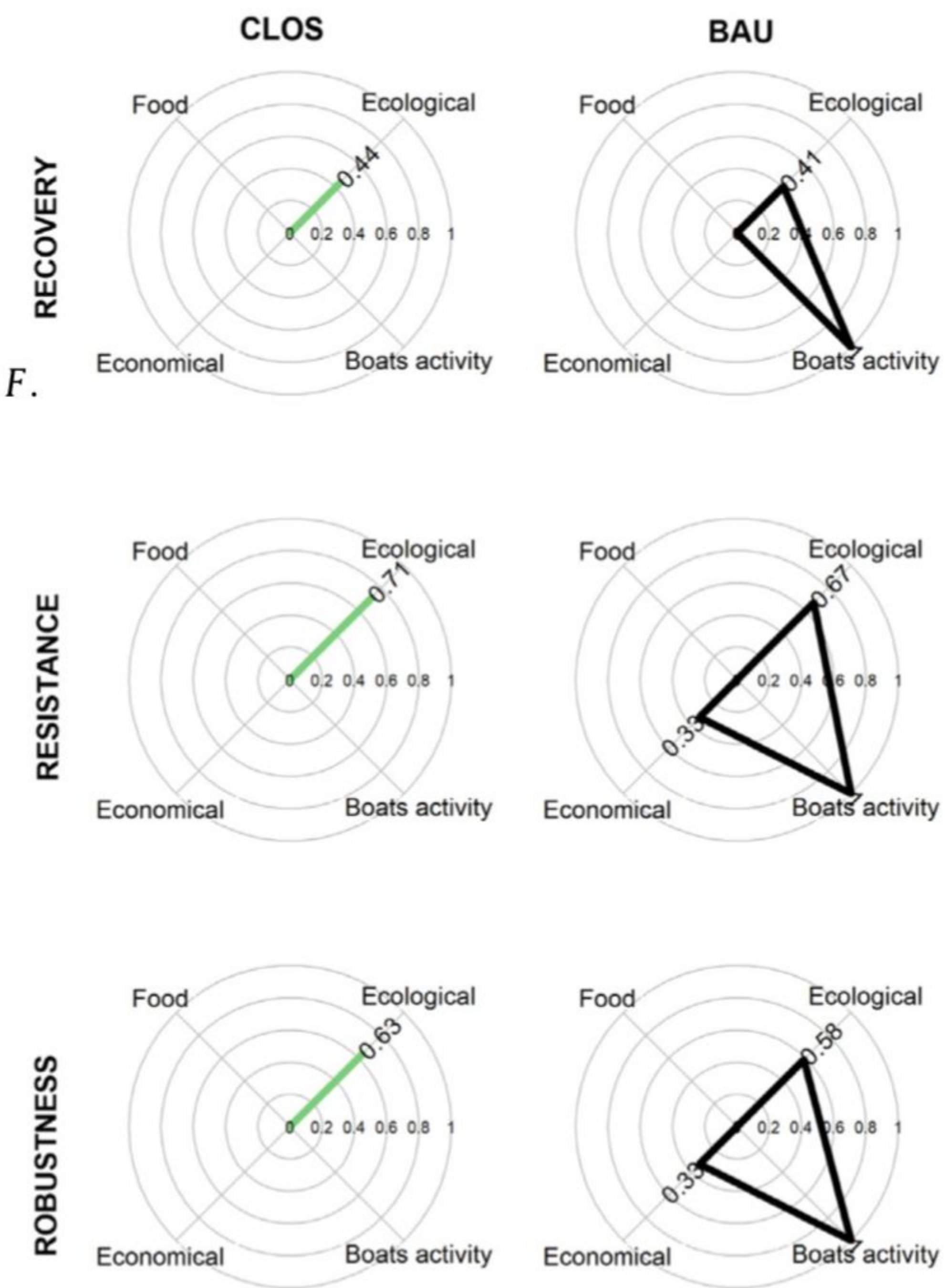
=> Weak Economically and Unviable for food security (Cissé *et al.* 2015, Cuilleret *et al.* 2022)

$$E_f^{BAU}(t+1) = E_f^{BAU}(t)(1+\delta_f^{hist}), \qquad \forall t = t_c, \ldots, T, \ \forall f = 1, \ldots, F.$$

- Closure :

=> Unviable from social viewpoint and for food security (Cissé et al 2013, Cuilleret *et al.* 2022)

$$E_f^{CLOS}(t) = 0, \qquad \forall t = t_c, \ldots, T, \ \forall f = 1, \ldots, F.$$



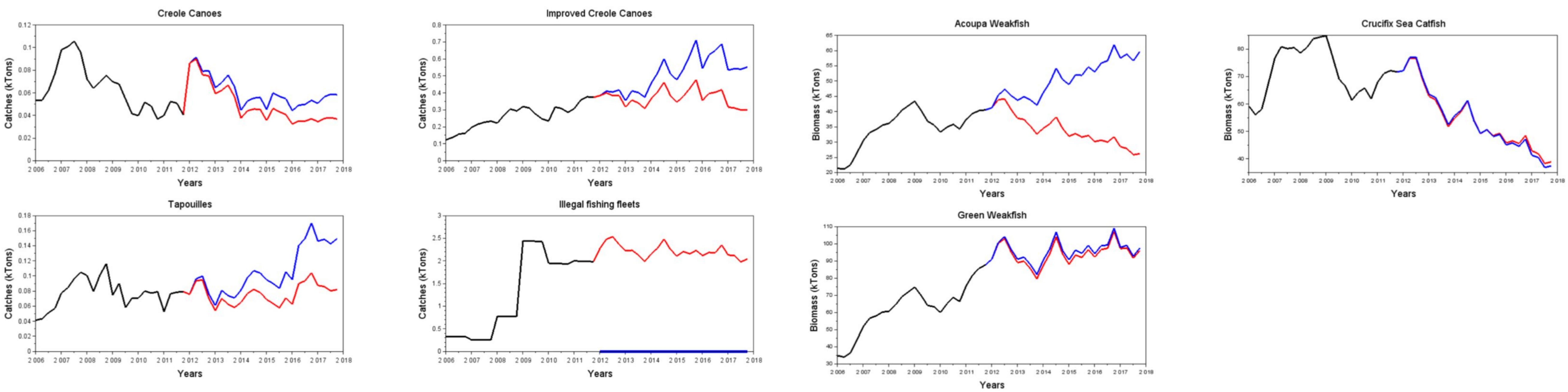
Cuilleret *et al. 2022*

2- Methods and main results : Explorative scenarios

Explorative IUU fishing scenarios 4th fleet => calibration

$$H_{i,IUU}^{data}(t) = H_{IUU}^{data}(t) * \frac{H_i^{data}(t)}{\sum_{j=1,\ldots,N} H_j^{data}(t)}.$$

- Monetary and biodiversity losses with IUU activities
- Economic gains biodiversity perservation with no IUU fishing : around 5 millions euros per year



Kersulec *et al.* 2023

2- Methods and main results : Explorative scenarios

Explorative climate change scenarios (RCP2.6, RCP8.5)

$$B_i(t+1) = B_i(t)\big(1 - M_i + G_i(t)\big) - H_i(t).$$

with

$$G_i(t) = g_i a_{res,i} B_{res}(t) \gamma_i\big(\theta(t - \tau_i)\big)$$

- Explorative climate change scenarios (RCP2.6, RCP8.5)
- Intergovernmental Panel on Climate Change (IPCC) scenarios
- RCP2.6 : optimistic climatic scenario (increase on average by about 0.64◦ C in 2031–2050 and by about 0.73◦ C in 2081–2100)
- RCP8.5 : pessimistic climate scenario (a mean increase of 0.95° C in global SST in 2031-2050 and of 2.58° C in 2081–2100)

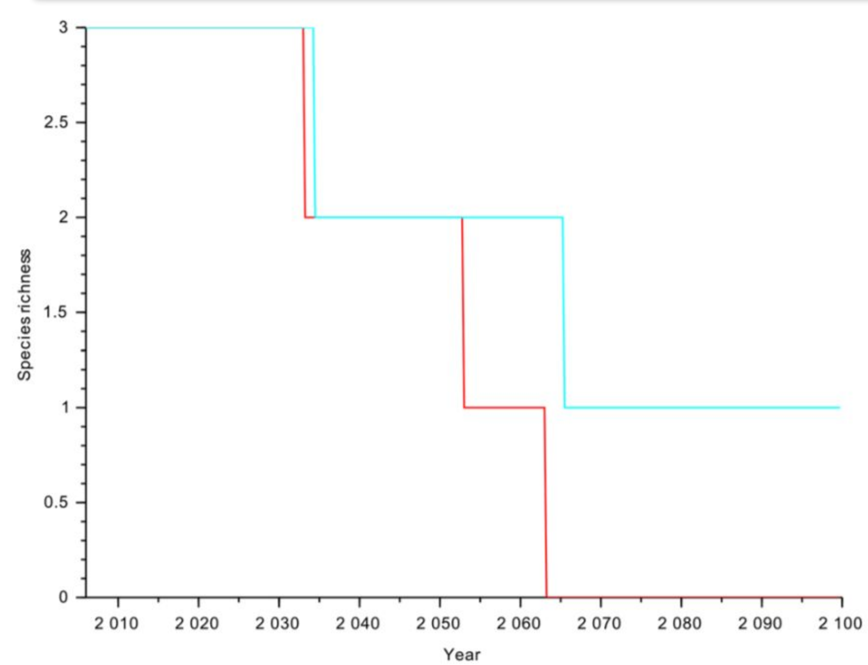
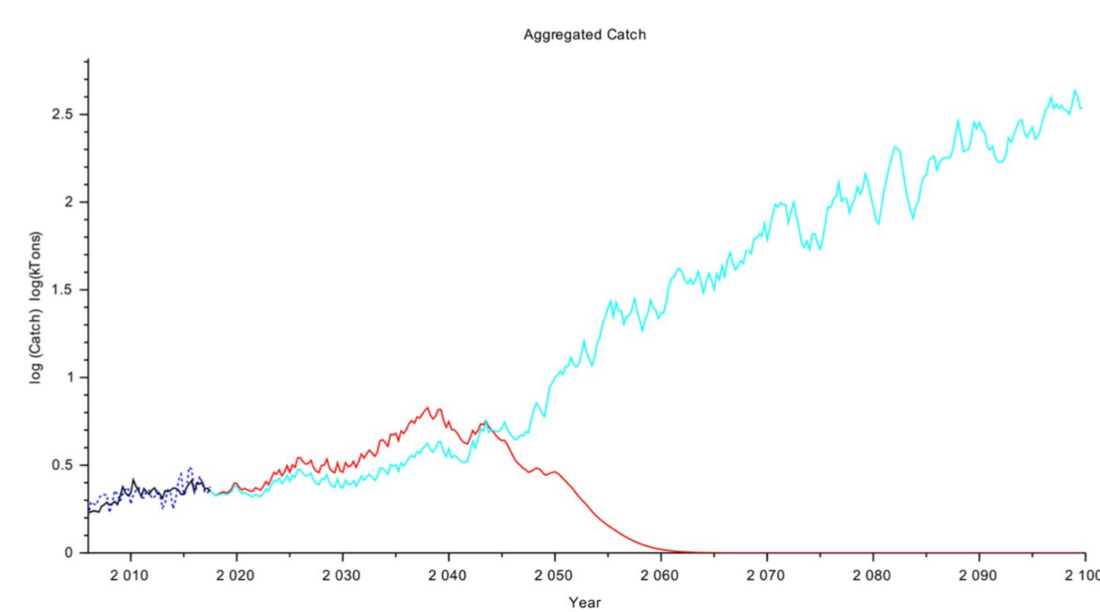


Fig. 9 Estimated number of non extinct species among the three species taken into account for RCP 8.5 (red) and RCP 2.6 (blue) under the PS fishing scenario

Fig. 10 Aggregated catch on a logarithmic scale for RCP 8.5 (red) and RCP 2.6 (blue) under the PS fishing scenario



Gomes *et al.* 2021

2- Methods and main results : Normative scenarios

- Multi-species maximum sustainable yield (MMSY) :

=> maximizing the expected aggregated catches over the projeted period with respect to the fishing effort.

=> Better resilience for food security (Tromeur and Doyen 2018, Cuilleret *et al.* 2022)

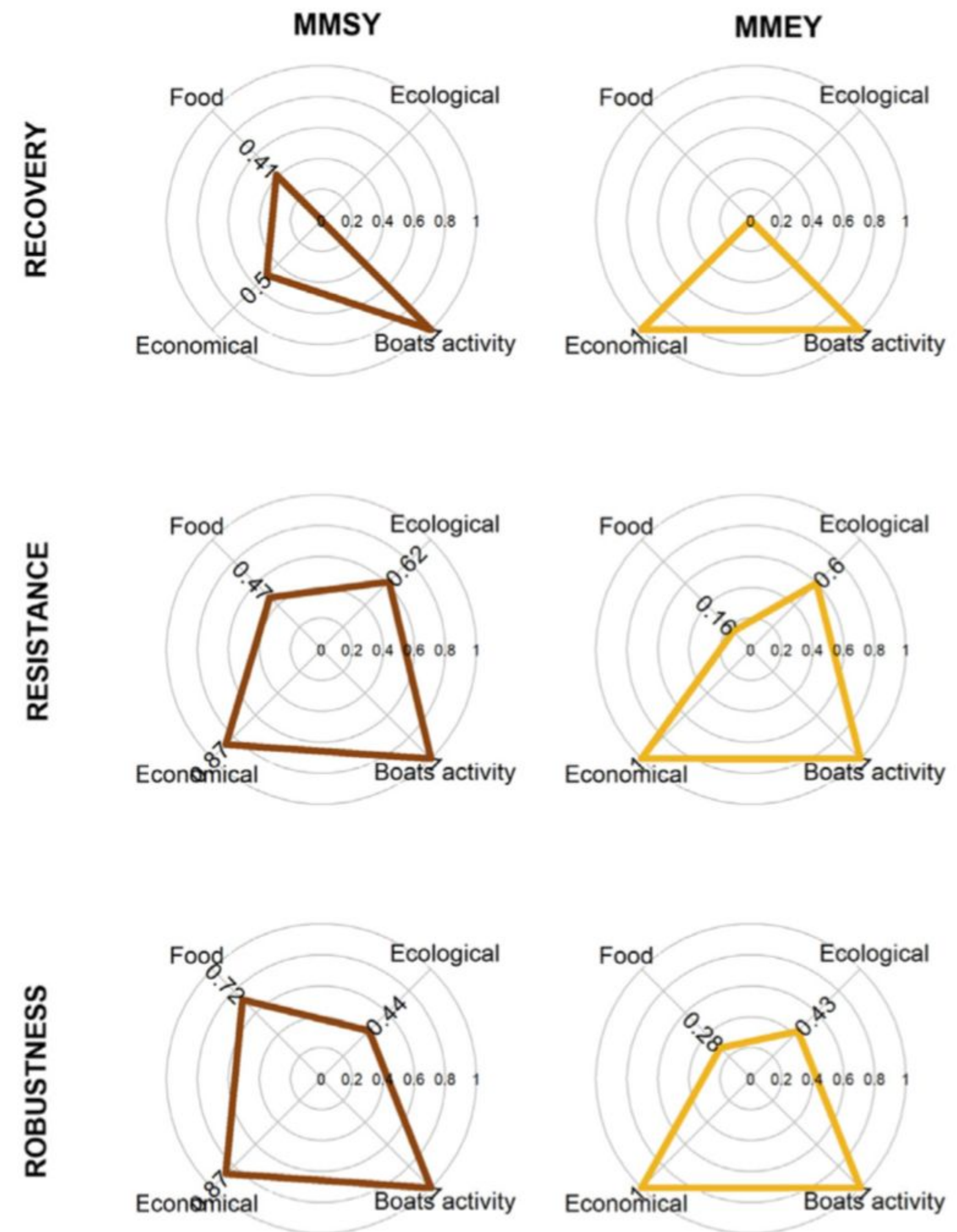
$$H(E^{\text{MMSY}}) = \max_{E_f,\, f=1,\ldots,F} \mathbb{E}_{\theta,Coil}\left[H(E)\right]$$

- Multi- species maximum economic yield (MMEY) :

=> maximizing, the net present value of the fishery over the simulation period.

=> Better economic resilience (Tromeur and Doyen 2018, Cuilleret *et al.* 2022)

$$\text{NPV}(E^{\text{MMEY}}) = \max_{E_f,\, f=1,\ldots,F} \mathbb{E}_{\theta,Coil}\left[\text{NPV}(E)\right]$$



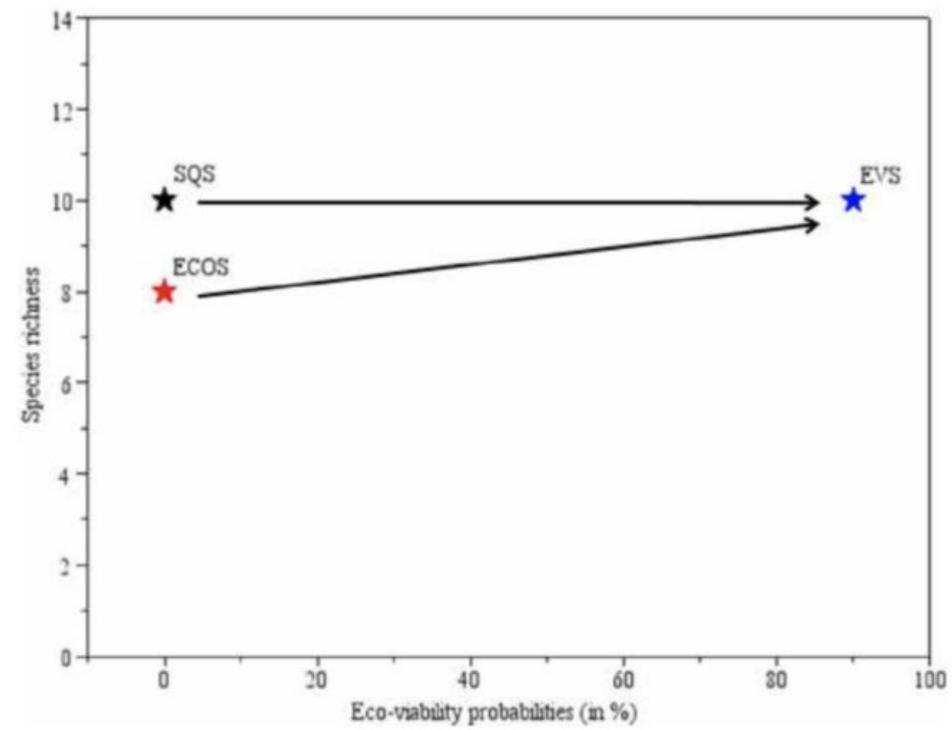
Cuilleret *et al. 2022*

2- Methods and main results : Normative scenarios

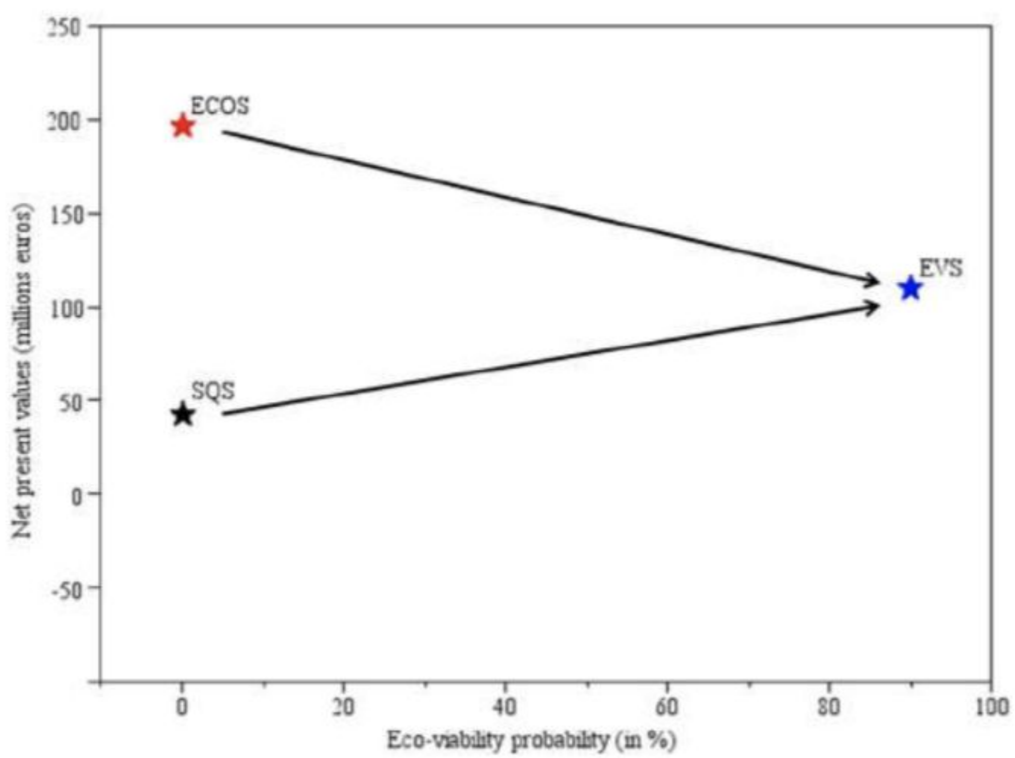
<u>Ecoviability scenario :</u>

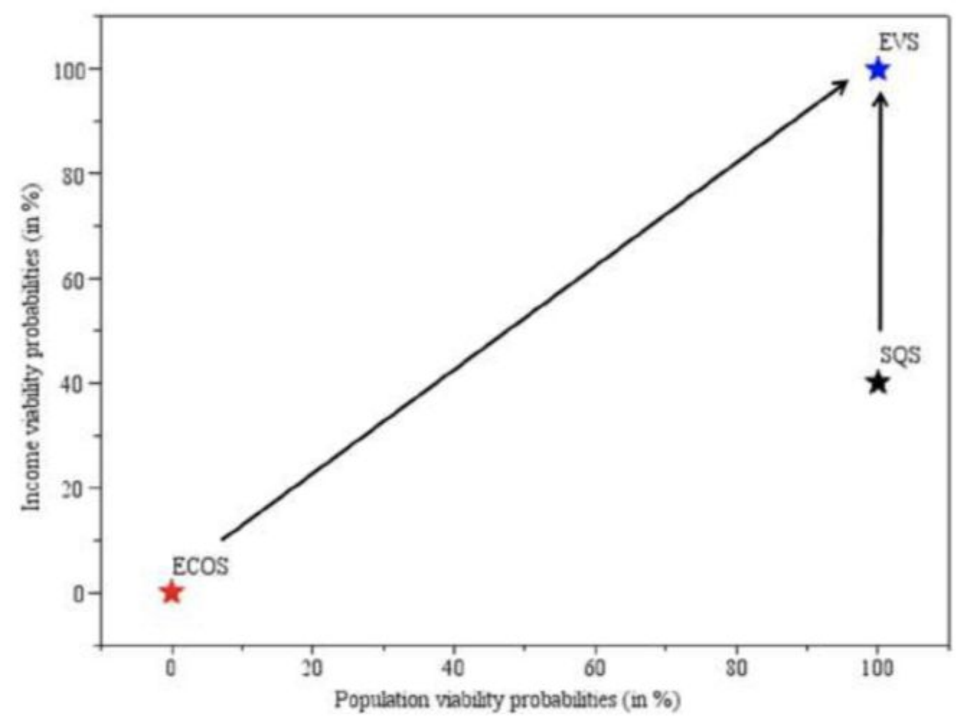
- Economic constraint : profitability
- Ecological constraint : Blim
- Social constraint : seafood demand

$$\max_{e_k(t)} \prod_{t=t_1}^{t_f} \mathbf{1}_{\{]0,+\infty[\}}(\pi_k(t))\mathbf{1}_{\{]0,+\infty[\}}(\mathrm{SR}(t)-11)\mathbf{1}_{\{]0,+\infty[\}}\cdot(H(t)-H(2009)\cdot(1+d)^t)$$



<u>Ecoviability scenario</u> : a way to integrate ecological, economics but also Social considerations (Cissé *et al.* 2015)





Cissé *et al.* 2015

3- Resume : Bioeconomic modelling and scenarios

Profitability and viablity under conditions
(Cuilleret *et al*. 2022; Gomes *et al.* 2021; Cissé *et al*. 2013)

Negative impacts on the resource
(Kersullec *et al.* 2023)

Legal Fishery

Illegal foreign Fishery

Local market

French Guiana
Coastal fishery
resources

Foreign markets

Demograhic pressure
(Cuilleret *et al.* 2022; Cissé *et al.* 2015)

Demand caracterization and label
(Kersullec *et al.* 2023)

Global changes

Long term detrimental impact of climate change
(Cuilleret *et al.* 2022; Gomes *et al.* 2021)

4- Perspectives

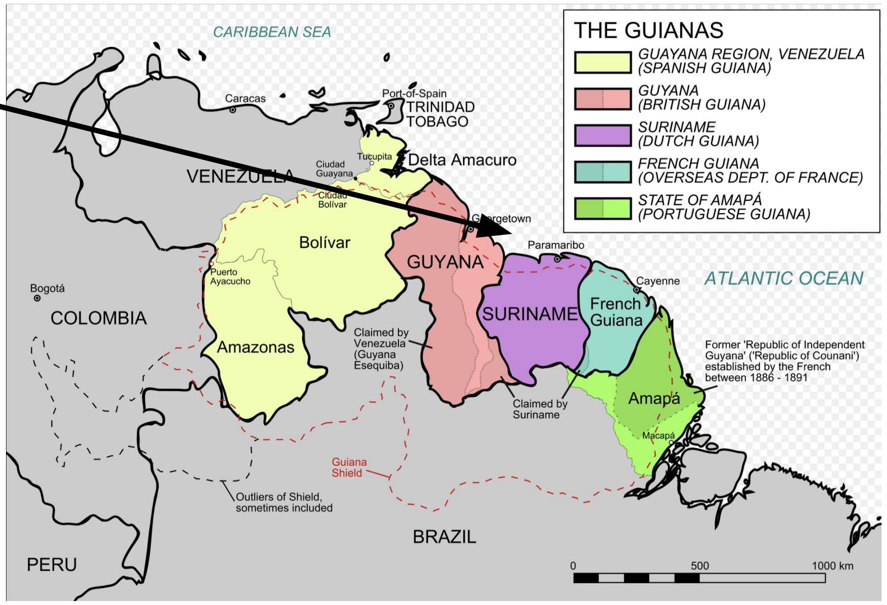
- On going stock assessments and socio-economic survey
  => first results in 2024

- On going illegal fishing evaluation
  => first results in 2024

Refine bioeconomic parameters for calibration and simulations

Analyse the IUU fishing activities with the rational choice theory and the game theory approaches

Bioeconomic model for SSF in the north eastern south america



Thank you for your attention!!

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