An eco-viability approach for the management of mixed fisheries under output controls

Olivier Thébaud

3 days MESSH 2023, Sète, France

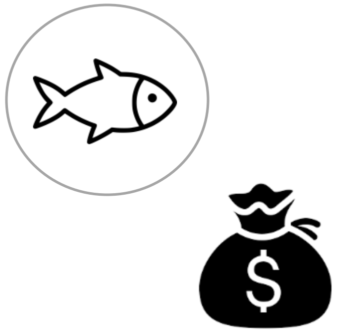
Acknowledgements:

Michel Bertignac, Florence Briton, Luc Doyen, Nick Ellis, Caleb Gardner, Sophie Gourget, Sarah Jennings, Christelle Legrand, Rich Little, Claire Macher, Vincent Martinet, Mathieu Merzéréaud, …

Context

Fisheries management

Traditional
fisheries management



- « Single-species » approaches : assessment and objectives set at the species-level
- Management objectives → reference points
  - Limit reference points = thresholds that should not be crossed
    e.g. limit biomass
  - Target reference points = states to aim for
    e.g. Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY)

Sustainable harvest of fish stocks

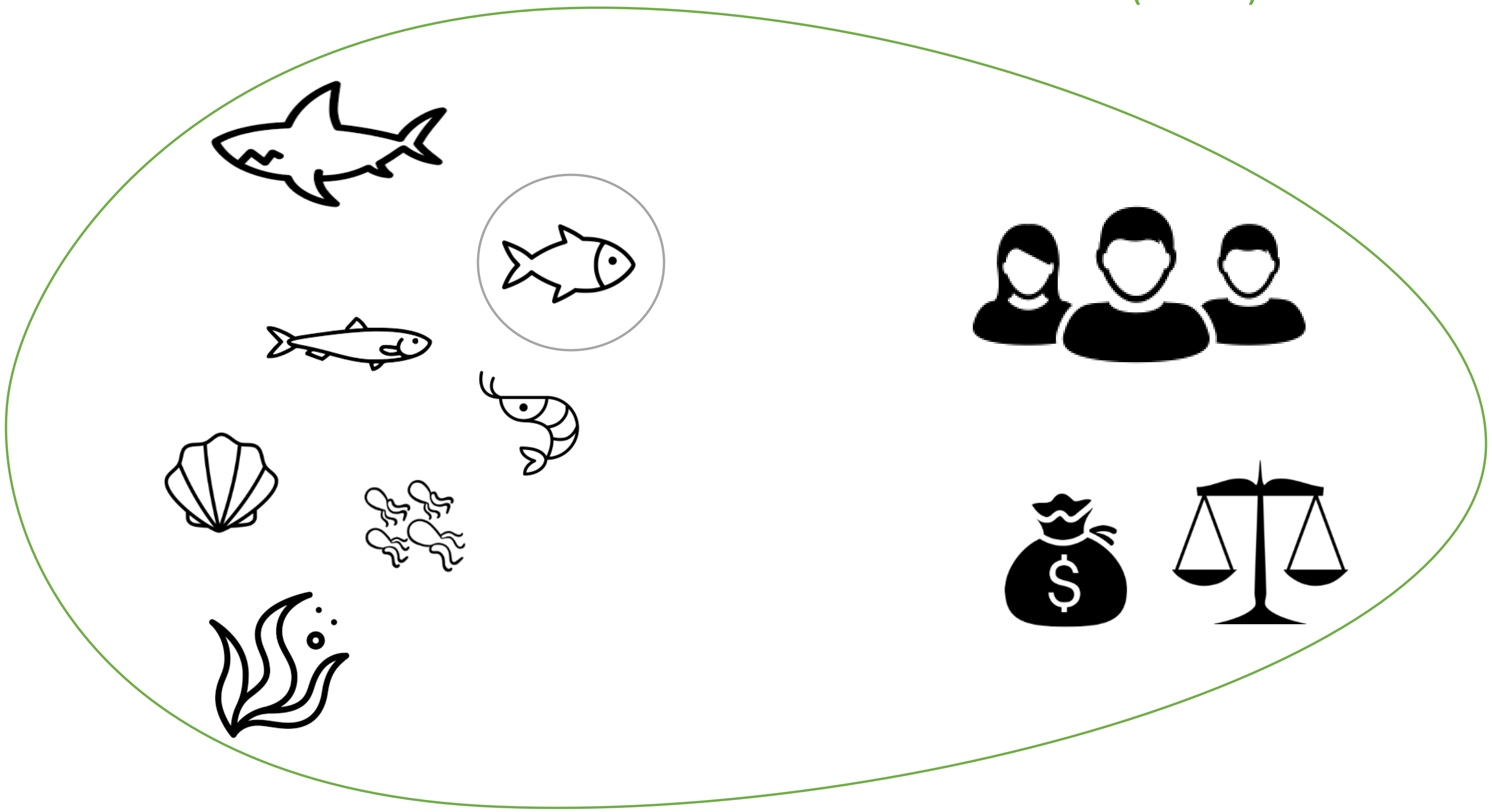
Briton, 2019

Context

Fisheries management

FAO (2002, 2003)
Garcia (2003)

Traditional fisheries management → Ecosystem-based fisheries management (EBFM)



Sustainable harvest of fish stocks

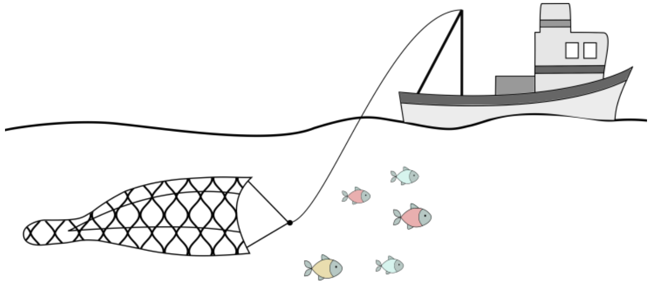
Sustainability of the social-ecological system

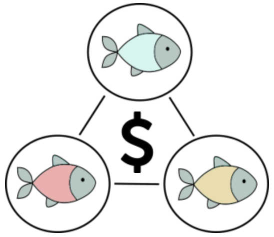
Briton, 2019

Mixed fisheries

Fisheries characterized by various interactions :

In particular: **technical** **& economic interactions**





Complicates the task of setting Total Allowable Catch limits (TACs) for individual species:

- « Choke species » problem & incentives to exceed quotas of limiting species & discard over-quota catches *(Ulrich et al. 2012)*

- Potentially complex economic & social trade-offs

→ Motivated development of mixed fisheries management plans & supporting scientific advice

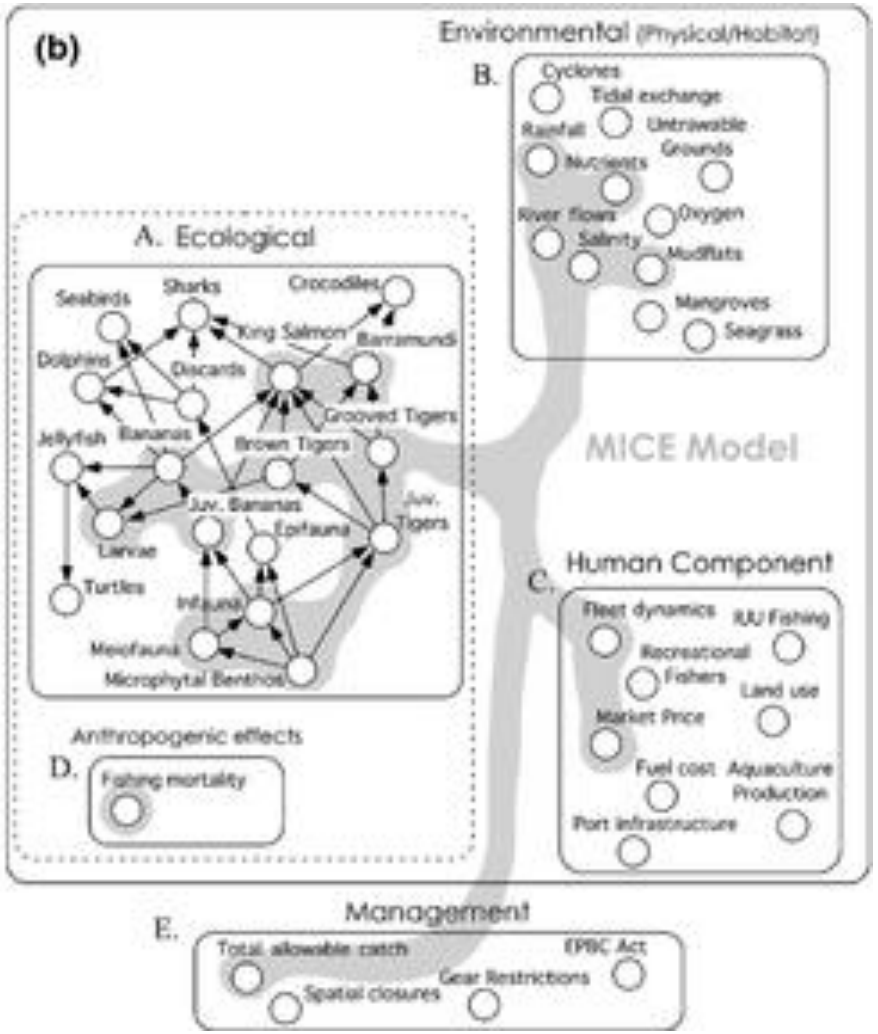
Briton, 2019

Focus

Decision support tools

- Temporal scale: short to medium-term (« tactical »)
- Capacity to build on existing information basis used to inform management
- Ability to develop / use the models in collaboration with stakeholders

Models of Intermediate Complexity



Plaganyi et al., 2012

Additional requirements

1. **Account for system dynamics**

2. **Explicitly account for ecological, economic and social dimensions → multiple evaluation criteria**

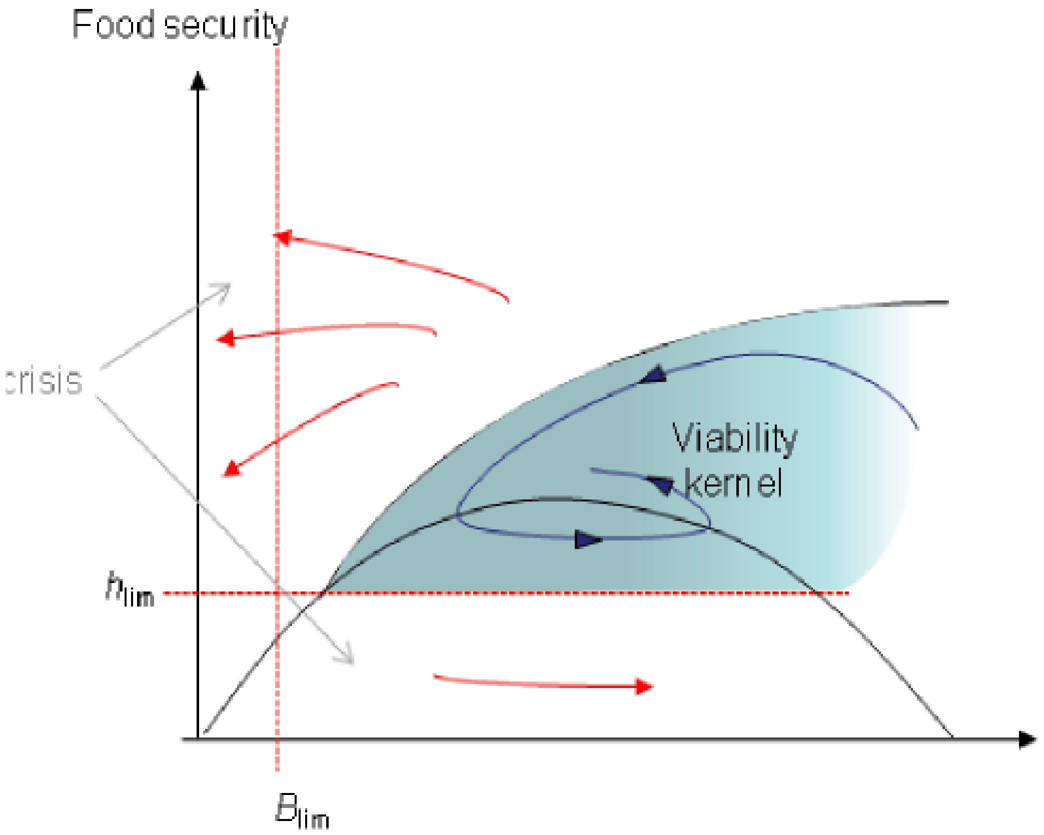
3. **Importance of distributional aspects (across time, space, economic & social groups, …)**

→ Viable (rather than optimal) control approaches

Viability ??

Aubin, J.-P. (1991). Viability theory. Birkhauser: Springer; De Lara and Doyen. Sustainable Management of Natural Resources. Mathematical Models and Methods. Springer-Verlag, Berlin. 2008; Béné, C., Doyen, L., & Gabay, D. (2001). Ecological Economics, 36, 385–396.

Applying viability analysis to fisheries management



Doyen, 2017

Seaview network

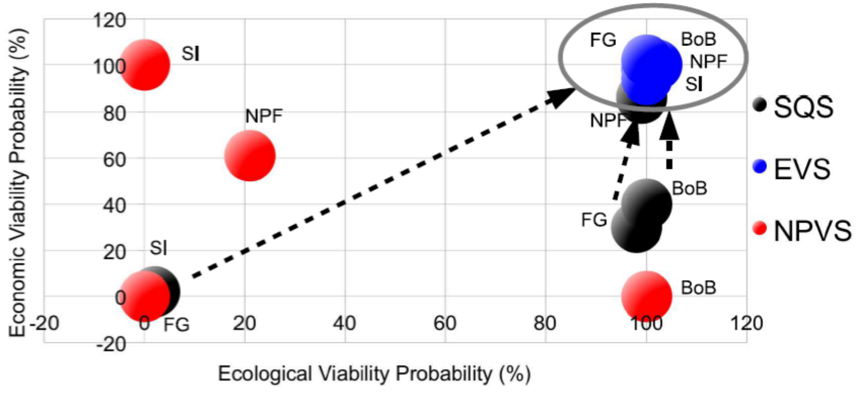
funded by BELMONT FORUM

FG : French Guiana ; NPF : Australian Northern Prawn ; SI : Solomon Islands ; BoB : Bay of Biscay

WILEY FISH and FISHERIES

Ecoviability for ecosystem-based fisheries management

Luc Doyen[1] | Christophe Béné[2] | Michel Bertignac[3] | Fabian Blanchard[4] | Abdoul Ahad Cissé[4] | Catherine Dichmont[5] | Sophie Gourguet[6] | Olivier Guyader[6] | Pierre-Yves Hardy[7] | Sarah Jennings[8] | Lorne Richard Little[9] | Claire Macher[6] | David Jonathan Mills[10,11] | Ahmed Noussair[12] | Sean Pascoe[5] | Jean-Christophe Pereau[1] | Nicolas Sanz[4] | Anne-Maree Schwarz[10] | Tony Smith[9] | Olivier Thébaud[5,6]



Ecoviability for EBFM, Fish and Fisheries, 2017

Key steps

Resource system dynamics

$$B(r, t+1) = F(B(r,t), h(r,t), \omega(r,t)), \quad t \in T \equiv \{t_1, \ldots, t_{n_T}\}$$

Ecological & social performance scores

$$I_k(r,t) = G(B(r,t), h(r,t), \omega(r,t)), \quad r \in R \equiv \{1, \ldots, n_R\} \quad t \in T$$

Viability thresholds

$$v\left(r, t, \theta_k, \omega\right) = \begin{cases} 1 & I_k(r,t) \quad \geq \theta_k \\ 0 & I_k(r,t) \quad < \theta_k \end{cases}$$

"Local" viability index

$$V\left(r, t, \theta, \omega\right) = \prod_{k=1}^{K} v\left(r, t, \theta_k, \omega\right)$$

"Regional" viability index

$$V_R\left(r, \theta, \omega\right) = g_R\left(V\left(\cdot, t, \theta, \omega\right)\right)$$

"Global" viability index

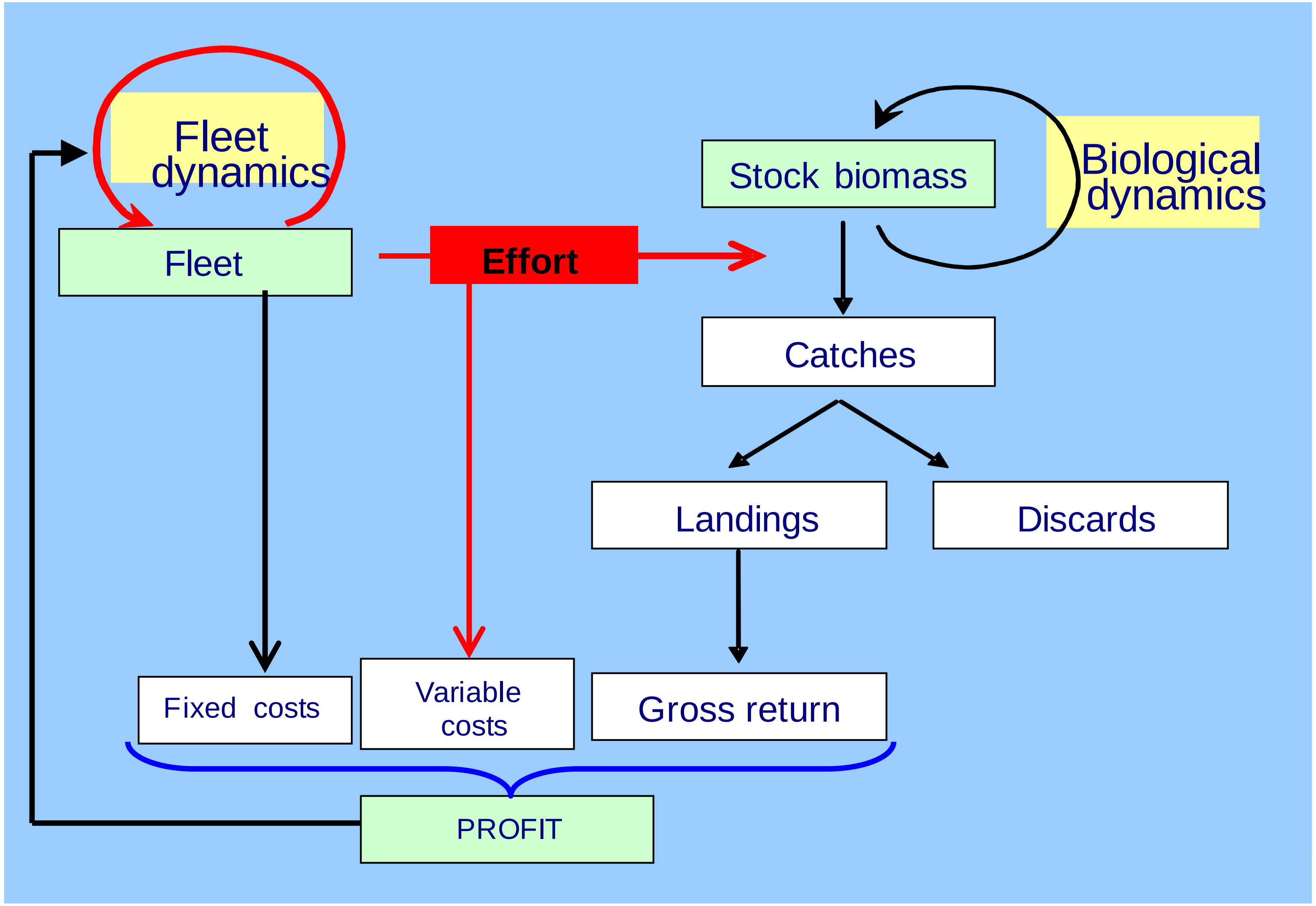
$$V_{RT}\left(\theta, \omega\right) = f_T\left(V_R\left(\cdot, \theta, \omega\right)\right)$$

Expected viability

$$\overline{V}(\theta) = E_\omega\left[V_{RT}\left(\theta, \omega\right)\right]$$

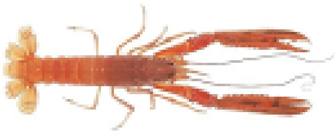
Thébaud et al, 2014. Ecological Indicators.

We started off with ....



Martinet et al., 2007. Ecological Economics.

Applied to the Bay of Biscay Nephrops Fishery



- Surplus-biomass model calibration

  Economics: survey based estimates

  Biology: non-parametric adjustment of CPUE time series

- Historical situations

	2003	1994
Estimated stock biomass (tons)	18,600	14,300
Fleet size (vessels)	235	309
Profit (euros per vessel)	165,000	78,000
Catches (tons)	5,769	5,179

Viability constraints

- Biological :

Min. stock biomass : 5,000 T

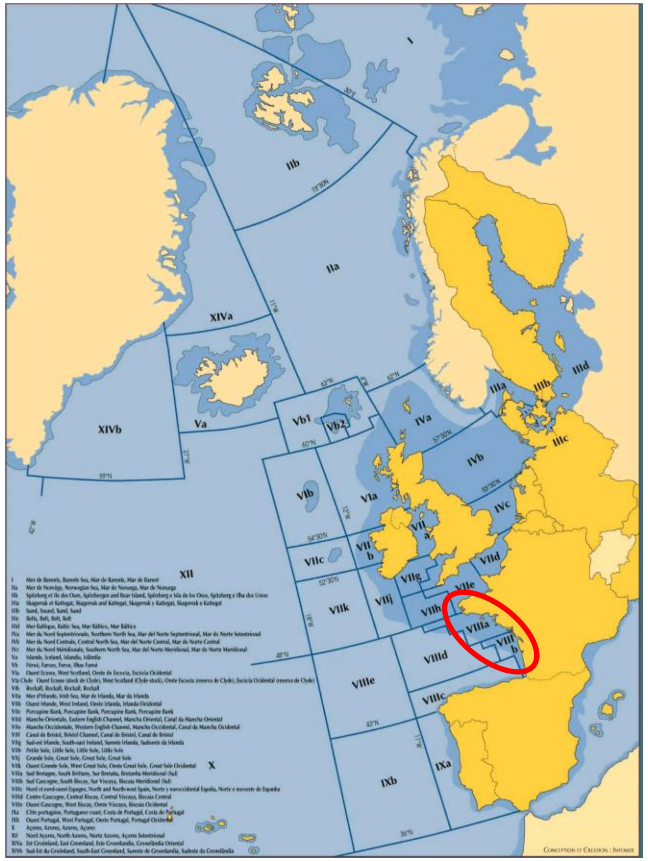
- Economic :

Min. annual profit/v.: 130 k€

- Social :

Min. fleet size: 100 vessels

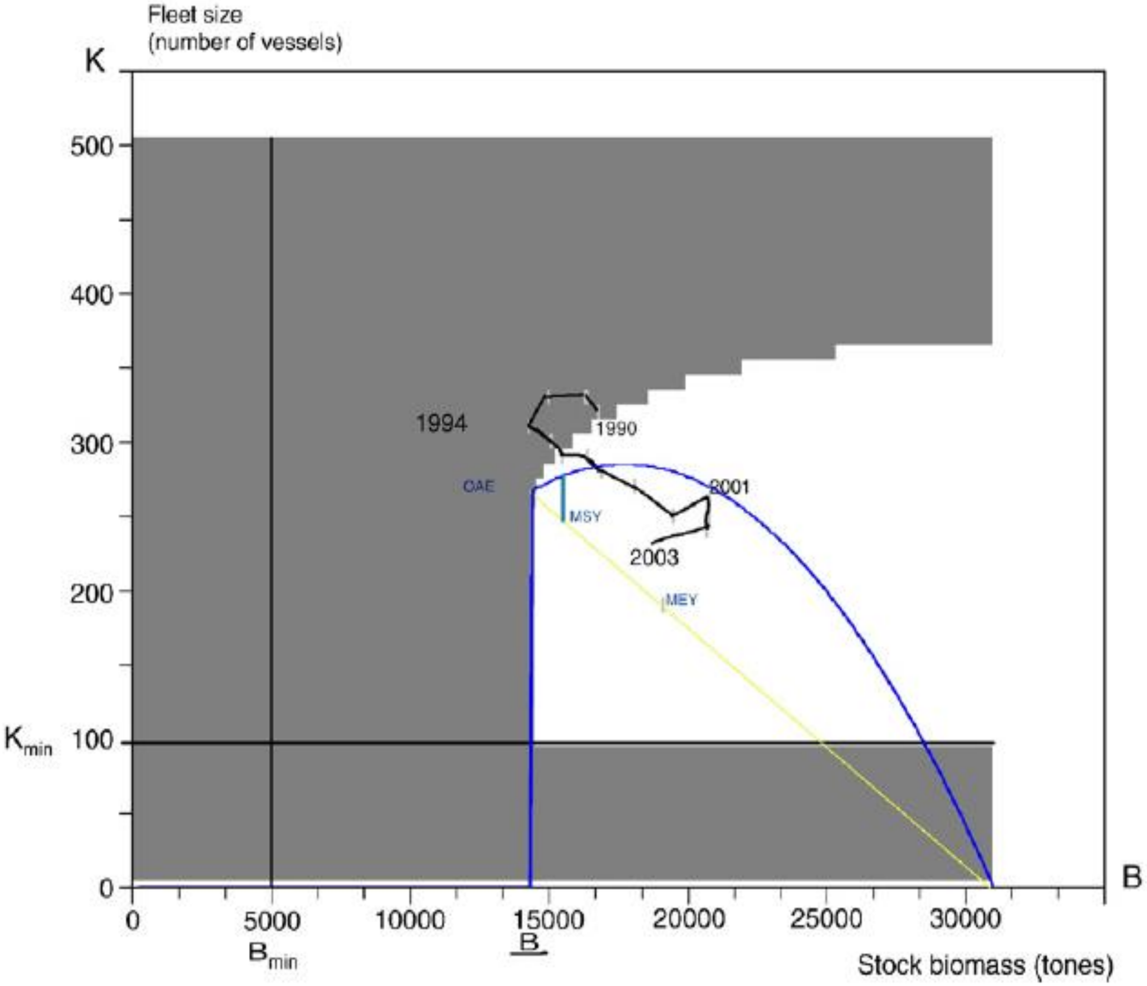
Max variation: 10 v./yr

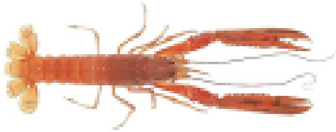


- **Control: fishing effort (vessel.days)**

Martinet et al., 2007. Ecological Economics.

Viability kernel





Martinet et al., 2007.

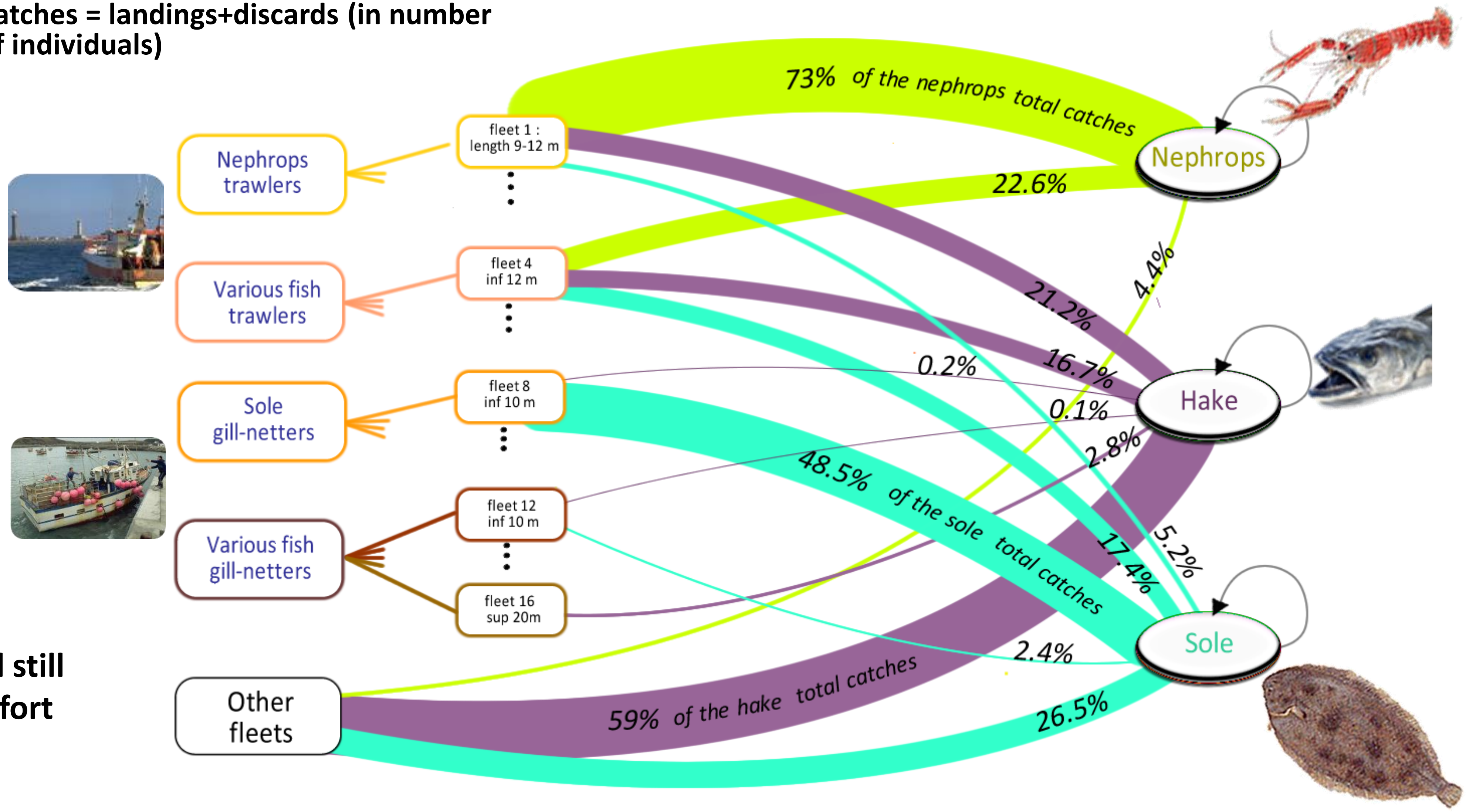
Viability kernel (in white) and historical dynamics of the fishery as estimated via the model → 1994 not viable

Martinet et al., 2007. Ecological Economics.

… then we moved to a more complete picture of the fishery

Doyen et al., 2012; Gourguet et al., 2013

Catches = landings+discards (in number of individuals)



→ Control still fishing effort

Multiple fleets with variable levels of dependence on different species, stochastic fish prices & viability constraints / fleet

Technical interactions through mixed catches

Age-structured population dynamics models with stochastic recruitment & viability constraints / species

Dynamics, controls and management strategies

$$\vec{N}_s(t+1) = f_s\Big(t, \vec{N}_s(t), \vec{F}_s(t)\Big)$$

Population dynamics

$$N_{s,1}(t+1) = \varphi_s\Big(SSB_s(t), \omega_s(t)\Big)$$

(Uncertain) recruitment

$$F_{s,a} = \sum_{f=1}^{17} q_{s,a,f} E_f(t_0) u_f K_f(t_0)$$

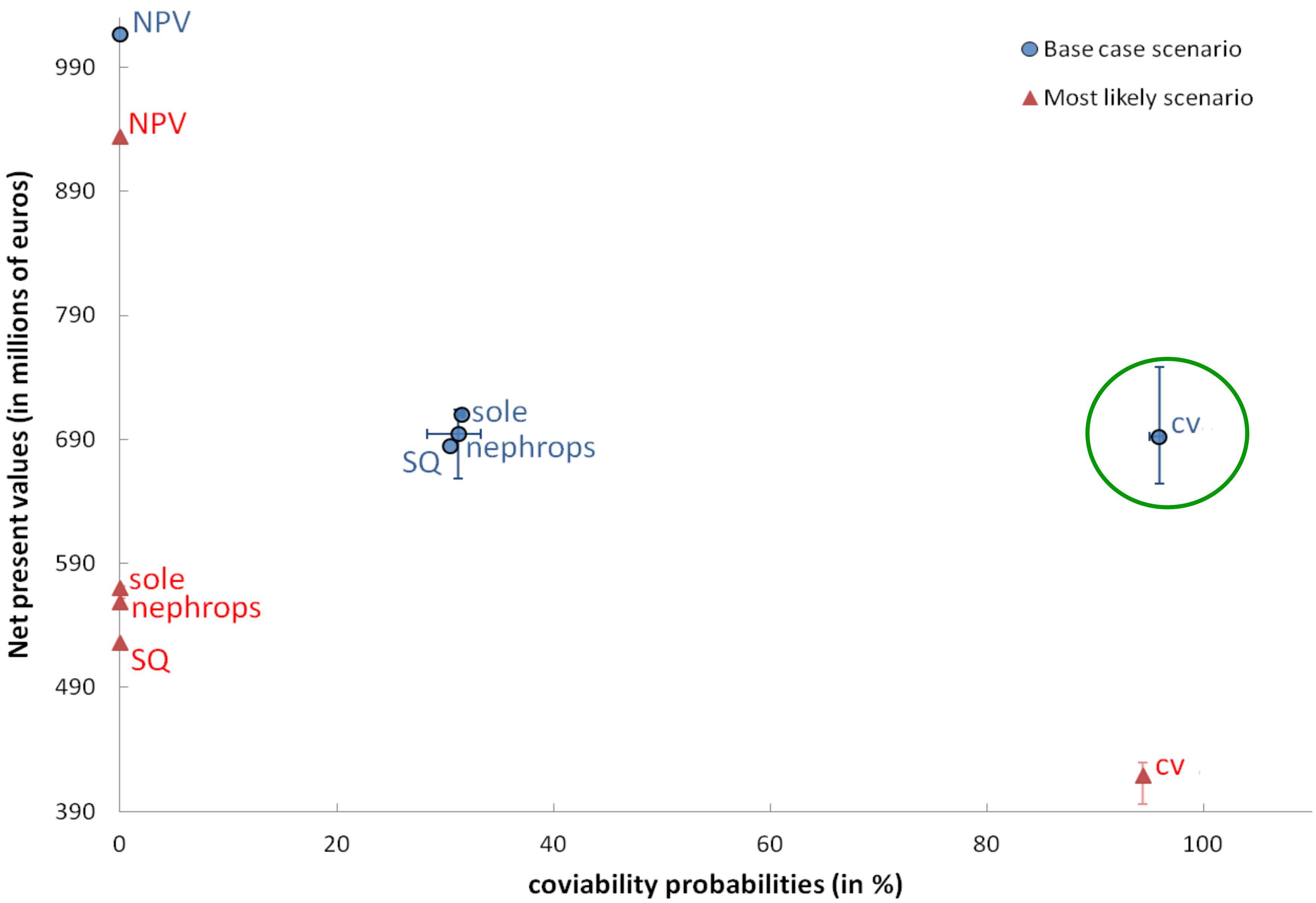
Fishing mortality

- SQ: status quo: $u_f^{SQ} = 1,$
- NPV: find u^{NPV} such that $\max_u \mathbb{E}_{\omega(.)}\Big[NPV\big(u\big)\Big]$ with $NPV = \sum_{t=0}^{t_f} \frac{\pi(t)}{(1+r)^t}$
- CV: find u^{CVA} such that $\max_u \mathbb{P}\Big(\text{constraints are satisfied}, t = t_0, \ldots, t_f\Big)$

With constraints: $SSB_s(t) \geq B_s^{pa}, \quad \pi_f(t) > 0,$

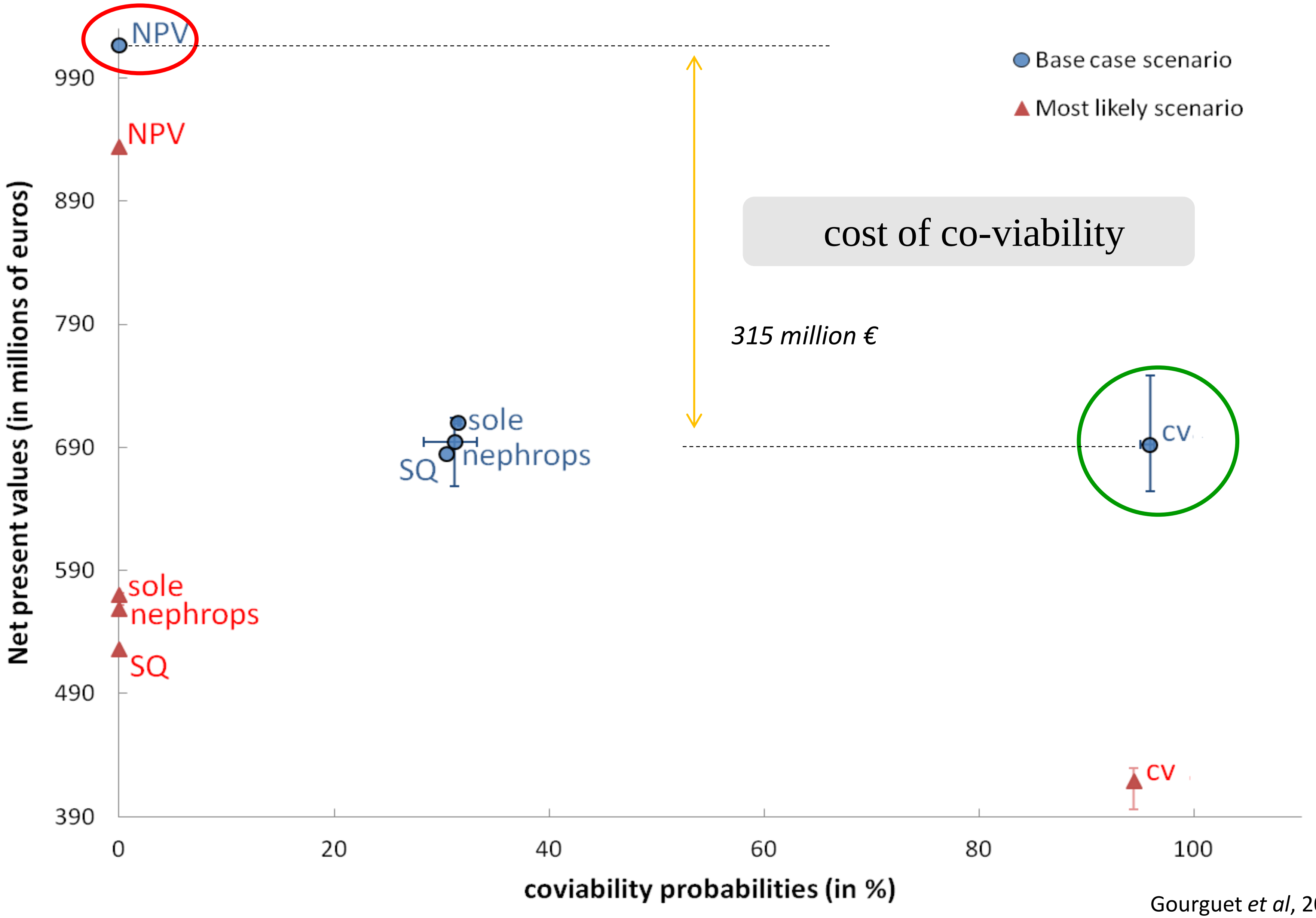
Gourguet et al., 2013

Comparing alternative management strategies



Gourguet *et al*, 2013. Fisheries Research

Identifying tradeoffs between economic yield and coviability

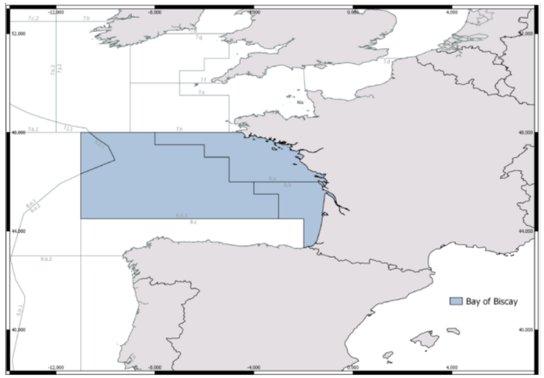


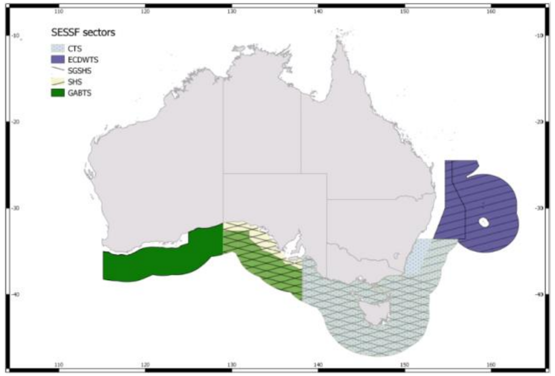
Gourguet *et al*, 2013. Fisheries Research

… and on to introducing more realistic viability criteria & controls

Bay of Biscay demersal fishery

(France)





Southern and Eastern Scalefish and Shark Fishery

(Australia)

Stock biomass | Fleet gross and net profits | Crew wage

Thresholds

B_{lim}	0	$Wage_{opp}$	
B_{lim}	0	$Wage_{opp}$	P_{lim}

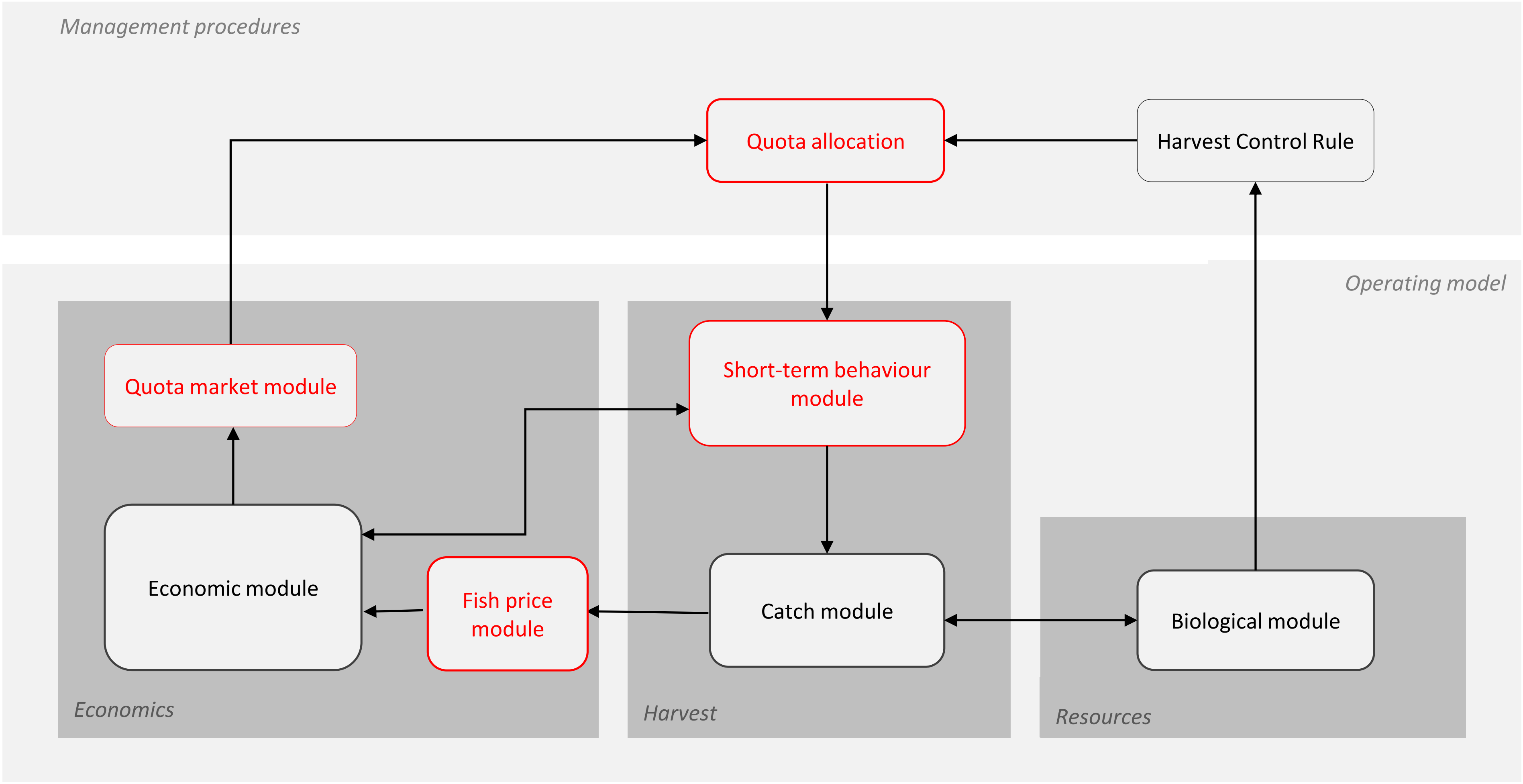
- **Controls = setting individual TACs → implies modelling of the process of quota allocation and uptake**

Fish price

Briton, 2019

Using the Integrated Assessment Model (IAM) model developed by Ifremer

IAM model (Ifremer) = multi-species, multi-metier and individual-based simulation model



Merzereaud et al. 2011; Guillen et al. 2013, 2014; Bellanger et al. 2017

Short-term effort determination based on quota in the Bay of Biscay model

→ Determine individual fishing efforts at métier level ($E_{i,m,t}$), with métier = combination of gear and targeted species

National quota allocated to producer organisations (POs), and in turn to individual harvesters following an allocation key Qshr$_s$ provided as an input: $Q_{i,s,t} = Qshr_{i,s} \times Q_{s,t}$

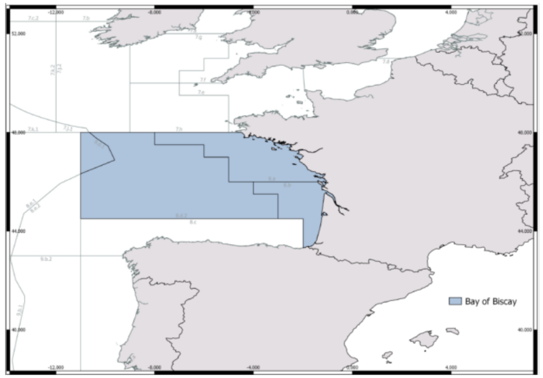
1. Calculation of the effort $E_{i,m,s,t}$ required to catch the quota $Q_{i,s,t}$ for each individual harvester *i*, metier *m* and stock *s*

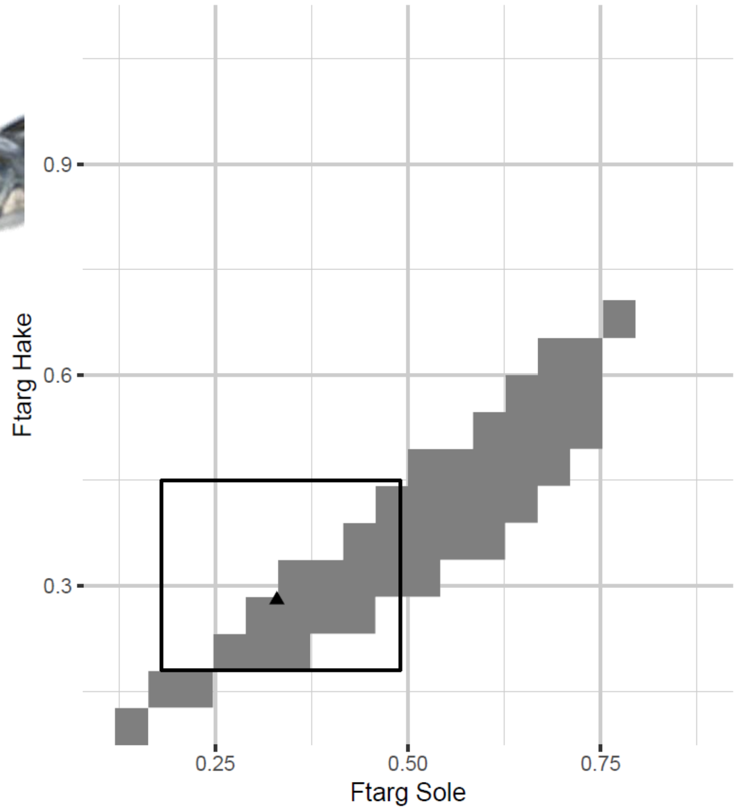
$$\text{Find } \lambda_{i,s,t} \text{ such that } \begin{cases} \sum_m L_{i,m,s,t} & = Q_{i,s,t}, \\ E_{i,m,s,t} & = E_{i,s,t} \times \alpha_{i,m}, \\ E_{i,s,t} & = E_{i,t_0} \times \lambda_{i,s,t}. \end{cases}$$

With $\alpha_{i,m}$ the proportion of total effort of *i* attributed to metier *m, and* $L_{i,m,s,t}$ *a function of* $E_{i,m,s,t}$

2. Stop fishing with métier *m* when most constraining quota is exhausted or when reaching $E_{max,i,m}$

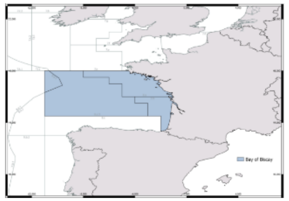
Identifying the operating domain of the fishery



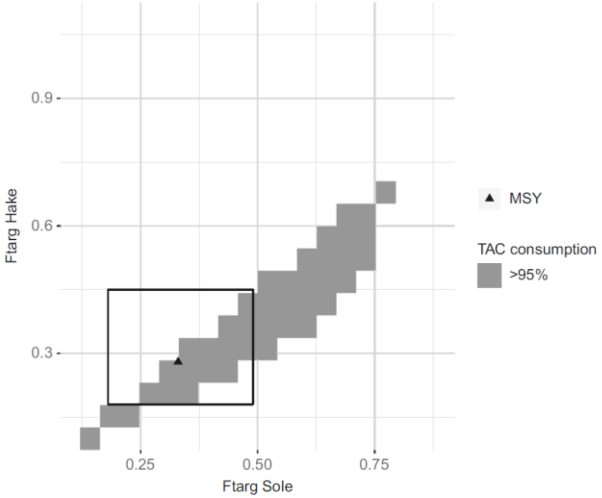


Operating domain

Briton, F. et al., 2019. Environmental Modeling & Assessment

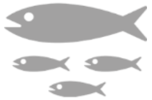


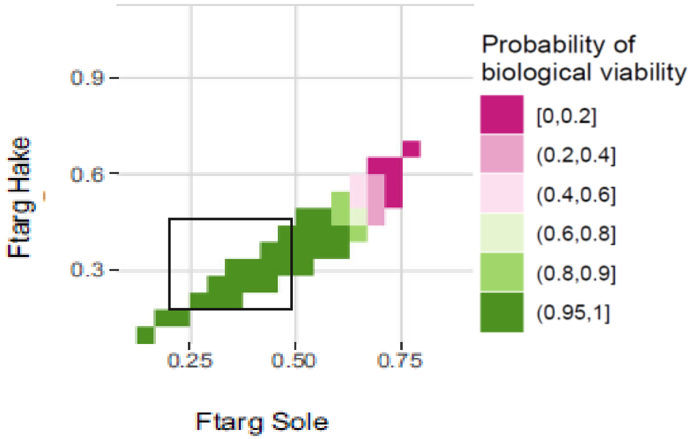
Identifying biological, economic and social viability domains



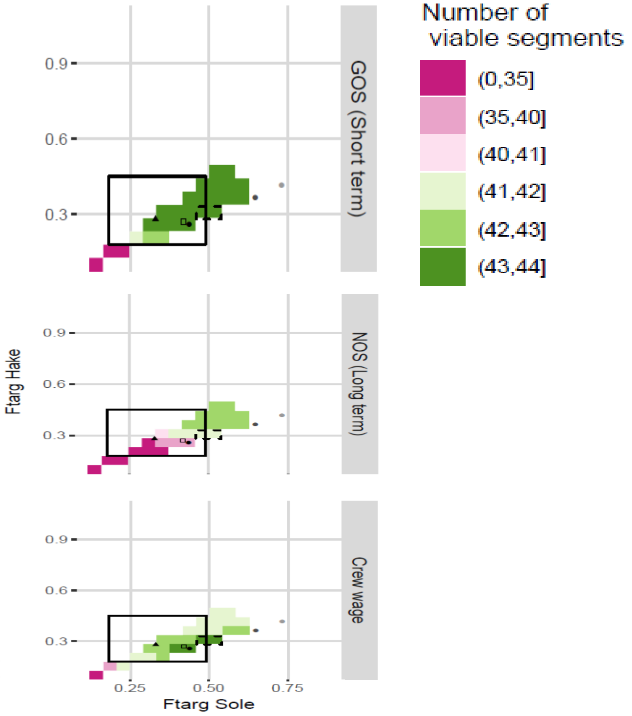
Operating domain

4 key species



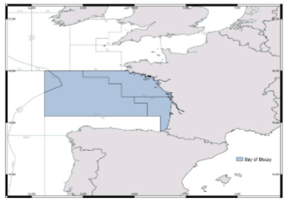


Biologically viable domain

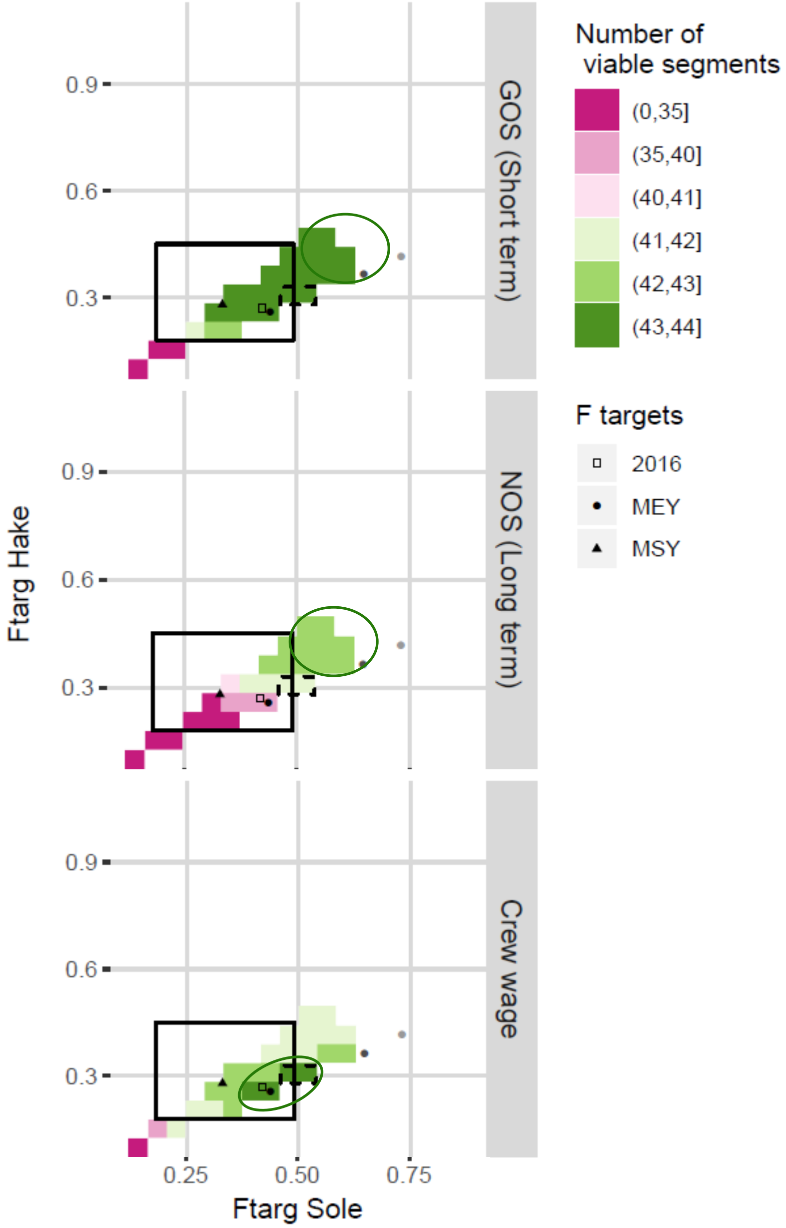


Socio-economically viable domain

Briton, F. et al., 2019. Environmental Modeling & Assessment



Trade-offs across viability criteria & possible compromises

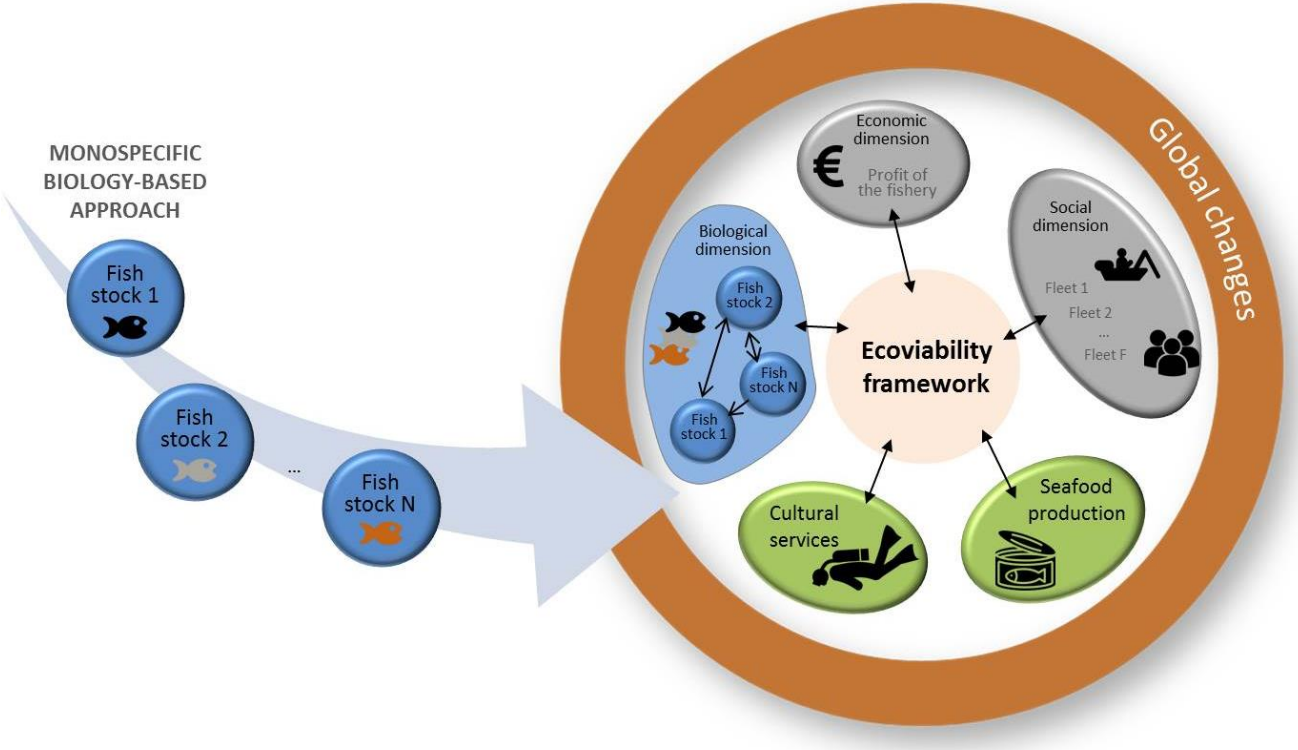


- Long-term economic viability of entire fleet not possible
- Trade-off between surplus of capital owners and wages of fishing crews
- Improvement possible relative to reference year

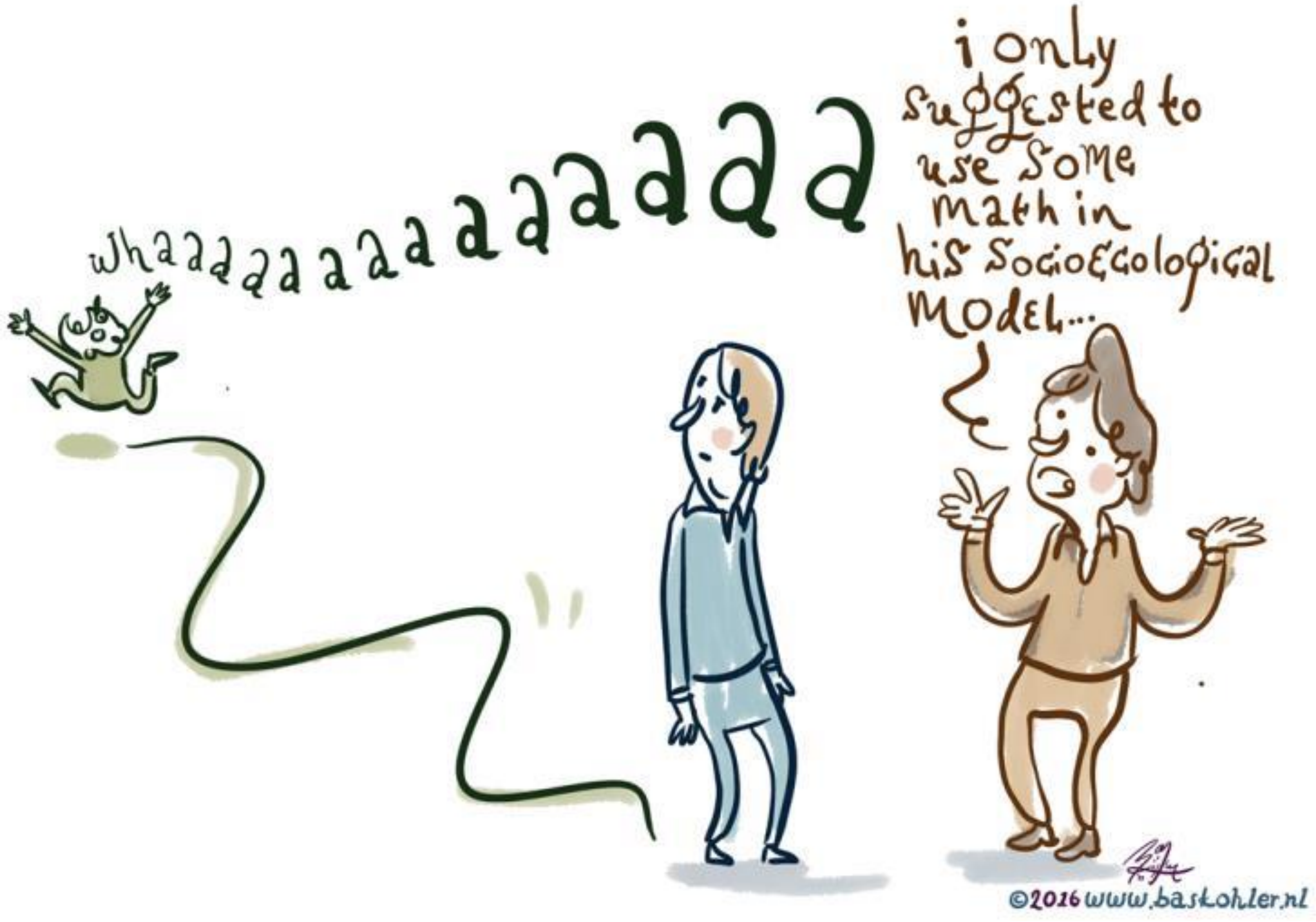
Briton, F. et al., 2019. Environmental Modeling & Assessment

Some challenges

- Identify & model key processes driving system dynamics, including economic decisions
- Specify elements which determine the persistence of the system, i.e. which variables should be constrained
- Define the acceptability threshold for the identified variables
- Identify tolerance levels regarding the frequency with which these thresholds should be met (in stochastic systems)
- Explore decision space with more than two dimensions



Working across disciplines …



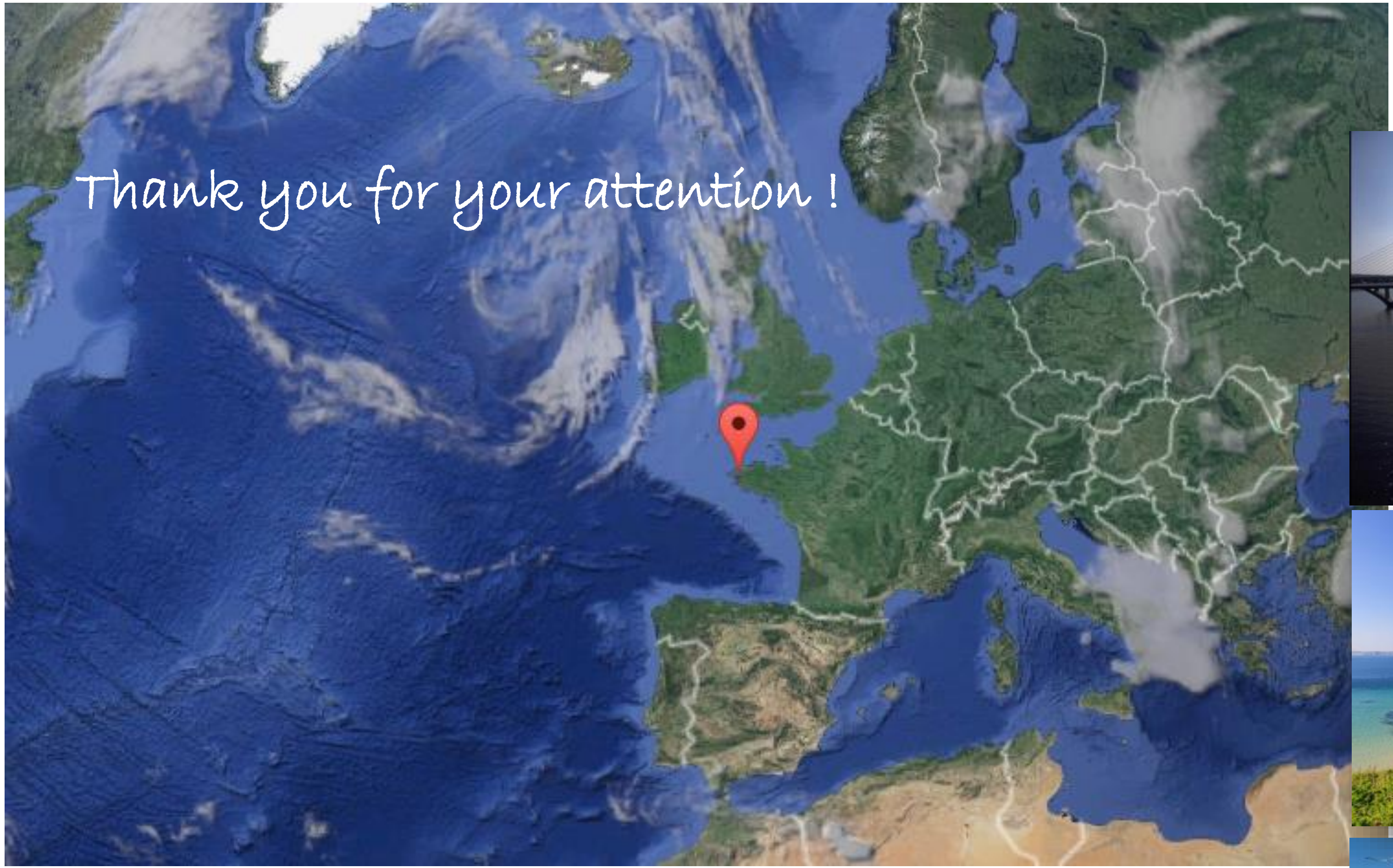
UBO
Université de Bretagne Occidentale

Ifremer

CNRS

AMURE
CENTRE DE DROIT ET D'ÉCONOMIE DE LA MER

http://www.umr-amure.fr



Images ©2015 Landsat,Data SIO, NOAA, U.S. Navy, NGA, GEBCO,IBCAO,U.S. Geological Survey,Données cartographiques ©20