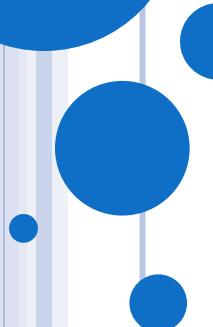


# **ANALYSE DE SENSIBILITÉ ET OPTIMISATION POUR LA GESTION DES PÊCHES**

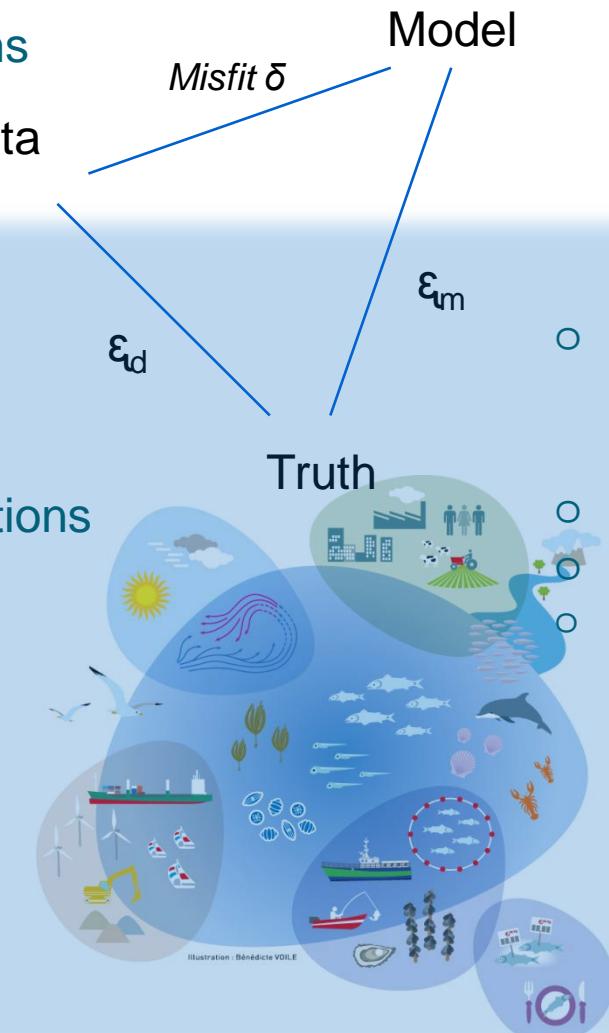
**Sigrid Lehuta**



**Rencontres Mexico-MascotNum  
Nantes, 23-24 Novembre 2016**

# THE UNCERTAIN CONTEXT OF FISHERIES

- Experimental platforms

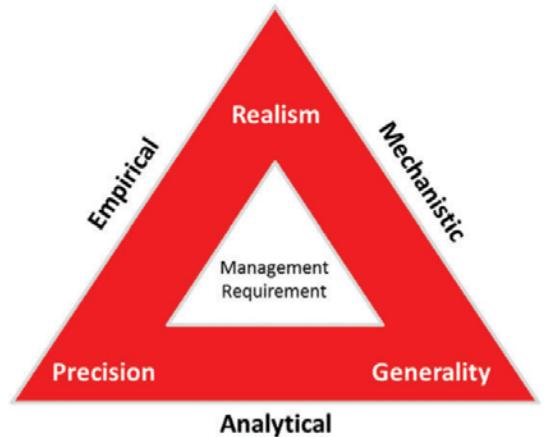


- Observations—Estimations
- Few expensive data
- Limited understanding
- No control on drivers

- EAFM : Wild development of complex models
- Multiples objectives
- Mistrust issues
- Decision making support ?

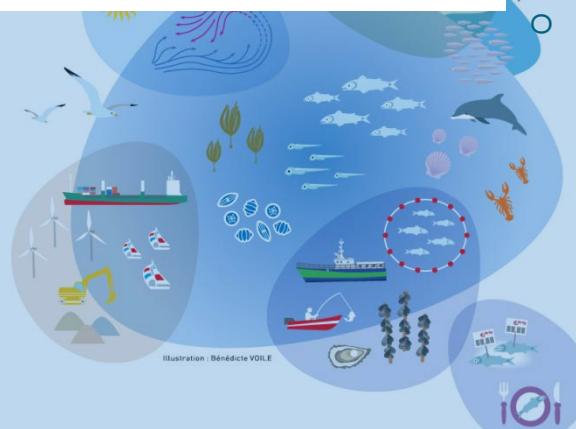
# THE UNCERTAIN CONTEXT OF FISHERIES

- Experimental platform



**Figure 2.** The trichotomous model classification scheme based on Levins (1966) and adapted from Guisan and Zimmermann (2000) and Sharpe (1990). Models are assumed to have two of the three attributes and can be considered empirical, mechanistic, or analytical. Management requirements, however, often lie at the intersection of these attributes, an area which Levins (1966) proposes to be inaccessible.

- Observations—Estimation
- Few expensive data
- Limited understanding
- No control on drivers



- EAFM : Wild development of complex models
- Multiple objectives
- Mistrust issues
- Decision making support ?

# COMPLEX ECOSYSTEM MODELS AS DECISION SUPPORT TOOLS ?

ICES Journal of Marine Science Advance Access published January 9, 2014

ICES Journal of Marine Science

International Council for the Exploration of the Sea  
ICES CIEM Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science; doi:10.1093/icesjms/fst215

## Food for Thought

Hazard warning: model misuse ahead

**Simulation-based management strategy evaluation: ignorance disguised as mathematics?**

Marie-Joëlle Rochet and Jake C. Rice

ICES Journal of Marine Science Advance Access published September 7, 2015

ICES Journal of Marine Science

International Council for the Exploration of the Sea  
ICES CIEM Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science; doi:10.1093/icesjms/fsv155

## Food for Thought

Projecting the future state of marine ecosystems, “la grande illusion”?



FISH and FISHERIES

**On scientists' discomfort in fisheries advisory science: the example of simulation-based fisheries management-strategy evaluations**

Sarah B M Kraak<sup>1,2</sup>, Claran J Kelly<sup>2</sup>, Edward A Codling<sup>3</sup> & Emer Rogan<sup>1</sup>

Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science

Publication details, including instructions for authors and

Marine Policy 61 (2015) 291–302

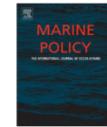
Contents lists available at ScienceDirect



ELSEVIER

Marine Policy

journal homepage: [www.elsevier.com/locate/marpol](http://www.elsevier.com/locate/marpol)



Making modelling count – increasing the contribution of shelf-seas community and ecosystem models to policy development and management



Kieran Hyder<sup>a,\*</sup>, Axel G. Rossberg<sup>a</sup>, J. Icarus Allen<sup>b</sup>, Melanie C. Austen<sup>b</sup>, Rosa M. Barciela<sup>c</sup>, Hayley J. Bannister<sup>d</sup>, Paul G. Blackwell<sup>e</sup>, Julia L. Blanchard<sup>d,f</sup>, Michael T. Burrows<sup>g</sup>, Emma Defriese<sup>h</sup>, Tarquin Dorrington<sup>i</sup>, Karen P. Edwards<sup>j</sup>, Bernardo Garcia-Carreras<sup>a,h</sup>

**End-to-end models for marine ecosystems:  
Are we on the precipice of a significant advance  
or just putting lipstick on a pig?**

KENNETH A. ROSE



Downloaded from <http://icem.int>

Aquat. Living Resour. 29, 208 (2016)  
© EDP Sciences 2016  
DOI: [10.1051/alr/2016022](https://doi.org/10.1051/alr/2016022)  
[www.alr-journal.org](http://www.alr-journal.org)

Aquatic  
Living  
Resources

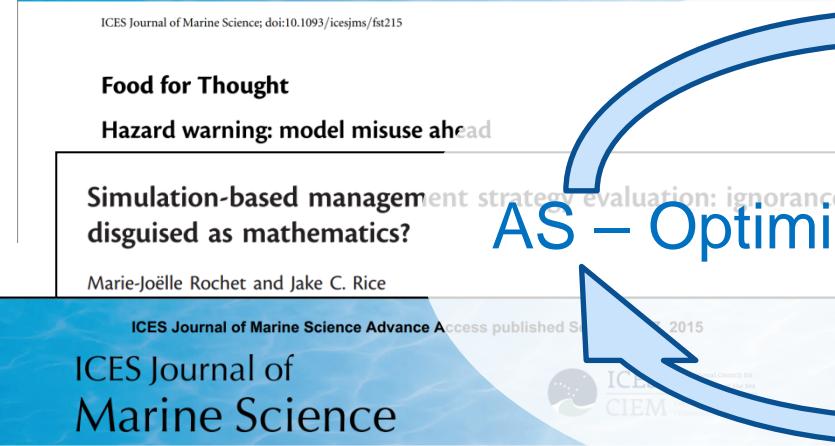
**Reconciling complex system models and fisheries advice:  
Practical examples and leads**

Sigrid LEHUTA<sup>1,a</sup>, Raphaël GIRARDIN<sup>2</sup>, Stéphanie MAHÉVAS<sup>1</sup>, Morgane TRAVERS-TROLET<sup>2</sup>  
and Youen VERMARD<sup>1</sup>

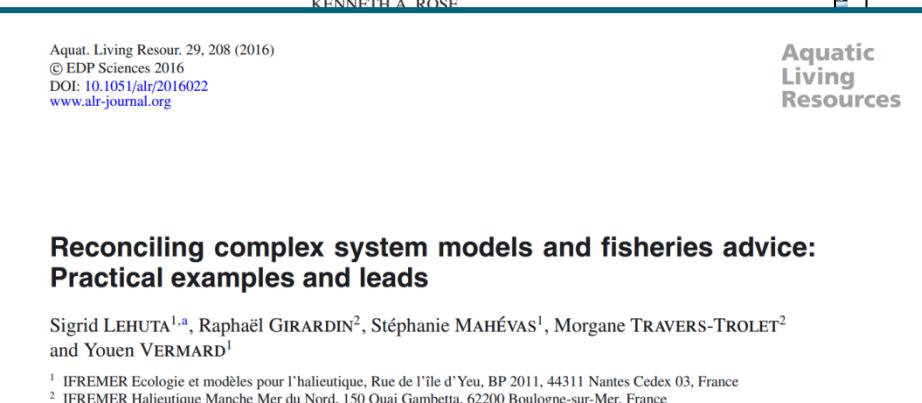
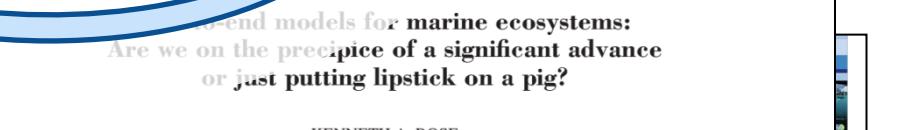
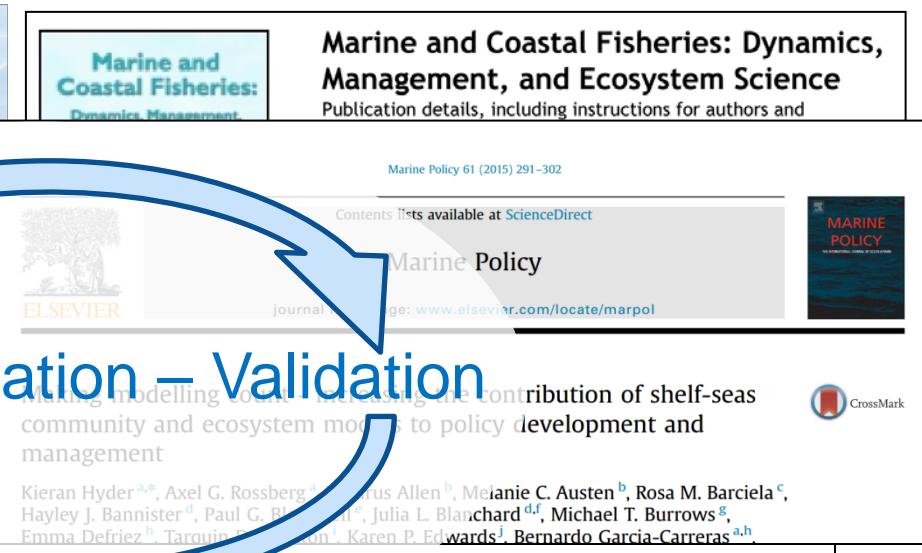
<sup>1</sup> IFREMER Ecologie et modèles pour l’halieutique, Rue de l’île d’Yeu, BP 2011, 44311 Nantes Cedex 03, France

<sup>2</sup> IFREMER Halieutique Manche Mer du Nord, 150 Quai Gambetta, 62200 Boulogne-sur-Mer, France

# COMPLEX ECOSYSTEM MODELS AS DECISION SUPPORT TOOLS ?



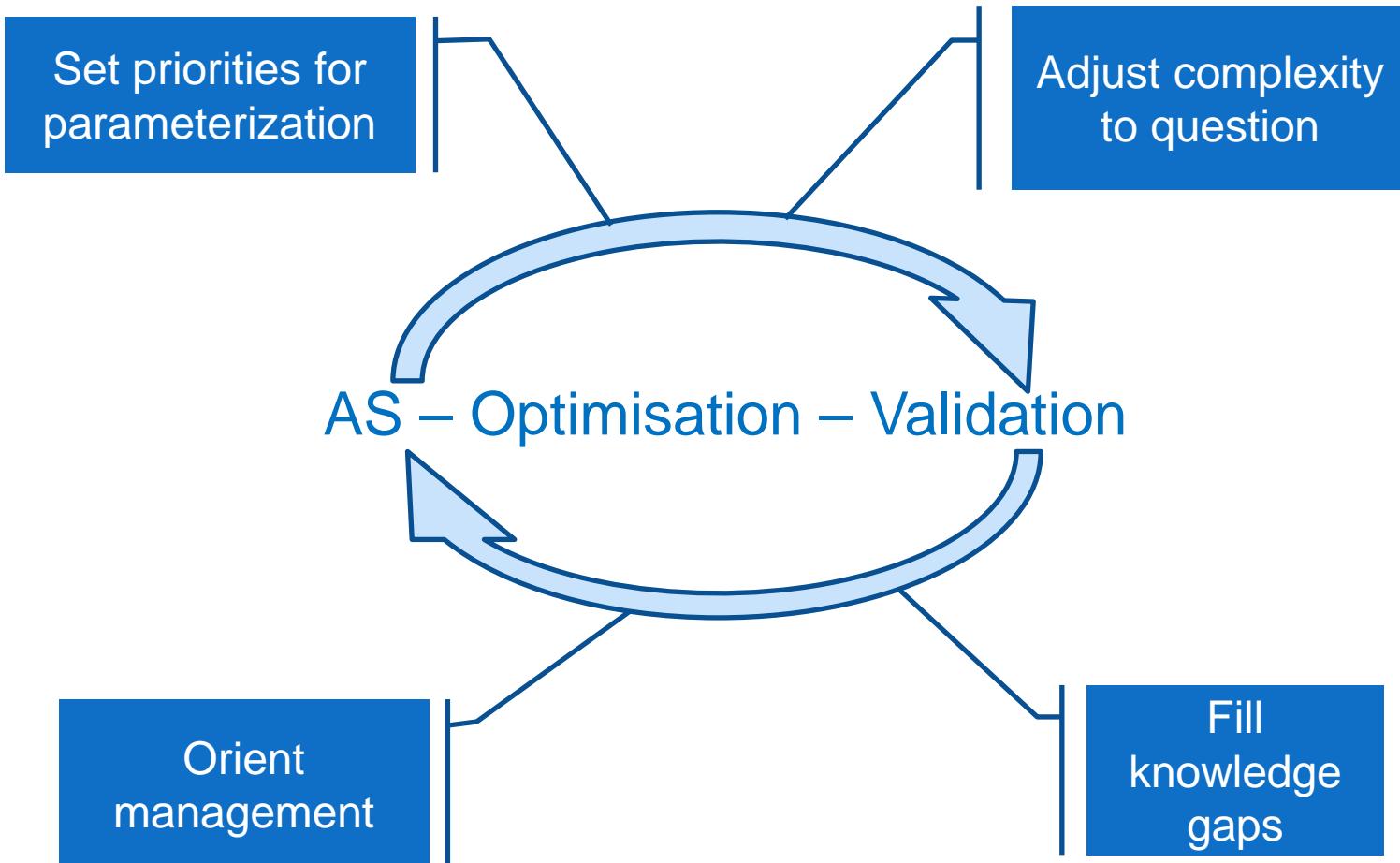
Sarah B M Kraak<sup>1,2</sup>, Claran J Kelly<sup>2</sup>, Edward A Codling<sup>3</sup> & Emer Rogan<sup>1</sup>



<sup>1</sup> IFREMER Ecologie et modèles pour l'halieutique, Rue de l'île d'Yeu, BP 2011, 44311 Nantes Cedex 03, France

<sup>2</sup> IFREMER Halieutique Manche Mer du Nord, 150 Quai Gambetta, 62200 Boulogne-sur-Mer, France

# IN THE NEXT HALF HOUR...



# ADJUST COMPLEXITY TO THE QUESTION

Model fit and efficiency evolve with complexity  
(Costanza and Sklar, 1985)

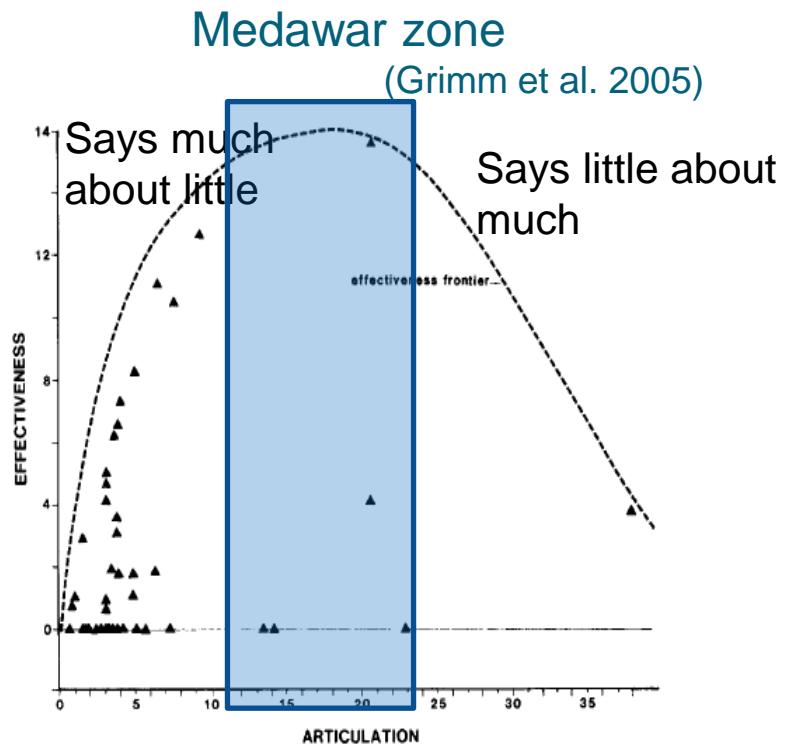
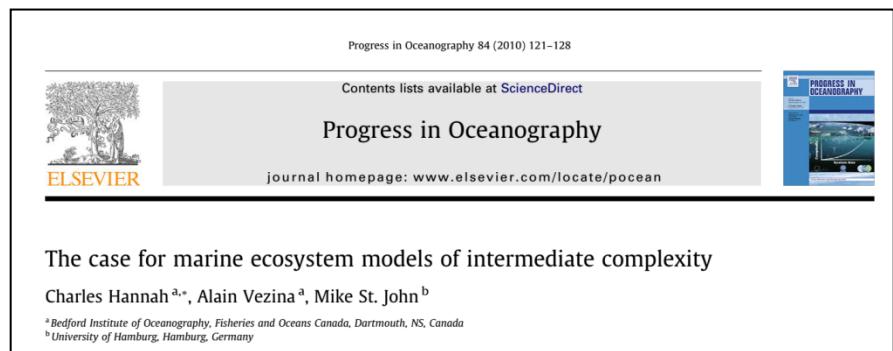


Fig. 2. Plot of articulation index vs. effectiveness index showing the current effectiveness frontier.

complexity →



How ?  
○ Common sense  
○ Available data

# ADJUST COMPLEXITY TO THE QUESTION

Model fit and efficiency evolve with complexity  
(Costanza and Sklar, 1985)

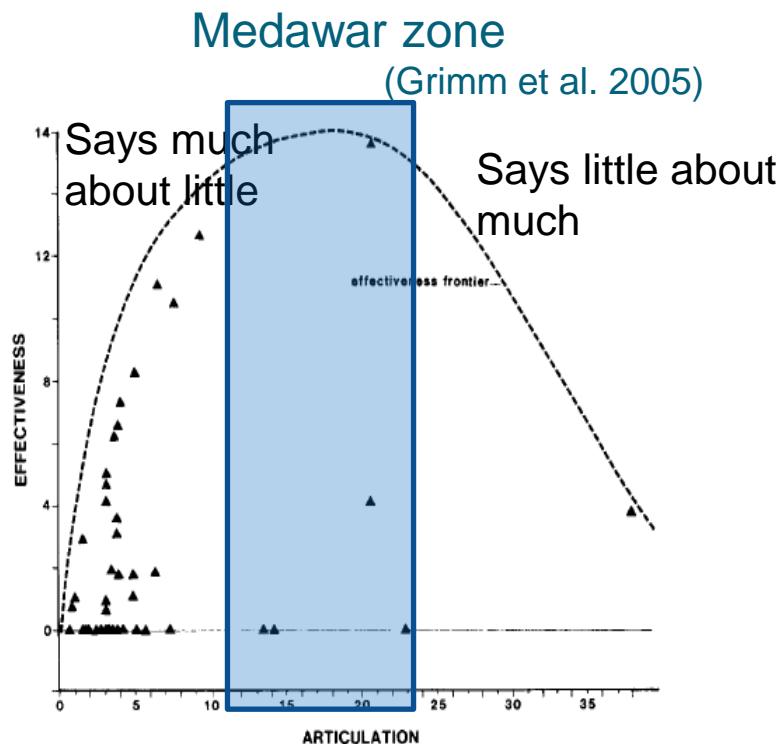


Fig. 2. Plot of articulation index vs. effectiveness index showing the current effectiveness frontier.

complexity →

Progress in Oceanography 84 (2010) 121–128  
Contents lists available at ScienceDirect  
Progress in Oceanography  
journal homepage: [www.elsevier.com/locate/pocean](http://www.elsevier.com/locate/pocean)

PROGRESS IN OCEANOGRAPHY

The case for marine ecosystem models of intermediate complexity  
Charles Hannah<sup>a,\*</sup>, Alain Vezina<sup>a</sup>, Mike St. John<sup>b</sup>  
<sup>a</sup>Bedford Institute of Oceanography, Fisheries and Oceans Canada, Dartmouth, NS, Canada  
<sup>b</sup>University of Hamburg, Hamburg, Germany

How ?

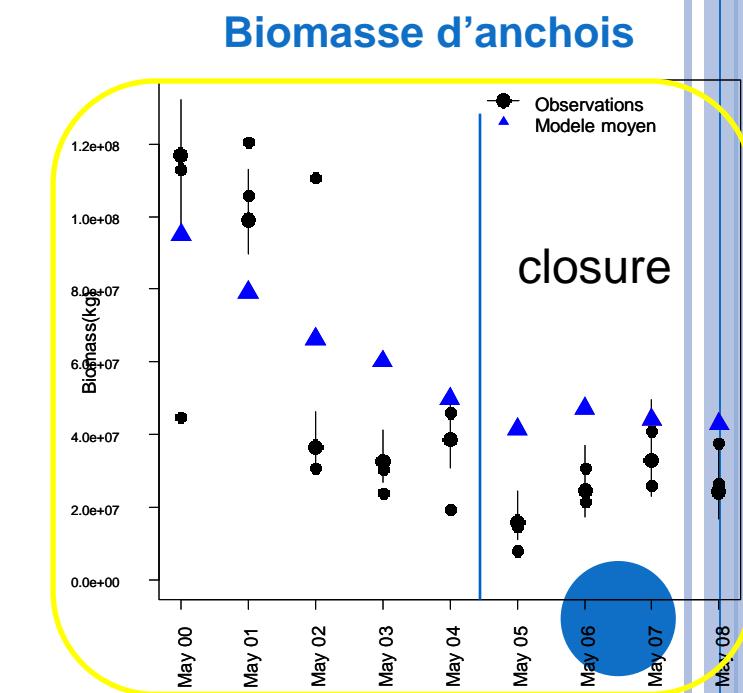
- Common sense
- Available data
- + Sensitivity analysis

# ADJUST COMPLEXITY TO THE QUESTION

EG. HOW TO DESCRIBE ANCHOVY LARVAL SURVIVAL ?



Pelagic fishery Bay of Biscay



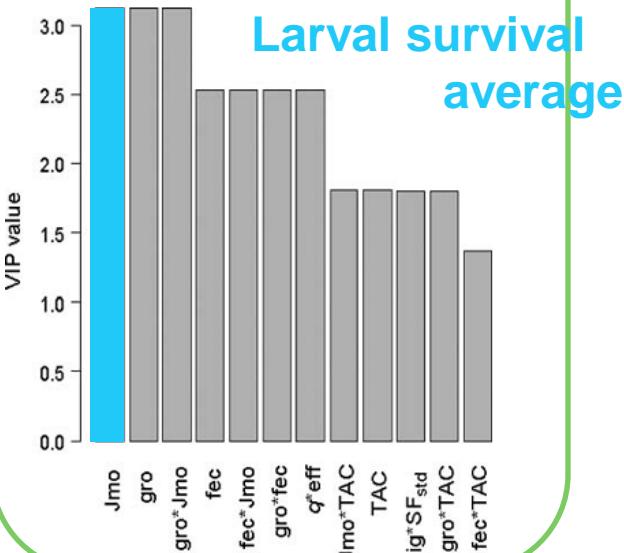
# ADJUST COMPLEXITY TO THE QUESTION

EG. HOW TO DESCRIBE ANCHOVY LARVAL SURVIVAL ?



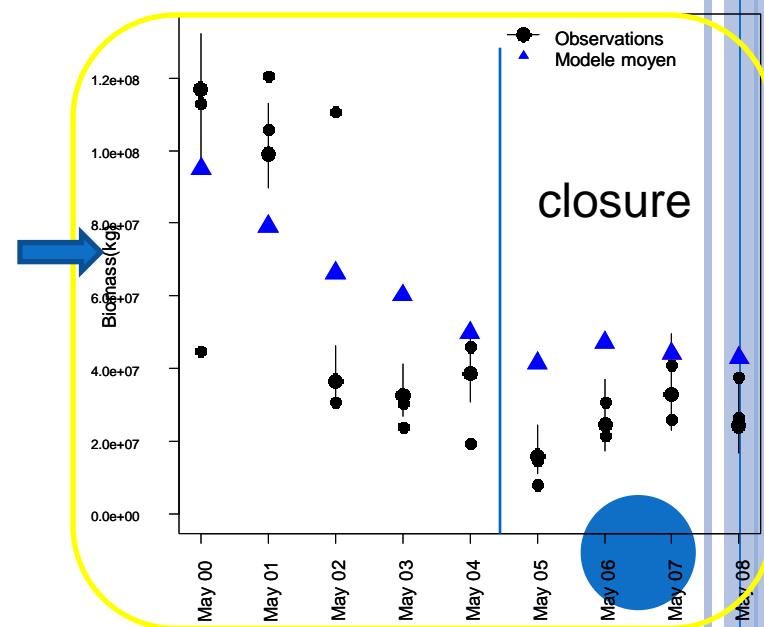
Pelagic fishery Bay of Biscay

Sensitivity Analysis



- 100 parameters
- Run 20 min
- Group screening
- 4 outputs of interest
- PLS Regression

Biomasse d'anchois



# ADJUST COMPLEXITY TO THE QUESTION

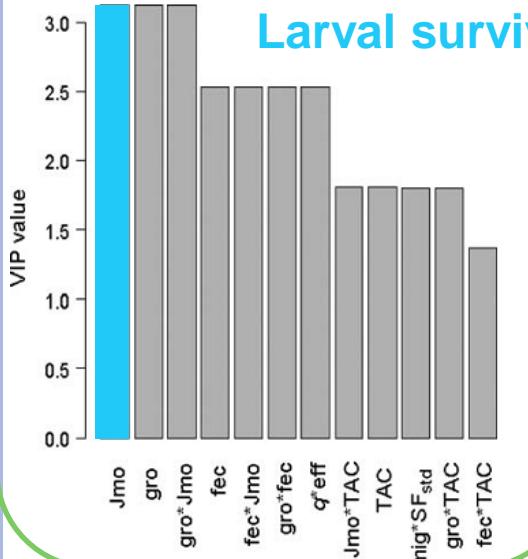
EG. HOW TO DESCRIBE ANCHOVY LARVAL SURVIVAL ?



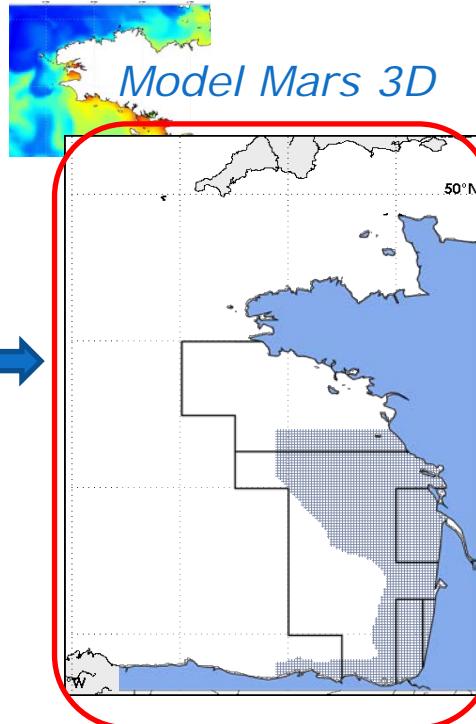
Pelagic fishery Bay of Biscay

Sensitivity Analysis  
PLS Regression

Larval survival



Re-estimation –  
Change of scale



Huret et al. 2010.

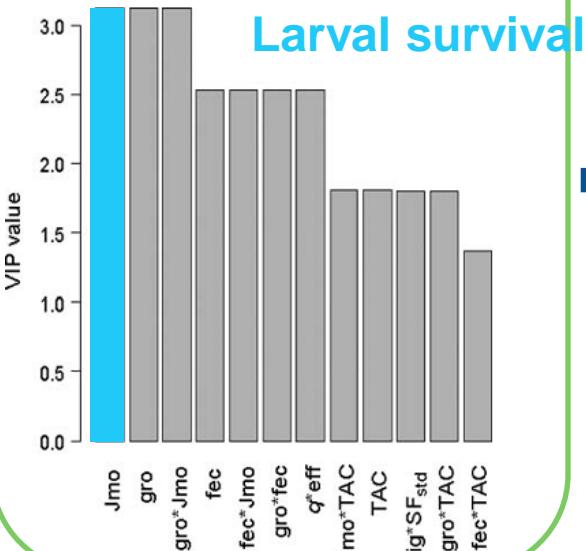
# ADJUST COMPLEXITY TO THE QUESTION

EG. HOW TO DESCRIBE ANCHOVY LARVAL SURVIVAL ?



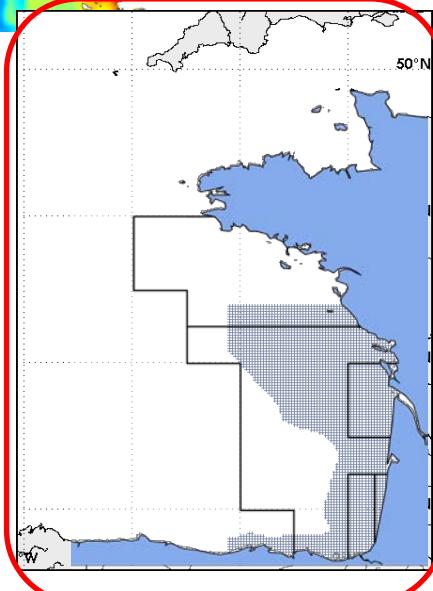
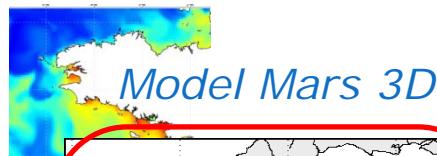
Pelagic fishery Bay of Biscay

Sensitivity Analysis  
PLS Regression

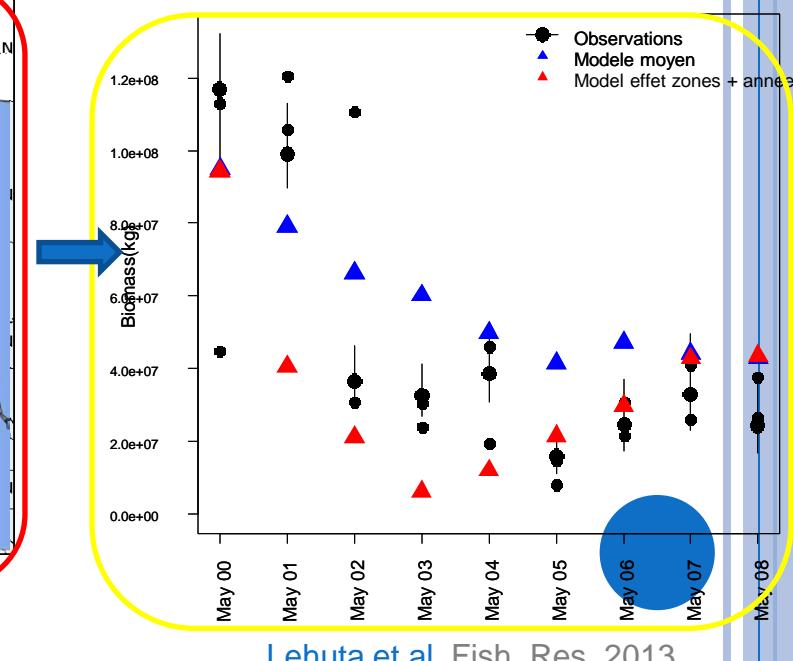


Lehuta et al. ICES J. Mar. Sc. 2010

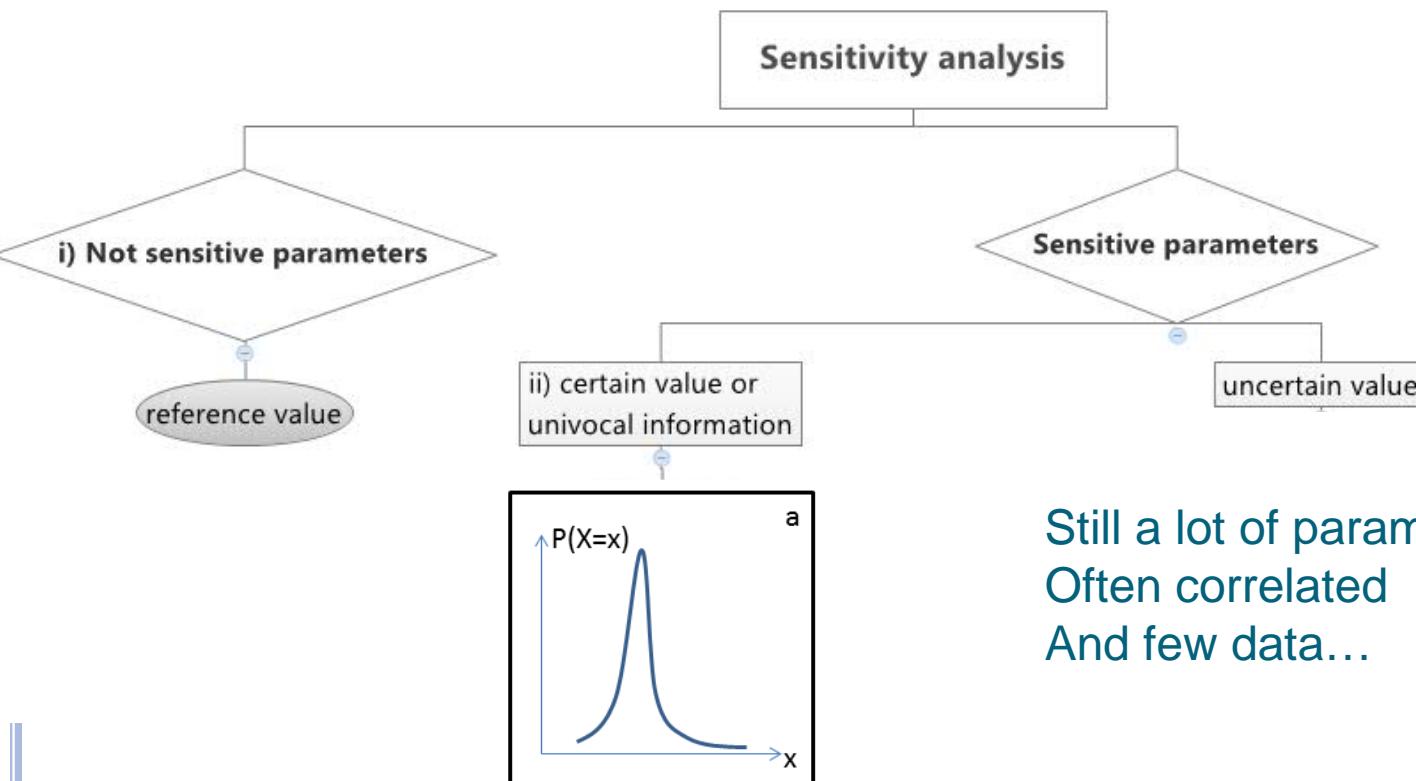
Re-estimation –  
Change of scale



And forcing  
Biomasse d'anchois

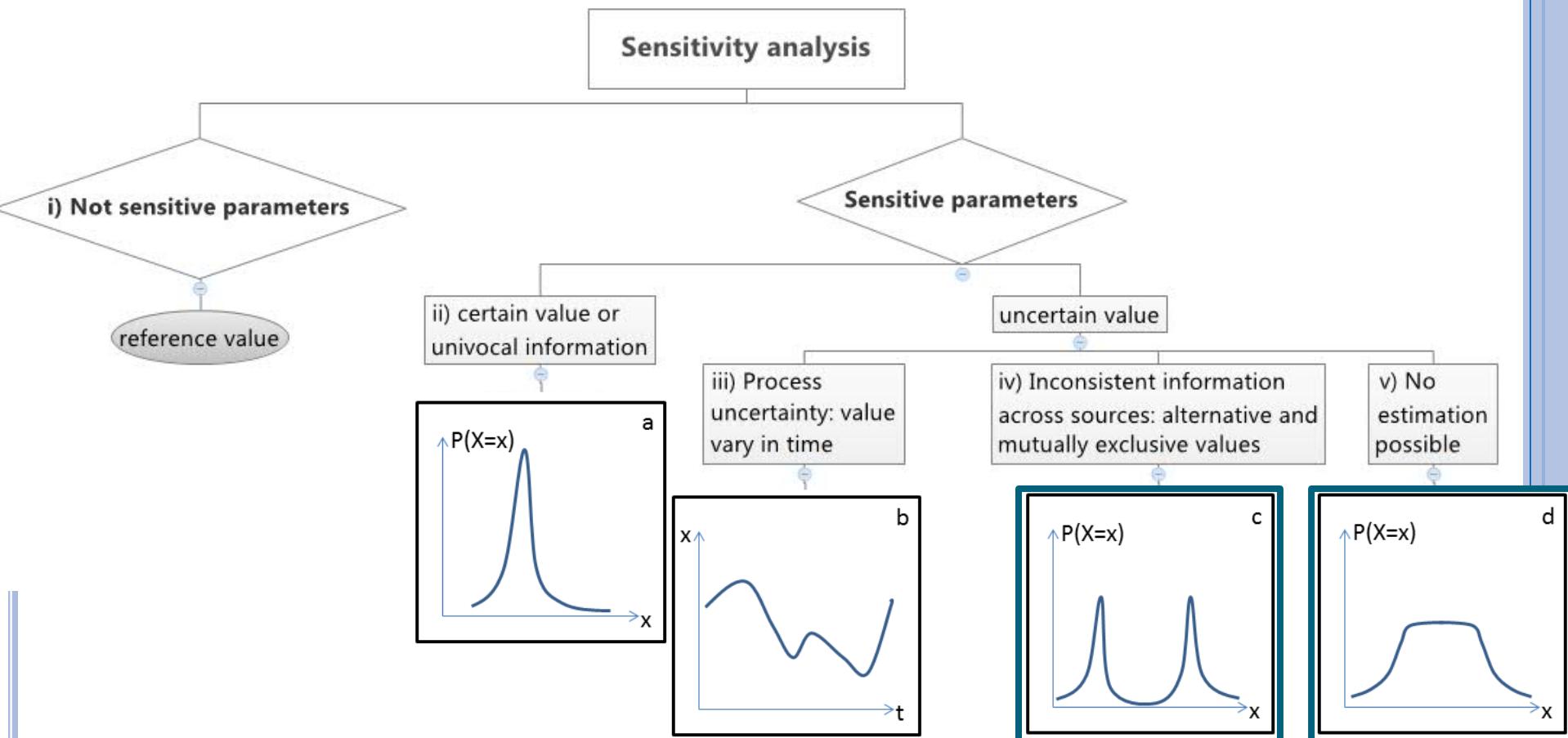


# SET PRIORITIES FOR PARAMETERIZATION

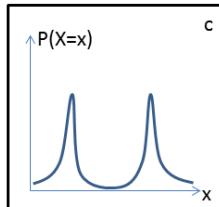


Still a lot of parameters !  
Often correlated  
And few data...

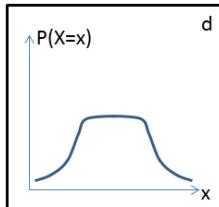
# SET PRIORITIES FOR PARAMETERIZATION



# SA-CALIBRATION-VALIDATION FOR PARAMETERIZATION



Param 1 : mortalité des oeufs  
Param 2 : durée de la ponte  
Param 3 : date de migration  
⇒ 8 alternative parameterizations

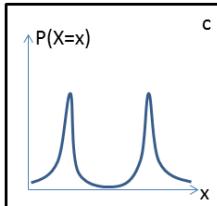


Param 4 : accessibilité  
Param 5 : mortalité adultes  
⇒ Calibration

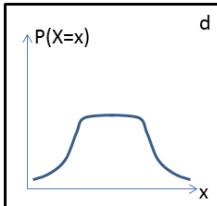


1 run = 20 min

# SA-CALIBRATION-VALIDATION FOR PARAMETERIZATION



Param 1 : mortalité des oeufs  
Param 2 : durée de la ponte  
Param 3 : date de migration  
⇒ 8 alternative parameterizations



Param 4 : accessibilité  
Param 5 : mortalité adultes  
⇒ Calibration

- Systematic building alternative parameterizations
- Calibration of continuous parameters

## Alternative hypotheses definition

Param1 { Hypothesis 1

Hypothesis 2

Alternative parameterization 1

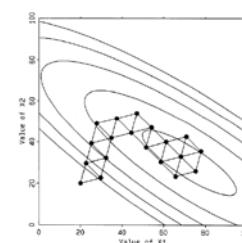
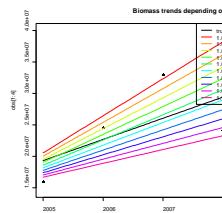
Alternative parameterization 2

Param2 { Hypothesis 1

Hypothesis 2

Alternative parameterization 3

Alternative parameterization 4



 ISIS-Fish  
Pêcherie pélagique

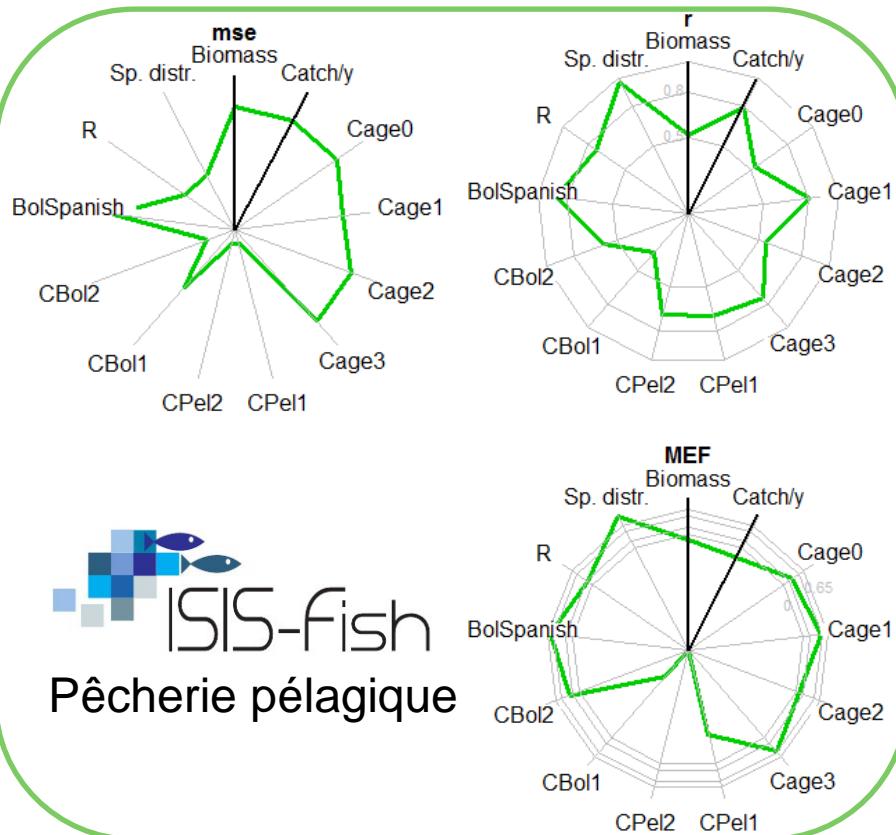
# SA-CALIBRATION-VALIDATION FOR PARAMETERIZATION

- Systematic building alternative parameterizations
- Calibration of continuous parameters
- Evaluation of alternative parameterizations against observations

Alternative parameterizations

- Megg1,R2,migApr
- Megg1,R2,migJan
- Megg1,R1,migApr
- Megg1,R1,migJan
- Megg2,R2,migApr
- Megg2,R2,migJan
- Megg2,R1,migApr
- Megg2,R1,migJan

« Model skill assessment »  
Multi-variables and multi-criteria validation and model selection



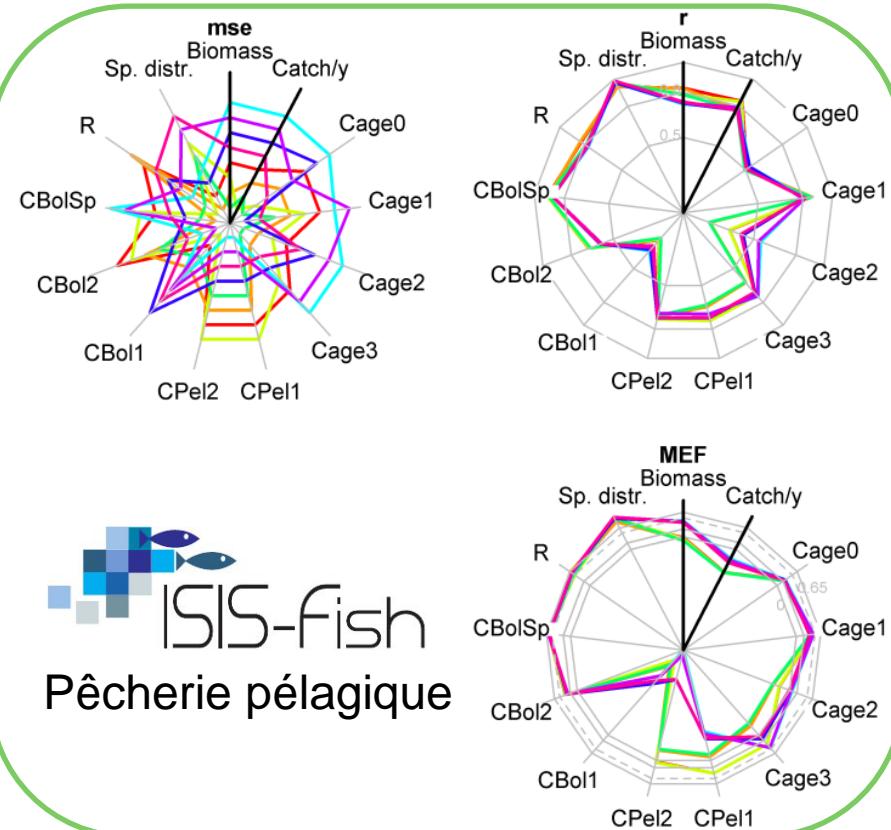
# SA-CALIBRATION-VALIDATION FOR PARAMETERIZATION

- Systematic building alternative parameterizations
- Calibration of continuous parameters
- Evaluation of alternative parameterizations against observations

Alternative parameterizations

- Megg1,R2,migApr
- Megg1,R2,migJan
- Megg1,R1,migApr
- Megg1,R1,migJan
- Megg2,R2,migApr
- Megg2,R2,migJan
- Megg2,R1,migApr
- Megg2,R1,migJan

« Model skill assessment »  
Multi-variables and multi-criteria validation and model selection

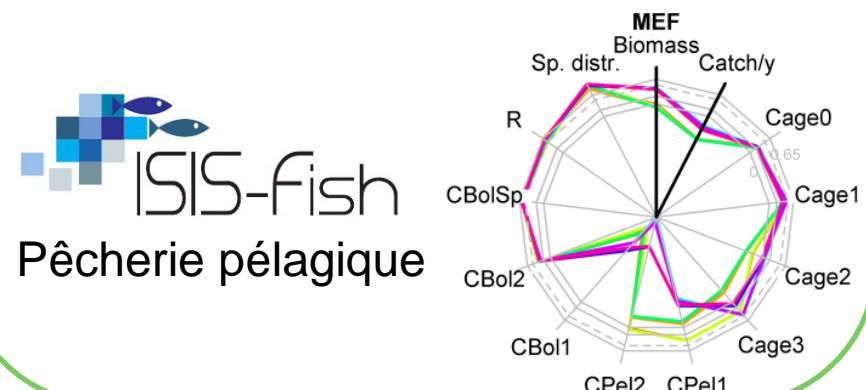
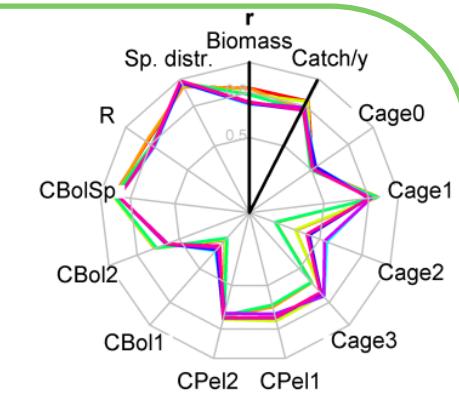
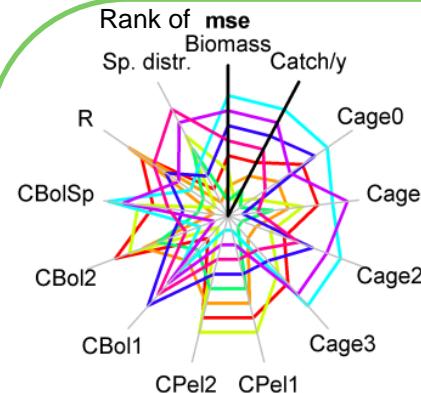


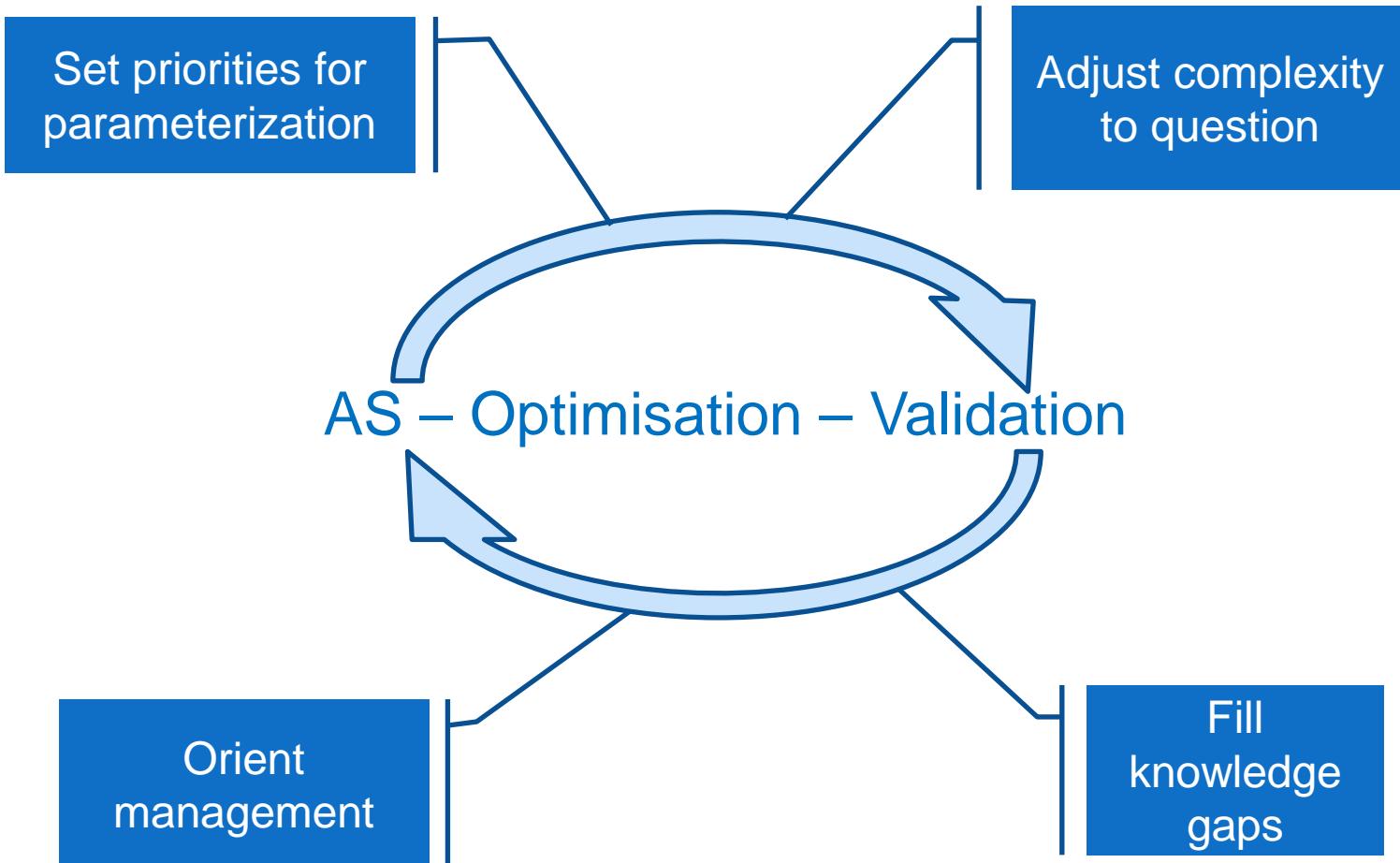
# SA-CALIBRATION-VALIDATION FOR PARAMETERIZATION

- Systematic building alternative parameterizations
- Calibration of continuous parameters
- Evaluation of alternative parameterizations against observations

Limits :  
Caricature of parameter space to limit alternatives

« Model skill assessment »  
Multi-variables and multi-criteria validation and model selection

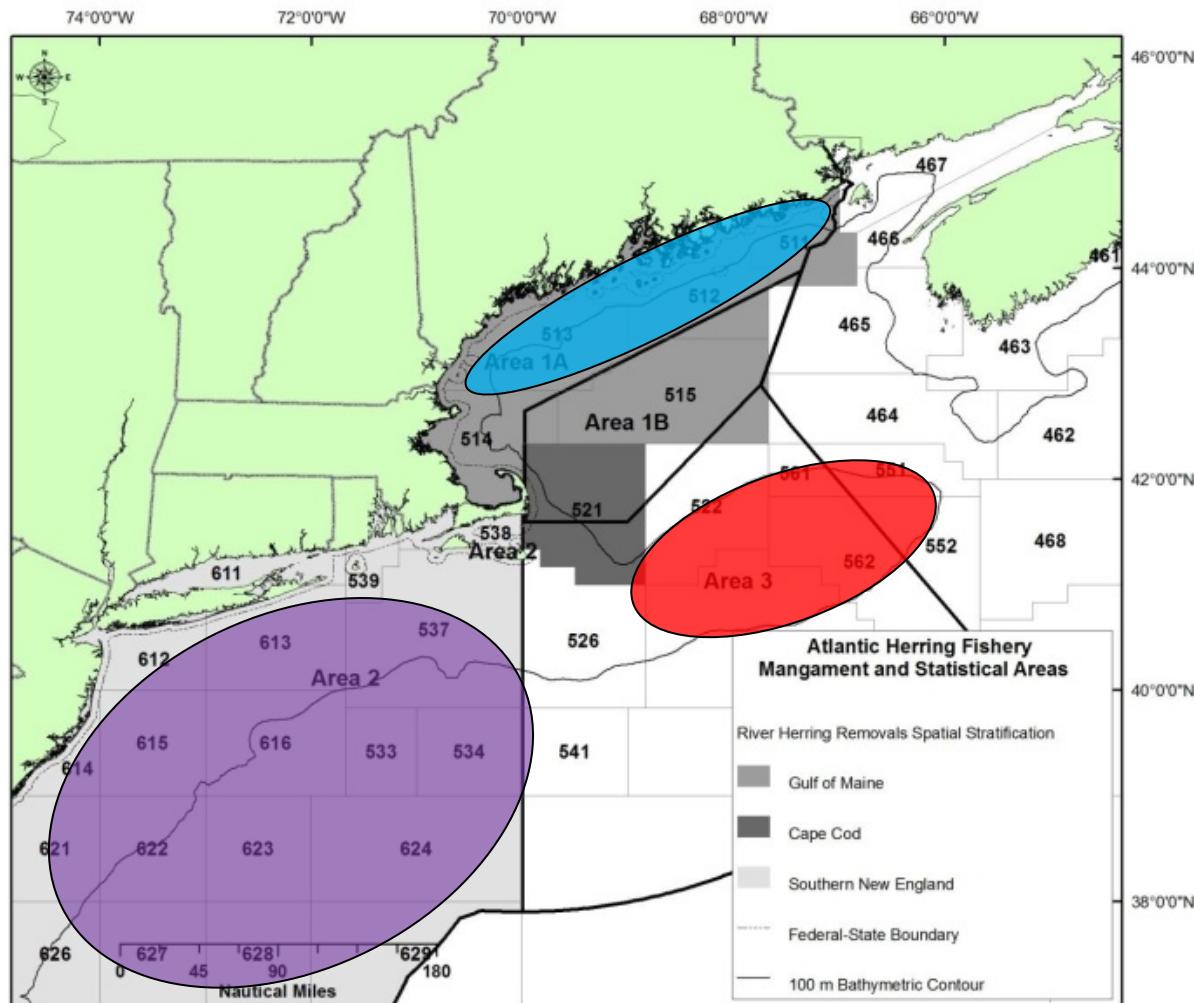
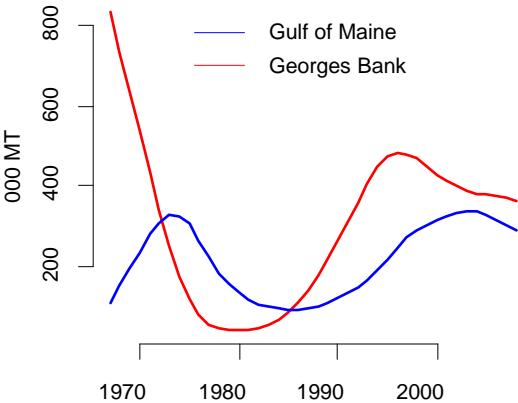




# FILL KNOWLEDGE GAPS: HERRING META-POPULATION GULF OF MAINE

1 unique quota

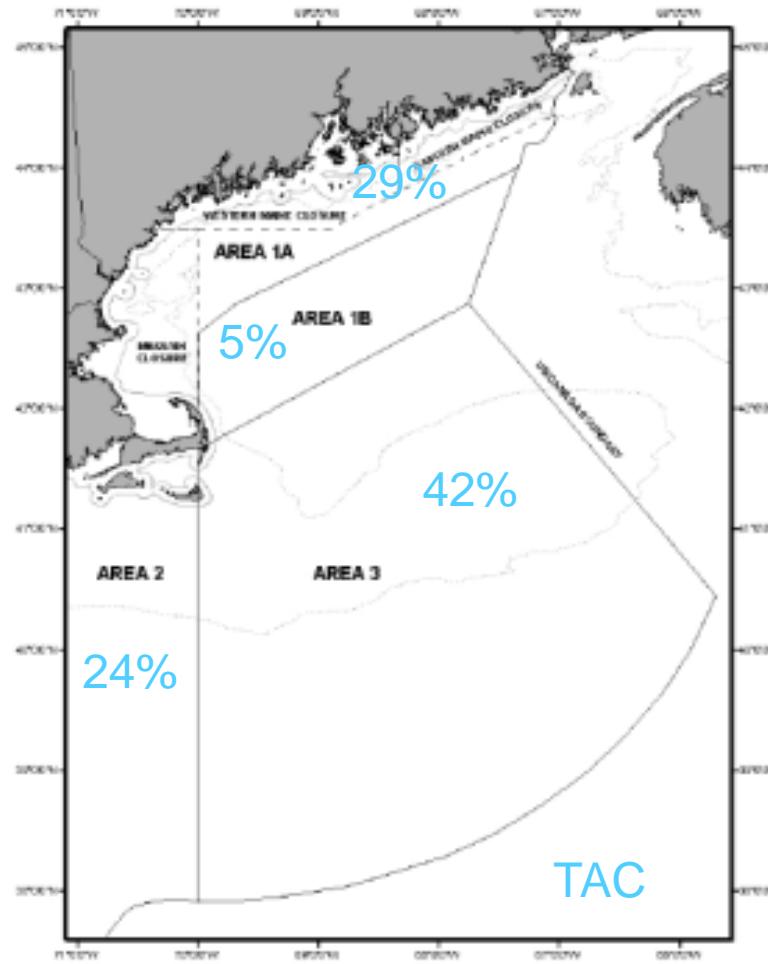
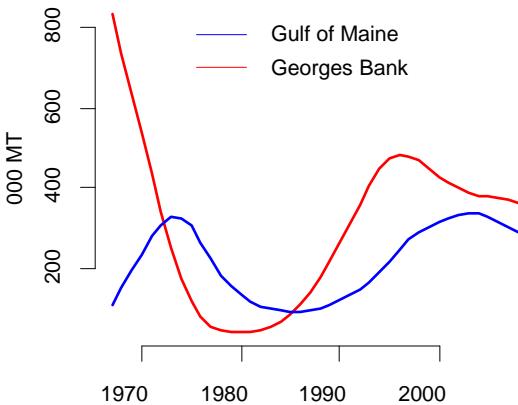
Herring biomass



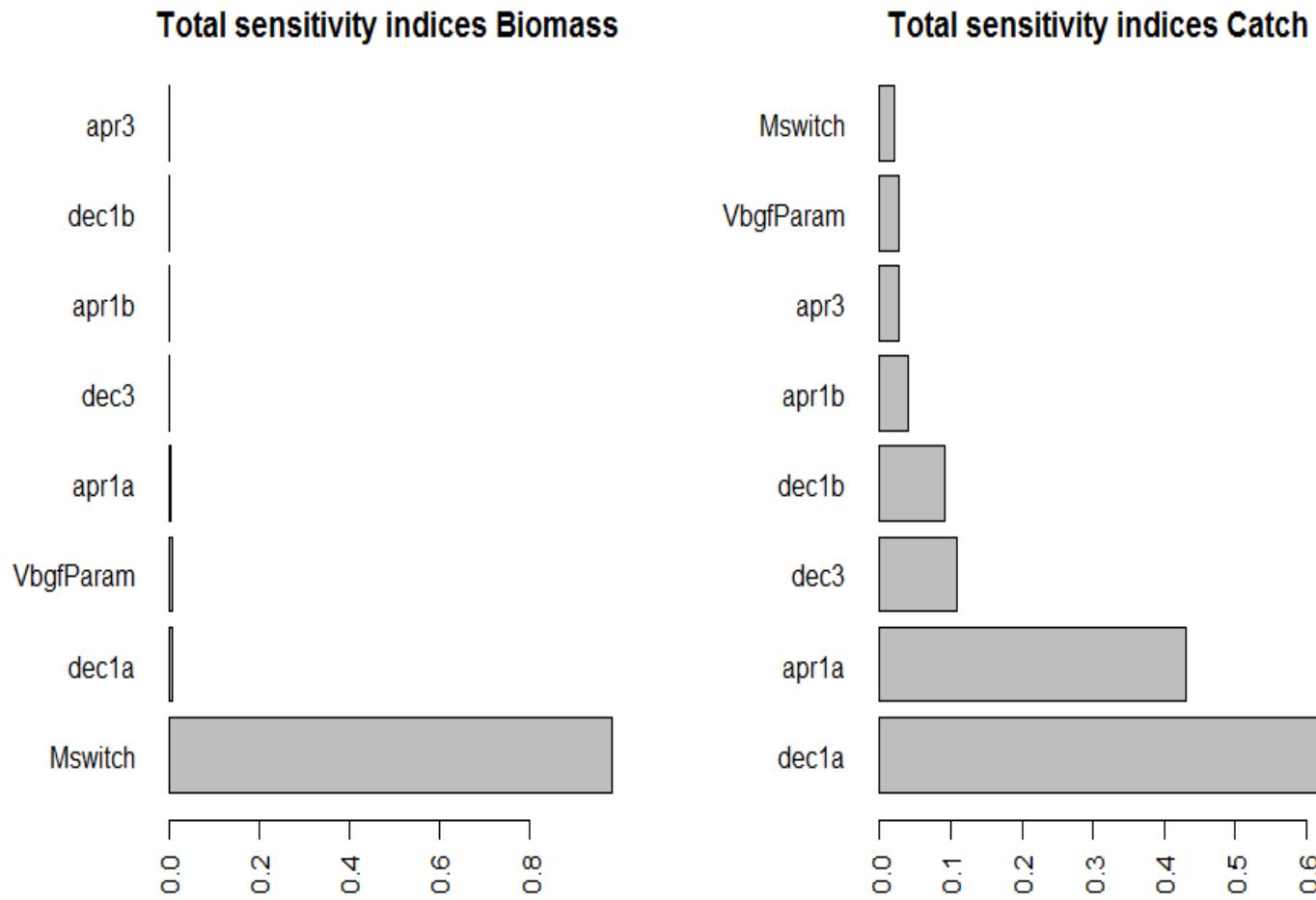
# FILL KNOWLEDGE GAPS: HERRING META-POPULATION GULF OF MAINE

1 unique quota

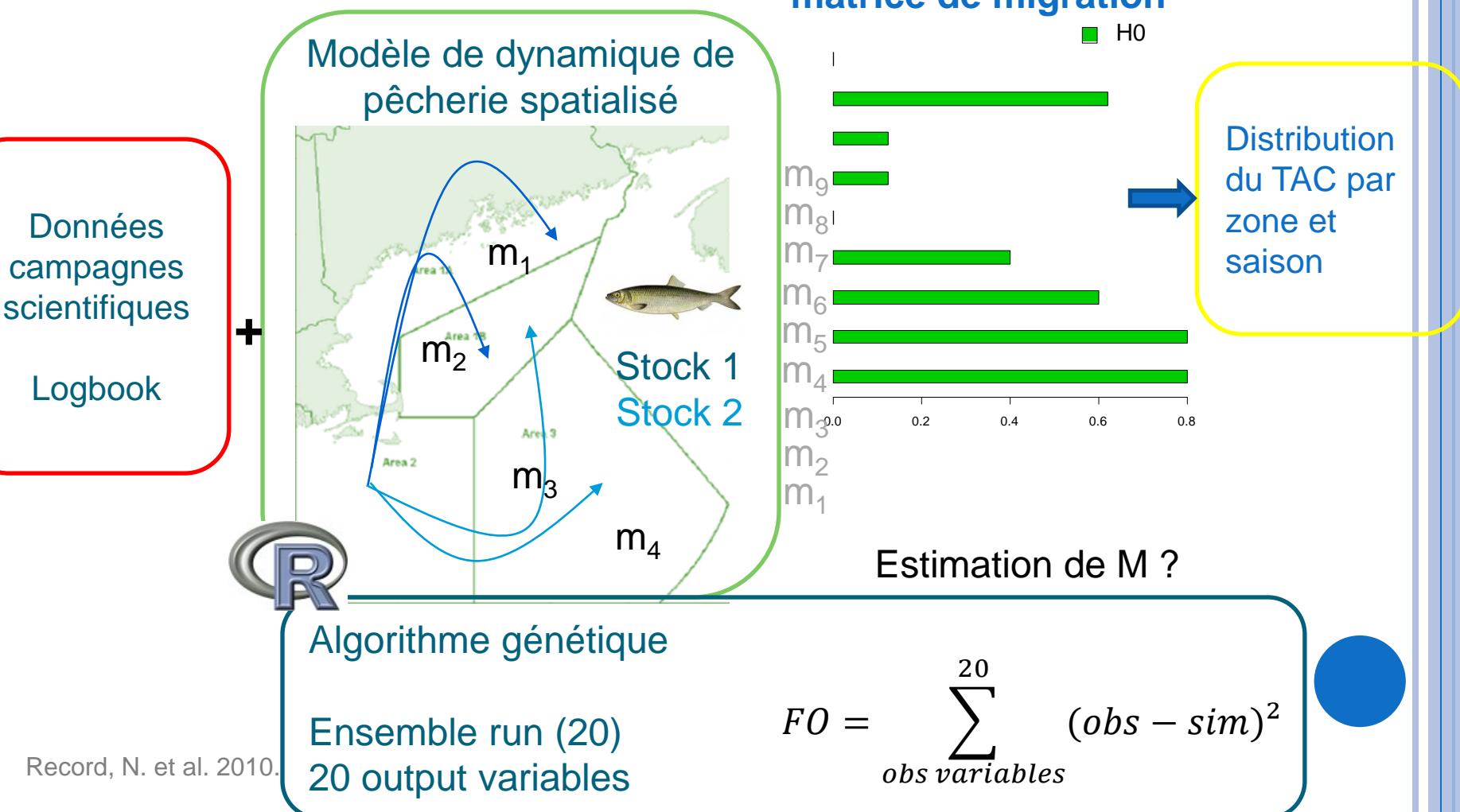
Herring biomass



# FILL KNOWLEDGE GAPS: SENSITIVITY ANALYSIS HERRING META-POPULATION GULF OF MAINE



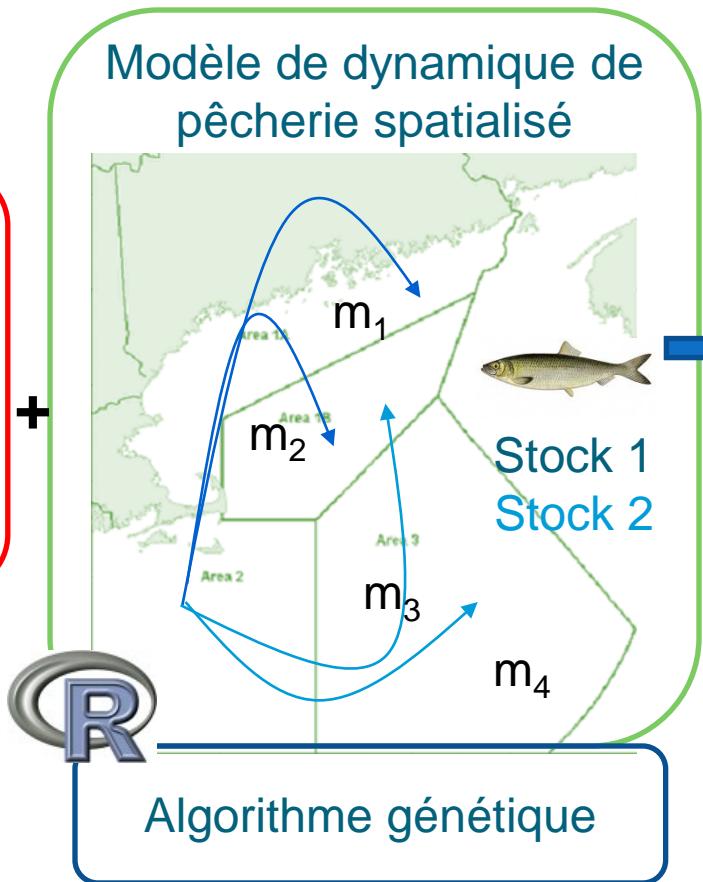
# FILL KNOWLEDGE GAPS: CALIBRATION HERRING META-POPULATION GULF OF MAINE



# FILL KNOWLEDGE GAPS: CALIBRATION HERRING META-POPULATION GULF OF MAINE

Données campagnes scientifiques

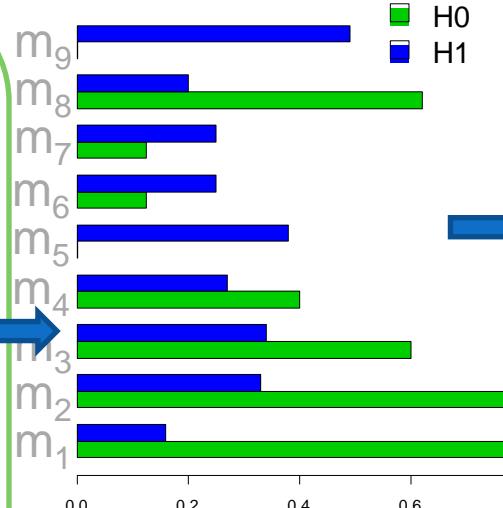
Logbook



Record, N. et al. 2010.



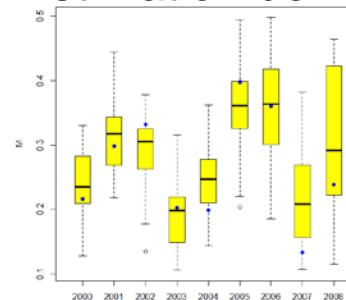
## Coefficients de la matrice de migration



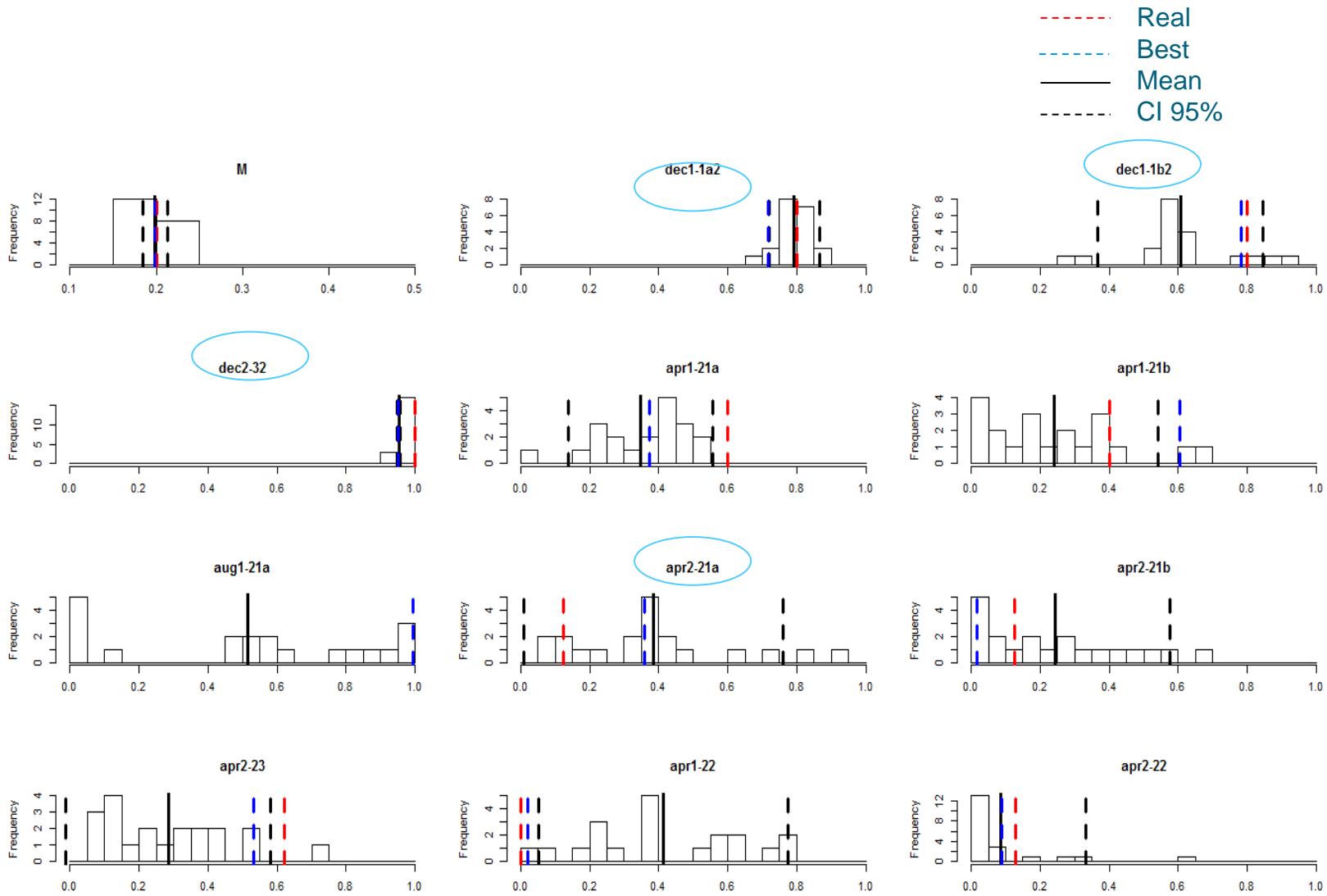
Distribution du TAC par zone et saison

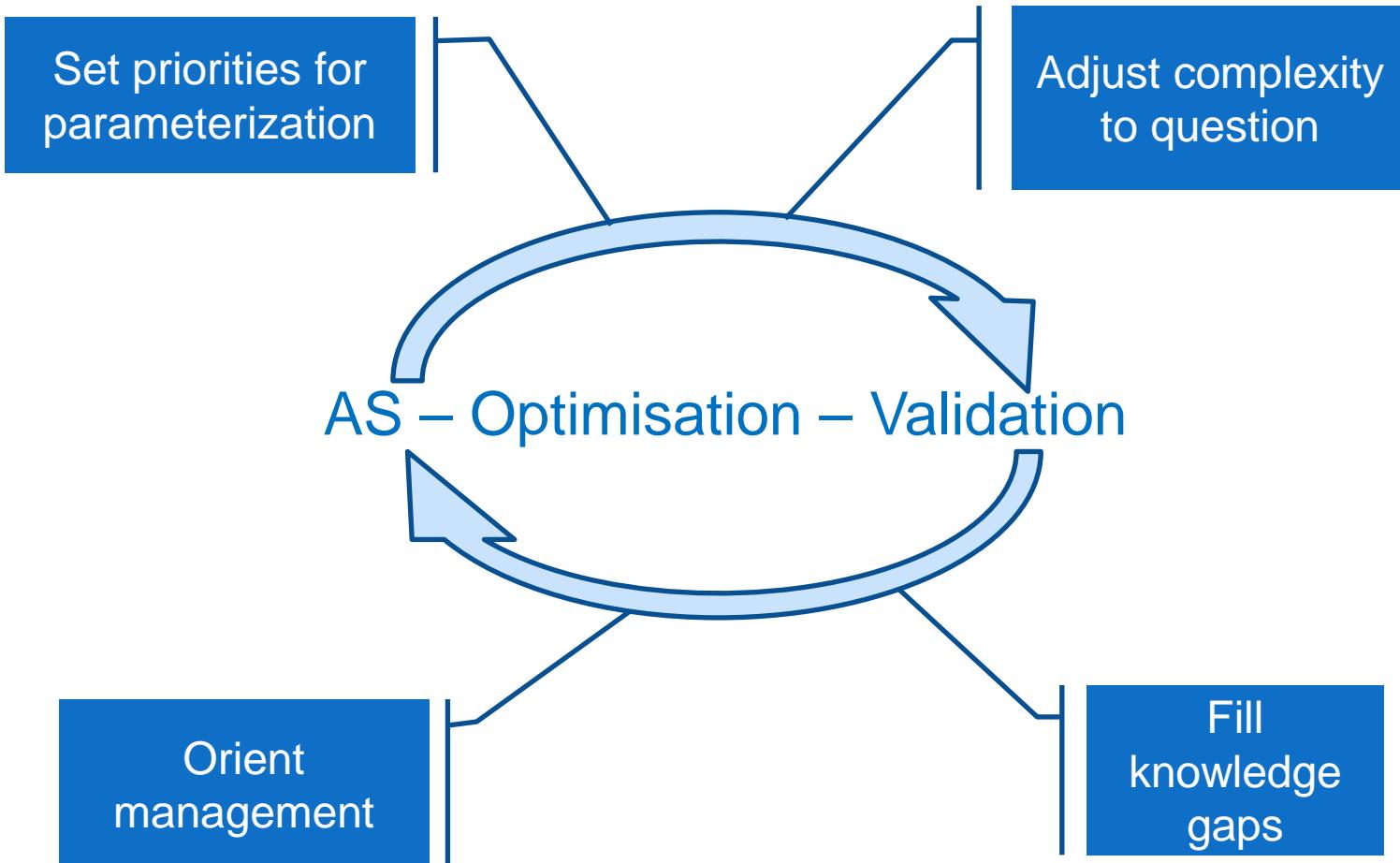
Vision très différente des migrations

## Estimation de M



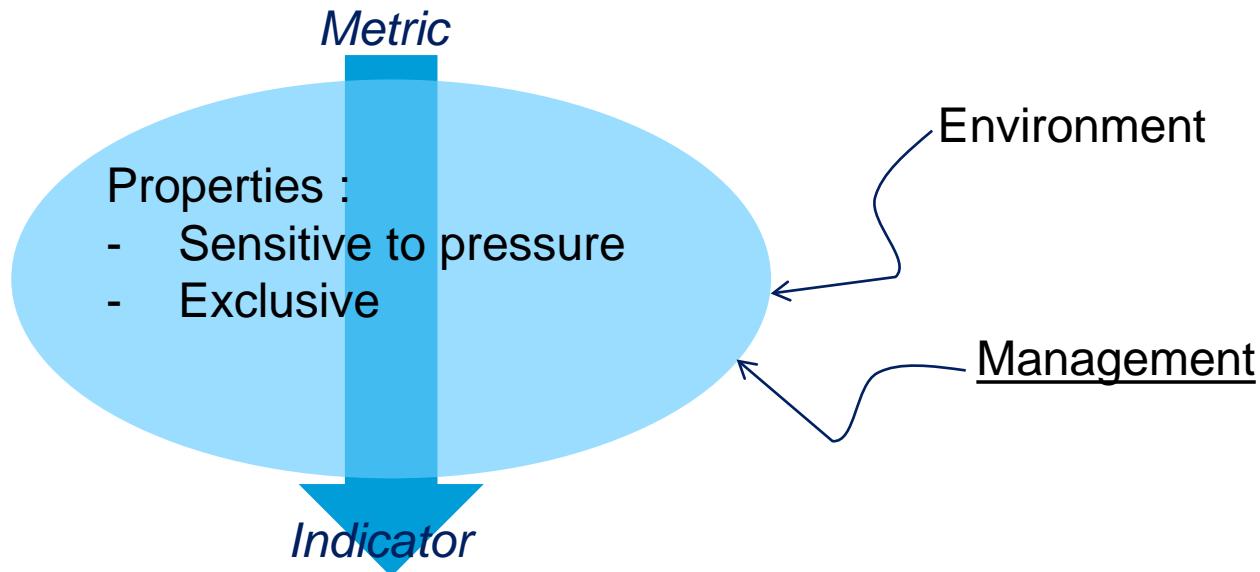
# FILL KNOWLEDGE GAPS: TWIN EXPERIMENT & ENSEMBLE RUN (20) HERRING META-POPULATION GULF OF MAINE



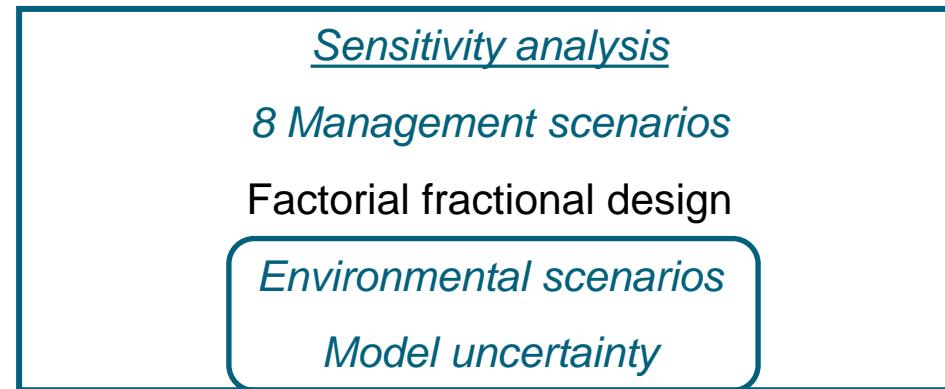
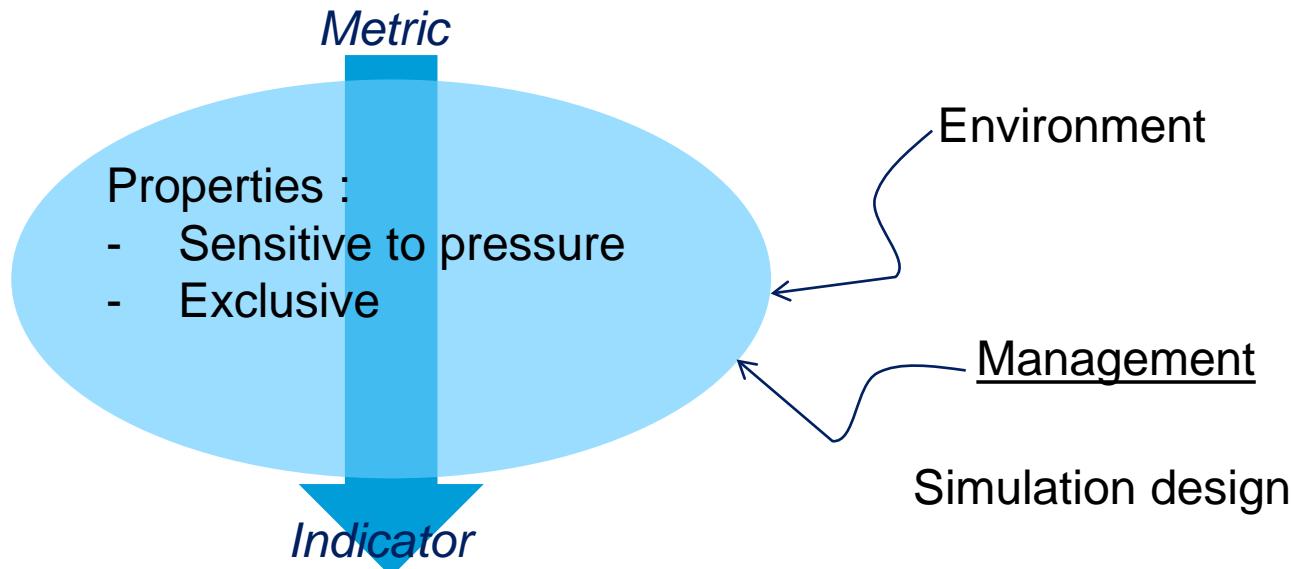


# IDENTIFICATION OF INDICATORS OF THE IMPACT OF MANAGEMENT

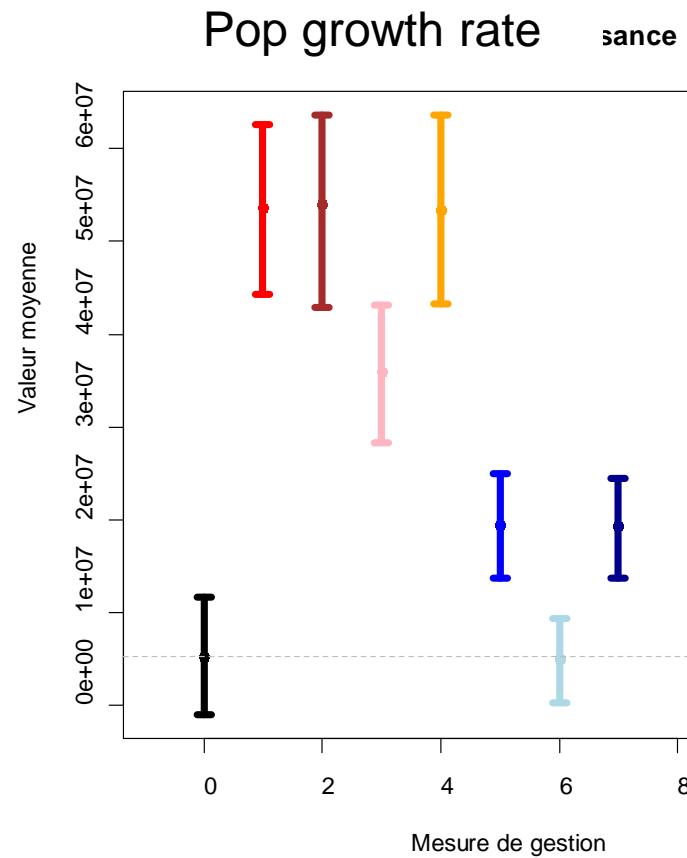
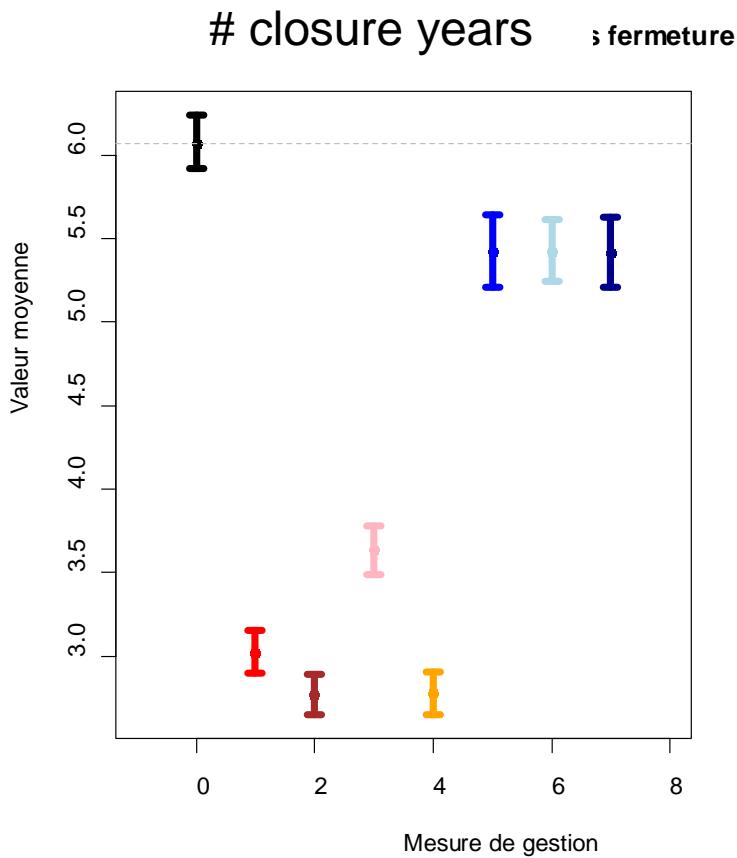
## PELAGIC FISHERY IN THE BAY OF BISCAY



# IDENTIFICATION OF INDICATORS OF THE IMPACT OF MANAGEMENT PELAGIC FISHERY IN THE BAY OF BISCAY



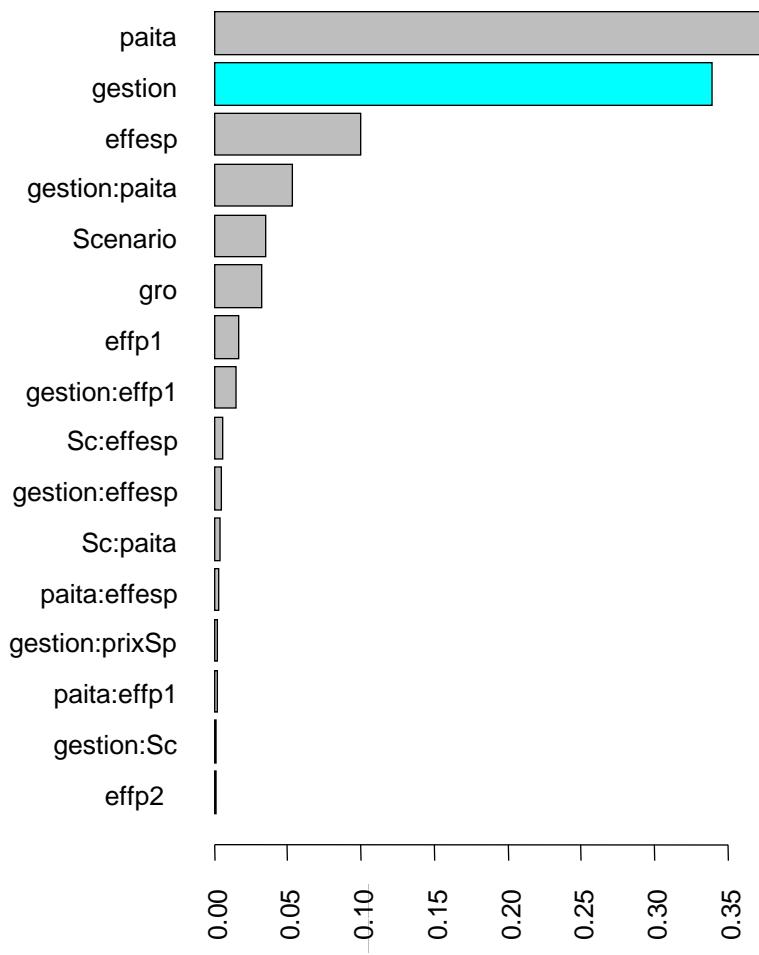
# Metrics sensitivity to management



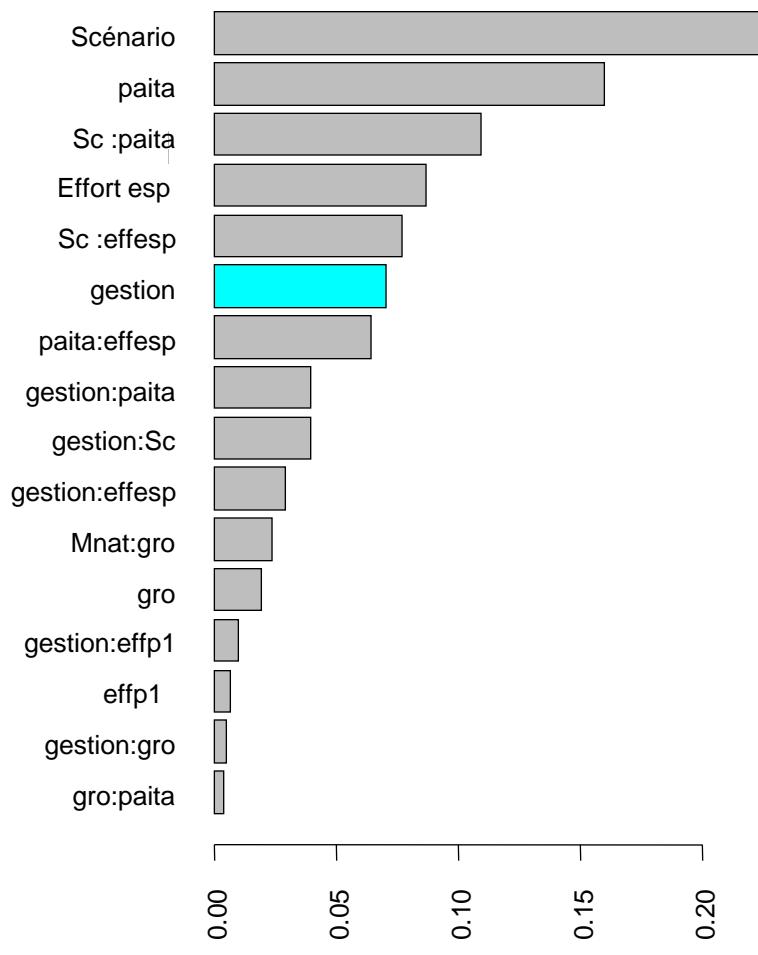
# Performance metrics exclusivity

Management

# closure years



Pop growth rate



# Performance metrics exclusivity



Management

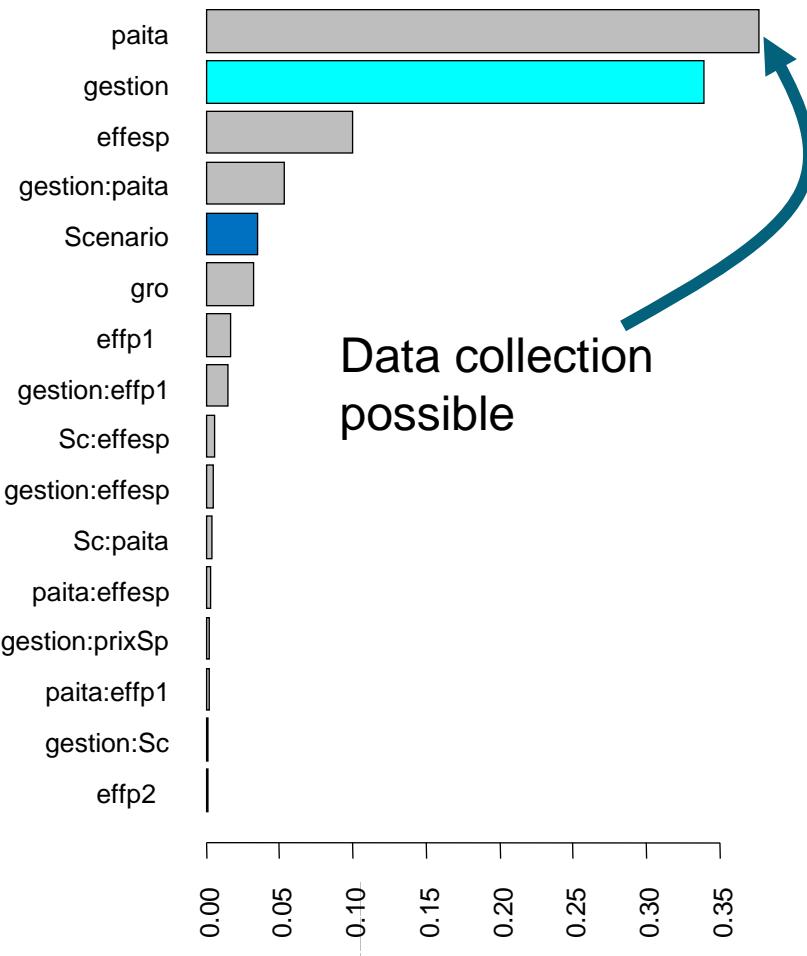


Environment

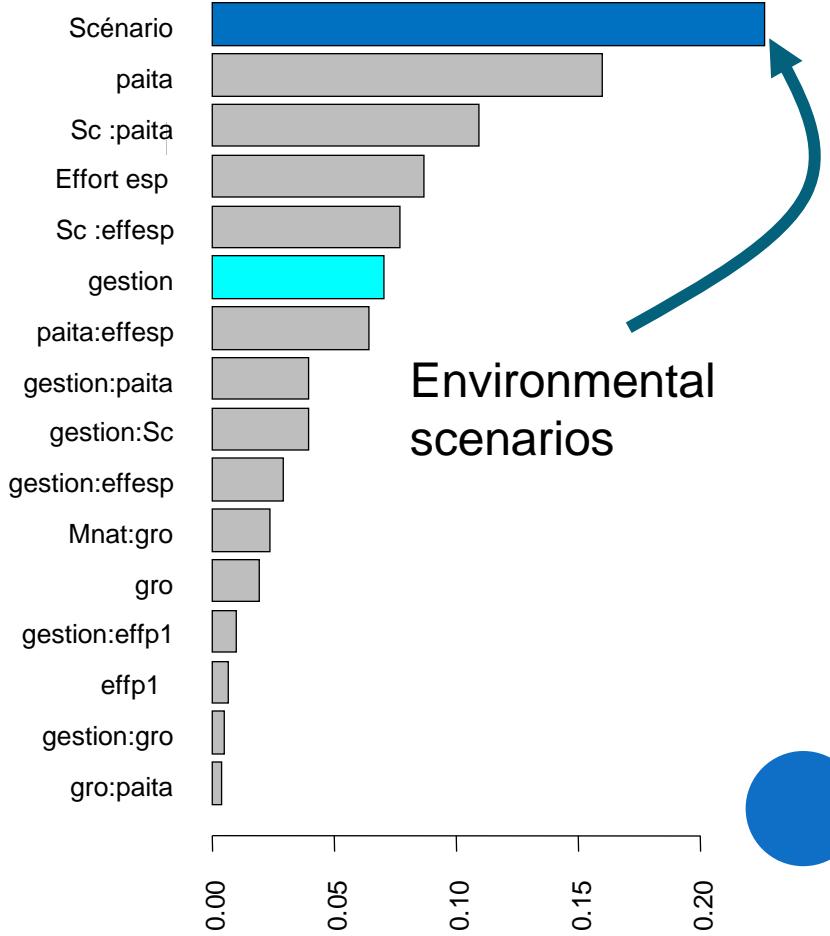


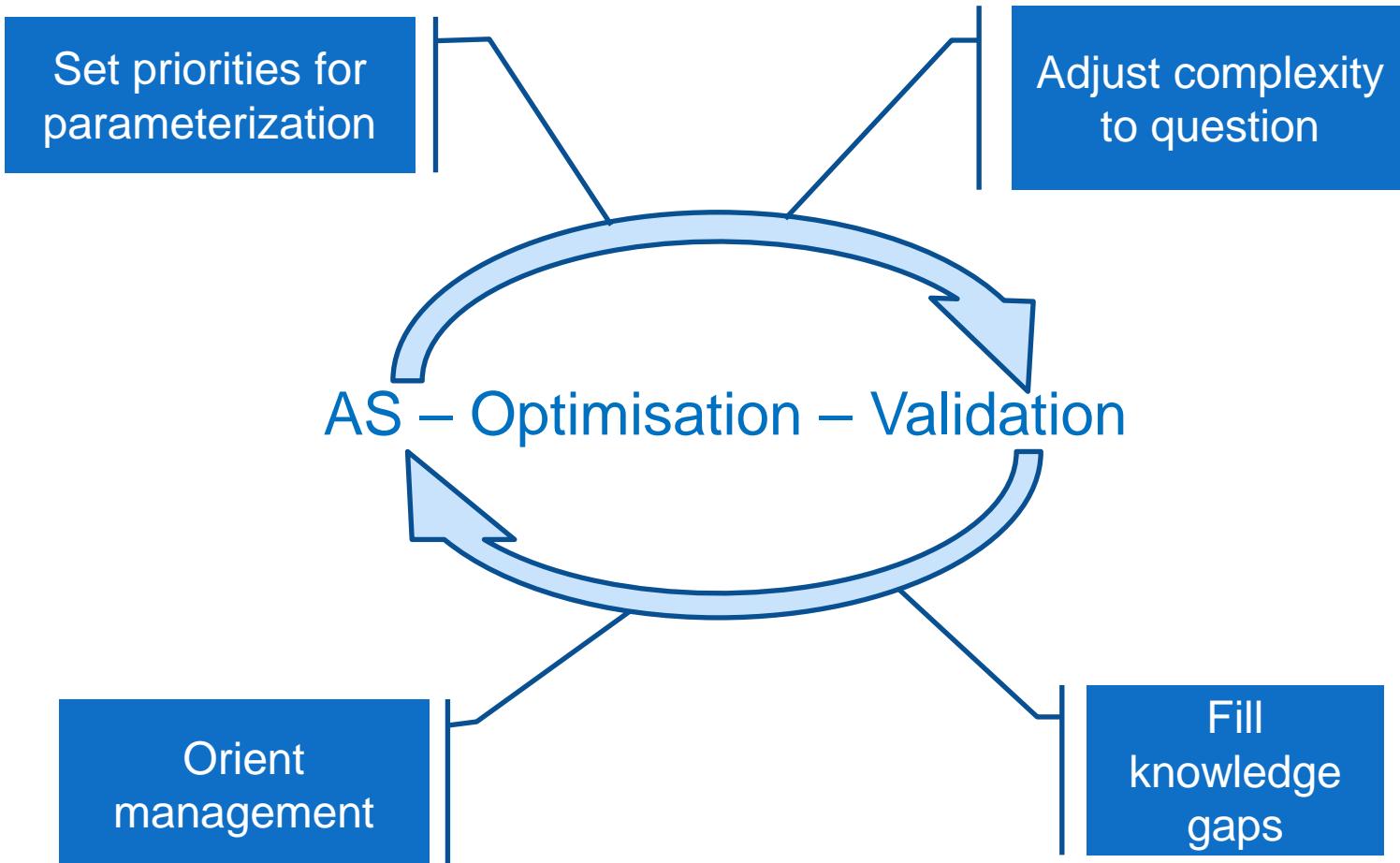
Model uncertainty

Ind. Se # closure years



Pop growth rate

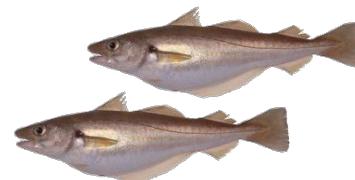




# MANAGEMENT STRATEGY OPTIMISATION MIXED FISHERIES



Fmerlan



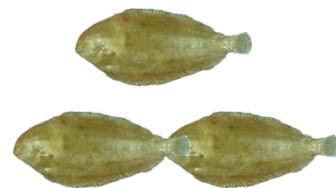
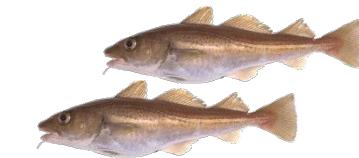
Fplie



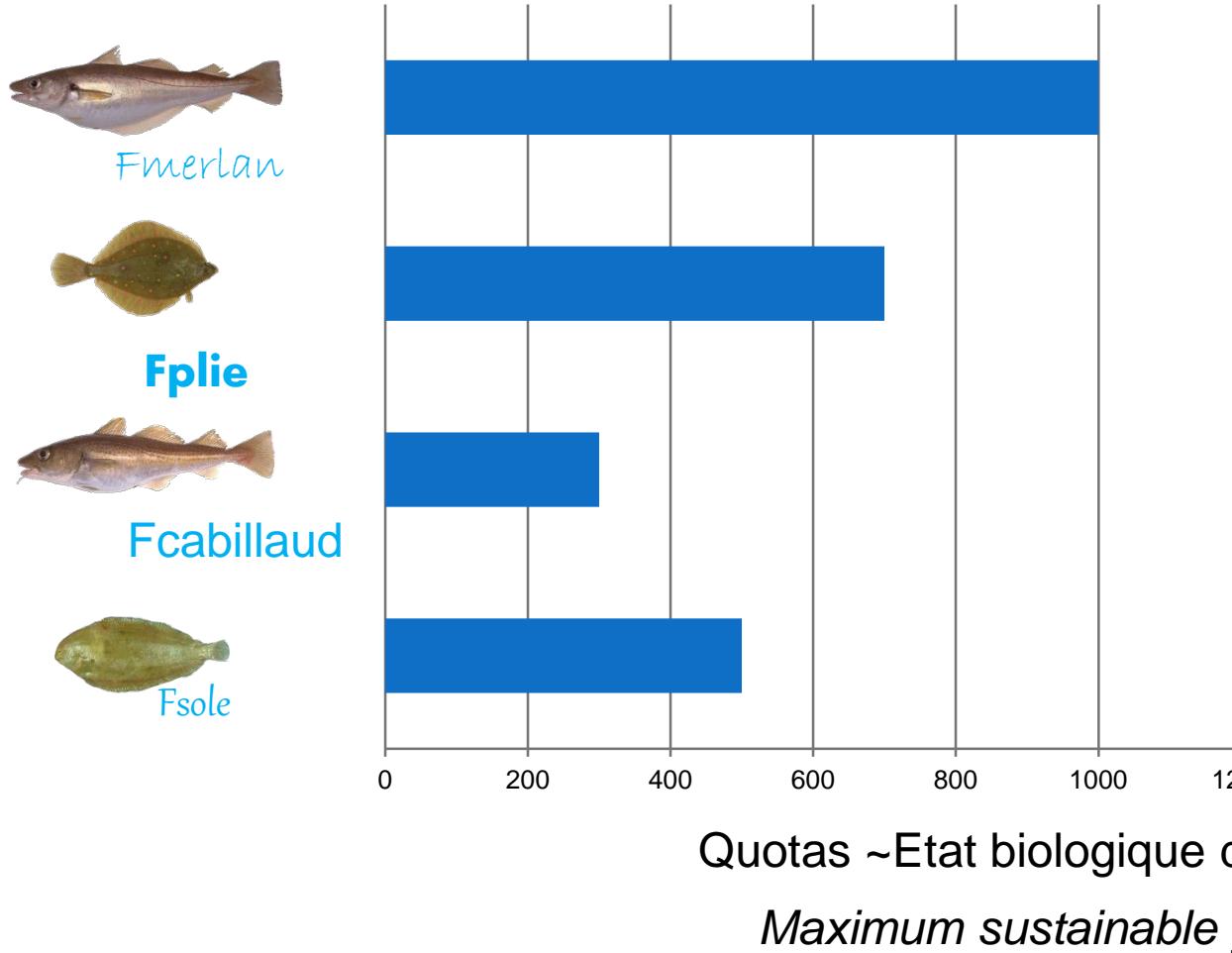
Fcabillaud



Fsole



# MANAGEMENT STRATEGY OPTIMISATION MIXED FISHERIES



# MANAGEMENT STRATEGY OPTIMISATION MIXED FISHERIES

Sc. Max : Effort E1 = Effort 1 + Effort 1



Fmerlan



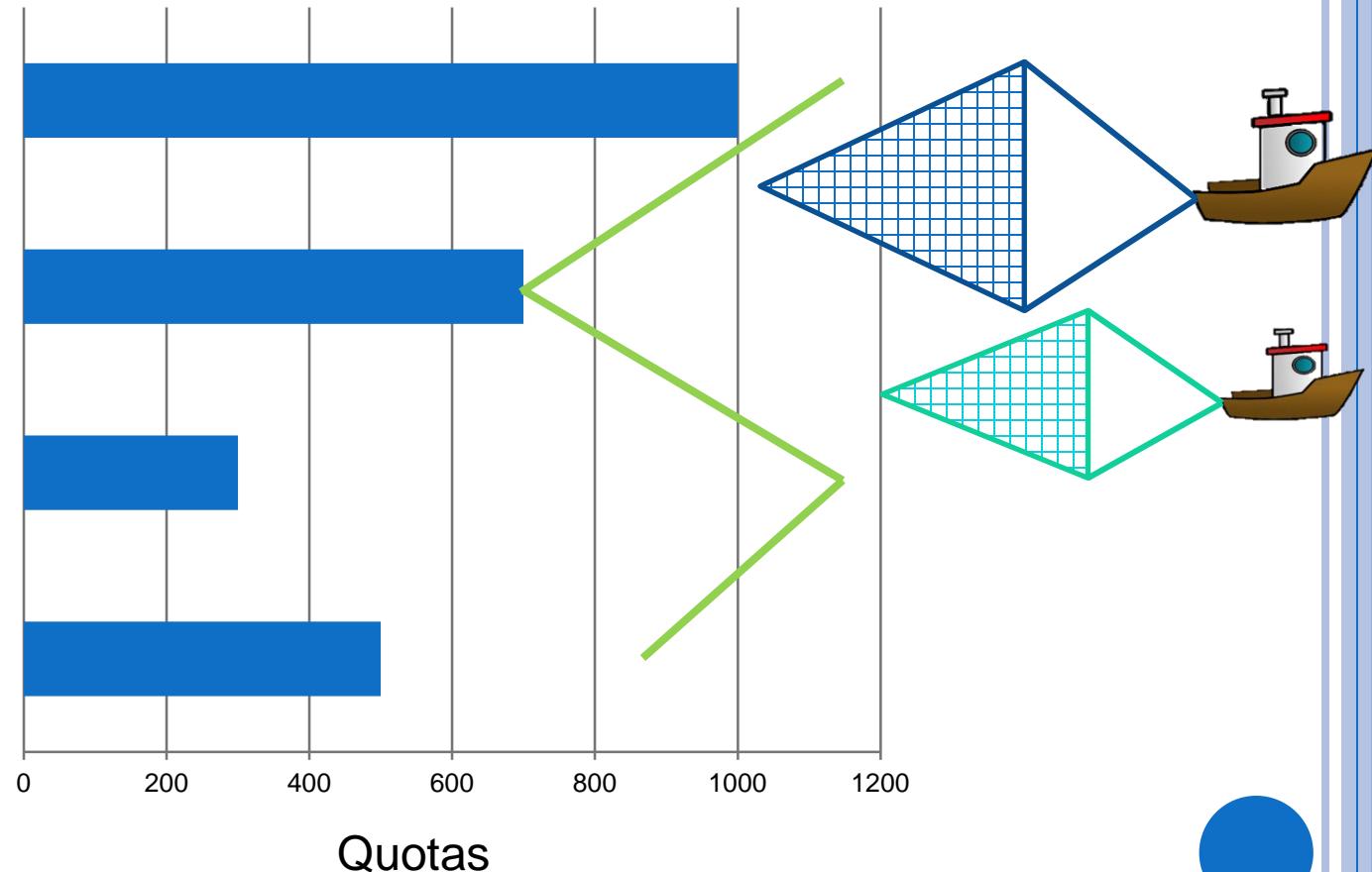
Fplie



Fcabillaud



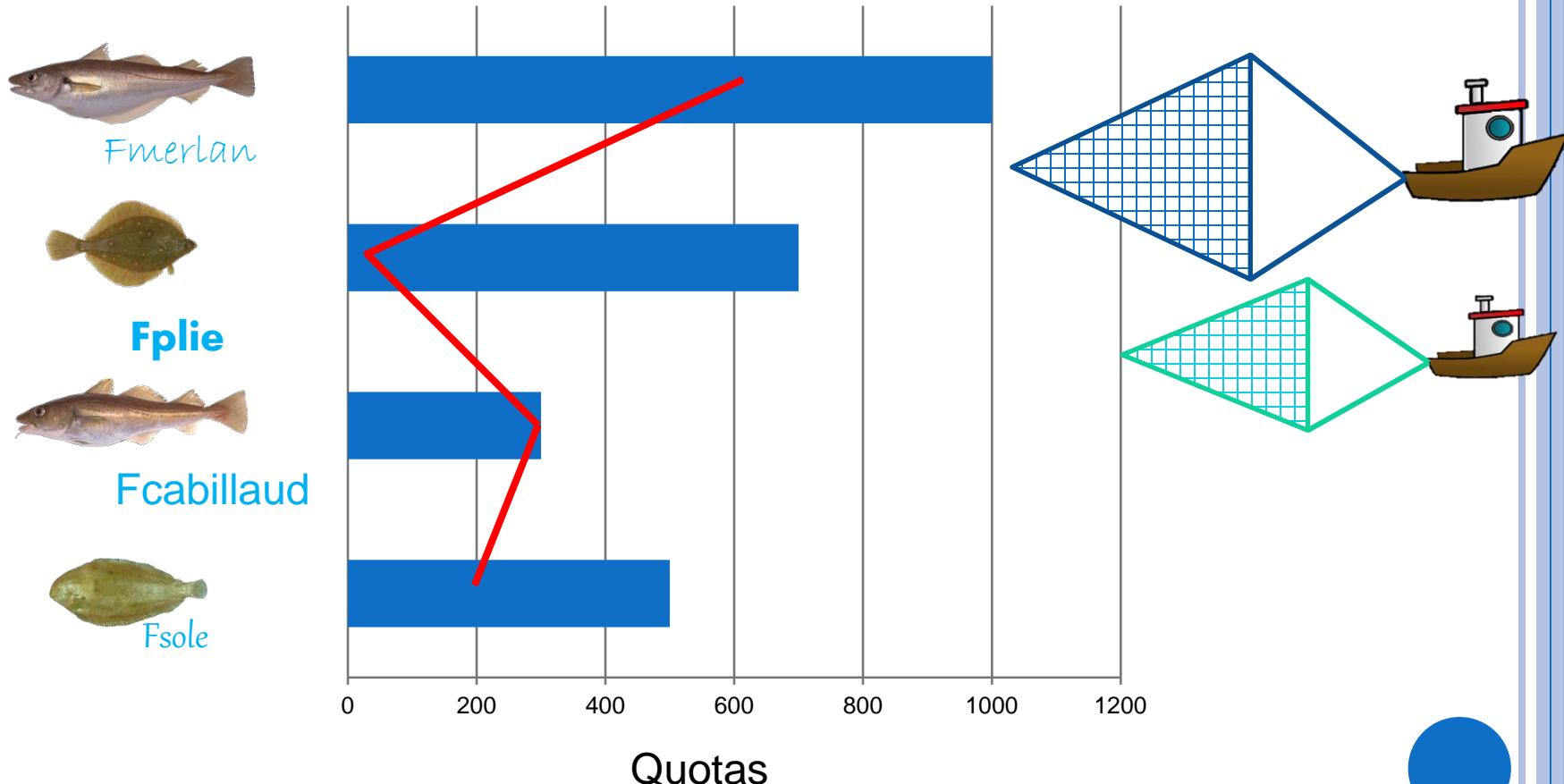
Fsole



Maximum sustainable yield

# MANAGEMENT STRATEGY OPTIMISATION MIXED FISHERIES

Sc. Min : Effort E2 = Effort 2 + Effort 2



*Maximum sustainable yield*

# MANAGEMENT STRATEGY OPTIMISATION MIXED FISHERIES



Fmerlan



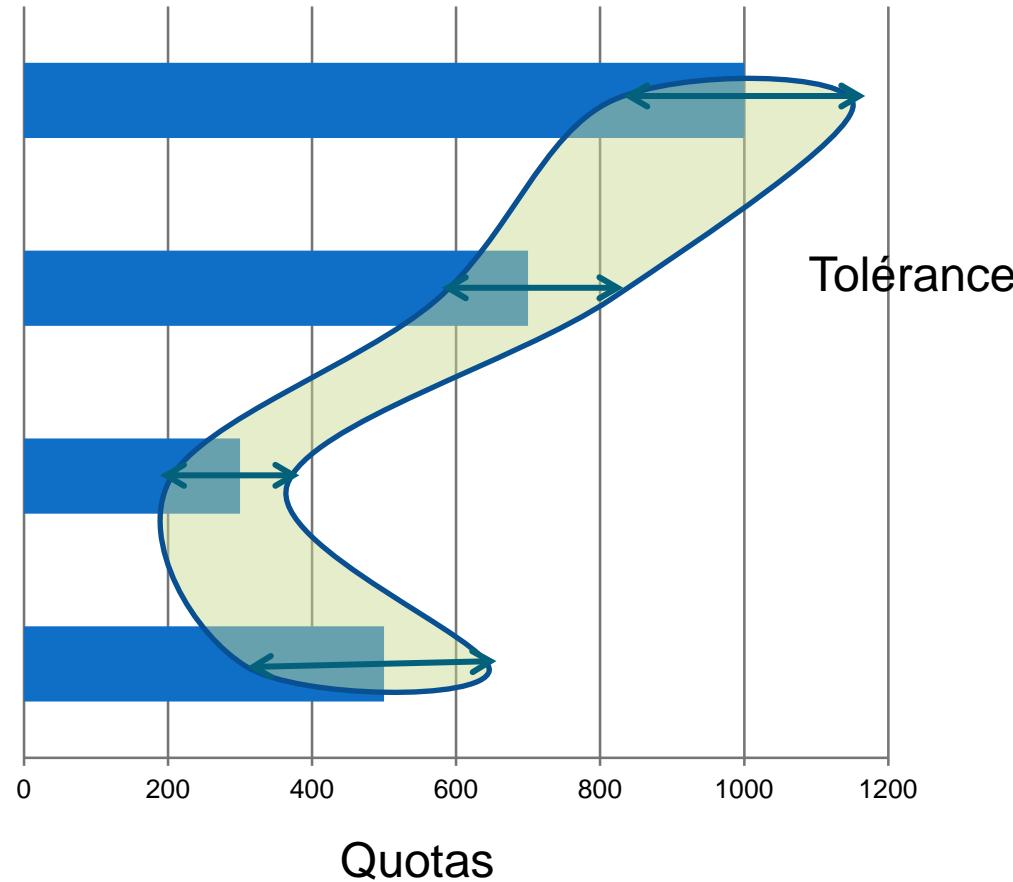
Fplie



Fcabillaud



Fsole



(Rindorp et al. 2016)

# MANAGEMENT STRATEGY OPTIMISATION MIXED FISHERIES

*Search for {quotas} optimal within constraints  
That minimizes (Catch Sc. Max – Catch Sc. Min)*



Fmerlan



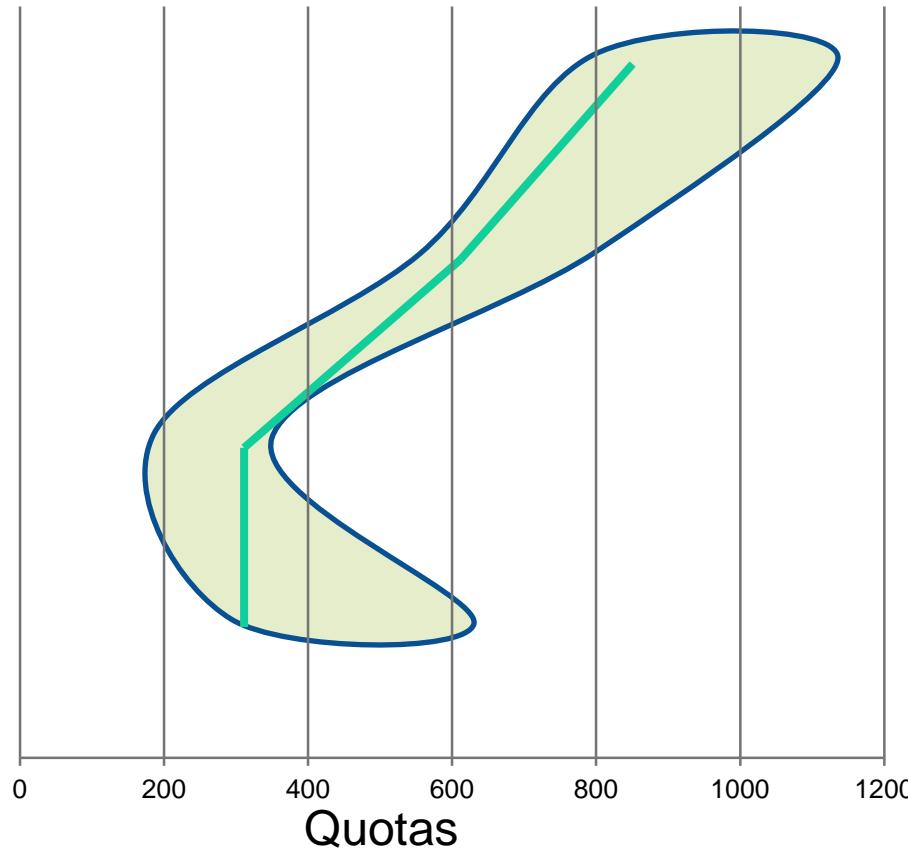
Fplie



Fcabillaud



Fsole



Genetic algorithm

Pretty good yield

Ulrich et al. 2016

# CONCLUSION



- In fisheries,
  - Use of these methods is in its infancy
  - These are not sophisticated methods
  
- Powerful tools to
  - Explore our understanding of the system
  - Make parameterization efficient and objective
  - Improve confidence in models
  - Control and assess uncertainty
  - Provide operational results for fisheries management



# PERSPECTIVES AND CHALLENGES (SOS MEXICO !)

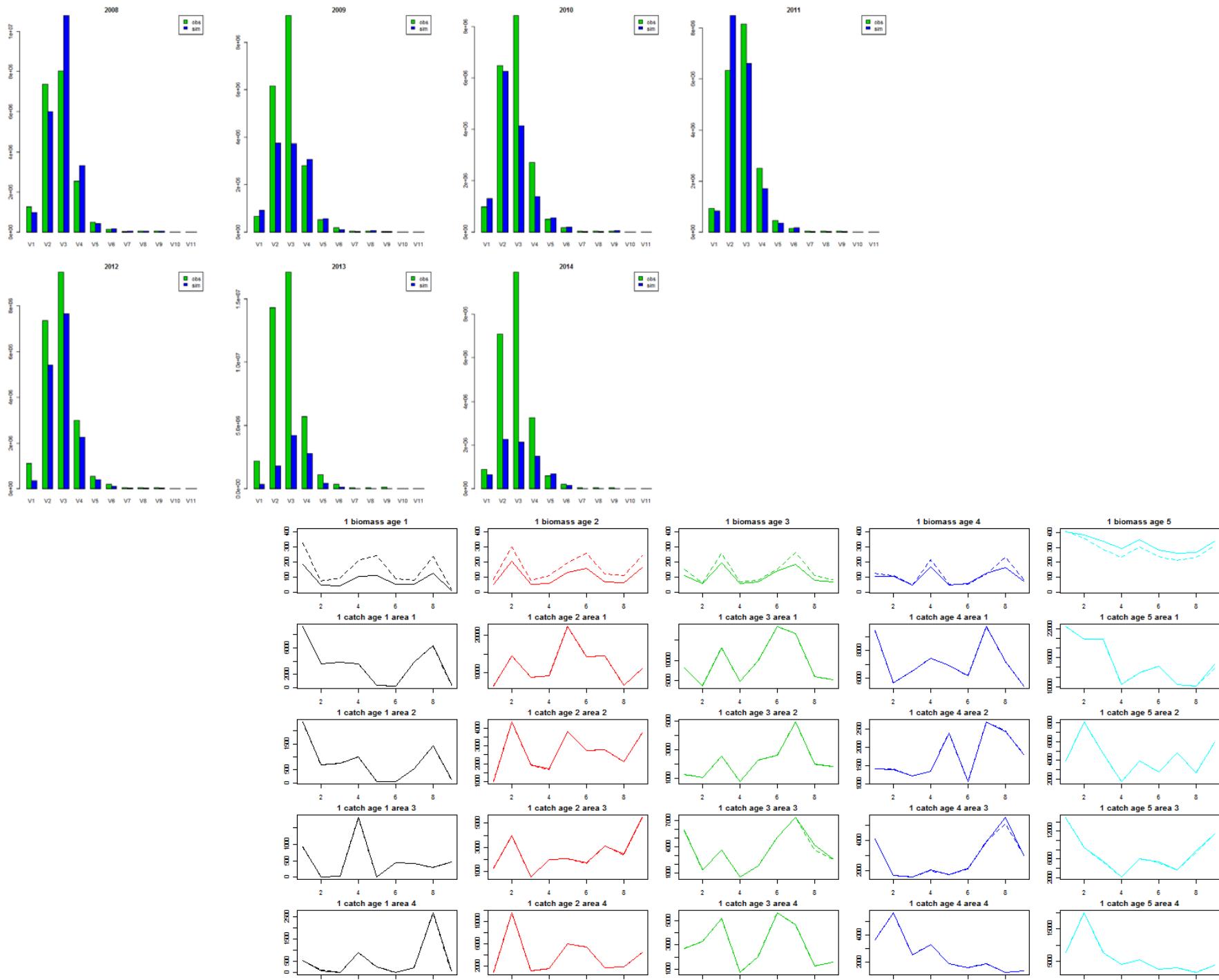
## ○ Analyse de Sensibilité

- Mélange var discrètes (non ordonnées ex. climato) et continues
- Variables corrélées et domaine des possibles
- AS guidé par objectif

## ○ Estimation intégrée sur modèle complexe

- Variété d'algorithmes
- Metamodélisation : simulation de séries temporelles nombreuses variables d'intérêt, objectifs parfois flous (seuils...)
- Fonction objectif
  - Au delà de SCE (tendances, distribution)
  - Données incertaines

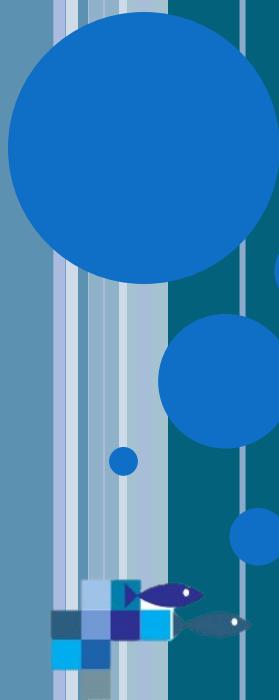




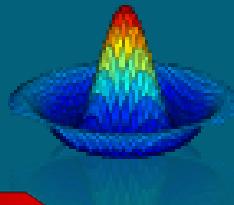
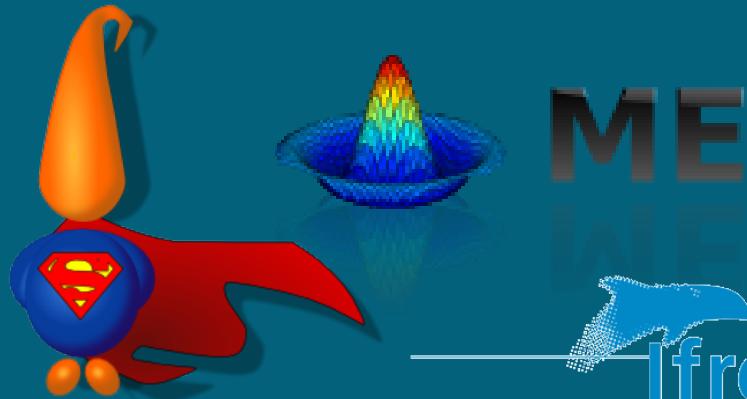
# PERSPECTIVES AND CHALLENGES (SOS MEXICO !)

- Optimisation en grande dimension
- Approches multi-modèles
  - ID et exploitation des forces et faiblesses de chaque modèle (décomposition en dimensions)
- Augmenter la transparence et la confiance (Acteurs et décideurs)
  - AS et analyse de perturbation
  - Confrontation aux données
  - Online tools !





MERCI



MEXICO  
MEXICO  
Ifremer

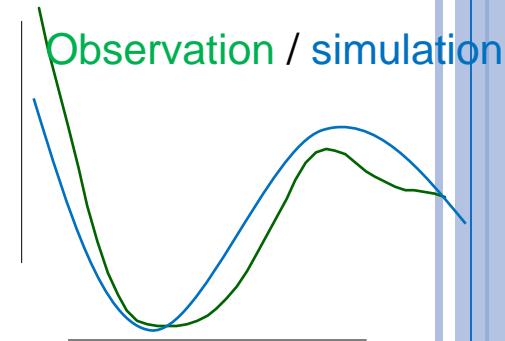
# FONCTION OBJECTIF

- $d_i = 1 / (1 + x_i)$ ,

with  $x_i = \text{Sum\_over\_time} ((\text{Sim}_t - \text{Obs}_t)^2 / \text{Obs}_t^2)$ ,

Period 2000-2008

- Annual **catches at age** per area (20 functions)
- Annual **biomass at age** assessed in January (5 functions)
- Annual Autumn survey's spatial distribution for each age class (**Abundance index** in 1A / Global abundance index) (5 functions)
- Annual Spring survey's spatial distribution for each age class (Abundance **index in Ai** / Global abundance indice, for  $A_i$  in {1A, 1B, 3}) (15 functions)
- The overall objective function D is the sum of the sub-functions thus a perfect fit would give  $D = 45$



# EXPÉRIENCES

- Twin experiment:

Simule les observations ! À paramètres connus.

Est-ce que l'algorithme retrouve les paramètres utilisés ?

- Scénarios sur M:

- Scénario 1 : M constant identique à tous âges
- Scénario 2 : M ~année identique à tous âges
- Scénario 3 : M constant mais varie avec l'âge

$$M(\text{length}) = \text{Exp}(\textcolor{red}{a+b} * \log(\text{length}))$$

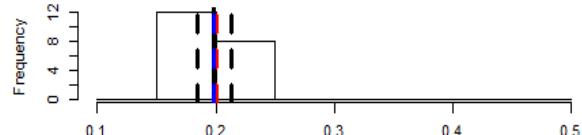
Algorithme : Record et al. 2010

Ensemble : > 20 runs

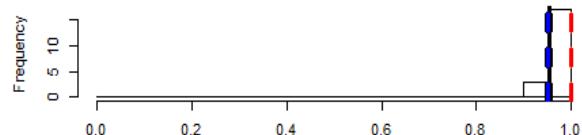


# TWIN EXPERIMENT

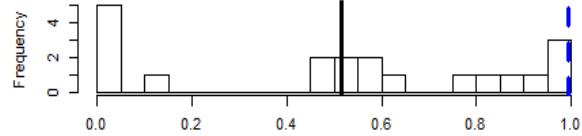
M



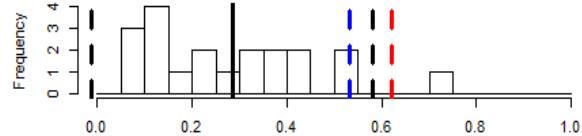
dec2-32



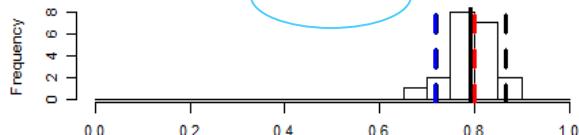
aug1-21a



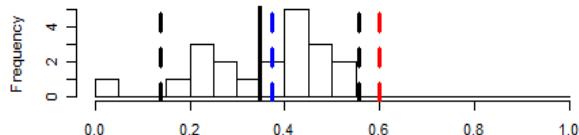
apr2-23



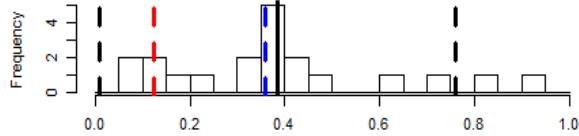
dec1-1a2



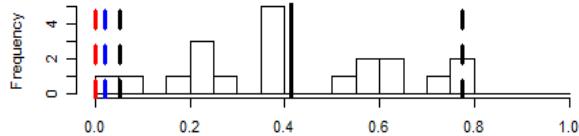
apr1-21a



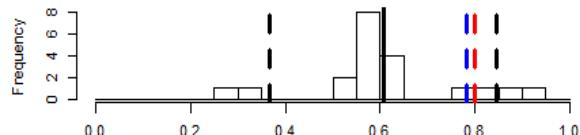
apr2-21a



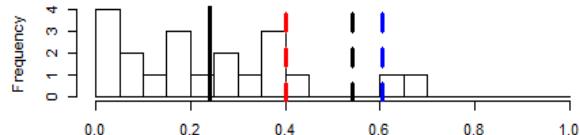
apr1-22



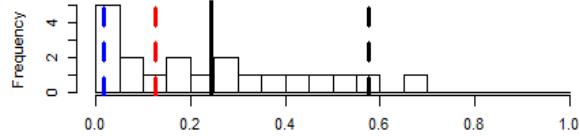
dec1-1b2



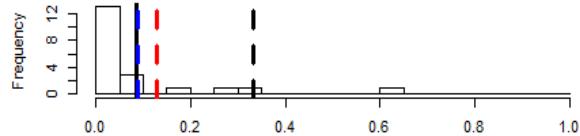
apr1-21b



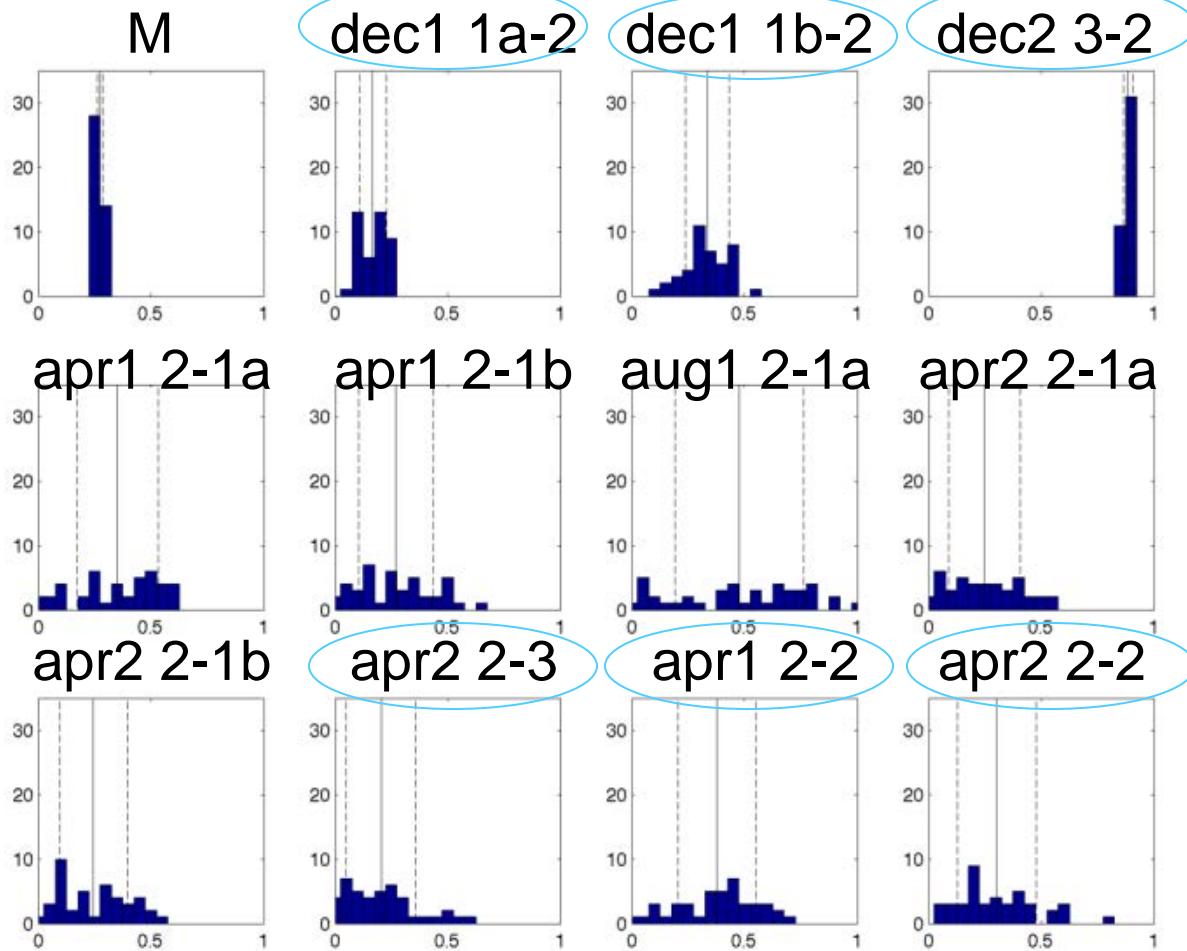
apr2-21b



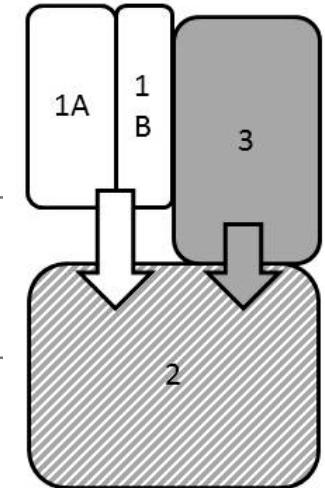
apr2-22



# RÉSULTATS SCÉNARIO 1

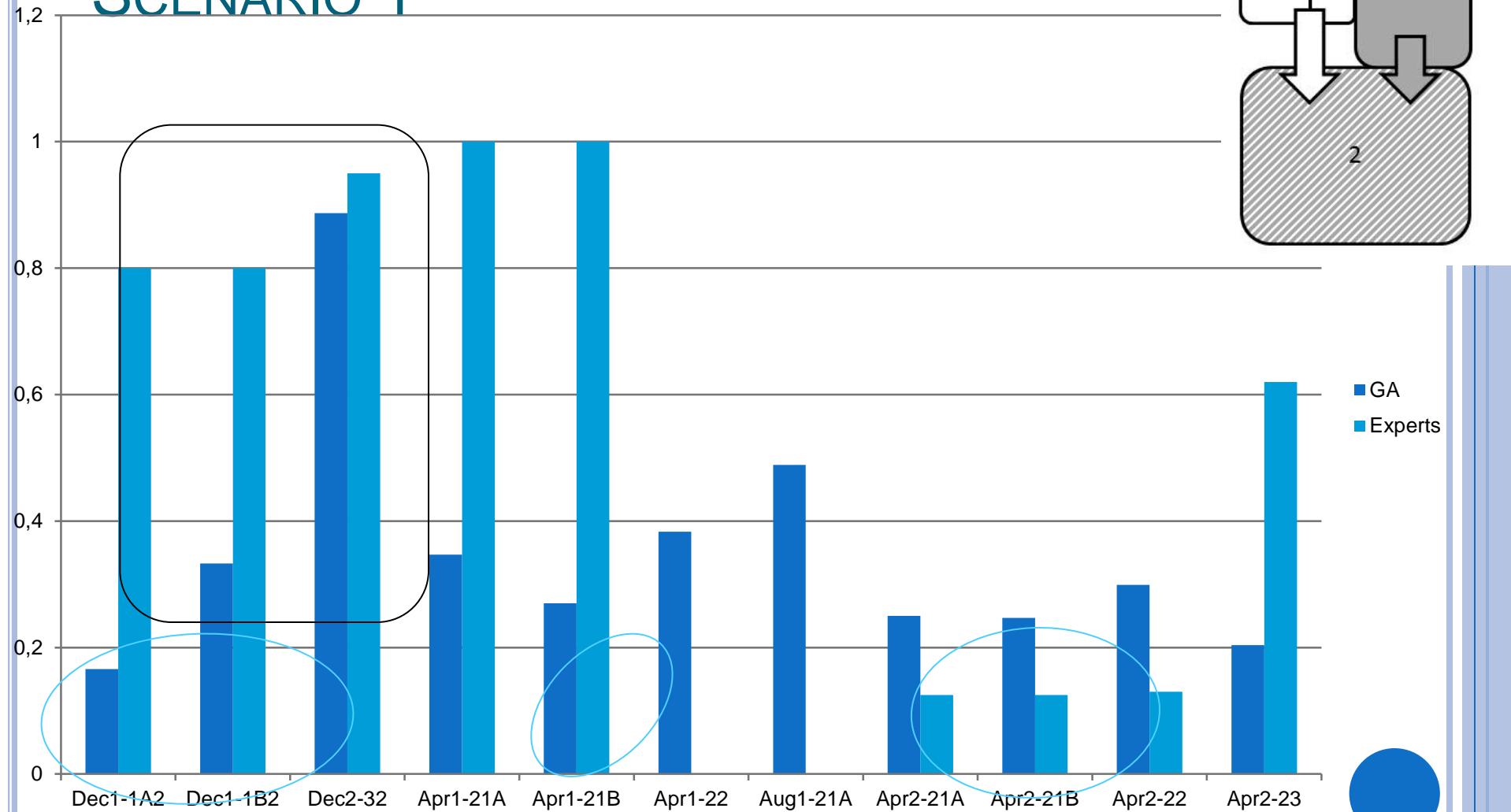


Winter



$M = 0.27$  (Fit = 29)

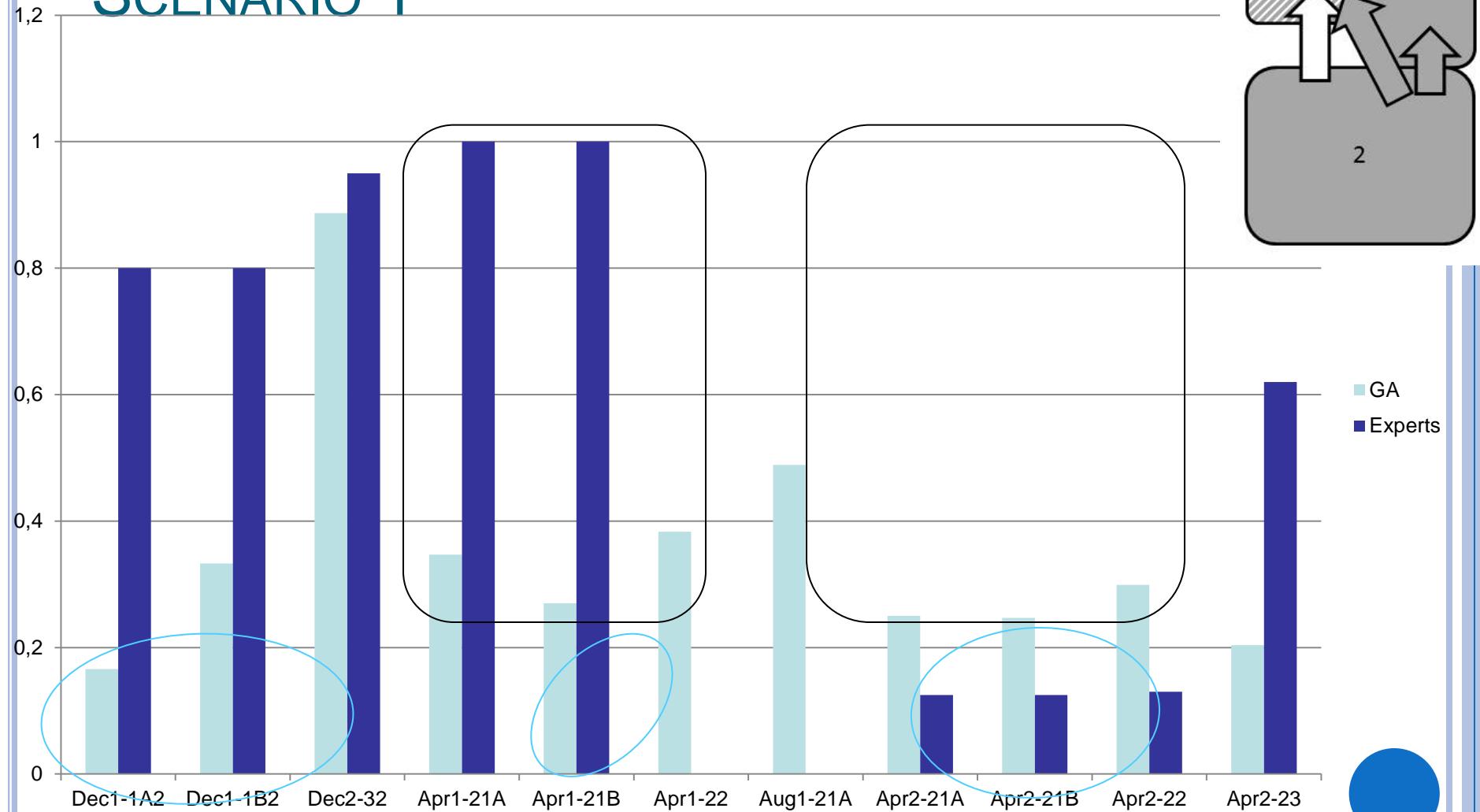
## SCÉNARIO 1



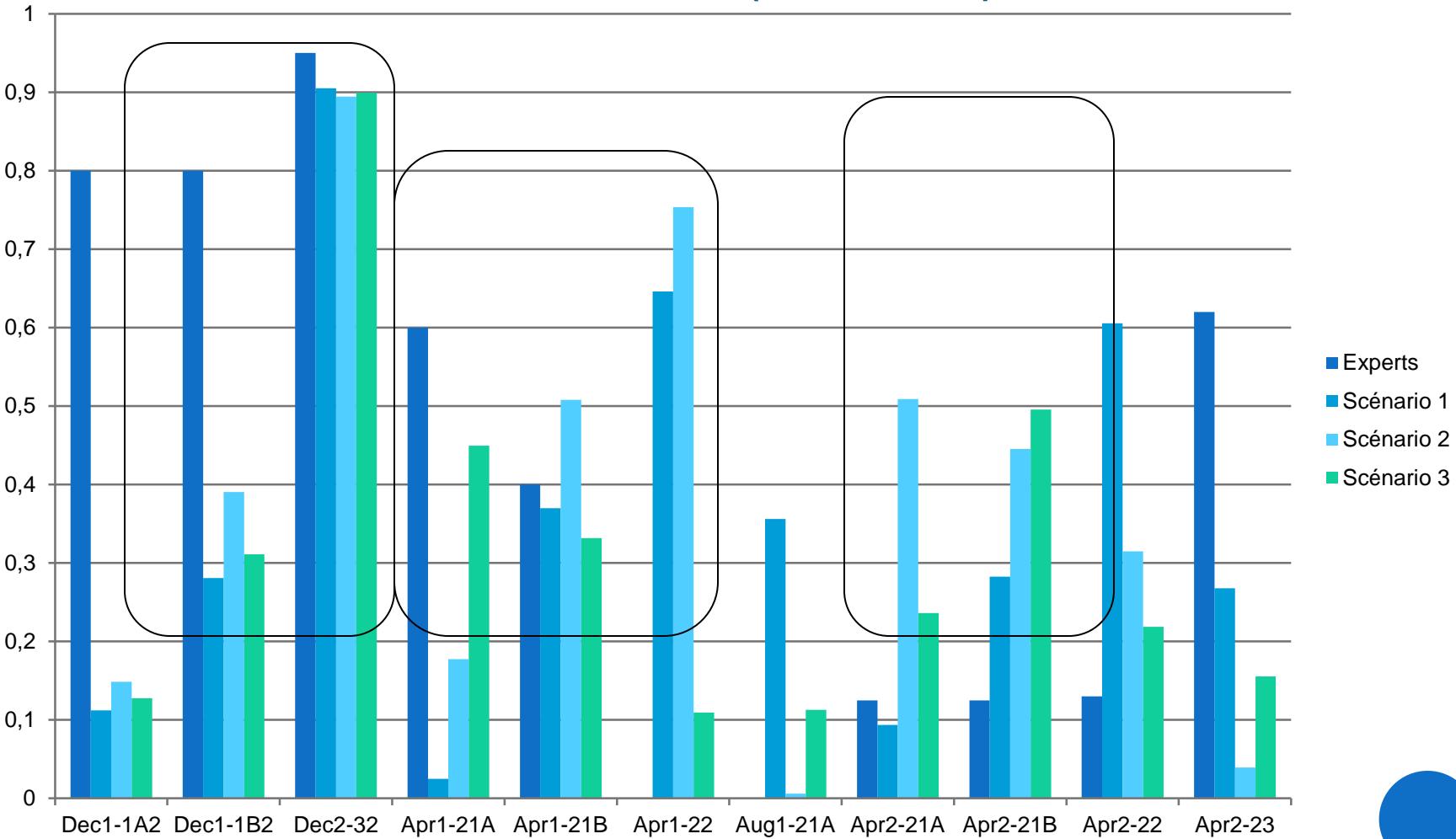
Spring-Summer

M = 0.27

## SCÉNARIO 1

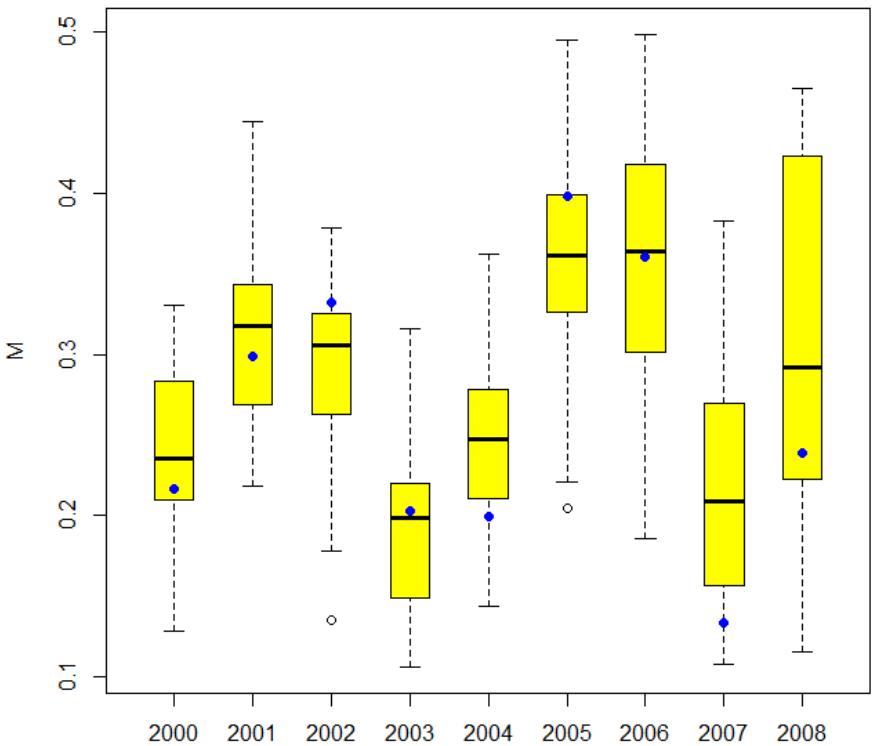


# Migration / Scenarios (Fit : 29)

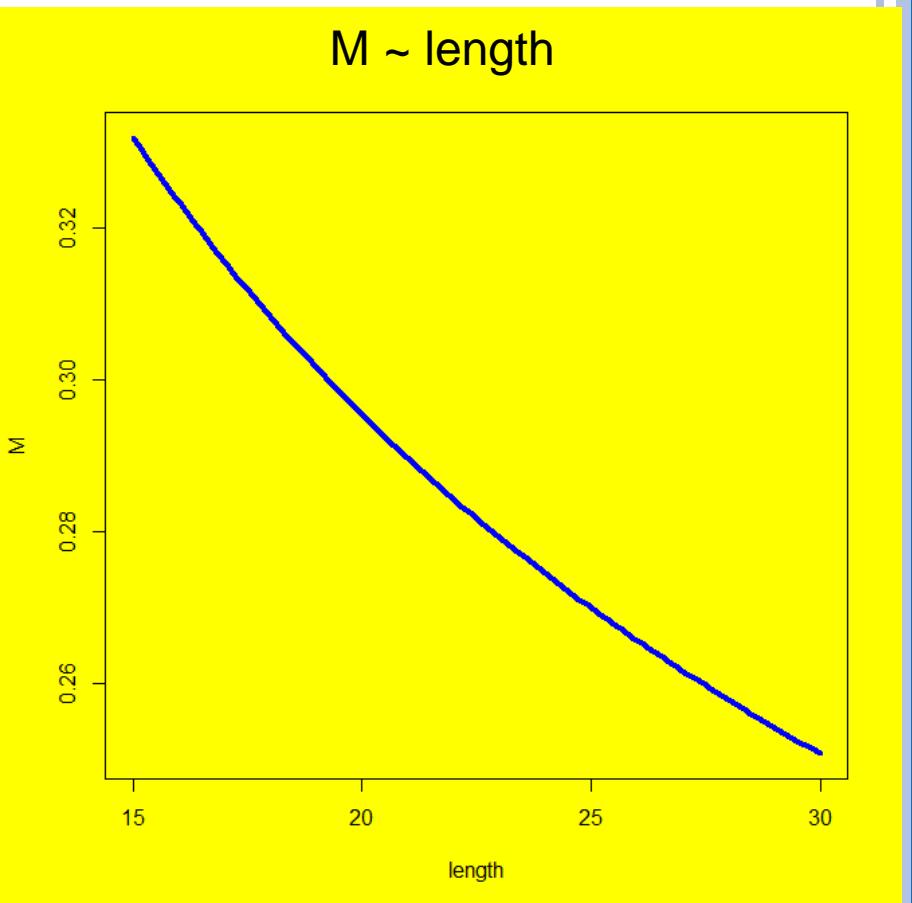


# M SCÉNARIO 2/3

$M \sim \text{years}$



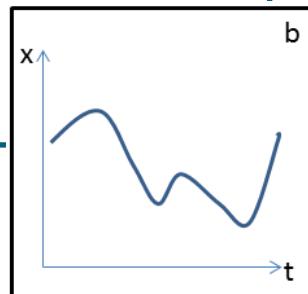
$M \sim \text{length}$



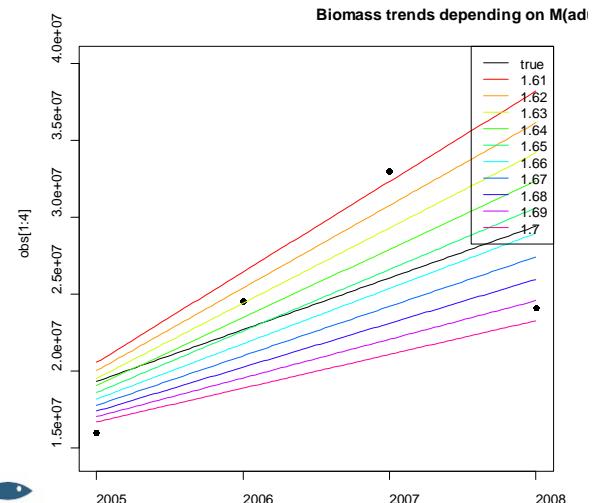
# SA-CALIBRATION-VALIDATION FOR PARAMETERIZATION

Sequential method

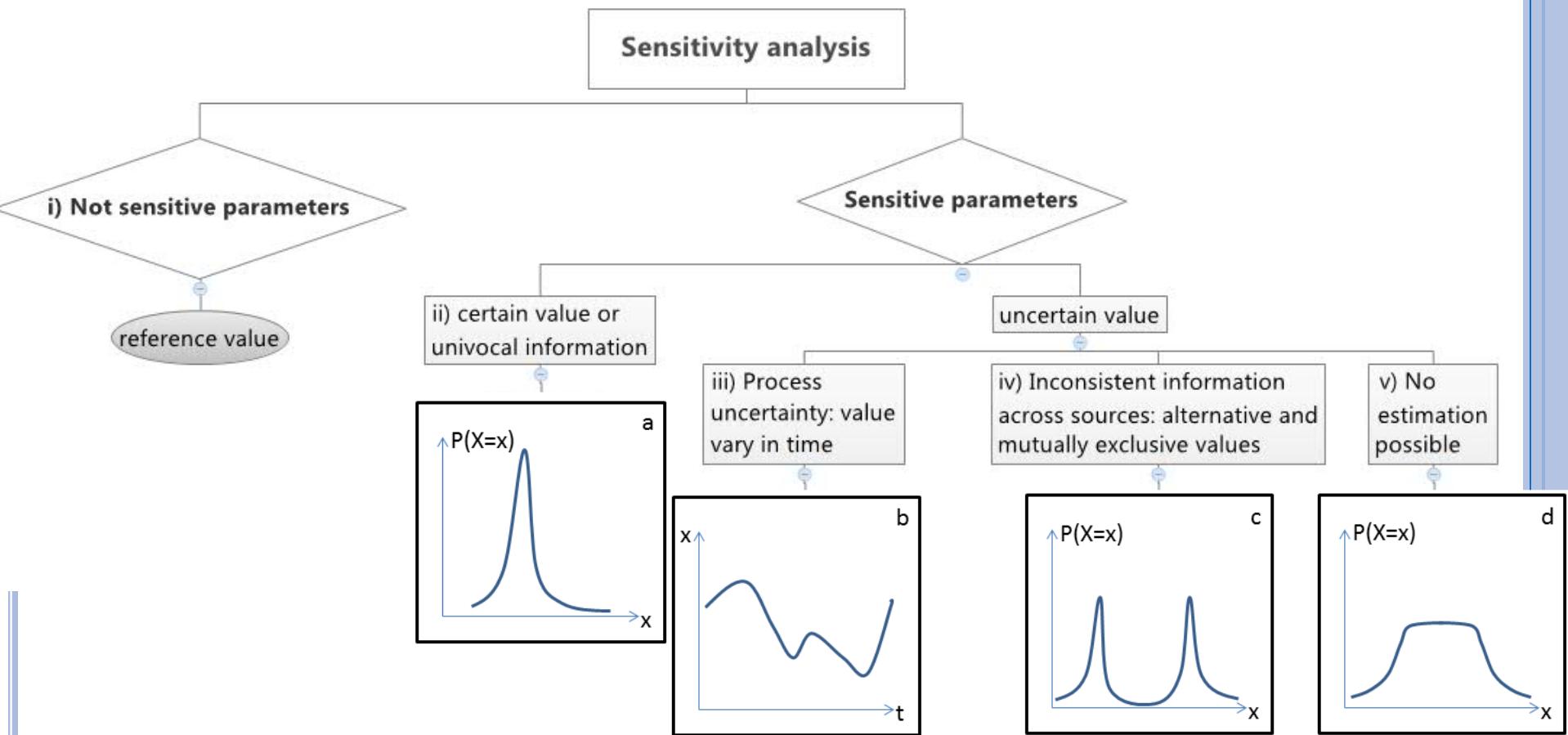
- Calibration of adult mortality ( $M$ ) on biomass trends



 ISIS-Fish  
Pêcherie pélagique



# SET PRIORITIES FOR PARAMETERIZATION



# SET PRIORITIES FOR PARAMETERIZATION

