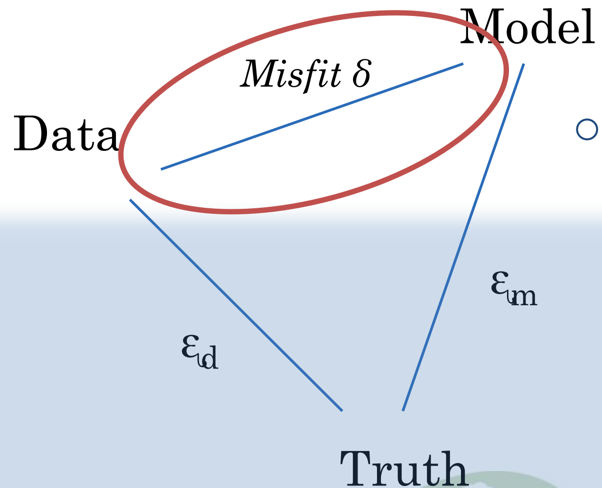
Analyse de sensibilité et optimisation pour la gestion des pêches

Sigrid Lehuta

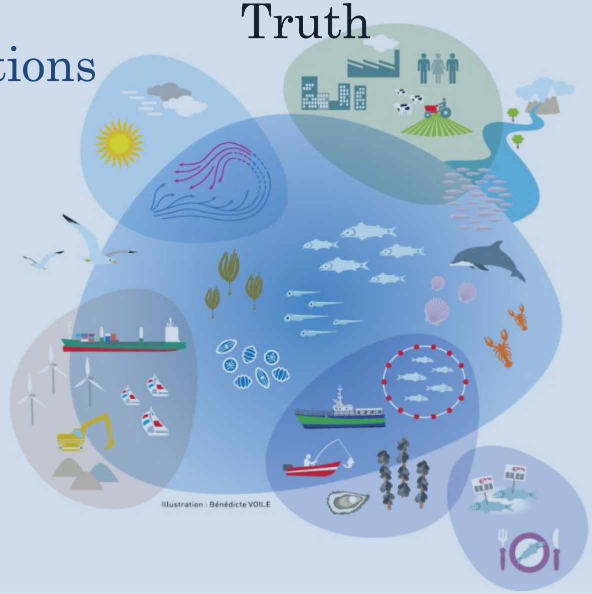
Ecole chercheur Mexico: Optimisation
La Rochelle, 26-30 Mars 2018

The uncertain context of fisheries



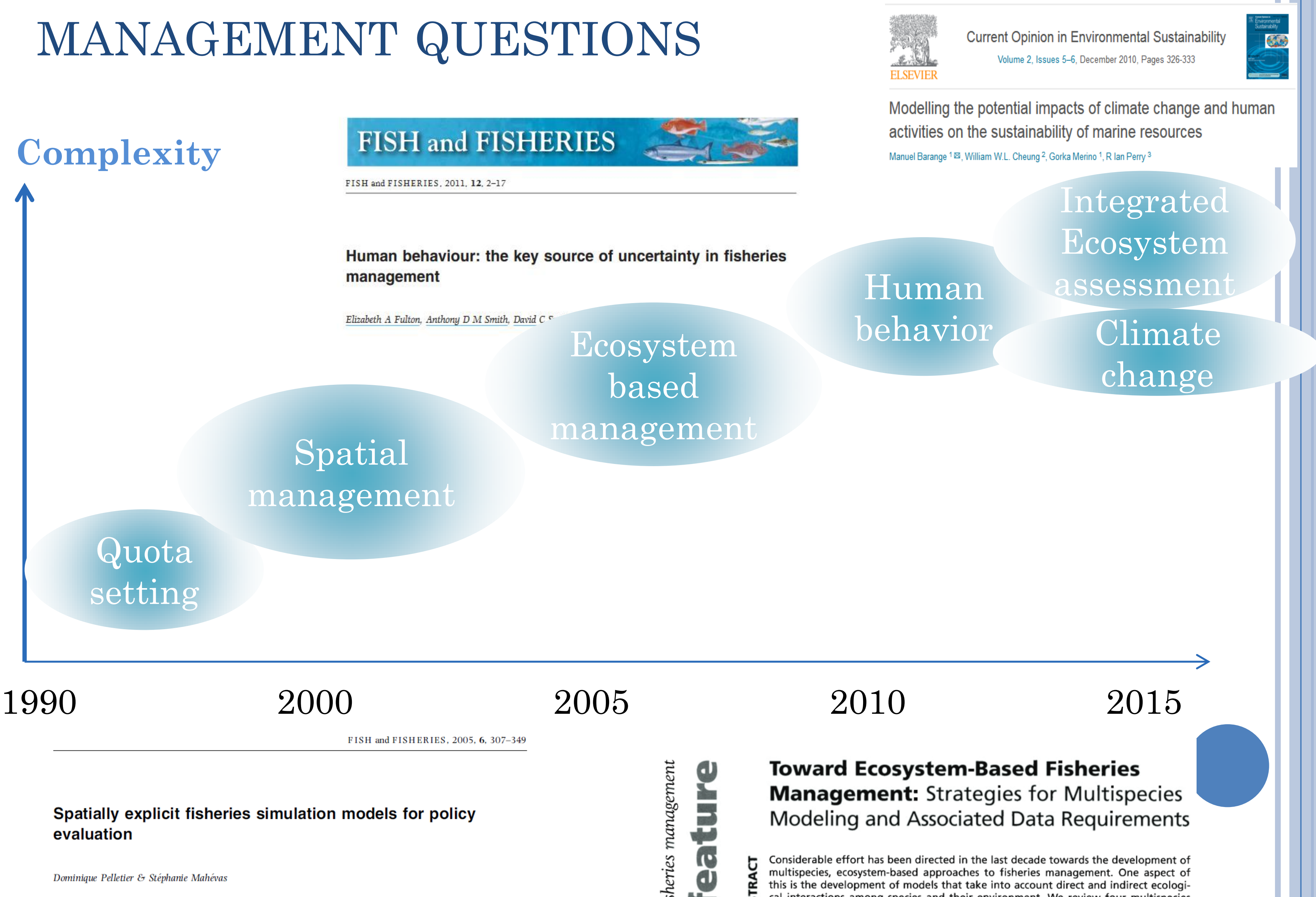
- Experimental platforms

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



Lynch, 2009

Increased complexity in fisheries management questions



Complexity and uncertainty

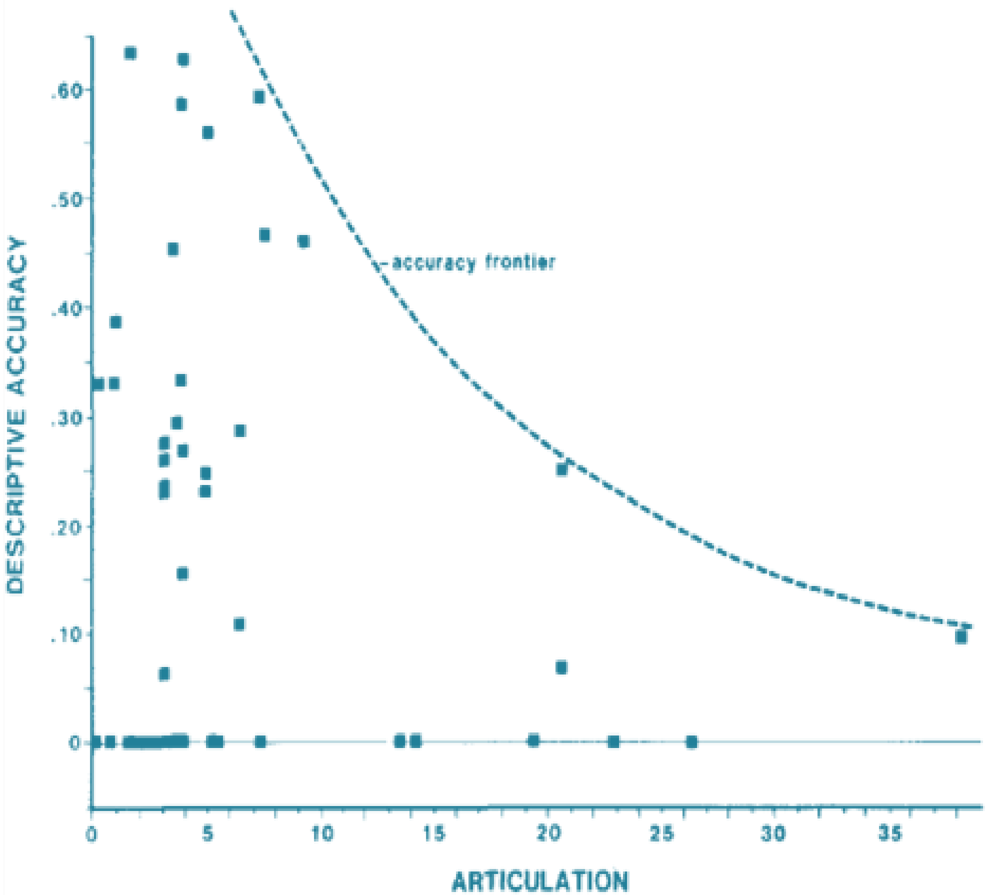


Fig. 1. Plot of articulation index vs. descriptive accuracy index for the models reviewed in this study, showing the current accuracy frontier.

Model precision evolves with complexity
(Costanza and Sklar, 1985)

Complex models as decision support tools ?

Levins 1966
Guisan and Zimmermann 2000
Sharpe 1990
From Dickey-Collas et al 2014

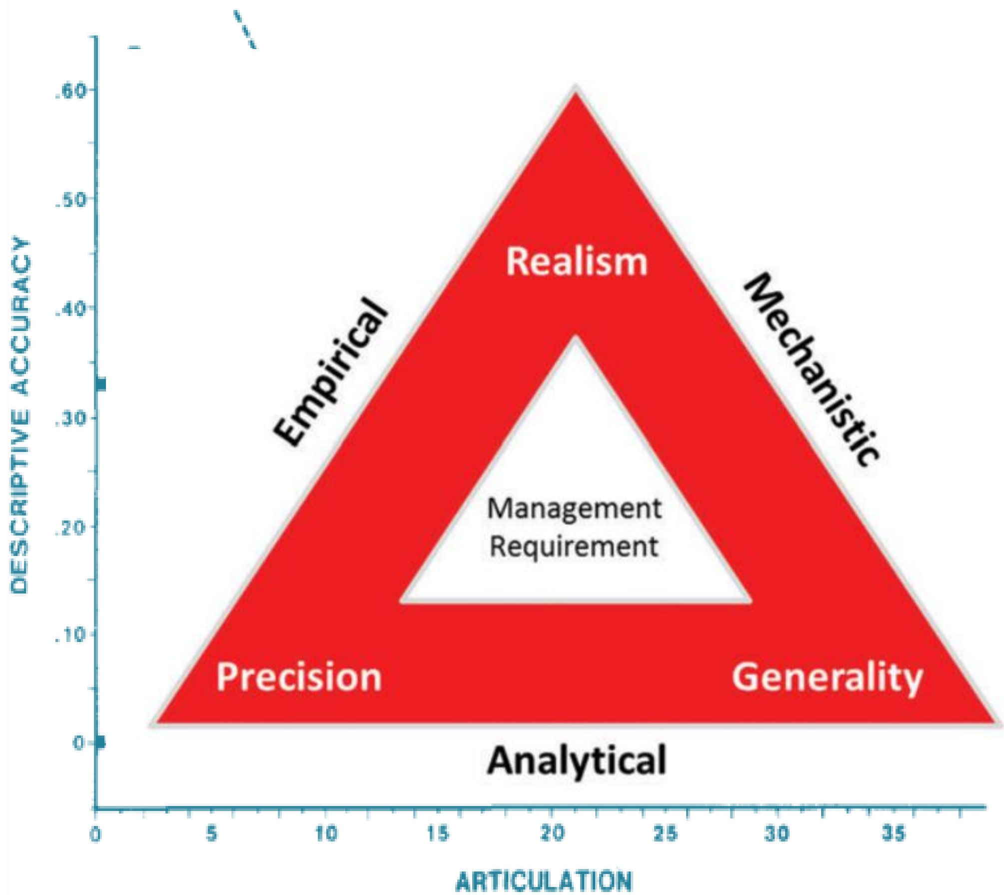


Fig. 1. Plot of articulation index vs. descriptive accuracy index for the models reviewed in this study, showing the current accuracy frontier.

Complex ecosystem models as decision support tools ?

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

Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science
Publication details, including instructions for authors and subscription information:

Contents lists available at SciVerse ScienceDirect
Progress in Oceanography
journal homepage: www.elsevier.com/locate/pocean
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Dealing with uncertainty in ecosystem models: The paradox of use for living marine resource management

J.S. Link[a,*], T.F. Ihde[b], C.J. Harvey[c], S.K. Gaichas[d], J.C. Field[e], J.K.T. Brodziak[f], H.M. Townsend[b] R.M. Peterman[g]

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

Food for Thought

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

Marie-Joëlle Rochet and Jake C. Rice

End-to-end models for marine ecosystems: ...ice of a significant advance ...g lipstick on a pig?

...NETH A. ROSE

...s in Oceanography
...: www.elsevier.com/locate/pocean

...dels of intermediate complexity

Complex dynamics may limit predicti...

Sarah M Glaser[1,2], Michael J Fogarty[3], Hui Liu[4], Irit Altman[5], Chi... Alec D MacCall[7], Andrew A Rosenberg[8], Hao Ye[9] & George Sugiha...

Food for Thought

Projecting the future state of marine ecosys... illusion"?

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

Aquatic Living Resources

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

Sigrid Lehuta[1,a], Raphaël Girardin[2], Stéphanie Mahévas[1], Morgane Travers-Trolet[2] and Youen Vermard[1]

[1] IFREMER Ecologie et modèles pour l'halieutique, Rue de l'île d'Yeu, BP 2011, 44311 Nantes Cedex 03, France
[2] IFREMER Halieutique Manche Mer du Nord, 150 Quai Gambetta, 62200 Boulogne-sur-Mer, France

FISH and FISHERIES

FISH and FISHERIES

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

Sarah B M Kraak[1,2], Ciaran J Kelly[2], Edward A Codling[3] & Emer Rogan[1]

[1]Department of Zoology, Ecology and Plant Science, University College Cork, Ireland; [2]Marine Institute, Rinville, Oranmore, Co. Galway, Ireland; [3]Departments of Mathematical Sciences and Biological Sciences, University of Essex, Wivenhoe Park, Colchester, CO4 3SQ, UK

Marine Policy 61 (2015) 291–302
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Marine Policy
journal homepage: www.elsevier.com/locate/marpol
ELSEVIER

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

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Marine and Coastal Fisheries
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Article

Recommendations on the Use of Ecosystem Modeling for Informing Ecosystem-Based Fisheries Management and Restoration Outcomes in the Gulf of Mexico

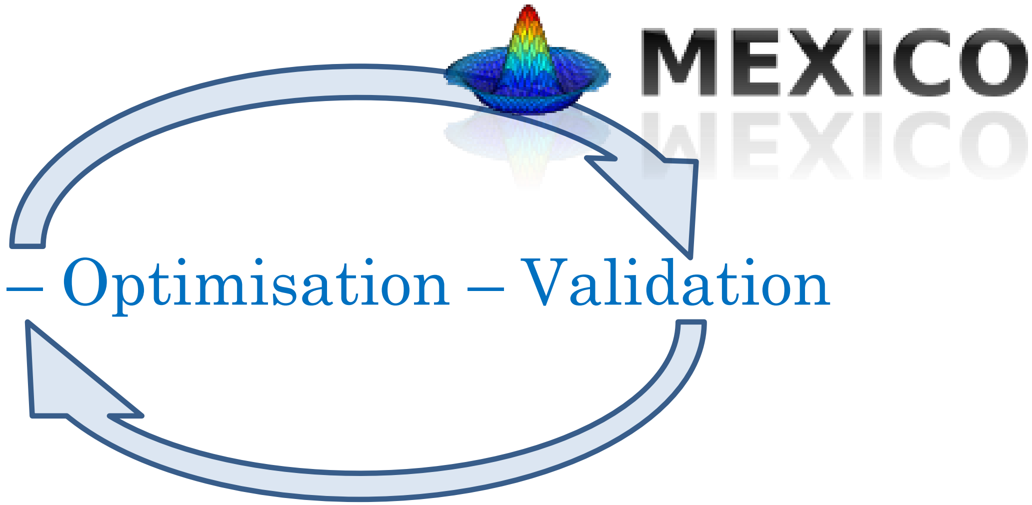
View issue TOC
Volume 9, Issue 1

Models are not perfect but they are needed

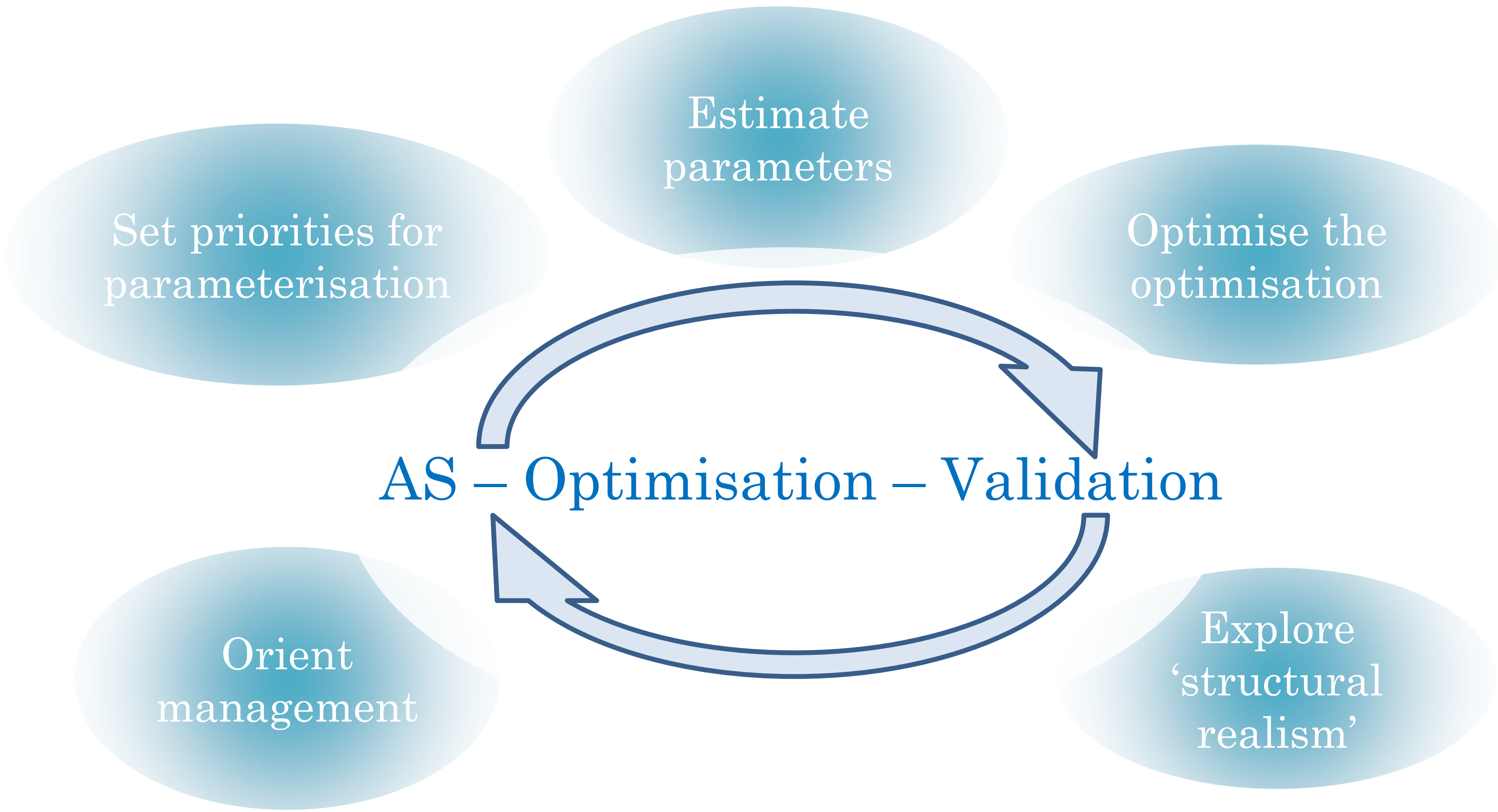
BUILD CONFIDENCE

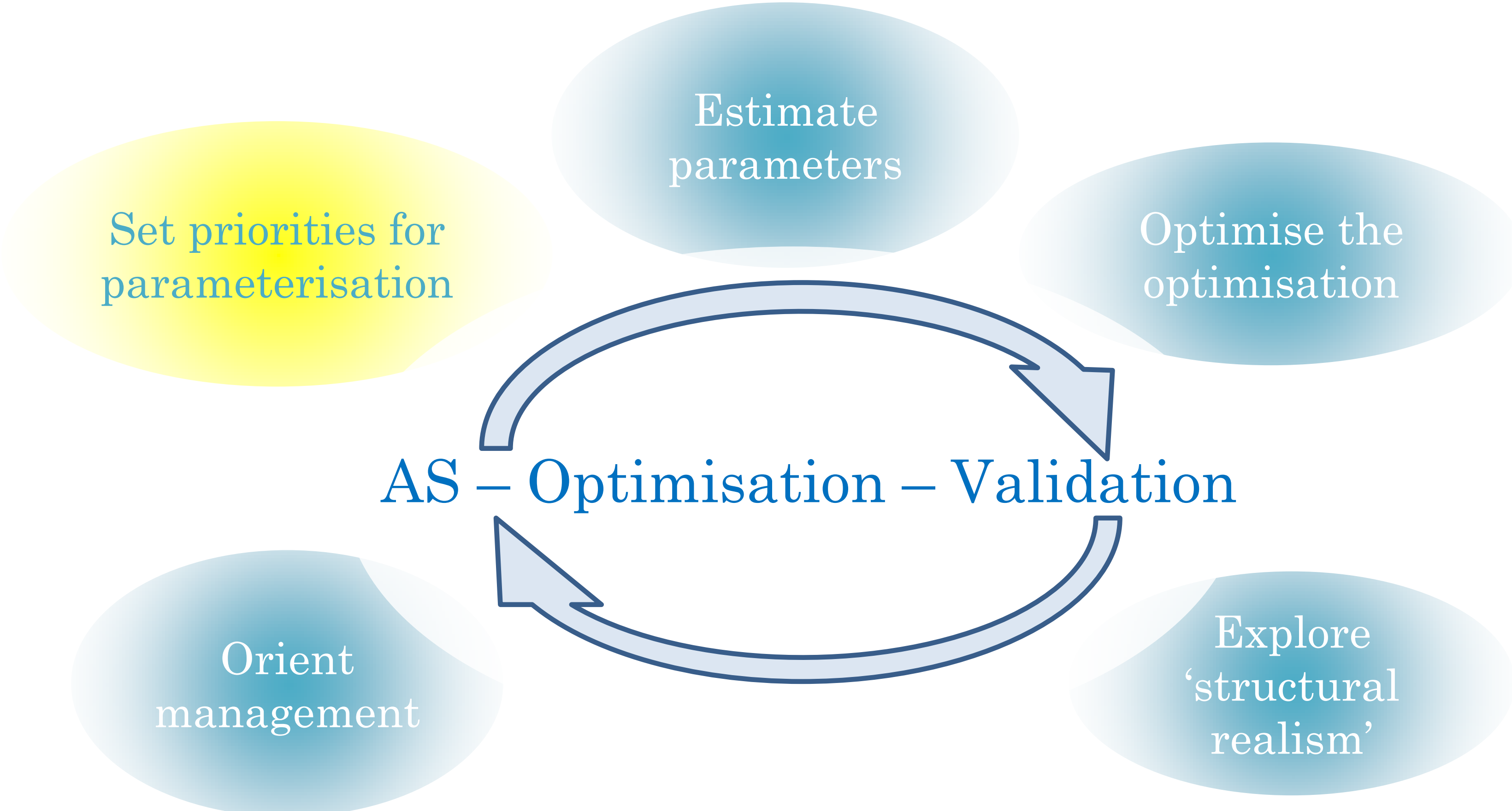
Through generic, rigorous, transparent development frameworks

BUILD CONFIDENCE



Through generic, rigorous, transparent development frameworks


Estimate parameters
Set priorities for parameterisation
Optimise the optimisation
AS – Optimisation – Validation
Orient management
Explore 'structural realism'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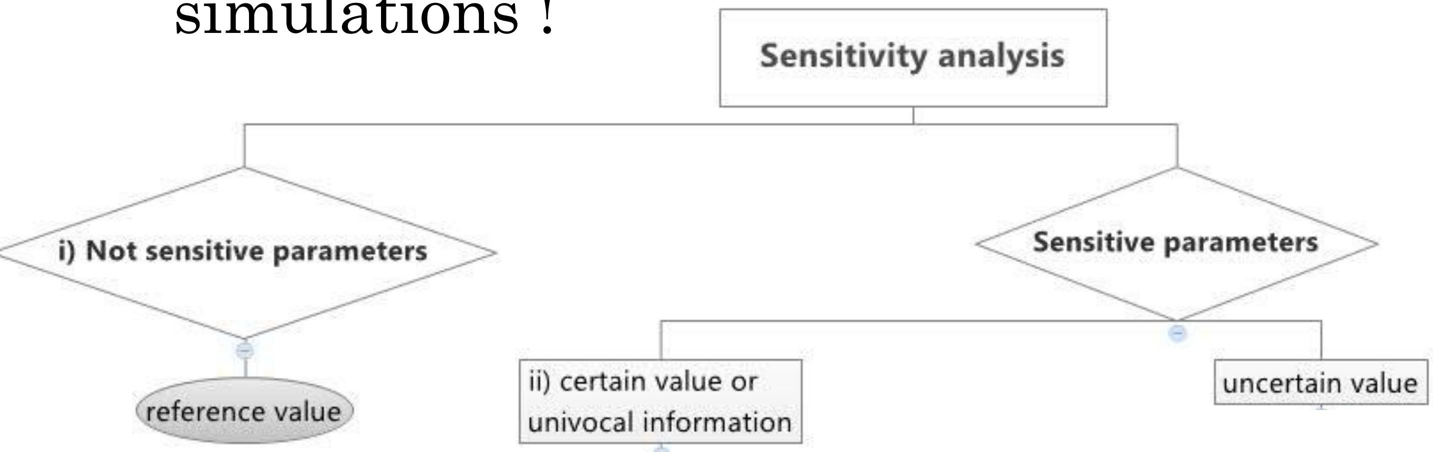
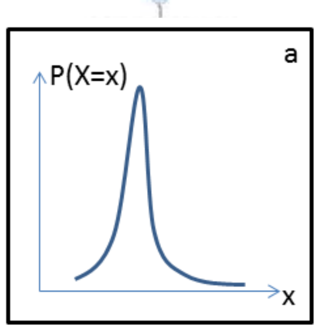
Set priorities for parameterization

- Too many parameters, too few data and/or simulations !

Set priorities for parameterization

- Too many parameters, too few data and/or simulations !

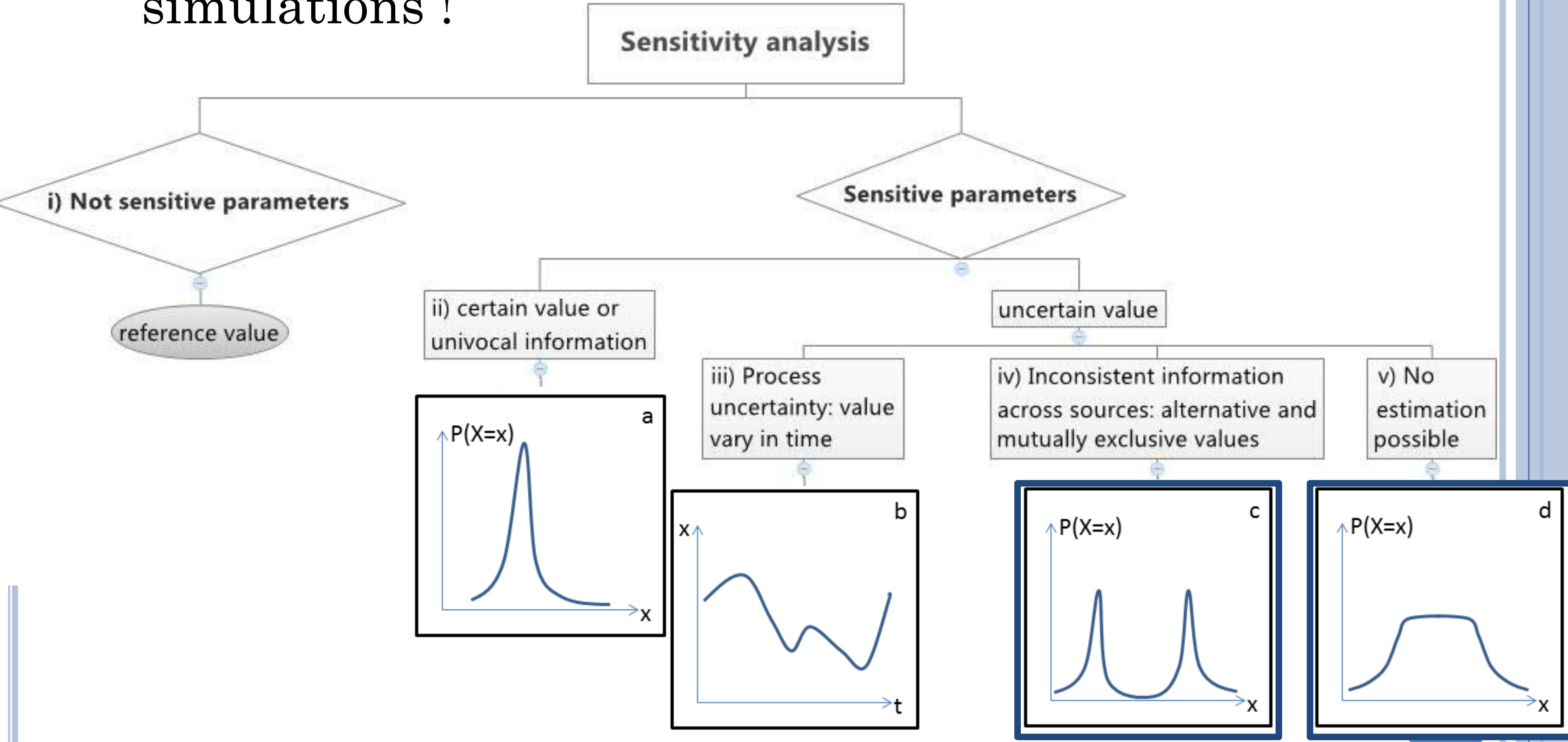




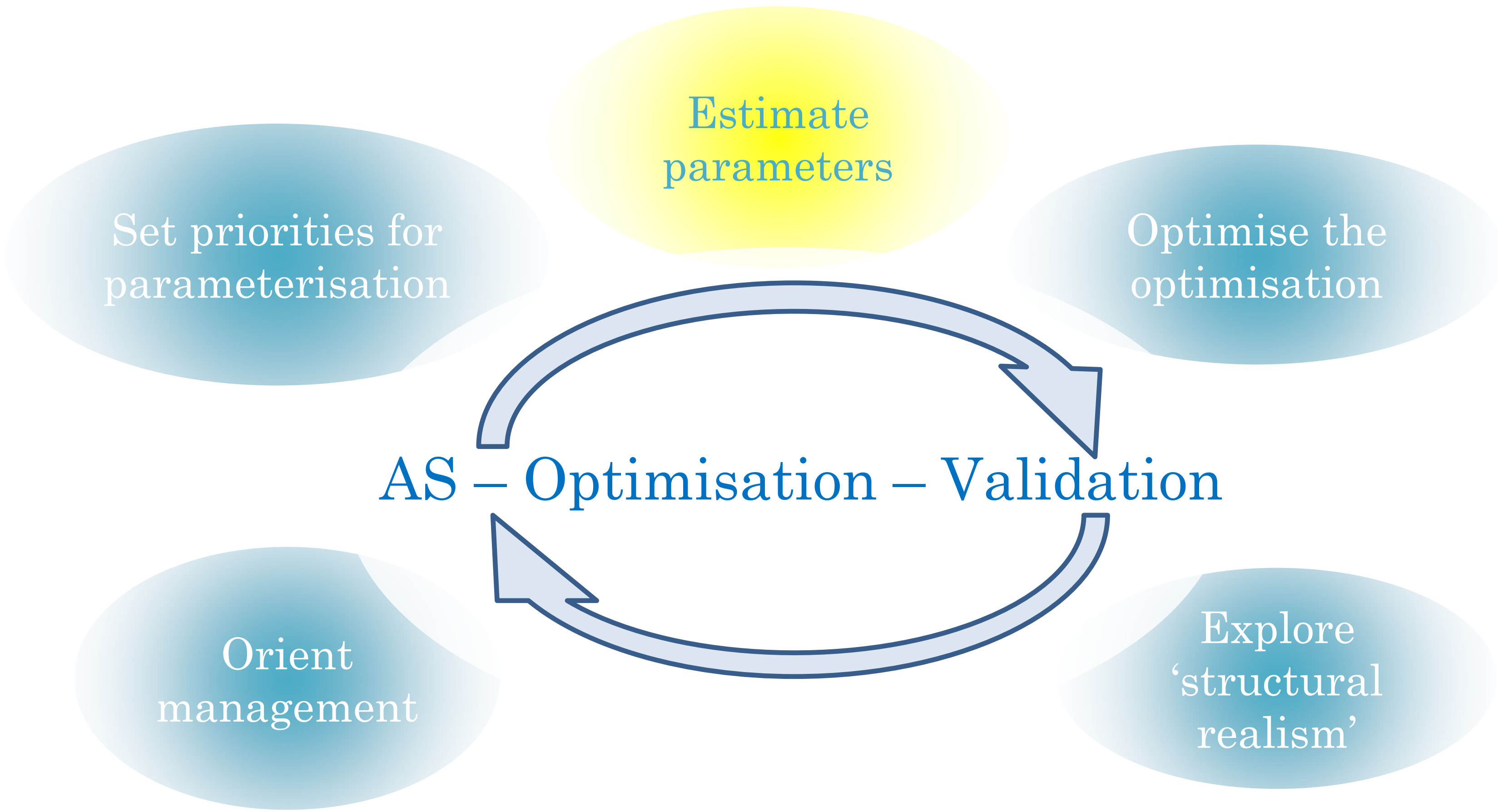
Still a lot of parameters !
Often correlated…

Set priorities for parameterization

- Too many parameters, too few data and/or simulations !



Lehuta et al. 2013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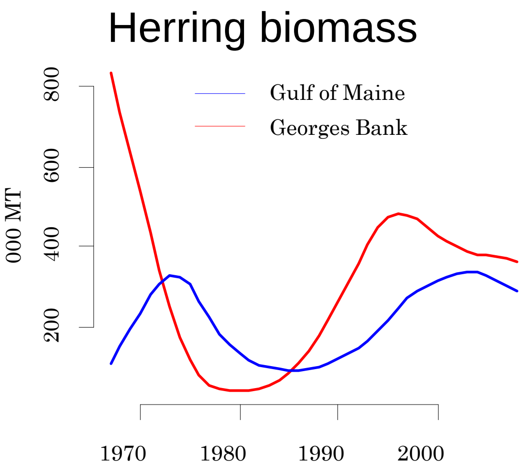
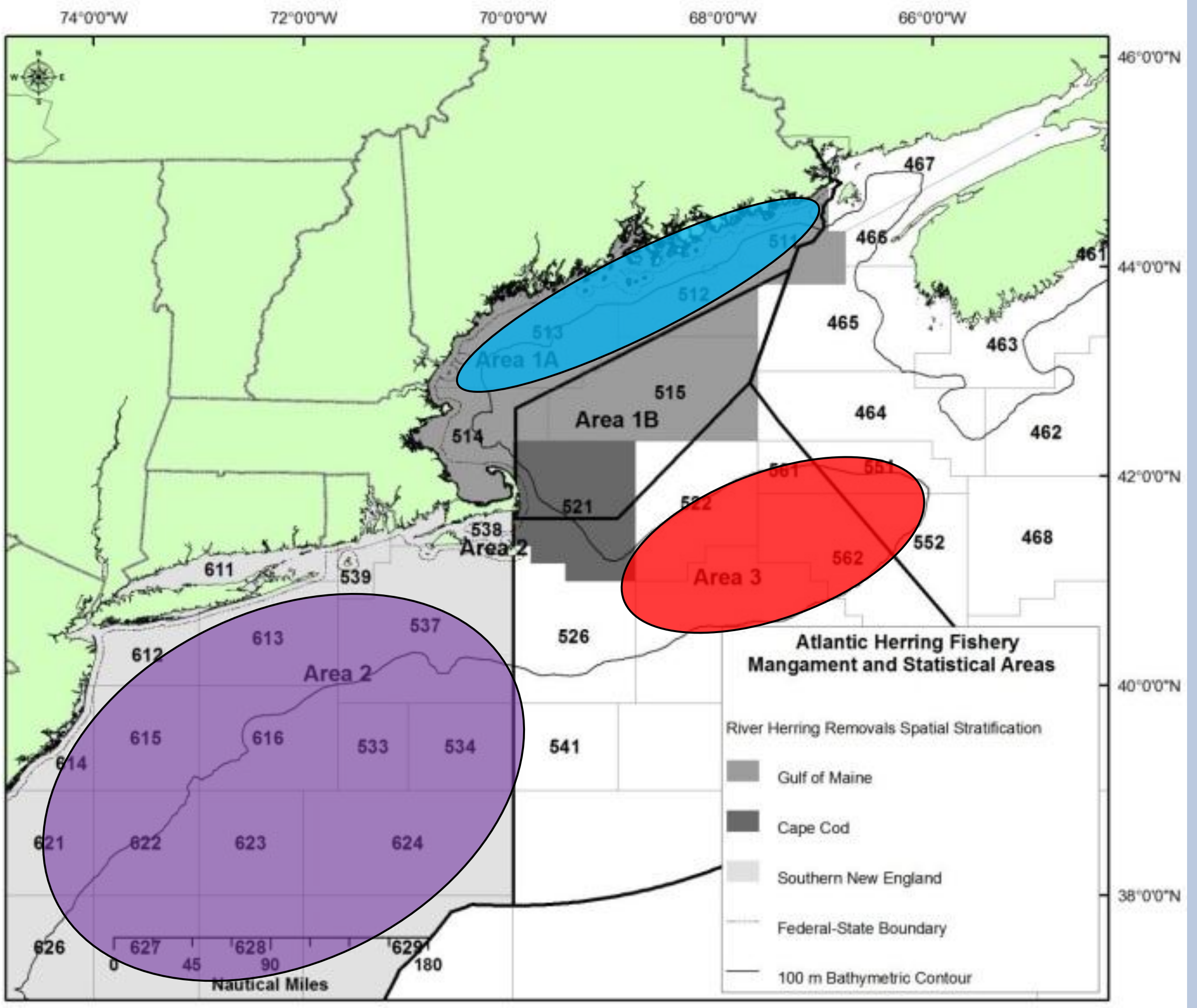
Estimate Parameters: Herring meta-population Gulf of Maine

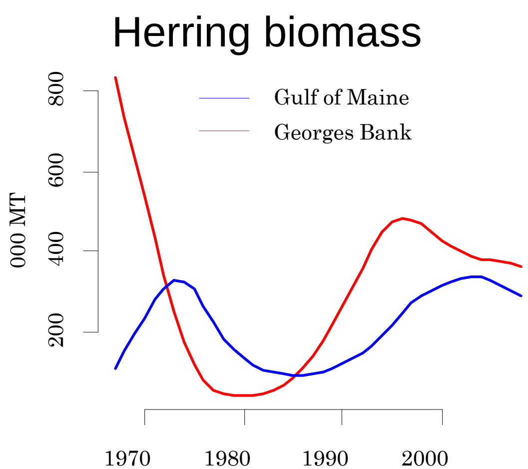
1 unique quota

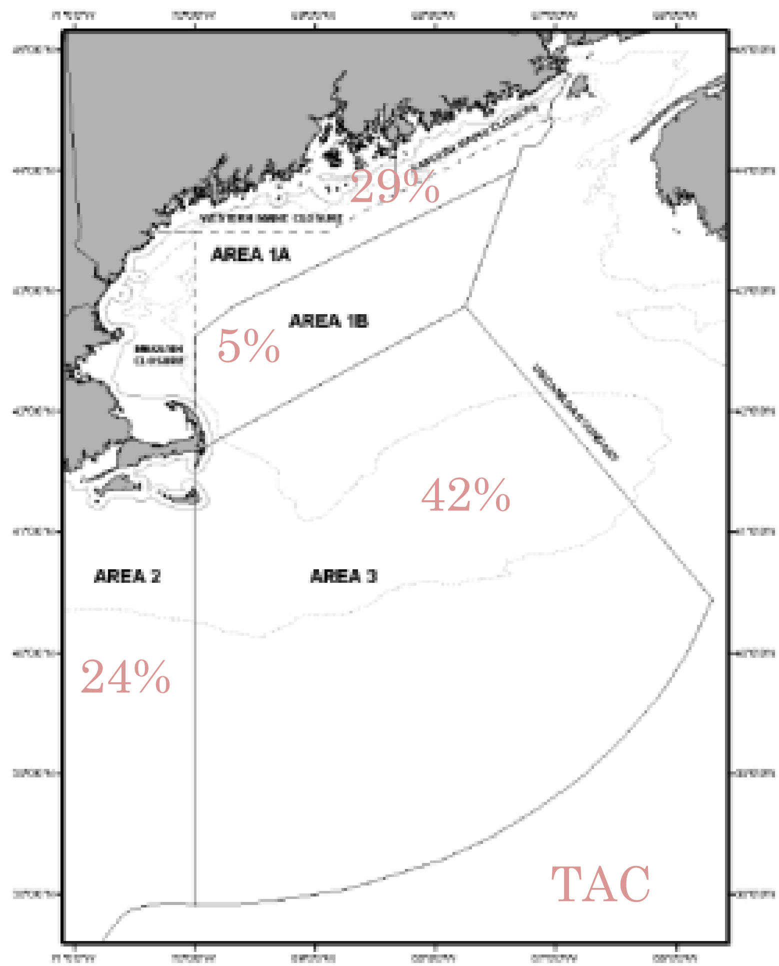




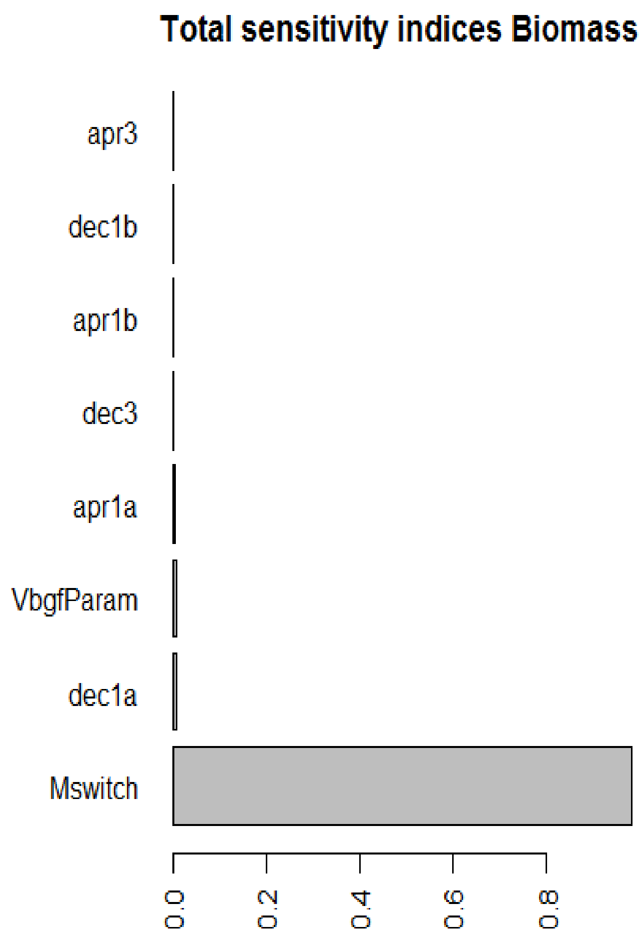
Estimate Parameters:
Herring meta-population Gulf of Maine

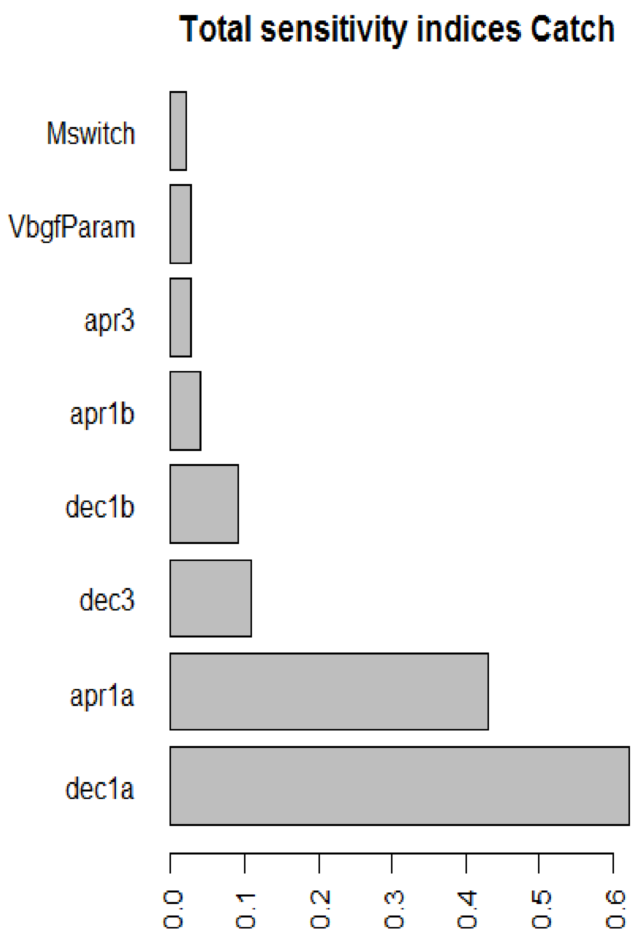
1 unique quota





Estimate Parameters : Sensitivity analysis Herring meta-population Gulf of Maine





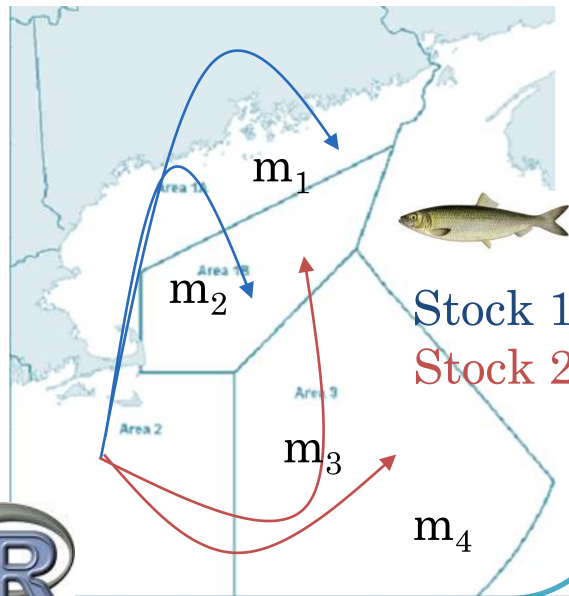
Estimate Parameters: Calibration Herring meta-population Gulf of Maine

Données campagnes scientifiques

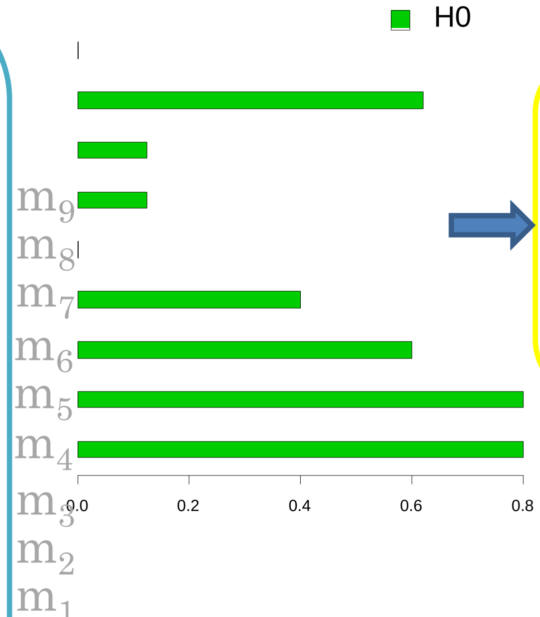
Logbook

+

Modèle de dynamique de pêcherie spatialisé



Coefficients de la matrice de migration



Distribution du TAC par zone et saison

Estimation de M ?

Algorithme génétique

Ensemble run (20)
20 output variables

$$FO = \sum_{obs\ variables}^{20} (obs - sim)^2$$

Record, N. et al. 2010.

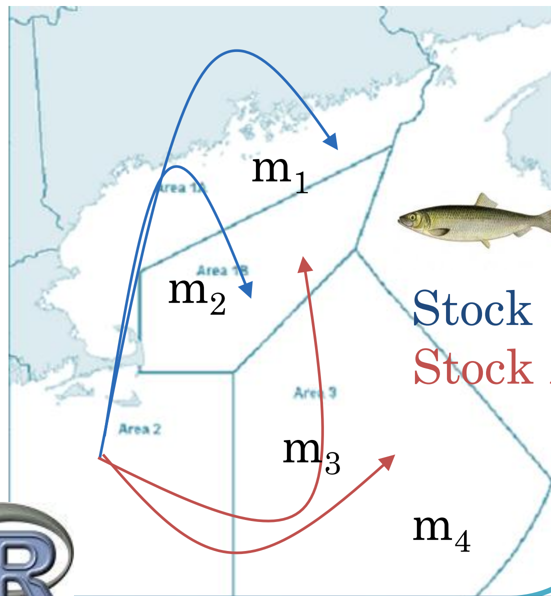
Estimate Parameters: Calibration Herring meta-population Gulf of Maine

Données campagnes scientifiques

Logbook

+

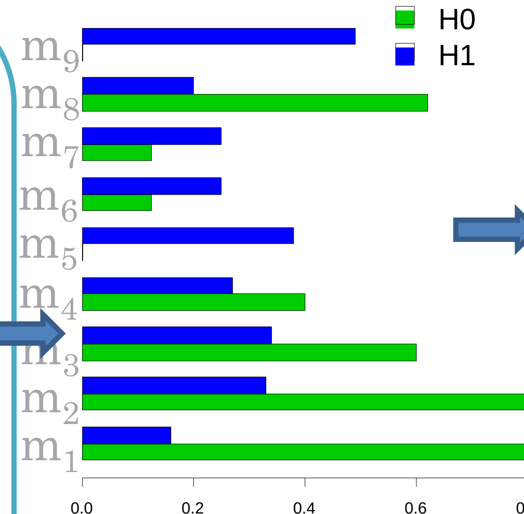
Modèle de dynamique de pêcherie spatialisé



Algorithme génétique

Record, N. et al. 2010.

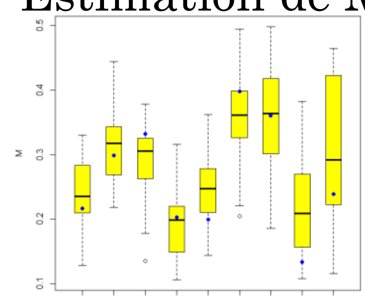
Coefficients de la matrice de migration



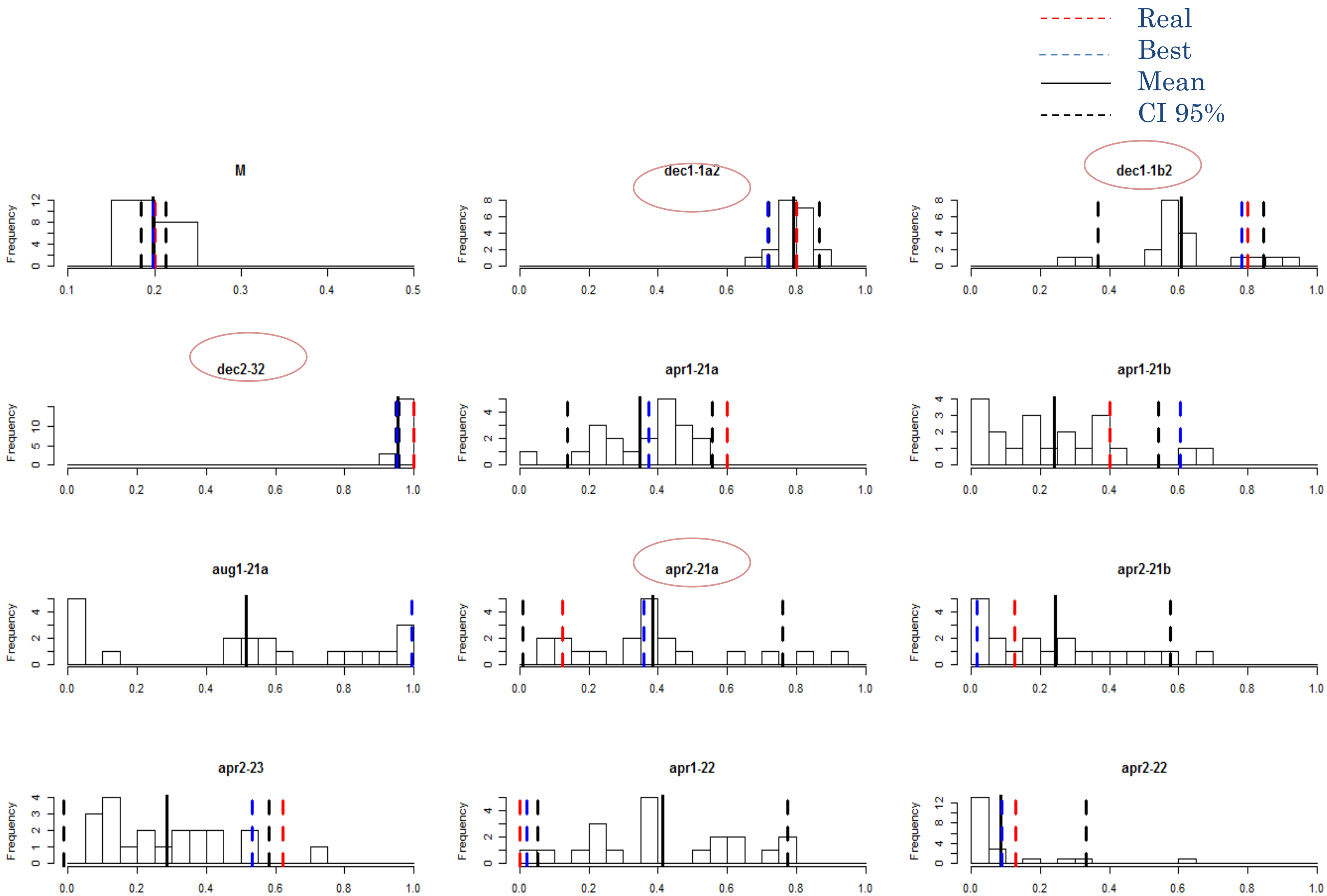
Distribution du TAC par zone et saison

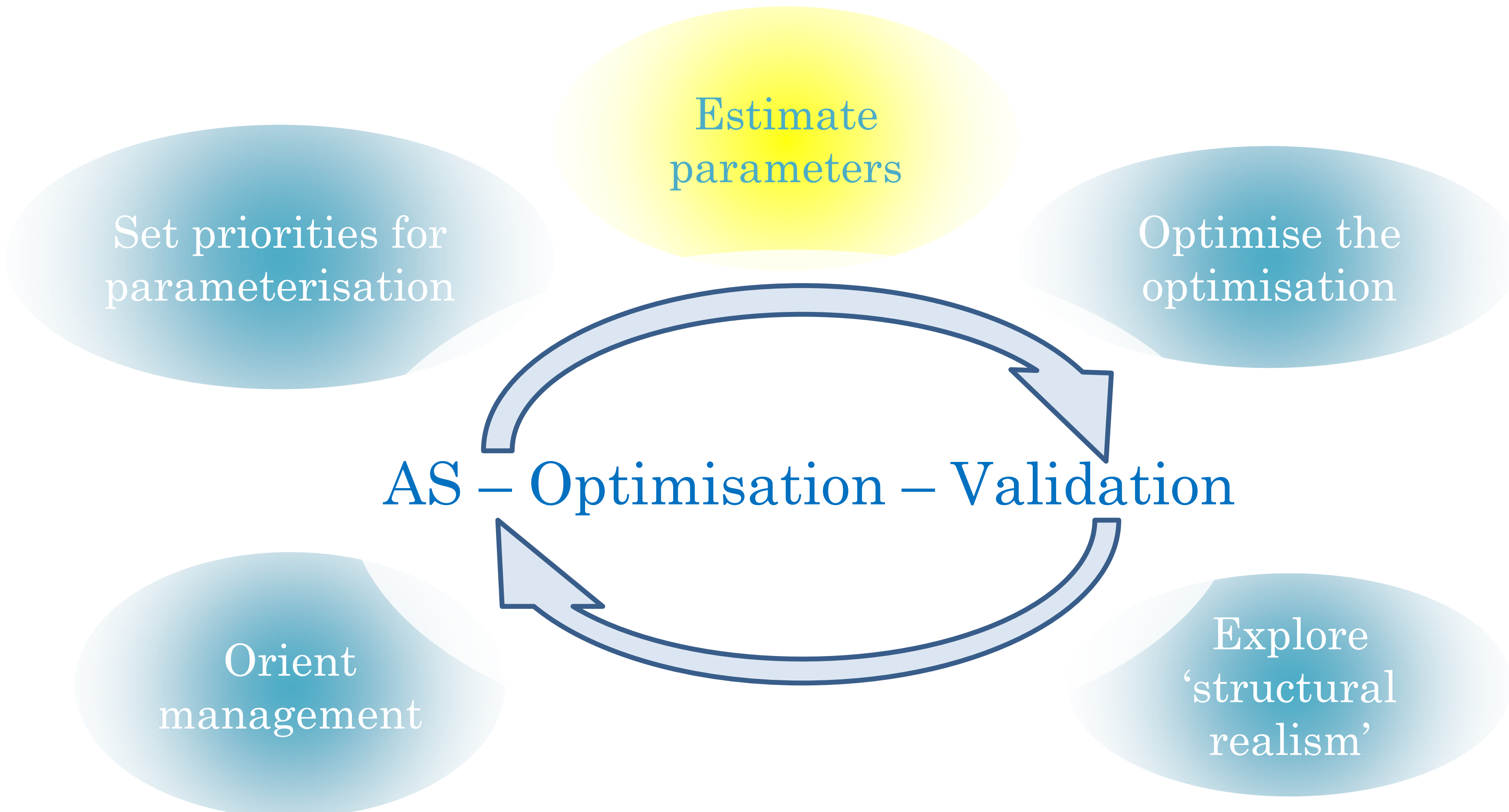
Vision très différente des migrations

Estimation de M

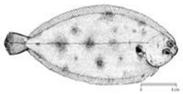


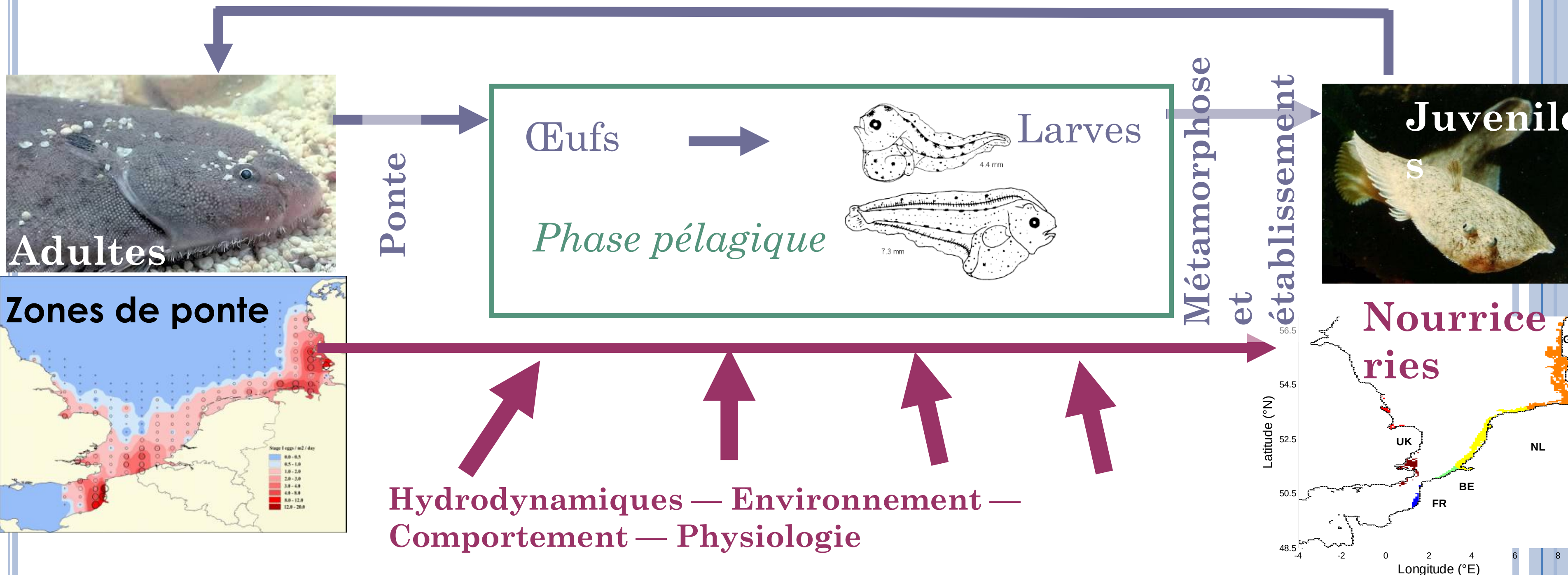
Estimate Parameters:
Twin experiment & ensemble run (20)
Herring meta-population Gulf of Maine




Estimate parameters
Set priorities for parameterisation
Optimise the optimisation
AS – Optimisation – Validation
Orient management
Explore ‘structural realism’

ESTIMATE PARAMETERS: DERIVE LARVAIRE DE LA SOLE DE MER DU NORD (BARBUT ET AL., IN PREP.)

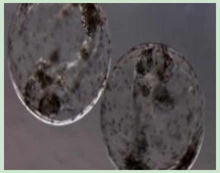




❖ **Choisir les paramètres permettant de reproduire le recrutement dans les nourriceries de manière la plus réaliste**

❖ **Comprendre les processus biologiques et environnementaux qui influent sur le recrutement de la sole**

ESTIMATE PARAMETERS: 11 PARAMETRES INCONNUS



Eggs

Yolk-sac larvae

First-feeding larvae

Metamorphosing larvae

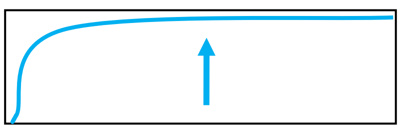
Durée du Stade

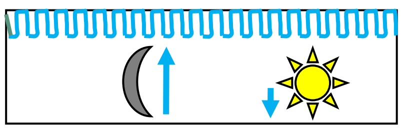
Mortalité

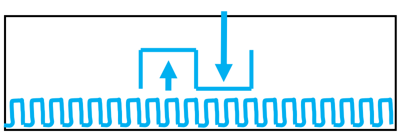
Cst

Cst

Migration

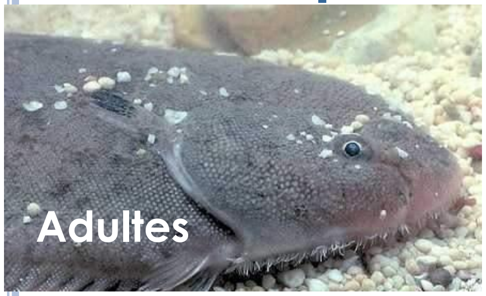






Période de ponte

établissement

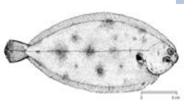


10 Continu

1 Discret (8)

1 an de simulation = 12h

ESTIMATE PARAMETERS: MULTIPLES OBJECTIFS



Estimation du recrutement (âge 1) pour l'ensemble du système entre 1995-2006 (Stock assessment in IV Area ICES)

- ***Global***, représente la taux d'écart entre recrutement prédit et simulé

$g_y = \frac{Ny - \widehat{N}y}{Ny}$ Ny & $\widehat{Ny}$: recrutement standardisé total observé et prédit par le modèle pour l'année y

Variations de g(y | Θ)

Indicateur d'abondance locale (âge 0) entre 1995-2006 (Demersal Young Fish Survey, ICES)

- ***Local*** montre la différence en terme d'anomalie de recrutement dans chacune des nourriceries (NL, UK, GE, BE).

Données et résultats sont standardisés ($N_i|\theta$), et on calcule un taux d'écart pour chacune des nourriceries:

$l_{iy} = \frac{Ind\ iy - \widehat{Ind}\ iy}{Ind\ iy}$ $Ind\ iy$ & $\widehat{Ind}\ iy$: recrutement standardisé observé et simulé dans la nourricerie i, l'année y

$variations\ de\ l_i|\theta$

Calibration

Estimate Parameters: In summary

- Discrete and continuous parameters
- Multiple objectives
- Long simulation runs

=> Difficult optimisation problem

Estimate Parameters: Strategy

Etapes	Questions	méthodes
Etape 1: Analyse de sensibilité	• Quels paramètres ont une forte influence sur les prédictions du modèle?	Plan factoriel optimisé sur une année moyenne
Etape 2: Calibration	• Quel est le meilleur modèle?	Plan complet sur les paramètres identifiés comme très influents sur toutes les années

Plan complet : 472392 simulations * 12h = 647 ans

Estimate Parameters: Strategy

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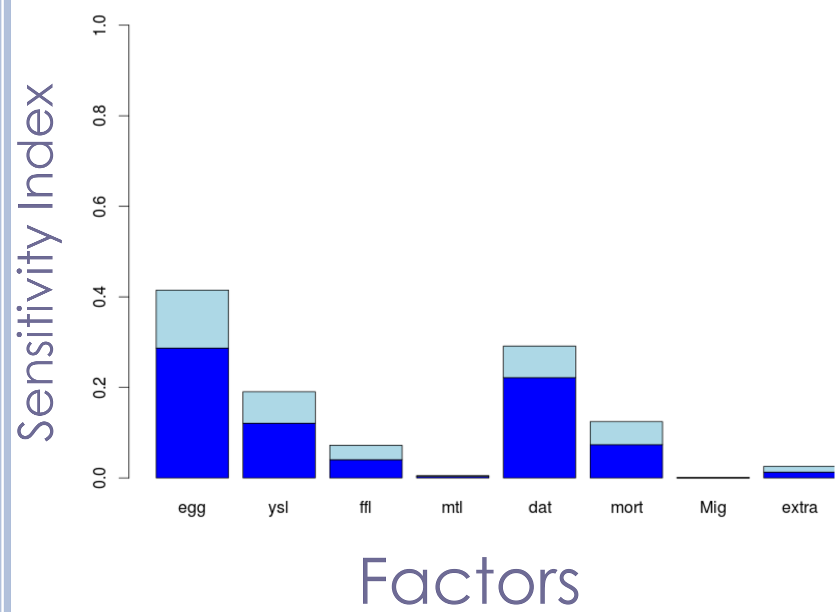
Etape 2: Calibration	• Quel est le meilleur modèle?	Plan complet sur les paramètres identifiés comme très influents sur toutes les années

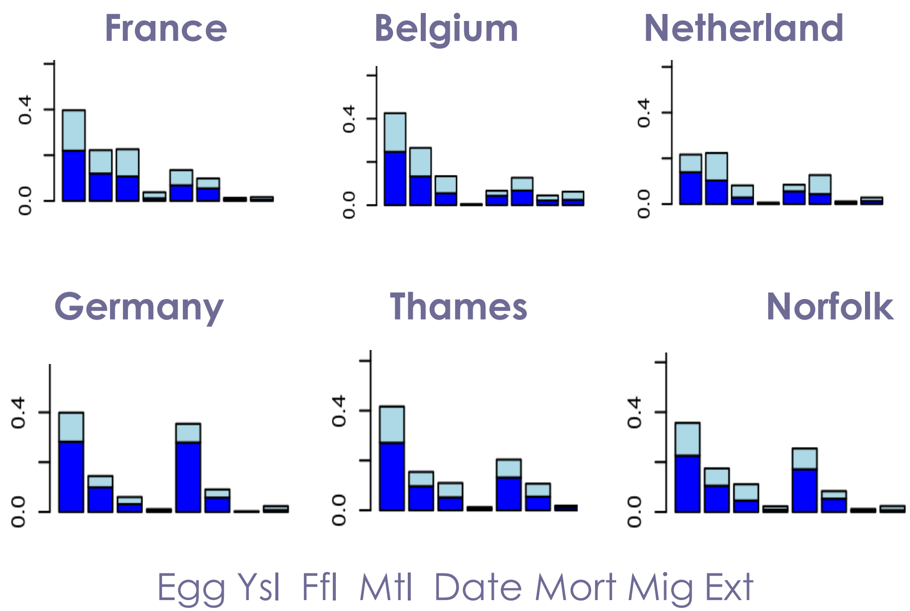
~~Plan complet : 472392 simulations * 12h = 647 ans~~

Plan optimisé : 353 simulations * 12h = 176 jours

Estimate Parameters: Sensitivity analysis

Principal effect
Interaction effect





Results / global

Résultats / nourricerie

Estimate Parameters: Strategy

Etapes	Questions	méthodes
Etape 1: Analyse de sensibilité	• Quels paramètres ont une forte influence sur les prédictions du modèle?	Plan factoriel optimisé sur une année moyenne **Durée larvaire** **Période de ponte** **Mortalité**
Etape 2: Calibration	• Quel est le meilleur modèle?	Plan complet sur les paramètres identifiés comme très influents sur toutes les années

Plan complet sur la période 1995-2006 pour les paramètres:

- Durée larvaire (continue avec 3 modalités)
- Migration verticale (discret 3 modalités)
- Période de ponte (continue avec 3 modalités)
- Mortalité (continue avec 3 modalités)

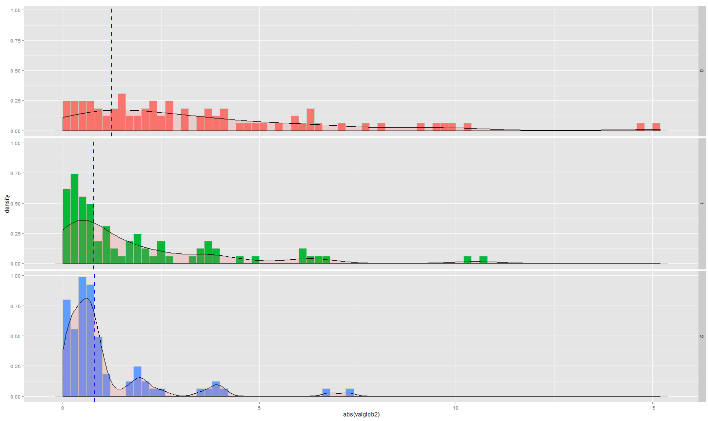
Estimate Parameters: Résultats

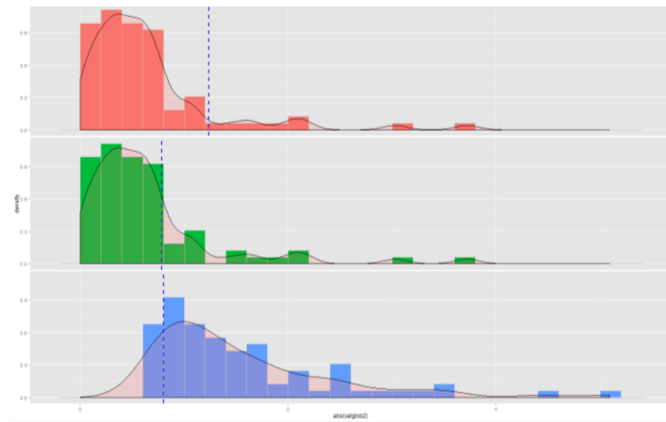
- **Période de ponte: distribution de la valeur absolu du taux d'erreur entre observé et simulé**

1995

2001

Globa



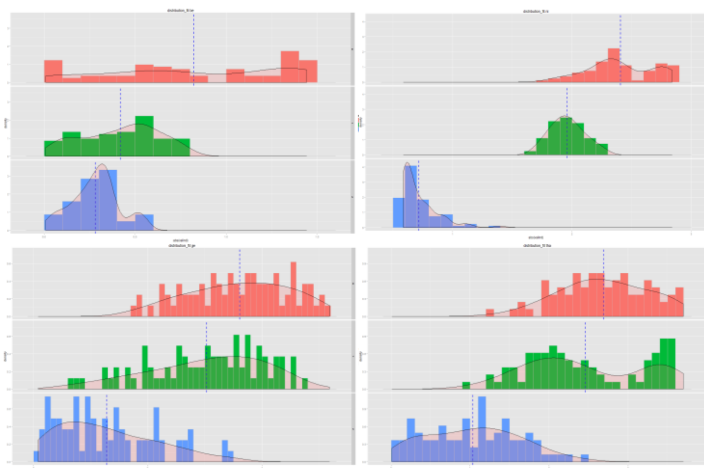


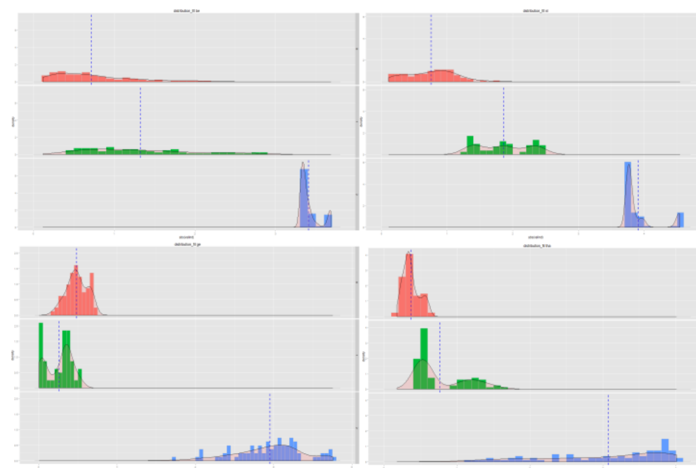
Période de ponte
- Précoce
- Moyenne
- Tardive

Belgium Netherland

Belgium Netherland

Local



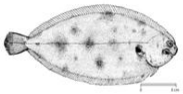


Germany Thames

Germany Thames

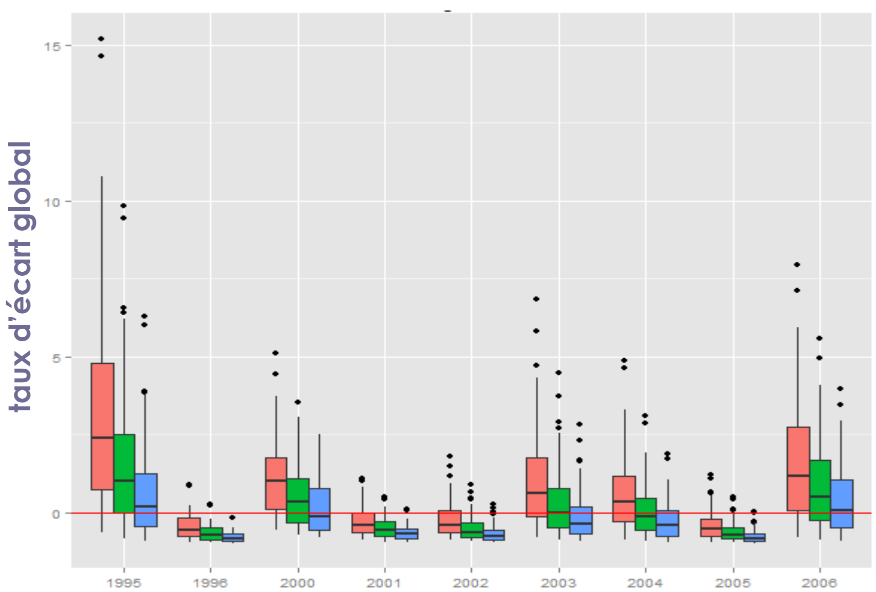
Calibration

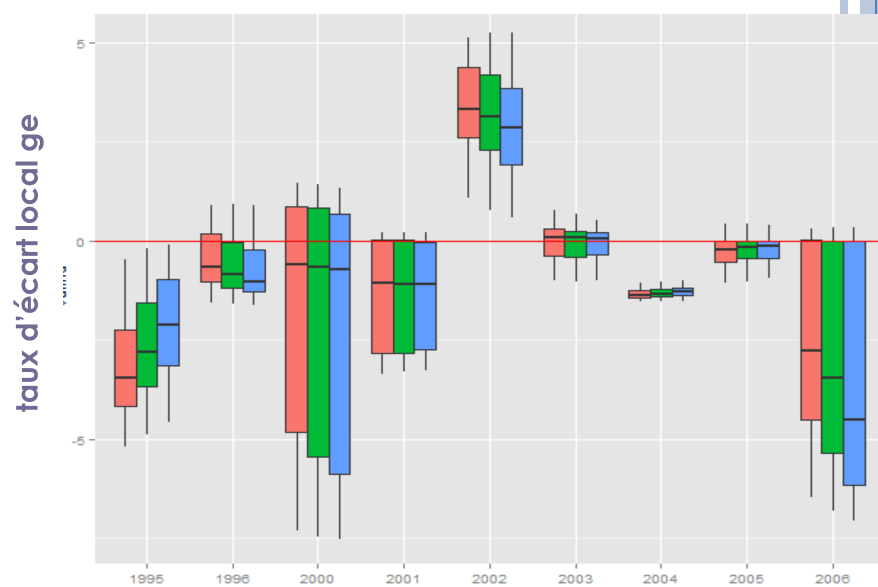
Estimate Parameters: Résultats



Mortalité
Faible
Moyenne
Haute

❖Mortalité





Calibration

Estimate Parameters: Strategy

Etapes	Questions	méthodes
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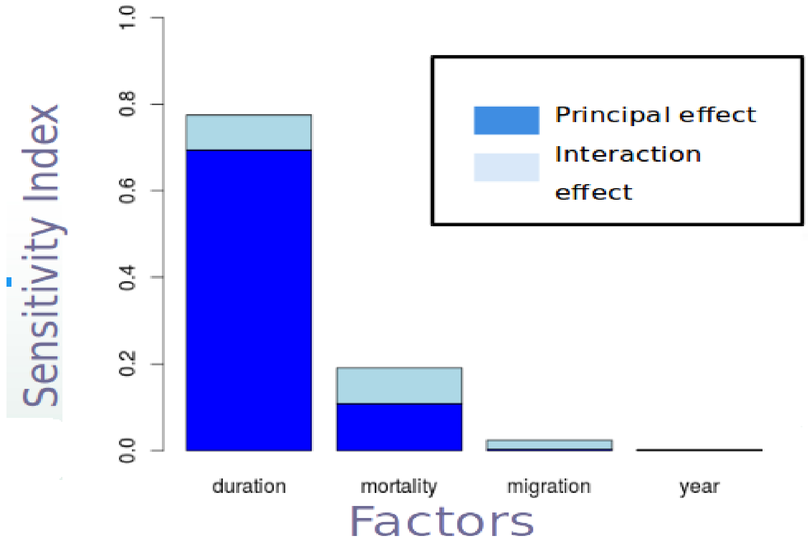
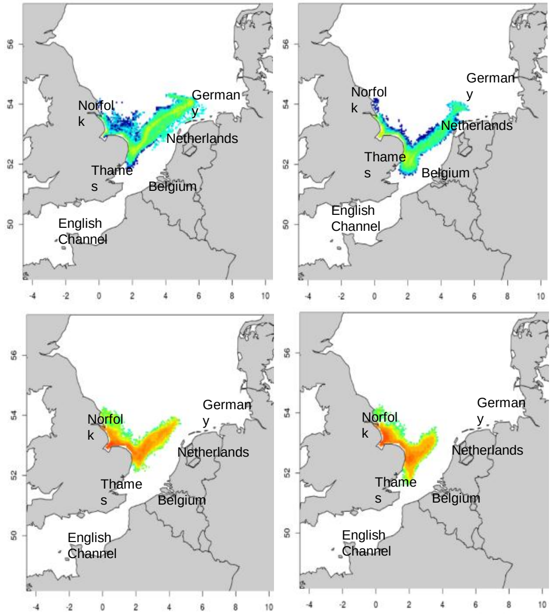
Etape 2: Calibration	• Quel est le meilleur modèle?	Plan complet sur les paramètres identifiés comme très influents sur toutes les années **Disapointing!**

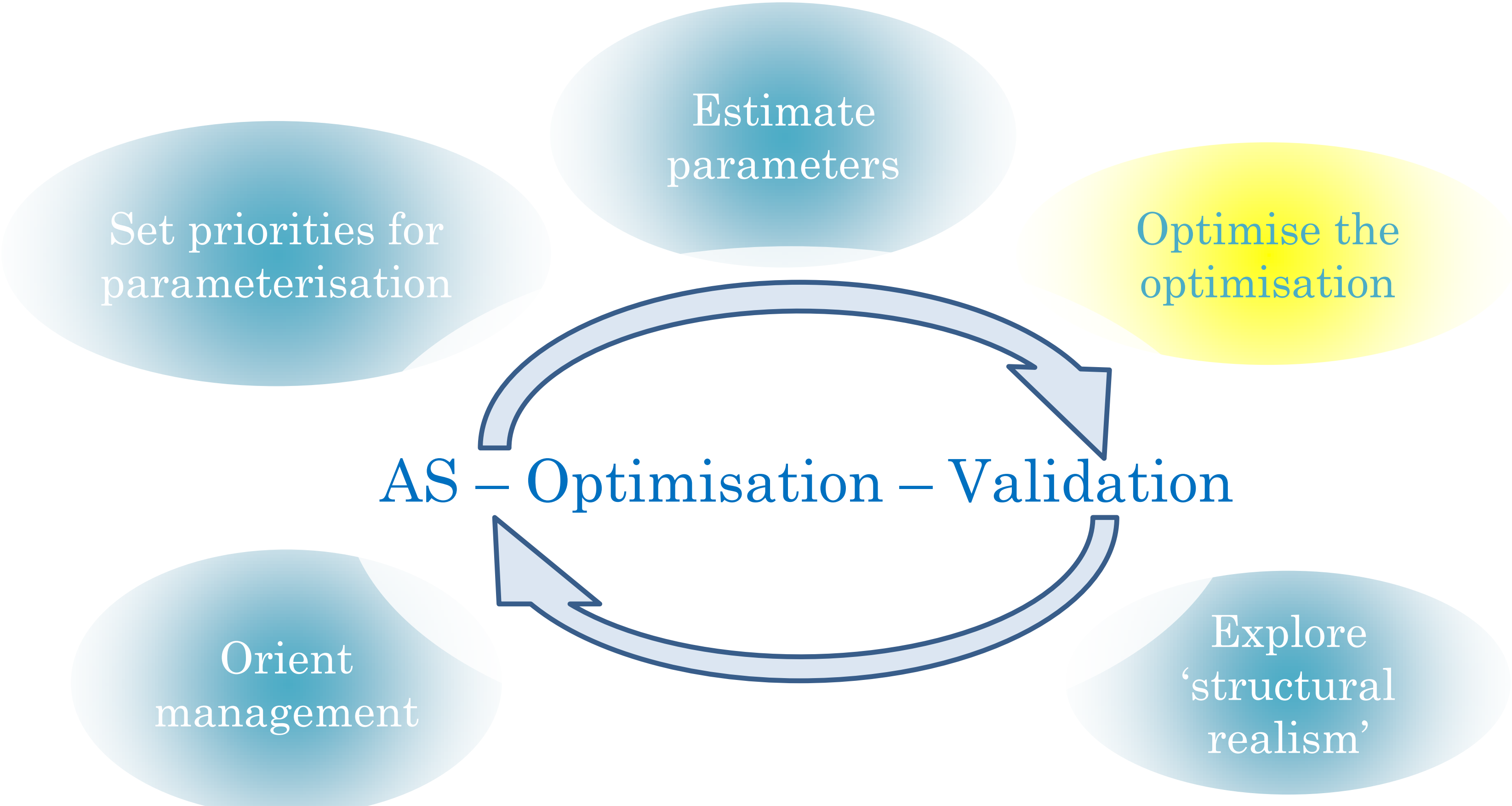
ESTIMATE PARAMETERS: DISAPPOINTING!

- We should have planned ahead
- Years were neglected in the first AS





- AS on the indices and not the FO !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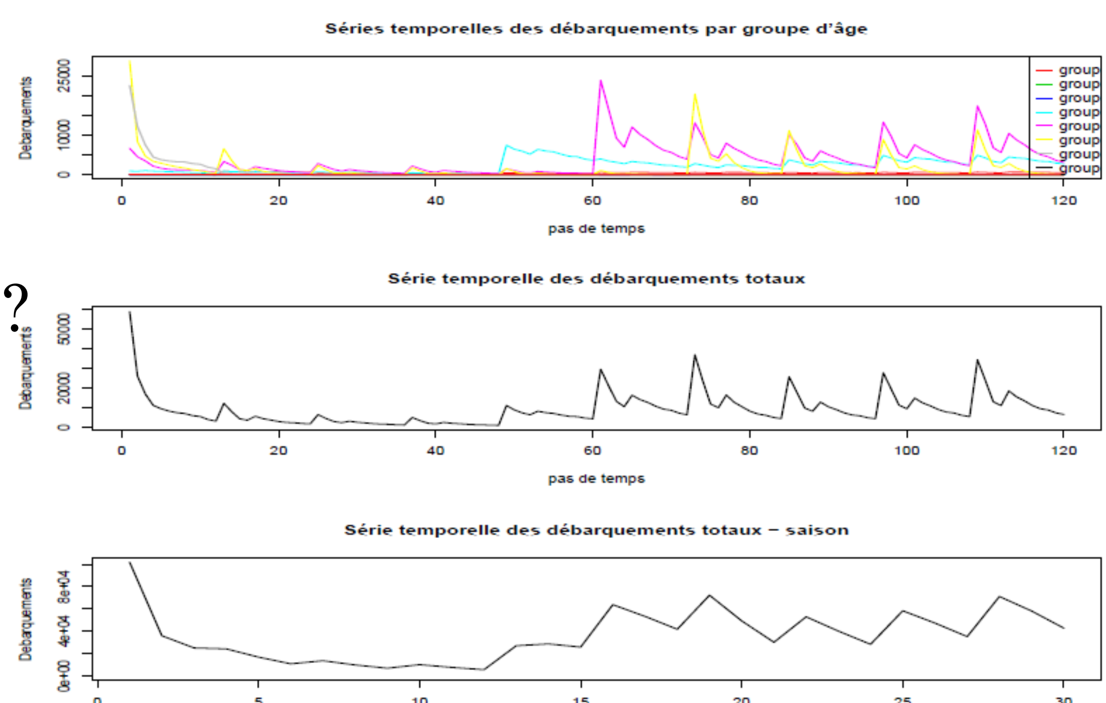
Optimise the optimisation

- Which objective function to use ?
- Objective :
  - reproduce catch at age, each month over ten years
  - Estimate catchability parameters
- parameters:

10 catchability at age



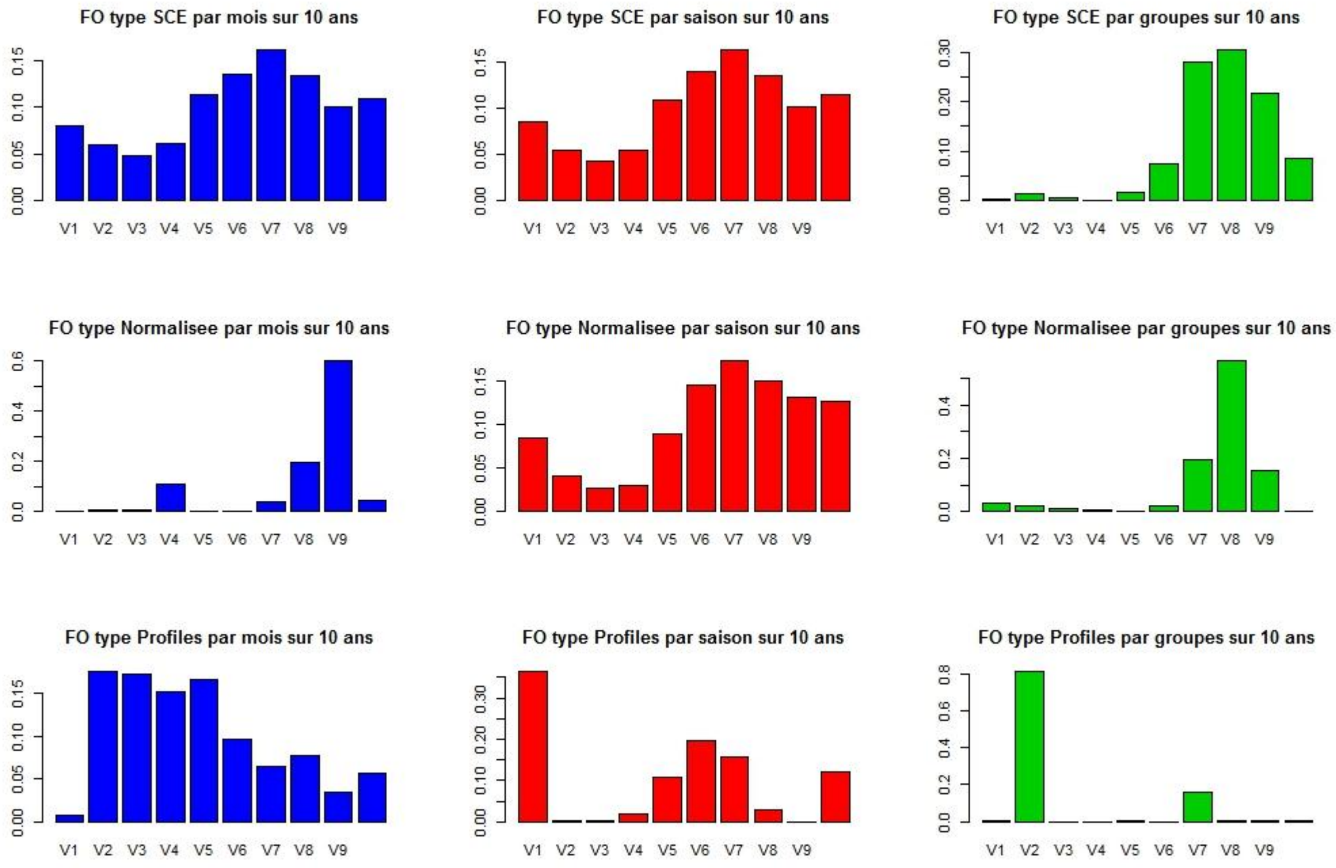
- How to build the OF ?
  - What time scale ?
  - Disagregate per age ?

Optimise the optimisation
9 alternative objective functions

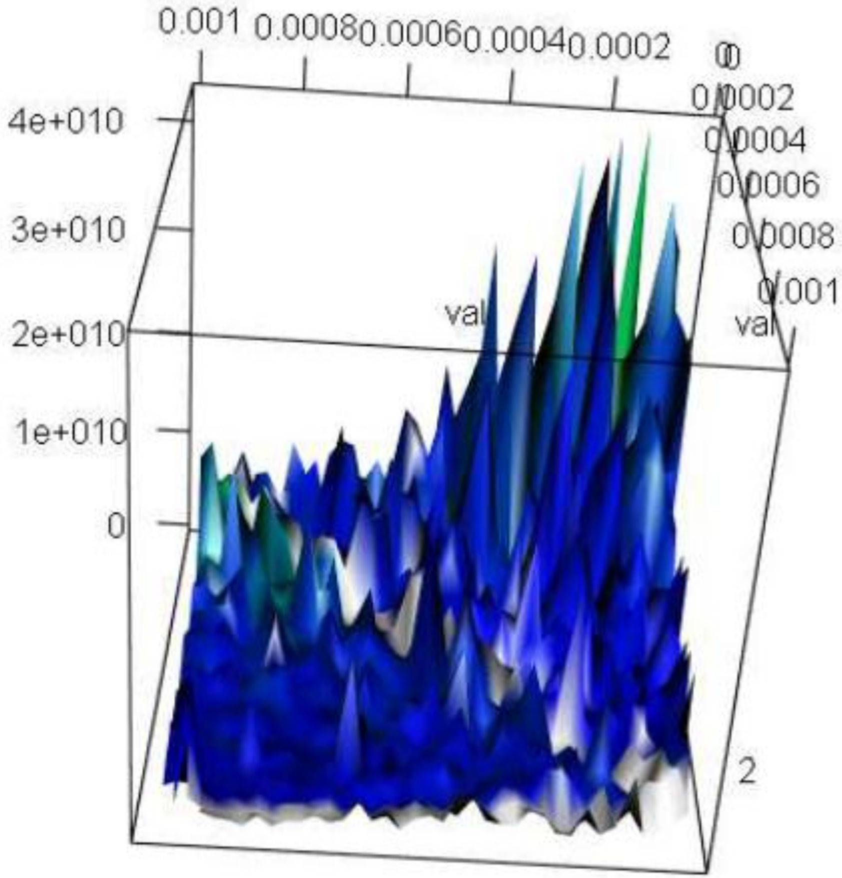
Échelle	Fonction d'objectif = SCE
Sur Y années par t mois	$\sum_{y=1}^{Y}\sum_{t=1}^{12}(D^{obs}_{y,t,.}-D^{sim}_{y,t,.})^2$
Sur Y années par les saisons de S	$\sum_{y=1}^{Y}\sum_{s\in S}(\sum_{t\in s}(D^{obs}_{y,t,.})-\sum_{t\in s}(D^{sim}_{y,t,.}))^2$
Sur Y années par G groupes d'âge	$\sum_{y=1}^{Y}\sum_{t=1}^{12}\sum_{g=1}^{G}(D^{obs}_{y,t,g}-D^{sim}_{y,t,g})^2$
Échelle	**Fonction d'objectif = SCE standardisée**
Sur Y années par t mois	$\sum_{y=1}^{Y}\sum_{t=1}^{12}\frac{(D^{obs}_{y,t,.}-D^{sim}_{y,t,.})^2}{(\sum_{i=1}^{12}D^{obs}_{y,i,.})^2}$
Sur Y années par les saisons de S	$\sum_{y=1}^{Y}\sum_{s\in S}\frac{((\sum_{t\in s}D^{obs}_{y,t,.})-(\sum_{t\in s}D^{sim}_{y,t,.}))^2}{(\sum_{y=1}^{Y}\sum_{t\in s}D^{obs}_{y,t,.})^2}$
Sur Y années par G groupes d'âge	$\sum_{y=1}^{Y}\sum_{t=1}^{12}\sum_{g=1}^{G}\frac{(D^{obs}_{y,t,g}-D^{sim}_{y,t,g})^2}{\sum_{i=1}^{12}(D^{obs}_{y,i,g})^2}$
Échelle	**Fonction d'objectif = Profil**
Sur Y années par t mois	$\sum_{y=1}^{Y}\sum_{t=1}^{12}\left(\frac{D^{obs}_{y,t,.}}{\sum_{i=1}^{12}D^{obs}_{y,i,.}}-\frac{D^{sim}_{y,t,.}}{\sum_{i=1}^{12}D^{sim}_{y,i,.}}\right)^2$
Sur Y années par les saisons de S	$\sum_{y=1}^{Y}\sum_{s\in S}\left(\frac{\sum_{t\in s}D^{obs}_{y,t,.}}{\sum_{y=1}^{Y}\sum_{t\in s}D^{obs}_{y,t,.}}-\frac{\sum_{t\in s}D^{sim}_{y,t,.}}{\sum_{y=1}^{Y}\sum_{t\in s}D^{sim}_{y,t,.}}\right)^2$
Sur Y années par G groupes d'âge	$\sum_{y=1}^{Y}\sum_{t=1}^{12}\sum_{g=1}^{G}\left(\frac{D^{obs}_{y,t,g}}{\sum_{i=1}^{12}D^{obs}_{y,i,g}}-\frac{D^{sim}_{y,t,g}}{\sum_{i=1}^{12}D^{sim}_{y,i,g}}\right)^2$

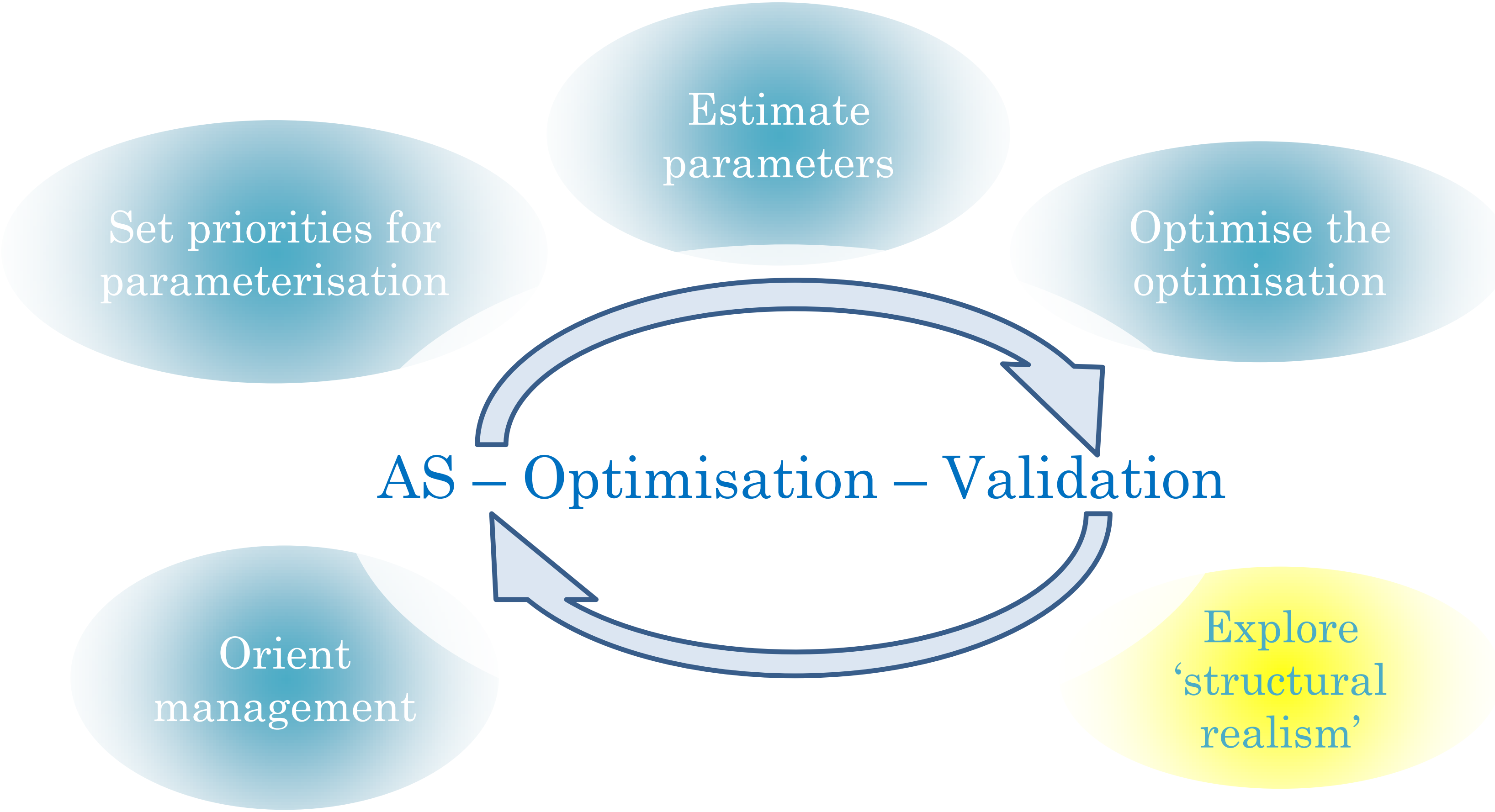
Optimise the optimisation
Find the most sensitive FO to all parameters

- LHS 2000 + anova (sans interaction)



Optimise the optimisation
Gain a first exploration of the parameter space





Estimate parameters
Set priorities for parameterisation
Optimise the optimisation
AS – Optimisation – Validation
Orient management
Explore 'structural realism'

Explore structural realism

Is the model ~~« Valid »~~?

«Useful », «Inspiring confidence», «Convincing», »Illuminating», « suitable for a particular purpose »

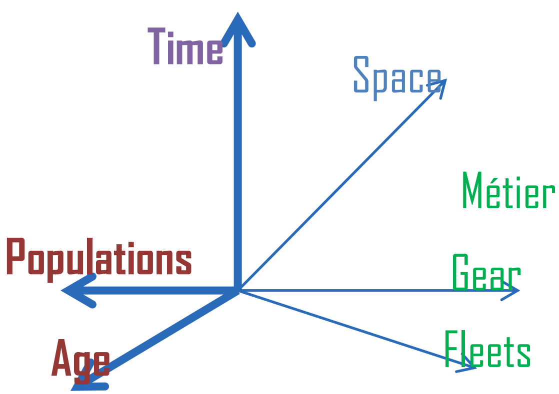
1. INTRODUCTION

System Dynamics modelers are often faulted for their reluctance to employ formal measures of goodness-of-fit when assessing the historical behaviour of models. As a result, the validity of system dynamics models is often questioned even when their correspondence to historical behaviour is quite good. This paper argues that the failure to present formal analysis of historical behaviour creates an impression of sloppiness and unprofessionalism. After reviewing the theory of validity in system dynamics, the paper proposes a simple set of summary statistics appropriate for system dynamics models. The statistics allow the error due to individual behaviour modes to be analysed, do not require the use of formal parameter estimation procedures, and can be conveniently computed.

Sterman, 1984

Explore structural realism
Calibration/validation

- ISIS-Fish model of the Eastern English Channel



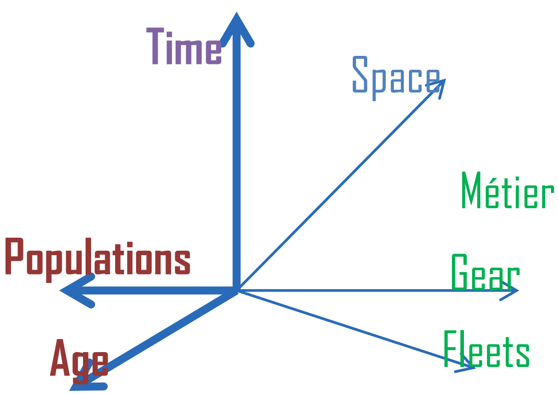
Calibration
Catch@age2008-2011

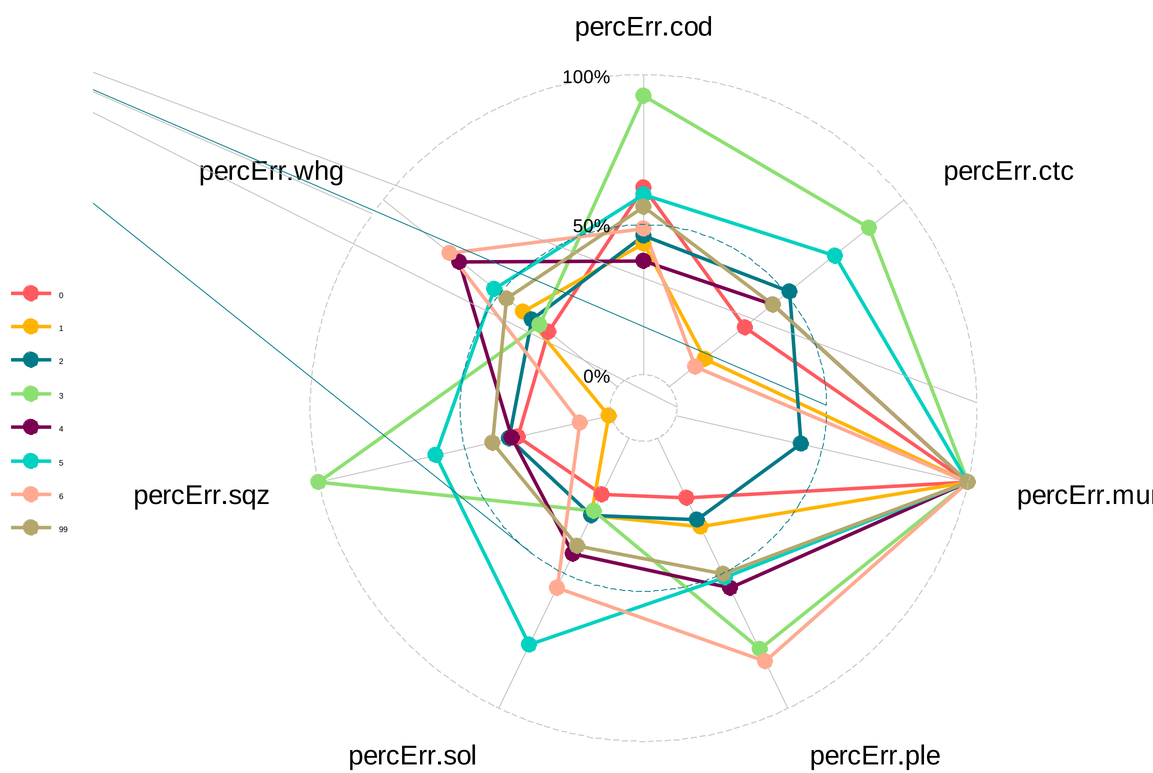
Validation
Autres échelles
Multi-variée
2008-2014

Explore structural realism
Calibration results / species

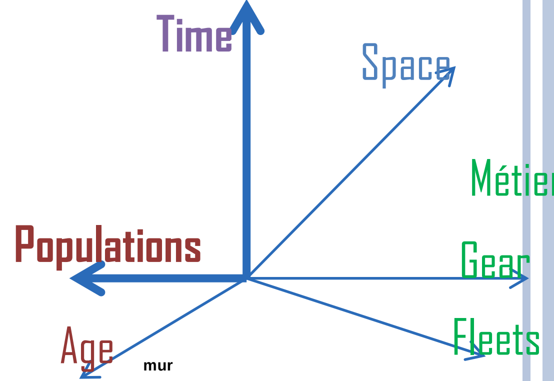
- Radar plot %err moyen /sp (par an)

Id problematic
- species : RedMullet
- Years : 2011, 2013

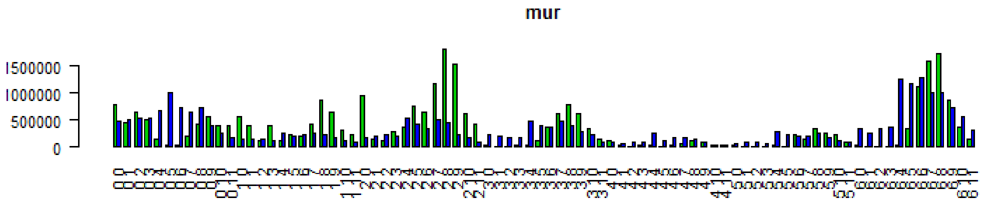




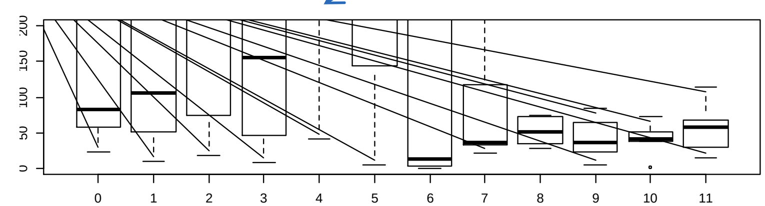
Explore structural realism Validation



Seasonnal patterns

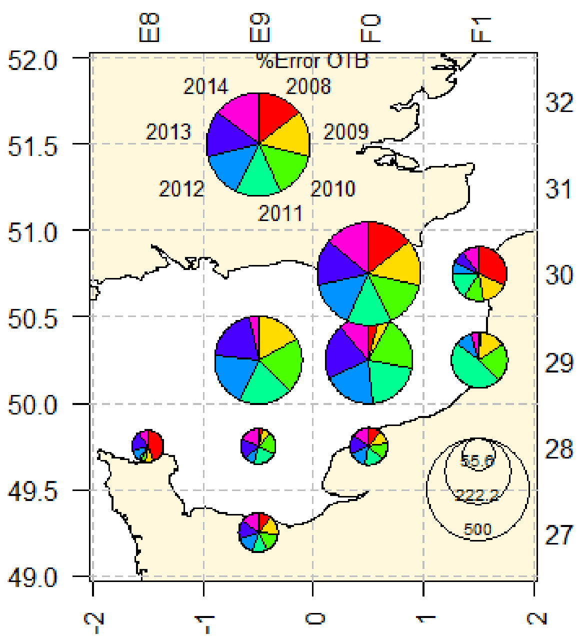


%error

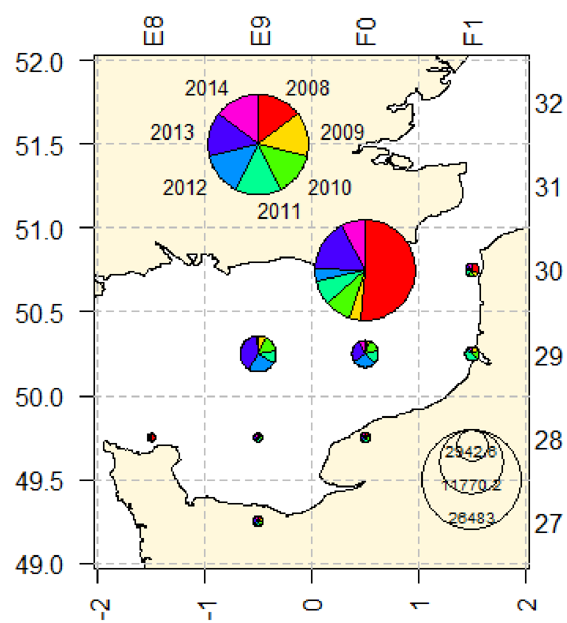


Spatial patterns / Gear & Year

%error



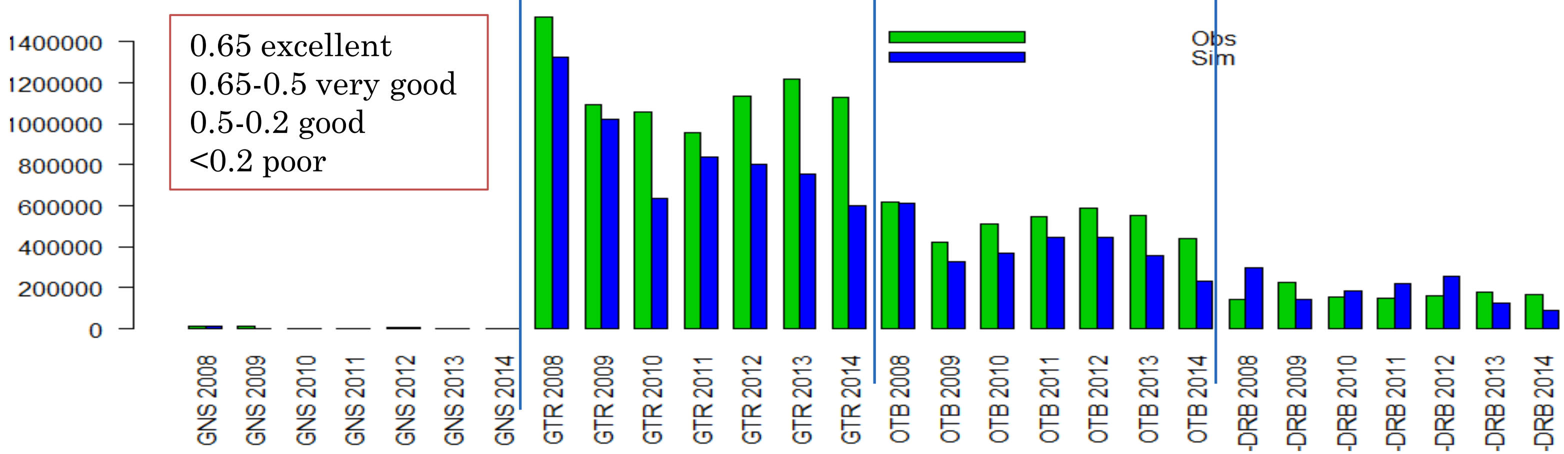
Absolute difference

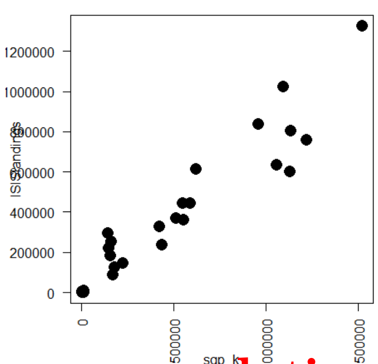


Explore structural realism
Validation: metrics

	Nets	gillnets	trawls	Dredges - beam trawl
MEF	0.41	-3.4	-3.3	-10

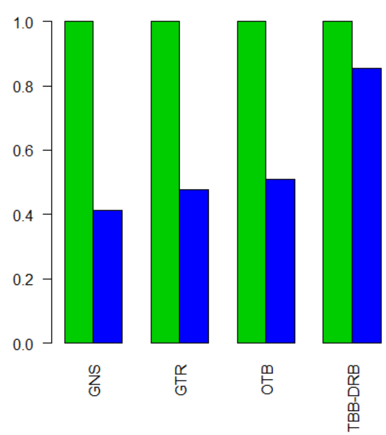
0.65 excellent
0.65-0.5 very good
0.5-0.2 good
<0.2 poor

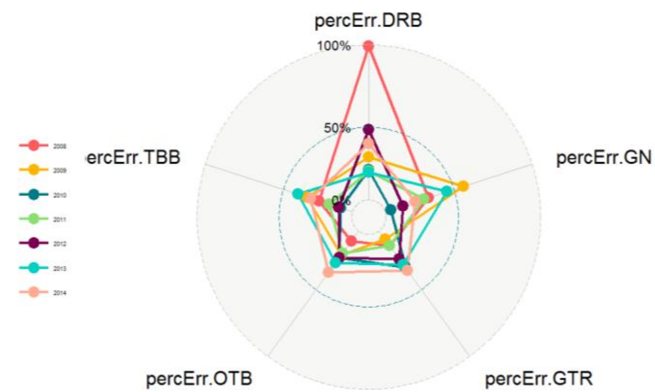


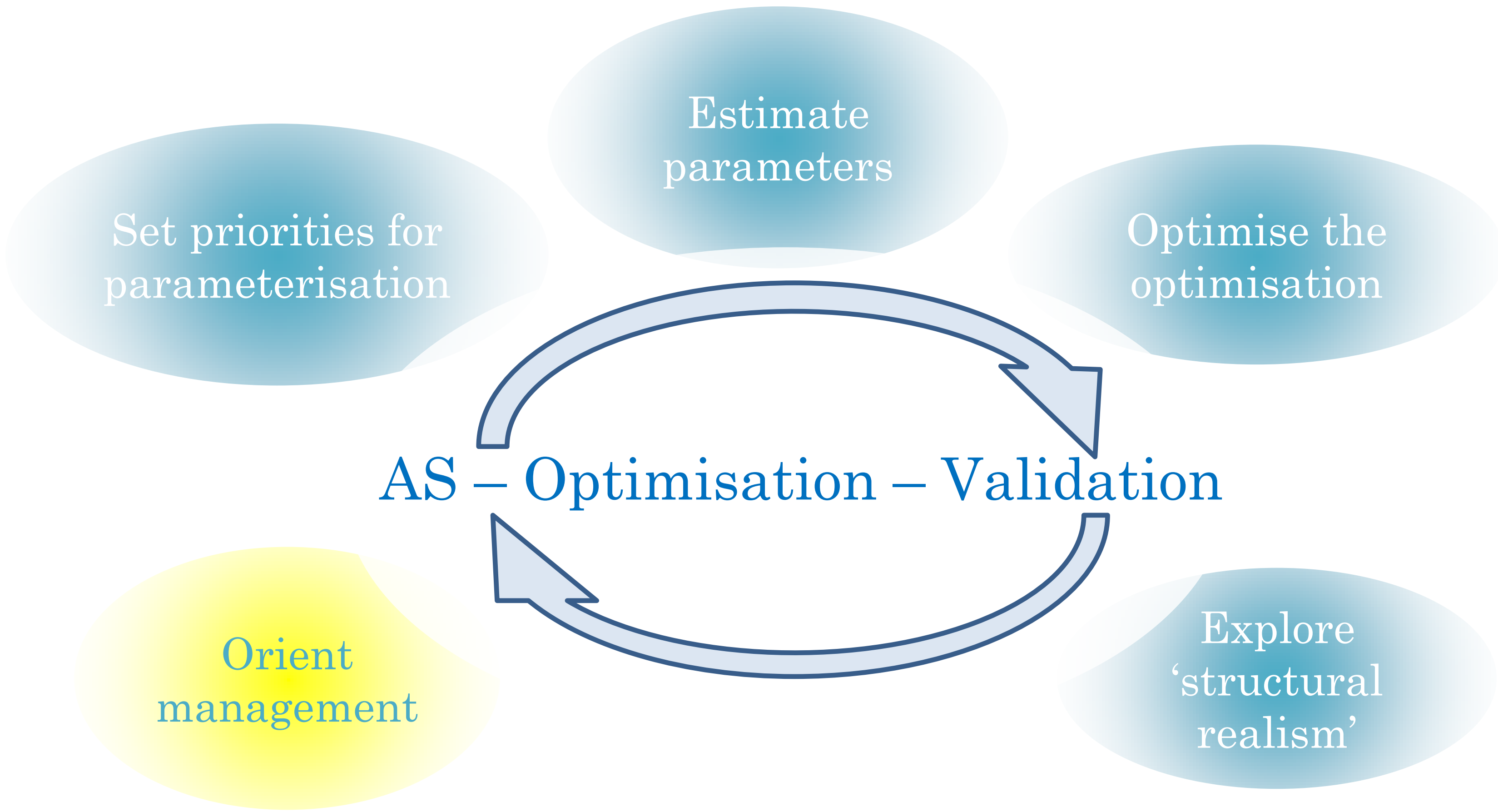


Linear correlation : 0.9536
Rank correlation : 0.93

Cumulated catches over year
% error per gear



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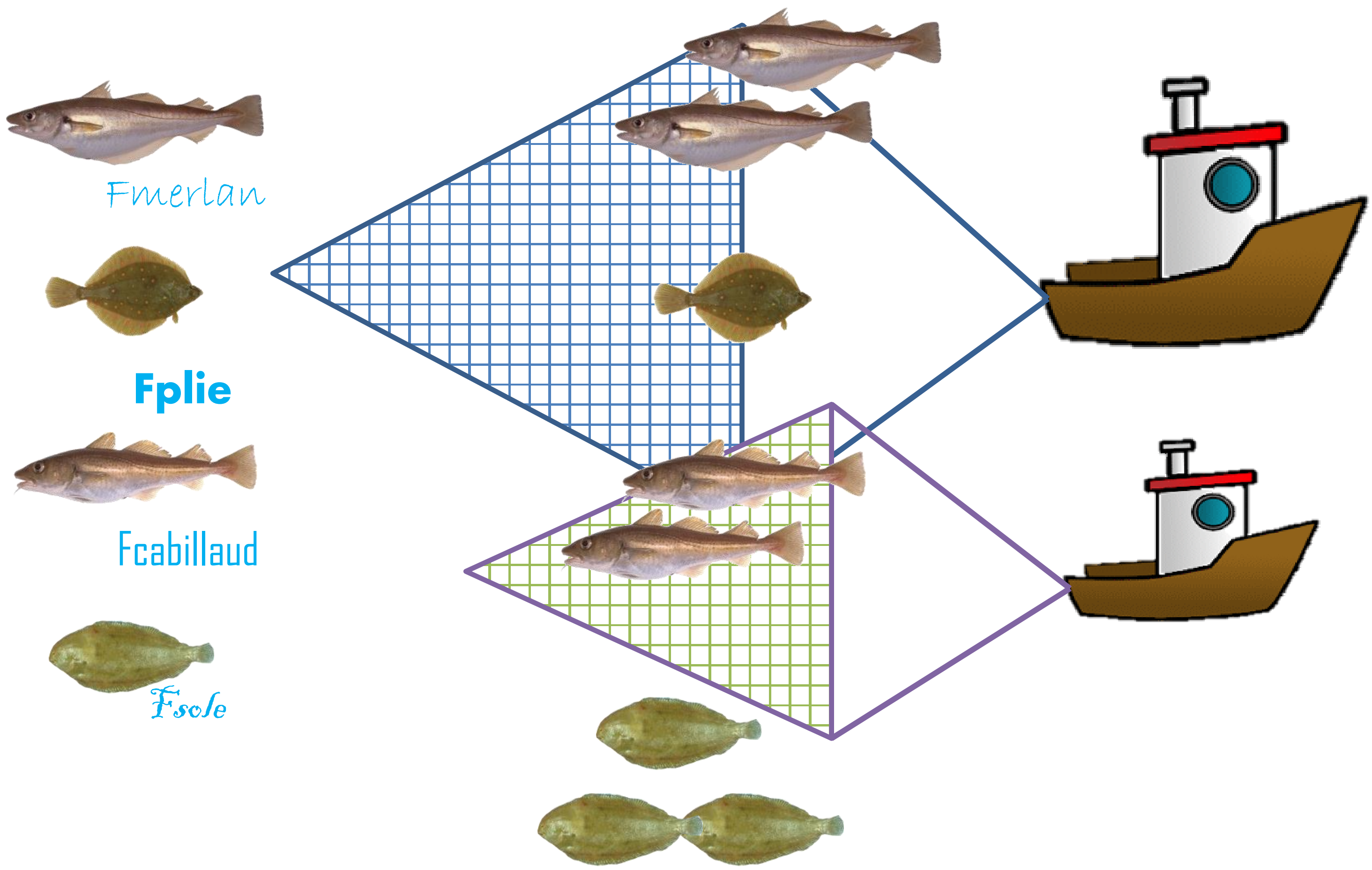
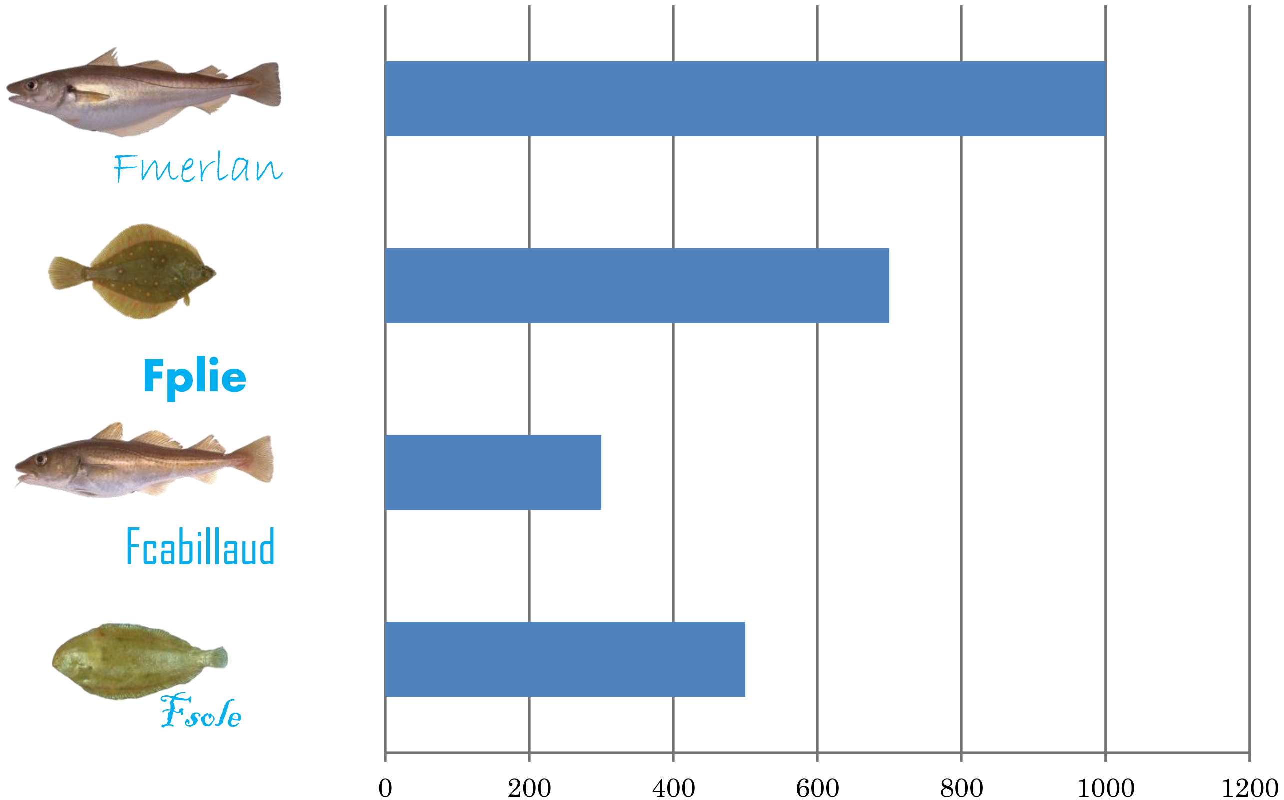
Management strategy optimisation
Mixed Fisheries



Management strategy optimisation
Mixed Fisheries

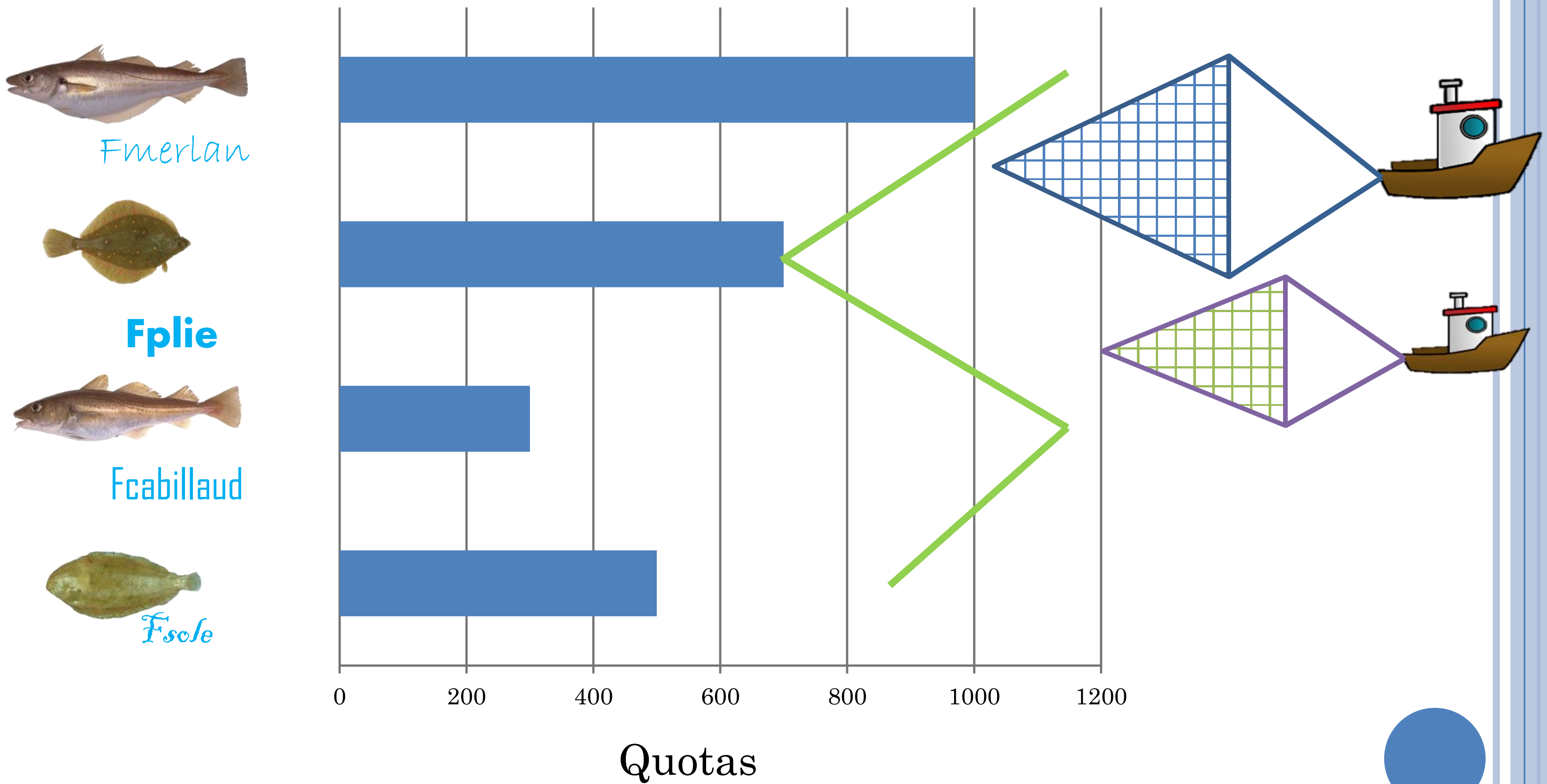


Quotas ~Etat biologique du stock

Maximum sustainable yield

Management strategy optimisation
Mixed Fisheries

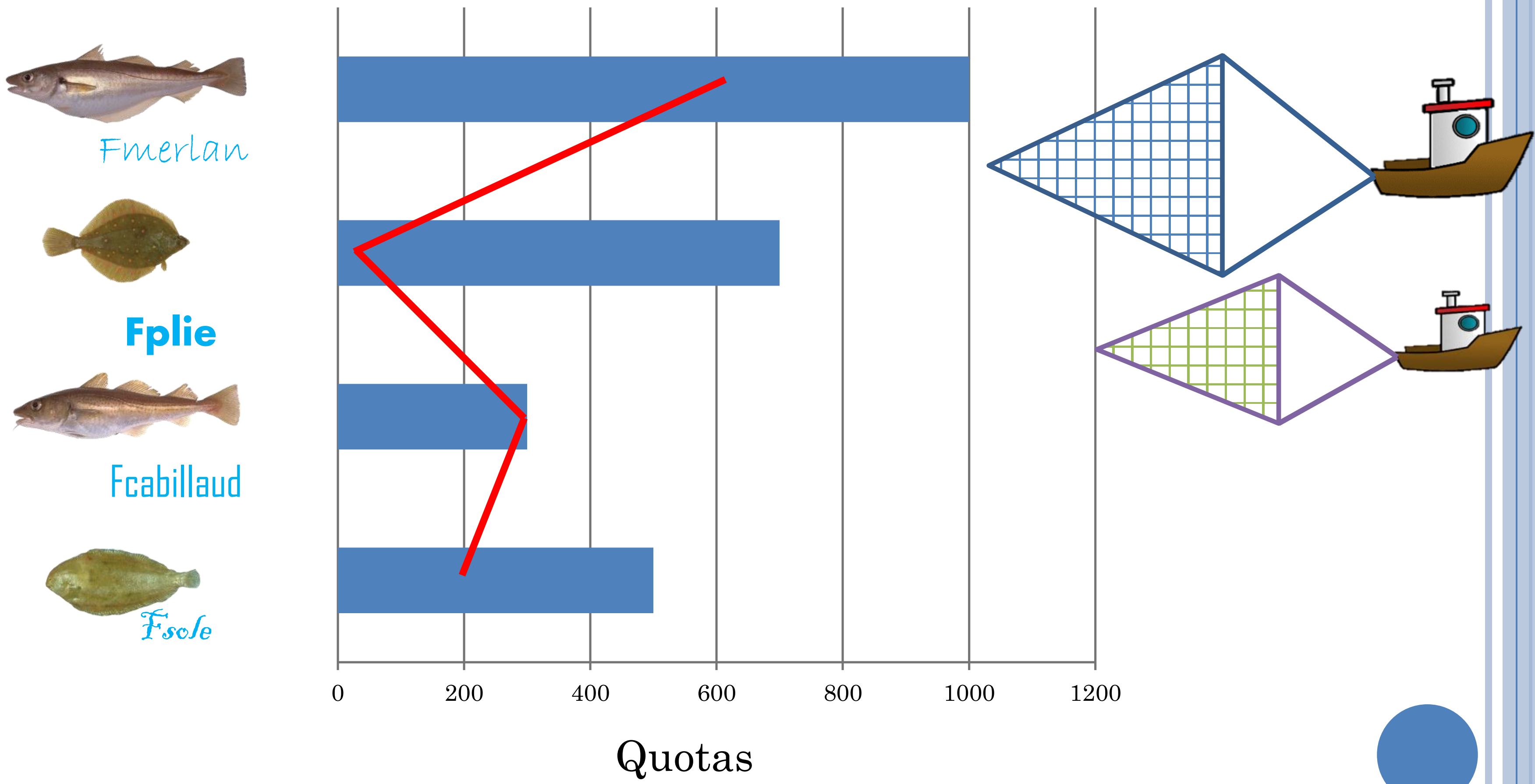
Sc. Max : Effort E1 = Effort 1 +Effort 1



Maximum sustainable yield

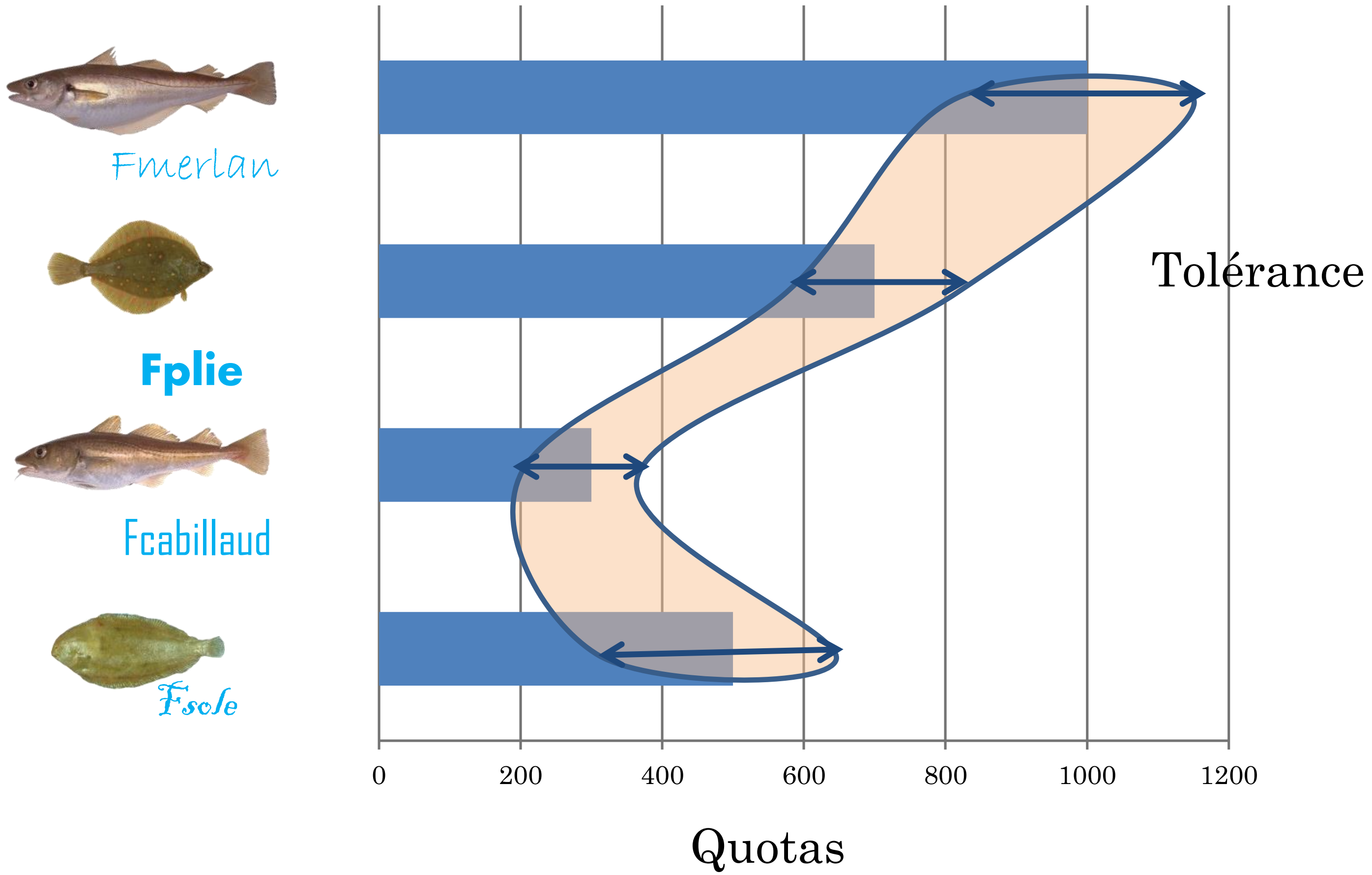
Management strategy optimisation Mixed Fisheries

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



Maximum sustainable yield

Management strategy optimisation
Mixed Fisheries



Pretty good yield

(*Rindorp et al. 2016*)

Management strategy optimisation
Mixed Fisheries

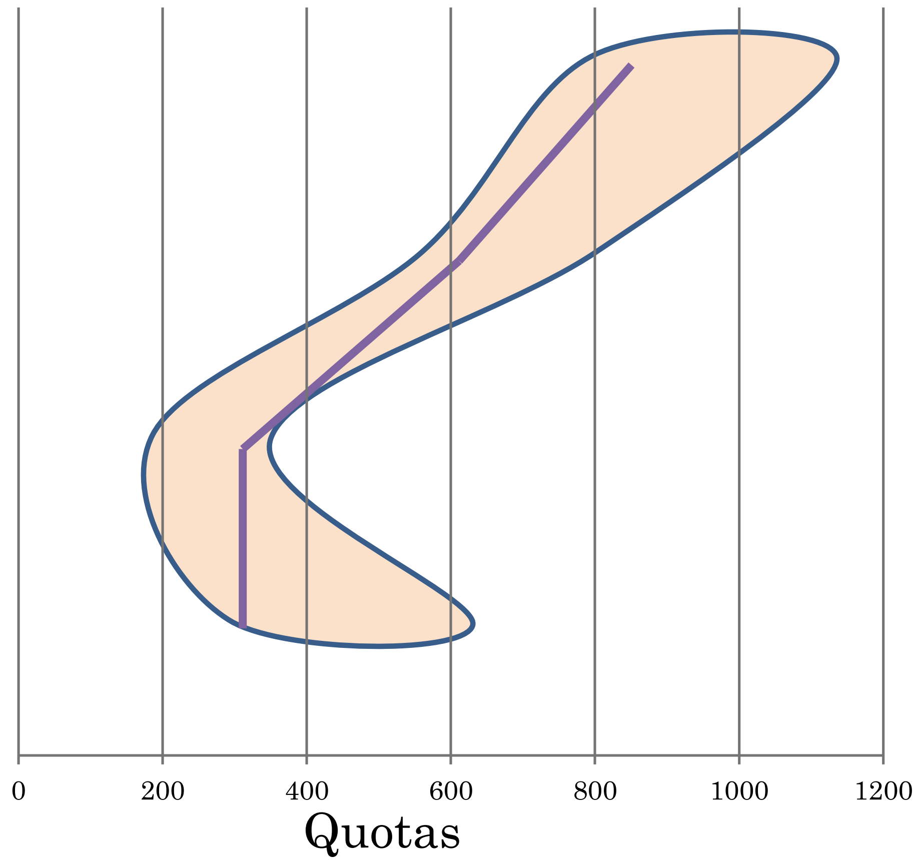
Search for {quotas} optimal within constrainsts
That minimizes (Catch Sc. Max – Catch Sc. Min)

Fmerlan

Fplie

Fcabillaud

Fsole



Genetic algorithm

Pretty good yield

Ulrich et al. 2016

« The cautious modeler : Craftsmanship without wizardry »

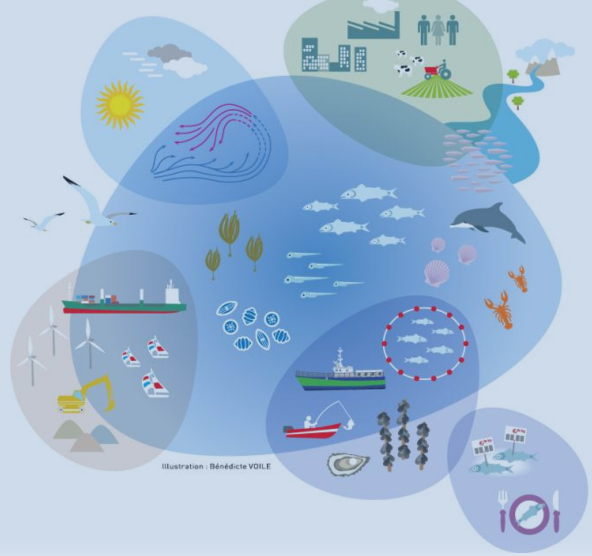
Andréa Saltelli

Misfit δ

Data

Model

Truth



MERCI!