Development of a robust Marine Protected Area impact diagnosis…

ISIS-fish

…in a context of uncertainty and global change

ifremer

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Goals

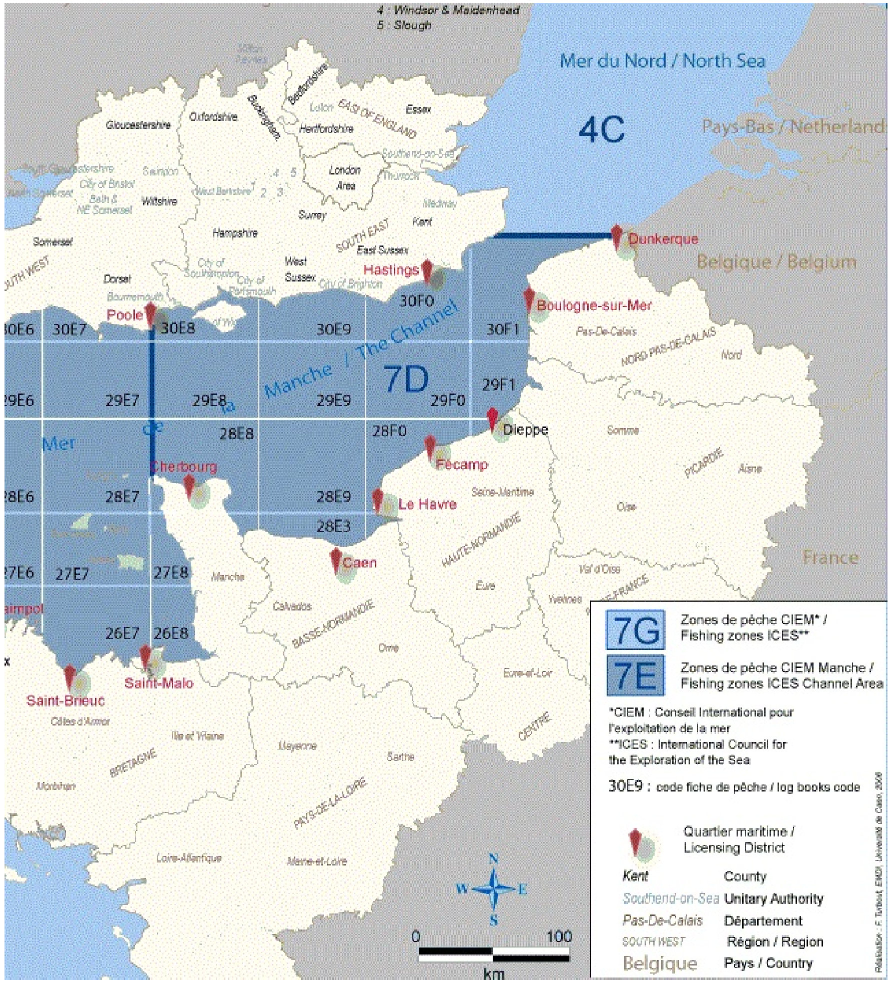
Determine the consequences of various management measures, either direct or indirect, on marine populations and activities in the Eastern Channel.

Develop a simulation model of marine ecosystem that is robust to uncertainties.

VECTORS

Eastern Channel ecosystem

ICES area 7D



Species:

Sole, Plaice, Cod, Red mullet,...

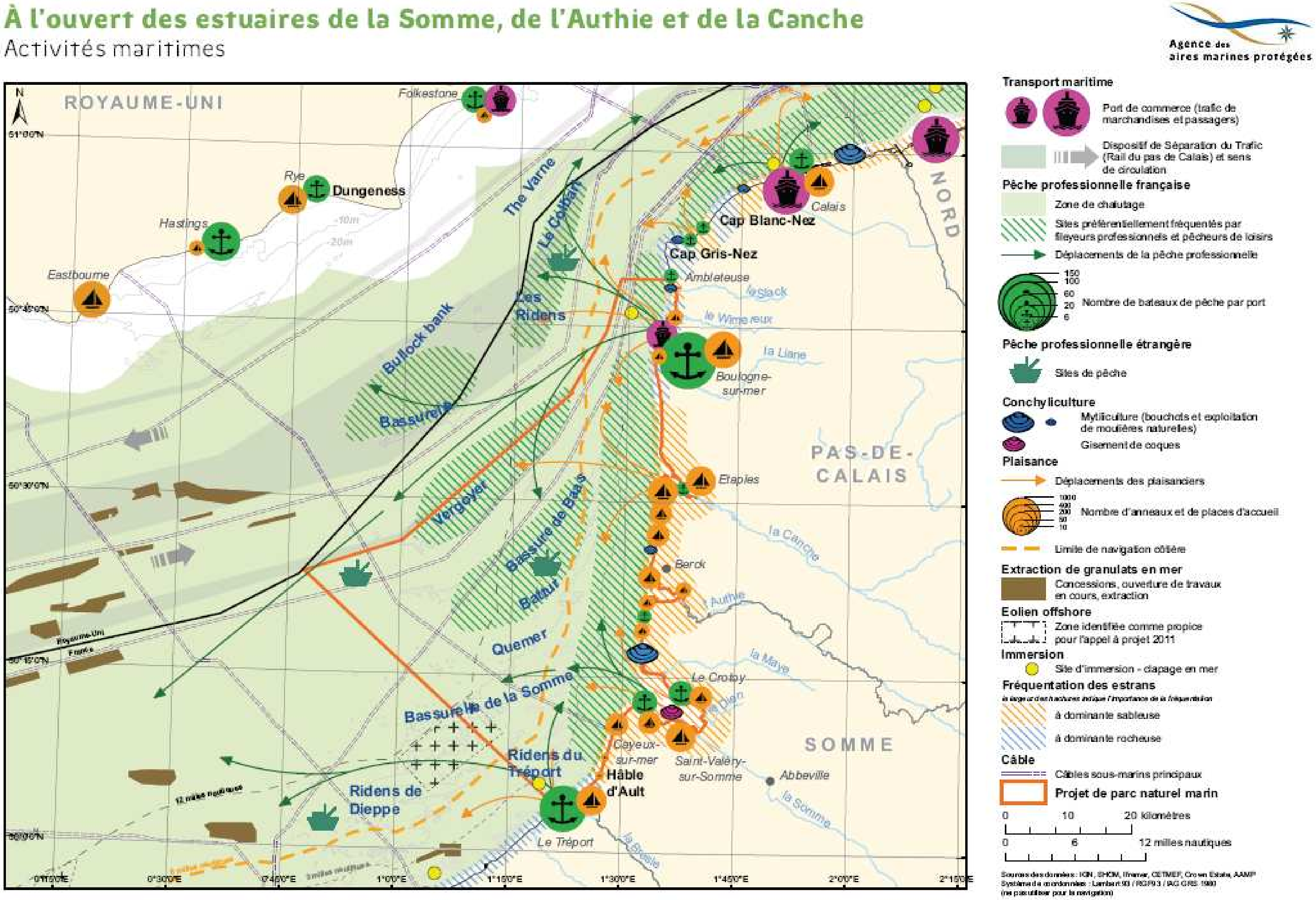
Activities:

Fishing, extraction,wind-farming, …

Management measures:

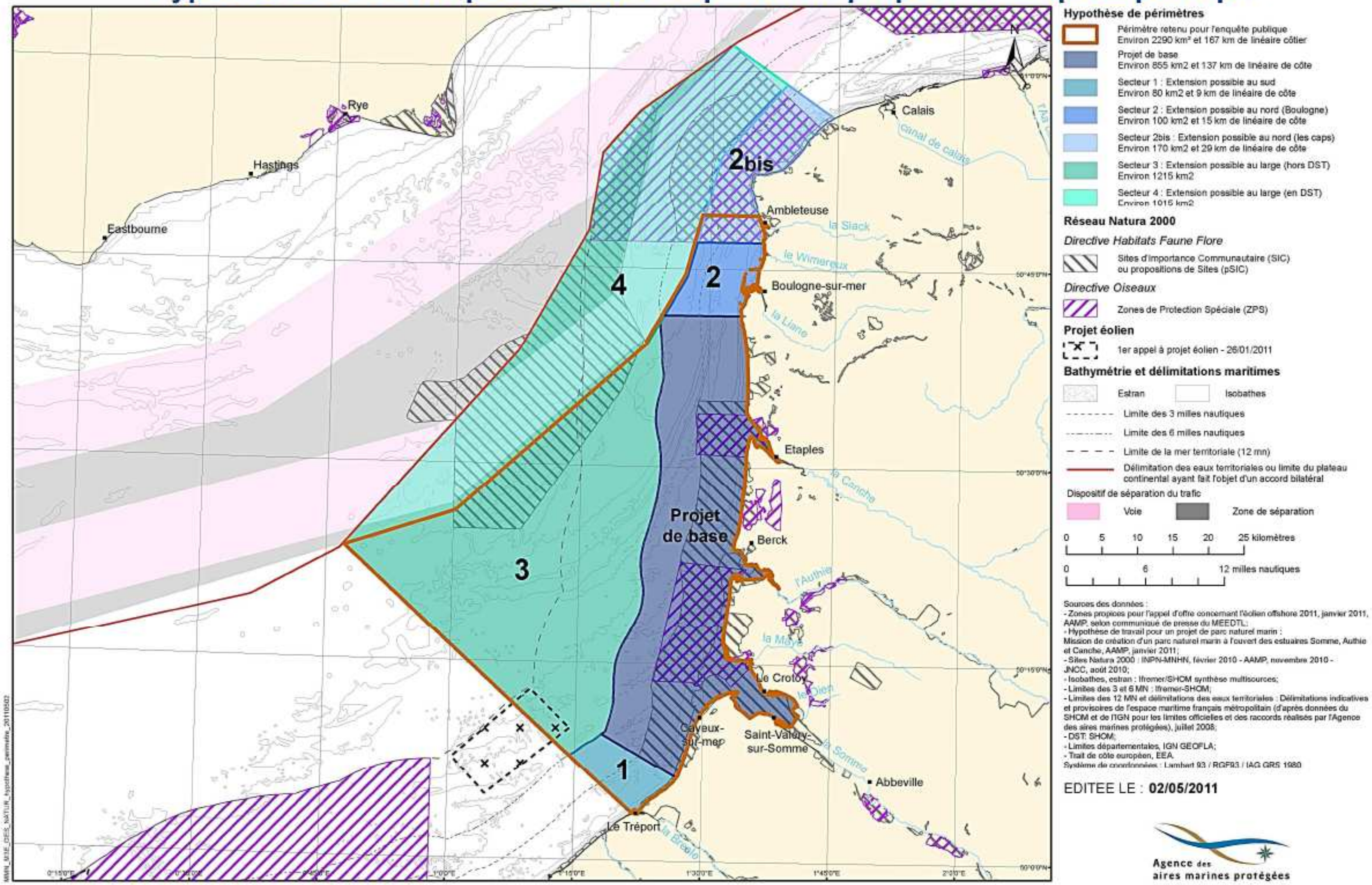
MPAs (permanent or seasonal), wind-farms, dredging, **quotas, effort limitations, minimum fish sizes**, ban of discards,…

Eastern Channel ecosystem



Eastern Channel ecosystem

PROJET DE PARC NATUREL MARIN A L'OUVERT DES ESTUAIRES DE LA SOMME, DE L'AUTHIE ET DE LA CANCHE
Hypothèses de travail pour le choix du périmètre proposé à l'enquête publique



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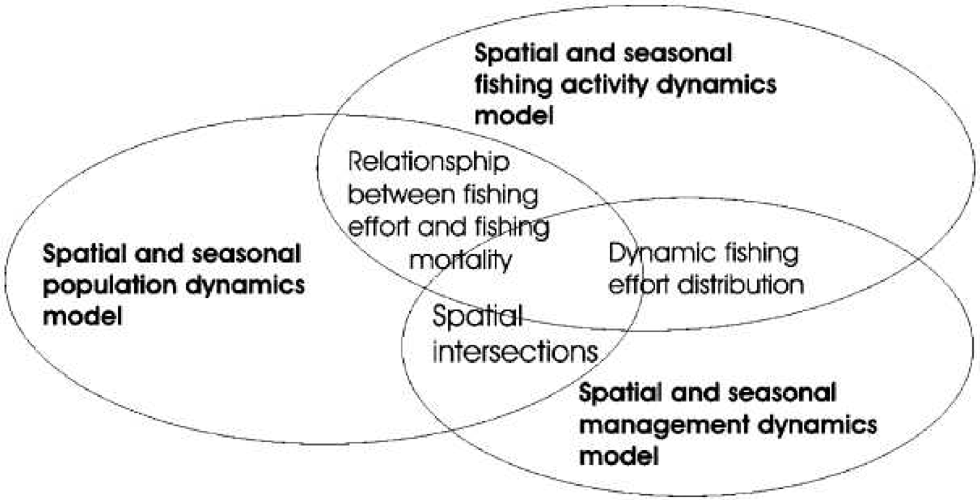
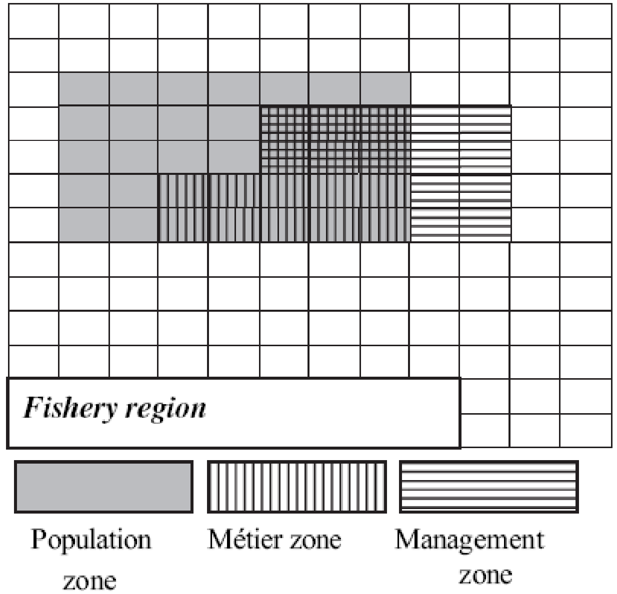
The ISIS-fish bio-economic model

Superimposition of 3 sub-models that interact in time and space.





Mahevas and Pelletier (2004), Pelletier et al. (2009)

The ISIS-fish bio-economic model

A complex model that:

-Allows making more explicit uncertainty and its origin, taking into account many potential sources of uncertainty.

-Causes the introduction of new uncertain parameters.

-Can be seen as increasing the complexity of uncertainty as the number of interacting sources increases.

Uncertainty in the model

Five categories of sources of ucertainty in modelling:

(i) **observation error**, leading to uncertain parameter estimates;

(ii) **variability of natural processes** (probability distribution function around a point parameter estimate);

(iii) **structural uncertainty** (lack of knowledge of the studied system);

(iv) **model error** (equations choice, ways to model relationships between groups, etc);

(v) **secondary sources** of uncertainty coming from interactions between these primary sources

(Francis and Shotton, 1997; Charles, 1998; Cochrane, 1999; Sethi et al., 2005; Punt and Donovan, 2007).

Why reduce uncertainty ?

Uncertainty is a source of risk !

-A great uncertainty with negligible consequences does not matter much.

-A little uncertainty with huge consequences may be worth taking into account.

« The US Nuclear Regulatory Commission (NRC) specifies that reactor designs must meet a 1 in 10,000 year core damage frequency, but modern designs exceed this. US utility requirements are 1 in 100,000 years, the best currently operating plants are about 1 in 1 million and those likely to be built in the next decade are almost 1 in 10 million. »

World Nuclear Association

Risk

Risk

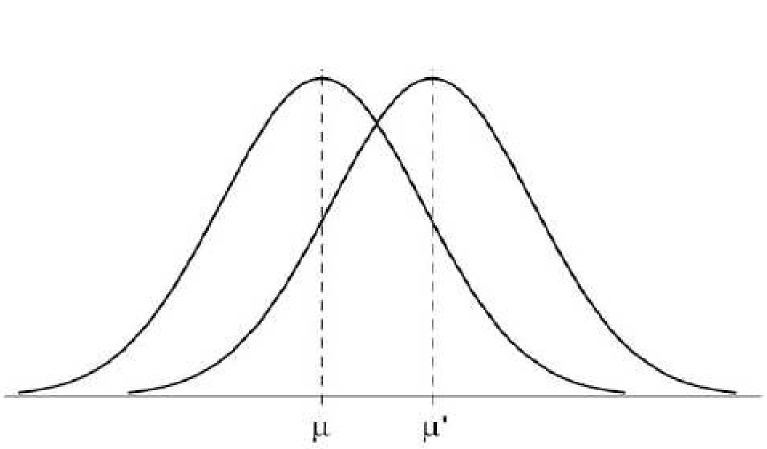
=

probability of occurrence

X

consequences of risk event

Probability of occurrence ?



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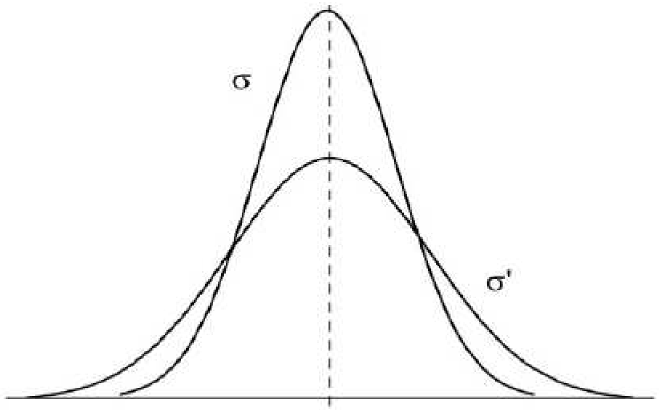
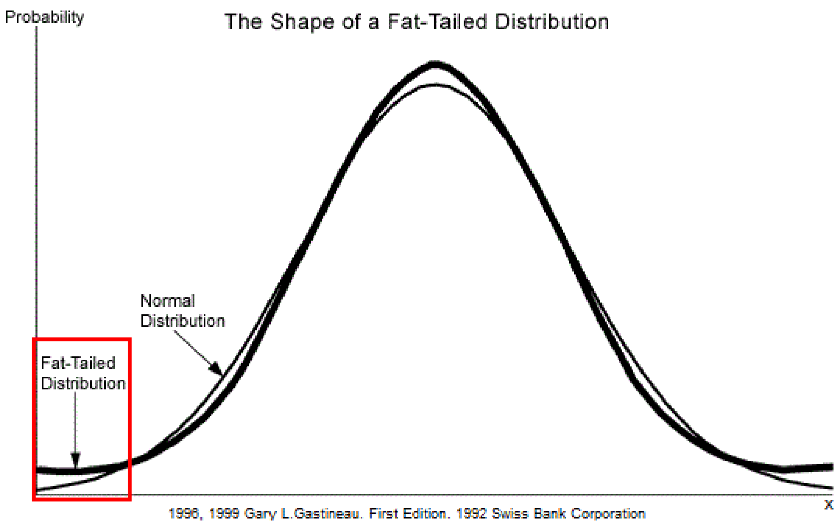
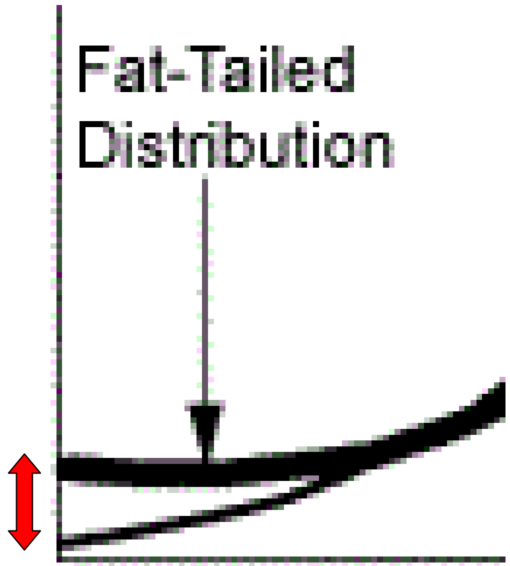
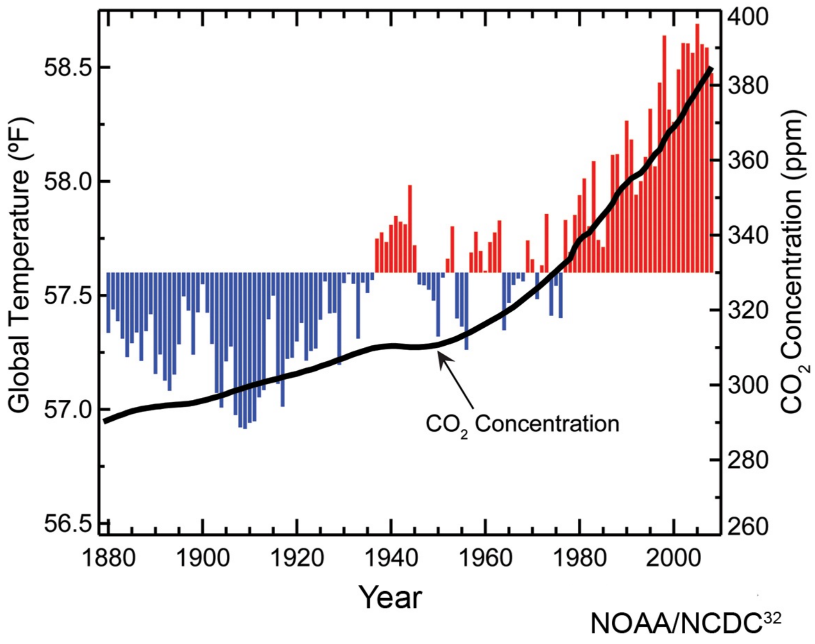


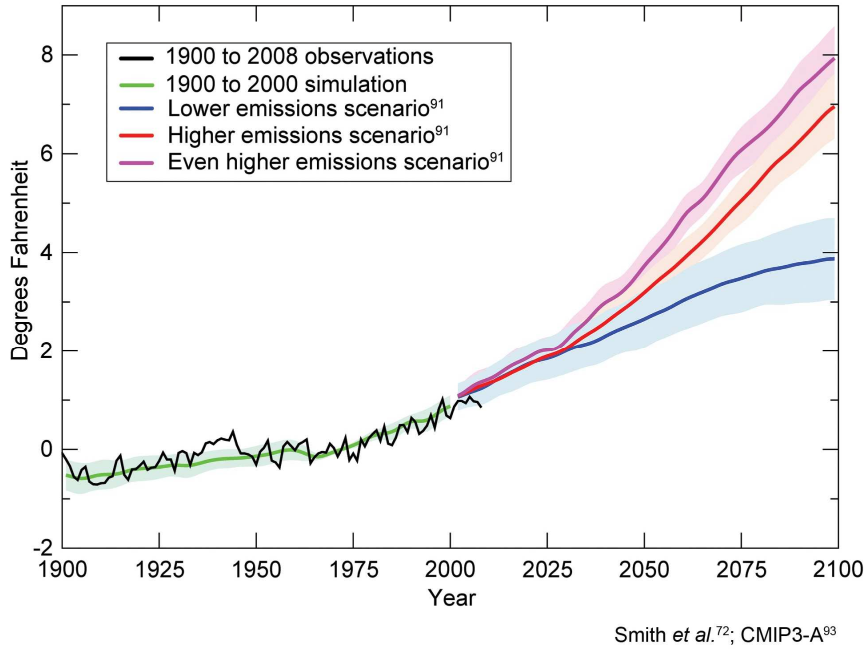
INPL, T. Verdel





Probability of occurrence ?





In decision theory, the likelihood of occurrence of an extreme event is deemed too uncertain to be taken into account in the definition of risk.

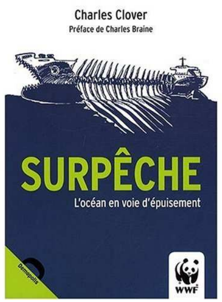
Consequences of risk event

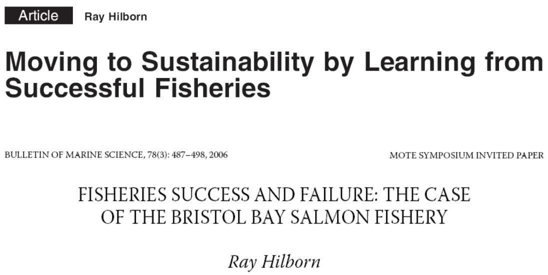
Even if we do not know where we are heading to, we can anticipate the consequences and distinguish between those that would be acceptable to society, and those that would not.

Politicians and managers have defined goals and thresholds

- How to reach these goals ?
- How no to go beyond inacceptable thresholds ?

→ How to be robust to uncertainty ?



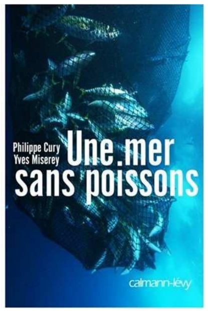

Article Ray Hilborn

Moving to Sustainability by Learning from Successful Fisheries

BULLETIN OF MARINE SCIENCE, 78(3): 487–498, 2006 MOTE SYMPOSIUM INVITED PAPER

FISHERIES SUCCESS AND FAILURE: THE CASE OF THE BRISTOL BAY SALMON FISHERY

Ray Hilborn



Risk

Risk

=

~~probability of occurrence~~

X

impact of risk event

→ How to deal with our uncertainty on the input parameters to avoid unwanted situations ?

How to be robust to uncertainties ?

What conditions on the input parameters have to be fulfilled to always reach a fixed goal ?

Where is the safe side (if there is one) in the space of the input parameters?

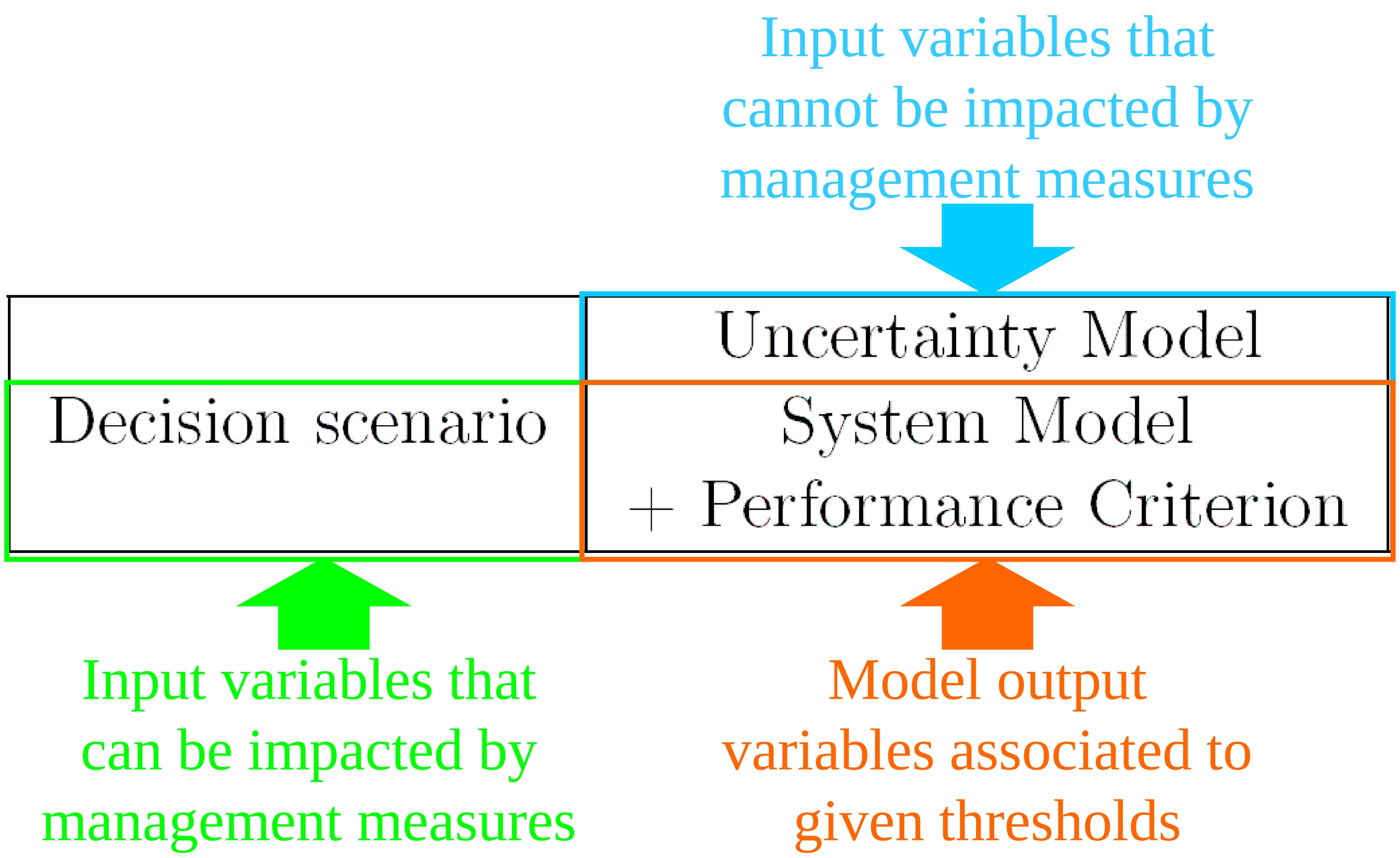
How to be robust to uncertainties ?

- Make no hypothesis about:
  - The probability density function of input parameters
  - The domain of variation of these parameters

- Seek as many sources of information as possible
- Have an iterative approach
- Limit complexity and avoid overparameterisation

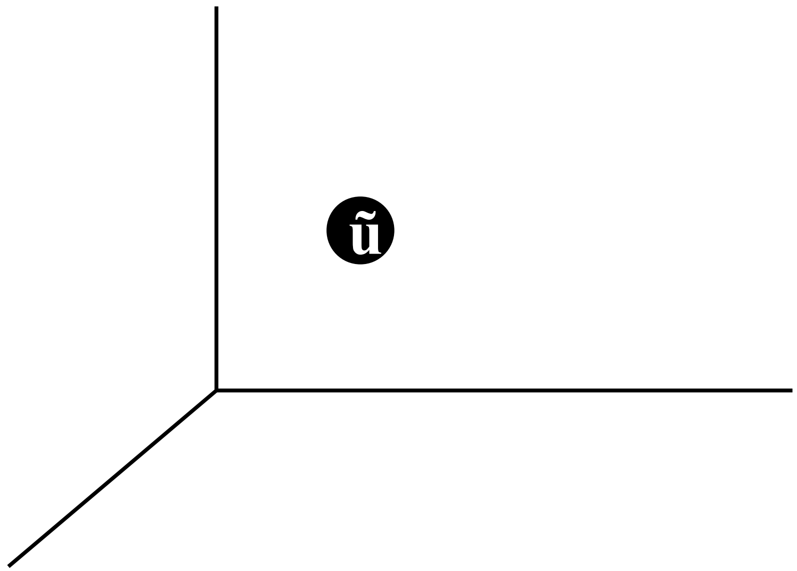
- Use of an « info-gap » approach derived from Game Theory and Wald's statistical decision function theory

How to be robust to uncertainties ?



Looking for the gap…

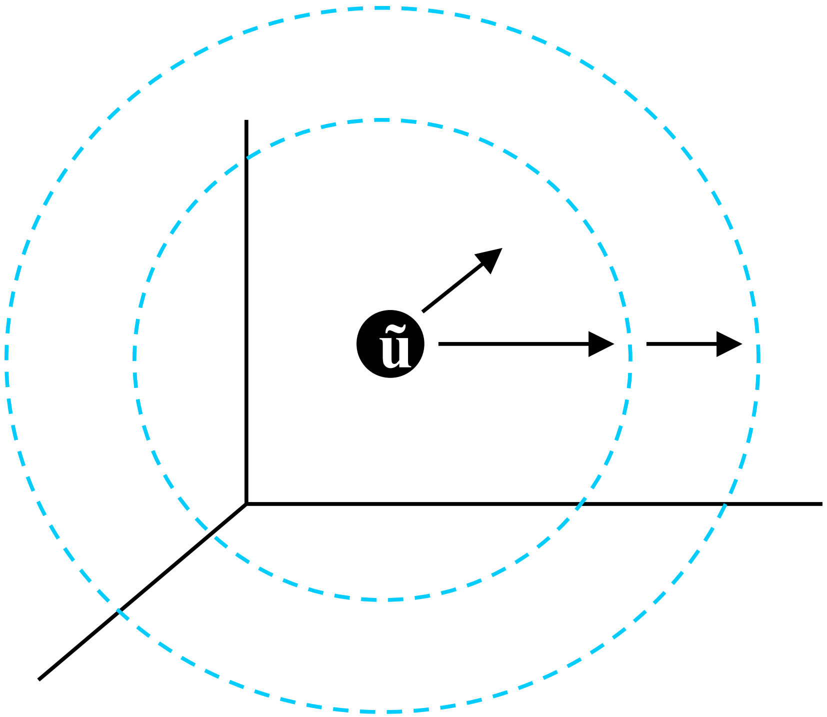
What do you see ?



$\tilde{u}_{ref}$ is the point of coordinates $(X_{1,ref}, X_{2,ref}, \ldots, X_{n,ref})$ in the n-dimensional input parameters space.

It is the nominal value of our model parameters.

Looking for the gap…



What is the input parameter space corresponding to a given value of a chosen output ?

Two « big » hypotheses.

Looking for the gap…

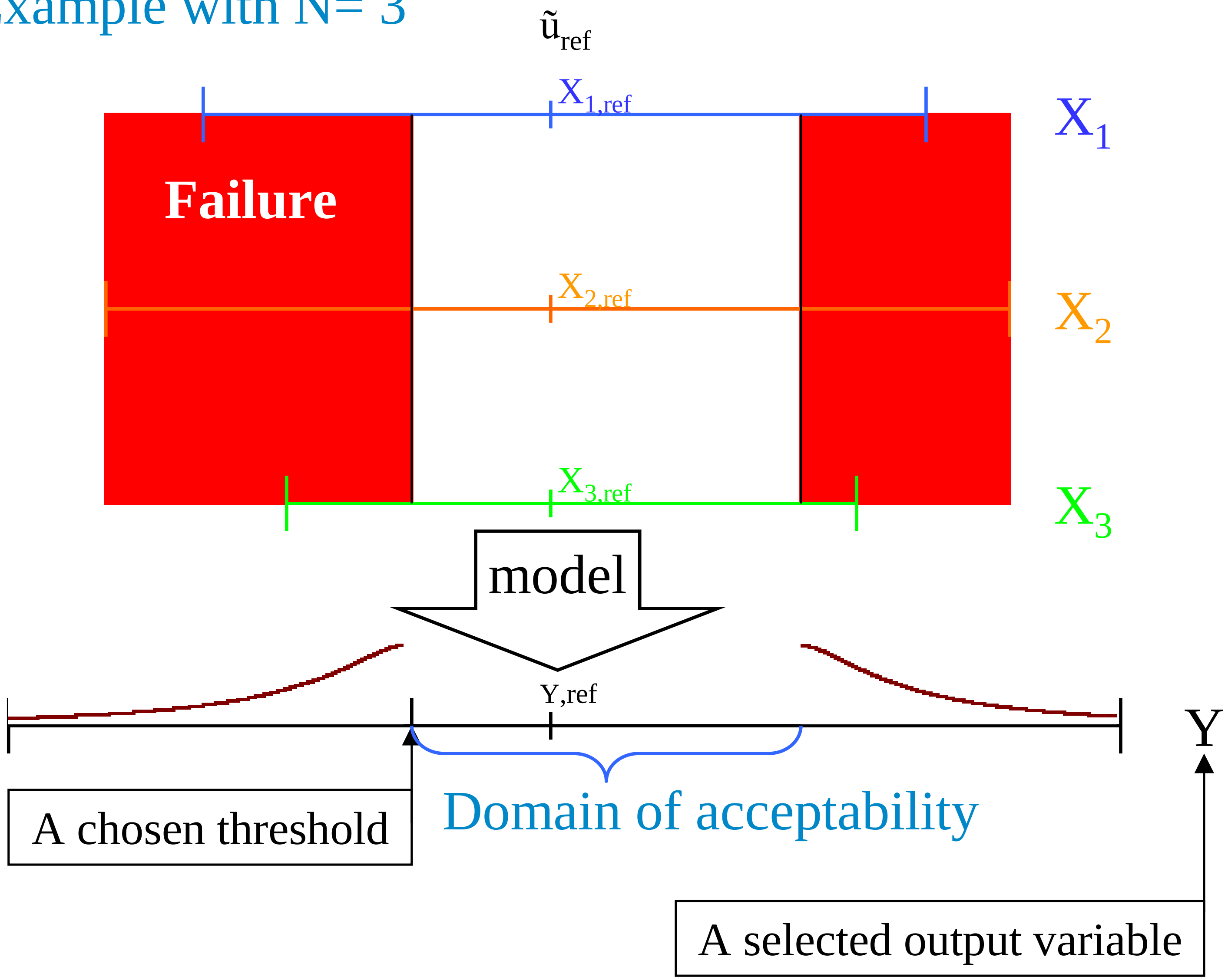
⊕ ← Robustness ← ⊖

F \ M	0	0.05	0.1	0.15	**0.2**	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65
0	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65
0.05	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7
0.1	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75
0.15	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8
0.2	0.2	0.25	0.3	0.35	**0.4**	$\longleftarrow \alpha(q, r_c) \longrightarrow$				0.65	0.7	0.75	0.8	0.85
0.25	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
0.3	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
0.35	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1.0
0.4	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1.0	1.05
0.45	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1.0	1.05	1.1
0.5	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1.0	1.05	1.1	1.15
0.55	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1.0	1.05	1.1	1.15	1.2
0.6	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1.0	1.05	1.1	1.15	1.2	1.25
0.65	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1.0	1.05	1.1	1.15	1.2	1.25	1.3

A quick example with fishing mortality and natural mortality: What choices do we have if we want total mortality not to be over 0.6 ?

Looking for the gap…

Example with N= 3



Looking for the gap…

Classically, the model studied using info-gap can be solved analytically (Ben-Haim 2001, Regan 2005, van der Burg and Tyre 2011)

The ISIS-Fish model has no global explicit solution: need to perform simulations to explore simultaneously the input and the output space.

How to correctly explore a potentially infinite space in a reasonable amount of time ?

The Need for Sensitivity Analysis

Sensitivity analysis has two main assets:

- It provides efficient statistical methods to evaluate the variation of the outputs conditional on the inputs
- It is associated with powerful tools to explore spaces in a limited number of simulations (Saltelli et al. 1999, 2000 and 2004)

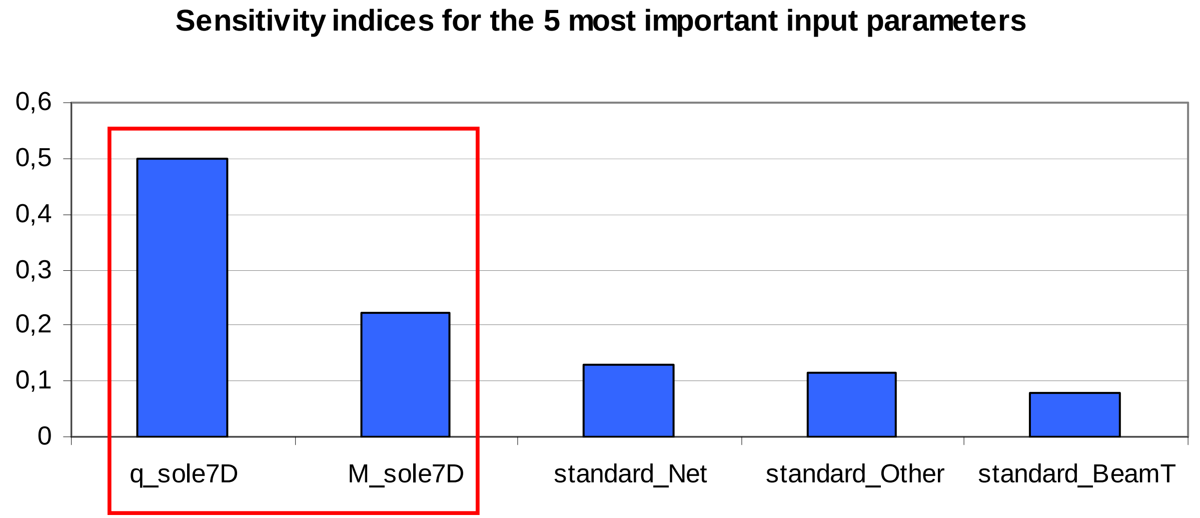
Sensitivity Analysis can be an interesting source of information and simplification, much needed before the use of info-gap

Sensitivity Analysis of the current Model

N=32 input parameters of the initial simplified model tested:

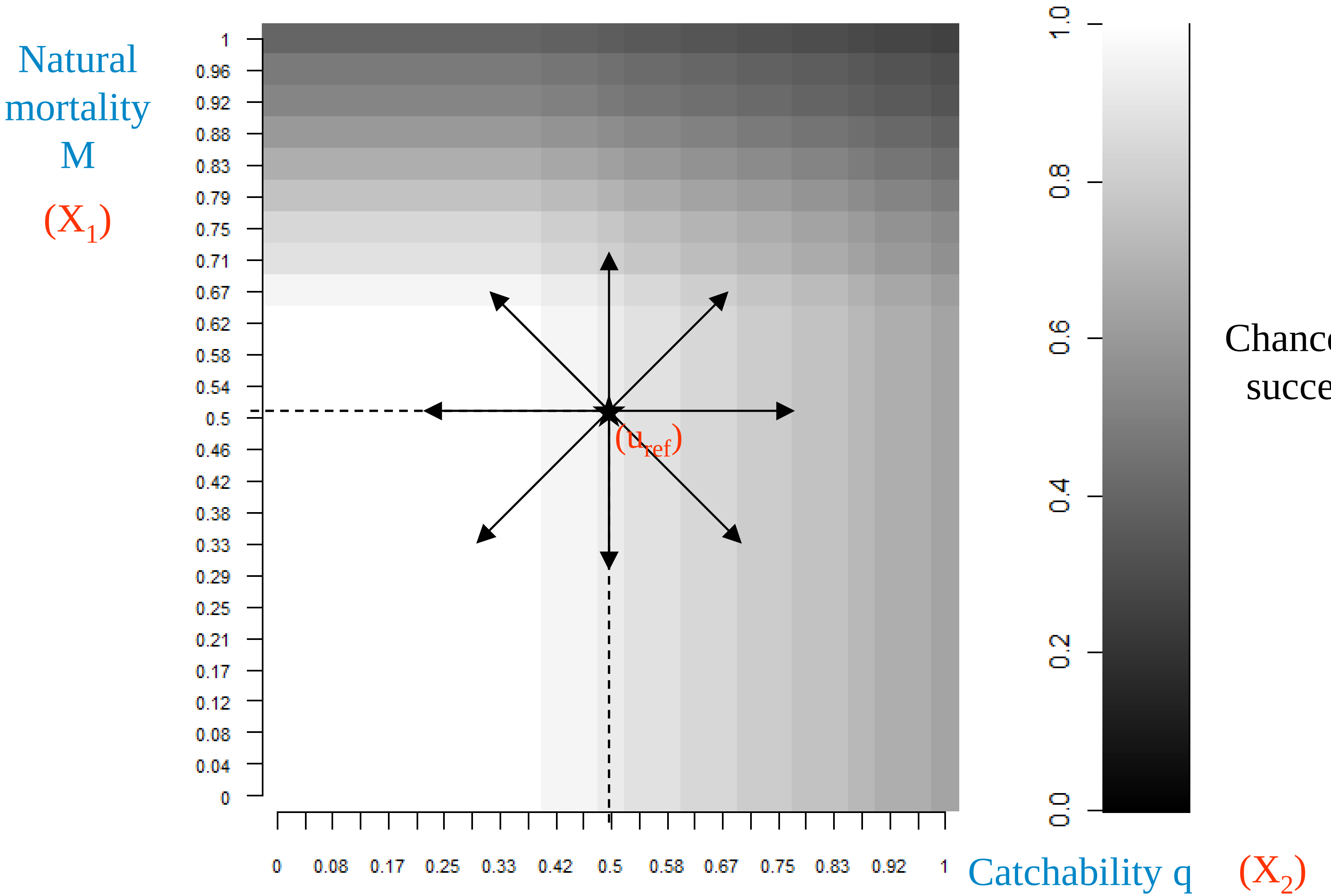
Category	Nb of parameters
Gears	3
Fleets	9
Plaice Biology	10
Sole Biology	10

To a reduced list of important input parameters :



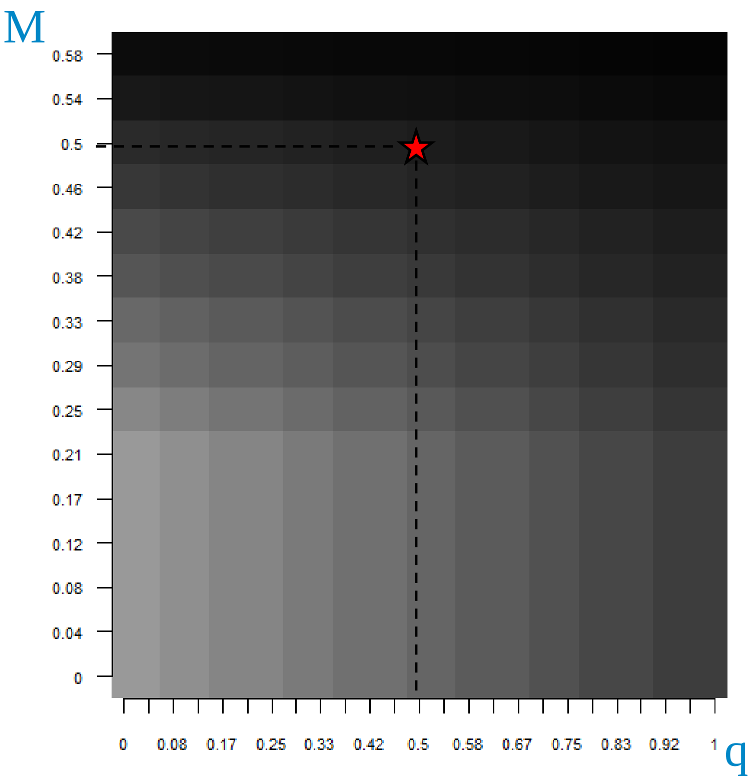
Chances to reach the threshold

Sole 7D, Criterion : Biomass of Sole > **10000t**, N=2,
u_{ref} = (0.5,0.5), qref ~3.10^{-3} , Mref =0.1, alpha = 100%



Chances to reach the threshold

Sole 7D, Criterion : Biomass of Sole > **20000t**,N=2, u_{ref} = (0.5,0.5), qref ~3.10^{-3} , Mref =0.1, alpha = 100%

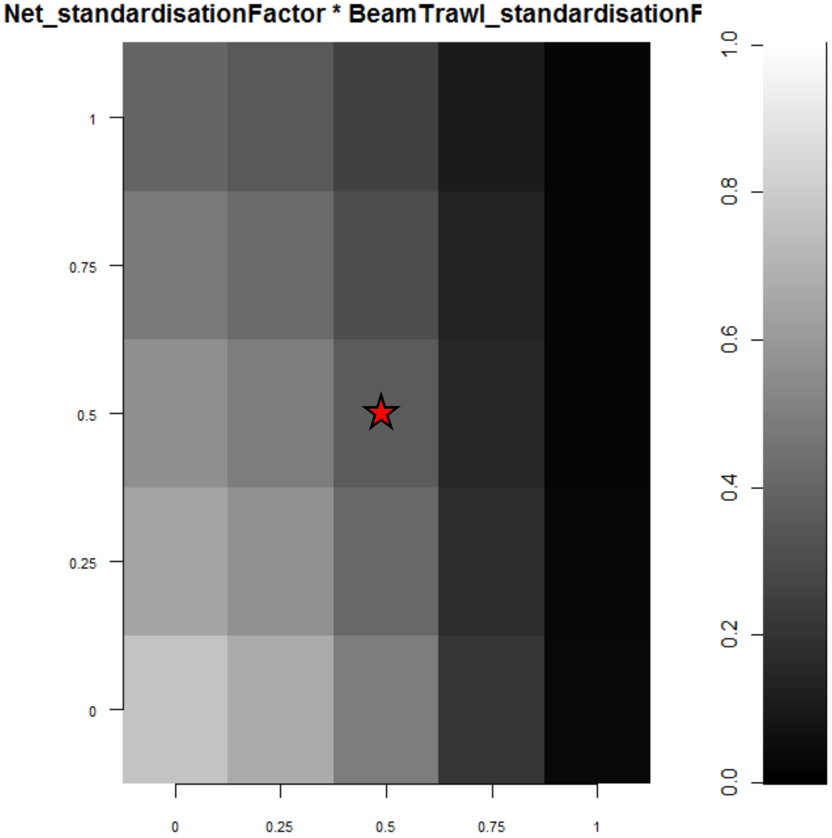


The user can choose which decision to make, depending on his level of knowledge, his confidence in it, his goals, his level of aversion to risk , etc.

Impact of management measures

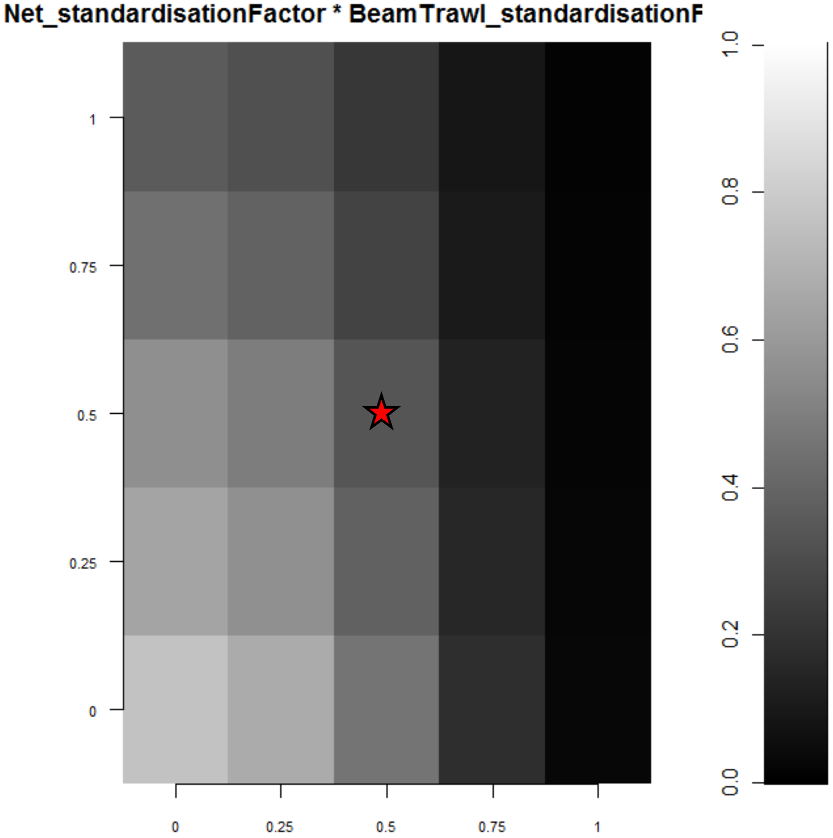
V4 !

Current effort



Sole 7D, Criterion : Biomass of Sole > **20000t**,N=2, u_{ref} = (0.5,0.5), Net_S=1 , Beam_S=1, alpha = 50%

Effort reduced by 25%



Sole 7D, Criterion : Biomass of Sole > **31000t**,N=2, u_{ref} = (0.5,0.5), Net_S=1 , Beam_S=1, alpha = 50%

Prospects

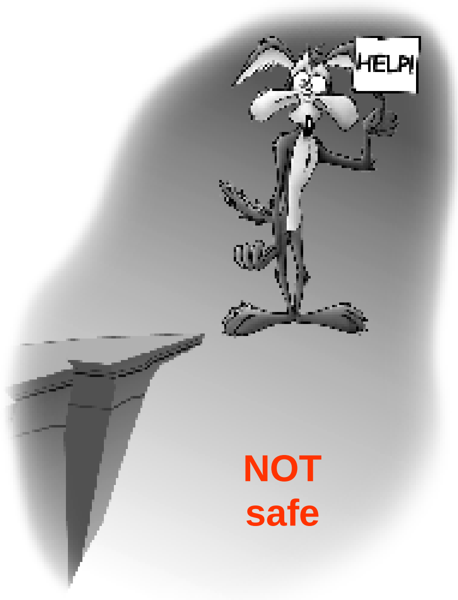
Set up a more complete model of the Eastern Channel

Test all sensitive parameters
→Need to find SA techniques as efficient as possible

Take stochasticity into account

Collaborative approach with stakeholders

Use this model as a support to decision making ?



Thank you for your attention !