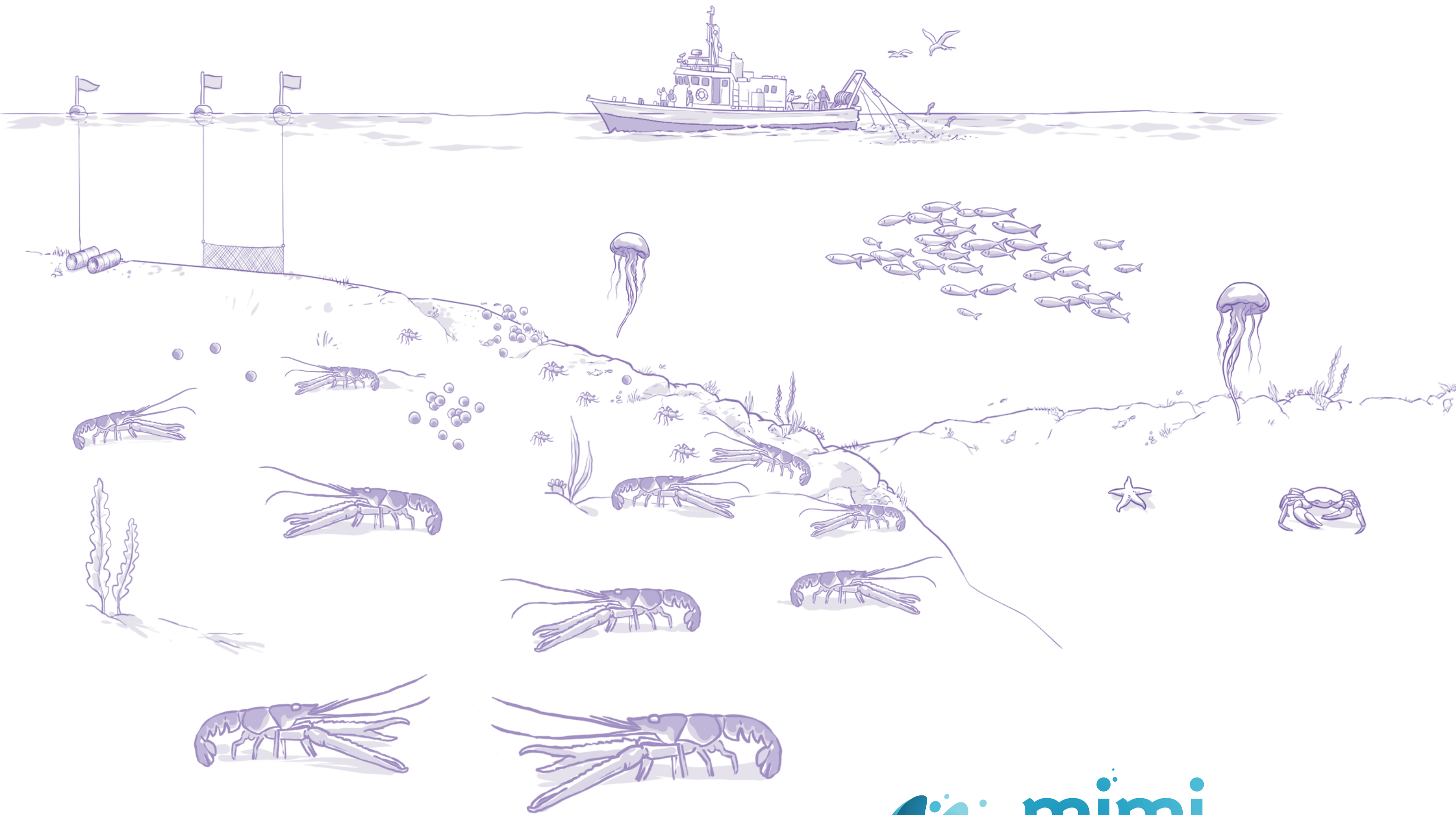
CHOOSING A SCENARIO BY EMBRACING UNCERTAINTY WHAT REPRESENTATION?

MIMI PROJECT – WORKSHOP 2 - 3 February 2023

ORGANIZED WITHIN THE FRAMEWORK
OF THE CNPMEM-IFREMER PARTNERSHIP GROUP.



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CHOOSING A SCENARIO BY EMBRACING UNCERTAINTY

WHAT REPRESENTATION?

"Expect the unexpected,"
said Edgar Morin

Preparing for the unexpected means anticipating that the future will surely not be the one we imagined, so as not to remain motionless. It means accepting uncertainty in action.
Fisheries management is no exception to this maxim, which challenges all stakeholders in the sector.

Implemented at the European scale through the Common Fisheries Policy, fisheries management aims to ensure the sustainable exploitation of marine natural resources, in line with desirable development objectives for 2030. A widely used approach to anticipate the future of fisheries is to build scenarios of the evolution of marine fish stocks and fishermen's catches using models.

Uncertainty is inherent in models and therefore present in the scenarios produced by these models. But how can it be represented? How can we choose fisheries regulations based on predictions from a model in which uncertainties have been identified?

As part of the MIMI project (Models, Imaginaries and Uncertainties), a first CNPMEM-IFREMER partnership workshop, "Modeling marine ecosystems without hiding uncertainty," enabled us to share graphical representations of the marine ecosystem and to identify uncertainties in these models. Based on the outcomes of this first workshop, a second CNPMEM-IFREMER partnership workshop was held to study and select graphical representations of uncertainty. These graphical representations concern both the inputs and outputs of a model used to predict quantities of Norway lobster (Nephrops norvegicus) in the sea and fishermen's catches.

Based on these choices, the participants explored scenarios for the fishery's evolution and made a diagnosis of the consequences of fisheries regulations in order to achieve the objectives of sustainable fisheries management.

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WORKSHOP PRESENTATION

The workshop was held online over a full day. This workshop, much more technical and guided than the first one (September 30, 2021), assumed that participants already understood the concepts of models and uncertainty discussed in the first workshop (Workshop 1 restitution booklet*). The aim of this workshop was to select a fisheries regulation based on scenarios generated by a model simulating biomass and catches of a fishery at a 5-year horizon, with uncertainty.

During the workshop, participants characterized uncertainties, learned how to handle them, and selected ways to represent them graphically. The workshop was structured into 3 phases, each organized with a scientific presentation followed by polls and discussions using a participatory method involving a digital whiteboard and quizz (Klaxoon software/tool).

* Restitution booklet link

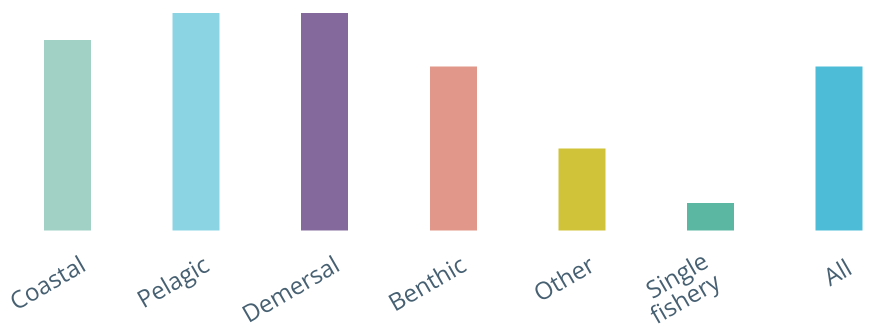
This booklet reports on the course and outcomes of the workshop. A glossary of the main technical terms is available on the last page. The graphs and overlays included in the booklet provide a way to visualize some of the results.

17 PARTICIPANTS

INCLUDING 6 SCIENTIFIC FACILITATORS (5 FISHERIES SCIENTISTS, 1 ECONOMIST), **2 ARTISTS, 2 COMMUNICATORS/OUTREACH SPECIALISTS, 7 FISHERIES STAKEHOLDERS**

The MiMi team present consisted of 6 scientists (facilitation team) and 2 participating artists. Most fisheries stakeholders had already attended the first workshop, except for 2 new participants.
All maritime areas of mainland France were represented, and 56% of respondents were interested in several of them. Similarly, 90% of fisheries stakeholders were interested in at least two fisheries.

FISHERIES OF INTEREST



Other:

- Offshore
- Oceanic purse seine
- Shellfish gathering

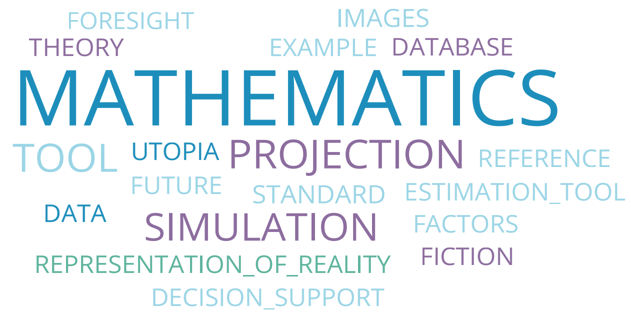
WORKSHOP OUTLINE

	PHASE 1	PHASE 2	PHASE 3	
Introductory quiz + presentation of the ISIS-Fish fishery	Characterization and representation of input uncertainties in the model	Characterization and representation of output uncertainties in the model	Analysis of management scenarios with uncertainties	**Final discussion**

INTRODUCTORY QUIZ - DEFINITIONS

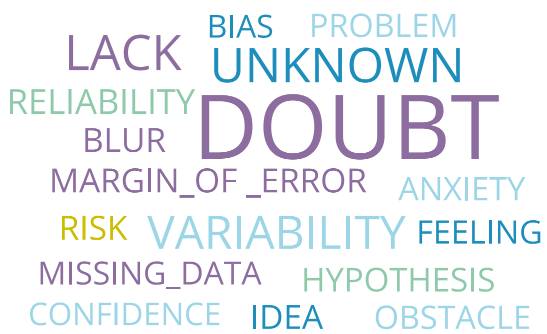
MODEL WORD CLOUD

The term "Mathematics" is by far the most common used to describe the notion of a "Model", reflecting the specific context of the workshop. Other terms that stand out (simulation, projection, tool)—and more generally, most of the less frequently mentioned terms—are precise and demonstrate knowledge of the concept and its use for prediction. Only three terms (utopia, fiction, images) broaden the meaning of the word "model" to a more subjective interpretation.



UNCERTAINTY WORD CLOUD

The term "Uncertainty" is strongly linked to the notions of "Error" and "Lack of knowledge." The other associated terms (risk, doubt, imprecision, variability, margin of error, confidence interval) are very precise and stem directly from the vocabulary of modeling. A few less frequent expressions (beauty, human) broaden the definition of uncertainty to a more subjective or sensitive interpretation.



ISIS-FISH WORD CLOUD

The terms used to describe ISIS-Fish are precise and largely technical. They relate to the representation of fisheries (fishing mortality, fleets, gears, catches, stock) and to ecosystem compartments (resources, natural environment, socio-economic environment, management). These expressions reflect the participants' familiarity with the model as a scientific simulation tool specifically designed to study fisheries, while some longer expressions echo the vocabulary employed during the model construction activity.

REPORTING ON ACTIVITIES

PRESENTATION OF THE CASE STUDY AND THE UNCERTAIN PARAMETERS EXPLORED

With ISIS-Fish, we configured a Norway lobster fishery inspired by the fishery of the “Grande Vasière” in the Bay of Biscay, which we deliberately caricatured and modified to facilitate the organization of this workshop. A full parameterization is available as part of the FFP Macco project (https://www.macco.fr/).

The life cycle of the Norway lobster is described in the model through 10 age classes distributed spatially across 9 rectangles of 1 degree longitude by 0.5 degree latitude. Each age class is characterized by an average carapace width (cephalothorax length), which makes it possible to model the regulation prohibiting the landing of lobsters with a carapace smaller than 20 mm (minimum landing size regulation). If an undersized lobster is caught, it is discarded back into the sea with a chance of survival (**survival rate = 0.5**).
Annual recruitment of juvenile lobsters depends on the quantity of mature lobsters capable of reproducing (Beverton and Holt stock–recruitment relationship). In this description, it is assumed that there is no larval dispersal of Norway lobster outside the 9 rectangles or between them. Each month of the year, the model produces a map of the number of lobsters by age class (abundance or biomass by weight).

Norway lobsters are caught by several groups of fishing vessels (trawlers) differing by their home port, length, target species (metiers: lobster trawlers, benthic fish, demersal fish), and their annual métier practices (strategies). Fishing effort (time spent fishing) is spatially distributed and varies across métiers and seasons within the 9 rectangles. Depending on the métier, this fishing effort is more or less effective at catching lobsters, and fishing efficiency may change over time (**efficiency drift = 0**). Each month of the year, by multiplying fishing effort by a factor called catchability, the model calculates a map of fishing mortality for lobsters for each métier.

Three regulations are considered: **minimum landing size** (SCENARIO_1, reference scenario), **a catch limitation by quota** (SCENARIO_2 = TAC = 500 tonnes), **and a marine protected area** (SCENARIO_3 = MPA = zone 23E6 – 24E6).

The fishery is simulated with the model over a 5-year period. The model simulates catches, abundance, and biomass of Norway lobster by rectangle, overlapping the métier fishing mortality maps with the abundance map of lobsters.

In Workshop 1, participants identified uncertain elements in the models described. For this second workshop, **we chose to explore the representation of uncertainty for four input parameters of the model, which had been identified as uncertain elements in the first workshop and are present in the ISIS-Fish model.**

THE PARAMETERS ARE:

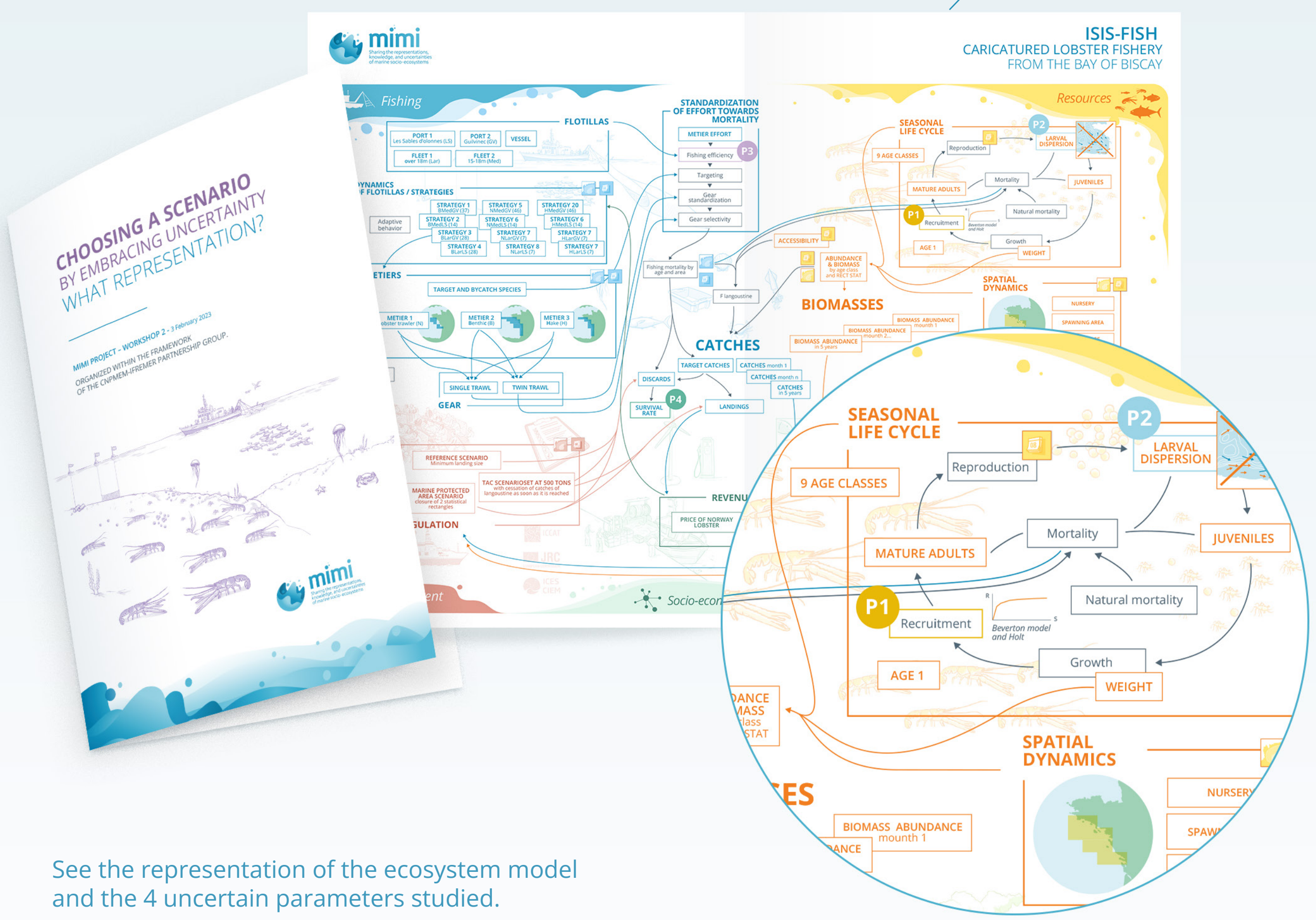
P1 — **The stock–recruitment relationship**
Link between the number of juvenile fish becoming available to the fishery and the number of spawners, approximated by the spawning biomass.

P2 — **Larval dispersal**
Larval dispersal includes spawning, larval transport (i.e., movement of larvae resulting from physical transport and larval swimming behavior in the water column), larval survival, and finally settlement of larvae at the end of the larval phase.

P3 — **Fishing efficiency drift**
Average change in the ability to catch accessible fish
(efficiency/power = capacity to catch accessible fish).

P4 — **Survival rate**
Percentage of survival of discards (catches not landed for various reasons such as undersized individuals, damaged animals, no market, or quota exceedance) (source: Ifremer, Gardons la Pêche).

Figure 1



See the representation of the ecosystem model and the 4 uncertain parameters studied.

DURING THIS WORKSHOP, WE FOCUS ON ANSWERING THE FOLLOWING QUESTIONS BY PROPOSING A DIDACTIC APPROACH AND TOOLS:

PHASE 1

- *What is the uncertainty regarding the model’s input parameters? How can it be represented?*

PHASE 2

- *What is the uncertainty in the model outputs (biomass and catches) induced by the uncertainty in the input parameters? How can it be represented?*

PHASE 3

- *Can we make a diagnosis of management scenarios despite this uncertainty?*
- *Can we identify the parameters that have the greatest influence? Can we sort them out and identify those on which collective work could be done to reduce output uncertainty?*

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ISIS-FISH
CARICATURED LOBSTER FISHING ACTIVITY FROM THE BAY OF BISCAY

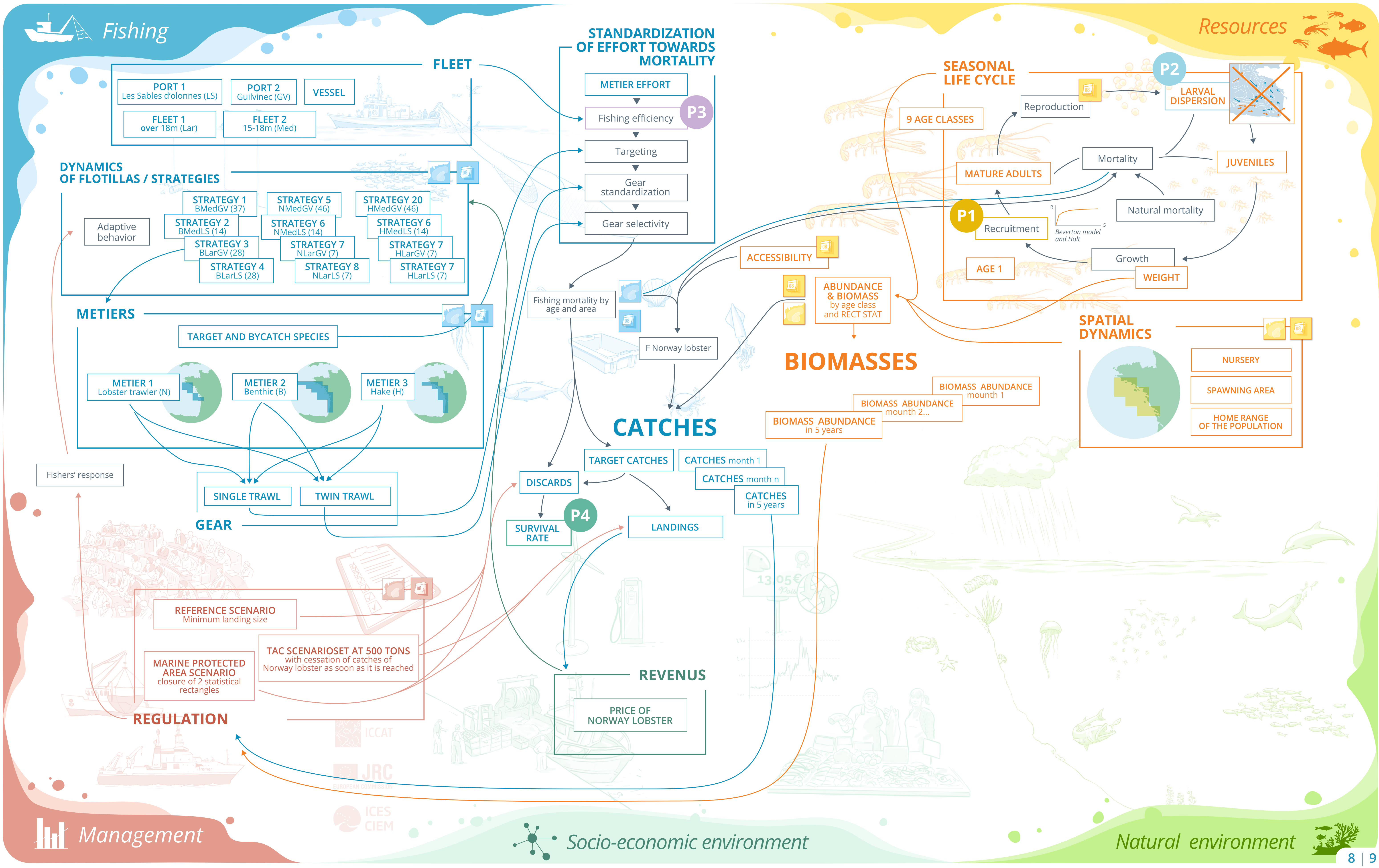


Figure 1

TEACHING TOOL
CHARACTERIZATION OF THE UNCERTAINTY OF AN INPUT PARAMETER AND OF AN OUTPUT VARIABLE

During this workshop, we proposed and explained a set of possible representations of uncertainties in the model inputs (INPUT) (for parameters P1, P2, P3, P4) and in the model outputs (OUTPUT) (biomass, spawning biomass, and catches). During the workshop, participants voted to identify the mode of representation they felt was the most appropriate (practical and visual).
See the 8 types of representation proposed: Figure 3 (diagrams 1, 2, 3,and 4) and Figure 4 (diagrams 5, 6, 7, and 8) with the associated layers. The majority choice is presented* in the booklet for each parameter and output variable.

* The majority choice

Figure 3
Representation diagrams 1/2

Layer 1
Model input (parameter)

Layer 2
Model output (variable)

Figure 4
Representation diagrams 2/2

Layer 3
Model input (parameter)

Layer 4
Model output (variable)

PHASE 1
What is the uncertainty regarding the model's input parameters? How can it be represented?

PRESENTATION OF THE VALUES CHOSEN FOR EACH PARAMETER AND THEIR ASSOCIATED UNCERTAINTY

P1 THE STOCK/RECRUITMENT RELATIONSHIP

The stock–recruitment relationship (S/R relationship, see glossary) is not always well defined depending on the stocks studied. Several S/R relationships exist, each associated with different biological and ecological hypotheses (changes in fecundity with size, importance of habitat and currents, competition between adults and juveniles, etc.). To determine which S/R relationship to use, scientists rely both on available data and on their knowledge of the stocks, acquired for example through a review of the literature.
We reproduced this process of selecting an S/R relationship by first fitting 5 types of S/R relationships to the data (scatter plot) from the Norway lobster stock assessment. We then carried out a first evaluation of which S/R relationship to use by asking participants to identify the one that seemed most appropriate.

SPAWNING BIOMASS

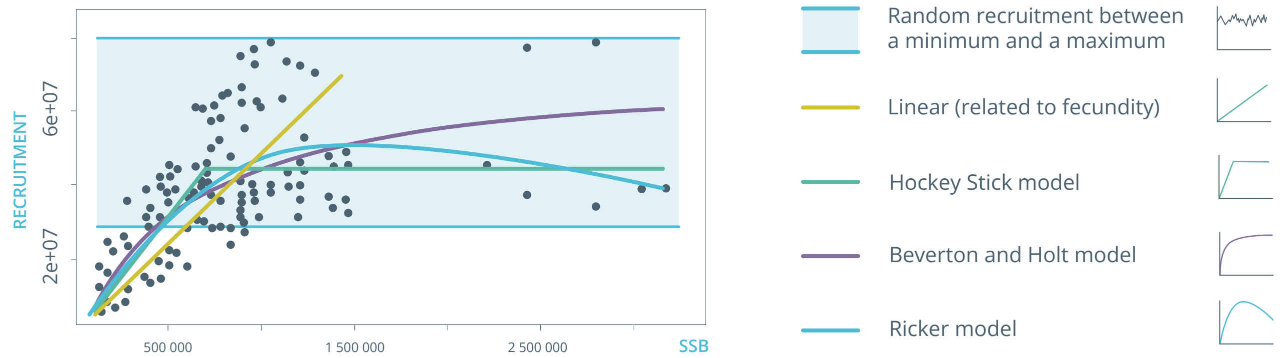


Figure 2 - Illustration of the fitting of different types of S/R relationships (listed on the right) to the data points from the Norway lobster stock assessment. The different S/R relationships all appear to be valid for this case study, highlighting the existing uncertainty as to which S/R relationship should be used for this stock.

Three documents were then presented in order to provide knowledge to help in choosing which S/R relationship to use. The first document, a rather old scientific article, indicated a linear relationship between the number of eggs and the size of the Norway lobsters. The second document, stemming from a recent Master's thesis, showed that a current model could explain part of the variability in recruitment. The third document presented photographs of Norway lobster burrows, accompanied by expert explanations on how burrows are used to characterize the relationship between adults (stock) and juveniles (recruitment).

After reviewing these documents, another survey was conducted to assess which S/R relationship seemed the most appropriate. The comparison of the surveys and the ensuing discussions showed that the contribution of knowledge through the three documents modified the participants' perception of the scatter plot and of the S/R relationship that seemed the most appropriate. The importance of having knowledge about the species' biology and ecology was emphasized, although not all documents were judged equally useful. Thus, the predominant source of information in the final choice of the S/R relationship remained the scatter plot from the stock assessment data (15 votes), followed by the documents on currents (9 votes) and the burrow photos (9 votes), and finally the document on fecundity (7 votes).

The contribution of knowledge can also make S/R relationships appear valid that did not initially seem so. It was also noted that several choices could be considered valid for this stock, which may lead to a "default" choice. In such cases, the S/R relationship associated with randomness is generally used as the default. However, in the absence of consensus, it is possible to use several types of S/R relationships in the 5-year simulations. This is, in fact, what scientists generally do when uncertainty persists about the appropriate form of the S/R relationship.

REPRESENTATION DIAGRAMS 1/2

INPUT SETTINGS

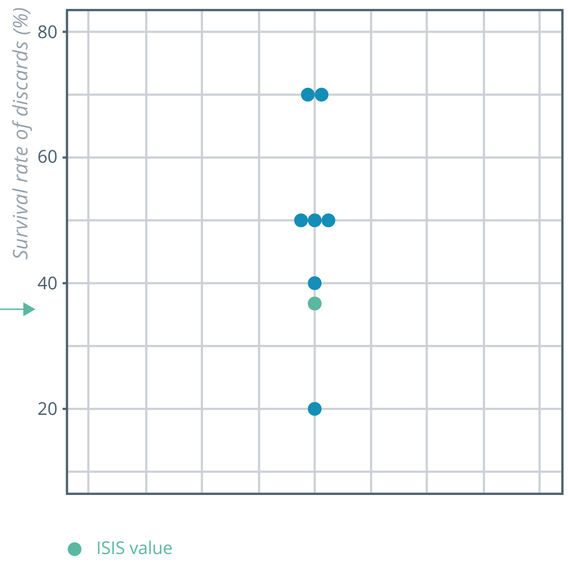
OUTPUT VARIABLES

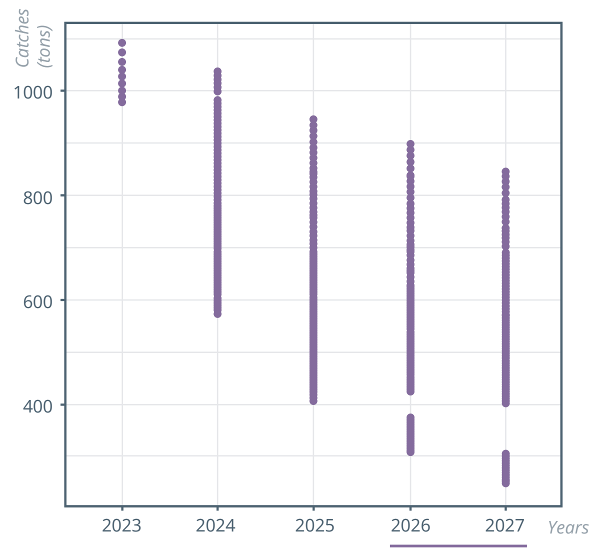
1_ GRAPHIC WITH POINTS

The points represent all the values obtained.
This clearly shows dispersion (minimum and maximum), continuity (are there points everywhere? gaps?).
However, if two observations have the same value, the points overlap, so the frequency of occurrence of values (the distribution) is not visible.
In the case of simulation outputs, it is not known which points were obtained within the same simulation.

The lowest value (20% survival) was chosen by only one participant. The most frequently chosen value was a survival rate of 50% (3 responses), followed by 70% (2 responses), and finally 40% (1 response). All participants therefore consider that a portion of the discarded Norway lobsters survives fishing operations and subsequent discarding.

Discontinuity in the values obtained in the 4th and 5th year.

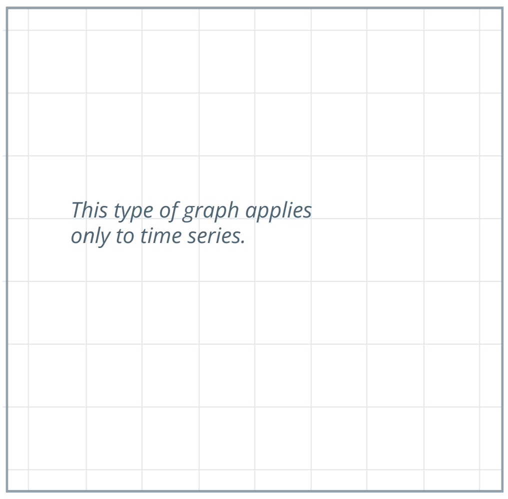


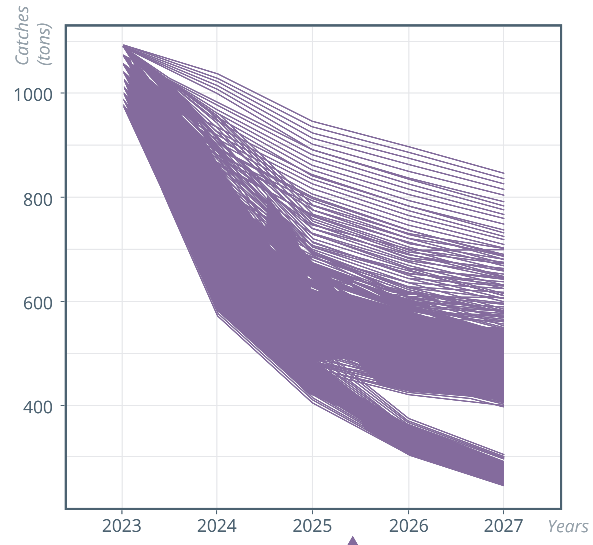


2_ LINE GRAPH

The lines connect the values obtained during the same simulation and allow visualization of the trajectory (or time series). This is particularly useful when trends differ from one simulation to another, as the density of the lines provides an idea of how many simulations follow the same pattern. However, this type of graph becomes very difficult to read when there are many trajectories and they intersect.

Downward trajectories during the simulation. Often, a rapid decrease in the first years followed by a slower one (stabilization). It is observed that most trajectories (high black density) show stronger decreases in catches, and two discontinuous groups of trajectories appear from the 4th year onward.

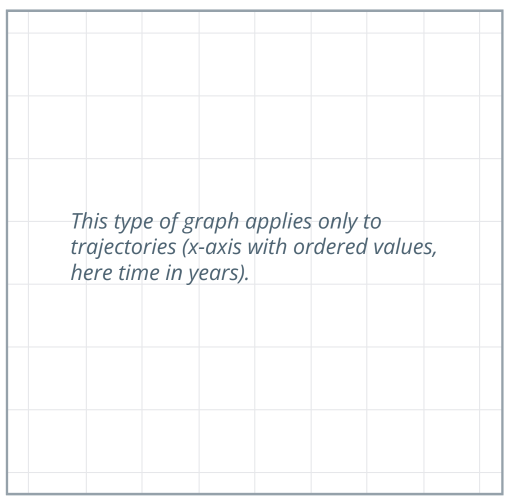


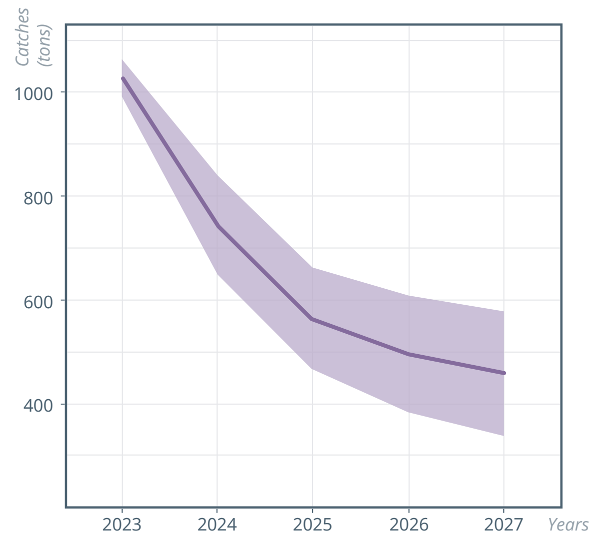


3_ ENVELOPE GRAPH

The envelope representation illustrates the spread of the trajectories. The wider the envelope, the more the results are spread over a wide range. The envelope can represent different measures of value dispersion: the minimum and maximum, for example, or the standard deviation, as is the case here (this should be stated in the legend).

Downward trajectories during the simulation. Often, a rapid decrease in the first years followed by a slower one (stabilization).
On average, catches decrease from 1031t in the 1st year to 457t in the 5th year. Uncertainty is greater at the end of the simulation, with a standard deviation from the mean of 120t compared to 36t at the beginning of the simulation.



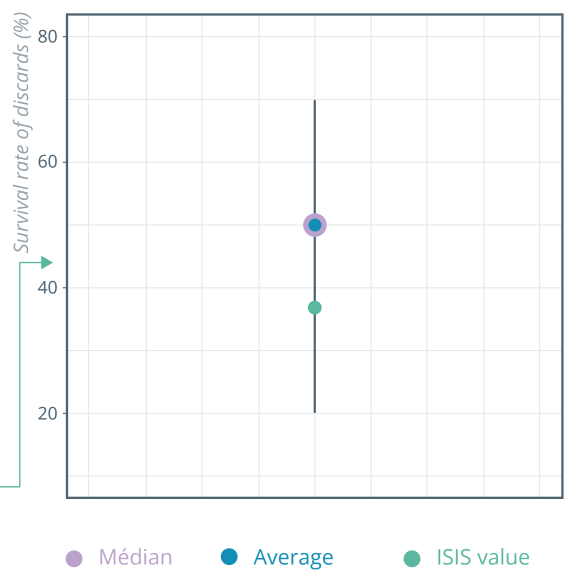


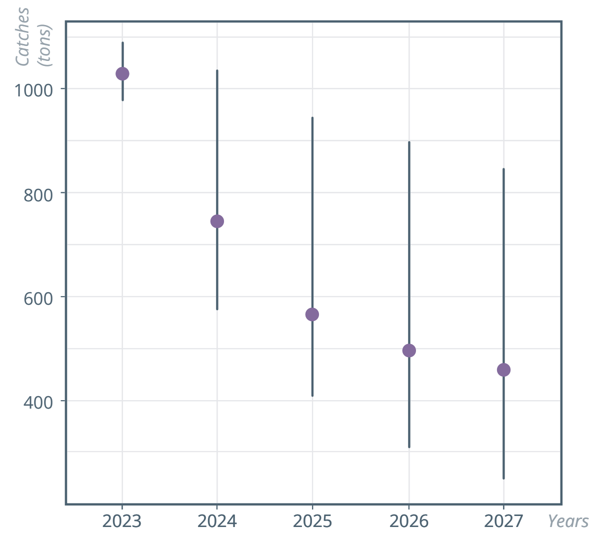
4_ ERROR BARS

Value ranges represent metrics that summarize the distribution of observations. Often, the mean of the observations is used, represented by a point, and a measure of the distance of the points from the mean, represented by vertical bars on either side of the mean.
Here, this is the standard deviation (see glossary), but other statistics can be used (indicated in the legend).
These are very synthetic and easy-to-read graphs.
However, they can give a possibly misleading impression of symmetry (if the point in the bar is the mean) and of continuity of values.
Moreover, the statistics used may not be intuitive and may fail to illustrate the full spread of observations.

The minimum and maximum discard survival values considered by the participants are 20% and 70%. Here, the mean and the median values overlap and are equal to 50%.

Downward trajectories during the simulation.
On average, catches decrease from 1031t in the 1st year to 457t in the 5th year. Uncertainty is greater at the end of the simulation, with a standard deviation from the mean of 120t compared to 36t at the beginning of the simulation.





Uncertainty about catches from the first year (979t to 1091t) which increases over time (247t to 846t).

Figure 3

REPRESENTATION DIAGRAMS 2/2

INPUT SETTINGS

OUTPUT VARIABLES

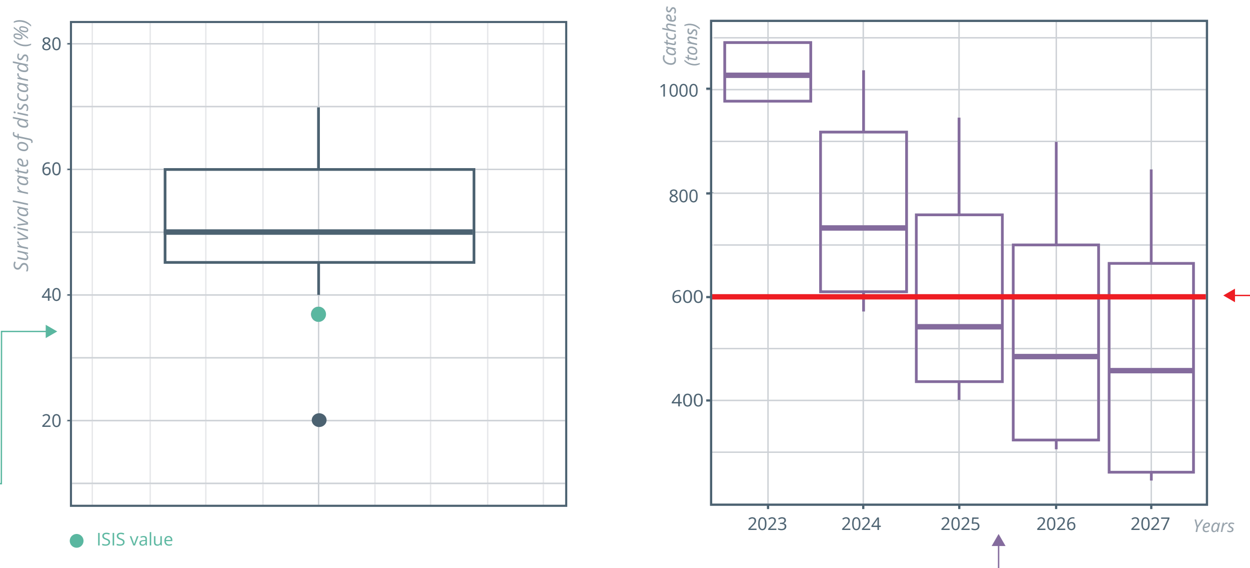
5_ BOXPLOT

The boxplot shows the frequency of values, this time using quantiles.
By convention, the central bar represents the median of the observations (see glossary). The edges of the box generally represent the values between the first and third quartiles (see glossary, i.e., the values outside represent a quarter of the lower and upper values) and the ends of the lines (the "mous-taches") delimit the quantile interval at 5% and 95%, (90% of the values around the median, choice made for the inputs) or the minimum-maximum range of values (choice made for the outputs).

When the whiskers show the range of 5% and 95% quantiles, we observe the outliers outside the range. It is therefore important to read the legend carefully to know which quantiles were chosen for the box and for the whiskers. This graphic representation illustrates the possible asymmetry of the distribution of observations with respect to the central bar.

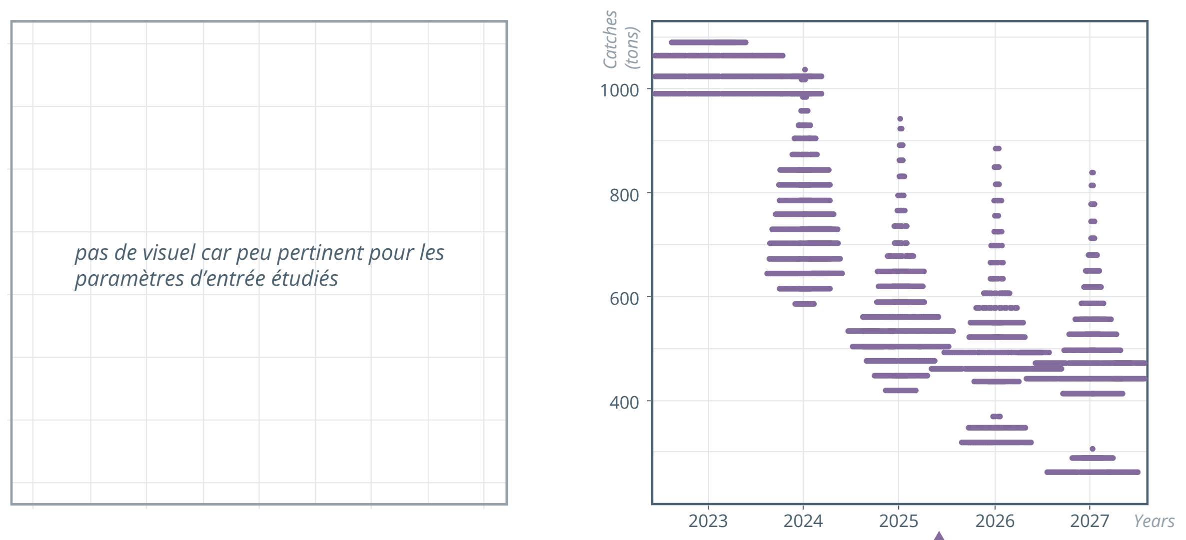
The median (purple dot) of the survival values (see glossary) is equal to the mean (blue dot). In this representation, the limits of the "whiskers" (or lines on either side of this box) approximately represent the 95% confidence interval. A survival of 20% is therefore considered a potential outlier.

Uncertainty in catches from the first year (979 to 1091t) which increases over time (247t to 846t). In 2027, 50% of the simulations have catches greater than 458t and 5% are greater than 663t. Asymmetric distribution: greater dispersion for high catch values. On the contrary, the lowest 5% values are very close around the 5% quantile.



6_ DOT PLOT DIAGRAM

A dot plot represents the frequency of values grouped by interval by plotting side by side all the points associated with the values in the interval.
When used for multiple values on the abscissa (horizontal axis), as shown for a trajectory, they can be misleading because the points are no longer aligned with their abscissa value, so one might think they are obtained for different abscissa values.

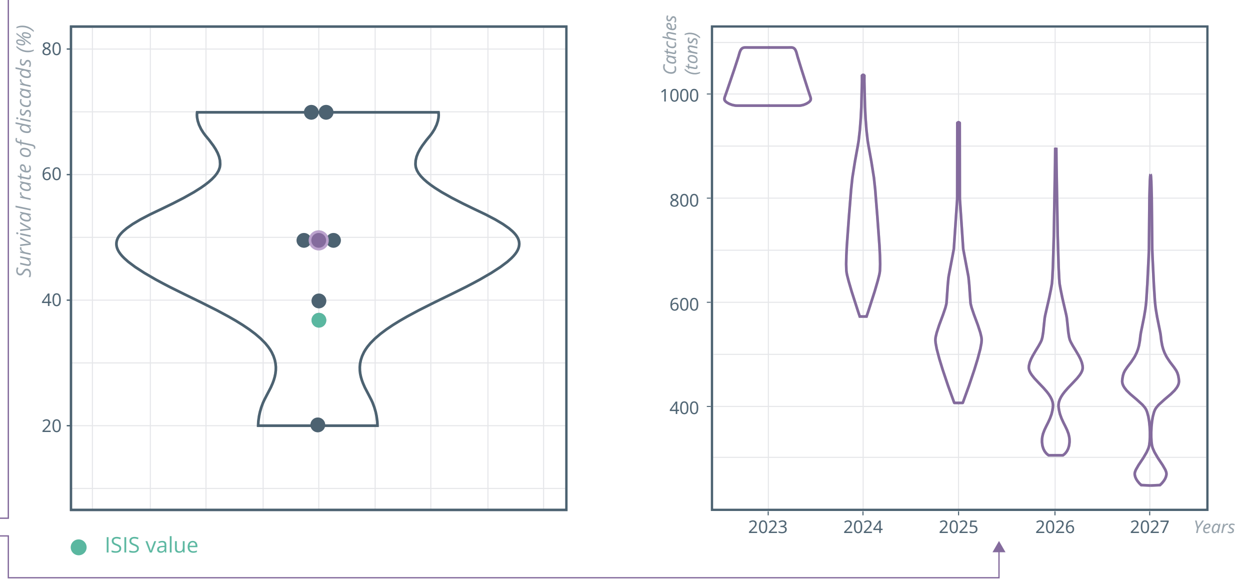


7_ VIOLINS

The violin plot allows us to account for the frequency of each value. It's like drawing the contours of the dotplot. The wider the violin plot, the more frequent the value.
However, to draw them, interpolation is performed and can be misleading: the violin plot may have thickness for values that do not exist in the observations. In fact, the violin "smoothes" the contour to obtain a rounded shape.

The asymmetry of the distribution is even more visually evident than with box plots. The dispersion is greater for low values compared to the average. This distribution is "driven" by the estimated survival of 20%

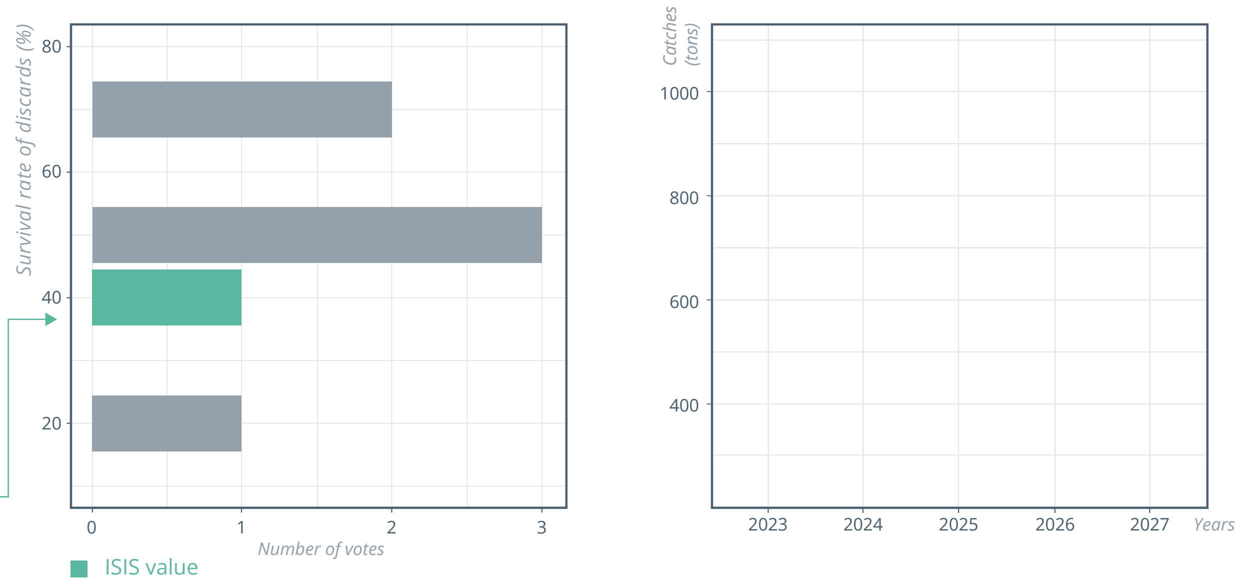
Discontinuity in the values obtained in 4th and 5th year. Asymmetric distribution: greater dispersion for higher catch values. In 2027, the majority of simulations are around 450t, with fewer and fewer simulations for higher values. Conversely, for lower values, there is a discontinuity between 430t and 300t, and many simulations below this level.



8_ BAR CHART OF DENSITY

The density bar plot shows how often each value occurs.
As with the violin, the density is an interpolation and can be misleading because it gives the illusion that all the values on the x-axis exist in the observa-tions. The frequency of the value in the observations can be read on the y-axis (approximate probability).

The most common value is 50%



The red horizontal line indicates the target to be achieved (here 600t). It allows you to calculate the risk of not reaching the objective each year. For each year, the risk is the proportion of simulated values below the line divided by the total number of simulated values. For example, in 2023 the risk is zero, while in 2027 it is high and equal to 90%.

Uncertainty about catches from the first year (979t to 1091t) which increases over time (247t to 846t).

Figure 4

P2 LARVAL DISPERSAL

80% of participants believe that there is larval dispersal in Norway lobster.
To represent the responses to this two-modality survey (yes/no), two representation modes were proposed (bar representation or pie chart). A pie chart representation was unanimously chosen, considered to be the most visual and the most practical

REPRESENTATION IN PIE CHART *

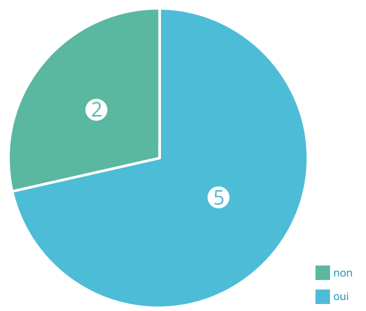


Figure 5

P3 THE EFFICIENCY DRIFT

86% of participants believe that there is a drift in fishing efficiency over time. To represent the responses to this sixmodality survey (-5, 0, 5, 10, 15, 20% drift in efficiency), a bar graph is used. unanimously accepted.
Of all the votes, only one person considers that there is no drift, a majority thinks that the drift is between 5 and 10% and one person considers that this drift reached 20%.

REPRESENTATION IN BARS *

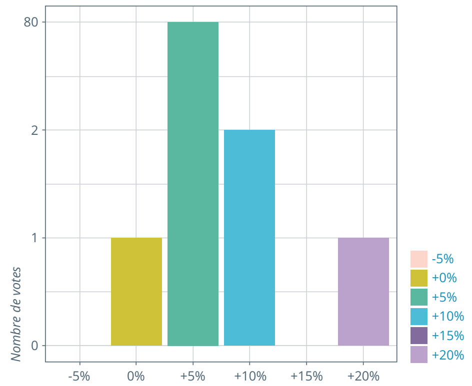


Figure 6

P4 SURVIVAL PROPORTION

All participants considered that some of the Norway lobsters survived during the discarding process. To represent the responses to this survey, violin plots and boxplots were used. Across all the votes, the lowest survival percentage reported was 20% by one participant and the maximum percentage was 70% by two participants.

BOXPLOT *

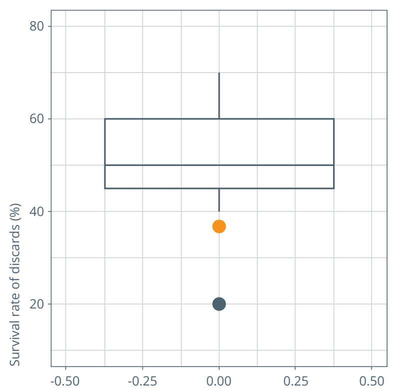


Figure 7

VIOLIN *

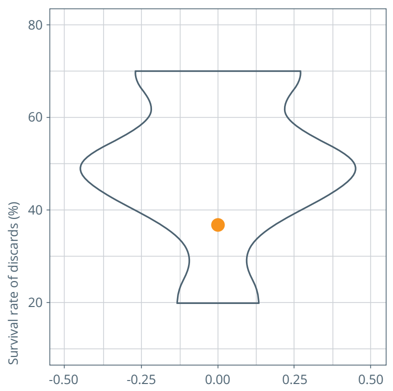


Figure 8

Presentation of possible values and the representation of the chosen uncertainty: combination of the results of the E3 and E4 surveys (output Klaxoon)

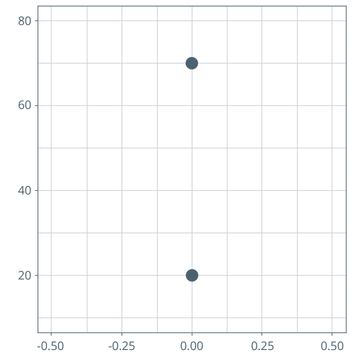
● ISIS value

TEACHING TOOL
DO YOU BUILD A BOXPLOT AND A VIOLIN?

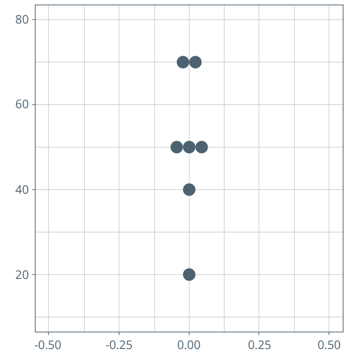
STEP 1

The first step consists of characterizing the minimum and maximum values of the parameter. For the proportion of survival of the rejects, the participants chose 20% and 70% respectively (Min-Max). This representation makes it possible to account for the possible range of variation of the parameter and the positioning of the average value in this interval.

MIN-MAX



ALL VALUES



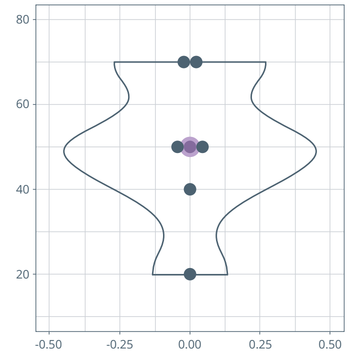
STEP 2

The second step consists of representing all parameter values. The lowest value (20% survival) is chosen by only one participant. The most frequently chosen value is a survival rate of 50% (3 responses), then 70% (2 responses), and finally 40% (1 response).

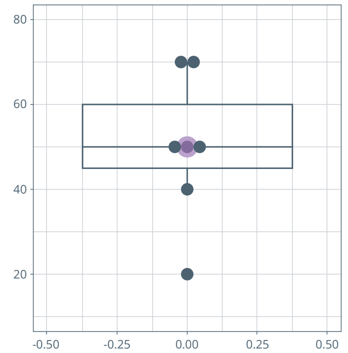
STEP 3

The third step consists of reporting the distribution of values and their frequency of occurrence; **3 modes of representation** are classically used.

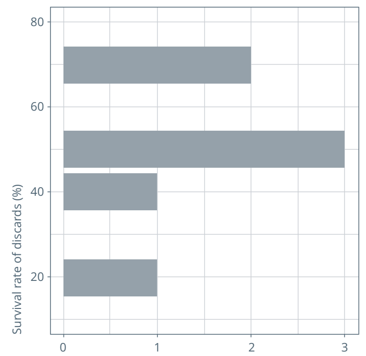
VIOLIN



BOXPLOT



BARS



● Median ● Average

Figure 9

The violin plot is the result of two interpolations. Interpolating the frequencies of occurrence of the values allows us to obtain the probability density of observation of these values. The violin plot consists of representing this density with its symmetrical relation to the central axis. In addition to the mean value, we can also add the median value (in purple, see glossary). This "continuous curve" representation method encourages us to extrapolate frequencies for unobserved values.

The box and whisker plot is a second method of representation. The box represents all values between the first and third quartiles (see glossary). This representation positions all values relative to the median (horizontal bar in the box). The vertical bars above and below the box indicate the inter-quartile limits (at 5% and 95%) representing the distribution of 90% of the values around the median. These bars are called whiskers. Points beyond the whiskers are values often referred to as "outliers". For example, here the survival probability equal to 20% is considered an outlier. This type of representation shows a distribution of values that is asymmetrical relative to the median and a greater dispersion for low values.

The bar chart directly represents the frequencies of each value or of the values grouped into classes (Fig.9 - BARS). Here we are talking about values and not classes. This last representation allows you to quickly visualize the range of values and the most frequently given value (50%).

PHASE 2

What is the uncertainty in the model output (biomass and catches) induced by the uncertainty in the input parameters? How to represent it?

SIMULATE CATCHES AND BIOMASS OVER 5 YEARS
WITH REFERENCE VALUES

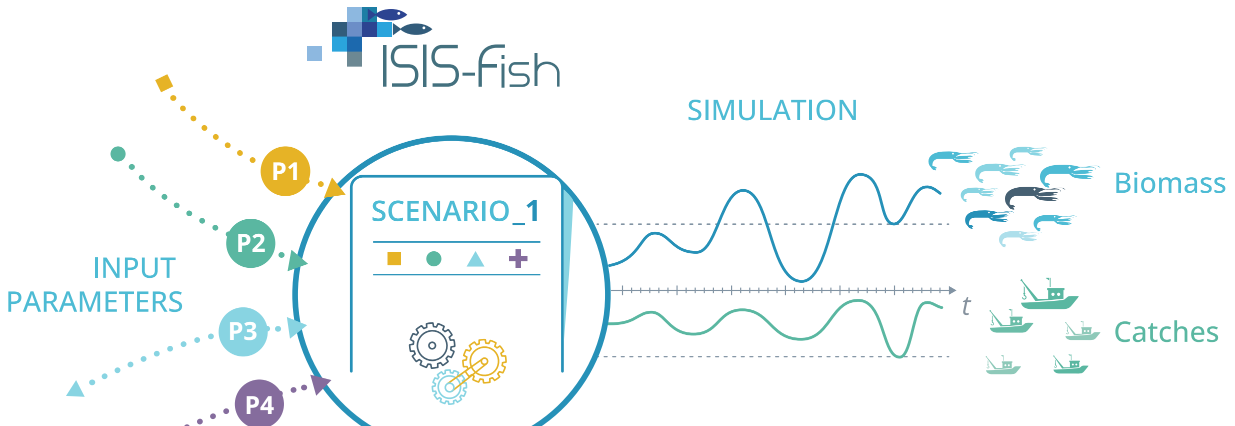


Figure 10

The reference simulation (SCENARIO_1) corresponds to the initial parameterization (described on page 4, Presentation of the case study) of P2 the fishery with the minimum size regulations. SETTINGS To assess the consequences of uncertainty in the four input parameters of the model (the stock- INPUT relationship P3 recruitment, survival proportion, larval dispersal and fishing efficiency drift) on the Catch variables model output (catch and biomass of Norway lobsters over 5 years), we simulated the Norway lobster fishery for a set of possible values.

> As output, we analyze the monthly values of catches and biomass of Norway lobster for the period 2023 to 2027. This simulation plan is repeated for the other 2 management scenarios (SCENARIO_2 and _3)

SIMULATION PLAN
WITH UNCERTAIN VALUES

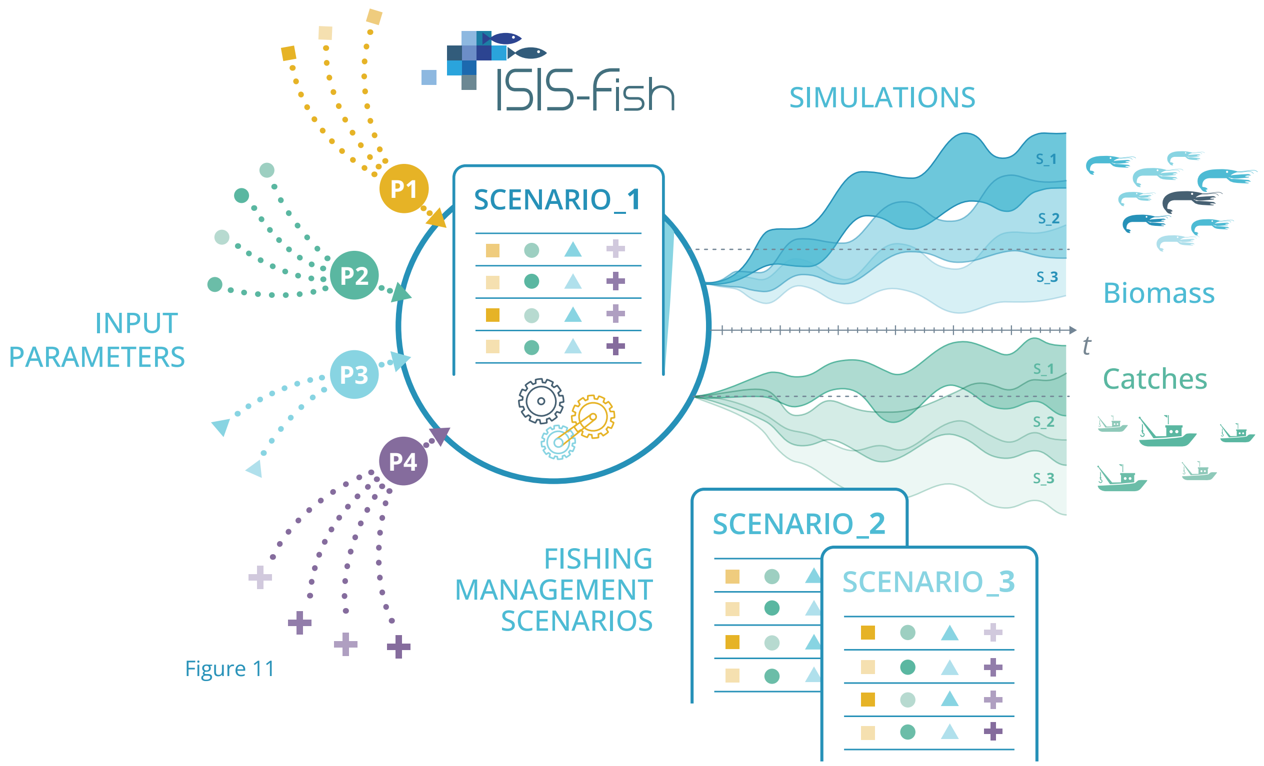


Figure 11

REPRESENTING UNCERTAINTY ON THE MODEL OUTPUT VARIABLES

In the case of the reference scenario, we observe the evolution over time of the three output variables: biomass, annual catches and spawner biomass (Fig. 12). Among all the proposed representations of the uncertainty of the output variables (Fig. 3 and 4, layers 2 and 4), the one that is mostly preferred is the envelope.

Biomass and catches decrease over the five years of simulation. SSB decreases in the first year and increases again in the 4th and 5th years, without reaching the initial level. Uncertainty increases over time; this is referred to as uncertainty propagation, particularly for biomass. For SSB, there is no uncertainty in the first three years of simulation, reflecting the fact that the uncertain parameters that concern small individuals through discards (survival probability) and recruitment (stock-recruitment relationship) do not greatly influence mature individuals before 4 years of simulation. The efficiency drift uncertainty values are only very different after 3 years of simulation and therefore cannot greatly influence outputs during the first 3 years of simulation. **The same uncertainty therefore does not impact outputs of the same way.**

BIOMASS ENVELOPE

CATCHES ENVELOPE

SPAWNING STOCK BIOMASS (SSB) ENVELOPE

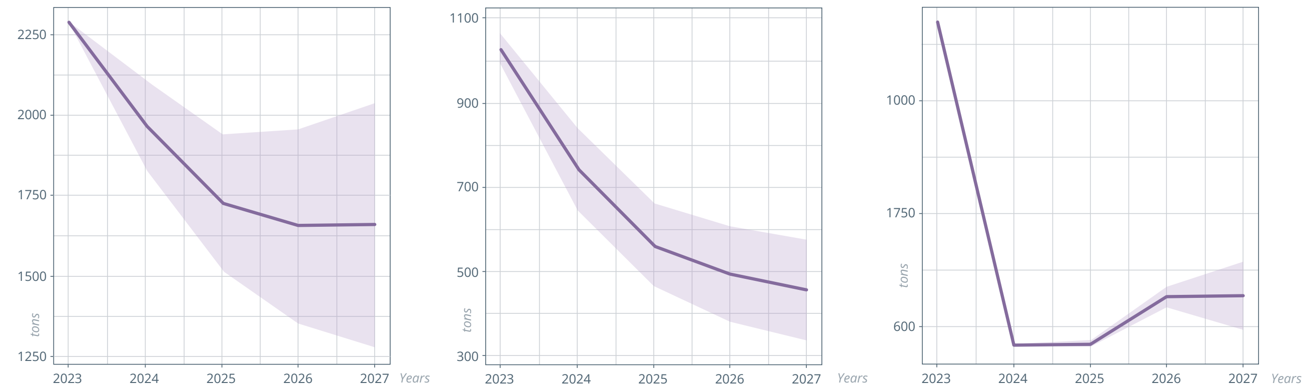


Figure 12 - Presentation of SCENARIO_1 with the uncertainty induced by P1, P2, P3 and P4. Evolution trajectory of biomass (left), annual catches (center) and spawner biomass (right) using a line for the average of the simulations and an envelope to visualize the standard deviation.

The standard deviation from the mean in the 5th year of simulation is 300 t for biomass, 100 t for catches and 50 t for SSB. Other graphical representations (not shown) highlight a detachment of certain simulations from the general trend (one of the selected stock-recruitment relationships producing biomass values much lower than the others). Some representations highlight that for more than 5% of the simulations the final biomass is higher than the initial biomass.

REPRESENTING THE UNCERTAINTY OF THE DIAGNOSIS ON MANAGEMENT SCENARIOS USING MODEL OUTPUT VARIABLES

Representing the values of the output variables for the 3 scenarios on the same graph allows us to compare their results and their uncertainty and thus to conclude on the significance of the differences between scenarios. For example, in the case of the SSB (Figure 13), the trajectories of the AMP and reference scenarios are close for the first three years. However, the uncertainty is low and we can therefore conclude that the SSB will be higher in the AMP scenario in the second year but lower in the first year. At the end of the simulation, despite greater uncertainty, the values are quite distinct and the envelopes do not overlap.

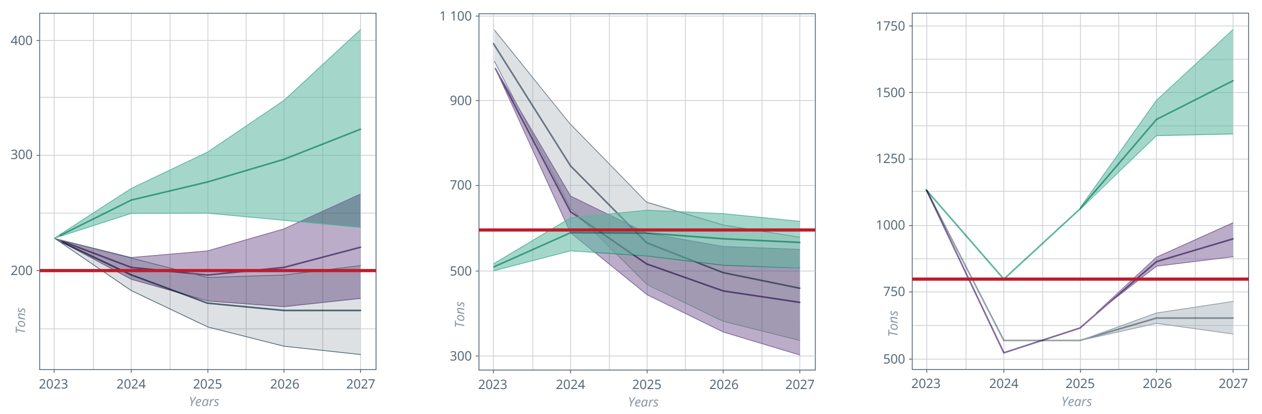
We can therefore conclude that the TAC scenario will significantly increase the SSB compared to the MPA scenario, and that whatever the TAC or MPA scenario, the SSB will be greater than with the reference management (minimum size). For catches, the superposition of uncertainty envelopes makes it difficult to classify the scenarios, even if the lines of average values position the MPA scenario below the reference and TAC scenario.

Indeed, quickly during the simulation, the envelopes overlap and it is risky to conclude based on the averages. Other representations nevertheless show that the TAC frequently produces (> 95% of simulations) catch values higher than those of the other two scenarios (75% quantile) in the last year of simulation. They also show that for rare combinations of parameters (< 1% of simulations), catches are higher with the reference scenario than with the TAC.

BIOMASS ENVELOPE

CATCHES ENVELOPE

SPAWNING STOCK BIOMASS(SSB) ENVELOPE



SCENARIOS : Reference TAC AMP

Figure 13 - Evolution trajectories of biomass (left), annual catches (center) and spawner biomass (right) in the three simulated scenarios (reference, TAC and MPA) represented by different colors. The representation uses a line for the average of the simulations and an envelope to visualize the standard deviation. The horizontal red line represents the target value for each variable

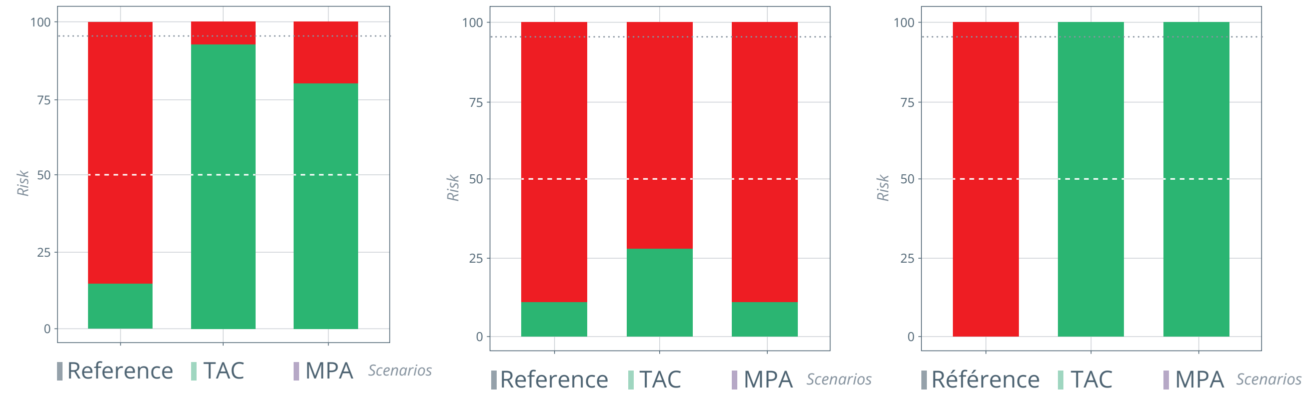
RISK

Risk can only be quantified by comparing outputs to management objectives (symbolized by the red line in Fig. 13). Simulations show that the biomass objective is not achieved on average in the reference scenario and that it is achieved on average in the case of a TAC (Fig. 13 - BIOMASS). However, risk is more easily understood by evaluating the frequency of achieving (or not achieving) an objective than through envelopes around the average. Thus, the box-and-whisker representation is interesting since it gives access to the proportion of simulations above (resp. below) a certain value. The representation of risk as a bar (red/green) where the height of the red bar is equal to the proportion of simulations not achieving the objective and the height of the green bar is equal to the proportion achieving the objective was favored by the workshop participants.
Here we represent the risk of reaching the management objective in 2027 (Fig. 14). We can therefore see that even if on average the objective is reached at the end of the simulation with a TAC, there is a risk greater than 5% that it is not.

BIOMASS RISK

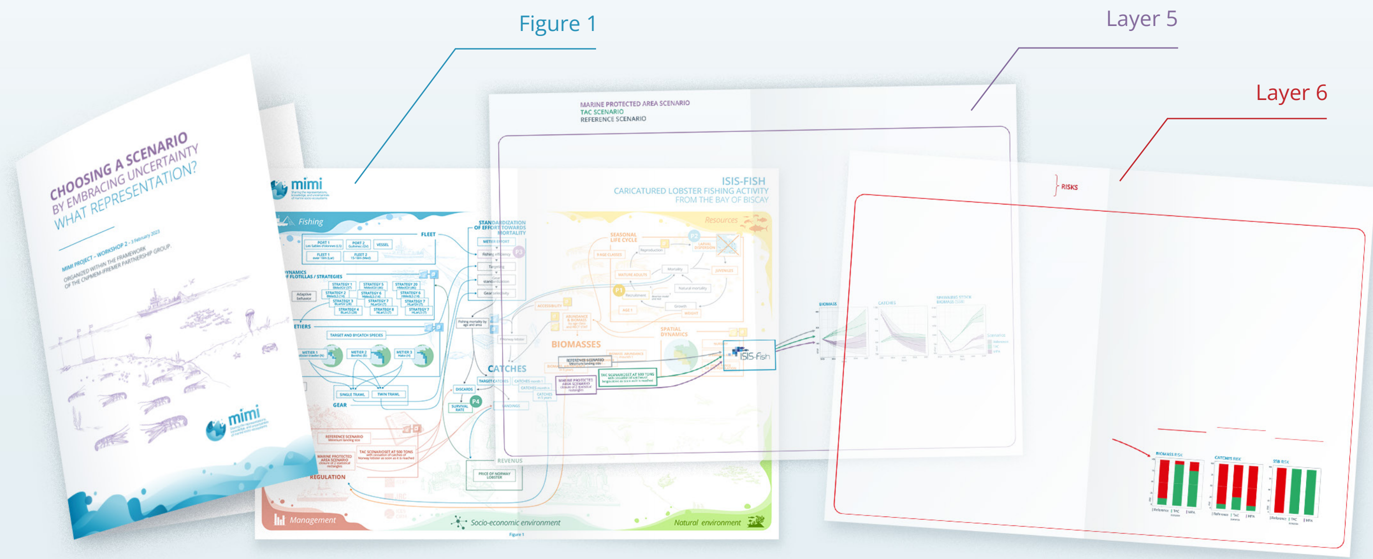
CATCHES RISK

SPAWNING STOCK BIOMASS (SSB) RISK



Risk of not achieving the objective
Risk of reaching the objective

Figure 14 - Risk associated with achieving the objectives at the end of the simulation for the three variables considered: biomass (left), annual catches (center) and spawner biomass (right) in the three simulated scenarios (reference, TAC and MPA). It is calculated as the proportion of simulations in which the objective is achieved.

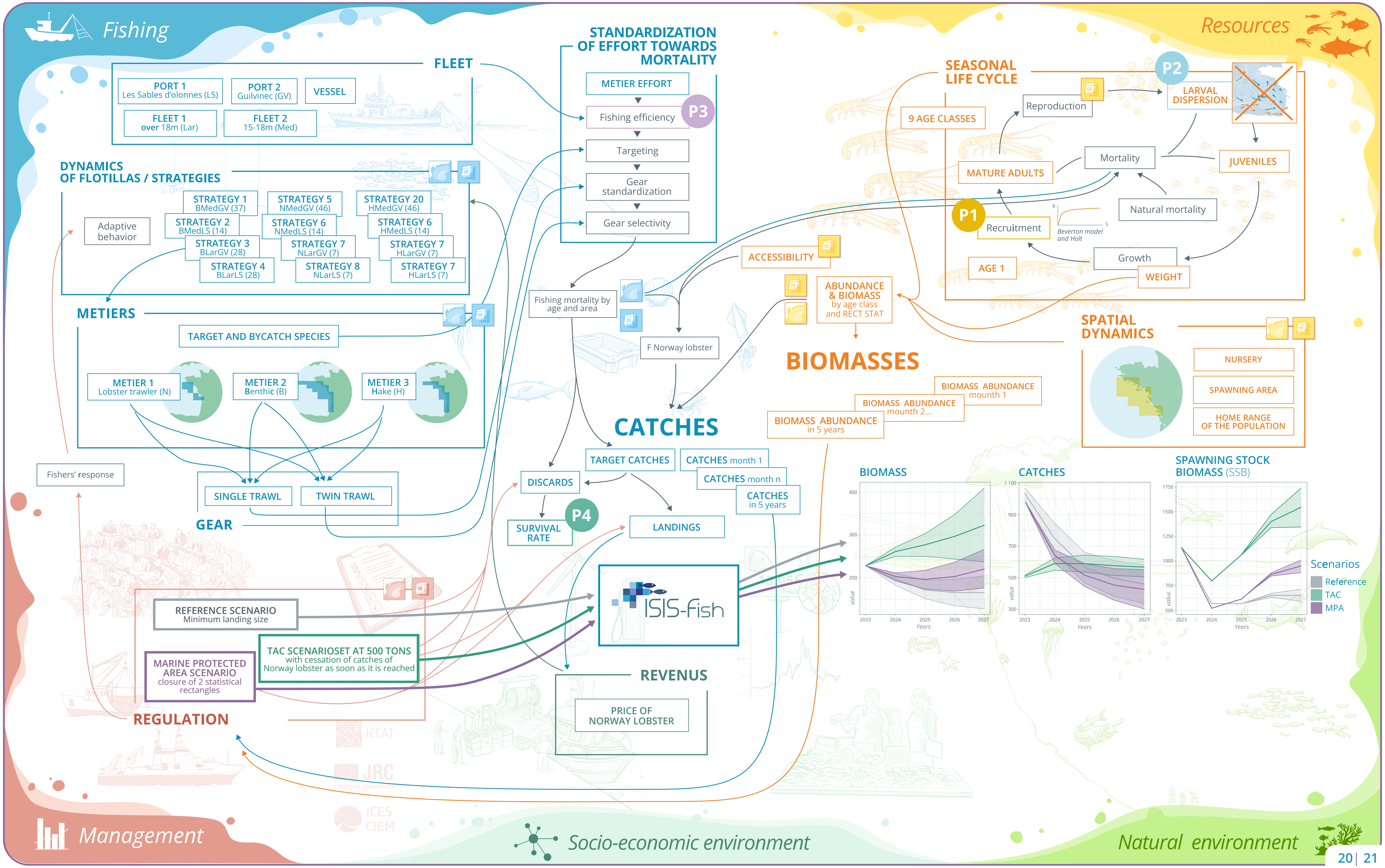


See Figure 1, placing layer 5 to visualize the 3 management scenarios and layer 6 for the risk representation.

mimi
Sharing the representations, knowledge, and uncertainties of marine socio-ecosystems

MARINE PROTECTED AREA SCENARIO
TAC SCENARIO
REFERENCE SCENARIO

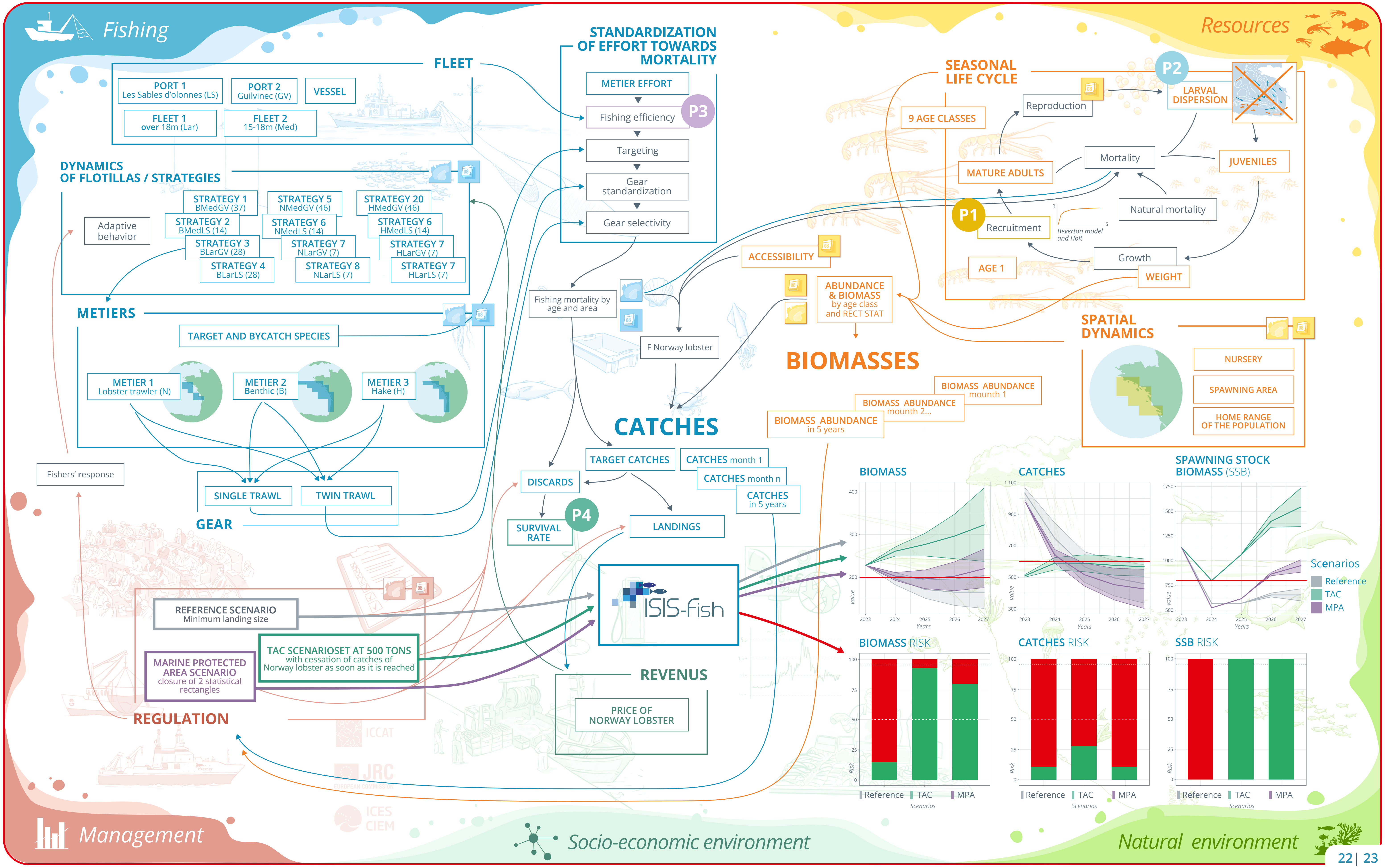
ISIS-FISH
CARICATURED LOBSTER FISHING ACTIVITY FROM THE BAY OF BISCAY



mimi
Sharing the representations, knowledge, and uncertainties of marine socio-ecosystems

MARINE PROTECTED AREA SCENARIO
TAC SCENARIO
REFERENCE SCENARIO
} RISKS

ISIS-FISH
CARICATURED LOBSTER FISHING ACTIVITY FROM THE BAY OF BISCAY



Can we identify the parameters that have the greatest influence? Can we sort them and identify those on which we could work collectively to hopefully have less uncertainty in the output?

PRESENT THE IMPORTANCE, THE POTENTIAL FOR IMPROVEMENT AND THE ACCURACY OF VARIABLES

Uncertainties in the model input lead to uncertainties in the catches and biomass simulated by the model, which sometimes make it difficult to choose one management measure from among several, as we have seen for catches (Fig. 13). To avoid this pitfall, parameter uncertainties must be reduced by improving knowledge of all parameters. Such a strategy can be very costly. To prioritize the parameters on which we will seek to reduce uncertainty, it is useful to estimate the influence of each parameter on the outputs and to identify those that have both the strongest influence and the greatest potential for reducing uncertainty.

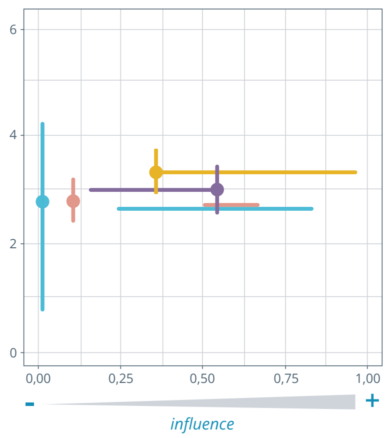
Sensitivity analysis is a method that quantifies the influence of parameters on catches and biomass. By using the simulations from the simulation plan, we can calculate a sensitivity index per parameter on each output (catch and biomass) and order the uncertain parameters according to their influence.

In the model, the most influential parameter on catches is the fishing efficiency drift, followed by the stock-recruitment relationship, while only the stock-recruitment relationship strongly influences biomass (Fig. 15). The two least influential parameters on the two output variables are larval dispersal and Nephrops survival.

It is interesting to compare this result from the model with the a priori of the participants we questioned before running the model. The estimates are quite different between the participants, except for the survival of the Norway lobster (horizontal bars, Fig. 15). Relative to the model estimate, it appears that they overestimate the influence of the biological parameters and underestimate that of the fishing efficiency. If we average the participants' estimates, the strongest influence according to the participants on the two output variables is attributed to the 3 biological parameters (Fig. 15).

To assess the potential for reducing uncertainty in each parameter, we asked participants about possible improvements in knowledge of the 4 parameters (on a scale of 1 to 5). Participants considered that all parameters had good potential for improvement (around 3 out of 5), although perceptions were more variable for larval dispersal (longest vertical bar, Fig. 15). The two parameters with the greatest potential for improvement (in order of stock-recruitment relationship and fishing efficiency) were also those with the greatest influence on catches and biomass (Fig. 15). This configuration is very favorable for seeking to improve the accuracy of catches and biomass output from the model and facilitating the choice of a management scenario.
In this perspective, one could focus on reducing uncertainty about the stock-recruitment relationship and fishing efficiency drift.

RELATIONSHIP **CATCHES**



RELATIONSHIP **BIOMASS**

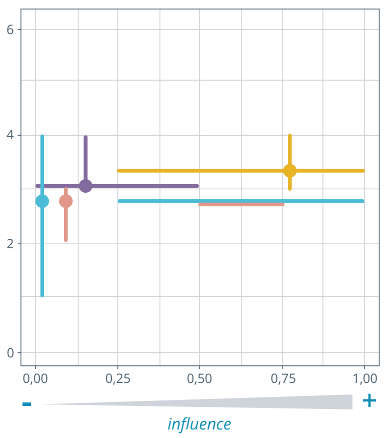


Figure 15 - Representation of the influence of parameters on the catches and the potential for reducing their uncertainty. The point designates the estimation with the model of the influence of the parameter between 0 and 1. The further the point is to the left (close to 0) the less influential it is, and conversely the further a point is to the right the more influential it is. There is one point per parameter. For each parameter (each point), the horizontal bar designates the range of relative influence estimated by the participants at the beginning of the workshop, and the vertical bar the relative range of potential reduction of their uncertainty.

● Stock-Recruitment Relationship ● Larval dispersal ● Fishing efficiency ● Survival of Norway lobster

CONCLUSIONS

The work of this workshop was based on a highly stylized model of the Norway lobster fishery inspired by the fishery of the large mudflat in the Bay of Biscay (for a more realistic parameterization, see the FFP Macco project, www.macco.fr).

The results thus obtained, particularly in terms of scenario choice, must be interpreted in light of this simplification and cannot be generalized.
On the other hand, the approach to characterizing and representing uncertainty is reproducible for more complex models of fisheries and for other parameters than those retained here following workshop 1. Furthermore, the overall approach built on the two workshops can be applied to models other than the model ISIS-FISH.

This workshop demonstrated how to diagnose the consequences of management scenarios despite uncertainties about the functioning of a fishery.

The graphical representations of the models and the uncertainty of the input parameters and output variables of the models, produced during these workshops, are intended to be used as educational support, made available to workshop participants.

The approach made it possible to identify the uncertain parameters of a 5-year catch and biomass model, and to qualify their influence and their potential for improvement. A follow-up to these workshops will be to work collectively to improve knowledge of potentially improvable influential parameters, by producing scientific knowledge and integrating the field or empirical knowledge of fishermen.

GLOSSARY

FISHING EFFICIENCY DRIFT: Average change in the ability to catch accessible fish (efficiency / power = ability to catch accessible fish) (https://halieutique.institut-agro-rennes-angers.fr/files/fichiers/pdf/136.pdf)

SURVIVAL RATE OF DISCARDS: Proportion (between 0 and 1) of survival of catches not landed for various reasons (illegal size, damaged fish, lack of market or exceeding quotas) (source: Ifremer, Gardons la Pêche)

LARVAL DISPERSAL: Larval dispersal includes egg-laying, larval transport (i.e. movement of larvae resulting from physical transport and the vertical swimming behavior of the larvae), larval survival, and then the settling of the larvae at the end of their larval life span. (https://emarinlab.obs-banyuls.fr/plus/images/Observer/Glossaire-dispersion-larvaire.pdf)

STOCK-RECRUITMENT RELATIONSHIP S/R: Link between the number of young fish becoming accessible to fishing (Recruitment) and the number of spawners approximated by the fertilizing biomass (Stock)

AVERAGE: The average is the simplest indicator for summarizing the information provided by a set of statistical data: it is equal to the sum of these data divided by their number.

MEDIAN : The median is the midpoint of a set of ordered data, such that 50% of the observations have a value less than or equal to the median and 50% of the observations have a value greater than or equal to it. It is also the 2nd quartile.

BOXPLOT: Graphical representation of the distribution of data based on 5 elements of the distribution: minimum, first quartile, median, third quartile, maximum. The length of the whiskers can be 1.5 interquartiles.

RISK: In MiMi, risk is defined by the probability of not reaching the set objective (e.g. that biomass <Blim).

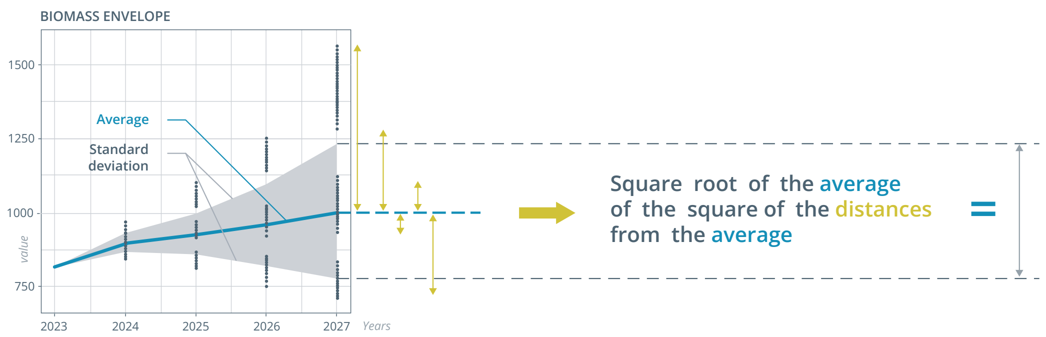
SENSITIVITY INDEX: The sensitivity index of a parameter on a variable, a measure of the influence of the parameter on a variable.

QUANTILE : Quantiles are values that divide a data set into intervals of the same frequency.

QUARTILE : There are 3 quartiles. Each of the three values divides the sorted data into four equal parts, so that each part represents 1/4 of the values. The quartile is one of the quantiles. The first quartile is the value that delimits the first quarter of observed values. The second quartile is the median. The third quartile is the value beyond which the last quarter of the largest values are found.

STANDARD DEVIATION: The standard deviation is a measure of the dispersion of observed values around their mean. It is obtained by calculating the deviation of each value from the mean (yellow arrows), averaging these squared deviations, then taking the square root of this mean. This is the "standard" deviation of the observed variable. It is equal to the square root of the variance.

UNCERTAINTY: Uncertainty is the dispersion of possible values of a variable. It is measured using dispersion statistics (standard deviation, variance, quantiles, etc.).



ACCURACY AND CONFIDENCE: Accuracy represents the uncertainty relative to a confidence level. For example, 90% accuracy is the spread of 9 out of 10 values. The lower the uncertainty, the greater the accuracy. The greater the confidence level, the lower the accuracy.

DISTRIBUTION: The distribution of a variable is the profile of values, that is, the set of possible values and their frequency of occurrence.

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DATA

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https://projet-mimi.fr