WGNAS-SalmoGlob ToolBox

A WEB APPLICATION FOR SUPPORTING ATLANTIC SALMON STOCK ASSESSMENT AT THE NORTH ATLANTIC BASIN SCALE

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Abstract

We built a database and developed a web application to support and promote the use of the new Bayesian integrated life cycle model developed for Atlantic salmon stock assessment at the north Atlantic basin scale. It is accessible online at

https://sirs.agrocampus-ouest.fr/discardless_app/WGNAS-ToolBox/

The WGNAS-SalmoGlob ToolBox aims at strengthening the robustness and efficiency of the use of the new life cycle model for Atlantic salmon stock assessment and catch advices. The database collates all inputs and data needed to feed the Bayesian life cycle model. This represents a huge improvement as all data and inputs for all SU of both Europe and North America are centralized within a single and secured database. The web app proposes interactive tools to visualize export and update the data (including versioning). Updated data are then automatically formatted in the appropriate format to be passed to the Bayesian life cycle model. This increases transparency in the way the data are used, and strengthens data quality control. It also provides a tool to visualize and to communicate model outputs among WGNAS members and with stakeholders, what builds confidence in stock assessment results among experts, managers and stakeholders. The database and the associated web app constitute key pieces of the puzzle for a new WGNAS stock assessment workflow.

Important note

This WP is based on the version of the Shiny web app and of the model developed in 2021. Some modifications have been brought since then.

1 Background

Atlantic salmon (*Salmo salar)* (hereafter A. salmon) that reproduce in rivers of eastern North America and Northeast Atlantic countries of Europe undertake wide-ranging migrations to common feeding grounds in the North Atlantic, where they are exposed to common marine environmental conditions and fisheries (Beaugrand and Reid, 2003; Beaugrand and Reid, 2012; Friedland et al., 2014; Mills et al., 2013). A. salmon are susceptible to be harvested at several stages in their life cycle. Some fisheries operate in high seas when population originating from various continental habitats regroup on high seas foraging areas, in coastal areas when salmon navigate before entering their natal river, or in freshwater (estuarine or river areas) during the final stages of their spawning migration. In particular, when present in the feeding grounds of West Greenland or in the vicinity of the Faroe Islands, they may be harvested in mixed stock fisheries, referred to as the high seas (or distant water) fisheries (Chaput, 2012; ICES, 2017).

Over the last decades, the annual stock status reports developed by the Working Group North Atlantic Salmon of the International Council for the Exploration of the sea (ICES/CIEM WGNAS) and the subsequent scientific advices provided to the North Atlantic Salmon Conservation Organization (NASCO) have formed the basis for the management of these fisheries. ICES WGNAS provides catch advice based on a forecast of A. salmon abundance prior to the high seas fisheries exploitation (Pre Fishery Abundance, hereafter denoted PFA). A fixed escapement strategy has been adopted with the objective of achieving the spawners (or eggs) requirements for the contributing stocks on both sides of the Atlantic Ocean (Chaput, 2012; Crozier et al., 2003; Crozier et al., 2004; Potter et al., 2004).

Stock assessment models for Atlantic salmon have been developed based on data aggregated at the scale of regional or national stock units (SU) over the North Atlantic area within three continental stock groups (CSG): eastern North America (NA), Southern European (SE) and Northern European (NE) (Crozier et al., 2004; Potter et al., 2004; Chaput et al. 2012). The rationale of these models (hereafter denoted *PFA models*) is to reconstruct long-term series (starting in the early 1970’s) of abundance at sea before any marine fisheries (PFA) and to forecast the returns of adult salmon to their natal rivers (homewaters). These models have been incorporated in a risk analysis framework to assess the consequences of mixed stock marine fisheries at West Greenland and Faroes on the returns (Friedland et al., 2005; ICES, 2015) and to assess compliance of realized spawning escapement to conservation limits (biological references point below which the stock should not pass) at both the SU and CSG scales.

A new Bayesian life cycle modelling (LCM) framework was recently developed to improve Atlantic salmon stock assessment (Rivot et al. 2021). This framework relies upon the work of Massiot-Granier et al. (2014), extended by Olmos et al. (2019) and Olmos et al. (2020) to represent all SU from the three North Atlantic CSG (Northern Europe, Southern Europe and North America) within a single unified hierarchical Bayesian life cycle approach where all populations follow a similar life history process.

This model brings a major contribution to improve the scientific basis for Atlantic salmon stock assessment (Rivot et al., 2021). Considering the dynamics of all SU in Northern Europe, Southern Europe and North America (25 SU) within a single model represents a paradigm shift from the stock assessment and forecasting approach currently used by ICES that considers the North American and European (Southern and Northern) continental stock groups separately (Chaput, 2012; ICES, 2017).

The new modelling approach drastically affects the streamlines from data preparation to the analysis of outputs and poses challenges for data management (Fig. 1). Indeed, it involves a large amount of data on salmon population status and fishing pressure, for multiple life stages (from eggs to spawners, in river and high seas), life history strategies (e.g., number of winters spent at sea) and geographical origins (stock units); all these data requiring to be consistent and to be updated each year. Additionally, such complexity in the model implies difficulties in analyzing, discussing and communicating the results.

To further strengthen the new workflow, we developed the **WGNAS-SalmoGlob ToolBox**, a database and a web application that strengthen the robustness and efficiency of the use of the new life cycle model for Atlantic salmon stock assessment and catch advices. The database centralizes and consolidates all inputs and data needed to feed the life cycle model. This represents a huge improvement as all the data and input for all SU of both Europe and North America are now centralized within a single and secured database. The web app proposes interactive tools to visualize export and update the data. Updated data are then automatically formatted in the appropriate format to be passed to the Bayesian life cycle model. This increases transparency in the way the data are used, and strengthens data quality control. It also provides a tool to visualize and to communicate model outputs (hindcasting and forecasting, including risk analysis for catch advices). These tools may reduce the time spent collecting and handling data, make easier the modeler day-to-day work, and build confidence in stock assessment results among experts, managers and stakeholders.

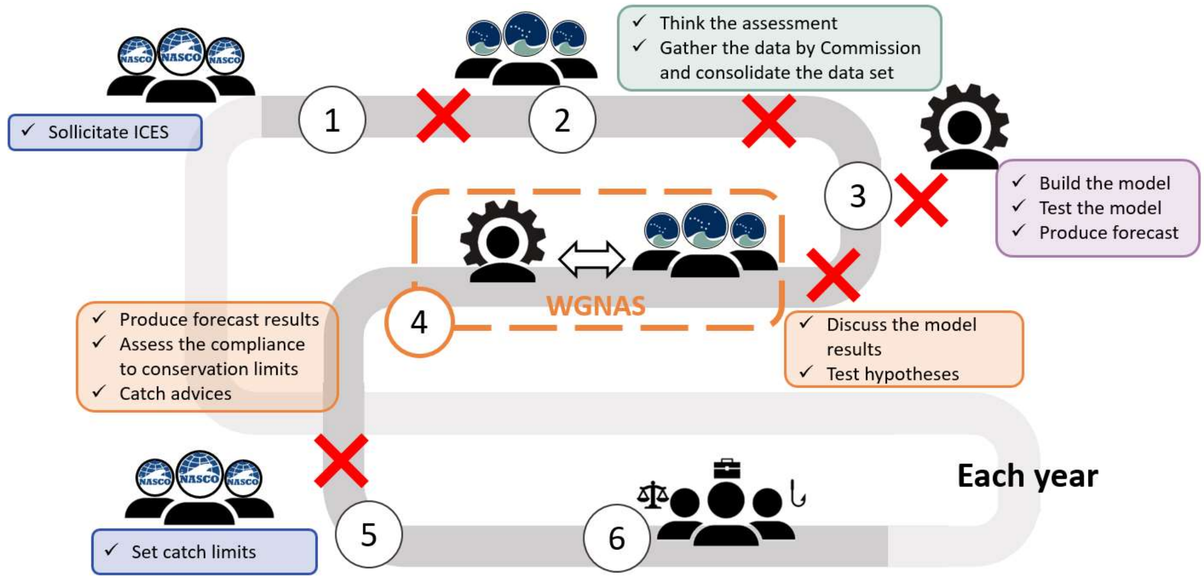

Figure 1 - Workflow of North Atlantic salmon stock assessment. The red crosses highlight the key stages of the streamlines, from data preparation to the provision of catch advices that are strengthened to increase robustness and efficiency of the stock assessment workflow.

The WGNAS-SalmoGlob ToolBox is built under R using the Shiny package, which is designed to build interactive web applications. The connections of the different modules of the ToolBox are described at Fig. 2. It is structured by a dashboard in which are displayed the different tools, accessible via a navigation bar that tackle specific steps of the workflow. An authentication (username and password) is required to access some specific tools such as data updating.

The WGNAS-SalmoGlob ToolBox can be accessed online via any web browser at https://sirs.agrocampus-ouest.fr/discardless_app/WGNAS-ToolBox/. The home page from which can be accessed all functionalities of the ToolBox is displayed in Fig. 3.

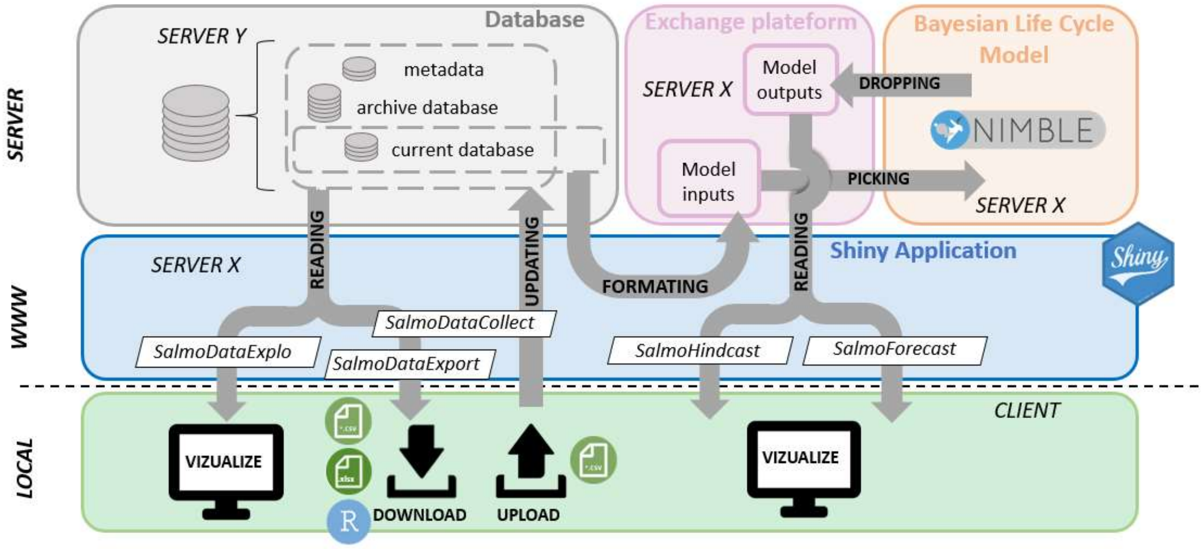

Figure 2 - Scheme of the ToolBox. Connections between the different modules and interactions between the Shiny application, the salmon database and the Bayesian life cycle model of North Atlantic salmon.

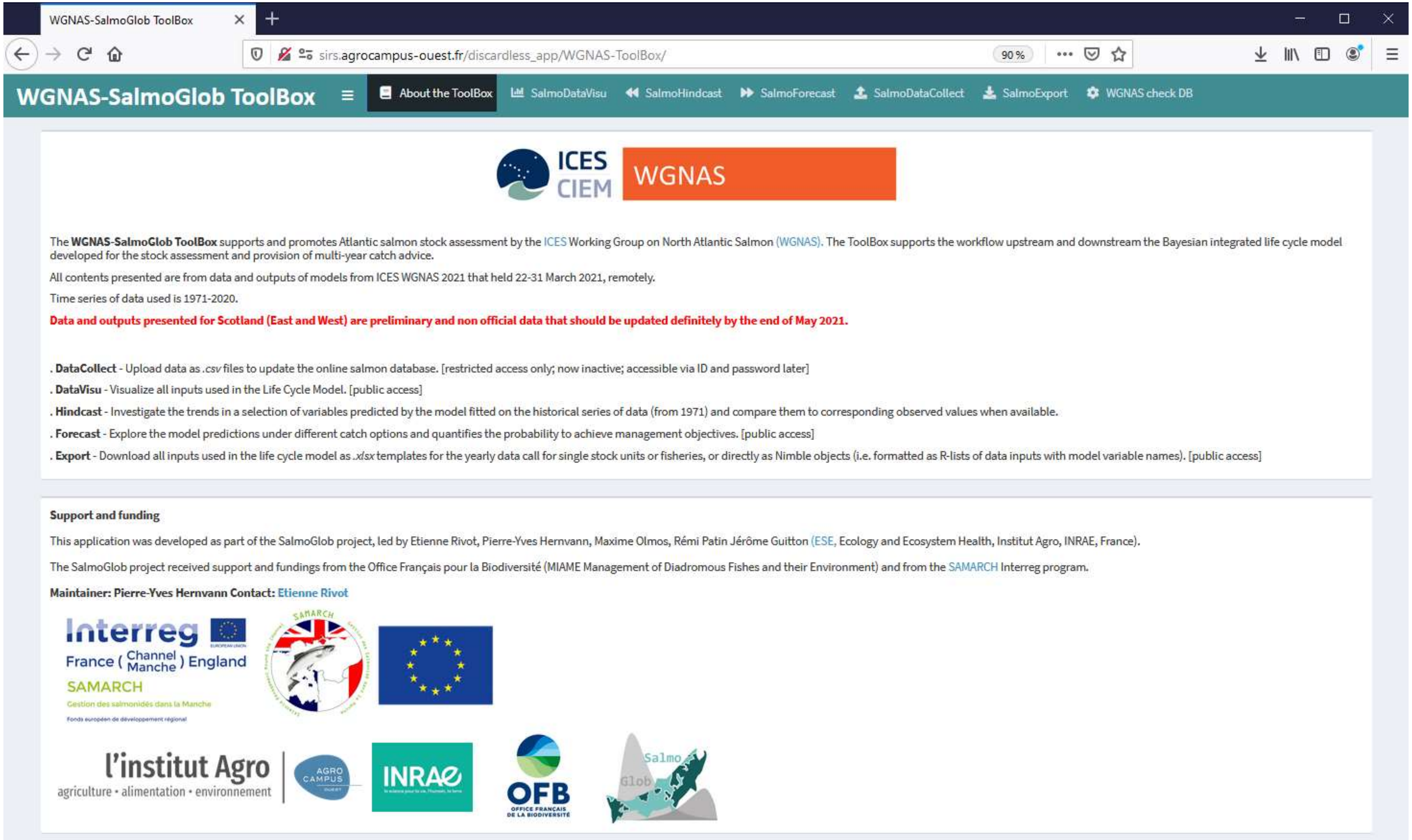

Figure 3 – Screenshot of the WGNAS-SalmoGlob application's homepage.

2 Centralizing and maintaining salmon data integrity - SalmoGlobDatabase

The life cycle model that constitutes the core of the new stock assessment workflow articulates and assimilates a huge amount of input data provided by all the different jurisdictions and from the high seas marine fisheries (Tab. 1). Most of those data are time series collected by each jurisdiction (i.e., returns and catches in home-waters) or experts (i.e., sea catches on shared stocks) and collated by WGNAS. These time-series are usually specific to each life stages considered in the model and to each of the 25 SU. Some of them are assimilated with observation errors. In this case, data comes in the form of a mean and standard deviation (or a coefficient of variation).

The complexity of salmon data and the substantial amount of information it represents stresses the need of organizing it so that it is easier to browse and handle. We developed the `SalmoGlobDatabase` that represents a huge improvement as all the data and input for all SU of both Europe and North America are now centralized within a single and secured database. `SalmoGlobDatabase` constitutes a single and secured version of the data used for salmon stock assessment. Its online access may facilitate the sharing of a common version of the data with all people requiring it, from the modelers to WGNAS members and stakeholders, and even more. It also enables data versioning hence strengthening data quality and security, which is particularly relevant for the yearly update made at each WGNAS meeting prior to stock assessment release (see Section 4). The `SalmoGlobDatabase` is finally a way to materialize and valorize the work of data collection led by the WGNAS. To this database can be associated a citation for further reference in future work of the WGNAS.

The `SalmoGlobDatabase` is organizing and storing the salmon data across a set of interrelated and complementary tables.

The main table is the `database` table. `database` is a long-format object storing the most up-to-date values of all the variables and parameters required by the LCM, for all years and possible combinations of geographical origin, fisheries and life-history trajectories. The `database` table is the one that is used to produce the LCM inputs.

The `database_archive` table allows for data versioning to strengthen the data security and quality. Its content matches that of the `database` table plus supplementary information, i.e. the date (day-month-year/hour-minute) when the data has been updated and an identifier to register the author of data updating (the corresponding information on the author, i.e. first name, name, email address and institute affiliation can be retrieved from the `users` table - not presented here). The database_archive table contains the data present in the `database` table and all its previous versions, which are referred by a version number (one single version number by variable). At any time, an older version of `database` can hence be retrieved from `database_archive`.

The metadata table classifies all the variables used in the model, both inputs or outputs, referencing the by their name in the nimble model. For each variable, it precises the dimension of the corresponding object in the model, i.e. single value, matrix, or array, and what it represents, e.g.

years, stock units, freshwater age, number of sea winters. One other useful information included in this table is a text definition of the variable, which could be consulted as a glossary of the model codes, hence facilitating the appropriation of the model codes (See Annex – Tab. A1). Similarly to the `database` table, it also includes information related to the type of data, life stages concerned etc.

Important note on hosting and maintenance

The `SalmoGlobDatabase` was developed at Institut Agro and is currently hosted on the SIRS server of the fisheries center of Institut Agro in Rennes, France. This facility and the structure of the database enables to manage it remotely using classical relational database management systems such as the open-source *PostgreSQL*. This can be conducted, for instance, through user-friendly web interfaces like *Pgadmin* or from coding software like *R* with the relevant packages (e.g. `postgresql` library). Systems such as *PostgreSQL* also allow for access restrictions controlled by username and password, with the possibility of customizing the rights given to a particular user (e.g., read-only of modifications allowed). The last WKSalModel 2021 (report in prep.) was the opportunity to discuss about potential alternative hosting of the database in the future, notably via the ICES facilities.

Table 1 - Summary of the data used in the life cycle model. Most of the data are provided as time series specific to each of the 25 SU (indicated Year x SU) and eventually for the two sea-age classes of returns separately. Some inputs data are assimilated with observation errors. In this case, data come in the form of a mean and standard deviation.

Data type	Dimension	Observation errors
Returns	*Year x SU x 1SW/2SW sep.*	*~ LogNormal(mean, sd)*
Catches	*Year x SU x 1SW/2SW sep.*	*~ LogNormal(mean, sd)*
Number of eggs per fish (proportion of females x fec)	*Year x SU x 1SW/2SW sep.*	No uncertainty
Eggs to smolt survival	*x SU*	*~ LogNormal(mean, sd)*
Proportion of smolt ages	*Year x SU*	No uncertainty
Catches at sea (mixture of stocks)		
- Total catches	*Year x SU x 1SW/2SW sep.*	*~ LogNormal(mean, sd)*
- Proportions to allocated total catches among SU	*Year x SU x 1SW/2SW sep*	*~ Dirichlet* or proportional to abundance
Time interval between sequential fisheries	*(Year) x SU x 1SW/2SW sep.*	No uncertainty

3 Data exploring and visualizing - `SalmoDataVisu`

We developed `SalmoDataVisu`, an interactive tool that directly loads the `database` table by remotely connecting to the `SalmoGlobDatabase` and provides tools to navigate through it and produce visual representation of the data.

Exploring and visualizing the content of the salmon data collected by the WGNAS is critical part of the stock assessment streamline. The `SalmoDataVisu` interactive tool provides an efficient way to explore the large amount of information contained in `SalmoGlobDatabase`. It enhances transparency about the way that data is used, facilitates exchanges between WGNAS experts and provides standard graphs to feed annual reporting of ICES WGNAS. Visual checks of the data ensure that the information collected by the WGNAS members is consistent and that the model runs on the correct values of data input. It helps to crosscheck the model behavior and output with the data. Finally, `SalmoDataVisu` is a showcase for the ICES WGNAS' work. In particular, it enhances transparency about how the input data provided by numerous institutions across the North Atlantic basin is used. It is also a tool to communicate to a wider audience.

The `SalmoDataVisu` tool works with drop-down menus to select sequentially:

- The type of data to represent: returns, home-water catches, sea catches, origin distribution of sea catches, survival rates, smolt age structure, etc. (see Tab. 1 for a summary);
- The life histories concerned: the number of sea winters, mature or immature, freshwater ages;
- The areas (stock units) or fisheries concerned;
- One additional precision related to fisheries definition.

The choices displayed by each drop-down menu are updated according to the items chosen in the previous menus. By default, the drop-down menus automatically display all possible choices but the selection can then be modified. The chart type produced is defined *a priori* in the application and depends on the data type selected: linetypes, barplots, satcked areas etc. (Fig. 4 & 5).

`SalmoDataVisu` proposes several graphical options according to the variables selected. Catch and abundance input data, can be displayed in log scale or in the natural scale. They can also be visualized through as many line plots as areas considered (stock units, fisheries; Fig. 4) or cumulated as stacked area plots for each life history trajectory selected (Fig. 5). A scale option allows to scale differently the separate graph windows regarding the y-axis to facilitate comparisons of values or trend.

All graphs represented in the `SalmoDataVisu` are built using the `plotly` package, hence displaying each element values when hovering above the mouse cursor, enabling the user to zoom in on a graph, and exporting the figure as *.png*.

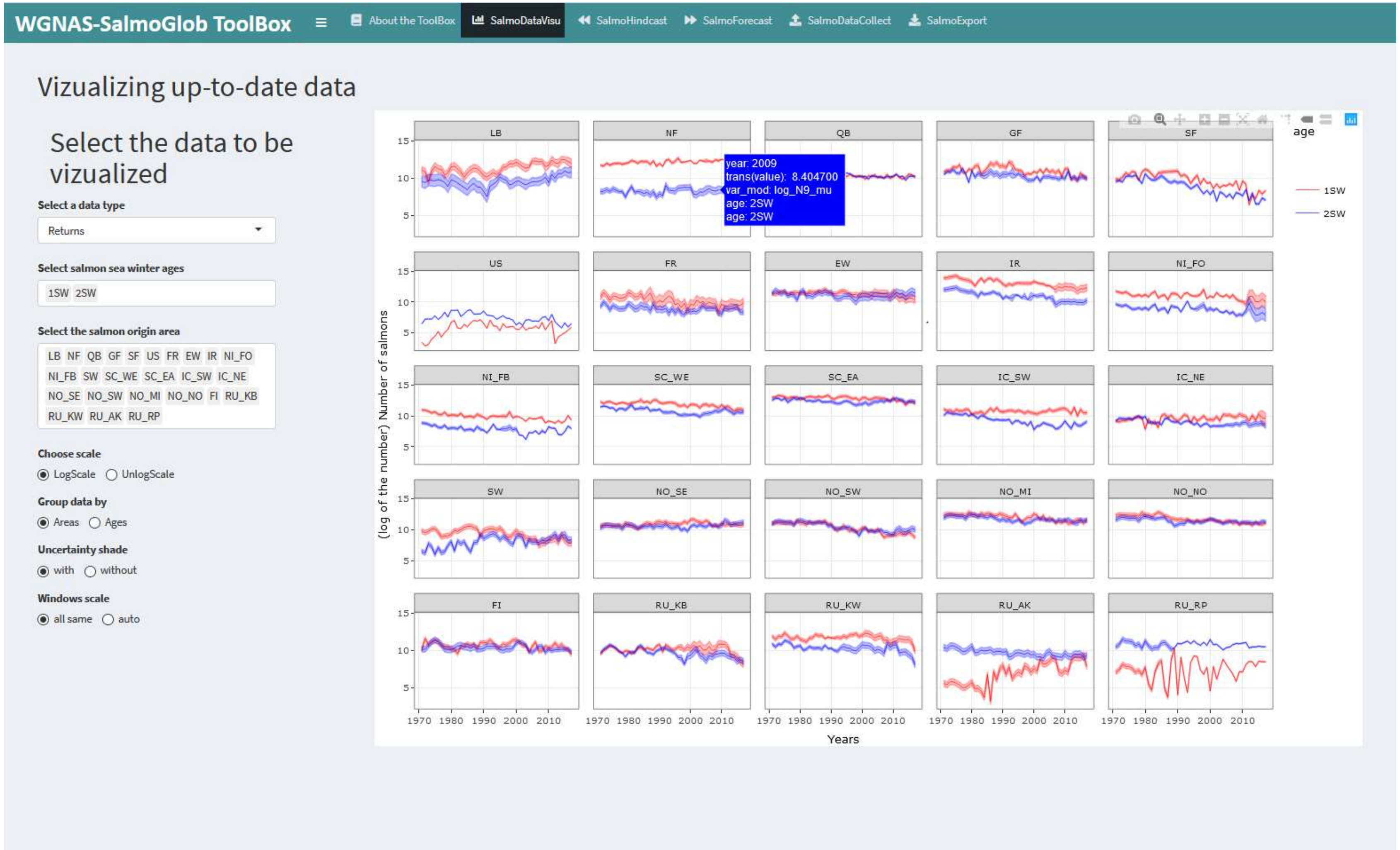

Figure 4 - Screenshot of the SalmoDataVizu page. This tool allows for exploring the main data used by the LCM. Here, the window displays the input data for returns of all sea winter ages and for all the areas.

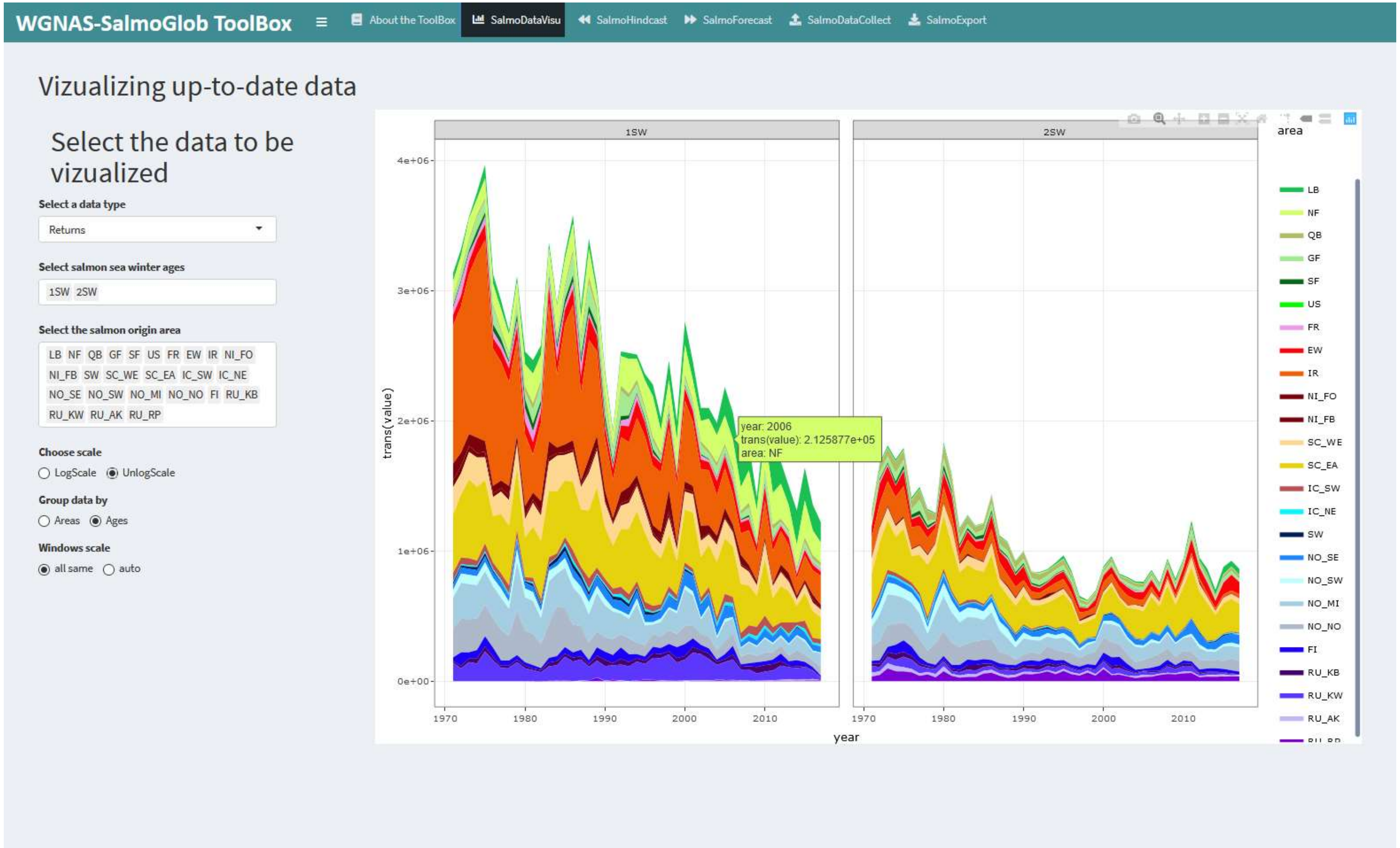

Figure 5 – Screenshot of the SalmoDataVizu (continuing). This figure illustrates how the plotting options of this tool enables different visualization of the same data.

4 Supporting data calls and facilitate data updating

The stock assessment model is run every year with updated data. Updating the data is always critical step. It is highly time consuming, and the multiple and hazardous manipulations of the data are error prone and may critically endanger the data quality.

The *WGNAS-SalmoGlob* ToolBox provides tools to facilitate the updating process.

4.1 Providing templates for data calls - `SalmoExport`

The `SalmoExport` tool was developed to automatically export the current data in a format appropriate for the data updating process, so that experts can easily update the data directly from the template. The `SalmoExport` tool directly connects to the `database` table of the `SalmoGlobDatabase` and extracts the most up-to-date information while conserving the table format and highlighting the new data that should be provided (typically and additional year).

The templates exported from the `SalmoExport` ensure that data providers correctly identify what should be produced for the next stock assessment. Thus, it may prevent for collecting incomplete data and can enhances data quality control. It has also the potential to smoothen the interactions between experts, WGNAS members in charge of the data call, and modelers.

Two different file types can be exported through the part of `SalmoExport` dedicated to data call (Fig. 6):

- Templates can be downloaded that collate all data relative to any specific stock unit. This provides a file to jurisdictions experts containing all SU specific data used in the model: returns, home-water catches, proportion of females in returns, average fecundity per females, and smolt age-structure;
- Other templates can be downloaded for a specific fishery, to provide a file that contains all data related to high seas catches and their distribution among ages, complex and stock unit origin.

The data call templates come in classical *.xlsx* format with one sheet per variable that should be provided. Note that the sheets are identified by a code, which is the name of the variable in the model. An additional sheet automatically produced establishes the correspondence between the variable name in the model and a readable definition of the variable.

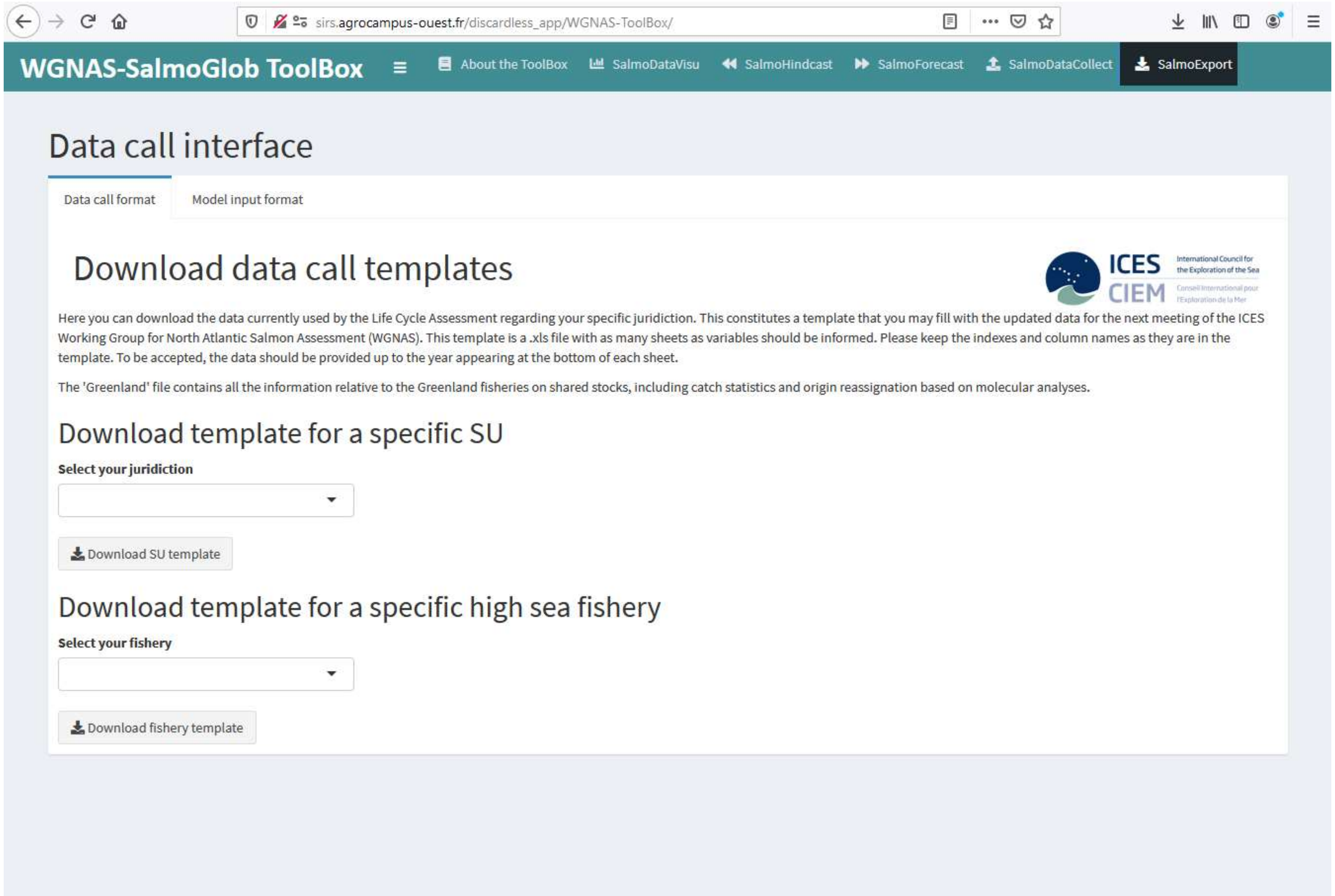

Figure 6 - Screenshot of the SalmoExport page. Tab for exporting the data call templates per jurisdiction or fishery.

4.2 Facilitating the data updating - SalmoDataCollect

The SalmoDataCollect tool allows for updating SalmoGlobDatabase with new time-series. SalmoDataCollect uses these time-series provided through file uploading to simultaneously update the database and database_archive tables of SalmoGlobDatabase. The SalmoDataCollect tool is a major progress in the optimization of the salmon workflow. By proposing automated and visual tests when uploading new data, it substantially enhances data quality control by decreasing the probability of making any errors during the updating procedure. Additionally, the automatic versioning through the database_archive tables brings additional security as it enables to track eventual errors in the updating process and recover previous version of the database if needed.

Note that, for now, the access to SalmoDataCollect is restricted to a few members of the WGNAS. To open this tool, users has to identify via a username and a password (Fig. 7). The use of the SalmoDataCollect tool is organized in 4 steps (Fig. 8):

- The SalmoDataCollect tool can update one single variable in SalmoGlobDatabase, for specific or all areas, i.e. one variable in the Nimble model, for any number of areas from one to all, but with all its dimension (depending on the variable: years x sea-ages …). Following the same principle as in the SalmoDataVisu, a set of drop-down menu and radio button allows for selecting the data to update. The former is used to select a single type of data (see section 2) and the second to indicate a single metric (i.e. "mean value", "standard deviation", etc.). A third drop-down menu proposes to select the variable name matching both these type and metric (name in the model code). The identification of the variable gives access to a .csv file that is the current state of this variable in the up-to-date database table. This file can be used as a template for the member of the WGNAS in charge of updating this data. Additionally, a plotting window appears and represents the up-to-date values of the variable (note that the .csv template has the same format as the sheet for a given variable of the .xlsx template issued from the SalmoDataExport tool) except that it collates the information for all areas, fisheries, life history trajectories etc. The plotting window displays the values of the variable for a specific area/fishery/life history trajectory combination and lateral buttons near the figures enable navigating among all combinations.
- The identification of the variable activates the possibility to upload a .csv file containing the updated values of the variable to update. The uploaded file must respect a specific format, which can be accessed via the .csv template mentioned above. To ensure that the uploaded file is correctly read by the application, checkboxes are used to specify which separator and decimals should be considered for the importation. If the uploaded file only contains the data for a limited number of areas, the application will detect it and the plots showing the values currently stored in the database will be updated to only show the values for the uploaded areas.

- Once the file uploaded, a first check of the data format is automatically run by the application to ensure that the uploaded data matches the required format. The test consists in checking the number of columns, the column names, the presence of numeric/character elements in the expected columns, the absence of any NA value and duplicates, the correct writing of all character variables. This test also verifies that the newly entered series cover at least the same period as the previous version. If any test fails, an error message gives indications on the potential origin of the problem. If the test succeeds, the uploaded table is displayed and the uploaded values are overlaid on a graph together with the previous values stored in the database for visual checking (or printed side-by-side with it depending on the variable type). For the area-specific variables, the lateral "previous" and "next" buttons should be used to check data consistency for all areas. The Fig. 9 summarizes the tests conducted before validation.
- Once the new data uploaded on the application and the tests passed, the data is considered valid for integration in the database and the `database` and `database_archive` tables of the `SalmoGlobDatabase` can be modified. To make the integration of the modifications effective, the user needs to provide personal information (first name, name, email address, affiliation) needed to monitor the database modifications performed on the `database` and `database_archive` tables. By default, this information is automatically filled by the application using the `user_table`. A "validate" button can then be clicked on so that the application establishes a connection to the `SalmoGlobDatabase`. The uploaded table replaces the value of the corresponding variable in the database table and old values are added to the `database_archive` table.

Note that, because not all eventualities can be anticipated, the check procedure could fail to identify a problem. In that case, the correction of the error by uploading a file at the good format could be hindered by the wrongly updated data, which may prevent the newly uploaded file to pass the tests required for validation (the checks are performed based on the comparison of format and content between what is in the database and the uploaded tables). This could be particularly problematical when time for data updating is limited (e.g., during the WGNAS meeting) and the ToolBox maintainer is not available. Therefore, we built an emergency procedure to shunt the checks relative to the content of the correct table uploaded. During this procedure, basic format checks (number of columns, column names, absence of NA and duplicates) are still performed.

At any time, the updating status of the whole `SalmoGlobDatabase` can be monitored in the `Database status` tab of the `SalmoDataCollect` tool (Fig. 10). Timeline graphs show the smaller period covered by each data type and selected variable (among areas and ages) in the `database` table. Additionally, two information boxes give the proportion of variables that has been updated and the year until which can be run the LCM hindcast giving the progress of the updating.

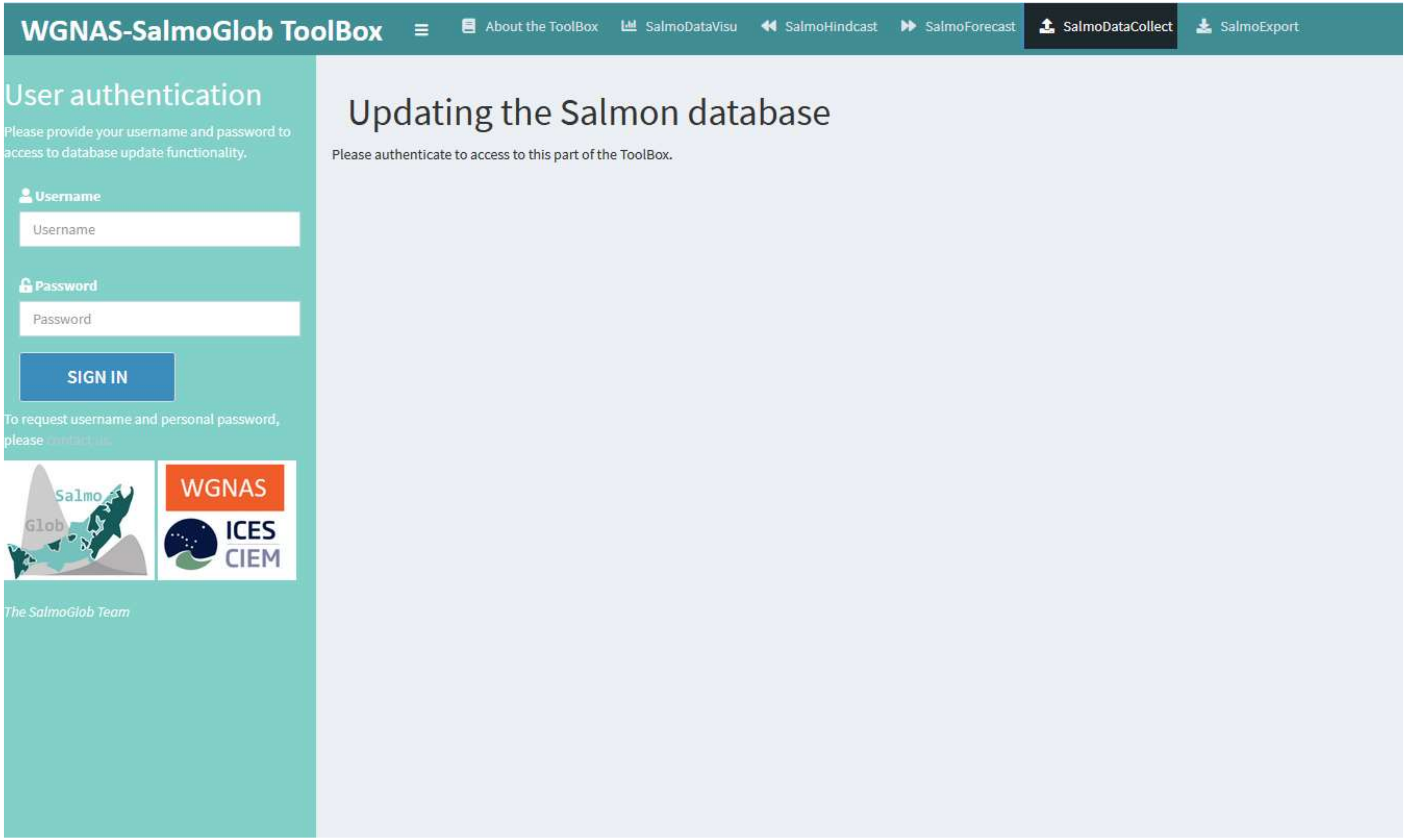

Figure 7 - Screenshot of the SalmoDataCollect page. The access to this part of the application is secured by a login (username and a password).

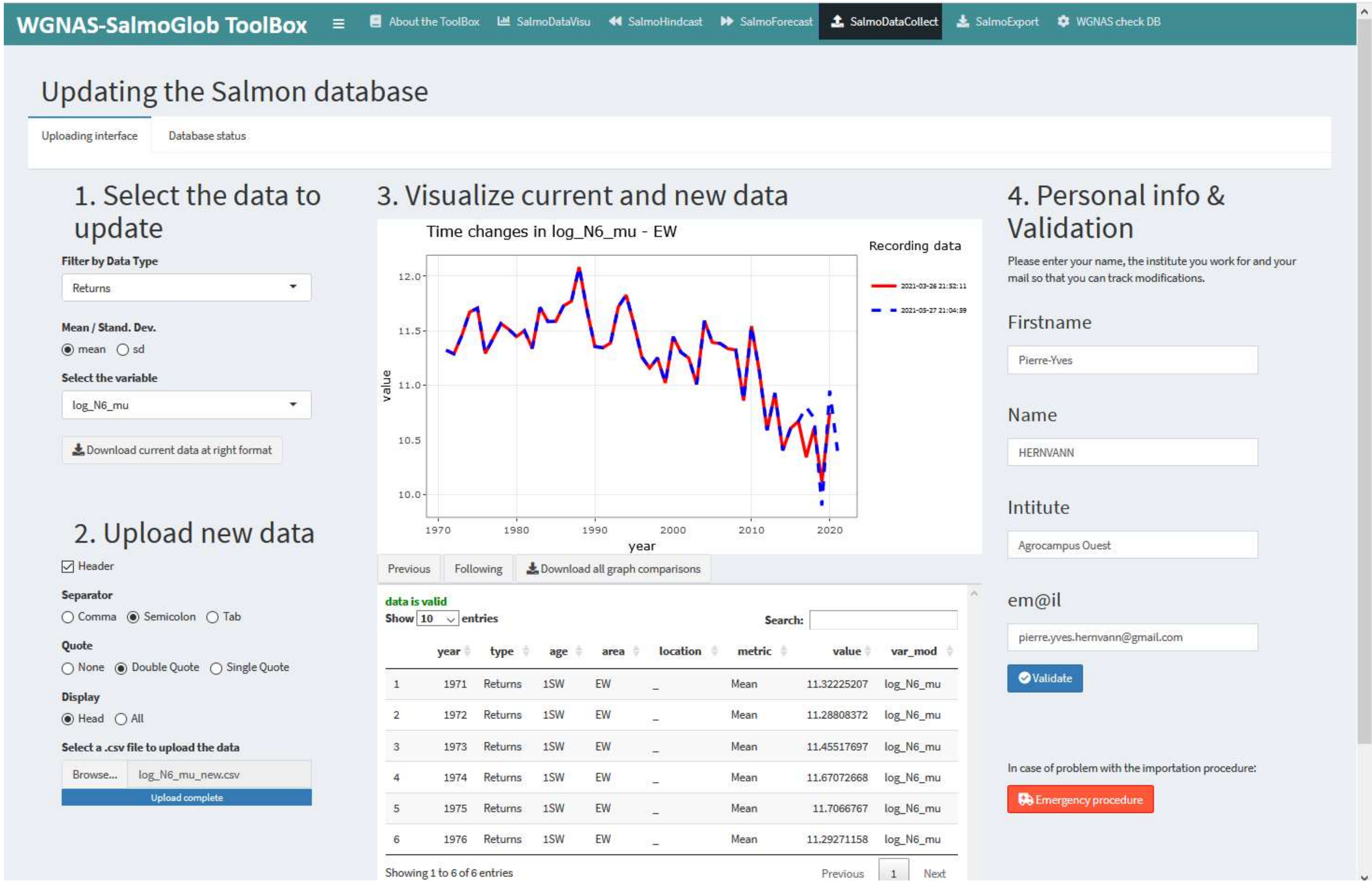

Figure 8 – Screenshot of the SalmoDataCollect page / Updating interface. Updating under progress: In box 1, the variable of the model to be updated has been informed; In box 2, the uploading interface allows to load the .csv file containing the new data on the application; In box 3, a table displays the values of the updated data when the data has passed machine tests and a figure compares the old and the new data for a visual check of the user. The "previous" and "next" buttons make possible to navigate between graphs for different areas; In box 2, the person in charge of the upload indicates its personal info to improve the modifications tracking.

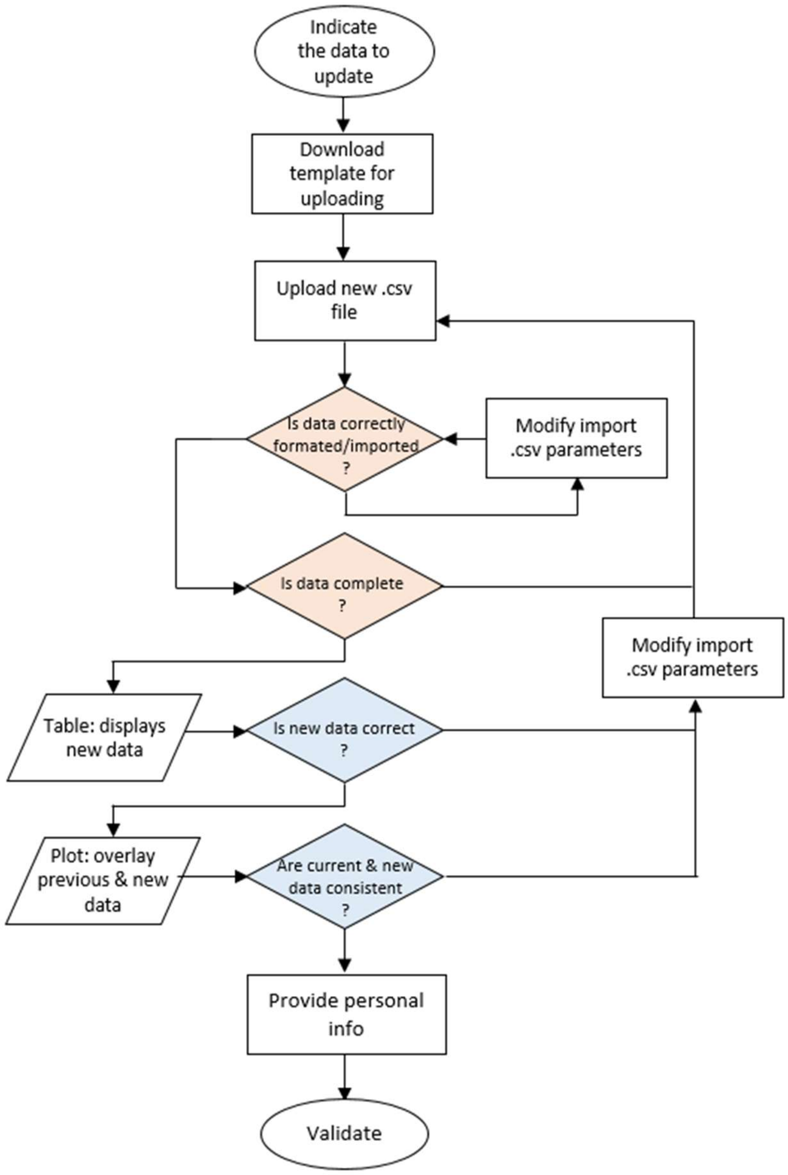

Figure 9 - Process for data updating. Ellipsoids correspond to initial and final steps, rectangles to actions made by the user, rhombus to checks performed by the user (blue) or by the machine (orange), and trapezoids to outputs produces by the application.

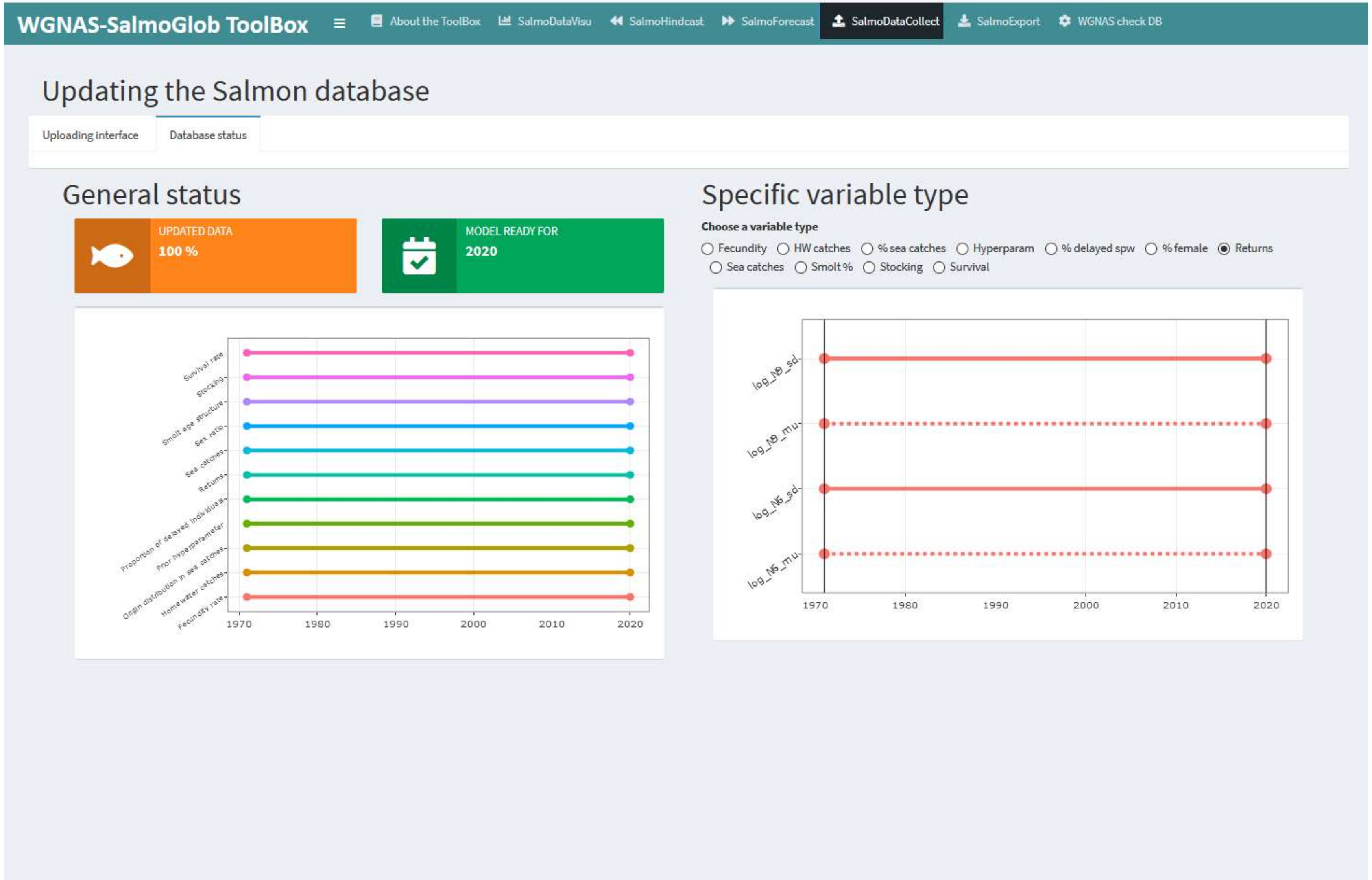

Figure 10 - Screenshot of the SalmoDataCollect page / Database status interface. Updating complete: The orange and green infoboxes indicate the % of time-series updated and the year for which can be run the model, respectively. Timelines on the left indicate the minimum temporal coverage of the time-series of each type. Timelines on the right indicate the minimum temporal coverage of the time-series for each variable of the type selected via radio-buttons.

5 Establishing a database-to-LCM information flow: Nimble inputs formatting

The Nimble platform used to code the Bayesian LCM for the North Atlantic salmon (https://r-nimble.org/) requires the data is passed into a specific format. The ToolBox has an internal procedure to automatically generate the Nimble data input files from the most up-to-date values directly read in the `SalmoGlobDatabase`. This automatic production of the Nimble data files formatted for Nimble represents a tremendous gain of time for the modelers as it avoids manipulating a large amount of variables, and it also enhances data quality control.

To run the Nimble model, the data has to be supplied as lists objects containing the different data as single values, vectors, matrices and arrays. Two different data objects have to be provided: `Data_Nimble` and `Constant_Nimble`. `Data_Nimble` contains the variables that are no considered to be observed with errors (*e.g.*, returns; see the Nimble manual for more details). `Constant_Nimble` contains all other data (*e.g.*, the value of the natural mortality rate during the second year at sea).

The internal procedure of the ToolBox generates the `Data_Nimble` and `Constant_Nimble` files as .rds files in a folder called `exchange_plateform`, whose access is given to the Nimble LCM. When running the model, input data are directly loaded from the `exchange_plateform` folder.

Note the Nimble life cycle model only can work if all time-series inputs have the same length. Thus, the transformation of the `database` table content into Nimble objects is activated only after a complete updating of the data, i.e. when all the variables have the same number of years in the model. Otherwise, the previous version of `Data_Nimble` and `Constant_Nimble` remain unchanged.

The `Data_Nimble` and `Constant_Nimble` files can be downloaded at the .rds format in the dedicated tab of the `DataExport` tool of the *WGNAS-SalmoGlob* ToolBox.

6 Visualizing outputs

The `SalmoHindcast` and `SalmoForecast` tools were built for easy exploration of the model outputs, relative to both the hindcast and the forecast of North Atlantic salmon population dynamics.

When the MCMC model run is complete, the program generates graphical outputs for the main variables of interest and stores them both as .png files (for direct integration into the WGNAS report), and as .rds files that contains all necessary info to produce the plot using R devices. Relying upon the `exchange_platform` described in Section 6, we configured the LCM script to directly save the .rds files in a `Nimble_output` folder that can be accessed from the *WGNAS-SalmoGlob* ToolBox.

6.1 Exploring model hindcasts

The `SalmoHindcast` tool (Fig. 11) focuses on representing the variables for which the fit can be compared to some data. The variables concerned are: salmon returns (as time series x SU x sea-ages), homewater catches (as time series x SU x sea-ages) and variables related to the sea catches, i.e. the total catches per fishery (as time series x sea-ages) and the proportion to allocate those catches to the different SU. Similarly to other tools previously described, drop-down menus allow to select the variable type, ages (only one at a time) and stock units / complex to visualize. The graphics allow for visual comparison of the posterior distribution of any variable with the data and the associated observation errors. For each variable selected, the user can select or unselect the stock units and the same options as for the other tools enable downloading the figures as *.png* files.

In future work, the trends of other variables with no data observed, such as the high sea harvest rates could also be represented using this tool.

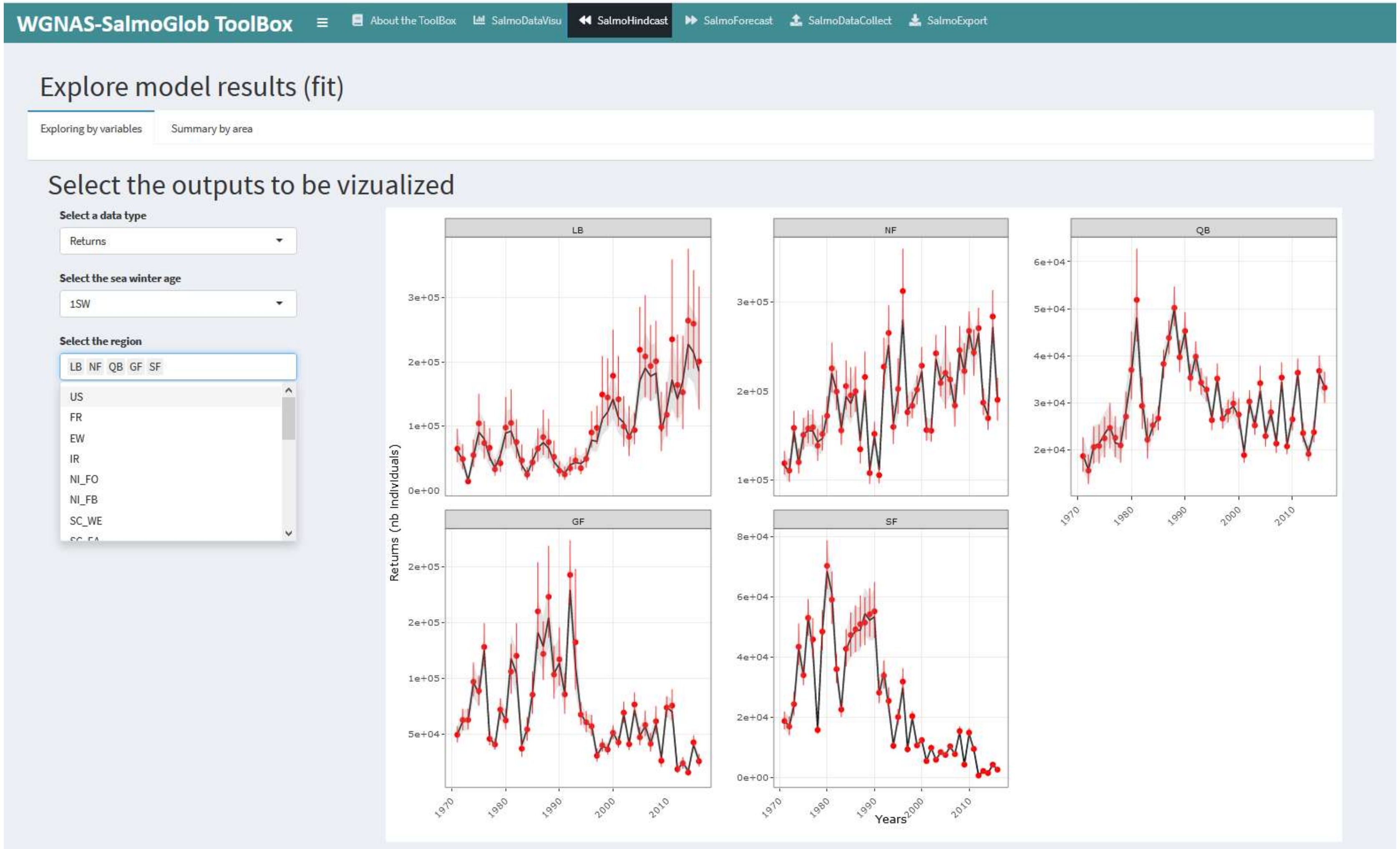

Figure 11 - Screenshot of the SalmoHindcast page. In this tool, the posterior distribution (dark line and grey envelop) are compared to the model input data (red points and error bars).

6.2 Exploring model forecasts

The `SalmoForecast` tool is composed of two tables for two different ways of exploring the short-term predictions made by the LCM. Forecast are provided for different management options represented as different values of Total Allowable catches (TAC) at Faroes and Greenland.

The `Regional exploration` tool (Fig. 12) allows visualizing the forecast as a continuation of the hindcast for all key variables in the model. In the dedicated tab, drop-down menus are used to select the geographic scale of the area explore, including here stock units too, then select the area, the type of fishery regulation scenario to explore and the variables to plot. Predictions for a specific scenario display the historical trend from the hindcast with associated uncertainty, and the projections and uncertainty resulting from random walk in population dynamics and survival processes for 9 key stage variables (the number of eggs, returns of 1SW and 2SW, the total, maturing and non maturing PFA, the post-smolt survival, the probability of maturing after 1SW and the proportion of eggs deposited by 2SW). When comparing the forecasts obtained for several scenarios (TAC ranging from 0 to 500 tons in Faroes or Greenland), one can visualize (i) the mean historical trend and the mean of short-term projections for the gradient of TACs of the mean trends of this variable or (ii) the predicted probability of reaching conservation limits over the next 5 years.

The `Global diagnosis` tool (Fig. 13) is designed to assess the probability to reach conservation limits and the proportion of 2 sea-winter spawners among complexes and countries under different catch options. Drop-down menus enable the selection of the geographic scale of the areas to compare, complexes or stock units, and of the high seas fishery concerned by the TACs.

Figure 12 – Screenshot of the SalmoForecast page. View by area. In this tool is displayed the temporal variation of 9 key life stages variables. The hindcast is shown in purple and the predictions for the 5 next years for demographic transitions (random walks with resulting uncertainty represented by the grey and blue envelopes) and abundance at different life stages according to various TAC scenarios (gradient of TAC, from low values in blue to high values in red).

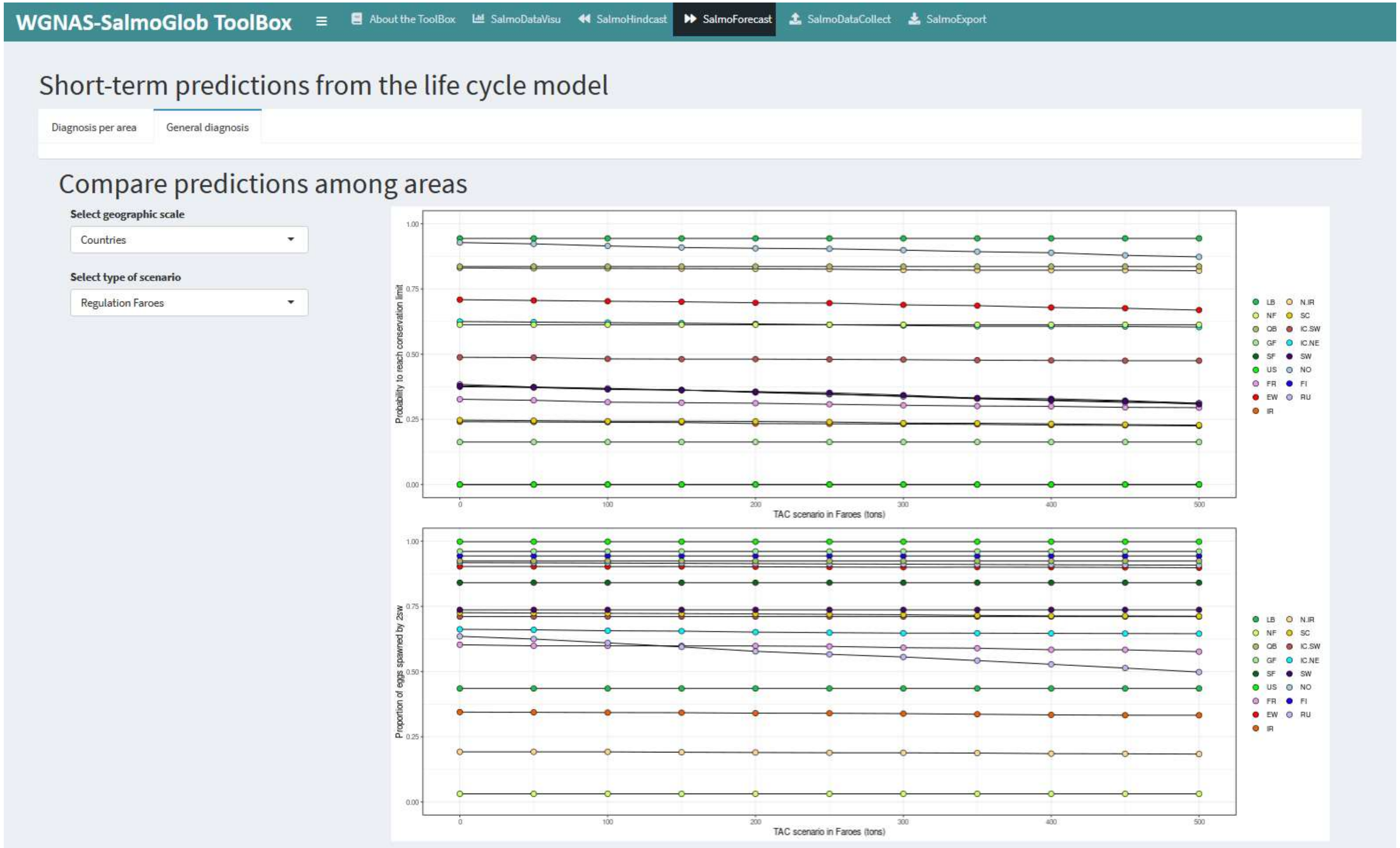

Figure 13 – Screenshot of the SalmoForecast page. Global view allowing comparing predicted conservation targets (last year of prediction) among areas for a gradient of TAC values (0-500t).

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8 Annexes

Table A1 - Metadata table from the SalmoGlob_database. Variables are referred using codes. The type of object (sv = single value, m=matrix, v=vector, a=array) and dimensions (Y=Year, SU=Stock unit, SWA= Sea water age, FWA=Fresh water age) of the corresponding object in the model are indicated The "Nimble" column indicates whether the variable is an input (Constant_nimble or Data_nimble) or an latent state variable (LSV), that is a state variable estimated by the model. Other columns correspond to the area, life-stage and fisheries concerned. A short definition enables better understanding of the role of the variable. This Table is based on the version of the LCM developed in 2021. Some modifications have been brought since then.

Variable code	Obj	dim 1	dim 2	dim 3	Name dim1	Name dim2	Name dim3	Nimble	Type	Location	Fishery	Metric	Complex	ages stage	definition
C5_NAC_1	m	47	6		Y	SU NAC		State_var	Sea catches	Bef. Gld fish.	neNF fish.	Est.	NAC	1SW mat.	Catches of 1SW mature fish from the NAC complex in early NFL/LB fisheries (for each SU separately)
C5_NAC_1_tot	v	47			Y			State_var	Sea catches	Bef. Gld fish.	neNF fish.	Est.	NAC	1SW mat.	Catches of 1SW mature fish from the NAC complex in early NFL/LB fisheries (sum over all SU in NAC)
C5_NAC_2	m	47	6		Y	SU NAC		State_var	Sea catches	Bef. Gld fish.	LB-LB/SPM/swNF fish.	Est.	NAC	1SW mat.	Catches of 1SW mature fish from the NAC complex in late NFL/LB and SPM fisheries (for each SU separately)
C5_NAC_2_lab								State_var	Sea catches	Bef. Gld fish.	LB-LB/SPM/swNF fish.	Est.	NAC	1SW mature	Catches of 1SW mature fish from the NAC complex in late NFL/LB and SPM fisheries (Fish from Labrador origin only)
C5_NAC_2_other								State_var	Sea catches	Bef. Gld fish.	LB-LB/SPM/swNF fish.	Est.	NAC	1SW mature	Catches of 1SW mature fish from the NAC complex in late NFL/LB and SPM fisheries (Fish from all SU except Labrador)
C5_NEC_1	m	47	19		Y	SU NEC		State_var	Sea catches	Bef. Gld fish.	FAR fish.	Est.	NEC	1SW mature	Catches of 1SW mature fish from the NEC complex in Faroes (for each SU separately)
C5_NEC_1_tot	v	47			Y			State_var	Sea catches	Bef. Gld fish.	FAR fish.	Est.	NEC	1SW mature	Catches of 1SW mature fish from the NEC complex in Faroes (sum over all SU in NEC)
C6_hw	m	47	25		Y	SU		State_var	Homewater catches	_	main	Est.	Multiple	1SW	Homewater catches - 1SW
C6_hw_delSp	m	47	25		Y	SU		State_var	Homewater catches	_	delayed spawners	Est.	Multiple	1SW	Homewater catches delayed spawners - 1SW
C8_2	m	47	25		Y	SU		State_var	Sea catches	Gld fish.	GLD fish.	Est.	Multiple	2SW	Catches of 2SW fish at WG (for each SU separately)
C8_2_comp	m	47	2		Y	Complex		State_var	Sea catches	Gld fish.	GLD fish.	Est.	Multiple	2SW	Catches of 2SW fish at WG (sum over all SU for each complex NAC and NEAC separately)
C8_2_tot	v	47			Y			State_var	Sea catches	Gld fish.	GLD fish.	Est.	Multiple	2SW	Catches of 2SW fish at WG (sum over all SU)
C8_NAC_1	m	47	6		Y	SU NAC		State_var	Sea catches	Bef. Gld fish.	neNF fish.	Est.	NAC	1SW non mature	Catches of 1SW non mature fish from the NAC complex in early NFL/LB fisheries before the WG fishery (for each SU separately)
C8_NAC_1_tot	v	47			Y			State_var	Sea catches	Bef. Gld fish.	neNF fish.	Est.	NAC	1SW non mature	Catches of 1SW non mature fish from the NAC complex in early NFL/LB fisheries before the WG fishery (sum over all SU in NAC)
C8_NAC_3	v	47			Y			State_var	Sea catches	Aft. Gld fish.	neNF fish.	Est.	NAC	2SW	Catches of 2SW fish from the NAC complex in late NFL fisheries (for each SU separately)
C8_NAC_3_tot	v	47			Y			State_var	Sea catches	Aft. Gld fish.	neNF fish.	Est.	NAC	2SW	Catches of 2SW fish from the NAC complex in late NFL fisheries (sum over all SU in NAC)
C8_NAC_4	m	47	6		Y	SU NAC		State_var	Sea catches	Aft. Gld fish.	LB-LB/SPM/swNF fish.	Est.	NAC	2SW	Catches of 2SW fish from the NAC complex in late LB and SPM fisheries
C8_NAC_4_lab	v	47			Y			State_var	Sea catches	Aft. Gld fish.	LB fish.	Est.	NAC	2SW	Catches of 2SW fish originated from Labrador in late LB fishery
C8_NAC_4_other	v	47			Y			State_var	Sea catches	Aft. Gld fish.	LB/SPM/swNF fish.	Est.	NAC	2SW	Catches of 2SW fish from NAC SUs except Labrador by late LB and SPM fishery
C8_NEC_1	m	47	19		Y	SU NEC		State_var	Sea catches	Bef. Gld fish.	FAR fish.	Est.	NEC	1SW non mature	Catches of 1SW non mature fish from the NEC complex in Faroes fishery (for all SU separately)
C8_NEC_1_tot	v	47			Y			State_var	Sea catches	Bef. Gld fish.	FAR fish.	Est.	NEC	1SW non mature	Catches of 1SW non mature fish from the NEC complex in Faroes fishery (total sum over all SU in NEC)
C8_NEC_3	m	47	19		Y	SU NEC		State_var	Sea catches	Aft. Gld fish.	FAR fish.	Est.	NEC	2SW	Catches of 2SW fish from the NEC complex in Faroes fishery (for all SU separately)
C8_NEC_3_tot	v	47			Y			State_var	Sea catches	Aft. Gld fish.	FAR fish.	Est.	NEC	2SW	Catches of 2SW fish from the NEC complex in Faroes fishery (total sum over all SU in NEC)

Variable code	Obj	dim 1	dim 2	dim 3	Name dim1	Name dim2	Name dim3	Nimble	Type	Location	Fishery	Metric	Complex	ages stage	definition
C9_hw	m	47	25		Y	SU		State_var	Homewater catches	_	main	Est.	Multiple	2SW	Homewater catches - 2SW
C9_hw_delSp	m	47	25		Y	SU		State_var	Homewater catches	_	delayed spawners	Est.	Multiple	2SW	Homewater catches delayed spawners - 2SW
cons_lim	v	17			CO			Const_nimble	Conservation limits	_	_	Mean	Multiple	Multiple	Conservation limits (number of eggs, for each country)
CV_N1_pr	sv	1			_			Const_nimble	Initialization first year	_		SD	Multiple	eggs	CV for Number of eggs deposited in rivers by spawners - Initialization first years
CV_theta1	v	25			SU			Const_nimble	Survival rate	_		SD	Multiple	eggs	CV of the logNormal distribution of the egg-to-smolt survival rate
date_begin	sv	1			_			Const_nimble	Number of years	_		Index	_	_	First time-step of the model
date_end	sv	1			_			Const_nimble	Number of years	_		Index	_	_	Final time step of the up-to-date data
date_end_hindcast	sv	1			_			Const_nimble	Number of years	_		Index	_	_	Final time-step of the hindcast period
deltat5_1	v	25			SU			Const_nimble	Time spent at sea	Bef. Fish.		Mean	NEC	1SW mature	Time spent at sea (number of months) for 1SW mature fish before Newfoundland fishery
deltat5_2	v	25			SU			Const_nimble	Time spent at sea	Return aft. First fishery		Mean	NEC	1SW mature	Time spent at sea (number of months) for 1SW mature fish after Newfoundland fishery and before Labrador fishery
deltat8_1	v	25			SU			Const_nimble	Time spent at sea	Bef. Fish.		Mean	NAC	1SW non mature	Time spent at sea (number of months) for 1SW non mature fish before early catches by Newfoundland and Labrador fishery
deltat8_2	v	25			SU			Const_nimble	Time spent at sea	Aft. First fish.		Mean	NAC	1SW non mature	Time spent at sea (number of months) for 1SW non mature fish after early catches by Newfoundland and Labrador fishery and before reaching Greenland
deltat8_2_1	v	25			SU			Const_nimble	Time spent at sea	Aft. Second fish.		Mean	NAC	2SW	Time spent at sea (number of months) for 2SW fish between the WG fishery and late Newfoundland, Labrador and St Pierre et Miquelon fishery
deltat8_2_2	v	25			SU			Const_nimble	Time spent at sea	Return aft. Second fishery		Mean	NAC	2SW	Time spent at sea (number of months) for 2SW fish after late Newfoundland, Labrador and St Pierre et Miquelon fishery
E_M	sv	1			_			Const_nimble	Natural mortality rate	_		Mean	Multiple	Mixed	Average natural mortality rate (per month)
E_theta1	m	47	25		Y	SU		Const_nimble	Survival rate	_		Mean	Multiple	eggs	Average egg-to-smolt survival rate
E_theta1_pr	m	7	25		Y	SU		Const_nimble	Initialization first year	_		Mean	Multiple	eggs	Average egg-to-smolts survival rate - Initialization first years
eggs	a	2	25	47	SWA	SU	Y	Const_nimble	Fecundity rate	_		Mean	Multiple	eggs	Fecundity of females - of 1SW and 2SW separately
h5_NAC_1	v	47			Y			State_var	High seas harvest rates	NF/LB fish.	neNF	Est.	NAC	1SW mature	Harvest rate fish from the NAC complex due to early Newfoundland fisheries - 1SW
h5_NAC_2	m	47	6		Y	SU NAC		State_var	High seas harvest rates	NF/LB/SPM fish.	LB-LB/SPM/swNF fish.	Est.	NAC	1SW mature	Harvest rate of fish from the NAC complex due to late Newfoundland, Labrador and Saint Pierre et Miquelon fisheries - 1SW
h5_NEC_1	m	47	19		Y	SU NEC		State_var	High seas harvest rates	FAR fish.	FAR fish.	Est.	NEC	1SW mature	Harvest rate of 1SW fish from the NEC complex due to exploitation in Faroes fishery
h6_hw	m	47	25		Y	SU		State_var	Homewater harvest rates	_	main	Est.	Multiple	1SW	Harvest rate of homewater fishery - 1SW returns
h6_hw_delSp	m	47	25		Y	SU		State_var	Homewater harvest rates	_	delayed spawners	Est.	Multiple	1SW	Harvest rate of homewater fishery - 1SW delayed spawners 1SW

Variable code	Obj	dim 1	dim 2	dim 3	Name dim1	Name dim2	Name dim3	Nimble	Type	Location	Fishery	Metric	Complex	ages stage	definition
h8_2	m	47	25		Y	SU		State_var	High seas harvest rates	GLD fish.	GLD fish.	Est.	Multiple	2SW	Harvest rate due to WG fishery - 2SW - all SU
h8_NAC_1	v	47			Y			State_var	High seas harvest rates	NF/LB fish.	neNF	Est.	NAC	1SW non mature	Harvest rate of 2SW fish from the NAC complex due to NFDL and LB fishery before reaching WG
h8_NAC_3	v	47			Y			State_var	High seas harvest rates	NF fish.	neNF	Est.	NAC	2SW	Harvest rate of NAC 2SW fish due to late NFL fisheries
h8_NAC_4	m	47	6		Y	SU NAC		State_var	High seas harvest rates	LB/SPM fish. tot	LB-LB/SPM/swNF fish.	Est.	NAC	2SW	Harvest rate of NAC 2SW fish due to late LB and SPM fisheries
h8_NAC_4_lab	v	47			Y			State_var	High seas harvest rates	LB/SPM fish. in Lb	LB fish.	Est.	NAC	2SW	Harvest rate of NAC 2SW fish originated from Labrador due to late LB fishery
h8_NAC_4_other	v	47			Y			State_var	High seas harvest rates	LB/SPM fish. out. Lb	LB/SPM/swNF fish.	Est.	NAC	2SW	Harvest rate of 2SW fish originated from NAC SUs except LB due to late LB and SPM fishery
h8_NEC_1	m	47	19		Y	SU NEC		State_var	High seas harvest rates	FAR fish.	FAR fish.	Est.	NEC	1SW non mature	Harvest rate of 1SW non mature fish from the NEC complex due to Faroes fishery
h8_NEC_3	m	47	19		Y	SU NEC		State_var	High seas harvest rates	FAR fish.	FAR fish.	Est.	NEC	2SW	Harvest rate of NEC 2SW fish due to Faroes fishery
h9_hw	m	47	25		Y	SU		State_var	Homewater harvest rates	_	main	Est.	Multiple	2SW	Harvest rate for 2SW spawners due to homewater fishery
h9_hw_delSp	m	47	25		Y	SU		State_var	Homewater harvest rates	_	delayed spawners	Est.	Multiple	2SW	Harvest rate due to homewater fishery - 2SW delayed spawners
log_C5_NAC_1_lbnf_mu	v	47			Y			Data_nimble	Sea catches	Bef. Gld fish.	neNF fish.	Mean	NAC	1SW mature	Total catches of NAC in early NFDL fishery - 1SW mature fish - mean of the log catches
log_C5_NAC_1_lbnf_sd	v	47			Y			Const_nimble	Sea catches	Bef. Gld fish.	neNF fish.	SD	NAC	1SW mature	Total catches of NAC in early NFDL fishery - 1SW mature fish - sd of the log catches
log_C5_NAC_2_lbnf_lab_mu	v	47			Y			Data_nimble	Sea catches	Bef. Gld fish.	LB fish.	Mean	NAC	1SW mature	Catches of Labrador-origin fish in late NFDL, LB and SPM fisheries - 1SW mature fish - mean of the log catches
log_C5_NAC_2_lbnf_lab_sd	v	47			Y			Const_nimble	Sea catches	Bef. Gld fish.	LB fish.	SD	NAC	1SW mature	Catches of Labrador-origin fish in late NFDL, LB and SPM fisheries - 1SW mature fish - sd of the log catches
log_C5_NAC_2_lbnf_oth_mu	v	47			Y			Data_nimble	Sea catches	Bef. Gld fish.	LB/SPM/swNF fish.	Mean	NAC	1SW mature	Catches of fish originated from all SU in NAC except LB in late NFDL, LB and SPM fisheries - 1SW mature fish - mean of the log catches
log_C5_NAC_2_lbnf_oth_sd	v	47			Y			Const_nimble	Sea catches	Bef. Gld fish.	LB/SPM/swNF fish.	SD	NAC	1SW mature	Catches of fish originated from all SU in NAC except LB in late NFDL, LB and SPM fisheries - 1SW mature fish - sd of the log catches
log_C5_NEC_1_far_mu	v	47			Y			Data_nimble	Sea catches	Bef. Gld fish.	FAR fish.	Mean	NEC	1SW mature	Total catches in Faroes - 1SW mature fish - mean of the log catches
log_C5_NEC_1_far_sd	v	47			Y			Const_nimble	Sea catches	Bef. Gld fish.	FAR fish.	SD	NEC	1SW mature	Total catches in Faroes - 1SW mature fish - sd of the log catches
log_C6_delSp_mu	m	49	25		Y	SU		Data_nimble	Homewater catches	_	delayed spawners	Mean	Multiple	1SW	Catches of delayed spawners - 1SW <96> Mean of the log catches
log_C6_delSp_sd	m	47	25		Y	SU		Const_nimble	Homewater catches	_	_	SD	Multiple	1SW	Catches of delayed spawners - 1SW <96> sd of the log catches
log_C6_mu	m	47	25		Y	SU		Data_nimble	Homewater catches	_	main	Mean	Multiple	1SW	Homewater catches - 2SW <96> mean of the log catches
log_C6_sd	m	47	25		Y	SU		Const_nimble	Homewater catches	_	_	SD	Multiple	1SW	Returns - 1SW - Sd of the log returns
log_C8_2_gld_tot_mu	v	47			Y			Data_nimble	Sea catches	Gld fish.	GLD fish.	Mean	Multiple	2SW	Total catches at Greenland - 2SW - mean of the log catches

Variable code	Obj	dim 1	dim 2	dim 3	Name dim1	Name dim2	Name dim3	Nimble	Type	Location	Fishery	Metric	Complex	ages stage	definition
log_C8_2_gld_tot_sd	v	47			Y			Const_nimble	Sea catches	Gld fish.	GLD fish.	SD	Multiple	2SW	Total catches at Greenland - 2SW - sd of the log catches
log_C8_NAC_1_lbnf_mu	v	47			Y			Data_nimble	Sea catches	Bef. Gld fish.	neNF fish.	Mean	NAC	1SW non mature	Catches in NFDL, LB fisheries - 1SW non mature - mean of the log catches
log_C8_NAC_1_lbnf_sd	v	47			Y			Const_nimble	Sea catches	Bef. Gld fish.	neNF fish.	SD	NAC	1SW non mature	Catches in NFDL, LB fisheries - 1SW non mature - sd of the log catches
log_C8_NAC_3_lbnf_mu	v	47			Y			Data_nimble	Sea catches	Aft. Gld fish.	neNF fish.	Mean	NAC	2SW	Catches in early NFDL, LB fisheries <96> 2SW - mean of the log catches
log_C8_NAC_3_lbnf_sd	v	47			Y			Const_nimble	Sea catches	Aft. Gld fish.	neNF fish.	SD	NAC	2SW	Catches in early NFDL, LB fisheries - 2SW - sd of the log catches
log_C8_NAC_4_lbnf_lab _mu	v	47			Y			Data_nimble	Sea catches	Aft. Gld fish.	LB fish.	Mean	NAC	2SW	Catches of fish originated from LB in late NFDL, LB and SPM fisheries - 2SW - mean of the log catches
log_C8_NAC_4_lbnf_lab _sd	v	47			Y			Const_nimble	Sea catches	Aft. Gld fish.	LB fish.	SD	NAC	2SW	Catchesof fish originated from LB in late NFDL, LB and SPM fisheries - 2SW - sd of the log catches
log_C8_NAC_4_lbnf_oth _mu	v	47			Y			Data_nimble	Sea catches	Aft. Gld fish.	LB/SPM/swNF fish.	Mean	NAC	2SW	Catches of fish originated from all SU in NAC except LB in late NFDL, LB and SPM fisheries - 2SW - mean of the log catches
log_C8_NAC_4_lbnf_oth _sd	v	47			Y			Const_nimble	Sea catches	Aft. Gld fish.	LB/SPM/swNF fish.	SD	NAC	2SW	Catches of fish originated from all SU in NAC except LB in late NFDL, LB and SPM fisheries - 2SW - sd of the log catches
log_C8_NEC_1_far_mu	v	47			Y			Data_nimble	Sea catches	Bef. Gld fish.	FAR fish.	Mean	NEC	1SW immat.	Total catches in Faroes - 1SW non mature - mean of the log catches
log_C8_NEC_1_far_sd	v	47			Y			Const_nimble	Sea catches	Bef. Gld fish.	FAR fish.	SD	NEC	1SW immat.	Total catches in Faroes - 1SW non mature - sd of the log catches
log_C8_NEC_3_far_mu	v	47			Y			Data_nimble	Sea catches	Aft. Gld fish.	FAR fish.	Mean	NEC	2SW	Total catches in Faroes - 2SW - mean of the log catches
log_C8_NEC_3_far_sd	v	47			Y			Const_nimble	Sea catches	Aft. Gld fish.	FAR fish.	SD	NEC	2SW	Total catches in Faroes - 2SW - sd of the log catches
log_C9_delSp_mu	m	49	25		Y	SU		Data_nimble	Homewater catches	_	delayed spawners	Mean	Multiple	2SW	Catches of delayed spawners - 2SW <96> Mean of the log catches
log_C9_delSp_sd	m	47	25		Y	SU		Const_nimble	Homewater catches	_	_	SD	Multiple	2SW	Catches of delayed spawners - 2SW - Sd of the log catches
log_C9_mu	m	47	25		Y	SU		Data_nimble	Homewater catches	_	main	Mean	Multiple	2SW	Homewater catches - 2SW - Mean of the log catches
log_C9_sd	m	47	25		Y	SU		Const_nimble	Homewater catches	_	_	SD	Multiple	2SW	Homewater catches - 2SW - Sd of the log
log_N1_pr	m	7	25		Y	SU		State_var	Initialization first year	_		Mean	Multiple	0SW	Number (log scale) of eggs deposited in rivers by spawners - Initialization first years
log_N6_mu	m	47	25		Y	SU		Data_nimble	Returns	_		Mean	Multiple	1SW	Returns - 1SW - Mean of the log returns
log_N6_sd	m	47	25		Y	SU		Const_nimble	Returns	_		SD	Multiple	1SW	Returns 1SW - Sd of the log returns
log_N9_mu	m	47	25		Y	SU		Data_nimble	Returns	_		Mean	Multiple	2SW	Returns - 2SW - Mean of the log returns
log_N9_pr	v	25			SU			State_var	Initialization first year	_		Est.	Multiple	2SW	Number (log scale) of 2SW adults returning to homewaters - Initialization first year
log_N9_sd	m	47	25		Y	SU		Const_nimble	Returns	_		SD	Multiple	2SW	Returns 2SW - Sd of the log returns
logit_theta3	m	47	25		Y	SU		State_var	Survival rate	_		Est.	Multiple	PFA	Survival between smolt and pre-fishery stage - logit scale
logit_theta3_pr	v	25			SU			State_var	Initialization first year	_		Est.	Multiple	PFA	Survival between smolt and pre-fishery stage - Logit scale - Initialization first year

Variable code	Obj	dim 1	dim 2	dim 3	Name dim1	Name dim2	Name dim3	Nimble	Type	Location	Fishery	Metric	Complex	ages stage	definition
logit_theta4	m	47	25		Y	SU		State_var	Maturation rate	_		Est.	Multiple	PFA	Maturation rate after the PFA stage - logit scale
logN2	m	47	25		Y	SU		State_var	Abundance	_		Est.	Multiple	Smolt	Total number of smolt produced in one cohort - log scale
logN2_pr	m	7	25		Y	SU		State_var	Initialization first year	_		Mean	Multiple	Smolt	Total number of smolt produced in one cohort - log scale - Initialization first year
max_log_N9	v	25			SU			Const_nimble	Initialization first year	_		Bound	Multiple	2SW	Upper bound for the prior on abundance of 2SW adults returning to homewaters - Initialization first year
mean_log_N9_pr	v	25			SU			State_var	Initialization first year	_		Mean	Multiple	2SW	Mean of the prior for distribution for abundance (log scale) of 2SW adults returning to homewaters
min_log_N9	v	25			SU			Const_nimble	Initialization first year	_		Bound	Multiple	2SW	Lower bound for the prior on abundance of 2SW adults returning to homewaters - Initialization first year
mu_N1_pr	v	25			SU			Const_nimble	Initialization first year	_		Mean	Multiple	Eggs	Mean of the prior distribution of the abundance eggs deposited in rivers by spawners - Initialization first year
N	sv	1			N			Const_nimble	Number of SU	_		Index	_	_	Number of Stock units
N_NAC	sv	1			N_NAC			Const_nimble	Number of SU	_		Index	_	_	Number of SU in the NAC complex
N_NEC	sv	1			N_NEC			Const_nimble	Number of SU	_		Index	_	_	Number of SU in the NEC complex
N_Sample	v	47			Y			Const_nimble	Prior hyperparameter	_		HP	Multiple	Mixed	Equivalent sampling size in the Dirichlet distribution used for fish distribution between SUs
N1	m	47	25		Y	SU		State_var	Abundance	_		Est.	Multiple	Eggs	Number of eggs deposited in rivers by spawners
N1_pr	m	7	25		Y	SU		State_var	Initialization first year	_		Est.	Multiple	Eggs	Number of eggs deposited in rivers by spawners - Initialization first year
N10	m	47	25		Y	SU		State_var	Abundance	_		Est.	Multiple	2SW	Abundance of 2SW spawners in homewaters after all fisheries
N2_pr	m	7	25		Y	SU		State_var	Initialization first year	_		Mean	Multiple	Parr	Pre-smolt abundance - Initialization first year
N3	a	47	6	25	Y	FWA	SU	State_var	Abundance	_		Est.	Multiple	Smolt	Abundance of smolts of each smolt age
N3_pr	a	13	6	25	Y	FWA	SU	State_var	Initialization first year	_		Est.	Multiple	Smolt	Abundance of smolts of each smolt age - Initialization first year
N3_tot	m	47	25		Y	SU		State_var	Abundance	_		Est.	Multiple	Smolt	Total abundance of smolts migrating each year (sum over all smolt ages)
N4	m	47	25		Y	SU		State_var	Abundance	_		Est.	Multiple	PFA	Abundance - PFA stage
N5	m	47	25		Y	SU		State_var	Abundance	_		Est.	Multiple	1SW mature	Abundance - maturing PFA
N6	m	47	25		Y	SU		State_var	Returns	_		Est.	Multiple	1SW	Abundance of adults returning to homewaters - 1SW
N7	m	47	25		Y	SU		State_var	Abundance	_		Est.	Multiple	1SW	Abundance of spawners in homewaters - 1SW
N8_1	m	47	25		Y	SU		State_var	Abundance	_		Est.	Multiple	1SW non mature	Abundance of 2SW individuals from the NAC complex after early catches by Newfoundland and Labrador catches
N8_2	m	47	25		Y	SU		State_var	Abundance	_		Est.	Multiple	2SW	Abundance of 2SW individuals (mixed complexes) just before WG fishery
N9	m	47	25		Y	SU		State_var	Returns	_		Est.	Multiple	2SW	Abundance of adults returning to homewaters - 2SW
nSm	sv	1			_			Const_nimble	Number of smolt ages	_		Index	_	Smolt	Number of smolt ages

Variable code	Obj	dim 1	dim 2	dim 3	Name dim1	Name dim2	Name dim3	Nimble	Type	Location	Fishery	Metric	Complex	ages stage	definition
omega	m	25	25		SU	SU		Const_nimble	Prior hyperparameter	–		HP	_	_	Identify m for the formulation of Wishart priors
p_C5_NEC_1	m	47	19		Y	SU NEC		State_var	Proportion of origin in sea catches	FAR fish.		Est.	NEC	1SW mature	Proportions to allocate catches to the SU in Europe - 1SW mature
p_C5_NEC_1_far_mu	m	47	19		Y	SU NEC		Data_nimble	Proportion of origin in sea catches	FAR - by SU	FAR fish.	Mean	NEC	1SW mature	Proportions to allocate catches to the SU in Europe - 1SW mature
p_C8_2_NAC	m	47	6		Y	SU NAC		State_var	Proportion of origin in sea catches	GLD fish.		Est.	NAC	2SW	Proportions to allocate catches at WG among SU within NAC
p_C8_2_NAC_gld_mu	m	47	6		Y	SU NAC		Data_nimble	Proportion of origin in sea catches	GLD - by NAC SU	GLD fish.	Mean	NAC	2SW	Proportions to allocate catches at WG among SU within NAC
p_C8_2_NEC	m	47	19		Y	SU NEC		State_var	Proportion of origin in sea catches	GLD fish.		Est.	NEC	2SW	Proportions to allocate catches at WG among SU within NEAC
p_C8_2_NEC_gld_mu	m	47	19		Y	SU NEC		Data_nimble	Proportion of origin in sea catches	GLD - by NEC SU	GLD fish.	Mean	NEC	2SW	Proportions to allocate catches at WG among SU within NEAC
p_C8_2_NECNAC	m	47	2		Y	Complex		State_var	Proportion of origin in sea catches	GLD fish.		Est.	Multiple	2SW	Proportions to allocate catches at WG between NEAC/NAC
p_C8_2_NECNAC_gld_mu	m	47	2		Y	Complex		Data_nimble	Proportion of origin in sea catches	GLD - by cplx	GLD fish.	Mean	NEC	2SW	Proportions to allocate catches at WG between NEAC/NAC
p_C8_NEC_1	m	47	19		Y	SU NEC		State_var	Proportion of origin in sea catches	FAR fish.		Est.	NEC	2SW	Proportions to allocate catches at Faroes to the SU in Europe - 1SW non mature
p_C8_NEC_1_far_mu	m	47	19		Y	SU NEC		Data_nimble	Proportion of origin in sea catches	FAR - by SU	FAR fish.	Mean	NEC	1SW not maturing	Proportions to allocate catches at Faroes to the SU in Europe - 1SW non mature
p_C8_NEC_3	m	47	19		Y	SU NEC		State_var	Proportion of origin in sea catches	FAR fish.		Est.	NEC	2SW	Proportions to allocate catches at Faroes to the SU in Europe - 2SW
p_C8_NEC_3_far_mu	m	47	19		Y	SU NEC		Data_nimble	Proportion of origin in sea catches	FAR - by SU	FAR fish.	Mean	NAC	2SW	Proportions to allocate catches at Faroes to the SU in Europe - 2SW
p_smolt	a	47	6	25	Y	FWA	SU	Const_nimble	Smolt age structure	_		Mean	Multiple	Smolt	Proportions of smolt age
p_smolt_pr	a	7	6	25	Y	FWA	SU	Const_nimble	Initialization first year	_		Mean	Multiple	Smolt	Proportions of smolt age - Initialisation first years
prop_female	a	2	25	47	SWA	SU	Y	Const_nimble	Sex ratio	_	_	Mean	Multiple	Multiple	Proportion of females - for 1SW and 2SW separately
Stocking_2SW	m	47	25		Y	SU		Const_nimble	Stocking	_		Mean	Multiple	2SW	Stocking of 2SW from aquaculture
tau_theta3	m	25	25		SU	SU		State_var	Survival rate	_		Prec.	Multiple	PFA	Precision matrix for the multivariate random walk on the marine survival theta3(logit scale)
tau_theta4	m	25	25		SU	SU		State_var	Maturation rate	_		Prec.	Multiple	PFA	Precision matrix for the multivariate random walk on the proportion of maturing PFA (logit scale)
theta1	m	47	25		Y	SU		State_var	Survival rate	_		Est.	Multiple	Eggs	Eggs-smolts survival rate

Variable code	Obj	dim 1	dim 2	dim 3	Name dim1	Name dim2	Name dim3	Nimble	Type	Location	Fishery	Metric	Complex	ages stage	definition
theta3	m	47	25		Y	SU		State_var	Survival rate	_		Est.	Multiple	PFA	Smolt-PFA survival rate
theta3_pr	v	25			SU			State_var	Initialization first year	_		Est.	Multiple	PFA	Smolt-PFA survival rate - Initialization first year
theta4	m	47	25		Y	SU		State_var	Maturation rate	_		Est.	Multiple	PFA	Proportion of maturing PFA
theta5_1_NAC	v	6			SU NAC			State_var	Survival rate	Bef. NF/LB fish.		Mean	NAC	1SW mature	Survival rate of 1SW fish from the NAC complex before Newfoundland fishery
theta5_1_NEC	v	19			SU NEC			State_var	Survival rate	Bef. FAR fish.		Mean	NEC	1SW mature	Survival rate of 1SW fish from the NEC complex before Faroes fishery
theta5_2_NAC	v	6			SU NAC			State_var	Survival rate	Aft. NF/LB fish.		Mean	NAC	1SW mature	Survival rate of 1SW fish from the NAC complex after Newfoundland fishery and before Labrador fishery
theta5_2_NEC	v	19			SU NEC			State_var	Survival rate	Aft. FAR fish.		Mean	NEC	1SW mature	Survival rate of 1SW fish from the NEC complex after Faroes fishery
theta6_delSp	m	47	25		Y	SU		Const_nimble	Proportion of delayed individuals	_		Mean	Multiple	1SW	Proportion of delayed spawners - 1SW spawners
theta6_surv	m	47	25		Y	SU		Const_nimble	Survival rate	_		Mean	Multiple	1SW	Survival rate to account for the additional mortality in home waters - 1SW spawners
theta8_1_NAC	v	6			SU NAC			State_var	Survival rate	Bef. NF/LB fish.		Mean	NAC	1SW non mature	Survival rate of 2SW fish from the NAC complex before Newfoundland and Labrador fishery
theta8_1_NEC	v	19			SU NEC			State_var	Survival rate	Bef. FAR fish.		Mean	NEC	1SW non mature	Survival rate of 2SW fish from the NEC complex before Faroes fishery
theta8_2	v	25			SU			State_var	Survival rate	_		Est.	Multiple	1SW non mature	Survival rate of NEC and NAC 2SW fish after early fisheries and before reaching Greenland
theta8_2_1_NAC	v	6			SU NAC			State_var	Survival rate	Btw. NF/LB - GLD fish.		Mean	NAC	2SW	Survival rate of NAC 2SW fish after Greenland fishery and before late NFDL, LB and SPM fishery
theta8_2_1_NEC	v	19			SU NEC			State_var	Survival rate	Btw. FAR - GLD fish.		Mean	NEC	2SW	Survival rate of NEC 2SW fish after Greenland fishery and before Faroes fishery
theta8_2_2_NAC	v	6			SU NAC			State_var	Survival rate	Btw. GLD - NF/LB fish.		Mean	NAC	2SW	Survival rate of NAC 2SW fish after late NFDL, LB and SPM fishery
theta8_2_2_NEC	v	19			SU NEC			State_var	Survival rate	Btw. GLD - FAR fish.		Mean	NEC	2SW	Survival rate of NEC 2SW fish in the environment after late Faroes fishery
theta9_delSp	m	47	25		Y	SU		Const_nimble	Proportion of delayed individuals	_		Mean	Multiple	2SW	Proportion of delayed spawners - 2SW spawners
theta9_surv	m	47	25		Y	SU		Const_nimble	Survival rate	_		Mean	Multiple	2SW	Survival rate to account for the additional mortality in home waters - 2SW spawners