BEMTOOL VERSION 2

USER'S MANUAL

Authors:

Isabella Bitetto[1], Maria Teresa Facchini[1], Maria Teresa Spedicato[1], Paolo Accadia[2], Monica Gambino[2], Marisa Rossetto[3], Paco Melià[3] and Giuseppe Lembo[1]

[1]COISPA, Tecnologia&Ricerca, Bari, Italy
[2]NISEA, Fishery and Aquaculture Economic Research, Salerno, Italy
[3]Department of Electronics, Information, and Bioengineering, Politecnico of Milano, Italy

IB, MTF, MTS, PL contributed to the model design, the development of the population and pressure components, the MCDA, the impementation of the platform and R-GUI.

PA and MG contributed to the development of the economic components.

MR and PM contributed to the development of the MCDA.

Correspondign author:

bitetto@coispa.it

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The opinions expressed are those of the Authors of the studies only and do not represent the Commission's official position.

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1. Foreword

BEMTOOL v.1 (June, 2013) was developed and released for the first time as an output of the BEMTOOL project, Specific Project N.4 (SI2.613770) of MAREA (Mediterranean hAlieutic Resources Evaluation and Advice) Framework contract (MARE/2009/05_Lot1).

BEMTOOL v.2 (December, 2014)

BEMTOOL model was upgraded in the LANDMED project, Specific Project N.11 (SI2.678902) of MAREA with new features that make it more in line with the Management Strategy Evaluation framework New functions were introduced regarding the uncertainty model and the relationship between fishing mortality by fleet-stock and effort. Discard and selectivity modelling were further improved. Some technical aspects to improve the user accessibility were also implemented.

BEMTOOL v.2.0.6 (current release)

The relevant upgrades implemented in BEMTOOL v.2.0.6 in the context of SEDAF project, Specific Project N.10 (SI2.666117) of MAREA regarded the economic module with a more refined association of a price to the discard (options: constant price or price depending on the discard volume by elasticity coefficient), so that the revenues take into account both the income related to the sale of landing of the target species and the income from the sale of the discard of the target species.

In ALADYM core a new facility has been introduced in order to parameterize the biological simulation with entry by F (fishing mortality) also in case the F by fleet segment is not available.

Also a revision of all the tables and graphs produced by BEMTOOL and ALADYM has been done in order to avoid redundancy in the variables and graphs saved in BEMTOOL and ALADYM folders.

2. Introduction

BEMTOOL is a platform incorporating 6 operational modules (Biological, Pressure, Economic, Behavioural, Policy/Harvest Rules and Multi-Criteria Decision Analysis – MCDA) characterized by components communicating by means of the relationship and equations.

BEMTOOL application is used to define a case study and assess different scenarios from the biological, impact/pressure and economic point of view. In this document we will refer to *simulation* for the past and current years and we will name *forecast* the future years. The process of the bio-economic modelling can be summarized in the following steps:

1 **Case study configuration**, including the name of the case study, species, fleet segments, simulation and forecast period;

2 Parameterization of the **biological simulation** entering biological parameters by species in ALADYM or, optionally, selecting the assessment tool (VIT, XSA, SURBA or Report) and importing the outcomes;

3 Input of **effort and landing data** time series;

4 **Diagnosis** to visualize the state of the stocks, the impact/pressure, the state of the fleet and the economic indicators in the past/present;

5 Parameterization of the **economic simulation;**

6 Selection of the **management (harvest) rules** for the planning of the forecast scenario or, alternatively, the selection of the option for the **MEY calculation**;

7 Implementation of the **forecast** to predict the state of the stocks, the impact/pressure and the state of the fleet and the economic indicators in future after the implementation of management trajectories;

8 Parameterization of the **Multi Criteria Decision Analysis (MCDA)** entering the utility parameters and weights for the indicators and estimation of the results.

3. Requirements

The requirements to run BEMTOOL application are listed below:

1. The BEMTOOL application works under Windows XP SP3, Windows Vista, Windows 7, both Bit and 64Bit versions. The correct functioning is not guarantee on Linux-like Operative systems.

2. R-CRAN software version > 2.14.2 must be installed on your computer. R installer for Windows and other OS can be found at http://cran.r-project.org.

3. In the R-CRAN installation the following R packages must be installed: **FLXSA** library and linked **FLAdvice**, **Flash**, **FLAssess**, **FLBRP**, **FLCore** packages; also **akima**, **ggplot2**, **ggplotFL**, **plyr**, **proto** and **reshape** are required to be installed; also **RGtk2** package is needed to run R graphical interface.

4. RGtk2 package requires the installation of the GTK+ Toolkit. It can be found at http://ftp.gnome.org/pub/GNOME/binaries/win32/gtk+/2.22/gtk+-bundle_2.22.1-20101227_win32.zip.

BEMTOOL application can be run on machines having at least Pentium 4 and 512 Mb RAM.

In order to give an idea of the computation time of the software, the time needed for the calculation of confidence intervals (CI) has been monitored, on PC with 16 GB RAM. The computation time of this operation has been reported, being in this version the calculation more time consuming.

Lifespan	Nb fleet segments	N Runs	Time
6 years	7	500	2:00

8 years	8	500	2:15
15 years	7	500	2:30

It is suggested to re-run the forecast with the CI, only after the finalization of the forecast without CI (when the results are considered satisfactory).

4. Installation

Install the BEMTOOL application following the steps below:

1) Install R environment (version R > 2.14.2[1]) downloading it from R-CRAN web site.

2) Open R console and launch the script *RUNme.r*. The software will auto-install all the needed libraries downloading the packages from the R-cran web site.

3) When installing the RGtk2 package, the downloading from the GTK+ Project web site and the installation of the GTK+ Toolkit is automatically launched. Select “Install GTK+” and click “OK” button on the dialog box.

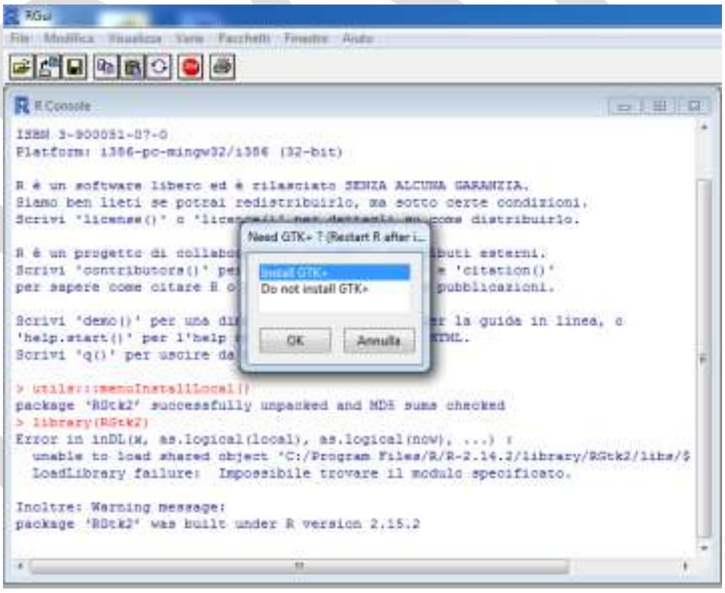


Figure 1 – Dialog box for the automatic installation of the GTK+ Toolkit.

4) Place the main BEMTOOL folder in any location of your computer (in this document referred as *BEMTOOL Application path)*. See the images below for the content of the *BEMTOOL Application path*.

[1] BEMTOOL app is tested with 2.14.2, R 3.0.1, R 3.0.2, R 3.0.3 version.

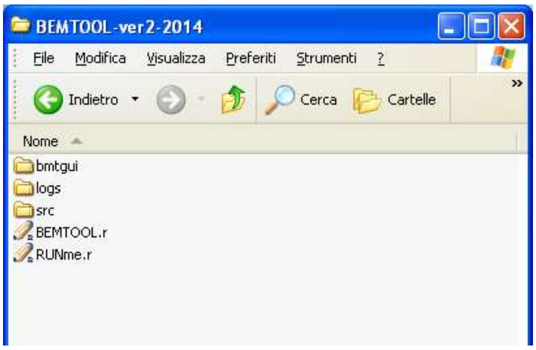


Figure 2 – Content of *BEMTOOL Application path*.

5) To run BEMTOOL application correctly, it is strongly recommended to set International Language Settings from Control Panel on your own computer:

    a. use semicolon as field separator in .csv file;

    b. do not use symbol as thousands separator in numeric values;

    c. use full stop as decimal separator in numeric values.

6) <u>Be sure that every time you run BEMTOOL application all input and output files are not in use!</u>

5. Running the application

To run the application follow the steps below:

1) Open R console
2) Change working directory from File → Change dir... select the BEMTOOL folder
3) Launch the *BEMTOOL.r* script from File → Source R code... The BEMTOOL GUI will appear (Figure 3).

A folder named ***bmtdocs*** containing the templates to construct the necessary files to run BEMTOOL and ALADYM component is included within the BEMTOOL application folder.

In Case study configuration tab, click on LOAD Case Study definition button and choose the configuration file in .csv format previously compiled following the *bmtconfigTemplateSimulation.xlsx* (in *bmtdocs* folder) to load the whole configuration for the simulation phase (past and current years).

Move forward and backward among the tabs using *Next* and *Prev* buttons until Economic data tab. Then, click on Run SIMULATION button. The ALADYM GUI for the first species of the case study will be loaded: load the ALADYM configuration file previously compiled following the *CONFIGURATION file.csv* (in *bmtdocs/ALADYM_input* folder) to parameterize the model for the first stock in the simulation phase and click on run SIMULATION button. Secondly, the ALADYM GUI for the second species of the case study will be loaded: load the ALADYM configuration file and click on run SIMULATION button to start the simulation also for this species. Go along the simulations until the last species. After the ALADYM simulation, the BEMTOOL GUI will be again activated and the DIAGNOSIS tab will show the results of the simulation phase.

After clicking on “Next buttons” until Economic parameters tab, click on LOAD Scenario configuration and choose the scenario configuration file in .csv format previously compiled following the *bmtconfigTemplate Scenario.xlsx* (in *bmtdocs* folder) to load the whole configuration for the forecast phase (future years).

For all scenarios is possible to check the confidence intervals calculation for each stock. The confidence intervals calculation requires a computational time that can vary depending on the power of the computer used (see paragraph 3 for further details).

The results are visualized in FORECAST tab.

6. Case Study Configuration

The *Case Study Configuration* screen is the basic screen of the application. The user interacts with the application and enter the required initial information. The type of information needed to be input concerns: application path of BEMTOOL (in this document referred as *BEMTOOL R-core path*), case study path for the saving of the outputs (in this document referred as *BEMTOOL casestudy path*), geographical area, involved stocks and fleet segments (fishing techniques and LOA), start and end of the simulation period, start and end of the forecast period. Only when all the aforementioned inputs have been provided, the user can proceed with the parameterization of the model.

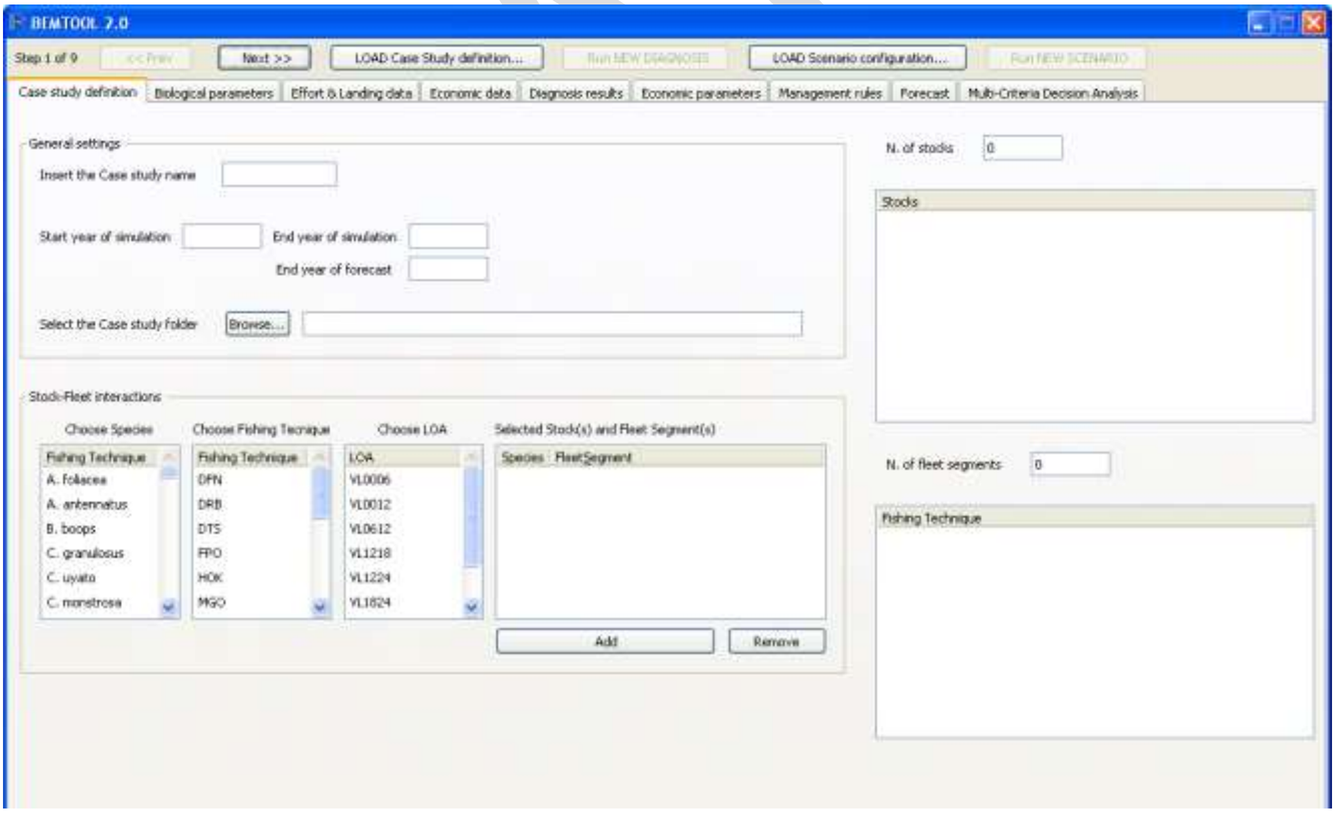


Figure 3 – BEMTOOL case study configuration tab.

The possibility to load an existing case study is given. When a case study is launched, BEMTOOL saves the related configuration file named *bmtconfig.csv* in the root of the application.

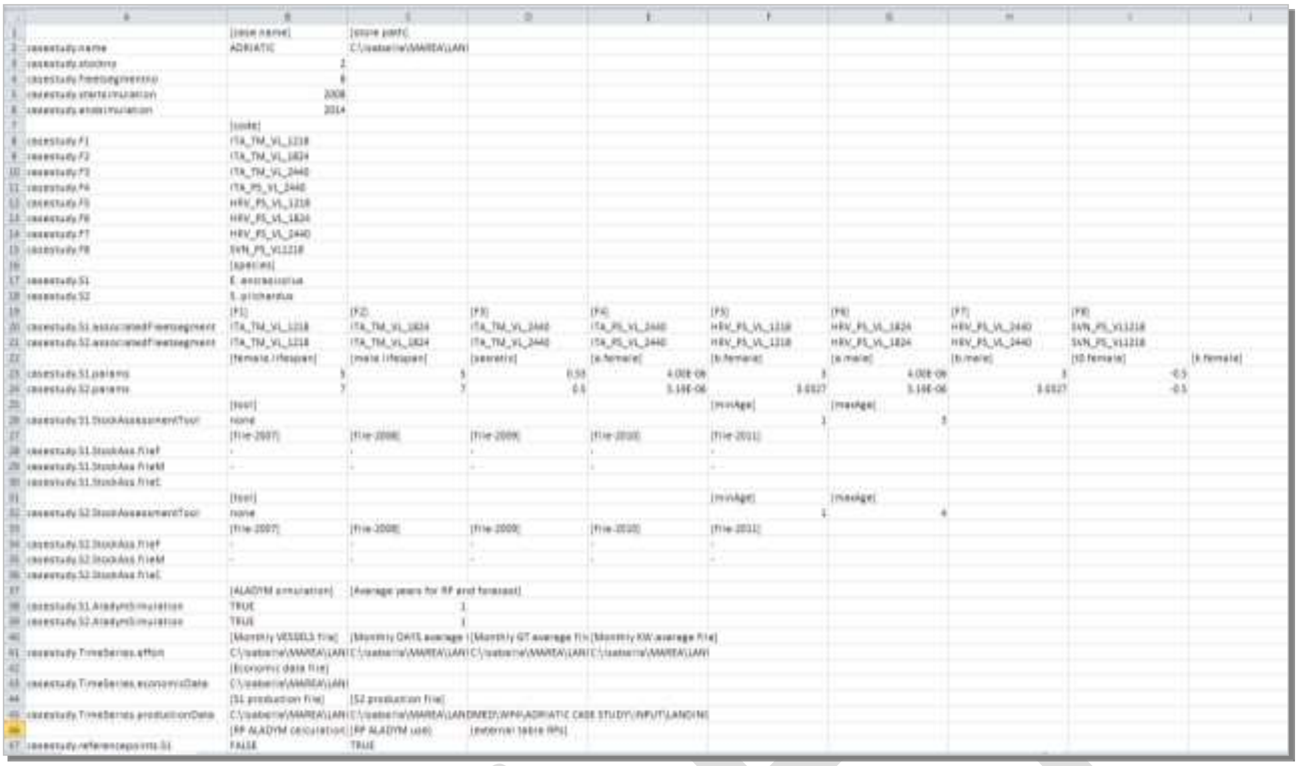


Figure 4 – Content of the configuration file (bmtconfig.csv).

All the steps of the case study configuration are detailed below. In case that a *bmtconfig.csv* file from a previous run is loaded, the user has to move from the first tab (Case study definition) from the fourth tab (Economic data).

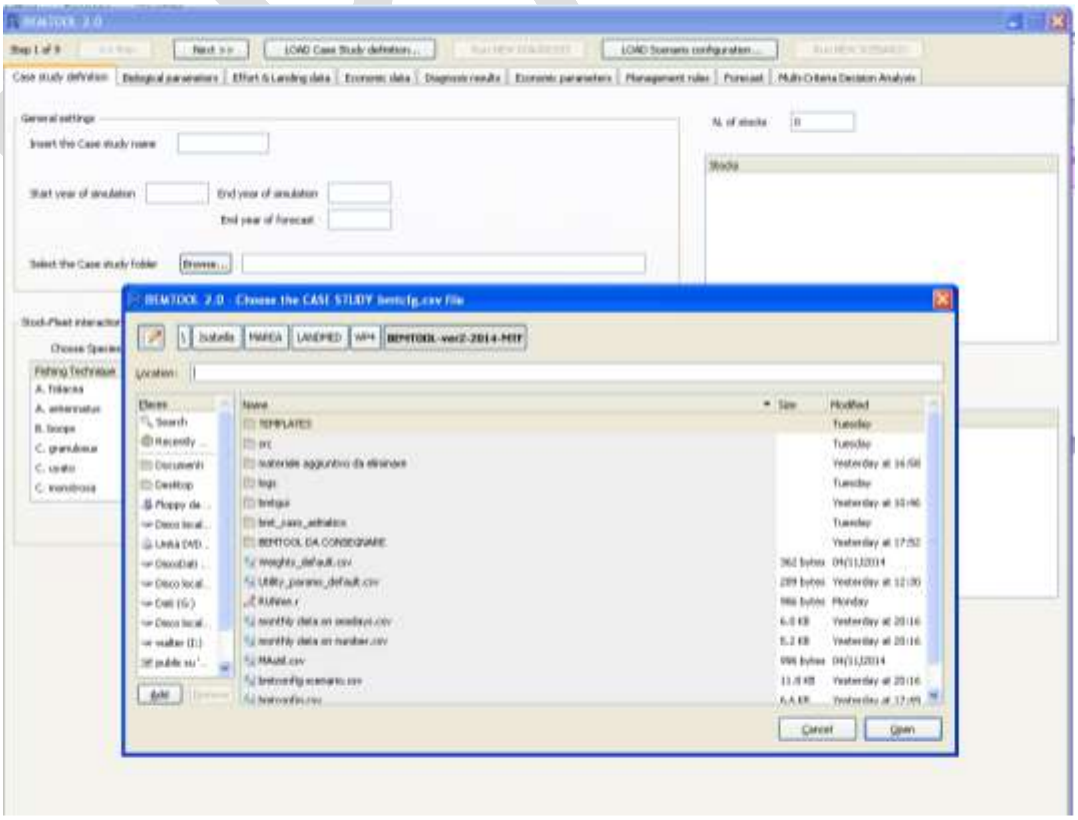


Figure 5 – Case study configuration tab: LOAD Case Study definition button.

1) Set a short name for the case study (less than 10 characters), the period of simulation and forecast and the ***BEMTOOL casestudy path***, that is the location where the outputs (graphs and tables) from the application will be written. For control reasons, the case study path is written in the “Case study path” field, above the path selection window. To select the BEMTOOL casestudy path, double click on the directory explorer window until the desired location is reached.

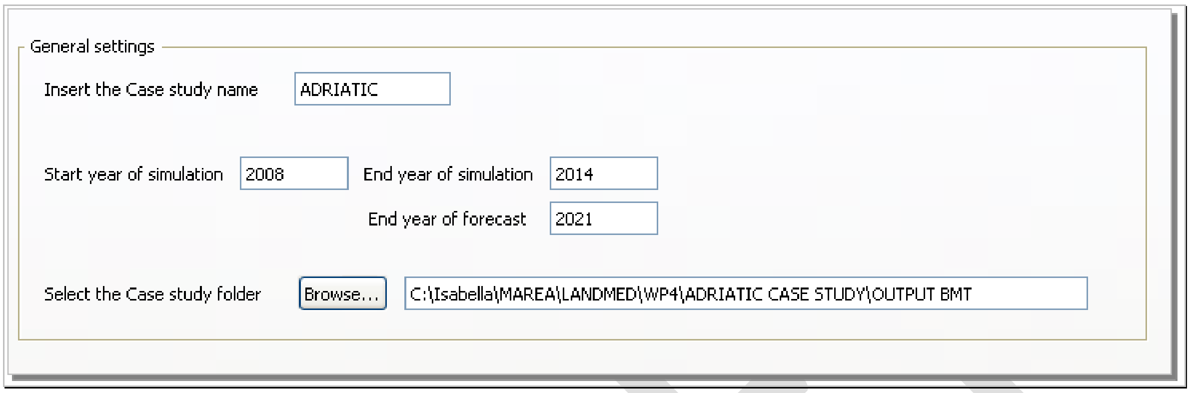


Figure 6 – Case study configuration tab: select the case study folder.

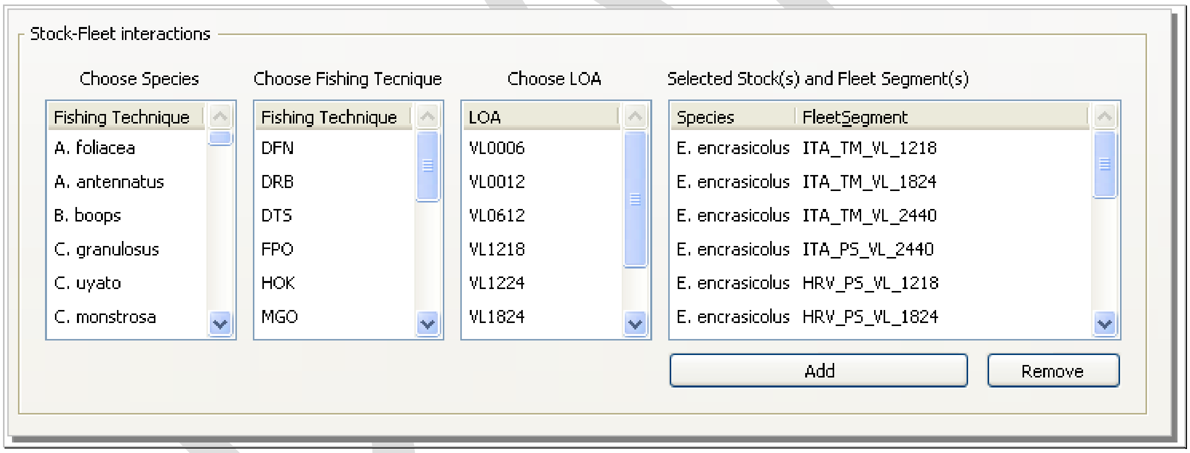


Figure 7 – Case study configuration tab: define the fleet-stock interactions.

2) Select the **species** involved in the case study clicking on the desired scientific names in the “Species” list. The combination of species, fishing techniques and LOAs, defines the associations between species and fleet segments. One species at a time can be selected with the related fishing techniques and LOAs. For a second species, another combination of fishing techniques and LOAs can be set. The file of species list *species.bmt* is located on *bmtgui\utils* folder. Any text editor or Excel can be used for editing and saving the .bmt file.

3) After the selection of a species, the **fishing technique(s)** must be defined, clicking on one fishing technique in the “Fishing Techniques” list. If more than one fishing techniques wants to be selected, the shortcuts SHIFT + click or Ctrl + click can be used for selecting continues items from the list or

separately items respectively. The file of fishing techniques list *Gear.bmt* is located on *bmtgui\utils* folder. Any text editor or Excel can be used for editing and saving the .bmt file.

4) After the selection of a species and fishing technique(s), the **LOA(s)** must be defined. Click on one LOA in the "LOA" list. If more than one LOA wants to be selected, the shortcuts Ctrl +click or Ctrl + click can be used for selecting continues items from the list or separately items respectively. The file of LOA list *FleetSegment.bmt* is located on *bmtgui\utils* folder. Any text editor or Excel can be used for editing and saving the .bmt file.

5) Once a species, fishing technique(s) and LOA(s) have been selected, press the "Fleet stock interaction" button to add the defined **fleet-stock interactions** to the case study. A list of the combinations is produced and displayed on the "Selected Stock(s) and Fleet Segment(s)" area. The process 4-7 has to be repeated for the other species. This fleet-stock interactions list can be modified in sense to delete item(s) or clear all items. To delete an item, click on the item and push the "Del an item" button. The "Clear all items" button delete all items from the list. The number of stocks and number of fleet segments as well as a list of each of them are displayed in the bottom of this area.

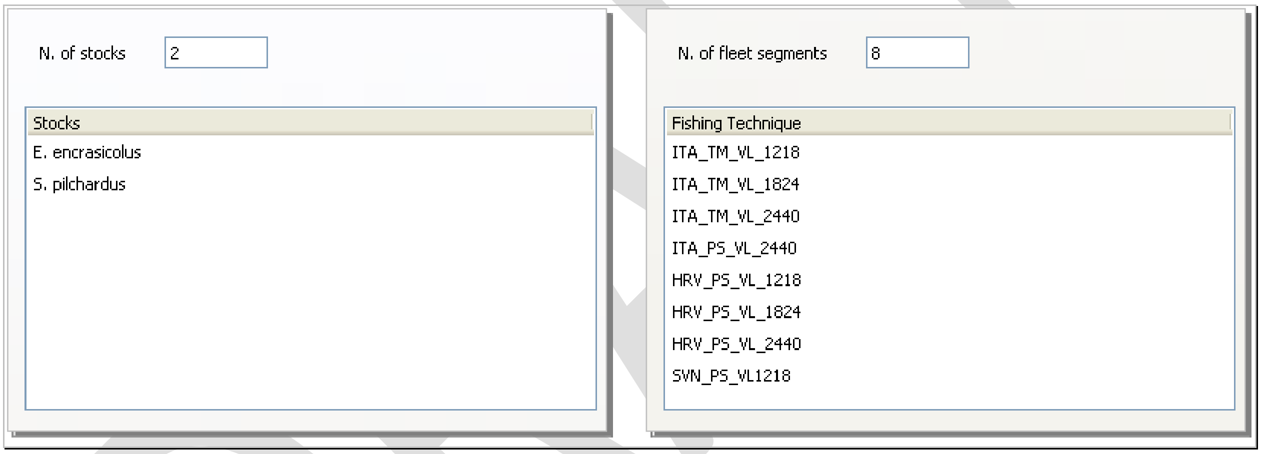


Figure 8 – List of fleet-stock interactions added to the case study.

Once the user has completed the configuration of case study, he/she can pass to the next screen (Biological Assessment Simulation), clicking on "Next" button.

Refer to the bmtconfigTemplateSimulation.xlsx and bmtconfigTemplateScenario.xlsx files provided with the BEMTOOL application in *bmtdocs* folder to build correctly a *bmtconfig.csv* file. In these two files there are comments and explanations for each cell. After the compilation, the *bmtconfig TemplateSimulation.xls* has to be saved as .csv and can be load from the BEMTOOL GUI from the button "Load Casestudy Definition". Similarly, after the compilation of the *bmtconfigTemplateScenario.xls*, it has to be saved as .csv and can be load from the BEMTOOL GUI from the button "Load Scenario configuration".

7. Biological parameters

The Biological Assessment Simulation screen covers the entry of all the information related to the parameters of the life history traits and tools used for the assessment of the stocks involved in the case study.

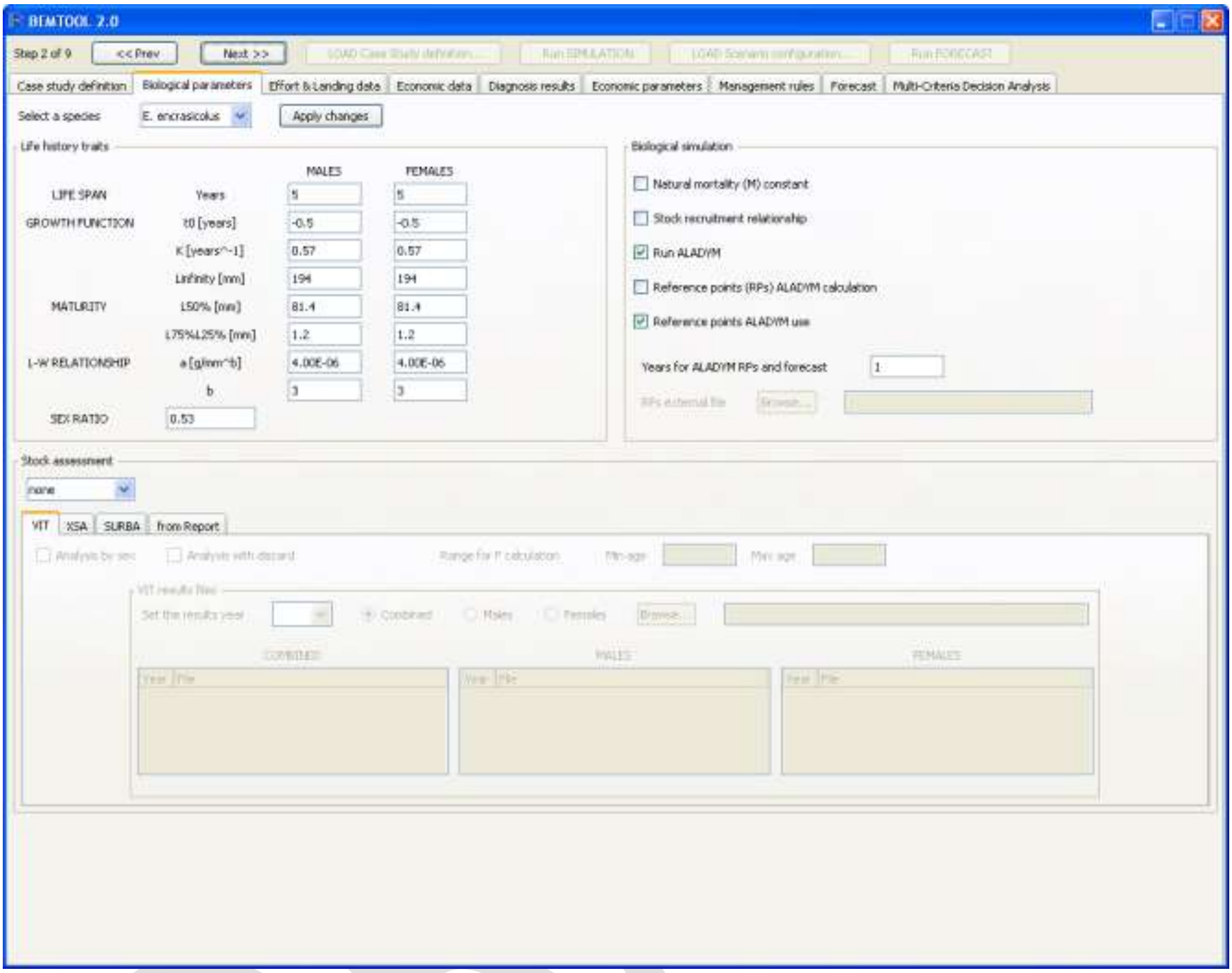


Figure 9 - Biological Assessment Simulation screen.

On the left part of the screen, a dropdown menu with the defined stocks is displayed. For each stock, the biological parameters and outputs from assessment tools must be given selecting the stock, inputing the parameters and clicking on Apply changes. The biological parameters that have to be entered are the following:

- life span (in years) by sex;
- sex ratio (F/F+M);
- length-weight relationship coefficients (a and b) by sex (<u>attention to the units</u>: **mm/g**);
- von Bertalanffy parameters by sex (<u>attention to the unit</u>: L_∞ in **mm**);
- maturity ogive parameters (size at first maturity and maturity range, <u>attention to the unit:</u> **mm**);
- natural mortality constant (flag: TRUE/FALSE);
- stock-recruitment relationship (flag: TRUE/FALSE).

The natural mortality and the stock recruitment relationship (if present) will be entered directly in ALADYM GUI.

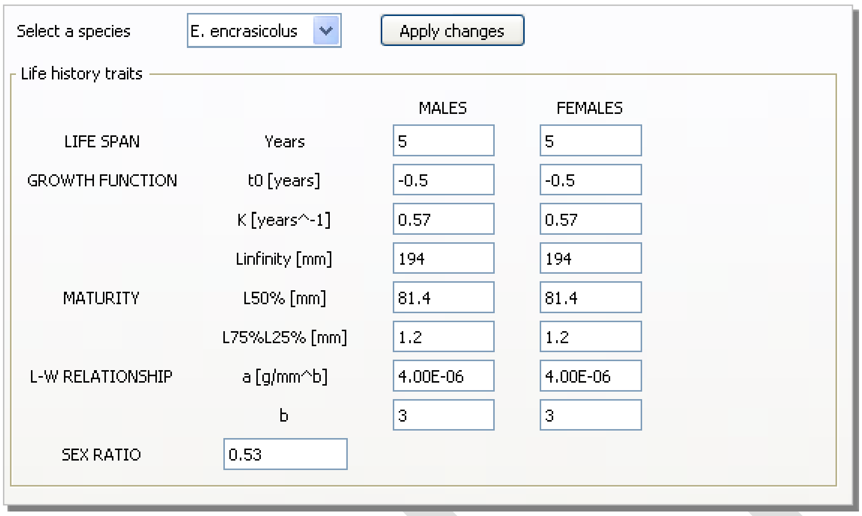


Figure 10 – Example of parameterization of *E. encrasicolus* by sex: lifespan, von Bertalanffy growth function coefficients, maturity ogive parameters, length-weight relationship coefficients and sex ratio.

The user can decide to parameterize ALADYM simulation model starting from VIT, XSA, SURBA output or to use the results from any stock assessment report. Alternatively, ALADYM model can be run without this automatic parameterization. When an assessment tool is selected, the software shows the needed input. According to the assessment tool used, a different number of input has to be entered.

6.1 Parameterization from VIT output

If the state of the stock has been evaluated with VIT (Lleonart et al., 2003) by age, the output of the analysis can be recalled from the BEMTOOL GUI, indicating "VIT" in the "Stock Assessment" drop-down menu of the Biological parameters tab and set if the analysis has been performed:

- by sex (select/deselect the "Analysis by sex" checkbox)
- with discard (select/deselect the "Analysis by discards" checkbox)

Pay attention on selecting "Analysis by discards" checkbox. Select it, if you have any information on the discard that you want is taken into account by the model (also if the discard is equal to 0). Deselect it if you have no information on the discard (the discard is not available).

Moreover, the user has to enter the age range to calculate the F current, the same for males and females in "Min age" and "Max age" text areas. For each year and sex in which the VIT analysis has been performed, the user has to specify the output file: select for each year the output file by means of browse button.

Only in case the user chose to run ALADYM and parameterize it with VIT output, it may happen that the VIT analysis has not been performed for every year in the simulation period. In this case, the ALADYM GUI will contain the VIT output only for the years indicated by the user: the lacking years of the simulation period have to be filled in from ALADYM GUI before running the simulation (see paragraph 9.1 ALADYM Simulation).

If the user deselects the flag by sex, he/she has to enter the path of the VIT output files (see paragraph 16.1 VIT output stock assessment .csv file) at row *Combined* (see Figure 11); alternatively, if the user has performed an analysis by sex, the path of the VIT output files have to be entered at rows *Females* and *Males*.

Figure 11 – Example of stock assessed by VIT for 2008; the assessment of the considered stock has been performed off-line with sex combined and with no discard.

Before run the simulation, the user has to prepare a .csv file on the basis of the following structure:

- LCA results (just copy and paste from the VIT graphical interface);
- Reference points in terms of factors from Y/R analysis;
- Y/R analysis results (for all the factors from 0 to 2).

All the tables have to be pasted without empty rows among them. An example of output VIT file compatible with BEMTOOL is provided in *Stock assessment template* folder (see paragraph 16.1 VIT output stock assessment .csv file).

To have a detailed description about how run VIT, see VIT Manual[2] *off-line Stock Assessment tools/VIT*.

ATTENTION: VIT model should be used to assess the stock only in case of short times series or in case of evidence of population in steady state, that is the main assumption which VIT is based on (Ratz et al., 2010). In case this assumption is not met, VIT output should not be used to parameterize ALADYM model that works in cohort approach.

6.2 Parameterization from XSA output

If the state of the stock has been evaluated by XSA, the user has to choose “XSA” in the “Stock Assessment” drop-down menu and set the number of age classes in the “Number of age classes combined”, since the XSA analysis is performed for sex combined.

[2] VIT: software for fishery analysis User’s Manual by Jordi Lleonart and Jordi Salat (FAO COMPUTERIZED INFORMATION SERIES), available to the address: http://www.fao.org/docrep/W7219E/W7219E00.htm

In order to parameterize BEMTOOL model using the XSA estimates, the user has to run the code provided in *off-line Stock Assessment tools/XSA* folder (*XSA_BEMTOOL.rar*) to produce off-line the 4 files needed to run the simulation.

Then, the user has to specify the path of 4 files:

- XSA Results (.dat file, containing the FLXSA object with the XSA results; see paragraph 16.2 Preparation of XSA output object point *a*)
- Catch by fleet file (.csv containing the number of individuals by age, fleet and year in the catch; see point 11 of input in paragraph 16.2 Preparation of XSA output object*)*
- F by fleet (.csv containing the F disaggregated by fleet segment; see paragraph 16.2 Preparation of XSA output object point *b*)
- Reference point table (.csv file with the main results related to the reference points; see paragraph 16.2 Preparation of XSA output object point *c*)

Locate each file by means of the browse button.

Figure 12 – Form for the input of stock assessed by XSA.

For a detailed description of how to save the 4 files needed for the parameterization, see Appendix 1, paragraph 16.2 Preparation of XSA output object.

6.3 Parameterization from Report

If the user prefers to parameterize the ALADYM model with estimates from external sources (for example from any stock assessment report), he/she has to select “from Report” in the “Stock Assessment” drop-down menu, insert the number of age classes and indicate the external file to be read, locating it by means of the browse button.

In BEMTOOL package a template to store the stock assessment results from external source has been provided in *Stock assessment template* folder.

Figure 13 – Form to input indications on the external .csv file containing the estimates from a stock assessment report.

The necessary estimates to configure the BEMTOOL objects for the simulation phase from a stock assessment report are:

- Fishing mortality by age and year;
- Natural mortality by age and year;
- Proportion of matures by age and year;
- Stock in numbers by age and years (thousands);
- Mean individual weight of the stock by age and year (kg);
- Catch in numbers by age and year (thousands);
- Mean individual weight of the catches by age and year (kg);
- Catch by fleet segment, age and year;
- Landing in numbers by age and year (thousands);
- Mean individual weight of the landings by age and year (kg);
- Landing by fleet segment, age and year;
- Discard in numbers by age and year (thousands);
- Mean individual weight of the discard by age and year (kg);
- Discard by fleet segment, age and year;
- Fishing mortality by fleet segment, age and year;
- Reference points;
- Age range for mean F.

Pay attention to put the fleet segments in the <u>same order</u> of the BEMTOOL configuration settings also in the template of stock assessment results.

For details on the preparation of the format to load report data see paragraph External report stock assessment .csv file)

6.4 Parameterization from SURBA output

If the user prefers to parameterize the ALADYM model with estimates from SURBA (Needle, 2003), he/she has to indicate "SURBA" in the "Stock Assessment" drop-down menu, chose the file containing the output of SURBA (see paragraph 16.3 SURBA output stock assessment .csv file) locating it by means of the browser; also the number of age classes on which the model will calculate the average total mortality has to be inserted in the "Number of age classes" text area.

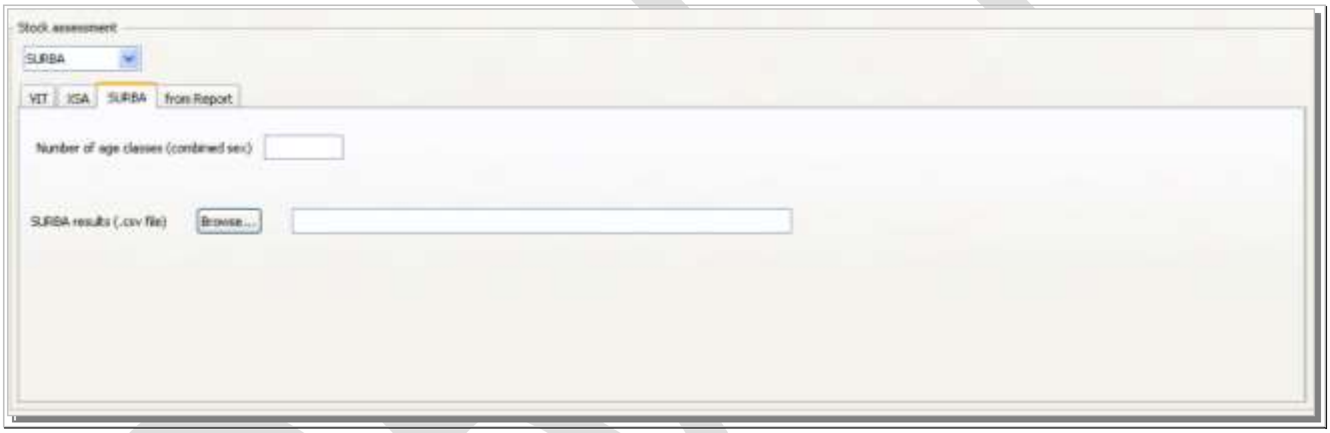


Figure 14 – Form for the input of stock assessed by SURBA.

To have a detailed description about how to run SURBA, see SURBA Manual[3] provided in *off-line Stock Assessment tools/SURBA* folder.

For a detailed description of the preparation of SURBA output file readable by BEMTOOL model, refer to paragraph 16.3 SURBA output stock assessment .csv file. A template is provided in folder *Stock assessment template* folder.

[3] SURBA 3.0: Technical Manual (first draft) Coby L. Needle FRS Marine Laboratory Aberdeen August 22, 2005

6.5 Settings for ALADYM simulation

For each stock involved in the case study, if the user wants to simulate the stock for present and past years using ALADYM, he/she has to select "Run ALADYM" check box. In case of selection of an off-line stock assessment tool (e.g. VIT, XSA, etc…), the stock assessment output are used to parameterize ALADYM model.

Moreover, if the ALADYM simulation is selected, the user has to indicate in the "Number of years for average in forecast" text area a number of years on which the model will calculate the average of the total/fishing mortality to be used both in the forecast phase and for reference points calculation (for which also for average recruitment is used).

The "Run ALADYM" check box must be selected in case of stock assessment results are not available and deselected if the user chooses to not perform ALADYM simulation. The "Run ALADYM" check box could be selected also in combination of other assessment tools: in this case ALADYM will be parameterized with the available output of the stock assessment.

If "Run ALADYM" is deselected for one of the stocks, only *Change of Total F* management rule (performed by Medium Term Forecast SGMED scripts) can be applied for the forecast.

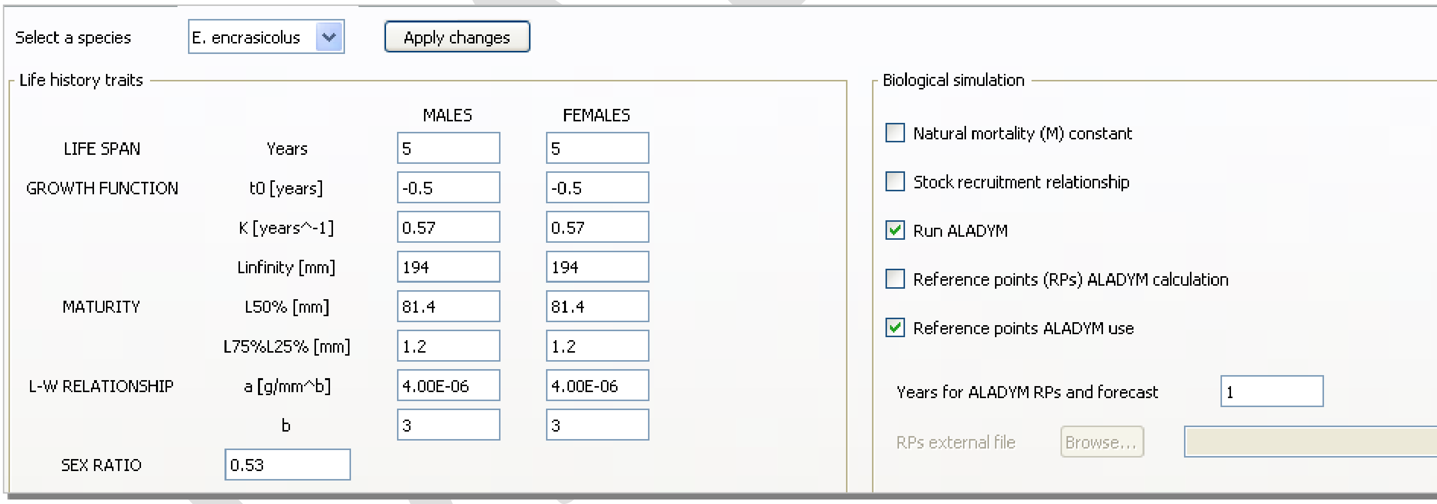


Figure 15 – Example of configuration about ALADYM simulation and reference point by stock; in this case, for all the stocks the reference points previously calculated by ALADYM will be taken into account.

Moreover, the user has to decide which reference points will be taken into account in *Diagnosis* phase for each stock; if the user prefers to use the reference points contained in stock assessment output, he/she has to **deselect** the "Reference points ALADYM calculation" check box, while if he/she prefers to use ALADYM reference points, the check box has to be selected.

If the user has already calculated the reference points with ALADYM for the considered stock in a previous run of the model, he/she can select the "Reference points ALADYM use" check box without selecting "Reference points ALADYM calculation". **Be sure that the *Reference points.csv* and *YpR Results.csv* files previously saved by ALADYM in the *Diagnosis\Biological Pressure Impact\ALADYM – [species]* directory under the folder related to the considered stock are present.**

Another possibility is that the user decides to use reference points from the stock assessment. If he/she is parameterizing the model with the stock assessment results from VIT, XSA or external source, doesn't need to specify any other information. But if he/she is not using the stock assessment results or is using SURBA output (that does not perform Reference point calculation), he/she has to specify for each species the path where table with the information of reference points (see 16.5 Reference points .csv file) is located in the related text area.

If any indication about reference points isn't provided, the model will not be able to produce the diagnosis results.

8. Effort and Landing Data

Once all parameters are filled correctly in the "Biological parameters" tab, click on the "Next" button in order to continue the process and pass in Effort and Landing data tab.

7.1 Effort data

The effort data consists of number of vessels, average days at sea, average GT and average KW by fleet segment and month during the simulation period.

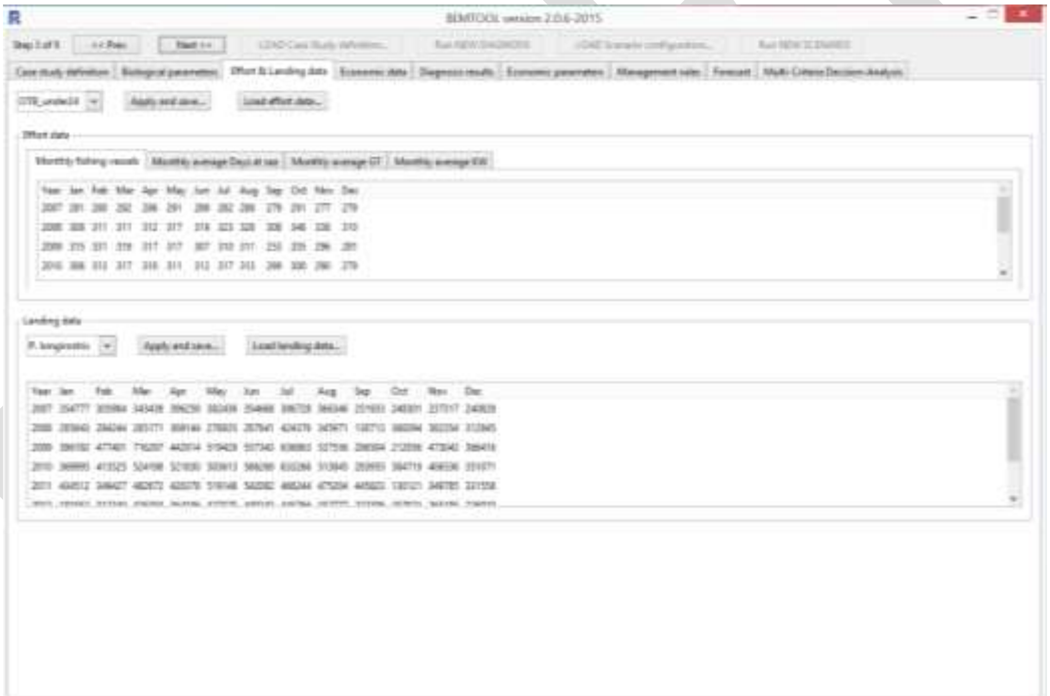
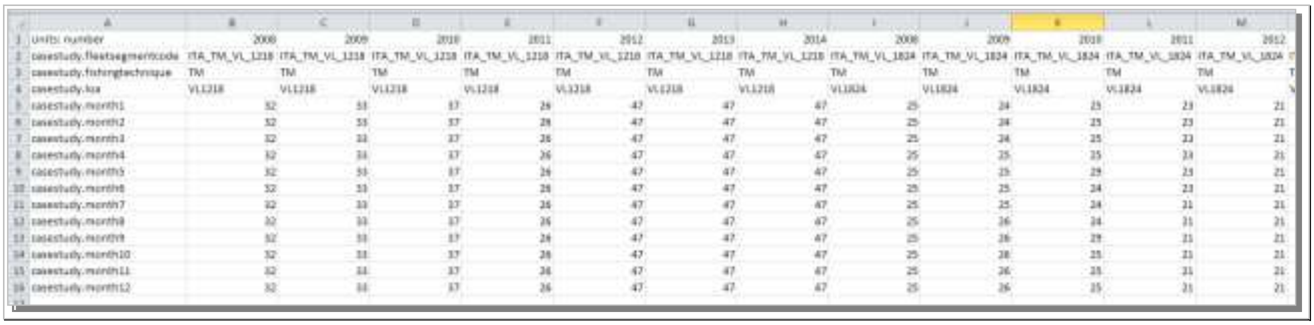


Figure 16 - Economic Simulation screen.

The "Effort & Landing data" tab supports the entry of the fishing effort and landings by month that can be load from external files (Load landing data and Load effort data buttons) showed in the figure below. For further details see the files provided with the application (in *bmtdocs\ECONOMIC_timeseries* folder).



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Units: number	2008	2009	2010	2011	2012	2013	2014	2008	2009	2010	2011	2012
2	casestudy.fleetsegmentcode	ITA_TM_VL_1218	ITA_TM_VL_1218	ITA_TM_VL_1218	ITA_TM_VL_1218	ITA_TM_VL_1218	ITA_TM_VL_1218	ITA_TM_VL_1218	ITA_TM_VL_1824	ITA_TM_VL_1824	ITA_TM_VL_1824	ITA_TM_VL_1824	ITA_TM_VL_1824
3	casestudy.fishingtechnique	TM	TM	TM	TM	TM	TM	TM	TM	TM	TM	TM	TM
4	casestudy.loa	VL1218	VL1218	VL1218	VL1218	VL1218	VL1218	VL1218	VL1824	VL1824	VL1824	VL1824	VL1824
5	casestudy.month1	32	33	37	26	47	47	47	25	24	23	23	21
6	casestudy.month2	32	33	37	28	47	47	47	25	24	23	23	21
7	casestudy.month3	32	33	37	26	47	47	47	25	24	25	23	21
8	casestudy.month4	32	33	37	26	47	47	47	25	25	25	24	21
9	casestudy.month5	32	33	37	26	47	47	47	25	25	29	23	21
10	casestudy.month6	32	33	37	26	47	47	47	25	25	24	23	21
11	casestudy.month7	32	33	37	26	47	47	47	25	25	24	21	21
12	casestudy.month8	32	33	37	26	47	47	47	25	26	24	21	21
13	casestudy.month9	32	33	37	26	47	47	47	25	26	29	21	21
14	casestudy.month10	32	33	37	26	47	47	47	25	28	25	21	21
15	casestudy.month11	32	33	37	26	47	47	47	25	26	25	21	21
16	casestudy.month12	32	33	37	26	47	47	47	25	26	25	21	21

Figure 17 – Format to load fishing effort data: number of vessels, average days at sea, average GT, average KW. Example related to number of vessels.

A .csv file has to be created for each of the four effort variables and recalled in BEMTOOL GUI in this tab.

Moreover, fishing effort by fleet segment and stock can be modified in the GUI and saved by *Apply and save* buttons as showed in the figure below.

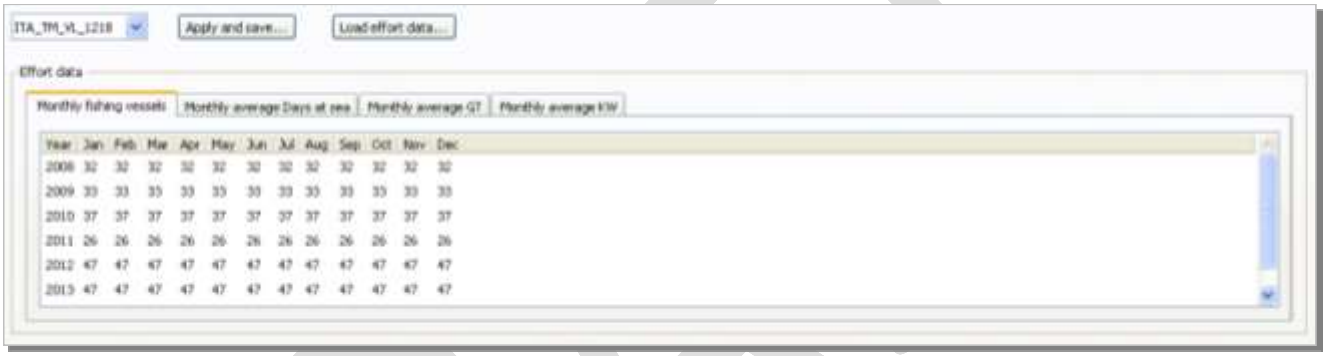
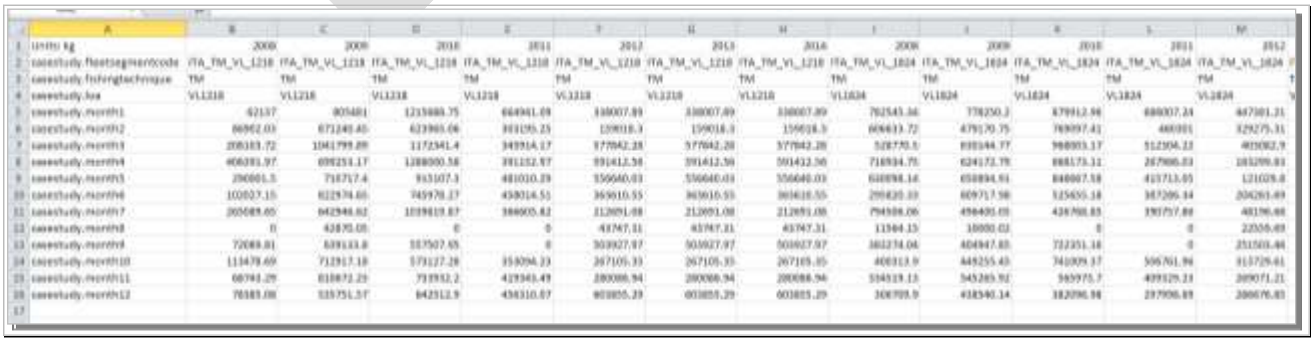


Figure 18 - Form for edit/view/save effort parameters: number of fishing vessels, days at sea, GT and KW.

7.2 Landing data

The landings data consists of landings in weight (expressed in kg) by fleet segment and month during the simulation period for each of the stock involved in the case study. A .csv file has to be created for each stock. The .csv file has the format showed below. **In the months in which landings are not present, the 0 value has to be entered in the cell.** For further details see the files provided with the application (in *bmtdocs\ECONOMIC_timeseries* folder).



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Units: kg	2008	2009	2010	2011	2012	2013	2014	2008	2009	2010	2011	2012
2	casestudy.fleetsegmentcode	ITA_TM_VL_1218	ITA_TM_VL_1218	ITA_TM_VL_1218	ITA_TM_VL_1218	ITA_TM_VL_1218	ITA_TM_VL_1218	ITA_TM_VL_1218	ITA_TM_VL_1824	ITA_TM_VL_1824	ITA_TM_VL_1824	ITA_TM_VL_1824	ITA_TM_VL_1824
3	casestudy.fishingtechnique	TM	TM	TM	TM	TM	TM	TM	TM	TM	TM	TM	TM
4	casestudy.loa	VL1218	VL1218	VL1218	VL1218	VL1218	VL1218	VL1218	VL1824	VL1824	VL1824	VL1824	VL1824
5	casestudy.month1	62137	805481	1215888.75	664941.09	338007.89	338007.89	338007.89	782543.34	778250.2	879912.98	688007.24	447301.21
6	casestudy.month2	86962.03	871240.45	623965.06	303195.25	159018.3	159018.3	159018.3	606613.72	479170.75	769097.41	480301	329275.31
7	casestudy.month3	208183.72	1041799.89	1172341.4	349914.17	577042.28	577042.28	577042.28	528770.5	898144.77	998093.17	512904.22	403082.9
8	casestudy.month4	408281.97	698251.17	1288000.58	391152.97	591412.58	591412.58	591412.58	718934.75	624172.79	888173.12	267908.83	183299.83
9	casestudy.month5	290001.5	718717.4	913107.3	481010.29	556640.03	556640.03	556640.03	618898.14	658894.91	848007.58	415713.05	121028.8
10	casestudy.month6	103027.15	822974.65	745978.27	458014.51	369610.55	369610.55	369610.55	299820.33	609717.58	525655.18	387206.34	204261.69
11	casestudy.month7	205089.65	842946.82	1039819.87	384605.82	212691.08	212691.08	212691.08	794508.06	496401.05	426760.83	190757.88	48196.68
12	casestudy.month8	0	42870.05	0	0	43747.31	43747.31	43747.31	11564.15	10000.02	0	0	22508.69
13	casestudy.month9	72088.81	639133.8	337507.65	0	503927.97	503927.97	503927.97	382274.04	404947.85	722351.18	0	251501.44
14	casestudy.month10	111478.69	712917.18	573127.28	353094.23	267105.33	267105.35	267105.35	400313.9	449255.43	741009.37	596761.94	313729.61
15	casestudy.month11	68743.29	818872.29	719932.2	429341.49	280088.94	280088.94	280088.94	514519.13	545265.92	565975.7	409329.23	289071.21
16	casestudy.month12	78183.08	535751.57	842512.9	434310.07	603855.29	603855.29	603855.29	308709.9	438540.14	382096.98	297906.89	286676.83

Figure 19 – Format to load landings data by stock.

ATTENTION: In order to obtain simulated landing consistent with observed data, the production data entered in the model have to be consistent with the production data used in the off-line stock assessment.

Moreover, monthly landing by fleet segment and stock can be modified in the GUI and saved by Apply and save button as showed in the figure below.

Figure 20 - Form for edit/view/save monthly landings data.

9. Economic data

Clicking again on "Next" button, the Economic data tab will be activated: in this tab are displayed all the economic data related to the simulation.

In the first part are displayed the costs, then the revenues per species related to landings and also those related to discards and finally other economic observed data.

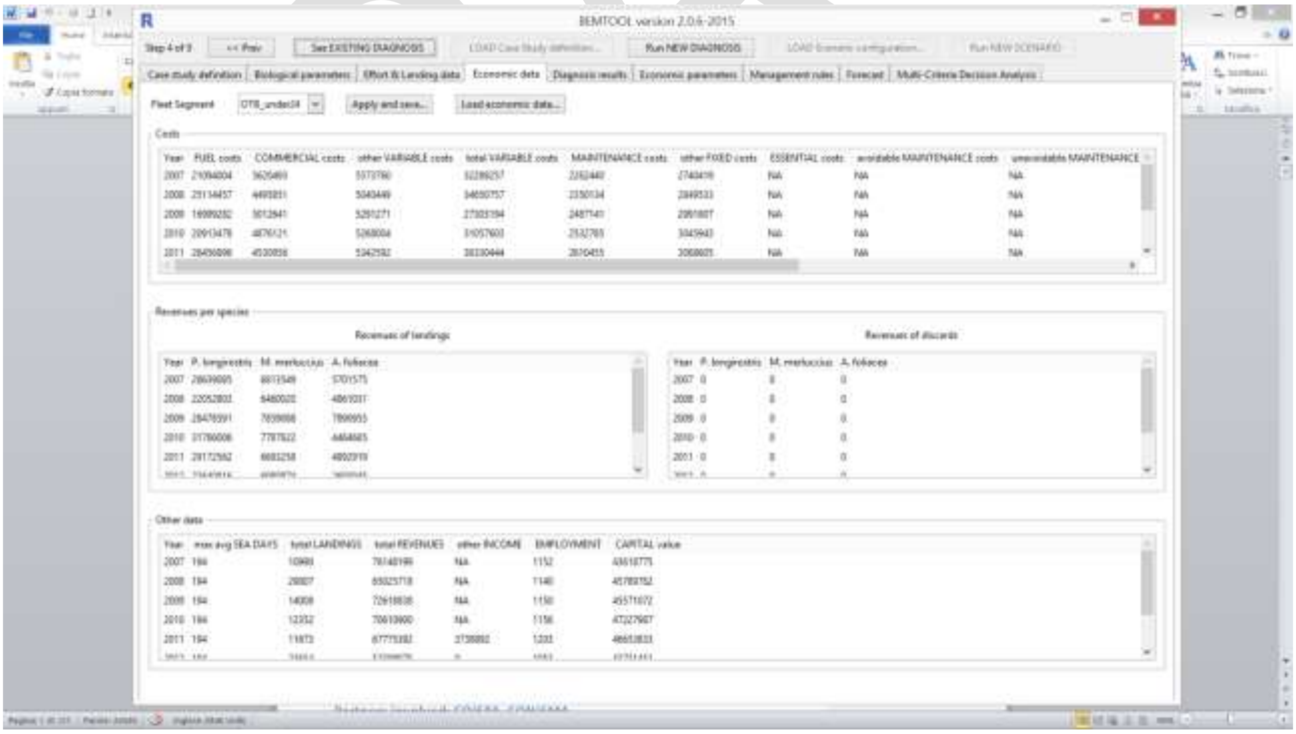


Figure 21 – Format to load economic data

The economic data consists of 22 items plus an item on revenues for each of the stocks defined above. Data is aggregated by fleet segment for each year of the simulation period. A .csv file in the format showed below has to be prepared to save the economic data. For further details see the files provided with the application (in bmtdocs\ECONOMIC_timeseries folder).

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Units: days, kg, euro, employees	2007	2008	2009	2010	2011	2012	2013	2014	2007	2008	2009	2010
2	casestudy.fleetsegmentcode	OTB_under24	OTB_under24	OTB_under24	OTB_under24	OTB_under24	OTB_under24	OTB_under24	OTB_under24	OTB_over24	OTB_over24	OTB_over24	OTB_over24
3	casestudy.fishingtechnique												
4	casestudy.loa												
5	casestudy.maxavgseadays	194	194	194	194	194	194	194	194	2039	2039	2039	2039
6	casestudy.totallandings	10990	29007	14008	12352	11673	23654	7614	7614	9361	7503	8850	6888
7	casestudy.revenues.S1	28639085	22052803	28478591	31766006	29172562	22640816	19309837	19309837	29946878	21305807	19893789	21853089
8	casestudy.revenues.S2	6813549	6460020	7859088	7787622	6693258	6980874	6037858	6037858	3096112	2443084	2442528	2171912
9	casestudy.revenues.S3	5701575	4863031	7890955	4464665	4892919	2693945	4647678	4647678	24527256	19103854	21570854	25701643
10	casestudy.totalrevenues	76148199	65025718	72618838	70610900	67775392	52398975	45350847	45350847	94051745	69468400	63780299	69228085
11	casestudy.revenues.discard.S1	0	0	0	0	0	0	0		0	0	0	0
12	casestudy.revenues.discard.S2	0	0	0	0	0	0	0		0	0	0	0
13	casestudy.revenues.discard.S3	0	0	0	0	0	0	0		0	0	0	0
14	casestudy.fuelcosts	21094004	25114457	16999282	20913478	26456896	19336652	14591529	14591529	28827244	30358606	20113155	25621118
15	casestudy.commercialcosts	5620403	4405851	5012641	4876121	4530956	3522202	3126958	3126958	5922724	4330890	3967362	4306234
16	casestudy.othervariablecosts	5573760	5040449	5291271	5268004	5342592	3013719	2643127	2643127	7757164	6253384	6163024	6354486
17	casestudy.totalvariablecosts	32288257	34650757	27303194	31057603	36330444	25872573	20361614	20361614	42507132	40942880	30243501	36281837
18	casestudy.maintenancecosts	2262440	2350134	2487141	2532785	2610455	1721637	1510392	1510392	3280085	3351252	3355350	3468090
19	casestudy.otherfixedcosts	2740419	2849533	2991807	3045943	3068605	2127877	1923765	1923765	4115853	4198792	4061697	4198170
20	casestudy.essentialcosts												
21	casestudy.avoidablemaintenancecosts												
22	casestudy.unavoidablemaintenancecosts												
23	casestudy.totalfixedcosts	2740419	2849533	2991807	3045943	3068605	2127877	1923765	1923765	4115853	4198792	4061697	4198170
24	casestudy.labourcosts	18364025	11267811	18386341	16005102	12118301	11510088	12536136	12536136	21973568	13240249	16070549	15787563
25	casestudy.depreciationcosts	10577768	11059536	11030896	11314098	11220963	10554994	9020806	9020806	20906612	20270505	21843578	22135758
26	casestudy.opportunitycosts	1766560	1950644	1968670	1893842	2449326	2303958	1969073	1969073	3855679	3913229	4141823	3951389
27	casestudy.totalcapitalcosts	12344329	13010180	12999566	13207940	13670289	12858952	10989879	10989879	24762310	24183734	25985400	26087146
28	casestudy.otherincome					3738892	0	1804054	1804054				
29	casestudy.employment	1152	1140	1150	1156	1203	1053	886	886	1186	1154	1095	1106
30	casestudy.capitalvalue	43618775	45789762	45571072	47227987	46653833	43731451	37855489	37855489	95201940	91859843	95875531	98538176
31													

Figure 22 – Format to load economic data

The user can load the economic data .csv file by means of the Load economic data button.

Moreover, economic data can be modified in the GUI and saved by Apply and save button.

Among the items included in the economic data, only some of them are compulsory for running scenarios. As the BEMTOOL economic module allows selecting different modelling solutions and each solution has different data requirement, the need for these variables depends on the modelling solutions selected by the user.

Compulsory data for all possible modelling selections are:

- *casestudy.totallandings*: total landings in weight by fleet segment and year expressed in kg (this include both target and non-target stocks);
- *casestudy.totalrevenues*: total landings in value by fleet segment and year expressed in euro (this include both target and non-target stocks);
- *casestudy.totalvariablecosts*: total variable costs by fleet segment and year;
- *casestudy.totalfixedcosts*: total fixed or non-variable costs by fleet segment and year;
- *casestudy.labourcosts*: total labour costs by fleet segment and year;
- *casestudy.totalcapitalcosts*: total capital costs by fleet segment and year;
- *casestudy.otherincome*: income other than revenues by fleet segment and year;
- *casestudy.employment*: number of people employed by fleet segment and year;
- *casestudy.capitalvalue*: capital value by fleet segment and year;

- *casestudy.revenuesSx*; landings in value for stock Sx by fleet segment and year (the user has to provide the value for each of the stock defined above).

- *casestudy.revenues.discard.Sx*; discards in value for stock Sx by fleet segment and year (the user has to provide the value for each of the stock defined above).

Compulsory data when Option 1 and Option 2 are selected to simulate variable costs in the forecast:

- *casestudy.fuelcosts*: variable costs related to the use of fuel by fleet segment and year;

- *casestudy.commercialcosts*: variable costs related to the selling of landings by fleet segment and year;

- *casestudy.othervariablecosts*: variable costs not included in the previous two items by fleet segment and year.

Compulsory data when Option 3 is selected to simulate variable costs in the forecast:

- *casestudy.fuelcosts*: variable costs related to the use of fuel by fleet segment and year;

- *casestudy.othervariablecosts*: variable costs not included in the previous two items by fleet segment and year.

Compulsory data when Option 1 is selected to simulate fixed costs in the forecast:

- *casestudy.maintenancecosts*: fixed costs related to the maintenance of the vessels by fleet segment and year;

- *casestudy.otherfixedcosts*: fixed costs not included in the previous item by fleet segment and year.

Compulsory data when Option 2 is selected to simulate fixed costs in the forecast:

- *casestudy.essentialcosts*: fixed costs not related to the maintenance of the vessels, like harbour costs, license, insurance, etc., by fleet segment and year;

- *casestudy.avoidablemaintenancecosts*: fixed costs related to the maintenance of the vessels, which can be avoid in case of negative profits, by fleet segment and year;

- *casestudy.unavoidablemaintenancecosts*: fixed costs related to the maintenance of the vessels, which cannot be avoid, by fleet segment and year.

Compulsory data when Option 1 or Option 2 are selected to simulate capital costs in the forecast:

- *casestudy.depreciationcosts*: costs associated to the deterioration of the capital by fleet segment and year;

- *casestudy.opportunitycosts*: costs associated to the use of the capital invested by fleet segment and year.

When this tab has been filled in, click Run SIMULATION button to run the simulation. In case ALADYM run has been selected, the ALADYM GUI will appear; alternatively, the Diagnosis tab will be activated showing all the results from stock assessment as well as the economic times series entered by the user in the previous tabs.

10. RUN SIMULATION

When the first 4 tabs have been filled in, the user can visualize a previous Diagnosis (status of stocks and situation of the fleet segments) clicking on the button “Next”, or can produce a new Diagnosis clicking on button “Run NEW DIAGNOSIS”. In case the checkbox Run ALADYM in Biological parameters Tab has been checked, clicking on button Run Simulation the ALADYM GUI will appear to allow the user to complete the parameterization and run the simulation from ALADYM GUI. In case the checkbox Run ALADYM has not been checked, the Diagnosis will be directly displayed in the tab.

9.1 ALADYM Simulation

For all the stocks for which the user selected ALADYM simulation in the *Biological simulation* part of Biological parameters tab, the graphical ALADYM interface, which is wrapped in BEMTOOL GUI, is recalled in order to allow the user to visualize the input parameters coming from the stock assessment and to complete the parameterization.

In case the user has not entered any stock assessment output, these cannot be loaded in the ALADYM graphical interface and the user has to proceed with the ALADYM parameterization directly from the GUI, typing the input or loading the files by the appropriate buttons and the specific templates provided with the software.

9.1.1 Tab General Data

In the *General Data* tab, all the general information about the case study is stored, for example the scientific and the common name of the species, as well as the geographical study area. Also the number of years to be pre-simulated has to be entered, according to the life span of the species (a pre-simulation of at least 3 times life span of the specie is suggested).

In this tab, BEMTOOL automatically fills in the ALADYM GUI with:

- the start and the end years of the simulation;
- the numbers of years for averaging mortality (e.g. in case of *status quo* scenarios) in the forecast or also recruitment in reference points calculation.

according to the specification in the BEMTOOL GUI.

The time slice per year (=12, because the model works by month) and the number of runs for seed randomization are fixed values and cannot be changed.

If the user decided in BEMTOOL configuration to calculate reference point (see 6.5 Settings for ALADYM simulation), the box for the reference point calculation will be automatically checked. The choice of calculating or not the reference points has to be made in BEMTOOL GUI.

For the stocks with stock-recruitment relationship, F_{msy} and Z_{mbp} are calculated; for the stocks without stock-recruitment relationship, $F_{0.1}$, $F_{0.2}$ and F_{max} are calculated.

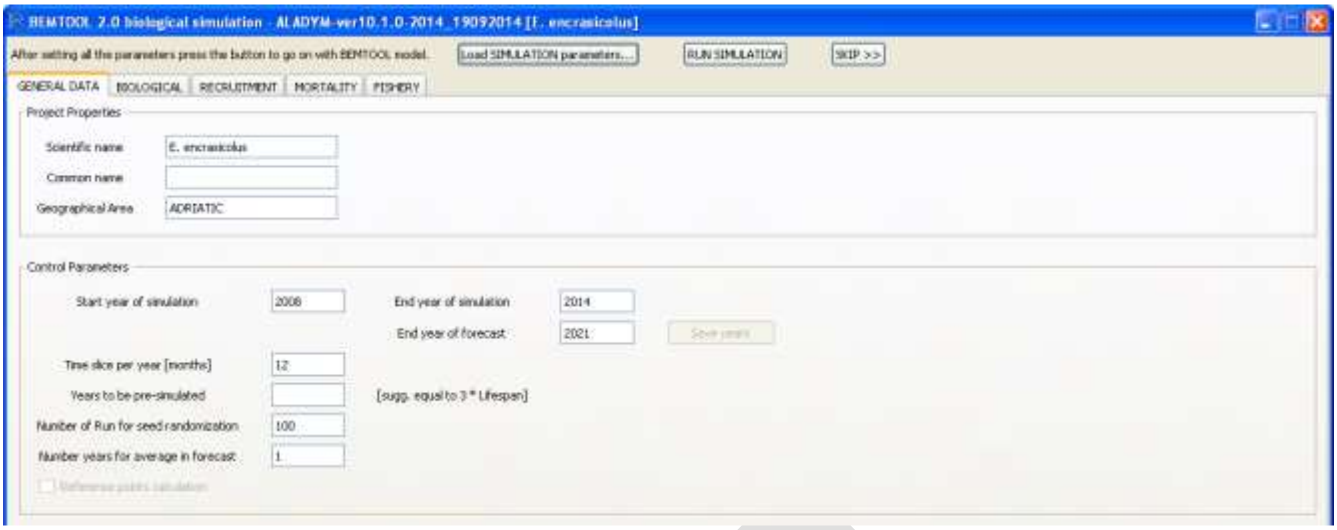


Figure 23 – Tab General Data of ALADYM GUI.

The user can load all the parameters (also contained in the other tabs) not included in BEMTOOL configuration, using a .csv file having the format showed below and for which examples have been provided with the software (as example see *CONFIGURATION file.csv* in *bmtdocs\ALADYM_input*).

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Parameters	Distribution	Min	Max	A	B							
2	Scientific name	P.longirostris											
3	Common name	Pink shrimp											
4	GSA	18											
5	start - end simulation - end forecast	2007	2014	2021									
6	Years to be presimulated	12											
7	Number of years for average	1											
8	gears												
9	Sex ratio	0.5											
10	L-W parameters - Male				0.0043	2.3757							
11	L-W parameters - Female				0.0043	2.3757							
12	Lifespan - Male	4											
13	Lifespan - Female	4											
14	Growth T0 - Male	4	-0.3	-0.1									
15	Growth T0 - Female	4	-0.3	-0.1									
16	Growth K - Male	3	0.55	0.65	0.6	0.07							
17	Growth K - Female	3	0.55	0.65	0.6	0.07							
18	Growth Linf - Male	3	44	46	45	1.41							
19	Growth Linf - Female	3	44	46	45	1.41							
20	Maturity Ogive L50 - Male	4	18.2	18.4	0	0							
21	Maturity Ogive L75L25 - Male	4	2.3	2.5	0	0							
22	Maturity Ogive L50 - Female	4	18.2	18.4	0	0							
23	Maturity Ogive L75L25 - Female	4	2.3	2.5	0	0							
24	Offspring R	4	509000	510000	0	0							
25	Offspring proportion	0	0	0	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0	0
26	Recruitment file	C:\ALADYM-ver10.1.2-2015\caso_DPS_GSA18\Recruitment_PAPELON.csv											
27	Recruitment calibration	FALSE											
28	Tr	0											
29	Spawners	2	1										
30	Age range of F calculated - Male		0	2									
31	Age range of F calculated - Female		0	2									
32	M file - Male	C:\ALADYM-ver10.1.2-2015\caso_DPS_GSA18\Natural_mortality_PAPELON.CSV											
33	M file - Female	C:\ALADYM-ver10.1.2-2015\caso_DPS_GSA18\Natural_mortality_PAPELON.CSV											
34	Mortality type	F											
35	Z file		C:\ALADYM-ver10.1.2-2015\caso_DPS_GSA18\Z original papelon.csv										
36	F type	O	[allowed values: F, O]										
37	F splitting type	P	[allowed values: CAA, P]										
38	F file		C:\GSA18_DEM\INPUT\aladym input\P. longirostris\FISHING_MORTALITY_DPS_GSA18.csv										

Figure 24 – Format of the file to load parameters for general, biological and recruitment tabs.

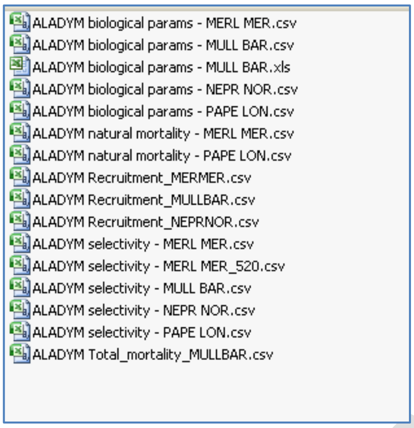


Figure 25 – Example of loading biological parameters.

The user has to compile the configuration table considering that the *distribution* field can assume values from 1 to 4 according the codification in the table below.

Table 1 – Codification for the distribution functions.

Legend			
	Distribution	A	B
1	Lognormal	Mean ln(x)	Ds ln(x)
2	Gamma	Shape	Scale
3	Normal	Mean (x)	Ds (x)
4	Uniform	None	None

In case the simulation for one stock has been performed at least one time , the SKIP button can be used to go directly to the next stock.

Before use SKIP button, be sure that the BAS, GLO, INP, RND, SRO .Rdata files for the species to be skipped and also some other GUI working .Rdata files (GUIfle, GUIsim and GUIpop) are located in the folder *Diagnosis\working files*.

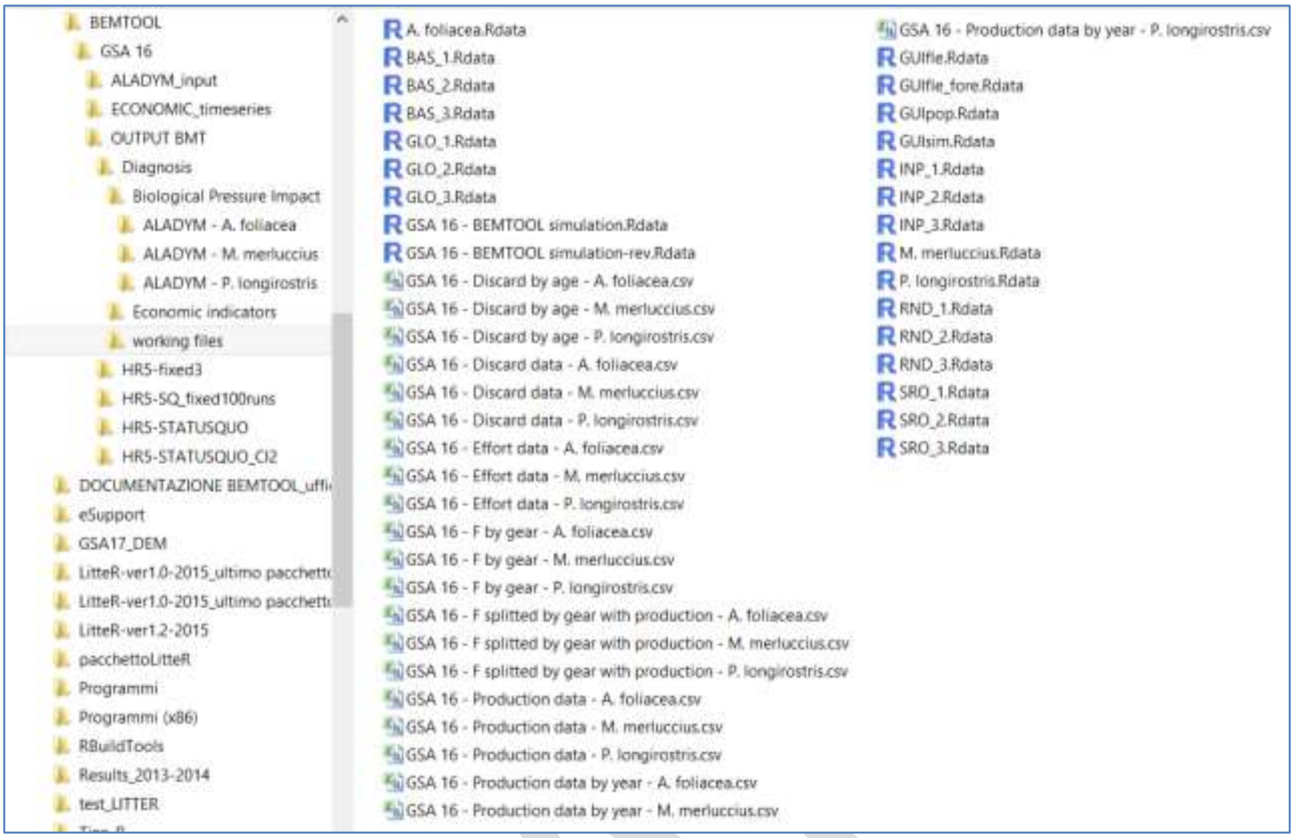


Figure 26 – List of output files needed to skip ALADYM simulation.

9.1.2 Tab Biological

In this tab, the parameters automatically filled in, according to the values entered by the user in the BEMTOOL GUI, are:

- the length-weight relationship coefficients;
- life span by sex;
- sex ratio (F/(F+M)).

The user has to input the probability distribution functions and related parameters of:

- Maturity ogive parameters (L_{m50} and maturity range) by sex;
- von Bertalanffy growth function parameters.

The available probability distribution for maturity ogive and growth parameters are:

- Uniform (the expected parameters are: min, max, range of interval);
- Normal (the expected parameters are: min, max, mean and standard deviation);
- Log-normal (the expected parameters are: min, max, log-mean and log-standard deviation);
- Gamma (the expected parameters are: min, max, shape and scale).

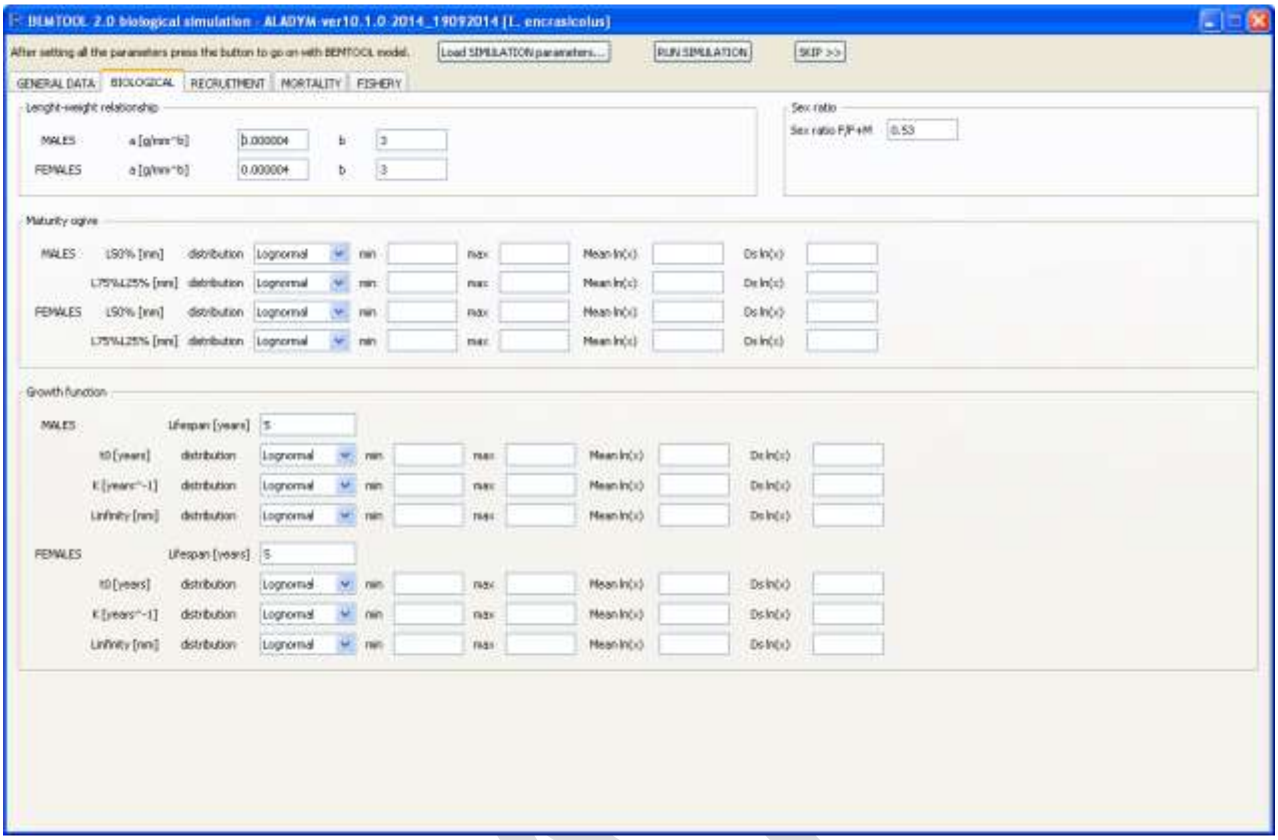


Figure 27 – Tab Biological of ALADYM GUI.

9.1.3 Recruitment

The user has to choose a probability distribution and related parameters for the recruitment used in the first 100 runs (needed to initialize the model, see Lembo et al., 2009 for details) as well as the monthly proportion of offspring entering in the population each month and the age of recruitment (in months). This vector of monthly proportion of offspring is used to simulate the peaks in recruitment during the year.

The user can also choose a stock recruitment relationship among:

- $R = \dfrac{S}{(\alpha + \beta S)}$ (Beverton and Holt , 1957) **(1)**

- $R = \alpha \cdot S \cdot e^{-\beta S}$ (Ricker, 1954) **(2)**

- $R = \alpha \cdot \dfrac{S}{1 + \left(\dfrac{S}{\gamma}\right)^{\beta}}$ (Shepherd, 1982) **(3)**

- $R = \alpha \cdot \min(S, S^*)$ (Hockey stick, Barrowman and Myers, 2000) **(4)**

- $$R = \begin{cases} \alpha \cdot S & if\ S \le S^* \cdot (1-\delta) \\ \alpha \cdot \left(S - \dfrac{(S - S^* \cdot (1-\delta))^2}{4\delta \cdot S} \right) & if\ S^* \cdot (1-\delta) < S < S^* \cdot (1+\delta) \\ \alpha \cdot S & if\ S \ge S^* \cdot (1+\delta) \end{cases}$$ (Quadratic hockey stick) **(5)**

where *R* and *S* represent respectively the number of recruits and biomass of spawners at the previous time, whilst *α, β, γ, δ* and S^* are input parameters .

If the stock-recruitment relationship has been selected, the related parameters have to be input; moreover, the user has to indicate the unit for the spawners to be used to calculate the recruits. The spawners can be considered in biomass (tons) or in numbers (thousands), depending on the settings used in the stock-recruitment relationship. The recruits are always considered in thousands.

Moreover, also another option is provided: the recruitment can be also entered as a vector.

In the vector the recruits have to be entered in thousands.

The user can also choose if consider spawners only the females or both sexes and if there is a delay for spawners calculation (in months) (e.g. the spawners of the month *x* produce the recruits at the month x+1 as in the spawning pattern of some species; see Lembo et al., 2009).

ATTENTION: the spawning stock biomass calculated in ALADYM model is related to the average potential spawning stock in the year.

In ALADYM the maturity ogive is used to calculated the number of spawners as follows:

$$S(j) = N(j) \cdot M(j) \qquad \textbf{(6)}$$

where *j* is the length class, *N(j)* is the number of individuals in the population at length class *j* and *M(j)* is defined by:

$$M(j) = \frac{1}{1 + e^{\frac{\ln(9)}{MR} \cdot (L_{m50\%} - j)}} \qquad \textbf{(7)}$$

where *M(j)* is the proportion of mature individuals at length or age *j*, $L_{m50\%}$ is the size at which the 50% of the population is mature (size at first maturity) and $MR = L_{m75\%} - L_{25\%}$ is the maturity range.

The SSB is calculated multiplying the number of spawners at length-age class by the related individual weight.

In any case the times series of absolute recruitment is not available, the calibration option can be used to rescale an abundance index from scientific survey of recruitment according to the observed total production. If the calibration has been selected, the user has to indicate also a range to be used by the optimization procedure to search the scaling factor and derive the absolute recruitment that better approximates the real recruitment according to the production data. In case the range selected by the user is not appropriate, in the console will appear a message suggesting to choose a higher max or a smaller min for the range.

The user can verify the difference between the abundance index entered as input and the final recruitment from the calibration in the Tables and Graphs sub-folders of ALADYM, for the stock for which the run of ALADYM and the calibration have been selected.

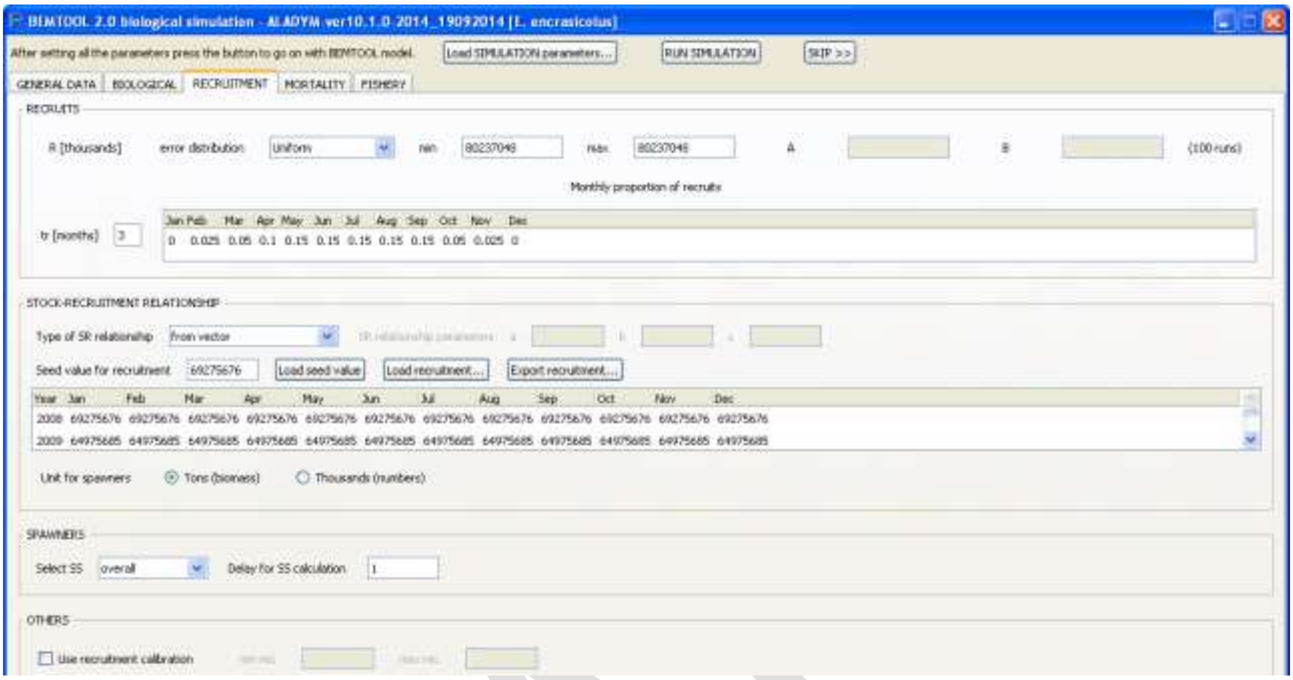


Figure 28 – Tab Recruitment of ALADYM GUI.

At *spawners* row in the ALADYM configuration file the chosen option about the selection of the spawners to be used in S-R relationships has to be specified (under *distribution* column): the user has to input 1 if only females have to be considered as spawners, 2 if females and males have to be considered as spawners. Moreover, the user must select the unit for spawners between tons (biomass) and thousands of individuals filling the second column at *spawners* row respectively with 1 or 2.

The last row of the table must contain 12 values indicating the monthly proportions of offspring.

The recruitment by month of simulation (in thousands) can be also loaded from a .csv file in the format showed below.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	year	seed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	2008	69275676	69275676	69275676	69275676	69275676	69275676	69275676	69275676	69275676	69275676	69275676	69275676	69275676
3	2009		64975685	64975685	64975685	64975685	64975685	64975685	64975685	64975685	64975685	64975685	64975685	64975685
4	2010		59731183	59731183	59731183	59731183	59731183	59731183	59731183	59731183	59731183	59731183	59731183	59731183
5	2011		64595944	64595944	64595944	64595944	64595944	64595944	64595944	64595944	64595944	64595944	64595944	64595944
6	2012		70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055
7	2013		70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055
8	2014		70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055	70427055
9														

Figure 29 – Format of the file to load recruitment by month.

See examples of these files in the *bmtdocs/ALADYM_input* folder.

To account for recruitment pulses, the number of recruits *R*, derived from one of the 6 options described above, is multiplied by the proportion of off-springs PoO_m related to the specific month:

$$R_t = R \cdot PoO_m \quad \textbf{(8)}$$

where *t* is the month of the simulation, *R* is calculated according to 1 of the 6 options described above, *m* varies from January to December and R_t are the recruits effectively entering the population at month *t*. This number is then split by sex using the monthly sex-ratio given in the input, according to the biological knowledge on the species.

9.1.4 Mortality

In the mortality tab the user has to enter all the information related to the natural mortality and the total mortality or alternatively the fishing mortality acting on the populations.

The model foresees 2 possibilities to run the simulation:

- F-mode: the F by fleet segment, age (unit: years) and year of simulation has to be entered in the FISHERY tab;
- Z-mode: the total mortality by year as well as the selectivity model and parameters by month of simulation and fleet segment have to be provided.

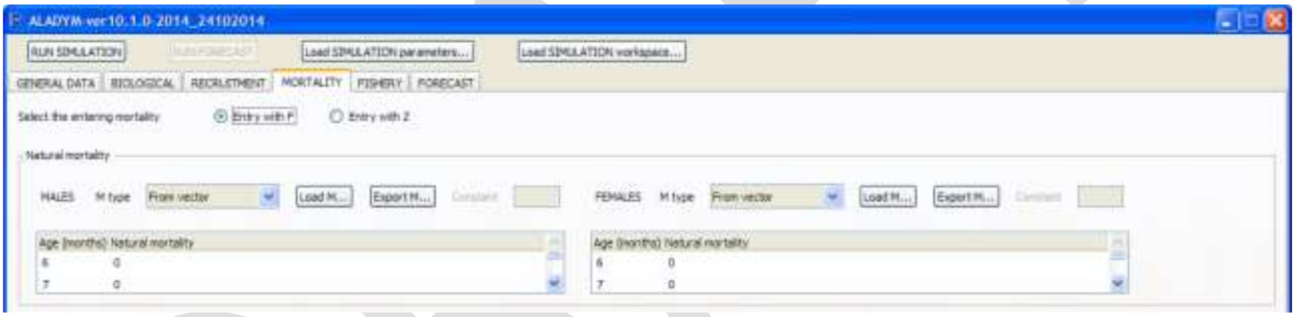


Figure 30 – Mortality tab with the possibility to select F or Z-mode.

The Z-mode should be used in case a fishing mortality by fleet segment is not available, but a recruitment index, a total mortality from survey and the selectivity model for each fleet segment are available, thus also for stock in data-poor situation (without commercial data); while, the F-mode can be used in case an F by age and year is available. In case the F is not by fleet segment, it is suggested to split the overall F following the proportions in the production among the fleet segments.

The natural mortality can be simulated by choosing among 3 options:

- constant value by sex;
- vector by age (in months) and by sex;
- Chen and Watanabe model according to the following equation:

In case Chen and Watanabe (1989) model has been selected, the equation used to calculate *M* by age-length class inside the model is:

$$M_j = \begin{cases} \dfrac{k}{1-e^{-k(j-t_0)}} & for\ j \le j_M \\ \dfrac{k}{1-d+k\cdot d\cdot(j-j_M)-\dfrac{1}{2}k^2\cdot d\cdot(j-j_M)^2} & for\ j > j_M \end{cases} \qquad \textbf{(9)}$$

where $d = e^{-K(j_M - j_0)}$ and $j_M = -\dfrac{1}{K}\ln\left|1-e^{Kj_0}\right| + j_0$, while t_0 and k are the von Bertalanffy growth function parameters and j_M represents the age at the end of the reproductive span. This model works for negative values of t_0.

For the species for which a stock assessment output has been selected, the natural mortality and the total mortality by year (respectively years of age and years of simulation) will be <u>automatically</u> filled in exactly in this tab, in order to be visualized and eventually modified or modulated by month.

In case the user has not selected any assessment tool, the ALADYM interface will be empty and the user has to select the option to enter the total mortality (entering Z by month (for the simulation) and by sex) or to enter directly the fishing mortality by year, fleet segment and age in the FISHERY tab. If the user has selected the entry with F (ALADYM in F mode), it is not necessary to input Z.

The natural and the total mortality vector can be also loaded in the GUI from a .csv file by the browse button. In the case of Z-mode, the .csv file have to be in the format showed below.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	year	seed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	sex
2	2007	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	M
3	2008		1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	M
4	2009		1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	M
5	2010		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	M
6	2011		1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	M
7	2012		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	M
8	2013		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	M
9	2007	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	F
10	2008		1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	F
11	2009		1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	F
12	2010		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	F
13	2011		1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	F
14	2012		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	F
15	2013		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	F

Figure 31 – Format of the file to load total mortality by month.

An example file to load total mortality is provided in *bmtdocs/ALADYM_input* folder.

To load the natural mortality vector, the format showed below has to be used.

age_month	M	sex
0	3.063	M
1	2.113	M
2	2.113	M
3	2.113	M
4	1.638	M
5	1.353	M
6	1.163	M
7	1.027	M
8	0.925	M
9	0.846	M
10	0.782	M
11	0.731	M
12	0.687	M
13	0.651	M
14	0.62	M
15	0.592	M
16	0.569	M
17	0.548	M
18	0.529	M
19	0.512	M
20	0.497	M
21	0.484	M
22	0.472	M
23	0.46	M

Figure 32 – Format of the file to load natural mortality by age (months).

An example file to load natural mortality is provided in *bmtdocs/ALADYM_input* folder.

As the fishing mortality for males and females is given by fleet segment, it has to be inserted in the Fishery Tab (see paragraph 9.1.5).

Finally, BEMTOOL model enters the age range on which calculate the mortalities for both sexes, as indicated by the user in BEMTOOL GUI for the stock assessed with VIT, SURBA and from reports.

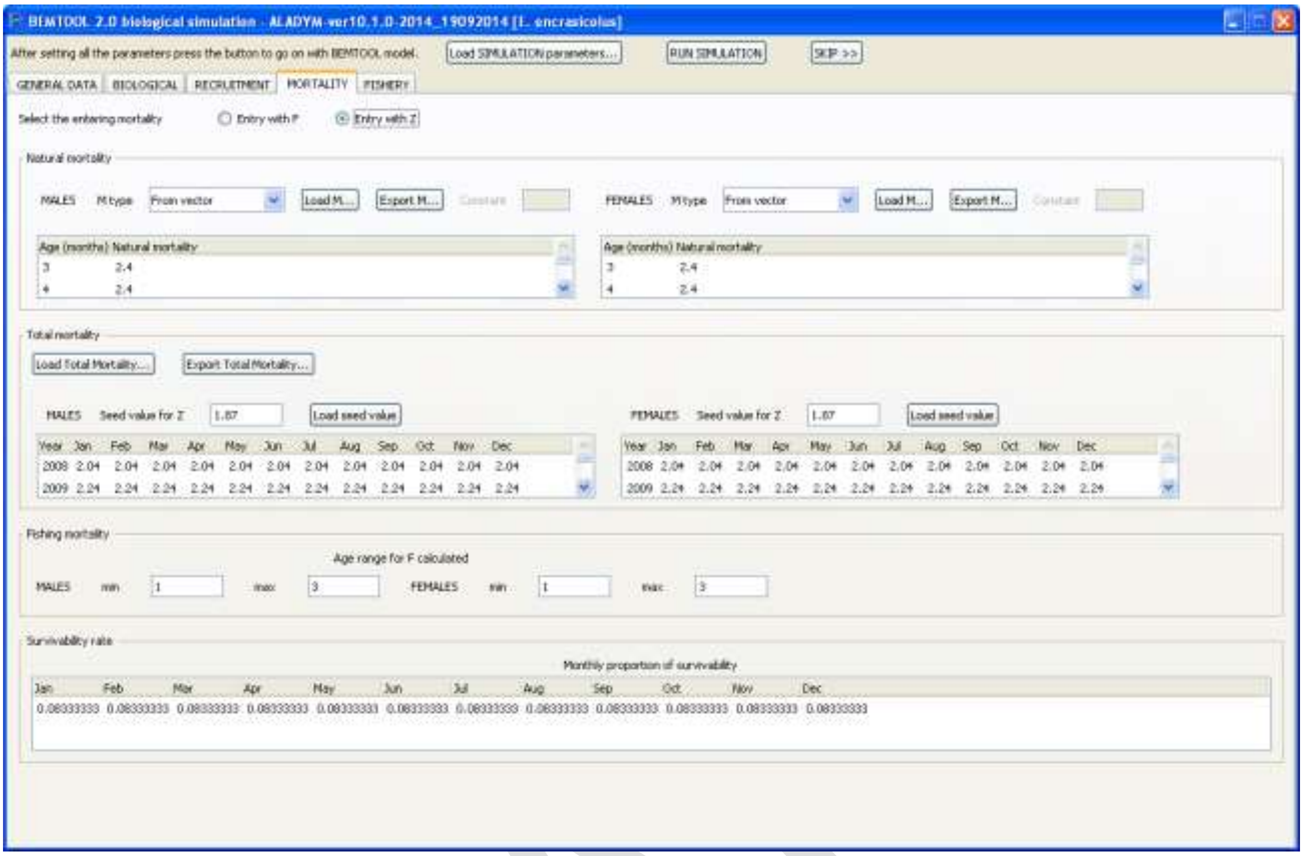


Figure 33 – Tab Mortality of ALADYM GUI.

Finally, in the bottom of the tab there is the monthly survivability to be used in case the discard survivability is set not null and also to survivability of the discard could be taken into account (see paragraph FISHERY tab).

9.1.5 Fishery tab

In this tab all the information regarding the fleet segments involved in the case study is stored. For each fleet segment (chosen by the drop down menu) the user has to input information about:

- Selectivity (only if Z-mode has been selected);
- Catch data;
- Discard;
- Survivability;
- Fishing effort;
- Fishing mortality (only in F-mode).

in the corresponding sub-tabs.

9.1.5.1 Selectivity sub-tab

In the first sub-tab, activated in Z-mode, the user has to set the selectivity model, choosing among:

- classical ogive;

- ogive with de-selection;
- normal;
- log-normal;
- bi-normal;
- two-sided;
- external vector by age.

The first six models follow respectively the equations listed below:

Classical ogive: $$Sel(j) = \frac{1}{1+e^{\frac{\ln(9)}{SR}*(SL_{50\%}-j)}} \quad \mathbf{(10)}$$

Ogive with deselection: $$Sel(j) = \frac{1}{1+e^{\frac{\ln(9)}{SR}*(SL_{50\%}-j)}} * \frac{1}{1+e^{-\frac{\ln(9)}{DR}*(DL_{50\%}-j)}} \quad \mathbf{(11)}$$

where $SL_{50\%}$ is the length at first capture, $SR=SL_{75\%}-SL_{25\%}$ the selectivity range, $DL_{50\%}$ the 50 % deselection size.

The normal and the log-normal distributions belong to this family; their equations are reported below

Normal: $$Sel(j) = e^{-\frac{(j-mean)^2}{2*sd^2}} \quad \mathbf{(12)}$$

Log-normal[4]**:** $$Sel(j) = \frac{1}{j} e^{mean-\frac{sd^2}{2}-\frac{(\log(j)-mean)^2}{2*sd}} \quad \mathbf{(13)}$$

where mean and standard deviation are the parameters of normal and log-normal distributions.

Bi-normal: $$Sel(j) = \left[e^{-\frac{(j-mean_1)^2}{2*sd_1^2}} + b*e^{-\frac{(j-mean_2)^2}{2*sd_2^2}} \right] \quad \mathbf{(14)}$$

Two-sided: $$Sel(j) = \begin{cases} e^{-\frac{(j-mean)^2}{2*sd_1^2}}, & for\ j <= mean_1 \\ e^{-\frac{(j-mean)^2}{2*sd_2^2}}, & for\ j > mean_2 \end{cases} \quad \mathbf{(15)}$$

[4] In this case the mean has to be the logarithm of the real mean and the same is for standard deviation.

where $mean_1$ and standard deviation sd_1 are the parameters of the first normal component of the distribution, $mean_2$ and standard deviation sd_2 are the mean and standard deviation of the second normal component of the distribution and b the “weight” of the second normal component. $Mean_1$ is referred to the normal component of the distribution with weight 1.

After the model selection, the user has to input or load the parameters of the chosen model.

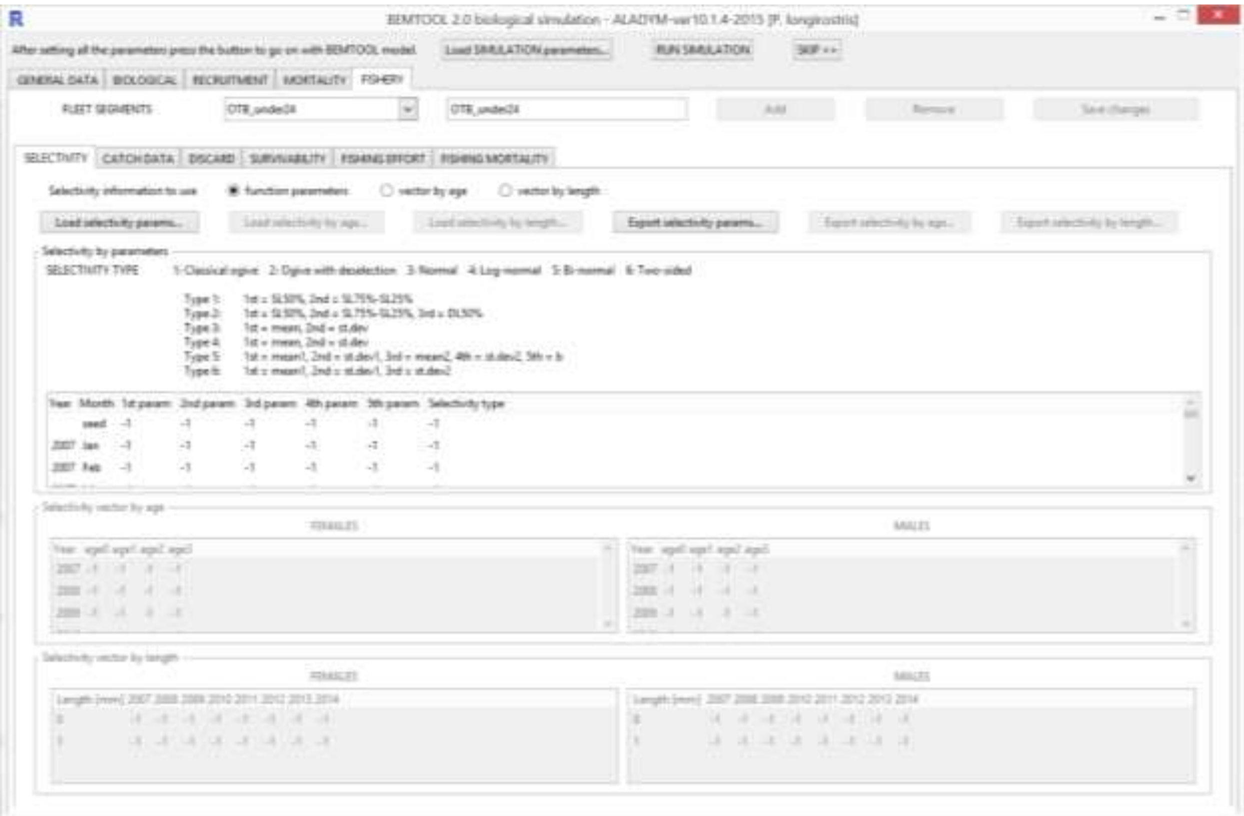


Figure 34 – Tab Fishery, sub-tab Selectivity of ALADYM GUI.

For each fleet segment the user can choose to model selectivity with a function selecting among different selectivity models and inputing different parameters **by month**; or use external vector by age and sex, inputing the proportion of caught animals in the given classes by year; or use external vector by length and sex, inputing the proportion of caught animals by length and by year.

The user has to load the settings of the selectivity for all the fleet segments at once (pushing the button *Load selectivity params…* in *Fishery Tab*, in case of information from function parameters, or *Load selectivity by age…* or *Load selectivity by length…* in case of external vector) from .csv files (see formats below) or type directly the values in the graphical interface. The user can save the selectivity parameters or external vectors in the format required in order to use it in a next run.

year	month	param1	param2	param3	param4	param5	sel_type	fleet_segment
	seed	100	25				1	DTS_VL0006-VL1218
2007	Jan	100	25				1	DTS_VL0006-VL1218
2007	Feb	100	25				1	DTS_VL0006-VL1218
2007	Mar	100	25				1	DTS_VL0006-VL1218
2007	Apr	100	25				1	DTS_VL0006-VL1218
2007	May	100	25				1	DTS_VL0006-VL1218
2007	Jun	100	25				1	DTS_VL0006-VL1218
2007	Jul	100	25				1	DTS_VL0006-VL1218
2007	Aug	100	25				1	DTS_VL0006-VL1218
2007	Set	100	25				1	DTS_VL0006-VL1218
2007	Oct	100	25				1	DTS_VL0006-VL1218
2007	Nov	100	25				1	DTS_VL0006-VL1218
2007	Dec	100	25				1	DTS_VL0006-VL1218

Figure 35 – Format to load the selectivity parameters for all fleet segments at once.

The user should compile the table above considering that the *sel_type* field can assume values from 1 to 6 according the codification in the table below.

Table 2 – Codification for the selectivity functions.

Type	Model	Param1	Param2	Param3	Param4	Param5
1	Classical ogive	$SL_{50\%}$	$SL_{75\%}$-$SL_{25\%}$			
2	Ogive with deselection	$SL_{50\%}$	$SL_{75\%}$-$SL_{25\%}$	$DL_{50\%}$		
3	Normal	mean	st.dev			
4	Log-normal	mean[5]	st.dev			
5	Bi-normal	mean1	st.dev1	mean2	st.dev2	b[*]
6	Two-sided	mean1	st.dev1	st.dev2		

[*] The first normal distribution has to be the one with weight 1; the second one can be weighted with b.

In case the external vector option has been chosen to model the selectivity, the user could decide to use a selectivity vector differentiated by sex, where for each length or age class the proportion of retained individuals has to be indicated; in both cases the proportion indicated in the external vector for the specific age or length class is applied to the individuals of all the length/age classes belonging to that age or length class. For example, if the user indicated that the selectivity of the fleet segment 1 for age class 2 is 0.8, this selectivity is applied to all the length-age classes belonging to age 2, by the rounding of the vector of length or age classes to the corresponding integer size (in mm) or age (in years). The user can choose one selectivity vector for the simulation phase and another one for the forecast phase.

[5] In this case the mean has to be the logarithm of the real mean and the same is for standard deviation.

[*] The first normal distribution has to be the one with weight 1; the second one can be weighted with b.

Age	Year	fs1	fs2	fs3	fs4	fs5	fs6	fs7	fs8	Sex
0	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
1	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
2	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
3	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
4	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
0	2009	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
1	2009	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
2	2009	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
3	2009	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
4	2009	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
0	2010	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
1	2010	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M

a)

Length	Year	fs1	fs2	fs3	fs4	fs5	fs6	fs7	fs8	Sex
0	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
1	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
2	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
3	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
4	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
5	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
6	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
7	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
8	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
9	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
10	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
11	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
12	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
13	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
14	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
15	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
16	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M

b)

Figure 36 – Format to load the selectivity from external vector for all fleet segments at once by age (a) or by length (b).

The example files to load selectivity parameters are provided in *bmtdocs\ALADYM_input* folder.

It is suggested to choose the selectivity model according to the prevalent gear used by the fleet segment; in case it is bottom trawls the ogive and the ogive with de-selection model are suggested (Sparre and Venema, 1998; de Cárdenas et al., 1997), while for longlines, gill-net and trammel net is suggested to use a normal-like or a bimodal function (Yamashita et al., 2009; Hovgård H. and Lassen H. ,2000; Tang et al., 2010).

In order to verify if the selectivity function for a particular fleet segment has been correctly chosen, the user can compare the observed catch at age with the simulated one that are automatically saved in the *Diagnosis\Biological Pressure Impact\ALADYM – [species]* folder.

9.1.52 Catch data sub-tab

The *Catch data* sub-tab is automatically filled in by BEMTOOL with the production monthly data by fleet segment. These data are used in order to calculate the *production* coefficients, which are used in the model in Z-mode to derive the fishing mortality due to the different fleet segments. The *production* coefficient is calculated only if the user has selected the entry with Z; in this case, the difference between Z and M is split among the fleet segments using the *production* coefficients that represent the proportion of production caught by each fleet segment, according to the equation below:

$$F_f(a) = (Z_{inp} - mean(M)) * Sel_f(a) * f_{act,f} * p_f \quad \textbf{(16)}$$

where $f_{act,f}$ is the fishing coefficient of fleet *f*, $Sel_f(a)$ the selectivity of fleet *f* in the age class *a*, Z_{inp} the total mortality in input, *mean(M)* the average natural mortality on all the age classes and the production coefficient p_f is an estimate of the proportion of *F* due to fleet segment *f*.

The production coefficient in the simulation phase (past/present years) and at month scale is calculated as:

$$p_f = \frac{Production_f}{\sum_{i=1}^{N} Production_i} \quad \textbf{(17)}$$

where *N* is the total number of fleet segments. In the forecast phase the production ratio is set equal to the average of the production ratio of the last n years, as set by the user. Only the fishing coefficient modulates the monthly differences.

The monthly production data are automatically saved in *Diagnosis\working files* folder as a .csv file in order to track what the model is using in the simulation phase. In the forecast phase the *production* coefficient are taken equal to the average of the coefficients of the previous x years (x is decided by the user as described in paragraph **Settings ALADYM simulation**).

If ALADYM operates in F mode then it takes the fishing mortality as input by age, fleet segment and time. Then, this fishing mortality is adjusted using the fishing coefficient:

$$F_f(a) = F_{inp,f}(a) * f_{act,f} \quad \textbf{(18)}$$

where $f_{act,f}$ is the fishing coefficient of fleet *f.*

The overall *F* is calculated as a sum of *F* by fleet both in F-mode and in Z-mode:

$$F_{tot}(a) = \sum_f F_f(a) \quad \textbf{(19)}$$

In this sub-tab the information about the discard in weight should to be also entered.

This tab there contains also information about the discard data by month and year in weight (kg); these data are used in the calculation of the production coefficient that, in case the discard is present, is estimated on the catch. Moreover, these data are used in the comparison graphs and tables where the simulated discard is compared with the observed one as already happened with landing by fleet segment.

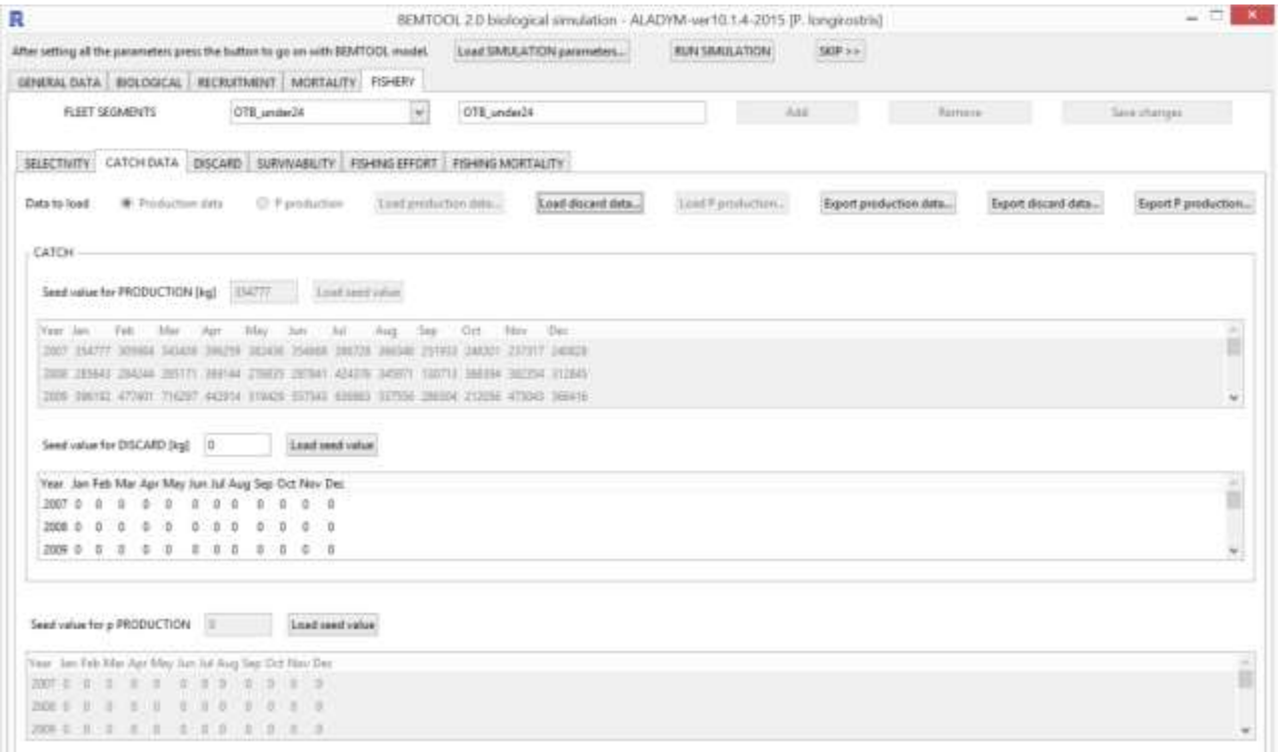


Figure 37 – Tab Fishery, sub-tab Production of ALADYM GUI.

9.1.5.3 The Discard sub- tab

In this tab for each fleet segment has to be selected if the discard is null, not available or not null. Only in this last case, the user has to choose how to model the discard.

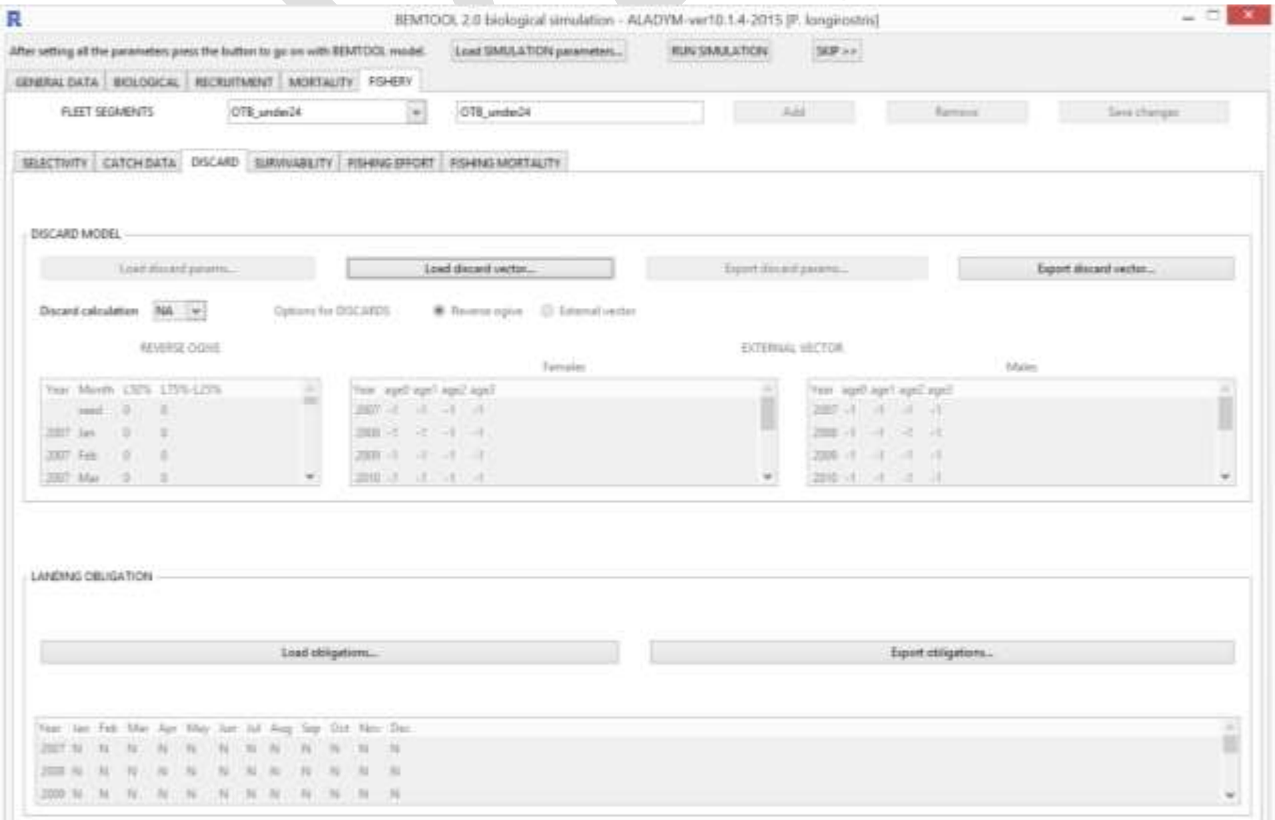


Figure 38 – Discard tab.

The options provided are:

- reverse ogive model;
- an external vector.

Reverse-ogive model (Borges et al., 2006 and Machias et al. 2004) should be chosen in case the sorting of a species is made mainly according to the minimum conservation reference size (MCRS) with a buffer given by a range around MCRS given by the difference between the length at which the 75% of individuals are discarded (L75%) and the length at which the 25% of individuals are discarded (L25%). In this case the equation the model refers to the following equation for the calculation of discarded individuals by length-age class:

$$Dis_f(a) = \frac{1}{1 + e^{-\frac{\ln(9)}{DisR_f} * (DisL_{50\%,f} - a)}} \tag{20}$$

where DisL50%,f is the size at which the 50% of the population is discarded by the fleet f, DisRf is the difference between size at which 75% and 25% of the population is discarded by the fleet f and a is the length-age class.

This option can be used when the discard is selected with a knife-edge function, just setting a narrow L75%-L25%. The assumption is that the individuals bigger than MCRS damaged by gear and thus discarded are negligible.

Discard of trawlers can be generally assumed depending on size by a reverse ogive model (Borges et al., 2006). For the discard modelling of bottom trawlers, the work of Machias et al. (2004) can be useful, because the length at which 50% of the individuals were discarded was estimated for 29 species using logistic regression.

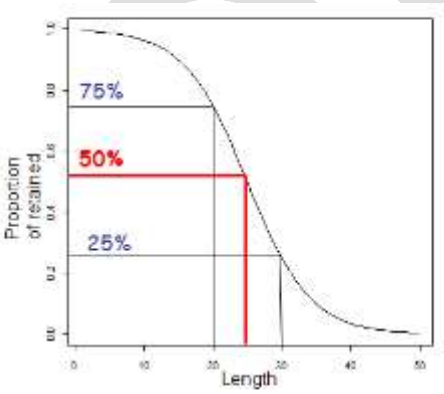


Figure 39 – Example of reverse ogive model for discard modelling

In this new version of the model, is foreseen also the possibility to simulate the discard according to a general external vector, that could be also different form a reverse-ogive model. This option is useful in case the proportion of discarded individuals by age does not follow a knife-edge or more in general a reverse ogive model; in other words, this option has to be used when the individuals captured are discarded not only on the base of MCRS, but also because damaged individuals can occur in the catch and thus are discarded. This option should be used when the fraction of individuals belonging to an age group characterized by average length bigger than MCRS and discarded are not negligible.

In this case the user gives the proportions by age ($Dis_f(a)$), fleet segment and year to be applied to the catch in order to obtain the discard.

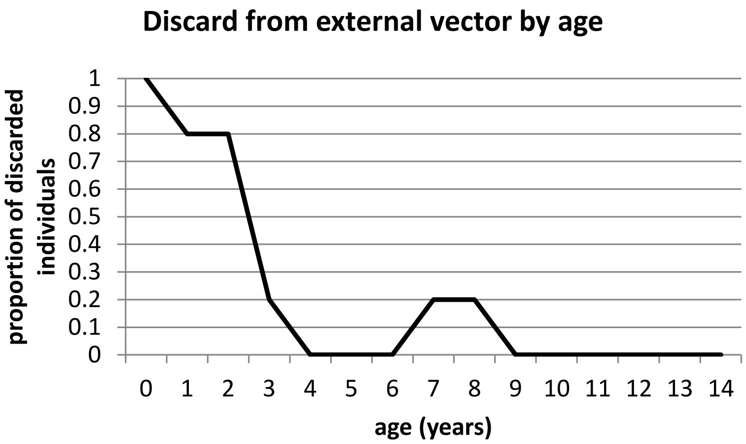


Figure 40 - Example of external vector for discard modelling

In both cases (reverse-ogive or external vector) the discard volume is then calculated as a part of the simulated catch.

For both discard modelling types, the loading from .csv files (see formats below) is available. The example files to load discard information are provided in *bmtdocs/ALADYM_input* folder.

year	month	L50	L75_L25	discard	fleet_segment
	seed	0	0	YES	DTS_VL0006-VL1218
2007	Jan	0	0	YES	DTS_VL0006-VL1218
2007	Feb	0	0	YES	DTS_VL0006-VL1218
2007	Mar	0	0	YES	DTS_VL0006-VL1218
2007	Apr	0	0	YES	DTS_VL0006-VL1218
2007	May	0	0	YES	DTS_VL0006-VL1218
2007	Jun	0	0	YES	DTS_VL0006-VL1218
2007	Jul	0	0	YES	DTS_VL0006-VL1218
2007	Aug	0	0	YES	DTS_VL0006-VL1218
2007	Sep	0	0	YES	DTS_VL0006-VL1218
2007	Oct	0	0	YES	DTS_VL0006-VL1218
2007	Nov	0	0	YES	DTS_VL0006-VL1218
2007	Dec	0	0	YES	DTS_VL0006-VL1218
2008	Jan	0	0	YES	DTS_VL0006-VL1218
2008	Feb	0	0	YES	DTS_VL0006-VL1218
2008	Mar	0	0	YES	DTS_VL0006-VL1218
2008	Apr	0	0	YES	DTS_VL0006-VL1218
2008	May	0	0	YES	DTS_VL0006-VL1218
2008	Jun	0	0	YES	DTS_VL0006-VL1218
2008	Jul	0	0	YES	DTS_VL0006-VL1218
2008	Aug	0	0	YES	DTS_VL0006-VL1218

Figure 41 – Format to load discard parameters in case of reverse ogive.

Age	Year	fs1	fs2	fs3	fs4	fs5	fs6	fs7	fs8	Sex
0	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
1	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
2	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
3	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
4	2008	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
0	2009	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
1	2009	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
2	2009	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
3	2009	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
4	2009	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
0	2010	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M
1	2010	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	M

Figure 42 – Format to load discard from external vector.

Another important input that the user has to specify by fleet segment and month of simulation is related to landing obligation: in case the fleet segment has the obligation to land the discard, the user has to put "Y" in the corresponding cell.

9.1.5.4 The survivability sub-tab

In this tab are contained all the information related to the discard and escape survivability; in other words, we refer respectively to the survivability of the discard thrown at sea and to the survivability of the individuals escaped by the fishing gear.

Figure 43 – Survivability tab.

Discard suvivability

In this version of BEMTOOL model has been introduced the possibility, on the basis of reliable references and/or experiments, to assume a discard survivability rate different from 0 and thus to simulate the effects on the population at sea, as well as on the yield, of the survivability of a part of the discard in case it is thrown into the sea.

If the discard survivability has been set "Y", this can be considered:

- Constant (all the individuals discarded have the same probability to survive independently from the length, see Gasche et al., 2013)

- Depending on size according to an ogive model (the bigger individuals have much probability to survive respect to the smaller ones, see Methot R. D., 2005).

In case the first option is selected, the user has to indicate by sex the probability to survive of the discard, while in case of ogive model selected, the user could indicate the L50% and the L75%-L25% to allow the model to derive the survivability by size *dsr* (and eventually by sex, in case of growth parameters different by sex), according to the following equation:

$$dsr_f(l(a)) = \frac{1}{1 + e^{\frac{\log(9)}{L75\% - L25\%}(L50\% - l(a))}} \tag{21}$$

where L50% is the length at which survive the 50% of discarded individuals, L25% is the length at which the 25% of discarded individuals survives and L75% is the length at which the 75% of discarded individuals survives.

The discarded individuals that survive are then derived as follows:

$$Dis_{f,survived}(l(a)) = Dis_{f,at\_sea}(l(a)) * dsr_f(l(a)) * surv(month) \tag{22}$$

where:

- *l(a)* is length associated to the age *a* according von Bertalanffy growth function;
- $Dis_{f,survived}(l(a))$ are the survived individuals in the discard thrown at sea ($Dis_{f,at\_sea}(l(a))$);
- $surv(month)$ is the proportion of individuals discarded that survives depending only on the month of the year and linked to the environmental conditions (temperature and climatic conditions among the months can differently affect the survivability of the discard).

In case the discard survivability rate has been assumed constant, *dsr* is set equal to for all sizes. In both cases will be taken into account also the monthly probability to survive according to environmental factors, as parameterized in the Mortality tab.

For species which have high survival rate, both the proportion of deaths on the vessel and the individuals deaths after the discard has been thrown at sea have to be taken into account in the survival rate.

If the mortality of discarded individuals is low, the issue of discarding becomes less of a concern (Mesnil, 1996). Generally, the discard is not negligible for trawl-like gear; however the state of the discarded individuals is usually more or less bad according to the kind of fishing technique and then the discard survival rate, especially for small pelagic stock, can be approximated to 0. However, the probability that the discarded individuals survive could be not negligible for some species as elasmobranchs (Mandelman J. W. and Farrington M. A., 2007) or other species with high resistance to the capture stress (e.g. some crustaceans or anguilliforms.

Generally, the assumption of not null discard survival rate could lead to an underestimation of stock for species with a certain probability of survive to the discard process; to take into consideration the discard survivability factor would allow to obtain more precise estimates of population at sea with consequent more optimistic yield for all the fleet segments.

Mesnil (1996) highlighted that if for VPA the actually removed individuals (discard + landing-survived discard) are used instead of the captured (discard + landing), not only the estimated fishing mortality is smaller but also the stock in numbers estimated to produce the removed individuals. And this is due to the fact that to produce the removed individuals (they are less than the catches, because some discarded individuals are not all died) a relatively smaller stock is needed.

ATTENTION: **In case this BEMTOOL option has to be used, a stock assessment performed of removed individuals (and not on captured) should be used for the parameterization, in order to not arbitrarily overestimate the stock and the consequent landings**.

Escape suvivability

In this version of BEMTOOL model has been introduced the possibility, on the basis of reliable references and/or experiments, to assume an escape survivability rate different from 1 and thus to simulate the effects on the population at sea, as well as on the yield, of the damages that could be subject the individuals entered but escaped from the net.

If the escape survivability has been set “Y”, this can considered:

- Constant (all the individuals escaped have the same probability to survive independently from the length;
- Depending on size according to an ogive model (the bigger individuals have much probability to survive respect to the smaller ones, see Ingolfsson et al., 2007);
- Depending on size according to an external vector.

In case the first option is selected, the user has to indicate by sex the probability to survive of the escaped individuals, while in case of ogive model selected, the user could indicate the L50% and the L75%-L25% to allow the model to derive the survivability by size (and eventually by sex, in case of growth parameters different by sex). In case the external vector has been chosen, this can be loaded by sex using the ALADYM configuration file.

In option 2 the *esr* depends on the age-length class according to a logistic function, as follows:

$$esr_f(l(a)) = \frac{1}{1 + e^{\frac{\log(9)}{L75\% - L25\%}(L50\% - l(a))}} \qquad \textbf{(23)}$$

where L50% is the length at which survive the 50% of escaped individuals, L25% is the length at which the 25% of escaped individuals survives and L75% is the length at which the 75% of escaped individuals survives. In option 3 the user gives directly the $esr_f(l(a))$.

The survived individuals escaped from fleet *f* are a part of escaped according to the escape survival rate (esr_f) following the formulas below:

$$N_{escape,f}(l(a), m) = (p_f(m) * N_{intermediate}(l(a), m) - Catch_f(l(a+1), m+1)) * esr_f(l(a)) \qquad \textbf{(24)}$$

$$N_{intermediate}(l(a), m) = N(l(a), m) + Total\_Catch(l(a+1), m+1) \qquad \textbf{(25)}$$

where N(l(a),m) is the number of individuals in the population of length *l(a)*at month *m*, *Total_Catch(l(a+1),m+1))* is the number individuals in the overall catch at age a+1 in month m+1, pf is the proportion of simulated catch of fleet segment f on the total production and esr_f is the escape survival rate for fleet segment f and $N_{intermediate}$ is the intermediate population that has been affected only by the natural mortality.

The sum of $N_{escape,f}(l(a),m)$ by fleet segment represents the population actually survived at month m.

According to Ingolfsson et al. (2007) the escape mortality from trawl gear for haddock was inversely related to fish length according to a logistic curve. Also Sangster et al (1996) and Soldal et al. (1993) observed that mortality decreases with length, while Breen M. and Cook R. (2002) use a constant value for all the sizes both for escape survival rate, performing different scenarios with different levels.

Generally, the assumption of escape survivability equal to 1 could lead to an overestimation of stock for species for which only one part of escaped individuals from the net survives; to take into consideration the escape survivability factor would allow to obtain more precise estimates of population at sea with consequent more pessimistic yield for all the fleet segments.

The example file to load escape survivability by age and sex (see format below) is provided in *bmtdocs/ALADYM_input* folder.

Age	fs1	fs2	fs3	fs4	fs5	Sex
0	1	NA	NA	NA	NA	M
1	0.8	NA	NA	NA	NA	M
2	0.8	NA	NA	NA	NA	M
3	0.2	NA	NA	NA	NA	M
4	0	NA	NA	NA	NA	M
5	0	NA	NA	NA	NA	M
6	0	NA	NA	NA	NA	M
7	0	NA	NA	NA	NA	M

Figure 44 – Example of escape survivability file.

9.1.5.5 The Fishing effort sub-tab

The *Fishing effort* sub-tab is automatically filled in by BEMTOOL with the effort monthly data by fleet segment and cannot be changed. These data are used in order to calculate the fishing coefficients to modulate the fishing mortality in the different months and to simulate fishing bans as well as any variation in the effort.

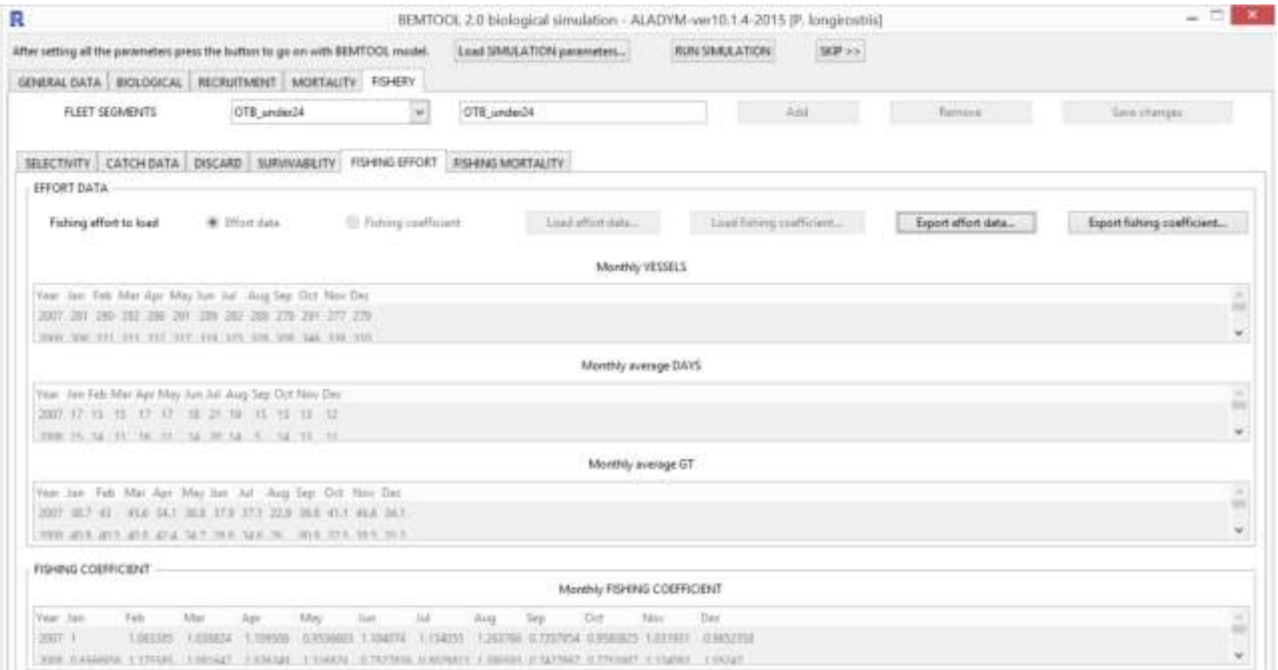


Figure 45 – Tab Fishery, sub-tab Fishing effort of ALADYM GUI.

The fishing coefficient in the simulation phase is calculated every month for each fleet segment as follows:

$$f_{act,f} = \frac{FD_f * Nb\_vessels_f * GT_f}{annual\_mean(FD_f * Nb\_vessels_f * GT_f)} \qquad \textbf{(26)}$$

as the product among the average fishing days FD, the number of vessels Nb_vessels and the average GT and the divided by the annual mean of the same product of effort variables.

These data of the monthly effort variables are <u>automatically</u> saved in ALADYM Tables folder as a .csv file in order to track what the model is using in the simulation and in the forecast phases.

9.1.5.6 Fishing mortality sub-tab

In the *Fishing mortality* sub-tab the user has to insert the values for F only if he has selected the option “Entry with F” (i.e. ALADYM in F mode) in the *Mortality* tab according the following options:

1. F values by age and sex for each fleet segment
2. overall F values by age (in case the F by fleet segment is not available).

In the second option, the possibility to split the overall F is implemented in the model according two different options:

- Calculation of the F (by age and sex) by fleet segment splitting the overall F (by sex and age) in input, according to the proportions of the given catches in numbers by sex and age.
- Calculation of the F (by age, equal for males and females) by fleet segment splitting the overall F (by sex and age) in input, according to the proportions of the landing data by fleet segment (BEMTOOL input).

The fishing mortality input is used according to equation (18) in Mortality paragraph.

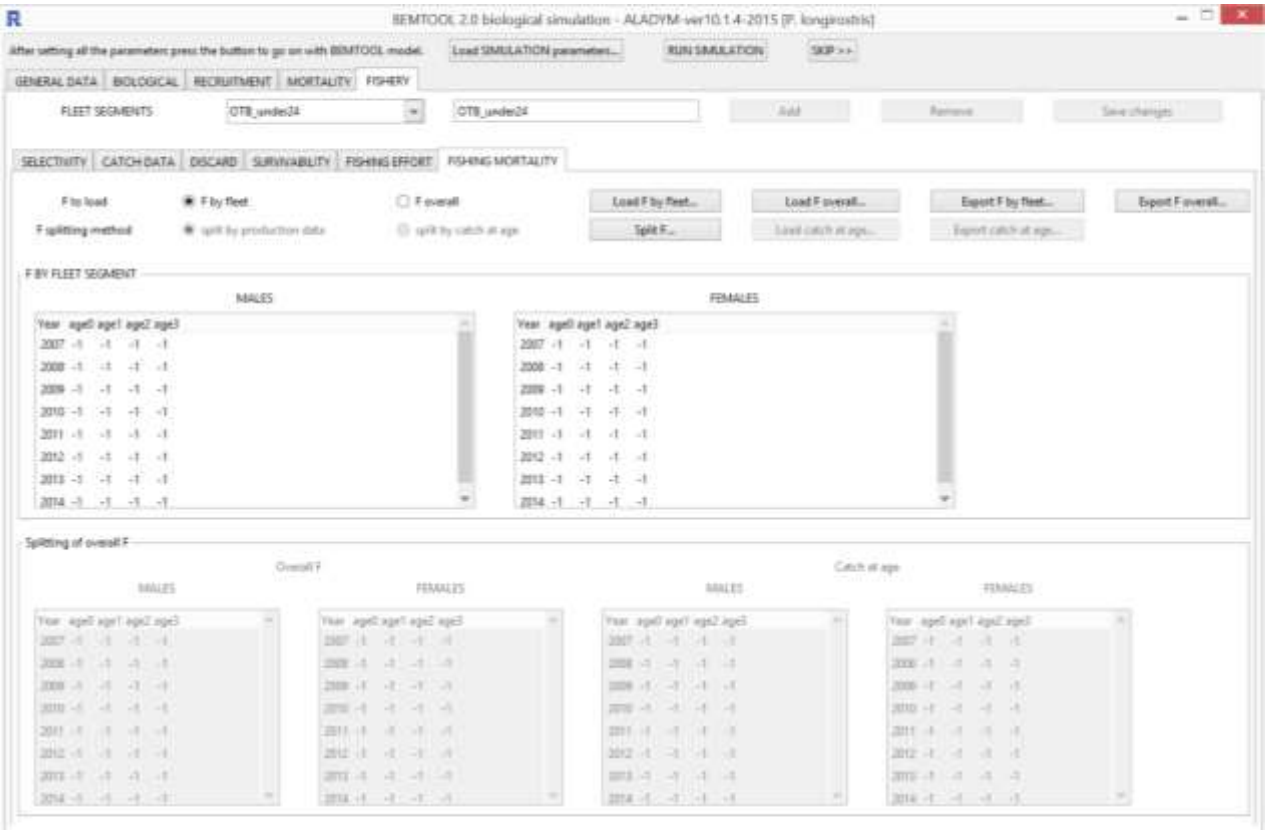


Figure 46 – Tab Fishery, sub-tab Fishing Mortality of ALADYM GUI.

To load the fishing mortality matrix by fleet segment, the format to be used to import all the fishing mortalities at once pushing *Load F by fleet...* is reported below.

Age	Year	fs1	fs2	fs3	fs4	fs5	fs6	fs7	fs8	Sex
0	2008	0.000789	0.002607	0.00911	0.003275	0.00012	0.000563	0.000932	4.46E-05	M
1	2008	0.014191	0.046903	0.163869	0.058916	0.002153	0.010127	0.016757	0.000801	M
2	2008	0.05686	0.187932	0.656595	0.236067	0.008628	0.040577	0.067142	0.003211	M
3	2008	0.088203	0.291527	1.018535	0.366196	0.013384	0.062945	0.104153	0.004981	M
4	2008	0.088203	0.291527	1.018535	0.366196	0.013384	0.062945	0.104153	0.004981	M
0	2008	0.000789	0.002607	0.00911	0.003275	0.00012	0.000563	0.000932	4.46E-05	F
1	2008	0.014191	0.046903	0.163869	0.058916	0.002153	0.010127	0.016757	0.000801	F
2	2008	0.05686	0.187932	0.656595	0.236067	0.008628	0.040577	0.067142	0.003211	F
3	2008	0.088203	0.291527	1.018535	0.366196	0.013384	0.062945	0.104153	0.004981	F
4	2008	0.088203	0.291527	1.018535	0.366196	0.013384	0.062945	0.104153	0.004981	F

Figure 47 – Accepted formats to load fishing mortality by fleet segment in ALADYM.

The format to be used to import the overall fishing mortality matrix pushing *Load F overall...* is reported below.

Age	2007	2008	2009	2010	2011	2012	2013	2014	Sex
0	0.039557	0.039557	0.037779	0.05212	0.0985	0.116729	0.153662	0.153662	M
1	0.254565	0.254565	0.330252	0.356294	0.66681	0.900334	0.865966	0.865966	M
2	0.565769	0.565769	1.252448	1.598939	1.351534	2.043063	0.867613	0.867613	M
3	4.859327	4.859327	3.729596	5.315888	7.966936	5.166007	4.68516	4.68516	M
0	0.039557	0.039557	0.037779	0.05212	0.0985	0.116729	0.153662	0.153662	F
1	0.254565	0.254565	0.330252	0.356294	0.66681	0.900334	0.865966	0.865966	F
2	0.565769	0.565769	1.252448	1.598939	1.351534	2.043063	0.867613	0.867613	F
3	4.859327	4.859327	3.729596	5.315888	7.966936	5.166007	4.68516	4.68516	F

If the user chooses to calculate the F (by age and sex) by fleet segment splitting the overall F (by sex and age) according to the proportions of the catches in numbers by sex and age, he/she has to import the catches by age by fleet segment pushing the button *Load catch at age…*, after importing the overall F, and then click on the *Split F…* button.

Example files to load fishing mortality are provided in *bmtdocs/ALADYM_input* folder.

10. Diagnosis

If the user has chosen to input to the BEMTOOL model stocks simulated by ALADYM, he/she interacts with ALADYM as many times as the stocks under consideration. The produced outputs, graphs and tables in .csv format are stored in the Case study path selected by the user in the "Case study configuration" tab. Results concerning the state of the stocks, impact/pressure and state of the fleet are presented in 3 tabs inside the "Diagnosis" tab shown in the figure below (Figure 48).

The computation time for the ALADYM simulation (if chosen by the user) depend on the number of fleet segments and stocks involved in the case study as well as on the number of years of the simulation.

In case the diagnosis has been performed in a previous run and the results are present in the *BEMTOOL casestudy path*, the software is able the load the previous results.

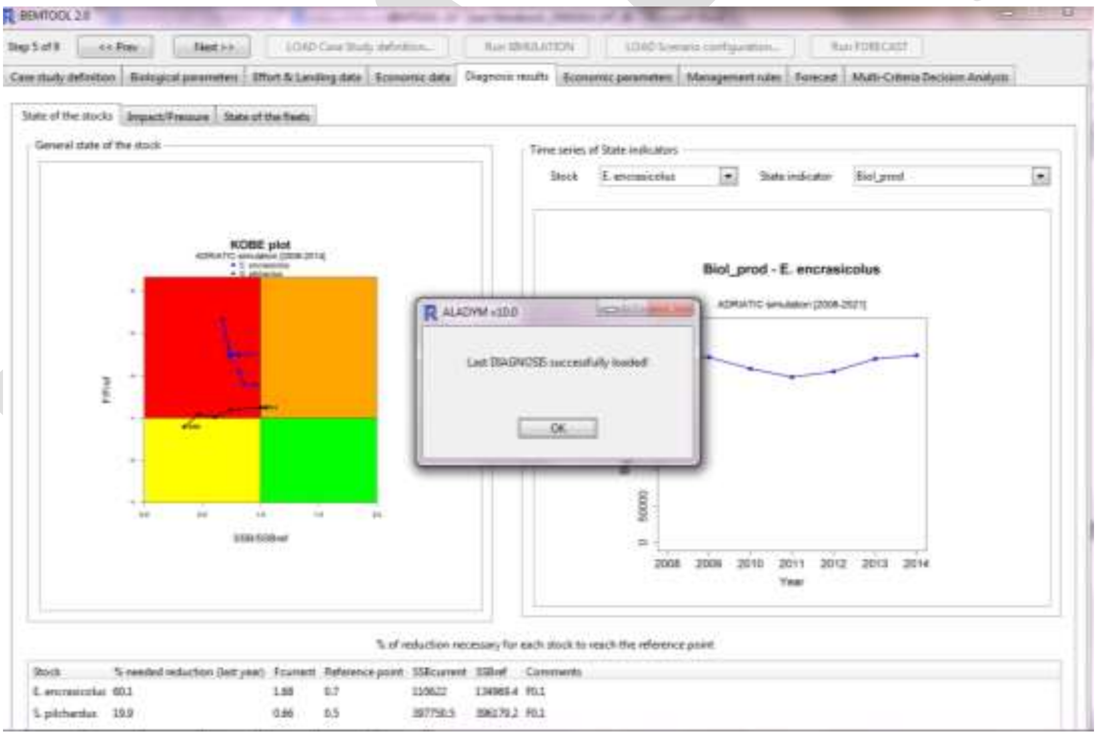


Figure 49 – Loading of Diagnosis from a previous run.

10.1 State of the stocks

In the "State of the stocks" tab the following type of information is presented: a) a KOBE plot for the case study area, b) a table showing % of reduction necessary for each stock to reach the reference point and c) time series of different state indicators by species. Since a species is selected from the stock list box, a list of indicators is presented in the window below. Navigate on the indicators list using the mouse or up and down arrows keys from keyboard.

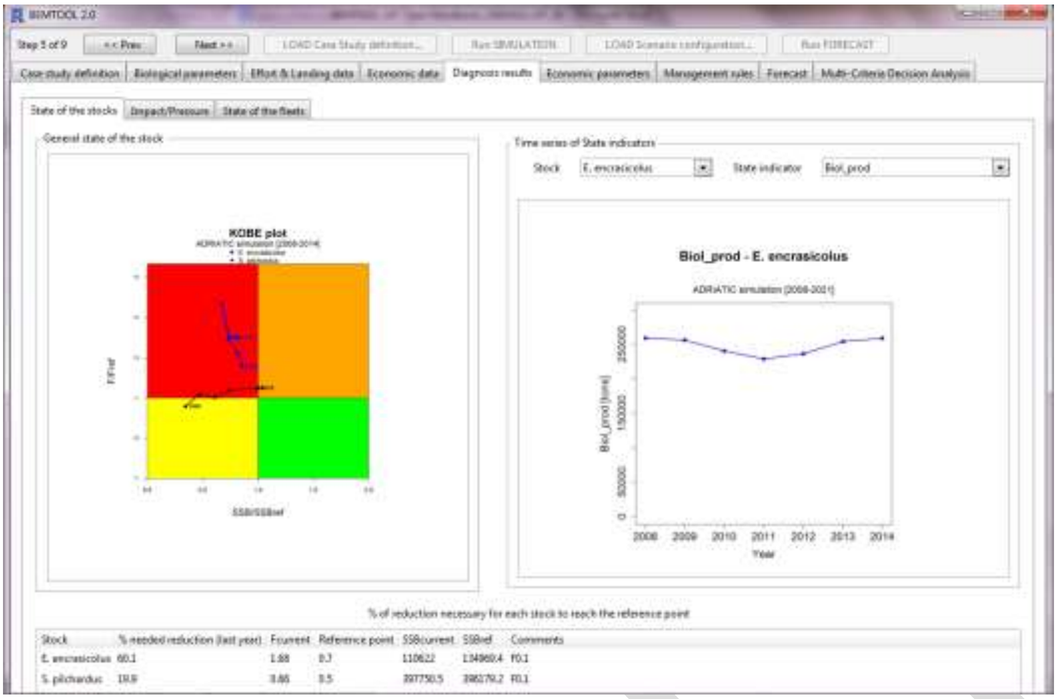


Figure 50 - State of the stocks screen. Example of Kobe plot: the 2 stocks are in the risky zone. Table summarizing for each stock the percentage of reduction needed to reach the reference point (stored in *Reduction by stock.csv* file). Example of plot of *Biological production*.

The Kobe plot is a global output summarizing the state of all the stocks respect to the situation with a system exploited under safe limits in terms of fishing mortality and spawning stock biomass.

On the x-axis there is the ratio between SSB and reference SSB (SSBref). For the stocks for which a stock-recruitment relationship has been provided, reference SSB is the spawning stock biomass at level of F equal of F_{msy}; for the stocks for which the recruitment is entered by a vector, reference SSB is equal to the SSB at level of F equal to $F_{0.1}$, used as proxy of F_{msy}.

On the y-axis there is the ratio between fishing mortality and reference F (Fref). As for SSB, for the stocks for which a stock-recruitment relationship has been provided, reference F is equal of F_{msy}, while for the stocks for which the recruitment is entered by vector, reference F equals $F_{0.1}$, is used as proxy of F_{msy}. In the same kobe plot F_{msy} and $F_{0.1}$, can be used for two different species thus labels on the x and y axis are generically referred as “Fref” and “SSBref”.

For each stock, these 2 ratios are plotted one versus the other year by year (each point represents one year for a particular stock) in order to obtain a trajectory describing the situation of the stock in the past and present years.

According to the position of the points in the Kobe plot area, the diagnosis about the state of each stock is different:

- Red zone: risky;
- Yellow zone: overfished;
- Orange zone: overfishing;
- Green: healthy.

10.2 Impact/Pressure

In the “Impact/pressure” tab the total F and F by fleet segment (by stock), the composition of the total yield (by stock) and % of fishing mortality due to the different fleet segments (by year) are presented.

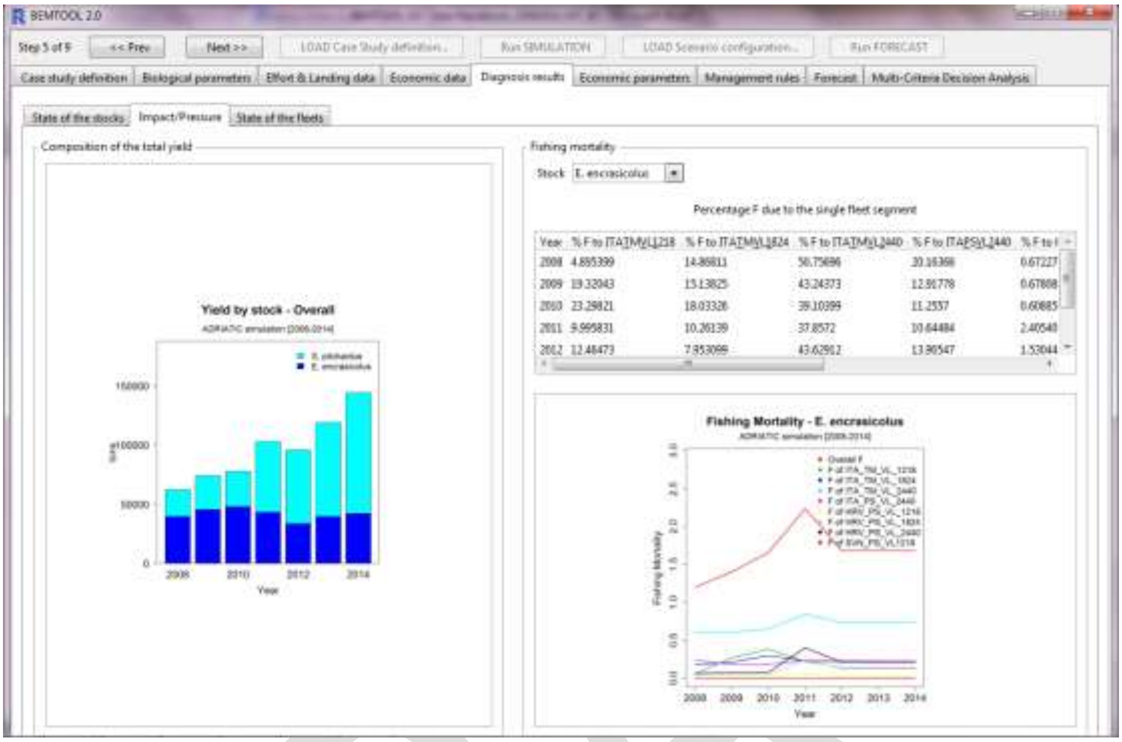


Figure 51 - Impact/Pressure screen. Example of plot of *Pressure indicators* (fishing mortality by fleet segment); b) plot of total yield by stock ; c) summary table by stock with the percentages of F due to the different fleet segments (stored in *Percentage F by fleet.csv* file).

10.3 State of the fleets

In the “State of the fleets” tab the following information by fleet segment and “overall” is portrayed: a) total landings and total revenues, b) profits, salaries and capital costs, c) average salary and number of employees and d) indicator revenues/break even revenues and net profits.

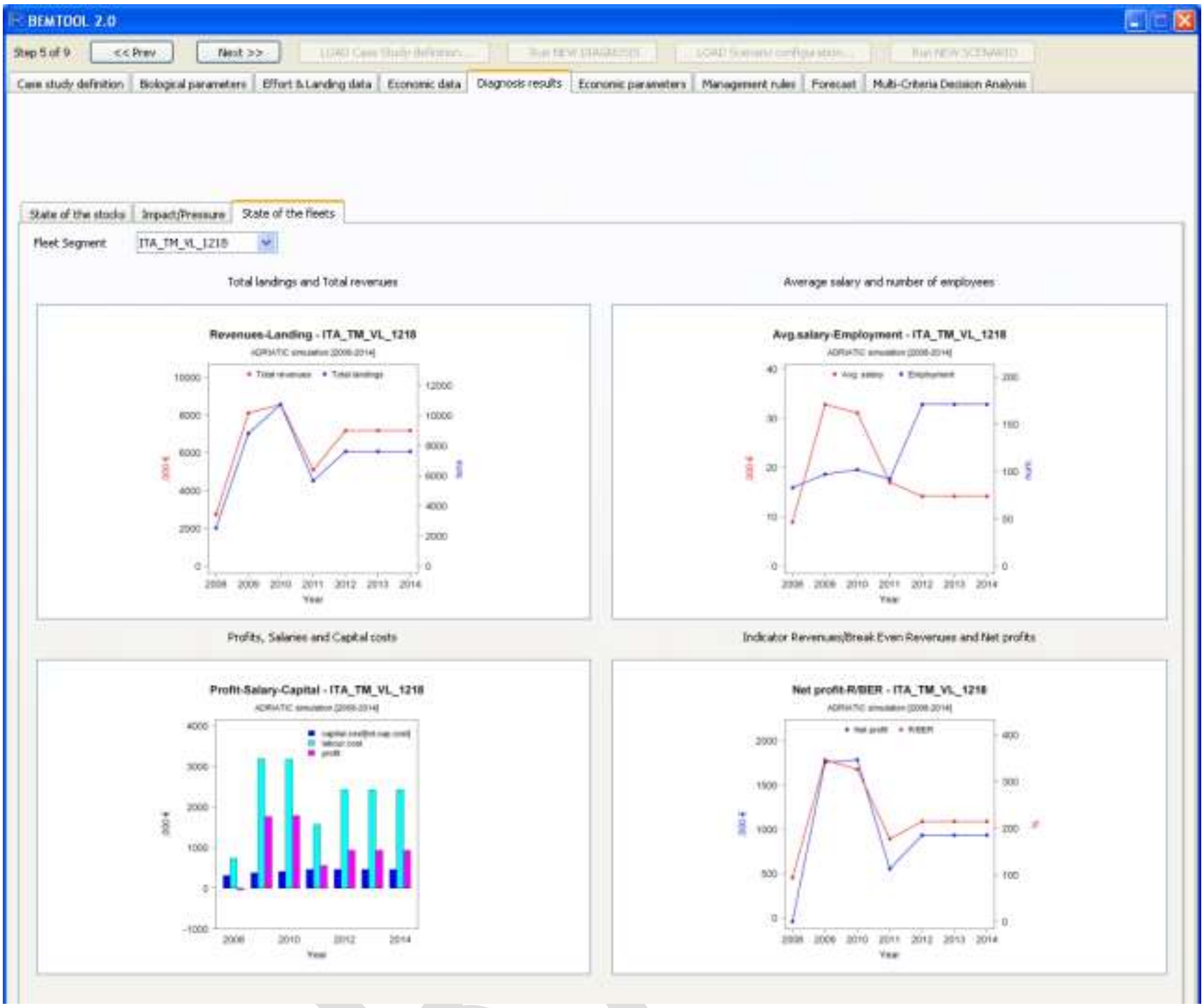


Figure 52 - State of the fleet screen. Example of plot of *Economic indicators:* total revenues and total landing; average salary and employment (on the top); profit, labour cost and capital cost by fleet segment; net profit and revenues/break even revenues (on the bottom).

According to the results in this overview of the indicators, the user could choose a management strategy that would allow to one or more stocks to return under safer biological limits; for example, if most part of the stocks are showing a decrease of the mean length in the catches and in the stock as well as a decrease of the SSB, the manager could decide to implement a mesh size restriction in the forecast phase.

Different management scenarios can be adopted for stock recovery and the same option can be implemented along different time spans and affecting different fleet segments. Decisions on timing to be adopted and the fleet segments to be interested by the implementation of a management measure can be taken analyzing the economic and social indicators of each fleet segment. Furthermore, objectives in fisheries management are not limited to stock recovery, but include also the economic viability of the sector. For example, if a fleet segment shows negative profits, assuming the presence of overcapacity, the manager could decide to reduce the fleet in order to achieve a situation of profitability for the sector.

10.4 Output of the simulation

Under the *BEMTOOL casestudy path* one folder named *Diagnosis* will be created; in this folder 3 .csv files will be saved containing the values of the indicators for diagnosis. The format of these tables is showed below. Moreover, also the Kobe plot related to the case study (simulation phase) is produced and saved in the folder *Diagnosis*.

Case_study	Scenario	ID_scenario	Fleet_segment	Stock	Year	Variable	Value	Unit	Comments
GSA 18	Diagnosis		ALL	M. barbatus	2007	Biol_prod	2719.673774	mm	
GSA 18	Diagnosis		ALL	M. barbatus	2008	Biol_prod	1765.866809	mm	
GSA 18	Diagnosis		ALL	M. barbatus	2009	Biol_prod	1640.791806	mm	
GSA 18	Diagnosis		ALL	M. barbatus	2010	Biol_prod	1055.837689	mm	
GSA 18	Diagnosis		ALL	M. barbatus	2011	Biol_prod	1136.97622	mm	
GSA 18	Diagnosis		ALL	M. barbatus	ALL	Bref	2515.6352		BF0.1
GSA 18	Diagnosis		ALL	M. barbatus	ALL	SSBref	2244.2836		SSBF0.1
GSA 18	Diagnosis		ALL	M. barbatus	2007	SSB	657.6685989	tons	
GSA 18	Diagnosis		ALL	M. barbatus	2007	B	1159.91728	tons	
GSA 18	Diagnosis		ALL	M. barbatus	2007	SSB_SSBref	0.293041663		SSB_SSBF0.1
GSA 18	Diagnosis		ALL	M. barbatus	2007	B(F=0)	12022.11743	tons	
GSA 18	Diagnosis		ALL	M. barbatus	2007	SSB(F=0)	11484.55803	tons	
GSA 18	Diagnosis		ALL	M. barbatus	2007	Exp_pop_nb	138195.7546	thousands	
GSA 18	Diagnosis		ALL	M. barbatus	2007	Unexp_pop_nb	268106.4608	thousands	

Figure 53 – Format of output table containing the indicators for diagnosis related only to the simulation phase.

Moreover, three sub-folders will be automatically created in the *Diagnosis* directory, containing all the plot of the indicators needed for the diagnosis before the forecast:

- *Biological Pressure Impact* (biological indicators for all the stocks and pressure and impact indicators for each stock and fleet segment);
- *Economic indicators* (economic indicators for all the fleet segments);

Figure 54 – Folders created by BEMTOOL after the simulation phase.

The complete lists of the indicators produced in the diagnosis phase are reported in the following table. The same indicators will be calculated in the forecast phase.

Table 3 – List of a) biological, b) pressure impact indicators and c) economic.

Biological indicators
Bref
Critical_length_expl_pop
Mean_length_of_exploited_pop
Mean_length_SS_of_exploited_pop
SPR
SSB_exploited_pop
SSB_SSBref
SSB_unexploited_pop
SSBref
Total_biomass_exploited_pop
Z

a)

Pressure impact indicators
Catch
Discard
Discard_ratio
Exploitation_rate
F
F_Fref
Fref
Landing
Mean_length_catch
Mean_length_discard
Mean_length_landing
Yref

b)

Economic indicators	
average.wage	investment[number]
capital.cost[depreciation]	investment[value]
capital.cost[interest]	KW.annual
capital.cost[tot.cap.cost]	KW.average.annual
capital.value	KW.DAYS.annual
DAYS.annual	labour.cost
DAYS.average.annual	landing.weight
discard.weight	MAXDAYS.average.annual
Economic.indicators[break.even.revenue]	Min.national.wage
Economic.indicators[CR.BER]	net.profit
Economic.indicators[GCF.vessel]	new.equipment.cost
Economic.indicators[GVA.vessel]	other.income
Economic.indicators[net.profit.vessel]	price
Economic.indicators[NP.cap.value]	price.discard
Economic.indicators[NPV.discounted]	profit
Economic.indicators[profit.vessel]	revenues.discard
Economic.indicators[RoFTA]	revenues.landing
Economic.indicators[ROI]	taxes
Economic.indicators[tot.landings.day]	technology
Economic.indicators[tot.landings.vessel]	total.cost
Economic.indicators[tot.revenues.day]	total.discards
Economic.indicators[tot.revenues.vessel]	total.income
Economic.indicators[vessel.util.ratio]	total.landings
employment	total.revenues
fixed.cost[avoid.main.cost]	total.revenues.discard
fixed.cost[ess.cost]	total.revenues.landing
fixed.cost[maint.cost]	variable.cost[commercial.cost]
fixed.cost[other.fix.cost]	variable.cost[fuel.cost]
fixed.cost[tot.fix.cost]	variable.cost[other.var.cost]
fixed.cost[unavoid.main.cost]	variable.cost[tot.var.cost]
fuel.price	VESSELS.annual
gross.cash.flow	
gross.value.added	
GT.annual	
GT.average.annual	
GT.DAYS.annual	

c)

In each sub-folder the plots of the biological and pressure indicators and economic indicators are saved. Moreover, also all the ALADYM results (for the stocks the user choose to simulate with ALADYM), divided by stock, are saved in *Diagnosis\Biological Pressure Impact* folder.

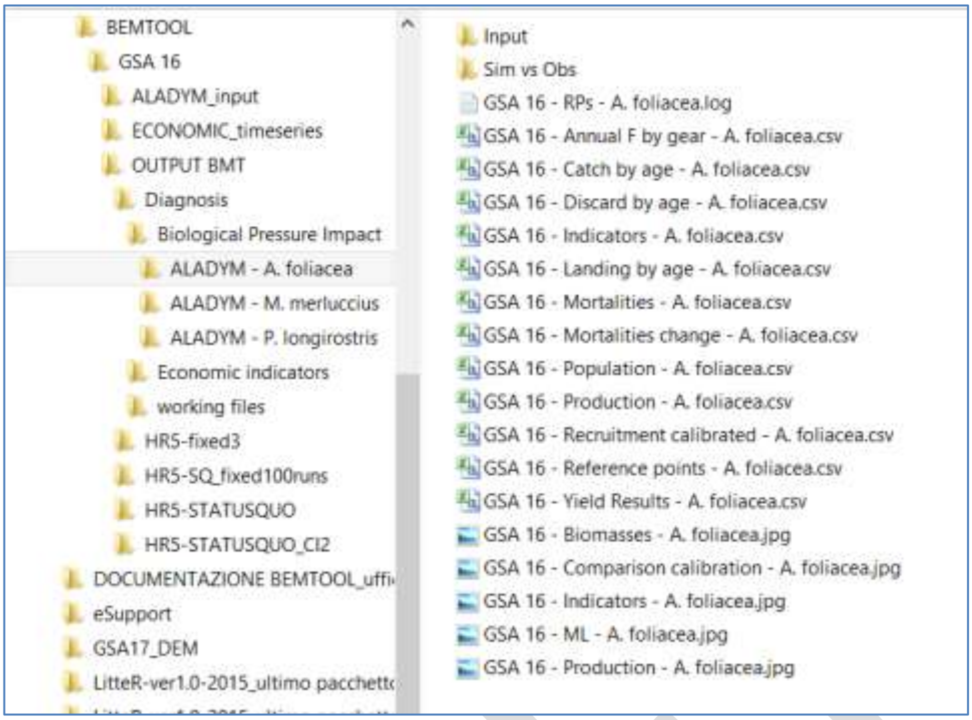


Figure 55 – ALADYM results after the simulation phase in the Diagnosis folder.

Finally, also two tables are saved, containing the percentage of reduction needed to reach the reference point (in the *Diagnosis* folder) for each stock and the proportion of F due to the different fleet segment year by year and for each stock (in the *Biological Pressure Impact* folder).

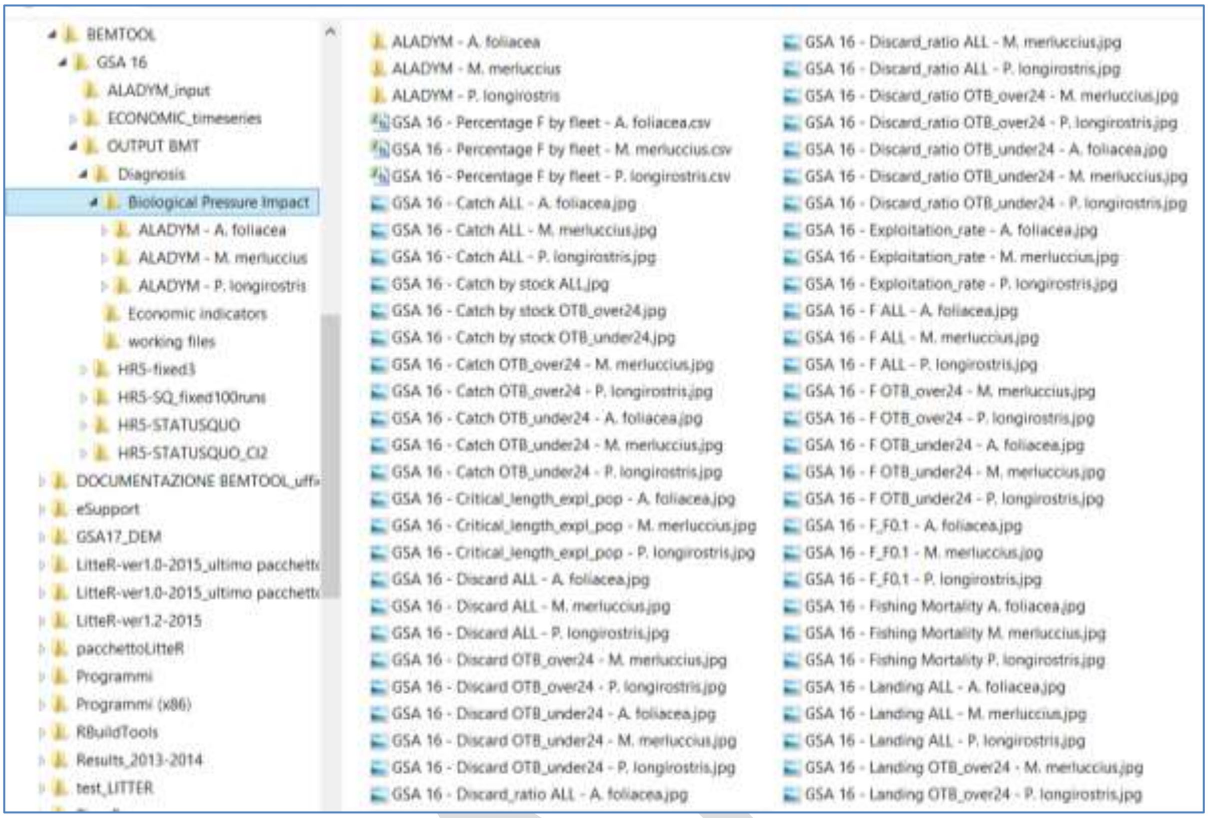


Figure 56 – Plots contained in the folder Biological indicators.

After visualizing the Diagnosis results in the GUI, the user has to click on NEXT button to start the definition of a scenario.

11 Economic parameters

The Economic parameters tab is the first step towards the definition of a scenario to simulate in the forecast. The user can type the needed parameters directly in the tabs, or load a predefined scenario clicking on LOAD scenario configuration button. The template of the configuration file for the scenario is provided in the *bmtdocs* folder.

The economic settings consist of parameters on price function, variable costs function, labour cost function, fixed costs function, capital costs function, economic indicators, and taxes and subsidies. Generally, each of the above components can be simulated by using different modelling options. Depending on the model selected for the specific component, coefficients to be entered can change.

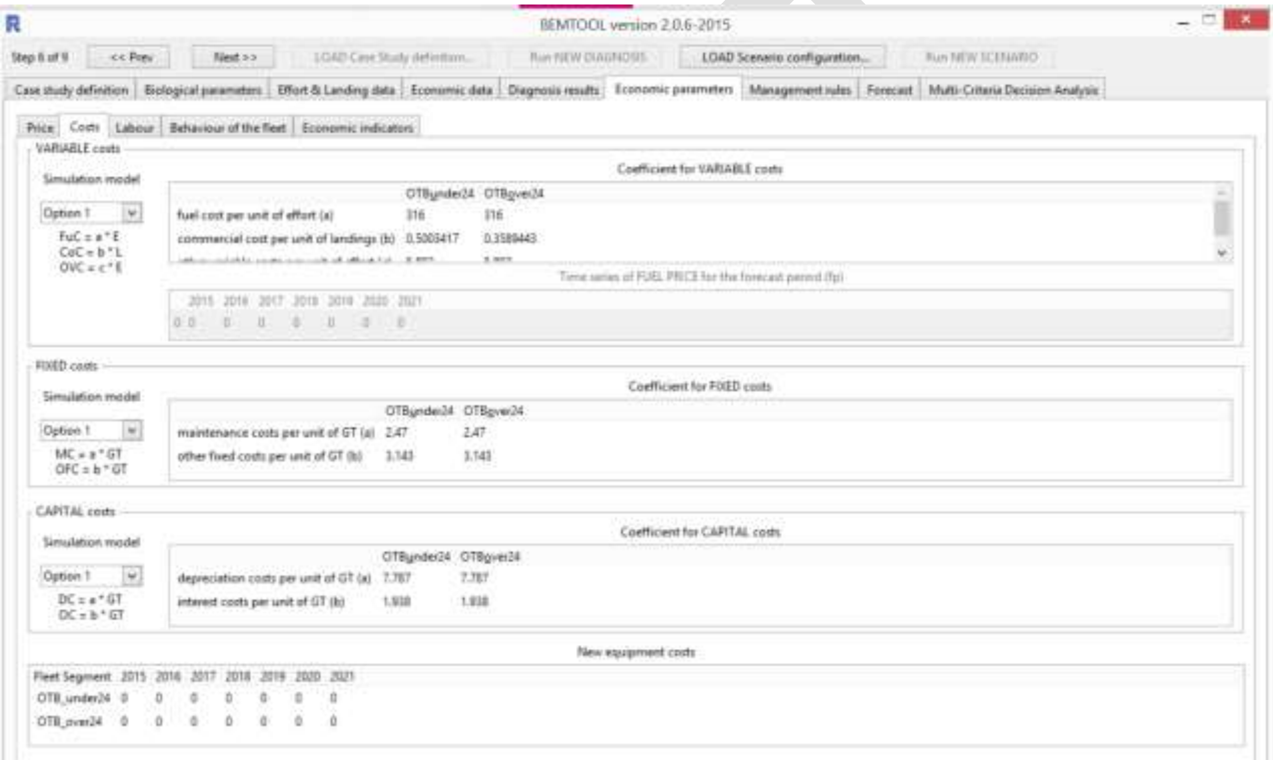


Figure 57 – Economic parameters BEMTOOL tab

11.1 Price

Several kinds of market models can be simulated in BEMTOOL: constant price assumptions, price-quantities relationship, price-importations relationship. In all models above mentioned the price of a species can be affected by a number of exogenous factors, among these changes in production and in imports, differences in the quality and size of the product can affect its price.

For landing one of the five implemented models can be selected according to the following equations:

Option 1:

$$p_{s,f,t} = p_{s,f,t-1}\left(1+\varepsilon_{s,f,landing}\frac{L_{s,f,t}-L_{s,f,t-1}}{L_{s,f,t-1}}\right) \qquad \textbf{(27.a)}$$

where:

$p_{s,f,t}$ is the price of the species s, for the fleet segment f at time t; (€)

$L_{s,f,t}$ is the landings of the species s, for the fleet segment f at time t (Kg);

$\varepsilon_{s,f,landing}$ elasticity coefficient price-landings for species s and fleet segment f (€/kg).

According to this option the ex-vessel mean price of stock *s* landed by fleet segment *f* at time *t* is a function of the same price at time *t-1* and the relative increase of landings (at the same level of aggregation than price) from time *t-1* to time *t* given a flexibility coefficient ε estimated for that stock and fleet segment, which represents the parameter to estimate.

For each combination stock-fleet segment one **input parameter** to be estimated is ε, the elasticity coefficient price-landings.

This option is available also to model the price of the discard, in case of sale of it (in case of landing obligation):

$$p_{s,f,t} = p_{s,f,t-1}\left(1+\varepsilon_{s,f,discard}\frac{D_{s,f,t}-D_{s,f,t-1}}{D_{s,f,t-1}}\right) \qquad \textbf{(27.b)}$$

where:

$D_{s,f,t}$ is the discard of the species s, for the fleet segment f at time t (Kg).

$\varepsilon_{s,f,discard}$ elasticity coefficient price-discard for species s and fleet segment f (€/kg).

Option 2:

$$p_{s,f,t} = p_{s,f,t=last}\,\overline{\omega}_{s,f,t}^{\gamma_{1,f}}\,L_{s,f,t}^{\varepsilon_{s,f}}\,imp_{s,t}^{\gamma_{2,f}} \cdot \qquad \textbf{(28)}$$

where:

$p_{s,f,t}$ is the price of the species s, for the fleet segment f at time t (€);

$p_{s,f,t=last}$ is the price of the species s, for the fleet segment f in the last year (€);

$L_{s,f,t}$ is the landings of the species s, for the fleet segment f at time t (kg);

$\overline{\omega}_{s,f,t}^{\gamma_1}$ is the mean weight of the species s, the fleet segment f at time t (kg);

$\gamma_{1,f}$ elasticity coefficient price-mean weight of landings;

$\gamma_{2,f}$ elasticity coefficient price-imports;

$\varepsilon_{s,f}$ elasticity coefficient price-landings for species s and fleet segment f

$imp_{s,t}$ total imports of the species s at time t (kg).

This option should be used in case the mean price of stock *s* landed by fleet segment *f* at time *t* is a function of the same price at a base time (*t* = last year of simulation), the mean weight *ω* of the landings and the imports *imp*, given a flexibility coefficient ε for that stock.

In order to model a price decreasing for increasing landing, the elasticity coefficient should be set as negative.

For each combination stock-fleet segment input parameters to be estimated from the observed data used in the simulation phase are: ε_s , $\gamma_{1,f}$ and $\gamma_{2,f,}$.

Time series of imports by stock for the forecast period have to be entered, if this option is selected, as *exogenous variables*.

In most cases, an increase of the individual weight of fish implies an increase of its unitary price. For this reason, this second option is particularly useful to estimate the effects of undersize landings in case of the introduction of the landings obligations.

Option 3:

$$p_{s,f,t} = p_{s,f,t=t-1} \frac{L_{s,f,t}}{L_{s,f,t-1}} \tag{29}$$

where:

$L_{s,f,t}$ is the landings of the species s, for the fleet segment f at time t (kg);

$p_{s,f,t}$ is the price of the species s, for the fleet segment f at time t (€).

This option is useful when the ex-vessel price of stock *s* at time *t* is a function of the same price in the previous year and the relative change in landings *L* from time *t-1* to time *t*.

No input are required if this option is selected.

Option 4:

$$p_{s,f,t} = p_{s,f,t=last} e^{\varepsilon_{s,f} L_{s,f,t}} \tag{30}$$

where:

$p_{s,f,t}$ is the price of the species s, for the fleet segment f at time t (€);

$p_{s,f,t=last}$ is the price of the species s, for the fleet segment f in the last year(€);

$\varepsilon_{s,f}$ elasticity coefficient price-landings for species s;

$L_{s,f,t}$ is the landings of the species s, for the fleet segment f at time t (kg);

This option should be used when the average price of stock *s* at time *t* is a function of the same price at a base time (*t* = last year of simulation) and the landings of stock *s* at time *t* given a flexibility coefficient ε estimated for that stock.

In order to model a price decreasing for increasing landing, the elasticity coefficient should be set as negative.

For each combination stock-fleet segment one **input parameter** to be estimated is ε, the elasticity coefficient price-landings.

Alternatively, it is possible to assume constant prices as follows:

Option 5:

$$pL_{s,f,t} = pL_{s,f,t=t-1} \qquad \textbf{(31.a)}$$

In this case no input is required, because the price of the last year will be used for all the future years.

This option is available also to model the price of the discard, in case of sale of it (in case of landing obligation):

$$pD_{s,f,t} = pD_{s,f,t=t-1} \qquad \textbf{(31.b)}$$

Option 6:

$$p_{s,f,t} = C \qquad \textbf{(31.c)}$$

In this case the constant price (in €) is required by fleet segment and species. The price in input will be used for all the future years.

This option is available also to model the price of the discard, in case of sale of it (in case of landing obligation):

$$pD_{s,f,t} = D \qquad \textbf{(31.d)}$$

How to estimate elasticity coefficients

All equations included in BEMTOOL simulate price dynamic by using the price flexibility (ε), which measures the effect changing quantities have on prices and is assumed constant over the range of landings data. Both for simple and multiple regression models the random error parameter has been omitted for simplicity.

It is also considered as the inverse of price elasticity of Demand (*e*), which measures the rate of response of quantity demanded due to a price change:

$$e = \frac{(\Delta Q / Q)}{(\Delta P / P)} \qquad \textbf{(32)}$$

Hence, while the demand quantity-price elasticity parameters allow to measure the sensitivity of demand when prices change, the price flexibility can be defined as the percentage change in the price of a good brought about by a one percent increase in demand for that good:

$$\varepsilon = \frac{1}{e} = \frac{(\Delta P / P)}{(\Delta Q / Q)} \qquad \textbf{(33)}$$

Provided that the flexibility lies between 0 and –1, the price is inflexible. If the flexibility lies between –1 and –∞, the price is flexible (Means, 1935). Large literature analyzing quantity-price relationships of fresh fish generally show that prices vary less than production. A survey in Nielsen (2000), which reports the price flexibilities by main group of species at European level, highlights that average price flexibilities range between -0.3 and -0.4 for flatfish, pelagic fish and round fish and -0.5 for crustaceans and bivalves.

In mostly cases, however, the flexibility coefficient is complex to estimate because of the heterogeneity of the existing information and because the regression models require a long time series of data. As a consequence, when a wide uncertainty in prices dynamic is detected on time series data, another option is to select a price flexibility parameter computed exogenously on the basis the existing seafood demand literature.

In the upper part of the price sub-tab a list of six options (one for each model described above) is available.

For each option, the related tables are activated and ready to accept input.

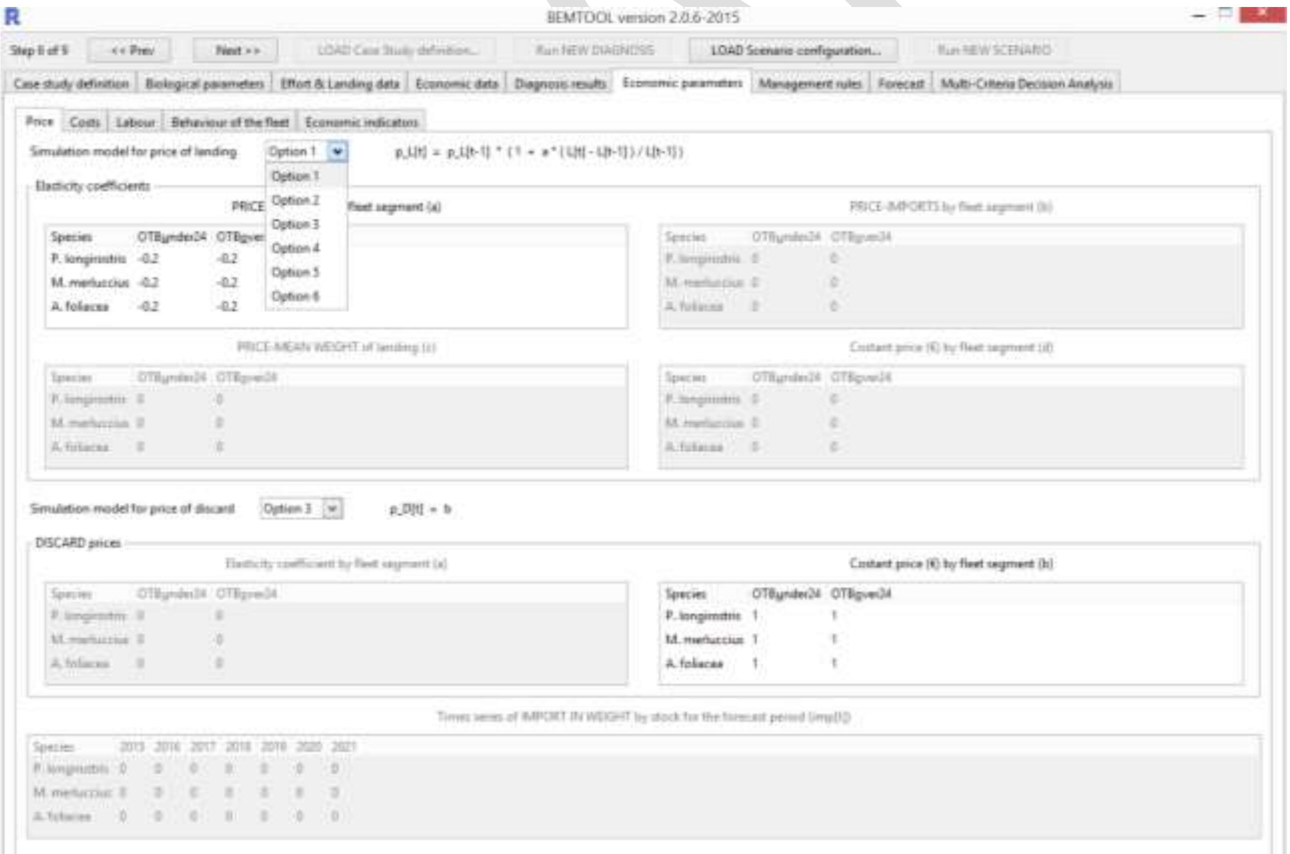


Figure 58 - Economic parameter data entry form: Price component, **Option 1** model.

11.2 Costs

In this tab are contained all the parameters needed to simulate the variable, fixed and capital costs in the forecast.

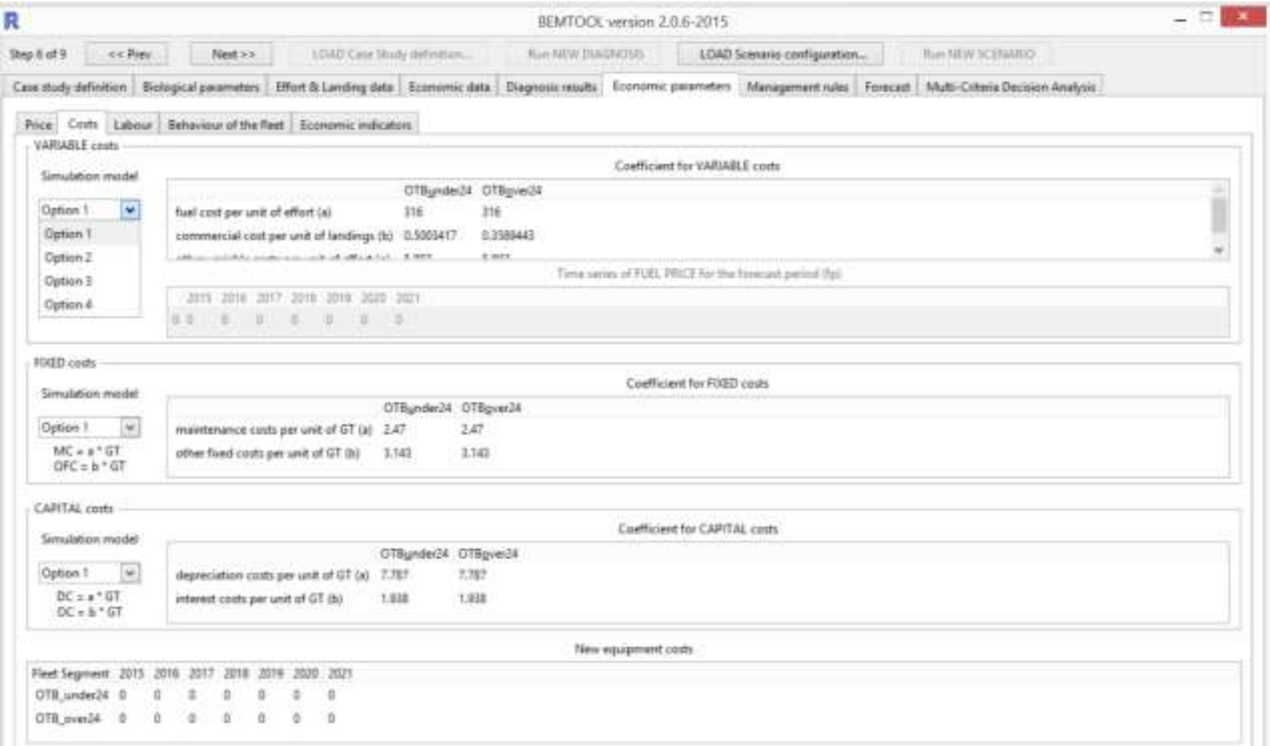


Figure 59 - Economic parameter data entry form: Variable, Fixed and Capital costs parameterization.

11.2.1 Variable costs

In BEMTOOL the operational costs are differentiated by fleet segment and divided into: variable costs, labour costs and maintenance and fixed costs.

In the upper part of the form a list of four options (one for each model) is available. For each option, a related table is activated and is ready to accept input. In Figure 59, the required data for each model are displayed.

Four models are provided in BEMTOOL model to simulate the variable costs in the forecast. In each option name is indicated with the model from which the variable costs equation has been taken and in some cases modified.

Option 1:

Variable costs in the model 1 of BEMTOOL are separated in fuel costs, commercial costs and other variable costs. The three costs functions can be represented by the following equations:

$$FuC_{f,t} = \alpha'_f E_{f,t} \tag{34}$$

$$CoC_{f,t} = \alpha''_f L_{f,t} \tag{35}$$

$$OVC_{f,t} = \beta'_f \, E_{f,t} \qquad \textbf{(36)}$$

where:

$FuC_{f,t}$ are the fuel costs for the fleet segment f at time t (€);

$E_{f,t}$ is the effort (in terms of total annual fishing days) of fleet segment f at time t;

$CoC_{f,t}$ are the commercial costs for fleet segment f at time t(€);

$L_{f,t}$ is the total landing (target species+ other species) of the fleet segment f at time t (kg);

$OVC_{f,t}$ are the other variable costs for fleet segment f at time t (€);

α_f' fuel cost per unit of effort for fleet segment f;

α_f'' commercial cost per unit of landing for fleet segment f;

β_f' other variable costs per unit of effort for fleet segment f .

This option is useful when fuel costs $FuC_{f,t}$ and the other variable costs $OVC_{f,t}$ by fleet segment *f* at time *t* are functions of fishing effort *E* of the same fleet segment *f* at time *t*, while commercial costs $CoC_{f,t}$ by fleet segment *f* at time *t* are assumed to be a function of the total amount of landings *L* for the fleet segment *f*.

For each fleet segment input parameters to be estimated for each fleet segment are α', α'' and β'.

Option 2:

This model makes a similar distinction between variable costs coming from trade activities and those associated to fishing effort. Commercial costs are the costs related to the operations of selling and are normally estimated as a function of revenues $R_{f,t}$:

$$CoC_{f,t} = \alpha''_f \cdot R_{f,t} \qquad \textbf{(37)}$$

The other variable costs functions can be expressed as follows:

$$FuC_{f,t} = fp_f \alpha'_f E_{f,t} \qquad \textbf{(38)}$$

$$OVC_{f,t} = ice_f E_{f,t} + \alpha'''_f E_{f,t} \qquad \textbf{(39)}$$

where:

$FuC_{f,t}$ are the fuel costs for the fleet segment f at time t (€);

$E_{f,t}$ is the effort (in terms of total annual fishing days) of fleet segment f at time t;

$CoC_{f,t}$ are the commercial costs for fleet segment f at time t (€);

$R_{f,t}$ are the total revenues (target species+ other species) of the fleet segment f at time t(€);

$OVC_{f,t}$ are the other variable costs for fleet segment f at time t (€);

α_f' fuel consumption per unit of effort for fleet segment f;

α_f'' commercial cost per unit of revenue for fleet segment f;

α_f''' other variable costs per unit of effort for fleet segment f ;

ice$_f$ is the ice cost per unit of effort for fleet segment f (€);

fp$_f$ is the fuel price for fleet segment f for fleet segment f (€/l);

This option should be used when fuel costs depend on fuel price *fp*, fuel consumption per unit of fishing effort α' and fishing effort *E*, and the other variable costs are a function of the consumption of ice per unit of effort *ice*, the other costs per unit of effort α''' , and the fishing effort *E*.

For each fleet segment input parameters to be estimated are α_f', α_f” and α_f'''. The time series of fuel price assumed for the forecast period has to be entered as exogenous variable.

Option 3:

In this model, variable costs are separated in fuel costs and other variable costs. Fuel cost depends on fuel price *fp*$_f$, fuel consumption per unit of fishing effort α' and fishing effort *E* (as in option 2). The other variable costs depends on the revenues .

$$FuC_{f,t} = fp_f \alpha'_f E_{f,t} \qquad \textbf{(40)}$$

where:

$FuC_{f,t}$ are the fuel costs for the fleet segment f at time t(€);

fp$_f$ is the fuel price for fleet segment f (€/l);

$E_{f,t}$ is the effort (in terms of total annual fishing days) of fleet segment f at time t.

α_f' fuel consumption per unit of effort .

$$OVC_{f,t} = \alpha''_f \cdot R_{f,t} \qquad \textbf{(41)}$$

where:

$OVC_{f,t}$ are the other variable costs for fleet segment f at time t (€);

$R_{f,t}$ are the total revenues (target species+ other species) of the fleet segment f at time t (€).

α_f'' other variable costs per unit revenue.

The total variable costs is the sum of fuel costs and other variable costs:

$$VC_{f,t} = FuC_{f,t} + OVC_{f,t} \tag{42}$$

For each fleet segment input parameters to be estimated are α_f' and α_f''. The time series of fuel price assumed for the forecast period has to be entered as exogenous variable.

Option 4:

In this simulation model a very simple approach has been adopted to simulate variable costs. Variable costs (not separated in fuel, commercial and other costs, but as a single item) are here expressed in a single equation as a linear function of fishing effort *E* and the coefficient β'':

Fixed costs

where:

$VC_{f,t}$ are the variable costs for fleet segment f at time t (€);

$E_{f,t}$ is the effort (in terms of total annual fishing days) of fleet segment f at time t;

β_f'' total variable costs per unit of effort.

For each fleet segment the only **input parameter** to be estimated is β''.

The coefficients involved in the calculation of variable costs can be easily estimated by a linear regression of the type of variable cost on the variable on which depends. For example, in case option 1 is used to model the fuel costs, the α'_f coefficient can be estimated as the slope of the linear regression $FuC_{f,t} \sim \alpha'_f E_{f,t} + err$ (without intercept).

Alternatively, an average of the ratios between fuel costs and annual fishing days in the past years can be also used, or, in case the situation of the last year is very different from the previous years, an average of the same ratios among the last three years or only the ratio of the last year.

In an analogous way can be estimated all the coefficients of the different options.

11.2.2 Fixed costs

Fixed or non-variable costs consist of costs sustained by vessels independently on the fishing activity, like administration, obligatory insurance, fishing license, harbor charges, etc. Maintenance or repair costs are costs for maintenance and repairs of fishing equipment, gears and vessel parts.

In the upper part of the form a list of three options (one for each model) is available. For each option, a related table is activated and is ready to accept input.

In each option name is indicated with the model from which the variable costs equation has been taken and in some cases modified. Three options are provided by BEMTOOL model.

Option 1:

According to model 1, both fixed costs *OFC* and maintenance costs *MC* are directly linked to the total annual gross tonnage *GT*. These functions can be represented as follows:

$$MC_{f,t} = \alpha''_f GT_{f,t} \tag{44}$$

where:

$MC_{f,t}$ are the maintenance costs for the fleet segment f at time t (€);

$GT_{f,t}$ is the annual gross tonnage;

α_f' other fixed costs per unit of GT.

$$OFC_{f,t} = \alpha'_f GT_{f,t} \tag{45}$$

where:

$OFC_{f,t}$ are the other fixed costs for the fleet segment f at time t (€);

$GT_{f,t}$ is the annual gross tonnage for fleet segment f at time t;

α_f'' maintenance costs per unit of GT.

For each fleet segment input parameters to be estimated are α_f', α_f''.

Option 2:

In this model maintenance and fixed costs are divided in essential costs, like harbor costs, license, insurance, etc., and maintenance costs used to maintain the vessel at its maximum performance level. Essential costs are supposed to be constant for each vessel over the simulation horizon. Essential costs are assumed here as a function of the number of vessels and a coefficient α'. Maintenance costs are divided in two groups: avoidable and unavoidable costs. The first group can be reduced when profits decrease, while the second group is assumed to be constant as these represent the minimum costs to maintain active a vessel. As a consequence, the avoidable maintenance costs at time *t* will be simulated as a function of profits at time *t-1,* the number of vessel *N* of the fleet segment *f* at time *t* and a coefficient α''', while the unavoidable maintenance costs will depend on the number of vessel N belonging the fleet segment under analysis and a coefficient α''.

The fixed costs described above can be expressed as follows:

$$EC_{f,t} = \alpha'_f N_{f,t} \tag{46}$$

$$UMC_{f,t} = \alpha''_f N_{f,t} \tag{47}$$

$$AMC_{f,t} = \min(\alpha_f''' N_{f,t}; \max(\alpha_f''' N_{f,t} + \Pi_{f,t-1}; 0)) \quad \textbf{(48)}$$

where:

$EC_{f,t}$ are the essential costs for fleet segment f at time t (€);

$UMC_{f,t}$ are the avoidable maintenance costs for the fleet segment f at time t (€);

$AMC_{f,t}$ are the avoidable maintenance costs for the fleet segment f at time t (€);

$\Pi_{f,t-1}$ is the profit for the fleet segment f at time t-1 (€);

$N_{f,t}$ is the number of vessels for fleet segment f at time t;

α_f' essential costs per vessel for fleet segment f ;

α_f'' avoidable maintenance costs per vessel for fleet segment f ;

α_f'' unavoidable maintenance costs per vessel for fleet segment f .

This option is useful when essential costs (EC) and unavoidable maintenance costs (UMC) depend on the number of vessels, while avoidable maintenance costs (AMC) are assumed as a function of the number of vessels when profits are positive. When profits are negative, avoidable maintenance costs will be reduced by the amount of losses.

For each fleet segment input parameters to be estimated are: α_f' ,α_f'' ,α_f''.

Option 3:

The third option consists in handling fixed and maintenance costs as a single item proportional *FC* to the number of vessels *N* belonging to the fleet segment *f.*

$$FC_{f,t} = \alpha_f' N_{f,t} \quad \textbf{(49)}$$

where:

$FC_{f,t}$ are the fixed costs for the fleet segment f at time t (€);

α_f' total fixed costs per vessel;

$N_{f,t}$ is the number of vessels for fleet segment f at time t;

For fleet segment only **input parameter** to be estimated is α'_f.

As described above, BEMTOOL simulates fixed costs as a function of the vessels number or the GT. Significant changes in the average GT or kW over time for a fleet segment generally are not expected for short time series and the use of the vessels number can be acceptable. However, splitting costs among different fleets needs to take into account fleet size. As a consequence, GT and kW are suggested as potential cost drivers or explicative variables for fixed costs.

11.2.3 Capital costs

Capital costs represent the costs associated to the use of capital. In fishery economic accounts, these are generally differentiated in depreciation costs and interest or opportunity costs. Depreciation is the cost associated to the deterioration of the capital, and opportunity costs is the cost of using the capital invested. This is estimated considering the profitability of alternative use of the capital.

In the upper part of the form a list of three options (one for each model) is available. For each option, a related table is activated and is ready to accept input.

In each option name is indicated with the model from which the variable costs equation has been taken and in some cases modified. Three options are provided by BEMTOOL model.

Option 1:

A first option simulate depreciation costs *DC* and interest or opportunity costs *OC* by linear functions of the annual gross tonnage *GT* of the fleet segment *f.*

$$DC_{f,t} = \beta_f' GT_{f,t} \tag{50}$$

$$OC_{f,t} = \beta_f'' GT_{f,t} \tag{51}$$

where:

$DC_{f,t}$ are the depreciation costs for the fleet segment f at time t;

$GT_{f,t}$ is the annual gross tonnage for fleet segment f at time t;

β_f' depreciation costs per unit of GT for fleet segment f;

β_f'' interest costs per unit of GT for fleet segment f;

$OC_{f,t}$ are the opportunity costs for fleet segment f at time t.

For each fleet segment input parameters to be estimated are β_f' and β_f''

Option 2:

In model option 2 depreciation costs $DC_{f,t}$ and interest or opportunity costs $OC_{f,t}$ can be simulated by linear functions of the capital value *K*.

$$DC_{f,t} = \beta_f' \cdot K_{f,t} \tag{52}$$

$$OC_{f,t} = \beta_f'' \cdot K_{f,t} \tag{53}$$

Where:

$DC_{f,t}$ are the depreciation cost for fleet segment f at time t;

$K_{f,t}$ are the capital value for the fleet segment f at time t;

$OC_{f,t}$ are the opportunity costs for the fleet segment f at time t;

β_f' depreciation costs per unit of capital value for the fleet segment f;

β_f'' interest costs per unit of capital value for the fleet segment f.

For each fleet segment **input parameters** to be estimated are β_f' and β_f''.

Option 3:

A third option uses a single function to simulate total capital costs as a single item linearly dependent on the number of vessels *N* belonging to the fleet segment *f*.

$$CC_{f,t} = \beta_f' N_{f,t} \tag{54}$$

where:

$CC_{f,t}$ are the total capital costs;

$\beta f'$ capital costs per vessel for the fleet segment f;

$N_{f,t}$ is the number of vessels for fleet segment f at time t.

Controllare se manca qualche formula!!! (55)

For each fleet segment the only input parameter to be estimated is β_f'.

The selections among these three options should depend on the methodology applied to estimate capital cost and the value of vessel. If the estimation method is based on the Perpetual Inventory Method (Capital study ,see Irepa Onlus et al. ,2005), option 1 based on a price per capacity unit should be followed. Alternatively, if reliable data on the value of vessels are available, linear relationships based with the value of vessel as independent variable should be tested (option 2). Finally in some contexts, capital costs are directly related to the number of vessels (option 3).

11.3 Labour cost

In this sub-tab are contained all the input related to labour cost.

The simulation of the labour cost is particularly relevant to estimate the effects of management measures from a social point of view. This variable allows some social indicators, such as the average salary per man employed, to be evaluated through time (Prellezo *et al.,* 2011).

The definition of the labour costs function depends on the working contract in the specific fishery under analysis. Usually the tradition-based income sharing system between the ship-owner and the crew is the most prevalent in Mediterranean countries. Consequently, wages are assumed to be strictly related to the revenues.

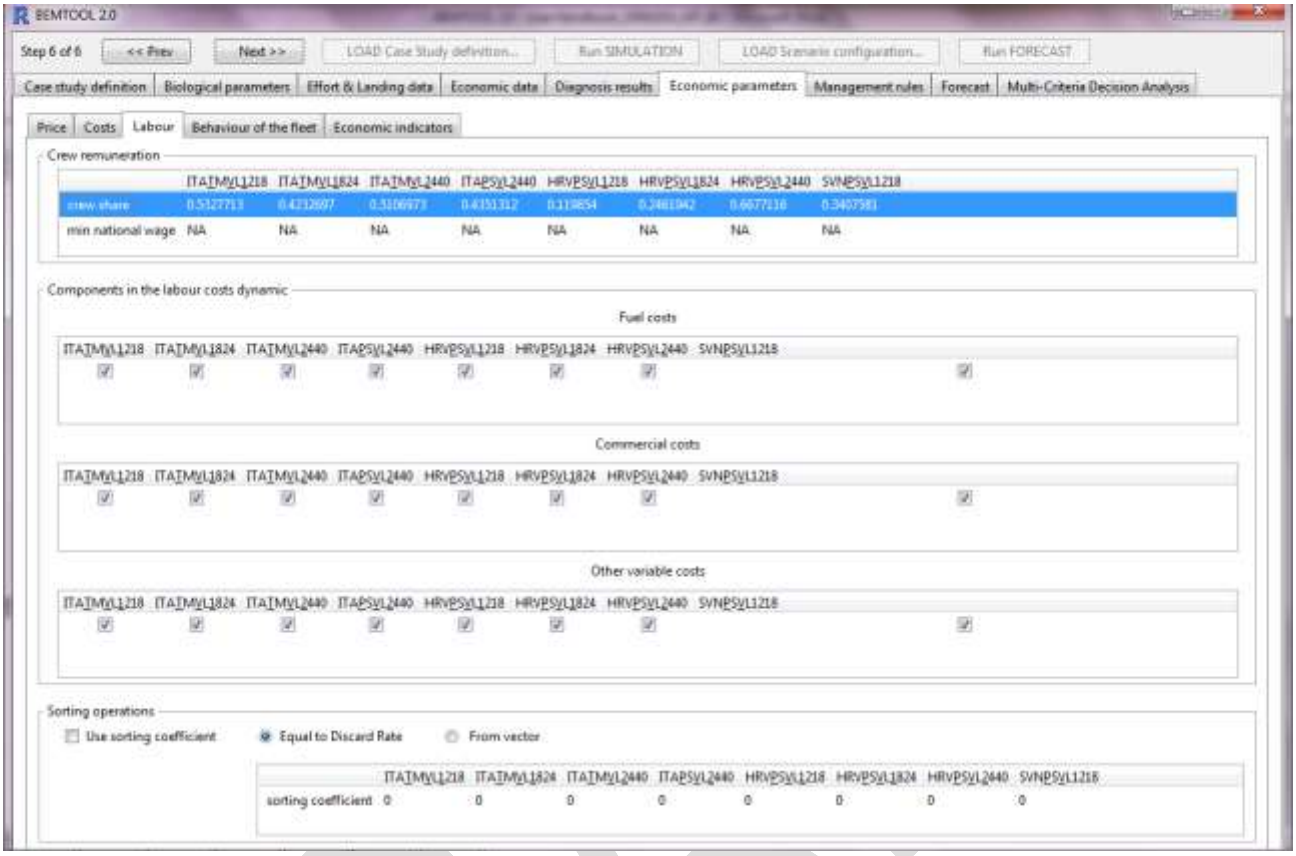


Figure 60 - Economic parameter data entry form: Labour cost component.

Following the approach of the models developed for Mediterranean fisheries, such as BIRDMOD and MEFISTO, the labour cost is estimated as a percentage (generally around 50%) of the difference between revenues and variable costs (including fuel costs) plus a quantity linked to the obligation to land the discard:

$$LC_{f,t} = cs_f \left(R_{f,t} - VC_{f,t}\right) + \beta(LC_{f,t}) = cs_f (R_{f,t} - \alpha'_f FuC_{f,t} - \alpha''_f CoC_{f,t} - \alpha_f''' OVC_{f,t}) + \beta(LC_{f,t,only\_land})$$

(56)

where:

$LC_{f,t}$ is the labour cost of the fleet segment f considering the work due to the managing of landing and discard for the fleet segment f at time t (€);

$LC_{f,t,only\_land}$ is the labour cost of the fleet segment f considering the work due to the managing only of landing for the fleet segment f at time t(€);

$R_{f,t}$ are the total revenues (target species+ other species) of the fleet segment f at time t (€);

$VC_{f,t}$ are the variable costs for the fleet segment f at time t(€);

$FuC_{f,t}$ are the fuel costs for the fleet segment f at time t (€);

$CoC_{f,t}$ are the commercial costs for fleet segment f at time t (€);

$OVC_{f,t}$ are the other variable costs for fleet segment f at time t (€);

β additional coefficient due to landing obligation;

cs_f crew share for the fleet segment f;

α'_f coefficient equal to 1 (0 otherwise) if the fuel costs have to be included in the labour costs calculation for the fleet segment f;

α''_f coefficient equal to 1 (0 otherwise) if the commercial costs have to be included in the labour costs calculation for the fleet segment f;

α_f''' coefficient equal to 1 (0 otherwise) if the other variable costs have to be included in the labour costs calculation for the fleet segment f.

The user can decide by checking the checkbox in the GUI which variable costs among fuel, commercial and other variable costs to consider in the labour cost formula respectively by means of coefficients α'_f, α''_f and α'''_f (that can be assume value 0 or 1). Moreover, the introduction of the landing obligation would imply the provision of handling unwanted catches and therefore changes of on board procedures. For this reason the Labour costs equation has been adapted in order to make assumptions on possible additional costs, as those related to additional sorting costs. Labour costs in case of landing obligation will increase proportionally to the additional coefficient β. Such coefficient can be automatically computed as the ratio between discard volume and total catch (assuming that to the increase in variable costs as a consequence of the increase in the discard ratio) selecting “Equal to Discard rate” option by the GUI or alternatively can be indicated by the model user selecting “From vector” option by the GUI.

For each fleet segment input parameters to be estimated are cs_f, α'_f, α'_f, α''_f and α'''_f and β_f.

The selection of the crew share (and the corresponding costs to include in the equation) strictly depends on the working contract in force for the fishing sector analyzed. If the information about the working contract should not be available, a regression based on the relation between the crew cost and the difference between revenues and variable costs should give information about the incidence of salary on the revenues.

11.4 Investments in new equipment

Total investments in new equipment or technology by vessels, as those required for the application of new regulations, is estimated as the product between the average new investments per vessel and the number of vessels:

$$NEquipC_{f,t} = AvgNEquipC_{f,t} * N_{f,t} \qquad \textbf{(57)}$$

where:

$NEquipC_{f,t}$ are the new equipment costs for fleet segment f at time t (€);

$N_{f,t}$ is the number of vessels for fleet segment f at time t;

$NEquipC_{f,t}$ are the new equipment costs for fleet segment f at time t per vessel (€).

Average new equipment can be sourced from external sources or estimated as percentage of existing fixed (non-variable costs).

Depreciation charges by year are an additional components of fixed costs and should be included in total fixed cost.

11.4 Behaviour of the fleet

This component simulates the fishermen behaviour, i.e. their investment/disinvestment decisions in the fishery (and its consequences on the fishing effort) as a response to changes in the profitability of the fishery itself.

It consists of three components: fleet dynamics, activity dynamics and technological progress. Fleet and effort dynamics respectively reflect long-term and short-term decisions in fishermen's behaviour and are both affected by expectations of profit. The theory of the Firm and Market Supply, in fact, suggests that the primary goal of the agent is to maximize profits. Therefore, external factors, like the implementation of a new management measure, a significant change in fuel price or the deterioration of stock conditions, can affect fisher's behaviour and determine reactions of fishermen in the long and short term.

In Figure 61 the required data by fleet segment are displayed.

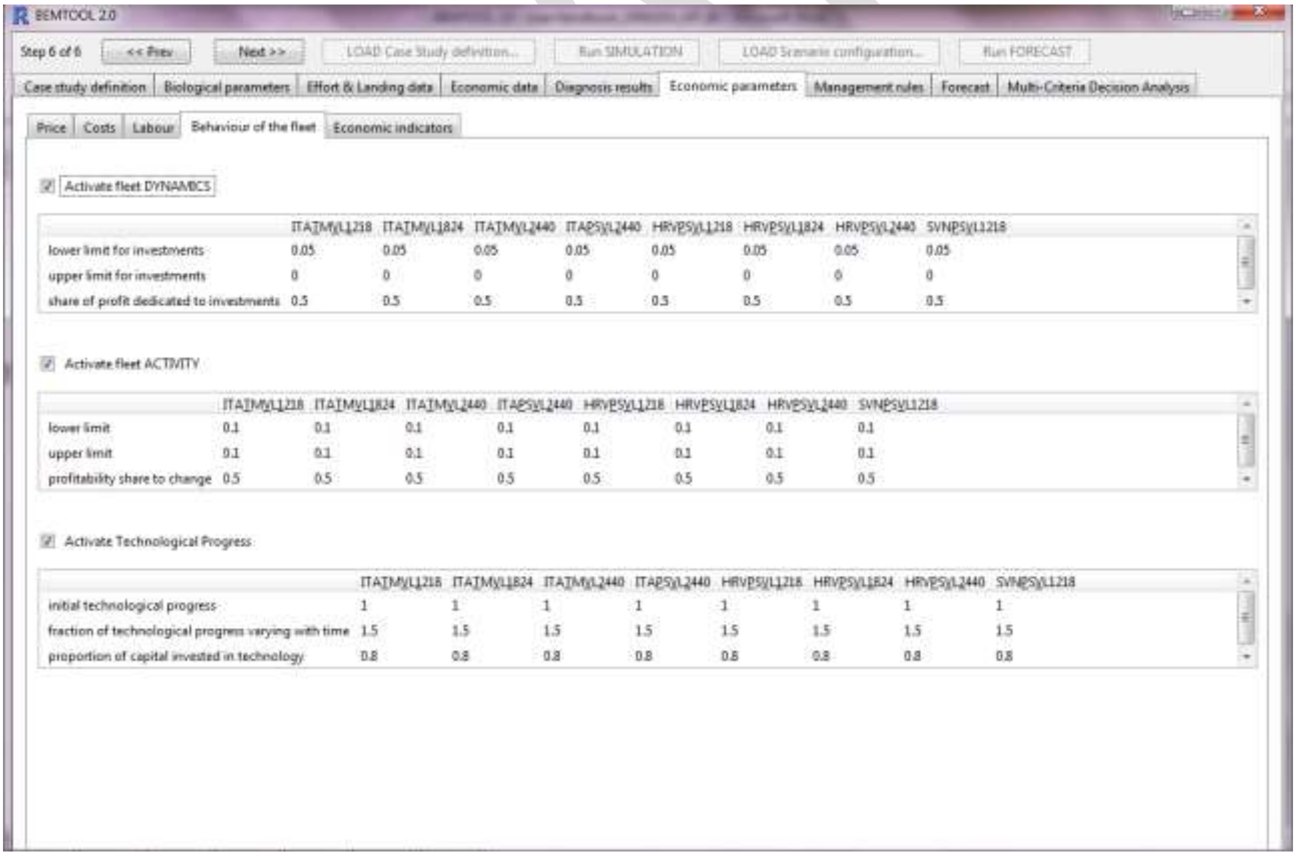


Figure 61 - Behaviour of the fleet sub-tab.

11.4.1 Fleet dynamics.

This module is aimed to incorporate long-term decisions in the BEMTOOL model. These decisions are generally simulated by investment/disinvestment functions (I), which can be directed to sell the vessel (stop the fishing activity) or buy a vessel (restart the fishing activity).

The function incorporated in BEMTOOL is that proposed in the model FISHRENT, where the changes of the fleet size are determined with an investment function, which in its turn is related to profit level of the previous year, using the ratio between realized revenue and break-even revenue.

In the equation below, the number of vessels $N_{f,t}$ at time t is estimated by adding (deducting) a certain number of units I, defined as investment (if positive, disinvestment if negative) from the value $N_{f,t}$ at time t-*1*:

$$N_{f,t} = N_{f,t-1} + I_{f,t-1} \tag{58}$$

where:

$N_{f,t}$ is the number of vessels for fleet segment f at time t;

$I_{f,t}$ is the number of vessels added (if is a positive number) of subtracted (if is negative) to the number of vessels of the previous year.

Investments (disinvestment) depend on profitability, the inertia of the sector and the average number of days at sea, where perceived profitability is expressed as ratio between break-even revenues (BER) minus realized revenues divided by realized revenues; the break-even revenues is the level of revenues allowing the vessel owner to cover variable and fixed costs. When BER exceeds realized revenues than the fleet will expand and vice versa.

This inertia of the sector is based on the actual restrictions to fleet capacity enforced by the CFP and MS fishery regulations As the inertia of the system does not allow full flexibility in fleet dynamic, parameters have been introduced to limit the maximum annual investments (disinvestments).

When perceived profitability is positive, it is assumed that the active fleet will first achieve a certain minimum number of days-at-sea per vessel before the number of vessels will be expanded. Therefore, investments will be positive only if this level of activity has been reached.

This system of rules can be formalized as follows:

$$IF\left(BER_{f,t-1} < 0\right) \Rightarrow I_{f,t} = -lLim_f N_{f,t-1} \tag{59}$$

where:

$BER_{f,t-1}$ is the break even revenue for the fleet segment f at time t-1;

lLim is the decline percentage if the break even revenue is negative.

The fleet will decline by a percentage equal to lLim if the break even revenue is negative

Otherwise, a share of the relative difference between revenues and break even revenues will represent the percentage variation in the number of vessels, which defines upper limit for investments (uLim). This percentage variation will be within –lLim and uLim.

$$ELSE\ IF\left(\Pi sh_f\,(R_{f,t-1} - BER_{f,t-1})/R_{f,t-1} > uLim_f\right) \Rightarrow I_{f,t} = uLim_f N_{f,t-1} \tag{60}$$

$$ELSE\ IF\left(\Pi sh_f\,(R_{f,t-1} - BER_{f,t-1})/R_{f,t-1} < -lLim_f\right) \Rightarrow I_{f,t} = -lLim_f N_{f,t-1}$$

$$ELSE \Rightarrow I_{f,t} = \left(\Pi sh_f\,(R_{f,t-1} - BER_{f,t-1})/R_{f,t-1}\right)N_{f,t-1}$$

where:

uLim is the upper limit for investments for fleet segment f;

$R_{f,t}$ are the total revenues (target species+ other species) of the fleet segment f at time t (€);

$BER_{f,t-1}$ is the break even revenue for the fleet segment f at time t-1;

Πsh_f is the share of the relative difference between revenues and break even revenues for the fleet segment f.

Alternatively, when lower limit and upper limit for investments are set at 0, no variation is possible and the simulations would assume a constant number of vessels or a full control of the fleet size by the public managers.

Given the difficulty to estimate parameters related to the upper and lower limits of the number of vessels and to the share of the relative difference between revenues and break even revenues, it is suggested to use some default values. The upper limits of investments can be assumed equal to 0 as a consequence of the inertia of the system. The default lower limit can be assumed to 5% if the break even revenue is negative. Πsh_f can be assumed equal to 50% of the relative difference between revenues and break even revenues.

11.4.2 Activity dynamics

This module is aimed to simulate the dynamic of the fishing effort in terms of average days at sea. As reported above, fishers are expected to maximize their profit. This is carried on by short-term decisions, which can be seen as tactical adaptations producing variations in fishing effort. For instance, changing the number of fishing days or their duration in hours, changing the fishing area and switching among different fishing gears (for polyvalent vessels) can be considered as short-term decisions.

As full flexibility in effort dynamics could be not realistic, parameters have been introduced to limit the maximum annual increase (decrease) in the fishing activity.

This system of rules can be formalized as follows:

$$IF\left(BER_{f,t-1} < 0\right) \Rightarrow \overline{d}\overline{d}_{f,t} = (1 - dlLim_f)\overline{d}\overline{d}_{f,t-1} \tag{61}$$

where:

$BER_{f,t-1}$ is the break even revenue for the fleet segment f at time t-1;

$\overline{d}\overline{d}_{f,t}$ is the annual average days at sea for the fleet segment f at time t;

dlLim is the lower limit of the percentage change of annual average days at sea for fleet segment f.

The annual average days at sea ($\overline{d}\overline{d}$)will decline by a percentage equal to lower limit for changes in fishing activity if the BER is negative.

Otherwise, a share of the relative difference between revenues and break even revenue will represent the percentage variation in the annual average days at sea. This percentage variation will be within the limits entered by the user, lower limit for changes in fishing activity(-dlLim) and the upper limit for changes in fishing activity (duLim):

$$ELSE\ IF\left(Dsh_f\,(R_{f,t-1} - BER_{f,t-1})/R_{f,t-1} < -dLim_f\right) \Rightarrow \overline{d}\overline{d}_{f,t} = (1 - dlLim_f)\overline{d}\overline{d}_{f,t-1} \qquad \textbf{(62)}$$

$$ELSE\ IF\left(Dsh_f\,(R_{f,t-1} - BER_{f,t-1})/R_{f,t-1} > duLim_f\right) \Rightarrow \overline{d}\overline{d}_{f,t} = \min(1 + duLim_f)\overline{d}\overline{d}_{f,t-1}; \overline{d}\overline{d}_{f,MAX}$$

Dsh_f share of the relative difference between revenues and break even revenue for the fleet segment f;

$R_{f,t}$ are the total revenues (target species+ other species) of the fleet segment f at time t (€);

$BER_{f,t-1}$ is the break even revenue for the fleet segment f at time t-1;

$duLim_f$ is the upper limit of the percentage change of annual average days at sea for fleet segment f.

$\overline{d}\overline{d}_{f,MAX}$ maximum of average days at sea allowed for the fleet segment f.

However, the average days at sea cannot be higher than a maximum defined by the user:

$$ELSE \Rightarrow \overline{d}\overline{d}_{f,t} = \min\left(\left(1 + Dsh_f\,(R_{f,t-1} - BER_{f,t-1})/R_{f,t-1}\right)\right)\overline{d}\overline{d}_{f,t-1}; \overline{d}\overline{d}_{f,MAX} \qquad \textbf{(63)}$$

Given the restrictions imposed by the management system and the maximum fishing days available in a year, the dynamic of the activity per vessel can be formalized as follows:

$$\overline{dd}_{f,t} = \min\left(\overline{dd}\max{}_f; \overline{dd}mng_t\right) \qquad \textbf{(64)}$$

where the average days at sea per vessel ($\overline{d}\overline{d}$)is estimated as the minimum between the maximum fishing days in a year ($\overline{d}\overline{d}\max$) and the fishing days established by regulations ($\overline{d}\overline{d}\mathrm{mng}$).

As for the fleet dynamics it is suggested to use some default values to estimate parameters related to the upper and lower limits for changes in fishing activity and to the share of the relative difference between revenues and break even revenue. Both upper and lower limits of days can be assumed equal to 10% and the share of the relative difference between revenues and break even revenue equal to 50%.

11.4.3 Technological progress

This module is aimed to simulate the potential increase in productivity as a result of the investments in technology.

The approach incorporated in BEMTOOL is that proposed in the model MEFISTO (Equation 39), which assumes that the technological progress at time t is given by the technological progress at time 0 multiplied by a variation component based on time (τ) and a variation component based on the amount of investments in technology (h K).

$$q_{f,t} = q_{f,0}\tau^{t}\frac{1-e^{-hK_{f,t}}}{1-e^{-hK_{f,0}}} \tag{65}$$

This equation allows the model user to make assumptions on the portion of technological progress due to the time and the portion due to investments in technology. However, when available data is insufficient to compute reliably these parameters, the endogenous adaptive behavior of fleets can be disabled by setting the technological progress parameters to a low value (e.g. 0.0001).

In case of absence of reliable information on capital and technological progress, the default value of the annual increment of technological progress can be assumed equals to 1, the fraction varying with time equals to 1.5 and the proportion of capital invested in technology equals to 0.8.

11.5 Economic indicators

In this tab are contained all the parameters needed for the calculation of the socio-economic indicators.

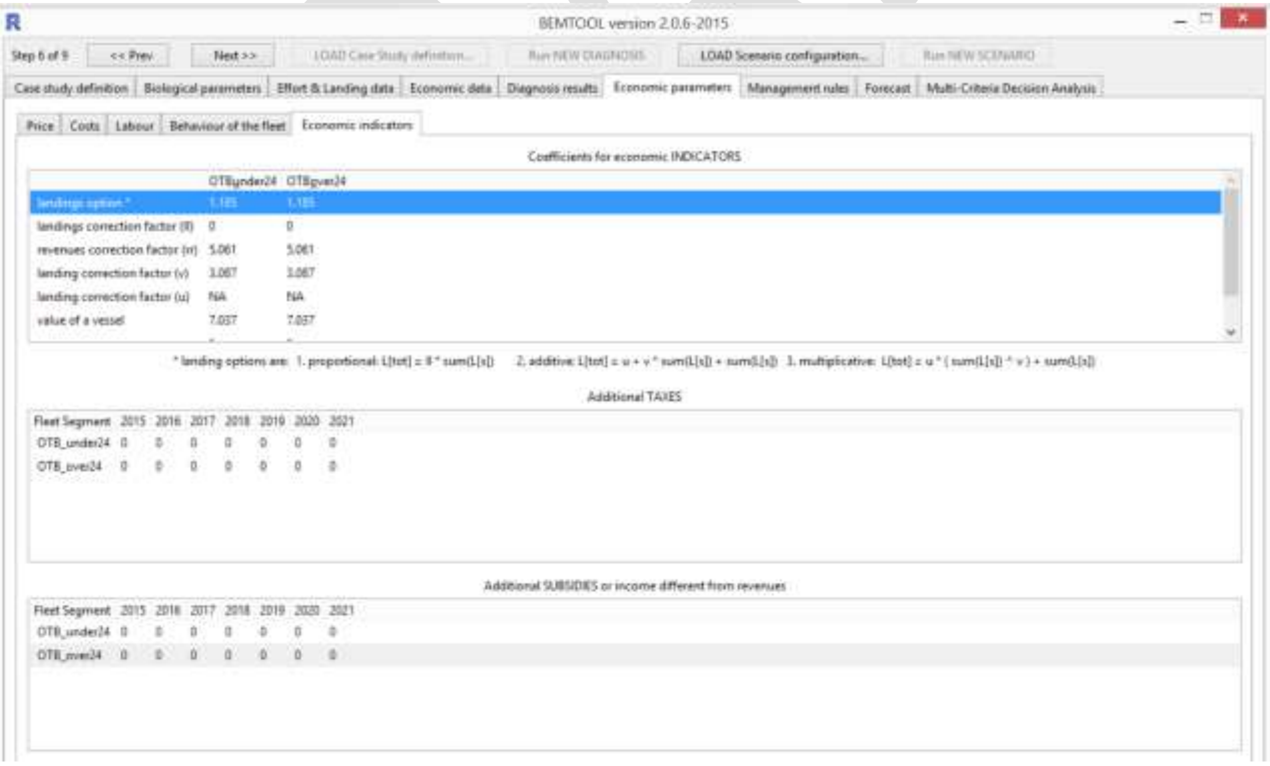


Figure 62 - Economic indicators sub-tab

The main social and economic outputs and indicators estimated on the basis of the economic parameterization are:

- Revenues, total revenues, other income and total income;
- Gross value added, gross cash flow and profit;
- Investment and capital value;
- Employment and average wage;
- The ratio of current revenue to break-even revenue (CR/BER).
- The capacity utilization per fleet segment (average days at sea / maximum observed days at sea).
- Return of fixed tangible assets
- Net profit over the 15 years and net present value of profit in the future (infinity).

11.5.1 Revenues, total revenues, other income, total income, taxes and subsidies.

Revenues by fleet segment and species are calculated by multiplying landings produced in the biological sub-model by the prices estimated on the basis of the price module. This approach allows to estimate revenues for all the stocks simulated in the biological sub-model (all stocks with sufficient data for the use of a biological and pressure modules).

As biological data are not available for all Mediterranean stocks only a part of total revenues can be estimated by this approach. The remaining part of revenues and landings for each fleet segment are assumed to be as a fixed percentage of the estimated revenues:

Option 1 :

$$R_{f,t} = rr_f \sum_{s=1:n} R_{f,s,t} \quad \textbf{(66)}$$

$$L_{f,t} = ll_f \sum_{i=1:n} L_{f,i,t} \quad \textbf{(67)}$$

where:

$R_{f,t}$ are the total revenues (target species+ other species) of the fleet segment f at time t (€);

$R_{f,s,t}$ are the revenues of the target species s of the fleet segment f at time t (€);

rr_f is correction factor to pass from the revenues of target species to the total revenues of the fleet segment f.

This option is suggested when the total revenues for a fleet segment is proportional by a correction factor (rr_f) to the sum of the revenues by stock of the fleet segment f. Also total landings can be estimated by using a correction factor ll_f applied to the sum of the landings by stock of the fleet segment.

In the above equation it is assumed that revenues and landings of secondary (non-target) species for each fleet segment are a fixed percentage of the total revenues and landings. This implies that any change in the landings or revenues from the "assessed species" proportionally affects the total profitability of the fleets, even if the "assessed species" represent just a minor share of the total revenues. This assumption might be appropriate in fisheries where a very large share of the landings and revenues come from the "assessed species". However, when assessed species represent a small percentage of the total landings and/or total revenues, a more flexible relations between "assessed species" and total species" should allow for a better estimation of the total landings and revenues from non –target species.

For the above mentioned reasons and following the approach of MEPHISTO model, an upgrading of BEMTOOL has been implemented in order to allow relationship between revenues of the other species and revenues of target species different from proportional.

Option 2 :

$$L_{other\_species,f,t} = u_f + v_f \sum_{s=1:n} L_{s,f,t} \tag{68}$$

Option 3:

$$L_{other\_species,f,t} = u_f \left(\sum_{s=1:n} L_{s,f,t} \right)^{v_f} \tag{69}$$

where:

$L_{other\_species,f,t}$ is the landing of the other species of the fleet segment f at time t;

$L_{s,f,t}$ is the landing of the species s of the fleet segment f at time t;

u_f correlation between the landings of the target species and the landing of the non-target species

v_f scale parameter which holds the conversion of landings of the target species to the landing of the non-target species.

Only in this last two options, the following formulas are applied to pass from the landing of the other species to the total landing as well as to the total revenues.

$$L_{f,t} = L_{other\_species,f,t} + \sum_{s=1:n} L_{s,f,t} \tag{70}$$

$$p_{other\_species,f} = \frac{R_{f,t=last} - \sum_{s=1:n} R_{s,f,t=last}}{L_{f,t=last} - \sum_{s=1:n} L_{s,f,t=last}} \tag{71}$$

$$R_{f,t} = L_{other\_species,f,t} * p_{other\_species,f} + \sum_{s=1:n} (p_{s,f,t} * L_{s,f,t}) \tag{72.a}$$

where:

$L_{f,t}$ is the total landing of the fleet segment f at time t;

$p_{other\_species,f}$ is the average price of the non-target species in the last year of simulation;

$R_{f,t=last}$ is the total revenues of the fleet segment f in the last year;

$R_{s,f,t=last}$ is the revenues of the species s for the fleet segment f in the last year;

$L_{f,t=last}$ is the total landing of the fleet segment f in the last year;

$L_{s,f,t=last}$ is the landint of the species s for the fleet segment f in the last year.

$p_{s,f,t}$ is the price of the species s for the fleet segment f at time t.

In case of landing obligation for a specific fleet segment, the formula of total revenues becomes:

$$R_{f,t} = L_{other\_species,f,t} * p_{other\_species,f} + \sum_{s=1:n} (p_{land,s,f,t} * L_{s,f,t}) + \sum_{s=1:n} (p_{disc,s,f,t} * D_{s,f,t}) \tag{72.b}$$

where:

$p_{land,s,f,t}$ is the price of landing of the species s for the fleet segment f at time t;

$p_{disc,s,f,t}$ is the price of discard of the species s for the fleet segment f at time t.

When v_f >0, the revenues obtained from the non-assessed species grows with increasing landings of the target species. When v_f <0, the reversal hold true and when v_f =0 then the non-target species is independent from the target species to which is associated.

Total income (TI) for a fleet segment is obtained by summing "other income" (OI) to total revenues:

$$TI_{f,t} = R_{f,t} + OI_{f,t} \qquad \textbf{(73)}$$

Other income mainly consists of subsidies paid by the public administration to vessels owners.

11.5.2 Gross value added, gross cash flow and profit

The gross value added (GVA) represents the added value that the fishery contributes to the economy; a value >0 means that the fishery is economically valuable. The GVA can be interpreted as a measure of the profitability of the sector. Even though other indicators, like ROI (Return on Investment) and net profit, are generally more suitable than GVA to measure profitability, some difficulties in their use arise in the Mediterranean fisheries sector. The low level of investments in Mediterranean fleets often produces unrealistic estimates of ROI. Furthermore, the coincidence between vessel owners and crew, particularly strong in small-scale fisheries, often does not allow a correct estimate of labour cost and therefore net profit.

The gross value added for the fleet segment f at time t ($GVA_{f,t}$) is calculated as the difference between revenues and the sum of total variable ($VC_{f,t}$), maintenance ($MC_{f,t}$) and fixed costs ($FC_{f,t}$):

$$GVA_{f,t} = R_{f,t} - VC_{f,t} - MC_{f,t} - FC_{f,t} \qquad \textbf{(74)}$$

The gross cash flow ($GCF_{f,t}$) for the fleet segment f at time t is the difference between revenues ($R_{f,t}$) and all operational costs (variable costs $VC_{f,t}$, maintenance costs $MC_{f,t}$, fixed costs $FC_{f,t}$ and labour costs $LC_{f,t}$):

$$GCF_{f,t} = R_{f,t} - VC_{f,t} - MC_{f,t} - FC_{f,t} - LC_{f,t} \qquad \textbf{(75)}$$

Profit by fleet segment at time t can be calculated as the difference between the gross cash flow ($GCF_{f,t}$) and the capital costs ($CC_{f,t}$):

$$\Pi_{f,t} = GCF_{f,t} - CC_{f,t} \qquad \textbf{(76)}$$

An additional measure of profit is net profit ($N\Pi_{f,t}$) for the fleet segment f at time t which is calculated deducting from profit $\Pi_{f,t}$ the taxes $T_{f,t}$ and adding the other income $OI_{f,t}$:

$$N\Pi_{f,t} = \Pi_{f,t} + OI_{f,t} - T_{f,t}. \qquad \textbf{(77)}$$

11.5.3 Investment, capital value, employment and average wage

Capital value $K_{f,t}$ is the value of a vessel for the fleet segment f at time t. This variable has its own dynamic, which depends on the capital in the previous year $K_{f,t-1}$minus the depreciation ($DC_{f,t}$) plus the value of investments ($VI_{f,t-1}$) in technology:

$$K_{f,t} = K_{f,t-1} - DC_{f,t} + VI_{f,t-1} \quad \textbf{(78)}$$

The investment in terms of value of the new vessels $VI_{f,t}$ for the fleet segment f at time t can be estimated by multiplying the investment ($I_{f,t}$) in terms of number of vessels by the value of a single vessel (vi_f) in the fleet segment:

$$VI_{f,t} = vi_f I_{f,t} \quad \textbf{(79)}$$

As for social aspects, the two selected indicators were employment and wage. Employment (EM) is a key indicator of the social viability of a fishery and its maximization is among the most common objectives of fishery management (e.g. Hilborn et al. 2007). Wage (W) represents the average salary that the crew receives, and is another important component of social wellbeing (e.g. Seung & Zhang 2011).

Employment is estimated by average number of employees per vessel in the fleet segment f (em_f) multiplied by the number of vessels for each fleet segment ($N_{f,t}$) for the fleet segment f at time t:

$$EM_{f,t} = em_f N_{f,t} \quad \textbf{(80)}$$

The average wage per employee ($W_{f,t}$) for the fleet segment f at time t is calculated by dividing the labour costs ($LC_{f,t}$) by the number of people employed in the fleet segment ($EM_{f,t}$):

$$W_{f,t} = \frac{LC_{f,t}}{EM_{f,t}} \quad \textbf{(81)}$$

In this equation , it is assumed that average wage includes both the crew wage and the value of unpaid labour.

11.5.4 Revenue to Break even revenue Ratio (CR/BER) and Return of fixed tangible assets

The Revenue to Break even revenue Ratio shows how close the current revenue of a vessel or fleet is to the revenue required for the to break even from an economic point of view. If the ratio is greater than 1, then enough income is generated to cover operational costs (variable and non-variable costs) and therefore break-even. If the ratio is less than 1, insufficient income is generated to cover operational costs and therefore the vessel or fleet is in a loss making situation indicating that the segment is unprofitable. If the ratio is negative, variable costs alone exceed current revenue, indicating that the more revenue is generated, the greater the losses will be.

According to the Economic performance indicator calculations provided in the 2013 Annual Economic Report on the EU Fishing Fleet (STECF 13-15), the current revenue to break even revenue ratio is calculated as Current Revenue (CR) divided by the Break Even Revenue (BER),as $\frac{R_{f,t}}{BER_{f,t}}$

where:

$$BER_{f,t} = \frac{OFC_{f,t} + DC_{f,t} + OC_{f,t}}{1 - \frac{LC_{f,t} + VC_{f,t} + MC_{f,t}}{R_{f,t}}} \quad \textbf{(82)}$$

where:

$OFC_{f,t}$ are other fixed costs for the fleet segment f at time t;

$DC_{f,t}$ are the depreciation costs for the fleet segment f at time t;

$OC_{f,t}$ are the opportunity costs for the fleet segment f at time t;

$LC_{f,t}$ are the labour costs for the fleet segment f at time t;

$VC_{f,t}$ are the variable costs for the fleet segment f at time t;

$MC_{f,t}$ are the maintenance costs for the fleet segment f at time t;

$R_{f,t}$ are the total revenues for the fleet segment f at time t.

The efficiency of economic sector can be assessed by considering the Return of fixed tangible assets ($RoFTA_{f,t}$), which is calculated as the ratio between the Net profit $N\Pi_{f,t}$ and tangible asset value (that is the vessel depreciated replacement value, that is the capital value $K_{f,t}$).

$$ROFTA_{f,t} = \frac{N\Pi_{f,t}}{K_{f,t}} \quad \textbf{(83)}$$

It is usually compared against the return on risk free long term investment minus inflation.

Another analogous indicator is defined in order to take into account also the taxes and other income, that could be due to subsidies or income coming from the sale of the discard:

$$ROFTA*_{f,t} = \frac{\Pi_{f,t}}{K_{f,t}} \quad \textbf{(84)}$$

11.5.5 Vessel utilization ratio

The vessel utilization indicator is calculated for the fleet segment f at time t as the ratio between average days at sea / maximum days at sea:

$$\text{Utilisation ratio}_{f,t} = \frac{\text{Average days at sea}_{f,t}}{\text{Maximumday satsea}_{f,t}} \quad \textbf{(85)}$$

It is used to assess the balance between fleet capacity and fishing opportunity (STECF 13 28). In BEMMTOOL, maximum days at sea by fleet segments are calculated on the basis of the maximum average days at sea available in the time series.

11.5.6 Net present value of the net profit over the 15 years (NPV15) and net present value of profit in the future or infinity

The last two economic indicators are directed to have an estimate of the economic outcomes in a period of time and refer to the present value of profit (Π) expected. To this end, the predicted profits are discounted by a discount rate (r) to take into account that the benefits will be obtained in the future. Usually, as for the ROFTA indicator, the rate by which expected profits are discounted is calculated by determining the amount of interest the fisher could earn if investing in a safer investment, such as the long term bonds rate.

These indicators are particularly useful to compare different management measures and their effects from an economic point of view over a number of years. By using the present value of the expected profits, in fact, different scenarios can be compared evenly and a decision made based on which is the most profitable.

The two indicators can be estimated as follows:

$$NPV\Pi 15_{f,t} = \sum_{t=1}^{15} \Pi_{f,t}(1+r)^{-t} \quad \textbf{(86)}$$

$$NPV\Pi_{f,t} = \sum_{t=1}^{15} \Pi_{f,t}(1+r)^{-t} + \frac{\Pi_{f,15}}{r}(1+r)^{-16} \quad \textbf{(87)}$$

where $NPV\Pi15_{f,t}$ is the net present value of profit in the next 15 years

$NPV\Pi_{f,t}$ is net present value of profit in the future. The net present value in the future (or for infinity) represent an estimation of the maximum resource rent from a fully adjusted fishery.

12 Forecast Scenarios

In the “Management Rules” tab there is possibility to define eleven type of scenarios, combining the main following options:

1. Change in gear selectivity;
2. Change in fishing effort;
3. Change of fishing mortality (by fleet segment) ;
4. Change of total fishing mortality;
5. Status quo;
6. Introduction/variations of TAC;
7. Answer of the fishermen (behavioral module activated);

Combining the 7 options listed above, it is possible to simulate:

- Change in selectivity and in fishing effort;
- Change in selectivity with behavioral module;
- Change in fishing effort with behavioral module;
- Change in selectivity and fishing effort with behavioral module;

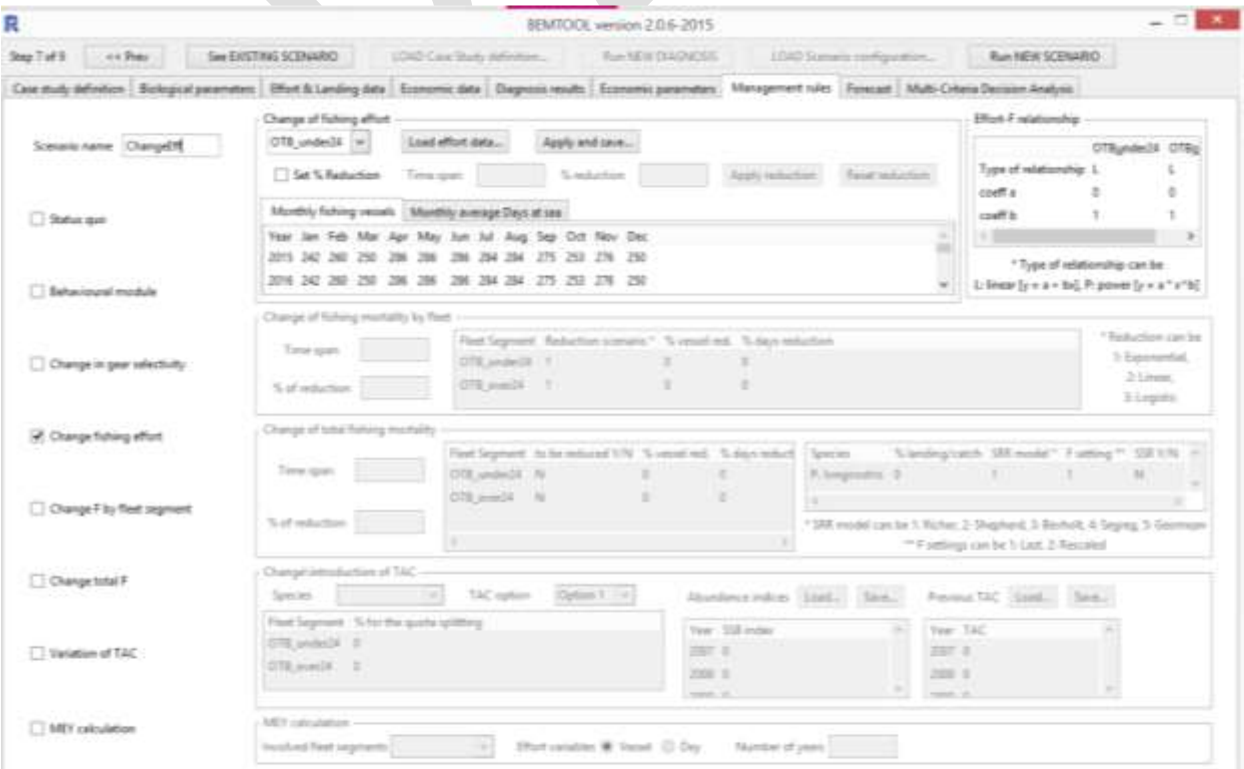


Figure 63 – Management rules scenarios.

In the left part of the tab it is possible to implement the 7 “basic” and the 4 combined scenarios just checking the checkboxes. The needed input are activated depending in the specific scenario chosen by the user. It is possible to load a bmtconfig_scenario.csv previously prepared or saved by the GUI in a previous run (an example file is provided with the software).

The same scenario can be executed at different level of change (for example, scenario 2 can be implemented with a change of the fishing days of the first fleet segment of 10%, but also of 20% related to the second fleet segment etc.) or time horizon (the reduction can be applied in 5, 10 years, etc.). In order to distinguish the results of the different scenarios, the user has to introduce a scenario code (short description) in the “Scenario name” field. This description, together with the harvest rule number, composes the name of the directory that holds the results that will be created under the *BEMTOOL casestudy path* at the end of the forecast phase. For example if Harvest rule 5 is selected and the description is “StatusQuo”, the directory “HR5-StatusQuo” will be created.

Before starting the forecast, set the needed input according the description below and then click the “Run Forecast” button in the right bottom of the form.

Uncertainty on recruitment and risk evaluation

For each scenario the uncertainty on recruitment can be taken into account in all scenarios; if no ALADYM simulation has been performed by the user, the only forecast scenarios that can be run is the reduction of overall F towards a reference F by means of Medium Term Forecast script incorporated in BEMTOOL model. The uncertainty on recruitment is evaluated in terms of SSB and Catch with the relevant percentiles in the forecast years and the input for this scenario has to be entered in BEMTOOL GUI.

In case ALADYM run has been performed in the simulation, the uncertainty on recruitment can be applied directly in ALADYM model for each stock of the case study both to a scalar recruitment and to a stock-recruitment relationship.

When Run New Scenario button is clicked, ALADYM GUI will appear to allow the user to enter the recruitment to be used for the future (scalar or from stock-recruitment relationship as well as eventually an error distribution to extract a certain number of errors to be used for the estimation of confidence intervals for all the BEMTOOL indicators taking into account the process error.

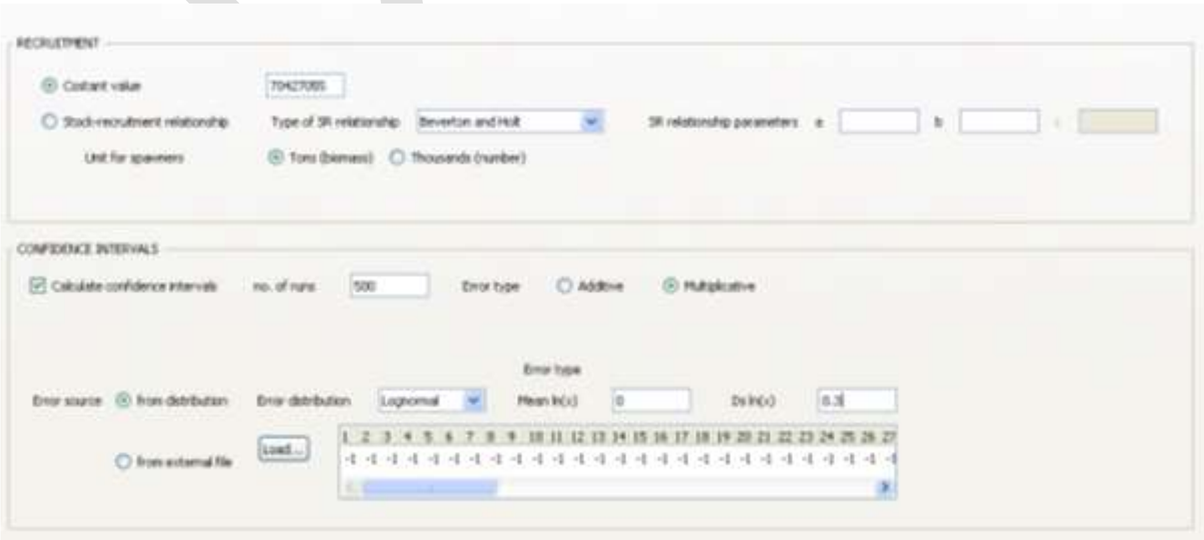


Figure 64 Confidence intervals settings on ALADYM forecast

A certain number N of runs (the number is chosen by the user) are performed with different levels of recruitment both in case of scalar recruitment and in case of stock-recruitment relationship; the different levels of recruitment can be derived applying a multiplicative or, alternatively, an additive error, as also foreseen in other models and case studies (Lleonart et al. 2003, Schweder et al. 1998, FLR medium term forecast scripts, Stock Synthesis model-Method 2005) through the following formulas:

$R_{rand} = R * err_{mult}$ with $err_{mult} \sim Probability\_distribution$ **(88)**

$R_{rand} = R + err_{add}$ with $err_{add} \sim Probability\_distribution$ **(89)**

Where R_{rand} is the recruitment with error, R is the recruitment value that could be a scalar value by year come from a stock assessment or could come from a stock recruitment relationship and err_{mult} and err_{add} are respectively the multiplicative and the additive error.

In case the recruitment is from a stock-recruitment relationship, the recruitment are calculated according to the following formulas in case of multiplicative error:

- $R = \frac{S}{(\alpha + \beta S)} * \varepsilon$ (Beverton and Holt , 1957; Jiao et a., 2004) **(90)**
- $R = \alpha \cdot S \cdot e^{-\beta S} * \varepsilon$ (Ricker, 1954; Jiao et a., 2004) **(91)**
- $R = \alpha \cdot \frac{S}{1 + \left(\frac{S}{\gamma}\right)^{\beta}} * \varepsilon$ (Shepherd, 1982)
- $R = \alpha \cdot \min(S, S^{*}) * \varepsilon$ (Hockey stick, Barrowman and Myers, 2000) **(92)**
- $$R = \begin{cases} \alpha \cdot S \quad * \varepsilon & if\ S \le S^{*} \cdot (1-\delta) \\ \alpha \cdot \left(S - \frac{(S - S^{*} \cdot (1-\delta))^2}{4\delta \cdot S} \right) * \varepsilon & if\ S^{*} \cdot (1-\delta) < S < S^{*} \cdot (1+\delta) \\ \alpha \cdot S \quad * \varepsilon & if\ S \ge S^{*} \cdot (1+\delta) \end{cases}$$ (Quadratic hockey stick)

  (93)

and according to the following formulas in case of additive error:

- $R = \frac{S}{(\alpha + \beta S)} + \varepsilon$ **(94)**
- $R = \alpha \cdot S \cdot e^{-\beta S} + \varepsilon$ **(95)**

- $$R = \alpha \cdot \frac{S}{1 + \left(\frac{S}{\gamma} \right)^{\beta}} + \varepsilon$$ (Shepherd, 1982) **(96)**

- $R = \alpha \cdot \min(S, S^{*}) + \varepsilon$ (Hockey stick, Barrowman and Myers, 2000) **(97)**

- $$R = \begin{cases} \alpha \cdot S \quad + \varepsilon & if\ S \le S^{*} \cdot (1-\delta) \\ \alpha \cdot \left(S - \frac{(S - S^{*} \cdot (1-\delta))^{2}}{4\delta \cdot S} \right) + \varepsilon & if\ S^{*} \cdot (1-\delta) < S < S^{*} \cdot (1+\delta) \\ \alpha \cdot S \quad + \varepsilon & if\ S \ge S^{*} \cdot (1+\delta) \end{cases}$$ (Quadratic hockey stick) **(98)**

where *R* and *S* represent respectively the number of recruits and biomass of spawners at the previous time, whilst *α, β, γ, δ* and S^* are input parameters and ε is the error that can be distributed as a normal, lognormal, gamma or uniform probability distribution.

The available probability distributions to extract the error on recruitment are: normal, lognormal, gamma and uniform (Lleonart et al. 2003, Taillie et al. 1995). A different extraction of error is made for each year, taking into account the uncertainty on recruitment year by year.

In case the user has a number of errors on recruitment estimated in previous runs or off-line by other tools, it is possible even to use these errors in equations (83) and (84) in the same way just selecting if the error is additive or multiplicative. This features could be useful also to use other approaches to take into account the uncertainty of recruitment, as for example Monte Carlo Markov Chain (Casal model -Bull et al., 2005, Coleraine- Hilborn et al. 2003).

Several checks have been also included in the software in order to avoid to run the simulations with negative recruitment levels due to a not proper parameterization as also foreseen in other software (for example Yield FAO package). In particular, if for some of N extractions the derived recruitment is negative or null, runs are performed only for the recruitment levels greater than zero.

It is strongly recommended to check the .csv file where are stored all the recruitment levels used for the calculation of confidence intervals that is automatically saved in the output folder, in order to verify that the parameterization is plausible. If not, the parameters of the probability distribution should be better specified.

After the N runs, the relevant quantiles (5%, 25%, 50%, 75%, 95%) are estimated for all the output of biological and pressure modules that are affected by the recruitment (SSB, biomass, yield, landing, etc…).

Once the quantiles of landing by fleet segment have been derived, the corresponding 5 quantiles for each economic indicator are calculated propagating the uncertainty in recruitment to the socio-economic part *via landing*.

In case the forecast scenario foresees the answer of the fleet to the change in profit, the change in effort for the fleet segment is based on the median value of the landing, and thus of profit, for the fleet segment.

On order to perform a risk evaluation of the different management scenarios, the probability to have an SSB greater than the reference SSB is also computed, as the ratio between the number of runs for which the SSB is greater than reference SSB and the total number of runs N. This ratio represents the probability the SSB of the stock was higher of the reference SSB and is calculated for each year of the forecast.

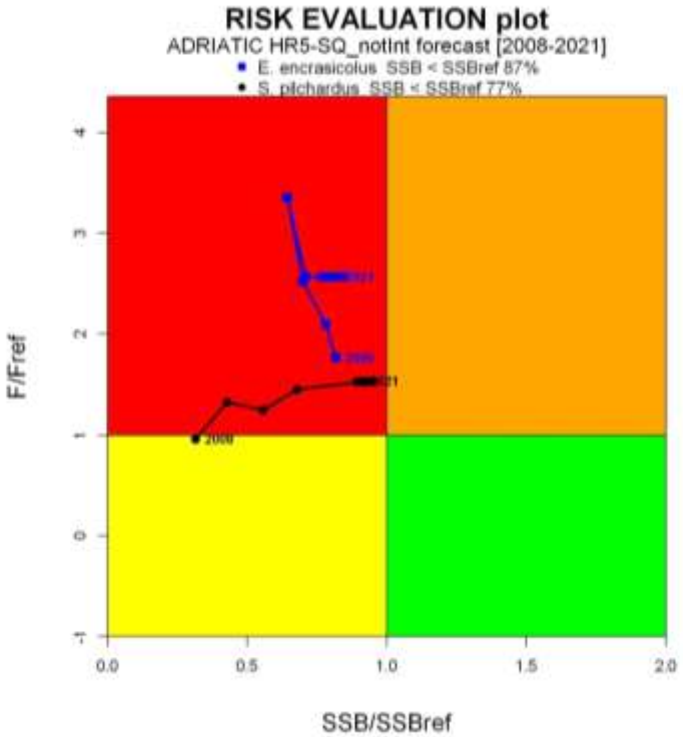


Figure 65 – Risk evaluation plot: in the upper part there is the proxy of probability that SSB is less than SSBref taking into account the uncertainty in recruitment.

This approach is also in line with the one followed by Gourguet et al. (2013) that described a bio-economic multi-species and multi-fleet model with technical interactions developed to examine the trade-offs between preserving Spawning Stock Biomass (SSB) of every species and maintaining the economic profitability of the various fishing fleets.

A number indicated by the user N of independent forecast projections with N recruitment levels are run and for each of them all the output of ALADYM model are derived and saved in tables in order to be recalled subsequently.

When the N runs have been completed, the relevant quantiles are calculated for all the output and in particular for the landing by fleet segment. Then all the indicators and quantities depending on landing are estimated for the 5 quantiles in order to have for each indicator 5 values for each years that takes into account the uncertainty on recruitment in the projections.

In case the forecast scenario is integrated (involving the answer of the fishermen to the change in profit), the communication between pressure and economic module occurs every years as without uncertainty.

The economic variables affected by the uncertainty in recruitment via landing are:

- Landing (weight and number), price and revenues by fleet segment and stock;

- Commercial and Labour costs;
- GVA and GCF (Gross Cash Flow);
- Profit and Net Profit;
- Employment and average wage (if behavioural module is activated);
- BER (Break even revenue), ROI (Return of Investment);
- Net Profit Value Discounted;
- RBER (Current Revenues/ BER);
- RoFTA (Return of fixed tangible assets).

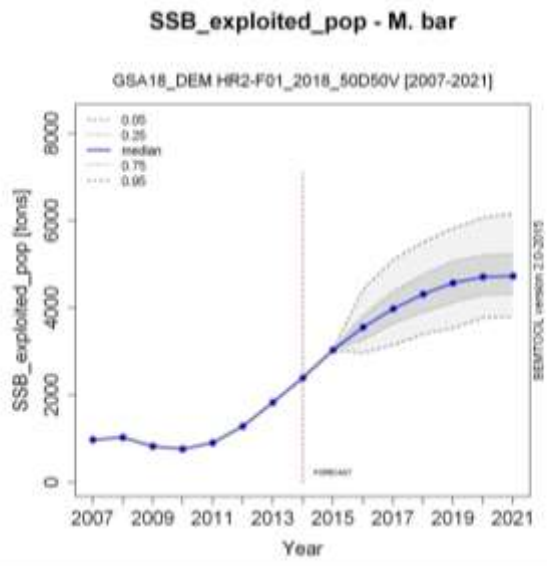


Figure 66 – Example of plot of biological and pressure/impact indicators.

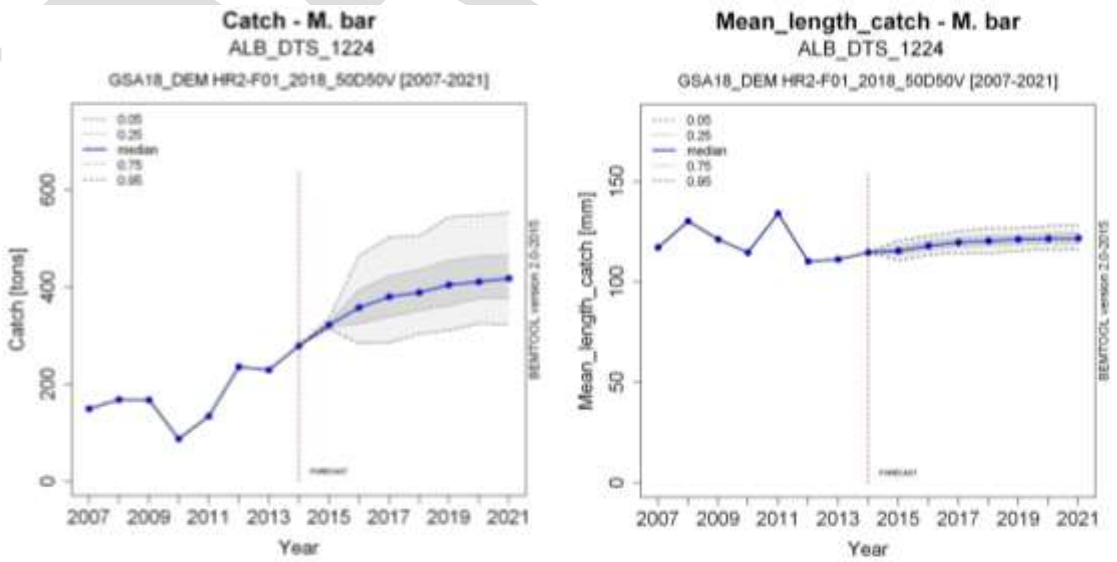


Figure 67 – Examples of plots of pressure indicators.

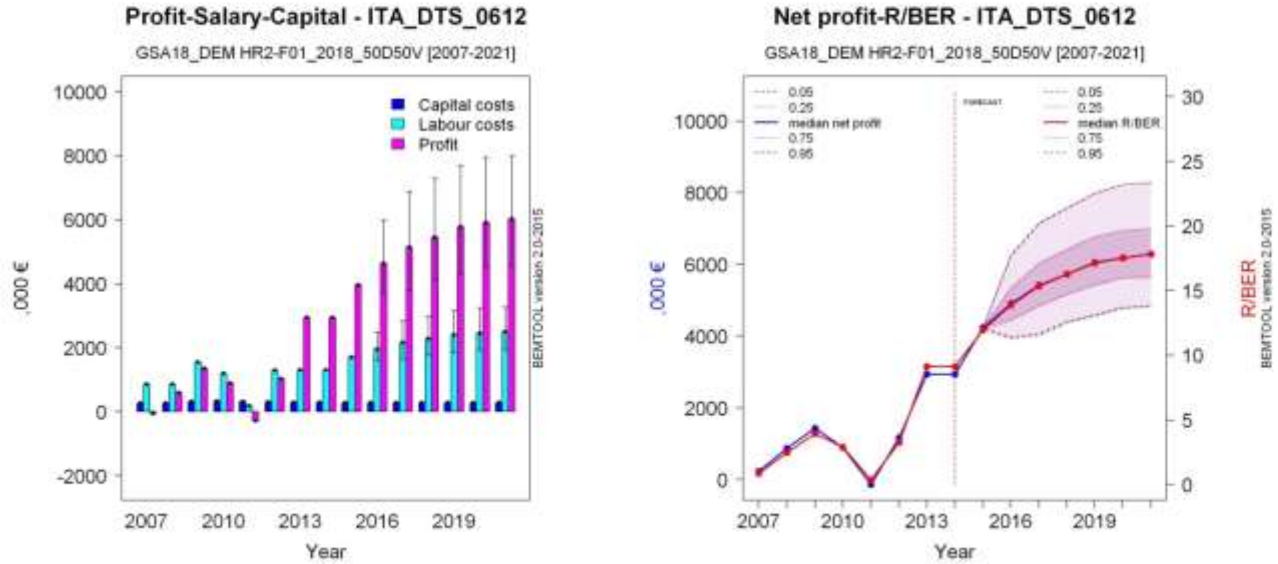


Figure 68 – Examples of plots of socio-economic indicators.

12.1 Change Selectivity

In this scenario the user can implement a change in the selectivity parameters by fleet segment, in order to simulate mesh size restrictions/changes.

For scenario of change of selectivity, no input is required in the "Management Rules" tab, because all the needed inputs have to be entered in the ALADYM GUI. If the user selects the change of selectivity scenario, the ALADYM GUI will be recalled <u>for each stock</u>, in order to set the selectivity for the future years through one of the available models or external vectors by age/length. By default the selectivities by fleet segment shown in the GUI are those used in the last year of simulation.

After setting the new selectivity, the user has to click on "RUN Forecast" button to run the forecast for that stock, until the ALADYM GUI re-appears to accept the selectivity for the next stock and so on.

The user can save the selectivity parameters or vectors pushing the respective buttons in order to use it in a next run.

In this scenario the effort does not change and it is set equal to the effort of the last year.

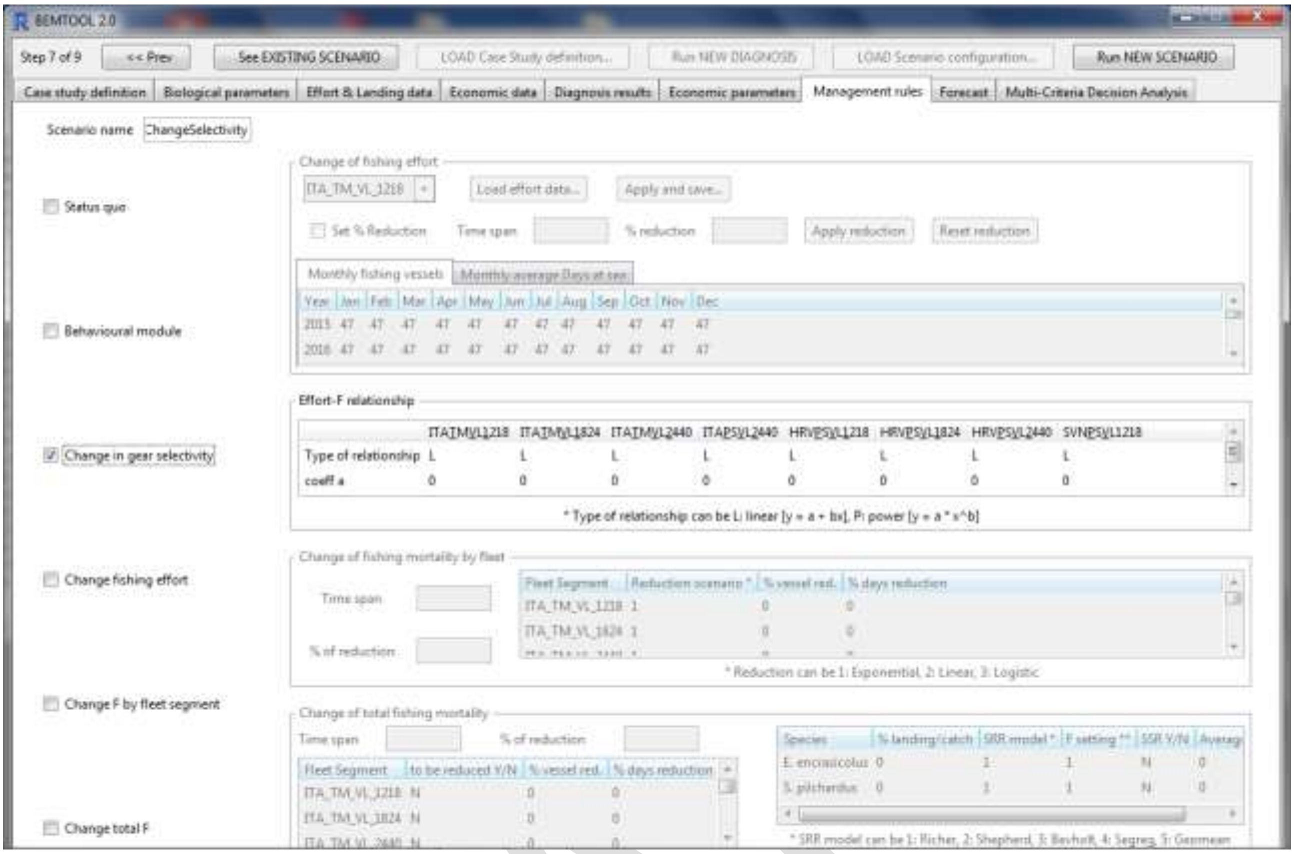


Figure 69 – Definition of change of selectivity scenario in Management rules BEMTOOL tab**.**

Both in case the discard has been modelled (by the reverse ogive or external vector) or not in the simulation phase, also the discard can be modelled/changed in the future (by default the values are the same of those used in the last year of simulation).

In case the user wants only to evaluate a change in the discard volume, due to a change in the legal size of a stock, the selectivity parameters can be left unchanged, while only discard parameters can be changed. Also in this case the discards configuration (reverse ogive or external vector) can be saved in .csv file.

Attention: If the change of selectivity scenario is selected it is very important that for all the stocks the selectivity parameters are changed. The ALADYM GUI will be recalled by BEMTOOL for each stock (the name of the stock is shown in the title bar of the window) in order to remember the user to change the selectivity parameters for each stock.

The other settings of the forecast are automatically filled in by BEMTOOL according to the settings entered in the “Biological parameters” tab. All the input in this tab cannot be changed by the user in order to avoid inconsistencies among the settings of all the stocks and with the parameterization of the whole bio-economic model.

12.2 Change Fishing effort

In this scenario the user can implement a monthly change in the number of vessels and/or in the fishing days; with this scenario it is possible to act in a selective way on the fleet segments, simulating fishing bans, temporary withdrawals or permanent withdrawals.

If the user wants to run a change of effort scenario, he/she has to provide the vessels and the average of days at sea by month for all the years of the forecast choosing one of the following two ways:

- the user can input given monthly numbers of vessels and monthly average days at sea preparing two .csv files and selecting the path of these files respectively in *Monthly VESSELS file for FORECAST* and *Monthly DAYS.average file for FORECAST* fields. Locate the file(s) using the browse button.
- the user can modify the values by fleet segment loaded automatically in the GUI and that are equal to the last year of the simulation period for all the years of the forecast and use the intelligent GUI to implement an automatic reduction on the effort of the last year of the simulation period just indicating:
  - the fishing effort to apply the reduction;
  - the time span of the reduction;
  - the percentage of reduction.

  Clicking on Apply reduction "button" the effort variable selected will be changed according to the indications of the user and the file can be also saved for further runs with the button "Apply and save". "Reset reduction" button allows to reset the effort variable and to set again the reduction and the time span.

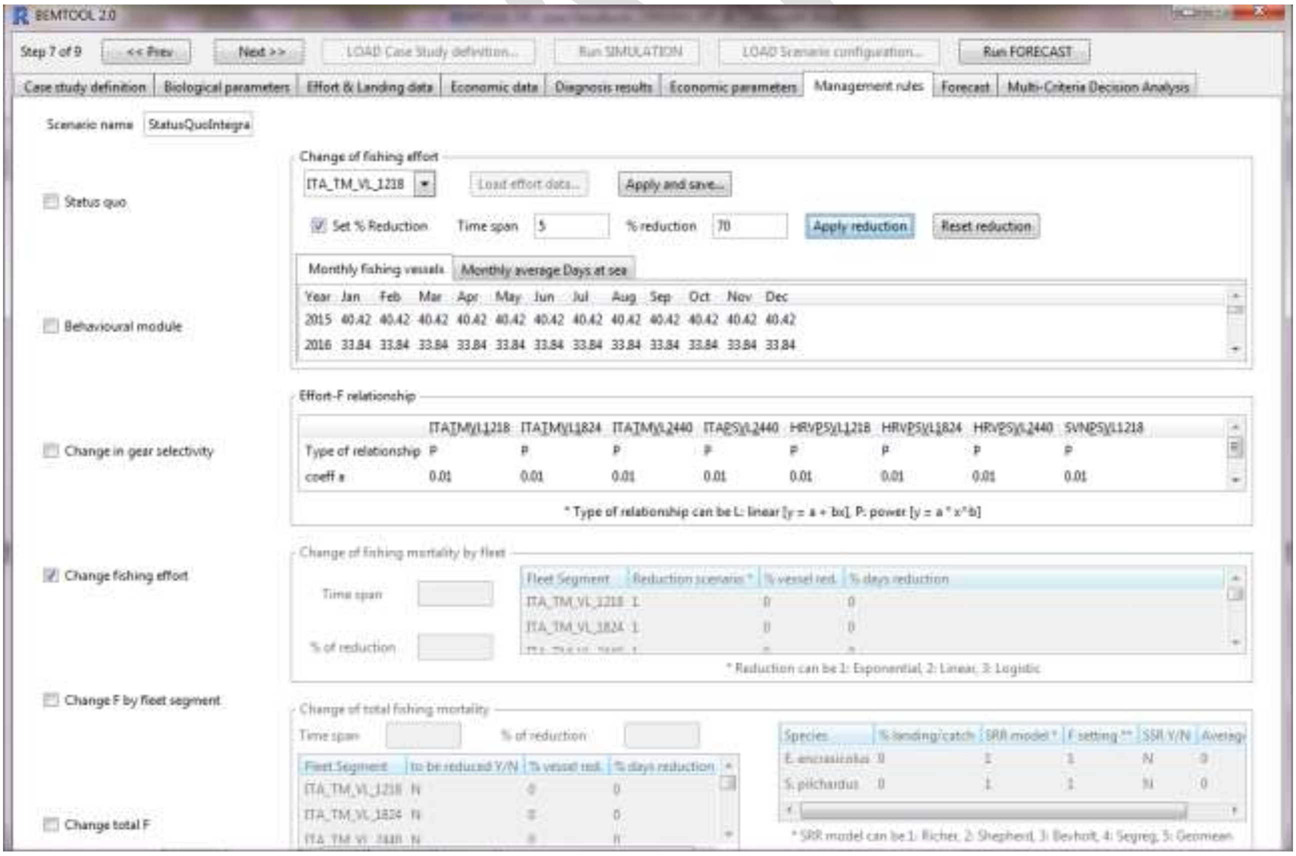


Figure 70 - Intelligent GUI for automatic calculation of the effort reduced of a fixed percentage split the a times span.

In this scenario the selectivity of the gears used by the fleet segment remains the same used in the simulation period.

Relationship between change in fishing effort and change in fishing mortality

In this version of BEMTOOL model the equation for the calculation of fishing coefficient has been generalized, in order to allow to model the change fishing mortality accordingly to the change in fishing effort through two relationships: power function (Angelsen and Olsen, 1987) and linear (Pinhorn, 1988) functions, as follows:

$$f_{act,f,linear} = f_{act,f} * \left(a + b * \frac{f_{act,f}}{f_{act,f,baseline}}\right) \quad \textbf{(99)}$$

$$f_{act,f,power} = f_{act,f} * \left(a * \left(\frac{f_{act,f}}{f_{act,f,baseline}}\right)^{b}\right) \quad \textbf{(100)}$$

here:

$$f_{act,f} = \frac{FD_f * Nb_{vessels_f} * GT_f}{FD_{f,baseline} * Nb_{vessels_{f,baseline}} * GT_{f,baseline}} \quad \textbf{(101)}$$

where FD_f, $Nb\_vessels_f$ and GT_f are respectively the number of fishing days, the number of vessels and the average GT of the fleet segment f for each month of forecast, while the $FD_{f,baseline}$, $Nb\_vessels_{f,baseline}$ and $GT_{f,baseline}$ are the same quantities in the last year of simulation that is considered as reference or baseline) for the application of change in fishing effort.

This fishing coefficient could be interpreted as a *proxy* of catchability coefficient (because linking not specific effort to specific fishing mortality); for each fleet segment can be used one relationship to be set in BEMTOOL and the same relationship and the same parameters are used to model the fishing mortality of all the stocks affected by the fleet segment.

In case a linear function is chosen, and there is a change in fishing effort of -20% (corresponding to multiply the product of fishing effort variables by 0.8), the corresponding change in fishing mortality is calculated as a+ b*0.8; if the power function has been chosen to transmit the change in fishing effort to the fishing mortality, the new fishing effort will be derived as a*0.8^b.

f_act/f_act_baseline	Linear	Power
2	4.2	3.2
1.9	4	2.888
1.8	3.8	2.592
1.7	3.6	2.312
1.6	3.4	2.048
1.5	3.2	1.8
1.4	3	1.568
1.3	2.8	1.352
1.2	2.6	1.152
1.1	2.4	0.968
0	0.2	0
0.1	0.4	0.008
0.2	0.6	0.032
0.3	0.8	0.072
0.4	1	0.128
0.5	1.2	0.2
0.6	1.4	0.288
0.7	1.6	0.392
0.8	1.8	0.512
0.9	2	0.648
1	2.2	0.8
	Linear	**Power**
a	0.2	0.8
b	2	2

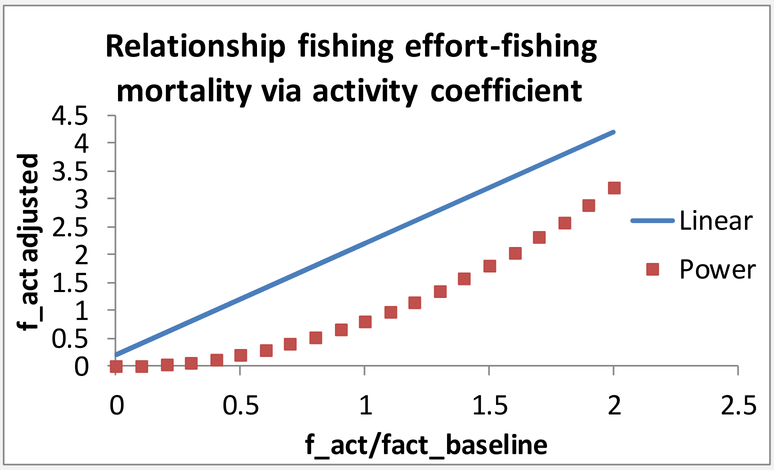


Figure 71 - Example of relationship between fishing effort and fishing mortality via fishing coefficient.

This new feature allows the user to model a change in fishing mortality consequent to a change in fishing effort not only in a proportional way but also by means of power and generic linear functions. The consequences of this type of assumption, leads that also to have a change in landing by fleet segment that does not answer necessarily in a proportional way to the change in effort, as in the previous version. Certainly, all the socio-economic variables and indicators in BEMTOOL depending on the landing are affected by this type of assumption, accordingly to their definition into the model.

This feature can be used only when a fishing effort change occurs, thus within change in fishing effort and TAC scenarios and when is activated the behavioral module as well as their combinations.

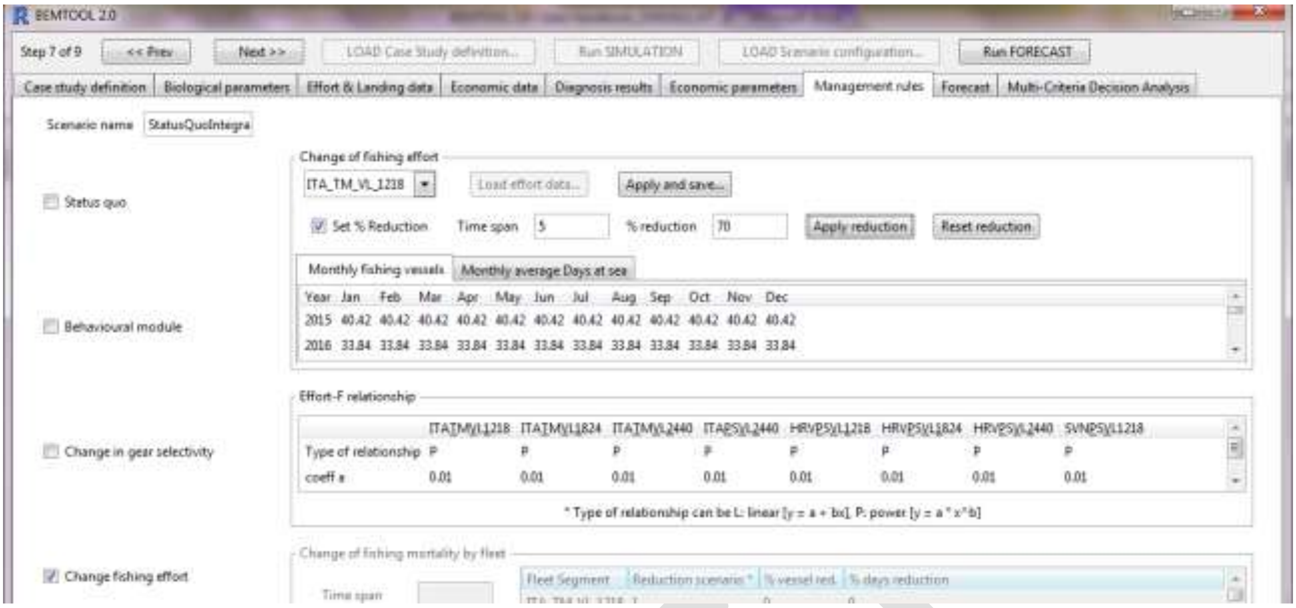


Figure 72 – Definition of change in fishing effort scenario in Management rules tab

12.3 Change of fishing mortality (by fleet segment)

In this scenario the user has to take a decision about the percentage of reduction to apply to the fishing mortality of all the stocks. This percentage of reduction should be decided by the manager according to different considerations; for example, according to the reduction needed to reach the reference point of the stock at more risk or according to the reduction needed for the at less risk. Moreover, the manager can also have a propensity for a compromise among the percentage reduction of all the stocks.

In any case, the percentage of reduction (numbers between 0 and 100 are allowed) inserted by the user in "% of reduction" field is applied to the total fishing mortality of each stock in the last year of the simulation (F current) in order to obtain a reference fishing level to be reached in the time span entered in the *Time span* field.

The percentage of reduction is proportionally transferred to each fleet segment according to the respective contribute to the catch (*via* the proportion of F by fleet segment on the total F), in order to calculate a reference level by fleet segment to be reached in the set time span.

Furthermore, each fleet segment can approach its reference level of F according to different types of reduction. To insert value into a reduction scenario field, click or move with arrow keys in the cell, and select a scenario from the drop down list among the following options:

- EXPONENTIAL
- LINEAR
- LOGISTIC

For each fleet segment the user has to select a type of reduction that is used for all the stocks.

Finally, the annual fishing mortality reduction has to be transformed proportionally in a reduction of vessels and fishing days. However, the user can decide in which measure to reduce the vessels and in which one to reduce the fishing days by means of two other percentages to be inserted in fields “% of red. for VESSELS” and “% of red. of DAYS”. The sum of these percentages have to be 100.

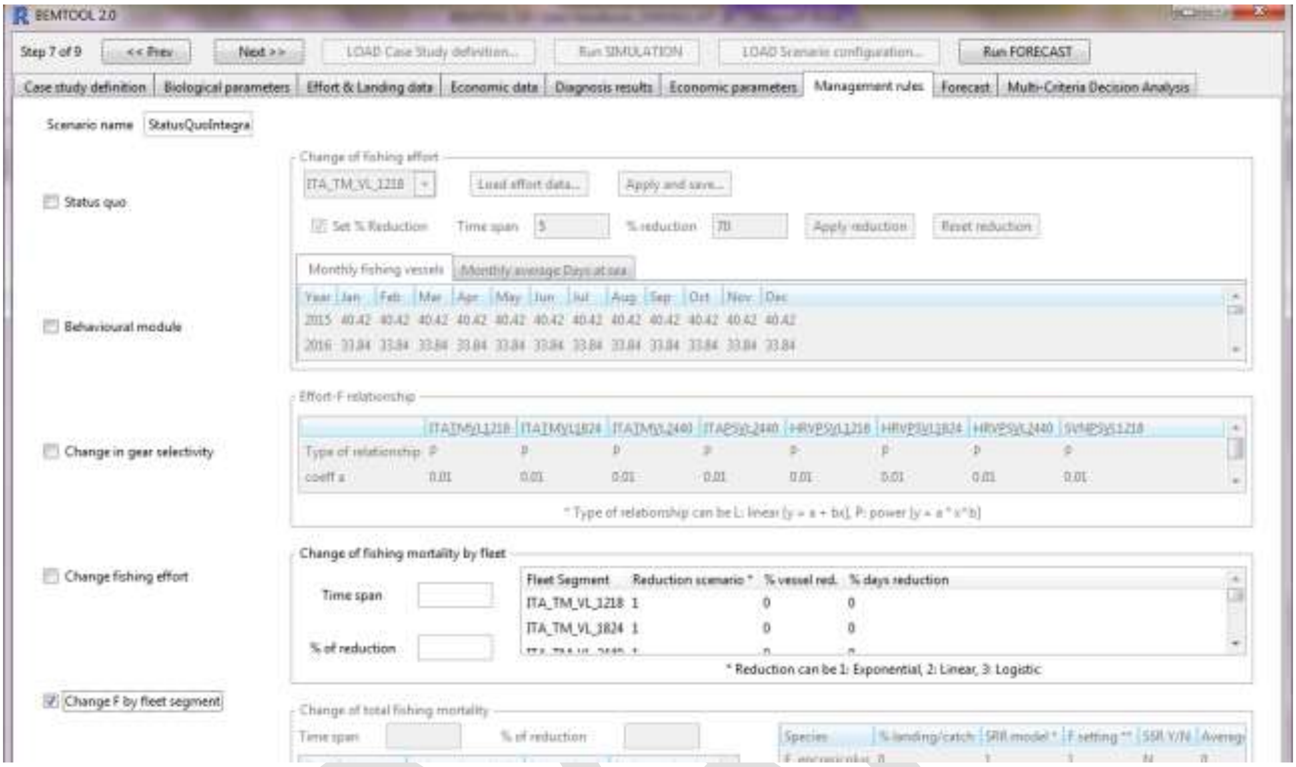


Figure 73 – Settings for scenario of change fishing mortality by fleet segment.

In this scenario the effort variables are <u>automatically</u> calculated according to the reduction imposed and according to the choices of the user; therefore, the effort variables are not an input but are intermediate outputs, provided by the software on a monthly basis and saved in a .csv file in the ALADYM results of the scenario folder. These intermediate outputs are used by the economic module.

12.4 Change of total fishing mortality

In this scenario the user has to set the percentage of reduction to apply to the fishing mortality of all the stocks, as in the previous scenario. However, in this case the reduction will be applied to the overall (total) fishing mortality and not by fleet segment.

The user has to insert the following settings needed to run the scenario:

- *Time span*
- *% of reduction*

Moreover for each stock the following settings have to be input:

- *SRR model* (allowed strings: *bevholt, ricker, shepherd, segreg, geomean*)
- F setting (allowed strings: *rescaled* and *last;* i.e. the fishing mortality of the last year or rescaled)

- SRR flag: Y/N
- number of years on which the model will calculate the average of recruitment and of total/fishing mortality to be used in the forecast phase.

If in this scenario the stock-recruitment relationship has to be used, SRR and SRR model have to be the same as XSA (if used in the stock assessment) and Reference point calculation.

F setting has to be set on “rescaled” if the user wants the F (F current by age) in the projections is calculated as average of the last x years (the number is set in **Settings ALADYM simulation** paragraph) and rescaled to the mean F of the last year; F setting is to be set as “last” if exactly the F of the last year is to be used in the projections.

Moreover, the user has to decide on which fleet segments the reduction has to be applied (using a flag for each fleet segment, column *to be reduced*) and the measure in which the reduction will be transformed in proportional reduction of vessels and fishing days (by means of the percentage to be put “% of red. for VESSELS” and “% of red. of DAYS” fields).

The effort variables are not an input but are intermediate outputs provided by the software; for this scenario the output is provided on an annual basis and saved in a .csv file in the scenario folder. These intermediate outputs are used by the economic module.

Finally, the percentage of landing on the total catch by stock has to be entered in field “% landings/catch” (in weight).

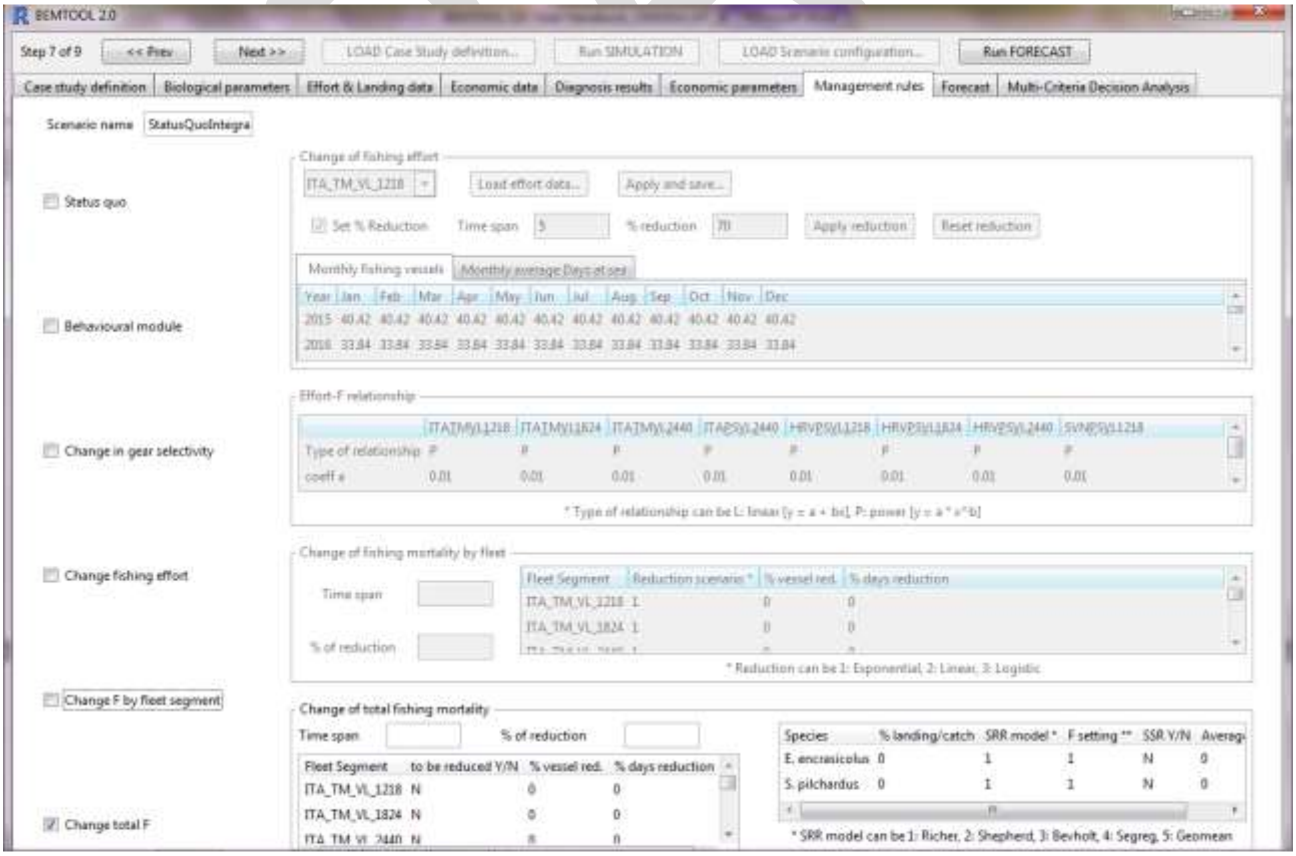


Figure 74 – Settings for scenario of change fishing mortality.

12.5 Status quo

In this scenario the user will perform a forecast in a status quo hypothesis. In this case, no inputs are required, as the model continues to project forward the system, applying the same effort and the same selectivity for all the fleet segments.

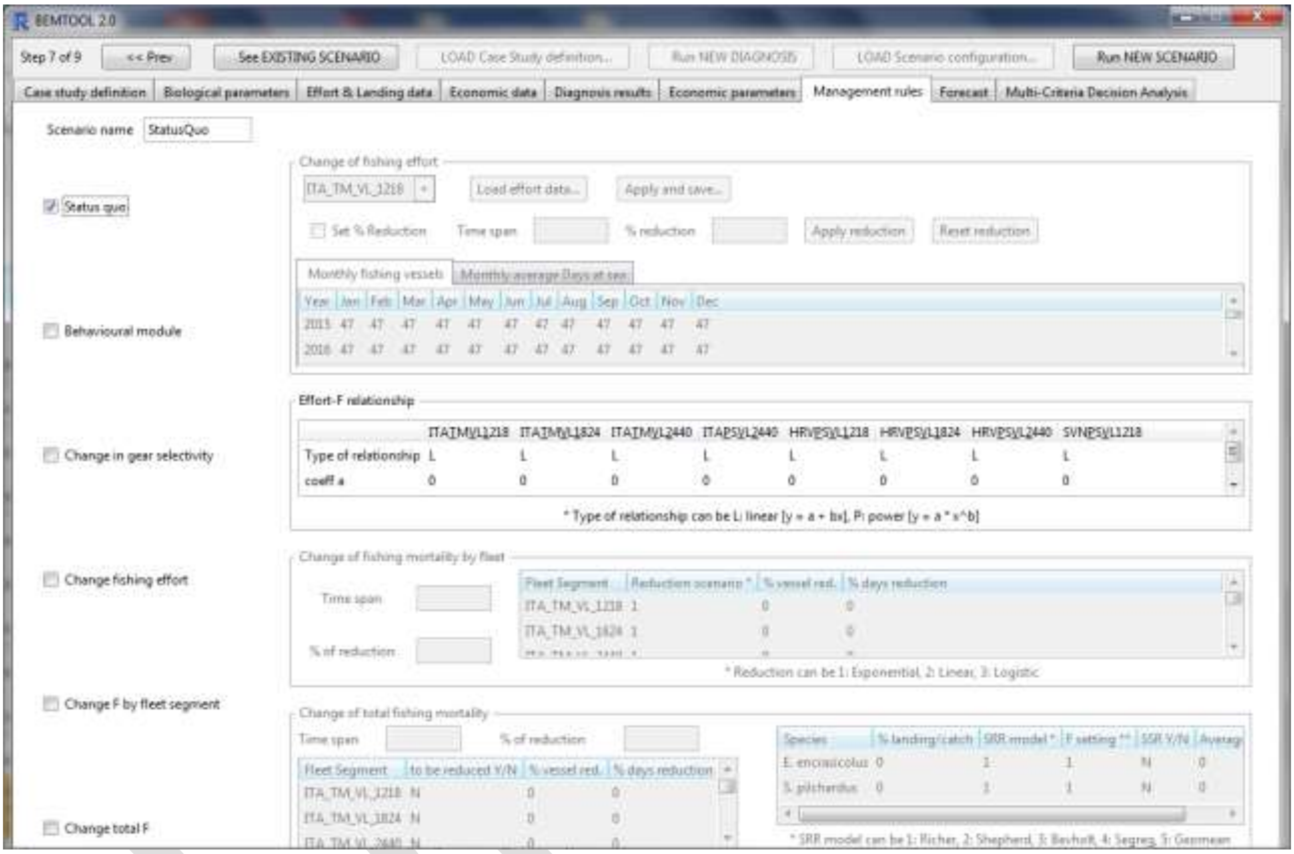


Figure 75 – Settings for status quo scenario.

12.6 TAC (Total Allowable Catch)

In this scenario the user has to set the following inputs:

- the species for the control of the catches selecting it from the drop down menu.
- the option TAC calculation from the dropdown menu “TAC Option” field. If the selected option is 3 also the “Abundance indices” and “Previous TAC” has to be specified loading the related files from the Load button. The user can save the data inserted in the GUI clicking on Save buttons.
- the user has to fill in the % quotas by fleet segments in the table. These % quotas have to be specified only for those fleet segments catching the reference stock and the sum of percentages has to be equal to 100.

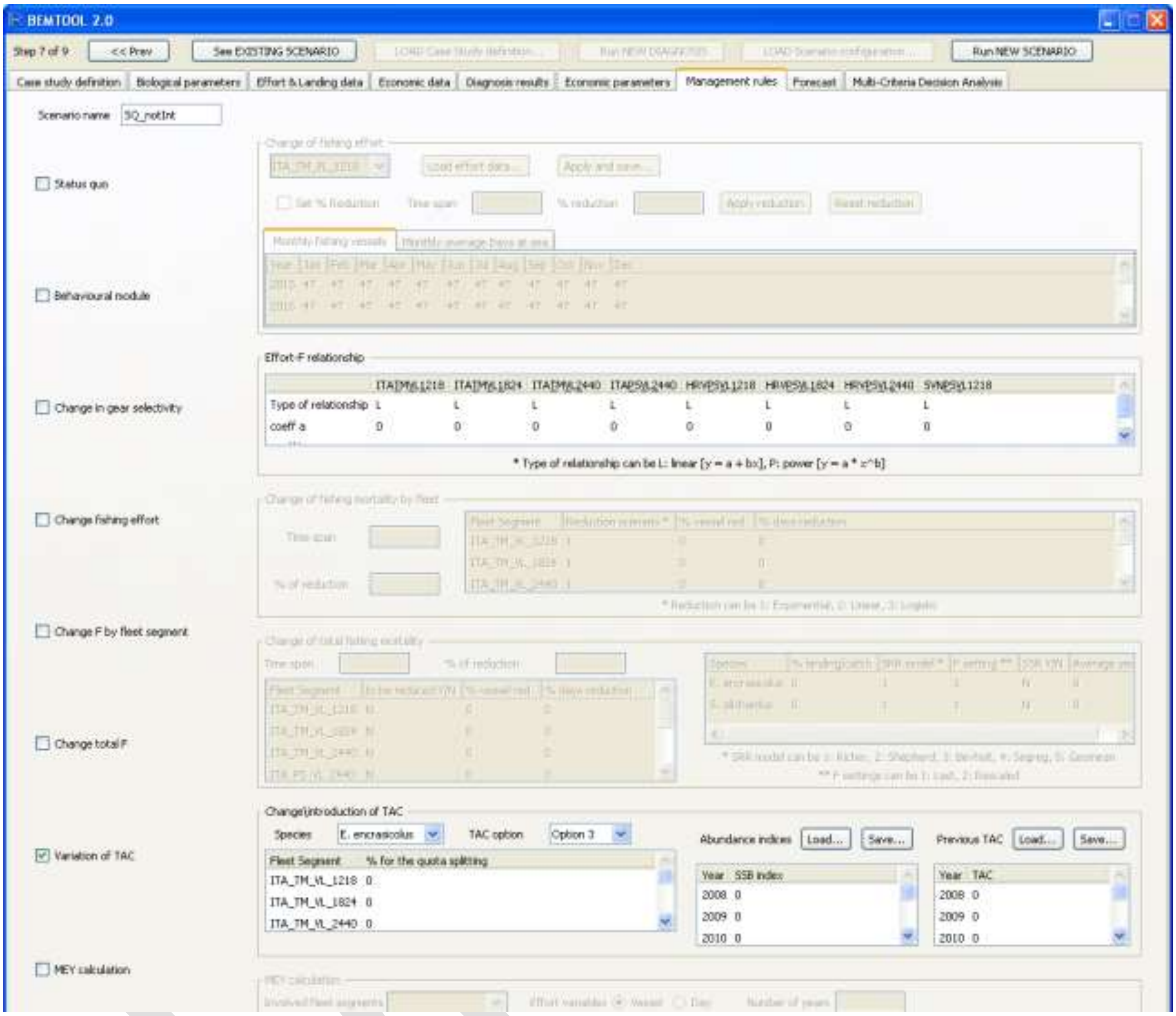


Figure 76 – Settings for scenario of TAC.

12.7 Answer of the fishermen (behavioural module activated)

The behavioral module of BEMTOOL consists of three components: fleet (capital) dynamics, effort dynamics and technological progress.

To use the behavioral module on fleet dynamics in BEMTOOL, the user has to input in the sub-tab behavior of the fleet in Economic parameters tab the following data for each fleet segment:

- a coefficient indicating the lower limit for investments: value between 0 and 1, representing the maximum percentage of decrease in the number of vessels;
- a coefficient indicating the upper limit for investments: value between 0 and 1, representing the maximum percentage increase in the number of vessels;

- a coefficient indicating the share of profit dedicated to investments in new vessels.

To use the behavioral module on effort dynamics in BEMTOOL, the user has to input the following data for each fleet segment:

- a coefficient indicating the lower limit for changes in fishing activity: value between 0 and 1, representing the maximum percentage decrease in the number of days at sea;
- a coefficient indicating the upper limit for changes in fishing activity: value between 0 and 1, representing the maximum percentage increase of days at sea;
- a coefficient indicating the relationship between profitability and changes in fishing activity.

To use the behavioral module on technological progress in BEMTOOL, the user has to input the following data for each fleet segment:

- an initial level of technological progress by fleet segment: this is generally equal to 1;
- a coefficient indicating the fraction of technological progress which varies with time: value should be higher than 1;
- a coefficient indicating the proportion of capital invested in technology: value should be higher than 0.

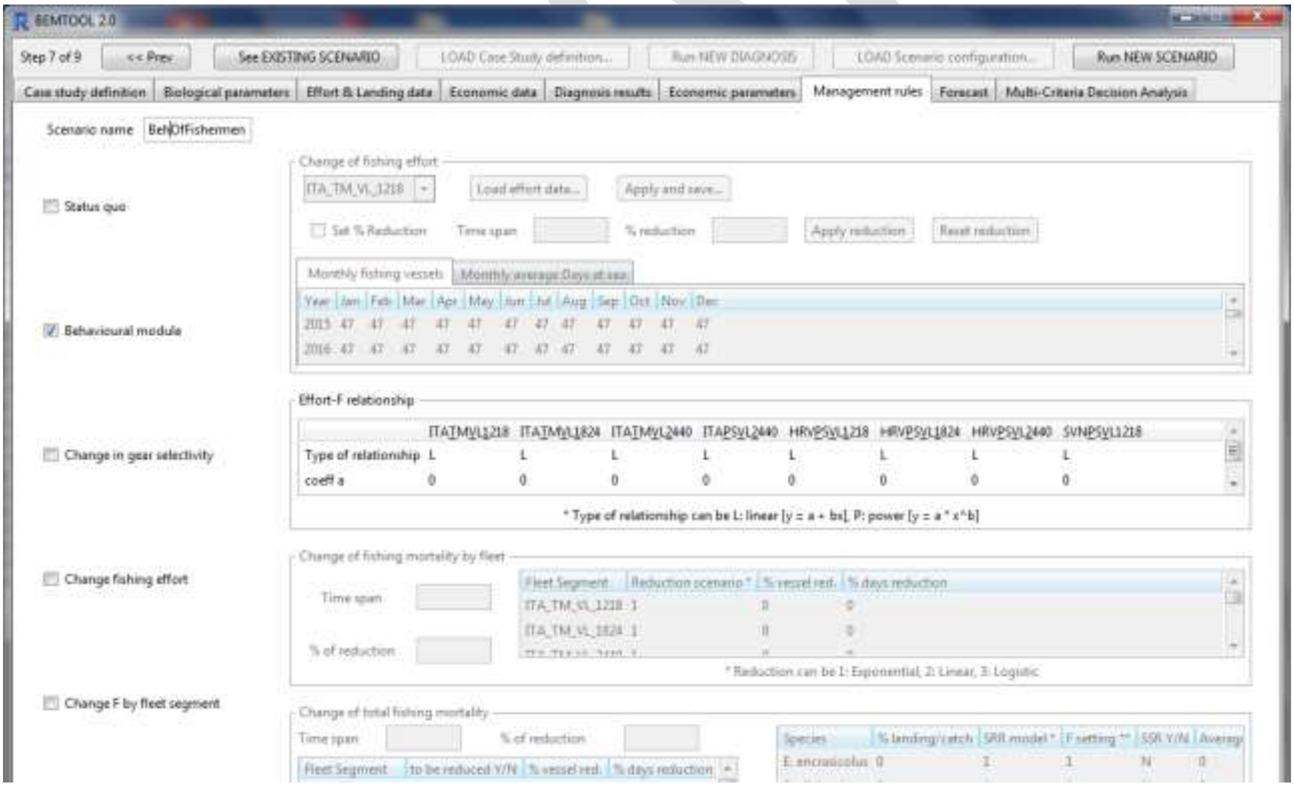


Figure 77 – Definition of scenario with behavioral module activated

12.8 Change in selectivity and in fishing effort

In this scenario the user can implement a combined harvest rule in order to simulate restrictions in mesh size and in fishing effort.

The settings related to the selectivity parameters have to be entered in the ALADYM GUI, as for scenario of change of selectivity, while the monthly data on the vessels and fishing days by fleet segment have to be saved in .csv file, whose paths have to be input in the related fields, as for scenario of change in effort. Locate the file(s) using the browse button. Alternatively the user can apply an automatic reduction to the effort values of the last year of simulation with the intelligent GUI (see scenario change in fishing effort).

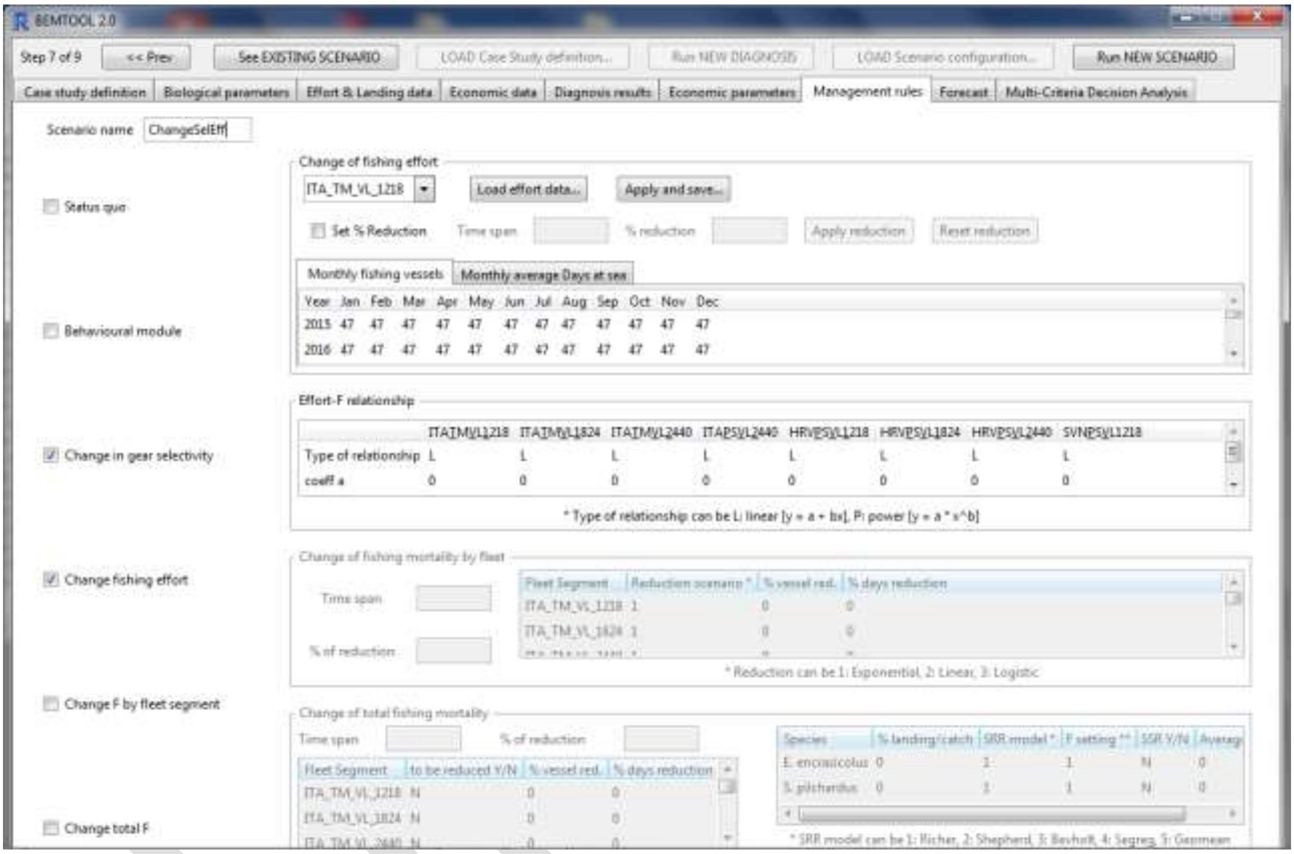


Figure 78 – Definition of scenario with change of selectivity and fishing effort

12.9 Change in selectivity with behavioural module

In this scenario another combined harvest rule can be simulated, applying restrictions in mesh size and activating the behavioural module (see paragraph Behavior of the fleet).

No inputs are required in the “Management Rules” tab for selectivity in this scenario, because the selectivity parameters have to be entered directly in ALADYM GUI.

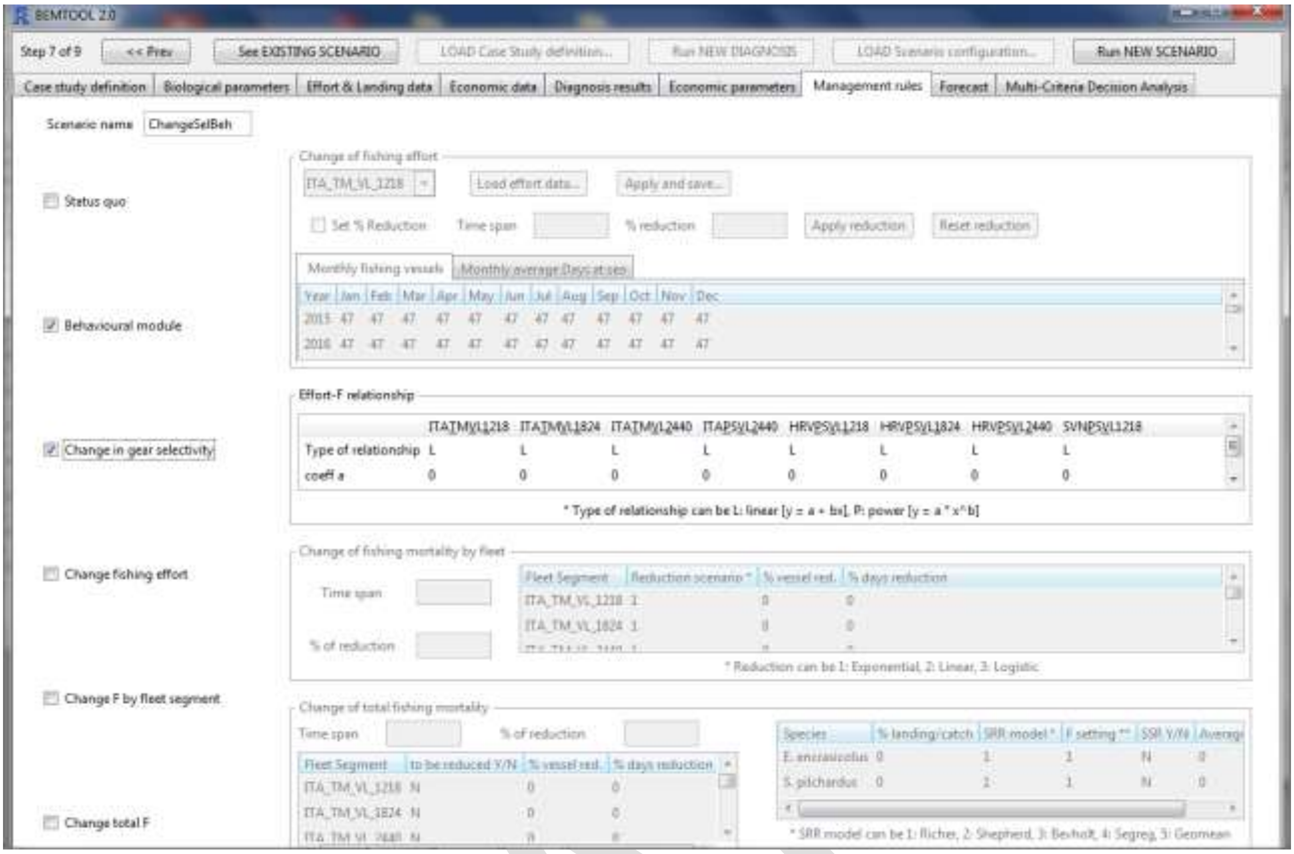


Figure 79 – Definition of scenario with change of selectivity and behavioral module

12.10 Change in fishing effort with behavioural module

In this scenario the user can apply to the system a change in the fishing effort by fleet segment in combination with the fishermen behavior.

This scenario below requires the same inputs as in the “Management Rules” tab of scenarios of change in fishing effort and activation of behavioral module (paths of monthly vessels and fishing days data files to be input in the related fields following the same procedure as the previous scenarios).

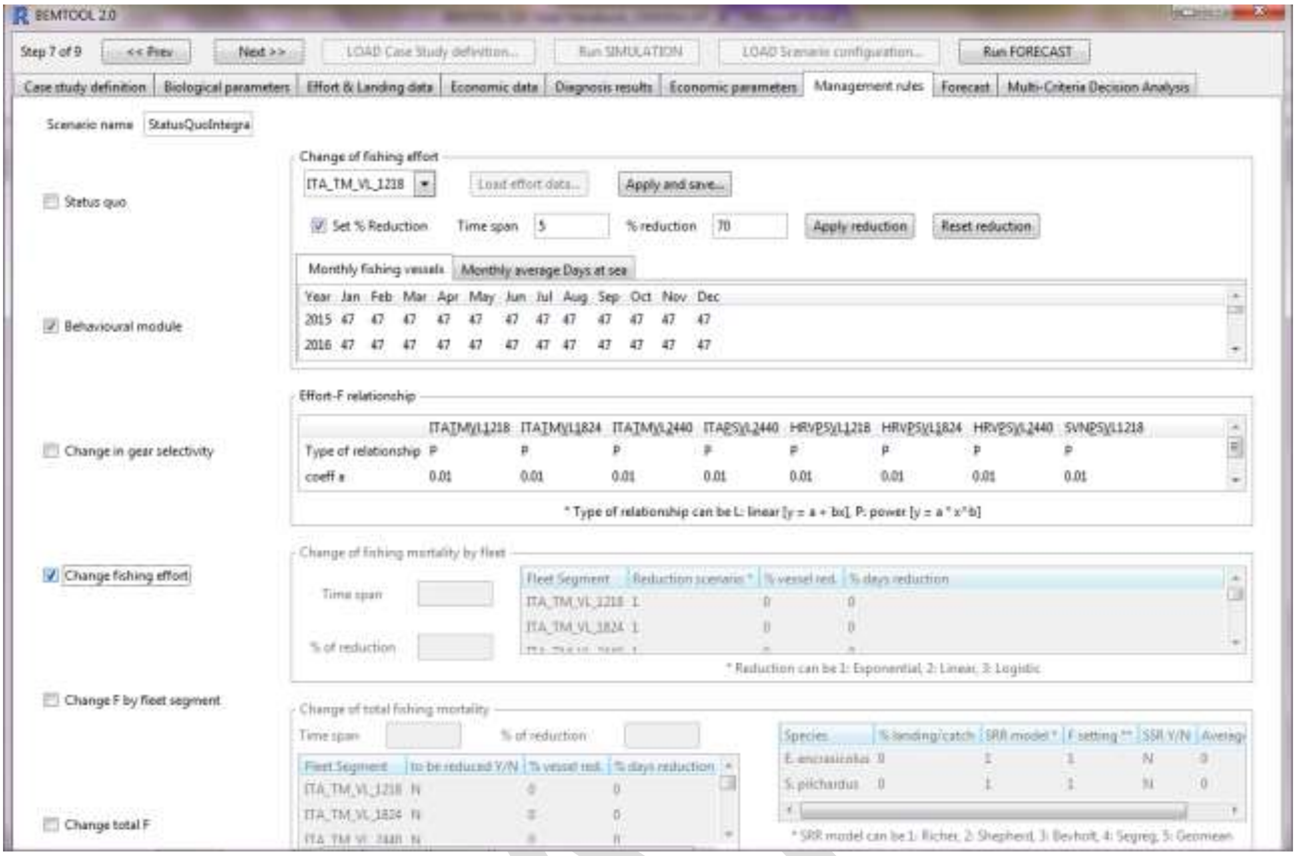


Figure 80 – Definition of scenario with change of effort and behavioral module

As for scenario of change in fishing effort, the user can load, modify and save the effort variable or use the intelligent GUI to apply a reduction in a certain number of years.

12.11 Change in selectivity and fishing effort with behavioural module

Scenario 10 is a combination of mesh size restrictions, change in fishing effort and behavioral module.

The settings needed to apply this harvest rule are the same as for scenarios of change in selectivity, in fishing effort and with activation of behavioral module (monthly vessels and monthly average of fishing days to be saved in .csv files whose location has to be input in the related fields following the same procedure as the previous scenarios).

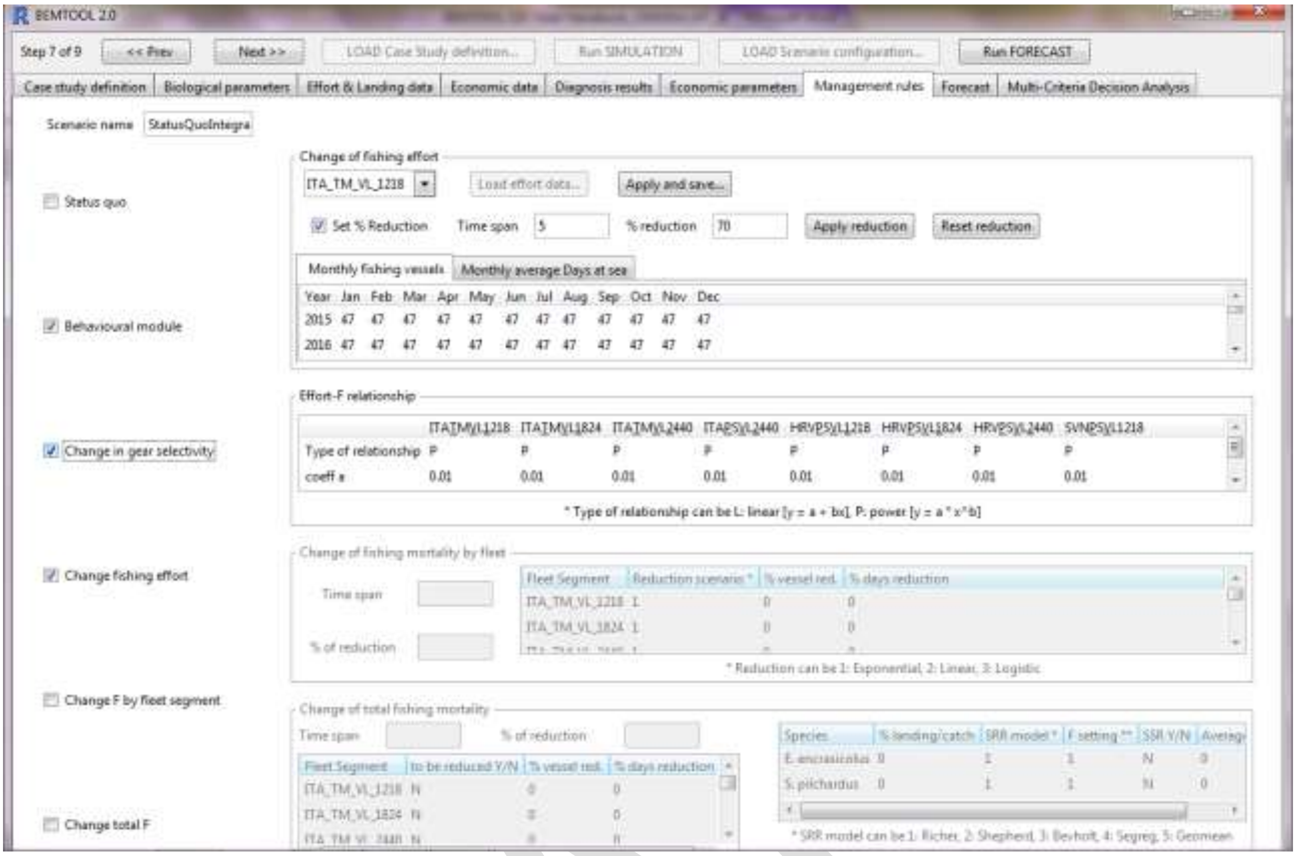


Figure 81 – Settings for scenario of (change in selectivity, in fishing effort with behavioural module).

As for scenario of change in fishing effort, the user can load, modify and save the effort variable or use the intelligent GUI to apply a reduction in a certain number of years.

13 Forecast

For every scenario, a new folder dedicated to the results of the run will be created in the BEMTOOL casestudy path, in order to allow the comparison among the scenarios. The same results produced in simulation phase will be also produced for each scenario run from the first year of simulation to the last year of the forecast and can be visualized in the tab FORECAST of BEMTOOL GUI.

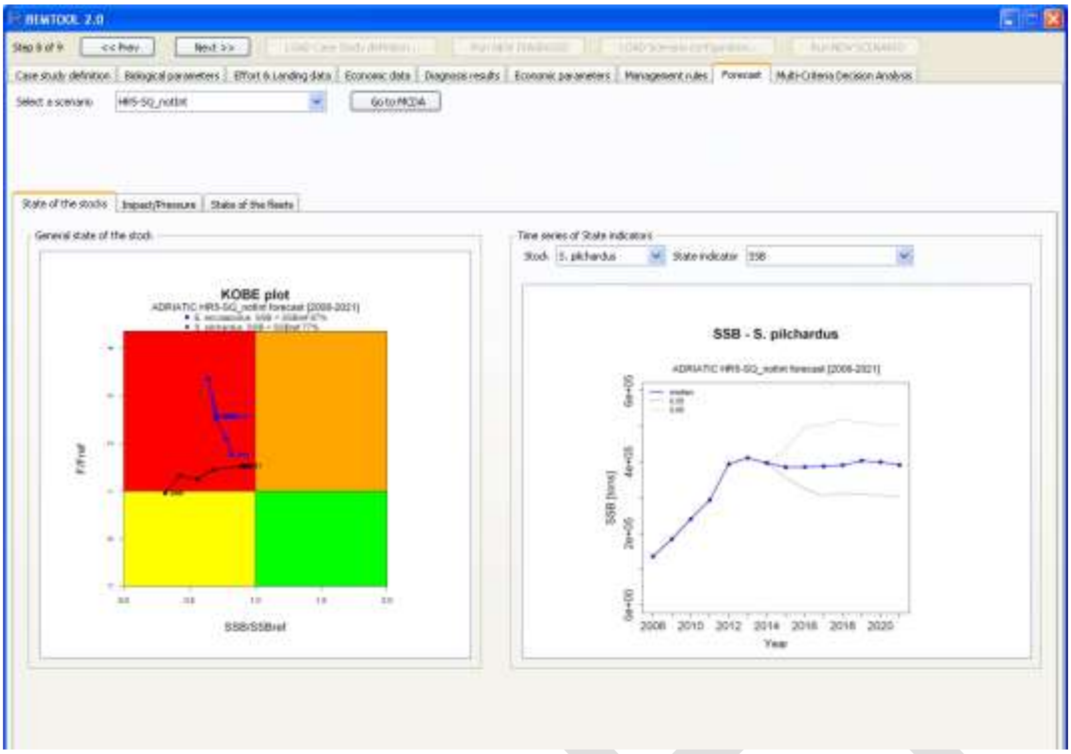


Figure 82 Tab FORECAST of BEMTOOL GUI: sub-tab state of the stocks

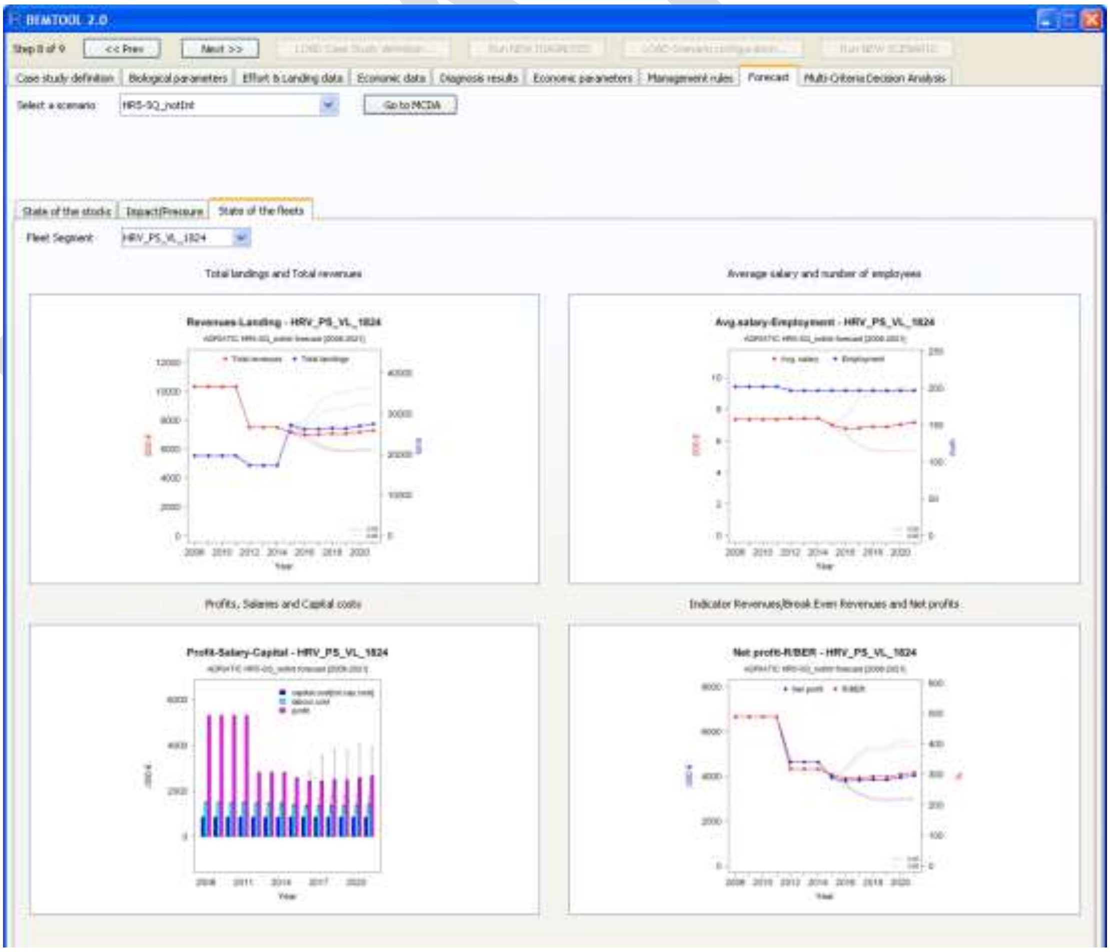
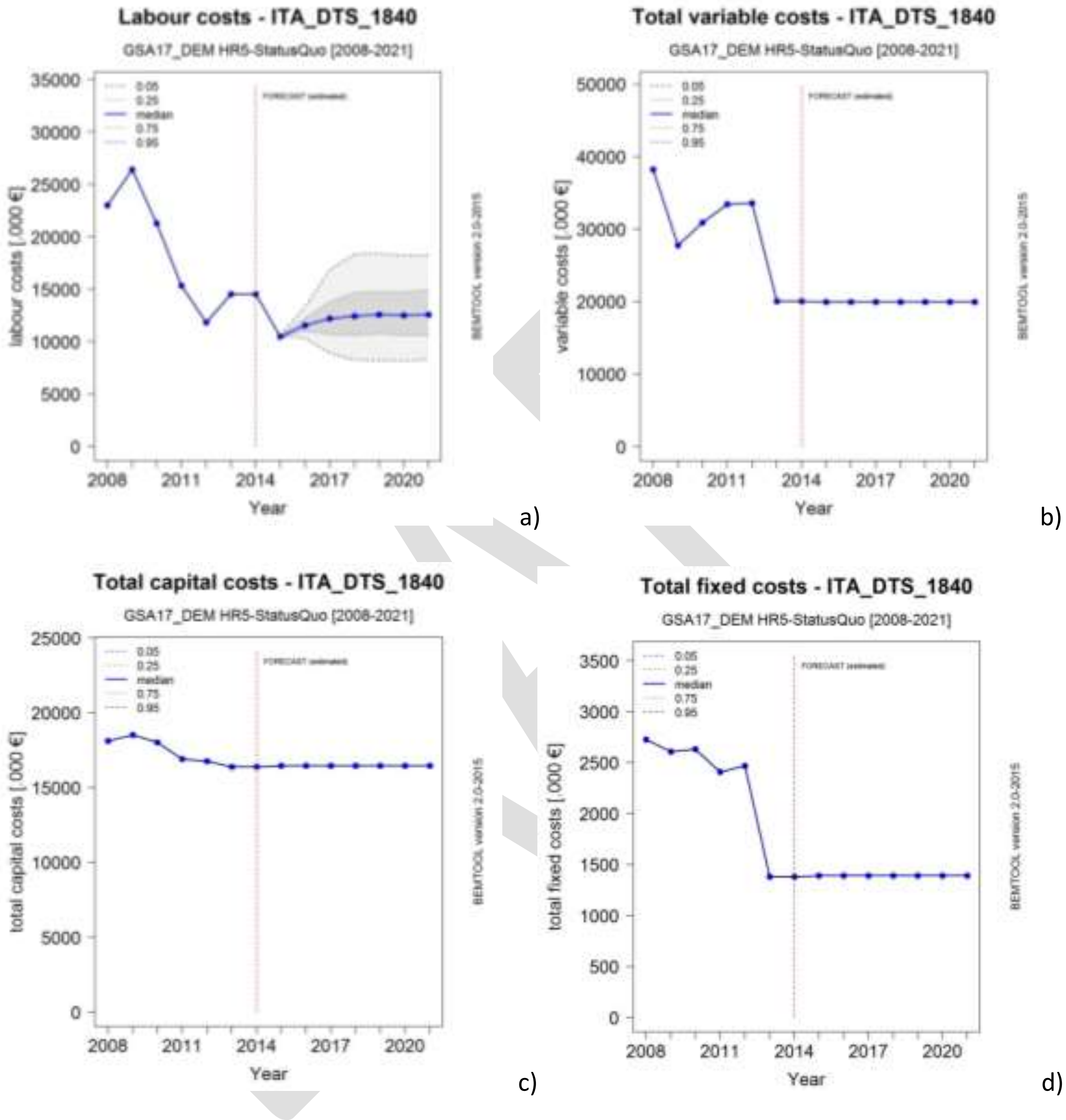


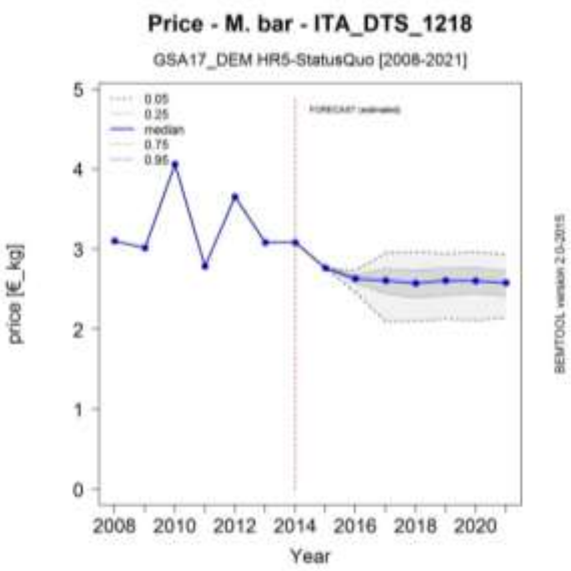
Figure 83 Tab FORECAST of BEMTOOL GUI: sub-tab state of the fleet

The manager can easily compare the results of the different scenarios, examining the tables and graphs stored in the folders dedicated to each scenario.

Moreover, plots related to the economic estimates are saved in the *Economic indicators* folder in order to check the economic parameterization of prices, variable costs, fixed costs, capital costs, labour costs and the uncertainty around them.



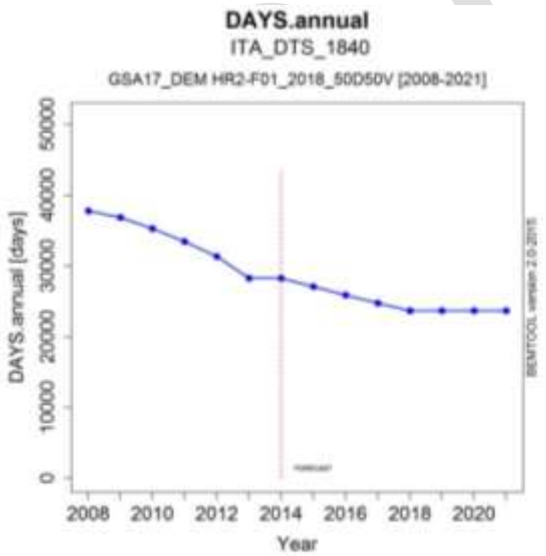
e.1)



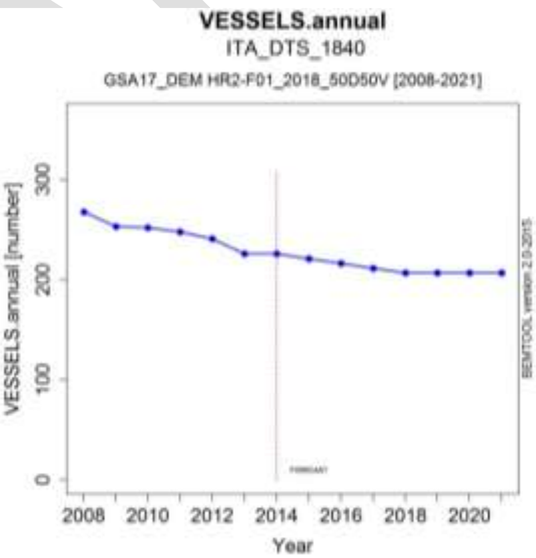
e.2)

Figure 84 – Example of plots of costs estimates: a) Labour costs, b) Total variable costs, c) Total capital costs, d) Total fixed costs and e) prices by species.

Also plots related to the effort variables: annual days at sea and annual number of vessels are saved in the *Economic indicators* folder in order to have a global view on the effort changes when management measures are simulated in the forecast.



a)



b)

Figure 85 – Example of plots of effort variables: a) Annual days at sea and b) annual number of vessels.

Additional graphs plotting some relevant economic indicators have been added, as RoFTA, GVA and NPV discounted.

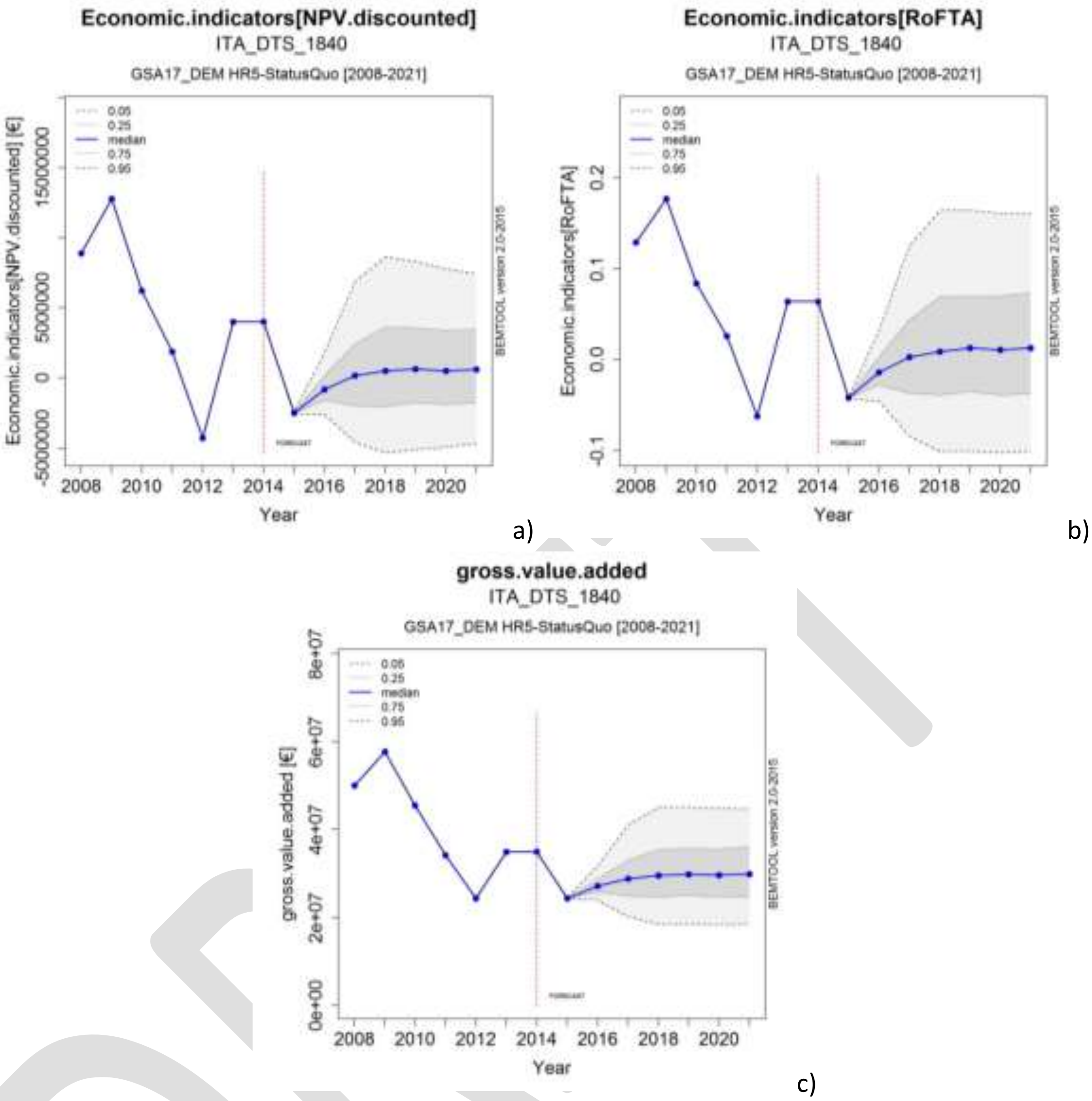


Figure 86 – Example of additional economic indicators graphs: a) NPV (Net Profit Value) discounted b) RoFTA (Return of Fixed Tangible Assets) and c) GVA (Gross Value Added).

In case for at least one stock the uncertainty on recruitment has been taken into account, the risk evaluation output will be available: in particular a table where year by year is estimated a proxy probability that the SSB by stock is less than the SSB of reference is produced.

This measure of the risk to have a an SSB smaller than the reference SSB for each stock is derived by the model as ratio between the number of runs with SSB < SSB_{ref} and the total number of runs (N). This can be interpreted as a proxy of the probability, for each year of forecast, to have a SSB < SSB_{ref} as consequence of the uncertainty in recruitment set by the user in the BEMTOOL scenario.

Moreover, also a risk evaluation plot is produced where for each stock is indicated this measure of risk related to the last year.

Table 4 - Measure of risk that SSB < SSBref by stock and by year taking into account the uncertainty on recruitment

year	E. encrasicolus	S. pilchardus
2015	99	94
2016	91	83
2017	88	75
2018	93	72
2019	86	68
2020	86	68
2021	87	77

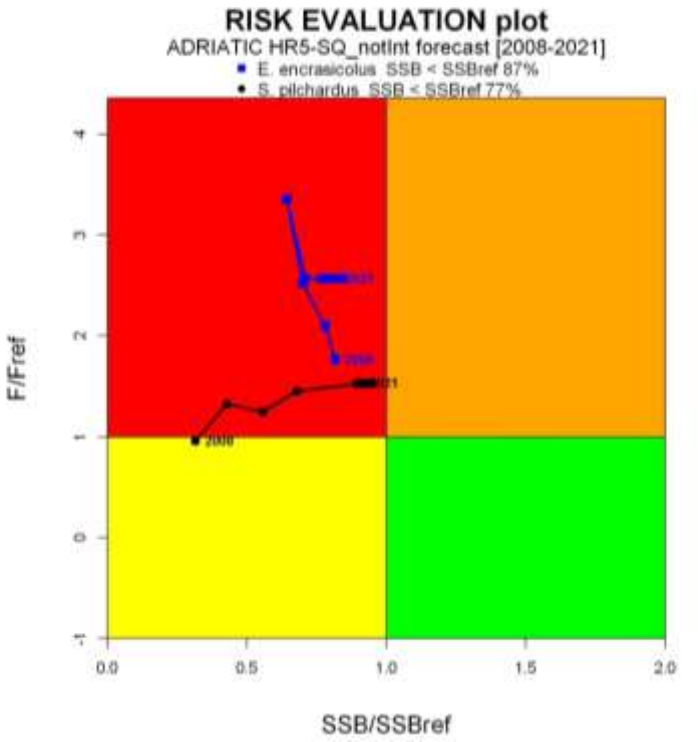


Figure 87 – Risk evaluation plot: in the upper part there is the proxy of probability that SSB is less than SSBref taking into account the uncertainty in recruitment.

The computation time for the forecast depends on the number of fleet segments and stocks involved in the case study as well as on the number of years of the forecast period.

14 Option to calculate Maximum Economic Yield (MEY)

The estimation of MEY is included in BEMTOOL as an option for the user. As the MEY is considered a theoretical long-term optimal level, this is estimated by assuming that fishermen will not react to changes in fishing effort. This means that the behavioral module is deactivated in the estimation of MEY.

The model user has to indicate that he/she wants to launch the MEY calculation selecting the MEY check box in the bottom. He/she can indicate a single fleet segment or all fleet segments (it is not allowed the selection of an intermediate number of fleet segments). Thus, in the drop down menu the user can choose the segment involved in the calculation or alternatively “ALL” the fleet segments.

Furthermore, the user has to select the effort variable (fishing days or number of vessels) to be modified for the estimation of MEY and the number of years needed to achieve the “long-term” (we assume that after such a number of interactions, all variables will be constant over time). Thus, the user has to select one between “VESSELS” and “DAYS” options. Finally, the number of years of forecast for each effort level has to be entered in the “Number of years” field.

The MEY is estimated as the long-term maximum economic output for the whole fleet, where the economic outcome is expressed in terms of gross value added or profit.

Figure 88 – Settings for the option of MEY calculation.

Once the fleet segment, the effort variable and the number of years have been selected by the user, BEMTOOL carries out 21 times the scenario of *change of effort* for the number of years selected by the user. The value of the chosen effort variable is changed for each forecast from zero to two times the current level.

For each effort level, all variables included in the logical-conceptual framework of the model are calculated and stored in a specific folder in the working directory.

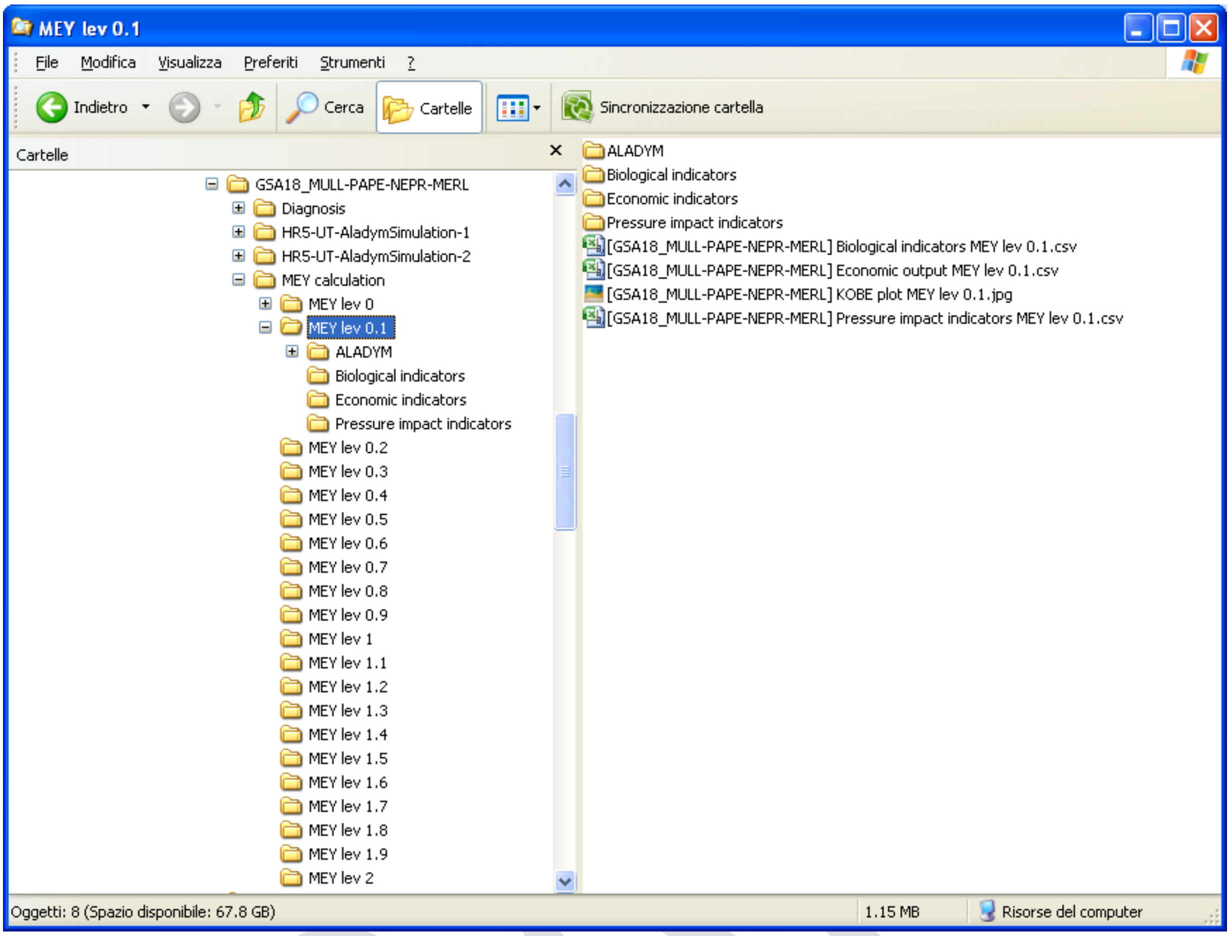


Figure 89 – Folders created by BEMTOOL to save the intermediate results of MEY calculation (for each level of reduction 0, 0.1, 0.2, …, 2 the same folder structure of a single scenario is built).

After the 21 runs, a summary table is produced containing only the gross value added and profit of the last forecast year for each effort level (see Figure below). Three possible MEYs are identified by selecting the highest values among those saved for the last forecast year: a MEY associated to the gross value added, one associated to profits and another one associated to the ROI. These results are saved in a table in same format of economic indicators (see Figure below).

Case study name	Effort level	Effort variable	Fleet segment	Number of years	Gross value added	Profit
GSA 18 Case study	0	DAYS	ALL	20	0	0
GSA 18 Case study	0.1	DAYS	ALL	20	100	200
GSA 18 Case study	0.2	DAYS	ALL	20	200	400
GSA 18 Case study	0.3	DAYS	ALL	20	300	600
GSA 18 Case study	0.4	DAYS	ALL	20	400	800
GSA 18 Case study	0.5	DAYS	ALL	20	500	1000
GSA 18 Case study	0.6	DAYS	ALL	20	600	1200
GSA 18 Case study	0.7	DAYS	ALL	20	700	1400
GSA 18 Case study	0.8	DAYS	ALL	20	800	1600
GSA 18 Case study	0.9	DAYS	ALL	20	900	1800
GSA 18 Case study	1	DAYS	ALL	20	1000	2000
GSA 18 Case study	1.1	DAYS	ALL	20	1100	2200
GSA 18 Case study	1.2	DAYS	ALL	20	1200	2400
GSA 18 Case study	1.3	DAYS	ALL	20	1300	2600
GSA 18 Case study	1.4	DAYS	ALL	20	1400	2800
GSA 18 Case study	1.5	DAYS	ALL	20	1500	3000
GSA 18 Case study	1.6	DAYS	ALL	20	1600	3200
GSA 18 Case study	1.7	DAYS	ALL	20	1000	2000
GSA 18 Case study	1.8	DAYS	ALL	20	900	1800
GSA 18 Case study	1.9	DAYS	ALL	20	800	1600
GSA 18 Case study	2	DAYS	ALL	20	700	1400

Figure 90 – Summary table containing results of the 21 runs for MEY calculation.

Case_study	Scenario	ID_scenario	Fleet_segment	Species	Year	Variable	Value	Unit
GSA 18	MEY	MEY	DTS_VL0006-VL1218	ALL	ALL	MEY.gross.value.added	136042472.4	euro
GSA 18	MEY	MEY	DTS_VL0006-VL1218	ALL	ALL	MEY.profit	21058633.5	euro
GSA 18	MEY	MEY	DTS_VL0006-VL1218	ALL	ALL	MEY.ROI	0.273479758	

Figure 91 – MEY results table containing the MEY values for GVA, profit and ROI.

The computation time for the MEY calculation depend on the number of fleet segments and stocks involved in the case study as well as on the number of years for MEY calculation. The computation time for MEY is approximately 21 times the time needed for the scenario HR2.

15 Multi-Criteria Decision Analysis (MCDA)

Multi-criteria decision analysis (MCDA) can be executed under the conditions that a more than one scenarios were completed. To run MCDA, two types of information are required:

a) utility value for several indicators

b) weights associated to each indicator

These two information can be loaded by the related buttons in the BEMTOOL GUI.

The associated files are located under *BEMTOOL R-core path* in *src\mcda* folder. In Figure 92 the functionality of MCDA is presented. To run MCDA click on “Run MCA” button. The results are automatically saved in the MCDA folder.

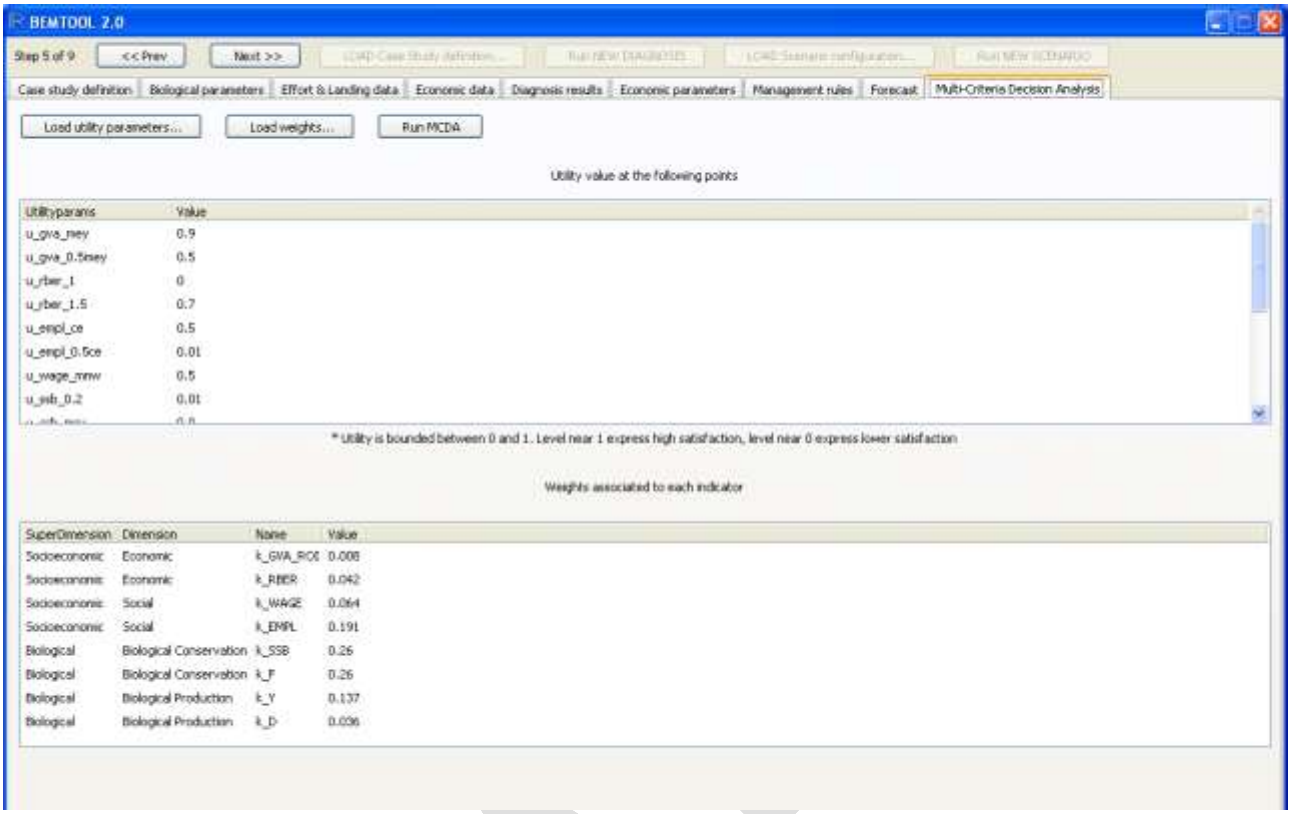


Figure 92 – Multi-criteria Decision Analysis screen for parameters and weights for each indicator.

Examples of the structure of the csv files and the graphs produced by the MCDA are reported below.

	HR1-ChangeSel	HR2-FmsyRedMullet10perm	HR2-FmsyRedMullet10temp	HR2-FmsyRedMullet5perm
u_GVA	0.0035	0.0034	0.0028	0.0035
u_RBER	0	0.0069	0	0.0105
u_WAGE	0.0424	0.0472	0.0389	0.0484
u_EMPL	0.0956	0.0116	0.0956	0.0073
u_SSB	9.00E-04	0.0041	0.0041	0.0369
u_F	0.041	0.2404	0.2404	0.2536
u_Y	0.0686	0.0522	0.0522	0.0534
u_D	0.036	0.036	0.036	0.036

	weights	HR1-ChangeSel	HR2-FmsyRedMullet10perm	HR2-FmsyRedMullet10temp	HR2-FmsyRedMullet5perm
u_GVA	0.008016032	0.4354	0.4283	0.3471	0.4356
u_RBER	0.042084168	0	0.1634	0	0.2487
u_WAGE	0.064128257	0.6617	0.7355	0.6069	0.7553
u_EMPL	0.191382766	0.4996	0.0604	0.4996	0.0381
u_SSB	0.260521042	0.0033	0.0158	0.0158	0.1417
u_F	0.260521042	0.1574	0.9227	0.9228	0.9733
u_Y	0.137274549	0.4994	0.3801	0.3801	0.3889
u_D	0.036072144	0.999	0.999	0.999	0.999

	MNW	WAGE	CE	EMPL	GVA	MEY_GVA	RBER	Fmsy M. barbatus	Fmsy M. merluccius	F M. barbatus	F M. merluccius
HR1-ChangeSel	7697	12035.802	1203	1202.78	16496246.96	38470908.89	0.974	0.208	0.097	0.542	0.104
HR2-FmsyRedMullet10perm	7697	14767.786	1203	843.749	16197191.02	38470908.89	1.042	0.208	0.097	0.227	0.05
HR2-FmsyRedMullet10temp	7697	10369.368	1203	1202.78	12884403.48	38470908.89	0.909	0.208	0.097	0.227	0.05
HR2-FmsyRedMullet5perm	7697	15630.938	1203	780.385	16502868.51	38470908.89	1.071	0.208	0.097	0.152	0.04
HR2-FmsyRedMullet5temp	7697	10139.019	1203	1202.78	12603160.63	38470908.89	0.909	0.208	0.097	0.152	0.04
HR3-FmsyHake10	7697	16925.959	1203	831.082	19915302	38470908.89	1.13	0.208	0.097	0.306	0.051
HR3-FmsyHake5	7697	19756.571	1203	742.012	22283572.08	38470908.89	1.202	0.208	0.097	0.246	0.041
HR3-FmsyRedMullet10	7697	17519.071	1203	702.171	17808498.16	38470908.89	1.13	0.208	0.097	0.221	0.036
HR3-HR3-FmsyRedMullet5	7697	20038.489	1203	566.823	17492950.17	38470908.89	1.176	0.208	0.097	0.145	0.024
HR5-StatusQuo	7697	10774.864	1203	1202.78	13404481.63	38470908.89	0.913	0.208	0.097	0.652	0.109

Figure 93 – Tables containing the outputs of the MCDA.

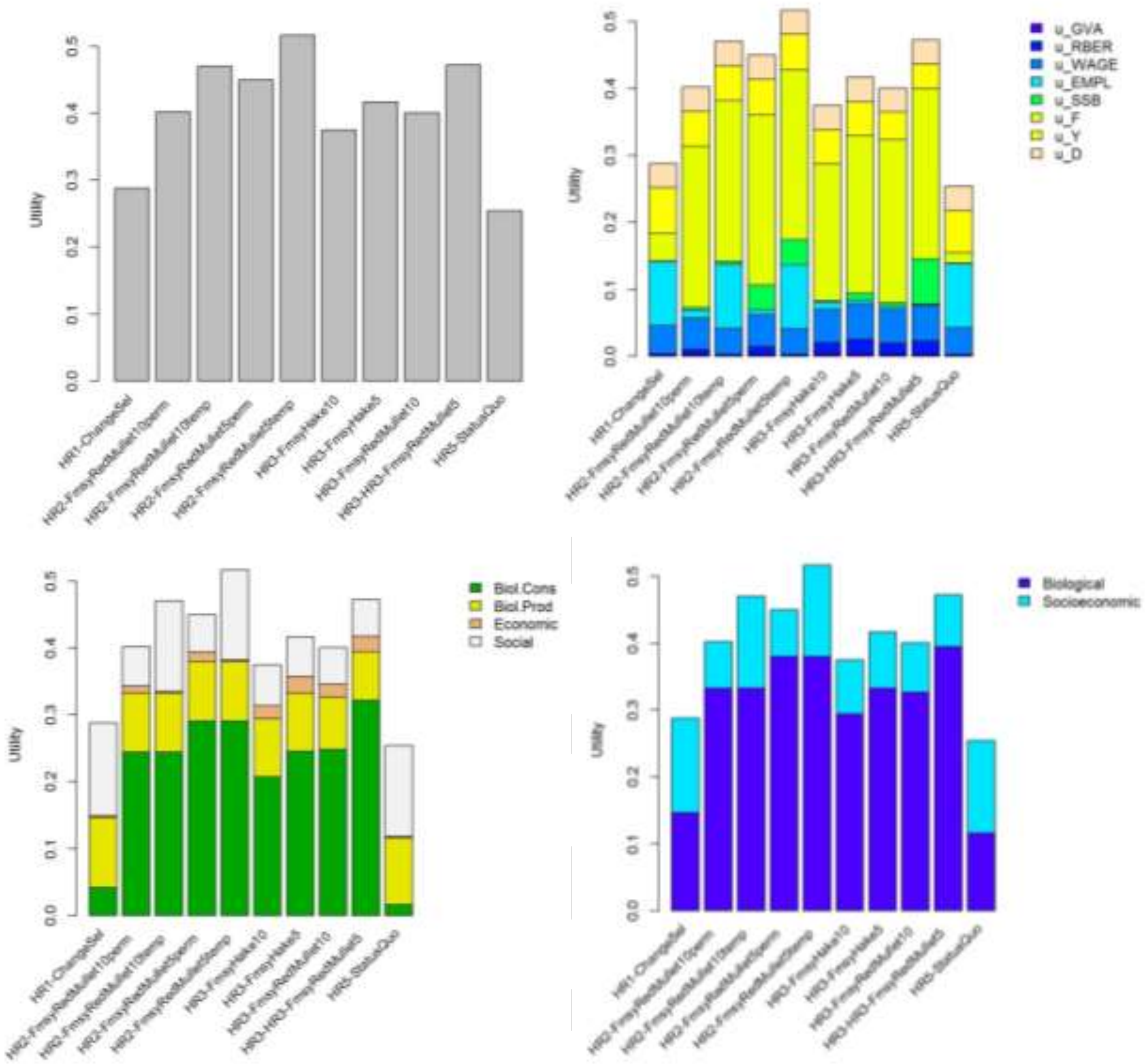


Figure 94 – MCDA results for each scenario.

16 Run Evaluation

Evaluation procedure can be executed under the condition that more than one scenarios were completed. To run Evaluation the user has only to click the button “Run evaluation”.

The evaluation procedure will save graphs comparing the values estimated in each scenarios of the relevant biologic, pressure/impact and economic indicators. The variables plotted in the graphs are listed below.

Table 5 – List of the graphs saved by the Evaluation procedure.

Biological indicators	Economic indicators	Pressure impact indicators
SSB	average.wage Economic.indicators[CR.BER]	Catch Discard

Biological indicators	Economic indicators	Pressure impact indicators
	Economic.indicators[NPV.discounted] Economic.indicators[RoFTA] employment gross.value.added total.landings total.revenues DAYS.annual VESSELS.annual	Mean_length_catch

For each variable listed above a plot for all the simulated period and a plot focusing on the projections are saved in which all the scenarios saved in the output folder are overlapped.

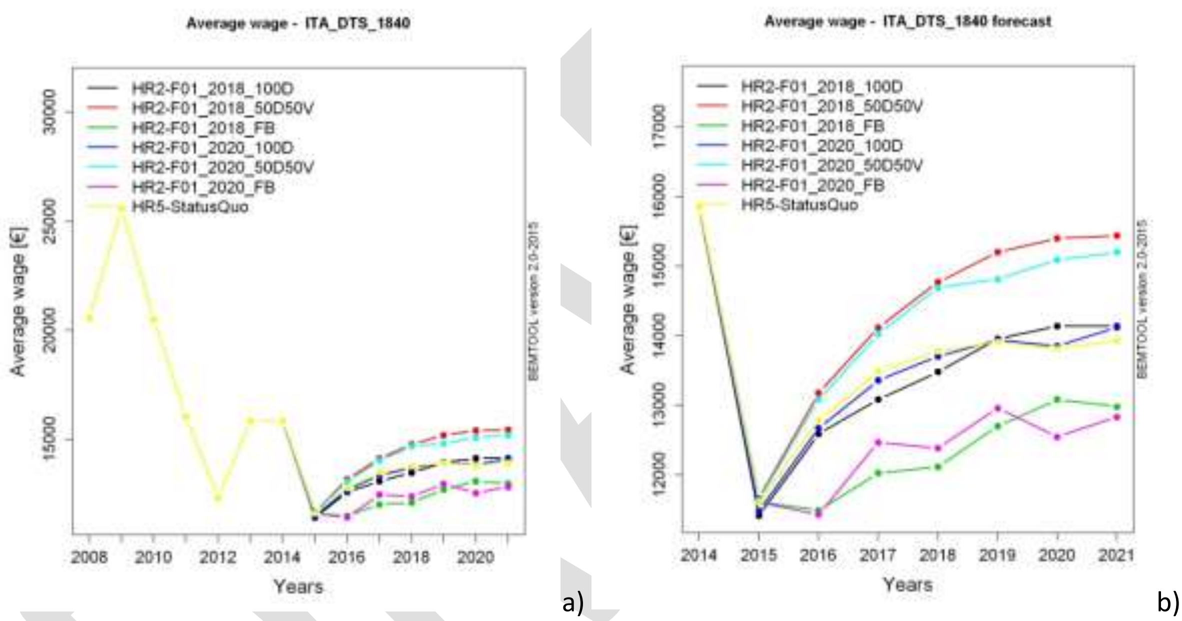


Figure 95 – Example of Evaluation plots for average wage of Italian DTS_1840 segment in SEDAF case study of GSA 17 Demersal in different projections until 2021 a) for all the period of simulation and b) focusing on the forecast period.

16 Appendices

16.1 VIT output stock assessment .csv file

Class	Lower Age	Mean Age	Lower Length	Mean Length	Lower Weight	Mean Weight	Maturity ratio
1	0	0.386	0.208	7.784	0	7.563	0.000414167
2	1	1.303	19.022	23.924	46.723	105.341	0.1232333
3	2	2.4	34.426	39.673	303.631	488.025	0.9233959
4	3	3.438	47.038	51.73	812.894	1109.518	1
+	4	5.587	57.363	68.601	1520.39	2865.868	1
upper bound	1.00E+12	---	104	---	9935.93	---	
Catch in Numbers							
Class	Total catch	Catch of gear 1	Catch of gear 2				
1	17277431.66	0	17277431.66				
2	23576553.84	80970.36	23495583.48				
3	1104597.55	232085.73	872511.82				
4	194701.68	89225.65	105476.03				
+	160981.94	110091.23	50890.71				
Total	42314266.66	512372.98	41801893.69				
Mean Age	0.984	3.092	0.958				
Mean Length	18.043	45.5	17.707				
Catch in Weight							
Class	Total catch	Catch of gear 1	Catch of gear 2				
1	130661880.4	0	130661880.4				
2	2483585718	8529526.49	2475056192				
3	539071335.7	113263663.9	425807671.9				
4	216025030.3	98997467.74	117027562.6				
+	461352932	315506897.3	145846034.7				
Total	3830696896	536297555.4	3294399341				
Percentage	100	14	86				
VPA Results--Numbers							
Class	Initial number	Mean number					
1	129479194.2	69501181.76					
2	31719394.05	11222280.64					
3	2307254.28	1325882.82					
4	672303.6	472555.08					
+	316933.2	503068.57					
Total	---	83024968.87					
Stock Mean Age	---	0.591					
Stock Mean Length	---	11.094					
VPA Results--Weight							
Class	Initial Weight	Mean Weight					
1	3915.51	525607930.7					
2	1482025789	1182170054					
3	700553204.6	647064105.3					
4	546511354.5	524308406					
+	481862789.5	1441727912					
Total	---	4320878408					
SSB	---	2709433067					

VPA Results--Mortalities							
Class	Z	Total F	F of gear 1	F of gear 2			
1	1.407	0.249	0	0.249			
2	2.621	2.101	0.007	2.094			
3	1.233	0.833	0.175	0.658			
4	0.752	0.412	0.189	0.223			
+	0.63	0.32	0.219	0.101			
Mean Mort. rates	0.63	0.32	0.219	0.101			
Global Fs	---	0.51	0.006	0.503			
---	Critical age	Critical length					
Current stock	1	19.022					
Virgin stock	3	47.038					
Total Biomass balance (D): 5938105461.08							
---	Biomass	Percentage					
Recruitment	3915.51	0					
Growth	5938101546	100					
Natural death	2107408565	35.49					
Fishing	3830696896	64.51					
R/B(mean)	0						
D/B(mean)	137.43						
B(max)/B(mean)	34.3						
B(max)/D	24.96						
Slope at origin	Virgin biomass	Method	Num_points	Resolution	Max factor of effort		
556.1125	1.79E+11	Calc. Mean wt.	200	0	2		
___	Factor	Y/R	B/R	SSB	Y/R Gear 1Y/R Gear 2		
F(0)	0	0	1381.036	1339.336	0	0	
Max Gear1	0.23	51.94	512.306	482.137	22.468	29.472	
F(0.1)	0.24	52.759	470.328	440.985	22.395	30.364	
Max(:)	0.3	53.581	381.076	353.666	21.643	31.938	
Max Gear2	0.42	51.243	234.437	210.998	18.124	33.119	
phi=1	1.01	29.585	33.371	20.926	4.142	25.443	
phi=2	2	16.466	7.348	1.029	0.292	16.174	
Slope at origin	Virgin biomass	Method	Num_points	Resolution	Max factor of effort		
556.1125	1.79E+11	Calc. Mean wt.	200	0.01	2		
point	Factor	Y/R	B/R	SSB	Y/R Gear 1	Y/R Gear 2	
0	0	0	1381.036	1339.336	0	0	
1	0.01	5.333	1317.36	1276.3	2.73	2.603	
2	0.02	10.231	1256.888	1216.455	5.202	5.029	
...	...	...	...	...	...	...	

16.2 Preparation of XSA output object

If the user wants to perform the assessment of one or more stocks with the FLXSA package provided in BEMTOOL platform, he/she has to prepare the input files for the XSA Analysis.

The list of input files .dat to be prepared is:

1. Text file containing the names of all the files from point 2 to point 10;
2. Landing by year;
3. Total catch in numbers by age and year;
4. Mean individual weight in catch by age and year;
5. Mean individual weight in the stock by age and year;

6. Natural mortality by age and year;
7. Proportion of matures by age and year;
8. Proportion of F acting before spawning;
9. Proportion of M acting before spawning;
10. Abundance indices by year and age from survey data;
11. Catch in number by fleet segment, age and year.

For the files from 1 to 10, it is suggested to follow the format described in the Virtual Population Analysis: version 3.1 (Windows/DOS) user guide (it is possible also to download it from: http://www.ices.dk/committe/acom/wg/asoft/VPA/VPAUSER-94.pdf).

The template to prepare the last file (point 11) is provided in the package (see Table 6). On the rows there are the age classes and on the column there are the catch in numbers by fleet segment and year. The order of the column is:

Age, 2007 fleet segment1, 2007 fleet segment2, ….,2008 fleet segment 1, 2008 fleet segment 2, etc..

Please, do not enter in the column names the fleet segment code; pay attention only to put the catch in numbers by fleet in the <u>same order</u> of the BEMTOOL configuration settings.

Table 6 - Catch in number by fleet segment, age and year.

Age	2007	2007	2007	2007	2008	2008	2008	2008	2009	2009	2009	2009
0	25363.99	6282.234	493.0941	0	7917.797	986.434	327.9338	0	14790.58	2848.644	1262.016	0
1	26550.78	6576.183	516.1661	0	18940.67	2359.712	784.4715	0	15003.6	2889.67	1280.191	0
2	1042.249	258.1477	20.26207	0	336.738	41.9523	13.94678	0	744.4981	143.3892	63.52478	0
3	39.87239	9.875722	0.775148	0	25.66645	3.19764	1.063035	0	16.59137	3.195473	1.415669	0

The code has been tested with R version 2.14.2.

Before running the `run_FLXSA&Refpoints.r` code, the following steps have to be followed:

1. Set the working directory (in R console: File -> Change dir…); the working directory has to be set and has to appear as follows:

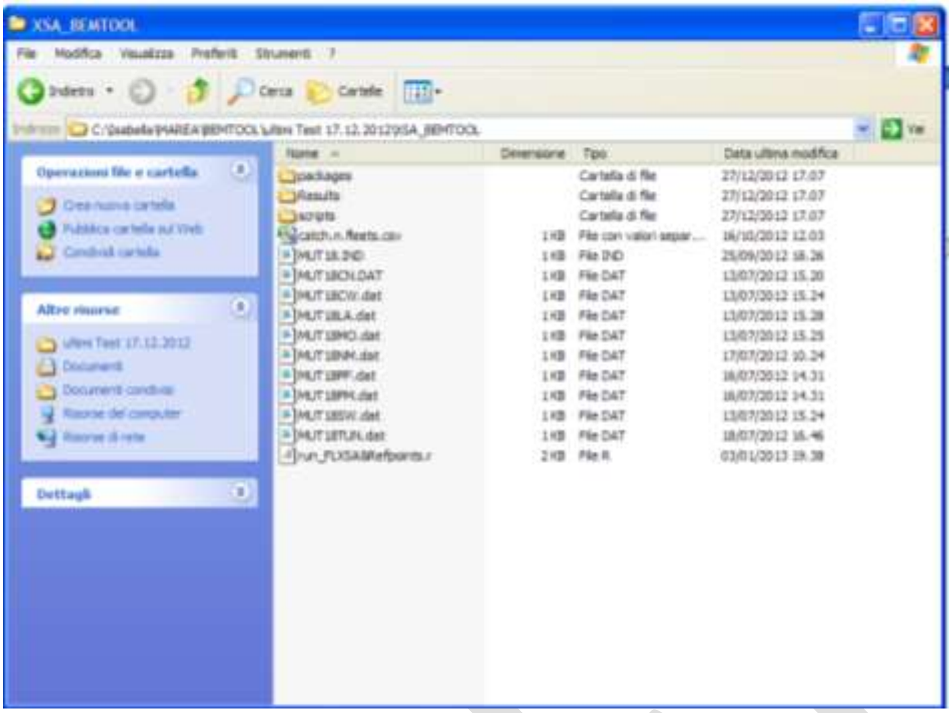


Figure 96 – Working directory for running the FLXSA&Refpoints.r script.

2. Set the variables needed to run the code:

    a. Name of the text file containing the names of all the files (point 1 listed above)

    b. Name of the tuning file (point 10 listed above);

    c. Name of catch by age, year and fleet segment file (point 11 listed above)

    d. Start and end year of data;

    e. Number of fleet segments (for disaggregate the fishing mortality calculated by XSA);

    f. Age range (min and max) for calculate the F current;

    g. Plus group.

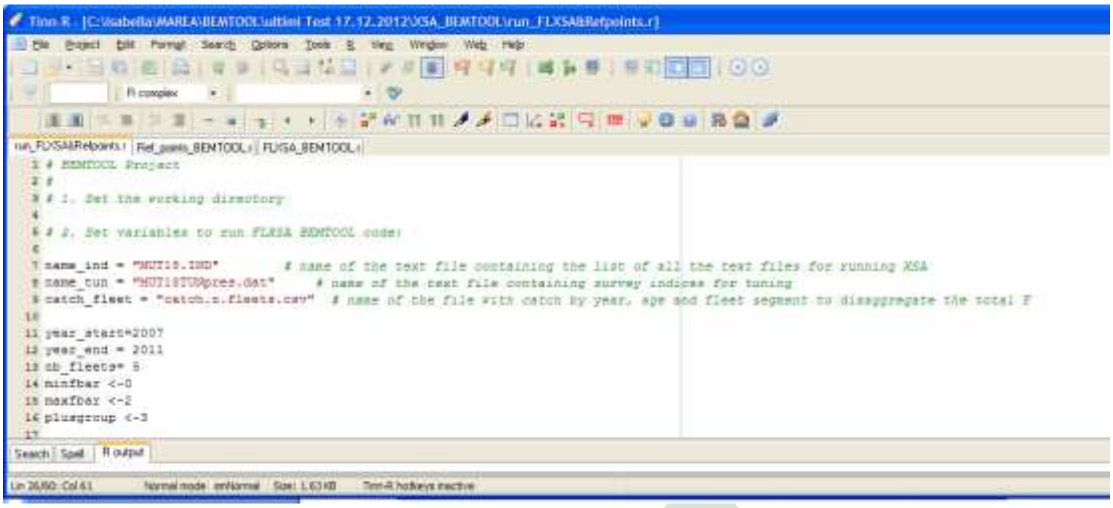


Figure 97 – Example of settings with start year 2007, end year 2011, age range 0-2 for average F used as F current and plus group 3+.

3. XSA settings: for all the settings for the analysis, see help of FLXSA function, typing on the console `?FLXSA`;

4. Settings for reference points calculation:

    a. Flag: Y/N;

    b. Model to select the stock-recruitment relationship among Ricker, Beverton-Holt, Shepherd , segmented regression and geomean.

Attention: If the calculation of the reference points has to be performed without stock-recruitment relationship, select "geomean", in order to derive reference points with recruitment calculated as the geometric mean of the recruits in all the years.

In this script modified for BEMTOOL, these 4 options have been made available, because more used in the assessment working groups and for harmonization with ALADYM model.

Other stock-recruitment models can be used in the function FLSR recalled in the `Ref_points_BEMTOOL.r`. For further details refer to FLSR help (type on R console `?FLSR`) (see Figure 98 below).

Figure 99 – Example of settings for running the FLXSA&Refpoints.r script.

5. Run the code (File->Source R code -> choose `run_FLXSA&Refpoints.r` script);
6. Select the Cran mirror from where download the libraries needed.
7. The results will be saved in the Results folder, in particular will be saved:
    a. FLXSA object (XSA_Results.dat file) containing all the estimates of XSA;
    b. F disaggregated by fleet segment - by means of the catch in numbers by age, fleet segment and year (see Table 7);
    c. Reference point table (see Table 8);
    d. Stock-recruitment relationship plots.

Table 7 - F disaggregated by fleet segment (by means of the catch in numbers by age, fleet segment and year).

Age	2007	2007	2007	2007	2007	2008	2008	2008	2008	2008	2009	2009	2009	2009	2009
0	0.3476	0.0861	0.0068	0	0	0.1514	0.0189	0.0063	0	0	0.3356	0.0646	0.0286	0	0
1	2.6872	0.6656	0.0522	0	0	2.0432	0.2545	0.0846	0	0	2.4699	0.4757	0.2107	0	0
2	1.5624	0.3870	0.0304	0	0	0.9525	0.1187	0.0395	0	0	1.4143	0.2724	0.1207	0	0
3	1.5624	0.3870	0.0304	0	0	0.9525	0.1187	0.0395	0	0	1.4143	0.2724	0.1207	0	0

Table 8 - Reference point table.

	F	Total Yield	Recruitment	SSB	Biomass
f0.1	0.5	1147.52664	104000	2244.2836	2515.6352
fmax	1	NA	NA	NA	NA
spr.30	0.7	NA	NA	NA	NA
msy	NA	NA	NA	NA	NA
mey	NA	NA	NA	NA	NA

16.3 SURBA output stock assessment .csv file

The user must copy the output from SURBA graphical interface and paste in a .csv file. The first lines of the pasted table are reported below.

SURBA	2.2									

Run	performe	at	11.18.03	on	########					

Analysis	will	use	data	from	Surba	ARISFOL	GSA10_19	slicing	qd-meno	0.dat
Survey:	GSA10	ARISFOL_1994-2011								
Index	dimensions									

Number	of	years	18	(1994-2011)						
Number	of	ages	4	(1-4+)						
Number	of	cohorts	21							
Start	(prop.	of	year)	0.5						
End	(prop.	of	year)	0.75						
Last	age	plus	group	Yes						
Mean	F	range	01-mar							
No.	years	for	forecast	F	9					
No.	years	for	forecast	M	9					
No.	years	for	forecast	Wt	9					
No.	years	for	forecast	Mat	9					
No.	years	for	GM	rec	8					
No.	years	for	forecast	8						
Default	age	weightings								
Age	1	2	3	4+						
w	1	1	1	1						
Default	catchabilities									
Age	1	2	3	4+						
q	1	1	1	1						
Survey	index	data	(CPUE)							
	Age									
Year	1	2	3	4+						
1994	50	124	91	18						
1995	168	39	20	3.7						
1996	42	97	20	3.9						
1997	529	81	40	8.4						
1998	146	154	31	6						
1999	214	226	47	4.9						
2000	81	156	88	10.2						
2001	99	136	45	3.2						
2002	122	67	25	6.8						
2003	288	161	23	4.8						
2004	59	136	19	0.5						
2005	497	181	44	6.9						
2006	242	227	86	8.4						
2007	56	56	42	13.6						
2008	261	153	34	7.7						
2009	197	214	56	10.8						
2010	333	223	56	4.8						
2011	71	234	86	8.1						
Natural	mortality									
	Age									
Year	1	2	3	4+						
1994	0.44	0.3	0.23	0.2						
1995	0.44	0.3	0.23	0.2						
1996	0.44	0.3	0.23	0.2						
1997	0.44	0.3	0.23	0.2						
1998	0.44	0.3	0.23	0.2						
1999	0.44	0.3	0.23	0.2						
2000	0.44	0.3	0.23	0.2						
2001	0.44	0.3	0.23	0.2						
2002	0.44	0.3	0.23	0.2						
2003	0.44	0.3	0.23	0.2						
2004	0.44	0.3	0.23	0.2						
2005	0.44	0.3	0.23	0.2						
2006	0.44	0.3	0.23	0.2						
2007	0.44	0.3	0.23	0.2						
2008	0.44	0.3	0.23	0.2						
2009	0.44	0.3	0.23	0.2						
2010	0.44	0.3	0.23	0.2						
2011	0.44	0.3	0.23	0.2						

Proportion	mature			
	Age			
Year	1	2	3	4+
1994	0.1	1	1	1
1995	0.1	1	1	1
1996	0.1	1	1	1
1997	0.1	1	1	1
1998	0.1	1	1	1
1999	0.1	1	1	1
2000	0.1	1	1	1
2001	0.1	1	1	1
2002	0.1	1	1	1
2003	0.1	1	1	1
2004	0.1	1	1	1
2005	0.1	1	1	1
2006	0.1	1	1	1
2007	0.1	1	1	1
2008	0.1	1	1	1
2009	0.1	1	1	1
2010	0.1	1	1	1
2011	0.1	1	1	1

Stock	weights	Kg		
	Age			
Year	1	2	3	4+
1994	0.01258	0.02086	0.02511	0.03255
1995	0.01258	0.02086	0.02511	0.03255
1996	0.01258	0.02086	0.02511	0.03255
1997	0.01258	0.02086	0.02511	0.03255
1998	0.01258	0.02086	0.02511	0.03255
1999	0.01258	0.02086	0.02511	0.03255
2000	0.01258	0.02086	0.02511	0.03255
2001	0.01258	0.02086	0.02511	0.03255
2002	0.01258	0.02086	0.02511	0.03255
2003	0.01258	0.02086	0.02511	0.03255
2004	0.01258	0.02086	0.02511	0.03255
2005	0.01258	0.02086	0.02511	0.03255
2006	0.01258	0.02086	0.02511	0.03255
2007	0.01258	0.02086	0.02511	0.03255
2008	0.01258	0.02086	0.02511	0.03255
2009	0.01258	0.02086	0.02511	0.03255
2010	0.01258	0.02086	0.02511	0.03255
2011	0.01258	0.02086	0.02511	0.03255

Survey	index	data	(mean-standardised)	
	Age			
Year	1	2	3	4+
1994	0.50678	1.25681	0.92234	0.18244
1995	1.70277	0.39529	0.20271	0.0375
1996	0.42569	0.98315	0.20271	0.03953
1997	5.36171	0.82098	0.40542	0.08514
1998	1.47979	1.56088	0.3142	0.06081
1999	2.16901	2.29064	0.47637	0.04966
2000	0.82098	1.58115	0.89193	0.10338
2001	1.00342	1.37844	0.4561	0.03243
2002	1.23654	0.67908	0.25339	0.06892
2003	2.91904	1.63183	0.23312	0.04865
2004	0.598	1.37844	0.19258	0.00507
2005	5.03737	1.83454	0.44596	0.06994
2006	2.45281	2.30077	0.87166	0.08514
2007	0.56759	0.56759	0.42569	0.13784
2008	2.64538	1.55074	0.34461	0.07804
2009	1.99671	2.16901	0.56759	0.10946
2010	3.37514	2.26023	0.56759	0.04865
2011	0.71962	2.37172	0.87166	0.0821

Scaling	factor	=	98.6625	
Smoothing	indices	by	cohorts	

	Smoothec	index	by	age					
YC	N	a1	a2	IFAIL	RSS	1	2	3	4+
1990	1	4	4	9	0	NA	NA	NA	0.182
1991	2	3	4	9	0	NA	NA	0.922	0.038
1992	3	2	4	9	0	NA	1.257	0.203	0.04
1993	4	1	4	0	0.05	0.571	0.343	0.188	0.094
1994	4	1	4	0	0.247	2.092	0.853	0.29	0.08
1995	4	1	4	0	0.804	0.685	0.475	0.224	0.075
1996	4	1	4	0	0.018	5.544	1.567	0.428	0.111
1997	4	1	4	0	1.797	2.736	1.361	0.399	0.066
1998	4	1	4	0	0.312	2.902	1.151	0.36	0.09
1999	4	1	4	0	0.816	1.34	0.681	0.239	0.064
2000	4	1	4	0	1.669	1.667	0.498	0.094	0.01
2001	4	1	4	0	0.775	1.838	0.784	0.254	0.074
2002	4	1	4	0	0.103	3.401	1.2	0.372	0.101
2003	4	1	4	0	1.122	1.047	0.975	0.576	0.224
2004	4	1	4	0	0.14	6.175	1.724	0.412	0.088
2005	4	1	4	0	0.13	2.148	0.756	0.289	0.112
2006	4	1	4	0	1.507	1.074	0.777	0.334	0.087
2007	4	1	4	0	0.389	3.688	1.476	0.452	0.109
2008	3	1	3	9	0	1.997	2.26	0.872	NA
2009	2	1	2	9	0	3.375	2.372	NA	NA
2010	1	1	1	9	0	0.72	NA	NA	NA

Smoothec index

	Age			
Year	1	2	3	4+
1994	0.57122	1.25681	0.92234	0.18244
1995	2.09172	0.34343	0.20271	0.0375
1996	0.68545	0.85345	0.18753	0.03953
1997	5.54353	0.47549	0.29023	0.09398
1998	2.7365	1.56654	0.22437	0.07966
1999	2.90179	1.36127	0.42791	0.07458
2000	1.3402	1.15071	0.39936	0.11091
2001	1.66709	0.68118	0.35964	0.06591
2002	1.83769	0.49832	0.23852	0.08978
2003	3.40065	0.78389	0.0944	0.06407
2004	1.04659	1.20017	0.25424	0.01026
2005	6.17533	0.97456	0.37207	0.0742
2006	2.14803	1.72354	0.57617	0.10061
2007	1.07375	0.7557	0.41175	0.2243
2008	3.68819	0.77727	0.28945	0.08786
2009	1.99671	1.47646	0.33371	0.11177
2010	3.37514	2.26023	0.45201	0.08727
2011	0.71962	2.37172	0.87166	0.10863

Linear regressior between mean-star survey indices at age

Y	age	X	age	I'cept	Slope	R2	(%)
	2	1	0.1703	0.3043	20.1162		
	3	1	-0.9251	0.1482	5.5873		
	4	1	-2.9049	0.2316	5.9456		
	3	2	-1.0774	0.6296	40.6566		
	4	2	-2.9138	0.2884	3.869		
	4	3	-2.5998	0.3013	4.4569		

Linear regressior between mean-star smoothed survey indices at age

Y	age	X	age	I'cept	Slope	R2	(%)
	2	1	-0.4646	0.6377	61.5054		
	3	1	-1.3229	0.285	14.962		
	4	1	-2.5582	0.0541	0.35		
	3	2	-1.1201	0.7654	59.5139		
	4	2	-2.5234	0.42	9.1271		
	4	3	-1.8083	0.6938	29.1334		

16.4 External report stock assessment .csv file

Below are reported the formats of the .csv files to be used when the reports on stock assessments are used to parameterize BEMTOOL.

Fishing Mortality			
Age	2008	2009	2010
0	0	0	0
1	0.1	0.2	0.1
2	1	0.9	0.4
3	2.4	2.6	2.4
4	2.1	2.3	2.7
5	1.6	1.9	1.8
6	1.6	1.9	1.8
Natural Mortality			
Age	2008	2009	2010
0	1	1	1
1	1	1	1
2	0.6	0.6	0.6
3	0.42	0.42	0.42
4	0.36	0.36	0.36
5	0.33	0.33	0.33
6	0.31	0.31	0.31
Maturity			
Age	2008	2009	2010
0	0	0	0
1	0.1	0.1	0.1
2	0.9	0.9	0.9
3	1	1	1
4	1	1	1
5	1	1	1
6	1	1	1
stock.n			
Age	2008	2009	2010
0	78262	51944	58061
1	78262	51944	58061
2	45420	26592	16216
3	10453	8822	6052
4	455	632	452
5	23	40	45
6	0	0	0
stock.wt			
Age	2008	2009	2010
0	0.005	0.005	0.005
1	0.01	0.01	0.01
2	0.04	0.04	0.04
3	0.056	0.056	0.056
4	0.062	0.062	0.062
5	0.106	0.106	0.106
6	0.117	0.117	0.117

catch.n												
Age	2008	2009	2010									
0	0	0	0									
1	3802.4	5038	2259.7									
2	23198	12214.2	4095.7									
3	8351.4	7186.5	4849.1									
4	353.26	506.52	379.2									
5	16.79	30.43	33.35									
6	0.23	0.04	0.02									
catch.wt												
Age	2008	2009	2010									
0	0.005	0.005	0.005									
1	0.01	0.01	0.01									
2	0.04	0.04	0.04									
3	0.056	0.056	0.056									
4	0.062	0.062	0.062									
5	0.106	0.106	0.106									
6	0.117	0.117	0.117									
catch by fleet												
Age	2008	2008	2008	2008	2009	2009	2009	2009	2010	2010	2010	2010
0	0	0	0	0	0	0	0	0	0	0	0	0
1	950.6	950.6	950.6	950.6	1259.5	1259.5	1259.5	1259.5	564.925	564.925	564.925	564.925
2	5799.5	5799.5	5799.5	5799.5	3053.55	3053.55	3053.55	3053.55	1023.925	1023.925	1023.925	1023.925
3	2087.85	2087.85	2087.85	2087.85	1796.625	1796.625	1796.625	1796.625	1212.275	1212.275	1212.275	1212.275
4	88.315	88.315	88.315	88.315	126.63	126.63	126.63	126.63	94.8	94.8	94.8	94.8
5	4.1975	4.1975	4.1975	4.1975	7.6075	7.6075	7.6075	7.6075	8.3375	8.3375	8.3375	8.3375
6	0.0575	0.0575	0.0575	0.0575	0.01	0.01	0.01	0.01	0.005	0.005	0.005	0.005
landing.n												
Age	2008	2009	2010									
0	0	0	0									
1	3041.92	4030.4	1807.76									
2	18558.4	9771.36	3276.56									
3	6681.12	5749.2	3879.28									
4	282.608	405.216	303.36									
5	13.432	24.344	26.68									
6	0.184	0.032	0.016									
landing.wt												
Age	2008	2009	2010									
0	0.006	0.006	0.006									
1	0.012	0.012	0.012									
2	0.048	0.048	0.048									
3	0.0672	0.0672	0.0672									
4	0.0744	0.0744	0.0744									
5	0.1272	0.1272	0.1272									
6	0.1404	0.1404	0.1404									
landing by fleet												
Age	2008	2008	2008	2008	2009	2009	2009	2009	2010	2010	2010	2010
0	0	0	0	0	0	0	0	0	0	0	0	0
1	760.48	760.48	760.48	760.48	1007.6	1007.6	1007.6	1007.6	451.94	451.94	451.94	451.94
2	4639.6	4639.6	4639.6	4639.6	2442.84	2442.84	2442.84	2442.84	819.14	819.14	819.14	819.14
3	1670.28	1670.28	1670.28	1670.28	1437.3	1437.3	1437.3	1437.3	969.82	969.82	969.82	969.82
4	70.652	70.652	70.652	70.652	101.304	101.304	101.304	101.304	75.84	75.84	75.84	75.84
5	3.358	3.358	3.358	3.358	6.086	6.086	6.086	6.086	6.67	6.67	6.67	6.67
6	0.046	0.046	0.046	0.046	0.008	0.008	0.008	0.008	0.004	0.004	0.004	0.004

discard.n												
Age	2008	2009	2010									
0	0	0	0									
1	760.48	1007.6	451.94									
2	4639.6	2442.84	819.14									
3	1670.28	1437.3	969.82									
4	70.652	101.304	75.84									
5	3.358	6.086	6.67									
6	0.046	0.008	0.004									
discard.wt												
Age	2008	2009	2010									
0	0.0038	0.0038	0.0038									
1	0.0076	0.0076	0.0076									
2	0.0304	0.0304	0.0304									
3	0.04256	0.04256	0.04256									
4	0.04712	0.04712	0.04712									
5	0.08056	0.08056	0.08056									
6	0.08892	0.08892	0.08892									
discard by fleet												
Age	2008	2008	2008	2008	2009	2009	2009	2009	2010	2010	2010	2010
0	0	0	0	0	0	0	0	0	0	0	0	0
1	190.12	190.12	190.12	190.12	251.9	251.9	251.9	251.9	112.985	112.985	112.985	112.985
2	1159.9	1159.9	1159.9	1159.9	610.71	610.71	610.71	610.71	204.785	204.785	204.785	204.785
3	417.57	417.57	417.57	417.57	359.325	359.325	359.325	359.325	242.455	242.455	242.455	242.455
4	17.663	17.663	17.663	17.663	25.326	25.326	25.326	25.326	18.96	18.96	18.96	18.96
5	0.8395	0.8395	0.8395	0.8395	1.5215	1.5215	1.5215	1.5215	1.6675	1.6675	1.6675	1.6675
6	0.0115	0.0115	0.0115	0.0115	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001
F by fleet												
Age	2008	2008	2008	2008	2009	2009	2009	2009	2010	2010	2010	2010
0	0.13619	0.13619	0.13619	0.13619	0.13619	0.13619	0.13619	0.13619	0.13619	0.13619	0.13619	0.13619
1	0.805321	0.805321	0.805321	0.805321	0.805321	0.805321	0.805321	0.805321	0.805321	0.805321	0.805321	0.805321
2	0.763602	0.763602	0.763602	0.763602	0.763602	0.763602	0.763602	0.763602	0.763602	0.763602	0.763602	0.763602
3	0.483268	0.483268	0.483268	0.483268	0.483268	0.483268	0.483268	0.483268	0.483268	0.483268	0.483268	0.483268
4	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876
5	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876
6	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876	0.65876
Reference points												
	F	Total Yielc	Recruitme	SSB	Biomass							
f0.1	0.45	NA	NA	880	NA							
fmax	NA	NA	NA	NA	NA							
spr.30	NA	NA	NA	NA	NA							
msy	NA	NA	NA	NA	NA							
Age range for F bar												
min	max											
1	5											

16.5 Reference points .csv file

Below is reported the formats of the .csv files to be used when the Reference Points to be used are derived from off-line sources.

	F	Total Yield	Recruitment	SSB	Biomass
f0.1	0.134927219	1650.902719	23105.19531	13630.54454	14609.08602
fmax	0.19073715	1740.443295	23357.51388	10242.21889	11191.321
spr.30	0.207675273	1742.335028	23446.06807	9431.359089	10372.48629
msy	0.202823297	1742.666572	23420.09053	9654.989265	10598.35565
mey	NA	NA	NA	NA	NA

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