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< Description of the Impact Assessment bio-economic Model for fisheries management (IAM) >

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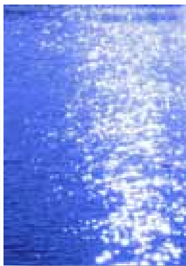


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** The date of the last on-line consultation*

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Description of the Impact Assessment bio-economic Model for fisheries management (IAM)

February 2011

1. Introduction

The Impact Assessment bio-economic Model for fisheries management (IAM) has been developed in the framework of the Bio-economic partnership working group project funded by the French Ministry of Agriculture and Fisheries in 2009-2010. The project aimed at gathering together an expert group of:
- fishermen/fishermen's representatives
- French administration
- Scientists (biologists, sociologists, fisheries economists,…)

to build methodologies to assess biological and socio-economic impacts of scenarios of :
- Fisheries management
- Evolution of the economic context (variation of input or output prices)
- Evolution of the environmental context (variation in recruitment…)

The methodological discussions and works have been based on three case studies covering the Channel, Atlantic and Mediterranean seas and characterized by various management and methodological context (figure 1). Some open interviews with the fishing sectors were conducted to evaluate the context and management stakes in the fisheries studied. Two working groups by case study (6 working groups in total) and two transversal working groups have gathered the participants. Fleets definitions, assumptions, limits and dynamics taken into account in the model were discussed in the project with participants. Several scenarios were tested for each case study and pertinent indicators to compare performances of various scenarios were selected.

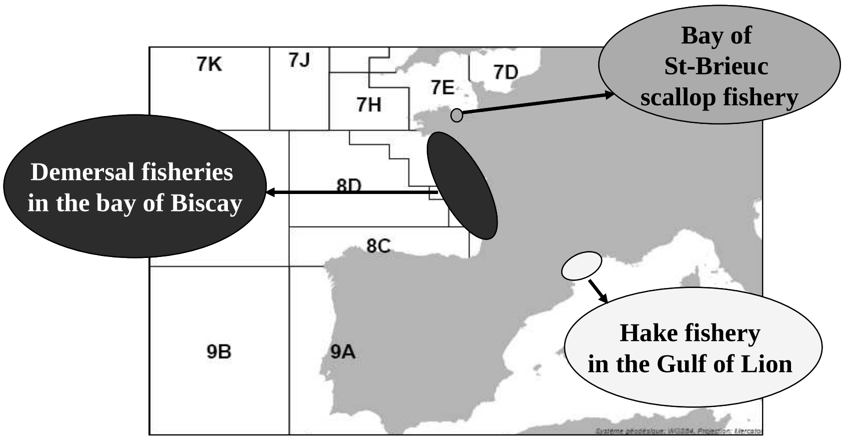

Figure 1- Case studies of the Bio-economic partnership working group project

The Impact Assessment bio-economic Model for fisheries management (IAM) developed in this context is described in this document.

2. Main characteristics of the IAM Model

The model has been developed in R/C++ to allow easy handling, flexibility and performance. The core of the program has thus been coded in C++ and the interface uses R for data handling, for outputs and to produce graphs.

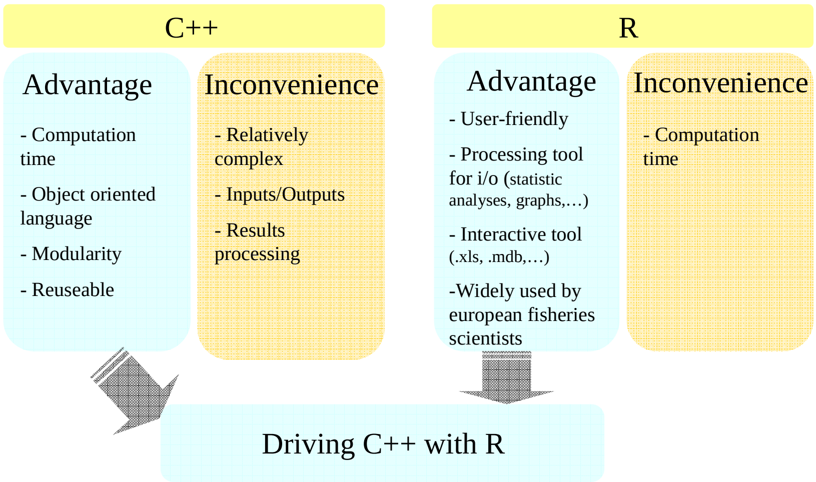

Figure 2- Compared Advantages and inconveniences of C++ and R

The use of two complementary programming languages (R/C++) enables to take advantage of both tools and to offset their disadvantages.

Parameterization is easy as the model uses directly the outputs of the assessment working groups (inputs for short term prediction) and a limited number of indicators calculated from DCF data. For the French fisheries, this process has been automated by linking the model to the Ifremer databases.

It is an integrated model coupling the biological dynamics of fish stocks with the economic dynamics to perform impact assessment for management plan taking into account the biological impacts and the economic impacts for fleets. The model assesses time step for each scenario the impacts in terms of F, SSB, Biomass, total catches, catches by fleet, Gross revenue, Gross cash flow.

It provides results on transition phases and can also provide results of cost benefit analysis of scenarios compared to status quo in terms of net present value.

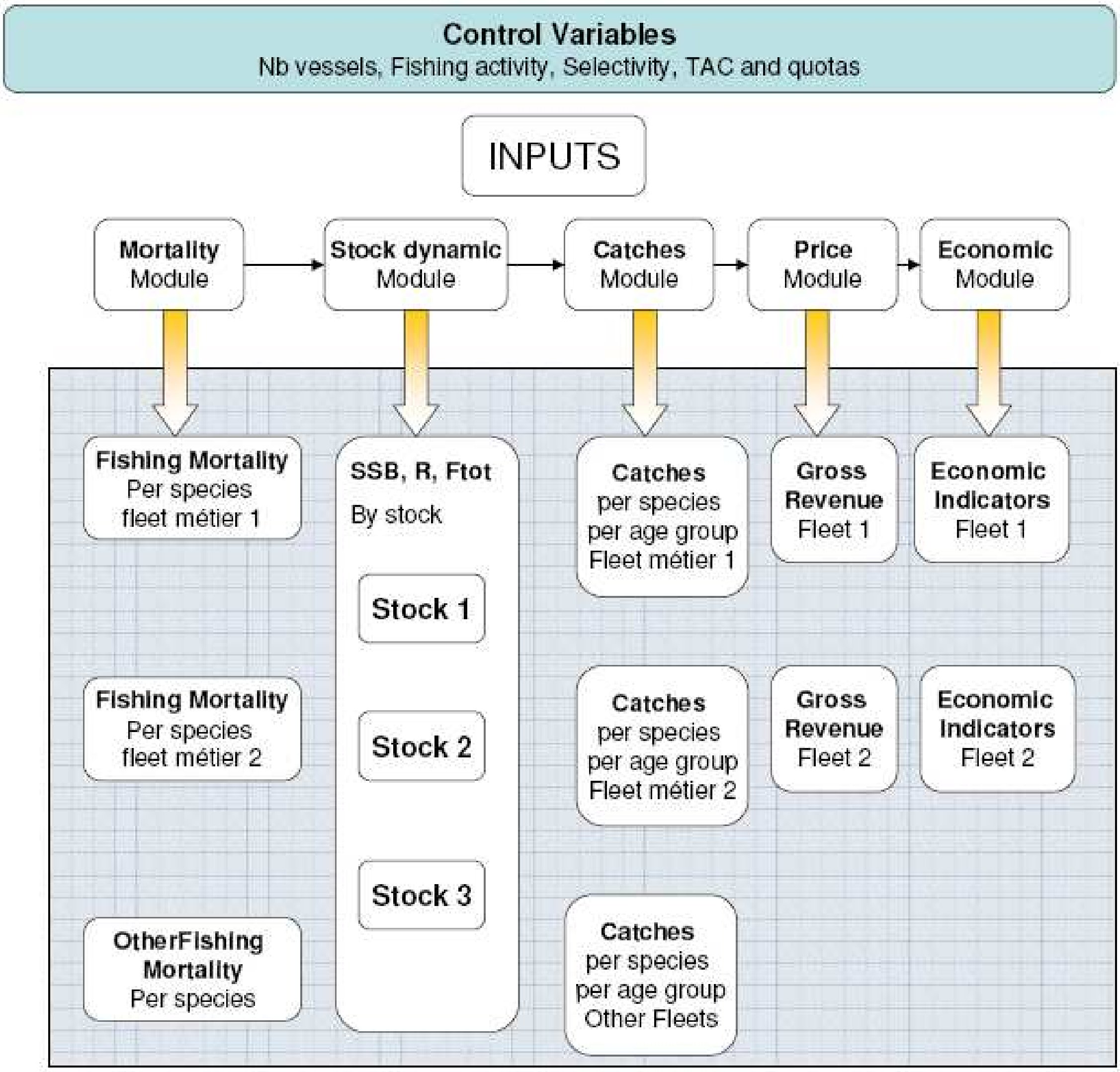

Figure 3- Simplified representation of the Impact Assessment bio-economic model for fisheries

The main characteristics of the model are the following:

- Stochastic model (only in recruitment for the moment).
- Age structured, yearly time steps, spatially aggregated.
- Multi species, multi fleet and multi-*métier*
- A mortality module splits fishing mortality between fleets according to métier by fleet based on landings proportion.
- Several kinds of market models are possible:
    - constant price assumptions
    - price-quantities relationship
    - price-importations/exportations relationship
- Economic dynamics such as fleet dynamics, catchability increase through investment or technical creeping, or short terms behaviours can been included.
- Several assumptions concerning impacts of scenarios on gross revenue are possible including reallocation of effort assumptions

The model is structured on a modular basis to allow flexibility in the development. Each module describes a process and works with a set of inputs and a declaration of the outputs. The modular structure enables to add extra functions.

The various control variables are:

- Selection pattern
- Fishing activity (i.e. fishing time, number of operations)
- Number of vessels
- TACs

The model can run simulations to test impacts of fixed TAC values or of fishing mortality objectives (FMSY) declined into a fishing mortality decrease schemes to reach objective a given year. Fishing activity or number of vessels are the control variables adapted accordingly.

When used for simulation, the program generates full time series data set and compiles several statistics:

- status of stocks (biomass, spawning biomass, fishing mortality, total catch)
- fleet performance (Total Gross Return, Total Gross Cash Flow of the fleet)
- individual performance by fleet (Mean Gross Return, mean Gross Cash Flow)
- total vessel number by fleet
- employment in the fishery
- crew salaries
- producer, consumer and state surplus variation ie rent (net present value)

The program can also be used through optimization (ex: rent maximization)

3. Notations and structure

3.1.Notations

The parameters of the bio-economic model use the following indices :

Symbols	Description
t	Time
f	fleet
m	métier
e	species
i_e	age (depends on species)
c_e	category (depends on species)

Table 1 – Definition of indices used in the model description.

3.2. Structure of the bio-economic model

The following flow-chart shows the variables of the simulation model and the relationship existing between them and more generally between the different modules. The input, intermediate and output variables have been separated and are presented, in the following sections, for each module.

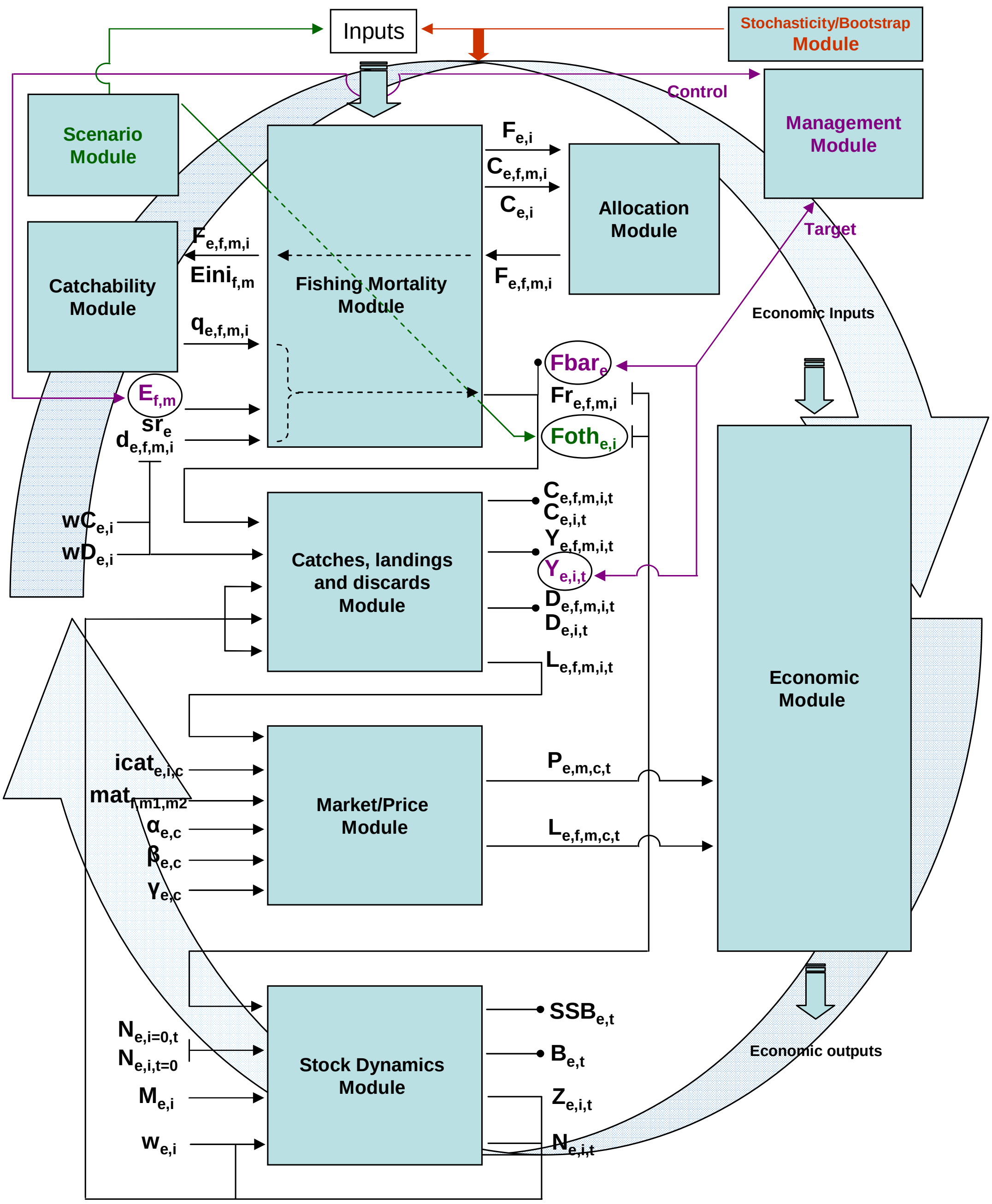

Figure 4 – Simplified flow-chart of the bioeconomic model.

4. Modules description

4.1. Fishing mortality and discards survival module

This module is divided into two sub-modules. The first sub-module carries out the splitting of total mortality rate into fleets, using their ratio in catch or landings at age. The second sub-module calculates a catchability coefficient which is used in the simulation to relate the control variable « effort » to the fishing mortality applied to the stock.

4.1.1. <u>Sub-module Fishing mortality allocation</u>

- **Initial parameters**

Notation	Description
$F_{e,i}$	Initial fishing mortality coefficient (here, by species and age)
$C_{e,f,m,i}$	Splitting variable at a given level (here, catch by species, métier and age)
$Ctot_{e,i}$	Total splitting variable (must be defined at the crossing level of the two previous variables)

Table 2 – Input parameters for the sub-module « fishing mortality allocation »

- **Calculated variable**

Notation	Type	Description	Equation
$F_{e,f,m,i}$	output	Instantaneous fishing mortality coefficient	$F_{e,f,m,i} = \frac{F_{e,i} \times C_{e,f,m,i}}{Ctot_{e,i}}$

Table 3 - Output parameters for the sub-module « fishing mortality allocation »

4.1.2. <u>Sub-module catchability estimation</u>

The catchability coefficient is estimated from the initial fishing mortality and corresponding fishing effort. In the simulation, fishing mortality rates are calculated from fishing effort assuming constant catchability.

- **Initial parameters**

Notation	Description
$Eini_{f,m}$	Initial effort by fleet and métier

Table 4 - Input parameters for the sub-module « catchability estimation »

- **Calculated variables**

Notation	Type	Description	Equation
$q_{e,f,m,i}$	Sortie	Catchability (by species, fleet, métier and age)	$q_{e,f,m,i} = \frac{F_{e,f,m,i}}{Eini_{f,m}}$

Table 5 - Output parameters for the sub-module « catchability estimation »

4.1.3. <u>Module Fishing mortality</u>

This module uses the two methods described above. It produces fishing mortality partitioned into fleets and métier. The *other* category contains residual fishing mortality not accounted for by the fleet or métier considered in the analysis.

- **Initial parameters**

Notation	Description
$d_{e,f,m,i}$	Percentage of total catch discarded in number (by species, fleet, métier and age)
sr_e	Survival rate of discards (by species)
$E_{f,m}$	Effort by fleet and metier

Table 6 - Input parameters of the module « Fishing mortality »

- **Calculated variables**

Notation	Type	Description	Equation
$K_{e,f,m,i}$	Internal	Correcting factor of fishing mortality linked to discards survival	$K_{e,f,m,i} = 1 - sr_e.d_{e,f,m,i}$
$Fr_{e,f,m,i,t}$	Output	Fishing mortality (by species, fleet, métier and age, at time *t*). Input for module *Catch* et *Population dynamics*	$Fr_{e,f,m,i,t} = q_{e,f,m,i}.E_{f,m,t}.K_{e,f,}$
$Foth_{e,i}$	Output	Initial morality « other fleets, other métier » by species and age. Input for module *Catch* et *Population dynamics*	$Foth_{e,i} = F_{e,i} - \sum_{f,m} Fr_{e,f,m,i,0}$

Table 7-Calculated parameters for module « Fishing mortality »

4.2.Module Population dynamics

- **Initial parameters**

Notation	Description
$N_{e,i,t=0}$ et $N_{e,i=0,t}$	Total number at age by species
$M_{e,i}$	Natural mortality rate by age and species
$w_{e,i}$	Weight at age by species

Table 8- Initial parameters for the module « Population dynamics »

- **Calculated variables**

Notation	Type	Description	Equation
$Z_{e,i,t}$	Output	Total mortality rate (by species and age at time t). Input to module *Catch*.	$Z_{e,i,t} = M_{e,i} + \sum_{f,m} Fr_{e,f,m,i,t} + Foth_{e,i}$
$N_{e,i,t}$	Output	Number at age by species at time t.	$N_{e,i+1,t+1} = N_{e,i,t}.e^{-Z_{e,i,t}}$, et $N_{e,i+1,t+1} = N_{e,i,t}.e^{-Z_{e,i,t}} + N_{e,i+1,t}.e^{-Z_{e,i+1,t}}$ For + group
$B_{e,t}$	Output	Total biomass by species at time t.	$B_{e,t} = \sum_{i} N_{e,i,t}.w_{e,i}$

Table 9 - Calculated parameters for the module «Population dynamics »

4.3.Module Catch, discards and landings

- **Initial parameters**

Notation	Description
$wD_{e,i}$	Average weight of discarded individual by species and age
$wC_{e,i}$	Average weight of individual in the catch by species and age

Table 10 - Initial parameters in the module « Catch, discards and landings »

- **Calculated variables**

Notation	Type	Description	Equation
$C_{e,f,m,i,t}$	Output	Catch in numbers (by species, fleet, métier and age over period t).	$C_{e,f,m,i,t} = \frac{Fr_{e,f,m,i,t}}{Z_{e,i,t}} \times N_{e,i,t} \times (1-e^{-Z_{e,i,t}})$
$C_{e,i,t}$	Output	Catch in numbers (by species and age over period t)	$C_{e,i,t} = \frac{\sum_{f,m} Fr_{e,f,m,i,t} + Foth_{e,i}}{Z_{e,i,t}} \times N_{e,i,t} \times (1-e^{-Z_{e,i,t}})$
$Y_{e,f,m,i,t}$	Output	Catch in weight (by species, fleet, métier and age over period t).	$Y_{e,f,m,i,t} = wC_{e,i} \times C_{e,f,m,i,t}$
$Y_{e,i,t}$	Output	Catch in weight (by species and age over period t).	$Y_{e,i,t} = wC_{e,i} \times C_{e,i,t}$
$D_{e,f,m,i,t}$	Output	Discards in weight (by species, fleet, métier and age over period t).	$D_{e,f,m,i,t} = d_{e,f,m,i} \times wD_{e,i} \times C_{e,f,m,i,t}$ si $wD_{e,i}$ disponible, $D_{e,f,m,i,t} = d_{e,f,m,i} \times Y_{e,f,m,i,t}$ sinon.
$L_{e,f,m,i,t}$	Output	Landings in weight (by species, fleet, métier and age over period t). Input in module *Market*.	$L_{e,f,m,i,t} = Y_{e,f,m,i,t} - D_{e,f,m,i,t}$

Table 11 – Calculated parameters for the module « Catch, discards and landings »

4.4.Market/price Module

The market/price module has two functions:
The first function is to aggregate productions by age and species into productions by grade and species according to an age-grade key matrix.
The second function is to calculate the price by grade and species that can either be an input parameter or result from a price model function (of the production by grade, the importations, exportations etc.). In the second case parameters of the price model are included in the input file. The following table gives an example of price function that could be implemented in the model.

- **Initial parameters**

Notation	Description
$\alpha_{e,c}$	Constant of the price model specific to each commercial grade *c*
$\beta_{e,c}$	Price elasticity of grade *c*
$\gamma_{e,c}$	Cross elasticity with other grades for grade *c*
$icat_{e,i,c}$	Transformation Matrix for age/grade by species: $P_e(c/i)$
$mat_{f,m1,m2}$	Correspondance métier-species-grade with métier

Table 12 –Initial Parameters for the Price/market module

- **Calculated variables**

Notation	Type	Description	Equation
$L_{e,f,m1,c,t}$	Internal	Catches in Weight (by species, fleet, initial metier-species, grade for t)	$L_{e,f,m1,c,t} = \sum_{i}(L_{e,f,m1,i,t} \times icat_{e,i,c})$
$L_{e,f,m,c,t}$	Output	Catches in Weight (by species, fleet, metier, grade for t) input of the economic module	$L_{e,f,m,c,t} = \sum_{(f,m1)\perp mat_{f,m1,m}=1} L_{e,f,m1,i,t}$
$P_{e,c,t}$	Output	Mean price (by species, grade for t) input of the economic module	$\ln P_{e,c,t} = \alpha_{e,c} + \beta_{e,c} \times \ln(\sum_{f,m} L_{e,f,m,c,t}) + \gamma_{e,c} \times \ln(\sum_{f,m,cat \neq c} L_{e,f,m,cat,t})$

Table 13 – Variables calculated for the Price/market module

4.5. Economic module

The economic module produces indicators of performances for consumers, state and producers including indictors for the whole fishery, by fleet, by mean vessel per fleet.
The economic module relies on input data based on data collected within the DCF[1]. Appendix VI of the European Decision No 199/2008 gives the following list of economic variables to be collected by fleet and member state.

Variable Group	Variable
Income	Gross value of landings Income from leasing out quota or other fishing rights Direct subsidies Other income
Personnel costs	Wages and salaries of crew Imputed value of unpaid labour
Energy costs	Energy costs
Repair and maintenance costs	Repair and maintenance costs
Other operational costs	Variable costs Non-variable costs Lease/rental payments for quota or other fishing rights
Capital costs	Annual depreciation
Capital value	Value of physical capital: depreciated replacement value Value of physical capital: depreciated historical value Value of quota and other fishing rights
Investments	Investments in physical capital
Financial position	Debt/asset ratio

[1] COMMISSION DECISION 2008/949/EC of 6 November 2008, adopting a multiannual Community programme pursuant to Council Regulation (EC) No 199/2008 establishing a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy.

Employment	Engaged crew FTE National FTE harmonised
Fleet	Number Mean LOA Mean vessel's tonnage Mean vessel's power Mean age
Effort	Days at sea Energy consumption
Number of fishing enterprises/units	Number of fishing enterprises/units
Production value per species	Value of landings per species Average price per species

Table 14 – Economic and transversal variables collected within the appendix VI (EC) No 199/2008

The model works with a subset of the economic and transversal indicators (landings data in quantity and value by species by fleet and metier) collected within the DCF and with other indicators from external data sources available. Inputs parameters are listed below.
The economic module calculates outputs indicators using economic indictors listed above and outputs from the biological and the market modules.

- **Input parameters**

Notation	**Description**	**Sources/ (type)**
TRANSVERSAL DATA		
nbv_f	Nb vessels	DCF/ (1)
nds_f	Days/ Days at sea	DCF/(1)
cnb_f	Employment	DCF/(1)
$GVL_{f,}$	Income_landing/ Gross value of landings	DCF/(1)
$L_{e,f}$	Landings by species and fleet, output from Catches module	DCF/(1)
$GVL_{e,f,}$	Income_landing/ Gross value of landings by species	DCF/(1)
If data by métier are available		
$L_{e,f,m}$	Landings by modelled species and fleet /metier, output from Catches module	DCF/(1)
$GVL_{e,f,m}$	Income_landing/ Gross value of landings by metier by modelled	DCF/(1)
$GVL_{f,m}$	Income_landing/ Gross value of landings metier	DCF/(1)
$nds_{f,m}$	Days/ Days at sea by fleet and métier	DCF/(1)
DCF ECONOMIC DATA		
Fc_f	Fuelcost/ Energy costs	DCF/(1)
$Fvol_f$	Fuelcons/ Energy consumption	DCF/(1)
ovc_f	Varcost/ variable costs	DCF/(1)
rep_f	Repcost/ Repair and maintenance costs	DCF/(1)
$Fixc_f$	Fixedcost/ non variable costs	DCF/(1)
ccw_f	Crew costs wages	DCF/(1)
dep_f	Depreciation	DCF/(1)

K_f	Capital	DCF/(1)
If data by métier are available		
Fc_{fm}	Fuelcost/ Energy costs	
$Fvol_{fm}$	Fuelcons/ Energy consumption	
ovc_{fm}	Varcost/ variable costs	
ECONOMIC DATA FROM EXTERNAL SOURCES		
lc_f	Landing costs (% GR)	External data sources/ (2)
nbh_f	Nb of hours at sea by year Harmonized reference 2000 h (250 days at sea* 8 hours/day)	External data sources/ (2)
$cshr_f$	Crew share (% of the Return to be Shared)	External data sources/ (2)
mwh	Net Minimum national wage	External data sources/ (2)
$mwhg$	Gross Minimum national wage	External data sources/ (2)
ic_f	Interest	External data sources/ (2)
eec_f	Crew costs contribution	External data sources/ (2)

Table 15 –Inputs parameters of the economic module

- **Calculated variables**

Indicators of type ini are intermediate indicators calculated at the beginning from the input data and used in the model after to calculate the output indicators. Indicators denoted 1 in the last column can be calculated only with DCF data, indicators denoted 2 requires external data sources that are not available in any case.

Notation	Type	Description	Equation	Data sources
Indicators ini				
$GVLoths_{f,}$	Ini	GR other species by fleet	$GVLoths_f = GVL_f - \sum_e GVL_{e,f}$	1
$GVLothsue_f$	Ini	GR other species by fleet and unit of effort in case uef=uefm	$GVLothsue_f = \frac{GVLoths_f}{ue_f}$	1
$GVLothsue_f$	Ini	GR other species by fleet and unit of effort in case Cas uef<>uefm	$GVLothsue_f = \frac{GVLoths_f}{(ue_f - \sum_m ue_{f,m})}$	1
If data by métier are available				
$GVLoths_{f,m}$	Ini	GR other species by fleet métier	$GVLoths_{f,m} = GVL_{f,m} - \sum_e GVL_{e,f,m}$	1
$GVLothsue_{f,m}$	Ini	GR other species by fleet and unit of effort métier	$GVLothsue_{f,m} = \frac{GVLoths_{f,m}}{ue_{f,m}}$	1
$GVLothmet_f$	Ini	GR other métiers by fleet	$GVLothmet_f = GVL_f - \sum_m GVL_{f,m}$	1
$GVLothmetue_f$	Ini	GR other métiers by fleet and unit of effort	$GVLothmetue_f = \frac{GVLothmet_f}{ue_f - \sum_m ue_{f,m}}$	1

pf_f	Ini	Fuel price euros/L	$pf_f = \frac{Fc_{fini}}{Fvol_{fini}}$	1
$Fvolue_f$	Ini	Fuel consumption by unit of effort (nb of days at sea)	$Fvolue_f = \frac{Fvol_{fini}}{nds_{fini}}$	1
$ovcue_f$	Ini	Other variable costs by unit of effort	$ovcue_f = \frac{ovc_{fini}}{nds_{fini}}$	1
$ovcGvl_f$		option b: ovcGvl: other variable costs as a percentage of the gross value of landings	$ovcGvl_f = \frac{ovc_{fini}}{GVL_{fini}}$	1
Output indicators				
GVL_f	Output	Total gross revenue by fleet	a. $GVL_f = \sum_{e,c}(P_{e,c} \times L_{e,f,c}) + GVLothsue_f * ue_f$ if it is assumed that the fleet has only one métier b. $GVL_f = \sum_{e,c}(P_{e,c} \times L_{e,f,c}) + GVLothsue_f * (ue_f - \sum_m ue_{f,m})$ if it is assumed that the GR other species comes from other metier and that there is a reallocation of effort when effort of the modelled metier decreases (requires an estimation of the effort by metier) c. $GVL_f = \sum_{e,c}(P_{e,c} \times L_{e,f,c}) + GVLoths_f$ if it is assumed that the GR other species comes from other metier and that there is no reallocation of effort (requires an estimation of the effort by metier)	1
If data by métier are available				
$GVL_{f,m}$	Output	Total gross revenue by fleet métier	$GVL_{f,m} = \sum_{e,c}(P_{e,c} \times L_{e,c,f,m}) + GVLothsue_{f,m} * ue_{f,m}$	
GVL_f	Output	Total gross revenue by fleet	a. $GVL_f = \sum_m GVL_{f,m} + GVLothmetue_f * (ue_f - \sum_m ue_{f,m})$ if it is assumed that there is a reallocation of effort when effort of the modelled metier decreases	

			b. $GVL_f = \sum_{e,c}(P_{e,c} \times L_{e,f,c}) + GVLothmet_f$ if it is assumed that there is no reallocation of effort	
Output indicators calculated regardless of métier data availability				
$GVLav_f$	Output	Mean gross revenue by vessel by fleet	$GVLav_f = \frac{GVL_f}{nbv_f}$	1
$rtbs_f$	Output	Return to be shared by vessel by fleet	$rtbs_f = GVLav_f - pf_f.Fvolue_f.nds_f - ovcu$	1
gva_f	Output	Gross Value Added by vessel by fleet	$gva_f = GVLav_f - pf_f.Fvolue_f.nds_f.$ $- ovcue_f..nds_f.- rep_f - Fixc_f$	1
gcf_f	Output	Gross Cash Flow by vessel by fleet	$gcf_f = GVLav_f - pf_f.Fvolue_f.nds_f$ $- ovcue_f.nds_f - rep_f - Fixc_f - ccw_f$	1
$ngcf_f$	Output	Net Cash Flow by vessel by fleet	$ngcf_f = gcf_f - dep_f$	1
gp_f	Output	Net Profit by vessel by fleet or Owner surplus	$gp_f = ngcf_f - ic_f$	1
If crew share unavailable				
Ccw_r_f	Ini	Crew costs share as a % of the RTBS	$Ccw\_r_f = \frac{Ccw_f Ini}{rtbs_f Ini}$ $= \frac{Ccw_f Ini}{(GVLav_f - pf_f.Fvolue_f.nds - ovc_f)Ini}$	1
Ccw_f	Output	Crew costs	$Ccw_f = Ccw\_r_f * rtbs_f$ $= Ccw\_r_f$ $*(GVLav_f - pf_f.Fvolue_f.nds_f - ovcue_f nds_f$	1
$CcwCr_f$	Output	Crew costs by crew member	$Ccw_{f\,f} = \frac{Ccw_f}{cnb_f}$	1
If crew share available				
$opersc_f$	Ini	Other crew costs = vacation, employer contribution, premium	$opersc_f = Ccw_f Ini - cshr_f * rtbs_f Ini$ $= Ccw_f Ini - cshr_f$ $*(GVLav_f - pf_f.Fvolue_f.nds - ovc_f)Ini$	2
Ccw_f	Output	Crew costs	$Ccw_f = cshr_f * rtbs_f + opersc_f$	2
$CcwCr_f$	Output	Crew costs by crew member	$Ccw_{f\,f} = \frac{Ccw_f}{cnb_f}$	2
$sshr_f$	Output	Owner share by vessel by fleet	$sshr_f = rtbs_f(1 - cshr_f)$	2
$cshrT_f$	Output	Crew share by vessel by fleet	$cshrT_f = cshr_f \times rtbs_f$	2

$wageg_f$	Output	Gross wage by crew member including crew contributions	$wageg_f = \frac{cshrT_f}{cnb_f}$	2
Surplus calculation				
csg_f	Output	Gross Labour surplus by fleet	$csg_f = cshr_f - oc\lg_f$	2
$oclg_f$	Output	Opportunity costs of Labour by fleet	$ocl_f = mwhg \times cnb_f \times nbh_f$	2
psg_f	Sortie	Total producer surplus by fleet (gross value)	$psg_f = nbv_f \times (csg_f + gp_f)$	2
$ncshr_f$	Output	Net crew share by fleet	$ncshr_f = cshrT_f - cce_f$	2
$wagen_f$	Output	Net wage by crew member	$wagen_f = \frac{ncshr_f}{cnb_f}$	2
cs_f	Sortie	Labour surplus by fleet	$cs_f = ncshr_f - ocl_f$	2
ocl_f	Sortie	Net Opportunity costs of Labour by fleet	$ocl_f = nmwh \times cnb_f \times nbh_f$	2
ps_f	Sortie	Total producer surplus by fleet	$ps_f = nbv_f \times (cs_f + gp_f)$	2
If landings costs available				
sts_f	Sortie	State surplus associated to one fleet	$sts_f = lc_f \times GVLav_f \times nbv_f$	2

Table 16 – Output variables of the economic module

Economic indicators can be calculated:

- by mean vessel by fleet
- by fleet
- for the whole fishery

to analyze impacts of scenarios on the individual performances of vessels, the performances of the fleets or the whole performances of the fishery.
Cost-benefit analyses of scenarios are evaluated through the total surplus variation (producer, consumer, and state surplus variation) of the scenario compared to status quo in term of net present value. Sensitivity to discount rate can be analysed.

4.6.Scenarios and management module

Control variables of the model are :

- The exploitation pattern through a selectivity factor
- The fishing effort through variations of the activity by vessel (number of days at sea) or of the number of vessels by fleet
- The TAC through the variation of activity and number of vessels such that the TAC is reached according to the stock abundance
- A Fishing mortality objective reached through time step decrease of number of days at sea or of number of vessels

Besides, all the input parameters can be modified through various scenarios at any time of the simulation. It is thus possible to test for example the impacts of evolution of :

- fuel price
- number of vessels by fleet
- ex-vessels prices
- …

4.7.Stochasticity module

For each variable of the model, this module can specify a probability law to take into account of uncertainties in the model.

4.8.Behaviour module

This module is under development. It is designed to include short and long term behaviours of investment/disinvestment, discarding, effort allocation, compliance, etc.

Tables and figures

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