Thessaloniki Cluster Meeting

20-21/10/2009

SSA 16 – Thermaikos Gulf, GR

“Sustainable management of mussel culture at the area of Chalastra”

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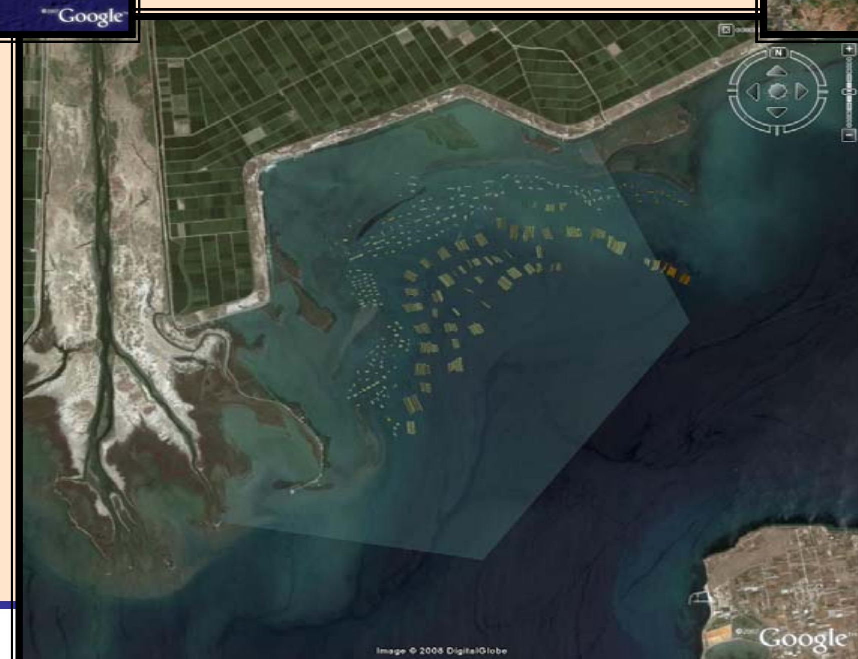
SIXTH FRAMEWORK PROGRAMME

THE STUDY AREA & THE POLICY ISSUE

Mytillus galloprovincialis - the Mediterranean mussel



- 55 long-line units
- more than 2000 people from the local population working at the sector

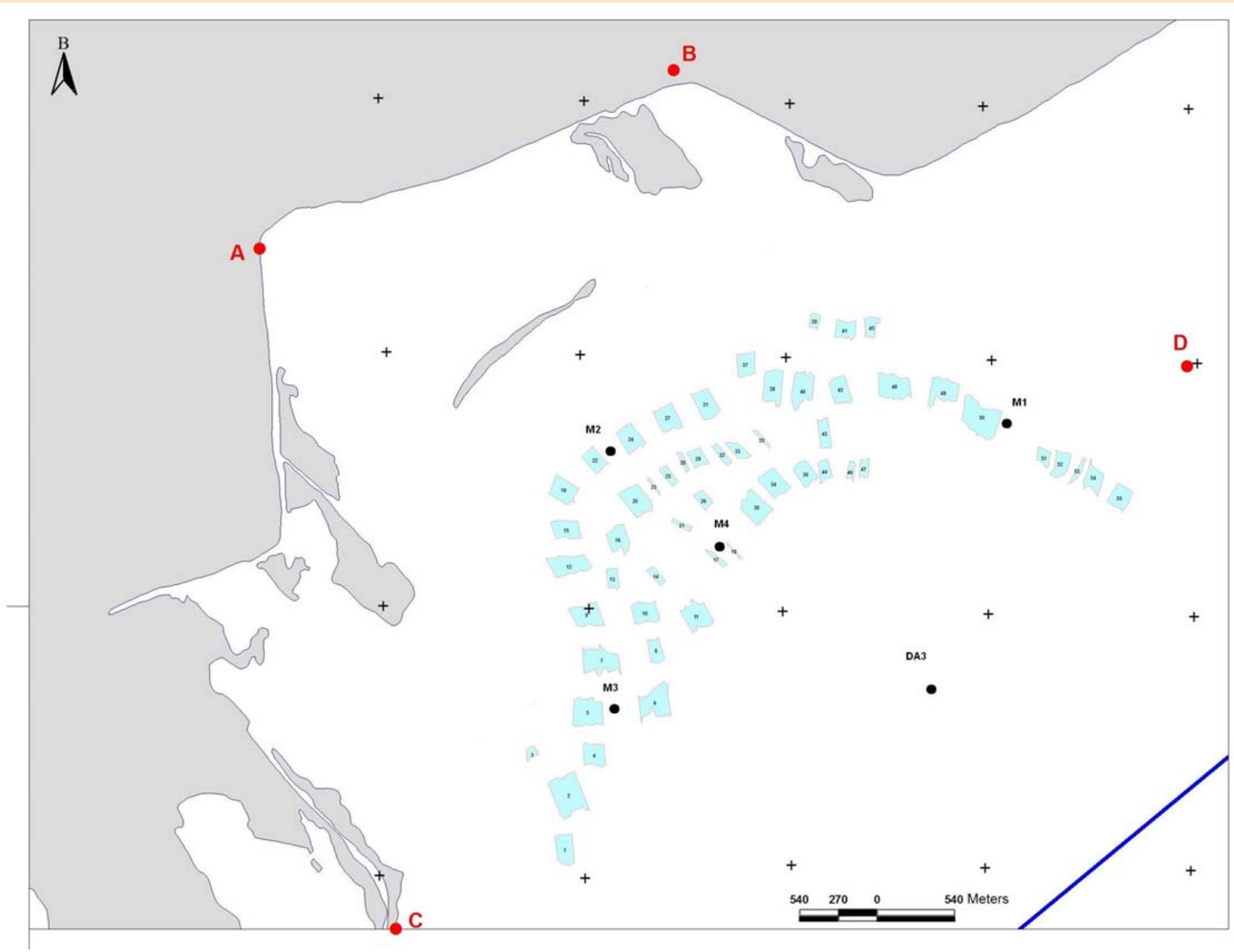
- 45-50% of the national production
- decline of the production
- severe institutional problems

THE STAKEHOLDERS & THE "REAL" PROBLEM

- the mussel farmers associations of Chalastra.
- the Authority for the Management of the Protection Area of Axios – Loudias – Aliakmonas estuaries.
- the Municipality of Chalastra.
- the Region of Central Macedonia (holding the property rights of the sea area and in charge for the activity permissions).
- the Organization for the Management of Thermaikos Gulf – Ministry of Macedonia and Thrace.
- the Ministry of Environment and Land Planning, Thessaloniki office.
- the Corporation of Water Supply and Drainage – Thessaloniki.
- the Prefecture of Thessaloniki.

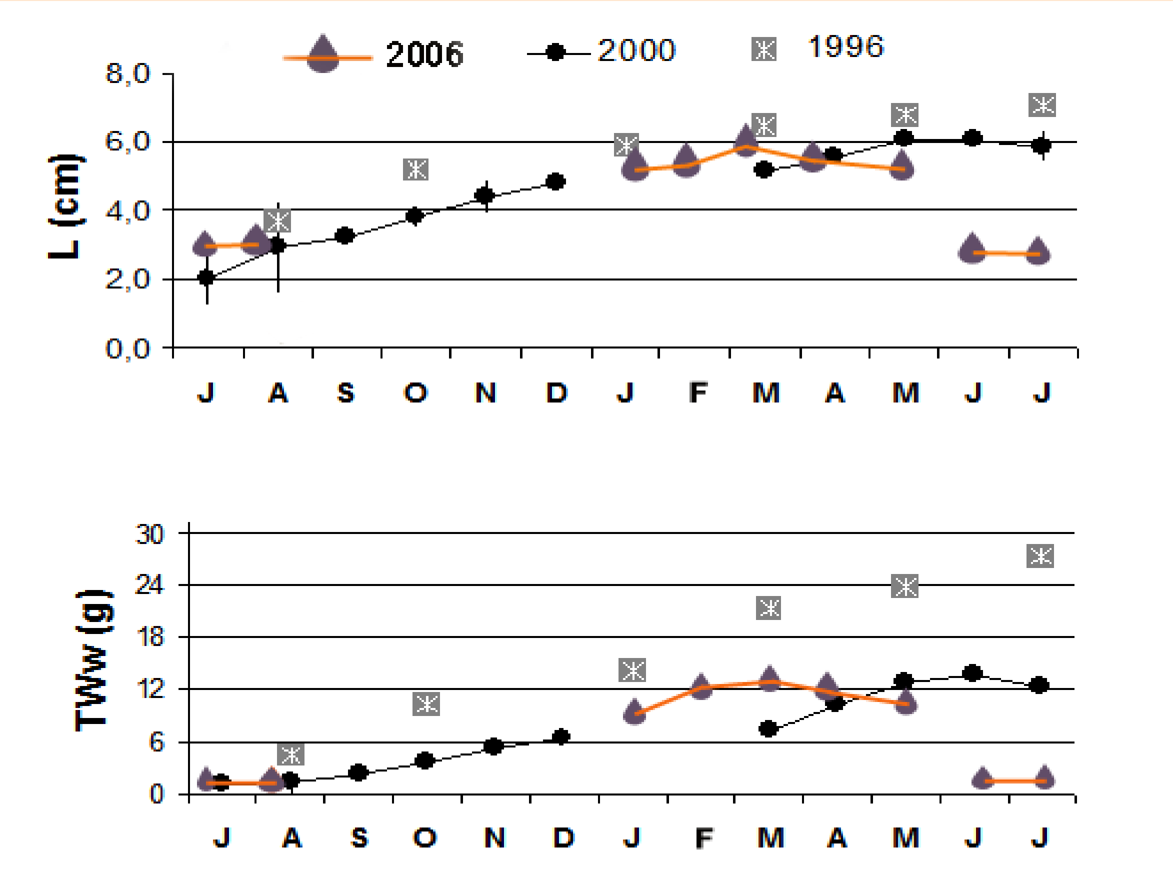
The mussel farmers, although they identify the modification of the environmental conditions in the area, do not want to confront the problem believing that they will be the ones that will be called to bear the "burden" of the solution. Also and most importantly, the farming area is a field of political and private interest, where multiple agreements are made "under the table". The Public Services knowing this situation are reluctant to participate.

FARMING AREA & SAMPLING STATIONS



- Stations M(i) are placed inside the farming area (data for chl-a, TOC, mean values of nutrients, mussels and management techniques).
- Station DA3 is placed near the farming area (data for chl-a, TOC, nutrients, salinity, etc).
- The quality of the data can not always be guaranteed.

DECLINE OF THE PRODUCTION

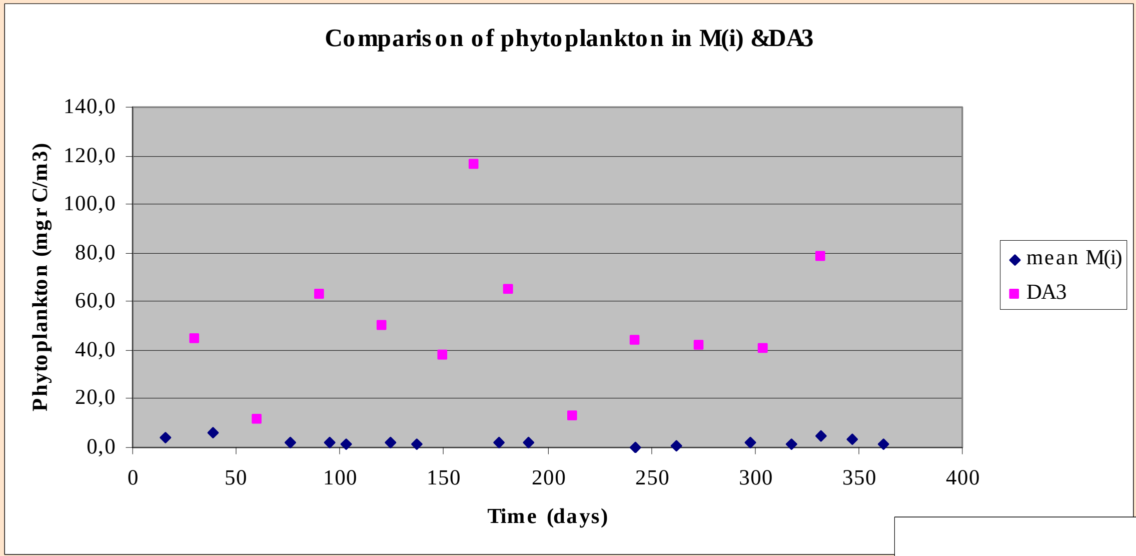


Source: (Kravva, 2000), (HCMR,2001), (ATEITh,2007)

- Between 1996 and 2000 there was an 40% increase of the number of the mussel farming units in the area.

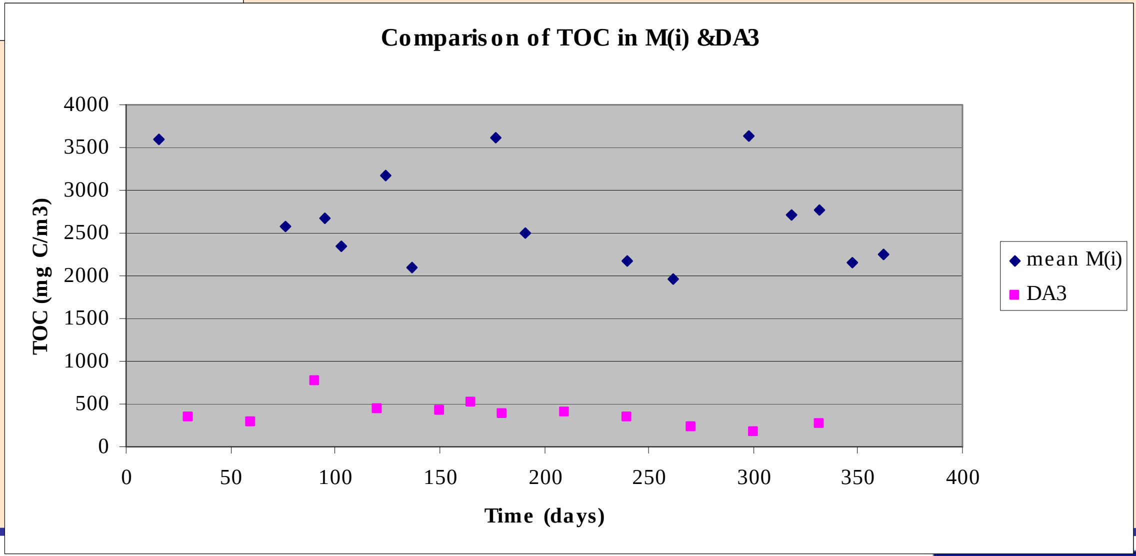
- The price of the mussels is the same for the last 10 years(0.40€/kg). Economically this mean a loss of value, controlled not only from the lower quality but also from intermediate dealers.

DATA COMPARISON



M(i): low chl-a concentrations – very high TOC concentrations compared to DA3. Also, although the values of NO2-NO3 are lower than in DA3, NH4 values are considerably higher than in DA3.

The way that the mussel farms are placed and the cultivation techniques are causing an important inhibition to distribution of the food and the "dilution" of the mussel's growth by-products, because of the reduction of the water velocity inside the area.



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A 3 COMPONENT MODEL

Model structure and components

Environmental comp

Exchange-Salinity

Biologically consumed Inorganic Nitrogen

Phytoplankton

TOC

Mussel farm comp

Available food

Assimilation efficiency

Cultivation techniques

Placing in the area

Total production

Socio-economic comp

Cost-Revenue-Profit

Legality costs

Benefits for the local community

(Environmental costs & benefits)

Mussel farm Component

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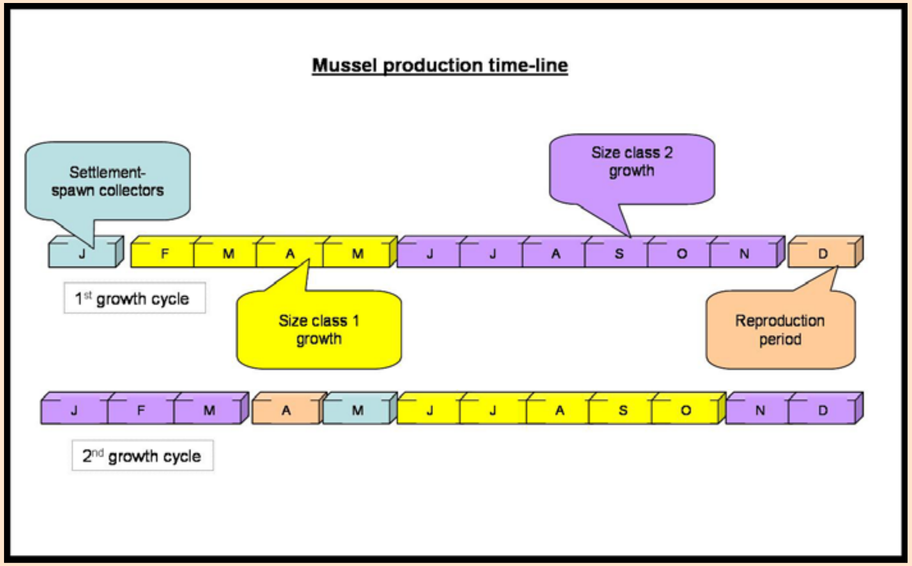
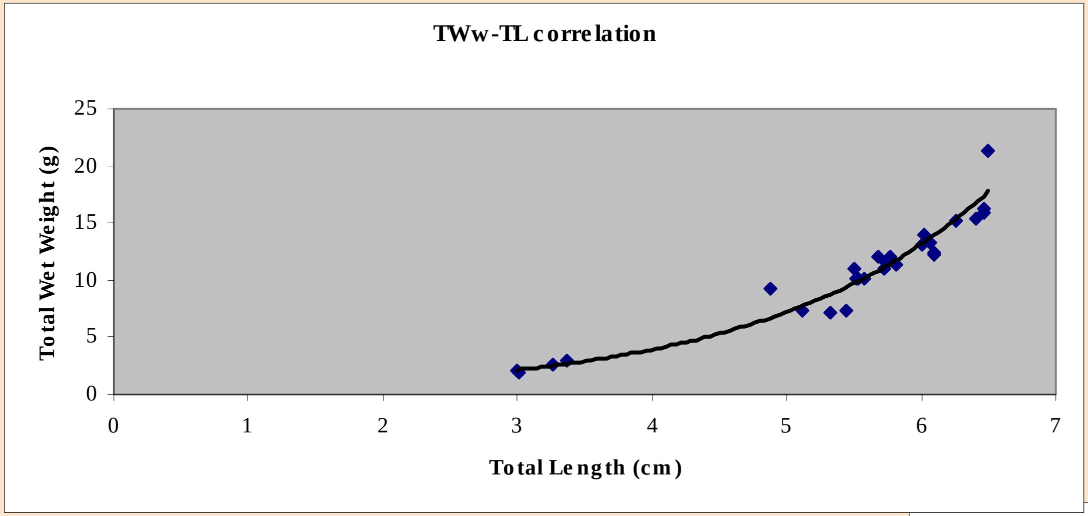
INTRODUCTIVE INFORMATION

- Two reproduction and growth circles that are occurring in the same year, in April and in December
- Although the spawn presents spatial variations, the produced quantity is in adequacy to support more farms than those established



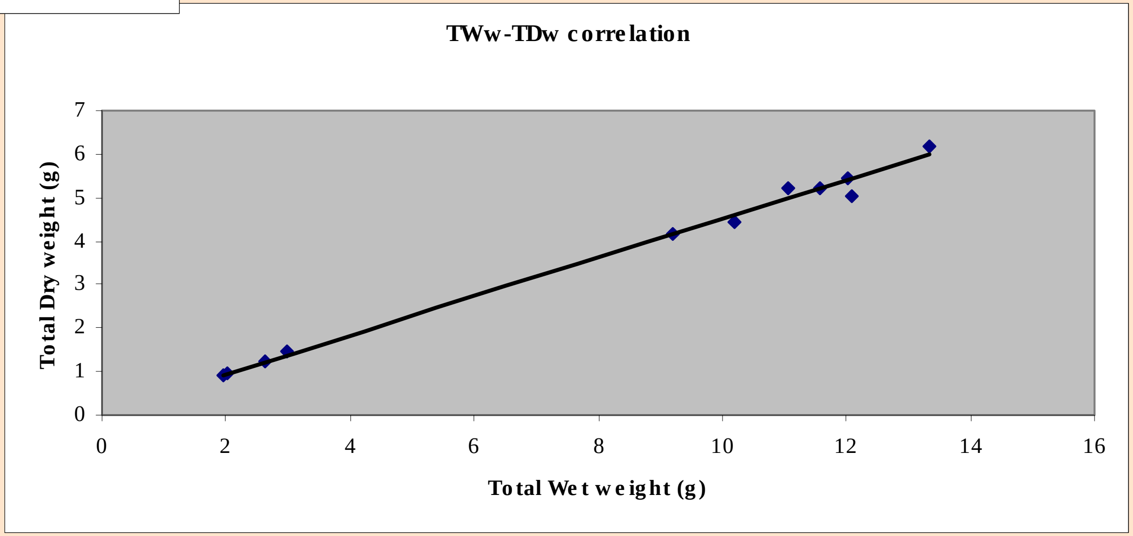
- Attempt to develop an approach fitting our requirements, representing the farm to the model and connecting the production both to **environment and cultivation characteristics**
- Results in **kg of mussels per m of cultivated sock,(kg mussels/m sock)**
- The farmers are placing the spawn collectors into the water during the two reproductive periods, until it reaches the critical size of 2 cm. Then they take the collectors out and the cultivation process begins, as they place the mussels into the first size class socks

INTRODUCTIVE INFORMATION



$$TWw=0.3557*e^{0.6018*L}$$
$$r^2=0.9659$$

$$TDw=0.4448*TWw+0.0562$$
$$r^2=0.9934$$



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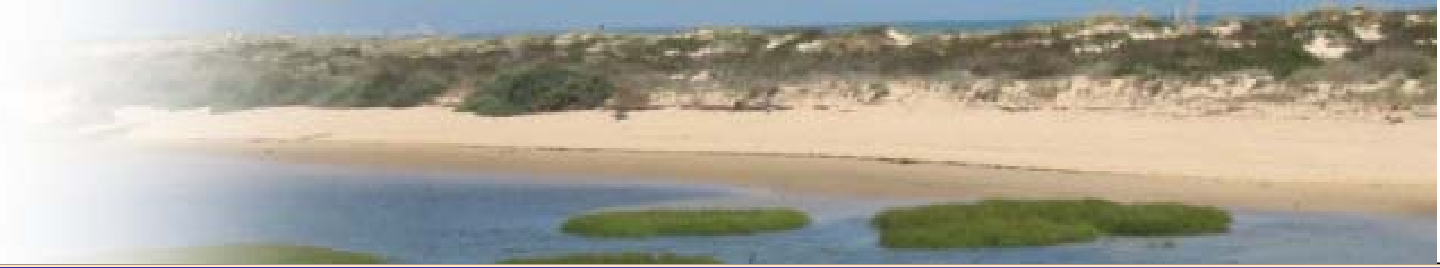
MUSSEL GROWTH EQUATION

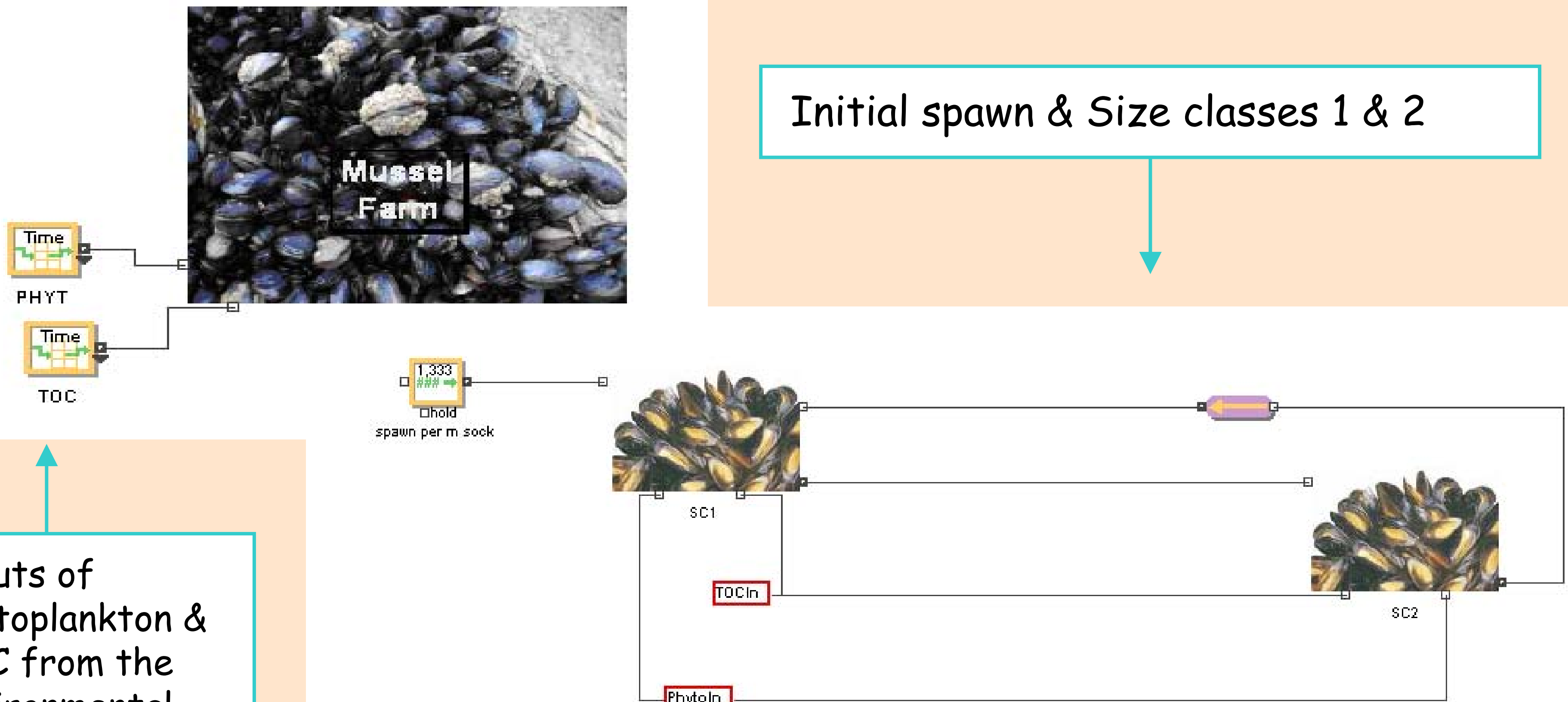
$$\frac{dMussels}{dt} = \begin{bmatrix} \{aMUSSELS \ * (fphyt \ * Gphyt \ + fpoc \ * Gpoc) * kDensity \ * k\} \\ - \{eMUSSELS \ + mMUSSELS\} \end{bmatrix} * Mussels$$

aMUSSELS	Maximum growth rate of the mussel's corresponded size class and reproductive period ($days^{-1}$)
fphyt	The assimilation efficiency of the mussels for phytoplankton (dimensionless)
fpoc	The assimilation efficiency of the mussels for POC (dimensionless)
Gphyt	Grazing factor of mussels on phytoplankton (dimensionless)
Gpoc	Grazing factor of mussels on POC (dimensionless)
km	Half saturation constant for mussel grazing (mg C/m^3)
kDensity	Coefficient describing the growth inhibition related to the farm density (dimensionless)
k	Coefficient, expressing the growth inhibition related to existence of the other mussel farms (dimensionless)
eMUSSELS	Excretion rate of the mussel's corresponded size class ($days^{-1}$)
mMUSSELS	The mussel mortality rate, strongly related to environmental conditions and most especially water temperature($days^{-1}$)

calculation of aMUSSELS from field observations – comparison to literature



MUSSEL FARM COMPONENT

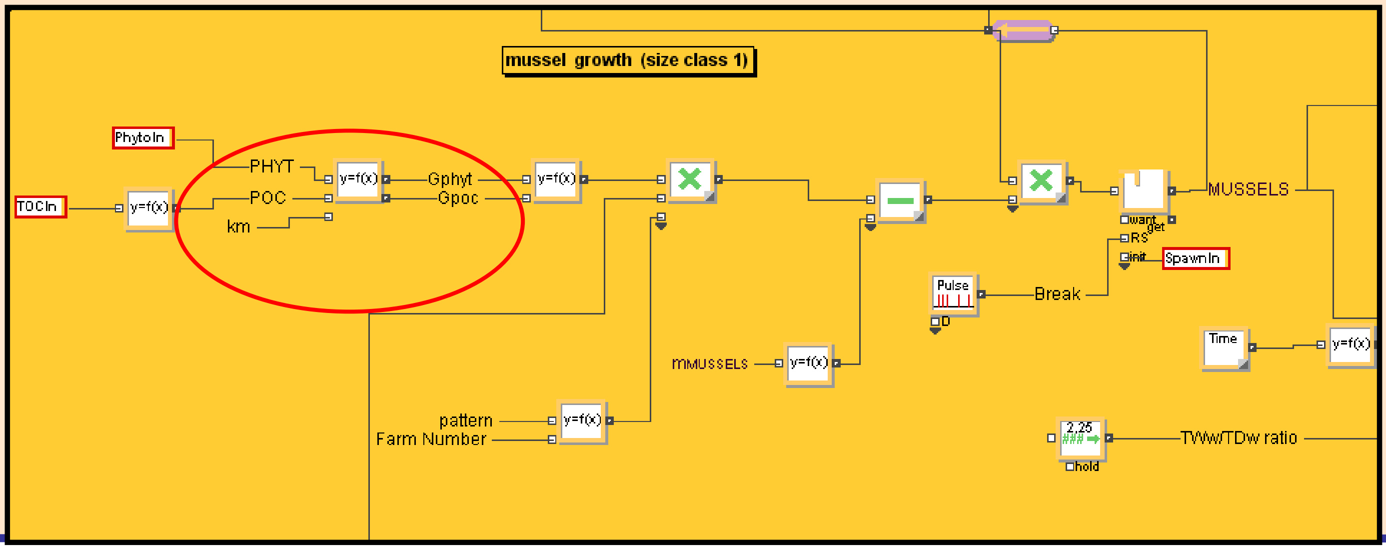


Initial spawn & Size classes 1 & 2

Inputs of phytoplankton & TOC from the Environmental component

MUSSEL FARM COMPONENT

(fphyt*Gphyt+fpoc*Gpoc) is representing the grazing of mussels on the available food. Gphyt & Gtoc are representing the corresponding grazing rates, using a Michaelis-Menten equation to express the effect of the food level on these rates and the fact that the mussels eat passively the most abundant food type. Fphyt & ftoc are representing the corresponding assimilation efficiencies of each food type



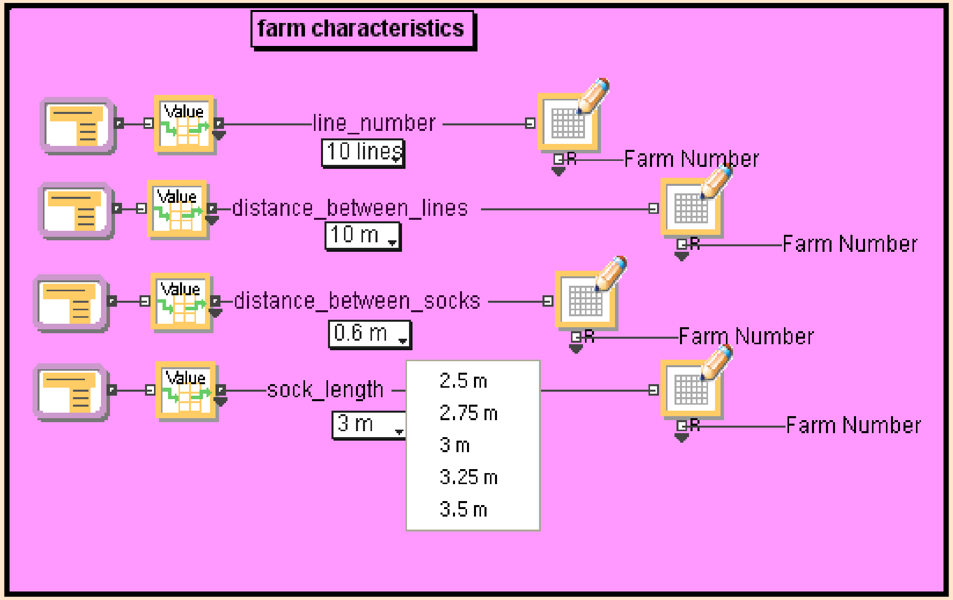
FARM'S CHARACTERISTICS

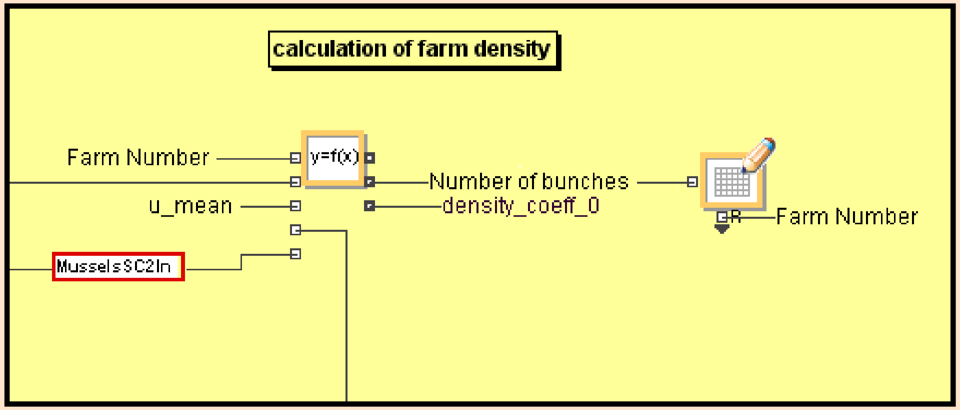
4 pop-up menus are controlling the farm's characteristics, used to calculate the density coefficient

the density coefficient produces a certain important inhibition to the production, as the more the density of the individual farm increases, more mussels are antagonizing for the same food and more the water circulation into the mussel farm is inhibited

$kDensity=\bar{u}/u_{required}$ where

U_{req}=f(mussels, farm characteristics

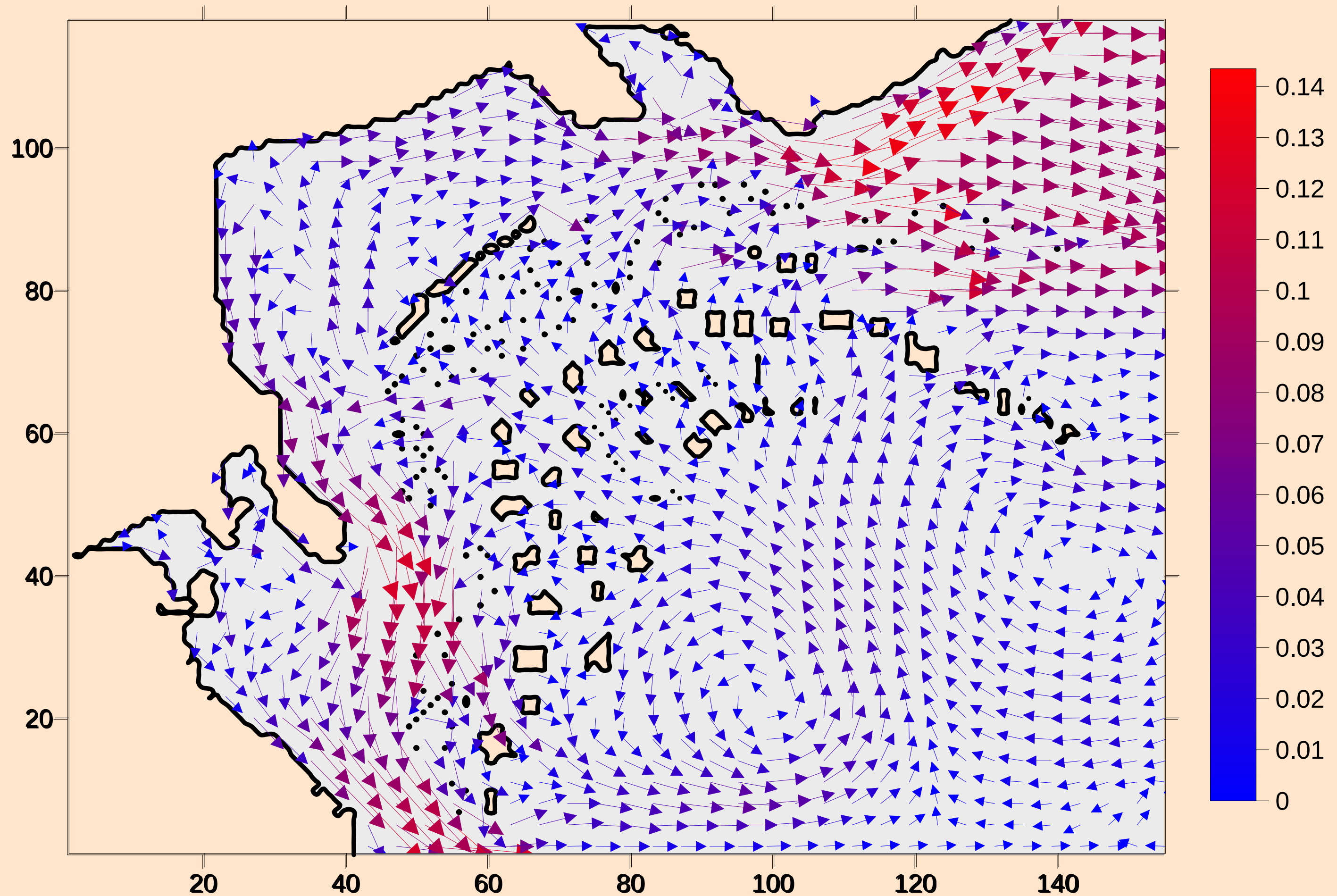




POSITION IN THE AREA

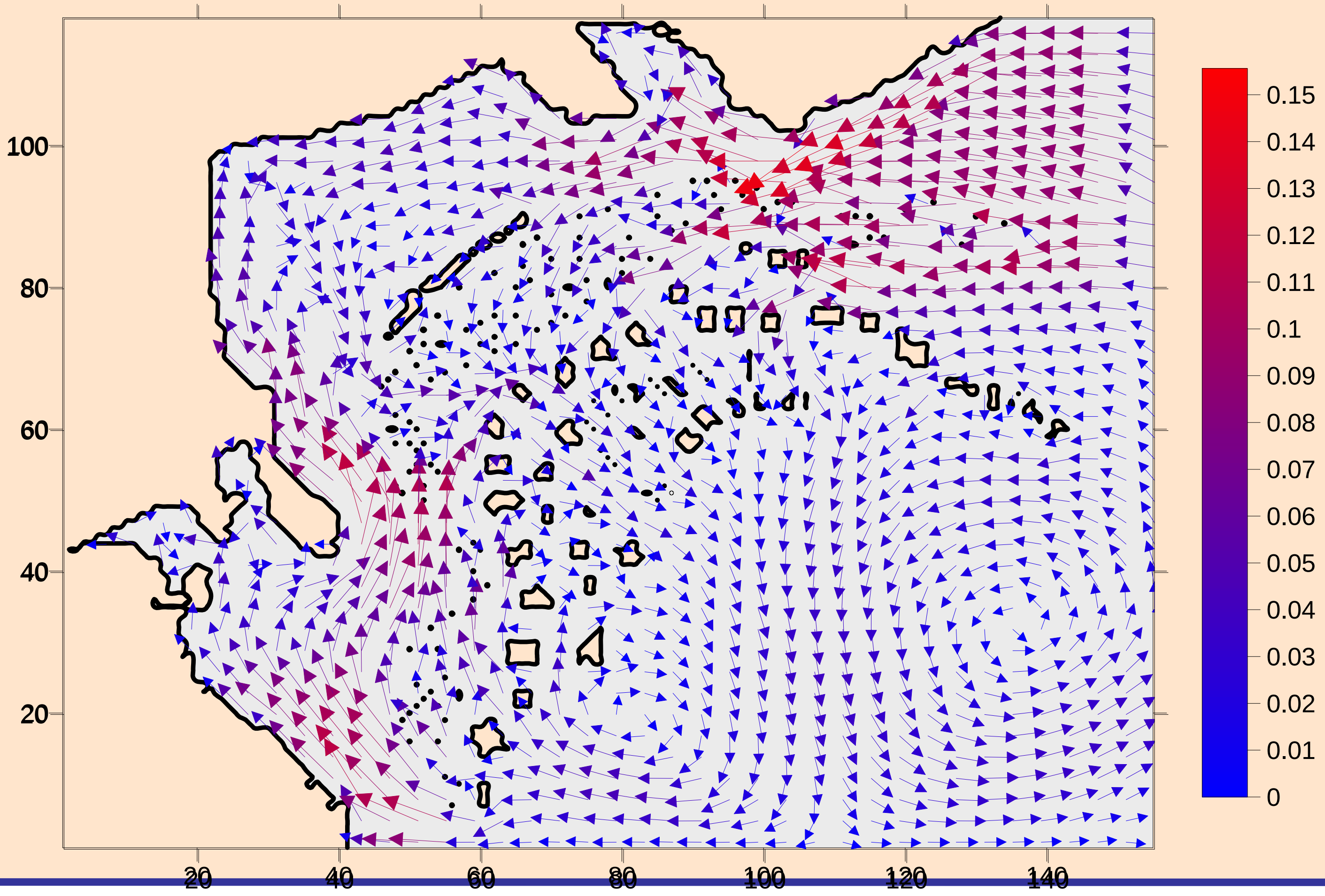
Circulation pattern under:

NW wind



POSITION IN THE AREA

Circulation pattern under:

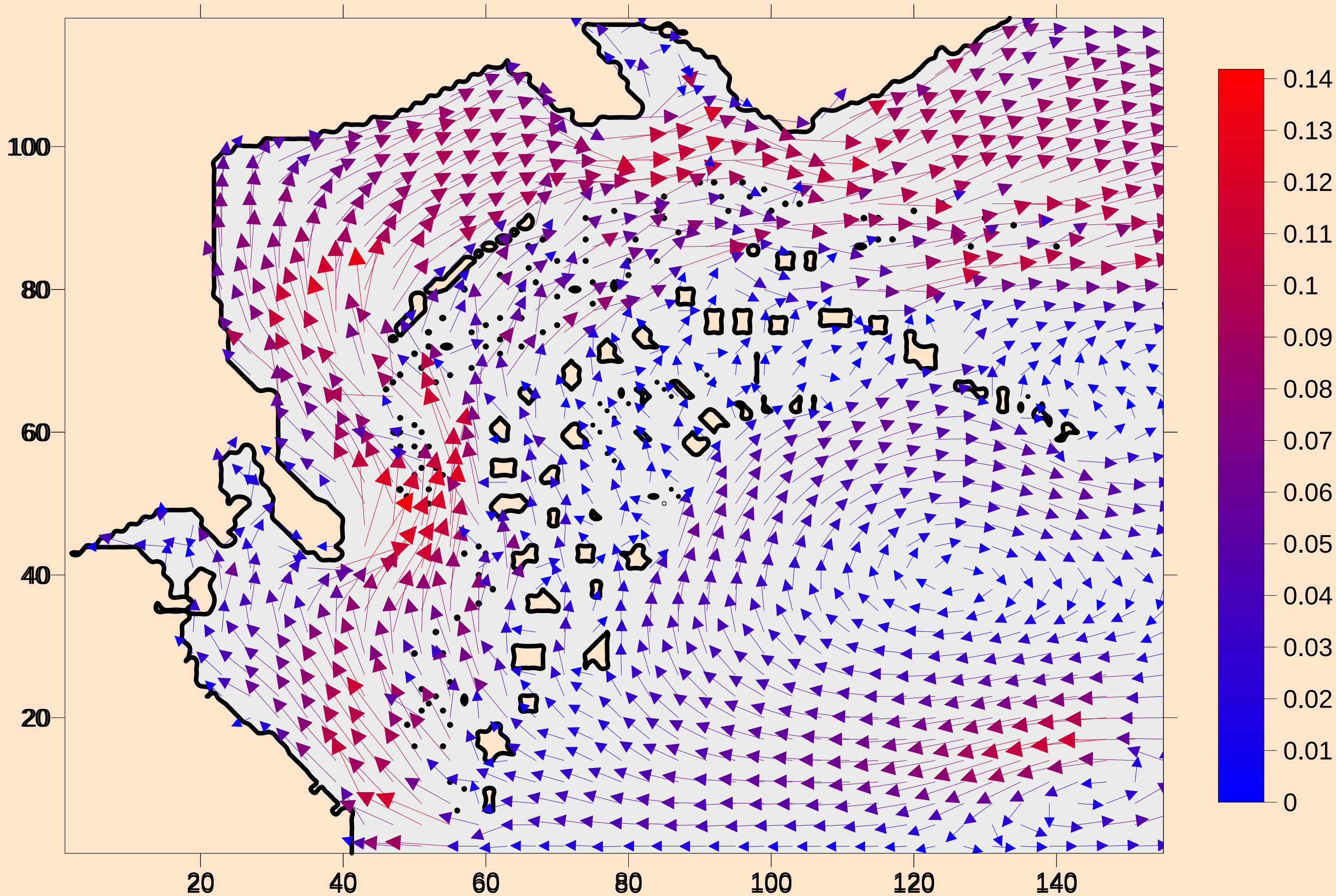


SE wind

POSITION IN THE AREA

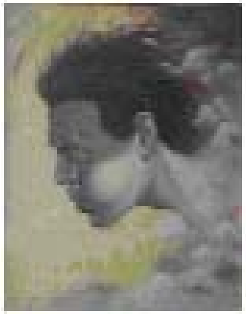
Circulation pattern under:

SW wind



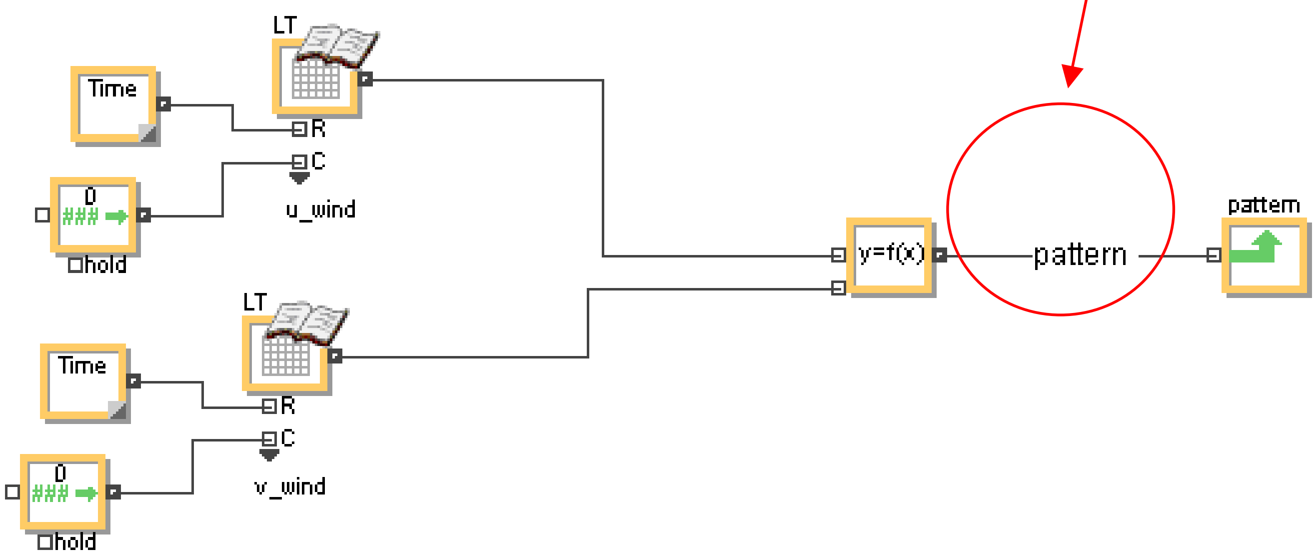
POSITION IN THE AREA

the k coefficient is changing with the circulation pattern determined from the wind observations at the area



wind current

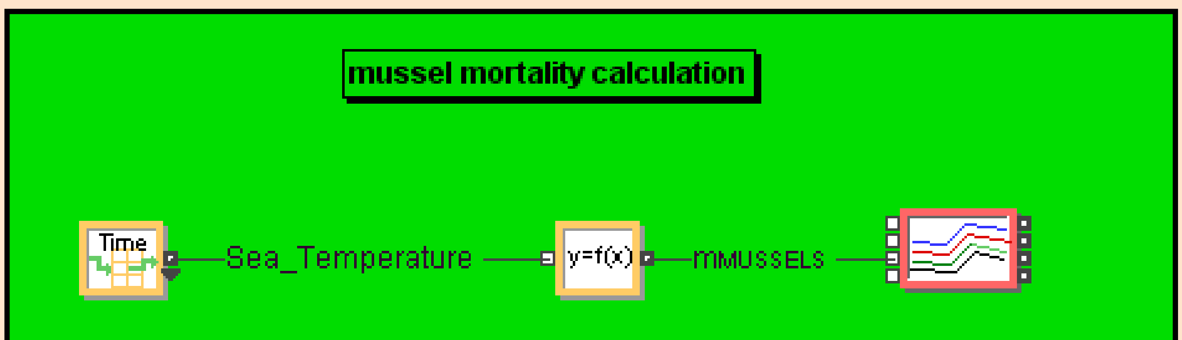
we combined wind observations with results from the circulation model and field measurements of the current velocity reduction to stations M(i) and produced the coefficient k that theoretically can take values between $0<k\leq1$, but in reality moves between 0.6 and 1, as the maximum current velocity reduction measured was 40%.



MUSSEL MORTALITY

If the Sea Temperature is not exceeding the threshold of $25\,^{\circ}C$, f = 0, i.e. the mussel mortality rate is neglected compared to the growth rate,
If the Sea Temperature is between 25 to $26\,^{\circ}C$ then f= 0,25 and
in the very rare occasion of water temperatures exceeding the $26^{\circ}\,C$, then f=0,5, i.e. the mussel mortality rate is 0,5 of the mussel's growth.

Mussel mortality rate is strongly connected to the water temperature, so if the temperature exceeds certain thresholds, mass mortality events occur.



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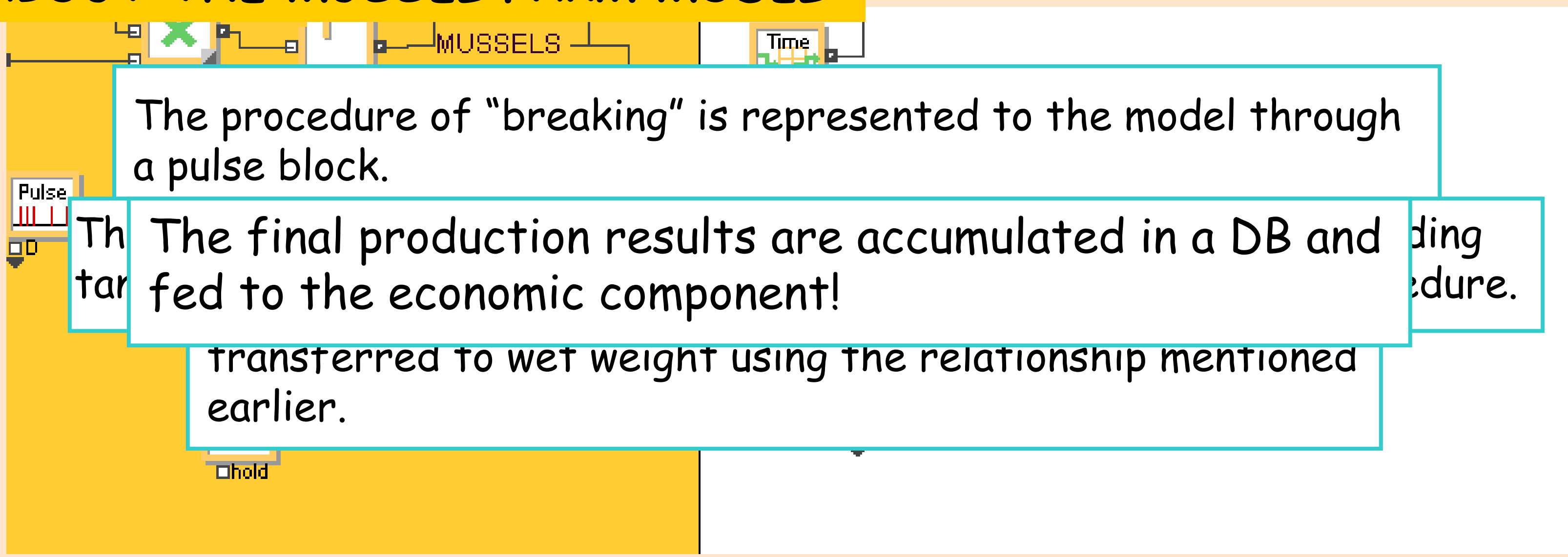
MORE ABOUT THE MUSSEL FARM MODEL



The procedure of “breaking” is represented to the model through a pulse block.

The final production results are accumulated in a DB and fed to the economic component!

Th... ding

tar... edure.

transferred to wet weight using the relationship mentioned earlier.

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Socio-Economic Component

Economic Component

Individual mussel farm characteristics

Questionnaire survey

Whole mussel farming area

Not part of the main model

Evaluates the environmental contribution of the mussel activity in the study area

Individual characteristics of mussel farms:

- Number of production lines
- Number of mussel bunches (socks)
- Sock length
- Productivity level (due to their orientation and placing)

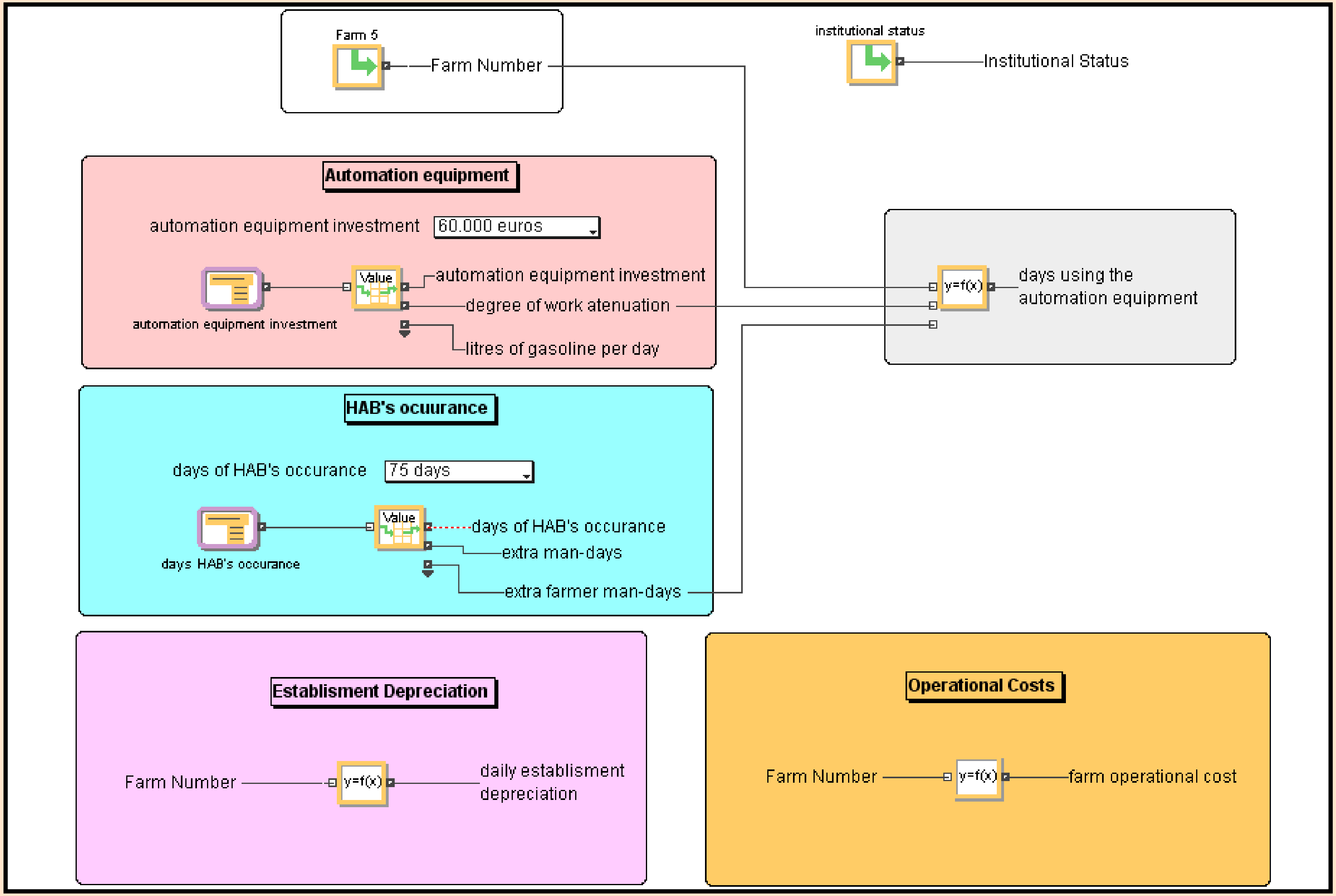
Need to examine the economic component at the (individual) farm level

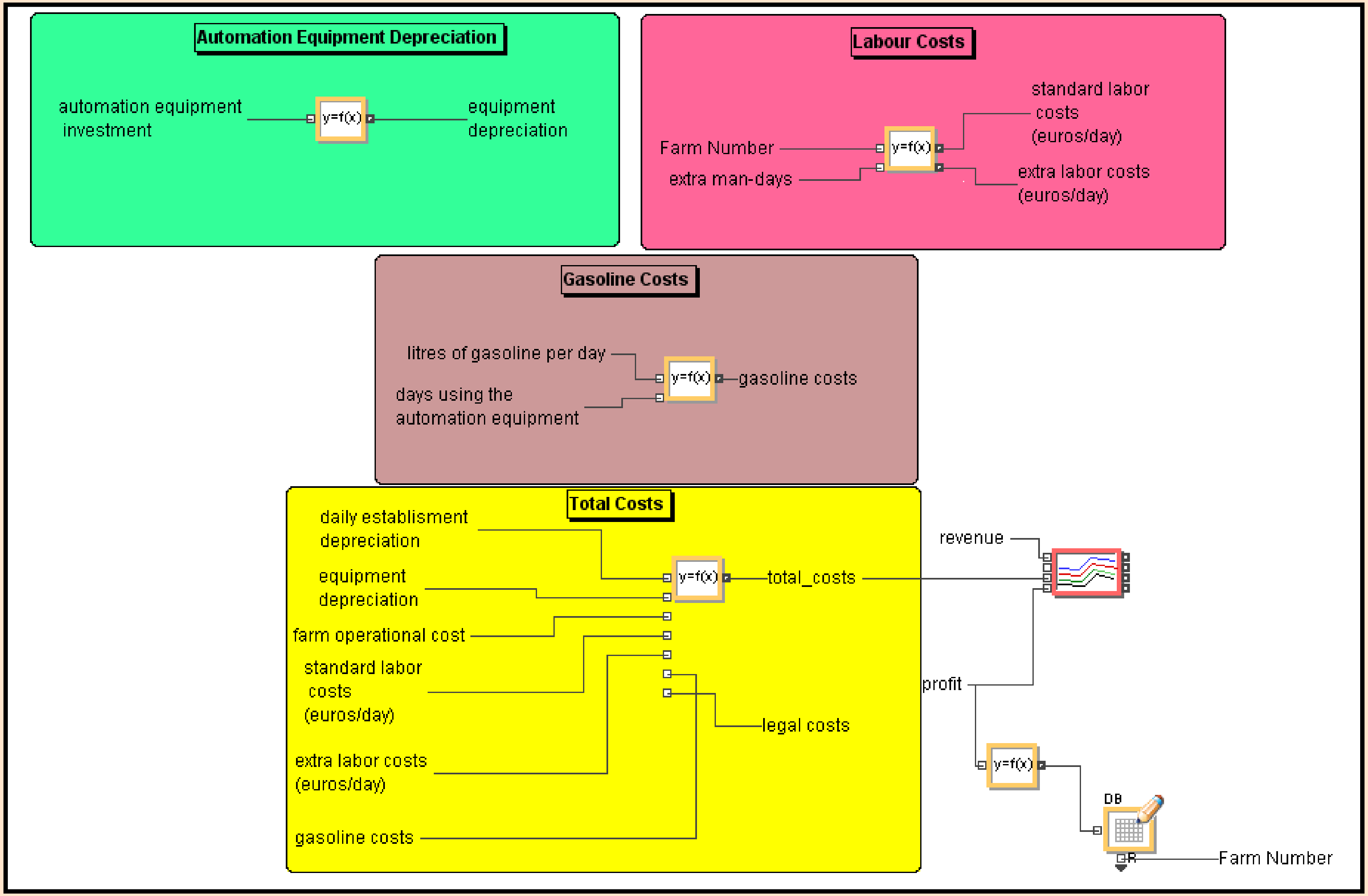
In general, individual costs, benefits and revenues depend on:

- Total production (link to the ecological component)
- Farmers' choices
- Environmental hazards (Harmful Algae Blooms occurrence)

FARMER'S PRODUCTION COSTS

1. Annual depreciation cost
   - Depreciation of farm installation cost and farm facilities
   - Depreciation of automation equipment (boats)
2. Operational and maintenance costs
   - Rope, nets, minor repair works
   - Gasoline cost
3. Labour cost
   - Owner/mussel farmer labour cost
   - External labour cost
4. Extra costs (due to HAB's occurrence)
5. Legality costs


Farm 5
Farm Number
institutional status
Institutional Status
Automation equipment
automation equipment investment
60.000 euros
Value
automation equipment investment
degree of work atenuation
litres of gasoline per day
automation equipment investment
y=f(x)
days using the automation equipment
HAB's ocuurance
days of HAB's occurance
75 days
Value
days of HAB's occurance
extra man-days
extra farmer man-days
days HAB's occurance
Establisment Depreciation
Farm Number
y=f(x)
daily establisment depreciation
Operational Costs
Farm Number
y=f(x)
farm operational cost



Automation Equipment Depreciation
automation equipment investment
y=f(x)
equipment depreciation
Labour Costs
standard labor costs (euros/day)
Farm Number
extra man-days
extra labor costs (euros/day)
Gasoline Costs
litres of gasoline per day
days using the automation equipment
gasoline costs
Total Costs
daily establisment depreciation
equipment depreciation
farm operational cost
standard labor costs (euros/day)
extra labor costs (euros/day)
gasoline costs
total_costs
legal costs
revenue
profit
DB
Farm Number

ANNUAL DEPRECIATION COSTS

Depreciation of farm installation cost and farm facilities

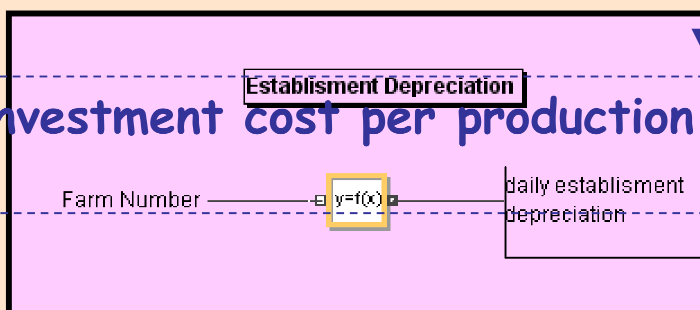
Initial cost of Assets, Years of life, Final Salvage value

Zero value assumption

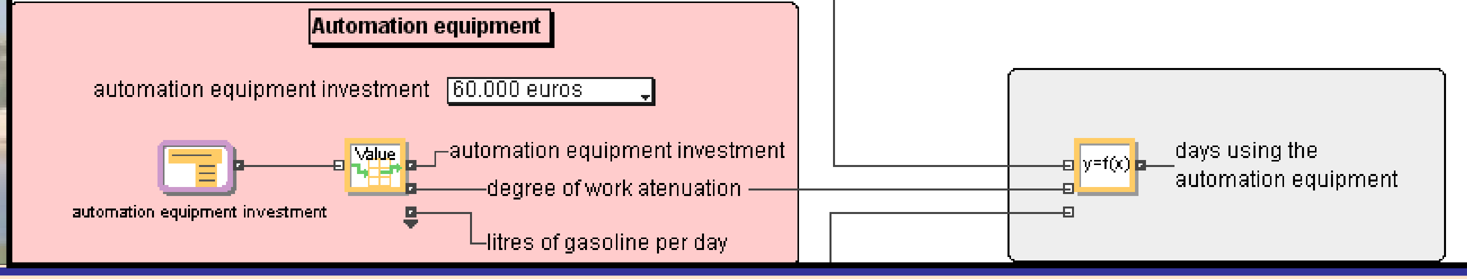
Annual depreciation cost = (Cost of fixed assets) / (Life Span)

30 years

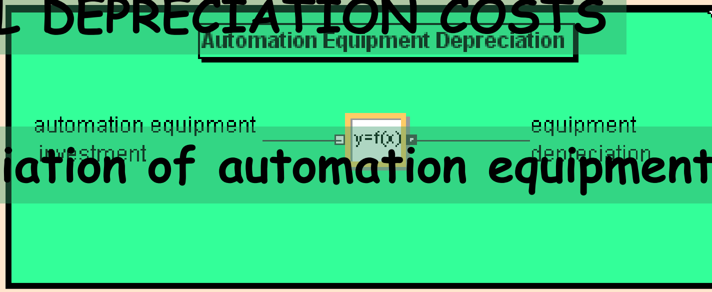
Initial investment cost per production line * number of lines



900€ / line



ANNUAL DEPRECIATION COSTS



Depreciation of automation equipment (boats)

Automation equipment costs: from € 20.000 up to € 100.000

Degree of automation: Strongly connected to the costs of: (a) labour and (b) gasoline

Activity depreciation method: Not based on time but on activity level (working hours)

Assumption: Final salvage value approximates zero

Daily depreciation expense:
(Initial investment) * (Number of hours using a boat) / (total lifetime hours of the boat)

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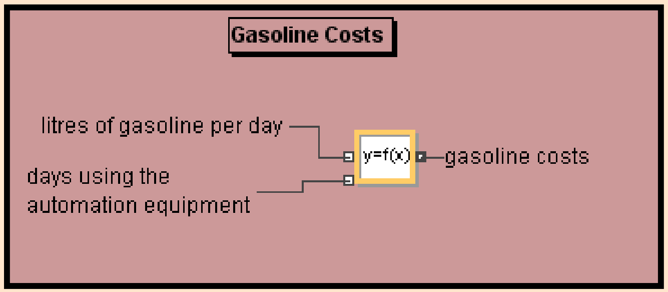
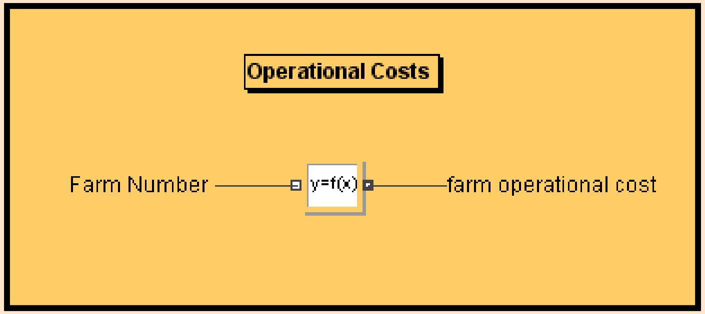
OPERATIONAL AND MAINTENANCE COSTS





Gasoline costs are **connected to:**

- the automation equipment investment
- the man-days of farmer's labour

Gasoline cost = a * (gasoline price per lt)

a= lit/working day

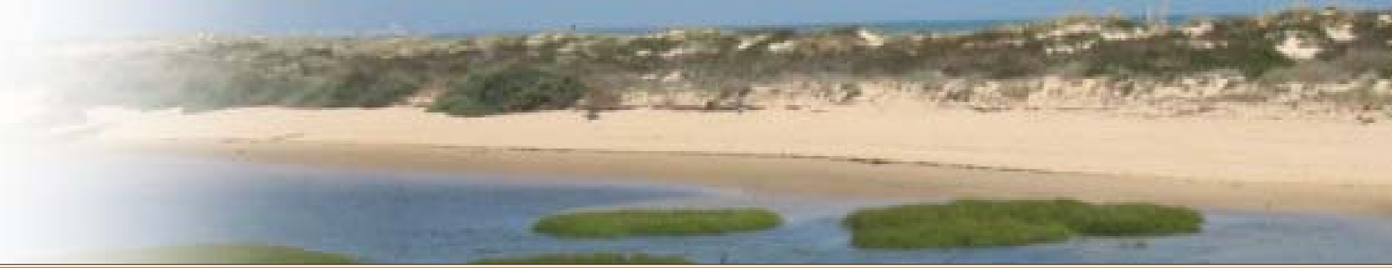
Cost of:

- Ropes, nets and other material used
- Minor works at the main farm structure

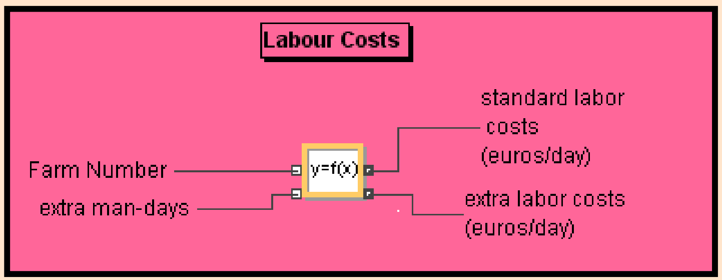
↓

Estimated through the questionnaire

Average cost = 300€/year/production line



LABOUR COSTS



Farmers (owners) Labour Cost

Estimation of the optimum labour per production line according to the survey results

e.g. optimum level = 30 man-days for the minimum investment on automation equipment

The **more investment** in automation equipment the **more work is needed**

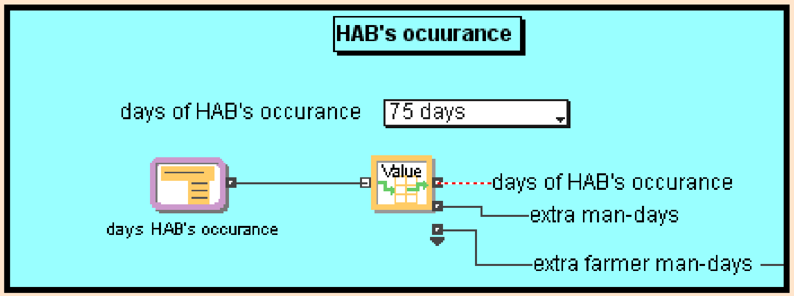
According to the survey: **5% of man-days increase** for every **€20.000 of investment**

External Labour Cost

Extra cost for unspecialized workers

Based on the survey analysis: **optimum external labour** = 15 man/days per production line, costing 35€/day

EXTRA COSTS (HAB's OCCURRENCE)



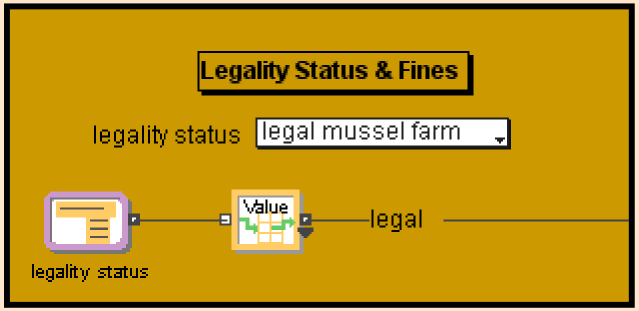
Cost related to selling delays due to HAB's

A day out of market → **extra working hours** (to maintain the quality and quantity of production) → **extra cost** on: (a) farmer's labour, (b) external labour, (c) gasoline

Example:

For a 30-day HAB's occurrence → no extra work needed
For every 15 days added → 3 man-days/line are required (2 days of external labour and 1 day of farmer's labour)

LEGALITY COSTS

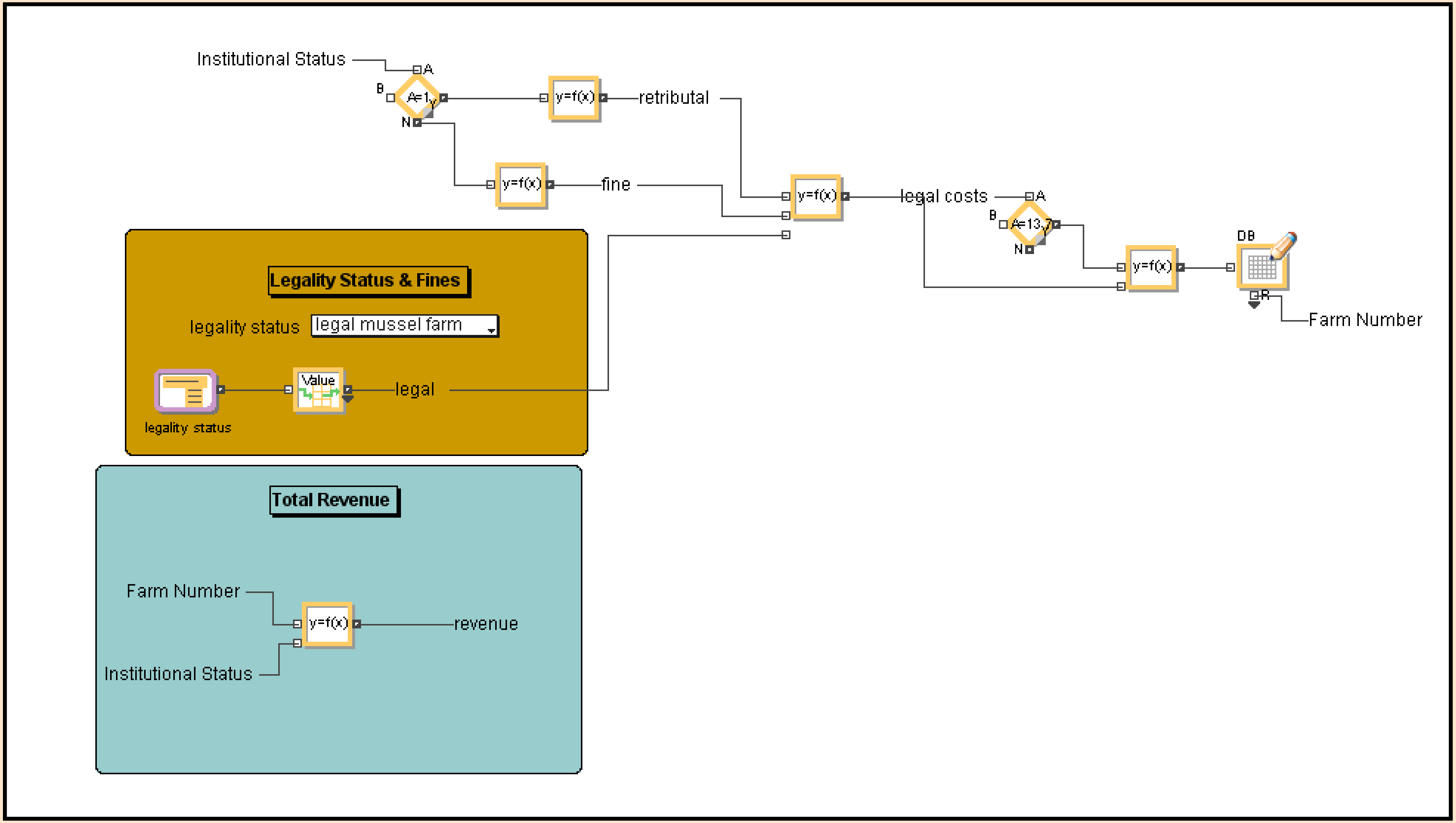


Administrative issue: legality of the mussel farms

Most licenses **have expired** and Public Authorities **postpone their renewal**

Mussel farmers with license: **pay a €5.000 rent per year**
Mussel farmers without license: **pay a €10.000 fine per year**

More info on the "Social Component"


Institutional Status
A
B
A=1
N
y=f(x)
retributal
y=f(x)
fine
y=f(x)
legal costs
A
B
A=13.7
N
y=f(x)
DB
R
Farm Number
Legality Status & Fines
legality status
legal mussel farm
Value
legal
legality status
Total Revenue
Farm Number
y=f(x)
revenue
Institutional Status

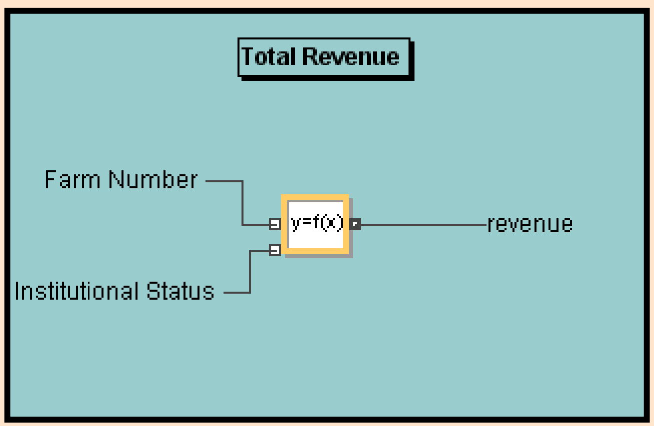
FARMERS REVENUES

Strong connection with the ecological component (total production of each farm)

Total Revenue = Mussel's Price * Total Production

The price of mussels remains unchanged the last 10 years

Total production = $P*L_s*N_s*NL$



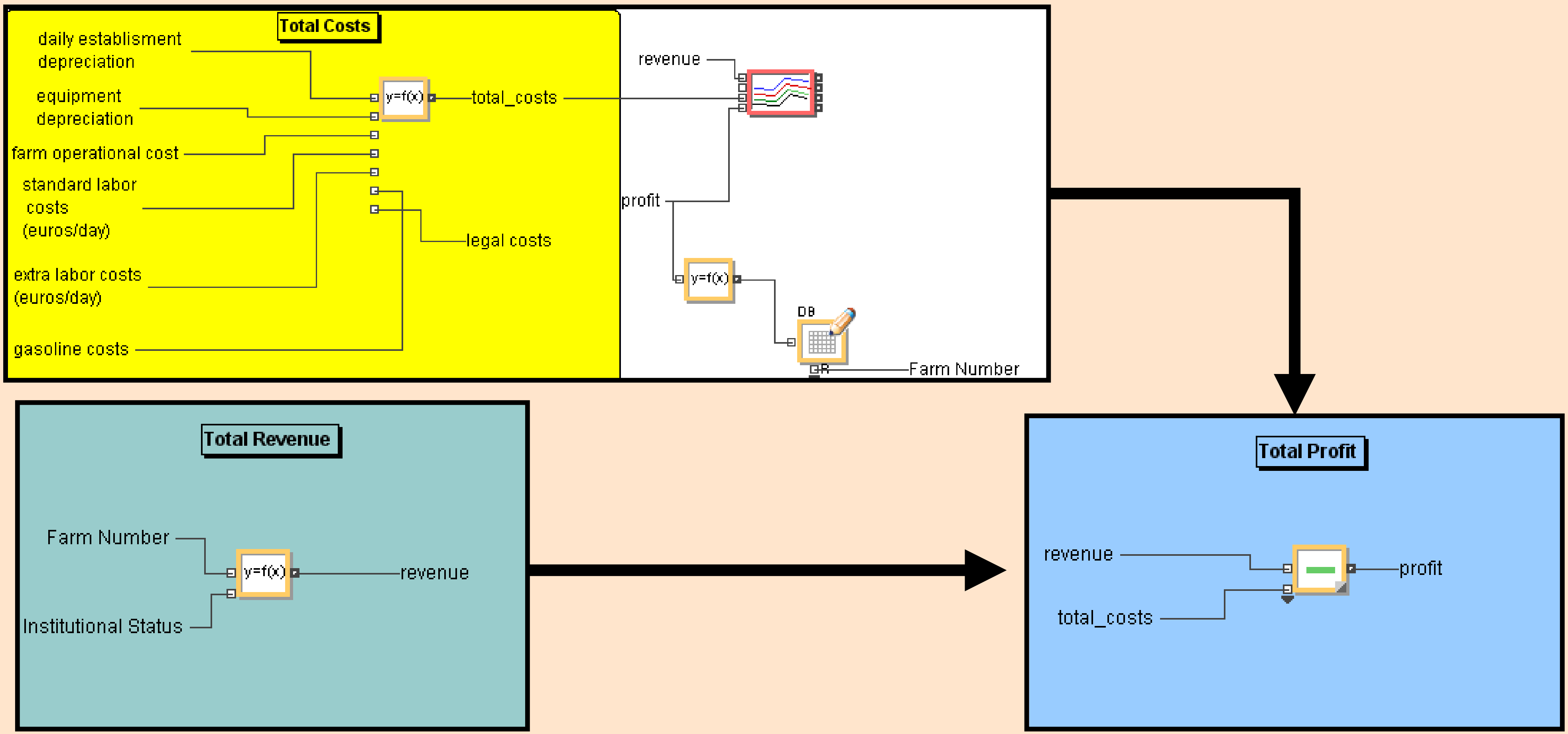
P = Mussel production (Kg) of every meter of sock
Assumption: the whole production of the area is finally sold

L_s =Length of the sock (m)
Assumption: same length for all the socks in the mussel farm (as declared in the mussel part of the model)

N_s=Number of socks in every line
Assumption: same for all the lines in the same mussel farm (as declared at the *mussel part*)

NL=Number of production lines

PROFIT FOR INDIVIDUAL MUSSEL FARM



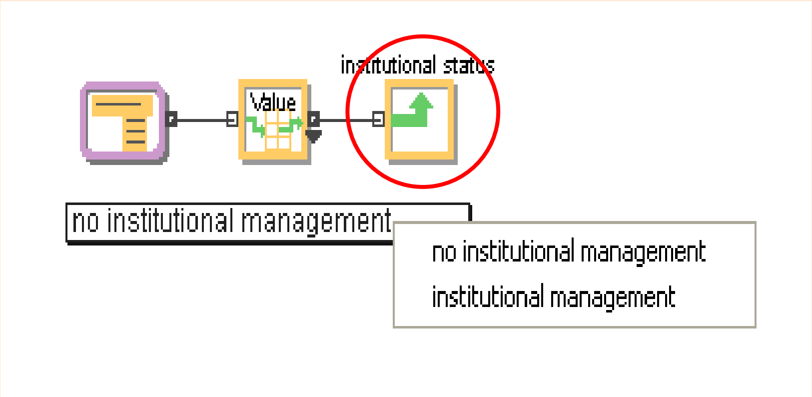
Social Component

the institutional component

the component of local community

INSTITUTIONAL STATUS

The "throw" block is connected with both the "mussel farm" & the "economic" components, controlling the relevant parameters.

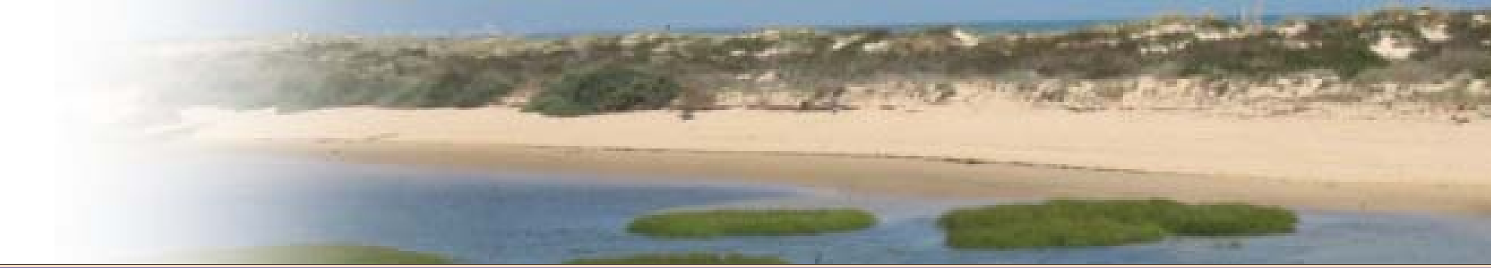


"no institutional management" represents the

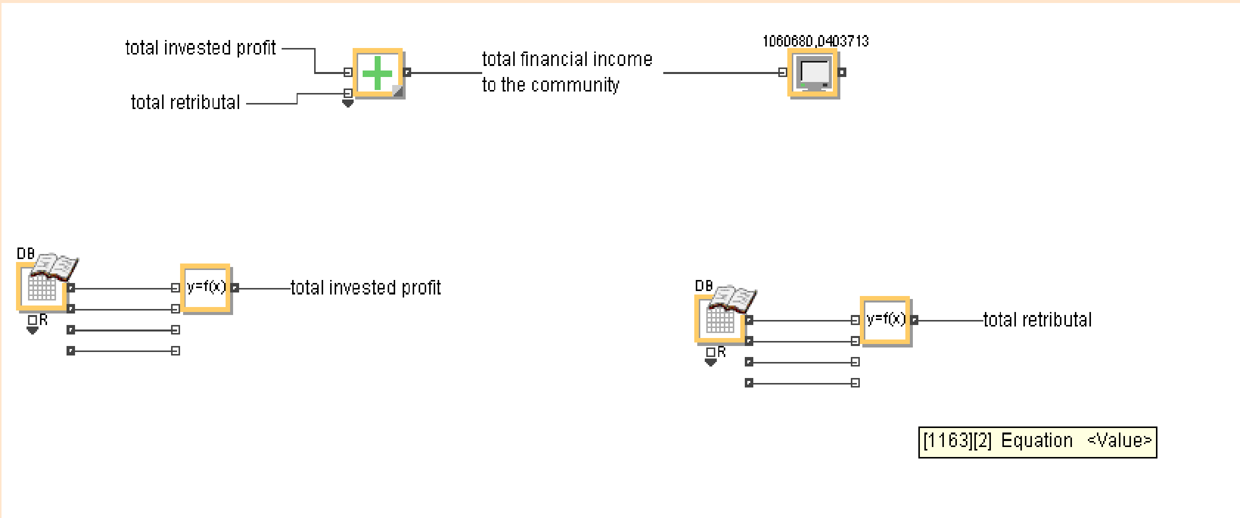
"institutional management" represents what should happen if the legislation was followed: all the farms having the same characteristics and all the farms are legal, not paying fines but only perquisites that are coming back to the community as retributive benefit.

Represents the operation or not of the current legislations

institutional status



LOCAL COMMUNITY

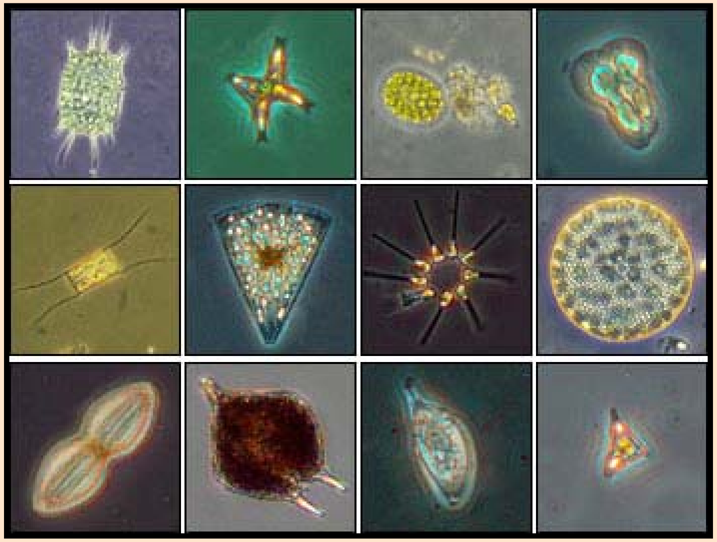


Represents the inflow of money to the local community from the activity

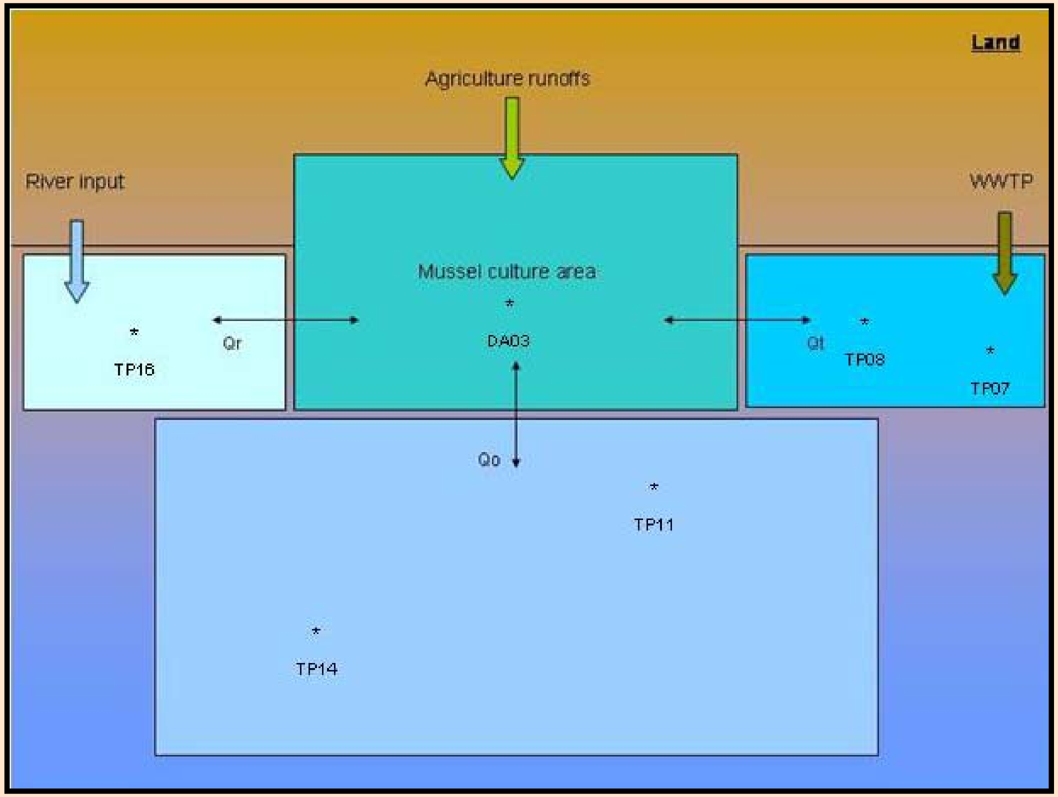
local community

We are also taking under account the amount of money that comes back to the community as retributive benefit from the perquisites of the legal units.

Environmental Component



"COMPARTMENTIZATION" OF THE AREA



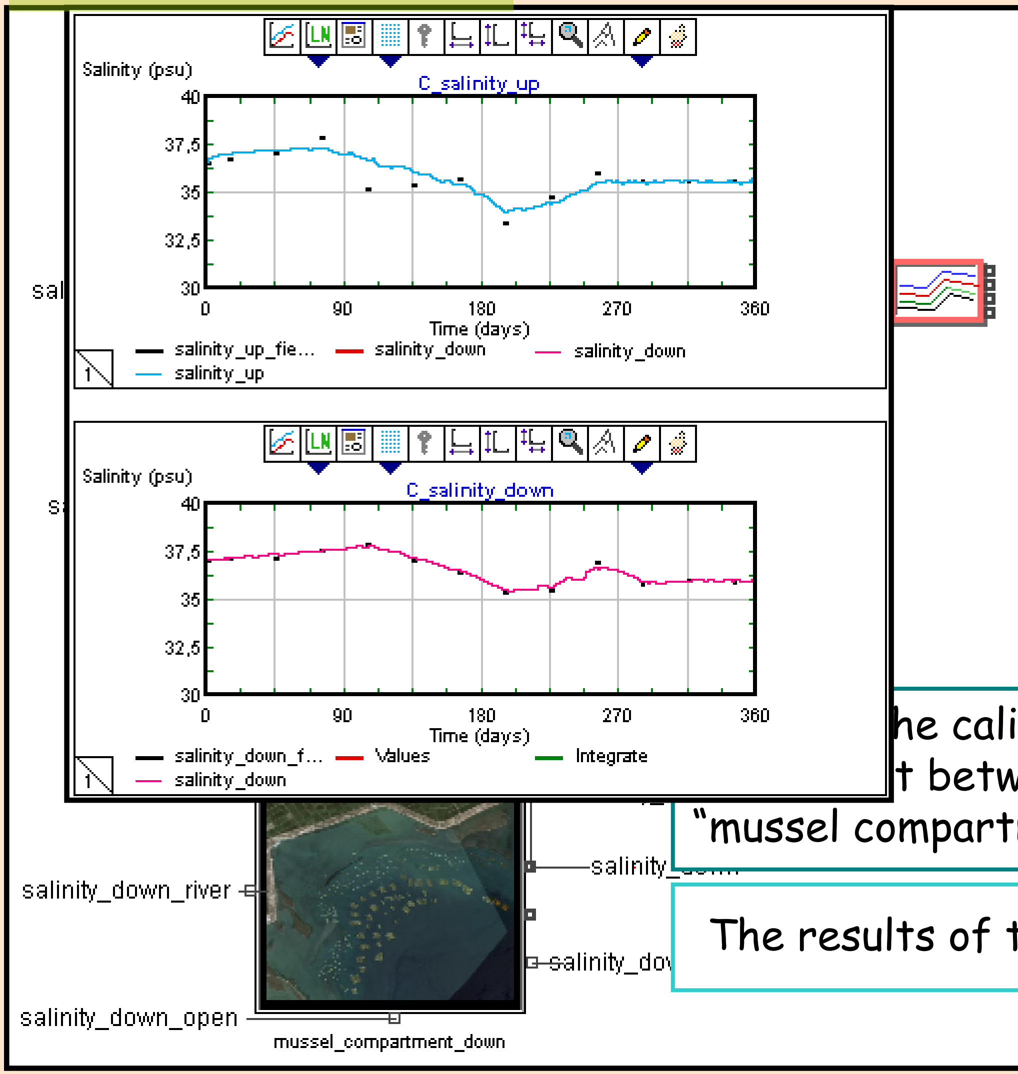
Our attempt to simulate the circulation of the area and the effects of the external inputs was constraint due to the lack of external and internal data sets.

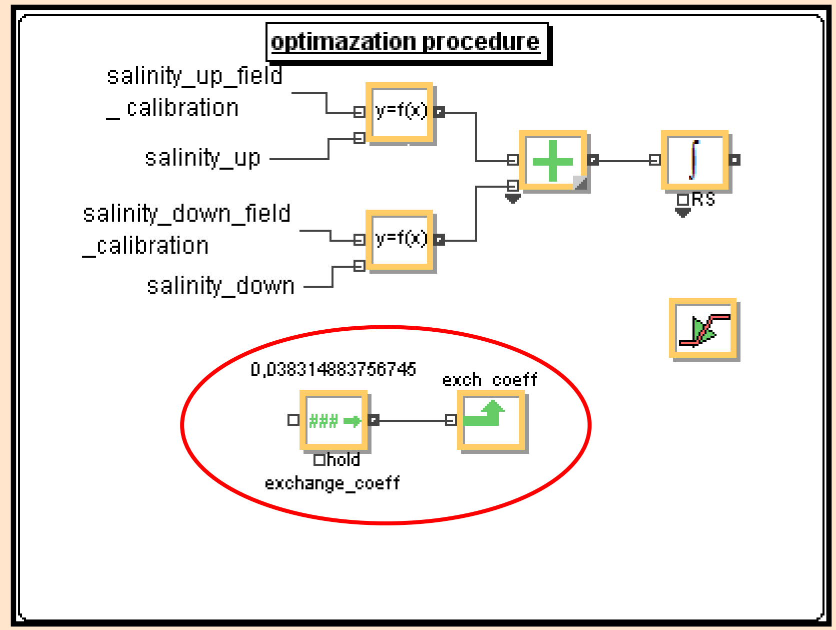
We used salinity data from the stations of the neighbor compartments and the results of current velocities of a 3D circulation model, already running for the area of Thermaikos gulf, in order to determine the salinity budget between the compartments, thus defining the exchanges between the compartments .

According to field data we determined that the thermocline is at the depth of 7m for almost the whole year, meaning that the mussel's are over it all the time.

We used salinity data from station DA3 to calibrate the results of the "model".

SALINITY BUDGET





...he calibration procedure we determined the exchange ...t between the upper and the bottom layer of the "mussel compartment".

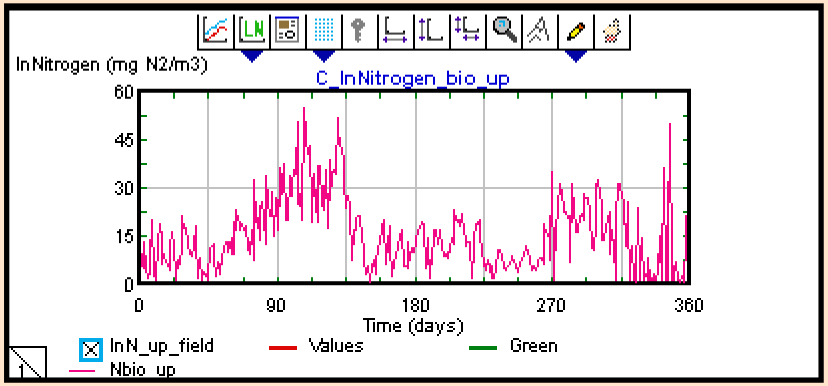
The results of the "budget model" are very satisfactory.

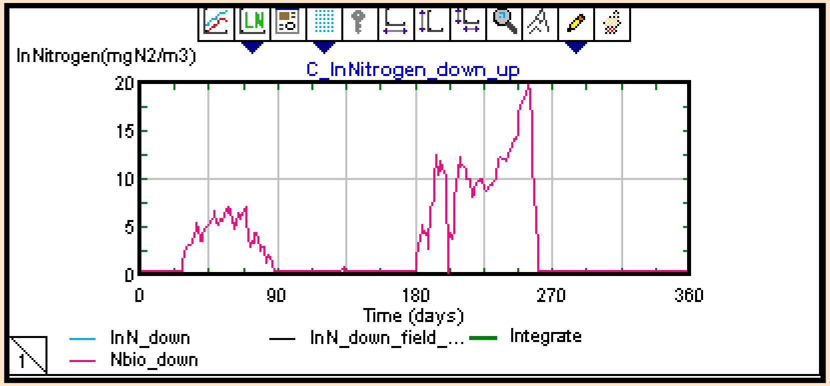
BIOLOGICALLY CONSUMED INORGANIC NITROGEN

Shortcut

We are not trying to predict nitrogen, but match the available data in order to “feed” phytoplankton. Using the Inorganic Nitrogen data from the neighbor compartments and the “salt budget” structure and exchange coefficient, we assume that:

$$InNitr_{bio}=InNitr_{exch}-InNitr_{obs}$$





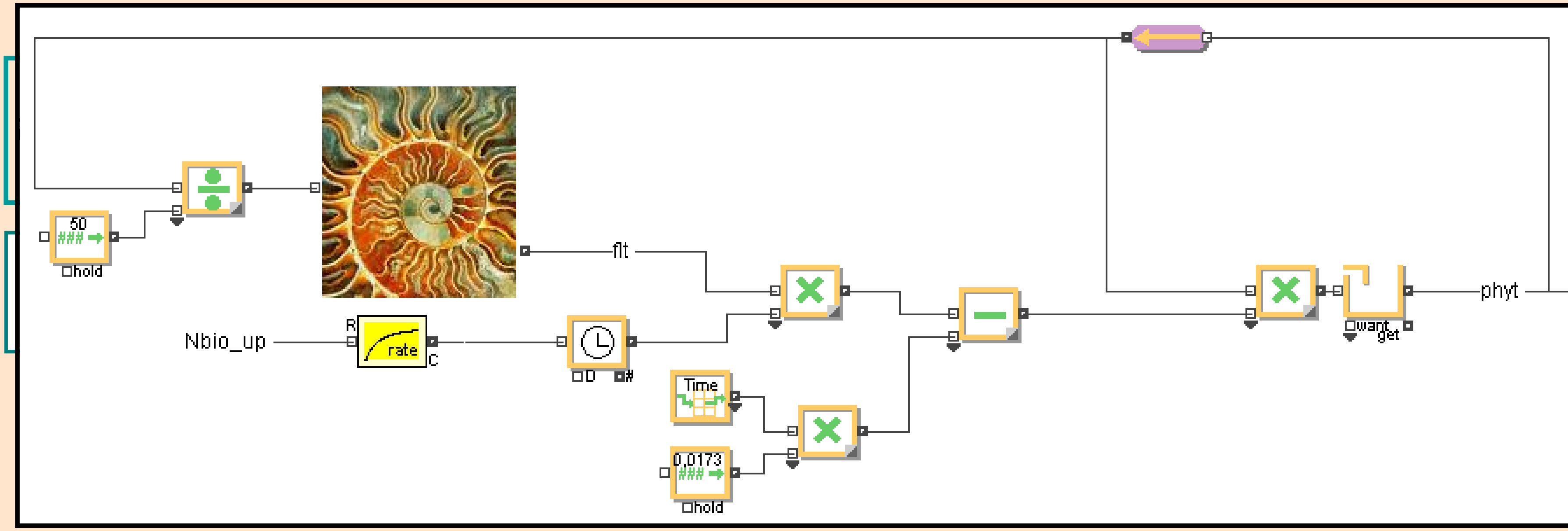
We assume that the $InNitr_{bio}$ is almost fully consumed for phytoplanktonic growth.

SPICOSA

SIXTH FRAMEWORK PROGRAMME

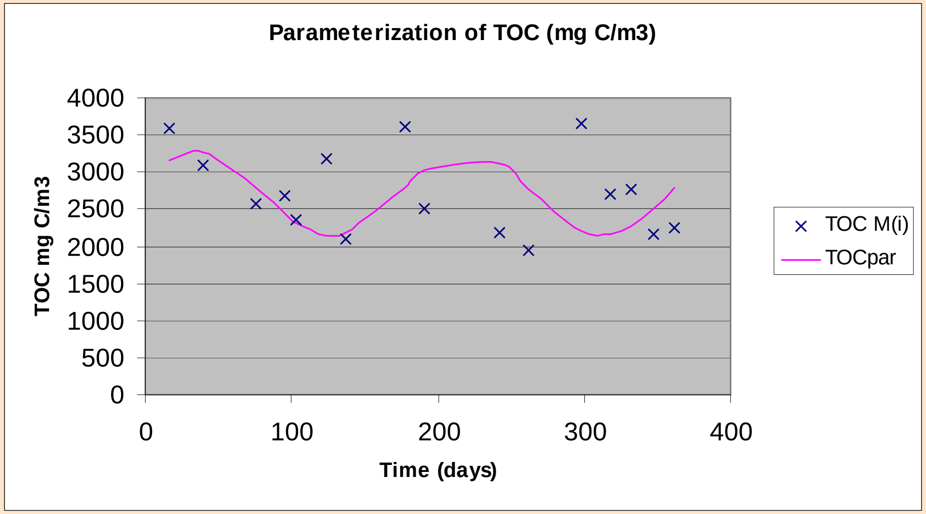
PHYTOPLANKTONIC GROWTH & CONSUMPTION

$$\frac{dPHYT}{dt} = \{aPNA * (1 - j) - kWS - fP * Mussels\} * PHYT$$

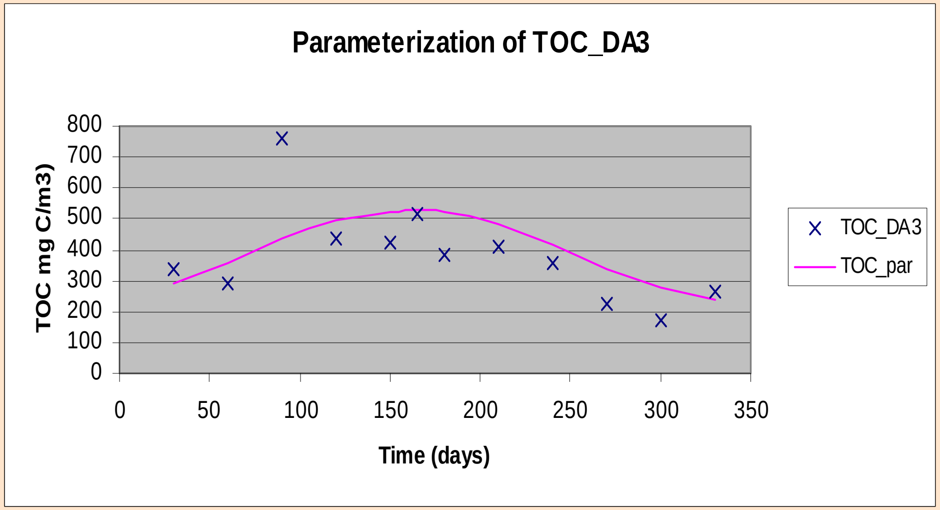


fp*MUSSELS is expressing the filtering of mussels to phytoplankton and is only used in the upper layer.

TOC PARAMETERIZATION



$$TOC\_M(i)_{par}=2707+564*\cos 4\pi[(t/365)-0.185)]$$



$$TOC\_DA3_{par}=381+147*\sin 2\pi[(t/365)-0.185)]$$

OBSTACLES & SCENARIOS IN APPRAISSAL STEP

Implementing SPICOSA in the area of Chalastra, proved to be a very challenging task. Many obstacles occurred: missing or bad quality data, poor collaboration (especially in the stakeholders sector) and other reasons…

The 3 component model of SSA 16 is not a predictive model, but a descriptive one. Yet, it targets to be a good representation of the system as it is nowadays and to qualify & quantify it's responses in several changes.

In a first approach we will examine:

- alterations of the farming characteristics of each unit to identify under which characteristics we can have the maximum productivity.
- alteration of the farming placing, by altering the inhibition coefficient k and testing of different scenarios.
- Legal status alterations-Welfare results to the community.

SPICOSA

SIXTH FRAMEWORK PROGRAMME

ECONOMIC COMPONENT AT THE APPRAISAL STEP

1. Cost benefit analysis for scenarios of more labour (extra work) or capital (extra machinery) intensive mussel production

2. Estimate the productivity limit in the study area (carrying capacity in terms of profit)

3. Analyze some mussel-quality scenarios (effect of better quality on their price and on individual profits)

4. Estimate the environmental value of mussel activity

ENVIRONMENTAL COMPONENT AT THE APPRAISAL STEP

1. Alteration of the neighbor compartment inflows – effects

SPICOSA

SIXTH FRAMEWORK PROGRAMME

SIMULATIONS & RESULTS

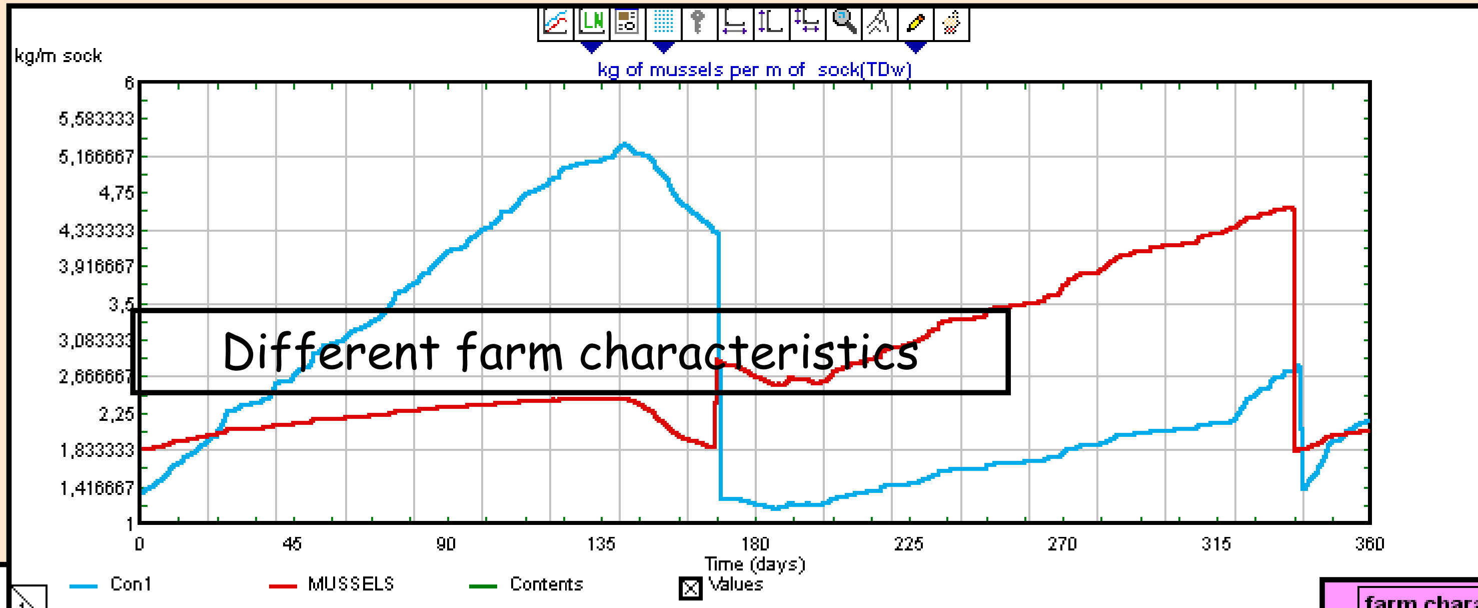
farm characteristics

line_number: 10 lines

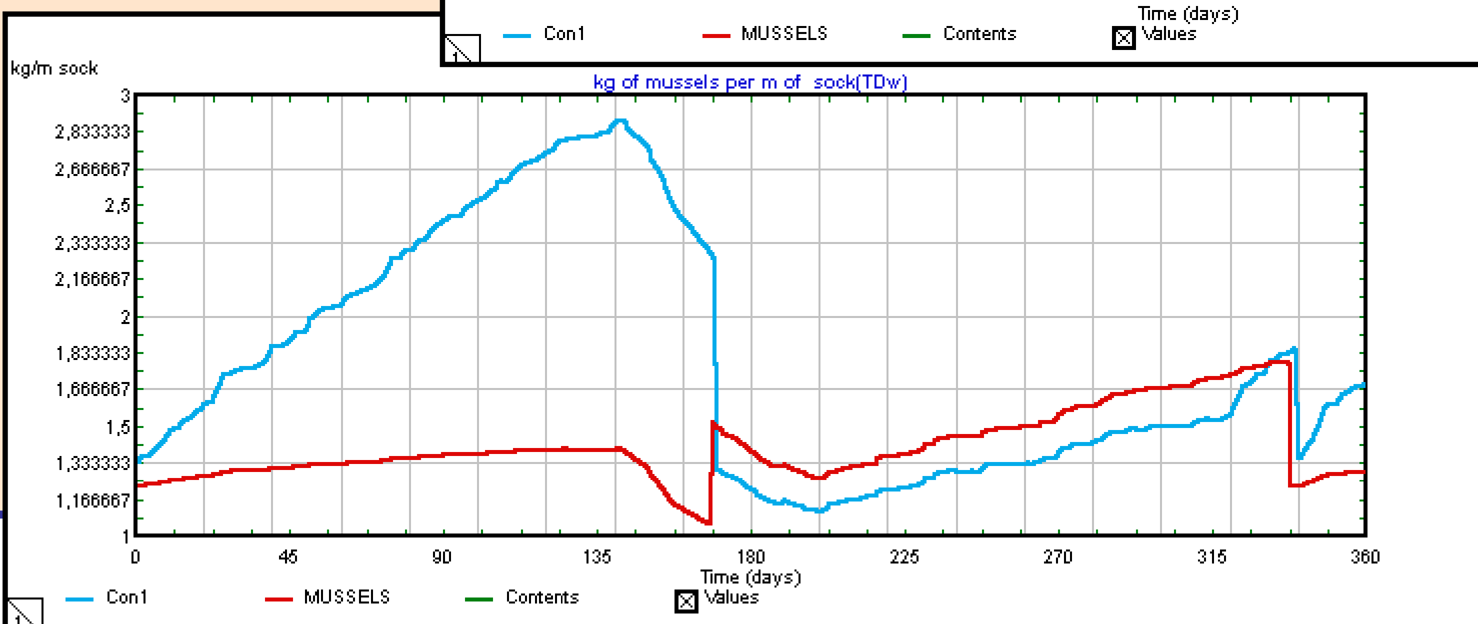
distance_between_lines: 10 m

distance_between_socks: 0.6 m

sock_length: 3 m



Different farm characteristics



farm characteristics

line_number: 16 lines

distance_between_lines: 7 m

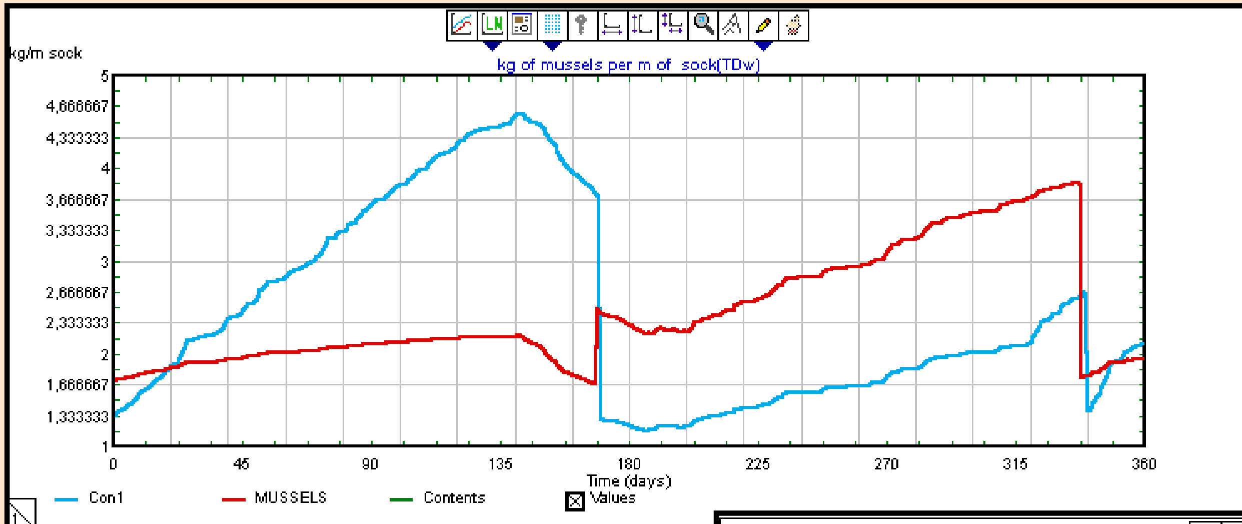
distance_between_socks: 0.4 m

sock_length: 3.5 m

SPICOSA

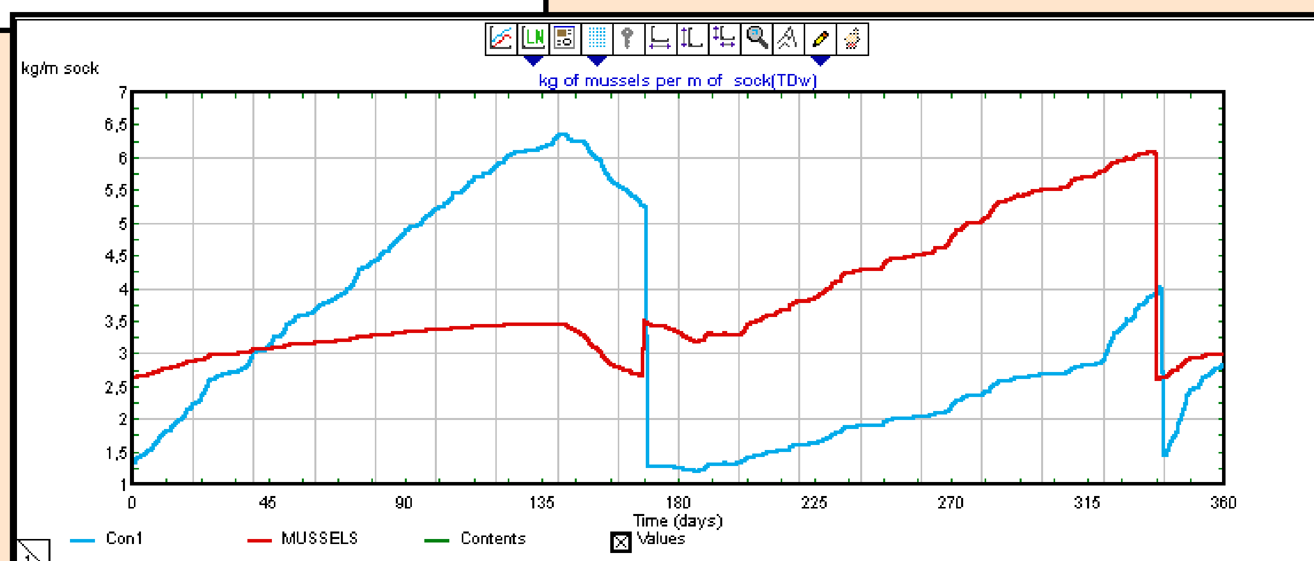
SIXTH FRAMEWORK PROGRAMME

SIMULATIONS & RESULTS



Inside the farming area

Outside the farming area



We would like to sincerely thanks Mrs. Sofia Mitsoudi & Mr. Yannis Savvidis from the Technological Educational Institution of Thessaloniki – Department of Fishing Technology and Aquaculture, for their valuable help by providing us data, guidelines and support.

Thank you for your attention