Studies to support the European Green Deal

Lot 1 Shellfish and algae

Final Report 2022/10/14

CINEA/EMFF/2020/1.3.1.16/Lot 1

WPM –Task 0: Management

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WPM –Task 0: Management: Overview

This study was commissioned by the European Commission (EC) to support **the European Green Deal**

The specific objectives were to:

- Assess the potential of shellfish and algae to recycle nutrients.
- Estimate the greenhouse gas emissions generated by their production.
- Produce digital raster maps of production potential across European marine waters.

This production potential was estimated through **numerical modeling** on the basis of data from the **Copernicus Marine Service** (CMS).

3 seaweed species:
- Saccharina latissima
- Alaria esculenta
- Ulva lactuca

3 shellfish species:
- Blue mussel (M. Edulis)
- King scallop (Pecten Maximus)
- Pacific oyster (C. Gigas)

3 scenarios for seaweed:
- Scenario A: No interaction between farms
- Scenario B: Nutrients may not be consumed twice
- Scenario C: Same as B but with no farm less than 1 mile from the coast

WPM –Task 0: Management: Schedule and Milestone

Today

	M0		M1		M2		M3		M4		M5		M6		M7	M8	M9		M10	
Task 0																				
Task 1																				
Task 2																				
Task 3																				
Task 4																				
Task 5																				
Deliv.	**IncR**									**dIR**		**IR**						**dFR**		**FR**
Pres	**P1**										**P2**								**P3**	

IncR : Inception report => **Validated by CINEA**

P1: Presentation of Inception Report to Steering committee => **Done**

dIR : draft Interim Report => **Sent to CINEA on 18/05/2022**

P2: Presentation of Interim Report (draft) to Steering committee => **23/05/2022**

IR : Interim Report feedback from the EC => **2 of June**

- Submission of Final version of the interim report : **Accepted**
- Submission of interim request for payment (50%) : **Accepted - Payment done**

dFR : draft Final Report + deliverables (T0 + 10 months) => 30 of September

P3: Presentation of Final Report (draft) to Steering committee => 14 of October at 2 p.m.

FR : Final Report + final version of deliverables (T0 + 11 months) => 27/10/2022

WPM –Task 0: Management - Achievements

Throughout the project, **monthly meetings** between the partners were held on the last Thursday of each month:

- 27 January 24 February 31 March 28 April
- 30 June 28 July 1st September 22 September

A **meeting with CINEA** was held on 15 February at the request of the consortium to clarify certain points concerning subtasks 2.3 (Nutrient availability model) and 2.6 (impacts on fishing)

WP1 Internal **weekly meetings** were held to review the progress of the developments

WP1 **meetings between partners** ARGANS/BMRS or ARGANS/COFREPECHE were held to clarify various points.

A **meeting with CINEA** was held on 20 September at the request of the consortium to outline some of the recent difficulties encountered that may affect delivery times and the solutions envisaged.

WPM –Task 0: Management - Deviation

- Some facts that have disrupt the planned course of the project:
  - Yéelen (Cofrepeche) was on maternity from April to 3 October
  - Chloé (Cofrepeche) has leave the project in April

  =>Thus Margaux (Cofrepeche) joins the project and must take over their projects

  - Nikolai (ARGANS-FR) has been on paternity leave in June
  - Gilbert (ARGANS-FR) had to leave the project for health reasons.

  =>Thus Quentin and Maël (ARGANS-FR) compensated for his absence

  => and Fatimatou Coulibali (ARGANS-FR) joins the project

WP 1 – Development – Task1 : Development & test software

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WP 1 – Development – Task1 : Development & test software - Overview

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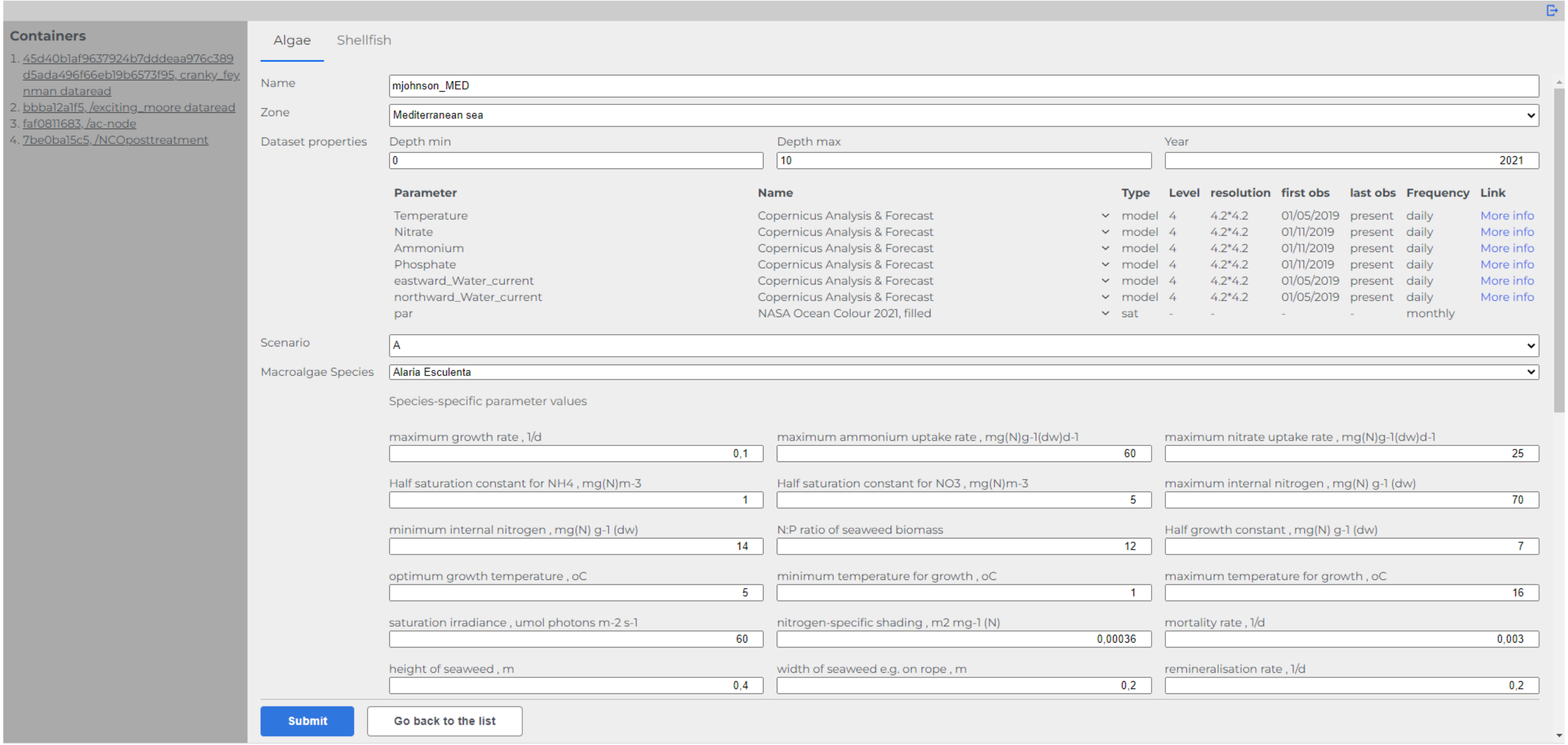
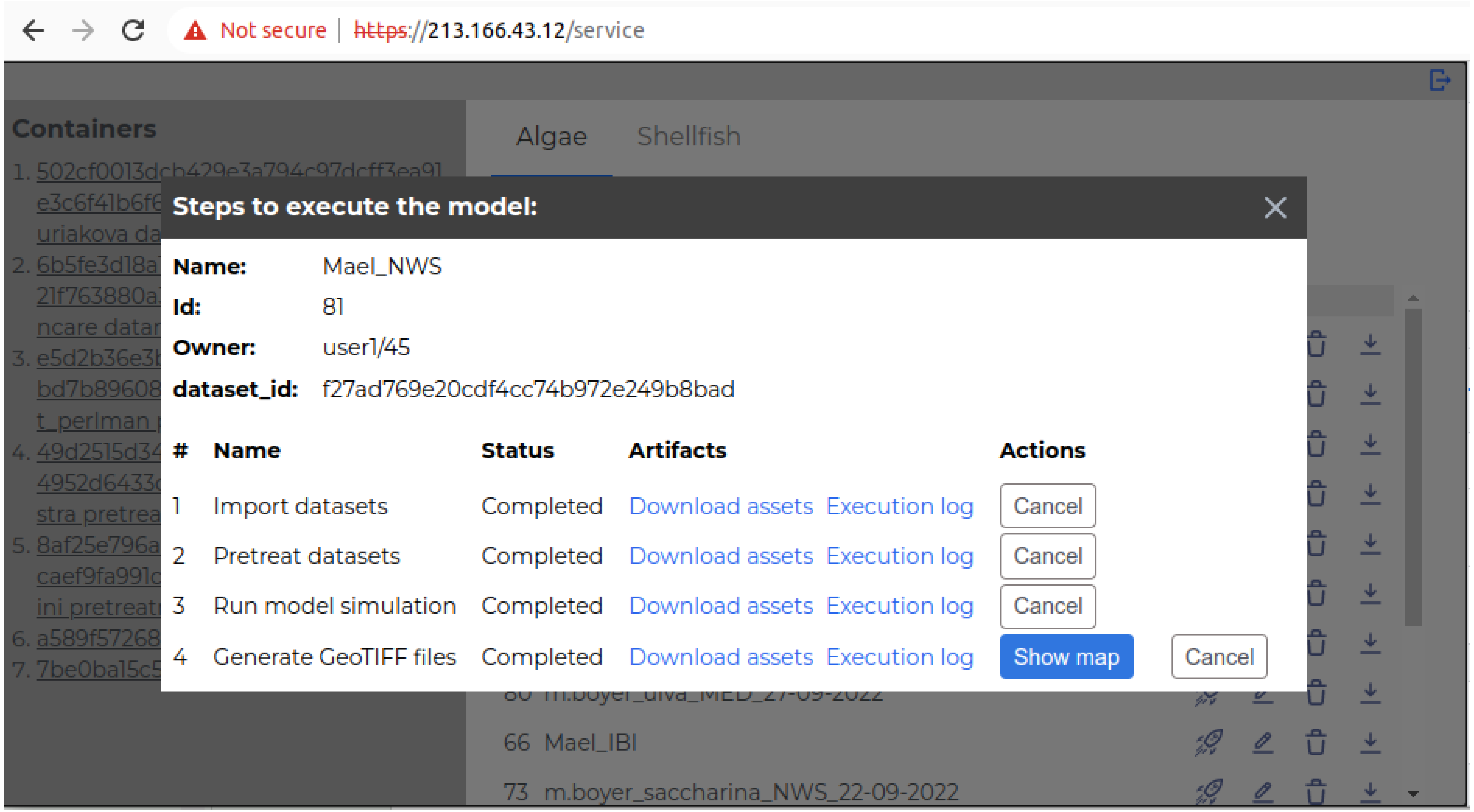
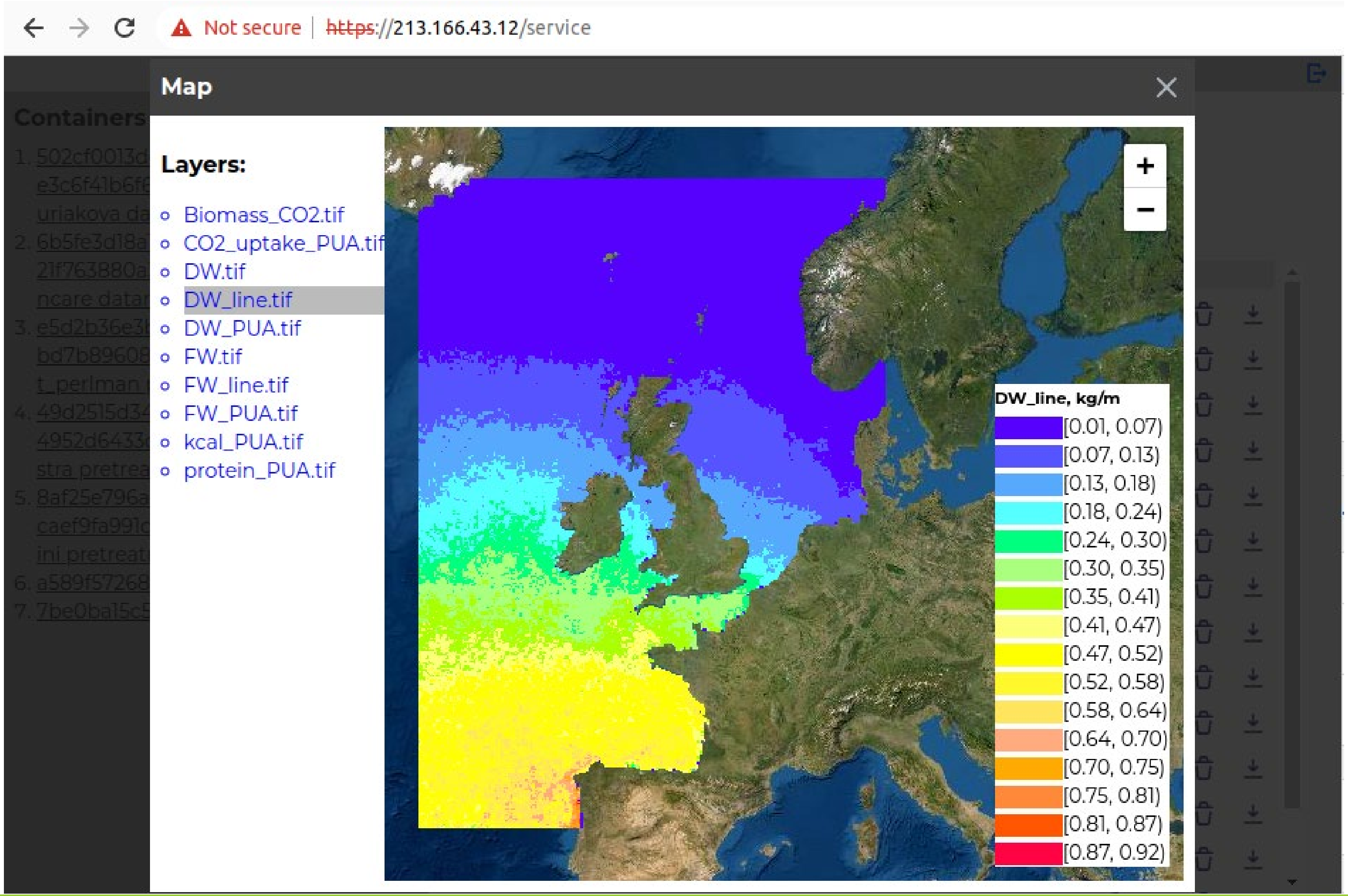


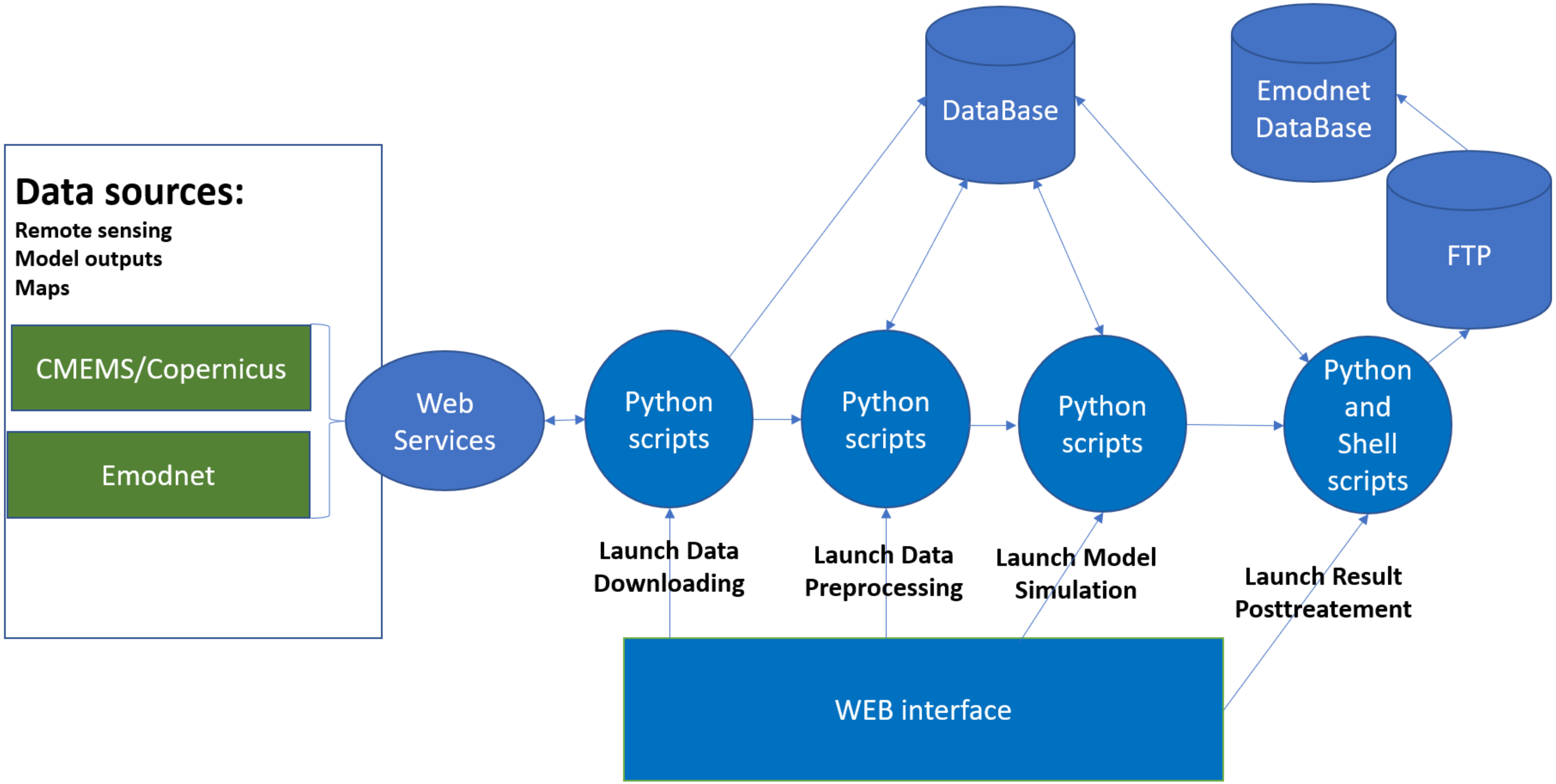
WP 1 – Development – Task1 : Development & test software - Overview



WP 1 – Development – Task1 : Development & test software - Overview



WP 1 – Development – Task1 : Development & test software - Achievements



WP 1 – Development – Task1 : Development & test software - Achievements

Data download and pretreatment:

-All data except the PAR are downloaded CMEMS

-The PAR is downloaded from the oceancolor data provided by the NASA.

-Arctic data are in stereopolar coordinates, we reproject them in Cartesian coordinates.

-We reproject all the data from the same area onto the same grid.

WP 1 – Development – Task1 : Development & test software - Achievements

Data posttreatment:

- Once our models have been run, we compute the interest variable
- The results are reprojected on 1 km $\times$ 1 km grid
- The results are combined to produce maps at European scale

WP-1 – Task 2 – Analysis – Subtasks 2.1-2.2-2.5-2.5:

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BANTRY MARINE RESEARCH STATION

WP1 – Task 2 - Analysis – Seaweed model

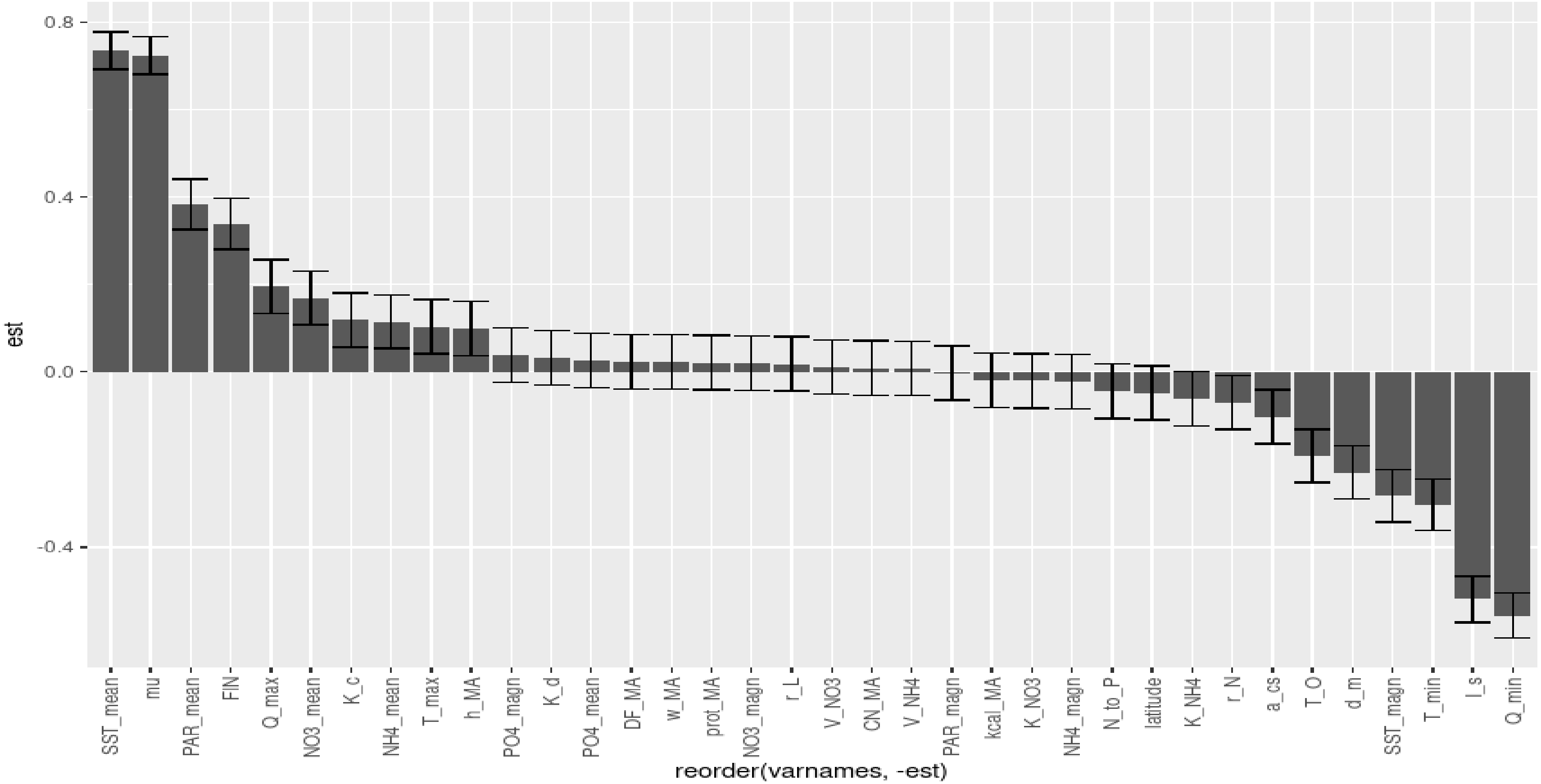
Seaweed models

- Steady state carrying capacity and mechanistic growth models developed and tested
- 3 species
- Validation / tuning
- Details in draft paper
- Implemented in scenario A and B on platform – results presented later in this report
- Remaining work – finalising nutrient interaction experiments for paper (preliminary results presented below)

Shellfish models

- Steady state carrying capacity and mechanistic growth models developed and tested
- 2 species
- Validation / tuning for Bantry Bay site (see slide on broad domain validation challenges)
- Details in draft paper
- Remaining work – finalising implementation of mechanistic model on the platform, scenario runs, final parameter set for P. Maximus (may need to pivot to another species if we cannot acquire parameters). Completion anticipated by end of project. In case of failure of mechanistic model implementation, carrying capacity model gives realistic species-specific fallback plan.

Sensitivity analysis on R model. (1000 member latin hypercube, partial rank correlation coefficient analysis on biomass per unit volume)



Ranges of input variables / seaweed parameters chosen to be representative of range of observed values / uncertainty on parameters.

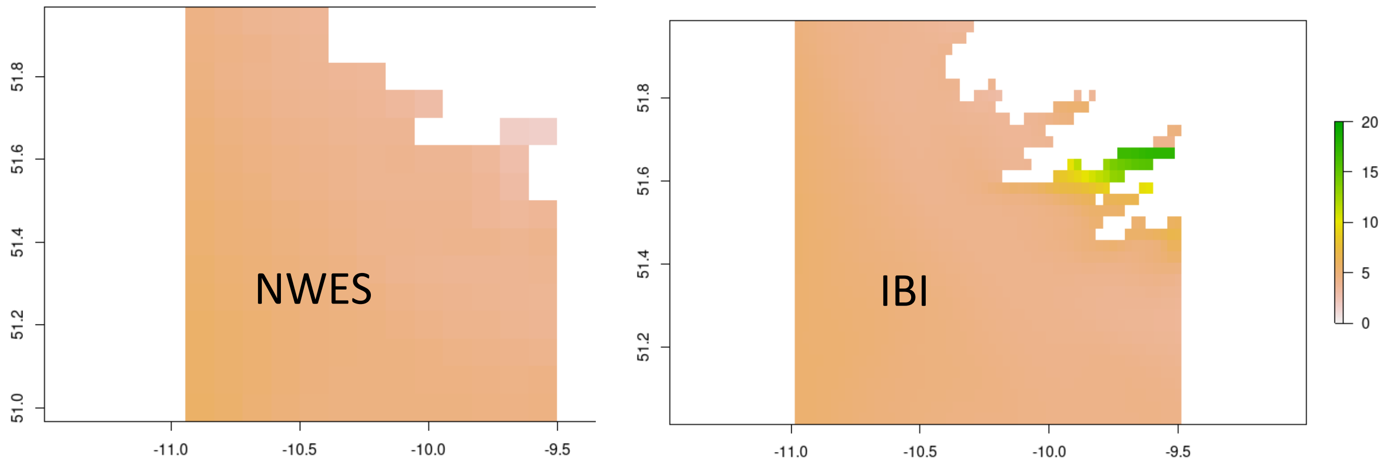
Key environmental controls are SST and light; nutrients and flow rate are secondary…

Specific growth rate (mu), nitrogen quotas (Qmin, Qmax), saturation irradiance are the major seaweed-specific parameters controlling biomass production.

WP1 – Analysis – Seaweed model

Input data challenges

Large uncertainty on nutrient fields in coastal zone, particularly in embayments where riverine influence is significant and may or may not be used to drive biogeochemical models. E.g. Bantry bay has river input in IBI analysis and predictions of yield are good. In NWES analysis, there is no river input to Bantry bay and yield is near-zero. In Kenmare bay neither IBI nor NWES models have river input and yield is low in either case, but in reality productivity is moderate.



Annual mean N concentration in uM. Same colour scale in both plots

Solutions

1. Caveat results are only as good as input data, which is of variable quality and reliability.
2. Highlight importance of riverine inflow to models.

WP1 – Task 2 - Analysis – Seaweed model

Validation / tuning challenges

1. Available validation data in kg/m of line

Model relates per unit volume productivity to per m (B_line) via an arbitrary ‘width’ of seaweed line (w_ma) and spacing of lines (density_MA). No other seaweed models of sufficient simplicity can do a better job.

2. Available data for farms much smaller than 1km 2…

Size of farm affects nutrient availability and thus productivity. Need to run validations separately for each validation point editing x_farm, y_farm as well as above properties, plus deployment and harvest dates.

3. Local aquaculture practices, subspecies variability, biomass at deployment and unquantified effects (e.g. wave action, salinity, grazing pressure) all also affect yield substantially.

4. Overall, validation of biomass yield is very difficult to constrain. Tuning to one location makes model less reliable in contrasting locations.

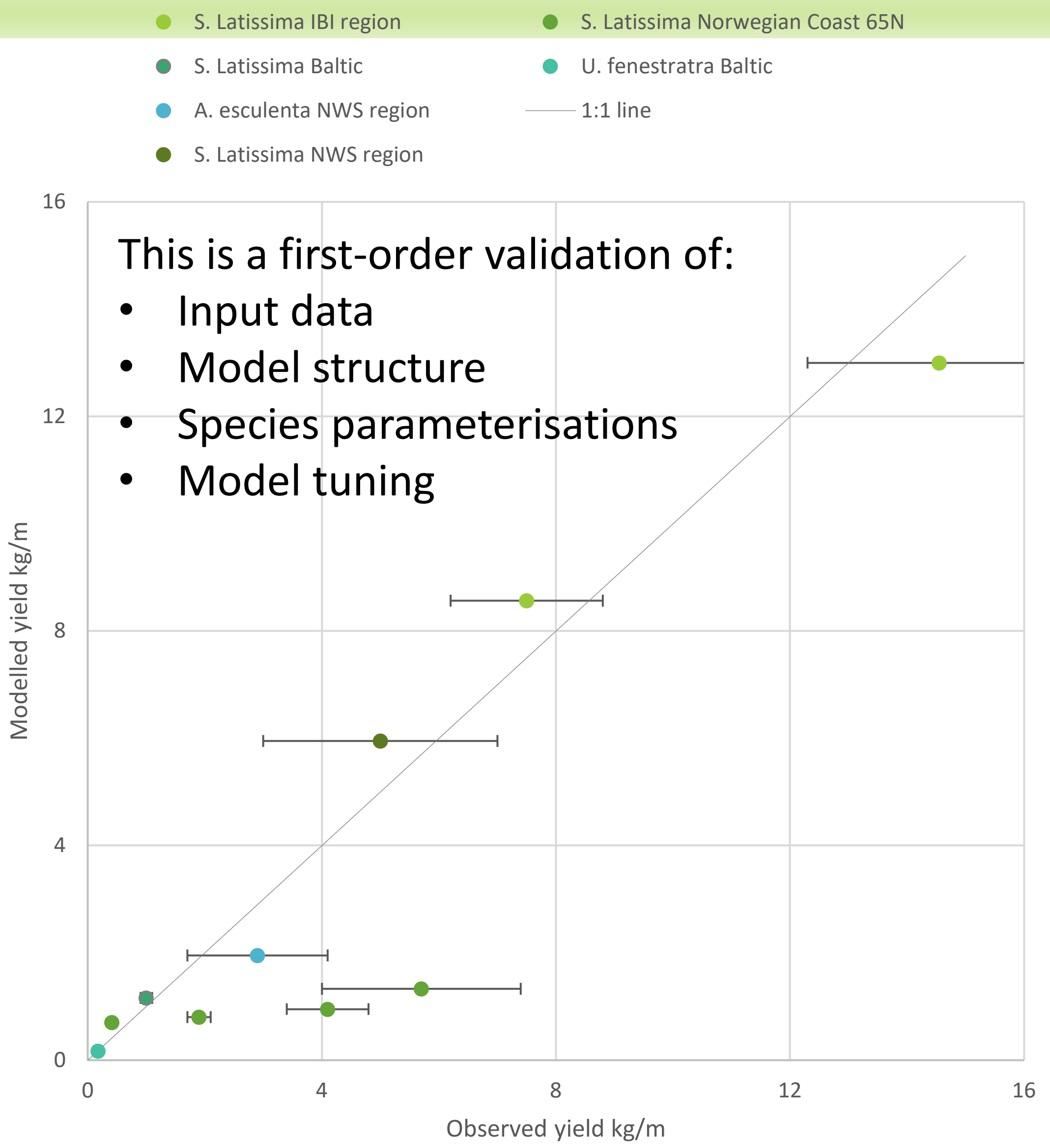
Solutions

1. Present validation challenges in peer-reviewed paper
2. Depending on application, present model as requiring further tuning before use.
   - For whole-domain scenario a/b analysis we can refer to other papers where limited or no tuning/validation is practicable when doing large-geographical-area analysis e.g. Lehman et al., 2016
   - For local predictions, recommend the model should be tuned to local data as is common with modelling studies of particular locations

WP1 – Task 2 - Analysis – Seaweed model

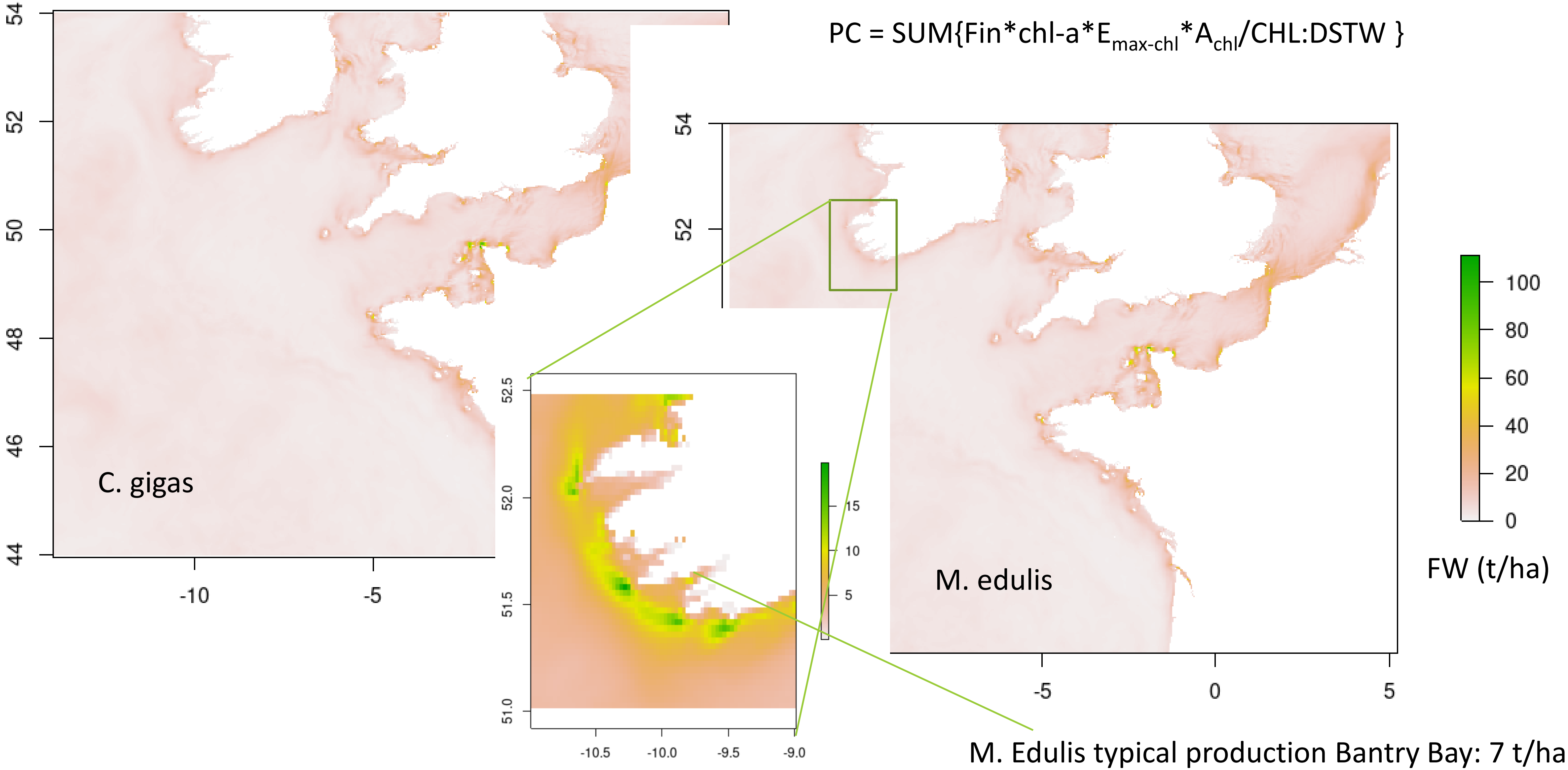
- Parameter sets for S. Latissima and A. Esculenta taken from literature synthesis and tuned to Bantry Bay data using poorly constrained parameters
- Platform model run using these input parameters and farm / cultivation / harvest parameters to match data in literature sources
- Performs well except at high latitudes in NWS (re-running these farms using Arctic model outputs). Possibly a light issue however.

Location	Latitude / Longitude	Species	Growth period	Reference
NW Spain coast	43.42 N 8.26 W	S. Latissima	December - April	Peteiro et al. 2013
N Spain coast	43.50 N 3.78 W	S. Latissima	March - June	Peteiro et al., 2014
NW Scottish Sea loch	56.38 N 5.54 W	S. Latissima, A. Esculenta	February - August	Kerrison et al., 2020
Danish Baltic coast	56.82 N 10.13 E	S. Latissima	September - June	Boderskov et al., 2021
Swedish Baltic coast	58.86 N 11.07 E	U. fenestrata	October - April	Steinhagen et al., 2021
Norwegian coast	63.65 N 8.65 E	S. Latissima	September - June	Fobord et al., 2020
Norwegian coast	63.78 N 5.54 E	S. Latissima	December – April, May, june	Monteiro et al., 2021



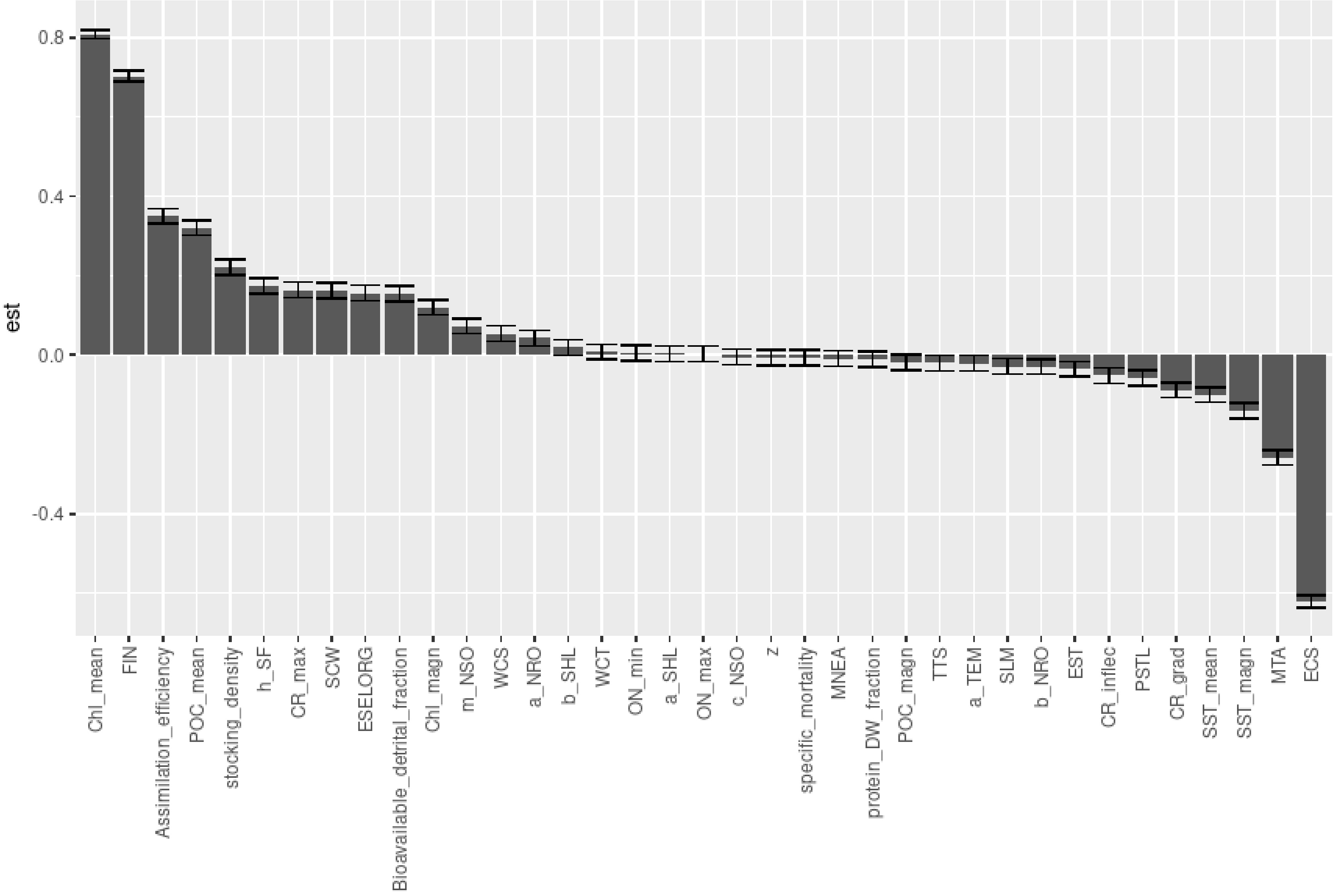
Shellfish carrying capacity model output (IBI subregion)

$$PC = SUM\{Fin*chl\text{-}a*E_{max\text{-}chl}*A_{chl}/CHL:DSTW\}$$



M. Edulis typical production Bantry Bay: 7 t/ha

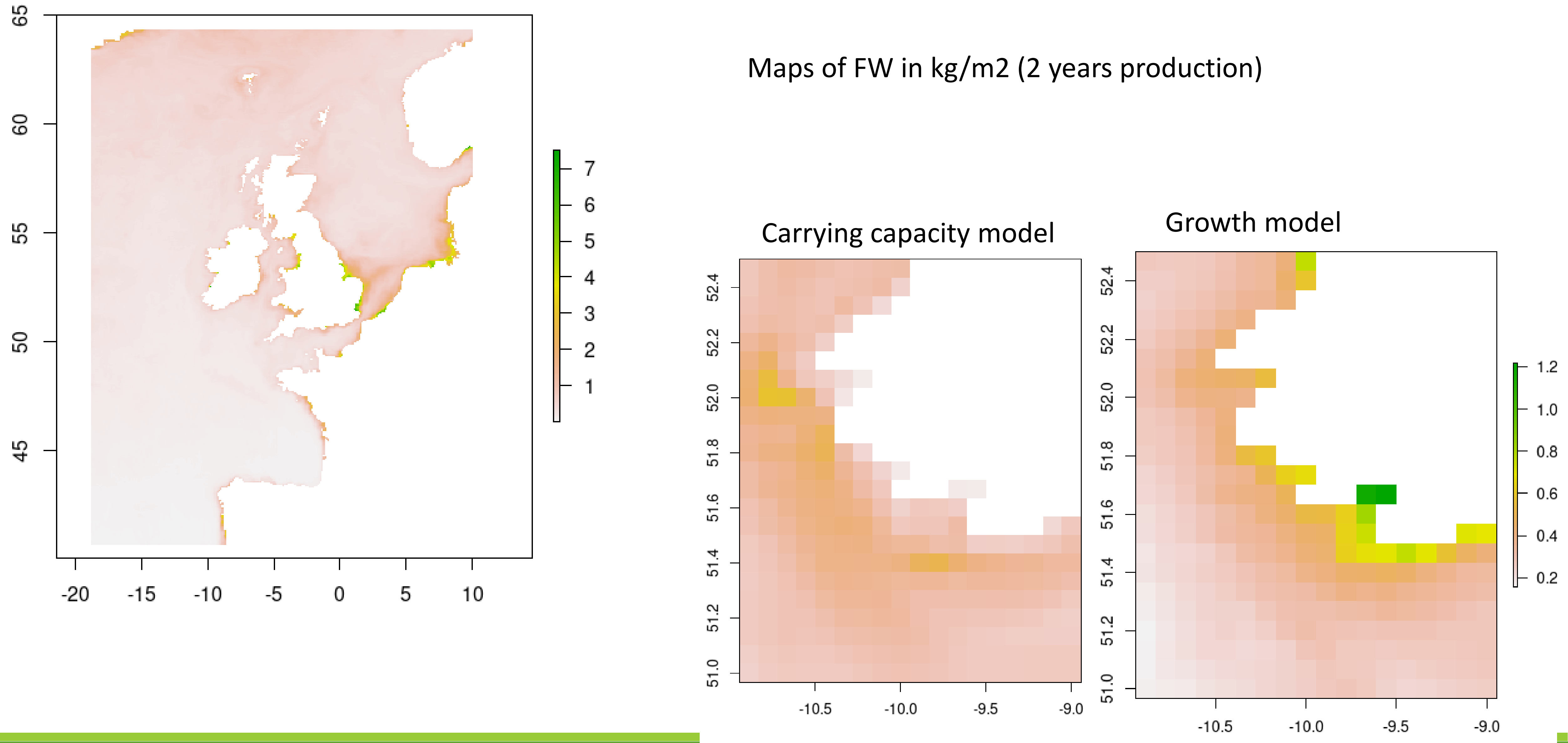
WP1 – Analysis – Shellfish model



Sensitivity analysis on R model. (10000 member latin hypercube, partial rank correlation coefficient analysis on Fresh Weight per unit area)

Shellfish prognostic growth model (Hawkins et al., 2013), NWS region

Maps of FW in kg/m2 (2 years production)



WP-1 – Task 2 – Subtask 2.3: Nutrient uptake model

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ARGANS

Numerical Modelling of Nutrients Uptake Dynamics.

An application in the Bay of Biscay

. *C* is the CMEMS Iberian/Biscay/Ireland regional solution (daily files).
. C' is the concentration of nutrient after introduction of algae farms.
. ε (the nutrient uptake) causes a variation *c* of the local concentration.

The 2D eq. of the advection of this deficit *c=(C-C')* may be written*:*

$$\frac{\partial c}{\partial t} + \frac{\partial (uc)}{\partial x} + \frac{\partial (vc)}{\partial y} = \epsilon$$

To remain consistent with the CMEMS calculation procedures, this equation of the nutrient deficit caused by algae production is then solved in a well mixed upper layer using the Euler Upwind numerical scheme

Nutrient uptake simulation

ϵ is the consumption of nutrients, from the biological model we have:

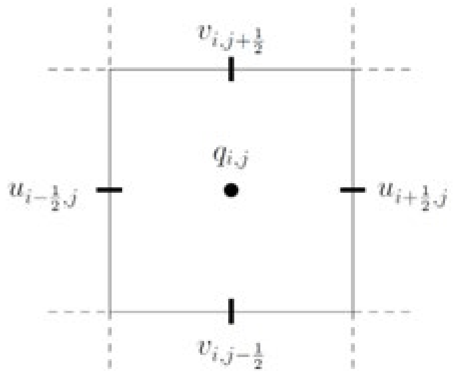
$$\epsilon_{\mathrm{NH4}} = (\mathrm{r}_L \cdot\ \mathrm{D} + \mathrm{d_M} \cdot\ \mathrm{N_s} - \mathrm{f}(\mathrm{NH}_4', \mathrm{Q}) \cdot \mathrm{B} - \mathrm{r_N} \cdot \mathrm{NH}_4')\frac{\mathrm{V_{MA}}}{\mathrm{V_{INT}}}$$

$$\epsilon_{\mathrm{NO3}} = (\mathrm{r}_N \cdot\ \mathrm{NH\_4}' - \mathrm{f}(\mathrm{NO}_3', \mathrm{Q}) \cdot \mathrm{B})\frac{\mathrm{V_{MA}}}{\mathrm{V_{INT}}}$$

We multiply by $\frac{\mathrm{V_{MA}}}{\mathrm{V_{INT}}}$, because the consumption and remineralization append in the algae volume, but it influences all the mixing volume

2 - Numerical scheme

We consider the following grid:



All data are centred except for the current velocities which are defined at the edges of the mesh.

To solve this equation, we consider a Euler-Upwind scheme:

$$c_{i,j}^{n+1} = c_{i,j}^{n} - \frac{\Delta t}{\Delta x}\left(F_{i+1/2,j} - F_{i-1/2,j}\right) - \frac{\Delta t}{\Delta y}\left(G_{i,j+1/2} - G_{i,j-1/2}\right) + \Delta t \cdot \epsilon$$

We use an adaptative time step to ensure CFL=0,9 and N_f>0

2 - Numerical scheme

With:

$$F_{i,j} = u_{i,j}\widehat{c_{i,j}}$$

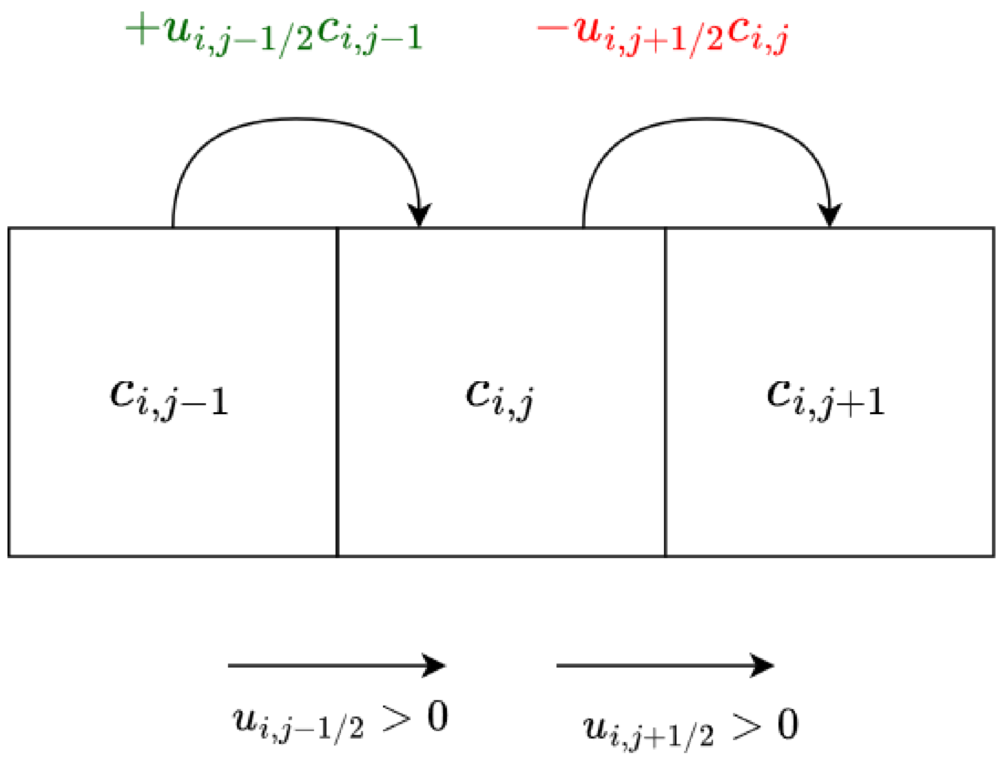
And

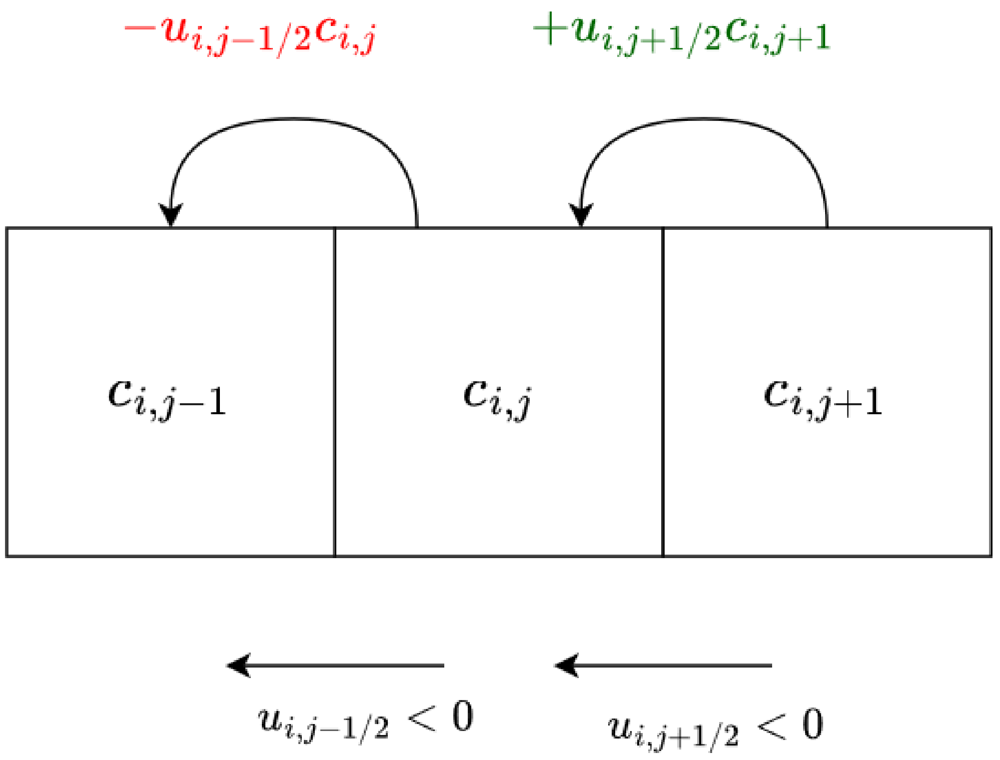
$$G_{i,j} = v_{i,j}\widehat{c_{i,j}}$$

$\widehat{c_{i,j}}$ depends on the direction of the current

$$c_{\widehat{i+1/2},j} = \begin{cases} c_{i,j} \text{ if } u > 0 \\ c_{i+1,j} \text{ if } u < 0 \end{cases}$$

Examples :


$+u_{i,j-1/2}c_{i,j-1}$
$-u_{i,j+1/2}c_{i,j}$
$c_{i,j-1}$
$c_{i,j}$
$c_{i,j+1}$
$u_{i,j-1/2} > 0$
$u_{i,j+1/2} > 0$


$-u_{i,j-1/2}c_{i,j}$
$+u_{i,j+1/2}c_{i,j+1}$
$c_{i,j-1}$
$c_{i,j}$
$c_{i,j+1}$
$u_{i,j-1/2} < 0$
$u_{i,j+1/2} < 0$

3 – Scenario A

In scenario A we study the production of algae in a mesh, we neglect the influence of the consumption of nutrients in this mesh on the concentrations of the neighboring meshes. This scenario is equivalent to considering that a farm is implanted alone in the environment, without any farm around. We do not consider diffusion terms. So, we have as evolution equation the equation used for scenario B but without the diffusion term:

$$\frac{\partial c}{\partial t} + \frac{\partial}{\partial x}(uc) + \frac{\partial}{\partial y}(vc) = \epsilon$$

However, we considered that the production of algae in the mesh (i, j) had no influence on the neighboring meshes, and respectively these neighbors have no influence on this mesh. So, when we study the evolution of nutrients in (i, j), we have

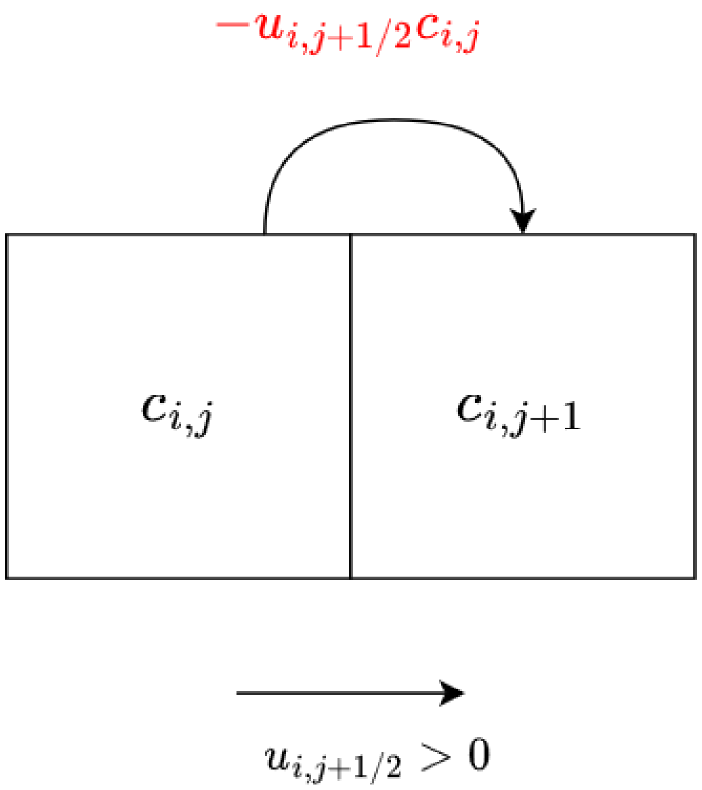
$$\forall (k, l) \neq (i, j), c_{k,l} = 0$$

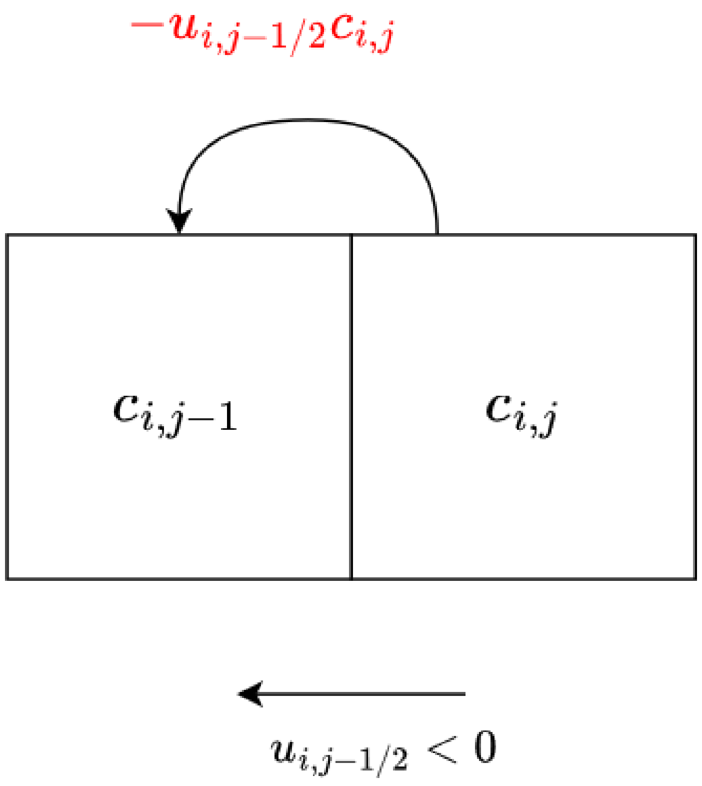
We can thus rewrite the numerical scheme as follows

$$\mathrm{c}_{i,j}^{n+1} = \mathrm{c}_{i,j}^{\mathrm{n}} \cdot \left(1 - \frac{\Delta\,\mathrm{t}}{\Delta\,\mathrm{x}} \left(\mathrm{u}_{i+\frac{1}{2},j} \cdot \mathbf{1}_{\mathrm{u}_{i+\frac{1}{2},j}>0} - \mathrm{u}_{i-\frac{1}{2},j} \cdot \mathbf{1}_{\mathrm{u}_{i-\frac{1}{2},j}<0} \right) - \frac{\Delta\,\mathrm{t}}{\Delta\,\mathrm{y}} \left(\mathrm{v}_{i,j+\frac{1}{2}} \cdot \mathbf{1}_{\mathrm{v}_{i,j+\frac{1}{2}}>0} - \mathrm{v}_{i,j-\frac{1}{2}} \cdot \mathbf{1}_{\mathrm{u}_{i,j-\frac{1}{2}}<0} \right) \right. + \Delta\,\mathrm{t} \cdot \epsilon$$

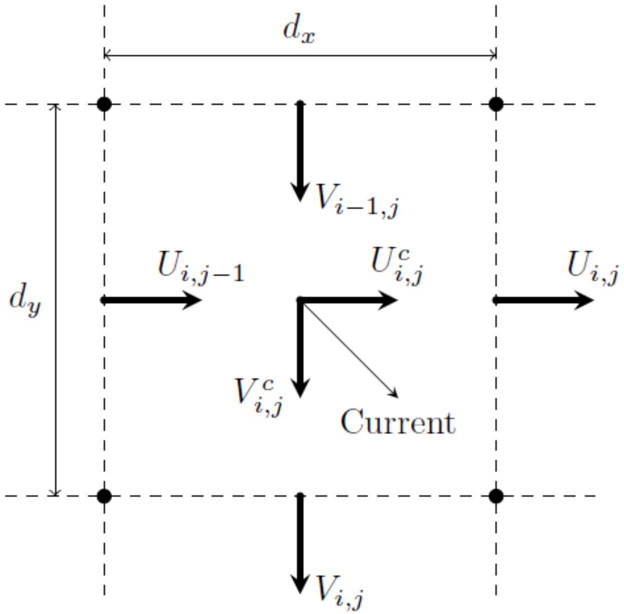
WP-1 – Task 2 – Subtask 2.3: **Nutrient uptake model** - Formalism

Examples :





WP-1 – Task 2 – Subtask 2.3: Nutrient uptake model – Current decentering



Statement of the problem

- From CMEMS data, we have a **2D field of currents estimated at the centre** of each grid cell (light arrow in figure, with components U^c and V^c)
- In order to run an advection field we instead need currents that:
  - Are **estimated at each cell "wall"** and normal to the walls
  - Are such that the sum total of entering and exiting flow is 0 (**incompressibility or zero divergence**)

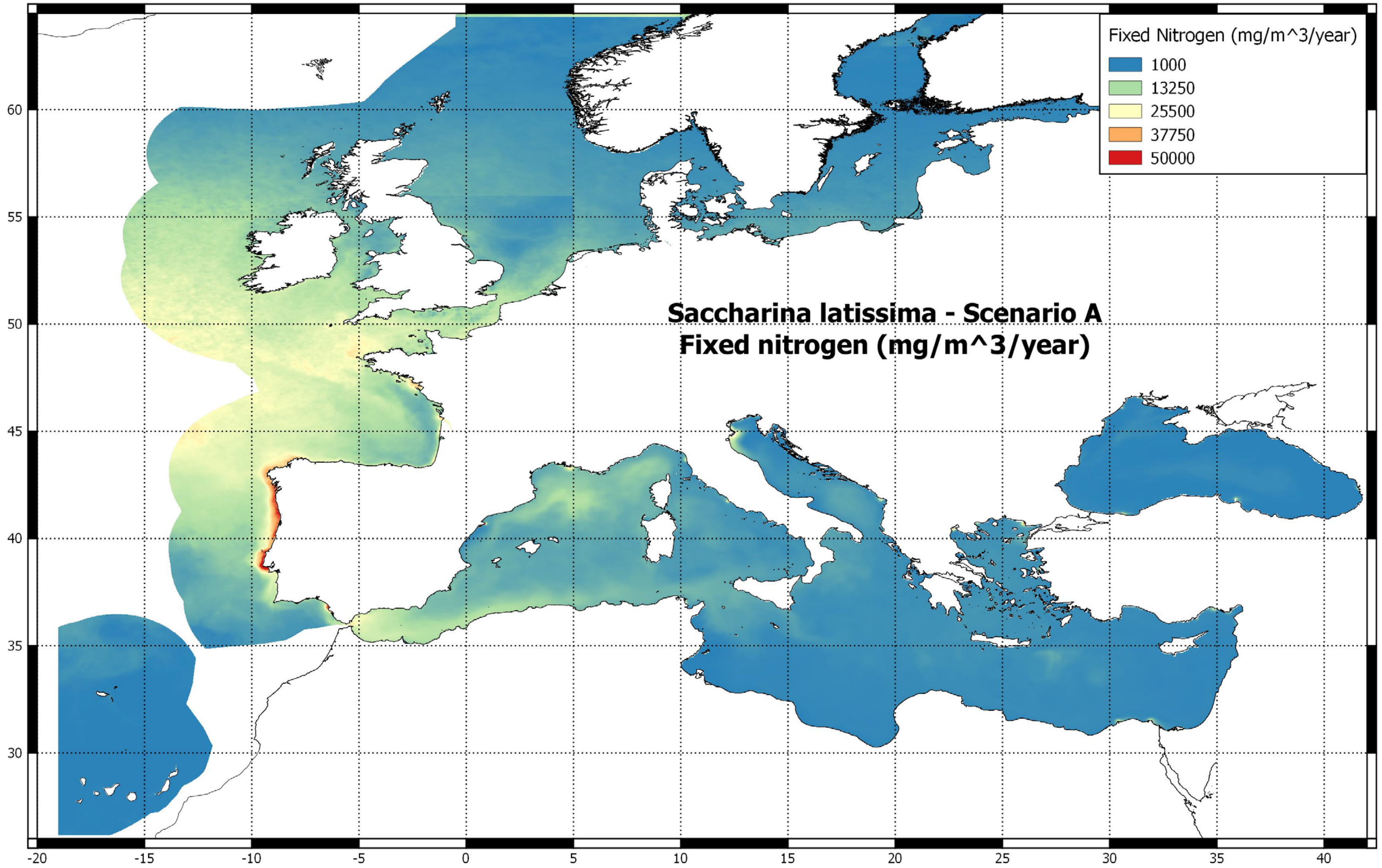
Chosen solution

- This problem can be formulated as a **constrained optimization problem** in which we want U and V to be as close as possible to U^c and V^c while respecting the incompressibility constraint.
- Using the **method of Lagrange multipliers**, we were able to make this problem equivalent to **solving a large linear equation system**. This can be done **relatively quickly during the simulation**, which is necessary because we have to run it for every day of the simulation because the input data changes.
- More details on this can be found in the document titled "Current_decentering_approach"

WP-1 – Task 2 – Subtask 2.3: **Nutrient uptake model** - Achievements

- Daily current velocity and nutrient files.
- Winter growth.
- t_0= 01/09/2021

Areas	Scenario A	Scenario B	Scenario C
NWS	18 mn	16 mn	6h15mn
IBI	4h30mn	4h	11h45mn
Baltic	24mn	25mn	1h
Arctic	29mn	30mn	14h50mn
Black Sea	15mn	15mn	56mn
Medit	1h	1h4mn	5h58mn



WP1 – Development – Task 2.6 : Impact on fishing

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COFREPECHE

ARGANS

WP1 – Development – Task 2.6 : Impact on fishing - Overview

Objectives of subtask 2.6

Identify the impacts of seaweed and shellfish aquaculture development on fishing activities and therefore its potential impact on fish stock in EU waters.

Two parts

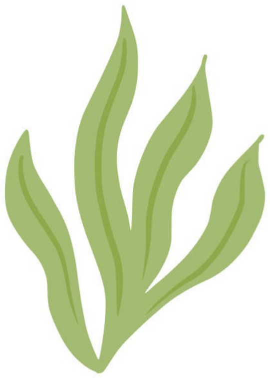
- Impact of seaweed and shellfish aquaculture on fisheries
- Link between nutrients and fisheries

WP1 – Development – Task 2.6 : Impact on fishing - Achievements

Achievements - Impacts of seaweed and shellfish aquaculture on fisheries

What has been done

- Broad bibliographic review using general key words but also more specific key words using species and regions (scientific papers and grey literature) + Impact specific search
- Reading through all the papers to find information on aquaculture impact on fishing activities
- Approx. 40 papers related to seaweed aquaculture impacts
- Approx. 85 papers related to shellfish aquaculture impacts



WP1 – Development – Task 2.6 : Impact on fishing - Achievements

***Achievements* -** Impacts of seaweed and shellfish aquaculture on fisheries

Main results

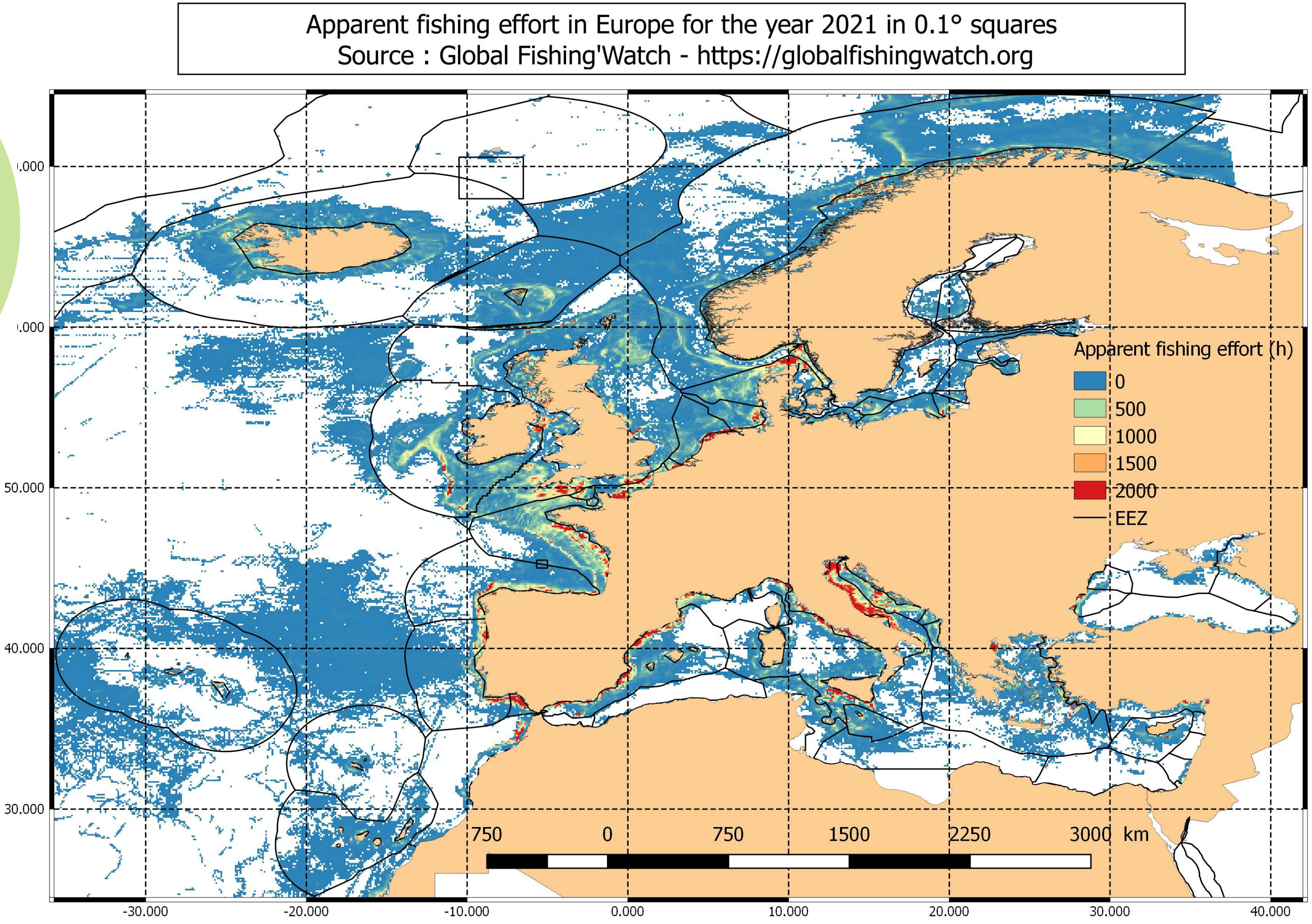
- The literature was scarce, and the information was diffuse and non-convergent
- No direct impact on fishing or fish stock could be found except for loss of fishing ground. Only indirect impacts and most of the time non-convergent depending on the aquaculture type but also on the environmental characteristics.
- Only convergence in the literature is : negative impact of aquaculture increases with farm size
- Two recap tables which can be seen here : https://drive.google.com/file/d/1ssdLv8a1aTYFxRrw8Qsl8_NesPn3_3U0/view?usp=sharing

Only sure impact: Loss of fishing ground
Couple fishing effort with farm location – Global Fishing Watch data

WP1 – Development – Task 2.6 : Impact on fishing - Overview

Apparent fishing effort in Europe in 2021

Coastal areas will compete with aquaculture



WP1 – Development – Task 2.6 : Impact on fishing - Achievements

Achievements - Link between nutrients and fisheries

What has been done

- Additional bibliographic review : 10 additional papers

Main results

- Few papers found and two particularly interesting taking place in Baltic and Black Sea (semi-enclosed seas)
- Nutrients **enrichment** can **affect both the growth** and **the reproduction** of exploited species (Viet Thanh, 2013, Knowler, Barbier and Strand, 2002) but it highly depends on the species and habitat (Viet Thanh, 2013).
- Difficult to know if **decrease** in nutrient concentration will have **a positive or a negative** impact on exploited species.

Compare a “before aquaculture” **nutrient budget** of each basin/UE scale and compare it with nutrient budget after each scenarios (CCTP)

WP1 – Development – Task 2.6 : Impact on fishing - Deviation

Deviation

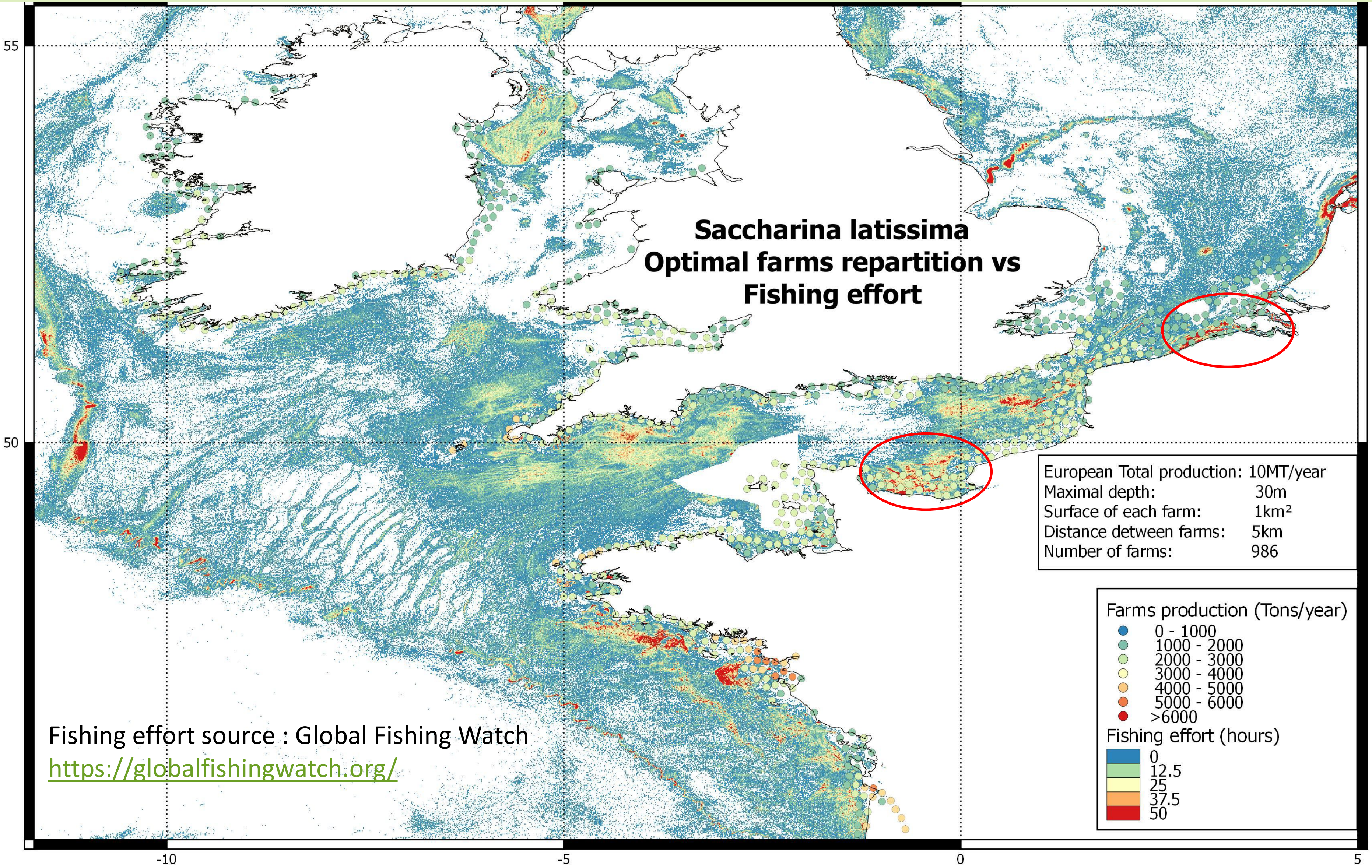
Problems encountered

Lack of information/literature regarding direct impact of aquaculture development on fisheries

Proposed solution

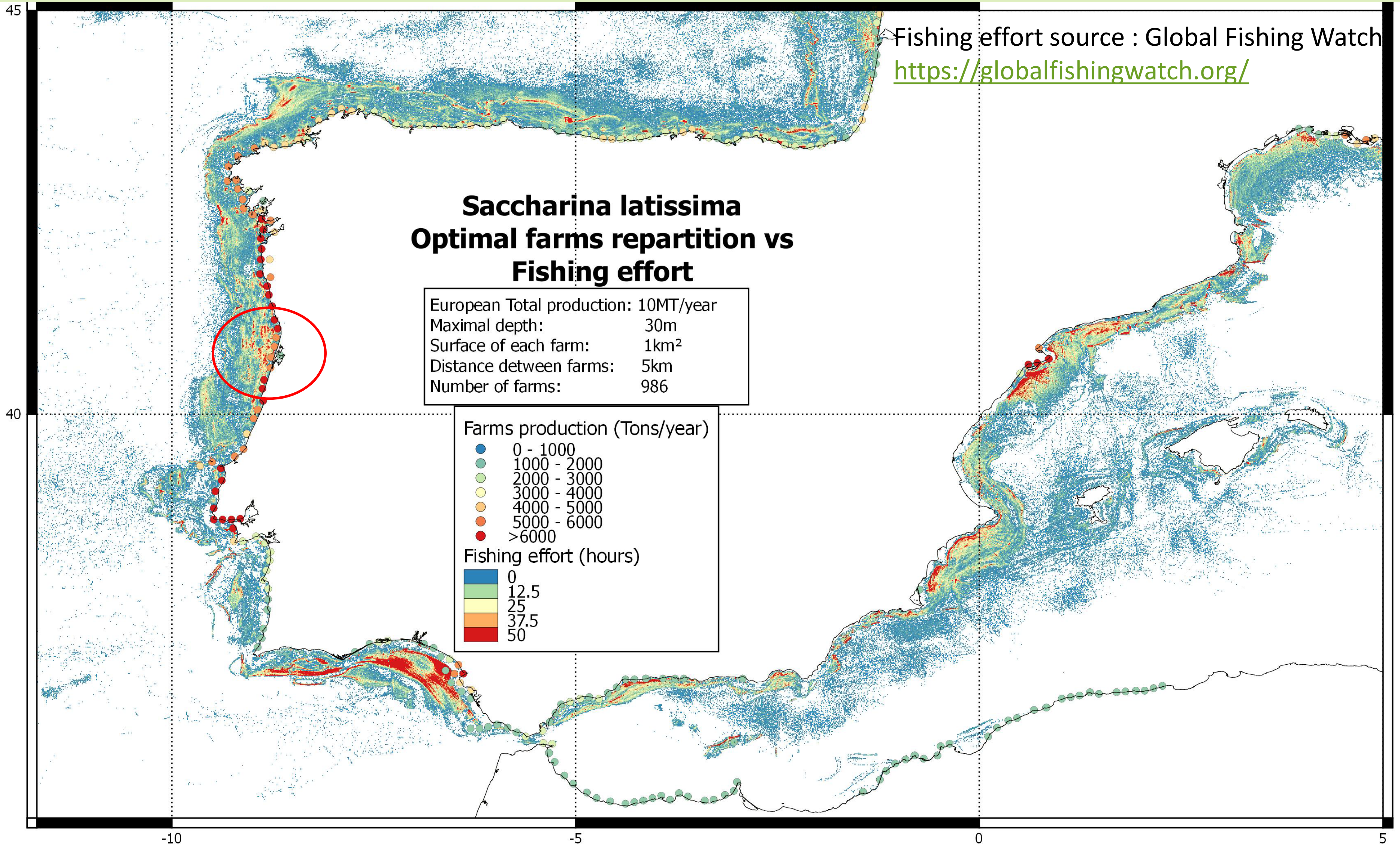
Additional research on links between nutrients and fisheries

WP1 – Development – Task 2.6 : Impact on fishing – Farms repartition vs Fishing effort



Conflict areas

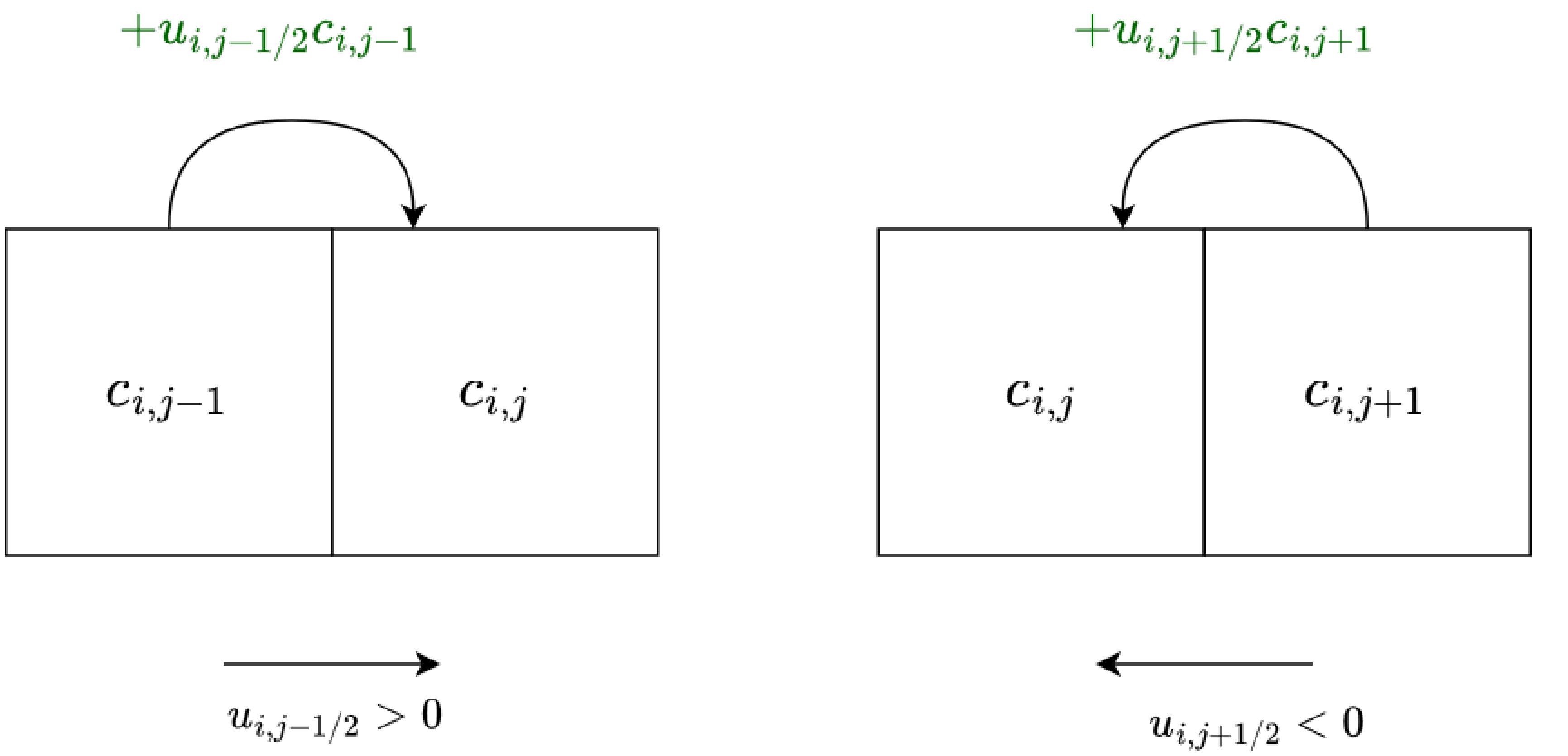
WP1 – Development – Task 2.6 : Impact on fishing – Farms repartition vs Fishing effort



Conflict areas

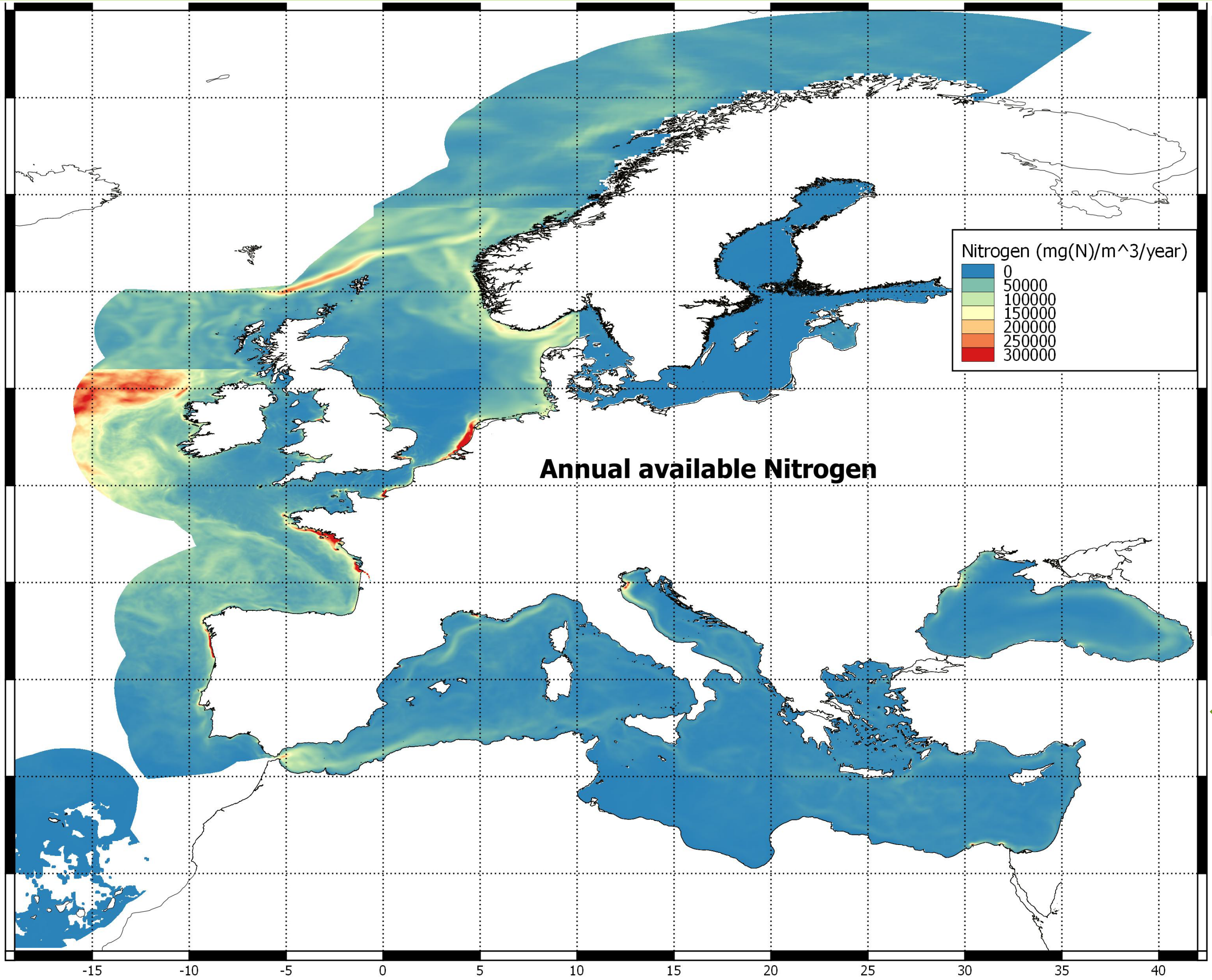
ARGANS

WP1 – Development – Task 2.6 : Impact on fishing – Available nutrients



- To obtain the available nutrients, we consider the nutrients that enter the cell, during the whole growth period

WP1 – Development – Task 2.6 : Impact on fishing – Available nutrients



CMEMS response to our questions on the BGC model in the Baltic Sea :

Thank you for your question regarding the differences in nitrate concentration for the present products for the Baltic Sea. The model results are from two different model systems.
We are currently working on harmonizing the model systems. That is why we have already replaced SCOBI with BSH-ERGOM for the forecast product.
Unfortunately, the nitrate concentrations in BSH-ERGOM are inaccurate. The seasonal dynamics are not well represented and consequently the nitrate concentration is too high in winter.
We have been working hard to improve the nutrient cycles and with the November update the product will be more reliable.

To overcome this anomaly we have recently used reanalysed CMEMS products from the Baltic Sea.

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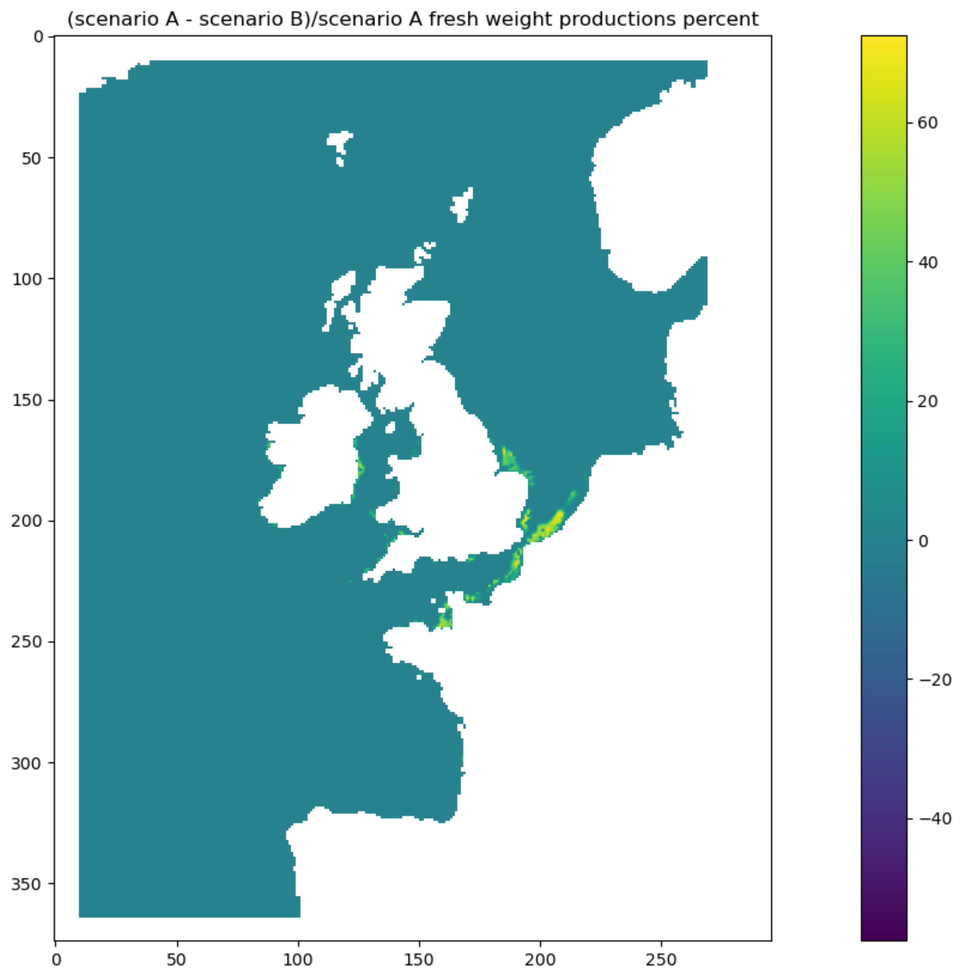
WP1 – Development – Task 2.6 : Impact on fishing – Available nutrients



Seaweed farms affect the productivity downstream **locally**

NWS region total N extracted is 290 T for the 10MT seaweed scenario.

North Sea total N input per year is 8870 +/- 4460 kT so at most (290/4410000) * 100% = ~0.007% of total available N.

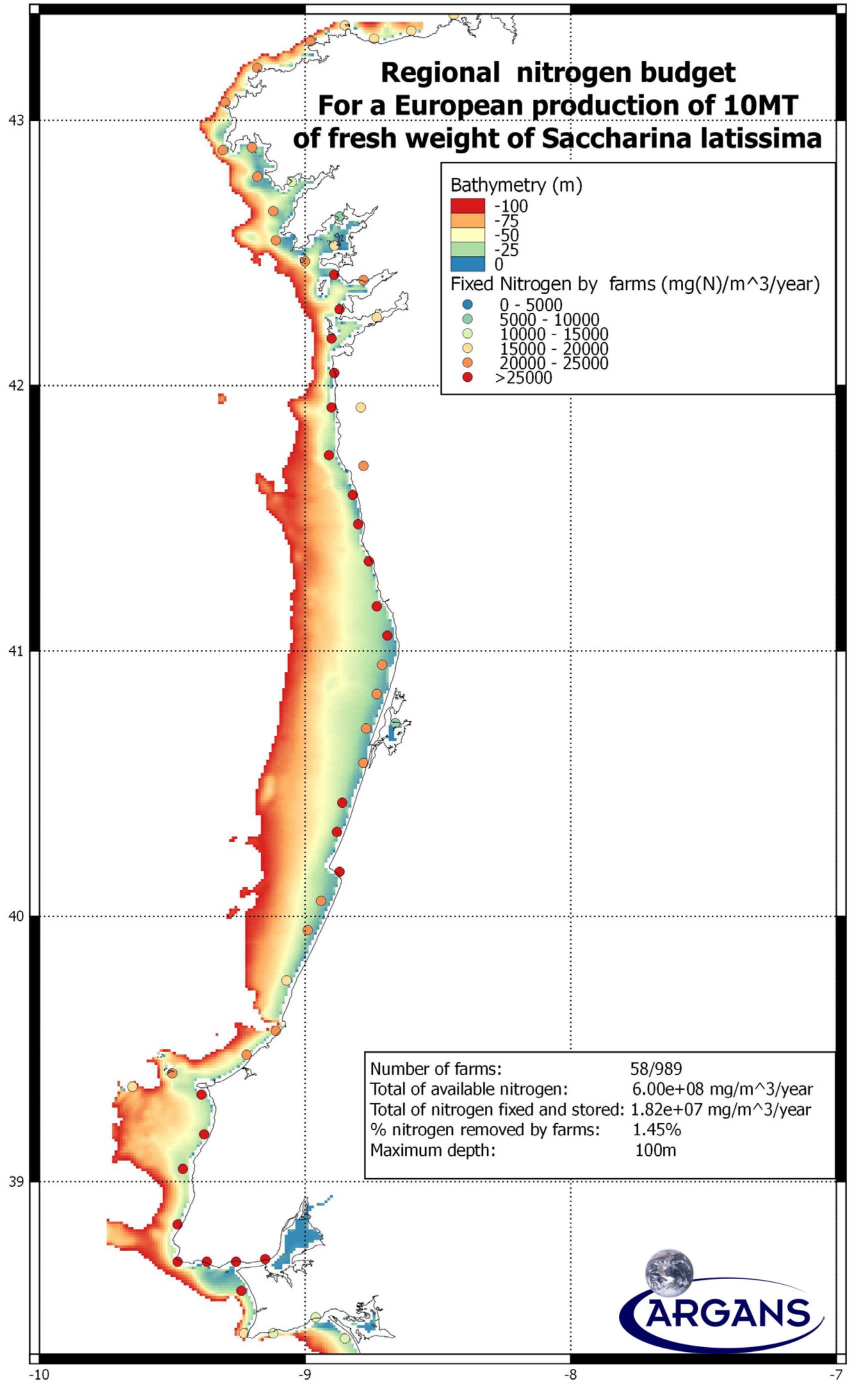
Regions of highest nutrient change are regions of highest nutrient concentration so local effect is ameliorating hypernutrification.

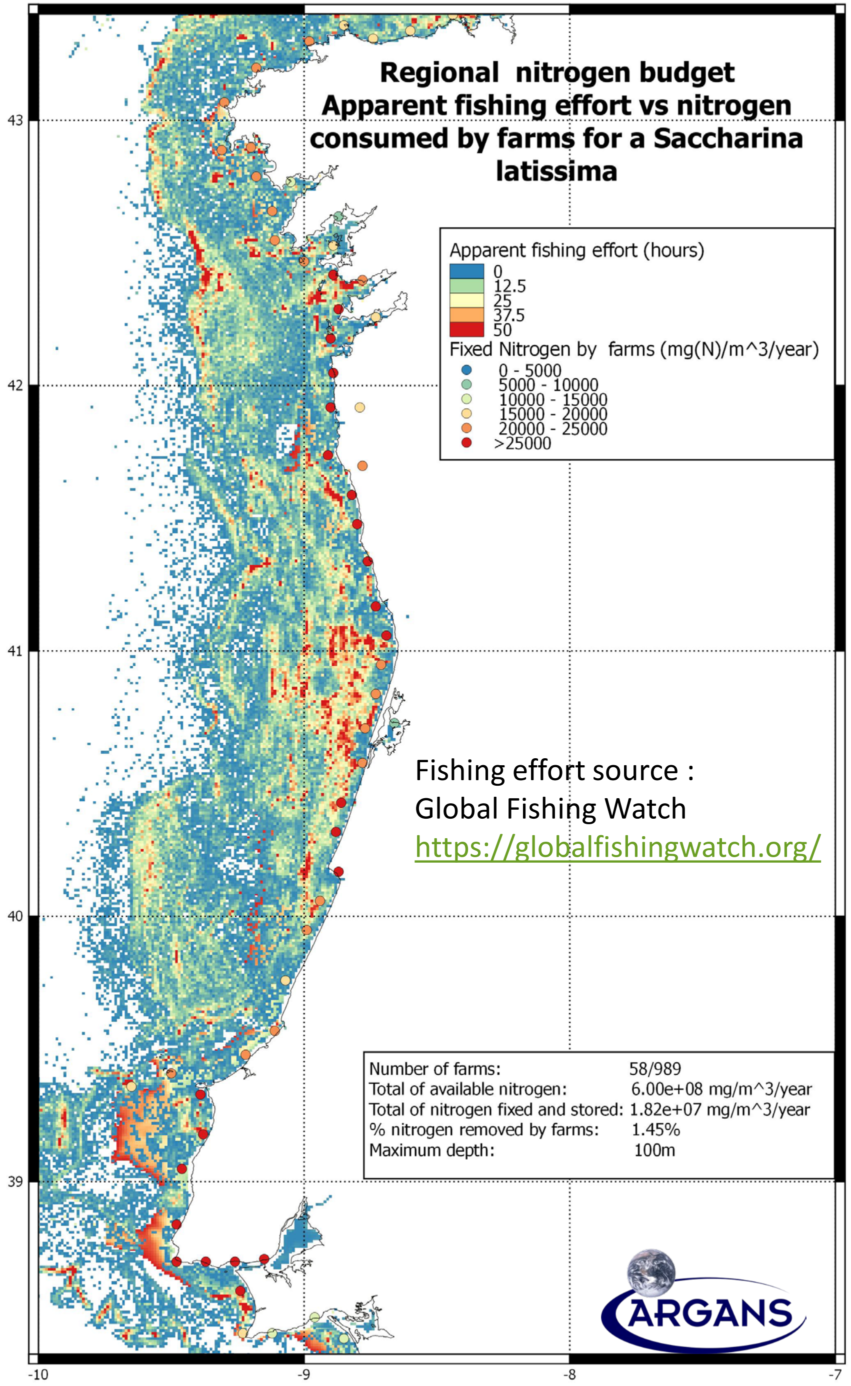
WP1 – Development –

Example of local nitrogen budget :

- For a European production of ***10MT of fresh weigth of Saccharina latissima***
- The chosen region is the most productive in Europe

- The total available nitrogen in the area corresponding to a bathymetry of -100m is considered
- The farms are separated by 10km in water up to -30m and produced ***1.208MT*** of fresh weight
- ***The nitrogen removed from the environment represents less than 1,5% of the available nitrogen***





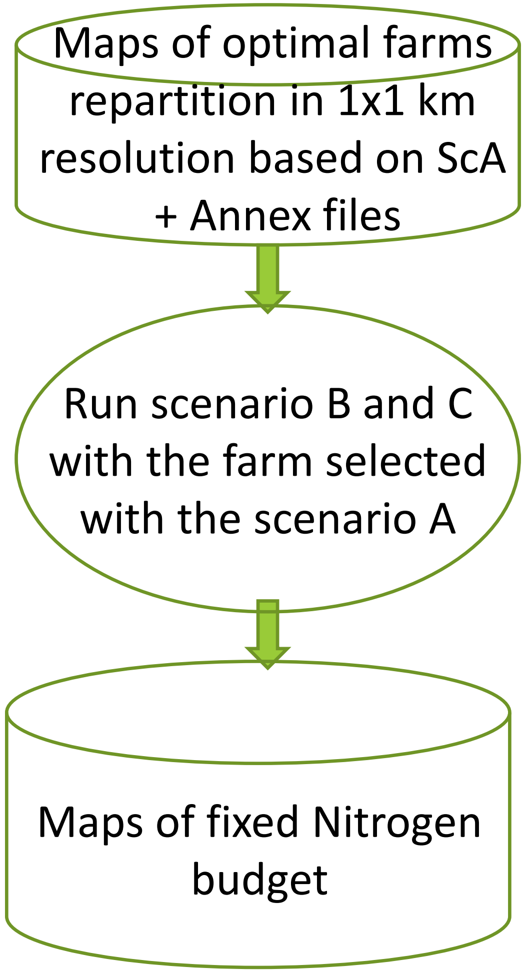
Fishing effort source :
Global Fishing Watch
https://globalfishingwatch.org/

WP1 – Development – Task 2.6 : Impact on fishing – Nitrogen budget

The farms selected with the scenario A are positioned in scenarios B and C to estimate the nutrient deficit due to an extensive aquaculture.

Output formats:

- GTIFF
- csv
- text



Needs some development
Will be done by the end of the project

WP1 – Development – Task 2.6 : Impact on fishing – Nitrogen budget

Summary of fixed and stored nitrogen for each species for the different productions

Nitrogen Tons/year	**Saccharina** - Annual Production of Fresh Weight			
	1 MT	2 MT	5 MT	10 MT
Fixed	1320	2760	6840	13560
Stored	960	1920	**4560**	8258

Nitrogen Tons/year	**Alaria**- Annual Production of Fresh Weight			
	1 MT	2 MT	5 MT	10 MT
Fixed	3600	7200	18000	43080
Stored	1728	5280	12360	**22560**

Nitrogen Tons/year	**Ulva** - Annual Production of Fresh Weight			
	1 MT	2 MT	5 MT	10 MT
Fixed	43008	86160	215640	432000
Stored	83400	160600	355680	**798600**

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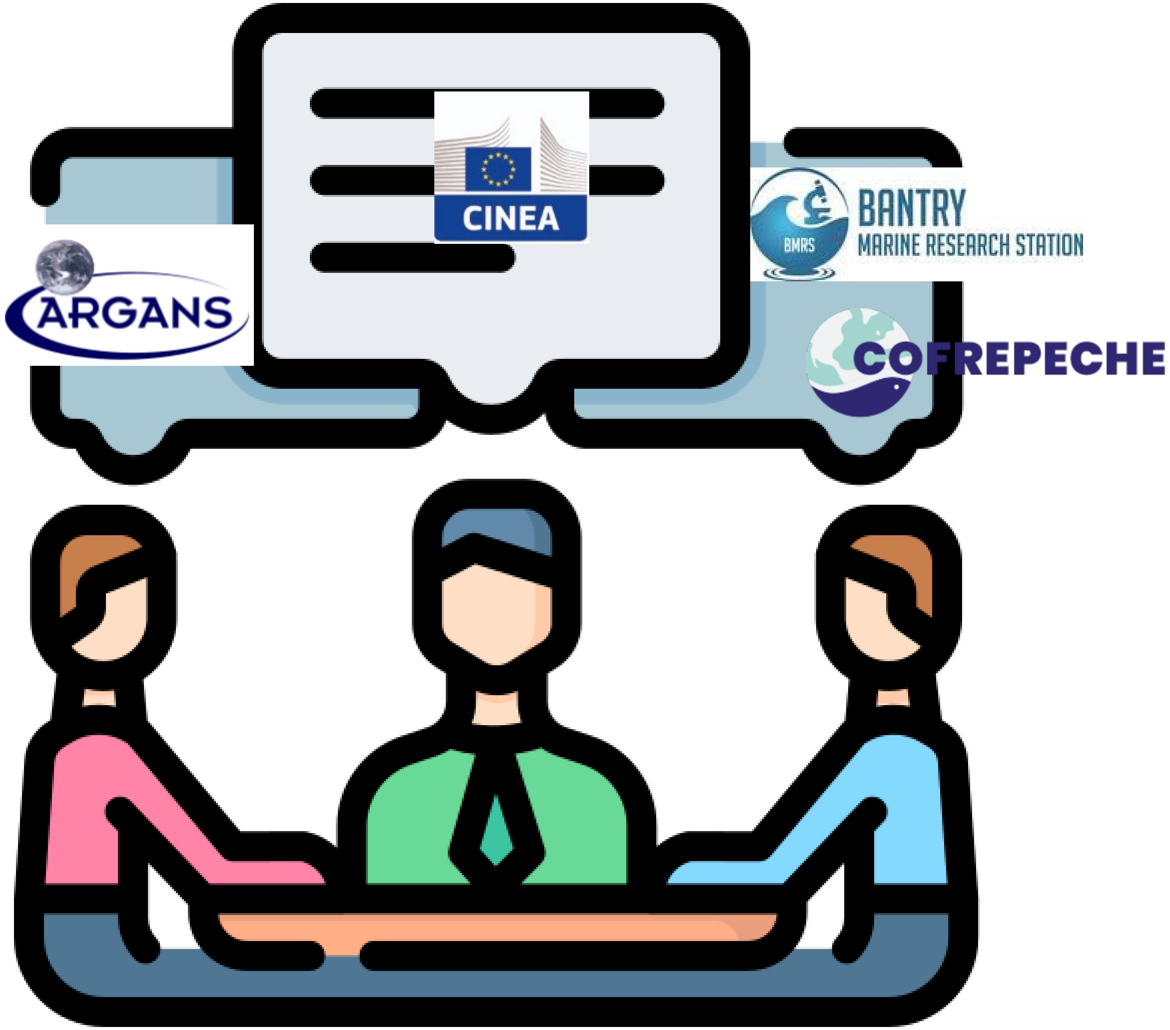
Discussion :

General discussion :



Studies to support the European Green Deal

Lot 1 Shellfish and algae

Final Report 2022/10/14

ARGANS

BANTRY MARINE RESEARCH STATION

COFREPECHE

CINEA/EMFF/2020/1.3.1.16/Lot 1

WP2 – Production – Task 3 : Preparing digital maps

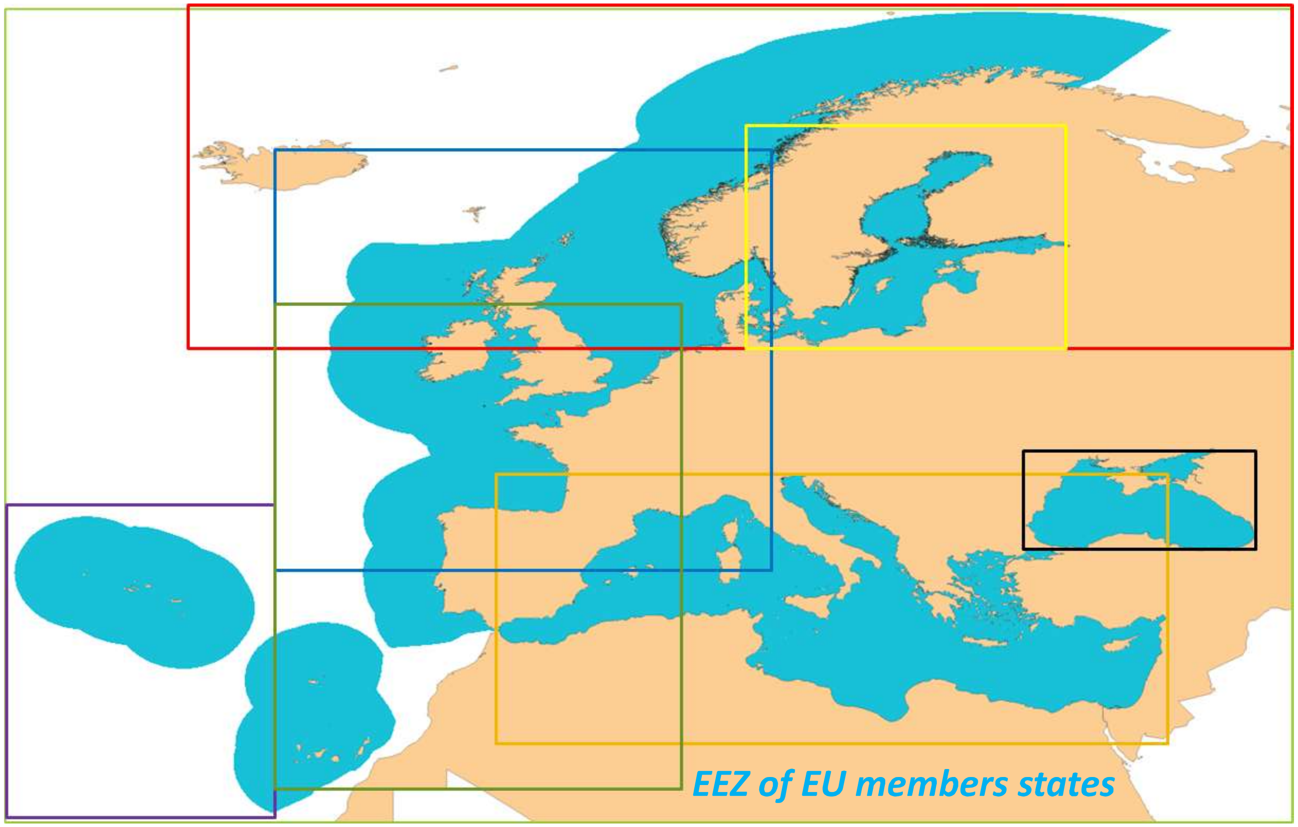
Philippe Bryère pbryere@argans.eu
Martin Johnson mjohnson@bmrs.ie

WP2 – Production – Task 3 : Preparing digital maps – Areas covered by the study

The study covered the entire area required by the tender i.e. complete coverage of the Baltic, Black, Mediterranean and North Seas; – coverage of jurisdictional waters (including continental shelf and claimed extended continental shelf) of EU Member States, UK and Norway for the North East Atlantic (Celtic Seas, Iberian Coast and Bay of Biscay, Macaronesia, Norwegian Sea).

Based on Copernicus database divided in 6 areas for European Seas:

- Artic
- Baltic sea
- North West Shelf
- Ireland-Biscay-Iberia
- Mediterranean sea
- Black sea



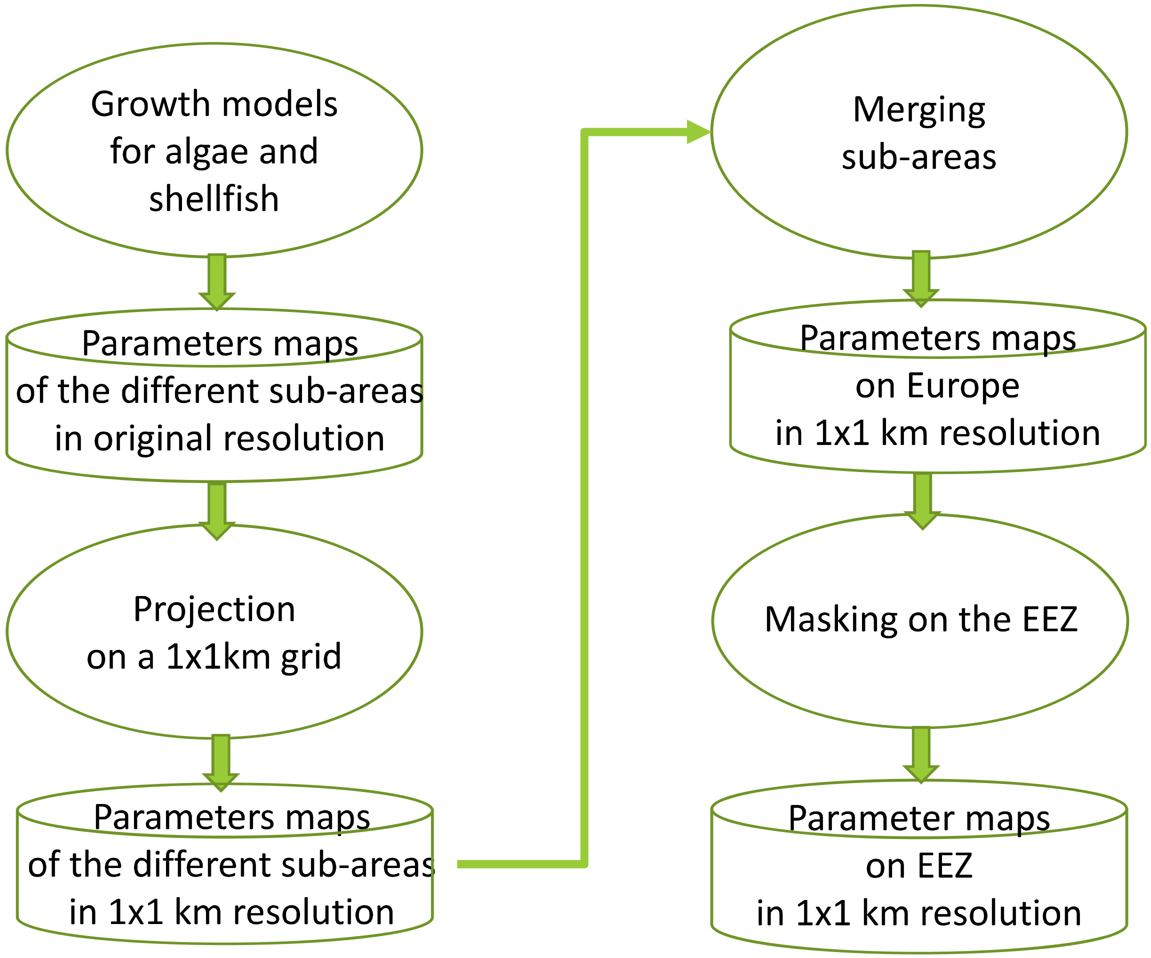
WP2 – Production – Task 3 : Preparing digital maps – Production - Methodology

This method is applied to all requested species for the scenarios A, B and C.

Coded in Python and using the gdal functions

Output formats:

- GTIFF
- NetCDF



WP2 – Production – Task 3 : Preparing digital maps – Production - Methodology

CINEA › scenA › saccharina Rechercher dans : saccharina

Nom	Modifié le	Type	Taille
ZEE_saccharina_Biomass_CO2_A_1km	28/09/2022 09:48	Fichier NC	157 370 Ko
ZEE_saccharina_CO2_uptake_PUA_A_1km	28/09/2022 09:48	Fichier NC	
ZEE_saccharina_DW_PUA_A_1km	28/09/2022 09:48	Fichier NC	
ZEE_saccharina_FW_PUA_A_1km	28/09/2022 09:48	Fichier NC	
ZEE_saccharina_kcal_PUA_A_1km	28/09/2022 09:48	Fichier NC	
ZEE_saccharina_protein_PUA_A_1km	28/09/2022 09:48	Fichier NC	

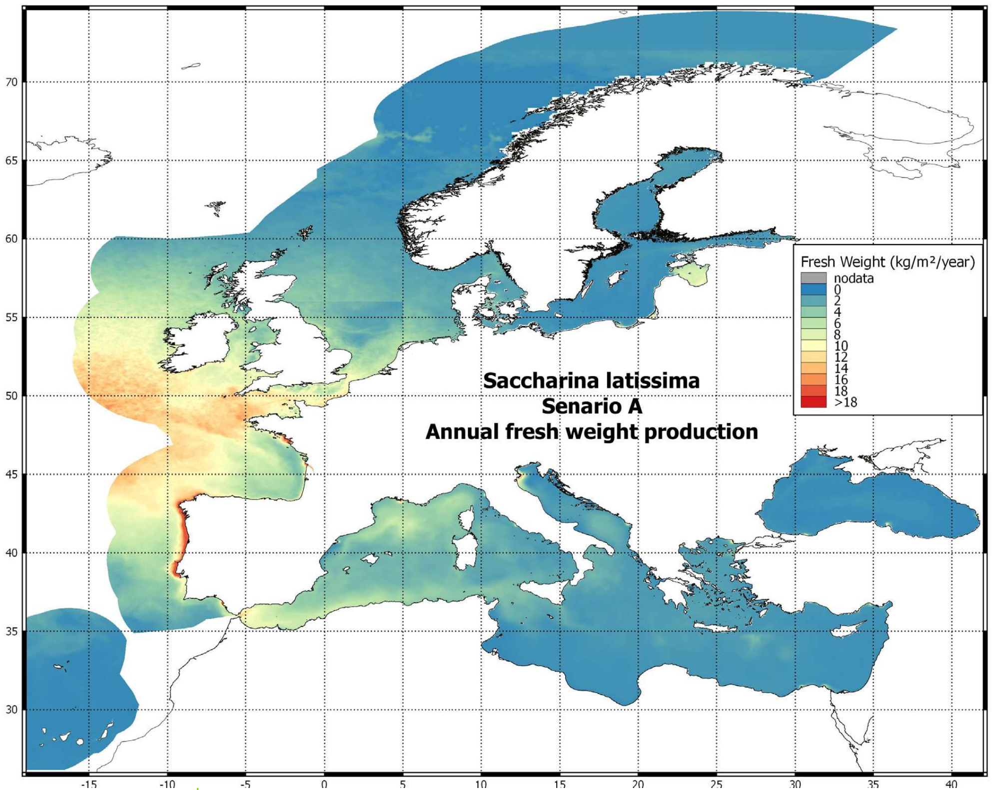
Example of a netcdf file header (Dry weight production of Saccharina - Scenario A)

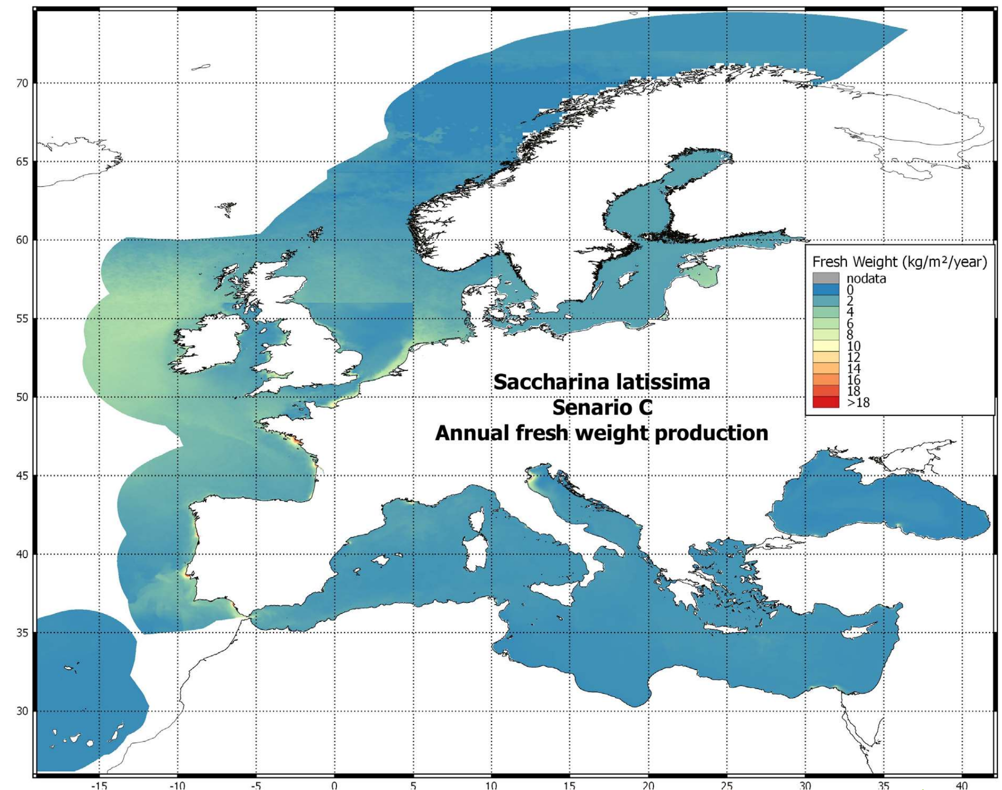
```
netcdf ZEE_saccharina_DW_PUA_A_1km {
dimensions:
        time = 1 ;
        lat = 5031 ;
        lon = 8005 ;
variables:
        float time(time) ;
                time:long_name = "time" ;
                time:units = "hours since 1900-1-1 0:0:0" ;
        float lat(lat) ;
                lat:long_name = "latitude" ;
                lat:units = "degrees_north" ;
                lat:standard_name = "latitude" ;
        float lon(lon) ;
                lon:long_name = "longitude" ;
                lon:units = "degrees_east" ;
                lon:standard_name = "longitude" ;
        float DW_PUA(time, lat, lon) ;
                DW_PUA:long_name = "Dry Weight (kg.m-2.year-1)" ;
                DW_PUA:units = "kg.m-2.year-1" ;
                DW_PUA:valid_min = 0.f ;
                DW_PUA:valid_max = 6.035753f ;
                DW_PUA:_FillValue = -999.f ;
                DW_PUA:missing_value = -999.f ;

// global attributes:
                :Conventions = "CF-1.0" ;
                :netcdf_version_id = "3.4" ;
                :project = "Studies to support the European Green Deal - Lot 1 Shellfish and algae: http://www.??????.com/" ;
                :institution = "ARGANS-FR, Bantry Marine reseach Station (BMRS), Cofrepeche" ;
                :production = "ARGANS-FR E-mails: contact@argans.eu" ;
                :WEB_visualisation = "http://www.????.com\"" ;
                :Author_e-mail = "contact@argans" ;
                :creation_time = "2022-09-28T09:48:09Z" ;
                :title = "Maps of Dry Weight (kg.m-2.year-1)" ;
                :file_name = "/mount/internal/work-he/apps/safi/data/EUROPE/CINEA/scenA/saccharina/ZEE_saccharina_DW_PUA_A_1km.nc" ;
                :spatial_resolution = "1km" ;
                :source = "CMEMS models, EMODNET, NASA/OCEANCOLOR" ;
                :image_type = "composite" ;
                :image_reference_date = "2020" ;
                :southernmost_latitude = "  24.258" ;
                :northernmost_latitude = "  74.568" ;
                :westernmost_longitude = " -35.860" ;
                :easternmost_longitude = "  44.190" ;
                :area = "European EEZ" ;
                :product_version = "1.0" ;
```

WP2 – Production – Task 3 : Preparing digital maps – Production - Results

Fresh Weight of Saccharina latissima (kg/m²/year) – Scenario A (left), B an C (right)

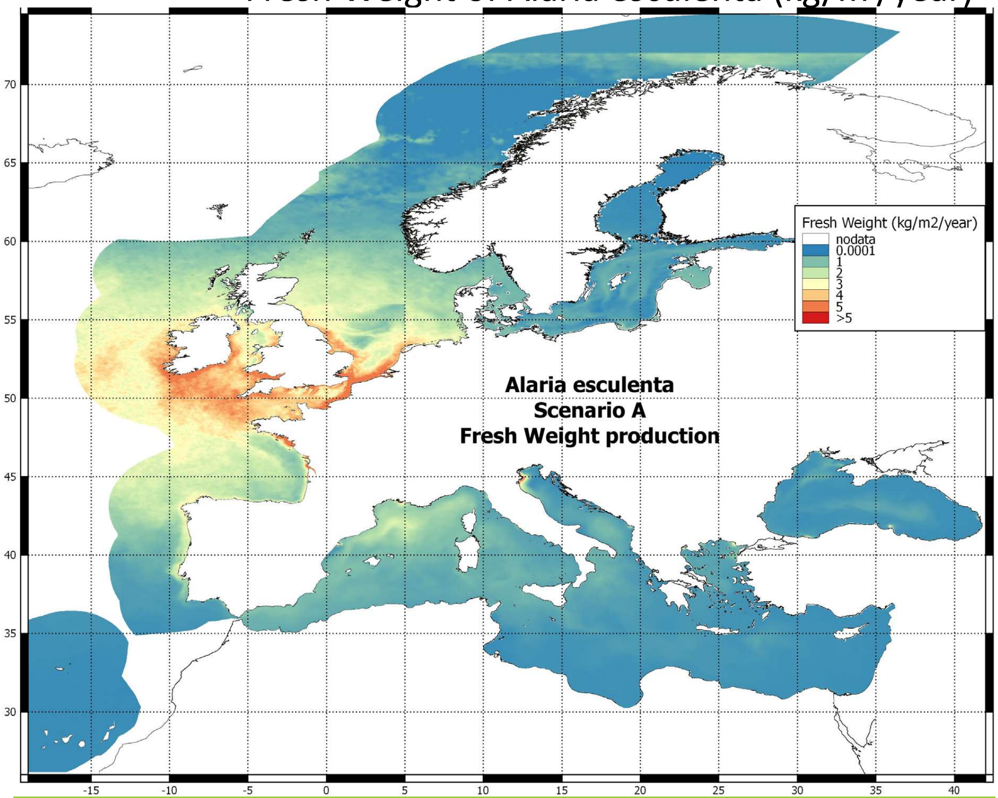


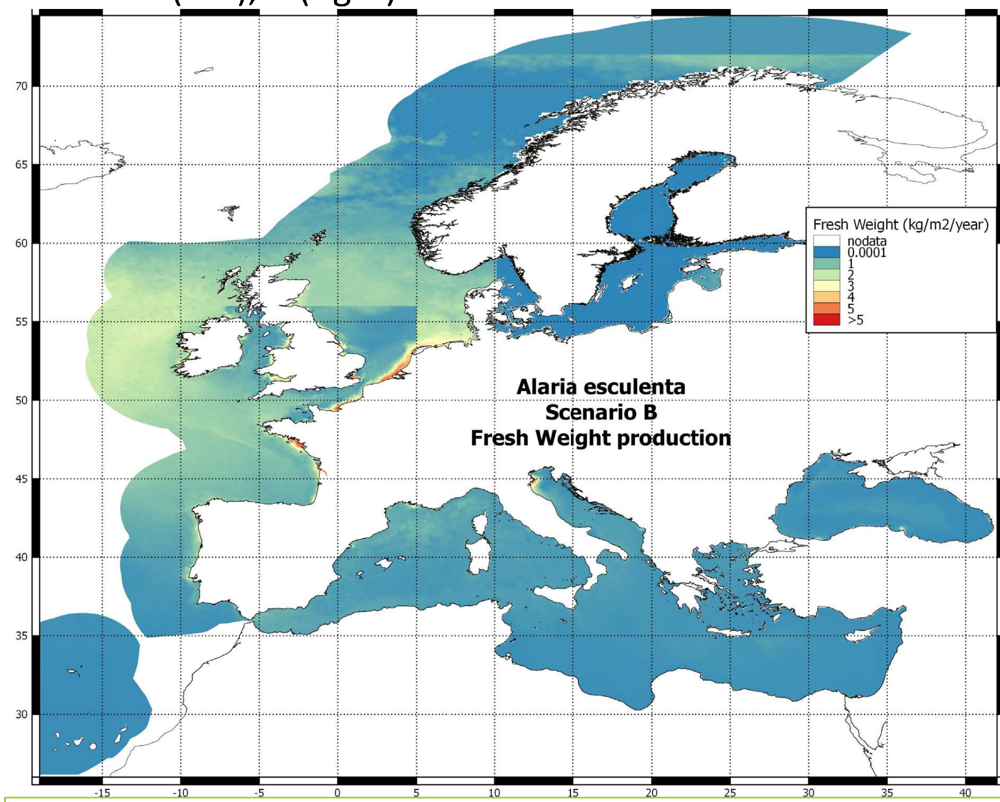


The most productive coastal area are along the Iberian Atlantic coast and int the plumes of the major rivers.

WP2 – Production – Task 3 : Preparing digital maps – Production - Results

Fresh Weight of Alaria esculenta (kg/m²/year) – Scenario A (left), B (right)



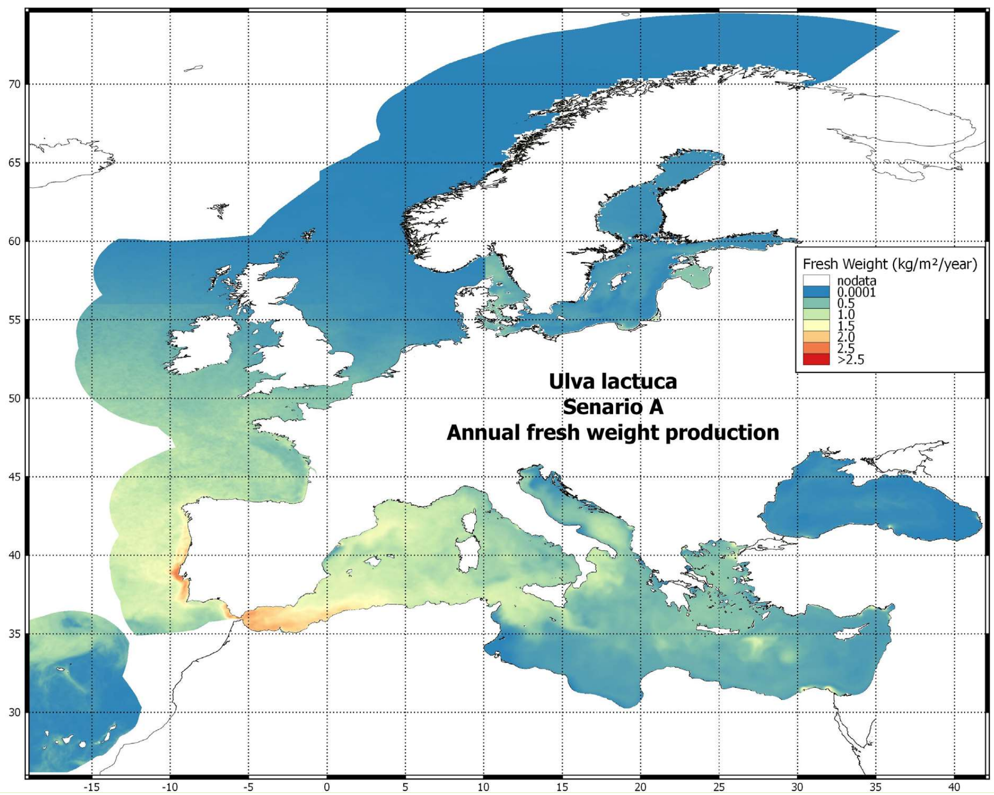


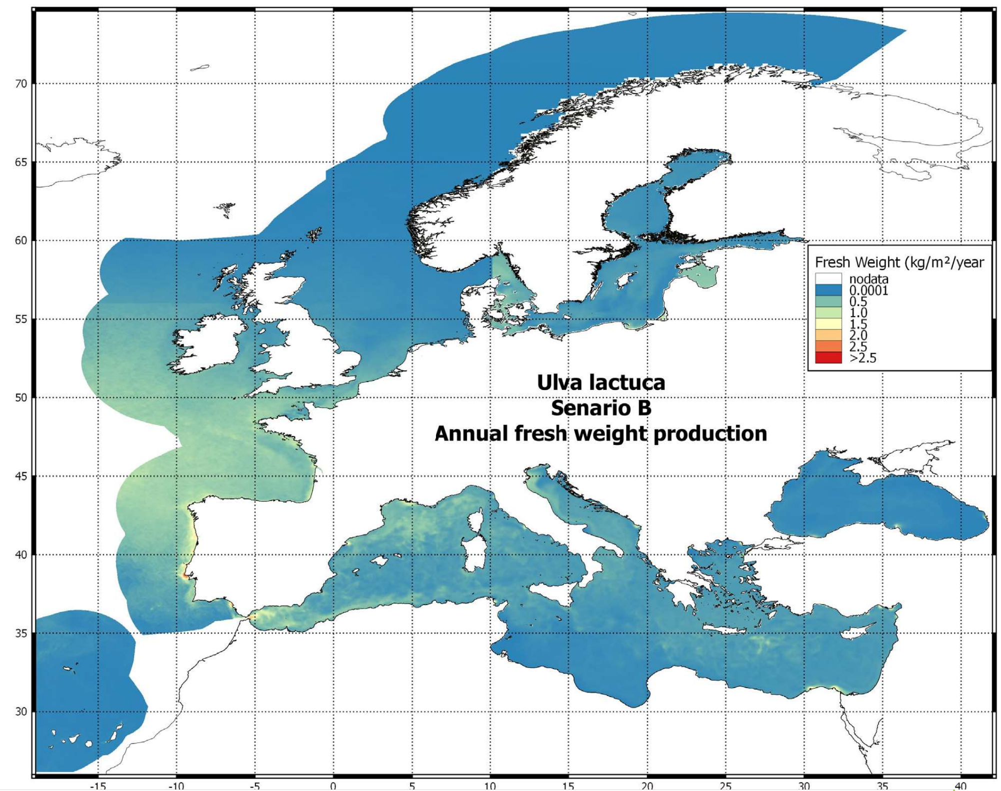
The most productive area are in the Channel, Celtic and North seas and in the plumes of the major rivers.

The most productive area are in the Belgian, Dutch and French coasts (Channel) and in the plumes of the major rivers.

WP2 – Production – Task 3 : Preparing digital maps – Production - Results

Fresh Weight of Ulva lactuca (kg/m²/year) – Scenario A (left), B (right)

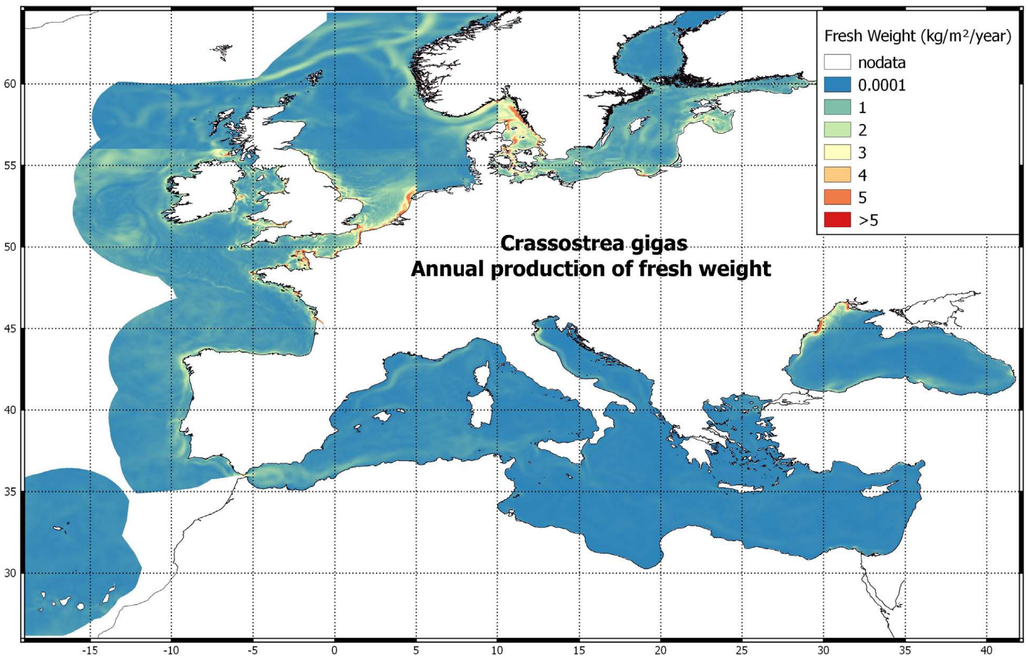


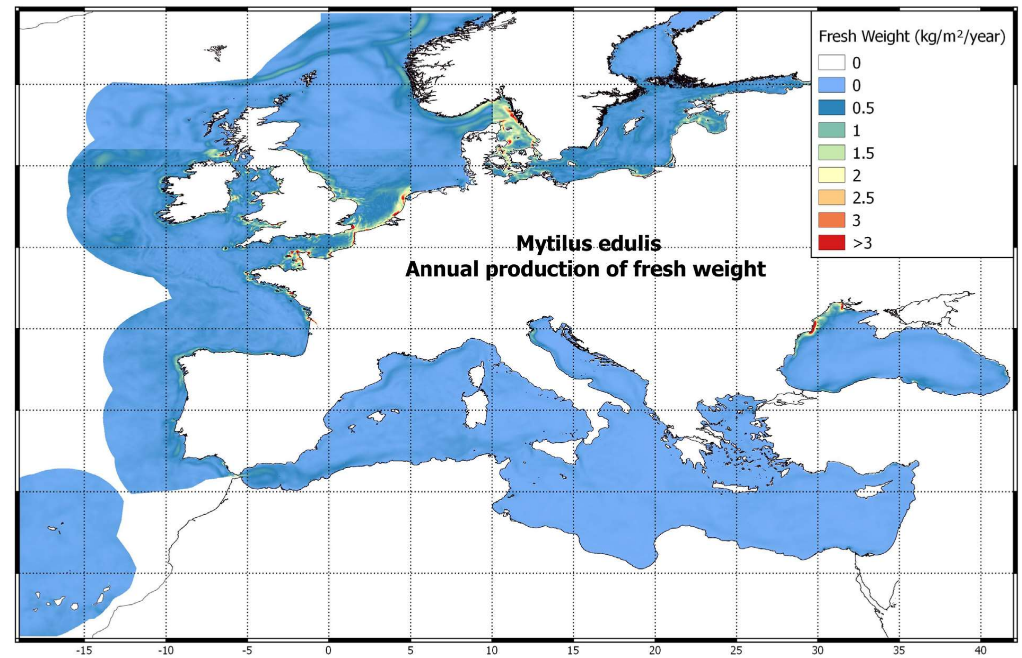


The most productive area are in south coast of Portugal and Spain, and Occidental Mediterranean Sea

WP2 – Production – Task 3 : Preparing digital maps – Production - Results

Fresh Weight of Crassostrea gigas (left) and Mytilus edulis (right)





The most productive area are in the Channel, the Bay of Biscay, the North Sea (Belgium and Netherland), Black Sea and the western part of the Baltic

WP2 – Production – Task 3 : Preparing digital maps – Optimal farms repartition

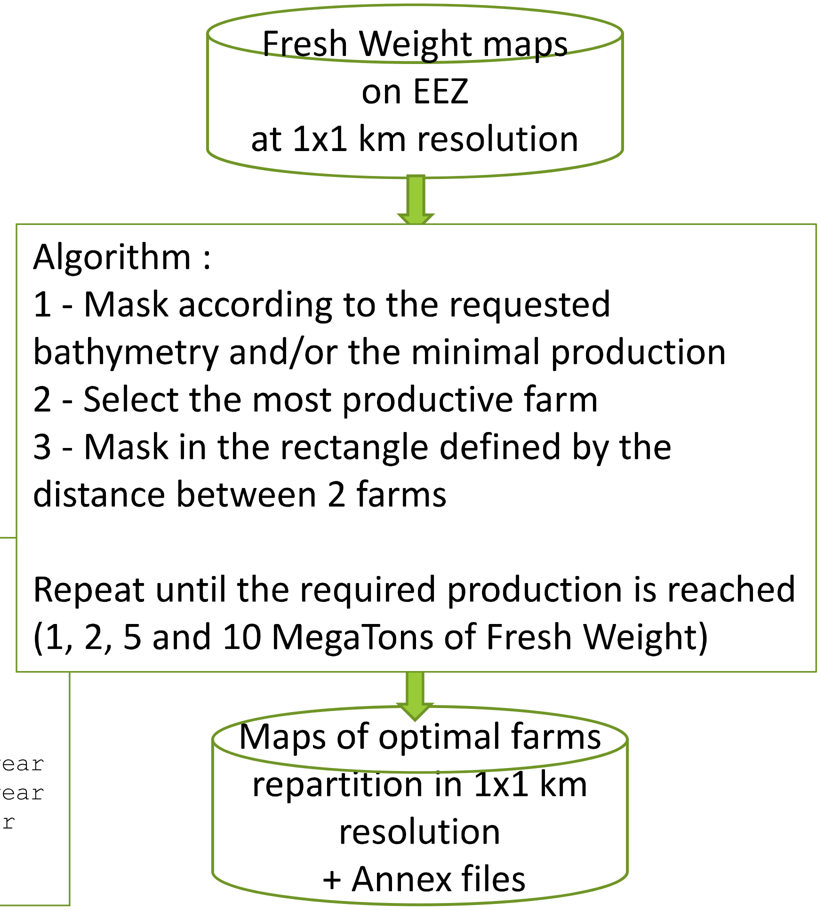
This method is applied to all requested species for the scenarios A.

Output formats:

- GTIFF
- csv
- text

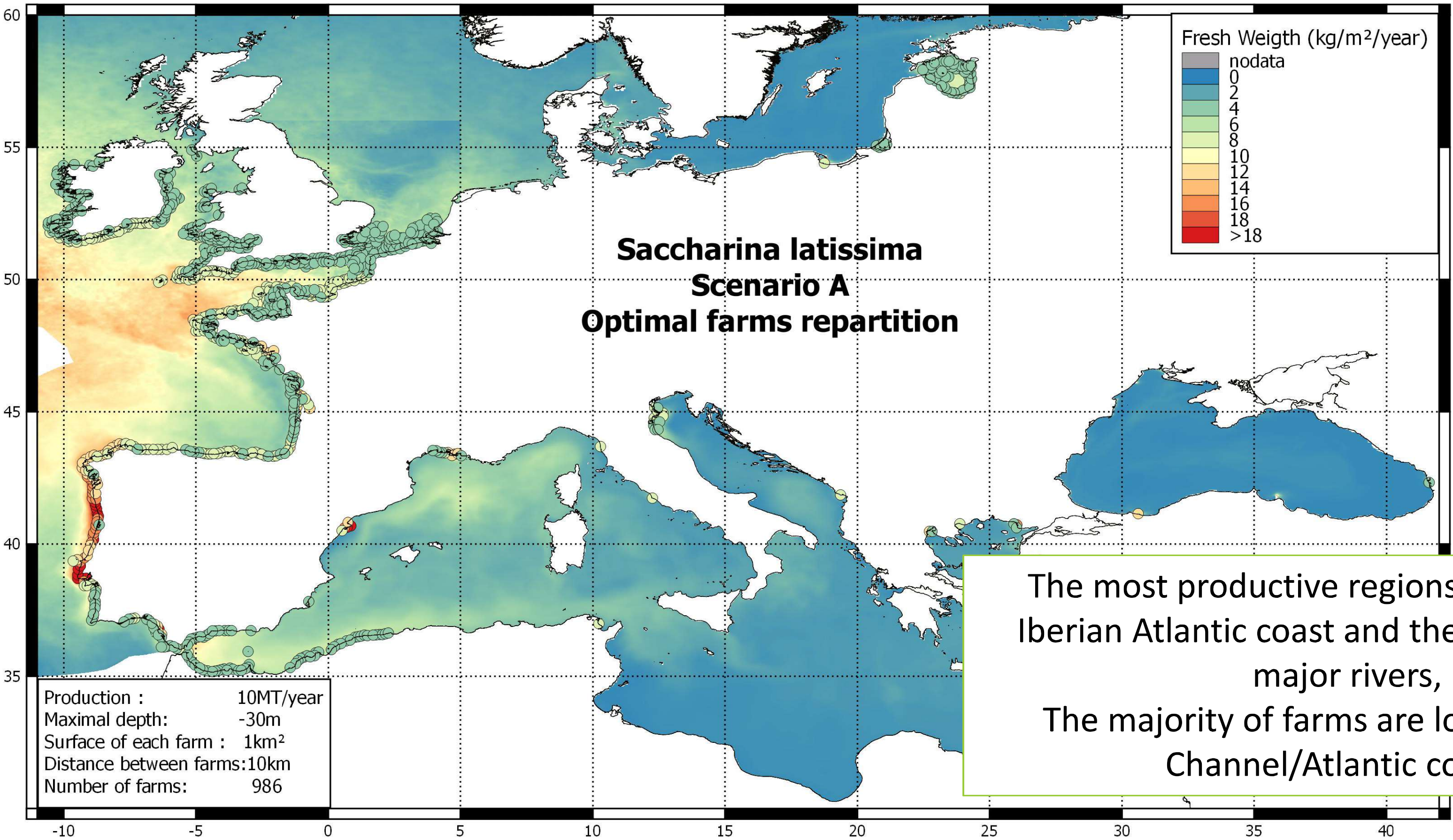
farm	lat	lon	fw	Nf	Ns
1	36.768000	-6.5100000	148717.	210063.	220683.
2	36.788000	-6.4000000	138678.	195883.	202803.
3	38.628000	-9.3800000	132631.	187342.	198705.
4	36.758000	-6.6200000	131526.	185781.	113752.
5	37.038000	-7.6800000	124767.	176233.	100481.
6	40.668000	0.92000000	124519.	175883.	194019.
7	38.598000	-9.2700000	123197.	174016.	134905.
8	39.408000	-9.4900000	116162.	164078.	130133.
9	40.108000	-8.9500000	114508.	161742.	120225.
10	39.378000	-9.6900000	113667.	160555.	106123.
11	39.508000	-9.1900000	110761.	156449.	120918.
12	37.198000	-7.3200000	110087.	155498.	52830.1
13	37.098000	-7.4300000	109587.	154792.	129314.
14	39.398000	-9.3500000	109302.	154388.	104421.
15	41.348000	-8.7700000	109084.	154081.	162359.
16	39.088000	-9.4500000	108841.	153738.	46598.5
17	40.578000	0.77000000	106595.	150565.	56604.6
18	38.488000	-9.2000000	106153.	149941.	72658.9
19	39.758000	-9.0700000	105255.	148672.	81528.8
20	43.328000	4.8100000	103747.	146543.	122012.
21	43.598000	13.740000	101473.	143331.	83418.7

```
Species:saccharina
Scenario:A
Production to be reached:10.0000MT/year
Maximal depth:-30.0000m
Surface of each farm :1.00000km²
Distance between farms:10.0000km
Number of farms:986
Minimal production of a farm:6375.63T/year
Maximal production of a farm:40797.3T/year
Total production of FW:1.00030e+07T/year
N_f total:1.13034e+07mg(N)/m^3/year
N_s total:6.90824e+06mg(N)/m^3/year
```



WP2 – Production – Task 3 : Preparing digital maps – Optimal farms repartition

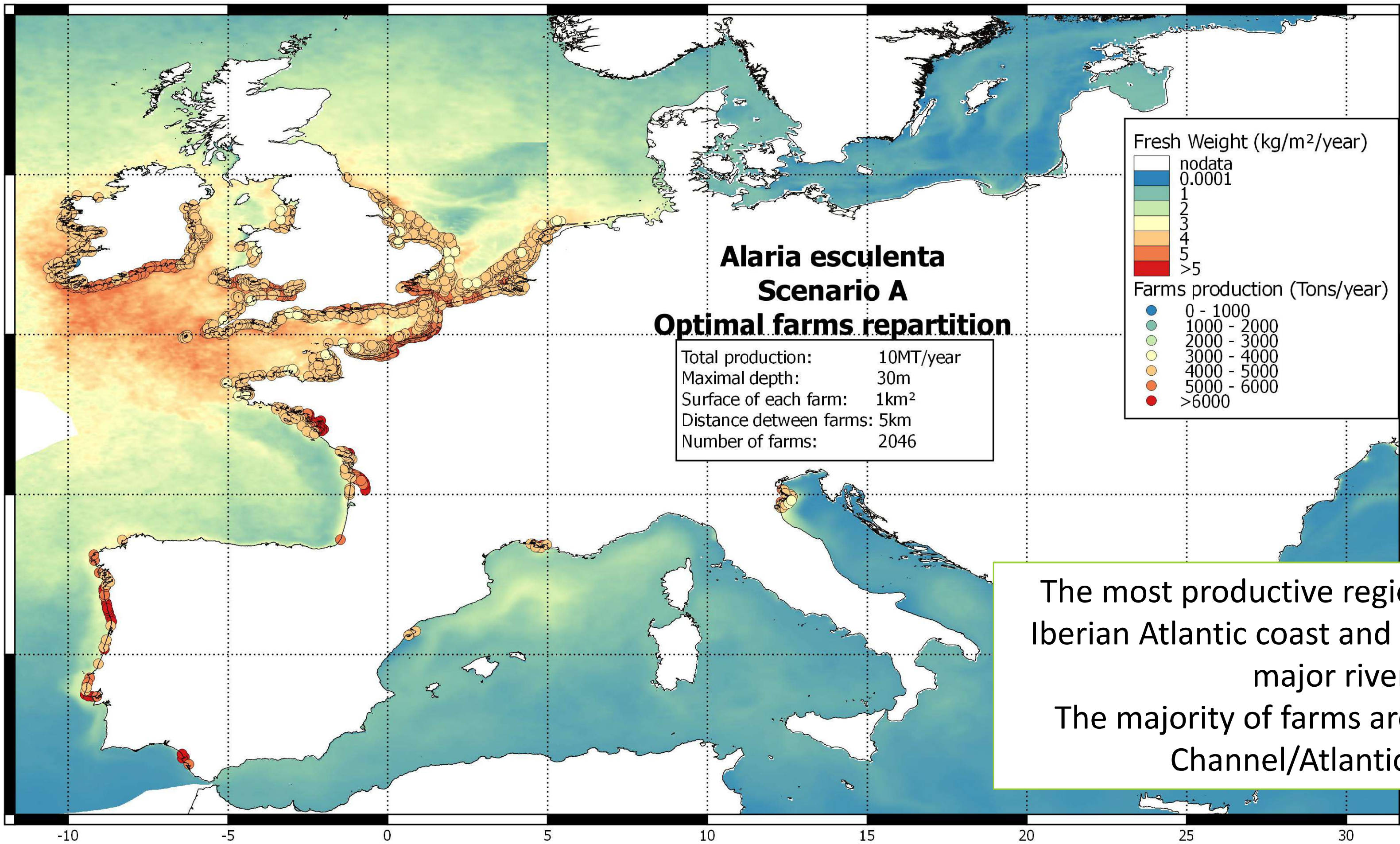
Saccharina latissima - Production of 1, 2, 5 and MT of fresh weight



The most productive regions are along the Iberian Atlantic coast and the plumes of the major rivers,
The majority of farms are located on the Channel/Atlantic coasts.

WP2 – Production – Task 3 : Preparing digital maps – Optimal farms repartition

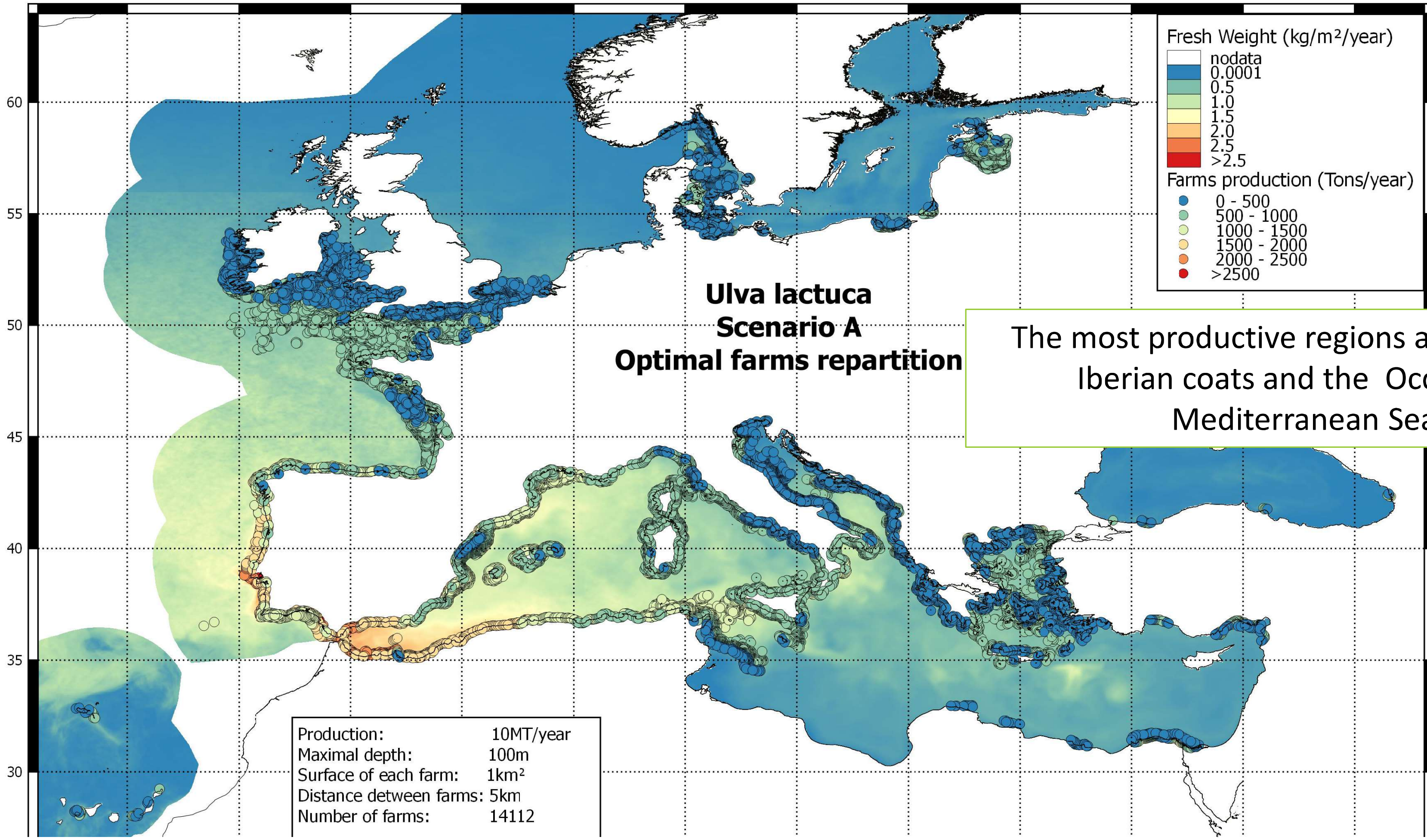
Alaria esculenta- Production of 1 , 2, 5 and 10 MT of fresh weight



The most productive regions are along the Iberian Atlantic coast and the plumes of the major rivers,
The majority of farms are located on the Channel/Atlantic coasts.

WP2 – Production – Task 3 : Preparing digital maps – Optimal farms repartition

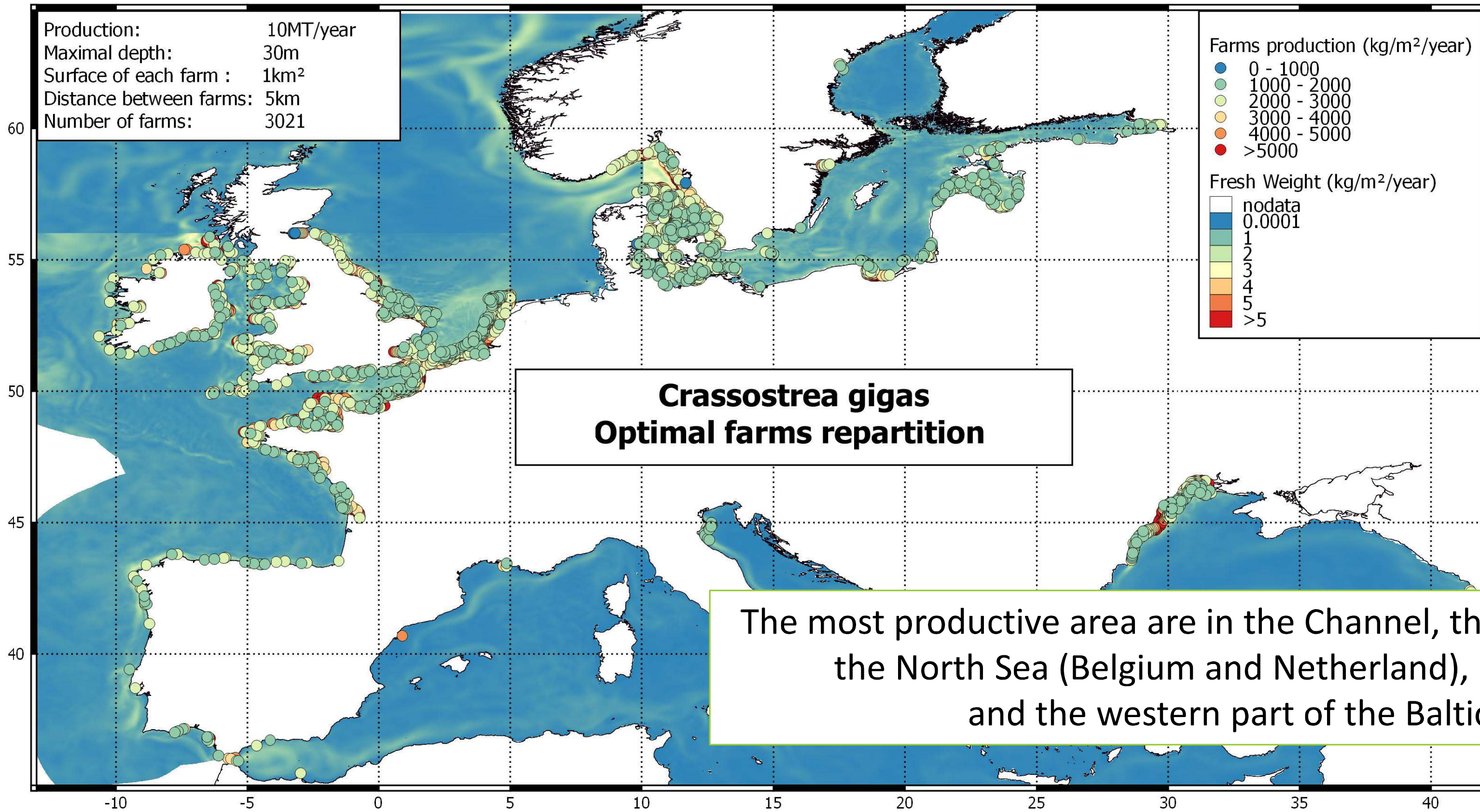
Ulva lactuca - Production of 1, 2, 5and 10MT of fresh weight



The most productive regions are along the Iberian coats and the Occidental Mediterranean Sea

WP2 – Production – Task 3 : Preparing digital maps – Optimal farms repartition

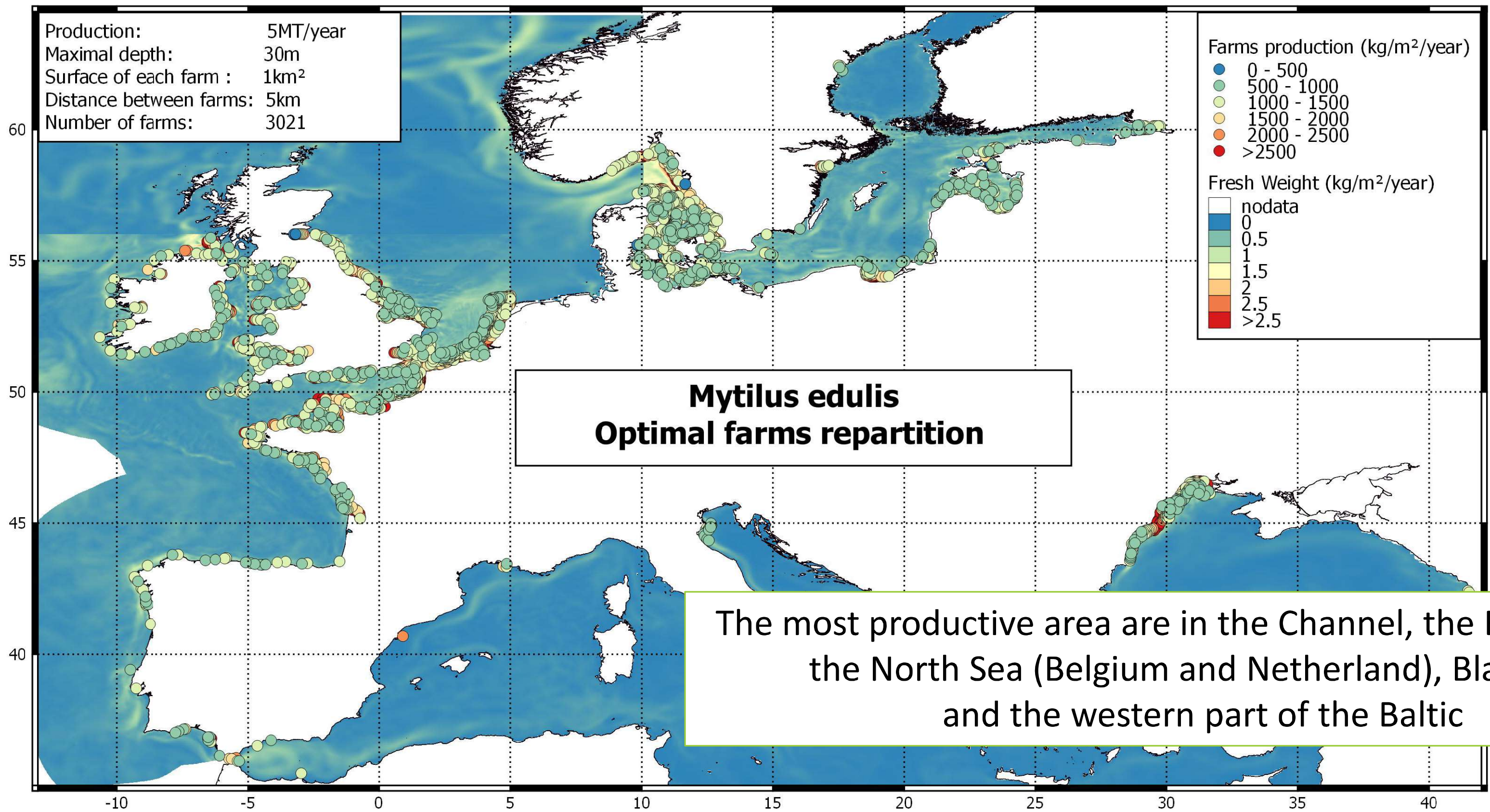
Crassostrea gigas - Production of 1, 2, 5and 10MT of fresh weight



The most productive area are in the Channel, the Bay of Biscay, the North Sea (Belgium and Netherland), Black Sea and the western part of the Baltic

WP2 – Production – Task 3 : Preparing digital maps – Optimal farms repartition

Mytilus edulis - Production of 1, 2, and 5MT of fresh weight (10MT are never reached)



The most productive area are in the Channel, the Bay of Biscay, the North Sea (Belgium and Netherland), Black Sea and the western part of the Baltic

WP2 – Production – Task 4 : Preparing results for a peer-revue journal

Martin Johnson mjohnson@bmrs.ie

WP2 – Production – Task 3 : Preparing results for a peer-revue journal

- Draft manuscript prepared and work ongoing
- Title: ***Towards a predictive capability for production capacity and nutrient impacts of macroalgal aquaculture in European waters using operational ocean model outputs***
- To be finalised when model outputs and analyses completed in the coming 2 weeks.
- Key points to be presented in paper
    - Challenges and shortcomings of operation ocean model outputs for application to near-shore biogeochemical questions
    - Benefits / drawbacks of yield prediction vs suitability index approach
    - Potential yield maps and scenarios presented for multiple seaweed and shellfish species and insights arising
        - E.g. benefit of alaria in lower nutrient locations, including potentially downstream of saccharina to optimise excess nutrient extraction
- Analyses / experiments to be presented – we need defensible, scientifically interesting analyses consistent with the aims and objectives of the project

WP2 – Production – Task 3 : Preparing results for a peer-revue journal

Objectives of the paper

- Present a computationally efficient geospatial analysis framework for predicting seaweed and shellfish aquaculture yields and impacts using operational oceanographic model output (as opposed to running computationally expensive coupled hydrodynamic-biogechemical-aquaculture models).
- Evaluate the capability of state of the art physical and biogeochmical model outputs from CMEMS to drive predictive models of seaweed and shellfish production capacity across European waters
- Compare outputs and performance of simple steady state carrying capacity models and published mechanistic, prognostic models of seaweed and shellfish production when applied across European waters
- Evaluate the effect of upstream seaweed farms on downstream productivity in scenarios of large-scale seaweed production
- Quantify the potential impacts on fisheries of large-scale nutrient drawdown by seaweed aquaculture
- Outline the steps needed to improve qualitative and quantitative estimates of biomass yield, farm interactions and impacts achieved by this approach.

WP2 – Production – Task 3 : Preparing results for a peer-revue journal

Analyses to be conducted

1) What is the 'nutrient footprint' of a seaweed farm

Motivation: to understand the typical area of influence of a seaweed farm in terms of nutrient drawdown

Experiment details:

i) Select locations of interest to evaluate local impact of seaweed farms – choose locations where we also have validation data. Some in embayments (e.g. Bantry bay), some on productive open coast (e.g. Portuguese coast). Theoretical farm offshore e.g. shelf break off Ireland would also be interesting.

ii) Run scenario B model with a farm at each location and nowhere else (i.e. no interactions between farms)

   a. Just for saccharina, or possibly compare the three species?

iii) Plot maps of nutrient deficit at harvest time (April/May). How far does the farm's influence reach?

2) How much does the interaction between farms affect productivity?

Motivation: to understand the impact of nutrient interaction between farms on total potential productivity in 2/5/10Mt scenarios [just pick 10Mt…]

Experiment details:

i) Use scenario A output to determine optimum locations for farms to meet target yield (pick one… suggest Saccharina, 10Mt)

ii) Run scenario B with farms at all of these locations

iii) Compare yields between scenario A analysis and new scenario B run

iv) Ideally we would then iterate to new optimal locations for farms to achieve target yield in scenario B, but this is probably outside of what we can achieve in the timescale.

3) What is the impact of scenarios on nutrient fields and potential impact on fishing?

Motivation: understand the degree to which large scale macroalgal aquaculture can impact natural systems including fin fisheries.

Experiment details:

i) Taking the outputs from experiment 2), consider total nutrient deficit at harvest time (i.e. maximum productivity / seaweed mass).

ii) Present geospatial plots of %reduction in nutrient per grid square

iii) Also calculate sum total nutrient deficit per region (Portuguese Atlantic coast, Mediterranean etc)

iv) Highlight local effects (refer back to experiment 1)

v) Consider total nutrient budgets for the regions (find literature values where possible and/or or look at average % nutrient utilisation from ii). If the relative magnitude is small, consider that the likely impact on fisheries is small.

WP3 – Uptake – Task 5 : Review of the documents and software

Margaux Boyer m.boyer@cofrepeche.fr

COFREPECHE

WP3 – Uptake – Task 5 : Review of the documents and software

Documents have been **reviewed** and the software has been **tested** as an average user

↳ This allowed the team to point out errors and bugs and to make suggestions to improve the software's practicality

↳ A user manual has been created

To be organized: sessions to explain how to use the software to any party to be designated by EASME

- How many people ? How many sessions ?
- Will they be people who are familiar with the project (simply to be trained in the software) or will the whole study need to be re-contextualized?

Discussion :

General discussion :