"Assessing the hazard for benthic biodiversity due to aquaculture activities using an integrated carrying capacity model.

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ScolaMAR
Erasmus+ Capacity building

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MAIN IMPACTS OF AQUACULTURE IN COASTAL AREAS:

In the last 65 years the aquaculture industry has increased by **a factor of 80**:

1 million tonnes (1950s) → 80 million tons (2016) *[The State of World Fisheries and Aquaculture, FAO 2018]*

↓

A suitable approach to guarantee the **sustainability of the aquaculture industry** is required

↓

EAA

Ecosystem Approach to Aquaculture, endorsed by FAO

Key concepts for implementing EAA:

AZA: Allocated Zone for Aquaculture;

AMAs: Aquaculture Management Areas

AZE: Allowable Zone of Effect

As any other food industry, **aquaculture** has **impacts** on the **environment**

Types of aquaculture activities

Extensive

The trophic resources of the environment sustain the biomass production (e.g. shellfish and algae aquaculture): low yield per unit volume/surface.

- Inorganic extractive
- Organic extractive

Semi-intensive & Intensive

Provide a much higher biomass yield per unit volume/surface, but requires the introduction of feed, i.e. organic matter and chemical

- Organic enriching

IMTA
(Integrated Multi-Trophic Aquaculture)

Potential impacts of finfish intensive mariculture: spatial scales

near-field (~ 100 m)

- disturbance of surrounding ecosystems, in particular benthic communities;
- short and long term effects of eutrophication;
- contamination by xenobiotics;
- **Fish Aggregating Device: a potentially positive effect**

Far-field (bay, fjord, ~Km)

- short and long term effects of eutrophication;
- contamination by xenobiotics
- cross-transmission of parasites and pathogens;
- Genetic "pollution"
- aesthetic deterioration in coastal areas
- **Cumulative impact**
- **Decrease of fishing pressure on local stocks**

Global

- **Fish meal trap**: most marine farmed species, including sebream and seabass, are carnivorous;

The feed industry is progressively substituing fish meal with land based protein sources: the impact of feed production is shifting from fish stocks to land use.

The **actual** impacts of mariculture depend on **both** :

- The **type** of **farming** and **husbandry** practises (Species, stocking density, feed composition, etc …);

- The **Assimilative Capacity** of the surrounding environment (Hydrodynamic circulation, Sediment textures etc…):

As a result the **Carrying Capacity, CC,** of a finfish farm is evaluated on the basis of the assimilative capacity of the surrounding environment.

In order to assess the **actual impact**, it is necessary:

- To identify a set of **cost-effective** indicators;
- To design a **cost-effective** sampling strategy .

However, mathematical models are viable tools for assessing the likely impact before licensing a given area to fish farmers: therefore, they can be used for identifying AZAs, AMAs and estimating AZEs, thus supporting maritime spatial planning and licensing.

The impact of cage culture in coastal areas has been investigated in several EU projects (e.g. FP6 ECASA, H2020 TAPAS …) and is well documented by the literature.

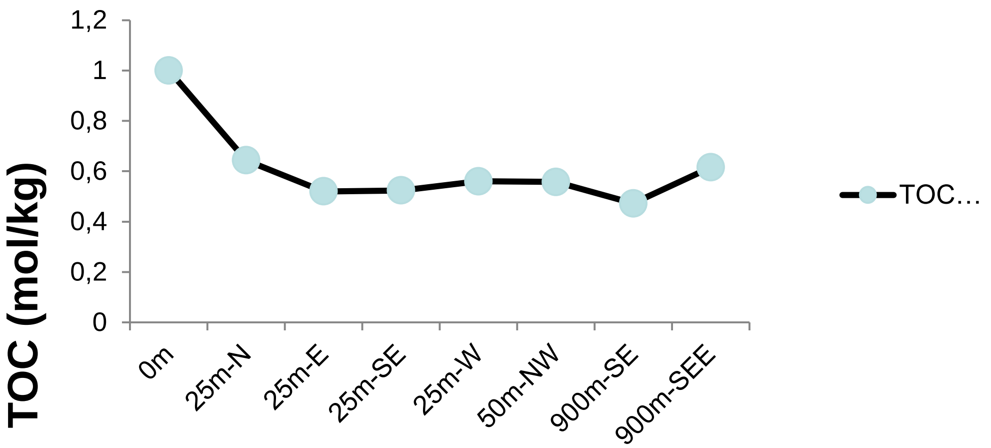
The large majority of studies show that the main local impact is due to the organic enrichment of surface sediment, which may cause:

- Depletion of dissolved oxygen concentration;
- Hypoxia in the water overlying the sediment;
- Increased sulphate reduction;
- Marked changes in benthic faunal and meiofaunal assemblages, in terms of species number, diversity, abundance and biomass.

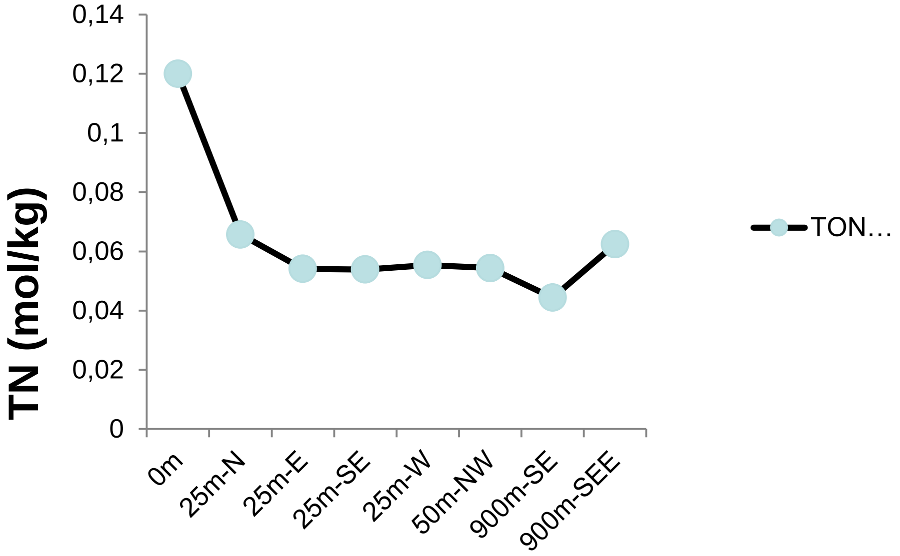
In the EU FP6 project ECASA, a set of comprehensive field surveys was carried out, across a range of cage farms representatives of the main species (atlantic salmon, seabass, seabream) and geographical regions (North Atlantic coast, Mediterranean coast). The results led to identify as key indicators of organic enrichment:

TOC: Total Organic Carbon

TN: Total Nitrogen



distance from Bisceglie fish farm (Puglia, Southern Italy)



distance from Bisceglie fish farm (Puglia, Southern Italy)

Aquaculture 293 (2009) 231–240

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Aquaculture

journal homepage: www.elsevier.com/locate/aqua-online

Assessing the suitability of a range of benthic indices in the evaluation of environmental impact of fin and shellfish aquaculture located in sites across Europe

Ángel Borja [a,*], J. Germán Rodríguez [a], Kenny Black [b], Alain Bodoy [c], Chris Emblow [d], Teresa F. Fernandes [e], Janez Forte [f], Ioannis Karakassis [g], Iñigo Muxika [a], Thom D. Nickell [b], Nafsika Papageorgiou [g], Fabio Pranovi [h], Katerina Sevastou [g], Paolo Tomassetti [i], Dror Angel [j]

ECASA findings also showed a correlation between organic enrichment and **indices for assessing the status of benthic communities.**

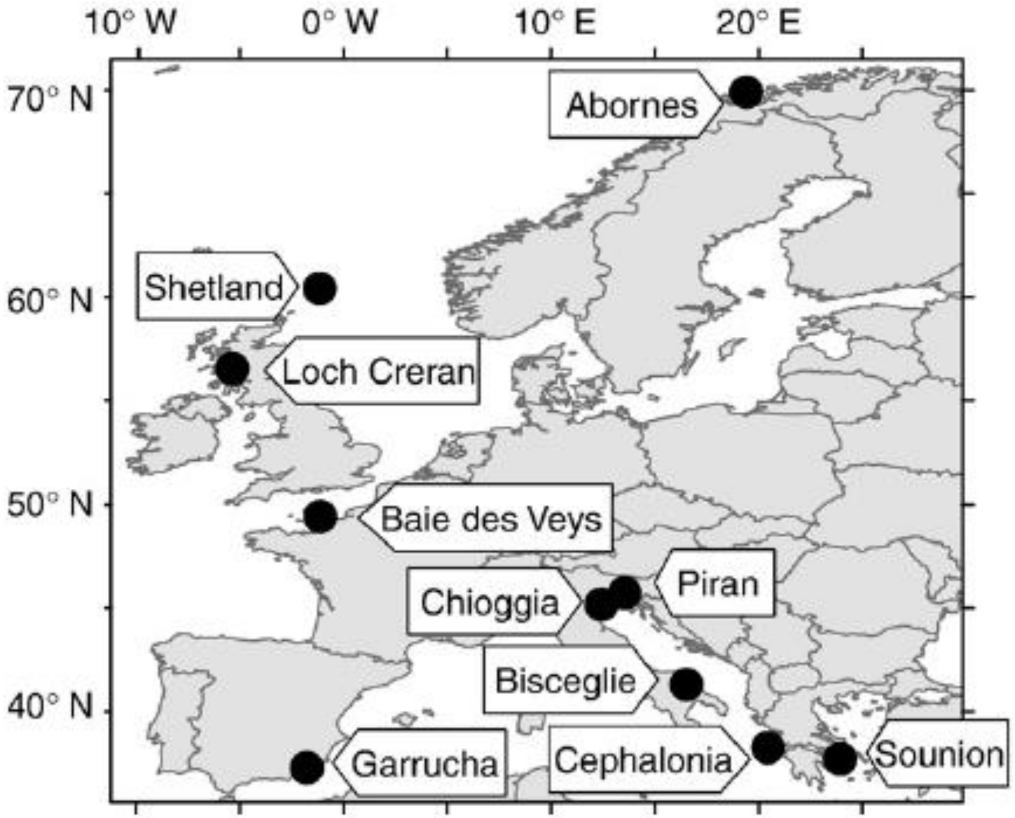


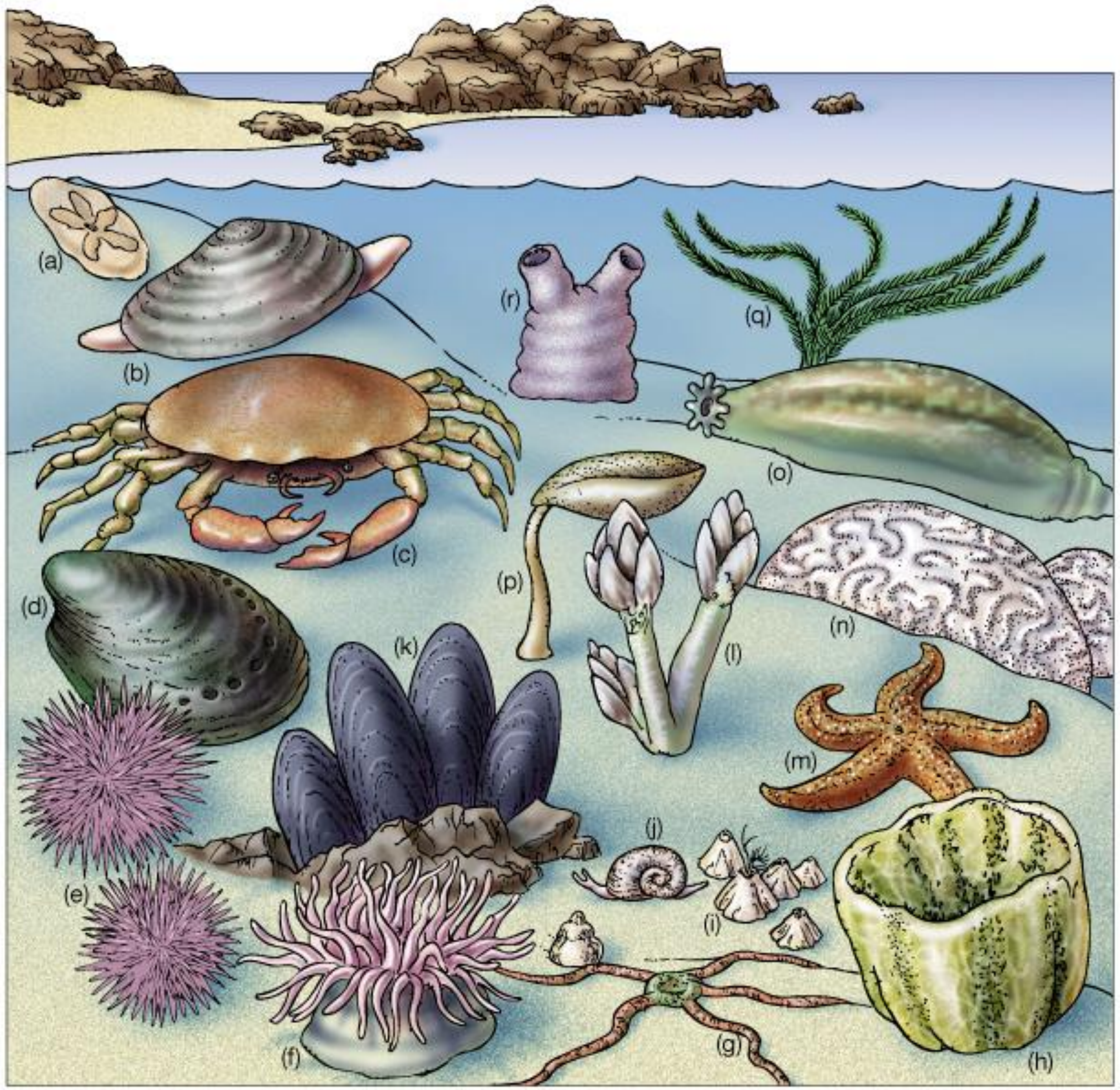
Fig. 1. Position of the sampling locations across Europe.

Benthos

Organisms living strictly linked with the sea bottom

Different classification criteria

- Sediment relationships
- Dimensional (body size)
- Functional

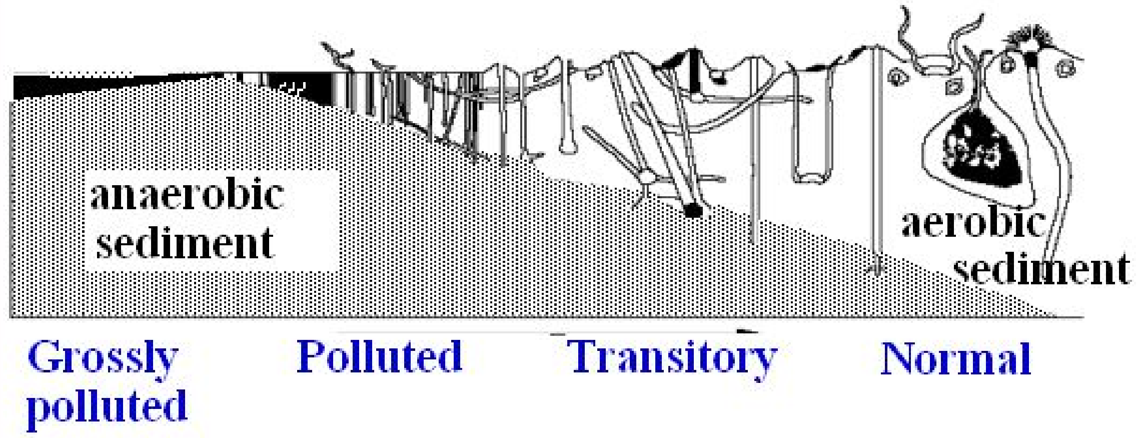


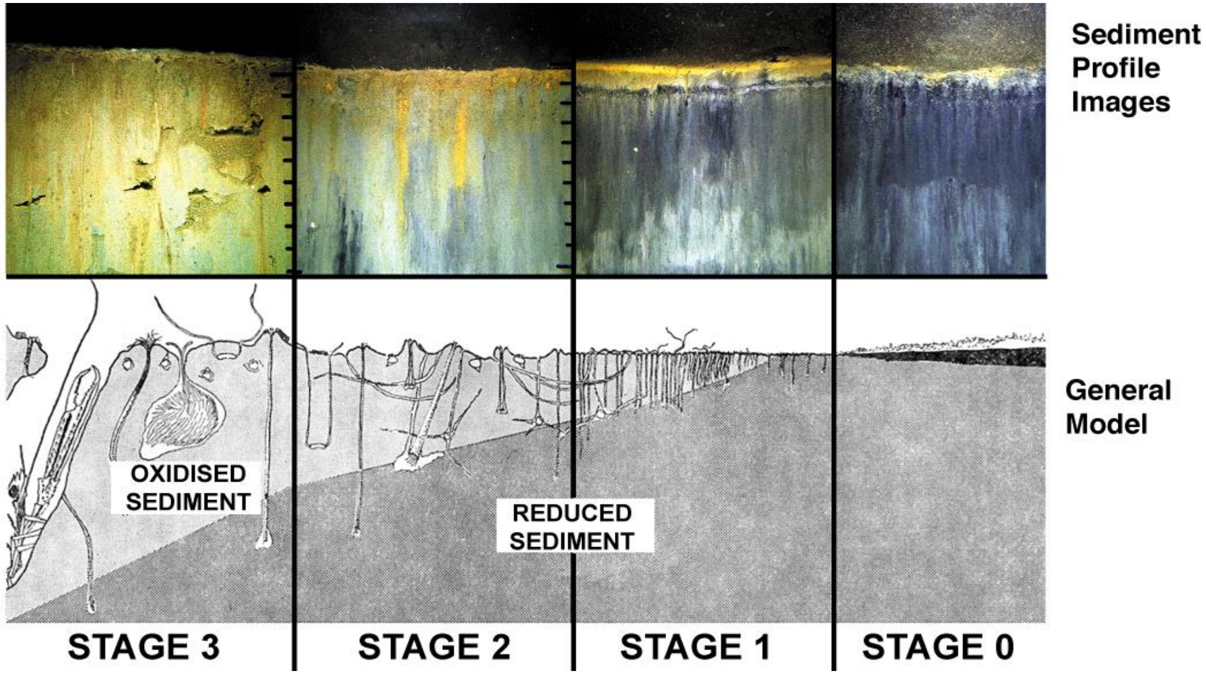
Organic matter

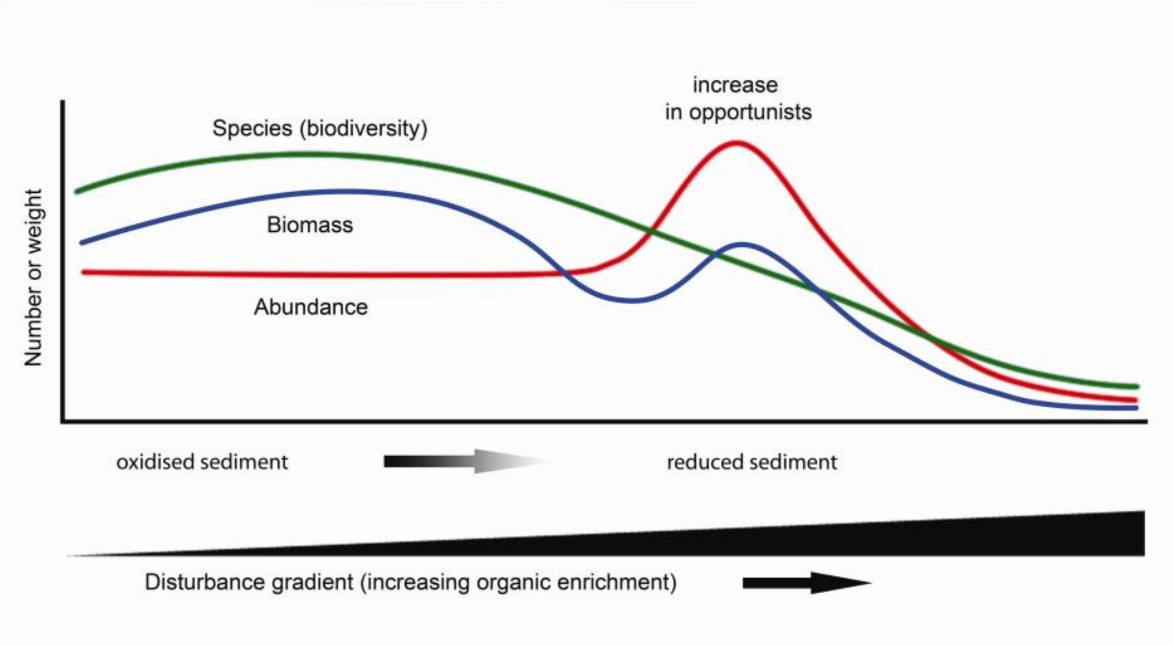
Enrichment conceptual model

Pearson & Rosenberg

(1978)







Nilsson & Rosenberg et al., 2002

Biotic coefficient (BC) - AMBI

The Azti Marine Biotic Index (AMBI) proposed by Borja et al (2000) classifies species according to Ecologica Groups (EG), depending on their ability to tolerate disturbance/pollution

I	**Sensitive** species, present only in un-polluted sediment
II	**Indifferent** species always present in small densities without significant fluctuation with time
III	**Tolerant** species. they may be found under natural conditions but their population growth is stimulated under organic enrichment
IV	**Second stage opportunists**. Mainly small-size subsurface deposit feeders (e.g. Cirratulidae)
V	**First stage opportunists**. Deposit feeders thriving in reduced sediments.

FiCIM: Fish Cage Integrated model for Carryin Capacity evaluation and assessment of risk for the benthic community

1) **Individual module**

INPUT: food from farmer (kg of food per cages and % pf carbohydrates, lipids and proteins), temperature;

OUTPUT: weight from faeces and uneaten food. From %C, %N and %P to grams of C, N and P.

2) **Population module**

simulates the population dynamic of farmed individuals in each cage, taking into account mortalities.

OUTPUT: total flow of OM, C, N, P (g/day) released by a cage

3) **Deposition module**

INPUT: intensity and direction of current, depth.

OUTPUT: daily depositions of organic C, N, P on surface sediment.

4) **Degradation module**

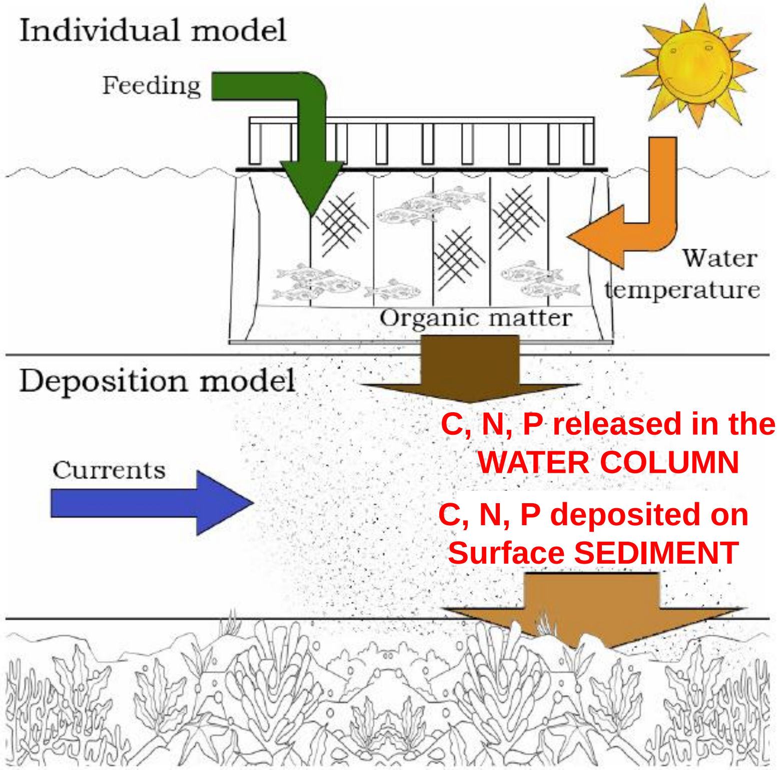
estimates OM and OC concentrations in surface sediment, based on deposition flows.

5) **Carrying Capacity module**

estimates AMBI and ES (Enrichment Stages), based on OM and OC concentrations

Input data

1) Fish meal (kg-quantity of food and diet composition);
2) Stocking density;;
3) Water Temperature;
4) Current density and direction;
5) Bathymetry of the area where the fish farm is settled.



Modules 1 & 2

Module 3

Module 4 and 5

OUTPUT

Water column:
DIN from Ammonia and urea excretions; DIN and SRP from faeces and feed pellet dissolution in the water column.

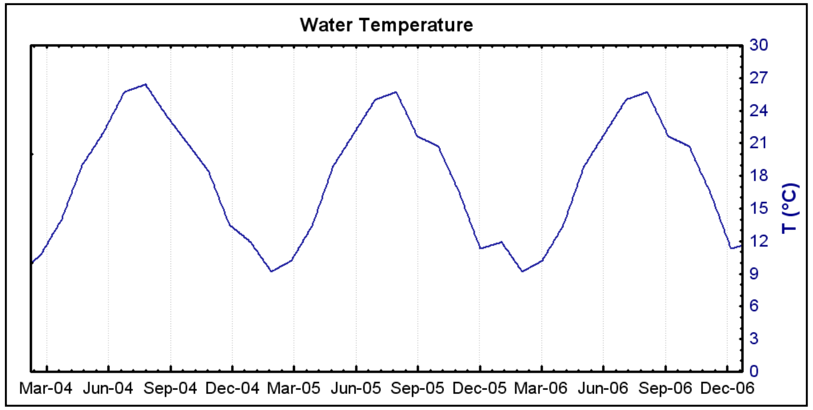
Sediment:
Maps of daily fluxes of OM, Carbon, Nitrogen and Phosphorus per m^2.
Maps of OC and ON concentrations

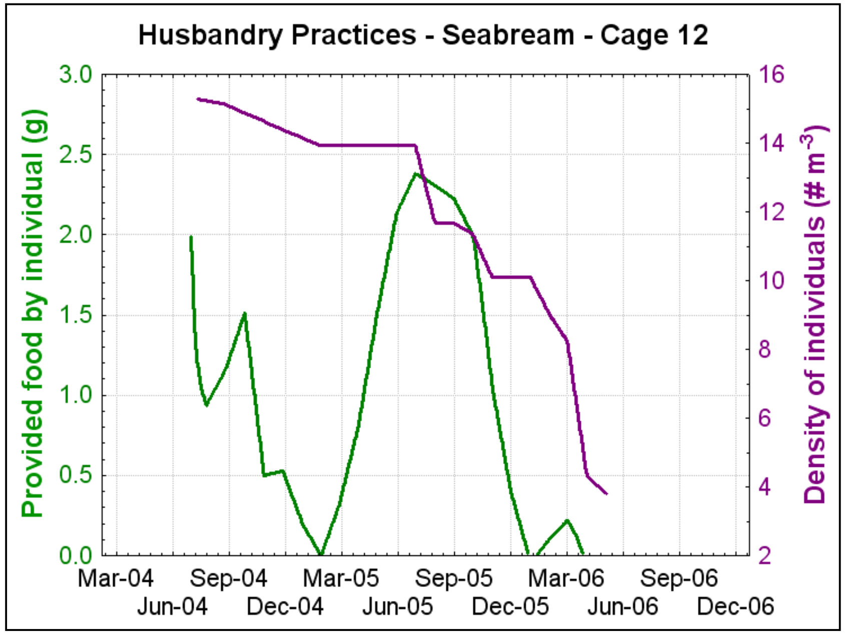
5. FiCIM – Application to a Mediterranean farm

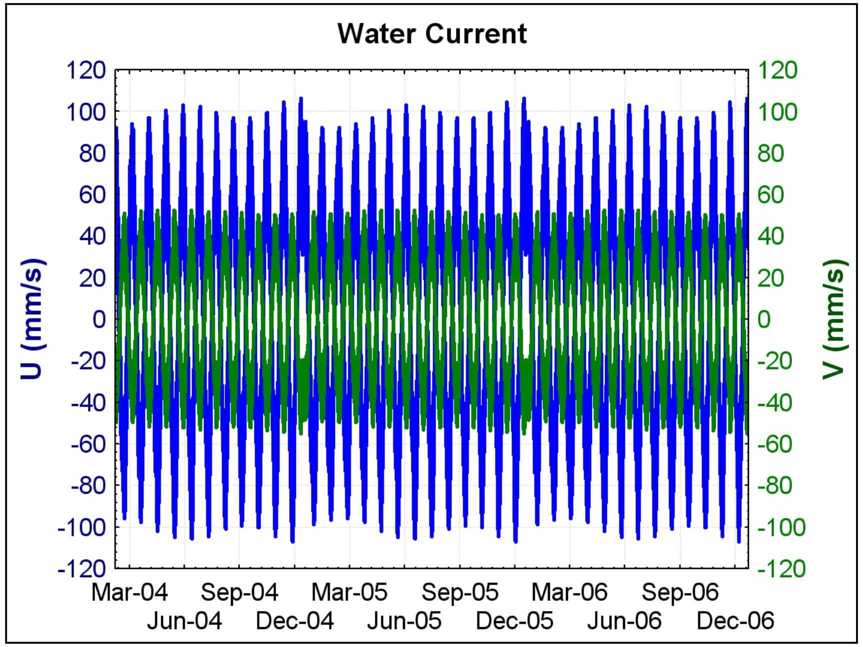
- Seabream and Seabass farm;
- Depth about 22m;
- Period of simulation: 24 months;
- Horizontal eddy diffusivity coefficient of 0.1 m^2 s^{-1};
- Vertical eddy diffusivity coefficient of 0.01

FiCIM: input data

Diet Composition	
Protein	0.44
Carbohydrates	0.21
Lipids	0.19







FiCIM: individual and population modules

Aquacult Int (2010) 18:149–163
DOI 10.1007/s10499-008-9232-4

ORIGINAL PAPER

Modelling the biomass yield and the impact of seabream mariculture in the Adriatic and Tyrrhenian Seas (Italy)

Daniele Brigolin · Roberto Pastres · Paolo Tomassetti · Salvatore Porrello

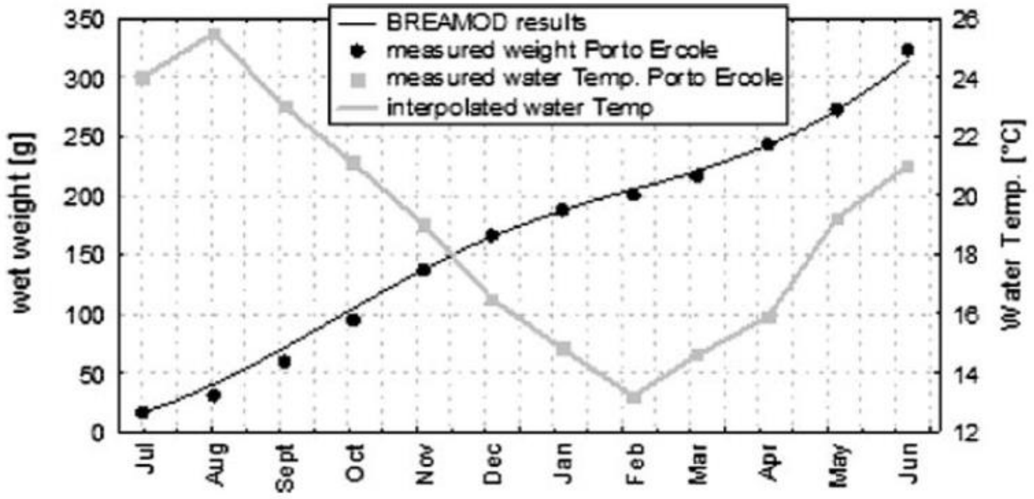


Fig. 2 Calibration of the seabream growth model

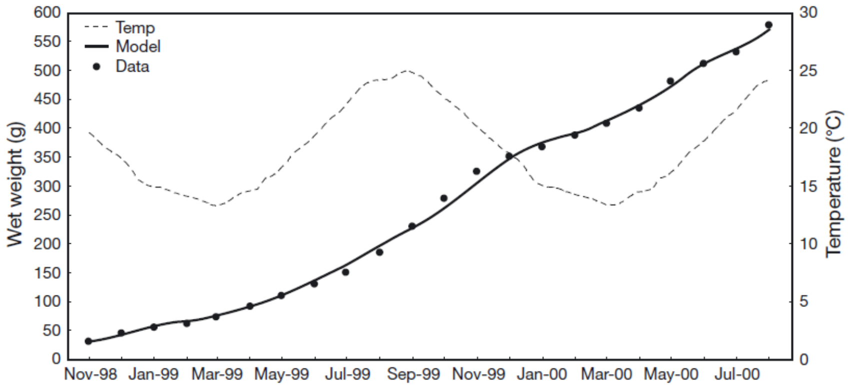
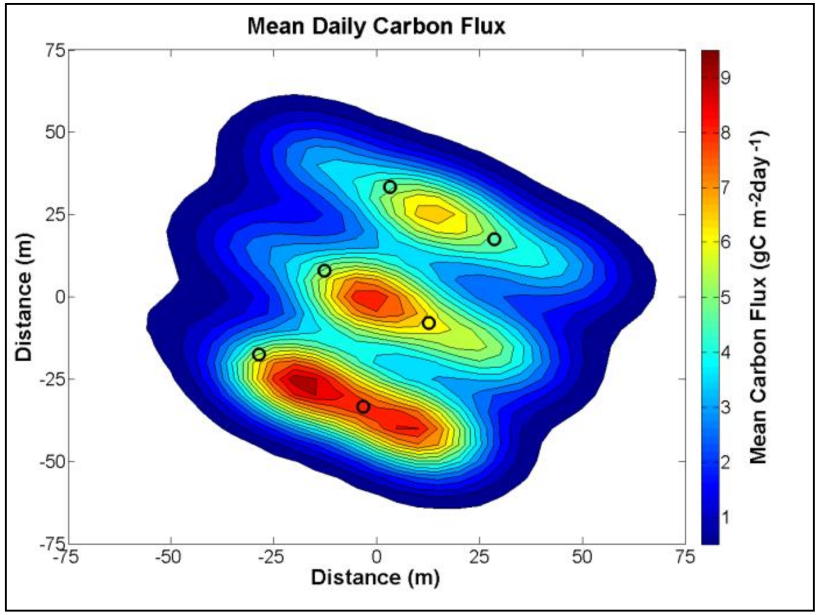
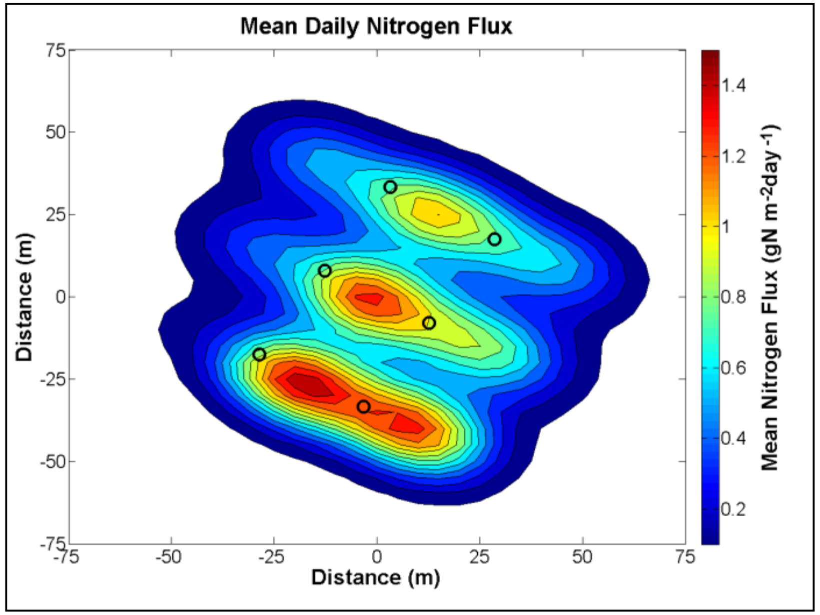
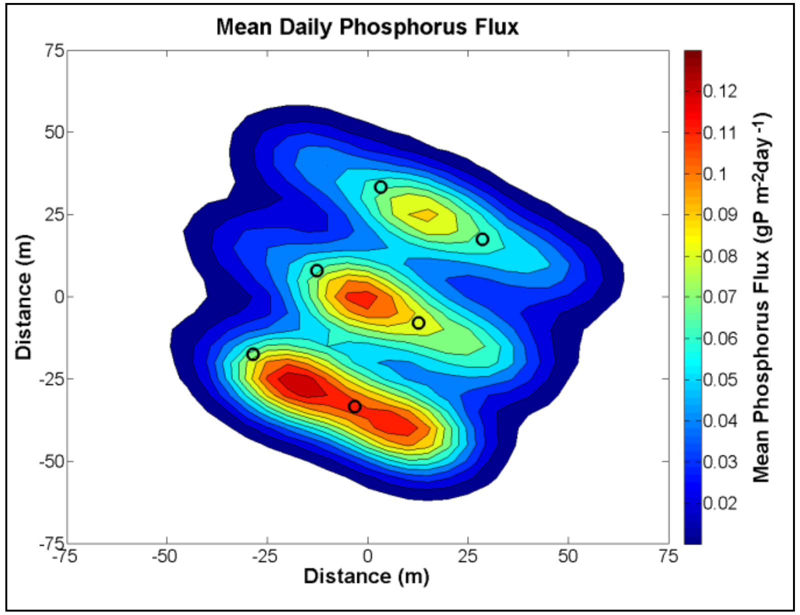


Fig. 2. Calibration of the *Dicentrarchus labrax* growth model. Dashed line corresponds to the water temperature (°C); continuous line represents the wet weight (g) predicted by the model; dots indicate the wet weight observations (g)

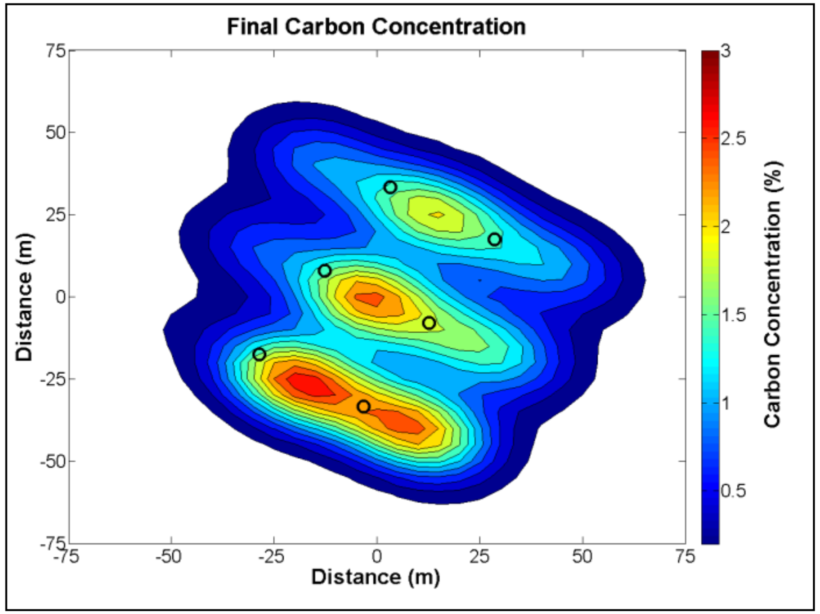
FiCIM: Results of the Deposition module

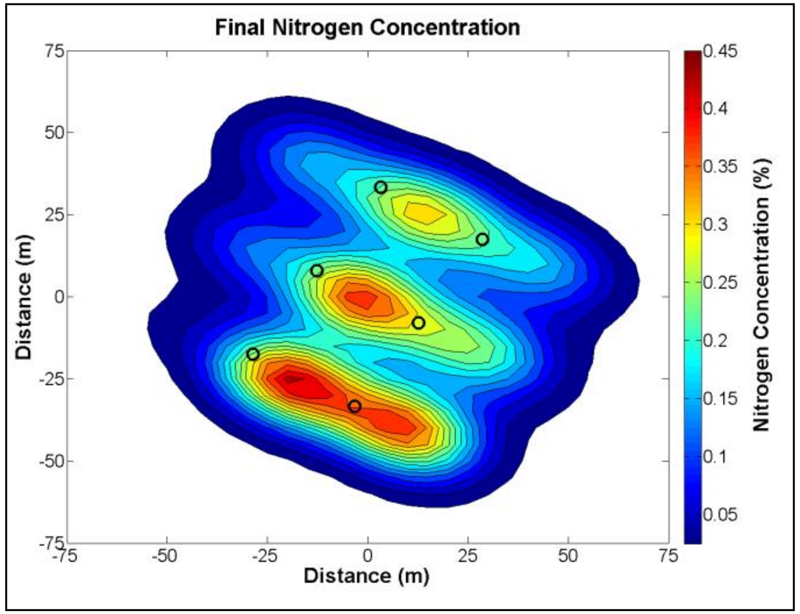


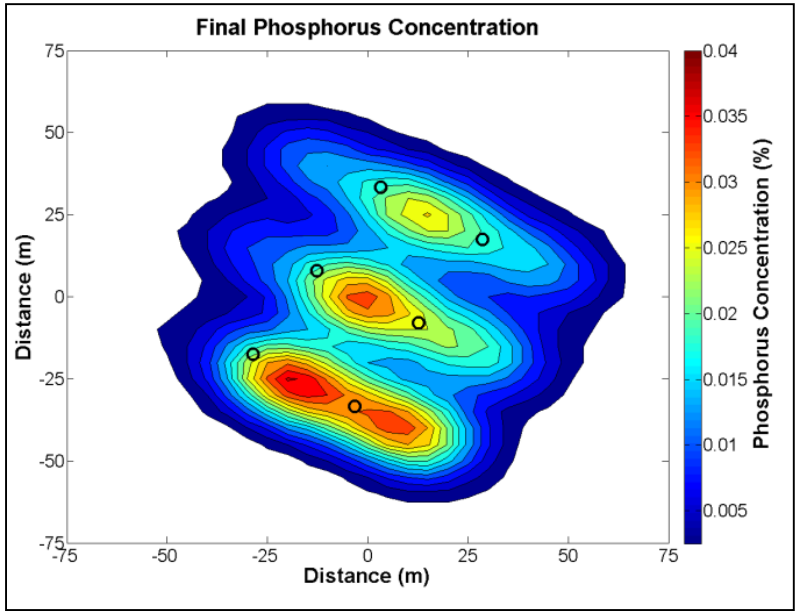




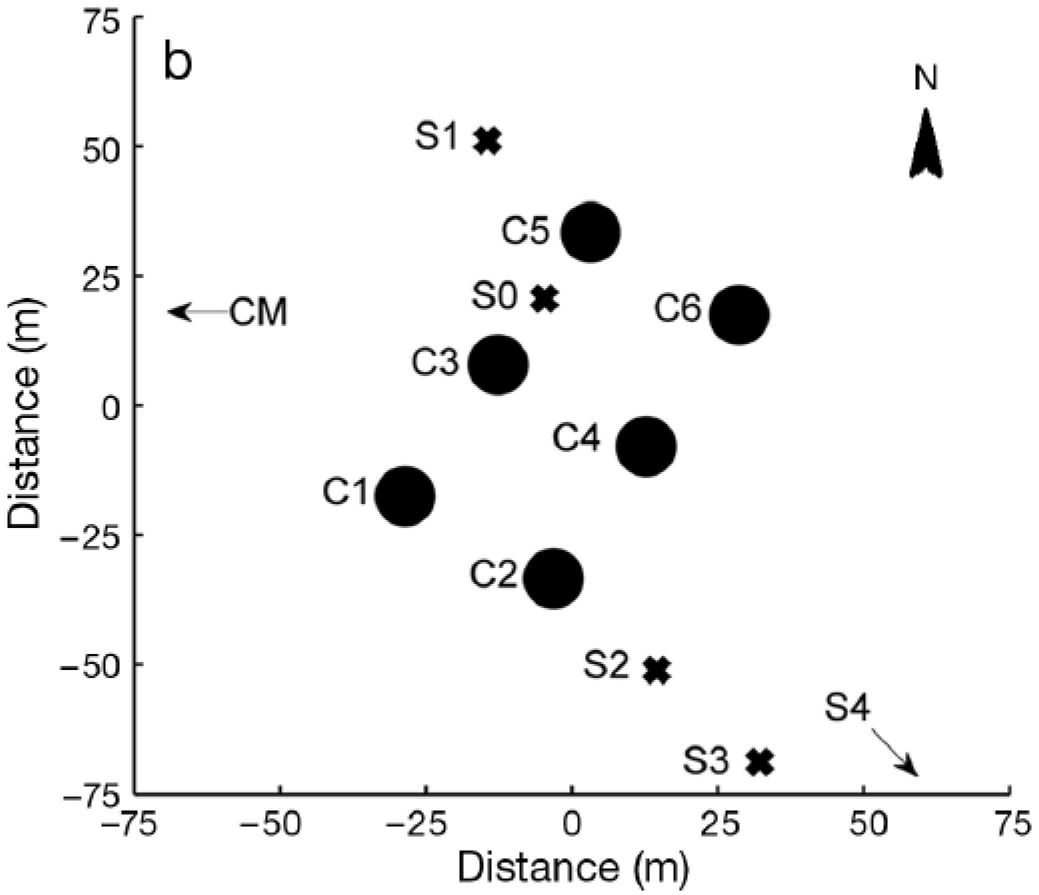
FiCIM: results of the Degradation module

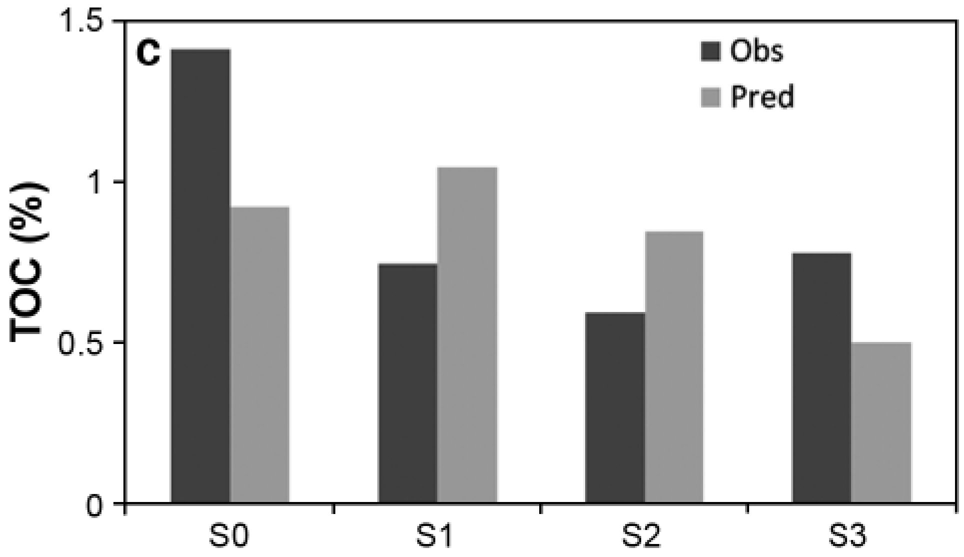




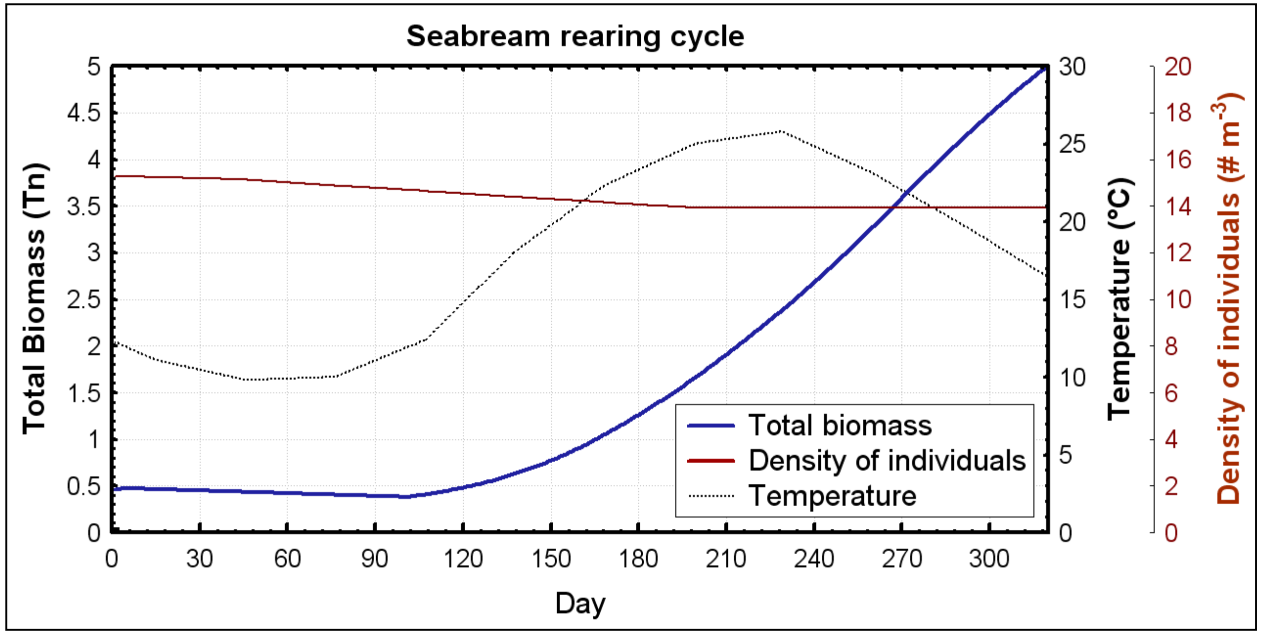


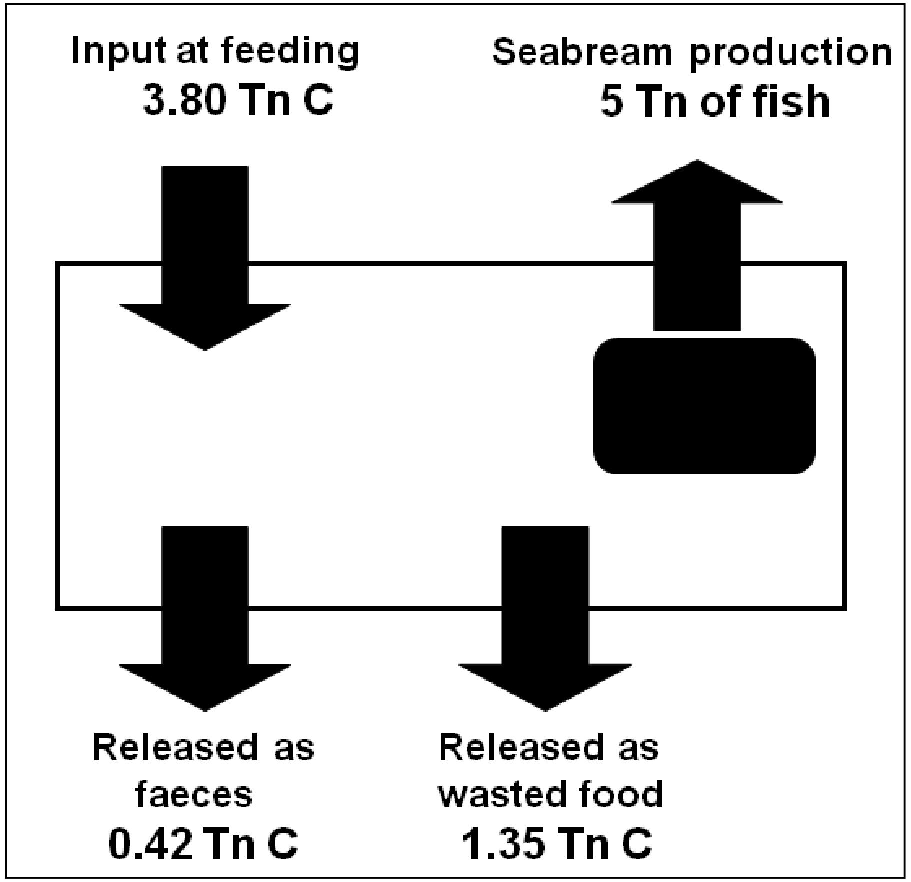
FiCIM – Degradation module





FiCIM: P, N and C budgets (could be relevant for IMTA implementation)





FiCIM: impact on the benthic community

The deposition of organic matter on the seabed is the main driver of the impact on the benthic community. However**, the actual impact** of organic enrichment on the benthic **communities is likely to be site-specific** and **depend on a range of factors, among which sediment type and resuspension**.

Quantitative relationships among:

Deposition flow of Organic Matter;

Surface sediment enrichment;

Effects on functioning of the benthic community

Are key for using FiCIM as a tool for assessing cage farm Carrying Capacity.

5. Integrated model: impact on the benthic community

Vol. 3: 275–291, 2013
doi: 10.3354/aei00068
AQUACULTURE ENVIRONMENT INTERACTIONS
Aquacult Environ Interact
Published online June 4

Predictive depositional modelling (DEPOMOD) of the interactive effect of current flow and resuspension on ecological impacts beneath salmon farms

N. B. Keeley[1,2,*], C. J. Cromey[3], E. O. Goodwin[1], M. T. Gibbs[4], C. M. Macleod[2]

Vol. 1: 33–46, 2010
doi: 10.3354/aei00005
AQUACULTURE ENVIRONMENT INTERACTIONS
Aquacult Environ Interact
Published online June 30

Empirical relationships describing benthic impacts of salmon aquaculture

B. T. Hargrave*

561 Balmy Beach Road, Owen Sound, Ontario N4K 5N4, Canada

Vol. 2: 157–176, 2012
doi: 10.3354/aei00034
AQUACULTURE ENVIRONMENT INTERACTIONS
Aquacult Environ Interact
Published online March 7

MERAMOD: predicting the deposition and benthic impact of aquaculture in the eastern Mediterranean Sea

Chris J. Cromey[1], Helmut Thetmeyer[2], Nikolaos Lampadariou[3], Kenneth D. Black[1,*], Jos Kögeler[4], Ioannis Karakassis[5]

FiCIM: impact on the benthic community

Based on a thorough survey of the recent literature, the following links between OC/OM deposition flows and im

Most studies agree in indicating that deposition flows of Organic Matter/Organic Carbon below 1 kg m^{-2} y^{-1} or 0.8 gC m^{-2} d^{-1} lead to moderate organic enrichment, (ES $\leq$ 3, AMBI $\leq$ 2, BEI $\geq$ 0) which could be probably tolerated in the AZE (Allowable Zone of Effect) of a fish farm.

Deposition flows in the range of:
1 – 6 kg OM m^{-2} y^{-1}
0.8-5 gC m^{-2} day^{-1}
are likely to lead to significant changes of the macrofaunal community (3 $\leq$ ES $\leq$ 5, -1000 $\leq$ BEI $\leq$ 0, 2 $\leq$ AMBI $\leq$ 5.

Deposition flows above these values could lead to severe organic enrichment, characterized by a peak of opportunistic species and anoxic/azoic sediment (ES > 6), in particular in non-dispersive site with little resuspension.

FiCIM: perspectives

The next release of FiCIM will be made available by Bluefarm (http://bluefarmenvironment.com/it/), a spin-off of Ca' Foscari University.

The model will be available through cloud computing: the user interface was tested during a 3 day training held in Rome on March 13th-15th , at GFCM head quarter, organized by GFCM in the framework of its supporting activities to ANDA.

The training was attended by three ANDA personnel: a report will be available by the end of May 2019

The next release will include the module for estimating the impact on the benthic community as well as a module for assessing the impact on DIN and DO. The latter could be relevant in closed and shallow bays.