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# Ecosystem-based approach: the FORWARD project - Framework for Ria Formosa water quality, aquaculture, and resource development

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12

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**CERF 2011** - 21st Biennial Conference of the Coastal and Estuarine Research Federation

# Ecosystem-based approach: the **FORWARD** project Framework for Ria **For**mosa **W**ater quality, **A**quaculture, and **R**esource **D**evelopment

C. Saurel, J. G. Ferreira, M.J. Botelho, M. Caetano, J. Lencart e Silva, D. Matias, J. P. Nunes, L. Ramos, M. Rocha, F. Soares, C. Vale, F. Vazquez

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http://ecowin.org/

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# The Project

Coastal Ecosystem Management challenge:

- Protect, optimize, manage in a sustainable manner the various activities and resources of coastal areas such as the Ria Formosa in Portugal

Aims:

- Assess the ecological integrity of the lagoon (field/laboratory studies, and simulation models)

- To stimulate the development of innovative and technologically advanced activities together with best environmental practices.

Ecosystem Approach to Aquaculture (EAA):

- Integrate ecological and screening models with social and economic aspects

- To provide support for optimal management of ecosystem goods and services in the Ria Formosa.

Only a part of the EAA may be addressed by simulation models

# Ria Formosa – Portugal (Europe)
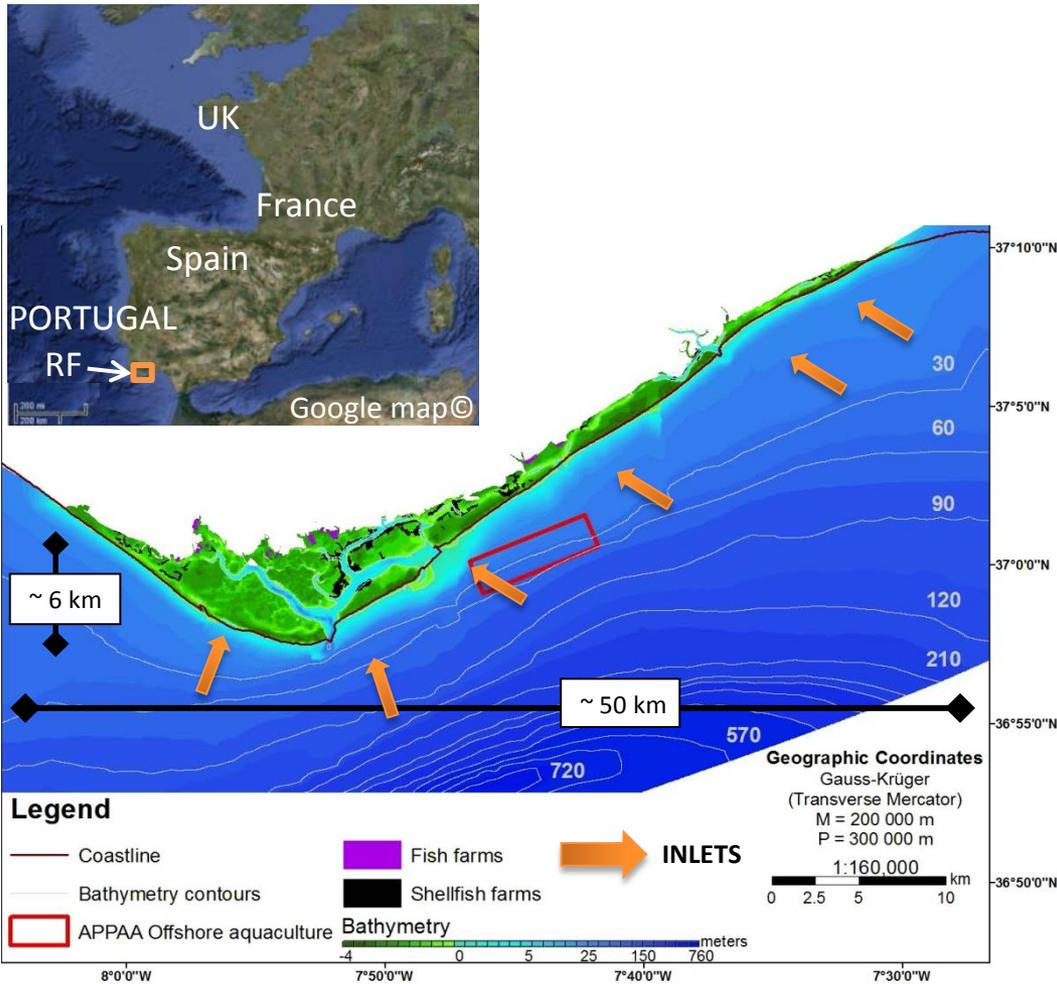


- Lagoon: high socio-economic & natural value. Native clams (*Ruditapes decussatus*)

- 40% of aquaculture products in Portugal (8 kton/y, 44.3 M€/y) originate from Ria Formosa

- 90% of the national production of clams, 26% of oysters.

- Total bivalve production 2750 ton/y for 26 M€/y (36 M$/y)

- 10 000 people involved in the clam industry

**Clam culture is an important activity, and over 10 000 people in the Ria Formosa**

# General model framework
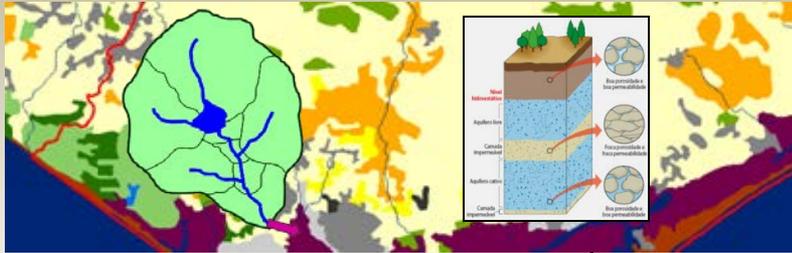


**Ecohydrological model:** SWAT
Wastewater discharges + Non-point sources
637 km² , 331 HRU
COASTAL BASIN

**Water flow**

**Nutrient loading**
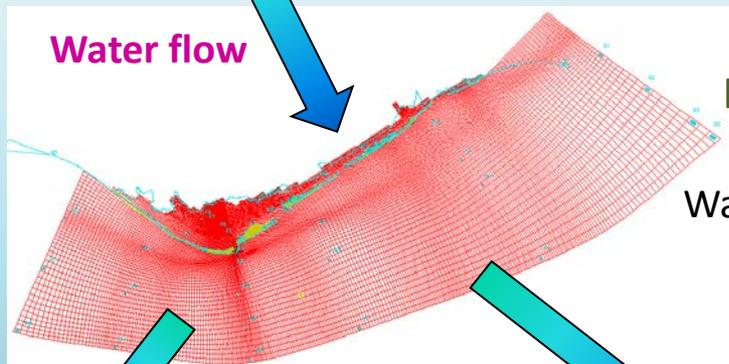
COASTAL WATERS

**Hydrodynamic model**
Delft3D – Flow:
Water flux from tide & waves
1600 km² , 30 000 cells

**Water flow**

**Water flow**

**Local scale models**
FARM – POND
<5 ha, 5-10 sections

**Ecological model**
EcoWin2000:
457 km² , 52 boxes

**Drivers**
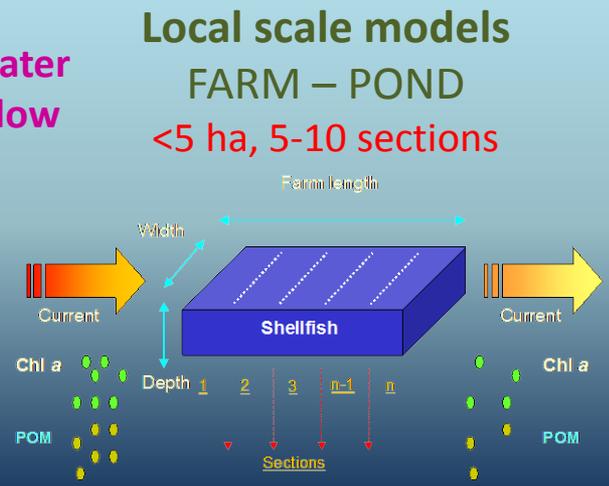
# Ecohydrological model: **SWAT**
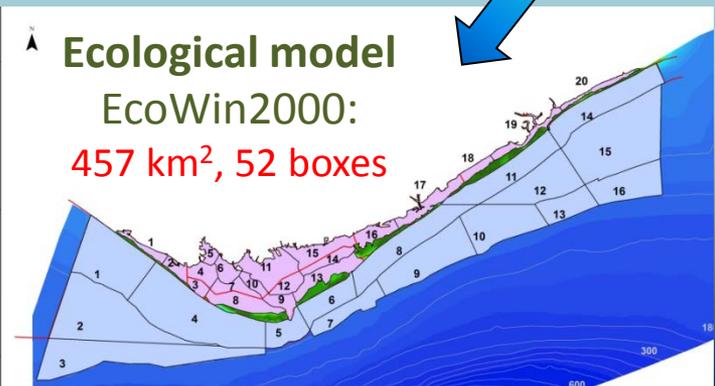## **S**oil and **W**ater **A**ssessment **T**ool

**Hydrological Response Units (HRUs)**

Nutrients: + Internal regeneration from the Ria
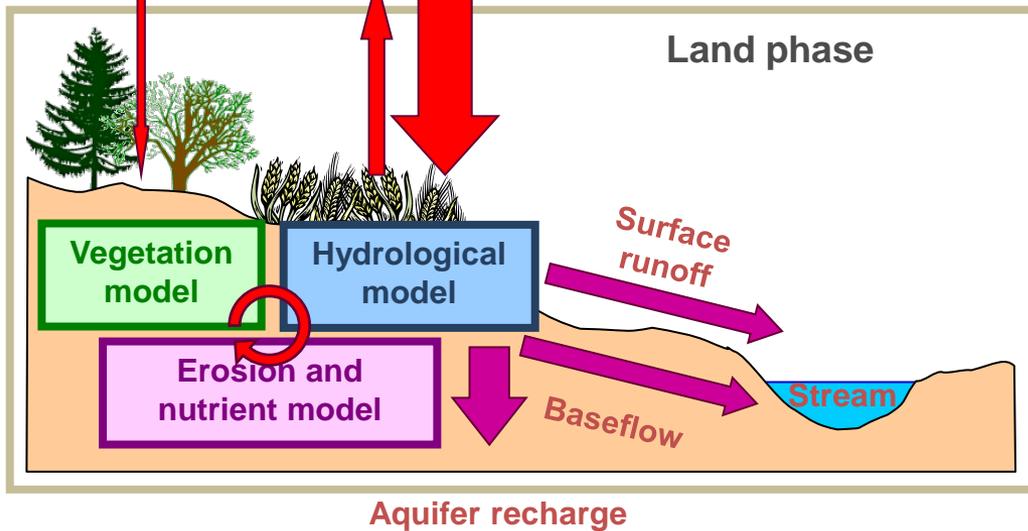
- 331 **HRU** for the Ria Formosa
- **Criteria**:
  - Water bodies from WFD
  - Main discharges of WWTPs
  - Transitions between soil types
  - Sampling stations

- **WWTPs**
- **Diffuse sources**

Agriculture management

Climate

Land phase

Vegetation model

Hydrological model

Surface runoff

Erosion and nutrient model

Baseflow

Stream

Aquifer recharge

- **First results**:
  Nitrogen (N ton / year):
  **WWTPs: 462**
  **Diffuse sources: 366**
  Phosphorus (P ton / year):
  **WWTPs: 70**
  **Diffuse sources: 138**

Diffuse sources are over 50% of the total phosphorus input

# Ecological modelling box criteria



-Physical (hydrodynamics, bathymetry…)
-Legislation (European WFD, national…)
-Aquaculture sites (farms, APPAA…)
-Activities (habitats, salt ponds, shipping lanes…)
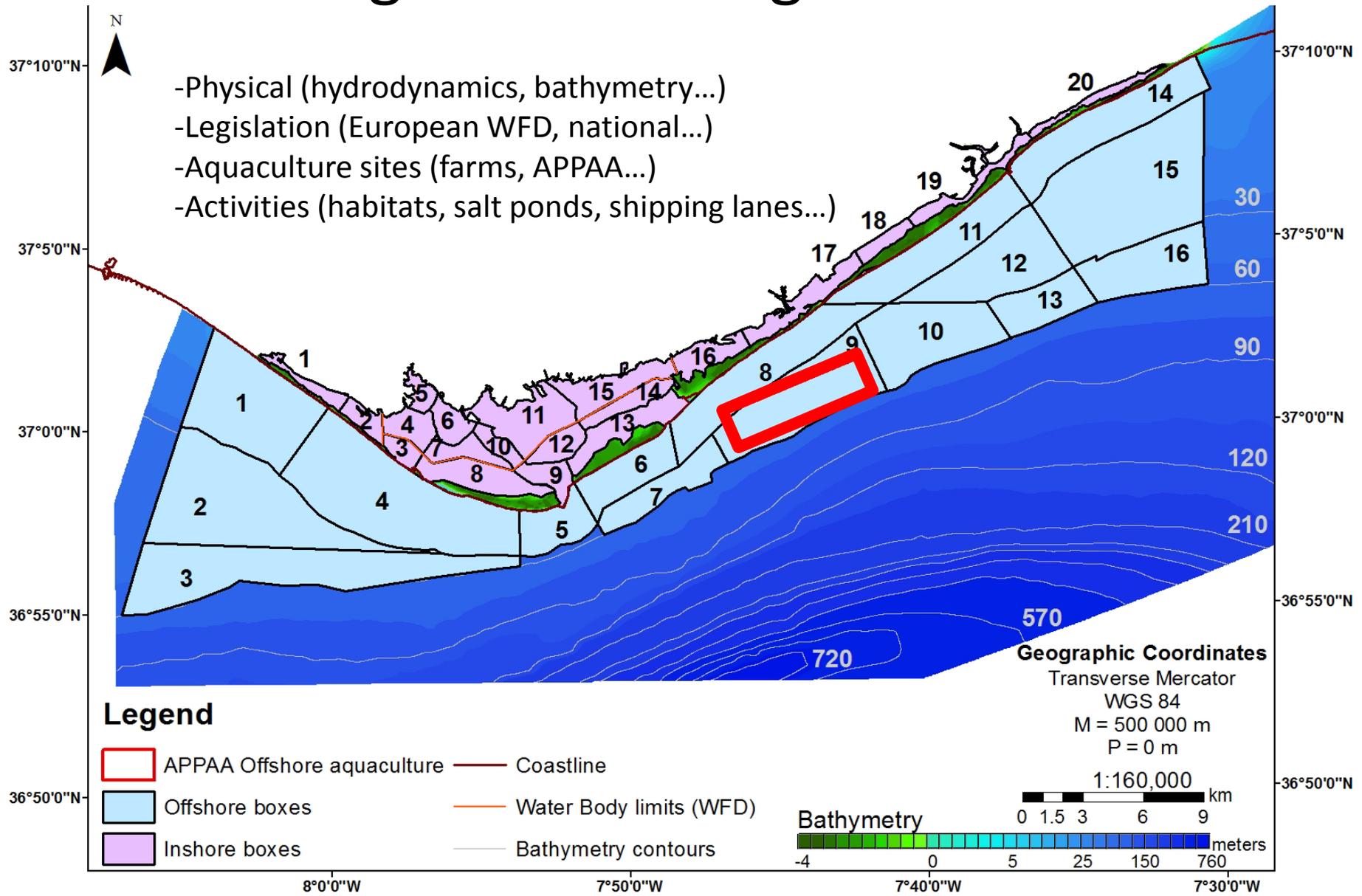
# Ecological modelling: EcoWin2000
## Example IMTA offshore aquaculture – Offshore box 9



● 60 leases: 12 x 5 boxes
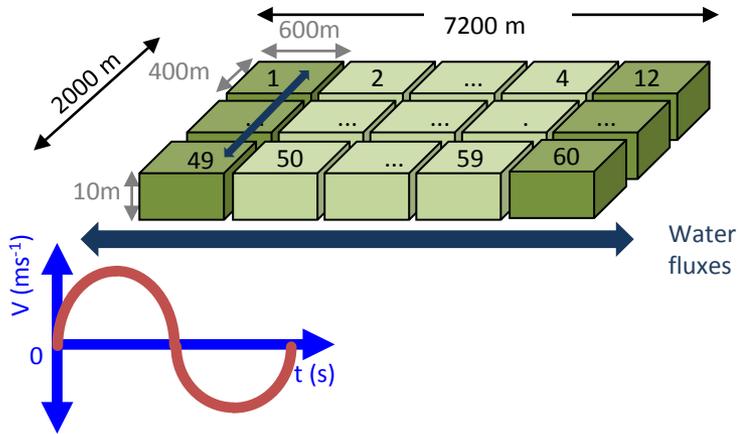
● Simulation: 3 years

● Water fluxes (up to 0.5 m s$^{-1}$)

● Measured environmental data

● Scenarios: 70% fish (gilthead bream) – 30% bivalves (Mediterranean mussels)

● Tests with 2, 10, 30 and 100 t ha$^{-1}$ of mussels
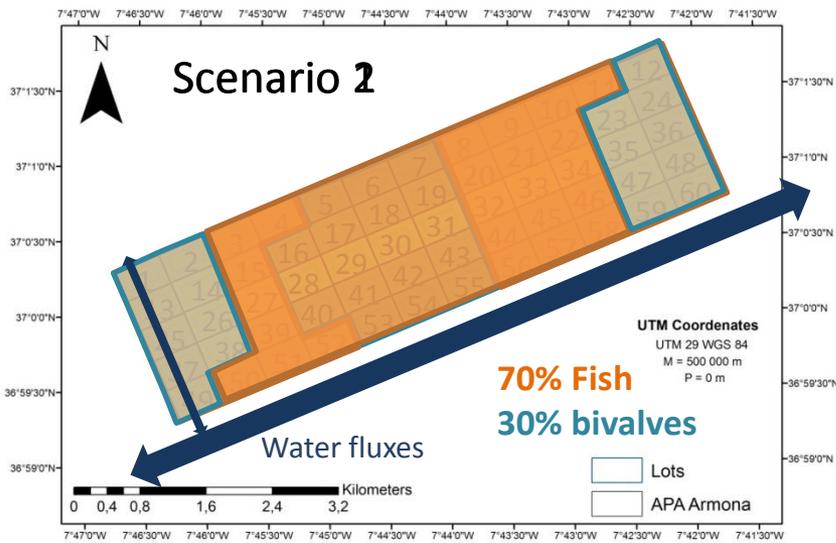
First results: Bivalve production at different mussel densities:

Scenario 1: +25% harvest

Scenario 2: +23% harvest

# Offshore aquaculture- EcoWin2000 model
## Annual mass balance for ecosystem services by shellfish

| Item | Value |
|---|---|
| **Carbon** | |
| Detrital POM removal (t C $y^{-1}$) | 176 |
| Phytoplankton removal (t C $y^{-1}$) | 1758 |
| Total POM removal (t C $y^{-1}$) | 1935 |
| **Nitrogen** | |
| Detrital POM removal (t N $y^{-1}$) | 27 |
| Phytoplankton removal (t N $y^{-1}$) | 273 |
| Total POM removal (t N $y^{-1}$) | 301 |
| **Ecosystem services** | |
| Population equivalents (PEQ) | 91216 |
| Externality value* (millions of USD) | 3.6 |

1 PEQ : 40 USD $y^{-1}$ (Lindahl et al., 2005)

# In situ Experiments



**ANIMAL: Clams** Behaviour/food

**FOOD:** Seston/micro-phytobenthos, POM

**HYDRODYNAMICS:** Advection/turbulence
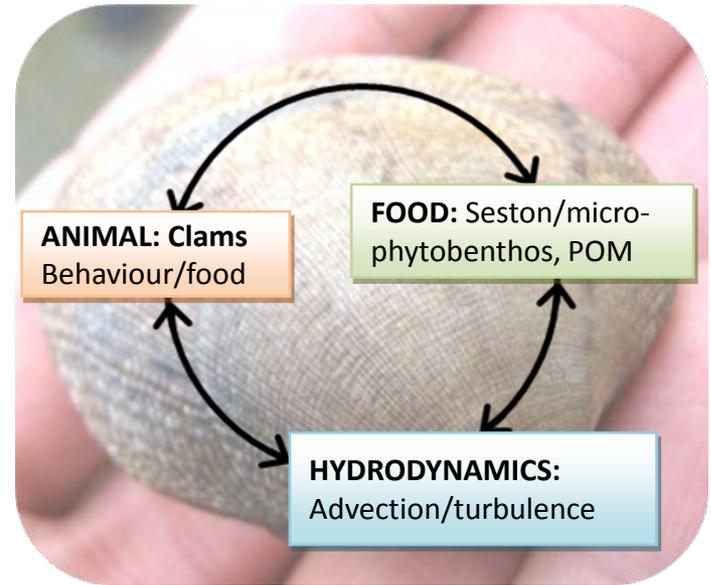
Velocity m s$^{-1}$

Intertidal velocity
Max 0.34 m s$^{-1}$
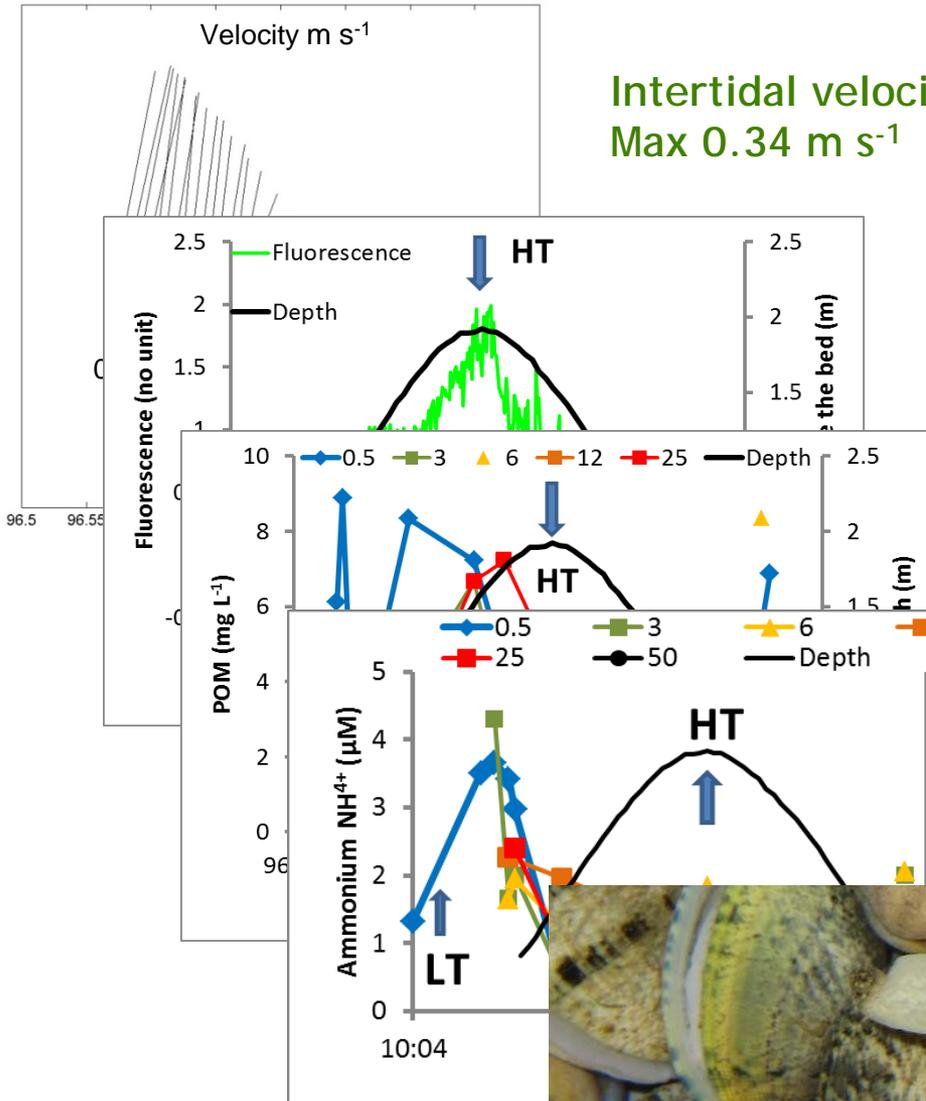
Food reduction with turning tide

High [POM] with Chl $a$ ~5% POM

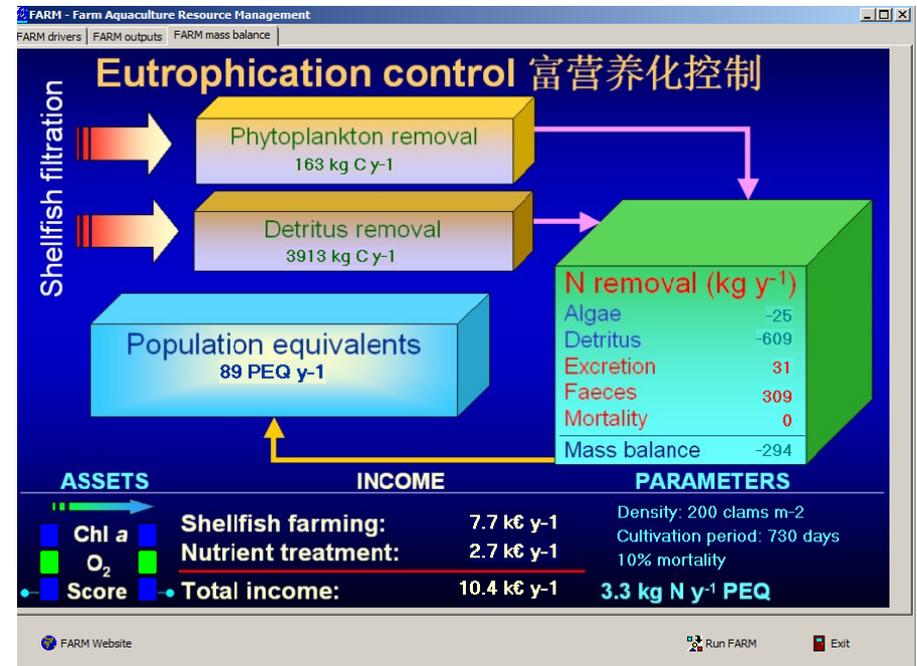Export of nutrients during the flood – internal recycling

Filtration rates
1.23 ± 0.5 (L g$^{-1}$ h$^{-1}$)

# Individual and FARM models



Simulated clam growth
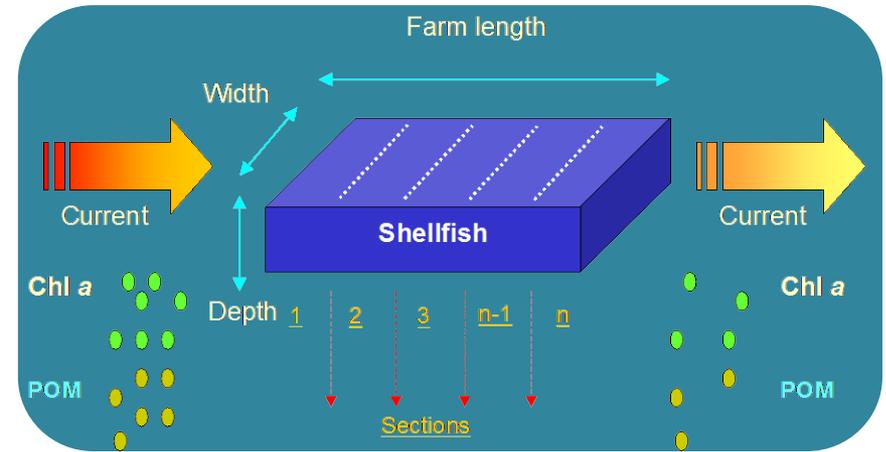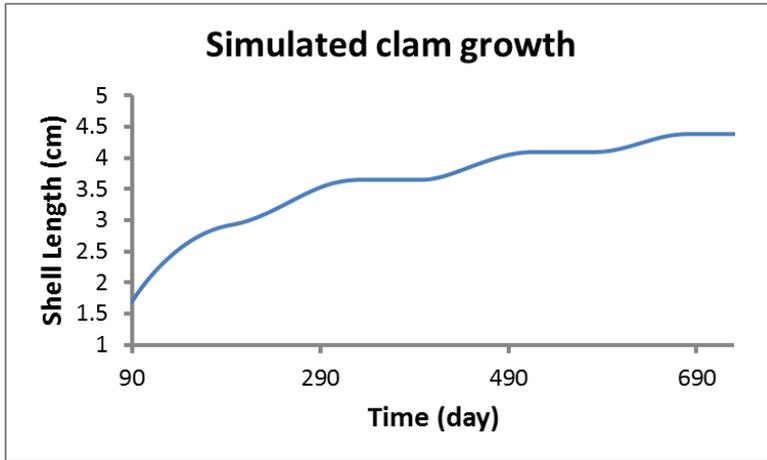


**Calibration of the individual clam growth model for integration in FARM and in system-scale models**

# There is much more to aquaculture carrying capacity than production…



**US, Europe, Canada**

**The four pillars of carrying capacity**

**Southeast Asia, China**

Production

Ecological

Governance

Social

Limiting

Limiting

Realities, awareness, legislation, and governance vary around the world

# Social and legal components

## Preoccupations

- Some farms - poor <u>culture practice</u>
  - Contravene Natural Park regulations
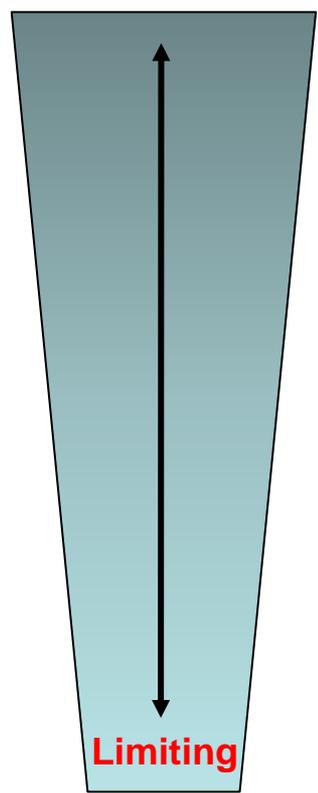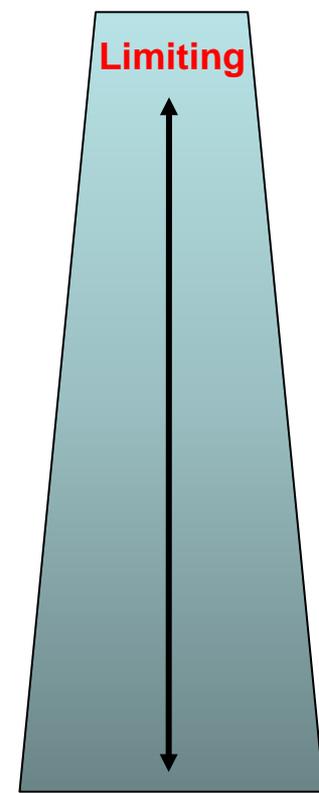  - Delimit lease areas with inappropriate materials
  - Alter the farm height above datum
- Lack of <u>business organization</u>
  - Small plots
  - High number of farmers/leases
  - Transfer of leases
- <u>Link</u> between regulatory institutions and the aquaculture activity
- Future use of the <u>models</u> in development in FORWARD
- <u>Management</u> of farmers' expectations

## Actions

- Analyse and improve the governance frameworks, including regulators, farmers, and other stakeholders
  - Harmonization of the Natural Park legislation with sustainable aquaculture development
- Establish a monitoring system to assess level of compliance with regulation
- Add value to the fishery through certification

# Improve management

**Ecological aspects**

**Social aspects**

Model interactions among nutrient loading, circulation and production

Define realistic lease sizes and effective farm-regulator dialog

Simulate optimal carrying capacity at the system scale

Certify the fishery for "good clam" for a core set of farms

Optimize seeding densities and profit maximization at the local scale

Extend good practices by example

Combine both parts into an effective management framework

# Synthesis

## Activities and products

- Clam cultivation in the Ria Formosa is two hundred years old. Shellfish harvest in the Ria dates back to Al Andaluz

- Ecological models, governance models – solving the 50% of the problem you like best does not solve the problem

- Many coastal systems show similar problems – social conflict is often more of a management challenge than ecological understanding

- Written products from FORWARD include a book and scientific papers (see ecowin.org/smile for an example)

- Digital products include the various models, a legacy program so local managers can apply them, and a GIS based interface to help keep things simple for everyone

http://www.polislitoralriaformosa.pt/forward/index.php

# Thanks for your attention…

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RIA FORMOSA
POLIS LITORAL

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