# Marine habitats evolution and populations adaptation: a step by step modelling strategy

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# Issues and challenges (1)

- **Coastal Ecosystems support essential ecological functions and services (biodiversity, productivity, recycling or organic matter, transfer of C, N to open oceans). They have important societal and economic values (fishery, aquaculture, sand and gravel extraction, recreational activities, supply of energy). Pressures related to human activities have large potential impacts on ecocological functions**

- **Marine Strategy Framework Directive emphasizes the need for system models which should take into account the underlying processes and the complexity of their interactions at the ecosystem level in order to assess ecosystem state and changes**

- **Disburbances of marine ecosystems result in individual responses (behaviour, physiology, evolution, ontogeny) to environmental stress which affect biological traits (growth, reproduction, fecundity, immunity, etc.), adaptive capacity of living organisms, and spatio-temporal dynamics of populations**

- **At a larger scale, physical habitats, distributions of populations and structure of communities are also modified by environmental changes - e.g. temperature, contamination by chemicals, eutrophication, hydrodynamics and morphodynamics**

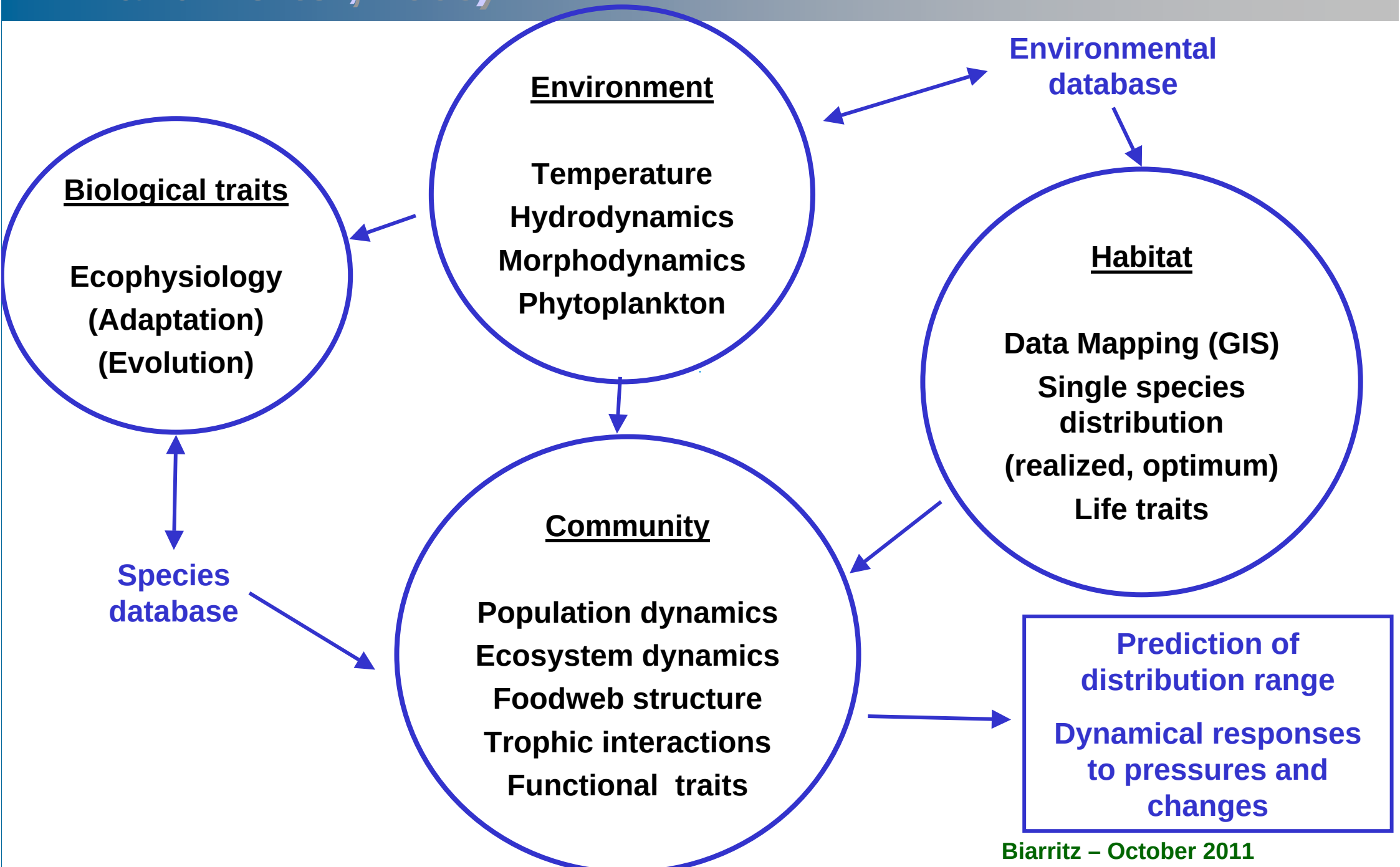
# Issues and challenges (2)

- **Kearney (2006) has listed some key concepts which are involved in the distribution and dynamics of species populations.**
  - ✓**Environment: the biotic and abiotic phenomena surrounding and potentially interacting with an organism**
  - ✓**Habitat: description of a physical place, at a particular scale of space and time, where an organism either actually or potentially lives. It remains associated with descriptive/correlative analyses of the environments of organisms**
  - ✓**Niche: a subset of those environmental conditions which affect a particular organism, and supports population growth, survival and reproduction**
- **Despite the large number of bio-physical interactions involved, most habitat and niche models still keep a low resolution regarding the biological mechanisms (Guisan and Thuiller, 2005)**
- **The coupling between population dynamics, models of bioclimatic envelopes, georeferenced environmental data and evolutionary biology is now emerging in terrestrial ecology (Keith et al., 2008 ; Kozak et al., 2008)**
- **Application of such concepts and tools to marine ecology is certainly innovative and would improve existing methods and models which have shown their limitations (Klok et al., 2009)**

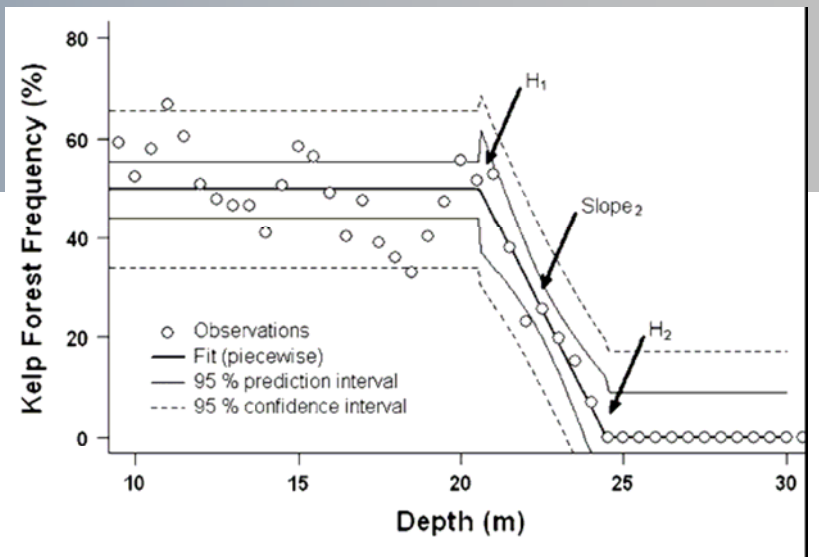
# Scientific objectives

- **Predict population dynamics and distribution from the interactions between individual physiology, environmental changes and ecosystem structure**
- **Develop and combine different types of models – e.g. habitat, population and ecological models, with special attention to spatial and ecological scales**
- **Apply these models in the frame of ecological status assessment, conservation and restoration strategies regarding functional biodiversity**

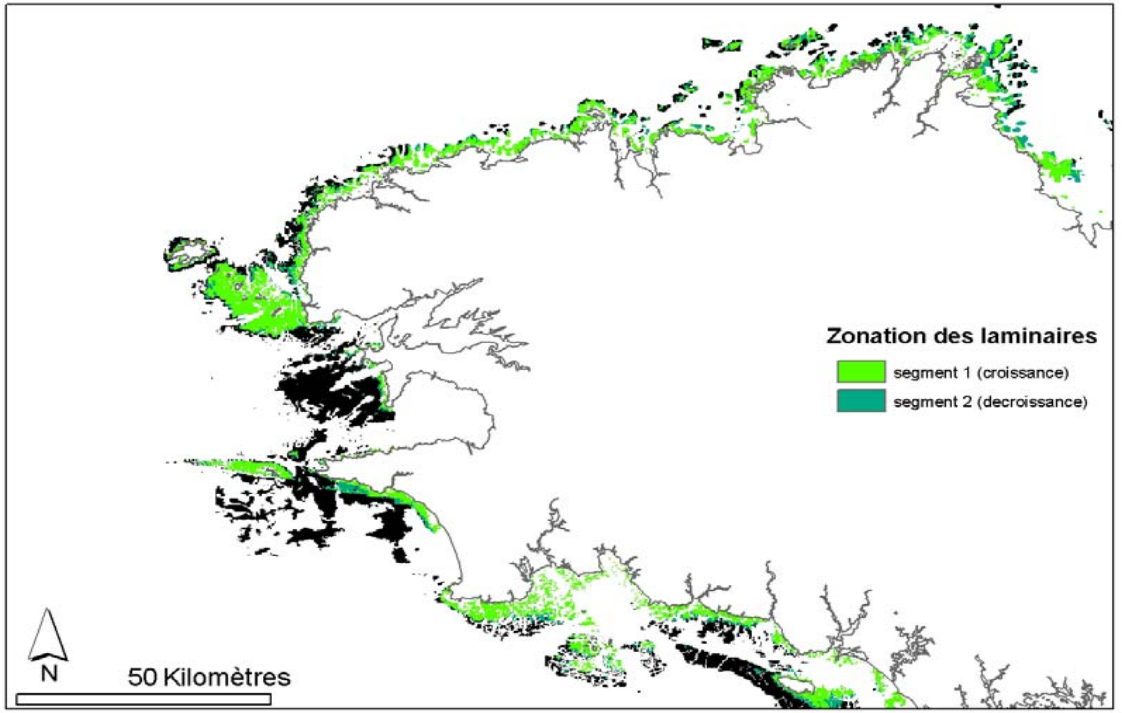
# Modelling strategy (adapted from Kearney and Porter, 2009)



# Habitat modelling



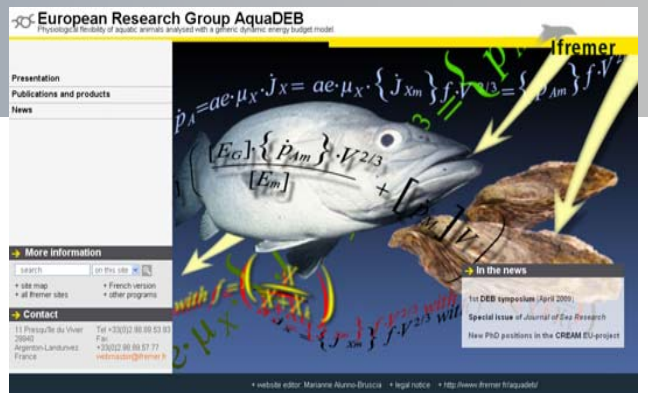

- **Scope**
  - ✓ **Predictive modelling of potential habitats for single species**
  - ✓ **Produce statistical rules to understand species distribution by using relevant spatial data**
    - ***Example : predicted distribution of kelp forrests based on the type of substrate, water depth, transparency, surface temperature, hydrodynamics***
  - ✓ **Combine data into a Geographical Information System**
  - ✓ **Assess the effect of climate Change on species distribution.**



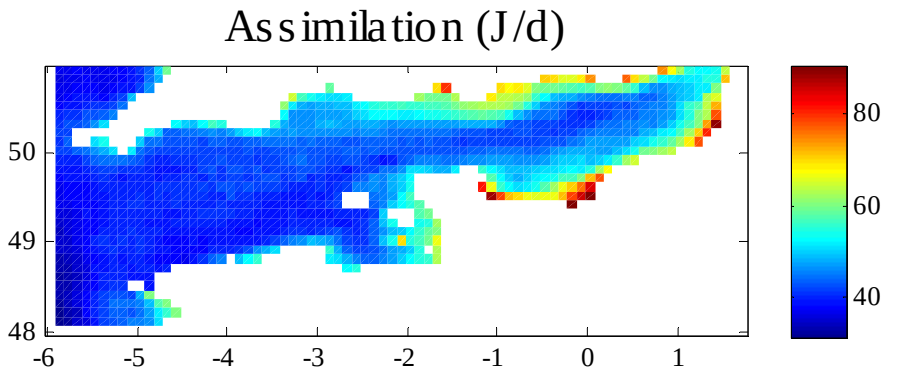

***Meleder et al., 2010. Predictive modelling of seabed habitats: case study of subtidal kelp forests on the coast of Brittany, France***

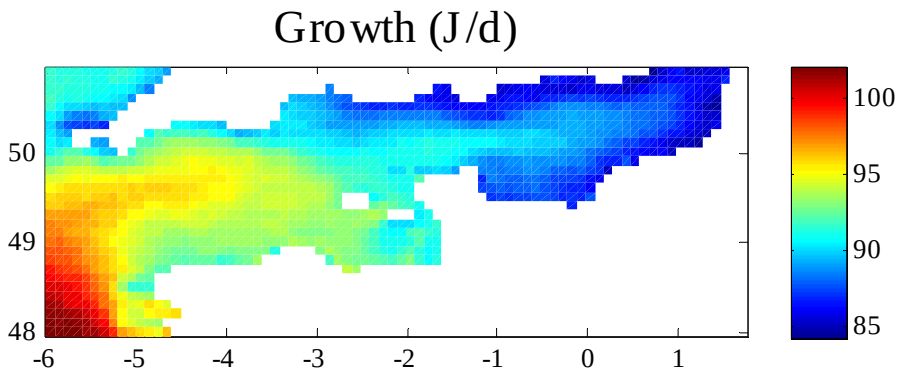
- **Challenges**
  - ✓ **Communities**
  - ✓ **Mechanisms and process**
  - ✓ **Dynamical responses**
  - ✓ **Finer space resolution (data)**

# Ecophysiological models




- **Scope**
  - ✓ **Predict energy allocation within individuals by considering environmental factors and generic physiology rules**
  - ✓ **Predict how disturbances related to pollutants, climate, new diseases, parasites or exploitation modify energy allocation in aquatic organisms and their biological traits**
    - ***Example: computation of individual energy flow for mussels in the English Channel, as a function of temperature and phytoplankton derived from satellite data***
- **Challenges**
  - ✓ **From individual to population: increasing complexity**
  - ✓ **Trophic interactions**



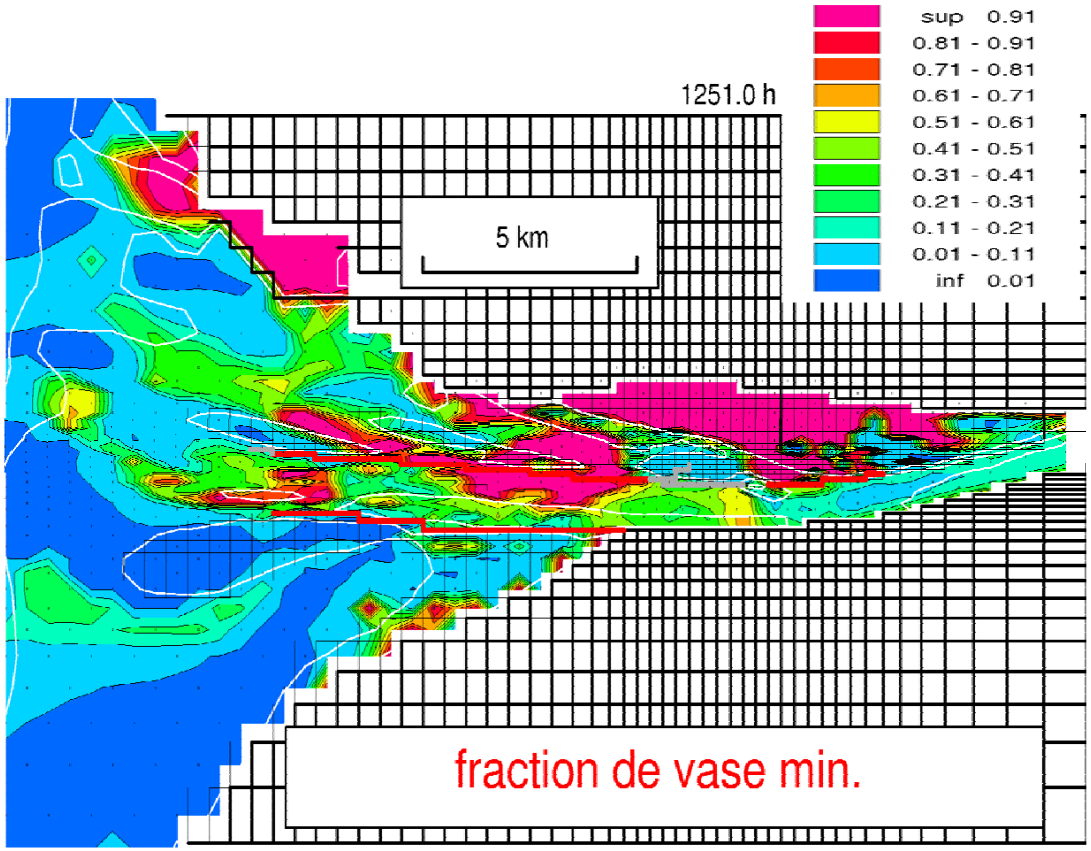




***Aroun, 2011. Utilisation des images satellites pour simuler la réponse des organismes aux changements environnemnteaux***

# Morpho-Sedimentary dynamics model

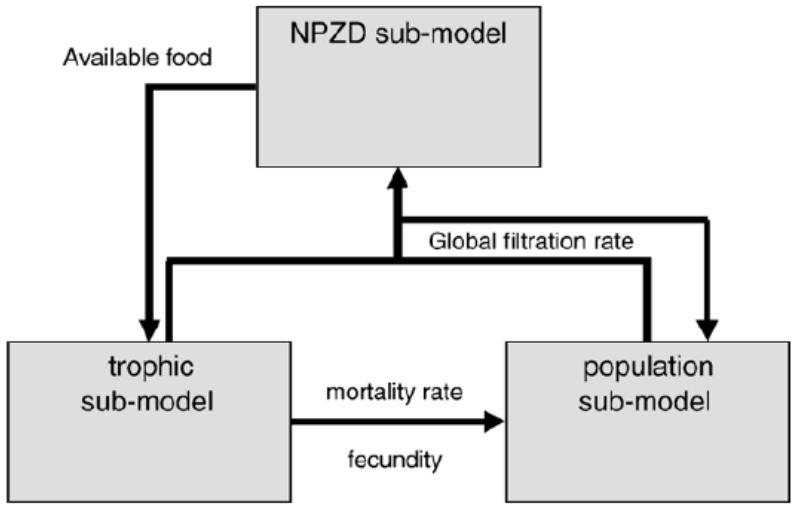
- **Scope**
  - ✓ **Predict hydrodynamics patterns, morphology and sediment cover and their evolution over several decades**
    - ▪ ***Example: prediction of mid-term bathymetry and morphological changes***

- **Challenges**
  - ✓ **Long term changes**
  - ✓ **Coupling within biophysical mechanistic and habitat models**



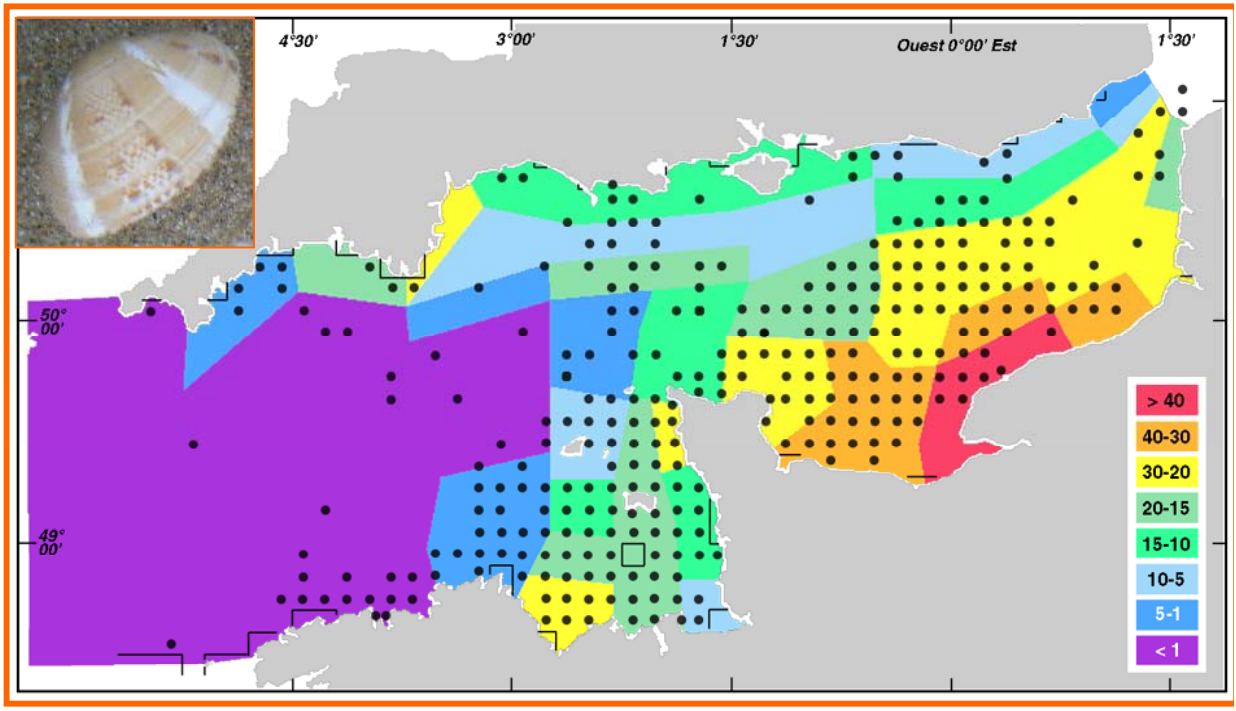

***Waeles et al., 2007. Modelling sand/mud transport and morphodynamics in the Seine river mouth (France): an attempt using a process-based approach***

# Population dynamics model




- **Scope:**
  - ✓ predict patterns of population distribution,
  - ✓ generic modelling framework based on age-structured population dynamics, mechanistic individual growth, hydrodynamics transport (connectivity), NPZ (Nutrients–Phytoplankton–Zooplankton) cycling
    - ***Example: predicted distribution in the English Channel of a benthic bivalve, Paphia rhomboïdes. The simulations converge to a steady state distribution after 15–30 years***

- **Challenges:**
  - ✓ Spatial resolution
  - ✓ Genericity of physiology
  - ✓ Long term changes of forcing and physical habitats
  - ✓ Multi-species and foodweb structure
  - ✓ Species adaptation and genetic evolution




*Savina et al., 2008. A deterministic population dynamics model to study the distribution of a benthic bivalve with planktonic larvae (Paphia rhomboïdes) in the English Channel (NW Europe)*

# Conclusion- workplan

- **Main challenge : combination of scales : spatial resolution and number of biological interactions**

- **Changing Ocean - Laboratory of Excellence – 2011/2015 : Institut en Sciences Marines, IUEM (Institut Universitaire Européen de la Mer), Ifremer, CNRS, IRD, Ecole Centrale de Nantes, UBS, Université de Nantes**
  - ✓ **Axis 6: Evolution of Marine Habitats and Population Adaptation – Coordination C. Bacher (Ifremer), C. Paillard (IUEM)**

- **Objectives**
  - ✓ **Characterise habitats and biological communities by analysing and identifying structuring factors (e.g. morphosedimentary and hydrodynamics forcing), mapping habitats mosaics and studying species assemblages in different types of environment,**
  - ✓ **Formulate and couple interactions to simulate**
    - ***physiological responses,***
    - ***changes of biotopes, distributions and ecological niches for target species,***
    - ***benthic and pelagic population dynamics,***
    - ***distribution of communities,***
  - ✓ **Reconstruct past changes, test hypotheses and simulate scenarios of future changes by integrating models at different scales (organism, population, habitat)**