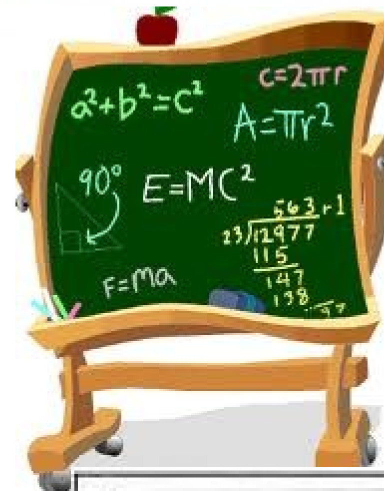
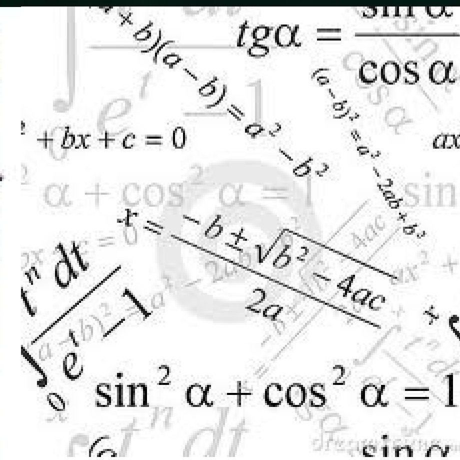
Management of eel species: a modelling problem

Marcello Schiavina*
Politecnico di Milano, Università degli Studi di Parma
* email: m.schiavina@gmail.com

Introduction: a good management

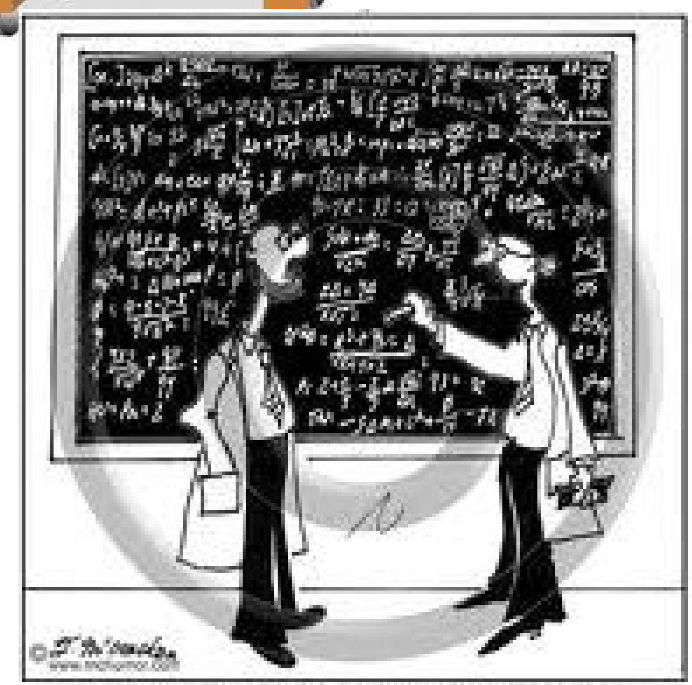




- A good management considers both the health of the species (sustainability) and the fishermen's yield (catches)

- A good management is possible when we have a good comprehension of all processes characterizing the species:
  - the understanding of a process means to know its mathematical formulation
    e.g.
    F = m·a (Galileo's princ.)
    $d = v_i \cdot t + 1/2 \cdot a \cdot t^2$ (kinematic princ.)

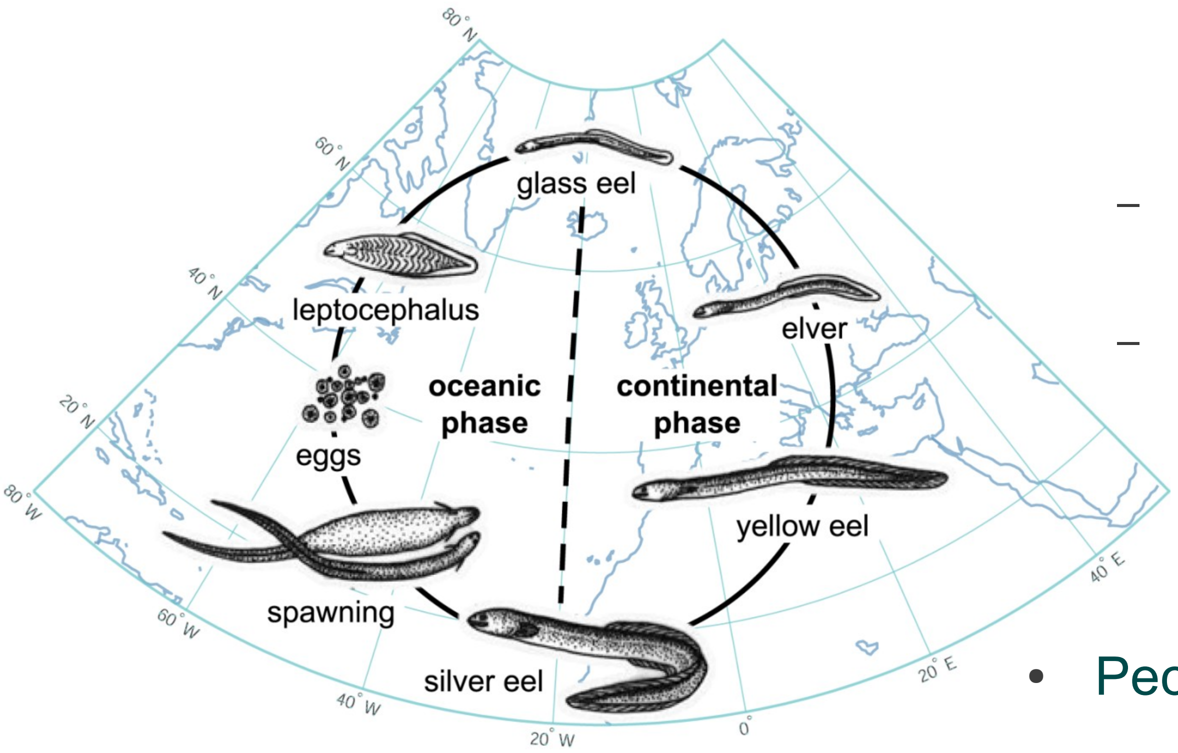
- Mathematical models allow to analyze different management scenarios in order to find the better trade-off



"There's really no need for confusion.
Part 95 of section 33 of article Q
in the formula quite clearly states ... "

The European eel life cycle and its life traits

European eel life cycle

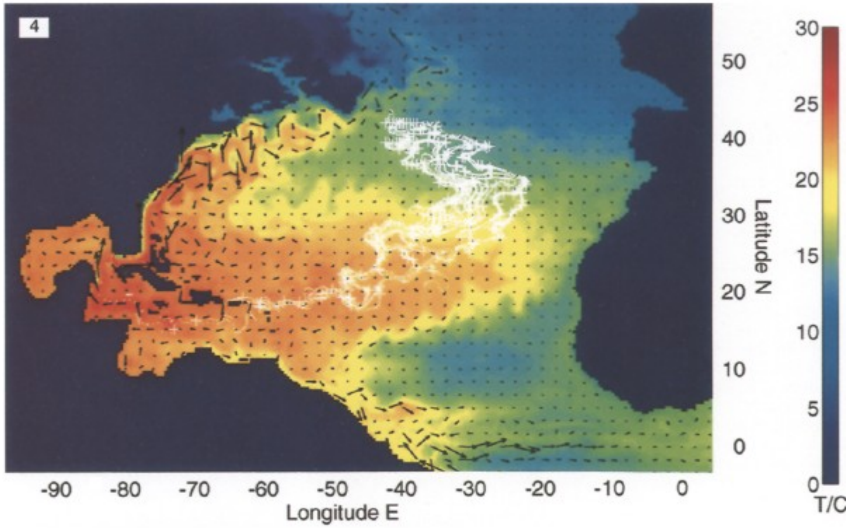


- A catadromous species:
  - larvae hatch out in the Sargasso sea and migrate towards European shelves where they metamorphose into glass eels
  - glass eels settle in brackish and fresh water and become yellow eels
  - mature eels metamorphose into silver eels and undertake the back migration towards spawning sites, where they mate and die

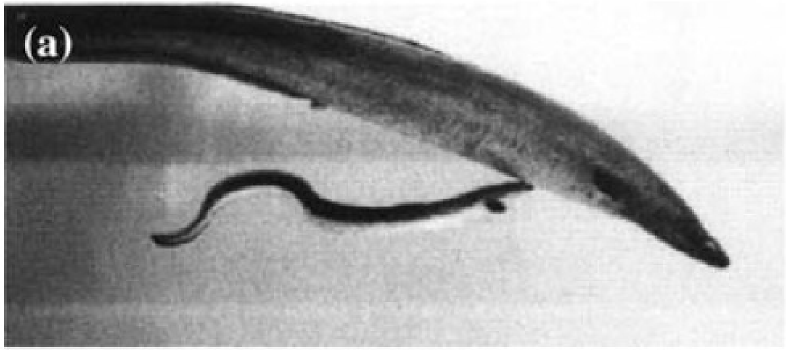
- Peculiarity:
  - one panmictic population
  - high growth plasticity (3-30 yrs)
  - sexual dimorphism

Spawning migration: almost unknown

- Link numbers of spawners that leave the continent with a number of eggs
- The back migration of adults is still a mystery:
  - few migrating individuals caught
  - tag experiments
- Not enough information to built a reliable model:
  - Migrating behavior?
  - Migrating routes?
  - Spawning triggers?
  - **Survival?**
- A first attempt in 1995 (Fricke & Kaese)

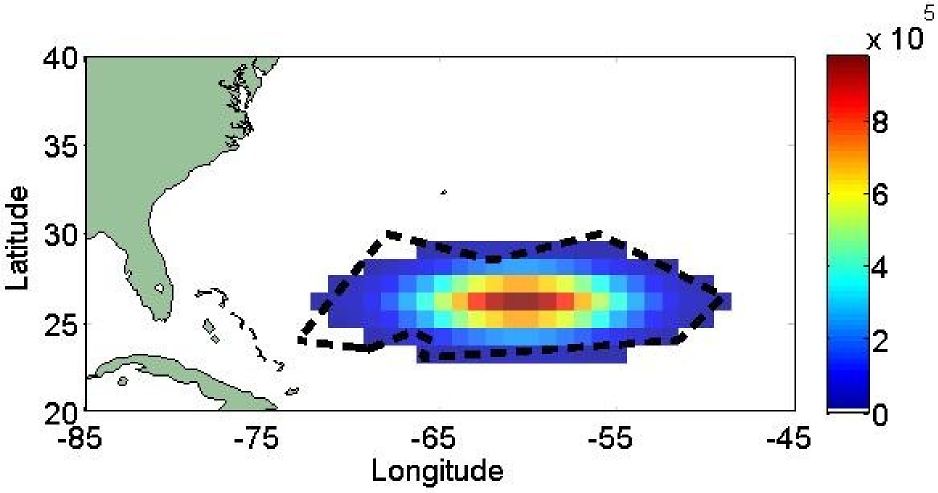


source:
Fricke H & Kaese R (1995) *Naturwissenschaften* 82:32-36

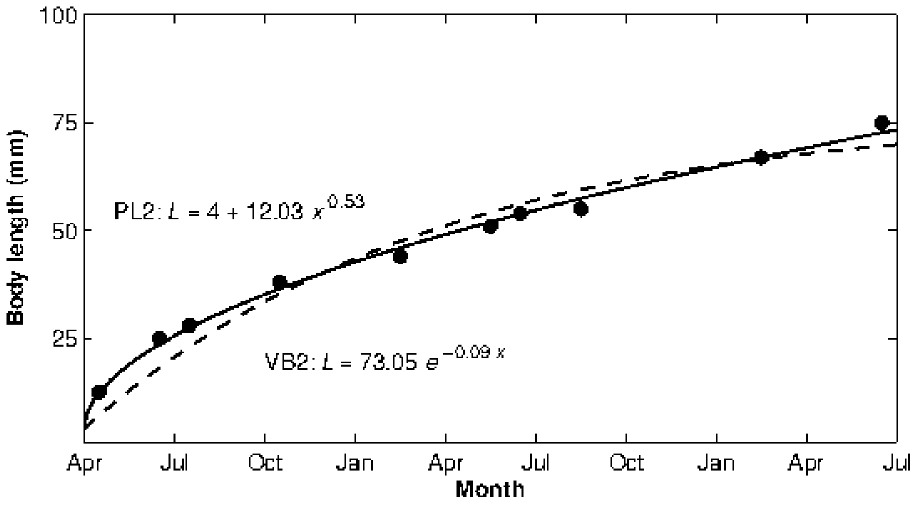


Larval migration: barely known

- Field sampling gave some ideas of:
  - migration routes
  - spawning grounds
  - spawning season
  - rough body growth
  - diel vertical migration



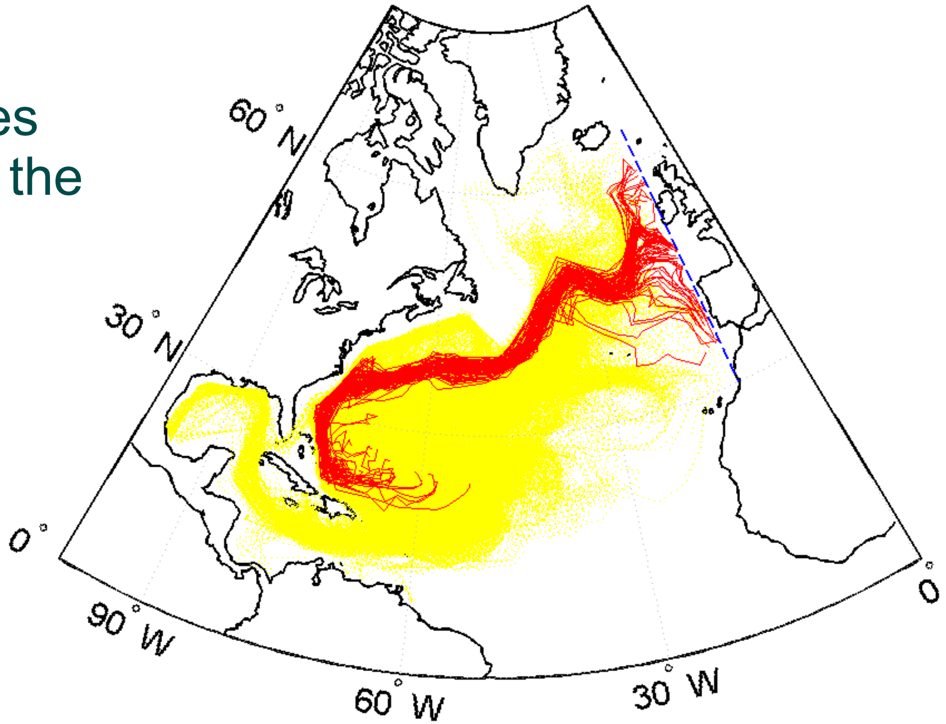
- Some hypotheses:
  - general mass & temperature dependent mortality (metabolic theory of ecology)
  - Passive vs active motion
  - Navigation



Larval migration: modelling ocean transport

- Reproduction of the ocean stream with a complex Ocean General Circulation Model
- Use the velocity field to move particles in the ocean and the temperature for the mortality
- Comparing results with field data to select the best scenario and characterize the migration:
  - duration of 2.5 years
  - active motion
  - identification of the body growth curve

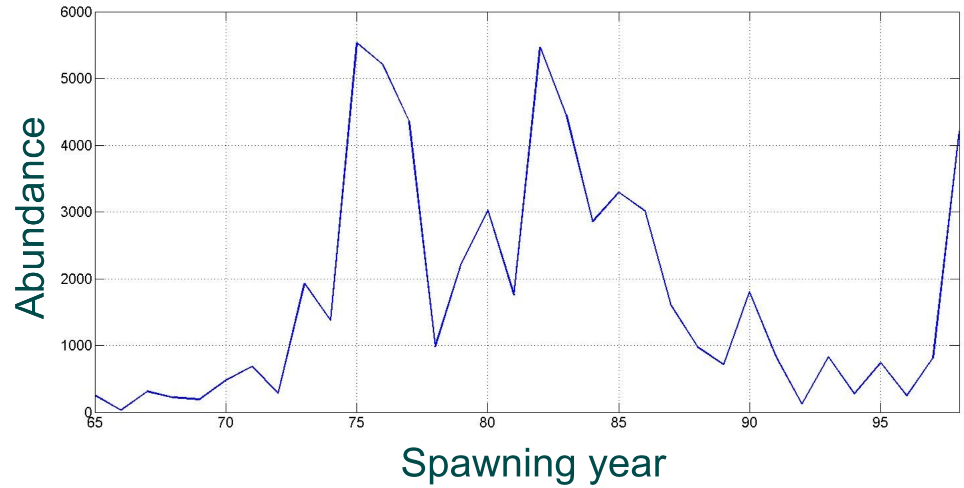
(Melià *et al*. *submitted*)

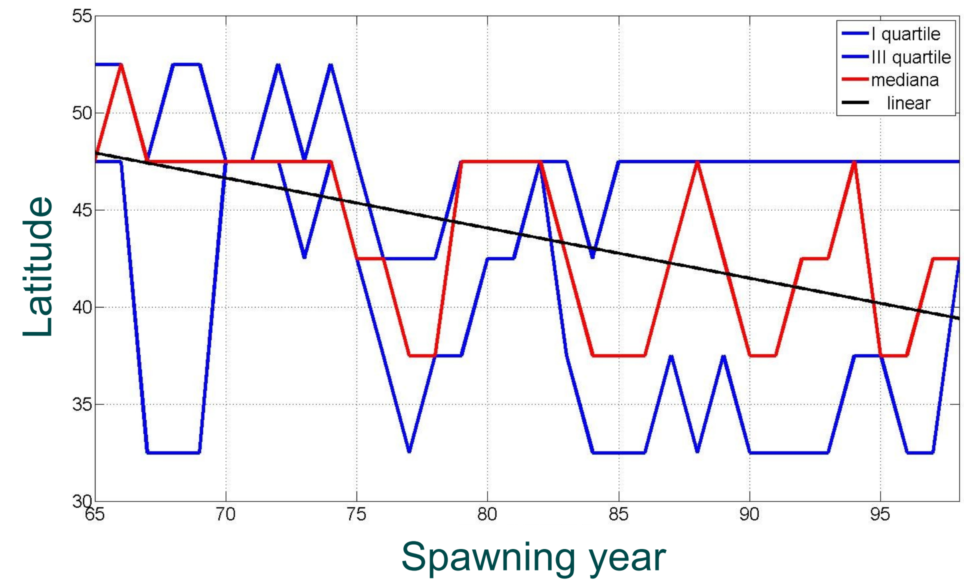


Larval migration: modelling ocean transport

- Preliminary results of 50 years simulation:
  - high inter-annual variability of abundance
    [hp constant eggs-spawners and spawning site]
  - decreasing average latitude of arrival along European shelves
  - physical parameters in the Sargasso Sea changes around the 80s

(Schiavina et al *in prep*)





Continental phase: more studied

- Field studies for the continental phase are more abundant

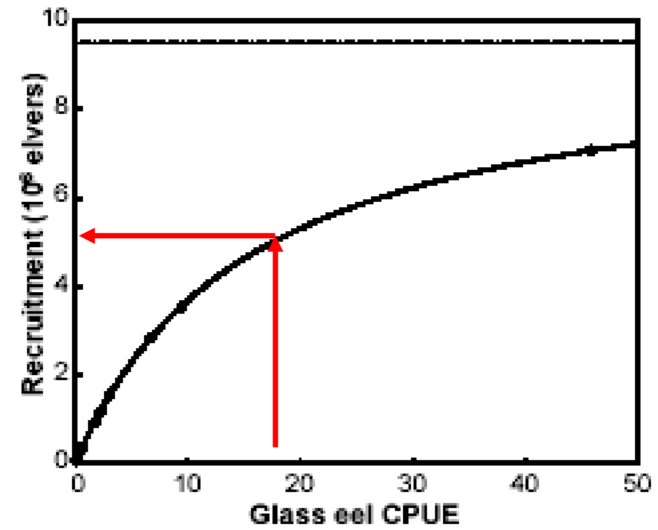
- Comprehension of each precess from data:
  - settlement
  - body growth
  - sexual differentiation
  - sexual maturation
  - natural mortality
  - fishing gears selectivity

- It is possible to develop detailed models of the population dynamics

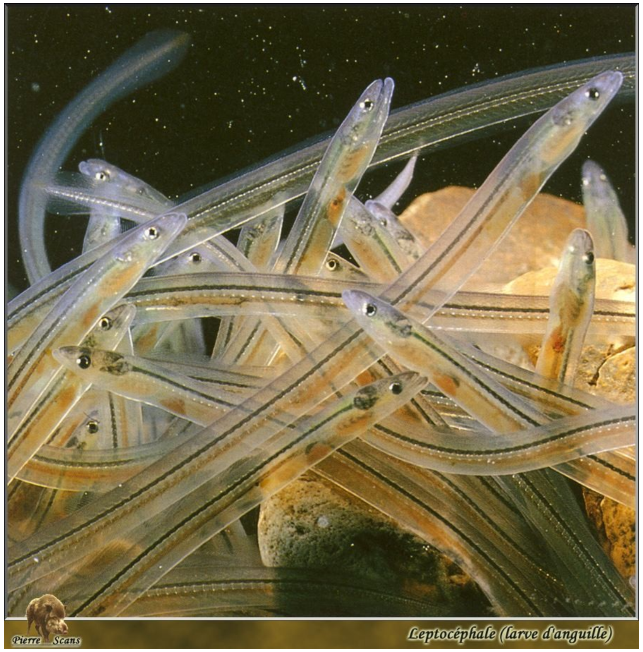
Density dependent settlement

- Glass eel entering in the lagoon suffer a density dependent mortality (Bevacqua *et al. submitted*)

$$Elver = \frac{Glass}{1 + \frac{Glass}{K}}$$

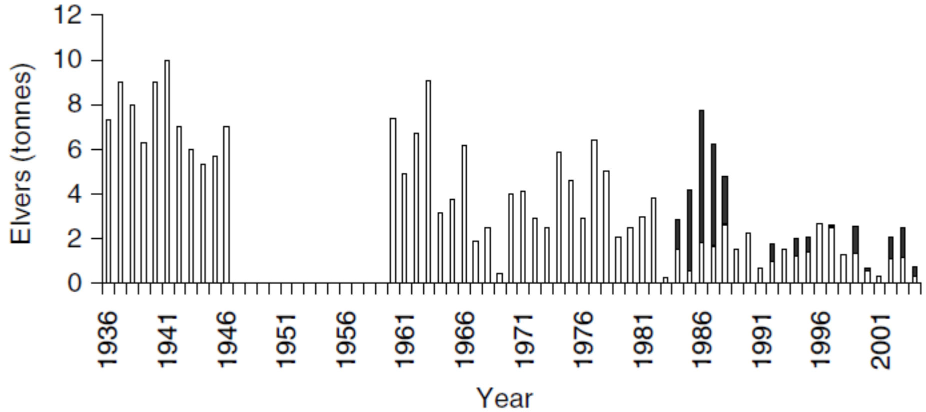


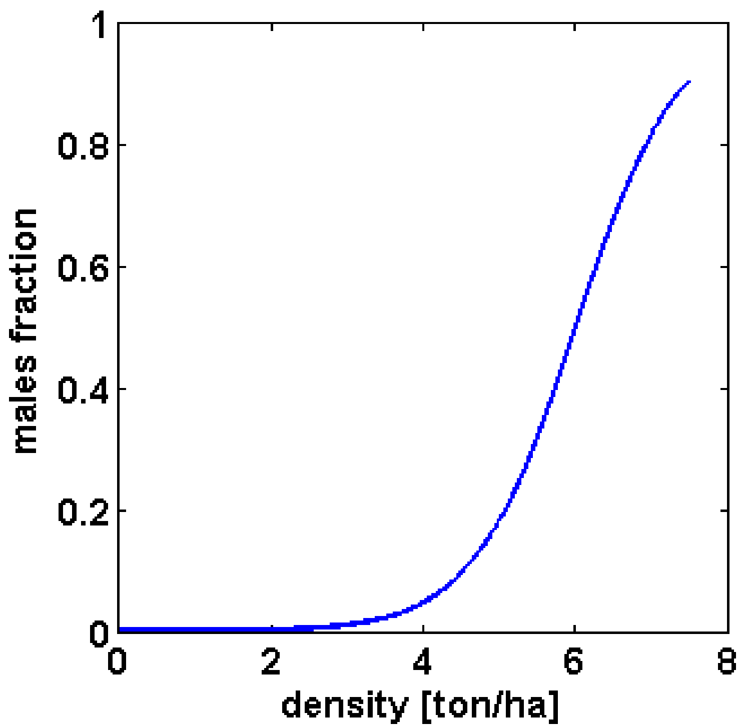
- K is the carrying capacity of the system (**maximum number of settlers**)
- Low productive Camargue lagoon has **K = ~500 ind/ha**
- Some lagoons in Italy (Sardinia and Apulia) have **K = ~1000 ind/ha**

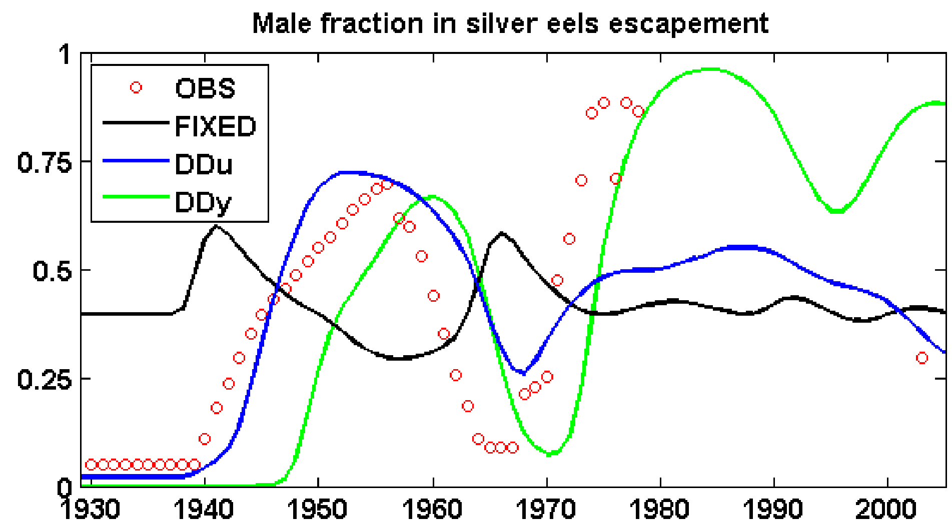


Sexual differentiation

- Sex ratio is probably determined by density (Schiavina *et al. in prep*)
- Preliminary results on LoughNeagh data and Vaccares lagoon confirm this hypothesis

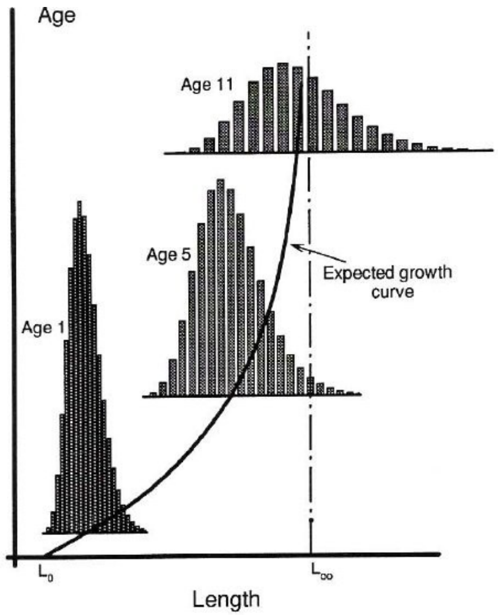


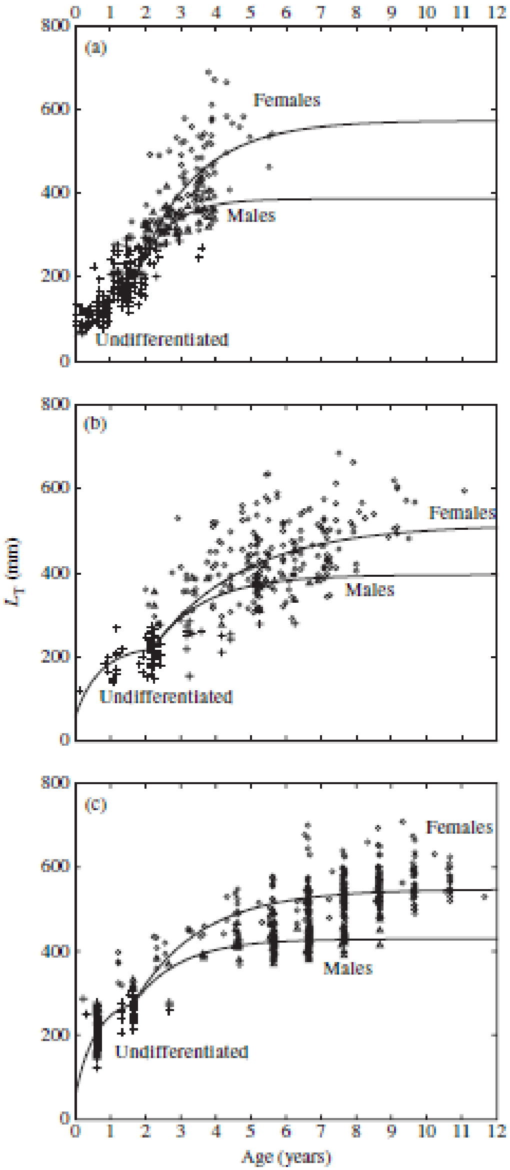




Body growth – sexual dimorphism - plasticity

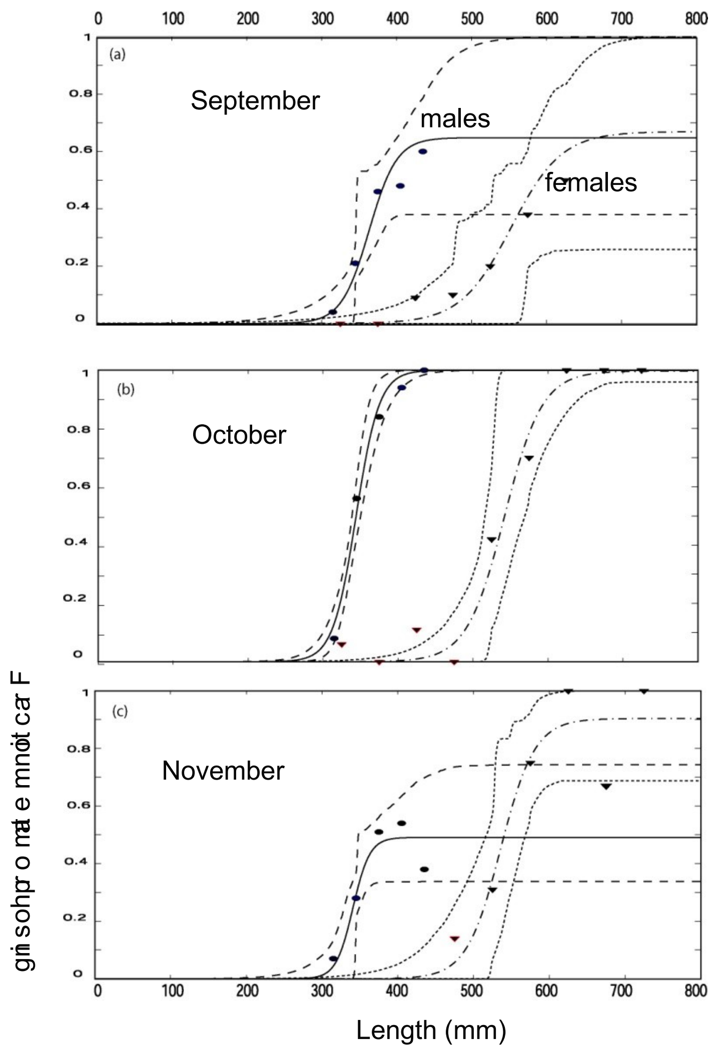
- Using length-age data of eels, obtained reading otolith annual rings
- Deterministic body growth curve divided into undifferentiated eels, males and females (Melià *et al.* 2006b) with high inter-individual variability (Kirkpatrick's assignment at birth log-normal distributed)
- Asymptotic lengths:
  - Fumemorte canal (fresh) ♀ **51.5 cm** and ♂ **39.5 cm**
  - Vaccares lagoon (saline) ♀ **57.3 cm** and ♂ **38.6 cm**
  - Comacchio Lagoon (saline) ♀ **54.7 cm** and ♂ **43.0 cm**





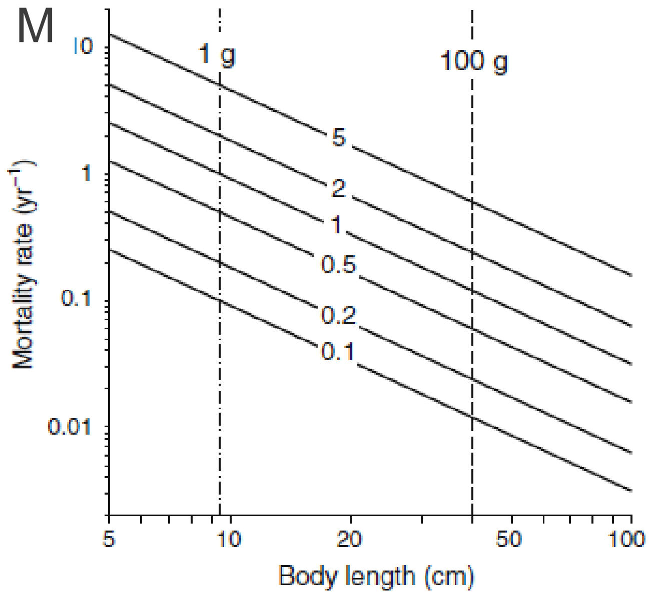
Metamorphosis into silver eels (maturation)

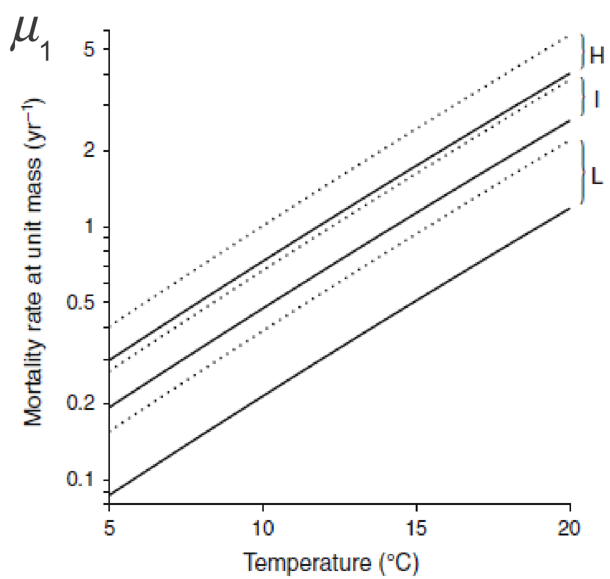
- The probability to become a silver eel depends on the body length
- Using data of silver eels abundance in catches and their body length it is possible calibrate this relationship
- Males and females have different curves
- Curves differs month by month
- In Camargue lagoon:
  - starting metamorphosis
    ♀ **~50 cm** and ♂ **~30 cm**
  - 50% probability of metamorphosis
    ♀ **~54 cm** and ♂ **~35 cm**
- Age of maturation:
  - ♀ **4-6 yrs** and ♂ **3-4 yrs**



Natural mortality

- There are some general rules about natural mortality (Metabolic theory of ecology):
  - The bigger you are, the less you die (Elephants have a longer life then ants)
  - Temperature accelerate all metabolic processes shortening life
- Using data about population structure it is possible to calibrate a general mortality function for eels (Bevacqua *et al.* 2011a)



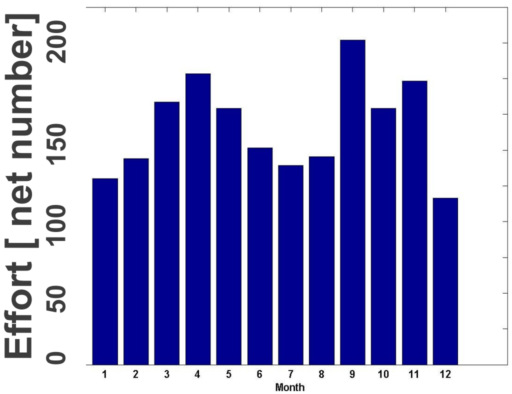


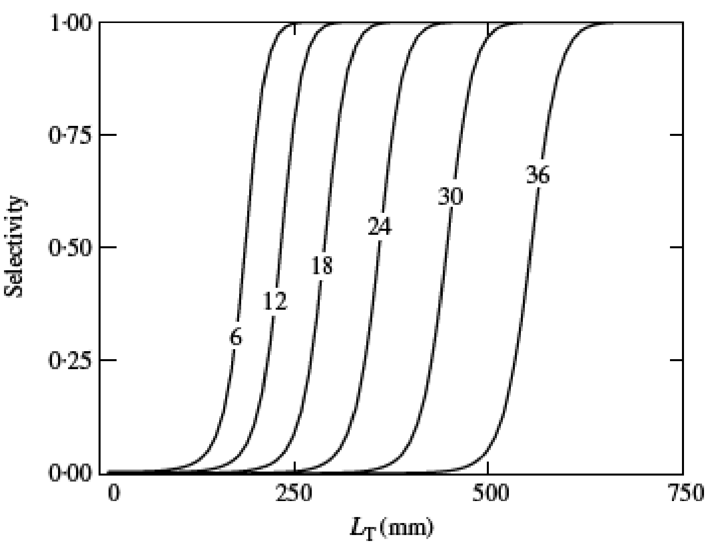
Fishing mortality

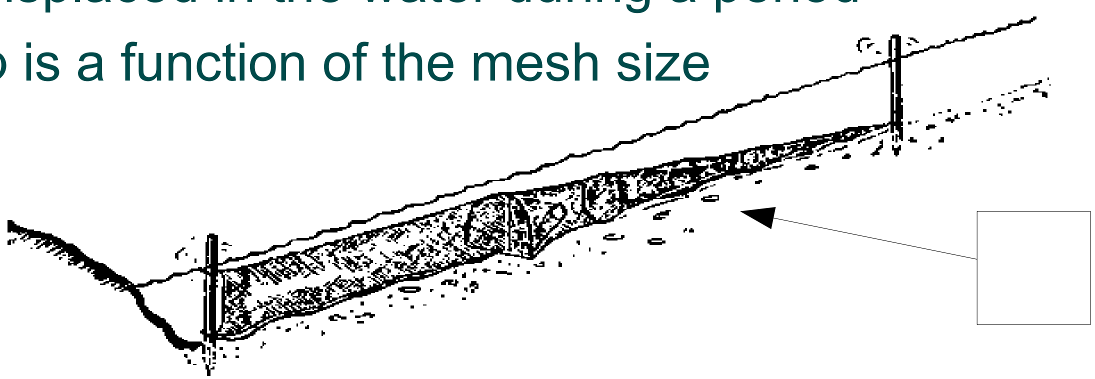
- Fishing mortality depends on the catchability, the effort and the selectivity of the fishing gear:

$$F = q \cdot E \cdot \phi$$

- q is a characteristic of the species and depends on its behavior (how much does it move in water) and probably on the temperature
- E is the number of nets that are displaced in the water during a period
- φ is a function of the mesh size

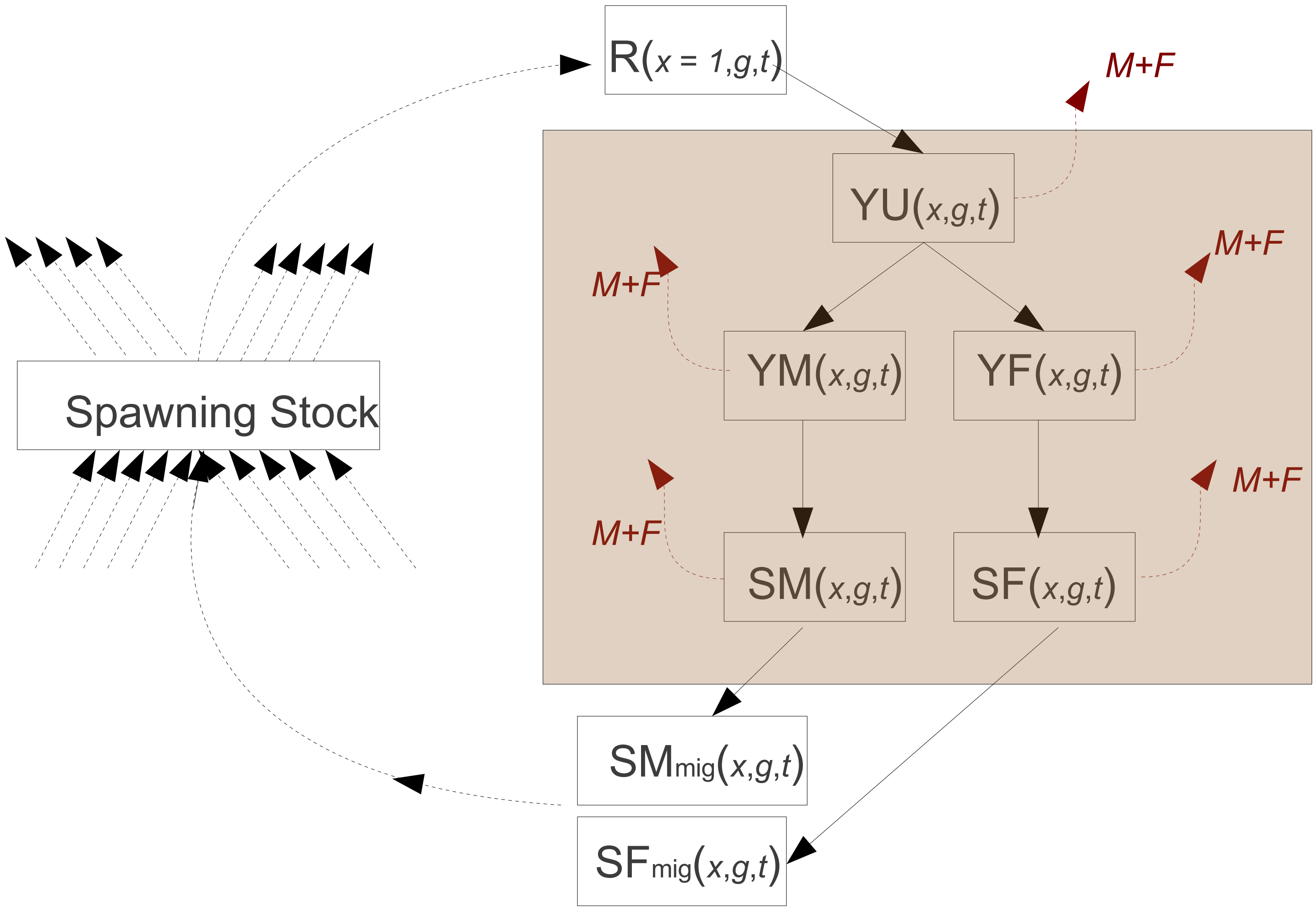






mesh size

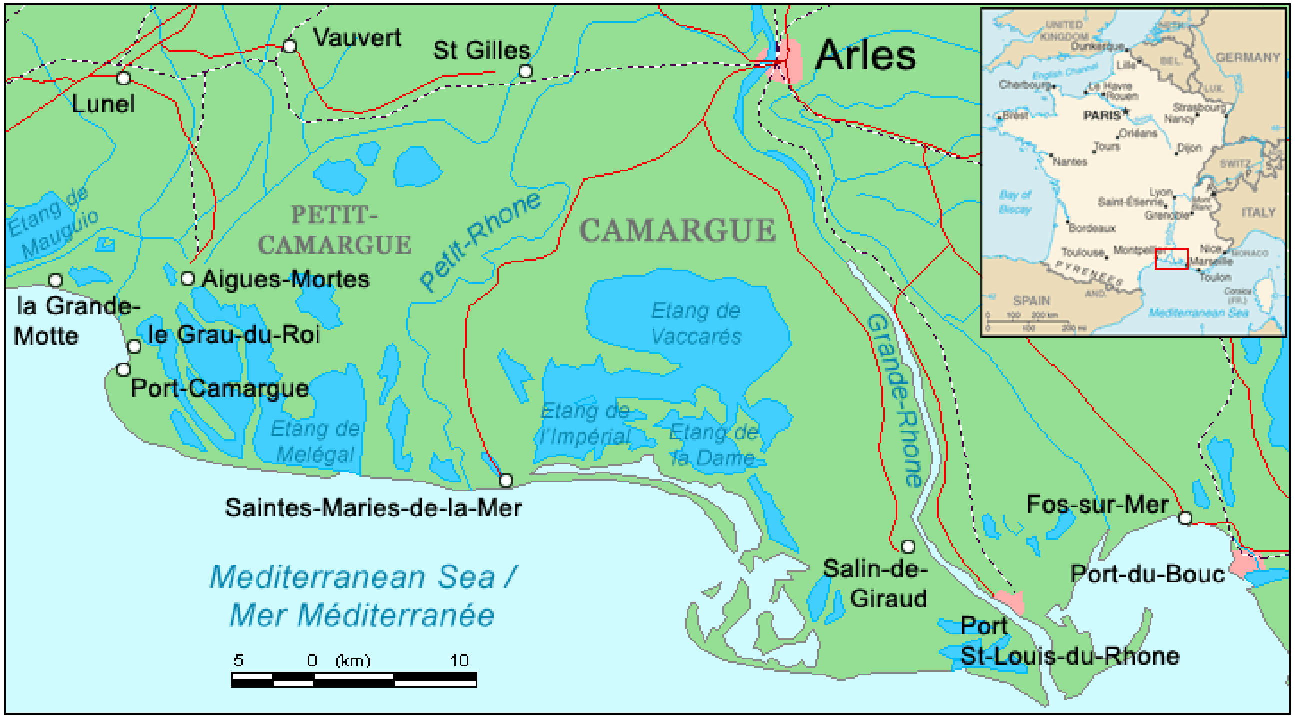
Coupling all processes in a population model



- R: recruitment
- U: undifferentiated
- YF: yellow females
- YM: yellow males
- SF: silver female
- SM: silver males

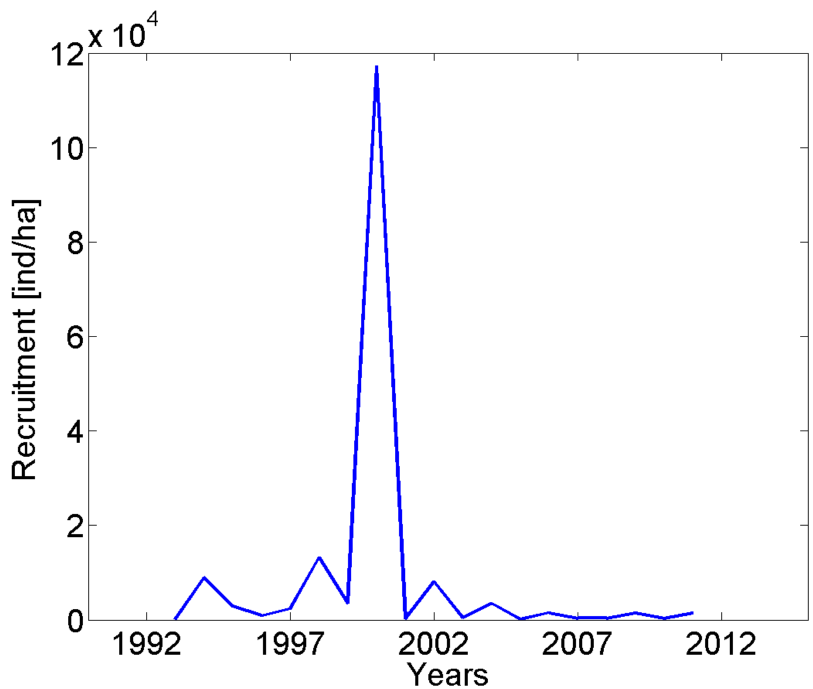
Case of study: a Camargue lagoon (Arles, Fr)

- Etang de Vaccares
  - Mediterranean area
  - 9200 ha
  - med salinity ~20g/l
  - 14°C
  - water exchange with the sea regulated by sluices
- Professional fisheries
  - 19 fishermen
  - known monthly effort
  - 6mm mesh size

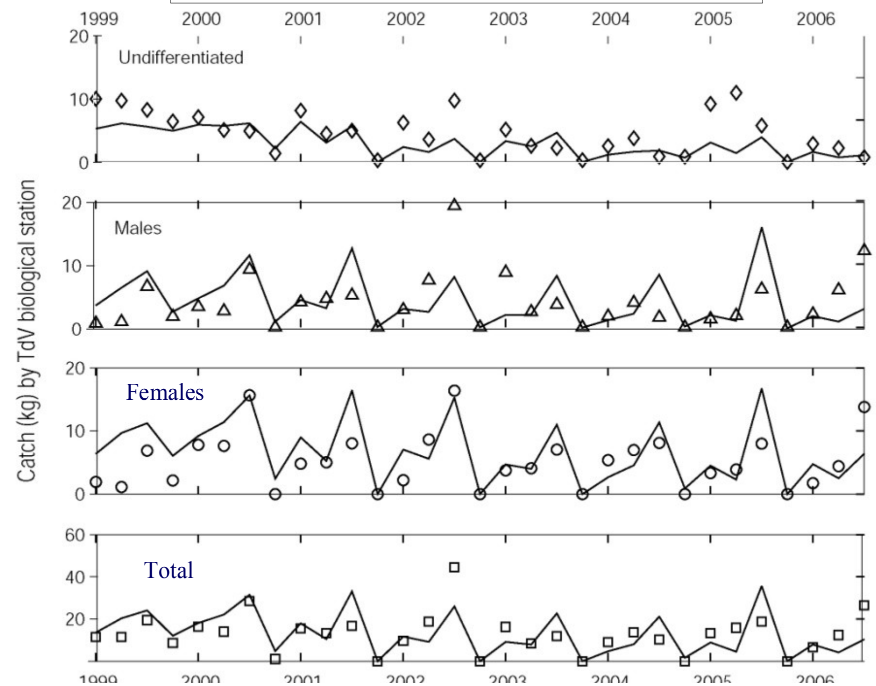


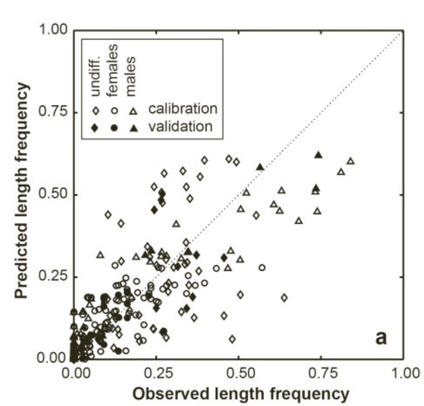
Calibrating the model

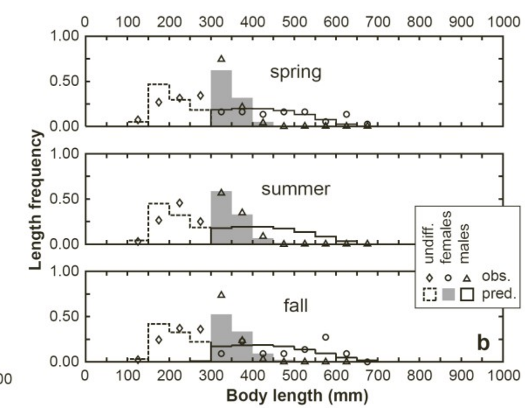
- Available data:
  - long time series of Recruitment (1993-2011)
  - monthly scientific catches (sex-ratio, length, maturation stage, structure)



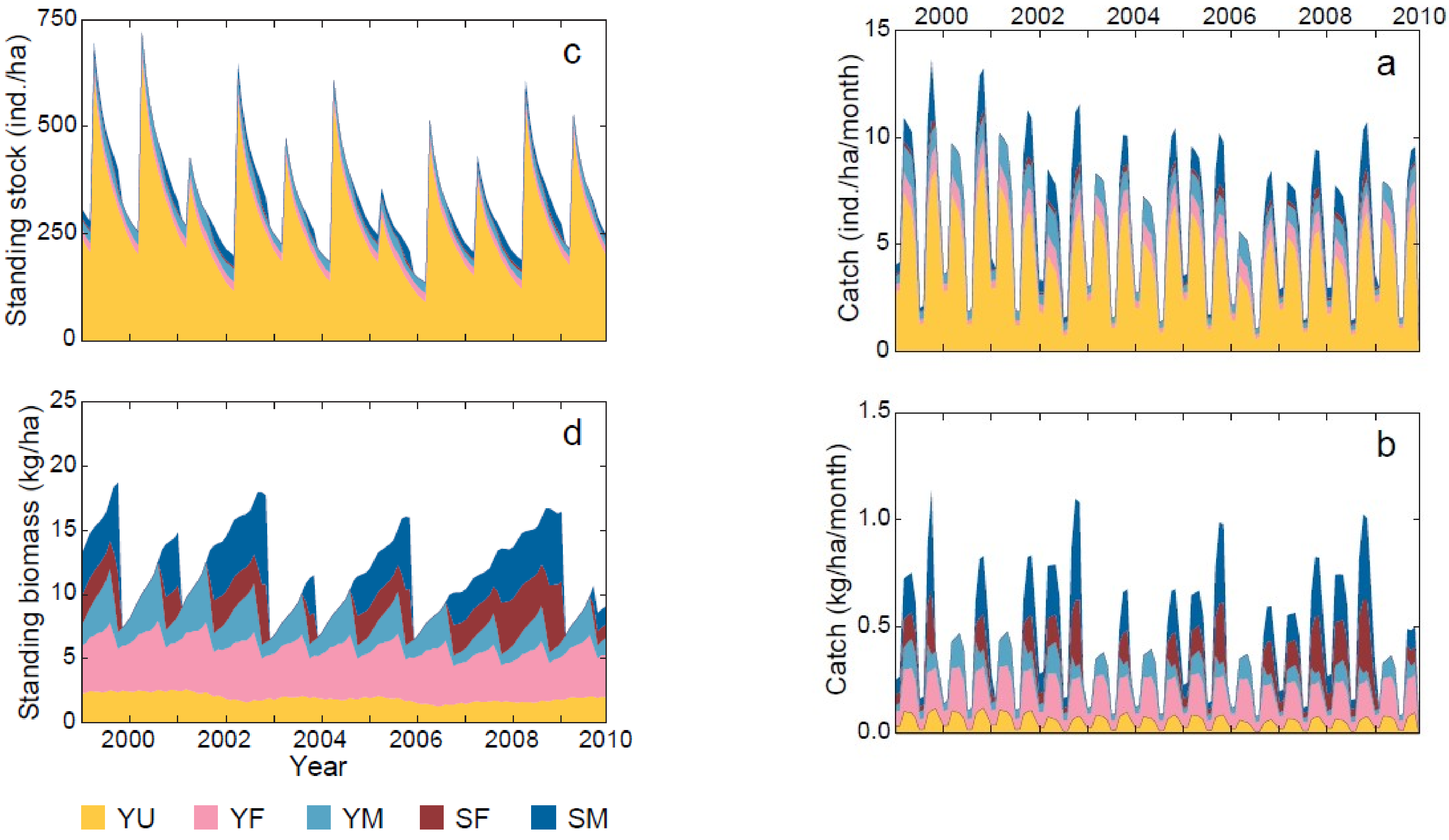
Estimating observed data







Results

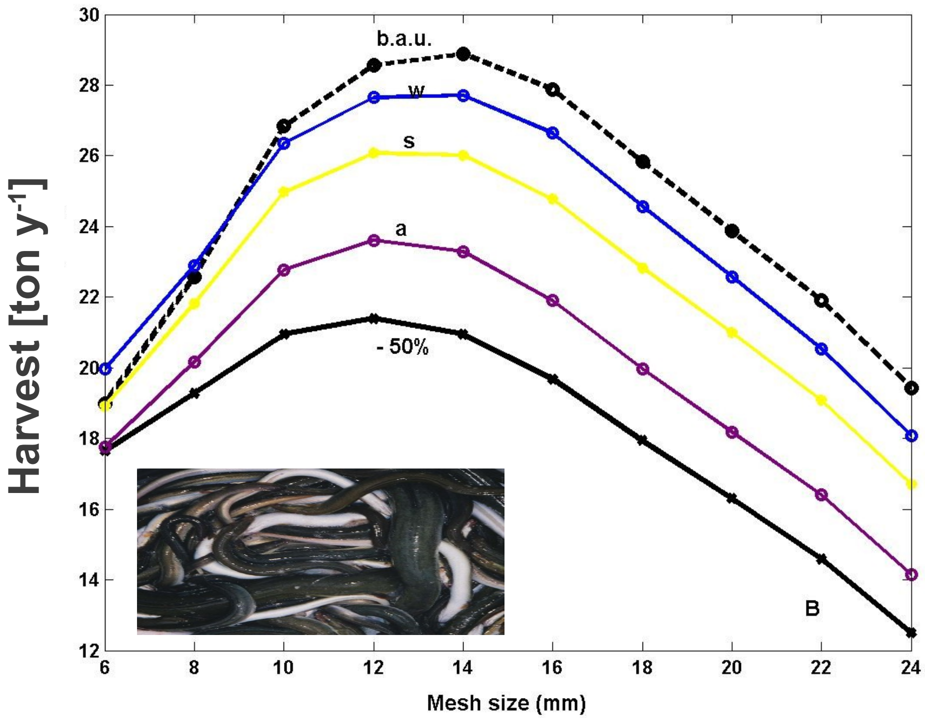


c
Standing stock (ind./ha)
0
250
500
750
d
Standing biomass (kg/ha)
0
5
10
15
20
25
2000
2002
2004
2006
2008
2010
Year
a
Catch (ind./ha/month)
0
5
10
15
b
Catch (kg/ha/month)
0.0
0.5
1.0
1.5
YU
YF
YM
SF
SM

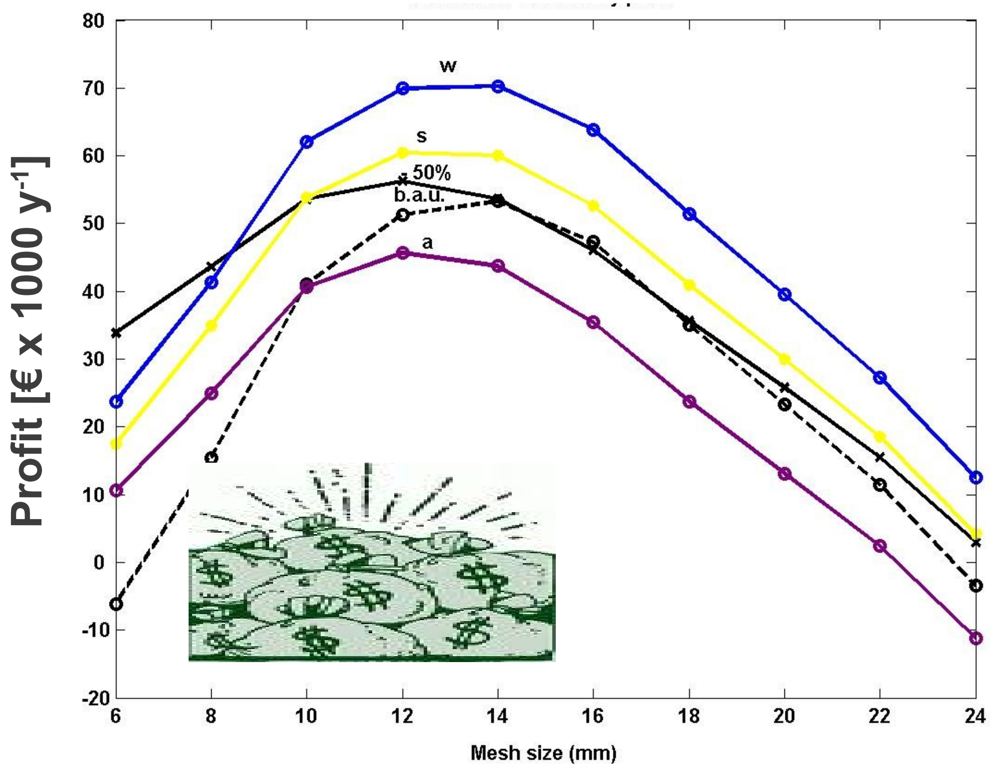
Management scenarios and bioeconomics implications

- With calibrated models is possible to compare different management scenarios comparing results not only for the escapement of silver eels but also for the catches or the fishermen profit

Harvest

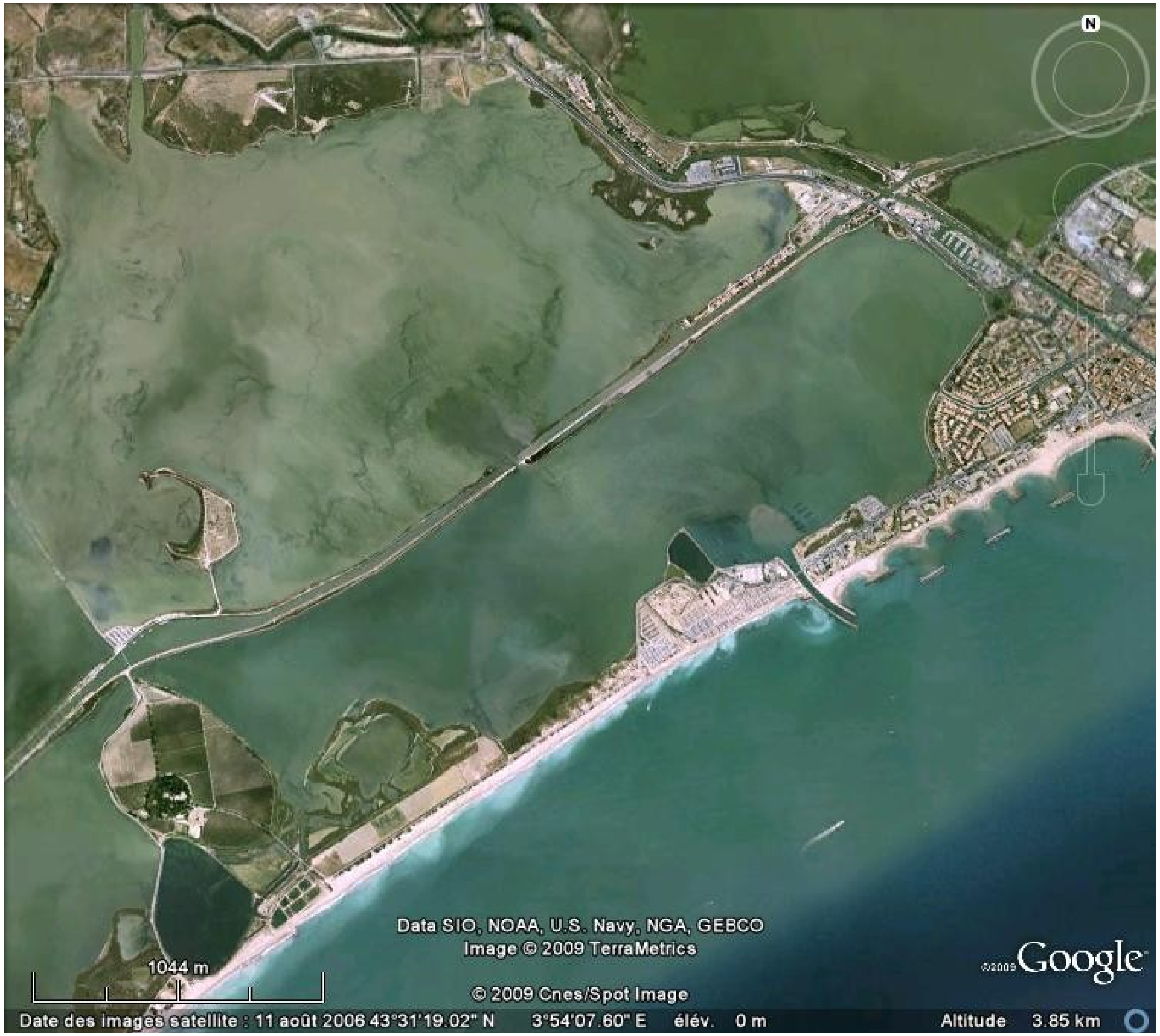


Profit



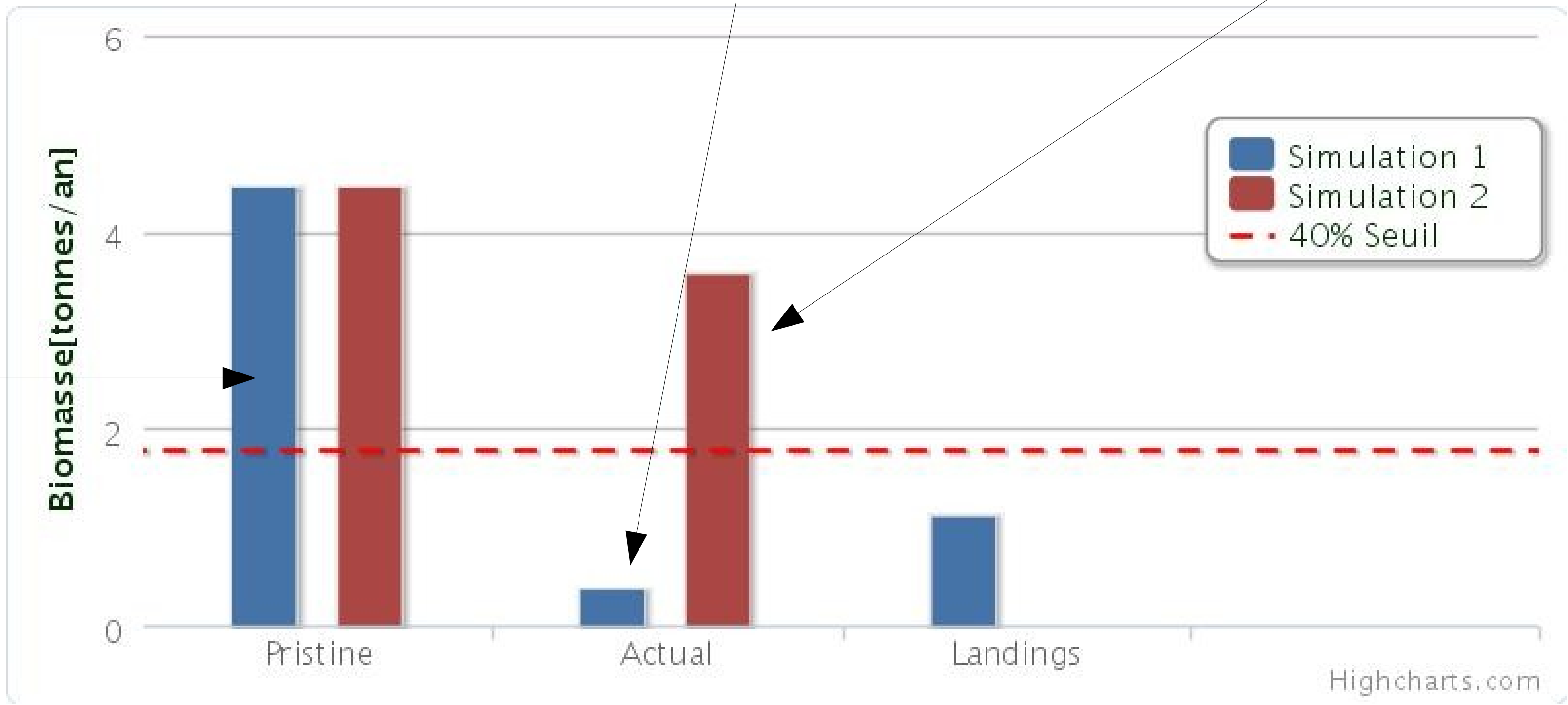
Case of study: Prévost lagoon

- Etang de Prévost
  - Private lagoon
  - Mediterranean area
  - 237 ha
  - high salinity ~32g/l
  - 14°C
  - No regulation of sea water exchange
- Professional fisheries
  - 1 fisherman
  - known monthly effort
  - 6mm mesh size



Preliminary results

- Pristine escapement of 4.5 tons/yr (18.8 kg/ha)
- Potential escapement of 3.6 tons/yr (15.1 kg/ha) [80% of pristine]
- Actual production of 0.4 tons/yr (1.9 kg/ha) [9% of pristine]
- Fisherman catches 1.1 tons/yr



Thanks for your attention