A user-friendly tool for the management of European eel fishery and conservation

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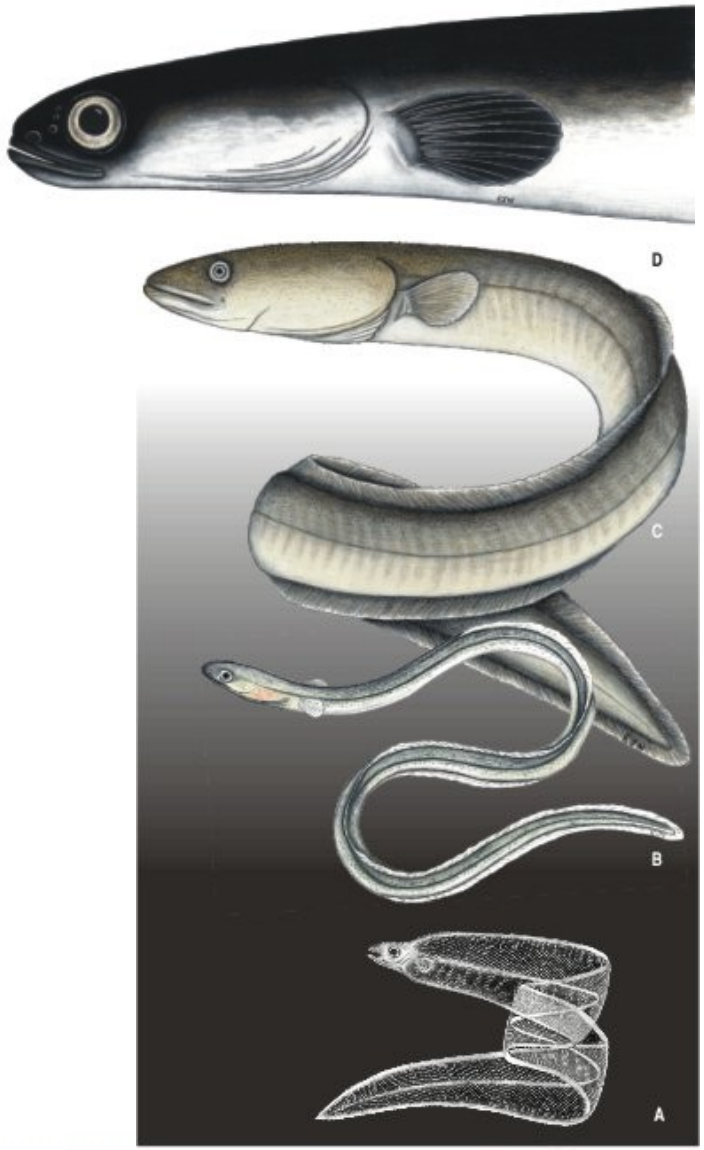
European eel life cycle

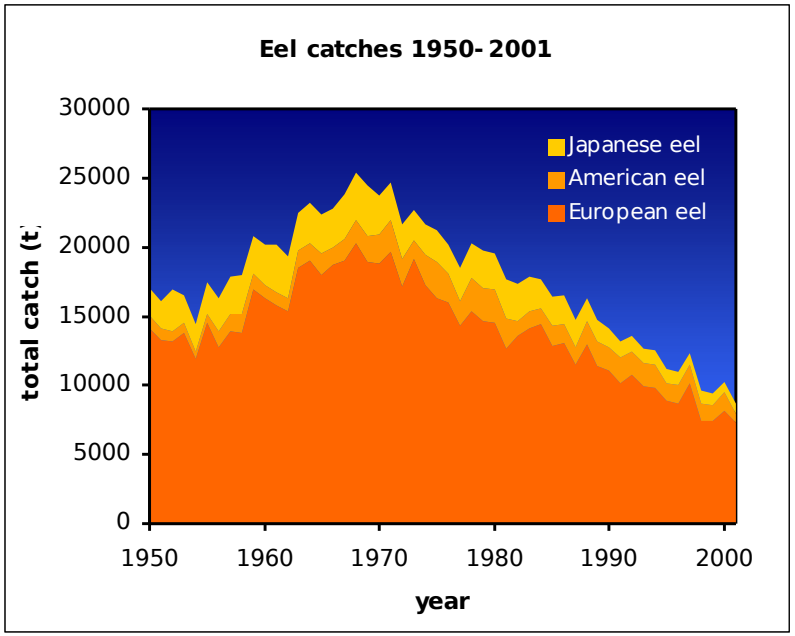
- A catadromous species:
  - larvae (a) hatch out in the Sargasso sea and migrate towards European shelves where they metamorphose into glass eels (b)
  - glass eels settle in brackish and fresh water bodies and become yellow eels (c)
  - mature eels metamorphose into silver eels (d) and undertake the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

- Peculiarity:
  - high growth plasticity
  - sexual dimorphism



European eel is out of safe biological limits

- Eel is worldwide suffering a dramatic decline
- European eel is listed in the IUCN Red List since the 2008 as critically endangered species:
  - catches are declining since the 70s
  - glass eel recruitment is 90% less than the historical benchmark
- Causes of the decline are still debated:
  - overfishing
  - parasite infection
  - habitat disruption
  - climate change
- **How is the recovery possible?**



source: FAOSTAT (2004)

Worldwide decline of eel resources necessitates immediate action
Québec Declaration of Concern

Ecology

Freshwater Eels Are Slip-Sliding Away

Eel populations worldwide are crashing; scientists don't know why precisely, and they can only guess at what it will take to save this beguiling fish

European Regulation EC 1100/2007

- Each EU Member State has to implement an Eel Management Plan (EMP) for each river basin
- Extensive measures for the recovery of the eel stock:
  - reduction of commercial and recreational fishing
  - restocking measures
  - structural measures to make rivers passable (by-pass or barriers removal)
- **Guarantee the 40% of pristine escapement for each EMP**
- Without EMP, forced 50% reduction of fishing effort

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doi:10.1038/news030929-1

News

World's eels on slippery slope

EU launches action plan to save threatened fish.

22.9.2007 EN Official Journal of the European Union L 248/17

COUNCIL REGULATION (EC) No 1100/2007
of 18 September 2007
establishing measures for the recovery of the stock of European eel

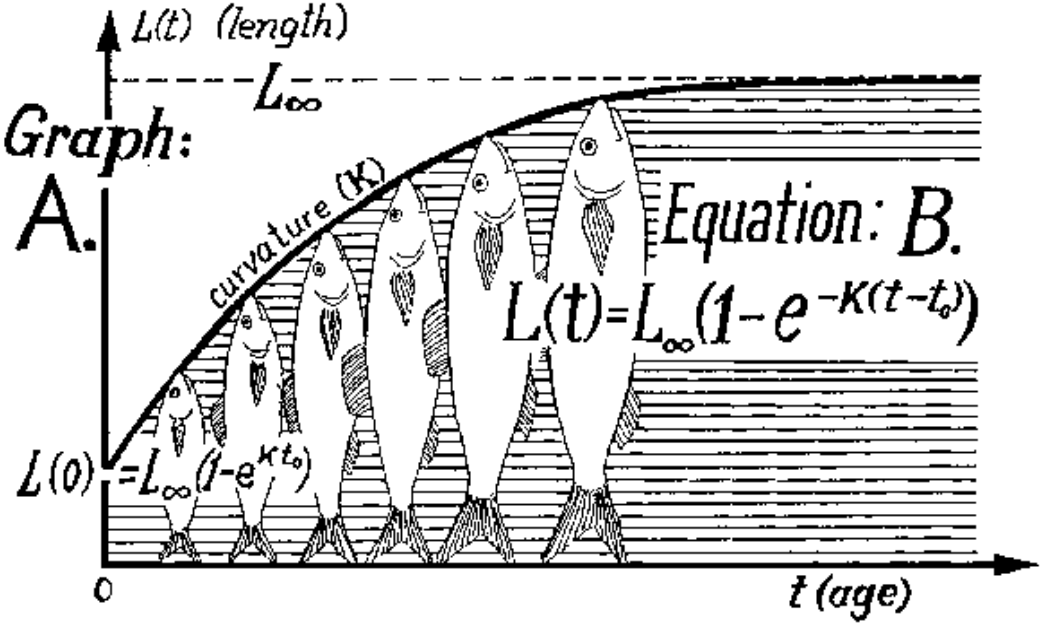
EMP's problems and effectiveness evaluation

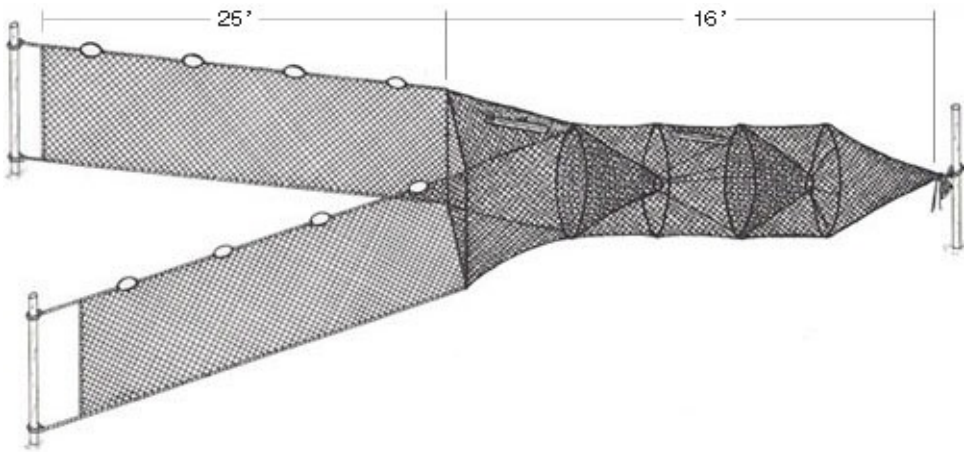
- Problems:
  - pristine escapement unknown
  - actual escapement predictable only through models
  - model implementation for each river basin

- There is a need to derive simulation tools to quantitatively and rigorously assess EMP and trade-off between conservation and fishermen's yield
  - simplified (user-friendly)
  - flexible
  - fast

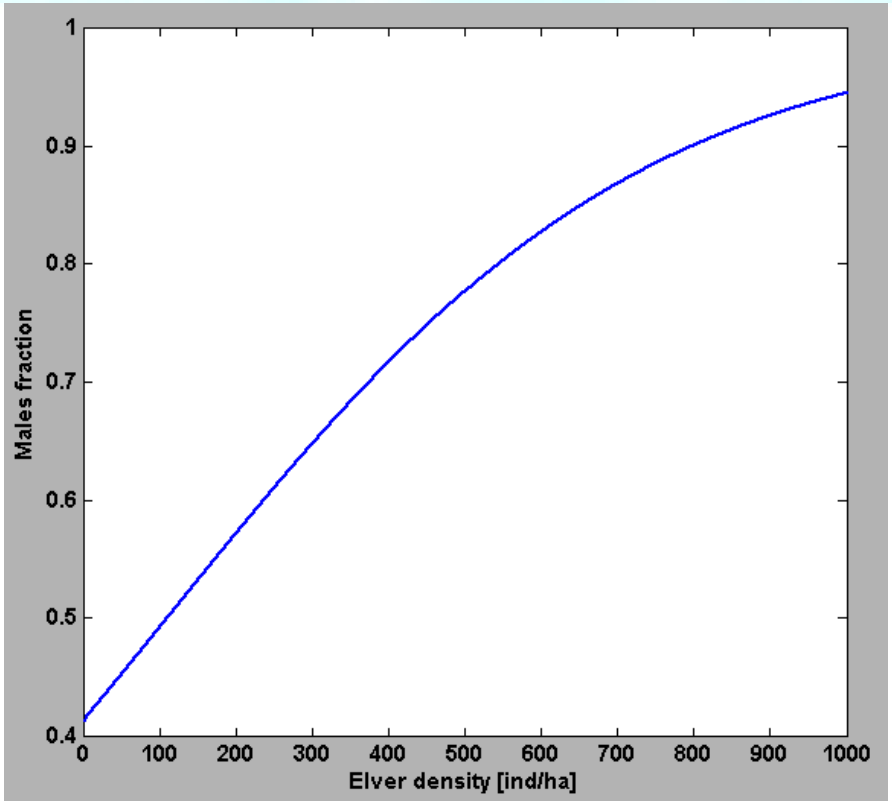
Model components

- Biological processes:
  - Recruitment/settlers relationship
  - Body growth
  - Natural mortality
  - Silvering
- Anthropic pressure:
  - Fishing mortality
  - Connection to the sea regulation
- Pristine conditions:
  - No fishing
  - Free connection to the sea
  - System at the carrying capacity

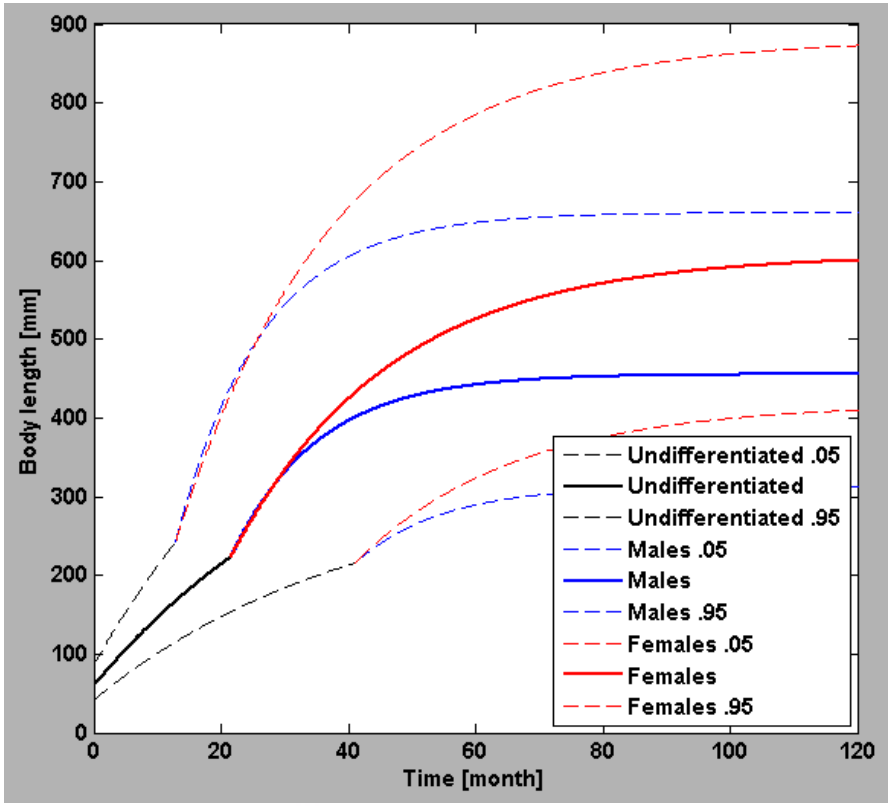




Model components

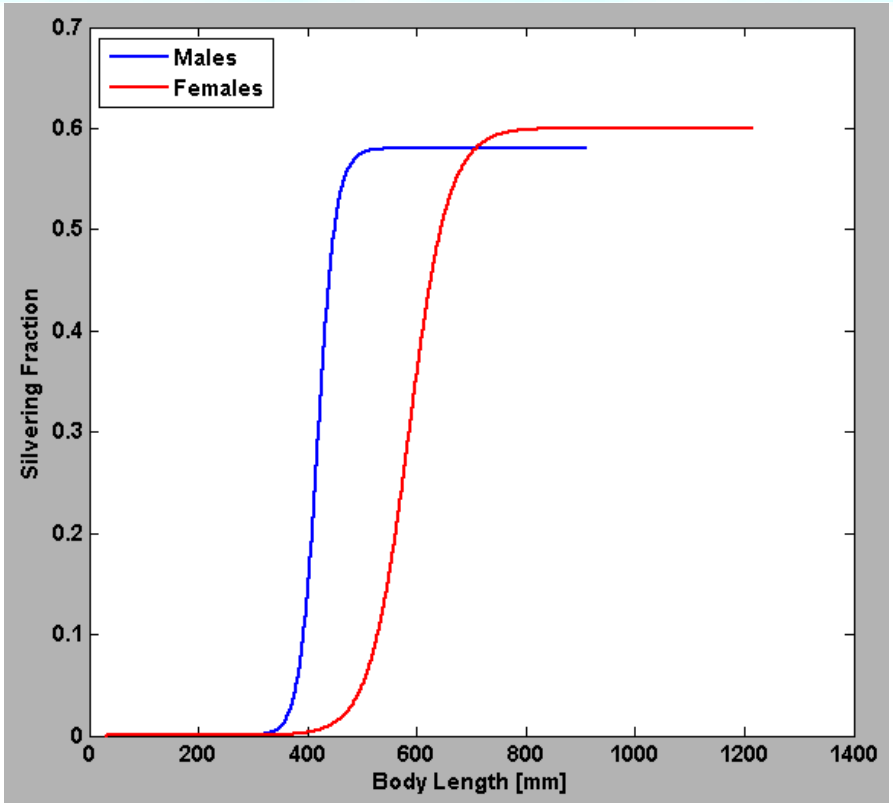


- Age-length structured model
- Density dependent settling (Bevacqua *et al*. *submitted*)
- Density dependent sex-ratio determination (Lambert & Rochard 2007, Schiavina *et al*. *in prep*)

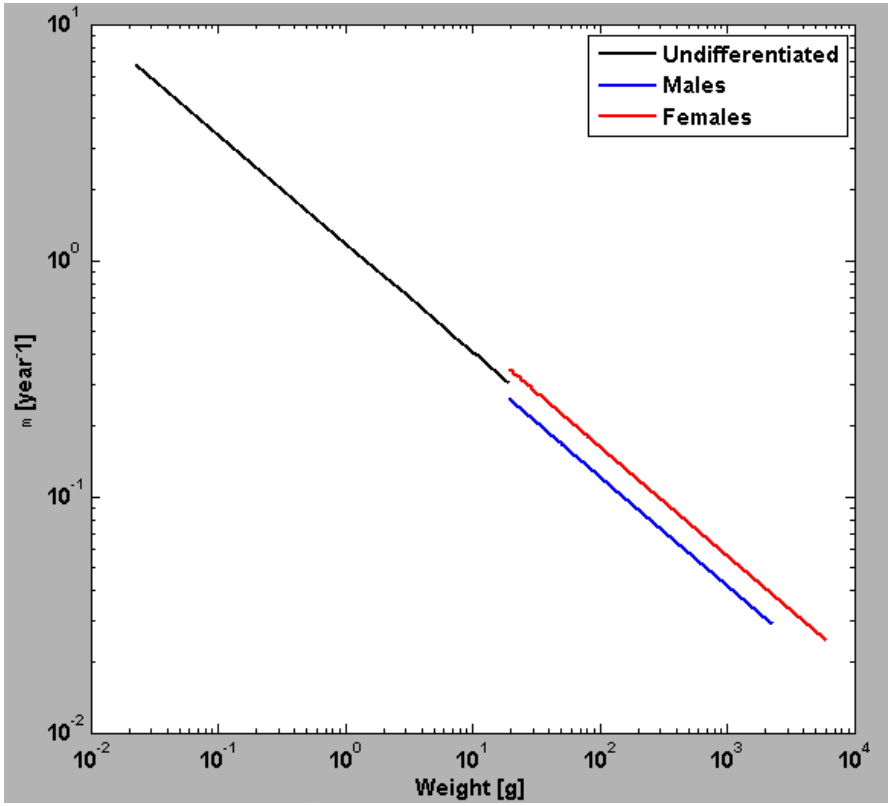


- Growth curve from Melià *et al.* (2006a)
  - growth plasticity taken into account with a log-normal distributed coefficient
  - different parameters for Mediterranean, Atlantic and Baltic (Andrello *et al.* 2011)

Model components



- Monthly silvering probability (Bevacqua *et al.* 2006)
- Body mass linked to the body length through an morphometric function (Melià *et al.* 2006a)



- Natural mortality function of the body mass and the water temperature (Bevacqua *et al.* 2011)
- Fishing mortality function of the effort, the mesh size (Bevacqua *et al.* 2009)

Software layout - www.eelmanagement.eu

Eel management software v1.0

The Eel management software (EMS) has been developed in order to provide a user-friendly tool to assess the effectiveness of management plans for the endangered European eel (Anguilla anguilla). This software allows evaluating both production (i.e. escapement to the sea) of silver eels and fishermen catches in a specific site, in different conditions as actual, pristine (i.e. uneffected by antropogenic impacts) and potential ones as required by the European Regulation EC 1100/2007. The flexibility of the tool allows the user to consider several environmental and management scenarios by defining the characteristics of the site, the exploitation level of the stock and the management plan constraints, and eventually comparing the results obtained under different scenarios.

Although the EMS is based on the most trustworthy and up-to-date knowledge about eel population dynamics, it is just an approximation of reality; therefore, the outputs of the model should not be considered reliable in absolute terms. In contrast, the great usefulness of this software is that it allows the user to compare the effects of different management actions, to evaluate the advantages or disadvantages (in terms of silver eels escapement and fishermen catches) of adopting different management policies and to assess the effectiveness of different management plans.

Site characteristics

Location and Surface

Location: Mediterranean / Atlantic EU / North EU

Area [ha]: 9200

Potential area [ha]: 9200

Salinity and Temperature

Mean annual salinity: River or Lake / Lagoon <10g/l / Lagoon 10-25g/l / Lagoon >25g/l

Mean annual water temperature [°C]: Default ☐ 14

Sea-water exchange

Connection to the sea: Free / Regulated

Recruitment

Recruitment level: Default

Eel biology

Set parameters: Advanced

Stock exploitation

Professional fishery

Professional fishery? No / Yes

Management plan

Enable EU management plan ☐

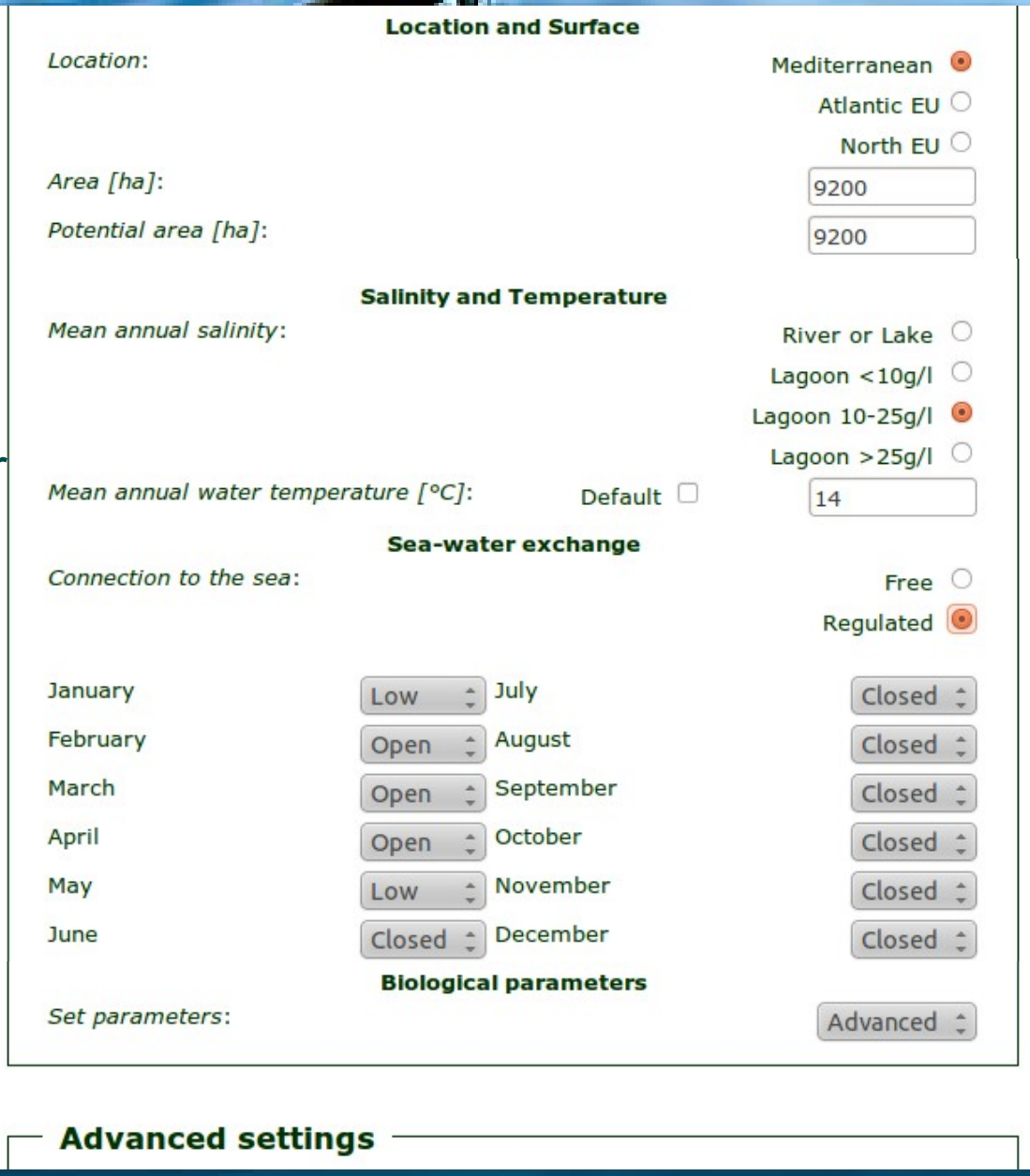
Run | Reset values | Reset session

Developed by:

Software inputs: characteristics of the area

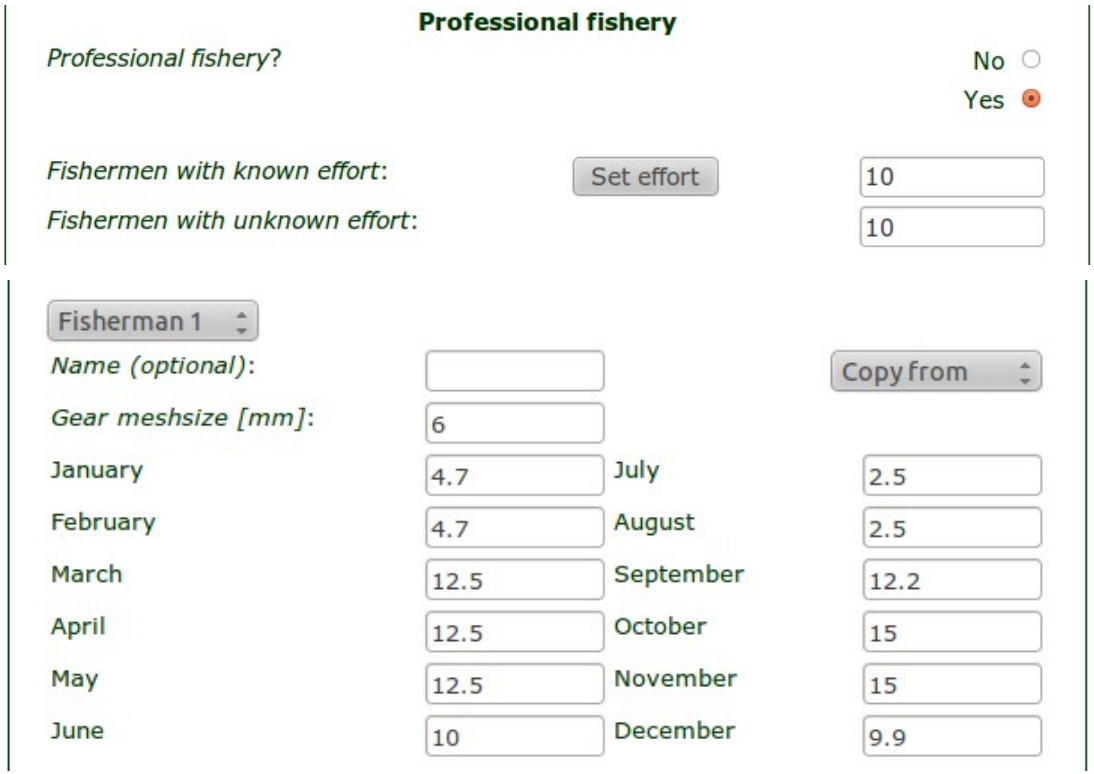
- Area characteristics
  - location (3 main areas)
  - surface of the watershed (ha)
  - salinity level
  - average annual temperature
  - monthly regulation of the water exchange with the sea

- Advanced users can modify biological parameters (not yet implemented)
  - recruitment (kg/ha)
  - biological parameters



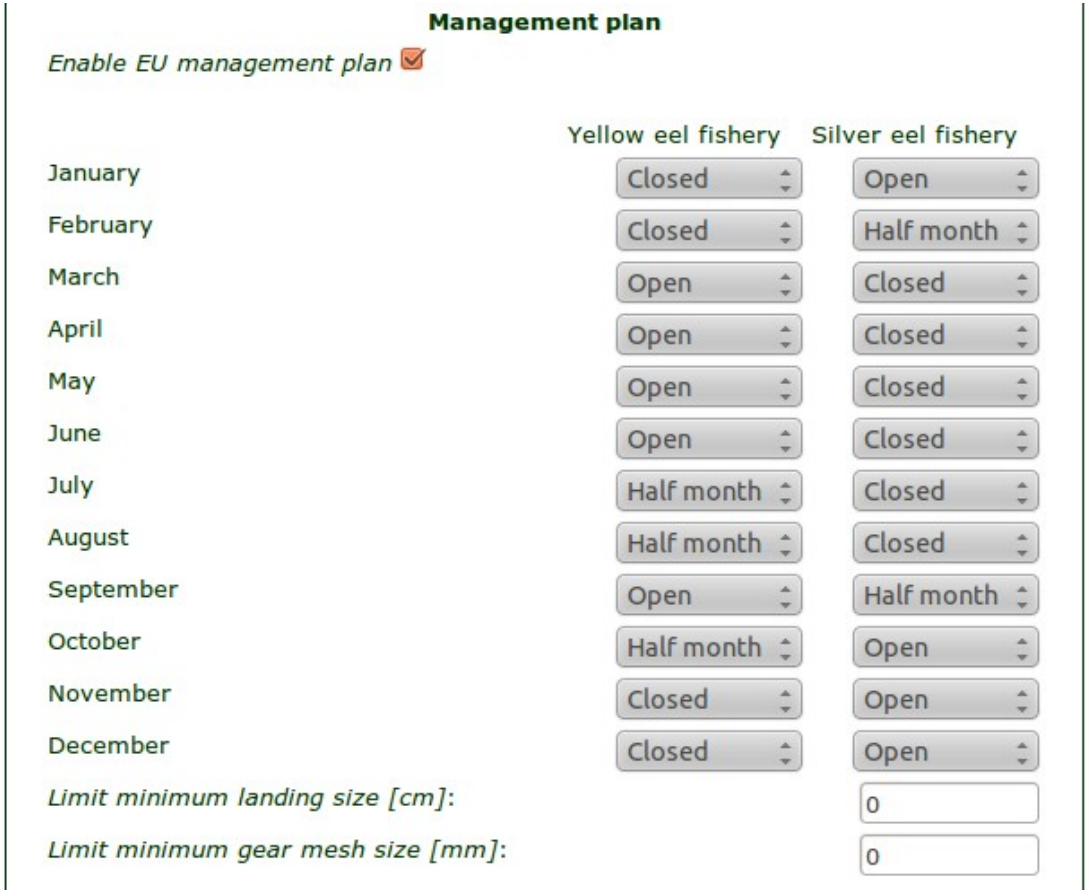
Software inputs: fishery and EMP

- Fishery:
  - number of fishermen with know effort:
    - mesh size (mm)
    - average number of nets used in a day during the month
  - number fishermen with unknown effort:
    - mesh size of 10mm
    - default effort



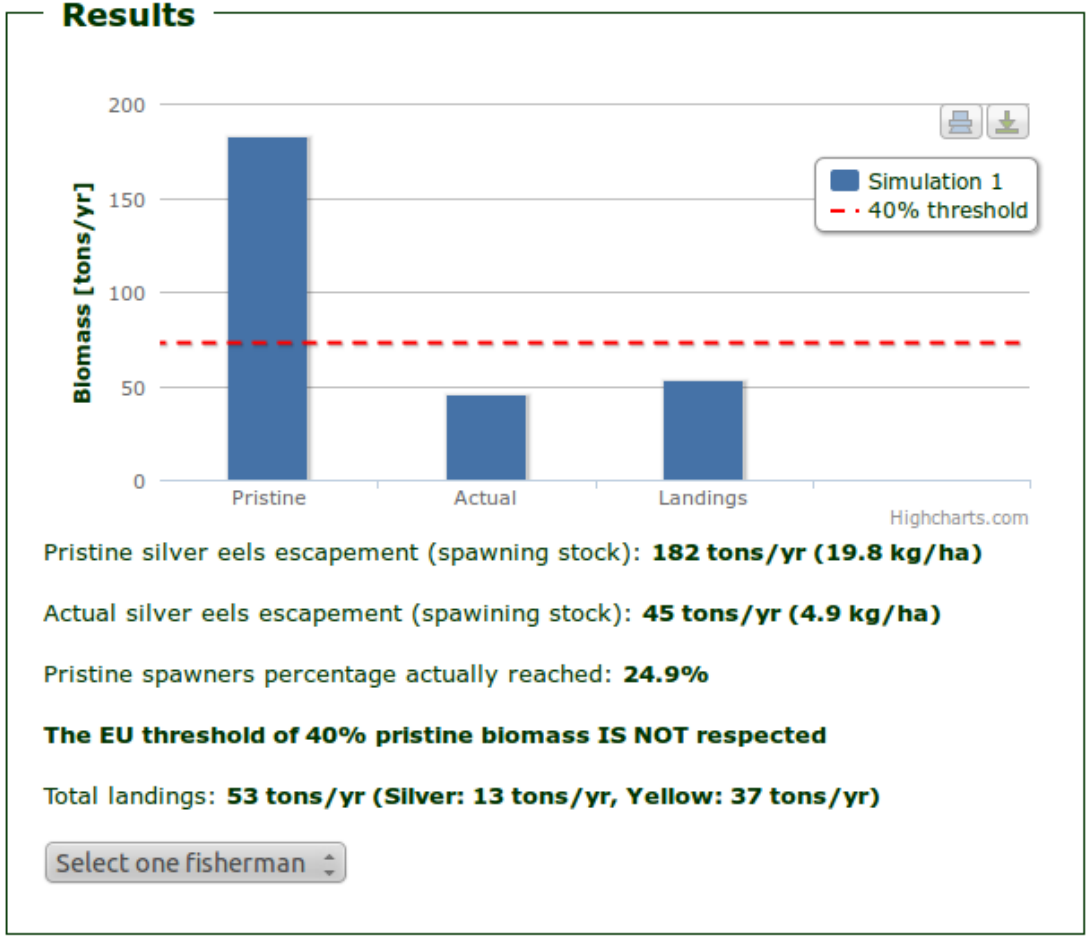
Software inputs: fishery and EMP

- Management plan definition:
  - yellow eels fishery allowed or not
  - silver eels fishery allowed or not
  - limit of the minimum marketable body length
  - limit of the minimum fishing-gear mesh size



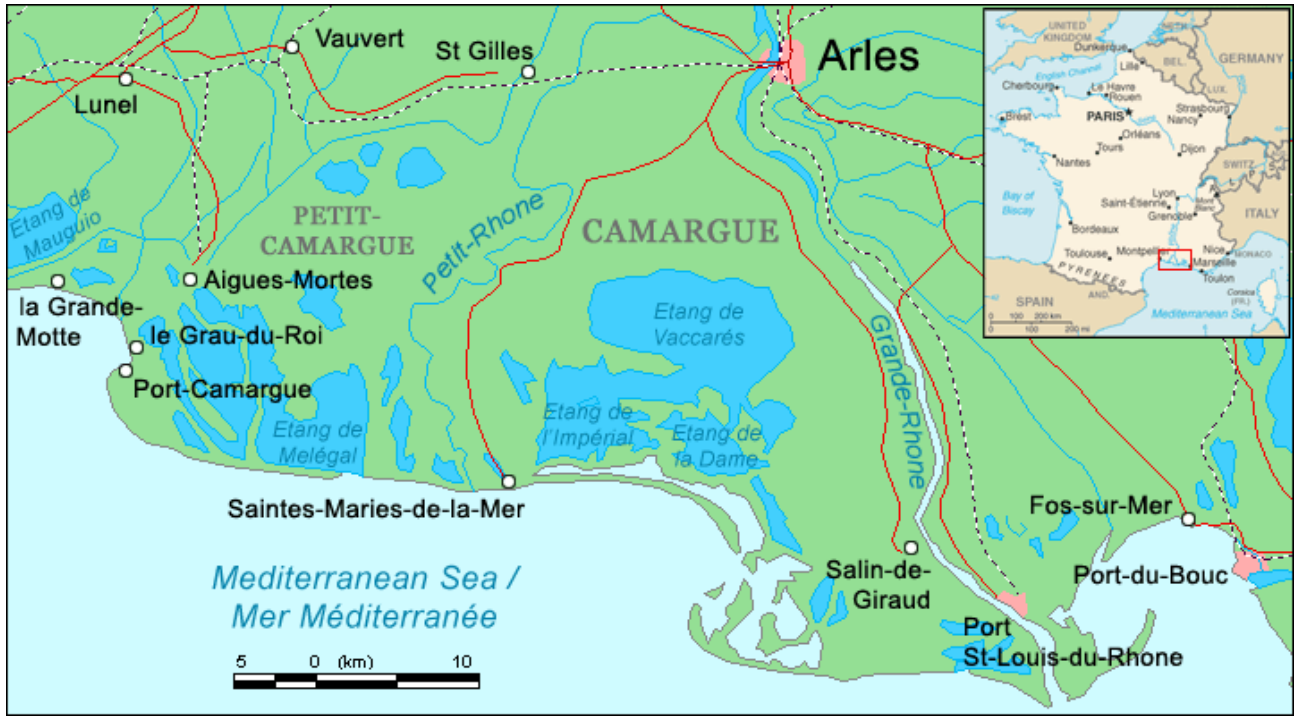
Software output

- Effectiveness of EMP
  - pristine theoretical escapement of biomass and relative 40% (red dotted line)
  - actual escapement of biomass and respect of the threshold
- Fishermen harvest
  - Silver eel and yellow eel biomass harvested by the whole fishery and details for each fisherman
- Graphical and numerical comparison between scenarios



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
- French EMP
  - yellow eels from 1/3 to 15/7 and from 15/8 to 31/12
  - silver eels from 15/9 to 15/2

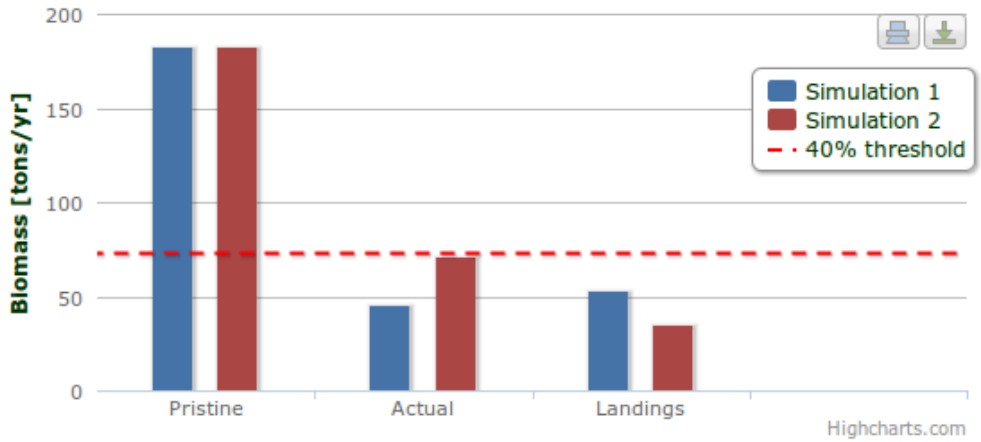


Actual situation

- Pristine conditions
  - silver eels escapement ~182ton (~20kg/ha)
- Before the application of the French EMP
  - fishery harvest ~53 ton
  - silver eels escapement ~45ton
  - actual/pristine 24.9% (26%)
- After the application of the EMP
  - fishery harvest ~35 ton
  - silver eels escapement ~71ton
  - actual/pristine 39.1% (41%)

- **The threshold of 40% imposed by the EU is not respected!**

Results



Pristine silver eels escapement (spawning stock): **182 tons/yr (19.8 kg/ha)**
[182 tons/yr (19.8 kg/ha)]

Actual silver eels escapement (spawining stock): **71 tons/yr (7.8 kg/ha)**
[45 tons/yr (4.9 kg/ha)]

Pristine spawners percentage actually reached: **39.1%**
[24.9%]

The EU threshold of 40% pristine biomass IS NOT respected
[The EU threshold of 40% pristine biomass IS NOT respected]

Total landings: **35 tons/yr (Silver: 2 tons/yr, Yellow: 30 tons/yr)**
[53 tons/yr (Silver: 13 tons/yr, Yellow: 37 tons/yr)]

Simulation 1