

VIRTUAL EXPERIMENTATION AS A COMPLEMENT TO OBSERVATION

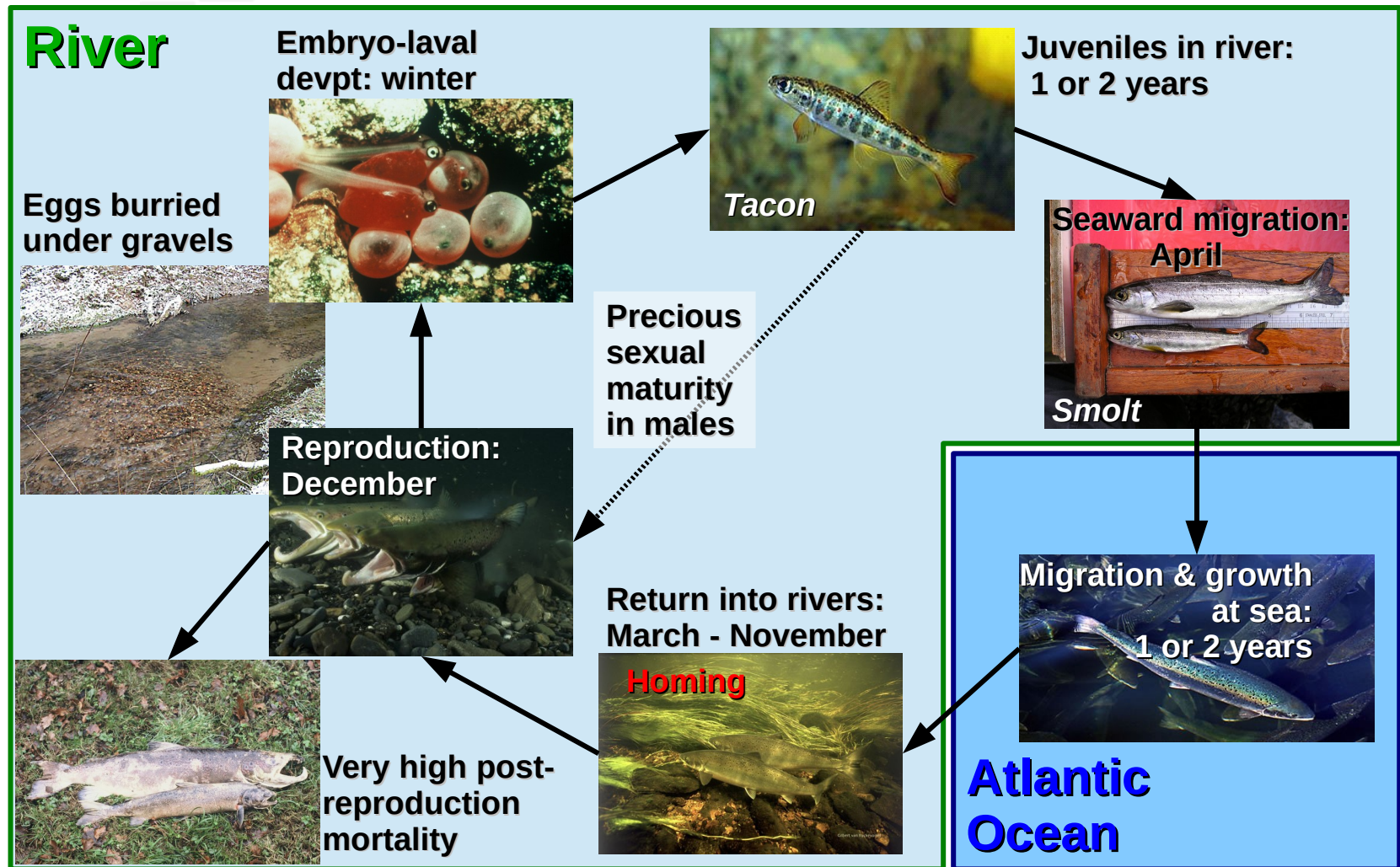
APPLICATION TO THE ASSESSMENT OF THE FUTURE AND POTENTIAL FOR ADAPTATION OF ATLANTIC SALMON FACING CLIMATE CHANGE IN SOUTHERN EUROPE

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Atlantic salmon life cycle



Climate Change : an additional stress in Southern Europe

- Salmon: a poikilotherm and cold water species
- France (& Spain): southern edge of species distribution
 - *Salmon could be strongly impacted by CC in Southern Europe*
- Salmon is an emblematic and threatened species
 - *Strong demand from society and management bodies for assessing the future and potential adaptation of salmon to CC*



Original pic from <http://www.wiseass.org/>

How to assess future CC effects on A. salmon at the population scale ?

- Real world experiment: impossible
- In silico experiments with virtual population: an alternative option
 - Test diverse CC scenarios
 - Replication of experiments under a given CC scenario
 - Complementary to broad-scale approaches such as niche modelling that ignore behavioural and evolutionary processes
- INRA has developed a salmon population simulator for virtual experimentation of CC: IBASAM (Individual Based Atlantic Salmon Model)
Piou & Prévost, 2012. Ecological Modelling, 231: 37-52



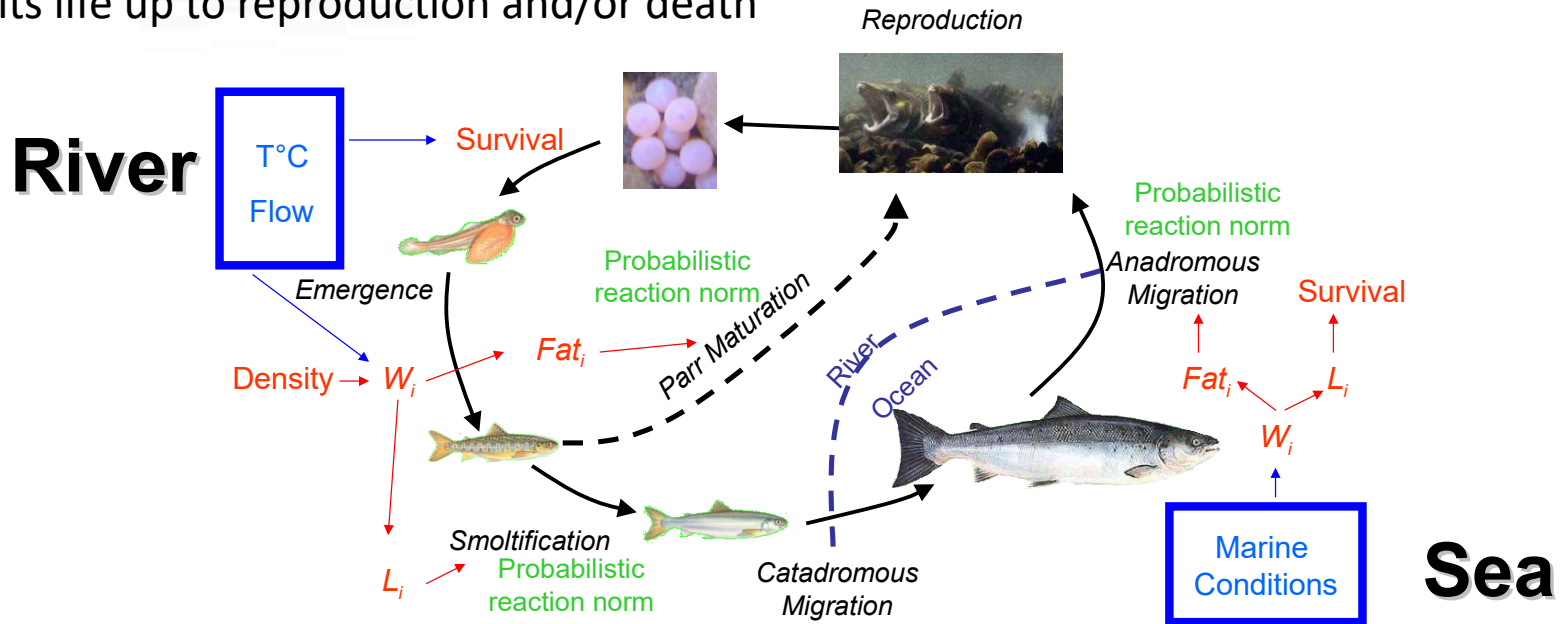
IBASAM : population simulator for the study of CC effects on Atlantic salmon

- Mimics a small population typical of french coastal streams
- CC is multiform
 - In rivers:
 - ↗ water T°
 - ↗ variability of flow
 - ...
 - At sea:
 - ↘ conditions for growth
 - ...
- Connect demo-genetic dynamics with riverine (T°, flow) and marine factors (conditions for growth)



IBASAM

- Every individual of a population is explicitly represented and followed through its life up to reproduction and/or death



- Summarizes and articulates available knowledge on demo-evolutionary processes in A. salmon
 - Emphasis on the plasticity of the species: individuals adjust phenotype to yearly environmental variations
 - Explicitly represents individual genetic variability which control plasticity mechanisms
 - Accounts for environmental and demographic stochasticity in population dynamics
 - Explicitly represents the link between climate related forcing factors and individuals
- Calibrated against 15 years series of real population databases (Scorff river, Brittany, France)

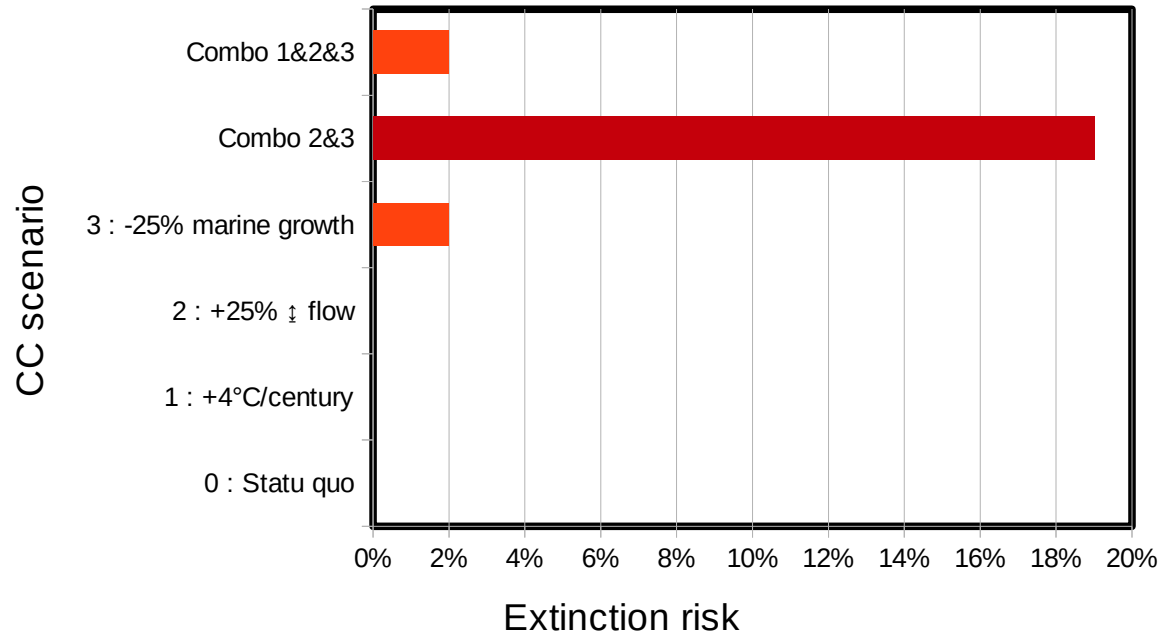
First virtual experiments of CC with IBASAM

Combining riverine and marine changes

- 27 CC scenarios tested
 - ↗ river water T° (3 modalities)
 - ↗ river flow variability (3 modalities)
 - ↘ conditions for growth (3 modalities)
- Time horizon: 3 decades (~2045)
- 300 replicates per scenario
 - Initial size ~215 adults returning from the sea
→ small population



Potential CC effect on salmon population persistence



- Apart from worst case scenario, extinction risk is low at the 2045 horizon
- From the scenarios tested:
 - Marine conditions have the strongest effect
 - Synergetic effect of flow variability with marine conditions
 - \nearrow river water T° mitigates the effect of the other 2 factors

First virtual experiments with IBASAM

CC & selective exploitation

- Selective exploitation is commonplace in salmon
 - Larger adults (maturing after 2 years at sea) are selectively harvested compared to smaller ones (maturing after 1 year at sea)
- CC and selective exploitation occur simultaneously → How to compare their respective effects while assessing their interactions?
- A virtual experimentation plan:
 - 5 CC scenarios X 5 exploitation scenarios
 - CC → only \searrow conditions for growth (main driver of CC effects)
 - Time horizon: 3 decades (~2045)
 - 30 replicates per scenario

CC vs selective exploitation

Phenotypic plasticity vs genetic evolution

CC only

↘ 25% growth at sea

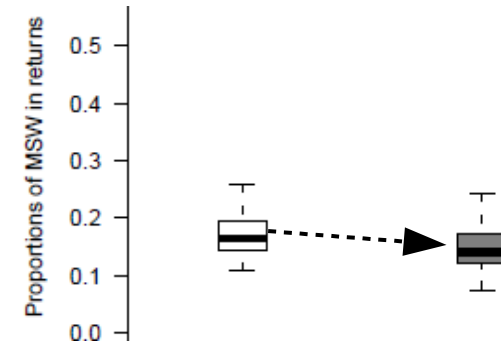
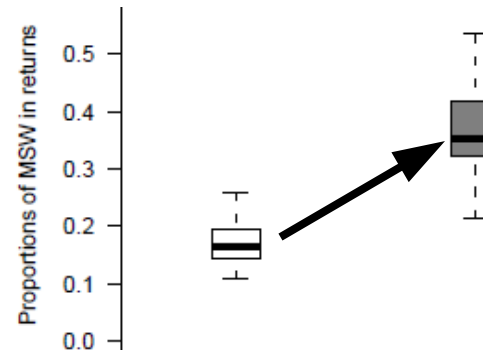
Selective fishing only

15% expl. rate 1 year at sea

↗ expl. rate 2 years at sea 15→75%

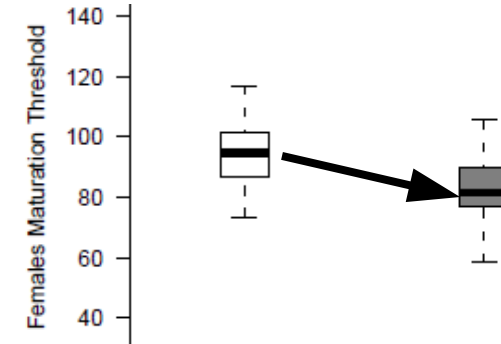
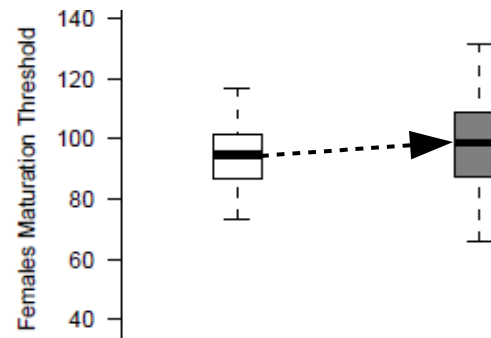
Phenotype

Prop. 2 years at sea



Genotype

Genetic threshold
triggering sexual
maturation in females



***Mostly plastic response
Little genetic evolution***

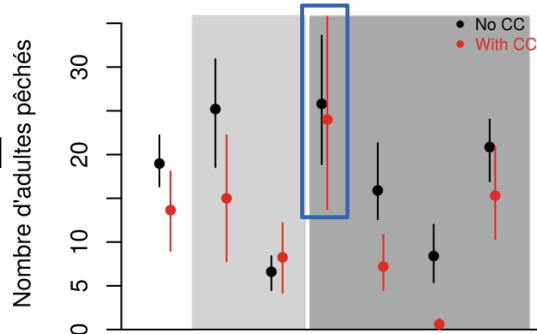
Stronger genetic evolution

Selective exploitation *for* adaptation to CC

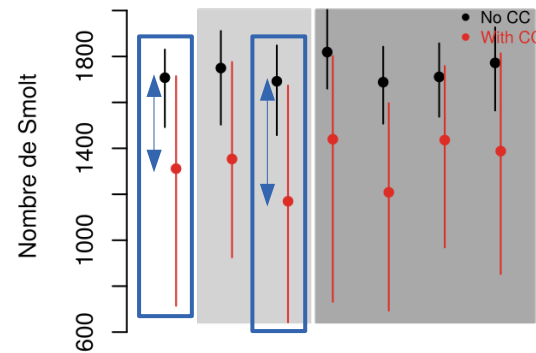
- Exploitation is an evolutionary force: could it be used on purpose to foster adaptation ?
 - SALMOCLIM Project (INRA funded)
- Virtual experimental design:
1 CC scenario X 6 selective exploitation scenarios
 - CC at sea and in river (strong)
 - Time horizon: 3 décades (~2045)
 - 100 replicates par scenario
- New version of IBASAM: includes genetic heritability of growth and a survival/growth trade-off

Selective exploitation for adaptation to CC

A) Exploitation

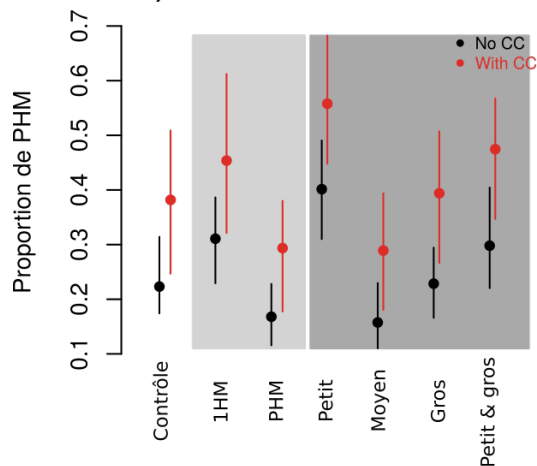


B) Démographie

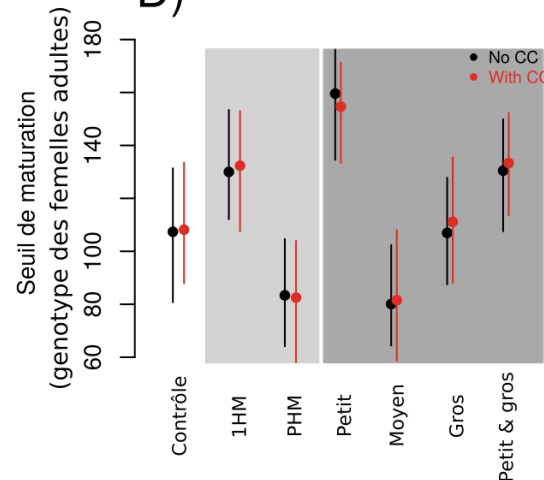


CC → ↓ pop size
→ ↑ variability
Selective expl.:
No gain
↑ increased gap
if fishing targets
MSW fish

C) Phenotype



D) Genotype



No genetic
evolution

CC → ↓ catch
Selective expl.:
Catch maintained
if fishing targets
small fish

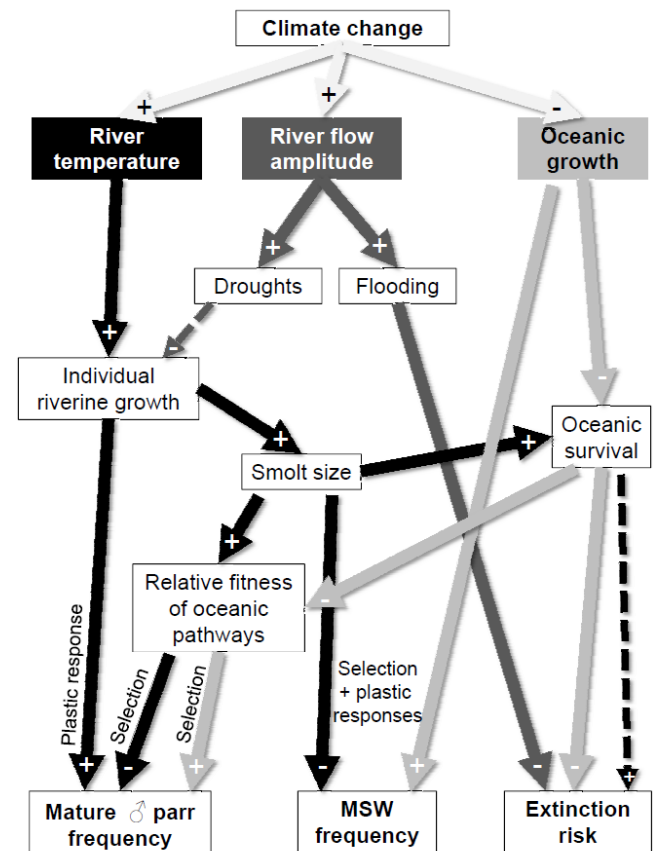
CC → ↑ % MSW

Stratégies d'exploitation

Stratégies d'exploitation

Demo-genetic simulation: a tool for making scientific progress

- Demo-genetic simulation: a powerful approach to explore CC consequences on A. salmon populations
 - No substitute for assessing the outcome of an unprecedented climatic future at scales which prevent real world experimentation
- CC consequences cannot be appraised by mere intuition
 - The effects of CC are mediated by a complex array of interacting biological traits which outcome is the resultant of contradictory forces
- IBASAM:
 - a tool for better understanding of these interactions
 - A tool for management advice ? → Be patient and very cautious



Demo-genetic simulation for assessing adaption of A. salmon to CC


Where are we? Where to go?

- It is just the beginning → field of active research but still scientifically immature
- Lack of understanding → any prediction is currently surrounded by (too) broad uncertainty (to be useful)
 - Acknowledge Science has still little to say to advise managers
→ despite strong demand for answers science must be cautious not to oversell preliminary results
- Not at the edge of population extinctions even in Southern Europe → must take advantage of the next two decades to improve :
 - Understanding of CC effects on A. salmon with IBASAM: considerable room for improvement
 - Improving realism of genetics of plastic traits → age at maturity reaction norm
 - Interacting populations → metapopulations
 - Scientific advice to A. salmon population management
 - Conceive management options that are robust to uncertainties
 - Exploring consequences of portfolio effects

First virtual experiments with IBASAM

What have we learned ?

- Some qualitative (not quantitative) results :
 - Complexity of interactions network → unexpected and non-intuitive outcomes
 - e.g. first results on population viability
 - CC may have strong/rapid demographic and phenotypic effects with (too?) little/slow genetic evolution
 - Selective exploitation :
 - might not be a way to foster adaptation
 - may well worsen CC effects



Thanks for your attention