

ASSESSING THE FUTURE AND POTENTIAL FOR ADAPTATION OF ATLANTIC SALMON FACING CLIMATE CHANGE IN SOUTHERN EUROPE

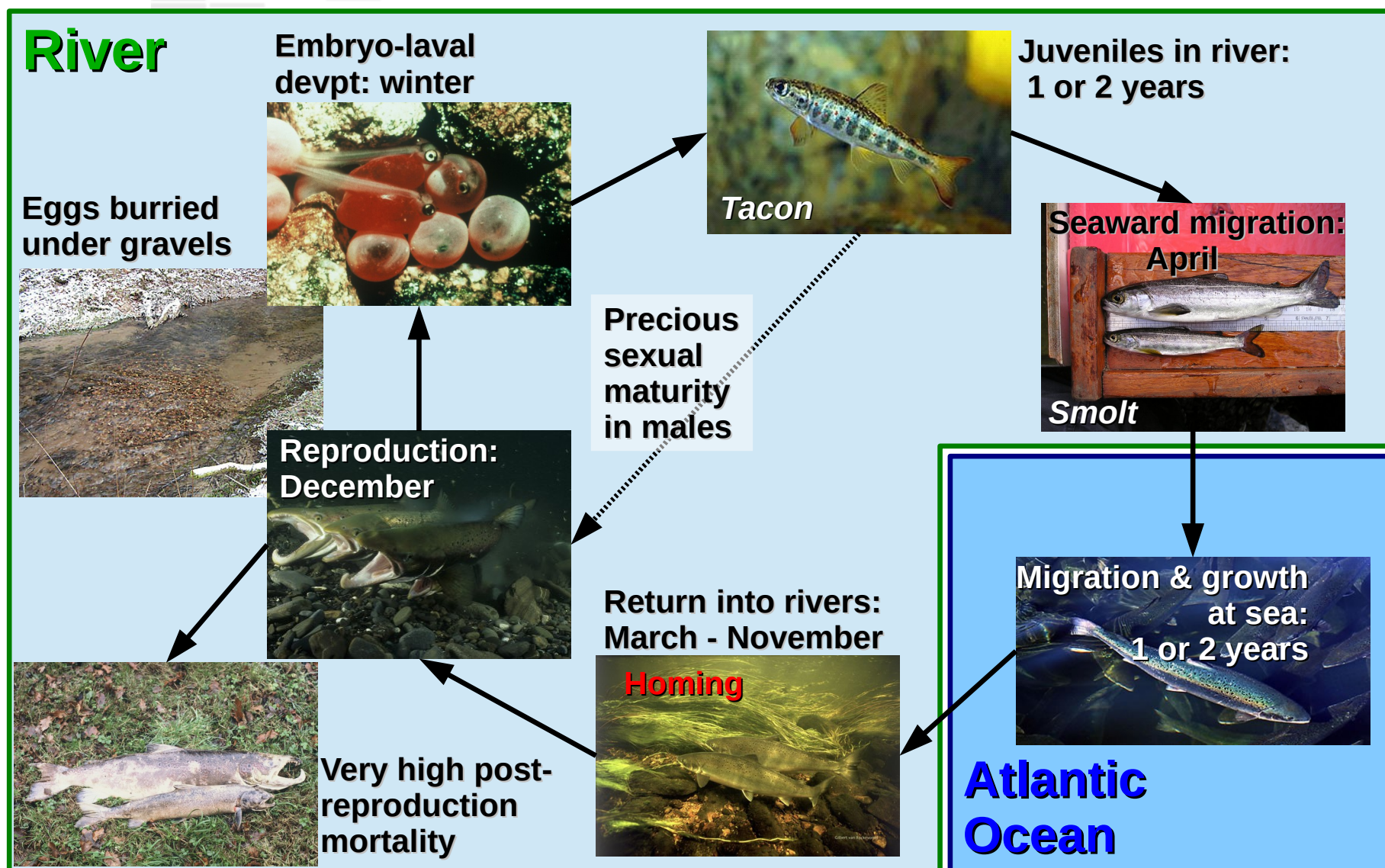
Etienne Prévost¹, Cyril Piou^{1,2}, Julien Papaix^{1,3}

1 INRA, UMR INRA/UPPA Ecobiop, Saint-Pée-sur-Nivelle, France

2 CIRAD, Département BIOS, UMR CBGP, Montpellier, France

3 CNRS, CEFE, Montpellier, France

Atlantic salmon biological cycle



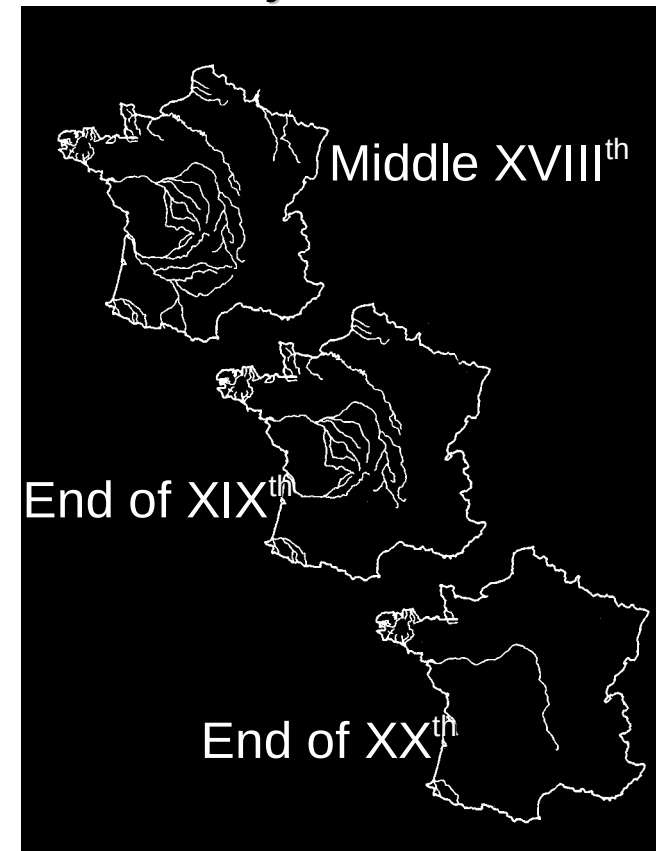
1 river -> (at least) 1 population: over 2000 populations in Europe

A natural heritage affected by human activities

- Damming → river fragmentation: main cause of population extinctions
- Physical & chemical pollution of waters
- Fisheries exploitation
→ *Salmon listed as threatened by EU Habitat Directive*



Evolution of the streams colonized by salmon in France



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 in front of CC*



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

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

- Real world experiment: impossible
- In silico experiments with virtual population: the only 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



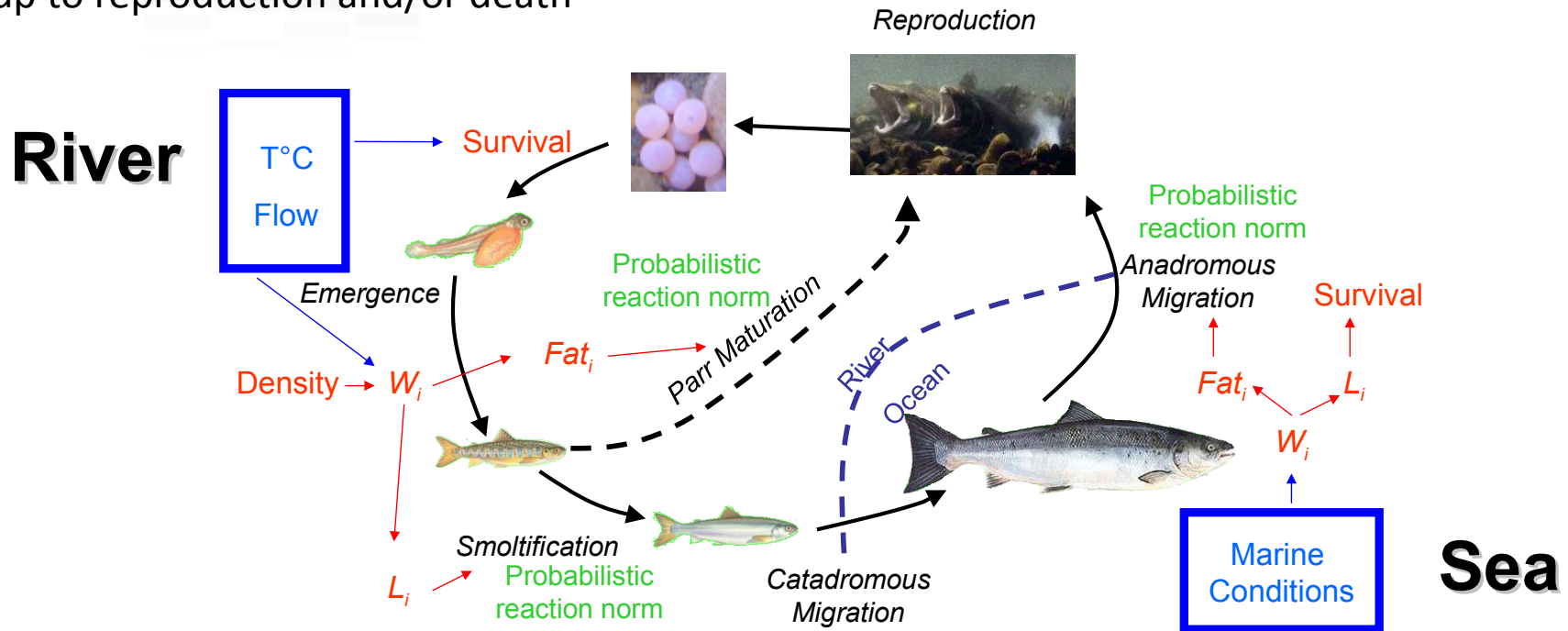
IBASAM

- 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 in the control of the plasticity mechanisms
 - Accounts for environmental and demographic stochasticity in population dynamics
- Calibrated against 15 years series of real population databases (Scorff river, Brittany, France)

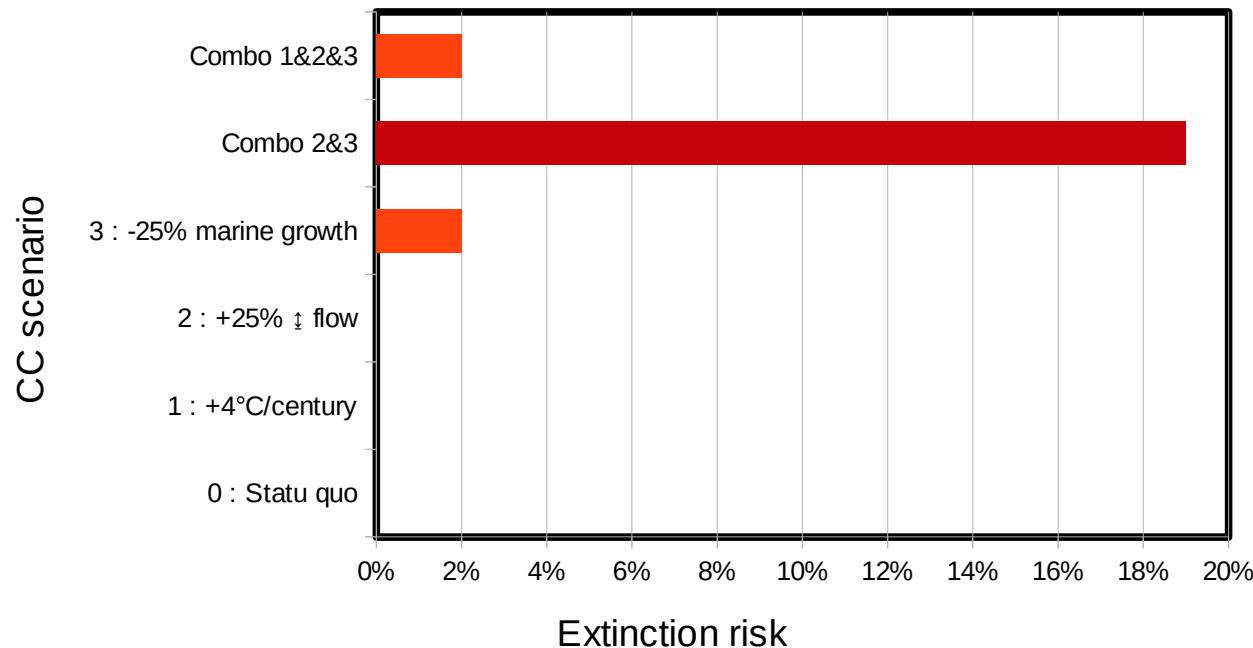
First virtual experiments of CC with IBASAM

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

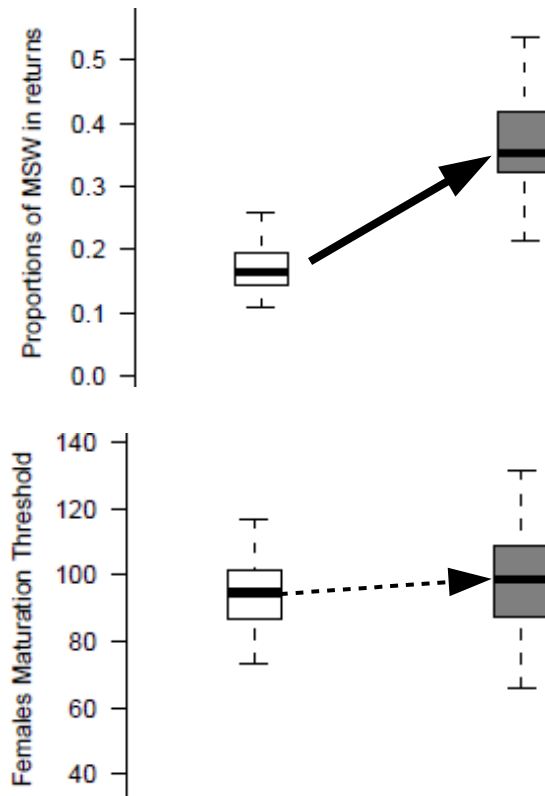
CC vs selective exploitation

Phenotypic plasticity vs genetic evolution

Phenotype
Prop. 2 years at sea

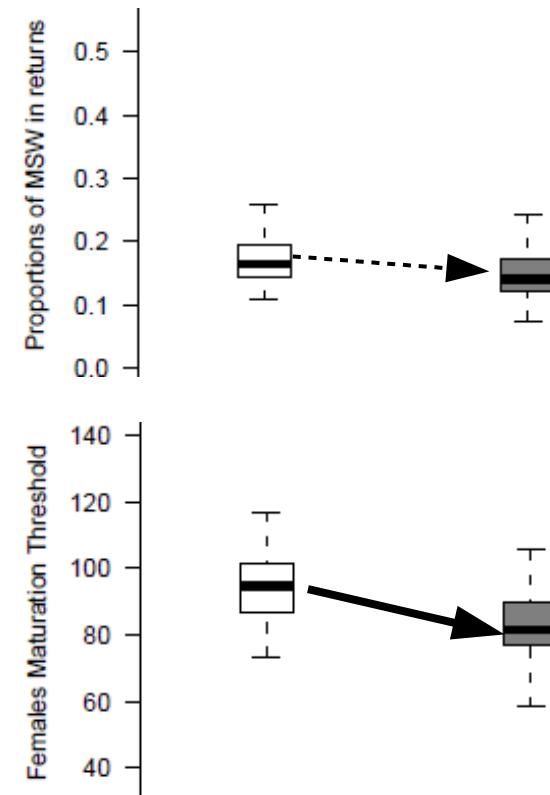
Genotype
Genetic threshold
triggering sexual
maturation in females

CC only
↘ 25% growth at sea



Mostly plastic response
Little genetic evolution

Selective fishing only
15% expl. rate 1 year at sea
↗ expl. rate 2 years at sea 15 → 75%

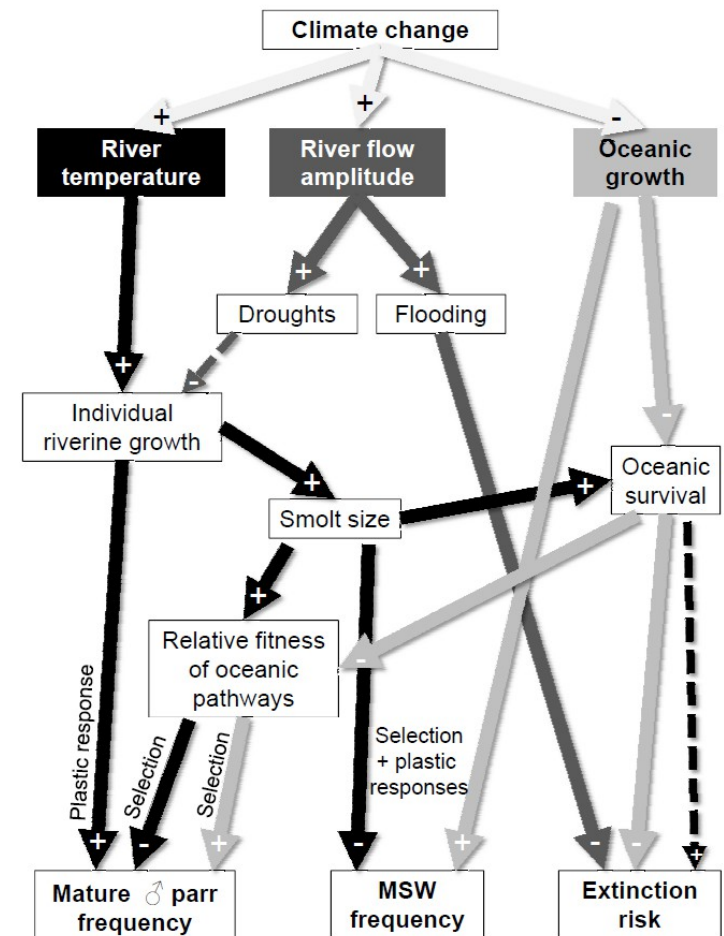


Stronger genetic evolution

Assessing the future of A. salmon in front of CC

IBASAM: a tool for making scientific progress

- Demo-genetic simulation (and IBASAM): a powerful approach to explore CC consequences on A. salmon populations
- 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



Assessing the future of A. salmon in front of CC

Where are we now ?

- 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
- Assessing potential consequences of CC on A. salmon: just the beginning
 - IBASAM: considerable room for improvement
- Not at the edge of population extinctions even in Southern Europe → must take advantage of the next two decades to improve scientific advice to A. salmon population management
 - Reduce prediction uncertainty
 - Conceive management options that are robust to uncertainties
 - Adapt (management) to foster adaptation (of A. Salmon populations)

Future of A. salmon in front of CC

From impact assessment

→ management for adaptation?

- Beyond the next 3 decades: pure plasticity might not suffice for population persistence in front of CC
- Rapid genetic evolution might be needed as well
- First virtual experiments with IBASAM suggest:
 - Plasticity dampen and could slow down genetic evolution in A. Salmon
 - Selective exploitation could drive rapid genetic evolution

Explore the potential of intentionally selective exploitation to foster evolution favoring adaptation of A. salmon populations to CC

- SALMOCLIM: a research project to address this issue
 - Funded by INRA under its Meta-programme ACCAF on Adaptation to Climate Change of Forest, Agriculture and Aquatic Ecosystems



Thanks for your attention !