Saumon & Truite de mer
MIEUX CONNAÎTRE.
MIEUX COMPRENDRE.
MIEUX GÉRER.

Samarch
FORUM INTERNATIONAL
MONT SAINT-MICHEL - 16 > 18 MAI 2018

Influence of climate change on salmon populations

Stephen GREGORY

GWCT

Interreg France (Channel Manche) England
SAMARCH
Gestion des salmonidés dans la Manche
Fonds européen de développement régional

NORMANDIE Grands Migrateurs

Agence de l'eau Seine Normandie

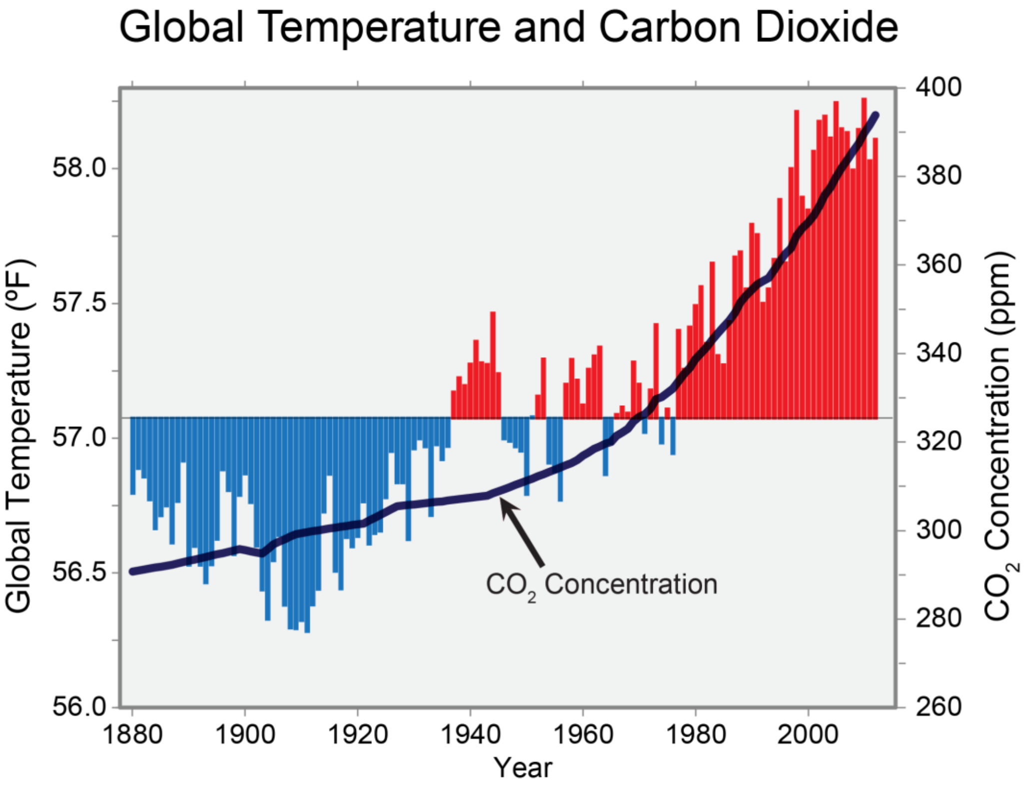
Fédération Nationale Pêche

La Manche Conseil Départemental

Région Normandie

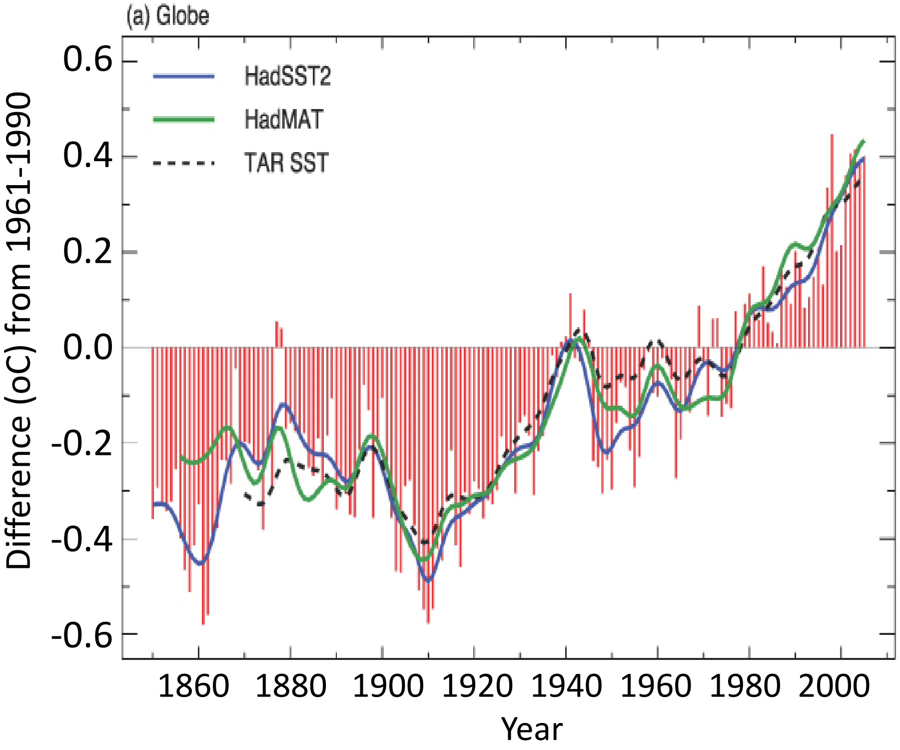

AMERICAN ENVIRONMENTAL POLITICS
THE NUCLEAR FUEL CYCLE
HOW THE COLD WAR TRANSFO
OPHY OF SCIENCE
Slopes of Logic
George A. Reisch
IN AMERICA

Climate change: past


Global Temperature and Carbon Dioxide

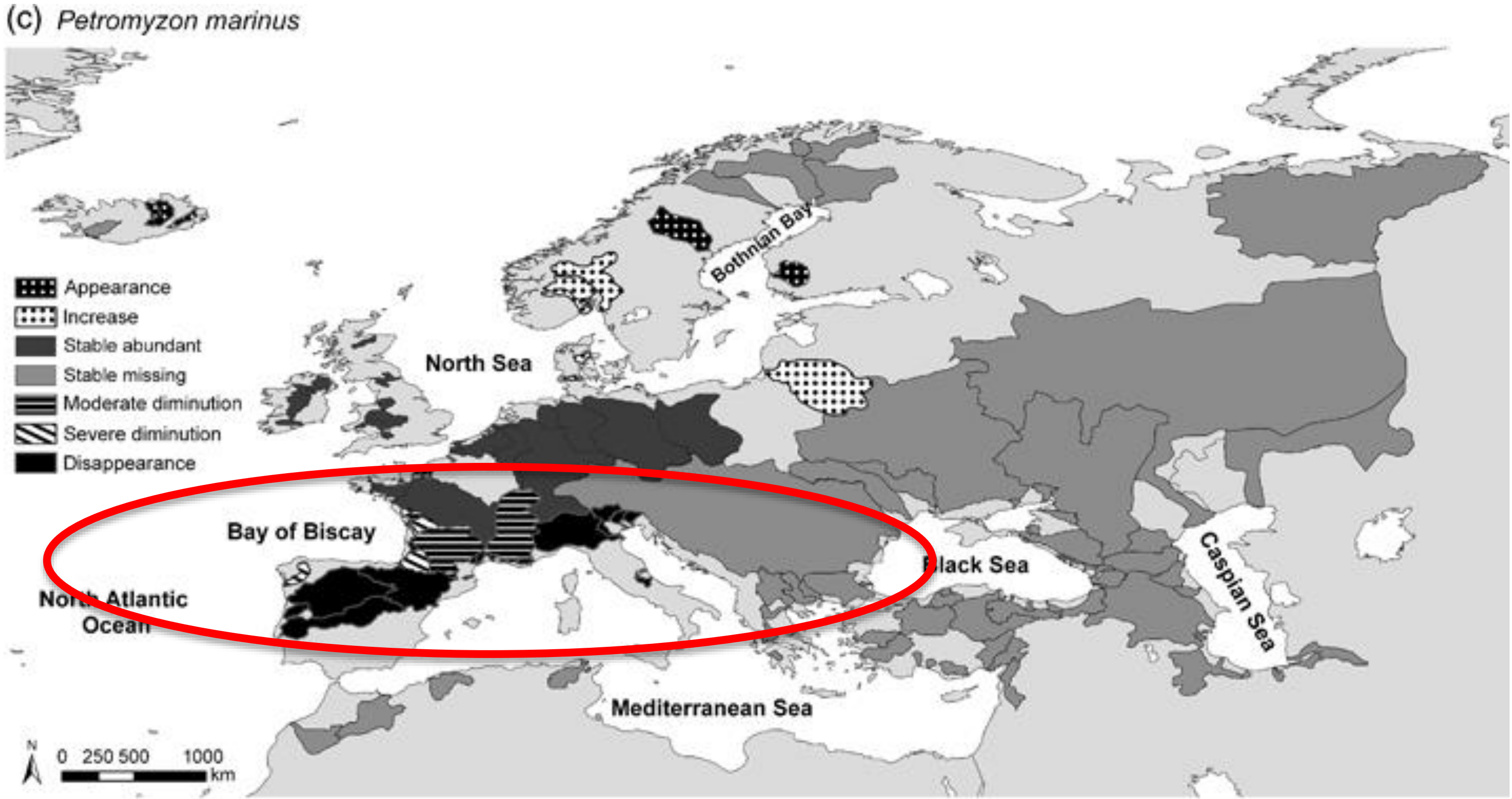
United States Environmental Protection Agency (EPA) 19 January 2018* snapshot of climate change FAQ

Climate change: past



IPCC AR4 WGI (2017)

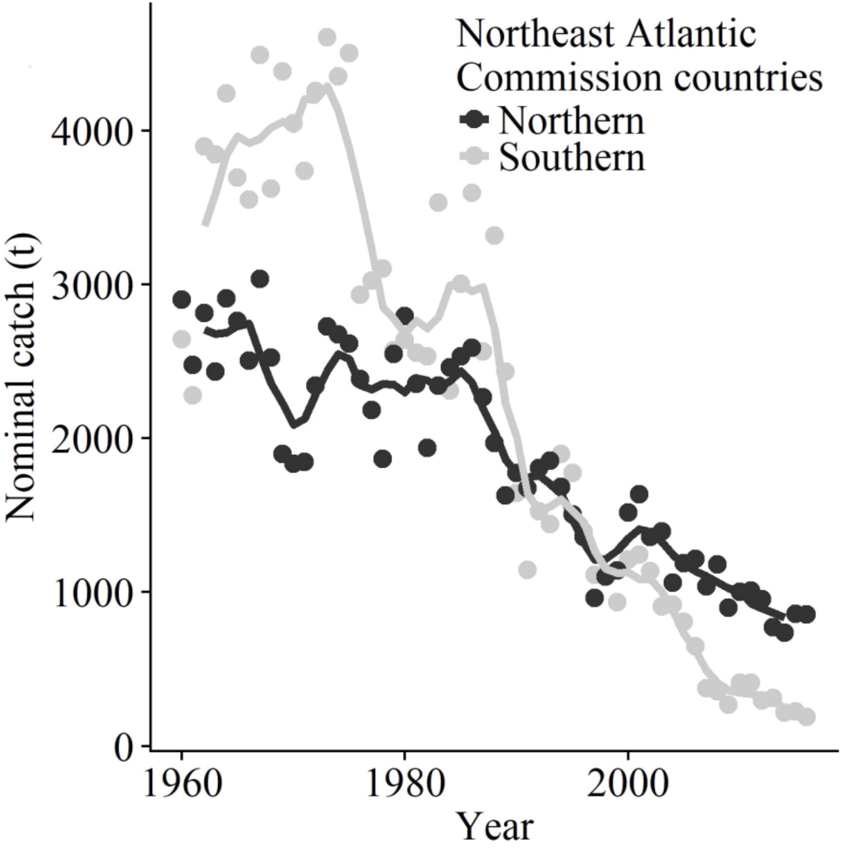
Lassalle *et al*. (2009) *Global Change Biology* **15**: 1072-1089

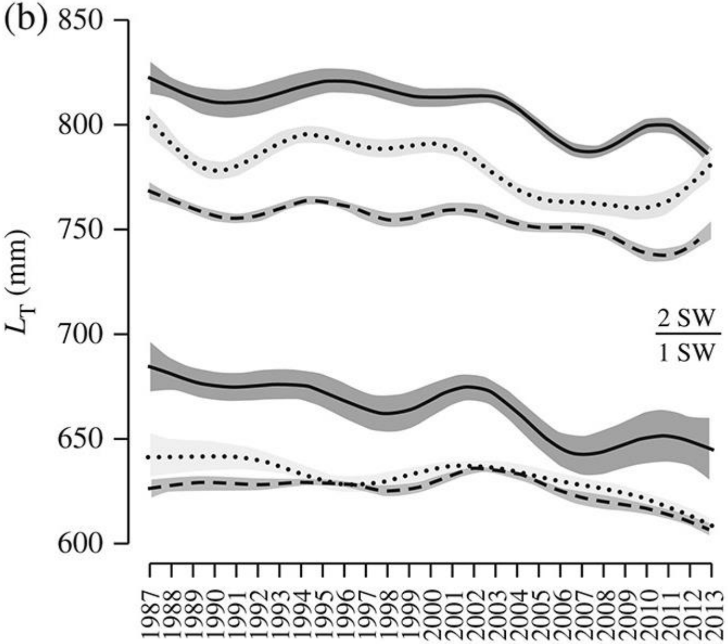


Lassalle *et al*. (2009) *Global Change Biology* **15**: 1072-1089

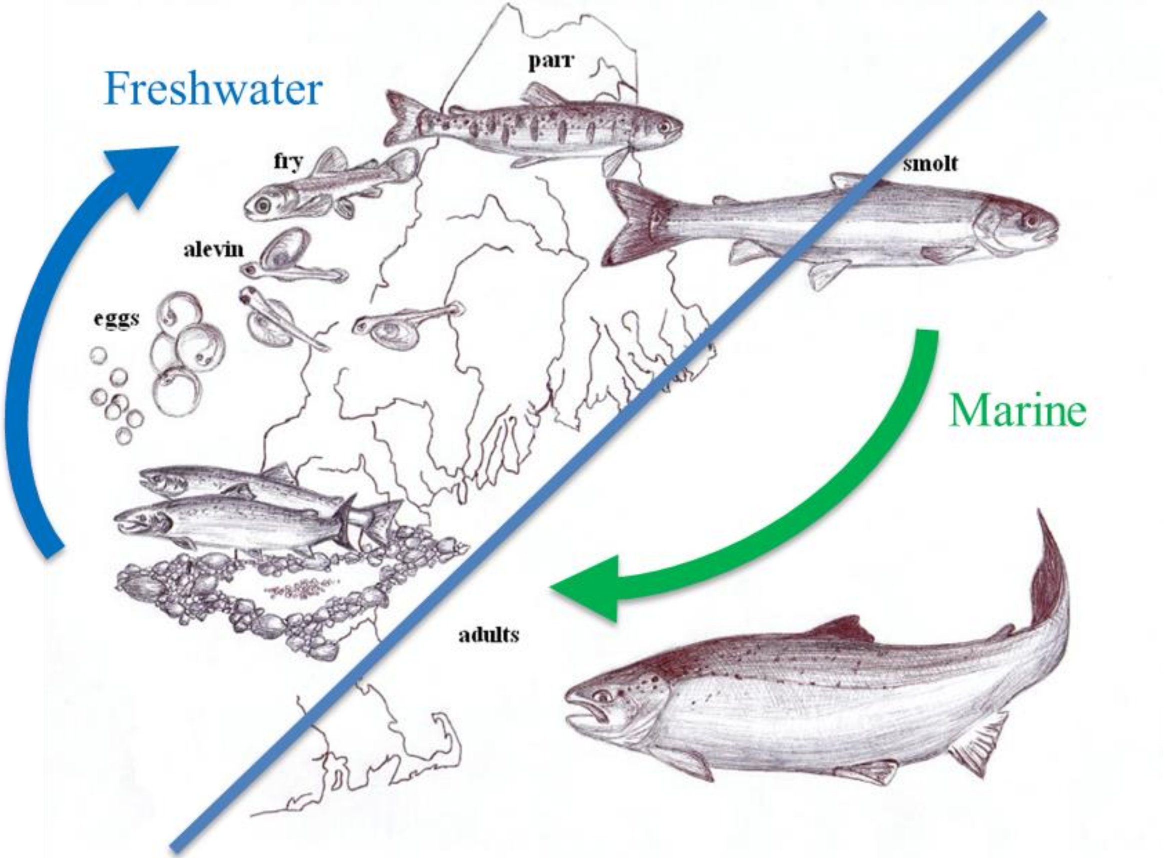
Atlantic salmon

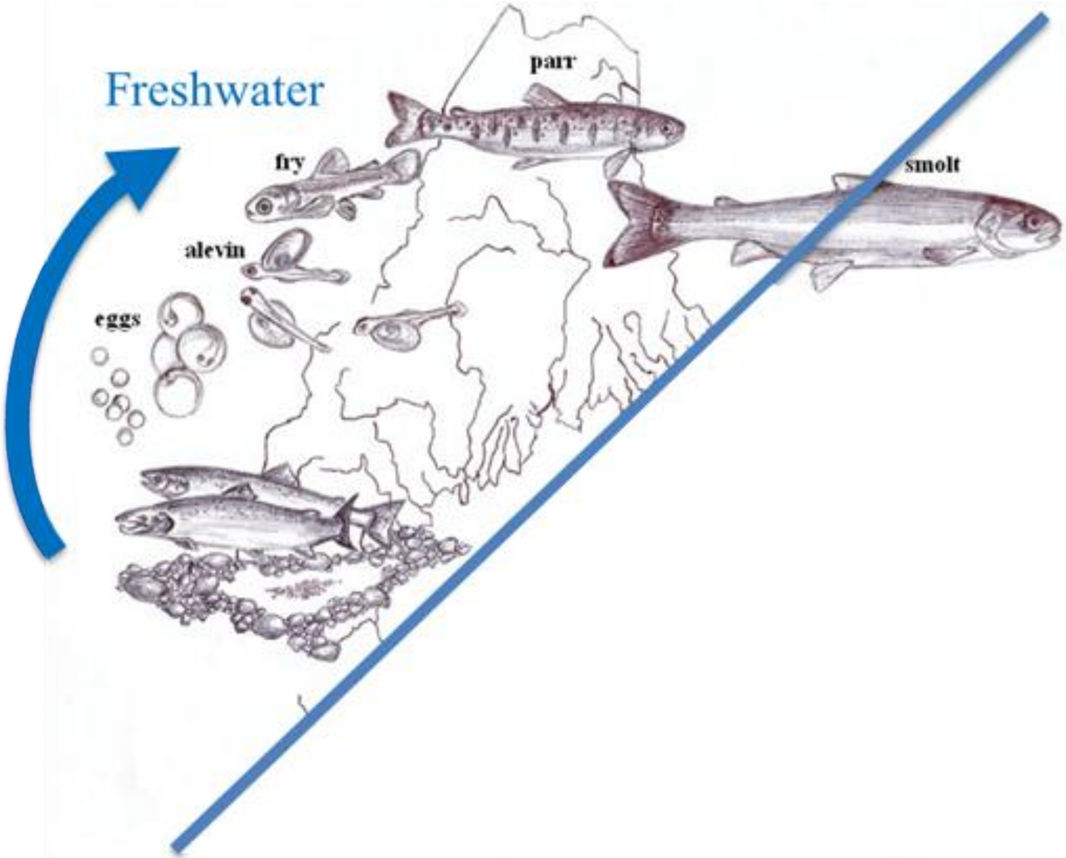
Atlantic salmon



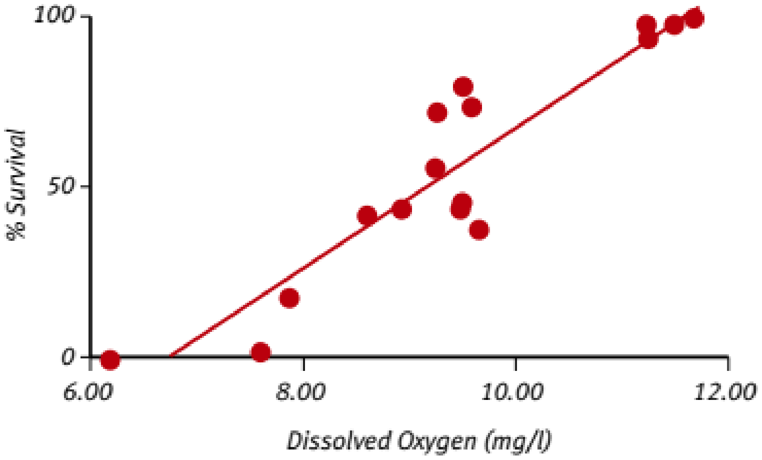


ICES WGNAS (2017); Bal *et al*. (2017) *Journal of Fish Biology* **90**: 2375-2393

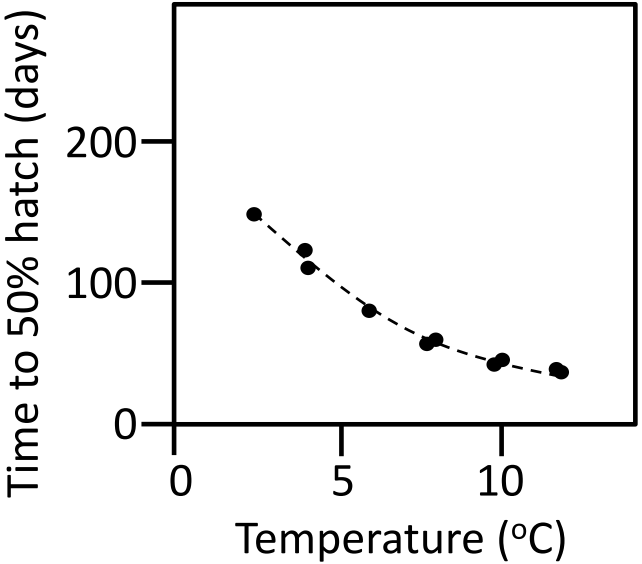

Freshwater
parr
fry
smolt
alevin
eggs
Marine
adults


Freshwater
parr
fry
smolt
alevin
eggs

Egg survival

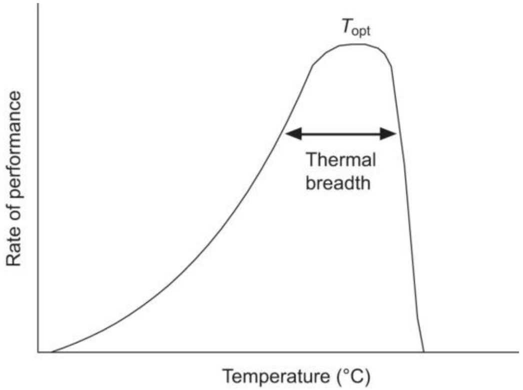


Egg survival rate is proportional to average oxygen concentration.



Crisp (1981) *Freshwater Biology* **11**: 361-368; Malcolm *et al*. (2003) *River Research and Applications* **19**: 303-316

Juvenile survival



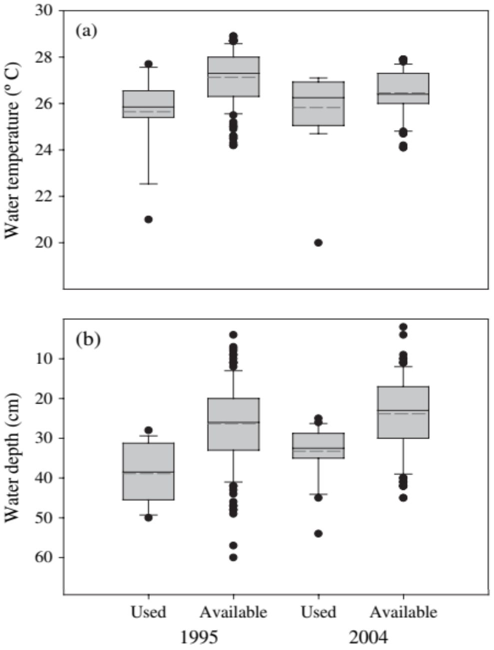


Fig. 4. Box-plots showing differences in (a) water temperature, (b) water depth and (c) mean water column velocity between locations with aggregations (used) and locations with no aggregations (available) within the thermal plumes for the high water temperature days during summer 1995 and 2004.

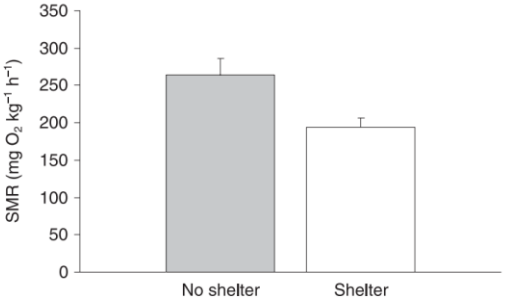


Fig. 1. Comparison of standard metabolic rate (SMR) of Atlantic Salmon parr in the absence and presence of a single shelter. The data are presented as means + SEM. The difference between the two groups was significant (paired *t*-test: $t = 3{\cdot}52$, 13 df, $P = 0{\cdot}004$).

Schulte (2015) *Journal of Exp. Biology* **218**: 1856; Breau *et al*. (2007) *Journal of Fish Biology* **71**: 1179-1191; Millidine *et al*. (2006) Function Ecology **20**: 839-845

Juvenile growth (i)

19 years / 1 river

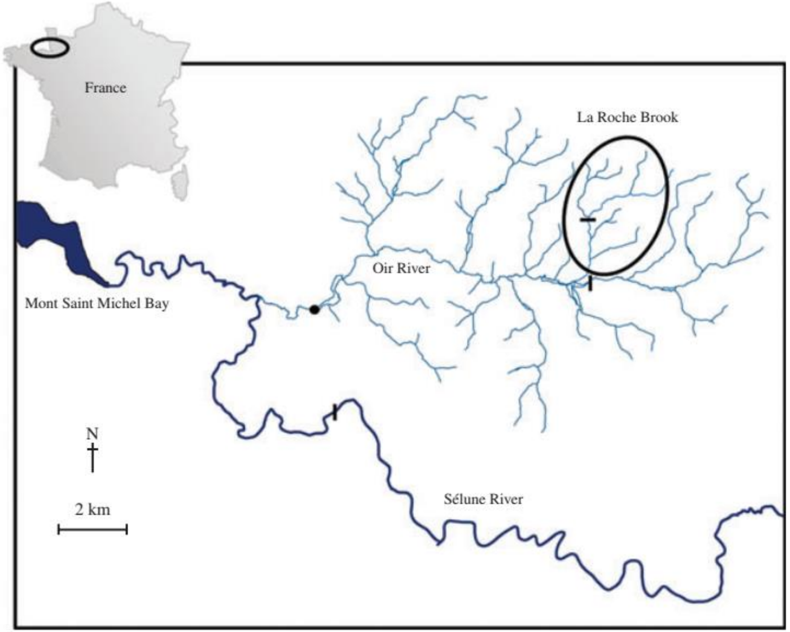


FIG. 1. The Oir River catchment (France) and the La Roche Brook. ▬, impassable dam; ●, partial fish trap (Cerisel Mill).

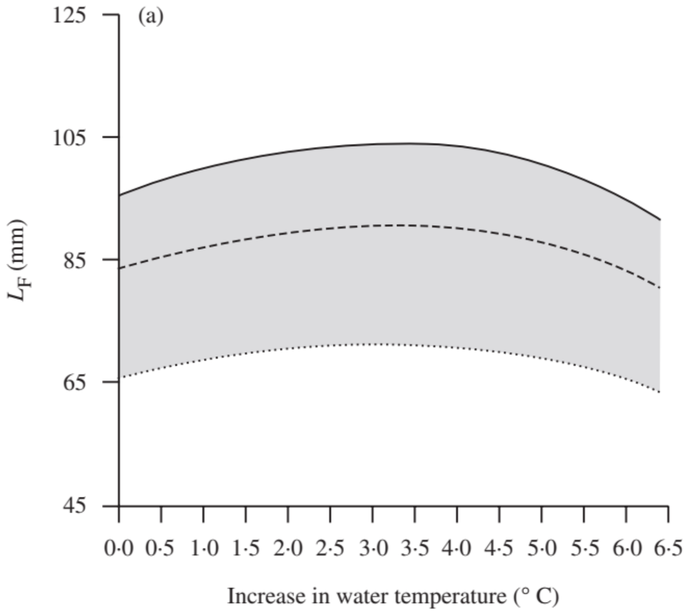
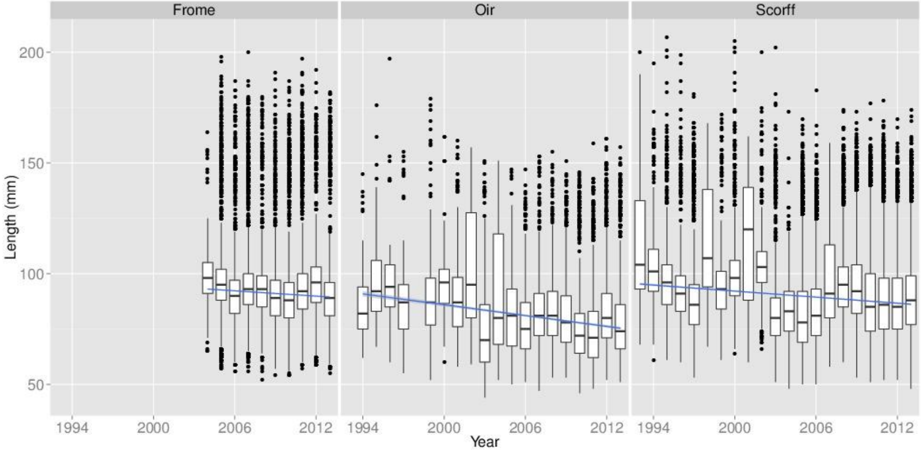


FIG. 6. Effects of increase in water temperature (T) and of the density (D) of juvenile salmonids (*Salmo salar* and *Salmo trutta*) on the length (L_F) reached by young-of-the-year *Salmo salar* on 15 October. Responses were drawn for three contrasted configurations of fixed parameters T_{min}, T_{opt} and T_{max} in equation (3b). Fork length reached in (a) $T_{min} = 6·8°$ C, $T_{opt} = 17·6°$ C and $T_{max} = 23·9°$ C. (b) $T_{min} = 5·8°$ C, $T_{opt} = 15·6°$ C and $T_{max} = 22·4°$ C. (c) $T_{min} = 7·8°$ C, $T_{opt} = 19·6°$ C and $T_{max} = 25·4°$ C. ——, L_F reached with $D = 24·2$ (minimum D observed). ----, L_F reached with $D = 65·6$ (mean density observed). ...., L_F reached with $D = 141·2$ (maximum D observed).

Saumon & Truite de mer
MIEUX CONNAÎTRE. MIEUX COMPRENDRE. MIEUX GÉRER.
Samarch
FORUM INTERNATIONAL

Bal *et al*. (2011) *Journal of Fish Biology* **78**: 1002-1022

Juvenile growth (ii)



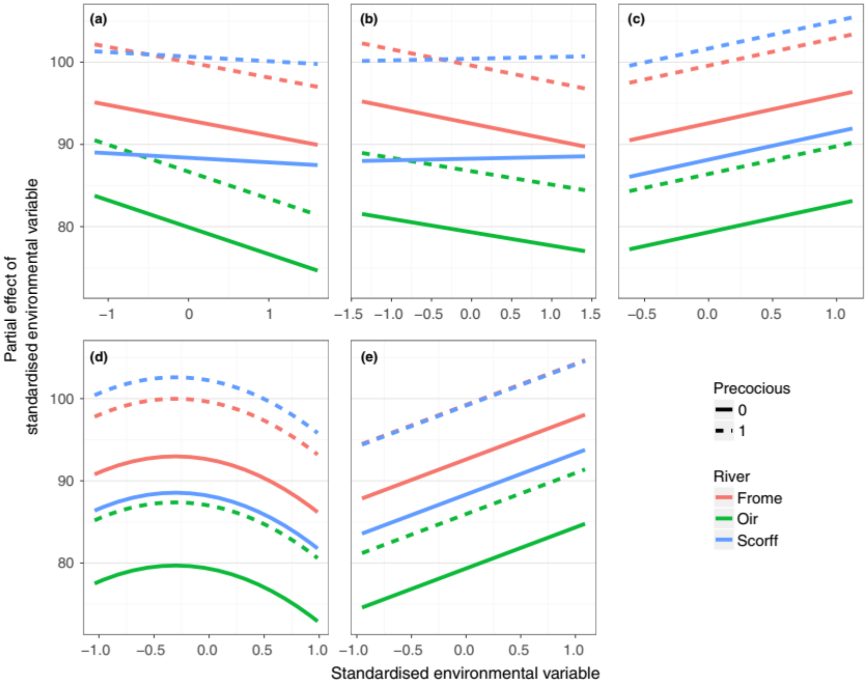


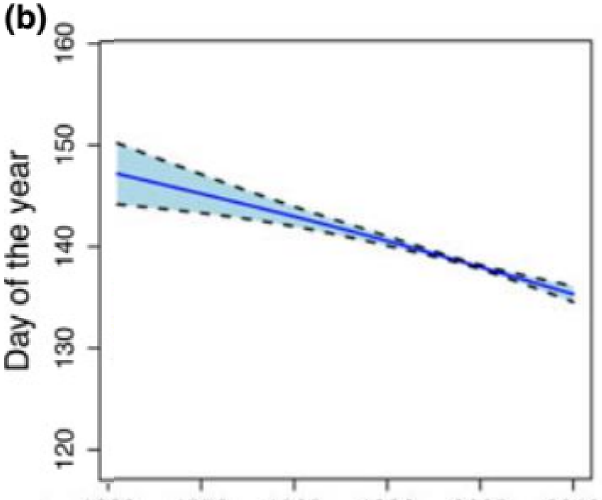
FIGURE 4 Partial effect plots for each of the environmental variables retained in the length model. Lines are plotted for immature and mature (Precocious = 1) parr separately for each river. Variables are plotted on their standardised scale. Panels are: (a) conspecific density (DEN) (b) conspecific density × total mean discharge (DENTMF) (c) summer minimum discharge (SMF) (d) spring mean temperature (SPT) and (e) winter degree days (WDD)

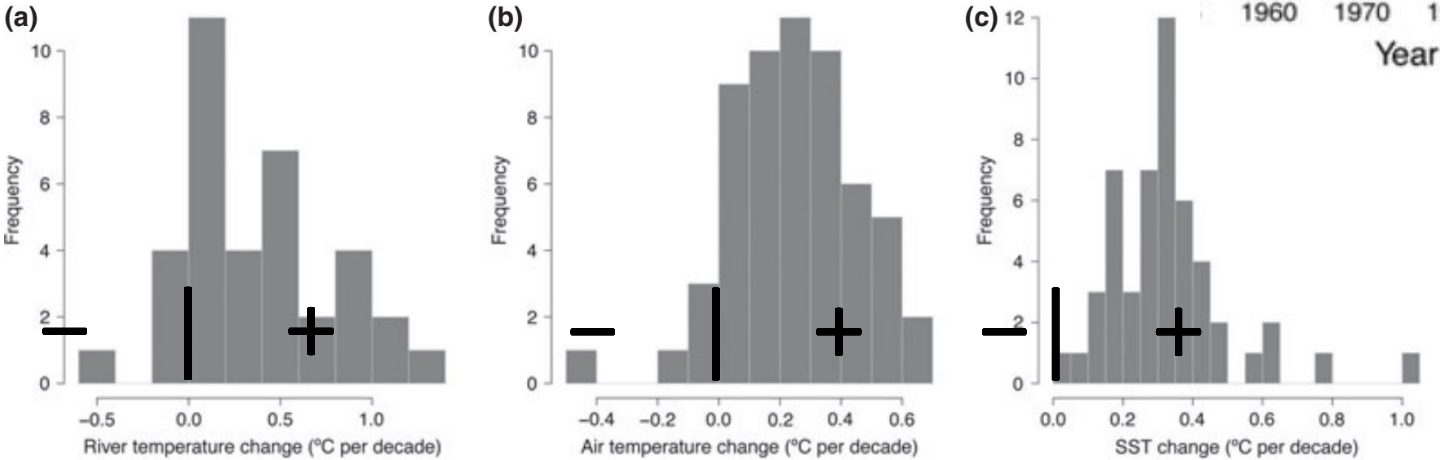
100k+ parr / 18 years / 3 countries

Gregory *et al*. (2017) *Freshwater Biology* **62**: 1117-1129

Seaward migration

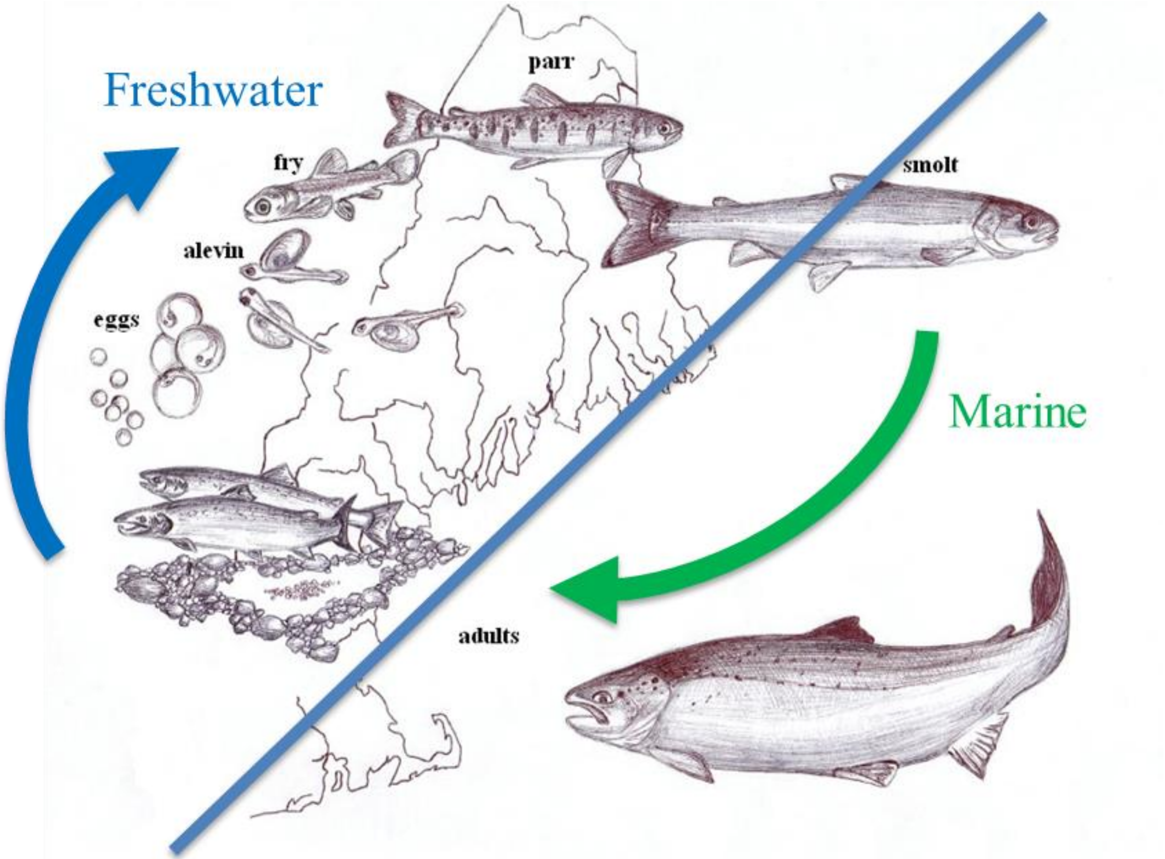
10-50 years / 67 rivers / 13 countries

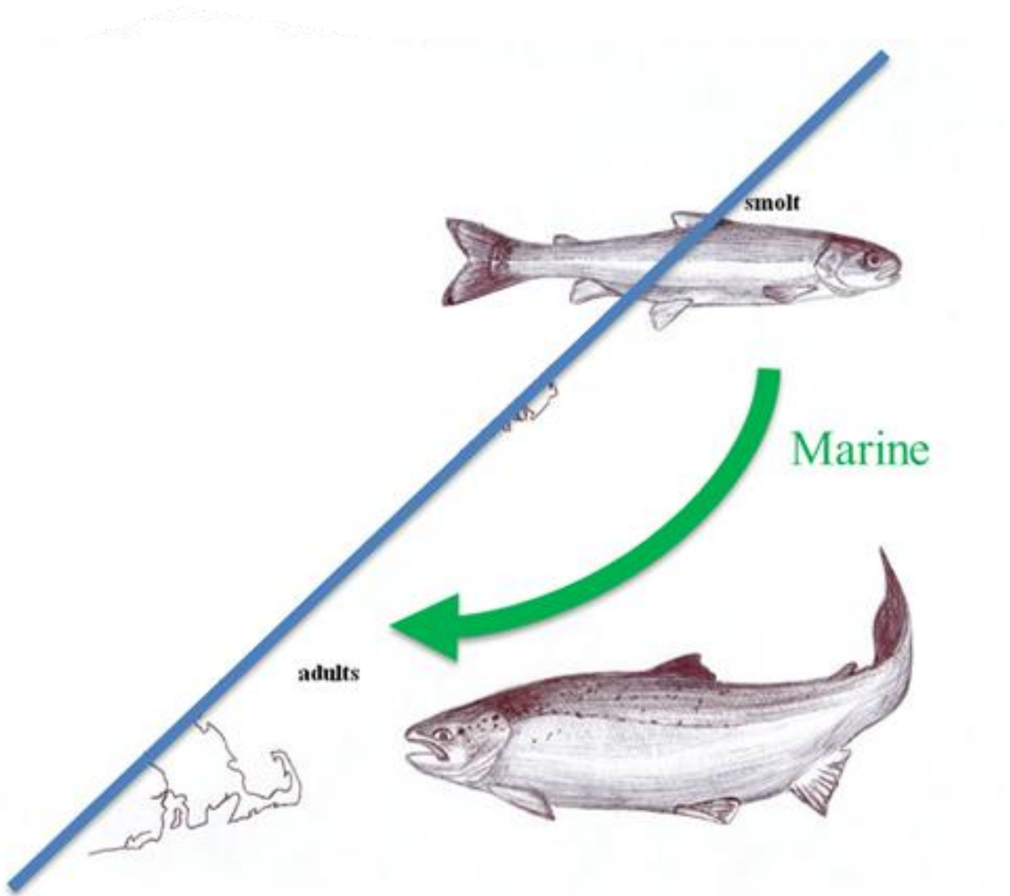




Otero *et al*. (2014) *Global Change Biology* **20**: 61-75

Saumon & Truite de mer
MIEUX CONNAÎTRE. MIEUX COMPRENDRE. MIEUX GÉRER.
Samarch
FORUM INTERNATIONAL


Freshwater
parr
fry
smolt
alevin
eggs
Marine
adults


smolt
Marine
adults

Smolt survival

15000 smolts / 15 years / 1 river

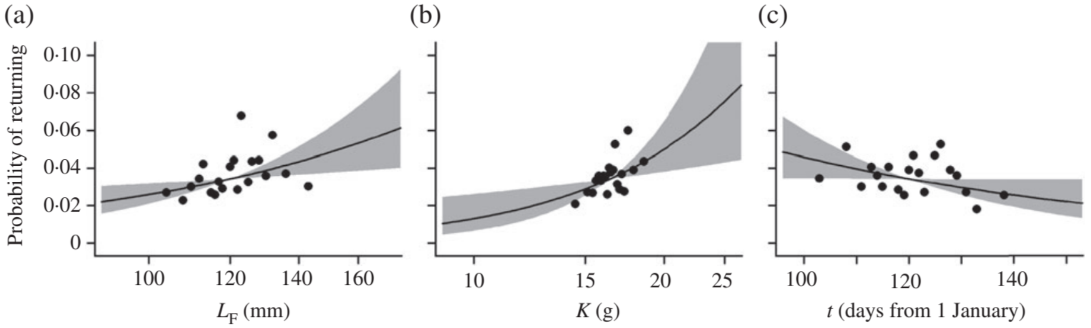
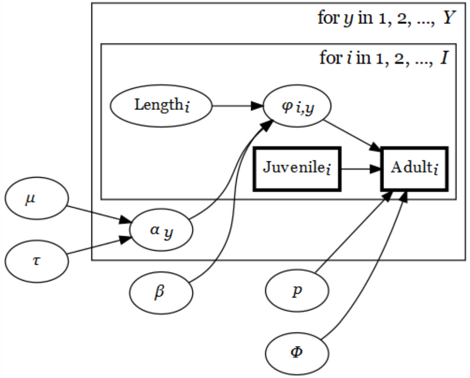


FIG. 2. The effect of (a) fork length (L_F), (b) condition (K) and (c) migration day (t) on the overall probability of individual *Salmo salar* returning. In each panel, the other explanatory variables are fixed at $L_F = 120$ mm, $K = 0$, $t = 120$ and a migration year of 2008. For ease of interpretation, the condition effect is presented as the equivalent effect of mass when standardized to a fish $L_F = 120$ mm.



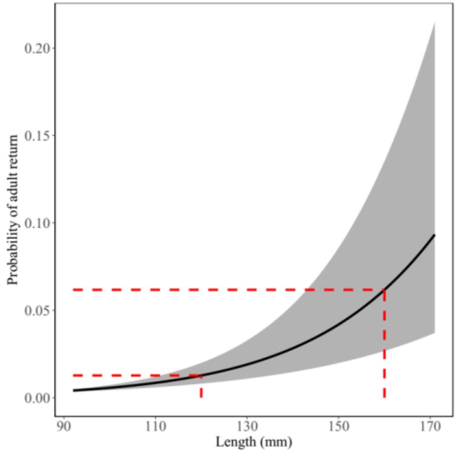


FIGURE 4. Fitted effect of length on probability that an individual smolt will return as an adult. Grey ribbon represents the 50% uncertainty range of the fit. Note that length is standardised by subtracting the mean and dividing by 1 standard deviation. Dashed red lines highlight the probability that a 12 and 16 cm smolt will return as an adult.

3500 smolts / 11 years / 1 river

Armstrong *et al*. (2018) *Journal of Fish Biology* **92**: 569-578; Gregory *et al*. (2018) *Journal of Fish Biology* **92**: 579-592; Gregory (2018) 33rd IWSM, 16-20 July 2018

Post-smolt growth (i)

34 rivers / 26 years / 1 country

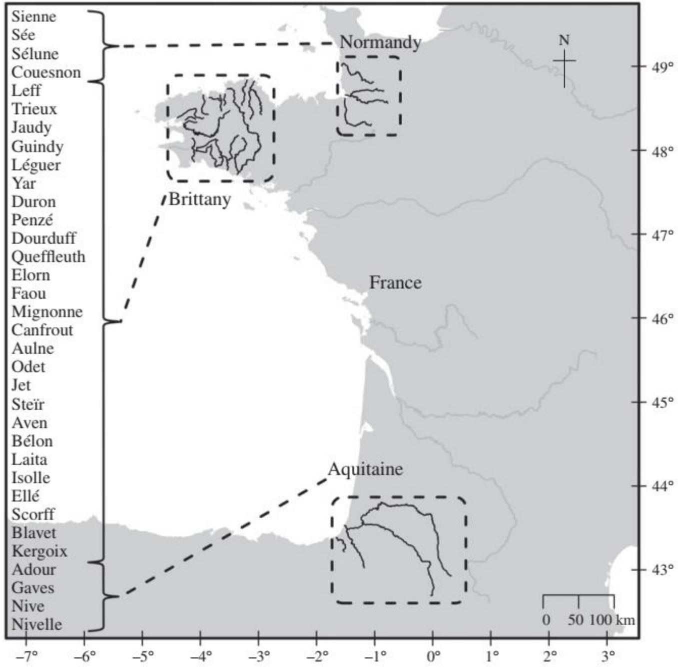
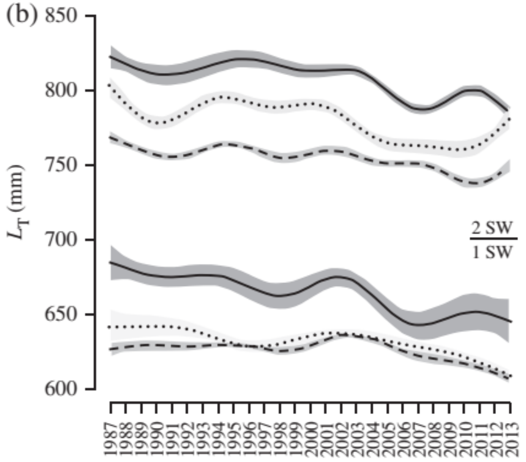
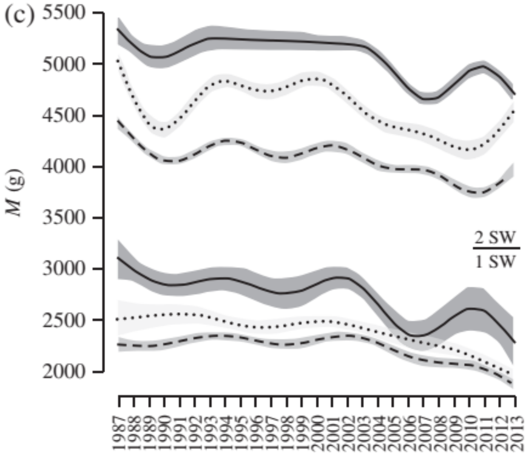


FIG. 1. The three regions considered in the analysis of French *Salmo salar*, Normandy, Brittany and Aquitaine, and their respective rivers.



Normandy (…….), Brittany (_ _ _ _) and Aquitaine (_____) 1997–2013. The shaded bands represent 95% C.I.



Bal *et al*. (2017) *Journal of Fish Biology* **90**: 2375-2393

Post-smolt growth (ii)

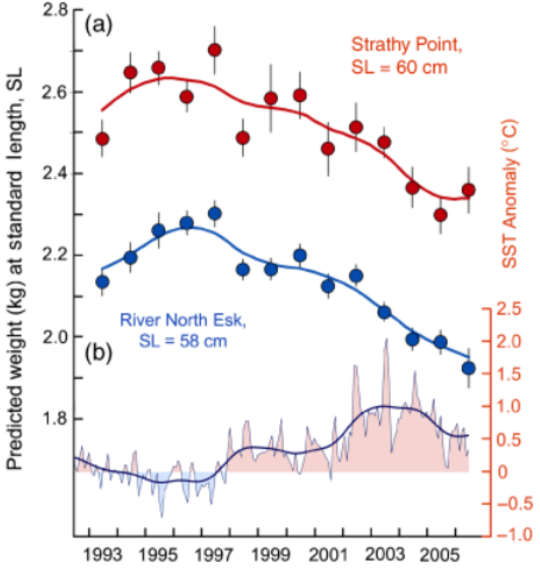


Fig. 6 (a) Predicted weight (PWt) ±95% CI at standard length (SL) for adult 1SW Atlantic salmon. A Generalized Additive Model, including a term for site, was used to obtain estimates of PWt on the median sample date (Day 200) at the observed overall mean lengths of 58 cm (RNE) and 60 cm (SP) for each year-class. (b) Example mean monthly SST anomalies for the eastern North Atlantic Ocean, calculated with a weighting kernel of $\sigma = 500$ km.

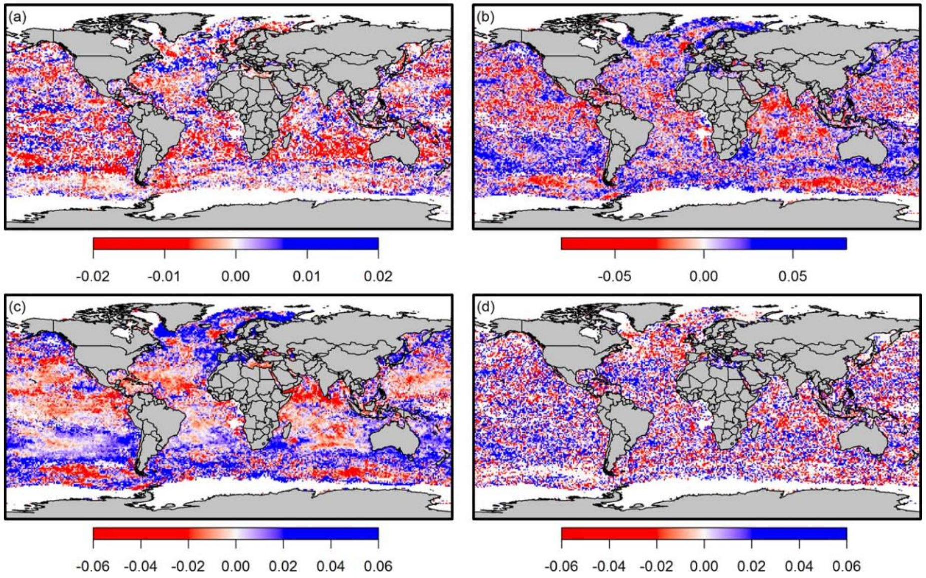


FIGURE 4 Relative Theil–Sen slope showing time series trends in start day (a), magnitude (b), intensity (c) and duration (d) for the dominant annual bloom based on a global 1° latitudinal/longitudinal grid over the study period 1998–2015. Only grid locations with ≥ 10 years with detected blooms were included. Blue shades denote positive change and red shades negative change

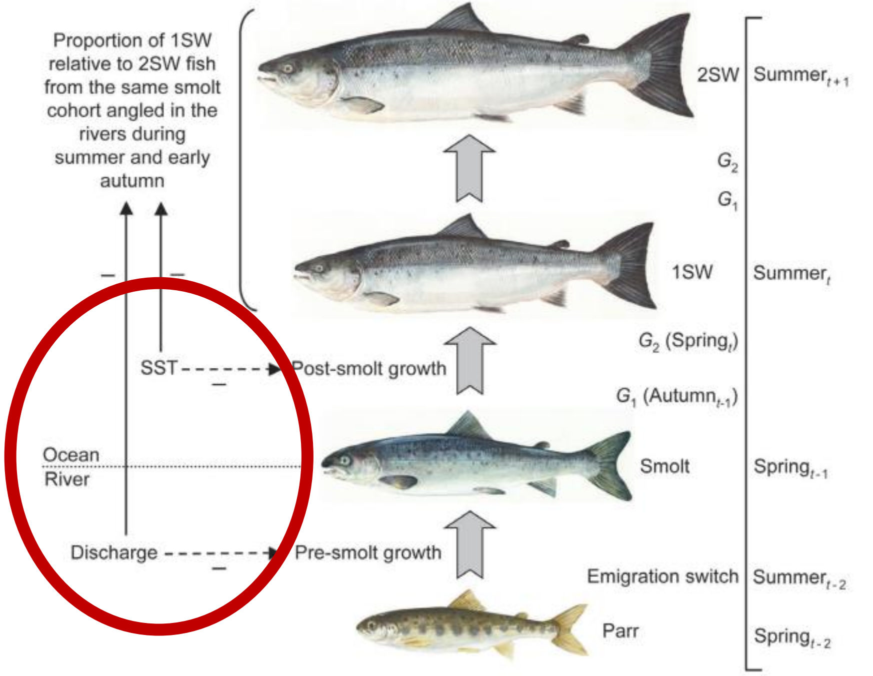
5300 salmon / 14 years / 1 river

Saumon & Truite de mer
MIEUX CONNAÎTRE.
MIEUX COMPRENDRE.
MIEUX GÉRER.
Samarch
FORUM INTERNATIONAL

Todd *et al*. (2008) *Global Change Biology* **14**: 958-970; Beaugrand *et al*. (2012) *ICES Journal of Marine Science* **69**: 1549-1562; Friedland *et al*. (2018) *Global Ecology and Biogeography* **27**: 551-569

Migration strategy

Figure 5. Schematic representation of the Atlantic salmon life cycle and the relationships reported in this study.



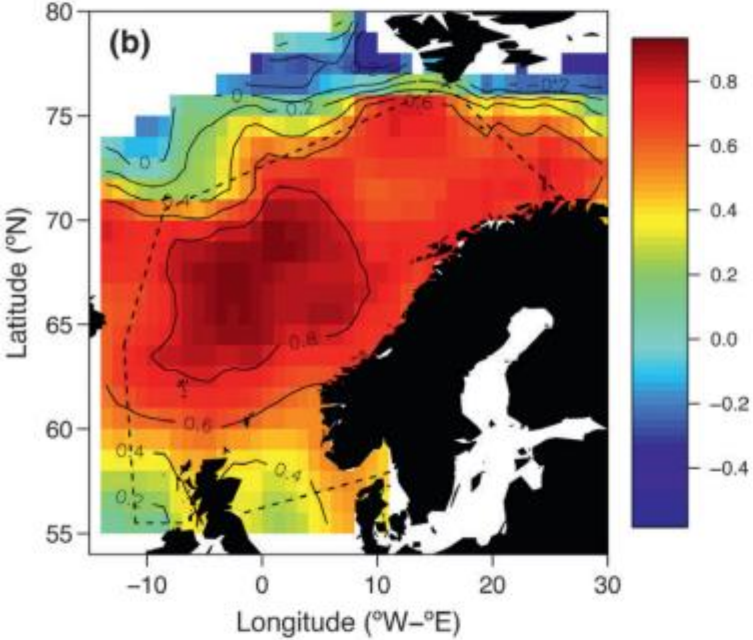


Figure 2. Large spatial patterns in SST in the Norwegian Sea.

59 rivers / 14 years / 1 country

Otero *et al*. (2012) *Ecology and Evolution* **2**: 2192-2203

Spawning migration

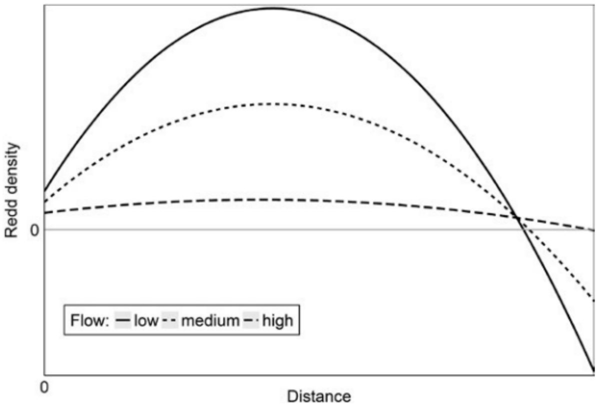


FIGURE 1 Diagram showing how the density of redds is predicted to change with distance from the tidal limit under low, medium and high flow conditions

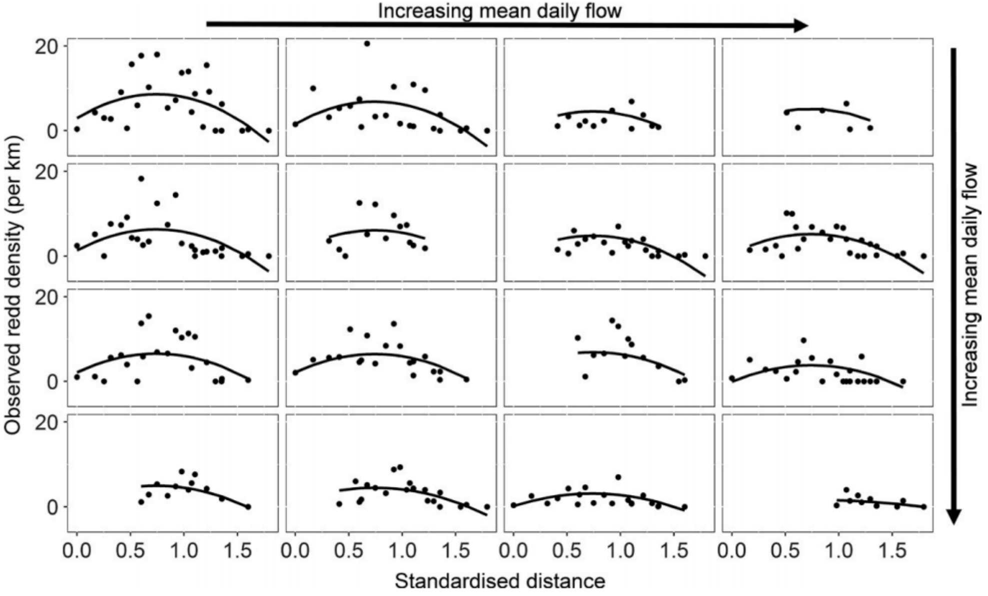


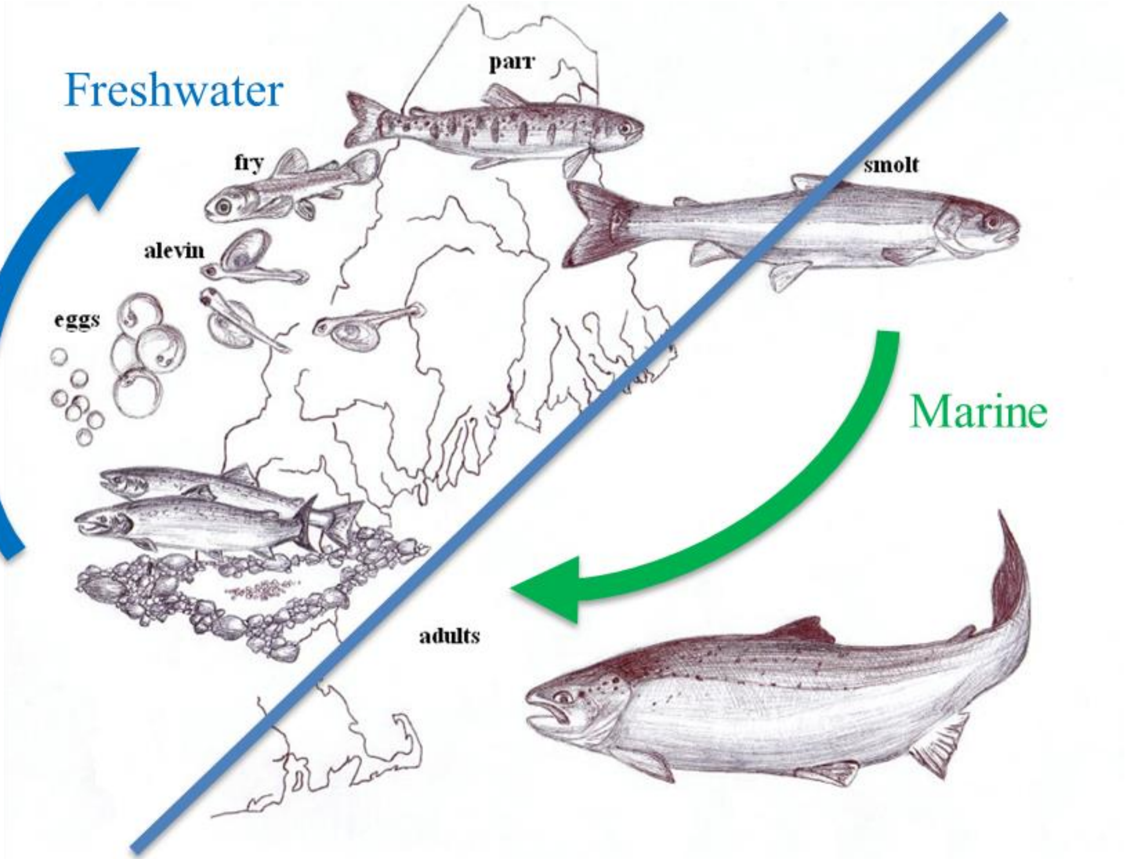
FIGURE 5 Scatter plots showing observed redd densities as a function of standardised distance from the tidal limit. Each panel represents a different year characterised by a measure of mean daily flow from 1 October to 31 December, and panels are ordered from low (top left) to high (bottom right) flow. Lines are the "top-ranked" model fits. As flow and distance were standardised, no units are specified for these variables

16 in 35 years / 1 river

Saumon & Truite de mer
MIEUX CONNAÎTRE.
MIEUX COMPRENDRE.
MIEUX GÉRER.

Samarch
FORUM INTERNATIONAL

Parry *et al*. (2017) *Ecology of Freshwater Fish* **27**: 128-137


Freshwater
parr
fry
smolt
alevin
eggs
Marine
adults

Full life cycle

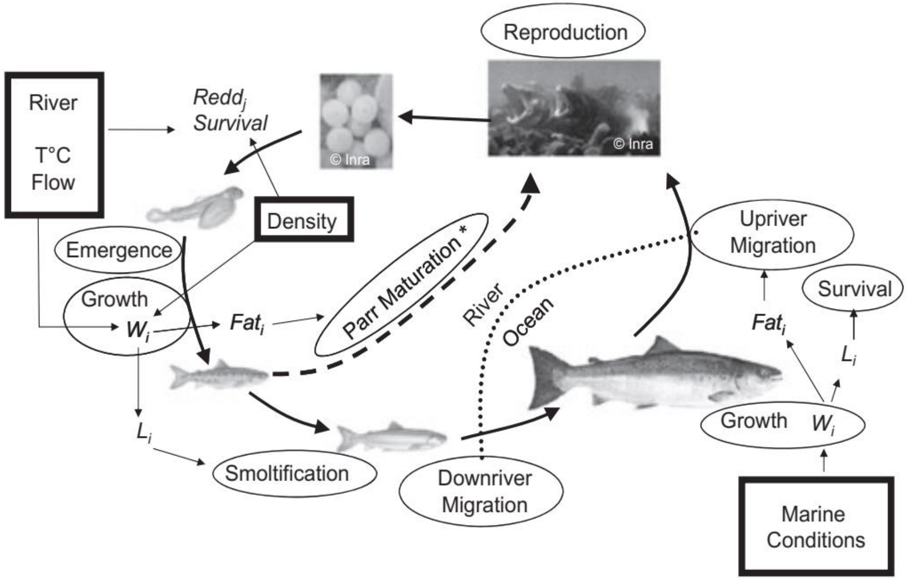


Fig. 1 Conceptual diagram of the life cycle of Atlantic salmon represented in IBASAM.

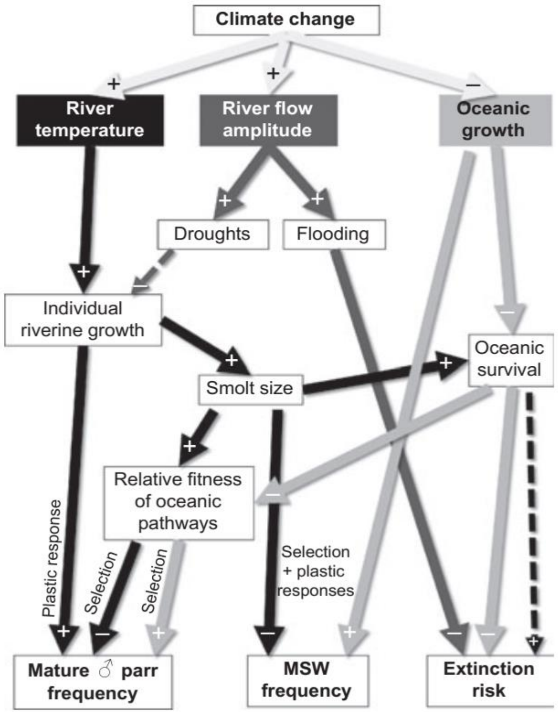
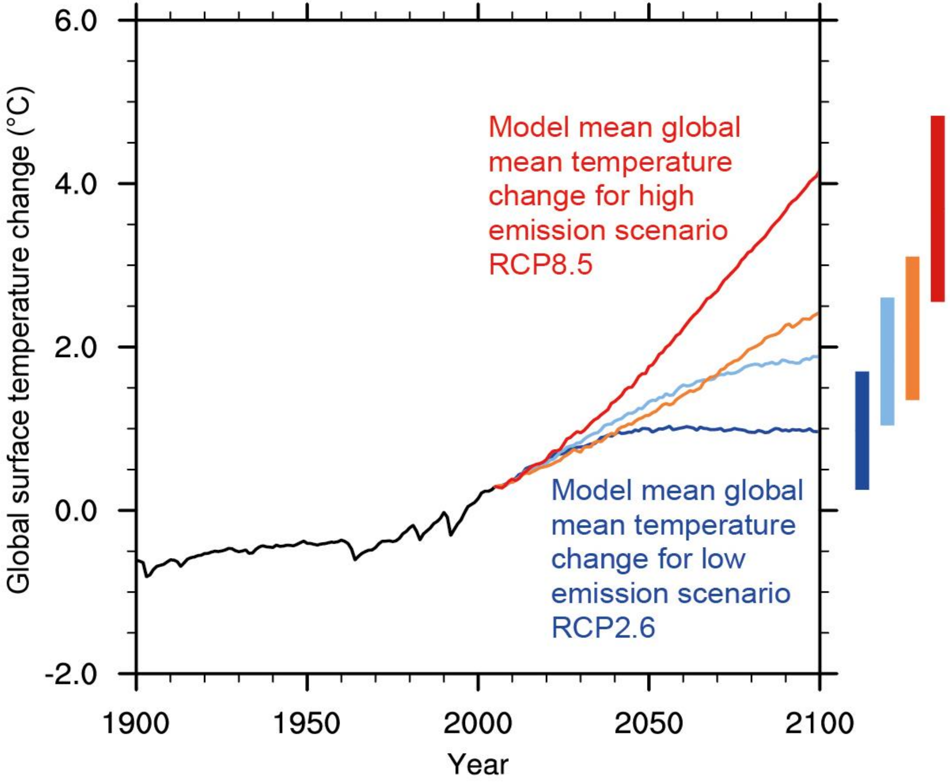


Fig. 5 Summary of the effects of climate change on Southern European populations of Atlantic salmon resulting from IBASAM simulations.

30 years / 1 river

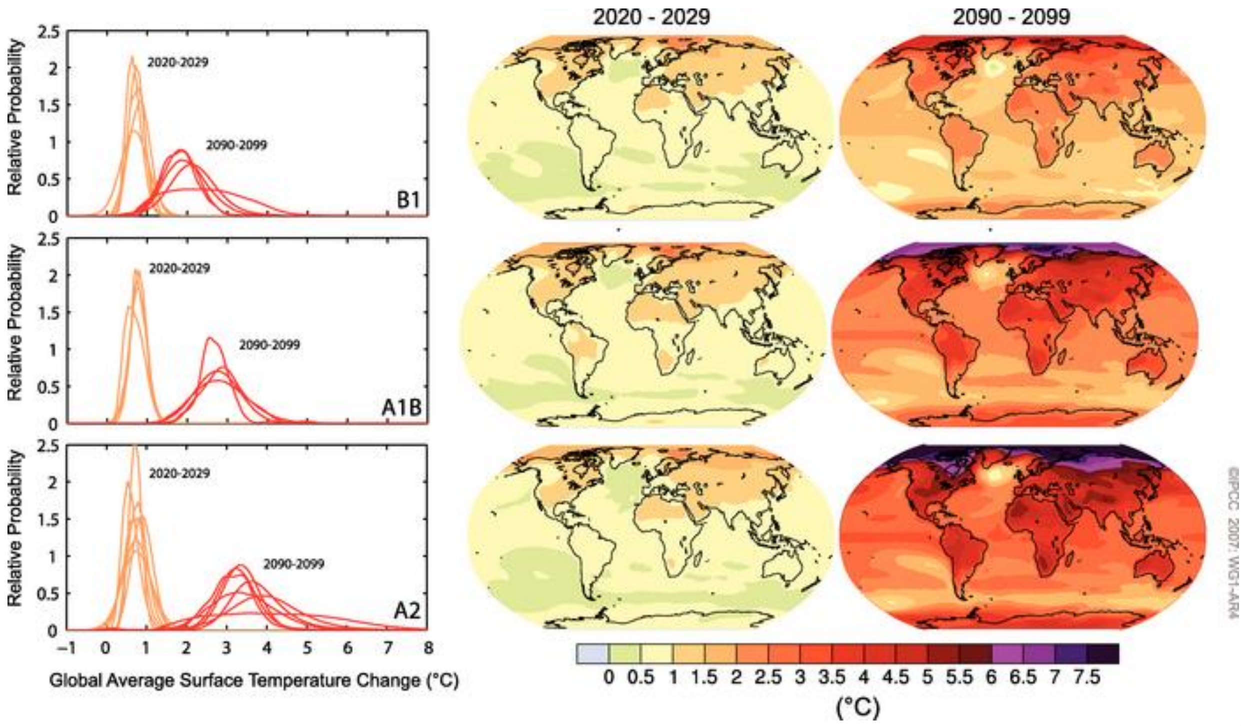
Piou *et al*. (2013) *Global Change Biology* **19**: 711-723

Climate change: future



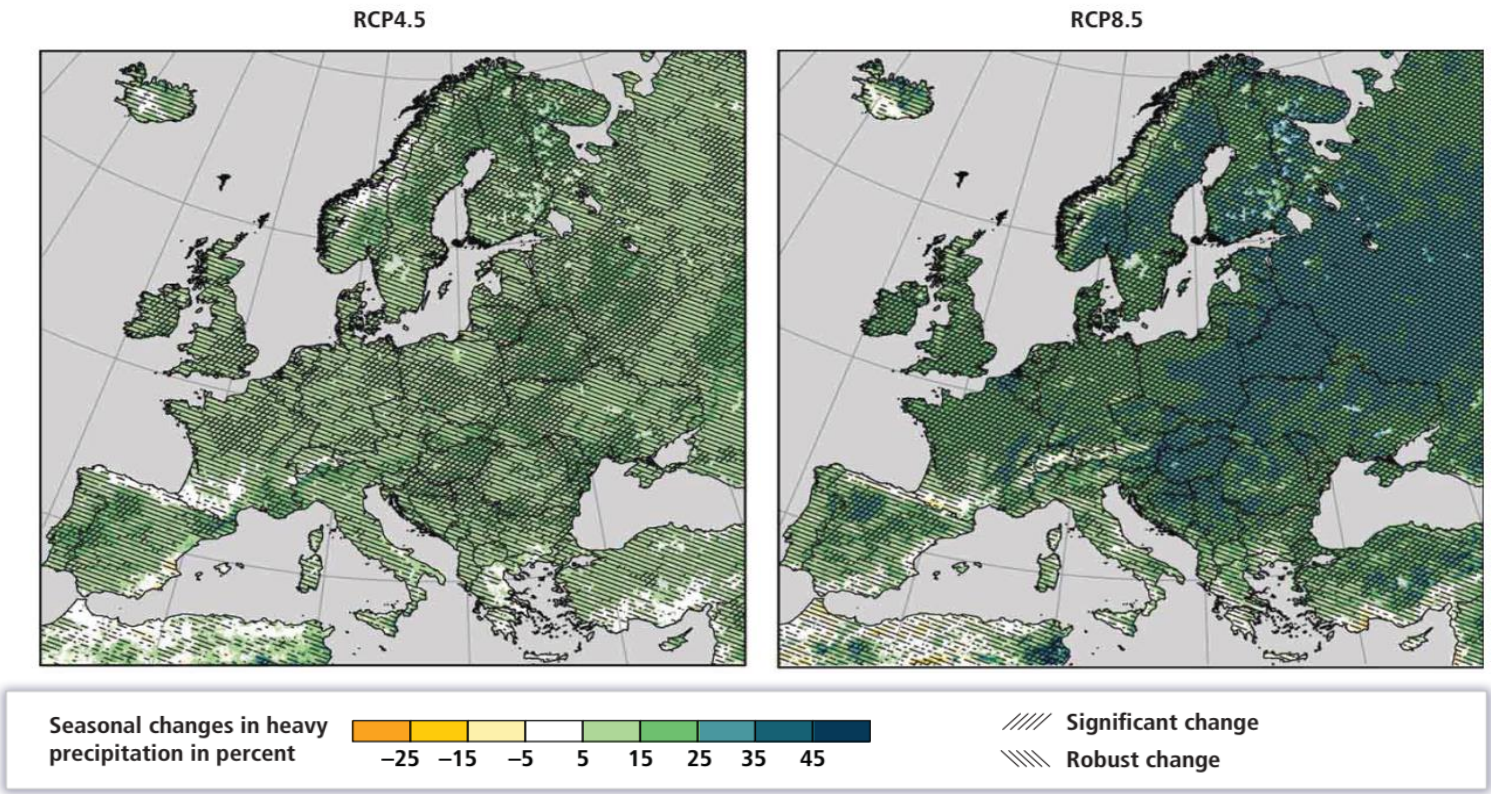
United States Environmental Protection Agency (EPA) 19 January 2018* snapshot of climate change FAQ

Climate change: future



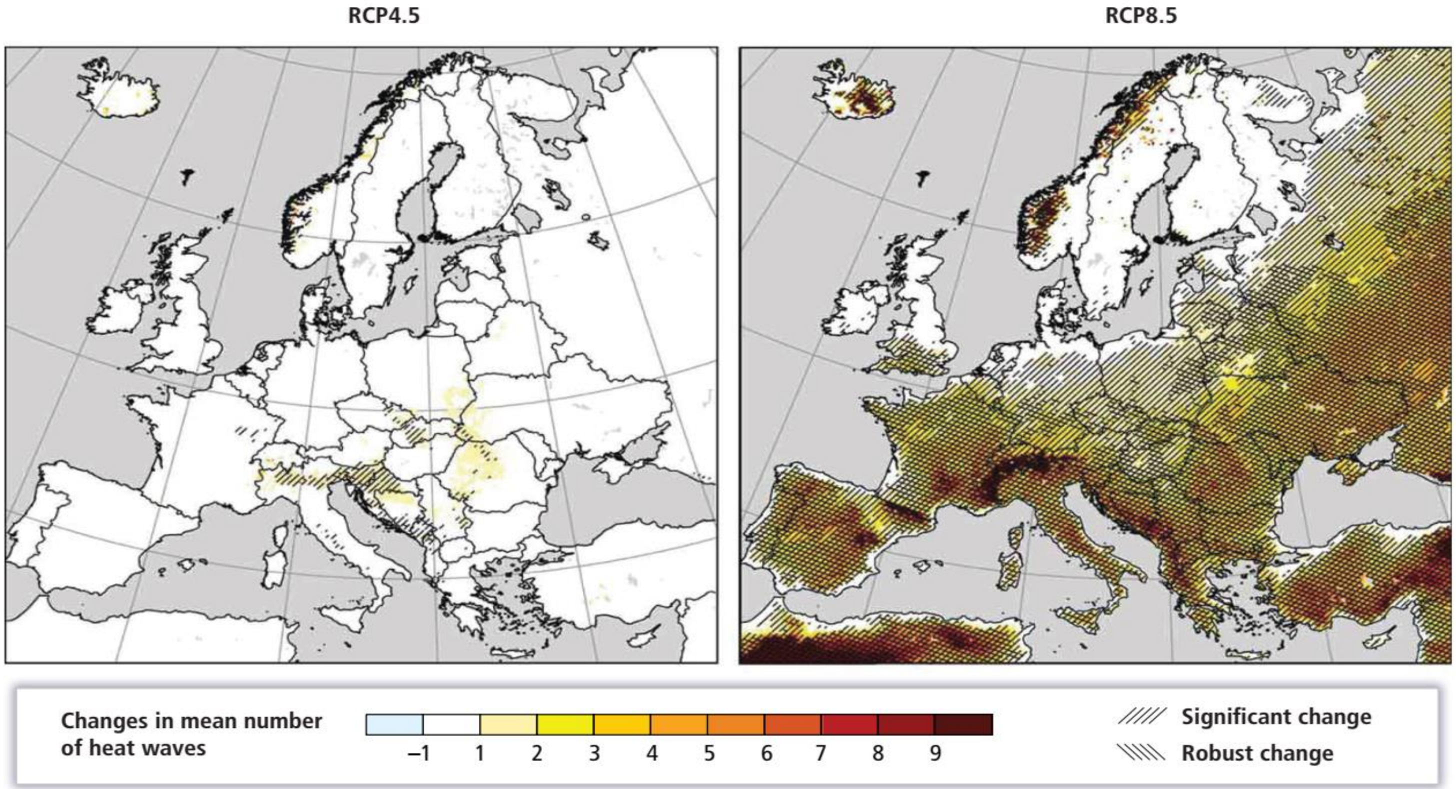
IPCC AR4 WGI (2017)

(a) DJF seasonal changes in heavy precipitation (%), 2071–2100 compared to 1971–2000



Kovats et al. (2014) Europe. In: *IPCC AR4*, pp. 1267-1326

(c) Changes in mean number of heat waves for MJJAS, 2071–2100 compared to 1971–2000



Kovats et al. (2014) Europe. In: *IPCC AR4*, pp. 1267-1326

Future climate change: fish

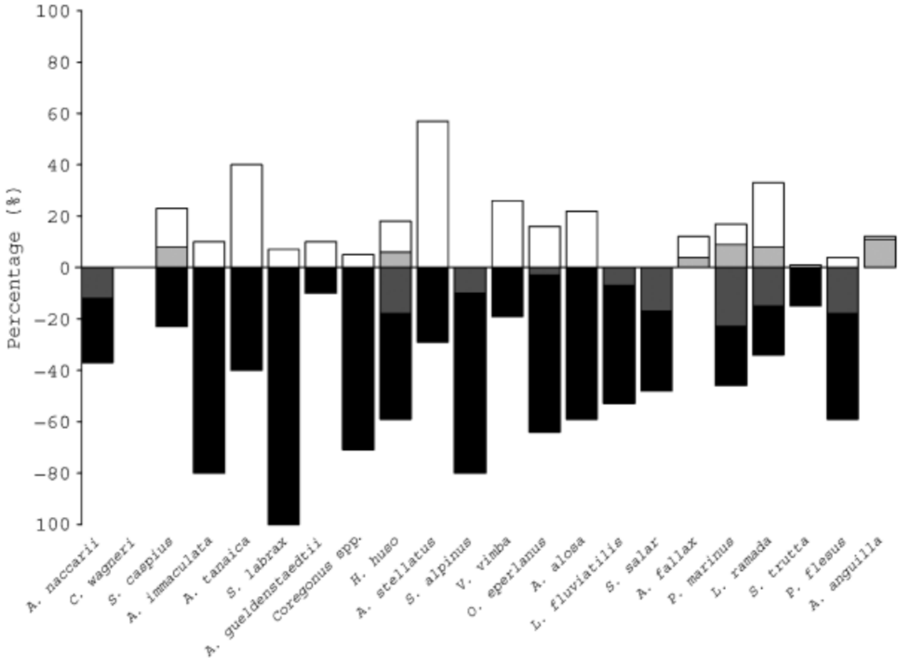


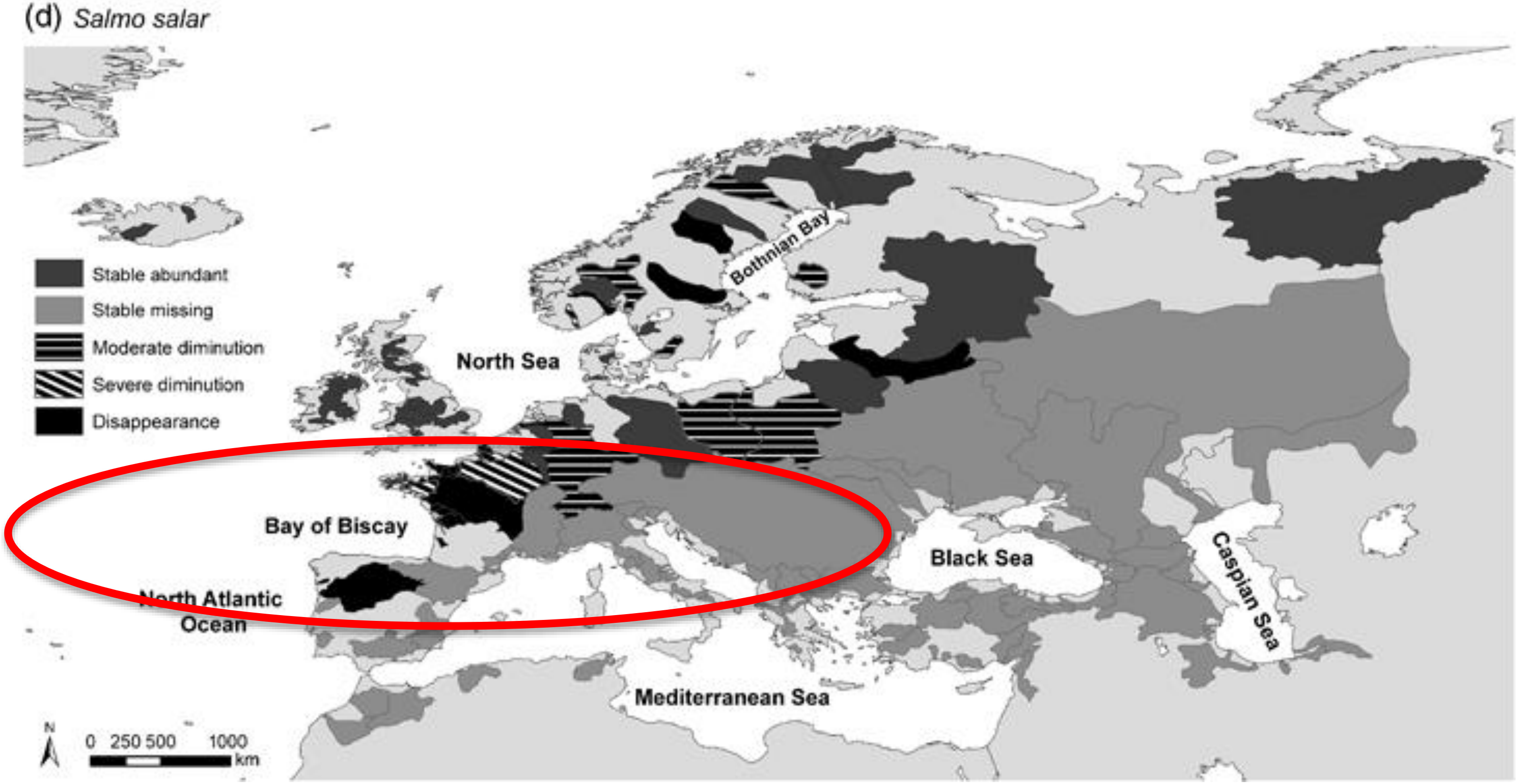
Fig. 2 Changes in distribution predicted for each species by the final models. Light grey and white bars represent increasing abundance and appearance, respectively. Dark grey and black bars represent decreasing abundance and disappearance, respectively. All the percentages correspond to a ratio between the number of changing basins and the number of basins where the species occurred in 1900. Basins for which the model did not succeed in predicting their 1900 abundance were not taken into account in this process. The species were sorted by increasing order according to the size of their 1900 distribution area.

Lassalle *et al*. (2009) *Global Change Biology* **15**: 1072-1089

Future climate change: salmon

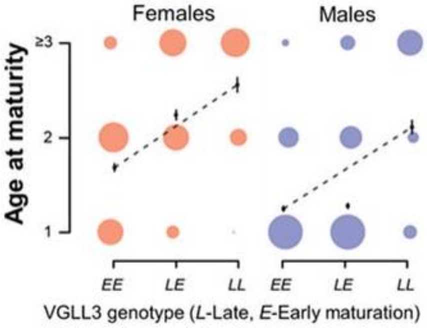
Saumon & Truite de mer
MIEUX CONNAÎTRE.
MIEUX COMPRENDRE.
MIEUX GÉRER.

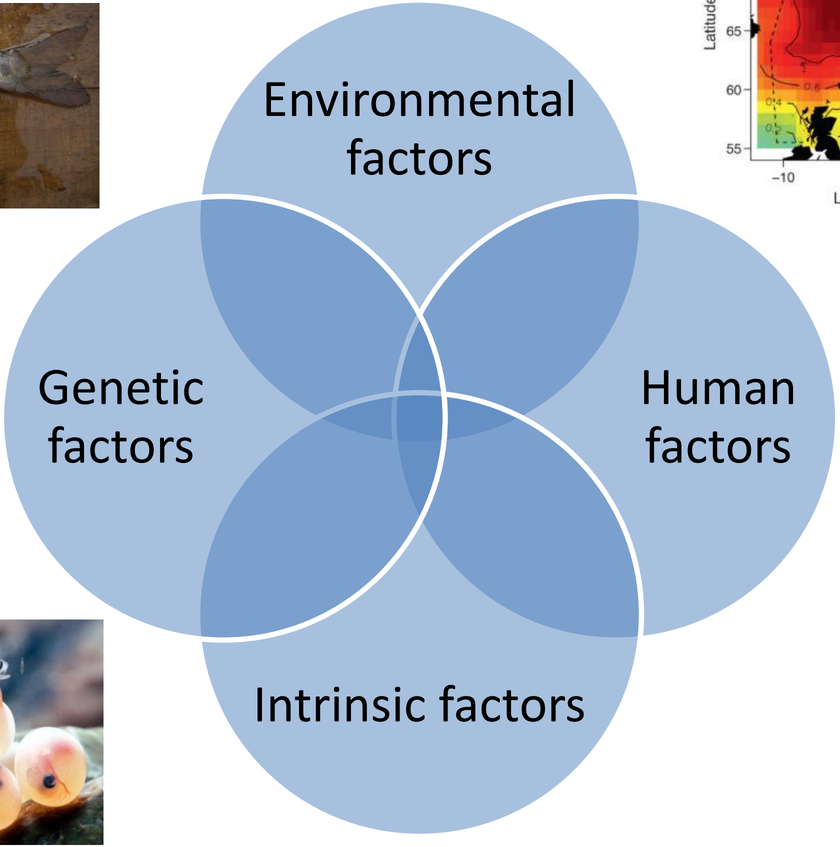
Samarch
FORUM INTERNATIONAL



Lassalle *et al*. (2009) *Global Change Biology* **15**: 1072-1089

Other factors



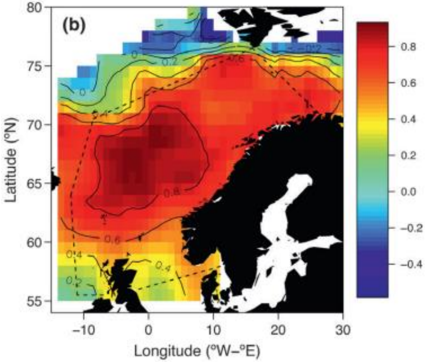


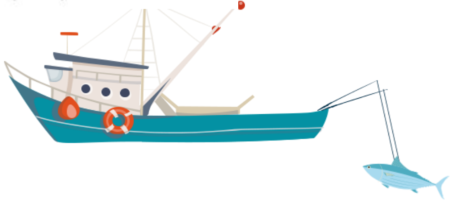
Environmental factors

Genetic factors

Human factors

Intrinsic factors





Saumon & Truite de mer
MIEUX CONNAÎTRE.
MIEUX COMPRENDRE.
MIEUX GÉRER.

Samarch
FORUM INTERNATIONAL

Thanks

INTERNATIONAL
YEAR OF THE SALMON

SALMON
AND
PEOPLE
IN A CHANGING WORLD

INTERNATIONAL
YEAR OF THE SALMON

YEAROFTHESALMON.ORG