

Impact of projected wind and temperature changes on larval recruitment of sole in the North Sea

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Projects & funding:

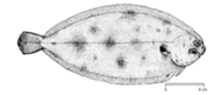
SOLEMOD
WESTBANKS



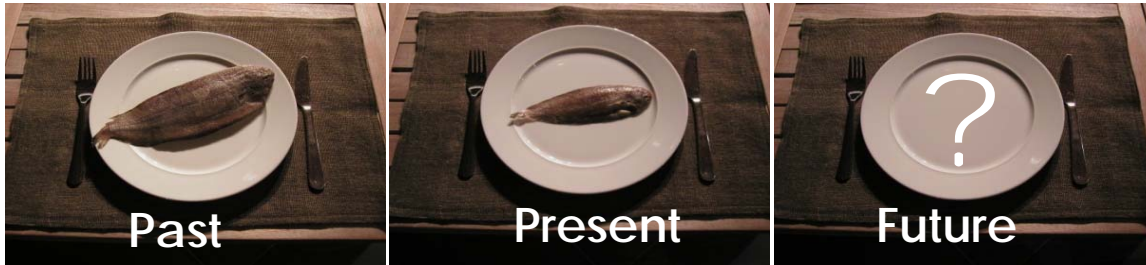
B-FishConnect (FWO)



The sole in the North Sea

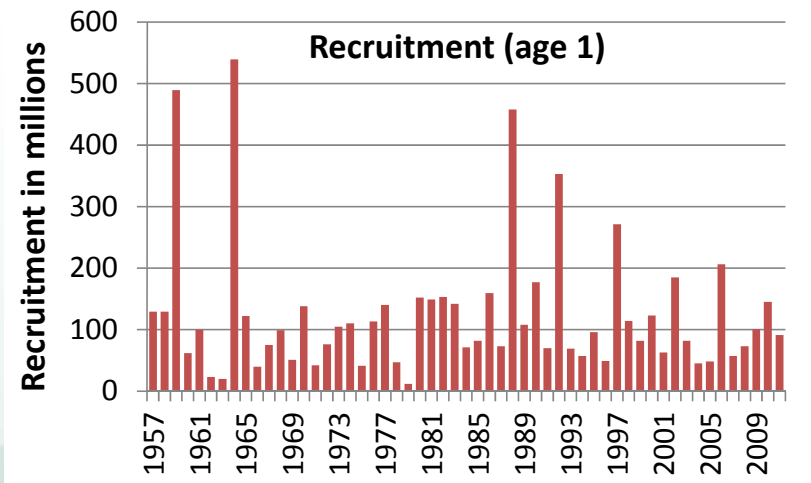


Tasty fish, economic value, high fishing pressure

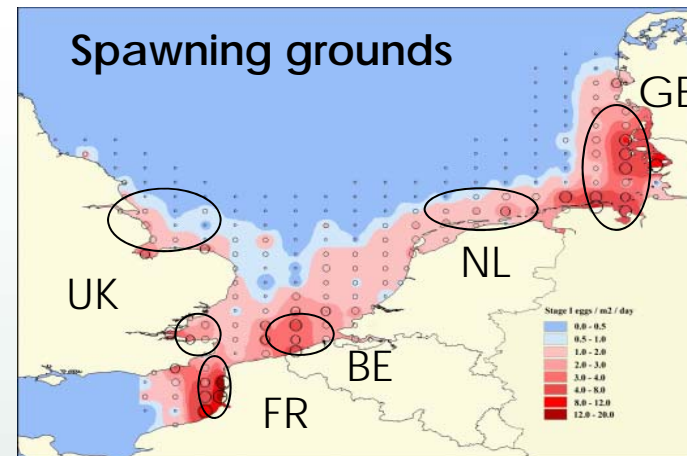


Concern:
Stock management sustainability

Interannual variability

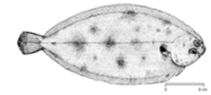


Connectivity?

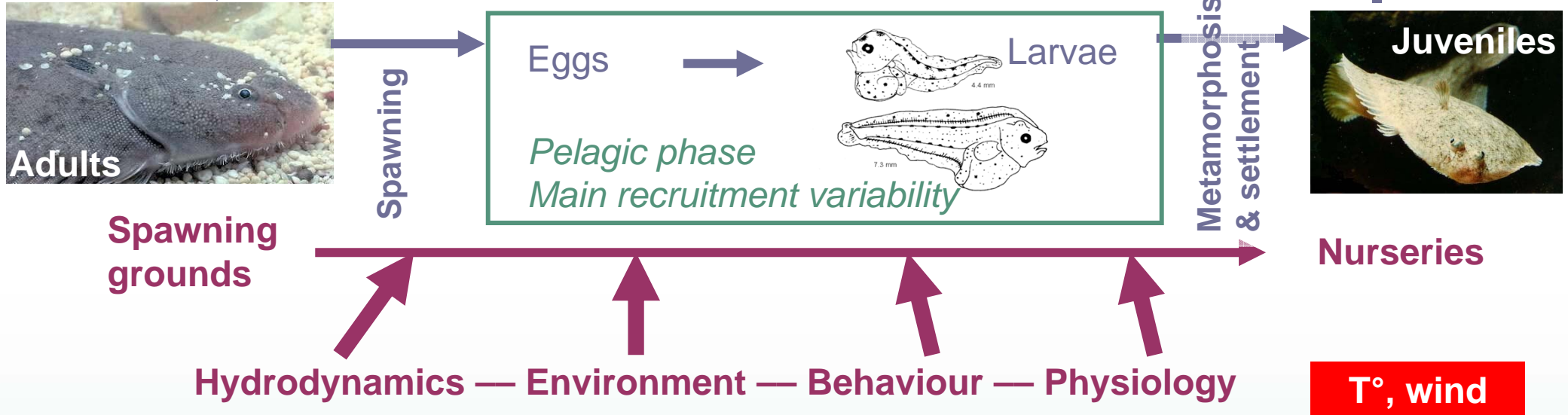


Climate change impact?

Sole life cycle



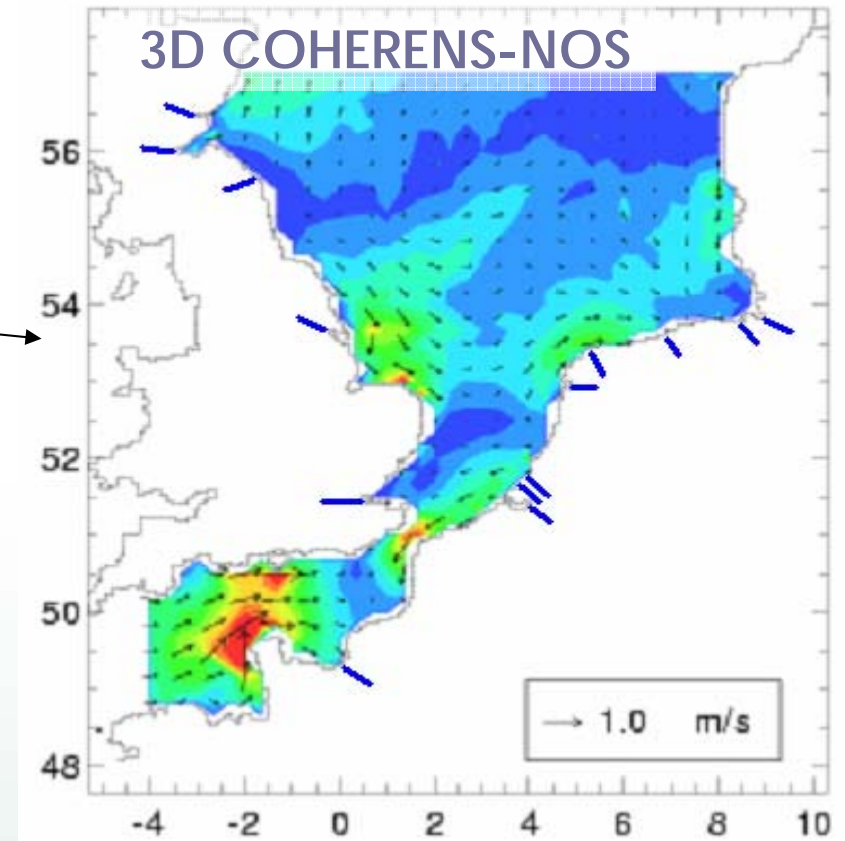
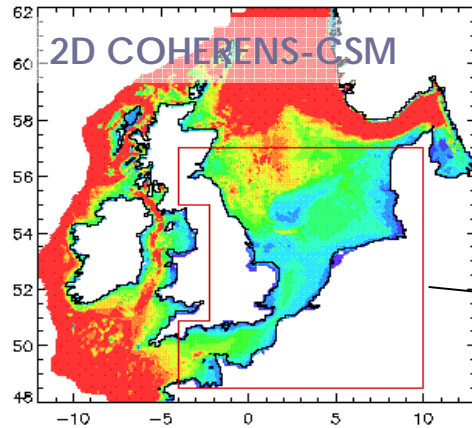
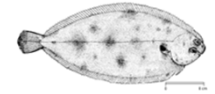
Strength of the age class: Planktonic phase and early demersal juvenile phase



Objectives

- **Impact of CC** on larval dispersal, recruitment at nurseries and connectivity
- **Match-mismatch** between larval food requirement and AB timing
Tool: hydrodynamic 3D model – Lagrangian particle model – IBM
Method: hypothetical changes T, wind / inspired from IPCC scenarios

3D hydrodynamic & particle tracking model



3D hydrodynamic model

- 2.5' (lat) x 5' (lon). 20 sigma-layers
- Currents (tide). diffusion
- Salinity and temperature
- Actual meteo (UKMO). SST (BSH). river flows
- BC from 2D Continental Shelf Model (CSM)

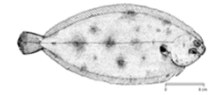
Particle tracking module (IBM)

Advection. vertical diffusion + vertical migration

SOLEMOD v2 [Lacroix et al.. 2013. JSR]

Period:
1995-2011

Individual based model (IBM)

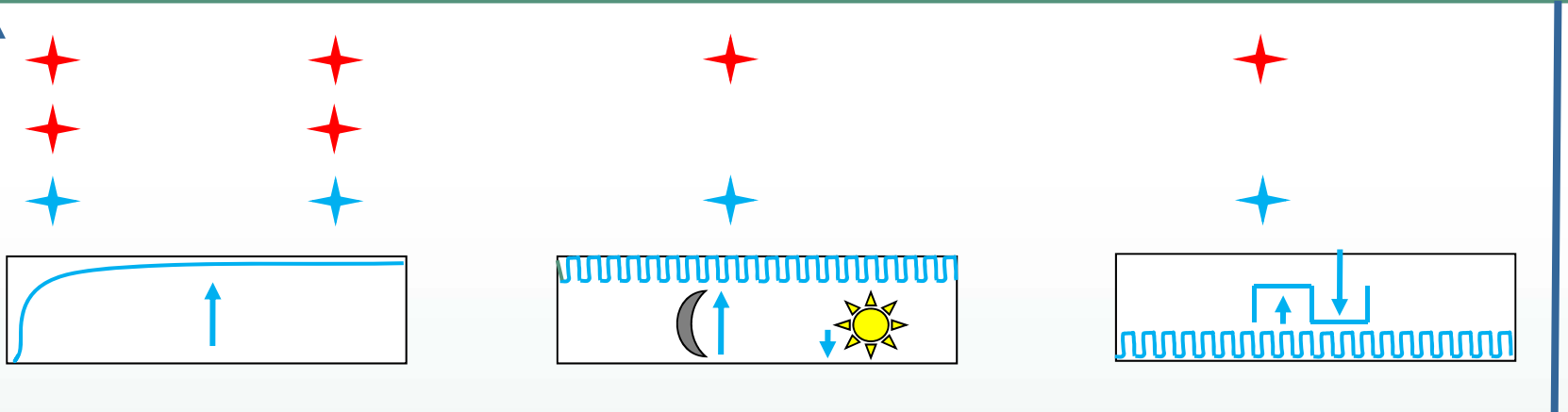


Stage duration

Mortality

Position

Spawning

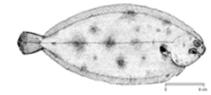


- ★ F(Temperature)
- ★ F(hydrodynamics, vert. migration)
- ★ F(depth, sediment type)

Settlement

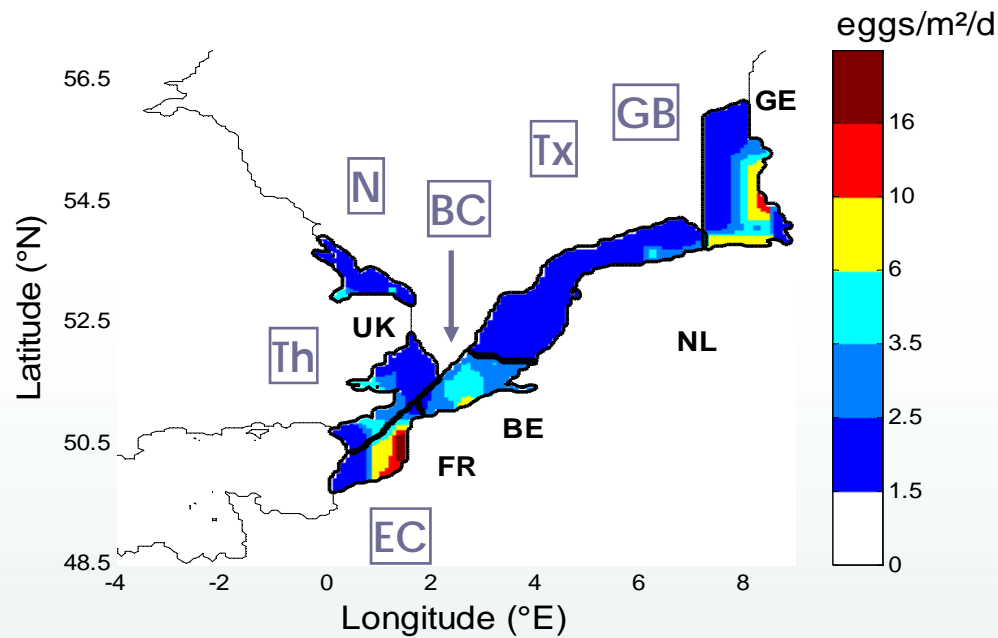


IBM: spawning grounds



6 spawning grounds

3 monthly spawning period, $peak = f(T)$

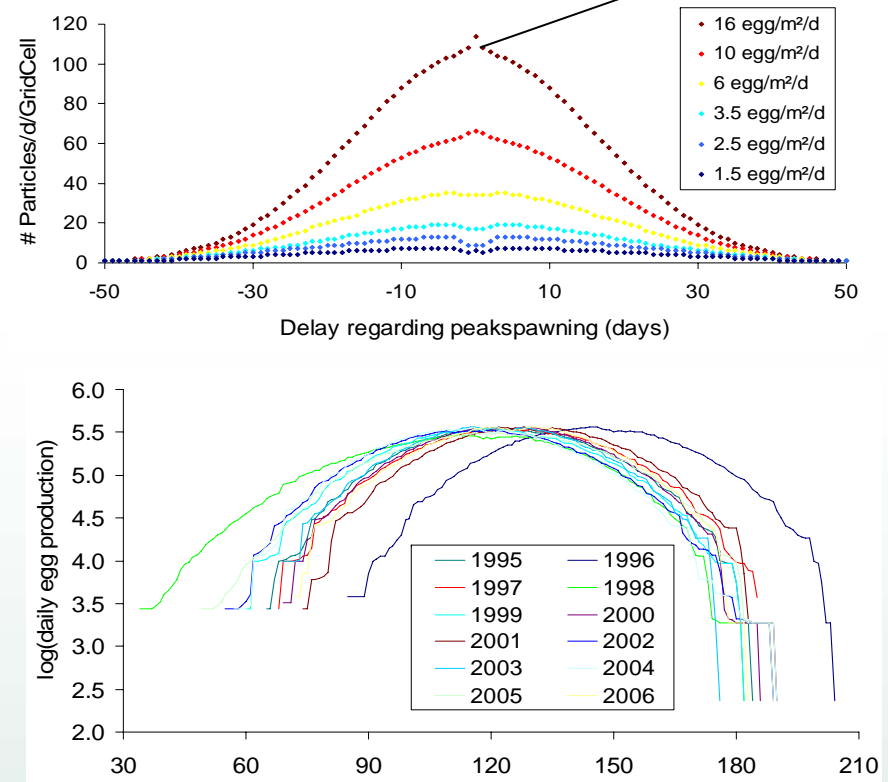


Redrawn from ICES. 2005.
Bolle et. In prep

Spawning grounds: Eastern Channel,
Belgian Coast, Off Texel, German Bight,
Norfolk, Thames

3 monthly spawning period

Peak spawning
1st day 10°C



Superindividuals (10^7 eggs/particle)
#eggs spawned: 1.89×10^{13}

IBM: spawning grounds & nurseries



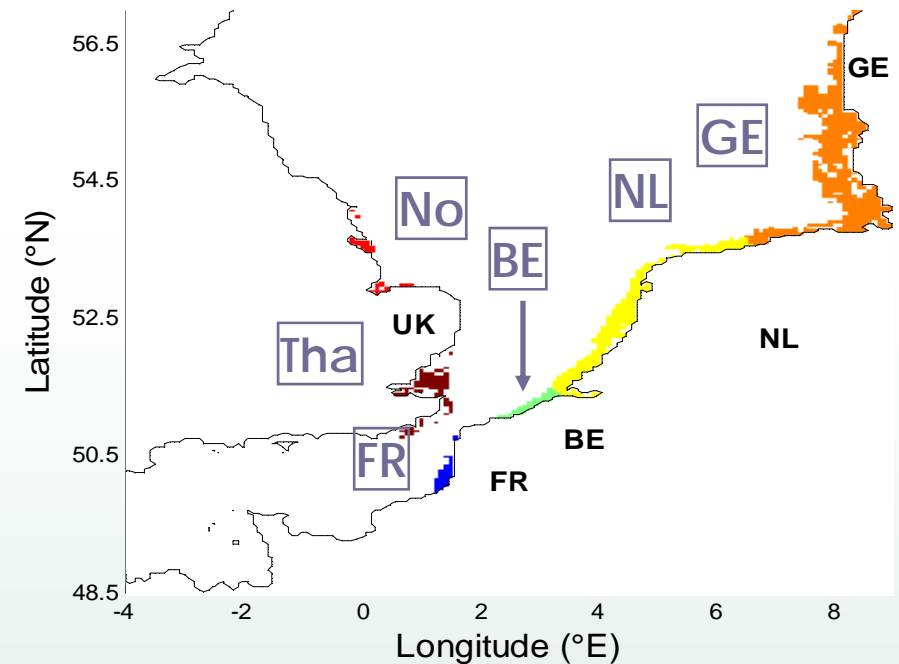
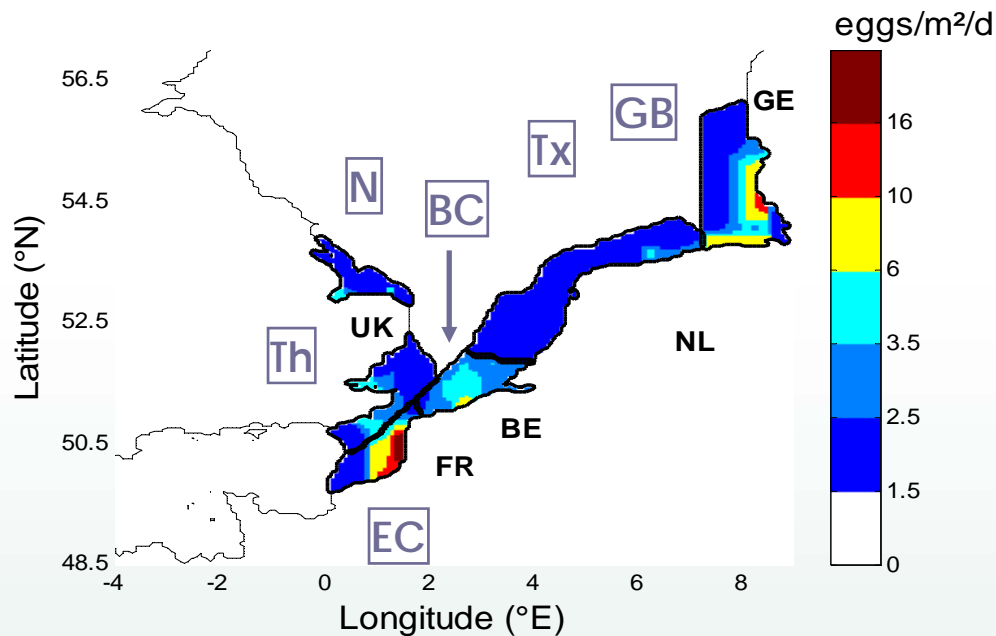
6 spawning grounds

3 monthly spawning period, **peak = f(T)**

6 nurseries

Coastal areas (< 20 m)

High proportion of sand and/or mud

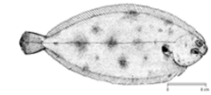


*Redrawn from ICES. 2005.
Bolle et. In prep*

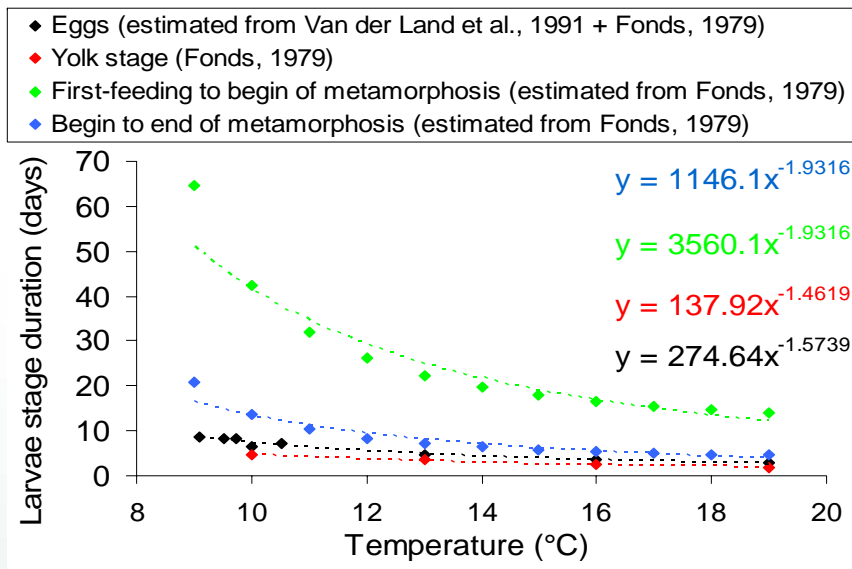
Spawning grounds: Eastern Channel, Belgian Coast, Off Texel, German Bight, Norfolk, Thames

Nurseries: France, Belgium, Netherlands, Germany, Norfolk & Thames (UK)

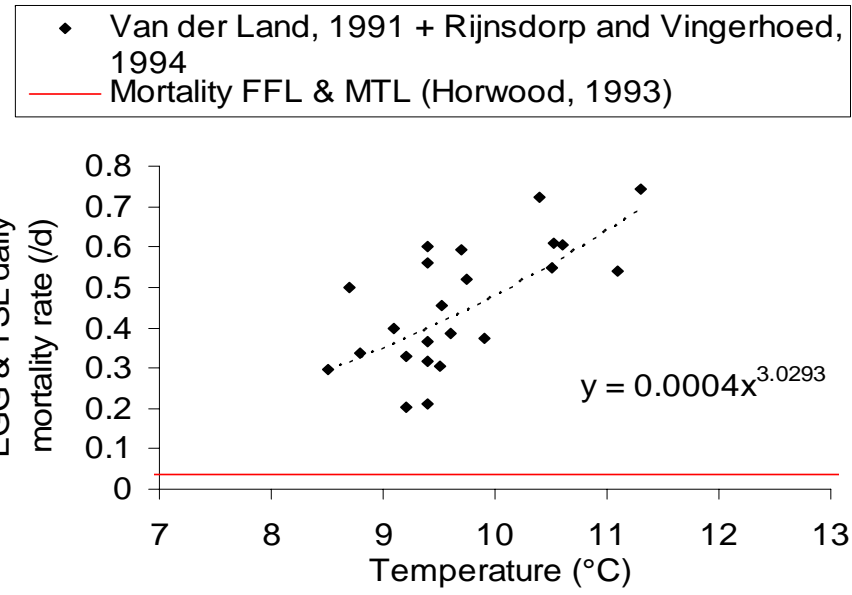
IBM: stage duration & mortality



Larval stage duration = f(temperature)



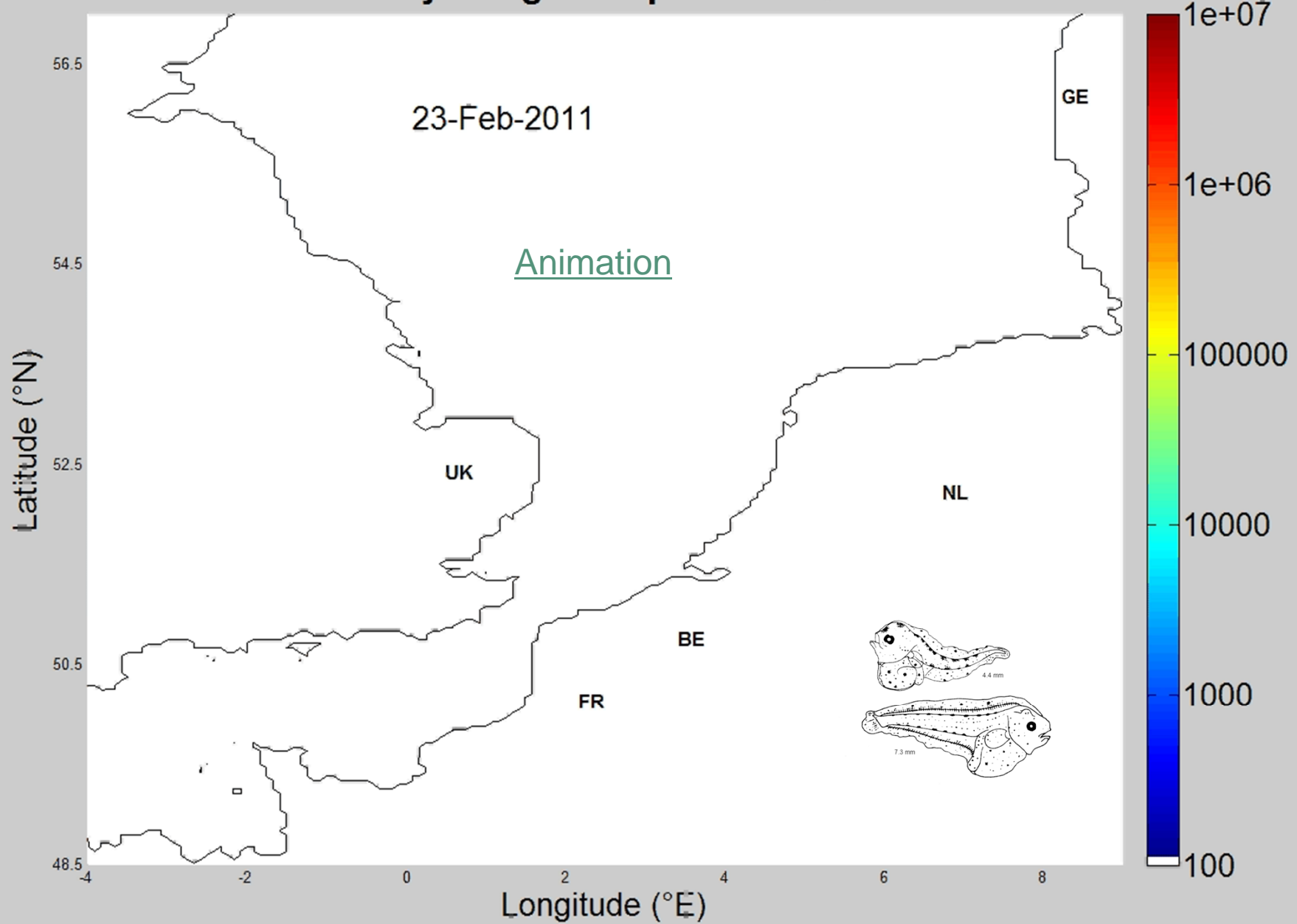
Mortality rate = f(temperature)
Eggs & Yolk larvae



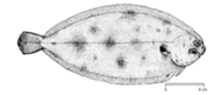
First-feeding larvae (FFL):
between 4 mm & 8 mm

Metamorphosing larvae (MTL):
Between 8 mm & 10 mm

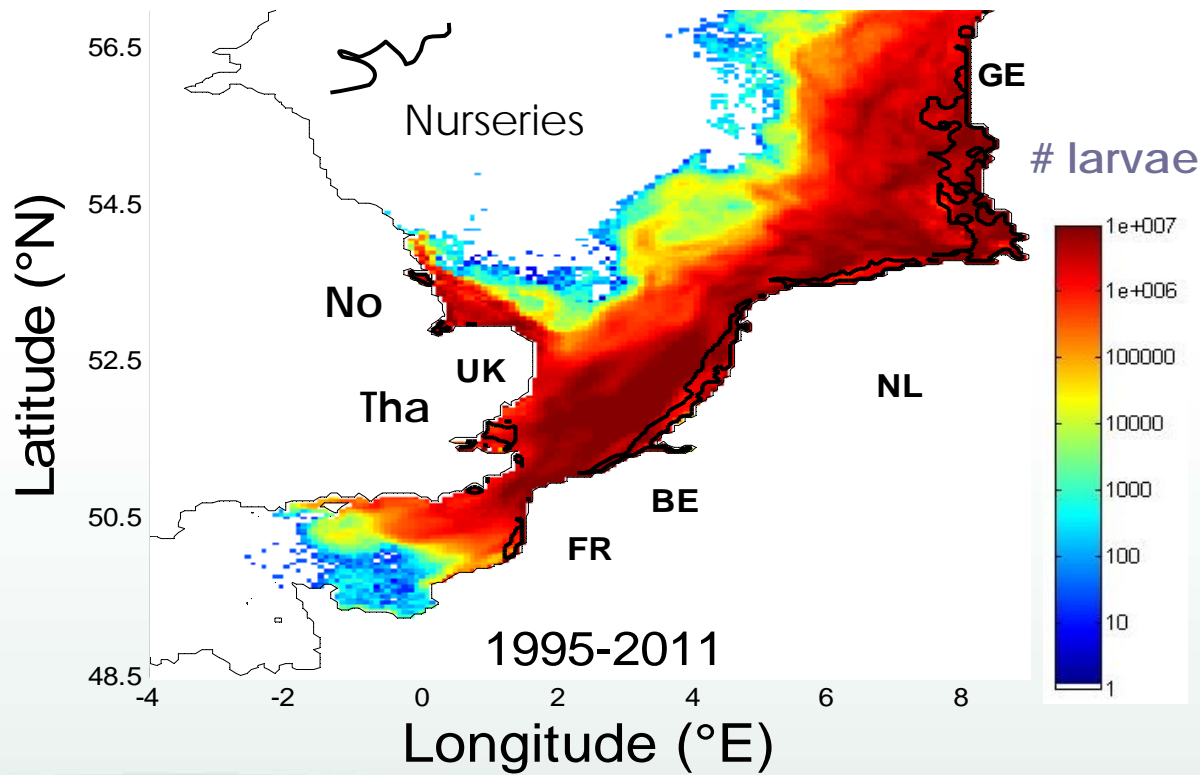
vertically integrated particle number



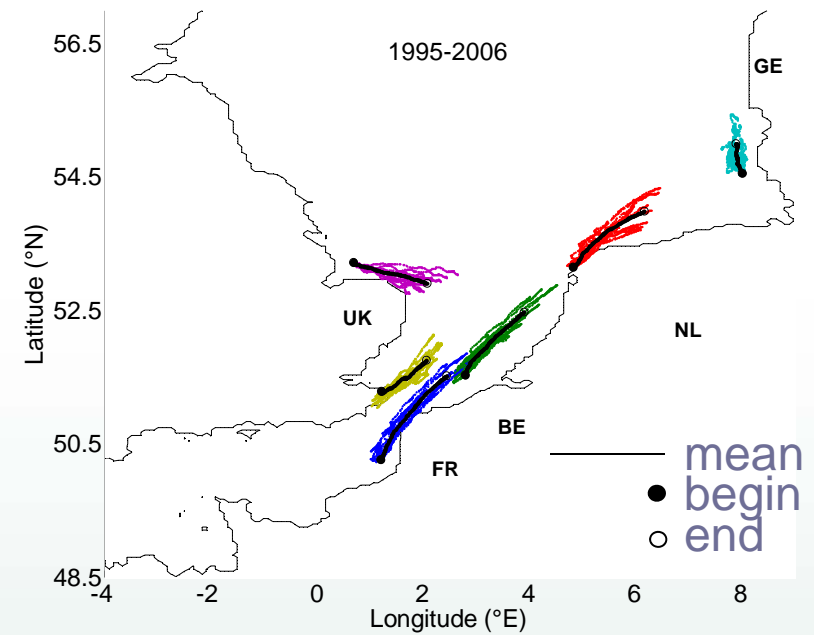
Final dispersal pattern & trajectories



Larval abundance

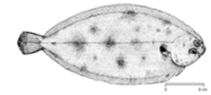


Trajectories of center of mass

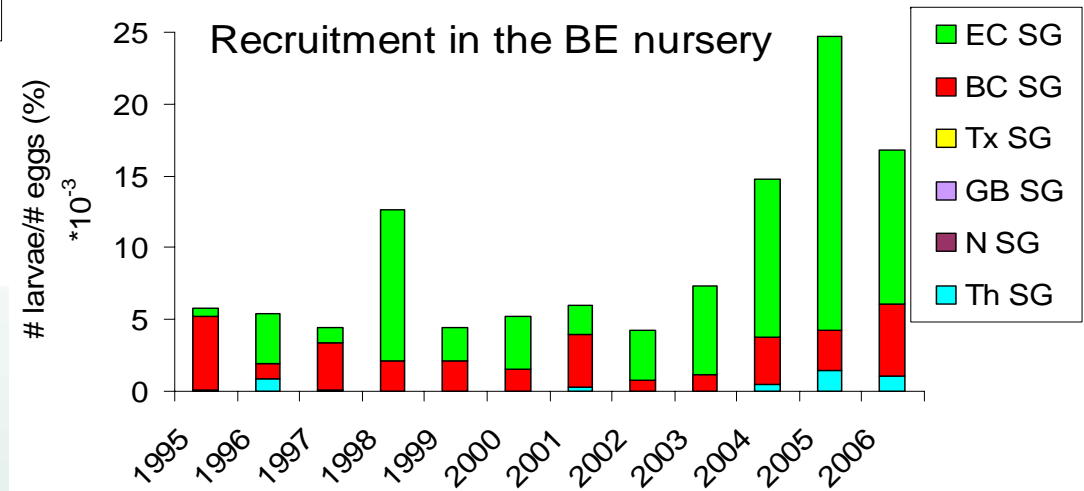
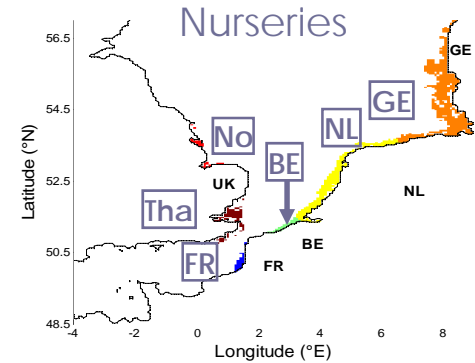
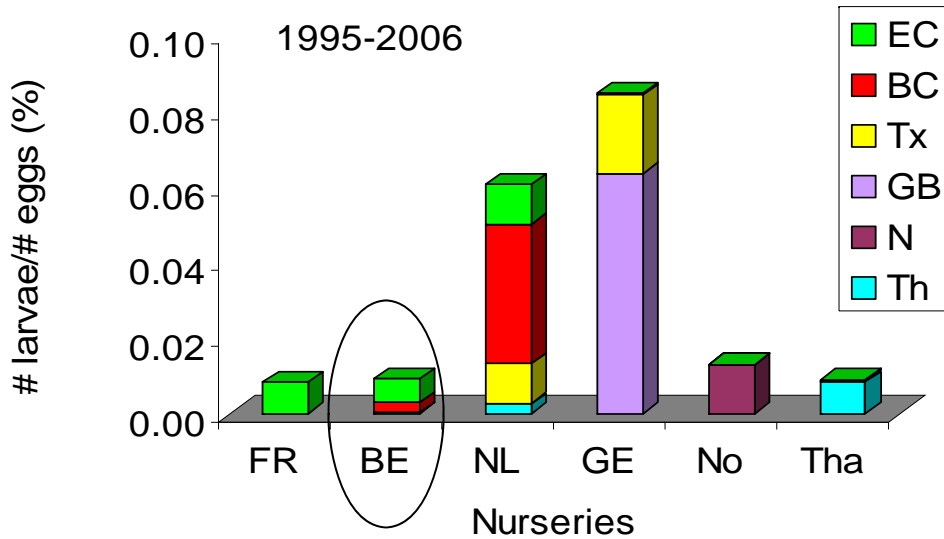


Significant interannual variability of larval dispersal

Larval recruitment & origin of larvae

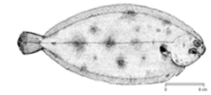


% of larvae at nurseries from different spawning grounds (end of pelagic phase)



Significant interannual variability of recruitment

Scenarios



Reference run

Scenarios inspired from IPCC '2040' (CLIMAR, Van den Eynde et al. 2011)
Expected future changes (T°, wind) on the basis of historical time series & trends (SNS)

Blue SW wind increase (+ 10 % → North ; + 20 % → East)

Green Wind magnitude + 4 %

Yellow SST + 2°C

Orange SST + 2°C & early spawning

Red Climate change 'A' (all perturbations)

Impact on:

Dispersal
(trajectories)

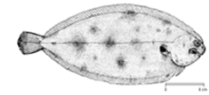
Larval duration

Larval duration
Dispersal

Larval duration
Dispersal

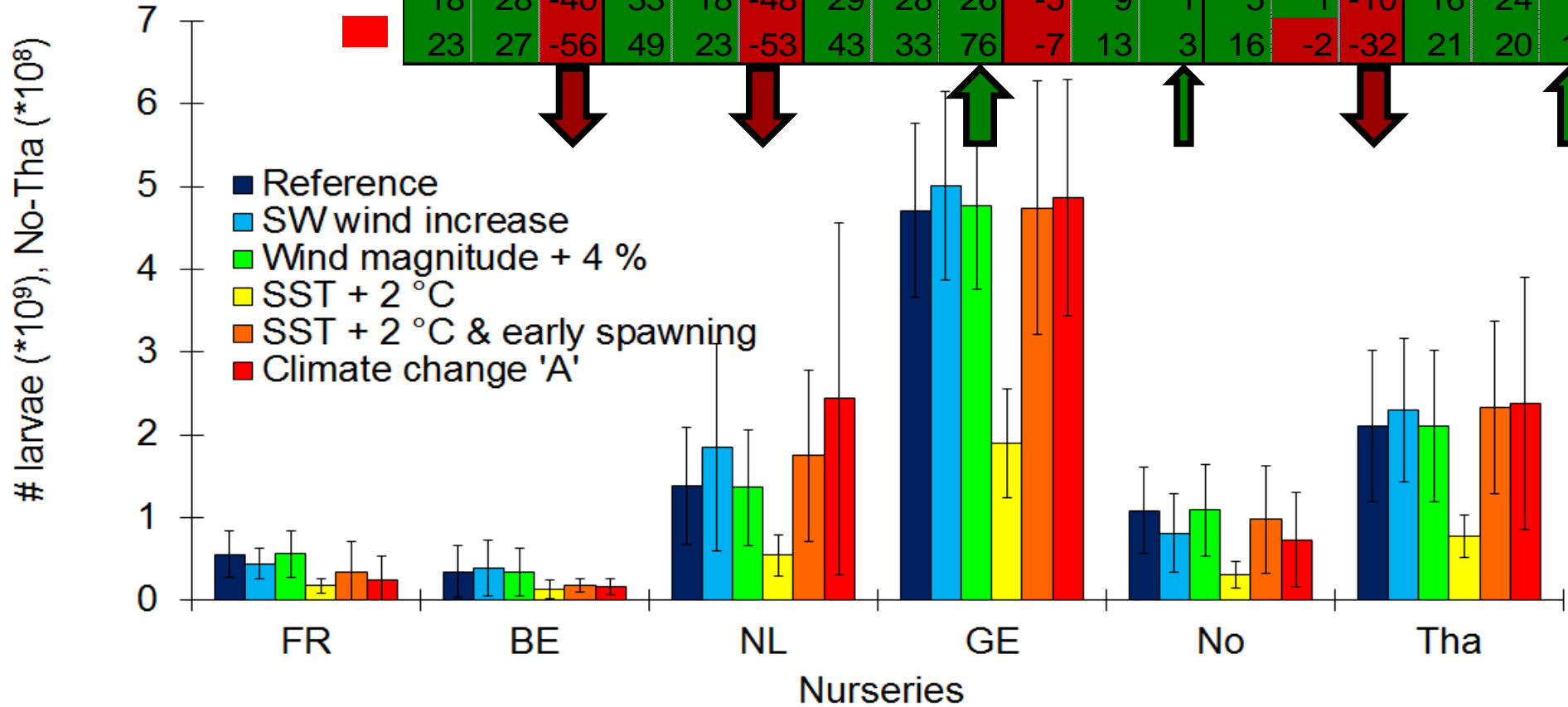
2005-2010

Impact on larval abundance

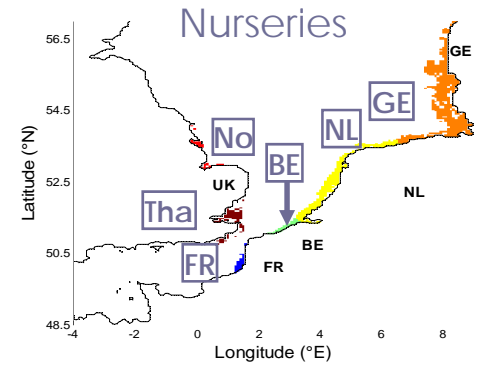
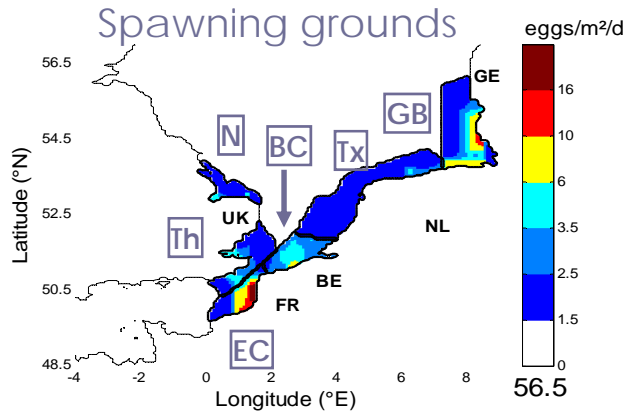
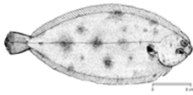


Relative change (%)
Mean 2005-2010

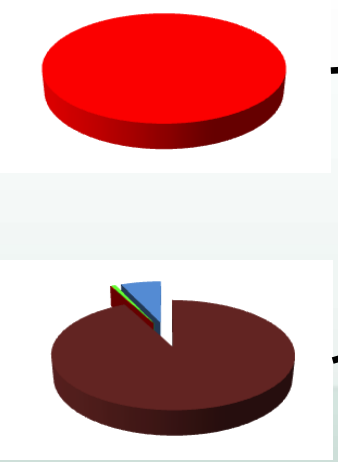
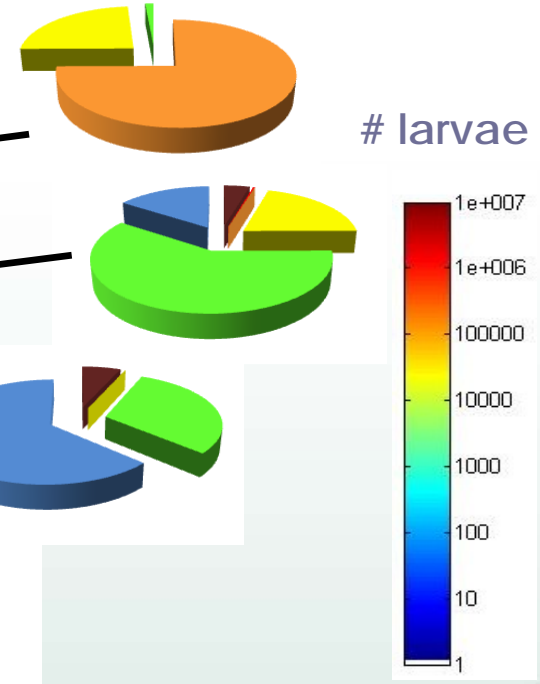
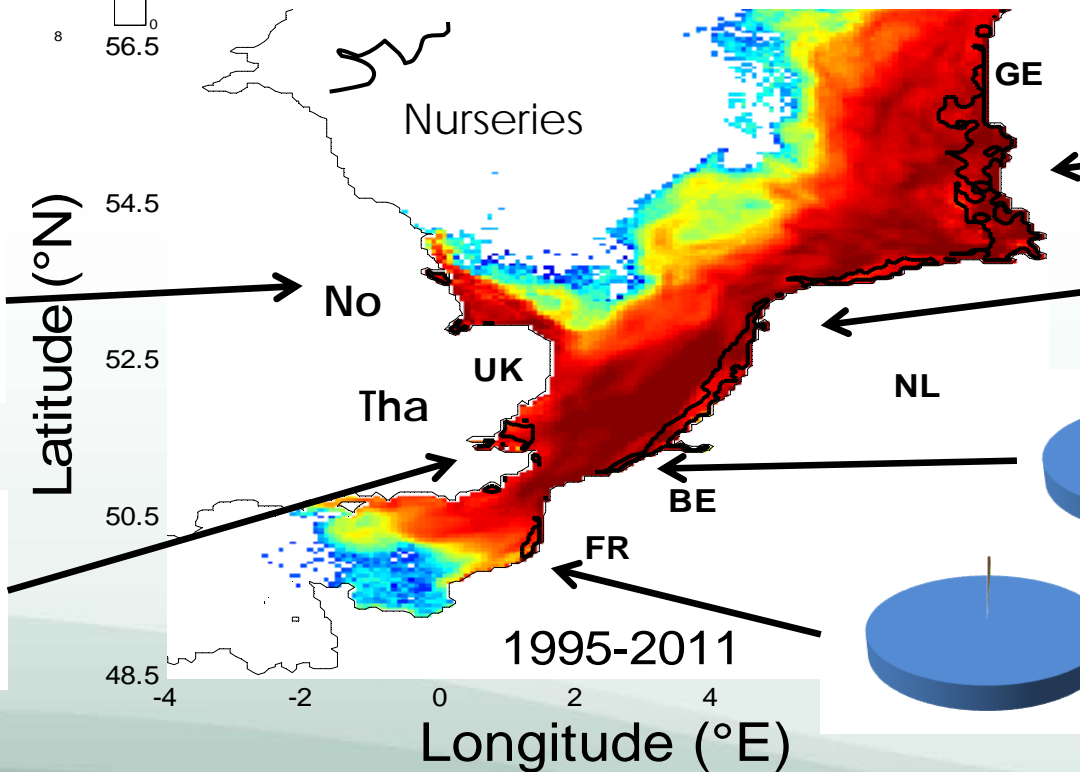
	FR			BE			NL			GE			No			Tha		
	Dist	Dur	R	Dist	Dur	R	Dist	Dur	R	Dist	Dur	R	Dist	Dur	R	Dist	Dur	R
SW wind increase	-6	0	-20	-1	-1	13	4	1	33	11	1	7	14	-1	-25	-5	0	9
Wind magnitude + 4 %	1	0	1	-8	0	-1	3	0	-1	11	0	1	14	-1	1	-2	0	0
SST + 2 °C	-17	-21	-69	-26	-22	-60	-23	-21	-61	-15	-19	-60	-1	-20	-72	-20	-19	-63
SST + 2 °C & early spawning	18	28	-40	33	18	-48	29	28	26	-5	9	1	5	1	-10	16	24	10
Climate change 'A'	23	27	-56	49	23	-53	43	33	76	-7	13	3	16	-2	-32	21	20	13



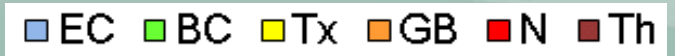
Origin of the larvae



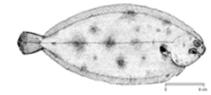
Final dispersal pattern



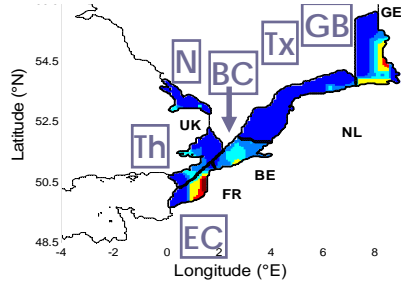
Origin



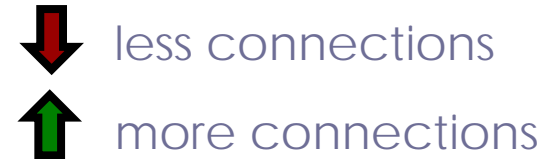
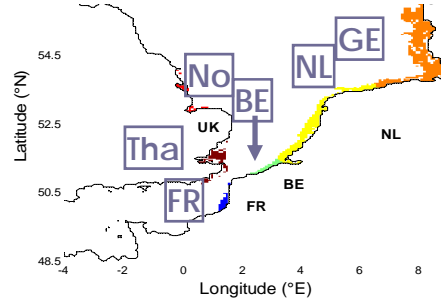
Connectivity



Spawning grounds



Nurseries



Reference

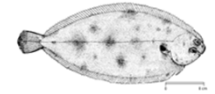
2003-2011

Climate change 'A'

	FR	BE	NL	GE	No	Tha
Th	7	9	9	0	0	9
N	0	0	3	0	9	6
GB	0	0	1	9	0	0
Tx	0	7	9	9	0	0
BC	2	9	9	7	0	9
EC	9	9	9	1	0	9

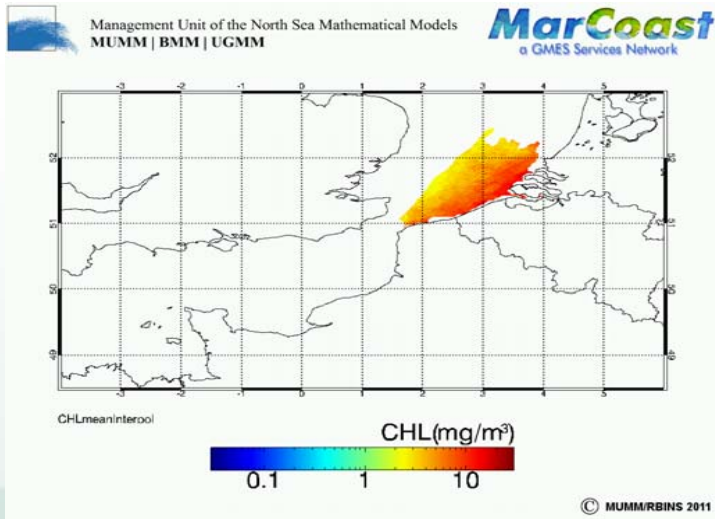
	FR	BE	NL	GE	No	Tha
Th	2 ↓	8 ↓	9	5 ↑	0	9
N	0	0	3	1 ↑	9	5 ↓
GB	0	0	1	9	0	0
Tx	0	4 ↓	9	9	0	0
BC	1 ↓	9	9	9 ↑	0	7 ↓
EC	9	9	9	9 ↑	0	9

Match-mismatch



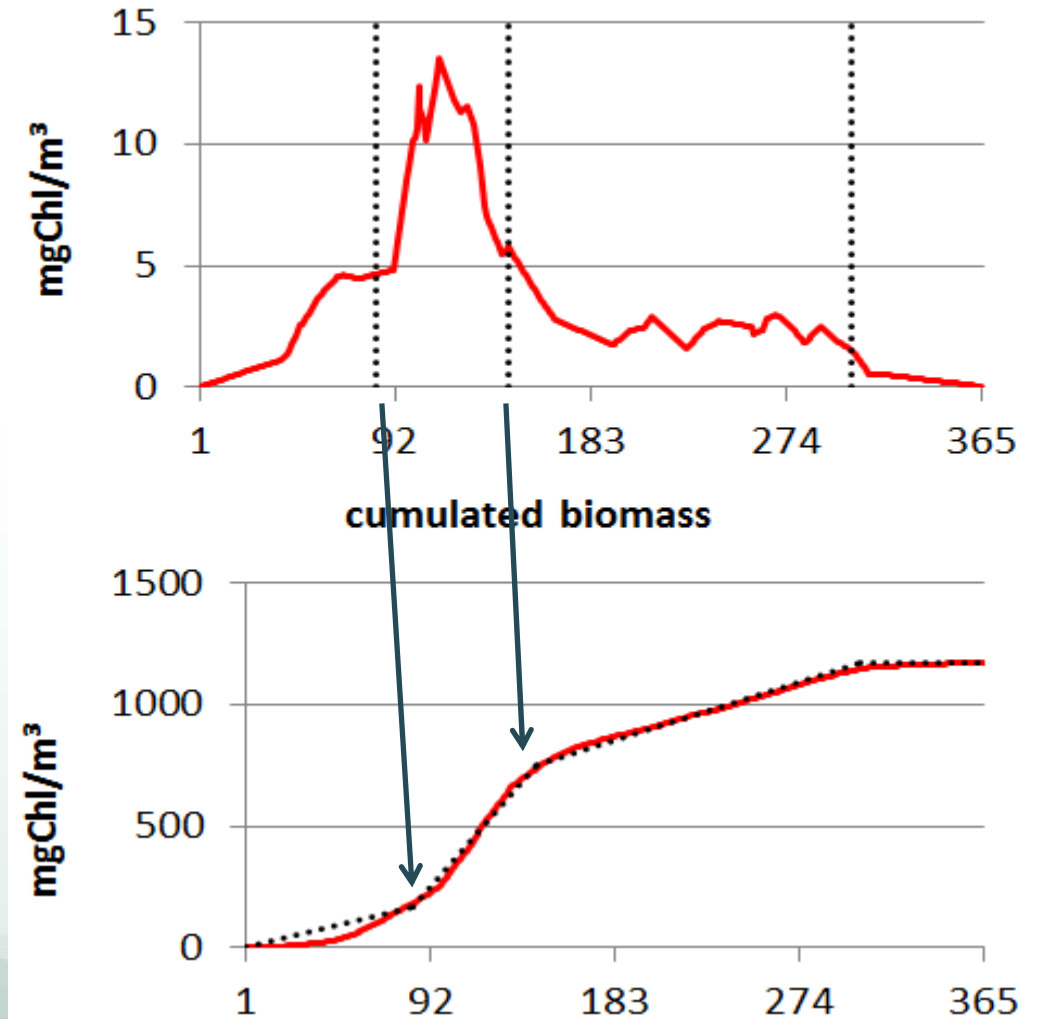
AB timing as a proxy

1. Mean chl *a* (area: mean # larvae > 10⁷)
2. Annual chl *a* time series
3. AB phenology (piecewise linear regression, Muggeo 2008)

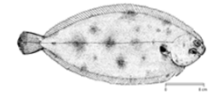


2008, larval area BC

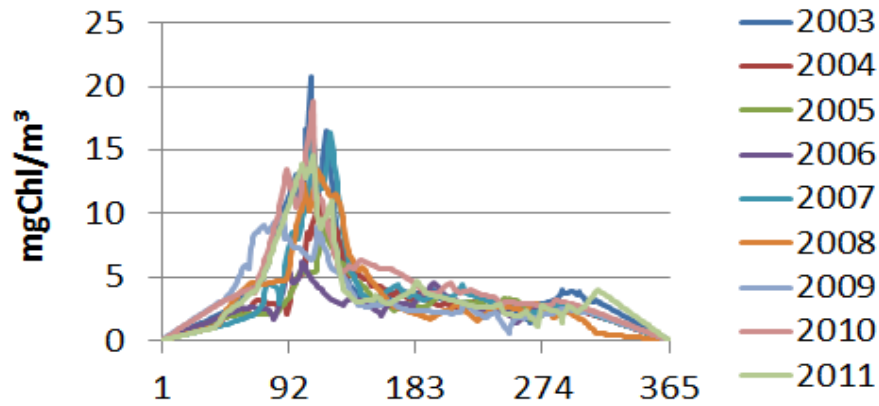
Mean chlorophyll on 'larval area BC'



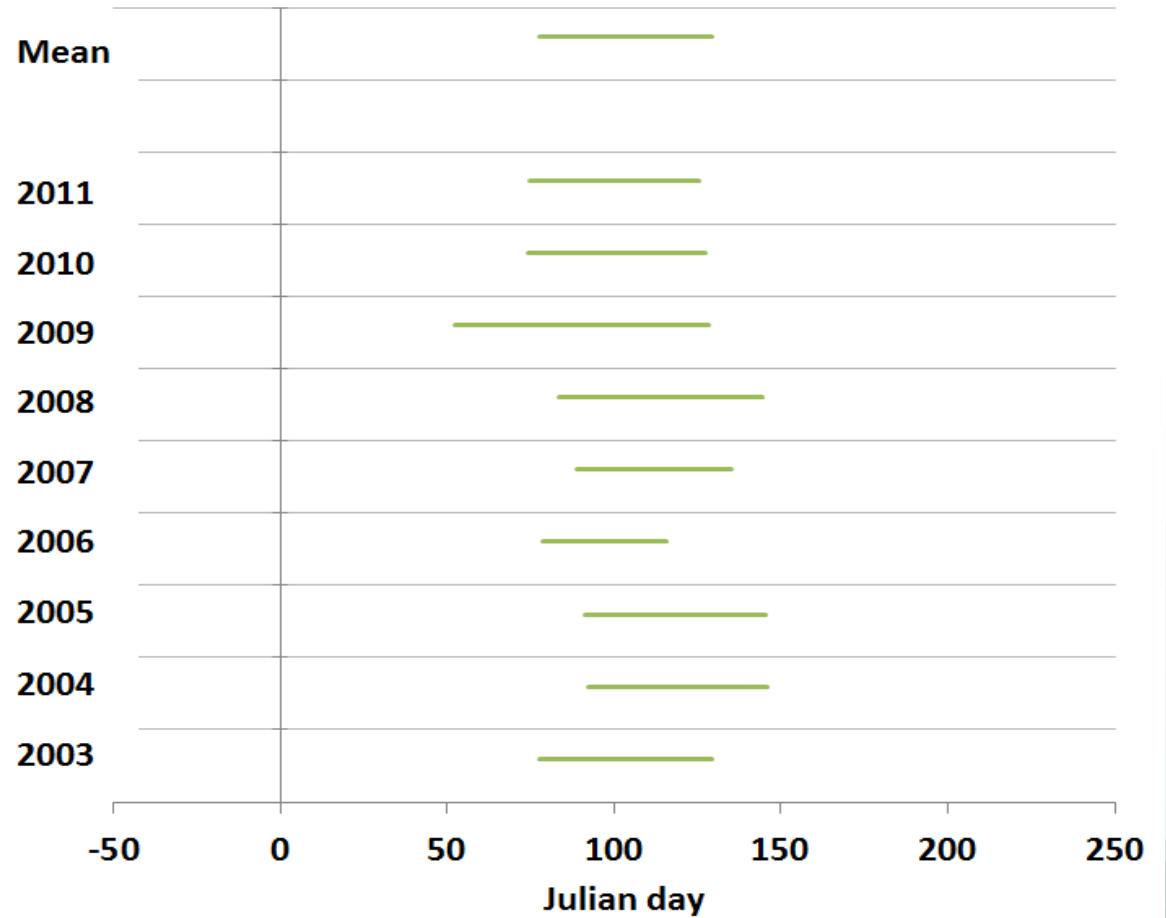
Match-mismatch



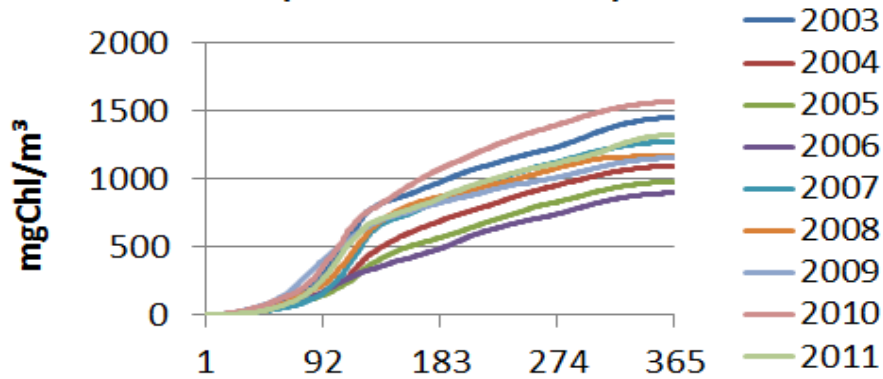
Mean chlorophyll on 'larval area BC'



— AB period (piecewise linear regression, Muggeo, 2008)



Mean chlorophyll 'larval area BC' (cumulated biomass)



Match-mismatch



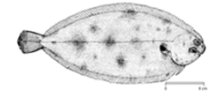
Larval food requirement =
'First-feeding larvae' period

AB, proxy for food
(early life stage)

Reference run



Match-mismatch



Larval food requirement =
'First-feeding larvae' period

AB, proxy for food
(early life stage)

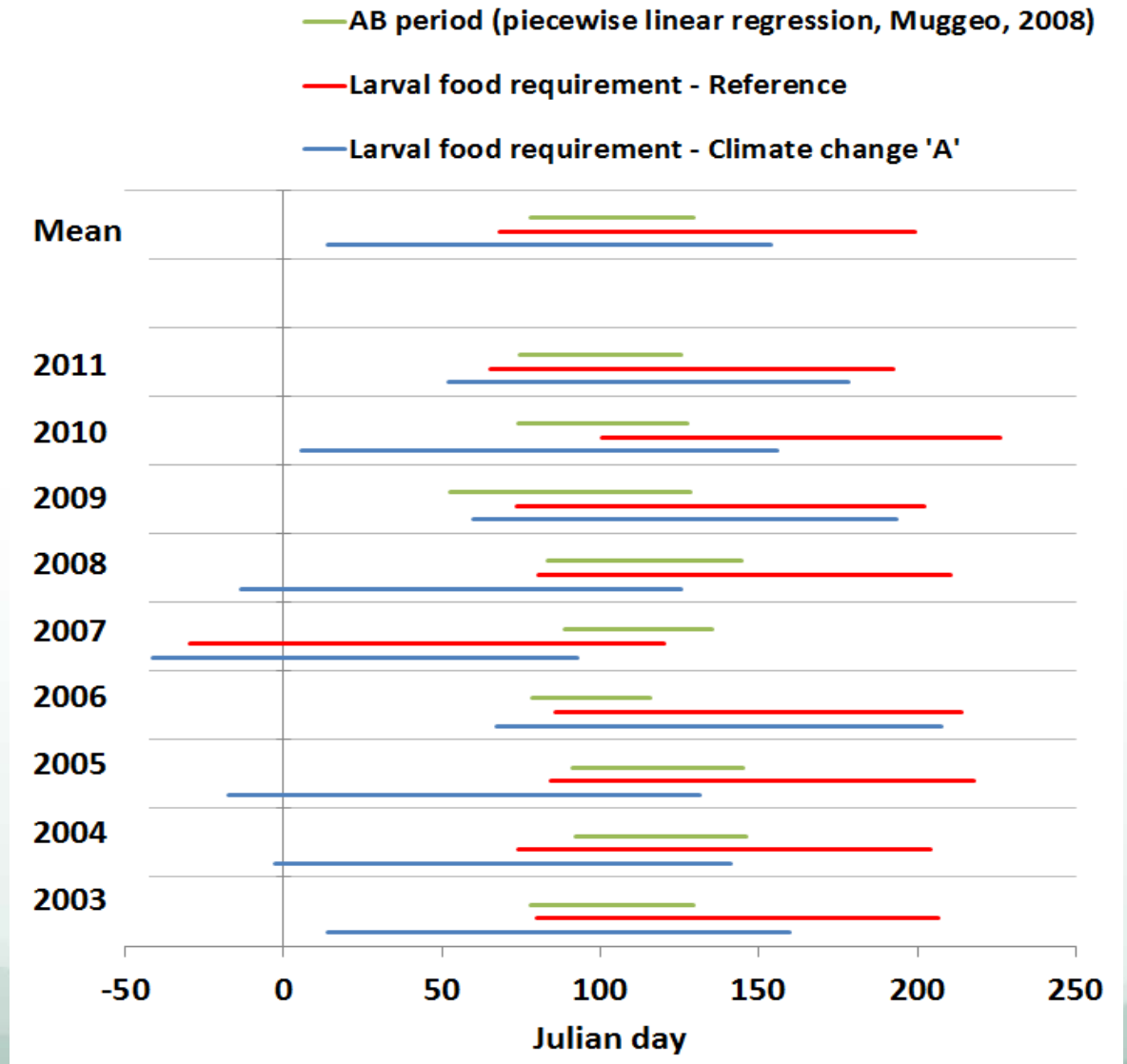
Reference run

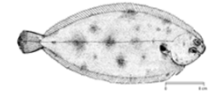
Climate change 'A'

Early spawning

→ increase mismatch?

→ More mortality?





Impact of CC (wind & T increase)

→ Larval recruitment at nurseries



FR, BE, No



NL, GE, Tha

→ Connectivity



FR, BE, Tha



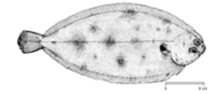
GE

From AB timing (proxy for food)

→ Increase of mismatch between food & larval food requirement

→ Increase of mortality?

But impact of CC on AB timing not taken into account



We have a tool (*Lacroix et al., 2013*)

- Study the causes of interannual variability
Hydrodynamics — Environment — Behaviour — Physiology
- Scientific support for fisheries management
larval recruitment, connectivity
- Future applications
 - Sensitivity analysis (behaviour), scenarios (CC, new hard structures)
 - Other species (ex. brill, plaice, turbot)

But needs accuracy, ecological significance

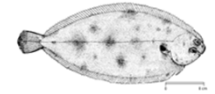
→ Improvements & future developments



B-FishConnect (2013-2016)
PhD Léo Barbut



Acknowledgements



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Questions?