Using modelling to investigate effects of climate warming on the reproduction of the Pacific oyster *C. gigas* in the bay of Brest: from 1960 to 2100

Mélaine Gourault - PhD

S. Petton, Y. Thomas, L. Pecquerie, G. Marques, C. Cassou, E. Fleury, YM. Paulet, S. Pouvreau.

5th International Symposium on DEB – 01/06/2017 – Tromsø

Climate change

- Increasing global mean temperature
- Ocean acidification (OA) and sea level
- Changes in climate variability (rainfall patterns, wind and hydrodynamic regimes…)

Physiology

Climate change

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Physiology

Abundance / Distribution

Climate change

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Physiology

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Phenology

Climate change

- Increasing global mean temperature
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Physiology

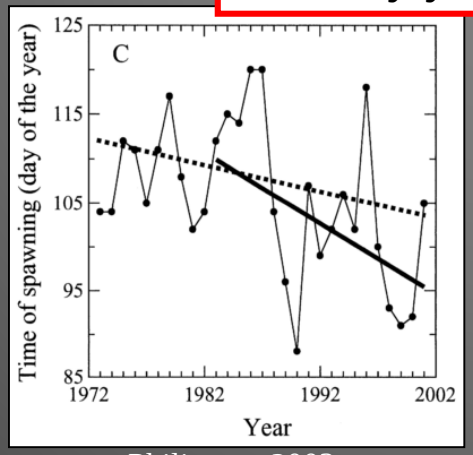
Abundance / Distribution

Phenology

Date of spawning

- 0.5 day/yr

Macoma balth.

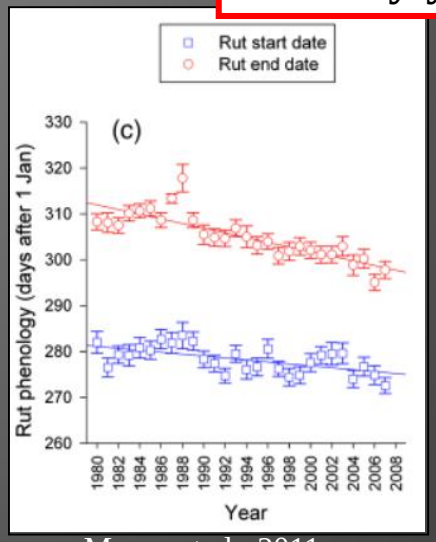


Philippart, 2003

Date of slab

- 0.2 day/yr

C. elaphus

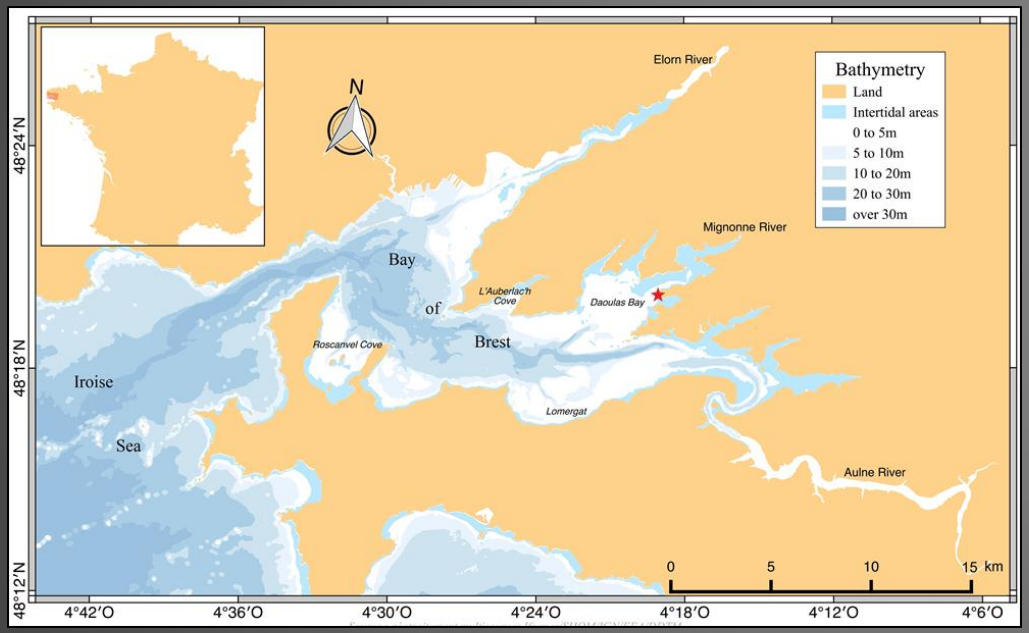


Moyes et al., 2011

Introduction

C. gigas

Filter feeder bivalve
Economic interest
Introduced in the 70's
Invasive



Bay of Brest = Northern site with very abundant wild biogenic oyster reefs (in France)

Introduction

C. gigas

Filter feeder bivalve
Economic interest
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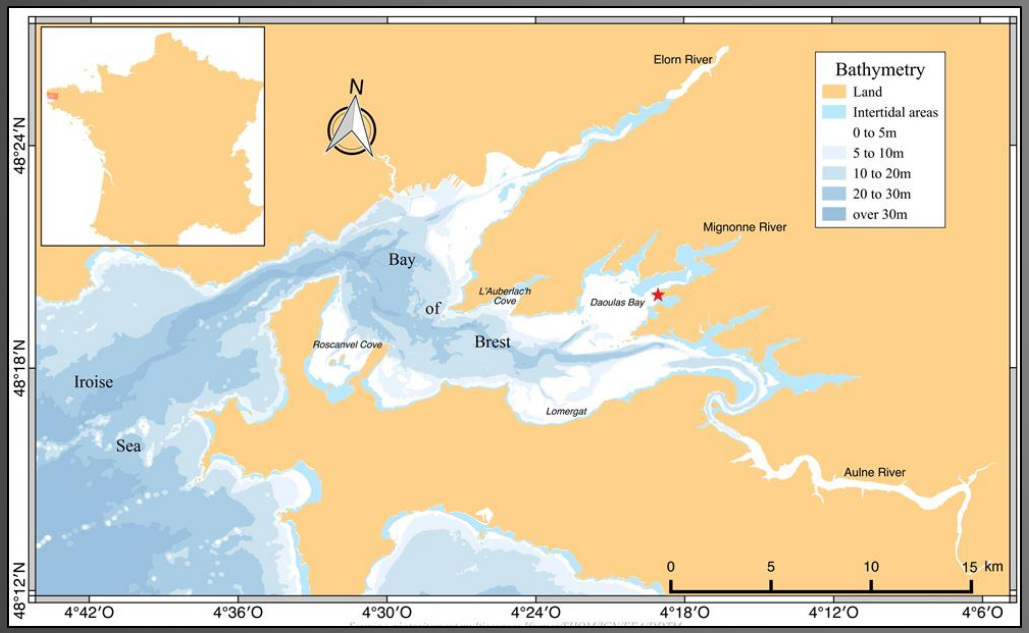
Any past, present, future changes in the spawning phenology of *C. gigas*?



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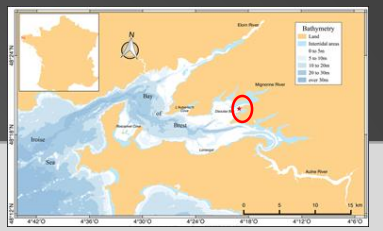
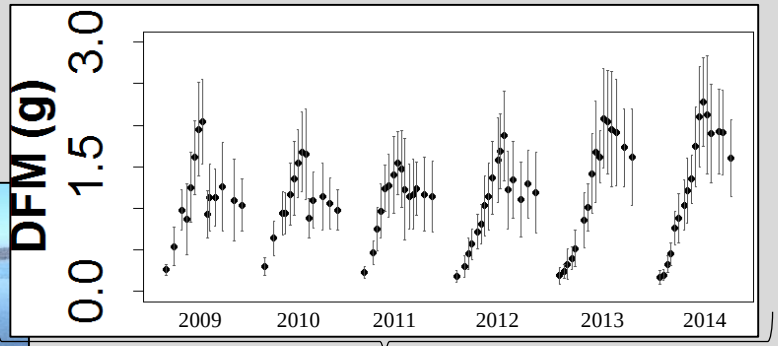
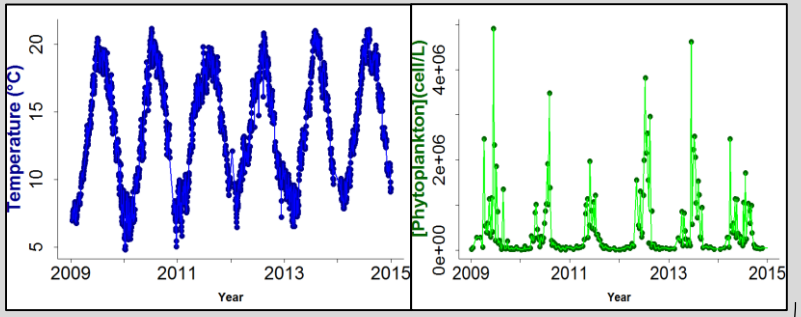
1- Validation



RESCO-VELYGER monitoring

Adult oysters





Biological data

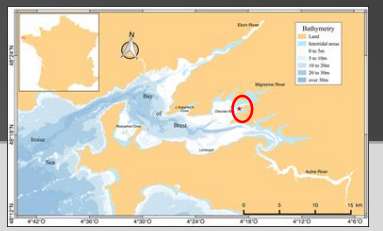
Gametogenesis / Spawning / Fecundity

Environmental data

Temp. : daily measurements

Phyto. : 1 to 4 counting per month

1- Validation



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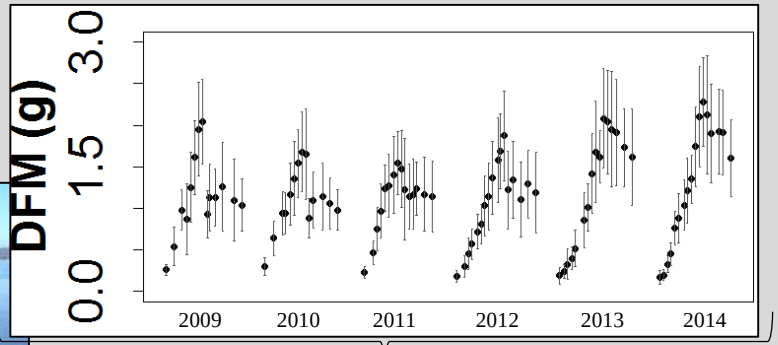

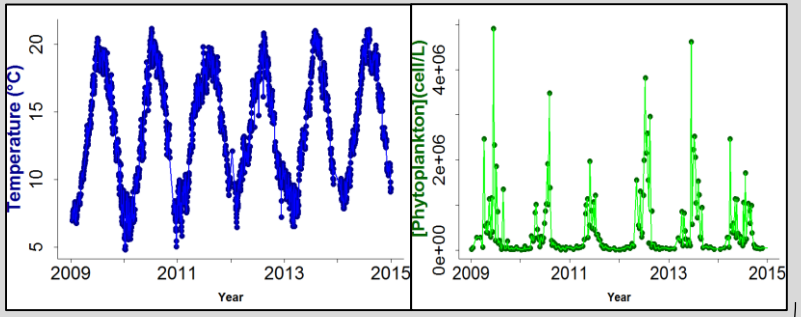

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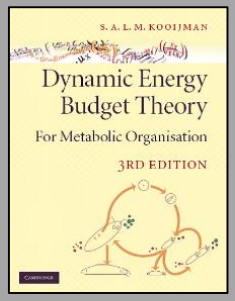
DEB *C. gigas* literature



2001

Ren et al., 2001

Van der veer et al., 2006

Pouvreau et al., 2006

Ren et al., 2008

Bourles et al., 2009

Rico-Villa et al., 2010

Alunno-Bruscia et al., 2011

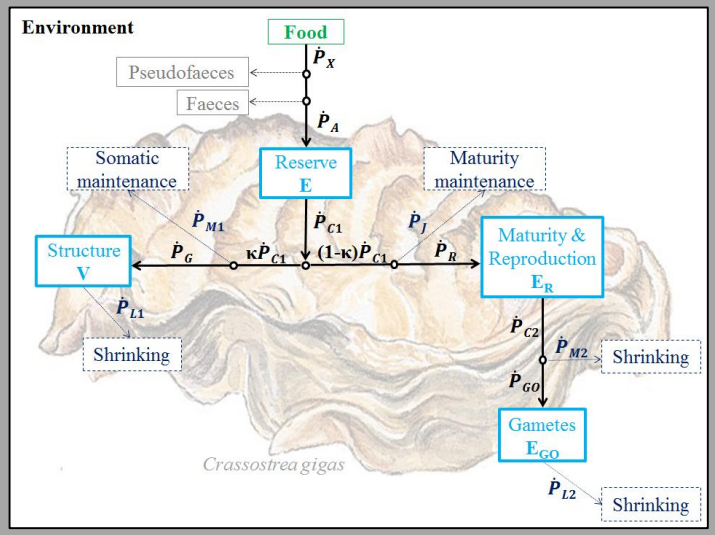
Barillé et al., 2011

Bernard et al., 2011

Emmery et al., 2011

Thomas et al., 2016

2016



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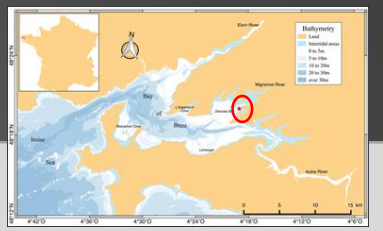

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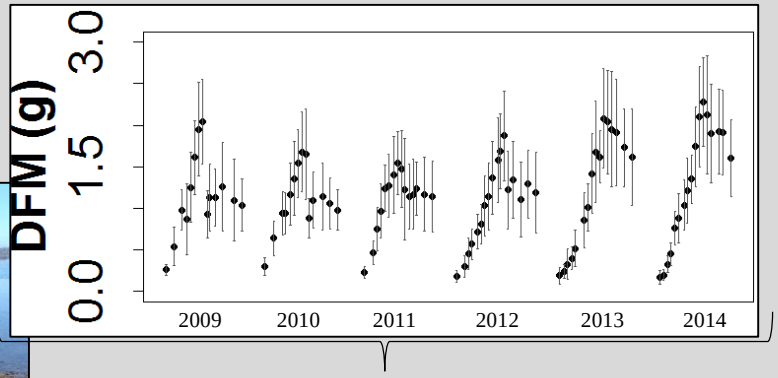
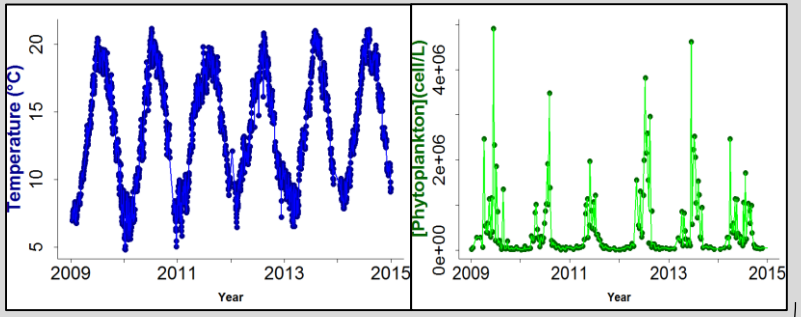
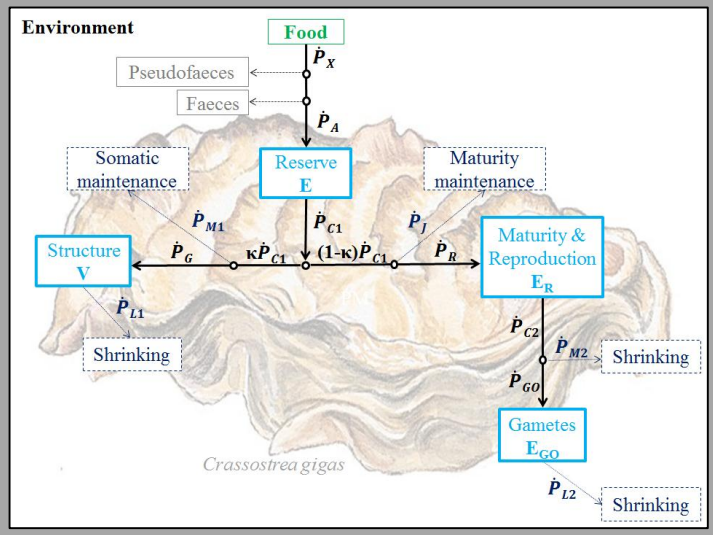
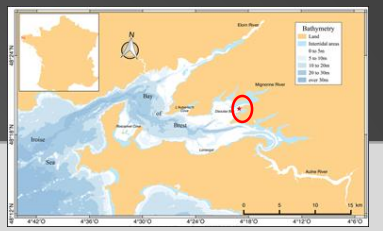




Forcing variables

DEB *C. gigas* literature





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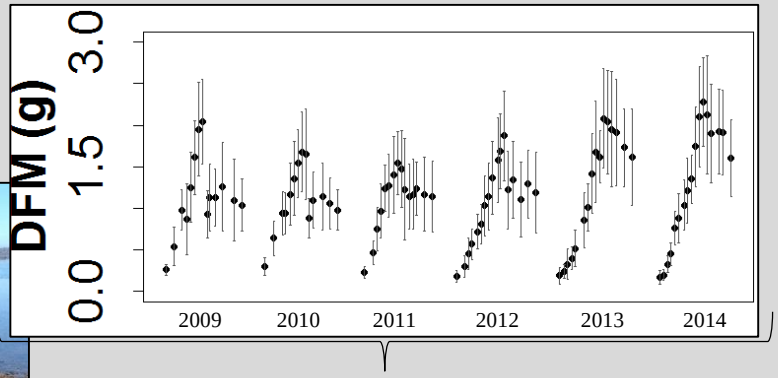
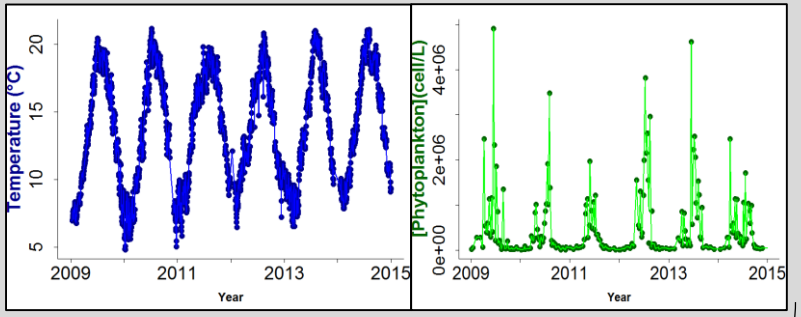
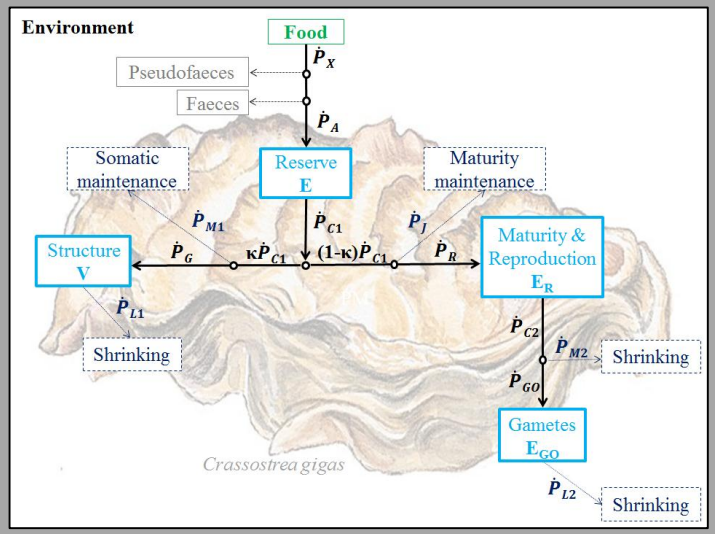




Initial values

Forcing variables

DEB *C. gigas* literature



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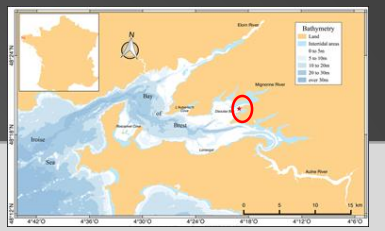

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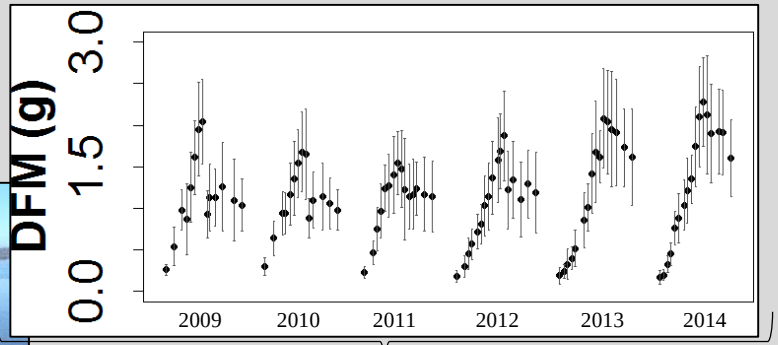
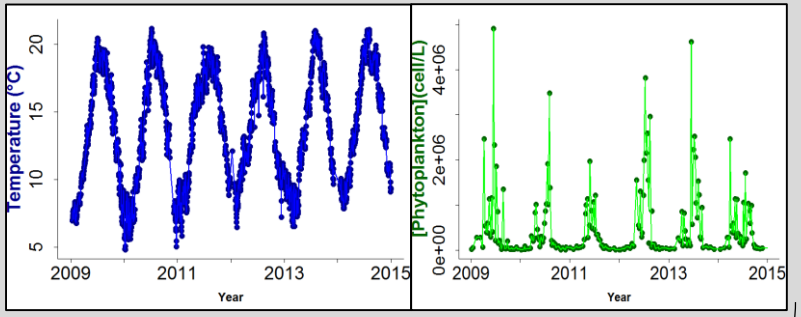


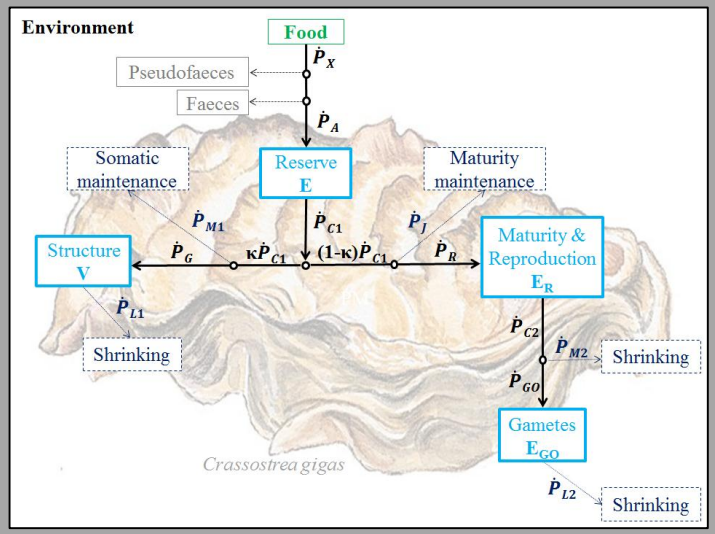


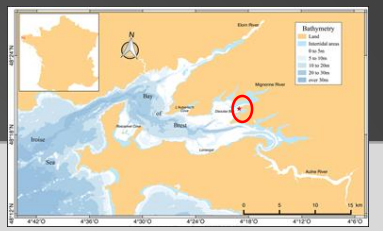
Initial values

Forcing variables

Description	Symbol	Value	Units
Biological parameters			
Shape coefficient	δ_M	0.175	-
Length at puberty	L_p	2.400	cm
Reserve parameters			
Maximum surface specific ingestion rate	$\{\dot{p}_{Xm}\}$	1025	J.cm^{-2}.d^{-1}
Volume specific maintenance cost	$[\dot{p}_M]$	44	J.cm^{-3}.d^{-1}
Energy conductance	$\dot{v}$	0.183	cm.d^{-1}
Assimilation efficiency	κ_X	[0;0.80]	-
Energy content of 1 g of reserve	μ_E	19600	J.g^{-1}
Structure parameters			
Volume specific cost for growth	$[E_G]$	3900	J.cm^{-3}
Allocation fraction to growth and maintenance	κ	0.45	-
Dry mass ratio of structure	d_V	0.15	$g_{dw}.g_{ww}^{-1}$
Energy content of 1 g of structure	μ_V	15600	J.g^{-1}
Yield of structure tissue used for maintenance	Y_{L1}	1	-
Reproduction parameters			
Reproduction efficiency	κ_{GO}	0.90	-
Dry mass ratio of gonad	d_{GO}	0.31	$g_{dw}.g_{ww}^{-1}$
Yield of gonad tissue used for maintenance	Y_{L2}	0.25	-
Energy content of 1 g of gonad	μ_{GO}	21630	J.g-1
Temperature threshold for spawning	T_S	18.70	°C
Ratio gonado-somatic threshold for spawning	R_{GS}	0.472	-
Environmental parameters (Bay of Brest)			
Food half saturation coefficient	X_k	500000	cell/L
PIM half saturation coefficient	X_{ky}	60	cell/L
Percentage of immersion (mean)	T_{im}	0.836	-
Temperature effect			
Arrhenius temperature	T_A	5800	K
Reference temperature	T_1	293.15	K
Lower boundary tolerance range	T_L	281.15	K
Upper boundary tolerance range	T_H	300.15	K
Arrhenius temperature for lower boundary	T_{AL}	75000	K
Arrhenius temperature for upper boundary	T_{AH}	30000	K

DEB *C. gigas* literature





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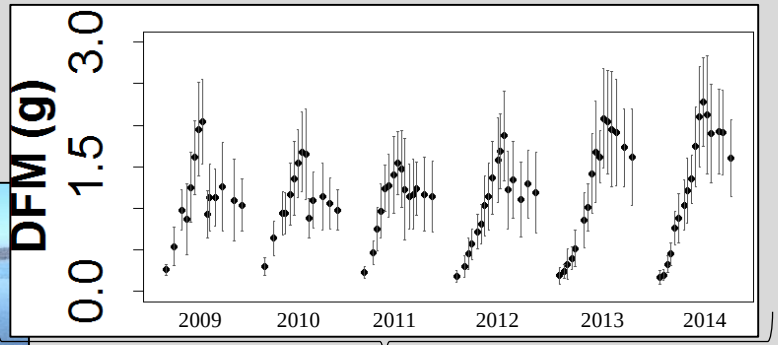

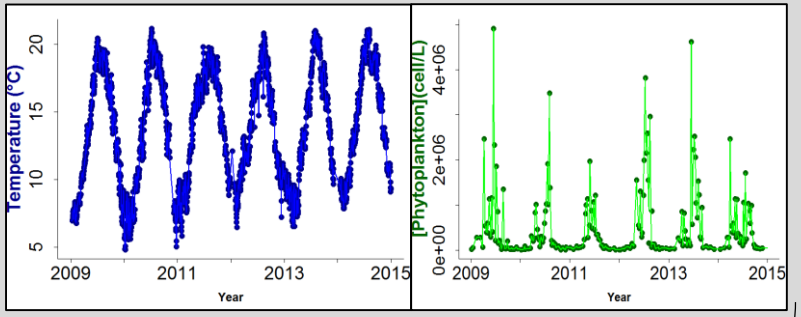

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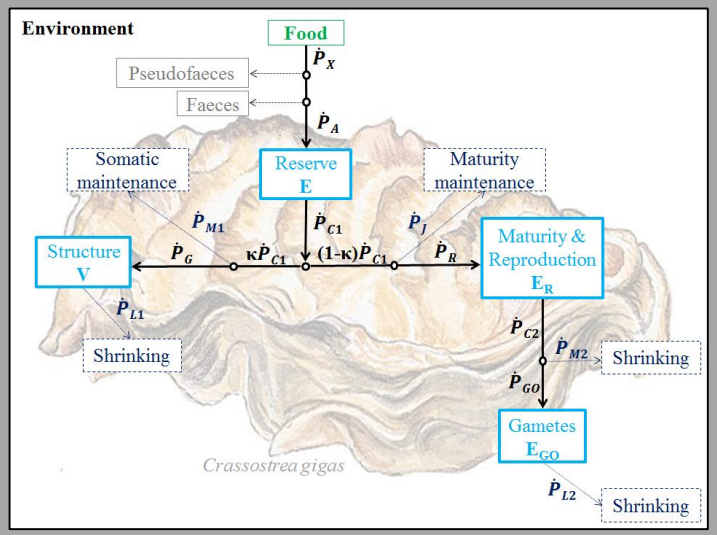
DEB *C. gigas* literature

Spawning triggering:
- Temperature
- Gonado-somatic ratio



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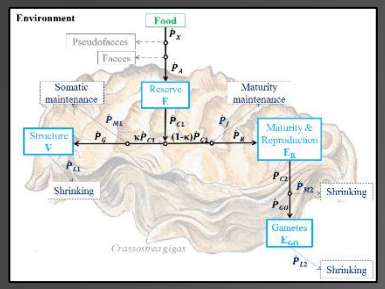
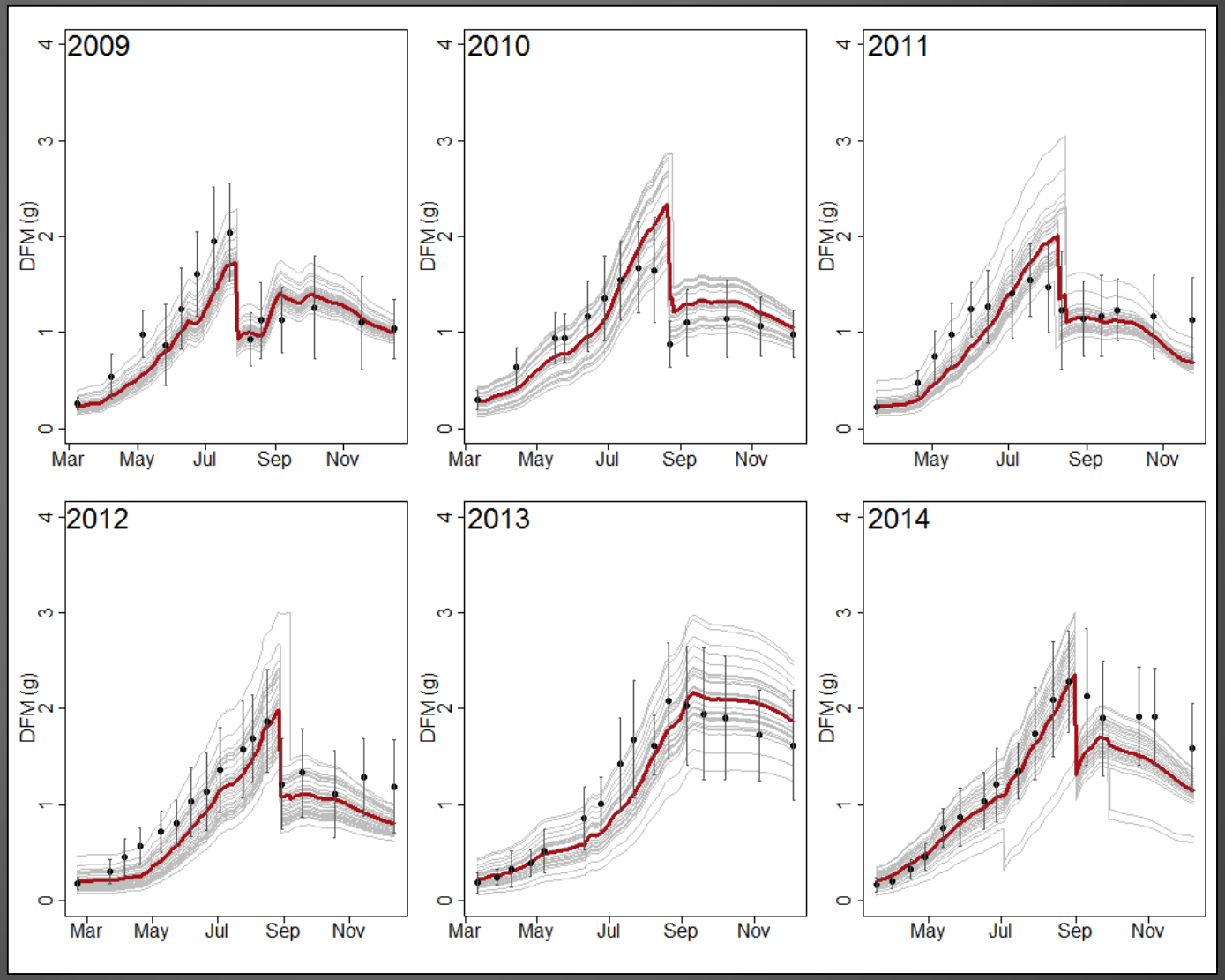


X 30 = 30 individuals per year

Sim. mean DFM
Sim. ind. DFM
Obs. mean DFM



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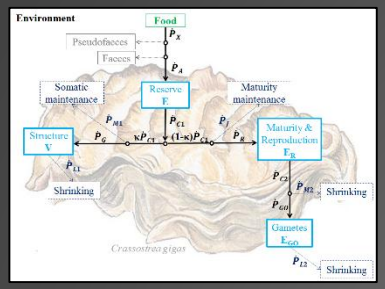
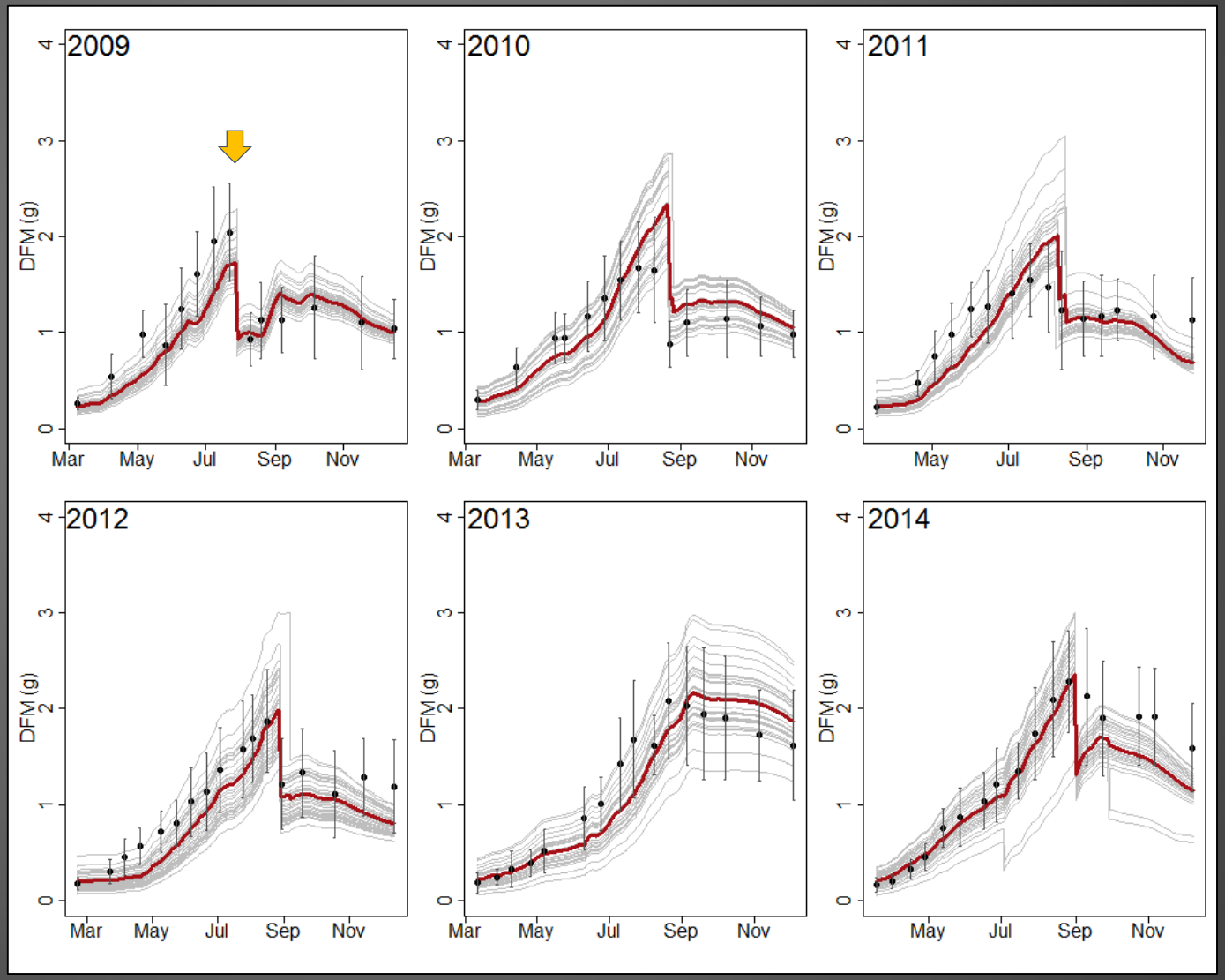


X 30 = 30 individuals per year

- Synchronous event: *2009*



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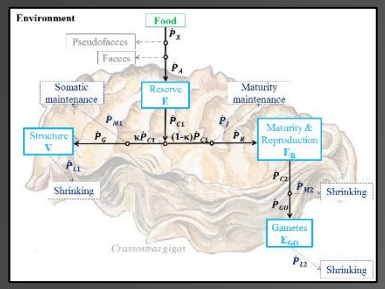

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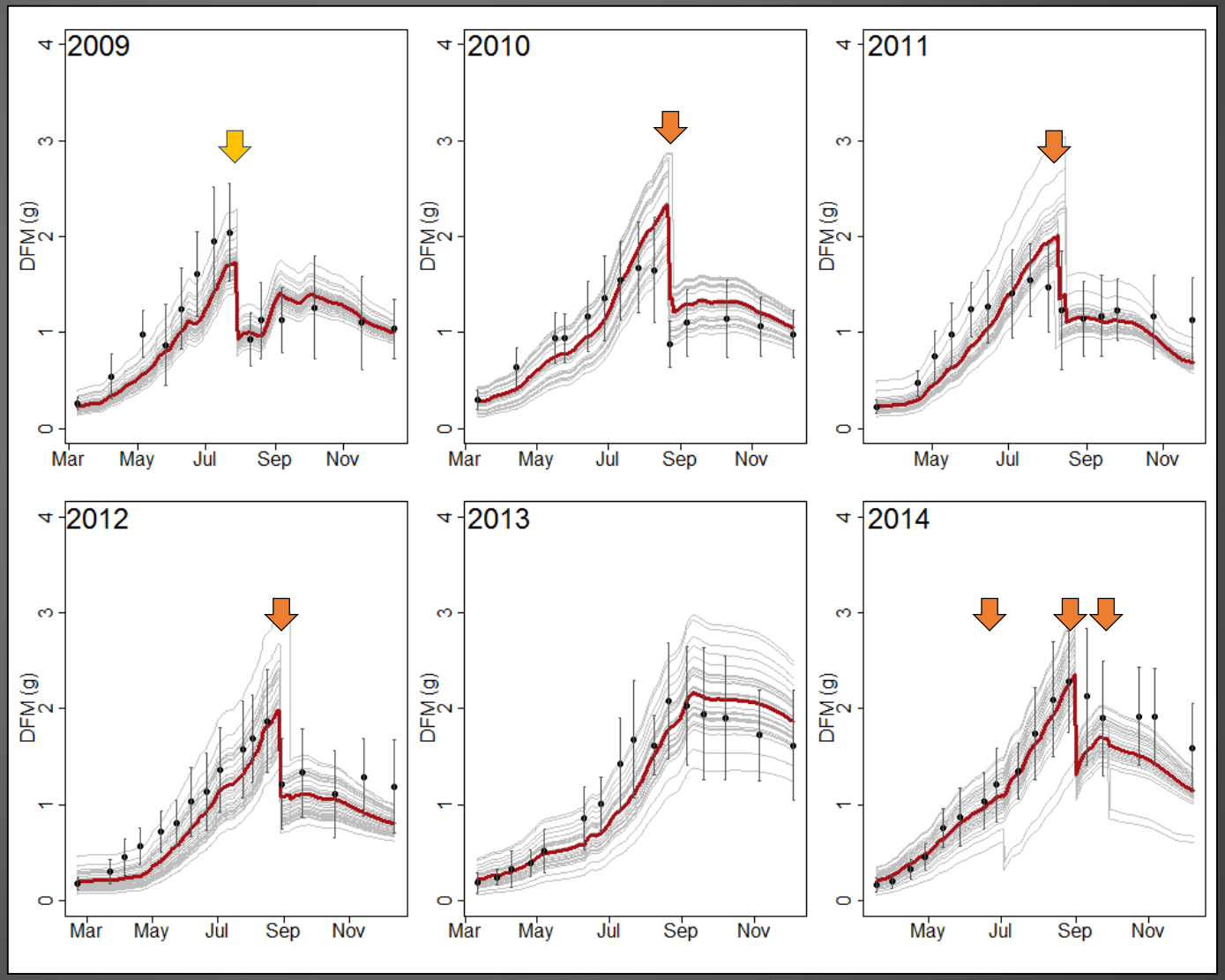

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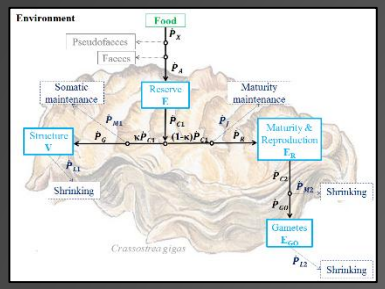
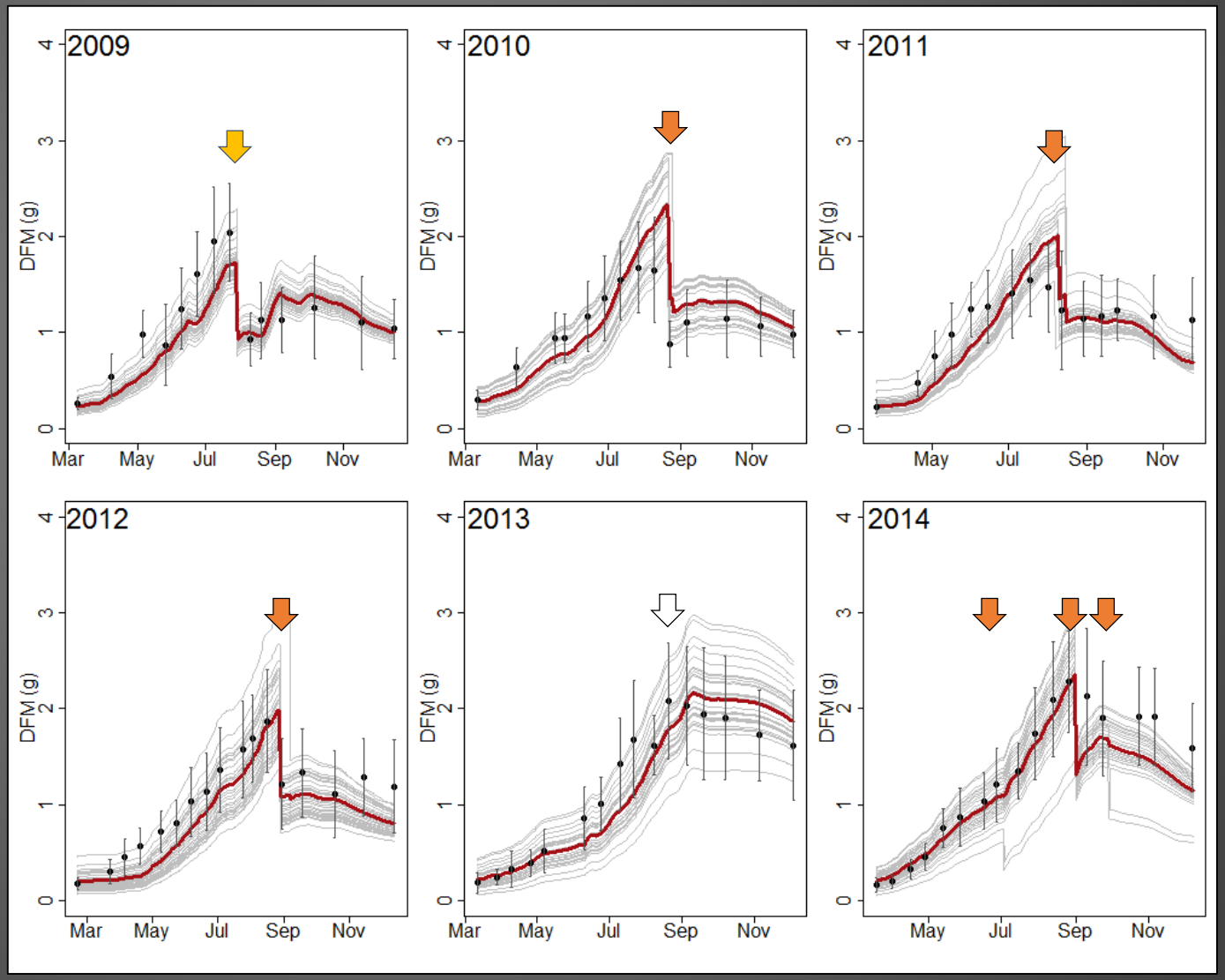


X 30 = 30 individuals per year

- Synchronous event: *2009*

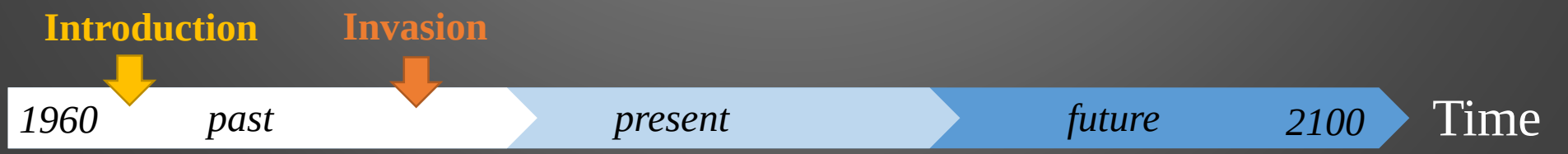
- Asynchronous event: *2010, 2011, 2012, 2014*

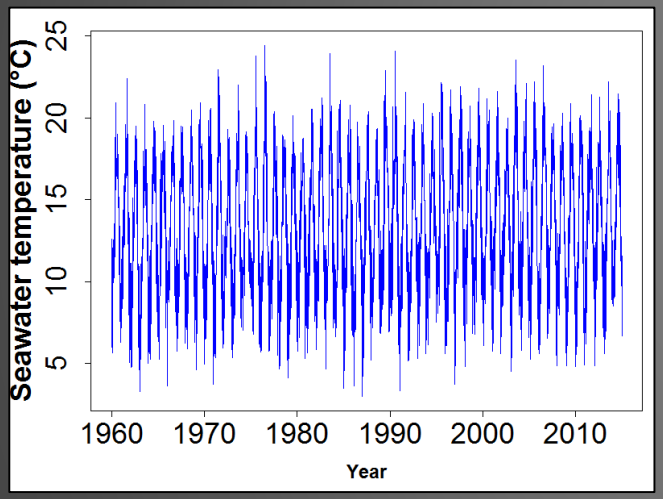
- No-spawning event: *2013*



Validation of the *C. gigas* DEB model

2009 to 2014



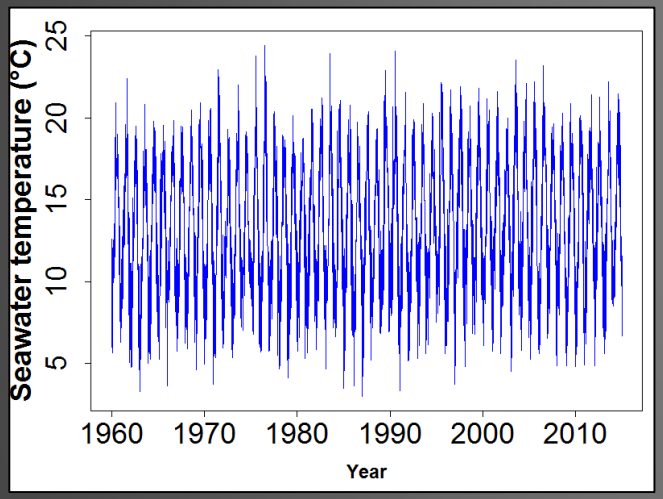


1960 to 2014

Validation of the *C. gigas* DEB model

2009 to 2014

1960 *past* *present* *future* *2100* Time



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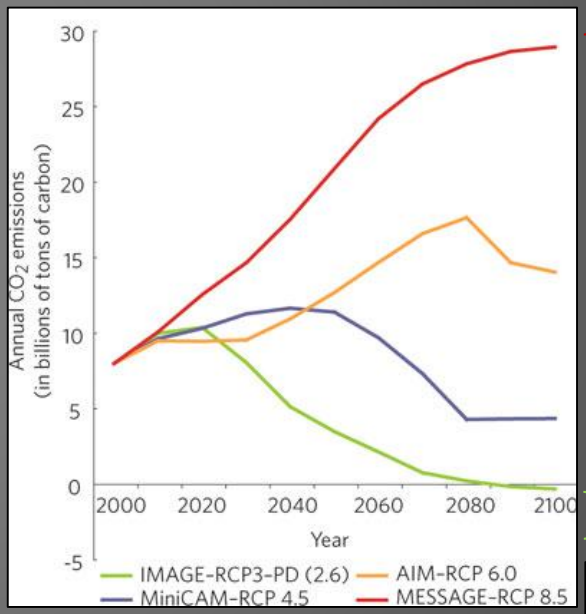
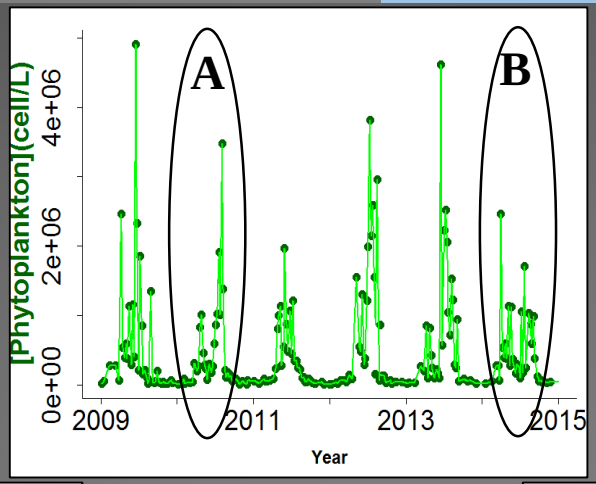


2040 to 2100

RCP8.5

RCP2.6

1960 *past* *present* *future* *2100* Time



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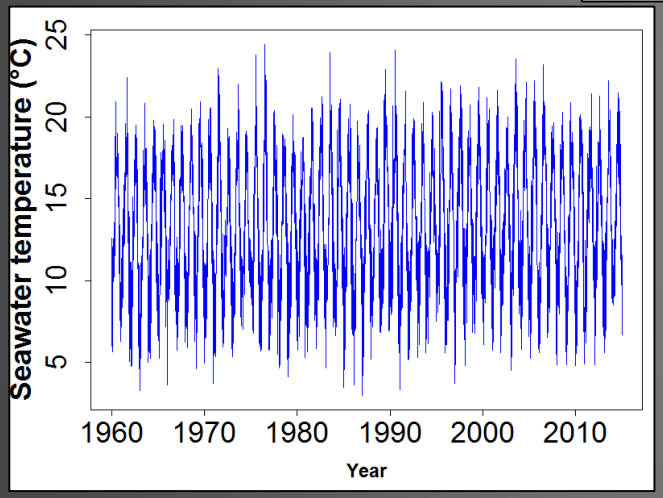

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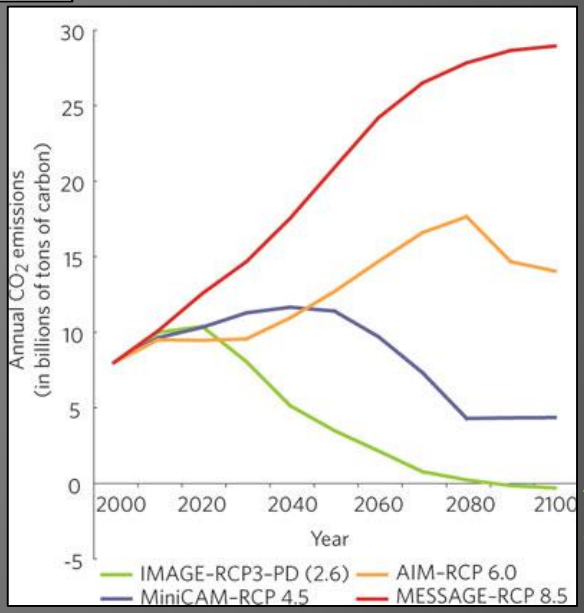

2040 to 2100

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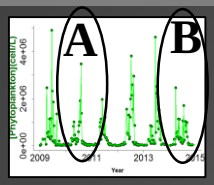
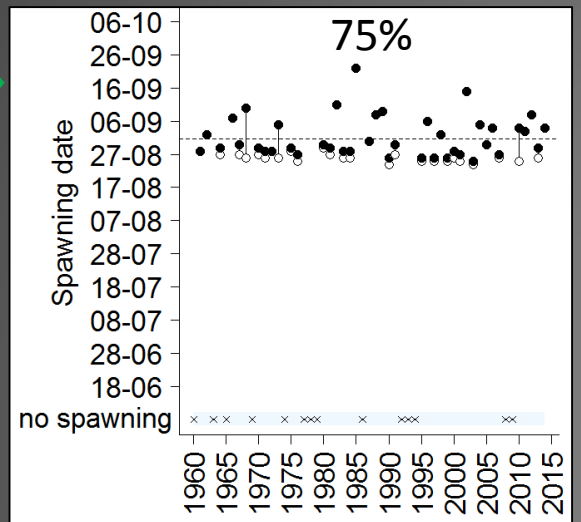


Historic

A



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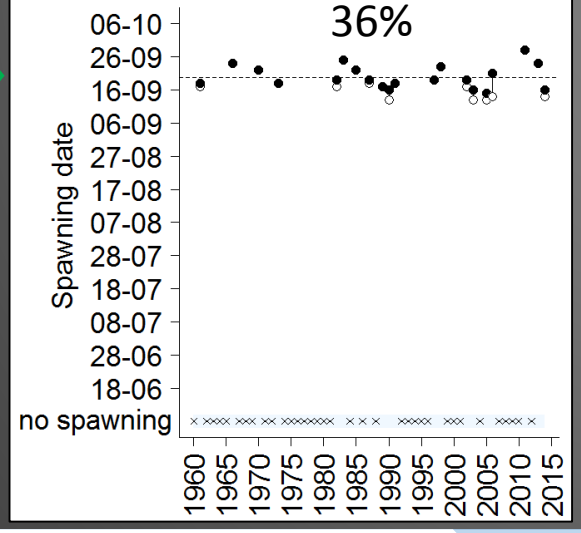
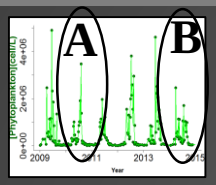


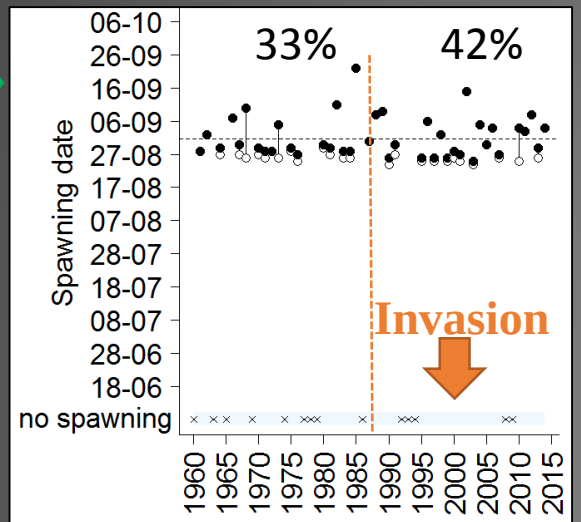
Synchronous event
Asynchronous event
No-spawning event

1960 *past* *present* *future* 2100 Time



Historic

A



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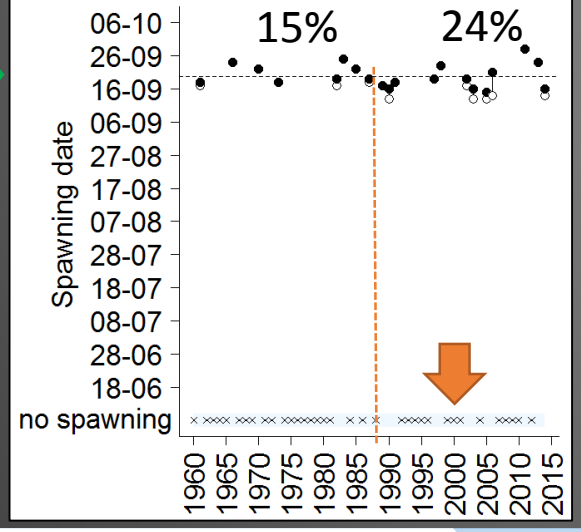
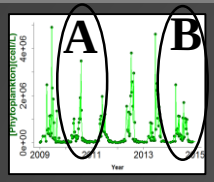


Synchronous event
Asynchronous event
No-spawning event

1960 *past* *present* *future* 2100 Time



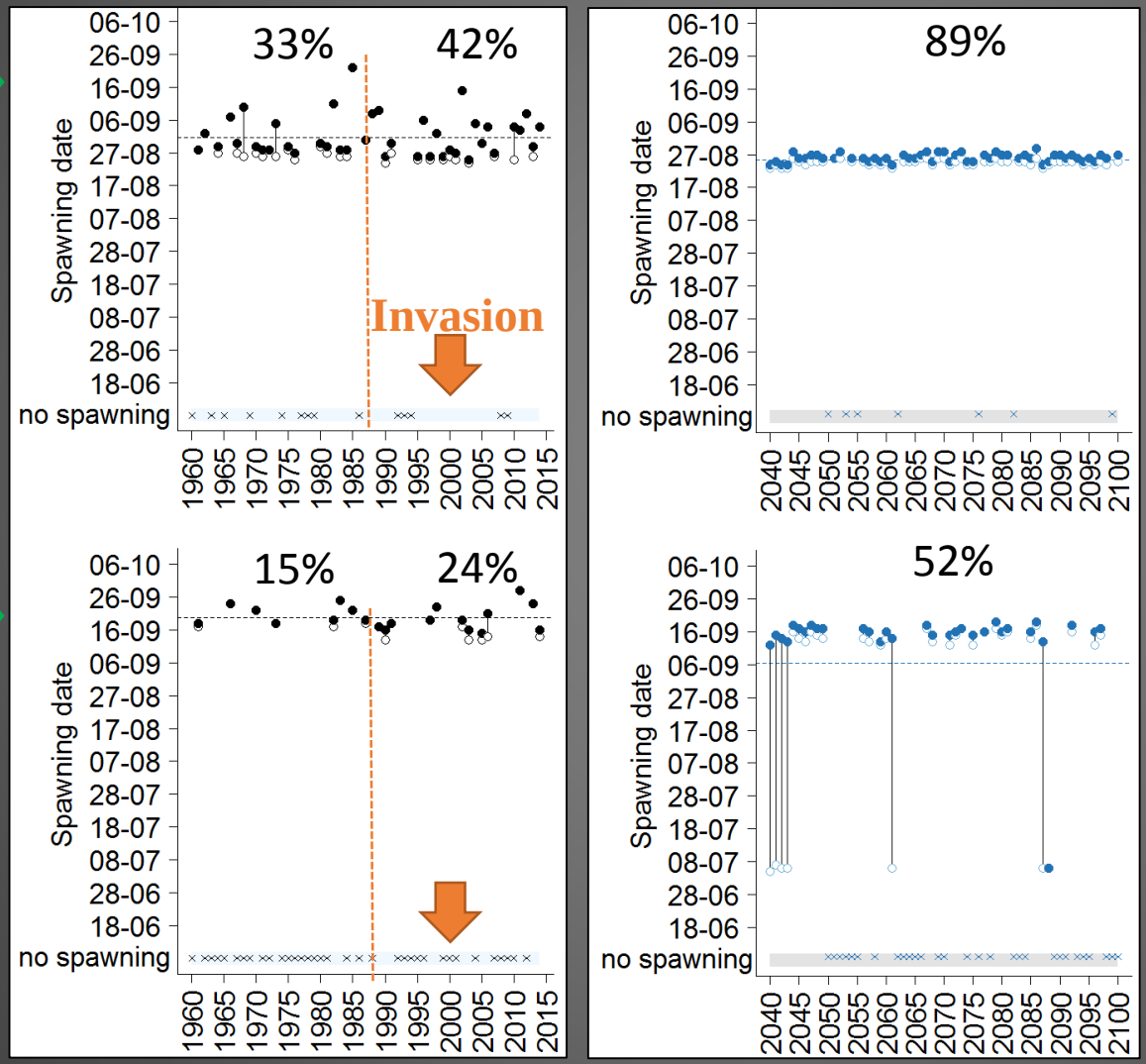
Historic

RCP2.6

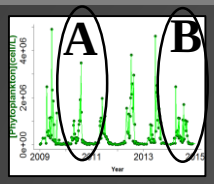
Synchronous event
Asynchronous event
No-spawning event

A

B



1960 *past* *present* *future* *2100* Time



Synchronous event
Asynchronous event
No-spawning event

Historic

RCP2.6

RCP8.5

A

B

Spawning date

no spawning

33%

42%

Invasion

89%

89%

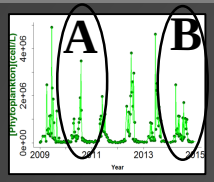
15%

24%

52%

74%

1960 past present future 2100 Time



Synchronous event
Asynchronous event
No-spawning event

Historic

RCP2.6

RCP8.5

A

B

33%
42%
89%
89%
15%
24%
52%
74%

Invasion

- 0.05d/yr

- 1d/yr

Spawning date

no spawning

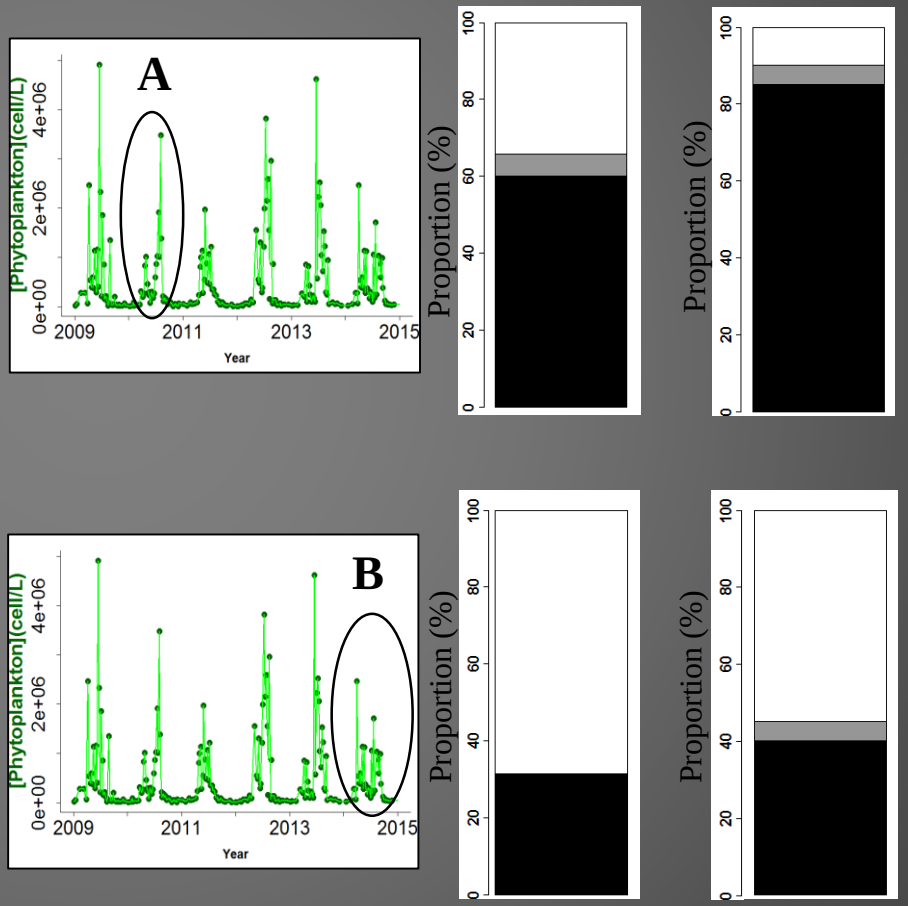
1960 past present future 2100 Time

Highlights of the study:

- Increase of spawning events since the 90's:

Historic

< 90's > 90's



Type of spawning: Synchronous Asynchronous No-spawning

Highlights of the study:

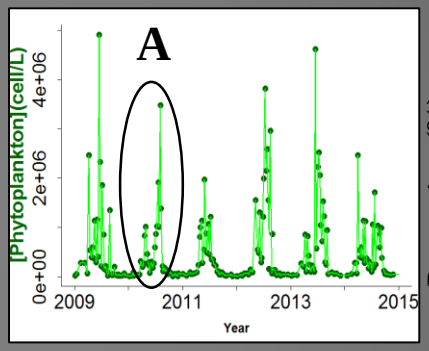
- Increase of spawning events since the 90's
- Unexpected effect of phytoplankton dynamics on the reproductive success of *C. gigas:*

Journal of Biogeography (J. Biogeogr.) (2015)

ORIGINAL ARTICLE

Global change and climate-driven invasion of the Pacific oyster (*Crassostrea gigas*) along European coasts: a bioenergetics modelling approach

Yoann Thomas[1]*, Stéphane Pouvreau[2], Marianne Alunno-Bruscia[2], Laurent Barillé[1], Francis Gohin[3], Philippe Bryère[4] and Pierre Gernez[1]



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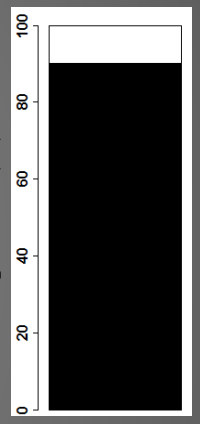

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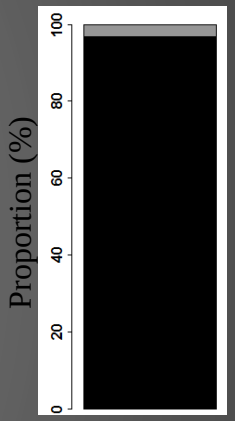
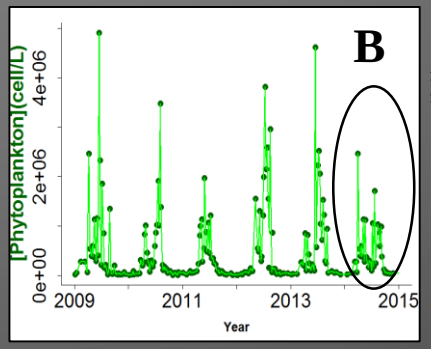
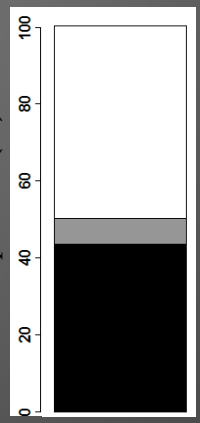
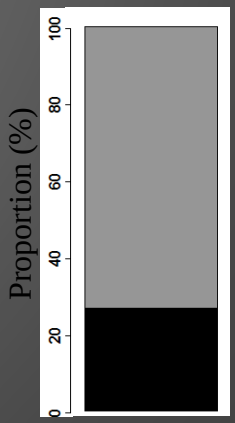




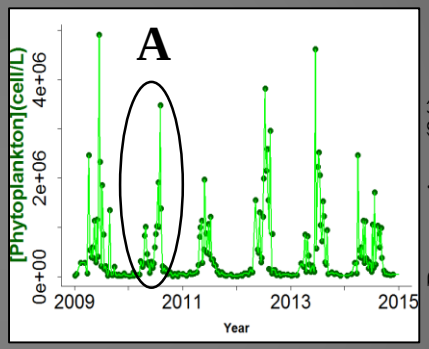




Type of spawning: ■ Synchronous ■ Asynchronous □ No-spawning

Highlights of the study:

- Increase of spawning events since the 90's
- Unexpected effect of phytoplankton dynamics on the reproductive success of *C. gigas:*



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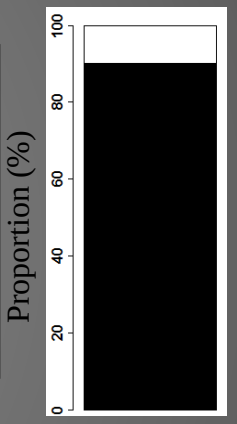

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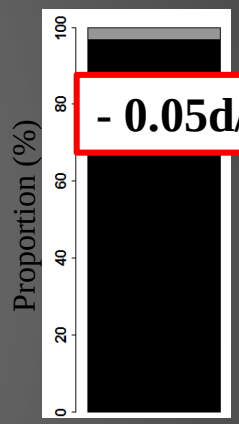
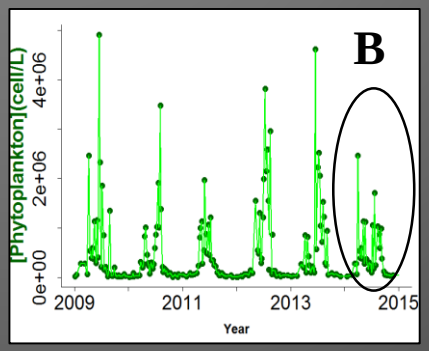
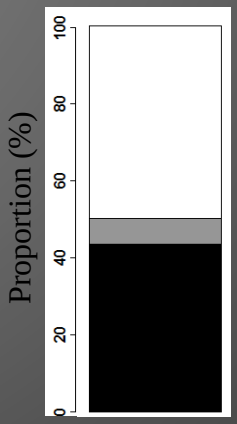
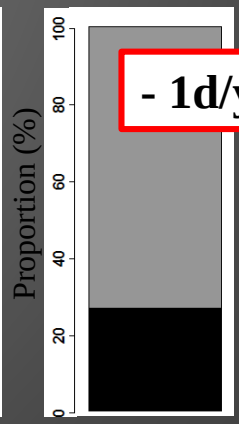


- 0.05d/yr







- 1d/yr

Type of spawning: ■ Synchronous ■ Asynchronous □ No-spawning

Highlights of the study:

- Increase of spawning events since the 90's

- Unexpected effect of phytoplankton dynamics on the reproductive success of *C. gigas*

What next?

- Improvement of spawning triggers
- Improvement in phytoplankton scenarios

Highlights of the study:

- Increase of spawning events since the 90's

- Unexpected effect of phytoplankton dynamics on the reproductive success of *C. gigas*

What next?

- Improvement of spawning triggers
- Improvement in phytoplankton scenarios

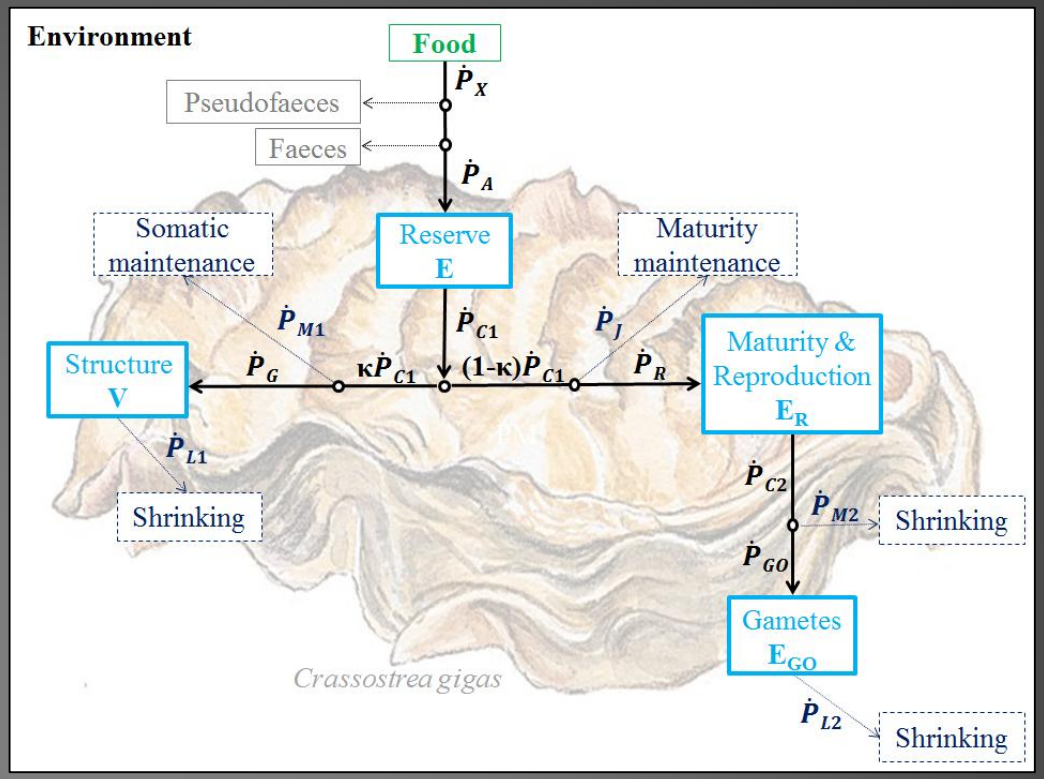
Recruitment dynamics of *C. gigas* accelerated: generalisation of oyster reefs landscapes in Brittany?


Thank you for your attention !
© S. Pouvreau / Ifremer

Initial value calculation:

```
e = phys[["e"]]
V   = (phys[["LEN"]] * Param$Shape)^3
E   = e * (Param$Em) * V
Ego = 0
Er = 0
```

e = scaled energy
LEN = length
Shape = form coefficient
V = energy of the structure
Em = maximum reserve density
E = energy of the reserve
Ego = energy for the gametes
Er = energy for the reproduction buffer



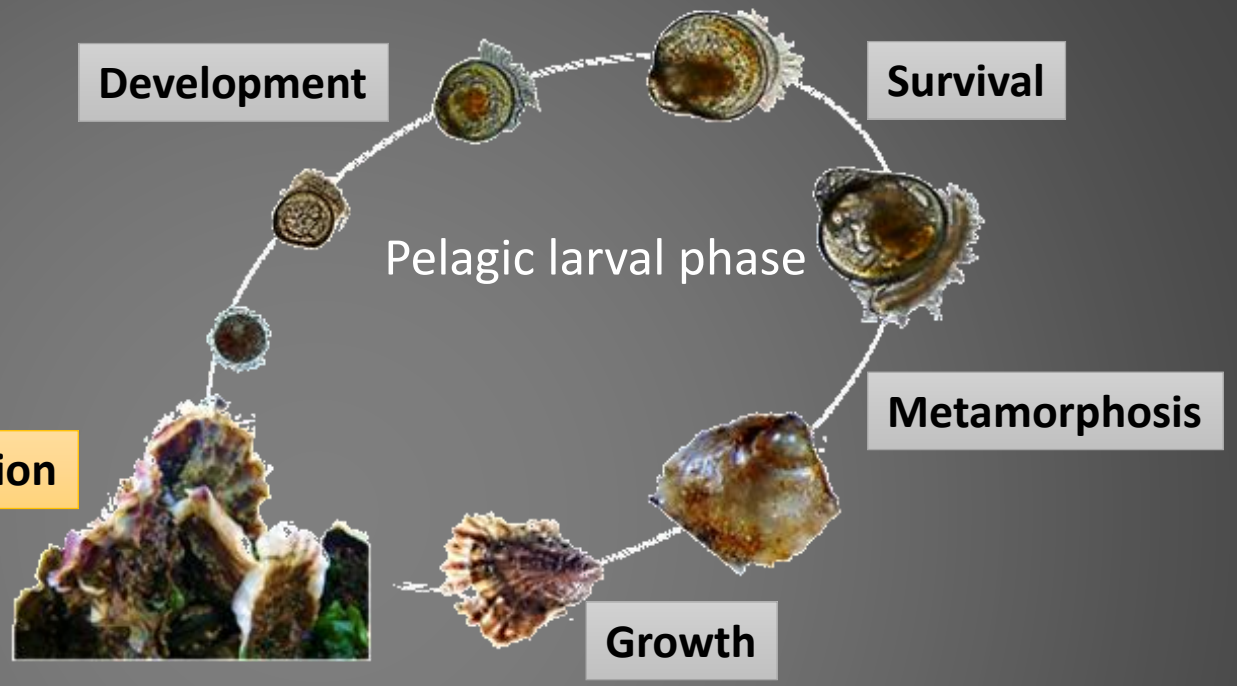
● Synchronous event

●–○ Asynchronous event

× No-spawning event

Oyster's life cycle

C. gigas



Spawning event

Individual strategy of spawning

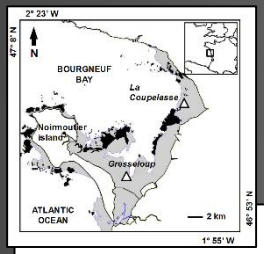
Introduction

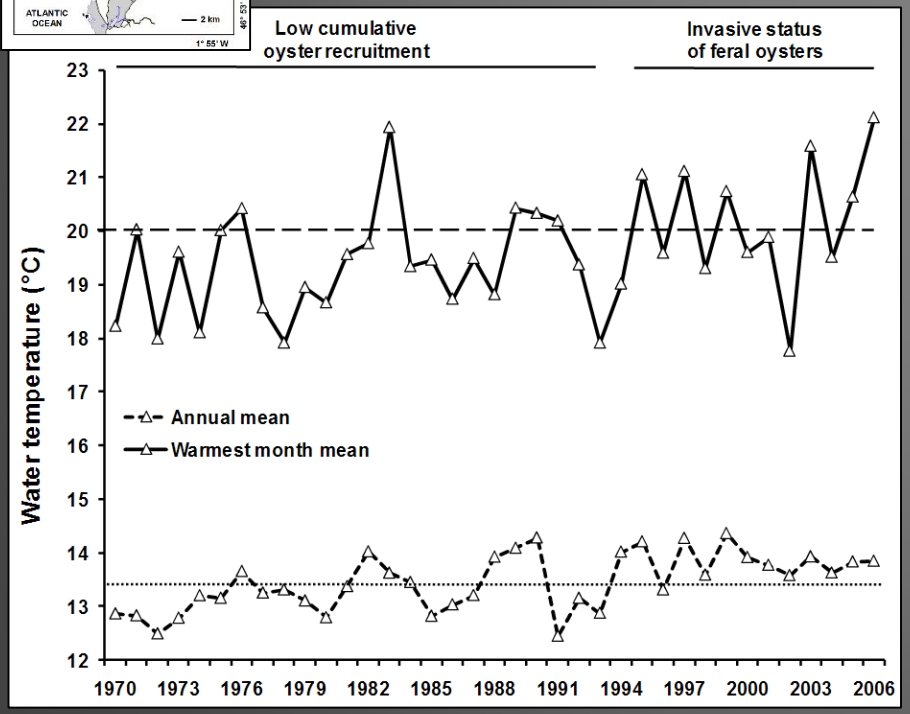
C. gigas

Filter feeder bivalve
Economic interest
Invasive

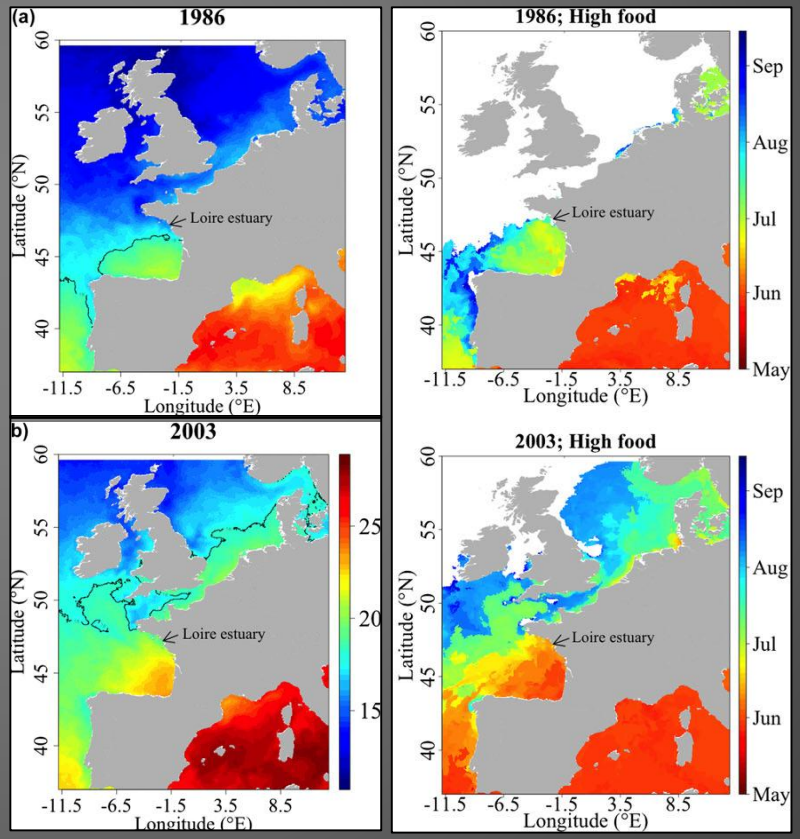
Is climate change directly linked to the invasion of this species?

YES !





Dutertre et al., 2010



Thomas et al., 2016

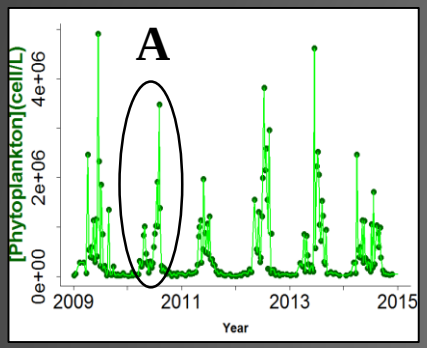
Type of spawning: Synchronous Asynchronous No-spawning

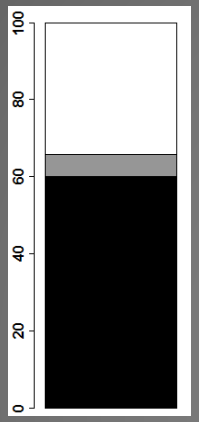
Historical

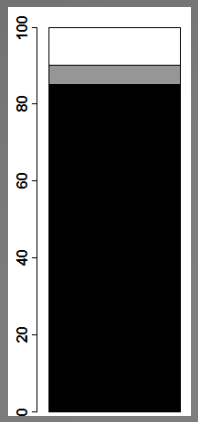
< 1995 > 1995

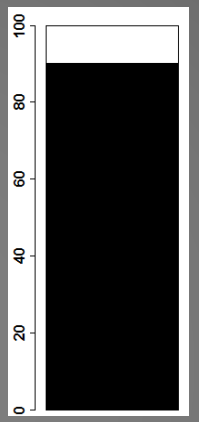
RCP2.6 (>2070)

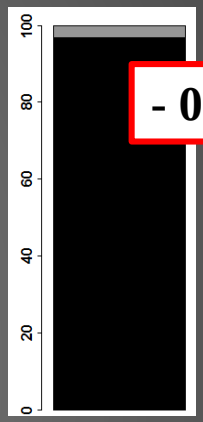
RCP8.5 (>2070)



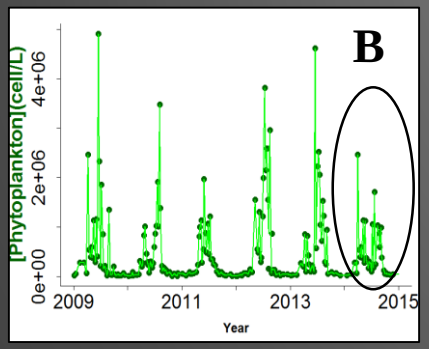


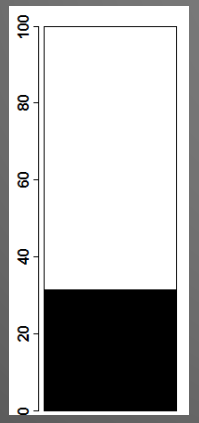


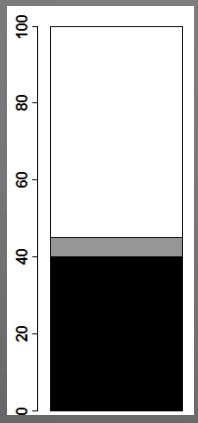


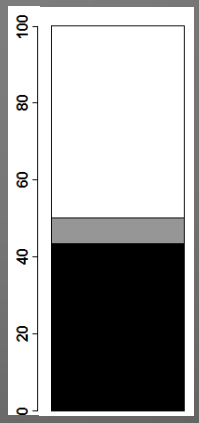


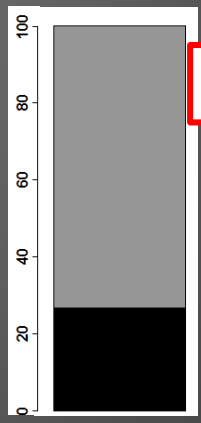
- 0.05d/yr









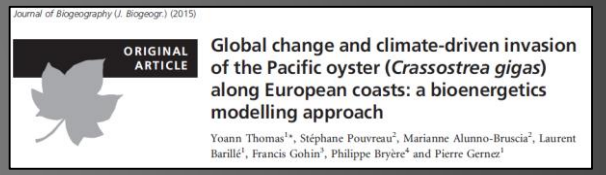


- 1d/yr

1960 *past* *present* *future* *2100* Time

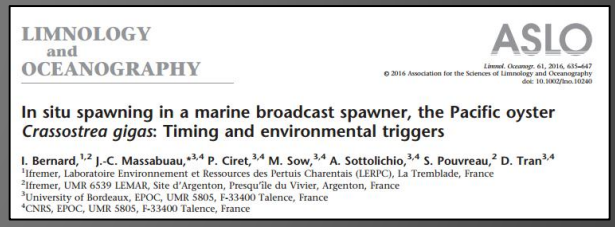
Highlights of the study:

- Increase of spawning events since the 90s
- Potential phenological change in spawning under RCP8.5 scenario
- Unexpected effect of phytoplankton dynamics on the reproductive success of *C. gigas*



What next?

- Improvement of spawning triggers
- Improvement in phytoplankton scenarios



Recruitment dynamics of *C. gigas* accelerated: generalisation of oyster reefs landscapes in Brittany?