Bio-energetics of *Crassostrea gigas* as modelled with the DEB Theory : 2. Application of the Oyster-DEB model in Arcachon Bay (France)

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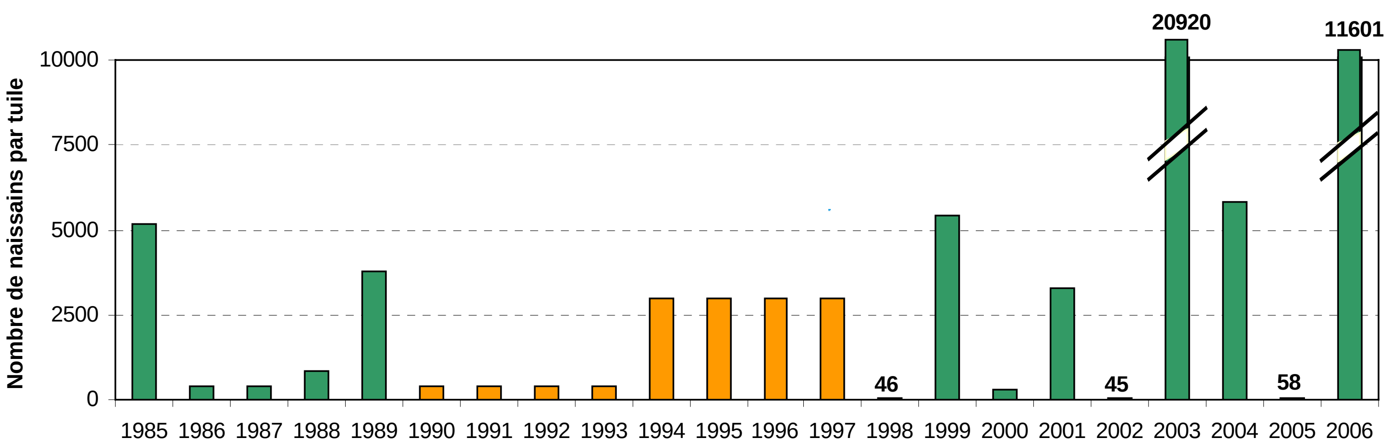
Ifremer

Context of the study

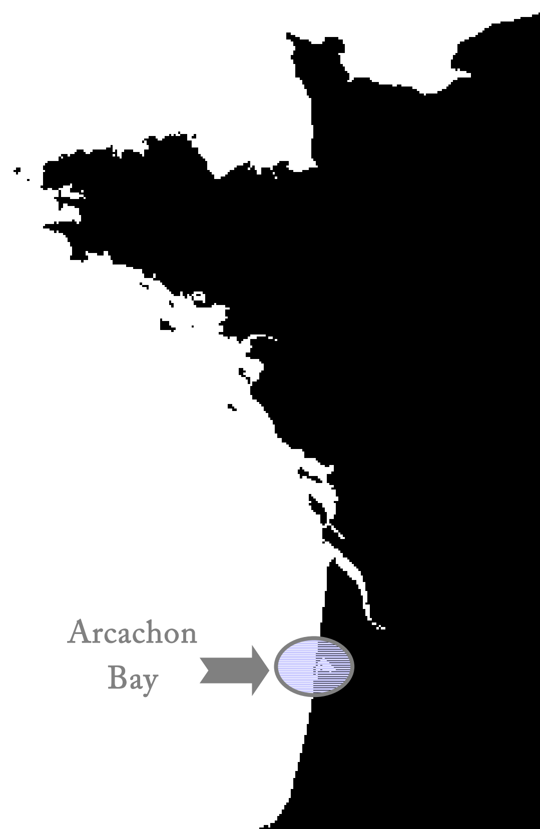
➢ The Arcachon Bay (France-SW) is the main spat productive center in France

- ✓ Production around 2 milliards of spat per year
- ✓ But with huge irregularities in the spatfall, especially for the last ten years



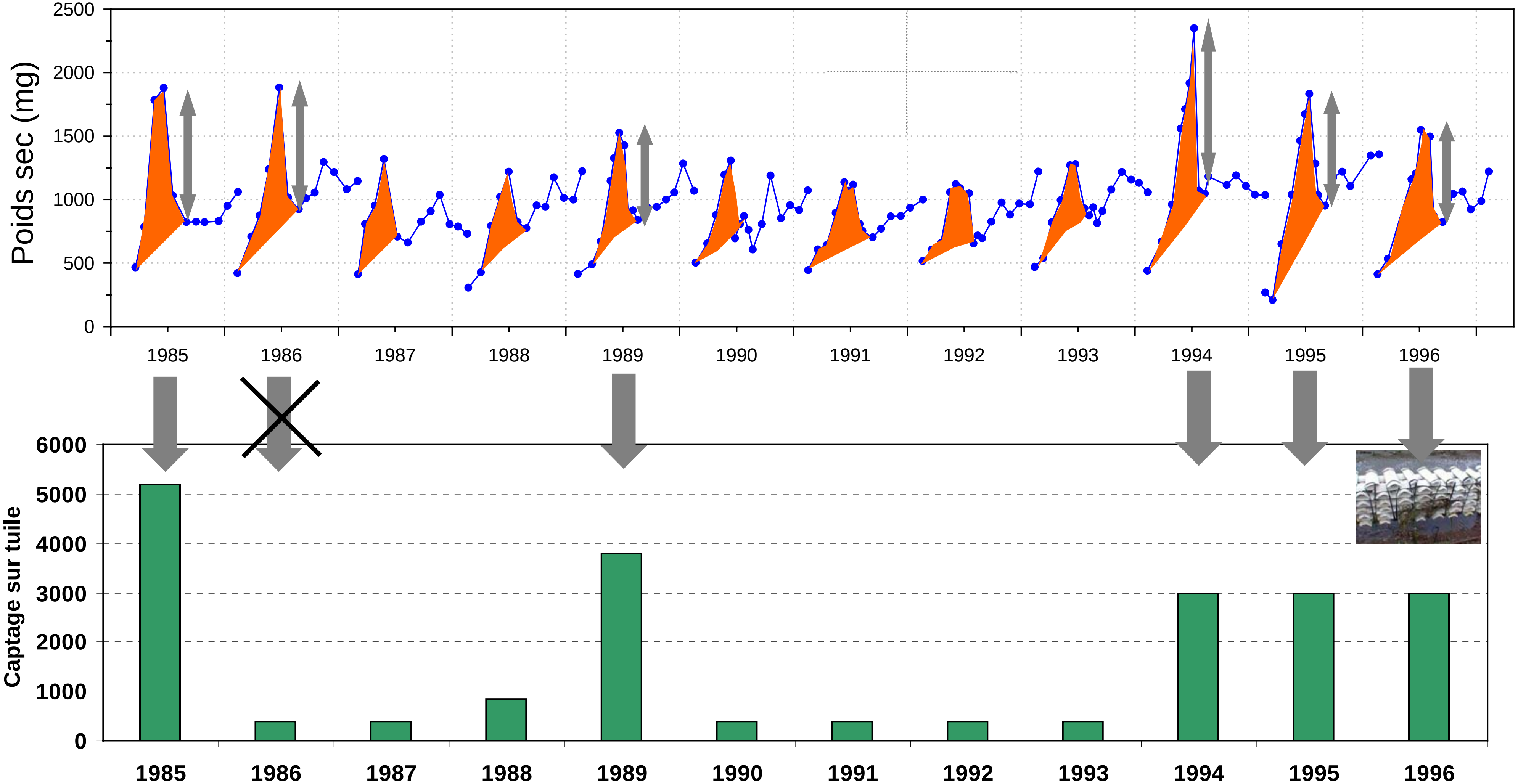
Variability of spatfall in the Bay of Arcachon since 1985.

(adapted from Auby et Maurer, 2004)



Context of the study

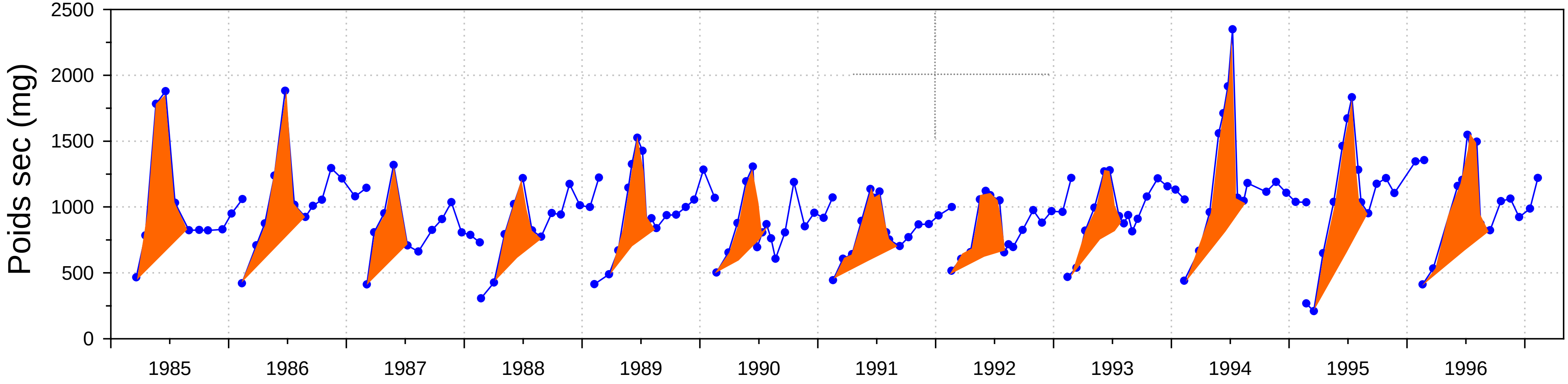
- These irregularities in spatfall are partly due to variability in gametogenesis of broodstock (but not systematically)



Adapted from Auby et Maurer (2004)

Aim of the study

➤ Aim of the study : Analyze if the inter-annual variability in gametogenesis is due to variability of environmental factors

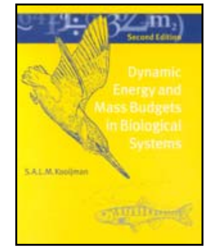


➤ General method : Relationships between environment and physiology can be quantitatively analyzed through bioenergetic model.

➤ Specific tool : The model based on DEB theory, previously published in JSR n°56 (Pouvreau et al., 2006) and recently improved by Bourles et al. (2007 - previous communication).

Material & methods : Modeling procedure

➢ General overview of the modeling procedure :



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Step 1 : Conceptualisation

Set of 10 mathematical keys-equations detailed by Kooijman (2000)

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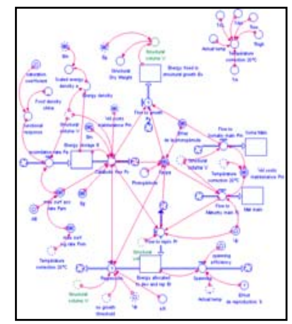
Step 2 : Parametrisation

List of 15 parameters values specially estimated for the Pacific oyster (Van der Veer et al., 2006 and Bourles et al., 2007) except X_K which is calibrated for each simulation



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Step 3 : Implementation

Implementation of equations and numerical computing under a modelling software (Stella)

Step 4 : Test and validation

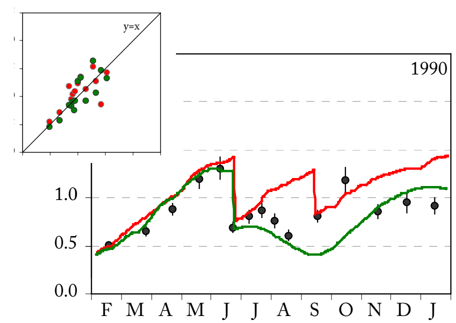
Over 9 years (1988-1996)

- 4.1 : Forçing
- 4.2 : Simulation

Forçing by temperature and food density

Calibration on X_K

Statistical comparisons of simulation vs observation



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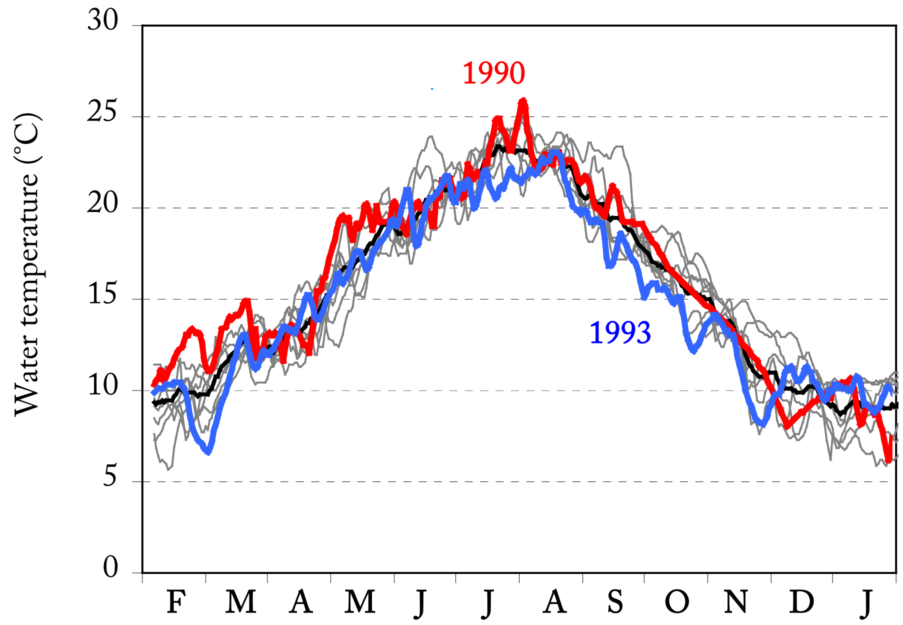
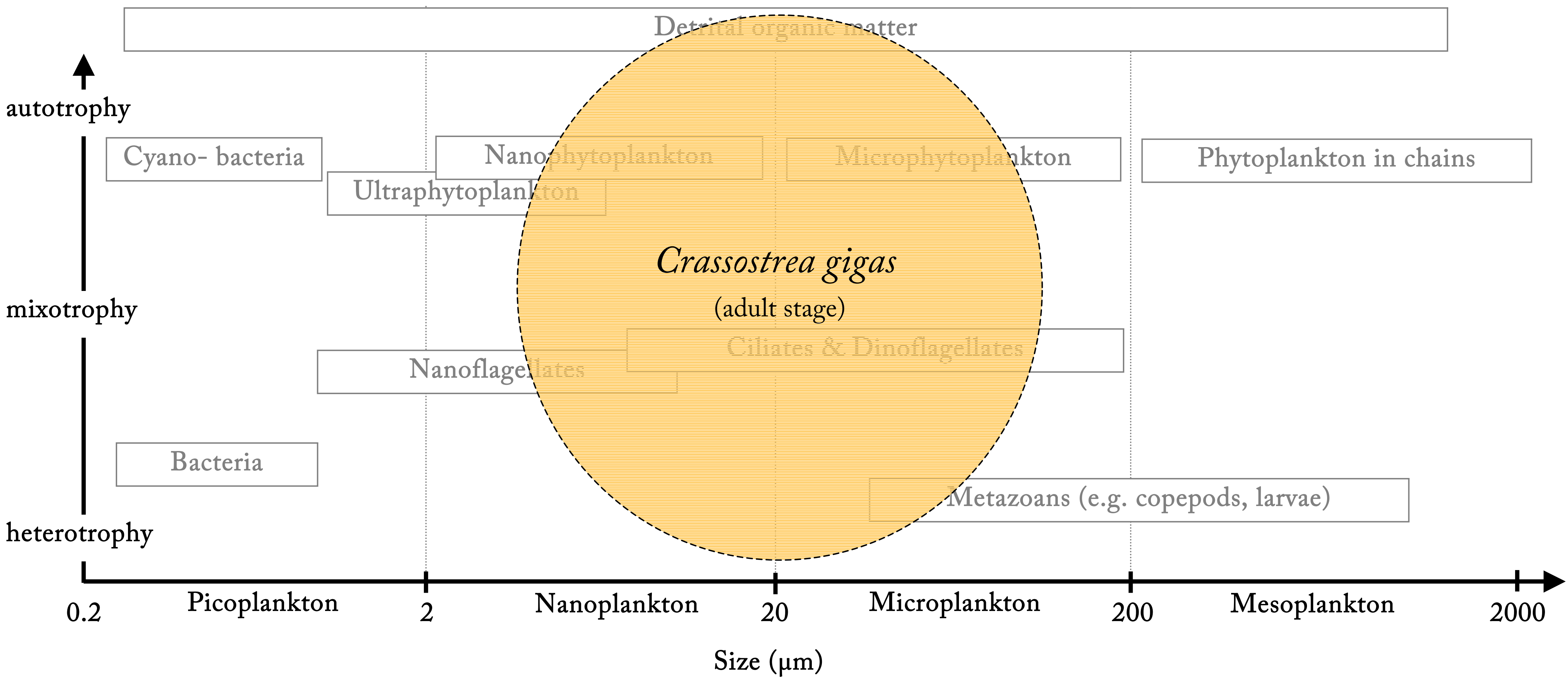
Material & methods : Forcing variables

- Physiological rates are forced in the model by temperature
  - ✓ Daily water temperature from 1988 to 1996 (nine years)
  - ✓ Water temperature varies from 9°C to 23°C
  - ✓ Some variability between years (e.g. 1990 vs 1993)



Material & methods : Forcing variables

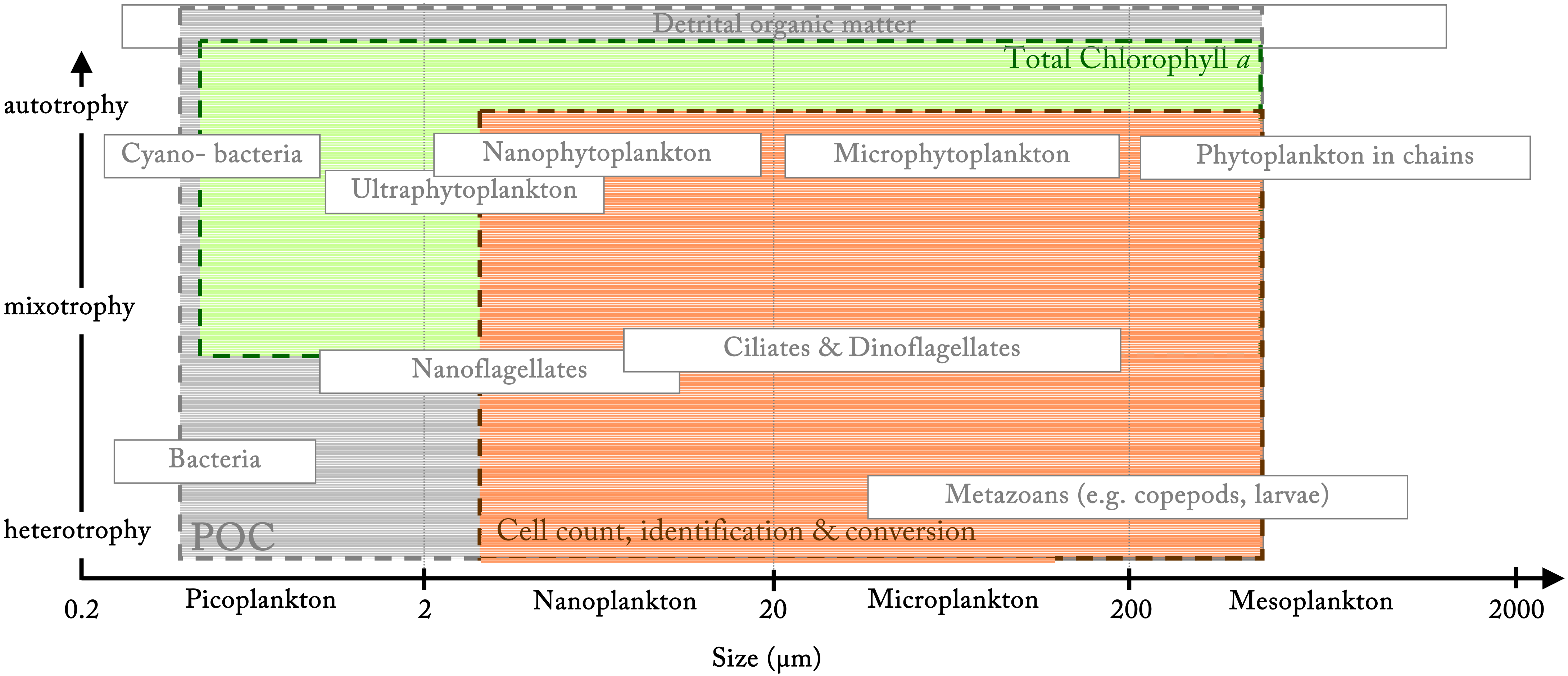
- ➢ The second forcing variable is food density , but what is 'Food' ?
  - ✓ Planktonic preys for filter-feeders like bivalves are various…
  - ✓ Adults of Pacific oysters eat presumably on nano and microplankton…



Material & methods : Forcing variables

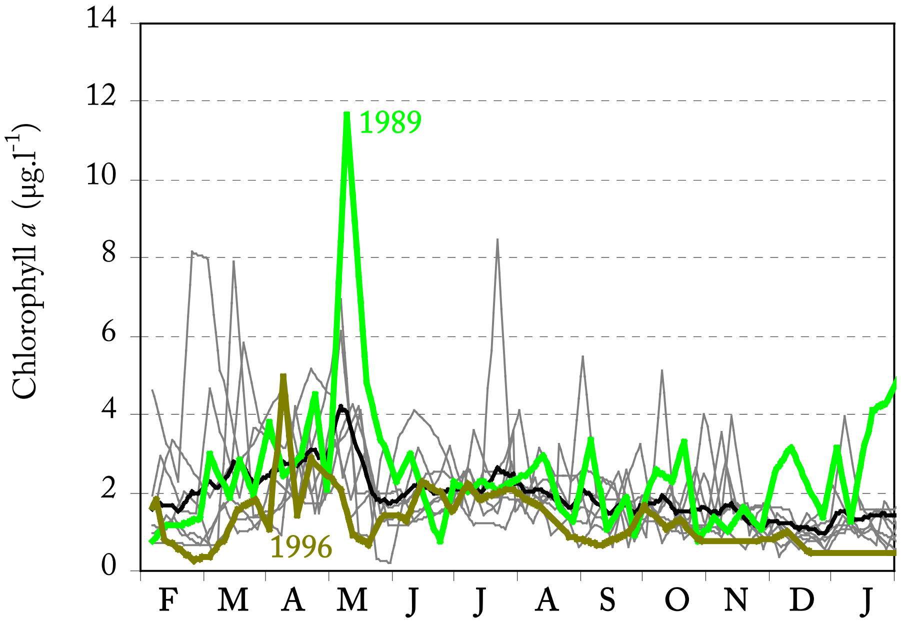
➢ How can we estimate this 'Food' ?

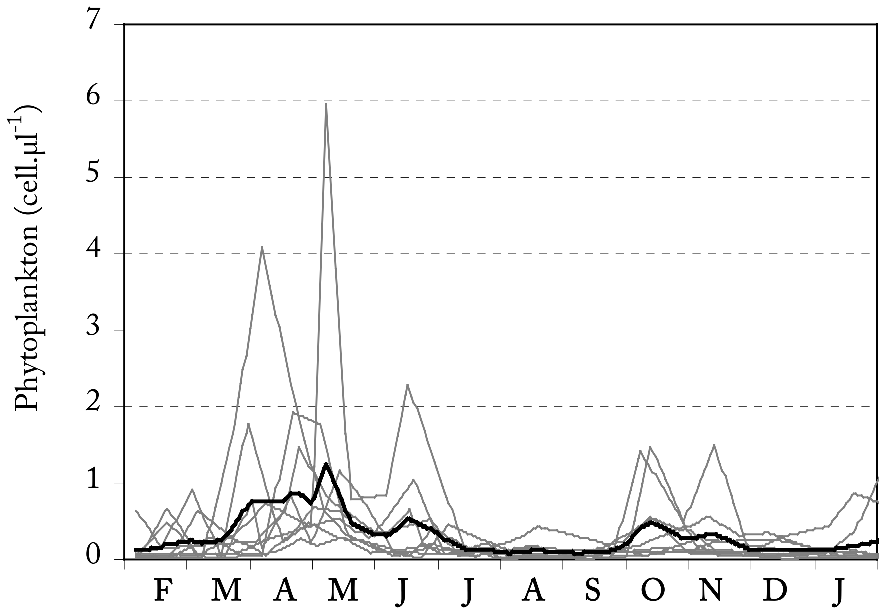
- ✓ Methods to quantify filter-feeders preys are not equivalent…
- ✓ Total POC, POM, PLC : easy but 'rough' (no distinction between living and non-living matter)
- ✓ Chlorophyll *a*, but quota per cell is not constant (varies with irradiance, temperature, nutrients)…
- ✓ Plankton abundance (microscopy cell count with species identification), but not a biomass
- ✓ Plankton biomass (volume measurement, carbon conversion), but time consuming and large SD.



Material & methods : Forcing variables

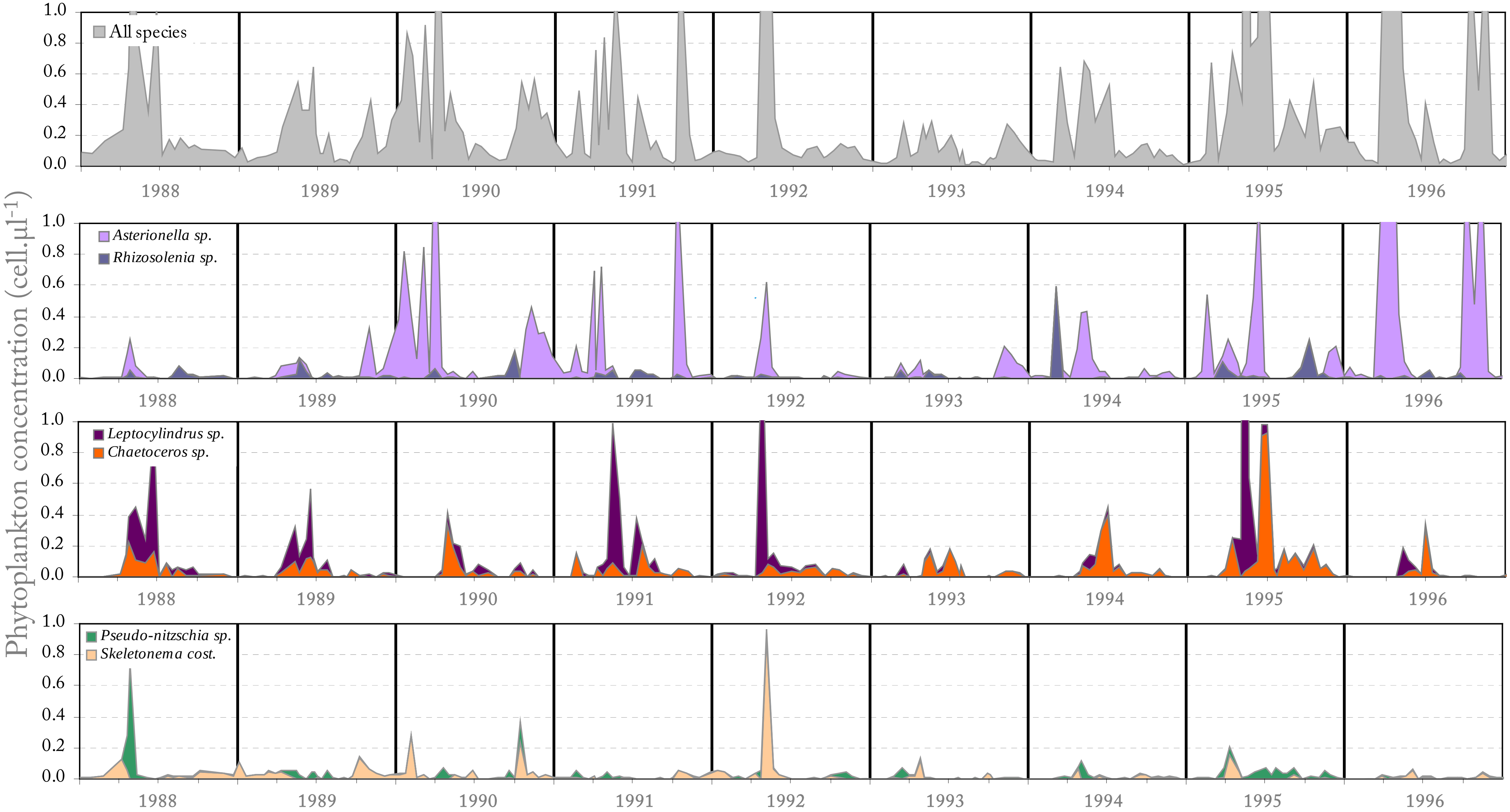
- At Arcachon, several 'quantifiers for food' were available from 1988 to 1996 :
  - ✓ POM, PLC (every month)
  - ✓ Total chlorophyll *a* (every two weeks)
  - ✓ Plankton abundance (cell count & species identification > 6 µm, every month)
  - ✓ Plankton biomass (volume measurement, every month)





Material & methods : Forcing variables

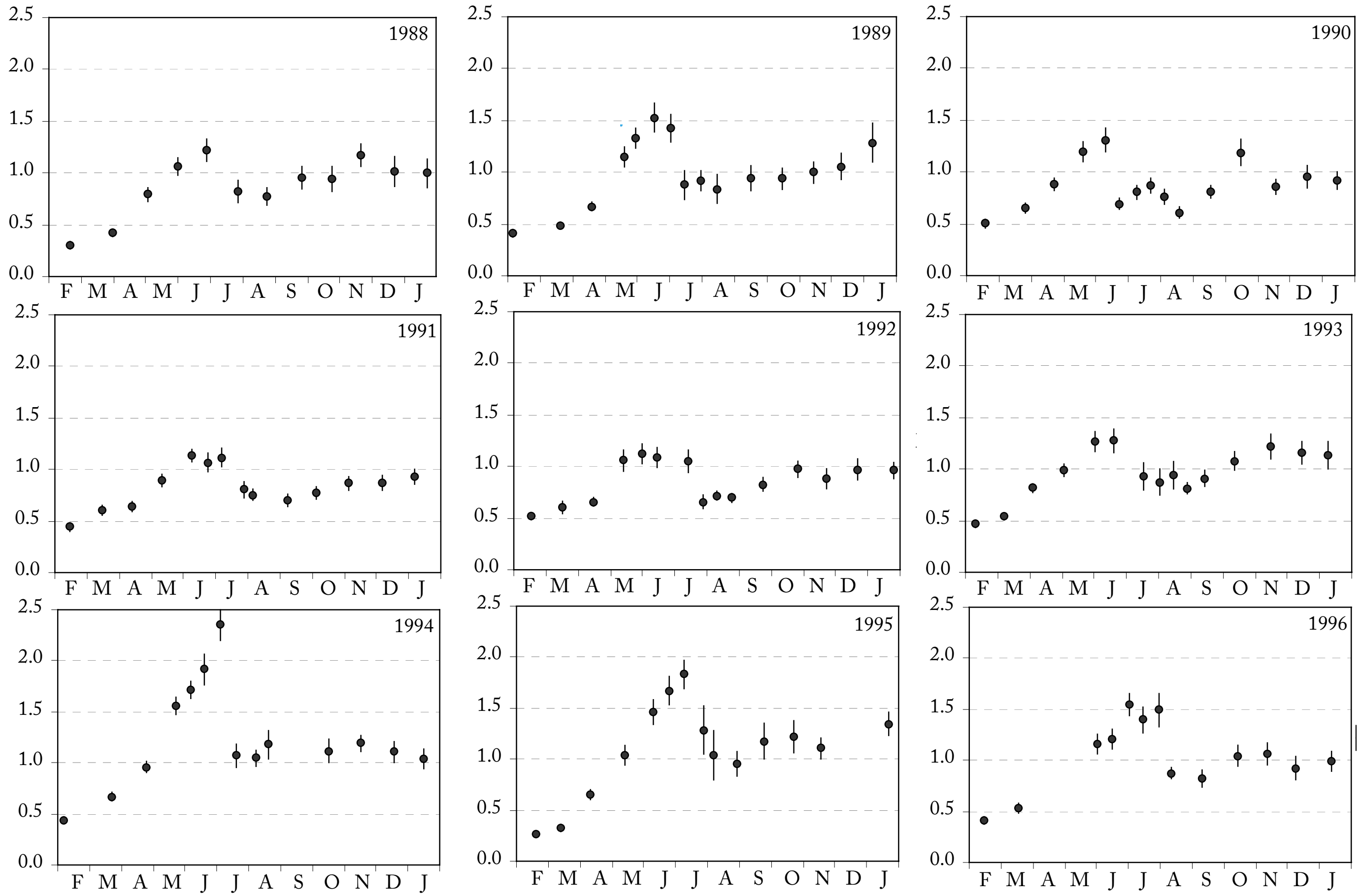
➢ Some details on the phytoplankton composition:



Material & methods : Validation data

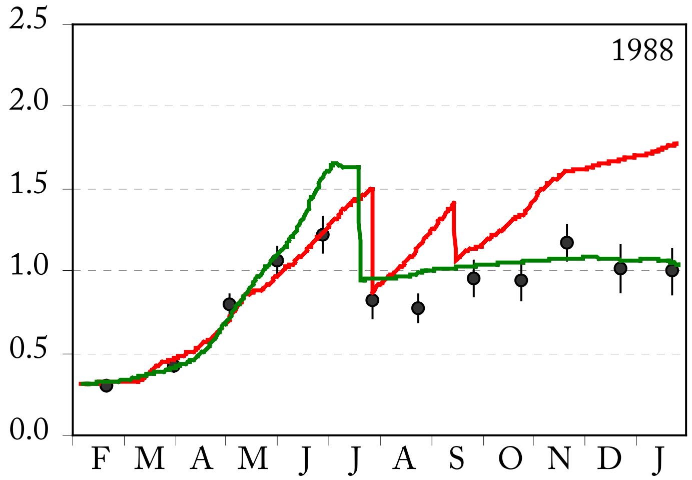
➢ Growth data were used to test the model in Arcachon Bay :

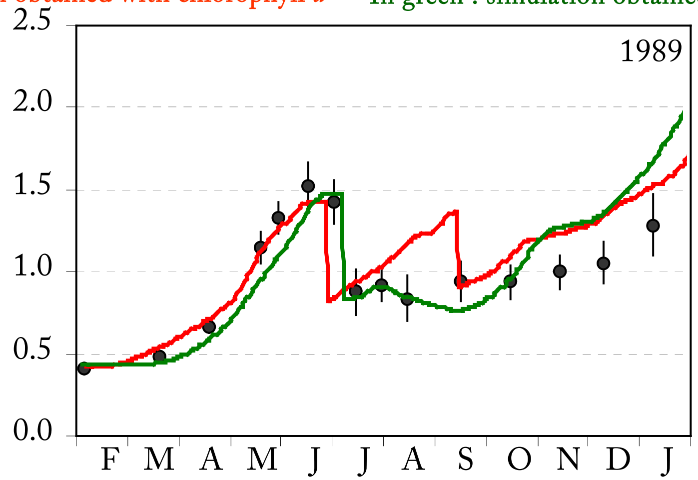
- ✓ Growth and gametogenesis were followed from 1985 to 1996
- ✓ Nine years (from 1988 to 1996) were in common with environmental datasets
- ✓ Sampling step was short enough to estimate gametogenesis & spawning intensity
- ✓ Slow increase during spring due to gametogenesis
- ✓ Sharp decline in July due to spawning event, with a variability in intensity between year.

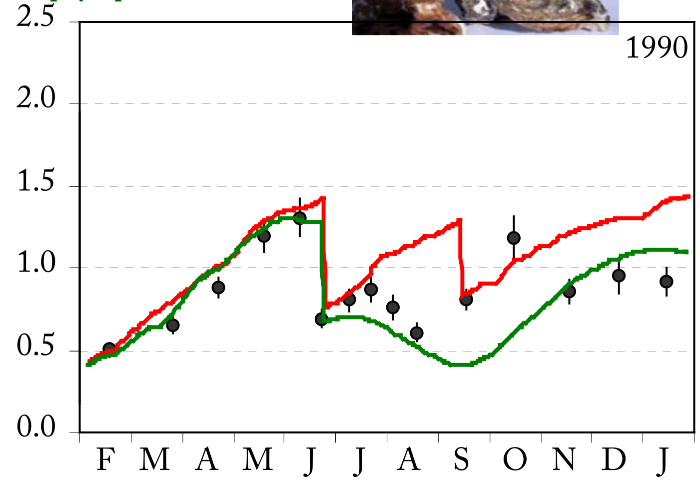


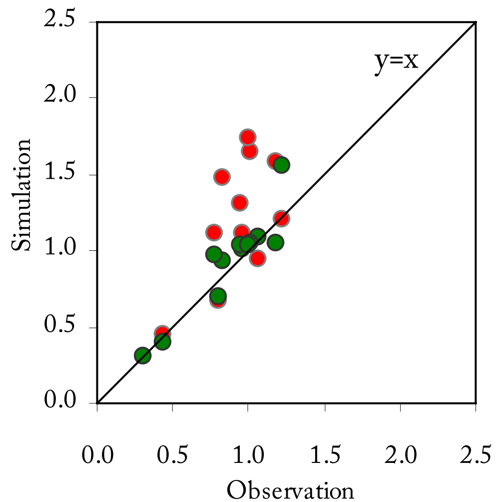
Results : Simulation obtained by the model

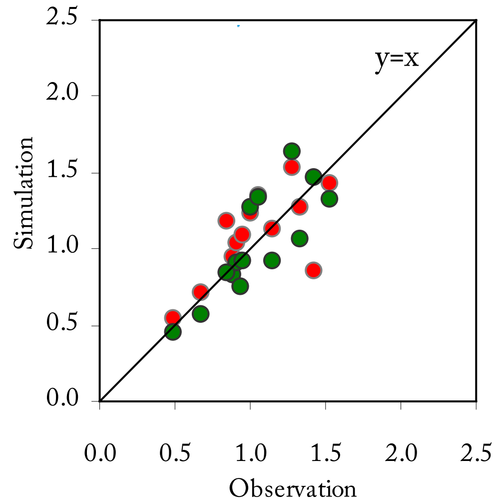
In red : simulation obtained with chlorophyll *a* In green : simulation obtained with phytoplankton

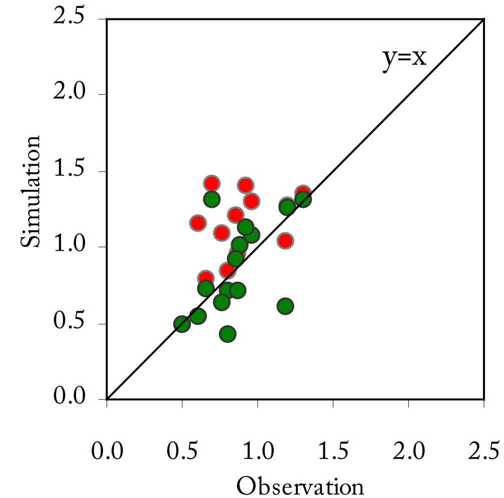












Year	Forcing variables	Best X_K value	Pearson correlation	p-values	Quality of adjustment
1988	*Chlorophyll a*	3.0 $\mu g.l^{-1}$	0.701	0.005	medium
	Phytoplankton	475 $cell.ml^{-1}$	0.932	0.0001	**high**

Year	Forcing variables	Best X_K value	Pearson correlation	p-values	Quality of adjustment
1989	*Chlorophyll a*	3.7 $\mu g.l^{-1}$	0.682	0.007	medium
	Phytoplankton	325 $cell.ml^{-1}$	0.828	0.0003	**high**

Year	Forcing variables	Best X_K value	Pearson correlation	p-values	Quality of adjustment
1990	*Chlorophyll a*	4.0 $\mu g.l^{-1}$	0.521	0.051	low
	Phytoplankton	500 $cell.ml^{-1}$	0.528	0.043	**medium**

Results : Simulation obtained by the model

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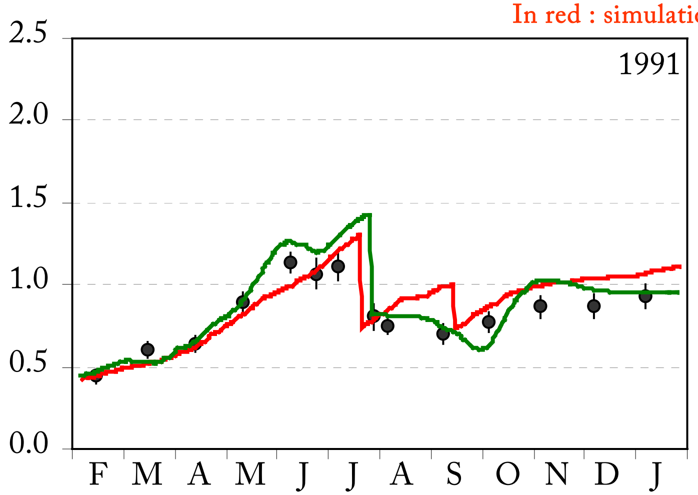

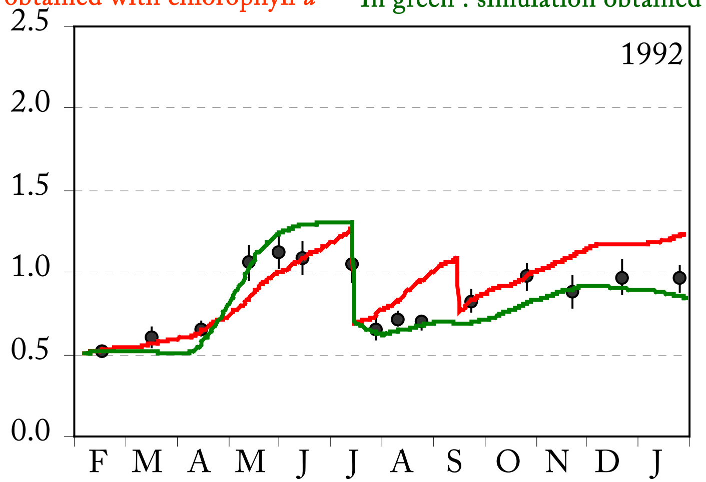

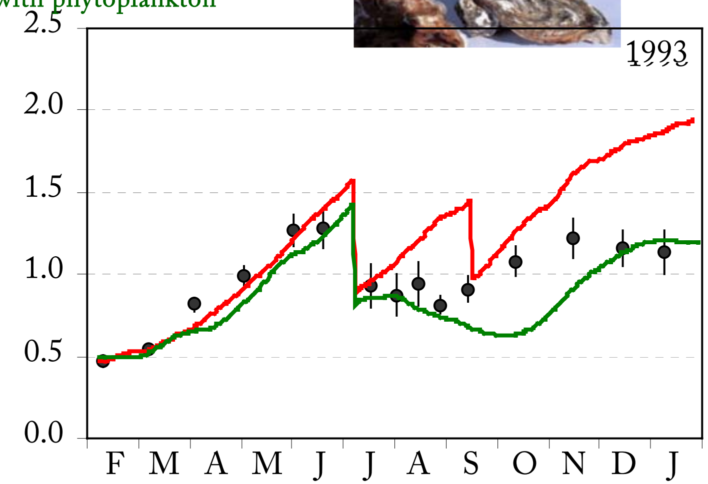

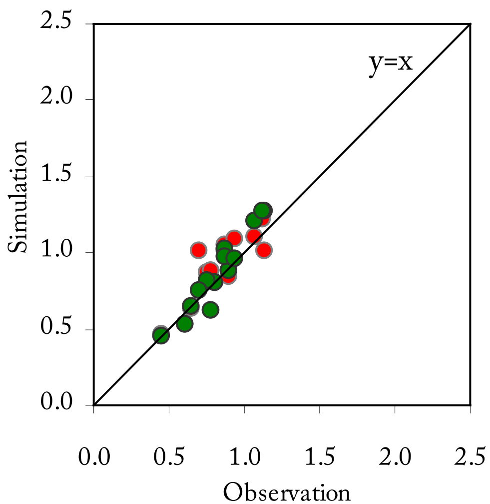

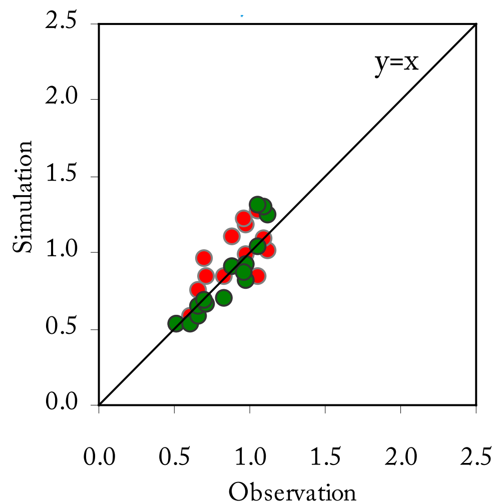

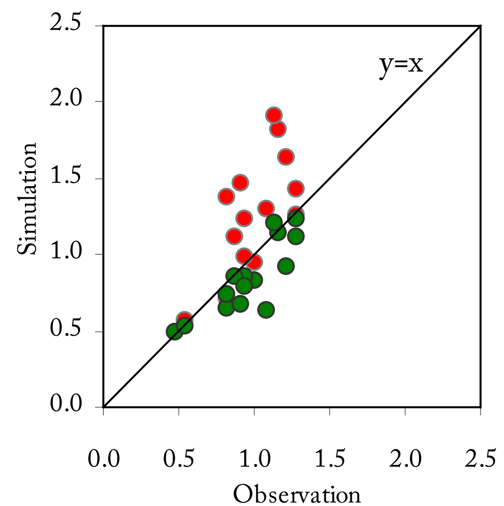

Year	Forcing variables	Best X_K value	Pearson correlation	p-values	Reliability of the model
1991	*Chlorophyll a*	3.2 $\mu g.l^{-1}$	0.859	0.0001	high
	Phytoplankton	550 $cell.ml^{-1}$	0.807	0.0001	high

Year	Forcing variables	Best X_K value	Pearson correlation	p-values	Reliability of the model
1992	*Chlorophyll a*	3.5 $\mu g.l^{-1}$	0.786	0.001	medium
	Phytoplankton	325 $cell.ml^{-1}$	0.917	0.0001	high

Year	Forcing variables	Best X_K value	Pearson correlation	p-values	Reliability of the model
1993	*Chlorophyll a*	2.4 $\mu g.l^{-1}$	0.772	0.001	medium
	Phytoplankton	225 $cell.ml^{-1}$	0.842	0.0001	high

Results : Simulation obtained by the model

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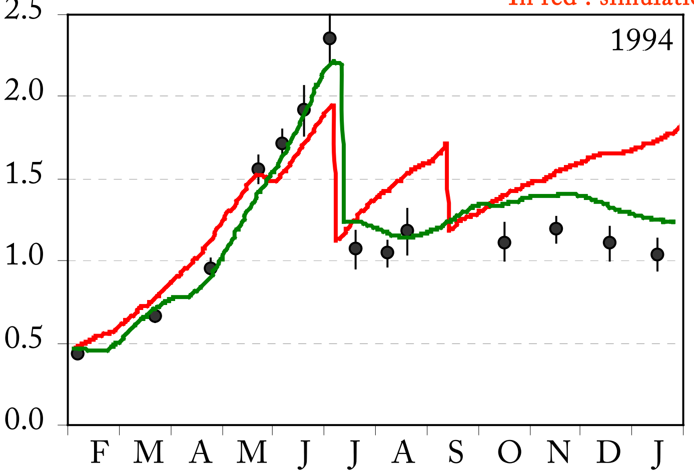
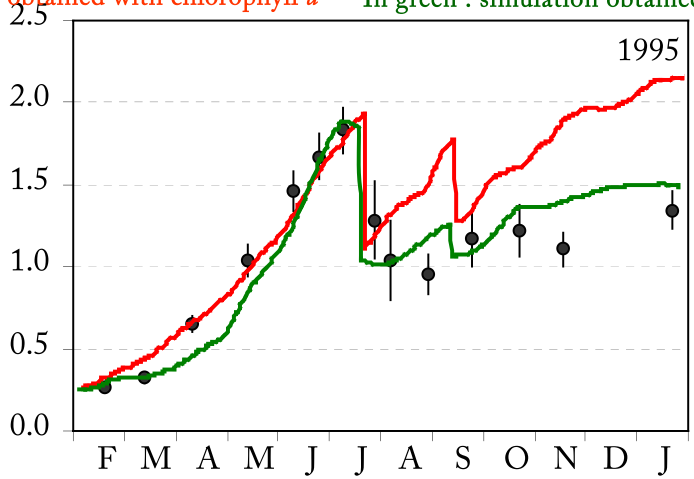
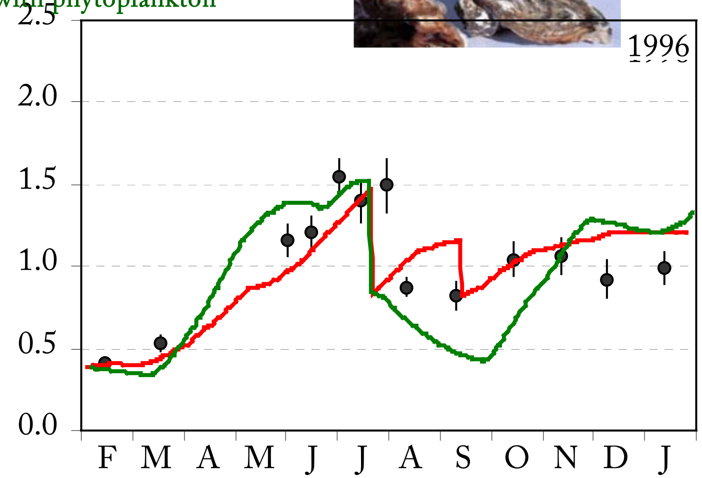
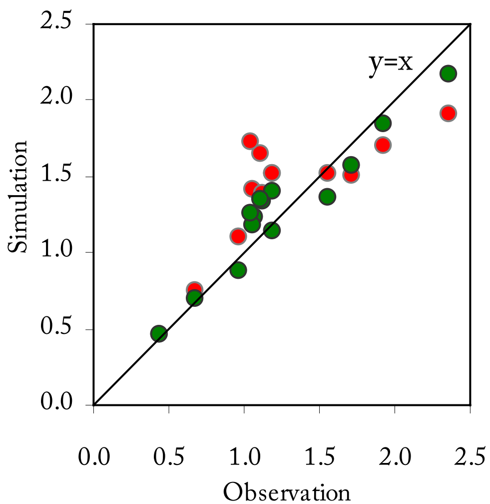
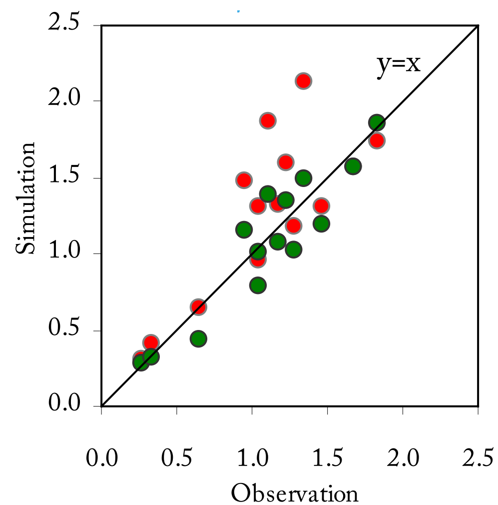
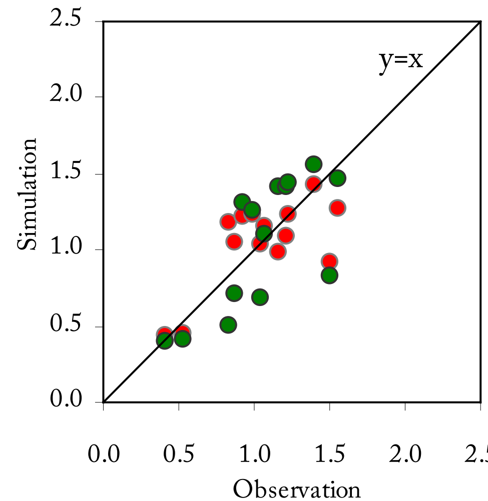










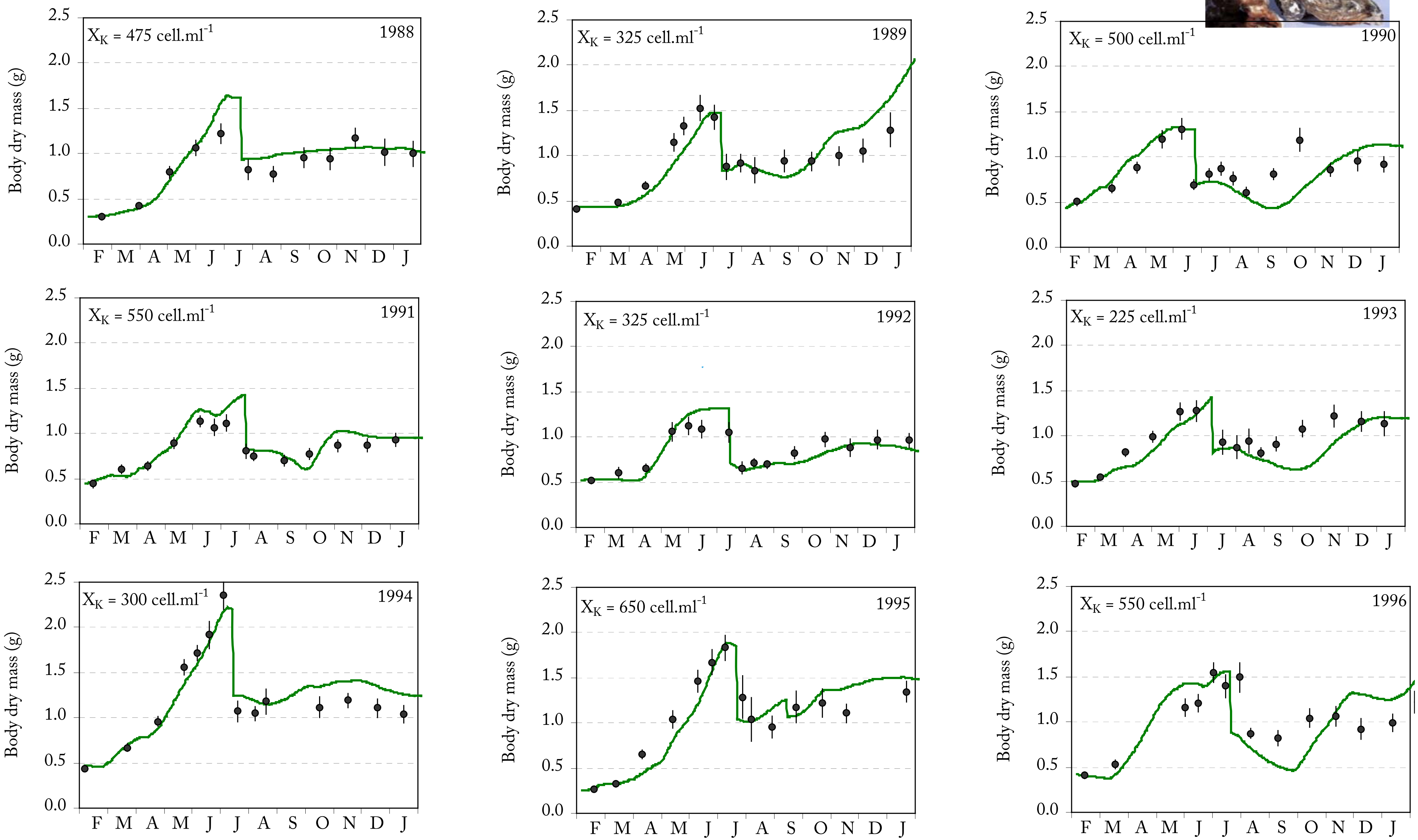


Year	Forcing variables	Best X_K value	Pearson correlation	p-values	Reliability of the model
1994	*Chlorophyll a*	2.75 $\mu g.l^{-1}$	0.785	0.001	medium
	Phytoplankton	300 $cell.ml^{-1}$	0.952	0.0001	high

Year	Forcing variables	Best X_K value	Pearson correlation	p-values	Reliability of the model
1995	*Chlorophyll a*	2.7 $\mu g.l^{-1}$	0.796	0.001	medium
	Phytoplankton	650 $cell.ml^{-1}$	0.927	0.0001	high

Year	Forcing variables	Best X_K value	Pearson correlation	p-values	Reliability of the model
1996	*Chlorophyll a*	2.2 $\mu g.l^{-1}$	0.693	0.009	medium
	Phytoplankton	550 $cell.ml^{-1}$	0.726	0.003	medium

Results : General overview of the best simulations



Discussion & Perspectives

➢ Main outputs of this study :

- ✓ DEB model developed for the Pacific oyster (cf JSR n°56) and adapted by Bourles et al. (2007) produces satisfying simulations in the Arcachon bay.

- ✓ For the moment, best results are obtained when food is quantified by phytoplankton count. Chlorophyll *a* gives over estimations, especially in summer and autumn.

- ✓ Discrepancies with chlorophyll *a* is presumably because of :
  - ✓ A 'part' of the total chlorophyll *a* is not available for Pacific oysters (picoplankton ?)
  - ✓ The quota per cell is not constant and depend on other environnental parameters
  - ✓ Perspectives : apply 'a seasonal correction' of the chlo *a* signal to obtain 'real biomass'.

> « Chl *a* concentrations are just that; they are not biomass measurements. »
>
> Kruskopf, M., Flynn, K J. (2005) New Phytologist 169 (3), 525-536.

- ✓ Satisfying adjustements with phytoplankton count is probably due to the fact that the main species of Arcachon Bay (*Asterionnella glacialis*, *Rhizosolenia delicatula*, *Leptocylindrus danicus*, *Chaetoceros* spp., *Pseudo-nitzschia* spp.) are in the same order of size (1000-2000 μm^3). In that context, count and biomass are proportionnal.

- ✓ Some imperfections still remain in the current model :
  - ✓ Over-estimation during phytoplankton bloom (e.g. 1989 & 1996)
  - ✓ Starvation period generally heavier in the model than in reality
  - ✓ Calibration is still necessary : X_K values varied from 225 to 650 $cell.ml^{-1}$

Discussion & Perspectives

Next improvements of the model :

- ✓ Why the half saturation coefficient X_K varies from one year to an other ?
- ✓ The value of this 'black box' parameter depends on :
  1. Size and 'quality' of food.
  2. Way of measurements for the food quantifier
  3. Phenotypic plasticity (relative sizes of gill or palp).
- ✓ But variation of X_K is not completely 'stochastic'
- ✓ Taking into account this depency should improve the generic property of the next model version