What does the DEB model enlighten on the physiology of a marine bivalve *Crassostrea gigas*?

Results from a collective work presented by M. Alunno-Bruscia[1]

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Context

- The Japanese oyster (*Crassostrea gigas*): either a pest or an important commercial species

Total world production of *C. gigas* in 2005
(FAO statistics, 2007):

4 497 085 t

China:	3 826 636 t (85%)
Korea Rep.:	251 706 t (6%)
Japan:	218 896 t (5%)
France:	118 120 t (3%)
USA:	21 323 t (0.5%)

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Context & objective

- The French oyster culture is faced with some variability in yields, which are related to variability in growth, spatfall (& gametogenesis) and survival of *C. gigas* among culture sites and over years.

- A saying goes...
  "When the French *Crassostrea gigas* gets a cold, the whole Ifremer is sneezing"

- Objective: to explain the inter-annual and spatial variability in growth and gametogenesis of oysters by testing if it is due to environmental variability (temperature, food)

Variability in growth & gametogenesis ← ? Environmental variability

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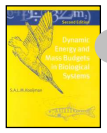
Material & methods: Modelling procedure

- General overview of the modelling procedure:

Step 1: Conceptualisation — 10 mathematical key-equations to describe the main physiological processes (Kooijman, 2000)



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Step 2: Parameters estimation — 15 parameter values estimated for *C. gigas* on the basis of ecophysiological experiments except X_K (calibration for each simulation)

2

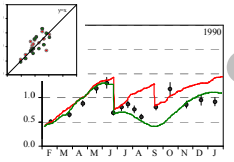
Step 3: Implementation — Implementation of equations and numerical computing under a modelling software (Stella)


3

Step 4: Test & simulations

- 4.1: Forcing — Forcing by temperature & food density
- 4.2: Validation — >Statistical validation by comparing simulations *vs* observations

9-year data set (1988-1996) in Arcachon Bay



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Material & methods: Modelling procedure

DEB parameters values (Pouvreau *et al.* 2006, Bourlès *et al.* in prep.)

Parameters	Symbol	Dimension	Estimate	References
Half saturation coefficient	**X_K**	***= f (food quantifier)***		Bourles *et al*., *in prep*.
Max. surface area-specific ingestion rate	**{ p_{Xm} }**	$J.cm^{-2}.d^{-1}$	560	Van der Veer *et al*., 2006
Assimilation efficiency	**AE**	%	75	Van der Veer *et al*., 2006
Maximum storage density	**[E_M]**	$J.cm^{-3}$	2295	Van der Veer *et al*., 2006
Volume-specific costs for structure growth	**[E_G]**	$J.cm^{-3}$	1900	Van der Veer *et al*., 2006
Volume-specific maintenance costs	**[p_M]**	$J.cm^{-3}.d^{-1}$	24	Van der Veer *et al*., 2006
pC fraction spent on maintenance + growth	**K**	-	0,45	Van der Veer *et al*., 2006
Structural volume at puberty	**V_P**	cm^{-3}	0,4	Pouvreau *et al*., 2006
Fraction of reproduction energy fixed in eggs	**K_R**	-	0,7	Pouvreau *et al*., 2006
Temperature threshold trigger. spawn.	**T_S**	℃	**20-22**	Bourles *et al*., unpubl. data
Gonado-somatic index trigger. spawn.	**GI**	%	**35-43**	Bourles *et al*., unpubl. data
Arrhenius temperature	**T_A**	K	5800	Van der Veer *et al*., 2006
Low boundary temperature	**T_L**	K	**276**	Bourles *et al*., *in prep.*
Upper boundary temperature for maint.	**$T_{H\ maint}$**	K	**308**	Bourles *et al*., *in prep.*
Upper boundary temperature for ing.	**$T_{H\ ing}$**	K	**299**	Bourles *et al*., *in prep.*

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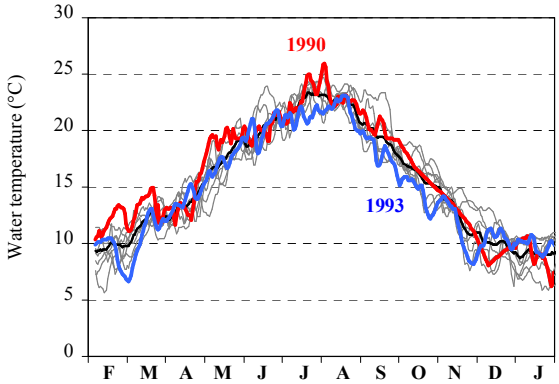
Material & methods: Forcing variables

- **Physiological rates are forced in the model by temperature**
  - ✓ Daily water temperature over 9 years (1988-96) in Arcachon Bay
  - ✓ Seasonal fluctuations from 9°C to 23°C
  - ✓ Inter-annual variability (*e.g.* 1990 *vs* 1993)



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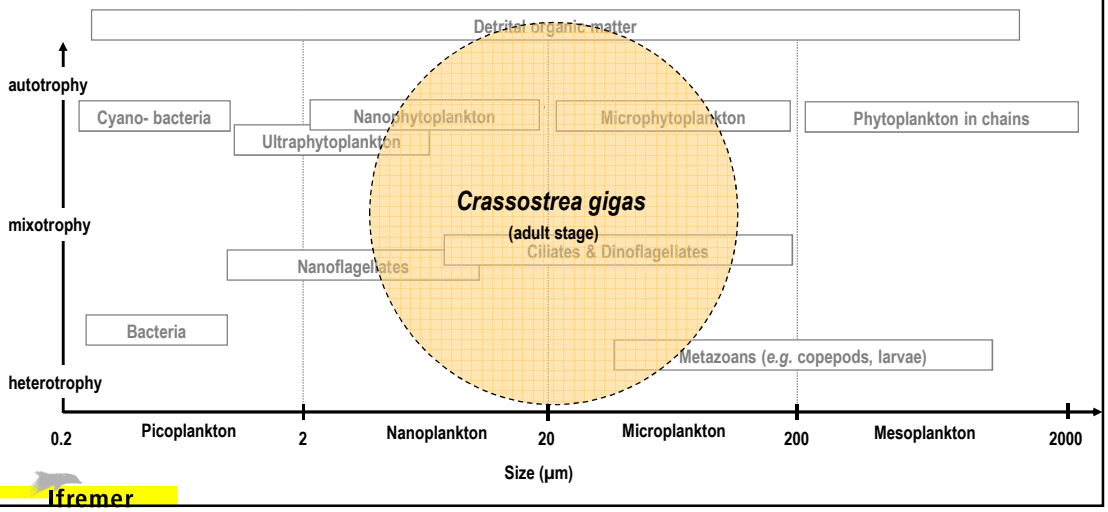
Material & methods: Forcing variables

➢ The second forcing variable is food density…, but what is 'Food'?

✓Planktonic preys for filter-feeders are various

✓Adults of *C. gigas* presumably feed on nanoplankton & microplankton



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Material & methods: Forcing variables

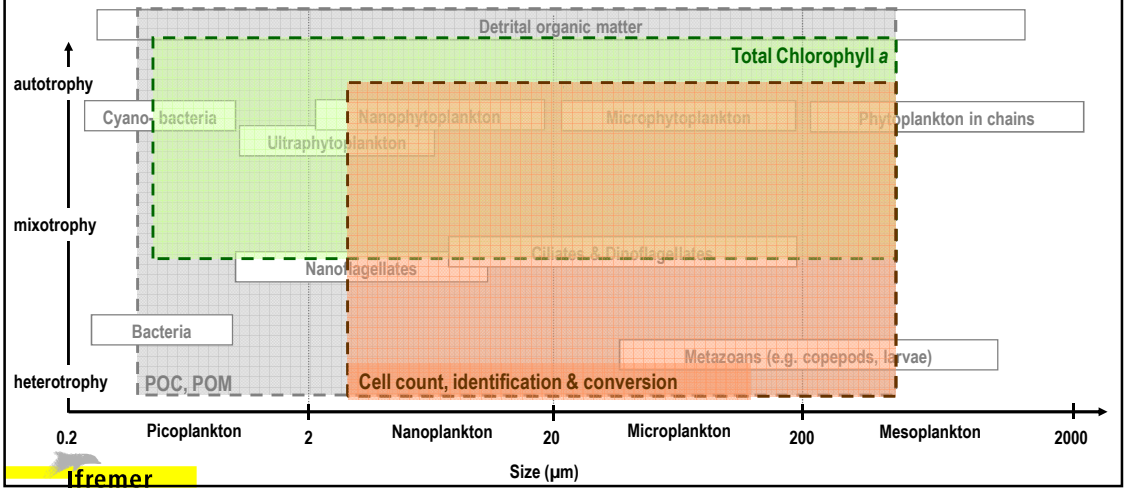
➢ How to estimate 'Food'?

✓ Total POC, POM: easy but 'rough' descriptors (no distinction between living and non-living matter)

✓ Chlorophyll *a*: commonly used, but quota per cell is not constant (varies with irradiance, T°C, nutrients)

✓ Plankton abundances (microscopy cell counts, species identification): more precise, but not a biomass

✓ Plankton biomass (volume measurement, carbon conversion): perfect (!), but time consuming



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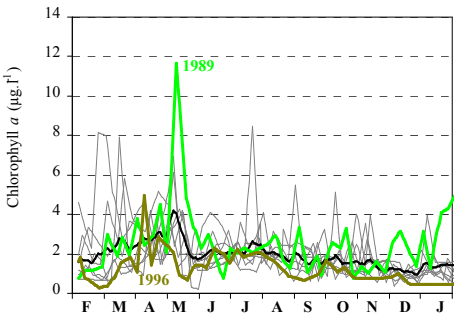
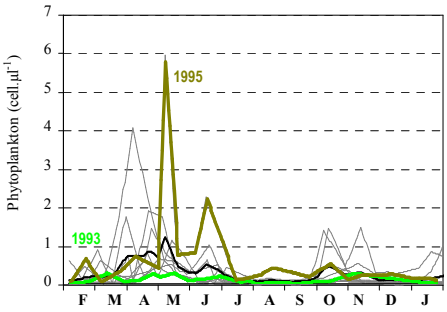
Material & methods: Forcing variables

- In Arcachon Bay, several 'food quantifiers' are available from 1988 to 1996:
  - ✓ POM (monthly)
  - ✓ Total chlorophyll *a* (fortnightly)
  - ✓ Plankton abundances, *i.e.* cell counts & species identification >6 µm (monthly)
  - ✓ Plankton biomass (volume measurement , occasionally)





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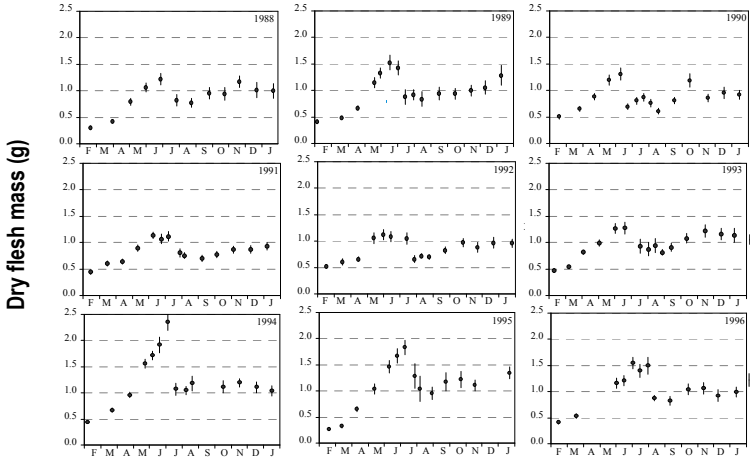
Material & methods: Validation data

- Growth data were used to test the model in Arcachon Bay:
  - ✓ Growth and gametogenesis were measured during the same period (1988-96)
  - ✓ In spring, increasing dry flesh mass was due to gametogenesis
  - ✓ In July, sharp decline in dry flesh mass was due to spawning event, with inter-annual variability



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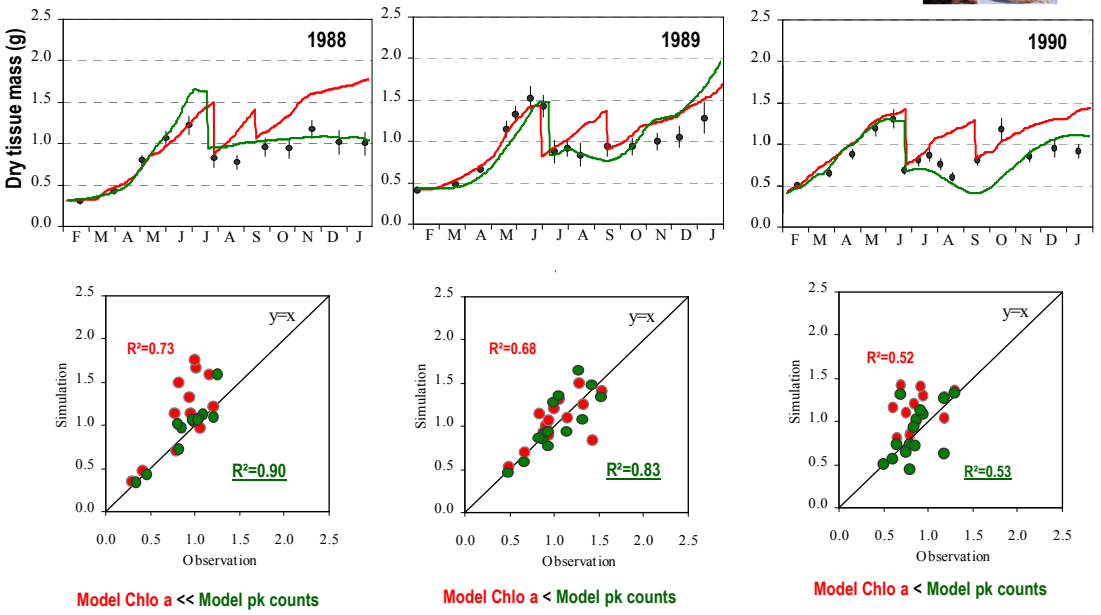
Results: Model simulations



Model Chlo a << Model pk counts

Model Chlo a < Model pk counts

Model Chlo a < Model pk counts

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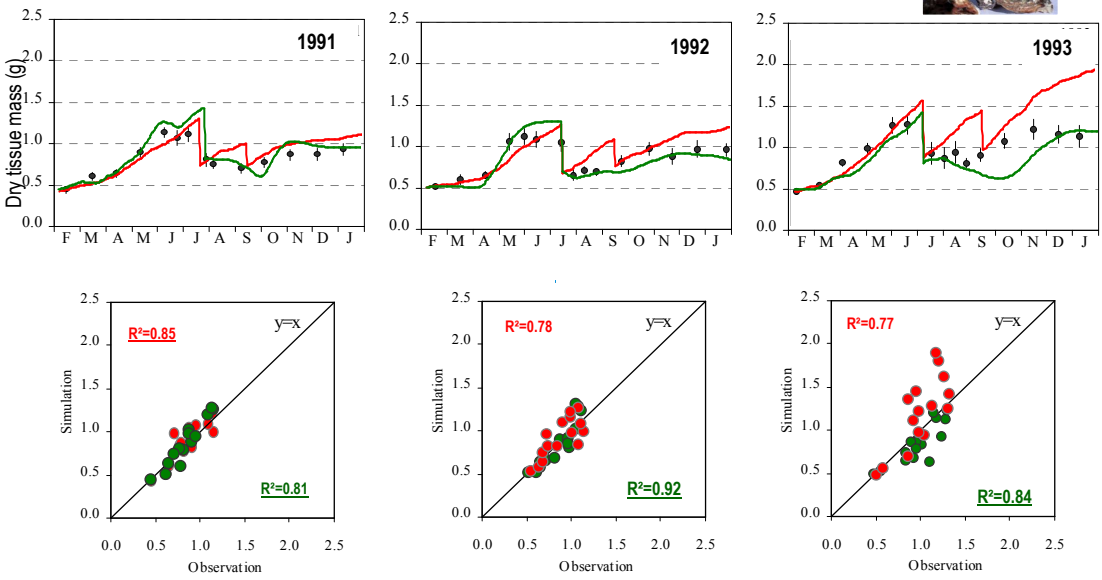
In red : simulation with chlorophyll *a*

In green : simulation with plankton counts

Results: Model simulations



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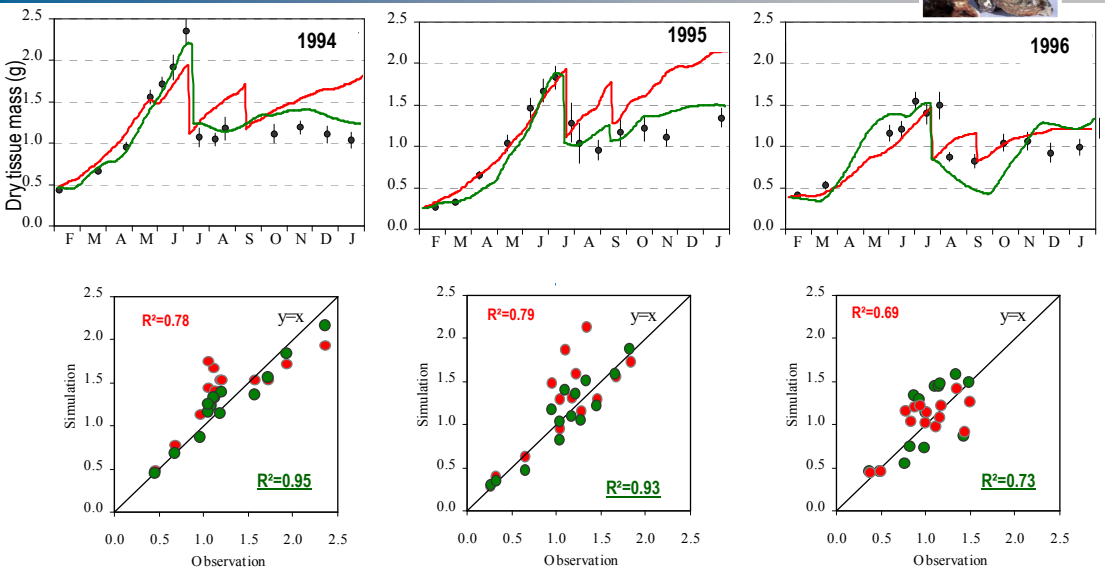

Model Chlo a < Model pk counts

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In red : simulation with chlorophyll *a*

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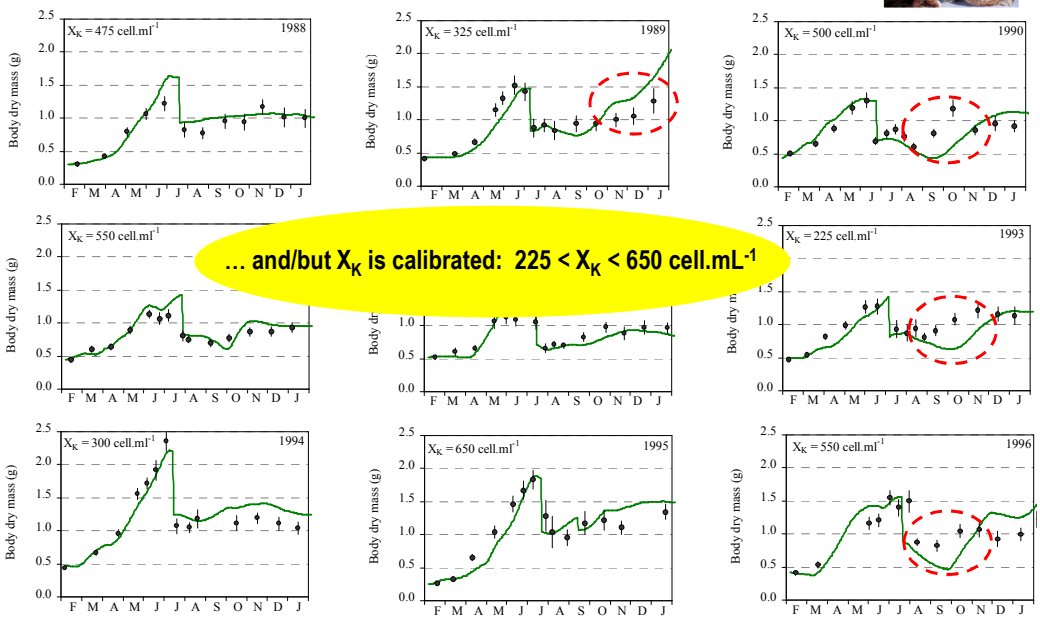
Results: Summary



… and/but X_K is calibrated: 225 < X_K < 650 cell.mL^{-1}

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Discussion

➢ Main outputs:

- ✓ The DEB model developed for *C. gigas* (cf. Pouvreau *et al.* 2006 *JSR* n°56; modified by Bourles *et al.* 2007) provided satisfying simulations in Arcachon Bay.
- ✓ **Variability in growth and reproduction** of *C. gigas* is mainly due variability in temperature and food.
- ✓ **Phytoplankton counts** provided the best simulations of oyster mass. Using chlorophyll *a* results in over estimating oyster growth, especially in summer and autumn.
- ✓ **Discrepancies with chlorophyll *a*** are likely due to:
  - ✓ Some 'part' of total chlorophyll *a* is not available for oysters (picoplankton ?);
  - ✓ The quota per cell is not constant and depends on other environnental parameters.

➢ Some problems need to be solved:

- ✓ The current model still suffers **some imperfections**:
  - ✓ Over-estimation of the flesh mass during phytoplankton blooms (*e.g.* in 1989 & 1996)
  - ✓ Under-estimation when [food] is low (*e.g.* in 1990, 1993 & 1996)
  - ✓ The model relies on the calibration of X_K and is not fully 'generic' yet.
  - ✓ The **next step** will consist in testing the model in **other envionments**.

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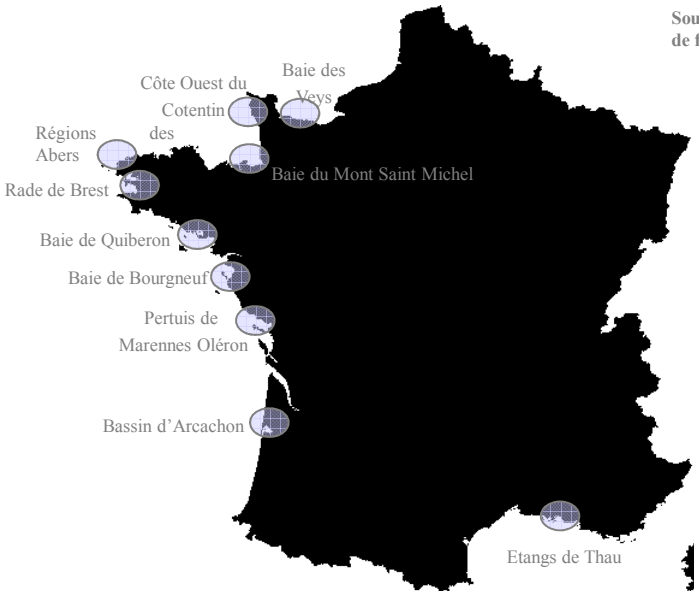
French oyster culture sites



Sources des données de forçage et de validation:
- REPHY
- LERs
- Données publiées
- MOREST/PNEC

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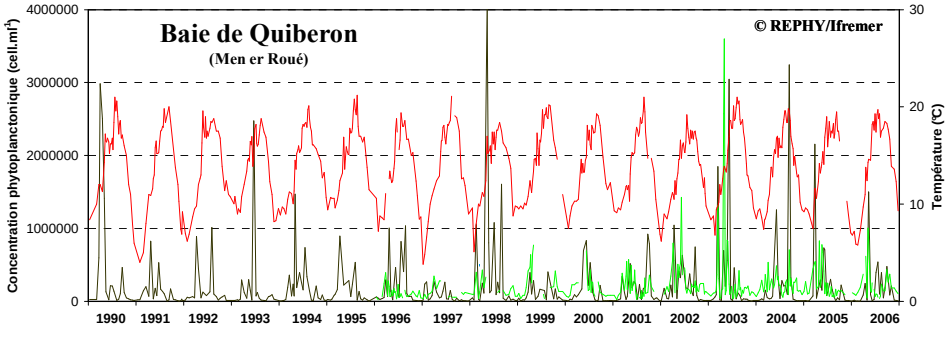
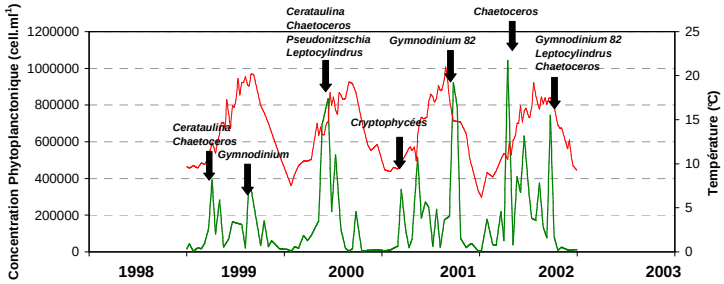
Another example: data from Baie de Quiberon





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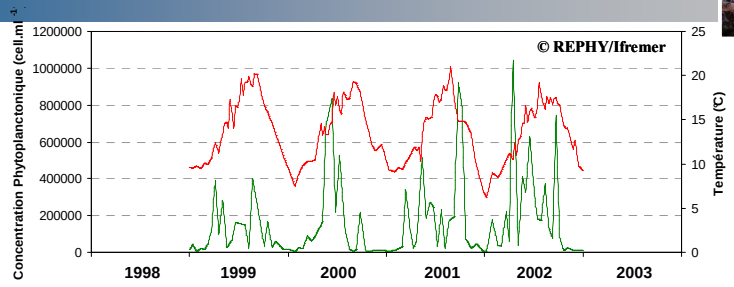
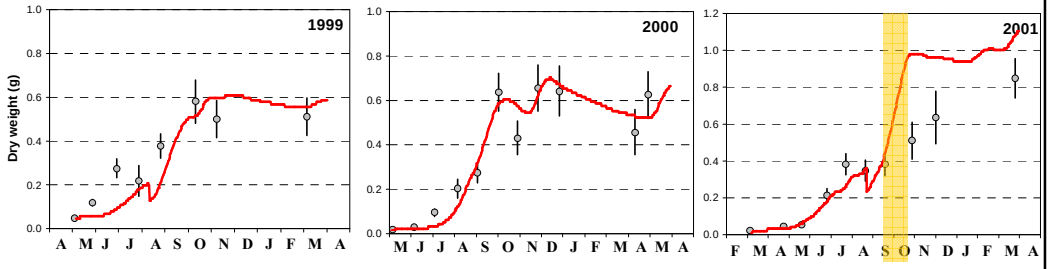
Model validation (Baie de Quiberon)



X_K = 350 cell.mL^{-1}

Vp= 0.3 cm^3



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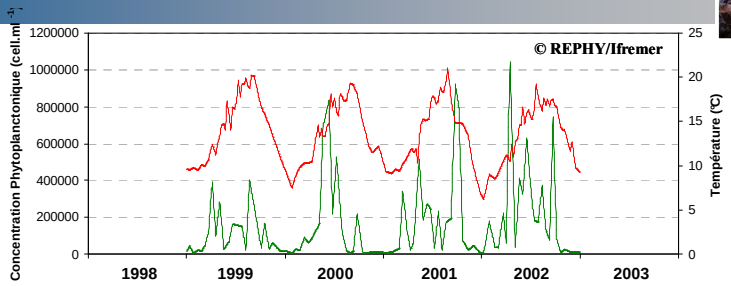
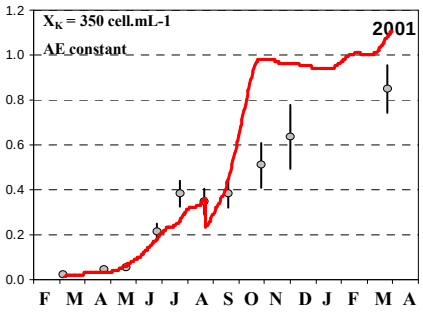
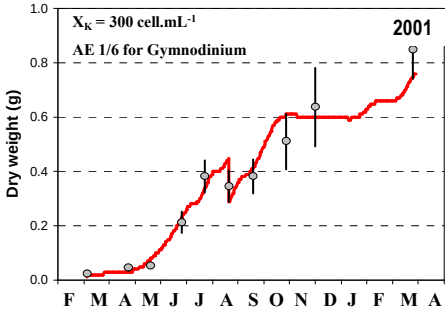
Data sources: J. Mazurié/PG Fleury LER-MPL, Ifremer

Model validation (Baie de Quiberon)







Data sources: J. Mazurié/PG Fleury LER-MPL, Ifremer

Perspectives & conclusion

- **Further improvements of the model:**
  - ✓ We need to understand the reasons/sources of **variations in X_K**
  - ✓ X_K is a 'black box' parameter, which depends on several factors especially **food quality**.
  - ✓ There is likely a relationship between the intensity of blooms and X_K value, which may help to improve the generic property of future versions of the model.