Mechanistic model of Paralytic Shellfish Toxins (PSTs) accumulation in the Pacific oyster *Crassostrea gigas*

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UBO Université de Bretagne Occidentale

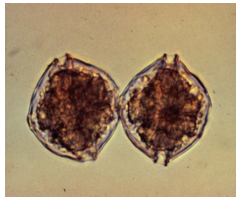
LEMAR laboratoire des sciences de l'environnement marin UMR CNRS/UBO/IRD/Ifremer

Context

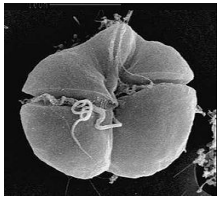
What?

Harmful algal blooms (HABs) occur when colonies of algae bloom at high concentrations while producing toxic or harmful effects on humans and/or marine organisms

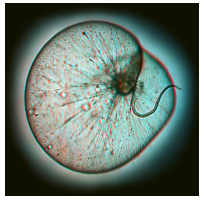
Who?



***Alexandrium* sp.**



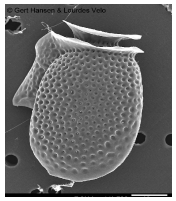
***Karenia* sp.**



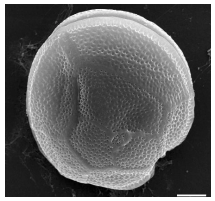
***Noctiluca* sp.**

***Prorocentrum* sp.**

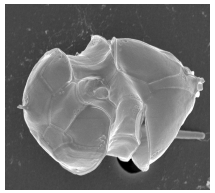
Dinoflagellates and diatoms



***Dinophysis* sp.**



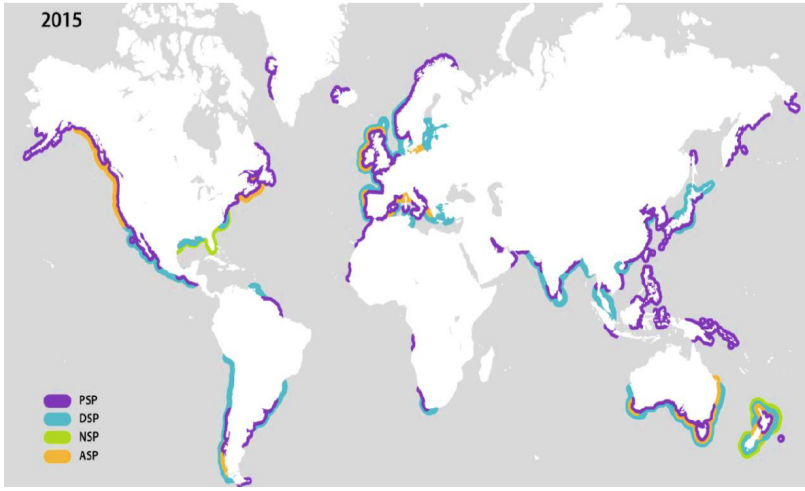
***Gambierdiscus* sp.**



***Azanadinium* sp.**

***Pseudonitzschia* sp.**

Where?

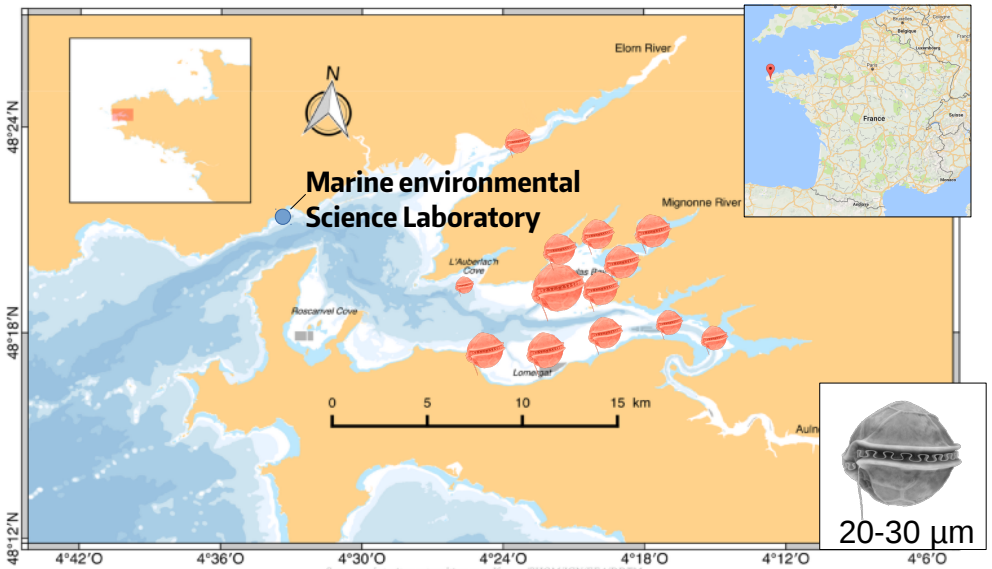


from Van Dolah 2000 and WHOI 2007
(in Boullot 2017)

A bloom of *A. monilatum*
at the mouth of the York river

Local context & objective

Alexandrium minutum blooms regularly in the bay of Brest (France)



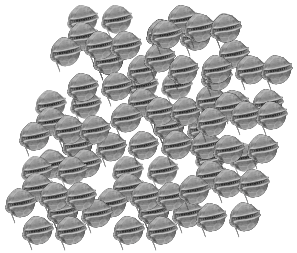
S.Petton, multisources geotreatment, Ifremer/SHOM/IGM/EEA/DDTM

Suitable environmental conditions for *A. minutum*

Production of saxitoxins

Consumed by different bivalves species

Shellfish culture area: 1,500 tons of cultured *C. gigas*, 15,000 tons of wild oysters



10,000 cells L^{-1}

80 µg STX 100 g^{-1}

Alert threshold → Sanitary threshold → Harvesting closure

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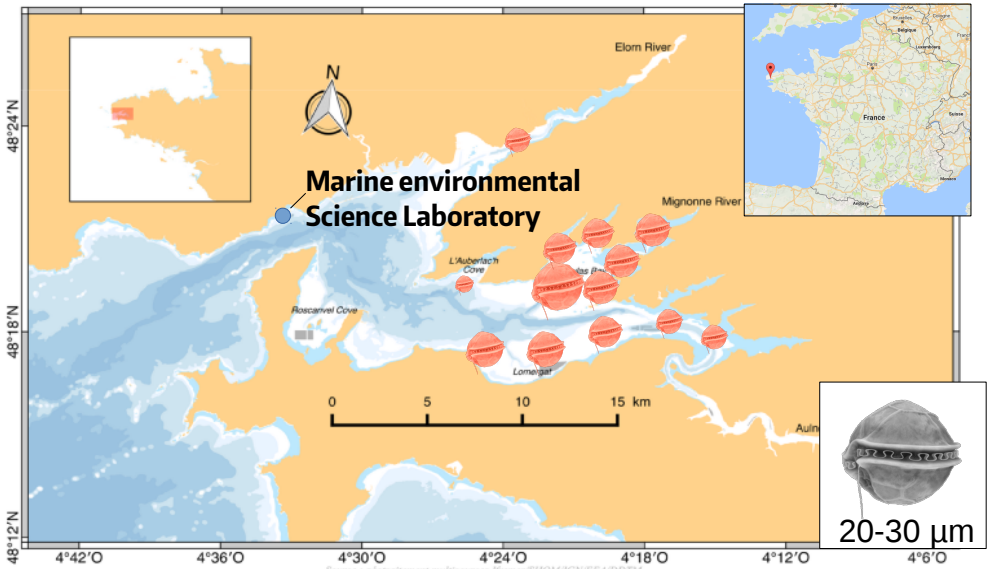

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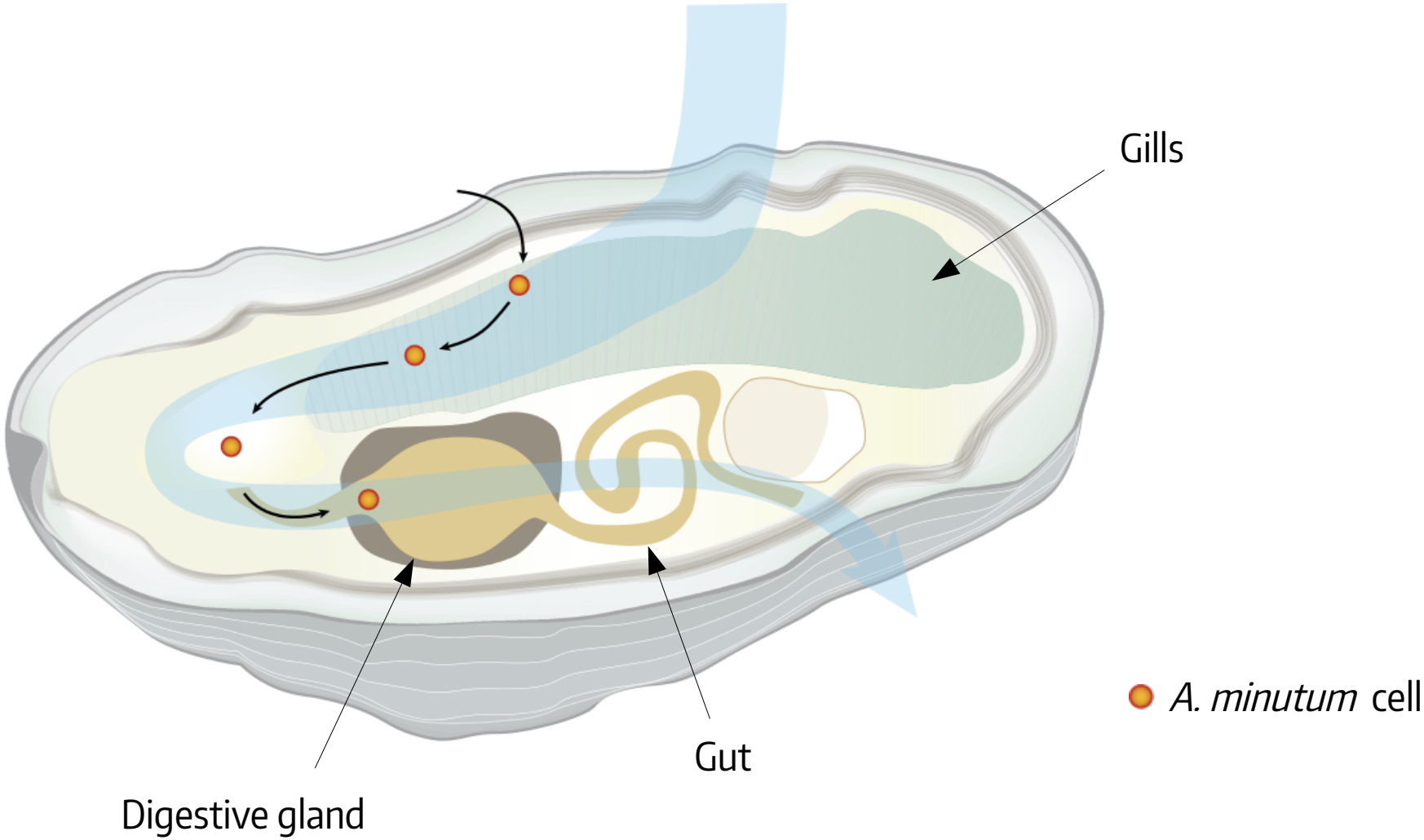
<u>Objective:</u>

To model the accumulation of paralytic shellfish toxins

in *Crassostrea gigas*

How do oysters accumulate paralytic shellfish toxins?



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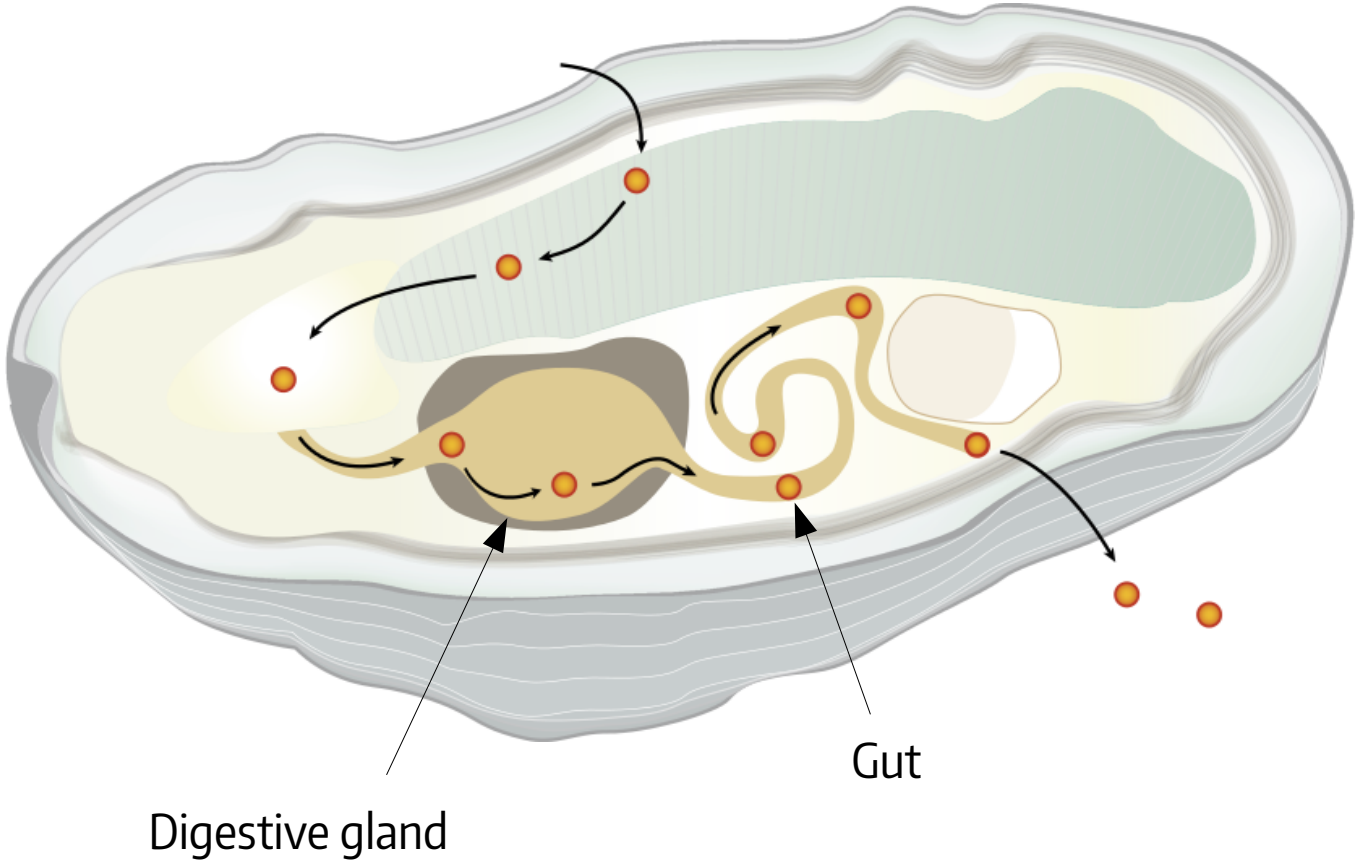

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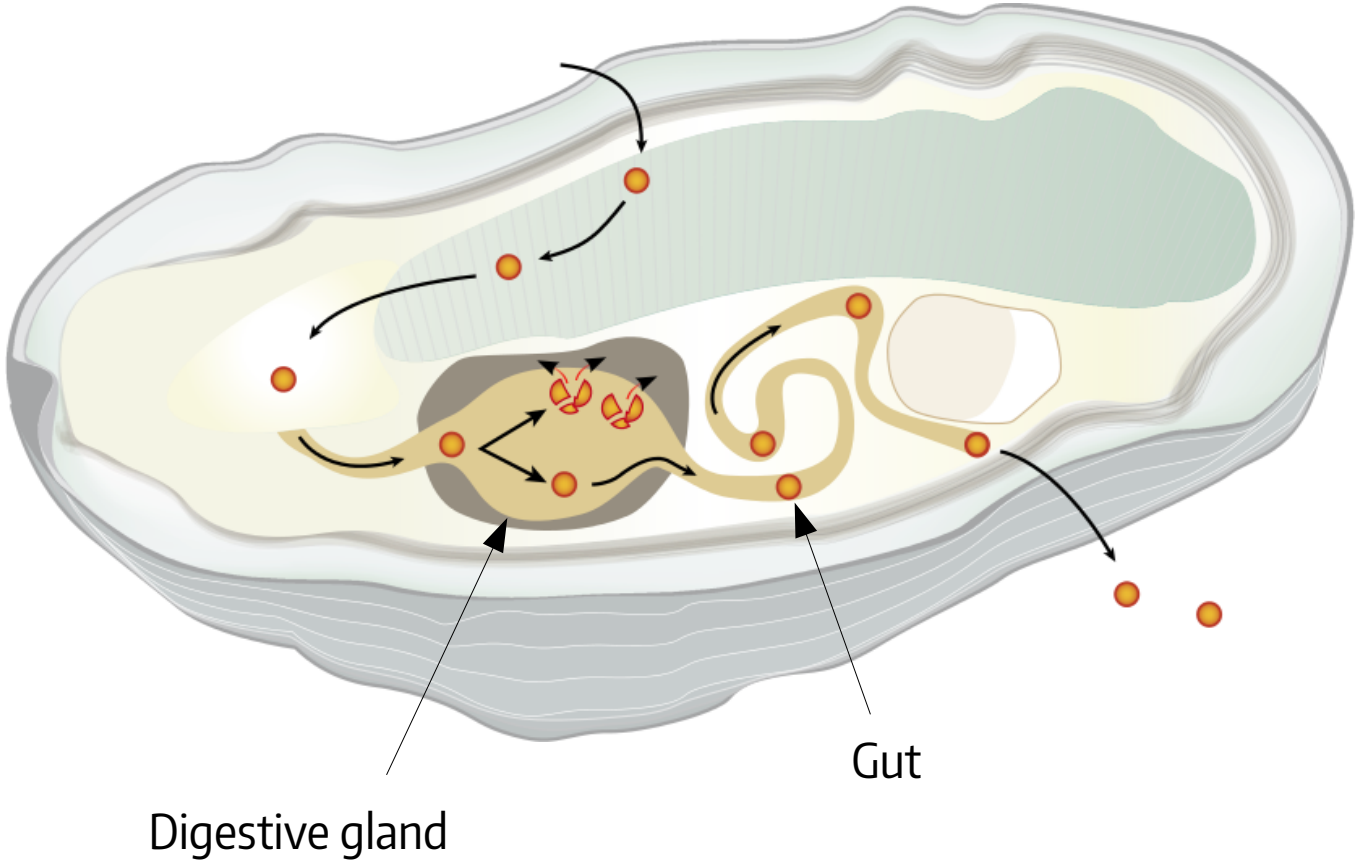

Assumptions for the model

- **2 compartments of accumulation:**

-Toxins from non-assimilated *A. minutum* cells in the digestive system (TOX_{NA})

→ Need to model dynamics of the digestive tract

-Assimilated toxins (TOX_A)

→ Without any distinction between the different tissues

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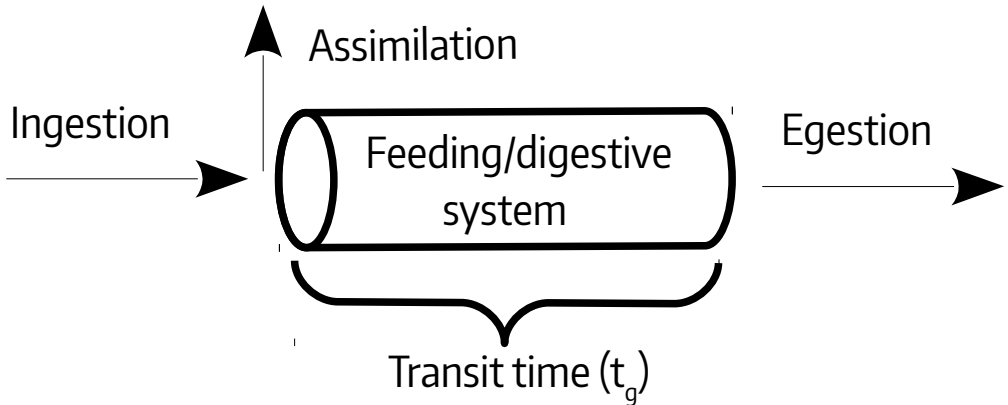
  → Determine the transit time (proportional to L)

  → The assimilation happens at the beginning of the digestive system



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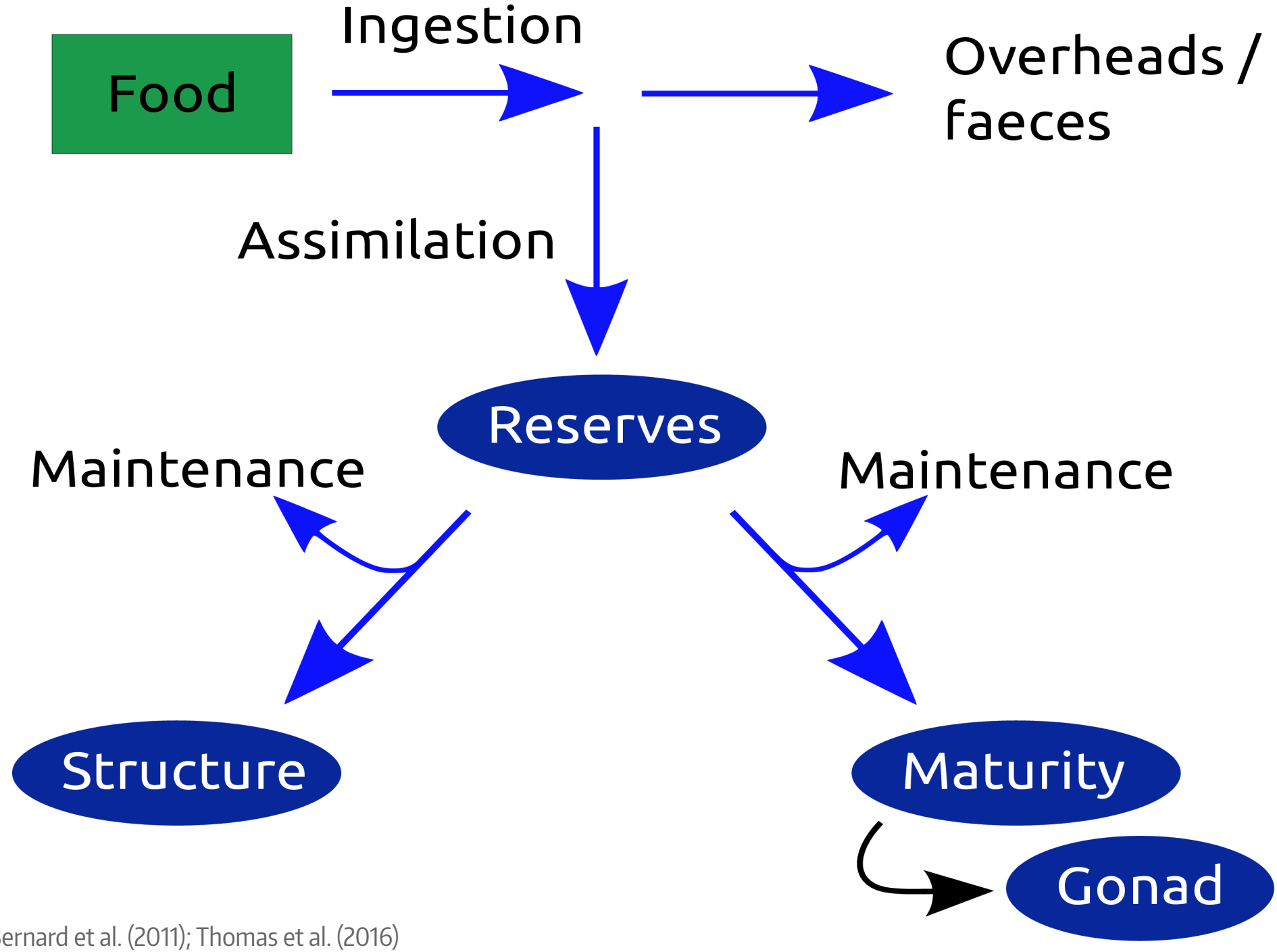
- **Toxins don't affect oyster bioenergetics**

4- state variables DEB model



From Bernard et al. (2011); Thomas et al. (2016)

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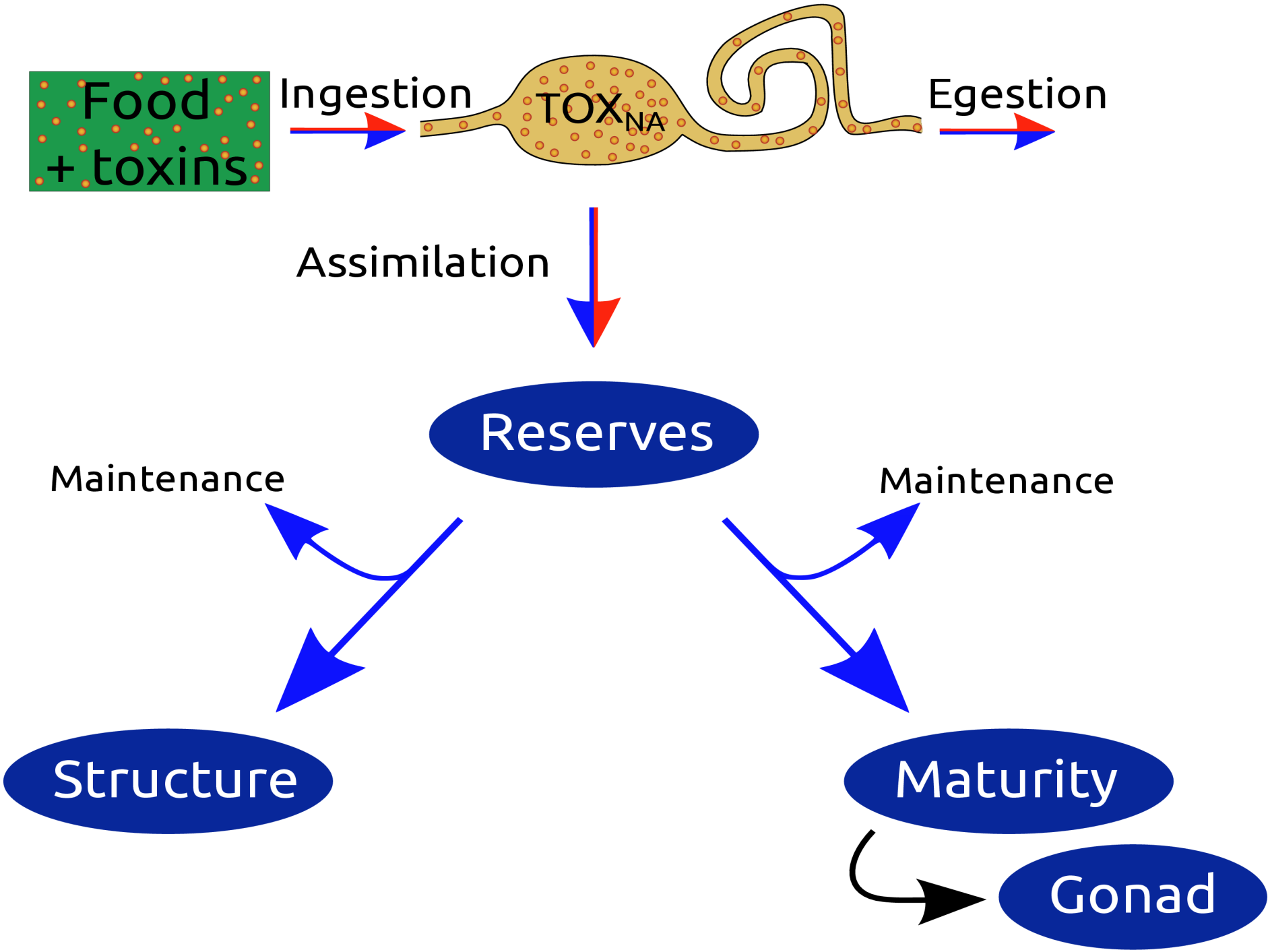

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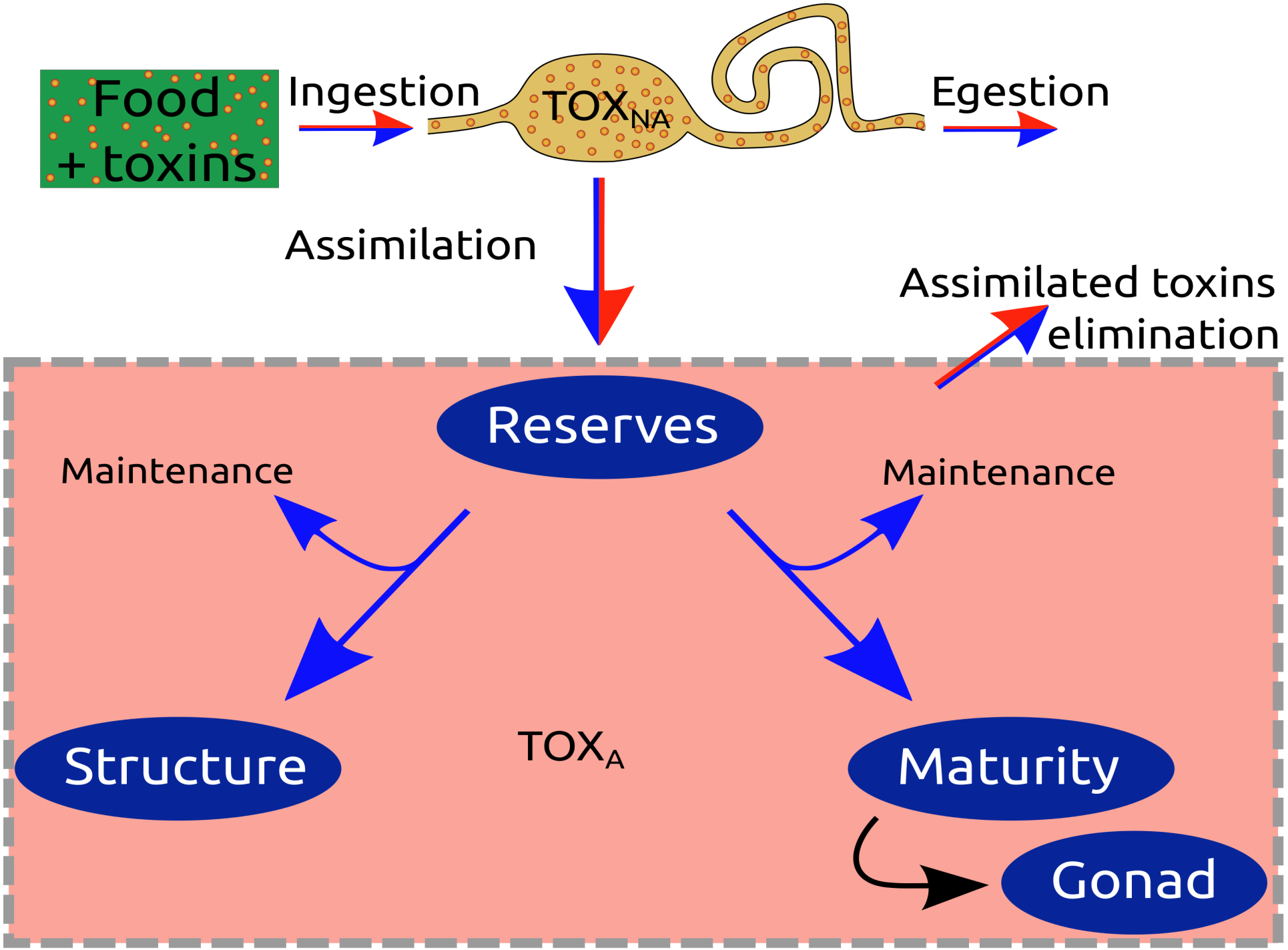


DEB-PST model

With: 2 state variables

$$\text{Non assimilated toxins } (\mu g\ STX) \quad \frac{dTOX_{NA}}{dt} = \dot{p}_{Xtox} - \dot{p}_{Atox} - \dot{p}_{Etox}$$

$$\text{Assimilated toxins } (\mu g\ STX) \quad \frac{dTOX_{A}}{dt} = \dot{p}_{Atox} - \dot{p}_{detox}$$

4 fluxes

$$\text{Toxin Ingestion} \quad \dot{p}_{Xtox} = \dot{p}_X\ \%_{\text{toxic algae}}\ \rho_{tox}$$

$$\text{Toxin assimilation} \quad \dot{p}_{Atox} = \dot{p}_{Xtox}\ \kappa_{Xtox}$$

$$\text{Toxin egestion} \quad \dot{p}_{Etox} = \dot{p}_{Xtox[t-t_g]} - \dot{p}_{Atox[t-t_g]}$$

$$\text{Assimilated toxins elimination} \quad \dot{p}_{detox} = k_e\ TOX_A$$

5 parameters

Description	Symbol	Unit
Toxin content per energy unit	ρ_{tox}	$\mu g\ STX\ J^{-1}$
Fraction of toxin assimilated	κ_{Xtox}	$-$
Elimination rate	k_e	d^{-1}
Transit time	t_g	d

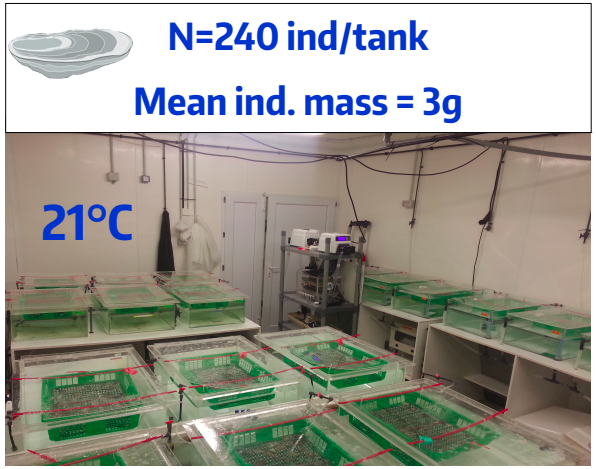
1 forcing variable

Ratio toxic algae/total algae	$\%_{\text{toxic algae}}$	$-$

Total toxin concentration (µg STX 100 g^{-1}): $c_{Tox} = \dfrac{(TOX_{NA} + TOX_A)}{W_w} \times 100$

Material and methods

Objective: to calibrate the model of the PST accumulation in *C. gigas*



X 3 replicate tanks
for each condition

	Conditions	
1	6 weeks	non-toxic algae
2	6 weeks	*A. minutum* + non-toxic algae
3	8 weeks	no food
4	2 weeks then 6 weeks	*A. minutum* + non-toxic algae no food

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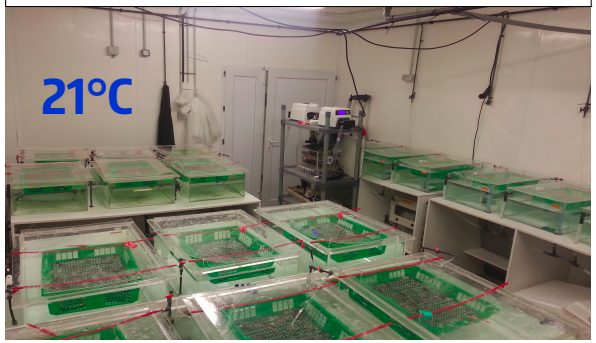
N=240 ind/tank

Mean ind. mass = 3g



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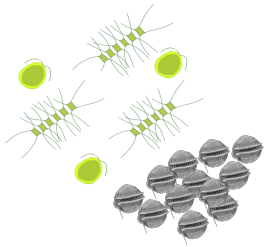
Daily



Algal concentrations

Material and methods

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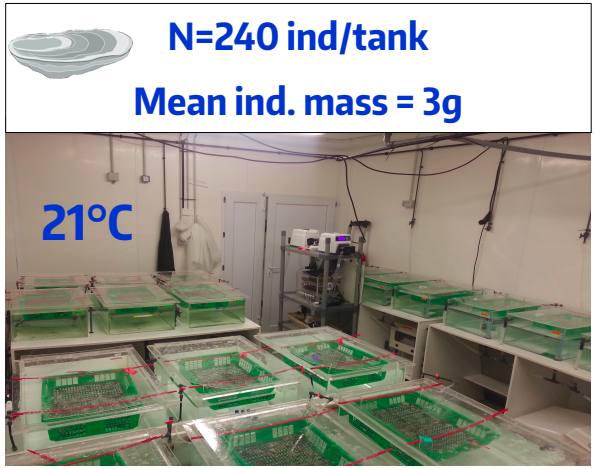

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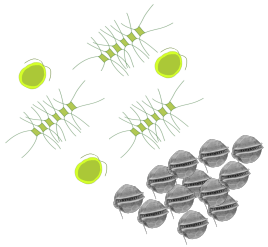


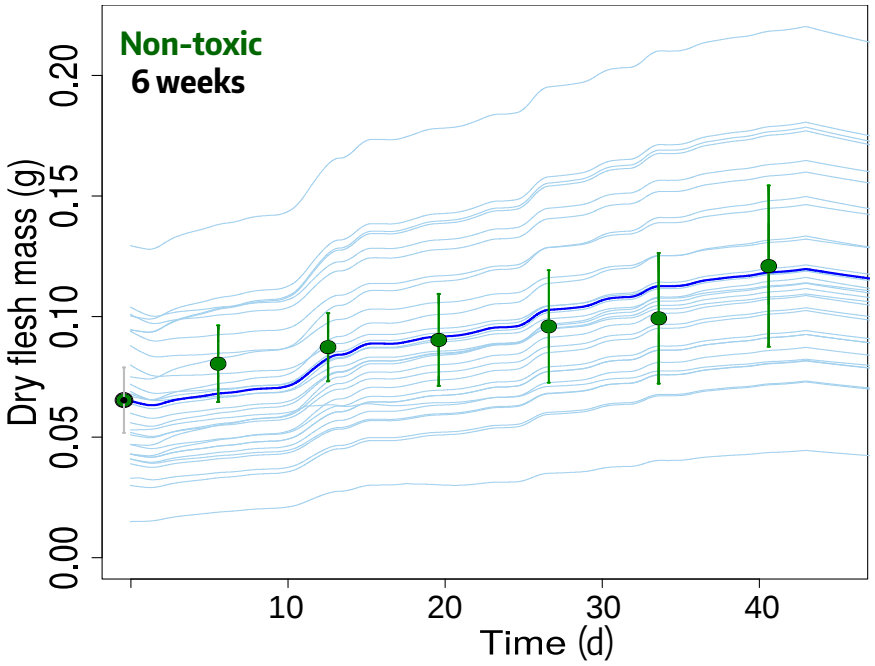
Algal concentrations

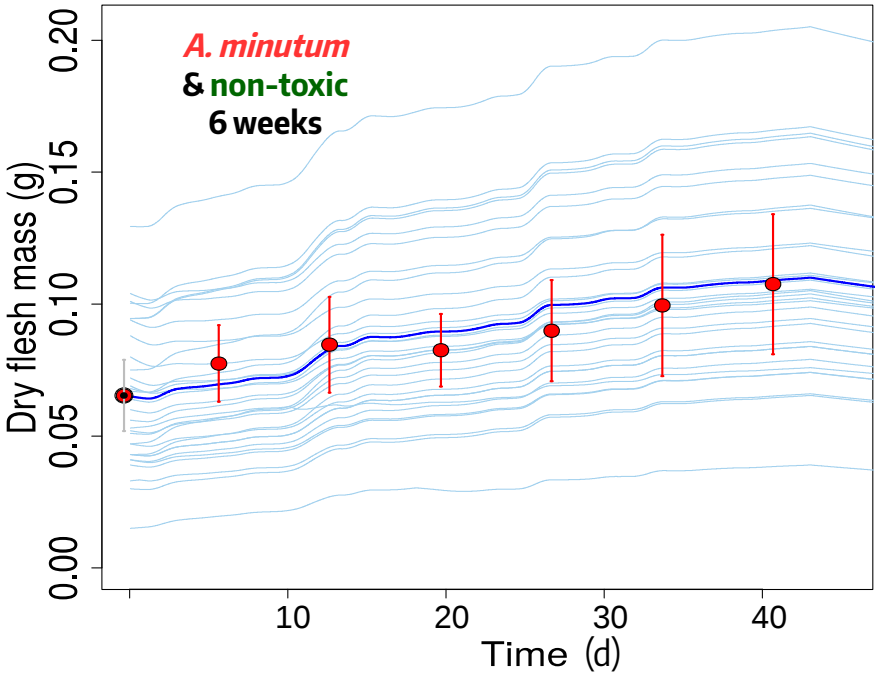
Weekly

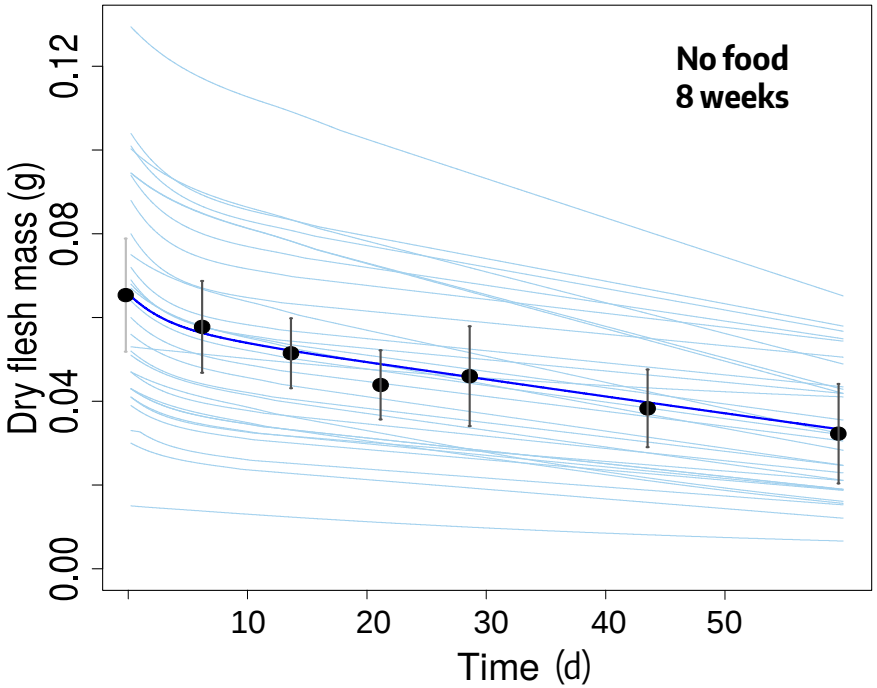
Dry flesh mass

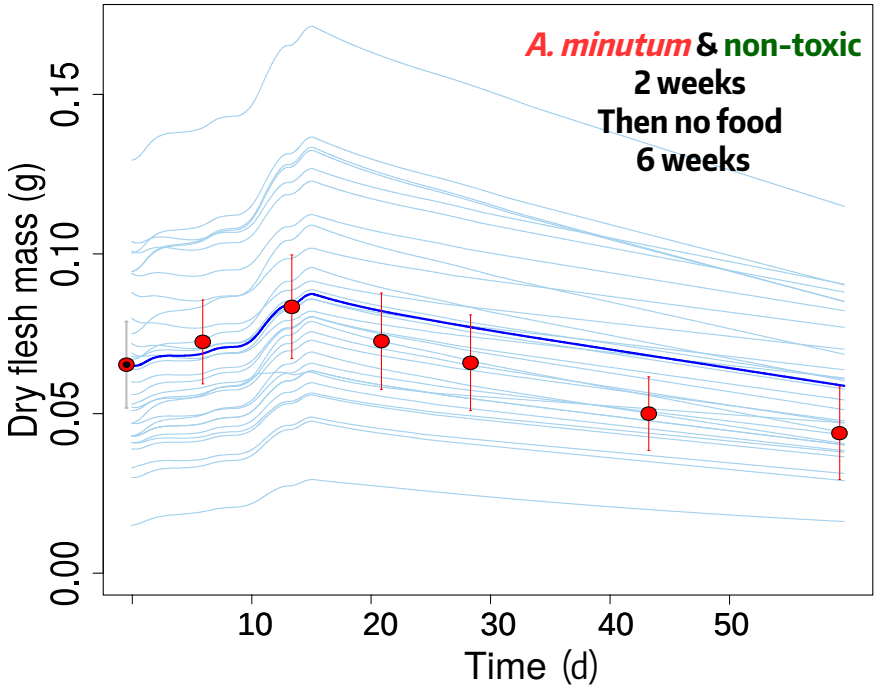
Toxin concentration

Results: model parameters









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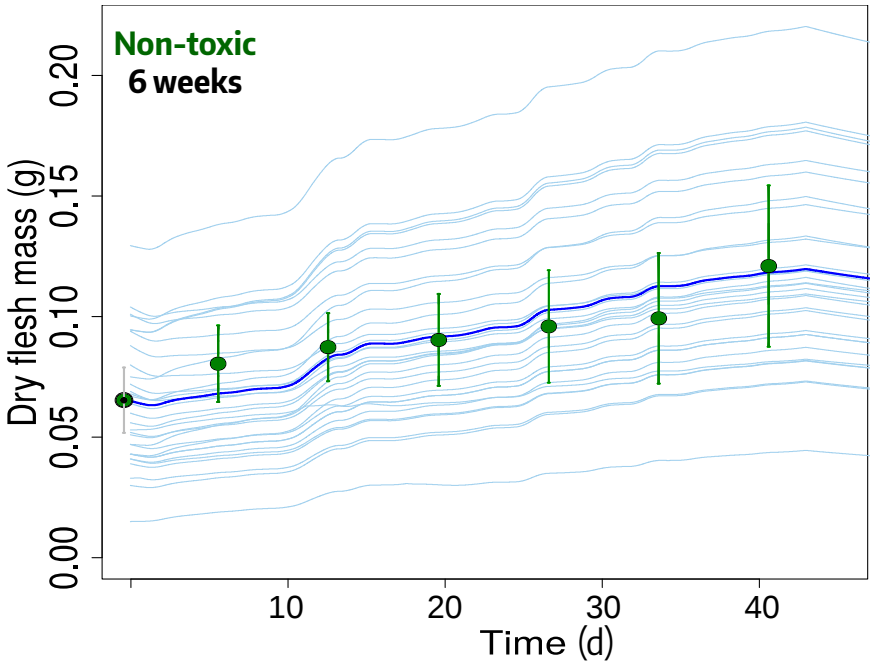
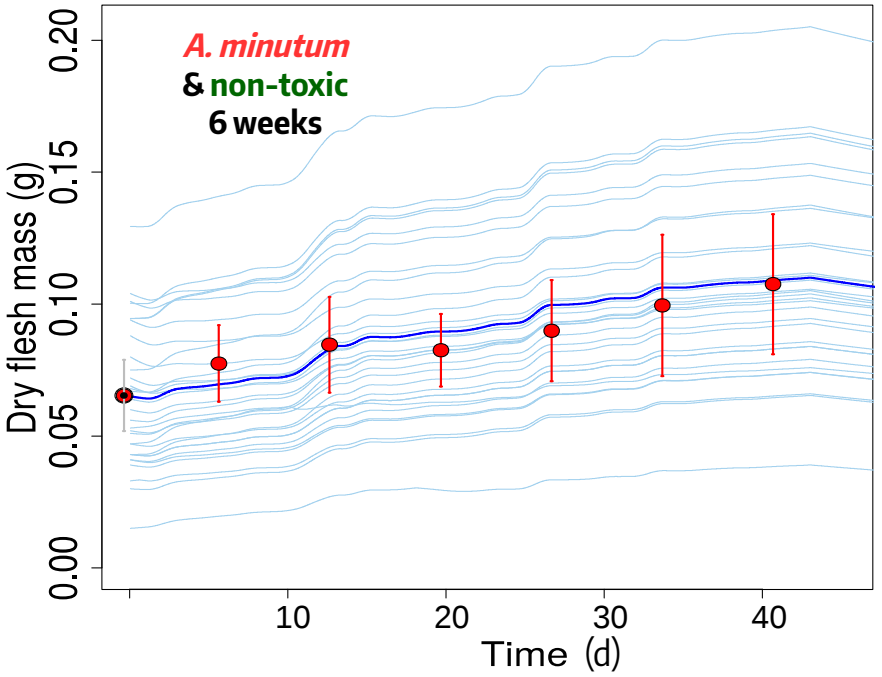
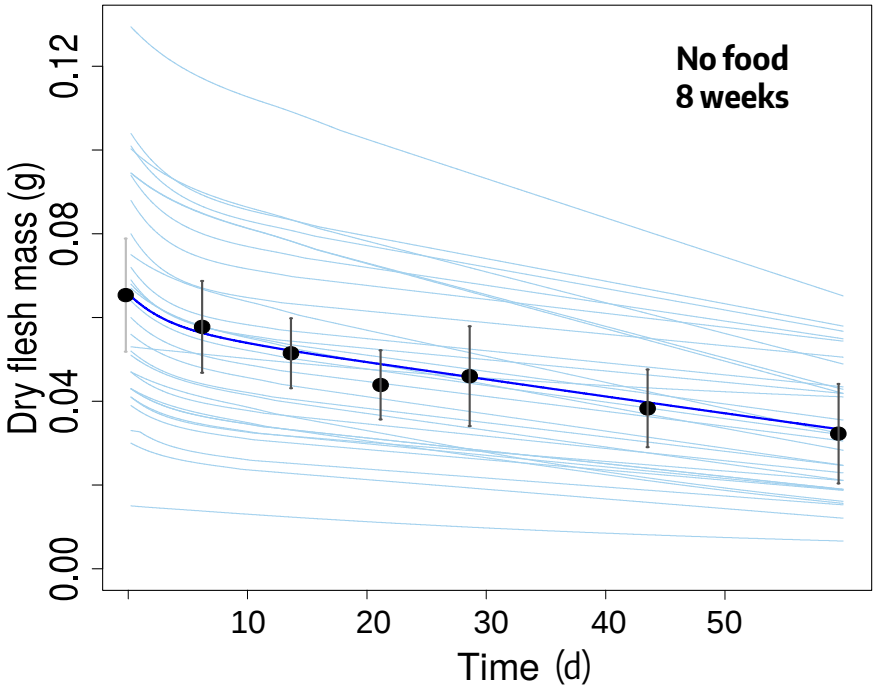
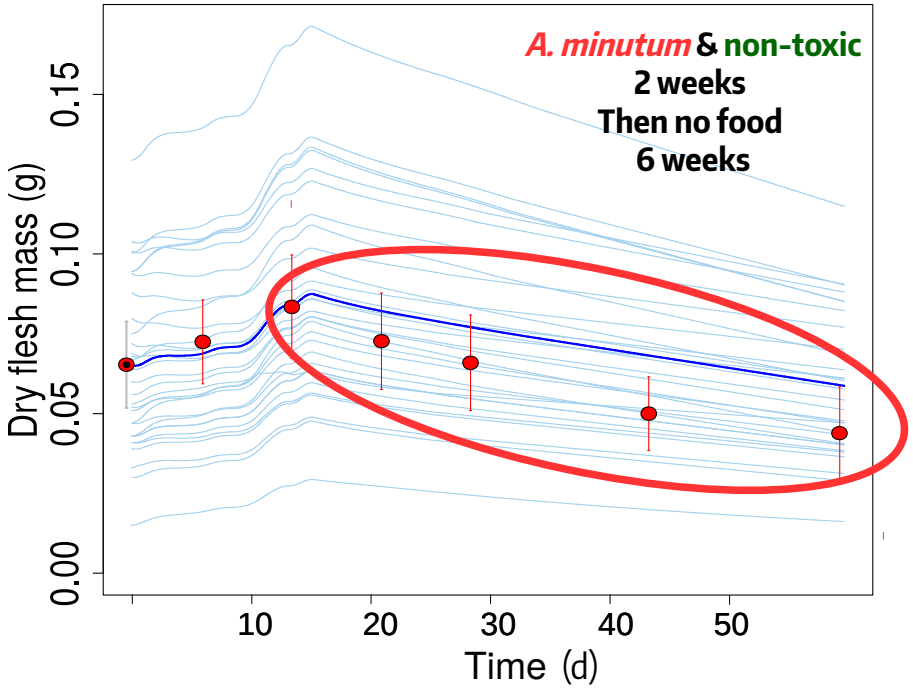
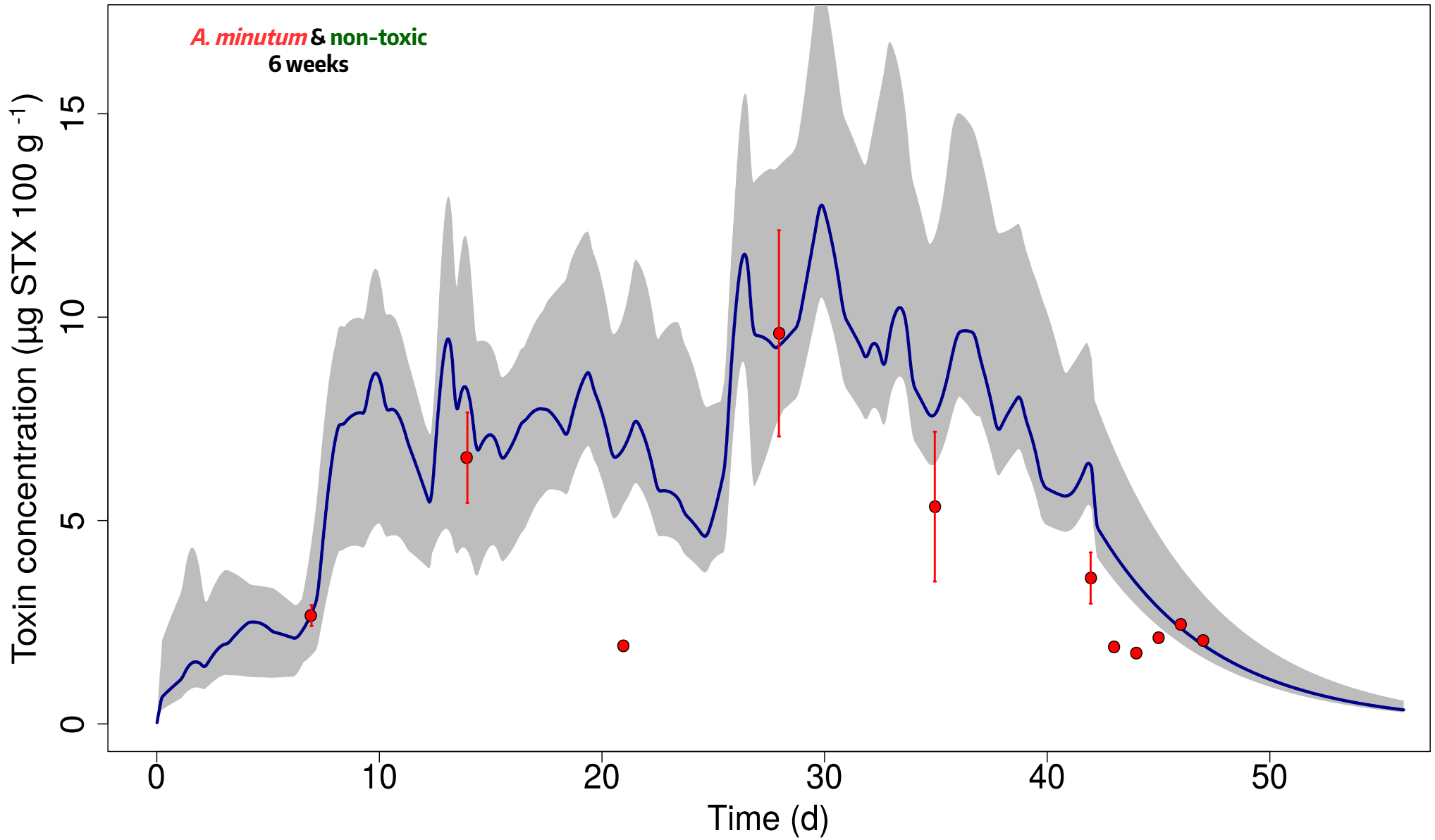








Results: toxin accumulation

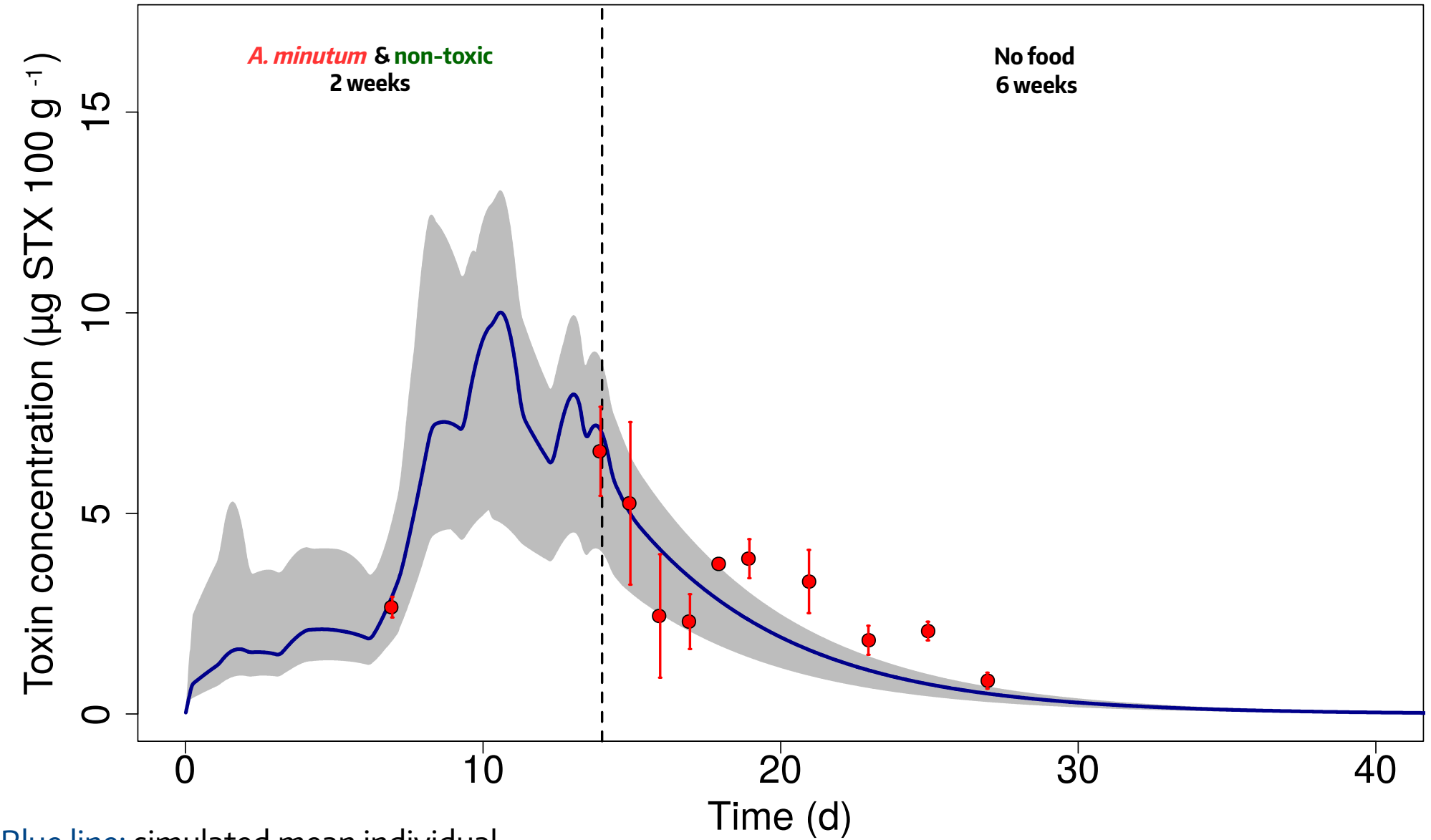


Blue line: simulated mean individual

Grey area: 95% confidence interval

Red points: observations (on a pool of 5 individuals) and standard deviation

Results: toxin elimination



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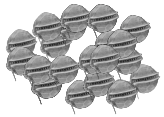
Results: model validation

2nd experiment:

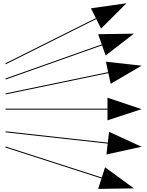
7 x 

2 days



mono-specific

6 times



A. minutum concentration

Results: model validation

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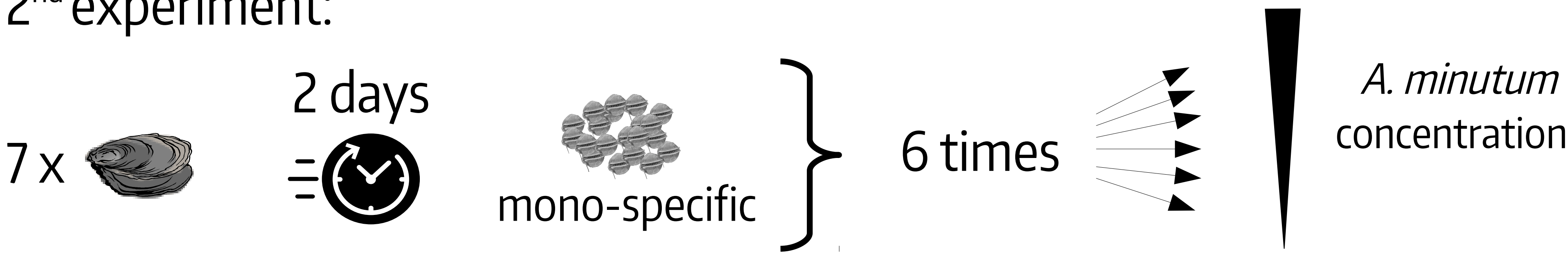

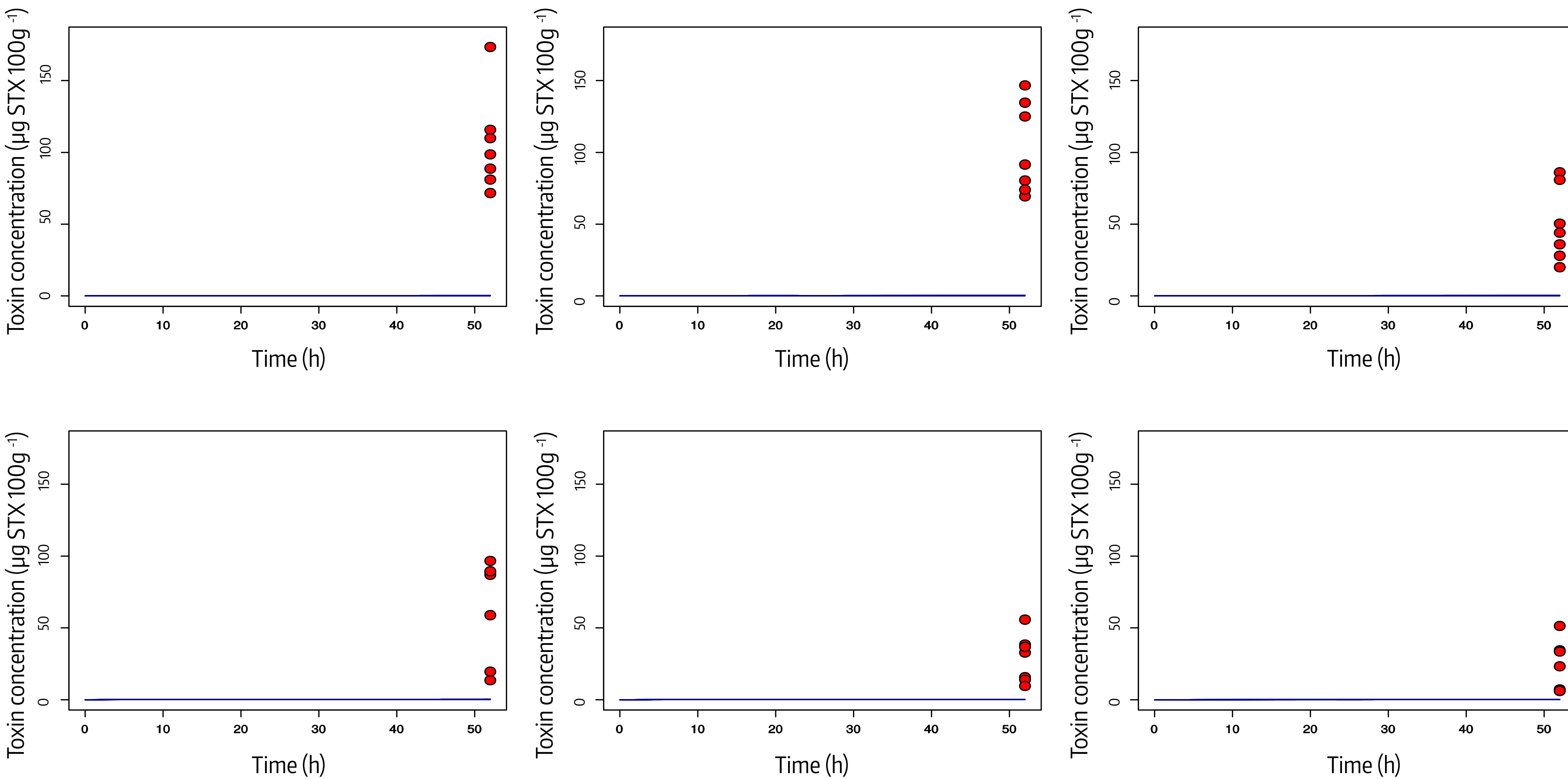

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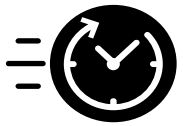
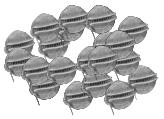
2 days 



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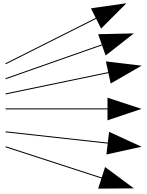

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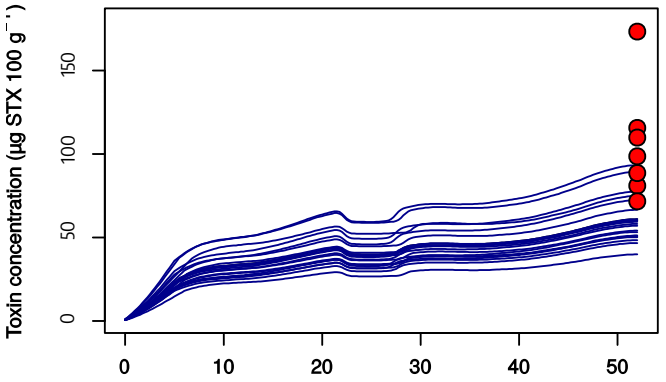
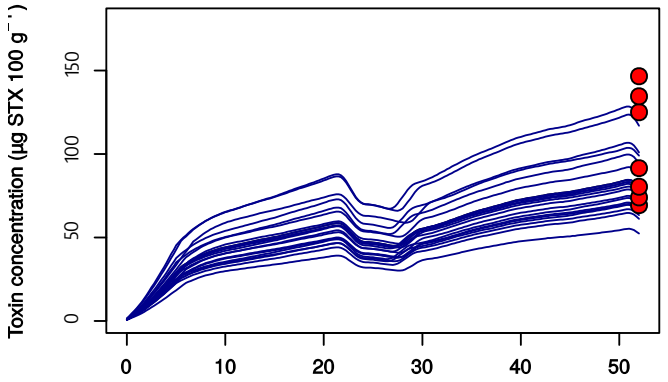
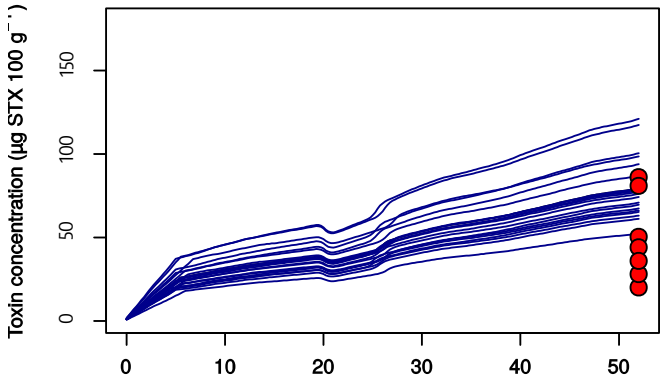
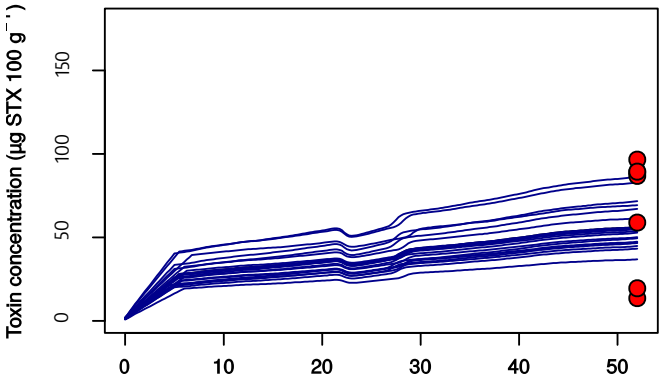
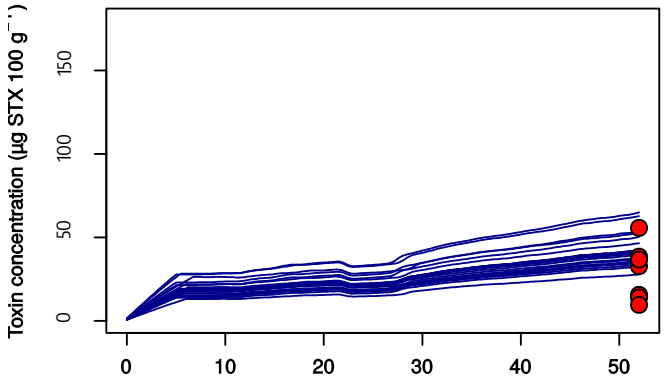


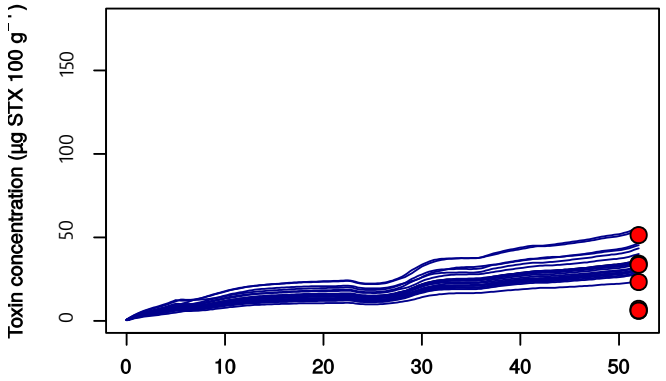




Toxin concentration simulated by the model x 25







Discussion

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→ By taking into account the food selection by oysters
→ Using the synthesizing units

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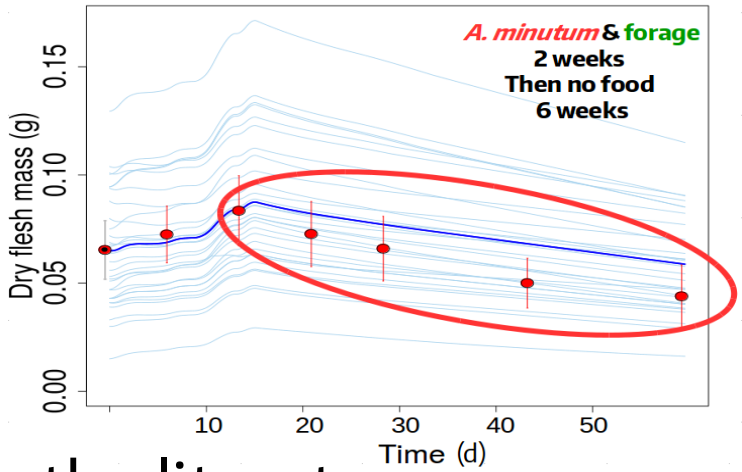
→ Using the synthesizing units

- **Do toxins affect oyster bionergetics?**



→ Yes, they do, cf our results and data from the literature


Myoatrophy


Overproduction of mucus


Defence system alteration


Gut inflammation


Overproduction of hemocytes


Spermatozoa alteration

Effect of paralytic shellfish toxins on oysters maintenance costs?

Haberkorn et al., 2010, Fabioux et al., 2015

Acknowledgements

Thank you for your attention

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