Impact of environmental stressors on organisms: Combining experimental and modelling approaches

DEB2019 Workshop, Brest, France

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April 9, 2019

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

Laboratory of Environmental Marine Sciences

- Local context very dynamic in Marine Sciences (human sciences, physics, ecology...): ISblue
- LEMAR : Interdisciplinary lab. grouping ecologists, biologists, biogeochemists, chemists, physists and environmental jurists.
- Among ecologists and biologists, various approaches :
  - Integration scales : molecular to ecosystem approaches
  - **Field observations and experimentation, lab. experimental approaches and modelling.**

Announcement !

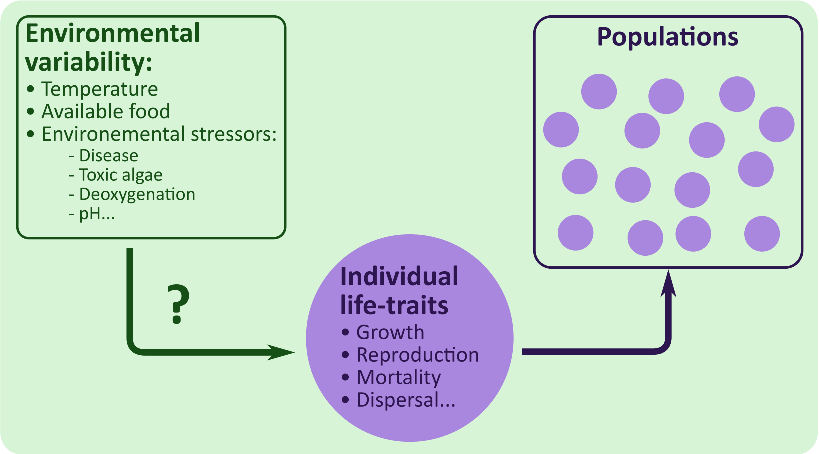
ISblue The interdisciplinary graduate school for the blue planet

Post-doctoral fellowship in Marine Sciences

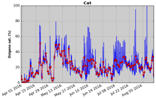
- 2-years fellowships (+ support money)
- Original research project relevant to ISblue research priorities
- Propose collaboration with a local host
- Application deadline: Friday 3rd May, 2019
- More information at : https://www.isblue.fr/funding-opportunities/

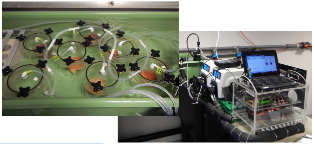
Brest DEB group research

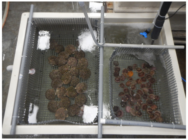
How **environmental variability** controls **life-traits** of fishes and bivalves?



Brest DEB group approach



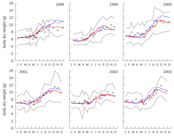


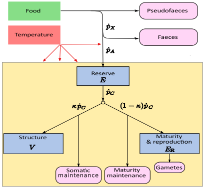


Field observation / experimentation

Laboratory experiments

Modelling





My research

Ecology of marine benthic organisms, mainly bivalves, some of my pets:


Ruditapes philippinarum

Mytilus edulis


Pecten maximus


Argopecten purpuratus


Magallana (Crassotrea) gigas

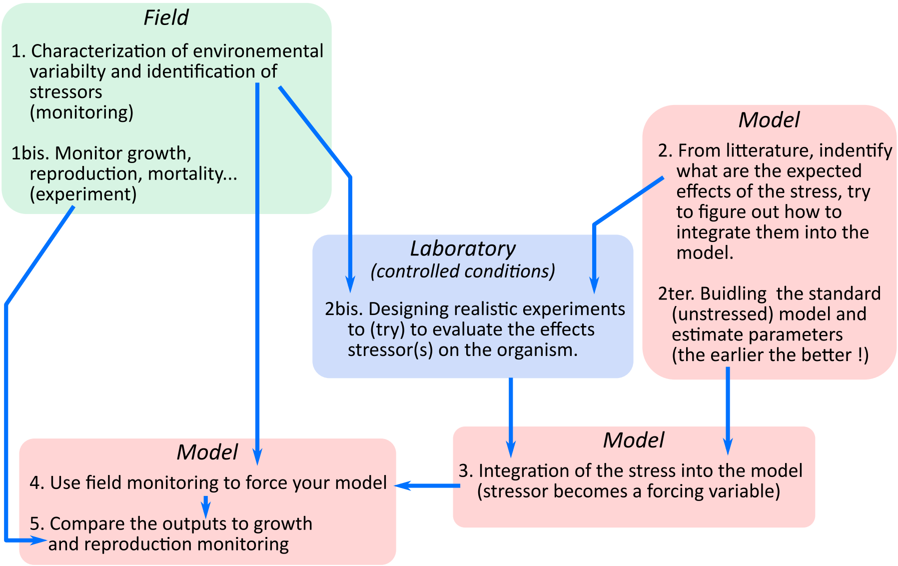
Mimachlamys varia

Combining field, experimental and modelling approaches.

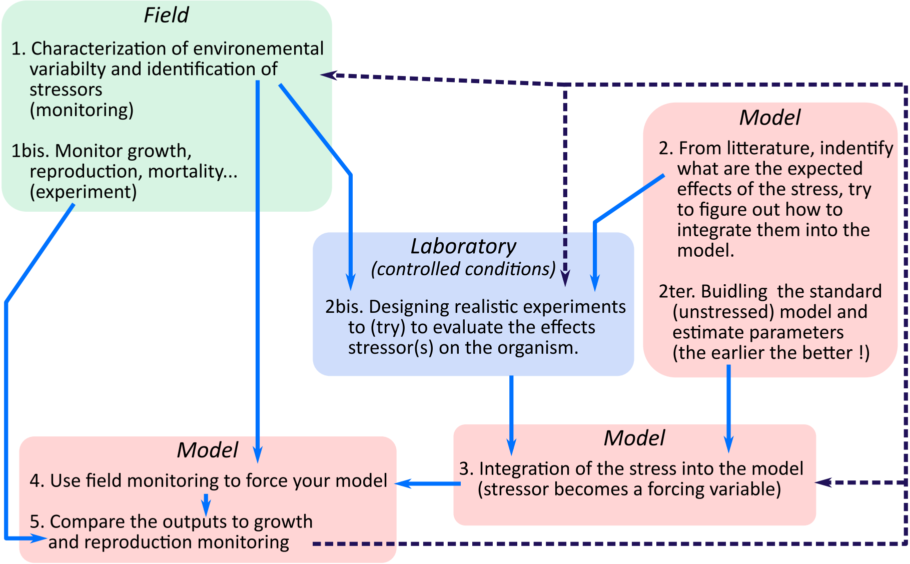
Objectives of the talk

1. Present our approach for the integration of environmental stressors (other than toxicants) in DEB models
2. (Try to) give advices for designing experiments producing useful data for DEB models
   $\rightarrow$ influenced by Brest's marine pets
3. Stimulate discussions in order to better integrate experimental and modelling approaches

General workflow



General workflow



Field monitoring

What are the useful data ?

- Long-term monitoring of environmental variables
  - Temperature
  - Proxies of food density : typically difficult (chlorophyll, phytoplankton count, particulate organic matter...)
  - Potential stressors : oxygen, salinity, toxic algae, pH,...
- Long-term biological monitoring
  - Growth (length, weight)
  - Reproduction (GSI)
  - Potential stressors : disease, phycotoxins...

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Difficulties:

- Very important effort : trade-off between the quantity of data and the cost
- Take care that the monitoring protocol don't disturbs growth
- Prefer long term to short term monitoring (uncertainty on initial conditions)

Designing useful experiments for DEB modelling

- The experiment(s) will consist in exposing organisms to a stress
- Field environmental data help to defined relevant stress levels to test:
  - Control (no stress)
  - Realistic stress (field monitoring)
  - Expected (ex. global change)
- What to measure ?
- How long should be the experiment ?
- In which feeding conditions ?
- ...

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- ...

You first need to have idea of how to proceed for modelling your stress !

Modelling has to be an early process in the workflow !

$\Rightarrow$ Early dialogue between modelling and experiment is usefull !

Expected effects of stress on the energy budgets?

- Indirect cost (negative effect on feeding processes)
- Direct costs (stress implies an additional energy demand)
- Modification of energy use (allocation or mobilization)
- More likely a combination !

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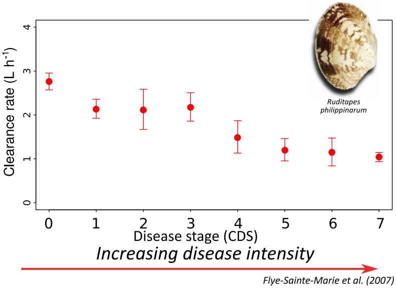

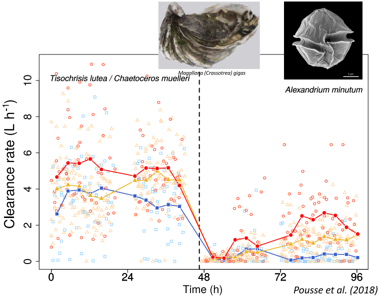

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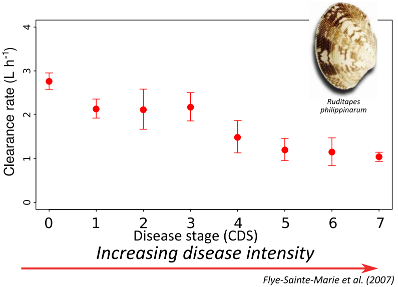

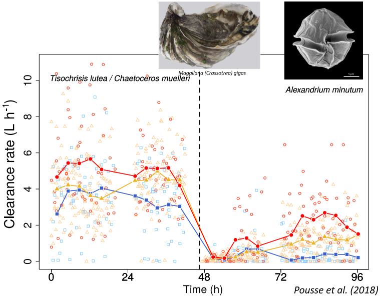

Very frequent in bivalves !

→ Directly measurable

⇒ Reduction of energy inputs

⇒ Should affect negatively growth and reproduction (under fed conditions)

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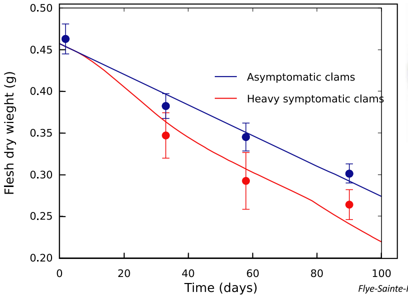

Flye-Sainte-Marie et al. (2009)

Ruditapes philippinarum

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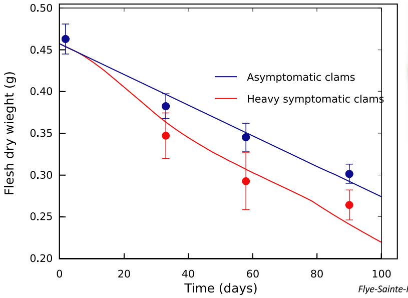


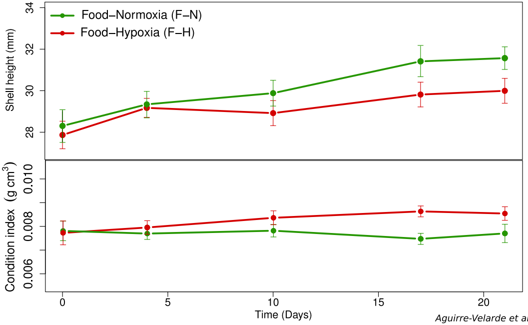
Ruditapes philippinarum

Flye-Sainte-Marie et al. (2009)

→ Difficult to measure directly !
→ But can be evidenced by differential weight loss under starvation
→ Sub-individual data may be also useful
⇒ Should also affect growth and reproduction under fed conditions

Expected effects of stress on the energy budgets?

- Modification of energy mobilization or allocation



Aguirre-Velarde et al. (2018)

Argopecten purpuratus

Decrease of energy mobilisation under hypoxia ?

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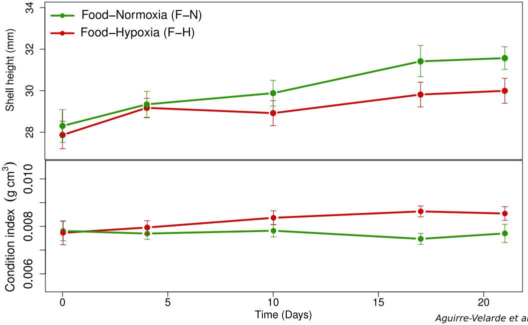

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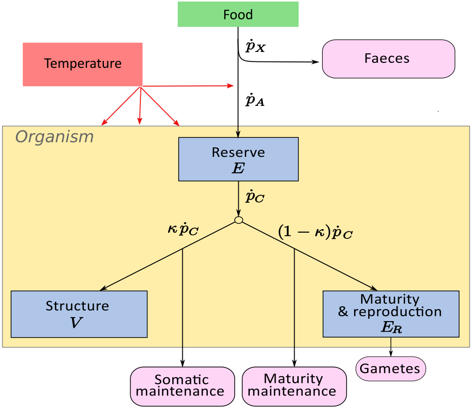
Decrease of energy mobilisation under hypoxia ?
→ Difficult to measure directly !
→ Effects depending of the mode of action of the stressor
→ Sub-individual data may be also useful

How to integrate them in DEB models ?

Same approach than for toxicants.



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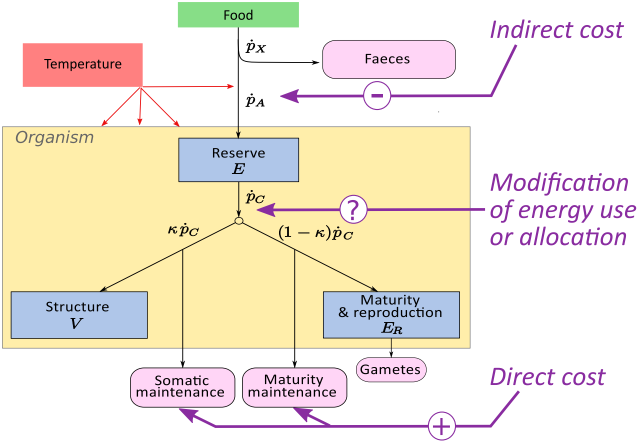

Model parameters become (variables) dependent on stress intensity

Allows to account for transitory effects of stress

Relating parameter value to stress intensity

$$par_{stressed} = par_{unstressed} \times C_{stress}(stress\ intensity)$$

What function relates stress correction to stress intensity ?

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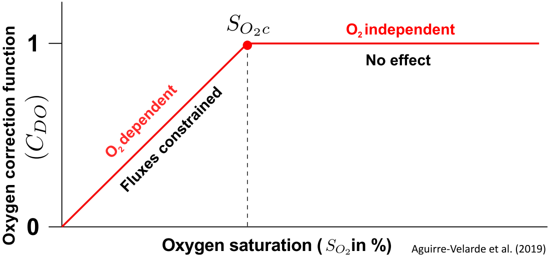
What function relates stress correction to stress intensity ?

- Semi-empirical approach (empirical function):



  - No that satisfying on a theoretical point of view
  - But generally allows low number of parameters

Relating parameter value to stress intensity

$$par_{stressed} = par_{unstressed} \times C_{stress}(stress\ intensity)$$

What function relates stress correction to stress intensity ?

- Mechanistic approach :
  Going deeper into the processes and try to build up a mechanistic function:
  - Our perspective for taking into account of the effects of oxygen (model based on supply and demand of oxygen)
  - More satisfying !
  - More parameters ?
  - Use of SU's

While conceiving experiments take care to:

Time scales :

- Experiments : time consuming and expensive
  → the shorter the better
- DEB models the full life cycle
  → long term processes, the longer the better
- Small effect : slow drift between stressed and control
  → combined to inter-indiv. variability : long time to evidence effect

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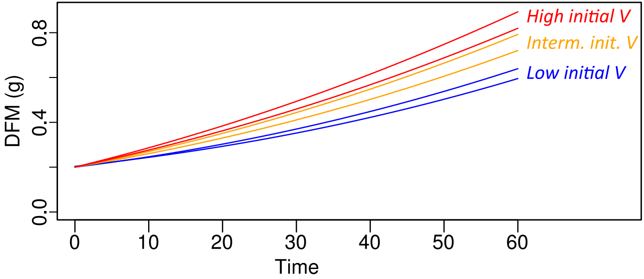
$\Rightarrow$ Short term responses may not be always useful
$\Rightarrow$ Long experiment: more compatible with DEB time scales; evidence smaller effects.
$\Rightarrow$ Trade-off between practicals aspects of the experiment (time, number of conditions, cost...) and the expected data.

While conceiving experiments, take care to:

Initial conditions and measurements:

- The smallest the individuals the highest their growth rate
  $\rightarrow$ Best starting with small individuals to evidence growth differences

- In DEB biomass is partitioned into V, E, E_R
  If you only know weight :



Best to measure : weight (WW, DW), length and gonad content to constrain partitioning at the beginning of a simulation.

While conceiving experiments, take care to:

Feedig rates and food conditions

- Fed and starved conditions may help to disentangle effects of stress
  $\rightarrow$ combining these conditions is useful
- Fed condition should differ form starved one
  $\rightarrow$ sufficient feeding is required
- Measurements of food intake will also help to disentangle effects of stress

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Temperature

- Temperature affects all rates
  → working at sufficiently high temperature will allow faster drift between stressed and unstressed condition
- Temperature itself should not be a stress
  → don't work too close to the upper limit of tolerance range

While conceiving experiments, take care to:

Sub-individual measurements/observation

- Histology
- Gene expression
- Proteomics
- ...

$\Rightarrow$ might help to evidence / disentangle the effects of stress

The data won't be integrated to the DEB model
$\rightarrow$ help in identifying what are the processes that are impaired in the model

Integration of sub-individual measurements has to be thought early in the conception of the experiments

Take home message

- Similarly to toxicants the effect environmental stressors can be intergated to DEB models
- Combining field observation, laboratory experiments and modelling is useful for better understanding the effects of environmental stressors on organisms life-traits
- Modelling should not be thought as an end process :
  $\rightarrow$ don't forget this when you apply for research funds !
  - Grab data and see which model you will be able to do with is a bad strategy !
  - Early dialogue between modelling and experimental approaches is useful
- Take care to time scales, initial conditions, feeding and temperature
- Combining your experiment with sub-individuals measurements will probably be helpful !