Design Project

Création d'un outil d'estimation de biofouling

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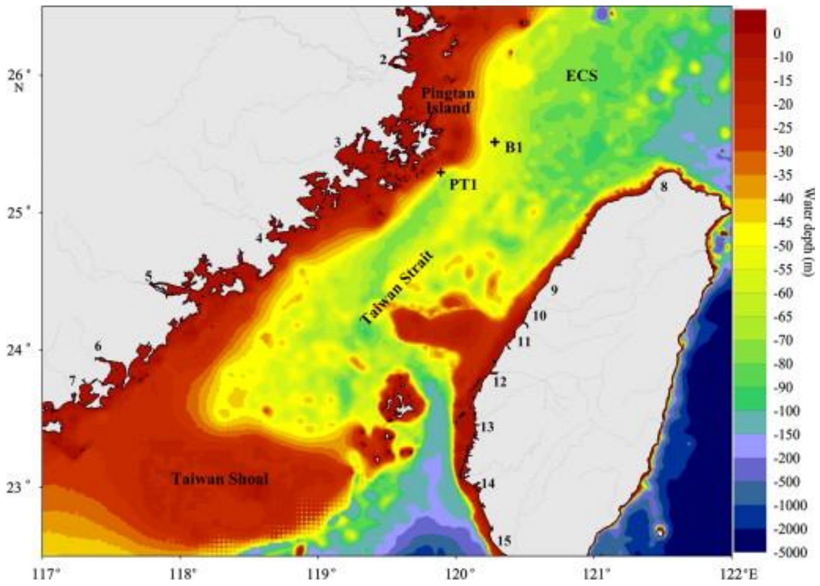
Location of interest

- Offshore wind farm in the Taiwan strait
- Biofouling leads to:
    1. Increase of diameter and mass of the masts
    2. Increase of surface roughness, though drag coefficient
- Species studied:
    1. ***Mytilus Edulis (Blue Mussel)***
    2. ***Crassostrea Gigas (Pacific Oyster)***



Bathymetry of Taïwan Strait [Wang et al., 2014]

General model of growth

Evolution = Growth - Decay - Mortality

1. Length model: $$\frac{\partial L}{\partial t} = L(T) - p_M L - m_M L[mm]$$

2. Weight model: $$\frac{\partial W}{\partial t} = W(T, I) - p_M W - m_M W[g_C.d^{-1}]$$

➔ Parameters depend on: water temperature (**T**), light intensity in water (**I**), phytoplankton concentration (**P**)

Initial conditions - *Mytilus Edulis*

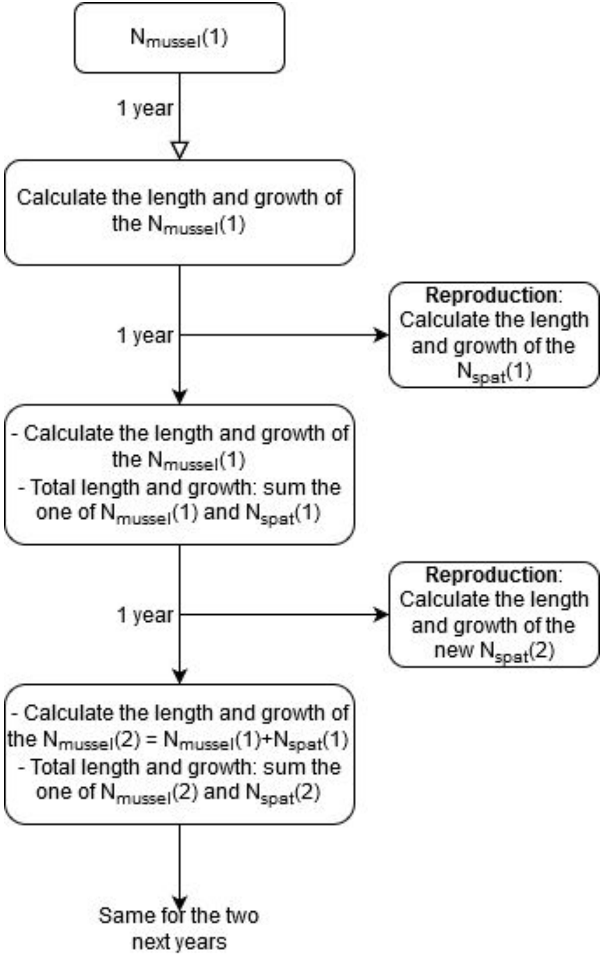
- Chosen offshore wind turbine: diameter of 4 meters
- Modelization over one meter high
- Initial length of mussels: $\mathbf{L_0}$ = 6 mm
- Initial weight of mussels: $\mathbf{W_0}$ = 0.031 g
- Initial number of mussels: $\mathbf{Nmussel_0}$ = 120

Source: Sandro Michaeli

Reproduction - *Mytilus Edulis*

- First spawn at one year old
- **5 millions** of larvae
- **1%** survive
- **0.1%** get attached to this wind turbine

➔ **50 larvae** per female mussel per year



Growth: Length & Mass

Length: von Bertalanffy model: $$\frac{\partial L}{\partial t} = kL_{\infty}e^{-k(t-t_0)}$$

Mass 1: Scope for Growth model: $$\frac{\partial W}{\partial t} = c_M W[\epsilon_M f_{MI} I_M * (1 - \sigma_{\gamma M}) - f_{MRS}\beta_{MRS}]$$

➔ Conversion of chlorophyll to phytoplankton concentration: $$P = \frac{[Chl]}{f_{Chl/C} * f_{C/P}}$$

Mass 2: depending on length only: $$W = 2.10^{-4} * L^{2.82}$$

Decay: Predation & Mortality

- Enemies: parasites, competitors and predators
  - One of the major predator: starfish
  - Coefficients of predation depending on mussel size
- Mortality:
  - Coefficients dependent on mussel age and seasons

Mussel size class [cm]	1.0 - 1.9	2.0 - 3.0	3.0 - 5.0	5.0 - 6.0
Percentage of reduction [day^{-1}]	46.7	25.6	18.9	9.1

Predation rate of Mytilus Galloprovincialis by starfish, as seen in [O'Neill et al.,1983]

Competition with the Pacific Oyster

- Limiting resource on wind turbine: **space**
  - ➔ Competition for attachment, feeding and reproduction space

Young mussels colonizing a surface [Sylvie Didier-Laurent, 2017]

- Competition model:

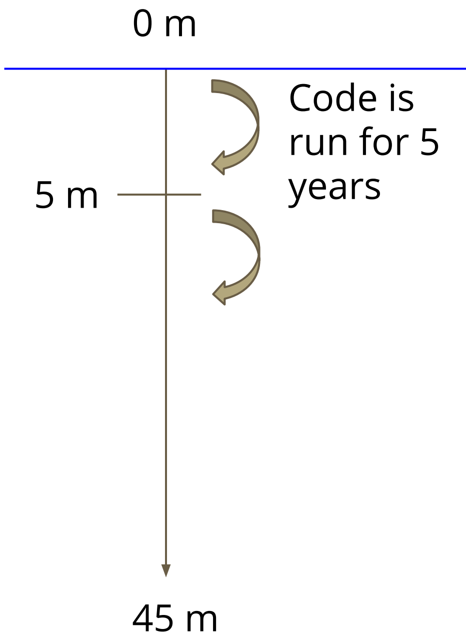
$$W(oyster) = -7.58 * \frac{Nmussel}{Noyster} + 59.39$$

Competitor: *Crassostrea Gigas*

- Initial length of oysters: $\mathbf{L_0}$ = 12 mm
- Initial weight of oysters: $\mathbf{W_0}$ = 5 g
- Initial number of oysters: $\mathbf{Noyster_0}$ = 17
- **Length model**: $\frac{dL}{dt} = aF^bT^cL^d$ **Mass model**: $\frac{dW}{dt} = aF^bT^cW^d$
- Reproduction: **10** spats per female per year

Depth

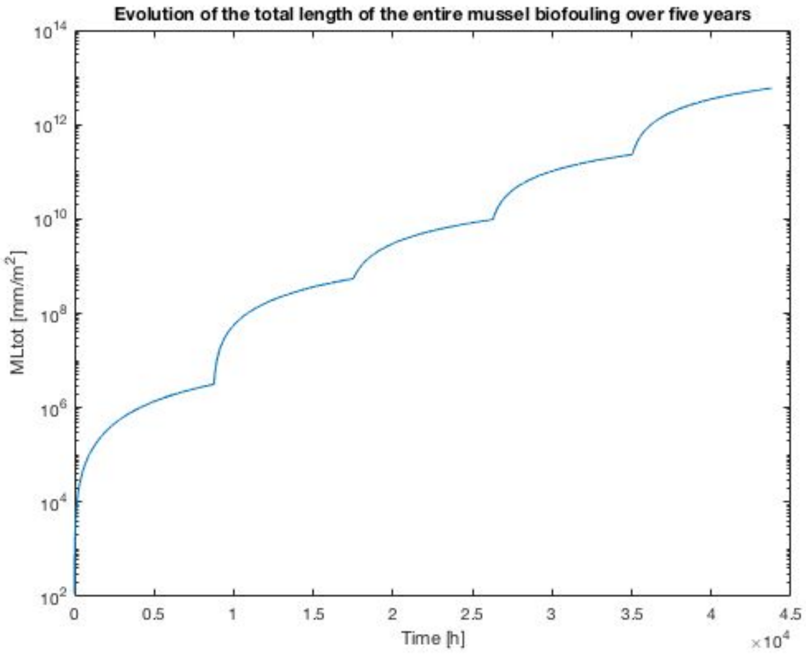
- The entire code is run for each depth: from 0 to 45 m deep
- Once the growth is computed for five years, it goes 5 m deeper



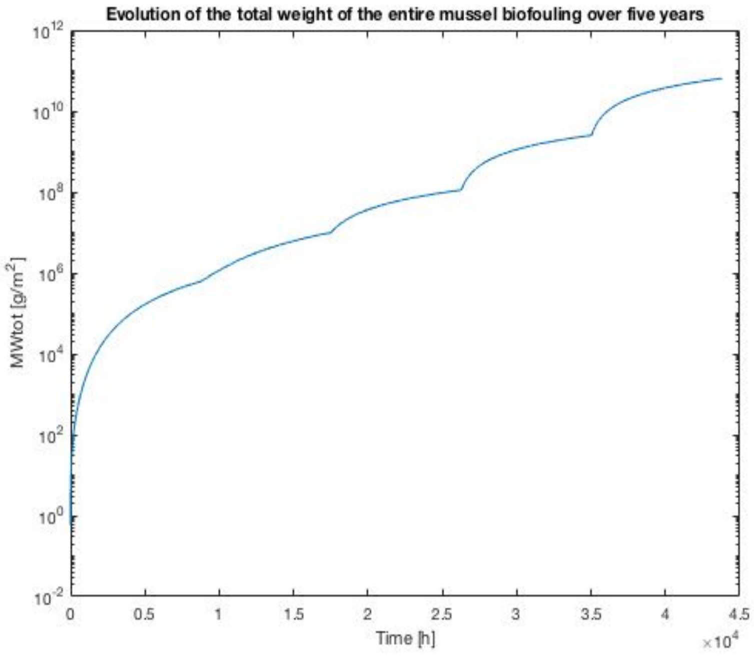
- Chlorophyll concentration at a certain depth depends on chlorophyll concentration at the surface:

$$Chl\ a\ (z) = \left(C_b - sz + C_{max} e^{-((z - Z_{max}/\Delta z)^2}\right) \overline{Chl\ a\ Z_{base}}$$

Mytilus Edulis model

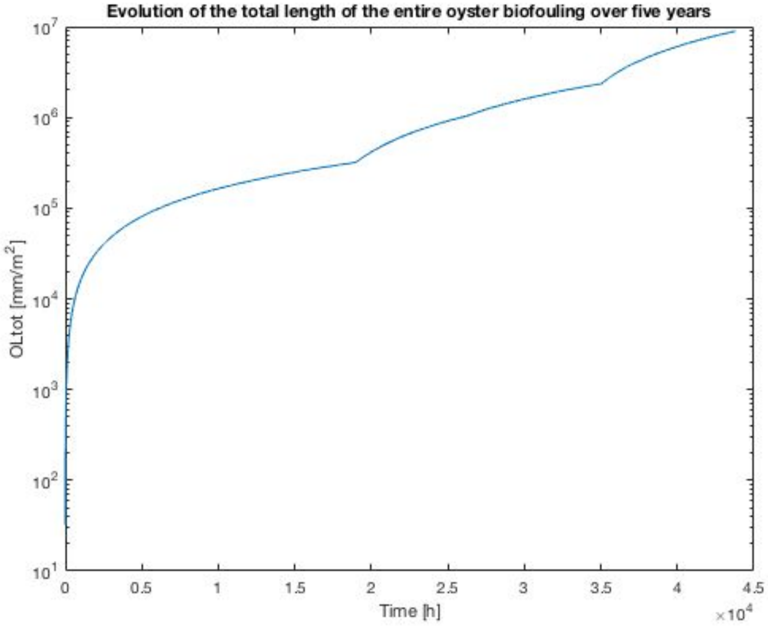


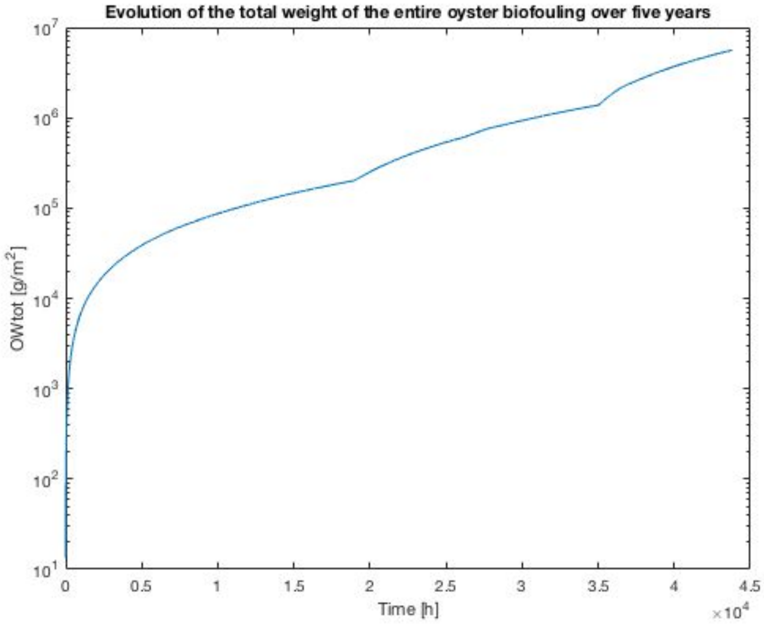
Total length: 5.95 * 10^9 m/m^2



Total weight: 64’300 ton/m^2

Crassostrea Gigas model

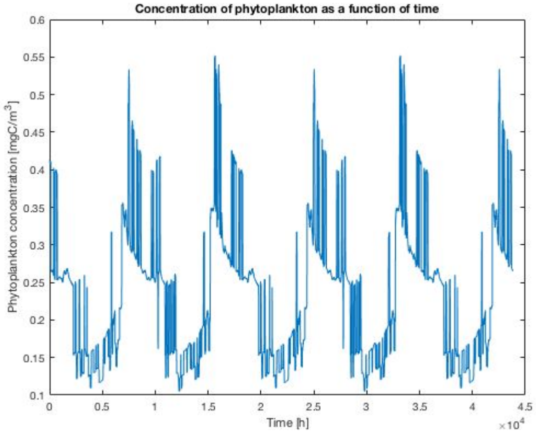


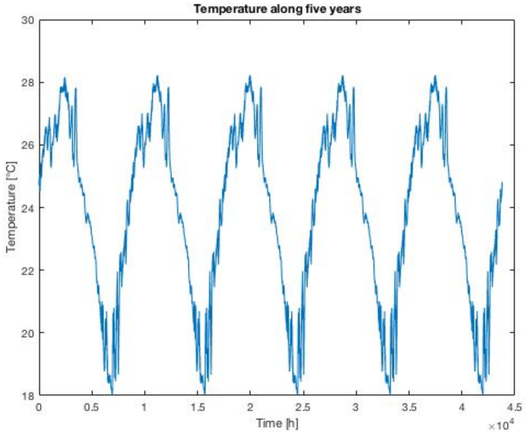


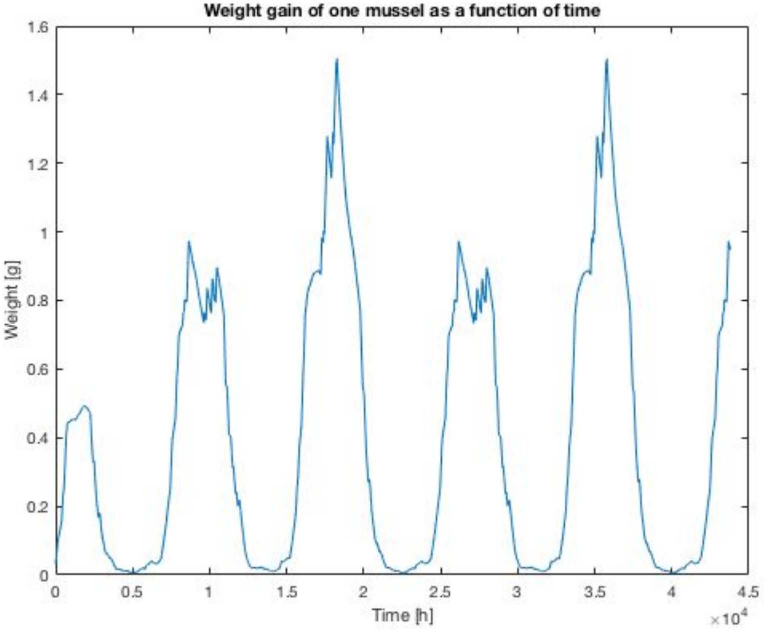
Total length: 8.92 * 10^3 m/m^2

Total weight: 5.62 ton/m^2

Influence of phytoplankton and temperature

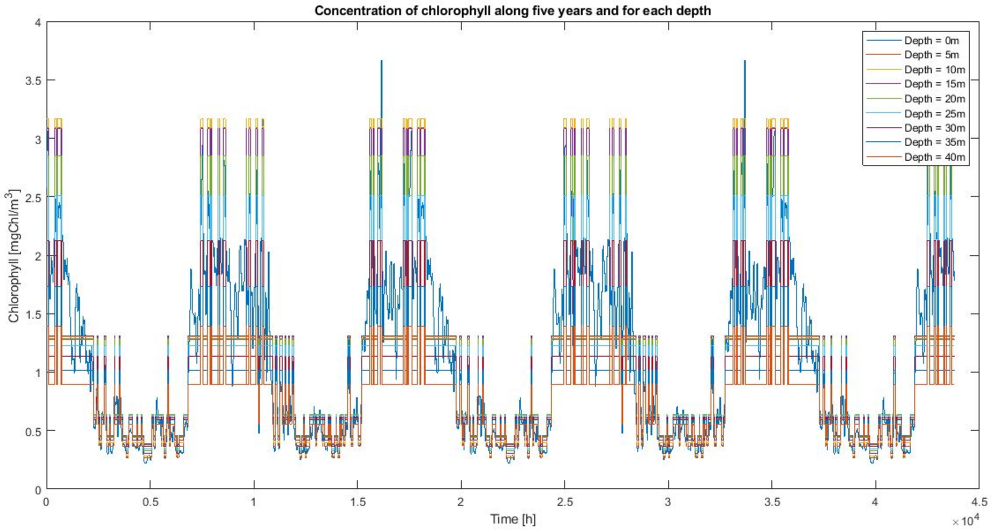


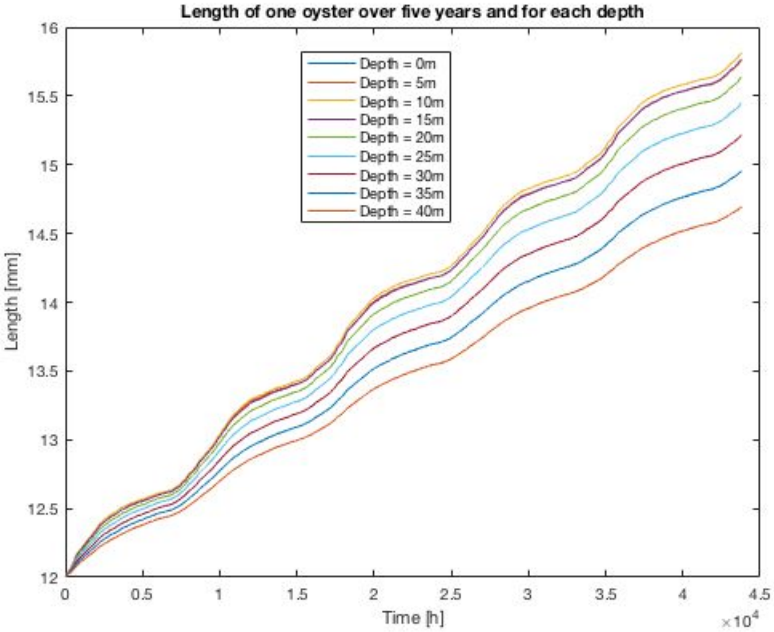




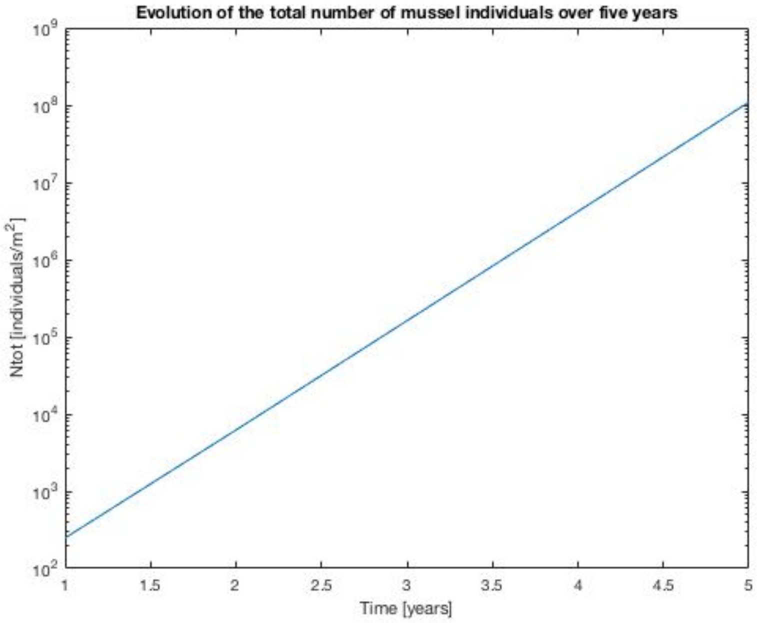
Weight model 1

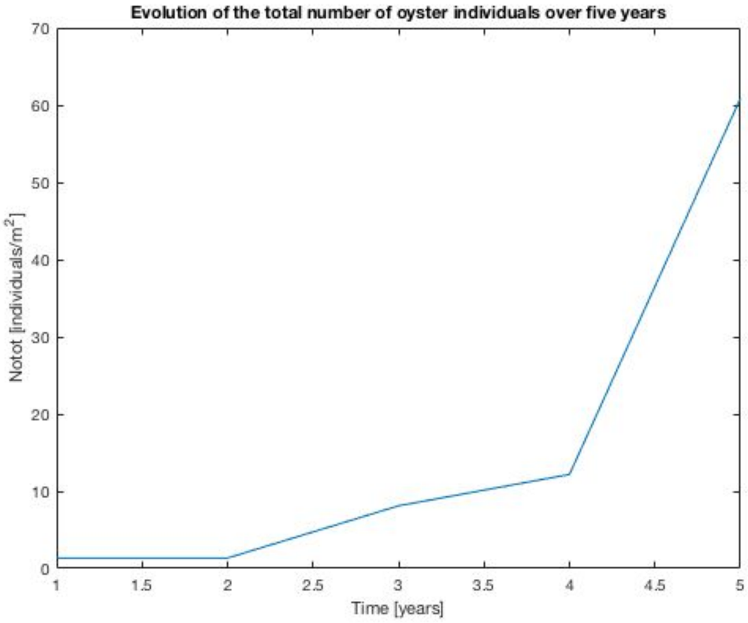
Influence of depth





Density of both species



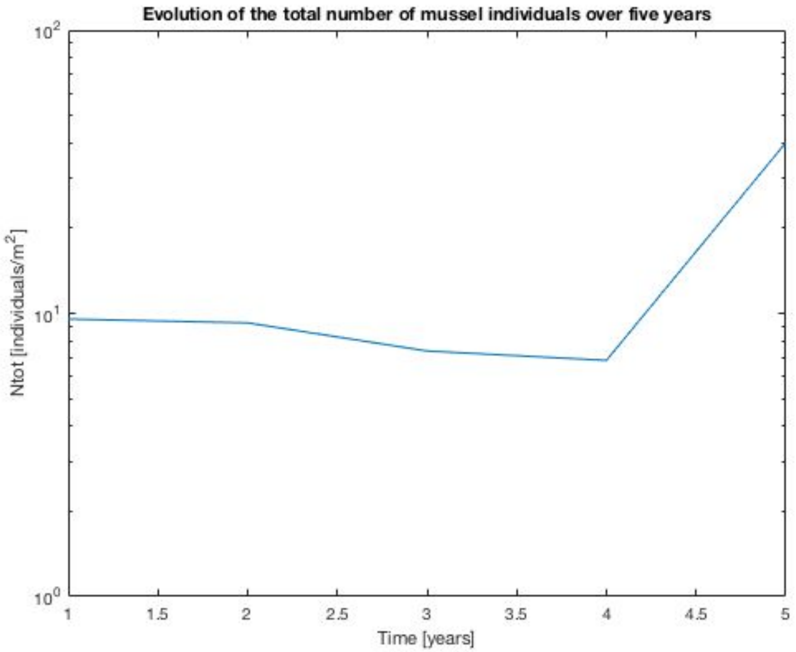


Mussels: $1.1*10^8$ individuals/m^2

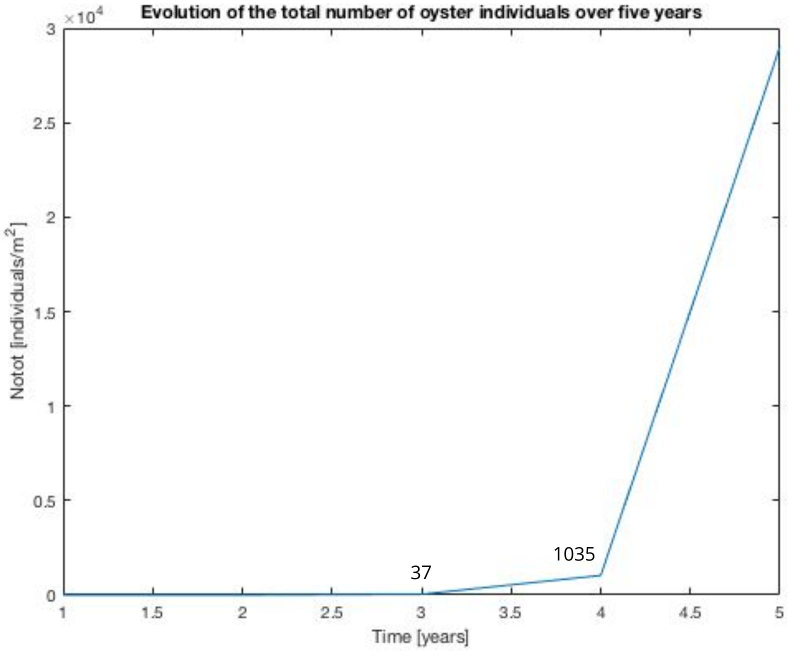
Oysters: 61 individuals/m^2

Competition model

$$W(oyster) = -7.58 * \frac{Nmussel}{Noyster} + 59.39$$



Mussels: 40 individuals/m^2



Oysters: 29000 individuals/m^2

Conclusion

- *Mytilus Edulis* and *Crassostrea Gigas* quickly reach high densities
- Crucial to study the impact of local ecosystems on immersed structures like wind turbines
- Even with two species, the model reaches high complexity

Source: Masha Basova/Shutterstock.com

Thank you for your attention !
Any questions?