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)
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: \[ \frac{\partial W}{\partial t} = W(T, I) - p_M W - m_M W[gC.d^{-1}] \]

→ 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: $L_0 = 6$ mm
- Initial weight of mussels: $W_0 = 0.031$ g
- Initial number of mussels: $N_{mussel_0} = 120$

*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: 
\[ \frac{\partial W}{\partial t} = c_M W[\epsilon_M f_{MI} I_M * (1 - \sigma_M) - f_{MRS} \beta_{MRS}] \]

→ Conversion of chlorophyll to phytoplankton concentration: 
\[ P = \frac{[\text{Chl}]}{f_{\text{Chl}/C} \ast f_{C/P}} \]

**Mass 2**: depending on length only: 
\[ W = 2.10^{-4} \ast L^{2.82} \]
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

<table>
<thead>
<tr>
<th>Mussel size class [cm]</th>
<th>1.0 - 1.9</th>
<th>2.0 - 3.0</th>
<th>3.0 - 5.0</th>
<th>5.0 - 6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Percentage of reduction [day^{-1}]</strong></td>
<td>46.7</td>
<td>25.6</td>
<td>18.9</td>
<td>9.1</td>
</tr>
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*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
  \[ \rightarrow \text{Competition for attachment, feeding and reproduction space} \]

- Competition model:

  \[ W(\text{oyster}) = -7.58 * \frac{N_{\text{mussel}}}{N_{\text{oyster}}} + 59.39 \]

Young mussels colonizing a surface
[Sylvie Didier-Laurent, 2017]
Competitor: *Crassostrea Gigas*

- Initial length of oysters: \( L_0 = 12 \text{ mm} \)
- Initial weight of oysters: \( W_0 = 5 \text{ g} \)
- Initial number of oysters: \( \text{Noyster}_0 = 17 \)
- **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:

\[
Chl \ a \ (z) = \left( C_b - s z + C_{max} e^{-((z-Z_{max}/\Delta z)^2)} \right) \frac{Chl \ a}{Z_{base}}
\]
Mytilus Edulis model

 Evolution of the total length of the entire mussel biofouling over five years

 Evolution of the total weight of the entire mussel biofouling over five years

Total length: $5.95 \times 10^9$ m/m$^2$

Total weight: 64'300 ton/m$^2$
Crassostrea Gigas model

Total length: $8.92 \times 10^3$ 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: $1.1 \times 10^8$ individuals/m$^2$

Oysters: 61 individuals/m$^2$
Competition model

\[ W(\text{oyster}) = -7.58 \times \frac{N_{\text{mussel}}}{N_{\text{oyster}}} + 59.39 \]

Mussels: 40 individuals/m²

Oysters: 29000 individuals/m²
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?