

Biofouling implementation in Lagrangian modelling and Northeastern Atlantic study case.

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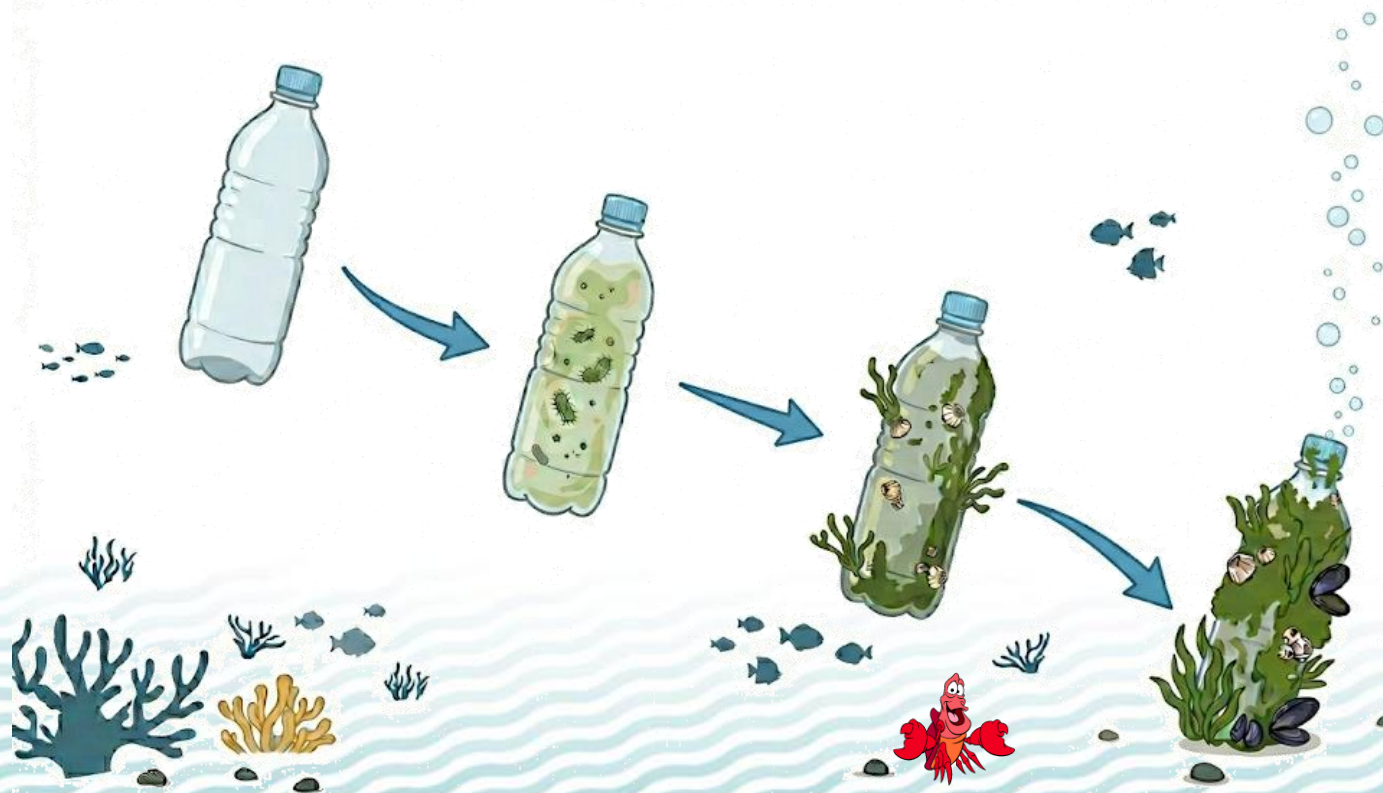
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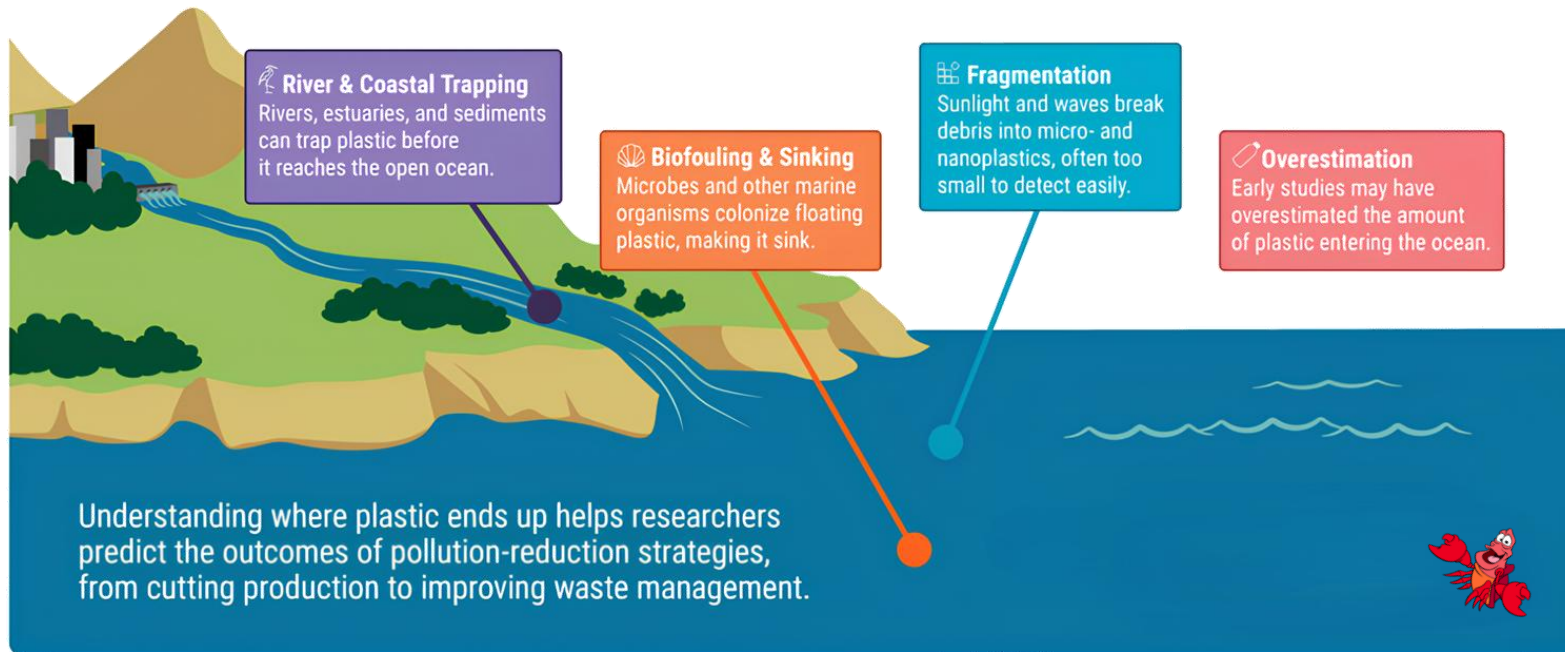
² CRETUS Research Center, Spain.

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> The missing plastic paradox

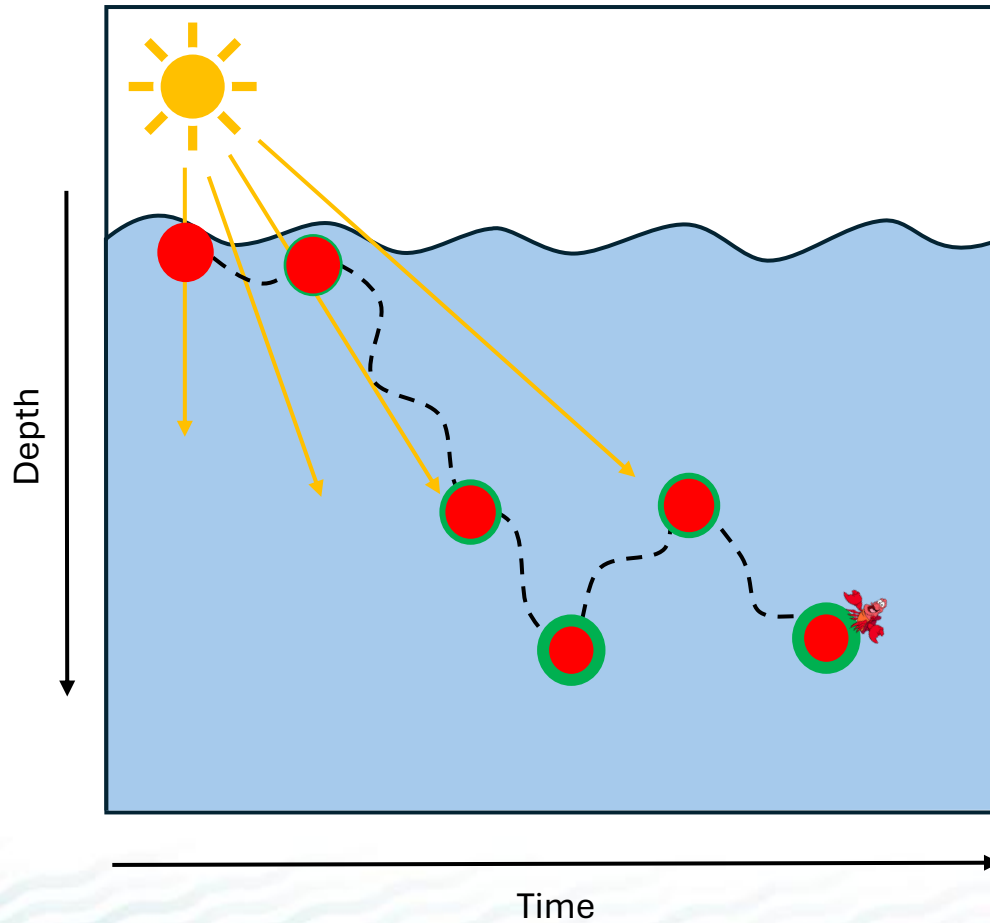


- Estimated plastic emissions:
5 – 13 million tons
- Plastic found on surface:
0.007- 0.25 million tons



Found around 2% of
estimated emissions

> What is biofouling?



Biofilm formation mainly depends on:

- Temperature
- Salinity
- Bacterial and algal concentration
- Light intensity
- Grazing mortality
- Algal respiration

Proper conditions tend to be found near sea-surface.

- Optimal conditions → Algal growth → Sinking
- Sub-optimal conditions → Algal death → Refloating

> What does it look like in a Lagrangian simulation framework?



> Biofouling model

* “Kooi equations produce unrealistic results for the sinking velocities of particles larger than 1 cm”
D. Lobelle et al., *Journal of Geophysical Research*. (2021).

Kooi model for biofouling



Plastic**Parcels**

Denes, M. C. et al. *The Journal of Open Source Software* (2024)

$$\rho_{tot}(z, t) = \frac{r_{pl}^3 \rho_{pl} + [(r_{pl} + t_{bf})^3 - r_{pl}^3] \rho_{bf}}{(r_{pl} + t_{bf})^3}$$

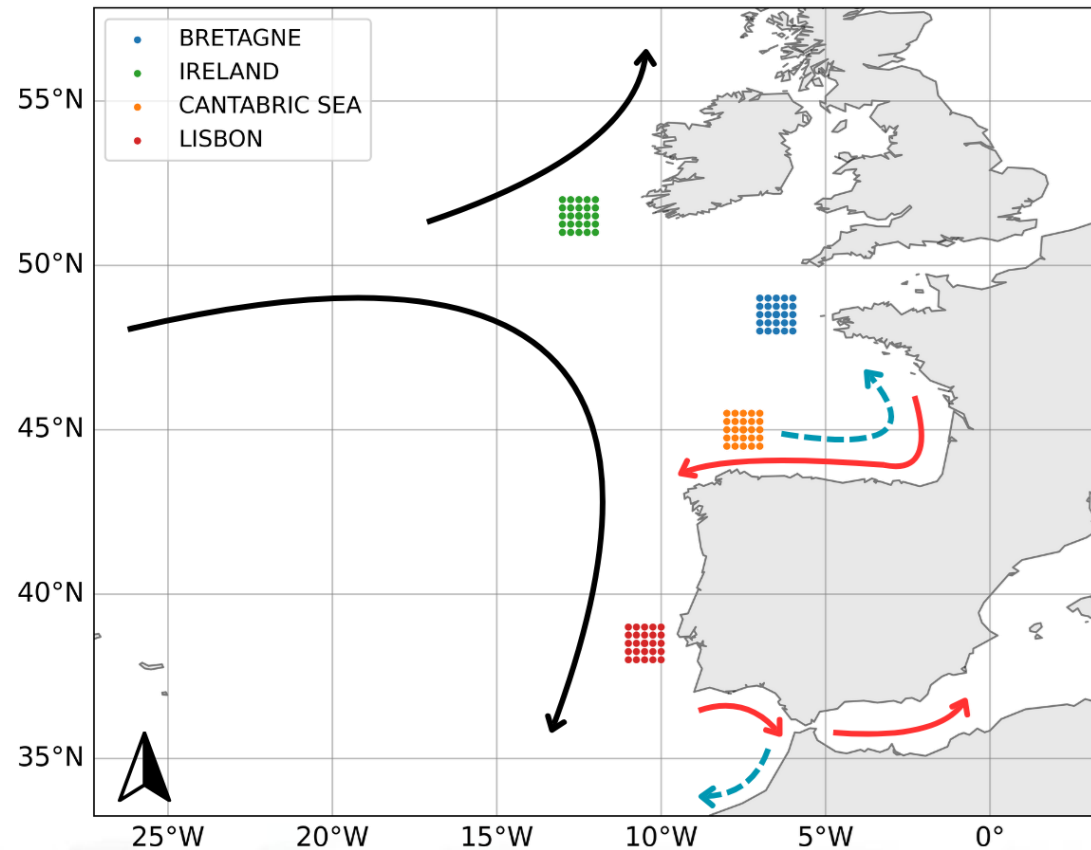
$$t_{bf} = \left(\frac{3V_{tot}}{4\pi} \right)^{1/3} - R_0, \quad V_{tot} = V_b + V_0, \quad V_0 = \frac{4\pi R_0^3}{3}, \quad V_b = V_A S_0 A$$

Algal growth, $\frac{dA}{dt}$, was dynamically modelled as,

$$\frac{dA}{dt} = \underbrace{\frac{\beta_A A_A}{S}}_{\text{Collision}} + \underbrace{\mu(T, I) A}_{\text{Growth}} - \underbrace{m_A A}_{\text{Mortality}} - \underbrace{Q_{10}^{\frac{T-20}{10}} R_A A}_{\text{Respiration}}$$

Kooi, M. et al. *Environmental science & technology* (2017)

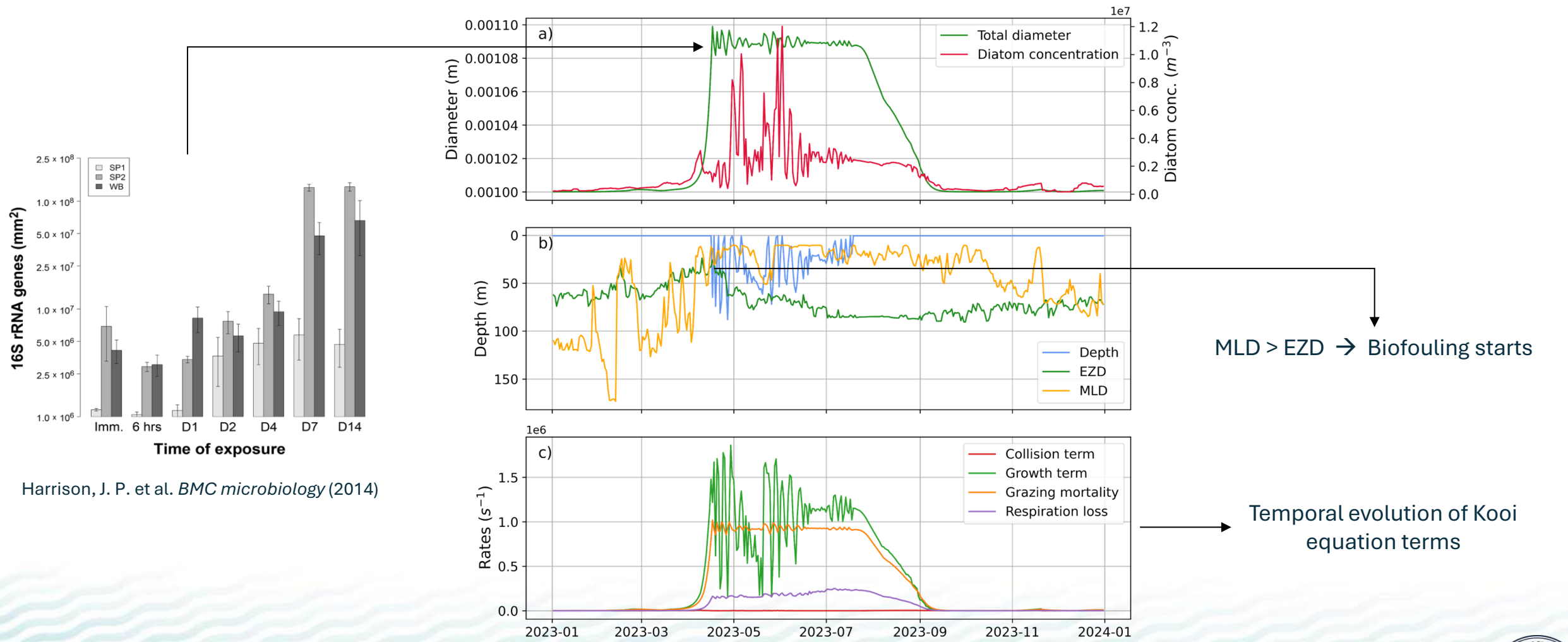
> Study Case Setup – Northeastern Atlantic Ocean



Density per material:

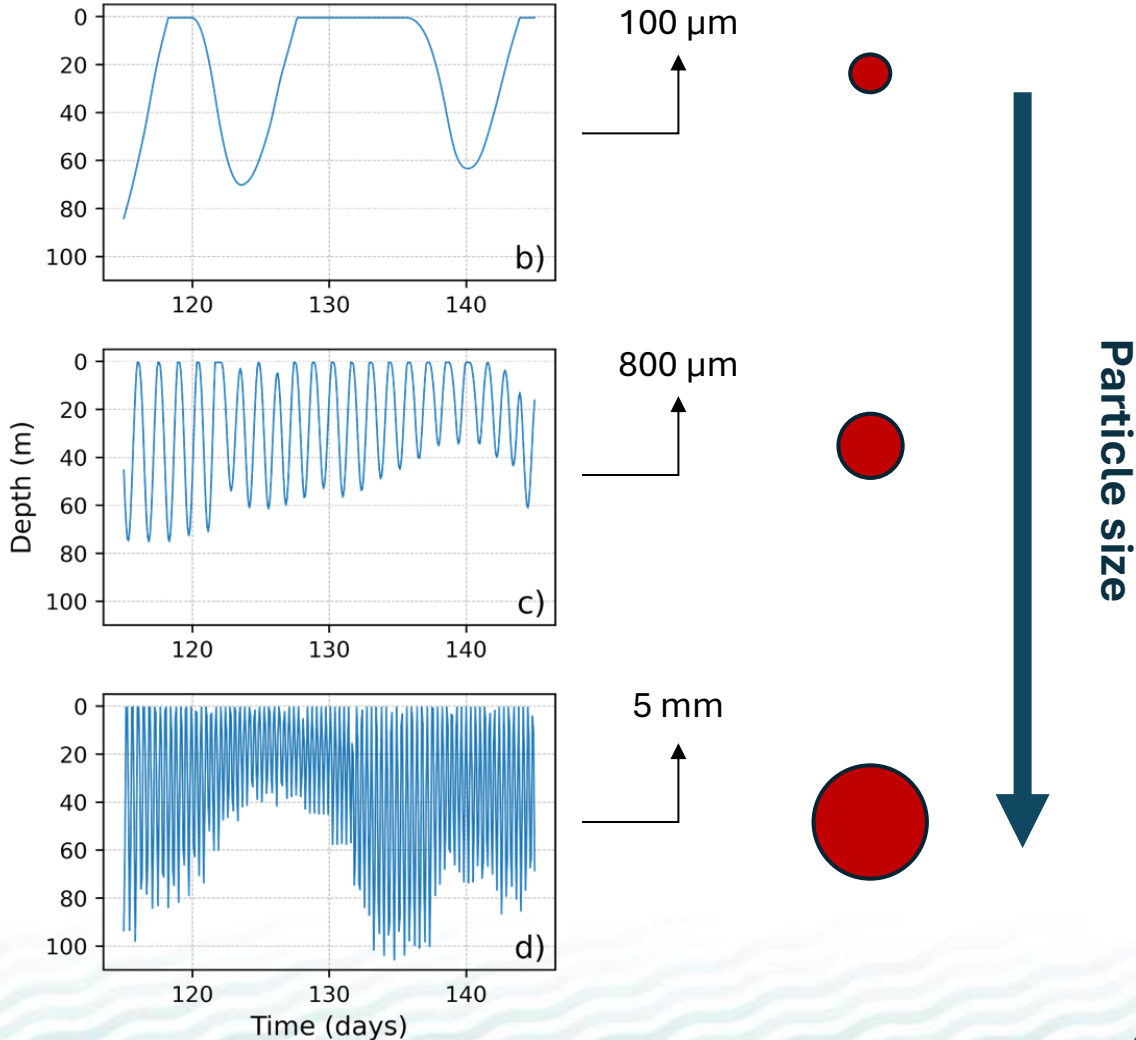
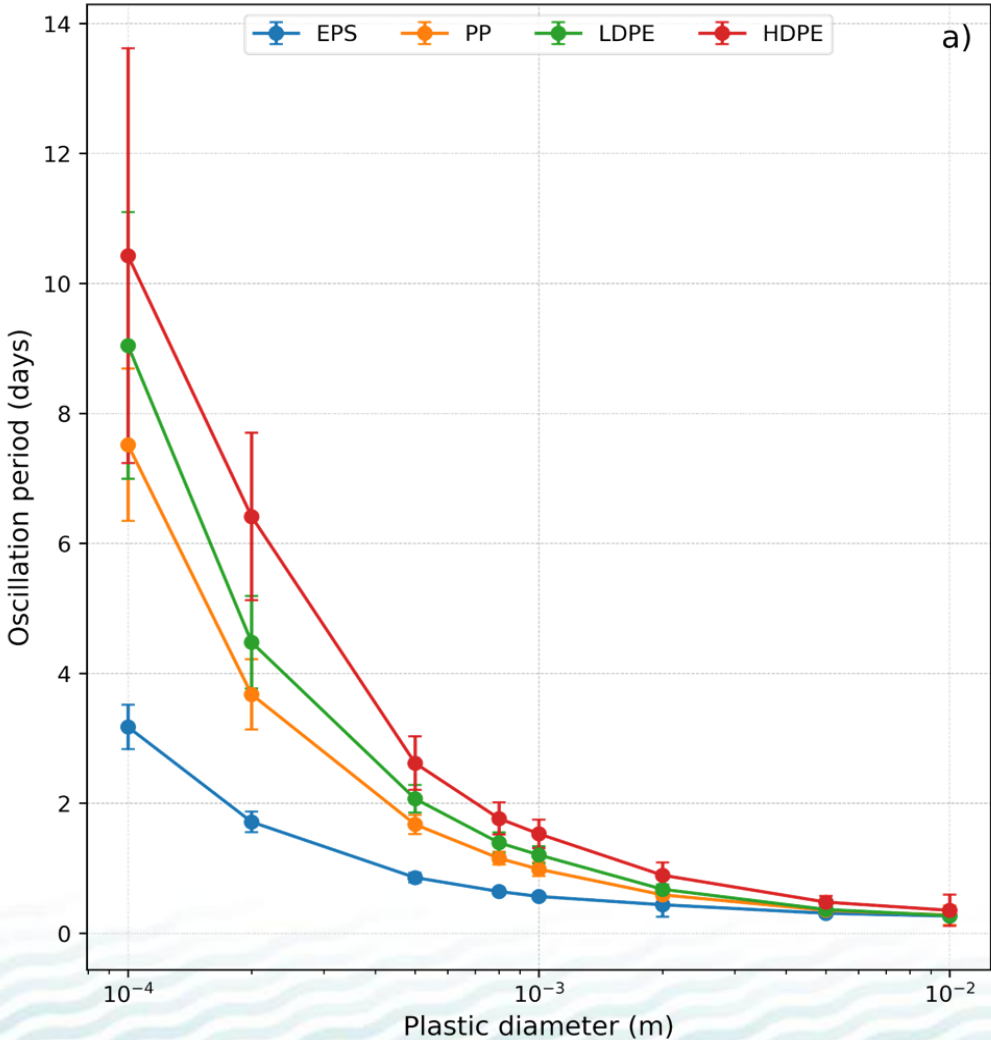
- EPS: 30 kg/m³
 - PP: 870 kg/m³
 - LDPE: 920 kg/m³
 - HDPE: 970 kg/m³
-
- Hydrodynamic data from Copernicus Marine Service (daily).
 - Biogeochemistry data from Mercator Ocean International (weekly).

> Temporal evolution and biofouling patterns



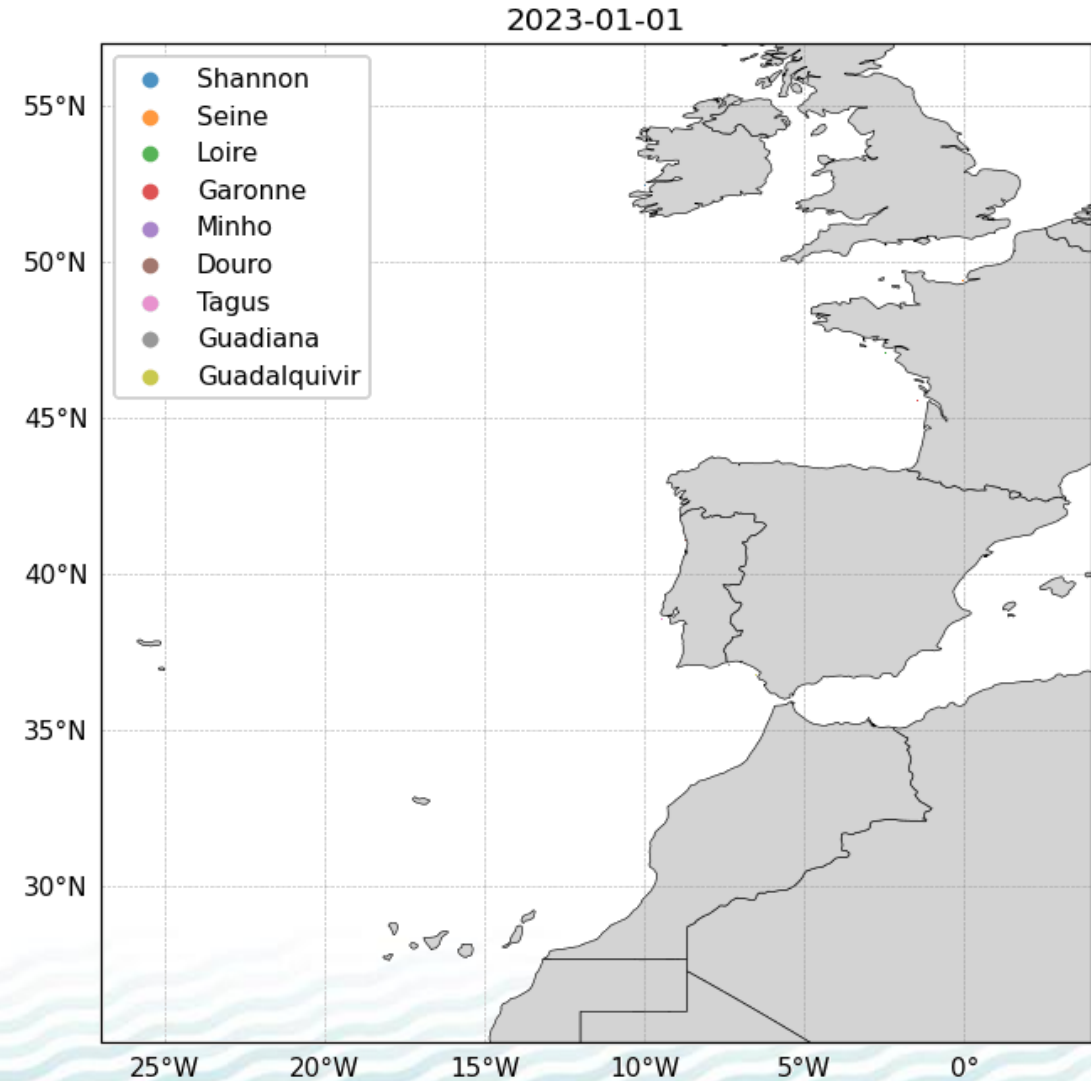
Harrison, J. P. et al. *BMC microbiology* (2014)

> Vertical oscillation period



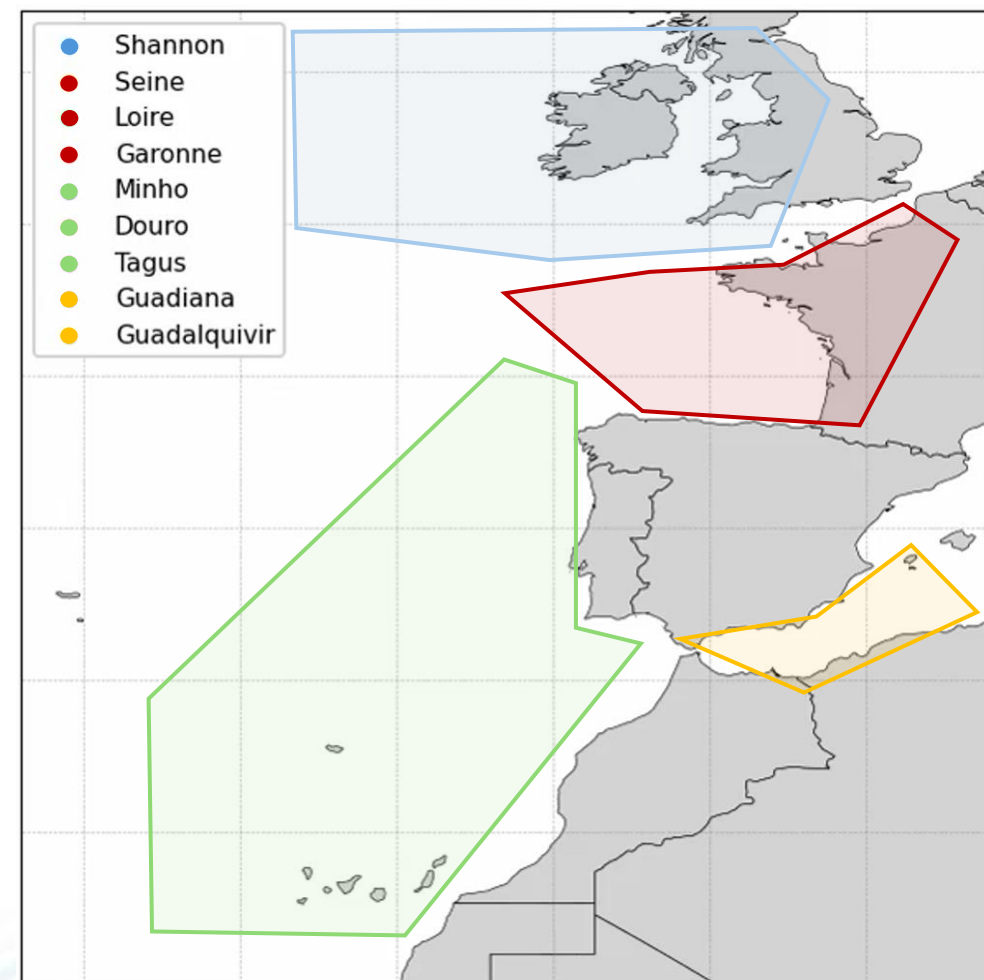
> Study Case – Riverine emissions to the European Atlantic

- Employed software: MOHID-Lagrangian
- 100.000 particles per river
- Emissions according to river flowrate
- Material: LDPE
- Density: 920 kg/m^3
- Diameter: 2 mm
 - Start date: 2023-01-01
 - End date: 2024-01-01



> Mean depth evolution per river

Seasonal growth coefficient (μ_A)



> Take home messages

- Biofouling dramatically modifies the plastics drift.
- Mixed Layer and Euphotic Zone depths play a crucial role in triggering the biofouling process.
- Growth times and vertical oscillation periods are significantly affected by plastic size and density.
- Particle sinking due to biofouling happens in the first months of spring, as diatom concentration increases in the domain, triggering the biofouling process.
- Plastic items travel submerged during long periods of time, affecting their final destination.
- **Kooi model has now been implemented in MOHID-Lagrangian model in order to run larger simulations with further statistical analysis.**

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