Sustainable Hull Maintenance Strategies and decision support tool HullMASTER

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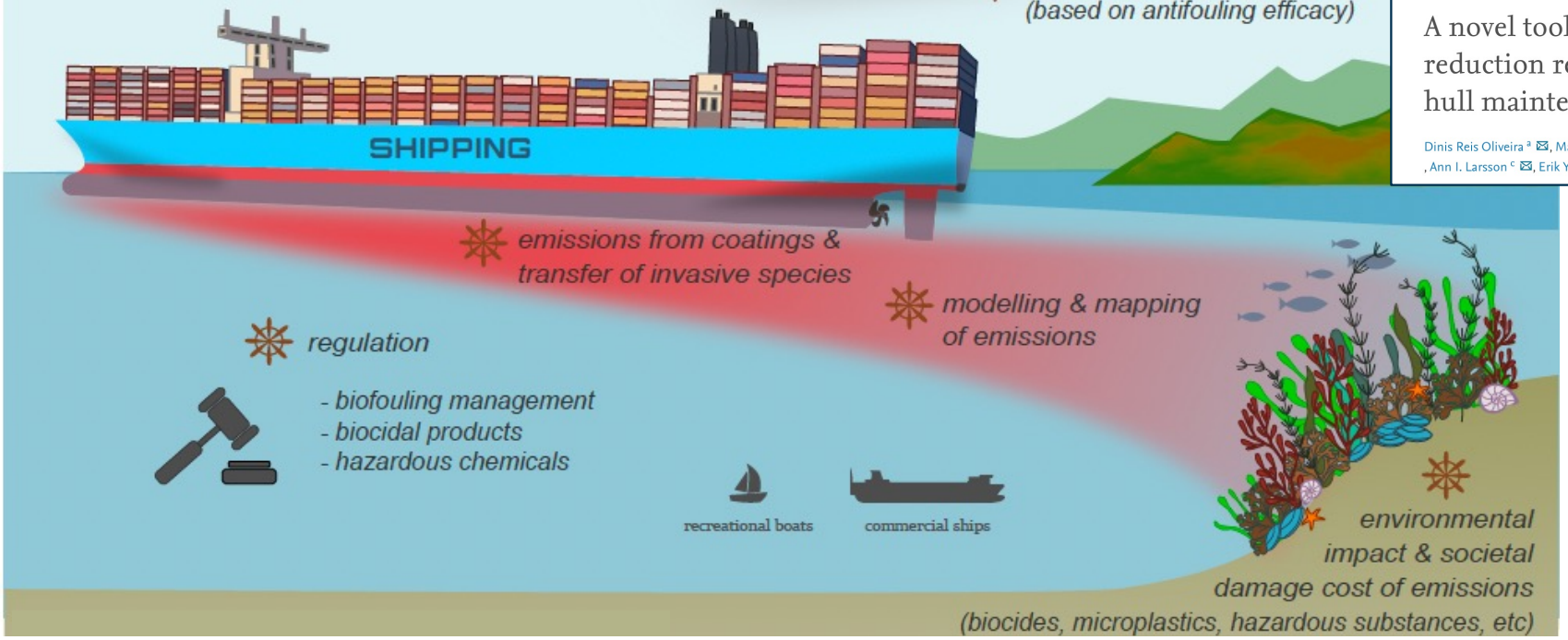
Research areas

Assessment of antifouling techniques with regards to their emissions, efficacy and regulation



Journal of Cleaner Production
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A novel tool for cost and emission reduction related to ship underwater hull maintenance

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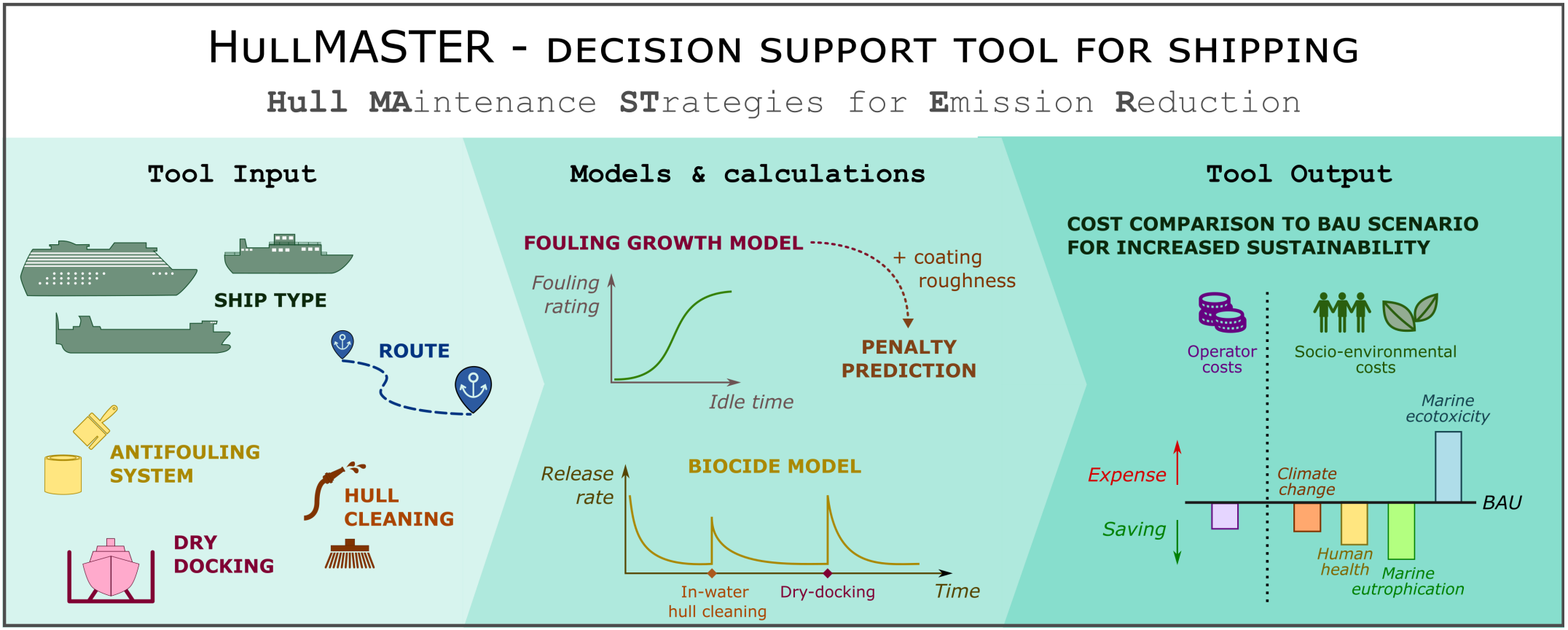
HullMASTER

Hull Maintenance Strategy for Emission Reduction

- Vessel-tailored decision-support tool
- Life cycle cost (LCC) analysis – both economic and societal (health + environment) costs
- Goal: **cost comparison** between different hull maintenance scenarios for a **single ship and route**

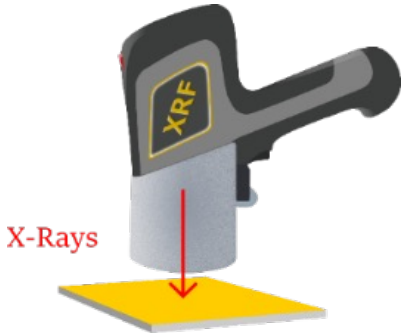


Oliveira, D. R., Lagerström, M., Granhag, L., Werner, S., Larsson, A. I., & Ytreberg, E. (2022). A novel tool for cost and emission reduction related to ship underwater hull maintenance. *Journal of Cleaner Production*, *356*, 131882.

Data sources

Fouling growth model	Biocide release model	Operator costs	Socio-environmental damage costs
• Own field studies	• Own field studies • Scientific literature (IWHC)	• Price estimates from industry	• Scientific literature

Field testing of coatings



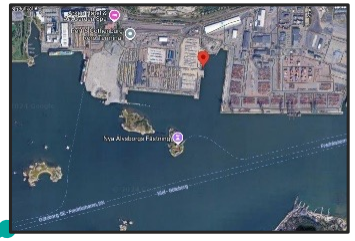
Biocide release measurements

Price estimates from industry

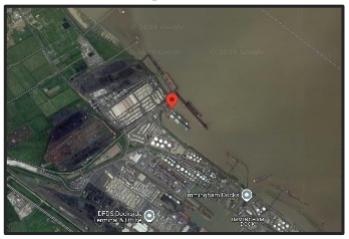
Scientific literature

Fouling growth model - Static Immersion Tests in European Seas

Gothenburg, Sweden
+ 3 locations on the Swedish coastline (HÅLL)

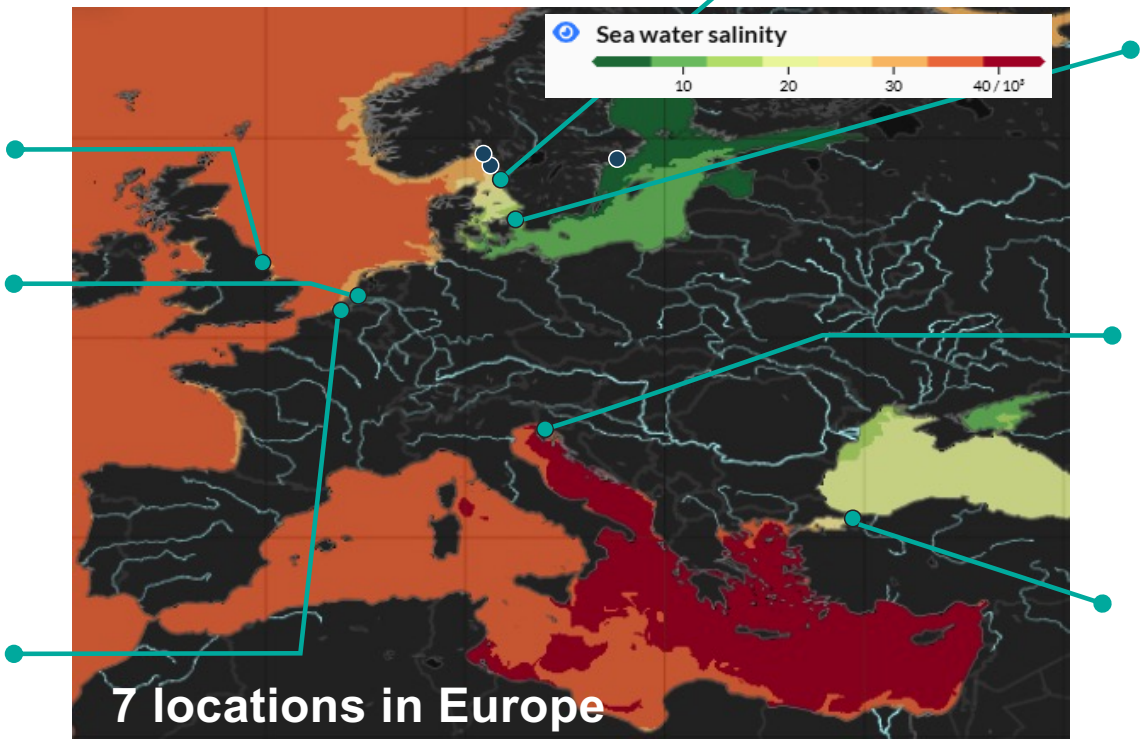


Immingham, UK



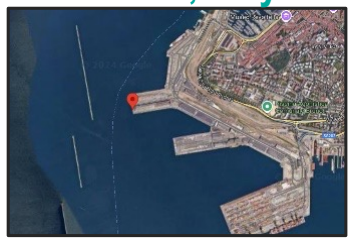
Vlaardingen, Netherlands

Ghent, Belgium

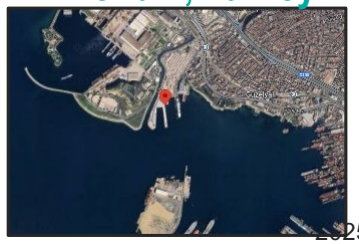


Copenhagen, Denmark

Trieste, Italy



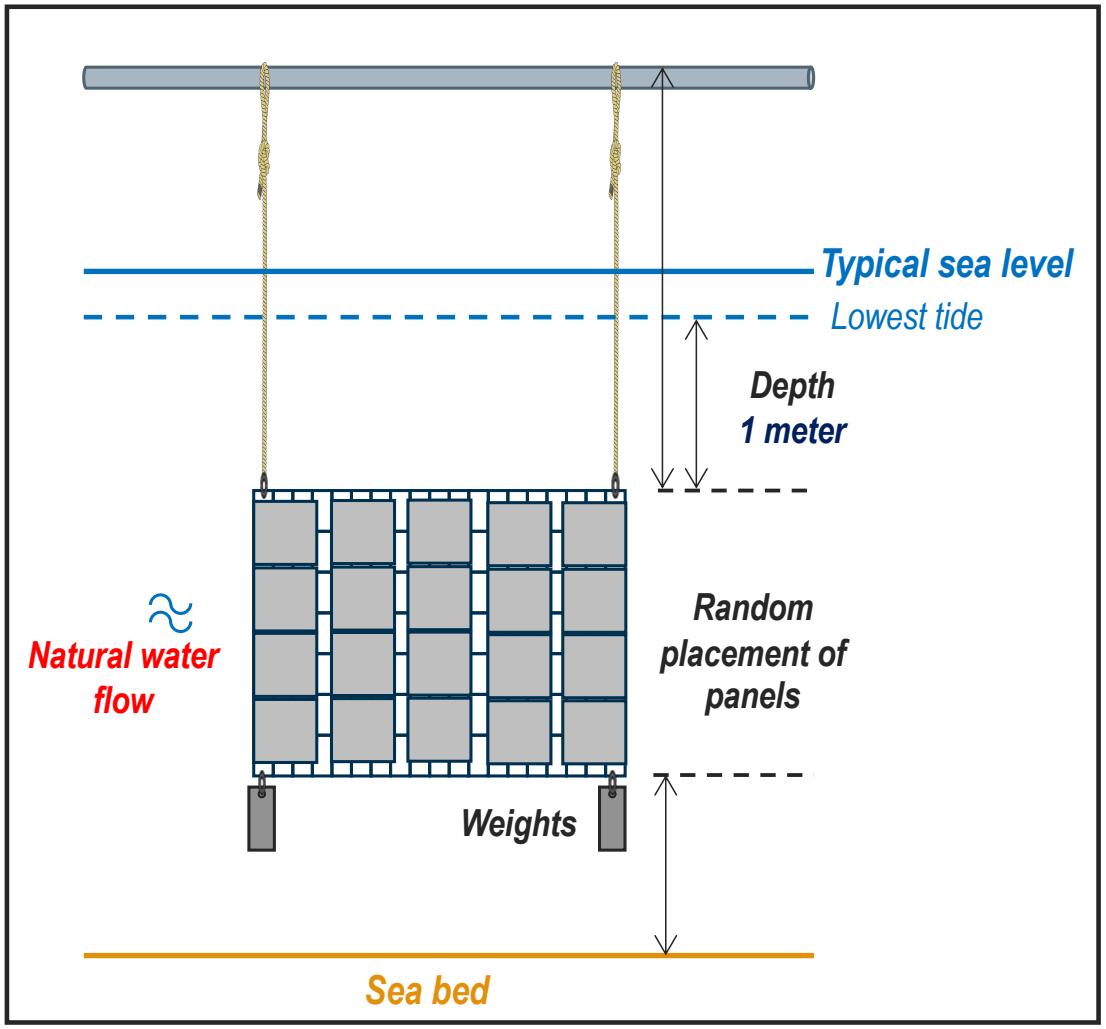
Pendik, Turkey

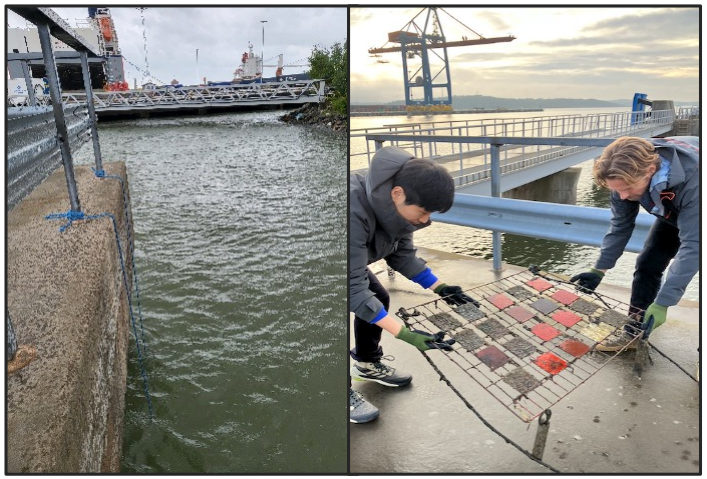


Source: Copernicus Marine Service (https://marine.copernicus.eu/)

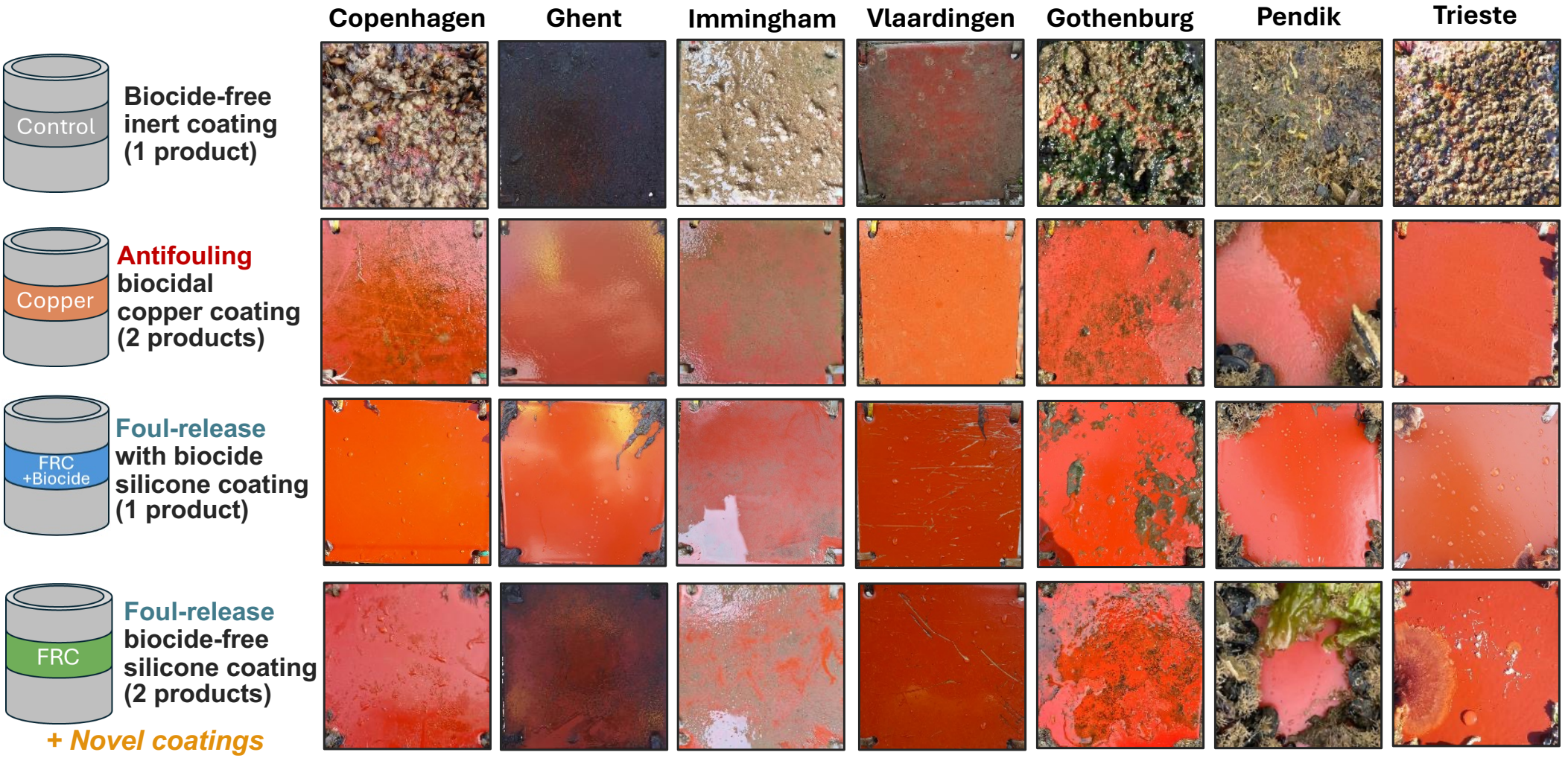
** Note: Some ports close to inland may not be accurate in salinity due to the inflow of rivers*

Experimental set-up





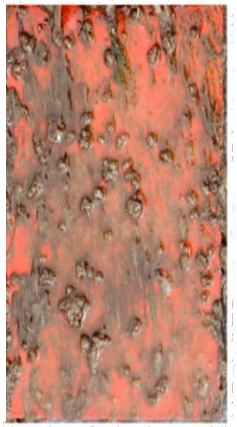
Fouling growth model (12 months static immersion)



* Note: Fouling at the edge of the panels from frame.

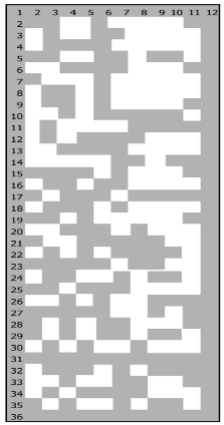
Fouling Rating Scale

Clean surface



Fouled surface

Visual Inspection



Coverage

Soft

Hard

fr_{NSTM} [-]	Type	Hull fouling condition
0	undetectable	Foul-free surface.
10	soft	Incipient slime, visible underlying paint/metal surface.
20	soft	Advanced slime, obscured underlying paint/metal surface. Juvenile barnacles ≤ 1 mm (Oliveira and Granhag, 2020).
30	soft	Soft fouling (e.g. filaments) <76 mm in length and <6.4 mm in height.
40	hard	Tubeworms <6.4 mm in height. Encrusting bryozoans (Oliveira and Granhag, 2020).
50	hard	Barnacles <6.4 mm in height.
60	hard	Combination of tubeworms and barnacles <6.4 mm in height.
70	hard	Combination of tubeworms and barnacles > 6.4 mm in height.
80	hard	Tubeworms closely packed and upright from surface, or barnacles on top of each other, < 6.4 mm in height.
90	hard	Densely packed tubeworms or barnacles, > 6.4 mm in height; presence of mussels or oysters; or slime/grass overlay.
100	composite	All forms of fouling; soft animal fouling (tunicates) growing on various forms of hard fouling

Degree of fouling (frNSTM)

$$\boldsymbol{Mean(frNSTM) = \frac{1}{100}\sum_{i=1}^{n} coverage_i \times frNSTM_i}$$

** US Naval Ships' Technical Manual (2006)*

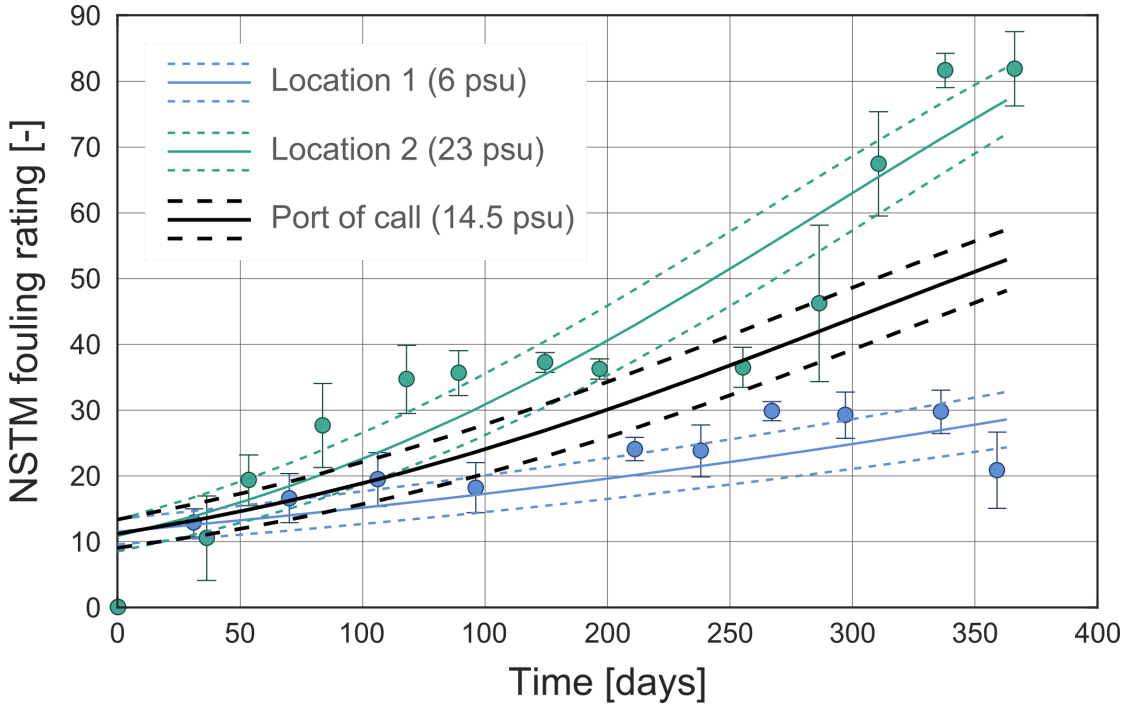
Fouling growth model

- Based on field data from static long-term testing of coatings
- Evaluation of fouling rating
- HullMASTER assumption: fouling only occurs during ship idle times.
- Salinity-dependent

Inert coating

Antifouling biocidal copper coating

Foul-release biocide-free silicone coating



The different steps of HullMASTER

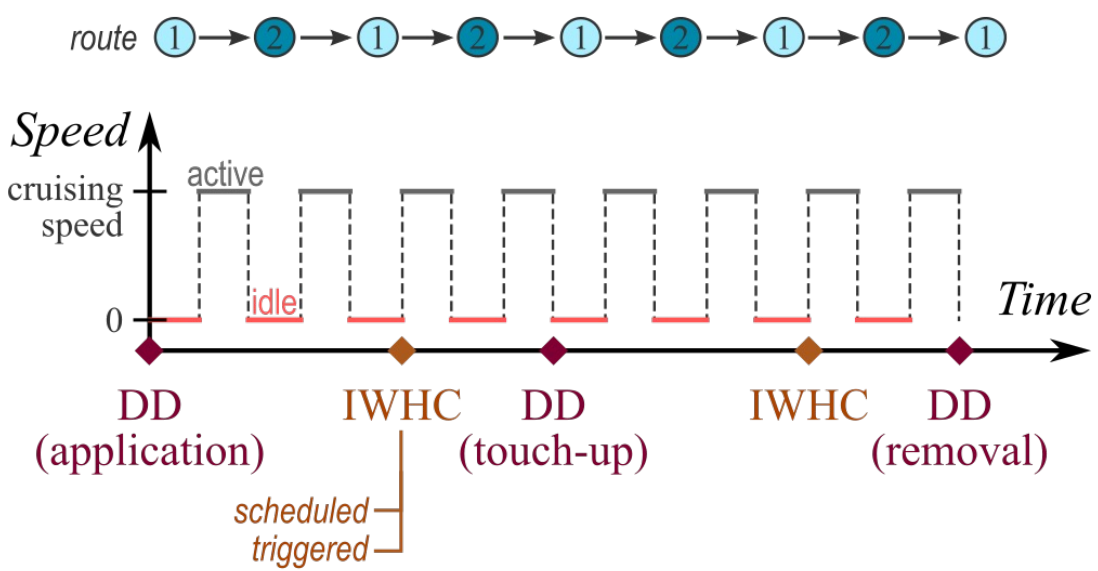
1. USER INPUT

- Vessel dimensions & engine type
- Cruising speed & activity profile
- Route: selection of 2 pendulum ports

port (1) ⇄ port (2)

salinity 1 *salinity 2*

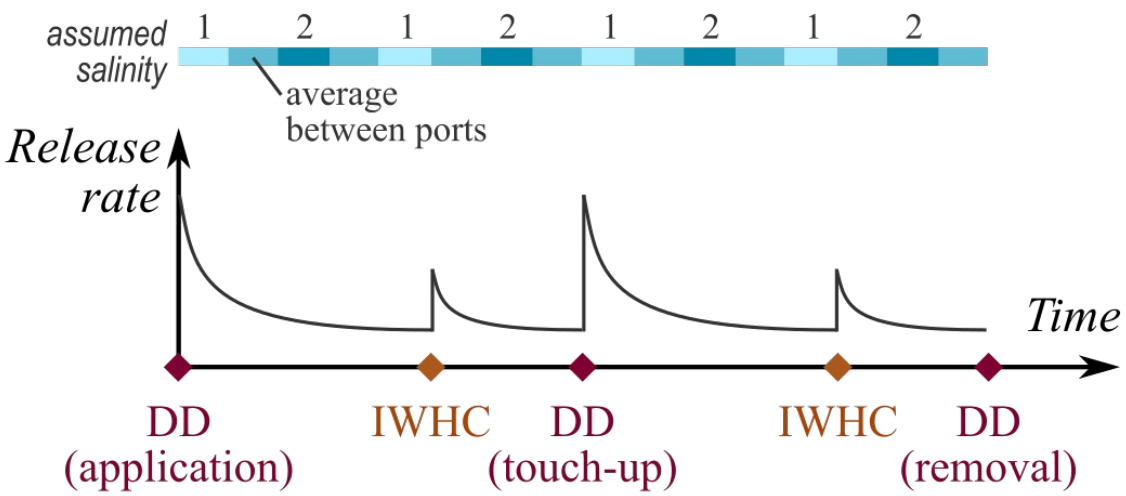
- Specification of **BAU** & **alternative scenarios** in terms of:
  coating & maintenance schedule
  - *biocidal (copper)*
  - *foul release (FR)*
  - *inert*
  - *dry docking (DD)*
  - *in-water hull cleaning (IWHC)*



2. MODELLING

Metal release from coating

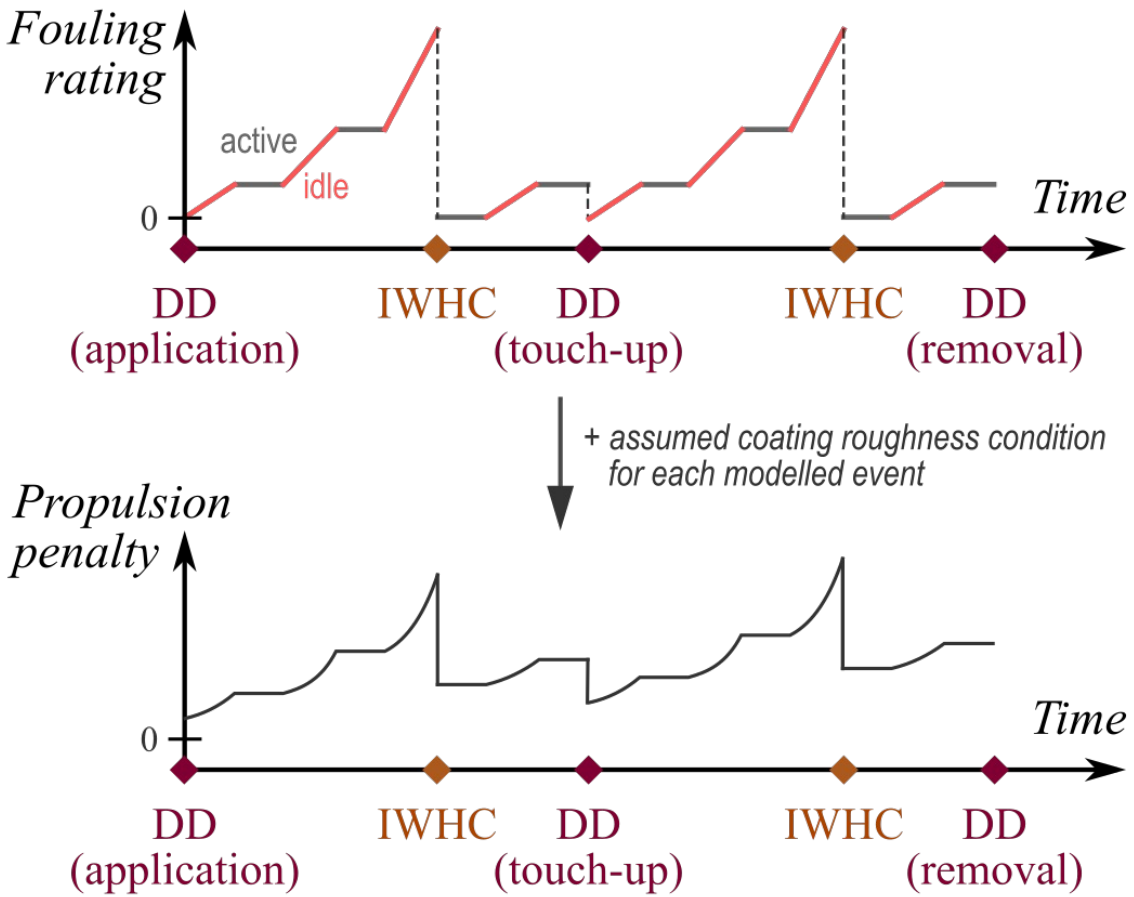
- Only modelled for biocidal coating
- Salinity-dependent Cu release rate
- Release during and after IWHC depends on user-specified degree of wear
  - *negligible*
  - *moderate*
  - *high*



Propulsion penalty

Propulsion penalty

- Fouling on hull assumed homogeneous and to only occur during idle periods
- Powering penalty calculated relative to hydraulically smooth hull
- Roughness height (k_s) of hull = coating roughness + fouling roughness
- Granville similarity-law scaling method used to derive powering penalty from k_s
- Powering penalty used to derive:
  - emissions due to energy (fuel) penalty
  - emissions from scrubber (if present) due to increased fuel consumption



3. Output

- Results for the **alternative** scenario given as the difference in cost relative to the **BAU** scenario
- Results presented with propagated uncertainties

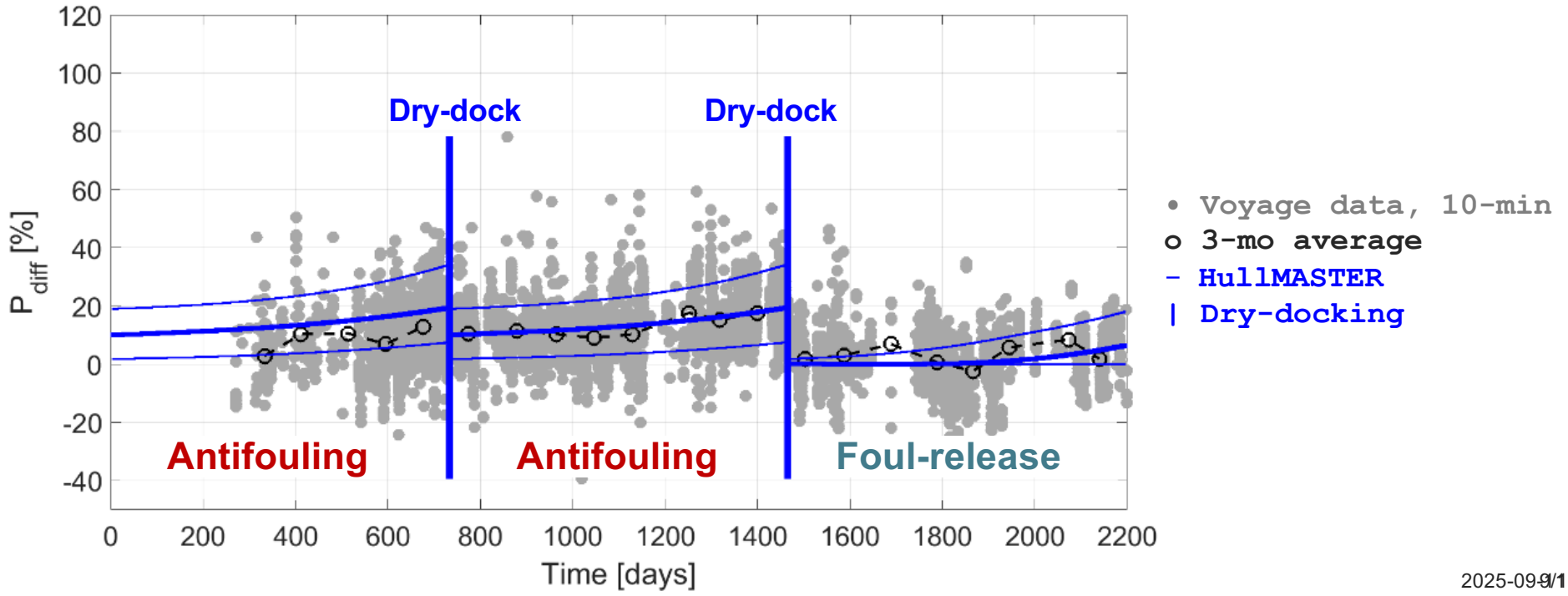
operator costs & emission costs

$$\Delta\ costs\ (€) = modelled\ costs_{alternative} - modelled\ costs_{BAU}$$

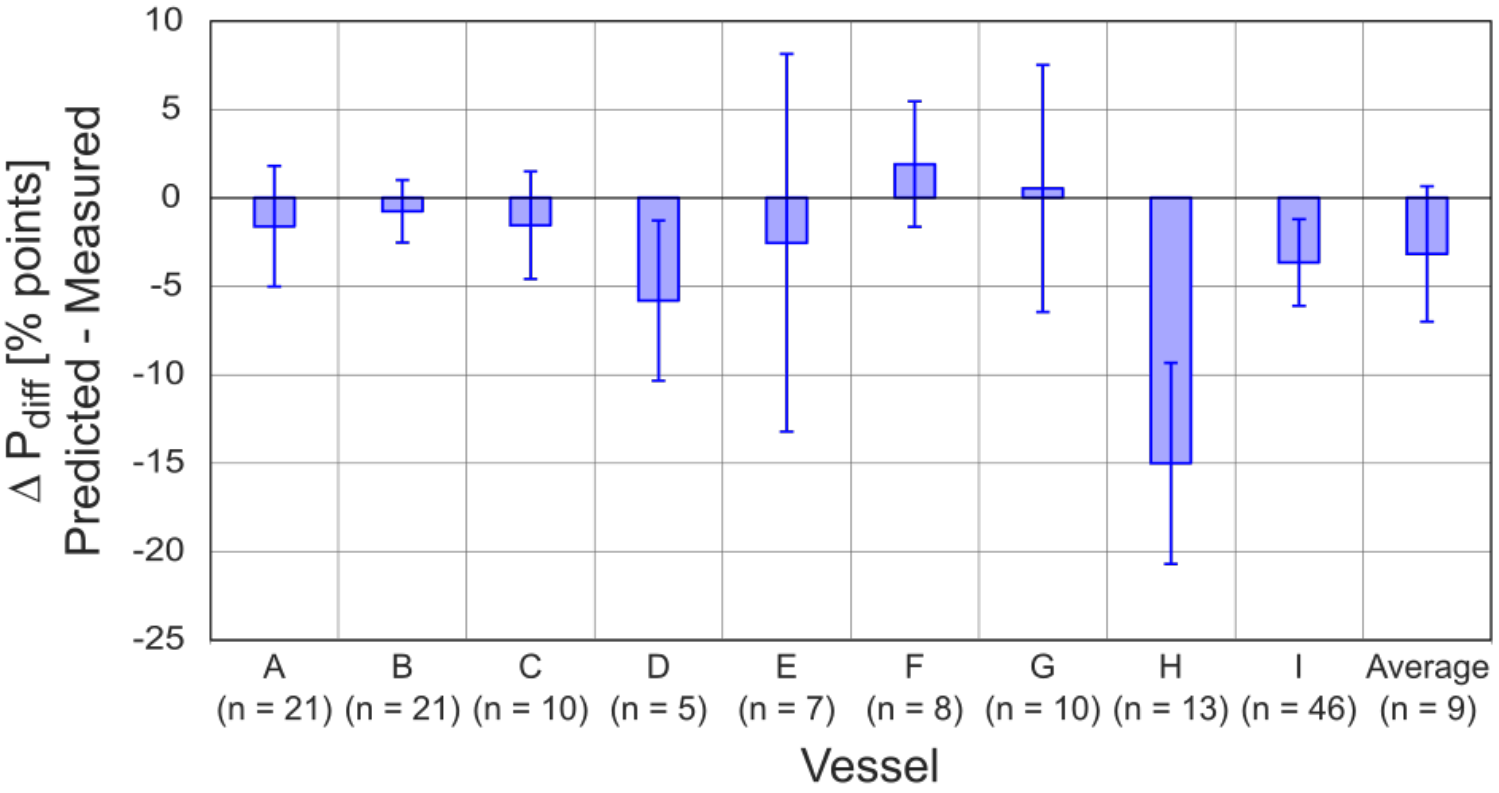
Validation of powering penalties

HullMASTER compared to **onboard measurements:**

% increase in propulsion power (kW) for a rough hull compared to smooth hull

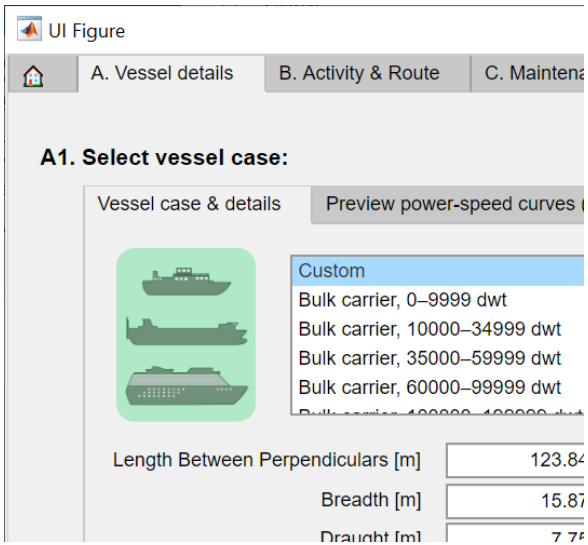


Validation of powering penalties

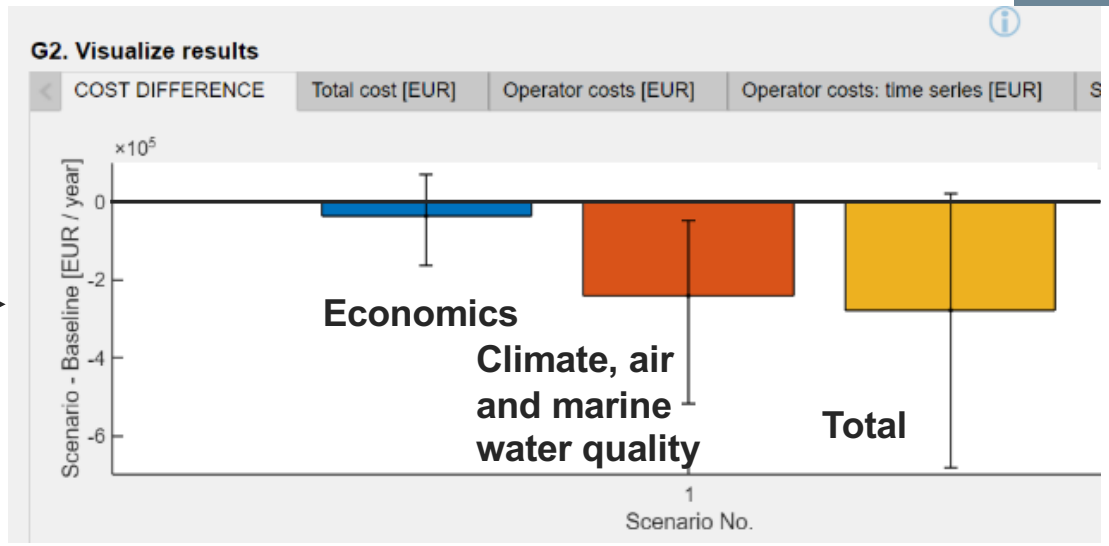


- HullMASTER predictions show good agreement with measured propulsion penalties
- average difference of -3.2 ± 3.8 percentage points

Cost calculation



Operators + Society = Total Diff.



BAU

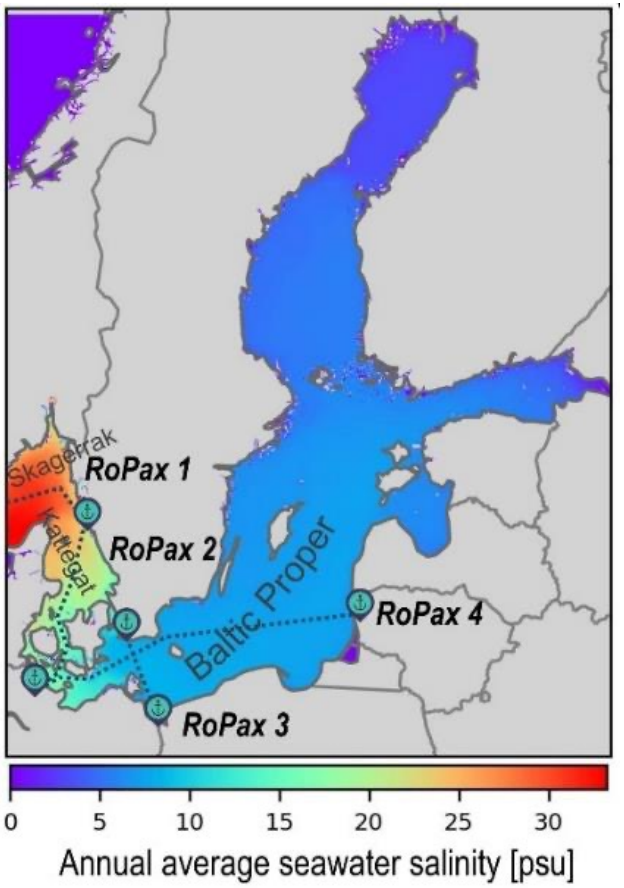
*BAU = *biocidal antifouling coatings*

Cost comparison with baseline scenario

Bunker penalty, Surface treatment & coating, IWHC

Health impact, Climate change impact, Marine eutrophication (N), Marine ecotoxicity (Cu, Zn), Indigenous alien species, Microplastic

Scenarios from the Baltic Sea



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Sustainable Hull maintenance strategies in Baltic Sea region through case studies of RoPax vessels

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ARTICLE INFO

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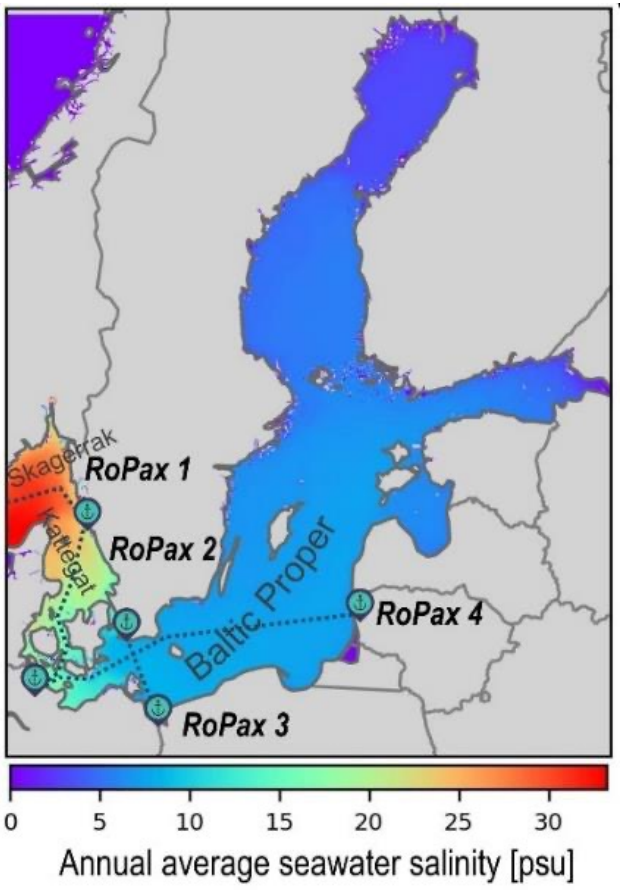
Hull maintenance
Antifouling efficacy
Biofouling
Cost-benefit analysis
Decision support tool

ABSTRACT

Determining optimal maintenance strategies in unique maritime environments like the Baltic Sea is challenging, as it should consider various aspects, including ship characteristics and environmental conditions. This study employs the decision support tool HullMASTER (Hull MAintenance STrategies for Emission Reduction) to assess the life cycle costs of different hull maintenance scenarios for RoPax vessels in the Baltic Sea. Findings indicate that optimal hull management can save operators up to €9.3 million and reduce socio-environmental damage costs by €7.9 million over ten years compared to a less proactive baseline. Notably, biofouling pressure decreases from the high-salinity Skagerrak and Kattegat to the low-salinity Baltic Proper, emphasizing the need for tailored maintenance strategies. Among the coatings analyzed, non-biocide foul-release coatings are the most sustainable choice, reducing emissions to the ocean and the atmosphere. These findings will provide practical guidelines for sustainable hull management strategies, contributing to enhanced operational efficiency and marine environmental protection.

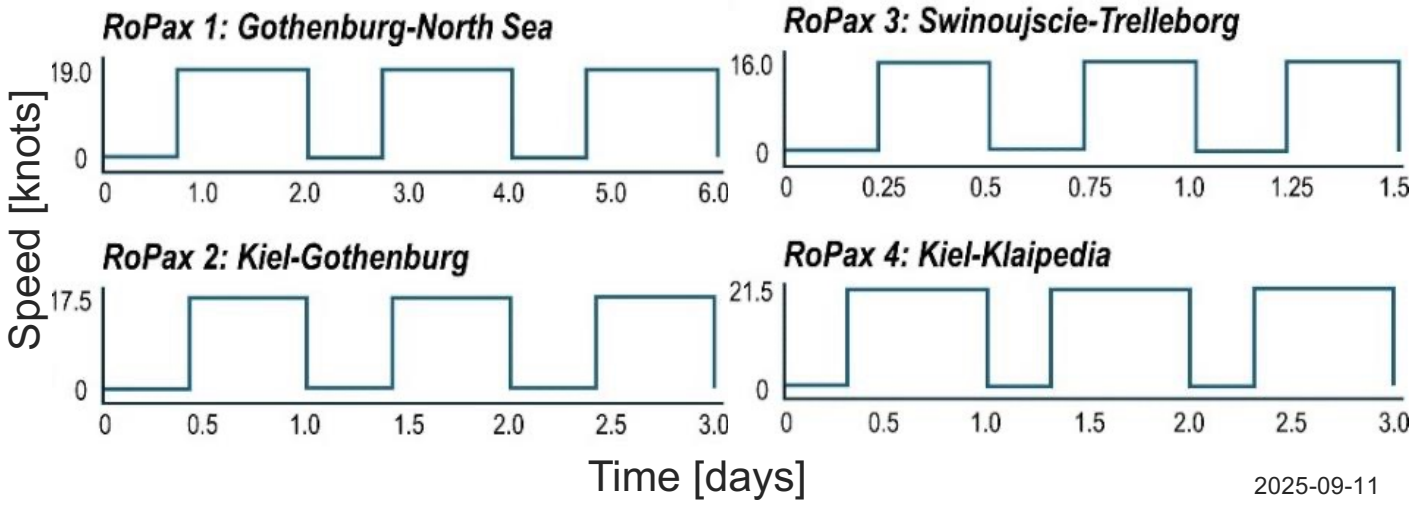
Vessel specs & operational profiles



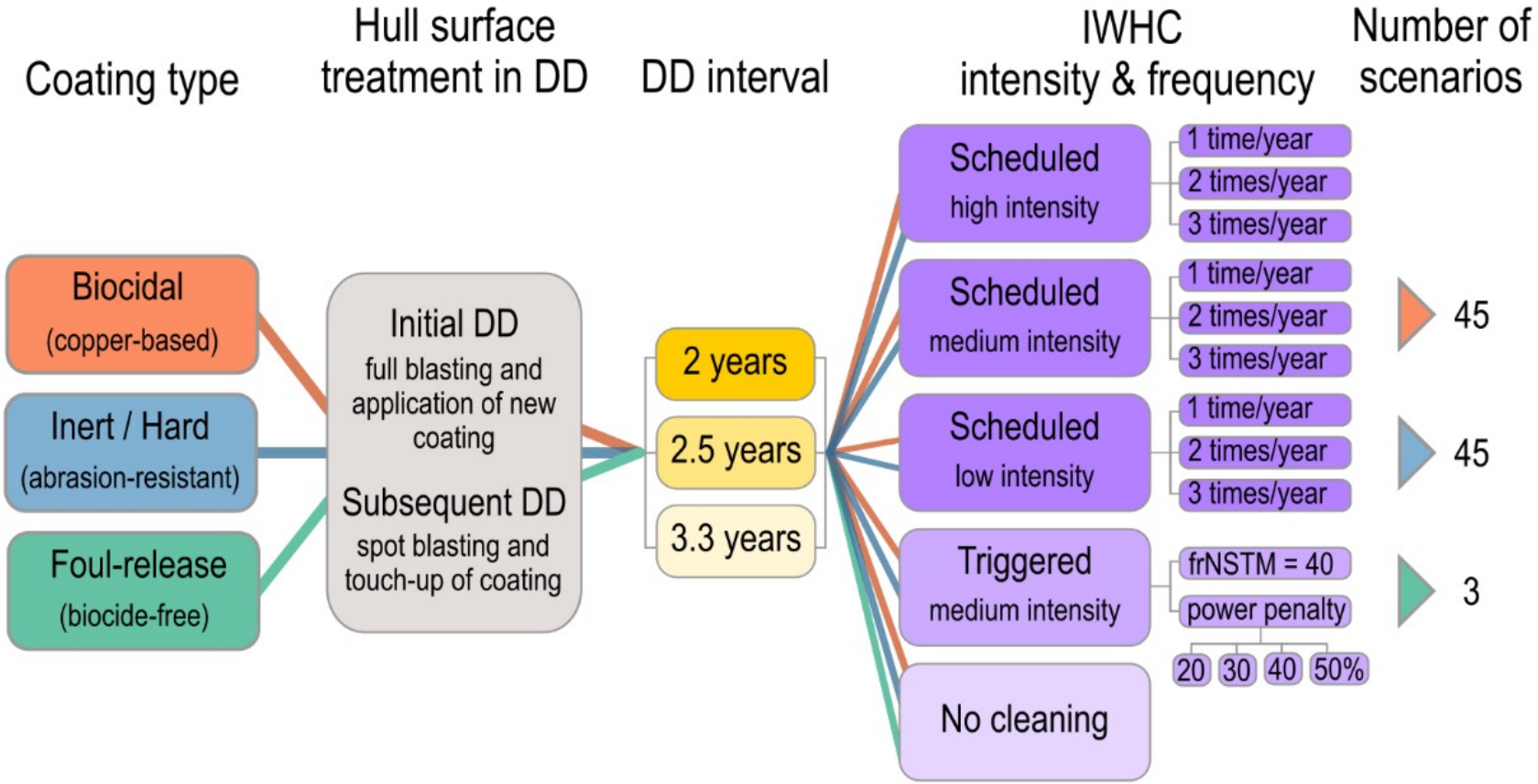
❖ Ship detail

Main dimension (m)	MCR (kW)	Fuel & Abatement techniques
Approx. L: 190/B: 26.5/T: 7.5	20,000	LSMGO (0.07% Sulphur) No scrubber/NOx abatement

❖ Operational profile



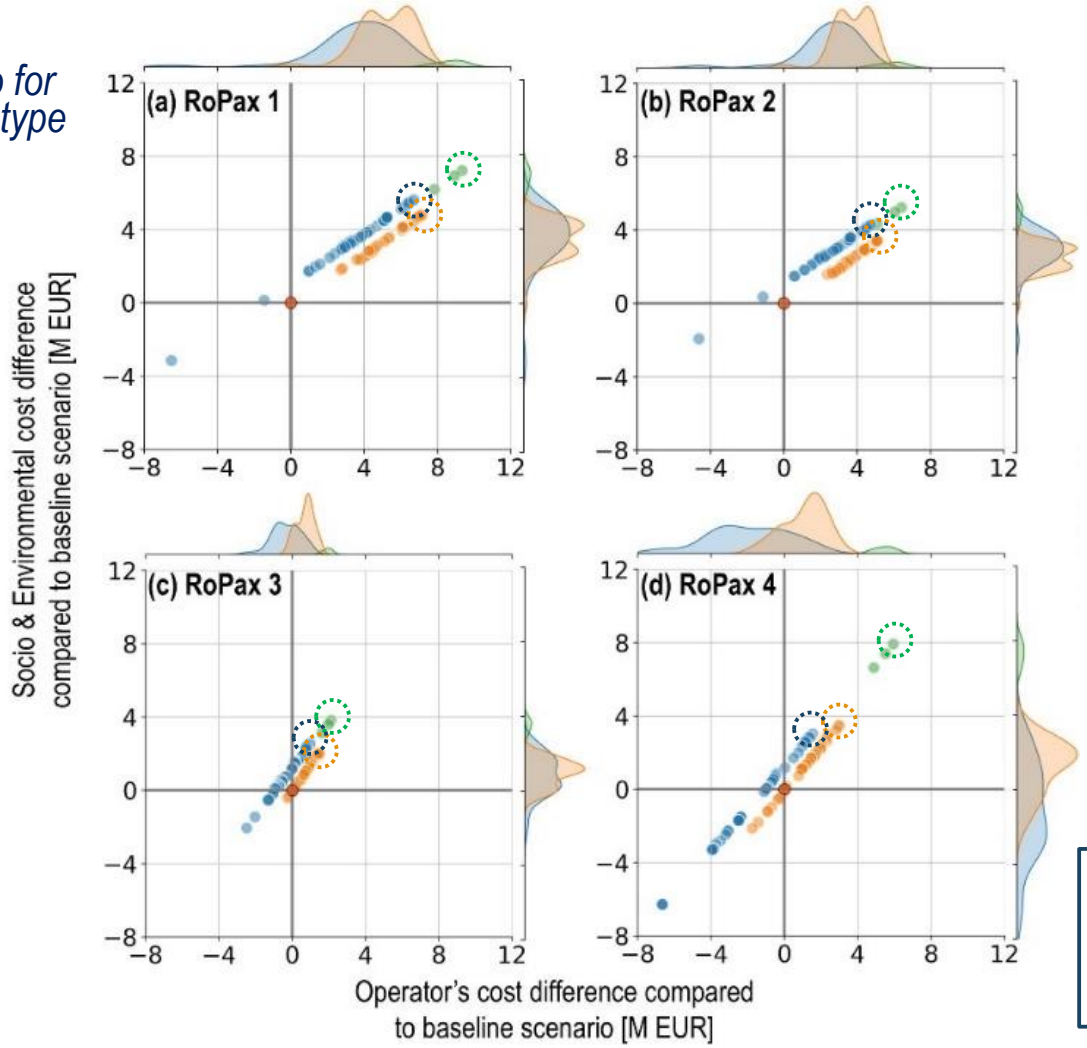
Hull maintenance scenarios



** Assuming 93 different hull maintenance scenarios in 10 years operation*

Cost-Benefit Analysis

Best scenario for each coating type



- Baseline [Worst case: Copper coating]
- Inert coating [45 cases]
- Copper coating [45 cases]
- Foul-release coating [3 cases] No IWHC

Interpretation

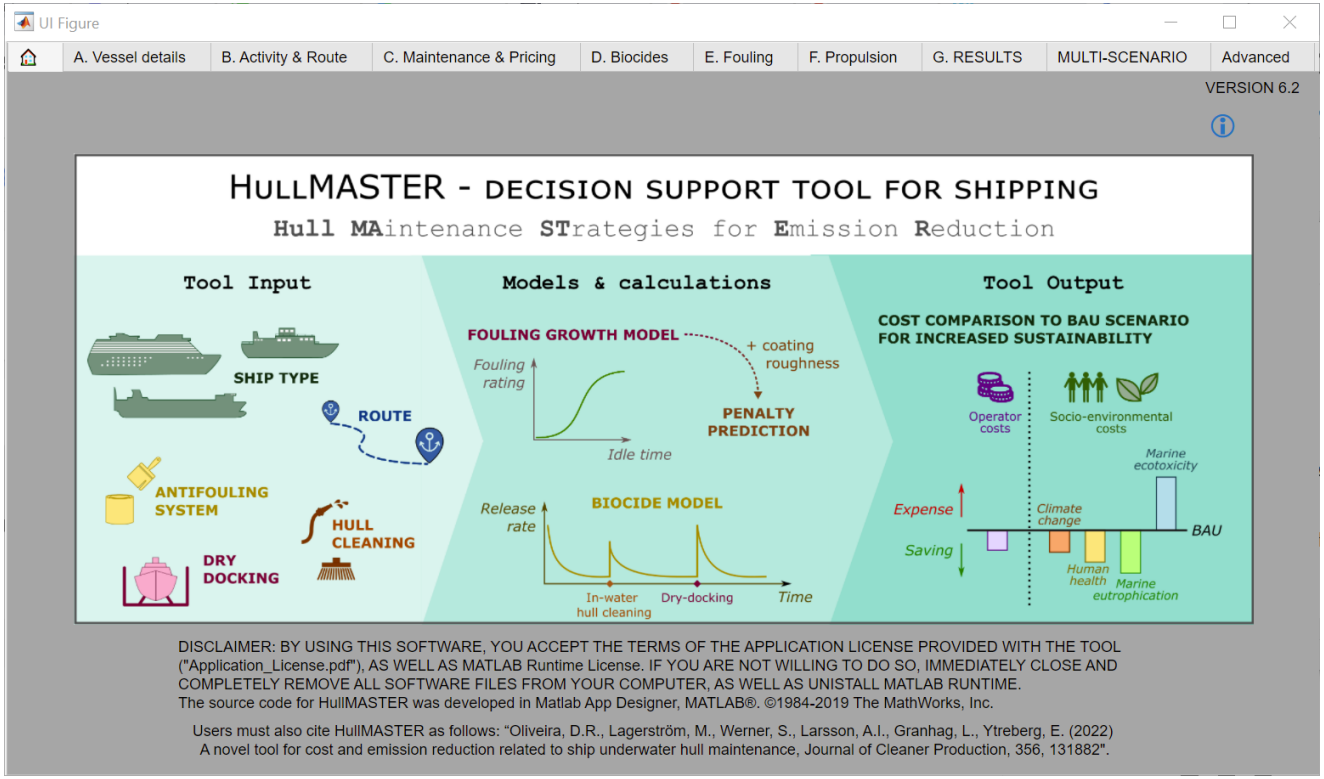
Savings (+) Socio&Env.	Savings (+) Operator
Expenses (−) Operator	Savings (+) Socio&Env.
Expenses (−) Operator	Savings (+) Operator
Expenses (−) Socio&Env.	Expenses (−) Socio&Env.

Baseline

Baseline

Savings for operators up to €9.3 million, and socio-environmental damage €7.9 million compared to baseline.

Input from experts like you most welcome!



Current version [Baltic Sea Region]

Funded by Lighthouse Swedish Maritime Competence Centre under the "Hållbar sjöfart" program

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