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impacts of shipping on water pollution

[redacted]

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GÖTEBORGS UNIVERSITET

OULUN YLIOPISTO

Norwegian Meteorological Institute

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UNIVERSITY OF Southampton

HELCOM

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IIASA International Institute for Applied Systems Analysis

Ca' Foscari University of Venice

UNIVERSITY OF THE AEGEAN

ICRA Institut Català de Recerca de l'Aigua

danaos SHIPPING CO LTD

Maritime Institute of Eastern Mediterranean

universidade de aveiro

creative nano

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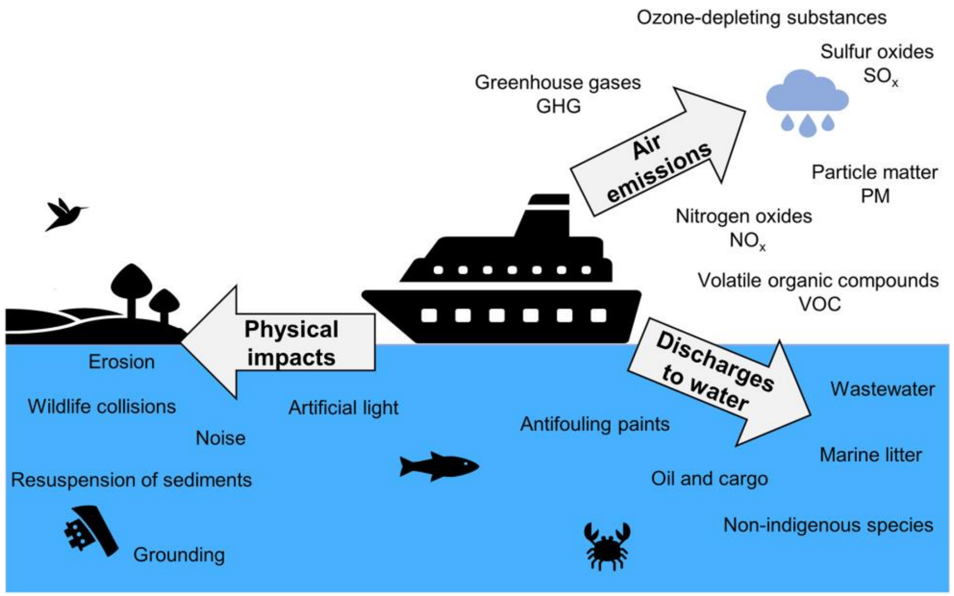
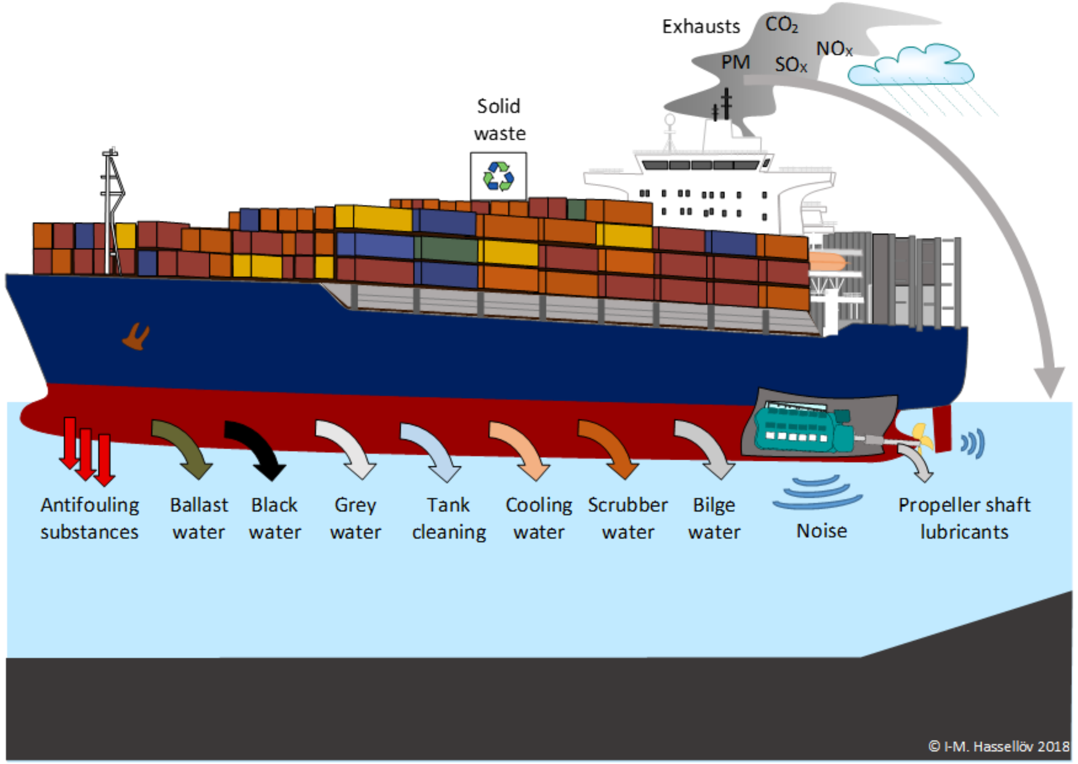
impacts of shipping on the marine environment- why ?

discharges to water, physical impacts, and air emission

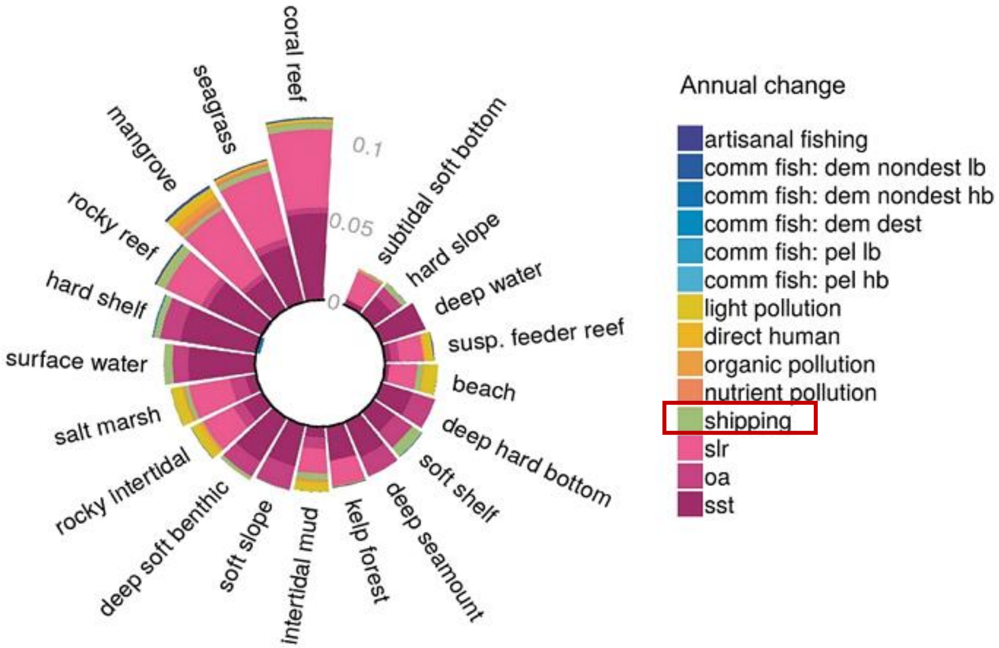


Jägerbrand et al. (2019) https://doi.org/10.1016/j.scitotenv.2019.133637

Different waste streams influencing *directly or indirectly* the marine environment



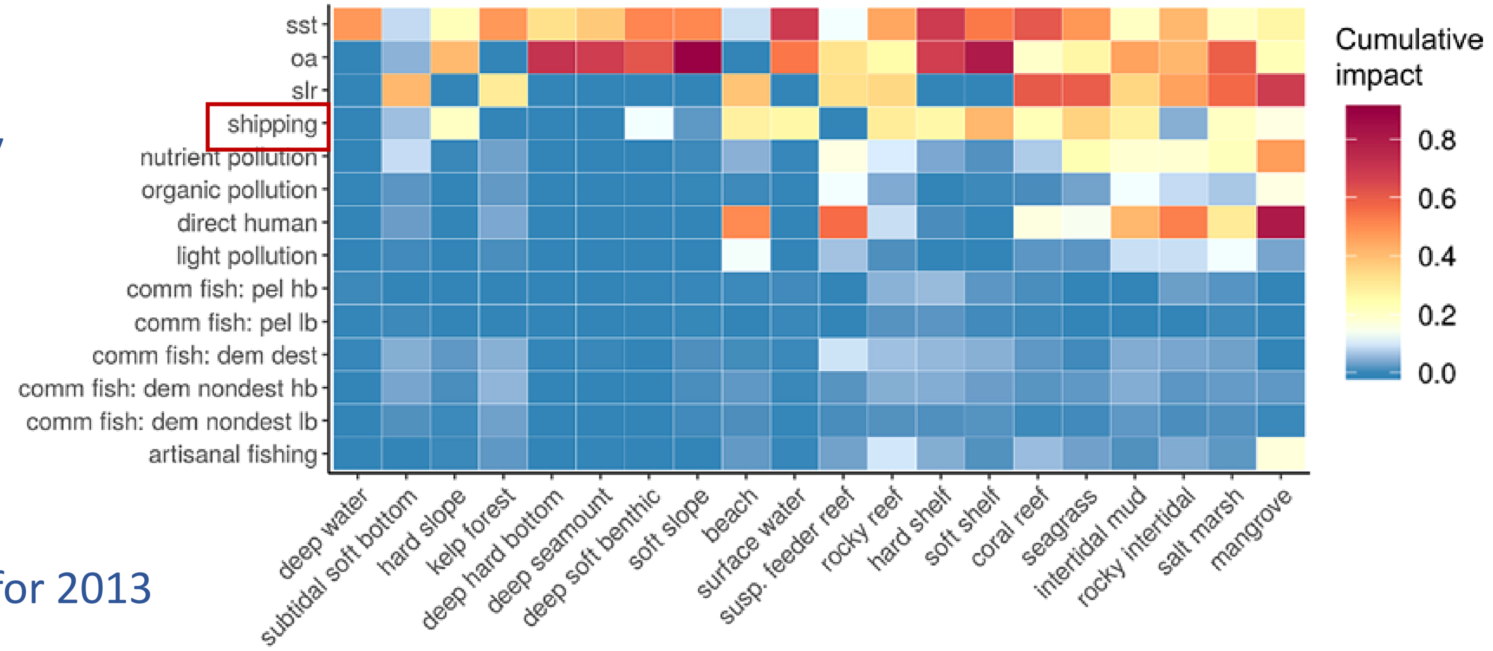
impacts of shipping on the marine environment



high resolution, annual data on the intensity of 14 human stressors and their impact on 21 marine ecosystems over 11 years (2003–2013) to assess pace of change in cumulative impacts on global oceans

Halpern et al. (2019) [*https://doi.org/10.1038/s41598-019-47201-9*](https://doi.org/10.1038/s41598-019-47201-9)

shipping impact increased notably for many ecosystems



cumulative impacts on ecosystems for 2013

impacts of shipping on the marine environment- why ?

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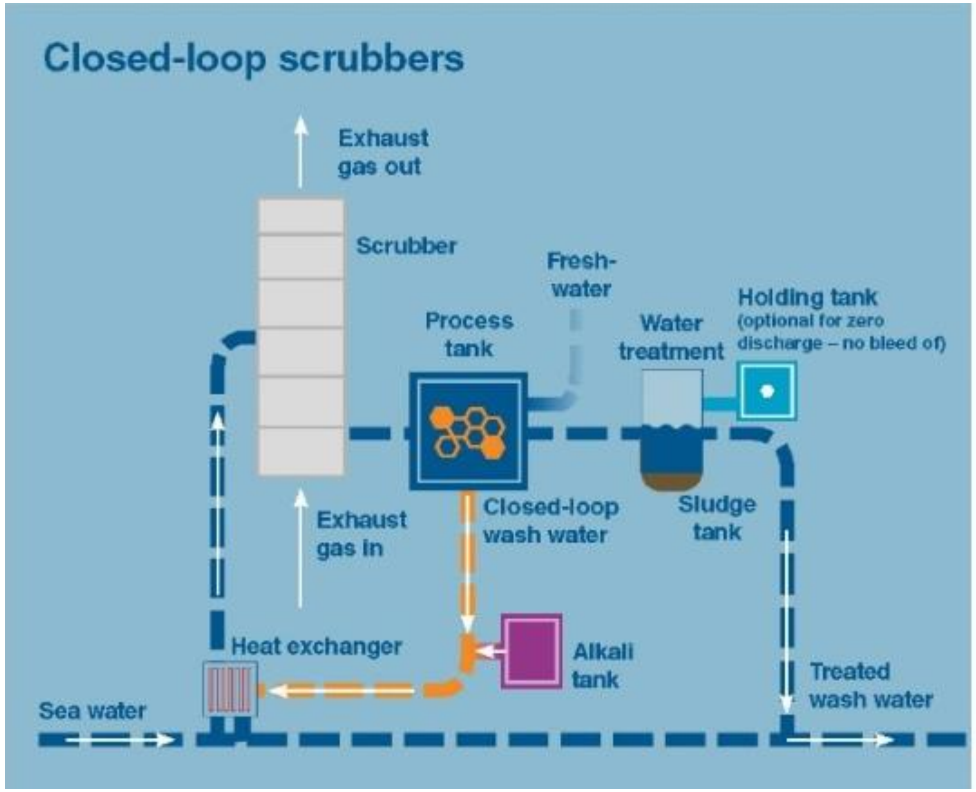
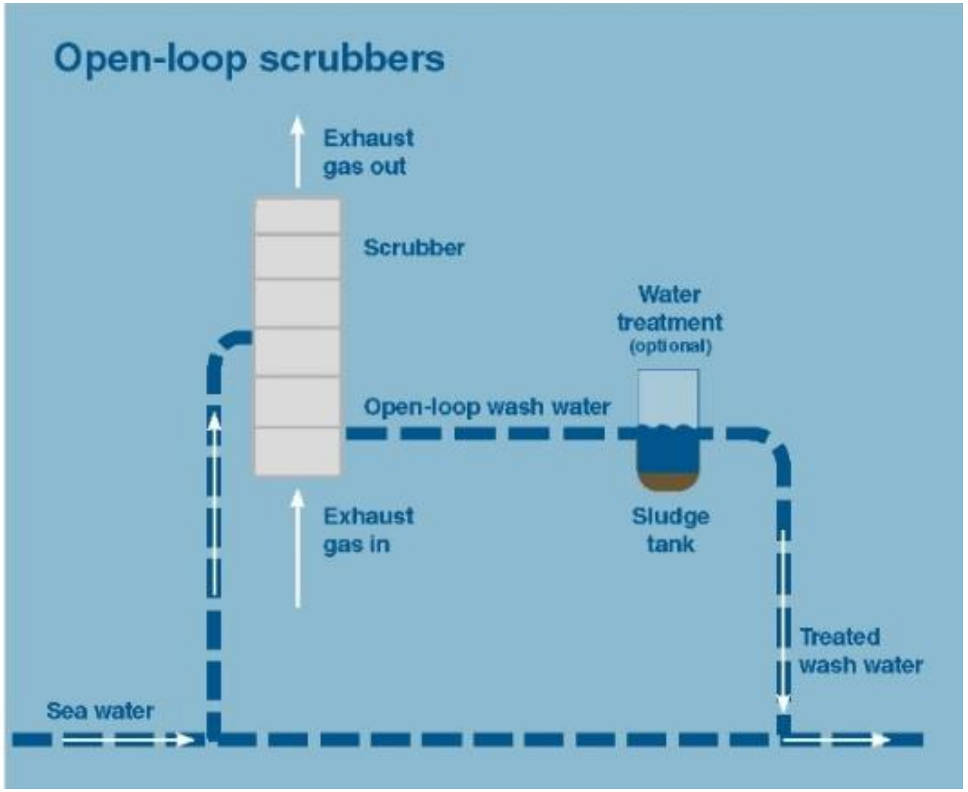
- Combustion in ship engines produces a range of primary and secondary pollutants ⇒ **environmental, health, economic and climatic impacts.**
- **New global standards** since 2020 for shipping emissions. The new limit for fuel sulphur content is 0.5 %. In **Sulphur Emission Control Areas (SECA’s),** a stricter regulation of 0.1 % fuel sulphur content has been in place since 2015.
- In complying with the limit values, ships are currently mandated either
  - to use fuel sulphur content within the limits, or
  - vessels may be equipped with exhaust gas cleaning systems (EGCS) - SOx scrubbers.
- An increasing number of ships have opted to install scrubbers due to the price difference between heavy fuel oil and low sulphur fuels
- The EGCS **use large volumes of seawater**. The **toxicity of scrubber washwater** released back to the sea is known poorly.

There are two main categories of scrubbers: closed- or open-loop.

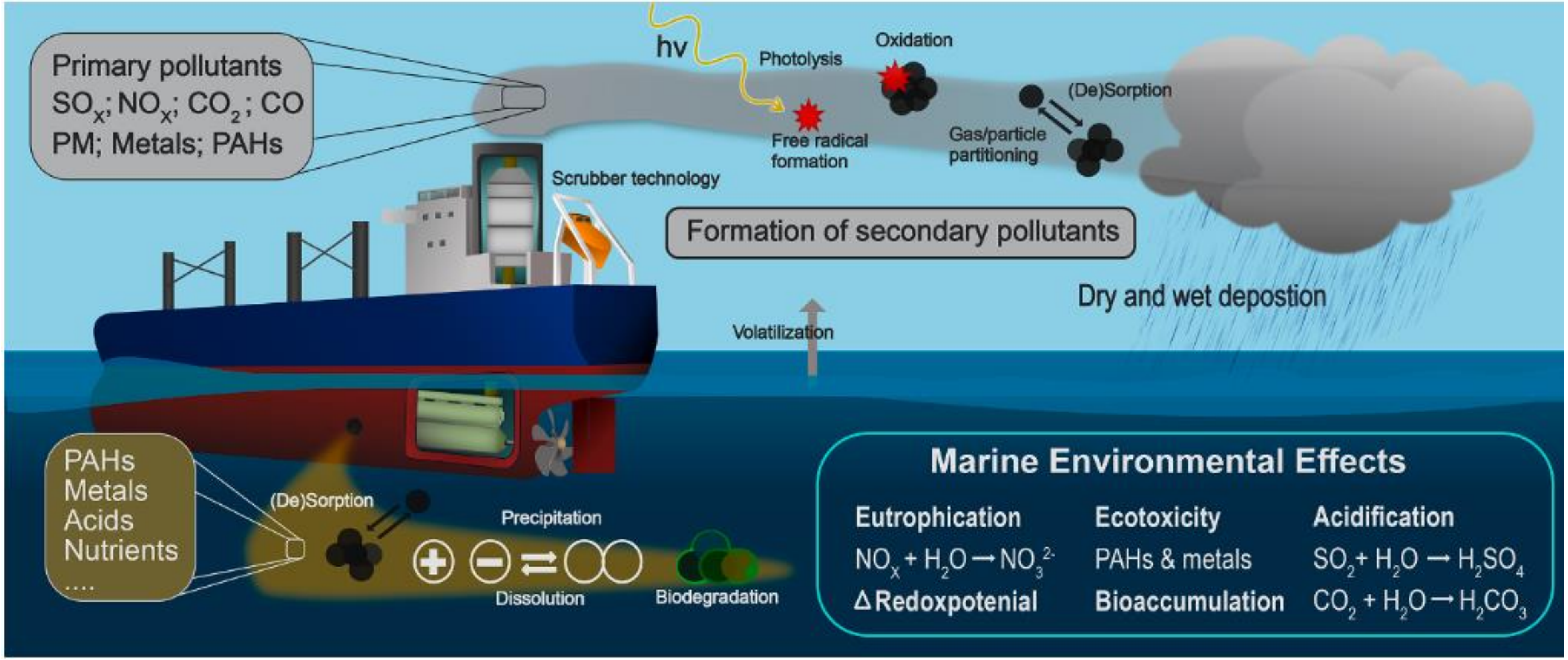




Schmolke et al. (2020) https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/texte_162-2020_environmental_protection_in_maritime_traffic_-_scrubber_wash_water_survey.pdf

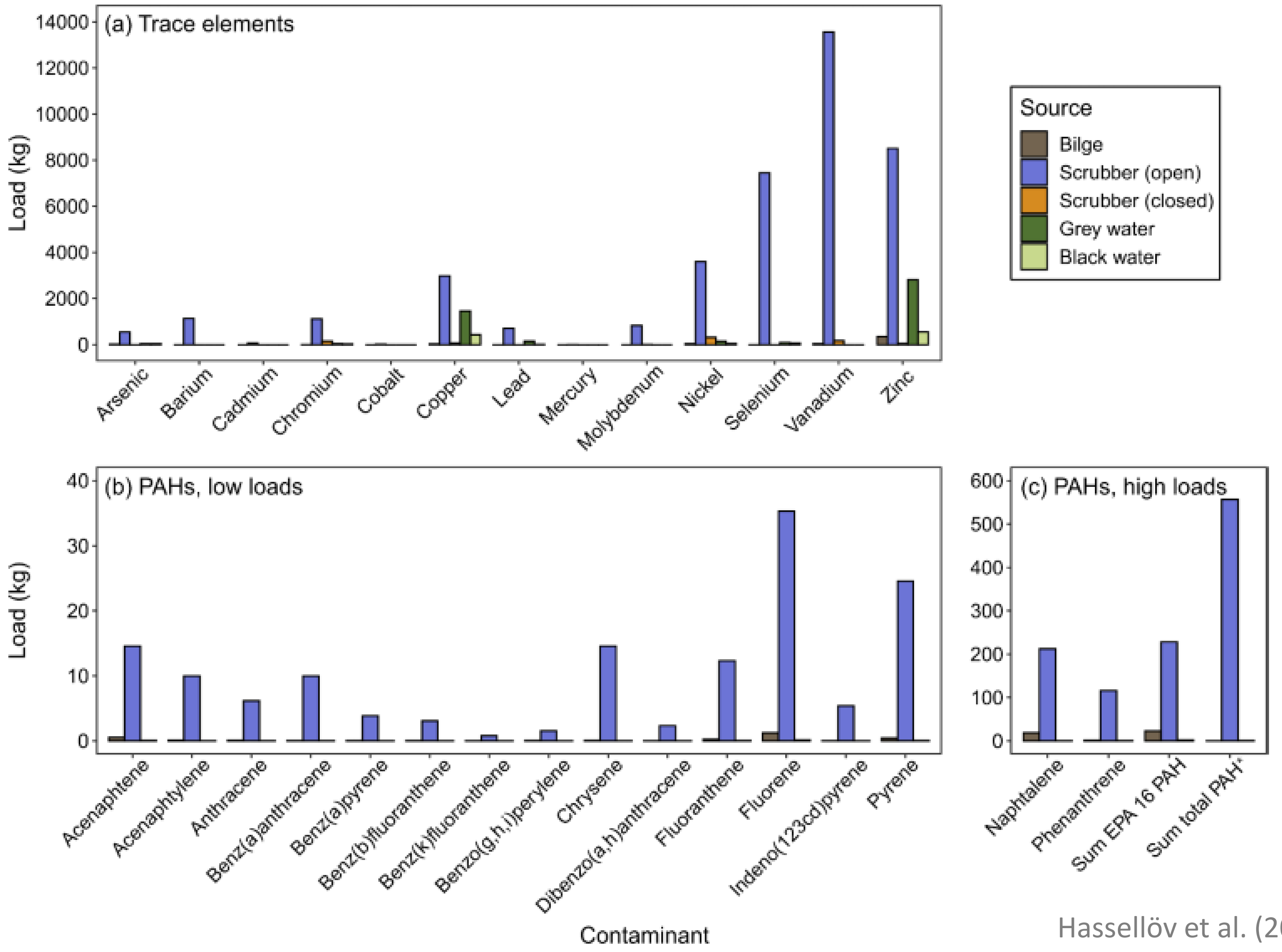
In **open-loop scrubbers**, acidic seawater is continuously discharged into the marine environment and in **closed-loop** ones, a smaller amount of water is released. Scrubbing SO_X with large quantities of seawater, with consequent release of wash water to the sea, may lead to substantial deterioration of marine water quality.

Within the scrubber, the exhaust gas passes through a fine spray of alkaline water which readily dissolves sulphur oxides (SO_X), nitrogen oxides (NO_X) and numerous other contaminants so that levels are sufficiently reduced in air emissions.



The resulting scrubber discharge water is a chemical cocktail of acidifying, eutrophying and contaminating substances and elements ⇒ toxic cocktail

load of contaminants from waste streams on board ships in Baltic Sea in 2018



Almost all 2000 ships were discharging bilge, black and grey water,
the load of metals and PAHs from the 99 ships equipped with scrubbers was higher by 10–100-fold, with the load from the open loop systems being dominant

Hassellöv et al. (2020) http://doi.org/10.17895/ices.pub.7487

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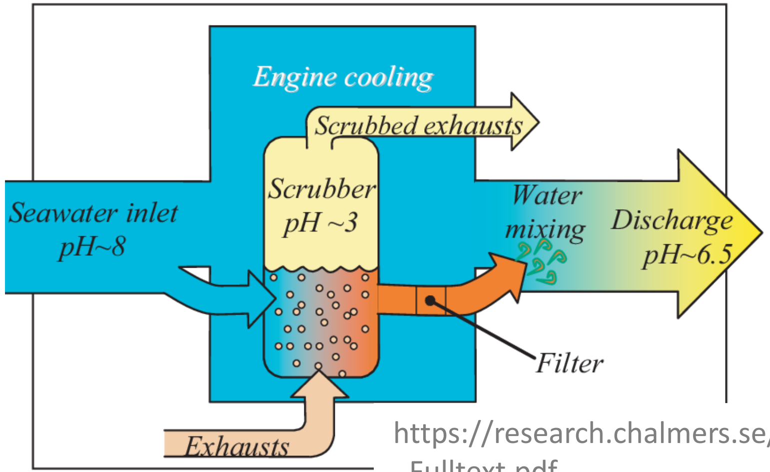
One Slide with Examples from the bibliography on the effects of scrubber discharge in organisms…….

pH, alkalinity, acidification

A pH decrease in the water used for SO_X-scrubbing is a result of the absorption of SO_2 and its transformation to sulphate species, which produces H^+ that increase acidity.
Studies have reported an acidic pH in OL discharge water samples (2.8–5.8), whereas the pH in CL discharge tends to be higher (4.9–7.6)

Alkalinity is a crucial parameter in the wash water to ensure efficient SO_X removal.
In OL systems, during the scrubbing process bicarbonate ions in seawater react with hydrogen ions neutralizing the acidity and raising the pH again; thus, enhancing further absorption of SO_2 by consuming the natural alkalinity of seawater.



https://research.chalmers.se/publication/106400/file/106400_Fulltext.pdf

alkalinity measurements showed a significant drop of alkalinity in OL systems (inlet values in the range of 1.6–2.6 mmol L^{-1} and outlet values between 0.0 and 1.4 mmol L^{-1}).
in CL systems, alkaline substances are added to the fresh water to adjust the pH level. It has been reported *zero (0 mmol L^{-1}*) alkalinity in all discharge water samples from CL systems.

Schmolke et al. (2020) https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/texte_162-2020_environmental_protection_in_maritime_traffic_-_scrubber_wash_water_survey.pdf

One Slide with some bibliographical estimations on the effects of scrubber discharge in pH/acidification…….

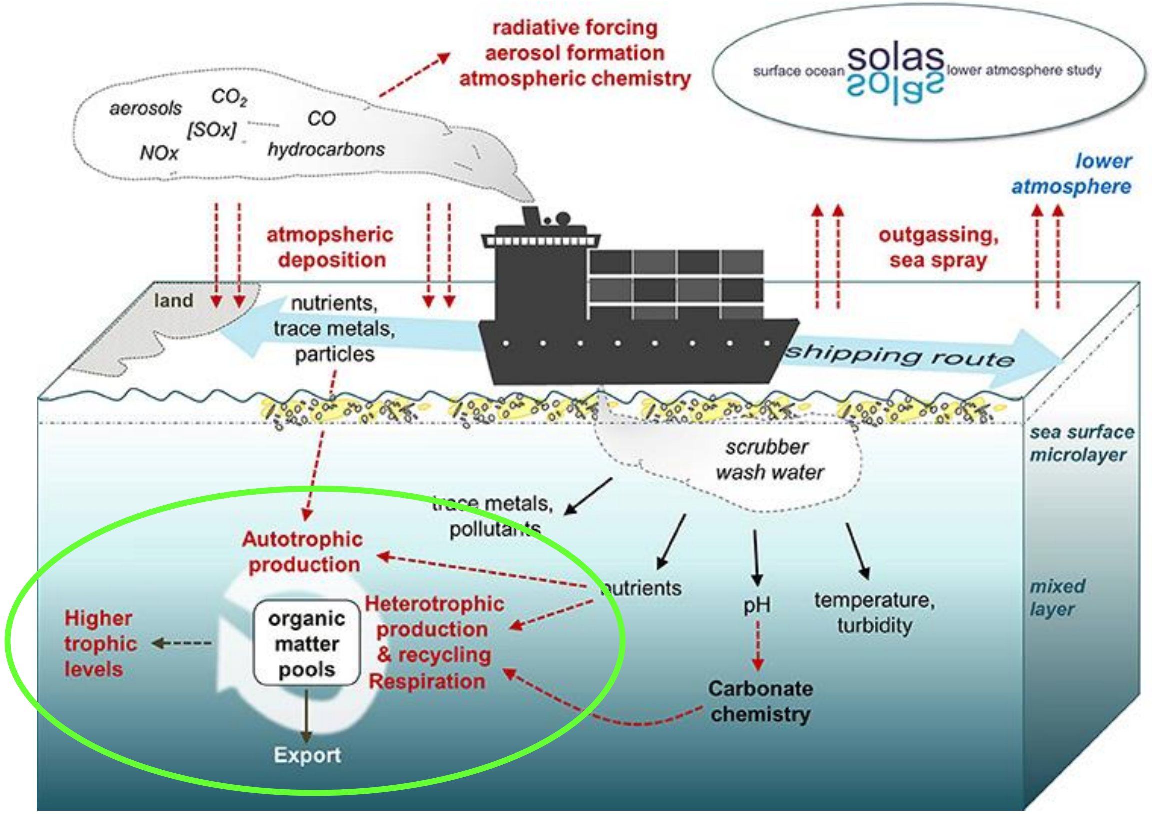
Nutrients, eutrophication

The shipping-related nutrient input is dominated (>99%) by atmospheric deposition of nitrogen originating from the formation of NO X during combustion of fuel.

In the EGCS Guidelines, there is a limit set for maximum allowed removal of 12% NOx in the exhausts by a scrubber, corresponding to a nitrate concentration of 60 mg L^{-1} (or 968 µmol L^{-1}) in the discharge water.

Therefore a more localized transfer of NOx from ship exhausts to the marine environment than the deposition of atmospheric emissions.

Shallow sea areas with limited water exchange and substantial nutrient input are prone to eutrophication phenomena accompanied by oxygen depletion of coastal waters, increased risk of harmful algal blooms, and reductions in biodiversity



Endres et al. (2018) https://doi.org/10.3389/fmars.2018.00139

Maybe one Slide with some bibliographical estimations on the effects of scrubber discharge nutrients loads…….

scope and approach of the EMERGE project.

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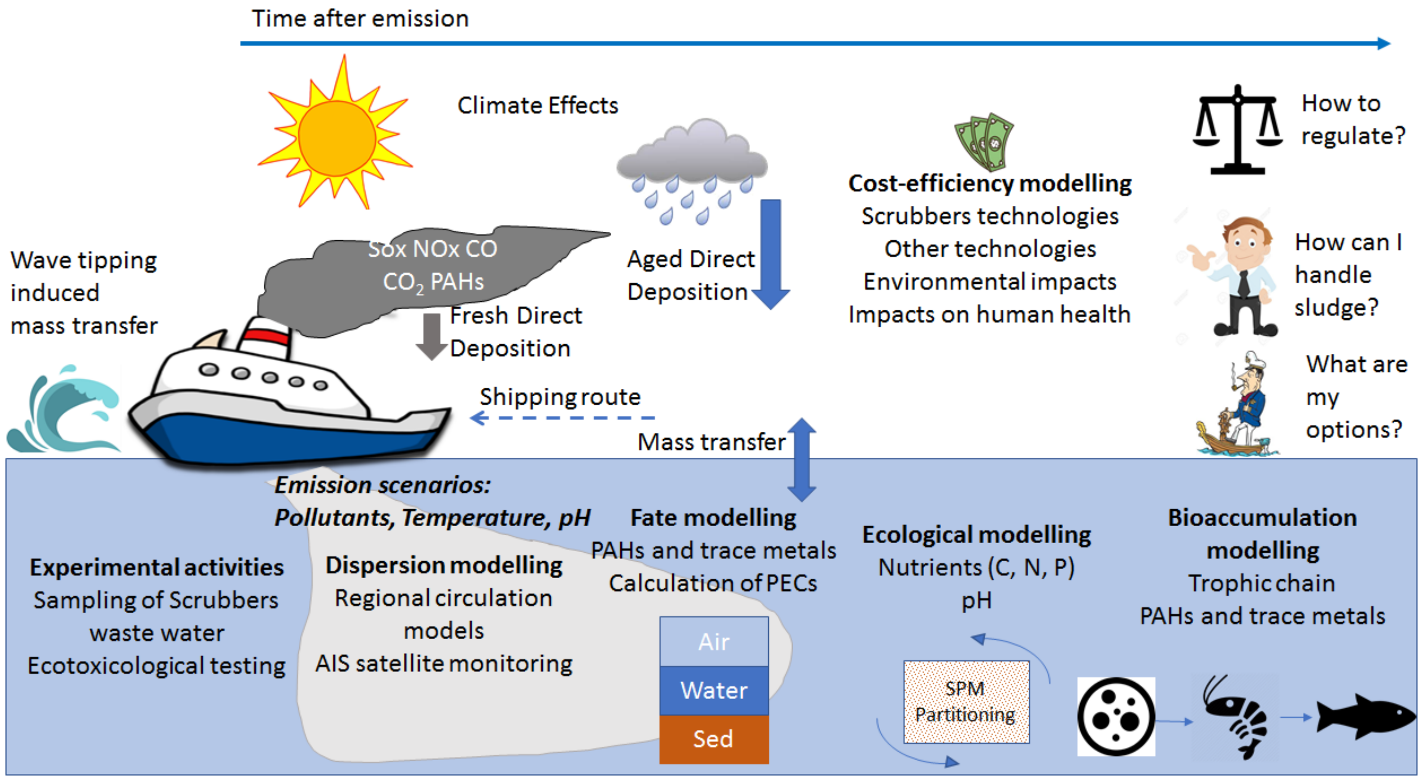
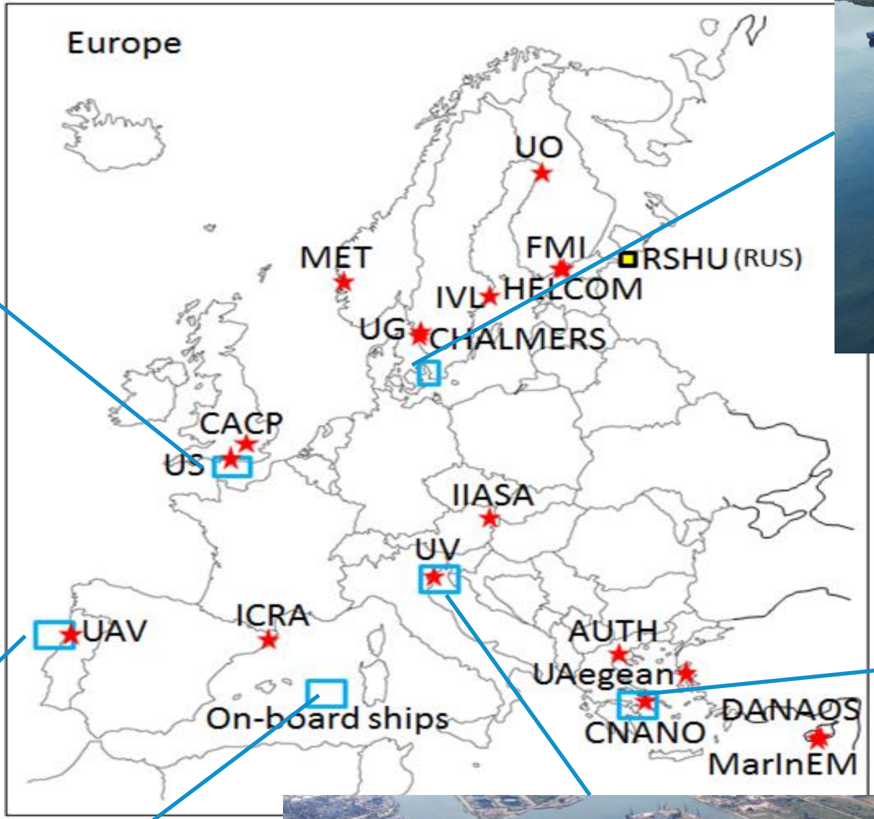


Notation: PEC = predicted environmental concentration, SPM = suspended particulate matter, PAH = polycyclic aromatic hydrocarbon.

WP2: Experiments to characterize waste streams to water from shipping, resulting from emission control technologies

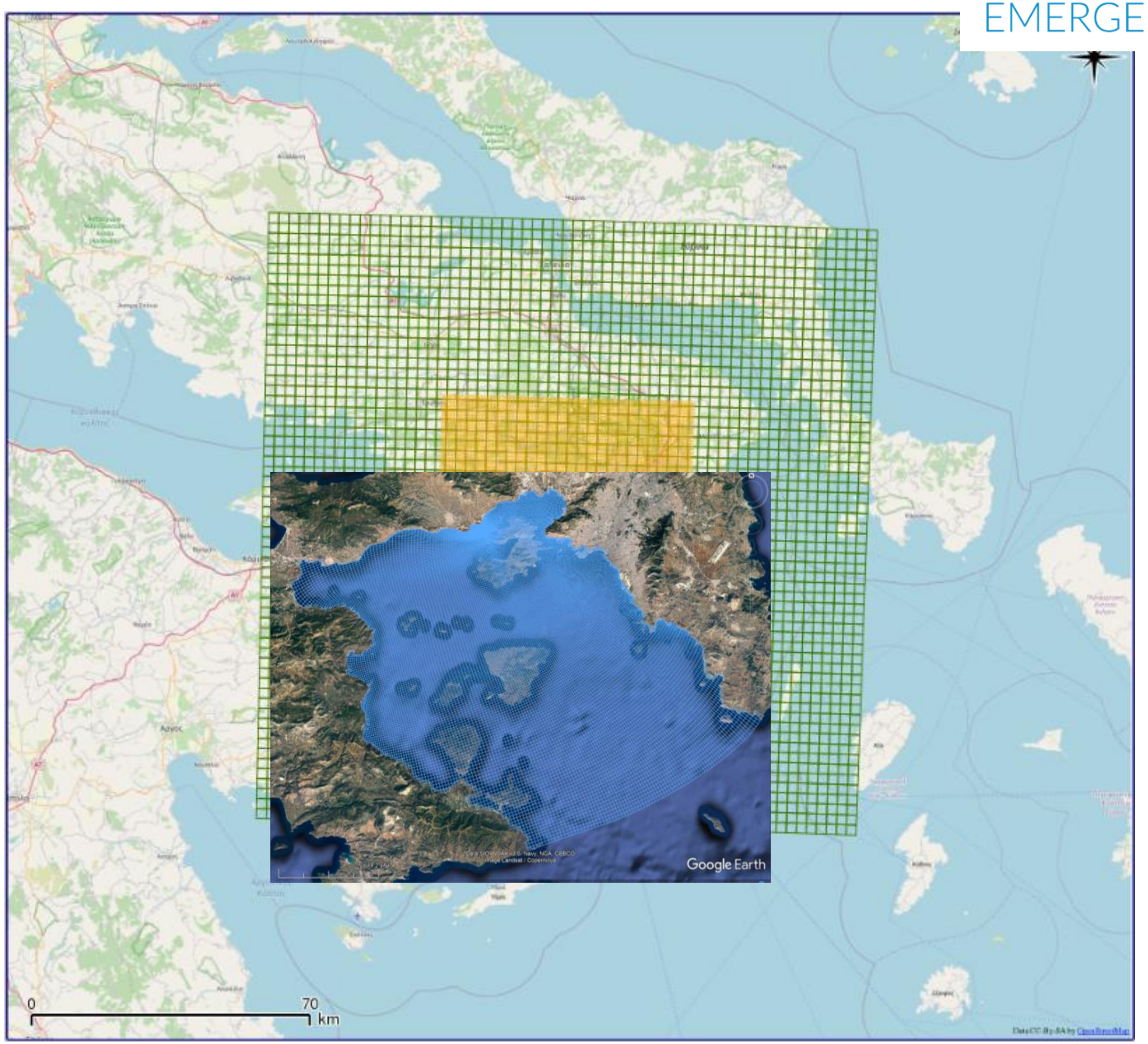
WP4: Modelling shipping emissions and their effects on marine ecosystems

Where are the case studies?



Case Study Piraeus, Saronikos Gulf

- Atmospheric and ocean circulation modeling: Well under way
- Meteo grid:
  - Outer grid: 120x120 km^2, res. 2 km
  - Inner grid: 50x50 km^2, res. 500 m
- Ocean grid:
  - Resolution 50-800 m
- Period of execution
  - 11/2009-11/2010 (validation)
  - 2018 (reference)
  - 2021, 2022 (experimental periods)
  - 2030, 2050 (only emission scenarios)



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Geochemical / pollution modeling

- Delft 3D-WAQ
- Set-up stage
- Simulating:
  - ✓ biochemical functioning,
  - ✓ Heavy metal fate
  - ✓ PAH species (organic micropollutants)

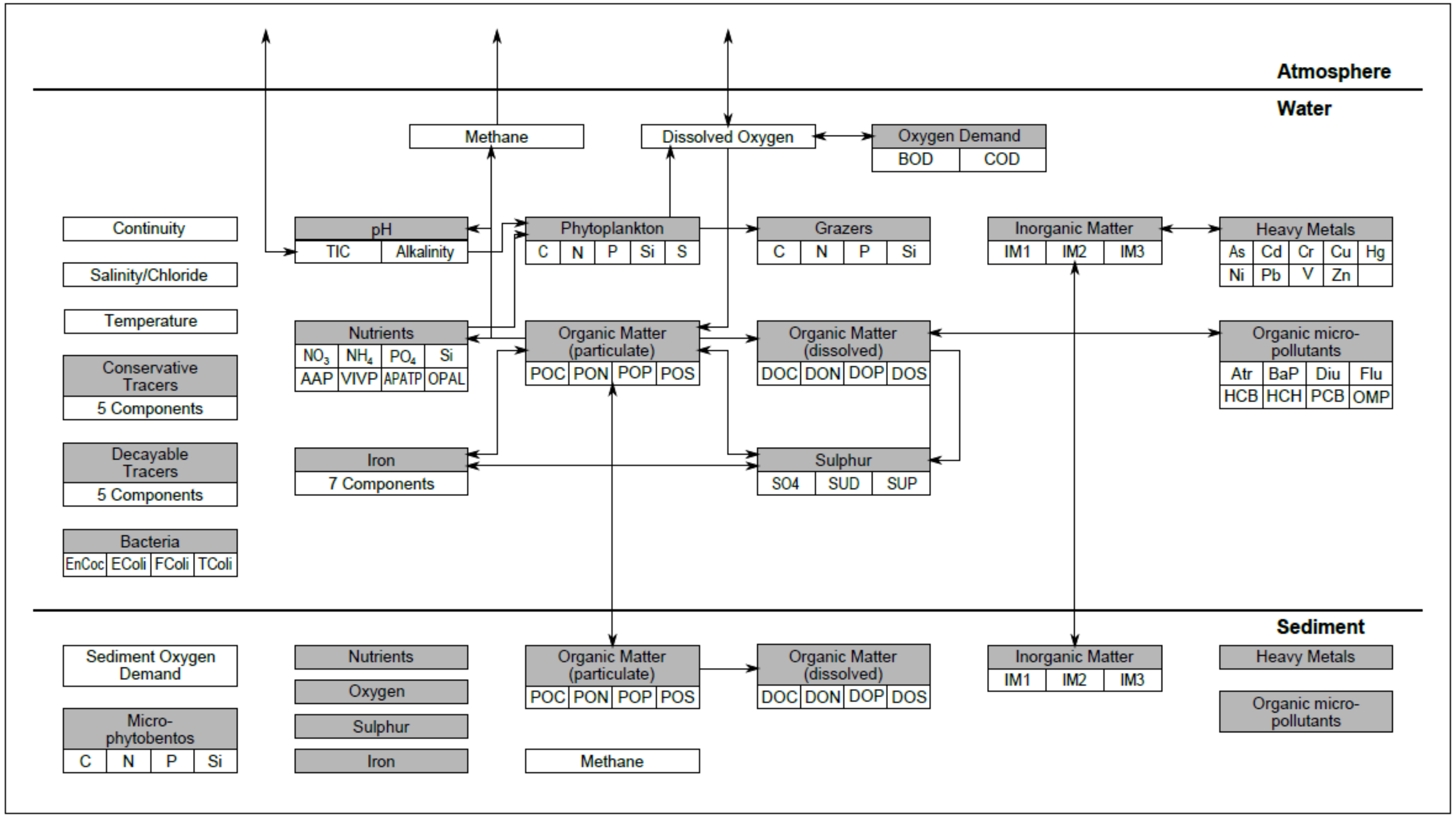
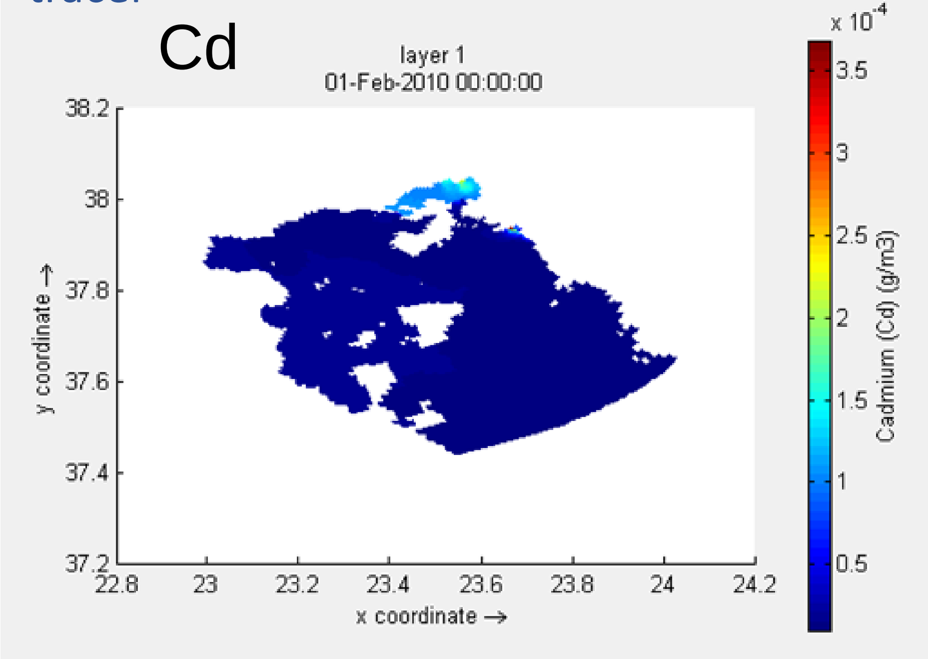


Figure 9.1: *General overview of substances included in D-Water Quality. Substances are*

Example: Cadmium, land source passive tracer



Seasonal sampling: (yellow pins)

Aim: investigate particulate inputs from scrubber water in relation to the shipping lanes of Piraeus port.

Additional samples were collected further away from the Saronikos Gulf and analysis is underway, aiming to compare those samples with the onboard campaign.

Sampling for Suspended Particulate Matter (CNANO, UGOT, Chalmers) Summer 2021 **(red squares)**

Data collection for model validation

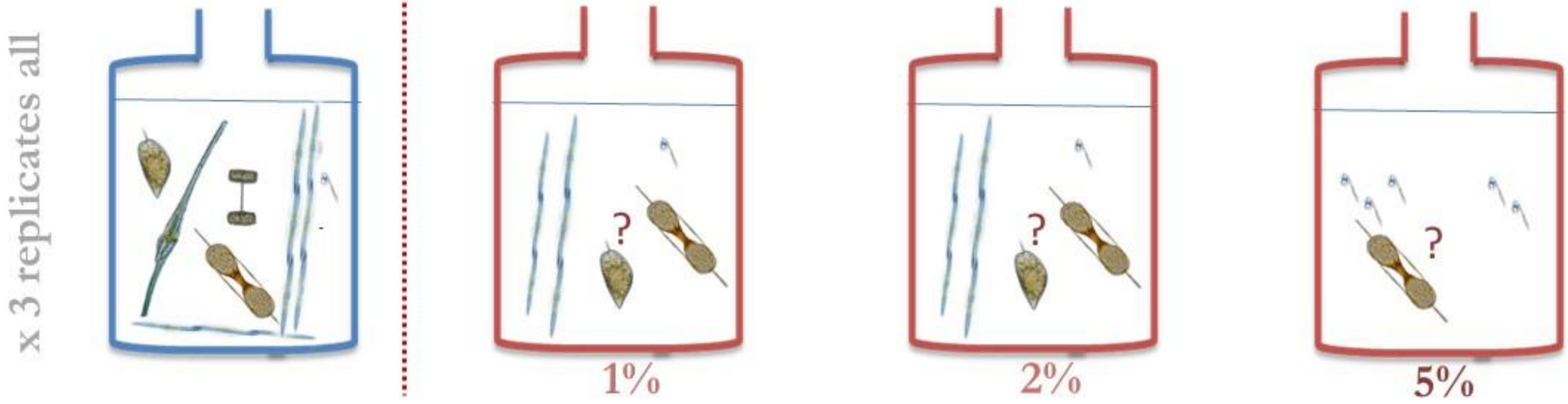
- Two field trips at mixed (Nov 2021) and stratified (May-June 2022) conditions, rosette and surface samples
- Sampling designed to record both large-scale gradients and single-ship impacts
- Large-Scale sampling network designed along and across navigational routes
- Air pollutants sampling:
  - O_3, SO_2, NOx, PM10, VOC, CO_2, Heavy Metals
- Water sampling:
  - Physical: T, S
  - Dissolved Oxygen, Chla, turb, Alkalinity/DIC, N-, P-, PAHs, Heavy Metals
- Experiments of scrubber water effects on natural phytoplankton community (AUTH)

AUTh/
LHTEE

Case-Study **Piraeus:** 2 sites (polluted & reference, 24 glass indoor mesocosms)

Control: Seawater

Treatments : Scrubber water %



Duration: 8 days, started 13 February 2022

Phytoplankton Sampling: every 24 hours for 96 hours and every second day until termination

And in the beginning, in the middle and in the end sampling for molecular analysis and nutrient analysis

Scrubber water origin : **Leo C, Station 11**

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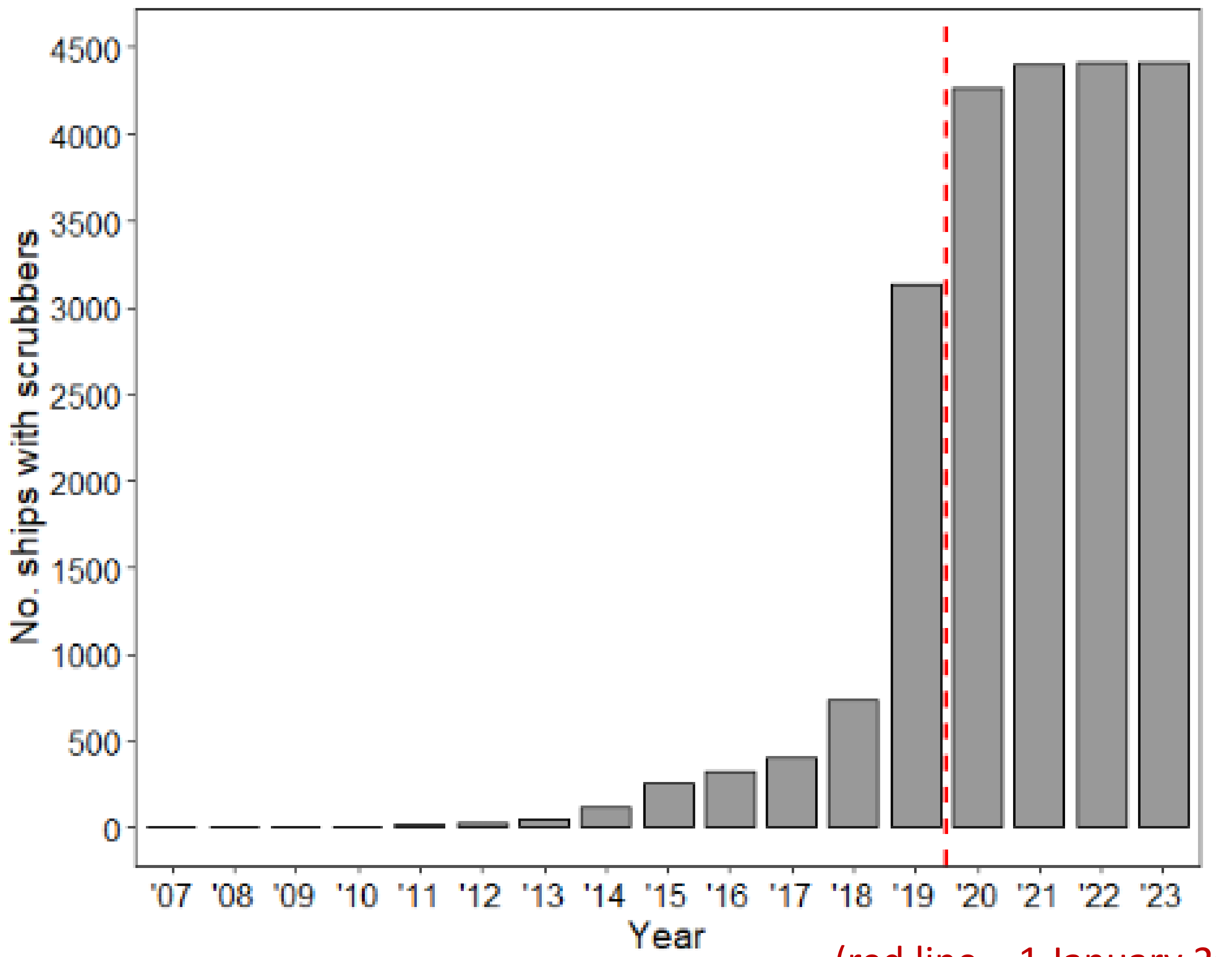
Thank you for your attention!

An increasing number of ships have opted to install scrubbers due to the price difference between heavy fuel oil and low sulphur fuels



(red line = 1 January 2020)

Hassellöv et al. (2020) http://doi.org/10.17895/ices.pub.7487