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Cosme, Nuno Miguel Dias; Dong, Yan; Hauschild, Michael Zwicky

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Large Marine Ecosystems and coastal water archetypes implemented in LCIA methods for marine eutrophication and metals ecotoxicity

Nuno Cosme (nmdc@dtu.dk), Yan Dong, Michael Z. Hauschild

TU260

Summary

- Modelling framework for **marine eutrophication (MEu)** and **marine metals ecotoxicity (MEc)**.
- Characterisation Factors (CFs) integrate **Fate, Exposure or Bioavailability**, and **Effect** Factors.
- 64 **Large Marine Ecosystems (LME)** – spatial units of coastal areas for spatial differentiation.
- Residence Time (RT)** for nitrogen and metals is required for the parameterisation of fate models.
- RT expresses the flushing of the system and the **losses** of nitrogen/metals by advection.
- RT data was found in **literature** or obtained from **4 archetypes** defined by hydrodynamics.

Conclusions!

- The **LME classification system** was chosen for its data availability, modelling feasibility, and adequacy of size and number of spatial units.
- Archetypical RT data** was a useful solution for the parameterisation needs of the fate models.
- The **spatial differentiation** of the resulting CFs was found essential to increase the discriminatory power of the models.

Background

Marine Eutrophication (MEu)

- Ecosystem response to excessive input of nitrogen (N) with increase of primary production in the photic zone of coastal waters [1].
- Heterotrophic bacteria respire the accumulated organic matter consuming dissolved oxygen.
- Excessive depletion of oxygen may lead to hypoxic stress of benthic organisms and loss of biodiversity.

Marine metals Ecotoxicity (MEc)

- Response of ecosystems to excessive level of metals in the integrated environment [2].
- Organisms become exposed to excessive metals concentration in marine water.
- Exposure may lead to uptake of metals and toxicity effect by e.g. decreasing or blocking the uptake of essential elements by binding with the transporters.

Life Cycle Impact Assessment (LCIA)

- Characterisation modelling of environmental mechanisms.
- Characterisation Factors (CFs) are used in LCIA to convert emissions into impacts.

Methodology

1 LCIA indicators

- The **MEu** indicator expresses the eutrophying impact of nitrogen (N).
- MEc** the toxic impact of metals emissions to the marine environment.

Characterisation Factor for Marine Eutrophication:

- Fate of N (FF), habitat Exposure Factor (XF), and Factor for the Effects on biota (EF).

$$CF_{[PAF \cdot m^3 \cdot d \cdot kgN^{-1}]} = FF_{[d]} * XF_{[kgO_2 \cdot kgN^{-1}]} * EF_{[PAF \cdot m^3 \cdot kgO_2^{-1}]}$$

Characterisation Factor for Marine metals Ecotoxicity:

- Fate of metals (FF), Bioavailability Factor of metals (BF), and Effect Factor on biota (EF)

$$CF_{[PAF \cdot m^3 \cdot d \cdot kgMetal^{-1}]} = FF_{[d]} * BF_{[-]} * EF_{[PAF \cdot m^3 \cdot kgMetal^{-1}]}$$

2 Models parameterisation

- Residence Time (RT) is applied in the Fate terms of both models:

Fate modelling in Marine Eutrophication:

$$FF_{LME} = \frac{\int_{exp}}{\lambda_{LME}} \quad f_{exp} [-] \text{ is the fraction of the emitted N that reaches coastal marine waters (exported)}$$

$\lambda_{LME} [d^{-1}]$ is the N-loss rate coefficient in each LME

- The N-losses (λ) can be caused by denitrification, advection and sedimentation:

$$\lambda_j = \lambda_{denitrification} + \lambda_{advection} + \lambda_{sedimentation}$$

- The N-loss by advection is estimated with the residence time (τ) on each LME:

$$\lambda_{advection} = \frac{1}{\tau_{LME}}$$

Fate modelling in Marine metals Ecotoxicity:

- Multi-media fate model embedded in USEtox[®].
- Models losses by advection with RT, plus metals removal by sedimentation and diffusion to sediment.

3 Residence time and archetypes

- The 4 archetypes are defined by the exposure to currents and regional marine circulation, depth and profile of the continental shelf, and water stratification:

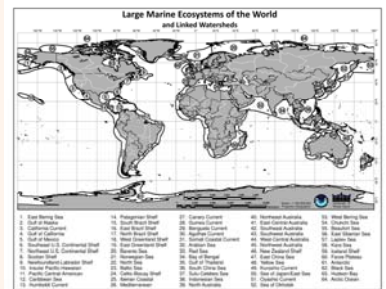
- Archetype 1 (high dynamics and exposure): RT=3 months**
- Archetype 2 (medium dynamics and exposure): RT=2 years**
- Archetype 3 (low dynamics): RT=25 years**
- Archetype 4 (very low dynamics, embayed, often stratified): RT=90 years**

- Assumption:** System dynamics determines the RT of both N and metals in the water column.

Results

Spatial units

- Biogeographical classification system.
- Large Marine Ecosystems (LME).**
- 64 spatial units** of coastal marine waters.
- Neritic zone from river basins and estuaries to the seaward boundaries of continental shelves.
- Distinct bathymetry, hydrography, productivity and trophically dependent populations [3].
- Mixing processes, light and nutrients.



The Large Marine Ecosystems (LME) spatial units

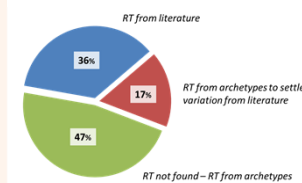
- Number and size of spatial units.**
- Integrated approach: productivity and oceanography, fish and fisheries, pollution and ecosystem health, socioeconomics, and governance [4].**

- Data availability for productivity, residence species, currents and circulation, and ease of adaptation to a climate zonation.**

- The LME classification system was adopted for both MEu and MEc, out of a comparison of 13 alternative zonation systems.**

Distribution of data sources for Residence Time (RT)

- RT from literature (36% of LMEs).
- 4 archetypes used for the remaining to:
- Provide RT data (47%),
- Settle differences in sources (17%).



References:

[1] Nixon SW (1995) Ophelia 41:199-219
[2] Truhaut R (1977) Ecotoxicol Environ Saf 1(2):151-173
[3] Sherman K & Duda AM (1999) Fisheries 24(12):15-26
[4] Spalding MD, Fox HE, Allen GR, et al. (2007) BioScience 57(7):573-583