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

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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:

$$FF_{LME} = \frac{f_{exp}}{\lambda_{LME}}$$

f_{exp} [-] is the fraction of the emitted N that reaches coastal marine waters (exported)
λ_{LME} [d^{-1}] is the N-loss rate coefficient in each LME

- The N-losses ($\boldsymbol{\lambda}$) can be caused by denitrification, advection and sedimentation:

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

- The N-loss by advection is estimated with the residence time ($\boldsymbol{\tau}$) on each LME:

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

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.

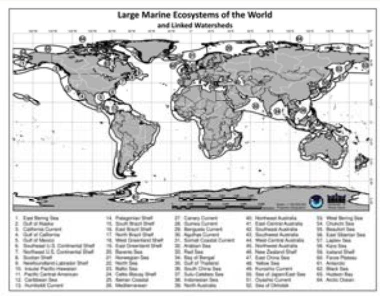
③ Residence time and archetypes

- 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.**

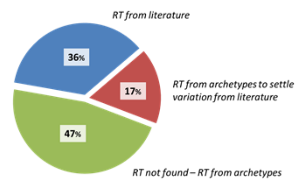
Residence Time (RT) dataset and sources: Literature and archetypes

LME #. name	RT [yr]	Source Archetype	Source Litterature
1. East Bering Sea	2.00	2	
2. Gulf of Alaska	0.25	1	
3. California Current	0.25	1	
4. Gulf of California	1.50		Lopez & Garcia (2003) J Geophys Res 108(C2):3048
5. Gulf of Mexico	90.00	4	** Turner & Rabalais (2009) 2009_Hypoxia_Forecast.pdf, www.gulfhypoxia.net USGS (2012) toxics.usgs.gov/hypoxia/mississippi/oct_jun/index.html Rivas et al. (2005) J Phys Oceanogr 35:1763–1781*
6. Southeast U.S. Continental Shelf	0.25	1	** Alegria et al. (2000) Mar Pollut Bull 40(12):1178-1185*
7. Northeast U.S. Continental Shelf	0.25	1	
8. Scotian Shelf	0.07	1	** Smith et al. (2003) J Geophys Res 108:8013*
9. Newfoundland-Labrador Shelf	0.25	1	
10. Insular Pacific-Hawaiian	0.25	1	
11. Pacific Central-American	0.25	1	
12. Caribbean Sea	0.21		Molinari et al. (1980) Proc 32 Ann Gulf & Caribbean Fisher Inst 106-113.
13. Humboldt Current	0.03		Hall et al. (1996) LOICZ/R&S/96-9
14. Patagonian Shelf	0.25	1	
15. South Brazil Shelf	0.25	1	
16. East Brazil Shelf	0.25	1	** Attisano et al. (2008) Braz J Oceanogr 56(3):189-200*
17. North Brazil Shelf	0.25	1	** Limeburner et al. (1995) J Geophys Res 100(C2):2401–2415*
18. West Greenland Shelf	0.25	1	
19. East Greenland Shelf	0.25	1	
20. Barents Sea	2.00	2	
21. Norwegian Sea	2.00	2	
22. North Sea	2.00		Blaas et al. (2001) Clim Res 18:47–54
23. Baltic Sea	25.00		Jansson B-O (1980) Ambio 9:128; Matthäus & Schinke (1999) Hydrobiologia 393:1–10
24. Celtic-Biscay Shelf	2.00	2	
25. Iberian Coastal	0.25	1	
26. Mediterranean	90.00	4	** Pinet (2008) Invitation to Oceanography. Jones & Barlett.*
27. Canary Current	0.25	1	
28. Guinea Current	3.10		Hall et al. (1996)
29. Benguela Current	0.25	1	
30. Agulhas Current	2.00	2	
31. Somali Coastal Current	0.25	1	** Naqvi (2012) www.unep.org/stap/Portals/61/stap/Naqvi.pdf*
32. Arabian Sea	6.50		Sarma (2002) Global Biogeochem Cycles 16(4):1082
33. Red Sea	40.00		Smeed (2010) krse.kaust.edu.sa; Grasshoff (1969) "Meteor" während Ind Ozean Exped 1964/65; Tomczak & Godfrey (2003) Regional Oceanography. Pergamon
34. Bay of Bengal	12.00		Sarma (2002) Global Biogeochem Cycles 16(4):1082
35. Gulf of Thailand	0.04		Dulaiova et al. (2006) Limnol Oceanogr 51(5):2232–2247
36. South China Sea	25.00	3	
37. Sulu-Celebes Sea	25.00	3	** Tessler (2012) PhD Thesis. Columbia Univ; Tessler et al. (2011) Geophys Res Lett 38:L18606*
38. Indonesian Sea	0.75		Ffield & Gordon (1992) J Phys Oceanogr 22:184–195
39. North Australia	0.25	1	
40. Northeast Australia	0.25	1	** Choukroun et al. (2010) J Geophys Res 115:C06013*
41. East-Central Australia	0.25	1	
42. Southeast Australia	0.25	1	
43. Southwest Australia	0.25	1	
44. West-Central Australia	0.25	1	
45. Northwest Australia	0.25	1	
46. New Zealand Shelf	0.25	1	
47. East China Sea	1.90		Tsunogai et al. (1997) J Oceanogr 53:9–17; Tomczak & Godfrey (2003) Regional Oceanography. Pergamon; Hall et al. (1996) LOICZ/R&S/96-9
48. Yellow Sea	2.00		Tsunogai et al. (1997) J Oceanogr 53:9–17; Tomczak & Godfrey (2003) Regional Oceanography. Pergamon
49. Kuroshio Current	2.30		Matsuno et al. (2009) Ocean Sci Discuss 6:741–764
50. Sea of Japan/East Sea	25.00	3	
51. Oyashio Current	0.25	1	
52. Sea of Okhotsk	2.00	2	Yamamoto et al. (2001) J Geophys Res 106(C12):31075–84
53. West Bering Sea	0.25	1	
54. Chukchi Sea	3.50		Schlosser et al. (1994) Deep Sea Res Part I 41(7): 1053–1068
55. Beaufort Sea	3.50		Schlosser et al. (1994) Deep Sea Res Part I 41(7): 1053–1068
56. East Siberian Sea	3.50		Schlosser et al. (1994) Deep Sea Res Part I 41(7): 1053–1068
57. Laptev Sea	3.50		Schlosser et al. (1994) Deep Sea Res Part I 41(7): 1053–1068
58. Kara Sea	3.50		Schlosser et al. (1994) Deep Sea Res Part I 41(7): 1053–1068
59. Iceland Shelf	0.25	1	
60. Faroe Plateau	0.25		Gaard (2000) ICES J Mar Sci 57: 1605–1671
61. Antarctic	6.00		Jacobs et al. (1985) In Jacobs, Antarctic Research Series 43:59–85
62. Black Sea	90.00	4	** Murray et al. (2007) In Yanko-Hombach et al., The Black Sea Flood Question. Springer*
63. Hudson Bay	6.60		Ingram & Prinsenberg (1998) In Robinson & Brink, The Sea, vol 11. John Wiley & Sons
64. Arctic Ocean	11.00		Jahn et al. (2010) J Geophys Res 115:C07015

** used to average or settle divergent data*

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%).



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