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

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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 (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.

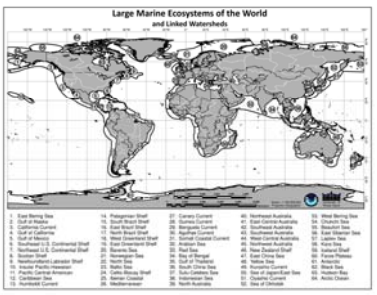
③ Residence time and archetypes

- 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.**

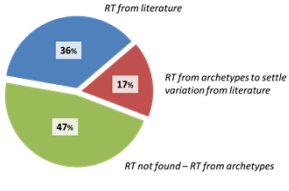
! **The LME classification system was adopted for both MEu and MEc, out of a comparison of 13 alternative zonation systems.**

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

LME #	LME_name	RT [yr]	Archetype	Source Literature
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. (2009) Mar Pollut Bull 60(12):2178-1185
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 306-113.
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. (2005) J Geophys Res 100(C2):2403–2415
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 & Bartlett.
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	* Nixpvi (2012) www.unep.org/ntap/Portals/60/ntap/Nixpvi.pdf
32	Arabian Sea	6.50		Sarma (2002) Global Biogeochem Cycles 16(4):1082
33	Red Sea	40.00		Smeed (2013) kmei.kaust.edu.sa; Grasshoff (1969) "Meteor" während Ind Ocean Exped 1964/65; Tomczak & Godfrey (2003) Regional Oceanography. Pergamon Sarma (2002) Global Biogeochem Cycles 16(4):1082
34	Bay of Bengal	12.00		Dulaiova et al. (2006) Limnol Oceanogr 51(5):2232–2247
35	Gulf of Thailand	0.04		
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		Fifield & Gordon (1992) J Phys Oceanogr 22:184–195
39	North Australia	0.25	1	
40	Northwest Australia	0.25	1	* Choukroun et al. (2010) J Geophys Res 115:C06013
41	East-Central Australia	0.25	1	
42	Southwest 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	0.60		Ingram & Prinsenberg (1998) In Robinson & Brink, The Sea, vol 11. John Wiley & Sons
64	Arctic Ocean	15.00		John et al. (2009) J Geophys Res 115:C05015
				* 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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