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Review on methodology for LCIA of marine eutrophication

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Introduction

As part of the ongoing EU FP7 project LC-Impact (www.lc-impact.eu) new life cycle impact assessment (LCIA) methods are going to be developed and tested on industry cases. Among the life cycle assessment (LCA) impact categories in focus are aquatic eutrophication. As related to especially the marine environment very few and restricted attempts have yet been done on trying to include eutrophication in LCA. The aim of LC-Impact is to develop both a global and a spatial (and temporal) differentiated model, as both central fate processes, sensitivities of receiving environments (e.g. differences in limiting nutrient and variations in this over the year) and the resulting damage can show important spatial variations. Both midpoint and endpoint (damage) modelling are included and the aim is to base the damage modelling on dose-response curves expressing the correlation between the (increase in) nutrient concentration and the potentially affected fraction of species in the marine ecosystem. This poster presents a review of the very limited existing attempts on how to include marine eutrophication in LCA and discuss alternative methodologies on how to model the environmental mechanism of this impact category.

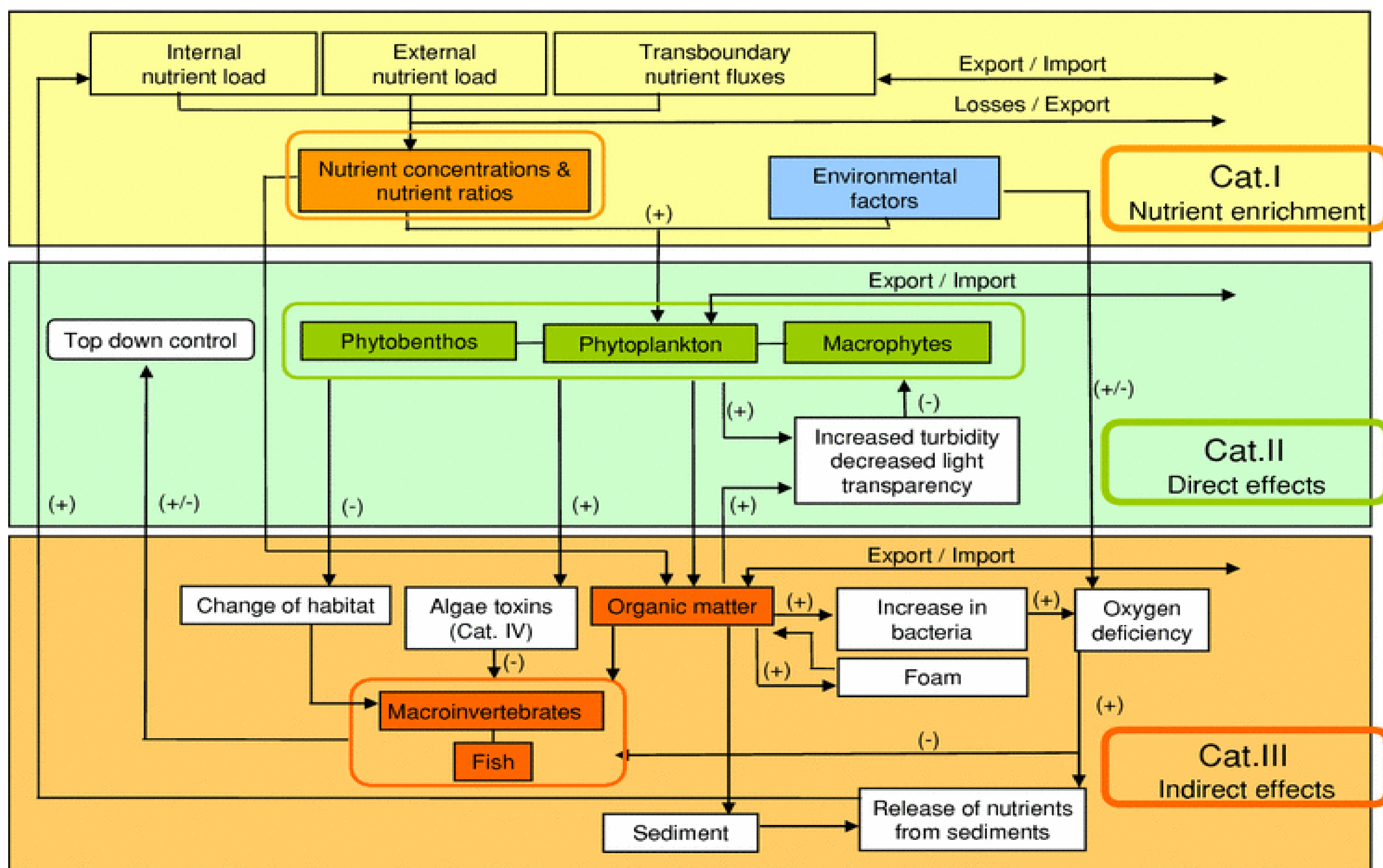


Figure 1. Interacting eutrophication processes divided into four categories (Cat.). (+): Enhancement of process. (-): Inhibition of process (Clausen et al. 2009)

What is marine eutrophication?

Eutrophication is quite complex as depicted in Figure 1. According to the review by Kitsiou and Karydis (2011) several definitions on eutrophication have been proposed during the last all most 100 years. Kitsiou and Karydis identify two main schools of thought, one focusing on the increase in organic matter and the other on the causal relationship between nutrients and plant biomass. As most reasonable definition "increased plant production stimulated by inorganic N and P compounds" is stated.

Existing LCIA methodology

No global LCIA model for marine eutrophication exists today. As part of ReCiPe 2008 (Struijs et al. 2009) a spatial differentiated European model has been developed but only midpoint characterization factors are available. As regards damage (endpoint) modeling only the Japanese LIME model (Itsubo et al. 2008) includes marine eutrophication and only regarding Japan.

Midpoint

In the recently published ReCiPe 2008 method the fate of N emissions to water (from waste water treatment plants, WWTPs), to soil (from agricultural land) and to air (from e.g. electricity production) are modeled by a combination of CARMEN and EUTREND (Struijs et al. 2009). The resulting fractions of the amount of total N emitted that will end up in coastal water are shown in Table 1. As evident from Table 1 the fate of N in the fresh water system (e.g. retention/denitrification) after emitted from WWTPs is not taken into account (100% reaching the coast). The ReCiPe midpoint indicator is based on the N-concentration increase in the receiving marine water compartment.

Emission type	Emission compartment	Average percentage reaching marine water (%)
Manure N	Soil and air	7,9
Fertilizer N	Soil and air	7,3
N from WWTPs	Fresh water	100
NH ₃	Air	11
NO ₂	Air	13

Table 1 Fractions of N emitted in Europe reaching coastal areas according to ReCiPe 2008 (based on data from Struijs et al.(2009))

Endpoint (damage)

Apparently only one damage model on marine eutrophication has been developed so far and is part of the LIME method (Itsubo et al. 2008). This model is based on 184 datasets from Japanese coastal marine areas on bottom water DO concentration and corresponding benthic species richness on which a statistical correlation (regression analysis) is performed:

$$SR = 0,3746 \cdot (DO)^2 + 2,0068 \cdot DO + 0,9831 \quad (R^2=0,4669)$$

where,

SR: Benthic species richness (dimensionless)

DO: Dissolved oxygen (mg/L)

It is assumed that no effects occur above DO = 6 mg/L. At this concentration the species richness (SR) becomes about 27. At DO = 1mg/L the corresponding SR is about 3 and at DO = 0mg/L the SR value is around 1. A damage model regarding the effect of changes in DO concentration on the biomass of benthos (biological production) and a model for damage on fishery production (assuming same rate of decrease as for benthos) has also been developed as part of LIME.

Alternative approaches

Besides the study used in the LIME method only a few studies have been made about the correlation between the nitrogen concentration (NO₃⁻, NH₄⁺/NH₃, tot-N) and the biodiversity in marine ecosystems. In the Gulf of Finland, part of the Baltic Sea, a paleolimnological based study on diatoms going back about 200 years has been made by Weckström et al. (2007). They found a significant correlation between increasing total dissolved nitrogen and decreasing species diversity (richness) among diatoms. At a threshold of 400-600 µg total dissolved nitrogen per liter the biodiversity starts decreasing. This decrease is due to disappearance of benthic species which is not fully counteracted by a simultaneous increase in the number of pelagic species (phytoplankton). The decrease is apparently due to the effect of eutrophication on the light climate, i.e. the inhibition of light penetration due to higher turbidity favorising planktonic taxa. A few other paleolimnological studies on fossil foraminiferans also indicate a correlation between N-concentration and species richness. Preliminary results of the literature review further shows that different parameters/indicators are correlated more or less with the degree of nutrient loading and hereby related to eutrophication. They include the degree of oxygen depletion, sediment TOC concentration, secchi depths (light climate) and algae biomass.

Conclusion

No global LCIA model for marine eutrophication exists today. As part of ReCiPe (Struijs et al. 2009) a spatial differentiated European model has been developed but only mid-point characterization factors are available. Regarding damage modeling only the Japanese LIME model (Itsubo et al. 2008) includes marine eutrophication and only regarding Japan. The goal of LC-Impact is to develop a spatially differentiated global eutrophication model with both mid-point and end-point indicators regarding emissions of total nitrogen.

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