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Revisiting the concept of Redfield ratios applied to plankton stoichiometry - Addressing model uncertainties with respect to the choice of C:N:P ratios for phytoplankton

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Ongoing Ocean Acidification (OA) and climate change related trends impact on physical (temperature), chemical (CO_2 buffer capacity) and biological (stoichiometric) properties of the marine environment. These threats affect the global ocean but they appear particularly pronounced in marginal and shelf seas.

Marine biogeochemical models are often used to investigate the impacts of climate change and changes in OA on the marine system as well as its exchange with the atmosphere. Different studies showed that both the structural composition of the models and the elemental ratios of particulate organic matter in the surface ocean affect the key processes controlling the ocean's efficiency storing atmospheric excess carbon. Recent studies focus on the variability of the elemental ratios of phytoplankton and found that the high plasticity of C:N:P ratios enables the storage of large amounts of carbon by incorporation into carbohydrates and lipids.

Our analysis focuses on the North Sea, a temperate European shelf sea, for the period 2000–2014. We performed an ensemble of model runs differing only in phytoplankton stoichiometry, representing combinations of C:P = [132.5, 106, 79.5] and N:P=[20, 16, 12] (i.e., Redfield ratio +/- 25%). We examine systematically the variations in annual averages of net primary production (NPP), net ecosystem production in the upper 30 m (NEP30), export production below 30 m depth (EXP30), and the air-sea flux of CO_2 (ASF).

Ensemble average fluxes (and standard deviations) resulted in NPP = 15.4 (2.8) mol C m^{-2} a^{-1}, NEP30 = 5.4 (1.1) mol C m^{-2} a^{-1}, EXP30 = 8.1 (1.1) mol C m^{-2} a^{-1} and ASF = 1.1 (0.5) mol C m^{-2} a^{-1}. All key parameters exhibit only minor variations along the axis of constant C:N, but correlate positively with increasing C:P and decreasing N:P ratios. Concerning regional differences, lowest variations in local fluxes due to different stoichiometric ratios can be found in the shallow southern and coastal North Sea. Highest variations appear in the central and northern North Sea with persistent seasonal stratification.

Our results show that a moderate variation of the elemental ratios of phytoplankton, which can be found in literature, yields relatively strong variations in marine biochemical key processes. This puts emphasis on the uncertainties in predicting ecosystem response to OA or climate change using ecosystem models.