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Dealing with several sources of uncertainty in modelling of community-level processes

Uncertainty is pervasive in ecological sciences and must be quantified properly for ecological assessment and management decisions at the scale of ecosystems. Nutrient fluxes are crucial to ocean productivity. Phytoplankton growth relies on the availability of essential nutrients, and cetacean communities could contribute significantly to the primary production dynamics by releasing nutrient-rich fecal matter in the photic zone. We used a bioenergetic model to estimate the amount of nutrients released by cetaceans, from large whales to small delphinids, in several large-scale areas around the globe. Model inputs included abundance data from broad-scale multispecies surveys, diet composition studies and analysis of nutrient concentrations in prey. The model also involved bioenergetic parameters such as body mass, metabolic cost factors, energy assimilation efficiency and elemental excretion rates, most of which were never actually measured on cetaceans. We faced several sources of uncertainty for all parameters of the model, from systematic error to natural variation or inherent (epistemic) randomness, sometimes combined. Using Monte Carlo simulations, we assumed a parametric distribution of the parameter to simulate data from statistical descriptors (mean, coefficient of variation, minimum and maximum). Parameters relevant to the composition of preys were associated to limited datasets, and we used bootstrapping, (i.e. sampling with replacement) to account for variability. We then conducted a sensitivity analysis to assess how the sources of uncertainty in the inputs affected the uncertainty in the output, and identify influential parameters using Sobol indices. Parameters resulting from bootstrapping could not be included in the sensitivity analysis, we were limited to more basic methods to assess the effect of the variability of these parameters on the output. The most influential parameter was the abundance of cetacean populations, the only parameter based on robust statistical survey methods (distance sampling), with inherent uncertainty due to sampling conditions, species and areas. Never measured parameters associated to flat distributions were only slightly influential. Our study illustrates how Monte-Carlo simulations combined with bootstrapping can be used to obtain intervals likely to contain true values of particular interest, considering several sources of uncertainty in parameters.