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Aquatic ecosystem modeling: use of screening sensitivity analysis methods to facilitate the calibration process

In ecological risk assessments, risks imputable to chemicals at the ecosystem level are usually estimated by extrapolation of single-species toxicity test results. But such approaches fail to account for the interactions that inevitably exist among the component species [1]. Alternately, modeling at the whole ecosystem level reveals to be a powerful tool by considering species interactions, and by predicting toxic effects on non-target species populations (indirect effects). The aims of our work are: (i) to develop a new mathematical model which comprehensively describes a whole aquatic ecosystem accounting for species interactions with a clear set of equations including both abiotic and biotic factors; (ii) to incorporate perturbation functions on chosen processes within the model in order to predict potential toxic effects at the ecosystem level and to identify functional groups at risk; (iii) to perform a sensitivity analysis, i.e., to screen parameters having the greatest influence on calculated target endpoints. An extensive literature review allowed us to conceptualize a whole non-contaminated aquatic ecosystem with a compartmental ecological model [2]. Compartments include primary producers (macrophytes and algae from phytoplankton and periphyton), primary consumers (juvenile fish and invertebrate grazers, shredders and collectors) and secondary consumers (invertebrate predators and fish). All compartments are related within a food web as well as to abiotic factors such as light, temperature and nutrients. Another literature review was carried on the most relevant perturbation functions mathematically describing how contaminants impact population dynamics, trophic relationships and ecosystem functionning. These two literature reviews also provided for all parameters point estimates as well as some probability distributions. With 13 state variables (compartments), 23 interactions between species and 63 ecological processes, the number of model parameters was necessarily very high (260), making the calibration process very complex and computationally expensive. To overcome these difficulties, sensitivity analyses (SA) seem particularly relevant [3]. They allow identifying non-influential parameters that can then be fixed at a nominal value without significantly reducing the variance of outputs. Among SA methods, screening ones could be preferred as they are computationally cheap, compared to global ones. But screening SA methods are only qualitative and do not compute an output variance decomposition based on the input uncertainties. Hence, we first tested and compared two screening SA methods: the Morris [4] method and the method developed by Klepper [4]. In order to check the reliability of their results, we second carried out a comparison with results given by two global quantitative SA methods: the Standardized Regression Coefficients (SRC) method and method FAST. As the last two methods are computationally expensive, we were only able to perform all our comparisons on a reduced version of our model, the "Periphyton-Grazers" submodel, which contained a very small number of parameters (20). The Morris method was finally the best compromise to screen non-influential parameters. Applied to the whole aquatic model, such a method allows one to reduce the complexity of the underlying equations (some parameters are fixed, the others have to be calibrated), and consequently to facilitate the calibration process from experimental data.

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