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Editorial

Ecological Models for Predicting Contaminant Effects

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Anthropogenic and natural environmental contaminants are a common problem and a source of concern to ecosystem health. Industrial toxins are one of the leading causes of pollution worldwide. Industrial toxins may arise as a result of air emissions, water releases, water seepage, air deposition or disposal and leaching of solid waste. The combination of natural and anthropogenic sources of toxins present challenges with respect to the protection of local ecological environments. Predicting the impacts of environmental contaminants on ecosystems become an important part of the decision-making process for managing environment problems. To protect ecological environments and species, it is necessary to assess the risk to organisms exposed to toxins, and find relevant factors that determine the persistence and extirpation of populations. Over the past several decades, ecotoxicological models have been widely applied to predict contaminant effects.

Why Ecological Models?

The effect of environmental contaminants can in principle be exerted on all levels of the biological hierarchy, from cells to organs to organism to populations to entire ecosystems. Ecotoxicological models mainly focus on risk at the level of individual organisms (e.g., survival, growth, and fecundity), without corresponding information on how population, group species, or whole ecosystems may respond to chemical stressors. However, in most cases the assessment and protection goal are populations rather than individuals. On the population level, effects of contaminants depend not only on exposure and toxicity, but also on factors such as life history characteristics, population structure, timing of application, presence of refuges in time and space, and landscape structure [1]. Consequently, approaches that allow extrapolations, for example, from laboratory to field, species to species, or region to region are needed. Ecological models are mathematical equations that can be used to describe or predict ecological processes or endpoints such as population abundance, community species richness, productivity, or distributions or organisms. Ecological models typically deal with endpoints at the population, ecosystem, or landscape level, which are directly relevant to natural resource managers. Thus, ecological models are able to bridge the gap between individual level laboratory experiments and field situations, or extrapolate the results of field studies to the ecosystem level. Moreover, in many of the ecological models, population are exposed to additional factors including, for example, spatial heterogeneity, temperature and other climatic variations, light, and predation. Many ecologists recognize the value of population and ecosystem modeling as applied to risk assessments for toxic chemical. Ignoring population- or higher-level effects and focusing only on individual-level endpoints can lead to inaccurate risk estimates and possible errors in environmental management decisions.

Model Categories

Ecological models used in environmental toxicology include population models, ecosystem models and landscape models [1,2]. These models are widely used to predict endpoints beyond the individual-organism level. Population models typically deal with the dynamics of the abundance or distribution of single species, sometimes with explicit descriptions of endpoints in time and space. Population models are the simplest possible representations of the biological processes that govern population growth, and they ignore much of the complexity of the ecological world. Usually, single-species models are identified as population models, and multispecies models are defined as ecosystem or landscape models, regardless of whether they include abiotic factors. An ecosystem model comprises a food-web model and descriptions of biological and ecological processes (e.g., photosynthesis, predation, and competition) as well as abiotic processes (e.g., nutrient and energy flows, temperature variations, drought stress). Many ecosystem models simulate the cycling of materials and the flow of energy through food webs and the abiotic environment, including soils, sediment, and the atmosphere. Landscape models describe large-scale spatial heterogeneity in the distribution and abundance of organisms, habitat features, and some ecosystem models, and include description of complex biotic and abiotic processes. Landscape models are therefore generally realistic for risk assessment. By incorporating spatial variability, they can become more realistic then ecosystem models for large-scale risk assessments. The landscape models can also characterize spatial-temporal variations in chemical exposures and corresponding ecological risks.

Model Selection

The selection of specific models for addressing an ecological risk issue depends on the habitat, endpoints, and chemical of interests, the balance between model complexity and the availability of data, the degree of site specificity of available models, and the risk issue [2]. The model must be appropriate for the context, whether for the evaluation of risks associated with new chemical and their uses, of ecological impacts and risks associated with past uses, or of clean up and restoration issues. The selection of the best model to apply for a specific problem depends on the risk hypotheses and the management objectives, which ultimately drive the receptors, endpoints, and levels of protection. The final selection of ecological models then depends on the desired level of detail in the analysis and the ease with which such models can interface with the chemical. Moreover, the complexity of the model selected to address a particular issue depends on the level of realism and precision desired as well as the quality and quantity of data.

Challenges

All ecological models have a number of input parameters that have to be determined previous to model application. In a risk assessment context, model parameterization may be the most important parts of the modeling process. Confidence in model results only can be achieved if the quality of the model for the specific risk assessment can be demonstrated. Although ecological models may be especially powerful for exploring the impacts of environmental contaminants on populations and ecosystems, highly complex models are hard to parameterize, many models include several parameter values that are based on expert knowledge rather than rigorous data analysis, which is common practice and acceptable in scientific publications, but may cause too high uncertainty for risk assessments, unless it can be demonstrated that the estimates are conservative [3]. Therefore, constraints on the immediate use of ecological models to address chemical risk issues most likely arise from lack of toxicity data, not from lack of appropriate models. Additionally, a high complexity level decreases the computational tractability of models [3], thus making them harder to understand and the results harder to communicate.

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