UNIVERSITEIT GENT

Limitations of current probabilistic ecological risk characterisation methods

Applied Mathematics Biometrics and Process Control

Frederik Verdonck[1], T. Aldenberg[2], J. Jaworska[3], O. Thas[1] and P.A. Vanrolleghem[1]

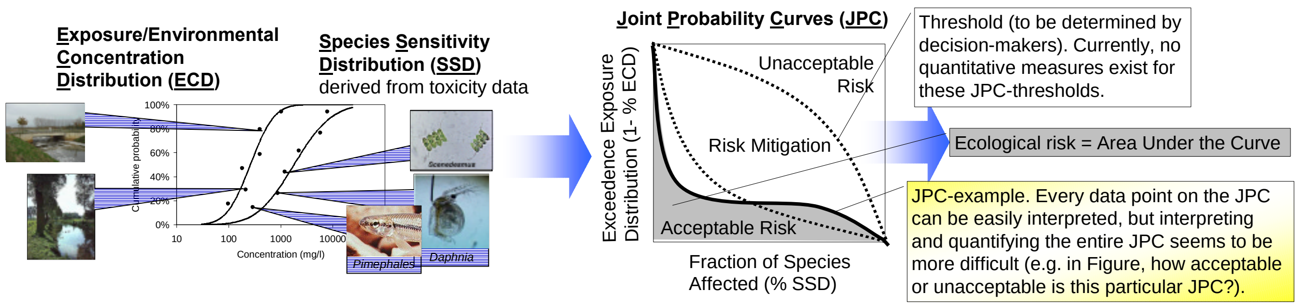
[1]Ghent University - BIOMATH, Department of Applied Mathematics, Biometrics and Process Control, Coupure Links 653, B-9000 Gent, BELGIUM

[2]RIVM, Antonie van Leeuwenhoeklaan 9, P.O. Box 1, NL-3720 BA Bilthoven, THE NETHERLANDS

[3]Procter & Gamble, ETC, Temselaan 100, B-1853 Strombeek-Bever, BELGIUM

Introduction

Probabilistic ecological risk assessment (PERA) estimates the likelihood and the extent of adverse effects of chemicals occurring in ecological systems. It is based on the comparison of:

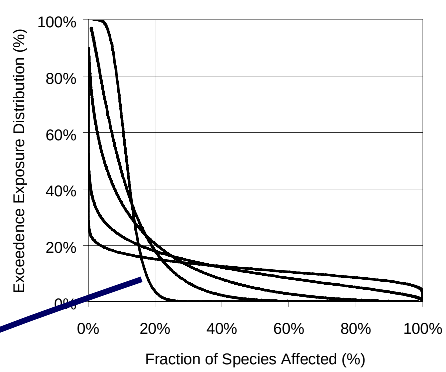


Goal: Show that current risk characterisation methods have the drawbacks that important ecological information and interpretation is lost when only the integrative risk is calculated.

Practical simulation study

Five JPCs are visualised and they **all result in the same risk** (12%). It is not straightforward to put thresholds of acceptability.

Depending on the interpretation of the ECD (and SSD), one JPC may be concluded to be better or worse than the other (even though they have the same risk). This difference in interpretation of the risk is also reflected in the shape of the JPC.



Better alternative if ECD represents temporal variability (at one monitoring location) (because most of the species will die all the time, but a certain percentage might survive, in the other cases: all species will die most of the time)

Worse alternative if ECD represents spatial variability (because most of species will die at all locations, in the other cases: all species will die in most of the cases, in some few remaining sites, no species are likely to die, resulting in larger biodiversity).

Theoretical considerations

RISK = the probability of some randomly selected log EC (Environmental Concentration) exceeding some randomly selected log SS (Species Sensitivity).

$$\textbf{Risk} = P(EC > SS) = P\left(\frac{EC}{SS} > 1\right)$$

$$= P\left(\log_{10}\left(\frac{EC}{SS}\right) > 0\right) = P(\log_{10}(EC) - \log_{10}(SS) > 0)$$

The difference of two independent normal distributions is also a normal distribution with parameters

$$\mu_{\log(EC/SS)} = \mu_{\log(EC)\text{-}\log(SS)} = \mu_{\log(EC)} - \mu_{\log(SS)}$$

$$\sigma_{\log(EC/SS)} = \sigma_{\log(EC)\text{-}\log(SS)} = \sqrt{\sigma^2_{\log(EC)} + \sigma^2_{\log(SS)}}$$

The risk of is given by the probability of $\log_{10}(EC/SS)$ to exceed 0. This is equal to one minus the cumulative probability of the above log(RQ) distribution for $\log_{10}(EC/SS) = 0$ or $EC/SS = 1$

The formula for the ecological risk in case of two normal distributions is

$$P(\log EC - \log SS > 0) = 1 - \Phi_{\mu_{\log EC} - \mu_{\log SS}, \sqrt{\sigma^2_{\log EC} + \sigma^2_{\log SS}}}(0)$$

$$= \Phi_{0,1}\left(\frac{\mu_{\log EC} - \mu_{\log SS}}{\sqrt{\sigma^2_{\log EC} + \sigma^2_{\log SS}}}\right)$$

When the difference between the mean EC and the mean SS is fixed, then interchanging the two standard deviations doesn't change the risk.

Or, in other words, a small variation in ECD and a large one in SSD yield the same risk as the reverse variations with the same means. However, ecological interpretations can be different.

TAKE HOME MESSAGE

- The current risk measures, such as the Area Under The Curve of a Joint Probability Curve (JPC), contain insufficient information to account for different ecological circumstances (i.e. different interpretations of the Environmental Concentration Distribution (ECD) and Species Sensitivity Distribution (SSD)) and to assess potential adverse effects towards ecological communities.
- Therefore, we recommend to always interpret the risk ecologically. This will force the environmental community to compare SSDs with adequate ECDs.
- Further research is needed on additional measures characterising the shape of the JPC and that has an ecological interpretation to help to quantify and manage the risk.

Acknowledgement

This research has been funded by scholarships from the Flemish Institute for the Improvement of Scientific-Technological Research in the Industry (IWT).

BIOMATH

frederik.verdonck@biomath.rug.ac.be - http://biomath.rug.ac.be