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EDITORIAL

Increased Use of Bayesian Network Models Will Improve Ecological Risk Assessments

Despite the continued advances in scientific knowledge of complex and dynamic ecosystems, it is still all too common to see ecological risk assessments (ERAs) that are based (at best) on very flimsy evidence, or in many cases on 'expert opinion' with neither the 'experts' named nor the basis for their opinions documented. Such findings are even more frustrating when vague conclusions are provided, such as the risk to an ecological asset is 'low'.

Given that the tools available for risk assessments have advanced substantially since the early 1990s, why is it that so many ERA applications still rely on archaic and sloppy methods? Is it because ecosystems are just too dynamic and complex that they defy a detailed scientific understanding? Or is it that we have difficulty in identifying and quantifying the important cause-effect relationships such that we cannot adequately quantify the way in which human changes will affect the ecosystem? Or is it simply easier (and cheaper) to use so-called 'expert opinion' rather than go to the effort of undertaking a risk assessment using quantitative evidence? And is all this a reflection of the lack of incentive offered by regulatory authorities to address this situation?

Clearly, there is no one answer to these questions. However, the effort and resources put into undertaking a risk assessment often don't depend on the ecological significance of a system being investigated, but on the social and political implications of the outcome.

This article argues that to improve the rigour of ERAs, all risk assessments should strive to be as quantitative as possible and seek to address limitations in the ecological knowledge available. One approach we have found particularly useful in fulfilling this need is the use of Bayesian network models.

To overcome the limitations of qualitative ERAs, empirical, statistical, and process-based models are quite commonly used. But, despite being more quantitative, they come with another set of major difficulties. For example, many such models are unable to examine impacts of multiple stressors in complex environments, and uncertainties are often unquantified, despite this being fundamental in assessing risk. To overcome such limitations, recently there has been a steady increase in the use of Bayesian network (BN) models within a risk assessment framework. Indeed, we have found that they offer a pragmatic and scientific approach to modelling complex ecological systems, particularly where high uncertainties exist (Pollino and Hart 2008).

BNs are graphical models. And unlike many other ecological modelling approaches, they are able to combine qualitative knowledge and quantitative data

to model a system using probabilities, which is consistent with the concept of risk being probabilistic (Pollino *et al.* 2007). Probabilities describe the strength of causal relationships between variables. Additionally, BNs are particularly effective in documenting and communicating causal assumptions not easily expressed using mathematical notation. Important knowledge gaps and priority risks can be identified using sensitivity analysis.

Being Bayesian, BNs use a *prior probability* to represent the likelihood that an input parameter will be in a particular state, a *conditional probability* calculates the likelihood of the state of a variable given the states of input variables affecting it, and the *posterior probability* is the likelihood that a variable will be in a particular state, given the input variables, the conditional probabilities, and the rules governing how the probabilities combine. A particular advantage of BNs is that algorithms in most software applications implement a form of Bayes' Theorem, which can be used to update, evaluate and revise the model when new data becomes available.

BNs are frequently used for integrating information across disciplines and are ideal for use within participatory settings, an approach widely advocated in modern risk assessments. BNs can be easily organised as a nested hierarchical framework to break down complex ecosystem processes into simpler levels of ecological organisation, which can then be more easily reassembled using a bottom up process. They also overcome the limitation of many existing risk analysis techniques as they can be used to analyse multivariate and complex relationships among variables. Indeed, we have used BNs to explore and display the strength of relationships between key variables, while quantifying uncertainties (Pollino *et al.* 2007).

A particularly attractive feature of a BN model is that it can be used either directly or interactively in risk management settings. Being causal, they can be used to assess the effectiveness of interventions (*e.g.*, management actions) and system changes (*e.g.*, those predicted for climate change) to the ecological endpoints. A BN that incorporates data (modelled and observed) across disciplines can be used to rapidly assess scenarios in a dynamic environment.

Regardless of these advantages, it is important to acknowledge that a number of limitations still exist with many of the commercially available software packages (*e.g.*, Netica, Hugin, Analytica). Such limitations include: difficulty with representing feedback loops and in handling time; the need to discretise continuous probability distributions, which can result in the state variable being over-simplified; and difficulties associated with parameterization of complex models.

However, despite these problems, we believe that on balance, a greater use of BN models can assist in promoting a more 'holistic' approach to risk assessment, where multiple stressors and their interactions across an ecosystem are better taken into account. BNs have proved powerful as an integration tool that prevents 'reinventing the wheel' and encourages the use of the best available science in decision-making. As BN models are iterative, they readily fit into an adaptive management framework, a widely promoted but rarely implemented practice.

We believe that Bayesian methods can be used to address many of the problems associated with risk assessments as they are routinely applied. BNs can still be used where limited resources exist, and most importantly, a greater use of BN models will provide a means for better analysing risk management decisions, particularly where

uncertainty is a key component of the analysis and where decisions are liable to be open to scrutiny.

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REFERENCES

Pollino CA and Hart BT. 2008. Developing Bayesian network models within a risk assessment framework. Proceedings of the International Environmental Modelling and Simulation Society, Barcelona, Spain

Pollino CA, Woodberry O, Nicholson AE, *et al.* 2007. Parameterisation of a Bayesian network for use in ecological risk management. Environ Modelling & Software 22:1140–52