



Bayesian modelling for risk-based environmental water allocation

Raising National Water Standards Program

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This fact sheet summarises a Waterlines report commissioned as part of a series of papers on issues relating to Australian aquatic ecosystems.

These Waterlines reports will contribute to improved environmental water management by stimulating discussion, synthesising current thinking, identifying knowledge gaps, and highlighting areas that warrant further investigation.

Current challenges in assessing environmental water allocations

Much effort has been put into reinstating environmental flow regimes to rehabilitate Australia's degraded rivers and wetlands. However, many of the approaches for determining environmental flow allocations lack data, transparency, and knowledge about important aspects of the ecosystem.

Given that our knowledge of these systems is often poor and such systems are inherently variable, environmental flow assessment and management methods should allow for an adaptive management approach, where environmental flow allocations are refined over time as new information is gained. Bayesian modelling has the potential to meet this need.



Photo courtesy of Carmel Pollino

Bayesian modelling and natural resources management

Bayesian modelling approaches are increasingly being used as decision support tools in many areas of natural resources management to:

- determine the risks to aquatic ecosystems from multiple threats, such as flow changes, excessive nutrients degradation of instream habitat, riparian vegetation and pest fauna and flora

- integrate qualitative and quantitative information across a range of disciplines and stakeholders
- prioritise management activities, within an adaptive management context, to achieve the best outcomes when resources are limited
- link investments to resource condition outcomes
- inform risk management strategies through scenario analysis.

Two Bayesian modelling approaches that have potential for assisting decision-making in relation to environmental water requirements for river and wetland ecosystems are Bayesian statistical modelling and Bayesian network (BN) modelling.

Bayesian statistical modelling

Bayesian statistical approaches have been successfully used to model and analyse a number of environmental problems over the past ten years. They have an advantage over standard statistical approaches in that they are inherently flexible and the models are built to match the requirements of the data.

Bayesian statistical approaches are mostly likely to find use in the analysis of monitoring data from environmental flow programs. They are suited to fitting models and testing hypothesis concerning the effects of flow on ecosystem endpoints. Bayesian hierarchical modelling is a form of Bayesian statistical modelling that is particularly suited to ecological investigations as Bayesian hierarchical models can reduce the impacts of low sample sizes that often characterise ecological data sets.

Bayesian network modelling

Bayesian network (BN) models are increasingly being used in natural resources management and more recently, specifically for determining environmental flow allocations. In Australia, BN-based environmental flow studies have been undertaken or are underway in Queensland, New South Wales and Victoria.

BN models can be used to integrate flow information and other biophysical factors with measurable ecological outcomes. They can also be used to integrate social and economic drivers and management outcomes. However, they have several limitations, most importantly feedback loops and time-dependency.

BN models have a number of properties that make them particularly useful for ecological data analysis. In particular, they:

- show cause–effect relationships directly through a simple causal graphical structure, but they are also easily constructed, extended and modified
- have a natural way to handle missing data
- incorporate uncertainty in relationships
- are an accessible and intuitive modelling approach
- can show good predictive accuracy even with rather small sample sizes
- allow the conditional probabilities between variables to be constructed using either observed data, other models, or expert knowledge
- are modular, where models are composed of a set of interacting components
- can be easily used to aid management decision-making.

Role in assessing environmental water allocation

Bayesian modelling approaches could play an important role in environmental flow assessment and decision-making in Australia. In particular, they can improve current methods by:

- providing simple, visual representation of conceptual models and causal links that are easily communicated
- documenting the rationale behind environmental flow recommendations for future use
- validating the science underpinning individual flow recommendations, and testing the effectiveness of an implemented flow regime
- facilitating adaptive management by using the data collected in monitoring programs to iteratively improve the models used to estimate the flow requirements for different parts of the ecosystem
- predicting and demonstrating the risks associated with not providing the agreed environmental flow regime
- providing potential for stakeholders representing different interests to use a single tool in scenario analysis and decision-making.

Research directions and training needs

Bayesian approaches in environmental flow assessment, management and monitoring of outcomes will be improved by:

- developing case studies to provide real examples of Bayesian approaches in environmental water allocation processes

- developing and testing of consistent methodologies and guidelines for best practice
- developing a series of new integrated BN models and applying them to decision-making related to maintaining the ecological health of rivers and wetlands
- applying Bayesian hierarchical models to extract more information from monitoring data about the relationships between flow and environmental endpoints
- developing a generic Bayesian network for undertaking risk-based assessments of species resilience and vulnerability under climate change
- developing user-friendly, fully documented BN software
- increasing the capacity of modellers, environmental managers and policy-makers through a nationally co-ordinated training program
- establishing a central knowledge manager for Bayesian approaches in environmental water allocation processes in Australia.



Photo courtesy of Wendy Merritt

For more information:

National Water Commission
95 Northbourne Avenue
CANBERRA ACT 2600
Phone: 02 6102 6023

www.nwc.gov.au

The National Water Commission is responsible for driving progress towards the sustainable management and use of Australia's water resources under our blueprint for water reform - the National Water Initiative.

The full report can be found under publications at:
www.nwc.gov.au