NPSI Project UMO45

Delivering Sustainability through Risk Management

Final Summary Report

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The National Program for Sustainable Irrigation focuses research on the development and adoption of sustainable irrigation practices in Australian agriculture.

The Program has 14 funding partners: Land & Water Australia (managing partner); Sunwater, Queensland; Horticulture Australia Limited; Goulburn-Murray Water, Victoria; Cotton Research and Development Corporation; Harvey Water, Western Australia; Lower Murray Water Authority, Victoria; Wimmera Mallee Water, Victoria; Ord Irrigation Cooperative, Western Australia; Australian Government Department of Agriculture, Fisheries and Forestry; Department of Natural Resources, Mines and Water, Queensland; Department of Primary Industries and Resources South Australia; Department of Environment Water and Catchment, Western Australia; and Department of Agriculture and Food, Western Australia.

Executive summary

This report summarise the outputs and key lessons from National Program for Sustainable Irrigation (NPSI) funded project UMO45 ***Delivering Sustainability through Risk Management***, which was designed to achieve an improved level of adoption of ecological risk assessment and risk management methods in the Australian irrigation industry and in regulatory agencies. Adoption of risk-based approaches is considered to be vital if the industry is to achieve its goal of long-term sustainability.

The project consisted of two activities:

- a series of regional awareness workshops aimed at explaining what is involved in ecological risk assessment and how risk management approaches might assist the irrigation industry in achieving the ultimate aim of long-term sustainability, and
- two case study partnership projects involving the irrigation industry and appropriate State irrigation regulators, aimed at developing capacity within the individual organizations to use risk-based procedures.

Full details of each of the project components are contained in four separate reports that are available on www.sci.monash.edu.au/wsc.

Regional workshops

Eight full-day regional awareness workshops were undertaken in Brisbane, Townsville, Deniliquin, Mildura, Shepparton, Bunbury and Darwin, with at total of around 200 irrigation stakeholders attending. Web-based training materials were developed for these workshops.

Feedback from workshop participants regarding their perceptions of ecological risk assessment (ERA) was formally captured through evaluation questionnaires. Findings indicated that the majority of participants saw ERA as a sound approach to sustainability of irrigation activities. There was strong support for including stakeholders in the process and strong agreement that ERA helps identify management priorities. However, there was some evidence that a substantial proportion of respondents viewed the time, data or expertise demands of ERA as onerous.

Workshop feedback also showed that the arguments for adopting (or delaying adoption) ecological risk assessment approaches are complex and multi-faceted. These complexities have only been made apparent through dialogue with irrigation stakeholders involved in the regional awareness workshops and the two case studies undertaken as part of this project. It is clear that progressing the adoption of risk-based approaches will involve a more targeted approach involving cultural change, technology transfer and a requirement to address broader institutional issues. These are fully discussed in the report.

Case studies

Two case study partnerships were established – one focused on the Murray Irrigation region in southern NSW and the other on the Lower Loddon River in northern Victoria. Both partnerships involved an initial problem formulation stage where the environmental values (or assets) to be managed were identified by the stakeholders, and a second stage to develop quantitative Bayesian Decision Network (BDN) models to assess the risks to the key environmental values identified during the problem formulation stage.

In the ***Murray irrigation region risk assessment***, the stakeholders identified two environmental assets as being at high risk from irrigation - the Black Box (*Eucalyptus largiflorens*) wetlands and native fish communities (river health).

A *Black Box BDN model* was developed to predict the condition and success of regeneration of these trees. These endpoints were assumed to be influenced by five major factors: land management, surface water condition, soil condition, groundwater condition and wetting regime, with altered wetting regime and grazing the most important factors.

Two management scenarios were tested to demonstrate application of the model in predicting the condition and regeneration of Black Box trees. The BDN model prediction supports the management actions (fencing and wetland watering) being promoted by Murray Irrigation Ltd, and promoted and implemented by Murray Wetland Working Group, on private lands as having a positive impact on the health of Black Box trees. A watering frequency of between one in five years and one in ten years was found to be optimal in maintaining tree health and promoting regeneration.

A preliminary *Fish Habitat BDN model* was also developed. This was based on the conceptual model developed in collaboration with key stakeholders, a previous Fish BDN developed for the Goulburn River in Victoria, and information adapted from the fish habitat condition model within the Murray Flow Assessment Tool (MFAT). At this early stage of development, the BDN model appears to have a number of advantages compared with the MFAT fish module.

Stakeholders involved in the ***Lower Loddon catchment risk assessment*** identified two ecological values potentially at risk - the ecological health of the Lower Loddon River and farmland ecological values.

The first BDN model focused on predicting *macroinvetebrate community diversity* as an indicator of the ecological health of the Lower Loddon River. Habitat variables (e.g. in-stream habitat, food availability, in-stream vegetation, turbidity, sedimentation, riparian vegetation, woody debris and roots, bank erosion) were found to have the greatest influence on the predicted macroinvertebrate community diversity. This model predicted that reducing stock access to the riparian zone and the channel will significantly improve the macroinvertebrate community diversity.

The second BDN model predicts the abundance of a common bird species - the *grey-crowned babbler* – as the measure of farmland ecological value. The structure of the BDN model was based on a conceptual map constructed by stakeholders in an initial workshop, and included three main factors that influenced population abundance of the grey-crowned babbler – habitat availability, food availability and biological factors (competition, reproduction & predation). The model predicted that reducing stock access to remnant forest area significantly improve the probability of medium to high abundance of grey-crowned babbler populations.

The results from both models support the current Loddon catchment management plan, where major on-ground fencing works are being implemented to reduce stock access to the riparian zone and the river.

Lessons from the case studies

A number of important lessons were learned from conducting the case studies. These are fully discussed in the report and are summarised below.

Stakeholder involvement

We have advocated the importance of engaging stakeholders in the early stages of the ERA process (particularly the problem formulation, hazard analysis and risk analysis steps). The advantages of early involvement of stakeholders include: (a) stakeholders bring realism to the process - they have views about the ecological values to be protected, the objectives of the risk assessment, and the way the system works (i.e. the important cause and effect relationships); (b) stakeholder engagement opens a dialogue, improves communication and enables an exchange of information between groups; and (c) if stakeholders are not involved in the ERA process, problems can emerge at a later stage because opposing views have not been considered in the process.

However, the involvement of stakeholders also has a number of challenges, including: (a) stakeholders can be defined very narrowly as only these having some expertise regarding the issues, which can lead to an unbalanced or biased ERA; (b) stakeholders often have very different opinions of cause and effect relationships, which can lead to divisions that require considerable skill to resolve; (c) it is extremely difficult to achieve a successful project without an enthusiastic *commitment* from the stakeholders. We found that the level of 'buy-in' was related to attitude to the risk assessment process and the level of interaction between the risk assessment team and the stakeholders.

Adoption of risk-based approaches

It is clear that legislative incentives are a key driver for adoption of risk-based approaches by the irrigation (and other) industry in Australia. Currently, such incentives exist in Victoria, but not in NSW. It is difficult to see irrigation companies going beyond a minimal Environmental Management System (EMS) to adopt risk-based approaches without some further legislative incentives.

Role of the ERA process in achieving sustainability

The generally accepted interpretation of sustainability is a balance between development and environment protection, where the current use of environmental resources should not deplete their availability for future generations. The current ERA process takes a reductionist view of environmental protection, focussing on a subset of environmental factors, which are not necessarily linked to ensuring the sustainability of a system. The application of ERA in the two case studies was useful in identifying the main cause-effect relationships influencing the selected ecological endpoints and in showing how various management actions could reduce the risks to the selected ecological values. But these ERAs did not incorporate economic factors, and therefore represent only one part in an overall assessment of sustainability of the systems studied.

The current application of the ERA process focuses on the risks to the ecological assets of the system that the community values. If the process was broadened to include economic (and perhaps political) aspects, and therefore became a more triple bottom line approach, it would be an improved decision support tool for assessing sustainability.

Role of BDN models in decision making

BDN modelling approaches are increasingly being used in the management of natural resources that are characterised by large uncertainties. These uncertainties can arise as a result of incomplete datasets for model parameterisation, subjective assessments from expert indecision or lack of consensus amongst experts. The representation of uncertainty in risk assessment is critical in assisting system managers faced with making decisions to minimise or eliminate risks.

The use of BDN models has a number of advantages including: the requirement that a conceptual model be developed showing explicitly the main cause-effect relationships (pathways), means that the structural relationships are transparent; they are a very useful mechanism for capturing stakeholder inputs; they can use both data and expert opinion; the probability that endpoints are being or will be met is the output of the model; they explicitly incorporate and report uncertainties; they can be updated when new data or new knowledge becomes available; and they are useful for prioritisation of risks.

However, the use of BDNs is not without some difficulties, including: establish of the network structure can be time consuming; the quality of the BDN is often very dependent upon the availability (and skill level) of the experts (stakeholders), the assembly of available data can be extremely time consuming; they generally represent dynamic systems poorly; complex BDNs are difficult to parameterise; it can be difficult for managers to interpret the (probabilistic) outputs from these model and to make decisions when confronted with results where the (often large) uncertainties are made explicit,

Currently, there is a lack of capacity in Australia to develop relevant BDN models, but we are confident that this will be addressed in the very near future.

Recommendations

1: that NPSI seek to update the current Irrigation ERA framework to reflect the recent learning regarding stakeholder involvement, and the development and use of Bayesian Decision Network models.

2: that NPSI continue to encourage and promote a range of activities aimed at achieving increased adoption of risk-based approaches in the Australian irrigation industry and associated stakeholders, including 2-3 day workshops, university-based coursework and higher degree training.

3: that NPSI continue to encourage and promote additional case study partnerships between the irrigation industry and associated regulatory agencies to further develop risk-based approaches to environmental management.

Contents

1. Introduction

The National Program for Sustainable Irrigation (NPSI) is committed to improving the sustainability of current and proposed irrigation schemes throughout Australia.

In support of this aim, NPSI has funded project UMO45 ***Delivering Sustainability through Risk Management***, which is designed to raise awareness of the Australian irrigation industry in adopting risk-based environmental management approaches. The adoption of risk-based approaches is considered to be vital if the industry is to achieve its goal of long-term sustainability. This project is a logical extension of an earlier NPSI project (UMO40) that developed an Ecological Risk Assessment framework for the Australian irrigation industry (Hart et al., 2005).

This *Delivering Sustainability through Risk Management* project aims to achieve an improved level of adoption of risk assessment and risk management approaches in environmental management and a greater capacity to use such approaches, within both the irrigation industry and regulatory authorities in Australia.

The overall aim of this project was to achieve an improved level of adoption of ecological risk assessment and risk management methods in the Australian irrigation industry and in regulatory agencies. Specifically, the project sought to:

- undertake a series of ***regional awareness workshops*** aimed at explaining the aims of this project, how risk management might be adopted by the irrigation industry and how this will assist in them achieving the ultimate aim of long-term sustainability of the industry,
- establish ***case study partnerships*** involving the irrigation industry and appropriate State irrigation regulators, and work with these partnerships to develop capacity within the individual organizations to use risk assessment and risk management procedures to improve the ecological sustainability of the irrigation region,
- work with ***selected Sustainable Irrigation projects*** (and their key stakeholders) in trailing different methods and approaches for adopting risk management procedures into their projects. This objective was largely undertaken as part of both the regional awareness workshops and the case studies

This report summarises the outputs and key lessons from this project. Full details of each of the project components are contained in separate reports (Walshe et al., 2005; Pollino et al., 2005; Westbury et al., 2005; Chan & Hart, 2005) available on www.sci.monash.edu.au/wsc.

2. Risk-based management

As noted above, an earlier NPSI project (UMO40) developed an *Ecological Risk Assessment (ERA) Framework* for the Australian irrigation industry (Hart et al., 2005). The objective of the ERA framework was to provide a robust process to incorporate a transparent, scientific, precautionary and ecologically sustainable approach to the irrigation industry's management of environmental risks.

The ERA framework is catchment-based and focuses on the difficult task of assessing the risks to multiple ecological assets from multiple hazards. This catchment-wide approach is needed since irrigation enterprises are normally only one of a number of human activities in the catchment (e.g. dryland grazing, forestry, urban, tourism) that can contribute to the degradation of environmental assets.

The framework synthesises the methods required to achieve successful adaptive management of natural resources. Although the focus of this framework is primarily on the risks to aquatic ecosystems (e.g. rivers, wetlands, estuaries), it is robust enough to be used to assess the ecological risks to other natural resource assets in catchments (e.g. land, soil, vegetation, biodiversity).

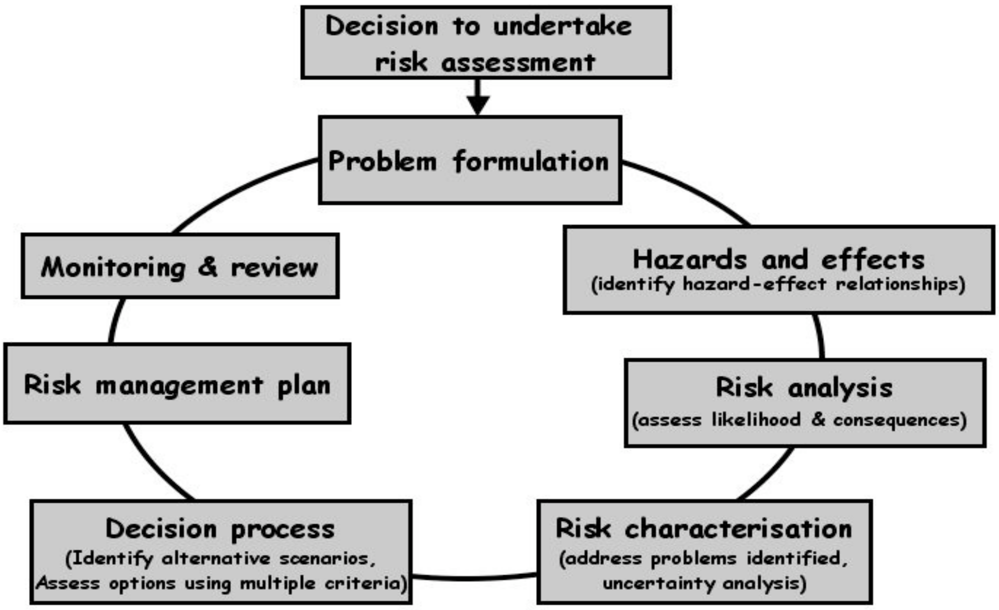

Figure 1: Overall risk assessment and management framework

Note: Stakeholders can be involved in all steps, but should be particularly involved in the early stages of the process (e.g. problem formulation, hazard & effects analysis, risk analysis and risk characterisation)

The ecological risk assessment framework involves a number of key steps (Figure 1), including:

- *Defining the problem* – this involves careful scoping of the problem, agreement on how it is to be assessed, and how the acceptability of actions will be judged.
- *Deciding on the important ecological values and hazards and threats to these values* – hazards are evaluated and priorities set by evaluating effects on valued elements of ecosystems and ecosystem services.
- *Analysing the risks to the ecological values* – the analysis process used needs to be appropriate for the situation in order to provide adequate information for decision-making. Guidance is provided on both qualitative and quantitative methods.
- *Characterising the risks* - the technical details of risk analyses needs to be made accessible to decision-makers and broader stakeholders. In particular, the uncertainties and assumptions associated with analyses require careful and transparent documentation.

- *Making decisions* – selection of the best management option or strategy will be the one that results in the effective minimisation of the ecological risks, while also being cost-effective and acceptable to the stakeholders. Technical and socio-economic information is needed here, and guidance is provided on a number of multi-criteria methods to assist this process.
- *Managing the risks* – a risk management plan provides recommendations on managing or mitigating all high or unacceptable risks. The risk management plan should include a robust program to *monitor progress* to ensure the strategies are working, and a *review and feedback process* for making changes if needed.

We believe it is particularly important that stakeholders are involved in the early stages of the ERA process (i.e. the first four steps - problem formulation, hazard & effects analysis, risk analysis and risk characterisation), although it may also be beneficial for them to be involved in all steps.

3. Regional awareness workshops

This section contains a summary of the full report on the regional awareness workshops by Walshe et al. (2005, available at www.sci.monash.edu.au/wsc).

3.1. Objective

The primary objective of the regional workshops was to raise awareness of the processes of ERA among irrigation stakeholders. As discussed in Walshe et al. (2005), the motivation of an individual organization to uptake ERA will be founded on (a) perceptions about the net benefits to be derived from ERA-based decision-making versus the *status quo*, and (b) perceptions about the option value of delaying where there are substantial costs associated with adoption. To address these considerations, secondary objectives of the workshops and seminars were:

- to make the benefits of ERA more readily visible and accessible to irrigation stakeholders,
- to encourage the adoption of ERA in the short term through emphasis on implementation flexibility.

The format of workshops involved a full-day exploration of core principles and tools, including how ERA can:

- identify socially relevant and environmentally important values,
- address multiple threats in a catchment-wide context,
- estimate the likelihood of adverse events that lead to environmental degradation,
- provide a framework for the development of conceptual models that underpin an explicit and transparent description of ecological risks in the face of uncertainty.

Typically, the workshops involve a mix of formal presentations, small group exercises and general discussion, that covered the modules listed in Table 1.

Table 1: Typical content of the regional awareness workshops

Module	Content

Introduction	• Overview - Why do ERA? • The ERA framework - the Australian standard and beyond • ERA case study – problem formulation, elicitation of ecological values, endpoints and hazards
Qualitative risk assessment	• Ranking risks – consequence and likelihood • Strengths and weaknesses of qualitative assessment
Building on qualitative risk assessment	• Introducing quantitative techniques • Conceptual models
Quantitative risk assessment	• Dealing with uncertainty – Interval Arithmetic, Monte Carlo and Bayesian Belief Networks • Revisiting the ERA framework

These modules were explored through a case study of regional interest for each location in which workshops were held. Where possible, these case studies involved environmental issues associated with NPSI-funded projects. Although specific case studies were used to stimulate practical thinking about how the ERA framework can be applied to real problems, it is important to note that outcomes sought from the workshops did not include direct contributions to planning and management beyond problem formulation. In their emphasis on equipping attendees with an overall understanding of core ERA concepts and principles, all of the awareness workshops devoted insufficient time to the elicitation, description and ranking of risks for outcomes to be considered robust enough for decision-making. Also, the open nature of invitations meant that stakeholder representation at the workshops was substantially biased (see Walshe et al. (2005) for list of participants) towards one group or another, depending on the region and the context.

Invitations to the workshops were loosely targeted, whereby initial contact was made to NPSI project leaders to identify key stakeholders. Direct phone calls or personal visits were made to these key stakeholders to 'seed' interest in the workshops, and email invitations distributed. Invitations encouraged identified stakeholders to forward the workshop details to wider contacts they thought might be interested in attending.

3.2. Overview of the workshops

The location, date, case study theme, and number of registered participants for the eight full day regional awareness workshops delivered under the project are shown in Table 2. In total, around 200 irrigation stakeholders registered their attendance at the workshops. Representation among stakeholders was substantially biased towards government agencies, with reasonable representation from researchers, the irrigation industry and Community NRM agencies. Relatively poor representation was seen among landholders and environmental groups, and limited interest was evident among consultants and other industries marginally affected by water resource issues.

Table 2: Full day regional awareness workshops delivered as part of the project

Where	When	Theme	Attendees
Brisbane	9 Dec 2003	Deep drainage	18
Deniliquin	31 Mar 2004	Murray Irrigation Ltd irrigation region	30
Deniliquin	11 Aug 2004	MIL drainage management plan	16
Mildura	20 Oct 2004	Open hydroponics	20
Townsville	10 Nov 2004	Lower Burdekin irrigation	19
Shepparton	17 Nov 2004	Broken Creek irrigation	21
Bunbury	15 Mar 2005	Peel-Harvey irrigation	26
Darwin	18 May 2005	Daly River irrigation	28
Townsville	1 Jun 2005	Wetlands, the Great Barrier Reef and irrigation	22
Total			**200**

3.3. Results

Feedback from workshop participants regarding their perceptions of ERA was formally captured through evaluation questionnaires administered at the conclusion of six of the workshops. The questionnaire responses of 98 individuals were collated for analysis. Questionnaires were designed to provide insights regarding:

- the perceived benefits and limitations of ERA,
- distinguishing characteristics of potential adopters and opinion leaders,
- perceptions of the applicability of ERA in the workplace of respondents,
- perceptions of what level of rigor might be appropriate for respondents' workplaces,
- the desirability of future training.

Findings indicated that the majority of participants saw ERA as a sound approach to sustainability of irrigation activities. There was strong support for including stakeholders in the process and strong agreement that ERA helps identify management priorities. However, there was some evidence that a substantial proportion of respondents viewed the time, data or expertise demands of ERA as onerous. Telephone interviews undertaken 2 months post-workshop with a subset of 28 questionnaire respondents suggested no significant or substantial changes in perceptions over this time.

Questionnaire feedback was also interrogated to identify any distinguishing characteristics among those more enthused (or more sceptical) about ERA. There was weak suggestion in the analysis that workplace and education level may be associated with attitude, however we do not regard these suggestive findings as a sound basis to inform targeted investment in the encouragement of ERA adoption.

3.4. Discussion

The collective insights obtained from this study (Walshe et al., 2005) suggest that ERA is generally regarded as a better approach to environmental planning and management than currently available tools, but that there are tangible and intangible costs associated with its adoption. Until the magnitude of net benefits is clarified, it is not unreasonable for individual organizations to exercise the option of delaying uptake. Organizations more likely to adopt in the near future are likely to hold one or more of following views:

- Commercial viability is sought over the long term and is dependent on sustainability of the resource base,
- The polluter-pays principle has at least some legitimacy,
- Consumer and stakeholder perceptions are important factors shaping access to markets and resources,
- Risk assessment is an effective means of demonstrating due diligence in environmental responsibilities.

The processes involved in ERA adoption are complex and multi-faceted. They involve elements of cultural change, technology transfer and addressing institutional issues. ERA challenges the prevailing culture of science and management to acknowledge uncertainty in decision-making. Technology transfer involves equipping organizations with the tools and techniques of ERA. Institutional issues include the tension between private property rights and the public good, and the possibility that ignorance of environmental risks may be preferable to knowledge in litigious settings.

Investment in further training in ERA will be especially worthwhile where an organization's culture is supportive of ERA, and a range of approaches could be explored including further workshops, case study partnerships and formal University-based education.

4. Case studies

4.1. General

Two case study partnerships were established – one focused on the Murray Irrigation region in southern NSW and the other on the lower Loddon River in northern Victoria. As noted above, these partnerships involved the irrigation industry and appropriate State irrigation regulators, and aimed to develop capacity within the individual organizations to use risk assessment and risk management procedures to improve the ecological sustainability of the irrigation region.

Both partnerships involved two stages:

- An initial problem formulation stage where the environmental values (or assets) to be protected or managed, and the associated (existing and potential) threats or hazards to these values or assets as a result of the irrigation activities, were identified.
- Development of quantitative Bayesian Decision Networks to assess the risks to the key environmental values identified by the stakeholders during the problem formulation stage.

A major difficulty faced by many natural resource managers wishing to predict the risk to key environmental assets is the lack of any quantitative models for this purpose. This is particularly so for aquatic and terrestrial resources, where there is a lack of both basic understanding of the cause-effect relationships between the threats and the biota, and also monitoring data for the specific systems that is needed to calibrate and validate the models.

For this project a decision was made to develop new decision-support tools based on Bayesian networks. Bayesian decision network (BDN) models are an ideal tool for situations where there is considerable uncertainty in knowing how the system works (Korb & Nicholson, 2004; Borsuk et al., 2004; Bromley, 2005; Pollino & White, 2005; Pollino et al. 2006). They are now being applied to diverse problems of increasing size and complexity, particularly as decision support tools to aid in the management of ecological systems.

A particular advantage of BDN models is that they can incorporate both quantitative information (obtained from existing models, monitoring and from site-specific investigations) and qualitative information (obtained mostly from expert opinion), and can be updated as new information or data becomes available.

Bayesian decision networks are graphical models used to establish the causal relationships between key factors and final outcomes (cause-effect relationships). BDN can readily incorporate uncertain information, with uncertainties being reflected in the conditional probabilities defined for the linkages. They are particularly useful in modelling ecological processes because Bayesian inference provides a probability-based approach that can update scientific knowledge when new information becomes available.

4.2. Murray irrigation region

This section contains a summary of the case study undertaken in the Murray irrigation region of southern NSW. The full report is available at www.sci.monash.edu.au/wsc (Pollino et al., 2005). The initial project partners for this case study were Murray Irrigation Ltd (MIL), NSW EPA (Department of Environment & Conservation) and the NPSI Risk Management project team (from Monash and Melbourne Universities).

4.2.1. Objective

The Murray irrigation region case study sought to work in partnership with the irrigation industry (in particular MIL) and appropriate State irrigation regulators (the NSW EPA) to develop capacity within the individual organizations to use risk assessment and risk management procedures to improve the ecological sustainability of the irrigation region. An underlying expectation was that the use of ecological risk assessment procedures would reduce the chance for conflicts between the industry and the government regulators.

4.2.2. Approach

This project was undertaken in two stages:

- Stage 1 (October 2003 – June 2004) focused on training key personal in risk assessment procedures, and undertaking a qualitative assessment of the key risks to environmental values in the Murray irrigation region (Pollino et al., 2004). The stakeholders identified two environmental assets assessed as being at high risk from irrigation - the Black Box (*Eucalyptus largiflorens*) wetlands and native fish communities (river health).
- Stage 2 (July 2004 – August 2005) involved the development of quantitative Bayesian decision network models for the above two environmental assets assessed to be at high risk from irrigation (Pollino et al., 2005).

4.2.3. Results

Black Box (Eucalyptus largiflorens)*Bayesian decision network model*

This BDN model predicts the following variables (endpoints):

- Black Box condition (as measured by percent canopy foliage), and
- Success of Black Box regeneration.

The model assumes these endpoints are influenced by five major factors: land management, surface water condition, soil condition, groundwater condition and wetting regime.

Sensitivity analysis of the model showed that altered wetting regime is the priority risk to maintaining the condition of Black Box trees and for successful regeneration. Fencing and grazing are also important factors in regeneration of these trees. In comparison, other factors (soil, groundwater and surface water salinity) only have a minor impact on tree health and regeneration.

Two management scenarios were tested to demonstrate application of the model in predicting the condition and regeneration of Black Box trees:

- Scenario A (No fencing, river is regulated, no artificial wetland watering (irrigation or environmental)) - the model predicted a 39% probability that Black Box condition would be intermediate to good, and a 56% probability that condition would be poor to very poor. The model also predicted a low (22%) probability that Black Box regeneration would occur.
- Scenario B (Area is fenced, river is regulated, wetland receives environmental water, but not irrigation water) - the model predicted an improvement in both condition and regeneration of the Black Box trees. For example, there was a slightly higher (42%) probability that the condition of Black Box trees would be intermediate to good, and a much lower (40%) probability that condition would be poor to very poor. However, this management scenario had greatest effect on the Black Box regeneration, increasing the probability of successful regeneration from 22% to almost 50%.

The results of the sensitivity analysis were used to simplify the complex model structure. This simple model is focused mainly on the wetting regime and fencing & grazing impacts. The simplified model performed more poorly than the complex model in all tests undertaken, but is still probably accurate enough for initial testing of different management scenarios.

The BDN model prediction supports the management actions (fencing and wetland watering) being promoted by Murray Irrigation Ltd, and promoted and implemented by Murray Wetland Working Group, on private lands as having a positive impact on the health of Black Box trees. A watering frequency of between one in five years and one in ten years was found to be optimal in maintaining tree health and promoting regeneration.

Fish Habitat Bayesian decision network model

During the Problem Formulation phase of the study, stakeholders assessed the degradation of 'river health' as a key risk from irrigation activities in the Murray irrigation region. However, there was disagreement between the groups on whether native fish communities in the region are under threat.

A Fish Habitat BDN model was developed to assist MIL, and potentially the Murray CMA, in managing irrigation and other activities that could threaten native fish communities and their habitat. This model is a sub-set of the much larger model that would be required to predict the effect of irrigation and other activities on 'river health'.

The Fish Habitat BDN model was based on the conceptual model developed in collaboration with key stakeholders, a previous Fish BDN developed for the Goulburn River in Victoria (Pollino, 2003), and information adapted from the fish habitat condition model within the Murray Flow Assessment Tool (MFAT). MFAT contains the most up to date knowledge regarding fish communities in the Murray Darling Basin.

The current Fish BDN model is spatially limited to the section of the River Murray from Yarrawonga Weir to Wakool Junction, and to the Edward River. Preference curves[1] relevant for this river section were set up as conditional probability tables in the BDN. Fish groups considered were flood spawners, freshwater catfish, main channel specialists and low flow specialists.

The Fish Habitat BDN model is still in the early stages of development with a number of components yet to be completed. However, even in this early stage the BDN model has a number of advantages compared with the MFAT fish module. These include: the capacity to *integrate model outcomes* for individual or groups of fish species, at one or more locations, and over broader spatial scales, easier testing of *management actions or system changes*, the BDN model is more *transparent* and *uncertainties* are built into the outputs (probabilistic distributions), and the model is easily updated as new data and information becomes available, making it compatible with *adaptive management* processes.

4.2.4. Discussion

A number of key lessons emerged from this project and these are summarised below (see Pollino et al. (2005) for more detail).

Clear definition of the objectives and scope of the project

Some stakeholders questioned the validity of the study once it became clear that the assessment would be limited to ecological values and would not address all issues of sustainability in the region. Despite the fact that it was never intended that this study would cover social and economic factors, the fact that this was not made absolutely clear from the start meant that stakeholder engagement (in itself an intensive process) in the project was poorly maintained. A problem with the Murray irrigation region case study from the outset was the poorly defined and amorphous objective of the assessment, the unclear and confused objectives of the project among stakeholders, and the lack of cohesiveness within the project team.

Values or threats?

Additionally, the project team did not spend enough time in defining the risk assessment language, e.g. there was confusion amongst stakeholders with the meaning of terms such as environmental or ecological value, environmental or ecological asset, threats and hazards, and risks. The objective of stakeholder interviews was to clearly define the ecological values (or assets) in the Murray irrigation region, and what the threats (or hazards) are to that value. It is crucial from the outset to define the distinction between these terms (although there can be cross over between terms), and to work through this with stakeholders.

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[1] Preference curves describe the response of a particular fish group to environmental conditions (e.g. a flow regime or a time of the year).

Scales of interest

The different scale of interest between stakeholder groups was quite apparent during the Problem Formulation phase. Environmental and indigenous groups focussed on broad scales that are long-term and span entire systems (e.g. focus on entire river systems and homelands), whereas landholders focused on short-term scales, which span the size of a landholding (e.g. soil integrity, vegetation loss). These conflicting scales of interest contributed to some landholders failing to see how the activities on their landholding impact broader ecological scales.

Commitment of project partners

There was a notable difference in the level of commitment by industry partners in this ERA case study compared with two other ERA studies we have undertaken (Goulburn River study with Goulburn Murray Water (Pollino, 2003) and Lower Loddon study with Vic EPA, North Central CMA and GMW (Westbury et al., 2005)). The differences may be linked to attitudes of industry staff, and to the resources available to undertake the study.

Adoption of risk-based approaches

It is clear that legislative incentives are a key driver for adoption of risk-based approaches by the irrigation (and other) industry in Australia. Currently, such incentives do exist in Victoria, but not in NSW. It is difficult to see irrigation companies going beyond a minimal Environmental Management System (EMS) to adopt risk-based approaches without some further legislative incentives.

The role of BDN models in decision making

When constructing models for an ecological risk assessment, uncertainties can arise as a result of incomplete datasets for model parameterisation, subjective assessments from expert indecision or lack of consensus amongst experts. The representation of uncertainty in risk assessment is critical in assisting system managers faced with making decisions to minimise or eliminate risks.

The BDN modelling approach is increasingly being used for predictive modelling of ecological systems with poor data and high uncertainties (Borsuk et al., 2004; Pollino & White, 2005; Ticehurst et al., 2006). The BDN models developed in this study, when used with other tools, will assist future decision-making in the Murray irrigation region. These BDN models are capable of being improved a new data and knowledge becomes available, making them an integral part of the adaptive management process.

4.3. Lower Loddon catchment

The Lower Loddon catchment ecological risk assessment was a collaborative project involving staff from EPA Victoria, Water Studies Centre Monash University, North Central Catchment Management Authority (NCCMA) and Goulburn-Murray Water (G-MW). The project was assisted by funding from the National Action Plan for Salinity and Water Quality and the National Program for Sustainable Irrigation (NPSI).

4.3.1. Objective

The aim of the project was to provide information and decision support tools to assist NCCMA, G-MW and Department of Primary Industries (DPI) in targeting on-ground management actions and monitoring programs, for rehabilitation of the lower Loddon catchment. The focus and scope of the risk assessment was developed during the Problem Formulation phase of the project in collaboration with stakeholders with an interest in the Lower Loddon area (see Westbury et al., 2005). The stakeholder group involved had considerable knowledge and experience in the management of the Lower Loddon Region, and included natural resource managers, landholders, regulators, local government and water authorities.

4.3.2. Approach

As noted above, the Lower Loddon catchment case study was undertaken in two stages. The first *problem formulation* stage focused on training key personal in risk assessment procedures, and undertaking a qualitative assessment of the key risks to environmental values in the Lower Loddon catchment. During this stage, stakeholders identified two ecological values potentially at risk to be the focus of a quantitative risk analysis - the *ecological health of the Lower Loddon River* and *farmland ecological values*. A full report on what was done and the outcomes is available (Westbury et al., 2005).

The subsequent *risk analysis* stage therefore focused on developing quantitative Bayesian decision network (BDN) models for these two environmental assets.

The first BDN model focused on predicting *macroinvetebrate community diversity* as an indicator of the ecological health of the Lower Loddon River. Stakeholders defined the area to be covered by the Lower Loddon River risk assessment as the Loddon River main channel downstream of Bridgewater. The risk analysis provided information at both an overall catchment scale and also separately at an individual Index of Stream Condition (ISC) reach scale (Westbury et al., 2005).

The second BDN model focused on *river farmland ecological values* in the Lower Loddon River. These values are defined as the value of farmland to the ecological assets of the larger catchment within which farms exist, but not values directly associated with agricultural production (i.e. the crops themselves are generally regarded as a separate 'value'). Specifically, the ecological values included the role of farmland and surrounding areas to wider biodiversity and to specific species of indigenous fauna and flora. This is essentially restricted to ecological uses of farmland for foraging or for habitat in the parts of farmland not affected by seasonal disturbances of harvesting, such as shelter-belts or riparian zones preserved for stream water quality. Areas of farmland under direct cultivation are generally unsuitable habitat for many indigenous species.

The abundance of a common bird species - the *grey-crowned babbler* – was used as the measure of farmland ecological value, and a BDN model developed to predict population abundance of the grey-crowned babbler.

4.3.3. Results

Macroinvertebrate community diversity Bayesian decision network model

This BDN model predicts macroinvertebrate community diversity in the Lower Loddon River downstream of Bridgewater (Westbury et al., 2005).

Sensitivity analysis showed that habitat variables (e.g. in-stream habitat, food availability, in-stream vegetation, turbidity, sedimentation, riparian vegetation, woody debris and roots, bank erosion) had the greatest influence on the predicted macroinvertebrate community diversity.

The Bayesian network predicted that the macroinvertebrate community diversity in all six ISC reaches in the Lower Loddon River would be poor, and this prediction certainly agrees with the small amount of field data available.

The BDN model has also been used to predict the effect on the macroinvertebrate communities of three levels of stock access (low, moderate, high) to the riparian zone and the channel. Reducing stock access significantly improved the macroinvertebrate community diversity in good to very good condition from 21% for high access to around 80% for low access.

These results support the current Loddon catchment management plan, where major on-ground fencing works are being implemented to reduce stock access to the riparian zone and the river.

Grey-crowned Babbler population abundance Bayesian decision network model

This BDN model predicts the abundance of a common bird species - the *grey-crowned babbler* – as the measure of farmland ecological value.

The structure of the BDN model was based on a conceptual map constructed by stakeholders in an initial workshop, and included three main factors that influenced population abundance of the grey-crowned babbler – habitat availability, food availability and biological factors[2]. Additional factors were included in the original model, but these were omitted in the final version because of a lack of data (Chan & Hart, 2005).

The BDN model predicts that for existing conditions, there is a high probability of low population abundance of the grey-crowned babbler. Sensitivity analysis showed that poor habitat and low 'biological potential' (i.e. the effect of a combination of biological factors such as competition, reproduction and predation) had the greatest influence on the abundance of the grey-crowned babbler populations.

The model was also used to predict the effect of stock access on remnant forest area and on the abundance of grey-crowned babbler populations. Reducing stock access was predicted to significantly improve the probability of medium to high abundance of grey-crowned babbler populations from around 40% when stock access was high to around 81% for low access.

These results support the current Loddon catchment management plan, where major on-ground fencing works are being implemented to reduce stock access to the riparian zone and will be extended to include fencing of remnant catchment vegetation.

4.3.4. Discussion

This project was highly successful in that there was considerable 'buy in' by the local landowners and resource managers (EPA, NCCMA, G-MW, DPI). The stakeholders participated enthusiastically in the both the problem formulation stage and in the development of the BDN models. Further, they urged that these BDN models be incorporated into existing Lower Loddon catchment management activities (e.g. Loddon Implementation Committees, Stressed Rivers Project).

The Bayesian network predicted that the macroinvertebrate community diversity in all six ISC reaches in the Lower Loddon River would be poor. The sensitivity analysis showed it is the habitat variables (e.g. in-stream habitat, food availability, in-stream vegetation, turbidity, sedimentation, riparian vegetation, woody debris and roots, bank erosion) that are

[2] These included competition from the noisy minor (*Manorina temporalis*), predators (e.g. feral cats) and reproduction.

having the greatest influence on macroinvertebrate community diversity being in a poor state.

The preliminary grey-crowned babbler BDN model predicted that the population abundance of this bird species would be low under existing conditions. Further, sensitivity analysis showed that poor habitat and low 'biological potential' (i.e. the effect of a combination of biological factors such as competition, reproduction and predation) had the greatest influence on the abundance of the grey-crowned babbler populations.

Unfortunately, there was insufficient data and information available to validate either of the BDN models developed. However, for the macroinvertebrate BDN model, EPA Victoria will be monitoring macroinvertebrates and the key influential habitat variables in the Lower Loddon catchment during 2005/2006. This data will be used to update the BDN and to validate the network. This will reduce the uncertainty and improve the robustness of the network, and provide a better understanding of the Lower Loddon system.

5. Conclusions and recommendations

The growing debate on water resource management in Australia suggests that the irrigation industry needs to be proactive in demonstrating tangible progress in sustainability. However, this project has shown that the arguments for adopting (or delaying adoption) of ecological risk assessment approaches are complex and multi-faceted. In many respects these complexities have only been made apparent through dialogue with irrigation stakeholders involved in the regional awareness workshops and the two case studies undertaken as part of this project.

Progressing ERA adoption - will involve a more targeted approach involving cultural change, technology transfer and a requirement to address broader institutional issues.

Cultural change

Although there appears to be widespread support for greater stakeholder involvement in planning and decision-making, the exact role of stakeholders in ERA requires clarification and refinement. The current Irrigation ERA framework (Hart *et al.* 2005) needs to be updated to reflect the recent learnings from this and other ERA projects.

The acknowledgment and transparent description of uncertainty in risk assessment as a means of overcoming overconfidence and myopia is inherently challenging to managers. Efforts to nurture an appreciation of the role of uncertainty in decision-making may be better directed toward researchers and policy-makers. As an interim strategy for irrigation industry managers, the advantages of a minimalist approach to ERA should be emphasized. Extensions that address weaknesses and pitfalls in this approach can then be phased in over time.

Incrementally greater effort should be made to include stakeholder involvement and the description of uncertainty in risk assessment protocols, as ERA becomes progressively embedded in the policy landscape.

Technology transfer

An emphasis on equipping an organization with *competency* in the tools and techniques of ERA is unlikely to be effective where the culture of an organization is hostile to the core principles of ERA. A coarse *awareness* of tools and techniques can encourage better risk assessments by demonstrating common pitfalls in conducting ERA and how they can be addressed. Web-based materials have been developed as part of this project.

A number of workshop participants identified workplace case studies as a preferred mode of training. Where possible, requests from industry and government to form case study partnerships should be supported, but only where the culture of the organization is supportive of ERA. There is reasonable evidence of demand for further formal training among irrigation stakeholders. Training options include extended 2-3 day workshops, university-based coursework and higher degree training.

Institutional issues

The role of the private and public sectors in the sustainability of non-market ecosystem services needs clarification. The capacity for ERA to act as a demonstration of due diligence against charges of environmental negligence requires administrative and legal clarification. In the absence of clarification, industry may be discouraged from adopting ERA because of fear of litigation where elicited information indicates any risk of environmental harm.

These broader institutional issues are unlikely to be resolved in the near future. In the meantime, the choice of an industry organization to delay adoption of ERA should be respected.

Two ***case study partnerships*** were established – one focused on the Murray Irrigation region in southern NSW and the other on the Lower Loddon River in northern Victoria. These partnerships involved the irrigation industry and appropriate State irrigation regulators, and aimed to develop capacity within the individual organizations to use risk assessment and risk management procedures to improve the ecological sustainability of the irrigation region.

Both partnerships involved an initial problem formulation stage where the environmental values (or assets) to be protected or managed were identified by the stakeholders, and a second stage to develop quantitative Bayesian Decision Networks to assess the risks to the key environmental values identified during the problem formulation stage.

Both projects were formally evaluated and this evaluation identified some clear lessons for the future application of risk-based approaches.

Lessons from the case studies

A number of important lessons were learned from conducting the case studies, and these are summarised below.

Stakeholder involvement

In this study, and other ecological risk assessment work (Hart et al., 2005), we have advocated the importance of engagement of stakeholders in the early stages of the ERA process (particularly the problem formulation, hazard analysis and risk analysis steps). This represents a major step forward from current Australian standards for environmental risk assessment (AS/NZS, 2000; 2004). The advantages of early involvement of stakeholders include:

- Stakeholders bring realism to the process. They have views about the ecological values to be protected, the objectives of the risk assessment, and the way the system works (i.e. the important cause and effect relationships).

- Stakeholder engagement opens a dialogue, improves communication and enables an exchange of information between groups. This can be particularly useful when stakeholders have divergent ideas (hypotheses) as these are exposed and can then be debated.
- If stakeholders are not involved in the ERA process, problems can emerge at a later stage because opposing views have not been considered in the process.

However, the involvement of stakeholders is not without its challenges, including:

- Stakeholders can be defined very narrowly as only these having some expertise regarding the issues, which can lead to an unbalanced ERA that is subsequently criticised for its lack of credibility. Additionally, it is not common to include social scientists and/or economists in the list of stakeholders consulted in an ERA.
- Stakeholders often have very different opinions of cause and effect relationships, which can lead to divisions that require considerable skill to resolve - this can be particularly difficult in cases where stakeholders are members of specific interest groups and are not prepared to even debate with those holding different views,
- It is extremely difficult to achieve a successful project without an enthusiastic *commitment* from the stakeholders (particularly the management agencies and industry stakeholders). We found that 'buy-in' was very good from the natural resource management agencies, but was patchy from the irrigation industry staff – this latter appeared to be related to the attitudes of industry staff to the risk assessment process (some were not convinced this level of assessment was necessary).
- The level of interaction between the risk assessment team and the stakeholders, which can be an important factor contributing to the success of stakeholder involvement. This interaction worked best in the Lower Loddon study where the level of resources available to undertake the study was greatest.

Objectives and scope of the assessment

A clear statement on the objectives and scope of the project is essential. If the assessment is to be limited to ecological values, and not include social and economic factors, this must be made clear from the outset. It is most important that the key stakeholders are involved in this process.

Adoption of risk-based approaches

It is clear that legislative incentives are a key driver for adoption of risk-based approaches by the irrigation (and other) industry in Australia. Currently, such incentives exist in Victoria, but not in NSW. It is difficult to see irrigation companies going beyond a minimal Environmental Management System (EMS) to adopt risk-based approaches without some further legislative incentives.

The role of the ERA process in achieving sustainability

The generally accepted interpretation of sustainability is a balance between development and environment protection, where the current use of environmental resources should not deplete their availability for future generations. The core principles of sustainability and sustainable development recognise that economic issues and environmental issues cannot be considered as independent entities as often development erodes environmental resources, and environmental degradation undermines economic development. Economic prosperity often forms the basis for social prosperity.

The current ERA process takes a reductionist view of environmental protection, focussing on a subset of environmental factors, which are not necessarily linked to ensuring the sustainability of a system. ERA was developed as a tool to develop, inform, or improve strategies for the management of stressors to reduce their impact on environmental resources.

The application of ERA in the two case studies was useful in identifying the main cause-effect relationships influencing the selected ecological endpoints and in showing how various management actions could reduce the risks to the selected ecological values. But these ERAs did not incorporate economic factors, and therefore represent only one factor in an overall assessment of sustainability of the systems studied.

Application of the ERA process currently focuses on the risks to the ecological assets the community values. If the process was broadened to include economic (and perhaps political) aspects, and therefore became a more triple bottom line approach, it would be an improved decision support tool for sustainability.

Role of BDN models in decision making

BDN modelling approaches are increasingly being used in the management of natural resources that are characterised by large uncertainties. These uncertainties can arise as a result of incomplete datasets for model parameterisation, subjective assessments from expert indecision or lack of consensus amongst experts. The representation of uncertainty in risk assessment is critical in assisting system managers faced with making decisions to minimise or eliminate risks.

The use of BDN models has a number of advantages including:

- The requirement that a conceptual model be developed showing explicitly the main cause-effect relationships (pathways), means that the structural relationships are transparent,
- They are a very useful mechanism for capturing stakeholder inputs,
- They can use both data and expert opinion,
- The probability that endpoints are being or will be met is the output of the model,
- They explicitly incorporate and report uncertainties,
- They can be updated when new data or new knowledge becomes available,
- They are useful for prioritisation of risks.

However, the use of BDNs is not without some difficulties, including:

- Establish of the network structure can be time consuming,
- The quality of the BDN is often very dependent upon the availability (and skill level) of the experts (stakeholders),
- The assembly of available data can be extremely time consuming,
- BDNs represent dynamic systems poorly (e.g. feedback loops & temporal relations),
- Complex BDNs (i.e. where there are many interactions) are difficult to parameterise,

- It can be difficult for managers to interpret the (probabilistic) outputs from these models,
- It can be difficult for managers to make decisions when confronted with results where the (often large) uncertainties are made explicit,

Currently, there is a lack of capacity to develop relevant BDN models, but we are confident that this will be addressed in the very near future.

Recommendations

Recommendation 1: that NPSI seek to update the current Irrigation ERA framework (Hart et al., 2005) to reflect the recent learning regarding stakeholder involvement, and the development and use of Bayesian Decision Network models.

Recommendation 2: that NPSI continue to encourage and promote a range of activities aimed at achieving increased adoption of risk-based approaches in the Australian irrigation industry and associated stakeholders, including 2-3 day workshops, university-based coursework and higher degree training.

Recommendation 3: that NPSI continue to encourage and promote additional case study partnerships between the irrigation industry and associated regulatory agencies to further develop risk-based approaches to environmental management.

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