An ecological risk assessment of irrigation in the Ord River catchment, a highly disturbed and poorly understood area in the wet-dry tropics of Australia

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Abstract:

An ecological risk assessment of the impact of irrigation on the ecological values of the Ord River was undertaken. The Ord River is located in the wet-dry tropics of Western Australia and has been highly disturbed by grazing and irrigation developments. The construction of two dams has changed the river from being seasonally dry to now having permanent flows downstream of the dams. The Ord River Irrigation Area (15,000 Ha) is fed by waters from the Kununurra Diversion Dam. Approximately 50% of the water is returned to the river downstream mixed with drainage from the farms. Comparatively little is known of the ecology of the Ord River, although recent research efforts are starting to address this. The risk assessment focused on the area between the Ord River Dam and upper boundary of the estuary. A mass balance of nutrients, sediments and water for the Lower Ord River clearly demonstrated that irrigation drainage was the principal source of nutrients. The low knowledge base for the system resulted in a qualitative risk assessment largely guided by expert opinion. Priority ecological consequences were identified as loss of biodiversity and biota kills (primarily through biocides), weeds and lastly algal blooms and channel infilling. The priorities were used to guide further research. Low stakeholder involvement in the assessment was believed to undermine the sense of ownership of the process. A low knowledge base limited the assessment to being purely qualitative and dominated by expert opinion. Further research should allow a second iteration of the process to produce more useful outcomes and some quantitative risk assessments.

Key Words:

biodiversity, grazing, dams

Introduction:

Ecological Risk Assessment (ERA) evolved from ecotoxicological risk assessments that examined the risk posed by a toxicant (e.g. heavy metal, pesticide) on a target species. This approach was adopted and broadened in the Australian and New Zealand Water Quality Guidelines (ANZECC and ARMCANZ, 2001). The guidelines encouraged risk assessments for specific sites and toxicants (for example see Muschal & Warne, 2003). Ecological risk assessment has now been expanded to a more holistic level, covering multiple environmental stressors and ecological consequences (e.g. Hart, Lake, Webb, & Grace, 2003). Although ERA has become an increasing important management tool, much of the assessment remains qualitative. Qualitative assessments while often considered the only possibility given poor data availability are fraught with subjectivity, linguistic uncertainty and rarely adequate recognition of the degree of uncertainty (Burgman, 2001). Quantification of ERAs have focused on the development of suitable models, particularly the use of Bayesian modelling, to overcome some of these limitations (e.g. Hart et al., 2003; Pollino, 2004; Webb & Chan, 2004).

The National Program of Irrigation Research and Development (Land and Water Australia) developed a research program that aimed to produce a generic ERA Framework for irrigation based on three case studies (Ord, Fitzroy (Queensland) and Goulburn-Broken (Victoria)) (see Hart, 2004; Hart et al., 2001). In collaboration with the Water and Rivers Commission (now Department of Environment), this paper reports on the Ord River case study.

The Ord River lies in the wet-dry tropics region of Western Australia which has a tropical climate characterised by an extended dry season and approximately 90% of rainfall occurring in summer. This region is frequently portrayed as a pristine wilderness, but grazing and irrigation have had a significant impact on the Ord River. The aquatic ecology of the Ord River is poorly understood, with virtually no research being undertaken on the system prior to 1998. The Ord River is over 3000 km from Perth and has until recently been neglected by natural resource managers. In some instances this neglect has been of a benign nature, but it has also permitted poorly managed pastoral leases to overgraze their properties leading to severe erosion, substantial alterations to river flow and the return of contaminated irrigation waters to the river. In 1997 a large fish kills in a major irrigation drain (D4) and major tributary (Dunham River) due to Endosulphan poisoning attracted public and media attention. This incident and a need to determine the amount of water potentially available for a proposed expansion of the irrigated farm land (Ord Stage 2) saw a dramatic increase in management interest in the Ord River. This resulted in a concerted effort to better understand the ecology of the system and to ensure that irrigation practices were inline with those elsewhere in the State. Water Corporation of WA also began the process of transferring the irrigation assets to the Ord Irrigation Cooperative. This sudden increase in regulation, examination and management from Perth caused some resentment in the irrigator community.

The Ord River case study provided an opportunity to attempt an ERA in a low knowledge environment, with low stakeholder involvement. This paper will review the ERA process undertaken and evaluate whether it is a useful management tool in this type of situation.

The Ecological Risk Assessment

Approach

A series of informal meetings were held with a group of scientific experts (Department of Environment and Perth based academics) to prepare a broad list of potential ecological consequences associated with irrigation and to determine project boundaries. A follow-up meeting was held in Kununurra on the 6th November 2000 with stakeholders from Agriculture WA, Ord Irrigation Cooperative, and local Department of Environment staff. Stakeholders from the Ord Land and Water Management Plan Steering Group (a community group) were also invited, but were unable to attend. In addition to comments received on the broad list of potential ecological consequences of irrigation, a key priority was seen as the development of a mass balance model for the Lower Ord catchment. This was intended to collate existing data and for irrigator's put their potential impacts into a catchment wide perspective. The outcomes of the mass balance clearly showed that irrigation return was the largest source of nutrients to the Lower Ord River (Lund & McCrea, 2001a)

A further workshop was held in Perth on the 14th February 2001 to review the mass balance findings and develop the conceptual models for key ecological consequences of irrigation. The revised mass balance models and conceptual model were then presented in a workshop in Kununurra held on the 16th March 2001. At this meeting, final revisions were made to the model, potential risks determined and priorities decided.

Project Boundaries

The most significant consequence of irrigation in the Ord catchment was the construction of the Ord River Dam forming Lake Argyle and the Kununurra Diversion Dam forming Lake Kununurra, which changed the Lower Ord River from a seasonal to permanent river with highly regulated flows. Consequently there have been substantial changes in river dynamics, sediment transport, channel morphology, biodiversity, and riparian vegetation. Water from Lake Kununurra is used to support two irrigated areas - Ivanhoe Plains and Packsaddle Plains. Designed as flow-through systems, these areas return significant quantities of drainage and unused irrigation water to the river either directly or via Packsaddle Creek into the Dunham River.

Proposals to develop new irrigation areas in Weaber, Knox, Carlton and Keep Plains, and Mantinea Flats (collectively referred to as Ord Stage 2) has meant that the Department of Environment has had to determine the Ecological Water Requirements for key components of the river system. These requirements were then used to develop the Interim Ord River Water Allocation Plan (WRC, 1999). The Interim plan was based on advice from an Expert Scientific Panel and a Community Reference Group. The Western Australian Environmental Protection Agency recommended that Ecological Water Requirement planning focus on maintaining and enhancing the post dam modified environmental conditions rather than attempting to return the river to a more natural condition. Ord Stage 2 proposals provided the context for the ERA. The Upper Ord River carries a high sediment load (23.49±4.70 million tonnes) from erosion of overgrazed soils. However 99% of the load is trapped in Lake Argyle (Wasson et al., 1994). As the river above Lake Argyle is unregulated, seasonal, and not subject to irrigation, the Ord River Dam effectively splits the river into two ecological systems. The ERA chose to exclude the effect of flow modification on the river and focus on the Lower Ord (downstream of the Ord River Dam). As little was known about the ecology of Cambridge Gulf, especially the impact of the large tidal variation (approx. 8 m), Carlton Crossing (the approximate extent of saltwater intrusion up the river) was taken as the lower limit of the ERA. Attention was given to the possible impacts of Stage 2 developments.

Ecological Consequences
The reports from the Scientific Panel and Community Reference Group provided a strong foundation for the subsequent development of a list of ecological consequences of irrigation. Key issues raised by the Community Reference Group related to the need to maintain the Lower Ord River in its current condition, by maintaining riparian zones, fish stocks, water quality, biodiversity and flow (to ensure adequate dilution of irrigation return). The Scientific Panel identified that water levels should be maintained to prevent pool formation, weed proliferation, and sedimentation, which was causing excessive channel infilling and loss of habitat. These findings were refined to five priority consequences: channel infilling, biota kills (biocides), loss of biodiversity, algal blooms and weeds. The refinement of the list of consequences is detailed in Lund and McCrea (2001a).

Conceptual Model
A simple conceptual model of the interactions between water quantity (as determined by Kununurra Diversion Dam releases) and irrigation return on ecological consequences was constructed (Figure 1). Reductions in the quantity of water primarily through increased irrigation usage can have two effects. The first is the reduced dilution rate for incoming irrigation return, which increases nutrient concentrations within the river. Coupled with this is the possibility of pools forming within the river channel, where the hydraulic residence time (time spent by the water in the pool) exceeds 3 days. This potentially could lead to a variety of ecological consequences, which would depend on the phosphorus (P) concentration. This assumes that P is limiting primary production in the river. Low P concentrations would encourage the growth of submerged macrophytes within the pools. High P concentrations could result in the development of potentially toxic cyanobacterial blooms. Under both scenarios excessive production of organic material could lead to high biological oxygen demand and subsequent reductions in the dissolved oxygen concentrations to levels that will result in the death of fish and other biota in the water. Conditions that favoured the growth of submerged macrophytes were also considered to suit the growth of weed/exotic species. Reduced dilution and longer hydraulic residence times will increase the chances of biocides reaching toxic levels. As the quantity of water declines its capacity to carry sediment will also tend to be reduced (assuming that velocity declines), this will reduce scouring and resuspension of sediment and encourage sedimentation. As sediment accumulates within the channel, it may become stabilised by vegetative growth (emergent followed by riparian), enhanced by the constant supply of nutrients. This is predicted to result in loss of habitat for benthic macroinvertebrates and shallows for fish.

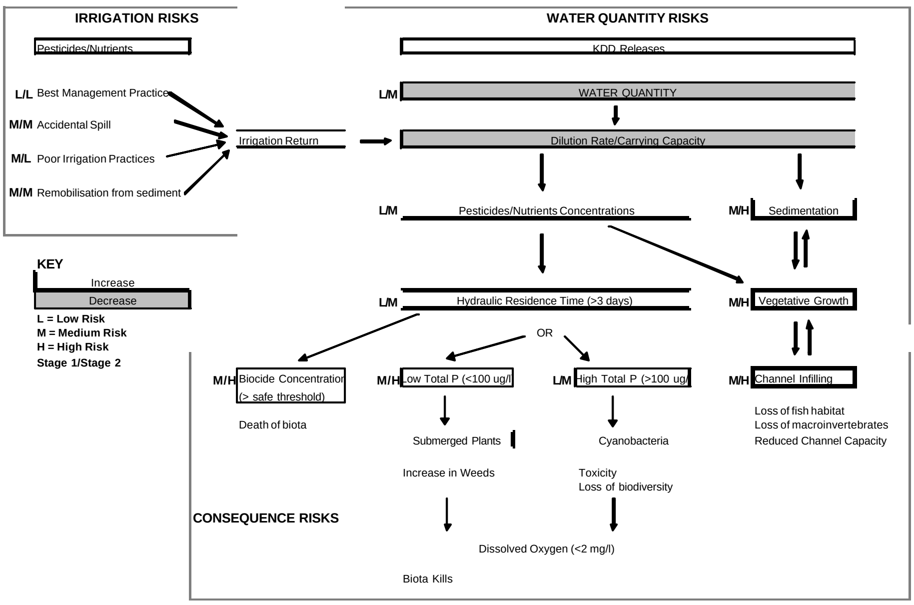

Figure 1. Conceptual model illustrating potential risks of stressors responsible for causing ecological consequences associated with irrigation in the Lower Ord River. The risks associated with water quantity changes are illustrated under Stage I and Stage II developments.

Risk assessment

In the conceptual model (Figure 1), interactions are spilt into three components, risks associated directly with irrigation, risks associated with water quantity and lastly risks associated with the consequence occurring. Initial risk values (Low, Medium & High) were assigned by expert opinion for each factor within each component. Under irrigation risks, pesticides and nutrients were considered to be the principal stressors. Accidental spills into the drain network of either pesticides or nutrients were considered a medium risk, as was scouring from drains of sediment bound pesticides and nutrients. Poor irrigation practices were considered to be more of a risk to the release of pesticides or nutrients under current conditions, rather than under the tighter regulations that would accompany Ord stage 2 developments. Best management practices were considered as might be expected to produce a relatively low risk for pesticide and nutrient release into the river. All these individual risks were considered together to produce an overall risk associated with irrigation. Reductions in the quantity of water released by the Kununurra Diversion Dam were seen to impact on rivers ability to dilute irrigation return and its capacity to transport sediment. These reductions would then increase hydraulic residence time to sufficient to cause problems (taken as 3 days). In the case of sedimentation, this becomes stabilised with vegetation, whose growth is enhanced by increased nutrients. This then led onto the final component, which were the consequences. The availability of the potentially limiting nutrient P was considered to be significant in determining the likely consequence which would occur; either growth of submerged plants under low P concentrations, or cyanobacteria under high P concentrations. The main impact of Ord Stage 2 developments was a reduction in the quantity of water available in the Lower Ord River and risks are therefore higher under Stage 2 than Stage 1.

Risks associated with each consequence were averaged over irrigation risks, water quantity risks and consequence risks after assigning a score to each risk factor (L = 1, M = 2 and H = 3). The overall risk for each consequence was the mean of the three major components. The calculations are shown below,

Example: Ord Stage 1 risks for Loss of Biodiversity

Consequence	Irrigation risks	Water Quantity risks	Consequence risks	Overall Risk
Loss of biodiversity	LMMM = 1.8*	LLLLMM = 1.5	LM = 1.5	1.6 = M

*For Irrigation risks all the risk values for the four factors (LMMM) were each assigned a score (1, 2, 2, 2) and then this was averaged to produce an overall risk of 1.8. In the other components only the risk values of factors relevant to each consequence were averaged. The overall risk was the average of the average risks of the three components.

The determination of risk equally weights all factors and ignores the number of factors that potentially lead to a consequence and as such is overly simplistic. The overall risk is presented purely as a method for comparison between consequences. The conceptual model shown is simple and contains some erroneous information, it is now believed that nitrogen is probably limiting. The conceptual model arises from discussions with stakeholders and represents knowledge at that time.

A risk matrix was produced that listed for each ecological consequence and the overall risk derived from the conceptual model. To the matrix were added expert assessments on how important the consequence would be at a local or broad scale within the catchment, the significance of irrigations contribution to the risk and lastly the level of knowledge of the processes underlying the consequence in the Ord River (Table 1). This table was then presented to the stakeholder group who commented on assigned risks. The consequences were prioritised based on the group's judgement of the importance of each of the assessments. For example, algal blooms were believed to be most significant at localised spots in the river, with irrigation return drainage likely to be the main cause, little was known of the likelihood of algal blooms and the risks under both Ord Stages 1 and 2 were considered to low to medium.

There was general agreement amongst all stakeholders on the risk values assigned although it was suggested that weeds posed a lower risk than Loss of Biodiversity. The top priorities were seen by stakeholders as:

1. Loss of biodiversity and biota kills
2. Weeds.
3. Algal blooms were believed to be relatively unlikely (low risk); while channel infilling was believed to be happening regardless of irrigation and the contribution of irrigation was believed to be minor.

Further research is now being undertaken into the risks posed by irrigation return to loss of biodiversity and algal blooms.

Table 1. Ecological effects ranking matrix table

Ecological Consequence	Importance in catchment		Impact of Irrigation	Risk		Knowledge
	Local	Broad		Stage I	Stage II	
Algal Blooms	M	L	H	L(1.3)	M(1.8)	L
Biota Kills (biocides)	H	L	H	M(1.6)	M(2.2)	L
Loss of biodiversity	M	M	M	M(1.6)	M-H (2.1-2.7)	L
Channel Infilling	M	L	L	M(1.8)	M(2.4)	L
Weeds	M	M	M	M(1.6)	M(2.2)	L

The role of ERA in Management of the Ord River

The ERA process has yet to be adopted into the management of the Ord River, although there is still interest in the process within management agencies. This project evolved over several years and during that time it missed becoming integrated into the Department of Environment planning cycle. It is hoped that when the results from the further research are completed that this will renew enthusiasm for the approach. The increasingly widespread use of ERA, particularly in Victoria is likely to further encourage the Department to continue the process. At the time of the initial stakeholder meetings, the Department of Environment had been building relationships with irrigators and so were reluctant to risk these relationships in broad stakeholder meetings. As a result the ERA was largely imposed by researchers and endorsed by agencies rather than being developed by all stakeholders. It is obvious that greater stakeholder involvement in the ERA would have been desirable but would have required more resources and time than were available. The use of Scientific Panel and Community Reference Group reports proved useful in gauging stakeholder views that were not tapped directly. However, the Community Reference Group was unable to include Indigenous perspectives into the EWR process and as a result the Department of Environment have moved to alternative models to involve Indigenous groups in the process. As a result the ERA was dominated by agency and scientist perspectives to the total exclusion of indigenous perspectives and limited inclusion of other community views.

The collation and review of existing data, and production of a mass balance of nutrients, water and sediment (see Lund & McCrea, 2001a, 2001b) was a particularly useful outcome of the ERA process. It was clearly able to show the significance of irrigation as a source of nutrients in the catchment, it also clearly highlighted where there were knowledge gaps. In many systems that are poorly understood, with low knowledge bases, it is important not to underestimate the value of whatever data is available to providing a basis for discussion. In this case study, the mass balance model for all its likely errors negated long held beliefs that grazing was having more impact than irrigation on the Lower Ord River.

The experience of this case study and others has contributed to the model developed by Hart (2004), Hart *et al.* (2001) and Hart *et al.* (2003) of the ERA process that commences with a problem formulation, issue/hazard assessment followed by a risk assessment. The risk assessment informs decision making which may trigger further more detailed investigations into assessment of the risk, or lead to risk management and monitoring. The whole process is iterative with monitoring results feeding back into the problem formulation stage. The ERA conducted for the Ord River would have benefited from the approach given in the model as this would have clarified the process and overcome some of the semantic issues. The initial reduction in the number of consequences that were to be considered was probably a mistake. In a low knowledge system, it would be more sensible to keep all potential consequences in the process and then evaluate all of them, rather than censor them near the beginning. This is because lack of knowledge may discount serious ecological consequences and it may also remove consequences that can be easily dealt with. It was not possible to develop quantitative assessments of risk given the lack of data; however it is the aim of the further research underway to provide quantitative assessments of risk.

The ERA undertaken for the Ord River was limited in stakeholder involvement and its risk assessment simplistic; however it does provide a framework to guide future research. As it is an iterative process the research should enhance the risk assessment, allowing priorities to be revisited. The success of the ERA depends on its adoption by stakeholders, in particular whether the Department of Environment adopts it.

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